ПУБЛИКАЦИЈЕ АСТРОНОМСКОГ ДРУШТВА "РУЂЕР БОШКОВИЋ" Св. 11
PUBLICATIONS OF THE ASTRONOMICAL SOCIETY "RUDJER BOŠKOVIĆ" No. 11

PROCEEEDINGS
OF THE VII BULGARIAN-SERBIAN ASTRONOMICAL CONFERENCE

Chepelare, 1-4 June 2010

Eds. Milcho K. Tsvetkov, Milan S. Dimitrijević,
Katya Tsvetkova, Ognyan Kounchev and Žarko Mijajlović

BELGRADE, 2012

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Chepelare, Bulgaria, June 1-4, 2010

Eds. M. K. Tsvetkov, M. S. Dimitrijević, K. Tsvetkova, O. Kounchev, Ž. Mijajlović

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PREFACE

The Seventh Bulgarian-Serbian Astronomical Conference was organized by Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences and took place in Grand Hotel Chepelare, situated near to the Rozhen Observatory in the period June 1 - 4, 2010.

The conference was dedicated to the topic Astroinformatics and was supported as coorganizers by: Institute of Mathematics and Informatics and Space Research Institute - both of the Bulgarian Academy of Sciences, Department of Astronomy - Faculty of Physics of Sofia University "St. Kliment Ohridski", Astronomical Observatory, Faculty of Mathematics and Department of Astronomy of University of Belgrade, Serbian Astronomical Society and Astronomical Society "Rudjer Boškovic".

Co-chairmen of the Scientific Organizing Committee were Milcho Tsvetkov and Milan S. Dimitrijević with members - Tanyu Bonev, Lachezar Filipov, Valeri Golev, Darko Jevremović, Ognyan Kounchev, Žarko Mijajlović, Nadežda Pejović, Luka Č. Popović, Katya Tsvetkova and Zoran Simić. In the Local Organizing Committee were Milcho Tsvetkov (Chairman), Nikola Petrov, Katya Tsvetkova, Ana Borisova, Vasil Popov, Momchil Dechev, Atanas Shtinkov, Assia Tsvetkova, Daniela Boneva, Krasimira Dimitrova, Valeri Golev, Orlin Stanchev, Ognyan Kounchev and Damyan Kalaglarsky.

Fifty-nine participants attended the conference. From Bulgaria were 30 participants: from the following institutes of the Bulgarian Academy of Sciences - Institute of Astronomy and National Astronomical Observatory, Institute of Mathematics and Informatics, Institute of Information and Communication Technologies, Central Laboratory for Geodesy, as well as from Faculty of Physics, Department of Astronomy of the Sofia University; Defense Advanced Research Institute and Technical University Sofia, branch of Plovdiv. From Serbia were 21 participants: Milan S. Dimitrijević, Luka Ch. Popović, Darko Jevremović, Vladimir Benišek, Aleksandar Valjarević, Dejan Urošević, Bojan Arbutina, Jelena Kovačević, Vojislava Protić-Benišek, Zoran Simić, Milica Andjelić, Marko Stalevski, Saša Simić, Dragana Ilić, Andjelka Kovačević, Nadežda Pejović, Žarko Mijajlović, Tatjana Jakšić, Sonja Vidojević, Tanja Milovanov, and Vladimir Srećković, from Belgrade Astronomical Observatory, Department for Astronomy, Faculty for Mathematics of the University of Belgrade, Department of physics, Faculty of Science of the University of Kragujevac, Institute of Physics – Belgrade and Faculty of Science of the University of Priština situated at Kosovska Mitrovica.

Besides participants from Bulgaria and Serbia the conference was attended by Emanuel Bertin (France), Jan Vondrák, Ciril Ron and Vojtech Stevka (Czech Republic) , Valery Hambaryan (Armenia), Renate Budell (Germany) and Natalia Chupina and Sergey Pirogov (Russia). During the conference 70 contributions in total were presented - 12 invited lectures, 22 short talks and 35 posters. In the conference proceedings are included in total 40 papers, 10 invited lectures, 13 contributed papers and 17 poster papers, as well as 37 PPT presentations.

Within the frames of the cultural program we enjoyed the hospitality of the local municipality of the town of Chepelare and the concert of the local folk ensemble during the official conference dinner in Grand Hotel Chepelare. Several excursions were organized: to the Rozhen National Observatory, to the regional central town of Smolyan and its remarkable ethnographic museum, to the natural rocky monument Wonderful Bridges, to the ethnographic complex known as Agushevi Konatsi near Smilyan village and to the national winter resort Pamporovo.

The Seventh Bulgarian-Serbian Astronomical Conference on Astroinformatics was very fruitful and important for the further development of the collaboration, common activities and planning of the joint scientific investigations and projects.

The Editors

ПРИВЕТСТВИЕ

Уважаеми дами и господа,

Като кмет на Община Чепеларе особено ми е приятно да Ви приветствам с добре дошли в нашия прекрасен град!

Щастливи сме, че именно тук ще се проведе настоящата 7-ма поред българо-сръбска конференция по астрономия, посветена на една от най-модерните области в астрономията, а именно астроинформатиката, която обединява усилията на математици, информатици и астрономи с цел да получат нови данни и нови резултати при настоящия терабайтов (ТБ) бум от данни при използването на съвременните средства от земни и космически наблюдения и достъпа до тях чрез ИНТЕРНЕТ.

Да бъде проведена тази конференция е от изключителна важност за всички нас.

Община Чепеларе е отворена и подкрепя този форум на научната мисъл. Надяваме се, че с участието си в подготовката на тази конференция ще допринесем за нейното ползотворно провеждане.

Желаем успех!

1 юни 2011 г.
Чепеларе

Георги Иванов Попов
Кмет на Община Чепеларе

WELCOME WORDS

Ladies and Gentlemen,

As Mayor of Chepelare I am particularly pleased to welcome you in our beautiful town!

We are happy that here will be held this 7th edition of the Bulgarian-Serbian Astronomical Conference, dedicated to one of the most advanced areas of astronomy, namely ASTROINFORMATICS, which brings together mathematicians, computer scientists and astronomers to new data and new results in the present terabyte (TB) data explosion as a result of modern ground and space observations and their access via Internet. It is especially important for all of us this conference to be held.

Chepelare supports this forum of scientific thought and hopes that the participation in the conference organization will contribute to its success.

Good luck!

June 1st, 2011.
Chepelare

Georgi Ivanov Popov
Mayor of Chepelare

INVITED PAPERS

Proceedings of the VII Bulgarian-Serbian Astronomical Conference (VII BSAC)
Chepelare, Bulgaria, June 1-4, 2010,
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Publ. Astron. Soc. "Rudjer Bošković" No 11, 2012, 13-23

VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND STARK-B DATABASE

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Abstract: Virtual Atomic and Molecular Data Center (VAMDC) is an European FP7 project with aims to build a flexible and interoperable e-science environment based interface to the existing Atomic and Molecular data. The VAMDC will be built upon the expertise of existing Atomic and Molecular databases, data producers and service providers with the specific aim of creating an infrastructure that is easily tuned to the requirements of a wide variety of users in academic, governmental, industrial or public communities. In VAMDC will enter also STARK-B database, containing Stark broadening parameters for a large number of lines, obtained by the semiclassical perturbation method during more than 30 years of collaboration of authors of this work (MSD and SSB) and their co-workers. In this contribution we will review the VAMDC project, STARK-B database and discuss the benefits of both for the corresponding data users.

1. VIRTUAL OBSERVATORIES AND SERBIAN VIRTUAL OBSERVATORY

For various applications in astrophysics, atmospheric physics, fusion, environmental sciences, combustion chemistry, and in industrial applications from plasmas and lasers to lighting, a reliable, critically selected set of atomic and molecular data is needed. However, the available data present in literature and databases are presented in different, non-standardized ways, so that their adequate exploitation is often difficult.

The need for a large amount of atomic and molecular data is in particular stimulated by the development of satellite astronomy, providing a huge amount of high quality astronomical spectra. This development produced an information avalanche and leaded to the creation of huge data collections as e. g. IUE and HST archive, or Sloan Digital Sky Survey SDSS, containing spectra of ~ 230 million objects.

In order to solve the problem of analysis and mining of such amount of data, the idea of Virtual Observatory was formulated at the end of 2000. It was realized as the FP5 project Astrophysical Virtual Observatory – AVO, the origin of European Virtual Observatory - EURO-VO (http://www.euro-vo.org), who started in 2001.

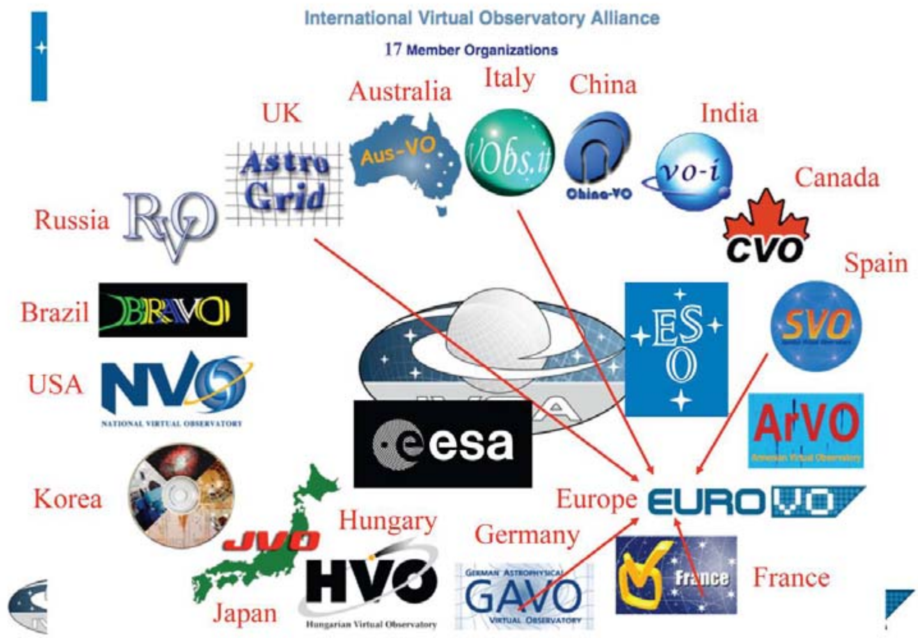


Fig. 1. International Virtual Observatory Alliance.

In order to coordinate the international collaboration in this field and develop and adopt the needed corresponding standards, International Virtual Observatory Alliance (IVOA, http://www.ivoa. net) was formed in June of 2002.

Serbia entered in such activities by creating SerVO - Serbian virtual observatory (http://servo.aob.rs/~darko), funded through the project TR13022 by Ministry of Science and Technological Development of Republic of Serbia (Jevremović et al., 2009, 2012). After establishing SerVO, our objective is to join

IVOA, if possibly on the interoperability meeting in Nara, Japan, 7-11 of December 2010, and the EuroVO. Our plan is also to establish SerVO data Center for digitizing, archiving and publishing in VO format photo-plates (Tsvetkova et al., 2009) and other data produced at Belgrade Astronomical Observatory and to develop tools for visualization of the corresponding data. Two of us (MSD-SSB) work on the development of STARK-B - Stark broadening data base containing, as the first step, our results for Stark broadening parameter determination obtained within the semiclassical perturbation approach, in VAMDC and VO compatible format. A mirror site of this database will be a part of SerVO. Also, within the frame of SerVO will be a mirror site for DSED (Darthmouth Stellar Evolution Database, Dotter et al., 2007, 2008) in the context of VO.

2. VAMDC – VIRTUAL ATOMIC AND MOLECULAR DATA CENTER

The need for an efficacious and adequate search and mining for available atomic and molecular data, highly fragmented and provided in different non standardized formats, which was an obstacle for their suitable use, leaded to the VAMDC idea. In order to make the search of atomic and molecular data efficacious, we need the search engines that must look "everywhere" for the needed A&M dat and to create an accessible and interoperable e-infrastructure.

This is in fact the main objective of Virtual Atomic and Molecular Data Center (VAMDC – Dubernet et al., 2010), a FP7 funded project which started on July 1st 2009 with budget of 2.9 MEuros over 42 months. The above mentioned objectives will be achieved by upgrading and integrating European (and wider) A&M database services and catering for the needs of variety of data users in science, research and development, and industry. In order to establish a better communication between data producers, data users and databases developers, one of the important VAMDC aims is also the creation of a forum for discussion of the corresponding subjects, as well as to organize the training of potential users in European Research Area and wider.

The VAMDC can be understood as a publisher infrastructure (Fig. 2), which will deploy yellow pages (registries) in order to find resources, design user applications, build data access layers above databases to provide unified outputs from these databases, and connect its infrastructure to the grid.

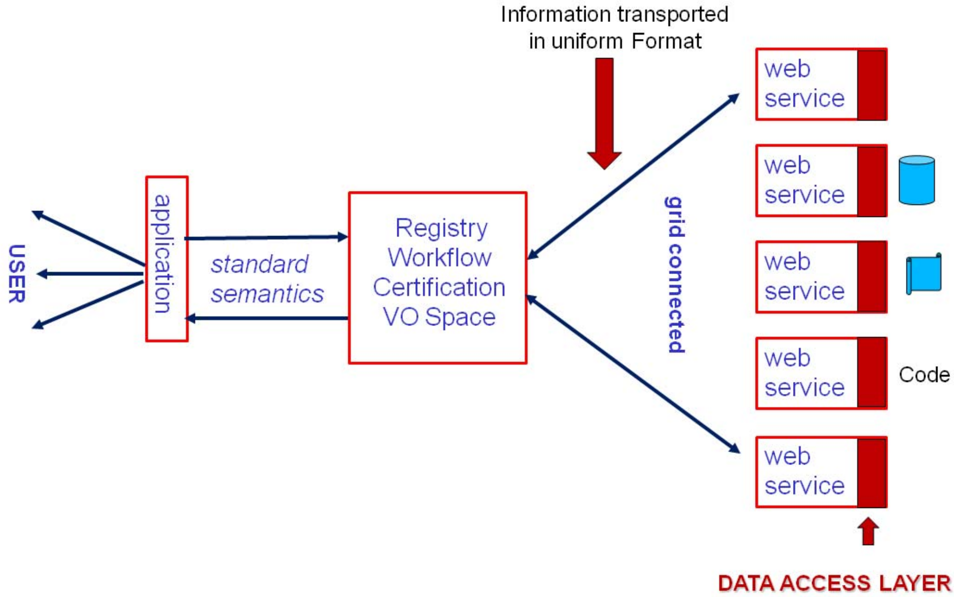


Fig. 2. Schematic diagram of the VAMDC infrastructure; note that it is a distributed system.

VAMDC

Virtual Atomic and Molecular Data Centre

VAMDC

Virtual Atomic and Molecular Data Centre

Fig. 3. VAMDC logo.

Project leader is Marie-Lise Dubernet from Observatoire de Paris and core consortium is made of 15 institutions with 24 scientific groups from France, Serbia, Russia, England, Austria, Italia, Germany, Sweden and Venezuela.

Partners in the Consortium of the Project are: 1) The coordinator, Centre National de Recherche Scientifique - CNRS (Université Pierre et Marie Curie, Paris; Observatoire de Paris; Université de Reims; Université Joseph Fourier de Grenoble, Université de Bordeaux 1: Université de Bourgogne, Dijon; Université Toulouse 3); 2) The Chancellor, Masters and Scholars of the University of Cambridge – CMSUC; 3) University College London – UCL; 4) Open University – OU (Milton Keynes, England); 5) Universitaet Wien - UNIVIE; 6) Uppsala Universitet – UU; 7) Universitaet zu Koeln – KOLN; 8) Istituto Nazionale di Astrofisica – INAF (Catania, Cagliari); 9) Queen's University Belfast – QUB; 10) Astronomska Opservatorija - AOB (Belgrade, Serbia); 11) Institute of Spectroscopy RAS – ISRAN (Troitsk, Russia); 12) Russian Federal Nuclear Center - All-Russian Institute of Technical Physics - RFNC-VNIITF (Snezhinsk, Chelyabinsk Region, Russia); 13) Institute of Atmospheric Optics - IAO (Tomsk, Russia); 14) Corporacion Parque tecnologico de Merida – IVIC (Merida, Venezuela); 15) Institute for Astronomy RAS - INASAN (Moscow, Russia).

External VAMDC partner is also NIST – National Institute for Standards and Technology in Washington.

The VAMDC facilities are dedicated to the various users in Astronomy, Plasma science, Atmospheric Science Radiation science and Fusion community as well as Industries using technological plasmas and Lightning industry

The basis of VAMDC e-infrastructure are the included databases upon which are actually:

VALD database (Kupka et al., 1999) of atomic data for analysis of radiation from astrophysical objects (http://vald.astro.univie.ac.at/).

CHIANTI (Dere et al., 2009), an atomic database for the analysis of optically thin collisionally ionised astrophysical plasmas. (http://sohowww.nascom.nasa.gov/solarsoft, http://www.damtp.cam.ac.uk/ user/astro/chianti/)

EMol Database, at the Open University in Milton Keynes (Mason, 2007), containing critically evaluated measured and calculated cross sections for electron interactions with molecular systems, and a suite of semi-empirical theoretical methods for the corresponding evaluation when there are currently no experimental data.

CDMS - Cologne Database for Molecular Spectroscopy (http://www.ph1.uni-koeln. de/ vorhersagen/) provides recommendations for spectroscopic transition frequencies and intensities for atoms and molecules of astronomical interest and for studying the Earth atmosphere. It is cross correlated with its US counterpart, the JPL Jet Propulsion Laboratory Submillimeter Catalogue (http://spec.jpl.nasa.gov/) (Müller et al., 2005).

BASECOL database (Dubernet et al., 2004) (http://basecol.obspm.fr) contains excitation rate coefficients for ro-vibrational excitation of molecules by electrons, He and H_2..

GhoSST (Grenoble astrophysics and planetology Solid Spectroscopy and Thermodynamics, http://ghosst.obs.ujf-grenoble.fr) database service, offers spectroscopic laboratory data on molecular and atomic solids and liquids from the near UV to the far-infrared.

UMIST - University of Manchester Institute of Science and Technology (UMIST) database for astrochemistry (Millar et al., 1991; Woodall et al., 2007) (http://www.udfa.net/), provides reaction rate data and related software for chemical kinetic modelling of astronomical regions.

KIDA - KInetic Database for Astrochemistry will contain data on chemical reactions used in the modelling of the chemistry in the interstellar medium and in planetary atmospheres (http://kida.obs.u-bordeaux1.fr).

PAHs (Polycyclic Aromatic Hydrocarbon) and carbon clusters spectral database (http://astrochemisty.ca.astro.it/database/) in Cagliari, developed in collaboration of CESR (Centre d'Etude Spatiale des Rayonnements) with CNRS (Malloci et al., 2007).

LASP (Laboratorio di Astrofisica Sperimentale) Database (http://web.ct.astro.it/weblab/ dbindex.html#dbindex) at the INAF (Istituto Nazionale di Astrofisica) - Catania Astrophysical Observatory, contains (i) infrared (IR) spectra of molecules in the solid phase (ii) IR optical constants of molecules in the solid phase and after processing with energetic ions; (iii) band strengths of the IR absorption bands ; and (iv) density values of frozen samples.

Spectr-W^3 (Faenov et al., 2002) atomic database (http://spectr-w3.snz.ru), created in collaboration between the Russian Federal Nuclear Centre All-Russian Institute of Technical Physics (RFNC VNIITF - Snezhinsk, Chelyabinsk Region, Russia) and the Institute for High Energy Densities of the Joint Institute for High Temperatures of the Russian Academy of Sciences (IHED JIHT RAS - Moscow). It lists experimental, calculated, and compiled data on ionization potentials, energy levels, wavelengths, radiation transition probabilities and oscillator strengths, and also parameters for analytic approximations for electron-collision cross-sections and rates for atoms and ions.

The V.E. Zuev Institute of Atmospheric Optics (IAO) in Tomsk (http://www.iao.ru/) hosts the following databases:

CDSD - The Carbon Dioxide Spectroscopic Databank (Perevalov and Tashkun, 2008) (http://cdsd.iao.ru and ftp://ftp.iao.ru/pub/CDSD-2008).

S&MPO - Spectroscopy & Molecular Properties of Ozone) relational database (Rothman et al., 2009) (http://ozone. iao.ru and http://ozone.univ-reims.fr/), developed in collaboration with the University of Reims.

"Spectroscopy of Atmospheric Gases" (http://spectra.iao.ru), containing HITRAN (Rothman et al., 2009) , GEISA (Jacquinet-Husson et al., 2008) and HITEMP (Rothman et al., 2010) databases.

W@DIS – Water Internet @ccessible Distributed Information System (http://wadis.saga.iao.ru) lists experimental water-vapour spectroscopy data from the literature and calculated line lists.

Databases under the management of Corporacion Parque tecnologico de Merida – IVIC (Instituto Venezoelano de Investigaciones Scientificas) and CeCalCULA (Centro Nacional de Cálculo Científico de la Universidad de Los Andes).

TIPTOPbase (Cunto et al., 1993) located at the Centre de Données astronomiques de Strasbourg, France (http://cdsweb.u-strasbg.fr/topbase/home.html), contains:

TOPbase: Atomic data computed in the Opacity Project, namely LS-coupling energy levels, gf-values and photo ionization cross sections for light elements ($Z \leq 26$) of astrophysical interest.

TIPbase: Intermediate-coupling energy levels, A-values and electron impact excitation cross sections and rates for astrophysical applications ($Z \leq 28$), computed by the IRON Project.

OPserver (Mendoza et al., 2007), located at the Ohio Supercomputer Center, USA, (http://opacities.osc.edu/), a remote, interactive server for the computation of mean opacities for stellar modelling using the monochromatic opacities computed by the Opacity Project.

Within VAMDC e-infrastructure are also:

XSTAR database (Bautista and Kallman, 2001), used by the XSTAR code (http://heasarc.gsfc.nasa.gov/ docs/software/ xstar/xstar.html) for modelling photo ionised plasmas.

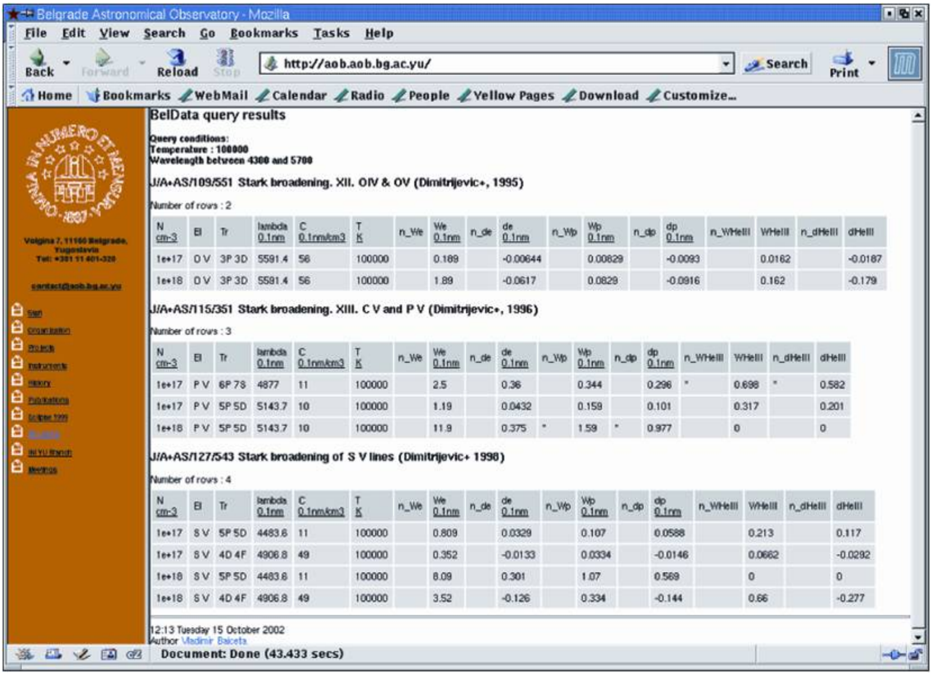
HITRAN - HIgh-resolution TRANsmission molecular absorption database (Rothman et al., 2008) (http://www.cfa. harvard.edu/hitran/).

GEISA - Gestion et Etude des Informations Spectroscopiques Atmosphériques database (Jacquinet-Husson et al., 2008)
(http://ara.lmd.polytechnique.fr/index.php?page=geisa-2 or
http://ether.ipsl.jussieu. fr/etherTypo/ ?id=950) is a computer accessible database system, designed to facilitate accurate and fast forward, calculations of atmospheric radiative transfer.

HITEMP, a high temperature extension to HITRAN (Rothman et al., 2010) containing data for water, CO_2, CO, NO and OH.

3. STARK-B DATABASE

The STARK-B database (http://stark-b.obspm.fr) (Sahal-Bréchot, 2010), is created in collaboration between Laboratoire d'Etude du Rayonnement et de la matière en Astrophysique of the Observatoire de Paris-Meudon and the Astronomical Observatory of Belgrade, and it enters also in the VAMDC e-infrastructure. It contains the theoretical widths and shifts of isolated lines of atoms and ions due to collisions with charged perturbers, obtained within the impact approximation (Stark broadening). At this stage it contains results obtained using the semiclassical perturbation approach (Sahal-Bréchot, 1969ab, for optimization of computer code and updates see e.g. Sahal-Bréchot, 2010; Dimitrijević, 1996).



Belgrade Astronomical Observatory - Mozilla

http://aob.aob.bg.ac.yu/

BelData query results

Query conditions:
Temperature : 100000
Wavelength between 4300 and 5700

J/A+AS/109/551 Stark broadening. XII. OIV & OV (Dimitrijevic+, 1995)

Number of rows : 2

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	O V	3P 3D	5591.4	56	100000		0.189		-0.00644		0.00829		-0.0093		0.0162		-0.0187
1e+18	O V	3P 3D	5591.4	56	100000		1.89		-0.0617		0.0829		-0.0916		0.162		-0.179

J/A+AS/115/351 Stark broadening. XIII. C V and P V (Dimitrijevic+, 1996)

Number of rows : 3

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	P V	6P 7S	4877	11	100000		2.5		0.36		0.344		0.296	*	0.698	*	0.582
1e+17	P V	5P 5D	5143.7	10	100000		1.19		0.0432		0.159		0.101		0.317		0.201
1e+18	P V	5P 5D	5143.7	10	100000		11.9		0.375	*	1.59	*	0.977		0		0

J/A+AS/127/543 Stark broadening of S V lines (Dimitrijevic+ 1998)

Number of rows : 4

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	S V	5P 5D	4483.6	11	100000		0.809		0.0329		0.107		0.0588		0.213		0.117
1e+17	S V	4D 4F	4906.8	49	100000		0.352		-0.0133		0.0334		-0.0146		0.0662		-0.0292
1e+18	S V	5P 5D	4483.6	11	100000		8.09		0.301		1.07		0.569		0		0
1e+18	S V	4D 4F	4906.8	49	100000		3.52		-0.126		0.334		-0.144		0.66		-0.277

12:13 Tuesday 15 October 2002
Author Vladimir Baiceta

Document: Done (43.433 secs)

Fig. 4. Output from the old BELDATA database.

STARK-B may be useful for modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, as well as for laboratory plasmas, analysis of laser produced plasma and laser equipment design and development, fusion plasma and technological plasmas. The database is currently developed in Paris, and a mirror site is planned in Belgrade, within the frame of SerVO. It is described in detail in Sahal-Bréchot (2010).

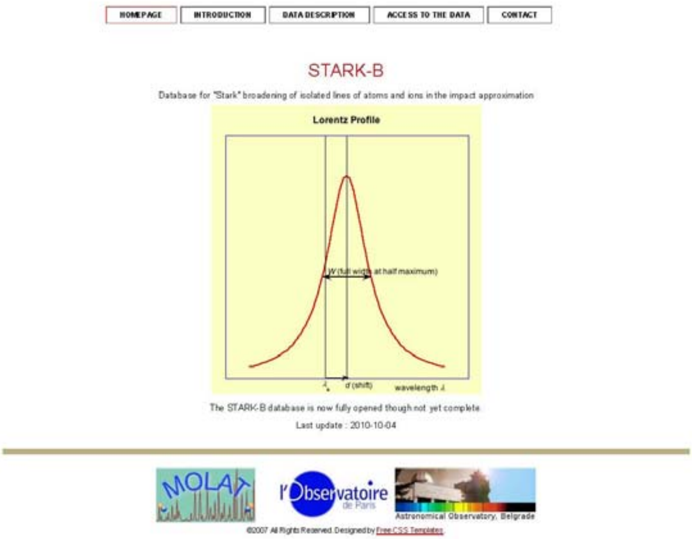


Fig. 5. The homepage of STARK-B.

On Belgrade Astronomical Observatory was created previously, as a precursor of STARK-B and SerVO, BELDATA database with Stark broadening parameters as its main content. A history of BELDATA can be traced in Popović et al. (1999ab), Milovanović et al. (2000ab), Dimitrijević et al. (2003) and, Dimitrijević and Popović (2006).

The participants of AOB (Astronomical Observatory – Belgrade) VAMDC Node are: Milan S. Dimitrijević, Luka Č. Popović, Andjelka Kovačević, Darko Jevremović, Zoran Simić, Edi Bon and Nenad Milovanović.

We also have a close collaboration with Sylvie Sahal-Bréchot from Paris Observatory, Nebil Ben Nessib, Walid Mahmoudi, Rafik Hamdi, Haykel Elabidi, Besma Zmerli and Neila Larbi-Terzi from Tunisia, Magdalena Christova from Technical University of Sofia and Tanya Ryabchikova from Institute of Theoretical Astronomy in Moscow.

Our ambition is that in the future, Group for Astrophysical spectroscopy and SerVO become a VAMDC regional center, in particular since it is expected that VAMDC, as an example of the global collaborations and innovations in e-science, will become one of major European cyber-infrastructures with a world wide impact.

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WIDE-FIELD PLATE DATABASE: DEVELOPMENT AND ACCESS VIA INTERNET IN THE PERIOD JANUARY 2009 - JUNE 2010

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Abstract. Here we describe the motivations and results from the 1.5 year period of the project Wide-Field Plate Database: Development and Access via Internet (DO-02-273/18.12.2008), dedicated to preservation, digitization, development and web access mainly of the astronomical plate archives of the 200 cm RCC and partly of the 50/70 cm Schmidt telescopes of the National Astronomical Observatory Rozhen received in the period of the first 20 years of operation 1979-1998. The basis of the work is set out in the following two publications of Tsvetkov (2006) and Tsvetkova and Tsvetkov (2006) motivating the project over the past 10 years. The WFPDB (www.wfpdb.org) represents a unique virtual instrument in astronomical research, which allows obtaining information on existing astronomical observations of celestial objects over the past 130 years with the professional astronomical telescopes at observatories worldwide.

1. INTRODUCTION

The Wide-Filed Plate Database (WFPDB) project practically presents an unique virtual telescope working as a "Time Machine" for obtaining information on historical observations of minor planets, comets, stars and galaxies. The project also aims to continue and expand the successful work initiated during the past 15 years by extending the provision of technical work on the base, and improving and extending the internal LAN (www.skyarchive.org), which ensures rapid online access to data, based on international standards of the International Virtual Observatory Aliance (IVOA) and the European Virtual Observatory (EURO-VO). The astronomical plate digitization and the web access to the large amount of the digitized data sets require maintaining the standard relational database and expanding the opportunities for search and retrieval of data (see www.skyarchive.org/search). It was also necessary to expand the volume of the database and to create new computer-readable versions of catalogues of photographic observations with their inclusion in the WFPDB.

The main directions of this project can be listed as: (1) to expand the WFPDB - reaching and exceeding the total number of observations involved to 600000 (i.e. more than 25% completeness), (2) improving WFPDB in terms of opportunities for search and retrieval of data from the database - data for original catalogues and "previews" - digital images of archived photographic plates for rapid visualization of observations made online and photometric studies, (3) establishing a numerical procedure for photometric calibration of photographic surveys as a tool for efficient photometric studies, (4) to make available the archive of the photographic observations with 2 m RCC telescope of NAO Rozhen producing inventory and including the plates obtained with the 50/70 cm Schmidt telescope with digitisation of selected samples, (5) to study the evolution of non-stationary stars by photometry of digitized photographic observations.

2. TECHNICAL SUPPORT AND INTERNAL LOCAL NETWORK DEVELOPMENT

To achieve the objectives of the project was necessary to improve the local computer network service of the WFPDB. This is related to one of the most important tasks of the project - digitization of photographic plates – it is connected with the need for very large capacity for storage of the digitized plate images. It is known that the volume of a separate digitized plate is of several hundred MB to 1 GB ~ depending on the size of the plate and the selected resolution of the scanning. For this purpose LAN is equipped with a storage platform with high capacity up to 16 TB. In the Sofia Sky Archive Data Center (SSADC) the device PROMIS VTRAC M610p with capacity of 6 TB at present was purchased and installed. It is expected to be expanded to 16 TB in the next contract period. Furthermore, the computer system of the project used for the plate digitization and processing with specialized software packages, was renovated. LAN has been expanded with three new computers to scan the plates in Sofia and NAO Rozhen. For the purpose the SSADC network was improved and renovated with the necessary routers, collectors and devices to stabilize the voltage – UPSs. Fig.1 shows the block diagram of the SSADC and the laboratory of astro-plate digitization, the network with the main servers, the Perkin-Elmer microdensitometer PDS1010^{Plus}, and the integrated data storage system PROMISE-Vtrac M610p.

3. MAINTENANCE OF THE DATABASE AND ORGANIZATION OF DATABASES OF IMAGES

The WFPDB management system is based on Firebird SQL Server platform to Linux.(http://draco.wfpdb.org/search/) developed in previous period. Now a new enhanced search page is introduced. New choices in WFPDB are extended with parameters of observations - the original logbooks and previews - compressed images of the original plates. Figs. 2-4 show samples of search in the WFPDB with copy of the original logbook of observations and an example of plate preview

- the all sky plate distribution in this case is for the updated catalog ROZ200 of the 2 m RCC telescope of the NAO Rozhen.

Under the construction is a website home page of the WFPDB in form as Wiki platform. A prototype of the page can be seen at:
http://trillian.magrathea.bg:2500/home/published/

New WFPDB mirror in the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, was established and maintained. An important part of the WFPDB is the StarGazer version 3.0, which can display and link existing catalogues with the region of observation obtained by the plate search in the database at:
http://wfpdb.org:8080/stargazer/.

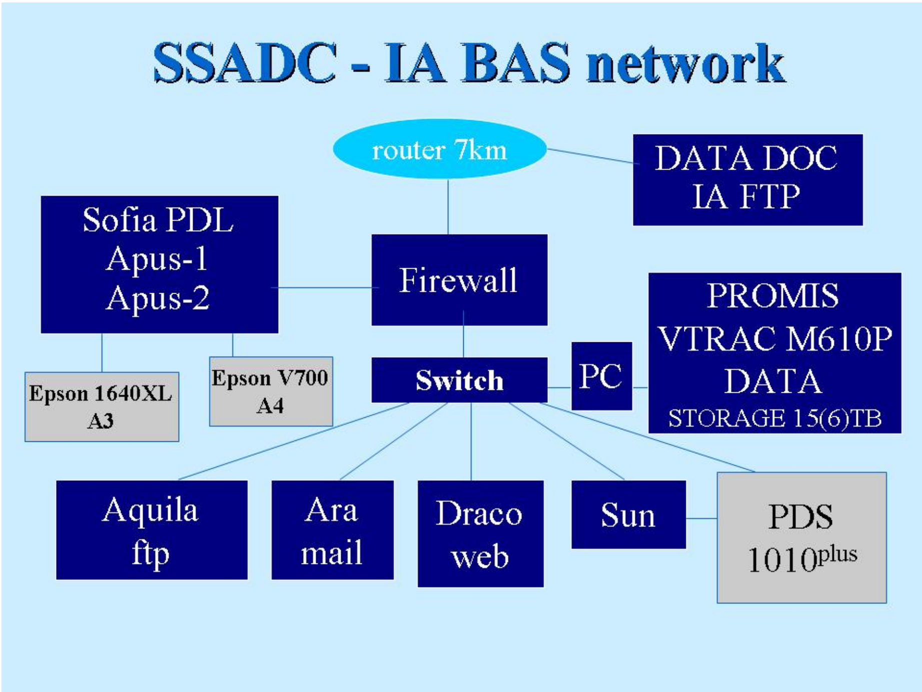


Figure 1. Block diagram of the network of the Sofia Plate Digitization Laboratory (SPDL) of the Sofia Sky Archive Data Centre with the main servers, Perkin-Elmer microdensitometer PDS 1010^{Plus} and flatbed scanners EPSON 1640 XL and EPSON V700.

4. PROGRAM PACKAGE FOR DATA REDUCTION OF THE ORIGINAL PLATE CATALOGUES

New advanced packages were developed for:

- Data reduction from the original plate catalogues to the accepted WFPDB standards;
- Optical Character Recognition (OCR) tool for converting the typed original plate catalogues in table form to electronic form applied to the plate catalogue of the Brashear astrograph of the Tokyo Astronomical Observatory (see Kirov, Tsvetkov, Tsvetkova and Kalagrarskiy at http://aquila.skyarchive. org/ DATABASE_NFNI273/publications/Chepelare_ Kirov_KTS_DKG.pdf);
- Inclusion of images from original catalogues and previews. (See (published Kirov and Tsvetkov, http://aquila.skyarchive.org/ DATABASE_ NFNI273/publications/ Ohrid_mil_nik_slides.pdf;
- Reading FITS and row TIF files and converting row TIF -> FITS (using standard packages, as well as own software packages;
- Data conversion and creation of tables in the WFPDB format (Package CuneiForm);
- Connection of the astronomical photographic plates scanned images from the WFPDB and the page images from the original astronomical journals;
- Segmentation of the images from the logbooks (experimental version of the software);
- Linking records of astronomical photographic plates from WFPDB and images of original pages of astronomical journals.

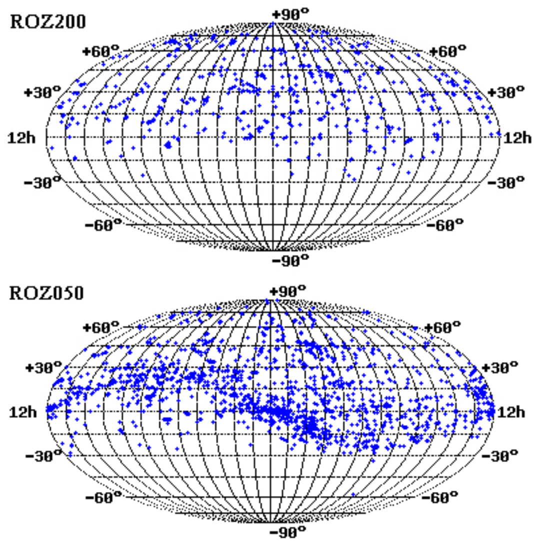


Figure 2. All sky distribution of the plate centres for the listed in the WFPDB plate collection of the Rozhen wide-field telescopes: the 2 m RCC (ROZ200 with 1984 plates) and 50/70/172 cm Schmidt (ROZ050 with 7359 plates).

From the given access to the plate logbooks from the site of the Harvard Observatory (http://hea-www.harvard.edu/DASCH/ExposureData/LogJpeg/) a mirror was made to all astronomical logbooks of the Harvard Observatory -the whole amount of data is 47GB, (see:

http://aquila.skyarchive.org/Astroinformatics/2_IA/1_IMI/Ohrid_mil_nik_slides.pdf).

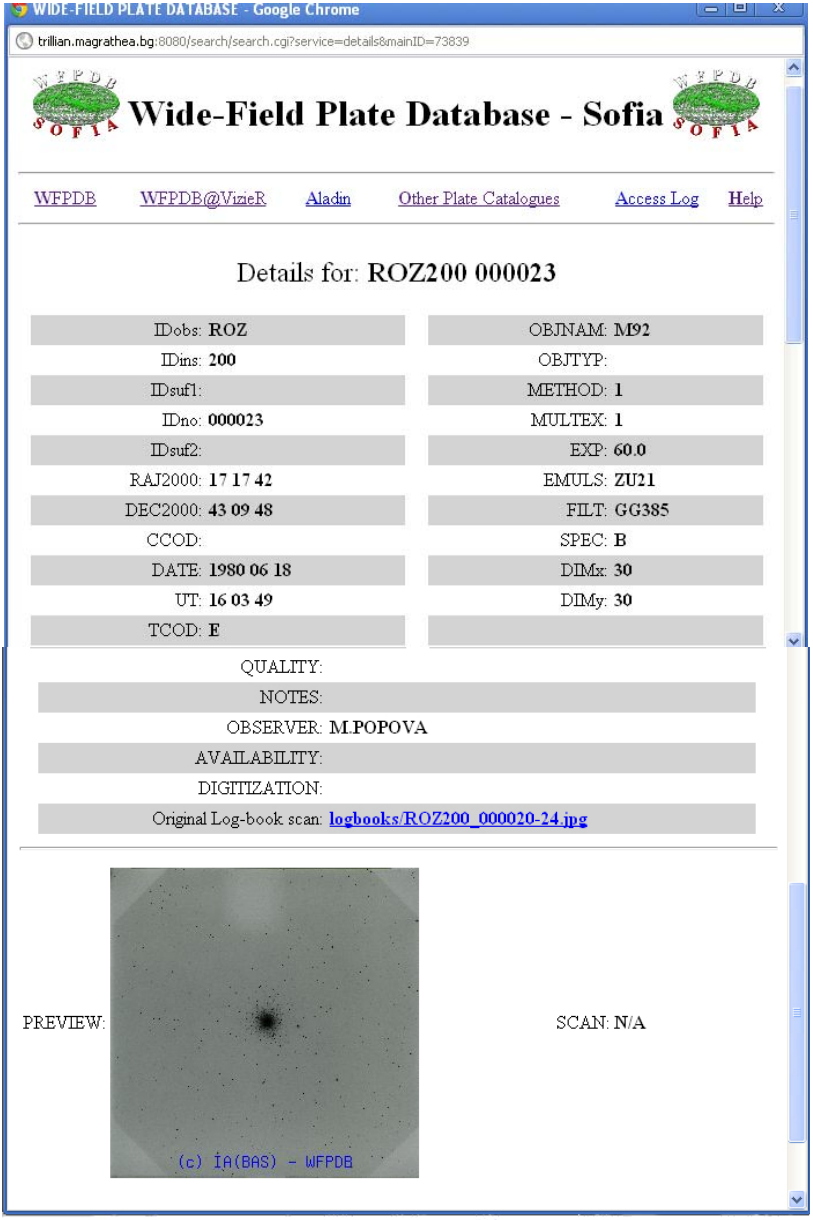
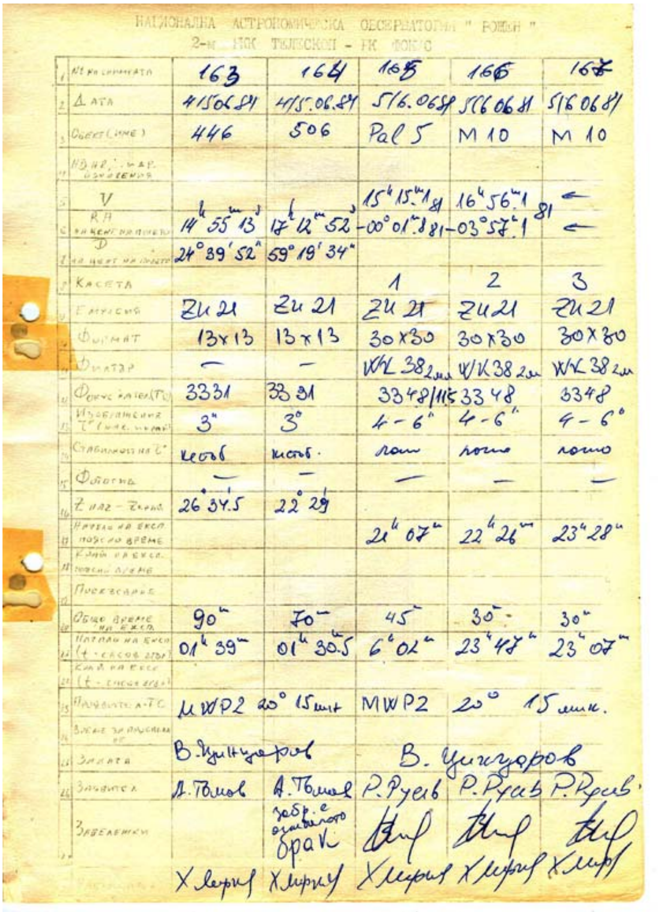


Figure 3. An example of the plate search in the WFPDB giving plate preview.

WFPDB currently provides information on 563,612 plates from 133 photographic archives (http://www.skyarchive.org/images/wfpdb_new.png) with different observing instruments. It represents about a quarter of the total number of photographic plates in the world.

We plan to include into the WFPDB within the 3-year period of the project about 50,000 plates, and the database to reach 600,000 complete observations. It has to be reported, however, that the most important activity in the expansion of WFPDB is particularly labor intensive and involves a number of difficulties. Still a significant part of the catalogues has no computer-readable versions and in these cases the team that supports WFPDB has to produce similar versions. In some cases, there are even no diaries of observations and then the only option is taking the information directly from the photographic plates or envelopes in which they are stored.



№ на снимката	163	164	165	166	167
Дата	4/5.06.81	4/5.06.81	5/6.06.81	5/6.06.81	5/6.06.81
Обект (име)	446	506	Pal 5	M 10	M 10
RA	14h 55m 13s	17h 12m 52s	15h 15m.1 81	16h 56m.1 81	←
D	24° 39' 52"	59° 19' 34"	-00° 01'.8 81	-03° 57'.1	←
Касета			1	2	3
Емулсия	ZU 21	ZU 21	ZU 21	ZU 21	ZU 21
Формат	13x13	13x13	30x30	30x30	30x30
Филтър	–	–	WL 38 2мм	WK 38 2мм	WK 38 2мм
Фокус	3331	3331	3348/11.5	3348	3348
Изображение	3"	3"	4-6"	4-6"	4-6"
Стабилност	[illegible]	[illegible]	лошо	лошо	лошо
[illegible]	–	–	–	–	–
Z	26° 34'.5	22° 29'			
Начало на експ. поясно време			21h 07m	22h 26m	23h 28m
Общо време на експ.	90m	70m	45m	30m	30m
[illegible]	01h 39m	01h 30.5	6h 02m	23h 47m	23h 07m
Проявител	MWP2 20° 15мин		MWP2 20° 15мин.		
[illegible]	В. Цинзаров		В. Цинзаров		
Заснел	Д. Томов	Д. Томов	Р. Руев	Р. Руев	Р. Руев
Забележки		забр. е ... брак			

Figure 4. Sample of the original plate logbook (plates ROZ200_000163-167) included in the WFPDB as a new opportunity of the extended search.

Table 1. New WFPDB catalogues with a total of 23,358 new plates

WFPDB Catalogue Identifier	Number of the Plates
MYK012	7438
TOK016	868
TOK020	1577
GUA040A	8486
GUA040B	649
GUA040E	3656
GUA070A	570
QUI021A	66
QUI021B	48
Total number	23358

Data for added new catalogues during the first phase of the contract (exactly new 23 358 plates) is given in Table 1. These catalogues are available for user mode online via Internet.

A new updated version of the Catalogue of Wide-Field Plate Archives (CWFPAs) version June 2010 with a total of 473 archives was prepared. In the contract period the number of records has increased from 440 to 473, or 33 new archives were added. The increasing of the number of direct plates in the catalogues during the contract period is with 221,046 new plates.

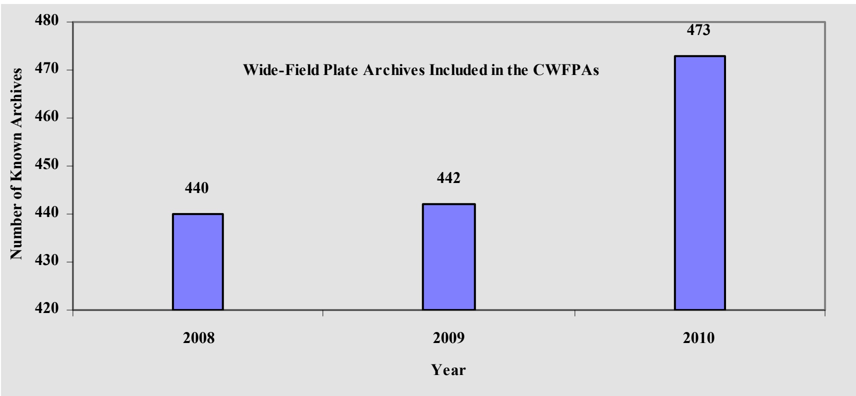


Figure 5. Status of the CWFPA version June 2010.

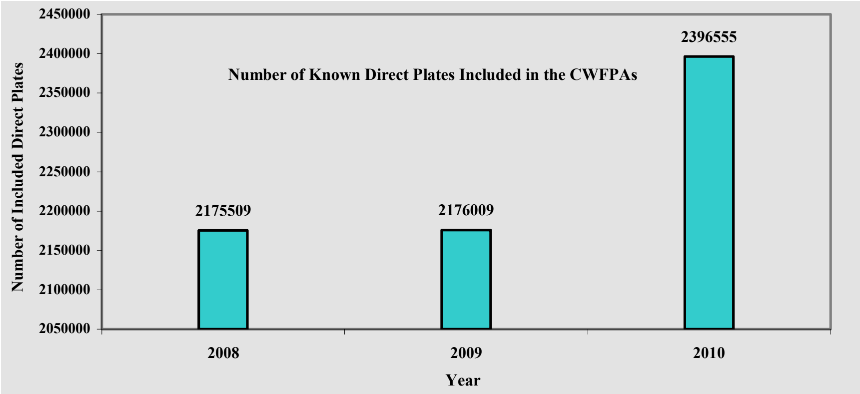


Figure 6. Increasing the number of direct plates in the CWFPA version June 2010.

5. DIGITIZATION OF THE PHOTOGRAPHIC PLATES - PREPARATION OF DIGITAL IMAGES WITH LOW AND HIGH RESOLUTION ACCORDING TO THE WFPDB REQUIREMENTS

About 3000 plate scans (preview images) of the Belgrade Astronomical Observatory and 1000 scan from Bucharest have been delivered to the WFPDB in order to be included into the database.

Substantial development work on creation of specialized digital archives of plates within the eScience and electronic connection between IBVS and WFPDB (Interlinking IBVS with WFPDB) was done with the new flatbed scanner of Konkoly observatory:

- 31 plates in Orion (with a total volume of data about 14.1GB) with EPSON PERFECTION V750 PHOTO scanner with scan parameters - 15x15 cm scanned field; 1200 dpi previews; 2400 dpi working scans. Source files in JPG format, have an average 1.5 MB in 52 MB TIF format in FITS format, 419 MB;
- 22 plates in the Pleiades ((total volume of data about 10.3 GB) with EPSON PERFECTION V750 PHOTO scanner with scanning parameters - 15x15 cm scanned field; 1200 dpi previews; 2400 dpi working scans. Source files in JPG format, have on average 1.5 MB in TIF format, 52 MB to 419 MB FITS format);
- 64 plates ((total volume of data about 26.2 GB) with EPSON PERFECTION V750 PHOTO scanner with scanning parameters - 15x15 cm scanned field; 2400 dpi working scans. Source files in FITS format are with a volume of about 419 MB.

Plate scanning laboratories were established with standard methods of scanning in astronomical institutes in Germany (Potsdam, Bamberg, Jena), Hungary (Konkoly), Romania (Bucharest), Belgrade, Ukraine (Kiev-Main Astronomical Observatory), Russia (Moscow- INASAN Zvenigorod) and others. Methodology (know-how) to digitise plates by flatbed scanners such as EPSON has been given also in Prague, Tatranska Lomnica, Cluj, Zvenigorod, etc.

Preparation of a new version of WFPDB, including new archives and catalogues is about to be published in the Astronomical Data Centre in Strasbourg. Within this task WFPDB was extended with digital images on photographic plates. The plates were scanned twice with precise commercial scanners (flatbed), type EPSON 10000XL, 1640XL and V700 - once a low-resolution colour and 8 bit, and a second time - with high-resolution 16 bit gray - FITS format. The purpose of scanning with low resolution, which is within the 600-1200 dpi (> ~ 40-20 μm), is to prepare digital images for rapid visualization of observations included in WFPDB. This provides an opportunity for preliminary examination (preview) of the selected sky region (plate) and its evaluation in terms of area covered by the celestial sphere, the visibility of certain objects, the limit magnitude (related to duration of exposure), image quality and others. The developed technology for plate scanning is accepted in observatories in Europe as a standard. Images of plates with high resolution, typically 1200-2400 dpi (<~ 20-10μm), are designed for photometry. These images are in greyscale and cleaned from possible dust and marks. Fig. 6 shows the Rozhen Digital Plate Laboratory equipped with flatbed scanner EPSON 10000XL.

The typical scan duration for one 30x30 cm plate with the cleaning, fitting on the scanner, setting scanning parameters, filling in the header file with the information and visual inspection of the resulting scan is about 30-40 minutes. The needed memory is about 0.7 GB. Only the scanning time of a plate with dimensions 30x30 cm (cleaned before scanning) with the EPSON 10000XL with 2400 dpi resolution is about 18 minutes. In some cases, for needed very high resolution (of a few μm), or for test and calibration measurements (densities to 5.0 D) the photographic plates were digitised by the high-precision microdensitometar PDS1010^{Plus} in SSADC (see

http://aquila.skyarchive.org/DATABASE_NFNI273/publications/reports/Nicola_Petrov_CHEPELARE.pdf).

Figure 7. Laboratory for scanning plates in NAO Rozhen, equipped with a scanner EPSON 10000XL (A3) and computer system APUS-3.

The technology of scanning plates with the same type of scanner is described in detail in the report of L. Schmadel from Heidelberg Astronomical Rechen Institute. In this project the digitization of a great amount of plates like Palomar sky surveys plates (POSS) with size 36x36 cm is described (http://aquila.skyarchive.org/DE_plate%20archives_pub/Heidelberg/Digitization_Stoss.ppt

5.1. Digitization of Roz200 Plate Archive

The digitisation of the plates obtained in the RC focus of the 2 m telescope of NAO Rozhen is one of the most important tasks in this contract. That is why a special inventory and search for the plates, which were stored by the individual observers, were made.

According to the information existing in the WFPDB the ROZ200 catalogue contains information for 1984 plates obtained in the period 1978 - 1993, after it the photographic observations were de facto suspended by the CCD cameras. With additional plates obtained by this telescope, especially with short exposures, which were not included in WFPDB, the number of the plates reached 2115. The number of the available plates in Rozhen and Sofia is about 880 plates. The rest plates are still in the individual observers or astronomers at home or abroad. A request for their return back and for centralized storage in NAO Rozhen was made. The plates obtained in the RC focus of the 2m telescope are with scale 12.89"/ mm, mostly with size 30x30 cm or 16x16 cm and they cover a sky region of one square degree.

The photographic plates of the 2 m telescope were scanned at low (600 dpi) for previews and with high resolution (1600 dpi) for FITS scans. Resolution of 1600 dpi corresponds to 15.9 μm/pixel and corresponds to the amount of - 0.20" per pixel. This value is comparable to the resolution of the CCD camera VersArray/1300B, which is currently used for observations with the 2-m telescope of NAO Rozhen pixel size of 0.26". Therefore it is suitable for efficient photometric image processing. With this resolution the volume of the scan of one plate is about 700 MB. Up to now according to the project programme for 2010 are scanned 496 plates from the Institute of Astronomy plate library: respectively - in Rozhen 424 plates and 72 in Sofia with size of 30x30 cm. Up to date (July 2010) from the catalogued 2115 plates from different observers 1100 plates were collected (not available 1015 plates present ~50%). The data from the scanned plates is available on the servers of the IA SSADC and NAO and a digital archive of photographic observations of the 2-m RCC telescope will be organized.

5.2. Digitization of Selected Photographic Plates from Roz050 Archive

The first step is the taken inventory of the available plates of this telescope. From those presented in the catalogue of the WFPDB for this telescope (ROZ050) for a period of about 20 years observations 7348 wide-field photographic plates mainly of small bodies of the Solar system, variable stars, star clusters and galaxies have been catalogued. The field of the telescope is 4.5 ° x 4.5

° at a scale of image 120 "/ mm and the dimensions of the plates are square 16x16 cm^2 and 13x13 cm^2 . Available in the plate library of IA with NAO are 1331 plates. The digitization of these photographic plates is also made in two steps - getting the "previews" with 1200 dpi (20 mic/mm) in TIF and JPG format and detailed scans in FITS format with 2400 dpi (10 mic/mm (1.2 "/pixel). So far with methods used 49 plates with the new EPSON Perfection V700 scanner in Sofia were preliminary digitized. Parallel with this goes digitization of selected samples to study different types of stellar objects: (a) eruptive stars, (b) minor planets, (c) before the main sequence stars and others. 200 Schmidt plates more are digitized and are available to the servers of NAO Rozhen and Sofia.

6. STUDY OF THE ACCURACY OF THE RESTORATION AND DEVELOPMENT OF NUMERICAL PROCEDURES FOR PHOTOMETRIC CALIBRATION

The important task was the testing the accuracy of the used methods especially with the available (commercial) flatbed EPSON scanners and with high accuracy microdensitometer PDS 1010 Plus. The task was divided into two stages: Investigation of the accuracy of digitization using the standard "driver" of the EPSON scanner (TWAIN-driver) and a new one of the commercial VueScan (VueScan - http://www.hamrick.com) and using the standard calibration procedure of de Vaucouleurs (1984). It was shown that the professional version of VueScan driver gives good results of scanning compared with the standard TWAIN EPSON driver is comparable with those of PDS1010^{Plus} (see Fig. 8 and http://aquila.skyarchive.org/ DATABASE_ NFNI273/ publications/reports/budell-2010. pdf). In this connection we plan to prepare a special software package and to replace the currently used “FitsScan”-driver of S. Motola (Barbieri et al. 2003) based on the EPSON TWAIN-driver, which allows to receive data directly from the VueScan row-tiff format to a standard FITS format applied for astronomical images.

In case of absence of internal calibration (f.e. photometric wedges), which is the often case in photographic wide-field observations it was proposed and tested a method of passing in the relative intensities, using profiles of star images. The restoration of the characteristic curve by this method was first proposed by de Vaucouleures (1984). In this case it is obtained that the method of stellar profiles allows to construct the characteristic curves of astronomical emulsion, which by its nature is comparable to that obtained from the photometric wedge. Since the method established ability to obtain internally consistent set of magnitudes with optimum accuracy – view at
http://aquila.skyarchive.org/DATABASE_NFNI273/publications/reports/Mapkov-atall-CHEP_2010% 20.pdf (see Fig. 9).

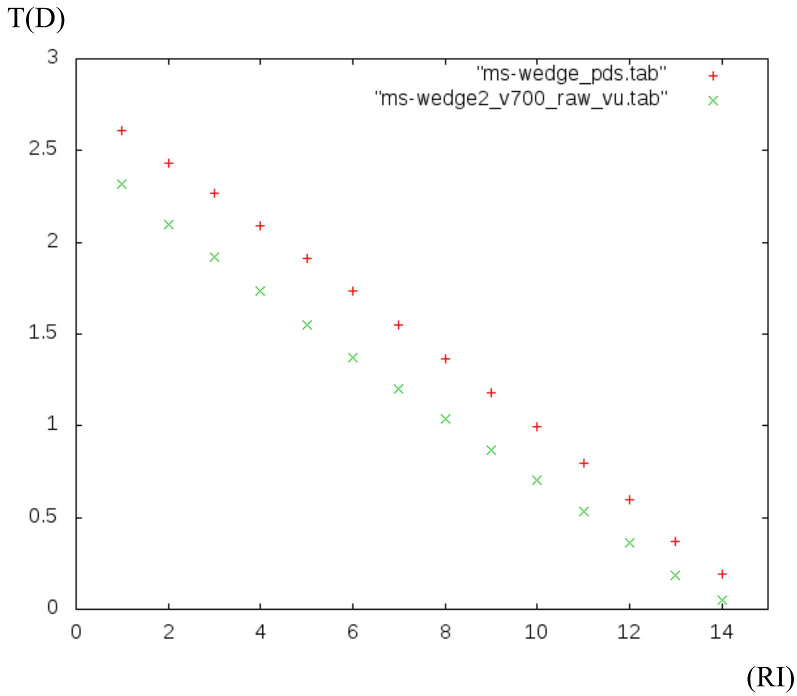


Figure 8. Comparative chart for photometric scan of EPSON V700 and PDS1010 Plus.

In this direction the research and development of technology and software for reading FITS and ROW TIF files were carried out and to convert them from ROW-TIF (product of the new program VueScan) in FITS.

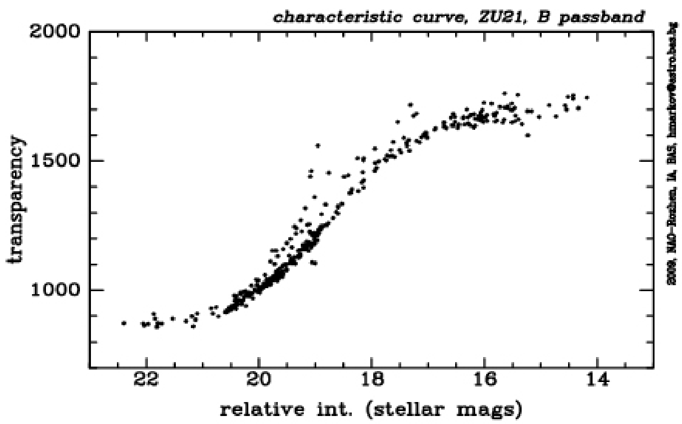


Figure 9. Chart of the photometric scan done by EPSON 10000XL of 30x30 cm^2 plate of the 2-m RCC telescope, emulsion ZU21 (B) in the star cluster M13 obtained in the calibration procedure applied to photometric plate processing. A test for digital aperture photometry of saturated star images was also performed.

7. RESEARCH AND RESULTS FROM THE USE OF ASTRONOMICAL PHOTOGRAPHIC PLATES IN THE WFPDB

Within the framework of research and application of WFPDB and photometric study of different types of variable stars a dissertation on the topic of the project was prepared http://aquila.skyarchive.org/
Astroinformatics/DISERTATIONS_PhD_275/Ana_Borisova_disertatsia/

The main results of this work can be summarized:

- Creation of a database of wide-field photographic astronomical observations in the Pleiades as an annex and extension of WFPDB;
- Combining data observations in a period of 115 years, the photographic observations (about 4000 plates);
- Hosted is a web-access data available through the interface of the WFPDB.

The photometric studies of selected southern active variable stars were executed using the digitized the Bamberg Southern Sky Survey plates. The analysis of the rotation curves for long period of the stars investigated confirms the observed rotation periods of CF Oct, YY Men and indicates the presence of long-term and changes in brightness of the star BBW 76 type FU Orionis and the long-scale changes of the YZ Men. The cyclical activity was proved using the method of Bayesian statistics. Conclusions are in agreement with the hypothesis of differential rotation of the star's photosphere. It was shown with a high probability of the existence of two cycles of approximately 7.13 and 9.81 years, and indications for the registration of three harmonics cycle with period 9.81 years, 6.66 years and 3.3 years.

Using the WFPDB and in particular the 2-m RCC and 50/70 cm Schmidt telescope plate collections for photometric variability survey of large intervals is of great importance for the study of stellar evolution and the study of no stationary processes were long requiring measurements of the brightness of stars . We scanned more than 220 plates as a special sample form the archives of 50/70 cm Schmidt telescope in combination with observations from observatories in Japan, Germany and others allowed to study of stellar evolution through the study of no stationary processes leading to change the brightness of stars.

In cases were studied FU Orionis (FUors) bursts of two stars located in a phase where not yet reached the main sequence. Physical causes are attributed to thermal changes caused changes of the nearby stellar disk. In the case was of star V1735 Cyg located in the nebula IC 5146 - a complex of active star formation. Based on the observed outburst and spectral properties, V 1735 Cyg is classified as an object FUOrioni and we are trying to build historically glow curve V1735 Cyg. Plates from the archive 50/70-cm Schmidt telescope of the observatory are 82 Rozhen received in the center of IC 5146. They were scanned with the Epson 1640XL scanner with 1600 DPI resolution, which corresponds to 16 μm/pixel. Aperture photometry was applied using the package DAOPHOT. Analysis of existing photometric data shows a slow decline in star brightness - 1.8 mag (R) for 44 years, which is typical of stars and FU Ori-. The data form the search shows that V 1735 Cyg should be added to the group of long FU Orionis type and that the time scale of this phenomenon FUOR should be much longer than assumed in previous studies.

