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OBSERVING AND MODELLING THE DUST IN NEARBY GALAXIES

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Abstract. Dust grains are a crucial ingredient in the interstellar medium of galaxies. They are efficient at absorbing and scattering UV/optical photons and then reradiating the absorbed energy in the infrared/submm wavelength range. The amount and spatial distribution of dust in galaxies can hence be investigated in two complementary ways: by its attenuation effects at short wavelengths, and by its thermal emission at long wavelengths. Both approaches have their advantages and challenges. We discuss a number of recent interesting results on interstellar dust in nearby galaxies. We particularly focus on the role of dust radiative transfer, which has advanced considerably in the past few years, and the wealth of observational results provided by the Herschel Space Observatory.

1. INTRODUCTION

Although dust only makes up a small part of the interstellar material (typically 1% in mass), its impact on the other baryonic components in galaxies should not be underestimated. For example, dust particles act as a catalyst for the formation of molecular hydrogen, regulate the heating of the neutral gas component through photoelectric heating and inelastic interactions, and provide shielding for molecules from the UV radiation of young stars. On galaxy-wide scales, interstellar dust affects our view on galaxies: on average, about 30 to 50% of the starlight in the Universe is absorbed by interstellar dust grains, and converted to FIR/submm emission (Xu & Buat 1995; Popescu & Tuffs 2002; Davies et al. 2012). It is hence important to carefully trace and map the dust in galaxies of different types and in different environments.

Broadly speaking, the dust in galaxies can be traced in two ways. The first is by studying the thermal emission of the dust at FIR and submm wavelengths. The advantage of this technique is that the dust emission is usually optically thin, such that it is relatively easy to translate FIR/submm luminosities to dust masses. The main disadvantages are that FIR/submm observations need to be done from space with cryogenically cooled instruments, and that the unfavourable diffraction limit results in fairly poor spatial resolution. An alternative method that does not suffer from poor spatial resolution consists of carefully modelling the attenuation effects of the dust on the stellar emission in the optical window. The main problem with this approach is that translating attenuations to dust masses is complex and subject to many different effects (e.g., Disney et al. 1989; Witt et al. 1992; Baes & Dejonghe 2001).

In this contribution we discuss some of the progress that has recently been made in our understanding of the distribution and characteristics of interstellar dust in nearby galaxies. We particularly focus on the role of dust radiative transfer (which has advanced considerably in the past few years), and the observational leap forward provided by the Herschel Space Observatory.

2. ATTENUATION BY INTERSTELLAR DUST

2. 1. DUST RADIATIVE TRANSFER

One of the ways to investigate the amount and spatial distribution of interstellar dust in galaxies is by analysing its effect on the starlight at UV and optical wavelengths. The proper way to do this is by means of radiative transfer calculations that take into account the relevant effects (absorption and multiple anisotropic scattering) in a realistic geometrical setting.

3D radiative transfer is generally considered to be one of the grand challenges in computational astrophysics (Steinacker et al. 2013). The main reason is that the underlying physical processes combine, in the stationary case, to a nonlocal and nonlinear 6D problem. The radiative transfer equation is an integro-differential equation that is usually nonlinearly coupled to other equations. Solving such a high-dimensional nonlocal, nonlinear problem requires substantial computational resources, affecting the solution algorithms and potentially limiting the model complexity.

In spite of the difficulties described above, significant progress has been made in the past decade, with an increasing number of codes capable of dealing with the complete 3D dust radiative problem. The vast majority of the codes that can handle the 3D dust radiative transfer problem today are based on the Monte Carlo technique (e.g., Gordon et al. 2001; Baes et al. 2003, 2011; Jonsson 2006; Bianchi 2008; Robitaille 2011; Camps & Baes 2015), with only a few other codes based on pure ray-tracing solvers (Steinacker et al. 2005; Natale et al. 2014). Both methods face the challenges of grid discretisation, determination of uncertainties in solutions, and accurate comparison between observations and the model calculations. Still, the future of 3D dust radiative transfer is bright, with a growing number of people actively involved, a continual refinement/improvement of existing codes, and the development of new codes and algorithms.

2. 2. SIMULATING THE EFFECTS OF EXTINCTION

One of the long standing questions in extragalactic astronomy is how much dust affects the apparent photometric properties of galaxies, such as apparent scale lengths,

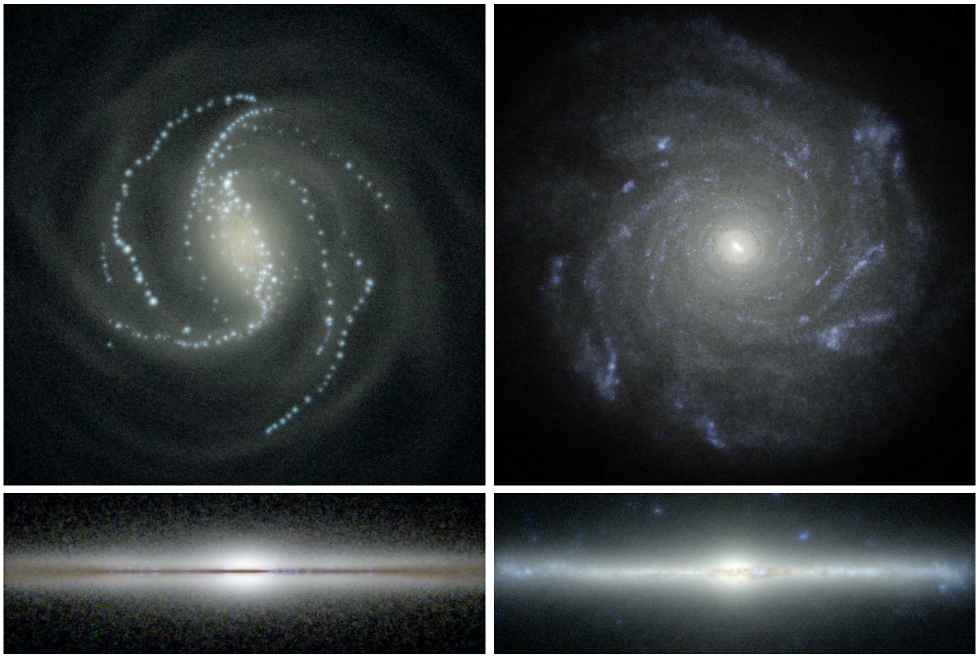

Figure 1: Mock face-on (top row) and edge-on (bottom row) views for two simulated galaxies, in which the effects of dust attenuation are fully taken into account. The left panels correspond to the Renaud et al. (2013) simulation, the right column is the Eris simulation (Guedes et al. 2011). The three-colour images are based on the r, g and u band images produced by the SKIRT radiative transfer code (Baes et al. 2003, 2011). Figure taken from Saftly et al. (2015).

surface brightnesses, luminosities, axial ratios, etc. This has been investigated through radiative transfer modelling with varying degrees of sophistication and geometrical realism. Byun et al. (1994) were the first to convincingly demonstrate that effects of scattering are often counter-intuitive and crucial to properly interpret the effects of dust. With the increase of computing power, these results have gradually been refined (e.g. Pierini et al. 2004; Tuffs et al. 2004). In general, it was found that the importance of dust attenuation varies as a function of wavelength, galaxy inclination and star-dust geometry.

An example of one such study is the work by Gadotti et al. (2010). They used radiative transfer simulations to create mock images of dusty galaxies, and subsequently applied 2D bulge/disc decomposition techniques to this set of models. Rather surprisingly, the effects of dust on the structural parameters of bulges and discs obtained from 2D bulge/disc decomposition cannot be simply evaluated by putting together the effects of dust on the properties of bulges and discs treated separately. Dust effects were found to be more significant for the bulge parameters than for the disc parameters, and, combined, they lead to a strong underestimation of the bulge-to-disc ratio up to a factor of two in the V band, even at relatively low galaxy inclinations and dust opacities. Similar results have been obtained by Pastrav et al. (2013a,b).

In recent years, N-body/hydrodynamical simulations have started to successfully reproduce the observed characteristics of spiral galaxies (Governato et al. 2009; Agertz et al. 2011; Guedes et al. 2011; Renaud et al. 2013; Marinacci et al. 2014). The spatial resolution of these simulations is sufficient to resolve both large- and small-scale inhomogeneities. The combination of such models with powerful 3D radiative transfer codes that can handle complex geometries thanks to advanced grids (Niccolini & Alcolea 2006; Saftly et al. 2013, 2014; Camps et al. 2013) opens up the possibilities to investigate the systematic effects of dust on the observable properties of galaxies in a realistic setting. This combination is particularly useful in the frame of large-scale cosmological hydrodynamical simulations, in which large numbers of galaxies of different types are formed that should ideally reflect the present-day Universe (Vogelsberger et al. 20134 Schaye et al. 2015). Given the significant effects of dust attenuation, 3D radiative transfer codes play a crucial role in this comparison process (Figure 1).

2. 3. RADIATIVE TRANSFER MODELLING OF NEARBY GALAXIES

Radiative transfer codes are powerful tools to systematically investigate the effects of attenuation on galaxy models. Often, however, we are interested in the dust content of a specific galaxy based on a set of UV/optical/NIR images, and a radiative transfer code by itself, no matter how advanced, is not sufficient to achieve this. This so-called radiative transfer modelling of galaxies is an inverted problem that requires the combination of a radiative transfer code and an optimisation procedure. Several fitting codes have been set up that combine a radiative transfer code with an optimisation algorithm (Xilouris et al. 1997; Bianchi 2007; Schechtman-Rook et al. 2012). All too often, however, this optimisation procedure is neglected and chi-by-eye models are presented as reasonable alternatives.

Edge-on spiral galaxies have been a preferred class for radiative transfer modelling, as the dust shows nicely as a thin dust lane. The pioneering work in this field by Kylafis & Bahcall (1987) and Xilouris et al. (1997, 1998, 1999) showed that dust is generally distributed in an extended and thin disk, with modest optical depths that would make the galaxies completely transparent if they were to be seen face-on. These results were confirmed by Bianchi (2008). De Geyter et al. (2013, 2014) recently combined a 3D Monte Carlo code with an optimisation library based on genetic algorithms into a code that can simultaneously fit arbitrary 3D models to a set of UV/optical/NIR images. This "oligochromatic" fitting has clear advantages over standard monochromatic fitting, as it can minimise the degeneracies that are hard to overcome when radiative transfer models are fitted to one band only. Applying this technique to a set of 12 edge-on spiral galaxies, De Geyter et al. (2014) find results that are on average consistent with previous results, although the median face-on optical depth is larger than in these previous studies (Figure 2).

3. THERMAL EMISSION BY INTERSTELLAR DUST

3. 1. HERSCHEL AND NEARBY GALAXIES

Besides modelling the attenuation in the optical regime, the dust in galaxies can also be traced by its thermal emission in the infrared. IRAS, ISO and Spitzer allowed us to study dust emission up to about 200 μm, butwere rather limited in spatial resolution.

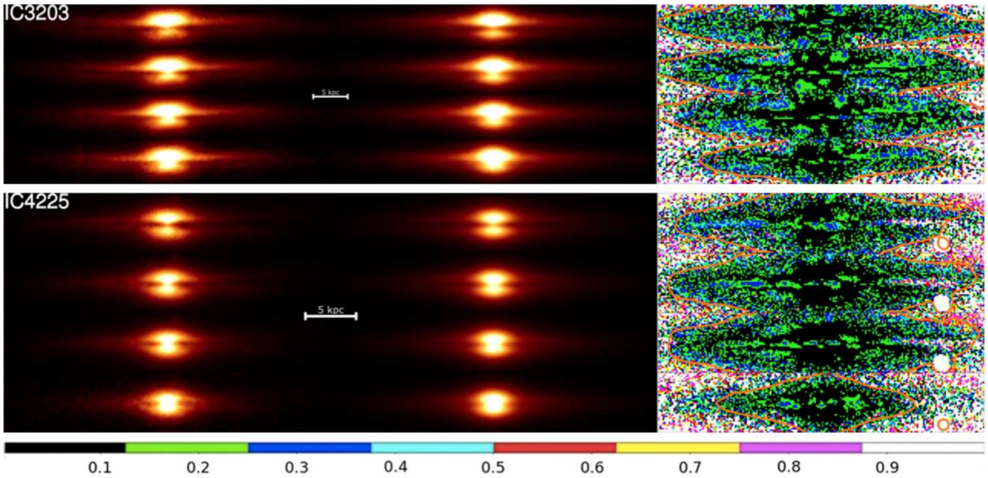

Figure 2: Results of the oligochromatic FITSKIRT radiative transfer fits to two edge-on spiral galaxies, from De Geyter et al. (2014) In each panel, the left-hand column represents the observed images in the g, r, i and z bands (from top to bottom), and the middle column contains the corresponding fits in the same bands. The right-hand column contains the residual images, which indicate the relative deviation between the fit and the image. A colour bar with the scaling of the latter is indicated at the bottom.

The Herschel Space Observatory (Pilbratt et al. 2010) opened a new window on the FIR/submm spectral domain, allowing us to probe the cold dust component in a large number of nearby objects. During its lifetime from 2009 to 2013, Herschel observed hundreds of nearby (and distant) galaxies with its two imagers, PACS (70–160 μm) and SPIRE (250–500 μm), with an unprecedented angular resolution and sensitivity.

Many Herschel key and normal programmes were devoted to nearby galaxies. A number of these were targeted surveys that focused on different samples of nearby galaxies (e.g., Boselli et al. 2010; Kennicutt et al. 2011; Verstappen et al. 2013; Madden et al. 2013). Other projects were blind surveys that mapped large areas of extragalactic sky, which can be used to investigate the dust properties of nearby galaxies (and galaxies at higher redshift) in a more statistical way (e.g., Davies et al. 2010; Eales et al. 2010). Covering all the achievements and results of these various programmes is an impossible task. We therefore select just a few remarkable results, and refer to e.g. Dunne et al. (2013) for more results and references.

One of the major achievements of Herschel on nearby galaxies is a solid characterisation of the cool dust budget of galaxies of different types and in different environments. The Herschel Reference Survey (Boselli et al. 2010) has imaged more than 300 stellar-mass-selected galaxies and allowed to investigate the dust scaling relations along the Hubble sequence (Cortese et al. 2012; Boselli et al. 2012; Smith et al. 2012a). It was found that the dust-to-stellar mass ratio anti-correlates with stellar mass, stellar mass surface density and NUV−r colour, and decreases significantly when moving from late- to early-type galaxies. These scaling relations are similar to those observed for the atomic gas fraction, supporting the idea that the cold dust

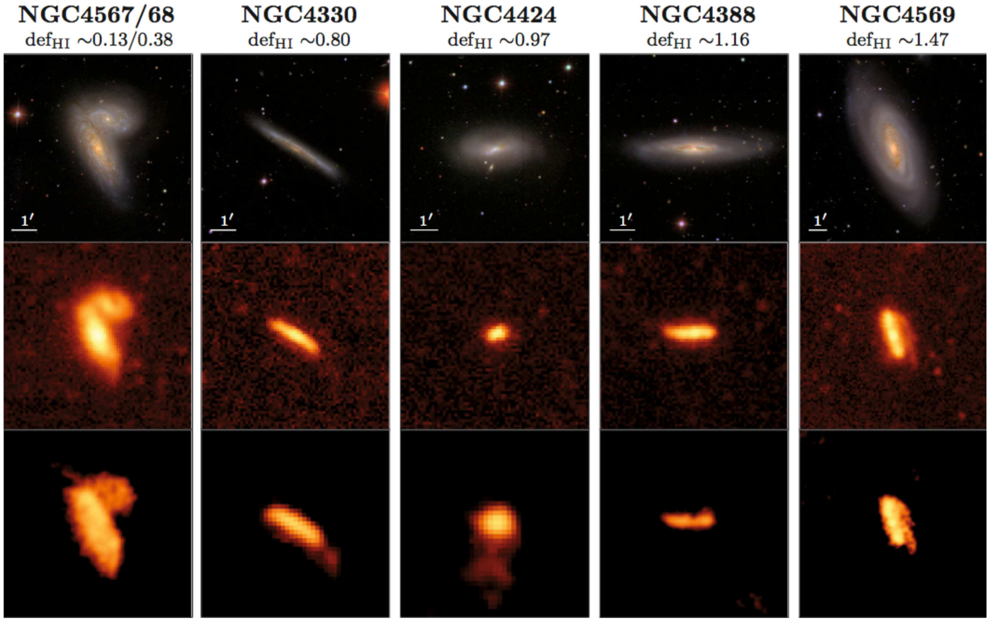

Figure 3: A comparison of the distribution of stars (top), cold dust (center) and atomic gas (bottom) in five Virgo Cluster galaxies. The galaxies are ordered from left to right according to HI deficiency. The extent of the dust disk is significantly reduced in HI-deficient galaxies, suggesting that the cluster environment is able to strip dust as well as gas (Cortese et al. 2010b).

is tightly coupled to the cold atomic gas component in the interstellar medium (see also Groves et al. 2015). Studying galaxies in the Virgo Cluster, clear evidence was found that dust can be efficiently removed from galaxies in a cluster environment (Cortese et al. 2010a,b; Gomez et al. 2010; Figure 3). Interesting trends were also found comparing populations of high- and low-metallicity galaxies. The dust characteristics and the gas-to-dust ratio alter substantially when going from high to low metallicity; these differences derive from a complex interplay between stellar mass, metallicity and star-formation activity (Madden et al. 2013; Rémy-Ruyer et al. 2014, 2015).

The superior spatial resolution of Herschel also enabled studies of the distribution and heating sources of dust in nearby galaxies, and many prototypical galaxies were examined in detail (e.g., Bendo et al. 2010, 2012; Baes et al. 2010b; Boquien et al. 2011; Aniano et al. 2012; Mentuch Cooper et al. 2012; Foyle et al. 2012; Parkin et al. 2012; Hughes et al. 2014). One of the most spectacular and iconic images of the Herschel mission is the 5.5 × 2.5 deg^2 FIR/submm image of the Andromeda galaxy, taken in the frame of the HELGA programme (Fritz et al. 2012). Even at the sparsest Herschel resolution (36” at 500 μm), physical scales of only 140 pc are resolved. Smith et al. (2012b) show that the gas-to-dust ratio appears to increase as a function of radius, from ~20 in the centre to ~70 in the star-forming ring at 10 kpc. This apparent radial variation can be explained by a similar metallicity gradient. Viaene

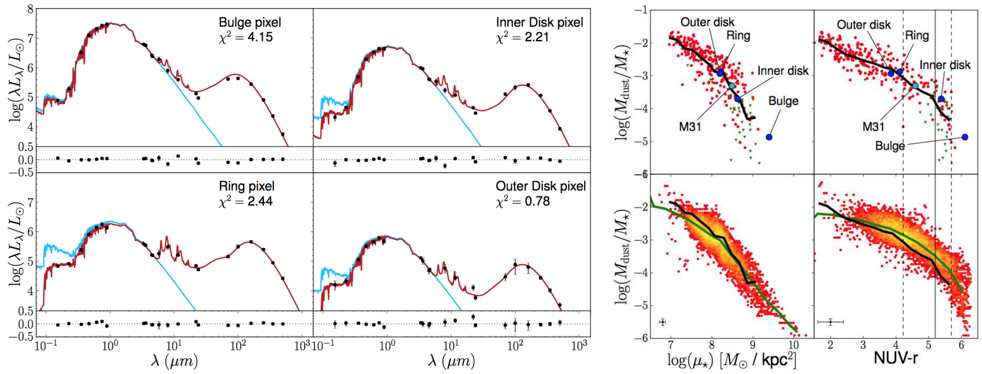

Figure 4: Left: panchromatic SED fits to four individual 36” pixels in different regions of M31. In each pixel, a physically motivated SED model is fitted to the observed fluxes. Right: a comparison of the dust scaling laws between the HRS galaxies (top panels) and the individual pixels in M31 (bottom panels). The similarity strongly suggests that these are in situ correlations, with underlying processes that must be local in nature (Viaene et al. 2014).

et al. (2014) modelled the panchromatic SED of M31 on sub-kpc scale, and found strong correlations between the dust-to-stellar mass ratio and various other properties, in particular the NUV$-r$ colour and the stellar mass surface density. Striking similarities with corresponding relations based on integrated galaxies (Cortese et al. 2012) are found, strongly suggesting that these are in situ correlations, with underlying processes that must be local in nature (Figure 4).

3. 2. PANCHROMATIC RADIATIVE TRANSFER MODELLING OF NEARBY GALAXIES

The availability of radiative transfer codes that can self-consistently model the attenuation and thermal emission by dust in 3D geometries opens up the possibility of dust energy balance studies of nearby galaxies. As the starlight that is absorbed by dust grains in the UV/optical/NIR region is re-emitted in the MIR/FIR/submm wavelength regime, one would expect the absorbed luminosity to be equal to the total thermal luminosity. Accounting for thermal emission in radiative transfer codes is a major complication, as the exact form of the thermal emission term usually depends on the intensity of the radiation field itself in a complicated and nonlinear way (Steinacker et al. 2013). It becomes extremely complex when the dust medium contains very small dust grains, including PAHs. Different approaches have been developed to calculate the emission spectrum due to very small grains and PAHs, and this has been built into several radiative transfer codes, using various approximations and/or assumptions (Misselt et al. 2001; Juvela & Padoan 2003; Baes et al. 2011; Camps et al. 2015).

Panchromatic radiative transfer modelling has mainly been applied to a number of edge-on spiral galaxies (Misiriotis et al. 2001; Alton et al. 2004; Bianchi 2008; Baes et al. 2010a; Popescu et al. 2011; MacLachlan et al. 2011; De Looze et al. 2012a,b; Schechtman-Rook et al. 2012), which have the advantage that the extinction and emission of dust can easily be observed along the line-of-sight, and that the dust can

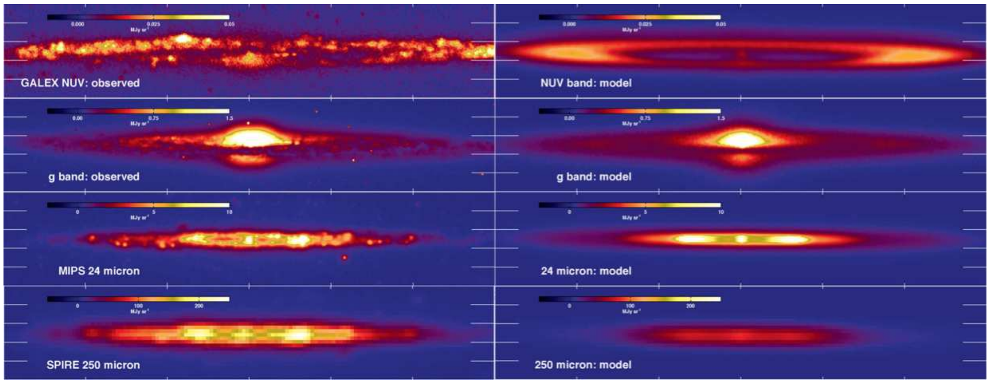

Figure 5: SKIRT dust radiative transfer modelling of the edge-on spiral galaxy NGC 4565 by De Looze et al. (2012b). The panels in the left-hand column are the observed GALEX NUV, SDSS g, MIPS 24 μm and SPIRE 250 μm images. The panels on the right-hand column are the corresponding radiative transfer model fits. The model reproduces the UV, optical and MIR images well, but underestimates the FIR/submm emission substantially.

be vertically resolved and traced out to large radii. The predicted FIR fluxes of self-consistent radiative transfer models that successfully explain the optical extinction generally underestimate the observed FIR fluxes by a factor of about three (Figure 5). The most preferred explanation for this energy balance problem is that a sizeable fraction of the FIR/submm emission arises from additional dust that has a negligible extinction on the bulk of the starlight, such as young stars deeply embedded in dusty molecular clouds. The presence of compact dust clumps can boost the FIR/submm emission of the dust while keeping the extinction relatively unaltered.

Recently, the first efforts have been undertaken to expand panchromatic dust radiative transfer modelling to face-on spirals galaxies. The complex morphology visible in face-on disk galaxies, in combination with the computational cost of the full radiative transfer treatment, makes this a challenging task. De Looze et al. (2014) present a full panchromatic radiative transfer model for M51, in which the dust geometry is constrained through the FUV attenuation. The model successfully reproduces the observed SED and the observed images from UV to submm wavelengths, and shows that young stellar populations provide two thirds of the energy for heating the dust.

Given the availability of extensive multi-wavelength imaging data sets and state-of-the-art 3D radiative transfer codes, more panchromatic radiative transfer modelling of galaxies of different types and in different environments can be expected in the near future.

4. SUMMARY AND CONCLUSIONS

This contribution can be summarised as follows

- Dust is an important ingredient of the interstellar medium. It can be traced by its attenuation effects on the starlight, or by its direct thermal emission at infrared and submm wavelengths. Both approaches have their advantages and challenges.

- Recent years have seen an enormous progress in the field of 3D dust radiative transfer, thanks to an increase in computing power, the development and maturing of different algorithms, and a wealth of multi-wavelength data. The Monte Carlo technique is the most popular and developed approach.
- Toy model studies indicate that the effects of absorption and scattering on the physical properties of galaxies are complex and sometimes counterintuitive. Hydrodynamical galaxy simulations become increasingly realistic, and 3D dust radiative transfer post-processing is important to compare the results of these simulations to the observed Universe.
- The Herschel Space Observatory revolutionised FIR/submm astronomy, and enabled for the first time to trace the dominant cold dust budget in galaxies across the Hubble sequence and in different environments. The dust scaling relations seem similar at the global and the local scale, which suggests that they are in situ correlations driven by local processes.
- Thanks to the coupling of radiative transfer codes to optimisation routines, detailed radiative modelling of individual galaxies has become possible. Most of the efforts so far have concentrated on edge-on disk galaxies, where an inhomogeneous dusty ISM needs to be invoked to reconcile the dust seen in attenuation and in emission.

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PARTICLE ACCELERATION BY SHOCKS

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Abstract. Astrophysical particle acceleration occurs on scales ranging from the heliosphere to clusters of galaxies. Particles can reach extreme energies measured in EeV. A number of different acceleration processes are possible but diffusive shock acceleration is widely invoked as the predominant mechanism. It operates on all these scales and probably to the highest energies. It is simple, robust and predicts a universal spectrum. However there are many unknowns and partial unknowns, especially regarding how acceleration operates in specific astrophysical contexts. Important questions are: what determines the maximum cosmic ray energy, how efficient is the acceleration, why does the observed spectrum not always match that predicted, how do cosmic rays escape the acceleration site, are protons accelerated beyond a few PeV in the Galaxy, what is the source of EeV cosmic rays, what is the balance between electron, proton and heavy ion acceleration? In this review I will show that the answers to these questions depend in large part on the detailed physics of diffusive shock acceleration. Much progress has been made in the past decade in confronting theory with observation and we now stand on the threshold of answering some of the most important questions.

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DARK ENERGY AND DARK MATTER AS CURVATURE EFFECTS

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Abstract. Extended Theories of Gravity, in particular $f(R)$ gravity, could be, in principle, able to explain the accelerated expansion of the Universe without adding unknown forms of dark energy/dark matter but, more simply, extending the General Relativity by generic functions of the Ricci scalar. However, apart from several phenomenological models, there is no final extended theory capable of fitting all the observations and addressing all the issues related to the presence of dark energy and dark matter. Astrophysical observations are pointing out huge amounts of "dark matter" and "dark energy" needed to explain the observed large scale structures and cosmic accelerating expansion. Up to now, no experimental evidence has been found, at fundamental level, to explain such mysterious components. The problem could be completely reversed considering dark matter and dark energy as "shortcomings" of General Relativity.

1. INTRODUCTION

Although being the best fit to a wide range of data, the ΛCDM model is affected by strong theoretical shortcomings that have motivated the search for alternative models (Copeland et al. 2006). Dark Energy (DE) models mainly rely on the implicit assumption that Einstein's General Relativity (GR) is the correct theory of gravity. Nevertheless, its validity on the larger astrophysical and cosmological scales has never been tested, and it is therefore conceivable that both cosmic speed up and Dark Matter (DM) represent signals of a breakdown of GR. Following this line of thinking, the choice of a generic function $f(R)$ as the gravitational Lagrangian, where R is the Ricci scalar, can be derived by matching the data and by the "economic" requirement that no exotic ingredients have to be added. This is the underlying philosophy of what is referred to as $f(R)$ gravity (Capozziello & De Laurentis 2011). It is worth noticing that Solar System experiments show the validity of GR at these scales so that $f(R)$ theories should not differ too much from GR at this level. In other words, the PPN limit of such models must not violate the experimental constraints on Eddington parameters. A positive answer to this request has been recently achieved for several $f(R)$ theories (Capozziello & Troisi 2005), nevertheless it has to be remarked that this debate is far to be definitively concluded. Although higher order gravity theories have received much attention in cosmology, since they are naturally able to give rise to the accelerating expansion (both in the late and in the early universe, it is possible to demonstrate that $f(R)$ theories can also play a major role at astrophysical scales (Capozziello et al. 2007, Capozziello et al. 2009). In fact, modifying the gravity action can affect the gravitational potential in the low energy limit. Provided that the modified potential reduces to the Newtonian one on the Solar System scale, this implication could represent an intriguing opportunity rather than a shortcoming for $f(R)$ theories. In fact, a corrected gravitational potential could offer the possibility to fit galaxy rotation curves without the need of Dark Matter. In addition, one could work out a formal analogy between the corrections to the Newtonian potential and the usually adopted Dark Matter models. In order to investigate the consequences of $f(R)$ theories on both cosmological and astrophysical scales, let us first remind the basics of this approach and then discuss dark energy and dark matter issues as curvature effects.

2. DARK ENERGY AS A CURVATURE EFFECT

From a mathematical viewpoint, $f(R)$ theories generalize the Hilbert - Einstein Lagrangian as $\mathcal{L} = \sqrt{-g}f(R)$ without assuming *a priori* the functional form of Lagrangian density in the Ricci scalar. The field equations are obtained by varying with respect to the metric components to get:

$$f'(R)R_{\alpha\beta} - \frac{1}{2}f(R)g_{\alpha\beta} \, = \, f'(R)^{;\mu\nu}\left(g_{\alpha\mu}g_{\beta\nu} - g_{\alpha\beta}g_{\mu\nu}\right) + T^{M}_{\alpha\beta} \tag{1}$$

where the prime denotes derivative with respect to the argument and $T^{M}_{\alpha\beta}$ is the standard matter stress - energy tensor. Defining the *curvature stress - energy tensor* as

$$T^{curv}_{\alpha\beta} \, = \, \frac{1}{f'(R)}\left\{\frac{1}{6}g_{\alpha\beta}\left[f(R) - Rf'(R)\right] + f'(R)^{;\mu\nu}(g_{\alpha\mu}g_{\beta\nu} - g_{\alpha\beta}g_{\mu\nu})\right\} . \tag{2}$$

Eqs.(1) may be recast in the Einstein - like form as :

$$G_{\alpha\beta} = R_{\alpha\beta} - \frac{1}{2}g_{\alpha\beta}R = T^{curv}_{\alpha\beta} + T^{M}_{\alpha\beta}/f'(R) \tag{3}$$

where matter non - minimally couples to geometry through the term $1/f'(R)$. The presence of term $f'(R)_{;\mu\nu}$ renders the equations of fourth order, while, for $f(R) = R$, the curvature stress - energy tensor $T^{curv}_{\alpha\beta}$ identically vanishes and Eqs.(3) reduce to the standard second - order Einstein field equations. As it is clear, from Eq.(3), the curvature stress - energy tensor formally plays the role of a further source term in the field equations so that its effect is the same as that of an effective fluid of purely geometrical origin. However the metric variation is just one of the approaches towards $f(R)$ gravity: in fact, one can face the problem also considering the so called Palatini approach where the metric and connection fields are considered independent. Apart from some differences in the interpretation, one can deal with a fluid of geometric origin in this case as well. The scheme outlined above provides all the ingredients we need to tackle with the dark side of the Universe. Depending on the scales, such a curvature fluid can play the role of DM and DE. From the cosmological point of view, in the standard framework of a spatially flat homogenous and isotropic Universe, the cosmological dynamics is determined by its energy budget through the Friedmann

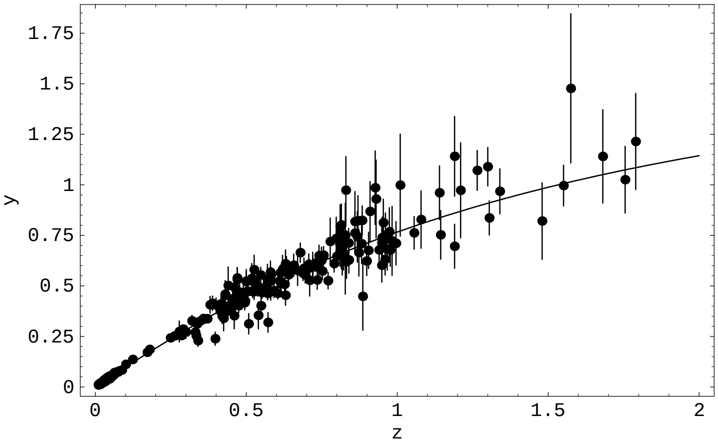

Figure 1: The Hubble diagram of 20 radio galaxies together with the "gold" sample of SNeIa, in term of the redshift as suggested in Daly & Diorgovsky 2004. The best fit curve refers to the $f(R)$ - gravity model without Dark Matter.

equations. The cosmic acceleration is achieved when the r.h.s. of the acceleration equation remains positive (in physical units with $8\pi G = c = 1$):

$$\frac{\ddot{a}}{a} = -\frac{1}{6}\left(\rho_{tot} + 3p_{tot}\right) \ , \tag{4}$$

where a is the scale factor, $H = \dot{a}/a$ the Hubble parameter, the dot denotes derivative with respect to cosmic time, and the subscript *tot* denotes the sum of the curvature fluid and the matter contribution to the energy density and pressure. From the above relation, the acceleration condition, for a dust dominated model, leads to:

$$\rho_{curv} + \rho_M + 3p_{curv} < 0 \rightarrow w_{curv} < -\frac{\rho_{tot}}{3\rho_{curv}} \tag{5}$$

so that a key role is played by the effective quantities:

$$\rho_{curv} = \frac{8}{f'(R)}\left\{\frac{1}{2}\left[f(R) - Rf'(R)\right] - 3H\dot{R}f''(R)\right\} \ , \tag{6}$$

and

$$w_{curv} = -1 + \frac{\ddot{R}f''(R) + \dot{R}\left[\dot{R}f'''(R) - Hf''(R)\right]}{\left[f(R) - Rf'(R)\right]/2 - 3H\dot{R}f''(R)} \ . \tag{7}$$

As a first simple choice, one may neglect ordinary matter and assume a power - law form $f(R) = f_0 R^n$, with n a real number, which represents a straightforward generalization of the Einstein GR in the limit $n = 1$. One can find power - law solutions for $a(t)$ providing a satisfactory fit to the SNeIa data and a good agreement with the estimated age of the Universe in the range $1.366 < n < 1.376$ (Capozziello et. 2003). The data fit turns out to be significant (see Fig. 1) improving the χ^2 value and, it fixes the best fit value at $n = 3.46$ when it is accounted that only the baryon contribute $\Omega_b \approx 0.04$ (according with BBN prescriptions). It has to be remarked that considering DM does not modify the result of the fit, supporting the assumption of no need for DM in this model. From the evolution of the Hubble parameter in term of redshift one can even calculate the Age of Universe. The best fit value $n = 3.46$ provides $t_{univ} \approx 12.41$ Gyr. It is worth noting that considering $f(R) = f_0 R^n$ gravity represents only the simplest generalization of Einstein theory. In other words, it has to be considered that R^n - gravity represents just a working hypothesis as there is no overconfidence that such a model is the correct final gravity theory. In a sense, we want only to suggest that several cosmological and astrophysical results can be well interpreted in the realm of a power law extended gravity model. This approach gives no rigidity about the value of the power n, although it would be preferable to determine a model capable of working at different scales. Furthermore, we do not expect to be able to reproduce the whole cosmological phenomenology by means of a simple power law model, which has been demonstrated not to be sufficiently versatile. For example, we can demonstrate that this model fails when it is analyzed with respect to its capability of providing the correct evolutionary conditions for the perturbation spectra of matter overdensity Pe. This point is typically addressed as one of the most important issues which suggest the need for Dark Matter. In fact, if one wants to discard this component, it is crucial to match the observational results related to the Large Scale Structure of the Universe and the Cosmic Microwave Background which show, respectively at late time and at early time, the signature of the initial matter spectrum. As important remark, we note that the quantum spectrum of primordial perturbations, which provides the seeds of matter perturbations, can be positively recovered in the framework of R^n - gravity. In fact, $f(R) \propto R^2$ can represent a viable model with respect to CMBR data and it is a good candidate for cosmological Inflation. To develop the matter power spectrum suggested by this model, we resort to the equation for the matter contrast obtained in Zhang 2006, in the case of fourth order gravity. This equation can be deduced considering the conformal Newtonian gauge for the perturbed metric:

$$ds^2 = (1 + 2\psi)dt^2 - a^2(1 + 2\phi)\Sigma_{i=1}^3(dx^i) \,. \tag{8}$$

In GR, it is $\phi = -\psi$, since there is no anisotropic stress; in extended gravity, this relation breaks, in general, and the $i \neq j$ components of field equations give new relations between ϕ and ψ. In particular, for $f(R)$ gravity, due to nonvanishing $f_{R;i;j}$ (with $i \neq j$), the $\phi - \psi$ relation becomes scale dependent. Instead of the perturbation equation for the matter contrast δ, we provide here its evolution in term of the growth index $f = d\ln\delta/d\ln a$, that is the directly measured quantity at $z \sim 0.15$:

$$f'(a) - \frac{f(a)^2}{a} + \left[\frac{2}{a} + \frac{1}{a}E'(a)\right] f(a) - \frac{1-2Q}{2-3Q} \cdot \frac{3\Omega_m\, a^{-4}}{n\, E(a)^2 \tilde{R}^{n-1}} = 0 \,, \tag{9}$$

$E(a) = H(a)/H_0$, $\tilde{R}$ is the dimensionless Ricci scalar, and

$$Q = -\frac{2 f_{RR}\, c^2\, k^2}{f_R\, a^2} \,. \tag{10}$$

For $n = 1$ the previous expression gives the ordinary growth index relation for the Cosmological Standard Model. It is clear, from Eq.(9), that such a model suggests

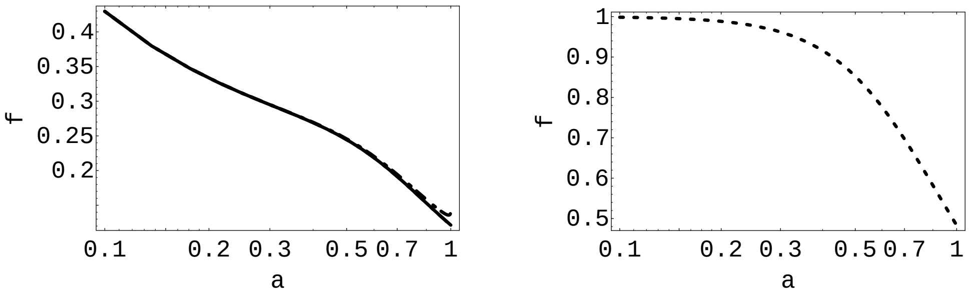

Figure 2: Scale factor evolution of the growth index f : (*left*) modified gravity, in the case $\Omega_m = \Omega_{bar} \sim 0.04$, for the SNeIa best fit model with $n = 3.46$, (*right*) the same evolution in the case of a ΛCDM model. In the case of R^n - gravity it is shown also the dependence on the scale k. The three cases $k = 0.01,\ 0.001,\ 0.0002$ have been checked. Only the latter case shows a very small deviation from the leading behavior.

a scale dependence of the growth index which is contained into the corrective term Q so that, when $Q \to 0$, this dependence can be reasonably neglected. In the most general case, one can resort to the limit $aH < k < 10^{-3} h\, Mpc^{-1}$, where Eq.(9) is a good approximation, and non-linear effects on the matter power spectrum can be neglected. Studying numerically Eq.(9), one obtains the growth index evolution in term of the scale factor; for the sake of simplicity, we assume the initial condition $f(a_{ls}) = 1$ at the last scattering surface as in the case of matter-like domination. The results are summarized in Fig.(2), where we show, in parallel, the growth index evolution in R^n - gravity and in the ΛCDM model. In the case of $\Omega_m = \Omega_{bar} \sim 0.04$, one can observe a strong disagreement between the expected rate of the growth index and the behavior induced by power law fourth order gravity models. These results seem to suggest that an extended gravity model which considers a simple power law of Ricci scalar, although cosmologically relevant at late times, is not viable to describe the evolution of Universe at all scales. In other words, such a scheme seems too simple to give account for the whole cosmological phenomenology. In fact, in Zhang 2006, a gravity Lagrangian considering an exponential correction to the Ricci scalar $f(R) = R + A\exp(-B\,R)$ (with $A,\ B$ two constants), gives more interesting results and displays a grow factor rate which is in agreement with the observational results at least in the Dark Matter case. To corroborate this point of view, one has to consider that when the choice of $f(R)$ is performed starting from observational data (pursuing an inverse approach) as in Capozziello et al. 2005, the reconstructed Lagrangian is a non - trivial polynomial in term of the Ricci scalar. A result which directly suggests that the whole cosmological phenomenology can be accounted only with a suitable non - trivial function of the Ricci scalar rather than a simple power law function. As matter of fact, the results obtained with respect to the study of the matter power spectra in the case of R^n - gravity do not invalidate the whole approach, since they can be referred to the too simple form of the model.

3. DARK MATTER AS A CURVATURE EFFECT

The results obtained at cosmological scales motivates further analysis of $f(R)$ theories. In a sense, one is wondering whether the curvature fluid, which works as DE, can also play the role of effective DM thus yielding the possibility of recovering the observed astrophysical phenomenology by the only visible matter. It is well known that, in the low energy limit, higher order gravity implies a modified gravitational potential. Therefore, in our discussion, a fundamental role is played by the new gravitational potential descending from the given fourth order gravity theories we are referring to. By considering the case of a pointlike mass m and solving the vacuum field equations for a Schwarzschild-like metric, one gets from a theory $f(R) = f_0 R^n$, the modified gravitational potential Capozziello et al. 2007:

$$\Phi(r) = -\frac{Gm}{2r}\left[1 + \left(\frac{r}{r_c}\right)^{\beta}\right] \tag{11}$$

where

$$\beta = \frac{12n^2 - 7n - 1 - \sqrt{36n^4 + 12n^3 - 83n^2 + 50n + 1}}{6n^2 - 4n + 2} \tag{12}$$

which corrects the ordinary Newtonian potential by a power-law term. In particular, this correction sets in on scales larger than r_c which value depends essentially on the mass of the system. The corrected potential (11) reduces to the standard $\Phi \propto 1/r$ for $n = 1$ as it can be seen from the relation (12). The result (11) deserves some comments. As discussed in detail in Capozziello et al. 2007, we have assumed the spherically symmetric metric and imposed it into the field equations (1) considered in the weak field limit approximation. As a result, we obtain a corrected Newtonian potential which accounts for the strong non-linearity of gravity related to the higher-order theory. However, we have to notice that Birkhoff's theorem does not hold, in general, for $f(R)$ gravity but other spherically symmetric solutions than the Schwarzschild one can be found in these extended theories of gravity. The generalization of Eq.(11) to extended systems is achieved by dividing the system in infinitesimal mass elements and summing up the potentials generated by each single element. In the continuum limit, we replace the sum with an integral over the mass density of system taking care of eventual symmetries of the mass distribution (see Capozziello et al. 2007 for details). Once the gravitational potential has been computed, one may evaluate the rotation curve $v_c^2(r)$ and compare it with the data. For extended systems, one has typically to resort to numerical techniques, but the main effect may be illustrated by the rotation curve for the pointlike case, that is:

$$v_c^2(r) = \frac{Gm}{2r}\left[1 + (1-\beta)\left(\frac{r}{r_c}\right)^{\beta}\right] . \tag{13}$$

Compared with the Newtonian result $v_c^2 = Gm/r$, the corrected rotation curve is modified by the addition of the second term in the r.h.s. of Eq.(13). For $0 < \beta < 1$, the corrected rotation curve is higher than the Newtonian one. Since measurements of spiral galaxies rotation curves signal a circular velocity higher than those which are predicted on the basis of the observed luminous mass and the Newtonian potential, the above result suggests the possibility that our modified gravitational potential may fill the gap between theory and observations without the need of additional DM. It is worth noting that the corrected rotation curve is asymptotically vanishing as in the Newtonian case, while it is usually claimed that observed rotation curves are flat (i.e., asymptotically constant). Actually, observations do not probe v_c up to infinity, but only show that the rotation curve is flat within the measurement uncertainties up to the last measured point. This fact by no way excludes the possibility that v_c goes to zero at infinity. In order to observationally check the above result, we have considered a sample of LSB galaxies with well measured HI + Hα rotation curves extending far beyond the visible edge of the system. LSB galaxies are known to be ideal candidates to test Dark Matter models since, because of their high gas content, the rotation curves can be well measured and corrected for possible systematic errors by comparing 21 - cm HI line emission with optical Hα and [NII] data. Moreover, they are supposed to be Dark Matter dominated so that fitting their rotation curves without this elusive component is a strong evidence in favor of any successful alternative theory of gravity. Our sample contains 15 LSB galaxies with data on both the rotation curve, the surface mass density of the gas component and R - band disk photometry extracted from a larger sample selected by de Blok & Bosma 2002 . We assume the stars are distributed in an infinitely thin and circularly symmetric disk with surface density $\Sigma(r) = \Upsilon_\star I_0 exp(-r/r_d)$ where the central surface luminosity I_0 and the disk scalelength r_d are obtained from fitting to the stellar photometry. The gas surface density has been obtained by interpolating the data over the range probed by HI measurements and extrapolated outside this range. When fitting to the theoretical rotation curve, there are three quantities to be determined, namely the stellar mass - to - light (M/L) ratio, $\Upsilon_\star$ and the theory parameters (β, r_c). It is worth stressing that, while fit results for different galaxies should give the same β, r_c is related to one of the integration constants of the field equations. As such, it is not a universal quantity and its value must be set on a galaxy - by - galaxy basis. However, it is expected that galaxies having similar properties in terms of mass distribution have similar values of r_c so that the scatter in r_c must reflect somewhat the scatter in the circular velocities. In order to match the model with the data, we perform a likelihood analysis determining for each galaxy, using, as fitting parameters β, $\log r_c$ (with r_c in kpc) and the gas mass fraction[1] f_g. As it is evident considering the results from the different fits, the experimental data are successfully fitted by the model (see Capozziello et al. 2007 for details). In particular, for the best fit range of β ($\beta = 0.80 \pm 0.08$), one can conclude that R^n gravity with $2.3 < n < 5.3$ (best fit value $n = 3.2$ which well overlaps the above mentioned range of n fitting SNeIa Hubble diagram) can be a good candidate to solve the missing matter problem in LSB galaxies without any Dark Matter. At this point, it is worth wondering whether a link may be found between R^n gravity and the standard approach based on Dark Matter haloes since both theories fit equally well the same data. As a matter of fact, it is possible to define an *effective Dark Matter halo* by imposing that its rotation curve equals the correction term to the Newtonian curve induced by R^n gravity. Mathematically, one can split the total rotation curve derived from R^n gravity as $v_c^2(r) = v_{c,N}^2(r) + v_{c,corr}^2(r)$ where the second term is the correction. Considering, for simplicity a spherical halo embedding a thin exponential disk, we may also write the total rotation curve as $v_c^2(r) = v_{c,disk}^2(r) + v_{c,DM}^2(r)$ with

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[1] This is related to the M/L ratio as $\Upsilon_\star = [(1 - f_g)M_g]/(f_g L_d)$ with $M_g = 1.4 M_{HI}$ the gas (HI + He) mass, $M_d = \Upsilon_\star L_d$ and $L_d = 2\pi I_0 r_d^2$ the disk total mass and luminosity.

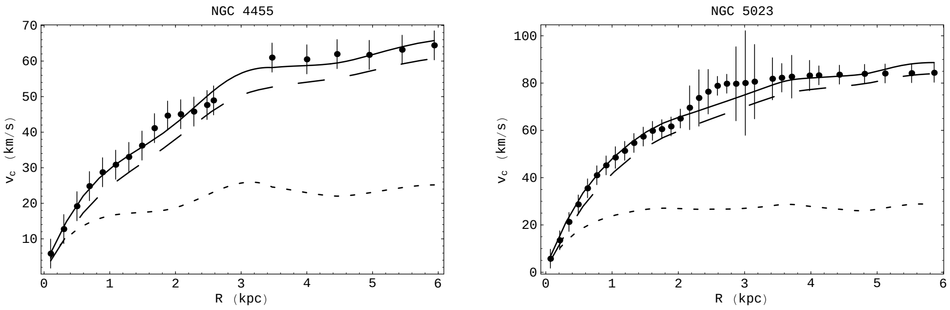

Figure 3: Best fit theoretical rotation curve superimposed to the data for the LSB galaxy NGC 4455 (left) and NGC 5023 (right). To better show the effect of the correction to the Newtonian gravitational potential, we report the total rotation curve $v_c(r)$ (solid line), the Newtonian one (short dashed) and the corrected term (long dashed).

$v^2_{c,disk}(r)$ the Newtonian disk rotation curve and $v^2_{c,DM}(r) = GM_{DM}(r)/r$ the Dark Matter one, $M_{DM}(r)$ being its mass distribution. Equating the two expressions, we get:

$$M_{DM}(\eta) = M_{vir}\left(\frac{\eta}{\eta_{vir}}\right)\frac{2^{\beta-5}\eta_c^{-\beta}(1-\beta)\eta^{\frac{\beta-5}{2}}\mathcal{I}_0(\eta)-\mathcal{V}_d(\eta)}{2^{\beta-5}\eta_c^{-\beta}(1-\beta)\eta^{\frac{\beta-5}{2}}\mathcal{I}_0(\eta_{vir})-\mathcal{V}_d(\eta_{vir})}\,. \tag{14}$$

with $\eta = r/r_d$, $\Sigma_0 = \Upsilon_\star i_0$, $\mathcal{V}_d(\eta) = I_0(\eta/2)K_0(\eta/2) \times I_1(\eta/2)K_1(\eta/2)^2$ and:

$$\mathcal{I}_0(\eta,\beta) = \int_0^\infty \mathcal{F}_0(\eta,\eta',\beta)k^{3-\beta}\eta'^{\frac{\beta-1}{2}}\mathrm{e}^{-\eta'}d\eta' \tag{15}$$

with $\mathcal{F}_0$ only depending on the geometry of the system and "*vir*" indicating virial quantities. Eq.(14) defines the mass profile of an effective spherically symmetric Dark Matter halo whose ordinary rotation curve provides the part of the corrected disk rotation curve due to the addition of the curvature corrective term to the gravitational potential. It is evident that, from an observational viewpoint, there is no way to discriminate between this dark halo model and R^n gravity. Having assumed spherical symmetry for the mass distribution, it is immediate to compute the mass density for the effective dark halo as $\rho_{DM}(r) = (1/4\pi r^2)dM_{DM}/dr$. The most interesting features of the density profile are its asymptotic behaviors that may be quantified by the logarithmic slope $\alpha_{DM} = d\ln\rho_{DM}/d\ln r$ which can be computed only numerically as function of η for fixed values of β (or n). As expected, α_{DM} depends explicitly on β, while (r_c, Σ_0, r_d) enter indirectly through η_{vir}. The asymptotic values at the center and at infinity denoted as α_0 and α_∞ result particularly interesting. It turns out that α_0 almost vanishes so that in the innermost regions the density is approximately constant. Indeed, $\alpha_0 = 0$ is the value corresponding to models having an inner core such as the cored isothermal sphere and the Burkert model (Burkert 1995). Moreover, it is well known that galactic rotation curves are typically best fitted by cored dark halo models. On the other hand, the outer asymptotic slope is between -3 and -2,

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[2] Here I_l and K_l, with $l = 1, 2$ are the Bessel functions of first and second type.

that are values typical of most dark halo models in the literature. In particular, for $\beta = 0.80$ one finds $(\alpha_0, \alpha_\infty) = (-0.002, -2.41)$, which are quite similar to the value for the Burkert model $(0, -3)$. It is worth noting that the Burkert model has been empirically proposed to provide a good fit to the LSB and dwarf galaxies rotation curves. The values of $(\alpha_0, \alpha_\infty)$ we find for the best fit effective dark halo therefore suggest a possible theoretical motivation for the Burkert-like models. Due to the construction, the properties of the effective Dark Matter halo are closely related to the disk one. As such, we do expect some correlation between the dark halo and the disk parameters. To this aim, exploiting the relation between the virial mass and the disk parameters , one can obtain a relation for the Newtonian virial velocity $V_{vir} = GM_{vir}/r_{vir}$:

$$M_d \propto \frac{(3/4\pi\delta_{th}\Omega_m\rho_{crit})^{\frac{1-\beta}{4}} r_d^{\frac{1+\beta}{2}} \eta_c^{\beta}}{2^{\beta-6}(1-\beta)G^{\frac{5-\beta}{4}}} \frac{V_{vir}^{\frac{5-\beta}{2}}}{\mathcal{I}_0(V_{vir}, \beta)} \ . \tag{16}$$

We have numerically checked that Eq.(16) may be well approximated as $M_d \propto V_{vir}^a$ which has the same formal structure as the baryonic Tully - Fisher (BTF) relation $M_b \propto V_{flat}^a$ with M_b the total (gas + stars) baryonic mass and V_{flat} the circular velocity on the flat part of the observed rotation curve. In order to test whether the BTF can be explained thanks to the effective Dark Matter halo we are proposing, we should look for a relation between V_{vir} and V_{flat}. This is not analytically possible since the estimate of V_{flat} depends on the peculiarities of the observed rotation curve such as how far it extends and the uncertainties on the outermost points. For given values of the disk parameters, we therefore simulate theoretical rotation curves for some values of r_c and measure V_{flat} finally choosing the fiducial value for r_c that gives a value of V_{flat} as similar as possible to the measured one. Inserting the relation thus found between V_{flat} and V_{vir} into Eq.(16) and averaging over different simulations, we finally get :

$$\log M_b = (2.88 \pm 0.04) \log V_{flat} + (4.14 \pm 0.09) \tag{17}$$

while a direct fit to the observed data gives McGaugh 2005 :

$$\log M_b = (2.98 \pm 0.29) \log V_{flat} + (3.37 \pm 0.13) \ . \tag{18}$$

The slopes of the predicted and observed BTF are in good agreement thus leading further support to our approach. The zeropoint is markedly different with the predicted one being significantly larger than the observed one. However, it is worth stressing that both relations fit the data with similar scatter. A discrepancy in the zeropoint can be due to our approximate treatment of the effective halo which does not take into account the gas component. Neglecting this term, we should increase the effective halo mass and hence V_{vir} which affects the relation with V_{flat} leading to a higher than observed zeropoint. Indeed, the larger M_g/M_d is the more the points deviate from our predicted BTF thus confirming our hypothesis. Given this caveat, we can conclude, with confidence, that R^n gravity offers a theoretical foundation even for the empirically found BTF relation. Although the results outlined along this paper are referred to a simple choice of fourth order gravity models ($f(R) = f_0 R^n$), they could represent an interesting paradigm. In fact, even if such a model is not suitable to provide the correct form of the matteCapozziello, S., Cardone, V. F., Troisi, A.: 2005, *Phys. Rev.* D, **71**, 043503. r power spectra, and this suggests that a more complicated Lagrangian is needed to reproduce the whole dark sector phenomenology at all scales, we have shown that considering extensions of GR can allow to explain some important issues of cosmological and astrophysical phenomenology. We have seen that extended gravity models can reproduce SNeIa Hubble diagram without Dark Matter, giving significant predictions even with regard to the age of Universe. In addition, the modification of the gravitational potential which arises as a natural effect in the framework of higher order gravity can represent a fundamental tool to interpret the flatness of rotation curves of LSB galaxies. Furthermore, if one considers the model parameters settled by the fit over the observational data on LSB rotation curves, it is possible to construct a phenomenological analogue of Dark Matter halo whose shape is similar to the one of the Burkert model. Since the Burkert model has been empirically introduced to give account of the Dark Matter distribution in the case of LSB and dwarf galaxies, this result could represent an interesting achievement since it gives a theoretical foundation to such a model. By investigating the relation among dark halo and the disk parameters, we have deduced a relation between M_d and V_{flat} which reproduces the baryonic Tully - Fisher. In fact, exploiting the relation between the virial mass and the disk parameters, one can obtain a relation for the virial velocity which can be satisfactorily approximated as $M_d \propto V_{vir}^a$. Even such a result seems very intriguing since it gives again a theoretical interpretation for a phenomenological relation. As a matter of fact, although not definitive, these results on $f(R)$ can represent a viable approach for future investigations and in particular support the quest for a unified view of the Dark Side of the Universe that could be interpreted as gravitational effects indeed.

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QUIET SUN MAGNETIC FIELDS

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Abstract. The quiet Sun is a highly turbulent plasma that exhibits a rich and complex magnetic structuring which is still not fully resolved nor understood. It has been shown recently that the magnetic flux of the quiet Sun is at least three orders of magnitude larger than the one of active regions. The amount of magnetic energy stored in quiet Sun magnetic structures is still unknown, but long standing questions on the physical origin of coronal heating and solar wind acceleration are probably related to magnetic mechanisms taking place in the quiet Sun. In the last ten years many studies, both observational and theoretical, have been devoted to the investigation of this essential aspect of the solar magnetism. Thanks to the advent of high-resolution, high-sensitivity spectropolarimetric observations from space and ground our vision of the solar magnetism is changing nowadays but many questions and matters of debate still remain.

1. INTRODUCTION

The quiet Sun (QS) is defined as the region outside sunspots and pores where strong coherent magnetic fields over large scales are observed. But the QS is far from being magnetic free. High spatial resolution and high sensitivity QS magnetograms show magnetic fields in network and internetwork (IN) elements. The network elements have strong fields of the order of 1 kG and are located at the borders of the supergranular cells with typical diameters of 30 000 km, while the internetwork ones, in the cell interior, show much weaker fields (for a review see Sánchez Almeida & Martínez González 2011). It has been estimated that a significant fraction of the total magnetic flux of the solar surface resides in the quiet Sun and a recent study by Gosic et al. (2014) from deep magnetograms at 0.3" spatial resolution, estimates that 14% of the quiet Sun magnetic flux is in the form of internetwork elements.

The origin of both network and internetwork elements is not clear. Numerical simulations by Vögler & Schüssler (2007), or Steiner et al. (2008), have shown that the vigorous convective motions in the solar photosphere, where the dynamic pressure of the flows exceeds the magnetic pressure, can cause an efficient amplification of the magnetic energy at small scales from a magnetic seed. This small-scale dynamo action could be the source of the quiet Sun magnetic fields, but another possible source could be the turbulent dissipation of active regions present at large scale associated to the global solar dynamo.

Quiet Sun magnetic fields are difficult to measure because they are organized on small spatial scales and seem to evolve rapidly. The polarimetric signals they produce are very weak and their interpretation involves ill-posed inversion problems. Developments of theoretical approaches and numerical simulations are in progress but they are presently not realistic enough to be quantitatively compared to observations.

So many issues are still under vigorous debate among the solar physicist community, in consequence the present paper is not intended to give a comprehensive view of the quiet Sun magnetism, but rather to show how our vision on this subject has been evolving and to present some of the debates presently going on.

2. A BRIEF HISTORICAL SURVEY

2. 1. LOW SPATIAL RESOLUTION ERA

In the presence of a magnetic field, spectral lines may be polarized by two different physical mechanisms, namely the Zeeman and Hanle effects. In the presence of Zeeman effect, magnetic sensitive lines show both circular and linear polarization profiles, the profile shapes depend on the strength and direction of the magnetic field with respect to the line-of-sight (see Landi Degl'Innocenti & Landolfi, 2004). In the weak field regime, when the Zeeman splitting is smaller than the line Doppler width, the amplitude of the circular polarization measured in the line wings may be approximated by

$$V(\lambda) = -f \Delta\lambda_B \cos\gamma \frac{dI_0}{d\lambda}, \tag{1}$$

where the Zeeman splitting $\Delta\lambda_B$ is given by

$$\Delta\lambda_B = 4.67\,10^{-13} \lambda_0^2 g_{eff} B. \tag{2}$$

The coefficient g_{eff} denotes the Landé factor of the line, B is the magnetic field strength (in Gauss) and γ is its angle with respect to the line of sight, λ_0 is the line center wavelength, in Å. If the magnetic field is not spatially resolved only the fraction of the pixel surface where the magnetic field is present is producing the signal. So the measured signal is proportional to the filling factor f of the magnetic element over the pixel. A strong field concentrated over a small fraction of the surface would give the same signal as a weak field covering the whole pixel surface.

One method to discriminate between both cases was introduced by Stenflo (1973). He pointed out that the ratio of circular polarization measured in two lines of the same multiplet with different sensitivity to Zeeman effect, but formed in identical conditions, is given by the ratio of their Landé factors if the magnetic field is weak, but saturates to one if the field is intrinsically strong. This allowed him to show that network elements have strong fields concentrated on sizes of the order of one hundred kilometers in diameter. However internetwork fields which have mixed polarities at small scales give very low circular polarization signal which could not be measured reliably. So the predominant view was that QS magnetic fields were formed of kilo-Gauss concentrated magnetic elements in the network and mixed polarity weak field in the internetwork.

Among the more recent studies performed from ground based observations, let us quote Bommier et al. (2009) and Bommier (2011) who used Themis observations to investigate the statistical properties of the QS magnetic fields. The inversion method which was implemented to interpret the observations allows to derive independently the filling factor and the magnetic field strength and direction. The results were quite different from the one recorded above. It was found that the photospheric internetwork field is mainly formed of scattered narrow fluxtubes consisting in a vertical field, which weakens in opening and widening with individual field line bending with height. The weakest fields then have a 2D horizontal structure, instead of the usually admitted 3D turbulent one.

These weak mixed polarity fields were investigated through the measurement of their Hanle effect on spectral lines. The Hanle effect gives rise to a depolarization and a rotation of the linear polarization plane in lines formed by scattering of photons (see Landi Degl'Innocenti & Landolfi 2004). It is a non-linear effect so the depolarization is not averaged out in the presence of mixed polarity fields. The magnetic field strength diagnostics then relies on the comparison of the observed polarization with the zero-field value derived from numerical modeling and polarized radiative transfer calculations (see Faurobert-Scholl et al. 1995, Faurobert et al. 2001). Line ratio methods may also be applied to the Hanle effect observed in several spectral lines with different magnetic sensitivity (see Stenflo et al., 1998, Berdyugina & Fluri, 2004). Typical intrinsic field strength of the order of 20 G were found in the internetwork from spatial averaging over large fields of view and long exposure times. The same observations were then interpreted with more sophisticated radiative transfer codes allowing for 3D structures in the solar granulation and larger mean field strength, of the order of 130 G were obtained (see Trujillo-Bueno et al. 2004). Detailed modeling of the center-to-limb variations of the linear polarization in C2 and MgH molecular lines observed at Themis by Faurobert & Arnaud (2002), together with a more sophisticated inversion method then showed that the mean field strength has a strong depth-gradient in the upper photosphere, where it varies from more than 100 Gauss at 200 km to 10 Gauss at 400 km above the base of the photosphere (Milic & Faurobert, 2012). This result is compatible with the results of Bommier (2011), as the weak fields detected from their Zeeman effect have mixed orientations in an horizontal plane and a depth-decreasing strength in the upper photosphere.

In the last decade significant progress have been made in the sensitivity and spatial resolution of polarization measurements. This progress was due to the implementation of adaptative optic systems on ground-based solar telescopes, and to the launch of space based and balloon instruments (SOHO, Hinode, SDO, Sunrise).

2. 2. HIGH SPATIAL RESOLUTION ERA

One of the important achievements of high spatial resolution polarization measurements is that the Zeeman effect can now be observed in internetwork elements as well as in the network. Figure 1 shows a comparison of quiet Sun magnetograms at low and high spatial resolution, respectively from ground based and space base instruments. At high resolution the internetwork appears filled of magnetic elements that are not detected at lower spatial resolution. The improvement of spatial resolution allowed to explore the distribution of the magnetic flux in the QS. Figure 2 shows that the distribution of flux has a fractal behavior with no characteristic scale, and that the contribution of the QS to the total solar magnetic flux is at least three orders of magnitude larger than the contributions of active regions (see Parnell et al. 2009)!

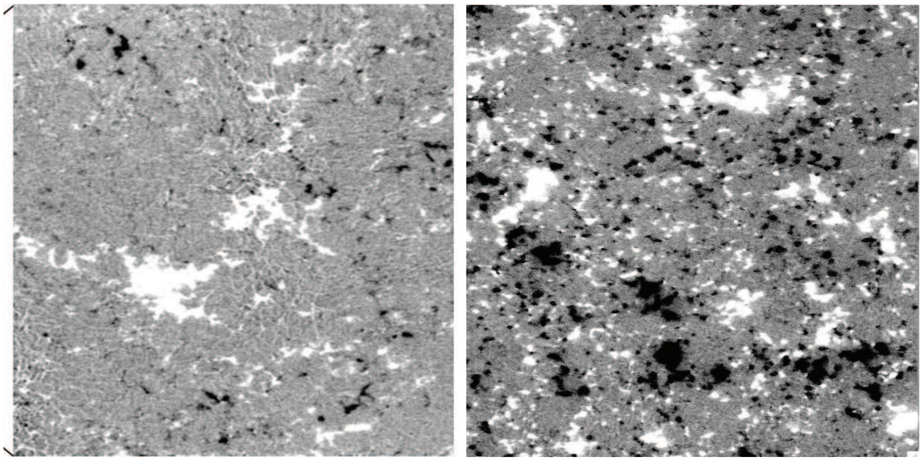

Figure 1: QS magnetograms: the longitudinal magnetic flux is coded in white for outward directions and in black for inward ones. Left panel: from ground-based instrument with 2" resolution, right panel: from Hinode NFI instrument with 0.2" resolution. Network magnetic elements are detected in the left hand figure, whereas IN elements also appear in the right hand figure

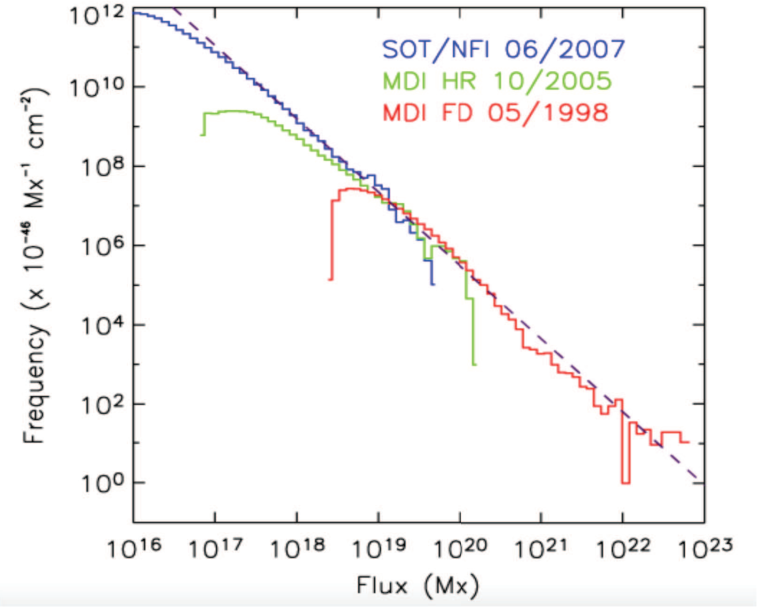

Figure 2: Distribution of longitudinal magnetic fluxes observed in Hinode/NFI magnetograms of the quiet Sun (blue curve) and SOHO/MDI high resolution and full disk magnetograms (green and red lines, respectively), from Parnell et al. 2009.

Many QS studies have been carried out in the last decade based on the high quality polarization measurements from the Hinode satellite (Lites et al. 2013). Its 50-cm SOT telescope with spectro-polarimetric facilities allows Zeeman magnetic field diagnostics using the FeI line pair at 630 nm. Both circular and linear polarization profiles are recorded, and the magnetic field is derived through different inversion methods depending on the authors. However even with the highest available spatial resolution (0.3" with the SOT telescope), it seems clear that we do not yet resolve the smallest magnetic structures (see Stenflo 2010). One of the evidences of this limitation is obtained from the high resolution observations of magnetic flux disappearance events. Magnetic flux is observed to disappear from the solar internetwork through cancellation and in-situ fading. Cancellation of flux arises when two magnetic patches of opposite polarities encounter each other due to their continuous motions, this phenomenon is observed in the Intranetwork (see Gömöry et al. 2010). The submergence of small-scale Ω-loops (see Iida et al. 2010) or the rise of a U-loop are also observed, they do not correspond to real flux removal from the solar surface. The most intriguing phenomenon is in-situ disappearance that has been observed in high resolution magnetogram movies where small magnetic flux elements disappear without interacting with other features. Statistical studies have shown that this is the most frequent mode of flux disappearance in the intranetwork (see Zhou et al. 2010, Lamb et al. 2013)! Some of these events are probably due to the presence of opposite polarity features which are not resolved by the instrument.Various magnetic instabilities taking place in small scale flux tube can also lead to in-situ disappearance, such as the interchange instability (Steiner 2007) or the Kelvin-Helmoltz instability.

Bearing in mind that, even with the best present instruments, the smallest magnetic scales are not yet resolved, various inversion methods have been designed to recover the magnetic field vector from the measured polarization profiles. However, different inversions methods may lead to different results for some of the statistical properties of the QS magnetic fields, as shown in the following.

3. WEAK OR STRONG FIELDS?

Typically, three kinds of inversion methods have been applied to Zeeman polarization data to infer the intrinsic magnetic field strength. The line ratio technique (Stenflo 2010) is based on the analysis of the ratio of circular polarization in the wings of two lines of the same multiplet with different Landé factors, the MISMA model (Sanchéz Almeida et al. 1996) for Micro-Structured Magnetic Atmospheres, assumes that each pixel contains a distribution of magnetic fibrils with different strengths and orientations, temperatures and velocities, whereas Milne-Eddington models assume that a fraction f of the pixel contains a depth-independent magnetic field with given strength and direction and the remaining fraction of the pixel is non-magnetic.

The line ratio technique applied to FeI lines at 524.7 nm and 525.02 nm first showed that in the network the magnetic field is strong, on the order of 1 kG, and with small filling factors on the order of 1%. Applied to internetwork regions, its results are more ambiguous, Keller et al. (1994) used observations at the German Vacuum Telescope with the ZIMPOL polarimeter and found an upper limit of 500 G for the strength of IN magnetic fields, but new observations performed at the Mc Math-Pierce telescope by Grossman-Doerth et al. (1996) led to strong fields of 1 kG. Many different studies were carried out with different pairs of lines in the optical

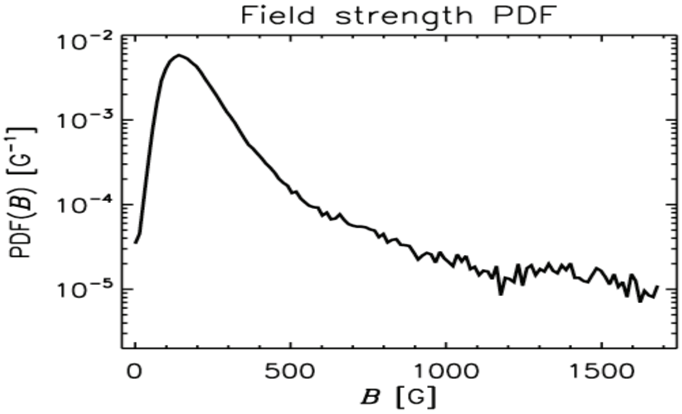

Figure 3: PDF of the magnetic strength in the internetwork derived from Hinode observations by Orozco Suárez & Bellot Rubio (2012).

and in the infrared domain where lines are more sensitive to the Zeeman effect, but the controversy between weak hG or strong kG fields was not solved. Finally Bellot Rubio & Collados (2003) showed that the line ratio technique is very much affected by photon noise in regions where the polarization signals are weak. So only pixels where the signal-to-noise ratio is larger than 10 should be inverted with this technique.

More recently a modified version of the line-ratio technique was applied to high spatial resolution observations performed in the FeI 630.15 an and 630.25 nm lines with the SOT/SP instrument onboard the Hinode satellite (Stenflo, 2010, Stenflo et al., 2013). The Probability Distribution Function (PDF) for the magnetic strength in the QS derived from these analysis shows two populations of magnetic regions, with respectively kG and hG field strengths.

Two populations of magnetic regions were also detected by Faurobert & Ricort (2013) from a cross-correlation analysis of Hinode/SP data. Polarization maps of the QS obtained at various limb-distances in the QS were cross-correlated with granulation images measured simultaneously. One magnetic population is well correlated with the granules whereas a second one is correlated with the intergranular lanes. This could correspond to the collapsed and uncollapsed populations described by Stenflo (2010). The physical origin of these two populations is supposed to be the convective collapse phenomenon (Parker 1975), which predicts that due to convective advection optically thick magnetic regions will get concentrated over small patches of kG strength in the inter granular lanes (downward velocities), whereas optically thin ones will not be sensitive to this instability mechanism.

The MISMA inversions performed by Sanchéz Almeida & Lites (2000) and Socas Navarro & Sanchéz Almeida (2002), considering two-magnetic components and one non-magnetic one inside each pixel, were applied to observations in the FeI 630 nm lines and the results were that a large fraction of the IN fields are in the strong kG field regime, but that weak fields also exist, both were found to occupy a few percents of the solar surface. The authors also concluded that an unknown amount of magnetic flux was still not detected. The MISMA inversion was also applied to observations

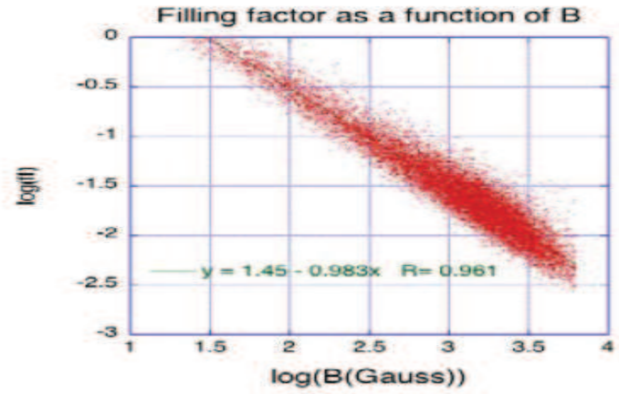

Figure 4: Filling factor of the magnetic fields in the quiet Sun as a function of the magnetic strength, from Bommier (2011).

obtained simultaneously at the German VTT in spectral lines of the visible and of the infrared domains (Domíngez Cerdena et al., 2006). Visible lines are more sensitive to the Zeeman effect of strong fields whereas infrared lines are sensitive to weaker fields. Actually both strong and weak fields were derived in the same pixels from the two spectral domains, and mixed polarity fields were also often detected.

The Milne-Eddington inversion method assuming one magnetic component with a filling factor f over the surface of the pixel was applied to invert both the circular and linear polarization recorded in the FeI 630 nm line pair with SOT/SP (Orozco Suárez et al., 2007, Lites et al. 2008, Ishikawa, R. & Tsuneta, S. 2011, Borrero & Kobel, 2012, Orozco Suárez & Bellot Rubio, 2012). Figure 3 shows the PDF of the magnetic field strength derived by Orozco Suárez & Bellot Rubio (2012). The magnetic strength peak at 100 G, and shows an extended tail to kG values. The high spatial resolution (0.3") and high sensitivity of the observations allowed to measure the linear and circular polarization in both lines. The temperature gradient was taken into account and both lines were inverted with the same atmospheric and magnetic parameters, but only the pixels where the signal-to-noise ratio is larger than 4.5 were considered. They represent a significant fraction, 27 % , of the observed area. Another noticeable result of this study is that the filling factor of weak fields is around 20% at 0.3" resolution, this is consistent with results found previously by Bommier (2011) from the inversion of Themis observations, where she showed that the filling factor of magnetic fields in the QS varies as the inverse of the magnetic strength (see Fig. 4).

The validity of Milne-Eddington inversions in the QS, based on the Zeeman polarizations of the FeI 630 nm line pair has been put into questions by various authors, (e. g. Martinez Gonzales et al. 2006, Lopez Ariste et al. 2007) because the line profiles are sensitive to temperature effects and this results in ambiguity in the inversion procedure between the temperature gradient and the magnetic field strength. As more observables are required, Lopez Ariste et al. (2007) proposed to use simultaneously the MnI line at 553.7 nm which is particularly well suited for magnetic strength diagnostics because of its strong coupling between hyperfine structure and Zeeman

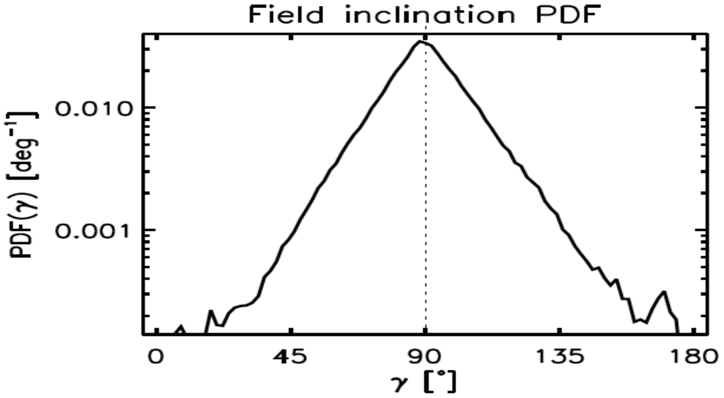

Figure 5: PDF of the magnetic inclination in the internetwork derived from Hinode observations by Orozco Suárez & Bellot Rubio (2012).

effect. In the presence of magnetic fields below 600 G the Stokes V profile shows an anomalous spectral feature between the two main Zeeman lobes. Such a feature disappears when the atom enters into Paschen-Back regime for magnetic strength stronger than 600 G. They applied this method to QS observations performed with the Themis telescope simultaneously in the FeI 630 nm line and in the MnI 553.7 nm line, showing that in some cases Milne-Eddington inversions of the FeI 630 nm data were not be able to distinguish between strong kG fields and hG ones, whereas the behavior of MnI stokes V profiles allows to conclude unambiguously.

4. ISOTROPIC OR HORIZONTAL FIELDS?

Another matter of debate is the orientation of the magnetic vector in IN regions. Here again various methods give different results. First let us recall that in order to retrieve the vector magnetic field from polarization measurements one needs to measure both the circular and linear polarization with good accuracy. At disk center (when the line of sight is perpendicular to the solar surface), the circular polarization is due to the vertical magnetic component whereas the linear polarization is due to the horizontal one. However, in the QS the linear polarization of spectral lines due to the Zeeman effect is intrinsically smaller by at least a factor 10 than the circular polarization, moreover it is more affected by instrumental polarization problems due to oblique reflexion of light inside the instruments. At low spatial resolution the linear polarization of the IN regions was hardly detected. So one of the first surprises which came from high resolution polarization measurements from space was that linear polarization was detected everywhere in the IN. The total amount of apparent horizontal flux was found to be five times larger than the apparent vertical one (Lites et al., 2008).

A PDF of magnetic vector inclination with respect to the vertical in the IN has been obtained from Milne-Eddington inversions of Hinode data by Orozco Suárez & Bellot Rubio (2012), it shows a striking peak at 90 which implies that most of the IN fields are horizontal. However, MISMA inversions and line ratio analysis,

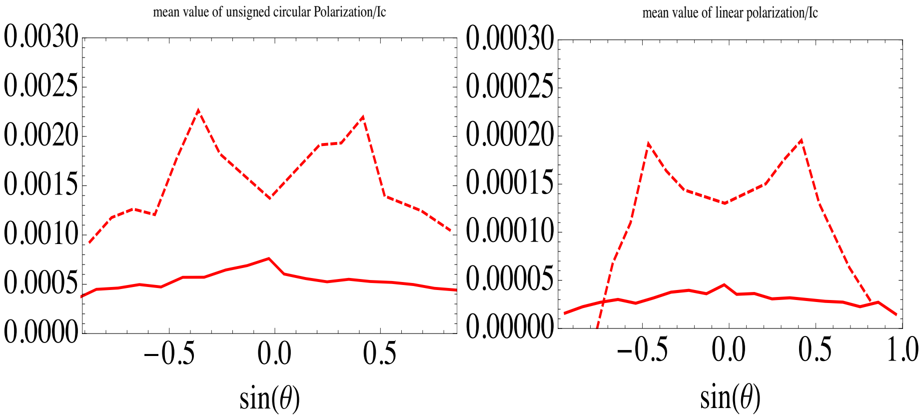

Figure 6: Center-to-limb variations of the mean polarization signals in the QS in December 2007 (full lines) and in December 2013 (dashed lines) measured with SOT/SP onboard the Hinode satellite. Left panel: unsigned circular polarization in the FeI 630.25 nm line, right panel: linear polarization in the FeI 630.25 nm line. One clearly sees the increase of signal in the Quiet Sun at active latitudes at the solar maximum.

on the contrary lead to mostly vertical fields! Bommier (2011) found that strong fields are mostly vertical and weak fields mostly horizontal. Stenflo (2013) used the polarization-free French solar telescope Themis to perform center-to-limb measurements of the linear polarization profiles in the FeI lines at 524.7 nm and 525.0 nm. Without any inversion, the symmetry properties of the linear polarization profiles observed away from the solar disk center, allow to distinguish between horizontal and vertical fields. He found that in the IN the magnetic fields are mostly vertical in the low photosphere, and become more and more horizontal in the upper photosphere. The spatial resolution of the Themis observations was 2” whereas the Hinode data have a better spatial resolution of 0.3”, this could be a source of discrepancy between both studies, if the magnetic fields in the weakest IN regions have mixed polarities on scales smaller than 1”. Further studies are needed to clarify this issue.

5. EVOLUTION WITH THE SOLAR CYCLE?

One way of testing the origin of IN magnetic fields is to see if they vary with the solar activity cycle. In that case they would be at least partly due to the decay of active regions, whereas if they are created by a local surface dynamo mechanism they would not vary with the solar cycle. Observational studies of this question require to have stable and accurate measurements of the IN polarization over at least one half of a solar cycle. This is now possible thanks to the Hinode satellite that was launched in 2006, at a solar minimum and is still in operation, at the present solar maximum.

Buehler et al. (2013) investigated the long-term evolution of weak IN signals observed at disk center with the Hinode satellite between 2007 and 2012. They detected no variations of polarizations signals or magnetic flux, and concluded that the weak IN polarization signals recorded by Hinode are not driven by the global dynamo but rather by a local surface dynamo. Lites et al. (2014) also studied

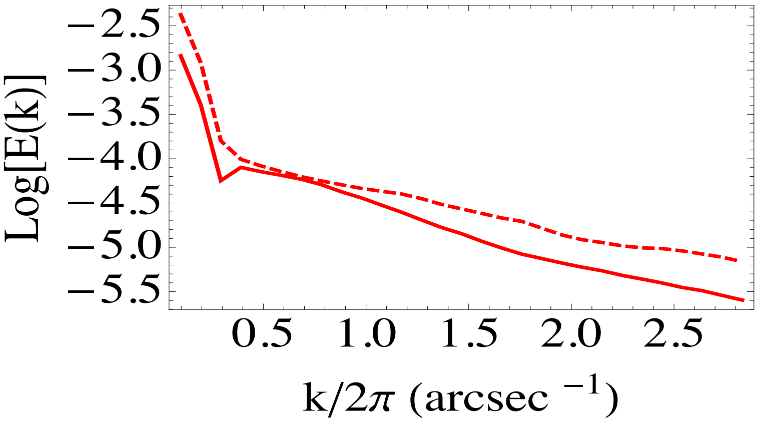

Figure 7: Fourier spectra of the spatial fluctuations of the unsigned circular polarization in the FeI 630.25 nm line in an IN region at $\cos\theta = 0.78$ (θ denotes the heliocentric angle). Full line: from 2007 data, dashed line: from 2013 data.

the same question from the analysis of center-to-limb measurements of the very weak polarization signals during the same period. They also found no solar cycle variations.

Faurobert at al. (2014) have compared the Fourier spectra of the polarization spatial fluctuations recorded with Hinode/SP in the QS at a minimum (December 2007) and at a maximum of the solar cycle (December 2013). They found that the decay of active regions is a source of magnetic fields in the QS (see Fig. 6). But they showed that in the IN regions the polarization spatial spectrum is unchanged at granular scales (spatial scales around 1.3 ”), whereas it increases in phase with the solar cycle at mesogranular and sub granular scales (see Fig. 7). This result indicates that a very efficient mechanism of magnetic field removal is operating in the QS at the granular scale so that the source of magnetic fields at large scale due to the decay of active regions is very rapidly dissipated or concentrated on smaller scales. The cycle-independent polarization signal that is measured at the granular scale is thus continuously created by a mechanism which is independent of the global solar dynamo. This mechanism may be identified to a local surface dynamo.

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GEOPHYSICAL FLUIDS, GEOMAGNETIC JERKS, AND THEIR IMPACT ON EARTH ORIENTATION

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Abstract. Geophysical fluids (atmosphere, oceans, and to some extent also continental water) have significant impact on Earth orientation parameters. Dominant is the excitation of polar motion and speed of rotation, much smaller but now measurable influence can be found also in precession/nutation. Recently Malkin (2013) found a correlation between the observed changes of Free Core Nutation parameters (phase, amplitude) and geomagnetic jerks (rapid changes of the secular variations of geomagnetic field). In our recent study (Vondrák & Ron 2014) we tested this hypothesis and found that if the numerical integration of Brzeziński broad-band Liouville equations (Brzeziński 1994) of atmospheric/oceanic excitations is re-initialized at the epochs close to geomagnetic jerks, the agreement between the integrated and observed celestial pole offsets is improved significantly. This approach tacitly assumes that the influence of geomagnetic jerks has a stepwise character, which is physically not acceptable. Therefore we introduce a simple continuous excitation function (having a "double ramp", or triangular, shape), centered on the epochs of geomagnetic jerks, and estimate its amplitude to fit best the integrated pole positions to its observed positions. The combined results of numerical integration of atmospheric/oceanic excitations plus this newly introduced excitation are then compared with the observed celestial pole offsets. The comparison shows that this approach improves the agreement between the two time series significantly.

1. INTRODUCTION

Earth rotation, in a wider sense, means the total orientation of the body in space (precession-nutation, polar motion, proper rotation), affected by

- external torques by the Moon, Sun, and to a lesser extent also by planets;
- geophysical influences (internal composition of the Earth, transfer of mass at core-mantle boundary, oceans, hydrosphere, atmosphere, magnetic coupling. . .).

Earth rotation has a fundamental importance in astronomy, especially for transformation between rotating terrestrial and non-rotating celestial reference systems, but also in many other applications, as, e.g., space navigation, geodesy, geophysics etc. . .

Precession was known already to Hipparchus (second century B.C.), polar motion was theoretically predicted by Euler (1765), observationally first detected by Kűstner

(1884/5), and its two main components of about 12 and 14 months determined by Chandler (1891). Since 1899 International Latitude Service (ILS) was set up to monitor polar motion, later replaced by International Polar Motion Service (IPMS) and finally by International Earth Rotation and Reference Systems Service (IERS). Nutation was observed by Bradley and theoretically explained by Euler, in the middle of the 18th century; since then systematic improvement of the model of nutation took place. Secular deceleration of Moon's motion, observed already by Halley (1695) and later studied by Laplace (18th century), was implied to be linked with the decelerating speed of rotation of the Earth by G. Darwin (end of 19th century). Only in the first half of the 20th century decadal and seasonal variations of Earth's spee d of ro tation were observed.

In the following, we shall first give a short description of the theory of Earth rotation to show how much the geophysical excitations can influence different Earth orientation parameters, and then we shall concentrate on nutation and its excitation by geophysical effects.

2. CONCISE THEORY OF EARTH ROTATION

Earth rotation can be simply described as a time-dependent relation between two reference systems (see Fig. 1):

1. xyz - rotating system, connected with the Earth,
2. XYZ - non-rotating system, linked to extragalactic objects.

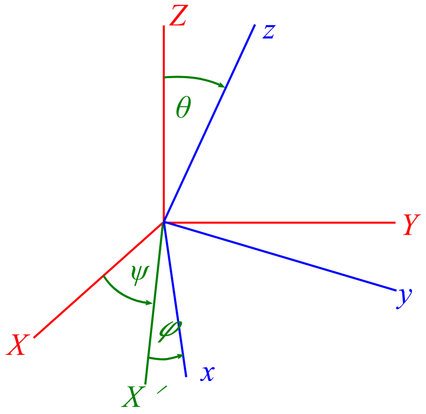


Figure 1: Transformation between rotating and non-rotating reference systems.

Mutual orientation of both systems is defined by three Euler angles (ψ - precession angle, θ - nutation angle, and φ - angle of proper rotation). Three consecutive rotations are necessary to go from XYZ to xyz: around Z-axis by ψ, then around new X'-axis by $-\theta$, and finally around z-axis by φ. According to laws of mechanics, time derivative of angular momentum of the Earth $\mathbf{H}$ must be equal to external torque $\mathbf{L}$, exerted by external forces (by the Moon, Sun, and planets). Expressed in a rotating system, the corresponding equation reads

$$\frac{\mathrm{d}\mathbf{H}}{\mathrm{d}t} + \omega \times \mathbf{H} = \mathbf{L}, \tag{1}$$

where $\omega = (\omega_1, \omega_2, \omega_3)^T$ stands for the vector of rotation. For a non-rigid body it holds $\mathbf{H} = \mathbf{C}\omega + \mathbf{h}$, in which $\mathbf{C}$ is the tensor of inertia and $\mathbf{h}$ is the relative angular momentum. Hence Liouville equations follow

$$\frac{\mathrm{d}}{\mathrm{d}t}(\mathbf{C}\omega + \mathbf{h}) + \omega \times (\mathbf{C}\omega + \mathbf{h}) = \mathbf{L}. \tag{2}$$

Taking into account that

$$\mathbf{C} = \begin{pmatrix} A + c_{11} & c_{12} & c_{13} \\ c_{12} & A + c_{22} & c_{23} \\ c_{13} & c_{23} & C + c_{33} \end{pmatrix}, \quad \mathbf{h} = \begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix} \tag{3}$$

(A and C being mean values of principal moments of inertia) and denoting $h = h_1 + \mathrm{i}h_2$, $c = c_{13} + \mathrm{i}c_{23}$, $L = L_1 + \mathrm{i}L_2$, $m = (\omega_1 + \mathrm{i}\omega_2)/\Omega$, $m_3 = \omega_3/\Omega$, in which Ω is the mean speed of Earth's rotation, we obtain linearized Liouville equations, the first one being given in complex form:

$$\begin{aligned} m + \mathrm{i}\dot{m}/\sigma_E &= \Psi \\ \dot{m}_3 &= \dot{\Psi}_3 \end{aligned} \tag{4}$$

with $\Psi = [\Omega^2 c + \Omega h - \mathrm{i}(\Omega\dot{c} + \dot{h} - L)]/\Omega^2(C - A)$, $\Psi_3 = -(\Omega\dot{c}_3 + \dot{h}_3 - L_3)/C\Omega$, called excitation functions, $\sigma_E = \Omega(C - A)/A$ is the Euler frequency. If we put $c_{ij} = h_i = 0$, the Eqs (4) become Euler equations, valid for rigid Earth. By solving Liouville equations, we obtain the position of the vector of immediate rotation m, i.e., polar motion components $x = m_1$, $y = -m_2$, and relative change of speed of rotation m_3.

The solution for *polar motion* has a free component, which has a period of 305 days for rigid Earth (Euler period), but its observed value for real Earth is 435 days (Chandler period). Forced components are mostly seasonal; geophysical influence, that is responsible for this motion, becomes dominant, because the changes of tensor of inertia $\mathbf{C}$ and relative angular momentum $\mathbf{h}$ are long-periodic in terrestrial system. External forces $\mathbf{L}$ have minimal effect since they are short-periodic and therefore strongly suppressed during integration.

Speed of rotation is constant for rigid Earth. For non-rigid Earth, the external torques (through zonal tidal deformation causing long-periodic changes of $\mathbf{C}$) and geophysical excitations, that are also long-periodic, are almost equal.

Position of axis z in non-rotating celestial system (angles ψ, θ) and angle of proper rotation φ are then given by integrating Euler kinematic equations

$$\begin{aligned} \dot{\psi}\sin\theta &= -\omega_1 \sin\varphi - \omega_2 \cos\varphi \\ \dot{\theta} &= -\omega_1 \cos\varphi + \omega_2 \sin\varphi \\ \dot{\varphi} &= \omega_3 - \dot{\psi}\cos\theta. \end{aligned} \tag{5}$$

During the integration, geophysical effects in precession-nutation are suppressed (they are short-periodic in celestial system) and external torques become dominant (being long-periodic).

2. 1. NUTATION MODELS

Usually, the nutation model is derived in two steps:

Step 1. Rotation of rigid Earth (Euler equations) is solved, under the influence of external torques (Moon, Sun, planets).

Step 2. Reaction of non-rigid parts of the Earth (visco-elastic mantle, fluid outer core, rigid inner core ...) on the external forces is calculated via frequency-dependent transfer function, which is the ratio between the amplitude of nutation and its value for rigid Earth.

Another option is the direct solution of Liouville equations with appropriate Earth model, but this approach (though theoretically more correct) has not led to satisfactory results so far.

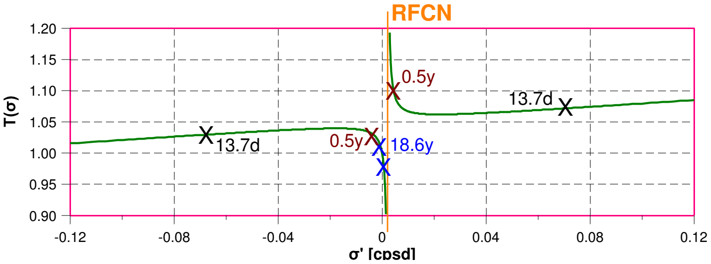


Figure 2: MHB transfer function - real part.

The most recent IAU2000 model of nutation is valid since 2003. It is based on solutions by Souchay et al. (1999) for the rigid Earth and Mathews et al. (2002) for transfer function. Rather complicated Earth model is used; visco-elastic mantle, outer fluid and inner rigid cores, atmosphere, oceans, electromagnetic coupling between outer core and mantle and inner and outer core are considered. The model contains 1360 periodic terms. Corresponding Mathews-Herring-Buffet (MHB) transfer function in complex form, whose numerical parameters were fixed to fit VLBI observations of celestial pole offsets, is

$$T(\sigma) = \frac{e_R - \sigma}{e_R + 1} N_\circ \left[1 + (1+\sigma) \left(Q_\circ + \sum_{j=1}^{4} \frac{Q_j}{\sigma - s_j} \right) \right], \qquad (6)$$

where σ is the frequency of nutation (in terrestrial frame), e_R is the dynamical ellipticity of the rigid Earth, N, Q are complex constants, and s_j are complex resonance frequencies, corresponding to: 1. Chandler wobble – CW ($P_{ter.} \doteq 435$d); 2. Retrograde Free Core Nutation – RCFN ($P_{cel.} \doteq 430$d); 3. Prograde Free Core Nutation – PFCN ($P_{cel.} \doteq 1020$d); 4. Inner Core Wobble – ICW ($P_{ter.} \doteq 2400$d).

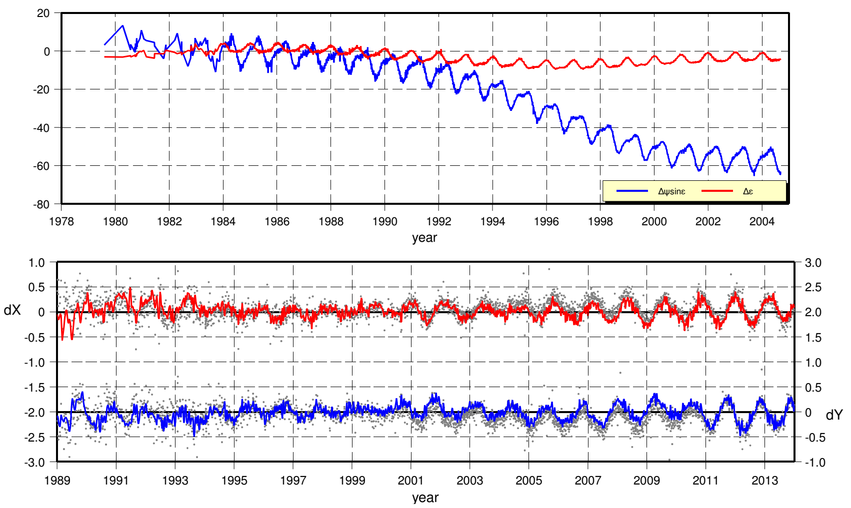


Figure 3: Celestial pole offsets from IAU1980 (top) and IAU2000 (bottom) models.

Graphical representation of MHB transfer function (its real part, corresponding to amplitudes) is displayed in Fig. 2, in which the argument is the frequency σ' in celestial frame (cycles per sidereal day). Important nutation terms are marked with crosses, and the dominant RFCN resonance is shown as a vertical line.

Figure 3 demonstrates how much the recent model of nutation IAU2000 improved the agreement with the observations, when compared with the previous one, IAU1980 (Wahr, 1981). The figure depicts the celestial pole offsets (i.e., the differences of the observations from the adopted model) in milliarcseconds (mas) – notice the difference of vertical scale of both plots. Bottom plot shows both the individual observed values (dots) and the filtered data used in our subsequent calculations (full line) – see Section 4 below. The newest model IAU2000 agrees with observations on the level of only ±0.2mas, the dominant term has a period of about 435-460d, and a variable amplitude of about 0.1mas, corresponding to RFCN which is not included in the nutation model IAU2000. Important is also quasi-seasonal term with a similar amplitude to RFCN, excited by geophysical processes (atmosphere, oceans...), as we shall demonstrate below.

3. GEOPHYSICAL EXCITATIONS OF NUTATION

In order to compute the effect of geophysical excitation, we use numerical integration of Brzeziński's broad-band Liouville equations (Brzeziński 1994) in celestial frame, based on an Earth model that is simpler than the one used by Mathews et al. (2002) – it accounts for only visco-elastic mantle and fluid outer core, and consequently has only two dominant resonances (Chandler and RFCN). It reads, in complex form

$$\begin{aligned}\ddot{P} - \mathrm{i}(\sigma'_C + \sigma'_f)\dot{P} - \sigma'_C\sigma'_f P = \quad & - \quad \sigma_C \left\{ \sigma'_f(\chi'_p + \chi'_w) + \sigma'_C(a_p\chi'_p + a_w\chi'_w) \right. \\ & + \quad \mathrm{i}\left. \left[(1+a_p)\dot{\chi}'_p + (1+a_w)\dot{\chi}'_w \right] \right\}, \qquad (7)\end{aligned}$$

where $P = \mathrm{d}X + \mathrm{i}\mathrm{d}Y$ is the motion of Earth's spin axis in celestial system due to excitation. σ'_C, σ'_f are Chandler and RFCN frequency in celestial frame, σ_C is Chandler frequency in terrestrial frame, χ'_p, χ'_w are the effective angular momentum functions (pressure and wind terms, respectively) in celestial frame, and $a_p = 9.509 \times 10^{-2}$, $a_w = 5.489 \times 10^{-4}$ are numerical constants, expressing different reaction on pressure/wind terms.

The effective angular momentum functions χ are dimensionless quantities expressing the excitations by the atmosphere (oceans), defined by Barnes et al. (1983). χ_p are calculated from air pressure changes measured at Earth's surface, χ_w from the velocity of the wind measured at different altitudes. Here we use only their two equatorial components, expressed as complex quantity $\chi = \chi_1 + \mathrm{i}\chi_2$. Because they are available from meteorological centra in terrestrial frame, they must be transformed into celestial frame, using a simple formula $\chi' = -\chi \mathrm{e}^{\mathrm{i}\phi}$, where ϕ is the Greenwich sidereal time.

Corresponding transfer function (in frequency domain) between excitation and nutation is

$$T_{p,w}(\sigma) = \sigma_C \left(\frac{1}{\sigma'_C - \sigma} + \frac{a_{p,w}}{\sigma'_f - \sigma} \right), \quad P_{p,w}(\sigma) = T_{p,w}(\sigma)\chi'_{p,w}(\sigma). \tag{8}$$

The two resonant frequencies mentioned above, rapid Chandler σ'_C and slow RFCN σ'_f with different response for pressure and wind terms, are evident. Transfer function is a practical tool for comparing the spectrum of geophysical excitations $\chi'(\sigma)$ with the spectrum of celestial pole offsets $P(\sigma)$.

3. 1. NUMERICAL INTEGRATION OF BROAD-BAND LIOUVILLE EQUATIONS

Equation (7) is a second-order differential equation in complex form. In order to facilitate its numerical integration, it is split into two first-order equations, by using a simple substitution $y_1 = P,\ y_2 = \dot{P} - \mathrm{i}\sigma'_C P$. Thus we have a system of two complex differential equations

$$\begin{aligned} \dot{y}_1 &= \mathrm{i}\sigma'_C y_1 + y_2 \\ \dot{y}_2 &= \mathrm{i}\sigma'_f y_2 - \sigma_C \left\{ \sigma'_f(\chi'_p + \chi'_w) + \sigma'_C(a_p\chi'_p + a_w\chi'_w) \right. \\ &+ \left. \mathrm{i}\left[(1+a_p)\dot{\chi}'_p + (1+a_w)\dot{\chi}'_w\right] \right\}, \end{aligned} \tag{9}$$

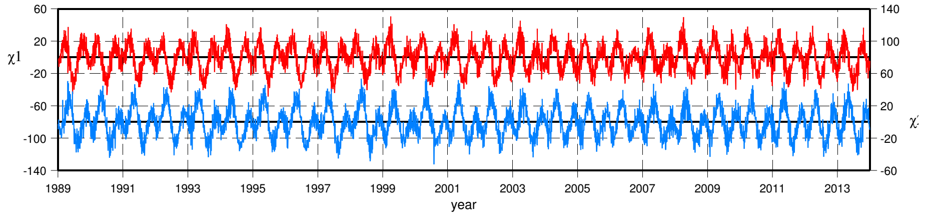
which we numerically integrate by using fourth-order Runge-Kutta method with 6-hour steps. We use the Fortran subroutine `rk4` (Press et al. 1992) that we re-wrote into complex form. Initial values $y_1(0) = P(0)$ and $y_2(0) = \mathrm{i}(\sigma'_f - \sigma'_C)P(0)$ are chosen so that the quasi-diurnal free motion disappears, and the best rms fit to observations is obtained. It is necessary to say that the choice of initial pole position influences only the amplitude and phase of RFCN; the forced motion remains intact by the choice.

4. DATA USED AND RESULTS

4. 1. DATA USED

In our recent study (Vondrák and Ron 2014) we compared different sources of geophysical excitations (European ECMWF for the atmosphere and OMCT for the oceans,

a) wind (motion) term



b) pressure (matter) term without and with IB correction

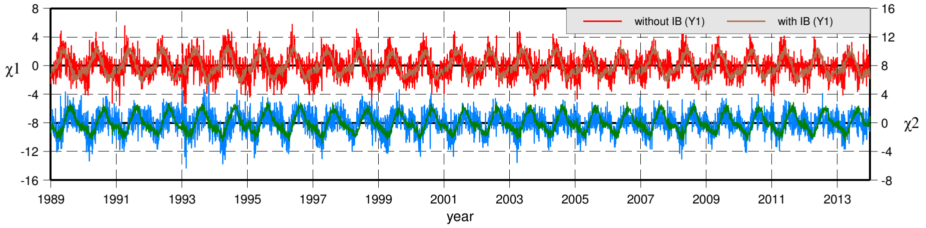


Figure 4: NCEP effective angular momentum functions.

American NCEP/NCAR for the atmosphere with and without Inverted Barometer – IB correction) and found that the best fit with VLBI-based observations of celestial pole offsets is obtained for NCEP/NCAR excitations with IB correction. European models yield systematically larger amplitudes, if compared with the observations. Consequently, we show in this paper only the results based on NCEP/NCAR atmospheric excitations in 1989.0–2014.0, given in terrestrial frame in 6-hour intervals. Prior to their use, they were re-calculated into celestial reference system, and smoothed (Vondrák 1977) to contain only periods longer than 10 days. The input data are shown in Fig. 4.

The integrated values are then compared with the observed values of celestial pole offsets, provided by International VLBI Service for Geodesy and Astrometry (IVS) as a combination from all their analysis centers, solution `ivs13q4X`, covering the same time interval, i.e. 1989.0-2014.0. These data are given in unequal intervals (from 1 to 7 days), so they were first filtered to contain only periods between 60 and 6000 days, and then interpolated to ten-day equidistant epochs. IAU2000 nutation model contains an empirical term with annual period (Sun-synchronous correction) that is supposed to account for the effects of geophysical fluids. In order to be directly comparable with integrated geophysical excitations, this term was removed from the celestial pole offsets. The input data are displayed in bottom plot of Fig. 3.

Recently Malkin (2013) showed that the changes of amplitude and phase of RFCN occur near the epochs of geomagnetic jerks (GMJ). GMJ are rapid changes of the second time derivative of intensity of the Earth's magnetic field, typically lasting from several months to a year (Mandea et al. 2010). We tested this in our recent study (Vondrák & Ron 2014) by re-initializing the numerical integration at the epochs of GMJ and found that the agreement with observations improved significantly. Here we use slightly different approach, since sudden stepwise changes of pole position

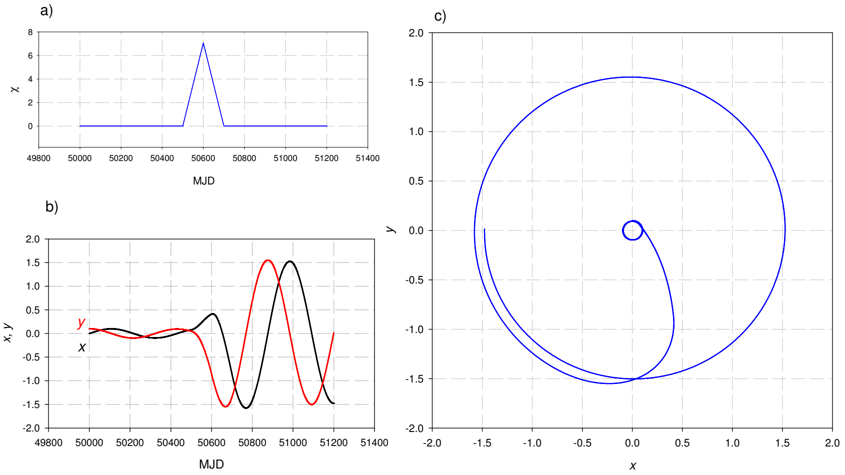


Figure 5: Schematic excitation and its effect in integrated pole position.

are physically not acceptable. Instead, we use a continuous additional excitation of 'double ramp' (or triangle) shape, centered at GMJ epochs and lasting 200 days. This simulated schematic excitation and its calculated effect on celestial pole position is depicted in Fig. 5; excitation a) causes continuous growth of the amplitude and change of phase during the 200 days covering the excitatio n, as shown in plots b) and c). Here we use the fixed GMJ epochs 1991.0, 1994.0, 1999.0, 2003.5, 2004.7 and 2007.5, taken over by Malkin (2013). Only their complex amplitudes are estimated to fit best to the observed celestial pole offsets.

4. 2. RESULTS

The results of numerical integrations and their fit to observed values are shown in Figs 6 and 7; GMJ epochs in Fig. 7 are marked by arrows. Fig. 6 displays significant differences, both in phase and amplitude, large values of rms fit and low correlations reflect this fact. The improvement of the fit when GMJ excitations are added, both in rms and correlation, between the two series is evident in Fig. 7. Also the solution with IB correction yields better agreement, in lower parts of both figures.

If we make a least-square fit to derive the complex amplitudes of annual and semi-annual terms from integrated values of Fig. 7, we get the results summarized in Tab. 1. The arguments of both terms are identical with those of nutation terms (l' for annual, $2F - 2D + 2\Omega$ for semi-annual), corresponding periods are 365.26 and 182.62 days, respectively. For comparison, the same terms obtained from the fit to IVS celestial pole offsets and the term that is the part of IAU2000 nutation model are shown in the lower part of the table. All these values mutually agree on the level of several tens of microarcseconds.

5. CONCLUSIONS

We demonstrate that the geophysical effects in nutation are significant and now mea-

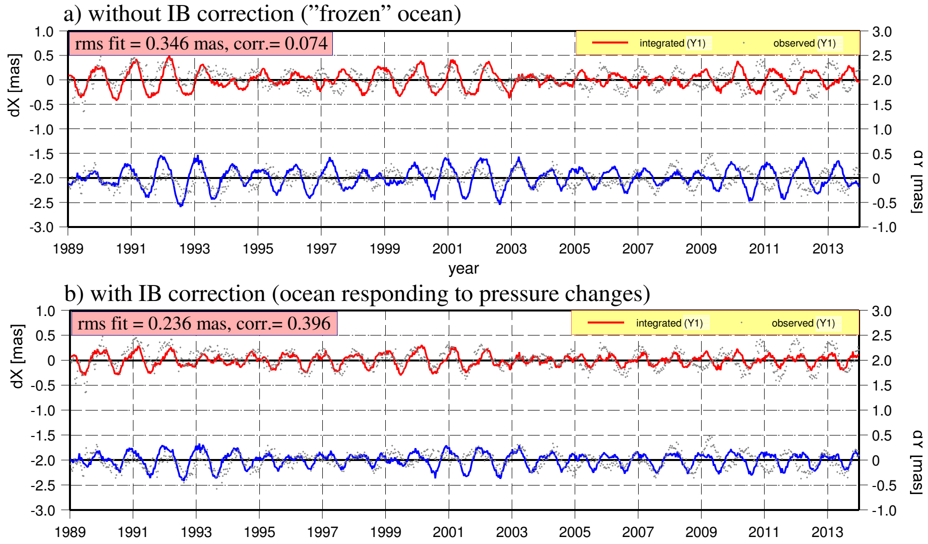


Figure 6: Integrated nutation with NCEP excitation.

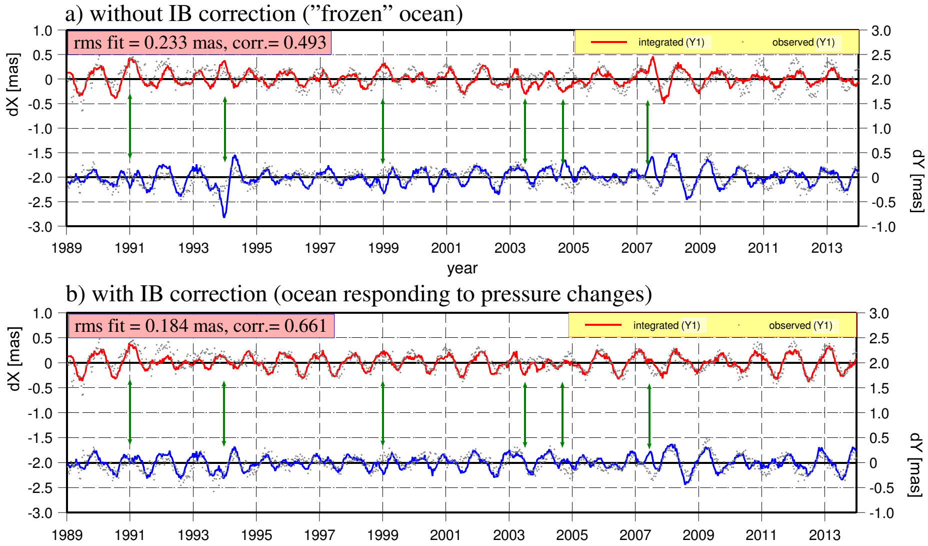


Figure 7: Integrated nutation with NCEP + GMJ excitation.

Table 1: Seasonal geophysical effects in nutation [μas]

solution	annual prograde Re	annual prograde Im	annual retrograde Re	annual retrograde Im	semi-annual prograde Re	semi-annual prograde Im	semi-annual retrograde Re	semi-annual retrograde Im
NCEP	−16	+81	−52	−8	−24	+50	0	−10
NCEP IB	−47	+90	−43	+37	−8	+69	0	−6
IVS	−17	+96	−11	+50	+3	+31	−16	−24
Sun-Synchr.	−10	+108	0	0	0	0	0	0

surable. Best agreement of integrated excitations with observed celestial pole offsets is obtained if NCEP/NCAR atmospheric angular momentum functions with Inverted Barometer correction are used, and the fit is further improved if additional excitations at the epochs of geomagnetic jerks are added. However, we do not offer physical explanation of the mechanism how GMJ could lead to the changes in nutation, we only demonstrate here that there is a remarkable coincidence between the two phenomena.

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CONDENSED MATTER PHYSICS AND IMPACT CRATER FORMATION

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Abstract. Various kinds of craters exist on solid bodies in the planetary system and some of them are due to impacts into the surfaces of the objects concerned. Impact craters are "by default" analyzed within the "scaling theory", based on dimensional analysis. The same problem can be analyzed by using standard laws of condensed matter physics. In this contribution the two approaches will be compared, and possibilities for future work discussed to some extent.

1. INTRODUCTION

Surfaces of solid bodies in the solar system are filled with craters of various sizes. Some of them are of volcanic origin, while others (which are the subject of the present paper) are the results of impacts of small bodies into the target surfaces. The existence of impact craters is an expectable consequence of the fact that a multitude of small solid bodies, remaining from the epoch of formation o the planetary system, is orbiting the Sun. Their study is attractive for two important reasons: on the fundamental level, analyzing these craters gives the opportunity of inferring conclusions about the impactors which made them. The "applied" interest in impacts and impact craters is much more important: the impact of a sufficiently large object into a sufficiently densely populated region on the Earth would provoke a catastrophe. Accordingly, developing the possibilities of predicting the place of an impact, the size of the possible crater, heating or melting of the target material or the height of a possible tsunami, is extremely interesting and important for humanity.

This paper is devoted to a comparison of two approaches to the problem of impacts and the resulting craters: the scaling theory (Holsapple 1993) and the approach based on standard laws of condensed matter physics (Celebonovic 2013). Each of the following two sections is devoted to brief outlines of each of these approaches, the section after to a comparison of their possibilities, and finally the conclusions.

2. THE SCALING THEORY

The crucial term in this approach is the notion of scaling. Scaling is defined as the application of some relation (called the scaling law) to predict the outcome of one event from the results of another. Parameters which are different between the two events are called *scaled* variables. It can also mean predicting the dependence of the outcome of a problem on its parameters (Holsapple 1993).

The form of scaling laws can be determined in three ways: by impact experiments, analytical calculations and approximate theoretical solutions.

The basic principle of impact experiments is very simple: projectiles of varied composition and mass are fired with different speeds into targets of differing chemical composition, and data are measured on the resulting craters. Such experiments are being performed for decades (some examples are Oberbeck 1971; Fujiwara et al., 1977; Baldwin et al., 2007; Suzuki et al., 2012) and they have given various interesting results. However, a common problem with all these experiments is that the projectiles are launched in them with velocities below those of interest for studies of creation of large craters. In a similar kind of experiments, solid targets are shock compressed by the impact of short-lived laser beams. For a recent report on a newly developed experimental platform for such experiments see, for example, (Gauthier et al., 2014).

Laws of physics needed for theoretical studies of impacts and the formation of craters are well known; these are the basic laws of classical physics,conservation of mass,momentum and energy, supplemented by knowledge on the equation of state (EOS) of the materials of the target and the impactor. However, this kind of work encounters a problem: lack of detailed knowledge on phase transitions in materials of ill defined chemical composition. The point here is that if the impactor is sufficiently massive and the speed of impact sufficiently high, at the moment of impact a transition solid → plasma occurs; the plasma cools rapidly, and the process ends-up in the domain of condensed matter physics.

Approximate theoretical solutions are based on a simple idea: the initial phase of the problem is approximated as a "point source" of shock waves propagating throughout the target after the impact. This approach was developed for studies of the effects of nuclear explosions. For details see (Holsapple 1993; Nellis, 2000) and references given there.

A good example of a scaling law is the problem of formation of a crater of volume V, resulting from the impact of an impactor of radius r, speed v and mass density ρ_1 into a target (planet) having surface gravity g, material strength X, and mass density ρ. Material strength is loosely defined as the ability of a material to whitstand load without failure. All material properties can be expressed as combinations of the dimensions of stress and mass density. This implies (Holsapple,1993) that the volume of an impact crater can be expressed as

$$V = f[\{r, v, \rho_1\}, \{\rho, X\}, g] \tag{1}$$

where the first three variables describe the impactor, the following two the material making up the planet, and the surface gravity of the planet. This expression is completely general, and scaling models are derived from it by dimensional analysis.

It follows from equation (1) that

$$\frac{\rho V}{m} = f_1[\frac{gr}{v^2}, \frac{X}{\rho v^2}, \frac{\rho}{\rho_1}] \tag{2}$$

where $m = \frac{4\pi}{3}\rho_1 r^3$ is the mass of the impactor. The quantity on the left-hand side is the ratio of the mass of the material within the crater to the mass of the impactor.It is usually called cratering efficiency and denoted by π_V. The first term in the function is the ratio of the lithostatic pressure ρgr to the initial dynamic pressure ρv^2 generated by the impactor. The lithostatic pressure at a certain depth is defined as the pressure exerted by the material above it. This ratio is denoted by π_2; the second term is the ratio of the material strength to the dynamical pressure, denoted by π_3. The final term is the ratio of the mass densities.

If all the parameters of eq.(2) were known, or could be measured or calculated, it would not be a particular problem to determine the volume of an impact crater. As this is far from being the case, solutions of this equation are usually studied in two limiting cases: the "strength" regime and the "gravity" regime. The "strength" regime is the situation in which the strength of the surface material is larger than the lithostatic pressure. Practically speaking, this implies impators with diameters of approximately one meter.This means that

$$\frac{\rho V}{m} = f_1[\frac{X}{\rho v^2}] \tag{3}$$

where it was assumed that the ratio of the densities is approximately one. In this regime, the volume of the impact crater increases linearly with the volume of the impactor, its mass and its energy. Any dimension of the crater increases with the radius of the impactor. In the opposite case, when the diameter of the impactor is of the order of a kilometer or more, the lithostatic pressure is bigger than the material strength,meaning that

$$\frac{\rho V}{m} = f_1[\frac{gr}{v^2}] \tag{4}$$

This is the definition of the "gravity" regime. Various experiments (discussed in Holsapple,1993) have been performed on the dependence of π_V on π_2, the result being an exact power law. This can be explained, as discussed in (Holsapple,1993) by the assumption that whenever there is a dependence on the impactor size and speed, it is actually the dependence on its kinetic energy. This idea was used in the early sixties, in scaling from a nuclear event called "Teapot ESS" to the creation of the Meteor Crater in Arizona.

The idea that the consequences of an impact depend on the kinetic energy of the impactor is equivalent to the "point source" approximation. The kinetic energy is given by $\frac{1}{2}mv^2$. Taking the cube root, introducing the mass density, and dropping the numerical factor, one gets the function

$$C = r\rho^{1/3}v^{2/3} \tag{5}$$

which can be generalized to

$$C = r\rho^{\mu}v^{\nu} \tag{6}$$

Using this, equation (1) becomes

$$V = f[r\rho^{\mu} v^{\nu}, \rho_1, X, g] \tag{7}$$

It can be shown by dimensional analysis (Holsapple, 1993) that in the strength regime the volume of a crater is given by

$$V \propto \frac{m}{\rho_1} \times (\frac{\rho_1 v^2}{X})^{3\mu/2} \times (\frac{\rho}{\rho_1})^{1-3\nu} \tag{8}$$

and a similar expression can be derived for the gravity regime. Values of scaling exponents can be determined in impact cratering experiments (such as Suzuki, 2012).Once they are known for a given material (or materials) calculations referring to the formation of the impact craters become possible.

3. CONDENSED MATTER PHYSICS

Surfaces of objects in the solar system on which impact craters exist are solid. As the impactors are solid objects, the question is what (if anything) can be concluded about the impacts by using laws of condensed matter physics. The aim of this section is to outline these possibilities, using recent results of the present author.

The first step in analyzing impact craters by the use of solid state physics, is to determine the minimal velocity which a projectile must have in order to form a crater. This was studied in (Celebonovic and Sochay,2010), where the condition for the formation of a crater was defined as the equality of the kinetic energy of a unit volume of the material of the impactor with the internal energy of the unit volume of the material of the target. It was shown that this speed is given by

$$v^2 = \frac{\pi^2}{5\rho_1} \frac{(k_B T)^4}{\hbar^3} (\frac{\partial P}{\partial \rho})^{-3/2} \tag{9}$$

where ρ_1 is the mass density of the impactor, T the temperature of the target, and P, ρ are the pressure and mass density of the material of the surface of the target. The dimensions of the impactor and of the resulting crater were not taken into account. As a test,this expression was applied to the case of an impactor made up entirely of olivine $(Mg, Fe)_2 SiO_4$. It was shown that the minimal impact speed of such an object should be $16.3 km/s$. For comparison, note that the impact velocity of a real object, asteroid 99942 Apophis, is estimated to be between 13 and $20 km/s$, which means that two completely different methods: celestial mechanics and condensed matter physics give very similar results. 99942 Apophis is an interesting object for such a comparison, because celestial mechanics indicates that there exists a small but non-zero probability that it collides with the Earth on April 13, 2036 (Giorgini et.al., 2008). Similar results have been reached for the asteroid $1950 DA$, for which a probability of impact exists for March,2880 (Farnocchia and Chesley, 2014).

The final result of any impact is a crater. If the impact is strong enough (if the kinetic energy of the impactor is high enough), and if the target has a suitable value of the heat capacity, a consequence of the impact will be heating of the target. Depending on the kinetic energy of the impactor, the target may heat enough so as to melt, and possibly even evaporate at the point of impact. In this regime condensed matter physics obviously cannot be applied. Regardless of the amount of heating in the impact, the outcome is always the same: a certain quantity of material of the target gets ”pushed aside” at the point of impact, thus creating a crater of given dimensions. The aim of the calculations outlined here is to draw conclusions about the impactor using measurable dimensions of the crater and various parameters of the target. Such an approach corresponds to what has earlier been named ”the inverse” problem (Holsapple,2003), where the aim was to deduce the impactor size and speed by analyzing the volume of impact melt.

Formation of impact craters was recently discussed as the following analogous problem in condensed matter physics: how big must be the kinetic energy of the impactor in order to produce a hole of given dimensions in a target material with known parameters (Celebonovic,2013)? It was assumed that the material of the target is a crystal, that one of the usual types of bonding exists in it, and that as a consequence of the impact the target does not melt, so that condensed matter physics can be applied. The problem of heating in impacts has recently been discussed in (Celebonovic,2012).

This calculation is based on a simple physical idea: the kinetic energy of the impactor must be greater than or equal to the internal energy of some volume, denoted by V_2, of the material of the target. The kinetic energy of the impactor of mass m_1 and speed v_1 is obviously

$$E_k = \frac{1}{2} m_1 v_1^2 \tag{10}$$

and the internal energy E_I consists of three components: the cohesion energy E_C, the thermal energy E_T and $E_H(T)$ - the energy required for heating the material at the point of impact by an amount ΔT. Therefore,

$$E_I = E_C + E_T + E_H(T) \tag{11}$$

and the condition for the formation of an impact crater as a consequence of an impact is

$$E_I = E_k \tag{12}$$

The details of the calculation are avaliable in (Celebonovic,2013) and the final result for the energy condition which must be satisfied to enable the formation of an impact crater is given by

$$\begin{aligned} 3k_B T_1 N\nu[1 - \frac{3}{8}\frac{T_D}{T_1} - \frac{1}{20}(\frac{T_D}{T})^2 + \frac{1}{10}(\frac{T_D^2}{TT_1}) \\ +(\frac{1}{560})(\frac{T_D}{T})^4 - \frac{1}{420}\frac{T^4}{T^3 T_1} - \frac{3\bar{u}^2\rho\Omega_m}{np\nu k_B T_1}] = \frac{2\pi\rho_1}{3} r_1^3 v_1^2 \end{aligned} \tag{13}$$

The number N is equal to the ratio of the volume of the crater, and the volume of the elementary crystal cell,v_e: $N = V/v_e$. The meaning of other symbols is: k_B Boltzmann's constant,T the initial temperature of the target,T_1 the temperature to which the target heats, T_D the Debye temperature of the target,ρ_1,r_1 v_1 - mass density,radius and impact velocity of the projectile,p,n - parameters of the interatomic interaction potential in the material of the target,ν the number of particles in the elementary crystal cell,$\bar{u}$ the speed of sound in the material of the target and Ω_m is the volume per particle pair.

Equation (13) may at first sight look a very complicated. In fact, it is simply an expression of the energy conservation law. Its main result is that it links parameters of the impactor, with those of the material of the target, which was the aim of the calculation.

This expression was applied to a well known case - the Barringer crater in Arizona, for which most of the experimental parameters are known. Assuming that the material of the crater is pure Forsterite (Mg_2SiO_4), and making plausible assumptions about other parameters of eq.(13), it was obtained that $v_1 \cong 41 km/s$, which is far larger than existing estimates. Assuming that only 10 percent of the material is Forsterite, and keeping all the other parameters constant, gave the value of $v_1 \cong 15 km/s$, for the impact speed, which is much closer to the results of celestial mechanics. Details of this calculation are avaliable in (Celebonovic,2013) .

The calculation outlined above was performed using the notion of cohesive energy of solids. The problem is that the cohesive energy is a very "impractcal"quantity: it is defined as the energy needed to transform a sample of a solid into a gas of widely separated atoms (Marder,2010). As a consequence of this definition, it is difficult to measure experimentally and it is not related to the strength of solids measurable in experiments.

A much more "practical" notion is the stress. It is defined as the ratio of the force applied to a body to the cross section of the surface of a body normal to the direction of the force. After an impact,a crater will form if stress in the material becomes sufficiently high for the formation of a fracture.

The critical value of the stress needed for the occurence of a fracture in a material is given by (Tiley, 2004)

$$\sigma_C = \frac{1}{2}\left(\frac{E\chi\tau}{r_0 w}\right)^{1/2} \tag{14}$$

where E is Young's modulus of the material, χ is the surface energy, τ is the radius of curvature of the crack, r_0 the interatomic distance at which the stress becomes zero and w is the length of a crack which preexists in the material. Defined in this way, σ_C has the dimensions of pressure.

At the moment of impact, the kinetic energy of the impactor is used for fracturing and heating the material of the target. Therefore:

$$E_k = \sigma_C V + C_V V(T_1 - T_0) \tag{15}$$

where V is the volume of the crater formed as a result of the impact, C_V is the heat capacity of the target material and T_0 the initial temperature of the target. In accordance with recent experiments (Suzuki et al.,2012) the volume of the crater is approximated by

$$V = \frac{1}{3}\pi b^2 c \tag{16}$$

where b is the radius of the "opening" of the crater and c denotes its depth.

It will be assumed that the impactor is a sphere of radius r_1, made up of a material of density ρ_1 having impact velocity v_1. Its kinetic energy is given by $E_k = \frac{2\pi}{3}\rho_1 r_1^3 v_1^2$. It follows from eq.(15) that

$$T_1 = T_0 + \frac{1}{C_V}(\frac{E_k}{V} - \sigma_C) \tag{17}$$

and after some algebra (Celebonovic, 2014)

$$V = \frac{2\pi}{3} \frac{\rho_1 r_1^3 v_1^2}{\alpha C_V T_0 + \sigma_C} \tag{18}$$

where $T_1 - T_0 = \alpha T_0$. Equation (18) can be expressed as

$$V = \frac{E_k}{\alpha C_V T_0 + \sigma_C} \tag{19}$$

implying that the crater volume is a linear function of the kinetic energy of the impactor. On the other hand, raw experimental data on crater volumes and the impactor energies in (Suzuki et al.,2012), can be fitted by an equation of the form $V[m^3] = V_0 \times Exp[E[J]/c]$, with $V_0 = (4 \pm 2) \times 10^{-7} m^3$ and $c = (583 \pm 56) J$. For sufficiently low energies E, this exponential expression reduces to the form $V - V_0 \cong (V_0/c)E$. Combining with results of the calculations reported here, it follows that $V_0/c = 1/(\alpha C_V T_0 + \sigma_C)$ The implication is that the results of the calculations reported here are relevant to low kinetic energies of the impactors.

Experiments such as (Grady and Lipkin, 1980) have shown that measured data for various materials can be fitted by an expression of the form $\sigma_C = a \dot{\epsilon}^n$ where $\dot{\epsilon}$ is the strain rate, and a, n are material dependent constants. This implies that the volume of an impact crater also depends on the rate of strain to which the target material is exposed at the point of impact.

Calculations outlined here open up the possibility of making various estimates of physical quantities occuring in the equations. Using known experimental data, and taking that the most abundant mineral at the site of the Barringer crater is SiO_2 it was shown in (Celebonovic, 2014) that at the moment of impact the site heated up to $T_1 \approx 1300K$. For another terrestrial entity, the Kamil crater on the border of Egypt and Sudan, it was shown that $\sigma_C \cong 1.56 \times 10^8 J/m^3$.

4. COMPARING THE TWO APPROACHES

In this contribution we have outlined to some extent two approaches to the problem of the impact craters on the surfaces of solid bodies in the planetary system. One is the so called scaling theory and the other is standard condensed matter physics. Both approaches have a similar goal: using avaliable experimental data, and relevant laws of physics, draw as much conclusions as possible on the impacts and the impactors.

Scaling theory aims at linking the craters of "celestial" origin with those resulting from man made,classical or nuclear explosions. Scaling in such a way gives encouraging results. This approach is very general,which is excellent, but there exists the problem of treatment of phase transitions. However,the main method of work with scaling theories is dimensional analysis. One of the results of the scaling approach is that the volume of a crater formed after an impact depends also on the mass density of the target. The same conclusion can be reached within the condensed matter physics approach (Celebonovic, 2014).

The approach based on condensed matter physics is rigorously based on well known physical laws. However, by its very nature,this approach has an inherent limitation: it can treat either slow impacts of "not very massive" projectiles,or the final phase (in which heating effects have cooled down). Future work in this approach could go along two lines: including in more details the effects of heating, and thus enabling the study of the "hot phase" of the formation of a crater, and exploring the upper mass limits of this approach and introducing (if it turns out to be necessary) some possible new factors which influence the final outcome.

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COMPUTATION OF TRANSIT ORBITS IN THE THREE-BODY-PROBLEM WITH FAST LYAPUNOV INDICATORS

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Abstract. We describe in this paper how to compute special orbits of the three-body problem which transit from a region which is internal to the secondary mass to the region which is external to the binary system, by using a recent variant of the Fast Lyapunov Indicator method. The orbits are obtained by slightly changing the initial conditions of orbits which are heteroclinic to Lyapunov orbits of the Lagrangian equilibrium points L_1 and L_2 of the restricted three-body problem.

1. INTRODUCTION

The orbits of gravitational systems may be very complicated, due to resonances and close encounters with massive bodies. An important example is represented by the dynamics of particles which pass close to the so-called Lagrangian collinear equilibrium points L_1, L_2, L_3 of the three-body problem. The importance of the dynamics near the Lagrangian collinear equilibria, especially L_1 and L_2, has been extensively discussed in the last years in connection with space-mission design for several reasons (see, for example, the review paper by Belló et al. 2010, and references therein). On the one hand, the collinear equilibria of the Earth-Moon and of the Sun-Earth systems, and the associated Lyapunov periodic orbits, may be considered as interesting orbits where to place spacecrafts; on the other hand, orbits transiting from the region which is internal to the region which is external to a binary system, with the lowest possible energies, are interesting for example for explaining the dynamics of some Jupiter-family comets (see Ross 2004) or that of Earth's Minimoons (Bolin et al. 2014). These orbits are constructed from the special dynamics which occur in the neighborhoods of L_1 and L_2 and are difficult to compute, since chaos dominates their dynamics: very small changes of the initial conditions may produce orbits which are qualitatively very different. In this context, numerical integrations of individual orbits are not very meaningful, since from the numerical integration of one or a few orbits it is difficult to understand how these orbits behave with small changes of the initial conditions, or of the model. After the first numerical detection of chaotic motions in Hénon and Heiles 1964, many methods of investigations of chaotic dynamics, based on numerical computations of large sets of initial conditions, have been developed. In particular, the topic had a certain relevance in celestial mechanics, where many examples of chaotic diffusion and chaotic transport related to resonances in the Solar System had been reported (see, for example, Laskar 1990, Milani et al. 1997, Murray et al. 1998, Morbidelli and Nesvorný 1999). In the last decade, many methods of numerical detection of the chaos related to resonances have been developed on the base of extensive computations of dynamical indicators on grids of initial conditions of the phase–space. These methods are essentially based on the computation of indicators derived from Fourier analysis–such as the frequency analysis (see Laskar 1990, 1993)– or on some indicators derived from the theory of Lyapunov exponents, such as the Fast Lyapunov Indicator (FLI hereafter) introduced in Froeschlé et al. 1997 (for applications of these methods see Robutel and Galern 2006, Guzzo 2005, 2006, Wayne et al. 2010, Guzzo et al. 2002). This paper is concerned with an application of the Fast Lyapunov Indicator, whose ability of detection of chaotic diffusion has been extensively studied in Lega et al 2003, Guzzo et al. 2005, 2011, Froeschlé et al 2000, 2005, Todorović et al 2011. More recently, the FLI has been used for a different purpose, that is for the computation of certain surfaces of the phase–space, the so called stable and unstable manifolds, whose structure is fundamental to understand the dynamics of a chaotic system (see Villac 2008, Guzzo 2010, Guzzo et al. 2009, Lega et al. 2010, Guzzo and Lega 2013). In particular, in the three–body problem these surfaces are called the 'tube' manifolds, and are defined by all the initial conditions of the phase–space whose orbits are asymptotic (in the past-for the unstable manifold- or in the future-for the stable manifold) to a Lyapunov periodic orbit of L_1 and L_2. These structures provide all important information related to the transit orbits (see, for example, Koon et al. 2008). Many methods of detection of the stable/unstable manifolds have been developed in the literature (see, for example, Simó 1989, Krauskopf B. and Osinga 2003), essentially based on extremely precise preliminary local approximations of the manifolds, combined with some advancing front technique of surfaces' reconstruction. We present here a computation of the tube manifolds of the restricted three-body problem recently obtained in Guzzo and Lega 2014, based on a modification of the traditional FLI. On the base of these computations, we produce, as an example, a peculiar orbit of the Sun-Jupiter three body problem which transits from the region which is internal to the orbit of Jupiter to the region which is external to the Sun-Jupiter system, and in particular the transit occurs after some librations around L_1 and L_2 and a close encounter with Jupiter.

The paper is structured as follows. In Section 2 we review the properties of the dynamics near the Lagrangian equilibrium points L_1, L_2, and the definition of the tube manifolds. In Section 3 we report the computations obtained with the modified Fast Lyapunov Indicators. Finally, in Section 4 we provide Conclusions.