It is necessary to continue research done on the basis of other existing historical photographic observations of V 1735 Cyg collections of the following telescopes: the 67/92-cm and 40/50-cm Schmidt telescope at Asiago (Italy) on 105/150-cm Schmidt telescope at Kiso Observatory (Japan), the 60/90-cm Schmidt telescope at Roma Observatory at Campo Imperatore (Italy) on 134/200-cm Schmidt telescope in Tautenburg (Germany) and 40 cm in telescope of Sonneberg Observatory (Germany). View.:

http://aquila.skyarchive.org/DATABASE_NFNI273/publications/T_Peneva_A&SS2009.pdf

Other similar star of FU Orionis candidate that was investigated - V733 Cep situated in the constellation Cepheus discovered by Persson in 2004. The star is located in the L1216 dark cloud near OB3 association Cepheus. As a result of scanning of 192 photographic plates found in the field of V733 Cep from different observatories selected on the bases of WFPDB search. The results of our photometric study form the digitized plates confirmed the affiliation of V733 CEp to no particular group of objects FU Orionis (Peneva et al. 2010 and Peneva et al.2010a). It is shown for the first time that in the optical band the star increase the brightness in the period 1971-1993. During the period 1993-2004 V733 Cep reaches its maximum brightness and the observed outburst amplitude exceeds 4.5 (R) magnitudes. In color BVRI photometric system data show that from February 2007 to October 2009, slowly the brightness of V733 Cep decreases. Development of the observed color index also suggest that V733 Cep currently is faint. Long time light curve of V733 is very similar to the usual curves of other objects FU Orionis.(see:

http://aquila.skyarchive.org/DATABASE_NFNI273/publications/Peneva_semkov1003.3744v1.pdf)

8. CONCLUSIONS

The important results from the work program under contract DO-02-273 in the first period of the grant can be summed up as:

1. The SSADC local computer network was improved and it was equipped with a new data storage capacity (PROMIS VTRAC V610p) of 15 TB (at present only 6TB are ordered). The steps are made to integrate the network of the SSADC to the network of the Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences.

2. There are existing "Mirror" database WFPDB in IMI and IA:
http://trillian.magrathea.bg:8080/, (www.wfpdb.org)
http://trillian.magrathea.bg:8080/search/,
http://trillian.magrathea.bg:8080/stargazer/,
http://trillian.magrathea.bg:8080/hyperleda/,
http://docs.astro.bas.bg/~pi/Data/www/picindex.html,
http://www.wfpdb.org/7_BSAC/

3. Catalogue records (CWFPA) was updated as new version is made (5.5), which includes information about new American observatories possessing such observations. So during the project work during the first stage the number of records increased by 33 new archive containing 221.046 plates - the total number of records reached number 473, the database (WFPDB) grew by 23,358 plates.

4. 15 publications are published on the topic of the project, 4 of them are in journals with high impact factor. Exported more than 20 reports of some international conferences and present, of which 6 invited.

5. Organized an international conference on “Astroinformatics” with over 65 participants, with over 50% participation from abroad, http://aquila.skyarchive.org/7_BSAC/. Organized was an international Workshop in Potsdam(AIP) to discuss a project on digitization of European cultural heritage (historical astronomical plates) in frame of the 7th Framework Programme.

6. The project research team has had and continues to provide expert assistance to astronomical institutes and observatories in Europe (Bamberg, Potsdam, Bucharest, Budapest, Moscow, Belgrade etc.) for the organization, digitization and the use of their photographic archives.

7. A doctoral thesis was defended connected with the topic of the project.

"WFPDB(Database of Wide-Field Photographic astronomical observations: Application for long-photometric study of different types of variable stars" Borisova 2010

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BAYESIAN PROBABILITY THEORY IN ASTRONOMY: TIMING ANALYSIS OF THE GIANT FLARE OF SGR 1806–20

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Abstract. For a photon-arrival times data sets the basics of a Bayesian statistical approach for detection and parameter estimation of periodic, variable and quasi-periodic oscillation (QPO) signal overviewed. An application to the complex data set of giant flare of Soft Gamma-ray Repeater (SGR) 1806−20 observed by *Rossi X-ray Timing Explorer (RXTE) Photon Counting Array (PCA)* on 27th of December 2004 is demonstrated. A comparison of Bayesian and classical approaches discussed.

1. INTRODUCTION

In X-ray and high energy astronomy modern instruments are able to register each individual photon. In particular, the position on the sky, energy of a photon, and its arrival time can be registered with very high accuracy.

This events can be very well described with a mathematical model *point processes.* First, they are point like in the sense of occupying a small and coextensive volume in the relevant space and secondly they are discrete, the degree to which they are distinct entities (Scargle and Bapu 1998).

These photon arrival times, while not binned, are quantized in microsecond-scale units sometimes called "ticks"– since they are in fact generated by the ticking of the computer clock on-board of the spacecraft. In the approximation where the ticks are short compared to time scales of interest, they can be very accurately modeled by a Poisson process. Depending on the nature of the variability of the process, different mathematical models apply. For instance, a *constant* signal as *homogeneous* Poisson process, *deterministic (e.g. periodic)* as *inhomogeneous* and *random* as *doubly stochastic* ones.

Here, we present the results of a Bayesian approach of timing analysis of the giant flare data set of SGR 1806−20 registered on 2004 Dec 27 by *RXTE PCA*, having extremely complex shape of the light curve (see next section for description of the data set). The data are viewed as a point process in time, and analysis seeks to determine whether there are temporal variations modeled by abovementioned three types of poissonian processes.

2. SGR 1806–20 SUPER FLARE ON 27 Dec 2004

2.1. What are SGRs? State of the art

Over the last few years, a number of observational discoveries have again brought Magnetars (ultra-magnetized isolated neutron stars) to the forefront of researchers attention. These extreme objects comprise the Anomalous X-ray Pulsars (AXPs; 10 objects) and the Soft Gamma-ray Repeaters (SGRs; 5 objects), which are observationally very similar classes in many respects (for a recent review see Mereghetti 2008). They are all slow X-ray pulsars with spin periods clustered in a narrow range ($P \sim 2$–$12\,$s), relatively large period derivatives ($\dot{P} \sim 10^{-13} - 10^{-10}\mathrm{s\,s^{-1}}$), spin-down ages of $10^3 - 10^4$ yr, and magnetic fields, as inferred from the classical magnetic dipole spin-down formula, of $10^{14} - 10^{15}$ G.

SGRs undergo periods of activity during which recurrent bursts with sub-second duration and peak luminosities of $\sim 10^{38} - 10^{41}$ erg/s are emitted. SGRs also show, on rare occasions, much more extreme events known as giant flares. These are characterized by an initial spike of duration comparable to that of recurrent bursts, but many orders of magnitude larger luminosity. Only three giant flares have so far been observed in over 30 yr of monitoring.

According to the magnetar model (Thompson and Duncan 1993, Thompson and Murray 2001) energy is fed impulsively to the neutron star magnetosphere when local "crustquakes" let magnetic helicity propagate outwards, giving rise to recurrent bursts with a large range of amplitudes. Giant flares are believed to originate from large-scale rearrangements of the inner field or catastrophic instabilities in the magnetosphere (Thompson and Duncan 2001, Lyutikov 2003). Most of this energy breaks out of the magnetosphere in a fireball of plasma expanding at relativistic speeds which results in the initial spike of giant flares. The decaying, oscillating tail that follows the spike displays many tens of cycles at the neutron star spin rate. This is interpreted as being due to a "trapped fireball" which remains anchored inside the magnetosphere and cools in a few minutes. The total energy released in this tail is $\sim 10^{44}$ erg in all three events detected so far.

Until 2004, the energy budget of SGRs and AXPs was believed to be dominated by their persistent emission at a level of $\sim 10^{35}\mathrm{erg\,s^{-1}}$. This translated into an internal field of $\sim 10^{15}$ G. The properties of the 2004 Dec 27 giant flare from SGR1806-20 imply that the emission budget of Magnetars is dominated by giant flares, see e.g. Stella et al. (2009). This therefore has important implications for several subjects at the forefront of research.

A power spectrum analysis of the high time resolution data from the 2004 Dec 27 event of SGR1806-20, observed with the X-Ray Timing Explorer (RXTE), led to the discovery of fast Quasi Periodic Oscillations (QPOs) in the X-ray flux of the decaying tail of SGR (Israel et al. 2005). QPOs of different frequencies were detected, some of which were active simultaneously and displayed highly significant QPO signals at about 18, 26, 30, 93, 150, 625 and 1840 Hz (Watts and Strohmayer 2006). A re-analysis of the decaying tail data from the 1998 giant flare of another Magnetar, SGR 1900+14, revealed QPOs around frequencies of 28, 54, 84 and 155 Hz (Strohmayer and Watts 2006). Hints for a signal at ~ 43 Hz in the March 1979 event from SGR

0526-66 were reported as early as 1983 (Barat et al. 1983). All QPO signals show large amplitude variations with time and especially with the phase of the stars rotational modulation.

2.2. Observational data

The giant flare of SGR 1806−20 has been observed by many space based missions. The data recorded by *RXTE PCA* instrument, consisting of five Xenon-filled detectors covering the energy range 2−50 keV, used the configuration GoodXenon, which records all good events detected in the Xenon chamber with full timing accuracy of 1 μs. Publicly available data were retrieved by the *XTE* Data Finder (XDF) user interface (Rots and Hilldrup 1997). Event data files have been created and photon arrival times were corrected for the solar barycenter using scripts provided in the package *XTE ftools*. The data set consists of 698770 registered photons. However, during the initial intensive spike phase of the giant flare the detectors were saturated. For that reason, in our analysis we use the data after $\sim$ 8.9sec of the flare onset, consisting of $\sim$ 650000 photon arrival times, clearly covering 51 rotational cycles of SGR 1806−20 (see Fig. 1).

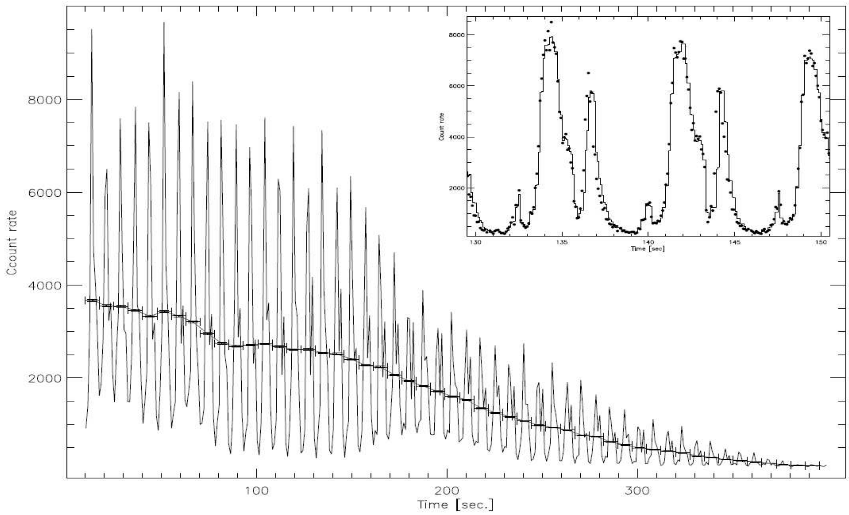

Figure 1. Light curve of the *RXTE* giant flare of SGR 1806−20 observed on 27th of December 2004. The general decay of the giant flare with a bumpy structure on top of it, namely a strongly periodic signal due to rotation (7.56 sec). The inset panel shows the rotational modulated light curve (filled circles) together with fitted piecewise constant model (solid line) (Hutter 2007), shown here only for 2.5 rotational cycles, with a very complex light curve structure. See text for details.

It is clear that observational detection and parameter estimation of QPO frequencies may play a crucial role for testing any theory predicting eigenfrequencies of the neutron star. In this connection, timing analysis of complex flare data set of SGR 1806−20, with the aim of QPO detection, may be divided into several mutually connected, challenging problems. They include the significance of quasi-periodic signal detection and parameter estimation with high precision. Indeed, the decaying tail, of the giant flare of SGR 1806−20, itself has a bumpy structure, very complex light curve shape modulated by rotation of the neutron star (see Fig. 1).

Thus, for investigation of this dataset a procedure properly should take into account all these variations.

2.3. Timing analysis with a Bayesian change point detection method

In order to study the changes of the photon arrival times (variability detection) we performed a timing analysis of the datasets using a Bayesian change point detection method[1] developed by Scargle (1998, 2000). This method is well suited for a statistical examination when the arrival times of individual X-ray photons are registered (see Hambaryan et al. 1999, Schwope et al. 2002). It is superior to methods which work on binned data, since it requires no a priori knowledge of the relevant time-scale of the variability structure which will be investigated.

Scargle's (1998, 2000) method decomposes a given set of photon counting data into Bayesian blocks with piecewise constant count-rate according to Poisson statistics. Bayesian blocks are built by a Cell Coalescence algorithm (Scargle 2000), which begins with a fine-grained segmentation. It uses a Voronoi tessellation[2] of data points, where neighboring cells are merged if allowed by the corresponding marginal likelihoods (Scargle 2000).

We repeat here the essential parts of the method, expanding upon particular modifications of the original method as used in the present application. Assume that during a continuous observational interval of length T, consisting of m discrete moments in time (spacecraft's "clock tick"), a set of photon arrival times D $(t_i, t_{i+1}, ..., t_{i+n})$ is registered. Suppose now that we want to use these data to compare two competing hypotheses, The first hypothesis is that the data are generated from a constant rate Poisson process (model M_1) and the second one from two-rate Poisson process (model M_2). Evidently, model M_1 is described by only one parameter θ (the count rate) of the one rate Poisson process while the model M_2 is described by parameters θ_1, θ_2 and τ. The parameter τ is the time when the Poisson process switches from θ_1 to θ_2 during the total time T of observation, which thus is divided in intervals T_1 and T_2.

By taking as a background information (I) the proposition that one of the models under consideration is true and by using Bayes' theorem we can calculate the posterior probability of each model by (the probability that M_k $(k = 1, 2)$ is the correct model, see, e.g., Jaynes and Bretthorst 2003)

$$Pr(M_k|D, I) = \frac{Pr(D|M_k, I)}{Pr(D|I)} Pr(M_k|I) \quad (1)$$

where $Pr(D|M_k, I)$ is the (marginal) probability of the data assuming model M_k, and $Pr(M_k|I)$ is the prior probability of model M_k $(k = 1, 2)$. The term in the

[1] In general terms, the change-point methodology deals with sets of sequentially ordered observations (as in time) and determines whether the fundamental mechanism generating the observations has changed during the time the data have been gathered (see, e.g. Csorgö and Horváth 1997).

[2] The Voronoi cell for a data point consists of all the space closer to that point than to any other data point.

denominator is a normalization constant, and we may eliminate it by calculating the ratio of the posterior probabilities instead of the probabilities directly. Indeed, the extent to which the data support model M_2 over M_1 is measured by the ratio of their posterior probabilities and is called the posterior odds ratio

$$O_{21} \equiv \frac{Pr(M_2|D,I)}{Pr(M_1|D,I)} = \left[\frac{Pr(D|M_2,I)}{Pr(D|M_1,I)}\right]\left[\frac{Pr(M_2|I)}{Pr(M_1|I)}\right]. \quad (2)$$

The first factor on the right-hand side of Eq. (2) is the ratio of the *integrated* or *global* likelihoods of the two models and is called the *Bayes factor* for M_2 against M_1, denoted by B_{21}. The global likelihood for each model can be evaluated by integrating over nuisance parameters and the final result for discrete Poisson events can be represented by (see, for details, Scargle 1998, 2000, Hambaryan et al. 1999).

$$B_{21} = \frac{1}{B(n+1, m-n+1)} \sum B(n_1+1, m_1-n_1+1) \times B(n_2+1, m_2-n_2+1)\Delta\tau\,, \quad (3)$$

where B is the *beta function*, n_j and $m_j, (j = 1, 2)$, respectively are the number of recorded photons and the number of "clock ticks" in the observation intervals of lengths T_1 and T_2. $\Delta\tau$ is the time interval between successive photons, and the sum is over the photons' index.

The second factor on the right-hand side of Eq. (2) is the prior odds ratio, which will often be equal to 1 (see below), representing the absence of an *a priori* preference for either model.

It follows that the Bayes factor is equal to the posterior odds when the prior odds is equal to 1. When $B_{21} > 1$, the data favor M_2 over M_1, and when $B_{21} < 1$ the data favor M_1.

If we have calculated the odds ratio O_{21}, in favor of model M_2 over M_1, we can find the probability for model M_2 by inverting Eq. (2), giving

$$Pr(M_2|D,I) = \frac{O_{21}}{1+O_{21}}\,. \quad (4)$$

Applying this approach to the observational data set, Scargle's (1998, 2000) method returns an array of rates, $(\theta_1, \theta_2, ..., \theta_{cp})$, and a set of so called "change points" $(\tau_1, \tau_2, ..., \tau_{cp-1})$, giving the times when an abrupt change in the rate is determined, i.e. a significant variation. This is the most probable partitioning of the observational interval into blocks during which the photon arrival rate displayed no statistically significant variations.

In Fig. 1 we visualize the outcome of the application to the observational data set, that divided it into time intervals (segments/blocks) within each of them a signal can be considered as a constnat with poissonian noise. In contrary, between those intervals significinat change of the observed count rate occured.

Thus, next we may perform a search for a periodic/quasi-periodic signal taking into account this segmentation.

2.4. The Gregory-Loredo (Bayesian) method for periodicity search.

The most widely-used procedure for detection of QPOs is an analysis of the power spectrum calculated from the fast Fourier transform (FFT) of uniformly sampled data. Application of the FFT to arrival time series data requires binning of the data to produce equally spaced samples. Binning is a subjective procedure; the choice of the bin width and edges can affect the apparent significance of a detection and limits sensitivity on short time scales. Moreover, the presence of the so-called red-noise (low frequency signal in the data, i.e. high calculated power can appear at low frequency because of long-timescale features of the data and at high frequencies from higher harmonics of complex shape strong periodic signal) may cause certain problems with the interpretation of the results (e.g. Bretthorst 1988). In the previous timing analysis of the giant flare data set of SGR 1806−20 by Israel et al. (2005) and Watts and Strohmayer (2006), an averaged power spectrum was considered. Namely, for each rotational cycle or certain rotational phase interval of SGR 1806−20 an independent classical power spectrum was determined depending on the phase of rotation and decaying tail of the giant flare, which were co-added and averaged subsequently. This approach divides the data set into small time intervals, which automatically reduces the significance of any periodicity detection and nearly takes into account the complex shape of the data set (rotational modulation and decaying tail of flare light curves, Fig. 1). Moreover, in some circumstances it may fail to detect the periodic signal (see e.g. Gregory and Loredo 1996). Indeed, as explicitly shown by Jaynes (1987) (see also, Bretthors 1988, 2001, Gregory 2005) the probability for the frequency of a periodic sinusoidal signal is given approximately by

$$p(f_n|D,I) \propto \exp\left[\frac{C(f_n)}{\sigma^2}\right], \tag{5}$$

where $C(f_n)$ is the squared magnitude of the FFT.

To avoid subjectivity and loss of sensitivity, we used a procedure which does not require binning and takes into consideration the rotational modulation and decaying tail of the flare (Bretthorst 1988, Gregory and Loredo 1992, 1996, Jaynes and Bretthorst 2003, Vaughan 2009).

For the analysis of the data for the search of QPOs during the giant flare of SGR 1806−20, we applied a Bayesian method developed by Gregory and Loredo (1992) (hereafter referred to as the GL method) for the search of pulsed emission from pulsars in X-ray data, consisting of the arrival times of events, when we have no specific prior information about the shape of the signal.

The GL method for timing analysis first tests if a constant, variable or periodic signal is present in a data set. As a prticular case of a QPO[3] can be considered a periodic signal with some length of coherence, i.e. a periodic signal with additional parameters of the oscillation with start and end times. In the GL method, periodic models are represented by a signal folded into trial frequency with a light curve shape as a stepwise function with m phase bins per period plus a noise contribution. With

[3]A QPO can be the result of a random process with a continuous power spectrum that contains a broad peak, or a locally monochromatic periodic signal, the frequency of which changes over time, either randomly or deterministically, or a combination of these.

such a model we are able to approximate a light curve of any shape. Hypotheses for detecting periodic signals represents a class of stepwise periodic models with the following parameters: trial period, phase, noise parameter and number of bins (m). The most probable model parameters are then estimated by marginalization of the posterior probability over the prior specified range of each parameter. In Bayesian statistics posterior probability contains a term that penalizes complex models (unless there is no significant evidence to support that hypothesis), hence we calculate the posterior probability by marginalizing over a range of models, corresponding to a prior range of number of phase bins, m, from 2 to 12. Moreover, the GL method is well suited for variability detection, i.e. to characterize an arbitrary shape light curve with piecewise constant function $Z(t)$ (Rots 2006).

For the search and detection of QPOs we used a slightly different version of the GL method (Hambaryan et al. 2010). First we determined $Z(t)$ - apodizing or weighting function (fitting with a piecewise constant model to characterize the complex light curve shape in the data set, giant flare decaying tail and rotational modulated light curve, see also previous section). Then we subsequently compare competing hypothesis, i.e. whether the data support a purely piecewise constant or piecewise constant+periodic model. If there is an indication of the presence of a periodic signal we determine also the time intervals where it has its maximum strength (e.g. amplitude or pulsed fraction) via a Markov Chain Monte Carlo (MCMC) approach using QPO start and end times as free parameters.

Finally, in the latter case, we estimate parameters (frequency, phase, amplitude, coherence length of QPO, etc.) of the periodic signal with high precision, using the posterior probabilities of frequencies in a periodic signal:

$$p(\omega|D, M_m) = \frac{C}{\omega} \int_0^{2\pi} d\phi \frac{1}{W_m(\omega, \phi)}, \tag{6}$$

where $C = \left[\int_{\omega_{lo}}^{\omega_{hi}} \frac{d\omega}{\omega} \int_0^{2\pi} d\phi \frac{1}{W_m(\omega,\phi)}\right]^{-1}$ and $W_m(\omega, \phi) = \frac{N!}{n_1! n_2! \cdots n_m!}$ are the normalization constant and number of ways the binned distribution could have arisen "by chance". $n_j(\omega, \phi)$ is the number of events falling into the j th of m phase bins given the frequency, ω, and phase, ϕ. N is the total number of photons (for details, see Gregory and Loredo 1992).

First, we applied the GL method as implemented by Gregory and Loredo (1992) to the 2004 Dec 27 giant flare whole data set of SGR 1806−20 observed by *RXTE PCA* and started the timing analysis by performing a blind periodicity search in the range of 12.0-160 Hz. Naturally, we found a very strong coherent signal at $\sim$ 7.56s, the pulsation period of the NS, followed by higher harmonics up to the 100Hz (see Fig. 2), which have to be excluded as potential QPO frequencies triggered by other phenomenon different than rotation of NS.

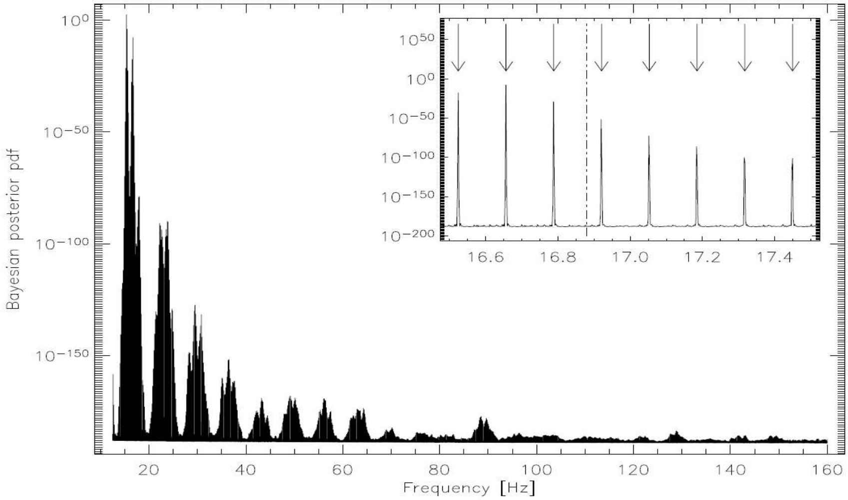

Figure 2. Application of the GL method for blind periodicity search to the complete data set obtained by *RXTE PCA* of giant flare of SGR 1806−20 2004 Dec 27 revealed a strong coherent signal at the frequency of 0.13219244 Hz and higher harmonics up to 100Hz. Bayesian posterior probability density vs frequencies in the range of 12.0-160 Hz is shown. The inset panel shows a zoomed part of it around 16.88 Hz. Arrows are indicating higher harmonics (from 125 to 132) of the fundamental frequency and the dash-dotted vertical line shows one of the detected QPO frequency in a short time interval (see text, for details).

Next, we divided the data set into 51 rotational cycles (see Fig. 1). Each of these subsamples were treated as independent data sets. We determined the Bayesian probability densities versus trial frequency. Final probabilities were derived in two ways. First, as the likelihood of those independent Bayesian posterior probability density functions and the second one simply summing those independent probabilities[4] (see Fig. 3).

This approach also revealed a number of rotational cycles within which the probability of the model of periodic signal is significantly higher than the constant one. Namely, during time intervals of 183.8−191.2, 244.3−251.9 and 259.4−267.1 seconds, from the flare onset, odds ratios of periodic vs constant models are ~ 10, ~ 30 and ~ 197, correspondingly.

[4]Addition rule of probabilities: probability that the QPOs at the given frequency are present Δt_1 or Δt_2 or both time intervals, while likelihood (i.e. summed power spectrum) defines the probability of presence QPOs during Δt_1 and Δt_2 (i.e. multiplication rule of probabilities, see also, Eq. 5)

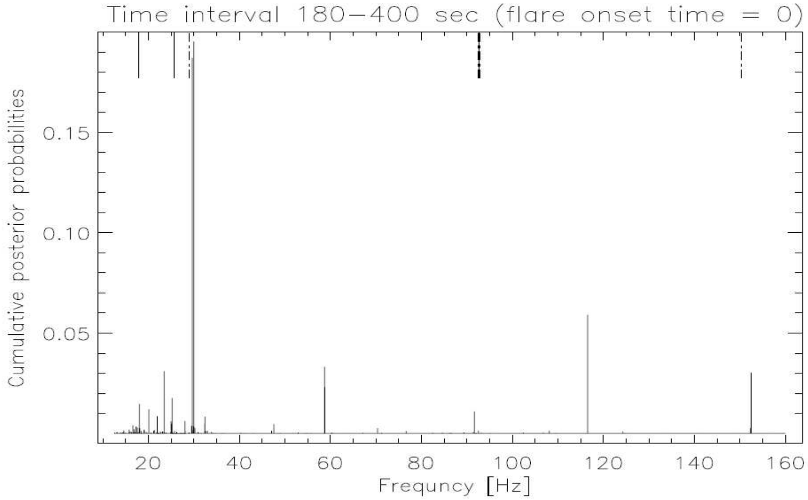

Figure 3. The Bayesian posterior probability density vs. trial frequency of the periodic signal for the giant flare data set of SGR 1806−20. QPO frequencies already detected by averaged power spectrum analysis and also with other mission *RHESSI* (Israel et al. 2005, Watts and Strohmayer 2006) are marked as small lines at the top axis. Those QPO frequencies are also detected by us. In addition, we have detected several more QPO frequencies (21, 59 and 116 Hz) with the Bayesian method, which were also predicted by Colaiuda et al. (2009).

In order to detect QPO start and end times we included also observational data of neighbouring rotational cycles (where a QPO with that frequency was not detected) and performed the periodicity search for an expanded time interval with additional two free parameters with the MCMC approach with Metropolis-Hastings algorithm. As initial values of these ($t_{QPOstart}$ and t_{QPOend}) parameters served start and end times of an observation, satisfying the condition: $t_{Obs.start} \leq t_{QPOstart} < t_{QPOend} \leq t_{Obs.end}$. In principle, starting with the abovementioned initial values can be considered as a good strategy, since the detected signal has a higher significance in a subinterval of the considered time interval and the fast convergence of the MCMC procedure already provided. This analysis via MCMC revealed even shorter time intervals within which periodic signal is stronger. The estimates of QPO frequencies and the corresponding 68% interval of the highest probability densities are presented in the Table 1 (see, also Fig. 4, 5).

Table 1: Detected QPO frequencies not reported in the literature (Israel et al. 2005, Watts and Strohmayer 2006, Strohmayer and Watts 2006).

f_{QPO} [Hz] (68% credible region)	Time intervals of detected QPOs[a]
16.88[b] (16.87 – 16.90)	259.4-267.1
21.36[b] (21.35 – 21.38)	244.3-251.9
36.84[b] (36.83 – 36.88)	183.8-191.2
59.04 (58.58 – 59.28)	146.0-176.2
61.26 (61.25 – 61.27)	251.9-395.6
116.27 (116.24 – 116.28)	168.7-198.9

[a] Giant Flare onset time is set to 0
[b] Highly significant detection (for details, see text)

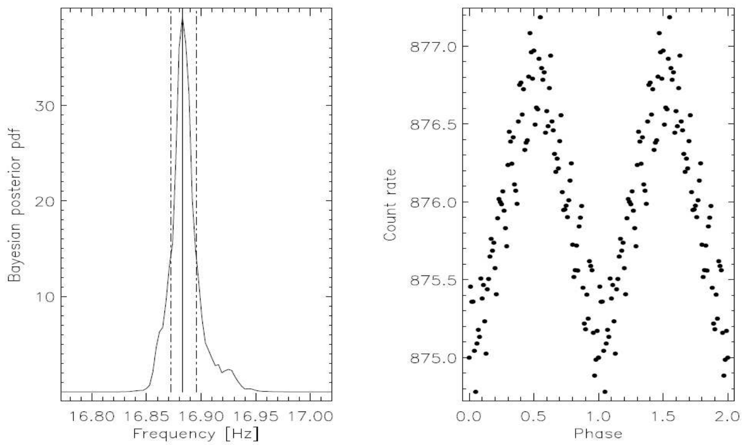

Figure 4. Bayesian posterior probability density vs frequencies in the time interval of 259-267 sec from the giant flare onset. By dashed vertical lines are indicated the 68% region of the highest probability density. Odds-ratio of periodic vs constant model is ~ 200. The right panel depicts the phase folded light curve with frequency $f_{QPO} = 16.88$Hz,it has almost perfect sinusoidal shape (for details, see text).

3. RESULTS

We report the detection of QPOs from SGR 1806−20 giant flare decaying tail recorded by the RXTE PCA by applying the GL method for periodicity search. We have confirmed the detections of QPOs at frequencies (in the range of $12 - 160$Hz) reported by Watts and Strohmayer (2006) and, in addition, we found some more QPOs at $f_{QPOs} = 16.9, 21.4, 36.8$Hz with corresponding odds ratios ~ 197, ~ 30 and ~ 10, in shorter time scales, i.e. within individual rotational cycles (see, Fig. 5). These odds ratios, describing the significance of presence of a periodic signal, are sensitive to the frequency search range. In contrast, detected frequencies of QPOs, found by locating maximums in the posterior probability density function, are insensitive to the prior search range of frequencies. We computed the uncertainty of f_{QPOs} at 68% confidence level ("posterior bubble") by using this posterior probability density function. In addition to that, we have also estimated the significance of our QPO detection by an empirically determined cumulative distribution (see, Fig. 5).

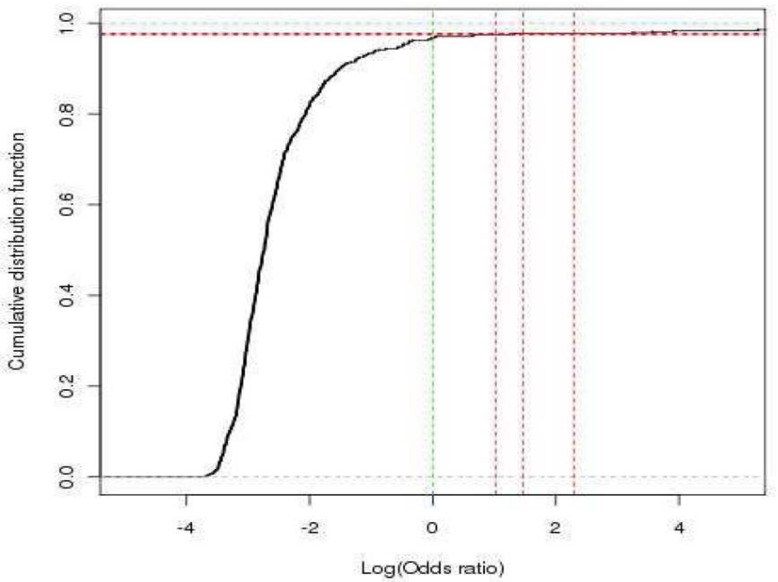

Figure 5. Empirical cumulative distribution function as a function of Odds ratio, i.e. the probability of periodic model vs constant one, on the base of simulations of QPO frequencies with different amplitudes and noise, as much as possible to the observed values in terms of number of registered photons, spanned times, etc.. Detected QPO frequencies indicated by vertical dashed lines, showing a high significance of detections.

The broad variety of neutron star oscillation modes (McDermott et al. 1985) is associated with their global structure as well as their internal characteristics. Neutron star seismology has already been proposed as a tool to understand their internal structure (Kokkotas et al. 2001). The various types of oscillations carry information about the equation of state, the thickness of the crust, the mass, radius and even the rotation rate (Gaertig and Kokkotas 2010). Still, modeling a truly realistic oscillating neutron star is difficult, however the potential reward is considerable. This has been demonstrated from the recent theoretical results for the QPOs which have been interpreted as magnetoelastic oscillations. These calculations have shown how the observations constrain both the mass, the radius, the thickness of the crust and the strength of magnetic field of these stars (Sotani et al. 2007, Samuelsson and Andersson 2007, Colaiuda et al. 2009, Cerdá-Durán et al. 2009). While one could even set severe constrains in the geometry of the interior magnetic field (see Sotani et al. 2008).

In particular, by studying Alfvén oscillations (Colaiuda et al. 2009) could find in the magnetar interior that there were no discrete modes but instead a continuum (as suggested by Levin 2007). The edges of this continuum have been used to explain the observed QPOs. It is worth noticing, that QPO frequencies found in this work have been predicted by Colaiuda et al. (2009).

Thus, by application of Bayesian approach to the photon arrival dataset of the giant flare of SGR 1806−20 (variability and periodicity search):

1. We found new QPOs applying a Bayesian timing analysis method of the decaying tail of the giant flare of SGR 1806−20 2004 Dec 27, observed by *RXTE PCA*, not yet reported in the literature.

2. Some of these QPO frequencies ($f_{QPOs} \sim 17, 22, 37, 56, 112$Hz) are predicted by the theoretical study of torsional Alfvén oscillations of magnetars (see, Table 2, by Colaiuda et al. 2009), suggesting APR_{14} (Akmal et al. 1998) EoS[5] of SGR 1806−20.

3. These preliminary results are very promising and we plan to extend our high frequency oscillations research (both the theoretical predictions as well as the observations) to both activity periods, as well as to the quiescent state of SGRs and AXPs, as well as to the isolated neutron stars with comparatively smaller magnetic fields.

Acknowledgements

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SERBIAN VIRTUAL OBSERVATORY AND VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC)

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Abstract. In this lecture we review recent developments in Serbian Virtual Observatory (SerVO) as well as its relation with the European FP7 project: Virtual Atomic and Molecular Data Center - VAMDC. Main components of SerVO are going to be the archive of photographic plates, database of Stark broadening parameters and stellar evolution database. Photographic plates were obtained at Belgrade Observatory from 1936 to 1996. Data for Stark broadening were obtained using semiclassical perturbation and modified semiempirical theories mainly in collaboration with Paris Observatory, and we are organizing them now in the STARK-B database, which will enter also in VAMDC, and will have a mirror site in SerVO. Serbian Virtual Observatory will contain as well a mirror of Darthmouth Stellar evolution database with improvements and VO compatible outputs.

1. VIRTUAL OBSERVATORIES AND SERBIAN VIRTUAL OBSERVATORY

The creation of datasets, connected with the space missions, in the NASA centers in early 90´s, and the huge quantity of data obtained in large all sky surveys (2MASS and SDSS) in the mid-90´s, available for the general use, posed the problem how to organize their search and use them for scientific investigations. The idea of virtual observatory originated from the efforts to solve this problem. Today, the objective of virtual observatories is not only to find, retrieve and analyze astronomical data from ground and space based telescopes worldwide, but also to combine research in different areas of astrophysics, like e.g. multi wavelength astrophysics, archival research, survey astronomy… They also provide data analysis techniques, common standards, wide network bandwidth and state of the art analysis tools. For the differences of classic observatories which have telescopes for gathering electromagnetic radiation or particles, instruments for analyzing and recording as well as different facilities for support of operation, the virtual observatories consist of data centers, loads of astronomical data, software systems and processing capabilities.

International Virtual Observatory Alliance (**IVOA**, www.ivoa.net), is formed in June of 2002, with objective to facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory. So its activity mainly focuses on the development and establishing of standards. The current set of standards as well as recommended ways of implementing them can be found at http://www.ivoa.net/Documents/.

European Virtual Observatory - EuroVO is an organization which aims at deploying VO in Europe. It is organized in three main parts:

Facility center (VOFC) provides the EURO-VO with a centralized registry for resources, standards and certification mechanisms as well as community support for VO technology take-up and dissemination and scientific program support using VO technologies and resources.

Technology center (VOTC) coordinates a set of research and development projects on the advancement of VO technology, systems and tools in response to scientific and community requirements.

Data Center alliance (DCA) is an alliance of European data centers who will populate the EURO-VO with data, provide the physical storage and computational fabric and who will publish data, metadata and services to the EURO-VO using VO technologies.

Serbian Virtual Observatory (SerVO – http://servo.aob.rs/~darko/**)** is a project, whose funding was approved through a grant TR13022 from Ministry of Science and Technological development of Republic of Serbia aiming to achieve the following goals:

1) establishing SerVO and join the EuroVO and IVOA;

2) establishing SerVO data Center for digitizing and publishing in VO photo-plates from the archive of AOB, and publishing other observational, theoretical, and simulated data obtained at Serbian observatories or by staff of Serbian observatories;

3) development of tools for visualization of data.

2. PHOTO PLATES

International Astronomical Union adopted in 2000 a resolution, which stated that all historic observations should be preserved, digitized and made available for use of wide astronomical community.[1] In particular photographic plates, which have a special historical, as well as scientific, significance for the astronomy.

From the mid-thirties till mid-nineties of the last century, photographic plates had been one of the recording media for the observations at the Astronomical Observatory in Belgrade, one of the oldest scientific institutions in Serbia, founded in 1887. From this period, more than fifteen thousand archived plates exist, and one of the main goals of SerVO for the beginning, is to digitize them and publish in the VO compatible format.

During this period of around sixty years, were used photo plates: Kodak (103aO, 2aO, 103aJ, 103aF), Ferrania Pancro anti-halo, Agfa Astro-Platten, Peruts Emulsion, Gevaert Super Chromosa, ORWO ZU 2 and ZU 21, Ilford etc, and variety of objects were observed.

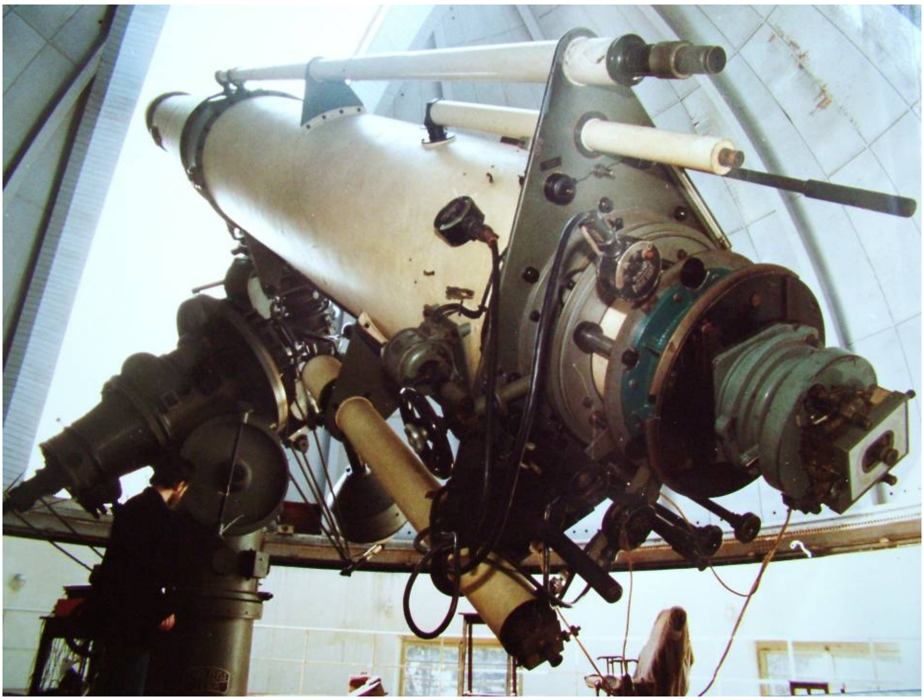

Fig. 1. Zeiss refractor (65 cm) of the Belgrade Astronomical Observatory.

[1] Resolution B3 of XXIVth International Union General Assembly, http://www.iau.org/static/publications/ib88.pdf p.40

For the beginning we are scanning plates with medium resolution (i.e. 1200 dpi) and prepare them for publication in VO compatible format. After completion of this 'preview' phase, we will scan them with high resolution (4800 dpi). In this phase, since the preview will be accessible on the SerVO, we will scan in priority the asked by the users. An example of a scanned plate is given in Fig. 3.

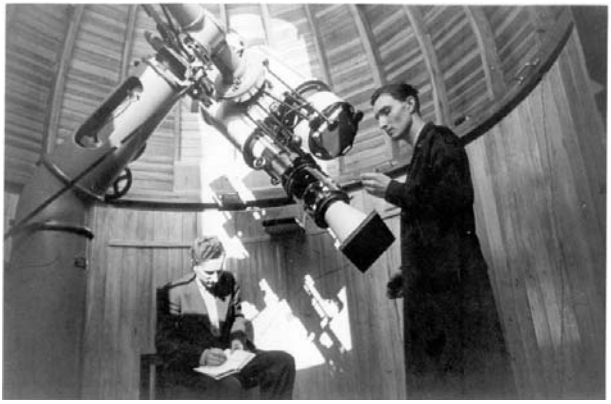

Fig. 2. Zeiss astrograph. M. B. Protitch and his asisstantn M. Simić (1936).

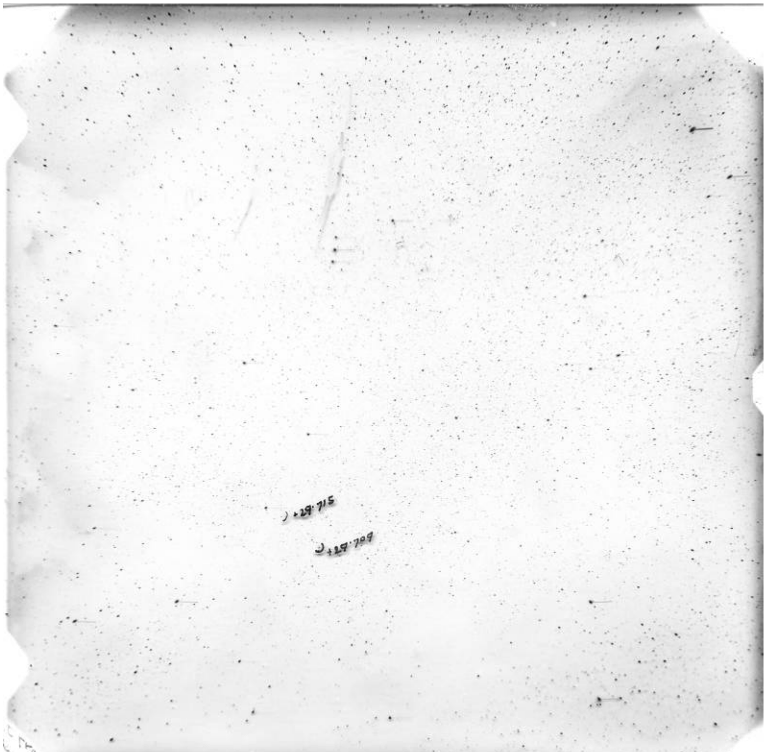

Fig. 3. Scanned photographic plate (from the very early datasets).

The meta data on each plate will contain: plate number, date and time, instrument, observer, coordinates, coordinates of guiding star, method of observations, exposure time, focal length, type and format of plate, air temperature and quality of exposure etc. Meta data are extracted from hand written records. The first results in archiving of photographic plates were presented in Protić-Benišek et al. (2006). Together with standard software (SQL, JAVA, Perl etc.), some EURO-VO tools will be used to build appropriate database. Handling will be achieved using linux Software RAID array with Linux Volume Manager.

3. SerVO – BELDATA - STARK-B

Theoretical data of interest for the modellisation and interpretation of various phenomena and objects in astronomy, are fairly new addition in the context of Virtual Observatory. The staff of Belgrade Observatory produced a large quantity of theoretical data for Stark broadening parameters (line width and shift), obtained mainly within the framework of fruitful collaboration with Observatoire de Paris in Meudon (MSD and SSB), lasting more than thirty years. This line broadening mechanism is generated by interaction of emitting/absorbing atoms and ions with charged particles.

The first attempt to organize these data, as well as other data existing at the Astronomical Observatory in a database, was the BELDATA project (Dimitrijević et al., 2003), the precursor of SerVO and its main content was database on Stark broadening parameters, which after intensification of collaboration between two of us (MSD and SSB) on the realization of this idea not in Belgrade but in Paris, and engagement of an informaticist (Nicolas Moreau) became STARK-B. This database is devoted to modellisation and spectroscopic diagnostics of stellar atmospheres as well as to laboratory plasmas, laser equipments, fusion and technological plasmas.

In the first stage, STARK-B (http://stark-b.obspm.fr) contains data determined using the semiclassical-perturbation approach developed by Sahal-Bréchot (1969ab; 1974), and the corresponding code, supplemented in Fleurier et al. (1977) and, Dimitrijević and Sahal-Bréchot (1984). The accuracy of the data varies from about 15-20 percent to 40 percent, depending on the complexity of the spectrum, degree of excitation of the upper level, and on the quality of the used atomic structure entering the calculation of scattering S-matrix leading to the widths and shifts. The more the upper level is excited, the semiclassical approximation is more suitable, but it is more difficult to find a sufficiently complete set of input atomic data. We note that the STARK-B database is included in the FP7 project European Virtual Atomic and Molecular Data Center (VAMDC). The data can be retrieved in two manners: as a text file or in VO table format.

4. DSED IN SerVO

Members of the group for Astrophysical spectroscopy (DJ) participated also in the development of Dartmouth Stellar Evolution Database which has been recently published (Dotter et al., 2007, 2008). It consists of evolutionary tracks and isochrones for initial stellar mass from one tenth to four solar masses. They were evolved from pre-main sequence state to either of runaway fusion or 100 Gyrs. One of us (DJ) contributed to this project calculating the outer boundary conditions for the atmospheric structures using general stellar atmosphere code PHOENIX. Using this kind of boundary conditions allows an easy generation of various parameters for population synthesis (i.e. colors , low dispersion spectra of star clusters and galaxies). We intend to add an option of "VO table output" for the whole set of data and host a mirror site at SerVO.

5. VAMDC – VIRTUAL ATOMIC AND MOLECULAR DATA CENTER

In order to enable an efficacious, productive and convenient search and mining of available atomic and molecular data and their adequate use, a FP7 founded project: Virtual Atomic and Molecular Data Centre (VAMDC – Dubernet et al., 2010), started on July 1 2009 with a budget of 2.9 MEuros over 42 months. Its aim are to build accessible and interoperable e-infrastructure for atomic and molecular data upgrading and integrating European (and wider) A&M database services and catering for the needs of variety of data users in science, research and development, and industry; creation of search engines that must look "everywhere" in order to map A&M Universe; and creation of a forum of data producers, data users and databases developers, as well as the training of potential users in European Research Area and wider.

VAMDC

Virtual Atomic and Molecular Data Centre

Fig. 4. VAMDC logo.

Project leader is Marie-Lise Dubernet from Observatoire de Paris and core consortium is made of 15 institutions with 24 scientific groups from France, Russia, England, Austria, Italia, Germany, Sweden, Serbia, and Venezuela.

Partners in the Consortium of the Project are: 1) The coordinator, Centre National de Recherche Scientifique - CNRS (Université Pierre et Marie Curie, Paris; Observatoire de Paris; Université de Reims; Université Joseph Fourier de Grenoble, Université de Bordeaux 1: Université de Bourgogne, Dijon; Université Toulouse 3); 2) The Chancellor, Masters and Scholars of the University of Cambridge – CMSUC; 3) University College London – UCL; 4) Open University – OU (Milton Keynes, England); 5) Universitaet Wien - UNIVIE; 6) Uppsala Universitet – UU; 7) Universitaet zu Koeln – KOLN; 8) Istituto Nazionale di Astrofisica – INAF (Catania, Cagliari); 9) Queen's University Belfast – QUB; 10) Astronomska Opservatorija - AOB (Belgrade, Serbia); 11) Institute of Spectroscopy RAS – ISRAN (Troitsk, Russia); 12) Russian Federal Nuclear Center - All-Russian Institute of Technical Physics - RFNC-VNIITF (Snezhinsk, Chelyabinsk Region, Russia); 13) Institute of Atmospheric Optics - IAO (Tomsk, Russia); 14) Corporacion Parque tecnologico de Merida – IVIC (Merida, Venezuela); 15) Institute for Astronomy RAS - INASAN (Moscow, Russia).

External VAMDC partner is also NIST – National Institute for Standards and Technology in Washington.

The main users of VAMDC facilities will be Astronomy, Plasma science, Atmospheric Science Radiation science and Fusion community as well as Industries using technological plasmas and Lightning industry

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NEW SOLUTION OF EARTH ORIENTATION PARAMETERS 1900-1992 FROM OPTICAL ASTROMETRY, AND ITS LINKING TO ICRF AND ITRF

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Abstract. In preceding years we collected and re-analyzed the optical astrometry data from 33 observatories, using a unique celestial reference frame. It was realized first by the Hipparcos Catalogue, and then by a group of our own Earth Orientation Catalogs (EOC), being obtained by combining Hipparcos/Tycho data with older ground-based observations. EOC catalogs, that are tied to Hipparcos Catalogue, are given in the International Celestial Reference Frame (ICRF). On the other hand, the underlying terrestrial reference frame is arbitrarily realized by adopted geographic coordinates (latitudes, longitudes) of participating stations. Small additional coordinate biases and drifts of individual stations are estimated in the solution, we also suppose that each station can exhibit apparent annual and semi-annual changes of geographic coordinates due to anomalous refraction. To remove the singularity of the solution, we apply 18 additional constraints, tying the biases, drifts and seasonal changes of individual stations. As a consequence, the terrestrial reference frame of the optical solution can deviate from the International Terrestrial Reference Frame (ITRF) by a constant, linear drift and seasonal (annual, semi-annual) changes, in all three axes. To estimate these deviations, we compare our most recent EOP series, referred to catalog EOC-4, with the one provided by space techniques in the common interval of observations. The deviations found are then applied to our EOP solution to link it more precisely to ITRF.

1. INTRODUCTION

Optical astrometry was, for most of the 20th century, the only technique measuring the Earth Orientation Parameters (EOP). EOP, that are the coordinates of the pole in terrestrial and celestial reference frames, and universal time UT1, respectively, are necessary to compute transformation between the celestial and terrestrial reference frames. The observations comprised the instantaneous values of latitude, and later on (after 1956) also differences between Universal and Atomic time scales. Method of equal altitudes then provided a combination of both, the differences between observed and computed altitude of the stars. We collected and re-analyzed these data using a unique celestial reference frame, close to the International Celestial Reference Frame (ICRF) with the best possible accuracy. It was first realized by the Hipparcos Catalogue, and then by a group of our own Earth Orientation Catalogs (EOC). The latter were obtained by combining Hipparcos/Tycho data with older ground-based observations, in order to improve the proper motions, and in some cases also to derive non-linear motions of a great proportion of the stars. Here we use our most recent catalog, EOC-4 (Vondrák and Štefka, 2010), for more details see the next section.

On the other hand, the underlying terrestrial reference frame is rather arbitrarily realized by adopted geographic coordinates (latitudes, longitudes) of participating stations. In addition, we tied the system to the plate motion model NUVEL-1A (Argus and Gordon, 1991) by correcting the observations for the linear motions of the stations computed for that model. Small coordinate corrections and drifts of individual stations with respect to individual plates are estimated in the solution. We also suppose that each station can exhibit apparent seasonal changes of geographic coordinates due to anomalous refraction. We apply 18 constraints, tying these parameters, to remove singularity of the solution. In all our preceding solutions we tacitly assumed that the selected geographic coordinates were referred to the International Terrestrial Reference Frame (ITRF), and that the average drifts and seasonal deviations of all stations have zero effect on the orientation of our terrestrial frame. If this is not the case, the terrestrial reference frame of the optical solution deviates from ITRF by a constant, linear drift and seasonal (annual, semi-annual) changes, in all three axes. Below we propose how to find corrections to refer our solution to ITRF more accurately.

2. CATALOG EOC-4

This catalog (Vondrák and Štefka, 2010) is the realization of the celestial frame in which we describe EOP based on optical astrometry. We used about 4.5 million observations of latitude / universal time / altitude variations at 33 observatories all over the world, and combined them with the catalogues ARIHIP (Wielen et al., 2001), TYCHO-2 (Høg et al., 2000) etc... in order to obtain this catalog. These observations are identical with those used to construct the previous version, EOC-3 (Vondrák and Štefka, 2007), but the procedure to obtain it was slightly different. Spectral analysis of ground-based data and comparison with the USNO Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf and Mason, 2006)was used to discover which of the observed objects display periodic motions. The corresponding amplitudes and phases were then estimated in one-step least-squares solution, together with positions and proper motions, which assured the full compatibility of the positions with the Hipparcos/Tycho Catalogues (ESA, 1997) at epochs close to its mean epoch, 1991.25, thus also to ICRF. Unlike in EOC-3, where annual averages were used, we used the individual nightly observations in the solution. The catalog contains 4418 different objects (i.e., stars, components of double stars, photocenters), out of which 599 have significant orbital motions. The procedure that we used also assures that the catalog is referred to ICRF (via the Hipparcos/Tycho Catalogues) with the highest possible accuracy.

3. SOLUTION OF EOP

During the past ten years or so, we made several solutions of EOP, historically the first one being OA97 (which stands for Optical Astrometry and the year of production). This solution, published in Vondrák et al. (1998), was based on the Hipparcos Catalogue, and all procedures and corrections used to derive it are described there in detail. Since that time, the procedures themselves did not change substantially, the subsequent solutions differed mostly in different star catalogs and number of observations used; beginning with OA03 we started to use the new IAU precession/nutation models (McCarthy and Petit, 2004). Our last solution that we call OA09, with catalog EOC-4, is described in Vondrák et al. (2010). All of these solutions are referred to ICRF, but the terrestrial frame is defined by the adopted mean values of geographic coordinates (longitudes, latitudes) of participating observatories. They were selected so that they are given as close as possible in ITRF, but there is still a possibility that their initial estimation was not accurate enough. The coordinates were corrected for the linear motions due to plate motions, using the model NUVEL-1A (Argus and Gordon, 1991). To account for small incompatibilities of the adopted coordinates, for the motion of the station with respect to the plate tectonic model, and also for seasonal refraction anomalies, we included biases, trends and annual/semi-annual deviations in longitude/latitude of each observation site in the list of parameters to be estimated from the solution.

As already mentioned, the data that we use to derive EOP are the following, based on observation of individual stars:

- the difference between instantaneous latitude from its mean value, $\Delta\varphi$;
- the difference between Universal Time 0 and Coordinated Universal Time, UT0–UTC;
- the difference between the computed and observed altitude, Δh. This value is a linear combination of $\Delta\varphi$ and UT0– UTC.

They come from 47 different instruments, working at 33 observatories. They are as follows

- 10 photographic zenith tubes (PZT), providing both $\Delta\varphi$ and UT0–UTC:
  - 3 at Washington; 2 at Richmond and Mizusawa; 1 at Mount Stromlo, Punta Indio and Ondřejov;
- 7 photoelectric transit instruments (PTI), providing only UT0–UTC:
  - 3 at Pulkovo; 1 at Irkutsk, Kharkov, Nikolaev and Wuhang;
- 16 visual zenith-telescopes and similar instruments, providing only $\Delta\varphi$:
  - 7 zenith-telescopes (ZT) at ILS stations (Carloforte, Cincinnati, Gaithersburg, Kitab, Mizusawa, Tschardjui, Ukiah); 2 ZT at Poltava; 1 ZT at Belgrade, Blagovestschensk, Irkutsk, Jósefoslaw and Pulkovo; floating zenith-telescope (FZT) at Mizusawa, visual zenith-tube(VZT) at Tuorla-Turku;
- 14 instruments for equal altitude observations, measuring Δh:
  - 1 Danjon astrolabe (AST) at Paris, Santiago de Chile, Shanghai, Simeiz and Wuhang; 2 photoelectric astrolabes (PAST) at Shaanxi; 1 PAST at Beijing, Grasse, Shanghai and Yunnan; 1 circumzenithal (CZ) at Bratislava, Prague and Pecný.

From these observations, we solve the following parameters:

- at 5-day intervals:
  - coordinates of the instantaneous pole of rotation in terrestrial frame, x, y;
  - the difference between Universal Time 1 and Coordinated Universal Time, UT1–UTC.
- for each instrument:
  - bias, trend, semi-annual and annual deviations in latitude/longitude, dev_φ, dev_λ;
  - rheological parameter, governing the tidal variations of local verticals, $\Lambda = 1 + k - l$.
- for the whole interval:
  - celestial pole offsets dX, dY with respect to the presently adopted IAU precession/nutation model (McCarthy and Petit, 2004), as a quadratic function of time.

The deviations in latitude/longitude mentioned above have the form

$$dev_{\varphi,\lambda} = A^{\varphi,\lambda} + A_1^{\varphi,\lambda} T + B^{\varphi,\lambda} \sin 2\pi t + C^{\varphi,\lambda} \cos 2\pi t + D^{\varphi,\lambda} \sin 4\pi t + E^{\varphi,\lambda} \cos 4\pi t \;, \quad (1)$$

where T is measured in Julian centuries from MJD=32000 (for latitude) and 43000 (for longitude), t is given in years from the beginning of the preceding Besselian year.

The observation equations for the three types of observations, slightly simplified, then read

$$\begin{aligned}
\Delta\varphi &= x\cos\lambda - y\sin\lambda - dX\cos\alpha - dY\sin\alpha + dev_\varphi + \Lambda D_\varphi, \\
15\cos\varphi(\text{UT0-UTC}) &= 15\cos\varphi(\text{UT1-UTC}) + \sin\varphi(x\sin\lambda + y\cos\lambda) + \\
&+ \cos\varphi\tan\delta(dY\cos\alpha - dX\sin\alpha) + dev_\lambda + 15\Lambda D_\lambda\cos\varphi, \qquad (2) \\
\Delta h &= 15\cos\varphi\sin a(\text{UT1-UTC}) + x(\cos\lambda\cos a + \sin\varphi\sin\lambda\sin a) - \\
- y(\sin\lambda\cos a &- \sin\varphi\cos\lambda\sin a) + dY(\sin q\sin\delta\cos\alpha - \cos q\sin\alpha) - \\
&- dX(\sin q\sin\delta\sin\alpha + \cos q\cos\alpha) + dev_\varphi\cos a + dev_\lambda\sin a + \\
&+ \Lambda(D_\varphi\cos a + 15D_\lambda\cos\varphi\sin a),
\end{aligned}$$

where φ, λ are the observatory's geographic coordinates, α, δ, a and q are right ascension, declination, azimuth, and parallactic angle of the observed star, respectively, and D_φ, D_λ are tidal variations of the local vertical computed for rigid Earth. In case two or more instruments of similar type worked at the same observatory, their results were homogenized (i.e., brought to the same point of the observatory), merged into a single series and treated as a single instrument.

The detailed inspection of the structure of observation equations (2) reveals that the system of normal equations based on them is singular, with deficit equal to 18. Therefore, we apply 18 independent constraints, tying the 12 parameters of Eqs. (1):

$$
\begin{aligned}
\sum pA^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix} &= \sum qA_1^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix}=\sum pB^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix}=0\\
\sum pC^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix} &= \sum pD^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix}=\sum pE^{\varphi}\begin{pmatrix}\sin\lambda\\ \cos\lambda\end{pmatrix}=0 \qquad (3)\\
\sum pA^{\lambda} &= \sum qA_1^{\lambda}=\sum pB^{\lambda}=\sum pC^{\lambda}=\sum pD^{\lambda}=\sum pE^{\lambda}=0.
\end{aligned}
$$

So far, we applied the indicated summations only to the stations that finished their observations after 1962, in order to tie the terrestrial system to the more recent observations. The weights p, q were proportional to the length of the interval covered by the observations and to its third power, respectively. So, e.g., the trend of the polar motion of the solution is given as a weighted mean of parameters A_1^{φ} of all stations inserted in the summation of Eqs. (3), projected into x, y axes.

4. LINKING THE SOLUTION TO ITRF

Our first idea was to simply compare our optical astrometry solution (x, y, UT1–UTC) with the one based on space geodetic techniques (provided by the International Earth Rotation and Reference Systems Service – IERS), and derive the deviations (bias, drift, and seasonal deviations) from the differences found by estimating all parameters of formula (1) in a least-squares fit. We however found soon that this was not the ideal procedure in case of the drift. The common interval of optical astrometry and space geodesy is relatively short, the differences have large dispersion, and they exhibit long-periodic changes. As a result, the drifts found are determined with large inaccuracies and the values found heavily depend of the time interval chosen for the comparison. Therefore, we chose a different approach, only for the case of the drift.

Our preceding solution OA09 (Vondrák et al., 2010) provided coefficients $A_1^{\varphi,\lambda}$, giving the drifts of individual stations with respect to the plates moving with the velocities of NUVEL-1A model. They are depicted, together with their error bars, in Figs. 1, 2 from which we see that they are mostly concentrated around zero, but some of them differ from the others significantly. This is namely true for Ondřejov (OJP), Bratislava (BRC), Prague (PRD) and Shaanxi (SXB). We decided to link the drift to the stable stations, i.e., all but the outlying ones mentioned above, by means of modifying the constraints (3). We apply them only to the stable stations, with weights p, q computed from the formal standard errors of the corresponding parameters of the solution OA09.

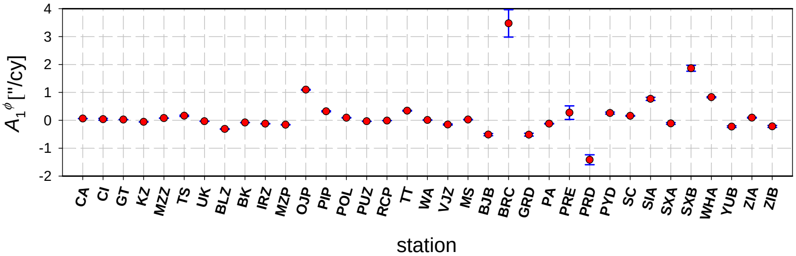

Figure 1. Observed drifts of individual stations in latitude, wrt NUVEL-1A.

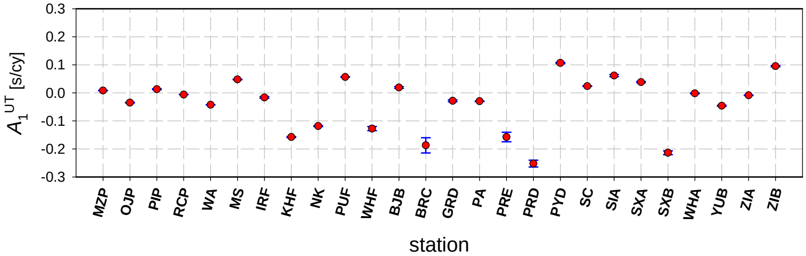

Figure 2. Observed drifts of individual stations in longitude, wrt NUVEL-1A.

Table 1 gives the list of the stable instruments, fixing the drift of the solution to NUVEL-1A plate model, and thus also to ITRF. From the dispersion of the drifts and their uncertainties we estimate that our solution is fixed to ITRF with the uncertainty of about $0.0095''/cy$ in x, $0.0075''/cy$ in y, and 0.0090s/cy in UT.

So we computed the solution again, with the newly defined constraints, and made comparison of the values x, y, UT1–UTC with the IERS solution C04, in the interval 1962.0 – 1992.0. The differences (in the sense C04 minus optical astrometry) are shown in Figs. 3 – 5 as black points for each five days.

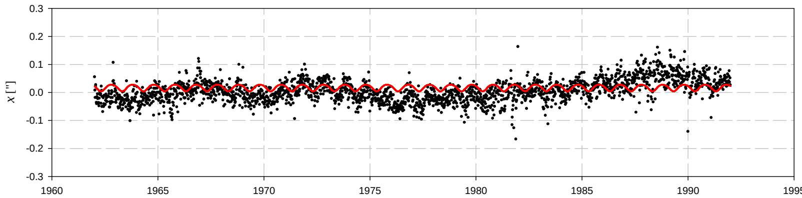

Figure 3. Differences in x-coordinate of the pole between IERS C04 and optical astrometry.

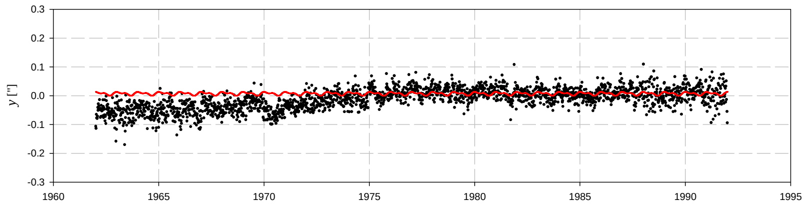

Figure 4. Differences in y-coordinate of the pole between IERS C04 and optical astrometry.

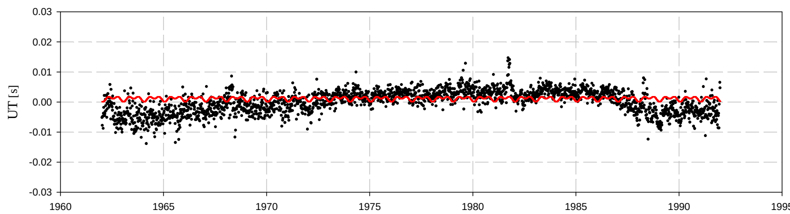

Figure 5. Differences in UT1 between IERS C04 and optical astrometry.

Table 1: Drifts of the stable instruments wrt NUVEL-1A and their uncertainties σ in latitude φ [$''$/cy] and longitude λ [s/cy]

Observatory	instrument	drift in φ	σ	drift in λ	σ
Beijing	BJB (PAST)	–0.5182	0.0374	0.02292	0.00304
Belgrade	BLZ (ZT)	–0.3019	0.0117	–	–
Blagovestchensk	BK (ZT)	–0.0871	0.0071	–	–
Carloforte	CA (ZT)	0.0748	0.0019	–	–
Cincinnati	CI (ZT)	0.0426	0.0346	–	–
Gaithersburg	GT (ZT)	0.0306	0.0028	–	–
Grasse	GRD (PAST)	–0.5050	0.0514	–0.02520	0.00312
Irkutsk	IRZ (ZT), IRF (PTI)	–0.1265	0.0091	–0.01221	0.00278
Jósefoslaw	VJZ (ZT)	0.1424	0.0205	–	–
Kharkov	KHF (PTI)	–	–	–0.15400	0.00186
Kitab	KZ (ZT)	–0.0531	0.0059	–	–
Mizusawa	MZZ (ZT+FZT)	0.0711	0.0019	–	–
	MZP (2x PZT)	–0.1670	0.0094	0.01198	0.00076
Mount Stromlo	MS (PZT)	0.0176	0.0097	0.05066	0.00098
Nikolaev	NK (PTI)	–	–	–0.11505	0.00183
Paris	PA (AST)	–0.1106	0.0113	–0.02657	0.00097
Pecný	PYD (CZ)	0.2717	0.0352	0.11025	0.00232
Poltava	POL (2x ZT)	0.1031	0.0092	–	–
Prague	PRE (CZ)	0.2861	0.2434	–0.15480	0.01697
Pulkovo	PUZ (ZT), PUF (3x PTI)	–0.0218	0.0014	0.06068	0.00183
Punta Indio	PIP (PZT)	0.3305	0.0198	0.01686	0.00187
Richmond	RCP (2x PZT)	-0.0064	0.0039	-0.00326	0.00034
Santiago de Chile	SC (AST)	0.1670	0.0134	0.02771	0.00097
Shaanxi	SXA (PAST)	–0.1180	0.0320	0.04211	0.00231
Shanghai	ZIA (AST)	0.0905	0.0141	–0.00511	0.00091
	ZIB (PAST)	–0.2260	0.0337	0.09874	0.00226
Simeiz	SIA (AST)	0.7781	0.0567	0.06525	0.00376
Tschardjui	TS (ZT)	0.1680	0.0248	–	–
Tuorla-Turku	TT (VZT)	0.3567	0.0173	–	–
Ukiah	UK (ZT)	–0.0364	0.0039	–	–
Washington	WA (3x PZT)	0.0149	0.0017	–0.03980	0.00050
Wuhang	WHA (AST)	0.8257	0.0182	0.00192	0.00107
	WHF (PTI)	–	–	–0.12415	0.00739
Yunnan	YUB (PAST)	–0.2301	0.0314	–0.04235	0.00215

The solution C04 is based on a mixture of observational techniques: optical astrometry at the beginning of the interval that is, step by step, replaced by modern space geodetic techniques (Very Long-Baseline Interferometry – VLBI, Satellite Laser Ranging – SLR, and Global Positioning System – GPS), so that the new techniques provided hundred percent of information at the end. Roughly saying, space techniques started to dominate after 1978. We suppose that the modern data are linked to ITRF, so we use only the data after 1978.0 to estimate systematic differences (bias, semi-annual and annual term) between optical astrometry and space techniques. Least-squares estimation yields the following results (in arcseconds for x, y, in seconds for UT1):

$$\begin{aligned}
\Delta x &= 0.0176 - 0.0111 \sin 2\pi t + 0.0040 \cos 2\pi t + 0.0012 \sin 4\pi t + \\
&\quad +0.0010 \cos 4\pi t \pm 0.0013 \ \pm 0.0019... \\
\Delta y &= 0.0076 + 0.0031 \sin 2\pi t + 0.0036 \cos 2\pi t - 0.0022 \sin 4\pi t + \\
&\quad +0.0024 \cos 4\pi t \pm 0.0008 \pm 0.0011... \\
\Delta \mathrm{UT} &= 0.00116 - 0.00016 \sin 2\pi t - 0.00050 \cos 2\pi t - 0.00029 \sin 4\pi t - \\
&\quad -0.00047 \cos 4\pi t \pm 0.00012 \pm 0.00017... \ .
\end{aligned} \tag{4}$$

These values are plotted, as full lines, in Figs. 3 – 5. In the next and last step, we subtracted them from the solution, the result being our most recent solution denoted as OA10. It is graphically presented in Fig. 6 (polar motion) and 7 (length-of-day, computed from UT1–UTC as its negatively taken time derivative). In both figures, the formal uncertainties are also given (σ in lower plot, two-times enlarged scale on the right).

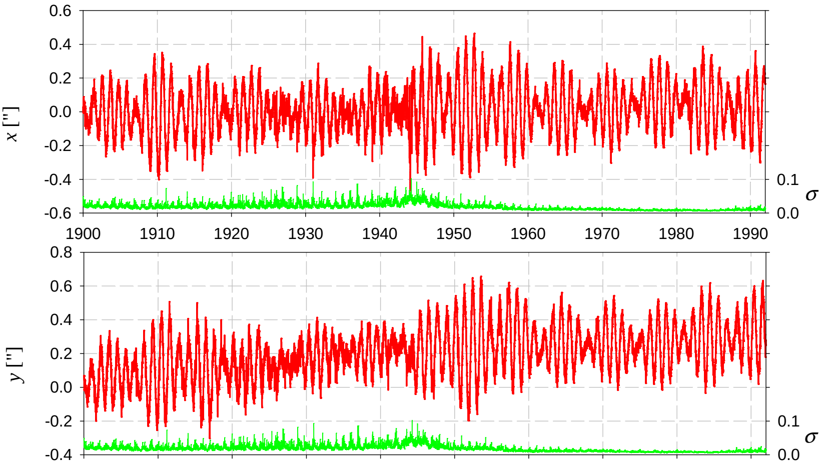

Figure 6. Polar motion.

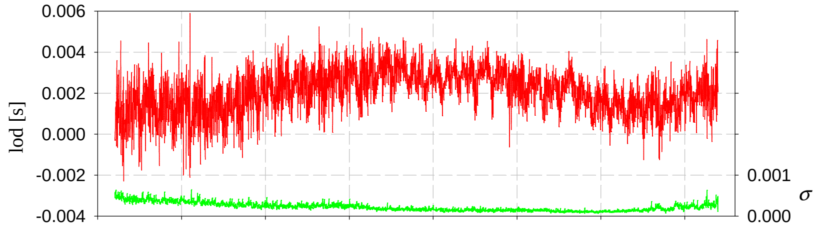

Figure 7. Length-of-day changes.

The celestial pole offsets are derived as quadratic function of time (in milliarcseconds); the third row gives the uncertainties of the coefficients:

$$\begin{aligned} dX &= -7.4 + 29.0T + 29.0T^2 \\ dY &= -6.1 + 8.9T - 1.2T^2 \\ \sigma_{X,Y} &= \pm 0.4 \ \pm 1.1 \ \pm 3.4 \ , \end{aligned}$$

where T runs in Julian centuries from 1956.0.

The solution contains also the small additions A^φ, A^λ to the originally adopted geographic coordinates of individual instruments, $\varphi_\circ, \lambda_\circ$. If combined with the biases $\delta x, \delta y, \delta\mathrm{UT}$ (constant parts of Eqs. (4)), we arrive at the definitive coordinates, defining the terrestrial frame to which the EOP solution is referred:

$$\begin{aligned} \varphi &= \varphi_\circ + A^\varphi + \delta x \cos\lambda_\circ - \delta y \sin\lambda_\circ \\ \lambda &= \lambda_\circ + 15(A^\lambda + \delta\mathrm{UT}) + (\delta x \sin\lambda_\circ + \delta y \cos\lambda_\circ)\tan\varphi_\circ . \end{aligned} \tag{5}$$

They are displayed in Table 2, where only values rounded to whole arcseconds are given for the instruments that do not measure the respective coordinate.

As a by-product of the EOP solution, we also calculated the rheological parameter $\Lambda = 1+k-l$, which is given as a combination of Love and Shida numbers. It expresses the reaction of non-rigid Earth to tidal forces exerted by the Moon and the Sun that cause small variations of the local verticals. Our solution provides the values of Λ for each instrument. In Fig. 8 we show the values for each observatory, together with their error bars. In case more instruments worked at the same observatory, the weighted average is displayed. The results are arranged by increasing geographic longitudes of the observatories, so that we can immediately see if there are some systematic differences among continents. Theoretical value of Λ is around 1.2, so the observed values seem to confirm it, although their dispersion is evidently larger than their formal errors. The values are practically the same for all continents.

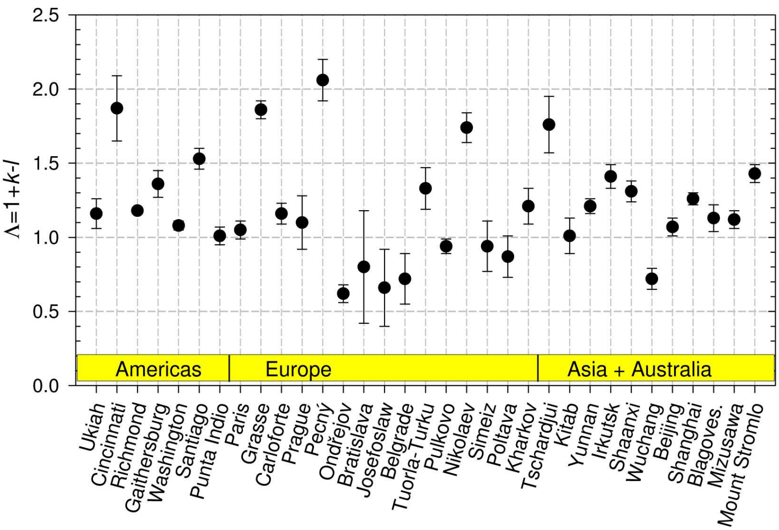

Figure 8. Rheological parameter $\Lambda = 1 + k - l$.

Table 2. The definitive geographic coordinates of the instruments, defining the terrestrial frame

	Code	latitude °	′	″	longitude E °	′	″
Photographic zenith telescopes	MZP	39	8	02.797	141	7	51.978
	OJP	49	54	55.122	14	47	09.177
	PIP	-35	20	40.622	-57	17	08.408
	RCP	25	36	47.046	-80	22	55.960
	WA	38	55	17.220	-77	3	55.985
	MS	-35	19	17.449	149	0	19.472
Photoelectric transit instruments	IRF	52	16	44	104	20	41.949
	KHF	50	0	00	36	13	58.093
	NK	46	58	18	31	58	28.151
	PUF	59	46	18	30	19	38.042
	WHF	30	32	29	114	20	41.668
Visual zenith telescopes	CA	39	8	09.160	8	18	44
	CI	39	8	19.430	-84	25	00
	GT	39	8	13.287	-77	11	57
	KZ	39	8	02.094	66	52	51
	MZZ	39	8	03.693	141	7	51
	TS	39	8	11.293	63	29	00
	UK	39	8	12.136	-123	12	35
	BLZ	44	48	10.463	20	30	50
	BK	50	19	09.610	127	30	00
	IRZ	52	16	44.369	104	20	43
	POL	49	36	13.086	34	32	53
	TT	60	24	57.509	22	27	00
	VJZ	52	5	56.211	21	0	00
	PUZ	59	46	05.651	30	19	40
Astrolabes and circumzenithals	BJB	40	6	03.970	116	19	41.015
	BRC	48	9	17.772	17	7	11.865
	GRD	43	44	55.389	6	55	37.167
	PA	48	50	09.275	2	20	15.461
	PRE	50	4	40.007	14	42	00.875
	PRD	50	6	20.402	14	23	20.816
	PYD	49	54	55.618	14	47	20.139
	SC	-33	23	56.869	-70	32	42.584
	SIA	44	24	12.388	33	59	48.789
	SXA	34	56	43.528	109	33	04.808
	SXB	34	20	35.782	109	8	05.362
	WHA	30	32	29.143	114	20	42.071
	YUB	25	1	45.334	102	47	40.441
	ZIA	31	11	25.136	121	25	37.604
	ZIB	31	11	26.174	121	25	39.246

5. CONCLUSIONS

The new solution OA10 is based on 4 505 442 optical astrometry observations of individual stars, covering the interval 1899.7–1992.0. The solution is linked to the ICRF via the star catalog EOC-4, and to the ITRF via the solution based on modern space techniques (SLR, VLBI, GPS) in the interval 1978.0–1992.0. We expect that the link of the new solution to ICRF is given with the same uncertainty as the Hipparcos Catalogue, i.e. 0.6 mas in bias and 0.25 mas/a in rotation around all three axes (Kovalevsky et al., 1997). The link to the ITRF, established in the present study, is estimated to be given with uncertainty of about 1–2 mas in bias, 0.09 mas/a in rotation around x, y axes and 0.9 mas/a around z-axis. Much worse link in rotation around z- axis is caused by the shortness of observations of Universal time (about one half of that of polar motion), and also by larger dispersion of the drifts (compare Fig. 1 with 2).

The total number of parameters, estimated from the least-squares solution, are 16 463 (5-day values of x, y, UT1-UTC, systematic deviations in latitude and/or longitude and rheological parameters for each instrument, 6 parameters for celestial pole offsets and 18 Lagrange coefficients for the constraints). The solution yields slightly better results than the ones based on previous versions of EOC catalog: the average standard error of one star observation is $\sigma_\circ = 0.184''$ (former value with EOC-3 was $0.190''$). The solution OA10 will be used to further analyze the rotational behavior of the Earth in the 20th century.

Acknowledgments

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NATIONAL SERBIAN DIGITIZATION PROJECT: ITS ACHIEVEMENTS AND ACTIVITIES

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Abstract. The aim of this paper is to present the efforts in the area of digitization and digital preservation of scientific and cultural heritage of a group of Serbian scientists from the Faculty of Mathematics of the University of Belgrade and the Mathematical Institute of the Serbian Academy of Science and Art. Virtual library, the repository of digitized books and other works of Serbian authors and E-Library of Serbian mathematical journals are presented.

1. INTRODUCTION

For almost fifteen years there is a group of mathematicians in Belgrade which is active in the area of digitization. The members of the group are mainly from the Faculty of Mathematics of the Belgrade University and the Mathematical Institute of the Serbian Academy of Science and Art. The starting point of this group is that digitized scientific works are one of the most helpful resource and tool for scientific works and fast exchange of scientific information. Also, we understand that every scientific work becomes after some time the part of history and the part of cultural heritage as well. So, our activities are oriented in building of electronic repositories of digitized books, journals and other scientific works.

This group is also active in other areas related to digitization. They built several databases containing digitized materials. Some of these Internet oriented databases are the largest ones in Serbia and probably in the whole Balkan area. We founded an informal organization, the National Center for Digitization (NCD) which gathered several Serbian leading institutions in science and culture (Faculty of Mathematics of the University of Belgrade, Mathematical Institute of the Serbian Academy of Science, National Library, National Museum and Serbian Archive). In spite of the fact that NCD is an informal organization, NCD is the main driver of many activities in the area of digitization in Serbia. It started in 2003 the journal *NCD Review.* Until now 16 volumes of the journal were published. Under the auspices of NCD nine national and three international conferences were organized since 2000. It is one of the founders of SEEDI, the South East European Digitization Initiative, and the seat of the messenger of SEEDI, *SEEDI communications*, is in Belgrade. In fact, *SEEDI Communications* is the second name of *NCD Review*. Finally, more than fifty papers were written by this group on the technical issues appearing in digitization and on digitized works.

The activities of this group have been supported since 1995 by the Serbian Ministry of Science through the technological projects. Up to now there were four such projects, the last one, *Applications of information technologies in digitization of the scientific and cultural heritage* is still running (up to end of 2010). In the next sections we shall describe two subprojects related to digitization of the scientific heritage.

2. VIRTUAL LIBRARY - DATA BASE OF TEXTUAL DATA, http://elibrary.matf.bg.ac.rs

Aritmetika, 1767
Vasilije Damjanović

There are a large number of rare books in Serbian public and private libraries. For the purpose of our project, we made an electronic catalog according to librarian standards of almost 500 books (published until the beginning of the 20th century) in possession of the Faculty of Mathematics in Belgrade. Just a few of them can be found in the joint catalogue of the network of the largest Serbian libraries (National Library, all university libraries, etc.). This was one of the reasons why we started the project of retro-digitization of mathematics-related works.

Around 1995, we digitized the collected works of the prominent Serbian mathematician Bogdan Gavrilović (1864–1947). Gavrilović obtained doctor’s degree in mathematics in 1887 at the Philosophical Faculty of the University in Budapest. He was appointed professor at the University of Belgrade, two times elected president of the Serbian Academy of Sciences (1931–1937), a member of Circolo matematico di Palermo, and doctor honoris causa of the University of Athens. He published two voluminous university textbooks which had the character of monographs: *Analytical Geometry* (1896) and *Theory of Determinants* (1899). Those books, together with his theses (in Hungarian), other papers and archive were digitized (1996–2001), put first in TEX frame, then in PDF, and published as a compact disk. Even if he introduced several mathematical disciplines in the studying at the university level, particularly algebra and geometry, he was almost forgotten by the modern Serbian mathematicians. This is the reason why we decided to digitize his works. This collection was the first retro-digitized corpus of the books in Serbia.

Besides the collected works of Bogdan Gavrilović, there are also collections devoted to other prominent Serbian scientist. Let us mention in this context the astronomers Đorđe Stanojević, Vojislav Mišković and Milutin Milanković.

The further steps in our work were related to the development of a digital library as a comprehensive and semantically interconnected collection of retro-digitized materials satisfying some of the following criteria:

- Books and manuscripts selected for digitization should be related with mathematical sciences: mathematics, mechanics, astronomy, physics, mathematical geography etc.

- Books considered for digitization had to be published before certain date in the past. We have chosen for this date the beginning of the World War II. (1941).

- Preference is given to Serbian authors, or to written works related to the area of Balkan.

So far, about 800 books, theses and manuscripts have been digitized, including first two books on mathematics written in Serbian language:

- Vasilije Damjanović, *Aritmetika* (*Arithmetics*), Venice, 1767, and
- Jovan Došenović, *Čislenica* (*Arithmetics*), Budim, 1809.

These two textbooks are very elementary, and their authors did not pretend to be original. They are, however, important for the cultural history of the Serbian people. For example *Čislenica* was the only printed textbook used in the Big School in Belgrade, in the first state created by the Serbian Revolution at the beginning of the 19th century. Thus, it could be considered the first Serbian university textbook, because the Big School is the forerunner of the University of Belgrade. Other digitized materials are works of Ruđer Bošković (1711–1787), two books of the famous Serbian scientist (mechanic, mathematician and astronomer), Milutin Milanković, including his celebrated work *Kanon Der Erdbestrahlung* (1935, 1941), all doctoral dissertations of old Serbian mathematicians (8), including the oldest one: Dimitrije Danić, *Conforme Abbildung des Elliptischen Paraboloids auf die Ebene*, Inauguration dissertation der Philosoph. Fakultaet zu Jena, printed in Belgrade, 1885.

Some of these theses were translated and whenever it was possible, the related documentation (biographies, archive materials, etc.) was also included. The

Internet presentation of this material can be found in the Virtual library. At the same address, part of the presentation and database contain more or less recent (published and unpublished) doctoral and master theses earned at the Faculty of Mathematics in Belgrade. The council of the Faculty decided in 2007 that all submitted theses must be given also in the digital form, so we expect that this part of the database will grow significantly in the next period. Now, there are in the Virtual library 360 doctoral dissertations of Serbian mathematicians of about 500.

An important collection of the Virtual library contains more than fifty Serbian books on astronomy. The oldest books from these collection were written in the XVIII century (books written by Zacharie Orfelin Stefanović (1726-1785), and Ruđer Bošković). The authors of other books are Atanasije Stojković (1773 - 1832), Đorđe Stanojević (1858 -1921), Milan Andonović (1849 -1926), Kosta Stojanović (1867 - 1921), Vojislav Mišković (1892–1976), Pavle Vujević (1881–1966), Tatomir Anđelić (1903-1993) and Jovan Simovljević (1929–2007). More details on this collection the reader can find in Pejović (2011).

The access to the Virtual library is free and open via Internet to the general public. There are about fifty visits to the Virtual Libray daily from all parts of the World.

3. E-LIBRARY OF SERBIAN MATHEMATICAL JOURNALS, http://elib.mi.sanu.ac.rs

Digitization of mathematical journals printed in Serbia started in 1995 with the oldest (founded in 1932) and most important one - *Publications de l'Institut Mathématique*. Until the Second World War it was published by the Belgrade University, and afterwards by the Mathematical Institute. More than 2000 articles appeared in about 100 volumes. The scope of the journal in the beginning was broader, including not only mathematics, but also papers from mechanics and astronomy. Almost every Serbian mathematician published there at least one paper, as well as many world leading mathematicians (Henri Lebesgue, Paul Montel, Waclaw Sierpinski, Paul Erdős, Saharon Shelah, Johan van Benthem, etc.). The first archiving technique was retyping articles using TeX. About 25 volumes (published between 1982 and 1995) were electronically archived in that way. The archive was very compact, having less than 100 MB. It included source (TeX) and output (device independent – DVI, and PDF) files. The archive has been permanently enlarged by adding all new volumes until these days. This archive is included in the Electronic Library of Mathematics (ELibM) offered through EMIS (European Mathematical Information Service, Mijajlović, 2003; Mijajlović et al., 2010).

However, since archiving using TEX system was expensive, it was decided that the remaining old volumes would be scanned. So, in 2007, the rest (since 1932) of *Publications* were completely retro-digitized. In the same period another journal, *Publications of the Faculty of Electrical Engineering, Series Mathematics and Physics* (today called *Applicable Analysis) and Discrete Mathematics*, was also retro-digitized (about 1000 papers). It was founded in 1956. In the beginning, each contribution appeared separately bound and numbered consecutively, several times a year. Since 1959, the issues have been appearing collected in one or more volumes per year. In the first years, the journal had contributions from different fields apart from mathematics: physics, mechanics, and electrical engineering, but in the course of time, the journal focused almost exclusively on mathematics, especially convexity, functional equations and differential equations. It repository currently contains 285 issues with 3762 articles.

As Internet became more and more popular, in the year 2002 we decided to create an Internet database and the corresponding presentation of freely accessible full-text mathematical journals. The following journals have been involved so far:

- *Publications de l'Institut Mathématique*, Mathematical Institute in Belgrade (since 1932),
- *Bulletin, Classe des Sciences Mathématiques et Naturelles, Sciences mathématiques*,
  Serbian Academy of Sciences and Arts (since 2001),
- *Kragujevac Journal of Mathematics*, Faculty of Sciences Kragujevac (since 2000),
- *Matematički Vesnik*, Mathematical Society of Serbia (35 volumes, since 1993),
- *Nastava Matematike*, Mathematical Society of Serbia (since 1992, in Serbian),
- *Review of the National Center for Digitization*, Faculty of Mathematics in Belgrade and
  National center for digitization (since 2002),
- *Teaching of Mathematics*, Mathematical Society of Serbia (since 1998),
- *Publications of Department of Astronomy,* Faculty of Mathematics in Belgrade (the whole
  period of publishing the journal1969-1990),
- *Zbornik radova*, Mathematical Institute in Belgrade (since the first volume, 1952).

The corresponding presentations of journals are dynamically generated from the database and can be searched (both in English and Serbian) by: authors' names, titles, titles of special sections within the journals, key words and words contained in abstracts, classification numbers, and downloaded and printed. The last version of the database and presentation of mathematical journals is given at the address

http://elib.mi.sanu.ac.rs, while the retro-digitized journal can be found on

http://pefmath2.etf.bg.ac.rs.

Since 1999 Mathematical Institute publishes the journal *Visual Mathematics* (Ognjanović, 2003) with the goal to show the beauty of mathematics in a broad artistic-scientific context. It was one of the first journals appearing in digital form only. All 39 volumes of the journal are available at http://www.mi.sanu.ac.rs/vismath.

Other activities

Our activities are not limited only to retro-digitization of printed matter, books and journals. We shall mention shortly other undertakings of our group.

Electronic catalog of cultural monuments in Serbia, http://spomenicikulture.mi.sanu.ac.rs. site includes various data, including GIS data and tracks (electronic paths) for more than 1500 most important monuments in Serbia (monasteries, archeological sites, historical sites). This is the most comprehensive Serbian Internet site of this kind and many there presented cultural monuments includes several hundred descriptions, data and other items. In recent years members of the Faculty of Natural Sciences of the University in Priština, now situated in Kosovska Mitrovica joined our project. They gave valuable contributions concernig digtization of cultural values in Kosovo and Metohia and Toplica region.

Clippings of Nikola Tesla, http://virlib.matf.bg.ac.rs/tesla. Nikola Tesla (1856-1943) is the great electrical engineer and inventor, world famous for his discoveries and innovations in the everyday use of electric power and electromagnetism. In Belgrade there is a museum devoted to Nikola Tesla. In the possession of the museum there are 57 books of clippings from news papers and professional journals related to science and collected by Tesla himself. Several members of the groups developed Internet oriented software and data base for the presentation of these clippings.

4. MEMBERS OF THE PROJECT

The members of the group are the specialists in the various areas of science. Here are the names of the professors of the Belgrade University and the senior researchers from the institutes of the Serbian Academy of Science, the members of the group: Žarko Mijajlović (mathematician, project leader), Zoran Ognjanović (mathematician), Nadežda Pejović (astronomer), Miomir Korać (archeologist), Dragan Blagojević (mathematician), Dragi Radojević (mechanics), Dragan Radovanović (geographist), Vesna Vučković, Nenad Mitić and Saša Malkov (computer scientists). The members of the project are also several graduate students and programmers: Aleksandar Pejović, Nadica Đorđević, Tijana Zečević and Aleksandar Valjarević.

5. CONCLUSION

The presented subprojects are oriented towards *Digital mathematical library*, a World project on which works many World institutions. The final aim of this project is the fulfillment of a mathematical dream of a digital archive containing all peer reviewed mathematical literature ever published, properly linked and validated and verified.

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Pejović, N., et al.: 2011, this Proceedings.

Related Internet sites

Virtual library: http://elibrary.matf.bg.ac.rs
eLibrary of mathematical journals: http://elib.mi.sanu.ac.rs
NCD Review: http://elib.mi.sanu.ac.rs/pages/browse_publication.php?db=ncd
NCD: http://www.ncd.org.rs
SEEDI: http://seedi.ncd.org.rs

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GRID COMPUTING: INFRASTRUCTURE, DEVELOPMENT AND USAGE IN BULGARIA

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Abstract. What's GRID? What is the structure and how to access to GRID resources? Here we try to answer to these questions. We also discuss the development of GRID infrastructure in Bulgaria and the main steps to become a GRID user. A simple example of submitting a job to the GRID is shown.

1.WHAT IS GRID?

1. Maybe the simplest explanation what is grid is done in http://ezinearticles.com/?Introduction-to-Cloud-Computing&id=4845331

- "Grid computing is a form of distributed computing and parallel computing, whereby a 'super and virtual computer' is composed of a cluster of networked, loosely coupled computers acting in concert to perform very large tasks"

That means we use large set of computer resources to process a task. The computer resources can be geographically interspersed, different types hardware and so on, but they work as one virtual computer. More, we can extend resources when we need more computing resources simply by adding new work nodes. That concept permits to solve very resource consuming tasks or large number of simultaneous running applications.

2.GRID STRUCTURE

The organization of the GRID can be divided as a simplification in logical and software structure. The logical structure is shown on Figure 1. The smallest logical unit is called site. One site contains the computers, disk missives, etc., i. e. all hardware.

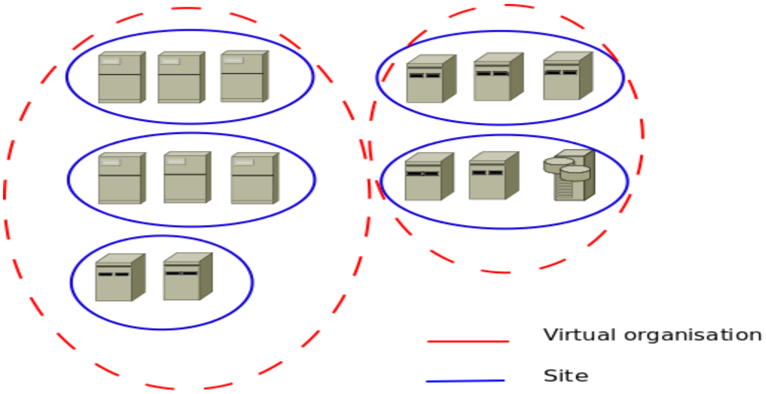

Figure 1: GRID Structure.

Some site form a bigger logical structure called Virtual Organization (VO). It is important to note that a site can be member of many VOs. As it concerns software structure, it can be divided in 4 layers:

- network layer: This is lowest layer which connects grid resources.

- resource layer: Actual grid resources, such as computers, storages and so on.

- middleware layer: This layer provides tools that enable various elements to form the grid.

- application layer: This layer supports various scientific applications. Users see and interact with.

Users and applications do not interact with the last layer and the middleware translates task to grid and give back results.

3. EGEE

The **Enabling Grids for E-sciencE** (EGEE) is one of the biggest grid projects. EGEE project is funded by the European Commission and aims to build on recent advances in grid technology and develop a service grid infrastructure, which is available to scientists 24 hours a day (http://public.eu-egee.org/). The project will concentrates on three core areas:

- The first area is to build a consistent, robust and secure Grid network that will attract additional computing resources.
- The second area is to continuously improve and maintain the middleware in order to deliver a reliable service to users.
- The third area is to attract new users from industry as well as science and ensure they receive the high standard of training and support they need.

EGEE provides a computing support infrastructure for over 14 000 researchers worldwide, from fields as diverse as high-energy physics, earth and life sciences. It brings together 300 sites, 90 organizations, 50 countries, more than 80 000 CPU, 20 PB disk storage and 14 000 users. As a sum we have 300 000 jobs per day with data transfer > 1.5 TB/s.

The EGEE project officially ended on the 31 March 2006. EGEE II started on 1 April 2006 and officially ended on April 30 2010.

4. BULGARIAN GRID

For development of grid infrastructure in Bulgaria a GRID consortium was founded. Members of the consortium are:

Institute for Parallel Processing,
Institute for Nuclear Research and Nuclear Energy,
Institute of Mechanics,
Institute of Electrochemistry and Energy Systems,
Institute of Astronomy,
Institute of Mathematics and Informatics,
Geophysical Institute,
Faculty of Mathematics and Informatics - Plovdiv University,
Faculty of Mathematics and Informatics - Sofia University,
Faculty of Physics - Sofia University,
University of Mining and Geology "St. Ivan Rilski",
Institute of Organic Chemistry with centre of Phytochemistry,
University of National and World Economics.

Soon after the GRID consortium establishment some grid sites were built.

Fig. 2 represents some statistics of these sites. Nowadays we have 5 fully functional grid sites and some more in test phase.

BA-04-PMFSA	Bosnia and Herzegovina	1	Certified	Production	SE: se - error SRM: se - error SRMv2: se - warn	3.9 d 3.9 d 3.9 d
BG01-IPP	Bulgaria	1	Certified	Production	CE: ce002 - ok SE: se001 - ok SRM: se001 - ok SRMv2: se001 - ok	4.6 d 21.6 h 5.2 d 1.6 d
BG03-NGCC	Bulgaria	1	Certified	Production	CE: ce - ok SE: se - ok SRM: se - ok SRMv2: se - ok MPI: ce - ok	13.0 d 13.0 d 13.0 d 1.6 d 31+
BG04-ACAD	Bulgaria	1	Certified	Production	CE: ce02 - ok SE: se03 - ok SRM: se03 - ok MPI: ce02 - ok	10.1 d 17.1 d 17.1 d 31+
BG05-SUGrid	Bulgaria	1	Certified	Production	CE: ce001 - ok SE: se001 - ok SRM: se001 - ok	4.1 d 21.6 h 18.1 h
BG06-GPHI	Bulgaria	2	Certified	Production	CE: ce1 - ok SE: se1 - ok SRM: se1 - ok SRMv2: se1 - ok	20.6 h 20.6 h 20.6 h 20.5 h
GE-01-GRENA	Georgia	2	Certified	Production	CE: ce - ok SE: se - ok MPI: ce - error	11.6 d 21.6 h 31+
GE-02-HEPI	Georgia	2	Uncertified	Candidate		
HG-01-GRNET	Greece	1	Certified	Production	CE: ce01 - ok SE: se01 - ok SRM: se01 - ok MPI: ce01 - ok	6.8 d 15.6 h 2.8 d 31+

Figure 2: Certified Bulgarian GRID sites.

5. HOW TO BECOME A USER?

The procedure to become a user of the grid structure is simple, but very strict. First step is to contact one of our Registration Authorities (RA) (http://ca.acad.bg) to make an appointment. Second - Meet the RA in person. You must bring with you:

- valid Identification Document - Identity Card, Driver's License, or Passport
- the declaration (official note) from your Institute/Employing Organization certifying that you are an employee of that organization.
- the removable media on which you store your certificate request (CR). It will be copied by the RA and the removable media will be returned to you. When you meet the RA, you will have to sign a statement that you have read the CP/CPS, so please make sure you have done so.

Figure 3 shows the Bulgarian Academic Certification Authority.

A good explanation of the role of Certification Authority for grid security is done in Pocotilenko et al. (2008).

BG.ACAD | CA

Bulgarian Academic Certification Authority

Registration Authorities

Location	Operated by	Jurisdiction	Manager	Telephone
Sofia	IPP-BAS	All of Bulgaria	Vladimir G. DIMITROV*	+359 2 9796615
Sofia	IPP-BAS	All of Bulgaria	Mariya K. DURCHOVA	+359 2 9796793
Sofia	IPP-BAS	All of Bulgaria	Rayna S. GEORGIEVA	+359 2 9796608
Sofia	IPP-BAS	All of Bulgaria	Sofiya L. IVANOVSKA	+359 2 9796608
Sofia	IM-BAS	BAS, Campus "4th Kilometre"	Kiril S. SHTEREV	+359 2 9796488
Sofia	GPhI-BAS	BAS, Campus "4th Kilometre"	Georgi K. GADZHEV	+359 2 9793708
Sofia	IA-BAS	BAS, Campus "7th Kilometre"	Momchil Ts. DECHEV	+359 2 9795929
Sofia	INRNE-BAS	BAS, Campus "7th Kilometre"	Elena P. PUNCHEVA	+359 2 9795532
Sofia	UNI-SOFIA|FMI	Sofia University	Radoslava D. GORANOVA	+359 2 8161508
Plovdiv	UNI-PLOVDIV	All of Bulgaria	Atanas T. TERZIYSKI*	+359 32 261449
Rousse	UNI-ROUSSE	Town of Rousse	Plamena S. NENKOVA	+359 2 9796626
Sofia	IOCCP-BAS	IOCCP-BAS	Nikolay G. Vassilev	+359 2 9606172

** Denotes a CA staff member.*

Figure 3: Bulgarian Academic Certification Authority.

6. RUNNING A TASK ON GRID

Every task on GRID is called job. Executing a task on GRID has some stages:

1. Grid job submission, certification and resources allocation
2. Upload of the computing application and the data
3. Queuing in the local queue
4. Initiation of the computing application
5. Processing
6. Monitoring
7. Download of the results

Stage 6 is not obligatory.

To run a job you have to be a certified user and you have to have so called user interface (UI). UI is part of the grid middleware and is your “door” to the grid resources. Here we summarize basic commands on UI to run a job:

First you need to prepare a jdl file, which will run your job. The structure of the jdl file is as follows:

hello.jdl

---l

Executable = "hello.sh";
StdOutput = "hello.out";
StdError = "hello.err";
InputSandbox = {"hello.sh"};
OutputSandbox = {"hello.out","hello.err"};
#Requirements = other.GlueCEUniqueID ==
"ce001.grid.bas.bg:2119/jobmanager-lcgpbs-
seegrid";
#Requirements = Member("GLITE-
3_0_1",other.GlueHostApplicationSoftwareRunTimeEnv
ironment);
RetryCount=0;
Arguments="test";
#Environment={"…","…"};

An example of a JDL file:

Red variables are mandatory. **Executable** is your program. As example hello.sh can be:

hello.sh

```
#!/bin/bash
sleep 100
echo HELLO GRID
```

----

1. StdOutput is where to be written the result of the hello.sh (or your job). Other variables are well explained in https://grid.ct.infn.it/twiki/bin/view/GILDA/SimpleJobSubmission.

To submit this jdl file you use:

glite-wms-job-submit -a hello.jdl,

to check the current status of a job:

glite-wms-job-status --noint -i /home/username/hello.jdl

and to retrieve the output files from job

glite-wms-job-output --dir <directorypath> -i hello.jdl.

To see information about current state of grid resources available for the given VO you should use:

lcg-infosites --vo $LCG_GFAL_VO ce
lcg-infosites --vo $LCG_GFAL_VO se
lcg-infosites --vo $LCG_GFAL_VO lfc,

here $LCG_GFAL_VO should be set to your Virtual Organization (VO)

And instead conclusion some sources of useful information are given:

- https://grid.ct.infn.it/twiki/bin/view/GILDA/UserTutorials
- https://grid.ct.infn.it/twiki/bin/view/GILDA/SimpleJobSubmission
- http://griddeployment.web.cern.ch/griddeployment/documentation/LFC_DPM/lcg_util/html/
- http://ppewww.physics.gla.ac.uk/~fergusjk/howtolowlev.html
- http://training.omii-europe.org/Tutorials/glite3.0/Tutorials.html

Acknowledgements

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TEACHING OF ASTROINFORMATICS AT THE UNIVERSITY OF BELGRADE

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Abstract. The aim of this paper is to present the studies of astroinformatics at the Faculty of Mathematics of the Belgrade University. The studies of astroinformatics were started in 2009 and they are organized according to the Bologna declaration.

1. INTRODUCTION

The Bologna Declaration is the main document which has conditioned the education reorganization throughout Europe. This declaration was signed in 1999 by the education Ministers of the EU member-countries. Till the present moment this document has been signed by a majority of countries including ours as well. The Bologna process is aimed at the formation of a unique European system of university teaching and scientific research till 2010. In this way one tends to form a more efficient system of advanced education in Europe which is in accordance with the world knowledge market.

From the school year 2006/07 at the Faculty of Mathematics the teaching in mathematics, informatics and astronomy has been reformed in accordance with the Bologna process. According to the Law of the Republic of Serbia concerning the post-secondary school education, which follows the Bologna Declaration, there are three levels of university education:

Basic academic studies lasting 3 or 4years. The condition to finish them is to collect 180 or 240 EPTS points. In this way a student acquires the bachelor degree and they may continue toward the master studies.

Diploma academic studies lasting 5 years and to finish them one needs 300 EPTS points. A student after finishing the basic studies may, possibly having also a working position, continue during one or two years in order to gather additional 60 or120 EPTS points (up to 300), through which one acquires the master diploma.

PhD academic studies last 3 years and to finish them one needs 180 EPTS points, provided that the diploma master studies have already been finished. By finishing these studies and passing the PhD examination one acquires the PhD degree..

EPTS (European Point-Transfer System) is a unique system of evaluating a student's effort in knowledge acquiring for each subject included in a curriculum. The number of points per subject is different. It is not directly dependent of the number of lessons (lectures and exercises), but it also involves the estimate of the total time which a student needs to master the subject. The points are not marks. Every student gets an equal number of points for the same subject, independently of the mark obtained at the examination. The points are assigned only after successful examination.

At the Faculty of Mathematics the Basic Academic Studies of mathematics and astronomy last 4 years (240 EPTS), i. e. 3 years in the case of informatics (180 EPTS). After finishing the Basic Academic Studies a student becomes: mathematician, informatician or astronomer. The novelty is that after finishing the studies in addition to the certificate a student also gets an official document named Supplement to Certificate. This document contains a number of details: curriculum, list of subjects, number of EPTS points for each subject, subject contents, as well as the mark obtained at the exam. The Certificate and Supplement are delivered in both Serbian and English and they are in accordance with the documents of European universities.

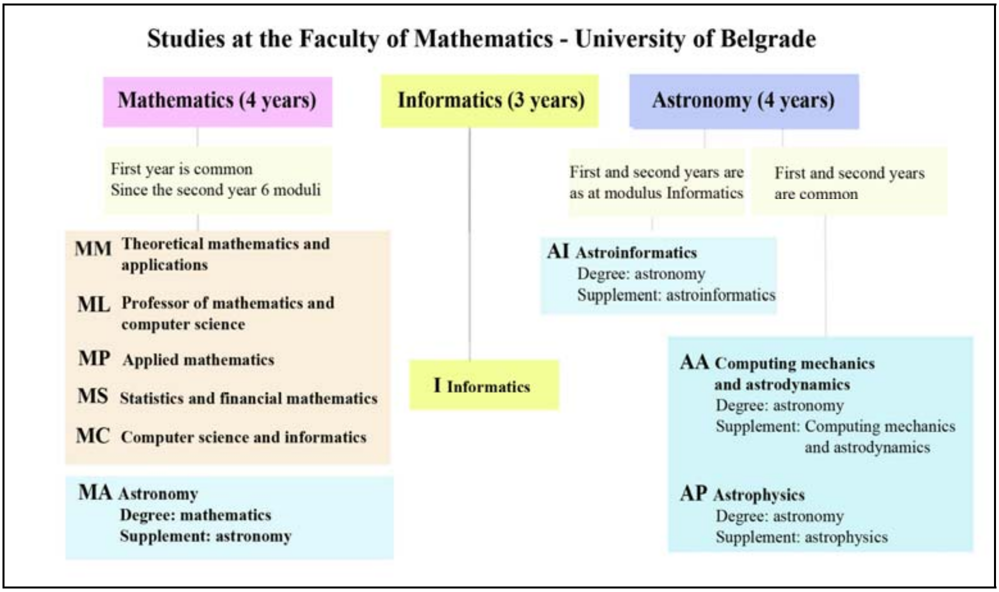
In the year 2009 the Faculty of Mathematics finished its accreditation for three directions of studies (mathematics, informatics and astronomy) which are subject to a further ramification of several moduli. The studies following new curricula also started in the autumn of 2009. The basic academic studies in mathematics after the first year have six moduli, in astronomy three moduli (two at the beginning and one after the second year), whereas in informatics there is only one modulus. The Certificate will contain the name, mathematician, informatician or astronomer, whereas the Supplement will give a detailed modulus description.

More detailed information concerning the studies within the directions of mathematics and informatics and the corresponding moduli can be found on the Internet Site of the Faculty of Mathematics. Here more detailed information will be given for the direction of astronomy only.

2. ASTRONOMY

From the scheme bellow one can see that astronomy is studied in the framework of four moduli. One of them belongs to direction of mathematics, the other three to direction of astronomy:

1. **MA** - direction **Mathematics** – modulus **Astronomy**
2. **AP** - modulus **Astrophysics**
3. **AA** - modulus **Computer Mechanics and Astrodynamics**
4. **AI** – modulus **Astroinformatics**



3. MODULI WITH TRADITION

Modulus MA – Astronomy has been present at the Faculty of Mathematics for decades. It is studied in the framework of the Direction of Mathematics and after the first year a student has the option of choosing the modulus of astronomy. According to the earlier curriculum a student after finishing the studies became a mathematician-astronomer; according to the new one in the Certificate it will be written mathematician and in the Supplement astronomy. As in the case of the earlier curriculum, students taking degree in the framework of this modulus may teach mathematics, informatics and astronomy in primary and secondary schools. This modulus offers the possibility of learning high-class mathematics which has many applications in astronomy. Only with such a high knowledge level in mathematics any person taking degree, in addition to the study of classical problems of astronomy, can be active in the field of the advanced research like studying cosmological models.

Modulus AP - Astrophysics has been also present at the Faculty of Mathematics for decades. According to the earlier curriculum a student after finishing the studies became an astrophysicist; according to the new one in the Certificate it will be written astronomer and in the Supplement astrophysics. Students studying in the framework of this modulus can learn high-class astronomy and physics so that with great success they can later study complex astrophysical processes on distant and not well-known celestial bodies and systems, such as stars, star clusters, nebulae, galaxies, active galaxies, black holes, quasars and blasars. The data about these distant worlds are collected at all wavelengths of the electromagnetic spectrum, from gamma to radio ones. After taking the degree astrophysicists will have the opportunity to get positions in addition to those concerning the astrophysical research, also as physicists at scientific institutes, universities and schools (primary or secondary).

4. NEW MODULI

Modulus AA **– Computer Mechanics and Astrodynamics** contains computer science dominant in the third and fourth years of studying**.** To this modulus and to that of Astrophysics the first two years are in common (see the scheme). After two years students have two options: towards physics by choosing the Astrophysics modulus or towards computer science by choosing the modulus of Computer Mechanics and Astrodynamics. Taking degree in Computer Mechanics and Astrodynamics students will get a certificate with name astronomer, whereas the Appendix will contain Computer Mechanics and Astrodynamics followed with the list of all subjects covering computer science, mechanics and astronomy. The contents of subjects from computer science will show what kind of new information technologies are mastered by students; they are applicable not only in astronomy and mechanics, but in economy, financial institutions and software houses, as well.

Modulus AI – Astroinformatics has two years in common with the direction of informatics. As the studies of informatics last 3 years, and those of astronomy 4 years, it follows that by taking degree at the four-year modulus of astroinformatics one also finishes the complete triennial studies of informatics. In the Certificate it will be written astronomer, in the Supplement astroinformatics. Similarly to the case of the preceding modulus, students will be able to apply the knowledge of informatics and information technologies, necessary in the space research, also in other situations with all rights as any student taking degree in Informatics.

5. PROGRAM OF STUDIES OF ASTROINFORMATICS

Among the products of our time is the informatic revolution. The data transfer becomes more and more. In this new world the role of computer science and informatics has grown enormously. There is practically no activity field deprived of applying computer science and informatics. On the other hand, in the world enormous means are invested into astronomy and space research. For instance, at the moment a few observatories orbit the Earth, such as the Hubble Space Telescope and Chandra, sending continually the data of high importance to the space research. In addition to them there are many cosmic vehicles sent to the most remote parts of the Solar System, then many artificial Earth satellites, as well as a large number of telescopes situated at observatories throughout the surface of the Earth. An enormous body of data about our cosmic neighbours, the Moon, the Sun, the planets, their satellites, asteroids, comets, meteors, trans-neptunian objects in the Kuiper belt, small icy bodies of the Oort cloud, but also about distant worlds, like stars, extrasolar planets, star clusters, nebulae, galaxies, black holes and quasars, are continually collected. The majority of instruments are computerized and the observations are automatic. Without mathematics, computer science and informatics any use of these world databases and data treatment is unthinkable. Astronomers after finishing these new directions can successfully apply their acquired knowledge of mathematics except in astronomy, also in all other activities where programmers and informaticians find their job. It should be mentioned that on lists of unemployed persons there are neither programmers nor informaticians.

Now we shall present in more details the program and the content of the subjects that are taught at the modulus astroinformatics. First, we note that the interest of students in studying astronomy considerably raised since the modulus of astroinformatics was introduced. For example, the number of the enrolled students in astronomy doubled in 2010 in respect to the previous school year. Most of them are in fact the students of astroinformatics.

The courses at the modulus of astroinformatics are divided into three almost equal in size groups: astronomy, computer science and mathematics. Mathematics and informatics are mostly taught in the first two years of studies. In the third year of studies, the number of courses in astronomy and informatics is same. In the fourth year of studies, students are specialized in astronomy. All main branches of mathematics are taught through the specialized courses such as discrete structures (mathematical logic and combinatorics), mathematical analysis (calculus), algebra, geometry, computational mathematics and probability and statistics. Courses in informatics are the modern subjects in computer science and they cover algorithms, data bases, programming languages and Internet oriented courses. Finally, courses in astronomy are the standard basic courses in astronomy and they give the sufficient knowledge to the student to continue further specialization in astronomy and graduate studies. There are several courses in astronomy with heavily use of computers. Such a course is for example *Processing of astronomical observations*. Every student who graduated astroinformatics also has the diploma of informatics (the modulus **I,** *Informatics*) and in fact he can further specialize in three professions: astronomy, programming and teaching astronomy and astroinformatics in the elementary and secondary schools. Even if the studies of astroinformatics just started (in 2009), our experience with students and teaching of astroinformatics is fine.

6. CONCLUSION

Anyone fond of astronomy can study it together with mathematics, physics, computer science or informatics by choosing one of the moduli named Astronomy, Astrophysics, Computer Mechanics and Astrodynamics or Astroinformatics.

A Certificate of the Faculty of Mathematics in Belgrade has been recognised abroad. Persons having it, in addition to positions in primary or secondary schools, universities and scientific institutes, can find positions within a wide range of various activities including financial institutions, economy, software houses. The internet site of the Faculty of Mathematics offers the possibility of more detailed informing not only concerning undergraduate studies, but the diploma and PhD ones as well, for the case of mathematics, informatics and astronomy.

The curricula with subject names and contents for each subject for all three directions of the Basic Academic Studies at the Faculty of Mathematics can be found at http://www.matf.bg.ac.rs.

The list of courses in Astroinformatics

First year – first semester					**First year – second semester**			
	Course	classes	EPTS			Course	classes	EPTS
1	Programming 1	3+3+0	8		1	Programming 2	3+3+0	8
2	Introduction to the organization of computers	3+2+0	6		2	Introduction to the architecture of computers	3+2+0	6
3	Discrete structures 1	3+2+0	6		3	Discrete structures 2	3+2+0	6
4	Linear algebra	3+2+0	6		4	Analysis 1	3+2+0	6
5	General astronomy A	2+2+1	5		5	General astronomy B	2+2+1	5

	Second year – first semester		
	Course	classes	EPTS
1	Algorithms and data structures	3+3+0	7
2	Architecture and operating systems	3+2+0	7
3	Geometry	3+2+0	6
4	Analysis 2	3+2+0	6
5	General astrophysics A	2+2+1	6

	Second year – second semester		
	Course	classes	EPTS
1	Analysis and construction of algorithms	3+3+0	6
2	Introduction WEB and Internet technologies	3+2+0	6
3	Object oriented programming	3+2+0	6
4	Analysis 3	3+2+0	6
5	Algebra	2+2+1	6

	Third year – first semester		
	Course	classes	EPTS
1	Relational data bases	3+3+0	8
2	Compiling of programming languages	3+2+0	6
3	Positional astronomy A	3+2+0	6
4	Processing of astronomical observations A	3+2+0	6
5	Probability and statistics	2+2+1	5

	Third year – second semester		
	Course	classes	EPTS
1	Artificial intelligence	3+3+0	8
2	Celestial mechanics	3+2+0	6
3	Practical astronomy A	3+2+0	6
4	Introduction to numerical mathematics	3+2+0	6
5	Selected topics	2+2+1	5

	Fourth year – first semester		
	Course	classes	EPTS
1	Selected topics	3+3+0	23
2	Selected topics	2+2+0	4

	Fourth year – second semester		
	Course	classes	EPTS
1	Operating systems	3+3+0	6
2	Theoretical astronomy A	3+2+0	5
3	Selected topics	3+2+0	5
4	Selected topics	3+2+0	5
5	Selected topics	2+2+1	5

Further details on the courses (the content, professors, etc) and selected topics (special courses) can be seen at the address http://www.matf.bg.ac.rs.

Note: 2+2+1 in the column **classes** in the table means that there is one lecture lasting two hours (2 X 45 minutes), one exercise lecture (oriented to problem solving) lasing three hours and one hour of practice (usually devoted to the student seminar works).

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GAMMA RAY BURSTS AND ACTUAL DATABASES

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Abstract. Nature of Gamma Ray Bursts (hereafter GRBs), are very demanding for observational and recording purpose. That is why we need refined observational equipment for recording of data, as well as intelligent system for early warning and initialization of interplanetary observational network. Such collected data are placed in to the sophisticated databases to be accessible for detailed analyze among the scientist. In this paper we have examined the actual databases for Gamma Ray Bursts events, their organization and accessibility. Also, we reviewed the actual process of acquiring the data from satellites and observational network.

1. INTRODUCTION

In recent years, multi-wavelength observations of afterglow emission of Gamma-Ray Bursts (GRBs) have provided great advancement in our knowledge of GRB progenitor, afterglow emission mechanism, and their environment. Nonetheless, the physical mechanism that creates the prompt gamma-ray emission with extremely short variability is still not resolved, thus understanding GRB prompt emission spectra remains crucial to revealing their true nature.

Currently, the most favored GRB emission mechanism is the simple emission scenario of optically-thin synchrotron radiation by shock-accelerated electrons ("synchrotron shock model"; Tavani, 1996). While the synchrotron shock model can account for many of the observed spectra, a considerable number of spectra exhibit behavior inconsistent with this theoretical model. Meanwhile, it is also true that many observed spectra could be fitted with various photon models statistically as well as each other, due to the limited spectral resolution of available data and detector sensitivity. Since the photon models usually used in GRB spectral analysis are parameterized differently, the resulting spectral parameters are found to be highly dependent on photon model choices (Preece et al., 2002; Ghirlanda et al., 2002). Additionally, to deduce the emission mechanism from observations, spectra with fine time resolution are necessary because of the short timescales involved in typical emission processes (i.e., the radiative cooling time, dynamical time, or acceleration time). This is also indicated by the extremely short variability observed in GRB lightcurves (e.g., Bhat et al., 1992), although the detectors' finest time resolution is still longer than the shortest physical timescales involved to produce GRBs. The integration times of spectra certainly depend on the capabilities of the detector systems as well as the brightness of events and photon flux evolution. GRB spectral analyses, therefore, have been performed on various timescales, yet a comprehensive study of the relations between time-averaged and time-resolved spectra, and the effects of various integration times on spectral properties has not been done. Thus, in order for the spectral parameters to meaningfully constrain the physical mechanisms, a comprehensive spectral study with finest possible spectral and temporal resolution, using various photon models, should be carried out with a sufficiently large database.

With such a large amount of data it is difficult to work, so they must be organized in to a database, with search functionality. This was the reason for formation of some of the largest databases of recorded GRBs. One of the most promising and used databases is the BATSE 4B catalog, consisting a several thousand of bursts with appropriate light curves and 4-channel spectra. However, in the recent years a new instruments like SWIFT satellite or XMM Newton has proven in the quality.

In this article we will analyze the available databases from two satellites, one obsolete (CGRO observatory) and one still functional (SWIFT satellite) in order to present current state for future investigations.

2. THE DETECTION AND BIRTH OF INTERLANETARY NETWORK

During the years immediately following the discovery of gamma-ray bursts (GRBs), many researchers believed that a few accurate locations would lead quickly to an understanding of the GRB phenomenon. Thus, beginning in the late 1970s GRB detectors were placed on various interplanetary and solar system probes, achieving interplanetary networks (IPNs) that produced arcminute sized error boxes calculated by arrival time analysis. While the original optimistic expectations were not realized, accurate locations continue to be of paramount interest.

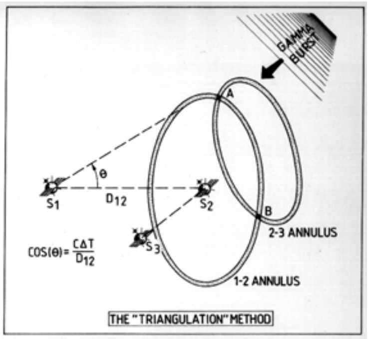

Figure 1. Principles of triangulation.

The group of spacecraft equipped with gamma-ray burst detectors is shown in the Fig. 1. By timing the arrival of a burst at those spacecrafts, its precise location can be found. The farther apart the detectors are, the more precise the location can be determined. The principle is illustrated in the figure above. Each pair of spacecraft, like S1 and S2, gives an annulus of possible arrival directions whose center is defined by the vector joining the two spacecraft, and whose radius theta depends on the difference in the arrival times divided by the distance between the two spacecraft.

The Vela group of satellites was originally designed to detect covert nuclear tests, possibly at the Moon's altitude. Thus, the Velas were placed in high orbits, so that a time delay would occur between spacecraft triggers. In addition, each satellite had multiple gamma-ray detectors across their structures; the detectors facing a blast would register a higher gamma count than the detectors facing away.

A gamma-ray burst was detected by the Vela group on June 3, 1969, and thus referred to as GRB 690603. The location was determined to be clearly outside of the satellites' orbit, and probably outside of the Solar system. After reviewing archived Vela data, a previous burst was determined to have occurred on July 2, 1967. Public reports of initial GRBs were not disclosed until the early 1970s.

3. GRB DATABASES

3.1. CGRO observatory

Gamma-rays can only be detected in space due to the atmospheric absorption of the high-energy photons. Starting from the Vela satellite, which discovered the phenomenon of GRB, a few dozen space-based gamma-ray detectors have observed GRBs. One of the most important was CGRO (Compton Gamma Ray Observatory). The CGRO was launched in April 1991, as one of NASA's Great Observatories: a series of four space-based observatories to study astronomical objects or phenomena in visible, gamma-ray, X-ray, and infrared energy bands. The CGRO observed the sky in high-energy gamma-rays and detected thousands of GRBs as well as many other high-energy transient phenomena in its nine-year lifetime that ended in June 2000.

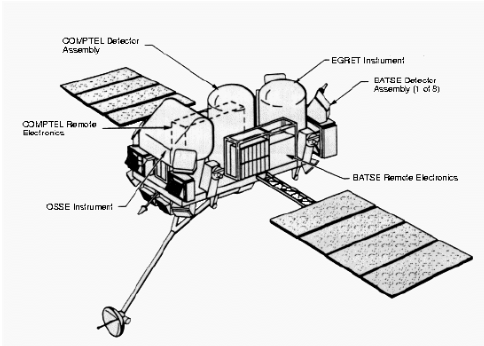

Figure 2. Sketch of the Compton observatory.

The Burst And Transient Source Experiment (BATSE) located at the CGRO was specifically designed to detect GRBs and study their temporal and spectral characteristics in much greater resolution than the previous experiments. Some of the observed events are shown in the Fig. 3., where we can see high variability of the released output energy in the first phase of event lasting a few tens of seconds.

After the launch of CGRO in 1991, BATSE began detecting one GRB a day, on average. Soon, the observations revealed an isotropic angular distribution (Fig. 4) and inhomogeneous spatial distribution for GRBs, with better and better statistics as more numbers of bursts were observed. The isotropy of GRB locations rejected the galactic disk population hypothesis, and confirmed homogenous distribution on the sky.

Along with the inhomogeneity, the indicated GRB distribution was a geocentric spherical distribution with decreasing number density at further distance. The distribution was not consistent with any known population of galactic objects. It was, however, consistent with a cosmological origin hypothesis since isotropy is naturally expected from the cosmological distribution and the inhomogeneity could be explained by the non-Euclidean geometry at very far distances.

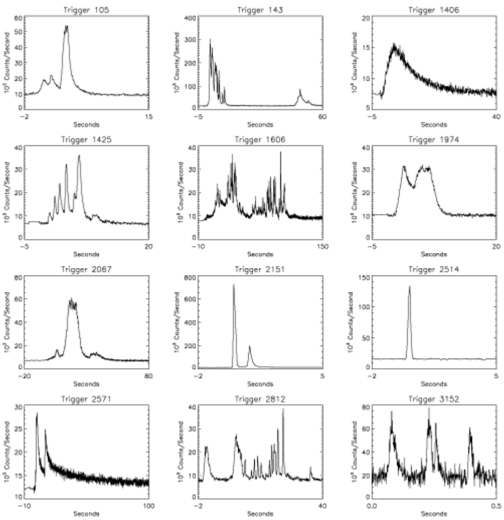

Figure 3. Examples of recorded GRB events in gamma phase.

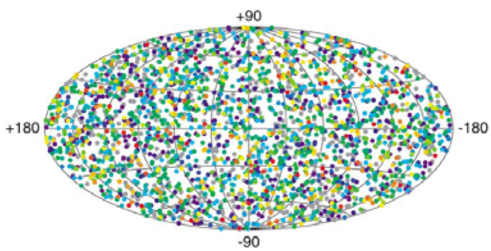

Figure 4. Homogenous distribution of GRB events throughout the whole sky.

3.2. BATSE database

Following the Internet link ftp://legacy.gsfc.nasa.gov/compton/data/ one can find the raw data from the CGRO observatory. They are separated in four directories regarding the on board instrument.

BATSE directory contains all the CGRO/BATSE data. The subdirectories are as follows:

- **SGRs** - soft gamma-repeater data (SGR 1806 only)
- **ascii_data** - simplified versions of certain burst data types for a subset of the mission
- **daily data** - Discriminator rate continuous, and corrected data from LADs and SDs
- **Occultation** - Earth occultation data products; light curves and 16-ch spectra as a function of time
- **pulsar** - Epoch (onboard and ground) folded data
- **single_sweep** - high-time resolution continuous data
- **trigger** - triggered data products, including GRBs and solar flares

Most interesting data connected with the GRB phenomena are in the ascii_data directory, especially concatenated 64-ms Burst Data in ASCII Format. This data type is a concatenation of three standard BATSE data types, DISCLA, PREB, and DISCSC. All three data types are derived from the on-board data stream of BATSE's eight Large Area Detectors (LADs), and all three data types have four energy channels, with approximate channel boundaries: 25-55 keV, 55-110 keV, 110-320 keV, and >320 keV. They are presented in the tables similar to this presented in the Figure 6.

```
trig#  npts nlasc 1preb    followed by 4-chan count rates (64-ms bins)
 3029  8187  1865     7
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84812500E+02  1.44437500E+02  1.13312500E+02  7.08750000E+01
 1.84500000E+02  1.45500000E+02  1.17312500E+02  7.29375000E+01
 1.84500000E+02  1.45500000E+02  1.17312500E+02  7.29375000E+01
 1.84500000E+02  1.45500000E+02  1.17312500E+02  7.29375000E+01
 1.84500000E+02  1.45500000E+02  1.17312500E+02  7.29375000E+01
 1.84500000E+02  1.45500000E+02  1.17312500E+02  7.29375000E+01
```

Figure 5. Example of ASCII table for 64-ms data.