2. THE TUBE MANIFOLDS OF THE THREE-BODY PROBLEM

In its simplest formulation, i.e. the planar circular restricted three-body problem, the problem is defined by the motion of a massless body P in the gravitation field of two massive bodies P_1, P_2, called primary and secondary bodies respectively, which orbit uniformly around their common center of mass. In a rotating frame xOy, the

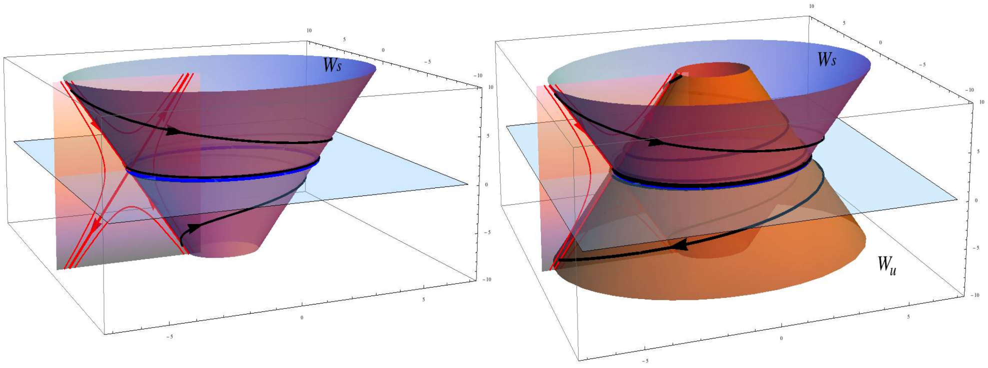

Figure 1: Sketch of the dynamics near a Lyapunov orbit, represented as the blue curve. In any section transverse to the orbits the dynamics is characterized by a curve of initial conditions which converge to the periodic orbit for positive times and a curve of initial conditions which converge to the periodic orbit for negative times; while converging to LL_1 (or LL_2), the orbits turn around the periodic orbit, so that there exist two surfaces, which topologically are cylinders, of orbits which converge to the periodic orbit for positive times (violet surfaces in the left panel) and also two surfaces of of orbits which converge to the periodic orbit for negative times (the additional surfaces in the right panel). These cylinders are the stable and unstable manifolds of LL_1 (or LL_2) respectively, that is the tube manifolds.

equations of motion of P are:

$$\begin{cases} \ddot{x} &= 2\dot{y} + x - (1-\mu)\frac{x+\mu}{r_1^3} - \mu\frac{x-1+\mu}{r_2^3} \\ \ddot{y} &= -2\dot{x} + y - (1-\mu)\frac{y}{r_1^3} - \mu\frac{y}{r_2^3} \end{cases} \tag{1}$$

where the masses of P_1 and P_2 are $1-\mu$ and μ respectively; their coordinates are $(-\mu, 0)$ and $(1-\mu, 0)$; their revolution period is 2π and: $r_1^2 = (x+\mu)^2 + y^2$, $r_2^2 = (x-1+\mu)^2 + y^2$. As it is well known, equations (1) have a constant of motion, the so–called Jacobi constant which we denote by $\mathcal{C}(x, y, \dot{x}, \dot{y})$, and five equilibria denoted by $L_1, \ldots, L_5$. The equilibrium L_2 is particularly important to study the dynamics of the orbits which transit from the region which is internal (external) to the orbit of the secondary mass to the region which is external (internal) to the binary system. In fact, these transits are in principle possible only for the orbits with values $\mathcal{C}_*$ of the Jacobi constant strictly smaller than the value $\mathcal{C}_2 = \mathcal{C}(x_{L_2}, 0, 0, 0)$ at L_2. Moreover, for $\mathcal{C}_* < \mathcal{C}_2$ close to $\mathcal{C}_2$, two periodic orbits around the equilibria L_1 and L_2 exist: the so called Lyapunov orbits of L_1, L_2, which will be hereafter denoted by LL_1, LL_2. Also, the region of the orbit plane x, y which can be visited by orbits with Jacobi constant $\mathcal{C}_*$ has the peculiar shape of a bottle-neck, and LL_1, LL_2 are located at the entry and exit of the bottle-neck. The orbits LL_1, LL_2 are normally hyperbolic: in any section transverse to the orbits the dynamics is characterized by a curve of initial

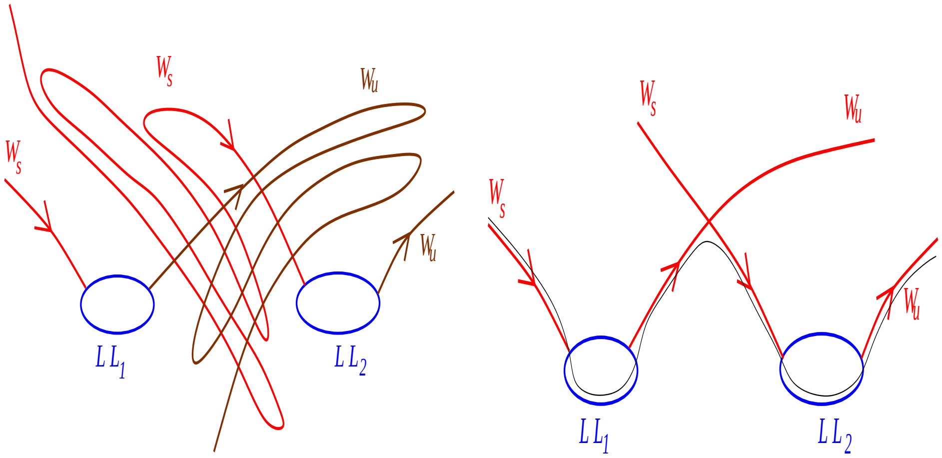

Figure 2: On the left panel we symbolically sketch the possible complicated structure of the stable and unstable manifolds of LL_1, LL_2. In particular, many intersections exist. Any intersection point (such as the one symbolically represented in the right panel) belongs to a heteroclinic orbit, which is asymptotic in the past to LL_1, and in the future to LL_2. With a suitable small variation of the initial conditions, we obtain a transit orbit, such as the black curve symbolically represented in the right panel.

conditions which converge to the periodic orbit for positive times and a curve of initial conditions which converge to the periodic orbit for negative times (see Figure 1-left panel); while converging to LL_1 (or LL_2), the orbits turn around the periodic orbit, so that there exist two surfaces, which topologically are cylinders, of orbits which converge to the periodic orbit for positive times and two surfaces of orbits which converge to the periodic orbit for negative times. These cylinders are the stable and unstable manifolds of LL_1 (or LL_2) respectively, that is the so called 'tube' manifolds.

3. COMPUTATION OF THE TUBE MANIFOLDS AND TRANSIT ORBITS WITH FAST LYAPUNOV INDICATORS

Stable and unstable manifolds in non-integrable systems usually have a complicated topology, characterized by many typical lobes (see Figure 2); this is also the case of the tube manifolds of the three body problem. Analytic methods allows us to compute only the local part of the manifolds, close to the Lyapunov orbits. To extend the knowledge of the manifolds beyond the local part we need to use numerical methods. In order to study the transit orbits we are interested, in particular, in the computation of the intersections between the unstable manifold of LL_1 with the stable manifold of LL_2. An initial condition in these intersections belongs to a so called heteroclinic orbit (see Figure 2), that is an orbit which is asymptotic in the past to LL_1, and in the future to LL_2. A recent variant of the FLI, specifically introduced in Guzzo and Lega 2014 for the detection of the stable or unstable manifolds of selected periodic orbits, allows to detect the heteroclinic intersections of different manifolds. The new indicator is defined as follows. Let us consider a system of first order differential equations $\dot{x} = F(x)$, $x \in R^n$, and a normally hyperbolic periodic orbit γ. The new indicator is defined with reference to some smooth window function $u(x) \geq 0$ such that $u(x) \sim 1$ close to γ, and $u(x) = 0$ for x distant from γ more than some threshold ρ (there is a certain freedom of choice of ρ; see Guzzo and Lega 2014, and below, for technical details). Then, for any phase–space initial condition $x(0)$ and any initial vector $v(0) \in R^n$ we denote by $x(t)$ the solution of the differential equations with initial condition $x(0)$ and by $v(t)$ the solution of the variational equations: $\dot{v} = \left(\frac{\partial F}{\partial x}(x(t))\right) v$. The Fast Lyapunov Indicator of $x(0)$ modified with the window functions $u(x)$, at time T is defined by:

$$FLI_u(x(0), v(0), T) = \int_0^T u(x(t)) \frac{v(t) \cdot \dot{v}(t)}{v(t)^2} dt. \tag{2}$$

For any selected periodic orbit γ, with a careful choice of the window function $u(x)$ and of the total integration time T, the FLI indicator (2) detects the stable manifold of γ if $T > 0$ (the unstable manifold if $T < 0$) with very high precision: as it is proved in Guzzo and Lega 2014, the modified FLI has its highest values on the points of the manifolds, and rapidly decays outside the manifold.

For the computation of the tube manifolds of LL_1, LL_2, we define the equations of motion of the three–body problem, and its variational equations, in the space of the variables obtained by regularizing equations (1) with respect to the secondary mass, as in Lega et al. 2011, Guzzo and Lega 2013; we use the window function

$$u(x) = \begin{cases} 1 & \text{if } \; x - \gamma \leq \frac{r}{2} \\ \frac{1}{2}[\cos((\frac{x-\gamma}{r} - \frac{1}{2})\pi) + 1] & \text{if } \; \frac{r}{2} < x - \gamma \leq \frac{3r}{2} \\ 0 & \text{if } \; x - \gamma > \frac{3r}{2} \end{cases} \tag{3}$$

where r is a parameter, and $x - \gamma$ denotes the distance between x and γ. Then, we obtained sharp representations of the intersections between the unstable manifold of LL_1 and the stable manifold of LL_2 with the two–dimensional surface of the space of the Cartesian coordinates and velocities $x, y, \dot{x}, \dot{y}$:

$$\Sigma = \{(x, y, \dot{x}, \dot{y}) : \quad y = 0 \quad , \quad \dot{y} \geq 0 : \quad \mathcal{C}(x, 0, \dot{x}, \dot{y}) = \mathcal{C}_*\} \tag{4}$$

by computing the modified FLI defined in (2) on a refined grid of initial conditions on Σ using the same initial tangent vector $v(0)$, a negative time $-T_1$ and $r = 10^{-3}$ for the unstable manifold of LL_1, and a positive time T_2 and $r = 5\ 10^{-4}$ for the stable manifold of LL_2. In such a way, for any $x, \dot{x}$ we obtained two modified FLIs, which we denote by FLI_1, FLI_2. Then, we represented on the same picture, for any initial condition $x, \dot{x}$, a weighted average of the two indicators:

$$\frac{w\ \mathrm{FLI}_1 + \mathrm{FLI}_2}{(w+1)}, \tag{5}$$

for a convenient choice of $w > 0$. The results are represented in Figure 3: the stable and unstable manifolds appear on the picture as the curves characterized by the highest values of the indicator, as it is expected from the theory.

We clearly appreciate different lobes of both manifolds, as well as many intersection points, providing heteroclinic orbits. The FLI computation can be repeated by zooming close to an intersection point, in order to detect the heteroclinic points with all the desired precision, such as in Figure 4: the heteroclinic point is obtained with

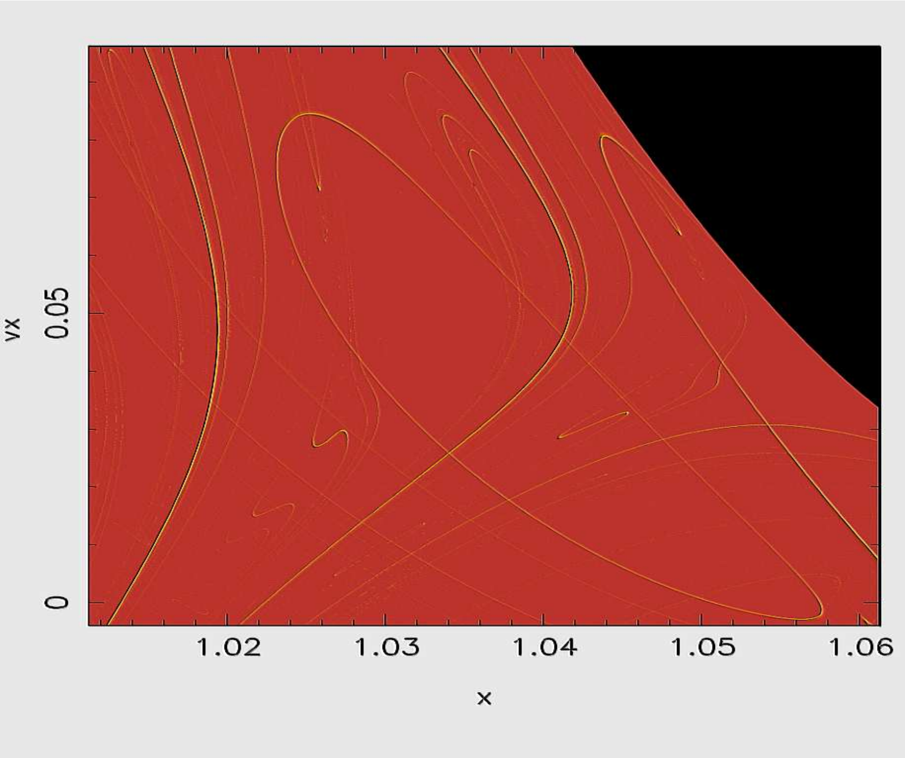

Figure 3: FLI computation of the unstable manifold of LL_1 and the stable manifold of LL_2 for the Sun-Jupiter systems and $\mathcal{C}_*$ slightly smaller than $\mathcal{C}_2$. The panel represents the values of the modified FLIs (5) computed on the section Σ: on each point $x, \dot{x} = vx$ of the panel we represent its FLI value with a color scale, so that the unstable manifold of LL_1 and the stable manifold of LL_2 appear as the yellow curves. The different lobes of the manifolds are clearly visible on this picture (obtained with $T_1 = T_2 = 5$) as well as many intersection points, which are the heteroclinic points described in the text. The figure, first obtained in Guzzo and Lega 2014, has been here represented with some graphic filter in order to appreciate more clearly the manifolds. *Copyright 2014 Society for Industrial and Applied Mathematics. Reprinted with permission. All rights reserved.*

15 digits of precision. In Figure 5, left panel, we report the orbit corresponding to this heteroclinic point. Since the heteroclinic orbit transit from LL_1 and LL_2, with a very small variations of its initial conditions we easily obtain the transit orbit reported in Figure 5, right panel.

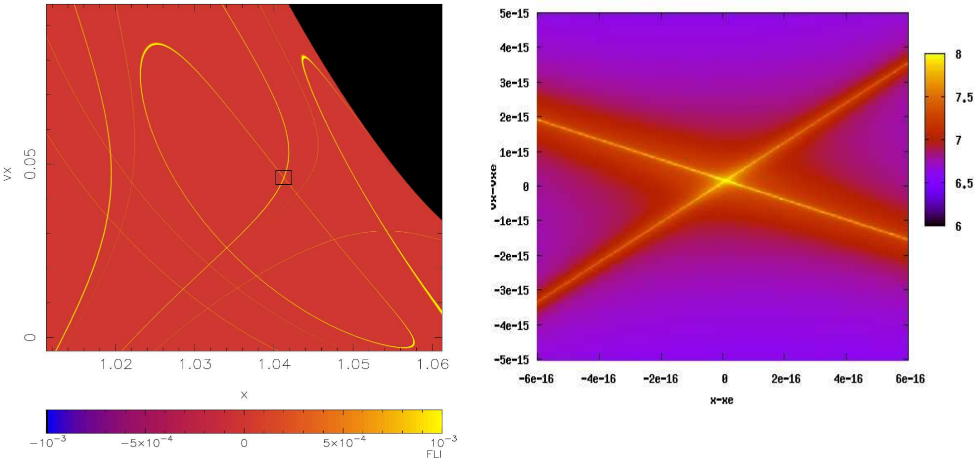

Figure 4: On the left panel (see Fig. 3) we select an heteroclinic point, in the box. On the right panel we zoom very close to it (set as the origin of the picture), so that we determine the heteroclinic intersection with 15 digits of precision. Both figures had been published in Guzzo and Lega 2014: *Copyright 2014 Society for Industrial and Applied Mathematics. Reprinted with permission. All rights reserved.*

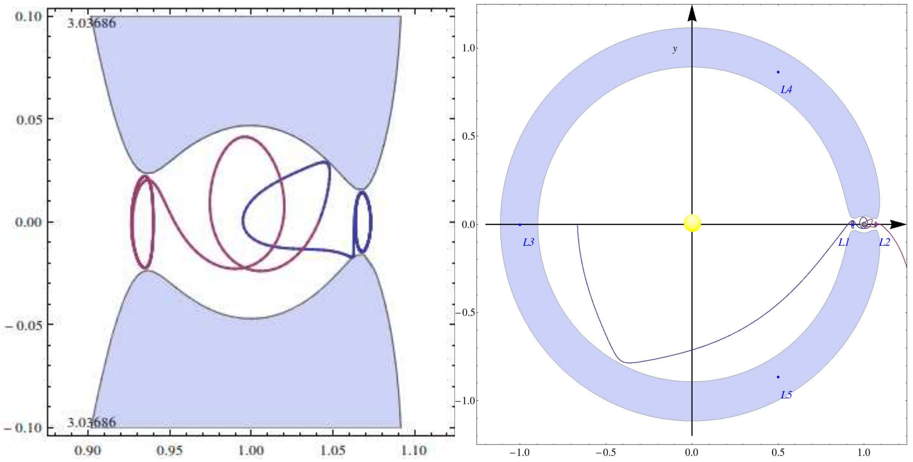

Figure 5: In the left panel we report the projection on the plane (x, y) of the heteroclinic orbit found with the FLI computation of Figure 4. The shaded area represents the region where orbits with Jacobi constant equal to $\mathcal{C}_*$ cannot enter. With a very small correction to the initial conditions of this orbit, we obtain the transit orbit reported in the right panel. The figure in the left panel had been published in Guzzo and Lega 2014: *Copyright 2014 Society for Industrial and Applied Mathematics. Reprinted with permission. All rights reserved.*

4. CONCLUSIONS

The modified FLI indicator introduced in Guzzo and Lega 2014 has been used to compute the heteroclinic intersections of different stable and unstable manifolds of the three body problem, and thus transit orbits. Since the application of the method is robust by considering more complicated dynamical models, we expect that it can be used to compute transit orbits in realistic models of the Solar System.

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ON DECOUPLING CIVIL TIMEKEEPING FROM EARTH ROTATION

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Abstract. During the recent 15 years intense efforts have been done in order to cease introducing leap second corrections in the UTC scale. Before, probably the final, decision at the World Radiocommunication Conference in 2015, we discuss some aspects and consequences of such a UTC redefinition, to present our own viewpoint as well.

1. INTRODUCTION

Coordinated Universal Time (UTC) is the basis for civil timekeeping in almost all countries of the world because this is a precise atomic time scale publicly available and which with an acceptable tolerance follows the Earth rotation so that we have a close approximation to the traditional, astronomically defined, mean solar time on the Greenwich meridian. Till now the level of this tolerance has been changed several times, whereas the way of monitoring has been changed only twice.

Within the first decade of its existence, from the early sixties to late 1971, UTC was kept close to the Universal Time (UT2) in the way that either the carrier frequency was corrected or small time steps were introduced ($\leq$ 100 ms). Because of this, apart from the advantages, the UTC of that time also had two drawbacks: time-unit (UTC second) duration was variable and discontinuity.

In the beginning of the seventies the UTC scale was redefined following the recommendation of the International Radio Consultative Committee (CCIR) and from January 1, 1972 it has been established in a well-defined standard way. UTC has the same unit as the International Atomic Time (TAI) scale to which it is syntonized and from which it is allowed to differ by integral number of seconds only. The absolute deviation from the Universal Time within conventional limits (at first 0.7 s and afterwards, from the beginning of 1974, 0.9 s) has been solved through the "leap-second" mechanism, i. e. by adding or removing one second at standardized moments if it is clear that the difference $|\mathrm{UTC} - \mathrm{UT1}|$ will exceed the allowed value.

Through the dissemination of UTC the standardized high-accuracy frequency is available to everyone, which is very important for many applications in science and engineering, but the discontinuity of UTC is still present so that in the late nineties first ideas arose to abolish the leap second as a corrective mechanism. Over the previous 15 years ideas about a continuous UTC scale have grown into serious proposals and actions. However, in spite of a strong support from respected experts and institutions, the proposal on adoption of the new UTC, without leap seconds, has found a positive consensus at no relevant-body meeting. The main reason has been its historical significance to civil timekeeping and non-ignorable opponent positions. The scientific and professional public is very polarized as to this proposal, and some of them have even mentioned the lack of competence of the leading proponent (e.g. Quinn 2011). Therefore, it is still impossible to anticipate if the proposal will be adopted in the future.

The initiative and actions towards the abolishment of UTC leap second are backed by the United Nations agency for radio and communication technology issues named International Telecommunication Union (ITU), or more precisely, its part specified as: Working Party 7A (Broadcast and Frequency Services) of Study Group 7 (Science Services) of Radiocommunication Sector of ITU (WPA7A, SG7, ITU-R). A number of articles followed the proposal of this reputable organization and several scientific meetings were held, where many distinguished experts from various fields expressed their opinions . Two working groups of International Astronomical Union (IAU) also considered the initiative of ITU-R, out of which the first one was operative for six years (2000-2006) and the second one for two years (2012-2014).

In the reference list of the present paper a few characteristic articles are indicated, and among the meetings at which the topic was discussed, we distinguish the following ones:

- ITU-R SRG 7A Colloquium on the UTC timescale, May 28-29, 2003, Torino;
- Colloquium "Decoupling Civil Timekeeping from Earth Rotation", Oct 5-7, 2011, Analytical Graphics Inc, Exton, Pennsylvania;
- ITU Radiocommunication Assembly, Jan 20, 2012, Geneva (RA-12);
- ITU World Radiocommunication Conference, Feb 14,2012, Geneva (WRC-12);
- ITU/BIPM Workshop on the future of the international time scale, Sep 19-20, 2013, Geneva

Many of well known authors advocate the leap second abolishment (e.g. Arias, Beard, Guinot, Klepczinsky, McCarthy, Nelson, ...), but there are many distinguished opponents also (e.g. Allen, Gambis, Finkleman, Seago, Seaman, Seidelmann, ...).

In our opinion it is much better to preserve the actual definition of UTC scale with leap seconds than that proposed by ITU-R.

2. DIFFERENCES UT1-TAI, UT1-UTC AND UTC-TAI

Bureau International des poids et Mesures (BIPM) is the institution authorized for the establishment and maintenance of the TAI. The metrological scale TAI is not distributed, but appears as the basis on which other time scales of special use are formed, such as, for instance, Terrestrial Time (TT) or UTC.

The BIPM physical time scales TAI and UTC count the same portions of time, SI seconds, and have syntonized frequencies. They are derived by using special statistical procedures on the basis of regular time comparisons among several hundreds of atomic clocks distributed in more than 70 metrological laboratories and scientific institutes all over the world.

On the other hand, the mean solar time, the traditional basis of civil timekeeping, which is very close to the astronomical UT1 time, depends on the work of only one clock governed by the rotation of our planet. True, the properties of UT1 due to the irregularities in the Earth rotation are worse than those possessed by the atomic time scales TAI and UTC, but UT1 can be in no way ignored in the time metrology. It is important to anyone needing information on the Earth space orientation, and also the notion of day is still unsuitable to be defined through work of technical devices only, no matter how sophisticated they are.

By introducing new intermediate reference systems (terrestrial and celestial) in modern astrometry from 2003, UT1 has been in a simple way related to the Earth Rotation Angle (ERA), precisely determined from the VLBI observations of extragalactic objects. The linear relationship between UT1 and ERA in radians is given by

$$\mathrm{ERA}(T_u) = 2\pi(0.7790572732640 + 1.00273781191135448\, T_u)\ ,$$

where T_u = Julian UT1 date − 2451545.0 UT1. For final derivation of UT1, or more precisely, of the Earth-rotation parameter UT1-UTC the responsibility belongs to International Earth Rotation and Reference System Service (IERS). IERS also determines predictions of UT1-UTC and, based on them, announces the date of UTC leap second correction several months in advance.

Beginning from January 1, 1972, since when the present form of UTC with leap seconds adjustment exists, the relationship between the scales UTC, TAI and UT1 is defined by the differences:

$$\mathrm{UTC} - \mathrm{TAI} = \mathrm{N} \qquad \text{and} \qquad \mathrm{UTC} - \mathrm{UT1} = \mathrm{L}\ ,$$

so that N is an integral number of seconds and $|\mathrm{L}| < 0.7\,\mathrm{s}$ (before 1974), or $|\mathrm{L}| < 0.9\,\mathrm{s}$ (from 1974), as said in the previous section. All the values of the differences UT1-TAI and UTC-TAI realized up to now in accordance with this convention are plotted in Fig. 1, and in the case of the difference UT1-UTC in Fig. 2.

On the basis of a clearly expressed linear trend of increasing differences UT1-TAI during the last half century, in the era of atomic clocks, we can conclude that an approximately constant difference in the size of units of the time scales UT1 and TAI has existed and the astronomical second (UT1 second), very close to the mean solar day duration multiplied by 1/86400, lasted longer than the SI second. Figuratively speaking, the rate of UT1 clock was slower than that of TAI and UTC clocks of the same technical specifications. The only difference between the latter two clocks is that the TAI one worked all the time and the UTC clock from 1972 till now has been 25 times set back by one second, in order to be caught up by the UT1 clock, i. e. that the times shown by them are approximately equal within the limits of conventional tolerance[1] L (see Table 1).

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[1] Before 1972 the UTC clock was several times set back by 100, 50 or 20 ms, and also a few times its rate was changed. (elastic second era)

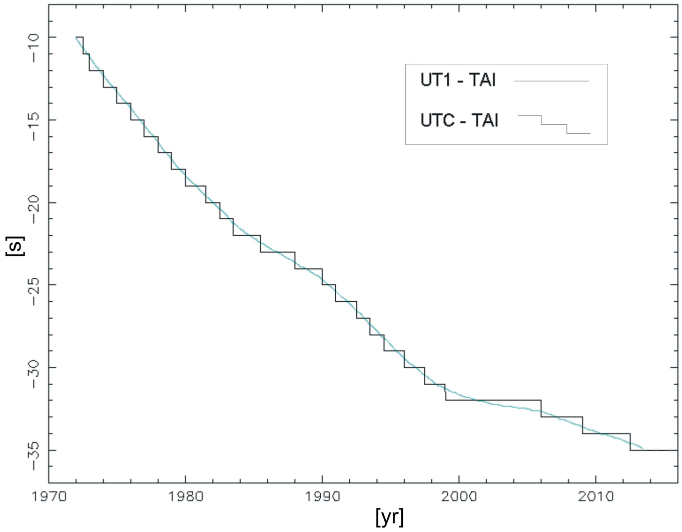

Figure 1: Differences UT1-TAI and UT1-UTC in the leap-second era (beginning from 1972).

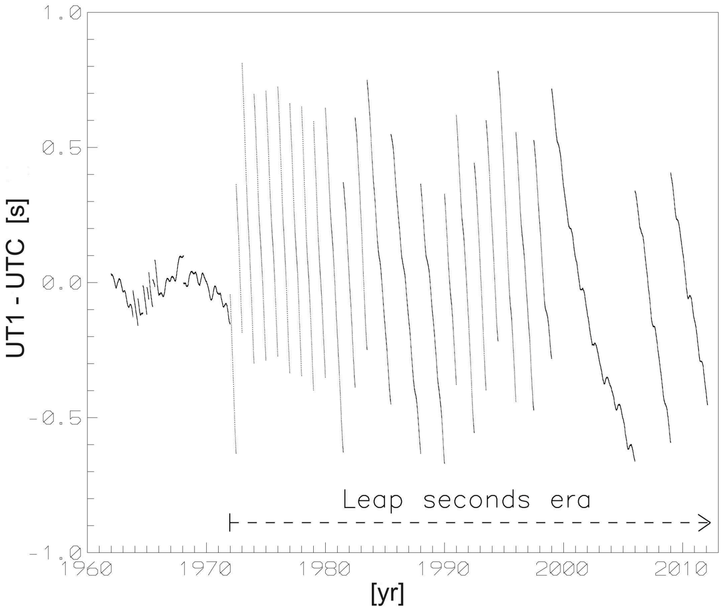

Figure 2: Discontinuities in the difference UT1-UTC.

Table 1: History of all UTC – TAI definitions

From	To	UTC – TAI [s]
1961.01.1	1961.08.1	$-1.422818 - (\text{MJD-37300}) \times 0.001296$
1961.08.1	1962.01.1	$-1.372818 - (\text{MJD-37300}) \times 0.001296$
1962.01.1	1963.11.1	$-1.845858 - (\text{MJD-37665}) \times 0.0011232$
1963.11.1	1964.01.1	$-1.945858 - (\text{MJD-37665}) \times 0.0011232$
1964.01.1	1964.04.1	$-3.240130 - (\text{MJD-38761}) \times 0.001296$
1964.04.1	1964.09.1	$-3.340130 - (\text{MJD-38761}) \times 0.001296$
1964.09.1	1965.01.1	$-3.440130 - (\text{MJD-38761}) \times 0.001296$
1965.01.1	1965.03.1	$-3.540130 - (\text{MJD-38761}) \times 0.001296$
1965.03.1	1965.07.1	$-3.640130 - (\text{MJD-38761}) \times 0.001296$
1965.07.1	1965.09.1	$-3.740130 - (\text{MJD-38761}) \times 0.001296$
1965.09.1	1966.01.1	$-3.840130 - (\text{MJD-38761}) \times 0.001296$
1966.01.1	1968.02.1	$-4.313170 - (\text{MJD-39126}) \times 0.002592$
1968.02.1	1972.01.1	$-4.213170 - (\text{MJD-39126}) \times 0.002592$
1972.01.1	1972.07.1	–10
1972.07.1	1973.01.1	–11
1973.01.1	1974.01.1	–12
1974.01.1	1975.01.1	–13
1975.01.1	1976.01.1	–14
1976.01.1	1977.01.1	–15
1977.01.1	1978.01.1	–16
1978.01.1	1979.01.1	–17
1979.01.1	1980.01.1	–18
1980.01.1	1981.07.1	–19
1981.07.1	1982.07.1	–20
1982.07.1	1983.07.1	–21
1983.07.1	1985.07.1	–22
1985.07.1	1988.01.1	–23
1988.01.1	1990.01.1	–24
1990.01.1	1991.01.1	–25
1991.01.1	1992.07.1	–26
1992.07.1	1993.07.1	–27
1993.07.1	1994.07.1	–28
1994.07.1	1996.01.1	–29
1996.01.1	1997.07.1	–30
1997.07.1	1999.01.1	–31
1999.01.1	2006.01.1	–32
2006.01.1	2009.01.1	–33
2009.01.1	2012.07.1	–34
2012.07.1	?	–35

3. SOME ESSENTIAL ISSUES REGARDING THE NEW UTC

The proposal for ceasing the further introduction of leap seconds in the UTC scale has caused many controversies because the acceptance of such a free atomic time scale for civil time keeping would *de facto* mean a complete end of its traditional link with the Earth rotation. Many questions concerning this can arise, from essential ones to quite formal, but we shall here consider only some of them and attempt answering them through brief discussions.

3. 1. IS THE UTC DISCONTINUITY A REAL NUISANCE?

Firstly, we can pose the question if UTC is discontinuous at all.

With regard to the interrupted lines representing the difference UT1-UTC in Fig. 2, the answer is certainly yes, but one should bear in mind that together with UTC a stable frequency of atomic time standard is continuously disseminated, so that the UTC scale is made of a continuous sequence of successive SI seconds. This means that every time interval between two moments t_1 and t_2, measured from the same initial epoch t_0 in seconds, is simply equal to the difference $t_2 - t_1$. Therefore, we can treat UTC as a continuous time scale when using the SI second, or any multiple of its, as unit.

Interruptions in the differences UT1-UTC are not due to interruptions in UTC, but to the conventional application of the change in duration of one UTC day at the moment of applying the leap-second mechanism. Then by shifting the marker for the beginning of a day in the UTC scale by one SI second, to either of the sides, we influence the shortening or lengthening of the preceding day[2]. For this reason the action for abolishing the leap second can be understood as a desire to equalize the UTC day duration and that it becomes a time unit always lasting exactly 86400 SI seconds.

Of course, we can ask the question, why it is important that a day has a fixed duration, when the months and years do not have such a property. The answer is simple: the number of days in any coming months and years can be always accurately determined, but not also their lengths, due to the variable Earth rotation and the existing limitation for the deviation |UT1-UTC|. However, this logically leads us to look for the answer to the following question.

3. 2. WHAT OR WHO NEEDS ABOLISHING THE UTC LEAP SECOND?

The only situation which we can imagine is programming of automatic activation of some technical device at a precisely defined moment of civil time, because with increasing the time distance of this moment the possible error in its location in the UTC scale also increases.

For instance, if we want this device to be automatically turned on in a fixed number of SI seconds, beginning from a defined moment, we cannot know precisely even the calendar date when this will occur in the future. Also the converse, if we wanted any activation of this device at an exact moment of the fixed calendar date, we would have to know precisely in how many SI seconds this will take place. In both cases, the actual UTC scale definition with leap seconds produces problems.

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[2] In each of the 25 cases till now the leap second has been inserted in the UTC scale, i. e. the UTC day lasted 86401, instead of 86,400 SI seconds.

We do not want to speculate here what kind of devices they could be and for what circumstances their work has to be programmed in civil time (not in another existing continuous time scale, e.g. TT, TAI, or UTC(GPS)), but in our opinion during the last 15 years the advocates of the UTC redefinition could have described in more detail "technical inconveniences" arising due to the UTC leap second. Especially, if borne in mind that there also exist users of modern computer, communication and satellite technologies to whom the leap second produces no technical problems.

At present it seems to us that the reasons for the proposed UTC redefinition are of administrative nature only.

3. 3. DO ANY SCIENTIFIC REASONS EXIST IN FAVOR OF THE UTC REDEFINITION?

The secular deceleration of the Earth rotation is one of them that is mentioned most frequently, but according to the results of the Earth rotation monitoring in the XX and XXI centuries it will be no serious argument for a long time in advance.

According to the geophysical studies the secular deceleration of the terrestrial rotation is equal to about 5.5×10^{-22} rad s^{-2} (Lambeck 1980). Based on this, the accumulated values for the UT1-TAI difference and the corresponding number of leap seconds, which would have to be introduced, can be estimated. In Fig. 3 we can see a presentation of such an estimate over the interval of 1000 years and it is can be noted that this number is expected to increase in five centuries from the value of 0.6, which it has now, to 4, and in the end of the millennium to even more than 6 per year (Arias, Guinot 2004).

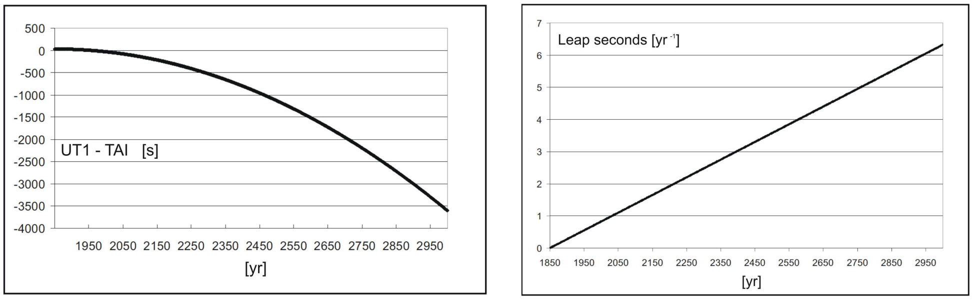

Figure 3: The projections of the UT1-TAI values(left) and increasing number of the leap-seconds per year (right) in the millennial time-span. (Arias, Guinot 2004).

However, the practical purpose for such crude and distant theoretical predictions is not clear since they do not suggest any urgency in solving the given problem. On the other hand, the observational data for the last hundred years do not indicate any deceleration in the Earth rotation, but quite the contrary.

In Figure 4 the length-of-day excess variations during the last four centuries (telescope era) and during the last five decades (atomic-clock era) are given in parallel. We can see that, though the theory and old observations indicate increasing in the day length, during the last 100 years, there exists a clear trend of its decreasing, i.e. of accelerating the Earth rotation.

Already now one can expect that in 2060, at the end of the first century of UTC existence, the real increase in day length, compared to that from the beginning of the 1960s, will be significantly different from $+1.7$ ms d^{-1} cy^{-1} (Stephenson, Morrison

1995), because from that time the average day length has already become shorter by about 2 ms (Figure 2, right), so that the increase rate is -4 $\mathrm{ms\,d^{-1}\,cy^{-1}}$ currently.

From Table 1 we can see that the number of leap seconds within the interval (1972-1993) is 17, whereas afterwards, during the next 20 years, only 8 leap seconds were introduced. This is a clear confirmation that the concern about increasing the number of leap seconds is unjustified, at least in the near future.

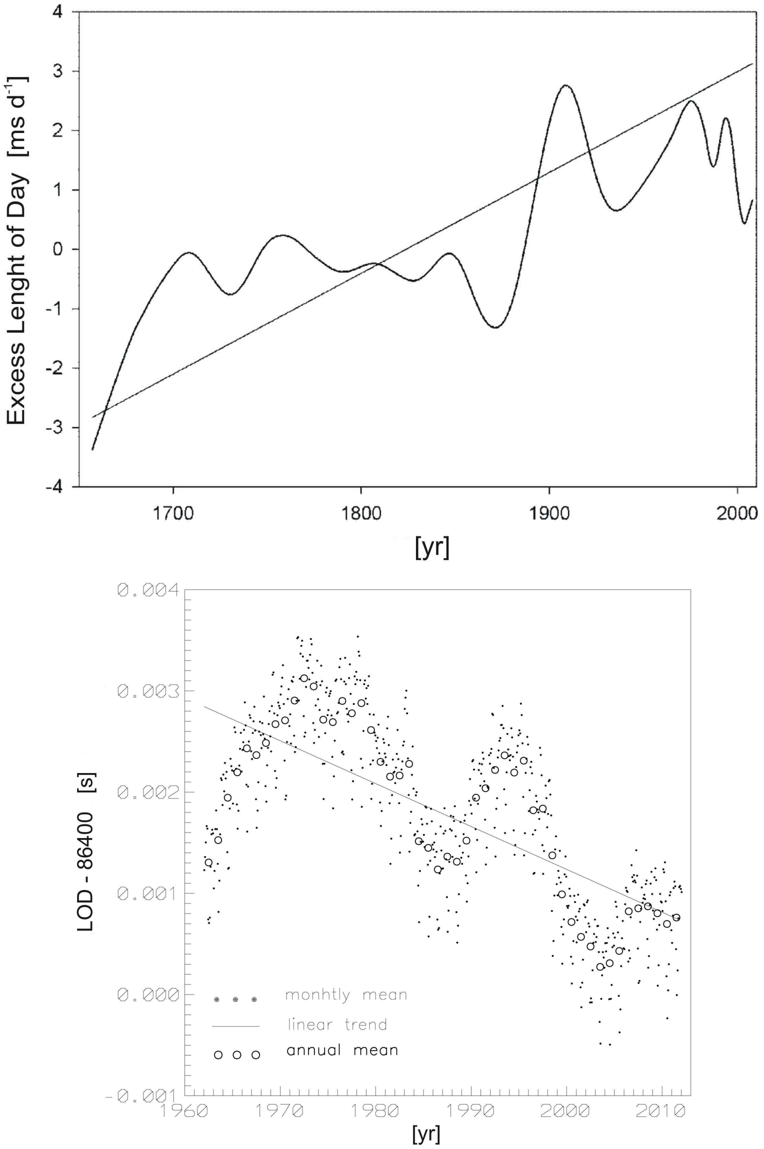

Figure 4: (Above:) Smoothed-out values of day-length excess and their linear (theoretical) trend in the telescope era (McCarthy, Seidelmann 2009) and (Below:) the mean monthly and mean annual values of the excess with linear trend in the atomic-clock era (according to the IERS data).

3. 4. CAN "THE DAY SAVING TIME" BE ARGUMENT IN THIS DISCUSSION?

Those advocating the new UTC, in order to diminish the importance of the increasing deviation of UTC from UT1, are inclined towards comparisons with seasonal legal-time shifting by ±1 h and they suggest a leap hour as a good substitution for the leap second.

For example:
"We especially wished to show that the public accepts a departure of the legal time with respect to solar time by an amount reaching hours and, in many countries, time steps of one hour twice a year. Compared with this offset, the abandonment of leap seconds would introduce possible offset of 3 or 4 min by 2100, and half an hour between 2500 and 2600. It would be quite sufficient, for many centuries, to have a unique, continuous and uniform world time and to adjust legal times according to the wishes of citizens by steps of one hour, exactly as is already done twice a year." (Guinot 2011)

We do not think that the entire public are keen to accept "the day-saving time", nor that it is anywhere introduced following the will of the majority of citizens. Any time scale with overlaps and gaps of 60 min width can be characterized anyway, but not as good one. This is a splendid example demonstrating drastically what takes place when the time policy is regulated by someone authorized to make decisions, but who at the same time has not yet understood what the purpose of a time scale is.

According to our standpoint it would be much better if distinguished authorities for the field of time, such as, for instance, the author of the quotation given above, and international organizations, such as ITU and IAU, recommended to the governments worldwide to abolish the nuisance known as "day-saving time", than the tenacious advocating decade and half long for UTC redefinition, which should ensure a more precise link between the future activities of some undefined automated devices and the civil time. The history of formation of time scales is too complex (see e.g. McCarthy, Seidelmann 2009) to deserve frequent changes without any strong reason. This is especially true if there is no general agreement of the scientific and other public, as is the case here (see e.g. Gambis 2014).

3. 5. IS AN ALTERNATIVE UTC REDEFINITION POSSIBLE?

UTC without leap seconds following UT1 over sufficiently long time intervals, of a few decades, perhaps a whole century, can be realized by changing the length of the time-scale unit and by increasing the tolerance for the difference |UT1-UTC|.

For instance, if for UTC only, instead of the SI second, another unit were used, let it be named astronomical or civil second, which were always determined on the basis of all previous UT1-TAI values with initial epoch January 1, 1958, we would get a scale with a frequency related to the standard TAI scale through one multiplier only and then by means of TAI it is related to the other scales having the SI second as the unit. In this way we would derive standardized UTC scales, easily convertible into one another, whereas the interval between two neighboring versions could be fixed, in earlier versions, say, to 50 years, and in later ones to 100 years (e.g. UTC_{2050}, UTC_{2100}, UTC_{2200}, etc.), because any future correction of the civil second would be finer than the preceding ones.

Such a conception of UTC would enable the preservation of a link with the Earth rotation and the precise scheduling of events in the civil time much farther into the future would be realizable. All of the existing time scales, all physical and astronomical constants, as well as the existing software and hardware infrastructure, based on the SI second, would not be changed and could be operative in the future.

Figure 5 shows how a hypothetical change of the atomic-second length would affect the differences UT1-TAI from 1955 to 1999 (Jones 2000). The SI-second length, equal to 9 192 631 770 specific transitions in the atom Cs 133, has been adopted because of the prevailing desire in the astronomical community according to which it should be as close as possible to the second of ephemeris time (ET) and the results of experiments from the late 1950-ties (Markowitz et al 1958). However, if it had been chosen to be larger by 167, i.e. to correspond to the UT second on January 1, 1958, the deviations UT1-TAI would have been almost four times smaller and an optimal result would have been obtained for +227. We have obtained for the optimum +212, but for the interval [1962-2011].

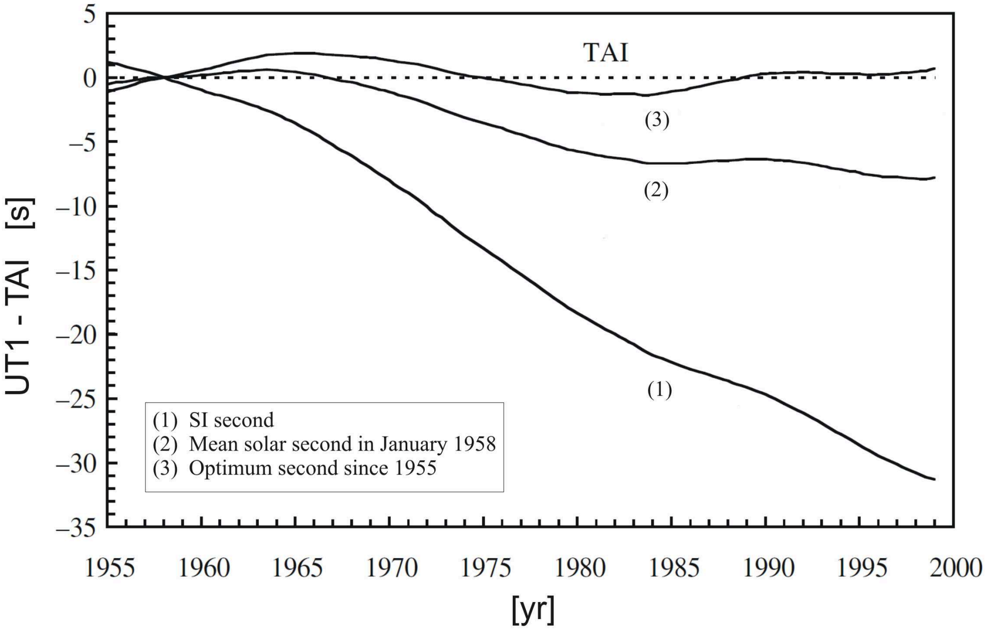

Figure 5: Dependence of deviations UT1-TAI on the size of TAI-scale unit. (Jones 2000).

4. CONCLUSION

In our opinion, the UTC scale should still maintain its present definition, since it successfully fulfills the purpose and meets the objectives of its establishment.

The adoption of the proposed UTC redefinition would have quantitative and qualitative impact on the present conception of civil timekeeping, based on not sufficiently persuasive arguments. As long as the progress in meeting the standpoints has not been made, the decision of such global importance should not be accepted by outvoting at any instance.

The options for another UTC definition can be found, however they have to be searched for in future carefully and in an unforced manner, simultaneously with analyzing all previous values of UT1-TAI deviations. Anyway, it is our opinion that civil timekeeping should preserve its astronomical basis with all the support that modern technology can provide, and not to abandon it for the sake of technological or some other comfort.

Acknowledgement

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ON THE INNER BORDER OF PHOCAEA GROUP OF ASTEROIDS

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Abstract. In this work we check wether or not the inner boundary of the region in term of semi–major axis, namely the 7J:-2A resonance with Jupiter, could be crossed under the influence of gravitational and non-gravitational forces. The obtained results show that a significant fraction of our test particles successfully transit across the resonance, without being removed from the region. This means that, despite being relatively effective in pumping up asteroid eccentricities in this region, the 7J:-2A resonance is not an absolute dynamical boundary.

1. INTRODUCTION - PHOCAEA REGION

The Phocaea group is located in the inner asteroid belt, and consists of asteroids having orbital inclination higher than about 20 degrees, with semi-major axis from 2.25 AU to 2.5 AU and eccentricity ranging between 0.15 and 0.3. The asteroids in this region are characterized by a very interesting dynamics. The region of the Phocaea group is delimited by the 7J:-2A mean motion resonance (MMR) at low a, by the 3J:-1A MMR at high a and by the $\nu_6 = g - g_6$ (where g is the secular frequency of precession of the pericentre, and the suffix 6 refers to Saturn) secular resonance at low i (Knežević & Milani 2003). In addition, as explained by Knežević & Milani (2003), the Phocaea group is characterized by a region of shallow close encounters with Mars at $e > 0.3$, which displays significant chaotic behavior.

Moreover, the Phocaea group itself is characterized by its interaction with the secular resonance $\nu_6 - \nu_{16} = (g - g_6) - (s - s_6)$, where s is the secular precession frequency of the asteroid node. For this resonance is shown to be important for the dynamics of the Phocaea asteroids, and that a significant fraction of them is locked inside it (Knežević & Milani 2003).

1. 1. THE AIM OF OUR WORK

In Phocaea region there are many mean motion and secular resonances. The one very interesting is mentioned 7J:-2A, which is located at about 2.256 AU, and seems to set the lower boundary of the region in terms of semi–major axis.

The impact of Yarkovsky thermal force (Neiman at al., 1965, Vokrouhlický, 2001) has been usually examined separately from the influence of resonances on the motion of an asteroid. For example, Carruba (2010) found the 7J:-2A resonance to be very efficient in pumping up orbital eccentricities, leading to close approach with Mars.

He investigated dynamical behavior of objects in neighborhood of this resonance, but without taking into account the impact of the Yarkovsky effect.

Our main purpose here is to analyze the dynamical behavior of objects close to the 7J:-2A resonance, but taking into account the Yarkovsky effect. More precisely, our aim is to answer the question: could 7J:-2A resonance be crossed under the combined impacts of gravitational and non gravitational forces?

2. THE METHOD

We want to study a possibility of the resonance crossing to occur. For this reason we performed numerical integrations on set of 20,000 fictitious asteroids initially located very close to the outer boundary of the 7J:-2A (Figure 1).

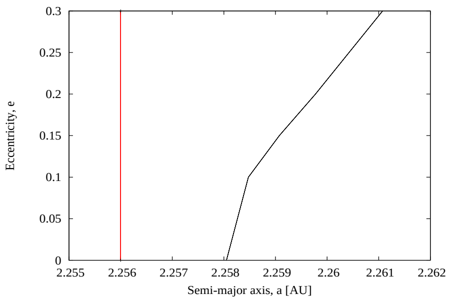

Figure 1: The outer (”entering”) border (black lines) and center (red line) of the 7J:-2A resonance.

The orbital motion of fictitious bodies was tracked for 20 Myr using the public domain ORBIT9 software (Milani & Nobili 1988), embedded in the multipurpose OrbFit package4. The dynamical model includes seven planets, from Venus to Neptune, as perturbing bodies. To account for the indirect effect of Mercury, its mass is added to the mass of the Sun and the barycentric correction is applied to the initial conditions. The Yarkovsky thermal force was also included in the model.

In order to generate this fictitious objects, we first took 1000 different asteroids, which lie on four straight lines with 300, 200, 200, 300 asteroids on this lines respectively. These lines are chosen to follow the ”entering” boundary of the resonance (Figure 1). The osculating eccentricity was equally distributed in each of four intervals $[0.0, 0.10]$, $[0.10, 0.15]$, $[0.15, 0.20]$, $[0.20, 0.30]$. Then the osculating semi–major axis was chosen in intervals $[2.25805, 2.258475]$, $[2.258475, 2.259075]$, $[2.259075, 2.259775]$, $[2.259775, 2.261075]$ in a such a way to satisfy equation $e = ka + n$ in each segment of a and e. k is coefficient of our line of the best fit and n is free parameter of equation. The osculating inclination was generated with random values within the interval $[18^\circ, 29^\circ]$. The longitude of node, the longitude of perihelion, and the mean anomaly are all taken randomly from the interval $[0^\circ, 360^\circ]$.

Second, for each of 1000 objects generated in the previous step we used 20 different Yarkovsky clones, by setting Yarkovsky drift to vary from -5.0×10^{-5}AU/Myr to -1.0×10^{-3} AU/Myr with the step of -5.0×10^{-5}AU/Myr. The negative Yarkovsky drift was adopted because we followed movement of asteroids from larger to smaller osculating semi–major axes. In this way we produced an input catalog with 20,000 fictitious objects in total.

ORBIT9 integrator has an option to perform on-line digital filtering in order to remove short periodic oscillations. In this way, mean orbital elements are obtained, and then used in all our analyses performed here.

Our next step is to define resonance crossing with following three conditions. The first condition is if an array of 1000 mean semi–major axes and mean eccentricities meets the one of the next seven terms (Table 1 and Figure 2):

Table 1: Terms for resonance crossing in terms of a_m and e_m. These limits follow very well the "leaving" border of the resonance.

1	$0.35 \leq e_m$,	$a_m < 2.2520$
2	$0.30 \leq e_m < 0.35$,	$a_m < 2.2525$
3	$0.25 \leq e_m < 0.30$,	$a_m < 2.2530$
4	$0.20 \leq e_m < 0.25$,	$a_m < 2.2535$
5	$0.15 \leq e_m < 0.20$,	$a_m < 2.2540$
6	$0.10 \leq e_m < 0.15$,	$a_m < 2.2545$
7	$0.00 \leq e_m < 0.10$,	$a_m < 2.2550$

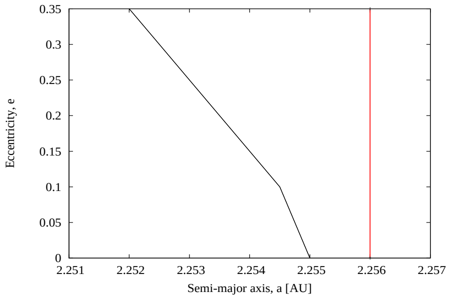

Figure 2: The inner ("leaving") border (black lines) and center (red line) of the 7J:-2A resonance.

From numerical integration we obtained mean orbital elements with the step of 200 yr. In order to define the second condition, we have applied the method of least squares to fit a linear model $a_m = kt + n$ at time t. From the fit we have calculated parameters k, n and their errors σ_k, σ_n.

The second condition is then fulfilled if coefficient of our line of the best fit k is negative, i.e. in agreement with assumed semi-major axis drift due to the Yarkovsky, for a period of at least 0.75 Myr and at most of 1 Myr, including 0.2 Myr from the first condition. Also, the ratio between coefficient of the linear trend and its error has to be greater than 30, because we decided to work with reliable values of k.

Finally, to characterize the third condition, we compared nominal values of expected and obtained semi–major axis drift. It means that obtained Yarkovsky drift speed has to be in interval $(k - \sigma_k, k + \sigma_k)$. If test particle meets all the three conditions, we considered that examined object crossed the 7J:-2A resonance.

3. RESULTS

Here, we applied the above described methodology to the set of 19,800 test particles that survived 20 Myr of numerical integrations. Let us first show an example of a test particle, which very quickly crossed the resonance (see Figure 3).

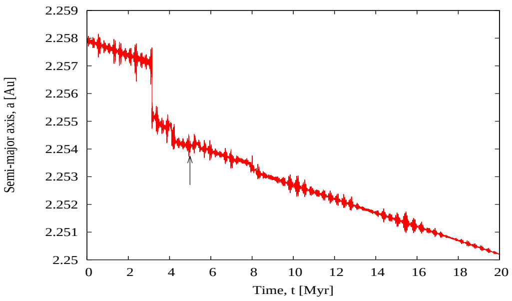

Figure 3: An example of test particle which successfully crossed the resonance without having close approach. The moment of crossing is shown by an arrow at $t \approx 5.0$ Myr. Assumed Yarkovsky drift speed of this particle is -2.5×10^{-4} AU/Myr, while from the linear fit we got $k \approx -2.46 \times 10^{-10}$ AU/yr, and $\sigma_k \approx 3.92 \times 10^{-12}$ AU/yr.

A different example of a successful crossing is shown in Figure 4. In that case considered object is captured by the resonance for a long time, from 2 Myr to about 17 Myr, before it finally crossed the resonance.

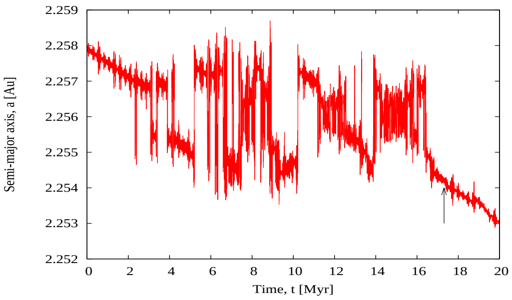

Figure 4: An example of test particle which successfully crossed the resonance without having close approach, with Yarkovsky drift speed -4.0×10^{-4} AU/Myr, $k \approx -4.03 \times 10^{-10}$ AU/yr, $\sigma_k \approx 3.16 \times 10^{-12}$ AU/yr. The moment of crossing is shown by an arrow at $t \approx 17.0$ Myr.

The distributions of moments of the resonance crossing, shown in Figure 5 and 6, are very similar. Most of the objects crossed the resonance in the first 8 Myr. The largest number of objects in both figures crossed the resonance between 4 and 6 Myr because they had certainly sufficient time for crossing.

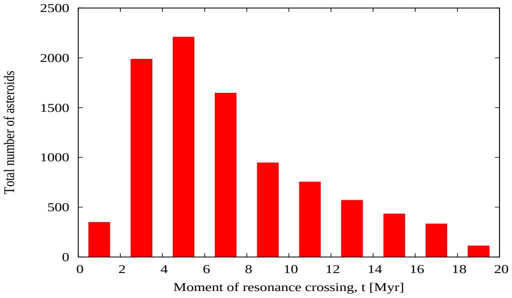

Figure 5: Distribution of the moments of crossing for 9330 particles that crossed the resonance.

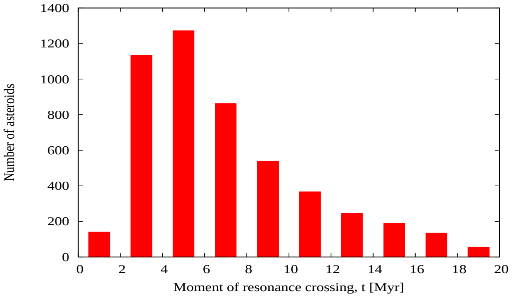

Figure 6: Distribution of the moments of crossing for 4937 particles that crossed the resonance without having close approach to any planet.

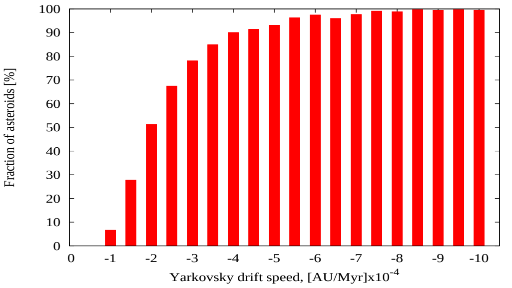

Figure 7: Fraction of objects that crossed the resonance as a function of Yarkovsky drift speed. Only those particles without having close approach to any planets are shown.

The goal of the next histogram is to analyze the number of objects that crossed the resonance as a function of Yarkovsky drift speed. We calculated the ratio between the number of objects that crossed the resonance and the total number of objects, for each of 20 different values of Yarkovsky drift speed. Here we considered only objects without having close approach to the planets. There are no objects with Yarkovsky drift speed of -5.0×10^{-5} that crossed the resonance without having close approach to the planets. Almost 100% of test particles with values of Yarkovsky drift speed higher than -5.0×10^{-4} AU/Myr successfully crossed the resonance (Figure 7).

4. CONCLUSIONS

At the beginning of the numerical integrations we had 20 000 test particles and almost all (19 800) survived integrations. A significant fraction of our test particles successfully transit across the resonance (9330), without being removed from the region, and 4937 particles crossed the resonance without having close approach to the any planet. Although some authors found the 7J:-2A being powerful dynamical boundary in this region, our results show that this resonance is not an absolute dynamical boundary at all.

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MEASUREMENTS OF VISUAL DOUBLE STARS BETWEEN 2011–2014

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Abstract. In the period from 2011 to 2014 we observed visual double and multiple stars at AS Vidojevica (ASV) and NAO Rozhen (NAOR) and measured the relative coordinates. Frames were taken by using three CCD cameras: SBIG ST-10ME and Apogee Alta U42 attached on the 60 cm telescope at ASV and VersArray 1300B attached on the 2 m telescope at NAOR. Analysing the relative coordinates of the same pairs obtained by using these two telescopes we detected a systematic difference in the separations. The reason of this is disagreement between the telescope focal length and that declared by the producer. We determined more correct focal lengths for both telescopes based on our measurements. Also, we give orbits, linear solutions and other parameters of visual double stars obtained in this period.

1. INTRODUCTION

The first observations of celestial bodies from the Astronomical Station on the mountain of Vidojevica (ASV) took place during the summer of 2011. More details can be found in Stojanović et al. (2012). Series of observations of double and multiple stars at the ASV have been made with a CCD camera attached to the 60-cm telescope. For these series we used either SBIG ST-10ME or Apogee Alta U42 CCD cameras. We obtained 10 frames per star: 5 in the Cousins/Bessel B filter and 5 in the Cousins/Bessel V filter. Series of observations of double and multiple stars at the Bulgarian National Astronomical Observatory at Rozhen (NAOR) have been made with the CCD camera VersArray 1300B attached to the 2 m telescope. For each double or multiple star, 10 frames were obtained: 5 in the Johnson B filter and 5 in the Johnson V filter. The basic characteristics of used cameras, including the field-of-view size, are given in Pavlović et al (2013).

In the period from 2011 to 2014 the Belgrade team has performed 15 series of observations of double and multiple stars at ASV and NAOR. In Table 1 we listed observational period and number of double or multiple stars of all 15 series for which we have taken frames.

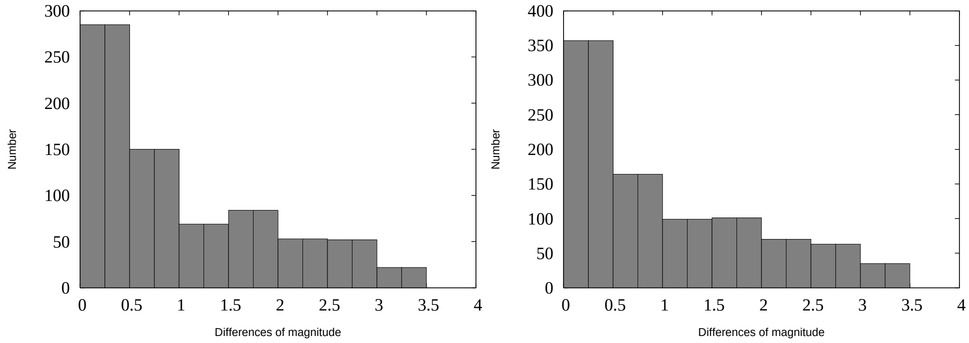

Figure 1: Distribution of the catalog magnitude differences between the components of a pair taken from WDS at ASV (left) and NAOR (right).

The histogram in Figure 1 presents the distribution of the catalog magnitude differences between the components of pairs, taken from the Washington Double Star Catalog, WDS[1] for double stars observed at both ASV and NAOR. The most of the observed pairs for both stations have differences in magnitude lower than 1 mag. In Figure 2 we present the distribution of angular separations of the components up to 20 arcsec. Our observational program of double and multiple stars contains mainly pairs with angular separations less than 10 arcsec and that is easily noted in Figure 2.

ASV			**N**AOR	
Year	Period	Number of double or multiple stars	Period	Number of double or multiple stars
2011	October 10/11	58	October 27/28	179
	November 2–4	379		
2012	April 22/23	16	April 24–26	174
	June 21–24	101	November 8–10	100
2013	March 4–5	43	April 14–16	88
	July 2–3, 12–15	190	October 7–10	190
	September 11/12	10		
2014	February 8/9	10	March 24–27	19
	April 1–3	30		

Table 1: The observational sessions of the Belgrade team at ASV and NAOR.

2. RESULTS

In this paragraph, we present the results which we obtained using our measurements at both ASV and NAOR in the period 20112014.

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[1] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/WDS

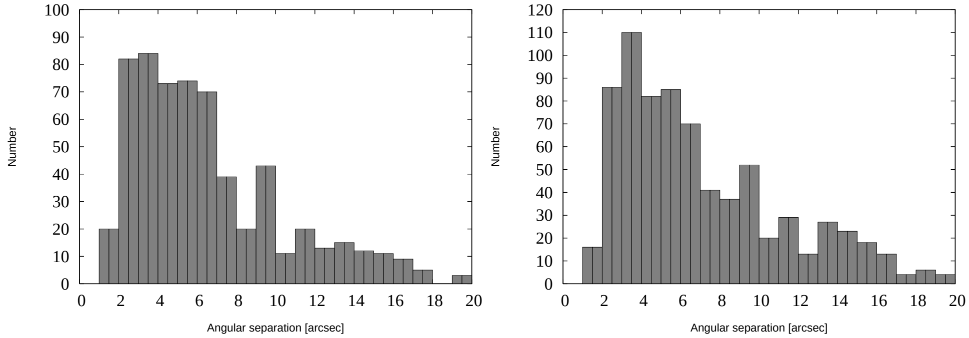

Figure 2: Distribution of the angular separations of the components taken at ASV (left) and NAOR (right).

2. 1. PRECISE FOCAL LENGTH OF THE TELESCOPES

During the autumn of 2011, we observed the same objects at both NAOR and ASV. We noticed that the measured separations (ρ_{NAOR}, ρ_{ASV}) differ for the same pairs of stars and the differences increase with increasing angular separation. Therefore, we measured the angular separations between the images of stars visible in our CCD frames. The results for measured separations for a selected sample of stars and their corresponding separation differences, $\Delta\rho = \rho_{NAOR} - \rho_{ASV}$ show a linear dependence and it can be given by the following equation: $\Delta\rho = 0,0019 + 0,0137\rho$.

The separation depends on the angle corresponding to one pixel, i.e., the focal length of the telescope. The result of determining the focal length of the 60 cm telescope at the ASV more precisely is given in Cvetković et al. (2012a), and for the 2 m NAOR telescope in Cvetković et al. (2013). The differences are relatively small: of the order of 1.4%. For pairs of stars with angular separations smaller than 10.., the differences are approximately equal to measurement errors. Therefore small deviations in separations resulting from inaccurate telescope focal length could not be noted previously.

2. 2. DETERMINING THE NATURE OF SYSTEM ADS 48

Using only our CCD observations we analyzed a multiple system ADS 48. Its number in WDS is 00057+4549. Our aim is to establish which of the seven components are gravitationally bound, i.e. have an orbital motion around the mass center, and which of them are mutually very distant in space so that only their projections are close in the field of view. We used the measuring results from our CCD frames obtained between 1994 and 2011. The first CCD frames of ADS 48 multiple system at our disposal were obtained in 1994 (Popović and Pavlović, 1997). We also used frames of this system obtained at NAOR in the period 20042011 and ASV in 2011. The selected CCD frames are overlapped and presented in Figure 3. The detailed analysis of the system ADS 48 is given in the paper Cvetković et al. (2012b). The conclusions combined with the criteria based on celestial mechanics lead us to the following: i) only stars A and B are gravitationally bound; ii) one very distant component has common proper motion with A and B, but is not bound to them; iii) all other components

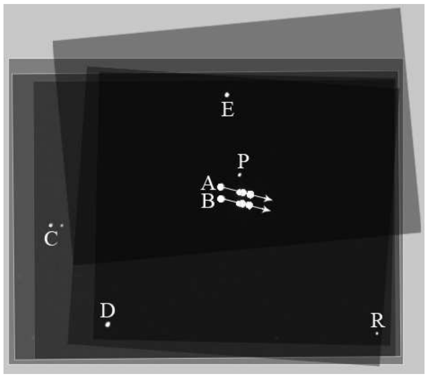

Figure 3: CCD frames of the multiple system ADS 48 obtained between 1994 and 2011 are overlapped in order to have at the same position images of the components (C, D, E, P, and R) for which the configuration is invariable. The motion of pair AB in the view field is clearly seen; the direction and sense are indicated by the arrow.

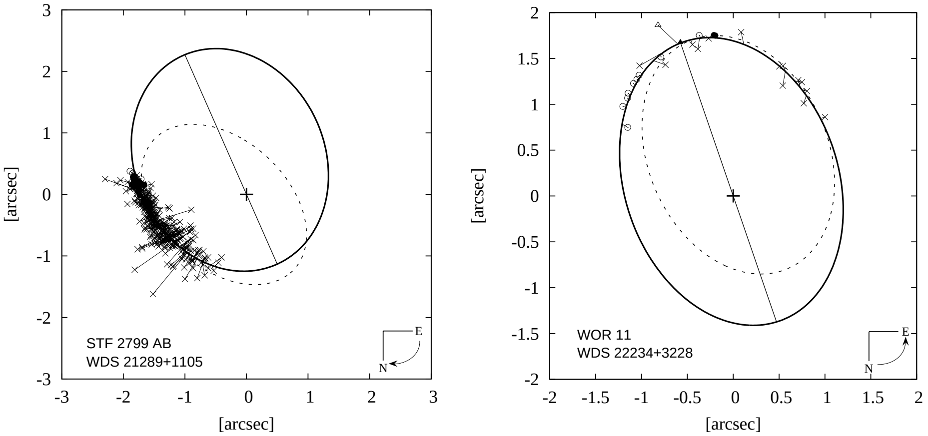

Figure 4: The recalculated orbits of two binaries STF 2799AB and WOR 11.

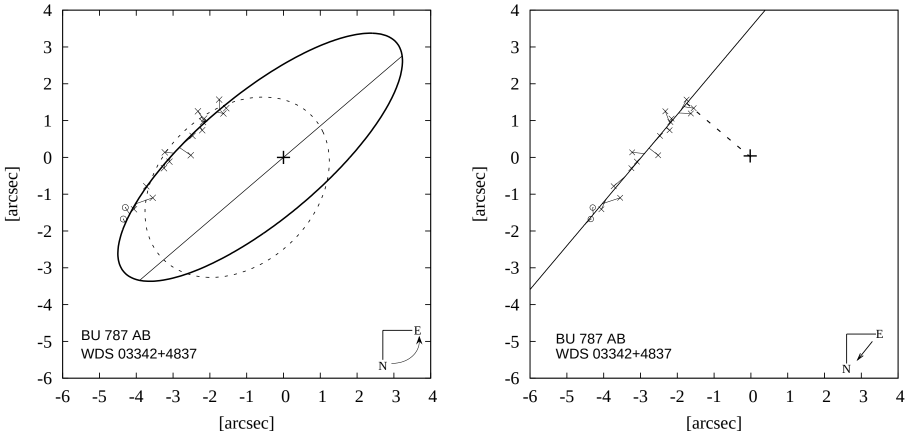

Figure 5: The recalculated orbit and linear solution of pair BU 787AB.

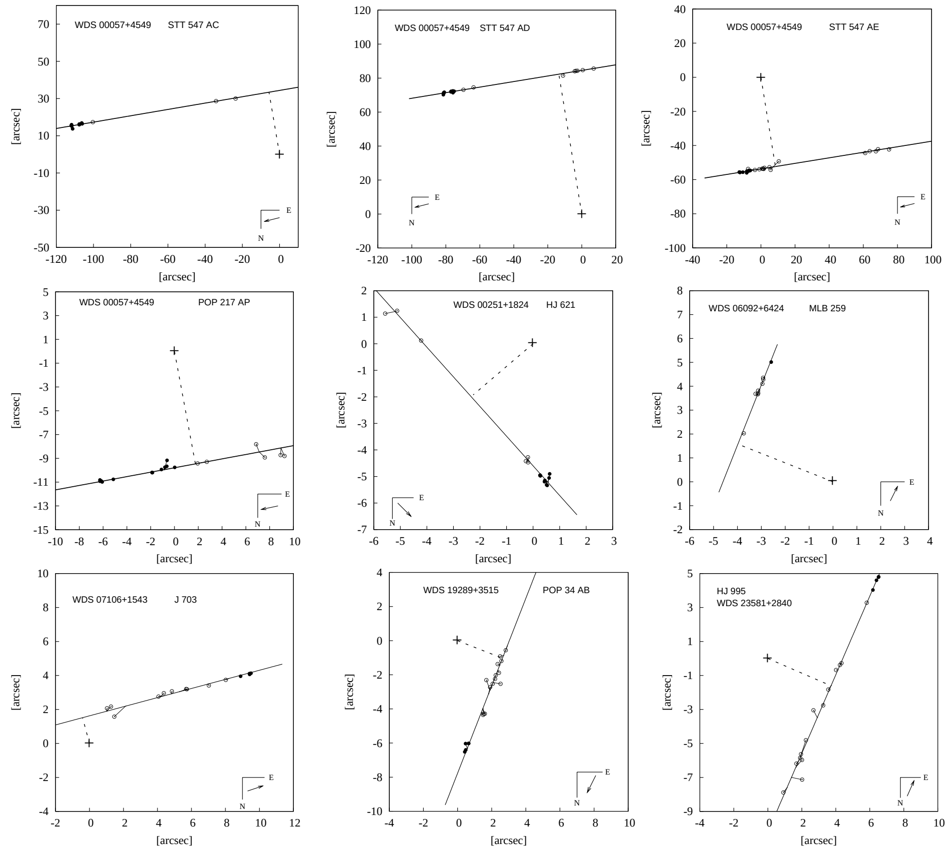

Figure 6: Linear fits for ten pairs: the arrow in the lower right corner indicates the direction of relative motion of the secondary; the dashed perpendicular line from the linear fit to the origin indicates the closest relative separation.

form optical pairs with AB.

2. 3. RECALCULATED ORBITS

Using the measurements obtained from the CCD observations at ASV and NAOR Cvetković has recalculated the orbits and masses for three binaries: WDS 03342+4837 = BU 787AB, WDS 2128+1105 = STF 2799AB and WDS 22234+3228 = WOR 11. The orbits, illustrated in Figure 4, were published in (Cvetković et al. 2011). The solid curves represent the newly determined orbits, while the dashed curves represent the previously published orbits. One pair, BU 787AB, has both orbital and linear solutions presented in Figure 5.

2. 4. LINEAR SOLUTIONS

We calculated the first linear solutions for ten pairs for which the measurements show a linear trend: WDS 00057+4549 = STT 547 AC, WDS 00057+4549 = STT

547 AD, WDS 00057+4549 = STT 547 AE, WDS 00057+4549 = POP 217 AP, WDS 00251+1824 = HJ 621, WDS 03342+4837 = BU 787 AB, WDS 06092+6424 = MLB 259, WDS 07106+1543 = J 703, WDS 19289+3515 = POP 34 AC and WDS 23581+2840 = HJ 995. For calculation we used the measuring results from our CCD frames obtained at NAOR and ASV. The linear solutions for pairs STT 547 AC, STT 547 AD, STT 547 AE, POP 217 AP and MLB 259 have been previously published in (Pavlović at al. 2013). The linear solutions for pairs HJ 621, BU 787 AB and HJ 995 have been previously published in (Cvetković at al. 2011). For the other two pairs J 703 and POP 34 AC, the linear solutions have been published in (Cvetković 2014).

In Figure 6 linear fits for ten pairs are presented. In the lower right (or left) corner the arrow indicates the sense of the motion for the secondaries with respect to the primary (brighter star). The linear solutions for these pairs have been determined from a set of measurements also including our ones from the frames obtained at NAOR and/or ASV. Our measurements are indicated by filled circles in Figure 6.

Moreover, we applied existing criteria for establishing the nature of these double stars (Cvetković et al. 2015). The criteria are mostly based on some fundamental properties, such as the energy-conservation law, Kepler's third law, etc, which should be obeyed by bound pairs. Our analysis shows that all eleven double stars are most likely not gravitationally bound, i.e. they are optical pairs.

3. CONSLUSION

In the period 20112014, we made 9 series of CCD observations of double or multiple stars with the 0.6 m telescope at ASV and 6 series with 2 m telescope at NAOR. We determined more precise focal lengths for both telescopes. Using only our CCD observations we analyzed a multiple system ADS 48 and we applied existing criteria for establishing the nature of this system. We obtained that only stars A and B are gravitationally bound and all other components form optical pairs with them. Also, we have used our measurements to recalculate three orbits and to calculate linear solutions of ten double stars for the first time. Our analysis shows that these ten double stars are most likely optical pairs.

Acknowledgments

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CALCULATION OF MEAN DENSITY OF SOLAR PLANETS BY MODIFIED SAVICH-KASHANIN METHOD

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Abstract. Savich and Kashanin in 1960-ties developed a mathematical model to calculate the mean density of solar planets. The model used van der Waals (vdW) equation of state for real gases, from which it follows that the volume of a substance at absolute zero temperature (V_0) is one third of volume at critical point (V_c), i.e. V_0=Vc/3. However, empirical data published more recently confirmed that V_0=Vc/4. Using this empirical fact we modified mathematical model of Savich and Kashanin thus enabling the more correct calculation of planet's mean densities.

MATERIAL DENSITY CHANGES ACCORDING TO SAVICH-KASHANIN THEORY

Savich and Kashanin believe that by the compressing of matter, its density alternates between intervals of gradual and abrupt changes (Figure 1) (Savić 1961, 1978, Savić and Kašanin 1962). The density is gradually changed from d_1^0 to d_1* in the pressure range from p_0* to p_1*. At the pressure p_1*, there is a jump of density from d_1* to d_2^0. Again, up to the pressure p_2* there is the interval of gradual change of density, and again there is a jump of density, etc... Substances can only have those values of density that correspond to intervals of 1, 2, 3, 4... Each interval corresponds to one phase state of matter. The density is gradually changing within a definite phase state. The transition from one phase to another is like a jump in terms of changes in density.

The causes of these alternating stepwise and gradual changes in the density of matter, Savich and Kashanin looked for in the combination of quantum-mechanical phenomena, which describes the structure and properties of atoms. When atoms approach each other, there arises the moment when the atoms are close enough to each other that their outer electron orbits "touch". Further compression is possible only if electrons leave their former paths and rebound from the atoms seeking a new space for their movement. Atoms, stripped due to these runaway electrons, can further approach each other until again "touch" the remaining outer electrons.

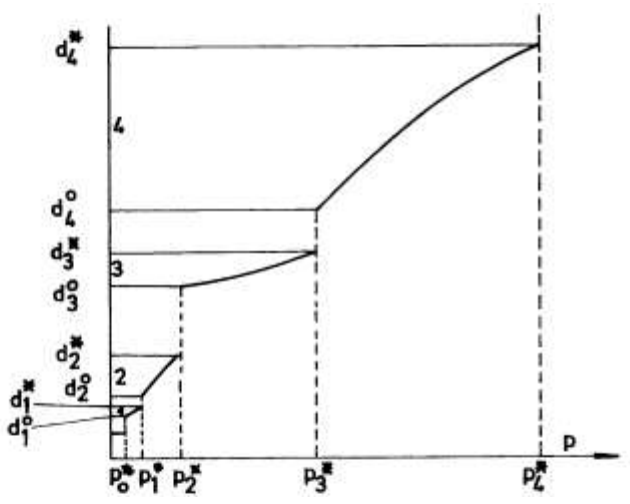

Figure 1: Changes of density of matter (d) with the change of pressure (p) according to Savich-Kashanin theory.

"Excitation and ejection of electrons under the influence of pressure leads to a number of new phenomena in macro-systems. We see that large and ultra-high pressure disrupts the inner micro-structure of the electron shells of chemical elements by pushing and ejecting electrons from them. Since the electrons are deployed by discrete, spaced levels, which are sharply separated from each other..., their ejection under this pressure will be in jumps. Accordingly, **material densities under pressure must be changed in jumps or sharp transitions from one value to another**. Due to the layered structure of the electron shells, by the displacement and ejection of electrons by the pressure, densities of the materials, as well as the properties of the macro-systems of particles, must exhibit abrupt changes" (Savić, 1978, p. 70).

Savich and Kashanin show the function in the form of a staircase diagram, which describes the change in density of matter at the beginning and at the end of certain phases (Figure 2).

The law of Savich and Kashanin for the stepwise change of density was not directly derived from the quantum-mechanical model of the atom. They empirically come to the law, however, that the density of matter at the end of subsequent phases changes abruptly, according to Eq. (1a). Density at the beginning of some phase d_i^0 is calculated by multiplying the density at the end of a that phase $d_i^*$with parameter α, where α = 3/5 and α = 5/6 for the even and the odd phases, respectively, Eqs. (1b and 1c).

$d_{i-1}^* = 2\, d_i^*$ (1a)
$d_i^0 = \alpha \cdot d_i^*$ (1b)
$\alpha = 3/5$ and $\alpha = 5/6$ for the even and the odd phases, respectively (1c)

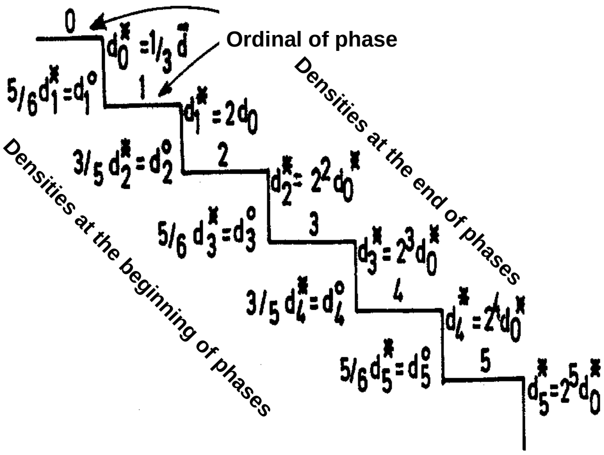

Figure 2: The density at the beginning of d_i^0 at the end d_i^* of individual phases (i = 1, 2, 3...) according to the Savich-Kashanin theory.

Savich and Kashanin calculated these values of parameter α by taking into account the van der Waals (vdW) equation of state for real gases (2).

$$(P + a/V^2)(V - b) = RT \tag{2}$$

P, V and T are pressure, specific volume and absolute temperature, respectively, a and b are the so-called van der Waals constants, R is the universal gas constant.

It follows from (2) that the constant b, so-called "covolume", is the specific volume V_0, which a gas would have at absolute zero (T = 0 K). (3). It is also known that it follows from (2) that covolume b is equal to one third of critical volume V_c, for given material at critical point. Respecting equation (2), Savich and Kashanin took into account relation (3) and calculated the values of parameter α as in Eq. (1c). It should be noted that relation (3) is one of the important assumptions built into obtaining the mathematical model of Savich and Kashanin (Figure 2).

$$b = V_0 = V_c/3 \tag{3}$$

It should be borne in mind that the specific volume of matter (V) is equal to the reciprocal of the density (d), Eq. (4), so it is easy to calculate the value of one of them if the other is known.

$$V = 1/d \tag{4}$$

Another important assumption of Savich and Kashanin used to derive their mathematical model is that matter at the end of the zero-phase has a volume, or density, which corresponds to the critical point (5).

$$d_0^* = d_c = 1/V_c \tag{5}$$

Savich and Kashanin applied the above mathematical model (Figure 2) to calculate the mean density of planets in the solar system and the results of their calculations they compared with astronomical data available by that time. According to their calculations some planets should have a density of 0.67 g/cm^3, which approximately corresponds to the density of Saturn (0.65 g/cm^3). For one group of planets the calculated density was 1.33 g/cm^3; which corresponds to Jupiter (1.34 g/cm^3), Uranus (1.36 g/cm^3) and Neptune (1.32 g/cm^3). For the second group of planets the calculated density was 5.33 g/cm^3; which corresponds to Earth (5.52 g/cm^3), Venus (5.21 g/cm^3) and Mercury (5.6 g/cm^3). The agreement of calculated and measured values is very good. A large discrepancy is only in the case of Mars: the calculated value is 5.33 g/cm^3, while the empirically estimated value is 3.94 g/cm^3. Savich and Kashanin believed that their calculation was correct, and the discrepancy with the observed value of the density indicated a possible error of astronomical data for the radius of Mars.

ADAPTATION OF STEPWISE MATHEMATICAL MODEL BY ACTUAL EMPIRICAL DATA

Analyzing the mathematical model of Savich and Kashanin we have noticed that some of their assumptions are not consistent with the recent empirical data.

Empirical data (Filippov 1978) show that the relations (3) are not correct, but the volume of material at critical point (V_c) is twice the value of covolume (b) (Dean 1979) and four-fold higher value than the volume of matter at absolute zero temperature (V_0), Eq. (6).

$$V_c = 2\ b = 4\ V_0 \qquad (6)$$

Analysis of the compressed gaseous ethylene showed that the different phases are indeed formed (Stoiljković 1981). However, the density of ethylene at the critical point corresponds to the end of the first phase ($d_1* = d_c = 1/V_c$), but not to the end of the zero phase, as it is proposed by Savich and Kashanin in relation (5).

In the theory of Savich and Kashanin the initial state of matter is the rarefied gas that is condensed into forming Sun and planets. This means that the beginning of the zero phase should have a density, which is close to zero. However, in their staircase model (Figure 2) the density at the beginning at the zero phase has some definite value higher than zero, i.e. $d_0^0=(3/5)\ d_0^*>>0$.

Due to these empirical facts, it was necessary to adapt the mathematical model so that it will be consistent with these empirical facts. This adaptation and theoretical derivation of our model is presented by Stoiljković and Jovanović (1983) and Stoiljković et al. (1995) in which the ratio of the characteristic volumes of matter to the critical volume is shown. The same model can be represented by the density of the matter, which is the reciprocal of the volume, Eq. (4). Hence, the adapted theoretical mathematical model was obtained that shows the relationship of mean density of the planet to mean density of the Sun (Figure 3).

According to our staircase model, the condensation starts with the gaseous matter where the density is close to zero and then the density increases in the phase transition from zero to the first phase, then to the second, then to the third phase and so on. The coefficients α that describe the ratio of density at the beginning to at the end of some phases are not 3/5 or 5/6, as in Savich-Kashanin theory (1c), but have the values according to Eq. (7).

$$\alpha(i) = d_i^0/d_i^* = 2^{-1/i} \qquad (7)$$

Where the number of the phase is i = –1, 0, 1, 2, 3...

Bearing in mind that the mean density of the Sun is equal to 1.41 g/cm^3, the values of mean density of the planets can be calculated by our model (Figure 3). Agreement with empirical data (Syunyaev 1986) was very good (Table 1). In addition, unlike the staircase model of Savich and Kashanin (Figure 2), our model shows that mean density of Mars should be about 4 g/cm^3, which is close to the empirical data.

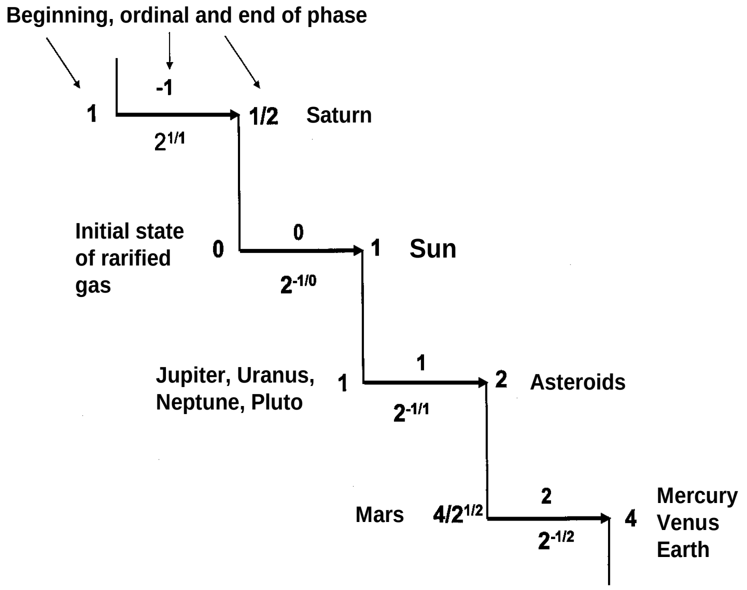

Figure 3: Our theoretical staircase model – the ratio of mean density of the planets with that of the Sun (d_s = 1.41 g/cm^3) (Stoiljković 1986).

Based on our staircase model, a celestial body (or bodies) with mean density 2.8 g/cm^3 could exist in the Solar system. Indeed, it corresponds to the asteroids whose density is in the range of 2.0 to 3.5 g/cm^3.

Although Pluto was recently removed from the list of planets, we also calculated by our model that its mean density would be 1.41 g/cm^3 which is in accordance with empirical data, i.e. 1.75 g/cm^3 (though in the literature one can find other, very different, values).

Table 1. Mean density of planets in the solar system

Planet	Mean density (g/cm^3)	
	Empirical data (Syunyaev 1986)	Calculated using our staircase model (Figure 3) (Stoiljković 1986)
Mercury	5.4	5.64
Venus	5.2	5.64
Earth	5.5	5.64
Mars	3.9	4.00
Jupiter	1.3	1.41
Saturn	0.7	0.71
Uranus	1.6	1.41
Neptune	1.7	1.41

The trend of densification is indicated by an arrow in Figure 3. If Saturn followed the same trend, then there would be no condensation, but a state of spreading rarefied gas. In other words, according to our model, planet Saturn could not have been condensed.

There is a hypothesis that the Sun has a twin star, which is called Nemesis. Mean density of Nemesis would be 79.21 g/cm^3 (Galaksija 1988). It can be calculated by extrapolation of our staircase model that there could be a body with density of 80.63 g/cm^3, which is in good agreement with the above data for Nemesis.

CONCLUDING REMARKS

Our modification of mathematical model given by Savich and Kashanin enables the more exact calculation of planet's mean densities. Furthermore, the same modified model enables calculation of densities of matter in its characteristics states (i.e. critical point, triple point, absolute zero temperature...) (Stoiljković et al 1995) as well as to predict the supra-molecular structure of fluids (real gases and liquids) (Stoiljković et al 1981, 1988; Radičević et al 1995), which has a great importance in physics and chemistry, too. The more detailed scientific and philosophical insight of Savich-Kahanin theory and its connection with Roger Boscovich’s theory of natural philosophy has been published, too (Stoiljković 1979, 2005, 2010, 2014).

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ASTEROID BELT AND THE FAST LYAPUNOV INDICATOR

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Abstract. Computing the Fast Lyapunov Indicator (FLI) is one of the fastest numerical ways to detect the stability properties of a given orbit. FLI quickly discriminates not only between stable and chaotic motion, but also between weak and strong chaos, as well as between regular motions inside and outside of a resonance. With such sensitivity, FLI is very convenient for the evaluation of dynamical maps, providing structural information of a given system, and a good starting point in further investigations of its dynamics. However, despite its efficiency, FLI was mostly used to detect structures in simplified and idealized systems, but rarely to study dynamics of the "real world". Therefore, we are interested to evaluate FLI maps able to show dynamical structures in our Solar System. The FLIs are determined from numerical integrations by using a model that includes seven planets (from Venus to Neptune). According to our results, we can say that once again FLI has shown its efficiency to detect structures in the Main Belt, with a surprisingly high clarity.

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DETERMINATION OF THE DIFFERENCE BETWEEN DYNAMICAL TIME AND UNIVERSAL TIME AND PREDICTIONS OF VARIATIONS IN THE EARTH'S ROTATION

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Abstract. The problem of precise prediction of the Earths spatial orientation is directly related to the knowledge of the forthcoming values of the Earths rotation parameters, by the use of which the transformations between celestial and terrestrial reference systems are carried out. These parameters depend upon a multitude of astronomical and geophysical causes; however, for their combined (simultaneous) effects no adequate theoretical models are available to describe precisely enough the changes in the Earths orientation. Therefore, the predictions of the Earths rotation parameters to a lower extent rely on geophysical theories, and more on mathematical modeling based on various numerical methods.

The objective of the thesis was to demonstrate that it is possible, applying mathematical approach exclusively (without using geophysical models and corrections) to achieve improvements in predicting the non-uniformities of UT1 universal time scale. It is a common knowledge that this parameter features the fastest and highest change, since it completely reflects the Earths rotation with all its non-uniformities, and consequently its predictions feature the lowest accuracy.

The original numerical method for deriving approximate functions having the form of the sum of harmonics and exponentials (HE) is applied in the thesis. Based on actual data, 10-day, 30-day and 500-day predictions were done in the continual one and a half year period. In addition, presented were the actual achievements of a long-term prediction that, applying the same method, had been accomplished before.

The obtained results were compared to the respective results of other authors, who applied different prediction methods in the course of the international project "Earth Orientation Parameters Prediction Comparison Campaign" (EOPPCC). The HE method proved to release similar results as other methods of 10-day and 30-day predictions; however, in case of 500-day predictions it produced convincingly superior results. This method is actually suitable for longer interval predictions; this fact is confirmed by so far (after eight years) achieved results of a ten-year prediction.

The implied conclusion is that the prediction of the value ΔT, which is released in astronomical almanacs, could be considerably upgraded by using the HE method.

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RELATIVE-COORDINATE DETERMINATION FOR VISUAL DOUBLE STARS BY APPLYING FOURIER TRANSFORMS

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Abstract. Here we discuss a software developed for the purpose of determining the relative coordinates (position angle θ and separation ρ) for visual double or multiple stars. It is based on application of the Fourier transforms in treating CCD frames of these systems. The objective was to determine the relative coordinates automatically to an extent as large as possible. In this way the time needed for the treatment of many CCD frames becomes shorter. The abilities and limitations of the software are also examined. Besides, the possibility of improving it is also considered. The software has been tested and checked on a sample containing CCD frames of 165 double or multiple stars, obtained with the 2m telescope at NAO Rozhen in Bulgaria in October 2011. The results have been compared to the corresponding results obtained by applying different softwares and the agreement is very good.

Acknowledgments

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THE LINK BETWEEN FUTURE GAIA CRF AND ICRF AND THE OBSERVING FACILITIES OF THE 60 cm ASV TELESCOPE

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Abstract. The Gaia satellite was successfully launched at the end of 2013. That astrometrical mission is the cornerstone of the European Space Agency (ESA). The main goal of Gaia, during its 5-year lifetime, is to map all sky, over one billion stars of our Galaxy and about 500,000 quasars (QSOs) and other extragalactic objects. It means, all objects with apparent V magnitude between 5.6 and 20. The results will be a unique time-domain space survey, and a dense optical QSO-based Gaia Celestial Reference Frame (Gaia CRF). For this purpose a high accuracy link between the future Gaia CRF and International CRF (ICRF) is necessary. The Gaia astrometry should include lots of effects, as the displacements of optical photocenter of sources (that effect is a possible consequence of astrophysical processes of QSOs). Nearly 90 % of the ICRF objects are not suitable for that link (the sources are not bright enough in optical band, with significant extended radio emission, etc.). And it is of importance to check other sources (weak extragalactic radio sources with bright optical counterparts, etc.). First of all, we need to investigate the flux stability of objects via their photometry monitoring. So, the photometry investigation of these objects and the analysis of variations of their light curves are of importance for the mentioned link. The part of that investigation is our observation of 47 objects (mostly QSOs, but not in the ICRF list) made in the B, V and R bands using the new telescope at the Astronomical Station Vidojevica (ASV) of Astronomical Observatory in Belgrade (AOB). Some preliminary photometric results for object BL 1722+119 in the frame of this investigation are presented.

1. INTRODUCTION

The Gaia is the first space – based ESA (the European Space Agency) mission after Hipparcos (ESA 1997, van Leeuwen 2007), and the next step of the European pioneering high-accuracy astrometry. The Gaia satellite was launched in December 2013, and it is going to revolutionize our knowledge of the Milky Way with observations of over one billion stars of our Galaxy; also, of about 500,000 quasars (QSOs) and other extragalactic objects. During its 5-year lifetime, it is going to map (repeatedly) all

Table 1: The main information on the ASV 60 cm telescope.

Site Telescope $D(cm)/F(cm)$	longitude - $\lambda(^o)$ latitude - $\varphi(^o)$ altitude - h (m)	CCD camera pixel array and scale ($''$) pixel size (μm) and field of view - FoV ($'$)
ASV (AOB)	21.5	Apogee Alta U42
Cassegrain	43.1	2048x2048, 0.46
60/600	1150	13.5x13.5, 15.8x15.8

sky as a unique time-domain space survey; all objects are with apparent V magnitude between 5.6 and 20. A dense optical QSO-based Gaia Celestial Reference Frame (Gaia CRF) is the main goal of the mission. The high accuracy link between future Gaia CRF and International CRF (ICRF) is of importance, but up to now nearly 90% objects from ICRF list have not been suitable for that link (Bourda et al. 2010, 2011; Petrov 2011, 2013; Taris et al. 2011, 2013) because: the objects are not bright enough in the optical domain, they have significant extended radio emission, etc. The relationship between morphology, magnitude variability and astrometry for QSOs is described by Popović et al. (2012). It is necessary to include in the link other objects (not from ICRF list), the weak extragalactic radio sources (ERS) with bright optical counterparts, but fist of all to investigate their flux variability via photometry monitoring and analysis of their light curves. Because of this, the observations of 47 objects (mostly QSOs, not from ICRF list) are going on during last few years. We took part in that monitoring (in BVR bands) using the new telescope at the Astronomical Station Vidojevica (ASV) of Astronomical Observatory in Belgrade (AOB). Preliminary photometric results concerning object BL 1722+119 (in Fig. 1) are presented.

2. OBSERVATIONS AND RESULTS

Since a few years ago astrometry with ground-based optical telescopes has become very actual part of astronomical investigation. The reason is the possibilities of ground-based instruments which are in line with the Gaia mission. These telescopes are useful for: the astrometric monitoring of Gaia satellite, the link between radio and optical positions of ERS, the realization of a catalogue of quasars, etc. To align the radio frame and optical frame with high accuracy, the common objects (ERS) are of importance. From mid-2013 we have taken part in the photometric ground – based observations of ERS which are visible in the optical domain and useful for establishing the link between the future Gaia CRF and ICRF. The ASV 60 cm telescope has been used (see Table 1). During 2013 and 2014, 47 sources, which are not in the ICRF list, were observed with that instrument (some of them more than once). Usually, we had three CCD images per filter.

Our preliminary photometric results, using the relative method, of the object BL 1722+119 (see Fig. 1) are presented in Table 2 (for July 9th 2013). The comparison stars (C1, C2, C3 and C4, see Fig. 1, and the first part of Table 2) were found and used via http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/. For processing the CCD images, the first step is to detect the star-like object (ERS) and

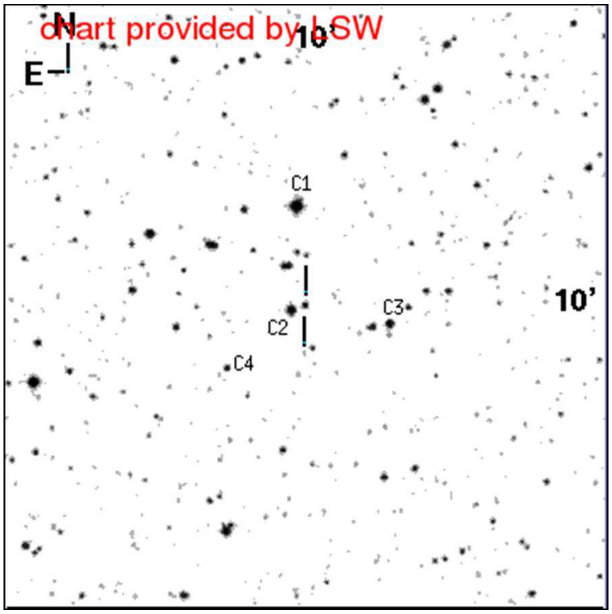

Figure 1: Object BL 1722+119 with calibrated stars (C1,C2,C3,C4).

comparison stars. The standard bias, dark and flat-fielded corrections were done. Also, hot/bad pixels were removed. All CCD exposures were guided. In our data (for July 9th 2013), C1 was saturated in the V and R bands. In the B band there are no input magnitude data (see the first part of Table 2). The calculated magnitude (presented in the second part of Table 2, for V and R filters) is an average value with standard error using 3 images per filter. The output magnitudes of C2, C3 and C4 are close to their input values (from mentioned site); it means the photometric calculation is correct. The MaxIm DL image processing package was applied to the CCD data for calibration and photometric calculation.

For the objects without charts and determined calibration stars we need to do it by ourself. This means to determine a set of calibration stars and to use the input magnitudes from a catalogue; it could be the SDSS catalogue with transformations (Chonis and Gaskell 2008) to calculate BVRI magnitudes from *ugriz* ones.

3. CONCLUSIONS

We present our preliminary photometric results for object BL 1722+119 using observations made with the 60 cm ASV telescope. The input photometry data of calibrated stars (C1,C2,C3,C4) were obtained via site

http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/, and close to calculated values. For other objects we need to determine a set of calibrated stars around each QSO, and to calculate the magnitudes in the B,V,R bands (of these stars) using *ugriz* ones from the SDSS catalogue and the transformations (Chonis and Gaskell 2008). All necessary steps for reduction of CCD data (the standard bias, dark and flat-fielded corrections, and removal of hot/bad pixels) were applied. Also, it is of

Table 2: Our photometry results of BL 1722+119 with standard errors.

type&name of object, filter	JD-2456000	mag.of object	mag.of star C1	mag.of star C2	mag.of star C3	mag.of star C4
B			-	-	-	-
			-	-	-	-
V			11.98	13.21	14.10	15.74
			(0.05)	(0.05)	(0.05)	(0.08)
R			10.93	12.62	13.64	15.14
			(0.05)	(0.05)	(0.50)	(0.08)
BL 1722+119 B	483.48651	-	-	-	-	-
		-	-	-	-	-
BL 1722+119 V	483.48129	15.32	-	13.22	14.10	15.67
		(0.02)	-	(0.01)	(0.01)	(0.01)
BL 1722+119 R	483.49204	14.87	-	12.63	13.62	15.15
		(0.01)	-	(0.01)	(0.01)	(0.01)

importance for high-quality data that the average seeing at the ASV site is nearly $1.''2$ and to observe during a moonless night. So, we could get the magnitudes of our objects (QSOs) with small standard errors which are of the order of 0.01 mag.

Some problems during the calculation of B,V,R magnitudes of QSOs can be due to: faintness of the optical counterparts to QSOs, atmospheric influences, technical problems, etc. For example, we could improve the quality of the ASV data by using a star guider (to use the exposures longer than 5 minutes for faint objects).

We conclude that this kind of observations (of QSOs with magnitudes less than about $V = 19.0$) and mentioned investigations are possible with data obtained with the 60 cm ASV instrument.

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STARK BROADENING IN ASTROPHYSICS

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Abstract. Significance for astrophysical plasma research and modelling of broadening of spectral lines by collisions with charged particles, or Stark broadening, is considered and analyzed here, as well as the corresponding applications of Stark broadening data.This line broadening mechanism is particularly of interest e.g. for the research of white dwarfs and hot stars of A and B type, and for the analysis and synthesis of their spectra. For example, a large number of data is needed for calculations of stellar opacities and modeling and investigation of stellar atmospheres. Data on Stark broadening of spectral lines are also important for diagnostics and research of laboratory, fusion, laser produced and technological plasmas.

Also, we will review and consider some results of Stark broadening research on Belgrade Astronomical observatory, as well as the organization of Stark broadening data in STARK-B database, a part of VAMDC (Virtual Atomic and Molecular Data Center).

1. INTRODUCTION

In comparison with laboratory plasmas, the plasma conditions in astrophysical plasmas are incomparably more various, so that broadening due to interaction between emitter and charged particles (Stark broadening) is of interest in astrophysics in plasmas of such extreme conditions like in the interstellar molecular clouds (electron temperatures Te around 30 K or smaller, typical electron density, Ne, 2-15 cm^{-3}) or neutron star atmospheres (T is 10^6 - 10^7 K and Ne of the order of 10^{24} cm^{-3}).

Here, we will consider astrophysical importance of Stark broadening investigations, theoretical methods for the determination of Stark broadening parameters, namely Full Width at Half Maximum (FWHM) of intensity of spectral line (W) and the shift (d), and results obtained by us. Also, we will consider the organization of Stark broadening data, obtained by us in STARK-B database (http://stark-b.obspm.fr - Sahal-Bréchot et al. 2014b) which is a part of VAMDC (Virtual Atomic and Molecular Data Center - http://www.vamdc.eu/, see Dubernet et al. 2010 and Rixon et al. 2011), founded and developed as an FP-7 european project.

2. STARK BROADENING IN ASTROPHYSICS

The importance of Stark broadening data for stellar plasma research obviously follows from the fact that line profiles enter the modeling of stellar atmospheric layers since they are needed to determine the absorption coefficient κ_ν at a frequency ν, and the optical depth τ_ν. If the atmosphere is in macroscopic mechanical equilibrium and we denote with ρ the gas density, and with z the direction of gravity, the optical depth is

$$\tau_\nu = \int_z^\infty \kappa_\nu \rho dz, \tag{1}$$

$$\kappa_\nu = N(A,i)\phi_\nu \frac{\pi e^2}{mc} f_{ij}, \tag{2}$$

where $N(A,i)$ is the volume density of radiators in the state i, f_{ij} is the absorption oscillator strength, m the electron mass and ϕ_ν spectral line profile, which, if plasma conditions are favorable, is influenced by Stark broadening mechanism.

In astrophysics, plasma conditions, favorable for Stark broadening, may be very different. For example in interstellar molecular clouds, where, as we stated earlier, typical Te are around 30 K or smaller, and typical Ne electron densities are 2-15 cm^{-3}, free electrons may be recombined in very distant orbit with principal quantum number (n) values of several hundreds and then deexcite in cascade to energy levels $n-1, n-2, ...$ radiating in radio domain. Since they are weakly bounded with the core, even very weak electric microfield may have a considerable influence, so that Stark broadening may be non-negligible. Similar situation is also in interstellar ionized hydrogen clouds, where Te are around 10 000 K and Ne is of the order of 10^4 cm^{-3}.

Favorable conditions for Stark broadening are also in atmospheres of hot stars. Namely, since for $T_{\rm eff} > 10^4$K, hydrogen, the main constituent of ordinary stellar atmospheres is mainly ionized, Stark broadening is the dominant among collisional broadening mechanisms for spectral lines. Such conditions are in atmospheres of white dwarfs and hot stars of O, B and A type. However, since Stark broadening depends not only on Te but also on Ne, the best conditions are in white dwarfs and in A-type stars, since towards B and O type, the temperature increases but electron density decreases. But Stark broadening may be of interest and for cooler stars, since its influence within a spectral series increases with the increase of the principal quantum number of the upper level and also is important for subphotospheric layers modelling and research.

Another type of astrophysical objects where Stark broadening is important are neutron stars, where surface temperatures for the photospheric emission are of the order of 10^6 - 10^7 K and electron densities of the order of 10^{24} cm^{-3}.

Of particular interest for Stark broadening applications in astrophysics are white dwarfs and the post Asymptotic Giant Branch (AGB) stars. AGB stars, with terminated hydrogen and helium but not carbon burning, forming a sequence of bright red giants. They are more luminous than the ordinary Red Giant Branch stars with electron-degenerate helium cores. AGB are often divided in AGB stars with carbon-oxygen cores and Super AGB, or SAGB, stars with heavier cores.

The principal division of white dwarfs is in the hydrogen-rich DA type, with spectra characterized by broade hydrogen lines and helium-rich DB type, with spectra dominated by neutral helium lines. Most of observed white dwarfs have the effective temperatures between around 8,000 K and 40,000 K so that Stark broadening is of interest for their spectra, particularly since the corresponding electron densities are much higher than in ordinary star atmospheres. White dwarfs cooled to so low effective temperatures that only continuum without helium or hydrogen lines is present in the spectrum, are of DC type. Sometimes, the spectra of DZ white dwarfs contain the lines of metal, introduced by accretion from the matter from outside. They are denoted as DZ, DAZ or DBZ type.

White dwarfs of DB type, now are divided in: DO type, with 40,000 K $< T_{eff} <$ 120,000 K (see e.g. Dreizler and Werner (1996), DB, with 12,000 K $< T_{eff} <$ 40,000 K, and DQ, with 4,000 K $< T_{eff} <$ 12,000 K (C lines and C_2 Swan band in the spectrum). The presence of carbon lines in the DQ white dwarfs is explained by convection from the deeper layers (Koester 2010).

We could add that in astrophysics, Stark broadening is of interest for many different problems, as for example for radiative transfer, opacity calculations, abundances, surface gravity and chemical composition determination, spectra analysis, interpretation and synthesis and astrophysical plasma modelling.

We note that for astrophysical applications we need an as much as possible large set of reliable Stark broadening data for, before not astrophysically important trace elements, due to development of space born spectroscopy. For example, according to Fontaine et al. (2008) FUSE Far Ultraviolet Spectroscopic Explorer satellite provided a great number of high resolution spectra within the wavelength range 907-1187 Å, associated with numerous ionization levels of several elements such as: C, N, O, Si, S, P, Cl, Ne, Ar, V, Mn, Cr, Fe, Co, Ni, Ge, As, Se, Zr, Te, I and Pb among others.

Researchers at Belgrade Astronomical observatory, investigated the influence of Stark broadening on Au II (Popović et al. 1999d), Zr II and Zr III (Popović et al. 2001a), Nd II (Popović et al. 2001b), Co III (Tankosić et al. 2003), Ge I (Dimitrijević et al. 2003a), Si I (Dimitrijević et al. 2003c), Ga I (Dimitrijević et al. 2004), Cd I (Simić et al. 2005), Cr II (Dimitrijević et al. 2007, Simić et al. 2013),Te I (Simić et al. 2009) and Nb III (Simić et al. 2014) spectral lines in the A type Star spectra, and found in all examined cases atmospheric layers where this broadening mechanism is of importance or at least should be taken into account. Investigating the influence of Stark broadening of rare-earth peak elements La II, La III, Eu II and Eu III, Popović et al. (1999c)found that serious errors in abundance determination for Ap stars occures if we neglect the Stark broadening contribution. In Dimitrijević et al. (2003c), the Si I lines in spectra of normal late type A star HD 32115, and Ap stars HD 122970 and 10 Aql have been investigated and it has been demonstrated that the synthetic profile of λ = 6155.13 Å Si I line fits much better with the observed one when Stark broadening is taken into account.

The significance of Stark broadening for DA, DB and DO white dwarfs, has been considered by Popović et al. 1999d, Tankosić et al. 2003, Milovanović et al. 2004, Simić et al. 2006, 2013, and Hamdi et al. 2008. it has ben shown that, for the difference from A typre stars, in the case of white dwarfs, Stark broadening is practically dominant in all atmospheric layers of interst.

Hamdi et al. (2008) analyzed Stark broadening of Si VI spectral lines for 50,000 K $\leq T_{eff} \leq$ 100,000 K and for $6 \leq \log g \leq 9$ DO white dwarf atmosphere models. It is shown that the influence of Stark broadening increases with log g and is dominant in broad atmospheric layers.

We note as well that for the interpretation and analysis of the newly discovered hot DQ white dwarfs with T_{eff} 18000 - 24000 K, and carbon atmospheres, we determined the corresponding Stark broadening parameters for C II lines (Dufour et al. 2011, Larbi-Terzi et al. 2012).

3. THEORETICAL METHODS

In the Group of Astrophysical Spectroscopy, we use for the calculation of Stark broadening parameters the semiclassical perturbation method (Sahal-Bréchot, 1969a,b). which for the full width at half-maximum intensity (FWHM), W, and the shift, d, of a Stark broadened line gives the expression (Sahal-Bréchot, 1969a,b, see also Sahal-Bréchot et al. 2014a):

$$W = N_P \int v f(v) dv \left(\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} \right). \tag{1}$$

Here, the perturbing levels of the initial level i and the final level f are denoted as i' and f'. The inelastic collision contribution is denoted as $\sigma_{jj'}, j = i, f$, and the elastic one as σ_{el}.

The shift, d, is given by (the dipolar interaction potential is the only one to be taken into account):

$$d = N_P \int v f(v) dv \int 2\pi\rho d\rho \sin(2\varphi_p), \tag{2}$$

where the phase shift φ_p is due to the dipolar potential, namely the polarization potential in the adiabatic approximation.

We developed also in Belgrade the modified semiempirical (MSE) approach (Dimitrijević and Konjević 1980,Dimitrijević and Kršljanin 1986, Dimitrijević and Popović 2001) for the calculation of Stark broadening parameters for non-hydrogenic ion spectral lines, which is especially useful when there is no corresponding set of reliable atomic data for the application of the full semiclassical perturbation method. According to the MSE, FHWM of an isolated ion line is given as

$$w_{MSE} = N \frac{4\pi}{3c} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\lambda^2}{\sqrt{3}} \cdot \{ \sum_{\ell_i \pm 1} \sum_{L_{i'} J_{i'}} \vec{\Re}^2_{\ell_i, \ell_i \pm 1} \widetilde{g}(x_{\ell_i, \ell_i \pm 1}) +$$

$$+ \sum_{\ell_f \pm 1} \sum_{L_{f'} J_{f'}} \vec{\Re}^2_{\ell_f, \ell_f \pm 1} \widetilde{g}(x_{\ell_f, \ell_f \pm 1}) + \left(\sum_{i'} \vec{\Re}^2_{ii'} \right)_{\Delta n \neq 0} g(x_{n_i, n_i + 1}) +$$

$$+ \left(\sum_{f'} \vec{\Re}^2_{ff'} \right)_{\Delta n \neq 0} g(x_{n_f, n_f + 1}) \},$$

where the $\vec{\Re}^2_{\ell_k, \ell_{k'}}$, $k = i, f$ is the square of the matrix element, and

$$\left(\sum_{k'} \vec{\Re}^2_{kk'} \right)_{\Delta n \neq 0} = \left(\frac{3 n_k^*}{2Z} \right)^2 \frac{1}{9} \left(n_k^{*2} + 3\ell_k^2 + 3\ell_k + 11 \right).$$

Here,

$$x_{l_k, l_{k'}} = \frac{E}{\Delta E_{l_k, l_{k'}}}, k = i, f,$$

where $E = \frac{3}{2} kT$ is the electron kinetic energy and $\Delta E_{l_k, l_{k'}} = |E_{l_k} - E_{l_{k'}}|$ is the energy difference between levels l_k and l_k ±1 (k=i, f),

$$x_{n_k,n_k+1} \approx \frac{E}{\Delta E_{n_k,n_k+1}},$$

where for $\Delta n \neq 0$ the energy difference between energy leves with n_k and n_k+1, $\Delta E_{n_k,n_k+1}$, is estimated as $\Delta E_{n_k,n_k+1} \approx 2Z^2E_H/n_k^{*3}$. $n_k^* = [E_H Z^2/(E_{ion} - E_k)]^{1/2}$ is the effective principal quantum number, Z is the residual ionic charge, for example Z=1 for neutral atoms and E_{ion} is appropriate spectral series limit.

With $g(x)$ (Griem 1968) and $\widetilde{g}(x)$ (Dimitrijević and Konjević 1980) are denoted the corresponding Gaunt factors.

In comparison with the full semiclassical approach (Sahal-Bréchot 1969ab) and the simpler Griem's semiempirical approach (Griem 1968) a considerably smaller set of input data is needed for the application of MSE, so that this method is particularly useful for stellar spectroscopy which needs a very extensive list of elements and line transitions with their Stark broadening parameters where it is not always possible to use the more sophysticated semiclassical perturbation approach.

Of particular interest for astrophysics could be the simplified semiempirical formula (Dimitrijević and Konjević 1987) for Stark widths of isolated, singly, and multiply charged ion lines, which is applicable in the cases when the nearest atomic energy level ($j' = i'$ or f') where a dipolly allowed transition can occur from or to initial (i) or final (f) energy level of the considered line, is so far, that the condition $x_{\mathrm{jj}'} = E/|E_{\mathrm{j}'} - E_{\mathrm{j}}| \leq 2$ is satisfied. In such a case FWHM is (Dimitrijević and Konjević 1987):

$$W(\mathring{A}) = 2.2151 \times 10^{-8} \frac{\lambda^2(\mathrm{cm}) N(\mathrm{cm}^{-3})}{T^{1/2}(\mathrm{K})} (0.9 - \frac{1.1}{Z}) \sum_{\mathrm{j=i,f}} (\frac{3n_{\mathrm{j}}^*}{2Z})^2 (n_{\mathrm{j}}^{*2} - \ell_{\mathrm{j}}^2 - \ell - 1). \quad (20)$$

Here, $E = 3kT/2$ is the energy of perturber, $Z - 1$ is the ionic charge and n the effective principal quantum number. This expression is of interest for a number of topics in astrophysics, like for example abundance calculations, or stellar atmospheres research.

4. STARK-B DATABASE AND VAMDC

Our results for Stark broadenning parameters, published in more than 150 papers, we have organized in the database STARK-B (formerly called BELDATA). It was initiated in the Astronomical Observatory of Belgrade (AOB) and the history of BELDATA can be followed in Popović et al. (1999a,b), Milovanović et al. (2000a,b), Dimitrijević et al. (2003b) and Dimitrijević and Popović (2006). Since the end of 2008, the STARK B database, is on-line in free access (http://stark-b.obspm.fr Sahal-Bréchot et al. 2014), and it is maintained and developed at Paris Observatory.

In the database STARK-B are Stark line widths W and shifts d as a function of temperatures and densities and for different perturbers. The accuracy of the Stark line widths varies from about 15-20 percent to 35 percent, and in some cases up to 50 percent.

Actually (1st of September of 2014) Stark broadening parameters obtained by using the SCP method for 79 transitions of He, 61 Li, 29 Li II, 19 Be, 30 Be II, 27 Be III, 1 B II, 12 B III, 148 C II, 1 C III, 90 C IV, 25 C V, 1 N, 7 N II, 2 N III, 1 N IV,

30 N V, 4 O I, 12 O II, 5 O III, 5 O IV, 19 O V, 30 O VI, 14 O VII, 8 F I, 5 F II, 5 F III, 2 F V, 2 F VI, 10 F VII, 25 Ne I, 22 Ne II, 5 Ne III, 2 Ne IV, 26 Ne V, 20 Ne VIII, 62 Na, 8 Na IX, 57 Na X, 270 Mg, 66 Mg II, 18 Mg XI, 25 Al, 23 Al III, 7 Al XI, 3 Si, 19 Si II, 39 Si IV, 16 Si V, 15 Si VI, 4 Si XI, 9 Si XII, 61 Si XIII, 114 P IV, 51 P V, 6 S III, 1 S IV, 34 S V, 21 S VI,2 Cl, 10 Cl VII, 18 Ar, 2 Ar II, 9 Ar VIII, 32 Ar III, 51 K, 4 K VIII, 30 K IX, 189 Ca, 28 Ca II, 8 Ca V, 4 Ca IX, 48 Ca X, 10 Sc III, 4 Sc X, 10 Sc XI,10 Ti IV, 4 Ti XI, 27 Ti XII, 26 V V, 33 V XIII, 9 Cr I, 7 Cr II, 6 Mn II, 3 Fe II, 2 Ni II, 9 Cu I, 32 Zn, 18 Ga, 11 Ge, 3 Ge IV, 16 Se, 4 Br, 11 Kr, 1 Kr II, 6 Kr VIII, 24 Rb, 33 Sr, 32 Y III, 3 Pd, 48 Ag, 70 Cd, 1 Cd II, 18 In II, 20 In III, 4 Te, 4 I, 14 Ba, 64 Ba II, 6 Au, 7 Hg II, 2 Tl III and 2 Pb IV are in STARK-B.

With the inclusion of all our SCP results the stage one of the STARK-B database is finished. The stage two started with the development and implementation of the formulae enabling to fit the tabulated data with temperature. We also started to implement Stark broadening parameters calculated by using the Modified semiempirical method (MSE) (Dimitrijević and Konjević 1980, Dimitrijević and Kršljanin 1986, Dimitrijević and Popović 2001). This method is used when the needed atomic data set is not sufficiently complete to perform an adequate semiclassical perturbation calculation. Stark line widths and, in some cases shifts of the following emitters have been determined by us:

Ag II, Al III, Al V, Ar II, Ar III, Ar IV, As II, As III, Au II, B III, B IV, Ba II, Be III, Bi II, Bi III, Br II, C III, C IV, C V, Ca II, Cd II, Cl III, Cl IV, Cl VI, Co II, Cu III, Cu IV, Eu II, Eu III, F III, F V, F VI, Fe II, Ga II, Ga III, Ge III, Ge IV, I II, Kr II, Kr III, La II, La III, Mg II, Mg III, Mg IV, Mn II, N II, N III, N IV, N VI, Na III, Na VI, Nb III, Nd II, Ne III, Ne IV, Ne V, Ne VI, O II, O III, O IV, O V, P III, P IV, P VI, Pt II, Ra II, S II, S III, S IV, Sb II, Sc II, Se III, Si II, Si III, Si IV, Si V, Si VI, Sn III, Sr II, Sr III, Ti II, Ti III, V II, V III, V IV, Xe II, Y II, Zn II, Zn III, and Zr II.

Up to 1st of September 2014, have been implemented the MSE results for the following emitters :

Al V, P VI, Cl IV, Cl VI, Ar IV, Mn III, Co III, Ga III, Ge III, Ge IV, Cd III and Ra II.

STARK-B database may be used for modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, as well as for laboratory plasmas, laser equipment and technological plasmas investigations but could be used for a much larger number of topics in astrophysics, physics and technology.

In Dimitrijević and Sahal-Bréchot (2014a), the analysis of citations of Stark broadening data obtained by semiclassical perturbation method, which are in STARK-B databases is performed. It is shown that the largest number of citations of these data is for astrophysical applications. Stark broadening parameters of He I, Na I, C IV, Si II, Si IV, Li I, N V, Hg II, O VI, S VI, Mg I, Mg II, Ba I, Ba II, Ca I and Ca II have been used for various investigations in astrophysics.

If we do not take into account the usage of Stark broadening data for theoretical and experimental research of Stark broadening, the applications of Stark broadening parameters obtained by semiclassical perturbation method are not so numerous in physics as in astrophysics. Semiclassical Stark broadening parameters of He I, Li II, Be II, Na I, Ca I, Ca II, Mg I, Mg II, Sr I, Ba I, Ba II, Zn I, Ag I, Cd I, Cu I, Ar I, Ar VIII, Al III, C IV and S V have been used for various physical problems.

From the analysis of aplications of Stark broadening parameters calculated using semiclassical perturbation method (Sahal-Bréchot, 1969a,b) one can conclude that principal users of such data are astronomers, using them especialy for the investigation of A and B type stars, white dwarfs and hot stars in evolved evolution stages (especialy PG1195 type). The most used data are for spectral lines of He I and Si II. Concerning plasmas in physics and technology, the most frequent applications concern laser produced plasma, and the most used data are Stark broadening parameters of Zn I.

The STARK-B database enters also in European FP7 project Virtual Atomic and Molecular Data Centre - VAMDC (Dubernet et al. 2010, Rixon et al. 2011). In Consortium are 15 institutions from 9 countries. Its objective is to build accessible and interoperable e-infrastructure for atomic and molecular data upgrading and integrating various existing database services containing atomic and molecular data.

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SPECTRAL LINES OF Zr IV IN THE ATMOSPHERE OF CHEMICALLY PECULIAR STARS

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Abstract. The electron-impact widths for seven Zr IV spectral lines have been calculated by using the modified semiempirical method. With obtained results, the importance of Stark broadening in the spectra of DB white dwarfs has been analysed.

1. INTRODUCTION

Stark broadening is usually the main pressure broadening mechanism for spectral lines from white dwarf and hot star atmospheres of earlier spectral types. Some of these stars, so-called *Chemically Peculiar Stars* (CP), show great anomalies in their abundances (see e.g. Leckrone et al, 1993), e.g. some elements are over- or underabundant compared with the solar ones. About 10-20 percent of A and B stars are classified as CP stars according to their physical characteristics and they can be found mostly in the upper quarter of Main-Sequence of the H-R diagram. Regarding the fact that we consider early-type stars younger than Sun, some of CP stars can provide us useful informations about early stage of stellar evolution.

A typical representative member of a non-magnetic subclass HgMn CP stars is a spectroscopic binary χ Lupi. Except Hg and Mn, Zr is also found overabundant in this double star. Zirconium has an important place in stellar spectroscopy investigations as a member of Sr-Y-Zr triad, appearing in s-process nucleosynthesis scenario. The Stark broadening of spectral lines of singly (Zr II) and doubly (Zr III) charged zirconium ion in stellar plasma has been investigated in the earlier researches (Popović and Dimitrijević 1996,1997, Popović et al 2001), especially related to the attempt to clarify the so-called “zirconium conflict”. Namely, the zirconium abundance values determined from weak Zr II optical and from strong Zr III UV spectral lines of χ Lupi differ from each other more then an order of magnitude (Leckrone et al, 1993, Sikström et al 1999). This strange result can be justified with inadequate use of stellar model, some non-LTE effect or radiative diffusion mechanism, but further researches in this case are needed. In spite of binary nature of χ Lupi, zirconium conflict also can be explained by some unknown interaction process between two stellar components. A better knowledge of Stark broadening is also of interest for the better understanding of this problem. In addition to the Stark broadening data for Zr II and Zr III spectral lines, it is of interest to also provide Stark width of triply-ionized zirconium (Zr IV) spectral lines, since they could be important for its abundance determination, avoiding the Zr II and Zr III lines for which the zirconium conflict has been established. Moreover, it has been already shown that the neglecting of the Stark broadening could lead to wrong values of abundances (Popović et al 2001).

Another type of celestial objects interesting for our investigation of Stark broadening are white dwarfs. In their case, not only the effective temperature, but also their log$g$ value is high, so that Stark broadening is dominant in comparison with thermal Doppler broadening.

Spectral lines of zirconium are observed in stellar spectra. In particular, observations of Zr IV lines have been reported in Chayer et al. (2006), who investigated 18 sdB stars and almost always found Zr IV lines, and also in Naslim et al. (2011, 2013) and Jeffery et al. (2015).

We are preparing a large study of Stark broadening of Zr IV lines and here, as a sample of results, will be presented only Stark Full Widths at Half intensity Maximum (FWHM) for seven Zr IV lines. The complete results and the analysis of their significance for Zr IV spectral lines observed in stellar plasma will be published elsewhere (Majlinger et al., 2015). The obtained results for Stark broadening of Zr IV lines will enter in STARK-B database (http://stark-b.obspm.fr - Sahal-Bréchot et al., 2014), a node of VAMDC (Virtual Atomic and Molecular Data Centre - http://www.vamdc.eu/) since the end of 2009 (Dubernet et al., 2010, Rixon et al., 2011), so that it is also accessible via the VAMDC portal (http://portal.vamdc.org/vamdc_portal/home.sea). A link through Serbian Virtual Observatory (SerVO - http://servo.aob.rs/) is also available.

2. CALCULATION METHOD

For evaluation of Stark widths and shifts of non-hydrogenic spectral lines of ionized atoms, various theoretical approaches have been used (Griem, 1974). Both semiclassical and fully quantum-mechanical methods can be used for the evaluation of isolated line widths of multiply charged ions. Whenever there is no sufficient set of atomic data needed for a reliable semiclassical or quantum mechanical calculation, or complicated and complex calculation methods should be avoided, one can use simpler, approximate formulas. Modified semiempirical method (MSE - Dimitrijević and Konjević, 1980) is one of such approximate approaches, whose convenience is that for calculation of electron-impact broadening parameters (widths and shifts) a considerably smaller number of atomic data, in comparison with the semiclassical method, is needed. Accuracy of MSE is usually not worse than ±50%, which is in a lot of cases enough for astrophysical purposes.

3. RESULTS AND DISCUSSION

We have determined the Stark widths of seven Zr IV spectral lines (λ=1536.67 Å, λ=1598.95 Å, λ=1607.95 Å, λ=2287.38 Å, λ= 2164.36 Å,λ= 5463.85 Å, and λ= 5781.45 Å) using the MSE method, and the obtained results are shown in Table

1. The atomic energy levels of Zr IV, needed for the calculation of electron-impact full widths at half maximum (FWHM) of spectral lines are taken from Reader and Acquista (1997). The needed matrix elements are calculated using the Coulomb approximation formalism of Bates and Damgaard (1949), while the corresponding line and multiplet factors are used from Shore and Menzel (1968) in all cases when they are needed. The Stark widths are calculated for the standard plasma density of 10^{23} m^{-3}. Temperatures are within the range of 10,000 K - 500,000 K, given with unequal steps, choosen to be more frequent towards lower temperatures where the change with temperature is more pronounced. There are still no available measured Stark width data for Zr IV spectral lines, and we can compare our results only to the estimates obtained by Purić and Šćepanović (1999). Comparing the great amount of Stark width data, published by M. S. Dimitrijević, S. Sahal-Bréchot and their co-workers in numerous papers (these data are now in STARK-B database, see Sahal-Bréchot et al. 2014), Purić and Šćepanović (1999) found the correlation between Stark width and difference between ionization energy and energy of the final state.

Table 1: Stark FWHM for seven transitions of Zr IV and the electron density $N_e = 10^{23}$ m^{-3}. Column T: Temperatures are given in 10^3 K. Column W_{MSE}: Stark widths based on our calculations using the MSE approach (Dimitrijević and Konjević 1980) given in Å; Column W_{Pur}: - Stark widths taken from Purić and Śćepanović (1999) given in Å.

Zr IV, Transition, λ[Å]	T[kK]	W_{MSE}[Å]	W_{Pur}[Å]	W_{MSE}/ W_{Pur}
5s $^2S_{1/2}$ - 5p $^2P^o_{1/2}$ 2287.38 Å	10	0.08435	0.06305	1.34
	20	0.05964	0.04459	1.34
	50	0.03772	0.02820	1.34
	100	0.02704	0.01994	1.36
	200	0.02154	0.01409	1.53
	300	0.01997	0.01151	1.74
	500	0.01048	0.00892	1.17
5s $^2S_{1/2}$ - 5p $^2P^o_{3/2}$ 2164.36 Å	10	0.07681	0.05645	1.36
	20	0.05431	0.03992	1.36
	50	0.03435	0.02525	1.36
	100	0.02457	0.01785	1.38
	200	0.01959	0.01262	1.55
	300	0.01811	0.01031	1.76
	500	0.01702	0.00798	2.13
5p $^2P^o_{1/2}$ - 5d $^2D_{3/2}$ 1546.17 Å	10	0.04218	0.05318	0.79
	20	0.02983	0.03760	0.79
	50	0.01887	0.02378	0.79
	100	0.01341	0.01682	0.80
	200	0.01064	0.01189	0.89
	300	0.01011	0.00971	1.04
	500	0.01005	0.00752	1.33

Zr IV, Transition, λ[Å]	T[kK]	W$_{MSE}$[Å]	W$_{Pur}$[Å]	W$_{MSE}$/ W$_{Pur}$
5p $^2P^o_{3/2}$ - 5d $^2D_{3/2}$ 1607.95 Å	10	0.04690	0.06058	0.77
	20	0.03316	0.04284	0.77
	50	0.02097	0.02709	0.77
	100	0.01488	0.01916	0.78
	200	0.01181	0.01355	0.87
	300	0.01120	0.01106	1.01
	500	0.01115	0.00857	1.30
5p $^2P^o_{3/2}$ - 5d $^2D_{5/2}$ 1598.95 Å	10	0.04631	0.05991	0.77
	20	0.03274	0.04236	0.77
	50	0.02071	0.02679	0.77
	100	0.01469	0.01916	0.77
	200	0.01166	0.01355	0.86
	300	0.01120	0.01094	1.02
	500	0.01101	0.00847	1.30
6s $^2S_{1/2}$ - 6p $^2P^o_{1/2}$ 5781.45 Å	10	1.9690	3.01090	0.65
	20	1.3920	2.12903	0.65
	50	0.9168	1.34652	0.68
	100	0.7647	0.95213	0.80
	200	0.6929	0.67326	1.03
	300	0.6597	0.54971	1.20
	500	0.6161	0.42581	1.45
6s $^2S_{1/2}$ - 6p $^2P^o_{3/2}$ 5463.85 Å	10	1.7840	2.68919	0.66
	20	1.2610	1.90155	0.66
	50	0.8283	1.20264	0.69
	100	0.6897	0.85040	0.81
	200	0.6263	0.60132	1.04
	300	0.5955	0.49098	1.21
	500	0.5573	0.38031	1.47

Using the relation derived on the basis of this correlation, they estimated Stark widths for spectral lines of a number of emitters, including Zr IV. In the second and third column of Tab. 1 there are Stark widths calculated here using MSE and calculated by Purić and Šćepanović (1999), respectively, as a function of temperature.

The dependence of the Stark width of Zr IV 5s $^2S_{1/2}$ - 5p $^2P^o_{1/2}$ λ= 2287.38 Å spectral line on the temperature is shown in Fig. 1, where Stark FWHM calculated here by using MSE method (Dimitrijević and Konjević 1980), is compared with the results of Purić and Šćepanović (1999) and with thermal Doppler width of the same line. Finally, using the obtained results, we investigated how Stark and Doppler width for the same spectral line change with the optical depth of the DB White Dwarf stellar atmosphere (Fig. 2). The numerical simulation is done for the optical depth corresponding to Rosseland mean opacity near the bluish green wavelenght band with the wavelenght λ= 5150 Å. To show this comparison of Stark and Doppler widths, the existing model atmosphere for DB white dwarfs is used with log g = 8 and T$_{eff}$ =15000 K (Wickramasinghe, 1972).

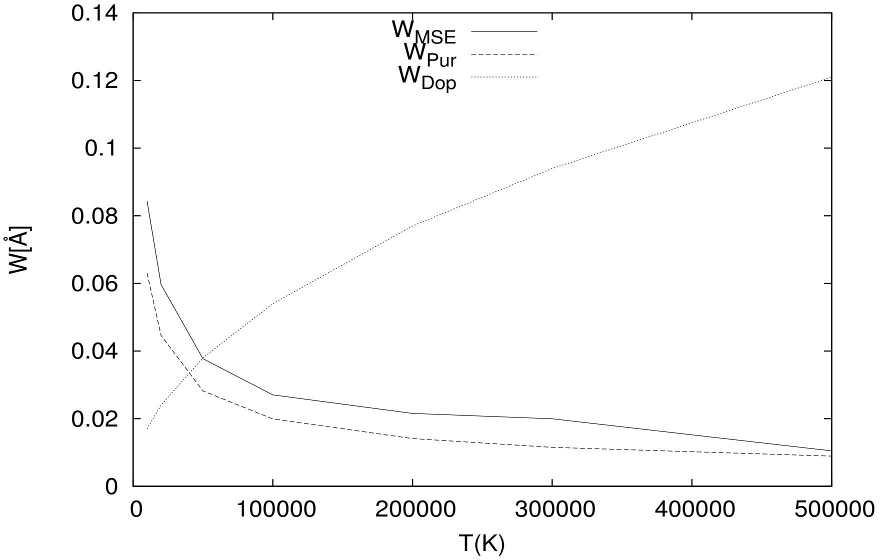

Figure 1: Comparison of Stark full widths at half maximum (FWHM) W_{MSE} - full line, calculated here by using MSE method (Dimitrijević and Konjević 1980), with the results for Stark FWHM W_{PUR} - dashed line of Purić and Šćepanović (1999) and thermal Doppler width - W_{DOP} - dotted line, for Zr IV 5s $^2S_{1/2}$ - 5p $^2P^o_{1/2}$ $\lambda =$ 2287.38 Å spectral line. The electron density N_e is 10^{23} m^{-3}.

The electron-impact widths obtained here by using the MSE method and those by Purić and Šćepanović (1999) are in majority in reasonable agreement taking into account that the results of Purić and Šćepanović (1999) are estimates. Their ratio increases with temperature and at 10,000 K it is 0.7-0.8 except for 5s-5p transitions, where it is 1.3-1.4. On the other hand, at 500,000 K, it is 1.7-2.1 for 5s-5p transitions and 1.3-1.5 for others. Stark broadening width decreases with temperature, and it is around 0.1 Å for T=10,000 K and around 0.6 Å for T=500,000 K, except for 6s-6p transitions where it is several times larger, reaching, at T=10,000 K 2 Å for W_{MSE} and 3 Å for W_{Pur}. It is expected, since with the increase of principal quantum number in a spectral series decreases the distance to perturbing levels and the corresponding Stark width increases. The decrease of Stark width with temperature can be also seen in Fig 1. Namely, the MSE formula for Stark widths has the inverse square root dependence at low temperature limit (Dimitrijević and Konjević 1980), while thermal Doppler broadening is purely square root dependent of temperature.

In Fig. 2 is shown the dependence of electron-impact FWHM and thermal Doppler width on logarithm of optical depth τ for standard wavelength of 5150 Å (log τ_{5150}) in the DB white dwarf atmosphere for Zr IV 5s $^2S_{1/2}$ - 5p $^2P^o_{1/2}$ $\lambda = 2287.38$ Å spectral line. The model atmosphere with log $g = 8$ and T_{eff} =15,000 K of Wickramasinghe (1972) is used. From Fig. 2 we can conclude that the electron-impact broadening has more influence on Zr IV spectrum than thermal Doppler broadening. For the investigated line, the Stark width is typically one order of magnitude larger than the Doppler one.

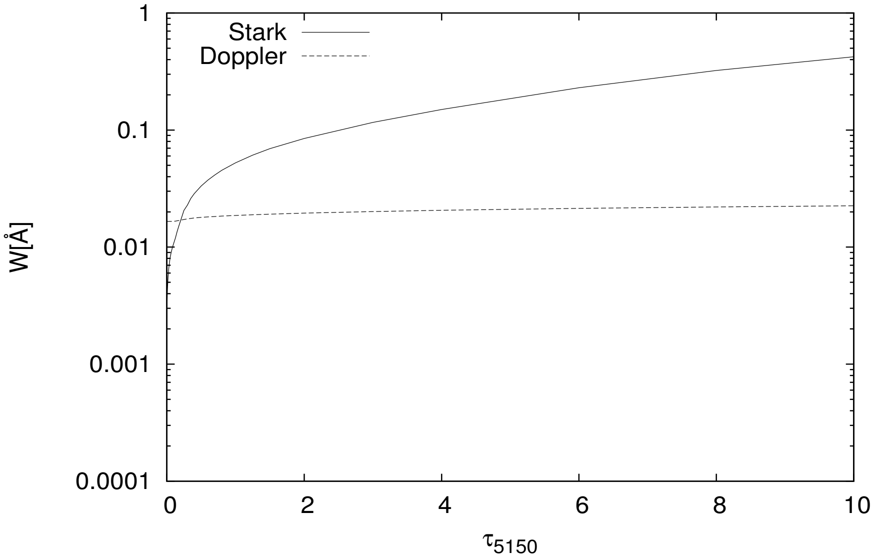

Figure 2: Dependence of electron-impact FWHM and thermal Doppler width on optical depth (log τ_{5150}) in the DB White Dwarf atmosphere for Zr IV 5s $^2S_{1/2}$ - 5p $^2P^o_{1/2}$ $\lambda = 2287.38$ Å spectral line. The model atmosphere with log $g = 8$ and T$_{eff}$ =15000 K of Wickramasinghe (1972) is used.

4. CONCLUSIONS

Stark FWHM for 7 Zr IV lines, needed for astrophysical plasma research, have been determined. Using the obtained results it has been demonstrated that Stark width dominates over Doppler width especially in the deeper layers of white dwarf atmosphere (difference becomes more important for larger optical depths). This conclusion concerning the importance of Stark broadening in white dwarf atmospheres is already confirmed with similar researches on spectral lines of other elements (Simić et al 2006). The difference between the Stark width and Doppler width is more resolute in white dwarf spectra than for main sequence stars, because Stark width in the impact approximation (Griem 1974) increases linearly with electron density, and it is much higher in white dwarf atmospheres. Since in Chayer et al. (2006) and Naslim et al. (2011, 2013), Zr IV lines have been used for zirconium abundance determination in several subdwarfs, we hope that Stark broadening data for Zr IV lines will be useful for further investigation of atmospheres of hot dense stars.

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QUASI-THERMAL NOISE SPECTROSCOPY IN EARTH'S MAGNETOSHEATH: THEORY AND APPLICATION TO PLASMA DIAGNOSTIC ON WIND SPACECRAFT

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Abstract. One of the most accurate techniques for in situ measuring the electron density and temperature in space plasmas is the quasi-thermal noise spectroscopy, which uses the voltage fluctuation spectrum on an electric aatenna immersed into plasma. This method has been used since the last three decades in different space plasma environments, since it is immune to spacecraft limitations. The method is based on the analysis of the electrostatic field spectrum produced by the quasi-thermal fluctuations of the electrons, and Doppler-shifted thermal fluctuations of the ions. Here, the method has been adjusted for plasma in magnetosheeth of Earth, just behind the Earths bow-shock, where flat-top velocity distribution function of electrons has been measured. Theory has been applied to measurements performed by WIND satellite.

1. INTRODUCTION

Although the conventional use of electric antennas is for remote sensing by detection of electromagnetic waves, they can also be used for in situ measurements, by detecting electrostatic waves produced by the random motion of the ambient plasma particles. When a passive electric antenna is immersed in a stable plasma, the thermal motion of the ambient particles produces electrostatic fluctuations, which can be adequately measured with a sensitive wave receiver connected to a wire dipole antenna. This quasi-thermal noise (QTN) is completely determined by the particle velocity distributions in the frame of the antenna. The problem is simplest in the absence of a static magnetic field or at frequencies much higher than the electron gyrofrequency, since in this case the plasma can be considered to be an assembly of "dressed" "test" particles moving in straight lines.

The QTN spectrum around the plasma frequency f_p, consists of a noise peak just above f_p, produced by electron thermal fluctuations. Since plasma density n_e is proportional to f_p^2, this allows an accurate measurement of the electron density.

In addition, the electrons passing within Debye length L_D from the antenna induce voltage pulses on it, producing in the spectrum a plateau just below f_p, and above f_p, a noise level which decreases as the observing frequency increases. The analysis of these spectrum regions gives the electron core temperature T_c (Meyer-Vernet and Perche, 1989). One of the main advantages of the QTN spectroscopy is its relative immunity to the spacecraft potential and photoelectron perturbations which, in general affect particle analyzers. This method, based on the electron contribution of the QTN, was first introduced for studies of the solar wind by (Meyer-Vernet, 1979).

QTN spectrum is determined by plasma properties, which are contained in particle velocity distribution function (VDF) in the frame of the antenna. Technique is independent of antenna orientation if VDF of plasma particles is considered to be isotropic.

In this work, technique has been adopted for usage in region of magnetosheath of Earth, just behind bow-shock. Location of bow-shock is easily detectable in QTN spectrum since plasma density increases for approximately factor of 4 as spacecraft passes from free solar wind to magnetosheath. As a consequence, frequency of ‘plasma peak‘ in the spectrum is increased approximately twice. Some preliminary testings on WIND spacecraft Thermal Noise Receiver (TNR) instrument data have been performed, and some predictions for future research are given.

2. QTN SPECTRUM FOR FLAT-TOP DISTRIBUTIONS

2. 1. BASICS OF THE METHOD

Spectrum which is measured by radio antenna consists of three different contributing noises: the electron quasi-thermal noise due to the ambient electrons thermal motion, the proton noise due to the protons thermal motion which is Doppler-shifted by the solar wind bulk speed and the shot noise decreasing as f^{-2}. As protons pass through the bow-shock, their motion gets thermalized so no bulk motion and no Doppler shift is present. For this reason, proton contribution to the spectrum can be completely neglected in the magnetosheath.

The voltage spectral density of QTN measured at the terminals of an electric antenna immersed in a plasma with drifting velocity $\vec{V}$ is (Meyer-Vernet, 1979)

$$V_\omega^2 = \frac{2}{(2\pi)^3} \int \left| \frac{\vec{k} \cdot \vec{J}}{k} \right| E^2(\vec{k}, \omega - \vec{k} \cdot \vec{V}) \mathrm{d}^3 k \tag{1}$$

The first term in the integral involves the antenna response to electrostatic waves, which depends on the Fourier transform $\vec{J}(\vec{k})$ of the current distribution along the antenna. The second term is the autocorrelation function of the electrostatic field fluctuations in the antenna frame. At frequencies much higher than the gyrofrequency, we have for electrons

$$E^2(\vec{k}, \omega) = 2\pi \frac{e^2 \int f(\vec{v}) \delta(\omega - \vec{k} \cdot \vec{v}) \mathrm{d}^3 v}{k^2 \epsilon_0^2 \left| \epsilon_L(\vec{k}, \omega) \right|^2} \tag{2}$$

where $f(\vec{v})$ stands for VDF of electrons and ϵ_L for the plasma longitudinal dielectric permittivity.

These equations can be simplified using few approximations. First, electron thermal velocity is higher than the plasma velocity ($\vec{v} >> \vec{V}$) and second, $f(\vec{v})$ is considered to be isotropic. In this case, we obtain (Chateau and Meyer-Vernet, 1989)

$$V^2(\omega) = \frac{16 m_e \omega_p^2}{\pi \epsilon_0} \int_0^{+\infty} \frac{F(kL_{ant})B(k)}{k^2 |\epsilon_L|^2} \mathrm{d}k \tag{3}$$

where L_{ant} is antenna length and $F(kL_{ant})$ is antenna response function for wire dipole antenna, given as

$$F(x) = x^{-1}\left[Si(x) - \frac{1}{2}Si(2x) - \frac{2}{x}\sin^2\frac{x}{2}\right] \tag{4}$$

($Si(x)$ stands for sine integral). Function $B(k)$ is, by definition

$$B(k) = \frac{2\pi}{k} \int_{\omega/k}^{+\infty} v f(v) \mathrm{d}v \tag{5}$$

and longitudinal dielectric permittivity is given as

$$\epsilon_L = 1 + \frac{2\pi\omega_p^2}{k} \int_{-\infty}^{+\infty} \frac{v_{||} f(v_{||})}{kv_{||} - \omega - i_0} \mathrm{d}v_{||} \tag{6}$$

where $v_{||}$ s the component of $\vec{v}$ parallel to $\vec{k}$.

2. 2. CHOICE OF THE DISTRIBUTION FUNCTION

We choose the following electron velocity distribution function

$$f(v) = \frac{A}{1 + \left(v/v_0\right)^8} \tag{7}$$

which is normalized by a factor

$$A = \frac{\sqrt{2 + (2)^{1/2}}}{\pi^2 v_0^3} \tag{8}$$

This function is reasonably simple and represents rather well the flat-topped shape of actual distribution functions measured in the Earth magnetosheath. This function has characteristic flat part at small velocities and power-low decrease to high velocities (approximately v^{-8}). This feature indicts larger portion of very fast, 'supra-thermal' electrons, compared to classic Maxwellian, with characteristic exponential velocity decrease.

Shape of QTN spectrum is obtained by replacing Equation 7 into Equations 5 and 6 and then into Equation 3. Details of the calculation are given elsewhere (Chateau and Meyer-Vernet, 1989), and we finally obtain

$$V^2(\omega) = \frac{4}{\pi^2 \epsilon_0} \frac{T^{1/2}}{r^2} \sqrt{6\left(2 + 2^{1/2}\right) k_b m_e} \int_0^{+\infty} \frac{z b(z) F[ru/z\sqrt{1 + 2^{1/2}}]}{\left|\epsilon_L(z)\right|^2} \mathrm{d}z \tag{9}$$

where we use following substitutes: $r = f/f_p$, $u = L_{ant}/L_D$, $z = \omega/kv_0$ and

$$b(z) = \pi - arctan(\sqrt{2}z^2 - 1) - arctan(\sqrt{2}z^2 + 1) + \frac{1}{2} ln\left(\frac{z^4 - \sqrt{2}z^2 + 1}{z^4 + \sqrt{2}z^2 + 1}\right) \quad (10)$$

As the analytic calculation of Equation 9 cannot be done in general, so it must be numerically computed.

2. 3. SHOT NOISE AND ANTENNA IMPEDANCE

Since the antenna is a physical object which disturbs the trajectories of the particles (they cannot pass through its surface) and furthermore the antenna surface can eject photoelectrons, there is an additional noise, which is called shot noise (Meyer-Vernet and Perche, 1989). For a thin antenna ($a_{ant} << L_{ant}$) and antenna potential ϕ which satisfies $e\phi/k_b T_e << 1$ shot noise can be well approximated by expression

$$V_{sn}^2 = 2e^2 N_{impact} |Z^2| \quad (11)$$

with $N_{impact} = n_e v_{the} S_{ant} (4\pi)^{-1}$ being electron impact rate on the antenna. Here, Z stands for antenna impedance, given by

$$Z(\omega) = \frac{4i}{\pi^2 \epsilon_0 \omega} \int_0^{+\infty} \frac{F(kL_{ant})}{\epsilon_L} \mathrm{d}k \quad (12)$$

Final step taking the receiver gain into account. Namely, antenna of impedance Z is connected to a receiver with a finite impedance Z_R containing ‘stray’ or ‘base’ capacitance $C_b \approx 33pF$. Relation between spectrum given in Equation 9 and spectrum measured by the receiver is

$$V_{obs}^2 = \frac{V^2 + V_{sn}^2}{\Gamma^2} \quad (13)$$

with

$$\Gamma = \frac{C_{ant}}{C_{ant} + C_b} = \frac{Z + Z_b}{Z} \approx 0.49 \quad (14)$$

Example of QTN spectrum in the magnetosheath is given on Figure 1.

3. APPLICATION TO WIND MEASUREMENTS

In this section, presented QTN method is applied to measurements from TNR instrument of WIND spacecraft. TNR consists of two multi-channel receivers that cover frequency range from $4kHz$ to $256kHz$ with 5 logarithmically-spaced frequency bands (Bougeret et al, 1995). Each band covers 2 octaves with 1 octave overlap, each containing 32 frequency channels. This leads, in total, to obtaining spectrum of 96 different frequencies.

Fitting procedure is a standard Levenberg-Marquardt χ^2 algorithm adopted for fitting the sum of expressions from Equations 9 and 11, with free parameters of electron density and temperature, defined as moments of flat-top VDF (defined in Equation 7), with taking receiver gain into account (Equation 14). Example of typical spectrum obtained in magnetosheath of Earth is given on Figure 2. It is important to

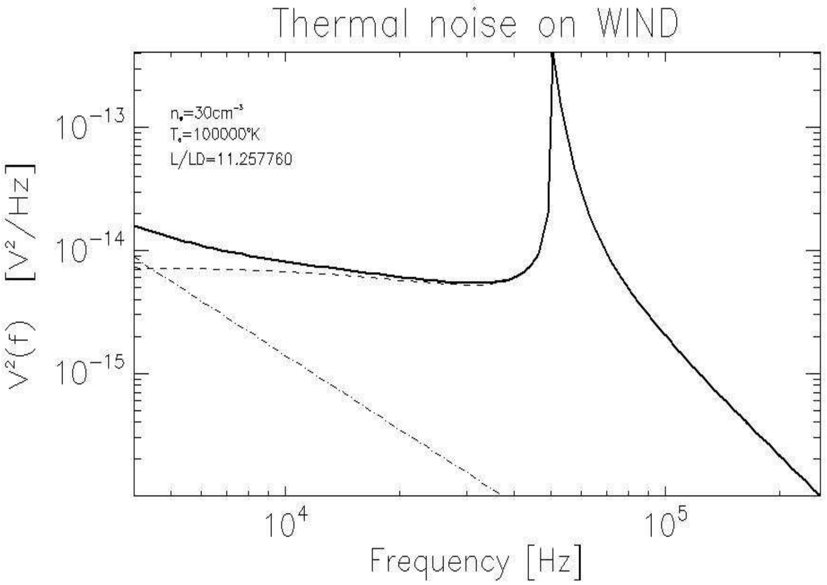

Figure 1: Example of theoretical spectrum of quasi-thermal noise in the magnetosheath of Earth. Spectrum is adopted for parameters of WIND spacecraft ($a_{ant} = 0.7mm$, $L_{ant} = 50m$). QTN spectrum is given by dashed line and shot noise contribution by dash-dotted line

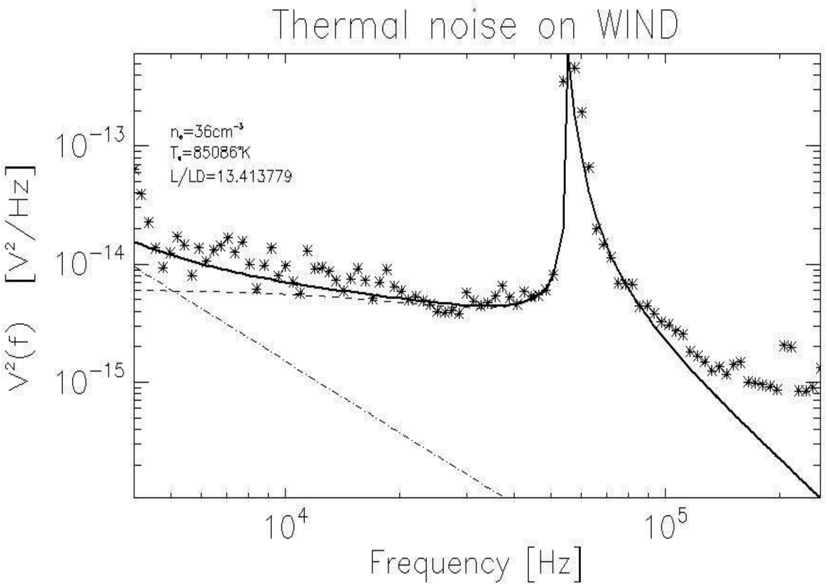

Figure 2: Spectrum from magnetosheath of Earth measured on 2.12.1996.

note that TNR spectrum is affected, on higher frequencies, by other factors, especially terrestrial and galactic background radiation. Consequently, measured high-frequency values are higher that intended. To avoid this problem influencing fitting procedure ‘points‘ in the spectrum above $90kHz$ are not taken into account.

4. CONCLUSIONS AND PERSPECTIVES

In this work, QTN fitting technique has been adopted for usage in magnetosheath of Earth. This implies use of ‘flat-top‘ VDF measured in these particular conditions. Method has been successfully applied to measurements of WIND spacecraft TNR instrument.

Procedure developed here can, in the future, be applied to comprehensive study of magnetosheath and bow-shock of Earth. Since this method is very well understood and applied in free solar wind (see, for example, Le Chat et al, 2009 and references therein) it is now possible to study in detail the radio spectra development as spacecraft passes the bow-shock, and how is it affected by the position with respect to Earth and Parker spiral.

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SWEEP-BY-SWEEP IMPLICIT LAMBDA ITERATION FOR NON-LTE RADIATIVE TRANSFER IN 2D CARTESIAN COORDINATES

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Abstract. We have recently developed a novel method for solving non-LTE radiative transfer problem in 2D media. The method can be considered as a generalization of the Forth-and-back implicit lambda iteration (FBILI), originally developed for 1D atmospheric models. In this so-called Sweep-by-sweep implicit lambda iteration short characteristics approach is used for the formal solution of the radiative transfer equation, whereas an extremely high convergence rate is achieved by means of multiple source function updates within one iteration and thanks to the use of quasi-invariant iteration factors. In this paper we briefly present its implementation in the case of two-level atom line transfer with complete frequency redistribution in a 2D Cartesian grid and we compare its convergence properties with those of the iterative methods currently in use (Jacobi and Gauss-Seidel iteration). We show that Sweep-by-sweep ILI converges 6-7 times faster than the Jacobi method and scales better with grid resolution.

1. INTRODUCTION

The aim of radiative transfer modeling is to properly treat the interplay between the radiation field and the matter, with the ultimate purpose of self-consistent modeling of various astrophysical objects. It is a challenging task both conceptually (different physical processes on various geometrical scales are involved) and numerically. This is so even in the so-called "reduced" problem of computing the emergent spectrum from a given model. Assuming the non-local thermodynamic equilibrium (NLTE) we are faced with the self-consistent solution of both the radiative transfer (RT) and the statistical equilibrium (SE) equations for the unknown radiation field and the atomic level populations. In general, the NLTE problem is non-local and non-linear and requires immense computational power for its solution.

A "classical" radiative transfer computations assume one-dimensional models where all quantities depend on only one spatial coordinate. The problem and the solutions are given in the excellent monograph by Mihalas (1978). However, there are many objects like solar prominences, accretion and circumstellar disks and rings, various kinds of jets, etc., for which 1D approximation is not adequate. Stellar atmospheres themselves are also highly inhomogeneous objects where lateral (i.e. horizontal) radiative transfer effects must not be neglected if we are to compute the emergent spectrum properly. However, 2D or 3D NLTE modeling is numerically much more intensive, and apart from parallelization strategies (see, e.g. Štepan & Trujillo Bueno, 2013), faster methods for the solution of the multidimensional NLTE problem are needed.

Here, we present our recent work on the generalization of Forth-and-back Implicit Lambda Iteration (FBILI, Atanacković-Vukmanović et al., 1997) to 2D Cartesian geometry. The basic equations of the problem are given in Section 2. In Section 3 we outline a variant of the short characteristics approach to the formal solution of the RT equation and its use in four iterative schemes: Jacobi method, Gauss-Seidel method, the Symmetric Gauss-Seidel iteration (SGS, not yet generalized to multidimensional geometries), and the Sweep-by-sweep Implicit Lambda Iteration (SsILI). In Section 4 we discuss the convergence and scaling properties of the iterative procedures, demonstrating the superiority of SsILI method. In Conclusions we give some possible directions for the future work.

2. NLTE PROBLEM

Here, we shall restrict ourselves to two-level atom line transfer with complete frequency redistribution and no background continuum in a static medium. If we assume that the medium is infinite and homogeneous in the z-direction, the RT equation has the following form:

$$\frac{dI(x,y,\hat{\Omega},\nu)}{d\tau} = \phi(x,y,\nu)\left[I(x,y,\hat{\Omega},\nu) - S(x,y)\right]. \tag{1}$$

Here, $I(x,y,\hat{\Omega},\nu)$ is the specific intensity at the chosen spatial point (x,y), in direction $(\hat{\Omega})$ and at frequency (ν), τ is the line-integrated optical path, $\phi(x,y,\nu)$ is the line absorption profile, and $S(x,y)$ is the line source function given as:

$$S(x,y) = \epsilon(x,y)B_P(x,y) + (1-\epsilon(x,y))\,J(x,y). \tag{2}$$

In the above expression, B_P is the Planck function, $\epsilon = C_{\rm ul}/(C_{\rm ul} + A_{\rm ul})$ is the photon destruction probability by collisional de-excitation, with $C_{\rm ul}$ and $A_{\rm ul}$ - collisional and radiative rates from the upper to the lower level of the transition, respectively, and

$$J(x,y) = \int_{-\infty}^{\infty} \phi(x,y,\nu)d\nu \oint I(x,y,\hat{\Omega},\nu)\frac{d\hat{\Omega}}{4\pi}. \tag{3}$$

is the scattering integral. Equations 1 and 2 are linearly coupled. In the case of the multilevel atom line transfer the coupling is non-linear and has to be treated iteratively. With the final aim to solve this general problem, first we develop the iterative procedures and test their properties using a simple two-level atom case for which the exact solution is known. First we shall present the *formal solution*, i.e. a way of computing the specific intensity with the given source function as it is the backbone of each iterative technique, and then we shall briefly describe its use in the four above mentioned iterative procedures.

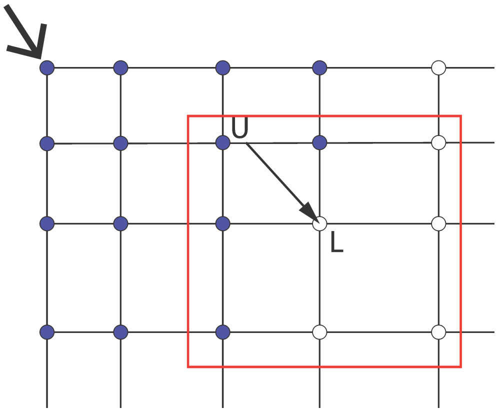

Figure 1: Example of one sweep of the spatial mesh. Full points are the ones where the formal solution has been performed and specific intensity is known while the empty ones are the ones where the formal solution is yet to be performed. Note that this implies the specific order in which the formal solution is done. The square emphasizes the source functions which contribute to the specific intensity at the local point.

3. METHOD OF SOLUTION

Proceeding from the integral form of the RT equation, we can see that the specific intensity at a given point $L = (i, j)$, in the given direction and at the given frequency can be expressed as (see Milić & Atanacković, 2014):

$$I_L = I_U e^{-\Delta} + p(\Delta) S_L + \sum_{i-1}^{i+1} \sum_{j-1}^{j+1} r_{i'j'}(\Delta) S_{i'j'}. \tag{4}$$

Here I_U is the specific intensity in the same direction and at the same frequency, but at the “upwind” point, i.e. the point of the first intersection between the ray and the grid, in the direction opposite to that of photon propagation. Since the point U is not on the spatial grid, I_U has to be found by spatial interpolation. Δ is the monochromatic optical path between U and L, S_L is the ”local” source function and the sum accounts for the contributions of the eight nearby source functions to the local specific intensity ($i' = i-1, i, i+1$, $j' = j-1, j, j+1$, $r_{ij} = 0$). For the formal solution in a given direction, one has to start from the corresponding given boundary condition and “sweep” the grid in the appropriate order (Fig.1). For example, if the angle ϕ in the x, y plane has values $0 < \phi < \pi/2$, one has to start from boundaries $x = 0$ and $y = 0$. We will refer to the computations of the specific intensities for a given quadrant of ϕ as one sweep. In 1D case there are two sweeps (”in-going” and ”out-going”), in 2D case there are four, and in 3D there are eight sweeps of the grid.

If we now integrate Eq. (4) over angles and line profile we get:

$$J_L = a + b S_L + \sum_{i-1}^{i+1} \sum_{j-1}^{j+1} c_{i'j'} S_{i'j'}. \tag{5}$$

Even if we know neither radiation field nor the source function, the fact that we can write an implicit linear relation (like Eq. (5)) between these unknowns enables the construction of the efficient iterative procedures to solve the problem equations (1) and (2).

We see that substituting Eq. (5) into Eq. (2) we get the expression for updating the source function

$$S = \frac{\epsilon B_P + (1-\epsilon)(a + \sum_{i-1}^{i+1} \sum_{j-1}^{j+1} c_{i'j'}(\Delta) S_{i'j'})}{1 - (1-\epsilon) b} \tag{6}$$

once all the coefficients a, b, $c_{i'j'}$ are known. The use of the above implicit linear relation instead of iterative computation of the unknown quantities themselves (as in the classical Λ iteration) greatly increases the convergence rate.

3. 1. ITERATIVE SCHEMES

The most straightforward accelerating iterative procedure performs formal solution in all directions, at all frequencies and over the whole grid in order to compute the coefficients a, b and c and then use them in Eq. (6) to update the values of the source function. This corresponds to the well-known Jacobi method (see e.g. Saad, 2003). Note that the source function is then updated *after* all four sweeps of the grid. Substantial acceleration can be obtained if the source function is updated *in the course of* the fourth sweep, that is, as soon as a, b and c coefficients are known. This procedure corresponds to the Gauss-Seidel method, which has been used in 1D NLTE radiative transfer computations by Trujillo Bueno & Fabiani Bendicho (1995) and extended to 2D by Paletou & Leger (2007). The GS approach can be further accelerated if, after the first iteration, the update of the source function is performed during *each* sweep (that is, four times per iteration). This procedure corresponds to the symmetric Gauss-Seidel (SGS) method, which (to our knowledge) was first generalized to multidimensional radiative transfer computations in the paper by Milić & Atanacković (2014).

Finally, even further acceleration is possible by the use of the iteration factors together with the implicit treatment of the source function and its derivatives (through the sum of eight neighboring source functions in Eq. (5)) based on the ideas introduced for 1D NLTE radiative transfer by Atanacković-Vukmanović et al. (1997) in the framework of Forth-and-Back Implicit Lambda Iteration (FBILI). Thus, proceeding from the form of Eq. (5) we introduce the ratio of the non-local intensity and the local source function as a quasi-invariant iteration factor into the "local" coefficient b:

$$b = \int_{-\infty}^{\infty} \phi(\nu) d\nu \oint [p + \frac{I_U e^{-\Delta}}{S_L} k(\varphi)] \frac{d\hat{\Omega}}{4\pi}, \tag{7}$$

where $k(\varphi)$ can be either zero or unity. The optimum results regarding acceleration and stability are obtained when the iteration factor is used in the so-called "in-going" sweeps (i.e. $k = 1$ for $0 < \varphi < \pi$) following tightly the idea of the FBILI method developed for 1D RT problems. We named this iterative procedure "Sweep-by-sweep Implicit Lambda Iteration."

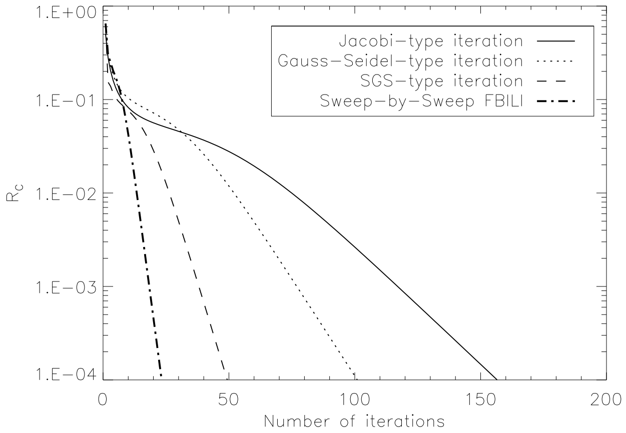

Figure 2: Evolution of the maximum relative change of S with iteration number for four described iterative procedures.

4. CONVERGENCE PROPERTIES

We tested the iterative procedures described above (Jacobi, Gauss-Seidel, Symmetric Gauss-Seidel, Sweep-by-sweep ILI) on a simple test problem given by Auer & Paletou (1994). They studied the two-level atom line transfer with complete frequency redistribution in a homogeneous and isothermal slab of dimensions $10^4 \times 10^4$. Planck function and opacity are equal to unity, and Gauss absorption-line profile is used. The slab is illuminated by the radiation field equal to unity from directions $\pi < \varphi < 2\pi$. For spatial discretization we use a 129×129 log-spaced grid.

In order to compare the convergence properties of various iterative procedures we computed and displayed the evolution of the maximum relative change of the source function between two successive iterations (R_c) with the number of iterations in Fig. 2.

It is obvious that each of the iterative procedures shows increase in the convergence rate with respect to the "previous" one. Let us note the amount of acceleration: Gauss-Seidel brings acceleration of about 70% with respect to the Jacobi iteration. It is somewhat less than in 1D case, which is the consequence of using comparatively lesser amount of new information in updating the source function (in 2D three out of four sweeps use the "old" source function values, while in 1D it happens in one out of the two sweeps). SGS is exactly two times faster than GS which is a significant improvement. Finally, the use of the iteration factor brings acceleration by more than a factor two with respect to SGS. In total, Sweep-by-sweep ILI is about 7 times faster than the state-of-the art Jacobi method, which is an improvement of almost an order of magnitude. More detailed analysis is given in Milić & Atanacković (2014), and additional test problem is studied in Milić (2014).

One of the properties of an iterative scheme which is of great importance in computations is its scaling with the grid resolution. Standard methods based on the approximate operator need more iterations to converge when the grid is refined. In 1D problems the total computing time of the Jacobi method scales with number of points like N^2, where N is the resolution of the spatial grid, since both the computational work of the formal solver and the number of iterations needed to reach

Table 1: Number of iterations needed by the Jacobi and SsILI method to reach $R_C = 10^{-3}$ for various grid resolutions.

Grid resolution	33×33	65×65	129×129	257×257
Jacobi iteration	30	63	118	204
Sweep-by-sweep ILI	7	12	19	30

the convergence scale with N. We expect SsILI method to behave differently due to the use of the iteration factor (Eq. 7) as well. We solved the test problem described above with four different grid resolutions. Table 1 shows number of iterations that the Jacobi and SsILI method need to reach maximum relative change of 10^{-3}.

The results show that SsILI method scales better with the grid resolution than the Jacobi method. For example, the increase in resolution by a factor of 8 decreases the rate of convergence of the Jacobi method by a factor of almost 7, while that of the SsILI by less than a factor of 4 in order to reach $R_C = 10^{-3}$. In addition, it is important to keep in mind that, due to slower convergence rate, more strict convergence criterion than $R_C = 10^{-3}$ might be required for the Jacobi method to achieve the “exact” solution.

5. CONCLUSIONS

In this paper we briefly presented Sweep-by-sweep Implicit Lambda Iteration, a new iterative procedure for NLTE line radiative transfer on 2D Cartesian grids. As an intermediate step, we have also generalized Symmetric Gauss-Seidel method into 2D geometry. Sweep-by-sweep ILI significantly outperforms the existing methods, at least in this simple test problem. Our next steps will be the analysis of its convergence properties on inhomogeneous models, modeling of realistic lines using multilevel atom models and application of this method to NLTE modeling of scattering polarization in spectral lines.

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THE APPLICATION OF THE FBILI METHOD TO THE SOLUTION OF RADIATIVE TRANSFER PROBLEMS IN MOVING MEDIA

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Abstract. The application of the fast convergent Forth-and-Back Implicit Lambda Iteration (FBILI) method to the solution of the two-level atom line transfer problems in moving media with low velocity fields is presented. Two astrophysically important problems are solved and discussed: (a) line formation in a plan-parallel moving slab of finite thickness, and (b) line formation in a spherically symmetric expanding stellar atmosphere

1. INTRODUCTION

For the modelling of many astrophysical objects it is necessary to solve the radiative transfer (RT) problem taking into account the motion of the medium. In the media with low velocity regime the radiative transfer is usually solved in the observer's (laboratory) frame of reference. As in the static case, the RT equation 'along the ray' is an ordinary differential equation, but the opacity and emissivity of the material, as seen by the observer at rest, depend on the direction of propagation of radiation due to Doppler effect. Angles and frequencies are coupled together by the Doppler shift. Using the observer's reference frame, most numerical techniques developed for static media can be straightforwardly applied to the RT in moving media with arbitrary (non-monotonic) velocity fields. Only a wider range of frequencies (due to Doppler shifts) and a larger number of angles (due to the coupling between the angle and the frequency) must be used.

For flows with speeds much larger than thermal, radiative transfer is preferably formulated in the Co-Moving Frame (CMF) of reference, although the disadvantage of CMF calculations is the imposition of monotonic velocity fields. In the study of high-speed outflows from stars, supernovae etc., where the velocity gradients greatly enhance the escape of photons, Sobolev (or the large-velocity gradient - LVG) approximation is commonly used (Sobolev 1957).

Here we solve the line formation problem in moving (plane-parallel and spherically symmetric) media by the use of a fast convergent method, Forth-and-Back Implicit Lambda Iteration (FBILI), developed by Atanacković-Vukmanović et al. (1997).

2. LINE TRANSFER IN MOVING MEDIA (IN THE OBSERVER'S FRAME)

We will consider the case of a two-level atom line formation in a spherically symmetric expanding stellar atmosphere (transition to the case of a plane-parallel expanding slab of finite thickness is straightforward). We shall assume that the physical properties vary only with radial distance r. The radiative transfer equation (RTE) in the observer's frame takes the following form:

$$\mu \, \frac{\partial I(r,\nu,\mu)}{\partial r} + \frac{1-\mu^2}{r} \, \frac{\partial I(r,\nu,\mu)}{\partial \mu} = -\,\chi(r,\nu,\mu)\,[I(r,\nu,\mu) - S(r,\nu,\mu)]\,. \qquad (1)$$

$I(r,\nu,\mu)$ is the specific intensity at point r, at frequency ν and in direction μ (cosine of the angle θ between the local outward radial direction and the direction of propagation of radiation at radius r). In moving media, the absorption coefficient $\chi(r,\nu,\mu)$ and the source function $S(r,\nu,\mu)$, as seen by the observer at rest, depend on the direction of propagation of radiation.

Instead of solving the RTE as the partial differential equation (**??**), we can perform a ray-by-ray computation of the specific intensities along the set of directions tangent to the spherical layers (like those shown in Fig. 1) using the ordinary differential RTE in the 'along the ray' form:

$$\pm \frac{dI^{\pm}(x,\mu)}{d\tau(x,\mu)} = I^{\pm}(x,\mu) - S(x,\mu)\ . \qquad (2)$$

Here, τ represents the optical distance along a given direction (ray) measured from the surface, whereas $I^{\pm}$ are the ingoing and outgoing specific intensities along the ray. The monochromatic optical distance along a given direction is given by

$$d\tau(x,\mu) = -\chi(x,\mu)dz \quad , \qquad (3)$$

and can be written as

$$d\tau(x,\mu) = d\tau^L\,[\beta + \phi(x,\mu)]\ \ , \qquad (4)$$

where dz is the corresponding geometrical path length, and χ contains both continuum and line contributions. $\beta = \chi^C/\chi^L$, $d\tau^L = -\chi^L(z)dz$, and Φ is the line absorption profile, which is in the case of pure Doppler broadening given as:

$$\phi(x,\mu) = \frac{1}{\delta\sqrt{\pi}} e^{-(x-\mu V)^2/\delta^2}\ \ , \qquad (5)$$

where $\delta = \Delta\nu_D/\Delta\nu_D^*$ is the ratio of the Doppler widths at a local temperature and at some standard temperature T^*.

In the case of a two-level atom and assuming the complete redistribution, the source function can be writen as

$$S^L = \epsilon B + (1-\epsilon)\bar{J}\ , \qquad (6)$$

where ε is the photon destruction probability, B is the Planck function and

$$\bar{J} = \frac{1}{2}\int_{-\infty}^{\infty} dx \int_{-1}^{1} d\mu I(x,\mu)\phi(x,\mu) \qquad (7)$$

is the scattering integral. The total source function is:

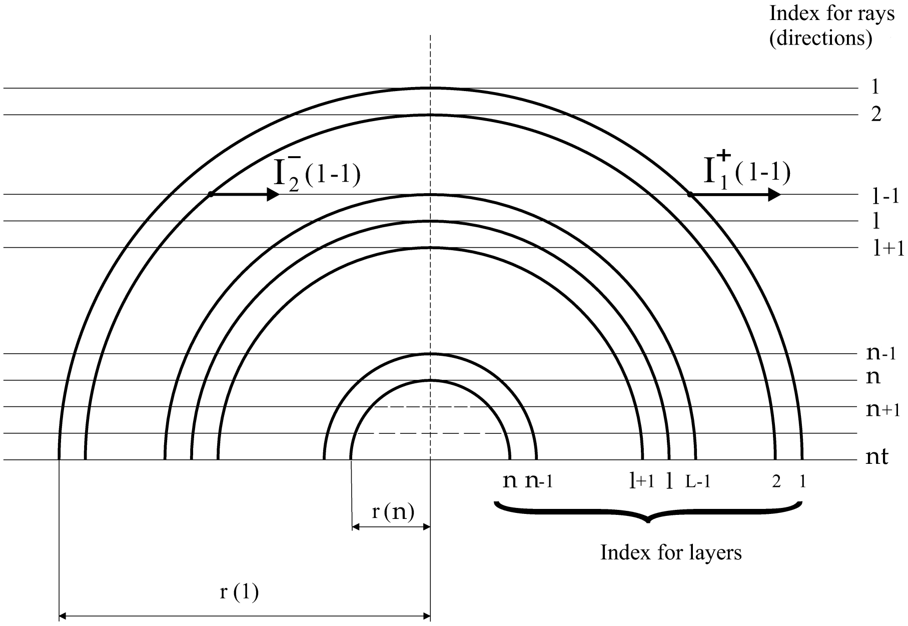
$$S(x,\mu) = \frac{\beta}{\beta + \phi(x,\mu)} S^C + \frac{\phi(x,\mu)}{\beta + \phi(x,\mu)} S^L \tag{8}$$

Once the line formation problem is defined by Eqs. (**??**) and (6)-(8), we can look for its numerical solution.

2. 1. DISCRETIZATION

For the numerical description of the radiation transport through 1D moving spherical atmosphere, a discrete set of radii $\{r_l\}$, $l = 1, n$ is needed (Fig.1). Let the radius r_1 corresponds to the upper boundary surface of the atmosphere. The radius r_n of the lower boundary is to be chosen so that the radiation field at that point is highly isotropic.

The solution of RTE (**??**) is performed along the set of rays $\{z_k\}, k = 1, n$ tangent to the spherical layers corresponding to the discrete set of radii $\{r_l\}$, as well as along a few additional, so-called core rays $\{z_k\}, k = n+1, nt$ that intersect the inner boundary surface (see Fig. 1).



3. FBILI SOLUTION OF THE LINE TRANSFER IN MOVING MEDIA (IN THE OBSERVERS FRAME)

Although the radiation field is unknown, using two-stream approximation we can represent its propagation by means of the integral form of the RT for both the in-going and the out-going specific intensities as follows

$$I_l = I_{l-1} e^{-\Delta} + \int_0^{\Delta} S(t) e^{t-\Delta} dt \ . \tag{9}$$

In order to solve this integral, we will assume parabolic behavior of the source function between two successive depth points. Proceeding in this way we will derive the implicit linear relation between the mean intensity of the radiation field and the local line source function

$$\bar{J} = a + bS^L \ . \tag{10}$$

This relation is implicit as the value of the source function is also unknown. It depends on the unknown radiation field via scattering processes. By substituting Eq. (**??**) into SE equation (**??**), we get the expression for updating the source function

$$S^L = \frac{\varepsilon B + (1-\varepsilon)a}{1-(1-\varepsilon)b} \ . \tag{11}$$

The iterative computation of these coefficients and not of the unknown functions ($\bar{J}$ and S^L) themselves like in the classical Λ iteration, speeds up the convergence dramatically.

3.1.1. Forward step

We start from the lower boundary condition ($I_1^- = 0$) and then solve the integral (9) for ingoing radiation for $l = 2, NL$. Then we perform numerical integration over directions and frequencies, so we get the mean intensity in the form

$$\bar{J}_l{}^- = \tilde{a}_l^- + \tilde{b}_l^- S_l + c_l^- S'_l \tag{12}$$

where we put all the non-local quantities in coefficient $\tilde{a}_l^-$.

In order to improve the convergence, we can 'pack' the coefficients differently:

$$b_l^- = \frac{\tilde{a}_l^-}{S_l^L} + \tilde{b}_l^- \ , \tag{13}$$

so we have

$$\bar{J}_l^- = b_l^- S_l^L + c_l^- S_l'^L \ . \tag{14}$$

Now, because $\frac{\tilde{a}_l^-}{S_l^L}$ is the ratio of two homologous quantities, it quickly gets its exact value speeding up the convergence of the whole iterativeprocedure. The coefficients b_l^- and c_l^- are stored for the use in backwards step.

3.1.2. Backward step

Now, we proceed from the bottom layer where the out-going specific intensities are known. For the rays with $k > n$ we use the diffusion approximation or we simply take that $I^+_{n,i,k>n} = S_{n,i,k}$, whereas for $k = n$ the condition $I^+_{n,i,n} = I^-_{n,i,n}$ is to be used. At all other upper points $l = n-1, 1$, we can compute $I^+_{l,i,k}$ using the integral form of the RTE (eq. (15)) for outgoing intensities. Here we also used parabolic approximation for the source function between two depth points. Again, after numerical integration, we will get

$$\bar{J}_l^+ = a_l^+ + b_l^+ S_l^L \tag{15}$$

Since we have b_l^- and c_l^-, and we know that (with assumption of parabolic behaviour of source function) $S_l'^L = 2\frac{S_{l+1}^L - S_l^L}{\Delta\tau} - S_{l+1}'^L$, we can now get a_l^- and b_l^-. Next, after computing a_l^+ and b_l^+ in the current layer, we can already update the source function and use this new value for computing the out-going intensities. The whole procedure is repeated until the convergence criterion is satisfied.

4. TEST PROBLEMS AND RESULTS

In order to test the FBILI method when applied to RT in moving media, we solved several benchmark problems.

4. 1. LINE FORMATION IN A PLANE-PARALLEL MOVING SLAB

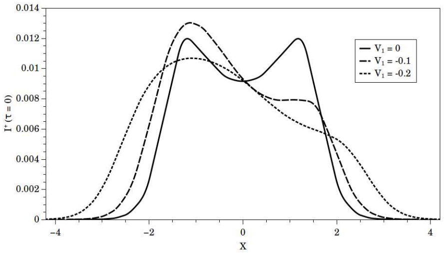
First we solved the problem of RT in plane-parallel expanding slab of finite thickness (Hummer and Rybicki, 1968). The center of the slab is at rest, whereas the part of the slab closer to the observer is moving towards and the part that is farther is moving away from the observer with the velocity normal to the surface. There is no incident radiation on the boundaries of the slab. This simulates the expanding emission nebula.

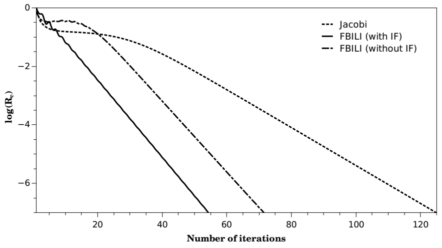
The velocity law is given by

$$V(\tau) = V_0 + \tau V_1,$$

with three values for the velocity gradient: $V_1 = 0$, $V_1 = -0.1$ and $V_1 = -0.2$. The parameters describing the slab are as follows: $\varepsilon = 10^{-3}$, $B = 1$, $T = 20$, $\delta = 1$.

The results we got are in agreement with those in H&R paper. The plot of intensity with frequency is presented on fig 2. The variation of maximum relative change with number of iterations for Jacobi and FBILI method (with and without iteration factor) is presented in Fig. 3.





4. 2. LINE FORMATION IN A SPHERICAL ATMOSPHERE

The use of the FBILI method for the solution of the line transfer in a spherically symmetric atmosphere is tested on the benchmark problem proposed by Avrett & Loeser (1984).

We consider a stellar atmosphere consisting of homogeneous spherical shells. We take that the radius of the first layer $r_1 = 30$ and the last one $r_n = 1$ (in the units of stellar radius). The opaccity is:

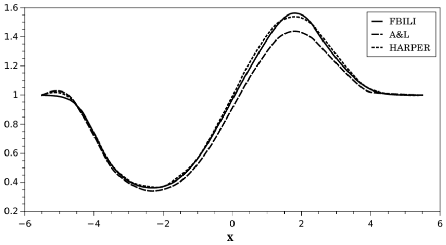
$$\chi(r, x, \mu) = \left[\frac{120}{29} + \frac{30000}{29}\phi(r, x, \mu)\right]\frac{1}{r^2}, \tag{16}$$

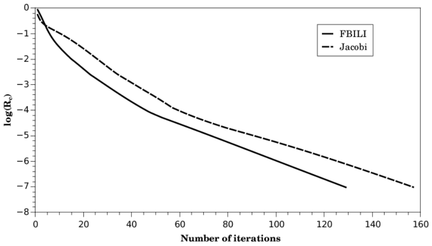
where the line profile ϕ is given by the Gaussian profile function (**??**). The velocity law is given by:

$$V(r) = \frac{6}{\pi}\left[\arctan\left(\frac{2r-31}{29}\right) + \frac{\pi}{4}\right] , \tag{17}$$

so that $V = 0$ at the bottom and $V = 3$ at the surface.

The line profile is presented on fig 4, while comparison of maximum relative change for FBILI and Jacobi method is in Fig 5.





5. CONCLUSIONS

The obtained results are in a good agreement with the results from four independent investigations performed by other authors. Due to the lack of the published results on the convergence properties of the iterative procedures used by other authors to solve these benchmark problems, we compared the convergence rate of the FBILI to Jacobi method, which uses the same formal solver. When applied to a plane-parallel moving slab, FBILI method is about 2.5-3 times faster. On the other hand, for spherically symmetric expanding atmosphere, the FBILI method is 1.4-1.8 times faster than the Jacobi method, which is a bit less than in the static case, where the convergence is 1.7-2 times faster.

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LINE PROFILE VARIABILITY IN B SUPERGIANTS

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Abstract. Many B-type supergiants are reported to show both spectroscopic and photometric variability. In addition, their line profiles show an excess broadening, typically referred to as macroturbulence. While the cause for these variabilities and the macroturbulence are not clear yet, pulsations seem to play an important role. They influence the measured radial velocity, width and shape of photospheric lines. We study a sample of Galactic B-type supergiants based on high-quality spectroscopic data. Applying the moment method to selected atmospheric absorption lines, we find that the line profile variability in our objects is caused by pulsations. In addition, Hα displays strong, often night-to-night variability, suggesting time-variable stellar winds. The photospheric lines show large contributions of macroturbulent broadening, which render it difficult to determine proper values of the projected rotational velocities.

1. INTRODUCTION

The study of massive stars is very important for understanding stellar and galactic evolution. The stars end their lives as supernovae, enriching their environments with large amounts of energy, momentum, and chemically processed material. B supergiants (BSGs) are a class of evolved massive stars with strong line driven winds. Their spectra typically display highly variable emission lines, such as Hα, and their photospheric absorption lines are widened far beyond rotational broadening (Simón-Díaz & Herrero 2007). This excess broadening is referred to as macroturbulence. Recent investigations of Aerts et al. (2009) revealed that macroturbulence might be a strong indicator for pulsation activity.

The location of BSGs in the HR diagram is shared by stars in very different evolutionary stages. On the one hand, we find BSGs that are stars which have just evolved off the main sequence. On the other hand, depending on the initial mass of the star, BSGs can be on a blue loop excursion, or in the post-red supergiant stage (Saio et al. 2013). It is, hence, non trivial to distinguish stars that populate the BSG part of the HR diagram. One way out is provided by the recent study of Saio et al. (2013), in which the authors found that BSGs in various evolutionary stages present very different pulsational behavior. An ideal tool to classify BSGs is, hence, provided by asteroseismic studies. Moreover, such investigations provide further insight into the stellar interiors and help us improving our understanding of massive star evolution.

In this work we examine the spectroscopic variabilities in three Galactic BSGs that were observed over a period of four years. We search for pulsational indications in the photospheric lines by analyzing their line profile variabilities.

2. DATA SAMPLE AND DATA REDUCTION

We monitored three BSGs over the period of four years (2009-2012). Apart from single spectra from different nights, we had a number of time-series, i.e., consecutive spectra taken in one night. The spectra were taken with the Perek 2m telescope at Ondřejov Observatory. Two spectral ranges were observed, in the red around Hα (6250Å - 6750Å, R $\approx$ 13000) and in the blue (4400Å - 4700Å, R $\approx$ 17000). Each night a standard star was observed, which was later used to correct the target spectra from telluric pollution. The spectra were reduced by standard procedures using IRAF[1]. We achieved SNR $>$ 250 per spectrum.

3. DATA ANALYSIS

3. 1. MOMENTS METHOD

To extract the physical properties of the atmospheric lines we use the moments method (Aerts et al. 1992, North & Paltani 1994). We calculate the moments using: $m_i = \int_{x_1}^{x_2} x^i(1 - F_x)dx,\ i = 0, 1, 2, 3.$ The parameter x represents either wavelength or velocity, and F_x is the normalized flux. The line profile moments m_0 to m_3 have their corresponding physical meaning, i.e. they are related to: equivalent width, radial velocity, line width, and line asymmetry, respectively. Based on the results from the moment analysis it is possible to distinguish different types of variability. In the case of pulsations the first and third moments vary in phase (Aerts et al. 1992).

3. 2. FFT METHOD FOR PROJECTED ROTATIONAL VELOCITY

The most commonly used method to determine the rotational velocity projected to the line of sight, $v \sin i$, is the Fourier transformation of atmospheric line profiles (Gray 2005). While the observed profile is a convolution of different broadening mechanisms, only the rotational profile possesses zero points in Fourier space. Hence, from the position of the first zero point in the Fourier transformation of the line profile we directly obtain $v \sin i$. The error for $v \sin i$ obtained from our data is $\sim$ 1 km/s.

4. RESULTS

Our sample consists of three Galactic BSGs. Their stellar parameters, taken from the literature, are given in Table 1. In the following sections, we present the results of the line profile variability (LPV) for each star individually.

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[1] IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation.

Table 1: Stellar parameters of the studied stars. The error in $v \sin i$ is ± 1 km s^{-1} for all measurements. References: 1-(Markova & Puls 2008) 2-(Crowther et al. 2006) 3-(Bieging et al. 1989).

Object	T_{eff} $[K]$	$\log L/L_{\odot}$	$\log g$	R_* $R_{\odot}$	M $M_{\odot}$	$v \sin i$ $[\mathrm{km\,s}^{-1}]$	$v \sin i$(this work) $[\mathrm{km\,s}^{-1}]$
HD 2905	$21500^{2)}$	$5.52^{2)}$	$2.45^{2)}$	$41.4^{2)}$	$30^{3)}$	$91^{2)}$	39-58
HD 91316	$22000^{2)}$	$5.47^{2)}$	$2.4^{2)}$	$37.4^{2)}$		$75^{2)}$	61-82
HD 202850	$11000^{1)}$	$4.59^{1)}$	$1.87^{1)}$	$54^{1)}$	$8^{+41}_{-3}{}^{1)}$	$33 \pm 2^{1)}$	20-40

4. 1. HD 2905

HD 2905 (=κ Cas) is classified as BC0.7 Ia. We have a total of 38 spectra in Hα, distributed over 13 nights. On the left panel of Figure **??** we can see that Hα is almost always in emission, except for a single spectrum, which shows a P Cygni profile. In contrast to the photospheric lines, Hα displays strong variability in both strength and shape, the intensity of the weakest line is only ≈30% of the strongest one.

In one night we collected 13 consecutive spectra (time-series) in the Hα region, covering a total of 2.83 hours. We applied the moments method to the HeI λ 6678 line. The first (radial velocity) and third (line assymetry) moment vary in phase (middle and right panel of Figure **??**), suggesting that the LPV is due to pulsations. The radial velocity varies for about 4 $\mathrm{km\,s}^{-1}$ during this observing period. As we did not observe any extrema, no conclusion about length or amplitude of possible period(s) was derived.

We collected 3 spectra in the blue part, encompassing MgII λ 4481, SiII $\lambda\lambda$ 4567,4574, OII $\lambda\lambda$ 4591,4596 and FeII λ 4552. We applied the Fourier transformation to these lines, as they were not blended. We obtained individual $v \sin i$ values ranging from 39 ± 1 to $58 \pm 1 \mathrm{km\,s}^{-1}$.

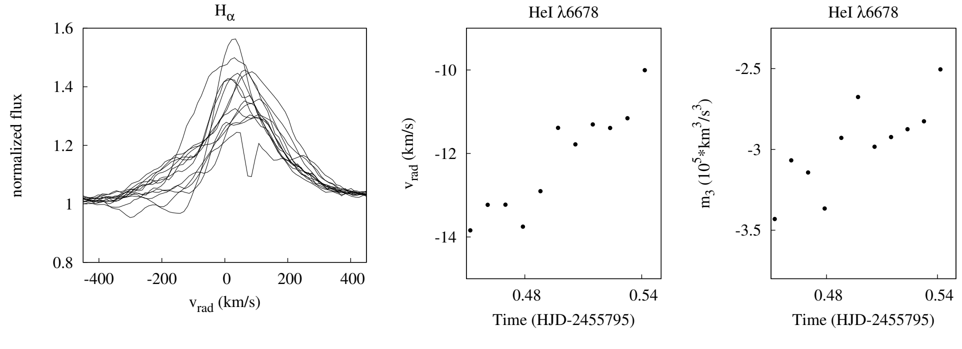

Figure 1: HD 2905: Long-term variability of Hα (left), short-term variability of radial velocity (middle) and line asymmetry (right).

4. 2. HD 91316

HD 91316 (=ρ Leo) is a Galactic B supergiant classified as B1 Iab. We had a total of 37 spectra in the Hα region, distributed over 11 nights. Hα is always in absorption, but displays in some nights a small emission peak superimposed on the absorption profile (see Figure **??**, left panel). This could indicate occasional mass ejections from the photosphere. The strength of Hα is very variable, with the weakest line being 40% weaker than the strongest line.

In one night we collected 16 consecutive spectra (time-series) over 4.75 hours. We performed the moment analysis on the HeI λ6678 line. The radial velocity within that period changes by 10 $\mathrm{km\,s^{-1}}$(Figure 2, middle panel). Although the noise in the third moment is large, the first and third moment seem to vary in phase (middle and right panel of Figure **??**), suggesting that the LPV is due to pulsations. We did not have sufficient data to perform a period analysis.

For this star, there were no spectra in the blue region available, therefore we used the HeI λ 6678 line to determine $v \sin i$. We obtained individual values ranging from 61 ± 1 to 82 ± 1 $\mathrm{km\,s^{-1}}$.

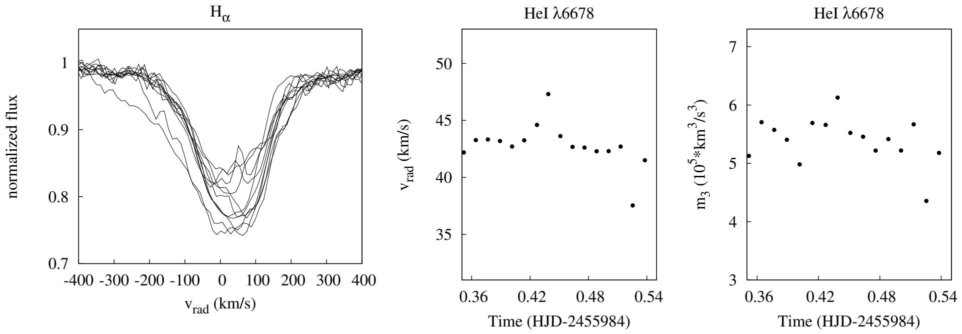

Figure 2: As in Figure 1, but for HD 91316.

4. 3. HD 202850

HD 202850 is a silicon rich supergiant (Markova & Puls 2008) classified as B9 Iab. In the Hα region we obtained 88 individual spectra, distributed over 11 nights. On the left panel of Figure **??** we can see that Hα is always in absorption. Compared to other photospheric lines, its strength is more variable, with the weakest line being 38% weaker than the strongest line.

We took 4 time-series in the Hα range and analyzed two silicon lines SiII $\lambda\lambda$ 6347,6371 and the helium line HeI λ 6678 with the moment method and discovered a 1.59 h pulsation period. Details of the analysis and the results are presented in Kraus et al. (2012) and Tomić et al. (2013).

From the data of one of these time-series, we determined $v \sin i$ using the SiII λ 6347 line. The values of $v \sin i$ found in a single night scatter over the interval of 25 ± 1 to 40 ± 1 $\mathrm{km\,s^{-1}}$ (see Figure **??**, right panel). There seems to be no clear pattern in this variability. We also obtained three spectra in the blue range. We analyzed three iron lines FeII $\lambda\lambda$ 4489,4515,4549 and a chromium line CrII λ 4558. These lines show individual $v \sin i$ values ranging from 20 ± 1 to 26 ± 1 $\mathrm{km\,s^{-1}}$.

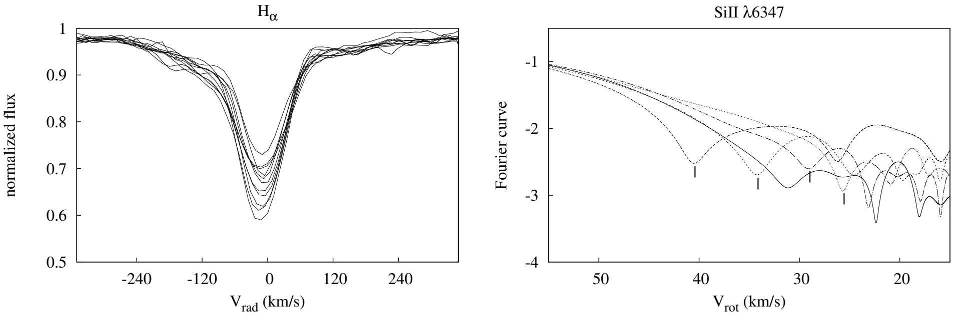

Figure 3: HD 202850: variability of Hα in different nights (left). Fourier transforms of SiII λ6347 from different spectra taken in the same night (right), each tick mark corresponds to $v \sin i$ value

5. CONCLUSIONS

We studied LPV in Hα, HeI λ 6678 and several metal lines in high quality spectra of three Galactic BSGs. We find that in all three stars Hα varies substantially in strength and shape. The variation in intensity reaches up to $\approx 60\%$. Hα is commonly used to determine mass-loss rates of BSGs. The variability found in our observations suggests that the winds of BSGs are variable, and hence reliable mass-loss rates cannot be obtained from a single snapshot spectrum.

From the moment analysis, we found that in all three stars the first and third moment vary in phase. This implies that variabilities are caused by pulsations. In one object, HD 202850, we were able to isolate a 1.59 h pulsation period. The short period we found is uncharacteristic for BSGs, and its nature remains unknown. For the other two objects, more observations are clearly needed.

The projected rotation velocities, $v \sin i$, were computed using the Fourier transformation. Surprisingly, we found a large discrepancy in values from different nights, and even within a single night. In addition, the atmospheric lines in all three stars are much broader than expected from pure rotational broadening. This indicates that the lines are additionally widened by macroturbulence and that the Fourier transformation, in this case, cannot provide a single value.

Acknowledgments

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ACTIVITIES OF THE GROUP FOR ASTROPHYSICAL SPECTROSCOPY 2011-2014

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Abstract. Results of activities of the fellows of the Group for Astrophysical Spectroscopy in the period 2011-2014 are reported.

1. GROUP FOR ASTROPHYSICAL SPECTROSCOPY 2011-2014

Group for Astrophysical Spectroscopy (GAS) is informal group created in 2002 at Astronomical Observatory in Belgrade but now, members coming to the regular meetings of GAS and taking part in all common activities, are also participants from other institutions from four projects financed by Ministry of Education, Science and Technological Development: 176001 "Astrophysical Spectroscopy of extragalactic objects", 176002 "Influence of collisions with charged particles on astrophysical plasma spectra", 176003 "Gravitation and Structure of Universe on Large Scales" and III 44002 "Astroinformatics: Application of IT in Astronomy and Related Fields of Research". Within the considered period we also participated in FP7 project "Virtual Atomic and Molecular Data Center" - VAMDC the first FP7 project in Serbian Astronomy. GAS members are also involved in the project "Large Synoptical Survey Telescope" a future 8.4 m ground based telescope where the Memorandum of Understanding is prepared. The main observational activities were: - Performed spectroscopical observation (in optical band) with the 6 m telescope Special Astrophysical Observatory (Nizhniy Arkhiz, Russia) Within the 1. 01. 2011 - 1. 07. 2014 period fellows of the Group published 75 papers in the international journals on the Science Citation Index list.

Among invited lectures given by the fellows of GAS, particularly important are:

1. Milan S. Dimitrijević, "New Chalenges of Astroinformatics - STARK-B Database, Serbian Virtual Observatory - SerVO and Relations to Virtual Atomic and Molecular Data Center - VAMDC" (Key Note Speaker), 12^{th} International Conference on Computer Systems and Technologies - CompSysTech11,16-17 June 2011, Wien, Austria.

2. Dragana Ilić, "Broad Emission Lines: A Tool For Studying Nuclei Of Active Galaxies" (Plenary Lecture), 21^{st}International Conference on Spectral Line Shapes, June 39, 2012, St. Petersburg, Russia.

3. Luka Popović: "AGN pairs and supermassive binary BHs: constraints from emission lines", European Weak of Astronomy and Space Science EWASS Turku, Special session 6: AGN, galaxy mergers, supermassive black holes and gravitational waves (Invited review Lecture), 8-12 July 2013, Turku, Finland.

4. Dragana Ilić: "Super-massive Black Holes And Spectral Emission Lines" (Plenary Lecture), 22^{nd} International Conference on Spectral Line Shapes, 16 June 2014 Tullahoma, United States.

We also have international collaboration with France, Greece, Italy, Russia, Germany, Austria, Tunisia, Spain, USA, Mexico, United Kingdom, Saudi Arabia, Belgium and Bulgaria and within the considered period we had around one hundred visits of foreign scientists and students.

Within the period 2011-2014, within the frame of GAS activity (the activity of the four mentioned projects) 4 PhD theses were defended. Additionaly, three Master Theses were defended on 27 july 2012 within the Astromundus European project, with Luka Č. Popović as mentor or co-mentor: 1. Payaswini Saikia: "The UV and Optical Spectral Properties of a Sample of Broad Line AGNs (which obtained from Astromundus the prize as the best Master Thesis); 2. Luca Grassitelli: "Physical Parameters of the Relativistic Shock Waves in a sample of Gamma Ray Bursts; 3. Nemanja Rakić: "Variability of AGN Spectral Properties - Intrinsic Baldwin Effect.

The lists of PhD Theses, monographs, papers published in the journals from Science Citation Index list and conferences organized by GAS is given below.

2. DEFENDED PhD THESES

1. M. Stalevski: 2012, "M.Investigating the Structure of Active Galactic Nuclei: The Dusty TorusFaculty of Mathematics", PhD Thesis, University of Ghent and University of Belgrade.

2. Sonja Vidojević: 2012, "Statistics of Langmuir Waves Associated with Type III Solar Radio Bursts", PhD Thesis, Paris.

3. Jelena Kovačević: 2012, "The Relationships Between Spectral Properties of Active Galactic Nuclei Type 1", PhD Thesis, Faculty of Mathematics, University of Belgrade.

4. Aleksandra Nina: 2014, "Diagnostic of Plasma of the Ionospheric D Region with Electromagnetic VLF Waves", PhD Thesis, Faculty of Physics, University of Belgrade.

3. MONOGRAPHS

1. Sonja Vidojević: "From an electron beam to the type III solar radio bursts", DISERTACIO, Zadužbina Andrejević, Belgrade, 2014.

4. PUBLICATIONS IN INTERNATIONAL JOURNALS FROM SCI LIST 1. 01. 2011-1. 07. 2014

1. L. Č. Popović, A. I. Shapovalova, D. Ilić, A. Kovačević,W. Kollatschny, A. N. Burenkov, V. H. Chavushyan, N. G. Bochkarev, J. Leon-Tavares: "Spectral optical monitoring of 3C 390.3 in 1995-2007: II. Variability of the spectral line parameters", Astron. Astrophys. 528 (2011) 13.

2. L. Č. Popović, J. Kovačević: "Optical Emission-line Properties of a Sample of the Broad-line Active Galactic Nuclei: The Baldwin Effect and Eigenvector 1", Astrophys. J. 738 (2011) 68.

3. I. Donnarumma, A. De Rosa, V. Vittorini, H. R. Miller, L. Č. Popović, S. Simić, M. Tavani, J. Eggen, J. Maune, E. Kuulkers, E. Striani, S. Vercellone, G. Pucella, F. Verrecchia, C. Pittori, P. Giommi, L. Pacciani, G. Barbiellini, A. Bulgarelli, P. Cattaneo, A. W. Chen, E. Costa, E. Del Monte, Y. Evangelista, M. Feroci, F. Fuschino, F. Gianotti, A. Giuliani, M. Giusti, F. Lazzarotto, F. Longo, F. Lucarelli, A. Pellizzoni, G. Piano, P. Soffitta, M. Trifoglio, A. Trois: "The remarkable Gamma-ray activity in the gravitationally lensed blazar PKS 1830-211", Astrophys. J. Lett. 736L (2011) 30.

4. M. Stalevski, J. Fritz, M. Baes, T. Nakos, L. Č. Popović: "AGN Dusty Tori as a Clumpy Two-Phase Medium: the 10 μ m Silicate Feature", Baltic Astron. 20 (2011) 490.

5. S. Simić, L. Č. Popović, P. Jovanović: "Influence of Microlensing on Spectral Anomalies of the Lensed Objects", Baltic Astron. 20 (2011) 481.

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7. G. La Mura, S. Ciroi, V. Cracco, D. Ilić, L. Č. Popović, P. Rafanelli: "Optical Emission Lines and the X-ray Properties of Type 1 Seyfert Galaxies", Baltic Astron. 20 (2011) 442.

8. V. Borka Jovanović, I. Radović, D. Borka, Z. L. Mišković: "High-energy plasmon spectroscopy of freestanding multilayer graphene", Physical Review B 84 (2011) 155416.

9. I. Radović, D. Borka, Z. L. Mišković: "Wake effect in doped graphene due to moving external charge", Physics Letters A 375 (2011) 3720.

10. D. Borka, I. Radović, Z. L. Mišković: "Dynamic polarization of graphene by moving external charges: Comparison with 2D electron gas, Nuclear Instruments and Methods in Physics Research B 269 (2011) 1225.

11. V. Borka Jovanović, D. Urošević: "Temperature, brightness and spectral index of the Cygnus radio loop", Revista Mexicana de Astronomia y Astrofisica 47 (2011) 159.

12. P. Jovanović, V. Borka Jovanović, D. Borka: "Influence of Black Hole Spin on the Shape of the Fe Kα Spectral Line: the Case of 3C 405", Baltic Astron. 20 (2011) 468.

13. A. A. Mihajlov, N. M. Sakan, V. A. Srećković, Y. Vitel: "Modeling of continuous absorption of electromagnetic radiation in dense partially ionized plasmas", J. Phys. A 44 (2011) 095502.

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18. M. Maksimović, S. Vidojević, A. Zaslavsky: ”Statistical Analysis of Langmuir Waves Associated with Type III Radio Bursts: II. Simulation and Interpretation of the Wave Energy Distributions”, Baltic Astron. 20 (2011) 600.

19. S. Vidojević, A. Zaslavsky, M. Maksimović, M. Dražić, O. Atanacković: ”Statistical Analysis of Langmuir Waves Associated with Type III Radio Bursts: I. Wind Observations”, Baltic Astron. 20 (2011) 596.

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23. E. Theodossiou, V. Manimanis, M. S. Dimitrijević: ”The Contribution of Bizantine Priests in Astronomy and Cosmology. II. Great Church Scholars in the Early Byzantine Empire”, Euopean Journal for Science and Theology 7 (4) (2011) 25.

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25. S. Sahal-Bréchot, M. S. Dimitrijević, N. Ben Nessib: ”Comparisons and Comments on Electron and Ion Impact Profiles of Spectral Lines”, Baltic Astron. 20 (2011) 523.

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5. CONFERENCES ORGANIZED BY THE GROUP FOR ASTROPHYSICAL SPECTROSCOPY 2011-2014

1. I Workshop on Astrophysical Spectroscopy, Orašac, 26-30 August 2011. SOC Co-chairs M. S. Dimitrijević, L. Č. Popović, LOC Co-chairs M. S. Dimitrijević, A. Kovačević.

2. VIII Serbian Conference on Spectral Line Shapes in Astrophysics, Divčibare, 6-10 June 2011. SOC Co-chairs L. Č. Popović, D. Jevremović, LOC Co-chairs D. Ilić, D. Jevremović.

3. II Workshop on Active Galactic Nuclei and gravitational lensing, Andrevlje (Fruška Gora) 24-28 April 2012. SOC Co-chairs L. Č. Popović, W. Kollatschny, LOC Chair M. Stalevski.

4. Regional Workshop on Atomic and Molecular Data, with introductory tutorial for Virtual Atomic and Molecular Data Center (VAMDC), Belgrade, 14-16 June 2012. SOC Chair M. S. Dimitrijević, LOC Chair A. Kovačević.

5. "Development of astronomy among Serbs VII", Belgrade, 18-22 April 2012. SOC Chair M. S. Dimitrijević, LOC Chair M. Dačić.

6. VIII Serbian - Bulgarian Astronomical Conference, Leskovac, 8-12 May 2012. SOC Co-chairs M. S. Dimitrijević, M. K. Tsvetkov, LOC Co-chairs M. S. Dimitrijević, Ž. Mijajlović.

7. IX Serbian Conference on Spectral Line Shapes in Astrophysics, Banja Koviljača, 13-17 May 2013. SOC Co-chairs L. Č. Popović, M. S. Dimitrijević, LOC Co-chairs Z. Simić, M. Stalevski.

8. II Workshop on Astrophysical Spectroscopy, Vrujci, 9-13. October 2013. SOC Co-chairs M. S. Dimitrijević, Z. Simić, LOC Chair Z. Simić.

9. "Development of astronomy among Serbs VIII", Belgrade, 22-26 April 2014. SOC Chair M. S. Dimitrijević, LOC Co-chairs M. Dačić, M. Jeličić.

10. 9th Bulgarian-Serbian Astronomical Conference "Astroinformatics", July 2-4, 2014, Sofia, Bulgaria. SOC Co-chairs O. Kounchev, D. Jevremović

11. III Workshop on Active Galactic Nuclei and gravitational lensing, Končarevo (Jagodina), 7-11 October 2014. SOC Co-chairs S. Simić, L. Č. Popović, LOC Chair S. Simić

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SUNSPOTS OPACITY: THE ION-ATOM ABSORPTION PROCESSES

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Abstract. As a continuation of the previous investigations of the symmetric and strongly non-symmetric ion-atom absorption processes within the models of the quiet Sun photosphere, we studied these processes within a model of the sunspots in the far-UV region. We considered the processes of the photodissociation of the H_2^+ and HM^+ molecular ions and absorption processes in the H(1s)+H^+ and H(1s) + M^+ collisions, where M is one of the metal atoms: M = Na, Ca, Mg, Si and Al. The significance of these processes in far UV and EUV regions in comparison with the concurrent absorption processes, especially with the processes of the photo-ionization of the metal atoms (Na, Mg, Ca, Al, Fe, etc.) was analyzed. Calculated results show that the influence of the analyzed ion-atom absorption processes on the opacity of sunspots in the considered spectral region, 100 nm $\leq \lambda \leq$ 250 nm, is not less and in some parts even larger than the influence of the referent electron-atom processes. It is shown that the considered ion-atom absorption processes should be included ab initio in the corresponding models of sunspots of solar-type and near-solar-type stars.

1. INTRODUCTION

In the previous investigations the significant influence of the relevant ion-atom absorption processes on the solar photosphere opacity was already demonstrated. So, in our previous papers have been studied such **symmetric ion-atom processes**, as the molecular ion H_2^+ photo-dissociation

$$\varepsilon_\lambda + \mathrm{H}_2^+ \longrightarrow \mathrm{H} + \mathrm{H}^+, \tag{1}$$

and the absorption charge exchange in (H^+ + H)-collisions

$$\varepsilon_\lambda + \mathrm{H}^+ + \mathrm{H} \longrightarrow \mathrm{H} + \mathrm{H}^+, \tag{2}$$

where H=H(1s), H_2^+ is the hydrogen molecular ion in the ground electronic state, and ε_λ - the energy of a photon with the wavelength λ.

The total contribution of the processes (1) and (2) to the solar photosphere opacity is characterized by the total spectral absorption coefficient which is defined by relation

$$\kappa_{sim}^{(tot)}(\lambda; h) = \kappa_{sim}^{(bf)}(\lambda; h) + \kappa_{sim}^{(ff)}(\lambda; h), \tag{3}$$

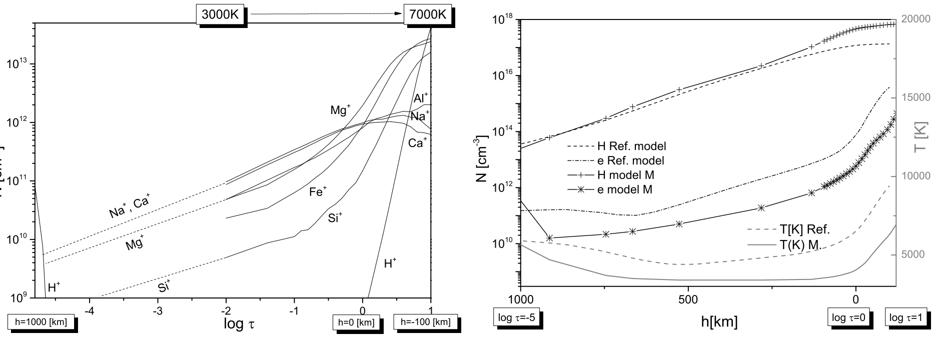

Figure 1: *Left:* The densities of hydrogen and metal ions N_{H^+} and N_{M^+} *Right:* The densities $N(e)$, $N(H)$ and T for the sunspot model M and referent model of the quiet Sun atmosphere (Maltby et al. 1986).

and described in details in Mihajlov et al. (2012, 2013). Then, in Mihajlov et al. (2013) was undertaken the investigation **non-symmetric ion-atom absorption processes**, namely the photo-dissociation and photo-association of the molecular ions

$$\varepsilon_\lambda + \mathrm{H}M^+ \longrightarrow \mathrm{H}^+ + M, \tag{4}$$

$$\varepsilon_\lambda + \mathrm{H} + M^+ \longrightarrow (M\mathrm{H}^+)^*, \tag{5}$$

and the absorption charge-exchange in the ion-atom collisions

$$\varepsilon_\lambda + \mathrm{H} + M^+ \longrightarrow \mathrm{H}^+ + M, \tag{6}$$

where M is the ground state atom of one of metals, relevant for the used solar photosphere model, whose ionization potential I_M is smaller than the hydrogen atom ionization potential I_H, M^+ - the corresponding atomic ion, HM^+ - the molecular ion in the electronic states which are adiabatically correlated (∞ internuclear distance) with the states of the ion-atom systems H + M^+ and H$^+$ + M respectively.

The basic task of this investigation is to estimate the significance of the symmetric and non-symmetric ion-atom absorption processes in the case of the sunspot with respect to the processes of the negative hydrogen ion H$^-$ photo-detachment and inverse "bremsstrahlung" in (e + H)-collisions, namely

$$\varepsilon_\lambda + \mathrm{H}^- \longrightarrow \mathrm{H} + e', \tag{7}$$

$$\varepsilon_\lambda + e + \mathrm{H} \longrightarrow \mathrm{H} + e', \tag{8}$$

where e and e' denote the free electron in initial and final channel, which are treated here as the referent processes.

It is clear that in the case of this atmosphere just the electron-atom processes (7) and (8) can be taken as the referent ones. Because of that in these previous papers many other radiative processes have not been considered, including the certainly important processes of the metal atom photo-ionization, which were already discussed in the literature in connection with the quiet Sun atmosphere. We mean the processes

$$\varepsilon_\lambda + (M)^*_g \longrightarrow M^+ + e', \tag{9}$$

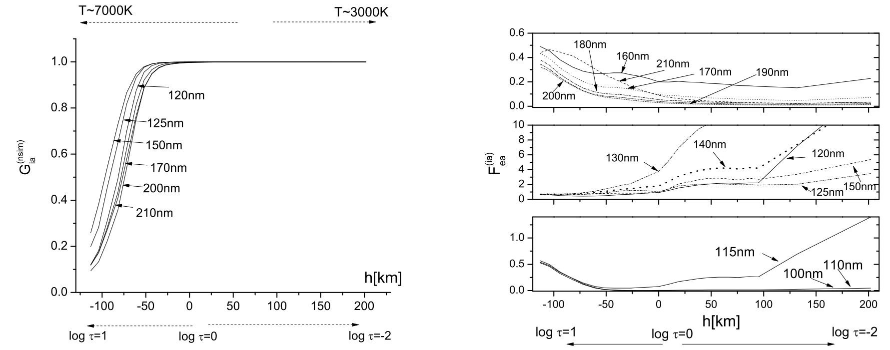

Figure 2: *Left*: The behavior of the quantity $G_{ia}^{(nsim)}(\lambda;h)$, given in Sec. 2. *Right:* The behavior of the quantity $F_{ea}^{(ia)}(\lambda;h)$, given in Sec. 2.

where $(M)_g^*$ denotes the given metal atom in the ground state, i.e. M, or in any possible excited state, i.e. M^*. However, within the sunspot we have a significantly smaller temperature than in the quiet Sun photosphere (see Fig. 1) and consequently it is possible to expect there more larger efficiency of these photo-ionization processes, so that the position of the mentioned electron-atom processes as the referent ones is not so clear. Because of that the processes of the metal atom photo-ionization were taken into account from the beginning of this investigation (some of them were considered already in Sreckovic et al. (2014)). It follows that the efficiency of bf-, ff- and fb-absorption channels (4)-(6) together for one of the considered metal species M is characterized by the partial absorption coefficient $\kappa_{\mathrm{H}M^+}(\lambda;h)$ defined by the

$$\kappa_{\mathrm{H}M^+}(\lambda;h) = \kappa_{\mathrm{H}M^+}^{(bf)}(\lambda;h) + \kappa_{\mathrm{H}M^+}^{(ff)}(\lambda;h) + \kappa_{\mathrm{H}M^+}^{(fb)}(\lambda;h), \tag{10}$$

and described in details in Ignatovic et al. (2014)a,b and Sreckovic et al. (2014). Consequently, the total contribution of the mentioned non-symmetric ion-atom processes to the absorption of the solar radiation on the height h is described by the total spectral absorption coefficient which is given by

$$\kappa_{nsim}^{(tot)}(\lambda;h) = \sum \kappa_{\mathrm{H}M^+}(\lambda;h), \tag{11}$$

where the summing is performed over all considered metal species M.

2. RESULTS AND DISCUSSION

Firstly, we performed the calculations and analysis of the spectral absorption coefficients $\kappa_{sim}^{(tot)}(\lambda)$, $\kappa_{nsim}^{(tot)}(\lambda)$ and $\kappa_{tot}(\lambda) = \kappa_{nsim}^{(tot)}(\lambda) + \kappa_{sim}^{(tot)}(\lambda)$ which characterize the total efficiencies of all, symmetric and non-symmetric ion-atom absorption processes. For that purpose we calculate the quantity $G_{tot}^{(nsim)}(\lambda) = \frac{\kappa_{nsim}^{(tot)}(\lambda)}{\kappa_{tot}(\lambda)}$, which describes the relative contribution to the sunspot photosphere opacity of the non-symmetric processes (4) - (6) with respect to the contribution of all ion-atom absorption processes. The behavior of this quantity (for several values of λ) is illustrated in Fig. 2 in the interval of heights: -125 km $\leq h \leq$ 200 km. Then we calculate the quantity

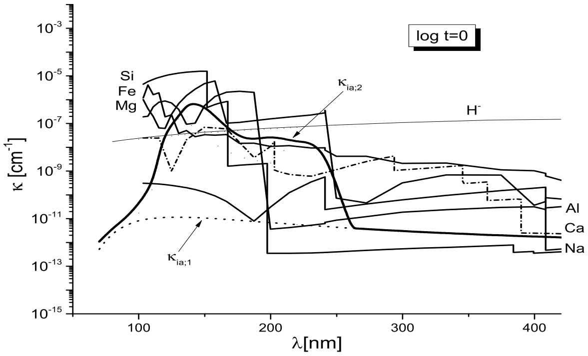

Figure 3: All considered absorbtion processes for log $\tau = 0$ in the case of the sunspot (model M): Mg, Si, etc. - the abbreviations for the spectral coefficients $\kappa_{phi;M}$ of the metal atoms photo-ionization processes; κ_{ea} - H$^-$-continuum; $\kappa_{ia;1}$ - symmetric ion-atom processes; $\kappa_{ia;2}$ - ion-atom symmetric and non-symmetric processes.

$F_{ea}^{(tot)}(\lambda) = \frac{\kappa_{tot}(\lambda)}{\kappa_{ea}(\lambda)}$, where $\kappa_{sim}^{(tot)}(\lambda)$ and $\kappa_{nsim}^{(tot)}(\lambda)$ are defined by Eqs. (3), (11) and $\kappa_{ea}(\lambda)$ - defined in Sreckovic et al. (2014). This quantity describes the relative contribution to the sunspot photosphere opacity of the all ion-atom absorption processes with respect to the contribution of H- continuum (presented in Fig 2). Finally, we compare within the same part of the sunspot (Fig.1) the total efficiencies of the ion-atom and referent electron-atom absorption processes together (H- continuum) and spectral coefficients $\kappa_{phi;M}$ of the metal atoms photo-ionization processes in the considered part of the far-UV region of λ with all ion-atom absorption processes. (Fig. 3). From the presented material, it follows that the considered ion-atom absorption processes should be included ab initio in the corresponding models of sunspots or solar-type stars.

Acknowledgement

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HF CHARACTERISTICS OF THE ASTROPHYSICAL PLASMAS

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Abstract. The values of electrical conductivity of plasma of stars with a magnetic field or moving in the magnetic field of the other component in a binary system could be of significant interest, since they are useful for the study of thermal evolution of such objects, cooling, nuclear burning of accreted matter, and the investigation of their magnetic fields. So, on the basis of numerically calculated values for the dense plasma conductivity in an external HF electric field, we determine the HF characteristics of astrophysical plasmas under extreme conditions. The examined range of frequencies covers the IR, visible and near UV regions and consider electronic number density and temperature are in the ranges of $10^{21}\text{cm}^{-3} \leq Ne$ and $20\ 000 \leq T$, respectively. The method developed here represents a powerful tool for research into white dwarfs with different atmospheric compositions (DA, DC etc.), and for investigation of some other stars (M-type red dwarfs, Sun etc.).

1. INTRODUCTION

In this paper a highly ionized plasma in a homogenous and monochromatic external electric field $\vec{E}(t) = \vec{E_0}\exp\{-i\omega t\}$ is considered . According to Sreckovic et al. (2010)a and Sakan et al. (2007), the dynamic electric conductivity of a strongly coupled plasma $\sigma(\omega) = \sigma_{Re}(\omega) + i\sigma_{Im}(\omega)$ is represented by the expressions

$$\sigma(\omega) = \frac{4e^2}{3m}\int_0^\infty \tau(E)\left[-\frac{dw(E)}{dE}\right]\rho(E)EdE, \tag{1}$$

$$\sigma_{Re}(\omega) = \frac{4e^2}{3m}\int_0^\infty \frac{\tau(E)}{1+(\omega\tau(E))^2}\left[-\frac{dw(E)}{dE}\right]\rho(E)EdE \tag{2}$$

$$\sigma_{Im}(\omega) = \frac{4e^2}{3m}\int_0^\infty \frac{\omega\tau^2(E)}{1+(\omega\tau(E))^2}\left[-\frac{dw(E)}{dE}\right]\rho(E)EdE \tag{3}$$

where $\rho(E)$ is the density of electron states in the energy space and $w(E)$ is the Fermi-Dirac distribution function, $\tau(E)$ is the relaxation time

$$\tau(E) = \frac{\tau(E)}{1 - i\omega\tau(E)}, \tag{4}$$

$\tau(E)$ being the 'static' relaxation time. The method of determination of $\tau(E)$ is described in the previous papers (Adamyan et al. (2006), Tkachenko et al. (2006) and Sreckovic et al. (2010)a,b) in detail.

Other HF plasma characteristics can be expressed in terms of the quantities $\sigma_{Re}(\omega)$ and $\sigma_{Im}(\omega)$.

Thus the plasma dielectric permeability is

$$\varepsilon(\omega) = 1 + i\frac{4\pi}{\omega}\sigma(\omega) = \varepsilon_{Re}(\omega) + i\varepsilon_{Im}(\omega), \tag{5}$$

where $\varepsilon_{Re}(\omega)$ and $\varepsilon_{Im}(\omega)$ are given as

$$\varepsilon_{Re}(\omega) = 1 - \frac{4\pi}{\omega}\sigma_{Im}(\omega), \quad \varepsilon_{Im}(\omega) = \frac{4\pi}{\omega}\sigma_{Re}(\omega). \tag{6}$$

The coefficients of refraction, $n(\omega)$, and reflection, $R(\omega)$, are determined as

$$n(\omega) = \sqrt{\varepsilon(\omega)} = n_{Re}(\omega) + in_{Im}(\omega), \tag{7}$$

$$R(\omega) = \left|\frac{n(\omega) - 1}{n(\omega) + 1}\right|^2 \tag{8}$$

where, bearing in mind that

$$|\varepsilon(\omega)| = \sqrt{\varepsilon_{Re}^2(\omega) + \varepsilon_{Im}^2(\omega)}, \tag{9}$$

the real and imaginary pert of refractivity, $n_{Re}(\omega)$ and $n_{Im}(\omega)$, are given by

$$n_{Re}(\omega) = \sqrt{\frac{1}{2}(|\varepsilon(\omega)| + \varepsilon_{Re}(\omega))}, \quad n_{Im}(\omega) = \sqrt{\frac{1}{2}(|\varepsilon(\omega)| - \varepsilon_{Re}(\omega))}. \tag{10}$$

From here the equation for the plasma reflectivity could be expressed as

$$R(\omega) = \left\{\frac{1 + |\varepsilon(\omega)| - \sqrt{2}\sqrt{|\varepsilon(\omega)| + \varepsilon_{Re}(\omega)}}{1 + |\varepsilon(\omega)| + \sqrt{2}\sqrt{|\varepsilon(\omega)| + \varepsilon_{Re}(\omega)}}\right\}^{1/2} \tag{11}$$

The other parameter of interest is the penetration depth of electromagnetic radiation into plasma, $\Delta(\omega)$. This quantity is just the skin-layer width determined as the inverse imaginary part of the electromagnetic field wave number

$$\Delta(\omega) = \frac{c}{\omega}\frac{1}{n_{Im}(\omega)}. \tag{12}$$

where c is the speed of light.

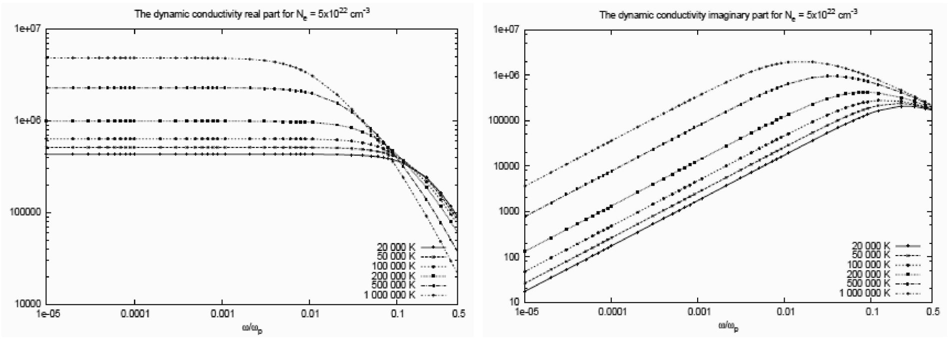

Figure 1: The dynamic conductivity real $\sigma_{Re}(\omega)$ and imaginary part $\sigma_{Im}(\omega)$ for $Ne = 5 \cdot 10^{22}$ cm^{-3} and $20,000\text{K} < T < 100,000\text{K}$.

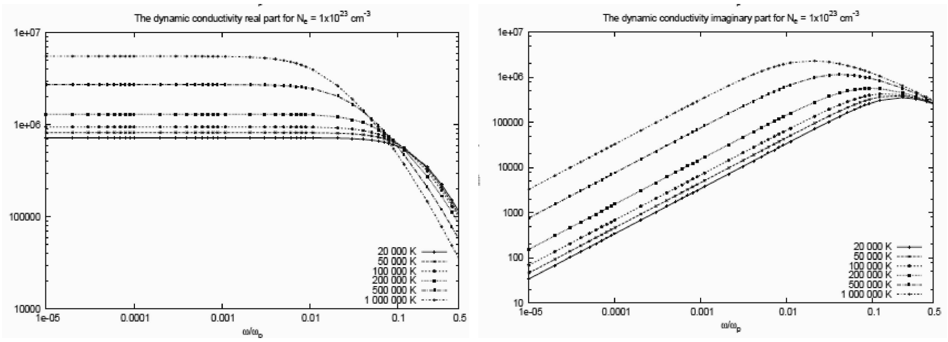

Figure 2: The dynamic conductivity real $\sigma_{Re}(\omega)$ and imaginary part $\sigma_{Im}(\omega)$ for $Ne = 1 \cdot 10^{23}$ cm^{-3} and $20,000\text{K} < T < 100,000\text{K}$.

2. RESULTS AND DISCUSSION

We here continue our previous investigations of plasma static electrical conductivity which are of interest for DB white dwarf atmospheres (see Sreckovic et al. (2010)b,c and Sreckovic et al. (2012)). So, in accordance with the aim of this work, we calculated HF plasma characteristics for vide plasma conditions in order to apply our results to the atmospheres of different stellar types.

Figures **??**-**??** illustrate the behavior of the HF conductivity for various plasma conditions which gives possibility to calculate other transport properties. Figures **??**-**??**, demonstrate the regular behavior of $\sigma_{Re}(\omega)$, i.e. the convergence to the corresponding values of $\sigma_0(n_e, T)$ when $\omega \to 0$, and the existence of the interval of variation of ω where $\sigma_{Re}(\omega)$ is practically constant. We observe the tendency of this interval to decrease when temperature T increases. Similarly, Figures **??**-**??**, demonstrate a regular behavior of $\sigma_{Im}(\omega)$, i.e. the convergence to zero when $\omega \to 0$, and the presence of a maximum in the interval $0 < \omega < 0.5\omega_p$.

The method developed in this paper represents a powerful tool for research white dwarfs with different atmospheric compositions (DA, DC etc.), and some other stars (M-type red dwarfs, Sun etc.). Finally, the presented method provides a basis for

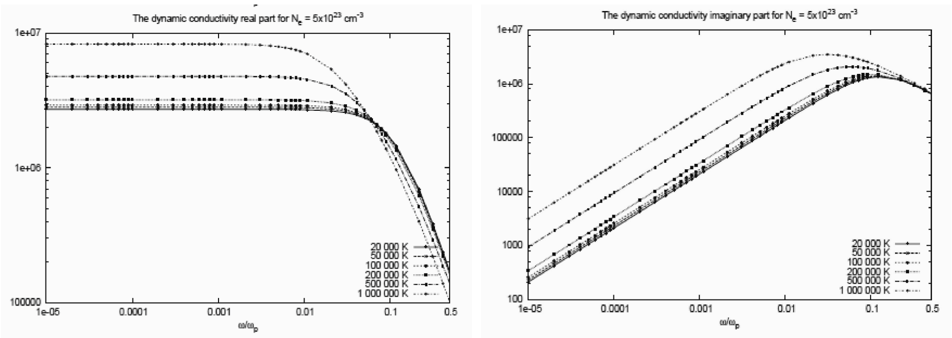

Figure 3: The dynamic conductivity real $\sigma_{Re}(\omega)$ and imaginary part $\sigma_{Im}(\omega)$ for $Ne = 5 \cdot 10^{23}$ cm^{-3} and 20000K $< T <$ 100000K.

the development of methods to describe other transport characteristics which are important for the study of all mentioned astrophysical objects, such as the electronic thermo-conductivity in the stellar atmosphere layers with large electron density, and electrical conductivity in the presence of strong magnetic fields.

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SUPERNOVA REMNANTS IN THE MAGELLANIC CLOUDS

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Abstract. We present initial results of an ongoing study of the supernova remnants (SNRs) and candidates in the Magellanic Clouds. Some 108 objects in both Clouds are considered to be either an SNR or a reliable candidate. This represents the most complete sample of known SNRs in any galaxy. therefore, this study allows us to study SNR population properties such as the size and spectral index distribution. Here, we also show 12 known Large Magellanic Cloud SNRs from type Ia SN explosions and briefly comment on their importance.

1. INTRODUCTION

The Magellanic Clouds (MCs), with their low foreground absorption and relative close proximity of 50 kpc and 60 kpc (di Benedetto, 2008), offers the ideal laboratory for the study of a complete sample of supernova remnants (SNRs) in great detail. The proximity enables detailed spatial studies of the remnants in the sample, and the accurately known distance allows for analysis of the energetics of each remnant. In addition, the wealth of wide-field multi-wavelength data available, from radio maps to optical emission-line images and broad band photometry to global X-ray mosaics, provides information about the contexts and environments in which these remnants are born and evolve.

A complete sample of SNRs provides the ability to study the global properties of SNRs, in addition to carrying out detailed analysis on the subclassed (e.g., sorted by X-ray and radio morphology or by progenitor SN type). Toward this goal, we have been identifying new SNRs using combined optical, radio, and X-ray observations.

A distinguishing characteristic of SNRs in radio frequencies is their well-established predominantly non-thermal continuum emission. Collectively, SNRs have a radio spectral index of $\alpha \sim -0.5$ (defined by $S \propto \nu^{\alpha}$), although may vary quite a lot due to the wide variety of SNRs, differing environments, and stages of evolution (Filipović et al. 1998). On one side, younger and very old remnants can have a spectral index of $\alpha \sim -0.8$, while mid-to-late-age remnants, or those which harbour a Pulsar Wind Nebulae (PWN), tend to have flatter radio spectra with $\alpha \sim -0.2$. As one of the most energetic class of sources in the Universe, these objects greatly impact the structure, physical properties and evolution of the interstellar medium (ISM). Conversely, the interstellar environments in which SNRs reside, will heavily affect the remnants' evolution. Here, we report on radio-continuum observations of the most up-to-date sample of MCs SNRs and SNR candidates, consisting of 83 objects in the Large Magellanic Cloud (LMC) and 25 in the SMC.

2. MAGELLANIC CLOUD SURVEYS

There are several present-generation multi-wavelength surveys that we used in our study. Radio-continuum surveys were predominately based on observations from the Australian Telescope Compact Array (ATCA), including the 20-cm mosaic by Filipović et al. (2002); Payne et al. (2004); Hughes et al. (2007); Wong et al. (2011a,b) as well as the 6-cm and 3-cm mosaics published by Dickel et al. (2005); Crawford et al. (2011); Wong et al. (2012). In addition, a 36 cm Molonglo Synthesis Telescope (MOST) mosaic image (as described in Mills and Turtle 1984) was used. We note that the former surveys (i.e., those from the ATCA) included a zero-spacing measurement from the single 64-m Parkes dish (Filipović et al. 1995, 1997), while the latter MOST image did not. This resulted in missing short spacings at λ= 36 cm, and therefore, the potential for missing flux may be an issue, especially for larger remnants.

Over the past several years we performed a number of X-ray surveys of both MCs using the *ROSAT*, *Chandra* and *XMM-Newton* observatory (Haberl et al. (2012); Haberl (2014)). For example, the *XMM-Newton* LMC large project comprises 25 ks observations of 70 fields, which together with archival data cover an area of about 10 square degrees. The *XMM-Newton* surveys provide a unique data set to investigate the X-ray source populations of the MCs including SNRs and candidates. Our latest search for the new LMC SNRs resulted in a discovery of 4 such objects (Maggi et al. 2014). The comprehensive review on the SMC X-ray sample can be found in Filipović et al. (2008) and Owen et al. (2011). Additional X-ray data were sourced from the Chandra Supernova Remnant Catalog.

Data from the Magellanic Cloud Emission Line Survey (MCELS) were used throughout this work. This survey was carried out at the 0.6 m University of Michigan/CTIO Curtis Schmidt telescope (Smith et al. 2006). Both MCs were mapped in narrow bands corresponding to Hα, [O III] (λ=5007 Å), and [S II] (λ = 6716, 6731 Å), plus matched red and green continuum bands. Our own spectroscopic surveys of the LMC (Payne et al. 2008) and SMC (Filipović et al. 2005; Payne et al. 2007) SNR sample are mainly taken with the SAAO 1.9-m and MSSSO 2.3-m telescope.

We use MCs infrared data from the *Spitzer* Space Telescope and *Herschel* surveys (Lakićević et al. 2014). The Multiband Imaging Photometer was used for *Spitzer* (MIPS) (24, 70 and 160 μm) and with SPIRE (Spectral and Photometric Imaging Receiver) at 250, 350 and 500 μm and with Photodetector Array Camera and Spectrometer at 100 and 160 μm.

3. RESULTS

We present size/diameter and radio spectral index distribution studies of SNRs from both Clouds as well as an initial study of 12 type Ia SNRs from the LMC. We point to a number of MCs SNRs studies that our group did over the past few years. Namely, Bojičić et al. (2007), Čajko et al. (2009), Crawford et al. (2010), Bozzetto et al. (2010), Owen et al. (2011), Grondin et al. (2012), Bozzetto et al. (2012a,b,c), de Horta et al. (2012), Kavanagh et al. (2013), Bozzetto et al. (2013), Brantseg et al. (2014), Bozzetto et al. (2014a,b), De Horta et al. (2014), Crawford et al. (2014) and Bozzetto and Filipović (2014c).

3. 1. SIZE OF MAGELLANIC CLOUDS SNRS

To measure the extent of the LMC SNR population, an ellipse was fitted to delineate the bounds of emission from all confirmed and candidate SNRs in this study. A multi-wavelength approach was used such that the given size takes into account the optical, radio and X-ray emission. The resulting histograms showcasing these data is displayed in Fig. 1, where the diameter is the average of the major and minor axes.

The mean diameter of LMC SNRs was estimated to be 39.4 pc, with a standard deviation (SD) of 22.2 pc for some 61 confirmed SNRs. The entire LMC sample of 83 SNRs has somewhat larger size of 44.8 pc with a SD of 28.1 pc. These values are moderately larger than the value found for M 83 in a study by Dopita et al. (2010), which showed a mean diameter of 22.7 pc (SD=10.3 pc) for the 47 measured remnants. Also, in a previous study of the SMC Filipović et al. (2005) found a mean diameter of the SMC sample to be ∼30 pc. They noted that such a value indicate that most of the remnants are in the adiabatic/Sedov evolutionary stage. The results of this study are more inline with those found by Long et al. (2010) in their study of M 33, finding a median of 44 pc and by Lee and Lee (2014) for M 31, which showed a strong peak at $D = 48$ pc.

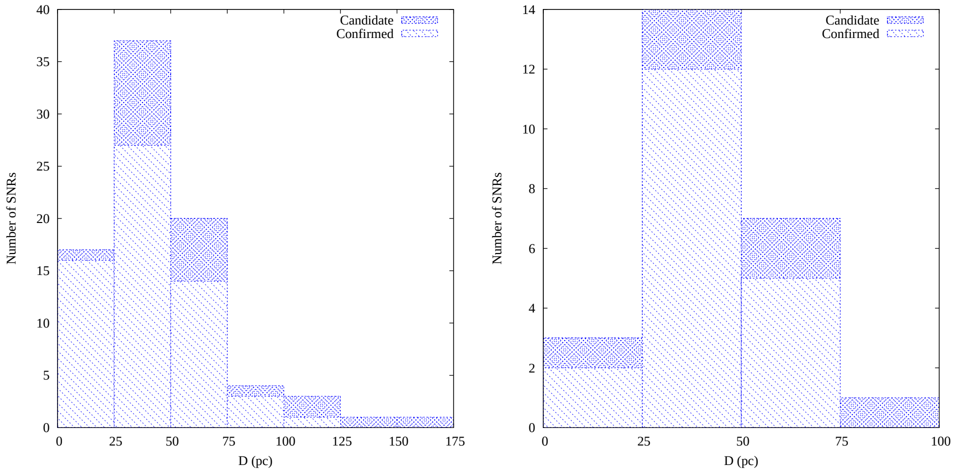

Figure 1: The size distribution for SNRs in the LMC (left) and SMC (right).

The SMC SNR sample diameter was measured in a similar way. Taking a 1-D slice of the remnants major and minor axes and measuring the extent at the 3σ noise level. The mean value of the SMC was estimated to be 42.6 pc with a SD of 15.8 pc for the confirmed 19 remnants, and 44.5 pc with a SD of 17.8 pc for the sample inclusive of candidate remnants (25). With the larger sample size in comparison to the earlier study by Filipović et al. (2005), we find both of these diameter estimates to be significantly larger than the previous measurement of 30 pc.

3. 2. SPECTRAL INDEX OF MAGELLANIC CLOUDS SNRS

In Fig. 2 we show the histograms of the radio spectral distribution of SNRs in the LMC and SMC. A mean spectral index of -0.52 is found with an SD of 0.13 for the LMC, while for the SMC we estimate a mean of -0.47 with an SD of 0.21. Therefore, both, the LMC and SMC values are inline with the theoretically expected spectral index of $\alpha = -0.5$ (Bell 1978).

Filipović et al. (2005) find a mean radio-continuum spectral index of -0.63 (SD=0.43) for confirmed and candidate SNRs in the SMC. In our Galaxy, Clark & Caswell (1976) find a mean of -0.45 with (SD$\sim$ 0.15), while Xu et al. (2005) find an average of -0.5 ± 0.25 using data from the Green (2004) catalogue.

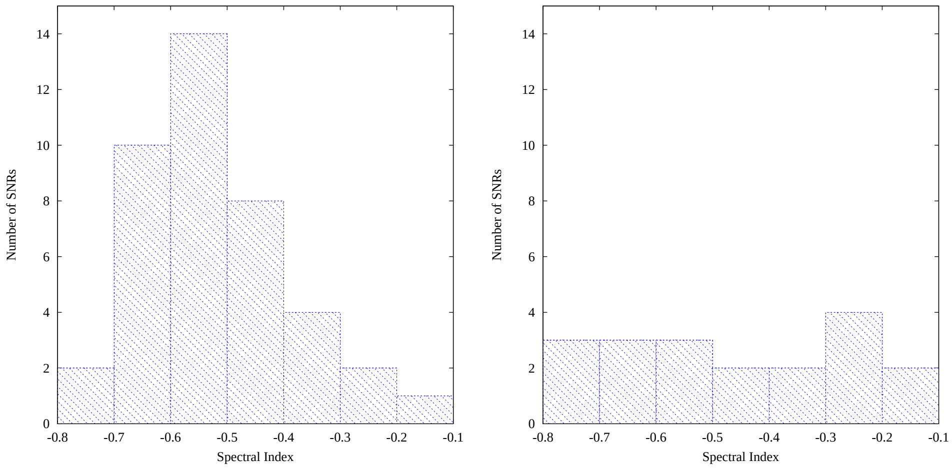

Figure 2: The radio-continuum spectral index distribution for SNRs in the LMC (left) and SMC (right).

3. 3. LMC REMNANTS FROM TYPE IA SN EXPLOSIONS

SNRs play a vital role in the physical evolution and chemical enrichment of the ISM. Their precursor, supernovae (SNe), are believed to occur through two main scenarios. The first being core collapse events, which are the explosions of massive stars (M $>$ 8–10 $M_{\odot}$), and release large quantities of α-elements into the ISM. Alternatively, thermonuclear SN (type Ia) progenitors are less massive and are believed to be the resulting detonation or deflagrations of carbon-oxygen white dwarfs (WDs) that have reached the Chandrasekhar limit ($\sim$1.4 $M_{\odot}$). This may be the rest of a single degenerate system, where a WD in a binary system will accrete matter from a large companion star, or a double degenerate (DD) system, in which two WDs merge (thus exceeding the critical mass) and explode as an SN. The study of type Ia SNe is not only important due to their use as "standard candles" in measuring cosmological distances, but also to ascertain the exact nature of the progenitor system.

Currently, twelve SNRs have been reliably classified as type Ia in the LMC. Six of these belong to a new sub-class of SNRs containing an iron-rich plasma in their core, including DEM L238 & DEM L249 (Borkowski et al. 2006), MCSNR J0508-6902 (Bozzetto et al. 2014), MCSNR J0508-6830 and MCSNR J0511-6759 (Maggi et al. 2014) and MCSNR 0506-7025 (Kavanagh et al. 2014). All twelve of these type Ia remnants appear prominently in X-ray observations (see Fig. 3). There have been previous sparse radio observations on a few of these sources, either taken with an insufficient *uv* coverage and/or resolution. An example of the benefits from higher resolution observations can be seen in our pilot study on type Ia LMC SNR B0509-67.5 (Bozzetto et al. 2014b), where the inclusion of the long baseline observations made it possible to resolve the radially orientated magnetic field and also, detect a previously unseen central ring within the remnant, Fig. 4.

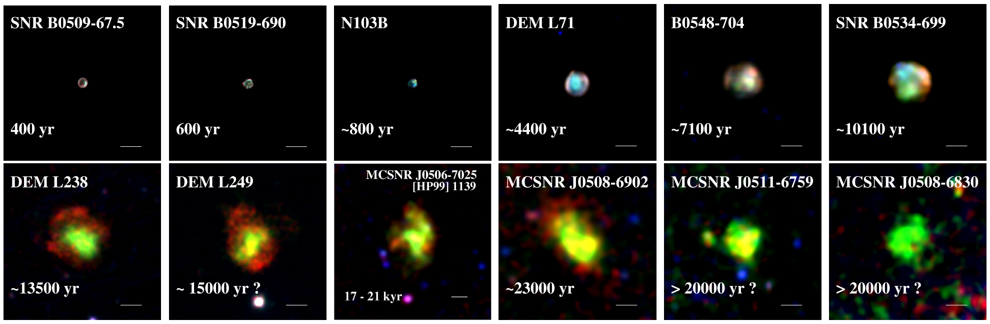

Figure 3: "Sequence" of all type Ia SNRs known in the LMC with available *Chandra* or *XMM-Newton* observations, shown on the same scale (the white bar is 1′), and sorted by increasing age. We note that, with the exception of the younger remnants, from whose ages were historic or based on light-echoes, the ages predominately are estimated from X-ray analysis, specifically fitting SNR parameters to the Sedov model, and, therefore, there may be a bias toward remnants following Sedov evolution in this relation. We used *Chandra* data for the three smallest SNRs. In *XMM-Newton* image the red, green and blue components are soft (0.3–0.7 keV), medium (0.7–1.1 keV), and hard (1.1–4.2 keV) X-rays. The medium band is dominated by Fe L-shell lines, and the iron-rich interior, appearing greenish, is readily distinguished from the softer, fainter shells of the more evolved type Ia SNRs (second row). Image and caption from Maggi et al. (in prep).

We also search for the remnant star (RS) companion (donor star with $L>10\ L_\odot$) in and around all these 12 LMC type Ia SNRs. Chu et al. (in priv. com.) initial results indicate a lack of expected "red-giant" RS within the central region of the SNR. Pagnotta & Schaefer (2015) also searched two LMC SNRs (SNR 0505–67.9 and SNR 0509–68.7) to identify the centre of the remnant and the 99.73% containment central region in which any companion star left over from the SN explosion would reside. They concluded that both remnants have a number of potential ex-companion stars near their centres and that either a single or double degenerate scenario may be possible. There are a number of other studies in our Galaxy (for example see Kerzendorf et al. (2014) on Kepler's SNR) that also confirms a lack of RS within type Ia SNRs. While this may strongly favour a DD scenario, one also should not disregard possible changes in the RS's outer layers which could make them difficult

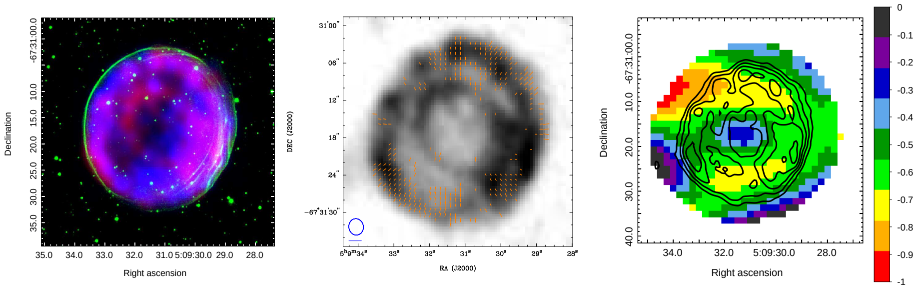

Figure 4: *Left:* Colour composite image of LMC SNR B0509–67.5 using radio (red), X-ray (blue) and optical (green) observations from the ATCA, *Chandra* and Hubble Space Telescope. *Middle:* Intensity image of B0509–67.5 overlaid with polarisation vectors at 6 cm (Bozzetto et al. 2014b; Fig. 6). *Right:* Spectral index map between 13 cm and 6 cm (Bozzetto et al. 2014b; Fig. 5).

to identify. Most noticeable, Ruiz-Lapuente et al. (2004) found a type G0-G2 star which appears to be the surviving companion of the Tycho SN.

4. FUTURE WORK

Our radio-continuum study of SNRs in the MCs are based on ATCA and MOST observations. However, new low-frequency radio-telescopes such as the Murchison Widefield Array (MWA) and Australia Square Kilometre Array Pathfinder (ASKAP) will significantly enhance our knowledge about these objects and will allow us to complete the sample of MCs SNRs. The luminosity-diameter distribution will be used to study the evolution of SNRs in a statistical sense. Also a comparison with the X-ray data will continue the radio – X-ray comparison. Comprehensive comparison with the optical and IR surveys such as Hα, [S II], [O III], *Spitzer* and *Herschel* surveys are planned as well.

In addition, we will continue our detailed studies on individual SNRs. Some of their characteristics may be related to peculiar properties of the interstellar medium around the explosion site and/or different precursor stars. Theoretical models indicate that changes in density, clumpiness and other properties of the surrounding medium can have a significant effect upon the evolution of an SNR and its emission. However, the collective properties of the SNRs in the MCs studied to date are surprisingly consistent and quite similar to the population of Galactic SNRs despite major differences between these galaxies.

Acknowledgments

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CENTRAL SUPERMASSIVE BLACK HOLE OF THE MILKY WAY

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Abstract. An overview of some important aspects of the supermassive black hole at the Galactic Center, such as evidences for its existence, its main features, effects on stellar kinematics, gas dynamics and distributions of dark and visible matter in its neighborhood, is given here. The possibilities to use the observations of these phenomena as a tool for testing some of the predictions of General relativity and alternative theories of gravity in such extreme conditions is also considered, and some of our recently obtained results in this field are presented. Besides, the influence of the central supermassive black hole on the evolution of the Milky Way is discussed, as well as whether it could trigger the activity of our Galaxy in the future, by starting to accrete the surrounding matter with much higher rate. Taking into account that the Milky Way is on a collision course with M31 Andromeda galaxy, and that their central supermassive black holes will become gravitationally bound and form a binary system of these objects at some stage in the evolution of the resulting merger, some properties and possible consequences of this supermassive black hole binary are also considered here.

1. INTRODUCTION

It is now widely accepted that the supermassive black holes (SMBHs) are located in the centers of most galaxies, including the Milky Way, and that they have fundamental influence on evolution of their host galaxies. Central SMBH of our Galaxy is located in a compact radio source Sgr A* at Galactic Center (GC), and here we will present the main observational evidences for its existence, its properties, effects on stellar kinematics, gas dynamics, distributions of dark and visible matter, structure and evolution of the Milky Way, including some possible future scenarios, such as potential activity of our Galaxy and formation of a binary system of SMBHs during the Milky Way and M31 merger. We will also give a short overview of our main investigations related to the above aspects of the SMBH in Sgr A*, such as: using the observed stellar orbits around GC for testing some predictions of General Relativity (GR) and alternative theories of gravity, studying the accretion physics and space-time geometry in vicinity of SMBHs and observational signatures of their binary systems.

2. OBSERVATIONAL EVIDENCES AND PROPERTIES

Compact radio source Sgr A* at GC was discovered in 1974 by Bruce Balick and Robert L. Brown using the Green Bank 35 km radio interferometer in West Virginia

(Balick and Brown 1974). As it can be seen from a wide-field radio image of the Galactic Center at 90 cm presented in the left panel of Fig 1 (LaRosa et al. 2000), Sgr A* is part of a more complex radio source known as Sgr A.

The first indication that Sgr A* may harbor a SMBH of $\sim 3\times10^6\ M_\odot$ was obtained by virial analysis of the ionized gas in the central parsec of the Milky Way by Lacy et al. (1982). All successive estimates, although obtained by different techniques, suggested that there was a large mass of $\propto 10^6\ M_\odot$, enclosed in a very small volume at GC (see the right panel of Fig. 1). For instance, $M_{BH}-\sigma$ relationship resulted with $M_{BH}\approx 9.4\times10^6\ M_\odot$ for the Milky Way bulge velocity dispersion of $\sigma = 103$ km/s (Tremaine et al. 2002).

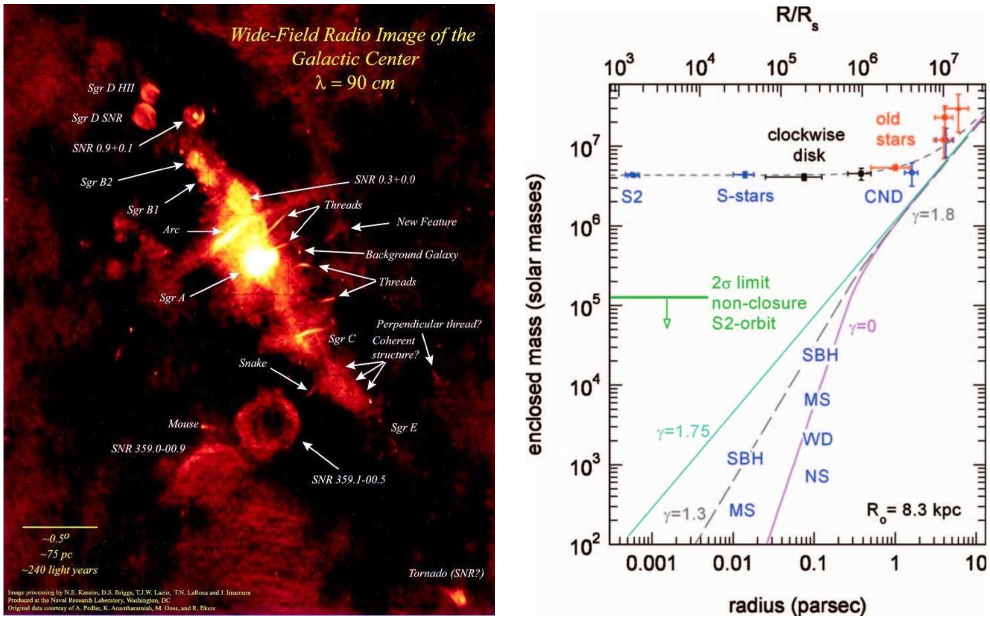

Figure 1: *Left:* a wide-field radio image of the Galactic Center at 90 cm (figure taken from LaRosa et al. 2000). *Right:* mass distribution in the central few parsec of the Milky Way (figure taken from Genzel et al. 2010). These estimations are based on: the orbits of S-stars (filled blue symbols), clock-wise rotating disk of O/WR stars (filled black squares), proper motions, radial velocities and the light of the old stars (red symbols), and the rotation of the molecular gas in the circum-nuclear disk (open blue circles).

The most direct evidence for the existence of the SMBH at GC would be a detection of its "shadow". Namely, event horizon of a black hole located in front of a planar-emitting source casts a relatively large "shadow" to a distant observer due to the bending of light (see e.g. Falcke et al. 2000 and references therein). Apparent diameter of "shadow" for Sgr A* is 52 $\mu as \approx 5\ R_{Sch}$ (Doeleman et al. 2008), and it should be observable by direct (Falcke et al. 2000) and/or polarimetric (Bromley et al. 2001) imaging (see the top and bottom panels of Fig. 2). In principle, such imaging should be feasible by the big triangle of submm VLBI (see e.g. Inoue et al. 2012), or by a larger array called Event Horizon Telescope, capable of angular resolutions approaching 20 μas (see e.g. Doeleman 2010).

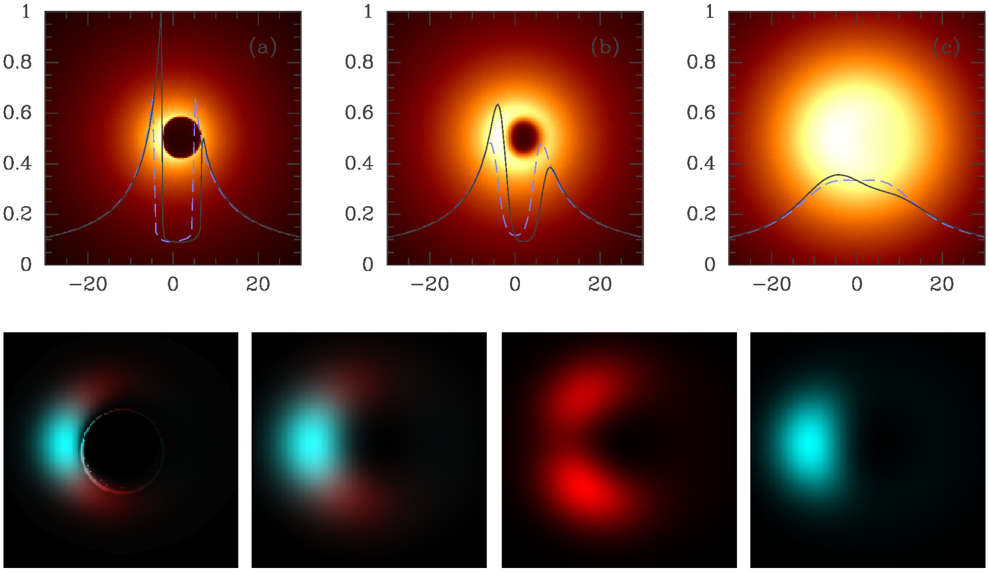

Figure 2: *Top:* GR ray-tracing simulations of "shadow" cast by the event horizon of a black hole with the characteristics of Sgr A* (figure taken from Falcke et al. 2000). The left to right panels show raw ray-tracing image and images seen by an idealized VLBI array at 0.6 and 1.3 mm wavelengths, respectively. *Bottom:* simulated polarization maps at 0.67 mm emission from Sgr A* (figure taken from Bromley et al. 2001). The left to right panels show: raw ray-tracing image, an image blurred to account for finite VLBI resolution and interstellar scattering, vertical and horizontal components of the polarized emission, respectively.

However, until this happens in the near future, the most reliable current evidences for the central SMBH of the Milky Way and estimates for its mass were obtained from Keplerian orbits of fast-moving ($v > 1000$ km/s) stars within $0''.3$ (0.01 pc) at GC. These, so called S-stars, have been monitored since 1995 by Keck 10 m telescopes (Ghez et al. 2008) and by New Technology Telescope/Very Large Telescope (NTT/VLT) (Gillessen et al. 2009a), yielding the following values for the black hole mass and distance to the GC, respectively: $M_{BH} = 4.5 \times 10^6\ M_\odot, R_0 = 8.4$ kpc (Ghez et al. 2008) and $M_{BH} = 4.3 \times 10^6\ M_\odot, R_0 = 8.3$ kpc (Gillessen et al. 2009a). These values indicated that Schwarzschild radius of SMBH at GC is $R_{Sch} \approx 10\ \mu$as (0.1 AU) at a distance of ≈ 8 kpc.

S-stars could be used as test particles to probe the gravitational potential in which they move. Two of them are of a special interest: S2 with mass of 15 $M_\odot$ and a highly elliptical Keplerian orbit around Sgr A* (although there are some indications that the observed orbit deviates from the Keplerian one) with a period of 15.6 yr (Schödel et al. 2002), and S0-102 with the shortest orbital period of 11.5 yr (Meyer et al. 2012). Therefore, these stars represent an ideal laboratory for studying the gravity under the extreme conditions, close to the central SMBH of the Milky Way. Especially, different theories of modified gravity which have been proposed as alternative approaches to Newtonian gravity, could be tested using the observed orbits of S-stars.

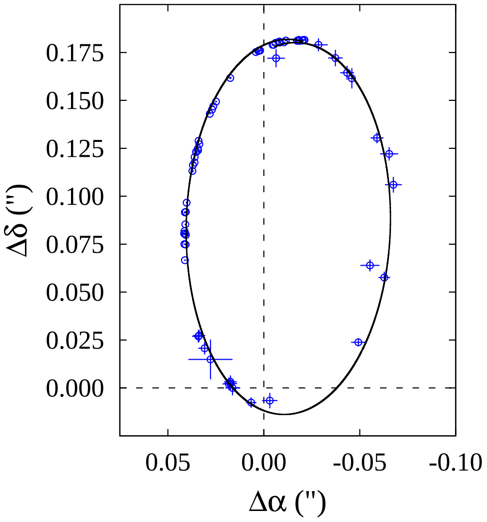

Figure 3: *Left:* fit of S2 star orbit around SMBH at GC in R^n gravity (black solid line) to the NTT/VLT astrometric observations (blue open circles) (figure taken form Borka et al. 2012). *Right:* The same as in the left panel, but for Yukawa gravity (figure taken from Borka et al. 2013).

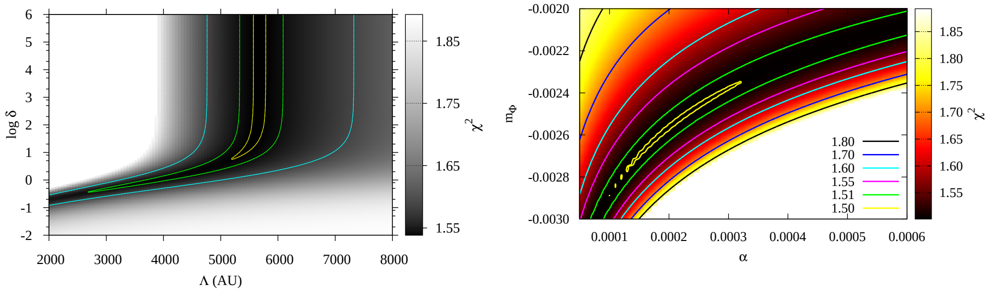

Figure 4: *Left:* χ^2 map over the parameter space of Yukawa gravity for the fits of S2 star orbit to the NTT/VLT observations (figure taken from Borka et al. 2013). *Right:* The same as in the left panel, but for $f(R, \phi)$ gravity (figure taken from Capozziello et al. 2014).

We studied whether the following three such theories: R^n, Yukawa and $f(R, \phi)$ gravity, as well as a bulk distribution of mass, are able to provide reasonable explanations for the deviations in the observed orbit of S2 star, and whether these observations could be used for constraining such modified gravity theories (see Borka et. al. 2012, 2013; Capozziello et al. 2014; Zakharov et al. 2014). Two examples of simulated orbits of S2 star in R^n and Yukawa gravity which give the best fit to the NTT/VLT astrometric observations (Gillessen et al. 2009b) are presented in Fig. 3, while Fig. 4 shows two corresponding χ^2 maps over the parameter spaces of Yukawa and $f(R, \phi)$ gravities.

Recently, a dense, ~ 3 Earth mass gas cloud on its way towards the SMBH at GC was discovered (Gillessen et al. 2012). This gas cloud, labeled as G2, was falling into accretion zone of Sgr A*, and an increase of the keV X-ray emission of Sgr A* and giant radiation flare were expected due to cloud disruption by SMBH. However, G2 was still intact during its closest approach to SMBH in March 2014, in contrast to a simple gas cloud hypothesis, so most likely it hosts a central star (Ghez et al. 2014).

Besides, dark matter (DM) might contribute to the extended mass in GC, and in that case DM evolution would be driven by the scattering of its particles by bulge stars, their accretion into SMBH and self-annihilation (Genzel et al. 2010). Recently, an excess in gamma-ray emission from GC was detected, most likely due to annihilations of DM particles, indicating that DM distribution around the SMBH could strongly affect this annihilation signal (Daylan et al. 2014).

It is also worth to mention that several alternative explanations for the massive compact object at GC, such as a dark cluster of faint stars (neutron stars, white or brown dwarfs), "fermion ball" and "boson star" were disproved, leaving the central SMBH as the most plausible explanation (Genzel et al. 2010).

3. POSSIBLE ACTIVITY OF THE CENTRAL SMBH AT GC

Despite the rich gas reservoir in its surroundings, Sgr A* is faint, with luminosity which is several orders of magnitude lower than the Eddington luminosity. This is due to decrease of accretion rate toward the SMBH, which falls from $\sim 0.01\ M_{\odot}/\mathrm{yr}$ at several tens pc to $\sim 10^{-9} - 10^{-7}\ M_{\odot}/\mathrm{yr}$ at several hundreds R_{Sch} (Genzel et al. 2010).

However, occasional rapid X-ray flares from Sgr A* were observed, providing evidences for activity of Sgr A* close to its event horizon (Porquet et al. 2008). Besides, Li et al. (2013) recently found an evidence for a parsec-scale jet from Sgr A* and a shock front along the jet (see the left panel of Fig. 5). Also, several echoes of multiple outbursts of Sgr A* in the past were recently detected by Chandra in the observed Fe Kα line emission from molecular clouds near GC (Clavel et al. 2013). The rapid variability of this emission indicated that it originated from the reflection of X-rays generated by SMBH which was much more luminous in the past, causing a highly variable active phase of Sgr A* which occurred sometime within the past few hundred years. This active phase was characterized by at least two luminous outbursts with typical time scales of a few years, during which the Sgr A* luminosity went up to at least 10^{39} erg/s (Clavel et al. 2013).

The observational studies of this sort motivated the corresponding theoretical investigations of Sgr A* activity, such as e.g. MHD simulations of its accretion disk (see e.g. Chan et al. 2009, as well as the right panel of Fig. 5). Moreover, they also indicate that the speculations about the potential future activity of Sgr A* are reasonable.

Our studies of SMBHs activity were mostly concentrated to the investigations of the broad Fe Kα spectral line which originates from the innermost regions of relativistic accretion disks around central SMBHs of active galaxies and quasars. For

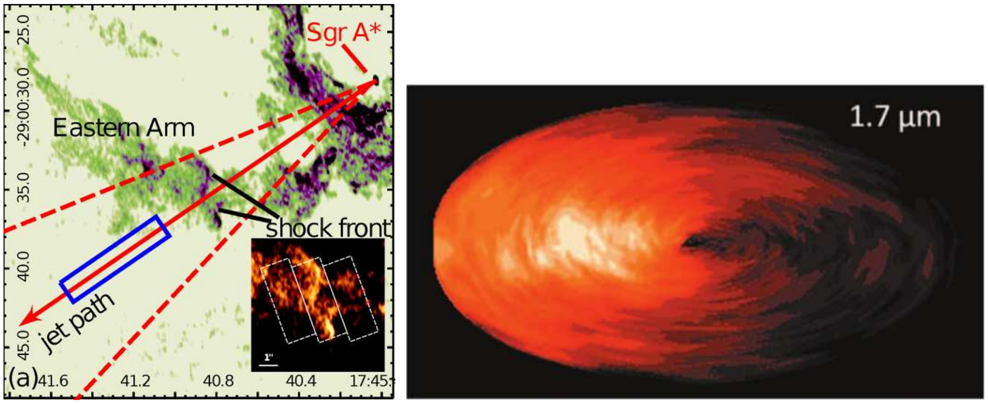

Figure 5: *Left:* evidence for a parsec-scale jet from Sgr A* and a shock front along the jet path (figure taken from Li et al. 2013). *Right:* Ray-tracing simulation of the accretion disk in Sgr A* observed at 1.7 μm (figure taken from Chan et al. 2009).

that purpose we developed a code to perform numerical simulations of radiation from such disks, based on ray-tracing method in Kerr metric and used it for studying the black hole masses and spins, space-time geometry (metric) in their vicinity (Jovanović et al. 2011), their accretion physics (Jovanović et al. 2010, Popović et al. 2012), probing the effects of their strong gravitational fields, and for testing the certain predictions of General Relativity (see e.g. Jovanović and Popović 2008, Jovanović

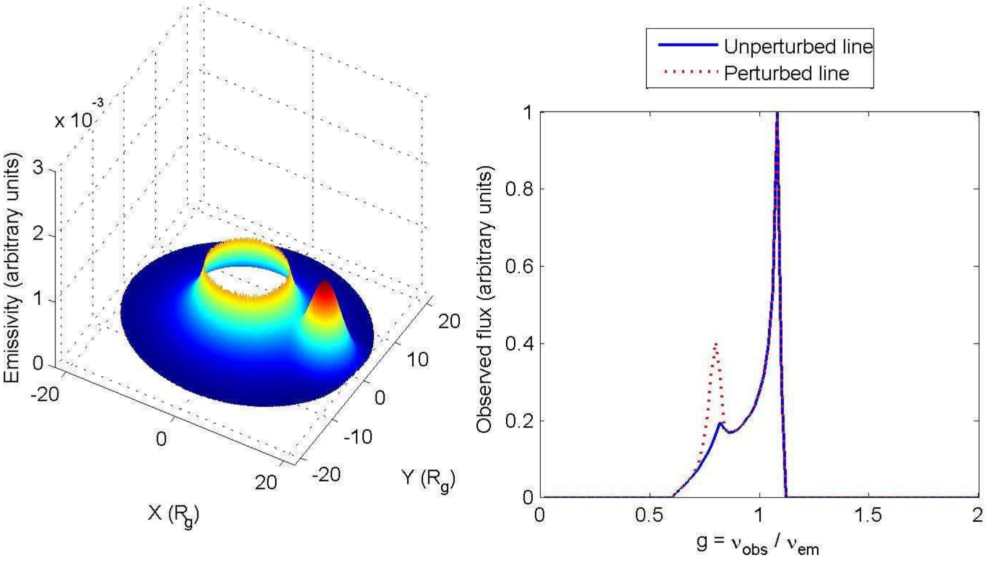

Figure 6: *Left:* emissivity of a relativistic accretion disk around a SMBH perturbed by a bright spot on the disk's receding side (Jovanović et al. 2010). *Right:* the corresponding perturbed (dashed line) and unperturbed (solid line) Fe Kα line profiles.

2012). An example of our investigations in this field is presented in Fig. 6, where we introduced a model of a bright spot (or flare) orbiting in an accretion disk, and used it for studying the variability of double peaked line profiles, emitted from accretion disk of active galaxies and quasars (see Jovanović et al. 2010 for more details). Besides, gravitational microlensing turned out to be very helpful in these studies (see e.g. Jovanović et al. 2008, 2009; Popović et al. 2003ab, 2005, 2006). For reviews of our previous investigations of emission lines emitted from accretion disks around central SMBHs of AGN see e.g. Jovanović 2012, Jovanović and Popović 2009.

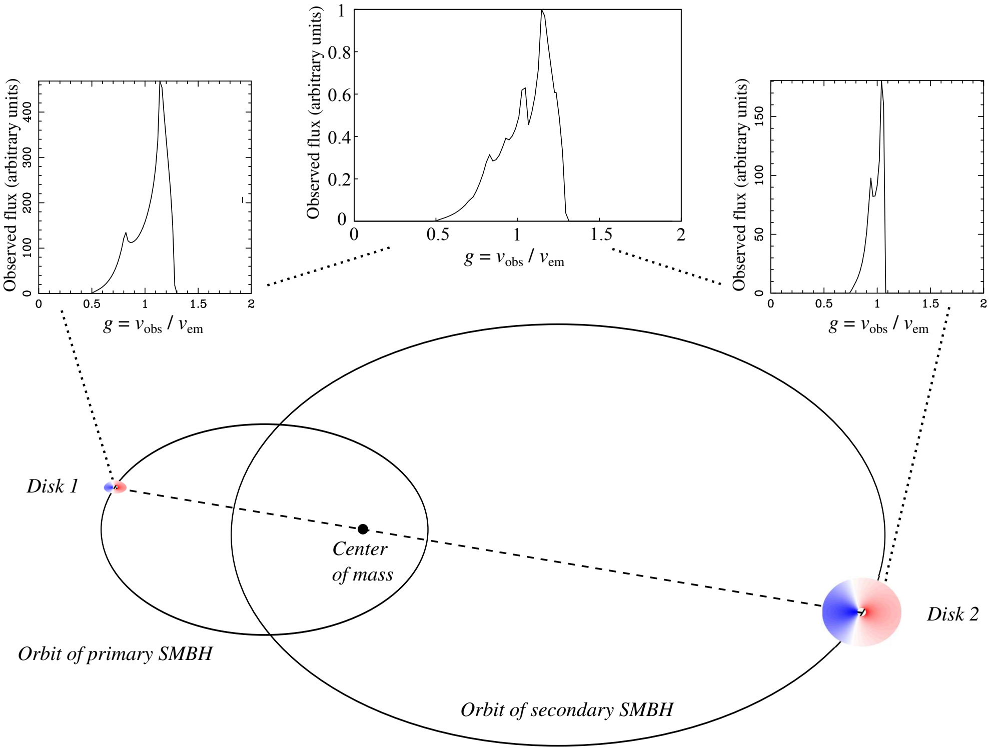

Figure 7: Illustration of two accretion disks around the components of a binary system of SMBHs rotating along a Keplerian orbit, and the corresponding simulated ”constituent” and ”composite” profiles of the Fe Kα line (see Jovanović et al. 2014 for more details).

4. THE MILKY WAY AND M31 MERGER: SMBH BINARY

It is well known that the Milky Way and Andromeda (M31), the two largest members of the Local Group of galaxies, are moving towards each other at $\sim$ 120 km/s and will collide in a few billion years - within the Sun's lifetime (see e.g. Cox and Loeb 2008; van der Marel et al. 2012). During their merger, the Sun will be most likely scattered to the outer halo and reside at radii larger than 30 kpc (Cox and Loeb 2008), while their central SMBHs will form a binary system, and according to some speculations, they could also produce a luminous quasar (Cox and Loeb 2008). Theory predicts that binary systems of SMBHs should spend a substantial amount of time orbiting along Keplerian orbits, and if they are surrounded by gas, accretion onto one or both SMBHs could occur, resulting with certain observational effects.

We used our model of relativistic accretion disk to study the variations of a composite line emitted from two accretion disks around SMBHs in a binary system (see illustration in Fig. 7), and found that such variations could be used as observational signatures of SMBH binaries (Jovanović et al. 2014). An important our result in this field was a recently found observational evidence for the first spectroscopically resolved sub-parsec orbit of a SMBH binary in the core of active galaxy NGC 4151 (Bon et al. 2012). We used a method similar to those typically applied for the spectroscopic binary stars to obtain radial velocity curves, from which we then calculated orbital elements and estimated masses of the components in this SMBH binary.

5. CONCLUSIONS

According to the results of the presented observational and theoretical studies of the Milky Way's central SMBH, one can derive the following conclusions:

1. Central SMBH of the Milky Way has a fundamental influence on the structure and evolution of our Galaxy;
2. In future it could trigger the activity of our Galaxy and form a binary system of SMBHs together with central SMBH of M31;
3. It represents a unique laboratory for testing some of the predictions of GR and alternative theories of gravity in such extreme conditions;
4. We developed a model of a relativistic accretion disk around a SMBH using numerical simulations based on a ray-tracing method in Kerr metric and applied it for investigation of the properties and accretion physics of SMBHs, space-time geometry and strong gravity effects in their vicinity, as well as the properties of their binary systems.

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Publ. AOB No. 94 DAS No.1 DepAstro No.21 (2016), 171 - 171*Inv.Lecture*

ON THE DIFFERENT FORMS OF CONTINUUM RADIO SPECTRA OF SUPERNOVA REMNANTS: THEORETICAL FUNDAMENTALS

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Abstract. In this lecture I briefly present the theoretical fundamentals of formation of the supernova remnant (SNR) continuum radio spectra. It represents necessary introduction for the main topic of the lecture: prediction of the different forms (linear or curved in log-log scale) of SNR radio spectra for both young and evolved SNRs. Also, all of these theoretically predicted forms of radio spectra are compared with real spectra obtained from observations. This analysis introduces some characteristic forms of the SNR radio spectra which can be used by radio observers to estimate age and evolutionary status of the new-detected Galactic and especially extragalactic SNRs.

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CONSTRAINTS ON $f(R, \phi)$ (SANDERS-LIKE) GRAVITY POTENTIAL FROM ORBIT OF S2 STAR

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Abstract. We investigate the possibility to explain theoretically the S2 star orbital precession around the massive object at Galactic Centre using Extended Theories of Gravity, specifically $f(R, \phi)$ a Sanders-like gravitational potential in total absence of dark matter. To this aim an analytic fourth-order theory of gravity, non-minimally coupled with a massive scalar field is considered. The interaction term is given by an analytic functions $f(R, \phi)$ where R is the Ricci scalar and ϕ is the scalar field. We simulated orbit of S2 star around Galactic Centre in Sanders-like gravity potentials and compared it with NTT/VLT observations. We presented maps of reduced χ^2 over the $\{\alpha - m_\phi\}$ parameter space in the case of NTT/VLT observations. The approach we are proposing seems reliable to constrain modified gravity models at astronomical level.

1. INTRODUCTION

Extended Theories of Gravity (see e.g. Capozziello & De Laurentis 2011) are alternative theories of gravitational interaction. These theories are developed from the exact starting points like General Relativity. They aimed from one side to extend the positive results of General Relativity and, on the other hand, to cure its shortcomings. These theories have been proposed like alternative approaches to Newtonian gravity in order to explain galactic and extragalactic dynamics without introducing dark matter (see e.g. Capozziello & De Laurentis 2012, Nojiri & Odintsov 2011, Capozziello

2002, Capozziello et al. 2003, Capozziello & Faraoni 2010).

S-stars closely orbit the massive compact object at the center of Milky Way, named Sgr A* (see e.g. Ghez et al. 2000, Gillessen et al. 2009a, Gillessen et al. 2009b, Genzel et al. 2010). These stars, together with recently discovered dense gas cloud falling towards the Galactic Centre (see e.g. Gillessen et al. 2012), indicate that the massive central object is probably a black hole. There are some observational indications, for at least S2, that its orbit may deviate from the Keplerian case (see e.g. Gillessen et al. 2009a, Meyer et al. 2012).

2. THEORY

2. 1. $f(R,\phi)$ THEORIES OF GRAVITY

We can consider a generic function of Ricci scalar and scalar field. Then the action becomes (see e.g. Stabile & Capozziello 2013):

$$\mathcal{A} = \int d^4x\sqrt{-g}\Big[f(R,\phi) + \omega(\phi)\,\phi_{;\alpha}\,\phi^{;\alpha} + \mathcal{X}\mathcal{L}_m\Big]. \tag{1}$$

We get $\phi = \phi^{(0)} + \phi^{(1)} + \phi^{(2)} + \ldots$ and the function $f(R,\phi)$ with its partial derivatives (f_R, f_{RR}, f_ϕ, $f_{\phi\phi}$ and $f_{\phi R}$) and $\omega(\phi)$ can be substituted by their corresponding Taylor series. In the case of $f(R,\phi)$, we have:

$$f(R,\phi) \sim f(0,\phi^{(0)}) + f_R(0,\phi^{(0)})R^{(1)} + f_\phi(0,\phi^{(0)})\phi^{(1)}... \tag{2}$$

In the $f(R,\phi)$-gravity the gravitational potential is found by setting the gravitational constant as

$$G = \left(\frac{2\,\omega(\phi^{(0)})\,\phi^{(0)} - 4}{2\,\omega(\phi^{(0)})\,\phi^{(0)} - 3}\right)\frac{G_\infty}{\phi^{(0)}} \tag{3}$$

where G_∞ is the gravitational constant as measured at infinity and by imposing $\alpha^{-1} = 3 - 2\,\omega(\phi^{(0)})\,\phi^{(0)}$, the gravity potential is (see e.g. Stabile & Capozziello 2013):

$$\Phi_{ST}(\mathbf{x}) = -\frac{G_\infty M}{|\mathbf{x}|}\left\{1 + \alpha\, e^{-\sqrt{1-3\alpha}\, m_\phi |\mathbf{x}|}\right\} \tag{4}$$

and then a Sanders-like potential is obtained (see e.g. Sanders 1990, Sanders 1984).

2. 2. SIMULATED ORBITS OF S2 STAR

In order to constrain the parameters of $f(R,\phi)$ model, we simulate orbits of S2 star in Sanders-like gravity potentials. We fit orbits to the astrometric observations obtained by New Technology Telescope/Very Large Telescope (NTT/VLT) (see e.g. Gilessen et al. 2009a) for different combinations of α and m_ϕ. Each simulated orbit is defined by four initial conditions: two components of initial position and two components of initial velocity in orbital plane at the epoch of the first observation. For each combination of α and m_ϕ, we obtain the best fit initial conditions corresponding to a simulated orbit. The fitting procedure is performed using LMDIF1 routine from MINPACK-1 Fortran 77 library which solves the nonlinear least squares problems by a modification of Marquardt-Levenberg algorithm (see e.g. Moré et al. 1980). Detailed descriptions are given in the papers of Borka et al. (2012, 2013).