Another very useful functionality is presented at the address http://gammaray.nsstc.nasa.gov/batse/grb/. It allow user ability to see light curves of wanted GRB events through the suitable user interface (see Figure 6). On the list box placed left one could select GRB event and in controls in the middle and right observational channel and type of file wanted. Then pressing the **Submit** button the results are given in the form of image and file to save. This method is very beneficial when we need to quickly review the GRB events and download chosen files.

During the years of successful operation CGRO with the BATSE experiment onboard, produce the vast amount of data. These are classified in the catalogs ranging from 1B to 4B and at the end so called Current catalog. Most comprehensive data set could be found in the BATSE 4B catalog where we can examine 1637 GRBs. In this tables we could find data sets which contain basic information about location and time of event in different coordinate systems as well as trigger and identification numbers. Also, there are detailed information's about flux and fluence in the of 64, 256 and 1024ms, peak count rates, duration, exposure and data about efficiency of detector which observe the event. Together with the data collected until end of its work in june 2000., CGRO and BATSE produced most comprehensive data sets which is vastly used among the researchers in this area of science.

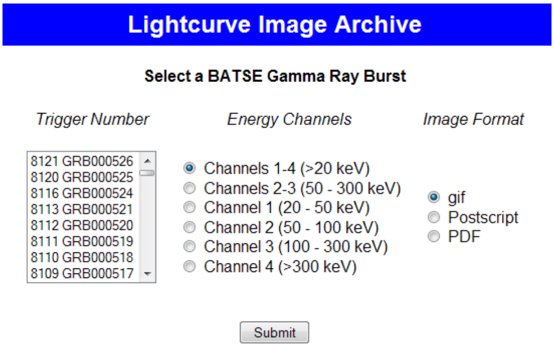

Figure 6. User interface for selecting the GRB event, channel and file tipe.

3.3. SWIFT satellite

SWIFT is a first-of-its-kind multi-wavelength observatory dedicated to the study of gamma-ray burst (GRB) science. Its three instruments work together to observe GRBs and afterglows in the gamma-ray, *X*-ray, ultraviolet, and optical wavebands.

SWIFT discovers approximately 100 bursts per year. The Burst Alert Telescope detects GRBs and accurately determines their positions on the sky. *Swift* then relays a 3 arcminute position estimate to the ground within 20 seconds of the initial detection. The spacecraft "swiftly" (in less than approximately 90 seconds) and autonomously repoints itself to bring the burst location within the field of view of the sensitive narrow-field *X*-ray and UV/optical telescopes to observe the afterglow. In addition to an accurate position, *Swift* provides multi-wavelength light curves for the duration of the afterglow, a gamma-ray spectrum of the burst, *X*-ray spectra of the afterglow, and in some cases can constrain the red shift of the burst.

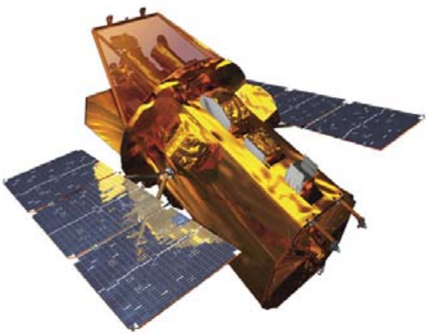

Figure 7. SWIFT satellite.

SWIFT satellite contain three main instrument which cover the electromagnetic spectrum from optical to gamma domain.

Burst Alert Telescope (BAT 15 - 150 keV): With its large field-of-view (2 steradians) and high sensitivity, the BAT detects about 100 GRBs per year, and computes burst positions onboard the satellite with arc-minute positional accuracy. Those data are recorded and passed to the other lower energy instruments in order to be properly guded. **X-ray Telescope** (XRT 0.3 - 10 keV): The XRT takes images and is able to obtain spectra of GRB afterglows during pointed follow-up observations. The images are used for higher accuracy position localizations, while light curves are used to study flaring and the long-term decay of the *X*-ray aferglow. And at the end with **UV/Optical Telescope** (UVOT 170 - 600 nm) a optical and UV observations are made. The UVOT is essentially a copy of the *XMM-Newton* Optical Monitor (OM). The UVOT takes images and can obtain spectra (via a grism filter) of GRB afterglows during pointed follow-up observations. The images are used for 0.5 arcsecond position localizations and following the temporal evolution of the UV/optical afterglow. Spectra can be taken for the brightest UV/optical afterglows, which can then be used to determine the red shift via the observed wavelength of the Lyman-alpha cut-off.

Complete process of acquiring the observation and extracting the data is shown in the Figure 8. Within minutes soon after a GRB is detected, TDRSS messages are broadcast via the GCN. After a few hours or a day telemetry arrives to the Malindi ground station and the data are available in the Quick look area on the SWIFT Internet site. Then about a week latter after an observation is completed, the data are made available in the archive and removed from the Quick-look area.

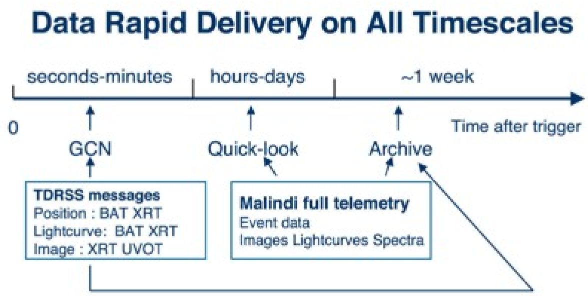

Figure 8. Data processing path in SWIFT satellite.

3.4. SWIFT database

The Swift archive can be accessed via the following interfaces (http://swift.gsfc.nasa.gov/docs/swift/archive/) (see Fig. 9). This address contains useful user interface which allow to setup query for detailed search. For example, one need to specify the some parameters which determine the object, like identification or observational number, object names, coordinates or date of observation. Also, interface offers to select what SWIFT instrument to search. Then the process is started by pressing the Start Search button.

Another way for examined the data is by using the Quick-look area located at the address (http://swift.gsfc.nasa.gov/cgi-bin/sdc/ql?). Figure 10. show example of this functionality.

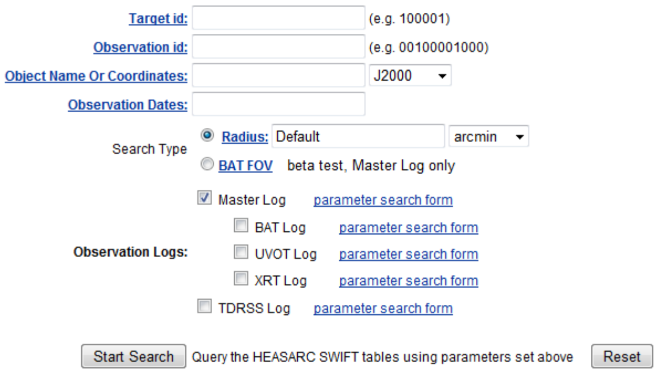

Figure 9. SWIFT user interface.

Figure 10. Data in the Quick-look area of SWIFT database.

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Publ. Astron. Soc. "Rudjer Bošković" No 11, 2012, 107-123

BAYESIAN PROBABILITY THEORY IN ASTRONOMY: LOOKING FOR STELLAR ACTIVITY CYCLES IN PHOTOMETRIC DATA-SERIES

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Abstract: The application of the Bayesian probability theory in a various astronomical research work over the past decade is discussed in the presented talk. The basic idea of the Bayesian approach to astronomical data is presented with a special attention for its plausibility to the subject of Astroinformatics. In Particular the Gregory-Loredo method for periodic signal detection of unknown shape in time-series with Gaussian errors is tested.

1. BRIEF HISTORY OF THE BAYESIAN PROBABILITY THEORY

At the present astronomical publications the adjective "Bayesian" is increasingly often in use in order to point at specific logical approach and to distinguish the "classical" statistical approach to observational data. As a part of Probability Theory, Bayesian probability theory exploits the idea of the probability as "a measure of state of knowledge" (Jaynes, 2003), rather than a long-run expected frequency of the occurrence of the event. This extended concept for probability comes close to the every-day meaning of this world as insufficient reasoning and is a base for advanced data analysis techniques, such as hypothesises testing, model comparison, subjective reasoning and data mining. At this point of view, following the inductive and deductive logic, Bayesian analysis can significantly improve the parameter estimation, allowing the researcher to assign probabilities to competing hypotheses.

The first fundaments of the Bayesian logic belong to Thomas Bayes (1702 – 1761), who was an English mathematician and Presbyterian minister (Encyclopædia Britannica, 2010). His main work “Essay Towards Solving a Problem in the Doctrine of Chances” (1763), was published in the Philosophical Transactions of the Royal Society. In this essay Bayes published the first version of what latter has become known as “Bayes's theorem”, a discussion of the binomial distribution as well as the first occurrence of a probability logic result involving conditional probability (Dale, 2003). According to Dale (2003), Bayes’ mathematical work include discussions of probability, trigonometry, geometry, solution of equations, series and differential calculus, but also he was interested in electricity, optics, astronomy and celestial mechanics.

The general version of the Bayes theorem, (the theorem that treats the conditional probabilities), and the early Bayesian probability theory were set up and developed by the French mathematician, astronomer, and physicist Pierre-Simon Laplace, (1749–1827). Laplace is well known for his solar system investigations, but he has also demonstrated the usefulness of probability approach to scientific data, especially in celestial mechanics, medical statistics and law sciences (Stigler, 1986). Laplace has also introduced the principle for assignment of the priors, called the principle of insufficient reason (Fienberg, 2006). He used uniform priors, which are the simplest non-informative priors, reasonable in case of insufficient knowledge for setting up the informed priors. Latter on this principle was called by De Morgan (Fienberg, 2006) , the inverse probability as it infers backwards from observations to parameters. After the 1920s, Laplace’s probability principles were argued mostly by Ronald A. Fisher, Jerzy Neyman and Egon Pearson and were substituted by a set of methods latter called frequentist or classical statistics (Fienberg, 2006). Neyman, in his work "Frequentist probability and frequentist statistics" (Neyman, 1977), developed the idea of confidence intervals because "the whole theory would look nicer if it were built from the start without reference to Bayesianism and priors". Actually *Bayesian* appeared as a terminology in the 1930s, and latter on it was used by those who have not accepted the limitations of frequentist statistics (Fienberg, 2006).

According to Daston (1994), “Between 1837 and 1843 at least six authors: … made similar distinctions between the probabilities of things and the probabilities of our beliefs about things." These two different approaches gave rise to the objective and subjective directions in Bayesian theory. In the objective direction the statistical analysis depends only on the data and the assumed models, and is not influenced by subjective decisions. For instance in the early 1920s, John Keynes represent the idea that the probability should be treated as “subjective degree of belief in a proposition”, while the classical approach to probability refers to the frequency of the occurrence of the event. Latter on at 1939 Harold Jeffreys (1939}, published his basic work “Theory of probability” (Jeffreys, 1939), were he developed the Objective Bayesian inference.[1] At 1957th Edwin Jaynes introduced the principle of entropy for priors constructing, and in 1965th Dennis Lindley with his book "Introduction to Probability and Statistics from a Bayesian" promoted the Bayesian methods.[2] The development of the Markov chain Monte-Carlo methods at eighties removed many computational problems in front of the Bayesian statistics. At present Bayesian approach is widely used in different applications for machine learning, data mining, Bayesian network.

2. BASIC CONCEPTS OF THE BAYESIAN PROBABILITY THEORY

In general Bayesian probability theory gives tools for evaluating of the probability of hypothesis, using the prior probability distribution, updated or affected by the relevant data and the available additional information. Thus the probability of a given hypothesis could be updated with the new data releases and might be interpreted as a “state of knowledge” (Jaynes, 2003). Contrary, in the frequentist approach a hypothesis is either accepted or rejected, without assigning to probability. Bayesian approach is based on the Probability theory rules, such as product and sum rules, Boolean algebra and the Bayes theorem. The Bayes theorem gives the rule for the conditional probability P(H|D,I) of the proposition H, given that the proposition D and information I are true (shortly – H given D and I) and its general form, according to Gregory (2005) is:

P(H|D,I)=P(D|H,I)P(H|I)/P(D|I), where

H is a specific proposition or set of hypothesis,

D is the evidence or the data that are observed,

I represent the prior information,

P(H|I) is the prior probability of H given the I, that was assumed before the data became available,

P(D|H,I) is the conditional probability of the data, given the H and I, also called the likelihood function,

P(D|I) is the marginal probability of the data given I: the prior probability of the data under all possible Hypothesizes: $P(D|I)=\square P(D|H_i,I)\ P(H_i|I)$, it’s a normalization factor that ensure the sum of all the probabilities of the hypothesizes to be 1.

[1]Wikipedia, History of statistics, http://en.wikipedia.org/wiki/History_of_statistics# Bayesian_ tatistics, Aug. 2010.
[2] Ibid.

P(H|D,I) is the probability of the proposition H (hypothesis) given the proposition D (data) and I (information)

The term in front the P(H|I), P(D|H,I)/P(D|I), describes the influence of the observational data to the probability of the hypothesis. When it is likely to observe the data under the hypothesis, then this factor will be large and it will result in a larger posterior probability of the hypothesis given the data. Contrary, if it is unlikely to observe the data if the hypothesis is true, then the term would reduce the posterior probability for the hypothesis. Thus the Bayes theorem measures the influence of the data on the on the probability of the hypothesis. Bayesian inference, when applied to scientific data analysis, rules the updating hypothesizes given to the new data or experiments by a basic schedule of few steps: (1) setting up the hypothesis space and the prior probabilities; (2) Data models and parameter space definition; (3) Hypothesis testing and (4) calculation of the global likelihood function.

At present, the definition of the hypothesis space in astronomy is based on the observational data, knowledge gained in the previous research or on theoretical consideration. There are two general approaches for assigning prior probability distributions of the parameters: informative, based on the previous evidence or on the expert opinion; and uninformative, based on general or obscure information. Useful practical approach for setting informative priors is to take a normal distribution with expected value based on the previous observation. The simplest rule for setting up uninformative priors is assignment of equal probabilities to all possibilities, but this encounters problems if the prior range of the parameter is infinite. There are also some other reasoning for priors set up: conjugate priors, which provide for the same type of the prior and posterior distribution, reduce the computational problems; the Jeffreys priors that assure that the statement of the prior believe are the same in different scales (such prior distribution is reasonable in time-series analysis to ensure equal results in terms of period and frequency).

Scientific data models in general are described by several parameters and are accounting for observational errors. In this case the Bayesian inference provides the computation of the joint likelihoods and probability distribution functions for each of the parameters. The marginalization (integration or summation of the joint posterior distribution function over the nuisance parameters) procedure gives the marginal probability of the parameter of interest and then the mean, mode values and the credible intervals are easily estimated.

Bayesian model selection answers the question how probable is a model given the data, if we consider a set of models (M_1 and M_2 for instance) independently of the model parameters. The models are evaluated by computing the odds factors (Q_{12}) and marginalization out all the parameters Gregory (2005):

$\mathbf{Q_{12}=P(M_1|D,I)/\ P(M_2|D,I)=[P(D|M_1,I)/\ P(D|M_2,I)][\ P(M_1|I)/\ P(M_2|I)],}$ where

$[P(M_1|I)/\ P(M_2|I)]$ is the prior odds of the model, often taken to be 1, assuming the models are of equal probability

$[P(D|M_1,I)/\ P(D|M_2,I)]$ is the Bayes factor (B_{12}), computed by the marginal likelihoods for each model.

3. BAYESIAN PROBABILITY THEORY, LAST DECADE IN ASTRONOMY

Increased impact of the Bayesian inference in astronomical research may be traced in professional literature, in modern statistical application as well as in the publications in the main astronomical journals. A reference into the Amazon.com book store returns several volumes, written by high level professionals in statistical studies and astrophysics:

The work of P.C. Gregory, “Bayesian Logical Data Analysis for the Physical Sciences: A Comparative Approach with Mathematica® Support” (2005, 2006), (Gregory, 2005) undergoes its third edition at 2010 and is a fundamental book that discusses application of the Bayesian statistics in physical sciences. The book gives detailed and clear exposition of the Bayesian concepts with number of useful examples, numerical techniques for Bayesian calculations, an introduction to Bayesian Markov Chain Monte-Carlo integration and least-squares analysis. In addition it is supported with a Mathematica notebook providing an easy to learning routines.

Modeling disc galaxies using Bayesian/Markov chain Monte Carlo is the subject of the recent book by D. Puglielli “Galaxy Modeling using Bayesian Statistics: A Bayesian/Markov chain Monte Carlo Approach to Modeling NGC 6503” (Puglielli, 2010). A large set of observations for the dwarf spiral galaxy NGC 6503 is examined for fitting with sophisticated dynamical models and the joint posterior probability function for the model parameters is obtained. This approach gives constraints of important properties of the galaxy as its mass and mass-to-light ratio, halo density profile, and structural parameters.

The application of the Bayesian methods in cosmological research is represented in the recent book by Michael P. Hobson and Andrew H. Jaffe “Bayesian Methods in Cosmology” (2010). The contribution of 24 experts in cosmology and statistics makes this book essential and competent guide for researches in cosmology. The book represents precise modeling of the Universe properties and gives a methodology (the basic foundations, parameter estimation, model comparison and signal separation) as well as a wide range of applications such as source detection, cosmic microwave background analysis, classification of galaxy properties.

It also worth mention the publication of the 27th International Workshop on Bayesian Inference and Maximum Entropy Methods, named “Bayesian Inference in Science and Engineering: 27th International Workshop on Bayesian Inference and Maximum Entropy Methods” (2007) by the edition of Kevin H. Knuth, Ariel Caticha, Julian L. Center, and Adom Giffin (2007). For 30 years the MaxEnt workshops have explored the use of Bayesian probability theory, entropy and information theory in scientific, engineering and signal processing applications. Volume No. 27 considers Methods, Foundations and Applications in astronomy, physics, chemistry, biology, earth science, and engineering.

A collection of essays “Blind Image Deconvolution: Theory and Applications” (2007), edited by P. Campisi, and K. Egiazarian expose up to day approaches theoretical fundaments of Blind Image Deconvolution techniques. A special chapter for application of the Deconvolution and Blind image Deconvolution techniques in astronomy is provided by Eric Pantin, Jean-Luc Stark and Fionn Murtagh, which also include Bayesian approach. Bayesian methodology for image deconvolution is also exposed in the book of J.-L. Starck and F. Murtagh, “Astronomical Image and Data Analysis” (2006).

A basic series of Astronomical statistics, “Statistical Challenges in Astronomy”, (2003, 2010), Statistical Challenges in Modern Astronomy II” (1997), edited by E. Feigelson, G. Babu, was released after the conferences of the same name. These volumes focus on the topics: Bayesian approaches to astronomical data modelling, the Virtual Observatory impact on present astronomical research, time series analysis, image analysis, statistical modeling of critical datasets and its application in cosmology. Many problems are introduces on the base of large astronomical projects, such as LIGO, AXAF, XTE, Hipparcos, and digitised sky surveys.

In the last decade several software applications were found to be in use for Bayesian astronomical data analysis:

BAYES-ME code of A. Asensio Ramos (2009), for investigations of spectropolarimetric observations with the *Hinode* solar space telescope;

MULTINEST/SUPERBAYES (http://superbayes.org/) - is a robust Bayesian inference tool for cosmology and particle physics;[3]

ARGO: **A**lgorithm for the **R**econstruction of **G**alaxy-traced **O**ver-densities (Kitaura and Enßlin, 2008) – gives methodology, inverse algorithms and numerical optimization for Bayesian reconstruction of the cosmological large-scale structure;

Bayesian Photometric Redshift code BPZ, http://acs.pha.jhu.edu/ ~txitxo/);

ZEBRA: Zurich Extragalactic Bayesian Redshift Analyzer, http://www.astro.phys.ethz.ch/exgal_ocosm/zebra/index.php, combines and extends several of the classical approaches to produce accurate photometric redshifts down to faint magnitudes; it uses template-fitting approach to produce Maximum Likelihood and Bayesian redshift estimates.

The most evident impact of the Bayesian approach to analysis of astronomical data and information could be seen in the publications in the professional journals. In the last decade more than 300 papers reports the application of the Bayesian methods, starting with about 15 papers at 2000 and ended up with more than 50 papers per year at the last two years of the decade. The Bayesian methodology was not only used for precise parameter estimation but also for Model Comparison, Hypothesis testing, Object detection, identification and classification, Image

[3] ”SuperBayes code”, http://superbayes.org/, Aug 2010

deconvolution. This approach has been applied to rather diverse astronomical topics; the main items are listed below in decreased number of publications:

◦ Cosmology: Uses the Bayesian inference for data analysis (most of the papers concern the data analysis of the Wilkinson Microwave Anisotropy Probe Observations), Estimation of the Cosmic Microwave Background, The Universe parameters and model estimation, Dark energy studies;

◦ Gravitational lensing: Uses the Bayesian inference for gravitational lenses detection and modeling;

◦ Variable stars: Uses the Bayesian inference for variable stars detection, identification and classification, Light and Radial velocity curves analysis - estimation of the light curves properties, SN identification and classification;

◦ Spectral fitting and deconvolution ;

◦ Extrasolar Planets: Uses the Bayesian inference for New planet searches (Bayesian Kepler periodogram), Orbit analysis of the Extrasolar planets;

◦ Solar astrophysics: Uses the Bayesian inference for solar flare predictions, magnetic fields estimation, solar oscillations detection;

◦ The Galaxy studies: Use the Bayesian inference for the dist and halo kinematics study, Star Formation Ratio estimation, The Velocity Distribution of Nearby Stars, HIPARCOS data analysis.

In principle, the Bayesian statistics is applied for analysis of mostly all astronomical type of data: Spectral (spectra fitting, Radial velocities, spectro-polarimetric data), Photometric, Kinematic (Velocity distribution, Kepler periodogram), and Image (optical, IR, Radio, X-ray data) series analysis.

4. GREGORY-LOREDO METHOD, GAUSSIAN NOISE CASE

In the frames of the Astroinformatics projects of the Bulgarian Academy of Sciences, we are interested of applying Bayesian statistical methods for analysis of the photometric data obtained by the digitization of photographic plates, combined with modern CCD photometry, and with published electrophotometric observations. Such data usually would exhibit random time distribution, wide time intervals with a lack of observations, and also different quality and observational errors. We find out that the Bayesian Gregory-Loredo (GL) method (Gregory, 1999) for time-series analysis with Gaussian error distribution is useful and practical for our research. The method gives robust and relatively fast tool for searching long-term photometric cycles with unknown shape. The GL method employs Bayes approach for signal detection and for the detected signal characteristics estimation. When using the Bayes statistics the first step is to determine the hypothesis space and its priori ranges, then to represent them with suitable models. In general, for stellar photometric data series we have three hypotheses - constant, variable, and periodic magnitude variations.

Time series of photometric data we had obtained, consist of the observed magnitude d_i, taken at the moment $\mathbf{t_i}$ and corresponding errors. So the data model for the observed stellar magnitude consists of model predicted magnitude $\mathbf{d_{pi}}$ plus an error term. The error term, $\mathbf{e_i}$, includes observational error estimated by the observer, $\mathbf{s_i}$ and any unknown noise or signal which is not represented in the model:

$d_i = d_{pi} + e_i$,

In this method we assume the noise variance, $\mathbf{e_i}$, is finite with Gaussian distribution with variance $\boldsymbol{\sigma_i^2}$.

In the GL method periodic models are represented by a signal folded into a stepwise function, similar to a histogram, with **m** phase bins per period plus a noise contribution. In principle, with such a flexible model we are able to approximate a light curve of any shape. Hypotheses for detecting periodical signals represent a class of stepwise periodical models with following parameters:

- **P**, or $\boldsymbol{\omega}$ - period or angular frequency, in the priori range of (p_{lo}, p_{hi});
- $\boldsymbol{\phi}$- phase of minimal brightness of the star;
- **m** – number of bins in the priori range from 2 to 12;
- $\mathbf{r_i}$ – light curve value in the ith bin;
- **b** - Noise scale parameter, (defined as $1/\sigma_i^2 = 1/s_i^2$), the ratio of the variances of ($d_i - d_{pi}$) and that of the observer noise estimates s_i. The priori range of is (0.05, 1.95);

The GL method uses Jeffreys priors distribution for **b** and $\tilde{\omega}$These priors give the good advantages to ensure the same Gaussian distribution for $\mathbf{s_i}$ and $\boldsymbol{\sigma_i}$ as well equal results in the period and frequency scales. The uniform priors are taken for phase and number of bins parameter. Based on the Bayes' theorem, Gregoty and Loredo (1996), and Gregory (1999), gave rules and equations for calculation of the global and marginal likelihood functions, and of the odds ratios of constant, nonperiodic and periodic models. The most probable model parameters are estimated by marginalization of the posterior probability over the priori specified range of each parameter.

We have tested the GL method using modeled datasets, with randomly distributed data-points over 100 years observed period and with data-gaps involved. Results for period detection are shown at Fig.1 (depending on the number of observations) and at Fig. 2 (depending on the amplitude of the light curve). The error bars at the Fig. 1 and 2 represent the deviation of the mode period, calculated by the use of bootstrapping method. Our test shows that the GL method gives reliable and accurate results even with sparse, randomly distributed data.

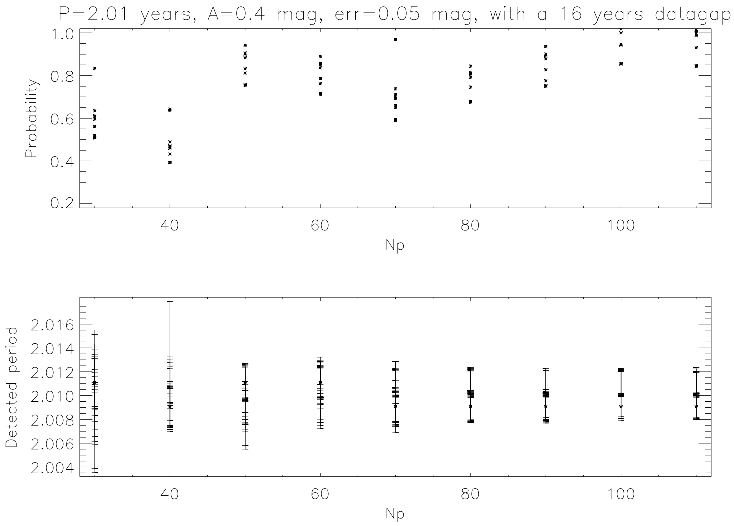


Figure 1. Results from the GL method for period detection: the most-probable detected period (bottom) and the Probability Density Function (top), depending on the number of observations. The modeled time-series are with period P=2.01 years, magnitude amplitude of 0.4 mag and observational error of 0.05 mag, and observed time span of 100 years with involved 16 years data-gap.

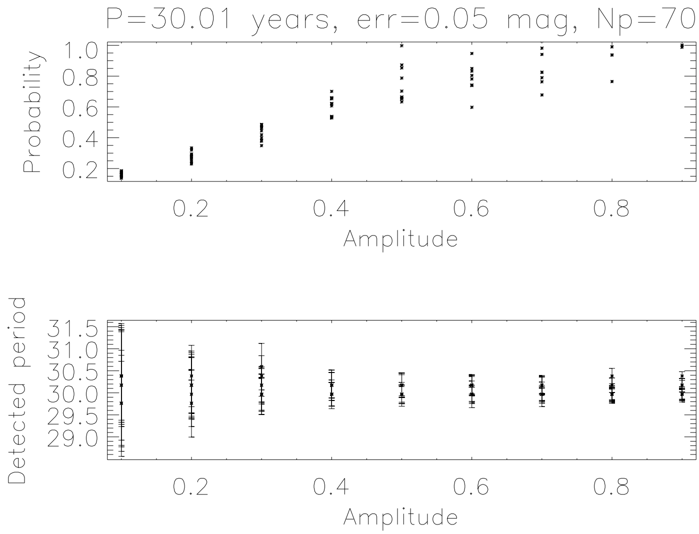


Figure 2. Results from the GL method for period detection, depending on the amplitude of stellar variability: the most-probable detected period (bottom) and the Probability Density Function (top), over modeled time-series, with period P=30.01 years, number of observations is 70, observational error of 0.05 mag and observed time span of 100 years.

5. GREGORY-LOREDO METHOD, APPLICATION FOR ANALYSIS OF THE CF OCT PHOTOMETRIC DATA

We applied the GL method for the analysis of the photometric data we have collected for the bright, southern active giant star CF Oct (HD 196818). Variability of this star was first noticed on the photographic plates from Bamberg Observatory Southern Sky Survey (BOSSS) (Strohmeier, 1967). The GCVS (Samus et al., 2009) mention CF Oct as a RS CVn variable with maximal brightness V=8.27 mag and relatively large photometric variations ~0.3 mag. We have digitized and analysed the early archival observations from the BOSSS (Innis et al., 2004). Photoelectric photometry for the star was published by Innis et al. (1983, 1987), Lloyd et al. (1987) and Pollard et al. (1989). The photometry studies show rotational modulation of 20 d, due to spotted activity. CF Oct is also reported to be a strong, flaring, microwave radio source by Slee et al. (1987), and appears at the ROSAT Bright survey catalogue (Fisher et al., 1998) with 1.12 counts per second in the energy range of 0.1 - 2.4 keV.

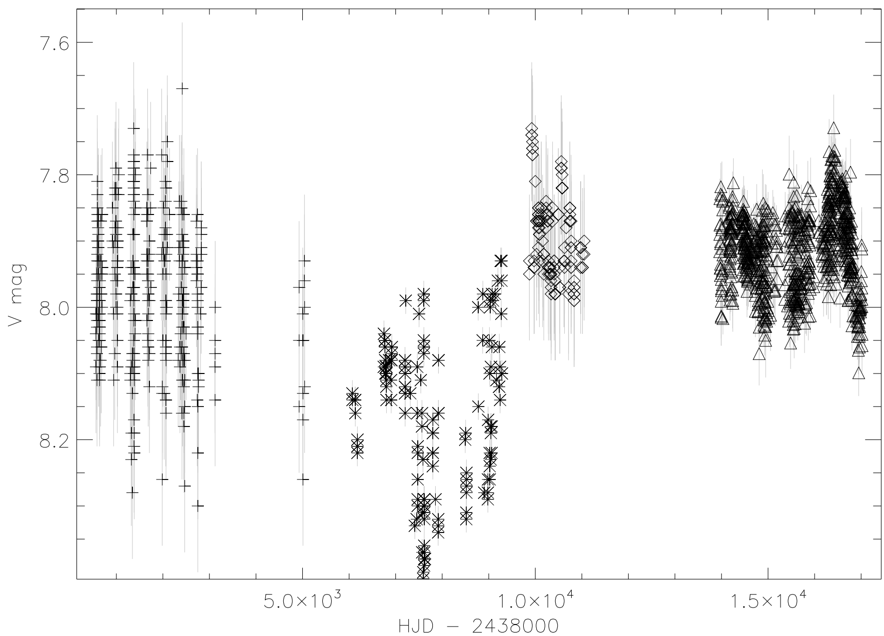


Figure 3. Light curve (with observational errors overploted) of CF Oct for the period 1964 – 2009.

The photometric data in use is collected from Bamberg Observatory Southern Sky Survey (BAM) (Innis et al., 2004), from published photoelectric photometry observations (PHOT) (Innis et al., 1983, 1987; Lloyd et al., 1987; Pollard et al., 1989), from the Hipparcos satellite time-series (HIP),[4] available via the Centre de Donnes astronomiques de Strasbourg (CDS), and from the All Sky Automated Survey (ASAS) data archive (Pojmanski, 2002) (http://www.astrouw.edu.pl/asas/).

The dataset contains data for HJD of the observation, V mag of the star, and corresponding errors. As far the data is taken from different sources, there are significant intervals with lack of data and the data distribution is non-uniform. The resulting V magnitude light curve with overploted errors is presented on Fig. 3, where the crosses represent BAM data, asterisk - PHOT data, diamonds - HIP data and triangles - ASAS data. The dataset statistically is presented in Table 1, with following information: Dataset; N_p - the Number of observations in the set; T_s - the time span of the set in days; HJD in the beginning of the set; V_{min}, V_{max} and <V> - minimal, maximal and mean values of V magnitude respectively.

Table 1. CF Oct photometric data description.

Dataset	Np	Ts	HJD	Vmin	Vmax	<V>
BAM	352	4484	2438560	7.67	8.3	7.98
PHOT	137	3212	2444071	7.93	8.41	8.16
HIP	130	1176	2447873	7.74	7.98	7.90
ASAS	705	3058	2452693	7.67	8.41	7.91

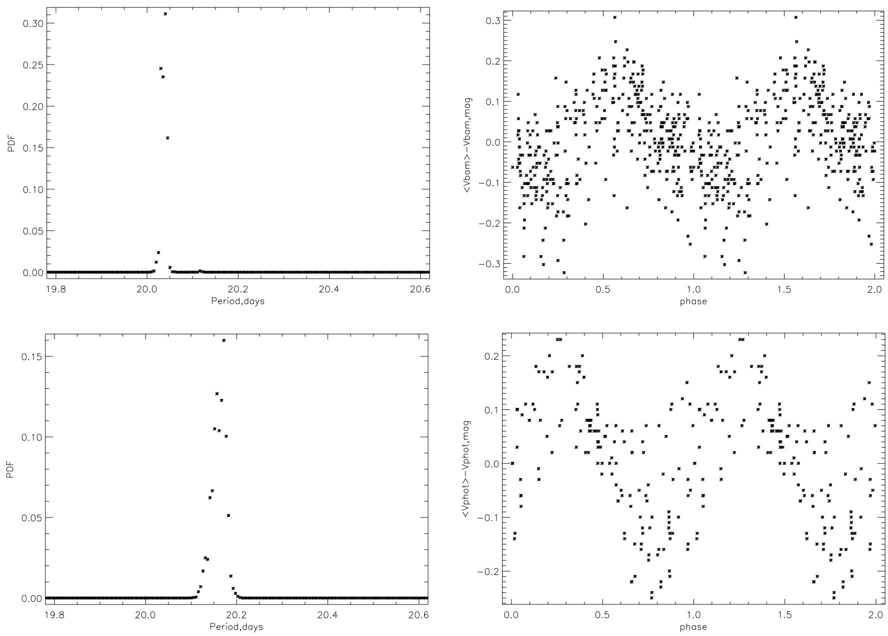
In order to reduce the likelihood of introducing unknown systematic errors into the periodicity study of CF Oct, due to the different observational methods and data reduction procedures employed, we analyze the variations of <V>-V, where <V> is the mean value of V for each dataset, i.e. <V>=(<Vbam>, <Vphot>, <Vhip>, <Vasas>).

With the collected data we are able to study variability of CF Oct in ranges from several days (this limit is set up by the average sampling frequency of our observations) to 15 years (1/3 of the covered observational time span). This is a rather large interval in frequency space, and was examined in several parts while detecting rotational or long-term variability, using a suitable number of frequencies in each case.

Previous periodical analysis (PDM and least-squares method) of photographic and photoelectric observations shows that CF Oct has a well established rotational variability with period near 20 d. Application of the Gregory-Loredo method for rotational variability study, with restricted priori range of model parameters and

[4] ESA,The Hipparcos and Tycho catalogues, ESA SP-1200, 1997.

based on all collected observations would result in more precise period estimation at different epoch. This analysis is relevant as already studied BAM and PHOT data shows slightly different periods (Innis et al., 2004), eventually due to the period estimation errors, phase shifting or more complex periodical modulation. For the separate datasets as well as for all the data combined, we have calculated the joint posterior probabilities for a class of models described by the parameters described above. The prior period P range is selected 19 to 21 days. By marginalization over the nuisance parameters we have computed the posteriori Probability Density Functions (PDF) of the number of bins and the period parameters and calculated their most probable (m_{max} and P_{max}) and mean (m_{mean} and P_{mean}) values. The PDF over the period is then normalized to have an integral over the priori range (19 to 21 d) to be 1. We have also computed the 68 per cent credible intervals (interval that contains 68 per cent of the PDF, and where the PDF is everywhere greater than the one outside the credible interval) for period detection. Table 2 represents our results: the most probable m (m_{max}), maximal probable period (P_{max}), maximal probability for the period ($Prob_{max}$), weighted mean period (P_{mean}) and the credible intervals. Number of bins parameter relates to the complexity of the light curve, to the light-curve shape and probably is connected with the structure of the stellar spots.



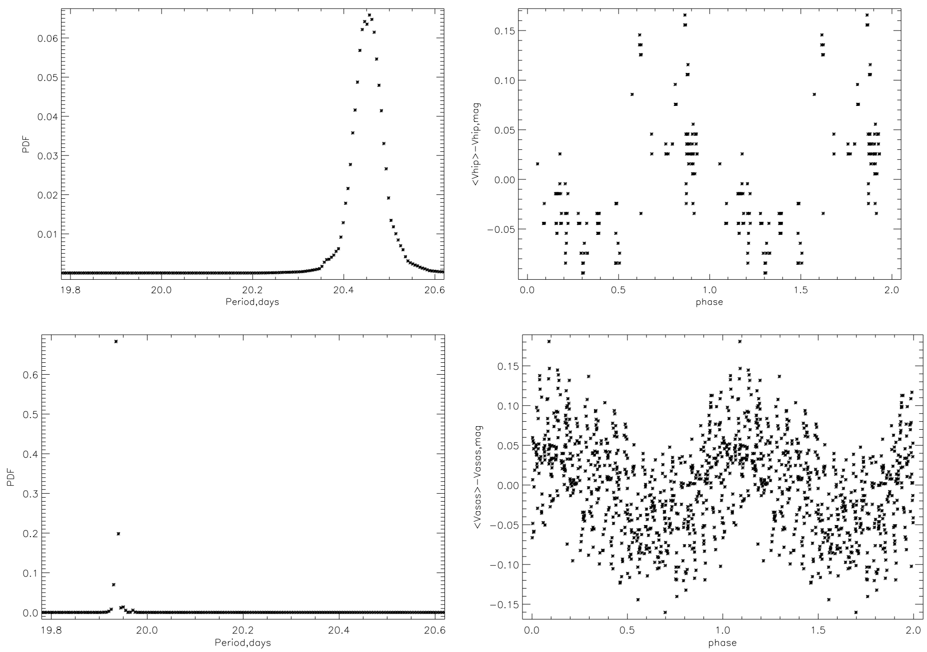


Figure 4. Normalized PDFs and light curves for the different datasets, top to bottom: BAM, PHOT, HIP and ASAS.

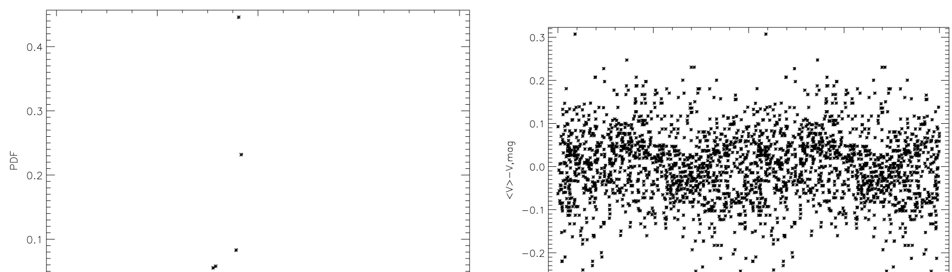


Figure 5. Normalized PDF and light curve for all the data.

Table 2: Derived periods, probabilities and 68 per cent credible intervals.

Dataset	m_{max}	P_{max}	$Prob_{max}$	P_{mean}	cre. int.
BAM	3	20.04	0.31	20.04	0.01
PHOT	2	20.17	0.16	20.16	0.03
HIP	2	20.46	0.07	20.45	0.05
ASAS	3	19.94	0.68	19.94	0.02
ALL	3	20.16	0.45	20.14	0.04

The normalized posterior PDFs for the period detection for the separate datasets as well as for all the data together are given on the left panels of Fig. 4 and Fig. 5. The mean subtracted V light curves, plotted with the most probable periods for each of the datasets and for all the data respectively, and with an epoch set at the beginning of observations at HJD=2438560.4 are presented in the right panels of Fig.4 and Fig. 5.

As it is seen from the PDFs, present Bayesian analysis confirms previous suggestions (Innis et al., 2004) for period changes. The relatively narrow credible intervals (period estimation error) result basically of the prior restriction of the parameters which is based on the previous information about variability of CF Oct and clearly demonstrates general advantage of the Bayesian statistics. Most probable periods obtained for photographic plate and photoelectric photometry data are close to the previous published ones. Scatter in the light curves from different datasets shows that the amplitude of brightness variations, light curve shape and phase of the minimal brightness change with the epoch of observation.

The GL method gives also opportunity for searching for long-term cycles with up to 6000 days length. We have evaluated the hypotheses for constant, for nonperiodic and for periodic signal, and have computed the odds ratios. The result shows that the periodic model is the best to represent the observational data and it is the most probable model. The variable model appears the second probable one and it is very reasonable since periodical models are a special case of variable ones. Searching for long-term periodic modulation over mean-subtracted, magnitude data, reveals three cycles with periods of 3582 d (~9.8 yr), 2432.5 d (~6.7 yr) and 1173 d (~3.2 yr). The marginal probabilities are 0.02, 0.008, 0.0003 and the credible intervals are 300, 150 and 20~d respectively. The normalized (PDF) plot is shown in Fig. 6. Although the shortest cycle has a very low probability and thus is statistically insignificant, the period values of the other two cycles show that there is an evidence for observation of a harmonic signal, more powerful in the longest cycle, with a period of 3583 d and with its two overtones.

6. BAYESIAN PROBABILITY THEORY AND ASTROINFORMATICS?

The astroinformatics appears at a merging area of astronomy with contemporary Information and Communication Technologies and is a consequence by the need of professional astronomers of unified access and tools for analysis of an enormous data volumes produced by multiple sky surveys. At present the Astroinformatics is a part of a common tendency for new sciences, called X-informatics (where X-refers to any scientific discipline), to be formed. The problematic of astroinformatics includes: data management and description, astronomical classification and semantics, data mining, visualization and astrostatistics.

The Bayes theory, for its logical approach can provide a base for creation of robust and practical tools for astroinformatics. The Bayes inference, especially in its objective direction is appropriate for data-mining heterogeneous data series. This approach is highly relevant in modern astronomical research if the analysis of multi-wavelength observational data obtained with various detectors is required, as it is in the astroinformatics research. Particularly the observational data series used in astronomy nowadays often suffer of random time distribution, sparse data, different quality and are usable to be analyzed by the Bayesian statistics . The possibility for updating the analysis results when, given by the Bayes theorem, with new data release and also with additional information coming from theoretical predictions and/or restrictions give the advantage of a deeper and comprehensive, data-driven researches and discoveries. Hypothesis testing in Bayesian theory can be a base for the future development of new ICT tools for updating the “state of the knowledge” in X-informatics sciences, taking in account the complexity of all the available observations, theoretical predictions and previous research experience. Subjective direction in Bayes theory could give also a base for the development of machine learning techniques in astronomy, in special interest in astronomical objects and source classification based on all the available observational data.

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CONTRIBUTED PAPERS

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ASTROINFORMATICS FOR THE FLARE STARS IN STELLAR CLUSTERS AND ASSOCIATIONS

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Abstract. Applying the subjects of Astroinformatics to the data concerning the photographic observations of the flare stars in stellar clusters and associations we aim to enable extracting unrevealed knowledge for this type of variable stars, as well as to re-use the accumulated observing material (photographic plates) already in digital form, supplying digital curation. The database for the detected photographically flare stars (UV Ceti type variability with designations in the General Catalogue of Variable Stars - UV and UVn) in stellar clusters and associations as the Pleiades, Orion M42/M43, Taurus Dark Clouds, Cygnus NGC 7000, Praesepe, NGC 2264, Cygnus IC 1318, Coma Open Cluster, Alpha Perseus Cluster, Scorpius-Ophiuchus, and others, is present. The metadata records for the flare stars and their registered flare-events is described, as well as the access, data mining, possibilities for information searches, and flare stars plate visualization. The automated flare stars search, started on the basis of scanned flare stars monitoring plates of the Rozhen Observatory obtained with the 50/70/172 cm Schmidt telescope in the period 1979 - 1995, is expected to increase the number of discovered flares compared to the visual inspection by a blink-comparator done before in the observatory.

1. INTRODUCTION

Very briefly Astroinformatics can be described as data-oriented astronomy including data organization and data description, information retrieval and data mining methods, information visualization and knowledge extraction. Astroinformatics has as one of its subjects Semantic Astronomy for precise representation of the astronomical object nature in order to provide useful data queries, mining, access, dissemination and as a result - knowledge extraction. Ruling by this principle as a definition of Flare Stars in Stellar Clusters and Associations we comprise all variable stars showing flare activity - a randomly quick increase of the brightness across the spectrum (with greater increase in the ultraviolet) and a decline from maximum to minimum by several tenths up to several magnitudes in U band for some minutes up to some hours (Fig. 1). One of the brightest stars observed photographically in the stellar clusters and associations and shown flare-event is V 1396 Cyg with maximum brightness 11.65 (pg). The amplitude of brightness increase can reach up to 9.0 (U) magnitude - examples of registered flare-events with a big amplitude can be found in the stars V1710 Cyg with Δm= 7.0 (pg), V669 Tau with Δm= 8.0 (U), V1125 Ori with Δm= 8.3 (U), SV Ori with Δm= 8.4 (U), V356 Tau with Δm= 8.5 (pg), V341 Tau with Δm= 9.0 (U), V 515 Per with Δm= 9.0 (U)**.** The flare stars being K-M spectral type dwarf stars belong to the population of young stellar clusters and associations. They are designated with “UV” type stars (from the prototype star UV Cet), and “UVn” (because the connection with nebulae) in the General Catalogue of Variable Stars (GCVS, Kholopov et al. 1985-1988). Flare-events can happen once every few days or less frequently. The flare activity is a common characteristic in the early evolution of all red dwarf stars. The evolution scenario follows the scheme:

T Tau Type stars ➔ Flare Stars ➔ Main Sequence Stars.

The UV Ceti type stars from the solar neighbourhood are the older red dwarf stars with smaller masses, which have survived their original aggregate, and now being already disintegrated belong to the general galactic field population.

Another flare-like activities were discovered in many types of stars across the HR diagram: some Wolf-Rayet stars, stars of B and A spectral types, RS Cvn system, some members of Algol and W UMa systems, FK Com stars, brown dwarfs, and even evolved systems, containing white dwarfs. All these phenomena (despite of the fact that many of them need confirmation) are very interesting for understanding of the flare activity nature. Thus the reason for the flare-like events occurring in the chromospherically active stars sometimes is a companion star in a binary system caused tangled magnetic field, another reason is an axial rotation of a star with spots.

The review of all observed characteristics - energy, amplitudes, time-scales, frequencies, shows differences, probably due to the different origin. That is why collecting flare star data we have restricted the observed phenomena - so called flares, classical flares, flashes, microflaring, to the UV Ceti type variability as is classified in the GCVS (http://www.sai.msu.su/gcvs/gcvs/iii/vartype.txt). The number of variable stars designated clearly as UV and UVn in the version from March 2011 of the GCVS (Samus et al., 2011) is 1559 with including UV Ceti type stars from the solar neighbourhood. The discovery of flare stars in stellar clusters and associations continue to happen now but with other types of observations – e.g. Chandra X-ray Observatory since its beginning of operation in 1999 has discovered a lot of X-ray flares from young stars (see in particular the results of Chandra Orion Ultradeep Project). The CCD observations having smaller field of monitoring in comparison with the earlier wide-field photographic observations also contribute to the increasing number of the flare stars. For example, on October 29, 2010 in the Pleiades cluster in a 19 mag (V) star, unknown up to the moment as variable star, a flare with amplitude 4.7 (V) was registered (Masi, 2010).

Applying the subjects of Astroinformatics to the data concerning only the photographic observations of the flare stars in stellar clusters and associations we aim not only to re-use the accumulated monitoring photographic plates already in digital form, supplying digital curation, but also to enable extracting unrevealed knowledge for this type of variable stars.

2. FLARE STARS SEARCHES IN STELLAR CLUSTERS AND ASSOCIATIONS

In order to investigate this phenomenon and to reveal its nature, flare star searches in stellar clusters and associations begun in the Pleiades and the Orion region in 1947 and later on done in the frames of the international cooperative programme of several astronomical observatories - Tonantzintla, Byurakan, Asiago, Abastumani, Konkoly, Rozhen, etc. by photographic multiple exposure plate observations up to the last ones in the Pleiades and Cygnus in 1986, and in the Orion region in 1989. A lot of observing material was collected in the form of multiple exposure plates obtained by the multi-exposure method (stellar chains) applied with wide-field telescopes (Schmidt or Maksutov type). According to this method after a single exposure with duration usually of 5 up to 10 minutes, the telescope is moved along the Right Ascension coordinate and a new exposure is made with the same duration. The number of stellar images in one such chain is optimal up to 6. At a star showing brightness variations within the time period less than 10 minutes, its images in the respective stellar chain would be not equal. Monitoring the stars in this way one can discover not only brightness variability, comparing the plates obtained in the same region but in different periods, but also to detect brightness variability with time resolution less than 10 minutes.

In Fig. 1 the two-dimensional contour plot and density tracing of the flare star V 1214 Ori with the registered flare-event on January 14, 1985 in quiet state of the brightness 16.75 (pg), and reached maximum of the brightness 15.60 (pg), is shown. This flare star has shown two flare-events known as AB145 and the shown in Fig. 1 - LS6.

We collected the data from the flare star photographic monitoring observations in the stellar clusters and associations done in the period of the 60s up to the middle of 90s of last century. The observations are done as in the frames of the international cooperative programme, as well as from incidental observations. The stellar clusters and associations, where the number of observing hours is more than 100, are given separately. The flare stars proved to be from the solar neighbourhood and observed photoelectrically are not included. Not taken in view are the applied different observing techniques for flare star observations in stellar clusters and associations such as the fibre-fed multi-object spectrograph FLAIR on the UK Schmidt telescope in Australia (Guenther, 1995), and CCD based photometer attached to the 70 cm Abastumani Observatory meniscus telescope (Kurtanidze, 1995) for time-resolved spectroscopy and multicolour photometry.

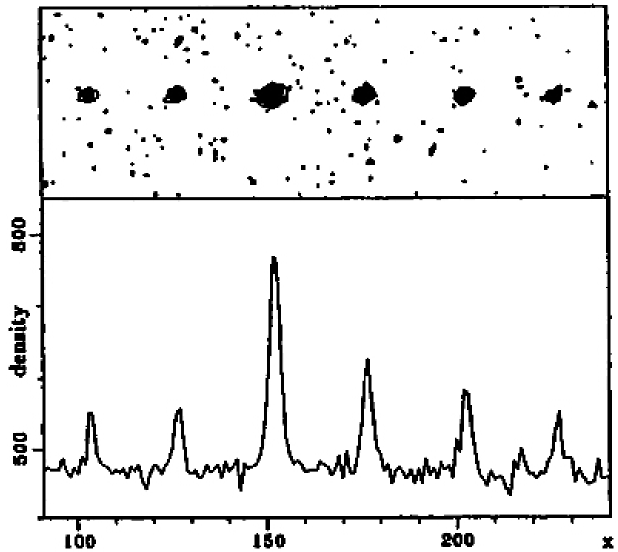

Figure 1. Two-dimensional contour plot and density tracing for a flare-event of V 1214 Ori.

Table 1: Flare stars photographic monitoring observations in stellar clusters and associations.

Stellar cluster or association	**Number of flare stars**	**Number of registered flares**	**Observing time (hours)**
Orion M42/M43	564	827	1591
The Pleiades	547	1635	3250
Taurus Dark Clouds	102	122	870
Cygnus NGC 7000	83	120	1168
Praesepe	59	146	680
NGC 2264	42	43	105
Cygnus IC 1318	17	18	300
Coma Open Cluster	14	21	338
Alpha Persei Cluster	7	7	128
Scorpius-Ophiuchus	14	15	321
Others	70	70	800
Total	**1519**	**3024**	**9551**

The distribution of the number of discovered flare stars (with total number 1519) and their registered flare-events (with total number 3024) in the respective stellar cluster or association (Fig. 2), as well as the distribution of the used observing time of 9551 hours versus the name of respective stellar cluster or association (Fig. 3) are given.

An automated flare search method was applied for some southern stellar aggregates with different age (Aniol et al., 1990, Winterberg et al. 1995). This method removed partially the selection effect due to the used 10-minute duration of the single exposure, which is a low time resolution. Thus it may preclude detection of energetic, but low amplitude flare-events on bright stars. So the flare star surveys with used flare star monitoring photographic method of multi-exposure images each of 10-minute duration usually discover the most chromospherically active stars. The less active stars could be missed. If the star is very faint it will be impossible to observe small flares. On the other hand this method increased the number of discovered flares (mainly slow flare events, flares on bright stars and on In-type variables) by 50 % compared to visual inspection by a blink-comparator.

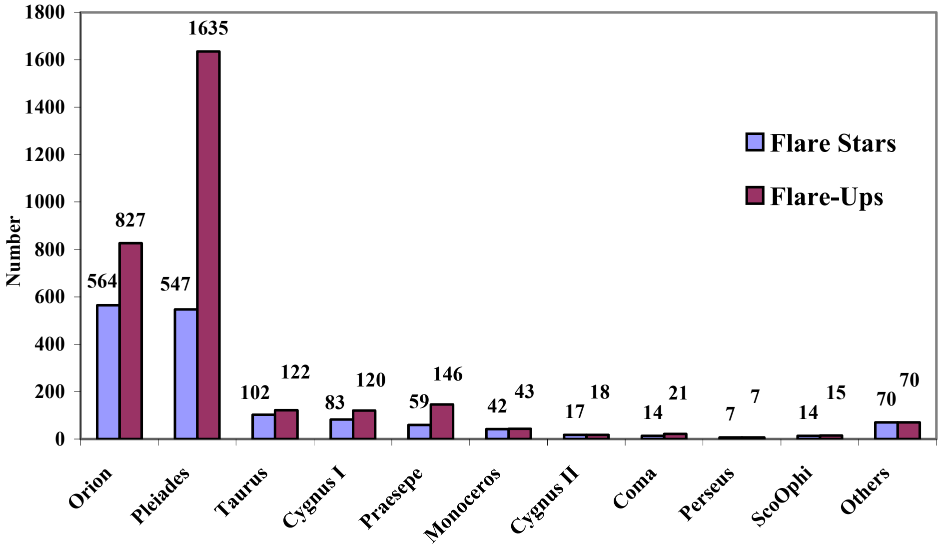

Figure 2. Flare stars and flare-ups in stellar clusters and associations.

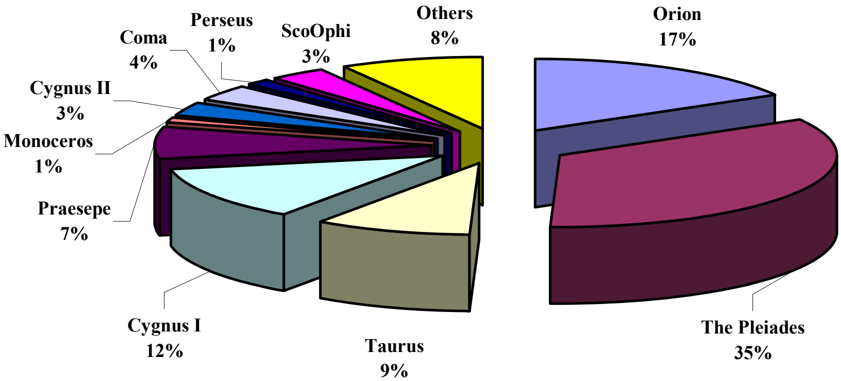

Figure 3. Used observing time for flare stars investigations in stellar clusters and associations.

3. EXISTING CATALOGUES OF FLARE STARS IN STELLAR CLUSTERS AND ASSOCIATIONS

We compiled catalogues or made computer-readable versions of already existing catalogues:

- Machine-readable version of the Tonantzintla Pleiades Flare Stars (Haro+, 1982, VizieR Catalogue - II/131 since 1987);
- Catalogues of the Cygnus flare stars (Tsvetkov and Tsvetkova, 1990);
- Catalogue of flare stars in the Praesepe cluster (Tsvetkova et al., 1991).

The original catalogues were checked by the help of a special programme package FLAREBASE (Tsvetkov et al., 1994). The aim was not only the preparation of master catalogues but also to make a critical evaluation and to ensure the homogeneity of the data, which are needed for basic statistical investigations, such as the construction of the number distribution of flare stars by stellar magnitude in quiescence or by outburst amplitude, time, and energy parameters in order to calculate the total flare event energy, etc.

4. FLARE STARS DATABASE

From the work on the flare stars catalogues in order to provide direct access to the original flare star data the Flare Stars Database (FSDB) was established (Tsvetkova et al., 1995; Tsvetkova et al., 1996). The FSDB is a database not only for UV Ceti type stars but also for their registered flare-events, which are missing in the other existing astronomical catalogues and data sets like GCVS, the Set of Identifications, Measurements and Bibliography for Astronomical Data

(SIMBAD), and the Database on UV Ceti Type Flare Stars and Related Objects (Gershberg et al., 1993, 1999).

The comparison with the mentioned catalogues and databases revealed that:

- in the GCVS, as well as in SIMBAD, the given information on stellar magnitude at minimum and maximum is not sufficient for assigning the flare event parameters. Very often, the lack of flare star identification charts is a reason for some misidentifications and errors in the GCVS (Tsvetkova and Tsvetkov, 1989),
- Gershberg's et al. (1993) database contains the data of only 230 UV Ceti type stars and some related objects. The complementary Catalogue and Bibliography of the UV Cet-Type Flare Stars and Related Objects in the Solar Vicinity of Gershberg et al. (1999) with 463 objects doubled the number of the stars and presented their astrometric, spectral, photometric data, as well as information on the infrared, radio and X-ray properties, and general stellar parameters.

Each flare-event is identified uniquely by the name of the variable star according to the GCVS (5 bytes); the name of the constellation (3 bytes); the date of the flare event - year, month, day (6 bytes); the consecutive number of events, occurring on the same date (1 byte). For example, the second flare-event happened and registered on the same date December 6, 1972 on the star V 426 TAU will have the identifier V_426TAU7212062.

After analysing the existing flare star data and having in mind the needed parameters describing the flare event we have adopted for the FSDB the following structure, shown in Table 2 with the flare stars metadata set.

The most serious obstacle for the FSDB is the lack for some stars in the literature of some necessary flare-event parameters as beginning and duration. Another lack is the flare star identification charts because of the faintness of some flare stars in minimum. That is why most of the astrometric works, as a rule, do not include flare stars yet (exceptions are the Pleiades flare stars and the works of Stauffer et al. 1991, and Prosser et al. 1991), but they go deeper and deeper reaching faint magnitudes.

5. DIGITAL PLATE ARCHIVES FROMMONITORING FLARE STARS PLATES

With collecting the observing material on whose basis these flare stars searches were made, and with preparing digital plate archives we aim search, preservation and re-usage of the world wide-field photographic monitoring flare stars plates. The digital plate archives can assemble and explore massive data sets and in this way to reveal a new knowledge existing in the data, but still not recognized in any individual data set. The next step towards the systematic astronomical research is the plate digitisation. The plate digitization makes possible automatic search for brightness increase, yielding in discovery of more flare stars in comparison with the usual plate checking. The organization of the plate scans in an image database and the development of a software system for object plate identifications and for searching in an image database with many data storage variants is the last step.

Table 2: Structure and Content of the FSDB.

MAIN DATA

↓ ↓ ↓ ↓

Flare-event identifier
Equatorial coordinates (R. A., DEC) of flare star for equinox J2000.0
Equatorial coordinates (R. A., DEC) of flare star for equinox J1950.0
Galactic coordinates in the l(II), b(II) system
Julian date of the flare-event
First registered flare-event
Telescope used
Stellar magnitude at minimum in U or Pg/ BPOSS bands
Stellar magnitudes at maximum in U- and Pg bands
Amplitudes in U and Pg bands
Criterion - $\Delta m > 5\sigma$
V magnitude, B-V and U-B indices at minimum
Spectral class
Aggregate membership

↓ ↓ ↓ ↓

CROSS-IDENTIFICATION
IDENTIFICATION CHARTS
REFERENCES
NOTES

The preparation of the digital plate archives of photographic monitoring flare stars plates began with the plates obtained in the Pleiades cluster as a good and accessible sample. The total number of the known Pleiades flare stars according to the Flare Stars Database (Tsvetkova et al., 1995) is 547, including some stars with doubtful membership to the flare stars class variables according to Tsvetkova and Tsvetkov (1989). The statistical evaluation of the total number of all flare stars in the Pleiades (registered and not registered up to now) is about 1000. Precise coordinates of the known Pleiades flare stars were determined as a necessary step to the further work of automated search for flare stars and investigations of long-term brightness variations. Searching the WFPDB for the Pleiades plates more than 3100 plates obtained in the period 1885 – 1998 were found in the observatories in Asiago (Italy), Sonneberg (Germany), Harvard (USA), Kyiv (Ukraine), Moscow (Russia), Rozhen (Bulgaria), Konkoly (Hungary), Byurakan (Armenia), Potsdam (Germany), Edinburgh (UK), Bamberg (Germany). The archive of the digitised plates in the Pleiades stellar cluster contained already about 1500 plates. One of these plates is present in Fig. 4 giving the low-resolution digitized image (with the kept marks of the observer) of the Rozhen

Schmidt telescope plate with the WFPDB identifier ROZ050_002278 taken on September 30, 1984 in the Pleiades cluster with the detected flare R24 in V 853 Tau. This large data set gives the opportunity to obtain almost continuous photometric data set for the red dwarf stars in the cluster and to search for probable cycles in the flaring activity as is found for some flare stars.

Figure 4. Plate with the WFPDB identifier ROZ050_002278 in the Pleiades cluster.

Another example is the Konkoly Flare Star Digital Archive containing representative plates obtained with the Schmidt telescope of Konkoly Observatory as one of the observatories taking part in the observation campaign for search and investigations of the flare stars in different stellar clusters and associations. Besides the primary aim to serve for investigations of the flare stars another result of this archive is the realization of an interlinking the electronic Information Bulletin on Variable Stars (IBVS) with the Wide-Field Plate Database (WFPDB). The plates are scanned with resolution up to 1200 dpi for plate visualization and to preserve the observer marks. The image is saved as TIFF (7322x7322 pixels) and as JPEG file (compressed to 2000x2000 pixels). After the cleaning the observer marks the plate is scanned with high resolution (2400 dpi) and saved as FITS file.

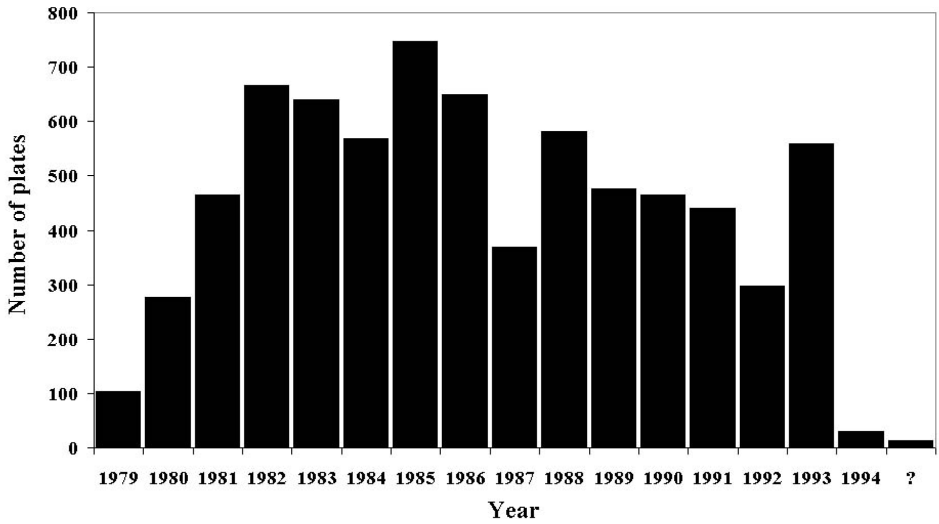

Figure 5. Time distribution of the Rozhen Schmidt telescope plates.