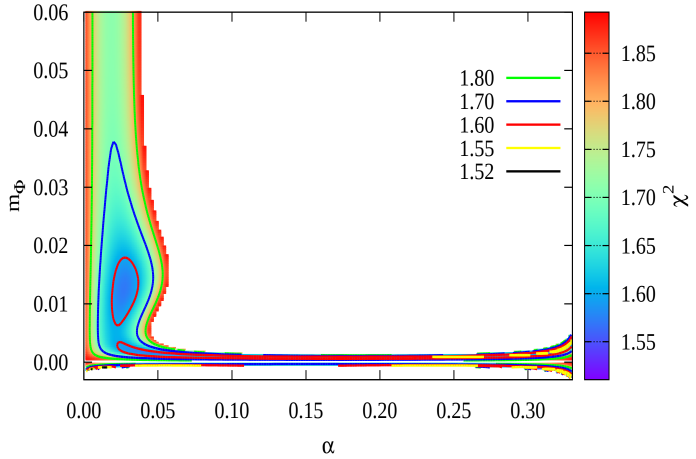

Figure 1: The map of reduced χ^2 over the $\{\alpha - m_\phi\}$ parameter space of $f(R, \phi)$ gravity in case of NTT/VLT observations of S2 star which give at least the same ($\chi^2 = 1.89$) or better fits ($\chi^2 < 1.89$) than the Keplerian orbits. The map corresponds to m_ϕ in $[0, 0.06]$ and α in $[0, 0.33]$. A few contours are presented for specific values of reduced χ^2 given in the legend.

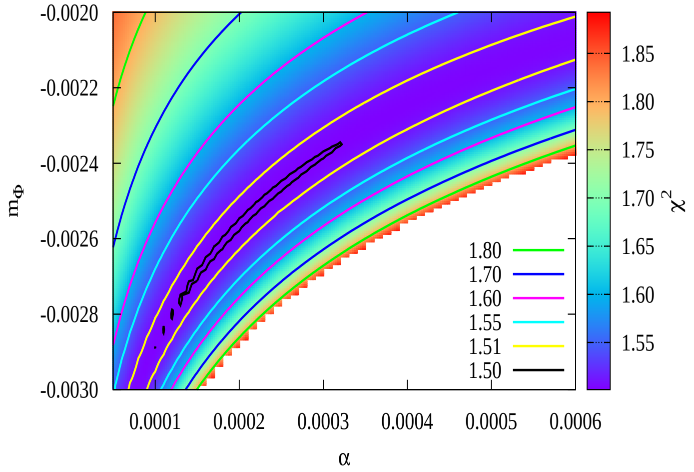

Figure 2: The same as in Figure 1, but for a narrow region in the $\{\alpha - m_\phi\}$ parameter space around the absolute minimum of the reduced χ^2. A few contours are presented for specific values of reduced χ^2 given in the legend.

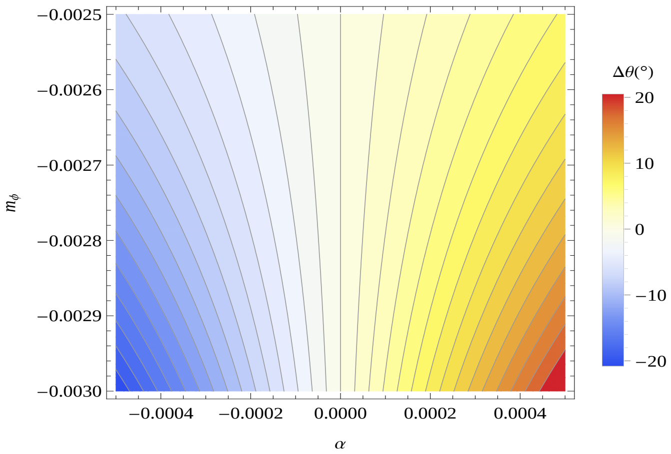

Figure 3: Numerically calculated angle of precession per orbital period as function of parameters α in the range $[-0.0005, 0.0005]$ and m_ϕ in the range $[-0.003, -0.0025]$ in case of Sanders-like potential. The pericenter advance (like in GR) is obtained for positive α, and retrograde precession for negative α.

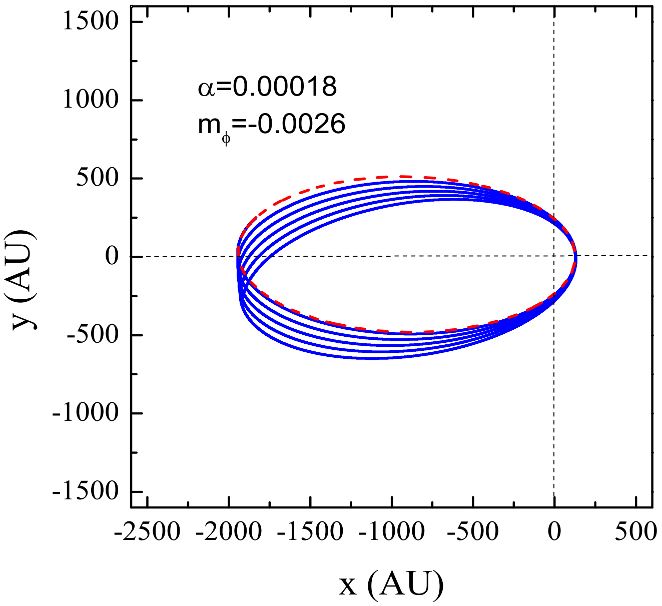

Figure 4: Comparison between the orbit of S2 star in Newtonian potential (red dashed line) and Sanders-like potential for the best fit parameters α = 0.00018 and m_ϕ = -0.0026 during 5 orbital periods (blue solid line).

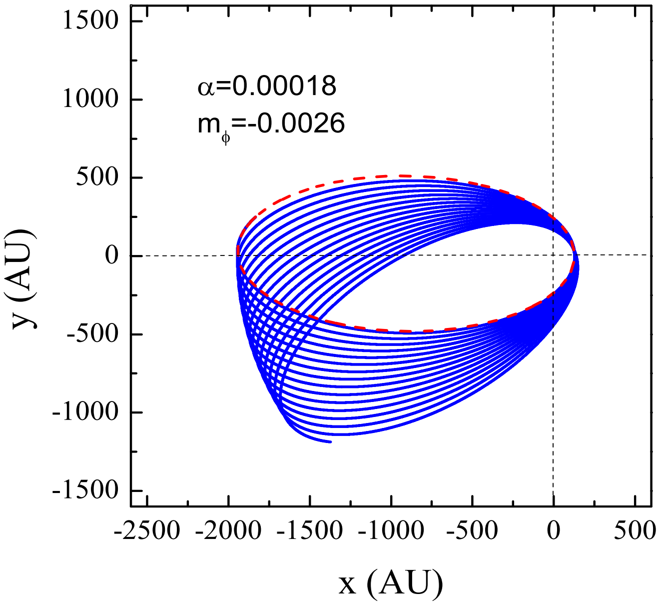

Figure 5: The same as in Figure 4, but for 15 orbital periods.

3. $f(R,\phi)$ RESULTS AND DISCUSSION

Our aim in this paper is to determine coefficients f_0, f_R, f_{RR}, f_ϕ, $f_{\phi\phi}$ and $f_{\phi R}$. For more details (see e.g. Stabile & Capozziello 2013, Capozziello et al. 2014). We obtained the following set of parameters $f_0 = 0$, $f_R = 3 - 1/\alpha$, $f_\phi = 0$, $f_{RR} = 0$, $f_{\phi R} = 1$ and $f_{\phi\phi} = -m_\phi^2$. These choices are physically reliable and mean that we can assume an asymptotic Minkowski background, i.e. $f_0 = 0$, that the General Relativity is recovered for $f_\phi = 0$, $f_{RR} = 0$, $f_{\phi R} = 1$, and effective massive modes (and then effective lengths) are related to $f_R = 3 - 1/\alpha$, and $f_{\phi\phi} = -m_\phi^2$. In particular, $f_0 = 0$ means that cosmological constant can be discarded at local scales.

Figures 1 and 2 presented the maps of the reduced χ^2 over the $\{\alpha - m_\phi\}$ parameter space in $f(R,\phi)$ gravity for all simulated orbits of S2 star which give at least the same or better fits than the Keplerian orbits ($\chi^2 = 1.89$). Figure 1 corresponds to m_ϕ in $[0, 0.06]$ and α in $[0, 0.33]$. Figure 2 corresponds to the zoomed range of parameters m_ϕ and α. For $\alpha < 0$, there is no region in the parameter space where $\chi^2 < 1.89$ (Keplerian case). For $0 < \alpha < 1/3$ there are two regions where $\chi^2 < 1.89$ (for $m_\phi < 0$ and $m_\phi > 0$), but the absolute minimum is for $m_\phi < 0$. We obtained absolute minimum of the reduced χ^2 for α in the interval $[0.0001, 0.0004]$, and m_ϕ in the interval $[-0.0029, -0.0023]$. The absolute minimum of the reduced χ^2 ($\chi^2 = 1.5011$) is obtained for $\alpha = 0.00018$ and $m_\phi =$ -0.0026, respectively.

Graphical presentation of precession per orbital period for α in the range $[-0.0005, 0.0005]$ and m_ϕ in $[-0.003, -0.0025]$ is given in Figure 3. As one can see pericenter advance (like in GR) is obtained for positive α, and retrograde precession for negative α. The fits better than Keplerian are obtained only for positive α, i. e. for the precession in the same direction as in GR.

The simulated orbits of S2 star around the Galactic Centre in Sanders gravity potential (blue solid line) and in Newtonian gravity potential (red dashed line) for α = 0.00018 and m_ϕ = -0.0026 during 5 and 15 periods, are presented in Figure 4 and Figure 5, respectively. We can see from Figures 4 and 5 that the best fit orbit in Sanders gravity potential precesses for about 3°.1 per orbital period. General Relativity predicts that pericenter of S2 star should advance by 0°.08 per orbital revolution (see e.g. Gillessen et al. 2009b) which is much smaller than the value of precession per orbital period in Sanders gravity potential, but the direction of the precession is the same.

Acknowledgments

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DISTRIBUTION OF RADIO SPECTRAL INDEX OVER THE LUPUS LOOP

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Abstract. We use all-sky surveys at 408 and 1420 MHz with aim to investigate properties of the Galactic radio source Lupus Loop. We estimate the brightness temperature, surface brightness and radio spectral index of this supernova remnant using the method we have developed. The non-thermal nature of its radiation is confirmed, and also the distribution of spectral index over its area is given.

1. INTRODUCTION

The Lupus loop is a large arc of emission of low surface brightness discovered by Milne in the vicinity of the supernova of 1006 AD (Milne 1971, Milne & Dickel 1974), but it is not associated in any way with another supernova remnant (SNR). The radio shell of Lupus Loop is approximately $180'$ in diameter (Kaplan et al. 2006). This remnant is known as old SNR, and has been observed in radio and X-ray wavelength range. In "A Catalogue of Galactic Supernova Remnants" by Green (2014a,2014b) it is labeled as G330.0+15.0.

2. DETERMINING OF LOOP'S BORDERS

For our calculation, we used data from the digital surveys of the sky, available from Max-Planck-Institut for Radioastronomy, Bonn, Germany (at the internet address http://www3.mpifr-bonn.mpg.de/survey.html), which enables users to pick a region of the sky and to obtain data and images at a number of wavelengths. The sky surveys are obtained from continuum radio emission at: 1420 MHz (Reich, Testori & Reich 2001) and 408 MHz (Haslam et al. 1982). Both surveys are all-sky surveys.

Lupus Loop center has the cordinates: $(l, b) = (330°15', 15°3')$ in galactic system, or $(\alpha, \delta) = (15h\ 10min, -40°)$ in equatorial coordinate system. In Fig. 1 we show the location of Lupus Loop at 1420 MHz using galactic coordinates. Also, the contours for brightness temperatures are added, and below there is colorbar for T_b in mK. The

3D plots showing brightness temperatures of this loop and its surrounding, at the same frequency of 1420 MHz, we show in Figs. 2 and 3.

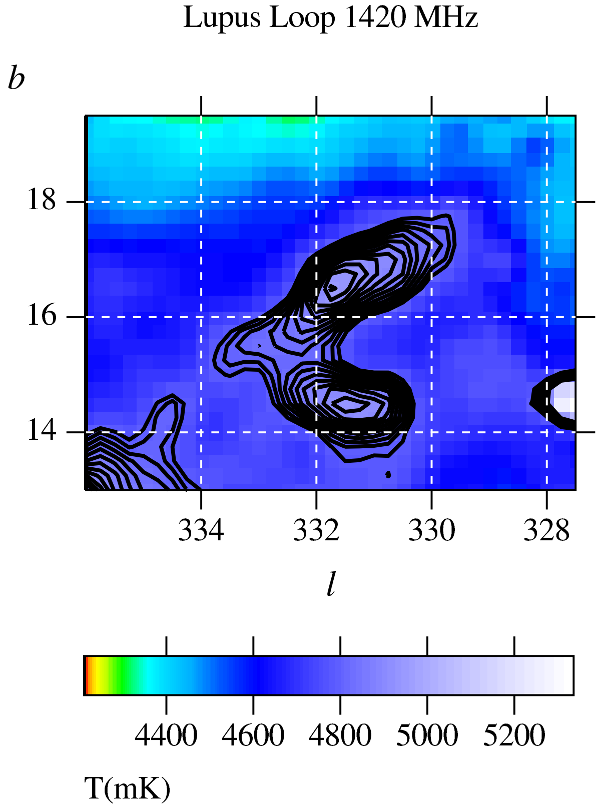

Figure 1: The area of Lupus Loop at 1420 MHz, with brightness temperature contours from 4.78 K to 4.96 K with step of 15 mK. Below, the colorbar is given for brightness temperatures in mK.

3. RADIO SPECTRAL INDEX DISTRIBUTION

Method of calculation is described, in detail, in Borka Jovanović (2012) and references therein. The method we have developed for large Galactic radio loops I-VI (Borka, Milogradov-Turin & Urošević (2006), Borka (2006), Borka (2007), Borka, Milogradov-Turin & Urošević (2008), Borka Jovanović & Urošević (2010) and Urošević & Borka Jovanović (2011)), we applied to angularly large SNRs: Mon, Cyg, HB 21 (Borka Jovanović & Urošević (2008), Borka Jovanović & Urošević (2009a,b), Borka Jovanović & Urošević (2010), Borka Jovanović & Urošević (2011), Borka Jovanović & Urošević (2011) and Borka, Borka Jovanović & Urošević (2012)), but also to the extragalactic radio sources: 3C 349, NGC 6251 (Borka Jovanović et al. (2012) and Borka Jovanović et al. (2013)).

Our motivation is to investigate the nature of emission for this SNR (thermal or non-thermal). If we express the flux density S_ν of some source as a function

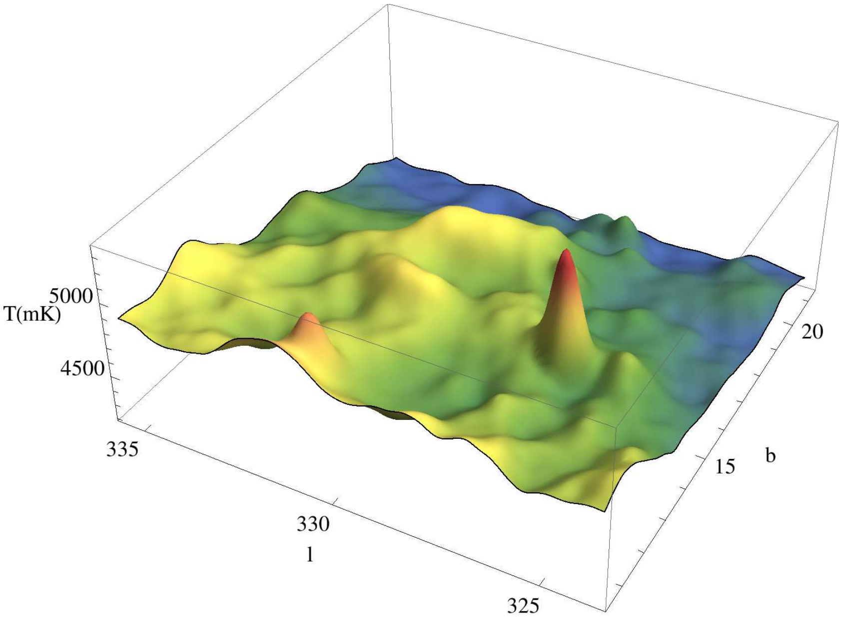

Figure 2: Lupus Loop and its surrounding at 1420 MHz. The brightness temperature is given in mK.

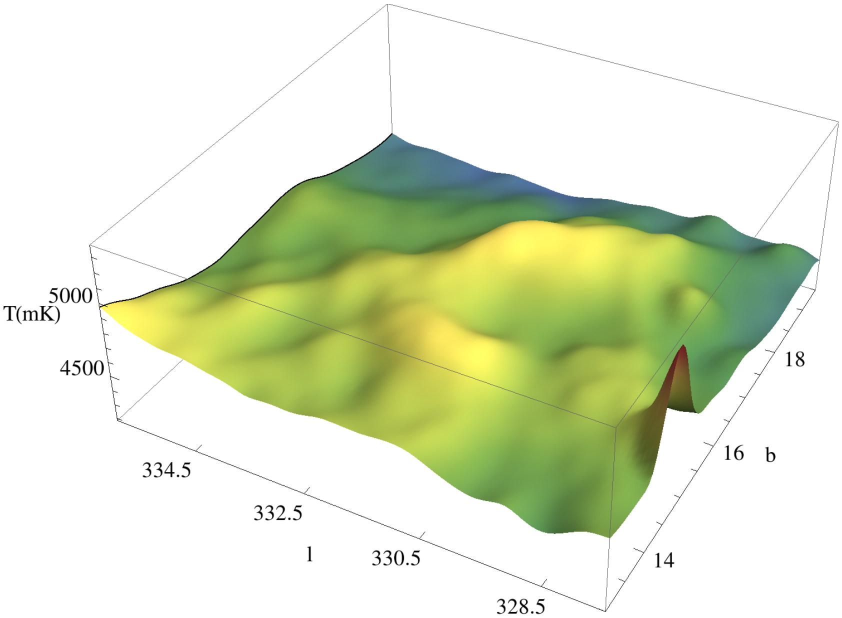

Figure 3: The same as Fig. 2, but for area closer to Lupus Loop.

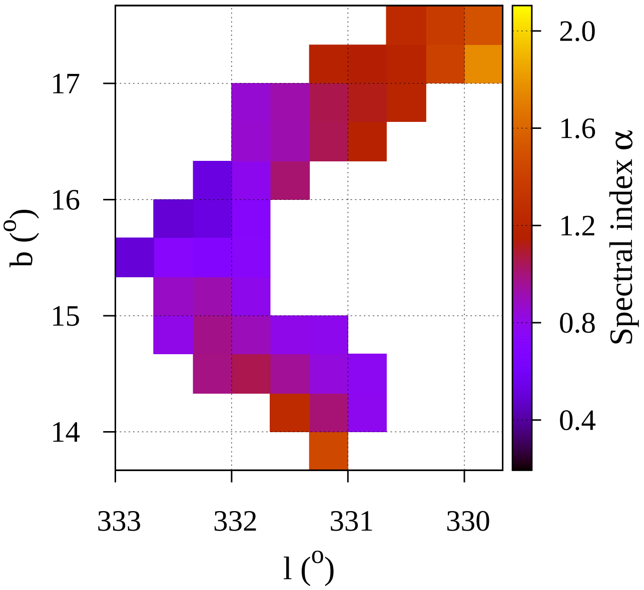

Figure 4: Radio spectral index distribution across the face of the Lupus Loop.

of frequency ν, we can define spectral index α in the following way: $S_\nu \sim \nu^{-\alpha}$. Its value could be then obtained as the slope in: $\log S_\nu = -\alpha \log \nu$, assuming that we have observations at two frequencies, at least. The obtained mean value of the radio spectral index between 408 and 1420 MHz is $\alpha \approx 0.95$, and it confirmed non-thermal emission of radiation for this source. The corresponding radio spectral index distribution is shown in Fig. 4, indicating that the greatest variations of α could be expected near the ridges of the loop.

When comparing our value for α with earlier results, these new observations yielded a greater value. Milne (1971) calculated spectral index between the following frequencies: 160, 408, 635, 1410, 1614, 2700 and 5000 MHz, and obtained mean value $\alpha = 0.38$, while Milne & Dickel (1974) used frequencies 1410, 1660 and 2700 MHz which resulted in $\alpha = 0.5$, although they mentioned that conclusions about Lupus Loop are uncertain and that more data were required. Our result is larger than the typical value for Galactic SNRs, but in Green's catalogue for spectral index about $\alpha \approx 0.5$ it is mentioned that it is not precisely determined, even a question mark is put as a notice that it should be recalculated. Probably previous authors took into account wider area for Lupus Loop (loop + part of the background) and in that way they lowered the brightness temperature of the loop and the value of mean spectral index. Also, we can notice tendency that more recent observations give higher value of α than previous. Because variation of spectral index over the loop is rather big, we think that distribution of spectral index over the loop is more adequate in description of the loop than mean spectral index. From our Fig. 4 it can be seen that most part of the loop's area has radio spectral index between 0.4 and 0.8. Greater values are connected with its ridges, and then as a whole it gives the mean value 0.95.

4. CONCLUSIONS

As we showed earlier (Borka Jovanović 2012 and references therein), the method for defining a loop border and for determining the values of temperature and brightness, which we developed for main Galactic Loops I-VI, could be applicable to all SNRs.

We used the spectral index to study the radiation mechanism of this radio source. The value of the radio spectral index $\alpha > 0.1$ confirmed non-thermal emission of radiation for this source. These new observations yielded value of α greater than Milne & Dickel (1974).

Besides the nature of the radiation, we also showed how spectral index varies across the face of the remnant.

Acknowledgments

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Publ. AOB No. 94 DAS No.1 DepAstro No.21 (2016), 183 - 188*PhD Thesis*

STATISTICS OF LANGMUIR WAVES ASSOCIATED WITH TYPE III SOLAR RADIO BURSTS

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Abstract. Sixteen years of radio, waves and particles data recorded by the Wind spacecraft are examined searching for type III solar radio bursts observed *in situ*. Applying rigorous criteria, a data set of 36 high-quality events is selected. With such a numerous data set, which is statistically representative of the studied phenomenon, it is possible to constrain observationally and with a better confidence the type III generation models. For each of the events, the precise shape of the Langmuir wave power distribution observed in the spectral domain is determined. These observed distributions are modeled by a Pearson system of probability distributions. It is shown that the probability distributions of the logarithm of the Langmuir waves power spectral density belong to three "main" types of Pearson's probability distributions: type I, IV and VI. In addition, the effects of the instrumental integration time of the Wind radio receivers on the observed Langmuir wave power distributions is modelled. The results imply that it is not possible to conclude definitively, that the distribution of the Langmuir waves energy in the real temporal domain is lognormal, as it is predicted in some theories as the Stochastic Growth Theory by Robinson, 1992.

1. INTRODUCTION

The fact is that the Sun blows away a wind, made of material particles, whose importance is highly considerable since the whole Solar System is immersed in, and all planetary environments are shaped by it. For the space plasma physicists and astronomers, the solar wind is a challenging wide field to explore and to find a number of stunning surprises and extreme conditions which are virtually impossible to simulate in the laboratory. The only stellar wind that can be studied in detail is from the Sun, our nearest star. Thanks to the huge amount of measurements collected by ground based and space missions during the last few decades, we are closer to understanding of some natural phenomena, keeping in mind that Nature always turns out to be more astonishing than we had imagined. And yet, from the first ideas about the existence of the solar wind to the present epoch, its intrinsic nature and origin have motivated, and still motivates, much debate.

Research in this doctoral dissertation explores only a part of the puzzle. Beginning with an energetic electron beam, without going into the mechanism of its formation, we shall track it along the solar magnetic field lines indirectly observing the type III solar radio bursts – its inevitable signature in radio spectrum. The type III radio bursts are created by a conversion of electrostatic Langmuir waves into electromagnetic radiation. Along the entire trajectory, electron beam generates locally Langmuir waves in an interaction with the particles of surrounding, much slower, solar wind. But, we are able to record these waves only accidentally, rarely – that is, when the satellite is just on the path of the electron beam, so the instruments can measure products of the interaction, i.e. Langmuir waves. In particular, as the main subject, we investigate here in details this intermediate gradient of that complicated space interplay. By using well established mathematical and statistical methods we have extracted and derived parameters of Langmuir waves energy probability distribution. Expecting to verify some existing theories, the results, on the contrary, led us to a conclusion that the conversion processes from an electron beam through the Langmuir wave to the type III radio bursts are more complex than it was anticipated and incorporated in existing models.

2. LANGMUIR WAVES

In situ observations of extremely bursty waves with widely varying electric fields are quite common in space physics. Examples include Langmuir waves seen in type II and III solar radio sources, the Earth's foreshock, Langmuir, beam, and z-mode waves in polar cap and auroral regions of the magnetosphere, and electromagnetic ion cyclotron and mirror-mode waves in the magnetosheath. Fields can rapidly fluctuate by orders of magnitude leading to extremely broad probability distributions of field strength. Herein, we discus the physical meaning of a probability distribution that could stand behind the observed electric field pattern and one of the theoretical approaches, namely the Stochastic Growth Theory.

For this study the used measurements are obtained by means of four different experiments onboard the Wind spacecraft, a laboratory for long-term solar wind measurements, launched on November 1, 1994. The Wind spacecraft is placed in the solar wind, often near the L_1 Lagrangian point about 200 Earth radii in the sunward direction from the Earth. The radio and electric field observations that we analyze, and that are the main focuss of this work, have been obtained by the WAVES experiment (Bougeret et al, 1995). On this instrument the locally generated Langmuir waves are recorded by both the Time Domain Sampler (TDS) module, which captures short waveform snapshots of the waves' electric field; and by the Thermal Noise Receiver (TNR), which performs onboard spectra of the electric fluctuations in a large frequency domain including the local plasma frequency, f_{p}. While the TDS transmits to the ground, due to telemetry allocation issues, only a small part of the Langmuir waves' snapshots that are observed (generally the most intense ones), the TNR records them in the spectral domain and transmits them continuously. The TNR is a double multi-channel receiver covering the frequency range from 4 kHz to 256 kHz in 5 logarithmically-spaced frequency bands. Each band covers 2 octaves with one octave overlap. Each of these bands is divided into either 32 or 16 logarithmically-spaced channels. TNR provides rapid measurements of the plasma electric field fluctuations. In the radio domain, where the electromagnetic type III bursts are observed, we use data from the RAD1 and RAD2 radio receivers. The RAD1 frequency range, from 20 to 1 040 kHz, is divided into 256 linearly spaced channels of 3 kHz bandwidth each. The frequency range of the RAD2 radio receiver, from 1 075 to 13 825 kHz, is divided in the same number of channels as RAD1, but with 20 kHz bandwidth. For the selection of a sample event we use, in addition to the WAVES data: (1) one minute averaged measurements of the interplanetary magnetic field vector in GSE (Geocentric Solar Ecliptic) cartesian coordinates from the Magnetic Field Investigation (MFI), Lepping et al, 1995; (2) full three-dimensional distribution of suprathermal electrons recorded by the three-dimensional Plasma and Energetic Particle (3DP) Investigation, Lin et al, 1995; (3) solar wind data from the Solar Wind Experiment (SWE), Ogilvie et al, 1995, which provides three-dimensional velocity, density and temperature of the solar wind protons. All these measurements, taken simultaneously by the four experiments, allow us to perform a qualitative analysis and selection of the events of interest.

The selection procedure was performed very carefully and thoroughly in two phases. The first phase of the selection was a purely visual recognition of the events. In the second phase, proceeding with additional criteria, inadequate events selected in the first phase were eliminated.

Type III solar radio bursts are easily recognizable on dynamical spectra plots. They are intense and have fast, nearly vertical, frequency drifts from higher to lower frequencies. Looking at dynamical spectra we can see sometimes a lot of type III bursts, but only rarely do the generating electrons pass over the spacecraft so that we can observe the Langmuir waves directly, *in situ*. Locally generated Langmuir waves can be recognized as intense narrowband emissions around plasma frequency, f_{p}. The increase in electrostatic energy around f_{p} that persists on dynamical spectra throughout the day varying between approximately 10 and 40 kHz (the typical variation range for f_{p} at $\approx$ AU) is due to the quasi thermal noise observed *in situ*, Meyer-Vernet and Perche, 1989. For the selection we look for times when very sharp intensity increases around the plasma frequency occur at approximately the same time when a type III burst is observed to reach frequencies close to f_{p}.

When dealing with empirical data with significant skewness and kurtosis, the normal distribution is not the best choice for modeling. The four parameter Pearson's system of distributions is a better choice. It represents a wide class of distributions with a wide variety of shapes, and thus provides more accurate representations of the observed data. On the other hand, it includes, as special cases, some well known distributions (normal, beta, gamma, Student's t-distribution etc.). Karl Pearson (1895) defined this distribution system by the following first order ordinary differential equation for the probability density function $p(x)$:

$$-\frac{p'(x)}{p(x)} = \frac{b_0 + b_1 x}{c_0 + c_1 x + c_2 x^2} \tag{1}$$

where b_0, b_1, c_0, c_1 and c_2 are five real parameters. After normalizing the fraction with any of them, only four independent parameters remain. The form of the solution of this differential equation depends on the value of these parameters, resulting in several distribution types.

The classification of distributions in the Pearson system is entirely determined by the first moment (mean–μ_1) and the next three central moments (variance–μ_2, skewness–μ_3 and kurtosis–μ_4). Pearson proposed two dimensionless parameters, i.e. the two moment ratios associated with the square of the skewness (β_1) and kurtosis (β_2):

$$\beta_1 = \frac{\mu_3^2}{\mu_2^3}, \quad \beta_2 = \frac{\mu_4}{\mu_2^2}. \tag{2}$$

These two parameters characterize the asymmetry and the peakedness of the distribution, respectively, and entirely determine the type of the Pearson distribution system through one parameter, κ, defined as:

$$\kappa = \frac{\beta_1(\beta_2+3)^2}{4(2\beta_1-3\beta_1-6)(4\beta_2-3\beta_1)}. \tag{3}$$

For $\kappa < 0$, $0 < \kappa < 1$ and $\kappa > 1$, the distributions are called type I, type IV and type VI, respectively. These three cases are known as "the main types" because they occupy areas in the (β_1, β_2) space, contrary to the other types which are represented by lines or points. Type III ($\kappa = \pm\infty$) lies on the boundary between type I and type VI. Type V ($\kappa = 1$) lies on the boundary between type IV and type VI. If $\kappa = 1$, an additional condition is needed for the classification. The distribution is classified as type II if $\beta_1 = 0$ and $\beta_2 < 3$, type VII if $\beta_1 = 0$ and $\beta_2 > 3$, and as a normal, also known as type XI, if $\beta_1 = 0$ and $\beta_2 = 3$.

When the type of the Pearson distribution is specified, all parameters (three or four, depending on the type) of the distribution can be determined from the mean, variance, skewness and kurtosis, i.e. from the first four moments.

3. RESULTS

Up to now, only a few studied cases of *in situ* type III bursts have been reported in the literature. The intent of this research was to examine statistically in details the basic and general characteristics of Langmuir waves associated with type III solar radio bursts and electron beams responsible for their generation, all observed *in situ* simultaneously. Thus, we have built an extensive set of type III events detected *in situ* by the Wind spacecraft over 16 years of observations. For each event, all the three of the Langmuir waves, the associated energetic electrons and the type III radio bursts are present. This is the first time that such an exhaustive data set is built, which can be used for further statistical analysis.

For each of the 36 events from our set we have constructed accurate Langmuir waves power distributions by previously correctly removing the background. A Pearson type I distribution seemed to be the best choice to fit the distribution of the logarithm of the electric field power provided at TNR's output. It has to be noted that the obtained Pearson distributions are characterized by an asymmetry in the direction of large electric field powers, a result in qualitative agreement with the one obtained by Bale et al (1997) in the terrestrial electron foreshock. In order to explore the meaning and the possibility of a physical exploitation of these electric field probability distributions, we examined the effect of the TNR instrumental transfer function and integration time on a Langmuir wave field which is known to be composed of short duration wave packets. Numerical simulations reproducing the response of TNR to various types of input Langmuir waves power distributions and for different wave packet frequency rates are performed. By comparing the amplitudes of variations of the simulated output distributions with those derived from Wind observations, we can conclude that the best agreement between simulations and observations is achieved when:

1. the shape of the input probability distributions is rather Pearson I or lognormal, but not a power law which should be definitively excluded;

2. the wave packets rate (λ) lies between 0.1 and 1;
3. the maximum value of the input wave packet amplitudes is about $5\times10^{-3}\mathrm{V\,m^{-1}}$.

A consequence of the nature of the Langmuir wave packet field and of the simulations is the fact that the power in output of the TNR is actually smaller than the "instantaneous" power in the wave packets. By examining the maxima of the input Langmuir waves power in the case of lognormal or Pearson distributions with the maxima of the Wind TNR output distributions, it appears that there is an overall normalization factor of about 100 that should be applied to the Wind data in order to retrieve the actual Langmuir waves power.

In further examination we have found preliminary relations between the Langmuir waves power, the electron beam fluxes, the energies and the densities. By using additional selection criteria, we extracted 19 events from the data set of 36 events used in previous analysis, taking those where an increase of electron fluxes was detected by 3DP instrument.

1. We found a strong linear dependence between logarithms of electron energies and their fluxes. The value of power-law index was found to be -2.47 ± 0.06. This result is in good agreement with the results obtained by Krucker et al (2009) for a statistical survey of the spectral shapes of 62 solar impulsive electron events detected within 1 to 300 keV, not necessarily accompanied by type III radio bursts, and Lin et al (1982) for nine events seen within 10 keV to 10 MeV almost all accompanied by type III radio bursts.

2. For variations of the Langmuir waves power as a function of the energy of the beam electrons, the Langmuir waves power is clearly an increasing function of electron energy within the range $\sim$ 2 to 7 keV. Above this energy, Langmuir waves power is presenting a "plateau" staying constant with energy increase. This experimental result is in quite good agreement with the simulations by Reid and Kontar (2012). The detailed comparison of our observational findings with their simulations will be the subject of a future work.

3. The next aspect of the relations between Langmuir waves power and energetic electrons examined in this research, was the relation between the normalized Langmuir waves power and the electron beam number density (n_b). The rate at which the Langmuir waves are generated (inverse of the quasilinear relaxation time) is roughly proportional to the electron beam number density $\tau_\mathrm{QL}^{-1}\propto n_\mathrm{b}(\sqrt{n_\mathrm{e}})^{-1}$. We have observed the proportionality up to a value of 10^{-10} for this ratio, where it reaches a maximum and then decreases. But, the expected dependence has not been found. Several reasons can be the cause for not obtaining the expected functional dependence. This result may be biased by instrumental effects, so it needs further consideration.

4. The relation between electromagnetic radiation in type III radio bursts and electrostatic radiation of Langmuir waves was tested for the type III radiation at the first harmonic of the plasma frequency, $2f_\mathrm{p}$. A rather not too strong linear dependence (in logarithmic scale) with slope of 0.45 and correlation coefficient 0.6 is found, but we consider it good enough, taking into account that the

background in type III radiation was not removed. This is the first observational statistical evidence of the proportionality between the electromagnetic radiation in type III radio bursts at $2f_{\rm p}$ and the electrostatic radiation of Langmuir waves ($P_{2f_{\rm p}} \propto P_{\rm LW}$).

These statistical results, obtained directly from the measurements, can be used as a reliable direction guidance for theoretical work, in understanding limitations of existing instruments and in construction of instruments for future missions, as well as in numerical simulations, comparison with solar flares X-ray, γ-ray, ground based radio, optical measurements etc. Additionally, this work is indirectly related to the acceleration of solar energetic electrons: the electron beams are source of electromagnetic emission, therefore the radio bursts can be used to track the escaping electrons from the Sun into the interplanetary medium. Furthermore, they provide a possibility to investigate the acceleration of electrons during a non-linear stage of the beam-plasma instability to the energies greater than the energies at which they were injected.

The research work on the data set of 36 high-quality events, selected for the research, is far from being exhausted. There is a plenty of room for the continuation of the investigation and improvements. For example, it is necessary to refine the analysis already done in many aspects; to understand the instrumental effects on the electron beam number density; to find the relation between the total power of Langmuir waves and total power of type III radio bursts; to improve the density model of interplanetary medium, and much more.

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SEARCHING FOR CHAOTIC PATTERNS IN THE X-RAY LIGHT CURVES OF AGN

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Abstract. We explored short-term X-ray light curves of several Type I active galaxies from XMM - *Newton* in order to search for signatures of low-dimensional chaotic behavior. For our analysis we used 8 light curves of 4 AGN, each consisting of a total of ~ 2000 to ~ 5000 equidistantly located points. The correlation integral method was applied to search for chaos. The preliminary results show possible indications for the presence of a low-dimensional attractor ($D < 5$) in some of the light curves, however the results are not entirely conclusive.

1. INTRODUCTION

Time series of many astrophysical objects, including AGN, show variability patterns that can often be described as "random" and "unpredictable". An example of "true" random behavior is e.g. the *Brownian* motion, where the dynamical system has an immensely large number of degrees of freedom, being in order of the number of particles in the liquid. In addition, however, there are cases of dissipative systems, where the dynamics is governed by only a few (3 - 5) degrees of freedom (variables), yet the behavior appears to be "random" or "chaotic". In the famous *Lorenz attractor* case (Lorenz, 1963), a system of $N = 3$ non-linear differential equations has a solution, which once entering some volume of the phase space, stays bound and never leaves a sub-space of (non-integer) dimension $d < N$. These solutions are so called "strange attractors" and such a behavior is often described as "deterministic chaos". Trajectories of a strange attractor evolve into a finite volume in the phase space, never returning to the same points. The divergence between two close trajectories increase exponentially in time and the long-term predictions are impossible. Consequently, each variable of a strange attractor system, represented as function of time, can mimic random behavior.

To check if the short-term X-ray variability of AGN could possibly be governed by a low-dimensional dynamical system, instead of a truly random process, we applied the *correlation integral* (CI) method (see Vio et al., 1992; Lehto et al., 1993; Provenzale et al., 1994) to XMM Newton publicly available time series of several AGN. This method is based on the construction of new (empirical) phase space from the available

Table 1: The list of used objects.

Object	*Observatory*	*Reference*
Akn 564	XMM-Newton	Vignali et al., 2004; McHardy et al., 2007
MCG 6-30-15	XMM-Newton	Vaughan & Fabian, 2004
Mkn 766	XMM-Newton	Mason et al., 2003
NGC 4395	XMM-Newton	Vaughan et al., 2005

N discrete data points. The data set (e.g. the light curve) is separated into strings of length d. Each string can be considered as a d-dimensional vector (X_i), embedded in the d-dimensional empirical phase space. The number of vector pairs with a distance smaller than r, as a function of r, is computed for different d and related to the total number of pairs (n_p) for that d. Thus, the correlation integral can be written as:

$$C_d(r) = \frac{1}{n_p} \sum_{i,j=1;j>i}^{N} \Theta(r - |X_i - X_j|), \tag{1}$$

where Θ is the *Heaviside* function. So, if the dimension of the attractor is D, then:

$$C_d(r) \propto \begin{cases} r^d, & d < D \\ r^D, & d > D. \end{cases} \tag{2}$$

Therefore, increasing the embedded dimension d leads to saturation when $d > D$, which is used for the estimation of the attractor dimension. Generally:

$$D_c = \lim_{r \to 0} \frac{d \ln C(r)}{d \ln r}, \tag{3}$$

where D_c is the correlation dimension of the attractor and can be a non-integral value. Knowledge of D_c allows determination of the number of differential equations, describing the dynamical system, N, i.e. the first integral value, larger than D_c and therefore makes possible drawing conclusions about the physical process driving the variability. As an example, Fig. 1 shows the 3D Lorenz attractor. The left panel shows the Lorenz system, the right ones – the temporal behavior of X, Y and Z, as well as the trajectory of the solution in the Y-Z plane of the phase space. The application of the CI method for the Lorenz attractor (right) and random noise (left) is demonstrated in Fig. 2. For the former case saturation is clearly seen at a slope of about 2.06, which is the correlation dimension of the attractor.

In this paper we analyzed several segments of XMM-Newton equally spaced X-ray light curves of several AGN in order to search for the presence of low-dimensional chaotic signatures in the light curves.

2. DATA AND RESULTS

The objects we tested for chaos (listed in Tab. 1) were chosen on a basis of the availability in the literature of long enough, good quality X-ray datasets.

The results, in terms of log(CI) vs. slope are shown in Figs. 3 and 4. Although some saturation is evident for some of the light curves, we were unable to firmly

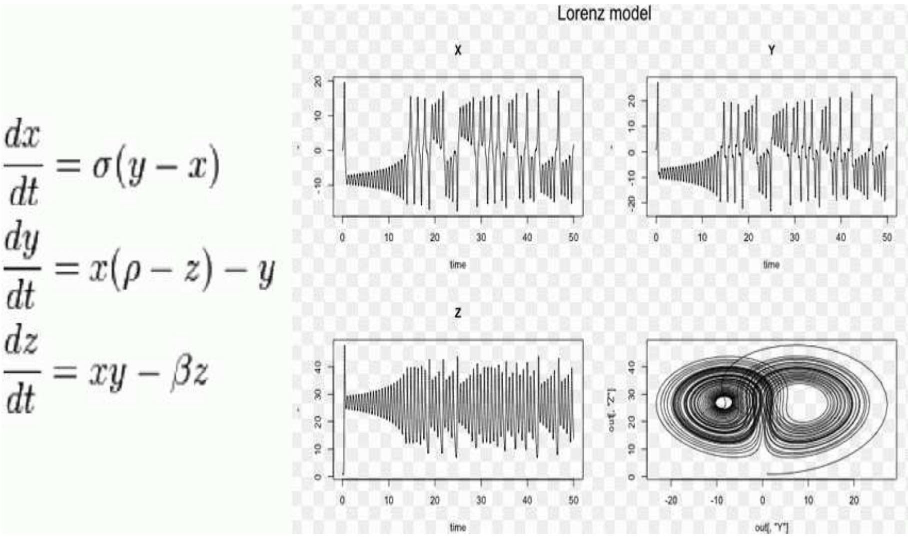

Figure 1: Lorenz attractor system and the temporal behavior of the variables (from Internet).

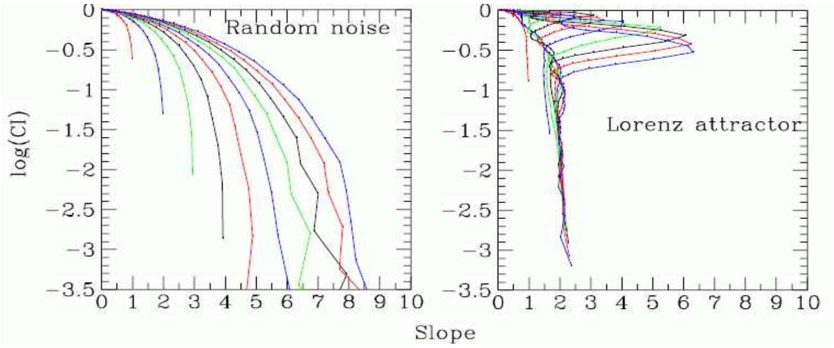

Figure 2: Application of the CI method to random noise and Lorenz attractor. Different embedded dimensions are shown with different colors. One sees that for the Lorenz attractor case there is saturation of the embedded dimensions for a slope of about $D \sim 2.06$, which is the dimension of the Lorenz attractor.

confirm the presence of low-dimensional attractor. The presence of noise in the light curves additionally complicates the situation.

Furthermore, when searching for low-dimensional chaos one is to take into account the so called *Ruelle criterion*, stating that the maximal attractor dimension that can be determined from a series of N points is $D_{max} \leq 2 \log N$, which in our case means about 5-6.

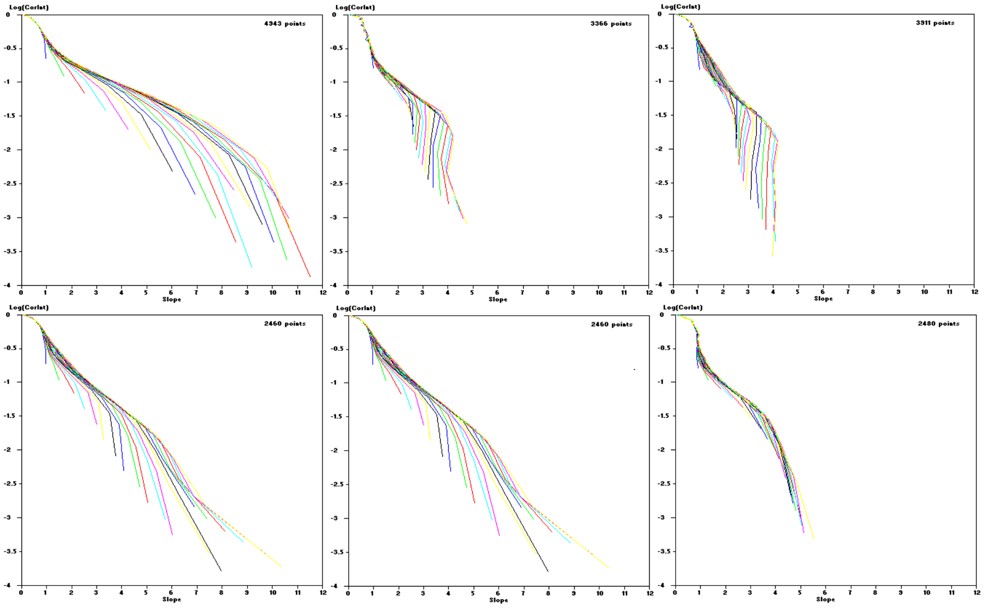

Figure 3: Log (CI) vs. its slope diagrams for 3 segments of Akn 564 X-ray LC (upper 3 diagrams) and MCG 6-30-15 (lower 3 segments).

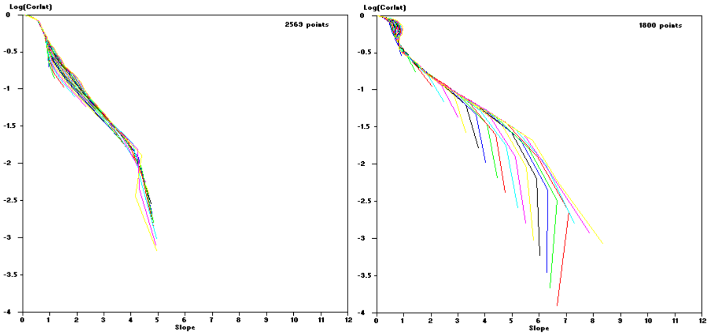

Figure 4: The same for Mkn 766 (left) and NGC 4395 (right).

3. SUMMARY

Despite we were not able to confirm the presence of low-dimensional attractor, our first results are still encouraging. If chaotic behavior is confirmed in the future studies it may have significant consequences for the accretion theory. Indeed, one may expect to find chaotic behavior in accretion systems as the process of accretion is governed only by a few parameters (equations), e.g. 5 or 6. As this is more or less our Ruelle limit, this may simply indicate that more data points are needed for a firm detection of the attractor. This work is in progress and the results are preliminary.

Acknowledgments

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UNTYPICAL PERTURBATIONS ON LF RADIO SIGNALS DURING SOLAR FLARES

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Abstract. The perturbations in the D-region induced by solar flares were studied using monitored amplitude and phase data from European very low and low frequency transmitters, in period 2008 - 2014. All data were recorded at the Belgrade station(44.85^0 N, 20.38^0 E) by the Stanford University ELF/VLF Receiver Atmospheric Weather Electromagnetic System for Observation Modeling and Education (AWESOME) installed in 2008. Statistical results show that in large number of examined events during small solar flares, the amplitude perturbation excess of NSC/45.90 kHz signal is in correlation with intensity of solar X-ray flux. The focus of this work is on the study of untypical change of perturbed amplitude on NSC/45.90 kHz signal. For example, on short path (D = 952 km) in December 2009 one C3.34 class solar flare induced great excess of perturbed amplitude $\Delta A = 4.58$ dB and reduced the effective reflection height H' from 74 km down to 71 km.

1. INTRODUCTION

The ionosphere is the part of the atmosphere and contains ionized gases, with tendency to separate in different regions, despite of the fact that different processes dominate in different latitudinal domains. D-region is the lowest region of the ionosphere, $50 \leq h \leq 90$ km. A range of dynamic phenomena occur in the D-region. Diurnal effect is result of changes in incident solar UV and EUV radiation. The passage of the seasons also has an impact on local ionospheric conditions. Both of these variations are stable and predictable. Phenomena, such as particle precipitation from the radiation belts and solar flares also influence the ionosphere, but they are unpredictable and associated with space weather. Radio signals in Very low frequency (VLF, 3 - 30 kHz) and Low frequency (LF, 30 - 300 kHz) ranges propagate from transmitters through a waveguide bounded by the Earth's surface and the D-region. This propagation is stable both in amplitude and phase and has a relatively low attenuation.

2. RESULTS AND DISCUSSION

Method of simulation VLF/LF data - Theoretical base for propagation of VLF/LF radio signals under normal ionospheric condition is developed by Wait & Spies (1964).

The influence of the D-region is taken into account by using the so called Wait's parameters: the sharpness β [km^{-1}] and the reflection height H' [km]. The NOSC, San Diego, USA has developed a computer program, the LWPC- Long Wave Propagation Capability, for simulation of VLF/LF propagation along any particular great circle path under different diurnal, seasonal and solar cycle variations in the ionosphere (Ferguson 1998). The LWPC program can take arbitrary electron density versus altitude profiles supplied by the user to describe the D-region and thus the ceiling of the waveguide. The electron density profile increases exponentially with height and can be associated with the above defined equations. The equation for the electron density in the D- region: $N_e(h, H') = 1.43 \cdot 10^{13} e^{0.15H'} e^{(\beta-0.15)\cdot(h-H')}$ derived by Thomson (1993) and we also use it in our work to calculate the vertical density profile in the range 50 - 90 km. Our intention was to calculate the electron density profile versus height, and/ or versus time during occurrence of solar flare.

Using the LWPC code the propagation path of NSC/45.90kHz signal was simulated in normal ionospheric condition, with goal to estimate the best fitting pairs of Wait's parameter β and H' to obtain values closest to the measured A and ϕ for selected day. The next step is to simulate propagation of NSC/45.90kHz signal through the waveguide in the disturbed D-region induced by additional X-ray radiation for selected moments during the solar flare development. The best fitting pairs of β and H' we used to calculate values of amplitude and phase at the receiver site.

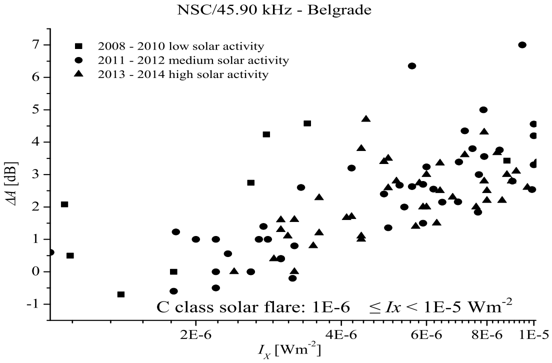

Figure 1: Measured amplitude excesses on NSC/45.90 kHz radio signal as a function of X-ray irradiance.

Statistical results -Simultaneous observations of amplitude (A) and phase (ϕ) in VLF/LF radio signals during solar flares could be applied to calculations of electron density profile. Therefore, the perturbation of amplitude was estimated as a difference between values of the perturbed amplitude induced by flare and amplitude in the normal ionospheric condition: $\Delta A = A_{per}$ - A_{nor}, where "per" means the perturbed and "nor" means normal condition. In the same way the perturbation of phase was estimated as: $\Delta\phi = \phi_{per}$ - ϕ_{nor}. During the occurrence of solar flares, classified as a minor and small flare up to the C3 class, the amplitude of the signal NSC/45.90 kHz does not have significant perturbations. A solar flare in the range from C3 to M3 classes induced an increase of the amplitude, which corresponds nearly proportionally to the logarithm of the X-ray irradiance maximum (Šulić & Srećković, 2014). Solar flare data were taken from GOES-15 satellite measurements of X-ray irradiance.

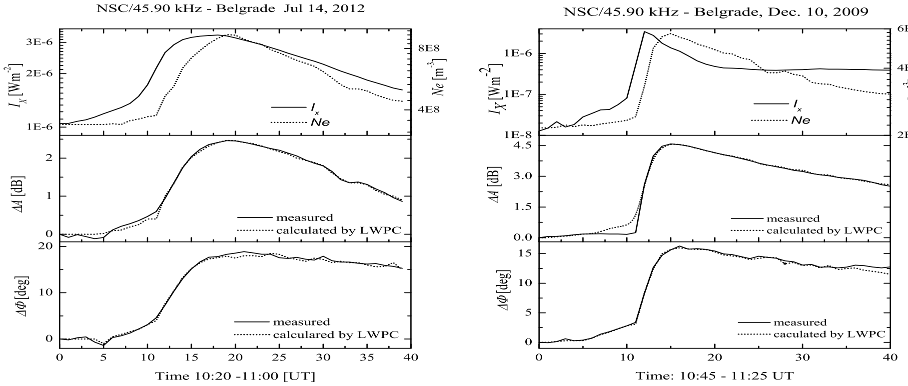

Figure 2: The time variations of the measured and calculated amplitude and phase excesses on NSC/45.90 kHz signal recorded on July 14, 2012 and December 10, 2009 (lower and middle panels). Time variation of the X-ray irradiance measured by the GOES-15 satellite and evaluated electron density profiles (upper panels).

Fig.1 shows the measured excesses of perturbed amplitude on NSC/45.90 kHz signal recorded at the Belgrade station as a function of the X-ray irradiance, in the range 1E-6 $\leq I_X <$ 1E-5 Wm^{-2}. The examined events were recorded around midday with solar zenith angle $\chi \leq 60^0$. during periods of low (2008 - 2010), medium (2011 -2012) and high (2013-2014) solar activity. There are some exceptions in measured excesses of perturbed amplitude induced by solar flares with very similar values of intensity. One of them is event caused by C3.44 class solar X-ray flare which occurred on December 10, 2009. The amplitude did not respond proportionately to the intensity of solar flare irradiance and the excess is $\Delta A = 4.58$ dB. This is an untypical perturbation of amplitude in comparison with other fourteen events induced by C3 class solar flares, with irradiance: 3E-6 $\leq I_X <$ 4E-6 Wm^{-2}. These solar flares had very similar characteristics and induced additional ionization in the D-region, causing perturbations of amplitude on NSC/45.90kHz signal. The measured excess of amplitude has values -0.2 $\leq \Delta A \leq$ 4.45 dB.

On July 14, 2012 were recorded eight solar flares and among them was C3.3 class solar flare with peak at 10:29 UT. The 1-min average values of solar flux, amplitude and phase of NSC/45.90 kHz radio signal are considered for analysis for the time interval of 40 minutes. In Fig.2a there are the X-ray irradiance, measured and calculated by LWPC code perturbations of amplitude and phase on NSC/45.90kHz signal versus time. During development of this solar flare intensity of X-ray irradiance changed from I_X =1.05E-6 Wm^{-2} to I_{Xmax} = 3.3E-6 Wm^{-2} and induced perturbations of amplitude $\Delta A = 2.46$ dB and phase $\Delta\phi = 19^0$ on NSC/45.90kHz signal. As presented in Fig.2a, the shapes of perturbed amplitude (middle panel) and X-ray irradiance (upper panel) are very similar to each other.

The bottom edge of the midday middle latitude ionosphere during summer condition was thus found to be well modeled by $\beta = 0.44$ km^{-1} and $H' = 71$ km (Thomson, 2010). With this starting pair of Wait's parameters we calculated changes in amplitude and phase on NSC/45.90 kHz signal and used them in evaluating electron density profile versus time. Figure 2a, upper panel, shows simultaneously the X-ray irradiance and calculated electron density at a reference height $H = 71$ km, as a function of time from 10:25 to 11:00 UT. It can be noticed that the time distribution of the electron density follows the variation with time of the registered solar flux on the GOES 15 satellite. Main numerical results are:

1. the sharpness increased from β =0.44 km^{-1} to β = 0.50 km^{-1};
2. the reflection height was reduced from H' =71 km to H' = 69 km;
3. at reference height electron density increased from Ne =3.4E8 to 9.36E8 m^{-3};
4. time delay of the peak electron density after the peak of X-ray irradiance is 1min.

Untypical perturbations on LF radio signal during solar flare - Few solar flares occurred during period of the low solar activity, but the effect of even weak solar flares can be seen on VLF/LF radio signals. One of them is C3.44 class solar X-ray flare, which occurred on December 10, 2009 with maximum at 10:57 UT.

Figure 2b shows time variation of X-ray irradiance (upper panel). Intensity of X-ray irradiance dramatically changed in few minutes from $I_X \sim$ 5E-8 Wm^{-2} to I_{Xmax} = 3.44E-6 Wm^{-2}. Radiation increased by $\sim$ 100 times. The middle and low panels show measured and calculated perturbations by LWPC program in amplitude and phase on NSC/45.90 kHz signal versus time, respectively. Additional X-ray radiation caused the increase of electron density in the D-region, making perturbations of amplitude and phase on LF signal. The amplitude did not respond proportionately to the intensity of solar flare flux intensity, ΔA = 4.58 dB. Simultaneously measured phase excesses are in correlation to the intensity of X-ray irradiance.

Fig.2b shows simultaneously the X-ray irradiance and calculated electron density at a reference height $H = 74$ km, as a function of time from 10:45 to 11:25 UT. It can be noted that the time distribution of the electron density follows the variation with time of the registered solar flux on the GOES 15 satellite. During solar flare characteristics of D-region were changed as:

1. the sharpness increased from β =0.30 km^{-1} to β = 0.324 km^{-1};
2. the reflection height was decreased from H' =74 km to H' = 71 km;
3. at reference height electron density increased from Ne =2.16E8 to 5.71E8 m^{-3};
4. time delay of the peak electron density after the peak of X-ray irradiance is 3min.

Discussion -During solar flare characteristics of D-region were changed as: β increased; H' was reduced; at reference height electron density increased and there is the time delay of the peak electron density after the peak of X-ray irradiance. The untypical perturbation of amplitude was caused by small solar flare C3.34 class in duration of six minutes. In December 2009 from day to day averaged intensity of X-ray irradiance was $\leq 10^{-7}$ Wm^{-2}. During this weak and short solar flare radiation increased by $\sim$ 100 times and induced larger amplitude excess according to the statistical results.

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EMISSION LINES AND INVESTIGATIONS OF THE CENTER OF ACTIVE GALACTIC NUCLEI

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Abstract. Active galactic nuclei (AGN) are hosting a super-massive black hole (SMBH) in their center, that is actively fueled by surrounding gas through an accretion disk that produces different physical processes. These give the powerful broad band continuum emission together with the prominent emission lines. Sometimes AGN contain emission lines that are very broad (line widths of several 10,000 km/s) and often show very complex and variable line profiles. Here we will summarize some tools and techniques for studying the properties of the SMBH and the geometry and physics of the surrounding gas using the broad emission lines properties and their variability.

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LITHIUM IN SMALL MAGELLANIC CLOUD: IMPLICATIONS FOR NEW PHYSICS

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Abstract. One of the main tests of the standard hot Big Bang model comes from predictions of abundances of primordial element, which have been synthesized during the epoch of the Big Bang nucleosynthesis. Though there is a general agreement, there is one more and more pressing disagreement that has not yet been resolved predicted primordial lithium abundance is about 4 times higher than what is observed in atmospheres of MilkyWay halo stars at wide range of low metallicities. To test this issue lithium was observed in the interstellar medium in the Small Magellanic Cloud. The measured abundance was found to be barely consistent with the predicted primordial value, but only very little lithium was made in the cosmic-ray interactions. However, unlike the Milky Way, the Small Magellanic Cloud has suffered a significant tidal disruption due to close galactic fly-bys. We point out that in those cases, tidal shocks can give rise to a population of cosmic rays in addition to standard galactic cosmic rays accelerated in supernova shocks. We demonstrate that significant amount of lithium can be produced in such a scenario where a small galaxy is tidally disrupted in close galactic interactions. In the specific case of the Small Magellanic Cloud, this could potentially be sufficient to make its lithium abundance also inconsistent with the predicted primordial value, leaving the new physics as the only remaining solution to this discrepancy.

1. INTRODUCTION

There are many ways to search and probe the physics beyond the standard model: hoping to see the unexpected in accelerator experiments, hoping to directly detect dark matter, or interpreting the actual detection of the unexpected as a signature of non-standard physics. An example of the "unexpected" would be the recent detection of the gamma-ray excess from the galactic center, which can be interpreted as a dark matter signal (Daylan et al. 2014), though more conventional solutions are also still possible (see e.g. Petrović et al. 2014a,b). Another way to test the non-standard physics is to search for the anomalies in the abundances of primordial elements.

Abundances of the primordial elements- hydrogen, helium and lithium-7, directly depend on the physical conditions of the early Universe and the physics that drives the big bang nucleosynthesis (BBN). The competition between the expansion rate of the Universe and rate of nuclear reactions, eventually comes down to one number that controls primordial element abundances- the baryon-to-photon ratio, or the baryon density. The WMAP (Wilkinson Microwave Anisotropy Probe) high-precision observations (Dunkley et al. 2009) of the cosmic microwave background (CMB) have marked the beginning of the era of precision cosmology because of the precision with which the baryon density is determined from the CMB, from which then primordial element abundances are determined. However, when theoretically predicted and CMB calibrated primordial abundances are compared to observations of these abundances in low-metallicity systems where the composition should be close to pristine, large discrepancies are found in some cases. Even though observations of helium, and especially deuterium abundance in low-metallicity systems match well with their predicted abundances, this is not the case for lithium. Namely, as we can see in Fig. 1, the primordial lithium abundance (7Li/H)p = $(4.79 \pm 0.96) \times 10^{-10}$ (Cyburt 2013) predicted by the standard BBN models with baryon density set by Planck (Planck Collaboration 2013), was found to be ≈4 times higher than lithium observed in low-metallicity halo stars where abundances show a trend in the form of the so-called "Spite plateau" (Spite & Spite 1982) at the level $(7\mathrm{Li/H})_{obs} = (1.23^{+0.68}_{-0.32}) \times 10^{-10}$ (Ryan et al. 2000). This has been known as the "lithium problem".

2. "LITHIUM PROBLEM" ISSUES

In order to understand the issues around the lithium problem we first must know its origin. Lithium-7 is made in the big bang nucleosynthesis process but is also made in neutrino process in type II supernovae, and together with its light isotope ^{6}Li, in cosmic-ray interactions (Reeves 1970) through fusion channel $\alpha + \alpha \rightarrow^{6,7} Li + ...$ and spallation reactions on heavier nuclei $p, \alpha + CNO \rightarrow Li, Be, B + ...$ As we can see, the spallation process also results in production of other light nuclei beryllium and boron, but due to necessary presence of CNO, this process is important at higher metallicities. It is also important to note here that unlike its heavy version, light isotope ^{6}Li is only made in cosmic-ray interactions. Pre-galactic lithium abundance that is supposed to reflect the primordial value, is observed in atmospheres of old, warm metal-poor halo dwarf stars. In their famous paper Spite & Spite 1982 have shown that lithium abundance observed in many of these stars over the range of low-metallicities does not change and forms a plateau value with very little scatter. The existence of the plateau is expected for all primordial elements, if observations are made at a sufficiently low metallicity with sufficient statistics. However, as it became evident, the observed plateau is by a factor of 4 lower than the expected primordial lithium abundance. Furthermore, more observations have also found that the plateau in fact has a slight slope and also it breaks down, i.e. shows large scatter at very low metallicities.

The solution to the lithium problem is either in correcting the observed abundances by changes in stellar modeling, by accounting for some stellar or pre-stellar destruction of lithium, or in changing the prediction of primordial lithium abundance due to any non-standard physics. One of the main issue in destroying lithium in stars (due to e.g. deep mixing) is how to do it uniformly over a large range of metallicities so that

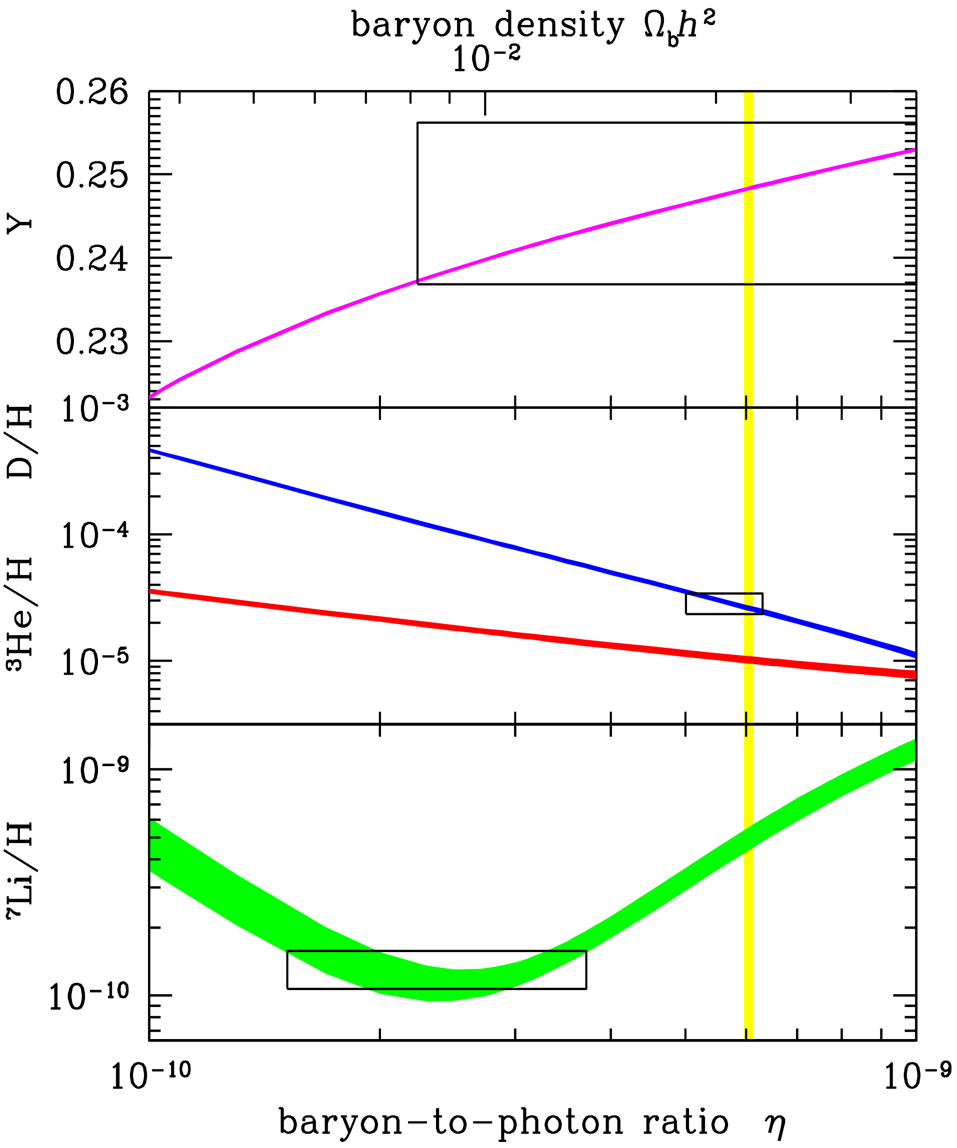

Figure 1: The so-called Schramm plot of primordial element abundances as a function of baryon-to-photon ratio and compared to abundances obtained from observations in low-metallicity systems presented as boxes (Cyburt 2013). The yellow band represents baryon density as determined by Planck Collaboration 2013.

very little scatter remains, especially when looking at the upper abundance envelope. Another issue is a worry that even this low lithium abundance observed in low-metallicity halo stars could have been contaminated (Suzuki & Inoue 2002) by post-BBN production of lithium in various processes such as for example interactions of cosmological cosmic rays accelerated during the large-scale formation process (Prodanović & Fields 2007). If there is any post-BBN and pre-galactic production of lithium that extra abundance will add to the lithium content in halo stars and must be corrected for when comparing it to the primordial lithium abundance. Given that the observed abundance is already lower than the primordial one, any additional lithium production channel would only make the problem worse. One way to constrain lithium production by any cosmic-ray population is to look into gamma rays since there is a unique and direct connection between expected gamma-ray emission and lithium production due to cosmic ray interactions (Fields & Prodanović 2005). Extragalactic gamma-ray emission due this cosmological cosmic-ray population was recently constrained (Dobardžić & Prodanović 2014) and can thus be used to constrain pre-galactic lithium production by this cosmic-ray population, which is now, due to lower level of the extragalactic gamma-ray background detected by Fermi-LAT lower than previous estimates (Prodanović & Fields 2007) but still allows for significant fraction of the lithium plateau to be made by cosmological cosmic rays (Dobardžić & Prodanović 2015).

3. NEW SITES FOR PRIMORDIAL LITHIUM OBSERVATIONS

One of the most useful tests of the nature of the lithium problem would be to measure lithium in the gas phase, rather than is stellar atmosphere, in some low-metallicity system. One such potentially suitable target system was suggested to be the high velocity cloud Complex C (Prodanović & Fields 2004). Unfortunately it turned out that there is no suitable line of sight along which lithium can be measured in this gas cloud, and the search for another site where lithium can be measured in gas phase has continued. Recently, Howk et al. 2012, have made the first observation of extragalactic gas-phase lithium. They have observed lithium in the Small Magellanic Cloud at metallicity $approx 1/5$ of solar. The abundance they measured was found to be consistent with prediction of primordial lithium abundance. However, in the system at fifth of solar metallicity, significant post-BBN production of lithium should have happened due to galactic cosmic-ray nucleosynthesis, and thus, the found lithium abundance is in tension with galactic chemical evolution models. Moreover, isotopic ratio of ^{6}Li/^{7}Li was found to be anomalously high, at the level of $^6\mathrm{Li}/^7\mathrm{Li} \approx 0.13$ (Howk et al. 2012). Given that ^{6}Li is only made in cosmic-ray interactions, high isotopic ratio implies a non-standard cosmic-ray history of the system.

However, it has been known that the Small Magellanic Cloud (SMC) has experienced close galactic fly-bys and tidal disruptions (Diaz & Bekki 2011). Galactic interactions can cause large scale tidal shock waves (Cox et al. 2006), which would in turn, result in particle acceleration and in a population of tidal cosmic rays (TCRs). As mentioned, any cosmic-ray population, additional to standard galactic cosmic rays (GCRs) accelerated in supernova remnants, would be contaminant when lithium abundance measured in low-metallicity systems is compared to its expected primordial abundance. Besides lithium, cosmic-rays also produce beryllium and boron, however at low-metallicities, spallation channel would be suppressed compared to fusion channel, so lithium would be affected most.

4. LITHIUM PRODUCTION BY TIDAL COSMIC RAYS

In Prodanović et al. (2013) we have explored the possibility of extra production of lithium by tidal cosmic rays, especially in the case of the Small Magellanic Cloud where lithium has recently been measured. The main question we tried to answer is whether it is possible energy-wise and sufficient flux-wise for close galactic fly-bys between the SMC and Large Magellanic Cloud and/or Milky Way to result in such tidal cosmic ray flux which would make comparable amount of lithium as standard GCRs have made over the history of the SMC. We have shown that the kinetic energy between SMC and the Milky Way at their current separation, is about 50 times higher than the energy needed to produce all lithium observed in the SMC. Continuing further, we have made a toy model comparing tidal shock that would arise due to a close galactic fly-by to a large-scale supernova shock. The main difference between cosmic rays accelerated in tidal shocks and supernova shocks then comes from the scale of the shock itself and from occurrence frequency where tidal shocks would arise due to a few episodes of close encounter while supernova shock are constantly occurring throughout the history of the SMC as long as there is ongoing star-formation.

As the result of our toy-model we have shown that in order for TCRs to produce same amount of lithium in isolated close fly-by events as GCRs have accumulated over the history of the system, the fraction of the entire gas of the system that needs to be shocked (so that particles get accelerated!) is a function of

$$M_{TCR}/M_{gas} \propto M_{Fe,SN}^{-1} y_{Fe} \tau_{TCR}^{-1} n_{ISM} R_{SNR} \tag{1}$$

mass of iron ejected by one supernova $M_{Fe,SN}$, metallicity y_{Fe} and density n_{ISM} of the system, radius R_{SNR} of the supernova remnant up to which GCRs are efficiently accelerated (note here that we have assumed the same efficiency in accelerating TCRs as well as GCRs), and the lifetime timescale of tidal cosmic-ray population τ_{TCR}. We have further found that for a system at solar metallicity it would be sufficient to shock the entire gas of the system 8 times in order for TCRs to produce as much lithium as GCRs have produced, while in the case of the SMC which is at 1/5 of solar metallicity, the entire gas of the SMC would need to be shocked only 2 times to achieve this, and we know that SMC has suffered at least 2 interactions with the LMC and one with Milky Way. Thus, production of lithium via TCRs can potentially be very important, especially in the case of the SMC where the first gas-phase measurement of lithium abundance outside our own galaxy has recently been made in order to test the lithium problem. In order to test this, one must first test all of the underlying assumptions. While some of our assumptions were reasonable and are not expected to change much, the main caveat comes from the TCR lifetime timescale assumption which can vary by an order of magnitude and can the shocked gas mass ratio. This has to be tested in numerical models and will be the topic of the followup work.

One other way to test any additional production of lithium would be to look into the isotopic ratio. As already mentioned, the isotopic ratio detected in the SMC was found to be anomalously high. Namely, isotopic ratio was observed to be at the level $^{6}\mathrm{Li}/^{7}\mathrm{Li} \approx 0.13$ (Howk et al. 2012), which is consistent with the isotopic ratio of $^{6}\mathrm{Li}/^{7}\mathrm{Li} = 0.1$ (Prodanović et al. 2013) that would be expected if 50% of total lithium abundance was made by TCRs, as opposed to the expected isotopic ratio of $^{6}\mathrm{Li}/^{7}\mathrm{Li} = 0.06$ where only lithium production by GCRs is included. Another observational way to test for the presence of TCRs would be to look into interacting systems of galaxies, especially into the smaller of the galaxies, and search for anomalously high non-thermal emission in radio frequencies that is inconsistent with that galaxies star-formation rate. Later on, tidal disruptions could trigger star-formation and result in an episode of enhanced star-formation in the smaller of the galaxies, but prior to that, TCRs should be accelerated resulting in enhanced synchrotron emission. Though further investigation is needed, our first estimates indicate that this might be true in the case of M51.

5. CONCLUSION

The discrepancy between expected primordial abundance of lithium and that observed in low-metallicity halo stars is an outstanding problem that can have important consequences for our understanding of the big bang nucleosynthesis and cosmology in general. One of the main issues related to the origin and nature of this problem is the fact that lithium has only been observed in stellar environment, where results depend on stellar modeling. The only measurement of lithium in a different low-metallicity environment was recently done in the interstellar medium of the SMC metallicity 1/5 of solar. Although observed SMC lithium abundance was found to be consistent with expected primordial abundance, this is only true if there was very little post BBN production of lithium in cosmic-ray nucleosynthesis and other processes, which is in strong tension with chemical evolution models of the SMC. Moreover, as we have pointed out in Prodanović et al. (2013), SMC is a system that has experienced a few close galactic fly-bys, which could have given rise to tidal shock waves in the SMC. Consequently this would lead to cosmic-ray acceleration and additional lithium production, and we have shown that in the case of the SMC, the entire gas of the SMC would have to be shocked only twice for TCRs to produce as much lithium as GCRs have produced. Even though our results come from a simple, but instructive toy model, we have shown that the existence of a tidal cosmic ray population might be important for smaller interacting galaxies.

If indeed significant fraction of the lithium in the SMC comes from an additional source like TCRs, this would mean that SMC lithium measurement is also inconsistent with predicted primordial abundance and consistent with lithium observed in low-metallicity halo stars, implying that the solution to the lithium problem should be sought in the form of the new physics which would either result in a lower primordial lithium abundance or would destroy lithium at very low metallicity, before halo stars were born. Furthermore, enhanced non-thermal emission due to a population of cosmic rays, which is not related to supernova rate would impact the far infrared-radio correlation (see e.g. Lacki et al. 2010), determinations of star-formation rates and have other important consequences. Thus, this is an issue that has to be further investigated in more detail, both numerically and by looking at surveys of interacting systems in different wavelengths.

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MASS ESTIMATION OF THE ELLIPTICAL GALAXY NGC 5846

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Abstract. Determining the masses of early-type galaxies remains a challenging task, especially probing the masses of their outer halos. In this contribution we constrain the mass of the well-studied elliptical galaxy NGC 5846, the brightest galaxy in the group. The isolation of the NGC 5846 Group is what makes it favourable for using different "test-particles" as mass tracers. We use the "tracer mass estimator" (TME) method on several different families of tracers such as globular clusters (GCs), planetary nebulae (PNe) and dwarf galaxies, thus probing the total dynamical mass to much larger radii than by using stellar kinematics. The mass of NGC 5846 is also assessed from the X-ray observations of hot coronal gas and compared to the results obtained using the TME methodology.

1. INTRODUCTION

Observations of cool gas through its 21-cm line emission in spiral galaxies established that these galaxies reside in massive dark halos. Since early-type galaxies lack this powerful tracer of overall mass distribution, their masses, and especially masses in their outer parts that are expected to be dominated by dark matter, are not so well constrained. Possible approaches in probing for the dark-matter halos in ellipticals include the study of stellar kinematics, X-ray halo properties, tracer methods and gravitational lensing. Stellar kinematics is very difficult to use in the outer parts because they are very faint, and various works suggest that dark matter is not dominant in the inner parts of early-type galaxies, to approximately $2R_e$, where R_e is the effective radius (see, for example, Deason et al. 2012; Samurović, 2012). On the other hand, the abundance and quality of the data available on various tracer populations are increasing.

In order to tackle the issue of early-type galaxies masses, we chose the elliptical NGC 5846 because of its favourable position. Elliptical galaxies are difficult to find in isolation, and NGC 5846 is no exception – it lies at the the center of a group of overwhelmingly ellipticals, and is the third biggest galaxy in the Local Supercluster. Nevertheless, NGC 5846 is found in relative isolation; there are no background sources, and also not that many foreground ones. This galaxy is thus very well observed. Its effective radius is equal to 61 arcsec (see Pota et al. 2013, hereafter P13).

In determining mass of the elliptical galaxy NGC 5846 we mainly concentrate on an approach based on the use of various tracers, "Tracer Mass Estimator" (TME) method, proposed by Evans et al. 2003. We used the following tracer populations:

globular clusters (hereafter GC, SLUGGS survey, P13), planetary nebulae (hereafter PNe, Coccato et al. 2009) and dwarf galaxies (hereafter dwE, Mahdavi et al. 2005). Its mass was also assessed using the X-ray methodology (Machacek et al. 2011). In Section 2 we present the methodology that we use and briefly compare our results with the results coming from the Jeans modelling; we present our conclusions in Section 3.

2. METHODOLOGY AND RESULTS

2. 1. TRACER MASS ESTIMATOR METHOD

TME is a simple method that is derived to deal with tracer populations in particular. It is a generalization of projected mass estimator methods (Bahcall & Tremaine 1981) for the most common case when the number density of tracer population does not follow the dark matter density. The estimate of the enclosed mass is derived based on the projected positions and line-of-sight (LOS) velocities (with respect to the systemic velocity) for a given population of tracers. The population of tracers is assumed to be spherically symmetric and with a number density that obeys

$$\rho(r) = \rho_0 \left(\frac{a}{r}\right)^{\gamma}, \tag{1}$$

for three-dimensional radius spanning from r_{in} to r_{out}.

Here a is a constant, and the exponent γ is determined from a surface density of a tracer population (see below).

The enclosed mass (supported by random motions) for isotropic case is given by:

$$M_p = \frac{C_{\text{iso}}}{GN} \sum_i v_{\text{losi}}^2 R_i, \tag{2}$$

where C_{iso} has a form

$$C_{\text{iso}} = \frac{4\gamma}{\pi} \frac{4-\alpha-\gamma}{3-\gamma} \frac{1-(r_{\text{in}}/r_{\text{out}})^{3-\gamma}}{1-(r_{\text{in}}/r_{\text{out}})^{4-\alpha-\gamma}} \tag{3}$$

for isothermal potential (gravity field is assumed to be scale-free, $\psi = -v_0^2 \log r$, see Evans et al. 2003 for details). It is reasonable to assume $r_{\text{in}} \approx R_{\text{in}}$ (the same is also true for the outermost radius), especially for larger radii.

The total mass of the galaxy must account in for the rotational component as well, given by

$$M_{\text{rot}} = \frac{v_{\text{rot}}^2 R_{\text{out}}}{G}. \tag{4}$$

We used three different populations of tracers: GCs, PNe and dwE. For all of them, the same methodology was applied, which we are going to present in detail only for the GC population, and for the other two samples only the outline of the results is given.

The GCs sample used in this paper is taken from the SLUGGS survey (P13), and it consists of 195 objects. First, we transfer from to the coordinate system fixed to the major and minor axes of the galaxy, and express galactrocentric distances as equivalent two-dimensional radius:

$$R = \sqrt{qX^2 + \frac{Y^2}{q}} \tag{5}$$

where q is the ratio between major and minor axes of the galaxy. Here we used the value from 2MASS Ks-band which is supposed to be least prone to extinction (Jarrett et al. 2003) of 0.95.

In order to extract the rotational component of the velocity from the total observed LOS velocity (with respect to the value of the systemic velocity taken from NED, Cappellari et al. 2011) the fit based on the cosine function was used (rotational velocity should change like the cosine function with the change of the phase angle in the system of the galaxy). The value of the rotational velocity that we obtained (see Figure 1) is $v_{\rm rot} = (5 \pm 24)$ km/s. Since this is consistent with zero, in our calculations we neglected the rotational component and only take into account the randomly supported component, $M \approx M_p$.

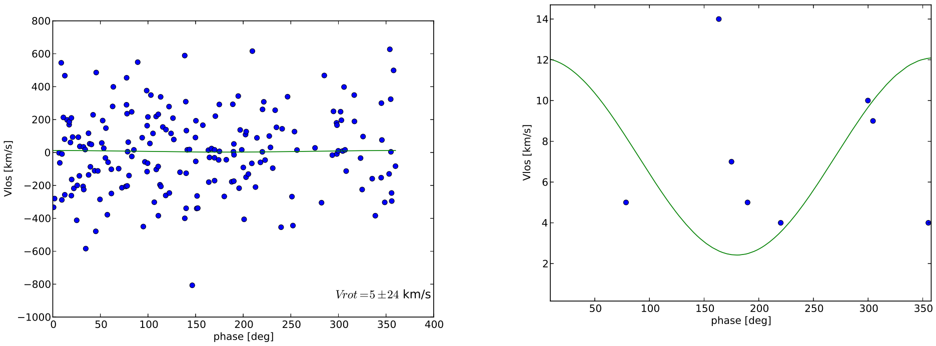

Figure 1: Left panel: Rotational velocity fitted to the observed $v_{\rm los}$, x-axis is the phase angle in the coordinate system where x-axis is fixed to the receding part of major axis. Right panel: zoomed in part of the plot in the left panel.

Surface density of GC population is shown in Fig. 2, and because we assumed that the number density is a power-low, the exponent γ is calculated from the least-square fit to the radial distribution of the objects. Here R is a two-dimensional radius, and to reconstruct the three-dimensional γ-parameter, we add one to the surface density value of the exponent. The best-fitting value is $\gamma = 2.48 \pm 0.44$.

Using this value for the exponent, and assuming $\alpha \approx 0$, we obtain the following value:

$$M_{\rm GC} = (3.4 \pm 0.2) \times 10^{12} M_\odot, \tag{6}$$

for $R \approx 10R_e$.

For the PNe population we obtained the following: $v_{\rm rot} = (-10 \pm 26)$ km/s, which is consistent with zero, so we can again consider that the contribution to the mass comes from the randomly supported component, M_p.

We calculated $\gamma = 2.46 \pm 0.21$, and used it to estimate the mass interior to $\sim 10R_e$:

$$M_{\rm PNe} = (1.25 \pm 0.02) \times 10^{12} M_\odot. \tag{7}$$

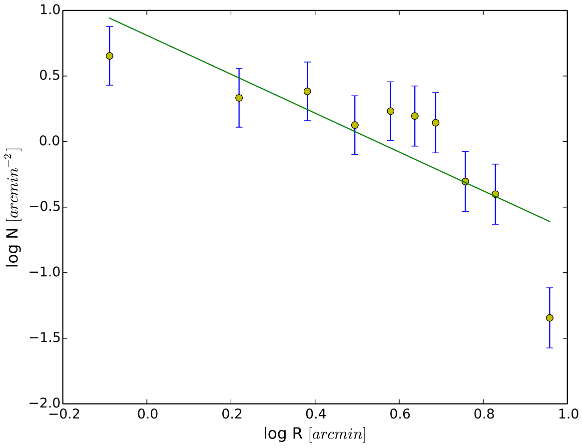

Figure 2: Surface density of the GC tracer population; $N \propto R^{-\gamma}$ is fitted.

For dwE we apply the same approach, but take into account that due to the larger radii at which those satellites reside, we are no longer probing the mass of the galaxy NGC 5846 only, but rather the gravitational potential of the group.

From the sample of 80 dwE (Mahdavi et al. 2005), we obtained the value: $v_{\rm rot} = (-92 \pm 58)$ km/s, thus here we take into account the rotational component.

Using Eq. 4 we obtain: $M_{\rm (dwE)\ rot} = (2.1 \pm 2.5) \times 10^{12} M_\odot$. Using $\gamma = 2.25 \pm 0.36$, we obtain the total mass of the group equal to:

$$M_{\rm dwE} = (6.6 \pm 0.4) \times 10^{13} M_\odot, \qquad (8)$$

at 145 arcmins.

2. 2. X-RAYS

In Fig. 3 we present the estimates of the cumulative mass and the mass-to-light ratio profile of NGC 5846 based on the X-ray methodology (see, e.g., Samurović, 2007 for details). The mean value of the temperature ($T \sim 1$ keV) is taken from Machacek et al. (2011) and is based on the Chandra observations.

2. 3. JEANS MODELLING FOR THE GLOBULAR CLUSTER POPULATION

In Fig. 4 we present the results of the dynamical modeling of NGC 5846 based on GCs. The details of the modeling are given in the contribution by Samurović (these Proceedings) and also in Samurović (2014). From Fig. 4 one can see that using the Newtonian approach, the increase of the mass-to-light ratio suggests significant amount of dark matter in this galaxy beyond $\sim 2R_e$. Using the Navarro, Frank & White (NFW, 1997) model one can fit the observed velocity dispersion throughout the whole galaxy: the parameters of a fit are given in the caption of Fig. 4.

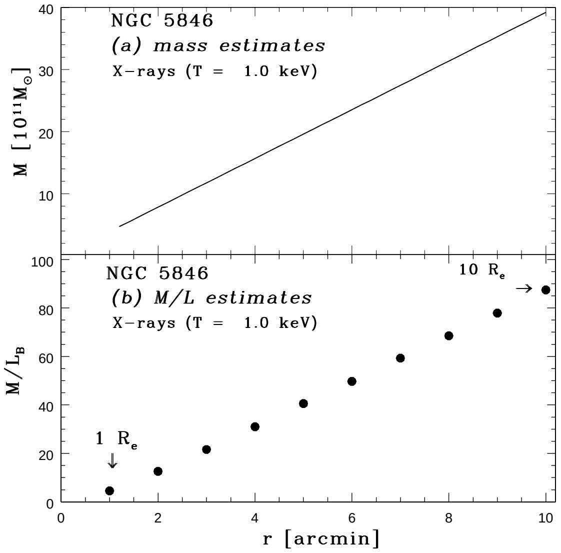

Figure 3: Upper panel: cumulative mass estimate of NGC 5846 based on the X-ray methodology is expressed in units of $10^{11}M_{\odot}$. Lower panel: mass-to-light ratio in the B-band of *NGC* 5846 based on the X-ray methodology. The estimates are given for ten positions and the innermost (at $1R_e$) and outermost ($10R_e$) points are indicated. In both panels, the value of the temperature used is $T = 1$ keV.

3. CONCLUSIONS

Our most important results are:

- We found that the TME approach (based on GCs and PNe) gives a good assessment for the mass of NGC 5846, which is also consistent with the estimate based on the X-ray methodology.
- Using the TME approach in the case of the population of dwE we get a significantly larger mass but at a significantly larger distance (at 145 arcmins; for the distance we used a value of $D = 25.0$ Mpc from Tully et al., 2009).
- Using the Jeans modelling, we confirm that a significant amount of dark matter is needed to fit the observed M/L_B beyond $\sim 2R_e$.

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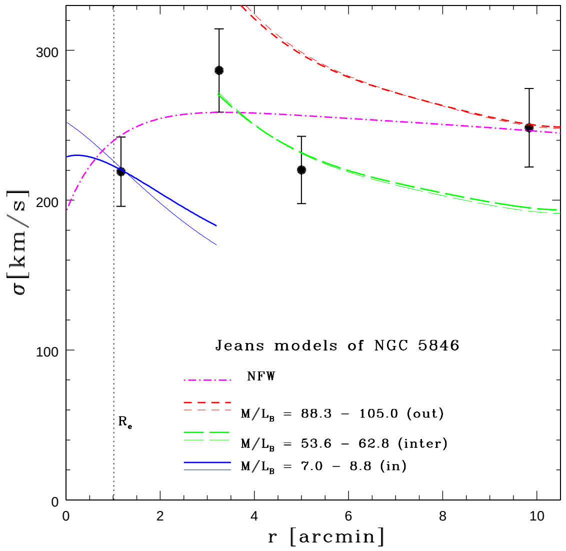

Figure 4: The Jeans Newtonian modeling of the projected velocity dispersion of NGC 5846. The thick lines are for isotropic cases and the thin lines are for fits based on $\beta_{\rm lit}$. The three regions are as follows: inner region (interior to $2R_e$, solid lines), intermediate region (between $2R_e$ and $6R_e$, long dashed lines), and outer region (beyond $6R_e$, short dashed lines). The mass-to-light ratio in these regions are $M/L_B = 7.0(8.8), 53.6(62.8)$ and $88.3(105.0)$ for the isotropic (anisotropic) cases. The thick dot-dashed line is for the isotropic NFW model for which the stellar $M/L_B^* = 7.0$, $r_s = 350$ arcsec, and $\rho_s = 0.0200\ M_\odot \mathrm{pc}^3$.

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HALO MASS FUNCTION: FROM CALCULATIONS TO COSMOLOGICAL SIMULATION AND BACK

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Abstract. One of the important ways in which we can study general distribution of the dark matter halos in Universe is through halo mass function. In this talk we will explore and discuss a means of calculation of theoretical halo mass functions and we will derive and compare several important halo mass function fits. We will discuss connection that permeates cosmological simulations and theoretically calculated fits. Theoretical fits will ultimately be compared with halo mass function derived from our cosmological pure N-body simulation. We will acknowledge that agreement on smaller redshifts is good, but, as will be seen, there is discrepancy on higher redshifts, both between different theoretical halo mass functions and from halo mass function derived from simulation.

1. INTRODUCTION

Most of the mass of matter in the Universe is in form of dark matter. It is a carrier of structure in the Universe and is organized into clusters, groups, filaments and voids dubbed "cosmic web" (Bond et al. 1996) whose building blocks are halos of dark matter. One way to examine properties of structure in the Universe, and its building blocks (halos) is through cosmological simulations.

Through the cosmological simulations we can observe formation of dark matter halos, their evolution, clustering and ultimately formation of large scale structure (Springel et al. 2006). In the current dominant, ΛCDM paradigm, small dark matter halos form and merge into larger halos and structures (eg. White 1994). Questions arise - when do the halos start to form? What is the mass range of halos? When can we expect halo of certain mass to appear in the history of the Universe? All these questions (and some more) can be answered with the halo mass function. It can be defined as number of halos in a volume of space and per unit of mass (Lukić 2008).

Halo mass function can be calculated analytically, derived empirically or directly from the cosmological simulations Lukić et al. (2007). Here we will show standard way for analytical and empirical derivation and briefly compare it to halo mass function from cosmological simulation.

2. CALCULATING HALO MASS FUNCTION

For representing and calculating halo mass function we will use the same principles as used in Lukić et al. (2007) and Murray et al. (2013). We define halo mass function as:

$$\frac{dn}{d\,lnM} = M\ \frac{\rho_0}{M^2}\ f(\sigma)\ |\frac{d\,ln\,\sigma}{d\,lnM}| \tag{1}$$

here n is the number density of the halos, M is the mass of the halos in question, ρ is the critical density of the Universe, $f(\sigma)$ is a fitting function (which can be either analytically or empirically derived) and σ is the mass variance. Basically we calculate number density in halo mass bins. Main issue here is deriving mass variance. Unlike for the variance of the density perturbations, here we are interested in mass variance across the mass bins, given as:

$$\sigma^2 = \frac{1}{2\,\pi^2}\int_0^\infty k^2\,P(k)\,W^2(kR)\,dk \tag{2}$$

where $P(k)$ is a power spectrum and $W(kR)$ is an introduced filter which we use to constrain variance over a certain mass range. Many filters can be chosen (Percival 2001), but usually top-hat filter is used, due to the fact that is robust enough and easy enough to implement:

$$W(kR) = \frac{3\ [sin(kR) - kR\ cos(kR)]}{(kR)^3} \tag{3}$$

As we mentioned, we were noting mass range, but it is obvious that top-hat filter is used against wave-number (k) and within a certain radius (R). That is because we can directly connect mass with the radius with simple equation:

$$M = \frac{4}{3}\ \pi\,\rho_0\ R^3 \tag{4}$$

To complete calculations of mass variance, obviously power spectrum calculations are needed. We use form of power spectrum that is similar to the expected form that power spectrum had during inflation after Big Bang:

$$P(k) = A\ k^n\,T^2(k) \tag{5}$$

Transfer function ($T(k)$) is used to translate power spectrum's smallest matter density perturbations across all scales. Here, n is the spectral index and A is the normalization constant, derived from mass variance retrieved for $R = 8Mpc/h$. There are several codes for the calculation of transfer function, here we use CMBfast (Seljak and Zaldarriaga 1996).

It should be clear by now that there is no direct link with time or more precisely scale factor (or redshift). Fitting function itself is derived in a way that it is insensitive to the redshift, where we introduce link to it by asuming that mass variance depends both on considered mass of the halos and current redshift, that is mass variance is connected with the redshift through the linear growth:

$$\sigma(M, z) = \sigma(M)\ d(z) \tag{6}$$

where linear growth factor is given as:

$$d(z) = \frac{D^+(z)}{D^+(z=0)} \tag{7}$$

and $D^+(z)$ can be calculated as:

$$D^+(z) = \frac{5\Omega_m}{2}\frac{H(z)}{H_0}\int_z^\infty \frac{(1+z')dz'}{[(H(z')/H_0]^3} \tag{8}$$

$H(z)$ is a value of Hubble constant at the redshift z, given as:

$$H(z) = H_0\sqrt{\Omega_m(1+z)^3 + (1-\Omega_m)} \tag{9}$$

2. 1. FITTING FUNCTIONS

For the fitting functions, we have selected several charateristic solutions, starting from the Press-Schechter (1974) (PS), a spheroidal halo aproximation, over Sheth et al. (2001) (SMT), which introduces eliptical correction for the shape of dark matter halos, to the empirically derived functions of Warren et al. (2006) and Angulo et al. (2013) for which they have used cosmological simulations - Warren used a series of zoom-in simulations with increasing mass resolution, while Angulo used one very large box with high number of particles which allowed him to span many orders of magnitude in halo size with a single simulation.

Fitting functions forms are given in Table 1. It should be noticed that with adequate factors SMT could be reduced to PS.

Table 1: Fitting functions used for calculating halo mass and halo growth function.

Press-Schechter (1974)	$f_{PS}(\sigma) = \sqrt{\frac{2}{\pi}}\frac{\delta_c}{\sigma}\ exp\Big(-\frac{\delta_c^2}{2\sigma^2}\Big)$
Sheth et al. (2001)	$f_{SMT}(\sigma) = A\sqrt{\frac{2a}{\pi}}\Big[1+\Big(\frac{\sigma^2}{a\delta_c^2}\Big)^p\Big]\frac{\delta_c}{\sigma}\ exp\Big[-\frac{a\delta_c^2}{2\sigma^2}\Big]$
Warren et al. (2006)	$f_W(\sigma) = 0.7234\,(\sigma^{-1.625}+0.2538)\ exp\Big[\frac{-1.1982}{\sigma^2}\Big]$
Angulo et al. (2013)	$f_A(\sigma) = A\Big[\Big(\frac{b}{\sigma}\Big)^a + 1\Big]\ exp\Big[-\frac{c}{\sigma^2}\Big]$

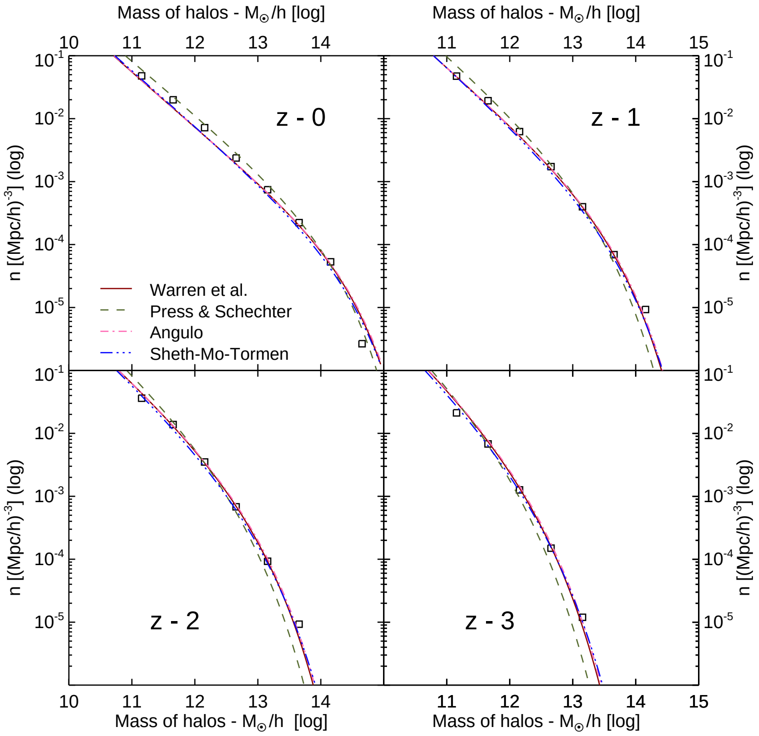

Figure 1: Plot of mass function: number density of halos as a function of halo mass (binned), plotted for 4 different redshifts. Results from simulation are compared to 4 different analytical fits (from Martinović (2015)).

2. 2. SIMULATION

For comparison with the calculated halo mass functions we use halo mass function derived from the $130 Mpc/h$ periodic box simulation with 512^3 particles executed with the GADGET2 code (Springel 2005), where we used ROCKSTAR (Behroozi et al. 2013) as the halo finder. Cosmological parameters used for the simulation are: $\Omega_m = 0.25$, $\Omega_\Lambda = 0.75$, $\Omega_b = 0.04$, $h = 0.7$ with $\sigma_8 = 0.8$ and $n_s = 1$.

Retrieved halos were binned for each simulation snapshot after which their number density for each bin was calculated. Halo mass function from the simulation was represented against the ones calculated, and those results are presented in Figure 1. (from Martinović 2015). Halo growth function (Heitmann et al. 2006) was calculated as the $n(M_1, M_2, z) = \int_{M_1}^{M_2} F(M, z)\, d\log M$ and those results are presented in Figure 2. (from Martinović 2015.) again with the rest of the calculated fitting functions.

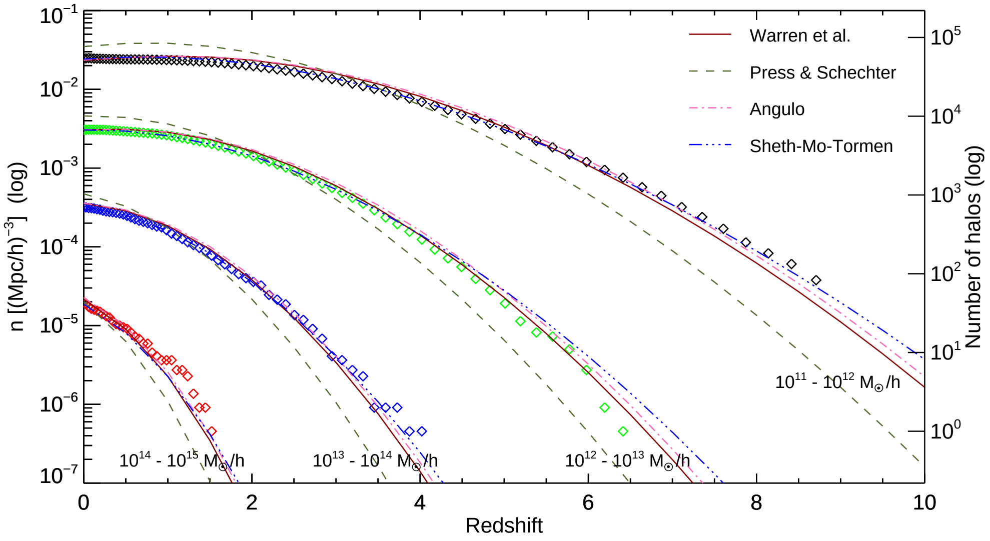

Figure 2: Plot of halo growth functions: number density of halos as a function of redshift presented for 4 mass bins. Results from simulation are compared to 4 different analytical fits (from Martinović (2015)).

3. DISCUSSION

We have used a method from Lukić et al. (2007), Murray et al. (2013), etc. for calculating dark halo mass function with various fitting functions. That method is used in calculating halo growth function as well and both functions are compared to the results derived from the cosmological simulation.

For halo mass function it can be seen in Figure 1. that there is a good agreement between all the calculated fitting functions and the one from cosmological simulation except for Press-Schechter one. As is obvious, it understimates the number of massive halos and overestimates number of less massive halos on all redshifts. Halo growth function of Figure 2. amplifies this result even further, where the same discrepancy between Press-Schechter and the rest of the fitting function is seen more clearly.

For more extensive analysis we point to the paper of Martinović (2015).

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RECOMMENDATION FOR RUNNING PURE N-BODY SIMULATIONS ON COMPUTING FACILITIES IN SERBIA

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Abstract. Pure (gravitational) N-body astrophysical simulations are an irreplaceable means of testing dynamics and evolution of astrophysical objects both on large scales (cosmological simulations) and on smaller scales (isolated galaxies, globular clusters, solar system dynamics, etc). One of the obvious major limitations is in computing facilities at disposal for running the simulations. In this talk we will present characteristics of computational facilities available in Serbia. We will discuss their advantages and disadvantages and we will try to give recommendation for optimum and maximum scope of both large scale simulations and small scale simulations which may be performed with those facilities. Quick overview of simulations completed so far will be given as well.

1. INTRODUCTION

For past several decades importance of N-body astrophysical simulations continues to grow. Today N-body simulations are wide-spread tool for analyzing dynamics of astrophysical objects on all scales (eg. Dehnen & Read 2011). Development of computing hardware, optimization of computing codes and their public availability are a reason why it has become standard to run tens of simulations within a single project.

Unfortunately one of the unpleasant issues when doing numerical astrophysics is estimating how much time, called wall time (in contrast to simulation time), it will take to complete a simulation. There is no equivalent to something like exposure calculators from observations, which makes the estimation even more harder. Usually researchers just acquire intuitive sense for duration of a simulation with a given number of particles after certain level of experience. To make things even worse - different codes, different computing hardware and different N-body problems in astrophysics all can yield significantly different simulation duration.

Considering that N-body astrophysical simulations (large scale and galactic simulations) are a relatively new field at Astronomical Observatory in Belgrade, researchers starting in the field have a hard time estimating how much time certain simulations will take, or related to that - on what number of processors simulation should be performed in order to take optimal time of execution. Here we will try to address that issue by giving estimate how much time will be needed for a simulation with N particles with different computational facilities available for use in Serbia. We hope that this will be at least good starting point that will mitigate away portion of time needed for reaching optimal configurations.

2. COMPUTING FACILITIES

There are several computing facilities in Serbia that have been used by the authors of this work, and although there are a few more that can be used as well, we will focus on those with which we had experience, especially because they are a good representation of a computing hardware of various properties and power.

Specifications are given in Table 1. Available machines that have been used cover wide range from single desktop computer ("Phobos"), to a supercomputing facility ("Paradox"). Training and test-model simulations are usually executed on less powerfull machines. Largest share of workload falls upon "Fermi" - a cluster located within Astronomical Observatory acquired through one of its projects. "Paradox" machines are located within Institute of Physics in Belgrade and they are previous iteration ("Paradox" - still available for use) and the new upgrade ("Paradox 4"), which has not yet been tested for astrophysical N-body simulations. Furthermore, Paradox supercomputers are important part of SEE-GRID-SCI[1] project and are part of PRACE[1] network.

Another interesting thing that can be seen in the table is presence of GPUs. Considering major speed-ups with inexpensive equipment (compared to similiar performance reached only with CPUs) when it comes to using GPU codes for N-body simulations, they represent both important testing ground for development and one possible future of the simulations (Aubert Dominique 2011). Focus is on GPUs with CUDA capabilities considering availability and quantity of work done with it so far. Significant speed-ups can be achieved even with commercial desktop CUDA GPUs, which will be shown later.

3. CODES

All the CPU codes that are beeing used for executing N-body astrophysical simulations are paralelized, which is a necessary condition to be able to fully utilize computing power available. Important part of a code is its optimization. Unoptimized codes are not able to fully utilize computing power available to them, rendering usage of higher number of processors or more powerfull machines completely useless (for example due to bad paralelization).

Although there are many publicaly available N-body codes, we focus on GADGET2 and P-GADGET3 (Springel 2005) - both are highly parallelized Tree-PM N-body codes with efficient and tested paralelization.

As for the GPU codes, so far only one has been succesfully run (many codes are still early in development). Code in question is BONSAI (Bedorf et al. 2011), fully GPU N-body Tree-code which does not (for now) support individual softenings and unfortunately it was succesfully run only in a single card mode.

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[1] http://www.scl.rs/about-us

Table 1: Computing facilites in Serbia. Specifications are for each node in the system, where second column gives total number of available nodes, third and fourth column are CPU type/number and number of cores (threads) per node, with the fifth column stating amount of RAM memory per node. Last column is GPU unit type (if exists) available on each node.

Name	Nodes	CPU	Cores per CPU	RAM	GPU
Paradox	89	2x E5345	4	8 GB	No
Paradox 4	106	2x E5-2670	8	32 GB	M2090
Fermi	12	2x X5675	6	24 GB	2x M2090
Phobos	1	i7-2600	4/8	8 GB	GeForce 650Ti
Office (Beowulf)	4	i5-3470	4	16GB	No

4. SPEEDUP

When running a simulation the most important issue becomes executing it with the available resources as quickly as possible. But simply increasing used number of processors does not (in vast majority of cases) yield equivalent acceleration in execution time. Not only that, but using number of processors greater than the optimization of a code allows is usually frowned upon due to wasting resources (for example: wasting electricity and/or locking processors thus making them unavailable to other users, but failing to utilize them properly).

Quantity that has been in use for determining optimal processor usage while running parallelized codes is speed-up (Hennessy & Patterson, 2012):

$$S(N) = \frac{T(1)}{T(N)} \tag{1}$$

where T(N) is a time the algorithm takes to finish running on N processors (or threads). So basically S(N) gives how quicker algorithm on N processors would finish than it would on a single processor (in a serial mode), although it can be calculated against execution time on any number of processors. Speed-up is considered linear if it rises as N. It can be super-linear if the speed-up is greater than the N (number of processors), although in vast majority of cases when it comes to N-body simulations it will be sub-linear, that is, it will rise more slowly than N. In those cases there will be a point after which further increase in number of processors wont yield in reasonable speed-up.

Understanding why this happens is given through Amdahl's law (Amdahl 1967) - it states that if P is the paralized portion of the algorithm and (1-P) is the part of the algorithm that can not be paralized (serial part), then algorithm will never execute quicklier than execution time of the serial part, and speed-up would perform as:

$$S(N) = \frac{1}{(1-P) + \frac{P}{N}} \tag{2}$$

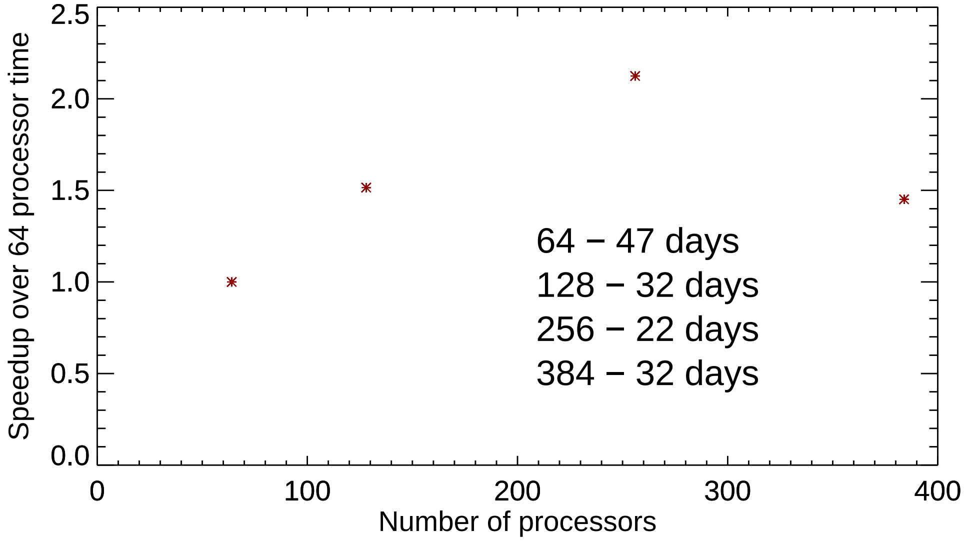

Figure 1: Empirically derived speed-up for an N-body cosmological simulation tested using GADGET2 code for 1 hour on each number of processors. Given are the estimates on total execution time for the simulation based on the retrieved results. It can be seen that there is a peak performance on 256 processors, which was ultimately chosen for the simulation run. Tests and simulation itself were performed at IPB's Paradox supercomputer.

So it is clearly seen that we can by using greater number of processors speed-up only parallelized portion of the code which would behave asymptotically after certain N.

Although it is quite difficult calculating which speed-up is the most optimal, in most cases that turning point can be acquired empirically, by testing at which point a further increase in processor number yields no significant acceleration. One of such tests is represented in Figure 1. where speed-up for a cosmological simulation that was perfomed on "Paradox" supercomputer was tested for a given number of processors prior to full run. Each test run was one hour long. After the tests 256 processors were choosen as platform to execute a simulation.

5. RESULTS AND DISCUSSION

As mentioned before, there is plethora of possible N-body astrophysical simulations with many parameters that can affect the length of execution. But in our case, constraining to a few N-body codes and to several computing facilities can provide enough insight into length of the different types of simulations. Results from some characteristic runs so far are given in Table 2. There we can see number of particles against type of the simulation and its total execution time on a given number of processors. All the simulations were performed using GADGET2, while the last one (isolated one) is performed using BONSAI GPU code.

Table 2: Characteristic results for various simulation types (last column) given against number of particles used in the simulation (first column), total simulation time (second column), number of processors used (third column) and wall-time (fourth column). Last, singled out entry, is the simulation performed with the GPU code.

N	Sim time	Proc	Total days	Type
440k	0.92 Gyr	24	3.4	Minor merger
550k	5 Gyr	24	2.0	Galaxy fly-by
2M	10 Gyr	24	0.65	Fornax
2.2M	10 Gyr	24	0.22	Dwarf Isolated
4.2M	10 Gyr	24	17.6	Dwarf/Fornax
2M	10 Gyr	650Ti	0.17	Fornax

Looking at Table 2 it is possible to gain expectation on running time of the simulations. Not only that, but simple execution time can hint us important things about simulation. For example: first simulation in the list behaves quite distinctly in comparison to the others. For a shorter simulation run it executes quite longer than the others. So here we use simple length of the simulation to assume that there are underlying problems with it - in this particulare case, galaxies involved were slightly unstable, which manifested some time into the simulation slowing it. Simulation was aborted for additional check-ups, revealing mistakes and thus saving wasting resources.

Another interesting thing from Table 2 are both "Fornax cluster" simulations. They were performed with identical initial conditions, but with CPU and GPU codes and here we can see how quicklier GPU code is - for the same simulation, running on only one GPU card (against 24 CPUs) we got speed-up of almost 4 times. If development of GPU codes continues, they will definetly play an important part in the future of the simulations.

In the end we have summarized our experience into the recommendations given in the following list:

- Processors strength is (usually, with modern processors) not an issue;
- For $\sim$ 100k particles, 8 processors is sufficient;
- For $\sim$ 1M particles, 30 processors is sufficient;
- For $\sim$ 10M particles, up to 100 processors;
- For $\sim$ 100M particles, up to several 100 processors;
- For 1000M+ particles - yet to be seen!

One last thing to consider are possible queues and other time consuming deviations that can be inherently connected with systems. In practice if you are choosing between two cluster (or supercomputers) from our experience the best is to use the one under less load, considering that you might spend significant time (in comparison to simulation length) for example in waiting for resources to be alocated for your simulation. For example, for test simulations with smaller number of particles the most efficient would be simply using "Phobos" or (yet to be named) office cluster (no queues, data immediately available, etc). On the other hand, full simulations with large number of particles should be run on larger supercomputers.

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AGN PHASE: MATCHING NUMERICAL SIMULATIONS TO OBSERVATIONS

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Abstract. We use high resolution cosmological numerical simulation to identify AGNs in field massive galaxies in redshift range z=[0.8, 2.5]. Assuming that their activity is merger driven and that the final product of their accretion is an M-σ SMBH, we calculate expected AGN luminosity at the peak accretion activity. We compare these luminosities to those observed in AGNs of the COSMOS survey and find that most of the observed AGNs have passed their peak activity, accreting at lower Eddington ratios. This explains why a large number of AGNs is observed in red sequence galaxies.

1. INTRODUCTION

SMBH masses correlate with the properties of their host bulges/spheroids (velocity dispersion, mass of the spheroid, total stellar mass, etc). They do not correlate with the mass of dark matter halos in all environments. Halos in, and around dense regions (large groups and galaxy clusters) are subject to stripping of material due to various dynamical processes (tidal stripping, dynamical friction, ram-pressure, etc.). These processes effect both dark and baryon matter. Hence, in dense environments, halo's mass does not correlate with mass of a host galaxy or a central SMBH. However, field halos evolve in relative isolation which in turn establishes relation between their masses and the mass of their stellar component. At the same time, properties of the spheroid are correlated with the SMBH mass. This provides the link between DMH and SMBH and for field halos there exists DMH mass - SMBH mass relation (Kormendy & Ho 2013).

In the most recent study of galaxy - halo relation, Behroozi et al. (2013a) match observed galaxies to simulated halos. They use observed galaxy stellar mass functions, specific star formation rates and cosmic star formation rates to constrain galaxy - halo relation. They present parametrization of this relation for a redshift range $0 < z < 8$ (equations 3 and 4, Behroozi et al. 2013a) together with the intrinsic parameters (section 5 of the same paper). We will address this relation as Behroozi relation from here on.

Haring & Rix (2004) have found that the relation between the mass of the SMBH in nearby galaxies, $\mathrm{M_{bh}}$, and the stellar mass of the surrounding spheroid or bulge, $\mathrm{M_{bulge}}$ can be written as:

$$\mathrm{logM_{BH}} = -4.12 + 1.12(\mathrm{logM_{sph}}) \tag{1}$$

It has been established recently that this relation evolves with redshift positively. Merloni et al. (2010) have measured rest-frame K-band luminosity and total stellar mass of the hosts of 89 broad-line AGNs detected in the zCOSMOS survey in the redshift range 1 < z < 2.2. They found that the local value of SMBH to total host galaxy stellar mass evolves with redshift as $(1+z)^{\gamma}$, where $\gamma = 0.68 \pm 0.12$, From here on we address the evolving SMBH - host galaxy relation as SMBH positive evolution relation:

$$\mathrm{logM_{BH}} = (-4.12 + 1.12(\mathrm{logM_*})) \times (1 + \mathrm{z})^{\gamma} \tag{2}$$

Note that Merloni et al. (2010) use total stellar mass instead of the bulge/spheroidal mass in Haring & Rix (2004) relation. This is due to the lack of any imaging information and reliable bulge-to-disk (B/T) decomposition. Bennert et al. (2011) have studied the evolution of this relation for a sample of 11 X-ray selected broad-line AGNs in the redshift range 1 < z < 2. They have managed to distinguish between $\mathrm{M_*}$ and $\mathrm{M_{sph}}$ by using deep multi-filter HST images. They found that SMBH to total stellar mass of the host evolves with γ coefficient of 1.15 ± 0.15.

In this work we first seed dark matter halos with galaxies using Behroozi relation. Then, we seed galaxies with black holes using SMBH positive evolution relation where we adopt both values for γ (0.68 and 1.15) in two separate models.

2. METHOD

2. 1. COSMOLOGICAL N-BODY SIMULATION

Using GADGET2 (Springel 2005), we performed a high-resolution cosmological N-body simulation within a comoving 130 Mpc^3 section of a ΛCDM Universe (Ω_{M}=0.25, Ω_Λ=0.75, σ_8=0.8 and h=0.7) from z=599 to z=0. We are using WMAP5 (Komatsu et al. 2009) cosmological parameters in this study, and 2LPT initial conditions. Mass resolution of dark matter particles is 1.14 x 10^9 $\mathrm{M}_\odot$.

2. 2. SIMULATIONS AND BLACK HOLE GROWTH WITHOUT A RECIPE

The essence of our method is to calculate the mass accreted by the SMBH in a newly formed halo after every halo merger without using any growth recipes. We do this by subtracting SMBH mass before the merger from the SMBH mass after the merger in the following procedure:

For the identification of dark matter halos and creation of their merger trees, we are using the ROCKSTAR phase space halo finder (Behroozi et al. 2013b). We focus on major mergers with mass ratio of merging dark matter halos of > 0.3. For every major merger we identify three specific moments. $\mathrm{z_{init}}$ - redshift when halos touch and when from this point on, smaller halo is inside larger halo at all times. At this moment we use Behroozi relation and SMBH positive evolution relation to obtain SMBH masses in both halos ($\mathrm{M_{BH,1}}$ and $\mathrm{M_{BH,2}}$) right before halos merge. The SMBH mass before the accretion starts is then $\mathrm{M_{BH,initial}} = \mathrm{M_{BH,1}} + \mathrm{M_{BH,2}}$. $\mathrm{z_{AGN}}$ - redshift when smaller halo can not be identified anymore inside the larger one which means that the merger of dark matter halos has finished and merger of their galaxies has started. We assume that this is the moment when the accretion onto the new SMBH starts and enters AGN phase. We follow newly formed halo through snapshots until redshift z=0 or until it merges with another halo. In each of these snapshots we use Behroozi relation and SMBH positive evolution relation to calculate the mass of SMBH hosted by this particular halo. $z_{\rm final}$ is then the redshift when halo is hosting the most massive black hole. In other words, we have traced the final mass of the SMBH ($M_{\rm BH,simulated}$) at the halo center through scaling relations and without using any growth recipes. The mass accreted by the SMBH has to be $M_{\rm BH,accreted}$ = $M_{\rm BH,simulated}$ - $M_{\rm BH,inital}$. We repeat that this method works only for the field halos where clear DMH - galaxy - SMBH relation can be established.

2. 3. OBSERVATIONS AND BLACK HOLE GROWTH WITH A RECIPE

The final goal of this paper is to determine if the Eddington ratios obtained from the observed AGN luminosities and simulated $M_{\rm BH,init}$ can produce $M_{\rm BH,simulated}$ in our simulation.

Bongiorno et al. (2012) have studied $\sim$ 1700 AGNs in COSMOS field obtained by combining X-ray and optical spectroscopic selections. They also study the properties of their hosts including the total stellar mass of galaxies hosting AGNs. As the result they present probability of a galaxy to host an AGN of a given luminosity as a function of stellar mass in three redshift bins: [0.3 - 0.8], [0.8 - 1.5], and [1.5 - 2.5] (Figure 14 in their paper, from here on F14). They group AGNs in four X-ray (2 - 10 KeV) luminosity bins in logarithm space: [42.8 - 43.5], [43.5 - 44.0], [44.0 - 44.5], and [44.5 - 46.0].

We combine black hole growth in our simulation with the observed probability functions for a galaxy to host an AGN in the following procedure.

First we assume that the moment when the accretion onto $M_{\rm BH,init}$ starts is $z_{\rm AGN}$ (the redshift when halo merger has finished and galaxy merger is occurring - AGN phase). The mass of the galaxy where $M_{\rm BH,init}$ is accreting, $M_{*,\rm AGN}$, is calculated from the Behroozi relation directly from the mass of the simulated host halo at $z_{\rm AGN}$.

We are focusing only on SMBH accretion which is activated by galaxy mergers. Merger activated black hole accretion is a characteristic of massive galaxies, log (M_* [$M_\odot$]) > 10.4. In lower mass galaxies SMBHs are more likely to accrete through secular processes related to channeling of the gas through bars or disk instabilities. We also focus only on halos which merge in the field so we exclude halos which are potential hosts to galaxy clusters. Since mass of the halo hosting most massive elliptical galaxy in the field in the simulations is $\sim 2 \times 10^{13}\,M_\odot$, we only study mergers which produce less massive halos. As additional measure of precaution, we exclude halos which host galaxies more massive than $10^{11.2}\,M_\odot$. In this manner we obtain a clean sample which matches 10.4 < log (M_* [$M_\odot$]) < 11.2 sample in F14, and we separate $M_{*,\rm AGN}$ into three galaxy-mass bins in logarithm space: [10.4 - 10.7], [10.7 - 10.9], and [10.9 - 11.2].

For every redshift and galaxy-mass bin we calculate the number of simulated galaxies which host AGNs by reading probability values ($P_{\rm AGN}$) directly from F14:

$$N_{\rm AGN,i} = \frac{P_{\rm AGN,i}}{\Sigma P_{\rm AGN,i}} \times N_{*,\rm AGN}, \tag{3}$$

where $P_{\rm AGN,i}$ is the probability function or, in other words, the data points in the

F14, and $N_{*,AGN}$ is number of galaxies in redshift and galaxy-mass bins.

Next we apply Monte Carlo procedure (10,000 realizations) where galaxies in each mass bin and each redshift bin are assigned a luminosity value from the corresponding probability function in F14. As the result, for each $M_{*,AGN}$ we have a set of 10,000 luminosities which we now can use to calculate Eddington ratios for each $M_{BH,init}$. Since these are X-ray luminosities, we use equation (2) in Hopkins et al. (2007) to calculate bolometric luminosities. Eddington ratio is then $\lambda = L_{bol} / L_{Edd}$, where $L_{Edd} = 1.26 \times 10^{38} \times M_{BH,init}$.

Note that we have decided to use $M_{BH,init}$ as a sum of SMBH masses in the merging galaxies at the moment z_{init}. Alternative approach would be to simply calculate SMBH mass at the moment z_{AGN} directly from SMBH positive evolution function. A problem with this approach is accuracy in determining masses of halos and galaxies at the peak of the merger when there is still a lot of unbound material.

For the accretion recipe we assume that $M_{BH,init}$ is accreting for Salpeter time (43 Myr) at the radiative efficiency of e=0.1 and previously calculated Eddington ratios λ. The underlying assumption here is that the observed luminosities are the peak luminosities. In other words, these are the luminosities when accretion onto the black holes is most efficient and where most of the black hole growth occurs. Final black hole mass after accretion at the Eddington ratios which are the result of the observed luminosities is:

$$M_{BH,observed} = M_{BH,inital} \times \exp(\lambda) \tag{4}$$

For each merger we have 10,000 $M_{BH,observed}$ from 10,000 Monte Carlo realizations of probability functions in F14. Now we can compare them to the $M_{BH,simulated}$. If the observed luminosities are peak luminosities when most of the black hole growth occurs, then mass of the grown black hole should match the mass of simulated one. We compare them to see how often observed luminosities can produce simulated SMBH mass and for what values of Eddington ratios.

3. RESULTS AND CONCLUSIONS

Assuming that major mergers are driving AGN activity in massive galaxies, we have selected simulated remnants of halo mergers and matched them to observed samples of AGNs in redshift and galaxy-mass bins in F14. All galaxies in the same mass bin host AGN with the probability defined in F14. They are more likely to host less luminous AGNs or, in other words, there are more galaxies of the same mass hosting lower luminosity AGN than more luminous ones. Galaxies selected in our simulation and separated in mass bins have SMBHs with masses which are not derived from their stellar mass but from the merger history. Masses of these black holes come from merging halos at higher redshifts and also depend on SMBH positive evolution recipes. The initial and final black hole masses are predetermined by the halo mass before and after the merger in our simulation. We accrete onto initial black hole with the Eddington ratios obtained from the luminosity which has a probability defined by F14.

Figure 1 represents mass the growth with positive evolution of γ=0.68 for SMBH in every AGN of a given redshift (rows) and host-galaxy-mass bin (columns), the black lines on the left mark initial black hole masses before the accretion, $M_{BH,initial}$,

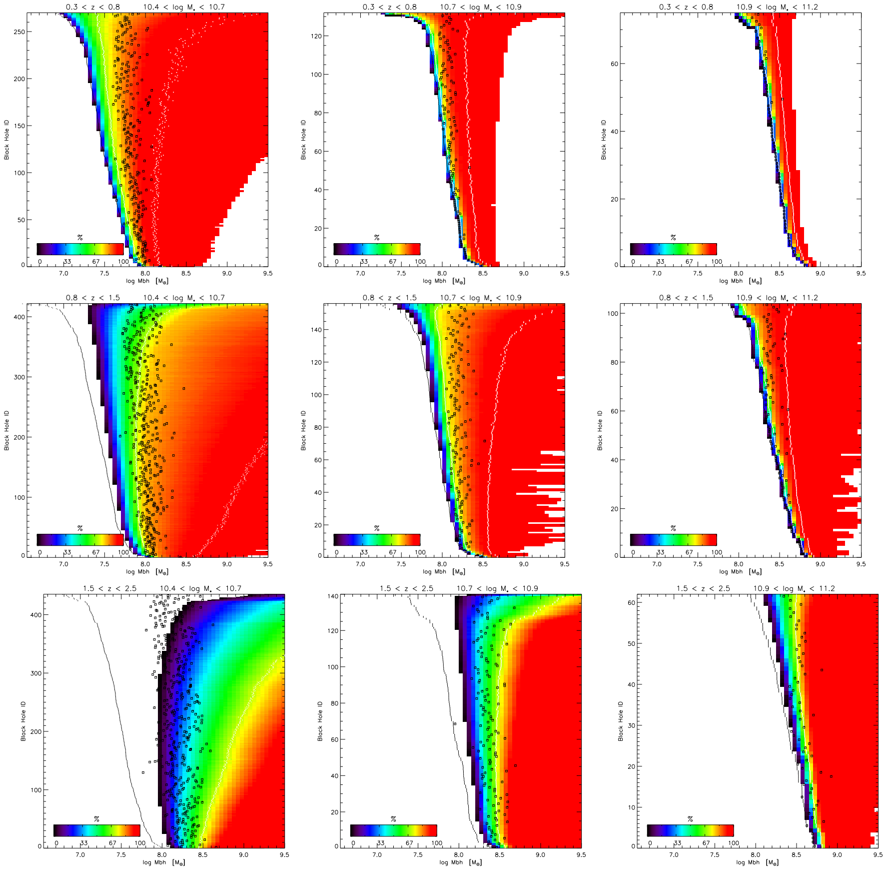

Figure 1: Color represents percentage of Monte Carlo realizations (through the parameter space of luminosities observed for COSMOS AGNs) necessary for simulated black holes (vertical black lines) to accrete accordingly and reach certain mass (X-axis). Squares represent final black hole mass in the simulation and mark the probability for the observed luminosities to grow black holes. Vertical white lines represent 1-σ and 2-σ. Each panel corresponds to the bin for merger redshift and stellar mass of the AGN host. The assumed slope for black hole positive evolution is $\gamma = 0.68$ (Merloni et al 2010).

and squares represent final simulated black hole mass, $M_{\mathrm{BH,simulated}}$. Color represents cumulative percentage of Monte Carlo realizations which is sufficient to produce black hole of a particular mass. White lines show 1 - σ and 2 - σ of the distribution. In other words, there are 68.27 % of realizations left of the first white line, and 95.45 % of realizations are left of the second white line. Small percentage of realizations means that it is very likely to reproduce simulated black hole (e.g. mass is easily obtained because it takes just few % of realizations). At the other end, large percentage of realizations means that it is not likely to reproduce simulated black hole (e.g. most of the realizations are left of the square representing final black hole mass). If we assume that 1 - σ marks probable event, then all squares on the left of it represent simulated black holes which can be reproduced by the observed luminosities. For all the squares on the right, observed luminosities can not provide large enough Eddington ratios to produce simulated black holes. If we compare panels in the first column, SMBHs growth in the same galaxy-mass bin, [10.4, 10.7], can not reach simulated mass values at $0.3 < z < 0.8$ for almost all of the black holes. For $0.8 < z < 1.5$, it does for about half of the SMBHs, and for $1.5 < z < 2.5$ almost all of the SMBHs do reach simulated mass. Since our assumption is that we are observing peak AGN luminosities, then conclusion is that at high redshift [1.5, 2.5], almost all of the AGNs we see are observed in the phase of their maximum growth and accretion efficiency corresponding to the starburst "green valley" phase in galaxy evolution. At the other end, for redshift range [0.3, 0.8], almost none of the observed AGNs are in the "green valley" galaxies. These are low Eddington ratio AGNs in "red sequence" galaxies.

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ON A HIDDEN PARAMETER IN FRIEDMAN EQUATIONS

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Abstract. Authors of this paper recently applied the theory of regularly varying functions in asymptotic analysis of cosmological parameters for the expanding universe. According to this theory, all cosmological parameters depend on a a 0-function $\varepsilon(t)$ which is "hidden" in the integral representation of regularly varying functions. We derived a differential equation for $\varepsilon(t)$ and discussed possible solutions.

1. INTRODUCTION

In our paper [Mijajlović et al., 2012], we applied the theory of regularly varying functions in asymptotic analysis of cosmological parameters for the expanding universe. For this analysis we used Friedman equations [see Friedman, 1924], which are derived from the Einstein field equations:

$$\begin{aligned} &\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2}, && \text{Friedman equation,} \\ &\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right), && \text{Acceleration equation,} \\ &\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) = 0, && \text{Fluid equation.} \end{aligned}$$

Cosmological parameters appearing in these equations are:

$a = a(t)$, the scale factor,
$\rho = \rho(t)$, the energy density, and
$p = p(t)$, the pressure of the material in the universe.

It appears that these parameters, including Hubble parameter, $H(t)$, and deceleration parameter, $q(t)$, are regularly varying functions. According to the representation theory for regularly varying functions, all these parameters depend on a 0-function $\varepsilon(t)$ which is "hidden" in the integral representation of regularly varying functions. Parameters $a(t)$, $\rho(t)$ and $H(t)$ uniformly depend only on $\varepsilon(t)$, but the parameters $p(t)$ and $q(t)$ depend on $\dot{\varepsilon}$ as well. While $\varepsilon(t) \to 0$ as $t \to \infty$, this is not necessary for

$\dot{\varepsilon}$, what may lead to various evolutions of these parameters. We derive a differential equation for $\varepsilon(t)$ and discuss possible solutions.

2. REGULAR VARIATION

We shall review briefly basic notions related to regular variation. We shall need particularly properties of regularly varying solutions of the following second order differential equation

$$\ddot{y} + f(t)y = 0, \quad f(t) \text{ is continuous on } [\alpha, \infty]. \tag{1}$$

Observe that the acceleration equation has the form (**??**). In short, the notion of a regular variation is a form of the power law distribution, described by the following relationship between quantities F and t:

$$F(t) = t^r(\alpha + o(1)), \quad \alpha, r \in \mathbb{R}. \tag{2}$$

Obviously, the most simple form of the power law is given by the equation $y = t^k$. It is said that two quantities y and t^r satisfy the power law if they are related by a proportion, i.e. there is a constant α so that $y = \alpha t^r$. This definition of power law can be naturally extended by use of the notion of slowly varying function introduced by J. Karamata, (1930).

A real positive continuous function $L(t)$ defined for $x > x_0$ which satisfies

$$\frac{L(\lambda t)}{L(t)} \to 1 \quad \text{as} \quad t \to \infty, \quad \text{for each real } \lambda > 0. \tag{3}$$

is called a slowly varying function. A physical quantity F(t) is said to satisfy the generalized power law if

$$F(t) = t^r L(t) \tag{4}$$

where $L(t)$ is a slowly varying function and r is a real constant. So to say that $F(t)$ is regularly varying is the same as $F(t)$ to satisfy the generalized power law. The simplest example of slowly varying functions are $\ln(x)$ and iterated logarithmic functions $\ln(\ldots\ln(x)\ldots)$.

Regularly varying function have the following representation. Namely, a function L is slowly varying if and only if there are measurable functions $h(x)$ and a zero function ε and $b \in \mathbb{R}$ so that

$$L(x) = h(x)e^{\int_b^x \frac{\varepsilon(t)}{t}dt}, \quad x \geq b, \tag{5}$$

and $h(x) \to h_0$ as $x \to \infty$, h_0 is a positive constant. For further properties of regularly varying functions, one may consult Bingham et al., 1987.

As we are dealing with solutions L of differential equations which model mechanical phenomena, it is quite safe to assume that L is a twice differentiable function. The function $\varepsilon(t)$ is not uniquely determined and in our context we shall call it a hidden parameter. We shall also assume that $L(t)$ is normalized, i.e. that $h(x)$ is a constant function. The class of normalized slowly varying functions will be denoted by $\mathcal{N}$. We shall see that the fundamental cosmological parameters depend essentially on the hidden parameter $\varepsilon(t)$.

For our study of Friedman equations we need several results on solutions of equation (**??**). There are various conditions for $f(t)$ that ensure that regularly varying solutions of $\ddot{y} + f(t)y = 0$ exist. We shall particularly use the following result, due to Howard and Marić, see Marić, 2000 and Kusano-Marić, 2010:

Theorem *Let* $-\infty < \Gamma < 1/4$, *and let* $\alpha_1 < \alpha_2$ *be two roots of the equation*

$$x^2 - x + \Gamma = 0. \tag{6}$$

Further let L_i, *i=1,2 denote two normalized slowly varying functions. Then there are two linearly independent regularly varying solutions of* $\ddot{y} + f(t)y = 0$ *of the form*

$$y_i(t) = t^{\alpha_i} L_i(t), \quad i = 1, 2, \tag{7}$$

if and only if $\mathbf{M}(f) = \lim_{x\to\infty} x \int_x^{\infty} f(t)dt = \Gamma$. *Moreover,* $L_2(t) \sim \dfrac{1}{(1-2\alpha_1)L_1(t)}$.

The limit of the integral in the theorem is crucial in our analysis and it is not always easy to compute.

As $\lim_{t\to\infty} t^2 f(t) = \Gamma$ implies $\lim_{x\to\infty} x \int_x^{\infty} f(t)dt = \Gamma$, we see that

$$\lim_{t\to\infty} t^2 f(t) = \Gamma \tag{8}$$

gives a useful sufficient condition for the existence of regularly varying solutions of the equation $\ddot{y} + f(t)y = 0$ as described in the previous theorem. By r.v. we shall denote the term "regularly varying".

3. R. V. SOLUTIONS OF FRIEDMAN EQUATIONS

As noted, the acceleration equation obviously has the form (**??**) so under appropriate assumptions, i.e. that the functions we encounter are continuously differentiable as many times as necessary, the analysis of the previous section, in particular the Howard-Marić theorem, can be applied to it. For this reason, we shall write from now on the acceleration equation in the form

$$\ddot{a} + \frac{\mu(t)}{t^2} a = 0, \tag{9}$$

where

$$\mu(t) = \frac{4\pi G}{3} t^2 \left(\rho + \frac{3p}{c^2}\right). \tag{10}$$

We found in [Mijajlovic et al. 2012] r.v. solutions of Friedman equations and determined cosmological parameters:

Scale factor $a(t)$: $a(t) = t^{\alpha} L(t)$, where $\alpha \neq 0$ with L having the ε-representation as in Karamata Representation theorem.

Hubble parameter $H(t)$:

$$H(t) = \frac{\alpha}{t} + \frac{\varepsilon}{t}. \tag{11}$$

Deceleration parameter $q(t)$:

$$q(t) = \frac{\mu(t)}{\alpha^2}(1+\eta) = \frac{1-\alpha}{\alpha} - \frac{t\dot{\varepsilon}}{\alpha^2}(1+\eta) + \tau, \tag{12}$$

where η and τ are zero functions.

Now we introduce a new constant w related to the scale factor $a(t)$ which satisfy the generalized power law. It appears that w is in fact the equation of state parameter. So assume $a(t) = t^{\alpha} L(t)$, $L \in \mathcal{N}$ and $\alpha \neq 0$. We define w by

$$w \equiv w_{\alpha} = \frac{2}{3\alpha} - 1 \quad \text{(equation of state parameter).} \tag{13}$$

Then cosmological parameters can be put in a more standard form, widely found in the cosmology literature.

$$\begin{aligned} \alpha \quad &= \frac{2}{3(1+w)}, \qquad a(t) &&= a_0 L(t) t^{\frac{2}{3(1+w)}} \\ H(t) \quad &\sim \frac{2}{3(1+w)t}, \quad \mathbf{M}(q) &&= \frac{1+3w}{2} \end{aligned} \tag{14}$$

By the representation theorem for regularly varying functions we see that the scale factor $a(t)$ and the deceleration parameter $q(t)$ depend on a hidden parameter ε and its derivative $\dot{\varepsilon}$. For the universe having the flat curvature one can infer the following relation between pressure and density parameters:

There are 0*-functions* ξ, ζ *such that* $p = \hat{w} \rho c^2$*, where* $\hat{w}(t) = w - t\dot{\xi} + \zeta$.

We see that the deceleration parameter $q(t)$, the equation of state and the pressure $p(t)$ contain not only the "hidden" parameter $\varepsilon(t)$, but $\dot{\varepsilon}(t)$ and $t\dot{\varepsilon}(t)$ as well.

While $\varepsilon(t)$ is a 0-function, $\dot{\varepsilon}(t)$ and $t\dot{\varepsilon}(t)$ need not to be. In fact they can be unbounded and oscillatory as well. Examples of this kind are:

$\varepsilon(t) = \cos(t^2)/t, \quad \varepsilon(t) = \sin(t^3)/t.$

It means that $q(t)$ and $p(t)$ can be unbounded and oscillatory as well. It seems that this fact is overlooked in the classical cosmology, mainly due to the absence of "microscopic" analysis which give us the theory of regularly varying functions.

Therefore, it is of interest to describe in more detail the hidden parameter ε. We found that ε is a solution of the Riccati differential equation:

$$t\dot{\varepsilon}(t) = (1 - 2\alpha)\varepsilon - \varepsilon^2 + \alpha(1 - \alpha) - \mu(t). \tag{15}$$

where $\mathbf{M}(\mu) = \alpha(1 - \alpha)$ and ε is a 0-function. If $\lim_{t\to\infty} \mu(t) = \alpha(1 - \alpha)$, then $t\dot{\varepsilon}$ is a 0-function, hence $\dot{\varepsilon}$ and $t\dot{\varepsilon}$ can be neglected in the representation of cosmological parameters. In this case $q(t)$ and equation of state reduce to their standard form in classical cosmology:

$$q(t) = \frac{1+3w}{2}, \quad p(t) = wc^2\rho(t)$$

where w is a constant (c is the the speed of light). Hence, the only interesting case would be when $\mathbf{M}(q) = \alpha(1 - \alpha)$ and $\lim_{t\to\infty} \mu(t)$ does not exist. Then the "hidden" parameter ε, in fact its derivative $\dot{\varepsilon}$, might have the strong influence in the asymptotical behavior of the parameters $q(t)$ and $p(t)$.

We note that J. Barrow (see, for example, J. Barrow, D. Shaw, 2008) also discussed the asymptotic behavior of cosmological parameters based on the theory of Hardy fields. We note that this theory precedes Karamata's theory of regular variation.

Several physical models can be proposed taking into account the "hidden" parameter $\varepsilon(t)$:

1. Dark matter and dark energy are in the equilibrium but small fluctuation in this state produce variation of $q(t)$ and $p(t)$.

2. Variations of $q(t)$ and $p(t)$ are the consequences of the echo effect which appeared in the inflationary epoch which lasted from 10^{-36} seconds after the Big Bang until 10^{-32} seconds (Alan Guth and Andrei Linde, 1981).

3. Variations of $q(t)$ and $p(t)$ are the consequences of the existence and the influence of the dual universe.

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MORPHOLOGICAL CLASSIFICATION OF GALAXIES: IMPACT FROM SPATIAL RESOLUTION AND DATA DEPTH ON NON-PARAMETRIC METHODS

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Abstract. We analysed the impact of survey depth and spatial resolution on some of the most used morphological parameters for classifying galaxies through non-parametric methods. We selected three different non-local datasets, ALHAMBRA and SXDS, as examples of deep ground-based surveys, and COSMOS, as an example of deep space-based surveys. We used a sample of 3000 local, visually classified galaxies. We first measured their morphological parameters at their real redshifts ($z \sim 0$). Secondly, we simulated them to match the redshift and magnitude distributions of galaxies in the selected non-local surveys. From the comparisons of the two sets we were able to put constraints on the use of each parameter for morphological classification, in each survey, at different magnitude cuts, and to evaluate the effectiveness of the commonly used morphological diagnostic diagrams.

1. INTRODUCTION

Morphology is one of the main characteristics of galaxies, and the morphological classification has been central to many advances in the picture of galaxy formation and evolution. The basic classification schemes come from early 20s (Reynolds 1920; Hubble 1926), dividing all galaxies into four main types: elliptical, lenticular, spiral, and irregular. Hereafter, when we speak about early-type galaxies (ET) we will refer to ellipticals and lenticulars, while in late-type (LT) galaxies we include spirals and irregulars. Moreover, LT_et and LT_lt include spirals Sa-Sbc and later than Sbc, respectively.

Non-parametric methods are based on measuring the different galaxy parameters that correlate with the morphological type, usually with light distribution: concentration of light within the galaxy, galaxy shape, or presence of small-scale structures. For intermediate- and high-redshift, low resolution, galaxy samples, and large data sets, typical for current (and future) deep photometric surveys, the application of automated non-parametric methods is very often the only way to obtain information about the morphology. Over the past years different diagnostic diagrams were developed, related to the use of two or more parameters to separate between ET and LT galaxies and to select mergers. However, each of the analysed parameters, and therefore the diagnostic diagrams constructed with a combination of them, can suffer important changes depending on the data quality, mainly spatial resolution and data depth, so special care should be taken into account when applying the same criteria on different datasets.

Here we present a systematic study on how spatial resolution and depth affects the most used morphological diagnostic diagrams based on the six commonly used parameters: Abraham concentration index (CABR; Abraham et al. 1994, 1996), Gini coefficient (GINI; Abraham et al. 2003), Conselice-Bershady concentration index (CCON; Bershady et al. 2000; Conselice et al. 2000), M20 moment of light (M20; Lotz et al. 2004), Asymmetry index (ASYM; Abraham et al. 1994), and Smoothness (SMOOTH; Conselice et al. 2000). We used a visually classified sample of local galaxies and simulated them to map the observational conditions of three different ground- and space-based deep surveys. Comparing the parameters of local galaxies measured before and after moving them in redshift and magnitude, we were able to put constraints on the main morphological diagnostic diagrams, observing how the position and shape of the regions typical of ET and LT galaxies change in local and simulated conditions. Moreover, comparing the diagrams between the ground-based and space-based surveys, and at different magnitude cuts, we quantified how strong is the impact from spatial resolution and survey depth.

2. DATA

Local sample

We used a sample of 3000 local galaxies at $0.01 \leq z \leq 0.1$ (mean redshift of 0.04), observed in the Sloan Digital Sky Survey (SDSS) Data Release 4 (DR4) down to an apparent extinction-corrected magnitude $g < 16$, and visually classified by Nair & Abraham (2010; hereafter N&A), using the g and r bands.

Non-local sample

We selected three non-local surveys for our analysis: The Advanced Large Homogeneous Area Medium Band Redshift Astronomical survey (ALHAMBRA) and Subaru/XMM-*Newton* Deep Survey (SXDS), that provide representative samples for deep ground-based surveys (ALHAMBRA being shallower than SXDS, but with a large covered area, and SXDS as an example of the deepest available ground-based data). The Cosmic Evolution Survey (COSMOS) is used as a reference of deep space-based surveys.

ALHAMBRA is described in Moles et al. (2008), while photometric and photometric redshift catalogues are described in Molino et al. (2014). SXDS is described in Sekiguchi et al. 2004, used images and photometric catalogues in Furusawa et al. (2008), and photometric redshift catalogues in Simpson et al. (2013). COSMOS survey, images, photometric, and photometric redshift catalogues are described in Scoville et al. (2007), Koekemoer et al. (2007), Leauthaud et al. (2007), and Ilbert et al. (2009), respectively. We selected only objects with magnitudes $\mathrm{F613W} \leq 23.0$, $i' \leq 24.5$, and $\mathrm{F814W} < 24.0$ in the ALHAMBRA, SXDS, and COSMOS surveys, respectively, since above these magnitude limits the photo-z accuracy decreases significantly.

3. METHODOLOGY

We used a sample of local galaxies with available detailed visual classification and measured their morphological parameters in two cases:

1) at their real redshifts (magnitudes), ie. at $z \sim 0$, and

2) moving them to higher redshifts (therefore to fainter magnitudes) and lower resolution, to simulate the conditions of galaxies on deep, ground- and space-based non-local surveys.

In both cases all parameters are measured in a completely consistent way. Finally, we compared the results obtained in cases 1) and 2) to quantify the impact from data depth and spatial resolution on each morphological parameter, for each of the three analysed surveys.

We measured all parameters, in both cases 1) and 2), using the public code of galaxy classification galSVM (Huertas-Company et al. 2008). To simulate the conditions of non-local surveys, we first randomly redshifted and scaled in luminosity the selected sample of local galaxies to match the distributions of non-local ones. Moreover, we re-sampled the local galaxies with the corresponding pixel scale for each selected non-local survey, and convolved with its PSF to match the spatial resolution. Secondly, we dropped the simulated galaxies, obtained in the first step, into the real background of the high-redshift survey images. Third, we measured CABR, GINI, CCON, M20, ASYM, and SMOOTH of the simulated (at higher redshifts) and local sample (at their true redshifts). We took care of the k-correction effect introduced by redshift, and depending on the band selected in each survey, and also depending on the redshift to which the local galaxy was moved, we measured the morphological parameters using the corresponding SDSS rest-frame band image (in both cases for simulated and local samples). Since the morphological classification directly depends on the source brightness, in each survey we analysed the observational bias at the three different magnitude cuts: mag1_cut ≤ 20.0, mag2_cut ≤ 21.5, and mag3_cut ≤ 23.0 in the F613W band in ALHAMBRA; ≤ 21.0, ≤ 23.0, and ≤ 24.5, in the i' band in SXDS; and ≤ 21.0, ≤ 23.0, and ≤ 24.0, in the F814W band in COSMOS. In all surveys we chose the first magnitude cut as that at which we have a sufficient number of sources to perform our analysis; the cut at which our selected photometric/photometric redshift sample is complete, is the last one; and we chose a cut intermediate to these two.

Figure **??** shows examples of LT local galaxies, after being scaled to the conditions of the ALHAMBRA (top), SXDS (middle), and COSMOS (bottom) surveys. In each survey, we show the galaxies being redshifted to the corresponding magnitude cuts, as explained above, providing for each cut the simulated values of magnitude and redshift. We can observe in each survey how the galaxy information changes when going from brighter to fainter magnitudes (from lower to higher redshifts), but even more, how important role the spatial resolution has when classifying galaxies. In COSMOS survey the galaxy information can be conserved up to much higher redshifts in comparison with the studied ground-based surveys.

4. RESULTS

We analysed some of the most commonly used diagnostic diagrams, and measured their effectiveness for each survey and magnitude cut in Pović et al. (2014). Here we

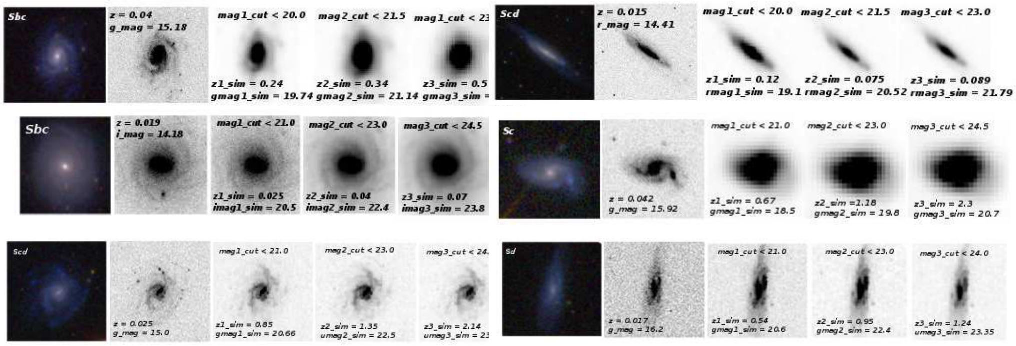

Figure 1: Example of simulated images of local LT galaxies after being scaled to map the conditions of the ALHAMBRA (top), SXDS (middle), and COSMOS (bottom). For each galaxy (in each row) we present the following (from left to right): colour image, used rest-frame image, and simulated high-redshift images at three magnitude cuts (as written on the top of each redshifted image). The real redshift and magnitude of the galaxy are noted on the corresponding rest-frame band image(s), while the simulated high-redshift and magnitude are noted on the scaled images of each magnitude cut.

present two of these diagrams: the relation between the CABR and ASYM (Fig. **??**, left), commonly used to distinguish between ETs and LTs, and that between M20 and GINI (Fig. **??**, right), mainly used for classifying mergers. In both figures, when observing the true parameters for local galaxies, we can clearly separate the regions typically occupied by ET, LT_et, and LT_lt galaxies, as expected. On the other side, we can observe how the position and the shape of the same regions change once we go to fainter magnitudes (higher redshifts). We measured the level of contamination for the highest density population (50%) of each analysed morphological group (ET, LT_et, and LT_lt) with the other two types, for the morphological diagrams presented (see Tab. 2 in Pović et al. 2014). We observed that the contamination levels in the morphological types increase with the data depth in all three surveys, being however significantly lower in the case of COSMOS.

5. CONCLUSIONS

Our main findings are:

- All six analysed morphological parameters suffer from significant changes in relation with both, the spatial resolution and the data depth.

- The impact of the spatial resolution on the morphology is much stronger than that of the data depth. Spatial resolution is therefore the most responsible for changing the parameters in the ground-based surveys, making in general galaxies to appear less concentrated and more symmetric.

- In surveys similar to ALHAMBRA, when analysing the highest density population regions of ET and LT galaxies in the main morphological diagnostic diagrams, spatial resolution and data depth introduces contamination levels of 5 - 30% for ET and 5 - 40% for LT galaxies (depending on the diagram), for the brightest galaxies with F613 $\leq$ 20.0. The diagrams that seem to work the best in this case are (CABR - ASYM), (CCON - GINI), and (CABR - GINI), while (CCON - SMOOTH) and (M20 -

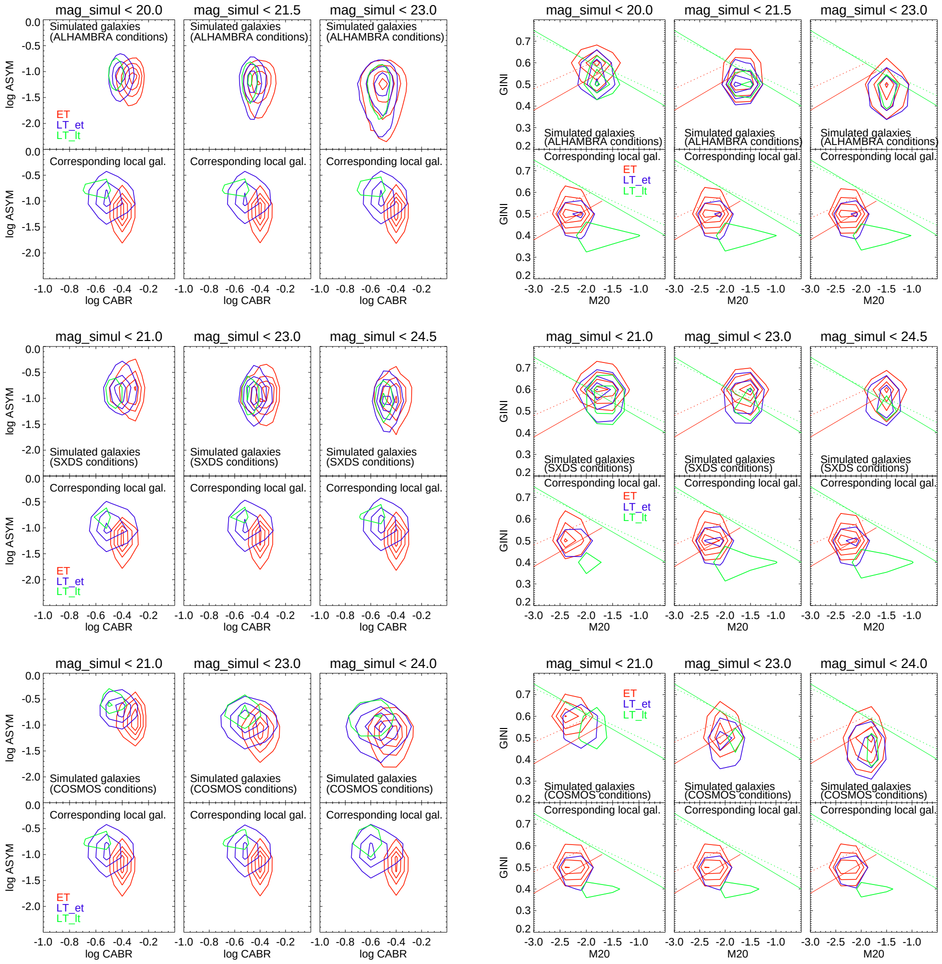

Figure 2: Left: Relation between CABR and ASYM, in the three analysed non-local surveys: ALHAMBRA *(top plots)*, SXDS *(middle plots)*, and COSMOS *(bottom plots)*. In each survey, the *top rows* represent the morphological parameters of the simulated sample obtained after moving the local galaxies to higher redshifts, considering three magnitude cuts (the first and last columns show the lowest and the highest analysed magnitude cut, respectively), while *bottom rows* show the corresponding true (local) values. Red, blue, and green contours represent ET, LT_et, and LT_lt galaxies, respectively. Right: Same as left, but for the relation between the M20 and GINI. The green (red) dotted and solid lines present the limits by Lotz et al. (2008) to distinguish between the normal galaxies and mergers (ET and LT galaxies), in the local universe and at $0.2 < z < 0.4$, respectively. In their classifications, mergers occupy the regions above the green lines, and ETs (LTs) are located below the green lines and above (below) the red ones.

Gini) are less efficient. At the faintest analysed magnitudes ($F613 \leq 23.0$) the contamination levels increase significantly, being as high as 60 - 100%, making each of the diagnostics useless if used separately. Similar results are obtained in the case of

SXDS, but at higher magnitude cuts (of order 1 - 2). Taking all this into account, when dealing with ground-based data sets, we suggest to avoid the use of 2 - 3 parameter diagnostic diagrams in morphological classification, and to apply instead the use of all morphological parameters simultaneously, and to use statistical approaches based on probability distributions for galaxies to be ET or LT. We applied this kind of methodology to classify galaxies in ALHAMBRA survey (see Pović et al. 2013).

- In space-based surveys similar to COSMOS, even at the highest magnitude cuts (F814 $\leq$ 24.0), the contamination levels are significantly lower than those at the brightest magnitudes in the ground-based surveys. The observational bias is insignificant for all parameters at magnitudes brighter than F814 = 21.0 (except for the LT_lt galaxies). However, when going to fainter magnitudes the contamination increases, and depending on the diagram it changes from 2 - 20% at F814 $\leq$ 23.0, to 10 - 30% for ET, and 20 - 70% for LT galaxies at F814 $\leq$ 24.0. In surveys similar to COSMOS, we again suggest to use several diagnostics to classify galaxies when going to magnitudes fainter than F814 = 23.0.

The results presented in this paper can be directly applied to any survey similar to ALHAMBRA, SXDS and COSMOS, and also can serve as an upper/lower limit to take into account when classifying galaxies using shallower/deeper data sets, including the future large photometric surveys like LSST, EUCLID, J-PAS, or DES.

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STAR FORMATION IN THE MOST LUMINOUS LINERs

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Abstract. Estimates of the star formation rates (SFRs) in local LINERs, based on different methods, can differ by large factors. This may be attributed to the confusion between active galactic nuclei (AGN) and star formation contribution from the host galaxy. We propose to obtain high spatial resolution, long slit spectra for a sample of local type-I and type-II LINERs at $0.04 < z < 0.11$. They will allow to distinguish between the AGN and starburst emission and to estimate the specific SFR (sSFR) by using the D_n4000 method. These observations will be used together with infra-red data (1) to determine the location of luminous local LINERs in the SFR vs. stellar mass diagram, (2) to compare them with local high ionisation AGN, and (3) to estimate the reliability of sSFR estimators based on UV, optical and IR indicators.

1. INTRODUCTION

Low Ionization Nuclear Emission line Regions (LINERs) are galaxies whose optical spectra are dominated by emission lines from low ionization species (e.g., [OI], [NII], [SII]). In the local universe they usually reside in early-type galaxies, and are the most common among galaxies hosting Active Galactic Nuclei (AGNs), with numbers that exceed those of high ionization AGNs (type-I and type-II Seyfert galaxies and quasars) by a factor of 10 or more (Heckman 1980). They are classified by their position in the BPT diagram (Kauffmann et al. 2003; Kewley et al. 2006) based on narrow emission line ratios, e.g. [OIII]/Hβ, [NII]/Hα and [OI]/Hα. Line ratios similar to those of LINERs are also observed in other sources such as evolved stars (e.g. Cid Fernandes et al. 2010) and regions of shock excited gas (e.g. Dopita et al. 1997). Thus additional diagnostics are required to distinguish such objects from AGN-type LINERs (the LINERs in the present work are excited by a central AGN; e.g. Ferland and Netzer 1983). They are distinguished from high ionization AGNs in two major ways: the level of ionization of their lines is much lower and the normalized accretion rate onto the central black hole is 1 - 5 orders of magnitude smaller. Like other AGNs, they can be divided into type-I (broad Balmer emission lines) and type-II (only narrow emission lines) LINERs.

The best studied very nearby LINERs (e.g. Ho 1997; Ho 2008) are found in the nuclei of galaxies with little or no evidence for active star formation (SF). In recently published paper by Tommasin et al. (2012), using Herschel/PACS observations the authors showed that the far infrared (FIR) luminosities of 35 out of 97 high luminosity LINERs at $z \sim 0.3$ are on average by 2 orders of magnitude higher than the FIR luminosities of nearby LINERs. Even assuming that all the observed Hα fluxes were due to SF (a wrong assumption since a non-negligible contribution is expected from the AGN excitation) it is still not possible to recover the SF rate (SFR) indicated by the FIR observations. Several possibilities could explain the obtained result: first, that smaller nuclear regions were analysed in local LINERs in comparison with the $z \sim 0.3$ sample and therefore the measured fluxes are contaminated from non-nuclear star-forming regions. Second, there might be a selection effect in FIR, since only 35 out of 97 sources were analysed. Third, it could be that still an insufficient population was studied systematically with sensitive FIR instruments in the local universe. Forth, it could be due to the real evolution in the AGN and SF properties from $z \sim 0$ to $z \sim 0.3$ LINERs. A combination of the previous possibilities may be also at work.

We suspect that active SF in LINER host galaxies has escaped the attention of most earlier studies that focused on the innermost part of nearby galaxies. The way to test this idea, understand the LINER phenomenon in relation to SF galaxies, and verify the evolution observed in Tommasin et al. (2012) is to conduct a detailed, ground based spectroscopy of luminous local ($z < 0.1$) LINERs and to use different methods to measure their SFR.

We suggest a systematic study of a flux limited sample of the most luminous (in terms of AGN luminosity) local LINERs, selecting a luminosity range that correspond to that of Tommasin et al. (2012) sample. We propose to obtain long slit spectra for a selected sample, which allows to distinguish between the AGN and starburst emission and to estimate the specific SFR using different methods.

2. SAMPLE SELECTION

We used the Sloan Digital Sky Survey (SDSS) Data Release 7 (DR7) data, and applied classical diagnostic diagrams (Kewley et al. 2006) to select LINERs. To measure the AGN luminosity, we used the method (Netzer 2009) based on Hβ and [OIII] lines. Finally, we selected 47 luminous LINERs, with AGN luminosities $10^{44.2} < \mathrm{L(AGN)} < 10^{45.2}$. We divided the sample into two groups using their Galex observations. 25 objects in the first group show FUV and NUV flux distributions that are consistent with the Galex Point Source Function (PSF), i.e. with a nuclear UV point source and are likely to be type-I LINERs. We refer to them as nuclear LINERs. The remaining sources show UV images that are consistent with uniform stellar emission across the host and are thus likely to be type-II LINERs. We refer to them as extended LINERs.

3. SAMPLE PROPERTIES

Using the SDSS spectroscopic data we estimated the continuum AB magnitude at $6500\mathring{A}$, whose distribution can be seen in Fig. **??** (top left). We divided the sample into a so-called bright sample ($\mathrm{m_{6500}(AB)} < 17.2$), and faint sample ($\mathrm{m_{6500}(AB)} > 17.2$).

The redshift distribution of the selected sample is shown in Fig. **??** (top right). As can be seen, the selected LINERs occupy the range $0.04 < z < 0.11$, with the mean values of 0.09, 0.084, and 0.094 for the total, bright, and faint samples, respectively.

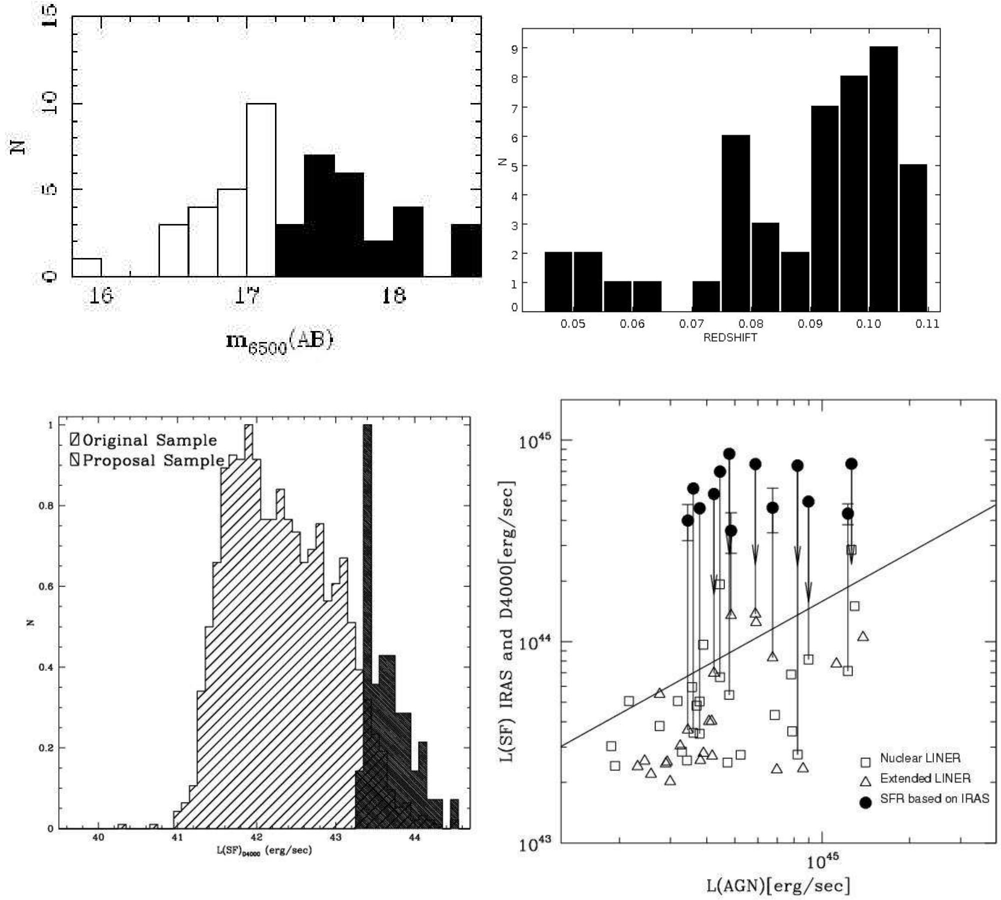

Figure 1: *Top left:* Distribution of m_{6500}(AB) magnitudes of the selected sample (faint LINERs in black). *Top right:* Redshift distribution of the selected sample. *Bottom left:* SF luminosity of the selected sample (in black) and all LINERs at $z < 0.11$. *Bottom right:* Relation between SF and AGN luminosities of selected sample, comparing the estimations provided by IR data (filled symbols) and those from D_n4000 (open symbols).

We used the D_n4000 method (Brinchmann et al. 2004) to estimate the SFRs which, combined with the SDSS-based estimates of the stellar mass, M_*, can be used to derive SFRs. The SF luminosities estimated in this way are shown in Fig. **??** (bottom left), where they are compared with all LINERs with $z < 0.11$. The selected sample is on the high D_n4000 of the histogram with a mean SFR(D_n4000) of about $\sim 1\,M_\odot$ yr$^{?1}$.

13 of the sources have 60 μm and 100 μm IRAS detections that, when transformed to SFR, provide SFR by an order of magnitude larger than the D_n4000 estimates, as shown in Fig. **??** (bottom right). Eleven more sources have WISE-based 22 μm measurements and those, when assumed to be entirely due to SF, give SFRs that are much smaller and more consistent (but still higher) than the D_n4000 estimates. Thus,

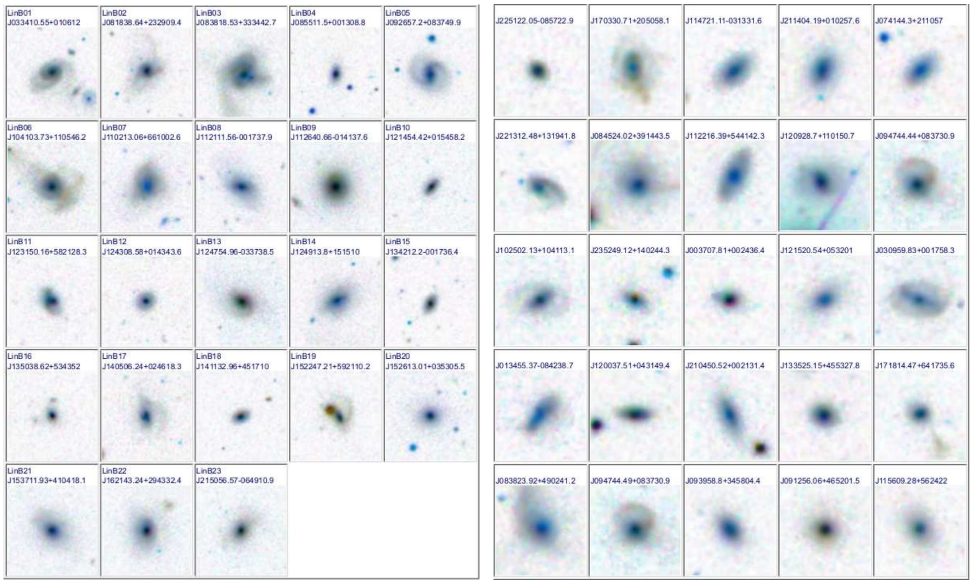

Figure 2: SDSS colour images of selected bright *(left)* and faint *(right)* sample.

we have three very different SFR estimates based on three different methods and an additional confusion due to the AGN. We suppose that most of the confusion is due to the use of the integrated line intensity from the central 3 arcsec of the galaxy in SDSS mixing up AGN and SF contributions. Spatially resolved spectroscopy is required to test this hypothesis.

We checked visually the morphologies of the selected sample (see Fig. **??**), finding both early- and late-type galaxies, as well as signatures of interactions in a number of cases.

4. DATA

We obtained ∼ 1" long-slit spectroscopic data with the CAHA/TWIN spectrograph, and for 10 bright sources, with the NOT/ALFOSC spectrograph. Standard reduction procedures were used. We also were awarded with priority 2 Herschel time (PI. Netzer) whose data will supply accurate SFR estimates for about 13% of the sources. IRAS and WISE IR data are also available for the galaxies in our sample.

Figure **??** shows an example of spectra obtained with the NOT/ALFOSC spectrograph for a sample of six bright LINERs (black solid lines). As a sanity check, we compared our spectra and [OIII]5007 flux measurements with that from SDSS, finding a good correlation.

5. WORK IN PROGRESS

The observations obtained within this project will help to separate between AGN and starburst emissions, and will be used: (1) to see what are the IR and SF properties of the most luminous local LINERs, (2) to test the possible evolution in the AGN and

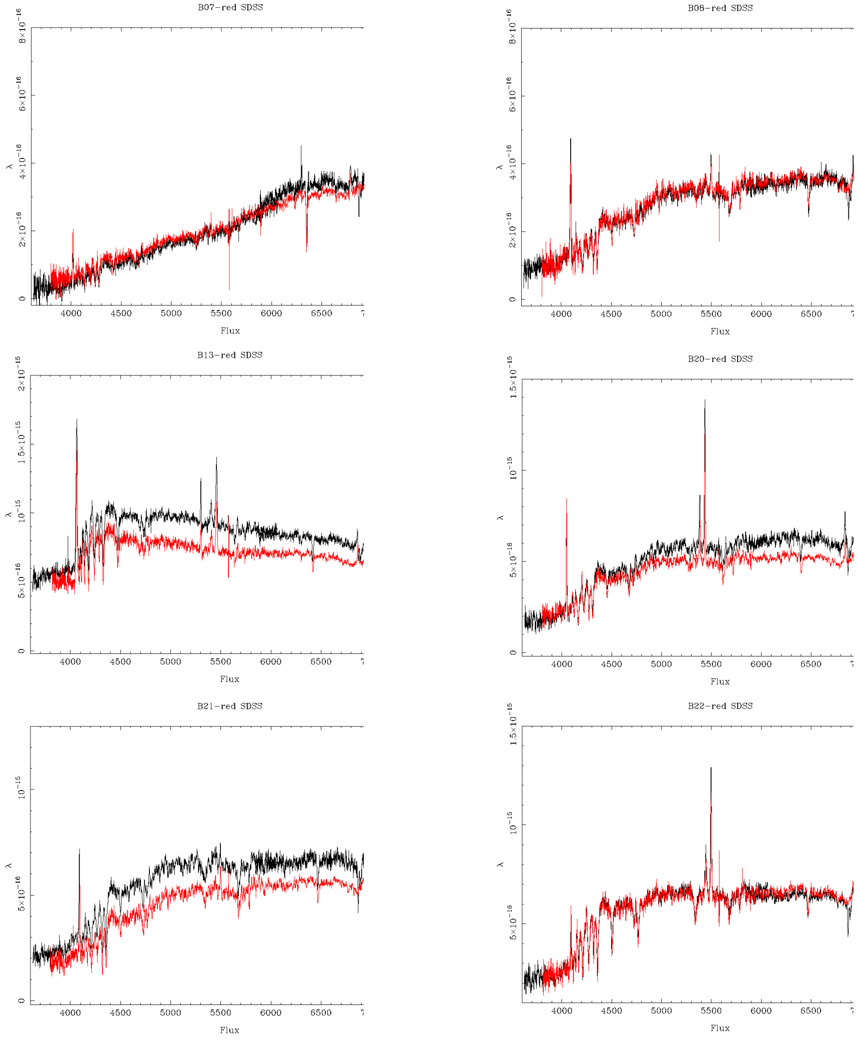

Figure 3: Example of ∼3” NOT spectra (in black), and their corresponding 3” SDSS spectra (in red).

SF properties, (3) to compare the selected sample with local high ionisation AGN, (4) to estimate the reliability of sSFR estimators based on UV, optical and IR indicators, and (5) to test if there are FIR differences between UV nuclear and extended LINERs.

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LYMAN-ALPHA BLOBS NUMBER DENSITY AND COLD GAS ACCRETION

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Abstract. In this work we attempt to model the observed evolution in comoving number density of Lyman-alpha blobs (LABs) as a function of redshift. Our model assumes that cooling radiation (CR) from the intergalactic gas is the main source of LABs emission. We have used the evolution of distribution of halo masses from a dark matter (DM) cosmological simulation and cold mode gas accretion rates as a function of halo mass and redshift from hydrodynamical simulation. In this work we present our results.

1. INTRODUCTION

Lyman-alpha blobs (LABs) are very luminous ($\sim 10^{43}$-10^{44} erg/s) and very extended (with diameters of $\sim$ 50-100 kpc and more) regions of Lyα emission, which are radio quiet. They are observed at a range of redshifts $z \sim$ 1-6.6, but the bulk of objects currently known is found between $z \sim$ 2-3 (e.g. Steidel et al. 2000; Matsuda et al. 2004, Yang et al. 2010; Erb et al. 2011). A search for LABs at $z = 0.8$ has found none (Keel et al. 2009), suggesting that their comoving number density (N_{LAB}) sharply decreases from $z \sim$ 2-3 to $z \sim$ 0.8, and that LAB might be only a high redshift phenomenon (see also Barger et al. (2012) and Prescott (2009)). LABs are rare (with comoving number density $\sim 10^{-6}$ Mpc^{-3} - 10^{-4} Mpc^{-3}) and preferentially found in overdense regions (e.g. Yang et al. 2010), which indicates that LABs could be sites of formation of most massive galaxies.

It is still not clear what is the mechanism that powers the intensive Lyα emission of LABs. One of the proposed mechanisms of emission is cooling radiation from cold streams of gas accreting onto galaxies (CR; e.g. Dijkstra & Loeb 2009). Numerical simulations show that not all the gas that is accreted onto galaxies is shock heated to roughly the virial temperature. Some fraction of the gas maintains a temperature of $T < 2.5 \times 10^5$ K and is accreted onto galaxies in the form of filamentary streams (e.g. Kereš et al. 2009). This is the cold mode gas accretion. While the cold gas is streaming towards the dark-matter halo potential well, gravitational binding energy is released and the hydrogen atoms are excited, followed by cooling emission of Lyα (e.g. Haiman et al. 2000). In cases where LABs are not associated with other sources that are powerful enough to explain the observed Lyα luminosities, CR could play a dominant role (Nilsson et al. 2006; Smith et al. 2008; Matsuda et al. 2006; Saito et al. 2006).

Previously a number of authors have created simulations and analytical models which try to explain LABs emission through the cooling radiation alone. Some of them simulated LABs with similar Lyα luminosities, Lyα line widths, and number densities as the observed LABs at $z = 3.1$ (e.g. Dijkstra & Loeb 2009, Goerdt et al. 2010, Rosdahl & Blaizot 2012), but others concluded that it is difficult to explain LAB radiation with CR (e.g. Faucher-Giguère et al. 2010, Cen and Zheng 2012). These results depend on detailed modelling of Lyα cooling radiation (such as radiative transfer and self-shielding) and on the resolution of the simulation.

In this work we attempt to once again investigate if CR can be the main source of LAB energy, but now including the whole range of redshifts where LABs are observed $z \sim$ 0-7, and using a simple (analytical) model in which we calculate Lyα emission from the released gravitational potential energy and from the cold gas accretion rates.

2. MODEL

Our model assumes that cooling radiation (CR) from the intergalactic gas is the main source of LAB emission. We have used the evolution of distribution of halo masses from a dark matter (DM) cosmological simulation and cold mode gas accretion rates as a function of halo mass and redshift from hydrodynamical simulation from Faucher-Giguère et al. (2011) (FG11). For every halo we calculated Lyα luminosity from the released gravitational potential energy.

Now we present an overview of equations we have used for computing Lyα luminosity, which are also derived in Goerdt et al. (2010) (G10). While cold gas is streaming from virial radius $R_{\rm vir}$ to some radius r_0 in a halo, gravitational energy is released. Lyα radiation originates from a fraction f_c of this energy that is heating the cold streams, while the rest is converted in kinetic energy or is heating the hot streams of the gas. A fraction f_α of this energy represents the radiation which we see at the Lyα line. It includes absorption by intergalactic medium and absorption by dust or HI inside a halo. If we assume that cold gas accretion rate $\dot{M}_c$ and the velocity of its accretion are roughly constant from $R_{\rm vir}$ to r_0 (as did G10; however, readers should be cautioned that later work of FG11 showed that $\dot{M}_c$ may in fact drop at smaller radii.), then the observed Lyα luminosity is

$$L_{Ly\alpha} = f_\alpha f_c \dot{M}_c |\Delta\Phi(R_{\rm vir}, r)|, \qquad (1)$$

where $\Delta\Phi(R_{\rm vir}, r)$ is a potential difference between virial radius $R_{\rm vir}$ and some radius r in a halo.

In our model we have used FG11 estimates of cold gas accretion rate, and fitted a polynomial which describes $\dot{M}_c$ as a function of halo mass $\log M$ and redshift $\log(1+z)$. Further details are described in our forthcoming paper in MNRAS.

For Navarro, Frenk & White (1997) halo mass density profile it can be shown that

$$|\Delta\Phi(R_{\rm vir}, r)| = {V_{\rm vir}}^2 \frac{C}{A_1(C)} \left[\frac{\ln(1+x)}{x} - \frac{\ln(1+C)}{C} \right], \qquad (2)$$

where C is a concentration parameter, $x = Cr/R_{\rm vir}$, $A_1(x) = \ln(x+1) - x/(x+1)$, and $V_{\rm vir}$ is the virial velocity, $V_{\rm vir} \simeq 236\,{\rm km\,s^{-1}} {M_{12}}^{1/3} {(1+z)_4}^{1/2}$ (Goerdt et al. 2010).

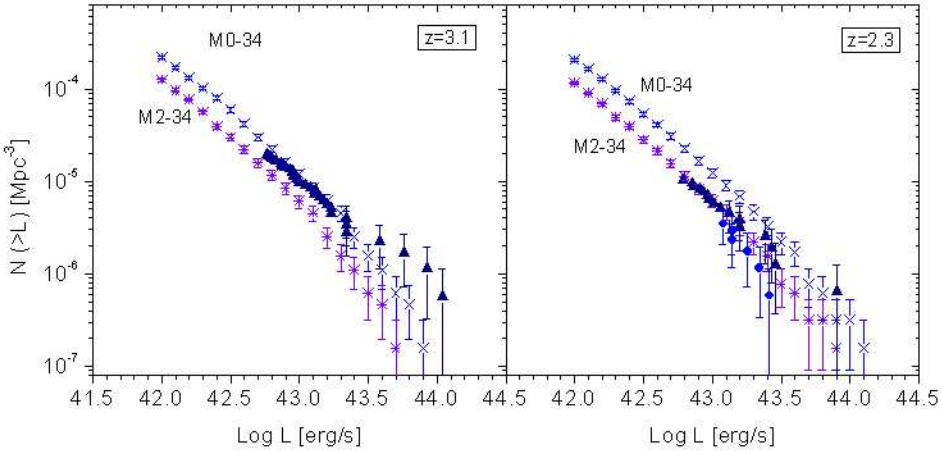

Figure 1: Luminosity function at $z = 3.1$ (left) and $z = 2.3$ (right), for cases M0-34 (blue x) and M2-34 (violet *). Data from observations: Matsuda et al. (2004) ($z = 3.1$; triangles), Yang et al. (2010) ($z = 2.3$; triangles), Erb et al. (2011) ($z = 2.3$; circles). Poisson errors for our model and for observations are indicated, except for less luminous LAB.

We use estimate of average concentration parameter from Bullock et al. (2001): $C \approx 3(M_{\rm vir}/10^{12}{\rm M}_\odot)^{-0.13}((1+z)/4)^{-1}$.

Now, for given values of f_α, f_c and r_0 one can determine luminosity of a halo at a given mass and redshift. We will assume that these parameters are equal for all halos, at all redshifts. The r_0 is radius inside a halo until which cooling luminosity is significant. Near the halo center cold gas accretion rate is smaller and dust near the galaxy in the halo center absorbs some fraction of Lyα photons. In this work we determine luminosities for $f_\alpha f_c = 0.34$, which is the value G10 used to reproduce observed values, for luminosities for 2 cases:

1) M0-34: $f_\alpha f_c = 0.34$, $r_0 = 0$ (accretion to the center of halo), and

2) M2-34: $f_\alpha f_c = 0.34$, $r_0 = 0.2R_{\rm vir}$ (accretion which does not include the central galaxy at $z \sim 2-3$),

and compare them with observations. We also determined N_{LAB} for a few other values of these parameters.

3. RESULTS AND COMPARISON WITH OBSERVATIONS

In this section we present our luminosity functions at $z = 2.3 - 3.1$, and comoving number densities at a redshift range $z = 0 - 7$. Observed number densities are previously corrected for the density contrast of Lyman-alpha emitting galaxies in the observed volume (this is further explained in our forthcoming paper in MNRAS, in preparation). Because of the large volume of our DM simulation, we will proceed with the assumption that our DM simulation results are indicative of an average number density of LABs.

3. 1. LUMINOSITY FUNCTIONS AND CONSTRAINING A FREE PARAMETER

In Figure 1 we compare cumulative luminosity functions (LF) at $z = 3.1$ and $z = 2.3$ from our model (for cases M0-34 and M2-34) and from observations (for Matsuda et al. (2004), Yang et al. (2010), and Erb et al. (2011)). For $z = 3.1$ we see that LF from our model for accretion to the center is in good agreement with observations at luminosities $L < 10^{43.5}$ erg/s. We note that for different values of $f_\alpha f_c$ we could get different values in LF, but still the same slope. Agreement between the slopes of LF from our model and from observations could indicate that cold gas accretion has an important role in luminosity of LAB, or that another mechanism of luminosity is related to mass of halo in similar way. For example, besides cold gas accretion $\dot{M}_c$, also star formation rate could be related in similar way with halo mass.

For $L > 10^{43.5}$ erg/s we get smaller values of LF than observed. This could partially be because of cosmic variance, as the most luminous LAB are rare, therefore the error bars are largest for the most luminous LABs and for larger observed volumes we would get smaller observed LF. The other possibility is that evolution of more luminous LAB is more rapid, and that there is additional mechanism of energy, so observed luminosities are larger than that from our model, which includes only cold gas accretion.

For $z = 2.3$ we get similar conclusions, but now we obtain agreement for different parameters, i.e. for accretion to $0.2R_{\rm vir}$. If we assume that our comparison with observations is correct, this difference could be explained if: 1) the rate $\dot{M}_c$ is smaller at $r < R_{\rm vir}$ than at $R_{\rm vir}$, more significantly as z decreases, 2) dust absorption (in the vicinity of galaxy) is larger at lower z, 3) f_c is smaller at lower z.

3. 2. COMOVING NUMBER DENSITY AS A FUNCTION OF REDSHIFT

We assume that all halos with $L_{Ly\alpha} > 10^{43}$erg/s, $\;d > 50$kpc are identified in observations as LAB, and compare its comoving number density (N_{LAB}) from our model and from observations. However, to estimate LAB diameters from a DM simulation properly would be difficult, as we would need to account for irregular LAB shape and estimate of surface brightness distribution with radius from the LAB center. For now we will just estimate N_{LAB} from the ratio of number density of 1) LAB with $L > 10^{43}$ erg/s (N_{43}), and 2) LAB with $L > 10^{43}$ erg/s and $d > 50$ kpc. We find this ratio in surveys from Matsuda et al. (2004) at $z = 3.1$ and in two surveys from Yang et al. (2010) at $z = 2.3$, and obtain that it is equal to ~ 2. We estimate N_{LAB} in our model as $N_{LAB} \sim N_{43}/2$.

In Figure 2 we compare N_{LAB} from our model for cases M0-34 and M2-34 (dotted lines), with the observed ones. We retrieve good agreement between observations and our model for case M0-34 at $z \sim 3$ and for case M2-34 at $z \sim 2.3$ (as for luminosity functions). All observed number densities at $z = 2.3$ are similar and in agreement with that from our model (accounting for errors), with exception of number density for Palunas et al. (2004), which is somewhat lower. At $z \sim 4$ for definition of LABs as $L_{Ly\alpha} > 10^{43}$erg/s our N_{LAB} for case M0-34 is almost identical to that from survey of Saito et al. (2006).

However, for both of these cases N_{LAB} from our model falls below observed N_{LAB} at high redshifts, and above at lower redshifts. At redshift $z = 0.8$ our N_{LAB} for M0-34 and M2-34 are at least $\sim$ 3-6 times larger than observed, and with corrections for overdensity of $\delta = 1$ and $\delta = 6$ larger by a factor of $\sim$ 5-10 and $\sim$ 20-45, respectively.

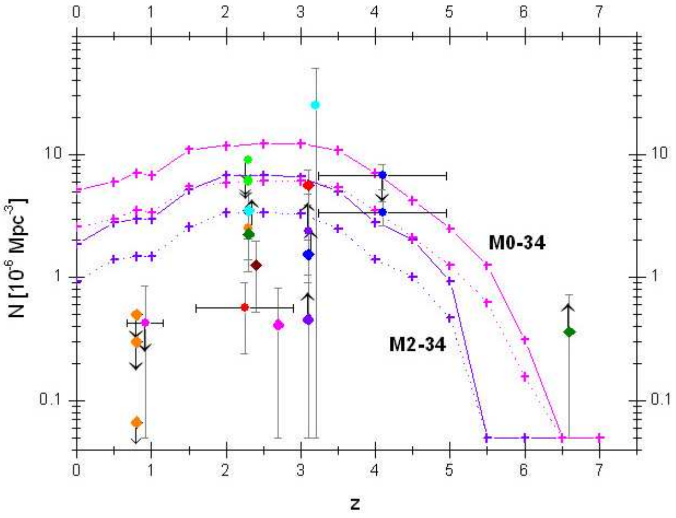

Figure 2: Comparison of comoving number densities of LABs from our model and from observations. Solid lines: N_{43} from our model for cases M0-34 (rose lines) and M2-34 (violet lines). Dotted lines: our estimate of N_{LAB}. At redshifts in which there are no LAB in our model we set $N = 0.05 \times 10^{-6}\text{Mpc}^{-3}$. Symbols are data from observations. At $z \sim 2.3$ these are, from the largest to the smallest number densities: Yang et al. 2010 (upper limits for three fields; light green), Erb et al. 2011 (light blue), Yang et al. 2009 (orange), Yang et al. 2010 (light green), Palunas et al. 2004 (dark red), Prescott (2009)(red). At $z \sim 3.1$: Nilsson et al. 2006 (light blue), Matsuda et al. 2004 (red), Matsuda et al. 2011 (violet), Matsuda et al. 2011 (dark blue), Matsuda et al. 2009 (violet). At $z = 2.7$: Prescott et al. 2008 (rose). At $z \sim 1$: Keel et al. 2009 (not corrected for density contrast), Barger et al. 2012 (rose), Keel et al. 2009 (orange, with different assumptions of density contrast). At $z \sim 3-5$: Saito et al. 2006 (dark blue); we also displayed densities divided by 1.7, 2, and 2.5. At $z = 6.6$: Ouchi et al. 2009 (dark green).

At redshift $z = 6.6$ we don't find LAB from our model for both cases, which is contrary to observations. For $f_\alpha f_c = 1$ our N_{LAB} are somewhat above observations (of one observed LAB at $z = 6.6$), and for $f_\alpha f_c = 0.1$ our N_{LAB} at $z \sim 1$ are still above the observations. This indicates that it is difficult to explain LABs with emission only from CR at a range of redshifts for a constant unknown parameters, but we need more detailed modelling in order to obtain more precise conclusions.

4. DISCUSSION AND CONCLUSIONS

For constant parameters, we obtained a good agreement between the slopes of luminosity functions from our model and from observations at $z = 3.1$ and $z = 2.3$, which could indicate that CR has an important role in luminosity of LABs, or that mechanism of emission is related to mass of halo in a similar way. However, the predicted comoving number density of LAB in our model falls below observed density at high redshift and above at lower redshifts, which could indicate that CR is in fact not the main source of energy of LAB at all redshifts and masses, for constant $f_\alpha f_c$. However, there are still many uncertainties in our model. Some of them are: 1) cold gas accretion rates are actually lower at smaller radii inside a halo, and their decrease along a halo radius is more significant at lower redshifts; 2) with detailed estimate of LABs emission and diameter above some surface brightness threshold our results could change; 3) factor f_c could change with redshift; 4) factor f_α could decrease with redshift if absorption by dust is significant in LABs and if it has more important role at low redshifts.

Our subsequent paper in MNRAS includes a more detailed model of Lyα emission from the cooling radiation, in which we estimate gravitational potentials directly from the dark matter simulation, we include dependence of cold gas accretion rates on radius inside a halo, we include propagation of Lyα photons through the intergalactic medium, and we accounted for Lyα emission just above some surface brightness threshold.

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AN ATTEMPT TO EXPLAIN THE EVOLUTION OF LYMAN-ALPHA BLOBS NUMBER DENSITY AT Z 1-6

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Abstract. Lyman-alpha blobs (LABs), very luminous ($\sim 10^{43} - 10^{44}$ erg/s) and very extended ($\sim 50 - 150$ kpc) radio quiet sources, are discovered 10-15 years ago, and observed in redshift range from 1 to 6.6. The source of their energy is still not clear. In this work we model the evolution in comoving number density of LABs as a function of redshift. Our model is based on empirical recipes for the cold mode accretion derived from cosmological hydrodynamical simulations. We assume that the cooling radiation (CR) from the cold mode accretion in intergalactic gas is the main source of LAB emission and we "paint on" empirical recipes on the numerical merger tree for dark matter halos in the post-analysis of high-res cosmological dark matter only simulation. In this way, we can calculate the Lyman-alpha luminosity expected in every dark matter halo at every redshift, and predict the theoretical luminosity and area functions of LABs at various redshifts. In this work we compared predicted luminosity functions and number densities to the observed ones for some parameters and at various redshifts, and we concluded.

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MODELING OF SUPERMASSIVE BLACK HOLE GROWTH AT REDSHIFT $Z = 7$

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Abstract. It is widely accepted that SMBHs reside in centers of massive galaxies and quasars. SMBHs are formed by a combination of gas accretion and merges with other massive BHs. Some SMBHs are detected in very early Universe ($\sim$ 800 Myr). We use Millennium II simulation in order to find out if SMBHs can be formed that early with known growth mechanisms. We find that BH seeds with masses $100\mathrm{M}_\odot$ that accrete at the Eddington ratio 2.9 can form SMBH with mass $10^9\mathrm{M}_\odot$ at $z = 6.2$ or at $z = 7.3$ for accretion at the Eddington ratio 3.2. Accretion at the Eddington ratio ~ 3 is still difficult to explain, but it might be possible especially after new observational evidence of quasars that accrete at super-Eddington ratio of the similar values.

1. INTRODUCTION

Massive elliptical and spiral galaxies host super-massive black holes (SMBHs) with masses $10^6\mathrm{M}_\odot$ to $10^{10}\mathrm{M}_\odot$ at their centers (Kormendy & Richstone 1995). Quasars, powered by SMBH with mass $\sim 10^9\mathrm{M}_\odot$ are discovered at redshift $z > 6$. The most distant SMBH known so far is the one with mass $2 \times 10^9\mathrm{M}_\odot$ detected at $z = 7.1$ (Mortlock et al. 2011). In order to grow to such massive SMBH, a single light BH seed (100 $\mathrm{M}_\odot$) need to continuously accrete at the Eddington luminosity for 840 Myr. This means that it would be impossible to grow SMBH from light BH seeds at the Eddington limit by $z = 7$. It raises a question how massive were the initial BH seeds and what values BH growth parameters can take?

1. 1. BH SEEDS FORMATION AND GROWTH PARAMETERS

Two main BH seed formation mechanisms are Pop III stars and direct collapse of gas into BH.

Pop III stars, the first metal-free stars, might be progenitors of BH seeds that grew to SMBHs at high redshift quasars (Madau & Rees 2001; Heger et al. 2003; Wise & Abel 2005). Masses of those BH seeds depend on the masses of Pop III stars, which could be in range $60 - 300\,\mathrm{M}_\odot$ (Bromm et al. 2009), or even $1000\,\mathrm{M}_\odot$ (Hirano et al. 2013). It is typically assumed in the literature that Pop III stars form BH seeds with masses close to $100\,\mathrm{M}_\odot$. Previous attempts to form $\sim 10^9\,\mathrm{M}_\odot$ SMBHs at $z \sim 6$

from Pop III seeds required continuous accretion close to or exceeding the Eddington limit (Haiman & Loeb 2001, Tyler et al. 2003, Volonteri & Begelman 2010, Whalen & Fryer 2012, Johnson et al. 2012). There are theoretical uncertainties whether BH seeds can sustain such high accretion rates for a long time (e.g., Milosavljević et al. 2009, Jeon et al. 2011).

Another possible mechanism for BH seed formation is direct collapse of gas into BH. Those BH seeds have masses in range $\sim 10^4 - 10^6 \mathrm{M}_\odot$ and can easier reach $10^9 \mathrm{M}_\odot$ at $z > 6$ (Loeb & Rasio 1994, Eisenstein & Loeb 1995, Oh & Haiman 2002, Bromm & Loeb 2003, Koushiappas et al. 2004, Begelman et al. 2006, Lodato & Natarajan 2006, Begelman et al. 2008). Direct collapse is possible if fragmentation and star formation are avoided. Fragmentation will not occur if gas has no metals and if formation of H_2 molecules is prevented via strong UV background. Alternatively, major mergers may lead to a rapid gas inflow. In such case, turbulence may be the inhibitor of fragmentation, and the requirement of metal-free gas may be relaxed (Mayer et al. 2010).

BH growth due to gas accretion depends on three gas accretion parameters. Those parameters are radiative efficiency, Eddington ratio and the time that a BH spends accreting.

Radiative efficiency, ϵ, is the efficiency of conversion of rest-mass into energy during accretion and it depends on BH spin. Mean value of radiative efficiency for quasars is $\epsilon \geq 0.1$ (Elvis et al. 2002, Yu 2002, Davis & Laor 2011) and can be estimated using Soltan's argument (Soltan 1982).

Eddington ratio is $f_{\mathrm{Edd}} = \frac{L}{L_{\mathrm{Edd}}}$, where L is a radiative luminosity of a BH and $L_{\mathrm{Edd}}[\mathrm{erg\ s}^{-1}] = 1.26 \times 10^{38} M_{\mathrm{BH}}\ [\mathrm{M}_\odot]$ is Eddington luminosity. It is usually assumed that BH luminosity during accretion cannot exceed the Eddington luminosity. However, recent observational (Kelly & Shen 2013, Du et al. 2014, Page et al. 2013) and theoretical (Volonteri & Rees 2005, 2006, Volonteri & Silk 2014, Dehnen & King 2013) works showed that quasars, at least at some point in their evolution, can accrete at the super-Eddington luminosities.

Quasars lifetimes can also be estimated using Soltan's argument (Soltan 1982). Observations usually show that quasars lifetimes are comparable with Salpeter's time (Salpeter 1964), which is e-folding time scale for SMBH growth:

$$t_{\mathrm{s}} = M/\dot{M} = 4.5 \times 10^7 (\frac{\epsilon}{0.1})(\frac{L}{L_{\mathrm{Edd}}})^{-1}. \tag{1}$$

Yu & Tremaine (2002) showed that quasar lifetime is a function of BH mass. They found that the mean lifetime is $t_Q = 3 - 13 \times 10^7$ yr for $\epsilon = 0.1 - 0.3$ and $10^8 < M_{\mathrm{BH}} < 10^9 \mathrm{M}_\odot$.

After the accretion episode, final BH mass is given by (Johnson et al. 2013):

$$M_{\mathrm{BH}} = M_{\mathrm{BH},0} \times \exp\,[\,\frac{f_{\mathrm{Edd}}\,(1-\epsilon)}{\epsilon}\ \frac{t_{\mathrm{f}} - t_{\mathrm{i}}}{t_{\mathrm{Edd}}}] \tag{2}$$

where $t_{\mathrm{Edd}} = 450$ Myr, t_{f} i t_{i} are the ages of the universe when the BH attains its final mass and at the time of seed formation, respectively.

We use data from Millennium II simulation (Boylan-Kolchin et al. 2009) to examine if BH mergers in merger trees of this simulation contribute to the growth of 10^9 $\mathrm{M}_\odot$ SMBH at $z > 6$.

2. METHOD

Our goal is to find out under what conditions BH seeds from various models can produce SMBH with mass $> 10^9 \mathrm{M}_\odot$ at $z > 6$. We use publicly available data from Millennium II simulation (Boylan-Kolchin et al. 2009) to make merger tree which tracks halo merger history from redshift $z = 19.9$ to $z = 6.2$. Millennium II simulation (Boylan-Kolchin et al. 2009) is large N-body simulation which follows 2163^3 particles within a periodic simulation cube of side length $L = 100h^{-1}$ Mpc. Each simulation particle has mass 6.885×10^6 $\mathrm{M}_\odot$.

We use Millennium II database to select halos with mass $> 10^{11} \mathrm{M}_\odot$ at redshift $z = 6.2$. For all selected halos we find their progenitor halos, i.e. halos that have merged at previous snapshot to form the selected halos. We repeat this procedure up to redshift $z = 19.9$ where first mergers are recorded. We assume that each newly formed halo hosts one BH and that two BHs merge right after their host halos merge. BHs can grow by merging with other BHs and by gas accretion. We treated separately minor and major mergers. Merger is major if $\frac{M_{\mathrm{halo1}}}{M_{\mathrm{halo2}}} \geq 0.3$ for $M_{\mathrm{halo1}} < M_{\mathrm{halo2}}$. In the case of minor merger mass of the newly formed BH is a simple sum of the previous BH masses and in the case of major merger gas accretion is triggered (equation 2).

2. 1. INITIAL BH MASSES AND PARAMETERS CHOICE

Final BH mass depends on the initial BH mass, Eddington ratio, radiative efficiency and quasars lifetime (equation 2.). For radiative efficiency we choose commonly accepted value $\epsilon = 0.1$ (Elvis et al. 2002, Yu & Tremaine 2002, Davis & Laor 2011). In each accretion episode BHs are able to accrete for a period of time given by Yu & Tremaine (2002).

Free parameters in our model are the initial BH mass and the Eddington ratio. In each of our semi-analytical simulation runs we vary the values of these two parameters with a condition that BH mass at $z = 7.3$, i.e $z = 6.2$, has to be $> 10^9$ $\mathrm{M}_\odot$.

3. RESULTS

Figure 1. shows the minimum value of the Eddington ratio (f_{Edd}) necessary to be assigned to BHs in every accretion episode along the merger tree, in order for merger tree to produce SMBH with mass $> 10^9$ $\mathrm{M}_\odot$ at redshifts $z = 7.3$ and $z = 6.2$. In every accretion episode radiative efficiency is fixed at $\epsilon = 0.1$, and quasar lifetime is taken from Yu & Tremaine (2002). Each point in Figure 1. is a result of one semi-analytic simulation which produces SMBH with mass $> 10^9 \mathrm{M}_\odot$ for the given combination of Eddington ratio and initial BH mass.

Figure 1. shows that light BH seeds with masses $100 \mathrm{M}_\odot$ need to accrete on the Eddington ratio $f_{\mathrm{Edd}} = 2.9$ in order to form SMBH with mass $> 10^9 \mathrm{M}_\odot$ at $z = 6.2$ (black line). At redshift $z = 7.3$ (red line) Eddington ratio $f_{\mathrm{Edd}} = 3.2$ is needed.

In further analysis we concentrate on one halo with the most massive BH at redshift $z = 7.3$ and its progenitors. We examine light BH seeds with masses $100 \mathrm{M}_\odot$ and assume that in every accretion episode radiative efficiency is $\epsilon = 0.1$ and Eddington ratios are $f_{\mathrm{Edd}} = 3.2$.

Figure 2. represents every major merger in the merger tree of the halo which hosts $> 10^9$ $\mathrm{M}_\odot$ SMBH at $z = 7.3$. It shows the mass of more massive halo in each major

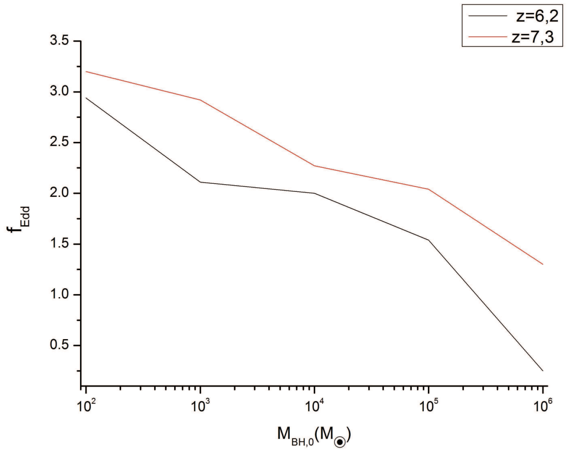

Figure 1: Eddington ratio as function of initial BH masses. Figure shows different combinations of Eddington ratio and initial BH masses that produce SMBH with mass $> 10^9 \mathrm{M}_\odot$ at redshift $z = 6.2$ (black line), and $z = 7.3$ (red line), respectively, with $\epsilon = 0.1$.

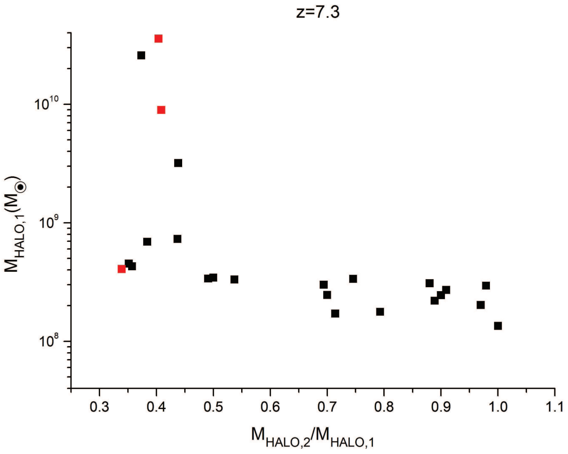

Figure 2: Mass of more massive halo in major merger as a function of mass ratio of these two halos. Red squares represent major mergers of the main halo, and black squares are major mergers of halos in the side branches of the merger tree. This figure shows parallel accretion.

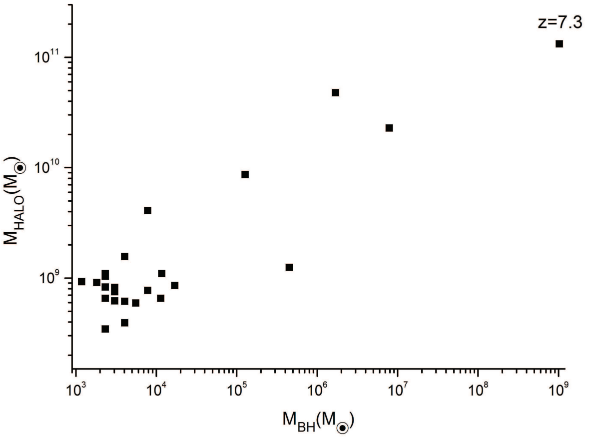

Figure 3: Halo mass as a function of BH mass in its center. BH have sufficient reservoir of gas for accretion and BH mass never exceeds 1% of the halo mass.

merger as a function of mass ratio of these two halos. Red squares represent major mergers of the main halo, and black squares represent major mergers of halos that will merge with the main halo later. This figure shows that beside the main halo accretion, there is a large number of halos that accrete at the same time and when they merge with the main halo they already host massive BH in their center, not only the BH with initial mass of $100\mathrm{M}_\odot$. Hence, instead of one BH constantly accreting we have many BHs in shorter, parallel accretion episodes. This approach increases impact of mergers, and reduces impact of accretion.

Figure 3. shows halo mass as a function of BH mass in its center. If we assume the cosmological ratio of dark and luminous matter, baryonic matter makes approximately 10% of dark matter. In other words, 10% of the halo mass makes gas that BH can accrete. This figure shows that BHs have sufficient reservoir of gas for accretion and that BH mass never exceeds 1% of the halo mass.

4. DISCUSSION AND CONCLUSION

Using Millennium II cosmological simulation (Boylan-Kolchin et al. 2009) we make merger tree which track dark matter halo merger history to $z = 6.2$. BH in their centers can grow in BH mergers and by gas accretion. In each accretion episode radiative efficiency is fixed at $\epsilon = 0.1$ (Elvis et al. 2002, Yu & Tremaine 2002, Davis & Laor 2011) and accretion timescale is given by Yu & Tremaine (2002).

We find that remnants of Pop III stars can produce $> 10^9$ $\mathrm{M}_\odot$ SMBH at redshift $z = 7.3$ if at each accretion episode they are able to accrete at the Eddington ratio of $f_{\mathrm{Edd}} = 3.2$, or at redshift $z = 6.2$ and the Eddington ratio $f_{\mathrm{Edd}} = 2.9$. Recent observations have suggested that moderate super-Eddington accretion ($1 < f_{\mathrm{Edd}} < 10$) might be possible (Kelly & Shen 2013, Du et al. 2014, Page et al. 2013) .

For typical values of the accretion parameters required to explain formation of $> 10^9$ $\mathrm{M}_\odot$ SMBH (100 $\mathrm{M}_\odot$, $\epsilon = 0.1$ and continuous accretion at $f_{\mathrm{Edd}} = 1$) the accretion lasts for 840 Myr or 280 Myr in case where $f_{\mathrm{Edd}} = 3$. In our model, the longest accretion episode is defined by Yu & Tremaine (2002) and it does not exceed 75 Myr. Thus, we have managed to significantly reduce the time that BH needs to spend accreting thanks to the parallel accretion onto BHs in side branches of the merger tree. Instead of one BH constantly accreting for a long time we have many BHs in shorter parallel accretion episodes. This approach increases the importance of mergers on SMBH growth. We also show that BH masses in our model never exceeds 1% of the host halo mass, and that BHs have enough gas for accretion.

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THE IMPORTANCE OF DARK MATTER IN NEARBY EARLY-TYPE GALAXIES

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Abstract. In this contribution we present the study of the dynamics of the sample of ten early-type galaxies in both Newtonian and MOND approaches. We use the measurements of the radial velocities of globular clusters detected in the galaxies in the sample to test the predictions of dynamical models with and without dark matter out to several effective radii. We solve the Jeans equations for both the Newtonian (mass-follows-light and dark matter models) and MOND approaches (three different MOND models) assuming spherical symmetry; for both approaches we assume various values of velocity anisotropy. We compare thus obtained estimates of the mass-to-light ratios with results obtained using stellar population synthesis models. We find that the Newtonian mass-follows-light models without significant amount of dark matter can provide successful fits for only one galaxy (NGC 2768), and for the remaining nine early-type galaxies various amounts of dark matter are required in the outer parts. With MOND models, we find that four early-type galaxies can be fit without dark matter and that the remaining six galaxies require an additional dark matter component to successfully fit the observed velocity dispersions.

1. INTRODUCTION

The problem of the existence and distribution of dark matter (DM) in early-type (elliptical and lenticular) galaxies remains poorly understood. In Samurović (2007) we listed the main reasons why early-type galaxies are studied to a lesser degree than their spiral counterparts. The studies of these galaxies performed so far show that some galaxies such as NGC 5128 appear to lack DM, or at least DM is not dynamically important out to approximately 6 effective radii (R_e) (Samurović 2010). Samurović (2012) recently analyzed the massive elliptical galaxy NGC 4472 and found that beyond $\sim 2R_\mathrm{e}$ DM or modifications of Newtonian dynamics are necessary to successfully fit the observed velocity dispersion.

In analogy with spirals, it is expected that all early-type galaxies also contain a significant amount of DM and analyses of early-types usually relied on Newtonian dynamics. However, the MOND (MOdified Newtonian Dynamics) theory, (Milgrom 1983) which was well tested on spirals, has proved to be capable of successfully fitting early-type galaxies as well. Its basic assumption is that the acceleration due to the gravitational force does not depend simply upon the mass m as in the Newtonian approach, but has a more complex form, $m/\mu(a/a_0)$, where a_0 is a universal constant, taken to be $a_0 = 1.35^{+0.28}_{-0.42} \times 10^{-8}$ cm s^{-2} (Famaey et al. 2007).

In the present study, we analyze a sample of ten massive early-type galaxies taken from the SLUGGS (SAGES Legacy Unifying Globulars and Galaxies Survey) database (available at `http://sluggs.swin.edu.au`) (Pota et al. 2013, hereafter P13). We use globular clusters (GCs) as tracers and consider both Newtonian (mass-follows-light or with additional Navarro, Frenk & White (1997, NFW) DM) and MOND dynamics (without DM), assuming isotropic, slightly tangential or increasingly radial orbits. The best-fit mass-to-light ratios are then compared with the results of various stellar population synthesis (SPS) models in order to assess the importance of DM at a given radius of a given galaxy in the sample. More details are available in Samurović (2014, hearafter S14).

In the MOND theory the interpolating function $\mu(x)$ is used assuming several forms: for $a \gg a_0$ the Newtonian acceleration is restored ($\mu = 1$), whereas for $a \ll a_0$ the interpolation function becomes $\mu = a/a_0$.

The galaxies from our sample are objects with a wide range of luminosities, morphological types (within the early-type class) and from different environments (from field galaxies to members of groups and clusters). We used the observational data from P13 and we decided to include in our sample ten out of twelve galaxies: NGC 1400, NGC 1407, NGC 2768, NGC 3115, NGC 3377, NGC 4278, NGC 4365, NGC 4486, NGC 4494 and NGC 5846. P13 split the GCs of each galaxy into blue and red population, we however chose to work with a *total* sample of GCs for each galaxy in order to have more clusters per bin because our goal is to determine as accurately as possible the velocity dispersion and departures from the Gaussian in the distribution of GCs. We assume the dimensionless Hubble constant $h_0 = 0.70$.

2. DYNAMICAL MODELS

For all ten early-type galaxies in our sample we solve the Jeans equation (e.g. Binney & Tremaine 2008) in a spherical approximation for both approaches, Newtonian and MOND:

$$\frac{\mathrm{d}\sigma_r^2}{\mathrm{d}r} + (\alpha + 2\beta)\frac{\sigma_r^2}{r} = a_{\mathrm{N;M}} + \frac{v_{\mathrm{rot}}^2}{r}, \tag{1}$$

where $a_{\mathrm{N;M}}$ is an acceleration term which is different for each approach: in the Newtonian ('N') approach it is equal to $a_{\mathrm{N}} = -GM(r)/r^2$ and for MOND ('M'), a_{M} satisfies (Milgrom 1983):

$$a_{\mathrm{M}}\ \mu\left(\frac{a_{\mathrm{M}}}{a_0}\right) = a_{\mathrm{N}}. \tag{2}$$

In eq. (1), σ_r is the radial stellar velocity dispersion, $\alpha = \mathrm{d}\ln\nu/\mathrm{d}\ln r$ is the slope of tracer density ν. The details and relevant plots are available in S14.

The non-spherical nature of the GC dispersion is expressed through the following well-known equation, $\beta = 1 - \frac{\overline{v_\theta^2}}{\sigma_r^2}$, where $\overline{v_\theta^2} = \overline{v_\theta}^2 + \sigma_\theta^2$ and $0 < \beta < 1$ means that the orbits are predominantly radial, whereas for $-\infty \leq \beta < 0$ the orbits are mostly tangential. We tested three cases of anisotropies: the isotropic case ($\beta = 0$), the mildly tangential case for which there is a hint from the observed kinematics ($\beta = -0.20$) and the theoretically based value ($\beta_{\mathrm{lit}}(r) = \beta_\infty r/(r + r_a)$), where $\beta_\infty \simeq 0.5$ and $r_a \simeq 1.4R_{\mathrm{e}}$; this estimate (radially dominated) comes from theoretical expectations from merging collisionless systems (Mamon & Łokas 2005).

3. RESULTS AND CONCLUSIONS

In Newtonian approach, for a constant mass-to-light ratio model we used a constant mass-to-light ratio (M/L_*) Sérsic model that uses a galaxy's field stars. DM is added to the stellar component in the form of an NFW DM halo.

We tested several MOND models using the Jeans equation in the spherical approximation: (i) the "simple" MOND formula from Famaey & Binney (2005), (ii) the "standard" formula (Sanders & McGaugh 2002), (iii) the Bekenstein's "toy" formula (Bekenstein 2004). The expressions, in terms of the Newtonian circular velocity and the radius, for the circular velocity obtained with MOND using these three formulae are given in Samurović & Ćirković (2008).

The best-fit values for each tested model are compared with the estimates coming from several SPS models (see S14 for details).

We used GCs as a tracer of the potential of the sample of ten early-type galaxies. To infer the existence of DM we used the Newtonian (mass-follows-light and stars + NFW DM) models and MOND models to calculate the mass-to-light ratios, which were compared with the predictions of various SPS models based on the stellar matter.

Our most important results and conclusions (see Table 1) are:

- We found that *only one* galaxy can be modeled with a single value of the constant M/L ratio approximately consistent with the value of the stellar component showing the lack of significant amount of DM: NGC 2768. Three more galaxies (NGC 1400, NGC 3377 and NGC 4494) show the increase of the total mass-to-light ratio with radius, which suggests the existence of DM in them. NGC 4486 is the only galaxy that needs significant amount of DM in its inner region. The remaining five galaxies require significant amount of DM beyond $\sim 2-3R_{\rm e}$ to explain their dynamics inferred using GCs: NGC 1407, NGC 4278, NGC 4365 (this galaxy because of its large effective radius requires significant amount of DM beyond one effective radius) and NGC 3115 require DM beyond $\sim 3R_{\rm e}$, whereas in NGC 5846 DM becomes important beyond $\sim 2R_{\rm e}$ and NGC 4486 requires DM in its inner parts (interior to $\sim 0.35R_{\rm e}$). For the effective radii of NGC 4365 and NGC 4486 we took the values of 184.22 and 703.91 arcsec, respectively (Kormendy et al. 2009). The largest estimated mass-to-light ratio was found in NGC 5846 for which $64.2 < M/L_B < 127.4$ beyond $\sim 6R_{\rm e}$ was established; the lowest mass-to-light ratio was found in NGC 4494 for which we find $2.6 < M/L_B < 5.7$. The NFW models provided the best fits for all the galaxies in the sample.

- We also solved the Jeans equation in the spherical approximation for three different MOND models (standard, simple and toy). We found that the following galaxies could be modeled with mass-to-light ratio consistent with the no dark-matter hypothesis assuming the values of the M/L ratios consistent with the stellar mass only: NGC 1400, NGC 2768, NGC 3377, and NGC 4494. The following galaxies require DM even in the MOND approach in their outer parts: NGC 1407, NGC 4278, NGC 5846 and NGC 3115 require DM beyond $\sim 3R_{\rm e}$ and NGC 4365 and NGC 4486 require DM exterior to $\sim 1R_{\rm e}$ (~ 20.7 kpc) and $\sim 0.35R_{\rm e}$ (~ 15 kpc), respectively.

Table 1: Summary of the results and conclusions

name (1)	N-noDM (int) (2)	N-noDM (out) (3)	N-DM (int/out) (4)	M-noDM (int) (5)	M-noDM (out) (6)
NGC 1400	√	–	√	√	√
NGC 1407	√	–	√	√	–
NGC 2768	∼	∼	√	√	√
NGC 3115	–	–	√	√	–
NGC 3377	√	–	√	√	√
NGC 4278	–	–	√	√	–
NGC 4365	–	–	√	√	–
NGC 4486	–	–	√	–	–
NGC 4494	√	√ –	√	√	√
NGC 5846	√	–	√	√	–

NOTES: 'N' is for Newtonian models and 'M' is for MOND models and 'DM' ('noDM') indicates the existence (lack) of dark matter in a given object; "int" is interior region (interior to $\sim 3R_e$) and "out" is exterior region (exterior to $\sim 3R_e$). Two exceptions are the galaxies NGC 4365 and NGC 4486: their inner regions are interior to 1 R_e and 0.35 R_e, respectively. The sign "∼" for galaxy NGC 2768 denotes that this galaxy can be fit with a constant mass-to-light ratio, but the value obtained is marginally higher than that predicted by SPS models. The combination of signs ("√ –") for NGC 4494 denotes that the mass-to-light ratio obtained for this galaxy in its outer parts is consistent with the value obtained using SPS models, but because of the increase of the mass-to-light ratio in its outer part, one cannot exclude the existence of DM (see S14 for details).

Acknowledgments

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LSST & SERBIAN SCIENCE

D. JEVREMOVIĆ[1] and LSST SERBIAN TECHNICAL GROUP[2]

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Abstract. We briefly review characteristics and current status of the Large Synoptic Survey Telescope (LSST). A group of Serbian astronomers formally joined the LSST project in November 2013. Our contribution to the project is building a simulator of a stream of alerts AlertSim. It will be used in commissioning and early operation phase of the survey. We expect many exciting developments in the next twenty years, influencing not only astronomy but physics, informatics and Big Data science in general

1. INTRODUCTION

LSST will be a large, wide-field ground-based optical telescope system designed to obtain multiple images covering the sky that is visible from Cerro Pachón in Northern Chile. The current baseline design, with an 8.4m (6.7m effective) primary mirror, a 9.6 deg^2 field of view, and a 3.2 Gigapixel camera, will allow about 10,000 square degrees of sky to be covered every night using pairs of 15-second exposures, with typical 5σ depth for point sources of r $\sim$24.5 (AB). The system is designed to yield high image quality as well as superb astrometric and photometric accuracy. The total survey area will include $\sim$ 30,000 deg^2 with $\delta < +34.5^o$, and will be imaged multiple times in six bands, ugrizy, covering the wavelength range 320−1050 nm.

The artistic impression of the telescope and its future housing on Cerro Pachón is shown in Fig1.

About 90% of the observing time will be devoted to a deep-wide-fast survey mode which will uniformly observe a 18,000 deg^2 region about 1000 times (summed over all six bands) during the anticipated 10 years of operations, and yield a coadded map to r$\sim$ 27.5. These data will result in catalogs including over 38 billion stars and galaxies, that will serve the majority of the primary science programs. The remaining 10% of the observing time will be allocated to special projects such as a Very Deep and Fast time domain survey.

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[2] LSST SERBIAN TECHNICAL GROUP CONSISTS OF THE SCIENTIST FUNDED THROUGH THE PROJECT III44002:ASTROINFORMATICS APPLICATION OF IT IN ASTRONOMY AND CLOSE FIELDS

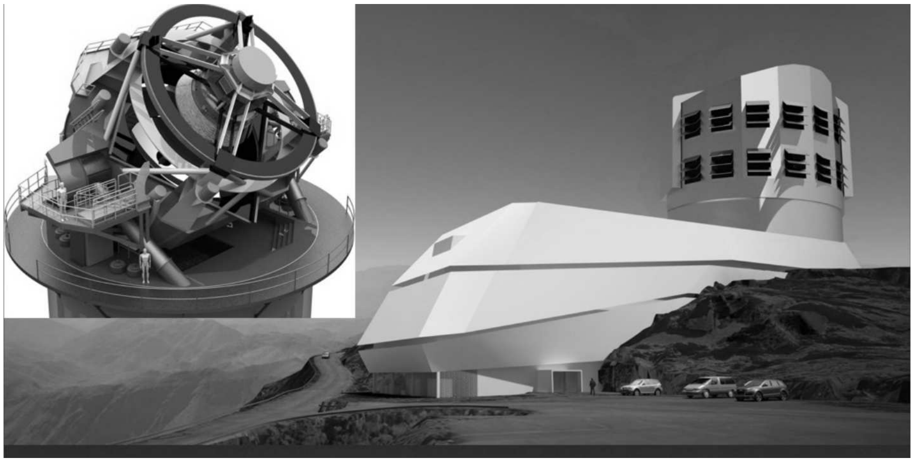

Figure 1: LSST telescope and future building on Cerro Pachón (artistic render).

The LSST is designed to achieve goals set by four main science themes:

1. Probing Dark Energy and Dark Matter;
2. Taking an Inventory of the Solar System;
3. Exploring the Transient Optical Sky;
4. Mapping the Milky Way.

The main science drivers are used to optimize various systems (Ivezić et al. 2014).

The LSST will be operated in fully automated survey mode. The images acquired by the LSST Camera will be processed by LSST Data Management software to a) detect and characterize imaged astrophysical sources and b) detect and characterize temporal changes in the LSST-observed universe. The results of that processing will be reduced images, catalogs of detected objects and the measurements of their properties, and prompt alerts to "events" { changes in astrophysical scenery discovered by differencing incoming images against older, deeper, images of the sky in the same direction (templates)}. Measurements will be internally and absolutely calibrated.

The project is scheduled to begin the regular survey operations at the start of next decade. In the beginning of August of 2014 the US National Science Foundation started a new phase of the project namely Major Research Facilities and Equipment Construction (in short Construction). The current expected time-line of the project is shown in Fig.2

2. SERBIAN ASTRONOMY AND LSST

There are two main institutions, carrying research in astronomy in Serbia; namely the Astronomical Observatory in Belgrade and the Department of Astronomy, Faculty of Mathematics, University of Belgrade. Astronomy in Serbia is almost exclusively funded by the Serbian government through the projects/grants. At the moment there are eight projects, which have a significant astronomical content. Out of eight, six projects supported the Serbian involvement in the LSST:

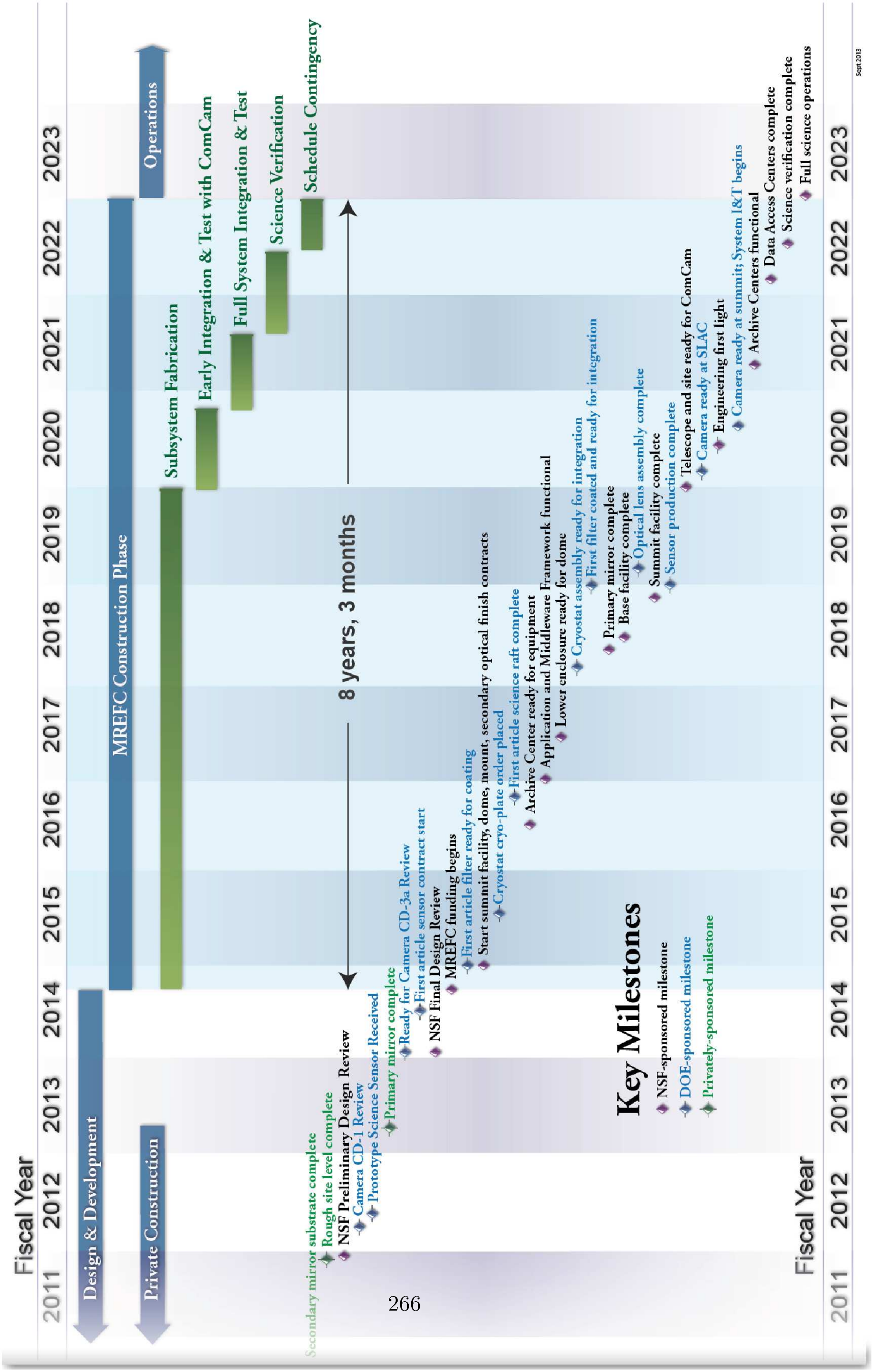

Figure 2: The integrated schedule of LSST.

- Astrophysical Spectroscopy of Extragalactic Objects (led by Luka Popović)
- Gravitation and the large scale structure of the Universe (Predrag Jovanović)
- Emission nebulae: structure and evolution (Dejan Urošević)
- Influence of collisions on astrophysical plasma spectra (Milan Dimitrijević, Zoran Simić)
- Dynamics and kinematics of celestial bodies and systems (Zoran Knežević, Rade Pavlović)
- Astroinformatics: application of IT in astronomy and close fields (Darko Jevremović)

From the scientific point of view, Serbian astronomers have interest in the following subjects:

- Variable phenomena
- Variable stars
- AGN variability
- Gravitational micro-lensing
- SNR & Planetary nebulae
- Small solar system bodies (orbits, elements...)
- Development of astroinformatics
- Development of algorithms, software

2. 1. INTERNATIONAL INVOLVEMENT IN LSST

The LSST is essentially a US project with the standard Chilean share (in exchange for providing the telescope site). In 2011 LSST solicited the Letters of Interest from the global astronomical community. The main reason was an estimate that some additional funds (contributions) would be necessary for the smooth operation of the Survey over ten years. France and Serbia have the special status because of the very early involvement (before the Decadal Survey in 2010) in the project, and got an opportunity to do some of the contributions as in kind support. France is involved in camera and software development, while Serbian contribution is described in the next section.

Sixty eight institutions from 25 nations outside US and Chilean Community have expressed their interest in being involved in LSST. Geographical distribution is shown in Fig.3 (from Hand 2012)

Since 2012 the international involvement in the LSST is measured in PI's. PI (principal investigator) is a senior scientist who can have a group of up to four students/postdocs. PI has essentially all the rights as someone from the US or Chilean community (access to documentation, software, data etc.) In exchange to that he/she

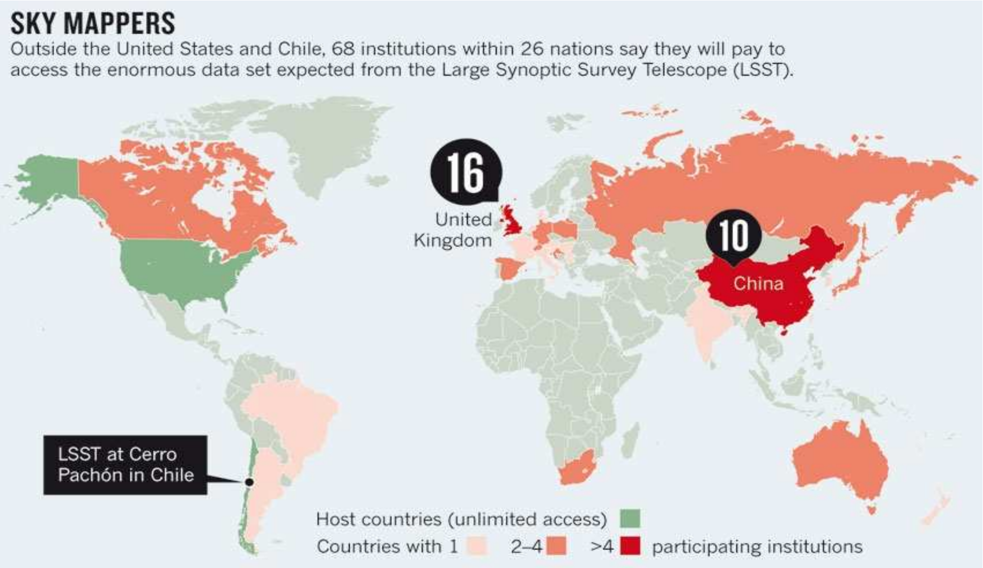

Figure 3: The world wide distribution of institutions committed to the LSST Hand (2012).

is expected to contribute 20k$/year toward the costs of the operations. For example China committed to fifty PI's, Great Britain to up to 120, France 50+50, Australia 25, Germany around 100, Hungary 3 etc. Serbia at the moment is committed to 2+2 PI's. Funds for two PI's are approved and for other two we are developing small suite of software as in kind contribution.

2. 2. ALERTSIM: SERBIAN IN KIND CONTRIBUTION TO THE LSST

Here we transmit parts of the document which defined Serbian in kind contribution and was part of the negotiations (Jurić et al 2013)

As a part of its nightly operations, LSST is expected to generate a transient alert stream of 10,000 events/visit. That stream is planned to be forwarded a) unfiltered, to a number of public event brokers, and b) to an internal simple transient filtering service designed to support the end-users (per the Science Requirement Document, Section 3.5 Ivezić et al. 2011). It is anticipated that due to bandwidth constraints only a limited number of public brokers (on order of ∼2 to ∼4) will be able to connect directly to LSST. Memorandums of Understanding (MOU's) will be signed with their operators, defining the technical and policy aspects within which they will be expected to operate.

Given the limited number of external brokers that will serve as the primary delivery mechanism of LSST transient data to the public, it is important to assure they are capable of receiving and processing the LSST event stream, both initially and throughout operations. An inefficient or buggy event broker results in opportunity loss for the LSST user community, and in helpdesk/technical support costs to LSST. To achieve the projected return of investment for LSST transient science, it is important to initially validate each external broker's capability, continually monitor it, and have the tools and support personnel to understand and resolve any issues as they arise.

The LSST MREFC Construction budget includes all work items needed to generate the transient alerts, transmit them to external brokers, build and operate the simple filtering service, and perform acceptance for all LSST-provided transient alert services. The LSST Operations budget anticipates the need for additional software development to validate and assess the performance of external brokers, develop capabilities for their continuous validation and troubleshooting, and monitor their performance. Furthermore, the LSST Operation budget anticipates the need for helpdesk and technical personnel to assist in troubleshooting external broker connectivity/functionality issues. The work provided by the SPG, defined below, is aimed to reduce these operation costs. In order to do so, the SPG will develop and contribute, in time for LSST Early Operations, a transient alert stream simulator and event broker validation suite ("AlertSim"). This software package will:

1. Be capable of generating realistic streams of LSST transient alerts, at data rates expected of LSST.
2. Be capable of simulating various failure or exceptional/extreme operation modes, including:

   a) Unexpectedly large numbers of spurious detections
   b) Unusually large numbers of detections, simulating observations of high-density fields
   c) Disruptions in the event stream (such as due to forced termination of difference image processing due to exceeding the 60-second maximum)
   d) Corruption of the event stream (e.g., due to software errors)
   e) Network connectivity interruptions and "bursty" transfer modes
3. Provide facilities to ease troubleshooting of problems with broker end-points (e.g., logging, VO Event packet inspection)
4. Be configurable, automated, and capable of keeping provenance information.
5. Be written following all applicable LSST software standards, conventions, and development processes, and executable on LSST Data Access Center hardware.
6. Be developed in coordination with and leveraging capabilities provided by the LSST Simulations Group.

This contributed package is expected to reduce LSST Operations cost by:

I. Delivering functionality early, that is currently planned to be developed in Operations.

II. Reducing the need for help desk and technical support personnel by automating the validation/troubleshooting activities and increasing this aspect of staff productivity.

III. Further reducing potential down-time and troubleshooting personnel costs by providing the capability for full characterization of the behavior of connected public brokers in the full suite of exceptional/extreme operation modes that may occur in Operations, but are unlikely to occur with real data in Commissioning.

The work on AlertSim will be done by the Serbian Technical Group(STG). This group is open for the suggestions, contributions and of course new members.

2. 3. OTHER SERBIAN SCIENCES, EDUCATION AND PUBLIC OUTREACH AND LSST

There is a potential of further involvement of Serbian scientists in LSST especially from the field of fundamental physics - namely Cosmology and new 'Dark Energy Science'. Also, the development of 'Big Data science' is very important and significant part will be in the development of algorithms, methods and visualization tools. Mathematicians, software engineers and scientists from many other fields which (will) have a significant Big Data component might find collaborating with LSST-STG very fruitful.

The important part of the project is the Education and Public Outreach. The target audience consists of general public, students and teachers, formal/informal venues and of course amateur astronomers. Goals of the program can be summarize as:

- Actively engage audience Citizen Science
- Increase public awareness of scientific research
- Contribute to Science Technology Engineering and Math education
- Enhance 21 st century workforce skills

3. CONCLUSIONS

We reviewed the current status of the Large Synoptic Survey Telescope and the Serbian involvement in the project. As a main conclusion we would like to point that international collaborations are probably the only way for a small country (with limited resources) to get involved in the top level science especially in the expensive disciplines such as an astronomy, particle physics etc.

Acknowledgements

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THE BELISSIMA PROJECT

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Abstract. We discuss the goals and achievements of BELISSIMA (BELgrade Initiative for Space Science, Instrumentation and Modelling in Astrophysics), the most ambitious infrastructural project currently active at the Astronomical Observatory of Belgrade (AOB). The FP7 REGPOT project BELISSIMA started in July 2010 and is extended to July 2015. The most important goals include the reinforcement of the AOB, purchase and installation of the 1.50 m-class telescope, training of the AOB staff, public outreach, dissemination and promotional activities. The activities and results of the local project ON176021 (Visible and Invisible Matter in Nearby Galaxies: Theory and Observations) are also briefly discussed.

1. INTRODUCTION

BELISSIMA is the FP7 (Seventh Framework Programme) project (call FP7-REGPOT-2010-5; funding scheme is “CSA Coordination and support action”) started its activities in July 2010. The initially planned duration was three years, but due to the various circumstances beyond the control of the management of BELISSIMA, in June 2013 the BELISSIMA project was extended by the European Commission to June 30, 2015.

The project is coordinated by the Astronomical Observatory of Belgrade (AOB) and is the most ambitious infrastructural project undertaken recently by AOB. The BELISSIMA project was evaluated very favorably by the European Commission and obtained 14.50 out of 15.00 points. Its “scientific and/or technological excellence” brought the projects maximal 5.00 points and he approval of the project was thus explained: “The BELISSIMA is an excellent project which is perfectly targeted and very clearly described. (...) The proposal to upgrade the research capacity of the AOB is based on the excellent competence and research activities which are on the cutting-edge of astrophysics and astronomy“.

The project has been described previously in English in Samurović (2012a, 2013a, 2013b), Samurović & Knežević (2013) and in Serbian in Samurović (2010, 2012b). For the sake of completeness, some details presented there were included in the present contribution and the updates were added wherever necessary.

2. WORK PACKAGES

The BELISSIMA project consists of five work packages (WPs), which are listed below with their leaders.

- WP1: Preparations and reinforcement of the AOB (leader: Dr. Zoran Knežević)
- WP2: Purchase, installation and testing of optical equipment (leader: Dr. Ištvan Vince)
- WP3: Human potential, training and public outreach (leader from March 2011: Dr. Miroslav Mićić; until March 2011 the leader was Dr. Luka Č. Popović)
- WP4: Dissemination and promotional activities (leader: Dr. Milan Ćirković)
- WP5: Project management (leader: Dr. Srdjan Samurović)

The coordinator of BELISSIMA is Dr. Srdjan Samurović, and the Management board of BELISSIMA consists of the leaders of WPs.

Below, we briefly describe the accomplishments of each WP and their importance for the AOB and astronomy in Serbia.

2. 1. WP1. PREPARATIONS AND REINFORCEMENT OF THE AOB

The very beginning of the BELISSIMA project was marked with the improving of human resources of the AOB. As soon as the positive outcome of the proposal was announced (the beginning of 2010), the Management board intensified the contacts with candidates for a total of 72 months of engagement intended for recruited researchers coming from abroad. This task was successfully handled by Director of the AOB, Dr. Zoran Knežević, the head of WP1.

The first researcher, Dr. Milan Bogosavljević was hired on July 15th, 2010. Dr. Milan Bogosavljević was born in Niš in 1977. He graduated from the University of Belgrade, Faculty of Mathematics, Serbia and obtained his PhD from California Institute of Technology (CalTech). He is an expert in observational astronomy with a significant experience with observations with the world's largest telescopes (such as Keck). Immediately after his hiring Dr. Bogosavljević was appointed technical director of the Vidojevica Astronomical Station (VAS) and initiated his numerous activities related to the design and construction of the planned telescope "Milanković" to be mounted at the VAS. He made numerous trips around Europe within the scope of the BELISSIMA project for the purpose of establishing the optimal design of the planned 1.50 m-class telescope and the construction of the dome where the telescope will be mounted; he visited the VAS on numerous occasions and participated in performing final activities regarding the mounting of the 60 cm telescope purchased by the AOB using the funds from Ministry of Science and Technological Development of Republic of Serbia and mounted at the VAS; he worked with young researchers at the AOB providing help with various aspects of observational activities and reductions of observations. At the time of this writing (November 2014) he is in charge of the supervision of the construction of the 1.40 m telescope currently being manufactured (see below).

The second researcher, Dr. Miroslav Mićić was hired on March 16th, 2011. Dr. Miroslav Mićić was born in Belgrade in 1977. He graduated from the University of

Belgrade, Faculty of Mathematics, Serbia and obtained his PhD from the Pennsylvania State University. He joined the BELISSIMA project coming from the University of Sydney where he had been working. He is an expert in astrophysical simulations, astronomical data processing and visualization of astronomical data. The activities of Dr. Mićić include: he initiated the collaboration with young researchers at the AOB regarding start of various research projects with numerical astrophysical simulations; he was appointed leader of WP3 of the BELISSIMA project; he joined the work of Dr. Srdjan Samurović, Dr. Milan Ćirković, Dr. Milan Bogosavljević, the AOB librarian Ms. Vesna Mijatović and designer of the publication Ms. Ivana Horvat and helped in the final stages of the production of the bi-lingual brochure dedicated to the AOB and BELISSIMA; he presented opportunities for the future research on supercomputers in Serbia with the talk on "Supermassive Black Holes" in the amphitheater of the Department of Natural Science and Mathematics, Niš University; he featured as guest at the astronomy seminar in the Research Center in Petnica.

The third candidate, Dr. Milica Mićić was hired on November 1, 2012. She was born in Kruševac in 1984, graduated from the Department of Mathematics at the University of Belgrade in June 2008 and later, in December 2008, also obtained the masters degree there. She obtained her PhD at the Institute for Theoretical Astrophysics at the University of Heidelberg (Germany). Dr. Milica Mićić is an expert in numerical astrophysical simulations in the field of massive star and molecular cloud formation, focusing on the influence of chemical processes on the gas dynamics; she is also an expert in astronomical data processing and visualization of astronomical data.

All three recruited researchers continued to work at the AOB after the expiration of the period of 72 person-months dedicated to this task. The Ministry of Education, Science and Technological Development of the Republic of Serbia (MESTDRS) continues to support the researchers and they all work as members of the AOB staff. They all perform various research activities through project ON176021 funded by MESTDRS as research associates (see below).

2. 2. WP2. PURCHASE, INSTALLATION AND TESTING OF OPTICAL EQUIPMENT

From the very beginning of BELISSIMA the Management board of the project began to work on the selection of the optimal configuration of the 1.50 m-class telescope to be purchased and mounted at the top of Vidojevica. The telescope will be named "Milanković" after the famous Serbian astronomer. Several manufacturers of telescopes were contacted and they provided their estimates of prices. The Management board of BELISSIMA applied to Ministry of Science and Technological Development of the Republic of Serbia (now MESTDRS) for additional funds needed for a purchase of a high quality 1.50 m-class telescope. We have asked for additional funds through a national project ON176021, "Visible and Invisible Matter in Nearby Galaxies: Theory and Observations" (see below for more details) that gathered 26 researchers from leading research institutions of Serbia, which would make it possible to purchase a telescope with targeted performances. The funds were granted and the contract for the purchase of the 1.40 m telescope was signed in March 2014 and, according to it, the telescope is expected to be mounted at the VAS by June 2015. All the foreseen tests are expected to be finished by that date.

2. 3. WP3. HUMAN POTENTIAL, TRAINING AND PUBLIC OUTREACH

In the first year of activity of the BELISSIMA project, numerous activities pertaining to human potential, training and public outreach were performed and below only the brief list is given. The reader is referred to the BELISSIMA Web site (see below) for the detailed information.

At the beginning of the project two events were organized. On September, 6th 2010 at the AOB the meeting of the Serbian astronomical community was organized and 40 colleagues from the AOB, Department of Astronomy (Belgrade University), Institute of Physics (Belgrade) and People's Observatory from Beograd took part in the discussions related to the needs of the community regarding the new telescope. Three weeks later, the executive meeting of the BELISSIMA project took place in Prokuplje, from 27th to 28th September 2010. The meeting "Network of Telescopes in the Western Balkans Region" gathered 30 participants, of which 13 were foreign experts from several European countries.

Within WP3, numerous visits to various European observatories and institutes were organized: Orliakas Astronomy Station (Greece) in August 2010; meeting "Big Science With Small Telescopes" held in Dornburg, near Jena, Germany, from October, 19th to 22nd 2010; observations at the Baja Observatory, Hungary (February 2011), visit to the telescopes at Tenerife and La Palma (February/March 2011); "Second Workshop on Robotic Autonomous Observatories" held in Malaga, Spain from 5th to 10th June 2011; "Hands-on Strong Gravitational Lensing School" held at Excellence Cluster Universe, Garching, Germany from 14th to 17th June 2011; summer school "Opto-Mechanical Design in Astronom", which was held at the Astrophysical Institute of Potsdam (AIP) in Potsdam, Germany from June 20th to 23rd, 2011; the observing NEON school held at Molutai Astronomical Observatory (Lithuania) from July 14th to 27th, 2011.

It is important to mention here two three-months visits of the participants of the BELISSIMA project and members of the AOB staff, Ms. Monika Jurković and Ms. Milena Jovanović, to the Leibniz Institute for Astrophysics (AIP) at Potsdam within the scope of the WP3. Since the AIP is one of the leading institutes in Europe for the development of the astronomical instrumentation, their training is important for the AOB and the work with the new robotic telescope "Milanković". Their host at the AIP was Dr. Michael Weber who collaborated with the BELISSIMA project. Ms. Monika Jurković, a research assistant from the AOB, visited AIP in the period from April to June 2012. During her three month visit she was involved in the calibration of the PARSES, parameter search package of the STELLA's echelle spectrographs. STELLA is a project of the AIP done in collaboration with the Instituto de Astrofisica de Canarias (IAC) and is located at the Teide Observatory on the Canarian island of Tenerife, Spain (see more details below). P.I. of the project is Dr. Klaus G. Strassmeier. The facility, the telescopes and the spectrographs are running automatically and autonomously. Ms. Milena Jovanović, a research assistant from the AOB visited the AIP from June to August 2012. The purpose of her visit is the training on the procedures of automated reduction of stellar spectra used in robotic observatories. At AIP she joined the Stellar Activity group and in particular the part of it connected to the STELLA project. STELLA is an observatory hosting two robotic telescopes (STELLA-I and STELLA-II) that operate in fully unattended mode. STELLA-I will host an optical CCD imager and photometer (WIFSIP) and an AO testbed, while STELLA-II fiberfeeds the STELLA echelle spectrograph. Both STELLA-I and STELLA-II are 1.2 meter telescopes. Ms. Jovanović visited again the AIP from July to August 2014 for the purpose of completing her work started there in 2012.

Also, foreign researchers came to the AOB after the invitation of the BELISSIMA project: Dr. Zach Ioannou came from Thessaloniki to Belgrade where he stayed from March 28th to April 2nd 2011. Dr. Ioannou is one of the creators of the Astronomical Station Orliakas. He came for two reasons: to help with the writing of the technical documentation regarding the construction and purchasing of the telescope "Milanković" (see above) and scientific collaboration with the AOB. Although his suggestions were mostly technical ones (parameters of the various parts of the telescope, details of the construction etc.) he also provided the participants of BELISSIMA numerous administrative details regarding European tenders which is very important for BELISSIMA and the AOB since this is the first time that such an international activity takes place at the AOB.

For the purpose of training of the AOB staff various activities were performed, such as: training at the VAS, training course related to photometry and spectroscopy held at the AOB in May 2011 by Dr. Ištvan Vince and training of data reduction at the AOB.

2. 4. WP4. DISSEMINATION AND PROMOTIONAL ACTIVITIES

We here list only a few dissemination and promotional activities (the reader is referred to the BELISSIMA Web site for a full list): the all-sky camera at the VAS recorded on November 12th, 2010 is (to the best of our knowledge) the only image of the meteor entering the atmosphere above Serbia and numerous media published it, thus promoting the BELISSIMA project, the VAS and the AOB in public; the AOB had the honor on November, 8th 2010 to host Prof. Sir Arnold Wolfendale, FRS, 14th Astronomer Royal and the participants of the BELISSIMA project discussed with him numerous astronomical issues; BELISSIMA has participated in the 4th Festival of Science held in Belgrade in December 2010; an article that describes the BELISSIMA project and telescope "Milanković" was published in "Danica 2011" (Samurović 2010); several BELISSIMA participants took part in various radio and TV programmes; the cooperation with Amateur Astronomers Association of Serbia has started from the very beginning of the work of the BELISSIMA project; the BELISSIMA project collaborated with the researchers from Serbian town of Niš through various initiatives – we mention here only one: Dr. Goran Sv. Djordjević who leads Southeastern European Network in Mathematical and Theoretical Physics organized a seminar "Trends in Modern Physics" for the elementary and high school teachers from Balkan countries and neighboring regions, held in August, 2011 in Niš and in agreement with the BELISSIMA project the teachers were taken to the VAS and the first TV material related to BELISSIMA was shot there; several BELISSIMA participants took part in the activities of the Research Center in Petnica. The AOB brochure mentioned above was printed in Serbian and in English: this is a booklet dedicated to the AOB, its history, its present activity and its future, which will be without doubt marked by the "Milanković" telescope. The publication presents in an accessible language the active projects, their leaders and participants and the BELISSIMA project is also covered in detail. The first BELISSIMA Workshop, "Science with 1.5

m telescopes", was organized from 13 to 14 October 2011, after the 16th National Conference of Astronomers of Serbia: it gathered approximately 50 participants out of which 21 were foreign experts who discussed with the BELISSIMA participants various aspects of observations possible with 1.50 m-class telescope. The CDROM with the presentations from the Workshop (together with some additional material) was pressed and distributed afterwards. From 18-21 September 2012, the large international BELISSIMA conference "Future Science With Meter-Class Telescopes" with approximately 100 participants was held in Belgrade. The presentations are available at the BELISSIMA Web site and the book of Proceedings was printed in December 2013 in the series of the Publications of the AOB (no. 92)[1]; the Proceedings were widely distributed and the copies are available at the AOB. The multimedia BELISSIMA DVD was printed in October 2013 and it includes various material describing the progress of BELISSIMA and its activities. The disk was widely distributed and is also available at the AOB.

Finally, within the WP4 of the BELISSIMA project four episodes of the BELISSIMA TV programme have been realized (until November 2014): the first episode presents the VAS, the second episode is dedicated to the 125 years of the AOB and shows its past, present and future and the importance of BELISSIMA for its activities, the third and fourth episodes were shot in September 2012 during the international BELISSIMA conference held in Belgrade and present the work of the world's leading researchers who participated in the work of the conference (these two episodes were subtitled in Serbian and in English as they are of interest to a wider astronomical community that can thus learn about the plans for the future of Serbian astronomy). All four episodes of the BELISSIMA TV programme are included in the BELISSIMA multimedia DVD and are available from the BELISSIMA Web site.

2. 5. WP5. PROJECT MANAGEMENT

The project management of the BELISSIMA project was done by the Management board of the project and coordinated by Dr. Srdjan Samurović. The Management board includes all the leaders of WPs and had meetings on a regular basis when the activities of the project were discussed and the tasks for a future work were created. The main remaining activity of the Management board is a successful manufacturing of the 1.40 m telescope and its mounting at the top of the VAS by June 2015. At the time of this writing (November 2014) the contacts with the MESTDRS have been intensified in order to secure a pavilion with a high-quality dome where the instrument will be mounted.

3. BELISSIMA AT THE HORIZON 2020 WEB SITE

The importance of BELISSIMA for astronomy for Serbia and the Western Balkans region was recognized by the European Commission (EC) and the project was presented within the section "Success Stories" at the EC Web site with the text "Serbia is a rising star in astronomical research". The story was first published on the FP7

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[1] As all AOB Publications, the BELISSIMA Proceedings were indexed at the NASA Astrophysics Data System (ADS) (`http://adsabs.harvard.edu`).

Web pages[2] and was later also put on the Horizon 2020[3] (the biggest EU Research and Innovation programme and successor of the FP7) Web page[4].

4. PROJECT ON176021

The activities of the BELISSIMA project are closely related to the work of the local, Serbian, project ON176021 ("Visible and Invisible Matter in Nearby Galaxies: Theory and Observations") funded by the MESTDRS. The duration of the project is 5 years, from 2011 to 2015, and the leader is Dr. S. Samurović.

The goal of the project is the study of the visible (stars, gas, dust) and invisible (hypothetical, dark) matter in nearby galaxies of various morphological types. One of the main goals is the creation of a sample which includes both early and late-type galaxies that is studied using their photometric and spectroscopic data coming from large available catalogs and databases. Their kinematics and dynamics are thoroughly studied and the anisotropies in the stellar motions are examined. The decomposition of their photometric profiles is performed for the purpose of discovering various structures (such as inner disks). Dark matter is studied in detail in nearby elliptical galaxies using various observational techniques and theoretical approaches. The studies of the Milky Way is used for the comparison with other galaxies. Also, within ON176021, the features of the Galactic habitable zone related to the kinematics and dynamics of the Milky Way and nearby spiral galaxies are studied. For some important recent results related to nearby galaxies obtained within ON176021, the reader is referred to the contributions by Vudragović et al., Jovanović et al. and Samurović in the present volume.[5]

Within project ON176021, through its main subproject (leader: Dr. M. Bogosavljević), we make preparatory studies, design and build of a robotic telescope "Milanković"; through the same subproject, the additional funds for the purchase of the telescope were asked from the MESTDRS and granted. Also, through the same subproject, the funds for the pavilion and dome are expected to be secured in 2015. Since March 2014, within ON176021 another subproject, "Investigation of Blazars", has been initiated; the leader is Dr. Oliver Vince who established a collaboration with colleagues who study blazars through several European projects. The future telescope "Milanković" will be also used for the study of blazars, using both photometry and spectroscopy.

5. CONCLUSIONS

The BELISSIMA project is of an immense significance for Serbian science. It created favorable conditions for the return of Serbian scientists working abroad and the three researchers that were recruited by BELISSIMA are now members of the AOB staff. By constructing the "Milanković" telescope Serbia is opening doors to the new technologies in the field of optics, astronomy, informatics, and electronics. The BELISSIMA

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[2] `http://ec.europa.eu/research/regions/index_en.cfm?pg=success_stories&lg=en&id=5`

[3] `https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020`

[4] `https://ec.europa.eu/programmes/horizon2020/en/news/serbia-rising-star-astronomical-research`

[5] All contributions in these Proceedings made within project ON176021 can be traced through the acknowledgment sections present at the end of each paper printed in this volume.

project will play an important role in improving scientific literacy in Serbia. BELISSIMA will strengthen and establish new regional collaboration with partners from the Western Balkans and with the leading European scientific institutions. In this contribution, the activities of the project from the beginning in July 2010 to November 2014 were presented. The BELISSIMA WWW site is: `http://belissima.aob.rs` and it contains various information and news related to the project.

Acknowledgments

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ALERT SIMULATOR - A SYSTEM FOR SIMULATING DETECTION OF TRANSIENT EVENTS ON LSST

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Abstract. Large Synoptic Survey Telescope will be a large ground-based optical telescope which will provide sky survey in unsurpassed details. One of the modules will be time-domain astronomy and detection of transient events. In order to properly design the system, a simulation framework is required to optimize algorithms to large data volumes and frequent events. In this paper, Alert Simulator, the Serbian contribution to the project will be presented. Alert Simulator will be a software package that will simulate detection of transient events well in advance of first light. Its main goal will be to test the ability to detect and identify transients, test the performance as well as various failures or exceptional/extreme modes of operation, so appropriate design can be made.

1. INTRODUCTION

Large Synoptic Survey Telescope (LSST) will be a large, ground-based, optical telescope that will obtain images over half the sky every few nights (Ivezić et al. 2014). It will contain an 8.4m primary mirror, 3.2 Gigapixel camera and will operate in six bands (*u,g,r,i,z* and *y*). After 10-years survey period, it is expected that total amount of about 100PB of data will be collected.

2. TRANSIENT EVENTS AND ALERTS

2. 1. LSST DATA PRODUCTS

LSST data products will mostly consist of catalogs and images (Jurić et al. 2013). Since they will be used for different purposes, there will be three main categories of data products. **Level 1** products are intended to detect time-domain events. These data are the product of continuous observations (nightly) followed by analysis of difference images. Variable and moving objects are the result of L1 data products. **Level 2** products are generated as part of a Data Release. These data are the product of yearly observations, followed by analysis of direct images. Catalogs and images are the result of L2 data products. **Level 3** products will be generated by users, using

LSST software and/or hardware. Various user-created data will be available that not belong to automatically generated L1 and L2 products (Jurić et al. 2013, Konnolly et al. 2013).

2. 2. TRANSIENT EVENTS

A transient astronomical event is the event where the image of observed object changes in time, usually in short time period. Roughly, they can be classified as variable objects, where flux changes are detected and moving objects, where position changes are detected.

Table 1: Some transient events

Variable objects (Flux changes)	Moving objects (Position changes)
Variable stars	Planets
Eclipsing binaries	Asteroids
Transits of extrasolar planets	Comets
Galaxies	Trans-Neptunian objects
AGN	
Bursts (optical)	

2. 3. TRANSIENT ALERT

A Transient Alert is a notification of the detection and characterization of a moving or variable object. Very simple procedure can be described as follows. A visit image is acquired from the telescope. A template image presents what should be seen. Visit image is compared against the template image, and if the difference exists, the alert is raised.

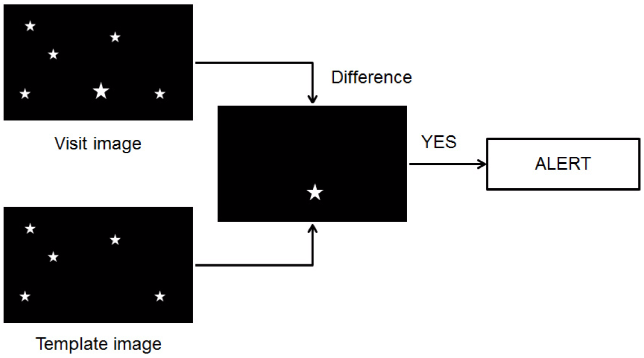

Figure 1: Basic procedure.

This explanation is very simplified. Actually, each of these steps consist several other subprocedures, but the core idea is as described.

A transient alert is a piece of information containing characterization of the object. Each alert contains several data:

- alert ID
- timestamp
- level1 database ID
- Science data
  - position
  - flux, size, and shape
  - light curves in all bands (up to a year; stretch: all)
  - variability characterization (e.g., low-order light-curve moments, probability the object is variable)
- cut-outs centered on the object (template, difference image)

In addition, alerts will have the following properties:

- Alerts will be available world-wide within 1 min of visit acquisition. This is the result of fast image processing as well as distributing procedures.
- The rate of generating alerts is expected to be quite high, about 10M per night or about 10k per visit. This assumption is included in design of Alert Simulator process.
- The format should be easy to read and process by variety of systems. The most appropriate format is XML, or even better VOEvent (XML record with defined structure, used to describe events in astronomy)

3. SIMULATOR

LSST will produce several millions alerts per night. Such amount of data requires particular approach of handling it. One of such approaches is filtering, a set of algorithms for analysing incoming alerts and to reduce their number to most relevant ones. In early design stage, useful tools are simulations, to test the performance well in advance of first light. Alert Simulator will be a software package whose main purpose will be to simulate input that is expected to encounter in operation mode, and then to test the behaviour of the system. In this way, the proper respond and performance will be predicted, so appropriate design can be made.

3. 1. REQUIREMENTS

In order to accomplish the tasks, this software package has to meet the following requirements (Jevremović et al. 2014):

- to generate realistic streams of alerts at data rates that are expected in operational mode

- to simulate various failures or exceptional/extreme cases that might occur:
    - large numbers of fake/spurious detections
    - unusually large numbers of detections simulating observations of high-density fields
    - disruptions in the event stream, which may occur due to forced termination of difference image processing
    - corruptions of the event stream, which may occur due to hardware or software errors
    - network connectivity interruptions
- to provide facilities to ease troubleshooting. This will be achieved through logging and packet inspection (VO Event is structured information, so it can be processed easily).
- to be configurable, automated, and capable of keeping provenance information
- to follow standards and conventions. The package will be written in accordance with standards, conventions, and development processes defined in LSST documents. Some examples are that it will be written in Python programming language and the format will most probably be VOEvent.
- to be developed in coordination with group. Alert Simulator will be just one part of the large software system. There are several groups working on simulations (photon, operations, catalog, image simulations), so Alert Simulator will be developed in cooperation with them to ensure integration and interoperability with other parts of the system.

3. 2. GOALS AND BENEFITS

The main goal of simulator is to evaluate whether the properties of as-delivered components are sufficient. It will also evaluate how design modifications or optimizations impact the overall science performance of the system. Finaly, it will verify that the algorithms used in the processing the LSST data are capable of characterizing the astrometric, photometric, and morphological properties of sources at the level of fidelity described in the SRD (Konnolly et al. 2013).

In addition, it will reduce LSST Operations cost by Jevremović et al. (2014):

- Delivering functionality early, that is currently planned to be developed in Operations
- Reducing the need for help desk and technical support personnel by automating the validation/troubleshooting activities and increasing this aspect of staff productivity.
- Further reducing potential down-time and troubleshooting personnel costs by providing the capability for full characterization of the behaviour of connected public brokers in the full suite of exceptional/extreme operation modes that may occur in Operations, but are unlikely to occur with real data in Commissioning.

4. CONCLUSIONS

Alert Simulator will provide predictions of system behaviour and its performance in case when frequent events are expected. This will allow to design the system appropriately and optimize algorithms before the first light, so the overall cost will be reduced.

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ON MHD WAVE COUPLING BETWEEN TERRESTRIAL IONOSPHERE AND MAGNETOSPHERE

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Abstract. We model the terrestrial ionosphere-magnetosphere system by a high plasma-β (low magnetic field) isothermal region separated by a horizontal boundary from a low plasma-β (strong magnetic field) domain above it. Perturbations induced by sudden impacts of the solar wind can generate MHD perturbations in the magnetosphere (the low plasma-β domain) that propagate downward and through the boundary into the ionosphere (the high plasma-β domain). Applying the VLF (very low frequency) technique, we are able to identify such hydrodynamic waves in the ionosphere by computation of characteristic oscillation spectra from amplitudes of reflected VLF radio-waves recorded in real time. As not all MHD waves can cross from the magnetosphere into the ionosphere, we present in this contribution the mathematical conditions required for MHD waves to enter the ionosphere and enable a magnetosphere-ionosphere coupling mechanism.

1. INTRODUCTION

The terrestrial atmosphere is a complex gaseous system separating the planet from the outer space. Its structure is not uniform, its physical properties depend on location above the Earth surface which results in standard division of the atmosphere into characteristic regions. In this work we consider two distinct domains: the lower ionospheric D-region and the highest magnetosphere located at the frontier to the outer space. These two regions are characterized by relatively high charge particle density, relatively low temperature and negligible geomagnetic field effects in the D-region, and a very low charged particle concentration, much higher temperature and pronounced influence of magnetic field in local phenomena. Both domains are subject to various external disturbances causing numerous local perturbations ranging from temporal alternations in ionization processes at atom and molecular levels, to macroscopic collective features such as magnetohydrodynamic (MHD) waves.

Our particular aim in this paper is to estimate a possibility of MHD wave transmission through a horizontal boundary separating the ionosphere from magnetosphere in a model of idealized two region terrestrial atmosphere. Such domain coupling by

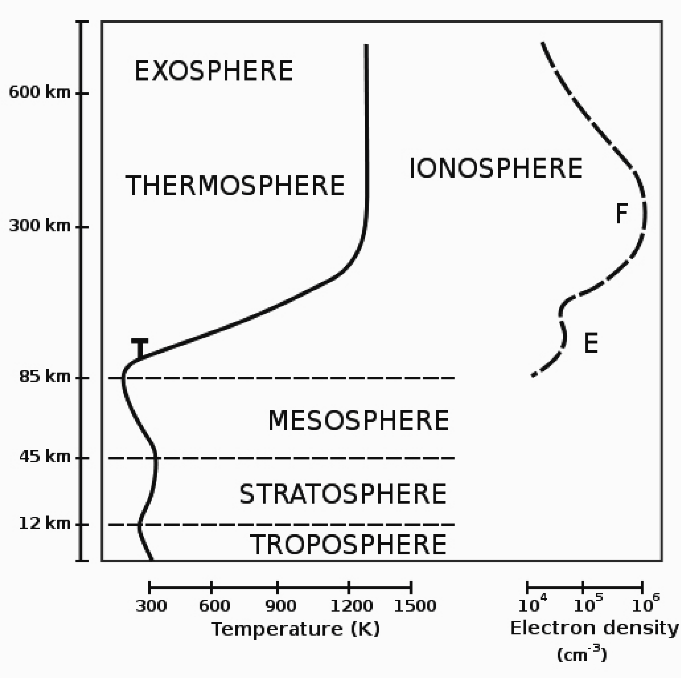

Figure 1: Typical vertical temperature profile in the atmosphere.

MHD waves is important in studying atmospheric (ionospheric as well as magnetospheric) responses to disturbances induced by various external perturbation sources. In particular, we are interested in resulting types of MHD waves and how far they can propagate through the nonuniform atmospheric plasma medium, i.e. whether the hydrodynamic waves, detected in the lower ionosphere by the VLF (very low frequency) radio wave reflection technique (for details see Nina & Čadež, 2014), can be generated far away in the magnetosphere by, say, some sudden solar wind impacts.

2. BASIC STATE AND EQUATIONS

According to the typical temperature profile in Fig.1 we model the terrestrial atmosphere as a simple system of two quasi-isothermal domains with the following properties:

- The ionospheric D-region with model values: T_0=250K, $V_s \equiv V_{si}$=700m/s $\gg V_{Ai}$.
- In the magnetospheric region with model values: T_0=1200K, $V_s \equiv V_{sm}$=12 km/s$\ll V_{Am}$=6500 km/s,

where:

$V_A^2 \equiv B^2/(\mu_0\rho_0)$, $V_s^2 \equiv \gamma R T_0$ and $V_c^2 \equiv V_A^2 V_s^2/(V_A^2 + V_s^2)$ are squares of the standard Alfvén, sound and cusp speed, respectively.

The considered atmosphere is assumed vertically stratified (along the z-axis), being in a hydrostatic equilibrium, and having constant Alfvén speed in both domains separated by a horizontal boundary. The resulting plasma density and magnetic field vertical distributions are given by:

$$\rho_0(z),\, B_0^2(z) \sim \exp^{-z/H}, \quad H \equiv \frac{V_s^2}{\gamma g} + \frac{V_A^2}{2g} = \text{const.}$$

Starting from standard MHD equations for linear, adiabatic perturbations in a dissipationless fully ionized stratified plasma we obtain the following general dispersion relation (Pinter & Čadež, 1999):

$$k_z^2 = A_2 A_3 - \left(A_1 - \frac{\gamma g}{2V_s^2 + \gamma V_A^2} \right)^2 \tag{1}$$

with:

$$A_1 = \frac{g\omega^2}{(V_A^2 + V_s^2)(\omega^2 - V_c^2 k_x^2)},$$

$$A_2 = \frac{\omega^2 - V_s^2 k_x^2}{(V_A^2 + V_s^2)(\omega^2 - V_c^2 k_x^2)} - \frac{k_y^2}{\omega^2 - V_A^2 k_x^2},$$

$$A_3 = (\omega^2 - V_A^2 k_x^2) \left[1 + \frac{g^2}{(V_A^2 + V_s^2)(\omega^2 - V_c^2 k_x^2)} \right] - \frac{2\gamma g^2}{2V_s^2 + \gamma V_A^2}$$

with perturbed quantities $\delta\psi$ being harmonic in space and time in the following way:

$$\delta\psi = \hat{\delta\psi}(z) \mathrm{e}^{i(k_x x + k_y y - \omega t)}.$$

Clearly, waves propagate if the condition $k_z^2 > 0$ holds for given values of $k_{x,y}$ and ω.

Dispersion relation Eq.1 with parameters typical of the model ionospheric D-layer reduces to:

$$k_z^2 = \frac{\omega^2 - V_{si}^2 k_0^2}{V_{si}^2} \left[1 + \frac{g^2(\gamma - 1)}{V_{si}^2 \omega^2} \right] - \frac{g^2}{V_s^4} \left(1 - \frac{1}{\gamma} \right)^2$$

where:

$$k_0^2 \equiv k_x^2 + k_y^2, \quad \lambda_0 = \frac{2\pi}{k_0}, \quad \lambda_z = \frac{2\pi}{k_z}, \quad \tau = \frac{2\pi}{\omega},$$

as treated by A. Nina & V. M. Čadež (2014). Fig.2 shows the resulting diagrams for propagating p- and g-modes with several weave periods τ obtained from the Fourier spectral analysis of recorded VLF radio waves after being reflected from the ionospheric D-layer. The plotted ranges of the horizontal and vertical wavelengths λ_0 and λ_z, respectively, reflect the allowed perturbation dimensions that do not violate physical conditions and geometrical dimensions of the medium assumed by the model atmosphere. Now, the question we are interested in is whether such waves that propagate in the ionospheric domain can also propagate in the domain with conditions typical of the magnetosphere.

The horizontal boundary, separating the ionosphere from magnetosphere in our simplified model, imposes boundary conditions on harmonic waves in the two domains saying that the wave frequency ω and the horizontal wavevector components $k_{x,y}$ do

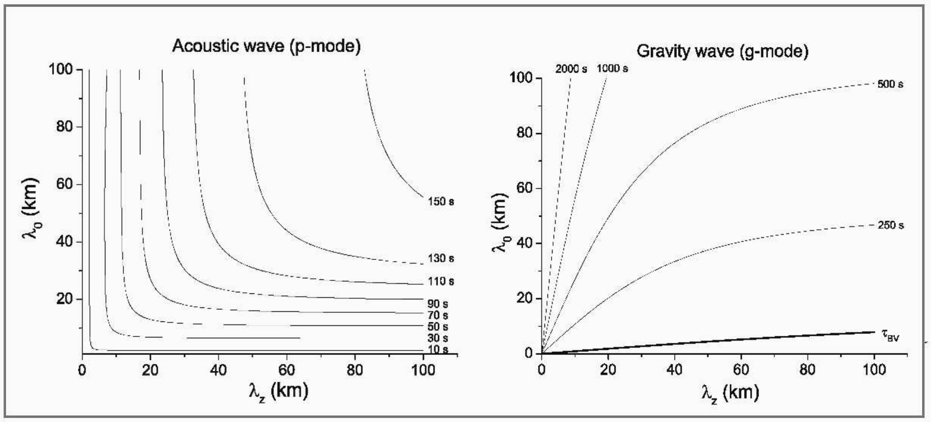

Figure 2: Computed dispersion curves for the acoustic p-mode (left panel) and gravity g-mode (right panel), respectively, under the assumed ionospheric conditions.

not change across the interface, while this is not true for the vertical component k_z. If k_z^2 remains positive, the two domains are coupled by such MHD waves meaning that disturbances generated in the magnetosphere can be present and detected also in the ionosphere. Consequently, we apply wave parameters for the D-region (plotted in Fig.2) in the dispersion relation (Eq. 1) with physical quantities relevant to magnetospheric conditions in the assumed model. A straightforward mathematical analysis shows that the resulting sign of k_z^2 is generally negative with an exception of a narrow domain close to the so called Alfvén resonance:

$$\omega^2 - k_x^2 V_{Am}^2 \approx 0, \quad \text{or} \quad \omega^2 - k_0^2 \cos^2\phi \, V_{Am}^2 \approx 0. \tag{2}$$

where it can be positive, which is the condition for the considered MHD waves to propagate in both regions. In this case, the dispersion relation Eq.(1) can be expanded for the horizontal propagation angle ϕ close to the resonant condition ϕ_{re} defined by:

$$\omega^2 - k_0^2 \cos^2\phi_{re} \, V_{Am}^2 = 0. \tag{3}$$

The resulting asymptotic expression is given by:

$$k_z^2 \approx \frac{2g^2k_0^2}{V_{Am}^2(\omega^2 - V_{Am}^2 k_0^2 \cos^2\phi)} \qquad \text{if} \quad \cos\phi \approx \cos\phi_{\rm re} \equiv \frac{V_{si}}{V_{Am}} \ll 1,$$

or:

$$\lambda_z^2 = \frac{V_{Am}^2(\lambda_0^2 - V_{Am}^2 \tau^2 \cos^2\phi)}{\tau^2} \qquad \text{if} \quad \cos\phi \approx \cos\phi_{\rm re} \equiv \frac{V_{si}}{V_{Am}} \ll 1 \tag{4}$$

with

$$\delta_\phi \equiv \frac{\phi - \phi_{\rm re}}{\phi_{\rm re}}$$

being a normalized propagation angle.

Fig.3 shows numerical values of the resonant propagation angle ϕ_{re} obtained from Eq.(3) under the assumed magnetospheric conditions for the range of wave periods

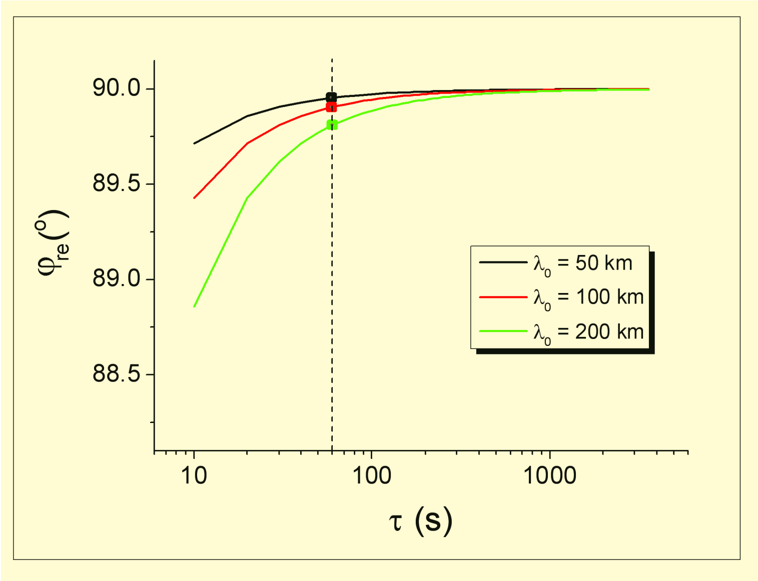

Figure 3: Resonant propagation angle ϕ_{re} dependence on wave periods τ for three typical horizontal wave lengths λ_0 at considered magnetospheric conditions.

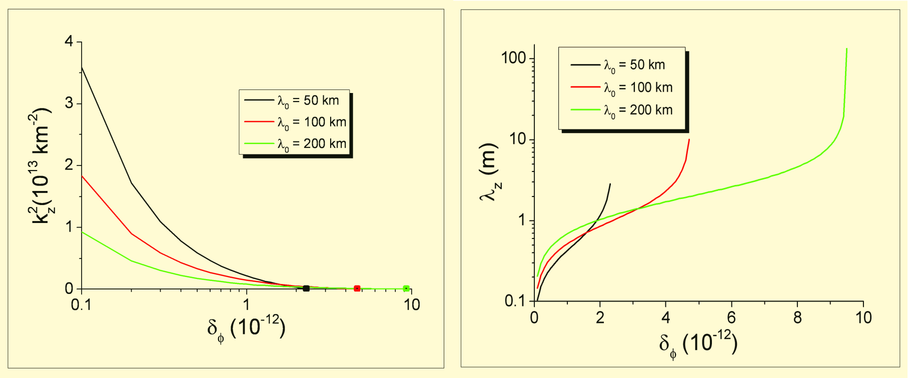

Figure 4: Vertical number k_z (left panel) and the related wavelength λ_z (right panel) dependences on the normalized propagation angle δ_ϕ for three typical horizontal wave lengths λ_0 at considered magnetospheric conditions.

τ registered in the lower ionosphere by the VLF radio-wave monitoring technique explained in A. Nina & V. M. Čadež (2014). As can be seen, the resonant condition Eq.(3) in our model can be satisfied for waves propagating almost parallel to the magnetic field.

The resulting vertical wavenumber k_z and the corresponding wavelength λ_z for the model magnetosphere are plotted in Fig.4. As can be seen, the vertical perturbation dimension defined by λ_z is real and grows rapidly with δ_ϕ for indicated horizontal perturbation dimensions λ_0.

3. CONCLUSIONS

The obtained results plotted in Figs. 3 and 4 show a possible existence of MHD wave coupling between the model ionosphere and magnetosphere through a restrictive Alfvén resonance. In other words, the coupling, i.e. wave transmission through the interface separating model ionosphere and magnetosphere, occurs for waves propagating almost perpendicularly ($\phi \approx \pi/2$) to the horizontal magnetic field of the model. In this case, hydrodynamic waves that can propagate in the ionosphere and be detected by the VLF radio wave reflection technique, may be generated in the magnetosphere the outermost part of the atmosphere, as a result of dynamical perturbations caused by solar wind variations and other phenomena depending on solar activity.

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REGIONAL ACTIVITIES RELATED TO IAU STRATEGIC PLAN AND INTEGRATION OF ARMENIA IN EUROPEAN ASTRONOMY

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Abstract. Armenia is one of the candidates to host a Regional Office of Astronomy for Development, according to the IAU Strategic Plan for 2014-2020 and further years. Armenian astronomers are rather integrated in the international and European astronomical communities, as well as BAO is one of the most important astronomical centres in the Middle East area. The Armenian Astronomical Society is one of the 25 EAS affiliated members and is rather active in organizing various events. The Armenian Virtual Observatory is a member of the International Virtual Observatory Alliance. We have started a series of Byurakan International Summer Schools for regional and European students with involvement of a number of European lecturers. Viktor Ambartsumian International Prize is one of the important international astronomy awards. Armenian astronomy integrated into the European one may serve much more efficiently both for Armenia, Middle East region, as well as Europe, particularly establishing a link between Europe and Eastern Partnership countries.