Now having at disposal an observing material (more than 1500 plates) from the monitoring flare star observations in Rozhen Observatory, done with the 50/70/172 cm Schmidt telescope in the period 1979 – 1995, we have started preparation of the Rozhen Flare Stars Digital Plate Archive in order to apply an automated flare stars search method on the basis of scanned flare stars monitoring plates of the Rozhen Observatory. Information for the plate archive of Rozhen Schmidt telescope (concerning the plate digitization as method of observation, plate size, etc.) can be found in Tsvetkova et al. (2010). Some useful characteristics of the plate material obtained with the Rozhen Schmidt telescope as time distribution of all plates, as well as observing programmes distribution, are presented in Figs. 5-6, respectively.

There are at disposal for plate scanning three EPSON flatbed scanners: EXPRESSION 1640XL and PERFECTION V700 PHOTO (in Sofia Sky Archive Data Center) and EXPRESSION 10000XL (in Rozhen Observatory). The plates are scanned in the whole density range 0 – 255 and Gamma = 1.00 twice according to a system for quick plate visualization (Preview plate images) with low resolution (1200 dpi), aiming easier web accessibility and storage of the information from the observer marks on the plate with Adobe Photoshop programme and plate storage in TIFF file format and compressed 1000x1000 pxl JPEG file format, and second time – after cleaning the plate with 2400 dpi resolution for further work (high-resolution scans) with the scanning programme SCANFITS in FITS file format. The volumes of the output files are given in Table 3.

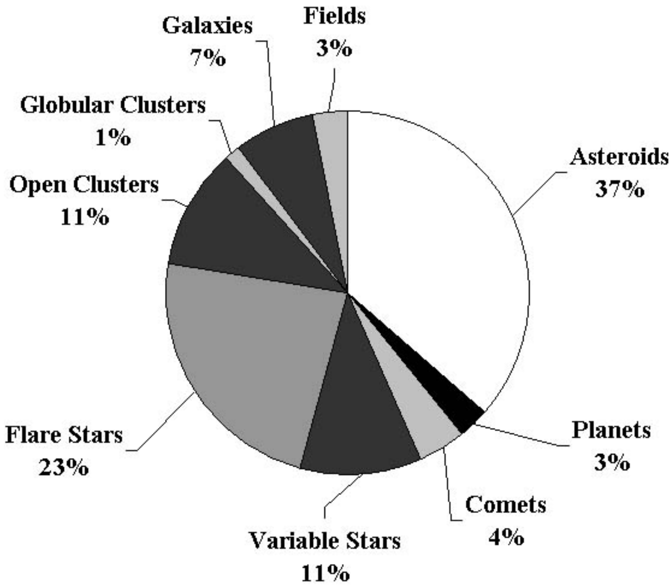

Figure 6. Used observing programmes for plate observations with the Rozhen Schmidt telescope.

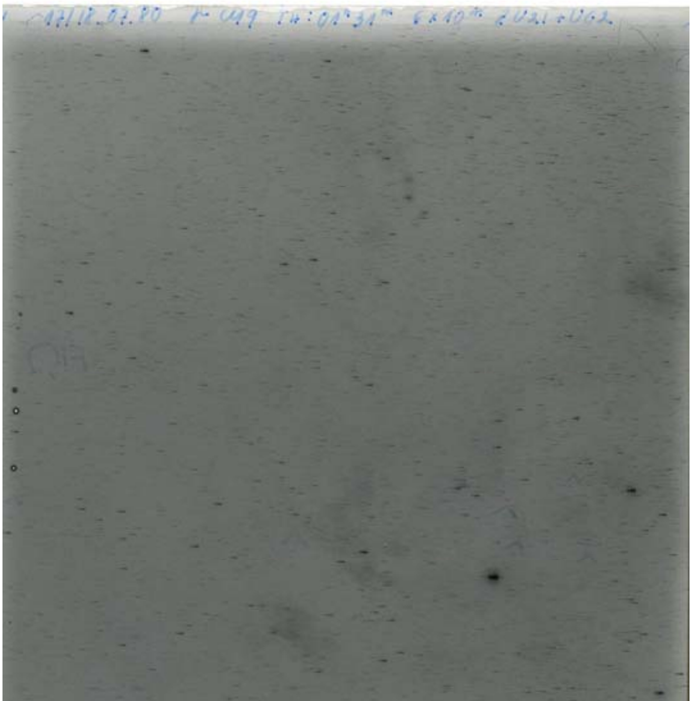

Figure 7. Plate with the WFPDB identifier ROZ050_000194 in the Gamma Cyg region.

Table 3: Output files volume of the Rozhen flare stars plate scanning.

File Format	Volume (MB)
JPEG	2.4
TIFF	107.0
FITS	286.0

The Rozhen Schmidt telescope plate with WFPDB identifier ROZ050_000194 was taken in the Gamma Cyg region on July 17, 1980. On the plate the flare R5 in the star V1757 Cyg with amplitude bigger than 4.8 (U) was registered.

It could be expected that the undertaken automated flare stars search will increase the number of discovered flare stars and flare-events compared to the visual inspection by a blink-comparator done before in the observatory.

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THE Fe II LINES IN AGN SPECTRA

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Abstract. We present a study of optical Fe II emission in 302 AGNs selected from the SDSS. We group the strongest Fe II multiplets into three groups according to the lower term of the transition (b ^{4}F, a ^{6}S and a ^{4}G terms). We calculate an Fe II template which takes into account transitions into these three terms and an additional group of lines, based on a reconstruction of the spectrum of I Zw 1. This Fe II template gives a more precise fit of the Fe II lines than other templates. We notice that the ratios of blue, red, and central parts of the iron shelf depend on some spectral properties as continuum luminosity and FWHM Hβ. We examine the dependence of the well-known anti-correlation between the equivalent widths of Fe II and [O III] and we found possible connection with the Baldwin effect.

1. INTRODUCTION

There are many unresolved questions concerning optical Fe II (λλ4400-5400 Å) lines. Some of them are: geometrical place of the Fe II emission region in AGN, processes of excitation which produce Fe II emission, as well as some correlations of the Fe II lines and other AGN spectra properties which need a physical explanation. It is established that the Fe II emission depends on the radio, X and IR parts of the continuum and also some correlations with other lines in spectra are observed (for review see Lipari and Terlevich, 2006). One of the most interesting is the relation between equivalent widths of the Fe II and [O III] lines, which physical background is still not explained (see Boroson and Green, 1992).

In this paper, we investigate the Fe II emitting region by analyzing the correlations between the optical Fe II lines and the other emission lines within a sample of 302 AGN from the SDSS. To do this, we construct an Fe II template. The strongest Fe II multiplets within the λλ4400-5400 Å range are sorted into three groups, according to the lower terms of the transitions. We analyze relationships between ratios of Fe II line groups and other spectral properties, as well as anticorrelation between EW Fe II and EW [O III].

2. THE SAMPLE AND ANALYSIS

Spectra for our data sample are taken from the 7th data release (Abazajian et al., 2009) of the Sloan Digital Sky Survey (SDSS). We used an SQL search to obtain the best sample of AGN spectra, with following requirements: high signal to noise ratio (S/N>20), good pixel quality, high redshift confidence (zConf > 0.95) and with z < 0.7, negligible contribution from the stellar component (EW CaK 3934 Å, Mg 5177 Å and Hd 4102 Å > -1).

Spectra are corrected for Galactic reddening, using procedure described in paper Schlegel et al. (1998). Continuum emission is substracted by DIPSO software.

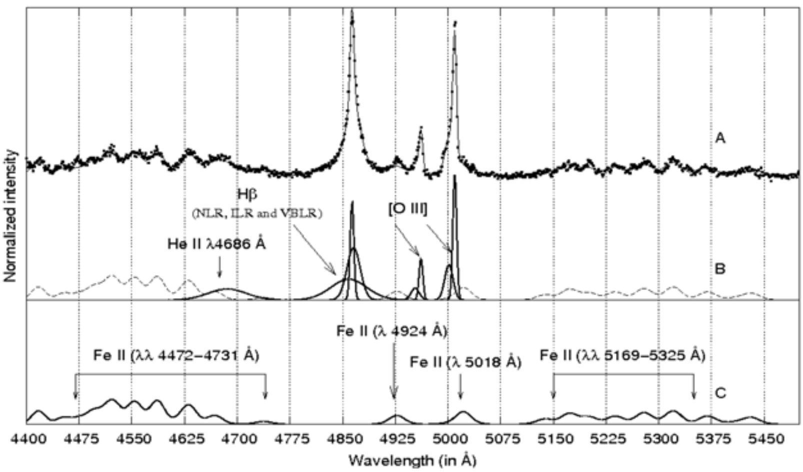

Figure 1. Example of fit of the SDSS J141755.54+431155.8 in the λλ4400-5500 Å range.

We fit all considered lines in λλ4400-5500 Å range (Fe II, [O III], Hβ), with a sum of Gaussian functions of different shifts, widths and intensities, which reflects physical conditions of emission regions where those components arise (see Fig. 1). We assume that Balmer lines have three components: NLR, ILR and VBLR (Ilić et al., 2006; Bon et al., 2006 ; Hu et al., 2008), and we fited them with three Gaussians of different width and shift. Optical Fe II lines were fited with calculated template.

3. RESULTS

The Fe II template

We calculated the Fe II template, using the 50 Fe II emission lines, identified as the strongest within the λλ4400-5500 Å range. The 35 of them are separated in the three line groups according to their lower level of transition: $3d^6$ (^{3}F2)4s ^{4}F, $3d^5 4s^2$ ^{6}S and $3d^6$ (^{3} G)4s ^{4}G (in further text F, S and G group of lines).

The lines from three line groups describe about 75% of Fe II emission in observed range (λλ4400-5500 Å), but about 25% of Fe II emission can not be explained with permitted lines which excitation energies are close to these of lines from the three line groups.

In order to complete the template for missing 25%, we selected 15 lines which probably arise with some of these mechanisms, from Kurutcz database (http://kurucz.harvard.edu/linelists.html). The selected lines have wavelengths on missing parts, strong oscillator strengh and their energy of excitation goes up to ~11 eV. Relative intensities of these 15 lines are obtained from I Zw 1 spectrum by making the best fit together with Fe II lines from the three line groups.

We have assumed that each of lines can be represented with a Gaussian, described by width (W), shift (d) and intensity (I). Since all Fe II lines from the template probably originate in the same region, with the same kinematical properties, values of d and W are the same for all Fe II lines in the case of one AGN, but intensities are assumed to be different. We suppose that relative intensities between the lines within one line group (F, S and G) can be obtained as:

$$\frac{I_1}{I_2} = (\frac{\lambda_2}{\lambda_1})^3 \frac{f_1}{f_2} \cdot \frac{g_1}{g_2} \cdot e^{-(E1-E2)/kT}$$

where I_1 and I_2 are intensities of the lines with the same lower level of transition, λ_1 and λ_2 are line wavelengths, g_1 and g_2 are corresponding statistical weights, and f_1 and f_2 are oscillator strengths, E_1 and E_2 are energies of upper level of transitions, k is Boltzman constant and T is the excitation temperature.

According to that, the template of Fe II is described by 7 parameters of fit: parameter of the width, parameter of the shift, four parameters of intensity – for F, S, G and group of lines obtained from I Zw 1 object, as well as excitation temperature.

We applied this template to our sample of 302 AGNs from SDSS database, and we found that the template can satisfactorily fit the Fe II lines.

The ratios of Fe II line groups vs. other spectral properties

Since line intensities and their ratios are indicators of physical properties of the plasma where those lines arise, we have investigated relations among the ratios of Fe II line groups with various spectral properties. The F, S and G line groups correspond approximately to the blue, central and red part of the iron shelf, respectavely.

We find that the ratios of different parts of the iron shelf (F/G, F/S, and G/S) depend on some spectral properties such as: continuum luminosity and Hβ FWHM. Also, it is noticed that spectra with Hβ FWHM greater and less than ~3000 km/s have different properties which is reflected in significantly different coefficients of correlation between the parameters.

We found that all three ratios (F/G, F/S and G/S) are in significant correlation with FWHM Hβ for subsample with FWHM Hβ > 3000 km/s. The obtained coefficients of correlation are: F/G vs. FWHM Hβ ($r = 0.36$, $P = 1.2E-5$), F/S vs. FWHM Hβ ($r = 0.59$, $P = 1.3E-14$) and G/S vs. FWHM Hβ ($r = 0.44$, $P = 6.1E-8$).

No correlations between these parameters are observed for subsample with FWHM Hβ < 3000 km/s. Also, we found the correlation between F/G ratio and continuum luminosity $\log(L_{5100})$, which is more significant for FWHM Hβ < 3000 km/s subsample: $r = -0.51$, $P = 5.7E-12$. The correlation between F/S and $\log(L_{5100})$ is also observed ($r = -0.41$, $P = 7.9E-8$), for the same subsample.

EW Fe II vs. EW [O III]

One of the problems mentioned in the introduction is the anti-correlation between the equivalent widths of the [O III] and Fe II lines which is related to Eigenvector 1 in the analysis of Boroson and Green (1992). Some physical causes proposed to explain Eigenvector 1 correlations are: (a) Eddington ratio L/L_{Edd}, (b) black hole mass M_{BH}, and (c) inclination angle (for detailed review see Kovačević et al., 2010). Wang et al. (2006) suggested that EV1 may be related to AGN evolution.

We confirmed the EW Fe II vs. EW [O III] anti-correlation in our sample ($r = -0.39$, $P < 0.0001$, see Fig 2).

To try to understand the EW Fe II vs. EW [O III] anti-correlation, we examined its relationship to continuum luminosity. We examined the relations of equivalent widths of Fe II and [O III] lines vs. L_{5100}. We confirmed a strong Baldwin effect (see Baldwin, 1977) for [O III] lines ($r = -0.43$, $P = 4E-15$), and an inverse Baldwin effect for EW Fe II lines ($r = 0.30$, $P = 2E-7$), i.e. we found that as continuum luminosity increases, EW Fe II also increases, but EW [O III] decreases (see Fig 3). In Fig 3, objects with redshift within range $z < 0.1$ are denoted with open squares, $0.1 < z < 0.2$ with filled triangles, $0.2 < z < 0.3$ with open circles, $0.3 < z < 0.4$ with filled squares, $0.4 < z < 0.5$ with open triangles, $0.5 < z < 0.6$ with filled circles and $0.6 < z < 0.7$ with stars.

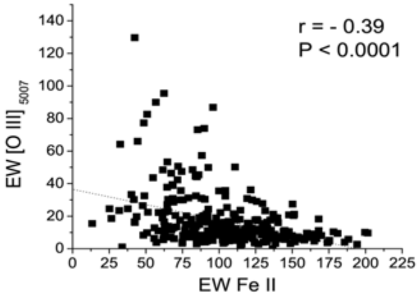

Figure 2. Relationship between the EW [O III] l5007 Å vs. EW Fe II.

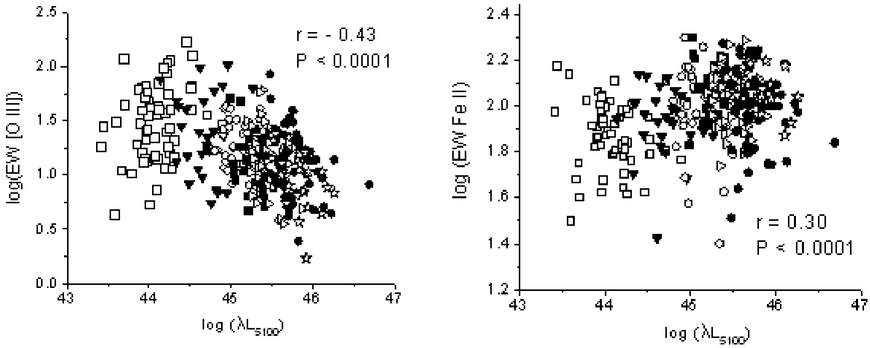

Figure 3. The Baldwin effect significant for the [O III] lines (left panel), while an inverse Baldwin effect is detected for the optical Fe II lines (rigth panel).

This implies that the EW Fe II - EW [O III] anti-correlation may be influenced by Baldwin effect for [O III] and an inverse Baldwin effect for Fe II lines. Also, in our analysis we found that the strength of the Baldwin effect depends on the FWHM Hβ of the sample. Note that FWHM Hβ is one of the parameters in Eigenvector 1.

The origin of the Baldwin effect is still not understood and is a matter of debate. The increase of the continuum luminosity may cause a decrease of the covering factor, or changes in the spectral energy distribution (softening of the ionizing continuum) which may result in the decrease of EWs. The inclination angle may also be related to Baldwin effect. The physical properties which are usually considered as a primary cause of the Baldwin effect are: M_{BH}, L/L_{Edd}, and changes in gas metalicity. Also, a connection between Baldwin effect and AGN evolution is possible (for detailed review see Kovačević et al., 2010).

Conclusions

1. We have proposed an optical Fe II template for the λλ4400-5500 Å range, which consists of three groups of Fe II multiplets, grouped according to the lower terms of transitions (F, S and G), and an additional group of lines reconstructed from the I Zw 1 spectrum. We found that template can satisfactorily fit the Fe II lines.
2. We find that the ratios of different parts of the iron shelf (F/G, F/S, and G/S) depend of some spectral properties such as: continuum luminosity and Hβ FWHM. Also, it is noticed that spectra with Hβ FWHM greater and less than ~3000 km/s have different properties which is reflected in significantly different coefficients of correlation between the parameters.
3. We confirm in our sample the anti-correlation between EW Fe II and EW [O III] which is related to Eigenvector 1 (EV1) in Boroson and Green (1992) and we examined its dependence on the continuum luminosity. We found an inverse Baldwin effect for Fe II lines, and Baldwin effect was confirmed for the [O III] lines. Since EW Fe II increases, and EW [O III] decreases with increases of continuum luminosity, the observed EW Fe II vs. EW [O III] anti-correlation is probably due to the same physical reason which causes the Baldwin effect. Moreover, it is observed that the coefficients of correlation due to Baldwin effect depend on Hβ FWHM range of a sub-sample, which also implies the connection between the Baldwin effect and EV1.

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BRASHEAR PLATE CATALOGUES IN THE WIDE-FIELD PLATE DATABASE

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Abstract. We present the work of reduction and inclusion of the Brashear Plate Catalogues in the Wide-Field Plate Database (WFPDB). About 5000 plates were obtained with the Brashear astrograph of the Tokyo Astronomical Observatory located in Mitaka in the period 1943-1962. The astrograph was equipped with two cameras: 16 cm Zeiss Tessar and 20 cm Petzval Triplet. The observing programme included mostly asteroids and comets. We divided the Brashear plates in two catalogues accordingly the both used cameras, to which were assigned the following WFPDB identifiers respectively TOK016 and TOK020. Analysis of the catalogues using the available data is present. Comparison of the original catalogues with the files obtained from the scanned in table form catalogues and following image processing is present too.

1. INTRODUCTION

With the Brashear astrograph of the Tokyo Astronomical Observatory located in Mitaka campus in the period 1943-1962 about 5000 plates were obtained according to Nakamura et al (1990). The Brashear astrograph was equipped with two cameras whose parameters satisfy the Wide-Field Plate Database (WFPDB, http://www.wfpdb.org) criterion for plate inclusion. According to the accepted WFPDB standards the Brashear astrograph cameras - Petzval Triplet and Zeiss Astro Tessar - received the WFPDB identifiers – TOK020 and TOK016 respectively. Table 1 presents the information concerning the camera parameters for the both instruments included in the Catalogue of the Wide-Field Plate Archives (Tsvetkova and Tsvetkov, 2006).

Table 1: The Brashear astrograph cameras parameters

WFPDB identifier	Camera	D cm	F. length cm	Field of view arcmin	Scale arcmin/mm
TOK020	Petzval Triplet	20	127	6.8 x 9.2	2.706
TOK016	Zeiss Astro Tessar	16	79	11.3 x 15.0	4.364

Nakamura et al (1990) presented lists of obtained plates. In Fig. 1 a part of these tables is given. We put the aim to convert the plate lists in a computer-readable form in order to include the plate information into the WFPDB.

2. OCR OF TABLES AND DATA TRANSFORMATIONS

We use OCR software (http://www.cuneiform.ru/) for extracting data having at disposal the tables (Fig. 1), given in Nakamura et al. (1990).

PLATE NO.		DATE	TIME	EXP	CENTRAL OBJECT	R.A.	DEC	NOTE
B3588	Z0878	1960/10/18	10:25:00	20:00	M-P	00:01.6	+17:25.7	103A-O-8
B2033		1950/09/16	22:59:03(J	42:00	M-P	00:03.3	-13:23.2	O.S.B.-8
B1761		1949/12/09	18:00:29(J	40:00	C-1949E	00:03.7	-04:07.5	O.H.P.-K
B3597	Z0887	1960/10/21	11:19:00	20:00	M-P	00:05.2	-02:02.5	103A-O-8

Figure 1. Part of the original tables of Nakamura et al. (1990).

When we finished this step, T. Nakamura sent us a file with the data. Thus we proved that OCR gives us 90% correct recognition of the table columns. This encourages us to recommend Cuneiform for OCR of tables.

We reduced the data to the accepted WFPDB format by:

- Conversion of the given time of observations JST (Japan Standard Time) to required Universal Time (UT), i.e. JST = UT + 9h.
- Conversion of the coordinates of the plate centers (RA and DEC) given according to Nakamura (2010) in equinox B1950 to equinox J2000.
- Assigning object code in the main data file.

3. STATISTICS

The metadata for total 868 plates for TOK016 and 1577 plates for TOK020 are included in WFPDB. The time distribution of the plates is presented in Fig. 2. The distribution of the number of plates versus used exposure is given in Fig. 3.

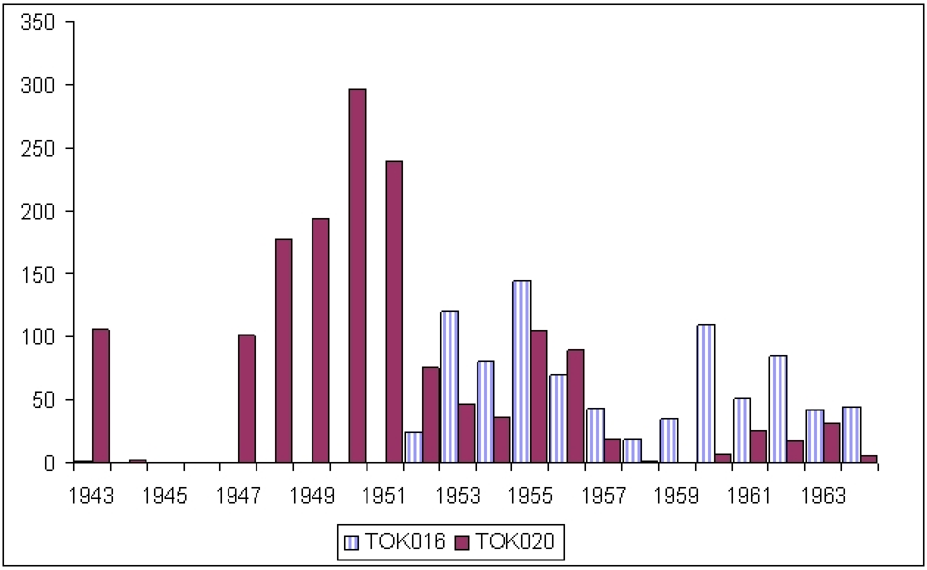

Figure 2. Time distribution of the plates.

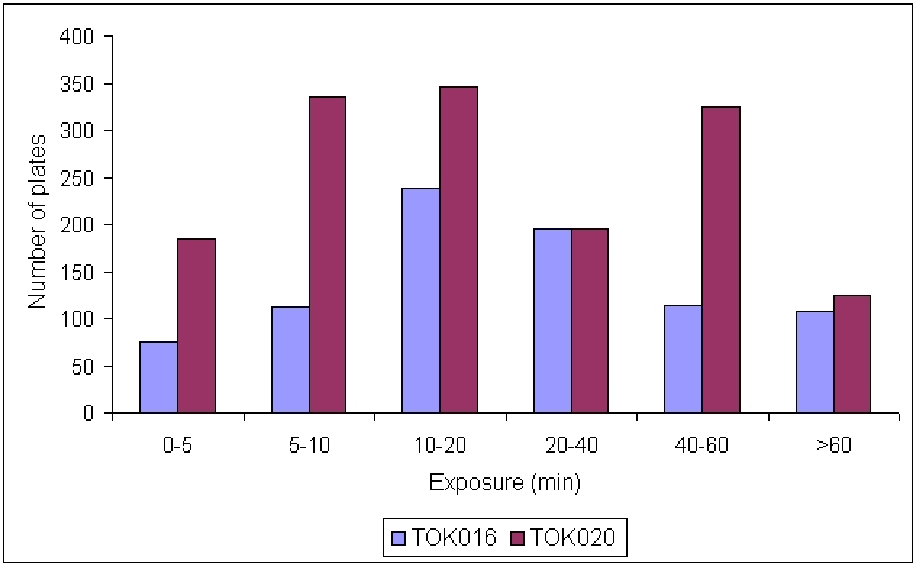

Figure 3. Distribution of the plates with respect to the used exposure.

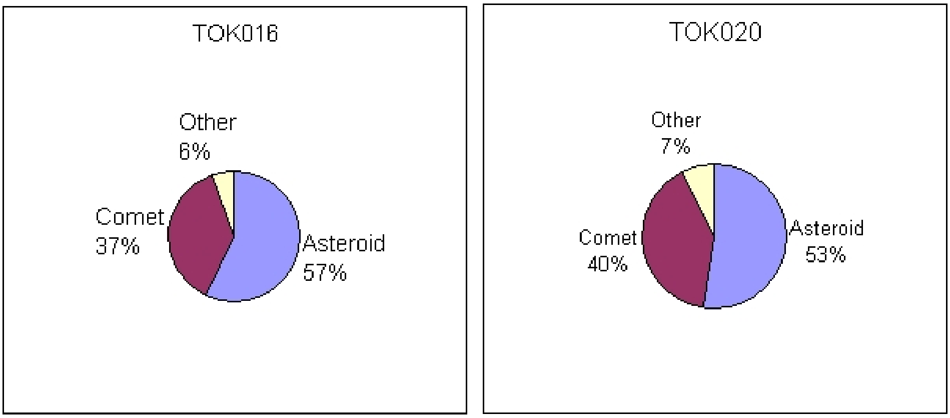

Figure 4. Distribution of the plates with respect to the type of the observed objects.

The most common objects of observations were asteroids and comets as can be seen in Fig. 4. The observations of variable stars, and especially supernova are presented in Table 3.

Table 3: Plate number used for variable stars observations.

Type of observed object	TOK020	TOK016
Variable stars	33	7
Supernova	1	6

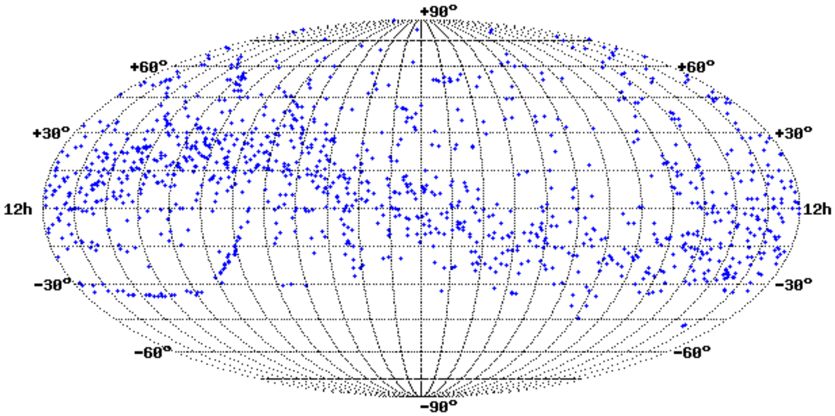

Figure 5. All-sky distribution for TOK020 plate centers.

Details for archive: **TOK016**

Location of the Archvie:	*Clear aperture:* **0.16** m
Site: **Mitaka**	*Mirror diameter:*
Country: **Japan**	*Focal length:* **0.79** m
Observatory:	*Scale:* **262** "/mm
Name: **Tokyo**	*Type:* **Cam**
Site: **Mitaka**	*Field size:* **15.7°**
Country: **Japan**	*Years of operation:*
Time zone: **+9** h	From: **1943**
East longitude: **139° 32.5'**	To: **1962**
Latitude: **35° 40.3'**	*P/F:*
Altitude: **62** m	

Number of direct plates: **703**	
Archive type: **C**	
Number of spectral plates:	
Archive type:	
Number of plates in WFPDB: **868**	
Quality:	
Astronomer in charge: **T.Nakamura**	

All-sky distribution of the plate centres:

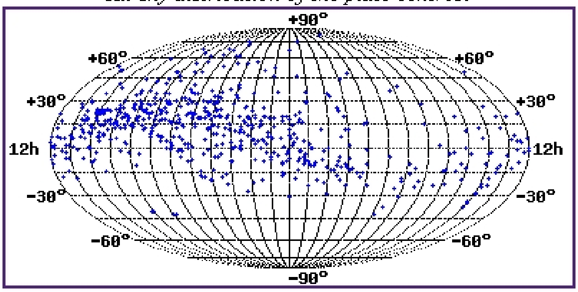

Figure 6. Description of the WFPDB TOK016 plate archive.

Details for: **TOK020 002589**

IDobs: **TOK**	OBJNAM: **M-P**
IDins: **20**	OBJTYP: **A4**
IDsuf1:	METHOD: **01**
IDno: **002589**	MULTEX:
IDsuf2:	EXP: **10.0**
RAJ2000: **03 41 10**	EMULS: **O.S.B.-8**
DEC2000: **13 13 11**	FILT:
CCOD:	SPEC:
DATE: **1953 11 13**	DIMx: **16**
UT: **17 35 38**	DIMy: **22**

Figure 7. Metadata for the WFPDB TOK020_002589 plate.

Figs. 5 – 7 presents different information for the WFPDB TOK020 and TOK016 plate catalogues.

Acknowledgments

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SEARCHING FOR PERIODICITIES IN AGN

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Abstract. Active Galactic Nuclei (AGNs) often show high variability in the spectral lines and continuum. This variability may be periodical, that may indicate a binary black hole in the center of some AGNs. Here we applied method of continuous wavelet transform for periodicity searching in the optical spectra of 3C390.3. There is a chance that long term variability is present.

1. INTRODUCTION

Active galactic nuclei (AGN) often exhibit variability in the broad emission lines. The region where broad lines are formed (hereinafter BLR – broad line region) is close to the central supermassive black hole and may hold basic information about the formation and fueling of AGN.

A long-term spectral monitoring of the nucleus of some AGN has revealed a time lag in the response of the broad emission lines relative to flux changes in the continuum. This lag depends on the size, geometry, and physical conditions of the BLR. Thus, the search for correlations between the nuclear continuum changes and flux variations in the broad emission lines may serve as a tool for mapping the geometrical and dynamical structure of the BLR (e.g., Peterson, 1993).

Studies of the variations in both the continuum and broad emission-line profiles and their correlations can provide information about the BLR physics (see e.g., Shapovalova et al., 2009).

2. OBSERVATIONS

Spectra of 3C 390.3 (during 158 nights) were taken with the 6 m and 1 m telescopes of the SAO RAS (Russia, 1995–2007) and with INAOE's 2.1 m telescope of the "Guillermo Haro

Observatory" (GHO) at Cananea, Sonora, Mexico (1998–2007). They were acquired using long-slit spectrographs, equippedwith CCD detector arrays. The typical wavelength interval covered was from 4000 Å to 7500 Å, the spectral resolution varied between 5 and 15 Å, and the S/N ratio was > 50 in the continuum near Hα and Hβ. Spectrophotometric standard stars were observed every night.

The spectrophotometric data reduction was carried out using either the software developed at SAO RAS or the IRAF package for the spectra obtained in Mexico. The image reduction process included bias and flat-field corrections, cosmic ray removal, 2D wavelength linearization, sky spectrum subtraction, addition of the spectra for every night, and relative flux calibration based on standard star observations.

3. METHOD AND RESULTS

Searching for periodicity has been an important part of variability studies of AGN, because the confirmed periodicity would strongly constrain possible physical models and help us to determine the relevant physical parameters of AGN.

We therefore applied a wavelet transform with the Morlet wavelet to see if there is periodicity in the continuum light curve. Wavelet analysis involves a transform from one-dimensional time series to a diffuse two-dimensional time-frequency image for detecting localized (pseudo-) periodic fluctuations from subsets of the time series corresponding to a limited time span (Torence and Compo, 1998).We employed the standard wavelet codes of Torence and Compo (1998) to look for periodicities in the 3C 390.3 optical-continuum and Hβ light curve.

A Morlet wavelet is particularly suited to the analysis of time series and has been successfully applied to study variability in AGN (i.e. Lachowicz et al., 2009).

We therefore employ a Morlet wavelet here, which is defined as

$$\Psi_t(s) = \pi^{-1/4} e^{ikt} e^{\frac{-t^2}{2s^2}}$$

where t is the time parameter, $\pi^{-1/4}$ is the normalization factor, and s, k are wavelet scale and oscillation frequency parameter, respectively. The parameter k has been set equal to 6 to satisfy the admissibility condition.

The continuous wavelet power spectra is subjected to the edge artefacts because the wavelet is not completely localized in time. It is useful to introduce a cone of influence (COI) in which the transform suffers from these edge effects (Torence and Compo, 1998). Periods inside the COI are subjected to edge effects and might be dubious.

Figures 1 and 2 show the continuous wavelet power spectra of the long-term light curve in the optical continuum and Hβ, respectively. There are evidently common features in the wavelet power of the tree time series. Both wavelet spectra have a long-term periodicity (1.7 and 2.17 yr) in the late part of the light curve, above the 95 % confidence level, but within the COI (periodicity being too close to the total signal length).

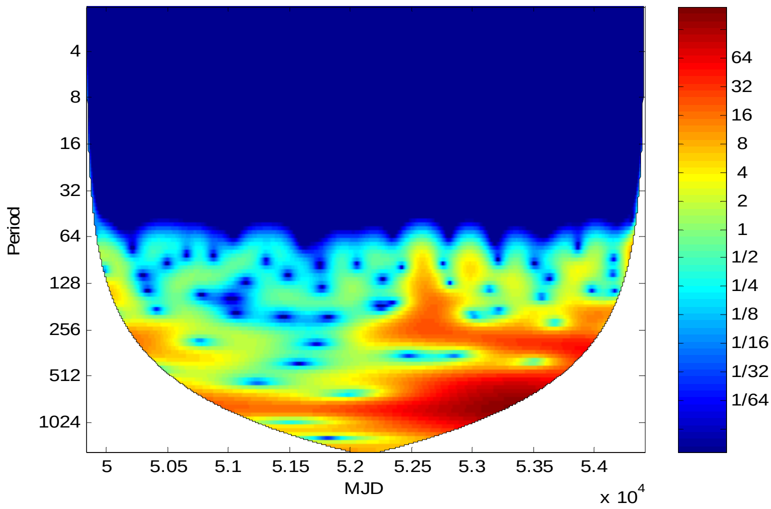

Fig. 1. Continous wavelet transform of optical continuum 3C3903.3 Calculated periodicity 630 days (1.7 years).

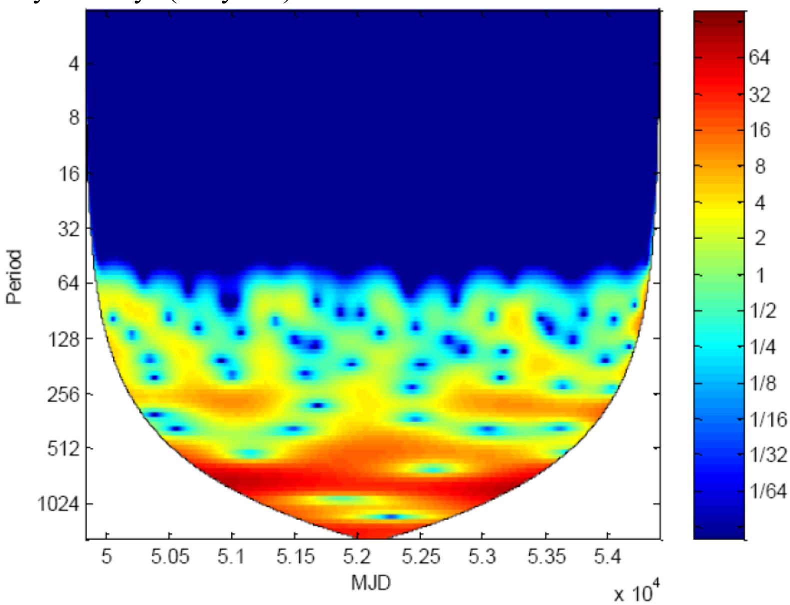

Fig. 2. Continous wavelet transform of Hβ light curve of 3C3903.3. Calculated periodicity 792 days (2.17 years).

3. CONCLUSIONS

We found indices of long term variability (LV) in the Hβ and continuum light curve, as commonly observed for stellar-mass black holes.

The periodicity of the light curves is probably connected with some shock waves near the supermassive black hole spreading in the outer part of the disk, but on the other hand, we cannot exclude the contribution of either ejection or jets to LV.

Acknowledgements

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WIDE-FIELD PLATES OBSERVATIONS OF STARS FROM EARTH ORIENTATION CATALOGS (EOC)

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Abstract. The Earth Orientation Catalogues (EOCs) are primarily meant to provide stable celestial reference frame in optical wavelengths for deriving Earth Orientation Parameters (EOP) from astrometric observations. The EOCs combine catalogues ARIHIP and TYCHO-2 with the rich observation material (variations of Latitude/Universal Time), obtained during the 20th century in programs of monitoring Earth orientation. Other possible source of information for improving the EOCs is the WFPDB (Wide-Field Plate Database). The number of plates, containing EOCs stars and their distribution in time are determined by means of the search engine of the WFPDB.

1. INTRODUCTION

A significant part of the scientific investigations in the field of geosciences is directly connected with astrometrical observations and star catalogues. Namely the sections of geosciences, which determine the Earth orientation in the space with respect to the Celestial Reference Frame: geodesy, geophysics, geodynamics, etc., are involved. The optical astrometry and the astrometrical observations are useful to study decadal variations of the Earth rotation and gravity. The long-term oscillations of the verticals, determined from universal time and latitude data in the 20th century, are useful for study of the local and regional gravity changes and their interconnections with some natural phenomena. The combination of optical astrometry data with modern space-based observational techniques, such as VLBI, GPS and SLR significantly expands the possibility of long-term analysis of Earth rotation and gravity.

The astrometrical observations of geographic latitude and universal time were a unique source of information of Earth orientation during the most of the last century. Nowadays the astrometrical observations from the period 1899-1992 are the only centenary series, used for determination of the variations of the local plumb-lines and Earth rotation and give us unique possibility of searching causality between these variations and global changes of the environment, climate, solar activity, ice melting and post-glacial rebound, mean sea level arising, earthquakes etc. Necessary precondition of successful utilization of the astrometrical observations in the field of modern scientific investigations is the improvement of the accuracy of star catalogues, where the proper motion of the stars (or their annual velocity on the celestial sphere) is a critical parameter. The determination of the proper motions with sufficient accuracy requires all star observations from the early epochs. The modern space observational campaigns that provide very accurate star positions are too short to allow estimation of the proper motions valid in a century spans. In this sense the accuracy increase of the proper motions is possible by using all possible star observations from the last century, which will facilitate the investigation of the decadal variations of the Earth gravity and rotation and their interconnection with some natural phenomena.

The optical astrometry data consist of more than 4 millions observations, collected from 33 observatories and the longest latitudinal series are from the observatories Carloforte, Gaithersburg, Kitab, Mizusawa, Ukiah, Pulkovo and Washington. The reliable astronomical observations have some advantages: they are directly connected with the Earth orientation parameters and gravity; they form a unique source of observations in the last 4 century, which is suitable for long-term analysis. The disadvantages of observations before 1992 from the optical astrometry are: less observations in the past, not suitable for short-term analysis and significant systematic errors in old star catalogues. The last disadvantage means that the successful use of optical astrometry data leads to necessity of improved star catalogues.

Nowadays we have four solutions for Earth Orientation Catalogs (EOC): EOC-1, 2, 3, 4 and six solutions for Earth Orientation Parameters (EOP): OA97, OA99, OA00, OA04, OA07 and OA10. Many observatories create their own individual solutions of star catalogues, for example - observatories Plana (Chapanov, 1998) and Ondřejov (Ron and Vondrák, 2003).

2. EARTH ORIENTATION CATALOGS IMPROVEMENT

The Earth Orientation Catalogs (EOC) are primarily meant to provide stable celestial reference frame in optical wavelength for deriving Earth Orientation Parameters (EOP) from astrometric observations. The general ideas of constructing these catalogs were outlined by Vondrák and Ron (2003). The principal source of information are the catalogs ARIHIP (Wielen et al., 2001) and TYCHO-2 (Høg et al., 2000), and the rich observation material (variations of latitude / Universal time) obtained during the 20th century in programs of monitoring Earth orientation. The main idea is to combine these two sources together.

The first version EOC-1 (Vondrák and Ron, 2006) was based on the combination of the observations made only in local meridian with ARIHIP, TYCHO-2, and some other catalogues. Later the observations by the method of equal altitudes (astrolabes, circumzenithals) were added, and the version EOC-2 constructed (Vondrák, 2004). This version was based on almost about 4.5 million individual observations made with 47 different instruments at 33 observatories all over the world, in the interval 1899 – 2003. The observations of latitude started in 1899, while the universal time observations were limited to period after 1956, when the International Atomic Time (TAI) became available.

The observed stars were identified in the following catalogs, from which the positions, proper motions, parallaxes and radial velocities were taken over: ARIHIP (2995 entries); TYCHO-2 (1248 entries); Hipparcos (144 entries); PPM (28 entries); local catalogs of individual observatories (3 objects). These stars formed zero-version catalog, called EOC-0, containing 4418 different objects (stars, components of double stars, photocenters).

The stars were checked for multiplicity whenever the statistically significant deviation of observed positions from catalog entry was met. In case of double stars, the displacement of the reference point (very often photocenter) was estimated and the position in EOC-0 was corrected. The individual values of deviations of measured universal time δUT, latitude $\delta\varphi$ and altitude δh from the catalog EOC-0 were then computed as the deviations from the mean value of the night, based on only astrometrically excellent stars.

To combine individual observations with catalog entry in EOC-0, the catalog is represented by three virtual observations of right ascension and declination in three epochs $t_1=t_0 - 90$y, $t_2=t_0$ and $t_3=t_0+10$y, where t_0 is the mean epoch of the catalog. Standard errors of these virtual observations, based on standard error of position and proper motion, are then calculated and used to determine their weights. They are chosen so that a linear regression through the three virtual observations yields exactly the original catalog entry, including the original standard errors. The weights of the real individual observations are all equal to 1. Linear regression through all observations (including the virtual ones) then provides the positions and proper motions of EOC-1 and EOC-2.

Because the periodic character of the residuals for certain stars was evident, another version of the catalogue, called EOC-3 was constructed later (Vondrák and Štefka, 2007), containing information on the periodicity of some of the observed objects. To this end, the same Earth orientation observations as in preparing EOC-2 were used. It was made in two independent steps:

- Improvement of positions and proper motions (identical with the procedure used for EOC-1 and EOC-2);
- Looking for periodic changes by analyzing annual averages of residuals (using spectral analysis proposed by Lomb (1976), and looking for periods in Sixth Catalog of orbits of visual binary stars (Hartkopf et al., 2006). In a positive case, the residuals were used to estimate sine/cosine terms of up to two different periods and their second-order higher harmonics, i.e., up to 16 sine/cosine terms. EOC-3 thus contains 586 objects with periodic motions.

Later some disadvantages of this catalog were discovered – the periodic terms are based on annual averages, not individual observations, which can lead to somewhat diminished amplitudes for shorter periods; and the periodic terms are derived independently of the positions and proper motions, which causes that the EOC-3 positions, calculated for the mean epoch of original catalogs (ARIHIP, TYCHO-2...) often significantly differ from the positions in these catalogs. Therefore, a new catalog EOC-4 was constructed, based on the idea that positions, proper motions and periodic terms are estimated in one-step solution, derived from combination of individual and virtual observations. First outline of this work and its main ideas were published by Vondrák and Štefka (2008).

The objects with periodic parts in EOC-3 were inspected again and some values of the periods were slightly changed. The total number of stars with periodic motions is equal to 599.

The following solutions of Earth Orientation Parameters, based on Earth Orientation Catalogs, were made:

- OA97 (Vondrák et al., 1998), OA99 (Vondrák et al., 2000), and OA00 (Ron and Vondrák, 2001) that were based on original Hipparcos Catalogue with only some of the proper motions improved;
- OA04 (Vondrák and Ron, 2005) with EOC-2;
- OA07 (Vondrák, Ron and Štefka, 2008) with EOC-3;
- OA10 (Vondrák et al., 2010) with EOC-4.

3. EOC-3 STATISTICS

The star catalog EOC-03 is available at Internet server (http://vizier.cfa.harvard.edu/viz-bin/Cat?J/A%2BA/463/783). The distribution of celestial coordinates, proper motions, parallaxes and magnitudes of the EOC-3 stars are given in Figures 1-7. The most EOC stars are distributed over the North sky, due to dominated number of observatories at the North hemisphere.

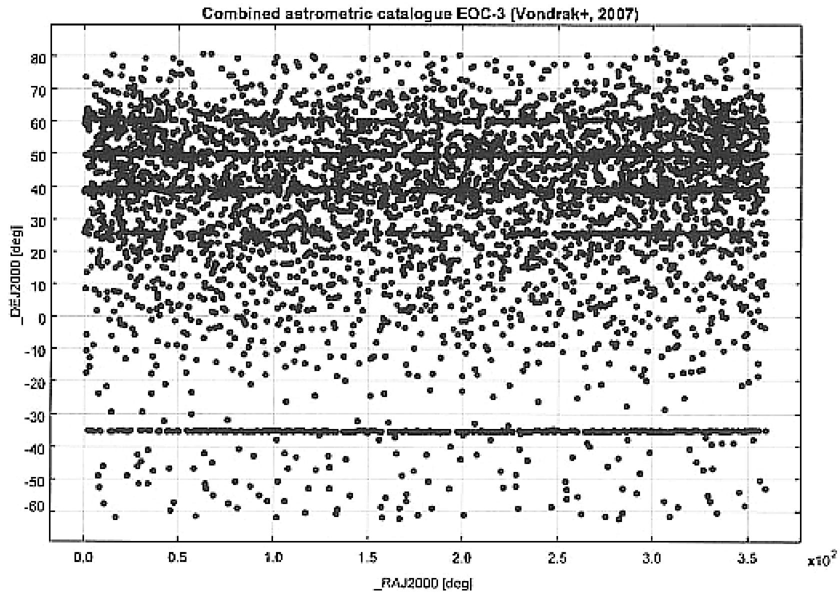

Figure 1. Celestial map of the star from the combined astrometric catalogue EOC-3.

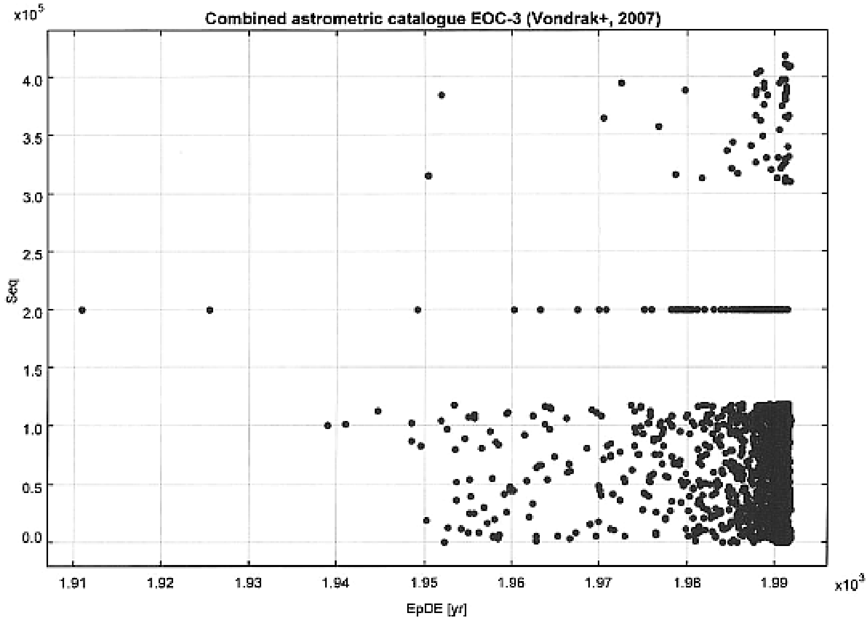

Figure 2. Epochs of the declinations of the stars from the combined astrometric catalogue EOC-3.

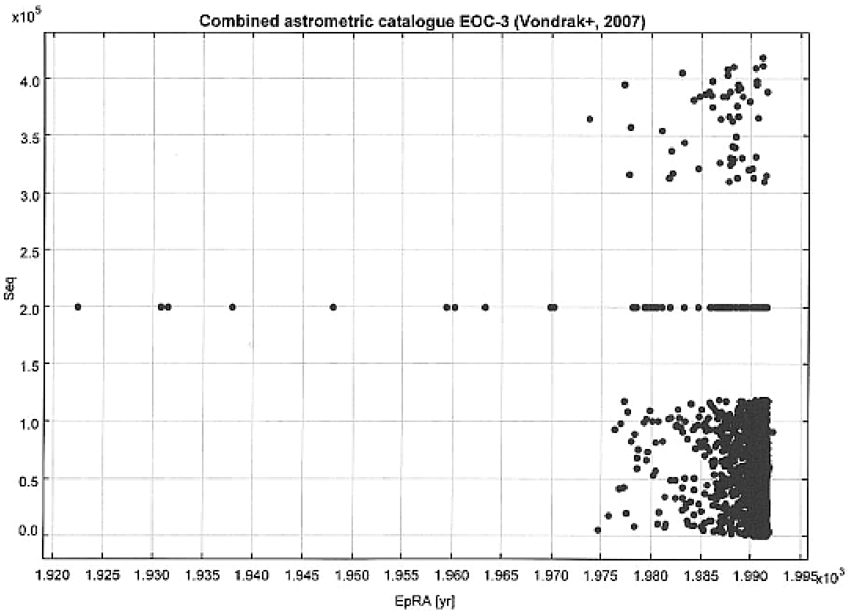

Figure 3. Epochs of the right ascensions of the stars from the combined astrometric catalogue EOC-3.

A significant part of the epochs of declinations and right ascensions of the EOC stars are before 1990. Some observational series of latitude variations cover time spans longer than 50 years and series of UT variations are shorter. These observational series are useful for proper motion improving.

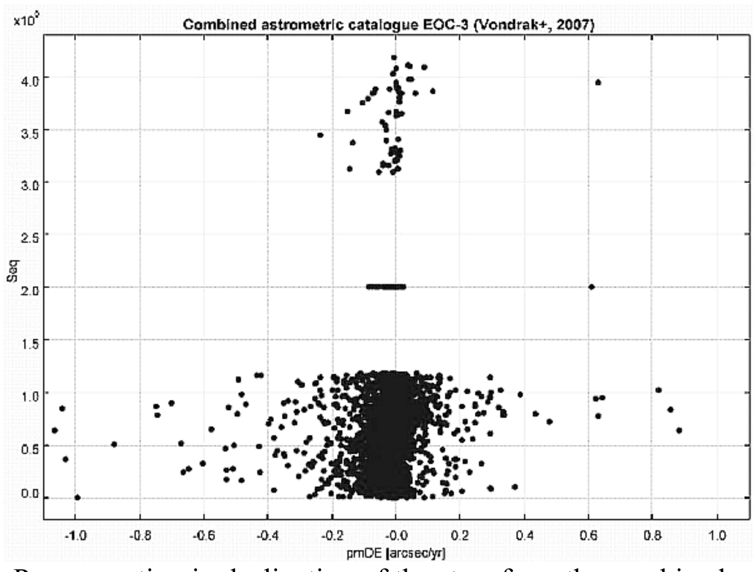

Figure 4. Proper motion in declination of the stars from the combined astrometric catalogue EOC-3.

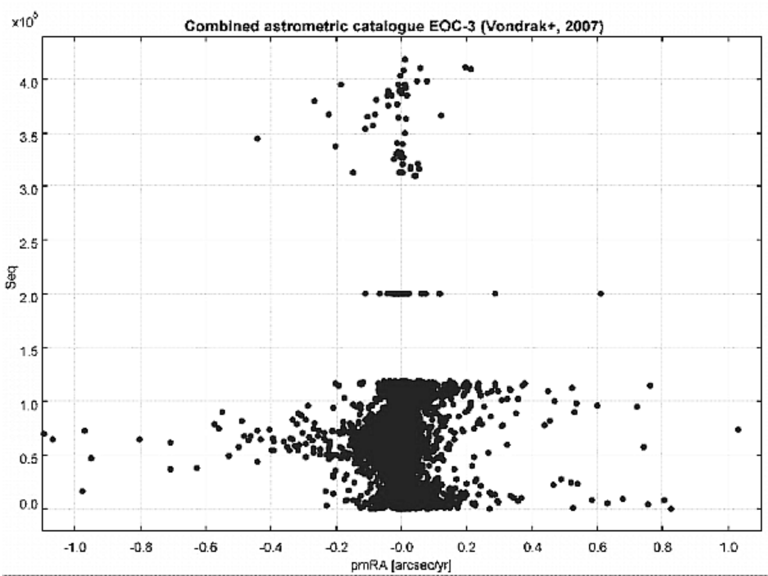

Figure 5. Proper motion in right ascension of the stars from the combined astrometric catalogue EOC-3.

A significant part of EOC stars have values of their proper motions in declination and right ascension greater than 0.1arcsec/a. These stars are with relative high absolute errors of the proper motion and they are potential candidates for proper motion improving.

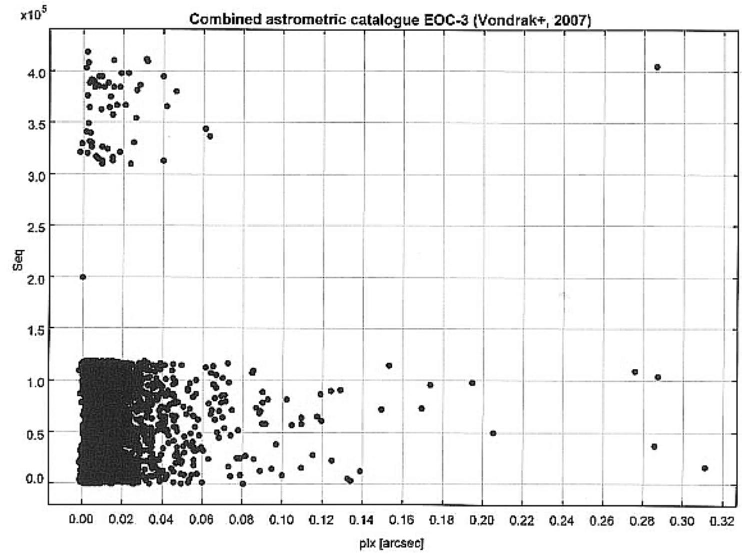

Figure 6. Distribution of the parallaxes of the stars from the combined astrometric catalogue EOC-3.

Some part of EOC stars are relatively close to the Earth as it is seen from the distribution of the parallaxes in Fig.6. These stars offer better resolution for their nonlinear motions and better possibility for successful detection of the double stars over a century observational spans. The magnitudes of the stars from the combined astrometric catalogue EOC-3 are below 12 (Fig.7). The most observed stars are with magnitude between 5 and 8 and minor part of stars is with magnitudes below 5. The bright stars cover several pixels in digitized astronomical images, which allow determining their coordinates with significant higher accuracy than the image resolution.

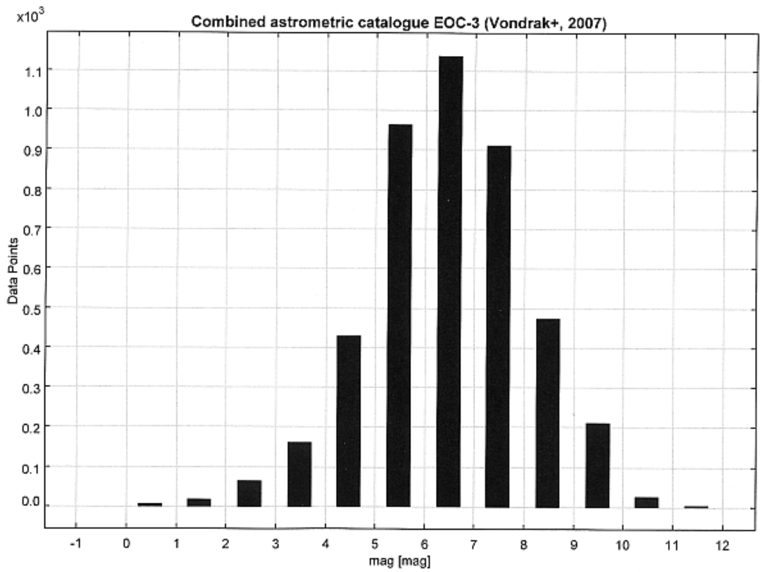

Figure 7. Distribution of the magnitudes of the stars from the combined astrometric catalogue EOC-3.

4. WIDE FIELD PLATES DATA BASE (WFPDB)

The Wide-Field Plate Data Base (WFPDB) is an information project of the Institute of Astronomy, Bulgarian Academy of Sciences, (IA) since 1991, which was initiated by a working group of the IAU and is unique of its kind on international scale (www.skyarchive.org). More than 150 000 plates from the European archives are stored and a collection of images of size of the order of 2TB is prepared. It has the potential of growth to more than 1000 TB. At present WFPDB consists of the following active interconnected parts: The Catalogue of Wide-Field Plate Archives (CWFPAs) and The Catalogue of Wide-Field Plates Indexes (CWFPIs). The CWFPAs http://www.skyarchive.org/catalogue.html is in a table format and describes the world-wide astronomical plate archives (Tsvetkova and Tsvetkov, 2006). The CWFPIs gives a complete information for the stored photographic plates (Tsvetkov at al., 2007). According to the CWFPAs, the full number of the astronomical observations on photographic plates is estimated to ~2 200 000. It contains information about objective and informative observations that cover the longest possible period of observations in astronomy - about 130 years. According to the CWPPIs, the data for about 531 000 astronomical plates are searchable through the web-based system of WFPDB, http://www.skyarchive.org/search.html. The WFPDB is unique with its internationally accepted standard for description of astronomical photographic observations into various archives. The enlarged regularly updated and developed version can be found since 2001 at Sofia Sky Archive Data Center giving information about 119 distributed plate archives and on-line access to their prepared computer-readable catalogues with about 531 000 plates. We may expect a wide use of digitized astronomical plates in star catalogs improving when the most of the existing plates will be digitized and free and fast access to them will be available.

4.1. Telescopes and digitized plates in WFPDB

A lot of different instruments had been used in the last century to create the astronomical plates. The used telescope have individual field of view, aperture and focal length. The WFPDB telescopes have the following fields of view and aperture:

- Field of view [degree]

- **1, 3, 5, 7**, *20, ...;*

- Aperture [cm]

- *10, 12, 14, 16, 34,* **40, 60, 67**, …

The telescopes with the field of view of 20 and more degrees have poor angular resolution and their astronomical plates are not compatible with the accuracy of the modern star catalogs. The same situation is with the small telescopes whose aperture less than 40cm. Thus, it is possible to filtrate the astronomical plates for star catalogs improving by choosing images from instruments with field of view 1-7degrees and aperture greater than 40cm. The WFPDB contain information about images with various plate scales – from 13arcsec/mm to 860arcsec/mm. The useful plate scales are below 115arcsec/mm, which allow astrometrical determination with sufficient accuracy. The most often used resolution for image scanning is 2400dpi, small number of plates is scanned with a higher resolution, but image preview is available with resolution 300 – 600dpi. The resolution 2400dpi is rather enough for astrometrical purposes.

- Plate scale ["/mm]

- \- *860, 830, 295, 258, 300,* **115, 102, 96**, …

- Scan resolution [dpi]

- \- 300, 600, 1200, **2400, 4800,** …

4.2. WFPDB's star position accuracy

The star position in the frame of the digitized astronomical plates should be determined with high enough accuracy in order to use the images for star catalog improvement. The maximum accuracy of a given star image is the angular size of a single pixel. It depends on the mean size of the silver grains from the plate emulsion, too. If we assume the mean silver grain size of about 10μm, then the expected accuracy will be as follow:

- According plate scale (emulsion grain 10μm)

- 100"/mm - ±0.5"
- 60"/mm - ±0.3"
- 13"/mm - ±0.06" (Observatory Rozhen)

The realistic maximum accuracy of a single star position determination is between 0.3arcsec and 0.5arcsec, but it depends on scan resolution, too:

- According scan resolution

- 300dpi=12d/mm+scale 13"/mm - ±0.5"
- 600dpi=24d/mm+scale 13"/mm - ±0.3"
- 1200dpi=47d/mm+scale 60"/mm - ±0.6"
- 2400dpi=94d/mm+scale 100"/mm - ±0.5"
- 4800dpi=189d/mm+scale 100"/mm – (±0.3")
- 9600dpi=378d/mm+scale 100"/mm – (±0.1")

It is possible to achieve the maximal accuracy by means of different scan resolution, even from preview images with 300dpi, in the case of combination with proper plate scales.

5. CONCLUSIONS

The optical astrometry data consist of more than 4 million observations of more than 4000 stars or star pairs, collected from 33 observatories since 1899. These observations are the only centenary series, used for determination of the variations of the local plumb-lines and Earth rotation and give us unique possibility of searching causality between these variations and global changes of the environment, climate, solar activity, ice melting and post-glacial rebound, mean sea level arising, earthquakes etc. Necessary precondition of successful utilization of the astrometrical observations in the field of modern scientific investigations is the improvement of the accuracy of star catalogues, where the proper motion of the stars (or their annual velocity on the celestial sphere) is a critical parameter. The Earth Orientation Catalogs (EOC) are primarily meant to provide stable celestial reference frame in optical wavelength for deriving Earth Orientation Parameters (EOP) from astrometric observations.

Some observational series of latitude variations cover time spans longer than 50 years. These observational series are useful for proper motion improving. A significant part of EOC stars have values of their proper motions in declination and right ascension greater than 0.1arcsec/a. These stars are with relative high absolute errors of the proper motion and they are potential candidates for proper motion improving. The most observed stars are with magnitude between 5 and 8 and minor part of stars is with magnitudes below 5. The bright stars cover several pixels in digitized astronomical images, which allow determining their coordinates with significantly higher accuracy than the image resolution.

The WFPDB provide significant number of plates, containing a given star. The observation epochs cover century time span, which is useful to improve star catalogs. It is necessary to improve the free access to the digitized plates and to add some new options in the search engine and tools:

- compressed images with resolution 2400dpi or more
- search for plates with scale <100arcsec/mm
- online tool for identification of a group of stars from a given plate sequence
- accurate determination of the plate centers and their orientation by 7-parameter transformation.

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PROPER MOTION ACCURACY OF WFPDB STARS

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Abstract. The accuracy of latitude and Universal time determination from the optical astrometry observations, obtained during the last century in programs of monitoring Earth orientation, strongly depends on the quality of the Earth Orientation Catalogs (EOC), where the stars proper motion is critical parameter. The possibility of improving the stars proper motions by WFPDB (Wide-Field Plate Database) is investigated by means of simulated observations. The model includes real star observations from the optical astrometry and simulated observations with epochs taken from the WFPDB, corresponding to existing plates containing the EOC stars. The simulated star coordinate deviations are generated as a sum of given proper motion and random noise, corresponding to the expected standard errors of WFPDB data. Three cases of astrometrical observations with simulated random errors are considered with standard errors 0.5arcsec, 1.0arcsec and 5.0arcsec. It is possible to estimate the star proper motion with sufficient accuracy by means of the corrected plates for image center and distortion with 100"/mm scale and scan resolution 2400dpi.