1. INTRODUCTION

During the International Year of Astronomy in 2009 (IYA-2009), IAU developed a long-term educational plan that would focus on using astronomy to stimulate capacity building and further sustainable global development. A world Office of Astronomy for Development (OAD) was established in South Africa and Regional Offices of Astronomy for Development (ROAD) will be established. Armenia is one of the candidates to host such an office in the Middle East region. Its activities include:

- Management and coordination of the IAU programs; Coordination of contacts between the IAU and national authorities; Establishment of the new IAU endowed lectureship program and organization of seminars and public lectures for the IAU lecturers; Liaison with other international unions
- Organization of regional scientific meetings; Support in organization of Byurakan International Summer Schools with an emphasis on regional students; Organization of regional astronomical Olympiads for pupils
- BSc/MSc/PhD studies for regional students at BAO, Yerevan State University (YSU), and Armenian National Academy of Sciences; Support to Galileo Teacher Training Program (GTTP); Production/publication of educational and

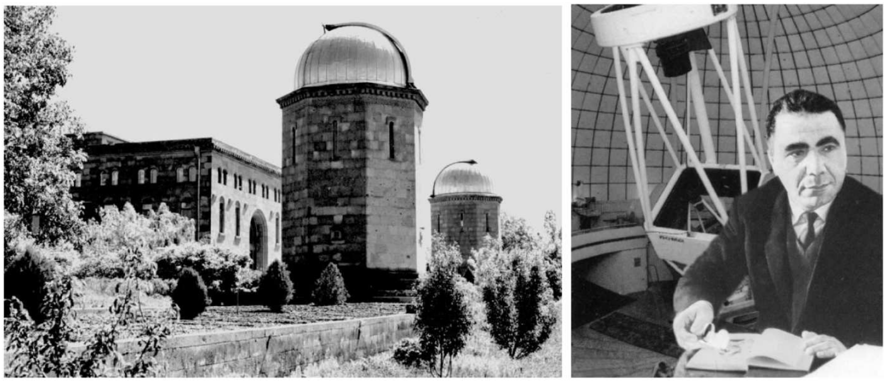


Figure 1: Byurakan Astrophysical Observatory and Viktor Ambartsumian.

promotional materials; Creation of an educational webpage for remote interactive regional teaching

- European Eastern Partnership liaison (collaboration with Europe, particularly with Eastern European countries, Sub-Regional European Astronomical Committee, SREAC, etc.)

2. BYURAKAN ASTROPHYSICAL OBSERVATORY

Byurakan Astrophysical Observatory (BAO) is a research institution of the Armenian National Academy of Sciences (NAS RA). It was founded in 1946 by the outstanding scientist of the XX century Viktor Ambartsumian (1908-1996) who became its first director and served until 1988. Main achievements of the Armenian astronomy are connected with him. He was the IAU President in 1961-64, twice elected ICSU President (1968-72), he was foreign or honorary member of 28 academies and societies. Ambartsumian was the President of the Armenian Academy of Sciences during 1947-1993 and the Director of BAO during 1946-1988.

Five important observational instruments are installed at BAO, the larger ones being 2.6m Cassegrain telescope (ZTA-2.6) and 1m Schmidt (the one used for the famous Markarian survey) telescopes.

The first studies at BAO related with the instability phenomena taking place in the Universe, and this trend became the main characteristic of the science activity in Byurakan. Discovery of stellar associations in 1947 (Ambartsumian 1949), hypothesis about activity of galactic nuclei in mid-1950s (Ambartsumian 1958), discovery and study of many Seyfert galaxies and QSOs, more than 1000 flare stars, dozens of SNe, hundreds of HH objects and cometary nebulae, works in the field of radiative transfer theory, are the main scientific achievements. The First and Second Byurakan surveys (FBS, 1965-1980, and SBS, 1978-1991) conducted due to Beniamin Markarian (1913-1985) brought to the well-known Markarian galaxies (Markarian et al. 1989) and SBS objects (Stepanian 2005). Surveys and search for new objects are traditional for Armenian astronomers: Markarian, Arakelian (1975) and Kazarian (Kazarian et al.

2010) galaxies, Shahbazian groups (Shahbazian 1996), cometary nebulae (Parsamian & Petrosian 1979) are well-known, as well as searches for blue stellar objects (BSO, Mickaelian 2008) and late-type stars (Gigoyan & Mickaelian 2012); optical identifications of IR, radio and X-ray sources.

Recently, in 2012, the Armenian Government awarded BAO a status of National Value. It is well-known not only for its scientific achievements; BAO can also be considered as an educational and touristic centre, unique architectural ensemble and it has a rich botanical garden. In 2011, FBS and its Digitized version (DFBS) were included in UNESCO Memory of the World international register. BAO collaborates with scientists from the USA, UK, France, Italy, Germany, Spain, Russia, Georgia, Bulgaria, Japan, China, Mexico, Australia, and other countries.

Armenia also has a rich tradition of organization of many international meetings since 1950s. A number of important scientific meetings have been held, including five IAU Symposia (1966, 1986, 1989, 1998, and 2013) and an IAU Colloquium (2001), and 5 international schools. BAO was one of the main organizers of the Joint European and National Astronomical Meeting in 2007 (JENAM-2007). The first international symposium on CETI also was organized in Byurakan in 1971.

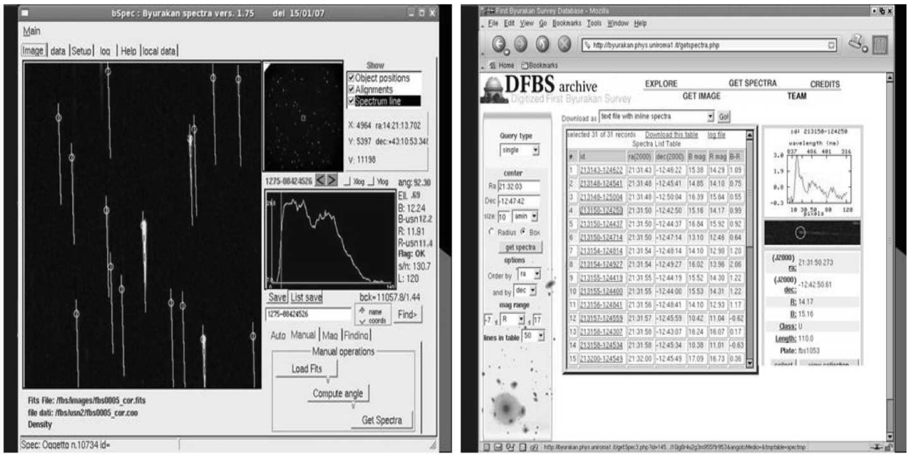
3. ARMENIAN ASTRONOMICAL SOCIETY

Armenian Astronomical Society (ArAS) is a Non-governmental organization (NGO) founded in 1999 and officially registered at the Armenian Ministry of Justice in 2001. It is an Affiliated Society in the European Astronomical Society (EAS), it is the official representative of the Euro-Asian Astronomical Society (EAAS) in Armenia, and the official representative of the International Astronomical Olympic Committee in Armenia. ArAS is based at BAO. ArAS has 95 members from 18 countries.

ArAS main activities are the establishment of contacts between astronomers and other scientists, establishment of contacts between BAO and other scientific organizations and NGOs, meetings, summer schools, public lectures, Electronic Newsletters, Annual Prizes for young astronomers, Astronomy and World Heritage, astronomical educational matters in Armenia, lectures by astronomers at schools, amateur astronomers, and popularization of astronomy in Armenia, webpage with a large number of astronomical information, etc. ArAS took most of the responsibilities for IYA-2009 activities in Armenia, as well as Beyond-IYA. ArAS was the main organizer of the Joint European and National Astronomical Meeting (JENAM-2007). Altogether, 13 ArAS annual meetings and seven summer schools for young astronomers and students, as well as a Conference for Young Astronomers have been organized. ArAS maintains at its webpage most of the information concerning BAO and the Armenian astronomy.

4. DIGITIZED FIRST BYURAKAN SURVEY AND ARMENIAN VIRTUAL OBSERVATORY

Markarian survey or FBS (1965-1980; Markarian et al. 1989) was the first systematic objective-prism survey in the world and it was a new method of search for AGN. Until now, it is the largest objective-prism survey of the Northern sky (17,000 sq. deg). It resulted in the discovery of 1515 UV-excess (UVX) galaxies, as well as to classification of Seyferts into Sy1 and Sy2 (Weedman & Khachikian 1971), into



selected 31 of 31 records Download this table log file

Spectra List Table

#	id	ra(2000)	dec(2000)	B mag	R mag	B-R
1	213143-124622	21:31:43	-12:46:22	15.38	14.29	1.09
2	213148-124541	21:31:48	-12:45:41	14.85	14.10	0.75
3	213148-125004	21:31:48	-12:50:04	16.39	15.84	0.55
4	213150-124250	21:31:50	-12:42:50	15.16	14.17	0.99
5	213150-124437	21:31:50	-12:44:37	16.84	15.92	0.92
6	213150-124714	21:31:50	-12:47:14	13.10	12.46	0.64
7	213154-124814	21:31:54	-12:48:14	14.10	12.90	1.20
8	213154-124927	21:31:54	-12:49:27	16.02	13.96	2.06
9	213155-124419	21:31:55	-12:44:19	15.52	14.30	1.22
10	213155-124400	21:31:55	-12:44:00	15.53	14.31	1.22
11	213156-124841	21:31:56	-12:48:41	14.10	12.93	1.17
12	213157-124559	21:31:57	-12:45:59	10.42	11.04	-0.62
13	213158-124307	21:31:58	-12:43:07	16.24	16.07	0.17
14	213158-124534	21:31:58	-12:45:34	10.38	11.01	-0.63
15	213200-124549	21:32:00	-12:45:49	17.09	16.73	0.36

Figure 2: DFBS spectra extraction and analysis software bSpec and DFBS webpage.

definition of Starburst galaxies (Weedman 1977). FBS also led to other projects, including FBS BSOs, late-type stars, optical identification of IRAS point sources: Byurakan-IRAS Galaxies (BIG) and Byurakan-IRAS Stars (BIS).

In 2002-2005, FBS plates were digitized (Mickaelian et al. 2007) in frame of collaboration between BAO, Universita di Roma “La Sapienza” (Italy) and Cornell University (USA). 1874 plates now have their FITS files and are available for users.

In 2005, Armenian Virtual Observatory (ArVO) was created based on DFBS. ArVO is one of the 19 national VO projects forming the International Virtual Observatories Alliance (IVOA) and is the only VO project in the region. Besides building of VO environment for efficient astrophysical research, VO serves as educational tool for the regional students and astronomers in general. A number of science projects have been proposed and are being accomplished based on DFBS and ArVO, such as: Search for new AGN, Search for variable objects in DFBS, Search for emission-line stars, Optical identification of X-ray, IR and radio sources, Search for asteroids in DFBS and others.

5. ASTRONOMICAL EDUCATION IN ARMENIA

The astronomical education in Armenia consists of 4 levels (school education, university B.Sc. and M.Sc. studies, and Ph.D. We also organizes annual astronomical Olympiads. During the IYA-2009, an Armenian Galileo Teacher Training Program (GTTP) was conducted to implement new methods in astronomy education and to train Galileo teachers in Armenia. A new initiative, Byurakan Science Camp, was organized recently in 2014 to encourage knowledge and science among school pupils.

BAO also has a tradition of teaching international PhD students under supervision of Armenian astronomers. Such a program started in 1960s. PhD students from Russia, Ukraine, Bulgaria, Hungary, Georgia, Uzbekistan, Azerbaijan, Jordan and some others spent several years at BAO and received their Ph.D. degrees from Armenia.

Figure 3: Byurakan International Summer Schools.

During 2006-2012, we have organized 4 Byurakan International Summer Schools (BISS), where more than 130 students from 21 countries (Europe, Middle East, FSU) participated. There were lecturers from 11 countries (USA, Germany, France, Italy, Spain, Belgium, Estonia, Russia, India, Australia, and Armenia). There is a series of Byurakan Summer Schools for YSU students as well (BSS). Based on our experience of astronomical schools, we have created a webpage with information on all major astronomical summer/winter schools in the world, including the name, organizers, countries, location, periodicity, duration, number of participants, level (BSc, MSc, PhD or other) links to the upcoming events, etc..

Armenian pupils participate in International Astronomical Olympiads (IAO) and International Olympiads of Astronomy and Astrophysics (IOAA). We have participated in 15 out of 19 IAO and 2 out of 8 IOAA. Armenian team is one of the best and has won altogether 9 gold, 7 silver, and 21 bronze medals. There are astronomical groups at some specialized schools, where Olympic teams are being trained.

6. AMATEUR AND POPULAR ASTRONOMY IN ARMENIA

There are thousands of amateur astronomers in Armenia, however they need both professional and organizational support from astronomers, and BAO and ArAS have started to provide such a support. There are plans to create an individual association of amateur astronomers in 2015. ArAS has initiated Scientific Journalism in Armenia and regular press-releases are being circulated to mass media on various topics of astronomy and astronomical events. Public Outreach Activities include public lectures at schools, universities, etc., informing public about astronomical events (Calendar of Events on ArAS webpage), scientific journalism affairs: mailing list, FB group, press-releases, seminars, prizes, online popular astronomy journal, digital book library on ArAS webpage, popular articles on astronomical hot topics ArAS webpage, etc.

7. EUROPEAN EASTERN PARTNERSHIP

The Eastern Partnership (EaP) is an initiative of the European Union (EU) governing its relationship with the post-Soviet states of Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine. Having objectives to start collaboration between different regions and support each other for astronomy development, we have established contacts with astronomers from Poland, Serbia, Bulgaria and some other EU and Eastern European countries. Visits to Poland (Warsaw, Torun) and Serbia (Belgrade) have been accomplished by Areg Mickaelian during Dec 2013 and Sep 2014, respectively. Talks were given and discussions were held with the interested people. A mailing list was created to continue discussions. It is regarded that Armenia may play a role of the link between Europe and Eastern countries.

8. SUMMARY AND CONCLUSIONS

Summarizing, here we give the main features of Armenian astronomy that make a good basis for hosting IAU ROAD, including those described above and some others:

- BAO; 2.6m and 1m Schmidt telescopes; Viktor Ambartsumian was IAU (1963-1966) and ICSU (1968-1972) president; Markarian survey was the 1st systematic objective prism survey and 1st search for AGN
- ArAS is one of the 25 EAS affiliated societies; Armenian is one of 4 ICRANet member states; ArVO is one of the 19 national projects in frame of IVOA; DFBS is one of the largest spectroscopic databases
- Six IAU meetings were organized in Armenia in 1966-2013; JENAM-2007 was organized in Armenia; BISS are one of regular astronomical summer schools in the world
- Many foreign astronomers have defended their PhD thesis in BAO; Armenia is one of the most successful teams in International Astronomical Olympiads
- Viktor Ambartsumian International Prize is one of the major astron. prizes

There is a number of supporting organizations, such as Ministry of Education and Science, Ministry of Culture, State Committee of Science, and National Academy of Sciences, as well as a number of international organizations and countries, such as IAU, IVOA, International Centre for Relativistic Astrophysics Network (ICRANet), EAAS, Sub-Regional European Astronomical Committee (SREAC), Georgia, Iran, and Bulgaria (Wide-Field Plate Database).

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FIRST RESULTS OF BOSNIA-HERZEGOVINA METEOR NETWORK (BHMN)

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Abstract. Modeled according to similar networks in the region, since the spring of 2013 in Bosnia and Herzegovina began operation of video meteor network, which currently consists of five stations. In preparation is expansion of the network by setting up another 5 stations. The Network is jointly managed by Astronomical Society Orion Sarajevo and Federal Hydrometeorological Institute in Sarajevo whose meteorological stations were used for installation of cameras. So far cameras of BH meteor network recorded over 9614 meteors and we calculated 1306 orbits. In this paper we present the results of the first year of operation of our meteor network and analysis of Geminids recorded during the peak of this meteor shower that occurred 12/13th December 2013., which confirms the high quality of the data obtained. The orbits obtained with the help of stations of our Network were compared to the orbits of the Geminid meteors obtained by Japanese video meteor network (SonotaCo) and the orbit of the presumed parent body of the shower - asteroid 3200 Phaethon, using Southworth-Hawkings D-criteria.

1. INTRODUCTION

Seen from the Earth, meteors are local phenomenon, i.e. meteors are visible only from a small region on the planet, below the point at which they start to burn. They are formed by penetration of small bodies from interplanetary space into the Earth's atmosphere at high speed whereas the friction with the upper atmosphere leads to ionization and heating of the air and at altitudes of about 100 km, the track due to their passage, becomes visible. In the classical era, meteors were observed visually, photographically or by radars.

The emergence of low-cost video camera has opened possibility of a very high quality monitoring of these phenomena with previously unimaginable precision. The basic operation of one meteor network consists of making video recordings of meteors, simultaneously with at least two separated video cameras. On this basis it is possible to determine the atmospheric trajectory of the meteor shower and its speed in each frame of video. Knowledge of this speed allows us to calculate the velocity and heliocentric orbits of meteoroid particles before the collision with the Earth, which in some cases receive its origin and relationship with the parent comet or asteroid. The Bosnia-Herzegovina meteor network (BHMN) has been created and developed in the preceding two years by Astronomical Society Orion Sarajevo and their cooperation with the Federal Hydro meteorological Institute.

2. STATIONS AND EQUIPMENT

Many CCTV cameras for video surveillance in low light conditions have sufficient sensitivity to, with high-quality lens and the field of view of the order of 80x60 degrees, detect stars up to magnitude 4. After a certain period of testing various models, we acquired 7 cameras from manufacturer iDEA Classic from Croatia (model DVC-CAM SM234LX-Ex) and 3 cameras from manufacturer KT & C of Korea, (model KPC-350BH). Both types of cameras use highly sensitive Sony Super HAD CCD chip. For all these cameras we purchased Tokina Lenses from Japanese manufacturer, model TVR0398DCIR. Specifications of the chips and camera lenses are given in Tables 1. and 2. below.

Figure 1: Two types of cameras and Tokina lens.

model	format	system	chip
DVC-CAM-SM234LX-Ex	1/3"	PAL 25 fps	ICX255AL
KPC-350BH	1/3"	NTSC 29.97 fps	ICX254AL

model	TVR0398DCIR
Focal length	3 - 8.2 mm manual
F number	0.98
Iris	automatic

Each station consists of a computer, UPS and camera placed in a classical frame of surveillance cameras with heating and front window. Internet connection and electric power are necessary. Computers must be Pentium IV-2 GHz because of the processor power required for further analyze of video records.

In cooperation with the Federal hydro meteorological Institute Federation of BiH, so far we have set up five permanent stations, mainly on buildings of existing hydro meteorological stations in various cities in BiH. One is on a private house in Croatia.

3. ACQUISITION AND PROCESSING

The cameras are monochromatic and have an analog output, so for a digitization and recording we need the TV card with video input or a special video grabber. The acquisition of data or recording a meteor from the digitized video is done with the help of a software package UFO produced by Japanese meteor network SonotaCo[1]. This package consists of 3 programs: UFOCapture - to record meteors, UFOAnalyzer - to calibrate the camera field of view and measuring meteor coordinate in every frame of video and UFOOrbit - to compute the atmospheric trajectory and orbit of simultaneously recorded meteors. To search for a simultaneous meteor in video over various cameras is essential that the system clocks of computers at each station synchronized at the same time. This is done with the help of Dimension 4 which adjusts the system time of computers over the Internet with the time of servers every minute. UFOCapture: monitors digital video camera frame by frame, calculates the average brightness value of all pixels in each frame, sets a certain brightness threshold that should be exceeded by a certain number of pixels in a certain number of successive frames and such significant change is the trigger for video recording. In doing so, the software can tune the parameters that will shut off the recording of transient flashes, slow moving objects like airplanes or such changes in which the resulting trajectory in the sky is too curved to be a meteor. The program may store in a buffer a given number of frames so that together with the appearance that triggered the recording he can capture a certain number of frames before and after the termination of this phenomenon. Along with the video text log file is recorded which specifies the coordinates of pixels in which there was a shift for each frame, the number of pixels in which there was a shift, the moment at which it happened and some data related to that video. In addition, as in the field of view of the camera there are stars, which also have the brightness above average, the program identifies and captures their positions in a bitmap image (scintillation mask), which is then used to analyze the video.

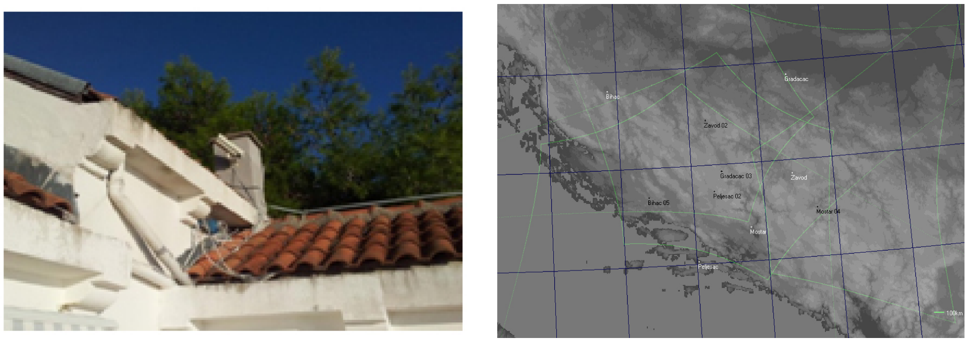


Figure 2: Southern camera in Lovište, Pelješac, Croatia.

location	lat (°)	E long (°)	alt (m)	resolution	FOV (°)	azimuth (°)	elevation (°)	'/ pixel
Pelješac	43.0272	17.0318	10	704x528	80x60	15.07	47.16	7
Bihać	44.8078	15.8667	301	704x528	80x60	160.37	37.66	7
Gradačac	44.87	18.45	230.5	704x528	80x60	217.15	31.2	7
Mostar	43.3483	17.7933	97	704x528	70x52	78.81	51.29	6
Sarajevo	43.8676	18.4228	631	720x480	90x68	309.57	36.71	7.5

In the clear night, in the camera field of view of 80x60 degrees, it is possible to see between 50 and 200 stars up to magnitude 4. These stars are used to calibrate the camera field of view in the program UFOAnalyzer. What is recognized as a star is overlapped manually with the positions of stars visible at a given time at a given position in the area of the sky. For this, software uses a catalogue that is in the program UFOAnalyzer. This allows roughly to locate the camera orientation, and then automatically the software connects all the other stars with coordinates from the catalog and compute constants of plate. In a large field of view there can be a significant distortion and in these calculations software going to the coefficients of the fourth order. Ultimately, this yields the equation which can be used for any of the coordinates (x, y) on the video frames to get the celestial coordinates of a given pixel or in the local horizontal either in the equatorial coordinate system, where the equatorial coordinates included atmospheric refraction. This, together with geographical coordinates of the stations, field of view and resolution of the camera, is saved as the camera profile and will be used for further analysis of the images of the meteor.

After each night of recording, the records are manually checked in order to remove objects which are are not meteors, and UFOCapture has not rejected them. These can be insects or birds that flew very close to the camera. Then, each meteor record is passed through an analysis in which in every frame of video is determined the position of meteor and recorded as a horizontal and equatorial coordinates, together with the number of pixels covered by a meteor and the overall brightness of these pixels. Finally the fitting of these positions with a large circle on the celestial sphere is made, and as a result we get a clip of the large circle that corresponds to the apparent trajectory of meteor on the celestial sphere. For each meteor all of this together with the coordinates of station is saved in one file, which is output of the analysis. Results for all meteors from a certain time interval, e.g. one night, you can save in the form of an Excel spreadsheet in which are written only the data that are relevant for calculating atmospheric trajectories and orbits, and this are data which are connected to clip of the great circle which corresponding to meteor trace, data on average angular velocity, time of occurrence and duration of meteor and position of the station.

After the processing of records from individual stations, the results are collected in one place in the program UFOOrbit. This software primarily checks whether among the recorded meteors from all stations are those that were recorded simultaneously with two or more stations, under certain time tolerance. If that is the case, next procedure is computing of atmospheric trajectory and orbit. UFOOrbit for calculation of atmospheric trajectory and orbit in Solar system use so-called Method of planes (described in paper of Zdenek Ceplecha from 1987 year [2]) in which, due to their very short duration, meteor trajectories considered rectilinear. Finally all parameters meteors are compared with parameters of known meteor showers and in the case of a match, meteor is associated with a given shower. UFOOrbit gives a graphical representation of the heliocentric orbit and projection of the atmospheric trajectory on the Earth's surface. The quality of the obtained orbit, i.e. uncertainty of the orbital elements and atmospheric path, depends significantly on the geometry of the certain case and the duration of the meteor. Best orbit are obtained in the case that the angle between the geometric planes of two stations is near 90 until the speed of the meteor is determined better if his duration is longer. Because of this UFOOrbit classifies orbits towards certain parameters of quality. The best orbits are called Q3 orbits.

4. SHOWERS STATISTICS AND SPECIAL CASES

In the whole period of our meteor activity, up to August 2014, cameras of Bosnia and Herzegovina meteor network recorded a total of 14,792 meteors, of which 2349 are recorded simultaneously with two or more cameras so they have calculated orbits.

Recorded meteorites are from all major showers and data about them are given in Table 4. From the calculated orbits, 329 are a high quality (Q3) according to the parameters of software UFOOrbit and projections of atmospheric trajectories of these meteors are given in Figure 4.

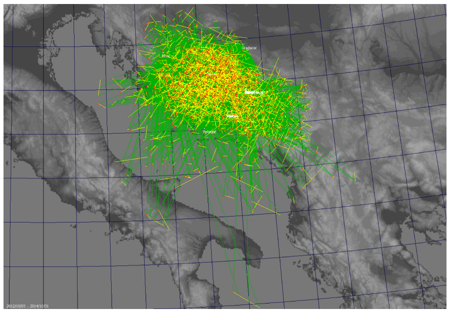
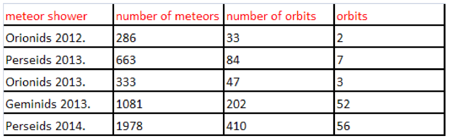


Figure 3: The ground projection of recorded meteors.



meteor shower	number of meteors	number of orbits	orbits
Orionids 2012.	286	33	2
Perseids 2013.	663	84	7
Orionids 2013.	333	47	3
Geminids 2013.	1081	202	52
Perseids 2014.	1978	410	56

We recorded a few very long meteors, earth grazers, 4 of them are longer than 100 km, and the longest had atmospheric path of 154 km. The vast majority of meteors have duration of less than 0.5 s, while during the entire operation of the network we recorded 44 meteors with duration of more than 1 second. It was recorded few fireballs - bright meteors whose flight was accompanied by explosions, some of which have absolute magnitudes greater than -5. Until now, the brightest fireball was captured on 01.11.2013. at 23:36:59 UTC and recorded by 3 station of BH network, 2 stations of Croatian Meteor Network and one station of Italian meteor network. His flight lasted longer than 3 seconds and started at an altitude of about 90 km and ended at about 34 km above the Zenica. According to the analyzes who are still in progress, absolute magnitude stood between -8 and -9, and it is possible that the initial mass of the object that caused it was over 10 kilograms.

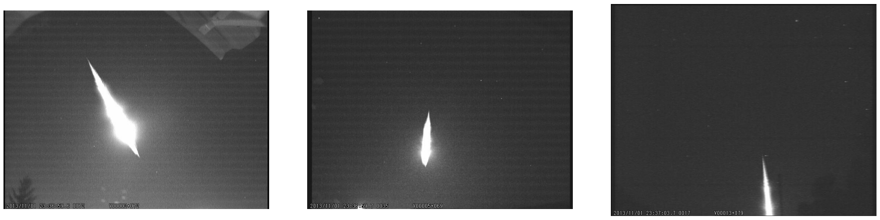
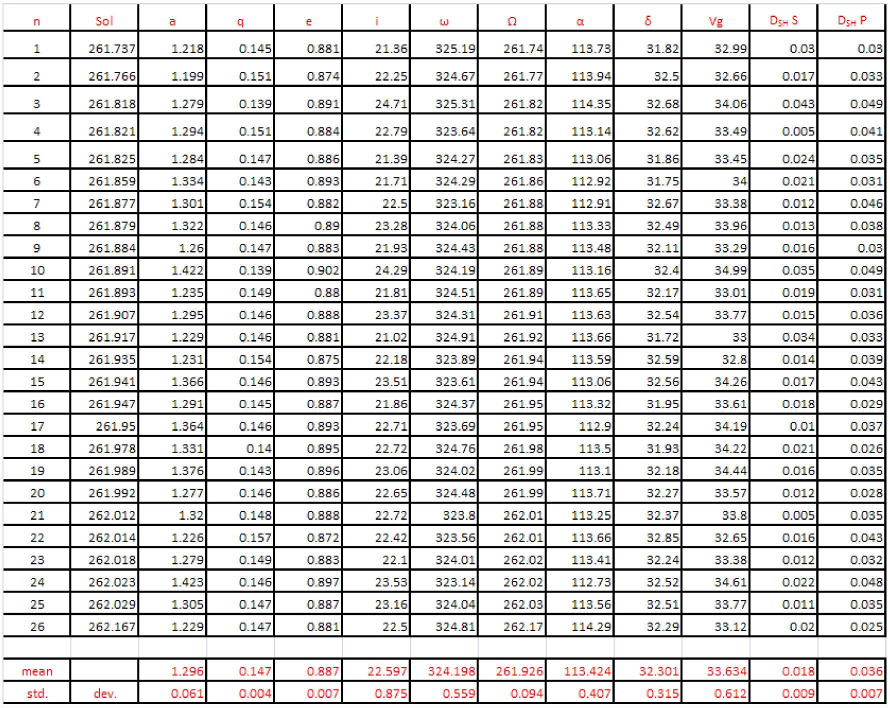


Figure 4: Bright fireball captured on 01.11.2013. from Sarajevo, Pelješac and Gradačac stations.



n	Sol	a	q	e	i	ω	Ω	α	δ	Vg	D_{SH} S	D_{SH} P
1	261.737	1.218	0.145	0.881	21.36	325.19	261.74	113.73	31.82	32.99	0.03	0.03
2	261.766	1.199	0.151	0.874	22.25	324.67	261.77	113.94	32.5	32.66	0.017	0.033
3	261.818	1.279	0.139	0.891	24.71	325.31	261.82	114.35	32.68	34.06	0.043	0.049
4	261.821	1.294	0.151	0.884	22.79	323.64	261.82	113.14	32.62	33.49	0.005	0.041
5	261.825	1.284	0.147	0.886	21.39	324.27	261.83	113.06	31.86	33.45	0.024	0.035
6	261.859	1.334	0.143	0.893	21.71	324.29	261.86	112.92	31.75	34	0.021	0.031
7	261.877	1.301	0.154	0.882	22.5	323.16	261.88	112.91	32.67	33.38	0.012	0.046
8	261.879	1.322	0.146	0.89	23.28	324.06	261.88	113.33	32.49	33.96	0.013	0.038
9	261.884	1.26	0.147	0.883	21.93	324.43	261.88	113.48	32.11	33.29	0.016	0.03
10	261.891	1.422	0.139	0.902	24.29	324.19	261.89	113.16	32.4	34.99	0.035	0.049
11	261.893	1.235	0.149	0.88	21.81	324.51	261.89	113.65	32.17	33.01	0.019	0.031
12	261.907	1.295	0.146	0.888	23.37	324.31	261.91	113.63	32.54	33.77	0.015	0.036
13	261.917	1.229	0.146	0.881	21.02	324.91	261.92	113.66	31.72	33	0.034	0.033
14	261.935	1.231	0.154	0.875	22.18	323.89	261.94	113.59	32.59	32.8	0.014	0.039
15	261.941	1.366	0.146	0.893	23.51	323.61	261.94	113.06	32.56	34.26	0.017	0.043
16	261.947	1.291	0.145	0.887	21.86	324.37	261.95	113.32	31.95	33.61	0.018	0.029
17	261.95	1.364	0.146	0.893	22.71	323.69	261.95	112.9	32.24	34.19	0.01	0.037
18	261.978	1.331	0.14	0.895	22.72	324.76	261.98	113.5	31.93	34.22	0.021	0.026
19	261.989	1.376	0.143	0.896	23.06	324.02	261.99	113.1	32.18	34.44	0.016	0.035
20	261.992	1.277	0.146	0.886	22.65	324.48	261.99	113.71	32.27	33.57	0.012	0.028
21	262.012	1.32	0.148	0.888	22.72	323.8	262.01	113.25	32.37	33.8	0.005	0.035
22	262.014	1.226	0.157	0.872	22.42	323.56	262.01	113.66	32.85	32.65	0.016	0.043
23	262.018	1.279	0.149	0.883	22.1	324.01	262.02	113.41	32.24	33.38	0.012	0.032
24	262.023	1.423	0.146	0.897	23.53	323.14	262.02	112.73	32.52	34.61	0.022	0.048
25	262.029	1.305	0.147	0.887	23.16	324.04	262.03	113.56	32.51	33.77	0.011	0.035
26	262.167	1.229	0.147	0.881	22.5	324.81	262.17	114.29	32.29	33.12	0.02	0.025
mean		1.296	0.147	0.887	22.597	324.198	261.926	113.424	32.301	33.634	0.018	0.036
std.	dev.	0.061	0.004	0.007	0.875	0.559	0.094	0.407	0.315	0.612	0.009	0.007

During the flight, it happened few explosions and there is a possibility that some of the fragments survive atmospheric flight and fell near Zenica. Another bright fireball was captured on September 13th 2014. at 00:54:41 UTC and recorded by 3 station of BH network. His flight lasted longer 6 seconds (the longest duration up to now) and started at an altitude of about 85 km over Travnik and ended at about 44 km above the Gradačac. During his flight, it happened at least 5 explosions and there is a possibility that some of the fragments survive atmospheric flight and eventually fell in Posavina region on the border between Bosnia and Croatia.

In the study of the small bodies of the Solar system, in particular, meteor showers, the most commonly used criterion of mutual associations of orbits of small bodies and their belonging to the same shower or their associations with some parental body is called Southworth-Hawkings criteria [3]. This criterion uses the orbital elements of the body and defines the "distance" between two orbits as:

$$
\begin{aligned}
D_{SH}^2 \; = \; & (e_B - e_A)^2 + (q_B - q_A)^2 + \left[2 \sin \frac{(i_B - i_A)^2}{2}\right]^2 \\
& + \; \sin i_A \sin i_B \left[2 \sin \frac{(Q_B - Q_A)^2}{2}\right]^2 + \left[\frac{e_B + e_A}{2} 2 \sin \frac{(Q_B + \omega_B) - (Q_A + \omega_A)}{2}\right]^2
\end{aligned}
$$

DSH value, below which, the two orbits are considered to belong to the same meteor showers various authors have taken a different values, and can be assessed for showers with known parent bodies. For Geminids, who are a very young shower with well-defined orbits and very sharp peak of activity, DSH is one of the smallest. To investigate the quality of the data that we get, thanks to very favorable weather conditions that we had during the peak of the Geminids in December 2013, we decided to compare the orbits that we get with the orbits of the data base of the Japanese meteor network SonotaCo and with orbit of assumed parental body of Geminids - asteroid 3200 Phaethon. The table 5 shows the orbital elements for 26 Geminids recorded on the night of their maximum December 13/14. 2013. For this analysis only the highest quality meteors were selected (Q3 criterion of program UFOOrbit).

5. CONCLUSION

The activities so far carried out in Bosnian and Herzegovinian meteor network showed extreme usability of cheap video surveillance equipment for recording meteors which allows serious research in this field. The results we get (and we will get in the future) with this the equipment and methods, will enable various statistical studies of meteor showers. In addition, as a patrol network that captures every clear night, one such meteor network will soon or later register fireballs that will survive atmospheric flight and fall as meteorites. After the analysis of these recordings it will be possible to calculate the site of crash. We have plans to expand our meteor network by setting up new stations that will allow more quality results. Finally it is very important educational aspects of this work. In activities of this network we may include secondary schools pupils or students of natural sciences who can conduct an initial analysis which allowing them first experiences in serious scientific research.

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SUMMARY OF THE IX BULGARIAN-SERBIAN ASTRONOMICAL CONFERENCE: ASTROINFORMATICS

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Abstract. We present a summary of the IX Bulgarian-Serbian Astronomical Conference: Astroinformatics (IX BSAC: Astroinformatics), held in Sofia in July 2014 (http://www.wfpdb.org/ftp/9_BSACA/), as well as our view on achieving the goal of these regular conferences started in 1998. We discuss the basic scientific directions and prospects of the Bulgarian-Serbian collaboration in Astronomy and Astroinformatics.

1. INTRODUCTION

The regular Bulgarian-Serbian/Serbian-Bulgarian astronomical conferences have been started in Belogradchik (Bulgaria) since August 1998. A brief overview of the goals, which these conferences have intended, includes:

- Increasing the visibility of the Bulgarian and respectively Serbian astronomical achievements;
- Effective use of the existing and future planned facilities and data sets in both countries;
- Enlarging the topics of the joint cooperation and experience exchange;
- Revealing the place and role of the Bulgarian and Serbian astronomy into international projects, and the strategy in development of a given project;
- Giving possibility of young scientists to present their work in the native language.

The regular biennial conferences that followed in the period 1998 - 2014 enabled to refocus the main topic - the last three conferences have been dedicated to Astroinformatics – in accordance with the existing trend in Astronomy – to develop from empirical one to theoretical, from computational one to data extraction and e-Science.

2. THE CONFERENCE ORGANIZATION

The IX BSAC: Astroinformatics was held in the period 2-4 July 2014 in Sofia, in the Institute of Mathematics and Informatics of the Bulgarian Academy of Sciences (IMI-BAS) under the auspices of BAS and Ministry of Education, Science and Technological Development of Serbia. The organizers were IMI-BAS and the Astronomical Observatory Belgrade (AOB) with co-organizers the Institute of Astronomy and National Astronomical Observatory (IA and NAO) of BAS, the Department of Astronomy of the Faculty of Physics of Sofia University (DAFPSU), the Department of Astronomy of Faculty of Mathematics to the Belgrade University (DAFMBU), as well as the Society of Astronomers of Serbia.

The Scientific Organizing Committee (SOC) was chaired by Ognyan Kounchev (IMI-BAS) and Darko Jevremovic (AOB). The SOC included also Milan S. Dimitrijevic (AOB), Milcho Tsvetkov (IA and NAO, and IMI-BAS), Luka Popovic (AOB), Zoran Simic (AOB), Žarko Mijajlovic (Mathematical Faculty, Belgrade University), Katya Tsvetkova (IMI-BAS), Vasil Popov (IA and NAO, BAS), Nikola Petrov (IA and NAO, BAS), Petko Nedialkov (DAFPSU). The Local Organizing Committee (LOC) included Ognyan Kounchev (Co-chairman) from IMI-BAS, Milcho Tsvetkov (Co-chairman) from IA and NAO and IMI-BAS, Viktoria Naumova (Secretary) from IMI-BAS, and the members Anna Sameva (IMI-BAS), Katya Tsvetkova (IMI-BAS), Svetlana Boeva (IA and NAO, BAS), Momchil Dechev (IA and NAO, BAS), Damyan Kalaglarsky (IMI-BAS).

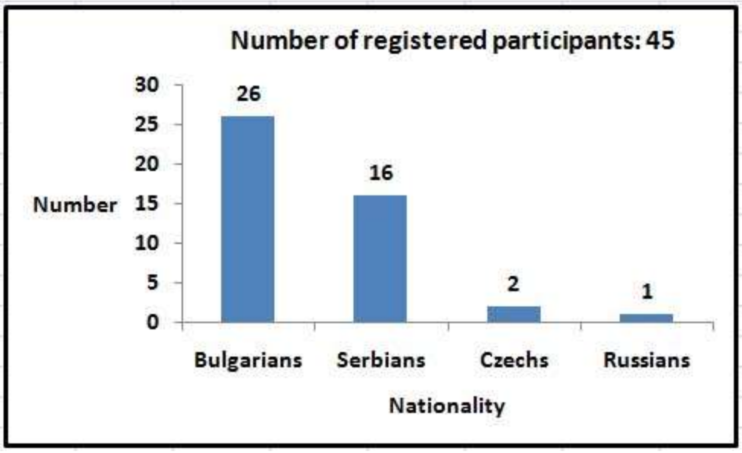

Figure 1: Distribution of the registered participants by nationality.

The total number of the registered participants was 45. The distribution of the registered participants by nationality is shown in Fig. 1. The youngest participant was 25 years old.

The official languages of the conference were announced to be English, Bulgarian and Serbian in the spirit and tradition of these conferences. But according to the distribution of the spoken languages presented in Fig. 2 from 30 oral presentations – invited lectures and contributed talks, only 6 or 20% of all were not in English. All 7 posters were presented in English. It deserves to mention two facts – the young astronomers for whom it had been supposed to use their native language spoke English; the astronomers who wanted to keep the tradition speaking Bulgarian or respectively Serbian had to overcome the inertia to speak English at other conferences.

3. BRIEF OVERVIEW OF THE SCIENTIFIC TOPICS

The main topic of the IX BSAC: Astroinformatics was Astroinformatics and that is why 4 sessions were devoted to Astroinformatics, 4 sessions were devoted to Astrophysics and to poster presentation. All abstracts and presentations of the 16 invited lectures, 14 contributed talks and 7 posters can be downloaded from the website of the IX BSAC Astroinformatics (http://wfpdb.org/ftp/9_BSACA/ Programme.html).

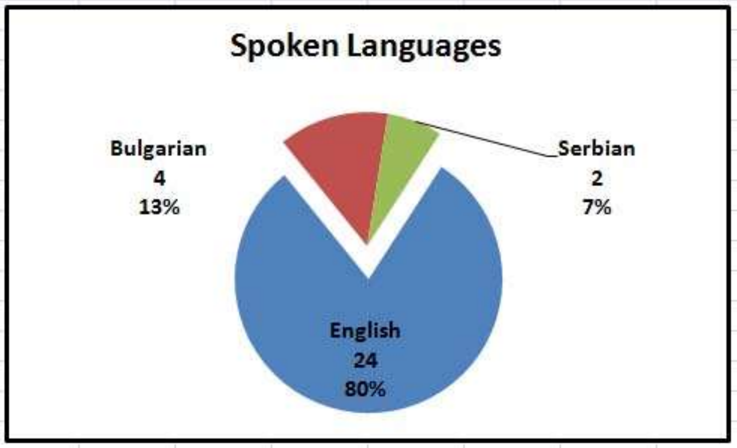

Figure 2: Distribution of the spoken languages in the IX BSAC Astroinformatics.

As conference highlight in the sense of what is done can be considered the invited lecture of D. Jevremovic *Astroinformatics in Serbia* devoted to the **development of Astroinformatics in Serbia**, and expectations in connection with the Large Synoptic Survey Telescope (LSST) project in which the Serbian astronomers participate. The Serbian Virtual Observatory (SerVO, servo.aob.rs) concept was presented with the main goals now: digitization and publishing the photographic plates from the collection of AOB and maintenance and development of the existed data bases. The STARK B database was presented by M. S. Dimitrijevic as invited lecture titled *Stark-B Database for Stark Broadening for Astrophysical Plasma Analysis and Modeling*, as well as in the contributed talks of Z.Simic et al. (*Atomic Data and Stark Broadening of Nb III)* and Z. Majlinger et al. (presented by Z. Simic) *On the Stark Broadening of Zr IV in the Spectra of DB White Dwarfs*). A special report of J. Aleksic was devoted to the Serbian contribution to the LSST project (*Alert Simulator - System for Simulating Detection of Transient Events on LSST*).

Such informative character also had the invited lecture of O. Kounchev, D. Jevremovic and D. Vinković who presented the **Cost Action TD1403 - Big Data in Sky and Earth Observations**, wherein some participants of this conference (D. Jevremovic, O. Kounchev, M. Tsvetkov, N. Kirov, J. Aleksic) were involved.

The work on the **development of Astroinformatics in Bulgaria** was presented by the invited lectures and contributed talks devoted to the main subject providing data – the Wide-Field Plate Database (WFPDB). Here can be referred the invited lecture *Wide-Field Plate Database: Software for Time and Coordinates Conversions* of N. Kirov et al. concerning the data reduction to the accepted standards, the invited lecture *Astroweb Astroinformatics Project and Comparisons of the Web-GIS Protocol Standards* of A. Kolev, contributed talks *WFPDB Upgrading Catalogue of Wide-Field Plate Archives* of D. Kalaglarsky et al. and S*ome Wavelet Processing for Scanned Astronomical Images* of V. Kolev. Here it has to be referred also the poster of O. Stanchev et al. titled *Extraction of Physical Quantities from Numerical Data Cubes by Use of the yt Package*.

The list of topics, separated according to the considered object of investigation, includes:

- **Variable stars in our Galaxy and in the Local Group of Galaxies** (invited lecture of A. Zubareva et al. *Variable Stars near B Cas Discovered on Scanned Photoplates at Sternberg Astronomical Institute*, contributed talk *UV Ceti Type Variable Stars Presented in the General Catalogue of Variable Stars* of K. Tsvetkova, and invited lecture *Structural Functions Analysis of Luminous Blue Variables in the Local Group* of G. Ganchev et al.;
- **Double stars** (contributed talk of Z. Cvetkovic et al. *Determination of Nature for Eleven Double Stars*, presented by S. Ninkovic);
- **Galaxies** – as M31 (invited lecture S*igns of Density Wave in M31 Galaxy: Luminosity, Age and Extinction Gradient across the Spiral Arm S4* of P. Nedjalkov et al., poster of N. Taneva et al. *A Search for Coherent Sites of Star Formation in M31 Galaxy*);
- **Active Galactic Nuclei** (invited lectures of D. Ilic *Use of Emission Lines Databases in AGN Research,* and A. Kovachevic *Time Series Analysis of AGNs*);
- **Quasi-Stellar Objects** (invited lecture of S. Simic et al. *Broad Spectral Line and Continuum Variabilities in QSO Spectra Induced by Microlensing: Methods of Computation*);

- **Supernova remnants** (invited lecture *Optical Detection of Supernova Remnants in the Nearby Galaxy IC342* of M. Vučetić et al. presented by D. Urošević);
- **Solar system bodies** (poster of V. Protic-Benishek et al. *Twenty Years of CCD Observations of Solar System Bodies from the Belgrade Astronomical Observatory*;
- **Solar Physics:** presented in the invited lecture *Multiwavelenght Observations of an Eruptive Prominence on 7 August 2010* of M. Dechev et al., and S. Vidojevic et al. *Simulations of an Instrumental Effect on Wind Observations*, as well as in the poster of Boris Komitov et al. *The Relation between Solar Proton Flares and the Background Concentrations of Nitric Oxides in the Troposphere*.

Theoretical Astrophysics was presented in the contributed talk of K. Yankova *Relationships in the System Corona-Disk*, as well as in the poster of D. Boneva *Fluctuations in the Flow and Development of Flare-ups in Compact Binary Stars*.

Astrometry was treated in the poster of G. Damljanović et al. *Observations at the 60 cm ASV Telescope and the Link Future Gaia CRF –ICRF*, presented the joint results of Serbian and Bulgarian astronomers. The invited lecture *Differences in Detection of D-Region Perturbations Induced by UV, X and Gamma Radiation from Outer Space Using VLF Signals* of A. Nina et al. treated an **interdisciplinary topic**. Two contributed talks were dedicated to the **legacy of famous astronomers** as Milutin Milanković (N. Pejović et al. *Milutin Milankovic Digital Legacy*) and Simon Marius (K.Tsvetkova et al. *The Mathematician and the Astronomer Simon Marius 1573 – 1624)*. The **activity of the society of astronomers of Serbia** was presented in the contributed talk of M. S. Dimitrijević *Society of Astronomers of Serbia, 2012-2014*. M. Christova presented through poster titled *On the Education in Physics and Astrophysics* her opinion about the present situation in the **education in Physics and Astrophysics**.

4. SCIENTIFIC COLLABORATIONS

Some of the presented reports and posters separated by different topics were done in the frames of certain bilateral cooperation and contain the results of them. Here we list such running projects showing the new ideas of the bilateral cooperation, enlarging the topics of the joint cooperation and experience exchange, effective usage of the technical potential - existing facilities and data sets in both countries, as well as prospects and future planned facilities.

4.1. BILATERAL ASTRONOMICAL COOPERATIONS

There are 4 running projects: ***Astroinformatics: way to future astronomy*** (IMI-BAS and AOB, with principal investigators Prof.Dr. Ognyan Kounchev and Dr. Darko Jevremovic); ***Optical search for supernova remnants and H II regions in nearby galaxies (M 81 and IC 342 groups of galaxies*** (DAFMBU and IA and NAO, BAS, with principal investigators Dr. Nikola Petrov and Dr. Dejan

Urosevic); ***Observations of ICRF (International Celestial Reference Frame) radio-sources visible in optical domain*** (IA and NAO, BAS and AOB with principal investigators Dr. Svetlana Boeva and Dr. Goran Damljanovic); and ***Investigation of visual double and multiple stars*** (IA and NAO, BAS and AOB with principal investigators Dr. Svetlana Boeva and Dr. Zorica Cvetkovic).

4.2. OTHER INTERNATIONAL PROJECTS

The results reported in the invited lectures by D. Jevremović (***Astroinformatics in Serbia***), D. Jevremović and O. Kounchev (***COST Action TD1403 Big Data Era in Sky and Earth Observations, 2014 – 2018***), C. Ron et al. (***Atmospheric, Oceanic and Geomagnetic Excitation of Nutation***), Y. Chapanov et al. **(*Rotation Excited by Insolation Variations Due to Orbital Harmonics*)**, and M. S. Dimitrijevic et al. (***Stark-B Database for Stark Broadening for Astrophysical Plasma Analysis and Modelling*),** as well as in the contributed talk of C. Yubero et al. ***A Method for Electron Density Measurement in Non-Thermal Plasmas from Optical Emission Spectroscopy*** (presented by M. S. Dimitrijevic), were received in the frames of other projects showing well the European integration of Bulgarian and Serbian astronomy.

5. SOME PROBLEMS

Some problems deserve to be mentioned here because they are problems not especially for this conference but they refer to science in general.

5.1. USED ABBREVIATIONS AND ACRONYMS

The problem of the used abbreviations and acronyms is a general problem in our fast-paced world. Very often one and the same abbreviation or acronym is used for different things and in different areas. One example from http://slang.org/ shows that "MTR" as abbreviation or as acronym is applicable for many things including the following: Metro (mtr); Meter (mtr); Meteor (mtr); Motor (mtr); Mountain Top Removal (MTR); Mass Transit Railway (MTR); Ministry of Tourism (MTR); Montreal (MTR), etc. In such cases one has to obey the relevant constraints of the communicative situation, i.e. the context. Otherwise the solution may be in AAAAA, which stands for American Association Against Acronym Abuse. The same is valid for the abbreviations and acronyms used in Astronomy. During this astronomical conference the usage of such acronyms as HPC (High-Performance Computing) or CEP (Complex Event Processing) out of the context has leaded to difficulties to follow the author's thought especially for astronomers who are not so familiar with computer terminology. The acronym BLR (standing for Broad Line Region) is very common for spectroscopists, but has to be used with attention to wider auditory.

5.2. TRANSLATIONS OF ENGLISH TERMINOLOGY

To speak in your native language during your first astronomical conferences, which you attend, is a good educational initiative. But it contains also a threat of inadequate translation of common astronomical terms. Some examples from this conference confirm this possibility. A Bulgarian speaker (even experienced one) translated the term *Passband* as *Lenta na propuskane* in Bulgarian instead of the better one *Ivitsa na propuskane*. A Serbian speaker had difficulty in finding the equivalent of the term *Cut off* in Serbian. It is a general problem - sometimes the translation of the word is not accepted because it is literal, while the adoption of foreign words retains the nuances in its use. Such is the case of the astronomical term *Bremsstrahlung*, which has a German origin, but continues to be used in the English astronomical terminology. Another quite recent example from our everyday life is the word *Selfie,* prepared for inclusion in the online version of the Oxford English Dictionary in 2013. *Selfie* will enter into a new version of the Dictionary of the Bulgarian language in 2014.

The problem of inadequate translation of common astronomical terms in Serbian language is about to be solved by the new ADICT – English-Serbian Astronomical Dictionary, prepared as a collaboration of astronomer and philologist (B. Arbutina and D. Momic, see these Proceedings).

6. ASTRONOMY/ASTRONOMER AND ART

The cartoons of Sydney Harris, distinctive with insight and humor, are on many scientific subjects, including astronomy too. During the conference the speakers used twice his cartoons:

- Darko Jevremovic illustrated his presentation *Astroinformatics in Serbia* with the cartoon *Astronomers at work,* where the boss is saying to three astronomers “Let’s dispel some common beliefs”. The first astronomer says “I never use a telescope”. The second adds “I never go near a telescope.” The third finishes “I never even look up.”
- Zoran Simic illustrated the situation in cosmology with his T-shirt with the cartoon *Cosmology marches on,* consisting of two pictures - in the first picture the caveman looking at the stars says “Where did it all come from?”In the second picture the modern astronomer, sitting in the office, again puts the same question “Where did it all come from?”

During the conference the astronomer and poet Petko Nedjalkov spread his Bulgarian translation of one of the most favorite hit songs of the singer Miroslav Ilic in Serbia “Voleo sam devojku iz grada” with text by Dobrica Eric and music by Obren Pjevovic.

7. CONCLUSIONS

The IX Bulgarian-Serbian Astronomical Conference Astroinformatics showed that despite of the limited size of the conference and respectively of the number of Bulgarian and Serbian astronomers and astroinformaticians the topics discussed cover completely the area of Astroinformatics developed in Bulgaria and Serbia, as well as they give good imagination for astronomy in the both countries. For the period of 16 years the progress made in achieving the conference goals is significant – full knowledge about the Bulgarian and respectively Serbian astronomical achievements; joint use of the 2m Ritchey-Chretien-Coude telescope at Rozhen Observatory, as well as the 60cm telescope of the Astronomical Station Vidojevica of the Belgrade Astronomical Observatory; shared information for integration into international projects; developed collaboration in the area of Astroinformatics.

All conference proceedings, including the last ones, are done in the context of improving the visibility of our astronomical achievements after reviewing by SOC and the editorial board. The number of pages has been never strictly limited. Since 2012 the conference proceedings are indexed by the largest abstract and citation database of peer-reviewed scientific journals, books and conference proceedings – Scopus. What concerns the prospects of the future bilateral conferences – the next SBAC will take place in Serbia in 2016. The future BSAC will be held in 2018 in Varna (Bulgaria).

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DETECTION OF TERRESTRIAL IONOSPHERIC PERTURBATIONS CAUSED BY DIFFERENT ASTROPHYSICAL PHENOMENA

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Abstract. In this paper, we present our results of investigation of perturbations in the ionospheric D-region caused by different astrophysical phenomena. We considered induced time variations of electron density during solar X-flares, generation of gravity and acoustic waves by solar terminator, and possibility of gamma ray burst detection by very low frequency (VLF) radio signals. The studies are performed through analyses of data bases related to VLF radio signals recorded in real time by the receiver located in Belgrade that are being emitted by worldwide distributed transmitters.

1. INTRODUCTION

In addition to a purely scientific interest, studying the effects of specific ionospheric plasma perturbers finds practical applications, primarily in telecommunications. Namely, changes in the signal characteristics caused by varying ionospheric plasma conditions, require perutbation predictions in order to deal with disturbances in signal reception.

This dissertation presents results of studying the ionospheric D-region plasma based on continuous, simultaneous registration of very low frequency (VLF) electromagnetic waves being emitted by transmitters distributed worldwide and recorded by the AWESOME (Atmospheric Weather Electromagnetic System for Observation Modeling and Education) receiver located at the Institute of Physics in Belgrade from 2008.

The investigations are done in three different fields related to calculations of plasma parameters, detection of hydrodynamic (HD) waves and investigation of possibility to detect events that weakly perturb the considered plasmas by using VLF receivers. We developed theoretical and numerical procedures which are based on recorded experimental data and Long-Wave Propagation Capability (LWPC) numerical model for simulation of VLF signal propagation (Ferguson 1998).

2. MOTIVATION

The motives for making this study were:

1. The analysis of the obtained data base which enables perennial continuous monitoring of both periodical and non-periodical disturbances of the D-region plasma induced by numerous processes in space and in various parts of the Earth.

2. Investigation of possibility to detect events that weakly perturb the considered plasmas by means of the experimental setup used in the dissertation.

3. EXPERIMENTAL SETUP

In our investigations we monitor the low ionosphere by VLF AWESOME receiver which is located in Institute of Physics and has been operating since 2008. The performed study utilizes signals emitted at different fixed frequencies from transmitters in Germany, Italy, UK, Island, USA, and Australia. The relevant characteristics are given in Table 1.

Table 1: Transmitter characteristics and path length of analyzed VLF/LF signals. The data for transmitters are found in the file AWESOME Transmitters.pdf on `http://nova.stanford.edu/~vlf/IHY_Test/TechDocs/`.

SIGN	LOCATION	FREQUENCY (kHz)	POWER (kW)	LENGTH (km)
DHO	Rhauderfehn Germany	23.4	800	1304
GQD	Anthorn UK	22.1	200	1935
ICV	Isola di Tavolara Italy	20.27	20	976
NRK	Grindavik Island	37.5	800	3230
NAA	Cutler Maine, USA	24.0	1000	6548
NWC	North West Cape Australia	19.8	1000	11974

4. THEORETICAL PROCEDURES

As said in Introduction, the investigations presented in PhD thesis are done in three research fields related to plasma parameters, hydrodynamic waves and detections of weak ionospheric perturbations. In all cases we developed numerical and theoretical procedures which are later applied to particular influences of astrophysical events or to statistical analyses based on registration of perturbations during periods of radiation impacts from events occurring in outer space.

Plasma parameters. Space-time variations of the electron density are obtained by comparisons of recorded signal amplitudes and phases with those simulated by the LWPC numerical model (Ferguson 1998). They are further used in a theoretical model of plasma in the relaxation period that is developed in this study. The obtained final results for a given model yield space-time distributions of electron gain and loss rates, and the coefficient for the effective electron loss process. The resulting time-dependencies converge to values typical of the unperturbed plasma at considered locations which, consequently, reveals their spatial distribution in the unperturbed D-region plasma.

HD waves. One of the consequences of a large radiation impact in the ionosphere is induction of HD waves. The properties of these waves induced by astrophysical phenomena are studied in literature. However, all these studies deal with altitudes above the D-region which was the motivation for us to include the D-region medium into consideration.

The goal of this theoretical procedure is finding oscillation frequencies of waves which are excited in time intervals after the considered perturbation process took place and compare them with the situation during time periods before the occurrence of the perturbation. To extract the influence of the considered phenomenon we introduce two additional criteria: attenuations of excited waves in time, and repeating relevant excitations and attenuations in many cases, e.g. finding a statistical proof for the obtained wave periods. The developed procedures are based on Fourier analysis of signal amplitudes registered in real time. Visualizations of excitations and attenuations were obtained by calculations ratios of Fourier amplitudes related to the corresponding two domains.

Detectability of weak perturbations. The ionosphere is under permanent variable influences of different phenomena. Because of that detections of particular events which weakly ionize plasma are not reliable. In this PhD thesis, we developed a statistical procedure to examine the possibilities to detect the influence of phenomena based on analysis of many events.

5. RESULTS

The mentioned procedures are applied in calculations of plasma parameters in the case of solar X-flare as perturber, determination of HD waves induced by solar terminator (ST) and detectability of weak ionospheric perturbations induced by γ ray bursts (GRBs) registered by the SWIFT satellite.

Plasma parameters. The investigations in this field are published in four papers in international journals: Nina et al. 2011,2012a,2012b and Nina & Čadež 2014. Here, we show a typical time evolutions of electron density N which are calculated from the recorded signal amplitude and phase variations and the LWPC numerical program for

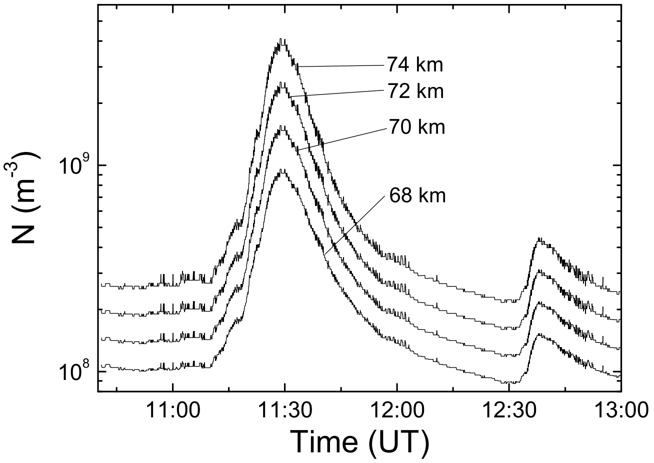

Figure 1: Time evolution of electron density during solar flares occurred on April 22nd, 2011 (Nina et al. 2011).

simulation of VLF signal propagation (Fig. 1). As an example of application of the developed theoretical procedure, we calculated the altitude distributions of electron gain rate $\mathcal{G}_{Ly\alpha}$ induced by Lyα radiation from the Sun (Fig. 2). All obtained results are in a good agreement with those in literature.

HD waves. The developed theoretical procedure for detection of HD waves are applied to events of sunrise and sunset during five days. The major conclusion of this study (Nina & Čadež 2013a) is that existence of such waves in the low ionosphere was proven for the first time. The obtained wave periods are within time domains 60 s - 100 s, 300 s - 400 s and 1000 s - 3000 s. The calculations of propagation characteristics of acoustic and gravity waves in conditions relevant to the low ionospheric medium show that the waves in the first time domain of waveperiods are acoustic waves, while the other two cases are related to gravity waves.

Detectability of weak perturbations. The obtained procedure for detection of weak low ionospheric perturbations is applied to the influence of γ-ray bursts. In addition to the observation of summary results for the entire sample of 54 registered events, this influence is considered to take into account the characteristics of the observed γ-ray bursts, characteristics of the ionosphere during the periods of their impacts and directions of rays impacts relative to the trajectory of the observed signal (Nina et al. 2013b, Nina et al. paper in preparation). The results prove the possibility of detection of low ionosphere perturbations induced by γ-ray bursts.

6. CONCLUSIONS

The main issues resulting from the dissertation are as follows:

1. Development of procedure for a continuous monitoring the electron density variations in the ionospheric D-region during a particular perturbation.

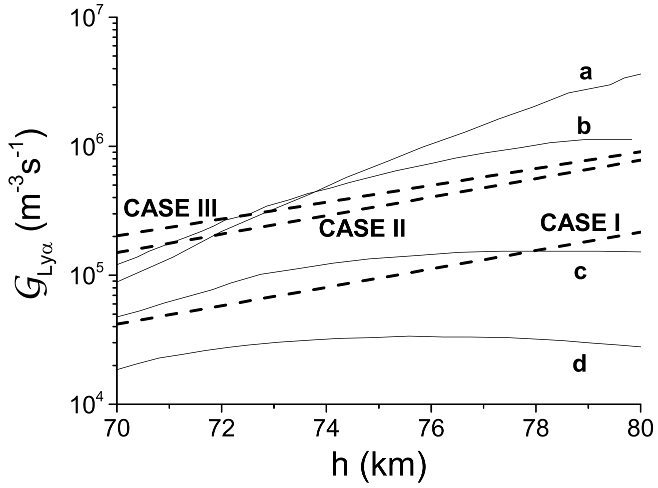

Figure 2: Altitude dependencies of the electron gain rate $\mathcal{G}_{Ly\alpha}$ for Case I, II and III related to flares occurred on May 5th, 2010, February 18th, 2011, and March 24th, 2011 analyzed in Nina and Čadež 2014, and their comparison with data presented in papers cited in Nina and Čadež 2014.

2. Development of procedure for determining the electron gain and loss rates, and the coefficient related to the electron effective loss in a unperturbed D-region from consequences of intense perturbations such as solar X-flares, for example.
3. Development of procedure for detection of hydrodynamic waves.
4. Detection of linear hydrodynamic waves in the D-region during the sunset and sunrise.
5. Development of procedure for detection of weak low ionospheric perturbations.
6. Proof of detectability of short living changes in electron density induced by γ-ray bursts.

All the developed procedures are universal in a sense that they are relevant to different perturbers and to different signals. Also, the procedures for detections of hydrodynamic waves and their detectability can be applied for studies in other fields.

In addition to the significance of these results it is important to emphasize that the registered data refer to specific parts of the D-region which are determined by locations of the considered transmitters and our receiver. For this reason, the corresponding data analysis provides an original contribution to the international studies of the ionosphere which, in addition to the scientific importance in astrophysics and geophysics, has also practical applications, for example in telecommunications.

Acknowledgment

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POSSIBLE EXOMOONS AS TARGETS FOR SETI

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Abstract. Using data from Planetary Habitability Labaratory Exoplanet Catalogue we find exoplanets possible to have big enough satellites to host life. We sugest radio astronomy based methods to search for life on a possible exomons.

1. INTRODUCTION

One of the leading models describing planetary satellites formation comes from a series of papers developed by (Canup & Ward 2006) and it is known as the actively supplied gaseous accretion disk model. Dust grains within a circumplanetary disk stick and grow to form satellitesimals, which then migrate via type I migration. Continuous mass-infall from the protoplanetary disk maintains a peak circumplanetary disk density of approximately 100 gcm^{-2}, allowing new satellitesimals to continuously grow. Once the planet has opened up a gap in the protoplanetary disk, the active supply halts and the circumplanetary disk rapidly diffuses in 10^3 yrs, thus freezing the remaining satellites in place.

The mass fraction of satellite system is regulated to approximately 10^{-4} M_P, where M_P is mass of planet (Canup & Ward 2006), by a balance of two competing processes: the supply of in owing material to the satellites, and satellite loss through orbital decay driven by the gas. An alternative model is the solids enhanced minimum mass model (see e.g. Masqueira & Estrada 2003). In this model a much longer satellite migration timescale is present than the associated formation timescale. The model only qualitatively describes the expected mass ratios, unlike the actively supplied disk accretion.

1. 1. SELECTION OF DATA AND METHOD OF ANALYSIS

Most of the detected exoplanets are gas giants, many of which are in the habitable zone. These gas giants cannot support life, but it is believed that the exomoons orbiting these planets could still be habitable. In our analysis, assuming that scaling law (Canup & Ward 2006) observed in the solar system also applies for extrasolar super-Jupiters (Heller & Pudritz 2014), we used planet's data from Planetary Habitability Laboratory Exoplanets orbital catalog and we selected only planets in the habitable zones more massive than Jupiter. They are presented in Table 1. We can see that

Table 1: Possible exomoons

Planet Name	*Mass*	*Star type*	*Distance*	*Satellite mass*
HD 10697 b	6.38 M_J	G star	106 ly	0.20 $M_\oplus$
HD 28185 b	5.7 M_J	F star	138 ly	0.18 $M_\oplus$
HD 23596 b	8.1 M_J	F star	169 ly	0.25 $M_\oplus$
HD 13908 c	5.13 M_J	F star	232 ly	0.16 $M_\oplus$
ups And d	10.19 M_J	F star	44 ly	0.32 $M_\oplus$
Kepler 419 c	7.19 M_J	Fstar	-	0.22 $M_\oplus$

selected planets orbit F and G stars. Maximum masses of possible satellites are all bigger than Mars mass.

Since we could not find exomoons with existing optical astronomy methods at least 10 years from present (Kipping 2014) we suggest to search for exomoons around these planets with radio astronomy based methods (see e.g. Noyola et all 2014) or SERENDIP (see e.g. SERENDIP) for extraterrestrial intelligence on possible exomoons.

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Planetary Habitability Laboratory http://phl.upr.edu/projects/habitable-exoplanets-catalog/catalog

SERENDIP seti.berkeley.edu/serendip/

Publ. AOB No. 94 DAS No.1 DepAstro No.21 (2016), 320 – 321 *Poster*

DESIGN OF A SAFE AND COMFORTABLE UNDERGROUND LUNAR HABITAT

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Abstract. Permanent human settlements on the Moon, and Mars, should be, not in small, flimsy modules with a rocket underneath, standing on four legs on wild and rocky terrain, exposed to all the perils; rather, they should be in a large system of tunnels, built by our self-replicating, remote-controlled robots over a long period of time, so that the inhabitants are protected by at least 200 m of solid rock from radiation, micrometeorites, extremes of temperature, vacuum, etc., and supplied by plentiful local production of air, water, food, fuel, energy, medical supplies, and thousands of other products needed for normal life, plus the centrifugal installations to compensate for insufficient gravity.

It would be irresponsible and inhumane to send human beings again to land dramatically, as Apollo 11 did, on wild and rocky terrain, and then expect them to live for many years in a flimsy, small, kiosk-like module, practically a tin-can standing on four legs, on the surface, exposed to micrometeorites, radiation, extreme changes of temperature, threatened by vacuum from all directions, with only a thin metal wall for protection, without even a bathroom, and without their own production of food, water, air, and many other necessities, all of which would have to be brought from Earth, always with much uncertainty, and at a terrible cost per ton.

Human beings can settle to live permanently on the Moon (and, equally, on Mars) only when a large landing zone is cleared and well marked, and when a large system of tunnels is built, so that people and equipment are protected by at least 200 meters of solid rock above and around them. These tunnels must be built, and industrially developed, by our remote-controlled machinery – the “robots”, carefully controlled, with programs extremely strongly encrypted against hacking by terrorists and fools, because, even on the Moon and Mars, the greatest danger to people will be other people.

Our first few, small robots must take temporary shelter in a natural cave, and begin to self-replicate, on Von Neumann principle – build many more copies of themselves, from local raw materials, and then much heavier machinery. Then they must build (however long it may take; perhaps hundreds of years) an appropriate underground habitat for people, with many kilometers of storage spaces, apartments (with normal bathrooms! kitchens, washing of laundry, etc.), garages, rescue ships, reservoirs of air and water, and with production of food, clothing, and many other items for normal living, and with large-diameter centrifugal devices for the human residents to compensate for weak lunar gravity, with rescue exits, a large medical facility, anti-epidemic security doors, and other necessities.

But the picture part of our presentation today is about the entrances. A thick, heavy gate is the first thought, but it would be a poor protection against a meteorite, with a mass of, let's say, 1 kg, zipping in at 30 km/sec. It could smash right through the airlock. So, we propose that the entrance should be inside a natural rift, between two hills, perhaps (ideally) in a deep canyon, with two cliffs, facing each other; so, a whole hill or a mountain would protect the entrance from a direct entry of a meteorite. But in the unlucky case of the explosion of a meteorite, or a falling spacecraft, exactly in front of the entrance, there should be about 100 m of straight, empty tunnel, with nothing in it; coming to a dead stop, a "blind alley", in a wall of rock.

After the first 50 meters, a second tunnel should go off, to one side, at a 90° angle, for a distance, perhaps also 50 m, then, one more turn (forward) at a 90° angle, and, 150 m farther, the gate; the real entrance.

If this looks like a small, defensive labyrinth – it is.

So, any kind of incoming hostile material would, probably, hurl itself straight through the vacuum of the primary tunnel, and into the solid mass of the hill (or mountain); and spend most of its force there, harmlessly. Only after two 90-degree turns, deep inside the mountain, would be the armoured gate, and the first airlock. That is our proposal.

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USE OF COMPLEX EVENT PROCESSING ENGINES IN TIME DOMAIN ASTRONOMY

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Abstract. The expansion of volume and complexity of events that need to be processed in high-growth industries (such as finance, telecommunications, banking, medicine) created the need for new paradigms and tools. CEP engines offer scalability which cannot be easily achieved through previous standard practices, loose coupling between event processing logic and the mainstream application code, and decoupling between event producers and consumers. In this document, basic concepts of CEP are introduced and it is discussed how they could be utilized in astronomical contexts.

1. INTRODUCTION

Large, deep and fast sky surveys of the future, such as LSST, will detect significant amount of near-real time transient astronomical events. In case of LSST, it is estimated that every visit will produce ∼2.000 alerts on average (up to 40.000), which sums up to ∼2 million alerts per night[1]. Software which will be handling these alerts will have to be able to act like a human expert, on a scale that is impossible for a human to ingest; it will need to know how to classify and discover, to dispatch and "ask for a second opinion", all in efficient and scalable manner. On top of that, a scientist should be able to describe inference mechanisms using a language with high level of abstraction. There are several CEP open-source solutions which could potentially be tailored to satisfy astronomical needs.

2. MECHANISMS OF EVENT PROCESSING

2. 1. FROM SIMPLE TO COMPLEX EVENTS

In an event-driven system, such as health monitoring, algoritmic trading, banking fraud detection or sky survey, we define a simple event as a *discrete incidence inside of a domain that system is capable of detecting.* After an image of the portion of the sky has been captured through the lens, data has been read from the CCD, image has been compared to a template image, astrometric and photometric properties have been calculated, we end up with a bunch of simple events: instances of astronomical objects in a particular moment of time which are either *1)* new to us *2)* known but have changed their properties significantly enough. Such simple events might be just false positives or a sign that something important is going on.

By putting related simple events into a common context and by applying pattern matching mechanisms we might eventually come to a conclusion that something important *has* happened. We call such a notable occurence a complex event: *an event that summarizes, represents or denotes a set of other events*[2].

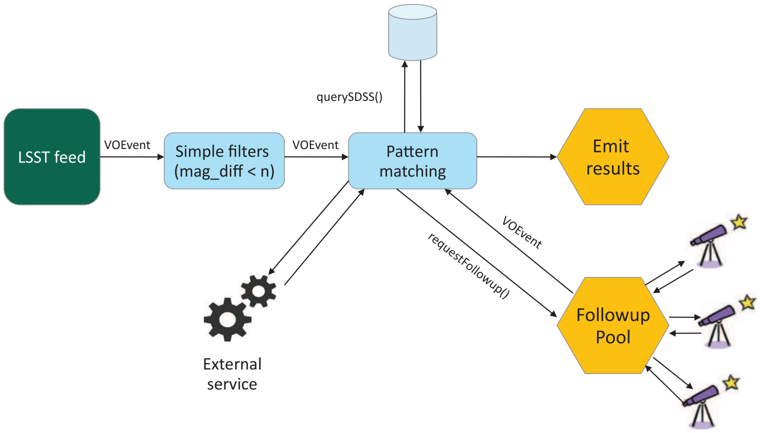

Figure 1: A simplified event processing network for a sky survey feed.

2. 2. EVENT PROCESSING LOGIC

An event processing agent (EPA) should be able to apply inference mechanism and temporal reasoning in order to give a high-quality conclusion whether a complex events has happened. Event processing includes concepts such as[3]:

- Sliding windows based on time or number of events.
- Applying spatial, spatiotemporal, segmentation or state oriented context.
- Filtering, transformation (splitting, aggregating, projecting, translating...) and pattern detection
- Enriching events from external service/db.

In a typical scenario, an interesting simple event would trigger EPA to open a temporal window, i.e to “wait” for the next event which pertains to the same astronomical object. Depending on the inference rules, EPA could apply aggregation function or statistical knowledge on a number of events related by context.

2. 3. BUILDING AN EVENT PROCESSING NETWORK

As shown on Figure 1, an event processing network may look like this: LSST feed is emitting simple events (in form of VOEvent XML objects) which are pulled through simple filtering agent which output a subset of interest; another agent applies pattern matching, and may consult historical data (e.g SDSS database), external classification engine or ask a followup pool if there are available telescopes; after a conclusion, complex event is dispatched to a channel which emits results to subscribers.

3. CURRENT STATUS OF TECHNOLOGY

3. 1. VOEVENT COMMUNITY

A significant amount of work has been done in VOEvent community. IVOA defined a standardized XML message structure for exchanging information about transient events - VOEvent[4]. Although XML is transport-agnostic, there is a TCP-based transport protocol for transmitting VOEvents - VTP[5] which supports concepts such as node roles. Dakota and Comet are VCP implementations available for free use, along with Skyalert - event stream collector, filter and distributor. There is a number of events streams available for subscription [6].

3. 2. OPEN SOURCE CEP

There is several open source CEP engines on the market which implement (subsets of) concepts of event processing stated earlier. Esper and WSO2 Siddhi implement SQL-based language (select... from... where...) while JBoss Drools works on top of a rule-base engine (when... then...). The market is dynamic with lots of merges and acquisitions from larger, commercial brands. Esper was used in internal monitoring and analysis for ATLAS experiment at CERN[7].

4. CONCLUSIONS

VOEvent community needs a tool which will be able to handle events from heterogenous and dynamic environment on a much larger scale than today. Skyalert has plenty of concepts implemented (multiple input streams, event portfolios, filtering, custom trigger funcions...) but lacks support for temporal reasoning (sliding windows) and doesn't scale well. XML format for VOEvent might be outdated, with substantial overhead and signing issues.

Open source CEP solutions claim to handle millions of events per second on single server with commodity hardware. Analyzing syntatic capabilities of Esper and Drools, we came to the conclusion that Esper offers stronger support for sliding windows and pattern matching by aggregation of attributes.

First step will be to build a prototype based on Esper which would plug-in to existing event streams and LSST alert simulator. This prototype should ingest events at realistic rates to test scalability and capabilities of declarative language syntax for scientific use. Further reasearch will include “factories” of CEP engines where a researcher could build her/his own engine using DSL statements at even higher domain-specific level of abstraction.

Acknowledgments

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ASTRONOMY AND MYTHOLOGY

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Abstract. The sky fascinated prehistoric man from the time immemorial. Our ancestors used to read heavenly messages according to their needs and fancy. At the same time they projected many earthly events and objects onto the celestial sphere. We shall discuss a number of general points regarding the link of mythological narratives with the heavenly constellations. We pay particular attention to three interesting mythological narratives, which happen all three to be linked with Egypt, one from the Jewish Bible and two from the Greek tradition. We show that the famous episode with Joseph and pharaoh's dream was inspired by the Egyptian interpretation of the specific significance of Pleiades constellation as the time marker. We briefly present the case of Berenice's hair and finally sketch an astronomical interpretation of Plato's famous myth on Atlantis.

1. INTRODUCTION

Sky appears a very special object of human experience. It is available to human perception for half of a human's life, yet it is literary untouchable. Unlike other earthly objects and events, which are accessible to a number of different sensory experience, like visual and acoustic, we are passive observers of the heavenly objects and events. It leaves much space to our imagination when attempting to compensate the lack of complete inference into the heavenly matters.

Sky offers to our eyes a number of types of celestial objects, like:

(0) Sun and Moon (i) fixed stars (celestial sphere(s)) (ii) irregular periodic motion (planets) (iii) very rare periodic appearances (comets) (iv) periodically changing brightness (Algol) (v) sudden appearance of bright stars (novae,supernovae) (vi) unpredictable atmospheric events (meteorits/falling stars).

Each of these types inspires our imagination, for various reasons, which might be: (i) curiosity (ii) explanatory needs (like Berenice's hair) (iii) predictive power (iv) religious tool (v) cosmological interest (vi) descriptive presentation (mythology) (vii) allegorical inspiration (Atlantis).

These interpretations appear common to all cultures on the globe, prehistoric and historic alike. They may differ from the society to the society, but in many cases one can discern particular pattern common to a number of cultures, as the case of Milky Way illustrates. Many of these pattern belong to the so-called mythemas, specific ready made constructs, which can be found in many mythologies, fairly tales etc. We shall start with one of these mythemas, as found in the Jewish Bible (Old Testament in the Christian tradition).

2. HEAVENLY BOOK

As pointed out by Galileo, who stated that Nature is a book whose language is mathematics, the sky is an open book which can be red by applying a proper exegesis, i.e. by trying to decode the message which gods or like have written across the celestial sphere. We start with the famous episode from biblical narrative as written in the book of Exodus.

2. 1. PHARAOH'S DREAM

Here is what pharaoh told Joseph he dreamt: (see, e.g. Hertz 1967):

In my dream I stood upon the brink of the river. 18. And behold, there came up out of the river seven kine, fat-flashed and well-favoured; and they fed in the reed-grass. 19. And, behold, seven other kine came up after them, poor and very ill-favoured and lean-flashed, such as I never saw in all the land of Egypt for badness. 20. And the lean and ill-favoured kine did eat up the first seven fat kine. 21. And when they had eaten them up, it could not be known that they have eaten them; but they were still ill-favoured as at the beginning. So I awoke. 22. And I saw in my dream, and behold seven ears came up upon one stalk, full and good. 23. And behold seven ears, withered, thin, and blasted with the east wind, sprung up after them. 24. And the thin ears swallowed up the seven good ears.

How did this narrative arise and what might be the inspiration for this mythema, we meet again in the similar episode in the Book of Daniel? We start with physical geography of the northern African continent, specifically with the region we call today Sahara.

2. 2. ANIMAL VENERATION

Geologists have for a long time estimated that Sahara was not always desert and climate changes have been taking place periodically. Recent investigations have revealed that for about 8.000 years Sahara was not arid, but green area, inhabited by nomadic people, who lived on hunting wild animals and domesticated cattle. Investigations of the area of Nabta Playa region, west from the present day Abu Simbel, show that about 5.500 BC nomadic people from the Eastern Sahara region settled there and subsequently mixed with Nile indigenous populations. Generally, Sahara desiccation ceased around 10.000 BC and there is evidence that the area was populated by people whose social structure was superior to their Nile Valley counterpart.

As the green areas started withdrawing before the advancing sand, population moved toward the Nile and began mixing with indigenous Egyptians. (Brass 2002). As hunters, Sahara population venerated animals, wild and domesticated alike. Kine played particular prominent role within their Pantheon, for obvious reasons. They provided almost everything they needed, from milk, meat, skin, horns to hoofs. Even dropping as fuel, since Nile valley was lacking woods. By mixing people it was inevitable that the resulting population, which will give rise to one of the most advanced civilization of the time, would meld two pantheons, animal based of the Sahara incomers and anthropomorphic of the Nile agricultural inhabitants. In this way hybrid divinities, with human bodies and animal heads populated Egyptian pantheon, as we

Figure 1: Anubis, god of the afterlife and mummification, with head of jackal.

know today. One of the best known example is that of the god Anubis, see Figure 1, with human body and jackal head.

As a reminiscence of this Egyptian tradition, many gods used to be represented with horns, even in the Greek pantheon, like Alexander's effigy with ram's horns on coins. Even Michelangelo could not resist putting bull's horns on Moses' head in his famous sculpture in Rome, although he was aware of the apocryphal interpretation of this biblical narrative..

2. 3. THE ROLE OF PLEIADES

The Pleiades (Seven sisters) is thought to be about 410 l.y. away from us. The cluster is around 76 million years old. This prominent open cluster, which contains about 300 stars, appears part of many myths around the globe, like Egyptian and Greek

The myth tells us they are daughters of Atlas and Pleione, who were pursued by Orion, but they were rescued by Zeus, who lifted them into Heaven. Merope married mortal Sisyphus and that's why her star is barely visible within the constellation.

Due to a high visibility, these stars gained a special place in many ancient cultures. They are winter stars in the Northern Hemisphere and summer stars in the Southern Hemisphere. These stars were known since the old times, by many cultures all around the world, including the Maori and Australian Aborigines, Chinese, Maya and Aztec and the Native people of North America. The Pleiades are particularly important in Hindu mythology as the six wives of the six sages. The number is not fixed but changing in the myths between six and seven. As Sparavigna emphasizes (Sparavigna 2008), representations of these stars in the local mythologies are different, but a rather common element is their female nature. For instance, in one of the Maori traditions, Matariki, the Maori name for the cluster of stars, is a mother with her six daughters.

Figure 2: Pleiades.

The Sioux of North America had a legend linking the origin of Pleiades to the Devil's Tower. The stars were seven women, pursued by a bear. They prayed the gods, who raised the ground where they were located high into the air, to save them from the bear. The maidens then turned into stars.

The Greek mythology

This narrative strikingly resembles that of Greek mythology. In the Greek myths, several of Olympian gods were engaged with the seven heavenly sisters. Merope, the youngest of the seven Pleiades, married Sisyphus and, becoming thus mortal, faded away: this is how the myth explains why in the Pleiades star cluster only six of the stars shine brightly and the seventh, Merope, appears faint. As Graves (1966) emphasizes it was wrong to consider they virgins, for all of them married with gods, except Merope.

The Pleiades start to shine over the horizon and set in the West, during October/November, the proper time of the year in Mediterranean area, to plough and sow the land.

The Egyptian religion

The ancient Egyptians divided their calendar into three principal seasons. The first of them was the inundation season. This was the time of the Egyptian calendar year when the Nile waters flooded the farmland. The last month of this season is Ahtyr: this name is a variant of Hathor, the goddess guardian of the tombs. At Plutarch's time, Athyr month was coincident with October/November. Known today by the Greek name, Hathor is the Egyptian patroness of lovers, the goddess of the

Figure 3: The goddess Hathor with horns and Sun disk.

sky, the protector of women and children, and beloved of both the living and the dead (Fig.3). Earliest references of this goddess date back to the second dynasty. In art, she was often depicted with just the head or the whole body of a cow, the Heavenly Cow. Worshipped at the city of the dead, at Thebes, she became the Goddess of the Dead.

To Egyptians Hathor, in her form as the celestial cow, provided the sustenance and in earlier myths she was responsible for the raising of the Sun to the sky with her horns (see Figure 3). The name Hathor means the "house of Horus" in the zodiac (the Heavenly Cow). During the Old Kingdom she assumed the properties of an earlier bovine goddess, Bat. She is also worshipped in the form of "Seven Hathors": these seven goddesses are the Pleiades shining in the sky, usually represented by seven cows, often associated with a bull, as a heaven herd providing the nourishment, bread and beer in the Underworld. We find again the Taurus, with Aldebaran its main red star, as one of the most ancient group of stars viewed as a constellation, also in Egyptian area. As the Seven Hathors, she was the goddess often present at birth.

What is the most significant to our subject Hathor was able to foretell the future, and that she was connected with the Nile inundation and the abundance of the grain harvest. The Seven Hathors of the Celestial Herd were named in a spell of the Book of the Dead and these names are: the "Lady of the Universe", the "Skystorm", "The hidden one, presiding over her place", "You, from Khemmis", the "Redhair", the "Bright Red" and "Your Name prevails over the West" (Sparavigna 2008). Often accompanied by Osiris/Apis, Bull of the West, and the oars representing the four cardinal points, in the vignettes enclosed to the text in the "Book of the Dead", the seven cows and the bull are depicted in front of the offering tables of worshippers.

2. 4. THE JOSEPH'S EXPLOIT

Among other features, Jewish Bible appears a collection of various narratives from other mythologies, fairy tales etc. Many of these borrowing are more or less well disguised and it takes a scrutinized effort to trace the origin of particular themes.

The case with Joseph and pharaoh's dream appears particularly interesting

It does not require particularly profound insight to see that the whole story is a paradigm o fairy tale. But it nevertheless still begs for an explanation of the specific setup we meet in this biblical episode. The principal question arises, as to how it happened that the link with the Egyptian religious beliefs was passed unnoticed. For once we read about the role of Hathor and Seven Cows, it becomes immediately clear that the ancient Egyptian representation of the Pleiades was instrumental in coining the biblical story.

We have to answer a number of questions. First: how it happened, if we believe in the veracity of the biblical story, that the very pharaoh, who must surely have been well acquainted with the role of Hathor, did not decode his own dream? In particular, in view that the allegory, well exposed by the second dream with her, was more than telling?

The puzzle points towards a convincing explanation. But before we attempt to provide it, a few words about Egypt and its influence on the neighboring nations seems in order.

Egyptian civilization was by far the most ancient in the region preceding by two millennia all its surrounding civilizations, including Greek one. It had very strong connections with neighboring people, first of all as a rich county, providing, among other things, the most important good - wheat, which has always been in the foundation of civilization as such. Its scientific and religious wisdom was notorious, acknowledged by very Greeks, who borrowed much of the Egyptian knowledge and skills. The attraction Egypt exercised on the surrounding population is testified by the very Bible, Jewish and Christian alike. Jacob's son Joseph, Jesus' father Joseph etc, to mention but a few examples. Alexander, Caesar and Napoleon, three greatest military leaders and statesmen, all visited Egypt, in a sort of pilgrimage.

There is no doubt that Israelis were frequent visitors to Egypt, for short or long stays. They must be well acquainted by their customs, mythology, religion etc. The author of Joseph's narrative, written probably in VII c. BC, had some knowledge of the Egyptian culture, but obviously counted on the poor acquaintance of his compatriots about the same. Otherwise he would not dare to transcribe so directly something that every Egyptian of the time knew, into a religious fable, with the pretence of both originality and veracity. The Book of Exodus was written outside Egypt, long time after the alleged Jewish sojourn in the Nile valley.

The seven cow-Goddesses used to nourish generations of the Nile people, but generations of Hebraic and Christian believers as well. Not with wheat, but mythological nourishment.

3. BERENICE'S HAIR

This narrative, well known, but in various presentation is interesting to us here for a number of reasons. First of all, it is not clear whether it refers to a historical event, or it is just another mythological fable. If it is the latter case it demonstrate the power of human attraction by supernatural explanations, even within an advance civilization, as the Ptolemaic Egypt was. It contains the same mythema we encountered with Pleiades, or Seven cows - rescue by lifting the earthly creatures to Sky, as a common heavenly abode. Another point to make is the presence of various variants, pointing the distortions which even presumably historical events are subject to.

Figure 4: Berenice's hair.

Ptolemy III (246 - 222 BC) was one of the most prominent member of the arguably the most prolific dynasty in the history (Pollard and Reid 2007). He married his daughter Berenice to Seleucian king Antiochus II Theos. After some struggle over throne of the dead king Berenice invited her father to intervene and the war was inevitable. The most important result of Ptolemy's victorious campaign were about two thousand items of spoils, which Cambis looted in Egypt, the pharaoh recovered. It was for this exploit the people gave him the title "Uergetes" - the Benefactor.

But the story does not end here. According to legend, Pharaoh's Cyrenian wife, Berenice, had promised to gods her beautiful hair, if the pharaoh returned victorious. She fulfilled the promise and after Ptolemy's arrival, deposited her hair in Aphrodite's temple. However, when the royal couple appered next morning at the shrine, the hair was missing. They were furious about the lost, but astronomer Conon save the situation, declaring that the hair was not looted, but taken by gods as an offering. Next evening he took the pharaoh and Berenice at the open air an showed to them the constellation we call today Coma Berenice(see Figure 4).

It sounds nice, but is there any truth in this story? And even if there is, should we believe the royal couple trusted the astronomer (and gods, for that matter)? This, otherwise legitimate question, lies outside our subject, however (see e.g. Veyne 1983).

4. THE ATLANTIS MYTH

This myth (quasimyth would be, perhaps, better term) appears one of the most curios narrative in the literature of ancients. Unlike majority of other stories which have reached us, it appears in a single source, Plato in this case (Timaeus, Critias, 421. BC). This story puzzles the Plato scholars, who hesitate to take it seriously. Is it a mere Plato invention, as an allegorical narrative, or it contains a grain of historical authenticity? Did Plato really heard this story from somebody, presumably Egyptian priests and just transmitted it to us? Are we to take seriously the numbers Plato quotes as of the years the narrative refers to. What was inspiration of the story, if it wasn't a mere invention (allegorical or otherwise)?

In his Dialogs Timaeus and Critias Plato talks about a story which, allegedly, Solon heard from a priest at Sais, c. 670 BC. Plato will himself learn the same story from priests Conuphice and Secnuphicen at Heliopolis, when visiting Egypt, c. 370 BC.

In his inspirative interpretation Reiche (1981) turned to Sky to decode Plato message about the island which disappeared some millennia before in a cataclysmic event. He first noticed that in the period (6.000 - 4.000) BC vernal points coincided with crossing of Milky Way with Ecliptic. Thus the Milky Way linked Gemini with Sagittarius, which crossed Ecliptic in the autumn equinox. It was the time when gods communicated with mortals (Golden Age). It ended in a fatal diversion of Sun from its usual path (myth about Faethon). Further corruption ensued and king Lykaon offered to Zeus flesh of his son - Silver Age arose (2.500. BC). Then Taurus and Scorpion came instead of Gemini and Saggitarius. When Zodiac constellations, following the eastward precession, successively dive behind the vernal point we have allegorical, Drang nach Osten of Antiquity. The role of conquerors is played by the Atlantic people, and the role of defenders of the civilization is played by whom else but Athenians. Gods are satisfied, but not completely. Athenians commit sin too (forest devastation of Attics?) and they dive themselves. Athenians are thus sacrificed for the wellbeing of mankind, after ensuring order and moderation.

It is not easy to decide about the veracity of the content of the story, as well as for the reality of the way the story saw light. Was this moral warning of Plato to his country fellows as for the ethics of his time? In his dialogue The Republic, Plato tells us another myth, that of Er who visited Underworld and witnessed the work of Mires, who decide human destinies. Both myths appear not only outside Plato's rational discourse, but lie opposite to his own critics of Greeks for paying to much attention, in his opinion, to the Homeric poetry as the standard of human ethics.

5. EPILOGUE

All three narratives have a number of features in common. First, they are linked in one or other way to Egypt, which to the Ancients was what now Hellada is for us. And all involve the Sky as Heaven, in the modern interpretation of the term. To the Ancients the Sky was a sheet of paper, on which divinities wrote messages to mortals. Starry constellations were seen as letters in the broad book of Nature, which were to be fathomed by mortals.

Our exegesis of the Book of Exodus attempts to show that this part of the Jewish Bible should be taken as an example of fairy tale, in which the Bible abounds. The story of pharaoh's dream seems to be, as far as the interpretation is concerned, too conspicuous to be noticed by scholars.

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IBSE METHOD IN ASTRONOMY TEACHING

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Abstract. The paper concerns astronomy teaching in Serbia. A special attention is paid to the teaching on the levels lower than university. The syllabus contains many topics which, no matter how strong efforts of teachers are, cannot be treated otherwise than by applying monologue. Application of a method, rather unknown in our milieu, can substantially improve the methodology in astronomy teaching. Its name is IBSE - Inquiry Based Science Education involving Experiment. A particular example of applying IBSE is described in detail.

The interest in astronomy in general, including also teenagers (pupils), can be best described by quoting Immanuel Kant (1724-1804): "Two things fill the mind with ever-increasing wonder and awe, the more often and the more intensely the mind of thought is drawn to them: the starry heavens above me and the moral law within me". However, the interest or, the state of being fond of astronomy, appears as a mere beginning on the thorny road of learning about celestial phenomena and including this subject in the teaching process. The scientists and teachers are aware of this fact because of their choice of profession. A completely different situation is met in the case of pupils. Their initial enthusiasm is gradually weakened by experiencing that astronomy is a complicated science requiring a multidisciplinary knowledge including mathematics, physics, chemistry etc. Astronomy teachers must overcome this problem.

Astronomy is the oldest science. In favour of this are images of constellations and attempts of time reckoning in the oldest living places of human race - caves [3-5]. Studying, training and teaching astronomy has advanced, directed and monitored thinking and science during the entire civilisation development. In Serbia astronomy was taught at first at the Faculty of Philosophy in Belgrade, later the department of this faculty for mathematics and natural sciences became a separate faculty where, finally, astronomy got its own department [10]. In the secondary school (gymnasium) astronomy had been taught in the framework of geography, to become a separate subject in the second half of the XX century. As for the primary school, astronomy is still present in teaching subjects named knowing nature, the world around us and geography.

There are two kinds of problems following teaching astronomy in Serbia. The first one concerns qualified teachers. In gymnasiums astronomy is still taught by physicists (not only by physicists, but also, due to lack of physicists with bachelor degree, by completely unqualified persons - SN) who during their undergraduate studies had no subject of astronomy or astrophysics. This was the situation also when astronomy existed as a separate subject, but from the time when astronomy entered the syllabus of physics, it has been manifested more strongly. In the last gymnasium form for classes of science and mathematics it is foreseen to devote to astronomy one lesson a week, out of the total of five which belong to physics. The majority of teachers even that lesson use to teach physics additionally! In the case of classes oriented towards humanitarian sciences the material of physics for the last form contains astronomical matter, it should be treated near the very end of the school year, but usually even then the pupils get no information on astronomy! [8]

The second kind of problems has a methodological nature. The material contains many topics which, no matter how strong efforts of teachers are, cannot be treated otherwise than by applying monologue. This is mainly an organisational problem! In order to overcome it one should organise a sufficiently large number of astronomy workshops through which astronomy teachers would become skilled to solve a majority of methodological problems. The Society of Astronomers of Serbia is expected to be seriously involved in improving astronomy teaching in Serbia. It could do this by forming a competent commission. The commission task would be to propose new syllabus and curriculum for astronomy teaching. Our recommendation is that the syllabus should not be too large so that according to the curriculum a sufficient number of classes could be devoted to observations and experiments (classes of hands-on type). We also point out that gymnasiums which possess proper equipment and software concerning astronomy are rare. Beyond the large centres, like Belgrade, Novi Sad, Niš, etc, this is expressed more strongly, because of the problems with a permanent access to Internet, video devices in specialiced classrooms, not to mention ordinary classrooms! Therefore, it is not surprising that the results of the pupils, as well as teaching astronomy in general, do not satisfy strong criteria.

The present paper is not aimed at dealing with the first kind of problems, it is aimed at giving contribution to the modern methodological approach in teaching astronomy by using the IBSE method.

A PEDAGOGICAL EXPERIMENT

Using his knowledge acquired during undergraduate, MsC studies in astrophysics and PhD studies in methodics of teaching physics and consulting his colleague from the Astronomical Observatory in Belgrade the first author carried out a pedagogical experiment in September 2013.

This pedagogical experiment containing parallel pupil groups has confirmed that it is justified to include IBSE (Inquiry Based Science Education involving experiment, research, self-organised work, critical thinking, treatment of the results and drawing conclusions on the basis of the results, as well as a written report at the end, [2]). The IBSE method is basically a scientific method which has existed even from the time of Galileo, in modern methodics it is also known as integrated scientific method, [7]. The dependent variables were scores of pupils, the independent variables were learning methods.

The sample was formed by three classes (90 pupils). All the three belong to the same orientation (science and mathematics), same form (fourth, the last) and school (Šabačka gimnazija, Šabac Gymnasium). The quality of groups was approximately equal, which is confirmed through the general score in learning and the average mark in physics. The first class formed the Control Group (K). In their case Kepler’s laws were taught in the classical way, the so-called transmission method, in which the pupils listen and the teacher speaks to them (lecturing and adopting knowledge) and all what the teacher uses are blackboard and chalk [6]. In the case of the experimental group 1(E1), the second class, the experimental factor, or independent variable, is the teaching following IBSE. In the second experimental group 2(E2), the third class, the experimental factor is the teaching supported with a demonstration experiment and multimedia. At the end of the study the final knowledge evaluation was done in each group. This evaluation was carried out by means of a test.

The study was aimed at establishing if the teaching following IBSE enlarges the quantity of knowledge of the pupils. On this basis the tasks were defined and the hypotheses formulated: the zero one (IBSE has no influence upon the knowledge of the pupils, i. e. the groups have equal scores) and the alternative one (IBSE leads to enlarging in the quantity of knowledge of pupils, i. e. there are statistically significant differences among the groups). In the treatment of the results the descriptive statistics with its parameters was used. In order to establish statistically significant differences in the results the variance analysis (ANOVA) was used, as well as the tests of Tukey, group and individual [9].

APPLICATION OF THE IBSE METHOD IN TEACHING KEPLER’S LAWS

The topic *Kepler’s laws* appears as one of the best examples for application of IBSE. These laws played an important role in the history of science in the way that their validity contributed significantly to eliminating the illusion of the geocentric system which had been a problem from Aristarchus to Galileo and Kepler.

In the case of the experimental group during the lesson *Kepler’s laws* were explained theoretically. The lesson started with the problem formulation and forming the hypothesis. For the purpose of simulating the initial studies from the time when the geocentric theory was accepted and sky was naked-eye observed, the teacher suggests the pupils that the initial hypothesis is: All celestial bodies move around the Earth!? In the next step one analyses the appearance of the sky over day-light and night and looks for the answer to the question: why when observing from the Earth it seems that stars and planets move around us (geocentric theory)? One explains the reasons for which the geocentric system persisted for so long time, also the historical importance of thinkers, like Aristarchus from Samos, who was the Library Director in Alexandria (II century BC). Aristarchus was the founder of the heliocentric system. Its doctrine for many reasons was neglected and the heliocentrism is attributed to Copernicus (1473-1543). The time difference of 18 centuries shows clearly that the road of acquiring scientific knowledge was hard, but nevertheless as such, the only right way. The teaching is continued through experiment Martian orbit [1] which has been conceived on the basis of Kepler's original work. For the necessities of the experiment the pupils were divided into groups. The special classroom for physics has been prepared for working of seven groups of pupils simultaneously. Every table contaned the group designation and every pupil at the moment of entering the room was given an identification card with the group designation (Fig. 1.).

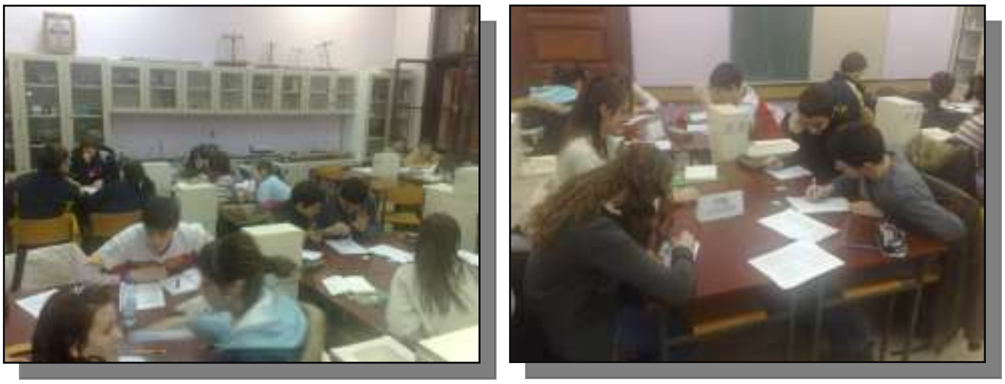

Figure 1: Exercise Martian orbit.

During the process the pupils participate in the IBSE phases: *Problem Definition*, Motion of Celestial Bodies; *Collecting the Data:* coordinates of planet Mars; *Formulating Hypothesis:* All celestial bodies move around the Earth!?; *Experiment:* The pupils are trying to draw the orbit of planet Mars with the Earth at the origin, (geocentric system) - a failure! Now the pupils are drawing the orbit of Mars again, but this time with the Sun at the origin (heliocentric system) – a success!; *Testing Hypothesis:* Bearing in mind the result of the experiment the pupils conclude that the initial hypothesis is wrong; *Conclusion:* Mars, just as the other planets, moves around the Sun!

In doing the experiment the pupils use the material necessary to the implementation and applying their general knowledge, they analyse its course and infer the shape of the orbit: as the first approximation one assumes a circular orbit centred on the point *G* shifted with respect to the circle centre (Fig. 2); the positions of the two planets, Earth and Mars, are determined on the basis of the circle centre which is also the centre of the ellipse; the centre of the circle (ellipse) and the centre of the auxiliary circle are along the same straight line, *AP*, which connects the perihelion and aphelion of the orbit.

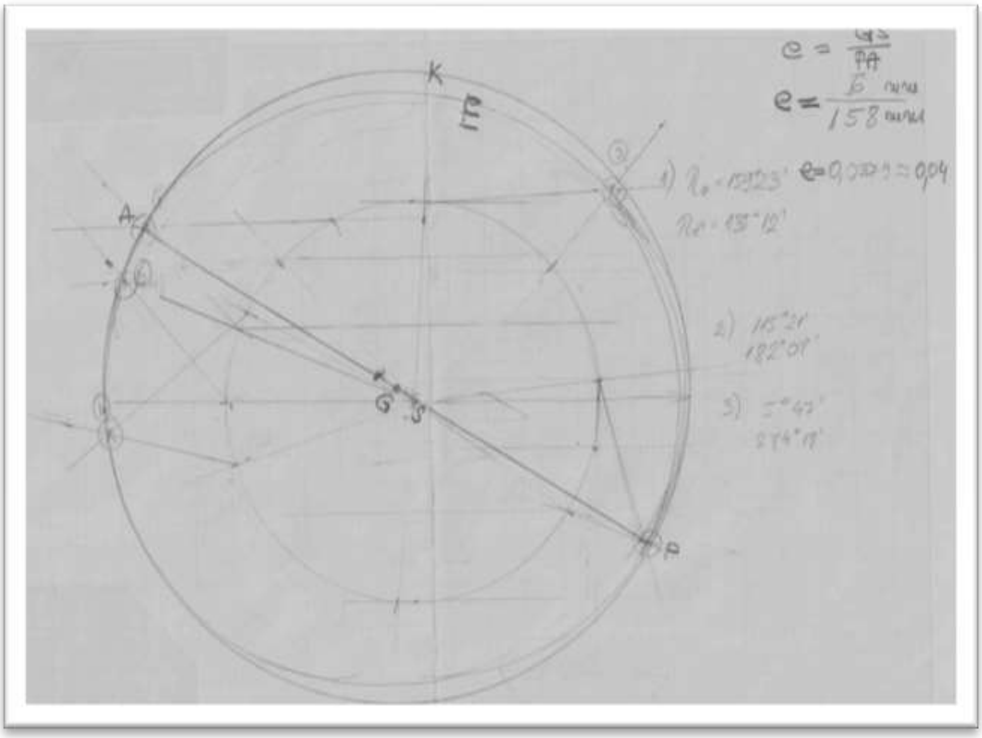

Figure 2: Drawing the orbit of Mars, a pupil’s work.

The centre of the auxiliary circle is one of the foci of the ellipse at which the Sun is situated; the position of the other focus is found by measuring the length of the segment *GS* (Fig. 2) and then the obtained value is used in the opposite sense with the origin at *G*. Using a pair of pins and a thread the pupils should draw the ellipse; finally they infer the eccentricity of the orbit. In most cases the pupils completed their task at school, the other ones might complete it at home, to bring then the drawing and show it to the teacher.

RESULTS AND DISCUSSION

The descriptive statistics of the final test shows that the quantity of knowledge was highest in the case of E, and lowest for Group K. The values of the descriptive statistical parameters indicating this fact are given in Table 1:

TABLE 1. Descriptive statistical parameters for the final testing

Group	AS	SD	Se	CV	Min	Max
Control	18.25	3.25	0.7623	18.46	11.00	25.00
Experimental 1.	24.35	2.72	0.6873	10.43	19.00	30.00
Experimental 2.	21.95	2.92	0.6886	13.30	18.00	29.00

AS – arithmetic mean, SD – standard deviation, Se – standard error of arithmetic mean, CV – variation coefficient and (Min, Max) – variation interval

The analysis of the descriptive statistical parameters for the final test shows that the highest value (number of points) occured for E1, it was 24.35 with a standard deviation of 2.78. The lowest value occurs for Group K:18.00±7.00. The variation coefficient for K is 18.46% being the highest value for this parameter. It is due to the large variation interval (14 points). In E1 and E2 the variation coefficients have values of 10.43% and 13.30%, respectively. With respect to all parameters examined here these are the smallest values, the data were homogeneous, and the variation intervals for both groups were equal to 11 points.

The results of the final test allow to establish a high quantity of knowledge in E1 and E2, compared to Group K. Between E1 (82.50%) and E2 (73.83%) there is a difference in the knowledge quantity. The circumstance that it is higher in E1 than in E2 can be explained by introducing IBSE.

The plot of knowledge quantity is presented in Fig. 3:

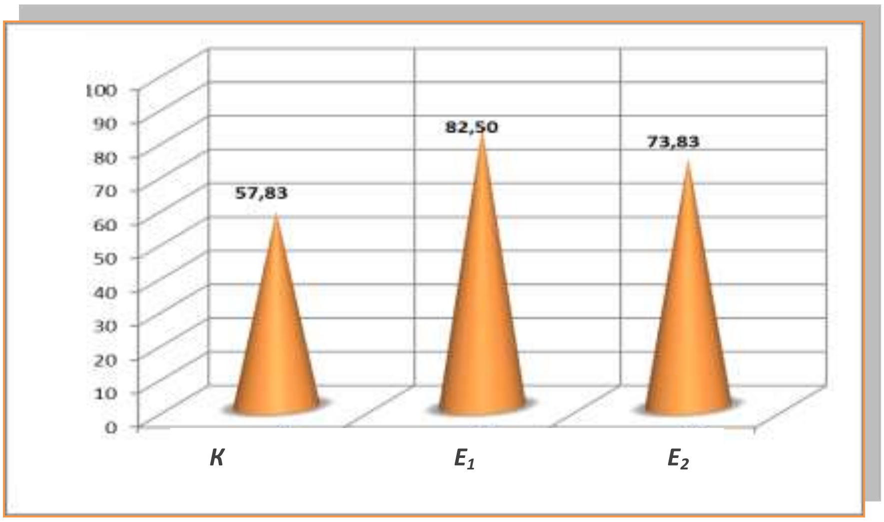

Figure 3: Knowledge quantity for pupils in % for the final test.

The statistical significance for the differences between the examined groups for the final test is given in Table 2.

TABELA 2. Statistical significance of differences

Group	AS	Experimental 1.	Experimental 2.	Control
Experimental 1.	18.35	/	1.60	**6.35***
Experimental 2.	24.35	/	/	**5.20***
Control	21.95	/	/	/

** r<0.01 – significance coefficient*

The significance of the differences between the groups is determined by using a completely random plan. The value found here *F* (23.22) indicates existence of very significant differences ($p \leq 0.01$) between the groups examined here. The difference significance between the experimental groups individually is established by using Tukey’s test. In this way one finds a very significant difference ($p \leq 0.01$) between K and E1 (6.35), as well as between K and E2 (5.20). The hypothesis that the groups E1, E2 and K are equal is not acceptable, which means that the work following the Enquiry Method has an influence on the process of learning the syllabus elements and quantity of knowledge. Between other groups participating in the experiment no significant differences are found ($p \geq 0.05$).

Based on the analysis of the present results it is possible to conclude that the alternative hypothesis: the IBSE method enlarges the quantity of knowledge for pupils – there are statistically significant differences between the groups, is here confirmed. In other words applying the IBSE method results in a higher quantity of knowledge for pupils; therefore this method appears as an efficient one and it deserves to be recommended to the teachers!

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ASTRONOMY EDUCATION IN SERBIA 2011-2014

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Abstract. A triennial review is given on astronomy education in Serbia at all levels (primary and secondary schools, and universities), on astronomy programmes of the Petnica Science Center, on the activities of amateur astronomical societies, and on the participation of the Serbian team in the International Astronomy Olympiads.

In this paper astronomy education in Serbia with an emphasis on the changes that occurred in the period from 1 November 2011 to 1 November 2014 is described. The previous period was covered in the papers by Atanacković (2009, 2012), Atanacković-Vukmanović (2006a,b) and by Milogradov-Turin (2002) and in the references therein.

1. PRIMARY SCHOOLS

In the elementary school curricula astronomy topics are taught as art of the courses of Natural History (IV), Geography (V) and Physics (VII and VIII year). Apart from the obligatory program, additional astronomical topics are taught as part of the activity of astronomy clubs organized by the enthusiastic teachers of physics, mathematics or geography in some primary schools. During the Conference we had a nice opportunity to learn about such kind of activities in two primary schools: "Jelica Milovanović" from Sopot and "Vasa Živković" from Pančevo (see the papers by Maričić - Mirilović et al. and Krstin in this volume).

2. SECONDARY SCHOOLS

It is worth remembering that after 25 years (from 1969 to 1994) of being a separate and compulsory fourth year one hour per week course, in 1990 astronomy topics became incorporated in the final (fourth) year physics courses. Since then, and especially during these past three years, attempts have been made to reintroduce astronomy as a separate (either compulsory or elective subject), but still without success.

New standards for teaching of Physics are introduced in the framework of the reform of the secondary schools education. Unfortunately, also in these reformed standards astronomy is still regarded as a part of Physics.

At regular annual meetings of physics teachers organized by the Serbian Physical Society, only one lecture on the topics related to astronomy, "European extreme large telescopes" (Ilić 2014), was given in the previous period.

The first School of Astronomy organized by the students of the Department of Astronomy of the Faculty of Mathematics in Belgrade was held in May and June 2014 (twice per week) in Dom omladine, Belgrade. It is intended for the young people (from 15 to 25 of age) and mainly for the secondary school students. In the 2014/2015 academic year the lectures are planned to be given during both semesters.

2. 1. PETNICA SCIENCE CENTER (PSC)

The reconstruction and modernization of Petnica Science Center, the biggest and the oldest center for extracurricular (informal) education in SE Europe, lasted from 2011 to 2013. The purchase procedure for new astronomical equipment, including 60cm telescope is in progress. The telescope is to be mounted at the new Observatory, which should be built on a hill above the PSC.

In the past three years the Program of Astronomy in PSC included 17 seminars for secondary school students interested in astronomy and involved 150 participants in total. About 35 researchers from the University, Astronomical Observatory and other institutes, as well as the students of astronomy, took part in their realization (Božić, 2014). The two cycles of seminars in astronomy organized by the PSC are described in more detail in Atanacković (2009). About 35 individual research projects were realized by the participants of the seminars that belong to the most advanced group. Twenty one of them (Andjelković, S., Vranješ, G., 2011; Arsovska A., 2014; Blagojević, M., 2014; Bogdanović, A., Rajić, M., 2013; Djošović, V., Ratković, J., 2014; Fuks S., 2014; Jovanović, M., 2011; Kabić, J., 2011; Majić, B., 2013; Marković, S., 2012; Milošević, A., Janješ, A., 2011; Mirković, S., 2011; Perić, D., 2014; Reljić, A., 2011; Stojanović, N., 2013; Šarković, V., 2012; Šarković, V., Živanović, F., 2011; Vukadinović, D., 2012; Vukadinović, D., Šarković, V., 2013; Vukadinović, D., 2014; Živadinović, L., 2014) were presented at the annual conferences ”A step into science” (in December) and published in four volumes (68, 69, 70 and 72) of ”Petničke sveske” (”Petnica notebooks”).

The first summer school for students, ”Petnica Summer Institute”, was held in August 2013. It was devoted to Cosmology. In 2014 the summer school was dedicated to Particle Physics. About 40 students participated, while 15 lecturers from SISSA, ETH, AOB and Petnica took part in their realization.

The 9^{th} and 10^{th} Petnica International Science Summer School was held in August 2013 and 2014. Participants from Japan, Russia, Poland, Romania, Spain, Bosnia and Hercegovina, Turkey, Greece and Serbia worked on 6 different scientific student projects in the fields of astronomy, physics & computer science, biology & chemistry and anthropology.

More details on the activities of PSC can be found at: http://www.psc.ac.rs.

2. 2. INTERNATIONAL ASTRONOMY OLYMPIADS

In the past three years (2012-2014) Serbian teams participated in the IOAA (International Olympiad on Astronomy and Astrophysics) and won 3 gold, 3 silver and 3 bronze medals in total, as well as 4 recognitions (Ninković, 2014; Vidojević et al. in this volume).

Let us recall that in 2002 Professor J. Milogradov-Turin (Milogradov-Turin 2003), then president of the Society of Astronomers of Serbia (SAS), initiated the participation of Serbia in the International Astronomical Olympiads. Since then Serbian teams won 9 gold, 16 silver and 24 bronze medals, as well as 2 special prizes and 7 recognitions in total.

3. UNIVERSITY EDUCATION

Astronomy courses are taught at five state universities in Serbia (University of Belgrade, University of Novi Sad, University of Niš, University of Kragujevac and University of Priština in Kosovska Mitrovica).

The University of Belgrade is still the only university with the Department of Astronomy (at the Faculty of Mathematics - FM). Students can major in astronomy from the first study year.

So far 278 students have graduated from the Department of Astronomy at the University of Belgrade, 25 students received Master degree, 69 students received MSc degree and 47 students - PhD degree. In the past three years, 13 students graduated, 13 students got master and 9 PhD degree.

The studies were performed according to the programs accredited in 2009/2010. The study program "Astronomy and astrophysics" consisted of 3 modules (Computational mechanics and astrodynamics, Astrophysics, Astroinformatics) at undergraduate level, 2 modules (Astronomy, Astrophysics) at Master level and one module (Astronomy and Astrophysics) at PhD level. New study programs are accredited at the end of 2014, and will be introduced in 2015/2016. The study program "Astronomy and astrophysics" will consist of 2 modules (Astrophysics, Astroinformatics) at undergraduate and Master levels, and will be one module at PhD level as before. Moreover, within the study program "Mathematics" there will be module "Astronomy" at undergraduate level, and module "Astronomy and Mechanics" at Master level.

Since 2011/2012 the Faculty of Mathematics of the University of Belgrade participates in "AstroMundus", a 2-year European Erasmus Mundus Joint Master program in astronomy and astrophysics of 5 universities: Innsbruck (coordinator), Rome 2, Padova, Gottingen and Belgrade (see website www.astromundus.eu). The University of Belgrade (Faculty of Mathematics) offers the 3rd and the 4th semester of the Master program. Since then, there were 4 classes of students (school years 2011/2012 - 2014/2015). Twenty students in total visited and were enrolled at the Faculty of Mathematics from all over the world (16 countries: Mexico, Spain, Italy, Pakistan, India, Macedonia, Georgia, Columbia, Peru, Turkey, Chile, Venezuela, Croatia, USA, UK, Slovenia), out of which 3 students defended the Master thesis in Belgrade (2011/2012). In the first year of Astromundus program, the Best Master thesis award was given to the student that defended the thesis in Belgrade. Additionally, there were 4 joint Master theses, two theses defended at the University of Innsbruck (2012/2013) and two at the University of Goettingen (2013/2014) (Ilić, 2014).

The students of the Department of Astronomy continued with the training in observations and data reduction at the Ondřejov Observatory (since 2007 they have 3-weeks summer practice there). Since 2012 three summer practices lasting 3-5 days

(June 2012, July 2013, October 2014) have been organized at the Astronomical Station on the mountain Vidojevica. Some 12 students from Belgrade and Novi Sad participated in this practice each year.

The Department of Astronomy continued to organize regular seminars on different topics in astronomy on every second Tuesday throughout the academic year, so that 43 seminars have been held in this triennial period. Eighteen seminars were also held at the Astronomical Observatory in Belgrade.

The Astronomy Students Workshops (ASWs) have been organized since 2007 at different locations by the Department of Astronomy in Belgrade, the Department of Physics in Novi Sad and Astronomical Observatory in Belgrade, aimed at improving contacts between the students of astronomy from Belgrade and Novi Sad and giving them an opportunity to present their work (seminars, master/PhD thesis research, and summer practice). The 5th ASW was held in November 2011 at the Public Observatory of the AS "Rudjer Bošković" in Belgrade, the 6th ASW in April 2013 at the Department of Physics in Novi Sad (23 students), and the 7th ASW in April 2014 at the Society "Milutin Milanković" in Belgrade (39 students). The ASWs are growing in popularity among students.

At the Faculty of Mathematics astronomy is also taught as a compulsory course "Introduction to astronomy" (3rd study year) for the students of L division (mathematics and informatics teachers), as an elective course "Selected topics in astronomy" (4th year) for all modules of the study program "Mathematics" and in two elective courses "Stellar astronomy" and "Ephemeris astronomy" (1st/2nd year) for the students of the study program "Informatics".

At the Faculty of Physics astronomy is taught as a compulsory one-semester course "Fundamentals of astrophysics" at the 1st year of master studies for physics teachers division, and as an optional one-semester course under the same name for the students of the 1st year of B (theoretical) and C (applied) division, and for the students of the 2nd or the 3rd year of A (general) division. In the past three school years, on average 25 students per year selected this course.

At the Faculty of Civil Engineering, a compulsory course "Geodetic astronomy" (4th year) is taught. At the Faculty of Geography, basic astronomical topics are taught within the first-year course (2+1) "Mathematical Geography" for the students of General division and Geography teachers division. Visits to the Planetarium and to the Astronomical Observatory, Belgrade are compulsory (Tadić, 2014).

New accredited studies at the Astronomy study group, founded in the 2002/2003 academic year at the Department of Physics of the Faculty of Natural Sciences (FNS) at **the University of Novi Sad** are of the model 4+1 (firstly, the model was 3+1+1, and then 3+2 in 2008/2009).

In the past three years 23 students enrolled astronomy studies at the Faculty of Natural Sciences in Novi Sad. Six students graduated and four students received the Master degree (Prodanović 2014).

At the Department of Geography of the FNS in Novi Sad, a course "Mathematical geography with the fundamentals of astronomy" (3+2) is taught in the first study year (Tadić, 2014).

At the Institute of Physics of the Faculty of Natural Sciences of **the University of Kragujevac** there is a one-semester (2+2) elective course, "Astrophysics and Astronomy", for the 5th-year students of Physics. The students use equipment (a

Carl Zeiss Telescope 150/2250 and a 200/1000 Newton telescope) of the Astronomical Observatory that belongs to the Faculty (Simić, 2014).

At the Department of Physics at the Faculty of Natural Sciences (FNS) of **the University of Niš**, an elective course "Introduction to Cosmology" is taught at the 3rd study year of undergraduate studies. At Master studies, a compulsory course "Fundamentals of Astrophysics" (2nd year) for the students of General Physics is taught. The same course is elective for the master students (1st year) of Physics - Informatics. At the PhD level, there are two elective courses: "Cosmic plasma" and "Fundamentals of cosmology" (Gajić, 2014).

At the Department of Biology, an optional course "Fundamentals of astrophysics with astrobiology" is taught at the first study year of Master studies. At the Department of Geography, an elective course "Astronomy" is offered to the first-year master students (Gajić, 2014). At the Department of Geography, a course "Mathematical geography" (2+2) includes some basic astronomical topics (Tadić, 2014).

Thanks to the Project "Armchair Astronomy" a dome is installed on the roof of the Faculty, Lunt telescope LS60T with Hα filter for the solar observations and the Mead Color CCD camera are bought for the students' exercises and popularization of astronomy (Gajić, 2014).

At **the University of Priština in Kosovska Mitrovica** a one-semester 2-hour per week course, "Fundamentals of astronomy and astrophysics", is taught to the second year students of physics.

At the Department of Geography at the FNS in Kosovska Mitrovica, a course "Mathematical geography" (2+2) includes some astronomical topics (Tadić, 2014).

In 2013, a new university textbook "Stellar Astronomy" by Trajko Angelov was published (edited by the Faculty of Mathematics, Belgrade).

3. 1. RESEARCH IN ASTRONOMY

Astronomy research in Serbia is mainly performed at the Astronomical Observatory in Belgrade (42 researchers) and at the Department of Astronomy, Faculty of Mathematics, University of Belgrade (11 professors+assistants + 4 PhD students). With the Institutes of Physics (Zemun and Vinca), University of Novi Sad, Kragujevac and Niš, there are about 70 researchers in astronomy in Serbia and about as many abroad. They participate in 8 national scientific projects and several international cooperations and projects (SREAC, VAMDC, Belissima, Astromundus, LSST, Stardust, Pavle Savić). The researchers of the Astronomical Observatory participated in the study programs at the Universities of Belgrade and Novi Sad.

The big news is that as of 2014 Serbian Astronomical Journal entered the SCI list (see Knežević et al. in this volume).

Let us mention here also that ADICT - an interactive English-Serbian astronomical dictionary/website is installed in January 2014 with the intention to help both the professional astronomers and non-professionals in writing and/or translating the scientific and popular papers (see Arbutina and Momić, in this volume).

4. PUBLIC EDUCATION

Public astronomy education in Serbia was realized mainly through the activities of 23 amateur astronomical societies (Table 1). In the past three years, three amateur societies were founded (”Vega” in Surdulica, ”Kraljevo” in Kraljevo, and ”Tycho Brahe” in Belgrade). Let us mention here that the AS ”Tycho Brahe” in Belgrade, which is mainly doing astrophotography (they use Newton telescope 150/750 and German equatorial amount EQ3) won the special recognition for the best poster during the XVII National Conference of Astronomers of Serbia.

Amateur astronomers association of Serbia (Savez astronoma amatera Srbije - SAAS, www.saasr.org) founded in February 2010, now contains seven registered societies (AS ”Orion” Ivanjica, AS ”Andromeda” Knjaževac, AS ”Aristarh”, Kragujevac, AS ”Novi Pazar” Novi Pazar, ”Magelanov oblak”, Prokuplje, ”Vlasina”, Vlasotinci, ”Gea”, Vršac).

In 2014 the AS ”Rudjer Bošković” (Belgrade) celebrated 80 years of the Society, 60 years of the Public Observatory and 45 years of the Planetarium (Aleksić, J. and Stanić, N., 2014). The AS ”ADNOS” (Novi Sad) celebrated 40 years of its foundation.

Many societies have a collaboration with schools and other institutions in their cities and many contacts with other astronomical societies in Serbia and in neighboring countries. A nice example of an intensive collaboration among the amateur astronomical societies in Serbia and professional astronomers is the international astronomical camp ”Letenka”, one of the biggest camps for the popularization of astronomy in Europe. It has been organized since 2001 every year in July (lasting four days) on the mountain of Fruška gora. This camp includes lectures, observation competition, and astronomy related documentaries. About 200 people (mostly secondary school and university students) take part in ”Letenka”. Also, the AS ”Lira”, AS ”Univerzum” and AS ”Novi Sad” organize the observation competition in the Messier marathon (Mm) every year (early in spring) at Letenka. For much more details on these joint activities of the amateur astronomical societies in Serbia, and on some of the joint public observations see the paper by Zorkić in this volume. For more information on the activities of the astronomical societies see their websites that are given in Table 1, the Astronomical Magazine (AM) website, the largest astronomical web site in the country, the astronomical review ”Vasiona” (published by AS ”Rudjer Bošković”, Belgrade), the annual bulletins ”Gea” (published by Astronomical group within the Natural History Society ”Gea”, Vršac), and the most recent contributed papers by Tomić, Janković et al., Jeremić, Milovanović et al., Aleksić and Stanić (this volume). Their usual activities and equipment are described in detail also in the paper by Atanacković (2012).

Since 2011 the AS ”Univerzum”, Bačka Palanka, possesses the robotized astronomical observatory they built by themselves. They observed tens of variable stars, and discovered one eclipsing binary, which is in the database of AAVSO (American Association of Variable Star Observers). They also detected 96 transits of extrasolar planets that are registered in ”Extrasolar transit database”. They took photographs of several supernovae, hundreds of galaxies, asteroids, comets, stellar clusters, and began to work on the photometry of asteroids. They exchange the data obtained by means of camera for detecting meteors with Croatian meteors network (Mravik, 2014).

The societies continued their usual activities. ”Astronomy courses for beginners” (one at each autumn and spring), Belgrade astronomical weekends (BAW), Summer Schools of Astronomy, as well as a special topical meetings ”Summer Astronomical Meetings” have been organized by AS ”Rudjer Bošković”, Astronomical Meetings of

Vršac (AMV) by the Astronomical group within the Natural History Society "Gea", Autumn and Spring Schools of Astronomy by the AS "Andromeda" (Knjaževac), and astronomical camps in Sivčina by the AS "Orion" (Ivanjica). Most of the societies participated in special events (Night of Museums, Book Fair, Festival of Science, Night of Researchers, etc.).

Many lectures have been also given in Dom omladine, as well as in the Students' Cultural Center in Belgrade.

In the past five years (2009-2014) Astronomical Society "Rudjer Boskovic" and Society of Astronomers of Serbia used the mobile planetarium as a tool for astronomy communication. During the 2013/2014 school year this equipment has been used in schools as an educational tool (for details see Stanić et al. in this volume).

Let us recall that astronomy has also been popularized by the "Mladi fizičar" ("Young Physicist"), a quarterly magazine for the elementary and secondary school students.

Table 1. Amateur astronomical societies in Serbia; AS - Astronomical Society, AG - Astronomical Group, SRAR - Society for Radio-astronomy Research

No.	name	year	town	website
1	AS "Rudjer Bošković"	1934	Belgrade	adrb.org
2	AG of the "Vladimir Mandić-Manda"	1973	Valjevo	istrazivaci.rs/
3	AS "Novi Sad" (ADNOS)	1974	Novi Sad	adnos.org.
4	AS "Alfa"	1996	Niš	alfa.org.rs
5	AS "Milutin Milanković"	1996	Zrenjanin	www.admm.edu.rs
6	AS "Lira"	1998	Novi Sad	astronomija.co.rs
7	AG within "Gea"	1999	Vršac	gea.org.rs
8	SRAR "Aurora"	2000	Bor	
9	AS "Magellanic Cloud"	2001	Prokuplje	
10	AS "Andromeda"	2003	Knjaževac	andromedaknj.wordpress.com
11	AS "Novi Pazar"	2004	Novi Pazar	
12	AS "Tesla"	2004	Belgrade	
13	AS "Univerzum"	2006	Bačka Palanka	univerzumad.com
14	AS "Orion"	2007	Ivanjica	
15	AS "Milutin Milanković"	2007	Pančevo	aumm.yolasite.com
16	AS "Aristarh"	2007	Kragujevac	
17	AS "Eureka"	2010	Kruševac	eureka.nebjak.net
18	AS "Bor"	2011	Bor	adbor.wordpress.com
19	AS "Kasiopeja"	2011	Leskovac	
20	AS "Vlasina"	2011	Vlasotinci	
21	AS "Vega"	2012	Surdulica	vega.edu.rs
22	AS "Kraljevo"	2012	Kraljevo	
23	AS "Tycho Brahe"	2010	Belgrade	aadtychobrahe.blogspot.com

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THE LANGUAGE OF SKY

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Abstract. Astronomy has passed the long way from the prehistoric man to the modern insight into the night sky and its conspicuous and hidden features. We review the role which night sky has played in everyday life and collective conscious of the prehistorical man and the traditional societies, with emphasis on the ecological unity which the ancients felt concerning Nature in general and heavenly objects in particular. We argue that the prehisorical man was much more familiar with the Universe as visible from Earth than the modern inhabitants of the Globe and examine a number of cases in point, characteristic for various regions and epochs linked with the traditional society.

1. INTRODUCTION

The subject of this paper belongs to archaeoastronomy, which is the study of how past people have understood the phenomena of the sky, how they used them and what role the sky played in their cultures. Here, we would deal with very distant past, i.e. with Prehistory, and with inheritance from this period. The Prehistoric man was unaware of vastness and nature of the heavenly space, but this very space was his immediate environment. He has nightly experience with stars, the Moon, comets, etc. On the other hand, the correlations between the Sun's (apparent) motion and the events on the Earth could not pass unnoticed. For every days life, it was of utmost importance to be able to read the messages from the Sky and infer the influences man could expect to suffer from the heavenly entities. It is this language of sky which is of primary interest here. The correlations between earthly events, in particular periodic changes and astral collective movements have been noted surely very early, possibly before Neolith, and the need for calendar forced humans to observe and record principal changes on the sky. These include short, medium and long period changes, like daily, monthly and seasonal changes, eclipses etc, as well as the unique events like passing of comets, novae, etc. The ability of heavenly events to catch the attention of prehistoric man depended on the frequency as well on the spectacular aspect of the phenomena. Daily changes were too frequent to figure prominently in the human mind, whereas motion with periods much longer than the duration of a generation, like equinoxes precession, were much more difficult to notice. Even if many successive generations were able to perceive those long-period phenomena they could hardly be able to pass the knowledge to other communities. The latter effect kept small communities (which prevailed during the Palaeolith and Neolith) isolated, what considerably slowed down the exchange of knowledge and the overall evolution of homo sapiens cultures. On the other hand the isolation effect kept many remarkable achievements of the prehistoric man hidden from our modern eyes and we are still discovering astonishing results "primitive societies" achieved. Many unexpected discoveries concerning archeological material make our remote past as unpredictable (better to say unretrodictable) as our future appears nonpredictable.

Once the sky has been lifted to a lofty level, it became profitable in many respects to link a number of earthly objects, and phenomena in general with heavenly entities. We shall consider here a number of instances where particular toponymes are coupled with celestial objects, mainly with the most prominent of them, the Sun.

2. THE WITNESSES OF THE PAST

Most of the Prehistoric culture has been preserved in the form of megalithic structures and cave paintings. In the first case, we will mention the most prominent site, Stonehenge, in comparison to less known ones. The cave painting will be discussed on the example of the famous Lascaux cave.

The megaliths (mainly from the Neolithic period) are found all over the globe. Beside Stonehenge in England (3500-2300 BC), there is a more recent similar structure at Sarmizegetusa in Romania (see e. g. Brown 1976, Hoyle 1977). At Brahmagiri in India there are stone circles dating around 900 BC (Rao 1999, Kak, unpublished), whereas at Wurdu Youang in Australia there is a pre-European stone structure built by aborigine people (Norris & Hamacher 2009). Most of these structures were relevant for astronomy: it was the need to "understand the language of heaven" which propelled the rise of astronomy in the prehistory. For example, at Stonehenge altitude, and only at this one, sighting lines of largest southerly monthly swing of the Moon and midsummer sunrise or sunset appear at right angles (Hoyle 1977, Figure 2.8). The axis of the horseshoe stone structure at Sarmizegetusa points towards midwinter sunrise, as compared with the same axis in Stonehenge, which points in the midsummer sunrise direction.

However, the earliest connections of the prehistoric man with night sky date from the Upper Palaeolithic. At that time, the painted walls caves flourished in several localities, including the North-West Europe. Caves are linked with night sky for obvious reason - they appear filled with darkness. If heavenly objects are to be reproduced, caves turn out to be the best places to choose. Their role was at least twofold: (i) as the canvas for paintings and (ii) as container which can "catch the sun-beam" at particular yearly instances, like equinoxes or solstices. Usually both instances used to be combined, so that "chosen cave" was decorated with figures, which we may interpret with astronomical or other meaning. Caves are linked with night sky for obvious reason - they appear filled with darkness. If heavenly objects are to be reproduced, caves turn out to be the best places to choose. Their role was at least twofold: (i) as the canvas for paintings and (ii) as container which can "catch the sun-beam" at particular yearly instances, like equinoxes or solstices. Usually both instances used to be combined, so that "chosen cave" was decorated with figures, which we may interpret with astronomical or other meaning.

The principal caves are found at south-east of France, in Vezere and Dordogne Valleys, as well as in the Cantabria, Spain. Some of them seem to be occupied by man from -35 000 years. (- sign means before present - BP.). Some examples are:

Chauvet (29 000 BC), Cosquer (23 000 BC) and Lascaux (16 500 BC) from France, and Altamira (34 000-15 000 BC) and El Castillo (39 000 BC) from Spain. In the following, we shall illustrate an astronomical explanation of the prehistoric painting on the example of Lascaux cave.

3. LASCAUX CAVE: A MAP OF THE SKY

This is actually a complex of caves near the village of Montignac, in Dordogne. The wall paintings, estimated -17 000 years old (belonging to the Magdalenien period), consist mainly of realistic images of large animals, mainly horses, bulls (aurochs) and deers (Fig. 1, Fig. 2) It is important to notice that there are no images of reindeers, the principal source of food for contemporary hunters. Hence the images do not represent hunted animals.

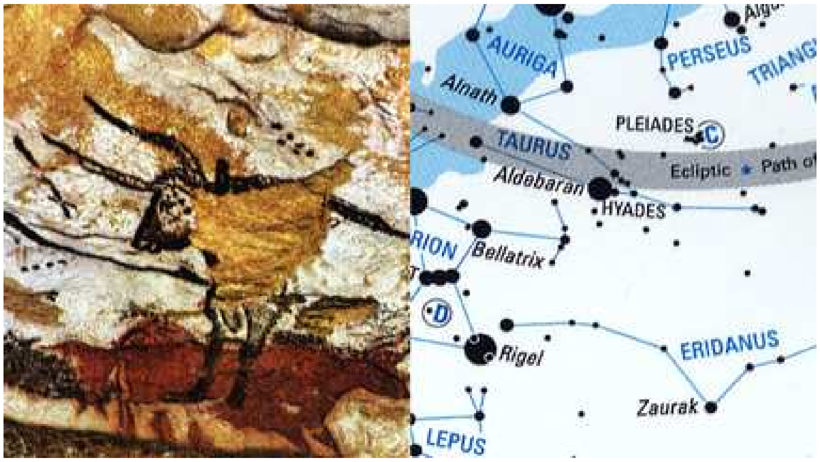

Figure 1: The prehistoric sky-map from Lascaux cave (detail, see text).

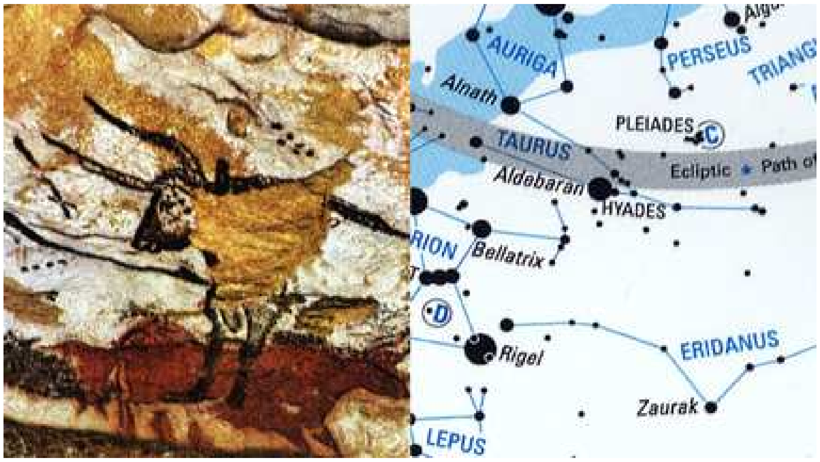

Figure 2: Lascaux cave paintings (detail, see text).

Several wall paintings were related to the night sky by some prehistory researchers. In the Hall of Bulls (Fig. 3) there are four black bulls or aurochs (a large species of wild cattle). The largest one is over 5 m long. According to the Spanish researcher Luz Antequera Congregado (doctoral thesis, 1992) the set of painted dots above the shoulder of the bull depicts the Pleiades cluster and the set of dots on the bull face (see Fig. 1) represents the Hyades constellation. Similar interpretations, including the correlations with the constellation of Taurus, are due to Rappenglueck and the American astronomer Frank Edge, as well as to some other researchers. Rappenglueck (1997) has also identified a star map from another painting, in the Shaft of the Dead Man (Fig. 4). The eyes of the lying birdman, the bull and the bird represented on this image would correspond to the three stars which were prominent in the spring 17 000 years ago. These are Vega, Deneb and Altair, known as the Summer Triangle, nowadays seen in the middle of the northern summer. Another idea of Rappenglueck is that some of the animal's paintings are symbolic representations of the phases of the Moon. The old lunar calendar would consist of groups of dots and squares painted alongside images of bulls, horses and antelopes, depicting the 29-day cycle of the Moon.

Figure 3: Hall of the Bulls (detail, see text).

Lascaux paintings can be considered as a proof that the beginning of the astronomical science dates before Babylonians (about 5000 BP). French ethno-astronomer, Chantal Jegues-Wolkiewiez noticed that the architectural structure of the Hall of Bulls makes an observer feels encapsulated, as if one watches the night sky motion from a hill. Looking at the various animals painted on the walls, she was able to recognize the zodiacal constellations of the Palaeolithic sky. To prove it, she had to use high-tech astronomical computer programs to reconstitute the map of the Magdalenian sky. She carried out numerous orientation measurements of the sets of dots and lines represented the painted animals, comparing the archeological and the astronomical data (Jègues-Wolkiewiez 2005). According to her one can recognize on the cave walls the stars forming the Capricorn, the Scorpio and the Taurus constellations. In the last case, the image of a bull was completed with the stars clusters Pleiades and Hyades.