1. INTRODUCTION

The astrometrical observations of geographic latitude and universal time during the most of the last century are a unique source of information of the local plumb-lines and Earth rotation variations and give us unique possibility of searching causality between these variations and global changes of the environment, climate, solar activity, mean sea level arising, earthquakes etc. The realistic maximal level of accuracy of parameters, estimated by optical observations is in positions 1-10mas (equivalent to 3-30cm on Earth surface) and in rates better than 1mas/a (3cm/a). This level of accuracy is achievable after excluding the systematic errors from the raw data by means of the star catalog improvement. The most stars from the combined Earth Orientation Catalogs (EOC) have accurate coordinates and proper motions. Some EOC stars are double and their periodical terms are determined. Chapanov et al. (2010) points out that some EOC stars are potential candidates for star coordinates and proper motion improvement by means of Wide-Field Plate Database (WFPDB). The possibility of improving the EOC stars proper motions by means of WFPDB data is investigated on the base of simulated observations with real epochs, taken from WFPDB.

2. DATA SELECTION

The WFPDB contains enough information about all stars from the EOC. It is possible to find more than 2000 plates, containing a given EOC star with angular distance to the plate center less than 5 degrees. We may expect significant growth of the plate numbers with a given star when all plates are digitized. The model of simulated observation is based on 3 sequences of plates with the scale less than 100"/mm and scan resolution 2400dpi. These sequences correspond to 3 stars from the EOC-3, whose coordinates are given in Table 1 together with the used box size and plates numbers. The numbers of the plates, containing these stars are between 150 and 2000 (Table 1). These sequences cover time spans longer than 1 century (Fig.1), so they are useful for star proper motion estimation.

Table 1: Plate sequences corresponding to 3 stars from the EOC-3.

Sequence Number	Right Ascension [h, m, s]	Declination [°, ', "]	Box Size [°]	Plate Number
1	11 59 31.80	+47 45 55.4	5	2000
2	01 02 54.26	+41 20 42.6	5	700
3	11 59 31.80	–35 18 30.7	3	150

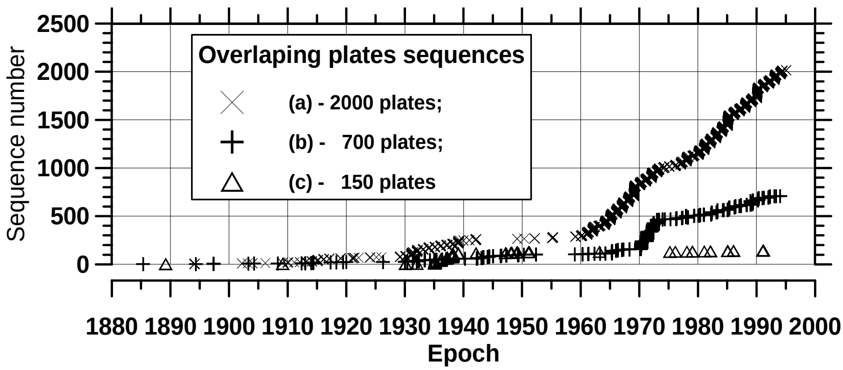

Figure 1. Overlapping plates sequences.

3. NORMALLY DISTRIBUTED RANDOM NUMBERS

The sequence of evenly distributed pseudorandom numbers is calculated by computer program, and used for modeling the observation errors. First, the sequence of evenly distributed pseudorandom numbers is transformed into a sequence of normally distributed numbers N(0,1) by means of Forsythe, Malcolm and Moler algoritm (1977). This algorithm consists of the following steps:

1. Two evenly distributed random numbers U_1 and U_2 from the interval [0, 1) are calculated;

2. Evenly distributed random numbers from the interval [−1, 1) $V_1=2U_1-1$ and $V_2=2U_2-1$ are calculated;

3. $S=V_1^2 + V_2^2$ is calculated. If S>1, thenV_1 and V_2 are discarded and step 1 is executed.

4. Normally distributed random numbers $X_1 = V_1\sqrt{(-2\ln S)/S}$, $X_2 = V_2\sqrt{(-2\ln S)/S}$ are calculated, which belong to N(0,1).

The numbers X_1 and X_2 are chosen independently. It is possible to norm the obtained pseudorandom numbers to a necessary dispersion (Fig.2, 3).

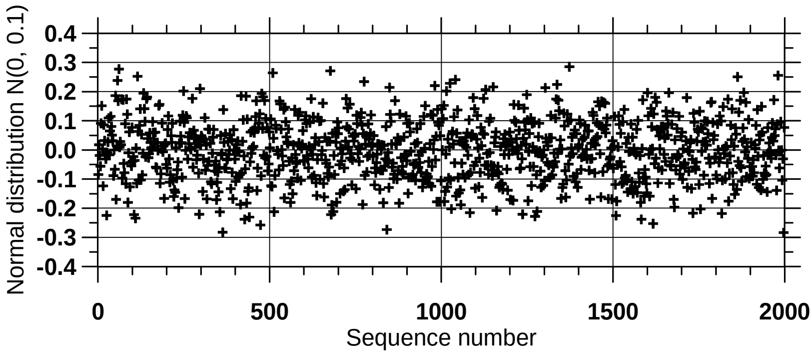

Figure 2. A sample of normally distributed pseudorandom numbers N(0, 0.1).

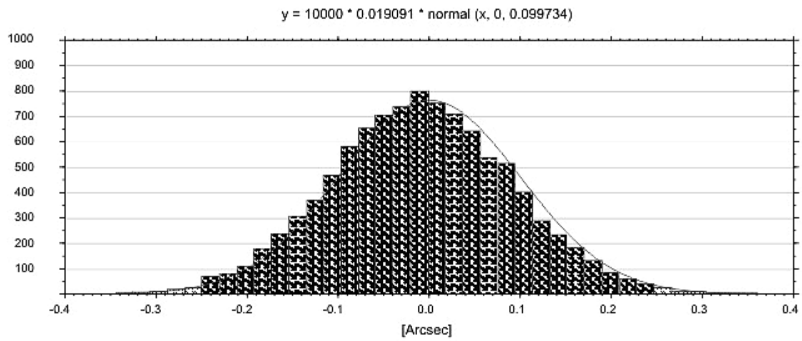

Figure 3. Normally distributed pseudorandom numbers N(0, 0.1).

4. A MODEL OF RANDOM ERRORS OF ASTRONOMICAL OBSERVATIONS

The error distribution of astronomical observations is rather different from the normal distribution, due to different instruments, observers and climatic conditions. Fig.4 shows a typical distribution of astrometrical errors, corresponding to daily residuals of latitude observations at observatory Plana for the period 1987.5-1997.0. The observations with small dispersion form a “hat” above the normal fit, while the less accurate observations form “arms” with significant great errors, but belonging to the confidential interval (-3σ, $+3\sigma$). A empirical model S_i of random errors of astronomical observations, which is close to the real distribution from Fig.4, is composed by 10000 normally distributed numbers N (0, 0.1), where 13% of the numbers are replaced by:

- 1% evenly distributed numbers from intervals (–0.8, –0.4], [0.4, 0.8);
- 6% evenly distributed numbers from intervals (–0.4, –0.1], [0.1, 0.4);
- 6% evenly distributed numbers from intervals (–0.06, 0.06).

The following algorithm is used to create sequence S_i containing 10000 numbers, satisfying the above conditions:

1. A sequence of 10000 normally distributed numbers X_i is computed by means of Forsythe, Malcolm and Moler method (1977) and computer generator of evenly distributed random numbers.

2. New 1300 evenly distributed random numbers U_n belonging to the interval [0, 1) are computed and a new sequence of evenly distributed random numbers $K_n = 9999\, U_n + 1$, belonging to the interval [1, 10000).

3. New 1300 evenly distributed random numbers U_m, belonging to the interval [0, 1) are formed, and following evenly distributed random sequences:

a) 100 numbers $P_m = \pm(0.4\, U_m + 0.4)$ belonging to the intervals (–0.8, –0.4], [0.4, 0.8);

b) 600 numbers $Q_m = \pm(0.3\, U_m + 0.1)$ belonging to the intervals (–0.4, –0.1], [0.1, 0.4);

c) 600 numbers $R_m = 0.12\, U_m - 0.06$ belonging to the interval [–0.06, 0.06).

4. The final sequence S_i is created by replacing the elements of sequence X_i by values of P_m, Q_m and R_m, whose places are determined by the sequence K_n.

The distribution of the errors, computed by the above algorithm is shown in Fig. 5.

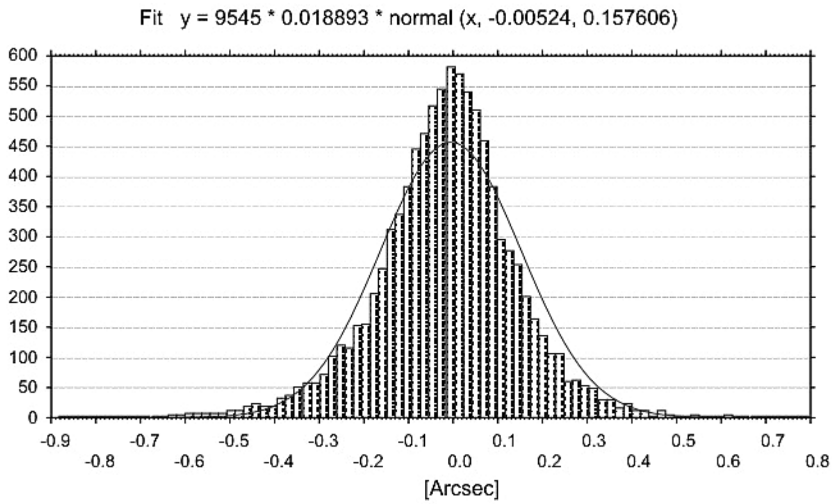

Figure 4. Typical astrometrical errors, corresponding to daily residuals of latitude observations at observatory Plana for the period 1987.5-1997.0.

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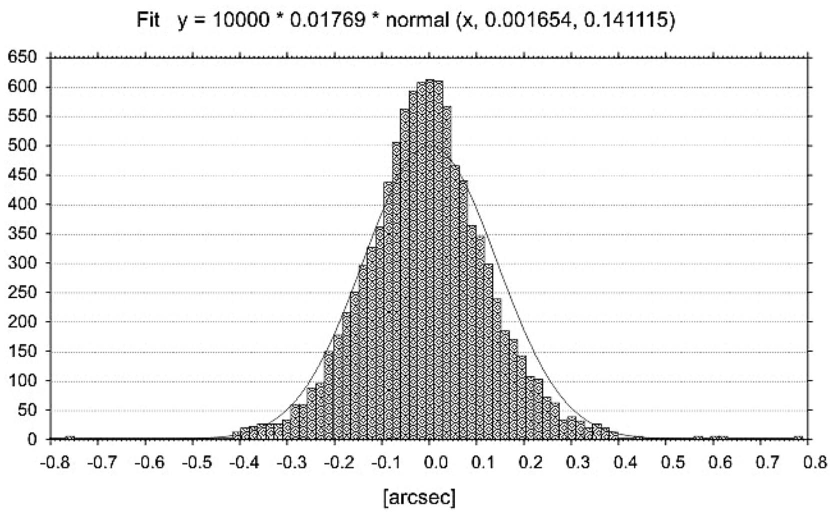

Figure 5. Distribution of errors, according to the model of random errors of astrometrical observations.

Three cases of astrometrical observations with simulated random errors are considered with standards 0.5arcsec, 1.0arcsec and 5.0arcsec. Three different sequences with 2000 random errors with these standards are shown in Figures 6, 7 and 8.

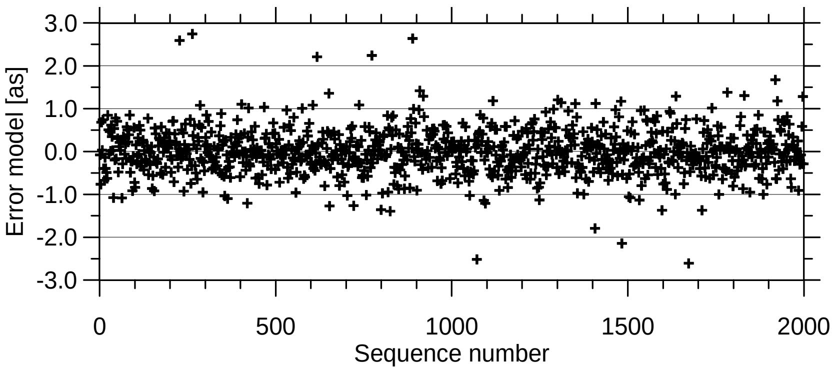

Figure 6. Error model of astrometrical observation from WFPDB with standard 0.5arcsec.

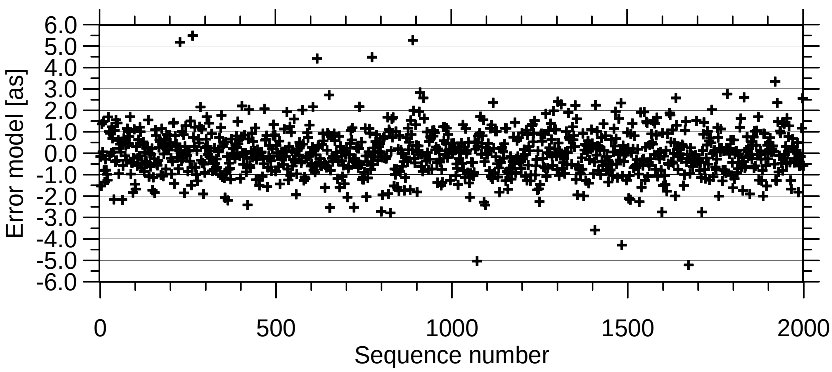

Figure 7. Error model of astrometrical observation from WFPDB with standard 1.0arcsec.

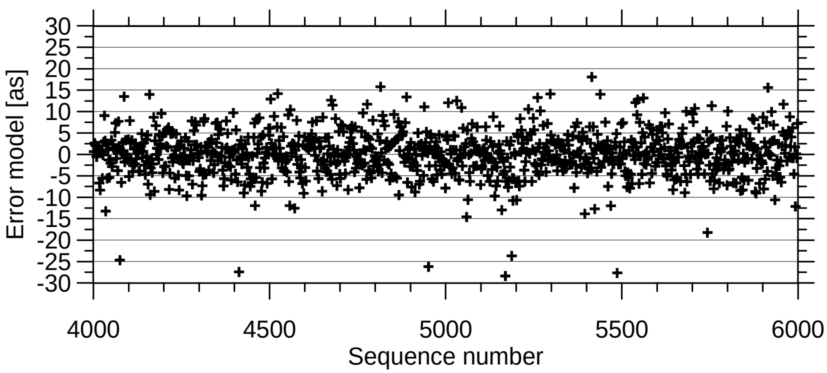

Figure 8. Error model of astrometrical observation from WFPDB with standard 5.0arcsec.

5. ESTIMATION OF THE PROPER MOTION ACCURACY OF WFPDB STARS

The proper motion accuracy of WFPDB stars is estimated by means of three overlapping plates sequences, containing 150, 700 and 2000 plates (Fig.1) and error models with standard 0.5arcsec, 1.0arcsec and 5.0arcsec. The model with standard 0.5arcsec corresponds to the case of corrected star images for the plate center and non-linear distortion. The model with standard 1.0arcsec corresponds to the case of raw plate center and corrected distortion and the last case with standard 5.0arcsec arise when no preliminary corrections of the plate center and distortion are applied. Three values of the modeled proper motion are used - 0.001arcsec/a; 0.01arcsec/a and 0.05arcsec/a. One of the resulting observational series is shown in Fig.9. The unknown parameters are estimated by the Least Squares Method as a linear regression to the data. The results are shown in Table 2. The observational series with standard error 0.5arcsec yield stable solution for stars with proper motion greater than 10mas/a and for slowly moving stars in case of a sufficient number of observations (here greater than 700). The observational series without preliminary corrections for plate center and/or distortion are applicable in the cases of big number of observations and great values (>10mas/a) of the proper motions. It is possible to improve their application by involving robust Danish method for parameter estimation (Kubik, 1982; Juhl, 1984; Kegel, 1987) or Hampel's method with Somogy's modification (Hampel, 1973, 1974; Somogyi, 1987). These methods allow to detect and isolate outliers and to obtain very accurate and reliable solution for the linear trends.

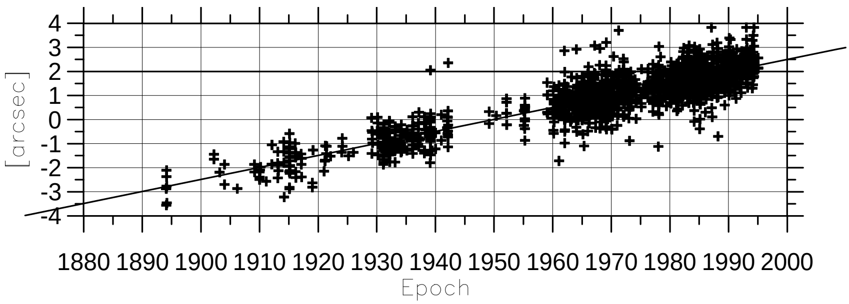

Figure 9. Simulated astrometrical observations with real epochs of a star from WFPDB and error model with standard 0.5arcsec. The number of the observation is 2000 and the modeled proper motion is 0.05arcsec/a.

Table 2: Estimated proper motion of stars from WFPDB with different error models and observation numbers.

Standard of the error model	Observations number	Initial proper motion [mas/a]		
		1	10	50
		Estimates		
0.5as	2000	0.84±0.59	9.8±0.6	49.8±0.6
	700	1.3±1.1	12.1±1.1	52.1±1.1
	150	-	11.9±2.5	51.9±2.5
1.0as	2000	-	9.2±1.1	49.2±1.1
	700	-	-	-
	150	-	-	-
5.0as	2000	-	7.4±4.9	48.4±5.9
	700	-	-	-
	150	-	-	-

6. CONCLUSIONS

- The WFPDB provide significant number of plates, containing a given star. The plate numbers vary from hundreds to several thousands and they cover a century time span. It is possible to estimate the star proper motion with sufficient accuracy by means of the corrected plates for image center and distortion with 100"/mm scale and scan resolution 2400dpi.
- It is possible to use the raw star images for estimation of the great proper motions, if the number of plates is greater than 1000.

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STARK-B DATABASE VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND DATA FOR WHITE DWARF ATMOSPHERES ANALYSIS

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Abstract. In a number of papers we have demonstrated the importance of Stark broadening mechanism for the modeling and synthesizing of lines observed in spectra of white dwarf atmospheres. We also determined a number of Stark broadening parameters of interest in particular for DB and DO white dwarf plasmas investigations. Now, work on their inclusion in STARK-B database and in Virtual Atomic and Molecular Data Center, an FP7 european project, as well as in Serbian Virtual Observatory is in progress. We review here the part of this work of interest for white dwarf atmospheres analysis.

1. INTRODUCTION

Virtual Atomic and Molecular Data Center (VAMDC) aims at building an interoperable e-Infrastructure for the exchange of atomic and molecular data. In a number of papers we have demonstrated the importance of Stark broadening mechanism for the modelling and synthesizing of lines observed in spectra of white dwarf atmospheres. We determined Stark broadening parameters for trace element: Te I, Cr II, Mn II, Au II, Cu III, Zn III, Se III, In III and Sn III of interest particularly for DB and DO white dwarf plasmas investigations. Now, work on their inclusion in STARK-B database and in Virtual Atomic and Molecular Data Center, an FP7 european project, as well as in Serbian Virtual Observatory is in progress.

As an example of this work, we will show here Stark broadening parameters for two Mn II lines and their relevance for white dwarf spectra analysis and synthesis.

2. RESULTS AND DISCUSSIONS

Calculations have been performed within the semiclassical perturbation formalism, developed and discussed in detail in Sahal-Breéchot 1969a,b. This formalism, as well as the corresponding computer code, have been optimized and updated several times (Sahal-Breéchot 1974, Dimitrijević and Sahal-Bréchot 1984, Dimitrijević et al. 1991).

Using the semiclassical perturbation method we obtained Stark widths and shifts for six Mn II lines (Popović et al. 2008) for perturber density of 10^{17}cm^{-3} and temperatures from 5000 to 100000 K. Here, as an example we will show data for two of them 2594.5 and 2950.1 Å. The needed atomic energy levels were taken from Bashkin and Stoner 1982. The oscillator strengths required were calculated using the Coulomb approximation method described by Bates and Damgaard 1949 and the tables of Oertel and Shomo 1968. For higher levels, the method described by van Regemorter et al. 1979 was applied. As an example of obtained results, Stark widths and shifts for these lines are given in Table 1.

Table 1: Electron-impact broadening parameters (full width at half maximum W and shift d) for Mn II (Popović et al. 2008) for perturber density of 10^{17}cm^{-3} and temperatures from 5000 to 100000 K.

Transition	T(K)	W(Å)	d(Å)
a ^{7}S - z ^{7}P^o 2594.5Å	5000	0.128	0.236E-03
	10000	0.948E-01	-0.996E-03
	20000	0.702E-01	-0.116E-02
	30000	0.598E-01	-0.956E-03
	50000	0.507E-01	-0.128E-02
	100000	0.435E-01	-0.118E-02
a ^{5}S - z ^{5}P^o 2950.1Å	5000	0.226	-0.394E-01
	10000	0.165	-0.302E-01
	20000	0.121	-0.234E-01
	30000	0.102	-0.193E-01
	50000	0.884E-01	-0.168E-01
	100000	0.800E-01	-0.137E-01

In order to investigate the importance of Stark broadening mechanism in DA and DB white dwarf atmospheres the atmospheric models of Wickramasinghe 1972, with T_{eff} = 15000-25000 K and log g=8, are used. Here, g is the gravitational acceleration on the stellar surface and log g=8 means that $g = 10^8$ m/s. Calculated thermal Doppler and Stark widths as a function of optical depth, for Mn II a ^{5}S - z ^{5}P^o (2950.1 Å), are compared in Figs. 1 and 2. for DA and DB white dwarfs plasma conditions. As in Wickramasinghe 1972, optical depth points at the standard wavelength 5150 Å are used. As one can see, for DB white dwarf atmospheres the Stark broadening mechanism is more important than for the DA white dwarf atmospheres, especially for atmospheric layers with the optical depth larger or approximatively equal to 0.1, where the Stark width is up to one or two orders of magnitude larger than the thermal Doppler width.

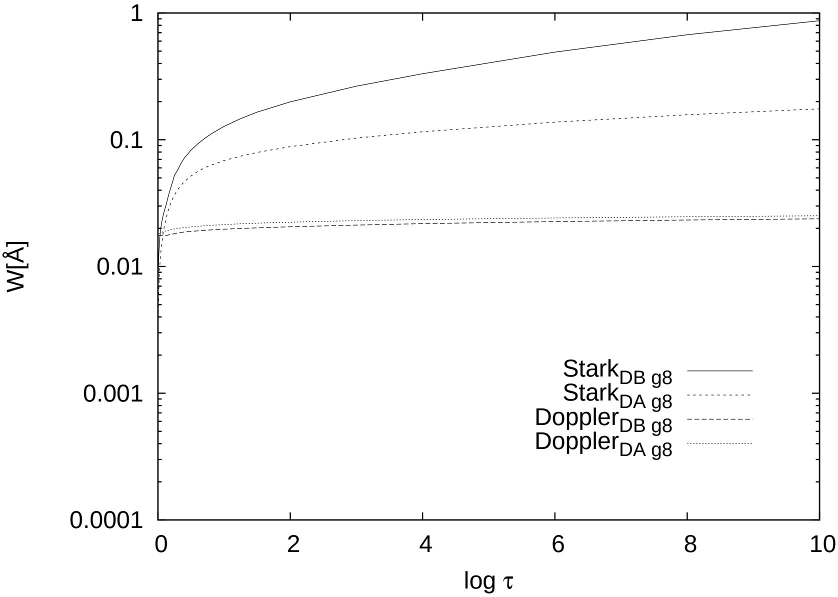

Figure 1. Thermal Doppler and Stark widths for Mn II spectral line a ^{5}S - z ^{5}P^o (2950.1Å) as a function of optical depth for DA and DB white dwarf models with T$_{eff}$=15000 K and log g=8.

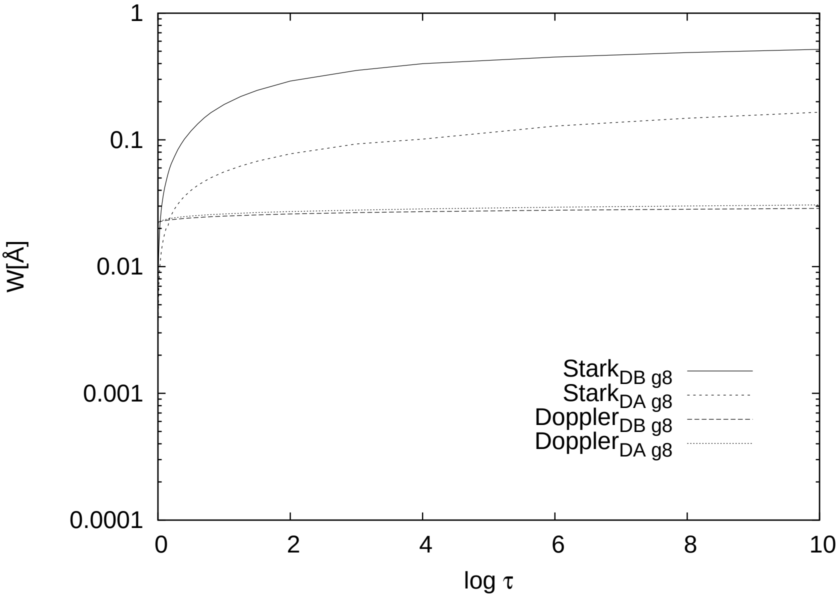

Figure 2. Thermal Doppler and Stark widths for Mn II spectral line a ^{5}S - z ^{5}P^o (2950.1Å) as a function of optical depth for DA and DB white dwarf models with T$_{eff}$=25000 K and log g=8.

Acknowledgements

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BG GRID FOR SCIENTIFIC APPLICATIONS. INSTITUTE OF ASTRONOMY APPLICATIONS

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Abstract. The development of the Bulgarian GRID for scientific applications and some basic astronomical GRID applications in the Institute of astronomy are presented. Among the applications are N_body simulations of binary open clusters, baryon-antibaryon universe simulations, modeling of comet dust structures, expressing of weak structures in galaxies, active processes on the Sun, etc.

1. INTRODUCTION

The Institute of Astronomy of the Bulgarian Academy of Sciences is included in the national initiative to exploit the opportunities of the Bulgarian GRID for scientific applications. The astronomical community will work with GRID in the following tasks:

Task 1: N-body simulation of diffuse star cluster system of two Cup.
Task 2: numerical simulation of non-homogeneous bariogenesis models.
Task 3: Monte Carlo modeling of comet dust structures.
Task 4: PIXON method for expression of weak structures in galaxies.
Task 5: Modeling of active phenomena on the Sun.

TASK 1: MODELLING OF N-BODY SYSTEM

1. Open star cluster
2. A system of two open star clusters

Method: The Particle-Particle method

* Accumulate forces by finding the force *F(i,j)* of particle *j* on particle *i*,
* Integrate the equations of motion (which includes the accumulated forces)
* Update the time counter.
* Repeat for the next time step.

For example, in a gravitational N-body simulation, a particle of mass M attracts another particle of mass m with a force: $-(GMm/r^3)*r$. You have N particles, which you are computing the force (N-1) times. Then you separate the equation into two first-order differential equations involving acceleration and involving velocity. Finally, use an integration scheme like Euler or Runge-Kutta to get the positions and velocities.

While the particle-particle method is the most straight-forward method of the N-body methods, the computational physicist must still think carefully about the numerical details of formulating the theoretical physics of the problem into a digital form, in order to derive results that are physically plausible. For example, as the particles approach each other, the forces between them, and hence the accelerations, become much larger. If one uses a constant time-step in the integration scheme in order to calculate the velocities and positions, then you're likely to encounter computer overflow errors giving nonsense numbers. To avoid this situation, you may want to consider a numerical integration scheme that uses variable time-steps, instead of constant time-steps. Such a scheme should automatically cut down the time-step when the particles are near each other, and increase the time-step when the particles are far away from each other.

Figure 1. Binary open cluster *h* and χ Persei.

The Particle-Particle direct integration approach is flexible but has a high computational cost: $O(N^2)$ operations are required to evaluate the forces on all N particles. If you have less than about N=1000 particles, and are interested in the close-range dynamics of the particles, (or if you have more particles but special hardware) then this method is the most straight-forward.

The evolution of the binary open clusters were studied in Portegies Zwart and Rusli (2007) and the problems of existence of binary/multiplicity of open clusters – in de La Fuente Marcos and de La Fuente Marcos (2009).

In the Fig. 1 the well-known binary open cluster *h* and χ Persei is shown.

TASK 2: GENERATION AND EVOLUTION OF BARYONS-ANTIBARION ASYMMETRY OF THE UNIVERSE

The question of the occurrence of observable baryons-antibarion asymmetry of the Universe (BAU) is one of the most interesting and studied questions in modern cosmology and physics particles. Still specify the exact model of bariogenesis based on a comparison of the parameters of models with observable characteristics of the universe.

Investigated our model is based on bariogenesis Affleck-Dine (AD) mechanism for the generation of baryon excess. In order publications it was shown that the analytical estimates baryon asymmetry by several orders of magnitude may differ of numerical estimates used the exact equations describing the generation and evolution of baryons. This requires the use of numerical modeling in the study of this type bariogenesis models.

Age of baryon excess generation is significantly earlier than the epoch of cosmological nucleosinthesis therefore follow the evolution of BAU since the creation until today requires serious computing power with great performance.

Even more serious is the problem of numerical modeling of non-homogeneous bariogenesis models, except where the long evolution of BAU is necessary to trace and its spatial variations.

Successful completion of the numerical analysis of the issue of model would help us to specify the parameters of model allows generation of locally observable BAU.

Observation of cosmological data would also be possible derive cosmological constraints on the range values of the parameters of supersymmetric theories in which realize the mechanism of AD-bariogenesis. The details of the problem are discussed in Kumar (2009) and using of AD - mechanism is demonstrated in Sasuya et al. (2008).

TASK 3: MONTE CARLO MODELING OF COMET DUST STRUCTURES

Use model based on the theory of Finson and Probstein (1968) on the dynamics of particulate matter. Unknown parameters are the amount of active area coordinates on the surface of the comet nucleus and range of particulate sizes. For rotation period and inclination of the axis of rotation are fixed values used in literature (Schleicher, 2001). By trial and error we found that when the axis of rotation coincides with the z axis then the model best reproduces the observations. If the surface of the comet nucleus has a small active pool area with coordinates and particulate matter leaves then their radial position after time t is given by the following equations:

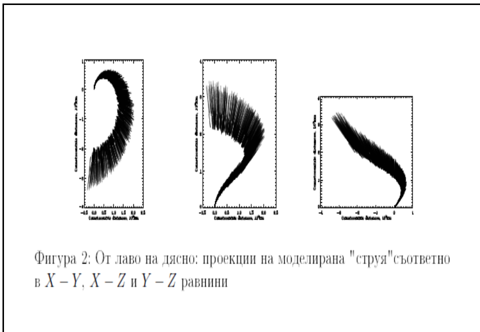
$$x = V_d t \sin\varphi \cos\theta - \tfrac{1}{2}\alpha t^2$$
$$y = V_d t \sin\varphi \sin\theta$$
$$z = V_d t \cos\varphi,$$

where a is the acceleration of the particles. Our model works with constant acceleration in the inertial coordinate system. This model is valid because they assume that these structures are short-. Dust particles must be evenly distributed in this area. Initial coordinates are described as follows:

$$\varphi = \varphi_0 - \tfrac{\mathrm{d}\varphi}{2} + R_i \mathrm{d}\varphi$$
$$\cos\theta = \cos\left(\theta_0 - 2\pi\tfrac{t}{P} - \tfrac{\mathrm{d}\varphi}{2}\right) + R_i \mathrm{d}\cos\theta,$$

where Ri is a series of uniformly distributed random numbers in the range (R € [0,1]).

Fig. 2 shows an example simulation of the "stream" derived from the active area on the comet nucleus coordinates latitude - 45 °. The structure is shown by the production release of particulate matter in comet half day.



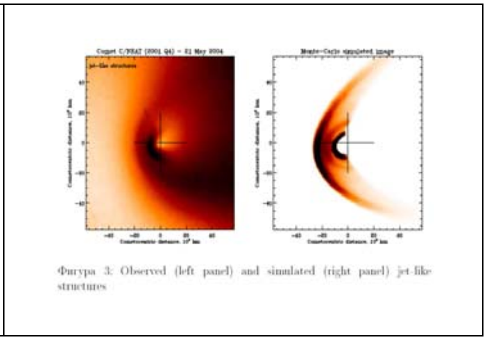


Figure 2a. From left to right: modeled projections of the "stream" respectively in the X - Y, X - Z and Y - Z planes.

Figure 2b. Observed (left panel) and simulated (right panel) jet-like structures.

The simulation at this stage is carried out for 10 comet days used were 101 particles with sizes from 10 to 100 mm with a time step 12 seconds. Provides simulation is several orders of magnitude more particles and much larger period.

TASK 4: PIXON METHOD FOR EXPRESSION OF WEAK STRUCTURES IN GALAXIES

Astronomers constantly want to detect fainter objects and discern finer details. The Pixon digital image processing technology offers the best improvements possible in image quality:

According to WEB_page of the PIXON team (see http://www.pixon.com) - *„The Sky is the Limit, not Diffraction or Seeing“* **.**

PIXON method, described by Pina and Puetter (1993) allows the users to:

- Deblur images to undo the blur caused by diffraction or atmospheric seeing.
- Denoise images without losing any of the resolution improvement achieved by deblurring.
- No introduction of spurious artifacts during image processing.
- Multiframe analysis to further improve the signal-to-noise ratio and resolution, including subpixel resolution.
- Multispectral/hyperspectral analysis to optimize image processing by taking advantage of information obtained at different wavelengths.
- Statistical flux conservation (nobias introduced).
- User control of the tradeoff between noise suppression and resolution improvement.
- Typical, artifact-free improvements in image quality are:

- Reduction of the full-width at half maximum (FWHM) of the blur by a factor of a few.
- Noise reduction by an order of magnitude or more.

In Fig. 3 from the Internet the reconstruction of the FIR image of well-known M51 galaxy (optical DSS image on the left) is shown.

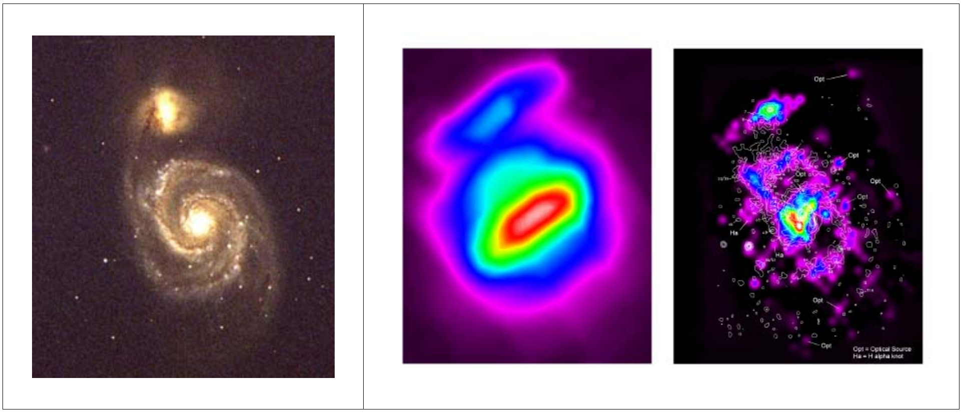


Figure 3. The reconstruction of the FIR image of M 51 galaxy.

A lot of frames, taken with the 2-m telescope at medium quality conditions will be reconstructed. A series of plates from the 2-m telescope, covering a dozen of known voids were scanned. The 15K x 15K sqr.px images were splitted on 256 sub-frames 1000 x 1000 sqr.px. each. These are ideal for parallel processing.

TASK 5: MODELING OF ACTIVE PHENOMENA ON THE SUN

The main goal of this task is modeling of prominence plasma behavior blasted by an external wave.

For this purpose we use a two-dimensional model of the protuberance in the form of an arch-shaped structure. We take standard plasma parameters values. For each step of model height we calculate conditions for generation of longitudinal currents. Also, we estimate the maximal height, where these currents close through the photosphere and the damping rate of the MHD wave.

Using GRID we hope to construct a 3D model, also to take into account fine structure of the prominence arch and to explore the nonlinear effects in the amplification of longitudinal currents.

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SINGULAR VALUE DECOMPOSITION OF IMAGES FROM SCANNED PHOTOGRAPHIC PLATES

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Abstract. We want to approximate the $m \times n$ image **A** from scanned astronomical photographic plates (from the Sofia Sky Archive Data Center) by using far fewer entries than in the original matrix. By using rank of a matrix, k we remove the redundant information or noise and use as Wiener filter, when rank $k < m$ or $k < n$. With this approximation more than 98% compression ration of image of astronomical plate without that image details, is obtained. The SVD of images from scanned photographic plates (SPP) is considered and its possible image compression.

1. INTRODUCTION

The need to minimize the amount of digital information stored and retrieved is an ever growing concern in the modern world. Singular Value Decomposition (SVD) (Andrews and Patterson, 1976) is an effective tool for minimizing data storage and data transfer. Application of SVD in astronomy can be found in (Boissel et al., 2001), where SVD is applied to a mid-infrared ISOCAM spectral map of NGC 7023 and a mathematical analysis of the map in terms of a linear combination of elementary spectra is provided. The spectrum observed on each pixel can be described as the physical superposition of four components - the intrinsic spectra of polycyclic aromatic hydrocarbons, very small grains, larger dust grains and a differential spectrum that could trace the ionisation state of polycyclic aromatic hydrocarbons.

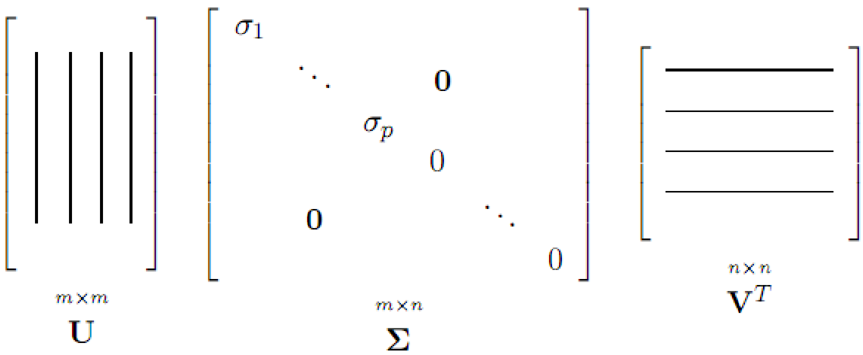


Figure 1. Structure of SVD matrices decomposition.

Other application of SVD is made for separation of image data and noise subspaces using SVD (Yatawatta, 2008). The SVD characterized the signal and noise subspace eigenmodes. Because the noise has much lower power compared with the signal, the eigenmodes corresponding to the dominant singular values.

SVD is applied also for detection of faint stars, noise removing, continuum subtraction of spectral lines for radio-astronomical images, and automatic image classification.

The goal of this paper is an application of SVD as a new approach for images analysis from scanned photographic plates (SPPs). This approach is in connection with a future creation of the image compression database of Rozhen Observatory SPPs.

The SPPs stored on the servers of the Sofia Sky Archive Data Center, are with large image sizes, which take a lot of space in the computer systems. In order to minimizing such image sizes there are different methods for image compression. One such method is a Singular Value Decomposition - very useful technique in data analysis and visualization. In linear algebra SVD is a well-known technique for factorizing a rectangular matrix, real or complex, which has been widely employed in signal processing, like image compression (Demmel, 1997; Nievergelt, 1997), noise reduction or image watermarking.

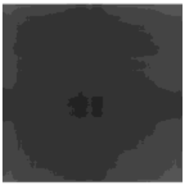
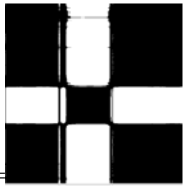
Recently, the SVD transform was used to measure the image quality under different types of distortions (Shnayderman, Gusev and Eskicioglu, 2004). Among all useful decompositions SVD - that is the factorization of a matrix **A** into the product $\mathbf{U\Sigma V^T}$ of a unitary matrix **U**, diagonal matrix $\mathbf{\Sigma}$, and another matrix $\mathbf{V^T}$ - assumes a special role (Fig.1). There are several reasons for it:

- The fact that the decomposition is achieved by unitary matrix, makes it an ideal vehicle for discussing the geometry of n-space;

- SVD is stable, small perturbation in **A** correspondent to small perturbation in $\mathbf{\Sigma}$ and conversely;

- The diagonality of $\mathbf{\Sigma}$ makes it easy to determine when **A** is near to rank-degenerate matrix, and when it is, the decomposition provides optimal low-rank approximation to **A;**

- Thanks to the pioneering efforts of Gene Golub, efficient and stable algorithms to compute the SVD have already existed.

a) $\mathbf{A}_1^w =$  b) $\mathbf{A}_2^w =$  c) $\mathbf{A}_3^w =$ 

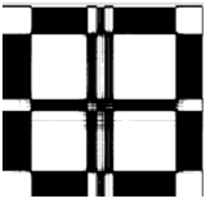
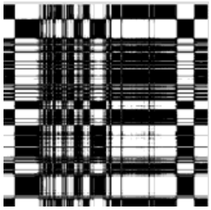
d) $\mathbf{A}_4^w =$  e) $\mathbf{A}_5^w =$ 

Figure 2. A weight matrix $\mathbf{A}_\mathbf{j}^w = u_j v_j^T$, $j = 1,2..5$

$$= 794.73 * \mathbf{A}_1^w + 71.841 * \mathbf{A}_2^w + 30.338 * \mathbf{A}_3^w + 29.161 * \mathbf{A}_4^w + 16.107 * \mathbf{A}_5^w$$

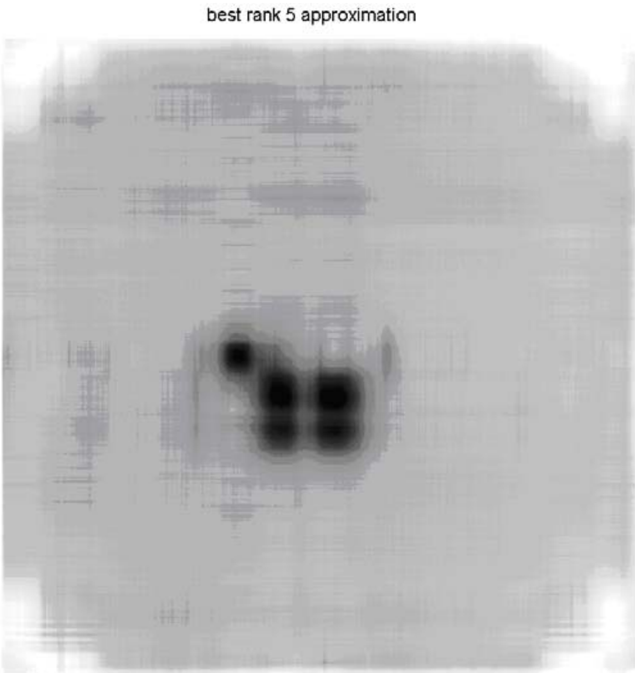


Figure 3. A weight matrix image decomposition of SPP ASI067 000556 (M45-556p.fits) in the region of the Pleiades stellar cluster.

SVD is an intriguing analogy between reduced rank approximations and Fourier analysis. Particularly in the discrete case Fourier analysis can be viewed as representing a data vector relative to a special orthogonal basis. The basis elements are envisioned as pure vibrations, that is sine and cosine functions, at different frequencies. The Fourier decomposition thus represents the input data as a superposition of pure vibrations with the coefficients specifying the amplitude of each constituent frequency. Often, there are a few principal frequencies that account for most of the variability in the original data. The remaining frequencies can be discarded with little effect. The reduced rank approximations based on the SVD are very similar in intent. However, SVD captures the best possible basis vectors for the particular data observed, rather than using one standard basis for all cases. For this reason, SVD - based reduced rank approximation - can be thought of as an adaptive generalization of Fourier analysis. The most significant vibrations are adapted to the particular data that appear.

2. SINGULAR VALUES AND THE MATRIX 2-NORM

Let us introduce matrix 2-norm for real –value matrix $\mathbf{A}$:

$$\|\mathbf{A}\|_2 = \max_{\|x\|_2=1} \|\mathbf{A}x\|_2 = \sqrt{\lambda_{\max}} \qquad (1)$$

where x is a vector and $\lambda_{\max}$ is the largest eigenvalue such that $\mathbf{A}^{\mathbf{T}}\mathbf{A} - \lambda\mathbf{I}$ is singular.

The matrix 2-norm inherits unitary invariance from the vector 2-norm: for any unitary matrices $\mathbf{U}$ and $\mathbf{V}$, $\|\mathbf{UAV}\|_2 = \|\mathbf{A}\|_2$, but did not provide a simple formula for this norm in terms of the entries of A, as we did for the induced matrix 1- and ∞-norms. With the SVD we can now derive such a formula. Recall that the vector 2-norm (and hence the matrix 2-norm) is invariant to premultiplication by a unitary matrix. Let $\mathbf{A} = \mathbf{U}\Sigma\mathbf{V}^{\mathbf{T}}$ be a singular value decomposition of A.

This $\|\mathbf{A}\|_{\mathbf{2}} = \|\mathbf{U}\Sigma\mathbf{V}^{\mathbf{T}}\|_{\mathbf{2}} = \|\mathbf{\Sigma}\mathbf{V}^{\mathbf{T}}\|_{\mathbf{2}}$. The matrix 2-norm is also immune to a unitary matrix on the right:

$$\|\mathbf{\Sigma}\mathbf{V}^{\mathbf{T}}\|_{\mathbf{2}} = \max_{\|\mathbf{x}\|_2=\mathbf{1}} \|\mathbf{\Sigma}\mathbf{V}^{\mathbf{T}}x\|_{\mathbf{2}} = \max_{\|\mathbf{y}\|_2=\mathbf{1}} \|\mathbf{\Sigma}y\|_{\mathbf{2}} = \|\mathbf{\Sigma}\|_{\mathbf{2}}, \qquad (2)$$

where we have set $y = \mathbf{V}^{\mathbf{T}}x$ and noted that $\|y\|_2 = \|\mathbf{V}^{\mathbf{T}}x\|_2 = \|x\|_2$, since $\mathbf{V}^{\mathbf{T}}$ is unitary matrix.

Let $p = \min\{m, n\}$, where m-size matrix $\mathbf{U}$, n-size matrix $\mathbf{V}$, Fig.1. Then $\|\mathbf{\Sigma}y\|_2^2 = \sum_{j=1}^{p} \sigma_j^2 y_j^2$ which is maximized over $\|y\|_2 = 1$ by $y = [1,0,...,0]^T$, giving

$\|\mathbf{A}\|_2 = \|\mathbf{\Sigma}\|_2 = \sigma_1$. Thus the matrix 2-norm is simply the first singular value and it is the largest singular value. Examples of singular values of full rank are shown in Fig. 4-6 and without zero eigenvalues in Fig. 7. The 2-norm is often the `natural' norm to use in applications, but if the matrix **A** is large, its computation is costly ($O(mn^2)$ floating point operations). For quick estimates that only require O (mn) operations and are accurate to a factor of $\sqrt{m}$ or $\sqrt{n}$, use the matrix 1- or ∞-norms. The SVD has many other important uses.

For example, if $\mathbf{A} \in \mathbf{C}^{\mathbf{n \times m}}$ is invertible and non singular, we have $\mathbf{A^{-1}} = \mathbf{V\Sigma^{-1}U^T}$, and so

$$\|\mathbf{A}^{-1}\|_2 = \frac{1}{\min\limits_{\|x\|_2=1}\|\mathbf{A}x\|_2} = \frac{1}{\sqrt{\lambda_{\min}}} = \frac{1}{\sigma_n} \tag{3}$$

where $\lambda_{\min}$ is the smallest eigenvalue such that $A^T A - \lambda I$ is singular. This illustrates that a square matrix is singular if and only if $\sigma_n = 0$.

We shall explore this in more details later using the SVD to construct low-rank approximations to A.

3. LOW-RANK MATRIX APPOXIMATION

For simplicity, assume $m \geq n$. Then the SVD of A can be written as $A = U\Sigma V^T$ can be written as the linear combination of m-by-n outer product matrices:

$$\mathbf{A} = \mathbf{U\Sigma V^T} = \begin{bmatrix}\sigma_1 u_1 & \sigma_2 u_2 & \dots & \sigma_n u_n\end{bmatrix}\begin{bmatrix} v_1^T \\ v_2^T \\ \vdots \\ v_n^T \end{bmatrix} = \sum_{j=1}^{n} \sigma_j u_j v_j^T \tag{4}$$

One of the key applications of the singular value decomposition is the construction of low-rank approximations to a matrix. Hence for any $x \in \mathbf{C}^{\mathbf{n}}$

$$\mathbf{A}x = \sum_{j=1}^{n} (\sigma_j u_j v_j^T)x = \sum_{j=1}^{n} (\sigma_j v_j^T x)u_j \tag{5}$$

since $v_j^T x$ is just a scalar. We see that $\mathbf{A}x$ is linear combination of the left singular vectors $\{\mathbf{u}_j\}$. The only catch is that u_j will not contribute to the above linear combination if $\sigma_j = 0$. If all the singular values are nonzero, set r = n; otherwise, define r such that $\sigma_r \neq 0$ but $\sigma_{r+1} = 0$. Then we have low-rank approximation to a matrix **A**:

$$\mathbf{A}\mathrm{x} = \sum_{j=1}^{r} (\sigma_j \mathrm{v}_j^{\mathrm{T}} \mathrm{x}) \mathrm{u}_j \tag{6}$$

We can approximate A by taking only a partial sum here:

$$\mathbf{A_k} = \sum_{j=1}^{k} \sigma_j \mathrm{u}_j \mathrm{v}_j^{\mathrm{T}} \quad \text{or} \tag{7a}$$

$$\mathbf{A_k} = \sum_{j=1}^{k} \sigma_j \mathbf{A_j} \tag{7b}$$

for $k \leq r$. The linear independence of $\{\mathrm{u}_1, \cdots \mathrm{u}_k\}$ guarantees that rank($\mathbf{A}_k$) = k with an $m \times n$ a weight matrix $\mathbf{A_j^w} = \mathrm{u}_j \mathrm{v}_j^{\mathrm{T}}$. Example, we can see that for $j = 5$, where eigenvalues are:
$\sigma_1 = 794.3, \sigma_2 = 71.841,\ \sigma_3 = 30338,\ \sigma_4 = 29.161,\ \sigma_5 = 16.107$.

Therefore we obtained matrix decomposition:

$$\mathbf{A_5} = \sigma_1 \mathrm{u}_1 \mathrm{v}_1^{\mathrm{T}} + \cdots + \sigma_5 \mathrm{u}_5 \mathrm{v}_5^{\mathrm{T}} = \sigma_1 \mathbf{A_1^w} + \sigma_2 \mathbf{A_2^w} + \cdots + \sigma_5 \mathbf{A_5^w} \tag{8}$$

and we can represent image with weight matrices (Fig.2) and example of (Fig.3) for j=5. Thus the terms $\sigma_j \mathrm{u}_j \mathrm{v}_j^{\mathrm{T}}$ with small σ_j contribute very little to original matrix. We can get rid of them and still to have a good approximation to matrix $\mathbf{A}$.

But how well does this partial sum approximate A? This question is answered by the following result (Nievergelt, 1997) that has wide-ranging consequences in applications.

Theorem: For all $1 \leq \mathrm{k} < \mathrm{rank(A)}$,

$$\min_{\mathrm{rank(X)=k}} \|\mathbf{A} - \mathbf{X}\| = \sigma_{k+1} \tag{9}$$

with the minimum attained by $\mathbf{A_k} = \sum_{j=1}^{k} \sigma_j \mathrm{u}_j \mathrm{v}_j^{\mathrm{T}}$

There is a full proof description in Yang and Lu (1995). Notice that we do not claim that the best rank-k approximation given in the theorem is unique.

4. EXAMPLE OF THE SINGULAR VALUE DECOMPOSITION

The standard algorithm for computing the singular value decomposition differs a bit from the algorithm described above. We know from our experiences with the normal equations for least squares problems that significant errors can be introduced when $A^T A$ are constructed. For practical SVD computations, one can sidestep this by using Householder transformations to create unitary matrices U and V such that $B=UAV^T$ is bidiagonal, i.e., $b_{jk} = 0$ unless $j = k$ or $j-1=k$. One then applies specialized eigenvalue algorithms for computing the SVD of a bidiagonal matrix. While this approach has numerical advantages over the method used in our constructive proof of the SVD, it is still instructive to follow through that construction for a simple matrix, say

$$\mathbf{A} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}$$

Step 1. First, form $\mathbf{A}^\mathbf{T}\mathbf{A}$:

$$\mathbf{A}^\mathbf{T}\mathbf{A} = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}$$

and compute its eigenvalues, λ , and (normalized) eigenvectors, v :

$$\lambda_1 = 3\,, \mathrm{v}_1 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix} \text{ and } \lambda_2 = 1\,, \mathrm{v}_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

Step 2. Set

$$\sigma_1 = \|\mathbf{A}v_1\|_2 = \sqrt{\lambda_1} = \sqrt{3} \text{ and } \sigma_2 = \|\mathbf{A}v_2\|_2 = \sqrt{\lambda_2} = 1$$

Step 3. Since $\sigma_1, \sigma_2 \neq 0$, we can immediately form u_1 and u_2

$$\mathrm{u}_1 = \frac{1}{\sigma_1}\mathbf{A}\mathrm{v}_1 = \frac{1}{\sqrt{6}}\begin{bmatrix} 1 \\ 1 \\ 2 \end{bmatrix} \quad \text{and} \quad \mathrm{u}_2 = \frac{1}{\sigma_2}\mathbf{A}\mathrm{v}_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}$$

The $\frac{1}{\sigma_j}$ scaling ensures that both u_1 and u_2 are unit vectors. We can verify that they are orthogonal:

$$u_1^T u_2 = \frac{1}{\sqrt{12}}\begin{bmatrix}1 & 1 & 2\end{bmatrix}\begin{bmatrix}-1\\ 1\\ 0\end{bmatrix} = 0$$

Step 4. At this point, we have all the ingredients to build the reduced singular value decomposition:

$$\mathbf{A} = \mathbf{U\Sigma V^T} = \begin{bmatrix}\frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}}\\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}}\\ \frac{2}{\sqrt{6}} & 0\end{bmatrix}\begin{bmatrix}\sqrt{3} & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}\\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}}\end{bmatrix}$$

The only additional information required to build the full SVD is the unit vector u_3 that is orthogonal to u_1 and u_2. One can and such a vector by inspection:

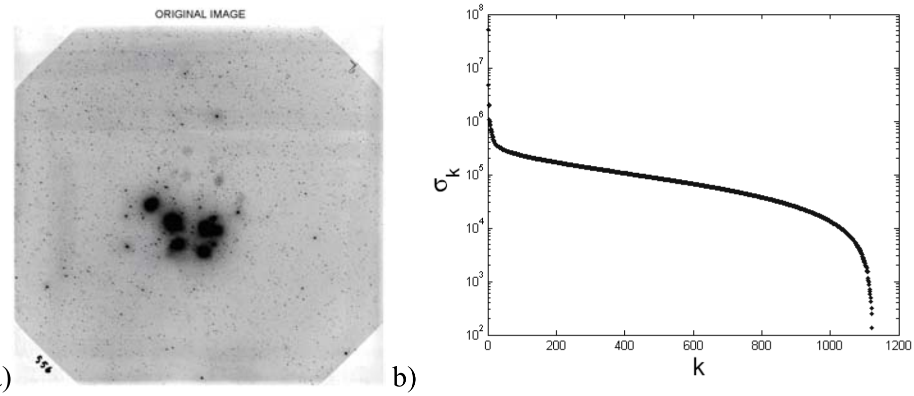
$$u_3 = \frac{1}{\sqrt{3}}\begin{bmatrix}1\\ 1\\ -1\end{bmatrix}$$

If you are naturally able to eyeball this orthogonal vector, there are any number of mechanical ways to compute u_3, e.g., by finding a vector $u_3 = [\alpha, \beta, \gamma]^T$ that satisfies:

$$\text{Orthogonality conditions } u_1^T u_3 = u_2^T u_3 = 0$$

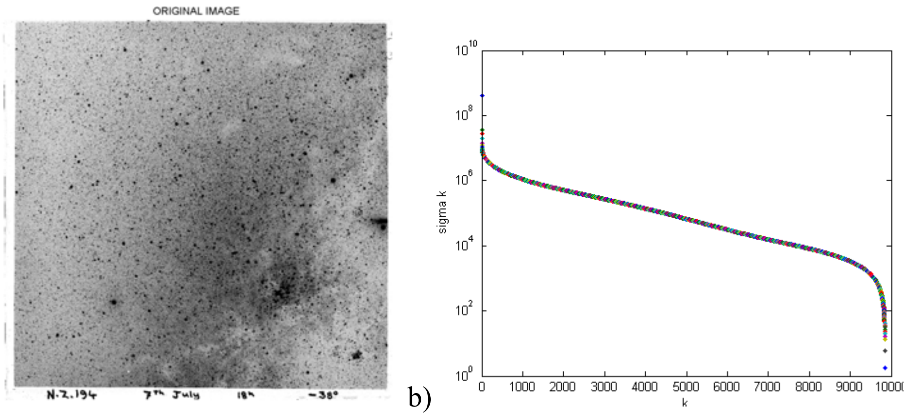
$$\text{Normalization condition } u_3^T u_3 = 1$$

We can find vector u_3 using the Gram-Schmidt process too.



a) b)

Figure 4. Image of SPP ASI067 000556 (M45-556p.fits) in the region of the Pleiades stellar cluster. a) Original image of SPP (size 1122x1122), b) Singular values.



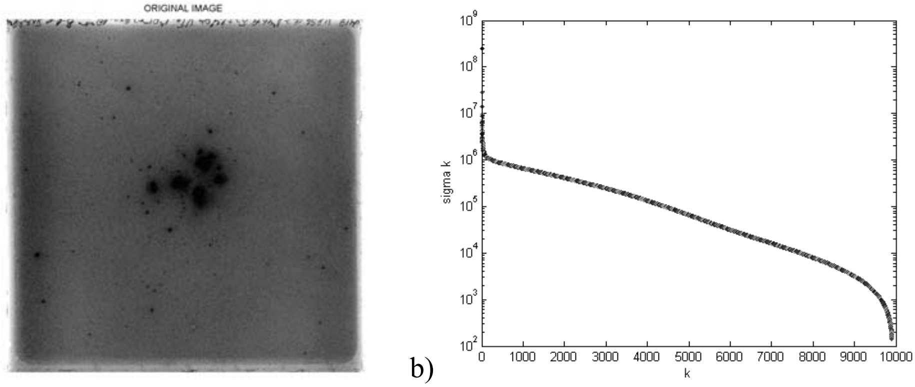
a) b)

Figure 5. Image of SPP BAM010M (nz194.fits); a) Original image SPP (size 9898x9897); b) Singular values.

5. APPLICATION OF LOW-RANK APPROXIMATION IN IMAGE COMPRESION

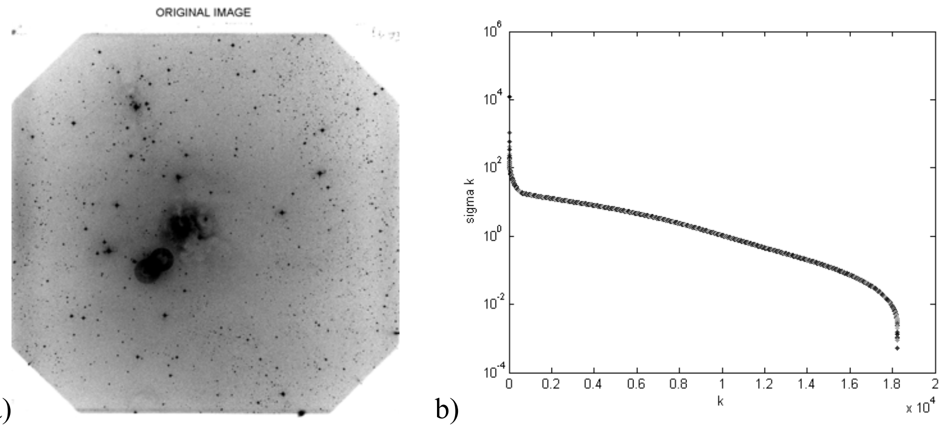
As an illustration of the utility of low-rank matrix approximations, we consider the compression of digital images. On a computer, the image is simply a matrix denoting pixel colors. Typically, such matrices can be well approximated by low-rank matrices. Instead of storing the mn entries of the matrix A, one need only store the $k(m+n)+k$ numbers that make up the various σ_j, u_j and v_j values in the sum:

$$\mathbf{A_k} = \sum_{j=1}^{k} \sigma_j \mathrm{u}_j \mathrm{v}_\mathrm{j}^\mathrm{T} \tag{10}$$



a) b)

Figure 6. Image of SPP ROZ050 006419 (6419.fits) in the region of the Pleiades stellar cluster a) Original image SPP (size 9906x10060); b) Singular values.



a) b)

Figure 7. Image of SPP ROZ200 001655 (ROZ200 001655a.fits), taken in the region of S MON a) Original image SPP (size 18898x18240); b) Singular values

When k<<min(m, n) this can make for a significant improvement, though modern image compression protocols use more sophisticated approaches.

Next, we show the singular values for one image matrix, the scanned plate ASI067 000556 (M45-556p.fits) in the region of the Pleiades stellar cluster, with image size 1112x1122 and 16bit pixel format. We see that the singular values decrease near linearly. Though the singular values are very large, $\sigma_1 > 10^7$, fig.4b, there is a relative difference of five orders of magnitude between the smallest and largest singular value. We see that the singular values decrease rapidly.

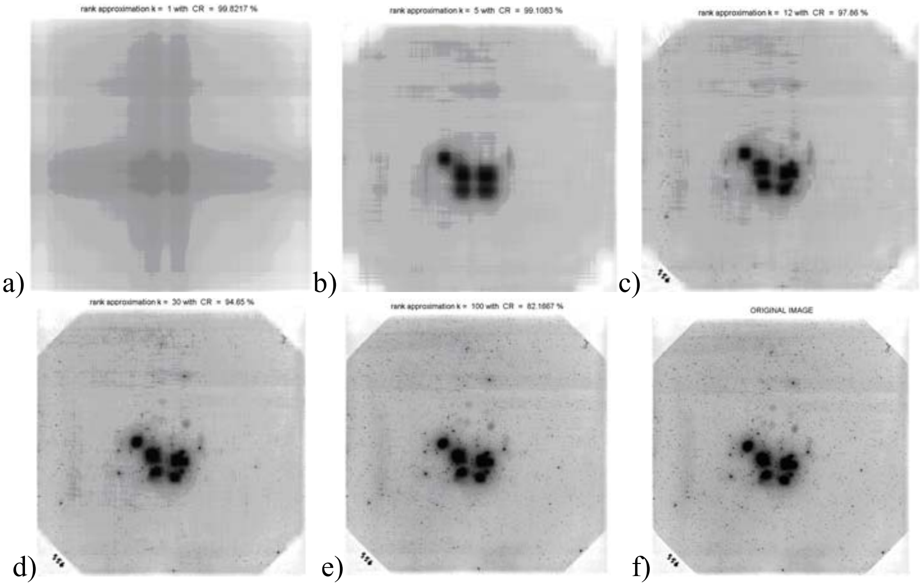


Figure 8. The SVD rank approximations for image SPP ASI067 000556 (M45-556p.fits) in the region of the Pleiades stellar cluster.

There are one greater than 10^7 and only four greater than 10^6. If all the singular values were roughly the same, we would not expect accurate low-rank approximations. We can approximate a matrix by adding only the first few terms of the series (Fig. 8).