"The paintings provide clear evidence that the artists were expert watchers of the sky, able to gather up these observations and inscribe them in the cave", maintains Jègues-Wolkiewiez. She found that the orientation of the cave was of primary importance. The plan and the section of the Lascaux cave entrance show that before the landslide blocked the access to the rotunda, at the time of summer solstice the rays of the setting sun would enter the cave and shine on the walls of the Great Hall of Bulls and on the axial diverticulum.

Figure 4: The prehistoric scene from Lascaux cave (detail, see text).

During the summer solstice 1999 Chantal Jegues-Wolkiewiez, and the Lascaux curator Jean-Michel Geneste, confirmed the above hypothesis: the setting sun illuminated completely the interior of the rotunda at the time of the creation of the images. This permitted painting under light during about one hour for several days in the beginning of the summer. Further, Jegues-Wolkiewiez verified that the similar phenomena occurred in other caves beside Lascaux. Actually, she found that the sunlight played the same role as in Lascaux in 137 other painted caves (Jegues-Wolkiewiez 2007). These caves were aligned with the sunrise or sunset on key days of the year - solstices or equinoxes. The Palaeolithic man could keep track of changing seasons by observing the sun sliding along the horizon as the months went by. This was important in connection with the migrations of the large mammal herds that they hunted. The accumulated astronomical knowledge passed from generation to generation without writing, in the "mythological" language of the Palaeolithic art. Not only astronomy, but also the mythology and legends of later periods, in Sumer, Babylonia, Mycenaean and Minoan civilizations and Egypt were most likely derived from the Palaeolithic proto-types represented in cave paintings (Brown 1976).

4. CONCLUSION

Passing from rural way of life into urbanization marked the transition from the prehistory to history, from the traditional society to the civilization. In this short essay we have argued that the same transition resulted in separation of man from the sky, a gradual moving of stars beyond the horizon of homo sapiense. This transition has been illustrated by a number of examples, some well known, like Stonehenge and Lascaux, whereas some recent research results are presented to illustrate that the archeology is still moving ahead by penetrating into our remote past. Archaeoastronomy appears as observational as anthropological research, examining the roots of our awareness of being an organic part of the Nature at large, of the Universe. Urban man has lost the night and thus the sky, except on the PC screen. To the "primitive man" sky was a paper to write and book to read, the language we have almost lost.

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COSMAS INDICOPLEUSTES AND HIS MODEL OF THE UNIVERSUM

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Abstract. The Nestorian Christian monk Cosmas the "Indicopleustes", wrote in 6th century the *Christian Topography*, a work through which he attempted to create a new system of geography and the representation of the World that would fit to the information contained in the Holy Scripture. His work and life, and his model of the Universum, are considered here.

1. INTRODUCTION

The first Christian centuries in the Empire, from the 3rd one to the 6th one, were those in which the new Christian religion had to consolidate its place as the dominant religion. Therefore, everything that seemed to contradict the Scriptures had to either disappear and be forgotten, or to be adapted to them. Therefore, since geography of the Greek and Hellenistic periods did not agree in several instances with the holy texts, and because the Scriptures could not be in error, geography as it was perceived at the time had to be harmonized with the holy texts of the new religion. This task was undertaken by a 6th-century Nestorian (heretic) Christian merchant, traveller and later monk in the Monastery of St. Catharine of Mt. Sinai. His name was Cosmas, the so-called "Indicopleustes" i.e. the one who had sailed to India.

Our full article on Cosmas Indicopleustes is published in Manimamis et al. (2013). Since this publication is not known in astronomical community, and work of Cosmas is of interest for the history of astronomy, we present here parts of our consideration, essential from the astronomical point of view. The more complete information is presented in Manimanis et al. (2013).

2. THE LIFE OF COSMAS INDICOPLEUSTES

Cosmas was of Greek origin and he became famous from the work he authored in the Monastery of St. Catharine around 547 AD. When he was still young, circa 520, he travelled as a merchant to the region around Egypt, i.e. the Red Sea (and to the east up to the Persian Gulf) (Cosmas, 1968, Book II, 29), the Kingdom of Axum and its vicinity (the region of the modern countries Ethiopia, Eritrea and Somalia) (Cosmas, 1968[2], Book II, 30), the Palestine and the Sinai peninsula (Cosmas, 1968, Book V, 8, 14, 51, 52).

After these first voyages and for about 15 years during the reign of Justinian I (527-565), Cosmas travelled in the Black Sea, east Africa and he sailed along the shore of the Indian Ocean, reaching India and Sri Lanka. For this reason he was later called Indicopleustes, not in the manuscripts about his work but around the 11th century (see e.g. Theodossiou and Danezis, 2010, p. 211).

Finally, our voyager returned to Alexandria and retreated to the famous Monastery of St. Catharine on Mount Sinai, where he became a monk in 535 and started to write down impressions and descriptions from his voyages around a large part of the then known world: He authored a geographical work entitled *Topographia Christiana* or simply *Cosmographia*, which consisted initially of five books, later of six and finally of twelve. With his *Christian Topography* Cosmas attempted to create a new system of geography, or just a representation of the World, in such a way that it would be in harmony with the teachings of the Holy Scripture. It is not absolutely certain that the name "Cosmas" was his real one; it is generally used because it is written in just one of the copies of *Topographia Christiana*, the one kept in Florence.

It seems that the writing of the Topographia Christiana was completed in the middle of the 6th century. According to Roger Pearce (2003): *The date of the work is fairly certain. In book 2, Cosmas tells us that it is 25 years since he was in Axum, and he was there when Elesbaas was preparing his expedition against the Homerites. That expedition probably took place in 525 AD, or possibly 522 AD. At the beginning of book 6, he refers to two eclipses, giving the dates as Mechir 12 and Mesori 24: these would seem to be the eclipses of 6 Feb. 547 and 17 Aug. 547. The logical inference is that the work was written around 550 AD.*

3. THE *TOPOGRAPHIA CHRISTIANA*

In the 12-book version of the *Christian Topography*, many useful pieces of geographical information are contained, which were correctly recorded by Cosmas as an in situ collector of information. He describes the places he visited himself, but also all what he heard about them by both the sailors and the inhabitants of these places. In addition, he drew many maps of these places and sketches of the peculiar animals he saw there. In parallel, he records valuable historical information of his age, since it is certain that he happened to *be there*, when historical events were taking place, such as the military preparations of the king of the Axumites, Elesba(a)s (or Kaleb or Chaleb) against the Jewish people of Yemen (the Homerites). Elesba(a)s, or Elesboas or Kaleb is honoured by the Ethiopian Church as a blessed person: his feast is on May 15. As a king of Axum (Aksum) in Ethiopia, he fought in 525 against the Jewish ruler Dhu-Nawas, who persecuted the Christians in Nedjran, a town in South-Arabia. Also, Emperor Justinian asked Elesbaas for his help against the Persians. Elesbaas lost a battle against an opponent, and retired to a cell near Axum. He died about 555. (Mertens, Article about: St. Elesba(a)s).

Cosmas had not received any special education (Cosmas, 1968, Book II, 1), and so it is natural that his work contains some very naive cosmographical views, which contradict the worldview of the great astronomer and geographer of the 2^{nd} century Claudius Ptolemaeus (Ptolemy). Cosmas outright condemns these views as "false".

The content of *Topographia Christiana*, being a compilation of various topics, does not really correspond to its title, but as a whole it does have an underlying aim: to set the foundations for a novel system of natural geography that would be totally based on the *Bible*. To this end, the polymath scholar and patriarch Photius I (820-893) of Constantinople calls *Topographia Christiana* a simplistic transfer of the descriptions of the *Pentateuch* and he characterizes Cosmas with some scorn as *closer to myth rather than to truth*(Theodossiou and Danezis, 2010, p. 211). Because his language is simple, Photius accuses him of "ignoring the Greek language" and concludes his mention to this work and its author by asserting that "[Cosmas] also writes some other, bizarre things" (Theodossiou and Danezis, 2010, p. 212).

4. THE COSMOLOGICAL VIEWS OF COSMAS INDICOPLEUSTES

Essentially, Cosmas is a zealot heretical (Nestorian) Christian, who has a tremendous zeal to defend the simple cosmology of the Jewish tradition. By combining his empirical geographical observations with certain Biblical references he accepts that, contrary to the then accepted Ptolemaic system that shape of the Earth is not spherical, but flat, long and narrow, like the tabernacle, the house of worship described to Moses by God during the Jewish Exodus from Egypt. In other words, according to Cosmas the Earth is a flat rectangular region - rectangular parallelogram. Similarly, the Universe is a two-floor rectangular parallelepiped box of vast volume, similar to the Arc of the Covenant, having the Earth as its base and the "first heaven" (the highest one) as its cover. This heaven is the one identified as the Heavenly Kingdom and it rests upon the firmament. The firmament in turn forms the "second heaven" which is the heaven of the mortals, in other words the kingdom of the Earth. In essence, this is a belief rooted in the ancient Egyptian cosmogony. The whole system is supported on its four edges, which, in the form of columns, rest upon the four "corners of the Earth" which, as we mentioned already, is believed by Cosmas to be a flat parallelogram area covered by the celestial dome, the firmament and surrounded by the ocean of the waters, beyond which the paradise is located. Cosmas believes that the flat Earth sits upon the bottom of the motionless Universe, which is also non-spherical: it is presented as a huge cubical chamber with a curved (concave) ceiling. Around a bell-shaped mountain towards the North, revolve the Sun, the Moon and the stars, tracing circular orbits, always in accordance with God's orders, who at any given moment can stop and redefine their course, as in the book of Isaiah, where the Sun moved backwards by 10 degrees:

> *I will make the shadow cast by the sun go back the ten steps it has gone down on the stairway of Ahaz. So the sunlight went back the ten steps it had gone down.* (The Holy Bible, 1984, Isaiah 38:8)

...and as happened in Gibeon, when Joshua, holding his hands outstretched during the battle of the Israelites with the Amorites, stopped the course of the Sun:

> *On the day the Lord gave the Amorites over to Israel, Joshua said to the Lord in the presence of Israel: "O sun, stand still over Gibeon; O moon, over the valley of Aijalon." So the sun stood still, and the moon stopped, till the nation avenged itself on its enemies, as it is written in the book of Jashar? The sun stopped in the middle of the sky and delayed going down about a full day.* (The Holy Bible, 1984, Joshua 10:12-13)

The Sun approaches alternatively the peak and the base of the bell-shaped mountain. This way Cosmas explains the succession of day and night. When the Sun shines and illuminates our part of the Earth, we have day, yet the tall bell-shaped mountain in the north prevents the rays of sunlight to shine on the regions of the Earth that are beyond the other side of the mountain, so darkness prevails upon these lands.

In summer, according to Cosmas, the Sun revolves around the narrow peak of the mountain, and therefore disappears from our view only for a short time span, since this part of the revolution was short; but in winter the Sun revolves around the wide base of the mountain and so the winter nights are longer than the days, since the revolution of the Sun around the huge base of the mountain lasts for a much longer time span.

In addition, Cosmas writes that the stars and the planets do not move by themselves, but they are moved by the "planetary angels", a belief that reached even the 17th century, the age of Johannes Kepler, the "law giver of the skies".

Despite its naive character and its extravagant statements, the *Topographia* was, and still is, important, not for his beliefs about the nature of the world, but for the valuable geographical, cultural and historical information it contains, which is based on his own experiences as an eye witness of the countries he travelled. His popular writing style made the Christian Topography a favorite reading among the less educated Byzantines, since it agreed with their daily experience.

However, most of the Byzantine scholars, rejected his views in the name of the Aristotelian-Ptolemaic Universe. For this reason, in the 12^{th} book, Cosmas tries to counter the criticism of other scholarly monks and the Christian Byzantine savants, who did not agree with his views. In the 11^{th} book he describes certain ports of India's west coast, where ships were loading pepper, and he also offers significant information about Sri Lanka, which he calls Taprobane: He explains its significance for commerce and he notes that on this island there existed a community of Nestorian Christians.

5. EXISTING COPIES OF *TOPOGRAPHIA CHRISTIANA*

The work of Cosmas, *Topographia Christiana*, is saved in three basic copies. One is in Vatican, it is the code Vaticanus Graecus 699, and it was written in the 9th century in Constantinople; it contains only the first ten books. The other two existing copies of the Topography contain all 12 books. They were both dated to the 11th century. The first one is an illustrated manuscript kept in the Monastery of St. Catharine on Mount Sinai (No. 1186), yet it is considered to be a copy written in Cappadocia. The second one, the code *Laurentianus Plutei IX. 28*, is kept in Florence, but it was written in the Iviron Monastery of Mt Athos. However, there are many more (at least 20) manuscripts that contain minor parts of the Topographia.

In Serbian, Christian Topography was translated in 1649, by monk Gavrilo Troičanin, in the Monastery of Holy Trinity, and illustrated by Andrija Raičević (Janković, 1989, p. 34). On the influence it had on the formation of erroneous comprehensions, witnesses the manuscript where Cosmas is named the Saint (Stojanović, 1903) as well as some icons and frescoes in Serbian monasteries where the Earth is represented as a flat tablet with a cone like mountain according to Cosmas (Janković, 1989, p. 37).

Cosmas also wrote other works, such as *Geographia* (Cosmographia) and *Astronomia* (astronomical tables), but these were lost; however, besides *Topographia Christiana*, there is one more work by Cosmas that was saved: this is the *Description of the Plants and Animals of India.*

6. CONCLUSIONS

For Cosmas the secular wisdom is of no value whatsoever; he elaborates on another logic, in which everything is explained with the use of the sacred texts and especially with the *Old Testament.* His views about the world are based on the theory of the flat Earth, which, in general, is supported by a literal interpretation of the holy texts of all three major monotheistic religions (Judaism, Christianity and Islam). Thus, a considerable part of the work written by Cosmas has as its deeper purpose to lay the foundations of a system of natural geography based on the *Bible.* For this reason, the scholarly patriarch Photius (810-891) labels *Topographia Christiana* as a naive interpretation of *Pentateuch's* contents and he looks down on Cosmas, writing about him rather scornfully.

Cosmas considerably influenced the simple, uneducated members of the lower priesthood, as well as the naive, uneducated laypersons in the Byzantine Empire, because his *Christian Topography* was an original and interesting work that contained a wealth of information of travel-oriented geographical and commercial interest given in a simple language, a fact that made it an easy-to-read and interesting work. While in its age it captivated its readers with its descriptions of exotic places and animals, which always fascinate the wider populace, it is still of interest to modern research scholars and scientists, since the Christian Topography continues to be a valuable source for the history of science, commerce and the sea routes of that remote period.

It should not be overlooked that the voyage of an average person to the kingdoms of east Africa, the Red Sea, the Palestine, to Mount Sinai, to the Arabian kingdoms, the Persian Gulf, and especially to India and Sri Lanka was an almost impossible feat.

The Topography of Cosmas, apart from its simplistic cosmology, is a significant opus, since it allows the modern reader to take a look upon the world of the sixth century, or at least upon a large part of it, through the pen of an *eye witness* who lived 15 centuries ago, complete with maps, sketches and drawings that decorate and strengthen the text.

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МОБИЛНИ ПЛАНЕТАРИЈУМ КАО НАСТАВНО СРЕДСТВО И СРЕДСТВО ЗА КОМУНИКАЦИЈУ

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Abstract. In the past five years (2009-2014) Astronomical Society “RudjerBoskovic” and Society of Astronomers of Serbia use the mobile planetarium as a tool for astronomy communication. During the 2013/2014 school year this modern technical equipment has been used in schools as an educational tool in the term of correlation with teaching subjects and particular lessons (geography, physics, mathematics, chemistry, history, biology, world around us, nature and society, literature and art). As we reached 15000 schoolchildren and 500 teachers, detailed analysis of these activities will be presented and discussed.

1. ОД СТАЦИОНАРНИХ ОПТИЧКО-МЕХАНИЧКИХ ДО ПОКРЕТНИХ ДИГИТАЛНИХ ПЛАНЕТАРИЈУМА

Планетаријумом бисмо могли назвати сваки покушај човека да на неки начин направи имитацију звезданог неба, небеске сфере и кретања небеских тела. Најранија позната макета звезданог неба пронађена је у Египатској гробници Сен-ен-мунт, 1500 година п.н.е. Механички модел (тзв. „Орариjум”) који је развио Еисе Есинг у Холандији (1744-1781), ради попут сатног механизма демонстрирајући кретања Земље, Месеца, Сунца и унутрашњих планета Сунчевог система.

Астроном Корнелијус Волф 1910. ради на теоријским решењима првог пројекционог уређаја који приказује небески свод, сазвежђа, кретања звезда и планета. Волтер Бауерсфелд, механичар и оптичар у периоду од 1912–1923 радина практичној реализацији Волфове идеје и конструише први планетаријумски пројектор као сложен оптичко-механички систем (на крову источно немачке компаније *Carl Zeiss*у Јени под куполом од 16 m пројектовано је 4900 звездаза одређену географску ширину). Модели који приказују звездано небо закуполе мање од осам метара (са ручном променом географске ширине 0°<φ< 90°) почели су да се производе 1953. године као модел *ZKP 1(Carl Zeiss Kleine Planetarium 1).*Овај модел је од 1969. године у употреби у планетаријумуАстрономског друштва „Руђер Бошковић”(АДРБ) на Калемегдану (фиксни планетаријум). У периоду од 2000–2014 забележено је 25000–40000 посетилаца сваке године. Слични модели су у свету изашли из употребе пре двадесетак година (Stanić, 2007).

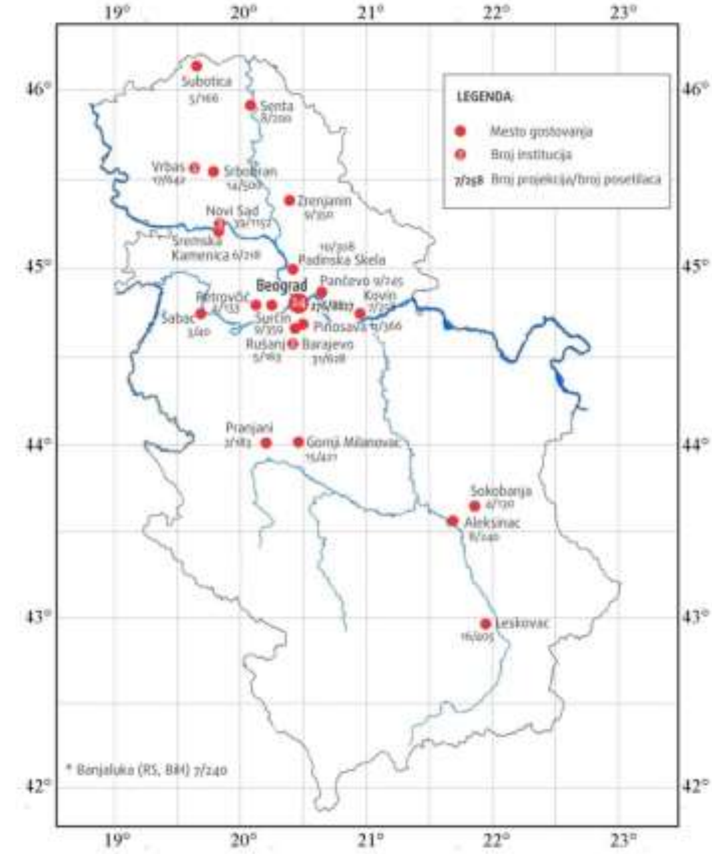
Компанија *Learning Technologies Inc.* у Масачусетсу (САД) дизајнира први преносиви покретни планетаријум 1977. године (патент Филипа Садлера) који пројектује звезде, фигуре сазвежђа (различитих митологија) и координатне системе. Данас постоји више десетина успешних произвођача мобилних планетаријума са пратећом опремом, даљинским управљањем, *full dome* видео пројекцијама (пројекције на полусферну куполу), компјутерском графиком, ласерским ефектима и куполама на надувавање различитих димензија.

2. КРАТКА ИСТОРИЈА РАДА МОБИЛНОГ ПЛАНЕТАРИЈУМА У СРБИЈИ

Почетком 2008. године, у оквиру припрема за обележавање Међународне године астрономије 2009 у Србији, написан је пројекат „First Mobile Planetarium in Serbia"са којим је Друштво астронома Србије конкурисало за донацију UNESCO Participation Program 2009, са циљем да се унапреде методе популаризације астрономије и започне процес увођења савремених планетаријумских технологија у наставни процес (Станић, 2010). Превод пројекта на енглески реализовао је др Слободан Нинковић,у припреми документације (стратешки план коришћења у школама широм Србије, очекивани резултати пројектаи др.) учествовали су др Олга Атанацковић (председник Националног комитета за астрономију), др Зорица Цветковић (председник Друштва астронома Србије) и аутор пројекта мр Наташа Станић.Национална комисија UNESCO-а за Србију, на челу са др Зорицом Томић, рангирала је пројекат на друго место по приоритету за 2009. годину.

Остварена је донација од 24500 $, која је искоришћена за набавку надуваавајуће куполе и дигиталног пројектора *Digitarium CU-1* произвођача *Digitalis Education Solutions Inc.* као прво инострано улагање на пољу популаризације астрономије.У периоду 2009–2012, мобилни планетаријум представљен је публици на фестивалу науке, јавним скуповима, конференцијама и манифестацијама, као и у многим школама на територији Србије (предавачи Горан Павичић и Јован Алексић).

Од марта 2013. године, посете школама постају редовна активност АДРБ (предавачи Александар Оташевић, мр Наташа Станић, Јован Алексић и Дарко Стругаревић). На тај начин,школе без додатних путних трошкова и организовања екскурзија (или излета) у фиксни планетаријум у Београду,уводе савремену планетаријумску технологију директно у наставни процес.За годину дана реализовано је 50 посета у 22 града. Пројекције дигиталног мобилног планетаријума видело је 16174 посетиоца, од тога 15000 деце основношколског узраста (сл. 1).



Слика 1: Размештај места у Републици Србији у којима је гостовао мобилни планетаријум (април 2013 – јун 2014).

3. МОБИЛНИ ПЛАНЕТАРИЈУМ КАО НАСТАВНО СРЕДСТВО

Организација.Предавања се реализују у просторијама школе, у оквиру редовне наставе, под називом „Школа као прозор у свемир” (Станић, 2014). Према договореном распореду, наставници са ученицима присуствују уводном предавању о технологији која се користи, темама које ће бити заступљене, активностима АДРБ (бесплатним курсевима астрономије, посматрањима телескопом са терасе Народне опсерваторије, летњим школама) као и о правилима за безбедан улазак и боравак у куполи.

Садржај предавања.У првом делу предавања (20 минута) обрађују се теме и појмови који су у корелацији са наставним садржајима из области природних наука (Станић, 2010). Предавање почиње причом о привидном дневном кретању Сунца. Затим се демонстрира ноћно небо и уводи појам небеске сфере, хоризонта и зенита, на основу чега се прати привидно дневно кретање небеских тела и наводе узроци и последице тог кретања (Земљина ротација, смена дана и ноћи). Уз причу о сазвежђима, као замишљеним сликама на небу које не представљају реалне физичке објекте (Станић и Тадић, 2005) уводе се основни појмови оријентације у простору – проналажење Северњаче и страна света, упознавање циркумполарног неба, небеског екватора и еклиптике. Дуж еклиптике поређане, планете Сунчевог система се најпре посматрају онако како би се виделе голим оком са Земље, а затим се, уз помоћ дигиталног увеличавања, видно поље сужава до изабране планете чије се карактеристике описују у складу са узрастом и заинтересованошћу присутне групе. Сценарио предавања предвиђа и упознавање Месијеових објеката, са посебним освртом на врсте, састав и особине галаксија. Необично звездано путовање (Станић, 2004) завршава се причом о Хабловом дубоком пољу и објектима на самом рубу свемира.

За ученике VII и VIII разреда детаљно се описује процес стварања хемијских елемената, од великог праска до експлозија супернових, као и њихова релативна заступљеност у свемиру.

У другом делу предавања,који траје 10 минута, (за ученике од I до VI разреда) пројектује се филм „Премеравање свемира” (*“Sizing Up Space”*). Пројекцију првих*full dome* филмова омогућили су сарадници АДРБ Јован Алексић и Бранко Симоновић.Јован Алексићје анализираои прегледао велики број филмова у бази бесплатних кратких образовних *full dome* филмова на интернету, изабраои превео неке од њих. Према урађеном преводу, Бранко Симоновић је изговорио текст који прати филм и снимио звучни запис, након чега су заједно извршили синхронизацију слике и звука, па се може рећи да је у оквиру АДРБ реализована и прва стручна припрема планетаријумских филмова у Србији.

Време трајања једног предавања је 30 минута, а број присутних ученика ограничен је на једно одељење (30 ученика). На пројекцијама је обавезно присуство предметног наставника који у дневник уписује наставну јединицу која је у корелацији са садржајем предавања.

Методички приступ. предавање се непрекидно одвија у атмосфери неформалног разговора. Предавач поставља питања, ученици одговарају или сами постављају питања на основу информација које добијају током излагања предавача. Хумор, асоцијације, поређење појава из свакодневног живота са појавама на небу, знатно повећавају успешност стицања нових знања и усвајања великог броја нових (научних, астрономских) појмова за веома кратко време (Станић и Тадић 2014).

После завршеног предавања ученицима се дају смернице (литература, интернет адресе итд) за будући рад и препоручују посета Народној опсерваторији на Калемегдану (где се уживо врше посматрања небеских тела) и фиксном планетаријуму (Курс астрономије за почетнике, Београдски астрономски викенд, Летњи астрономски сусрети).

Циљеви увођења планетаријумске технологије у план и програм редовне наставе за ученике основне школе.Основни циљ организованих посета мобилног планетаријума је повећање научне свести (код ученика и наставника), односно свести о томе да живот на Земљи зависи од њеног космичког окружења и да је развој науке и научног погледа на свет неопходан за опстанак на планети (Станић, 2009).

Слика 2: Монтирање куполе од платна (1-2-3); група ученика која испред куполе чека почетак уводног предавања са упутствима за безбедан улазак (2); предавачи Оташевић А., Станић Н. (3); купола од платна (звездани шатор) са групом ученика унутра (4).

Повећање научног знања (познавање што већег броја научних чињеница и њихово међусобно повезивање у трајан систем знања), стимулисање младих генерација за бављење природним наукама и даља научна истраживања, покретање процеса креативног решавања проблема су имплицитни циљеви који се систематски остварују у директном контакту са слушаоцима.

Сви поменути циљеви успешно су реализовани током једногодишњег циклуса рада покретног планетаријума, што потврђују коментари самих ученика после предавања: „Не бих никада излазио из ове учионице”; „Ово је нешто најбоље што сам видео у школи”, „Cool”, „Страва”, „Јел’ могу да останем са вама и да не идем на оне досадне часове где се само пише и пише?”и сл.

4. МОБИЛНИ ПЛАНЕТАРИЈУМ КАО СРЕДСТВО ЗА КОМУНИКАЦИЈУ

Као што добра комуникација између наставника и ученика представља суштину квалитетног наставног процеса, тако и комуникација између предавача у планетаријуму и слушаоца омогућава висок степен усвајања знања. За потребе анализе успеха на крају првог циклуса предавања са коришћењем дигиталне технологије одабрано је четири критеријума на основу којих се процењује и врста остварене комуникације.

I критеријум: ниво учешћа слушаоца у предавању. Током предавања у мобилном планетаријуму доминирају, не монолог, него дијалог и дискусија. Таквом комуникацијом могуће је готово тренутно добити повратну информацију о наученом и усвојеном градиву, што је за рад предавача од велике важности (Christensen, 2007).

IIкритеријум: коришћење техничких алата. Знање и чињенице преносе се путем техничке опреме: 1) компјутер са софтверским пакетима за симулацију небеске сфере, сазвежђа, планета, Сунца, маглина, галаксија; 2) пројектор који примљену слику (информацију, податак) у пикселима, претвара у визуалну информацију и емитује је у снопу светлости великог интензитета у простор око себе; 3) испупчено сочиво које прима сноп светлости из пројектора (спој пројектора и сочива најсложенији је део система мобилног планетаријума) и након проласка снопа светлости кроз расипно сочиво, ствара слику на унутрашњости полулоптасте куполе; 4)платнена купола која представља пројекциони екран, односно сферни застор на који се пројектује слика из сочива; 5) вентилатор за упумпавање ваздуха у куполу преко бочног ваздушног тунела. Да би систем успешно радио, све наведене компоненте техничке опреме морају бити међусобно фино усклађене. Могући проблеми током техничке реализације су прегревање лампе пројектора, померање фокуса пројектора, оштећење сочива прашином која пада на њега, неефикасно хлађење пројектора због блокаде прашином елиса вентилатора. Због коришћења сложених алата, комуникација између предавача и слушаоца преноси се уз помоћ наведених техничких алата, па се зато назива и технички медијатизована комуникација (Lantz, 2002).

IIIкритеријум: вербални материјал. С обзиром да се користе и вербални (текст, бројке, слова, различити подаци и информације) и невербални материјали (слике) тип комуникације са слушаоцем је двојног карактера – вербално-невербални.

IVкритеријум: врсте чула које се користе. Према овом критеријуму комуникација је визуална, пошто визуална информација (дражење чула вида) има далеко већи интензитет и утицај на нашу пажњу него информације које добијамо путем осталих чула (слуха, додира, укуса и мириса). Због тога је тип комуникације претежно визуалан, ученике можемо назвати гледаоцима (Fries, 2010).

ЗАКЉУЧАК

Мобилни планетаријум је својеврсна мултимедијална учионица под звезданим шатором са којом предавачи долазе ученицима (а не обрнуто) и предавање изводе у њиховим школама, у оквиру редовне наставе, тако да школе успешније реализују наставне планове и програме, уз мање трошкове.

У мобилном планетаријумусе остварује процес учења путем увиђања, као најквалитетнијег облик учења који повећава ефикасност дугорочног памћења (смањује ефекте заборављања). Визуелни ефекати, покретне слике, музика и укупни утисак зачуђености (који директно стимулише креативно решавање проблема и дивергентно мишљење) чине ефикасним трансфер знања из мобилног планетаријума у учионицу, или неку нову свакодневну ситуацију у природи.

Учењем кроз забаву, визуализацију и музику, која знатно доприноси динамици предавања и опуштеној атмосфери, деца демистификују звездано небо, развијају рационално мишљење и одбацују сујеверје, то јесте, откривају лепшу и забавнију страну науке од оне која се изражава строгошћу, прецизношћу и која се реализује методом „екс-катедра” („ћути, слушај и памти”).

Визуализација небеских тела и митологија сазвежђа, поред тога што задивљују дечији ум и развијају способности за дивергентно мишљење и креативно решавање проблема, могу бити инспирација за уметничке визије васионе (корелација са ликовном уметношћу) и креативно писање (корелација са књижевношћу).

Под планетаријумским „звоном” предавачи младим генерацијама популаришу астрономију, и преносе на њих свој ентузијазам и радост истраживања. Да би могли наставити са својим племенитим радом, у условима који владају у Србији данас, неопходне су иновације у планирању, организацији и реализацији наставног процеса у амбијенту мобилног планетаријума.

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СУНЧАНИ ЧАСОВНИК КАО СРЕДСТВО КОМУНИКАЦИЈЕ

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Abstract. "It is undoubtedly true that teaching with sundials would be easier and more effective than with books and other tools" – said professor V. V. Miskovic long time ago (1931) when he commented letters from teachers who asked him for advice in sundial construction for schools. Inspired by this comment and starting with the motto "Umbra docet" (written on many sundials) we discuss a sundial as a multifaceted means of science communication.

Nowadays the word "communication" is often widely used in various fields of human activity in the different meanings – as a connection of one object (or subject) with another (in social meaning), or as a process. Information exchange (communication as a process) can take place immediately, with the help of language, or indirectly - by means of certain technical equipment and supplies. In this paper we deal with technically mediated communication, in which the mediator (tool), is sundial.

We look at a sundial in two perspectives: 1) as an aid in teaching and popularizing astronomy in the classroom, astronomy courses, planetarium lectures etc) and 2) as an instrument which communicates with the user/viewer by all its elements - written message, artistic impression, technical solutions, settings (area, place, institution, constructor and particular historical moment) in several levels – educational, artistic, scientific, phylosophical and spiritual. Unlike direct communication, where communicator (teacher) have to be physically present in the process of communication, sundial offer indirect communication with the general public for many years and even further than one epoch of time.

This work includes an overview of all cuntructed sundials on theritory of Republic of Serbia (detailed map will be given and presented), especially in schoolyards and other cultural institutions.

1. СУНЧАНИ ЧАСОВНИЦИ НА ОБРАЗОВНИМ УСТАНОВАМА У СРБИЈИ

Према нашој евиденцији (септембар, 2014) на простору Србије постоји најмање 82 стационарна сунчана часовника. Од тога, само је један старовековни („Музеј Срема”, Сремска Митровица) и један средњовековни

(Манастир Студеница), три су из 18. и шест из 19. века; сви остали су млађи од 100 година, а већину чине сунчани часовници постављени у последње две деценије. Према начину конструкције највише је зидних сунчаних часовника (68) урађених у различитим техникама, десет је аналематских, два су скулптуре у слободном простору, и два екваторијална (Београд, Ниш).

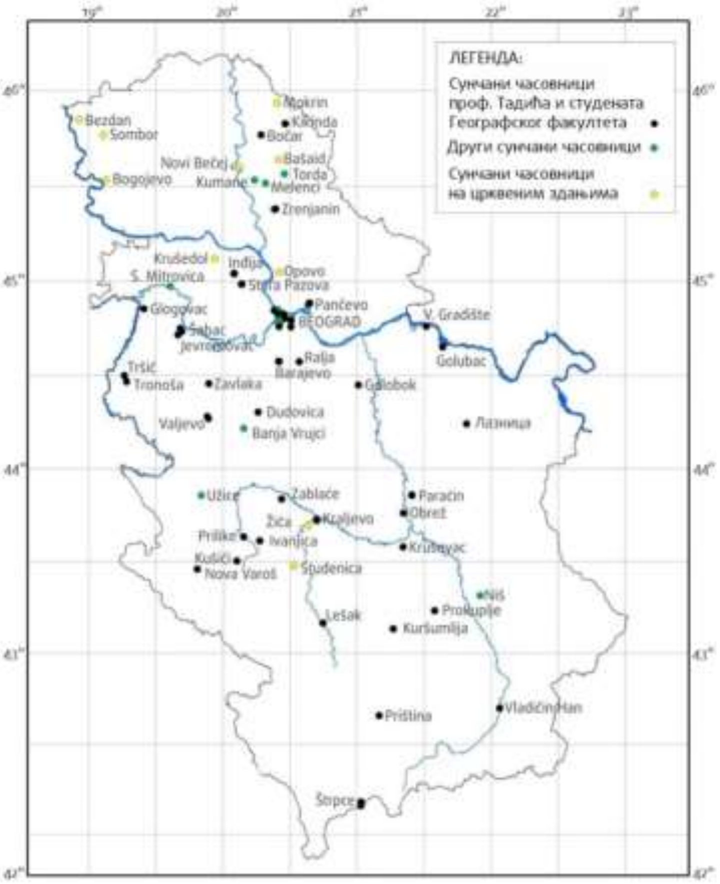
За ову тему битно је нагласити да се од укупног броја сунчаних часовника у Србији више од половине налази на зградама (зидни) или у двориштима (аналематски) образовних институција, а већина их је плански урађена школске 2012/13. и 2013/14. године, као практични радови студената Географског факултета у Београду, у склопу предмета Математичка географија, под менторством предметног наставника (сл. 1). Тако студенти, будући професори географије, кроз друштвено користан рад уче „занат”, док школама остајали сунчани часовници, као учила и украси. Осим зидних, студенти географије у последњих петнаестак школских година на вежбама из поменутог предмета обавезно праве преносиве хоризонталне сунчане часовнике. Сличне часовнике већ неколико година израђују основци у склопу наставе физике или географије (на пример, у ОШ „Свети Сава” у Београду, наставник мр Наташа Станић) (сл. 2.а) или у оквиру астрономских радионица: са „Научног пикника 2012”, око 350 основаца је понело кући хоризонталне сунчане часовнике које су сами направили у склопу програма радионице коју су одржали Центар за популаризацију науке „СФЕРА” (мр Наташа Станић) и Астрономско друштво „Руђер Бошковић” (мр Александар Оташевић).

Вештина градње сунчаних часовника постаје све популарнија (Тадић, 1989), и све више наставника у Србији је уводи у наставну праксу. А да ли данас конструкција школских сунчаних часовника представља анахронизам? Каква још може бити корист сунчаног часовника у добу дигиталне комуникације?

2. КОМУНИКАЦИОНЕ ОСОБЕНОСТИ И САДРЖАЈ СУНЧАНОГ ЧАСОВНИКА

Сунчани часовник, заједно са небеским глобусом и обртном картом звезданог неба, претечом планетаријума (Станић, 2009), те репликама античких астрономских инструмената, спада у „старинска” школска помагала, из времена пре дигиталне комуникације. Оставивши по страни комуникацију која се одвија између наставника физике и географије, и њихових ученика (у општем случају – између предавача и групе), окупљених око конструкције сунчаног часовника (Тадић, 2013), која [конструкција] ту комуникацију чини двосмерном, дијалошком, овога пута пажњу ћемо усмерити на комуникацију конструктора сунчаног часовника, то јесте – самог сунчаног часовника као његовог дела, са корисником, посматрачем.

Према критеријуму мере учешћа у процесу, то је *монолошка комуникација* јер информације теку само на једну страну, према критеријуму коришћења техничких средстава ради се о *технички посредованој* (медиатизованој) комуникацији, јер се информације не преносе непосредно (говором), према критеријуму коришћења вербалног материјала истовремено спада и у *невербалну* (прекослика) и у *вербалну* (преко натписа) комуникацију, а према критеријуму искоришћавања чулних органа – у *визуелну комуникацију*.



Слика 1: Карта размештаја сунчаних часовника на простору Србије (септембар 2014).

Комуникациона својства сунчаног часовника условљена су вишеслојношћу његовог садржаја којег, у општем случају чине: 1) егзактни садржај (астрономски или математичко географски, свеједно); 2) ликовни (декоративни) садржај; 3) писани садржај; 4) сенка. Сваким од њих, и свима њима заједно, сунчани часовник преноси одређене информације, то јесте, комуницира са корисником (сл. 2: b, c, d).

Конструктори користе све ликовне технике да би сунчани часовник био, не само буде тачан, него и леп за око. Информације које корисник прима преко усклађеног егзактног и ликовног садржаја спадају у визуелну невербалну комуникацију.

Сунчани часовници неретко садрже мото – кратки натпис (мисао, изреку, пословицу, цитат) којим конструктор шаље кориснику одређену поруку, некада директно, а некада говори у име сенке (Gatty, 1900). Преко порука корисник ступа у вербалну комуникацију са сунчаним часовником (конструктором).

Сенка на сунчаном часовнику, његова нематеријална казаљка, условно спада у егзактни садржај јер су њена величина и путање унапред израчунате.

3. ДИЈАЛОГ ПРОНИЦЉИВОГ ПОСМАТРАЧА И СУНЧАНОГ ЧАСОВНИКА

Лица: *УЧЕНИК ОСНОВНЕ ШКОЛЕ, тинејџер, загледан у линије и сенке осликаног зидног сунчаног часовником (сличног часовницима на сл. 2), на коме је уписан мото; КОНСТРУКТОР СУНЧАНОГ ЧАСОВНИКА, „скривен” иза сенке сунчаног часовника*

УЧЕНИК: Зашто је шипка која баца сенку закошена?

СЕНКА: Шипка је паралелна ротационој оси Земље, односно, постављена је тачно у небеску осу. Зато се и назива полос (грч. *πόλος – ротациона оса, небеска оса*). Продужена ка горе, завршила би у северном небеском полу (приближно – у Северњачи), а продужена до тла, заклопила би са равни хоризонта угао једнак географској ширини места.

УЧЕНИК: Зар није једноставније поставити шипку ортогонално на основу сунчаног часовника, рецимо, вертикалан штап (гномон) на хоризонталну основу?

СЕНКА: Јесте, али тада треба конструисати посебну скалу на којој се дневни часови очитавају, не према правцу сенке, како смо навикли, него према положају њеног краја. Додуше, на посебној врсти хоризонталног сунчаног часовника, аналематски часовници, часови се очитавају према правцу сенке корисника али он мора мењати стајну тачку током године. Аналематски часовници јесу занимљиви јер анимирају корисника, али више служе за забаву него за мерење времена.

УЧЕНИК: Шта представљају праве линије које се зракасто разилазе из тачке у којој је учвршћен полос.

СЕНКА: Полос сунчаног часовника се налази у небеској оси дуж које се секу деклинациони кругови небеске сфере. Истих дневних часова, сунце се увек налази на истим деклинационим круговима, тако да су њихове равни у једно и равни сенки полоса, а пресеци са основом сунчаног часовника – часовне линије сенки. Или, тачније, часовне линије су *гномонске пројекције* одговарајућих лукова деклинационих кругова небеске сфере. Заједно чине прамен правих чији је центар пол сунчаног часовника (тачка у којој је фиксиран почетак полоса).

УЧЕНИК: Како се очитавају дневни часови?

СЕНКА: Дневне часове показује правац сенке полоса, то јесте, положај сенке унутар прамена часовних линија. Очитавање се врши на бројчанику чије се цифре налазе на часовним линијама.

УЧЕНИК: Шта представља права линија која попреко сече часовне линије, а шта криве линије с обе стране те праве линије?

СЕНКА: Поменута права линија јесте гномонска пројекција лука небеског екватора, док су криве линије, хиперболе, пројекције небеских повратника. Или, то су гномонске пројекције дневних лукова привидних путања сунца за еквинокцијума и солстицијума (којима се могу додати и хиперболе за било који други дан у години). Једним именом, то су датумске линије које, заједно са часовним линијама чине часовну мрежу сунчаног часовника.

УЧЕНИК: Како сенка показује поменуте датуме?

СЕНКА: Солстиције и еквинокцијуме показује сенка *нодуса* (прстена, куглице, стрелице), ходом по одговарајућој датумској линији. Нодус се дограђује на одређено место полоса (не мора бити на врху полоса).

УЧЕНИК: На једном сунчаном часовнику стоји натпис – *Пре него провериш да ли сам ја у реду, прво провери да ли си ти у реду!* Шта је смисао те поруке.

СЕНКА: Натпис је шаљив (Станић и Тадић, 2014), а заснива се на уобичајном „потезу” посматрача пред сунчаним часовником: прво шта уради јесте да погледа на свој ручни часовник, да провери тачност сунчаног часовника. А та тачност је релативна: сенка сунчаног часовника показује право сунчево време, док наши часовници показују појасно средње сунчево време. Разлика је сваки дан другачија и у крајњем случају (место на граници часовне зоне) може достићи и 45 min; у најбољем случају, разлика се може свести на вредност временског изједначења (±15 min).

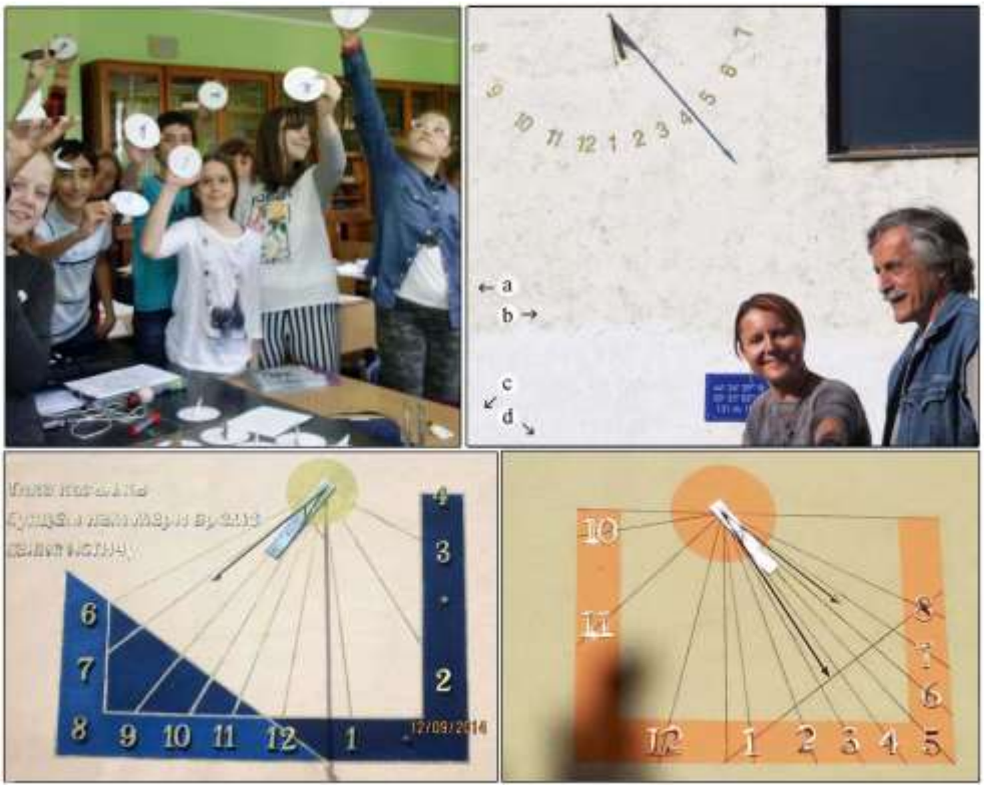
УЧЕНИК: Шта је затворена крива линија која се обавија око часовне линије за 12 х?

СЕНКА: То јепосебна врста часовне линије, *аналема*, скуп тачака сенки нодуса тачно у 12 х. Одређеног дана, долазак сенке нодуса на одговарајући лук аналеме, објављује да је тачно12 х одговарајућег појасног времена.

УЧЕНИК: Зашто часовници немају аналеме за сваки дневни час, били би „тачни”?

СЕНКА: Постоје такви сунчани часовници али им је часовна мрежа сложена и разумљива само малом броју корисника.

УЧЕНИК: Зашто је нацртана Земљина лопта, из чијег пола полази полос... зар лепше не изгледа стилозовани сунчав диск?



Слика 2: Ученици ОШ „Свети Сава” у Београду са сунчаним часовницима које су направили на часу физике са наставницом мр Наташом Станић (a); зидни сунчани часовници које су направили аутори овог рада пред 17. Националну Конференцију астронома Србије: Центар за културу Барајево (b), ОШ „Васа Живковић” у Панчеву (c), ОШ „Душан Јерковић” у Инђији (d).

СЕНКА: Полос који полази из центра сунчевог диска, или полос који је у компонован као стрела којом је прободен лико дређеног светитеља, могу бити занимљиви посматрачу, али нису занимљиви са астрономског становишта, не носе астрономску поруку.

Већ је друго ако полос, на пример, полази из пола Земљине лопте приказане у некој перспективној пројекцији: тако постављен, полос сугерише посматрачу свој положај у простору, паралелан Земљиној ротационој оси, и упућује га на принцип рада сунчаног часовника. То је још ефектније код вајарски обликованих сунчаних часовника, код којих полос полази из пола извајаног глобуса.

УЧЕНИК: На шта је циљао конструктор, када је на сунчаном часовнику написао – *Овако се свет окреће?*

СЕНКА: Натписи на сунчаним часовницима углавном су занимљиви и лепи, али са астрономске тачке гледишта не увек и сврсисходни. Натпис – *Дело Сунца и уметности* – већ се односи на сам сунчани часовник, натпис – *Показујем време, а ти?* – говори о сврси часовника, натпис – *Који је час? Види сенку!* – о начину очитавања, док се натпис – *Сунце је приморано да се влада по правилима дана* – већ приближава суштини сунчаног часовника. Међу свима њима, натпис – *Овако се свет окреће!* – јесте пример астрономски сврсиходног натписа јер кориснику указује суштину сунчаног часовника. Око полоса, као материјализоване небеске осе, привидно се окреће небеска сфера са свим небеским телима пројектованим на њу, укључујући и сунце: плански „ухваћена” у часовну мрежу, сенка полоса репродукује привидно кретање сунца, односно, стварно окретање планете Земље (нашег „света”).

УЧЕНИК: Шта је онда сунчани часовник – часовник, украс, учило?

СЕНКА: Сунчани часовник је све то заједно: показује дневне часове и изабране датуме, украшава зидове грађевине, паркове и тргове, и подучава проницљивог посматрача. Вештина градње сунчаних часовника јесте, према томе, и наука и примењена уметност, или „научна забава”, како ју је давне 1931. године лепо дефинисао професор Војислав В. Мишковић.

ЗАКЉУЧАК

Сунчани часовници су сведени на јасну визуелну форму која укључује графику (слику), текст и сенку, сложене у складну целину. Постављају се на јавним местима, најчешће на зидовима, тако да су уочљиви издалека. Осим што су часовници, они имају декоративну и образовну улогу: украшавају и оживљавају фасаде грађевина и градске тргове, и посматрачу лаконски преносе одређене информације, јасно и разумљиво.

Приморана да се влада према наметнутим правилима, бестелесна сенка преноси изабране информације, док ликовни садржај и натписи упућују корисника како те информације треба тумачити. Загледан у линије и сенке, корисник је у немој комуникацији са сунчаним часовником, или, у књижевном смислу речено, корисник „чита”садржај сунчаног часовника.

Сунчани часовници су својеврсни астрономски плакати, оживљени ходом сенке (која је и сама ликовно средство). Захваљујући комплексности садржаја, комуникација остварена посредством њих у основношколској настави има не само информациону, него и врло битну мотивациону функцију.

Професор Војислав В. Мишковић је давне 1931. године написао: „Несумњиво је тачно да ће се с тог [сунчаног] сата деца поучити и лакше и много чему више него из које књиге и многим другим средствима”– и ми се, закључујући, само можемо сложити са његовом тврдњом.

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ONE LETTER CONCERNING CALENDAR REFORM

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Abstract. In this work the authors present a letter from 1924, which was sent by director of National Observatory of Athens Dimitrios Aiginitis (1862-1934) as a response to the professor of Belgrade University Milutin Milanković (1879-1958). The letter was written in French and it explains why the resulting differences were existing in calculation of the Easter date, on which both of them worked separately, and that was the main object of interest in a letter previously sent by Milanković.

1. INTRODUCTION

The calendar reform issue was particularly actualized at the end of the nineteenth and in the first decades of the twentieth century. After World War I the Eastern European Orthodox countries adopted the Gregorian calendar in the state administration, while in the Church the Julian calendar still remained in usage, because of which started activities aimed at its reforming.

In 1923 in Constantinople the Panorthodox Conference was convened[1] where the question concerning the reform of the Julian calendar was being solved and where the official proposal of the Serbian Orthodox Church was the project of Maksim Trpković. Milutin Milankovic, as Serbian delegation member at this meeting, in order to achieve an agreement with the Gregorian calendar as long as possible, which was required at the meeting because of the socio-political circumstances of that time (Simovljević, 1996), proposed a change within the part of Trpković's calendar which concerns the intercalatuion rule but without changing the basis in it (Kečkić, 2001). The Congress adopted this proposal of reforming the Julian calendar which is known as Revised Julian calendar or New Julian calendar; also, after its authors the following names are used: the Trpković-Milankovićs calendar (or Milankovićs calendar).

Some Orthodox Churches have adopted this calendar, but some of them still use the Julian calendar.

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[1] During the meeting the name was changed into Panorthodox Congress

2. THE CONTENT OF THE LETTER

The content of the letter[2] wich was sent by the director of the National Observatory of Athens Dimitrios Aiginitis (1862-1934) as a response to Milutin Milanković (1879-1958), professor of Belgrade University, it concerns the questions of the calendar reform. The letter is dated November 7, 1924 and it was written in French, which was mostly used in that time in correspondence.

In this letter it was briefly explained why the resulting differences existed in the calculation of the Easter date, on which Aiginitis and Milankovic worked separately. This is the main object of interest in a letter previously sent by Milankovic.

On the first page of the letter the Easter dates are given for a set containing five years which were calculated by Milanković and by Aiginitis.

Table 1: Calculated Easter date according to Milanković ($Easter_M$) and Aiginitis ($Easter_A$)

$Year$	$Easter_M$	$Easter_A$
1927	24 April	17 April
1943	28 March	25 April
1954	25 April	18 April
1962	25 March	22 April
1967	2 April	26 March

As it can be seen in the table (given in the letter), their Easter dates are different. Aiginitis indicated that the cause of these differences arose from different principles of calculating the Easter date, i.e. due to Milankovićs calculating the Easter date on the basis of the full-moon day, though it must be calculated according to the Church rule, which is based on the fourteenth day of the lunation.

The traditional way of calculating the Easter date is based on the rule adopted at the Nicaea Council in 325, where in calculating one takes the fourteenth day of the lunation. Aiginitis adds that the Easter rule is followed by all Christian Churches and he mentions it briefly:

"Easter should be celebrated on a Sunday after the fourteenth day of the first lunar month (lunation) after the vernal equinox". Also, Aiginitis cites the reference "Les Constitutions apostoliques".[3]

And so in the end of the letter he recommended to Milanković: "If you take this difference into account, our tables will completely agree" ("Si vous tenez donc compte de cette difference nos tableaux seront completement daccord ").

About the Easter rule Maksim Trpković (1864-1924) writes in more detail in his work "Calendar Reform" published in 1900. He states also that according to the decision of the Nicaea Council in 325[4], "Easter has to be celebrated every year for

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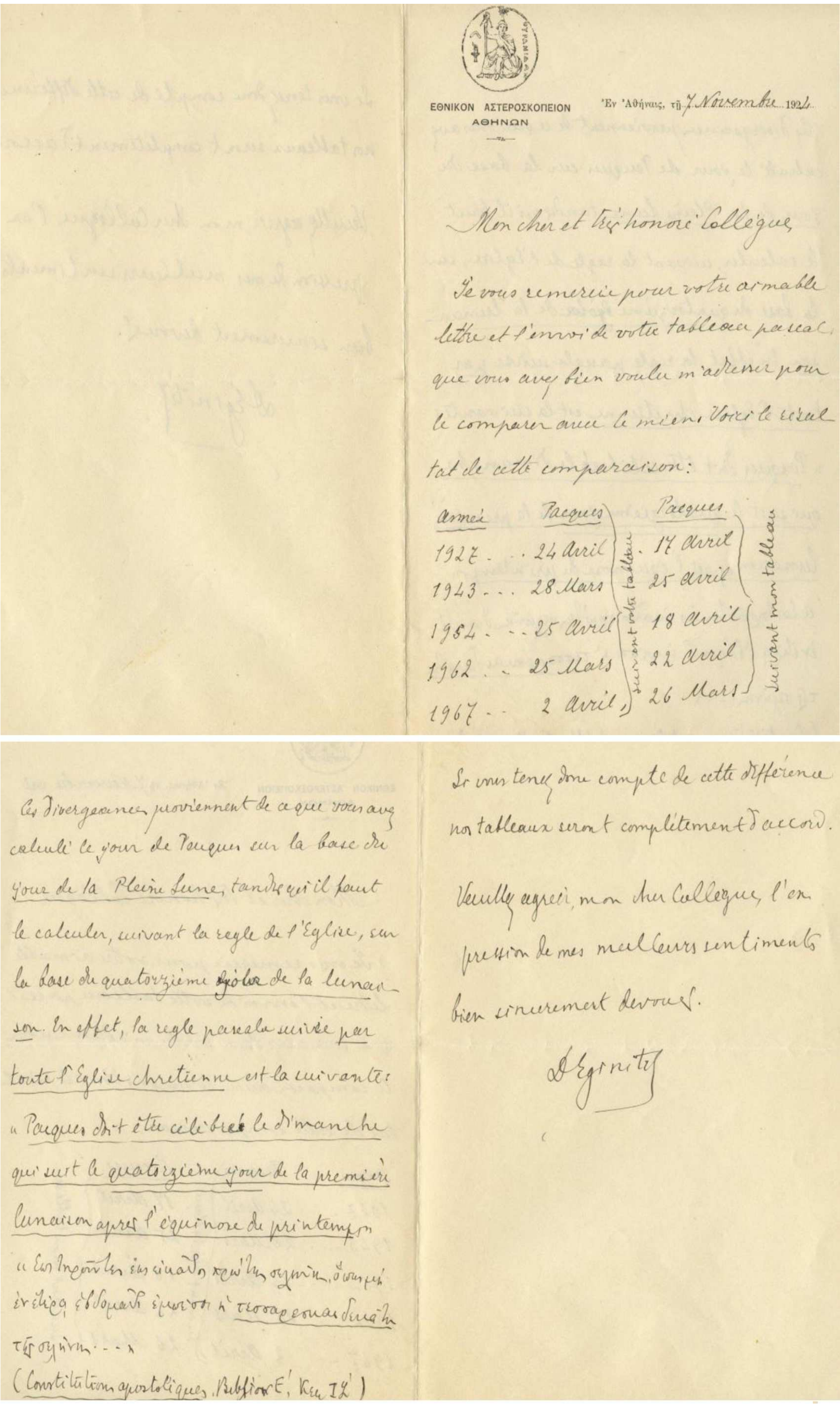
[2] This letter was for the first time exposed during the exhibition "House on the stellar road", in the SASA gallery on the occasion of 125 years of the Astronomical Observatory of Belgrade. Otherwise, the letter was borrowed from a private collection which belongs to Vojislava Protitch-Benishek.

[3] The "CHRISTIAN SOURCES" collection presents texts from the first centuries of Christianity, together with all the elements (notes, indices, etc.) which can facilitate the understanding or study.

[4] In such a manner some of the Christians had celebrated the Easter before Necaea decision.



ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ
ΑΘΗΝΩΝ

'Εν 'Αθήναις, τῇ 7 Novembre 1924

Mon cher et très honoré Collègue,

Je vous remercie pour votre aimable lettre et l'envoi de votre tableau pascal que vous avez bien voulu m'adresser pour le comparer avec le mien. Voici le résultat de cette comparaison:

Année	Pâques suivant votre tableau	Pâques suivant mon tableau
1927	24 Avril	17 Avril
1943	28 Mars	25 Avril
1954	25 Avril	18 Avril
1962	25 Mars	22 Avril
1967	2 Avril	26 Mars

Ces divergences proviennent de ce que vous avez calculé le jour de Pâques sur la base du jour de la Pleine Lune, tandis qu'il faut le calculer, suivant la règle de l'Église, sur la base du quatorzième ~~jour~~ de la lunaison. En effet, la règle pascale suivie par toute l'Église chrétienne est la suivante:

« Pâques doit être célébrée le dimanche qui suit le quatorzième jour de la première lunaison après l'équinoxe du printemps »

« [illegible] μετὰ τὴν ἰσημερίαν, [illegible] ἐν ἐκείνῃ ἑβδομάδι ἐμπίπτει ἡ τεσσαρεσκαιδεκάτη τῆς σελήνης . . . »

(Constitutions apostoliques, Βιβλίον Ε', Κεφ. ΙΖ')

Si vous tenez donc compte de cette différence nos tableaux seront complètement d'accord.

Veuillez agréer, mon cher Collègue, l'expression de mes meilleurs sentiments bien sincèrement dévoués.

D Eginitis

Figure 1: The faximil of Aiginitiss letter which was sent to Milanković.

the eternal time, in the spring, that is, after the vernal equinox on the first Sunday that comes after the 14th day of the first lunar month (lunation), which is (14 day of the lunation) can happen on the very equinoxes or later (Trpković, 1900).[5]"

The paschal moon or the lower paschal limit, which is the 14th day of the lunation, counting from the conjunction, is determined according to the19- years cycle or according to the golden number with epacts for each year. Trpković corrected the paschal reckoning (corrected the error in Metons cycle, using the contemporary astronomical data with respect to the meridian of Jerusalem.[6]

In this way, according to Trpković's proposal of calendar reform at the Pan-Orthodox Meeting in Constantinople in 1923, Easter will be celebrated after the equinox (March 21) on the first Sunday that falls from the14th day (exclusively) to the 21th day (inclusive) from the new moon (as defined in "The Apostolic Constitutions", vol V, Chapter 17.)

Milanković argued that the paschal reckoning should be replaced by exact astronomical reckoning for which the data would be obtained from four observatories (Athens, Belgrade, Bucharest and Pulkovo), and which was adopted at the Pan-Orthodox Meeting in Constantinople in 1923, i.e. to use the astronomical full moon in determining the Easter date. In the Church circles the decision on calendar reform was criticized and labeled as non-canonical due to the disrespect (irreverence) and replacement of the paschal reckoning i.e. Church rules, and because according to the adopted calendar the vernal equinox occurs more frequently on 20 March, following the Gregorian calendar (Trajkovska, 2003).

In his work Milanković (1923) in Appendix 9 gave a table with Easter dates for the next 50 years (since 1924) in parallel for the Eastern Church, i.e. for those calculated for the calendar solution accepted at the Meeting in Constantinople in 1923, taking the data for the astronomical moon and for the Western Church. In this table are observed differences in the dates of Easter for those 5 years that had been specified in the letter of Aiginitis. Milanković did not cited the data source of the Western Church. Bearing in mind the correspondence with Aiginitis and the already mentioned Easter date for the 50-year period in both cases (in the letter and in Appendix 9 of Milanković (1923) most likely Milanković reached these data through Aiginitis.

Milanković dealt with the calendar reform for a short time, only a month, studying it before the Meeting in Constantinople in 1923 and did not pay sufficient attention to the paschal reckoning, which he also mentioned.

Christian churches use their own method of calculating the Easter date and they have never implemented the procedure in relation to the astronomical account of the day of the full moon. Probably, bearing in mind the Church's paschal rule for the Easter date, Maksim Trpković notes in his project of calendar reform that the calculation taking into account the results of astronomical measurements is more accurate, but the paschal reckoning is more convenient and practical.

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[5] According to the Church calculation the full moon occurs on the 14. Day from the new moon counting from the appearing of the crescent moon.

[6] Before the paschal reckoning was made according to the Alexandrian time, because the author of the Julian calendar Sosigenes was born in Alexandria.

3. SOME NOTES ON THE WORKS OF AIGINITIS AND MILANKOVIĆ

Dimitrios Aiginitis was the director of National Observatory of Athens (NOA) in the period 1890-1934, when this institution experiences "renaissance". He obtained PhD degree in mathematics. In the period 1891-1896 in addition to the Astronomical Institute, two others were founded, the Meteorological and the Seismological Institutes with a new staff. Later the third departement of the Observatory was formed: the department of geodynamics. Almost in the same time in Belgrade the Observatory of Grand School was founded, by Milan Nedeljković (1857-1950) which was astronomical, meteorological and also covered seismology. Aiginitis reorganized the meteorological network and created a seismological service. With his efforts new instruments were ordered and installed. He organized the editing of the "Annales de l'Observatoire National dAthenes" in French . Aiginitis had significant role in the political and academic life in Greece. He was Minister of Education and in 1926 he founded the Academy of Science in Athens. His contribution in accepting the World Time Zone system and the Gregorian Style Calendar in Greece was also important (http://www.noa.gr/museum/english/history_en.html).

Milutin Milanković, professor of Belgrade University, as academician was Vice President of the Serbian Academy of Sciences in three terms between 1948 and 1958, and was appointed the director of the Belgrade Astronomical Observatory (duriing the period Jan 27 to June 26, 1951), whereas since 1948 as President of the Scientific Council of SASA he served as its director (Protić and Protić-Benišek, 1982; Ševarlić and Arsenijević, 1989). First he was an engineer in Vienna, having acquired a doctorate in engineering, and after appointment as professor of applied mathematics at the University of Belgrade, dealt with the topics of climatology, astronomy, and geophysics. His most important work is astronomical theory of climate changes published in the "Canon of Insolation of the Earth and its application to the problem of ice ages" (1941) in German ("Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem"), which represents his entire lifelong work. Also, he dealt with moving of the poles of Earth rotation, reform of calendar, history of science etc.

4. CONCLUSION

The authors of this paper consider that the correspondence between the Dimitrios Aiginitis and Milutin Milanković is very important as for history of science so as to the understanding of certain questions of significance concerning the application of the calendar for the Church purposes, particularly in the calculation of Easter date. So it is strange that this letter was not present in the correspondence given by Milanković to SASA.

Acknowledgment

The authors wish to express their gratitude to archpriest Radomir V. Popović for useful coments concerning the application of the Easter rule in the Churchs practice, as well as for his version of the translation of a part of the text from Aiginitiss letter.

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REPRESENTATION OF ASTRONOMY IN GEOGRAPHY CURRICULUM AND IN EXTRACURRICULAR ACTIVITIES

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Abstract. I have been working in Primary School "Vasa Živković" in Pančevo for a last twenty years. My mission is to provoke student's attention by creative lectures, interactive talks, hands-on activities and projects. Main goal of these activities is to make geography and astronomy subject interesting and comprehensive to all children. Presenting geography as a multidisciplinary science which is deeply correlated to astronomy, I try to prepare my students to think "out of the box" and to transfer their knowledge between social and natural sciences. This work points out representation of astronomy in fifth grade geography curriculum as well as extracurricular activities of school astronomy section.

GEOGRAPHY CURRICULUM WITH ASTRONOMICAL CONTENT

The fifth grade geography curriculum has 20 from total 36 lessons correlated to astronomical content. First part is in the textbook chapter T***he Universe and the Earth***and includes lectures: The Universe – Stars, Constellations, Galaxies, The Milky Way; The Solar system – The Sun and the planets; Satellites – The Moon, Lunar Phases, Small Solar System Bodies, The size and shape of the Earth. The second part is the chapter *The Planet of Earth* that includes study of Earth's movement and Earth's layers. To imagine the Universe and celestial body motion in it, plain textbooks are not enough. We assumed that new terms and new study subject should not be presented to children by plane talking, but with problem solving and practical activities. Since only one class per week is scheduled for geography, I suggest to all interesteed kids to join astronomy section once a week, that gives them one or two aditional hours of astronomy informal talk, discussions, internet research, hands-on activities and workshops.

ASTRONOMY SECTION – EXTRACURRICULAR ACTIVITIES

In astronomy section, started up in 2006 with significant help of planetarium lecturers MSc Nataša Stanić and Aleksandar Otašević, I gather 20-30 children each year. Teaching method that I use in this classes is informal and interactive. I use video presentation carefully prepared and revised by our long-standing cooperators from Astronomical Society „Ruđer Bošković“ and discuss astronomical images and processes in details. Beside presentations which are sometimes prepared and devised by children themselves, we use hand-made model of Solar system, magnetic globe, mini planetarium and telescope. Using these amusing teaching resources students understand astronomy topics much better and learning process is pleasant, that is the most important for memorizing the content.

Since 2006, we visit the Belgrade Planetarium once a year, take part in Belgrade Astronomical Weekend (2007/ 2008) and National Conference of Astronomers of Serbia (2008). We also host ascience performance „Baloon, glass of water and a mobile phone“ (by Mrs Stanić) once a year. Every April we organize The Earth Day, showing our activities to the public (other kids and parents) – we run astronomy presentation on a big screen, demonstrate school telescope (Optisan star, focal length 700mm, objectiv diameter 60mm, parent’s gift)and galileoscope.

In the cooperation with professor Tadić, this year we constructed a vertical sundial on the southern wall of our school so it can be seen from the main playground. Using the sundial we can demonstrate orientation in space, explain the equinoxes, summer and winter solstice, apparent daily Sun motion, celestial equator, direction to the celestial pole – The Polar Star (showed by the polos). Our sundial unlike the others in Serbia has two specific multidisciplinary details – haiku verses written by Nataša Stanić and painting byprofessor of art culture in our school, painter Tomislav Stošić.

The main goal of our astronomical team is to make astronomy popular in primary schools. We also want to show to other schools that astronomy should be present in everyday school activities, despite it is not included as a general school subject in curriculum.

CONCLUSION

During the last eight years more than 300 kids were engaged in astronomy in our section. We have increased the Universe awareness in our school as well as in our neighborhood, above all, by our extracurricular activities – telescopes and sundial. We have also increased ecology awareness talking about the single habituated planet in the vastness of the Universe, our home planet, Earth.

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NEKOLIKO PRINCIPA KLASIFIKACIJE I KLASIFIKACIJA SUNČANIH ČASOVNIKA SA PREGLEDOM NAJPOZNATIJIH IZVEDBI

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Abstract. U ovom radu je definisano nekoliko principa klasifikacije sunčanih časovnika, kako sa istorijskog, hronološkog stanovišta, tako i sa stanovišta umetničkog i zanatskog. Prepoznati su i moderni zahtevi prema fenomenu sunčanog časovnika i klasifikovane su dobijene realizacije, u glavnom, u svetskim razmerama. Prateći deo je dat kao foto-katalog najpoznatijih svetskih realizacija sa opisom.

1. UVOD

Sunčani časovnik je naprava koja pokazuje dnevno vreme prema poziciji Sunca, tako što Sunce baca senku pokazivača (gnomona) na površ sa linijama (cifarnik) koje obeležavaju sate. Ovako definisan sunčani časovnik funkcioniše samo u toku obdanice i to samo onda kada vremenske prilike to dozvoljavaju - kada oblaci ne zaklanjaju Sunce gledano sa mesta merenja. Klasifikacija sunčanih časovnika može biti sprovedena prema različitim kriterijumima:

- prema položaju ravni cifarnika u odnosu na ravan ekvatora ili horizonta (paralelna ekvatoru, tj. prati ugao geografske širine u odnosu na horizont, paralelna horizontu, upravna na horizont);
- prema tome da li je gnomon fiksiran na cifarnik ili se po njemu pomera;
- prema tome da li se meri časovni ugao Sunca (prikaz vremena na cifarniku) ili visina Sunca na nebu (prikaz vremena se odredjuje prema dužini senke);
- prema vrsti i složenosti podataka koji mogu da se očitaju: samo momenat podneva, vreme tokom cele obdanice, godišnje doba, tj. datum, geografska širina;
- prema položaju gnomona u odnosu na osu rotacije Zemlje ili na ravan horizonta (paralelan sa osom, tj, prati ugao geografske širine u odnosu na ravan horizonta, upravan na ravan horizonta);
- prema periodu u kom je sunčani časovnik napravljen;
- prema umetničkoj vrednosti itd.

Medjutim, ovakva klasifikacija sunčanih časovnika po različitim kriterijumima nije isključiva u smislu da sunčani časovnik zadovoljava kriterijume samo jedne klase časovnika. Moguće je da jedan sunčani časovnik ima fiksiran gnomon, meri časovni ugao Sunca i pokazuje vreme i datum, a da to ne isključuje da postoji sunčani časovnik koji, na primer, nema fiksiran gnomon, meri časovni ugao Sunca, pokazuje vreme i datum; ili nema fiksiran gnomon, meri visinu Sunca, pokazuje vreme i datum i slično.

U zavisnosti od kriterijuma klasifikacije moguće je ustanoviti i surogate odredjenih klasa časovnika. Na primer, minijaturne verzije džepnih i ručnih časovnika, kombinacije dve vrste časovnika u jedan (primer: diptih).

2. KLASIFIKACIJA SUNČANIH ČASOVNIKA

U ovoj klasifikaciji nabrojane su najčešće realizacije sunčanih časovnika u svetu i istoriji poznatih realizacija sunčanih časovnika.

1. Sunčani časovnici koji mere časovni ugao Sunca

1.1. Sunčani časovnici sa fiksiranim gnomonom

1.1.1. Ekvatorijalni sunčani časovnik

Cifarnik paralelan sa ekvatorijalnom ravni, gnomon paralelan s osom Zemljine rotacije i uperen ka severu, linije koje označavaju sate su medjusobno jednako udaljene i cifarnik iscrtan sa obe strane ravni.

1.1.2. Horizontalni sunčani časovnik

Cifarnik položen horizontalno, gnomon paralelan s osom Zemljine rotacije i uperen ka severu, ugao koji gnomon formira sa cifarnikom je jednak geografskoj širini mesta gde je časovnik postavljen, senka koju baca gnomon se po cifarniku ne kreće se ravnomerno, razmak izmedju linija koje označavaju sate nije isti. Postavlja se na zemlji, u parkovima, vrtovima, pa se zbog toga često naziva i baštenski, ili vrtni, sunčani časovnik.

1.1.3. Vertikalni sunčani časovnik

Cifarnik položen vertikalno, gnomon paralelan s osom Zemljine rotacije i uperen ka severu, ugao koji gnomon formira sa cifarnikom je jednak geografskoj širini mesta gde je časovnik postavljen, senka koju baca gnomon se po cifarniku ne kreće se ravnomerno, razmak izmedju linija koje označavaju sate nije isti. Najčešće se postavlja na zidovima (ponekad se zove i muralni sunčani časovnik) ili na kupolama (sa raznih strana kupole).

1.1.4. Sferni sunčani časovnik

Cifarnik iscrtan na sfernoj površi (u obliku prstena ili zdele) u krugu paralelnom ekvatorijalnoj ravni, gnomon paralelan s osom Zemljine rotacije i uperen ka severu, linije koje označavaju sate su medjusobno jednako udaljene.

1.1.5. Džepni sunčani časovnik

Minijaturna varijacija horizontalnog sunčanog časovnika, najčešće. često sadrži ugradjen kompas i može da se sklopi radi lakšeg čuvanja u džepu, po čemu je i dobio ime.

1.2. Sunčani časovnici sa pokretnim gnomonom

1.2.1. Prstenasti sunčani časovnik

Minijaturna varijacija sfernog sunčanog časovnika. Umesto gnomona ima nodus, može da se sklopi i nosi kao privezak na lancu, ili u džepu.

1.2.2. Analematski sunčani časovnik

Vrsta horizontalnih sunčanih časovnika, imaju vertikalan gnomon, gnomon nije fiksiran i mora dnevno da menja poziciju da bi pokazivao tačno vreme, vreme se čita na elipsi, senka koju baca gnomon se po cifarniku ne kreće se ravnomerno, razmak izmedju tačaka koje označavaju sate nije isti.

2. Sunčani časovnici koji mere visinu sunca

2.1. Ljudska senka

Dužina ljudske senke (ili bilo kog uspravnog objekta) može da se koristi za merenje vremena. Dužina senke će varirati na različitim geografskim širinama i u različito doba godine.

2.2. Šeferdovi časovnici

Cifarnik cilindričan, linije koje označavaju sate su iscrtane kao krive, blizu jedna drugoj u podne i u zimskim mesecima, meseci su iscrtani u krugu pri dnu cilindra. Podesiv je prema datumu, gnomon je uperen ka Suncu. Pravi se za odredjenu geografsku širinu. Nije baš tačan, ali se lako pravi i nije skup.

3. Kombinovani sunčani časovnici

3.1. Diptih

Sklopivi sunčani časovnik, malih dimenzija, pogodan za nošenje. Najčešće pravljen kao kombinacija horizontalnog i vertikalnog sunčanog časovnika.

3. NEKI OD NAJPOZNATIJIH SUNČANIH ČASOVNIKA

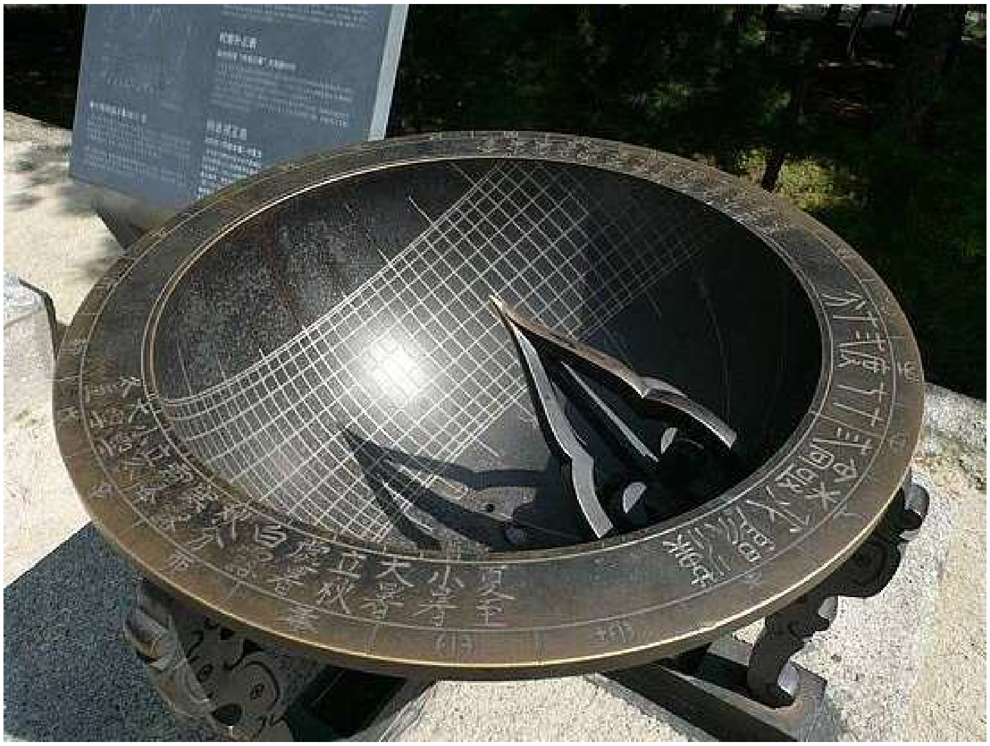
Vertikalni sunčani časovnik napravljen od drveta nalazi se u Klostersu, u Švajcarskoj. Cifarnik jednostavnim umetničkim duborezom pokazuje tok radnji seljaka u danu. Prikazuje vreme od deset časova ujutru, do sedam časova uveče.

Ekvatorijalni sunčani časovnik od nerdjajućeg čelika, širok 3,66 metara, nalazi se u Londonu, na obali Temze, u blizini čuvenog mosta - Tower Bridge. Napravljen je 1973. godine.

Horizontalni sunčani časovnik, napravljen preko reke Sakramento u Redingu (Kalifornija). Jedan je od najvećih sunčanih časovnika na svetu, podignut je 2004. godine po projektu španskog arhitekte Santjaga Kalatrave. Pilon mosta visok je 217 stopa (oko 66 metara), most je dug 700 stopa, a širok 23 stope. Zbog prevelikog luka koji pravi senka gnomona, časovnik pokazuje vreme samo četiri časa dnevno: od jedanaest časova ujutru, do 3 časa popodne.

Ekvatorijalni sunčani časovnik od mermera nalazi se u Zabranjenom gradu, u Pekingu. Napravljen za vreme vladavine dinastije Ming, u Palati zemaljskog spokoja u kojoj je živela carica.

Četiri vertikalna sunčana časovnika na osmougaonoj kupoli Houtn Hola, u Norfoku (Engleska). Na jednom cifarniku je moto "Vita in motu" (život u pokretu). Houtn je izgradjen početkom XVIII veka kao seoska kuća Ser Roberta Velpola, prvog premijera Velike Britanije.



Sferni sunčani časovnik u obliku zdele nalazi se u Seulu (Južna Koreja). Njegov tvorac je Jang Jong Sil, a ovom njegovom delu prethodile su izvedbe klepsidri - vodenih časovnika. Napravljen je u XV veku u bašti kraljevske palate, u blizini spavaćih sona kralja i kraljice.

Ekvatorijalni sunčani časovnik u Čikagu (SAD) delo je čuvenog vajara Henrija Mura iz 1980. godine, pod nazivom "čovek ulazi u kosmos". časovnik je postavljen povodom 500 godina od rodjenja Kopernika. Izliven je u bronzi, visok 3,36 metara. Nalazi se kod Adlerovog planetarijuma i Astronomskog muzeja.

Diptih od slonovače, delo čuvenog majstora za kompase Leonarda Milera, nastao je u XVII veku u Nurembergu (Nemačka). Ovaj časovnik je napravljen iz četiri dela, od kojih se na slici vide samo dva: na prvom je horizontalni sunčani časovnik sa kompasom i gnomonom u obliku uzice i sa dva cifarnika koja vreme pokazuju u različitim jedinicama; drugi deo je vertikalan i prikazuje u svom gornjem delu mesto Sunca u zodijaku, dok u svom donjem delu ima geografske širine raznih evropskih gradova i otvore za pričršćivanje uzice (gnomona) na različitim geografskim širinama.

Vertikalni sunčani časovnik na Novom koledžu oksforskog univerziteta postavljen je u septembru 1999. godine. Njegov dizajn je osnovan na zapisima o sunčanom časovniku iz XVII veka koji je ranije postojao na kuli, a koji je nestao u XIX veku. časovnik pokazuje lokalno vreme, koje se razlikuje od griničkog za pet minuta, jer je Oksford udaljen za jedan stepen zapadno od Griniča.

Šest vertikalnih sunčanih časovnika nalazi se na kuli nad kapijom Gonvil i Kajus koledža kembridžskog univerziteta. Datiraju iz 1963. godine, a napravljeni su od bronze, po uzoru iz XVI veka.

Analematski sunčani časovnik Torki (Torquay), nalazi se u blizini Melburna, Australija. Napravljen je kao mozaik od preko 120 hiljada delova. Analema se krije u telu ptice i pokretni gnomon (čovek) staje na nju da bi pomoću svoje senke očitao vreme.

Prstenasti sunčani časovnik sastoji se od unutrašnjeg prstena koji se postavlja u položaj paralelan ekvatorijalnoj ravni na kom su ugravirani časovi (po petnaest stepeni razlike izmedju dva časa), a čitaju se tako što svetlost prolazi kroz nodus na prečniku spoljašnjeg prstena (paralelnom osi Zemljine rotacije) koji može da se podesi prema odgovarajućoj geografskoj širini.

Džepni sunčani časovnik od srebra, filigranske izrade, delo je žan Batist Delura. Napravljen je u Parizu, Francuska, u prvoj polovini XVIII veka. Napravljen je po principu horizontalnih sunčanih časovnika. Njegov gnomon drži ptičica, a pored njega je i kompas, na osmougaonoj površi širine oko 7 cm. Ceo komplet sadrži tri cifarnika koja služe za različite geografske širine (40, 45 i 50 stepeni severne geografske širine).

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MODELI SUNČANIH ČASOVNIKA - UČENIČKA PRAKSA

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Abstract. U ovom radu učenici prikazuju na koje se sve načine vrši promocija nauke i povećava učenička motivacija kroz umetničke i praktične radove čija je tema nekom niti povezana sa astronomijom. Učenici predstavljaju nekoliko literarnih i likovnih učeničkih radova, a glavni deo rada je izložba modela različitih vrsta sunčanih časovnika o kojima izlaganja čine njihovi autori - učenici.

1. UVOD

Ovaj rad prezentuje rezultate aktivnosti grupe učenika, što sadašnjih, što bivših, okupljene oko astronomske sekcije O.Š. "Jelica Milovanović" iz Sopota. Komunkacija i rad obavljeni su tokom letnjeg raspusta 2014. godine, kroz sastanke, on-line dogovore, razgovore, grupnim praktičnim radom (crtanje analematskog sunčanog časovnika u školskom dvorištu, ali i velikim individualnim zalaganjima pojedinaca koji su samostalno izradili modele sunčanih časovnika. Napravljena su tri ekvatorijalna sunčana časovnika, dva horizontalna, jedan analematski, tri vertikalna, jedan sferni sunčani časovnik i jedan diptih.

Takodje, u pripremi rada učestvovali su, kroz rad na redovnim časovima likovne kulture i srpskog jezika svi učenici petog, šestog i osmog razreda, a najbolji likovni i literarni radovi su prezentovani na poster sekciji XVII NKAS.

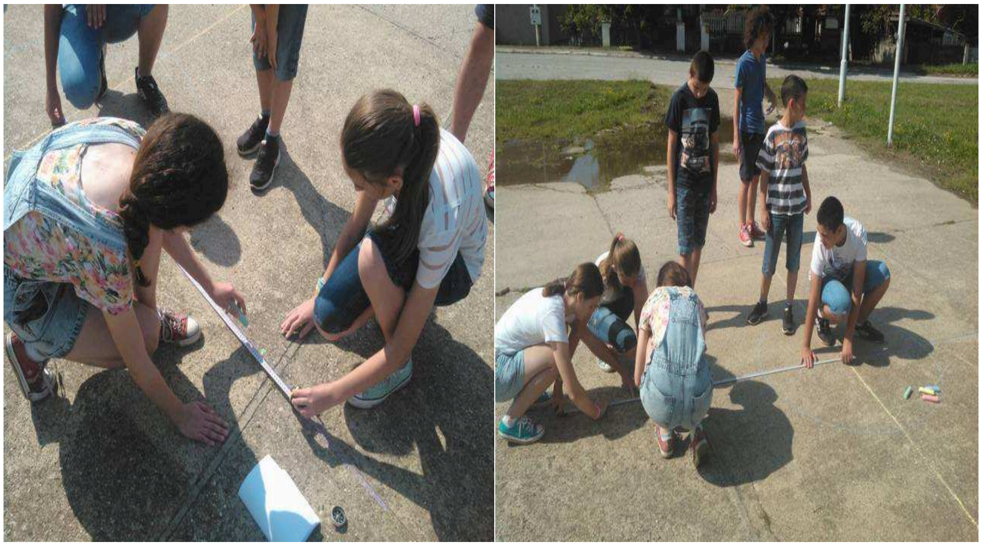

Figure 1: Slike gore: početak konstrukcije elipse na betonu, nakon odredenih strana sveta.

2. SUNČANI ČASOVNICI - GALERIJA

Slede fotografije koje prikazuju realizaciju analematskog sunčanog časovnika u školskom dvorištu, u nekim fazama izrade; i modele sunčanih časovnika u individualnoj izradi, gotove i u fazi izrade.

Faze stvaranja analematskog sunčanog časovnika u školskom dvorištu, grupni rad astronomske sekcije O.Š. "Jelica Milovanović", Sopot

3. LITERARNI RADOVI

Neki od najuspelijih literarnih radova:

3. 1. MOJ DRUG VANZEMALJAC

Dok sam šetala ulicom videla sam kako nešto sija u mraku! Prišla sam da pogledam: bilo je neverovatno!

On, ona ili ono nije umelo da priča, samo je zujalo kao pčela. Bila mu je potrebna pomoć. U početku, nisam mogla da ga razumem, ali on me je uhvatio za ruku i poveo.

Bila sam prestravljena, iznenadjena i zbunjena. Tamo se nalazio svemirski brod koji je bio od stakla, a umesto antena imali su drveće. Pometenoj od sijanja jake svetlosti, činilo mi se da je hteo da me odvede na put u svoj svet!

Kada smo stigli na njihovu planetu, Rajketifihinu, on je prestao da sija. Tamo je bio osamnaesti mesec, ili kako ga oni zovu - kohitiraona. Videla sam kako izgleda on i njegovih tri hiljade i devetsto devedeset i devet drugova. Imali su spojene prste, jezik kao kesa i mogli su samo da gutaju. Glave su im bile užasne! Hranili su se metalom i slatkišima. Pošto im je nestalo metala, morali su da nadju slatkiše.

Zato sam ja tu i bila.

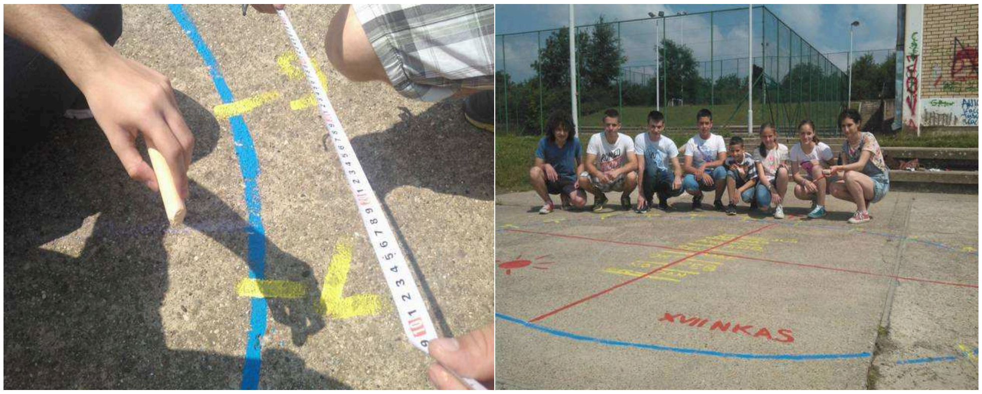

Figure 2: Slike dole: merenje i ispisivanje cifarnika (levo) i grupna fotografija autora sa završenim analematskim sunčanim časovnikom.

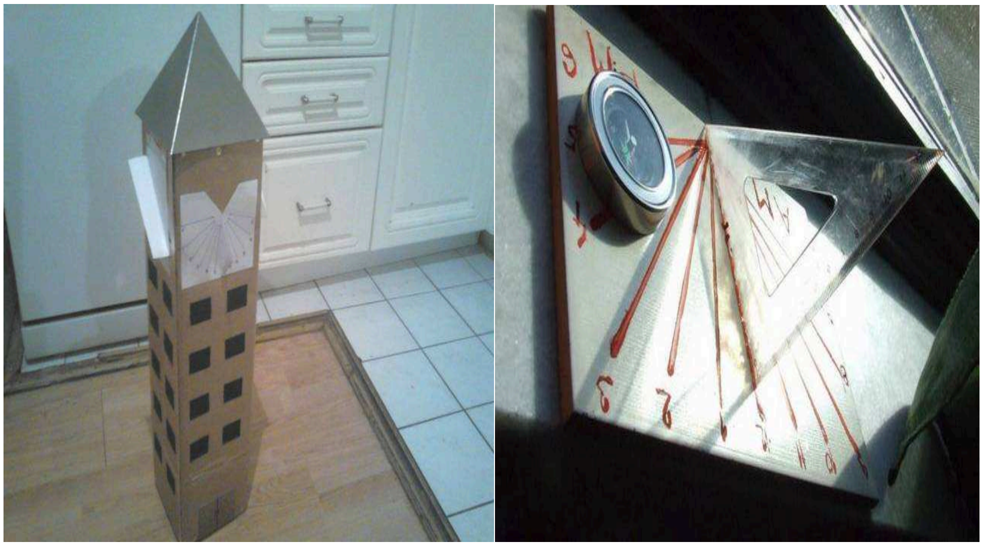

Figure 3: Model vertikalnog sunčanog časovnika, autora Lazara Janjić (levo); Model horizontalnog sunčanog časovnika, autorke Isidore Maričić (desno).

Figure 4: Faze stvaranja diptiha, autorke Andree Rajšić.

Ispostavilo se da sam skupila najviše slatkiša za Noć veštica... Jednom, kada su napravili kapiju za mene i uzeli slatkiše, pustili su me da prodjem kroz portal i odem kući.

Moj drug vanzemaljac zvao se Ratluk.

Isidora Maričić VI-1

3. 2. MOJ DRUG VANZEMALJAC

Ponekad se osećam kao da ne pripadam ovom svetu. Poželim da imam druga sa druge planete, koji bi bio sličan meni.

čak, nekada i zamišljam kako se družimo na njegovoj planeti. Zamišljam ga kao velikog, kamenog, snažnog ali i dobroćudnog vanzemaljca. On bi me uvek štitio kada bi neko pokušao da me povredi. Pored njega mi niko drugi ne bi bio potreban. Njegova planeta bi bila galaksijama daleko od Zemlje. Njegova rasa bi bila mnogo naprednija od naše. Mislima bi pomerali predmete, jeli bi hranu koju ja ne mogu ni da zamislim. Ne bi imali prevozna sredstva kao mi, već bi leteli raketnim rančevima.

Ko zna, ako jako priželjkujem možda i sretnem takvog vanzemaljca!

Luka Lukić VI-1

3. 3. MOJ DRUG VANZEMALJAC - ODLOMCI

...

Kada sam izašla iz rakete, otišla sam da razgledam tu planetu. Ubrzo sam se umorila i sela pored jednog žbuna. Iz njega je dolazio čudan zvuk. Odjednom je iskočilo čudovište! Gledalo me je duže vreme i bilo je mnogo ružno.

...

Vezali su me na jednom visokom drvetu. Princeza me je oslobodila zato što je bila dobra. Zvala se Dalila i bila je vanzemaljac. Raketa mi je bila polomljena i nisam mogla da se vratim na Zemlju.

Figure 5: Radovi i pripreme za XVII NKAS:

...

Stigla sam u jedno malo selo, bilo je lepo i imalo je dvorac. U dvorcu je živeo dobar kralj.

...

Na ulici sam srela jednog dečaka. Zvao se Srećko. Njegova majka me je pozvala na ručak, pošto sam bila gladna - otišla sam. Poslužila mi je crve, ali mislim da nisam bila baš toliko gladna.

...

Srećko, Dalila i ja smo otišli na Zemlju. Upisala sam ih u školu i išli su sa mnom. Srećko je rekao: Da sam znao da je škola ovakva, ne bih došao!

...

... i bili smo srećni do kraja života!

Medina Abazi VI-2

4. LIKOVNI RADOVI

Radovi i pripreme za XVII NKAS:
Klasifikacija i odabir likovnih radova izvedenih na časovima likovne kulture u petom i šestom razredu, u saradnji sa nastavnicom likovne kulture Irenom Mitrović; i literarnih radova viših razreda u saradnji sa nastavnicama srpskog jezika Dubravkom Ivković i Marinom Luković, koje su bile i lektori, i nastavnicom engleskog jezika Tamarom Samailović koja je odabrane radove prevela na engleski jezik.

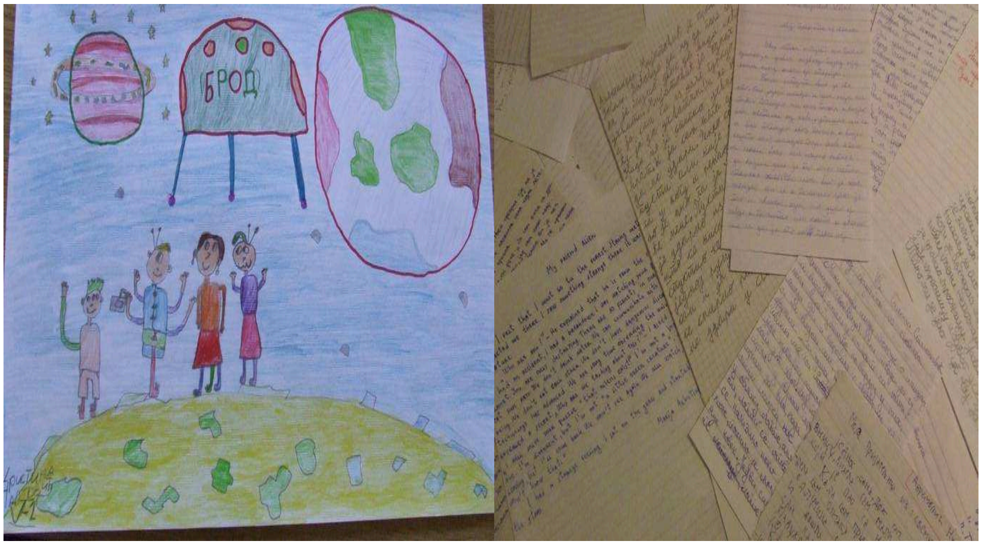

Figure 6: Klasifikacija i odabir likovnih radova

5. ZAKLJUČAK

Tokom rada astronomske sekcije zapažen je visok stepen motivacije kod učenika, delom zbog atraktivnosti sadržaja koji su obradjivani, delom zbog raznovrsnih nastavnih metoda i sredstava, a delom i zbog samostalnog dogovaranja i organizovanja faza izrade individualnih projekata, termina za konsultacije i grupnih sastanaka. Učenici su na kraju celokupnog projekta tražili nove zadatke za sledeću školsku godinu i njima se unapred radovali. Ovo iskustvo implicira da popularizacija nauke i podizanje motivacije kod učenika kroz slične projekte treba da budu uvršćene u redovne globalne nastavne planove, kao periodične aktivnosti.

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ACTIVITIES OF ASTRONOMICAL SOCIETY EUREKA IN PERIOD 2012 - 2014

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Abstract. Astronomical Society Eureka in Kruševac is successfully promoting Astronomy since 2010. Since then it has organized and successfully implemented a number of activities in and around the city of Kruševac in order to animate young people to engage in science and enabling the wider population to be familiar with the night sky. It has successfully implemented a number of projects. This paper briefly describes the results in the field of promotion of astronomy that members of Eureka achieved within the specified period, where the emphasis will be placed on the description of the project "Sky for all", IASC 2013, International Observe the Moon Night, activities in the field of informal education and about project for construction of the city's astronomical observatory called "Sky is (not) the limit".

INTRODUCTION

Astronomical Society Eureka was established on March 6th, 2010. The aim of the Society is to promote Astronomy and related sciences in Kruševac. Since the beginning Society started actively for the promotion of Astronomy. Society promoted Astronomy through the organization of:,

- Observation of night sky on many locations in city (Hill Bagdala, Kosturnica Square, center of the city)
- Pop-science lecture events
- Participation in projects
- Organization of special astronomy events (Moon Eclipse, Solar Eclipse, Transit of Venuse)

AS Eureka regularly throughout the year organizes public observing events for the citizens of Kruševac. Location that is most commonly used for the organization is hill Bagdala, where are the best conditions for the organization of public observing events during the year, if we take into account light pollution. In addition to these site observing events are often organized with the Kosturnica Square and from the city center. The most frequently organized observing events are about the Moon and planets because visitors are always interesting to observe these objects. Moon offers the possibility for visitors to use telescope and cameras on mobile phone to take photo of the Moon. In special situations observing events of deep sky objects are organized. During August members of Society always organize observing of Perseid meteor shower on Bagdala. In the period 2012-2014 Society has organized more than 15 observation events.

At the invitation of primary and secondary schools Society members always respond and organize the pop-science lectures for students. The most frequent topics of lectures are the Solar system, the Sun, Observational Astronomy and Telescopes. In the period 2012-2014, members of Eureka visited 10 schools in Kruševac where they held lectures for students.

Members regularly participate in international projects, especially in the International Observe the Moon Night and Great World Wide Star Count since 2010. Since 2014 AS Eureka participate at the event Night of Sidewalk astronomers. This year in two hours of observation more than 100 observers were in the city center. Members also participated in the 2013 IASC project of which will be further discussed in the sequel.

In the period 2012 - 2014 AS Eureka has actively started to engage in writing projects related to the promotion of Astronomy and Science. Eureka participated in several competitions organized by: Foundation Divac - Competition "Really important", Trag Foundation (formerly BCIF), calls of the Ministry of Youth and Sports, "Youth Rules". In this period members of Eureka successfully introduced and implemented the project "Sky for all" dedicated to the problem of light pollution, organized astronomy event at Science festival "Days of Eureka" in Kruševac, and started actively to engage in informal education in cooperation with the Society "Academy of National Development" from Belgrade where successfully organized a roundtable on the topic of informal education "Civil society organizations in the field of informal education" and prezentation of program "Go for the Future" from Niš in Regional Chamber of Commerce in Kruševac.

For efforts and work on promoting sicence in 2013 and 2014, Society received the award on the occasion of the youth day of the City Administration Kruševac and the Office for Youth, reward MLADGRAD 2013 by the Ministry of Youth and Sport, Ministry of local government and association Citizens' Initiative for cooperation between youth and local government, and Prize for the Promotion of Science from the Website Kruševac online. From Serbian Physical Society Society got lettor of thanks for help in the organization of the State contest in Physics for elementary schools in Kruševac in 2014.

Association organized and implemented activities about significant astronomical events such as: the transit of Venus on June 06th 2012, Occultation of Jupiter with the Moon on July 15th 2012, observing and recording comet PANSTARRS on March 17th 2013, and many other activities. Many of them had coverage by both local media and on national level.

The Association was regularly enrolled in scientific meetings in this period. Eureka had the opportunity to presentitself at a conference in the city of Volos, Greece from August 2nd to 4th, at an international conference "e-Infrastrucutre for an Engaging Science Classroom" which had a large number of people engaged in the research, education and promotion of science, especially Astronomy. Members of the AS Eureka participated in the conference with three papers: Sanja Jovanović and Zoran Tomić - "Teaching children about astronomy through the game", Zoran Tomić - "Work of AS Eureka on the promotion and popularization of astronomy in Kruševac" and Zoran Tomić, Gianluca Masi and Jovan Aleksić – "Application of the Internet in the promotion and popularization of Astronomy".

One of the major goals of the association members is to build city observatory that will serve to promote astronomy in Kruševac. Therefore, members of the association have written project "The sky is (not) the limit" which was sent to the competition of the International Astronomical Union - Office for Development and assessed as a high quality project. Project is currently on the list of 250 successful projects that the organization wants to assist in their implementation. Members of Eureka wrote another project for Observatory in Kruševac and in mid of December will get feedback about it.

For the first time AS Eureka with cooperation with AS "Plejade" from Tuzla, Bosnia and Hercegovina, realized project "EarthKam" in Kruševac.

In this paper will be described in more detail the implementation of projects in the period from 2012 to 2014, as follows: International observe the Moon night, Great World Wide Star Count, Transit of Venus 2012, Sky for all, IASC 2013, project Sky is (not) the limit for the construction of observatory in Kruševac, humanitarian event of astronomers in Kruševac, Be an Astronomer project, World Space Week 2014 and future plans for Society.

INTERNATIONAL OBSERVE THE MOON NIGHT

In OMN (International Observe the Moon Night) is an international project implemented since 2010 at the global level. The aim of the project is to motivate people to take a look to our nearest cosmic neighbor, the Moon. Every year an increasing number of public events are organized at the world level. Since 2010, Kruševac is one of the cities where these events are organized under the name "International Observe the Moon Night Kruševac" by the AS Eureka. By organizing popular lectures and public observing events at Kosturnica Square AS Eureka contributes to the realization of this project. The goal is to raise awareness about the importance of science and its promotion among young people, especially Astronomy.

In 2012, the project was implemented on 21st and 22nd September. The project was implemented in four locations in Serbia: Nis, Novi Sad, Bačka Palanka and Sremska Mitrovica. In Kruševac, the realization of the project began with a lecture on September 21st in the high school.

On 22nd September at the Kosturnica Square was held observing event. The observation began at 19 o'clock. Although it was planned to start half an hour later, at Square at that time was a large number of observers, so that the observation started earlier. For the occasion two telescopes were used, reflector 150/750 and refractor 60/900. Observers had the opportunity to observe the Moon and some details on its surface. Operators of the telescopes were Miloš Stanković and Zoran Tomić. In addition to observing all who brought their cameras and mobile camera phones were able to make photos of the Moon. It is estimated that a total of 150 citizens attended event. The observation ended at 21:30.

In 2013, the project was carried out on 12th October for the fourth time. That year this was the only event in Serbia, and one of three in the former Yugoslavia. It is estimated that the activities attended about 250 citizens who have observed and photographed the Moon.

Like every year, this action is most visited by youngest citizens. The observation started at 20 o'clock and lasted up to 23 o'clock. Although the clouds interfere with observation in the first hour of event, a large number of visitors decided to wait and it was worth. Anyone who had a camera or mobile phone camera was able to photograph the Moon. All attendees who were photographing the Moon were asked to send their photographs to mail in order to publish them on the web site. Large number of photos arrived and were published.

Figure 1: Observing of the Moon at Kosturnica Square.

This event was organized by Zoran Tomić, Sanja Jovanović, Miloš Stanković, Aleksandar Ristić, Aleksandar Jovanović, Nikola Nedeljković, Barbara Nedlejković and Stefan Anđelković. This event was supported by astronomical section of High School, Office for Youth and medias in Kruševac.

In 2014, members of Eureka implemented the project on 12th September on hill Bagdala. The activity was carried out as part of the project "Be an Astronomer" which ends in November 2014.

TRANSIT OF VENUS 2012

Astronomical Society Eureka in cooperation with the astronomy section of High School in Kruševac organized observation of the transit of Venus on Bagdala. Apart from Kruševac, observation was held in eight towns in Serbia.

For observing of transit two refractor telescopes were used with a protective filter. Weather conditions allowed visitors to observe one part of the transit. During this time, the transit was observed by around 70 people. Regional Television Kruševac attended and recorded observation. This was one of the more massive the activities of associations in this period and the second most visited in Serbia about the transit of Venus.

PROJECT "SKY FOR ALL"

Project "Sky for all" is realized within the project "BeEverGreen" implemented by association "Treehouse" which is funded by the US Embassy in Serbia in the period from June to September 2013. The project aims to conduct a series of educational, promotional and participatory activities to motivate the youth and residents of Kruševac to actively participate in environmental initiatives, with emphasis on recycling.

"Sky for all" aims to create awareness among citizens, mostly among the younger population, about the importance of preserving the night sky, which is important not only for astronomy but also for the living beings. Within the project, the public observing events in the city were organized in order to point out the problem of reducing the number of objects that can be seen trough telescope from the city because of light pollution. The intent of these events was to show to visitors how light pollution affects the reduction of the number of objects that can be observed at various locations. Therefore, the observations were carried out at locations:

- city center
- Kosturnica Square
- hill Bagdala
- river Rasina
- mountin Jastrebac
- Ribarska spa

Results of implementation of this project are that a total of 1000 observers attended events, awareness of the problem of light pollution was expanded, new equipment was obtained (CCD camera) and an initiative was launched to build in Kruševac an astronomical observatory. The results of the project and the initiative is written also in Vecernje Novosti national paper.

At the end of the project on December 3 presentation of results was organized in the White Hall of the Cultural Center Kruševac and also an exhibition of astrophotography and photos made during this project. The project was also presented at the ASTRO weekend event at the Youth Center in Belgrade from 27th until 29th December 2013, and at scientific symposium SDEV 2014 in Kruševac.

Figure 2: Map of light pollution in Kruševac for 2013.

One of the outcomes of the project is the map of light pollution. The aim is not only to show the level of pollution in Kruševac, but also to help in the search for a suitable site for the observatory, because of the associations active in raising funds for Observatory. In 2013 the survey was done with a record of 18 locations in the city and the following results were obtained: Center – 2, river Rasina – 3, Kosturnica Square – 3, Pioneer Park – 3, Miše Mitrovića Street – 3, Bagdala first part – 4, Bagdala second part – 4, Jasika – 4, Slobodište – 5, Tekije – 6, Lukavac – 6, Majdevo – 5, Jastrebac – 5, Ribarska spa – 4, Meševo – 5, Bivolje – 3, Dedina – 4 and Grkljan – 3. Results in 2014 are similar to this in 2013.

It can be seen that the situation is the best in Lukavcu and Tekije where the Milky Way can be seen, and even the Andromeda Galaxy and M13 star cluster with the naked eye. The worst situation is certainly in the city center.

Kruševac is the only city that in 2012 and 2013 took part in this global campaign, which aims to promote awareness of the problem of light pollution, but it is also a true example of a project for the promotion of Science. The activity will be continued in future.

IASC 2013

In the period from 22nd March to 26th April, the search for asteroids named IASC "International Asteroid Search Campaign" was realized. This campaign was carried out in the framework of the Global Month of Astronomy 2013. The right to participate had students from high schools and colleges around the world. In 2013 total of 15 teams from around the world have jointly carried out research in the Solar System searching for asteroids. Two teams were from Serbia and from Kruševac.

Two teams were from Serbia. First team named “Serbian Asteroid Search Team” consisted of high school student from Kruševac and: Miloš Stanković, Neda Aleksandrov, Veljko Đorđević and Nikola Nedeljković, under the supervision of physics teacher Nada Savić. The second team consisted of students from Mechanical School of Electrical Engineering Darko Jovanović and Nemanja Mijajlović, under the supervision of physics teacher Nataša Ralić. In this period students received nine sets of photos of a certain part of the sky. They used Astrometrica software to analyze and detect potential or existing asteroids. Training and assistance throughout the duration of this project was provided by Zoran Tomić from AS Eureka.

At the end of the project teams successfully completed the project activities. First team, according to the latest report, confirmed NEO objects 1866 and 99942, while second team confirmed 2013 AU76 object.

This was the first participation of the young astronomers on this project and we hope that the next year will be even more participants from Serbia.

PROJECT "SKY IS (NOT) THE LIMIT"

The project made by members of AS Eureka, titled "Sky is (not) the limit" for the International Astronomical Union - Office of Development, is placed on their wishlist. The project includes activities designed to promote astronomy among students in elementary and secondary schools. Within the project, the largest part of the budget is for purchase of computerized telescope that could be used for further promotion of astronomy, and also to be part of future observatory. Series of activities for the promotion of astronomy are planned in project which would enable students to acquire knowledge in the application of telescopes, astrophotography and be involved in the implementation of many astronomical projects that are available via the Internet.

Also with this project is planed the acquisition of 15 telescopes for a primary school in Kruševac. The goal is for schools to obtain an instrument with which they will be able to realize the practical part of the course in Geography and Physics related to the Space. For schools that receive telescopes, and also for all interested students and citizens free training to work on these telescopes is planed.

The project is by IAU - Office of Development put on the wish list. The project is good enough and that is in line with the objectives of the organization to gain their support and help in raising funds for implementation. The project was launched on the website of this organization and is marked on the map.

In 2014 project is modified and resubmitted to the IAU. In mid-December, is expected results, whether the corrected version will get financial support for implementation, whose primary goal is to build astronomical observatory in Kruševac.

HUMANITARIAN EVENT OF EUREKA ASTRONOMERS

On Friday 23rd May astronomers organized a humanitarian event in Kruševac regarding the floods that occurred in Serbia in May that year. This action was supported by the Red Cross, IdejNet club and local Mensa in Kruševac. The goal was to animate the citizens and to collect donations to help the endangered population from floods.

Figure 3: During the humanitarian event.

During event visitors could observe Jupiter, Mars and Saturn with telescope from Eureka, and all visitors had to do was either to send SMS to 1003 number or to donate money to a special box that was provided by the Red Cross. The event started at 20:30 and ended at 23:30. Around 200 visitors supported this event, large number of SMS were sent, and 9.560 RSD was collected. The collected money was paid into the account of the Red Cross.

WORLD SPACE WEEK 2014 IN KRUŠEVAC

On the occasion of World Space Week, in the foyer of the White Hall of the Cultural Center of Kruševac AS Eureka organized an exhibition of astrophotography made by Miodrag Sekulić from AS "Alfa" in Niš called "Cosmic quest". The author made more than 20 astrophotographs for this exhibition of his work in the field of astrophotography. The exhibition was opened by the President of the Astrological Society "Alfa" from Niš and professor at the Nis Faculty of Sciences prof. dr Dragan Gajić. He did lecture titled "Did they really walk on the Moon?", in which he showed that the astronauts were actually on the Moon in 1969, and that the human has indeed set foot on another object in the Universe except on Earth. The exhibition was closed by Jovan Aleksić, a member of the AS "Ruđer Bošković" with lecture "The discovery of Jupiter's satellites". The exhibition and the lectures were extremely popular and implemented within the project "Be an Astronomer".

ACTIVITIES IN THE FIELD OF INFORMAL EDUCATION

Informal education is increasingly gaining in importance. There are many activities organized for the purpose of acquiring new knowledge and upgrading of existing. Activities that AS Eureka conduct, and also organizations like Eureka fall into the category of informal education. With the start of the Internet knoweladge and information they have become more accessible, and thus opened a new channel and means for informal education. Therefore AS Eureka promote the concept of "Astronomy from the chair," which is about the application of the Internet in amateur astronomy. AS Eureka in cooperation with other organizations is working on organizing numerous activities and projects in the field of informal education.

The first in a series of activities was in Belgrade. In the business center Ušće Eureka organized with Academy of the National Development a roundtable on informal education and civil society organizations in this field. The round table was held on January 29th and the event was attended by over 20 representatives from 11 organizations in this field.

The meeting was opened by Filip Čolaković, Chairman of the Board of the "Academy of the National Development". After introductory remarks, all organizations participating in the round table presented their activities and results. The aim of the next set of discussions on the topic of informal education was mutually networking and establishing better mutual cooperation. After the presentation a discussion was held about issues in the field of education. In the discussion, the main topic concerned students who leave the country after graduation, because we are the third country in the world that has the large number of students who want to leave the country after the end of studies, and at the top (share second place) by the brain drain from the country, according to World Economic Forum. After discussion, it was concluded that students should be allowed and enabled to go abroad to acquire the necessary knowledge and improve it, but the state needs to stay in touch with them and to share their knowledge and experience to assist in the improvement of conditions for the development of country. It was also concluded that such events should be held several times a year, all for the purpose of interconnection and exchange of experience in the field of education.

The second activity was carried out in May 06th at Regional Chamber of Commerce Kruševac. Prezentation of program "Go for the future" was organized. The presentation was held by Mrs. Ljubica Maksimović. The goal of prezentation was to show good example of program in informal education for the local community. The presentation was attended by about 40 businessmen, representatives of NGOs, local governments, institutions who support the economy and young people, educational institutions and young people from the territory of a Rasinski district.

PROJECT "BE AN ASTRONOMER"

"Be an Astronomer" is a youth project implemented by AS "Eureka" with the support of Resource Center "Educational Center - Kruševac" within program "Youth Rules" funded by the Ministry of Youth and Sport. The aim of this project is to promote astronomy as a science, hobby and one of the ways how youth can use their free time. Two telescopes 60/900 refractors are bought which will be used in future astronomical activities in the city. The telescopes are owned by the city of Krusevac. Third telescope is bought and donated to elementary school in the village Ribare. This telescope is a donation from AS "Eureka" and association "Youth for Ribare".

During the project the following activities were realized: public observing events in Kruševac (Perseid Metheor Shower, observing of the Moon, Saturn, Jupiter), training of students and the study of the Sun's activity based on sunspots by 40 students from Kruševac, measuring light pollution and realization of World Space Week. The project ends in November and results of project will be prezented.

FUTURE PLANS

Members of the AS Eureka will actively work to promote astronomy in Kruševac and Serbia and to enlarge number of members which will allow the association to achieve its goals. The plan is to put more emphasis on training of members for writing projects related to the promotion of science and to apply at national and international competitions. The plan is also to register the association, when the conditions are right, to expand opportunities for access to resources and fundings for projects. The main objective of the association will be realization of the project "The sky is (not) the limit" for the construction of astronomical observatory in Kruševac, which will create the infrastructure requirements for constant work of the association and expand cultural, educational and tourist attractions of the city of Kruševac.

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ASTRONOMICAL SOCIETY "RUDJER BOSKOVIC": 80 YEARS OF THE SOCIETY, 50 YEARS OF PUBLIC OBSERVATORY AND 45 YEARS OF PLANETARIUM

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Abstract. Astronomical Society "Rudjer Boskovic" is one of the oldest astronomical societies in Europe and the oldest one in the Balkans. It was founded in 1934, and its main goal is popularization of astronomy. The Society is located in two buildings, Public Observatory and Planetarium. Both of them, as well as the society itself, are celebrating anniversaries this year - the Society 80 years, Public Observatory 50 years and Planetarium 45 years since the establishment. In this paper, a brief history of the Society and its activities are presented.

1. THE SOCIETY

Astronomical Society "Rudjer Boskovic" is among the oldest astronomical societies in Europe and the oldest one in the Balkans. The founding meeting was held on April 22, 1934, by group of students of Belgrade University (Djordje Nikolić, Pavle Emanuel, Frano Simović) when Academic Astronomical Society was found. The activity of the Society during this period was the organization of a large number of popular lectures, with the aim to contribute to education and cultural life in our midst. The Society also organized occasional observational expeditions and observations for citizens. In 1935 the Society started publishing the first magazine for the popularization of science in Serbia, Saturn. Soon afterwards, other members outside of the university joined the Society, so the word Academic was removed in 1936 and the name changed to Astronomical society. In this period, Yugoslav ideology was popular, so in 1939 the name changed to Yugoslav astronomical society. After the occupation of Yugoslavia by the Germans in 1941, all activities were forbidden. The Society continued to work in 1951 under the name Belgrade astronomical club "Rudjer Bošković", while the following year it was finally renamed to Astronomical society "Rudjer Bošković", the name that is current today. Since its founding in 1934, many eminent members of the cultural and scientific community have led the Society. At its head were Djordje Nikolić (1934-1936), Vojin Djuričić (1936-1941), Radovan Danić (1951-1966), Branislav Ševarlić (1966-1970), Pero Djurković (1970-1972), Nenad Janković (1972-1974), Božidar Popović (1974-1979), Zoran Knežević (1979-1982), Milan S. Dimitrijević (1982-2004), Jelena Milogradov-Turin (2004-2011) and since 2011, the current president has been Miodrag Dačić.

2. LOCATIONS

Figure 1: Public Observatory and Planetarium.

2. 1. PUBLIC OBSERVATORY

During and after the World War II, the army was located in the Kalemegdan fortress. Around 1950, the army left Kalemegdan and the fortress became abandoned. Thanks to the exertion of Pero Djurkovic, Radovan Danic and Nenad Jankovic with the authorities concerned, the Society obtained for itself the Despot Tower [Dimitrijevic]. It was adapted from 1962 to 1964, and was opened as Public Observatory on December 20, 1964.

Public Observatory includes a terrace, classrooms & library and offices. The terrace is located on the top of the tower, and its primary purpose is observation. The static telescope Zeiss (110/2050) is placed on the terrace, while other telescopes are brought from time to time, mostly Tall 200K (200/2000). Classroom and library are places for educative programmes, such as lectures, movies, meetings or workshops. Various activities are performed there. Offices are rooms for the staff. Administrative work is done in offices, and also organized activities, such as school visits etc. can be arranged there.

2. 2. PLANETARIUM

At the Technical Fair 1966, a German manufacturer of optical systems Carl Zeiss demonstrated Zeiss Kleine Planetarium (ZKP), a new instrument for projecting starry sky on a spherical dome. President Tito visited the fair and was so impressed by this instrument that he suggested to procure it. Soon thereafter, a meeting was arranged in the Republic Fund for education and the decision to purchase it was made. After procurement of the instrument, the need for projection dome emerged. The old steam bath-house, Turkish Hamam at Kalemegdan, was found as an ideal building for this purpose. Adaptation lasted 4 years, and Planetarium started working in 1969. First trial lecture was held on February 23,1969, the first trial show on March 16,1969, and the official opening was on February 27,1970. The main room is large, with the dome of 8 metres. It has 80 seats, although more than 100 visitors can attend the show. Due to its spherical shape, it is primarily designed for planetarium shows, but other activities are also held in this place.

3. ACTIVITIES

The Society realizes its goals through various activities.

- **Observations** - Basic activity is the observation of celestial objects and events from Public observatory terrace, using telescopes. Observations are followed by the comments of the associates. Daily observations of city landscape, using panoramic telescopes, are also performed.

- **Planetarium shows (fixed)** "Star cinema", where visitors can learn about celestial sphere, constellations and the sky view from different latitudes on the Earth. There are regular shows, open to public, without prior announcement, and scheduled ones, for organized groups (e.g. schools). The duration of the show is about one hour and there are about 20000 visitors per year.

- **Planetarium shows (mobile)** Several members of the Society have taken part in the performance of shows in mobile, digital planetarium. This equipment is mobile, so that visits to schools, science festivals etc. are carried out. Since it is digital, it allows full-dome projections, images and movies. About 14000 visitors attended the show in 2013, and 6000 in the first half of 2014.

- **Astronomy course** A complete course for beginners, covering all topics of basic astronomy. The course begins with celestial sphere, constellations and time, following by the Earth, going further to the Moon, the solar system (the Sun, planets, other objects), and beyond - stars, the Milky way, other galaxies, and finally the universe as a whole. The course lasts 3-4 months and contains 20-30 lectures. The level is popular and is free of charge.

- **Belgrade astronomical weekend** Various programmes for citizens, amateurs and fans of astronomy. Founded in 1983. by N.Čabrić and A.Tomić, it is held during 2 days in June. Amateur astronomers gather here and their activities and publications are presented. The programme contains lectures, movies, planetarium shows, observations, visit to AOB,

- **Summer astronomical gatherings** A series of about 6 lectures on some particular topic. Founded in 1999. by Milan Ćirković. Held in August.

- **Summer school of astronomy** A school with theoretical and practical content. Held during August on a mountain, away from the urban environment (to avoid light and atmospheric pollution). During the day, participants attend lectures, and observations are performed during the night. The school lasts a few days (recently eight), and the schedule is very intensive. Eleven schools were held, the first one in 2002, and then regularly from 2004 to 2013.

- **Conferences** The Society organizes or participates in professional conferences. The most noteworthy are Development of astronomy among Serbs, Serbian-Bulgarian astronomical conferences and National Conferences of astronomers.

- **Publishing** Publishing is one of the activities of the Society. Here, only brief review will be presented, and detailed survey including descriptions, publication years, sizes, number of pages, number of copies, ISBNs etc. can be found in [4]

  - *Saturn* was a magazine for astronomy, meteorology, geophysics and geodesy, but more than 80% of the content were astronomical topics. It was published from 1935. to 1940. with 12 volumes per year

  - *Vasiona* magazine started in 1953. as a magazine for astronomy and astronautics. The number of astronautical articles decreased over time, and since 1980. Vasiona has become the official magazine exclusively for astronomy. From 1953. to 1961. (9 years) the page size was A4, from 1962. to 2004. (43 years) B5 size, and since 2005. the page size is A4 again. From 1953. to 1983. (31 years) there were 4 volumes per year, then 5 volumes, while in recent years, there are 4 volumes.

  - *Publications ASRB* - "Publications ASRB" is a series of books and so far 13 volumes have been published. Volumes 1-3 are books covering one astrophysical and two historical topics, while volumes 4-13 include conferences proceedings. Volume 4 contains proceedings from the 7th national conference of Yugoslav astronomers (1984), and volumes 5-13 are proceedings from Serbian-Bulgarian astronomical conferences and Development of astronomy among Serbs. Most publications from this edition have been printed in 150 copies.

  - *Summer school handbooks* - The society publishes handbooks for summer school participants with relevant content. Ten handbooks have been published so far, each summer school one, from 2004 to 2013, each in up to 100 copies.

  - *Other books and printed materials* - Several books were published, such as Total Solar eclipse 1961 (1960), Comets - the witnesses of the past (1986), Rudjer Boskovic: Sun and Moon eclipses (1995). In addition, a variety of other printed materials has been published, such as Astronomical bodies and events, Sky maps, Constitution, flyers, posters etc.

Figure 2: Some volumes from the edition Publications ASRB.

4. CONCLUSION

Founded in 1934, ASRB is the oldest astronomical society in the Balkans. In its 80-year history, located at Public Observatory (since 1964) and Planetarium (since 1969), it greatly contributed to the popularization of astronomy. Due to numerous activities of the Society, many people got to know the universe, and it continues to be one on the most active societies today.

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ADICT – ENGLISH-SERBIAN ASTRONOMICAL DICTIONARY

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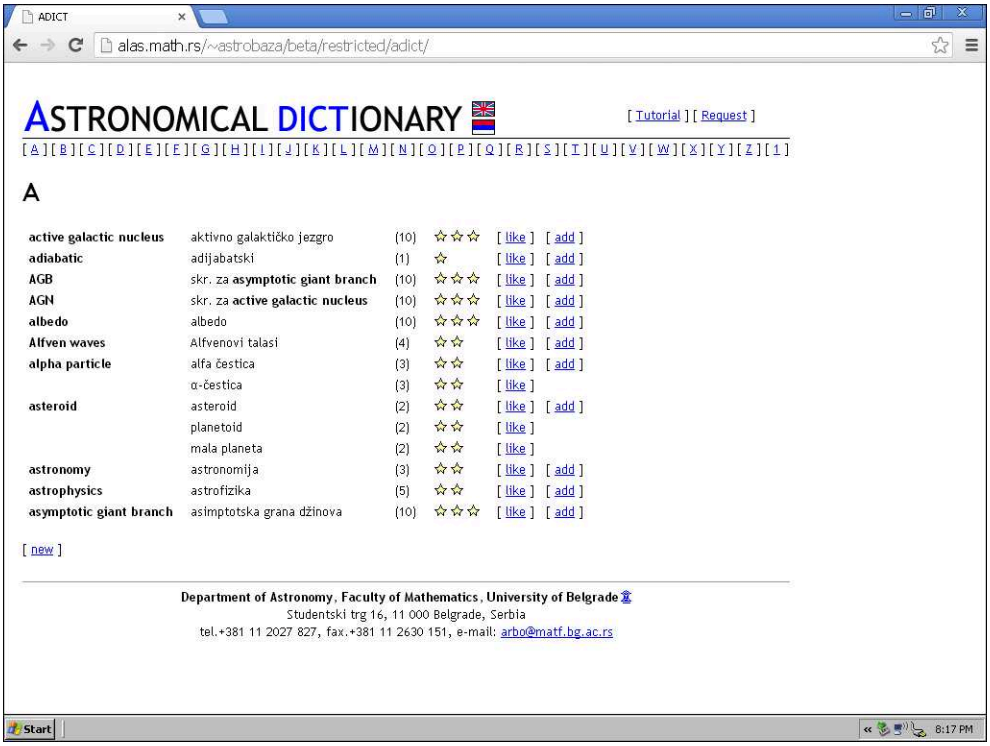
Abstract. ADICT is an interactive English-Serbian astronomical dictionary. The motivation for ADICT was a growing number of popular articles featuring mistranslated astronomical terms, as well as a lack of consensus on some terms among members of the academic community. ADICT has been developed following the principles of transparency, democracy and frequency of usage. While only professionals may contribute to its contents, ADICT is intended for professionals and non-professionals alike.

1. INTRODUCTION

ADICT is an interactive English-Serbian astronomical dictionary/website written in PHP and installed for the first time in January 2014. Due to the crash of the *Alas* web server all initial data were lost and the site was reinstalled in March 2014. It was made public in September 2014.

It is more in the form of classical dictionary than glossary, offering translations rather than definitions and explanations. The motivation for ADICT was a growing number of popular articles and news covering astronomical phenomena, written or translated largely by people without basic scientific knowledge, terminology and training in scientific writing. It is our belief that ADICT can help translators and non-professionals in getting the substance right, but it can be very helpful to professional astronomers as well.

Astronomical dictionaries are not that numerous but they are not uncommon, either. A good example is a multilingual dictionary in six languages (English, French, German, Italian, Russian and Czech) by Yugoslav-born Czech astronomer Josip Kleczek (Kleczek 1961). In former Yugoslavia, specially interested in the problem of translating astronomical terms to Serbo-Croatian were Djurković (1975), Ivanišević (1979, 1985), Ševarlić and Ivanišević (1982). Some work, not on a dictionary but on an electronic encyclopedia of astronomy in Serbian, was started by Zečević, Šegan and Šegan (2006).



ASTRONOMICAL DICTIONARY

[Tutorial] [Request]

[A] [B] [C] [D] [E] [F] [G] [H] [I] [J] [K] [L] [M] [N] [O] [P] [Q] [R] [S] [T] [U] [V] [W] [X] [Y] [Z] [1]

A

active galactic nucleus	aktivno galaktičko jezgro	(10)	☆☆☆	[like]	[add]
adiabatic	adijabatski	(1)	☆	[like]	[add]
AGB	skr. za **asymptotic giant branch**	(10)	☆☆☆	[like]	[add]
AGN	skr. za **active galactic nucleus**	(10)	☆☆☆	[like]	[add]
albedo	albedo	(10)	☆☆☆	[like]	[add]
Alfven waves	Alfvenovi talasi	(4)	☆☆	[like]	[add]
alpha particle	alfa čestica	(3)	☆☆	[like]	[add]
	α-čestica	(3)	☆☆	[like]	
asteroid	asteroid	(2)	☆☆	[like]	[add]
	planetoid	(2)	☆☆	[like]	
	mala planeta	(2)	☆☆	[like]	
astronomy	astronomija	(3)	☆☆	[like]	[add]
astrophysics	astrofizika	(5)	☆☆	[like]	[add]
asymptotic giant branch	asimptotska grana džinova	(10)	☆☆☆	[like]	[add]

[new]

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Figure 1: Screenshot of ADICT's private part.

2. ABOUT ADICT

ADICT has two parts: public and private. Access to the private part of ADICT at *http://alas.math.rs/˜astrobaza/beta/restricted/adict/* is limited to members of the Belgrade Astronomical Community (in Serbian, Beogradska astronomska zajednica or, in short, BAZA). BAZA is available at *http://astro.math.rs/astrobaza/* (see Atanacković et al. 2009). There are three types of users in BAZA:

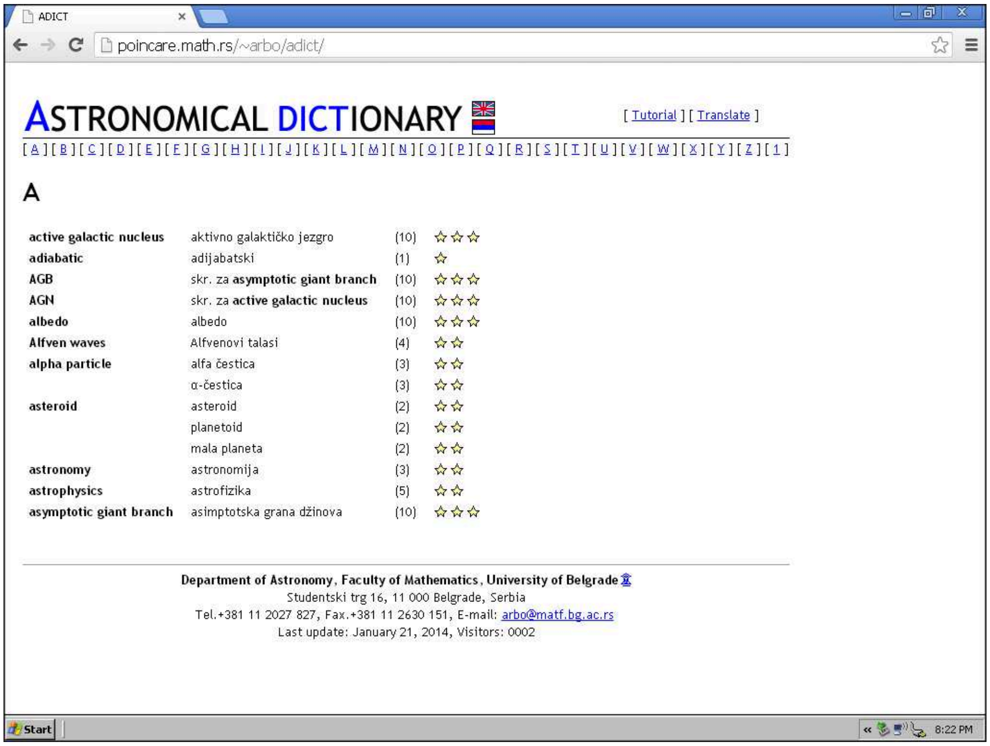
1) graduates (persons who graduated from the Department of Astronomy, Faculty of Mathematics, University of Belgrade),

2) colleagues (professors, researchers and post graduate students who are not among the above graduates),

3) students (undergraduates currently enrolled).

Only graduates and colleagues can offer translations and are hence ”authorised translators”. All users can support existing translations by ”liking” them, as we shall explain later.

ADICT is interactive meaning that users can interact and change its content, and ”democratic” in the sense that all ”authorised translators” can translate and vote for translations. Students become ”authorised translators” as a reward when they



ASTRONOMICAL DICTIONARY

A

active galactic nucleus	aktivno galaktičko jezgro	(10)	☆☆☆
adiabatic	adijabatski	(1)	☆
AGB	skr. za **asymptotic giant branch**	(10)	☆☆☆
AGN	skr. za **active galactic nucleus**	(10)	☆☆☆
albedo	albedo	(10)	☆☆☆
Alfven waves	Alfvenovi talasi	(4)	☆☆
alpha particle	alfa čestica	(3)	☆☆
	α-čestica	(3)	☆☆
asteroid	asteroid	(2)	☆☆
	planetoid	(2)	☆☆
	mala planeta	(2)	☆☆
astronomy	astronomija	(3)	☆☆
astrophysics	astrofizika	(5)	☆☆
asymptotic giant branch	asimptotska grana džinova	(10)	☆☆☆

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Last update: January 21, 2014, Visitors: 0002

Figure 2: Screenshot of ADICT's public part.

"turn 18" i.e. graduate. Each user can, of course, vote only once for each translation offered.

Translations are rated by the so-called three-star rating scheme, which indicates the degree of reliability of the translation and the frequency of the term usage. The scheme can be described as follows:

- ⋆ basic check/language editing (vote by the administrator),
- ⋆⋆ professional approval (vote by e.g. Head of the Department of Astronomy or Managing Director of the Astronomical Observatory),
- ⋆⋆⋆ public acceptance (which must be a compromise of some kind; in our case defined as: translation supported with 10 or more votes).

If we look at Fig. 1, in the upper right corner of the window there is a link *Tutorial* which directs to this paper, and *Request* which enables one to request from the administrator a translation of a term not yet included in the dictionary. Each letter in the English alphabet from A to Z has a separate page (with an extra page entitled 1 for words starting with a number or a special symbol, such as a Greek letter). Each page features an original term, translation, number of votes i.e. "likes", number of stars, the *like* button and the *add* button which serves to add an alternative translation of a term. Entries are presented in alphabetic order. At the end of each page there is the *new* button which adds a new term to the dictionary. If one moves a mouse over the number of "likes", he/she can see who suggested the translation and the users who voted for it.

Instead of offering a translation ADICT can also direct a user to a synonymous term, for example

astroparticle physics	vidi **particle astrophysics**
particle astrophysics	astrofizika čestica

and there are also inputs for abbreviations, e.g.

AGB skr. za **asymptotic giant branch**.

Bold face is achieved with the standard HTML command .... Similarly, one should use _{...} and ^{...} for subscripts and superscripts, respectively, etc. For entering special symbols one should use HTML character codes, e.g. *"* for double quotes or *α* for α.

The public part of ADICT is freely available at *http://poincare.math.rs/˜arbo/adict/*. It looks more or less the same as the private part except that it does not offer any interaction (Fig. 2). Basically, the public part is the private part that is made public regularly, thus providing new translations to the "world". BAZA users can move from public to private part by following the link *Translate* in the upper right corner of the window, after which a login screen appears.

ADICT is not fully prescriptive. It shows alternative translations and voting statistics and leaves freedom to users to use the terms they like best. Of course, for the sake of better understanding, which is the purpose of any communication, one should use approved translations and those that are used by most people (translations rated with three stars and with the highest number of votes).

The platform developed in ADICT can be used for languages other than Serbian. Because of language similarities extension to Croatian would be trivial[1] and there is already some interest by Bulgarian colleagues. With the interest and help of organisations such as the International Astronomical Union (IAU) ADICT could even become global, where IAU members would become "authorised translators" of astronomical terms, each member for his/her own language.

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[1] Especially if one adopts a viewpoint that Serbian and Croatian are two variants of the same polycentric language – Serbo-Croatian (Kordić 2010), and is not forcing Croatian translations to be different from Serbian and vice versa.

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UTICAJ KORPUSKULARNOG ZRAČENJA SUNCA NA METEORSKI ROJ QUADRANTIDI U PERIODU 2005-2014 GODINE

Ž. DISTERLO

Radio astronomski klub «Aurora» DMI Bor
ARAO https://radioastronomijaSrbija.blogspot.com

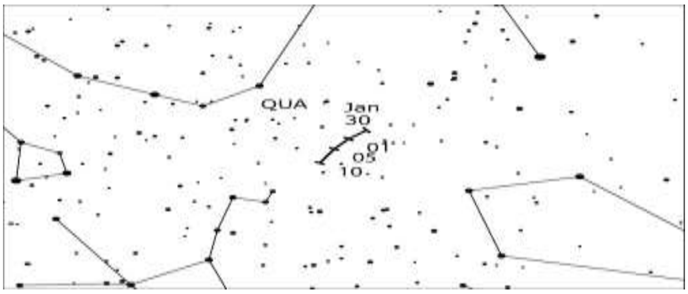
Abstract. Analiziran je uticaj korpuskularnog zračenja Sunca na meteorski roj Kvadrantidi u periodu od 2005. do 2014. godine a na osnovu podataka dobijenih od telemetrijskog satelita SOHO (http://sohowww.nascom.nasa.gov), (http://www.solen.info/solar) i (http://solarmonitor.org) . Radio odjek meteora vršen je radio-teleskopom na frekvenciji 150MHz, a obrada signala računarskim softverom Radio-SkyPipe. Povećanje broja meteora u 2007. 2011. 2012. i 2013. je pod uticajem Sunčevih regiona-vulkana kada su oni bili u geoefektivnoj poziciji ka Zemlji zajedno sa uticajem koronarnih rupa koje su u geoefektivnoj poziciji ka Zemlji i jačini njihovih eksplozija. U dane maksimuma meteorskog roja pored povećanja broja meteora primećeno je i grupisanje meteora. Povećano grupisanje meteora ka maksimumu je brže a sporije je opadanje broja meteora ka minimumu.

IZVOD

Osim elektromagnetnog zračenja Sunce ima i korpuskularno zračenje, u vidu čestica čije su dimenzije reda atoma ili čak manje od jezgra atoma. U suštini, Sunce odašilje u kosmos milione tona materijala od kojeg je sačinjeno. Mlaz čestica nazivamo Sunčev vetar, koji stalno duva od Sunca prema kosmosu brzinama koje se kreću od 200-2500 km/s. Srednja vrednost brzine Sunčevog vetra u blizini Zemlje je oko 375 km/s. Mahovitost Sunčevog vetra ima kosmičke vrednosti. Gustina Sunčevog vetra u jedinici zapremine kreće se od jedne čestice do više stotina čestica po kubnom centimetru. Kod energetskih čestica gustina dostiže astronomske vrednosti a potok čestica kroz kvadratni centimetar u sekundi ster radijana može dostići vrednost i do više desetina miliona. Svaki Sunčev vetar nosi magnetno polje Sunca i naziva se Interplanetarno magnetno polje. Osim magnetnog polja, čestice Sunčevog vetra nose i slobodna električna opterećenja i svojim kretanjem stvaraju električnu konvekcionu struju. Pored protona i elektrona u sastav Sunčevog vetra ima i jona mnogih hemijskih elemenata. Kod snažnih erupcija Sunčev vetar nosi visoko energetske čestice, nukleone, čija se energija meri u milion elektron volti. Tako snažna konvekciona električna struja koja teče od Sunca ka Zemlji ima veliki uticaj na sva dešavanja u našem okruženju. Presecanjem putanje radijanta meteorskog roja i njihov ulazak u zemljinu jonosferu stvara se jonizacija, ona može biti znatno povećano ako je u tom trenutku aktivno dejstvo Sunčevog vetra u geoefektivnoj poziciji ka Zemlji.