For image quality measure we use compressed ratio. It is given with:

$$\mathrm{CR} \equiv \text{compression ration} = \left(1 - \frac{\mathrm{rank(A)(sizeX(A)+sizeY(A)+1)}}{\mathrm{sizeX(A)sizeY(A)}}\right) \times 100,\ \%$$

Thus, one way of compressing the image is to compute the singular value decomposition and then to reconstruct the image by an approximation of smaller rank.

This technique is illustrated in Fig. 8, which shows respectively the terms $\mathrm{u}_j \mathrm{v}_\mathrm{j}^\mathrm{T}$ and the terms $\mathbf{A_k} = \sum_{j=1}^{k} \sigma_j \mathrm{u}_j \mathrm{v}_\mathrm{j}^\mathrm{T}$. As can be seen in Fig. 8 and Fig. 9, the image is reconstructed almost perfectly (according to the human eye) by a rank 40 approximation. This gives a compression ratio of:

$$\mathrm{CR} = \left(1 - \frac{40(1122+1122+1)}{1122 \times 1122}\right) \times 100 = 0.928667 \times 100 \approx 93\,\%$$

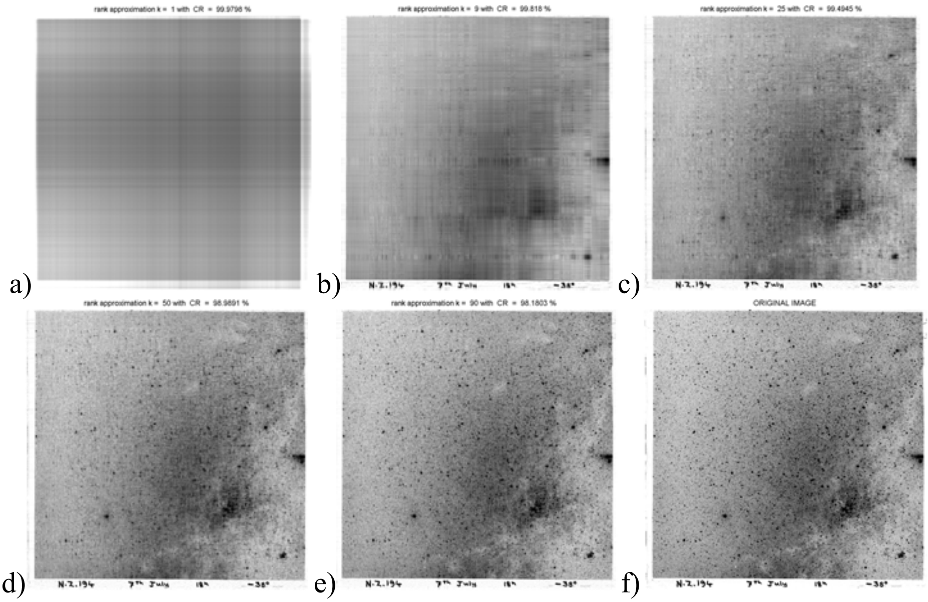


Figure 9. The SVD rank approximations for scanned image of SPP BAM010M (nz194.fits).

Let us to show rank approximation image matrix of a scanned plate BAM010M (nz194.fits), with image size 9898x9897 and 16bit pixel format. The first ten singular values are:

$\sigma_1 = 399\,935\,695$, $\sigma_2 = 36\,103\,983$, $\sigma_3 = 27\ \ 223\ \ 347$, $\sigma_4 = 19834987$,

$\sigma_5 = 13977320$ $\sigma_6 = 12295017$, $\sigma_7 = 10881892$, $\sigma_8 = 10418273$,

$\sigma_9 = 9\,556\,364$, $\sigma_{10} = 9037119$

…

$\sigma_{9849} = 5.954$, $\sigma_{9850} = 1.832$, and $\sigma_{9851} = 4.7 * 10^{-11}$!

We obtained that after a 9850 singular value all singular values are zeros (Fig. 5b).

Let us to show rank approximation image matrix of a scanned plate ROZ200 001655a.fits, with image size 18898x18240 and 16bit pixel format.

The first ten singular values are:

$\sigma_1 = 12246.0868$, $\sigma_2 = 1060.9436$, $\sigma_3 = 578.4546$, $\sigma_4 = 413.6548$,

$\sigma_5 = 333.3525$ $\sigma_6 = 267.0412$, $\sigma_7 = 222.5709$, $\sigma_8 = 199.2704$,

$\sigma_9 = 187.1444$, $\sigma_{10} = 183.6114$

… and $\sigma_{18240} = 5 * 10^{-4}$. The singular values are represented in Fig. 7b.

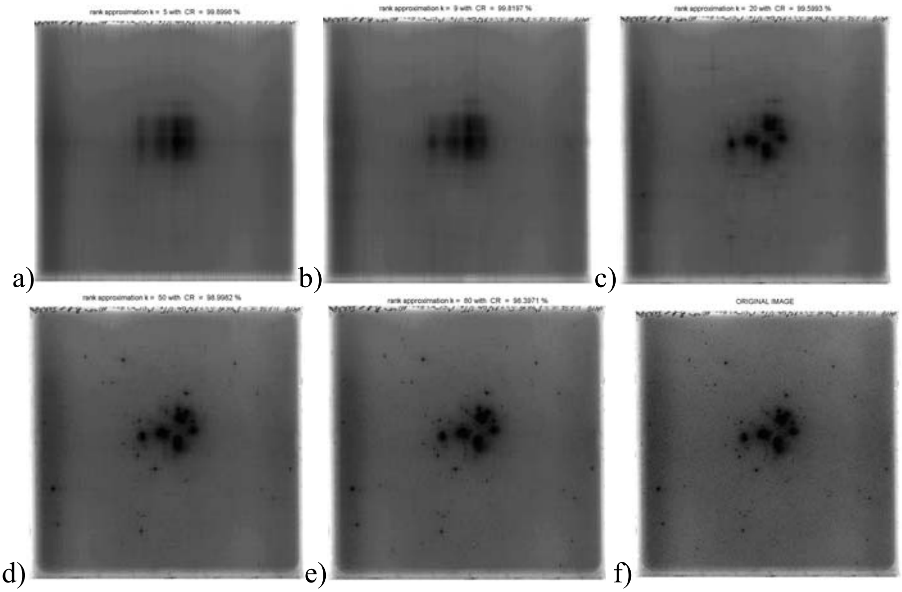


Figure 10. The SVD rank approximations for the scanned image of SPP ROZ050 006419 (6419.fits) taken in the region of the Pleiades stellar cluster.

6. CONCLUSIONS

Since matlab code for SVD calculate full rank SVD, we create matlab code for step by step rank approximation simulation for image processing of SPP.

As rank k increases, the images quality increases, but the same does the volume of memory needed to store the images. This means that smaller ranked SVD approximations (smaller values for j) are preferable.

By storing only the first columns of $\mathbf{U}$ and $\mathbf{V}$ and their respective singular values, the image can be replicated while taking up only:

- 5.35% for image of CR=94.65% with k=30, image size (1122x1122) (Fig. 8d),
- 1.01% for image of CR=98.99% with k=50, image size (9898x9897) (Fig. 9d),
- 1% for image of CR=99.00% with k=50, image size (9906x10060) (Fig. 10d)

of the original storage space.

We can actually see how the compression breaks down the matrix for a rank approximation. Notice that every row of pixels is the same row, just multiplied by a different constant, which changes the overall intensity of row. The same goes for columns: every column of pixels is actually the same column multiplied by a different constant (Fig. 3).

Notable those with minimum number rank,

- rank 12 with CR=97.86, image size (1122x1122) (Fig. 8c),
- rank 9 with CR=99.82%, image size (9898x9897) (Fig. 9b),
- rank 9 with CR=98.82%, image size (9906x10060) (Fig. 10b),

we read clearly the marks of the plates. With very big CR we can see image details. This can be use similar as filter and useful for image denoising. The rank image approximation is faster from wiener filter processing. This is important when there are large images (e.g. scanned plates). These low-rank matrix approximations to SPP images do require less computer storage and transmission time than the full-rank image.

The SVD facilitates the robust solution of a variety of approximation problems, including not only the least squares problems with rank-deficient A, but also other low-rank matrix approximation problems that arise throughout engineering, statistics, the physical sciences, and social sciences too.

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WFPDB DEVELOPMENT: RESTORING CHARACTERISTIC CURVE FROM DIGITIZED IMAGES OF SCANNED PHOTOGRAPHIC PLATES

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Institute of Astronomy and National Astronomical Observatory, BAS

Abstract. In progress is a process of cataloguing and digitization of direct observation astro-plates archives stored in the National Astronomical Observatory Rozhen, Bulgaria. This is a part of a project aimed to develop the Wide-Field Plate Database from direct astronomical observations archives of all astronomical institutions over the world being in possession of such observations. One natural step for the future appropriate processing of digitized images is their transfer into relative intensities as well the photographic emulsion is nonlinear detector of light. For this reason we offer an algorithm to restore emulsion characteristic curve. The algorithm is based on a method offered by de Vaucouleurs 1984. Our contribution is to develop the algorithm using IRAF routines only.

1. SAVING ASTRONOMICAL PHOTOGRAPHS

Today astronomical photography is rarely applied, but for the sake of this a huge amount of photographic plates and films with valuable and still only partially utilized information for the astronomical objects and phenomena have been accumulated in the archives of the astronomical observatories. The *preservation* and *utilization* of this treasure is of great importance for contemporary astronomy. In 1991 the IAU adopted a resolution, in which, underlining the importance of the astronomical archives, recommends to the astronomical institutions to exert efforts and allocate funds for their *preservation* and *cataloguing* (IAU Information Bulletin 1992, No. 67, p. 41). By initiative of the Working Group on Wide-Field Imaging at Commission 9 of IAU, the creation of a Wide-Field Plate Database (WFPDB) started in the Institute of Astronomy at the Bulgarian Academy of Sciences with the support of the National Science Fund (NSF) (research projects F-311/93 and F-650/96).

2. DEVELOPMENT OF THE PROCESS

WFPDB is generated by merging data from a number of observation catalogues, available in astronomical observatories around the world. In 1997 an on-line access was provided to WFPDB through the system VizieR of the Strasbourg Data Center (CDS) at address http://vizier.u-strasbg.fr/cats/VI.htx (catalogue number VI/90). Since years WFPDB is constantly among the first 100 most used astronomical catalogues from a total number of 3 000 catalogues disseminated by CDS and is regularly enlarged with new data. In 2001 a new enlarged version of WFPDB was installed at the Institute of Astronomy in Sofia http://www.skyarchive.com. The development of WFPDB is connected with the digitization of the astronomical plates and films. It was started with the micro densitometers devices like PDS and Joyce Loebl. Recently it is accomplished by help of appropriate scanners, and partially by digital cameras. Digital images of the photographic plates are obtained in two modes: low resolution preview image in JPG format (usually ≤600 dpi) and high resolution FITS format image (≥1200 dpi). An on-line access to the former – the so called "preview" – is provided for the WFPDB users. The process of digitization of the photographic plates has been started by scanning direct photographic plates found in the archive of the National Astronomical Observatory Rozhen taken in the RC focus of the 2-m telescope (scale 12.86 arcsec per mm).

3. DIGITIZATION PROCESS

At the moment more than 500 astro-plates with dimension 30x30 cm has been scanned with Epson Expression 10000XL Graphic Arts Scanner. This way astronomical information of more than 300 GB has been accumulated at the moment. The scanning procedure is performed in the conditions as follows:

- resolution 1600 dpi which corresponds to 16 microns pixel size
- output is 16 bit gray-scale image in FITS
- scanner speed 5.3 msec per line
- auto-focus mode on the every plate
- as a preview option, to take control on the quality of the astro-plate every plate is scanned additionally with a less resolution - 800 dpi, 24 bit color JPG image.

The scanning duration for 30x30 cm plate in FITS format mode is 18 minutes, but JPG format takes 8 minutes. For comparison reason we like to point out that scanning of the same plate with Joyce Loebl microdensitometer takes 50 hours.

Digitization of the astro-plates preserves the information stamped on for future analyze and gives the opportunity old astronomical observations to be processed and analyzed in digital manner. A serious disadvantage of the photographic emulsion is its nonlinearity. In order to overcome this problem one have to build-up the emulsion characteristic curve – the relation between photographic density and the relative intensity. The professional astronomy practice requires on every astronomical plate a photometric wedge_to be stamped additionally (see Fig. 1). Figure 2 demonstrates the characteristic curve of the emulsion recovered on the base of this wedge image. There are some exceptions of recommended astronomical practice - most often when the object of scientific interest is a globular cluster such wedge is missing as well as the calibration of the instrumental stellar images uses photometric stellar standard established for most clusters. In this cases the recovering of the emulsion characteristic curve is tricky in some sense.

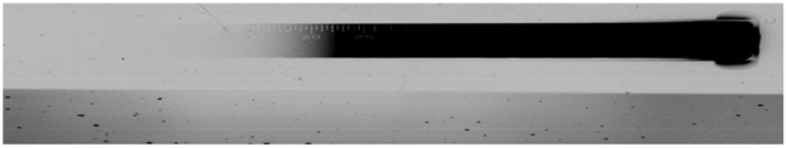

Figure 1. The wedge available at NAO Rozhen.

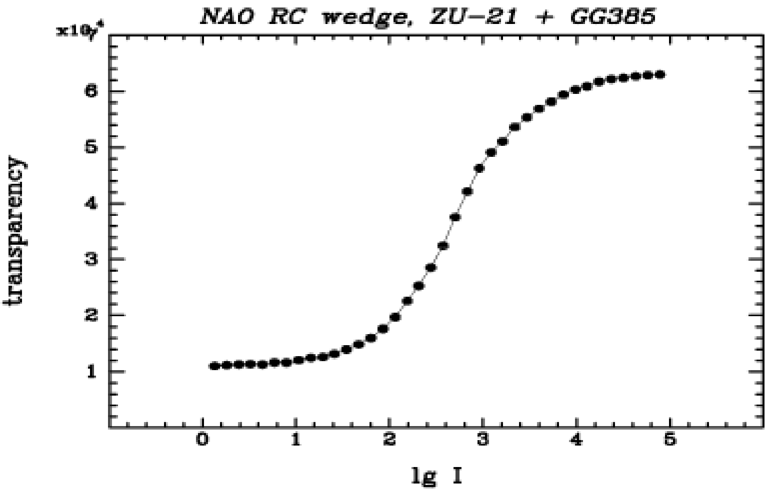

Figure 2. Characteristic curve of the emulsion gained via the wedge.

4. THE ALGORITHM

Our main goal was to develop an algorithm recovering the emulsion characteristic curve only by means of appropriate tasks available in IRAF packages. Here we demonstrate the principles of the algorithm we developed and would like to emphasize that no additional software or routines were used. Our presentation is not a review of the available methods to recover characteristic curves but will demonstrate one of them – a method offered by de Vaucouleurs in 1984 The method is based on azimuthally integrated stellar profiles extracted from a digital image. Important feature of the method is the stellar magnitudes of the stars which profiles will be exploited to be known very well. It gets clear that to apply the method of de Vaucouleurs one needs to identify in the field of the plate of interest some stars with known magnitudes as shown on figure 3 .

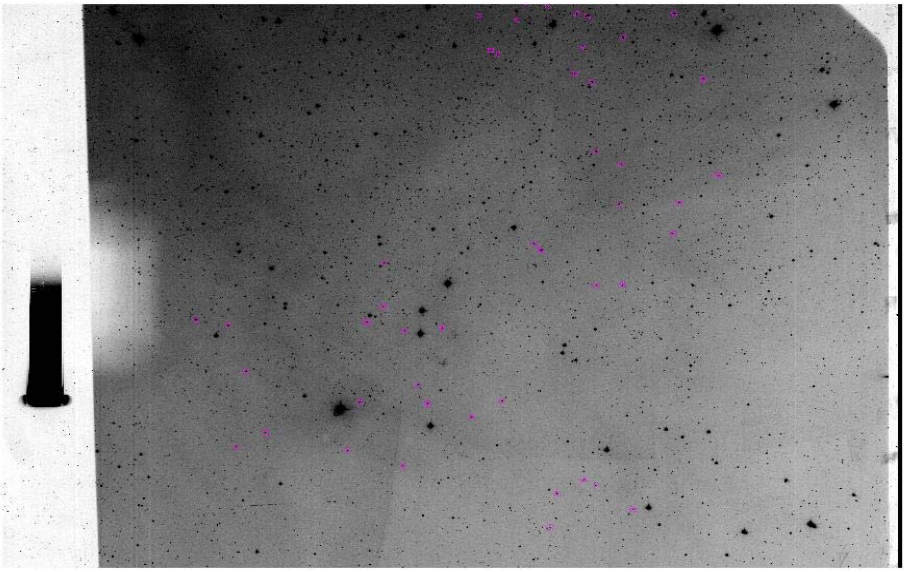

Figure 3. Image of scanned photographic plate with stamped wedge. Stars with known magnitudes are marked.

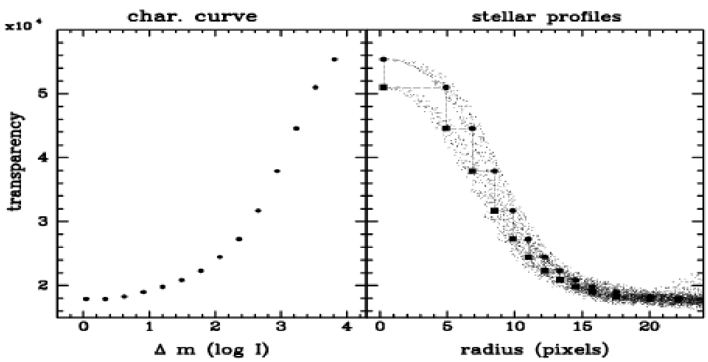

Figure 4. Graphical illustration of de Vaucouleurs method.

The method is demonstrated on figure 4. The right panel of Fig. 3 shows two stellar profiles. The abscissa presents the distance from the image center but the ordinate photographic density. It is easy to be realized that points corresponding to one and the same density on the two stellar profiles is cased by known light intensities – the magnitude difference between the two stars. “Jumping” between the two profiles we can mark those densities on one and the same profile caused by one and the same light intensity. This way we can construct a new graph on which abscissa are marked points with a constant step corresponding to brightness difference of the two stars, but on the ordinate their corresponding density values taken from the right panel (see left panel, Fig. 3).

As well as stellar magnitude scale is arbitrary and magnitude difference corresponds to the logarithm of relative intensities such figure actually presents the characteristic curve of the photographic emulsion. Important requirement for the two stellar profiles to be used in a couple is to merge in the same background. The background density over the plate could changes as result of non uniform sky illumination as well as result from the non-equal chemical fog caused by improper treatment of the plate during the development process. Any way profiles with non equal background are useless.

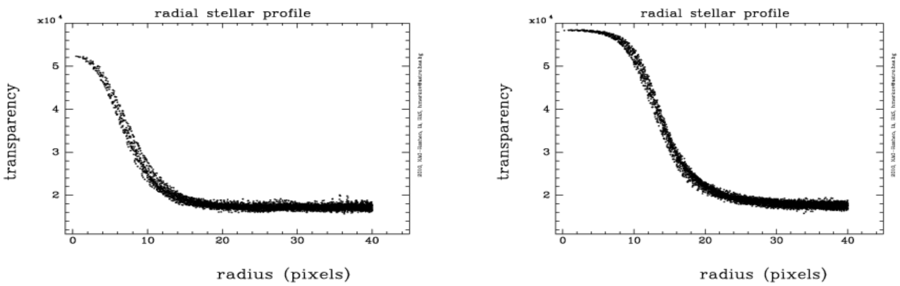

Figure 5. Azimuthally integrated stellar profiles of two stars.

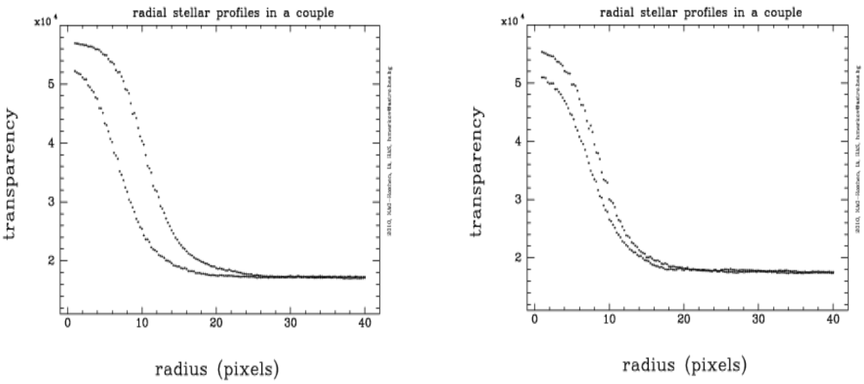

Figure 6. Stellar profiles with appropriate difference in brightness.

Concerning the above demonstrated method every two couples of stellar profiles contains information for the characteristic curve of the emulsion. It is evident that the more close profiles (in transparency) will produce more points on the characteristic curve.

Key moment to apply the above outlined method to achieve an appropriate characteristic curve is the accuracy of stellar magnitudes or at last their exact difference. On figure 7 is demonstrated the importance of adopted magnitude difference on the shape of the curve. On both panels of this figure with a curved line is shown characteristic curve obtained from direct scan of the wedge shown on fig.4(left) and with black dots is marked the characteristic curve of the same emulsion obtained by using couple of stars with known magnitudes (as referred from GSC). Left panel demonstrates the characteristic curve based on magnitude difference of 0.29 mag. Discrepancy of the two curves is obvious. The right panel demonstrates a new version of characteristic curve adopting magnitude difference 0.21 mag. More about conditions required for appropriate application of de Vaucouleurs method are discussed in Markov (1994).

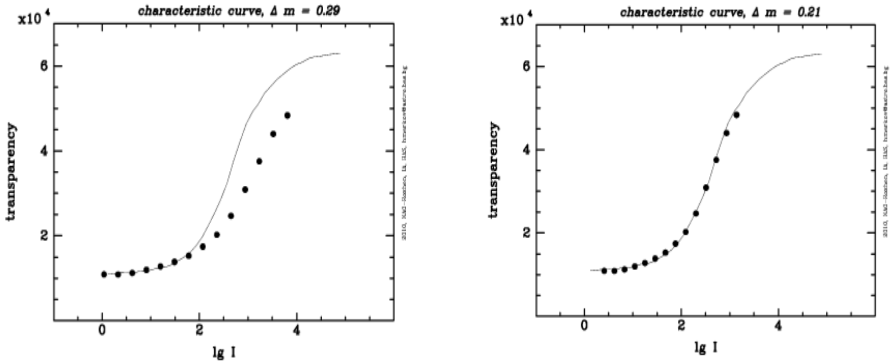

Figure 7. The importance of the magnitude difference on the shape of characteristic curve - left panel $\Delta m = 0.29$ *mag*; right panel $\Delta m = 0.21$ *mag*

5. ANOTHER APPROACH

One particular case of the outlined method to recover the characteristic curve of the emulsion uses rich sample of stars with known magnitudes. This approach relies on the fact that the top pixels of the stellar image (or the max values in the profile) are well proportional to the brightness of the star. So if we have rich sample of stars with known magnitudes (photometric standard) which cover the whole dynamic range in transparency (density) we can successfully build-up the characteristic curve of the emulsion. The most appropriate fields filling such requirements are the regions of globular clusters. where we can find many stars with well established brightness (Stetson, 2001, Catalog of CCD standards). Figure 8 shows CCD standard in the region of globular cluster M3 used to build-up the characteristic curve demonstrated on figure 9.

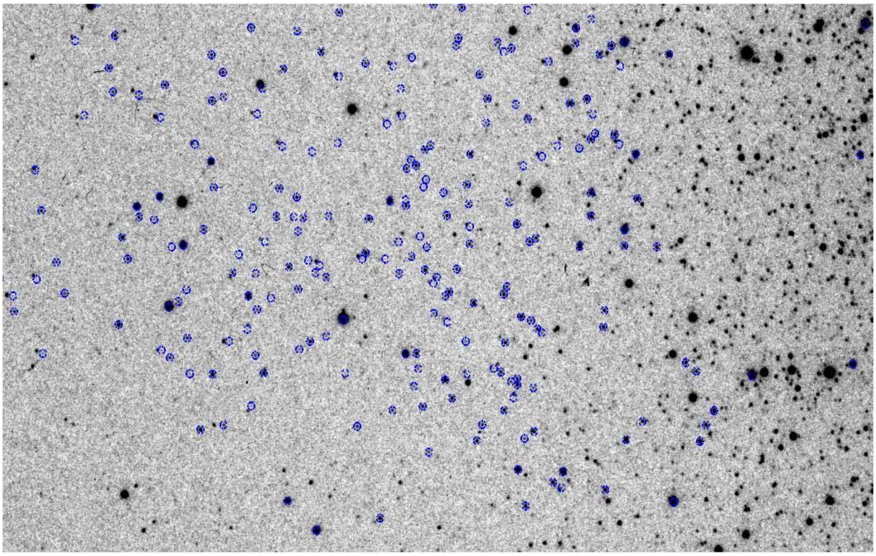

Figure 8. Stetson's CCD standard in the region of globular cluster M3.

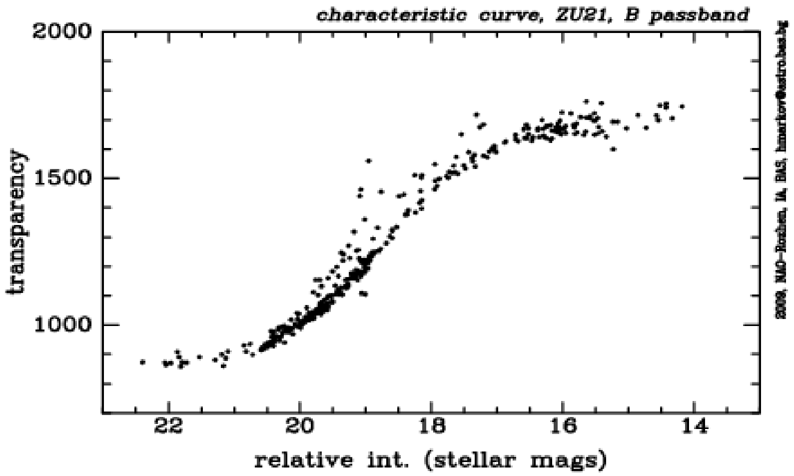

Figure 9. Characteristic curve based on Stetson's CCD standard in the field of M3.

6. BASIC IRAF PACKAGES AND ROUTINES

The main goal of this article is to demonstrate the ability to build-up the characteristic curve of an astro-plate using IRAF routines only. None additional software routines were used. The outlined algorithm uses a method offered by de Vaucouleurs (1984) and is based on azimuthally integrated profiles of stellar images with known difference in the brightness. Here are the IRAF packages and routines used to cover the entire process.

- **DAOPHOT** (*DAOFIND, PHOT*) - to find stellar images and to define their instrumental magnitudes;
- **APPHOT** (*RADPROF*) - this was used for the purpose of azimuthal integrated stellar profile establishment;
- **MATH** (*CURFIT*), **STSDAS** (*NFIT1D*) - for appropriate smooth fitting of the characteristic curve and establishing its analytic form;
- **IMAGES** (*DISPLAY, IMEXAM*) - supplementary routines for interactive analyzing of the digital images;
- **TABLES –** data files management and processing.

Acknowledgments

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THE ZVENIGOROD ASTRONOMICAL PLATE COLLECTION PRESENTED IN THE WIDE-FIELD PLATE DATABASE

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Abstract. The results of the plate cataloging and digitization in the Zvenigorod Observatory are described. The observational material was obtained in the period 1972 - 2005 with the 40 cm Carl Zeiss astrograph (F=200 cm, field size 8x8 sq. deg., scale 100 arcsec/mm). The archive includes at present 3703 plates – observations in the northern hemisphere mainly for mapping the sky according to the FON program. In addition, other objects as asteroids, minor planets, Pluto, Mars, etc. were observed too. A part of the archive is scanned already, as well as original observational logbooks. These results are included in the Wide-Field Plate Database in Sofia (www.skyarchive.org) and described in the site of the Institute of Astronomy, RAN (http://www.inasan.ru/ rus/scan/).

1. INTRODUCTION

The Zvenigorod Observatory of the Institute of Astronomy of the Russian Academy of Sciences has been built in the end of 50-th with the beginning of the era of the artificial satellites launched by the Soviet Cosmic Program. The primary goals of the observatory were monitoring of artificial objects and objects of solar system: minor planets, asteroids, comets. Stars for astrometry also were observed for the creation of astrometric catalogue (before the PPM era).

Now the Zvenigorod observatory manages an electronic library of astronomical negatives received with its own telescopes and instruments. Here we describe the Zvenigorod astrograph plate collection. It includes about 4 000 astronomical negatives. The digitization is carried out by means of two EPSON 1640 XL scanners.

2. CONTENT OF THE ZVENIGOROD ASTROGRAPH PLATE ARCHIVE

The Zeiss-400 astrograph is mounted in Zvenigorod in 1972. Its focus is 200 cm; the lens diameter is 40 cm. The plates have sizes 30 x 30 cm, covering the sky region 8 x 8 degrees. 3703 negatives have been received in the period 1972-2004. Distribution of plates with years is shown in Fig. 1. Fig. 2 shows the plate distribution according to observing programs.

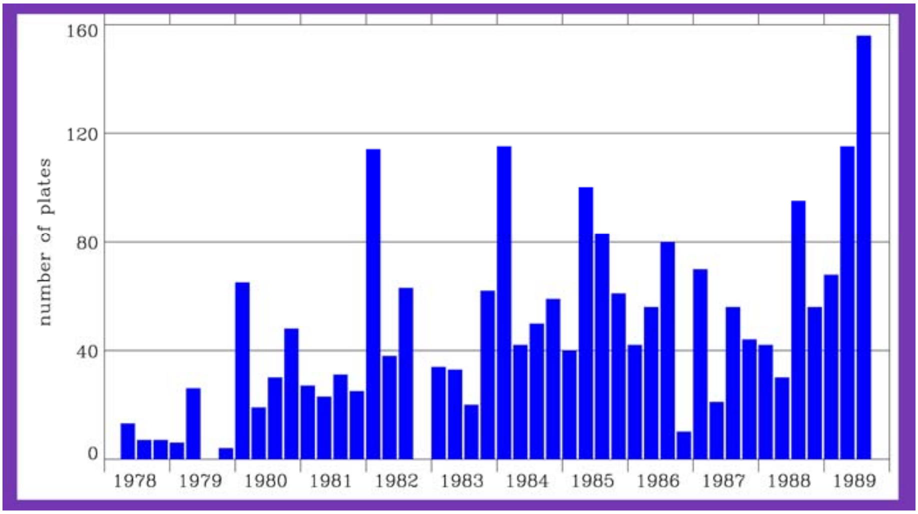

Figure 1. Distribution of the number of available Zvenigorod astrograph plates with years.

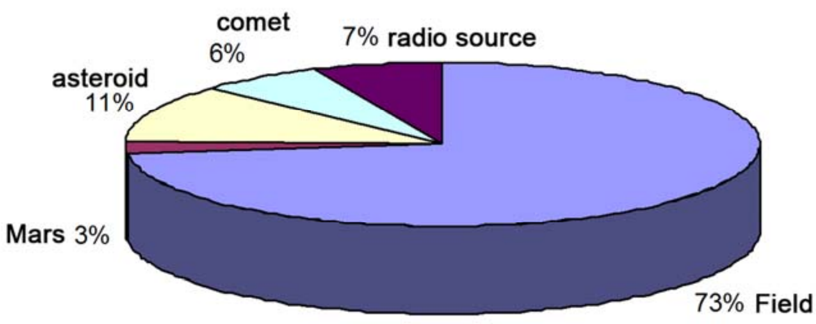

Figure 2. Plate Collection contents according to programs of observations.

2.1. The Fon Program

The Photographic Survey of the Sky (FON) was carried out in the period 1980 - 1992 for astrometric catalogue creation. The FON program comprises about 50% of the whole collection. It completeness is up to 16,5 magnitudes. It covers the sky between -6 to +90 degrees. The neighboring plates overlap each other 50%. There were exceptions in winter zones: R.A. from 4 till 9 h and DEC from -2 up to +25 degrees and a few ones from 16 till 18h at low delta. Each plate has two exposures with small shift of the telescope between them: long one is usual near 30 minutes and short one – 1-2 minutes. The exposures were set in the way that the plate images of stars up to 16.5 magnitudes to be well visible. Actually the limited magnitude is just beyond 14 - 15 magnitudes. V. P. Osipenko and V. A. Jurevich conducted the observations.

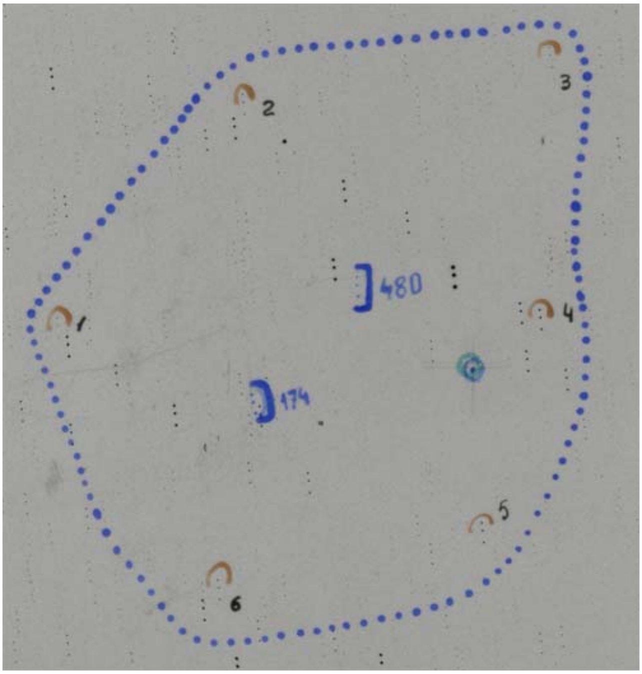

Figure 3. The astrograph plate fragments include the asteroid and stars images in the form of a chain with three exposures.

2.2. The Asteroids Program

The program of asteroids observations from 1978 up to 1992 was executed by ITA supervision and includes 20 selected asteroids. The second program was carried out under IAU from 1980 to 90-th years and it is a subprogram of the photographic observation of 15 selected asteroids. The program goal is the position specification at a point of a spring equinox. Three exposures with camera shifted in declination between exposures (which took usually a few minutes) were carried out. Thus the sequence of images of the observed minor planet is inclined in relation to a star image sequence and thus it is easy for finding the objects on a plate (see Fig. 3). The coordinates of the main object (a minor planet from the list of ITA RAN), as well as of other asteroids that have casually appeared on the same negative, were measured. The asteroids program comprises about 30% of photographic collection. V. P. Osipenko received more than 60% of the plates.

2.3. The Comets Program

The comets observations were additional for the observers - the observatory had not an official program for a long period. Later the Zvenigorod Observatory took a part in the respective international program with the observations of the comets of Giacobini-Zinner, Halley and Hale-Bopp. For the exact coordinates definition a star-shaped comet image was used. The astrograph allows receiving the coordinates of a comet with accuracy 3-5 arcsec. For this purpose a chain of exposures of 5 sec + 15 sec + 45 sec + 135 sec + 2 minutes + 6 minutes was used. Besides, observations for studying comet tails and different formations inside it (separations, condensations, turbulences) with exposure one or more hours were carried out. The guiding star was close to the comet head and displaced from the plate center. So it was possible to receive the tail image with length up to 7° (25 cm). The comets program comprises about 8% of the whole plate collection.

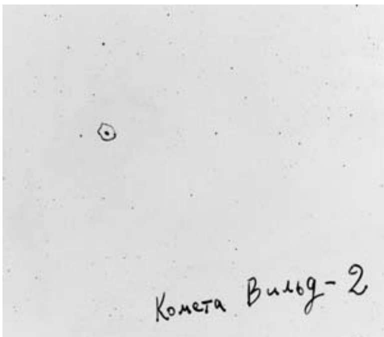

Figure 4. The star-shaped image of the comet of Hyakutake B2 passed on the shortest distance from the Pole (4 degrees).

2.4. The Radio Sources

The first joint program of the Soviet observatories where the astrograph has been involved was the observation of the nine bright quasars (up to 18th magnitude) with a point type images. The program goal was the construction of inertial coordinates system for which reference stars from the catalogue of star positions were used. In this case the long exposures were required. Our plates have been sent to Pulkovo Observatory where they were processed. Further the observatory participated in the program of drawing up of the catalogue of reference stars around 190 radio sources. The program coordinator was Dr. N.G. Rizvanov from Kazan Observatory. This program comprises about 8% of all negatives.

2.5. Pluto And Mars Observations

These plates comprise about 3% of the whole collection. The Pluto observations were carried out in 1998 - 2005 for specification of its orbit. The plates with size 9 x 12 cm were used for this purpose. The observation conditions were adverse: the planet moves at low distance above the horizon. The time of observations was limited: one week at the evening visibility at the end of Spring and one week of morning visibility at the end of Summer. Nevertheless V.P. Osipenko has received nearly 180 plates. The observations of Mars were used for maintenance of the flights of two Fobos satellites in 1988.

3. ACCESS TO ARCHIVE

The observatory working team put the specific target: creation of a database of a plate images at the Zvenigorod observatory, installation of the software and of the digital plate archives of the collection on the servers of the Institute of Astronomy and online access and support to them.

We scan the plates with the EPSON 1640 XL scanner. Two types of image data were obtained as a result of the scanning:

1) The full-colour preview JPG in low-resolution scans (3MB). They are useful for the users to get information about the plate quality, and see the observer remarks on the plate surface. Also we obtained the TIFF-preview images with resolution 1200 dpi (600MB) in the print case.

2) The main data are the plate scans with resolution 1600 dpi in FITS-format (700MB).

This archive is stored in the Zvenigorod Observatory.

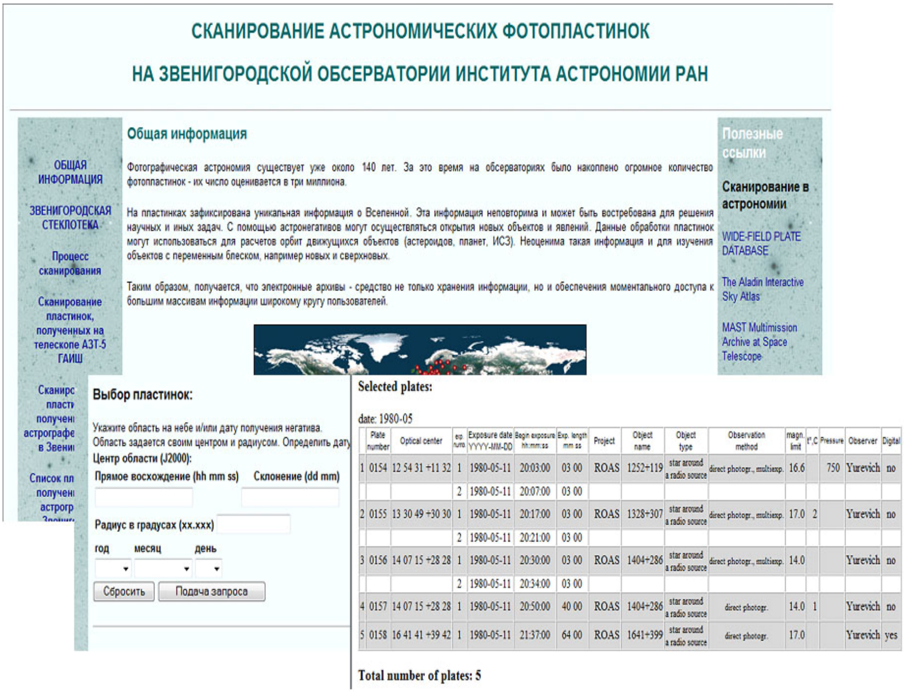

Figure 5. The description of the plate archives in the site of the Institute of Astronomy, RAS (http://www.inasan.ru/rus/scan).

We created the computer-readable catalogue of the astrograph plates (ASCII). Access to it is available both in INASAN server[1] and in the WFPDB (Tsvetkov, 2005; Tsvetkov and Tsvetkova, 2008).

In the INASAN site there is a detailed description of the instruments, archive and observational programs. Also there the plate information can be found and a search with various parameters is organized (see Fig. 5).

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[1] Chupina N., Vereshchagin V., The INASAN plate archive (http://www.inasan.ru/rus/scan).

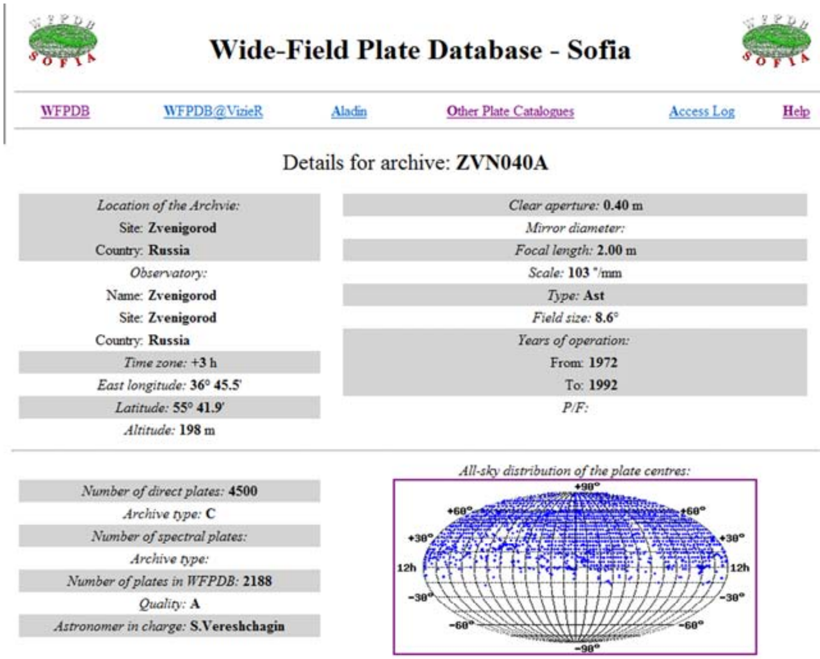


Figure 6. An example of WFPDB search: ZVN040 details with the all-sky distribution of the astrograph plate centers in the equatorial coordinates (J2000).

In the Wide-Field Plate Database - Sofia Search Page (http://www.skyarchive.org), the information on every plate from the catalogue can be retrieved using the observatory identifier (ZVN) followed by the instrument aperture (040), plus the original plate number. At WFPDB you can find more details for the location of the archives, the observatory specifications, the parameters of the telescope, and the period of its operation, the coordinates of the plate center in epoch 2000.0, the date and beginning of the observation in UT, object name and type, method of observation, number of exposures and their duration, type of emulsion, filter and spectral band, the size of the plate, the quality of the plate, the name of the observer, the status of plate digitization, the name of astronomer in charge (see Fig. 6 and Fig. 8).

The logbooks were digitized too. They can be seen in a database (see Fig.7). Each plate has the reference to corresponding record in digitized logbook.

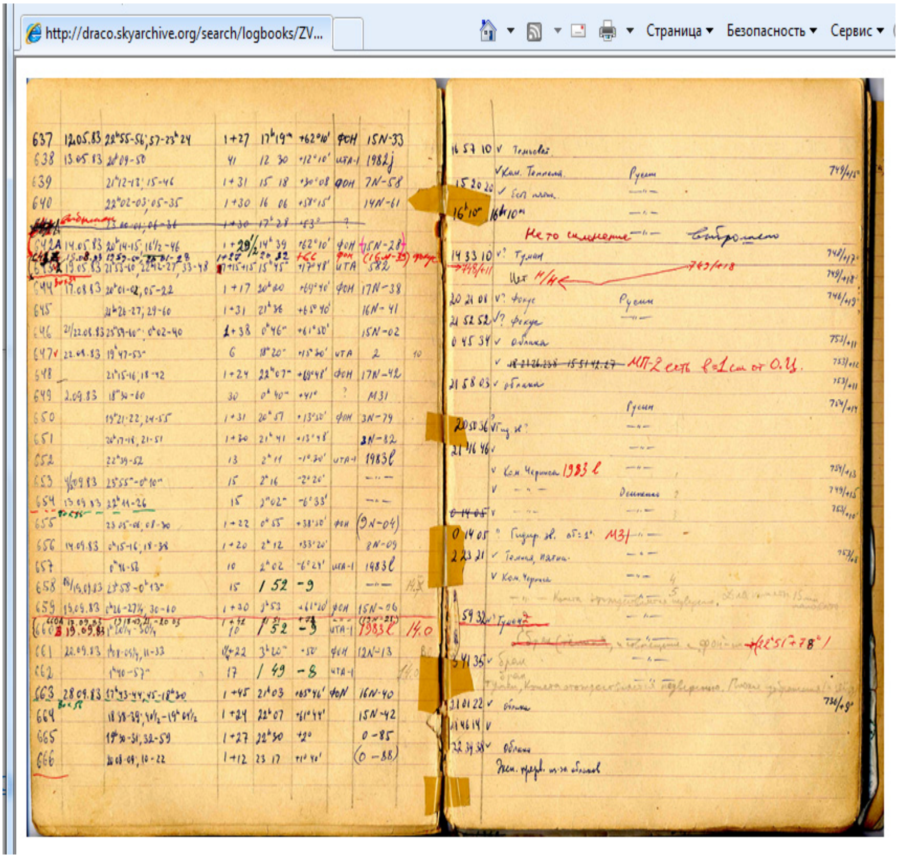
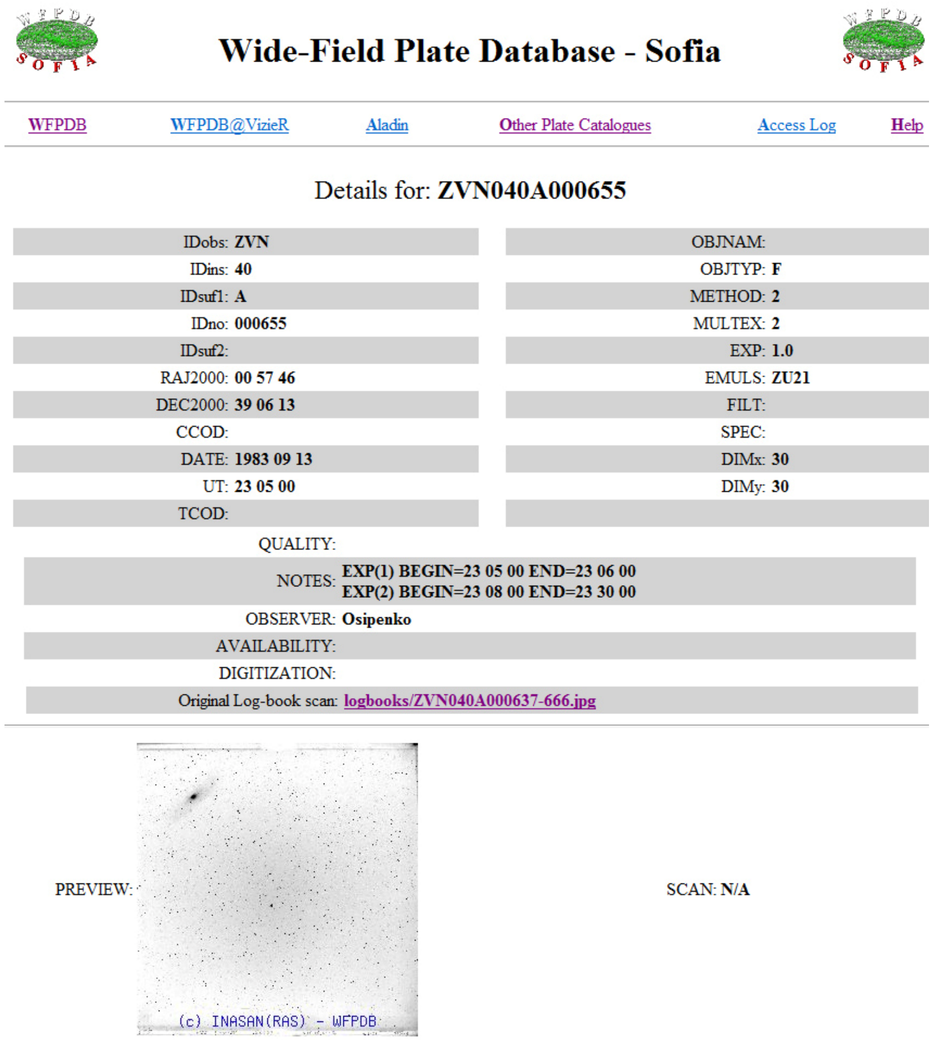


Figure 7. An example of WFPDB search: the logbook page for plates with numbers from 637 to 666.



Wide-Field Plate Database - Sofia

WFPDB | WFPDB@VizieR | Aladin | Other Plate Catalogues | Access Log | Help

Details for: **ZVN040A000655**

IDobs: **ZVN**	OBJNAM:
IDins: **40**	OBJTYP: **F**
IDsuf1: **A**	METHOD: **2**
IDno: **000655**	MULTEX: **2**
IDsuf2:	EXP: **1.0**
RAJ2000: **00 57 46**	EMULS: **ZU21**
DEC2000: **39 06 13**	FILT:
CCOD:	SPEC:
DATE: **1983 09 13**	DIMx: **30**
UT: **23 05 00**	DIMy: **30**
TCOD:	

QUALITY:

NOTES: **EXP(1) BEGIN=23 05 00 END=23 06 00**
EXP(2) BEGIN=23 08 00 END=23 30 00

OBSERVER: **Osipenko**

AVAILABILITY:

DIGITIZATION:

Original Log-book scan: logbooks/ZVN040A000637-666.jpg

PREVIEW: (c) INASAN(RAS) - WFPDB

SCAN: **N/A**

Figure 8. An example of WFPDB search: the details for plate with number 655.

Acknowledgements

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A DISTRIBUTED COMPUTER SYSTEM CONCEPT OF THE ASTROINFORMATICS PROJECT

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Abstract. The paper points to building of a R&D environment for the image processing of astronomical wide plates. Appropriate topics have been generally discussed like common environment architecture, scientific background of information storage, software tools for results presentation and usable fragments of software program code.

1. INTRODUCTION

The Astroinformatics' project[1] opens a wide range of separate problems in the cross border area of mathematics, astronomy, and informatics. The project general objective is digital preservation of the great amount of astronomical wide plate images collected in the years either in the country or world wide. The preserved astronomical images, we call them astro-images, should be well usable via Internet in the frames of a Virtual Observatory (Kounchev et al., 2009). Except the overall testing environment this paper discusses also many specific problems of the

[1] The present research has been conducted in the frames of Astroinformatics project supported by the National Science Fund at Bulgarian Ministry of Education & Science (grant # DO-02-275/2008).

intended distributed system for keeping and processing the collected astro-images. The structure of Astronomical Database (ADB) for astro-images is considered of main interest hereinafter. A specific viewpoint is put on the FITS file format that is wide spread for transferring of astro-images among systems and/or end-users (CFITSIO, 2009). In this line of thinking we also describe the practical usage of input/output software routines to obtain and modify tabular and graphics content of ADB. For the project presentation purposes ADB should also have a part for geo-referred data for the astronomy observatories around the world. ADB will also need the so called AstroWeb subsystem to be designed supporting the project specific data/information structures and presenting them in a web environment. Another specific problem of ADB is organization of the very large data flows between separate work places in distributed computer network of the Astroinformatics system we intend.

In this paper we describe the web-based geoinformation system proposed in the frames of the Astroinformatics project, stressing on the testing environment and user interfaces.

2. THE TEST ENVIRONMENT DIAGRAM

The main modules of testing environment proposed are shown in Fig. 1 with all its items explained as follows.

- **Remote Common Database** – still under construction it is designed for common usage of all participants of the project. It consists of 3 basic parts (sub-DBs). **Firebird RDBMS** – a well known database system, licensed under GPL (General Public License) that is already used to support the current WFPD (Wide Field Plate Database), to this end – observatory catalogs and pictures of WFP type. **FITS astro-database** – a part of ADB to be designed for keeping WFD astro-images given in FITS (Flexible Image Transport System) format. **Geodatabase** – consists of geographical data (geo-referred positions) of important objects, to this end – the astronomical observatories related to WFPD.
- **Application Server** – a high productive computer configuration of „server” type intended for astro-images processing. The respective software modules will be implemented herein as binary code and be directly managed by a web interface. The end-users will obtain definite information services via the respective web browser at their work places.
- **Web Server** – a high productive computer configuration with an IIS (Internet Information Services) or Apache system installed. It will support the web access information services exported by the Application Server.

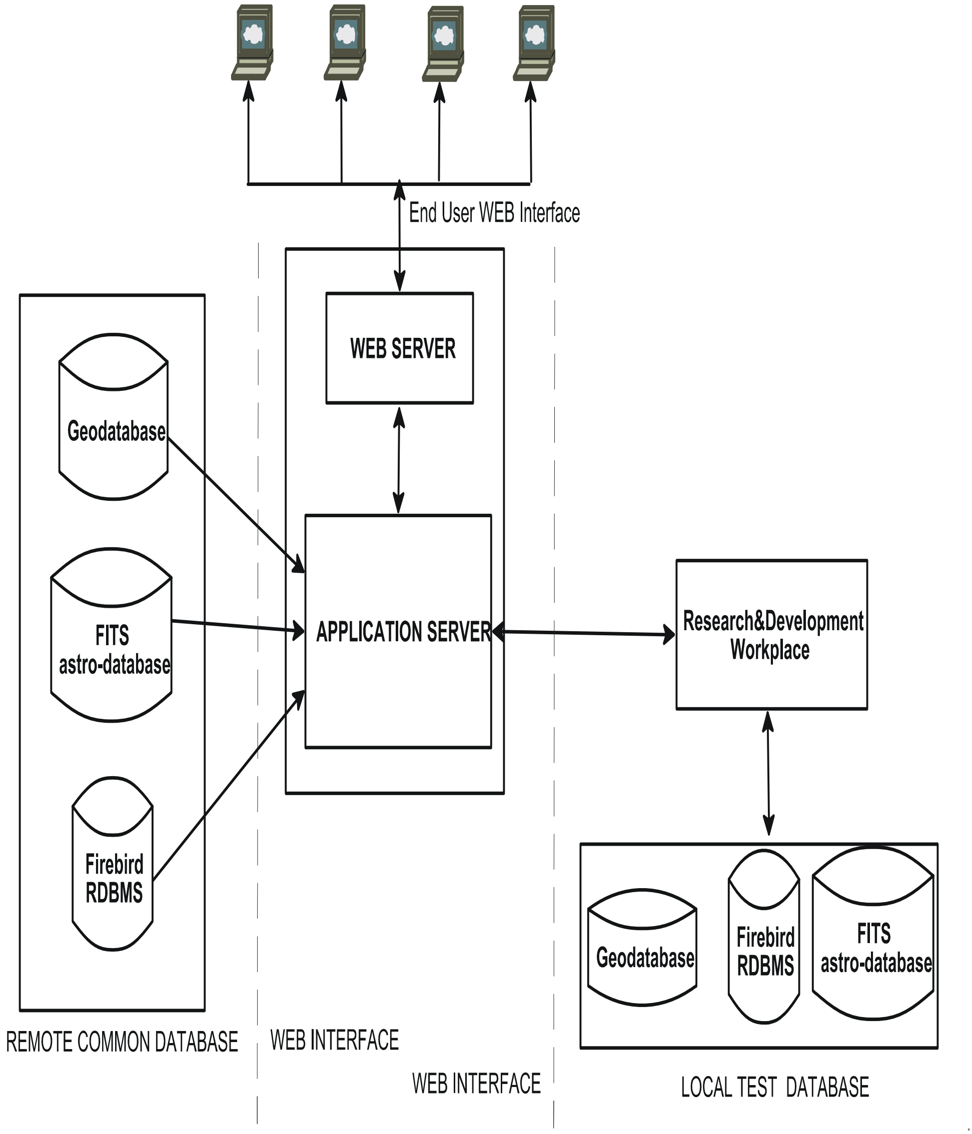

Figure 1. The main modules of testing environment.

- **Research & Development Workplace –** one or many workplaces (local or remote ones) designed for development and test of image processing modules. Many well known modules in astro-image processing practice will be set up and tested. Development of specific (original) modules is also intended by necessity. A stress will be given on modules supporting FITS format directly. Each workplace is considered to be equipped by a software development environment specific to the respective user and/or developer.

- **Local Test Database –** it is a local database for set up and test purposes at the application server place. It represents a test subset of the main database to be accessed only by the R&D workplaces but not by the user ones.
- **End User Web Interface –** it represents a web page delivering an user-friendly interface to several information services of Astroinformatics specifics.

3. WIELD FIELD PLATE DATABASE – A BRIEF PREVIEW

The Wide-Field Plate Database (WFPDB) (Tsvetkov et al., 2009) contains descriptive information for the astronomical wide-field photographic observations stored in numerous archives all over the world. It is capable to provide on-line access to the data for about more than 2 million of observations from nearly 500 archives obtained since the end of last century. Presently the WFPDB includes data for about 600 000 observations from 300 plate catalogues.

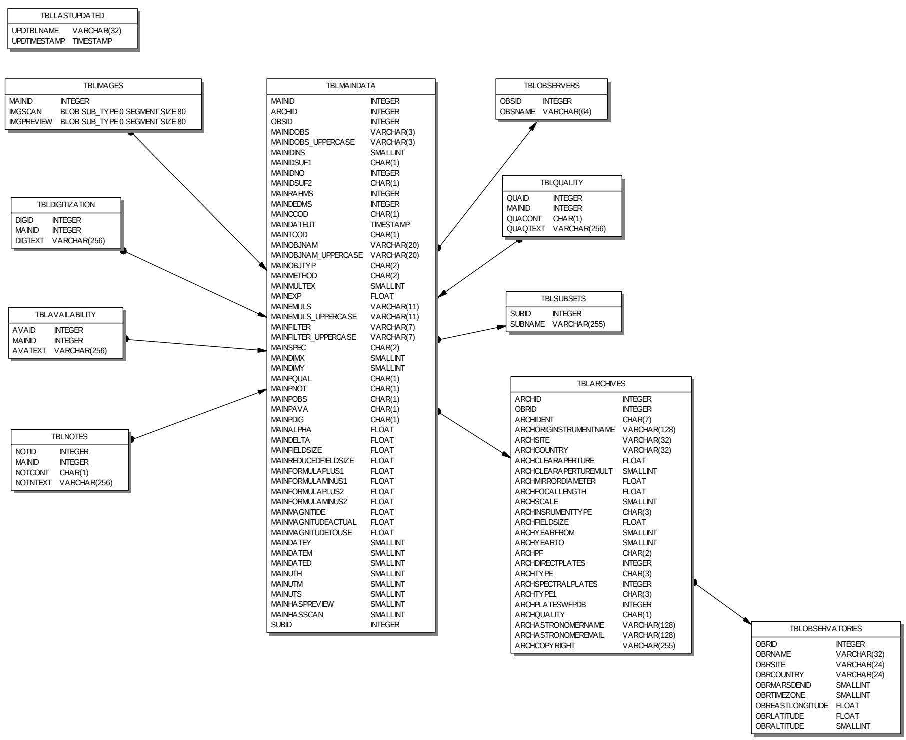

Figure 2. Tables from WFPDB.

The WFPDB provides for each observation a plenty of information for the corresponding archive, for the parameters of the observation instrument, for the observation parameters (position on the sky, observation time, object name, method, exposure time, emulsion type, filter type, spectral band, plate size), as well as data for the plate quality, for the observers and their comments written on/about the plates.

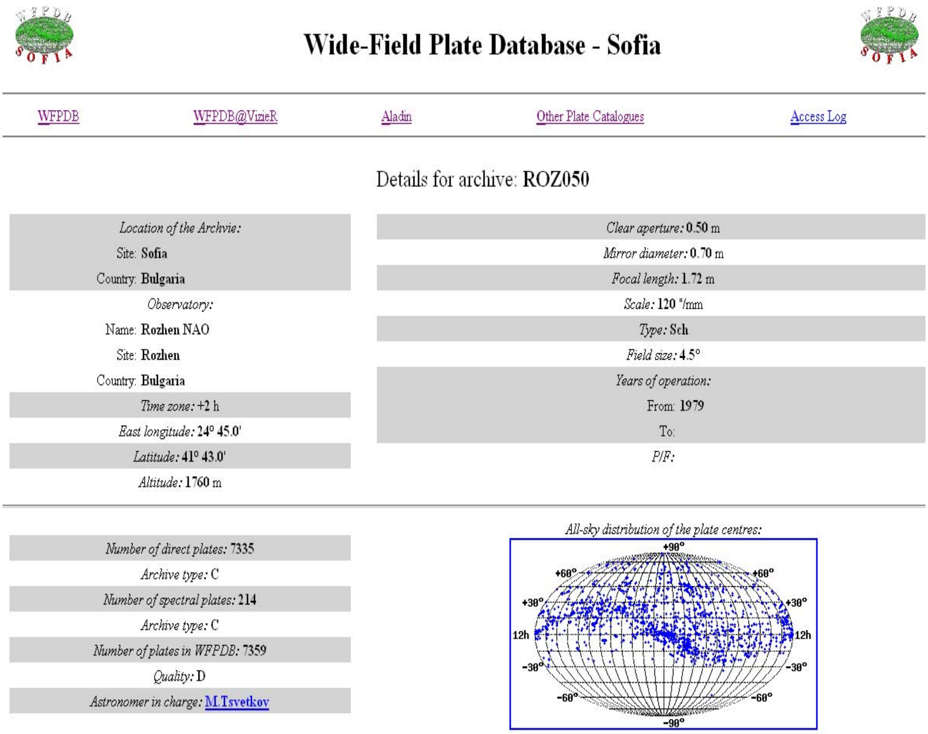

Figure 3. Details from archive.

A web based search engine was developed that may be assessed on web space by a properly user interface (Kolev, 2009). The WFPDB logical schema is illustrated in Fig. 2. The schema is generated using the reverse engineering tools (IB Expert 2004). A screenshot from currently used WFPDB is explained in Fig. 3.

There are envisaged several possible manners to user-friendly exploration of the large set of astronomical data in WFPDB. One of them is to select an observatory, then extract the subset of archives according to this observatory and at last get a limited list of astro-images. Each point in plate centers diagram corresponds to stored astro-image as shown in Fig. 4.

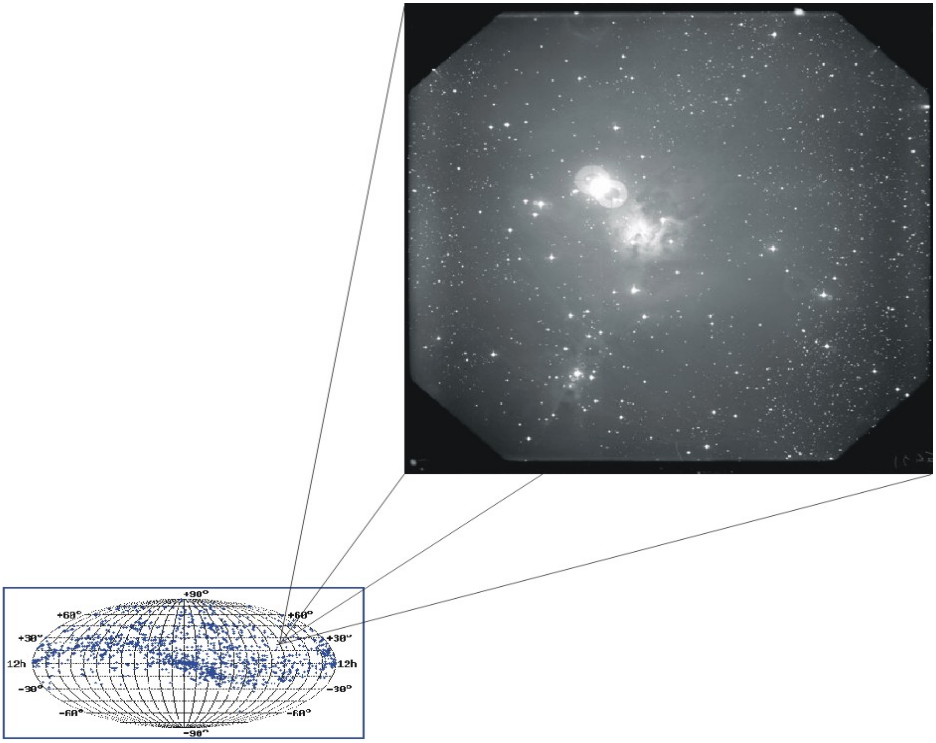

Figure 4. Plate center as astro-image preview.