UVOD

Kvadrantidi su jedan od najboljih meteorskih rojeva. Zemlja svake godine preseca radijant roja Kvadrantidi u periodu krajem Decembra, početkom Januara (1.-6.Januara). Brzina meteora je 41,5km/s, dolaze iz sazvežđa Kvadrans muralis koja se nalazi između Volar, Herkula i Drako. Zenitna satnica maksimuma je 120 meteora na sat. Vrhunac je prilično oštar.



Položaj Kvadrantida.

Maksimum ovog roja varira iz godine u godinu u opsegu od 0,15 stepeni ekliptičke longitude za većinu godina. Maksimum roja Kvadrantidi je na neki način asimetričan, broj refleksija posle maksimuma opada znatno brže nego što se povećava prema maksimumu. Krupniji i sitniji meteorski delovi pojavljuju se u skoro isto vreme, mada u nekim godinama dešava se da krupniji meteori kasne za neki sat u odnosu na glavni maksimum. Kometa od koje ovaj roj potiče još nije registrovana. Astronomski podaci za roj Kvadrantidi: E.L.282,55°, RA 232°, DEC +50°, brzina 41,5km/s. trajanje-pojave 1.-6. Januar, broj meteora/h 40-150. Najbolji radio odjek Kvadrantida je iz pravca NE-SW i SE-NW a relativno slab iz pravca N-S i E-W.

METOD RADA

Radio odjek Kvadrantida registrovan je radioteleskopom na frekvenciji 150MHz iz razloga što Kvadrantidi spadaju u grupu brzih meteora i daju dobre odjeke na višim frekvencijama.

Pomoću telemetrijskog satelita SOHO, (http://sohowww.nascom.nasa.gov), (http://www.solen.info/solar) i (http://solarmonitor.org), preuzeti su podaci o aktivnosti Sunca za period (2-4. Januar), za svaku godinu praćenja Kvadrantida. Podaci su sledeći:

1. Postojanje Sunčevog regiona ili koronarne rupe u geoefektivnoj poziciji ka Zemlji u periodu maksimuma meteorskog roja (2-4.januara)
2. Jačinu eksplozije-klase, i vreme dolaska čestica do Zemljine magnetosfere
3. Brzinu Sunčevog vetra
4. Sastav čestica Sunčevog vetra
5. Jačinu konvekcione struje čestica Sunčevog vetra

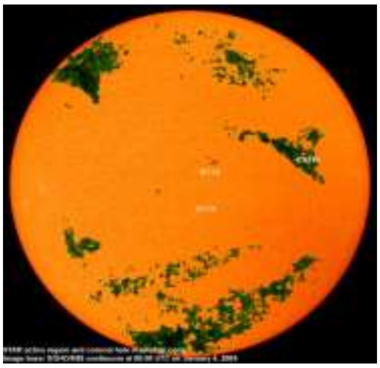
Dobijeni podaci korišćeni su za određivanje uticaja Sunčeve aktivnosti posredstvom Sunčevog vetra na radijant meteorskog roja Kvadrantidi u njegovom maksimumu aktivnosti za vremenski period od deset godina. Snimanje meteorskog roja Kvadrantidi započet je pri kraju 23. Sunčevog ciklusa. Praćenje će biti nastavljeno ceo period 24. Sunčevog ciklusa. ARAO prati još deset meteorskih rojeva: Liridi, Persidi, Delta Aurigidi, Septembarski Tauridi, Drakonidi, Orionidi, Novembarski Tauridi, Leonidi, Geminidi i Ursidi.

UTICAJ AKTIVNOSTI SUNČEVOG VETRA NA METEORSKI ROJ KVADRANTIDI:

2005.

23. Sunčev ciklus

Sunčev region u geoefektivnoj poziciji prema Zemlji
22.12.2005.

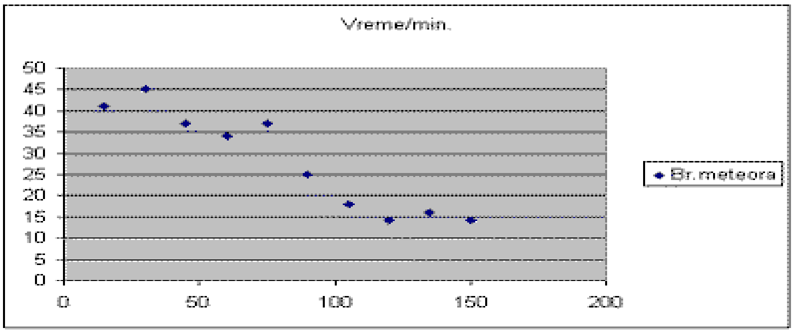


Sunčev region i koronarna rupa u geoefektivnoj poziciji prema Zemlji
3/4.1.2005.

Jačina konvekcione struje čestica u GW:

NOAA-15(S) 10716 22.7 GW 6 .787

Grafikon radio odjeka Kvadrantida 2005.

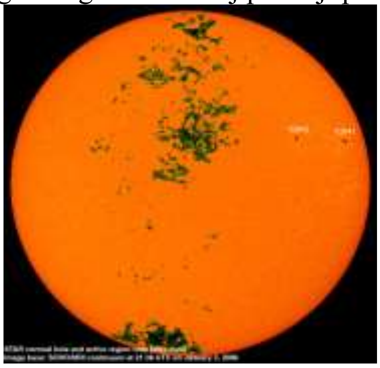


Maksimalan broj meteora: **96**

2006.

20.1.2006.

Sunčev region u geoefektivnoj poziciji prema Zemlji



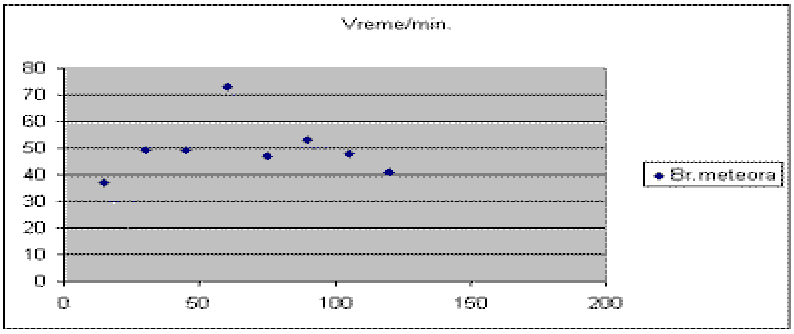
Sunčev region i koronarna rupa u geoegektivnoj poziciji prema Zemlji

3.1.2006

Jačina struje u GW:

NOAA-16(S)0010841 12.6 GW 5 1.066

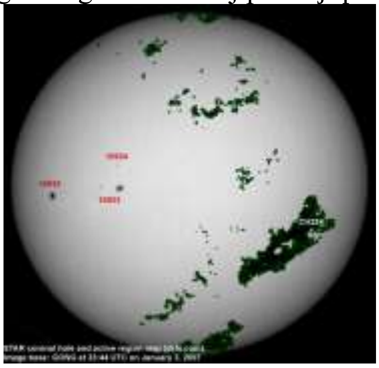
Grafikon radio odjeka Kvadrantida 2006.



Maksimalan broj meteora: **189**

2007. 24. Sunčev ciklus

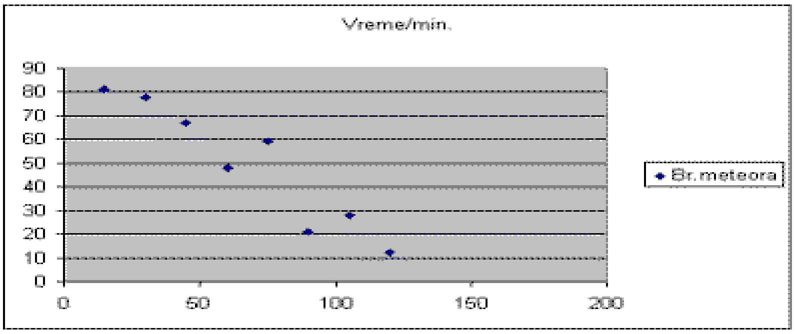
3.1.2007
Sunčev region u geoefektivnoj poziciji prema Zemlji



Sunčev region u geoefektivnoj poziciji prema Zemlji
3.1.2007.
Jačina struje u GW:

2007-01-03 04:27:47 NOAA-17 (N) 10 114.84GW 0.95
2007-01-03 11:17:23 NOAA-17 (N) 10 125.33GW 0.92

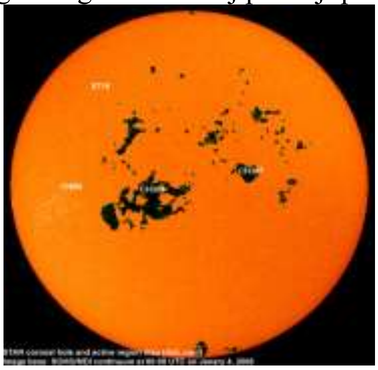
Grafikon radio odjeka Kvandratida 2007.



Maksimalan broj meteora: **274**

2008.

3.1.2008.
Sunčev region u geoefektivnoj poziciji prema Zemlji

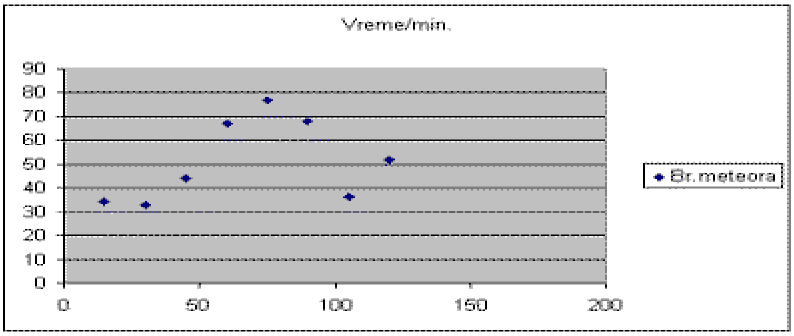


4.1.2008.
Sunčev region i koronarna rupa u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:

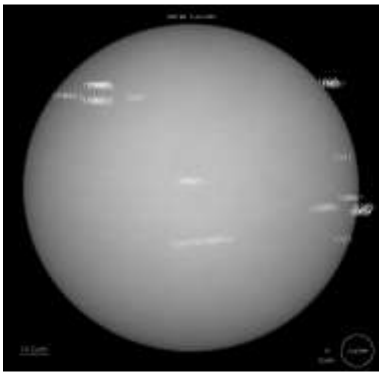
2008-01-03 09:17:24 NOAA-15 (S) 5 13.15GW 1.17
2008-01-03 22:12:30 NOAA-16 (S) 5 12.27GW 0.90

Grafikon radio odjeka Kvadrantida 2008.

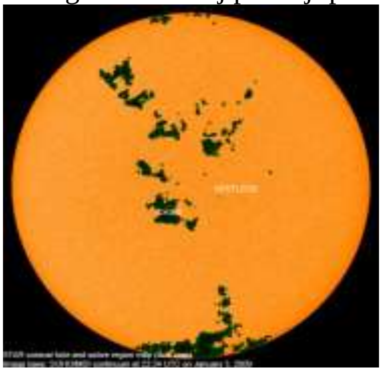


Maksimalan broj meteora: **213**

2009.

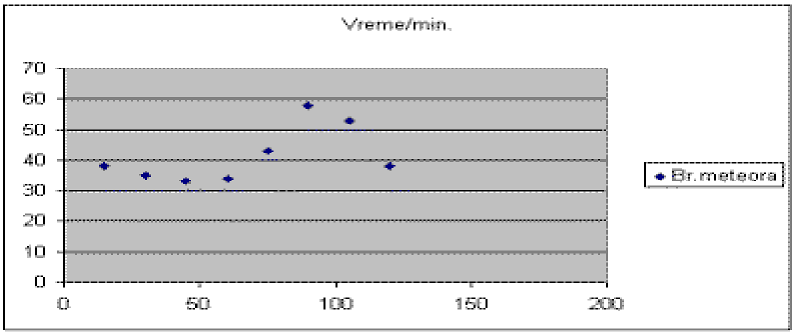


3.1.2009.
Bez regiona u geoefektivnoj poziciji prema Zemlji



3.1.2009
Koronarna rupa u geoefektivnoj poziciji prema Zemlji
Jačina struje u GW:
2009-01-03 09:27:42 NOAA-17 (N) 10 101.84GW 1.58
2009-01-03 17:04:30 NOAA-17 (S) 8 46.42GW 0.84

Grafikon radio odjeka Kvadrantida 2009.



Maksimalan broj meteora: **192**

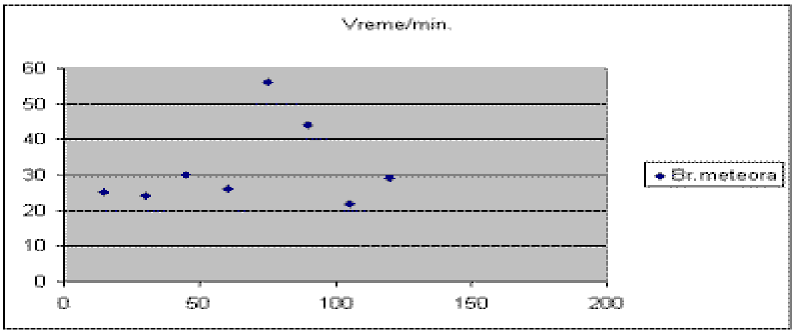
2010.

2.1.2010.
Sunčev region u geoefektivnoj poziciji prema Zemlji

3.1.2010
Sunčev region u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:
2010-01-03 11:28:01 NOAA-19 (S) 8 50.14GW 1.07

Grafikon radio odjeka Kvadrantida 2010.

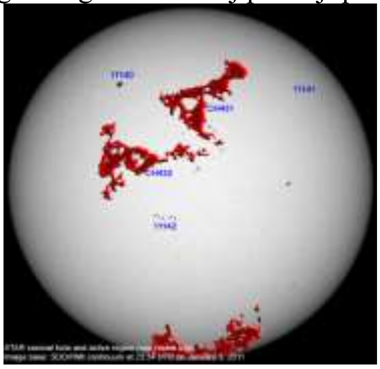


Maksimalan broj meteora: **152**

2011.

3.1.2011.

Sunčev region u geoefektivnoj poziciji prema Zemlji



3.1.2011

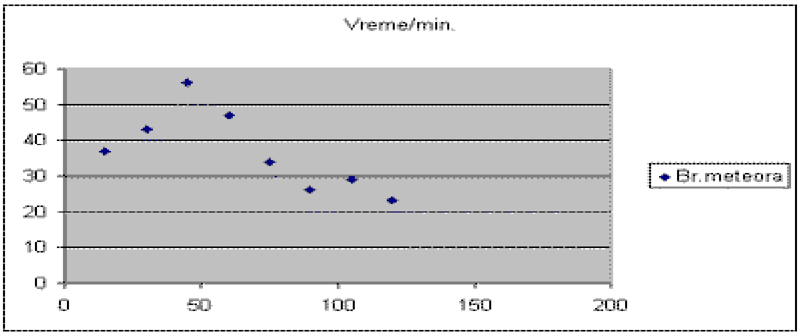
Sunčev region i koronarna rupa u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:

2011-01-03 14:13:54 METP-02 (S) 8 47.78GW 0.84

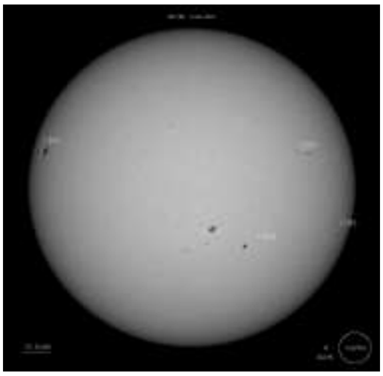
2011-01-03 20:44:50 NOAA-19 (S) 8 51.67GW 0.61

Grafikon radio odjeka Kvadrantida 2011.

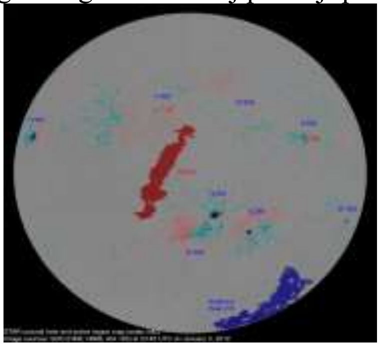


Maksimalan broj meteora: **183**

2012.



3.1.2012.
Sunčev region u geoefektivnoj poziciji prema Zemlji

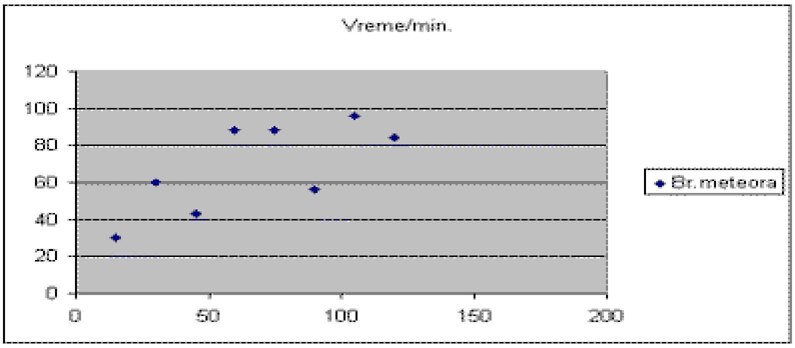


3.1.2012.
Sunčev region i koronarna rupa u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:

2012-01-03 04:43:22 NOAA-15 (S) 10 120.09GW 0.59
2012-01-03 08:58:18 NOAA-15 (N) 9 76.02GW 1.79
2012-01-03 12:19:38 NOAA-15 (N) 9 82.46GW 1.29

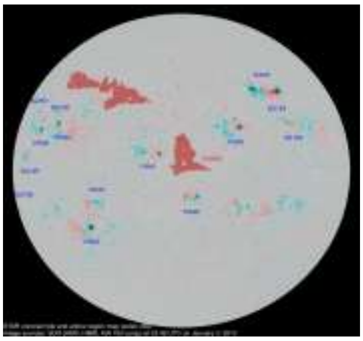
Grafikon radio odjeka Kvadrantida 2012



Maksimalan broj meteora: **324**

2013.

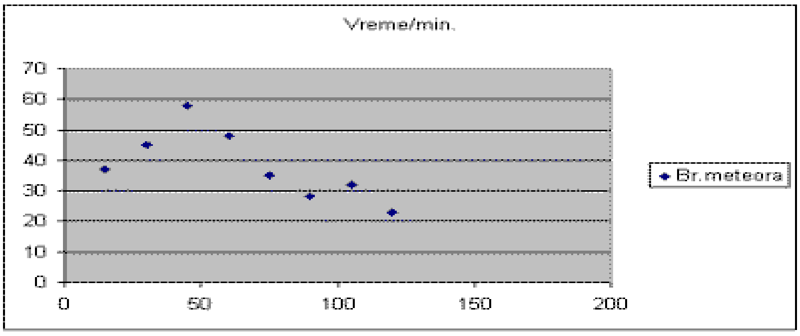
3.1.2013.
Sunčev region u geoefektivnoj poziciji prema Zemlji



3.1.2013.
Sunčev region i koronarna rupa u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:
2013-01-18 02:58:31 NOAA-15 (N) 10 124.04GW 2.35

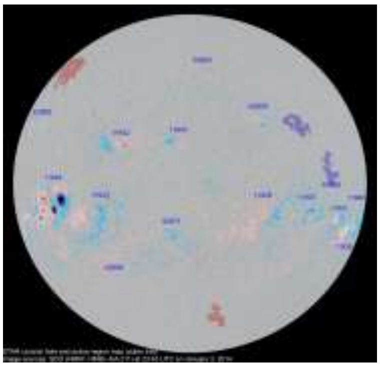
Grafikon radio odjeka Kvadrantida 2013.



Maksimalan broj meteora: **188**

2014.

3.1.2014.
Sunčev region u geoefektivnoj poziciji prema Zemlji

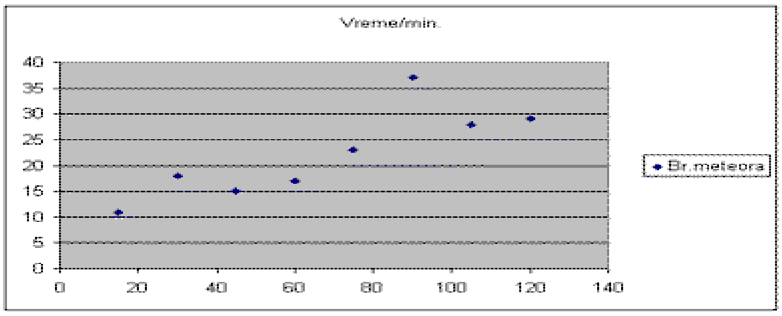


3.1.2014.
Sunčev region u geoefektivnoj poziciji prema Zemlji

Jačina struje u GW:

\-

Grafikon radio odjeka Kvadrantida 2014.



Maksimalan broj meteora: **117**

KOSMIČKA DEŠAVANJA U PERIODU 2005.-2014.

U periodu od 2005. do 2011. bilo je slabog uticaja kosmičkog zračenja i uticaja nukleona da bi 2011. godine došlo do povečanja kosmičkog zračenja i povečanog uticaja nukleona koji se nastavlja i u 2013 godinu, (tabela 1).

Brzina Sunčevog vetra je pojačana u periodu 2005.-2008. da bi u 2009. imao minimalnu brzinu koja je varirala od godine do godine kada je bila manja ili veća, (tabela 2).

Kosmičko zračenje-nukleoni u periodu 2005. – 2014.

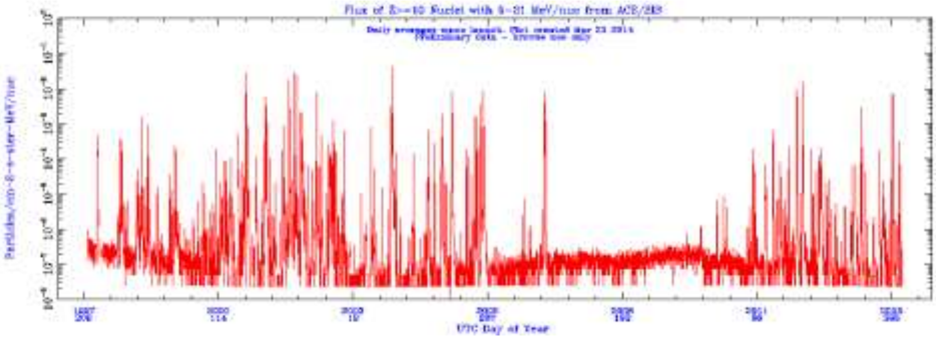


Tabela 1

Brzina Sunčevog vetra u periodu 2005. – 2014.

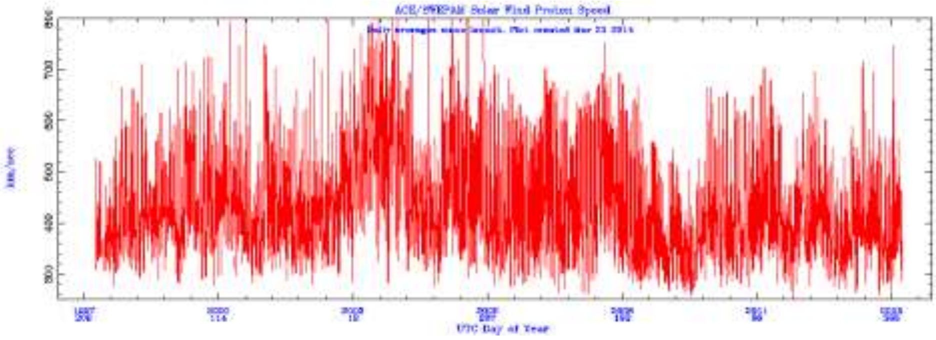


Tabela 2

REZULTATI ISTRAŽIVANJA

Stvoreni Sunčevi regioni-vulkani zajedno sa koronarnim rupama koje su nosioci čestica jakih električnih struja, imaju dodatni uticaj, svojim zajedničkim dejstvom kada se nalaze u geoefektivnoj poziciji ka Zemlji, doprinose grupisanju-povečanju broja meteorske prašine, a time je i broj meteora koji se registruje u Zemljinoj jonosferi, povećan.

Uticaj kosmičkog zračenja-nukleona u periodu od 2005.-2011. je bio veoma promenljiv, izuzetak je 2007. kada je došlo do blagog uticaja, a od 2011. do 2013. i povećanog. Što je prikazano u (tabeli 1) kao i povečanje brzine čestiva Sunčevog vetra prikazano u (tabeli 2)

Analiza dobijenih podataka merenjem

Godina istraživanja	Broj regiona-vulkana	Koronarna rupa	Jačina struje čestica-GW	Broj meteora max/h
2005.	3	-	22	96
2006.	3	-	12	189
2007.	4	-	125	274
2008.	1	+	13	213
2009.	-	+	101	192
2010.	1	-	50	152
2011.	3	+	51	183
2012.	6	+	120	324
2013.	8	+	124	188
2014.	9	-	-	117

ZAKLJUČAK

Uticaj nuklearnih eksplozija na Suncu i stvaranje Sunčevih regiona-vulkana zajedno sa uticajem koronarnih rupa koje se naleze u geoefektivnoj poziciji prema Zemlji imaju uticaja na grupisanje-povećanje broja meteorske prašine u Zemljinoj atmosferi. Ako su čestice-nukleoni, uticaj je izraženiji, dok sama brzina Sunčevog vetra nema uticaja jedino ako se ne poklapa sa vremenom presecanja radijanta meteorskog roja i Zemljine rotacije**.** Iz grafikona koji pokazuje porast broja meteora u dane maksimuma meteora može se predvideti praćenjem pozicije energetskih regiona-vulkana kao i pozicije koronarnih rupa kada su u geoefektivnoj poziciji ka Zemlji i tada imaju najveći uticaj posredstvom čestica Sunčevog vetra. Takođe je izraženo i povećano grupisanje meteora ka maksimumu i sporije opadanje broja meteora ka minimumu. Međutim, sigurniji zaključak o uticaju korpuskularnog zračenja Sunca na meteorski roj je moguće doneti znatno dužim vremenskim periodom praćenja.

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CULTURES ACROSS THE UNIVERSE AND THE ROOTS OF ARMENIAN ASTRONOMY

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Abstract. It is often proposed that people living in different cultural groups are brought up to perceive the world differently. The perception of celestial objects varies from culture to culture. Prehistoric cultures viewed the sky as the main leader of their life and they connected their fortune and daily life only with the Universe. This article mainly refers to the roots of Armenian Astronomy and how it is until now preserved and reflected on other cultures, especially on their mythology, astroterminology, cultivation, physical mobility, the ability to commune very subtly with nature. Consideration of the position of the earth in relation to the celestial bodies are often used in medicine, and until now it is used in the Indian culture, all this and much else has contributed to the great wisdom of ancient nations, the wealth of their culture and man's place therein and in the Universe, their understanding of the mechanisms of regulation of human life activity and vital potentials are reflection of their culture. Here we prove that mythology is preastronomy and it is the basis of cultures, and that national identities were shaped due to the nations special perception of celestial objects.

1. INTRODUCTION

Individuals raised in diverse cultures can actually sense the Universe differently. Throughout the history humans had always watched the sky and banded it to their culture in form of mythology, religion, folklore and art, later they even used the sky for timekeeping and night navigation. Early astronomy is the study of humankind's early attempts to understand the skies. All people have looked up and wondered about the Sun, Moon, planets, stars, and their complex ballet of motion. Interpretations vary widely among cultures, but often the sky is considered as the abode of gods, where humans can never touch. Astronomy has always had a significant impact on our world view. Early cultures identified celestial objects with the gods and took their movements across the sky as prophecy of what would happen in future, now we call this astrology. Often, when we are immersed in our own culture, it is difficult to understand how those from other ethnicities perceive the same Universe differently. In addition, some aspects of our culture are so ingrained in our minds and so commonplace to us that we begin to feel they are universally accepted.

2. ROOTS OF ARMENIAN ASTRONOMY

The perception of the Universe is especially unique in ancient cultures. Ancient astronomy was heavily tied to religious and spiritual outlook of the world, but it contained many accurate observations of phenomena. The influence of astronomy is especially significant in Calendar (Lunar and Solar, Lunisolar), Mythology (the names of the constellations), Religion, Linguistics, Philosophy, Folklore, Arts and Astroheraldry. The influence of astronomy is especially noticeable in ancient nations. The ancient Armenians seemed to consider knowledge and learning to be an important part of their culture – thus studying astronomy was a natural extension of that. Armenia is one of the cradles of ancient science, and astronomical knowledge was developed in ancient Armenia as well. Astronomy in Armenia was popular since ancient times: there are signs of astronomical observations coming from a few thousand years ago. Among the astronomical activities that have left their traces in the territory of Armenia are: the rock art (numerous petroglyphs of astronomical content), ruins of ancient observatories (two of them, Karahunge and Metzamor are especially well known; Karahunge is the Armenian twin of the Stonehenge and is considered even older), the ancient Armenian calendar, astronomical terms and names used in Armenian language since II-I millennia B.C., Anania Shirakatsi's heritage (Anania Shirakatsi 1940), sky maps from Middle Ages. It is believed that the division of the sky into constellations was made a few thousand years ago in the Armenian Highland. According to the American astronomer and historian of science Olcott (1911; 1914), the signs of Zodiac contain such animals that lived many thousand years ago in the territory of Armenia and around. It is very probable that ancient people named the constellations after animals living in their countries rather than known from elsewhere. Moreover, many constellations have their own Armenian names which were different from the Greek ones; however, many of them correspond to each other by the meaning. Studies of the Armenian rock art present in the territory of modern Armenia (historic Armenia was ten times larger, having 300,000 square km area) show that the Armenians were interested in heavenly bodies and phenomena. The Earth, the Sun, the Moon, planets, comets, Milky Way, stars, constellations are reflected in these pictures drawn on rocks in mountains around Lake Sevan and elsewhere in Armenia.

2. 1. ARMENIAN CALENDAR

According to investigations by H.S. Badalian (1970), B.E. Tumanian (1985), and G.H. Broutian (1997), the Armenian calendar was one of the most ancient in the world, may be even the most ancient one. Armenians used Lunar, then Lunar-Solar calendar, and since mid the 1st millennium B.C. they changed to Solar calendar, which contained 365 days (12 months by 30 days and an additional month of 5 days). The new year began in Navasard (corresponding to August 11), when the grape harvest was underway and the constellation Orion (Armenian "Haik") became visible in the night sky. Together with the months, all days of any month also had proper names. The year 2492 B.C. was adopted as the beginning. The Armenian Great Calendar was introduced in VI century, and the difference with the Julian one was re-calculated. It is remarkable that the Mkhitarians from Venice are the oldest publishers of the Armenian and world calendars (since 1775).

Figure 1: Left: The scene of Ar, Sun God worship on Rock Art, Rights: Rock-carved astronomical symbols in Geghama Mountains.

2. 2. ANCIENT OBSERVATORIES

The most fascinating historical astronomical building is Karahunge (the "Armenian Stonehenge", the name derives from kar "stone" and may mean "singing stones"; and the other famous name is Zorats Kar). It is a megalithic assemblage, 200 km from Yerevan, and 3 km from town Sisian; at an altitude of 1,770 m. The northern latitude is 39°34', and eastern longitude is 46°01'. It is an assemblage of many stones put in a circle and a few arms starting from it. As many other such buildings, Karahunge was thought to be a religious assemblage. However, only in the middle of 1980th, Karahunge was first interpreted as an archaeoastronomical monument and was studied by Prof. E.S. Parsamian (1999) and Prof. P.M. Herouni (1998). Estimations give from 7700 to 4000 years for the age of Karahunge. There are 222 stones with a total extent exceeding 250 metres, including 84 with holes (with 4-5 cm diameters). Dozens of astronomical stone instruments with accuracy of 30" may be found. 40 stones form the central ellipse with 45×36 m sizes, having a ruined stone-cluster in the centre. There is an 8m wide 8-stone road to N-E. Some stones were used to find the directions to definite stars. By some estimations (observations of definite stars), the observatory was used during 7700-2200 B.C., for about 5500 years. According to many authors (ex. Bochkarev & Bochkarev 2005), a comparison of the present state of the monument with its situation a hundred years ago reveals a considerable degradation. Thus, the monument needs an urgent protection. The monument is unique of its kind at least in the Trans-Caucasian region and could be even the oldest known observatory in the world. If the estimated age of Karahunge is confirmed by archaeological methods, it clearly should be included in the UNESCO World Heritage list of the most important cultural memorials of our planet. Metzamor is the other ancient observatory in Armenia. Metzamor was an ancient town near river Metzamor, 35 km from Yerevan, in Armavir province. There was a settlement since V millennium B.C. It was first interpreted as an archaeoastronomical monument in the middle of the 1960s by Prof. E.S. Parsamian (1985). There is an observatory out of the fortress. The most probably estimation of the age is 4600 years. As Karahunge, Metzamor also needs a better study and proper attitude both from the Armenian government and world archaeoastronomical community. There are a few other sites in Armenia that are associated with astronomical activity of our ancient habitants.

2. 3. HISTORICAL RECORDS OF ASTRONOMICAL EVENTS

One of the records of astronomical events by ancient Armenians is Halleys Comet depiction. Coins of Armenian king Tigranes II the Great (95-55 BC), silver and copper-bronze tetradrachms and drachms, clearly reveal a star with a tail on the royal tiara which may be associated with Halley's comet passage of 87 BC. If so, one has another case when astronomical events can be useful for historical chronological problems; this would be a far earlier record of Halley in Armenia than was previously known from chronicles and also one of the earliest known images of Halley's Comet.

It is also interesting that Armenians watched in May 1054 the Crab Supernova even earlier than Chinese in August.

2. 4. SUN AND SUN WORSHIP IN ANCIENT ARMENIA

Throughout the history the Sun symbol has been found nearly in all cultures, it has played an important role in shaping our life on Earth since the dawn of time. Since the beginning of human existence, civilisations have established religious beliefs that involved Sun's significance to some extent. Considered by most nations as a cosmic power, it's not surprising we see the Sun emblazed upon countless artifacts and writings. As new civilizations and religions developed, many spiritual beliefs were based on those from the past so that there has been an evolution of the Sun's significance throughout cultural development. Sun was personified as a cosmic eye viewing out upon its dominion during the day. For comparing and finding the origin of the term Sun we studied it in 66 languages and compared the roots of the words. For finding out from where these roots came from, we also studied 21 Sun Gods and Goddesses and proved the direct crossing of language and mythology.

While studying the terms the Chinese word "Ri" brought to our attention, which takes the same Egyptian hieroglyphic shape of a circle and a dot inside, means "sun" in Chinese too. In the Filipino language, we can find that the word (Aarau) means "the sun" too. Also, the English word (Ray), which means "a beam of light", is derived from the Latin (Rayon), very close to the meaning of "Sun". We can decide that the word "ray" is derived from "Ra" and then, all the Latin prefixes such as radio, radiation, etcetera, are derived from Latin Rayon and Rayon derived from Egyptian Ra. But what is the origin of the word Ra? According L. King and V. Fildnersi (Teryan 1995) worship of the god Ra had been arrived from Assyria (current Syria), which at that period was the neighbor of Armenia. The first and main god in Armenia was "Ar" (Mnatsakanyan 1948; Teryan 1995), which means sun or light. We conclude that the Armenian name "Ar" has given origin to many other names in various languages, including the Egyptian "Ra", which is known since the Pharaoh Amenhotep IV or Akhenaten (Mackenzie 1907) who married Nefertiti from the land Khuri-Mitani covering the territory of Armenian highlands.

As the source of life, the sun became equated with power and the supreme god. Beliefs of the ancient Armenians were associated with the worship of many cults,

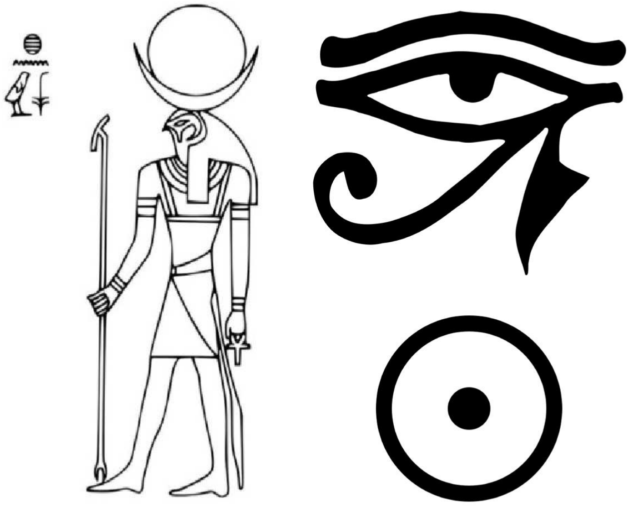

Figure 2: Left: Ra, Sun God, has the head of a falcon and the sun-disk resting on his head, Right: The alchemical glyph in the form of eye is used to represent the Sun since the ancient times.

mainly the cult of ancestors, the worship of heavenly bodies (the cult of the Sun, the Moon cult, the cult of Heaven) and the worship of certain creatures (lions, eagles, bulls). The main cult, however, was the worship of gods of the Armenian pantheon. The supreme god was the common Indo-European god Ar (as the starting point) followed by Vanatur. In southeastern Yemen, the word "Ra'" is used to mean the verb "to see". Similar to Yemen dialect Sha' means see (note that the word for "ray" in Arabic is "Shu'a", derived from the Arabic verb asha' = to shine). The verb Ra' in the sense of "to see" has a symbolic relationship to "the sun" and "the rays" one cannot see anything without the presence of sunlight, or more accurately, the presence of a beam of light, ray.

Sun worship is also present in Armenian calendars. The eighth month of the Armenian year and, what is more significant, the first day of every month, were consecrated to the sun and bore its name (Areg), while the twenty-fourth day in the Armenian month was consecrated to the moon (in Armenian calendar, all 30 days have proper names like the names of the months). The Armenians, like the Persians and most of the sun-worshipping peoples of the East, prayed toward the rising sun, a tradition which the early Armenian Apostolic Church adopted, so that to this day the Armenian churches are built and the Armenian dead are buried toward the east, the west being the dwelling of evil spirits.

Early symbols for gods are closely connected with astral symbols. The first use of the sacred swastika and cross are found in ca. 20,000-15,000 BC inscriptions in the Geghama Mountain Range. Carvings dating back to ca. 8500 BCE show symbols associated with astronomy, giving them a god like prominence: Sun, Moon, and constellations were thought to be deities in themselves, and astral occurrences such as an eclipse or a comet were considered communication from the gods.

3. SUMMARY AND CONCLUSIONS

It is shown that the perception of celestial objects varies from culture to culture and astronomy had a significant impact on humankind, particularly on cultural diversities. Armenians as one of the most ancient nations, have very old roots of astronomical knowledge, including the rock art, ancient observatories, astronomical terms and names used in Armenian language since II-I millennia B.C., Armenian mythology related to skies, three Armenian calendars, historical records of astronomical events, the great scientist Anania Shirakatsi's heritage, medieval sky charts, etc. Ancient Armenian calendar and ancient observatories Metsamor and Zorats Karer (also known as Karahunge) are described. The main emphasis is given to the worship of the Sun by ancient Armenians. We conclude that the Armenian name "Ar" has given origin to many other names in various languages, including the Egyptian "Ra", which is known since the Pharaoh Amenhotep IV or Akhenaten who married Nefertiti from the land Khuri-Mitani covering the territory of Armenian highlands.

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POSMATRANJE VANSOLARNIH PLANETA SA OPSERVATORIJE "NIGHT HAWK" U BAČKOJ PALANCI

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Abstract. In this paper we presented the results of photometric observations of extra solar planets from Observatory Night Hawk in Backa Palanka, which were sent to ETD - Exoplanet Transit Database (Tresca database). In the period from 05. 03. 2012.to 08. 05. 2014. we sent a total of 102 observations of 48 transits.

1. UVOD

Dana 15. aprila 2011. u Bačkoj Palanci je na petogodišnjicu osnivanja Astronomskog društva „Univerzum" otvorena prva amaterska robotizovana opservatorija u Srbiji. Opservatorija se nalazi kod rekreacionog centra "Tikvara". Napravljena je od jednog gradjevinskog kontejnera, koji je modifikovan na taj način da je pregradjen u dve prostorije. Jedna prostorija se koristi za upravljanje računarima dok je u drugom, manjem delu, postavljen astronomski teleskop i taj deo poseduje pokretni krov koji se tokom posmatranja otvara smicanjem na stanu kontejnera sa prvom prostorijom.

U opservatoriji su tri računara koji su umreženi i priključeni na internet, meteorološka stanica koja šalje sve merene podatke o vremenu na sajt Astronomskog društva „Univerzum" univerzumad.com , meteorska kamera, IP kamera preko koje se može videti unutrašnjost opservatorije u realnom vremenu, uredjajem za automatsko zatvaranje opservatorije u slučaju kiše i mnoštvo drugih propratnih uredjaja koji omogucuju korištenje opservatorije putem internet. Na početku je u opservatoriji bio instaliran teleskop GSO 250/1250 na EQ SkyScan pro montaži.

2. POSMATRANJE

Posmatranja tranzita exoplaneta su se na Opservatoriji „Night Hawk" vršila u periodu od 05. 03. 2012. do 08. 05. 2014. godine. Korišćena je fotometrijska metoda tranzita i u posmatranom periodu je napravljeno ukupno 102 posmatranja 48 exoplanete. U Tabeli 1. su navedene posmatrane exoplanete kao i broj posmatranja iste.

Tabela 1: Posmatrani tranziti sa Night Hawk opservatorije.

GJ1214 b	1
HAT-P-1 b	1
HAT-P-14 b	1
HAT-P-16 b	1
HAT-P-18 b	2
HAT-P-2 b	1
HAT-P-20 b	2
HAT-P-22 b	1
HAT-P-23 b	2
HAT-P-25 b	1
HAT-P-28 b	1
HAT-P-3 b	1
HAT-P-32 b	2
HAT-P-36 b	3
HAT-P-37 b	1
HAT-P-38 b	1
HAT-P-5 b	1
HAT-P-8 b	2
HAT-P-9 b	1
HD209458 b	4
Kepler-12 b	1
Kepler-15 b	1
Kepler-17 b	6
Kepler-5 b	1
Kepler-6 b	1
Kepler-7 b	1
KOI 0135 b	1
KOI 0196 b	2
KOI 0204 b	1
Qatar-1 b	8
TrES-1 b	2
TrES-2 b	6
TrES-3 b	7
TrES-4 b	1
TrES-5 b	6
WASP-1 b	1
WASP-10 b	3
WASP-12 b	2
WASP-16 b	1
WASP-21 b	1
WASP-3 b	6
WASP-33 b	1
WASP-37 b	1
WASP-48 b	4
WASP-58 b	3
XO-1 b	2
XO-2 b	1
XO-4 b	1

Korišćeno je nekoliko setupa teleskopa montaže i kamera (zadnji broj predstavlja broj merenja sa datom konfiguracijom opreme):

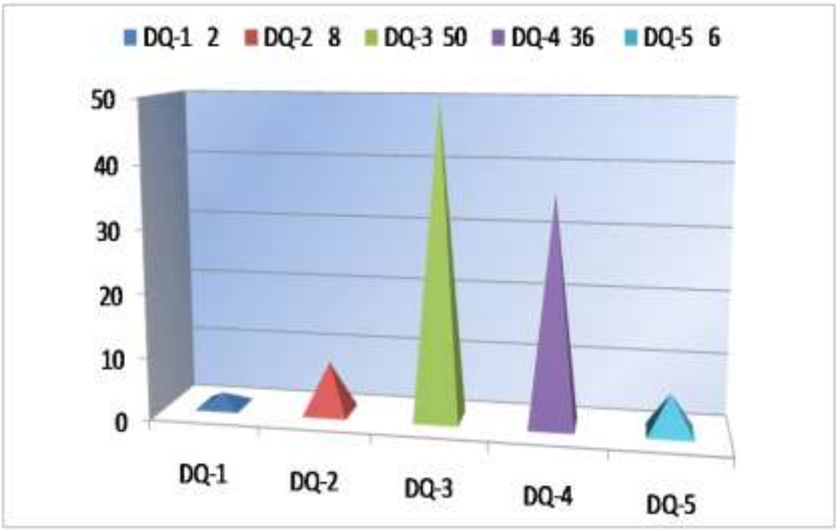
• GSO N250/1250 + EQ-6 + Astropix 1.4 CCD	12
• SW N150/750 + HEQ-5 + Astropix 1.4 CCD	1
• GSO N250/1250 + EQ-6 + SBIG ST7 CCD	30
• Objektiv Jupiter-6 f2.8 + EQ6 + SBIG ST7 CCD	3
• SW N150/750 + EQ-6 + Astropix 1.4 CCD	3
• SW N150/750 + EQ-6 + SBIG ST7 CCD	52
• SW 102/500 + CG5Adv + Astropix 1.4 CCD	1

Korišćene su različite vrednosti expozicije u zavisnosti od snimanog objekta i kretale su se od 8, 10, 15, 20, 30 ,60, 100, 150 do 200 sekundi.

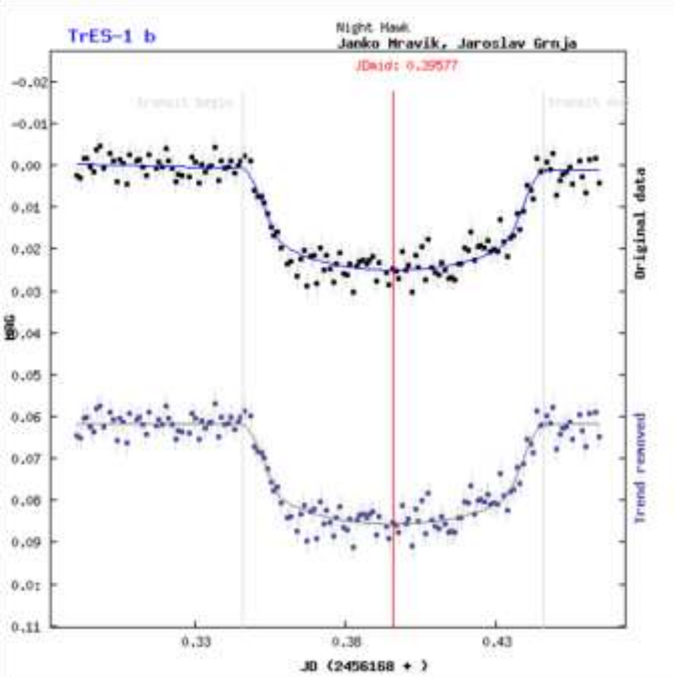
Slika 1: Teleskop, montaža i kamere korišćeni u posmatranju.

Posle standardne kalibracije dobijenih snimaka, fotometrijska obrada se vršila programima: Maxim DL (tri puta), MuniWin (16 puta) i Foto Dif (83 puta).

Sva naša merenja su poslata u ETD – Exoplanet Transit Database http://var2.astro.cz/ETD/index.php koju drži na svojem portalu Češko astronomsko društvo, Sekcija za promenljive zvezde i exoplanete. Na osnovu poslatih merenja generiše se kriva sjaja (Slika 3.) i dobije se ocena kvaliteta merenja DQ indeks od 1 do 5.



Slika 2: Raspodela kvaliteta naših posmatranja.



Slika 3: Primer fotometrijske krive tranzita exoplanete TrES-1b.

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ASTRONOMICAL SOCIETY "PLEJADE" TUZLA, BOSNIA AND HERZEGOVINA

E. TANOVIC

AD Plejade Tuzla, Bosna i Hercegovina
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Astronomical society "Plejade" from Tuzla was founded on 10.01.2009. and alongside Astronomical society "Orion"from Sarajevo is only full active association of this type in Bosnia and Herzegovina. Society "Plejade" is non-profit, non-political, and non-governmental organisation which has the following goals:

- Popularisation and expanding of astronomy knowledge;
- Equal development of technical and scientific aspects of astronomy;
- Helping the other educational institutions in deducing and improving astronomy classes;
- Gathering, organisation, qualification and broadening the membership base;
- Studying astronomical bodies and phenomena;
- Research in a field of astronomy and related natural sciences;
- Training and education of individuals in astronomical observation techniques;
- Training of members for participation in Society's astronomical activities;
- Duly informing of members and public about new astronomical discoveries in the world;
- Research and training in astronomy;
- Studying mysteries in astronomy and astroarchaeology;
- Publishing of scientific journals, fliers and similar promotional materials;

The society founders are: Ervin Adrovic-president, Nadir Ibrahimovic, Husein Hadzic and Sabina Husic. The seat of institution is in the most beautiful ambient promenade „Slana Banja“ in the house called „Kuća Plamena mira“. At this moment we have 150 members, and about 20 active members.

Among numerous activities of AS „Plejade“ members, the most important is annual manifestation „ 7 days of astronomy in Tuzla“, which is organised during summer months. The whole week is fulfilled with all day astronomy and related sciences contents, including lectures and workshops for kids, exhibitions, evening sky observations, astrocamps, movie projections and round tables. Manifestation „7 days of astronomy in Tuzla“ gathers visitors from Tuzla, Tuzla Canton, and from whole Bosnia and Herzegovina and countries in the region. Untill now, we have succesfully and continously managed to organize 4 such events.

It should be mentioned that great support came from Dragan Radmilovic, the man who indefatigably propagated astronomy in whole region and with his decades-long experience was on service to astronomical assotiations in genesis, such is „Plejade“ from Tuzla. Dragan Radmilovic was included in activities of AS “Plejade“ from the first day, and was participant in all three manifestation „7 days of astronomy in Tuzla“.His last activities in AS „Plejade“ have been linked with youth education, where we made the sunspots observation with his personal telescope. Dragan Radmilovic tragically deceased on 19.02.2014. in Sutomore, Montenegro, where he was participant of seminar on astronomy popularization in local elementary school.

Figure 1: Lectures and sky observations during „7 days of astronomy in Tuzla“.

Among numerous lectures which we organised for our members and local people, we would emphasize the organisation of „Yuri's Night“ and „World space week“, taking place traditionaly in Tuzla. Local citizens have opportunity to attend the lectures, documentary projections, and the most attended are telescope observations. Our Societyowns the next astronomical equipment:

- Telescopes: Sky Watcher 254/1200 (reflector), Sky Watcher 150/700 (reflector), Meade ETX 70 (Schmidt-Cassegrain), Meade ETX 80 (Schmidt-Cassegrain), Saturn 114/1000(reflector) i Galileoscop 60/400 (refractor).
- Mounts: EQ 5 GO-TO, EQ 2 and EQ 1 (few pieces), Camera Canon 550 D and other equipment.

Important segment of our society work is to provide help for educational institutions in Tuzla Canton in deducing and improving astronomy classes. AS „Plejade“ is active in educational field and astronomy popularisation. Pupils and students often visit our Society, and our members organised astronomy sections in a few schools in Tuzla.

Figure 2: Astronomy section in Elementary school „Tušanj“.

One segment of work in AS „Plejade“ is a journal for astronomy and similar sciences called „Plejade“. Concept or this journal is that Society members and all others with affinity for writing, can express themselves through different topics of interest in area of astronomy, astronautics, robotics etc. The Journal is free, and until now we have published five issues.

Figure 3: Journal for popularisation of astronomy and related sciences „Plejade“.

We must underline that AS „Plejade“ is full authorized partner of „SYNERGY MOON INTERNATIONAL SPACE AGENCY“, and Team leader for Bosnia and Herzegovina and Director of European Operations is secretary of our Society, Emir Tanovic. „Synergy moon“planning to send mission to the Moon, with intention to land it's lunar modul in crater Irene, where Apollo 17, landed once. The main goal is that rover „Tesla“will drive on Moon surface at least 500 meters and send to Earth HD photos and live stream video (AS „Plejade“ itself participate in constructing of rover „Tesla“). „Synergy Moon“ participates in competition in

„Google lunar Xprize program“, where the main award is 30 000 000 US dollars. Up to now, this Team is selected in groupe of 4 Teams who plan to launch rockets toward the Moon. After that mission, they will send their first crew in orbit around Earth, and one of those crew members will be Nebojsa Stanojevic, the founder of this respectable agency and member of AS „Plejade“. Their pleasure for having „Plejade“ with them, the Team members of „SYNERGY MOON PROJECT“ have expressed on official „Google lunar Xprize program“ and on official page of „SYNERGY MOON“.

Figure 4: Photos of planet Earth taken from ISS.

Nebojsa Stanojevic has linked our Society with Maria Catalina, who works in NASA. At that occasion, she ensured for us a few minutes of conversation with astronauts, which are settled at ISS. Through „Earth Cam project“ the Society members, students, pupils and all other interested persons, with help of ISS, can make photos of our planet from space. Until now we have finalised 8 missions with around 1000 photographies. Some of them can be seen on our official web page:www.adplejade.org.

On “Zeleni kamen” location, which is 15 km north of Tuzla, the members of our Society are preparing the terrain for the construction of the Observatory. We have a concept near the Observatory, among telescope with auxilliary equipment, establish meteorological station, which would be common good for our city. We are sure that our Observatory can signifficantly enrich the city contents, in scientific, cultural, amusement and touristic aspects. It should serve on longer period of time for all citizens, especially for educational purposes for all school students. The best solution is one that allows longterm stationary of the object, which implies constructing observatory from solid materials. As a temporary solution,it's acceptable the installing of cheaper container enabled for special purposes.

Figure 5: Location of future observatory in Tuzla “Zeleni kamen”.

Unfortunately, among all the activities which members of the Society practise for common good, the project financing is big problem, and sometimes, a problem without solution. For all those problems the „Plejade“ journal is temporary stopped, although some time was the only journal of this kind in the country. Without serious finacial support in the future, it is going to be more and more difficult to realize project ideas, which can make an enormous loss for a Society. For now, „Plejade“ can certainly rely only on enthusiasm and energy of its members.

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ZAJEDNIČKE AKTIVNOSTI U POPULARIZACIJI ASTRONOMIJE

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Postoje aktivnosti u oblasti popularizacije astronomije koje su rezultat saradnje dva ili više astronomskih društava ili pak nisu vezane ni za jedno astronomsko društvo. O tim aktivnostima govori se u ovom radu.

***

Svako astronomsko društvo povremeno piše izveštaje o svom radu i u njima iznosi detalje o svojim aktivnostima. Međutim postoje i neke važne aktivnosti u oblasti popularizacije astronomije koje nisu striktno vezene ni za jedno astronomsko društvo, ili su pak rezultat zajdeničkog delovanja više astronomskih društava. Zbog toga se dešava da neke aktivnosti u izveštajima ostanu nepomenute. U ovom radu izdvojićemo nekoliko takvih aktivnosti.

ASTRONOMSKI MAGAZIN

Astronomski magazin (AM, www.astronomija.co.rs) je elektronski časopis (*web site*) za popularizaciju astronomije i srodnih nauka. Nastao je mimo bilo kog astronomskog društva (mada je kasnije, iz birokratsko-administratinih razloga, oformljeno AD „Lira“, Novi Sad, koje formalno i danas stoji iza časopisa). AM je pokrenut novembra 1998. godine što predstavlja prilično davnu prošlost za jedan Internet sajt. U to vreme, krajem XX veka mnogi današnji giganti Interneta poput Wikipedie, Googla itd. nisu ni postojali ili su tek bili u povoju.

Za proteklih 16 godina za AM je stekao više stotina saradnika, različitih profesija i stepena obrazovanja – od učenika srednjih škola do univerzitetskih profesora, od fizičara, astrofizičara, matematičara, biologa itd. sve do književnika i slikara. Neki su napisali tek po nekoliko članaka za AM, ali neki i preko hiljadu. Neki nisu napisali ništa, ali su na drugi način doprineli razvoju časopisa – svojim likovnim radovima, fotografijama, promocijom časopisa, obezbeđivanjem tehničke podrške i slično.

Velik broj saradnika ukazuje na značajnu ulogu AM u okupljanju i povezivanju brojnih ljubitelja astronomije i nauke uopšte i to sa područja čitave bivše

Jugoslavije. Danas taj značaj bledi jer su se neslućeno razvile društvene mreže na Internetu, ali krajem prošlog i početkom ovog veka svako mesto na kome su se mogle razmeniti ideje i iskustva iz oblasti amaterske astronomije bilo je dragoceno.

Upravo iz ovih kontakata i uspostavljanja saradnje, poznanstava itd. iznikle su neke druge interesantne aktivnosti od kojih izdvajamo takmičenje u Mesijeovom maratonu i Astronomski kamp „Letenka“.

MESIJEOV MARATON

Prvi Mesijeov maraton u našoj zemlji organizovan je 2001. godine na Fruškoj gori u sportskom naselju Letenka. Formalno, taj maraton od početka organizuje Astronomski magazin, odn. AD „Lira“, ali zadnjih godina u organizaciju su se aktivno uključili AD „Novi Sad“ iz Novog Sada i AD „Univerzum“ iz Bačke Palanke tako da je to sada zajednički projekat ova tri astronomska društava.

U čitavom regionu jedino Hrvatska ima dužu tradiciju organizovanja Mesijeovog maratona. Značaj ovog takmičenja vidimo u doprinosu poboljšanja astronomskih osmatračkih sposobnosti naših takmičara. Dok su oni početkom protekle decenije bili inferiorni u odnosu na osmatrače iz zemalja u kojima je amaterska astronomija znatno razvijenija, danas su u najmanju ruku ravnopravni sa njima. S pravom možemo reći da su naši osmatrači ograničeni jedino instrumentima koje poseduju i koriste u astronomskim posmatranjima.

Članci o maratonima
http://www.astronomija.co.rs/mesije

ASTRONOMSKI KAMP „LETENKA“

Verovatno najznačajnija od svih aktivnosti od kojima govorimo je Astronomski kamp „Letenka“ koji se od 2001. organizuje na Fruškoj gori u naselju „Letenka“ (kao i Mesijeov maraton). I ovaj kamp je pokrenulo AD „Lira“, ali zadnjih sedam godina se organizovanje kampa se zasniva na saradnji više organizacija. Kamp finansijski pomažu Pokrajinski sekretarijat za nauku i tehnološki razvoj i Departman za fiziku PMF iz Novog Sada, dok čitavu organizaciju kampa drže, AD „Lira“ i AD „Novi Sad“.

Kamp se održava sredinom jula i traje od četvrtka do nedelje, zaključno. Učesnici kampa dolaze ne samo iz naše zemlje već i iz Slovačke, Slovenije, Hrvatske, Makedonije, Rumunije, itd. U kampu se okupi između 100 i 200 učesnika, a taj broj zavisi od finansijskih mogućnosti kampa i njegovih učesnika.

Za koga je kamp? Za sve koji žele ponešto iz nauke da saznaju, nauče ili da drugom prenesu svoje znanje. Uglavnom su to studenti i srednješkolci, ali ima i čitavih porodica sa sasvim malom decom – za koju se priprema poseban program.

Program kampa je raznovrstan i sastoji se od niza predavanja, radionica, demonstracija, prezentacija, tribina itd. Iako ima i stručnih predavanja, većinom su ona popularna i razumljiva za svakog sa srednješkolskim znanjem. Sem toga, teme predavanja su uvek zanimljive i aktuelne. Neki programi imaju takmičarski karakter (takmičenje u otkrivanju određenih nebeskih objekata, astronomski kviz itd.).

Neki programi su neprimetni iako se odvijaju. Recimo svako će dobiti potpune informacije o rukovanju teleskopom, o novostima iz sveta astronautike, astronomije itd. ako to zatraži, nezavisno od toga šta piše u zvaničnom programu kampa. Takođe, u kampu se vrši razmena softvera, ideja, znanja, informacija itd. To sve isto spada u program iako se ne odvija u nekoj prepoznatljivoj i vidljivoj formi.

Svi predavači su vrsni stučnjaci u svojoj oblasti. Među njima ima profesionalnih astronoma, profesora univerziteta, samograditelja teleskopa, književnika, iskusnih nebeskih posmatrača, studenata itd. itd.

Kamp ima svoj Organizacioni i Programski odbor, te posebnu službu koja brine da se život u kampu i program kampa odvija u redu (snimanje, fotografisanje, ozvučenje, čuvanje opreme itd.).

Ovaj kamp je sigurno jedan od najvećih kampova za popularizaciju astronomije u Evropi.

Višestruki je značaj kampa i on omogućava svakom gostu da čuje zanimljiva predavanja i vesti iz sveta nauke, da se upozna sa novim astronomskim isntrumentima, da se upozna sa nekim od naših najpoznatijih naučnika (jer uvek neko od njih boravi u kampu), a poneko od gostiju dobija priliku da održi prvi put svoje javno predavanje ili da se upozna sa svojim budućim profesorom na nekom fakultetu – jer zadnjih godina u kampu kraće ili duže boravi po neki od profesora sa Niškog, Beogradskog i Novosadskog univerziteta.

O kampu:
http://www.astronomija.co.rs/astronomski-kamp

JAVNA ASTRONOMSKA POSMATRANJA

Povremeno više astronomskih društava zajednički organizuju javna astronomska osmatranja. To je npr. bio slučaj sa projektom „Vojvodina posmatra Evropu" kada je šest društava iz Vojvodine organizovalo istovremeno javno posmatranje Jupiterovog satelita Evorpe u šest gradova Vojvodine. Ta društva bila su AD „Univerzum" iz Bačke Palanke, AD „Novi Sad" i AD „Lira" iz Novog Sada, AD „Milutin Milanković" iz Zrenjanina, PD „Gea" iz Vršca i astronomsko odeljenje Društva izviđača iz Sremske Mitrovice. Akcija je sprovedena 31. marta 2012.

http://www.astronomija.co.rs/posmatranja/5779-vojvodina-posmatra-evropu.html

Bilo je i drugih zanimljivih zajedničkih osmatranja, recimo posmatranje Urana tokom avgusta 2010. Ovu akciju je organizovao AM (www.astronomija.co.rs) zajedno sa sajtovima iz Hrvatske: Zvjezdarnica (www.zvjezdarnica.com), Astrovizija (www.astrovizija.hr), AU „Vidulini" (www.zvjezdarnica.org). Cilj je bio da se što veći broj čitalaca pomenutih sajtova navede da detektuje Uran i o tome popuni izveštaj, za šta je svakom sledilo elektronsko priznanje. Rezultat: više od 100 izveštaja je primljeno iz svih bivših jugoslovenskih republika.

http://www.astronomija.co.rs/posmatranja/3027-iusnop-2010.html

Da pomenemo i da su tri astronomska društva 2011. i 2012. u okviru Zmajevih dečjih igara u Novom Sadu organizovala javno osmatranje za decu i odrasle. Ta društva su bila AD „Univerzum“, „Novi Sad“ i „Lira“.

http://www.astronomija.co.rs/vesti/4377-am-i-zmajeve-igre-dan-etvrti.html

ŠTAMPANI ČASOPISI

U proteklom periodu dva puta je pokrenuto izdavanje štampanog časopisa – opet nezavisno od bilo kog astronomskog društva. Šest godina je izlazio časopis Astronomija, od 2003. do 2009. i za to vreme je objavljeno 36 brojeva, a nakon njega još jednu godinu izlazio je časopis Astronomski magazin (koji je zapravo bio nastavak Astronomije u svemu sem u imenu i izdavaču) u četiri broja 2011-te godine. Oba časopisa su imala popularno naučni karakter. Za oba pisalo je više stotina saradnika različitih profesija, stepena obrazovanja.

Nedostatak finansijskih sredstava je presudno uticao na prestanak izlaženja ovih časopisa iako su oba dobala zavidne ocene i čitalačke publike i profesionalnih astronoma.

Umesto ovih časopisa povremeno se objavljuje njihova PDF verzija.

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OPPORTUNITIES AND DIFFERENT APPROACHES TO FUNDING OF ASTRONOMICAL RESEARCH AND OUTREACH ACTIVITIES

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Abstract. This paper presents an overview of the funding of scientific research activities and popularization of astronomy in the region. The aim of this paper is to draw attention to the current situation, obstacles and opportunities for providing additional financial resources for scientific research institutions and amateur associations. This survey is based on reports of amateur organizations.

1. INTRODUCTION

Research was conducted by interviewing representatives of NGOs that are involved in astronomical research and outreach activities in South Eastern Europe, including organizations from Republic of Serbia, Republic of Croatia and Republic of Macedonia (FYROM). Objective was to cover organizations that are at least four years old and have done at least 10 successful projects in order to understand the way these organizations finance their activities. It is out of great importance from the organizational point of view to provide essential funds for progress and development of new projects and staff. Lack of funds and reliable sources can influence the motivation of staff and lead them to leave the projects and NGOs.

2. RESULTS

Results indicate that the biggest number of those organizations rely on funds provided by their members, from incomes such as memberships and from incomes generated from the realization of their program activities, as a seen in chart number 1.

Organizations covered by this survey annually have only up to four different types of incomes and up to five different sources that provide funding.

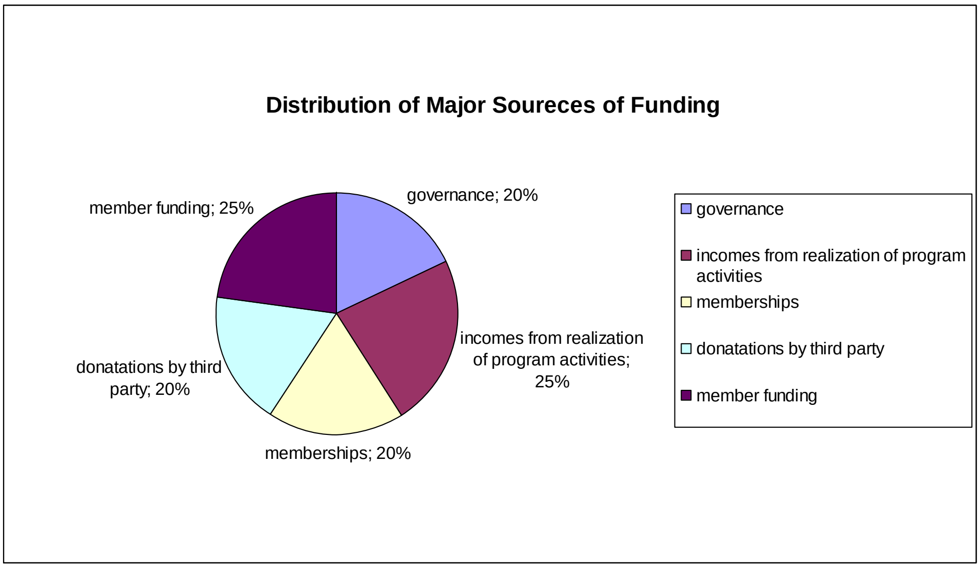

Fig. 1: The distribution of major sources of funds.

Although we recognize from Graph 1a limited capacity of organizations to provide their own sources such as incomes from business activates, not a big interest is seen when it comes to a seeking for new sources and types of incomes/donations.

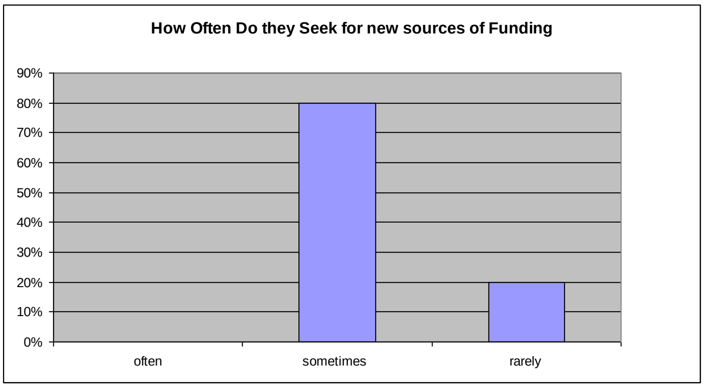

Fig. 2: Indicating the frequency of seeking for new funding solutions.

On average 30% of all annual outcomes are covered by institutional sponsors and the satisfaction of general financial situation is graded as 5 on scale from 1 to 10. Research also indicates that only 57.35% of overall regular outcomes are funded during one accounting period.

Programs and activities of over 60% of interviewed organization are totally dependent of their own private funds, since they cannot provide any extra source of funding.

Even 40% of organizations covered by this research do not believe that the increment of available funds and grants will result significantly in motivation of team members, enhancement of working conditions while conducting regular planned activates.

80% of them don’t have a specialized team member for fundraising activities, financial planning and budget planning. Only 45% of organizations sometimes think about hiring a professional fundraiser and much as 40% of them strongly believe that they don’t need fundraisers. 45% of contacted organizations did not reply after being contacted for a survey.

3. CONCLUSIONS AND DISCUSSION

In this paper, different approaches of funding projects are presented.

It has been demonstrated how astronomical research and outreach activates by NGOs in the region are funded and how organizations operate in these conditions.

It has been proven that organizations do not have sufficient capacities for fundraising activities, financial planning activities and related operations and that this is one of the reasons of poor funding.

As a result organizations seek 45% of annual funds from its members. This leads to a conclusion that those organizations are financially unstable and highly dependant of members (staff).

Organizations rarely recognize the importance, possibilities and the advantages of hiring professional team members which are devoted to fundraising

This paper represents an important review on the way how astronomical research and outreach activates are funded and it provides closer view on activities of organizations.

To a large extent, dependent of the funds provided by their members, and the fact that they are not capable to cover the costs of their activities, or to facilitate the donations of third parties indicate poor level human resources policy, wrong approach to the business.

References

Čolaković, Filip: 2014, “Fundraising and budgeting of astronomical research and outreach activities in our region” Survey, 20 September 2014.

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A.A.D. "TYCHO BRAHE" BEOGRAD

A. JANKOVIĆ, A. ANDJIĆ, B. NIKOLIĆ i P. PETROVIĆ

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Apstrakt. Amatersko astronomsko društvo "Tycho Brahe" osnovano je 7. juna 2010. godine u Beogradu od strane četvorice bliskih prijatelja koji dele zajedničku ljubav prema astronomiji i astrofotografiji. Naša oprema bazirana je na Njutnovom teleskopu aperture 150mm i fokalne dužine 750mm na motorizovanoj EQ-3 montaži, a za potrebe astrofotografije uglavnom koristimo primarni fokus i okularnu projekciju. Budući da se profesionalno bavimo poslovima koji nisu vezani za astronomiju, trudimo se da što više slobodnog vremena provodimo u prirodi pod otvorenim nebom i da našu ljubav prema vasioni i njene ne tako pristupačne lepote prenesemo što većem broju prijatelja, njihovim poznanicima i ostalima.

U cilju promocije astronomije, a za koju smatramo da na žalost još uvek nije u dovoljnoj meri zastupljena u našoj javnosti, u januaru 2011. godine pokrenuli smo i blog na Internetu pod nazivom "Urbani astronomski dnevnik" (*http://aadtychobrahe.blogspot.com*) putem koga redovno i detaljno izveštavamo o svim našim aktivnostima na jedan zabavan i prijemčiv način, dostupan najširoj publici svih uzrasta. Pored nezaobilazne osmatračke astronomije, veoma smo angažovani i po pitanju astrofotografije i za sobom već imamo značajan broj radova koji uključuju Mesec, Sunce, planete Sunčevog sistema, magline, zvezdana jata, galaksije i sve ostalo vezano za astronomiju što smatramo da je vredno ovekovečiti i podeliti sa drugima.

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LIČNA KARTA ASTRONOMSKOG UDRUŽENJA *ANDROMEDA*

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„Među astronomima važi nepisano pravilo, da astronomska udruženja dobijaju imena po prvom astronomskom objektu koji uoče na nebu“, rekao mi je Milan Jevtović, prvi predsednik AU Andromeda.

Astronomsko udruženje *Andromeda* osnovano je početkom septembra 2003. godine. U početku ga čine učenici i profesori Knjaževačke gimnazije, no tokom vremena udruženju pristupaju i učenici i profesori ostalih Knjaževačkih osnovnih i srednjih škola, kao i veliki broj građana. Društvo danas broji preko 350 članova. To je jedino takvo društvo na teritoriji Timočke krajne. Iako mlado društvo iza sebe ima rezultate. Skoro svake večeri su se u dvorištu Knjaževačke gimnazije vršila posmatranja neba teleskopom. Članovi društva su održali čitav niz predavanja sa ciljem popularizacije astronomije. Bili su česti gosti radio i TV emisija. Od 23. 02. 2004. godine obaveštavaju preko tadašnjeg Radio Knjaževca građanstvo o nebeskim koordinatama i nebeskim pojavama koje se tog dana mogu posmatrati.

Društvo je organizovalo i dolazak u naš grad poznatih astronoma i astrofizičara sa niškog Prirodno – matematičkog fakulteta i Narodne opservatorije iz Beograda. Naše astronomsko udruženje je u kontaktu sa desetak sličnih udruženja u zemlji i inostranstvu. U saradnji sa Narodnom opservatorijom iz Beograda naše društvo je organizovalo letnju astronomsku školu na Babinom Zubu u avgustu mesecu sada već daleke 2004. godine, i tada se smatralo da je to izuzetna prilika da se promoviše Stara planina i naš kraj.

Andromeda nije nastala iznenada ni slučajno, ona je samo konkretizacija priča, koje su tokom osamdesetih i devedesetih godina profesori fizike Knjaževačke gimnazije, Gradimir Jeremić i Milan Jevtović pričali svojim đacima. Andromeda je nastala i iz svih onih đačkih pitanja koja su nam postavljana: Zašto je nebo tamno, kako nastaju zvezde, gde su granice kosmosa? **Andromeda je morala da nastane.**

Nastala je ona još u februaru mesecu 2003. god. kad smo napisali projekat koji nazvasmo “Teleskop”i za koji nam Ministarstvo prosvete odobri sredstva, i od tih para kupismo prvi teleskop u septembru mesecu iste godine . Onda se latismo posla da napravimo i registrujemo drušvo. Izradismo statut i sva pravna akta. Društvo krstismo Andromeda po nama najbližoj galaksiji (jedina koja nam se približava, dok se sve druge udaljavaju i uporno beže od nas). Od samog početka krenusmo ambiciozno, našavši kutak u podrumu Knjaževačke gimnazije, koja nam pruži utočište i ljubav. Gimnazijski profesori se uključiše u rad društva i ostaše mu verni do današnjeg dana.

Na samom početku članovi Andromede postavili su jasne ciljeve: popularizacija nauke i razbijanje svih predrasuda koje su mučile kako mlade tako i stare. Zbog toga pokrećemo jesenju i prolećnu skolu astronomije koje traju do današnjeg dana. Knjaževac je jedan od retkih gradova u Srbiji koji ima tu privilegiju da svake godine u oktobru, novembru, decembru, februaru, martu i aprilu njegovi građani čuju razna predavanja iz oblasti astronomije, fizike i drugih prirodnih nauka. Grad je oberučke prihvatio Andromedu. Građani prisustvuju svim našim aktivnostima, a mi smo znali da izaberemo i teme ali i predavače koji bi zadovoljili znatiželju slušaoca. Naše aktivnosti prate i lokalni mediji ali i regionalna televizija, kao i list Timok. Tih godina je bila značajna saradnja i sa prvim programom radio Beograda, koji je pratio dešavanja u društvu kao i aktivnosti koje je ono sprovodilo. Andromeda polako osvaja Srbiju, uspostavlja se saradnja sa astronomskim društvom Ruđer Bošković iz Beograda, AD Alfa iz Niša, Prirodno-matematičkim fakultetom iz Niša, opservatorijom sa Zvezdare, Institutom za fiziku iz Zemuna kao i brojnim ljudima koji znače nešto u svetu astronomije. Srbija postaje mala za sve ono što članovi našeg društva znaju i žele da pokažu svetu, ali i da nauče nešto od tog sveta. Uspostavila se saradnja sa astronomima iz Bugarske iz grada Belogradčika, oni dolaze kod nas i mi idemo kod njih. Razmenjujemo iskustva ali i literaturu, sklapamo trajna prijateljstva koja do danas traju. Počinje saradnja sa Kalifornijskim tehnološkim institutom iz Amerike. Njihov stručnjak drži predavanja u Knjaževcu, a njihovi naučnici nam šalju svoje knjige i stručne časopise.

Kroz naše društvo prošlo je mnogo ljudi. Mnogi od njih su dali veliki doprinos da se čuje za Andromedu, da se čuje za Knjaževac. Zajedno smo proveli noći i noći posmatrajući nebo nad Knjaževcom i na tome smo im zahvalni. Zahvalni smo i onima koji su slušali naša predavanja, onima koji su nas bodrili da istrajemo u tome što smo radili. Čini mi se da smo svi mi koji smo otišli iz Knjaževca poneli taj komad neba iznad Knjaževačke gimnazije i da ga čuvamo u srcu kao nesto najdragocenije, pričao je Milan Jevtović...

Članovi Andromede, od kojih je većina srednjoškolskog i osnovnoškolskog uzrasta, predstavljaju bazu mladih ljudi zainteresovanih ne samo za proučavanje astronomije, već i ostalih prirodnih nauka i filozofskih disciplina. U toku svog već decenijskog postojanja njegovi članovi uspeli su da organizuju petnaestak škola astronomija sa preko 100 predavanja na kojima su gostovali mnogi eminentni profesori i poznavaoci prirodnih nauka u svojstvu predavača, koji su širokom auditorijumu i građanstvu uspeli bar malo da približe zakone i pojave koje se dešavaju u ogromnom prostranstvu našeg svemira. Ali, smatramo da je još veći uspeh to, što smo uprkos siromašnoj i nedovoljno prosvećenoj sredini u kojoj funkcioniše naše udruženje, uspeli da polovinu tih predavanja održimo sopstvenim snagama. Više desetina mladih ljudi (od kojih neki po prvi put) je dobilo šansu da pokažu svoja interesovanja i znanja iz oblasti astronomije i drugih prirodnih nauka, i naprave prve korake u izboru svoje profesionalne orijentacije i daljeg stručnog usavršavanja. Mnogi od njih su izabrali fakultete astronomije, fizike, filozofije, novinarstva... , podstaknuti radom i aktivnostima u okviru udruženja. Mnogima od njih su astronomija i posmatranja nebeskih objekata ostali samo hobi kojima će se vraćati iznova i iznova, kao i sećanjima na nezaboravne trenutke provedene u druženju i razmeni znanja i iskustava sa ostalim članovima našeg i drugih astronomskih udruženja.

Prilikom organizacije i realizacije svih aktivnosti imali smo odgovarajuću materijalnu i logističku podršku od strane lokalne samouprave, kao i od strane drugih društvenih i kulturnih organizacija, određenih privatnih preduzetnika i medija.

Ako posmatramo AU Andromeda u svetlu tadašnje 2009. godine koja je proglašena Svetskom godinom astronomije možemo reći da smo bili spremni da je u saradnji sa drugim astronomskim udruženjima u Srbiji dostojno obeležimo. Osim već tradicionalnih održavanja ciklusa predavanja u okviru prolećne i jesenje škole astronomije, organizovan je kviz iz oblasti astronomije republičkog karaktera, učestvovanje na letnjem kampu i drugim stručnim skupovima, organizacija posmatranja svih važnijih pojava na nebu u toku godine, kao i nabavka novog teleskopa sa pratećom opremom.

Na dugoročnom planu vidimo Andromedu kao galaksiju (udruženje) koja se sastoji od ogromnog broja malih i velikih zvezda (članova) čija svetlost ne obasjava samo lokalno nebo jedne male sredine kao što je naša već se prostire iznad svih delova naše planete pokazujući nam put u jednu prosperitetniju i lepšu budućnost.

Do sada je organizovano sedam prolećnih, sedam jesenjih i jedna letnja astronomska škola kao i škola fotografije u saradnji sa foto-radnjom ZOOM iz Knjaževca. Predavanja su realizovana kako u biblioteci Knjaževačke gimnazije tako i u prostorijama Doma kulture u Knjaževcu. Zastupljene teme bile su prilagođene kako učenicima osnovnih i srednjih škola, tako i građanima iskusnim u ovoj oblasti. Pored učenika i profesora Knjaževačke gimnazije, predavači su bili i gosti sa Niških, Novosadskih i Beogradskih fakulteta, kao i predstavnici drugih astronomskih udruženja iz različitih gradova Srbije. Građani su imali prilike da se upoznaju sa mnogim popularnim temama iz astronomije. Među predavačima su bili Dr. Dragan Gajić, Dr. Zoran Pavlović, Dr. Miodrag Radović, Aleksandar Otašević, Dr. Milan Ćirković, sada Dr. Bojan Nikolić, Milan Bogosavljević... Učenici Knjaževačke gimnazije, bili su dosta uspešni sa svojim predavanjima zahvaljujući pomoći profesora fizike Milana Jevtovića i Milijana Srejića, koji su se uvek trudili da izađu u susret željama i interesovanjima učenika. Od decembra 2006. godine, predsednik udruženja je Milijan Srejić, a od decembra 2010. Godine i danas udruženjem rukovodi Miljan G. Jeremić, profesor računarstva i informatike i ljubitelj astronomije.

Posle više od deset godina postojanja rad AU Andromeda dobro je poznat Knjaževčanima ali i šire. Današnji čanovi Andromede, srednjoškolci svojim aktivnostima doprinose radu i razvoju udruženja. Realizaciji njihovih ideja i želji za znanjem u susret izlaze profesori fizike Milijan Srejić i Milan Milošević, ali i drugi profesori Knjaževačke gimnazije, ljubitelji astronomije i srodnih prirodnih nauka. Ekipa mladih astronoma trudiće se da nastavi sa popularazacijom ove nauke.

U okviru AU Andromeda od nastajanja funkcioniše posmatračka sekcija. Cilj ove sekcije je popularizacija astronomije kao nauke kroz jedan praktičan pristup. Posmatranja se održavaju skoro svake nedelje (u zavisnosti od vremenskih prilika). Posmatranja se vrše pomoću dva teleskopa. Jedan je ručne izrade 200/1200mm, a drugi je marke Optisan 100/500mm. Svake godine posmatračka sekcija organizuje obuku za sve zainteresovane. Do sada su članovi posmatračke sekcije imali prilike da vide Sunce, Sunčeve pege, Saturn, Jupiter sa svoja četri satelita, Mars, Veneru, brojna zvezdana jata. Vođe posmatračke sekcije su bili Miloš Jeremić i Stefan Živković.

Od decembra 2006. godine AU Andromeda ima svoju internet prezentaciju koja je prvobitno bila na adresi www.anrdomeda.org.yu, a od kad su novi srpski domeni pušteni u rad, naša online prezentacija mogla se naći do skora i na adresi www.andromeda.rs. Sajt se sada nalazi na adresi www.andromedaknj.wordpress.com, gde se mogu nači predavanja koja su održana u okviru prolećnih i jesenjih škola astronomije.

Astronomsko udruženje Andromeda poseduje svoju biblioteku koja se nalazi u prostorijama udruženja. Biblioteka poseduje oko tridesetak stručnih knjiga i oko 300 časopisa, među kojima se nalaze *Galaksija, Astronomija, Andromeda, Sky and Telescope*.

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SERBIAN ASTRONOMICAL JOURNAL IN SCIENCE CITATION INDEX AND JOURNAL CITATION REPORT

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Abstract. We disscuss the first year Serbian Astronomical Journal bibliographic and citation data in the Thomson Reuters' Science Citation Index and Journal Citation Report.

1. INTRODUCTION

In 2014 Serbian Astronomical Journal (SerAJ) for the first time appeared in Thomson Reuters products (retroactively, from No. 182, 2011): Science Citation Index-Expanded (SCIE) including the Web of Science (WoS), Current Contents/Physical, Chemical & Earth Sciences (CC/PC&ES) and on July 29 in Journal Citation Report (JCR) - commonly referred as ISI or SCI list. The selection process was long and thorough, the parameters monitored were both qualitative and quantitative, including geographical distribution of authors, journal citation/impact factor (IF) (for details see Arbutina 2007, 2010, 2013), etc.

2. THE FIRST YEAR DATA

In JCR for 2013 SerAJ is at the position 41/59 on Astronomy and Astrophysics list with IF = 33/30 = 1.100. The journal immediacy index is II = 1/11 = 0.091 (JCR 2014).

These results are quite good and the only downside is a large self-citation - cites within the same journal, 57% (which is why some journals were even excluded from 2013 JCR). The reason for this is probably non-articles (materials such as editorials, book reviews or in memoriams) and "citations" in them which are routinely captured and processed when the journal is indexed, but were not counted in e.g. Arbutina (2013). Hence, we expect this number to drop somewhat in the following years.

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AKTIVNOSTI ASTRONOMSKE GRUPE DRUŠTVA ISTRAŽIVAČA "VLADIMIR MANDIĆ-MANDA" U PERIODU OD 2012. DO 2014. GODINE

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Abstract. Društvo istraživača "Vladimir Mandić-Manda" osnovano je 1969. godine u Valjevu. Danas u Društvu postoji šest aktivnih grupa medu kojima je i Astronomska, koja funkcioniše od 1973. godine. članovi ove grupe su većinom srednjoškolci amateri koji se astronomijom bave iz ljubavi kroz niz praktičnih vežbi i predavanja. Grupa se bavi posmatranjima i praćenjem meteorskih rojeva, Sunca i drugih nebeskih tela kao i praćenjem velikog broja dogadaja. Takode, jedan od važnijih ciljeva grupe je promocija astronomije medu mladima grada Valjeva kroz organizovanje javnih posmatranja i škole astronomije. U ovom radu su predstavljene najuspešnije aktivnosti grupe realizovane u periodu od 2012. do 2014. godine podeljene u tri celine: promocija nauke, istraživačka delatnost i naučno obrazovanje.

1. ISTORIJSKI PREGLED

Društvo istraživača "Vladimir Mandić-Manda" iz Valjeva je nevladina organizacija koja je osnovana 1969. godine. Od tada su u Društvu formirane mnoge grupe koje funkcionišu u zavisnosti od interesovanja mladih grada Valjeva. Zadatak ove organizacije je da okuplja mlade ljude koji žele da usavršavaju sebe i okolinu i da primenjuju stečena znanja boravkom u prirodi i delovanjem u Društvu, bavljenjem naučno-istraživačkim radom i kreativnim korišćenjem slobodnog vremena. Aktivnosti Astronomske grupe su zasnovane na popularizaciji astronomije, razvijanju naučno-istraživačkog duha kod mladih i edukaciji sredine u cilju približavanja ove nauke, koja nije toliko zastupljena u školskom sistemu. Većinu članova grupe čine srednjoškolci i broj aktivnih mladih je oko dvadeset. Grupa je u periodu od 2012. do 2014. godine organizovala veliki broj akcija, dogadaja i učestvovala na astronomskim kampovima i manifestacijama. Rezultati koje su članovi tokom ovih aktivnosti postigli su amaterskog karaktera i u skladu su sa mogućnostima grupe i Društva istraživača.

2. AKTIVNOSTI

2. 1. PROMOCIJA NAUKE

Grupa je od početka 2012. godine do septembra 2014. godine organizovala niz aktivnosti koje su imale za cilj promociju astronomije i srodnih nauka, ali je bila i učesnik raznih dogadaja slične sadržine. U njih se ubrajaju manifestacija "Sat za našu planetu", učešće na Tešnjarskim večerima, fotografske izložbe, javna posmatranja i predavanja koja grupa povremeno organizuje, kao i "Astrovikend" u Domu Omladine Beograda.

Tri godine za redom, članovi grupe su u Valjevu, u martu mesecu, organizovali manifestaciju "Sat za našu planetu". Osnovni cilj astronoma je bio da kroz manifestaciju skrene pažnju gradanima da gase svetla kako bi se svetlosno zagadenje smanjilo i posmatrački uslovi tokom noći poboljšali, ali i da štede resurse. Prvi put, 2012. godine manifestaciju su članovi realizovali u saradnji sa Podmlatkom Društva. Naredne godine grupa je samostalno organizovala dogadaj u samom centru Valjeva, gde je 60 svećica bilo poredano u obliku simboličnog znaka za ovaj dogadaj. Pored same postavke, prolaznici su svih godina bili u mogućnosti da posmatraju kroz teleskop, da saznaju mnoge astronomske i ekološke zanimljivosti i da se zabave uz muziku koju su na akustičnoj gitari pripremili članovi Astronomske grupe. Na sajtu "Nacionalne geografije", 2013. godine, objavljena je fotografija sa manifestacije, koju je napravio jedan od članova. U 2014. godini Speleološka grupa Društva se priključila manifestaciji i samim tim program je podignut na viši nivo. Za vreme trajanja manifestacije, svetla na centralnim lokacijama u gradu su bila ugašena.

Tešnjarske večeri, kao najznačajnija i najposećenija gradska manifestacija, pružaju sjajne mogućnosti za promociju rada grupe. Raznorazne aktivnosti kao što su: posmatranje teleskopom sa javnih mesta, puštanje edukativnih filmova iz oblasti astronomije, održavanje predavanja od strane članova grupe i profesora Valjevske gimnazije, postavljanje izložbi astrofotografija, ostvarene su i posećene od strane velikog broja ljudi.

Fotografske izložbe predstavljaju rezime aktivnosti uradenih u toku godine. U toku 2012. u okviru Tešnjarskih večeri organizovana je izložba pod nazivom "Zvezdani portreti" koja je, kako sam naziv kaže, predstavila astrofotografije nastale tokom pomenute godine. U 2013. godini izložba je zauzela deo programa u okviru dogadaja "40 godina Astronomske grupe", koji je održan 14. decembra u prostorijama Društva istraživača.

Jedan od dogadaja u okviru kojih je grupa ušestvovala u decembru 2013. godine bio je "Astrovikend" u Domu Omladine Beograda. Takode, javna posmatranja su organizovana uvek kada su vremenski uslovi povoljni, sa ciljem da se isprate aktuelne astronomske pojave.

2. 2. ISTRAŽIVAČKA DELATNOST

Katakteristične akcije u ovoj kategoriji jesu one koje imaju za cilj posmatranje meteorskih rojeva. Rojevi koji su najviše posmatrani tokom ovih godina su: Kvadrantidi, Liridi, Perseidi, Orionidi i Leonidi. Lokacije posmatranja navedenih rojeva bile su valjevske planine, dok su manji rojevi posmatrani u samoj okolini grada, gde je svetlosno zagadenje umanjeno. Dobijeni rezultati sa akcija su obradivani i slati u Internacionalnu meteorsku organizaciju (IMO). Značajnije akcije su Liridi 2012. i

2013. godine kao i Leonidi 2013. godine, pre svega zbog priliva novih članova u grupu. Organizovane su po završetku škole astronomije i bile su edukativnog i posmatračkog karaktera. Takode, akcija Perseidi '12 je bila značajna jer je, po prvi put, uspešno napravljena fotografija bolida (veoma sjajnog meteora).

Tranzit Venere je jedinstven i redak astronomski dogadaj koji je u junu 2012. godine bio propraćen od strane velikog broja članova. Za vreme ovog dogadaja napravljene su astrofotografije samog tranzita i isti je projektovan na papir kroz teleskop. Tokom 2013. godine, grupa je pratila i druge astronomske dogadaje kao što su Super Mesec u junu i kometa ISON u novembru. Svakodnevni rezultati dobijeni posmatranjem i projekcijom sunčevih pega su uozbiljili naše amatersko posmatranje Sunca. Tada je u grupi, nakon duže pauze, zaživelo računanje Volfovog broja. Astronomski kamp Letenka bio je posećivan od strane nekoliko članova tokom ove 3 godine, a znanja koja smo stekli na kampu primenjena su na konkretne probleme. U leto 2013. godine grupa je svoju pažnju posvetila Velikoj istraživačkoj letnjoj akciji, na kojoj je odradeno nekoliko praktičnih vežbi iz astronomije i fizike: matematičko klatno, odredivanje udaljenosti do galaksije M100 pomoću Cefeida, računanje Volfovog broja.

Tokom svih akcija na kojima je bilo moguće realizovati bavljenje etnoastonomijom, članovi su prikupljali materijal, koji je kasnije prezentovan na aktivnostima u okviru kojih su članovi grupe predstavili svoj rad. Od početka 2014. godine deo grupe povremeno radi na novom projektu osmišljavanja svemirske stanice, koji je raspisala Nacionalna aeronautička i svemirska administracija. Takode, deo članova posećuje seminare u Istraživačkoj stanici Petnica i svoje znanje prenosi ostatku grupe na sastancima i akcijama.

2. 3. NAUČNO OBRAZOVANJE

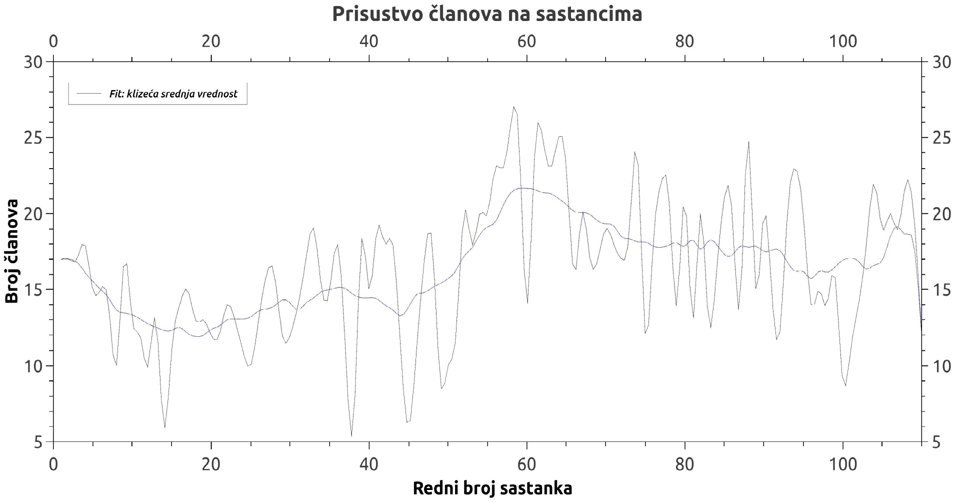
U martu mesecu 2012. godine, organizovana je prva aktivnost ove celine i to je bila škola astronomije namenjena svim zainteresovanim učenicima osmih razreda i učenicima srednjih škola. Nakon završetka škole usledile su Letnje aktivnosti koje su otpočele organizovanjem junske akcije, na kojoj su se mladi astronomi izmedu ostalog bavili astrognozijom. Tokom naredne godine Letnjim astronomskim aktivnostima pripala je organizacija prolećne škole astronomije koja se održavala u prostorijama Valjevske gimnazije.

Cilj edukativnih akcija tokom svih godina je bolje upoznavanje sa korišćenjem teleskopa i diskutovanje o aktuelnim astronomskim temama, kao i upoznavanje novih članova sa radom grupe.

Članovi grupe su, u periodu od 2012. do 2014. godine odlazili da posete Festival nauke u Beogradu, sa prvobitnim ciljem da isprate astronomske postavke na Festivalu, ali i da razmene iskustva sa članovima drugih srodnih društava iz zemlje i regiona. Na redovnim sastancima koji se održavaju jednom nedeljno u prostorijama Društva istraživača u Valjevu, članovi održavaju kratka predavanja o popularnim i zanimljivim astronomskim temama.

3. AKTIVNOST ČLANOVA U OVOM PERIODU

Aktivnosti organizovane u periodu od januara 2012. godine do jula 2014. godine bile su raznolike po svom sadržaju i kvalitetu organizovanja. Koja aktivnost će da se realizuje i na koji način zavisi od faktora kao što su: zainteresovanost aktivnih članova



Grafik 1: Broj članova u zavisnosti od rednog broja sastanka. Sastanci počinju 14. januara 2012. godine, a završavaju se 26. jula 2014. godine (razmak izmedu sastanaka je 7 dana, osim kada je sastanak odložen zbog neke aktivnosti).

za tekuća astronomska dešavanja, stepen organizacije dogadaja, doba godine (da li je zaključivanje ocena u školi ili je raspust) i drugih obaveza članova. Kako grupa jednom nedeljno (subotom) organizuje sastanke na kojima se dogovaraju aktivnosti koje treba da budu realizovane u narednom periodu, na grafiku 1 je predstavljen broj prisutnih (aktivnih) članova na sastancima u zavisnosti od rednog broja sastanka. Sastanci nisu organizovani za vreme dogadaja koji su se poklapali sa terminom sastanka (akcije, posmatranja, maksimumi meteorskih rojeva...).

Sa grafika 1 se može zaključiti da je maksimalan broj članova prisutnih na sastancima bio po završetku škola astronomije ili nakon akcija koje su bile najuspešnije i samim tim koje su bile dovoljan razlog da se novi članovi priključe grupi. Medu takve akcije spadaju Liridi 2013. godine, nakon koje se broj aktivnih članova znatno povećao, jer je ta akcija bila ujedno i prva akcija polaznicima škole astronomije. Veliki padovi broja prisutnih kada je u grupi bilo aktivno izmedu 5 i 10 članova nisu česti, ali da bi se takvi slučajevi izbegli, grupa intenzivno radi na informisanju zainteresovanih mladih o radu Astronomske grupe.

4. BUDUĆE AKTIVNOSTI

Plan aktivnih članova grupe je da u budućem periodu pored redovnih aktivnosti, osmisle ideju za pisanje naučno-istraživačkog rada na neku od zanimljivih astronomskih tema, kako bi Zbornik radova Društva istraživača ponovo, nakon dužeg vremenskog perioda bio izdat. Takode, u planu je saradnja sa drugim astronomskim društvima radi razmene iskustava i unapredenja rada grupe.

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PARTICIPATION OF SERBIA AT THE INTERNATIONAL OLYMPIADS IN ASTRONOMY AND ASTROPHYSICS IN 2012 AND 2013

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Abstract. The topic is the participation of contestants from Serbia in international contests in astronomy: 6th IOAA in Brazil 2012, 7th IOAA in Greece 2013 and the Saint-Petersburg Olympiad in 2013. Also, organisation and preparations of contestants, volunteer work of trainers and financial problems. Contribution of Mathematical Gymnasium in Belgrade. A presentation of contests within Serbia, which serve for the purpose of selecting contestants for international contests. Organisation and events during international contests, as well as the success of Serbian contestants.

1. INTRODUCTION

Serbian teams have been participating in international astronomical competitions since 2002 (under the name of Yugoslavia) with exception of year 2003 (due to insufficient funds). First participation was at the 7th International Astronomy Olympiad (IAO), in Nizhnij Arkhyz, in Russia. From 2009 through 2011 Serbia participated both in IAO and IOAA (International Olympiad in Astronomy and Astrophysics). In the following years Serbia attended IOAA only, because of their multiple advantages: democratic and transparent test preparation with discussions concerning problems formulations, problems solutions, also transparent grading of students work, well defined syllabus etc. In 2013 Serbia entered St. Petersburg Astronomy Olympiad, a correspondence competition, as the only guest country invited by the organizers which did not belong to the USSR. For further reference, see Eskin et al. 2012. Previous participations of Serbia in IAO and IOAA have been presented in Atanackovic-Vukmanovic (2006), Atanackovic (2012), Miler (2009, 2011), Ninkovic and Milic (2011, 2014).

2. NATIONAL COMPETITIONS

Astronomical competitions in Serbia are organized by NAOC annually on two levels: regional and national. Regional competition consists of one theoretical test with 3 theoretical questions and 4 problems. National Astronomy Olympiad consists of 3 parts: Theoretical part (5 problems, 240 minutes), Observational part - either outdoor (telescope and naked eye observations) or indoor (test with sky charts) and Data Analysis (120 minutes). Regional competition in astronomy in 2012 was on May 13th. There were 8 participants: 7 from Mathmemematical Grammar School in Belgrade (MG), and 1 from Gymnasium Jovan Jovanovic Zmaj. Luka Bojovic and Ivan Tanasijevic won 1st prize, Djordje Zikelic and Vanja Sarkovic 2nd prize, Vladimir Sladojevic and Predrag Obradovic 3rd prize, and Ivana Beslic honourable mention. National Astronomy Olympiad in 2012 was on June 16th (theoretical part) and 17th (indoor observational and Data Analysis round). Competition rounds were weighed in the following manner: Theory 55%, Data Analysis 30% and Observations 15%. Results: Luka Bojovic, I prise; Ivan Tanasijevic, I; Aleksandar Miladinovic I; Djordje Zikelic, II; Dusan Sobot II; Predrag Obradovic, III; Uros Ristivojevic, honourable mention; Vladimir Sladojevic, honourable mention.

Regional competition in astronomy in 2013 was on May 11th (the venue and test format unchanged). Out of 12 participants in Belgrade (all from MG) 9 qualified for the next stage. Jury members: Slobodan Ninkovic, Sonja Vidojevic and Stefan Andjelkovic. NAOC awarded 1st prize to Ivan Tanasijevic, 2nd prize to Djordje Zikelic and Predrag Obradovic, 3rd prize to Uros Ristivojevic and honourable mention to Mladen Dobrasinovic and Caslav Lukic.

National Astronomy Olympiad in 2013 (venues unchanged) was held on June 1st (theoretical and outdoor observations) and 2nd (data analysis). The criterion changed to: Theory 60%, Data Analysis 25% and Observations 15%. Results: Ivan Tanasijevic, I prise; Luka Bojovic, I; Aleksandar Miladinovic, II; Predrag Obradovic, II; Uros Ristivojevic, III; Djordje Zikelic, III; Marko Puric, honourable mention.

Prize "Jelena Milogradov-Turin" has been awarded both to Luka Bojovic and Ivan Tanasijevic in 2012 and Ivan Tanasijevic in 2013. Special award for scoring 100% on the Observational and Data Analysis rounds in 2013 was awarded to Uros Ristivojevic.

3. 6th IOAA IN BRASIL AND 7th IOAA IN GREECE

The teams were lead by dr Slobodan Ninkovic and dr Sonja Vidojevic on both occasions. The 6th IOAA was held August 4th 14th 2012, in Rio de Janeiro, Brazil. Due to financial issues Serbia was represented by only 3 students. Results: Luka Bojovic, silver madal; Aleksandar Miladinovic, bronze medal; Predrag Obradovic, honourable mention.

Approximately 200 participants from 35 countries attended the 7th IOAA - held from July 27th to August 5th, 2013 in Volos, Greece. Serbian team had 5 contestants.

Serbia ranked 3rd best country in the overall placement. Results: Ivan Tanasijevic, gold medal; Luka Bojovic, gold medal; Aleksandar Miladinovic, silver medal; Uros Ristivojevic, honourable mention; Predrag Obradovic, honourable mention.

Figure 1: Serbian national team at 7th IOAA – the 3rd best team in the world, from left to right: Predrag Obradovic – honourable mention, Ivan Tanasijevic – gold medal, Luka Bojovic – gold medal, Sabrina Lousini (volunteer assigned by Local Organizing Comittee), Uros Ristivojevic – honourable mention, Aleksandar Miladinovic – silver medal, dr. Sonja Vidojevic (team leader) and dr. Slobodan Ninkovic (team leader).

4. ST. PETERSBURG ASTRONOMY OLYMPIAD 2013

Serbia participated in St. Petersburg Astronomy Olympiad with 2 participants (both from MG): Predrag Filipovic (1st grade) and Marko Puric (2nd grade). This competition consists of 2 parts: Theoretical Part and Data Analysis Part. There are 3 different categories; our contestants were in separate categories. Marko Puric ranked 2nd (1st prize) with 52 points in total, after the absolute winner who had obtained 54 points.

5. ASTRONOMY PREPARATORY CLASSES

NAOC has been introducing prior contestants from IAO and/or IOAA as regular astronomy instructors for high school students since 2012. Students are divided into 2 groups: experienced contestants and beginners. The introductory course starts from the basics, but covers the entire syllabus. The advanced lectures are focused on deepening the understanding of astrophysical phenomena and applications of mathematics and physics. During the school year lectures were held in MGs classrooms during the weekend. In the school year 2012/2013 instructors for theoretical part of the courses were Stefan Andjelkovic and Filip Zivanovic (former IAO/IOAA contestants), while observational course (naked eye observations, telescope observations and lectures in planetarium) was held by Branko Simonovic. For the preparations of IOAA in 2013 Stefan Badza (former IAO/IOAA contestant) joined instructors team. After the IOAA in 2013, Vanja Sarkovic (former IAO contestant) joined as well. In the following year, more people are expected to join and help building a new system for astronomy competitions preparations and organizations, which would sustain the traditional success of Serbian national team in IOAA. This process is crucial due to the fact that we expect to host the 2021 IOAA in Belgrade, Serbia. One of the useful resources for preparing national team was a one week stay on mountain Avala in 2013 afore the IOAA, provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

6. PROSPECTS AND CONCLUSION

Serbian national team results in IOAA in last 2 years continue the 12 years long tradition of success in IAO and IOAA. A lot of effort has been put to maintain those results both in gathering human resources and financial support. In the recently held 8th IOAA in Suceava, Romania, Serbian national team won 1 gold medal (Ivan Tanasijevic), 1 silver medal (Luka Bojovic), 2 bronze medals (Predrag Obradovic and Djordje Zikelic), and 1 honourable mention (Marko Puric). NAOC is determinded to include schools all over Serbia in the programme of astronomy preparatory classes. This represents a colossal challenge for our team of instructors, and NAOC as well. The main goal remains to teach and prepare the students for the following competitions, and select the best ones for Serbian national team. In 2013, at the 7th IOAA, Serbia was nominated as the host for 15th IOAA in 2021. Representatives of NAOC are currently in talks with the Ministry of Education, Science and Technological Development of the Republic of Serbia with the goal of finding the way to organize this prestigious international event.

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SUNČANI ČASOVNIK KAO MULTIDISCIPLINARNA NASTAVNA TEMA U PREDŠKOLSKOJ I ŠKOLSKOJ NASTAVI

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Abstract. Sunčani časovnik je veoma korisna nastavna tema za podizanje učeničke motivacije, budjenje radoznalosti i promociju nauke. Njen poseban kvalitet u vaspitno-obrazovnom procesu je njena "očiglednost" i visok stepen korelacije sa raznovrsnim nastavnim sadržajima.

U ovom radu predstavljamo teoriju i praksu za izradu tri tipa sunčanih časovnika: ekvatorijalnog, horizontalnog i analematskog. Izbor metoda i materijala za izradu može se prilagoditi nivou obrazovanja i uzrastu učenika. U tom cilju u radu izlažemo neophodne pojmove iz prirodnih nauka i matematike, na opisnom i definicionom nivou, a u skladu sa uzrastom učenika. Dajemo uputstva za nekoliko praktičnih i istraživačkih projekata, kako u klasičnom okruženju papir-kreda-tabla-naracija, tako i na terenu (školskom dvorištu), uz eventualnu upotrebu računarskih resursa.

Na kraju, poseban akcenat dajemo slobodnoj interpretaciji vizuelnih i geometrijskih efekata i eventualnom umetničkom doživljaju teme i modela.

1. Uvod

Sunčani časovnik kao nastavna tema omogućava rad sa različitim uzrastima učenika, različite nivoe znanja i predznanja, multidisciplinarnost, različite obrazovne ciljeve i razne nastavne metode i sredstva. Ova nastavna tema povećava učeničko interesovanje za nauku, razvija dugotrajnu motivaciju, promoviše nauku i predstavlja učenicima naučne metode.

U cilju što kvalitetnijeg i uspešnijeg procesa vaspitanja i obrazovanja i ispunjenja ciljeva i zadataka obrazovanja i vaspitanja treba iskoristiti veliku korist koje tom procesu nude multidisciplinarne naučne teme koje mogu da se prilagode nastavnim sadržajima kroz časove redovne nastave, dodatne nastave ili sekcija u različitim uzrasnim grupama učenika.

Veoma je bitno da u toku nastavnog procesa učenicima pažnja bude podignuta na visok nivo, da budu zainteresovani i motivisani za čas. Čas ne sme da bude monoton i dosadan, već mora da bude brižljivo isplaniran i dinamičan. Dinamiku časa podstiče korišćenje raznovrsnih nastavnih sredstava, kao i promena oblika rada (frontalni, individualni, grupni, rad u parovima). Takodje, veliki uticaj na uspešnost časa imaju i dobro planirane i odabrane raznovrsne nastavne metode.

1. 1. CILJEVI I ZADACI

Sunčani časovnik kao nastavna tema ispunjava veliki broj obrazovno-vaspitnih ciljeva.

Vaspitno-obrazovni ciljevi mogu se grubo podeliti u tri grupe: obrazovni ciljevi, vaspitni ciljevi i funkcionalni ciljevi.

Obrazovni cilj vaspitno-obrazovnog procesa je sticanje kvalitetnih znanja, veština i navika, formiranje vrednosnih stavova, jezičke, matematičke, naučne, umetničke, kulturne, tehničke, informatičke pismenosti, neophodnih za život i rad u savremenom društvu.

Vaspitni cilj vaspitno-obrazovnog procesa je razvoj svesti o sebi, samoinicijative, sposobnosti samovrednovanja i izražavanja svog mišljenja, solidarnosti, razvoj i praktikovanje zdravih životnih stilova, svesti o važnosti sopstvenog zdravlja i bezbednosti, zaštite i očuvanja prirode i zaštite životne sredine, poštovanja drugih ljudi i principa demokratije, razvoj motivacije za učenje, razvoj tačnosti, marljivosti, urednosti, odgovornosti, radoznalosti...

Funkcionalni cilj vaspitno obrazovnog procesa odnosi se na psihički, tj. misaoni, čulni, verbalni, praktični, fizički razvoj učenika, odnosno, razvoj sposobnosti: razvoj stvaralačkih sposobnosti, sposobnosti komuniciranja i dijaloga, osposobljavanje za rešavanje problema i zadataka u novim i nepoznatim situacijama, analiziranja, povezivanja, razvoj kreativnosti, kritičkog mišljenja, sistematičnosti, razvoj sposobnosti imaginacije i realizacije problema, pronalaženja bitnih činjenica...

1. 2. MULTIDISCIPLINARNOST

Multidisciplinarnost ove teme zahteva širok dijapazon raspoloživih metoda za uspešnu realizaciju. Ova nastavna tema protkana je sadržajima iz brojnih nastavnih predmeta. Ona dodiruje matematiku, astronomiju, geografiju, istoriju, književnost, tehničko obrazovanje, likovnu kulturu i informatiku. Obzirom na širinu teme i njene raznovrsne sadržaje, zgodna je da se predstavi učenicima različitih uzrasta: od najmanjih, učenika nižih razreda osnovne škole, preko učenika viših razreda osnovne škole, pa sve do učenika srednjih škola. Tema se treba prilagoditi uzrastu učenika, njihovim dosadašnjim znanjima i sposobnostima koje imaju.

2. Rad sa različitim uzrastom učenika

2. 1. PREDŠKOLCI

Sa decom predškolskog uzrasta, od četiri do šest godina, moguće je, uz korišćenje gotovog modela sunčanog časovnika, posmatranjem senke gnomona i senke deteta, posmatranjem neba, učiti o prividnom kretanju Sunca, delovima dana (jutro, podne, veče), vremenskim mernim jedinicama, merenju vremena i pomeranju senke na nivou koji oni mogu da razumeju i shvate.

2. 2. MLADJI UČENICI OSNOVNE ŠKOLE

Učenicima od prvog do četvrtog razreda osnovne škole(uzrasta od sedam do deset godina) tema sunčanog sata treba da bude prezentovana kroz osnovne podatke, što slikovitije i prilagodjene njihovom uzrastu, korišćenjem ilustracija i slika, kao i maketa sunčanih časovnika. Učenicima se može pročitati deo iz Nušićeve Autobiografije u kom autor opisuje čas zemljopisa kada se učenici izvode pred katedru i imitiraju okretanje

Sunca, Zemlje i Meseca (ovo može da se pripremi dramatizacijom kroz nastavnu metodu igre uloga).

U radu sa analematskim sunčanim časovnikom, u praktičnom delu deca mogu, po uputstvima i uz nadzor nastavnika, da naprave u školskom dvorištu analematski časovnik, pomoću kanapa, metra, krede i farbe. Biće zanimljivo naučiti ih da prvo nacrtaju krug pomoću kanapa i krede, a zatim i elipsu. Učenicima treba podeliti i materijale sa uputstvima, uz podsticaj da ih koriste što samostalnije. Sva merenja učenici treba da obave sami. Crtež ortogonalnih elipsinih osa treba da izvedu sami, podsećajući se šta je to prav ugao, a ako ne znaju - to može da im se objasni vrlo slikovito: oni stoje pod pravim uglom, a onda kad se nakrive (potražiti još primera u prirodi i okruženju)... Učenici razumeju pojam kruga, elipse, sprovode merenja, praktikuju rad na tekstu i rad po šemi.

U radu sa ekvatorijalnim časovnikom učenici mogu sami da iskroje i sastave unapred pripremljeni materijal, četvrtaci čak i da nacrtaju sami ekvatorijalni časovnik po uputstvu i uz pomoć nastavnika. Za domaći mogu da ga oboje, ukrase i postave na sunčano mesto u svome domu, uz pomoć roditelja koji će pokazati pravac sever-jug. Učenici usvajaju pojam linije, paralelnih linija, pravougaonika, ugla, delova ugla, delova časovnika...

2. 3. STARIJI UČENICI OSNOVNE ŠKOLE

Sa učenicima od petog do osmog razreda osnovne škole (uzrasta od jedanaest do četrnaest godina) mogućnosti eksploatacije ove teme rastu. Sama tema može da se predstavi dublje, čak se u potpunosti može objasniti mehanizam smene godišnjih doba, noći i obdanice, odnosno uticaj revolucije i rotacije na princip rada sunčanih časovnika. U praktičnom delu deca koriste stečena znanja i veštine za merenje, računanje, proporcije, koordinatni sistem, konstrukcije paralelnih i ortogonalnih pravih, simetrale.

U radu sa analematskim časovnikom učenici prema podeljenim uputstvima i uz instrukcije nastavnika sami crtaju časovnik. Za domaći dobijaju zadatak da ga urade na papiru (kao timski rad, grupe od po 3-4 učenika) u razmeri 1:15 (vežbaju proporcije i račun) i postave u pravcu severa na osunčano mesto u svom domu. Drugi zadatak koji dobijaju za domaći je da prema datim koordinatama tačaka koje predstavljaju sate i žiže elipse, nacrtaju koordinatni sistem i elipsu. časovnik zatim ukrašavaju, ispisuju na njemu neki moto, po sopstvenom izboru i postavljaju ga na osunčano mesto u svome domu, vodeći računa o tomke da bude postavljen u pravcu severa.

U radu sa ekvatorijalnim časovnikom, prema uputstvu datom u ovom radu učenici samostalno prave ovaj časovnik, nastavnik nadzire rad i pomaže ako je neophodno. Za domaći, časovnik oboje i ukrase, ispisuju moto i postavljaju ga na osunčano mesto u svom domu u pravcu severa.

Za izradu horizontalnog časovnika, prema uputstvu nastavnika, učenici koriste internet za dobijanje tabele sa vrednostima uglova potrebnih za crtanje, a zatim crtaju, iskrajaju i prave časovnik. Ukrašavanje, bojenje, pisanje motoa i postavljanje na čvršću podlogu učenici obavljaju kao domaći zadatak.

Od napravljenih radova u školi ili u kulturnim institucijama lokalne zajednice učenici mogu napraviti izložbu i predavanje koje će samostalno da vode. Nastavnik organizuje izložbu, koordiniše pripremu i obezbedjuje literaturu, materijal i izvore informacija.

2. 4. SREDNJOŠKOLCI

Sa učenicima srednjih škola (uzrasta od petnaest do osamnaest godina) ova tema može da se odradi vrlo detaljno, jer već imaju dovoljno znanja da mogu da razumeju u potpunosti princip rada i metodologiju izrade sunčanih časovnika. Nakon predavanja održanog uz prezentaciju ilustracija i slika, učenici se upućuju na Youtube kanale Kurdistanskog planetarijuma i Science On Line:

www.youtube.com/user/KurdstanPlanetarium;

www.youtube.com/user/ScienceOnline.

U praktičnom delu učenici pored primene osnovnih matematičkih znanja primenjuju trigonometriju i sami prave interaktivne tabele u aplikacijama za rad sa tabelama koje na osnovu zadatih formula i poznatih vrednosti računaju potrebne podatke.

Analematski časovnik - učenicima se postavlja zadatak da koristeći poznavanje elipse osmisle samostalno njenu približnu konstrukciju na osnovu poznatih poluosa. Dalje, časovnik iscrtavaju prema podeljenim uputstvima u dvorištu.

Ekvatorijalni časovnik - Prema uputstvu učenici prave časovnik, sami računajući dužinu slamčice koristeći trigonometriju. Ukrašavanje i moto za domaći. Horizontalni časovnik -.samostalna izrada časovnika prema verbalnim uputstvima od nastavnika i objašnjavanja principa rada horizontalnog sunčanog časovnika: koriste programe za rad sa tabelama radi dobijanja vrednosti uglova, Google Earth, Google Maps ili GPS uredjaje za dobijanje geografske širine, internet i pretraživače za dobijanje pomeraja geografskog severa u odnosu na magnetni sever, sami postavljaju problem i rešavaju ga.

Učenici formiraju četiri tima koja će da predstave temu sunčanog sata drugim učenicima u školi:

- jedan tim drži predavanje uz prezentaciju o istorijatu, vrstama i principima rada sunčanih časovnika,
- drugi tim prezentuje izradu analematskog časovnika sa uputstvima,
- treći tim prezentuje izradu ekvatorijalnog časovnika,
- četvrti prezentuje izradu horizontalnog časovnika.

Učenici pripremaju mini-izložbu koju postavljaju u školi ili u kulturnom centru lokalne zajednice.

3. Uputstva za izradu sunčanih časovnika

3. 1. EKVATORIJALNI ČASOVNIK

Za ovaj model potrebno je:

1. papir dimenzija 26 cm x 12 cm,
2. slamčica,
3. pribor za crtanje i
4. makaze.

Uputstvo za izradu:

1. Nacrtaj na papiru linije tako da na njoj napraviš trake širine 1 cm, 10 cm, 14 cm i 1 cm. Obeleži te linije sa A, B i C, a zatim obeleži centar na liniji A slovom O, a centar na liniji C slovom P. Spoj tačke O i P.

2. Postavi centar uglomera na tačku O i ocrtaj luk uglomera. Probuši rupu kroz O, okreni papir, ponovo postavi centar uglomera na O i ocrtaj luk uglomera tako da imaš dva polukruga, ledja u ledja okrenuta jedan ka drugom na papiru.

3. Obeleži intervele od po 15 stepeni i numeriši ih satima tako što na svakih 15 stepeni pišeš pun sat, počevši od 6 ujutru na desnoj strani polukruga

4. Savij i preklopi papir duž linija A, B i C.

5. Proširi rupicu kod tačke O tako da kroz nju može da se provuče slamčica. Proveri da li je slamčica pod pravim uglom u odnosu na papir.

6. Pomeraj donji kraj slamčice duž linije OR sve dok ugao koji formira sa horizontalom ne bude jednak geografskoj širini mesta u kojem si (Beograd je na geografskoj širini od oko 45 stepeni, pa će dužina slamčice biti oko 10 cm)

7. Kada pronadješ tačno mesto za donji deo slamčice, fiksiraj je i stavi špenadlu kroz papir da drži slamčicu na pravom mestu.

8. Slamčica formira gnomon. Senka gnomona pašće na linije koje označavaju sate na prednjoj strani časovnika u leto, a na zadnjoj u zimu.

9. Oboj i ukrasi svoj časovnik i dopiši mu neki zanimljiv moto!

10. Ne zaboravi da gnomon uperiš ka severu!

3. 2. ANALEMATSKI ČASOVNIK

Za projekat analematskog časovnika koristićemo gotove proračune dobijene pomoću alata sa interneta (http://analemmatic.sourceforge.net/cgi-bin/sundial.pl) koji zahteva za obradu podatke o časovnoj zoni, geografskoj širini i geografskoj dužini, kao i opciono postavljanje proračuna za zimsko, odnosno letnje vreme. Uputstvo za izradu:

1. Nacrtaju se ose elipse, tako da kraća osa bude u pravcu sever-jug (geografski sever, ne magnetni). Dimenzije su prema proračunu dobijenom sa interneta;

2. Na betonu se nacrta elipsa pomoću kanapa i krede (farbe) tako što se krajevi kanapa fiksiraju u žižama elipse (pridržavaju ih učenici), a kredom se ostatak kanapa zategne vodoravno po podlozi i ocrtava se elipsa;

3. Pomoću metra i kanapa prenose se dužine dobijene proračunom sa interneta za beleženje cifara na cifarniku;

4. Provera ucrtanih pozicija za sate pomoću metra i kanapa;

5. Odmeravaju se pozicije za ucrtavanje pozicije gnomona po mesecima;

6. Označe se meseci i unese se korekcija časovnika u minutima.

Na ovakvom časovniku gnomon predstavlja čovek koji staje u odredjenu poziciju na iscrtanom časovniku u zavisnosti od doba godine u kojem se meri vreme. Njegova senka pokazuje vreme.

Zanimljivo je da bi ovakav sunčani časovnik mogao da pokaže doba godine, ukoliko je poznato tačno vreme. Zapravo, mogu se nacrtati odgovarajuće elipse i hiperbole na cifarniku koje odgovaraju datumima (mesecima). To je interesantan, ozbiljniji projekat, ali za talentovane učenike viših razreda srednje škole, uz upotrebu odgovarajućeg softvera.

3. 3. HORIZONTALNI ČASOVNIK

Prvi korak u pravljenju horizontalnog sunčanog časovnika jeste odredjivanje uglova izmedju linija koje označavaju sate. Polazna linija i normala kroz njeno središte pokazuje 6 časova ujutru, podne i 6 časova uveče.

Postoje različite metode za generisanje ostalih vrednosti uglova za položaje linija koje označavaju sate. Ovde ćemo koristiti računsku metodu. Formula za izračunavanje uglova je:

$\mathrm{tg}\ s = \sin l\ \mathrm{tg}\ (15\ t)$

U ovoj formuli s je ugao koji sat-linija pravi sa podnevnom linijom, to je vreme mereno od podneva u stepenima i minutima (Zemlja se oko Sunca okrene za 360 stepeni u 24 sata, pa je tako 1 sat = 15 stepeni), a l je geografska širina mesta gde časovnik treba da bude postavljen. Svaki ugao izračunat za vreme pre podneva takodje važi za ugao ekvivalentnog vremena posle podneva. Najbolje je dobijene podatke unositi u tabelu.

Kada se izračunaju svi potrebni uglovi tada se ucrtavaju linije za cele sate kao i one koje označavaju pola sata, deo koji daje senku, poznat kao gnomon može da se postavi duž podnevne linije ili pak uz pomeraj ka geografskom severu koji iznosi oko 8 stepeni.

Bilo bi dobro da crtež bude na papiru koji može da se fiksira za čvršću podlogu, a da se gnomon napravi od tankog kartona. Ovo će omogućiti da se projekat dobro proveri pre nego što se prepravi u trajniji. Ovaj sunčani časovnik treba postaviti na mesto gde je maksimalna količina sunčeve svetlosti tokom dana, vodeći računa o tome da ravan časovnika bude postavljena savršeno vodoravno sa gnomonom koji pokazuje pravo na sever.

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IMPLICATIONS OF THE KINEMATICS ON THE CHEMICAL AND DYNAMICAL PROPERTIES OF NEARBY ELLIPTICAL GALAXIES

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Abstract. We have selected 1450 elliptical galaxies from approximately 7000 galaxies presented in the Nearby Optical Galaxy sample, which is a complete, distance-limited (cz $\leq$ 6000 km/s) and magnitude-limited (B $\leq$ 14) catalog of nearby galaxies. By cross-matching this sample with SDSS database (DR10), we have found spectroscopical confirmation of 179 ellipticals with signal-to-noise ratio between 10 and 80, sufficient for calculation of full kinematical profiles of these galaxies. Also, we have calculated the Lick indices, including corrections due to the kinematics. Finally, we discuss the influence of the full line-of-sight velocity distribution on the mass estimates.

1. INTRODUCTION

The most general description of the line-of-sight velocity distribution of stars in a galaxy can be obtained using Gauss-Hermite series (van der Marel & Franx 1993, hereafter vdMF). Deriving theoretical line profiles for the outher parts of elliptical galaxies, vdMF showed that even modest velocity dispersion anisotropy when ignored yields systematic errors in both the mean radial velocity and velocity dispersion of 10% or more. This naturally influences the virial mass estimates, which correlates with σ^2, not to mention the black hole mass scaling relation ($\sim \sigma^4$), making precise calculation of velocity dispersion even more important.

In this paper, we will show that even medium resolution spectra of elliptical galaxies with very low signal-to-noise ratio (hereafter SNR) are useful for these purposes when a reliable stellar library is available. This issue is ignored in the Sloan Digital Sky Survey (hereafter SDSS) releases, for the reasons of the modest instrumental resolution ($\approx$ 70 km/s) and an assumption that the stellar kinematics has Gaussian shape. The former can be overcome by the usage of the complete as possible stellar library and the latter is close to the real picture, but deviations from Gaussian distribution, when properly taken into account, may lead to serious under/over estimation of galaxy masses.

The outline of the paper is as follows. In Chapter 2, we will present the sample of galaxies used in this paper, followed by the description of the method chosen for calculation of the full kinematical profile of galaxies in Chapter 3, along with comparison with existing work on the subject. Corrections of the measured Lick indices are presented in detail in Chapter 4.

2. DATA SAMPLE

We have selected early-type galaxies from the *Nearby Optical Galaxy catalog* (Giuricin et al. 2000) with spectral confirmation in SDSS DR10. Cross-match is performed using spatial information of galaxies as provided by the NED (*NASA/IPAC Extragalactic Database*)[1]. In the initial query we had 1450 elliptical galaxies, but were left with only 179 galaxies having spectal information. Our final sample has a median SNR of 50, from as low as 10 to 80 at the highest.

However, this was enough to obtain reliable estimates of even higher moments of the Gauss-Hermite series (h_3 and h_4), as will be described in Chapter 3. The limit was imposed by the instrumental resolution, making dispersions below this limit highly suspicious.

3. STELLAR KINEMATICS

Galaxy spectra may be regarded as a superposition of stellar spectra broadened due to the net motion of stars and redshifted. So, the observed spectrum is well described by the convolution of a stellar spectrum with the line-of-sight velocity distribution function modeled in the most general case as a Gauss-Hermite series (vdMF). However, absorption spectra resulting from stellar motions are often contaminated with emission lines produced by different mechanisms, such as recombination followed by cascade (most prominent in Balmer series) and collisional excitation followed by radiative deexcitation (responsible for the forbidden lines). Emission lines may be either masked during the determination of stellar kinematics or fitted along with some Gaussian templates having the ratio of different lines fixed (e.g. all Balmer lines will have the same disperison). The former case was used for measuring stellar kinematics, and the latter case was adopted for the Lick indices calculations for which one can clean up the spectrum easily by subtracting the best fitted emission pattern, leaving only absorbtion lines present.

We used Penalized Pixel-Fitting code (hereafter `pPXF`) presented in detail in Cappellari & Emsellem 2004, that makes fitting in the pixels space on the logarithmically rebinned spectra in order to make the redshift linear. All stellar spectra are degraded to spectral resolution of the galaxy spectrum and logarithmically rebinned. The linear combination of these spectra, having amplitudes as free parameters (i.e. weights) is broadened with Hermite polynomials normalized as in Appendix A of vdMF. The final form of the broadening function used in this paper is:

$$L(w) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp(-1/2w^2) \left[\frac{h_3}{\sqrt{6}}(2\sqrt{2}w^3 - 3\sqrt{2}w) + \frac{h_4}{\sqrt{24}}(4w^4 - 12w^2 + 3) \right], \quad (1)$$

where $w = (v - V)/\sigma$ (V being radial velocity and σ velocity dispersion) and h_3, h_4 are the Hermite coefficients characterizing asymmetric and symmetric deviations from the pure Gaussian, respectively. To quantify departures of the line profile from its best fitting Gaussian, vdMF found the relation between rms deviation (D) and Hermite coefficients:

$$D = \sqrt{\sum_{j=3}^{N} h_j^2}. \quad (2)$$

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[1] http://ned.ipac.caltech.edu/ngi/

Cappellari & Emsellem 2004 used this parameter to control the robustness while introducing additional parameters to Gaussian distribution defining penalized χ_p^2 as:

$$\chi_p^2 = \chi^2(1 + \lambda^2 D^2), \tag{3}$$

where $\lambda = (0, 1)$ is the so-called bias parameter, that one must determine for the problem in question since it depends naturally on the length of the stellar template used (number of points in the fit), but also on the SNR. We have used empirical Elodie stellar library of about 1000 stars of all spectral types in the spectral range of 3900 - 6800 $\mathring{A}$ with the observational resolution of 12 km/s for the reasons given in the Lalovic (2010).

To determine the bias parameter, we have chosen one star to mimic galaxy spectrum, convolved it with a Gaussian having Full Width Half Maximum[2] (hereafter FWHM) equal to the square root of the quadratic difference between stellar and galaxy resolution $S(x)$. Then, the spectrum is broadened with the function of the form Eq. 1 with $h_3 = 0.1$ and $h_4 = -0.1$ and velocity dispersion varying from the lowest 15 km/s to as high as 400 km/s ($GH(x)$). This spectrum is divided to the desired SNR to mimic the noise. And finally, the artificial galaxy spectrum can be written as:

$$G(x) = S(x) * GH(x; w, h_3, h_4) + S(x) * GH(x; w, h_3, h_4)/SNR. \times \mathrm{RNG} \tag{4}$$

Here, RNG is a function that generates pseudorandom numbers from a normal distribution with a mean of zero and a standard deviation of one (the random number generator). For a SNR=(5,80) with a step equal to 5, we have tried to recover Hermite parameters ($h_3 = 0.1$ and $h_4 = -0.1$), using `pPXF` and also varying bias parameter from 0.0 to 1.0 for the whole range of velocity dispersions and for each SNR. The largest bias parameter for which the reconstruction was successfull was chosen for the given SNR. In this way, we come up with the formula

$$\lambda = 0.007 \times S/N + 0.068. \tag{5}$$

To deal with errors properly, we created asymptotes as the 2nd polynomial fit to the limiting points output by Monte Carlo simulations inside 3-σ sliding median excluding points bellow the SDSS resolution. The addopted error is given as the spread of the points between the asymptotes at the position of the velocity dispersion calculated in the real case of the galaxy.

We have tested our results against SDSS and Hyperleda databases to find the overall agreement (Fig. 2, left). For the purpose of comparison we have used pure Gaussian functions, since higher moments were not calculated by the SDSS pipeline. The difference is quite small (Fig. 2, right), but it certainly affects virial mass[3] (Fig. 3, left) and black hole mass[4] (Fig. 3, right) estimates.

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[2] The width of the Gaussian function at the half of its maximum value.

[3] The virial mass inside virial radius R is proportional to $2R\sigma^2/G$.

[4] See Ferrarese & Merritt (2000) for a relation between black hole mass and velocity dispersion

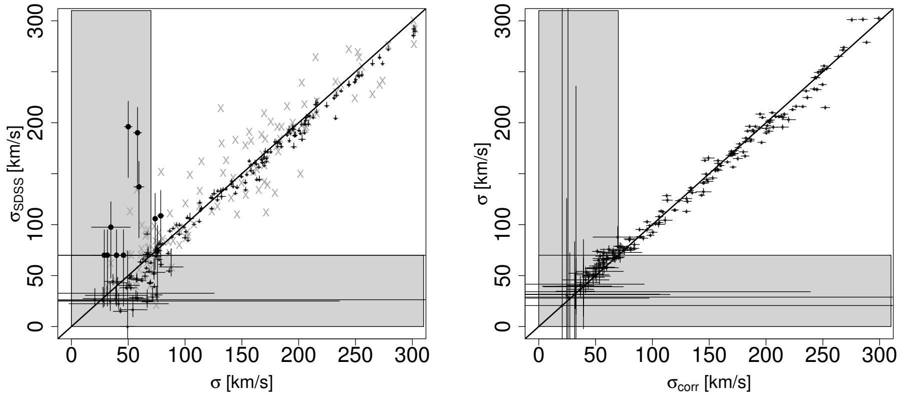

Figure 1: Left: Comparison of the calculated velocity dispersions to the SDSS pipeline values. Large points correspond to the values flagged by the SDSS and so should be considered unreliable. Overplotted are the values from Hyperleda database as gray crosses. Right: Comparison of the corrected and uncorrected values of velocity dispersion for the case h_4 parameter has nonzero values: $\sigma_{corr} = \sigma(1 + \sqrt{6}h_4)$. On both panels shaded areas lie bellow the SDSS instrumental resolution.

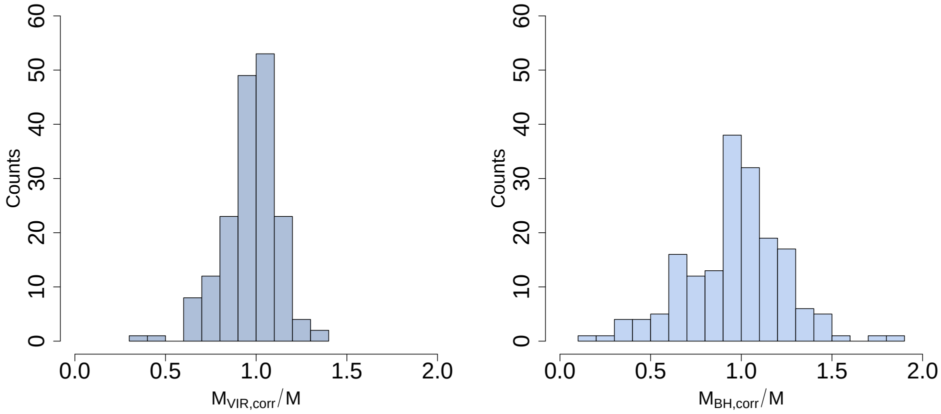

Figure 2: Left: Histogram of the virial mass estimates compared to the case where the line-of-sight velocity distribution is assumed to have Gaussian shape (scaled as σ^2). Right: The same as in the left panel, but for the black hole mass estimate $\sim \sigma^4$.

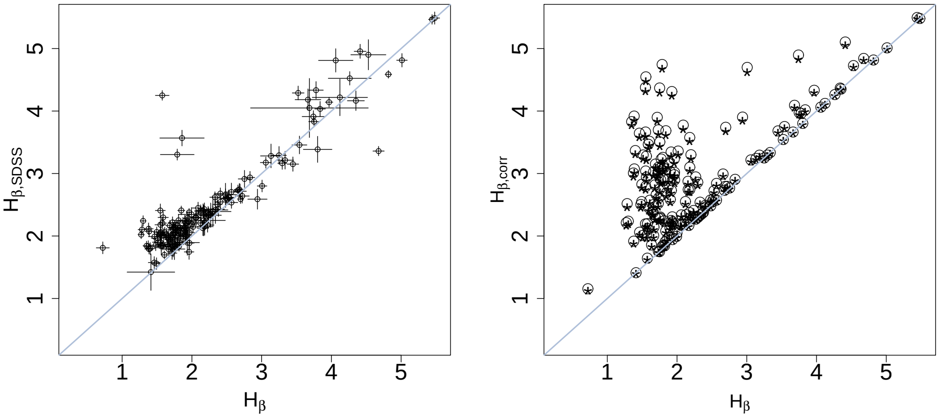

Figure 3: Left: Comparison of H_β index to SDSS pipeline values, where emission lines were subtracted. Right: Corrected vs. uncorrected values of H_β index for the impact of stellar kinematics, where broadenindg was expressed with Gaussian (circles) and Gauss-Hermite function (asterix), respectively.

4. LICK INDICES

The study of galaxy properties as composite stellar systems using absorption spectral lines led to the creation of the Lick/IDS system (Faber et al. 1985; Worthey et al. 1994; Worthey & Ottaviani 1997). This system defines the standard 25 absorption line indices, that are actually equivalent widths chosen in such a way to be prominent and free of emission lines as possible[5]. Absorption line strenghts are expressed in term of indices centered on the absorption feature of interest (*index bandpass*). To the blue and red side of the index bandpass are *blue* and *red continua* determining the end points of the continuum by the simple average. Joining these two (average) points with a straight line defines *pseudocontinuum* against which the index is calculated by the area encompassed by the line itself and pseudocontinuum. These indices were measured on a large sample of stars, globular clusters and early-type galaxies for the purpose of studying their stellar populations.

To address this issue properly, it is necessary to exclude the contribution from emission lines, but also to correct for the effect of the stellar kinematics broadening. We have adopted the approach based on two publically avaliable codes: Cappellari & Emsellem's (2004) pixel fitting method and Sarzi et al's (2006) `gandalf` code. The idea is to extract stellar kinematic using `pPXF` while masking emission lines, and then to clean up the spectrum from the nebular emission using `gandalf`. `Gandalf` starts from the information on the LOSVD provided by the `pPXF` to broaden the optimal stellar template and then models emission lines with Gaussian functions to obtain the best nebular emission template. Finally, this emission template is subtracted from the galaxy spectrum to leave pure absorption line spectrum sutable for deriving the

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[5] http://astro.wsu.edu/worthey/html/index.table.html

strength of stellar absorption-line features. Prior to this, galaxy spectrum is corrected for Galactic extinction using the E(B-V) value provided by NED.

For the calculation of the the Lick indices, we have used method presented in Cardiel et al. (1998) including the treatment of errors. In short, first we have degraded galaxy spectrum to Lick resolution and measured indices on both the optimal stellar spectrum before (I_0) and after broadening (I_σ) to yield the ratio. The correction for this effect is simply:

$$I_A^{corr} = I_{obs} \times \frac{I_0}{I_\sigma} \quad \text{and} \quad \mathrm{I_M^{corr} = I_{obs} + I_0 - I_\sigma}, \tag{6}$$

where $I_{A,B}^{corr}$ is the corrected index (the subscript A refers to atomic and M to molecular indices) and I_{obs} index measured on the emission-free galaxy spectrum (see Oh et al. 2011 for details).

We have satisfying agreement (Fig. 3, left) with the SDSS data, bearing in mind different teplate library used. All indices in Fig. 3 are corrected for the nebular emission. It is clear form Fig. 3 (right) that uncorrected indices are higly underestimated and this effect must not be neglected. Also, the impact of non-Gaussianity is within errors and so may be completely neglected.

5. ACKNOWLEDGEMENT

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