4. FITS IMAGE ASTRO-DATABASE SOFTWARE ACCESS

The acronym FITS stands for Flexible Image Transport System. The name itself expresses the general purpose of FITS to be a flexible mean for transferring image data (and extra information about them) between cooperating computer systems.

For astro-image processing purposes, where FITS file format is predominantly used, a specific software access to file data is necessary to be implemented. CFITSIO is a library of C and FORTRAN subroutines to read and write data files in FITS format (CFITSIO, 2009). CFITSIO is developed by the High Energy Astrophysics Science Archive Research Center (HEASARC). It provides simple high-level functions/routines for reading and writing of FITS files in this way insulating the programmer from the internal complexities of the FITS format. CFITSIO also gives many advanced opportunities for manipulate and/or filter the FITS information. CFITSIO is already tested on many operating systems and software platforms, most usable of which are:

OPERATING SYSTEM	COMPILER
HP-UX	gcc
IBM AIX	gcc
Linux	gcc
Windows 95/98/NT	Borland C++ V4.5
Windows 95/98/NT/ME/XP	Microsoft Visual C++ v5.0, v6.0
Windows 95/98/NT	Cygwin gcc
MacOS-X 10.1 or greater	cc (gcc)

The authors using specific FITS routines of CFITSIO library in a Windows OS environment have developed a simple test program. The main screen of this program is shown in Fig. 5.

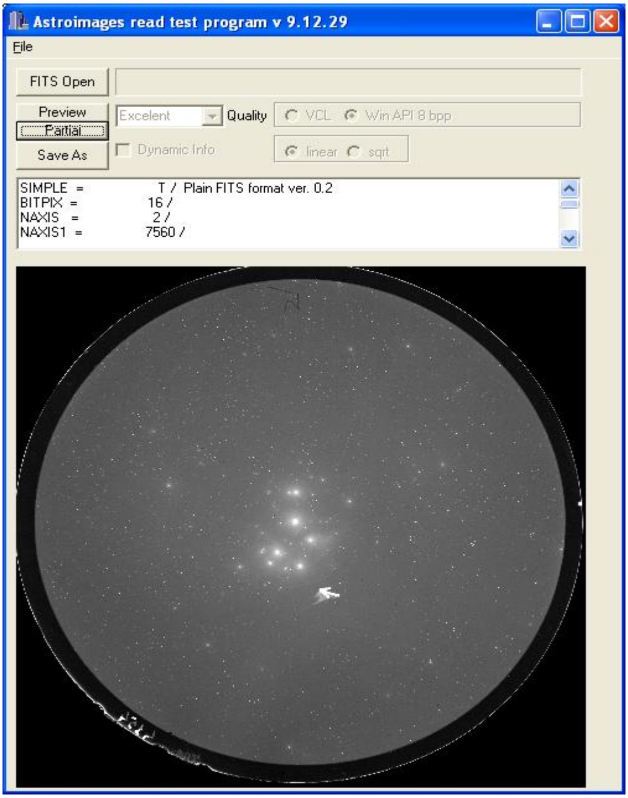

Figure 5. Main screen of the astro-images read test program.

The program opens the specified FITS file, prints out the keywords content of its header in the current HDU (header and data unit) and visualizes a preview of the graphical image content.

5. GEODATABASE

In the Astroinformatics project environment the term “geodatabase” is used to describe main data a subset of observatories and to represent the observatories positions on a world map. In its current version the geodatabase is presented via layers in ESRI shape-file format as follows:

- World layers describe countries, lakes, rivers, sites, etc. that are common geodata widely usable in any GIS (Geographical Information System) software;
- An observatories’ layer is specially designed for the Astroinformatics purposes and takes data from table TBLOBSERVATORIES in our main WFPDB data.

Software code for generating the observatories’ layer has been written using PHP script language.

The necessary graphical web interface to the geodatabase has been developed by the Open Source GPL products: MapServer and Chameleon PHP framework (Kalaglarsky, 2009). We call it AsrtoWeb engine (see Fig. 6).

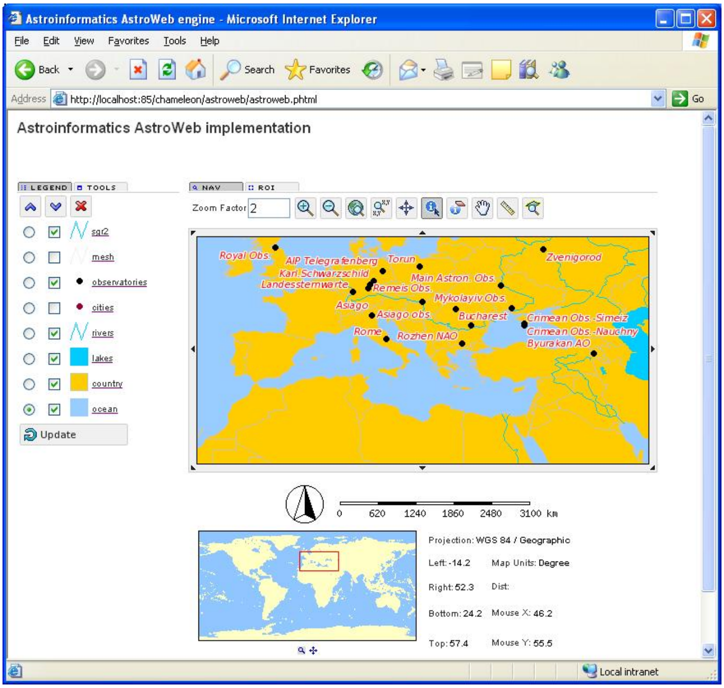

Figure 6. The AstroWeb main screen showing the location of some European observatories.

Fig. 6 demonstrates the Word and Observatories’ layers implemented in a classic web browser, namely the MS Internet Explorer. This web application has full control and nagation capabilities and is also intended to demonstrate graphical and tabular relationship existing in the Astroinformatics project data.

6. APPLICATION SERVER AND ASTRO-IMAGE PROCESSING SOFTWARE UNITS

Astro-image processing software units have to be installed on computer configuration named “Application Server”. These software units will represent pieces of program code, compiled to DLL or EXE format. All information services according astro-image processing will be managed via web interface. The Chameleon PHP framework (Chameleon, 2008) is mainly used in the AstroWeb implementation. Despite of not very known in similar context, the Chameleon PHP occurred very suitable to organize an user friendly web-interface in the frames of a classic HTML browser (with DHTML and AJAX support) and without any special plug-ins. The Chameleon framework itself represents a high customizable program interface based on “widgets”(see Fig. 7).

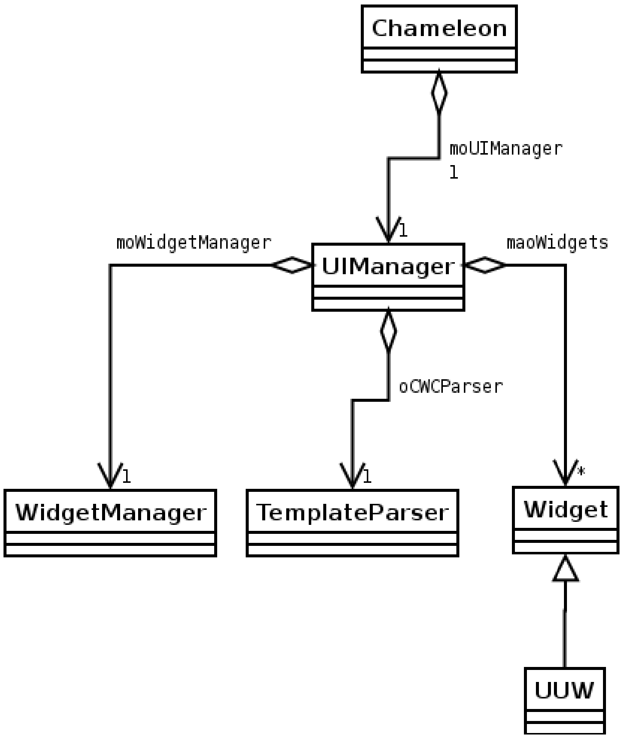

Figure 7. Chameleon framework architecture.

The last block of the diagram in Fig.7 points to a new widget designed according to needed information services. The program developer normally creates new widgets from already existed ones that provide a similar functionality starting from Widget Template and adding new functionalities incrementally. Besides the latter are often interface functionalities, but not necessarily action ones. A very important step is to create the wrapper unit that provides program interface between server-side PHP script implementation and DLLs that support astro-image processing. This task is similar to the one of creation a PHP extended DLL that can be performed using ZEND program interface (Extension writing Part I, 2009). Another Astroinformatics module, namely the wrapper module "AstroWrapper" is under current development. AstroWrapper is intended to link the WFPDB, the Geodatabase and the FITS image content together in a common web-based distributed computer system.

7. CONCLUSIONS

The present paper describes main modules that a R&D astro-image processing environment should generally consist of. The problem solutions here described can be resumed and ordered by their importance to closed future extension as follows:

- Software implementation of CFITSIO open source library for the case of an effective reading and writing of astro-images in FITS format;
- Development of AstroWrapper PHP extension that looks like a bridge between the image-processing executive code and the respective web user interface;
- Development of Chameleon widgets playing as a comfortable software tools for a user friendly web interface;
- Extension of the current AstroWeb implementation for an end-user HTML page to make it a high effective shell to access any information services that "Astroinformatics" project will need;
- Choice and implementation of a suitable communication technology to perform dataflow partnership with optimal security requirements among different workplaces.

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LOCAL NETWORK OF THE PLATE DIGITIZATION LABORATORY OF THE INSTITUTE OF ASTRONOMY WITH NATIONAL ASTRONOMICAL OBSERVATORY

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Abstract. Here we describe the local network and briefly the equipment of the Plate Digitization Laboratory dedicated to digitization of the existing wide-field plate collection of the Institute of Astronomy with National Astronomical Observatory of the Bulgarian Academy of Sciences during the period 1979 - 1995 of using photographic plates as a detector of the observations. The astronomical plate collection at NAO Rozhen contains more than 10000 wide-field plates received with the 50/70 cm Schmidt telescope and with the 200 cm RCC telescope of the observatory. The plate archives are incorporated in the existing Wide-Field Plate Database (www.wfpdb.org) according to the astronomical standards of Centre de Donnees de Strasbourg (CDS).

1. INTRODUCTION

The Plate Digitization Laboratory of the Institute of Astronomy with National Astronomical Observatory Rozhen is dedicated to digitization of the plate collection of the observatory received mainly during its first 15 years of operation in the period 1979-1995. In this period more than 10000 wide field plates using the 50/70 cm Schmidt telescope and 200 cm RCC telescope of the National Astronomical Observatory Rozhen of the Bulgarian Academy of Sciences were received. The plates received with the 200 cm telescope were taken in RC (Ritchey-Chrétien) focus with size mainly 30x30 cm and scale 12.8 arcsec/mm. In this case the field covered with exposed RC plate was about 1 degree and about 25 degree with used 16x16 cm Schmidt plates.

The photographic plates were extensively used as light detectors in astronomy during last century when the new technology of the CCD detectors has rapidly replaced the photographic plates. A detail description of the digitization of the wide-filed plate archives worldwide including the plate collection of the existing Bulgarian plate archives is given in the papers of Tsvetkov (2006) and Tsvetkov and Tsvetkova (2006) according to the development of the Wide-Field Plate Database project (WFPDB, www.wfpdb.org). At the present moment in the WFPDB 7021 plates from the Rozhen 50/70 cm Schmidt telescope and 1946 direct plates form the 200 cm RCC telescope are catalogued. About half of the plates is presented in the plate stacks at Rozhen and Sofia and their regular digitization has been started with the support of the Bulgarian National Science Fund of the Ministry of Education and Science – grants DO-02-273 and DO-02-275.

2. PLATE COLLECTION AND DIGITIZATION EQUIPMENT

The plate collection of the Institute of Astronomy is stored at present at National Astronomical observatory Rozhen and in Sofia – in the Sky Archive Data Center of the Institute of Astronomy. More details can be found in Tsvetkova et al. (2010).

Figure 1. Plate Library at the Rozhen National Observatory (status June 2010).

There are two equipped laboratories for plate digitization and plate processing. In Fig. 1 a picture of the plate stacks at NAO Rozhen is shown. The main part of the plate collection consists of the plates received with the Schmidt telescope and 200 cm RCC telescope. Beside the wide-field plates some thousand of spectral plates received with the Coude spectrograph of the 200 cm telescope are also collected at the Rozhen plate library but their inventory is postponed to the future project. At Sofia Sky Archive Data Center some hundreds of wide-field plates received mainly with the Rozhen Schmidt telescope are collected. For their digitization and inventory is equipped the Sofia Plate digitization laboratory (see the part of the plate library of the Sofia Sky Archive Data Center in Fig. 2.)

Figure 2. A part of the 50/70 cm Schmidt telescope plate collection in the Institute of Astronomy in Sofia.

The archive of the 50/70 cm telescope counts about 7500 photographic plates mainly with size 16x16 cm and about 2000 plates with size 30x30 cm obtained with the 200 cm RC telescope.

For the purposes of the digitalization of the NAO plate collection a Laboratory for digitalization, Storage and Access of the Astronomical Photographic Plates (LAPD) has been established . It is a part of the new established forth division - “Laboratory of Astroinformatics and Virtual Astronomical Observatory” (LAVAO) of the Institute of Astronomy and National Astronomical Observatory. One of the urgent tasks for the new division is to develop and unify the facilities of the plate digitization, storage and online access to the information from the photographic plates. Having this is view we list the existing scanners in Sofia (IA) and NAO Rozhen. In LADP there are 3 scanners in Sofia. The first one is the high-accuracy

Perkin-Elmer historic microdensitometer the PDS 1010^{plus} received as a present from the European Southern Observatory (ESO) in 1998 (Fig. 3). The second one is the professional flatbed scanner EPSON Expression 1640XL (Fig. 4), and the third one is EPSON V700 (Fig. 5).

Table 1: Available scanners in LAPD in Sofia and Rozhen Observatory and their characteristics.

SCANNERS	Plate Size-maximum (cm)	Density (D)	Pixel size (microns)
PDS 10- Perkin-Elmer	25x25	5.0	2
MDM6 – Joice_Loebl	25x25	4.0	2.5
EPSON Expression 10000 XL	30x30	3.8	10
EPSON Expression 1640XL	30x30	3.6	16
EPSON Perfection V700 Pro	18x18	4.0	10

Using these scanners and the plate digitization method described in Barbieri et al. (2003) we started a regular astronomical plate digitization.

Figure 3. The Perkin-Elmer historic microdensitometer of LAPD in Sofia - PDS 1010^{plus} still used for some tests and plates scan calibration.

The archive of the 2 m RCC telescope counts 2115 wide-field plates. About 1000 of them are digitalized with a resolution of 1600 dpi (15.9 µm). About the Schmidt telescope plate archive we digitized approximately 400 of them with a resolution of 2400 dpi (10.0µm/pix).

We estimate that the total amount of information is 4 TB (1.2 TB and 2.8 TB for each plate archive).

Figure 4. The EPSON Expression 1640 XL (A3) flatbed scanner of LAPD in Sofia.

Figure 5. The EPSON Perfection V700 flatbed scanner of LAPD in Sofia.

The NAO Rozhen scanners are:

- the old one Joyce-Loebl MDM6 (Fig. 6). This scanner can produce scans with high accuracy as fine as minimal step of 2,5 μm and minimal pixel of 5.0 μm. Unfortunately this scanner is very slow and needs e special care. The scanning process of a 30x30 cm plate takes more than 50 hours;
- the professional flatbed EPSON Expression 10000XL (Fig. 7). It produces preview scans with resolution of 600 dpi (40μm) and 24 bits color for previews and full scans with resolution of 1600 dpi (16 μm) 16 bits grayscale in FITS format.

Figure 6. The microdensitometer Joyce-Loebl MDM6 at NAO Rozhen.

Figure 7. The Rozhen Observatory EPSON Expression 10000XL (A3) professional flatbed scanner.

An example of digitized plate with the EPSON Expression 10000XL scanner is shown in Fig. 8.

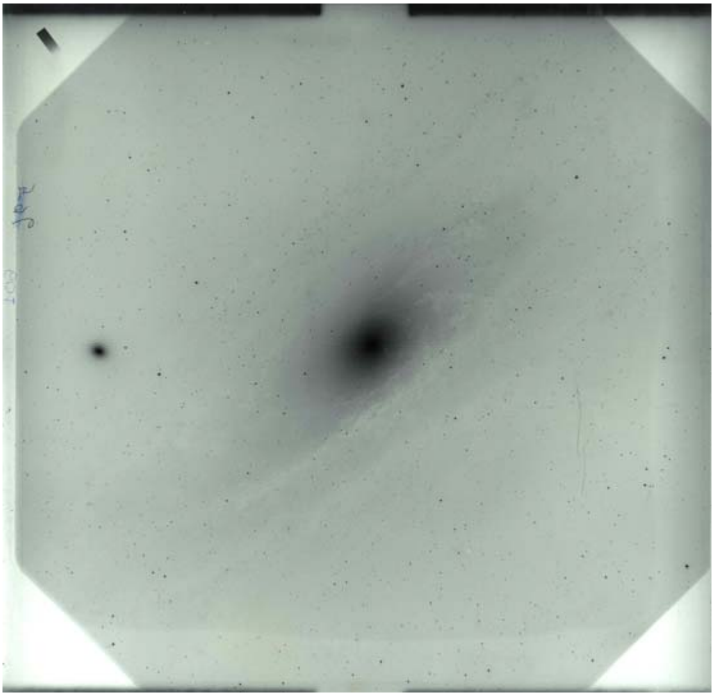

Figure 8. Example of plate preview of the scanned Rozhen 200 cm plate (30x30 cm size) with WFPDB Identifier: ROZ200_000610 taken in the field of M31 (Andromeda nebulae) on August 4, 1983 by T. Georgiev with exposure 20 min, and filter GG385 (B).

3. NETWORK, HARDWARE AND ACCESS TO THE DATA

The received data need a proper structure for access and storage. In Table 2 we list the hardware parameters of the local network infrastructure of the LPD in IA with NAO in Sofia. We list the computer name, type of the processor, and other computer parameters.

Table 2: Computer equipment of the Sofia Laboratory for Plate digitization at IA with NAO.

Computer Name	Processor	RAM	HDD	OS	Service
CORVUS	Core i3,	4GB,	2x2TB	Linux Debian	RAID1, DNS, Mail, Web
COLUMBA	Dual Core,	2GB	2x1TB	Linux Debian	RAID1, German VO backup
AQUILA	AMD	512MB	1x122GB 2x250GB 1x500GB	Linux Debian	DNS Astro server, Data FTP server
FW	Celeron	2GB	2x320GB 1x500GB	Linux Slakwere	Firewall
PHOENIX	Intel Xeon	1GB	3x160GB	Linux Debian	Storage M610p device service
STORAGE	PROMISE-Vtrak M610p, Ultra SCSI	*)	(16x1TB) 6x1TB	See above	*) Storage and access of the digitized astronomical wide-field plates

*) see description below.

The storage* element is a Promise Vtrak M610p. It has possibility to support 16 SATA disks. For the moment there are 6 x 1TB disks. Logically they are organized in 2 volumes – 1 RAID5 massive – 4 disks – 3TB and one RAID0 – 2 disks – 2TB. In the future a reorganization of the network structure is planned (see Fig. 10). The main difference is the existence of VPN, which will allow uniting geographically different networks to work together.

For the moment there are two ways to access the scanned data. The indirect one is through the search engine of the Wide-Field Plate Database (http://www.wfpdb.org/search.html). It is worldwide accessible. The second one is directly to the storage element. The granted users will access http://195.96.237.136. In the future all data from storage element will be also accessible through web access.

Fig. 9 shows the present block scheme status of the network infrastructure. There are 3 servers, one storage element, firewall and internal network behind the firewall. The future development of the local network is shown in Fig. 10.

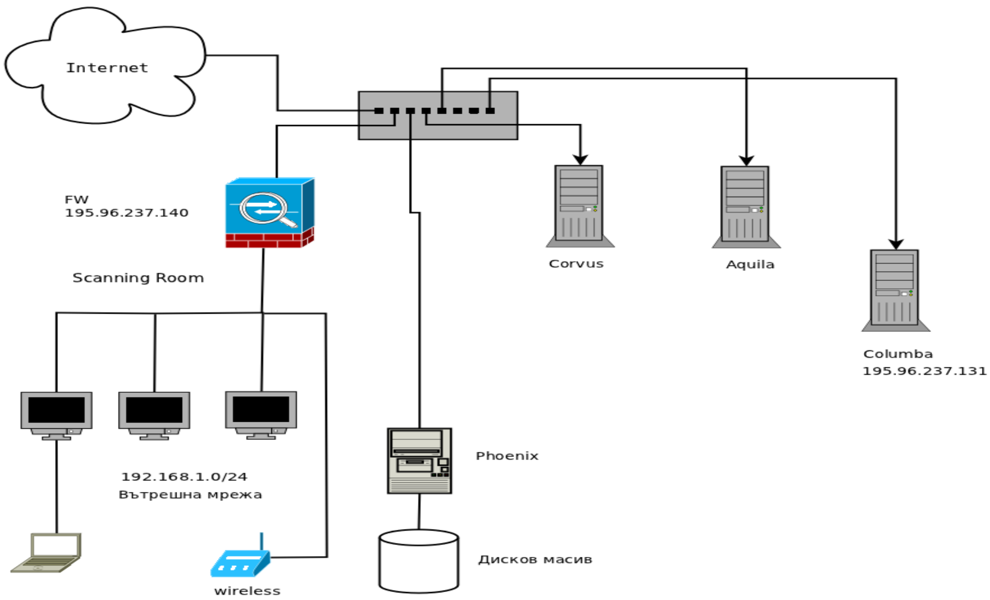

Figure 9. Present status of the Institute of Astronomy Sky Archive Data Center network infrastructure.

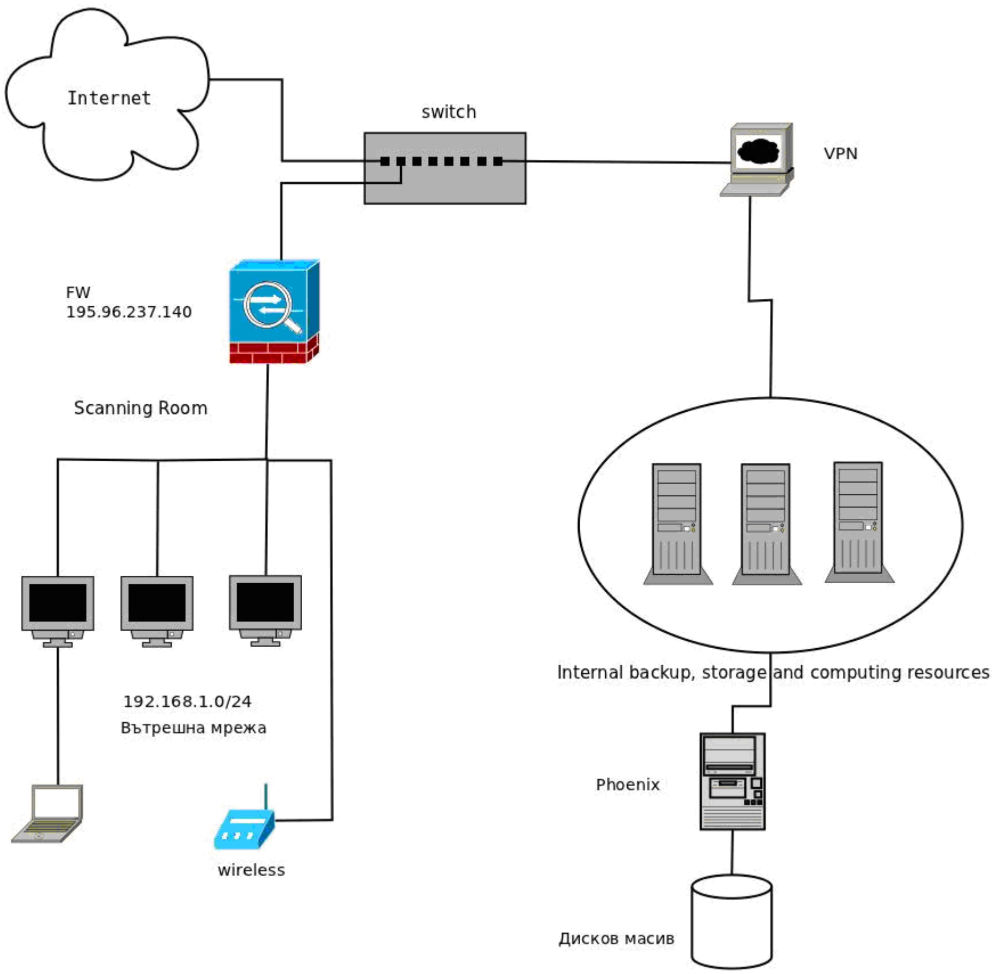

Figure 10. The planned new infrastructure of the IA with NAO network.

SUMMARY

Finally we like to mention that this work shows the present development of the Sofia Sky Archive Data Center and the future plans in connection of the establishment of the new Laboratory of Astroinformatics and Virtual Astronomical Observatory in the Institute of Astronomy with NAO, Bulgarian Academy of Sciences. This work is a step further in comparison with the Sky Archive Data Center Local Network described in Tsvetkov et al. (2007).

Acknowledgements

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POSTER PAPERS

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ON THE STARK BROADENING OF Ar XV SPECTRAL LINES

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Abstract. In order to provide Stark broadening data in X-ray and far UV wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we performed calculations of Stark broadened line widths and shifts for Ar XV using the semiclassical perturbation theory.

1. INTRODUCTION

New X ray space telescopes like "Chandra" enable the observation and analisys of cosmic X ray sources with such accuracy that the need for spectroscopic data on trace elements in this wavelength range increases. For example, far UV lines of Ar VII were discovered recently in the spectra of very hot central stars of planetary nebulae and white dwarfs (Werner et al. 2007), indicating the astrophysical interest for atomic and line broadening data for this element in various ionization states. Such data are also of interest for laboratory, laser produced and fusion plasma investigations.

In order to provide Stark broadening data in X-ray wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we have performed semiclassical calculations of Stark broadened line widths and shifts for 8 Ar XV multiplets with wavelengths less than 100 Å. As an example of obtained results, here are presented Stark broadening parameters for three ArXV singlets, for electron density of 10^{20}cm^{-3} and electron temperatures from 500000 K up to 6000000K.

2. THEORY

For determination of Stark broadening parameters, the semiclassical perturbation formalism, developed and discussed in detail by Sahal-Bréchot 1969a,b, was used. This formalism, as well as the corresponding computer code, has been optimized and updated several times (Sahal-Bréchot 1974, Dimitrijević and Sahal-Bréchot 1984, Dimitrijević et al. 1991).

Within this formalism, the full width of an isolated spectral line of a neutral emitter broadened by electron impact (W) can be expressed in terms of cross sections for elastic and inelastic processes as

$$W = \frac{\lambda^2}{\pi c} N \int v f(v) dv (\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} + W_R), \tag{1}$$

and the corresponding line shift d as

$$d = \frac{\lambda^2}{2\pi c} N \int v f(v) dv \int_{R_3}^{R_D} 2\pi \rho d\rho \sin 2\phi_p. \tag{2}$$

Here, λ is the wavelength of the line originating from the transition with initial atomic energy level i and final level f, c is the velocity of light, N is the electron density, $f(v)$ is the Maxwellian velocity distribution function for electrons, ρ denotes the impact parameter of the incoming electron, and ϕ_p is the phase shift due to the polarization potential. The inelastic cross sections $\sigma_{jj'}(v)$ (where $j = i$ or f) and elastic cross section σ_{el} are determined according to Chapter 3 in Sahal-Bréchot 1969b. The cut-offs (needed for the calculation of inelastic and elastic cross sections and the shift), included in order to maintain for the unitarity of the S-matrix, and to take into account Debye screening are described in Section 1 of Chapter 3 in Sahal-Bréchot 1969b. W_R gives the contribution of the Feshbach resonances Fleurier et al. 1977 and this term is zero if the emitters are neutral atoms. Other differences between neutral and ionized emitters is that for calculations of the cross sections rectilinear perturber paths are taken for neutral ones and hyperbolic paths for ionized species.

The formulae for the ion-impact broadening parameters are analogous to the formulae for electron-impact broadening. We note that the fact that the colliding ions could be treated using impact approximation in the far wings should be checked, even for stellar atmosphere densities.

3. RESULTS AND DISCUSSIONS

Using the semiclassical perturbation method we obtained Stark widths and shifts for eight Ar XV multiplets for a perturber density of 10^{20}cm^{-3} and temperatures from 500 000 up to 6 000 000 K. The needed atomic energy levels were taken from Bhatia and Landi 2008 and the energy of ionization of Ar XV from NIST database. The oscillator strengths required were calculated using the Coulomb approximation method described by Bates and Damgaard 1949 and the tables of Oertel and Shomo 1968. For higher levels, the method described by van Regemorter et al. 1979 was applied. As an example of obtained results, Stark widths and shifts for three singlet lines are given in Table 1. The quantity C (given in Å cm^{-3}), when divided by the corresponding full width at half maximum, gives an estimate for the maximum perturber density for which the line may be treated as isolated and the tabulated data may be used. WIDTH(Å) denotes the full line width at half maximum in Å, while SHIFT(Å) denotes line shift in Å. We note that, in the wings, the impact approximation for ions should be checked and that ions will be quasi-static in the far wings. For perturber densities lower than those tabulated here, Stark broadening parameters vary linearly with perturber density. The nonlinear behaviour of Stark broadening parameters at higher densities is the consequence of the influence of Debye shielding and was analyzed in detail in Dimitrijević and Sahal-Bréchot 1984.

Table 1: This table shows electron-impact broadening parameters for Ar XV for perturber density of $10^{20}\mathrm{cm}^{-3}$ and temperatures from 500 000 up to 6 000 000 K. Transitions and wavelengths (Å) are also given in the Table. By dividing C by the corresponding full width at half maximum (Dimitrijević et al., 1991), we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The validity of the impact approximation has been estimated for data shown in this table, by checking if the collision volume (V) multiplied by the perturber density (N) is much less than one (Sahal-Bréchot, 1969a,b).

PERTURBERS ARE:		ELECTRONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)
Ar XV 2s^{1}S-3p^{1}P^o	500000.	0.521E-03	-0.763E-06
24.7 Å	750000.	0.430E-03	0.325E-06
C= 0.38E+20	1000000.	0.377E-03	0.110E-06
	2000000.	0.277E-03	0.598E-06
	3000000.	0.233E-03	0.545E-06
	6000000.	0.176E-03	0.105E-05
Ar XV 2s^{1}S-4p^{1}P^o	500000.	0.783E-03	0.759E-05
18.8 Å	750000.	0.656E-03	0.786E-05
C= 0.12E+20	1000000.	0.580E-03	0.805E-05
	2000000.	0.439E-03	0.801E-05
	3000000.	0.376E-03	0.808E-05
	6000000.	0.293E-03	0.682E-05
Ar XV 3s^{1}S-3p^{1}P^o	500000.	0.133E-01	0.124E-04
74.6 Å	750000.	0.112E-01	0.259E-05
C= 0.18E+21	1000000.	0.994E-02	0.811E-05
	2000000.	0.756E-02	0.103E-04
	3000000.	0.650E-02	0.117E-04
	6000000.	0.509E-02	0.561E-05

There is no experimental or other theoretical data for the comparison with the calculated Stark broadening parameters of Ar XV spectral lines. Detailed analysis of the obtained results will be given elsewhere.

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SOME ASPECTS OF CIRCULAR RESTRICTED THREE-BODY PROBLEM FROM DIFFERENTIAL GEOMETRY POINT OF VIEW

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Abstract. This paper considers differential geometry methods for determining local geometrical parameters of zerovelocity curves (ZVC) and surfaces (ZVS) in the circular restricted three-body problem (CR3BP) and emphasizes some interesting characteristics. The obtained results indicate some principles in distribution of local geometrical parameters along ZVC and ZVS and their influence on orbital motion.

1. INTRODUCTION

Nowadays, papers that study three-body problem, mostly consider some specific cases like ZVS in CR3BP with variable masses (Luk'yanov, 1992), application to trojan asteroids (Bálint, 1978), capturing conditions (Szenkovits and Makó, 2005), and so on. Although CR3BP is the problem with a huge historical background, which occupied many great scientists including Newton, Lagrange, Gauss, Euler, Jacobi and many others, it is very difficult to find papers that consider fundamentals of this problem like the geometrical parameters of ZVC and ZVS and their influence on the orbit of the third body.

After some assumptions regarding units, ZVS are defined implicitly by the equation

$$f\left(x,y,z\right)=x^2+y^2+z^2+2\left(\frac{\mu_1}{\sqrt{\left(x+\mu_2\right)^2+y^2+z^2}}+\frac{\mu_2}{\sqrt{\left(x-\mu_1\right)^2+y^2+z^2}}\right) \quad (1)$$

Where C_J is the Jacobi constant (the only integral of motion of CR3BP) and μ_1 and μ_2 are gravitational constants of two large masses. The equation of ZVC is easily derived from the above equation by putting $z = 0$.

$$g(x,y) = x^2 + y^2 + 2\left(\frac{\mu_1}{\sqrt{(x+\mu_2)^2 + y^2}} + \frac{\mu_2}{\sqrt{(x-\mu_1)^2 + y^2}}\right) \tag{2}$$

From equations (1) and (2) can be seen that these curves and surfaces has complex analytical form and very complex geometry indeed, as it is shown in the figure below.

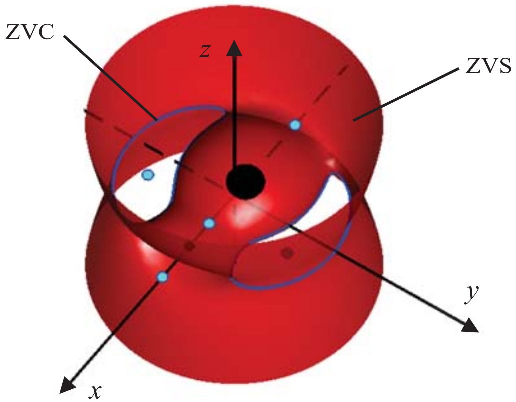

Figure 1. ZVS and ZVC.

2. METHODS

In order to find main geometrical characteristics of ZVC, ZVS and orbits, several numerical methods implemented in Matlab software were used. For determination of curvature of ZVC, a well known formula was used

$$\kappa = \frac{g_{xx}g_y^2 - 2g_{yy}g_xg_y + g_{yy}g_x^2}{\left(g_x^2 + g_y^2\right)^{\frac{3}{2}}} \tag{3}$$

where

$$g_x = \frac{\partial g(x,y)}{\partial x}, \quad g_y = \frac{\partial g(x,y)}{\partial y}, \quad g_{xx} = \frac{\partial^2 g(x,y)}{\partial x^2}, \quad g_{yy} = \frac{\partial^2 g(x,y)}{\partial y^2}, \quad g_{xy} = \frac{\partial^2 g(x,y)}{\partial x \partial y}.$$

For determination of main curvatures of ZVS, characteristic values of Hessian matrix were used

$$H = \begin{bmatrix} \frac{\partial N_x}{\partial x} & \frac{\partial N_x}{\partial y} & \frac{\partial N_x}{\partial z} \\ \frac{\partial N_y}{\partial x} & \frac{\partial N_y}{\partial y} & \frac{\partial N_y}{\partial z} \\ \frac{\partial N_z}{\partial x} & \frac{\partial N_z}{\partial y} & \frac{\partial N_z}{\partial z} \end{bmatrix}, \tag{4}$$

where N_x, N_y and N_z are components of normal unit vector defined by

$$\vec{N} = \frac{\vec{G}}{||G||}, \tag{5}$$

where

$$\vec{G} = \nabla f = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial z} \end{bmatrix}. \tag{6}$$

Two of three characteristic values of the Hessian matrix represent the main curvatures while the third one is equal to zero.

For determination of orbit of the third body, classical RK4 Runge-Kutta method was used to integrate equations of motion based on Newtons Low of gravitation. After discrete orbit of the particle was obtained, it was interpolated with the Lagrangian polynomial of the second degree in order to find curvature of the orbit. Since, the integration step in Runge-Kutta method was very small (1/1000 of the main bodies orbit) it was convenient to get good approximation of the real orbit by this method.

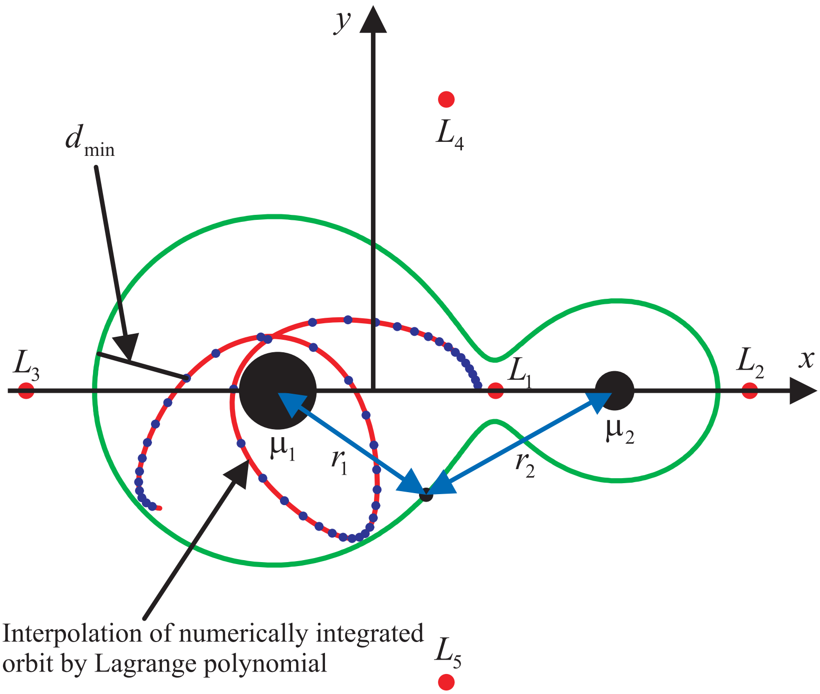

Figure 2. Orbit of the particle bounded by ZVC.

3. RESULTS AND CONCLUSIONS

In figures 3, 4 and 5 are shown typical distributions of local geometrical parameters of ZVS along ZVC. From these figures, it is obvious that the sum of distances from two large masses plays important role in geometry of ZVC and ZVS, because main, Gaussian and mean curvature have their local extremes in the narrow regions where this sum has its minimum.

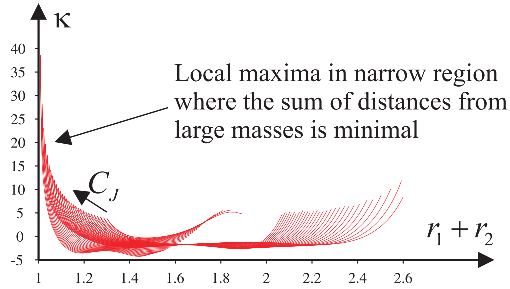

Figure 3. Typical distribution of main curvature along ZVC.

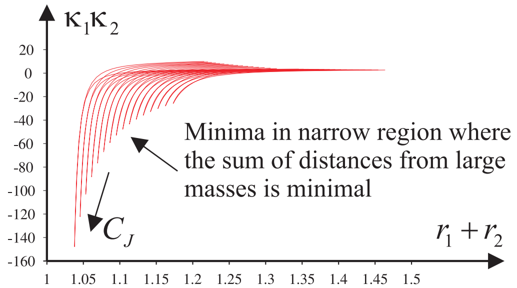

Figure 4. Typical distribution of Gaussian curvature along ZVC.

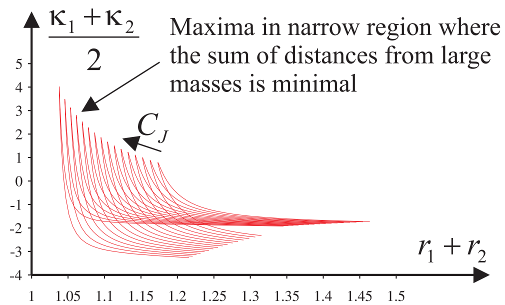

Figure 5. Typical distribution of mean curvature along ZVC.

In figure 5 is shown typical relation between curvature of the planar orbit and minimum distance from ZVC.

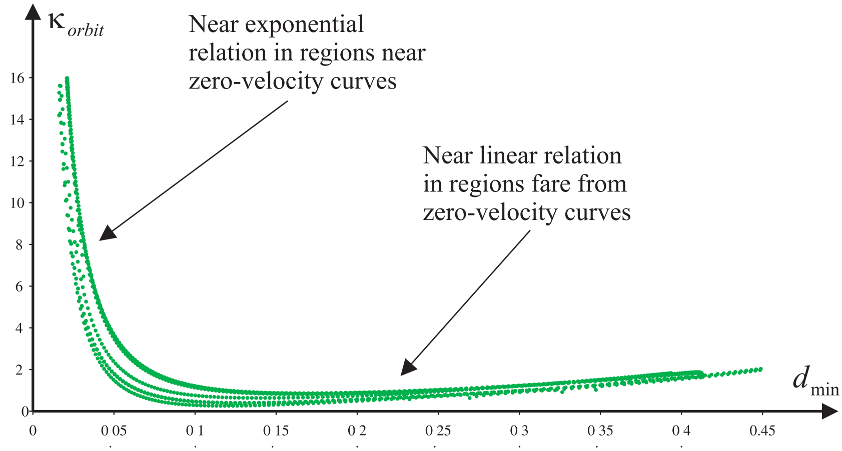

Figure 6. Typical relation between curvature of the planar orbit and minimum distance from ZVC.

From figure 5 one can se an interesting dependance of orbit curvature on minimal distance of the particle from ZVC. In regions near ZVC, orbit curvature has exponential decrease, while in the regions far from ZVC, orbit curvature has linear increase with minimal distance from ZVC.

From the all mentioned above, one can conclude that locations of the extreme values of the local geometrical parameters of ZVC and ZVC are related to the position of their points with reference to large masses. Also, local geometrical parameters of ZVC and ZVS may influence the local geometry of the orbit of the third body of the system.

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ASSIGNING WCS STANDARDS TO ROZHEN FITS ARCHIVE. PRELIMINARY TESTS

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Abstract. Assigning physical coordinates to FITS image pixels is important to standardize the Rozhen fits files. Among wide spread WCS software available, here we present tests based on the IDL implementation of the WCS standards. Our goal is to apply this implementation for calculating and adding the necessary WCS FITS keywords in the image headers. The obtained results are verified by comparing the image object positions with the astrometry from HIPPARCOS and USNO A-2.0 catalogs.

1. INTRODUCTION

There are several conventions that have been defined about specification of the physical or world coordinates attached to each pixel of an N-dimensional image (Greisen and Calabretta, 2002; Calabretta and Greisen, 2002). One common example is to link each pixel of an astronomical image to a specific direction on the sky (such as right ascension and declination). By world coordinates, one means coordinates which serve to locate a measurement in some multi-dimensional parameter space. In general the FITS world coordinate system (WCS)[1] of an image is defined by keywords in the FITS header. The basic idea is that each axis of the image has the following keywords associated with it:

- $\mathbf{CTYPE_i}$ - Type of coordinate on Axis **i**, 8 characters (The FITS WCS standard defined 25 different projections which are specified by CTYPE keyword.)
- $\mathbf{CRPIX_i}$ - Reference pixel on Axis **i**.
- $\mathbf{CRVAL_i}$ - Value of World Coordinate as Axis **i** at reference point ($\mathbf{CRPIX_i}$).
- $\mathbf{CD_{ij}}$ - A matrix of partial derivatives of the world coordinates with respect to the pixel coordinates.

[1] http://tdc-www.harvard.edu/wcstools/wcsprogsh.html

There are a number of software packages for reading, using or modifying the astrometric information and WCS parameters in the image header. Some of the most common packages are IRAF[2], WCSTools, WCSLib[3], TERAPIX Software and the packages in the astronomy IDL library.

In this work we use IDL astronomy library for computing the astrometric keywords. For visualization and inspection of the obtained results we use Aladin as a Java Standalone application by Centre de Données astronomiques de Strasbourg.

2. USED IDL ROUTINE:

STARAST - Computes an exact astrometric solution using the positions and coordinates from 2 or 3 reference stars and assuming a tangent (gnomonic) projection. If 2 stars are used, then the X and Y plate scales are assumed to be identical, and the axis are assumed to be orthogonal. Use of three stars will allow a unique determination of each element of the CD matrix and automatically append them as an appropriate FITS WCS keywords in the image header.

INITIAL DATA - For this work we used CCD images from two telescopes ar Rozhen National Observatory as well as plate archive data (WFPDB). Here are some technical details for the telescopes. In Table 1 we show the technical parameters of the VersArray CCD camera.

Schmidt telescope - Rozhen Observatory
Scale: 120 arcsec/mm
Scan resolution: 1600 DPI => 1px = 16 μm
The scans have nonstandard orientation - the image coordinates are transposed
1px = 1.92 arcsec = 5.333e-4 degrees

2mRCC Telescope with FoReRo2 - Rozhen Observatory
RC Scale: 12.89 arcsec/mm
FoReRo2 Scale: 36.8 arcsec/mm
1px = 0.88 arcsec = 2.444e-4 degrees

Table 1: Technical details for the VersArray CCD camera used with the 2mRCC telescope.

VersArray: 512B CCD camera parameters	
CCD CHIP MODEL	E2V CCD77-00

[2] http://iraf.noao.edu/
[3] http://www.atnf.csiro.au/people/mcalabre/WCS/

VersArray: 512B CCD camera parameters	
CHIP DIMENSIONS	512x512 pixels
PIXEL DIMENSIONS	24x24 μm
READOUT NOISE	3.3 electron/pixel RMS
CCD CHIP COOLING	liquid nitrogen

3. METHODS AND RESULTS

The coordinates of the center of the images are roughly known, so we need to perform a "3 stars astrometry", using STARAST IDL routine in order to determine them more precisely.

The procedure we used is as follows:

The first step is to choose 3 stars in the field of the image, which are apart from the center. With their catalog positions we compute the coordinates of the unknown center of the image. This is our "first approximation" astrometric solution.

The sub-figures 1 & 2 (indicated with "wcs1") represent the catalog coordinates (red circles) over plotted onto the FITS images. The figures clearly show that the obtained results are quite good.

We found even more simple approach which we call "zero approximation".

First we add the matrix elements CD1_2 and CD2_1 in the FITS header as zero values. These WCS keywords are connected with the frame orientation. Second, for the CD1_1 and CD2_2 values we use the pixel size in degrees. The pixel coordinates of the image center corresponds to the CRPIX1 and CRPIX2 WCS keywords. Initially predicted center coordinates (in degrees) are added in the FITS header as CRVAL1 and CRVAL2 keywords. According to the results (represented in subfigures 1 and 2, labeled with "wcs0") it seems that the astrometric solution could be used as a rough estimation of the standard FITS WCS keywords. The approach we use is a straightforward procedure for adding the FITS WCS keywords in the image header even during the observation, without using any third party software (IDL, IRAF, etc.)

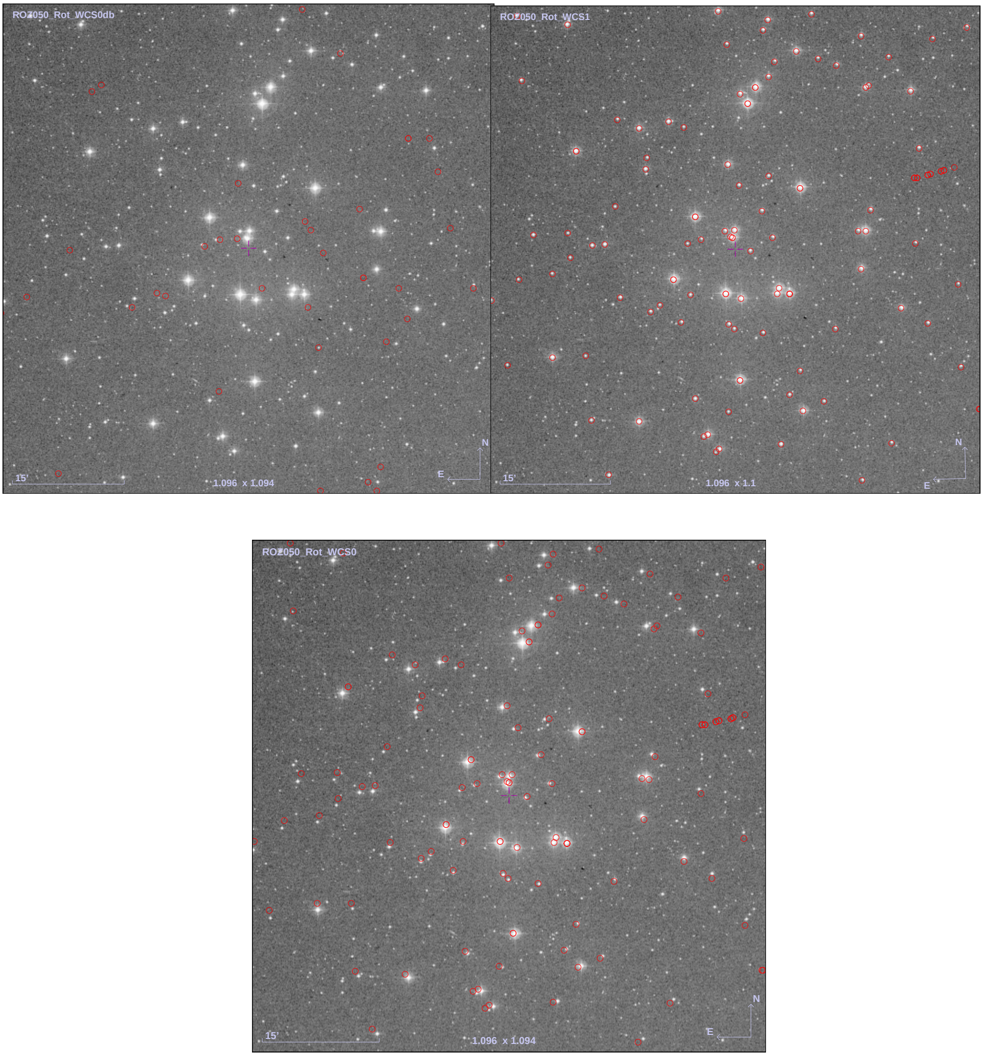

Figure 1. Central part of the Schmidt plate ROZ 050 002581, Object: Praesepe.

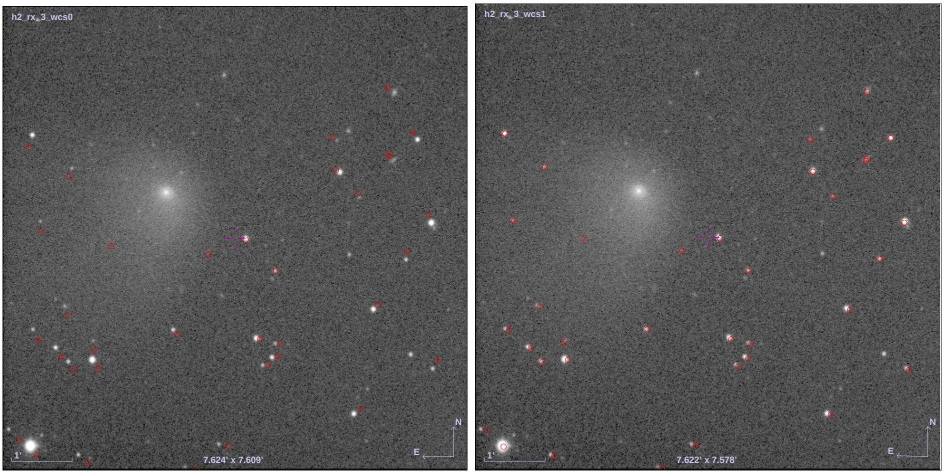

Figure 2. 2mRCC - FoReRo2 image of the comet P/2010 H2.

In the sub-figure 1 (indicated with “wcs0db”) it is obvious that when using the central coordinates available in the Wild Field Plate DataBase (WFPDB)[4] the “zero approximation” gives unsatisfactory results. We believe that this is due to some uncertainties in the proposed central coordinates.

4. CONCLUSIONS

Here we suggest several simple steps for adding standard WCS keywords in the headers for the Rozhen FITS images. This could be the first step to make the Rozhen Fits Archive more consistent with the VO standards.

Our results show that the “first approximation” solution (computing the unknown center coordinates of the image by using the catalog coordinates for 3 stars, chosen to lie remote from the image center) gives more appropriate results than the “zero approximation” approach when the WFPDB data were used.

Acknowledgments

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Greisen, E. W., Calabretta, M. R.: 2002, *A&A*, **375**, 1061.

[4] http://www.skyarchive.org/

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ON A POSSIBLE CYCLIC ACTIVITY OF THE PLEIADES FLARE STAR II TAU

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Abstract. We present preliminary results of a possible cyclic activity of the flare star II TAU based on flare activity observed during long monitoring campaign of the Pleiades region performed in 60-80-ies of the last century. Bayesian statistical analysis (Gregory-Loredo method for periodic signal detection of unknown shape in time-series with Poissonian and Gaussian errors) of the registered flare times and released energies during the maximum of the flares indicates on a 3-3.5 year activity period.

1. INTRODUCTION

Even historical observations of the Sun show increase and decrease sunspots numbers roughly in 11 year period. Because the sunspots are magnetic in nature, it is natural, that the cyclic activity is a result of a variation in a surface magnetism. Moreover, the solar cyclic activity in the form of flares and related phenomena has long been known, the discovery that such activity occurs on most stars, and that it frequently appears in more violent forms on stars other than the Sun, prompted a further reassessment of the nature of stars.

In particular, the flare activity of the red dwarf stars in stellar associations and star clusters, as well as in the solar vicinity can be considered as another important property common for them at some evolutionary stage.

However, in contrast, the cyclic activity of the flare stars is not enough investigated yet. In particular, as suggested by Mirzoyan & Oganyan (1977), according to the flare statistics, only half of the probable members of the Pleiades open cluster, having low luminosity ,exhibited flare activity during the period of all observations. To explain this discrepancy with ideas about the evolutionary significance of the flare phase of stars, through which all dwarfs pass, two suggestions are made: that the flare activity is cyclic and that there is a large dispersion in the duration of the flare activity phase for stars of the same luminosity. Some evidence for the first possibility is put forward, i.e the flare activity of the stars is cyclic, like the Sun: periods of maximal flare activity are followed by periods of comparative quiescence. Possible cases and other arguments in favor of this kind of variability are given elsewhere (Gurzadian 1985, Pettersen 1989, Parasamian and Andrews 1996, Akopian 1999, 2001, 2008, Akopian and Sargsyan 2002).

Here, we present preliminary analysis of possible cyclic activity of the flare star II TAU or HII 2411; T55; HCG 377; A11; A12; A41; A51; R9 based on the flare activity observed during long monitoring campaign of the Pleiades region performed in 60-80-ies of the last century. We used a Bayesian statistical analysis developed by Gregory & Loredo (Gregory and Loredo 1992, Gregory 1999) (henceforth GL method) for periodic signal detection of unknown shape in time-series with Poissonian/Gaussian errors, i.e an application to the registered flare times and released energies during the maximum of the flares of II TAU.

2. DATA ANALYSIS AND RESULTS

The flare star II TAU for observational period spanning over ~ 20 years is known as a most frequently flaring one in the Pleiades region (Haro et al. 1996). Having at disposal the Flare Stars Database (Tsvetkova et al. 1995, 1996) we took the data for all flares registered in the observational period, in total 132, of II TAU, in different photometric bands, mostly in U or photographic (Pg). The flare amplitudes were converted from Pg to U photometric band taking into account synchronous or parallel observations of some flares. Unfortunately, the exact times of registered flares of II TAU are not given in the published papers, and we adopted such with uncertainty of 6 hours. Since the characteristic time scales considered in this study are much longer than this uncertainty this assumption can not have crucial influence upon our results. The data set of flares of II TAU is shown in Fig. 1.

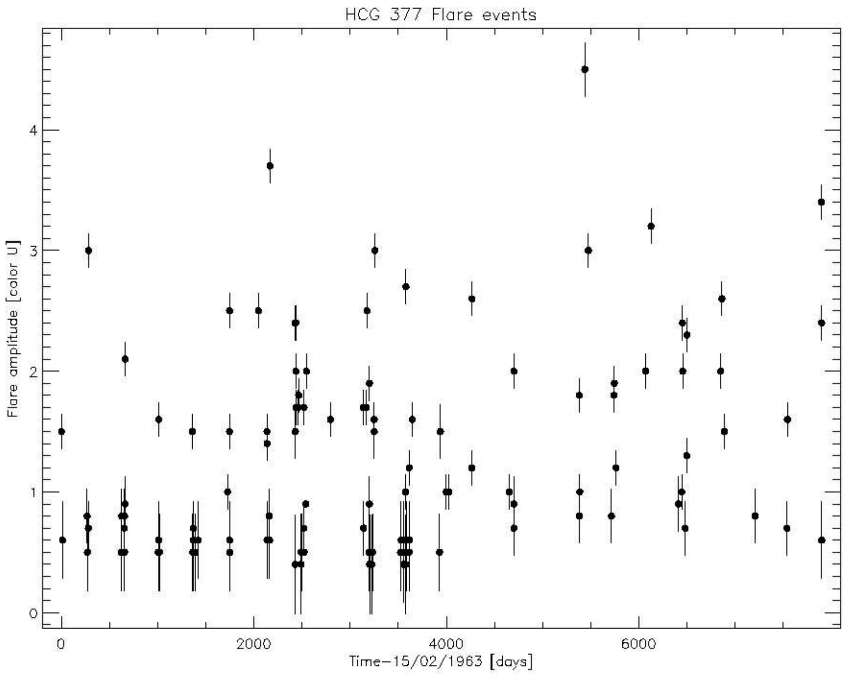

Figure 1. Long-term flare activity of II TAU, flare amplitude in U photometric band vs flare registered time, is shown spanning $\approx$ 8000 days. Error bars of the flare amplitudes are adopted according to the accuracy of the photographic photometry at the maximum of the flare. The GL method, a Bayesian approach for periodic signal detection of unknown shape with Gaussian noise is applied to this data set (for details, see text).

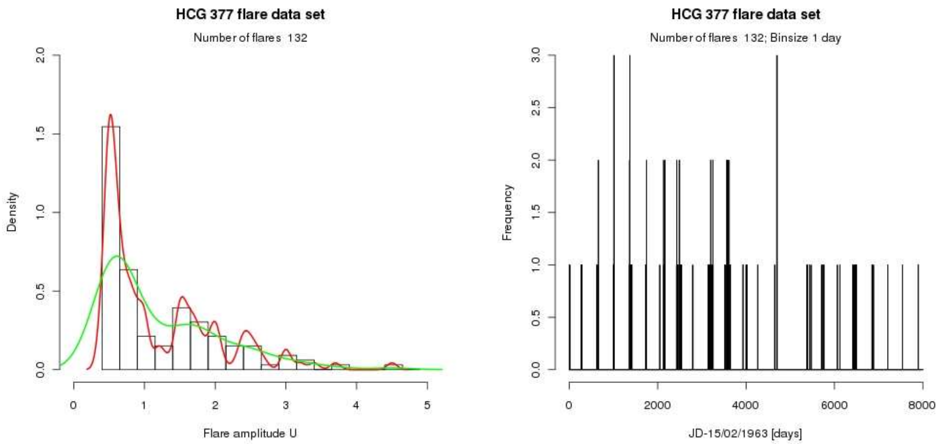

Figure 2. Distributions of ΔU amplitudes of flares (left panel) and registered times of flares (right panel) of the most frequently flaring star II TAU in the Pleiades region.

In order to detect cyclic activity of II TAU we first applied the GL method developed by Gregory & Loredo (1992) to the above described data set, assuming that the flare amplitudes in U photometric band at the flare maximum are in the case of Gaussian errors (Gregory 1999, 2005).

The method is using a Bayesian approach to the problem of detection and characterization of a periodic signal in a time series when we have no specific prior knowledge of the existence of such a signal or of its characteristics, including shape.

In the current approach, we are dealing with stellar magnitude measurements i.e. analyzing a sampled time series with Gaussian noise (Gregory 1999). This analysis does not assume uniform sampling; the approach allows us to draw optimal inferences about the nature of the signal for whatever data is available.

Thus, for the II TAU flare data sets, for which long term observations are available, we can represent the measurements of the flare amplitudes in $U - band$ and corresponding errors spanning more than 20 years, by the equation:

$$\Delta U_i^O = \Delta U_i^M + \epsilon_i + s$$

where ΔU_i^O is the measured flare amplitude at time t_i, ΔU_i^M the periodic model or constant model prediction at time t_i, ϵ_i the component of ΔU_i^O, which arises from measurement errors, and s is any additional unknown measurement errors plus any real signal in the data that cannot be explained by the model prediction ΔU_i^M.

Under the proposition that the quantity $\Delta U^O - \Delta U^M$ obeys to the Gaussian distribution, for the Bayesian posterior probability of the angular frequency ($\omega = \frac{2\pi}{P}$) of a periodic signal we may write (Gregory 1999, 2005):

$$Prb(\omega|\Delta U^O, M_m) = \frac{C}{\omega}\int_{s_{lo}}^{s_{hi}} \frac{ds}{s}\int_0^{2\pi} \exp(-\frac{1}{2}\sum_{j=1}^{m}\chi^2_{W_j})$$

$$\prod_{j=1}^{m} W_j^{\frac{1}{2}}[erfc(y_{jmin}) - erfc(y_{jmax})]d\phi,$$

where $C = \left[\int_{\omega_{lo}}^{\omega_{hi}} \frac{d\omega}{\omega} Prb(\omega|\Delta U_i^O, M_m)\right]^{-1}$, $\chi^2_{W_j} = \sum_{i=1}^{n_j} \frac{(\Delta U_i - <\Delta U_{W_j}>)^2}{(s^2+\epsilon_i^2)}$,
$W_j = \sum_{i=1}^{n_j} \frac{1}{s^2+\epsilon_i^2}$, $< \Delta U_{W_j} >= \frac{\sum_{i=1}^{n_j} \Delta U_i/(s^2+\epsilon_i^2)}{W_j}$,
and $erfc(y) = \frac{2}{\sqrt{\pi}}\int_y^\infty \exp{(u^2)}du$, $y_{min,max} = \sqrt{\frac{W_j}{2}}(\Delta U_{min,max} - < \Delta U_{W_j} >)$.

The GL method is intended to compute the ratio of the probabilities (odds ratio) of two models, i.e. periodic and constant. The periodic model is a family of models capable of describing a background plus a periodic signal of arbitrary shape.

A priori, we assume that the constant and periodic models have equal probability. Each member of the family of the periodic models is a histogram with m bins, with m ranging from 2 to some upper limit, typically 12. The unknown parameters are P (period), ϕ (phase offset of start of data and beginning of first bin), m (number of bins), and s (extra Gaussian noise parameter).

The long-term period search was performed in the range of 250 to 2500 days. As a result, we obtained a most likely periodicity of 1220 days with a 68 % credibility range of 1100 to 1300 days of activity cycle length.

Next, we applied the GL method in the case of Poissonian errors to the registered times of the flares of II TAU. Again we compared hypothesis constant vs periodic, i.e. flare arrival times are consistent with purely constant rate Poissonian process or there is an evidence of cyclic activity. Despite of the spare data set, we obtained result again supporting our idea on a possible periodicity of 3.0-3.5 years (see above) with analysis of the amplitudes of the flares of II TAU.

In addition, we have simulated large number of random data sets with a similar number of data points (e.g. 100 to 150), with a certain cycle length (e.g. 3-5 years), and also measurement errors ($\pm 0.1 - 0.3$ mag) to check, how precise we can then determine the cycle length with our method. It shows that for overwhelming majority cases our approach with Bayesian statistics has detected the periodic signal, i.e. possible cyclic activity of II TAU. Unfortunately, this powerful approach, certainly extracting more information from the available data than other methods, can be applied only in a few cases, when statistically significant number of flares have been registered. Nevertheless, an approach for a synthetic flare star could be applicable, assuming that the flare stars of the similar luminosities observed in the Pleiades region possess approximately the same flaring activity (Ambartsumyan 1978).

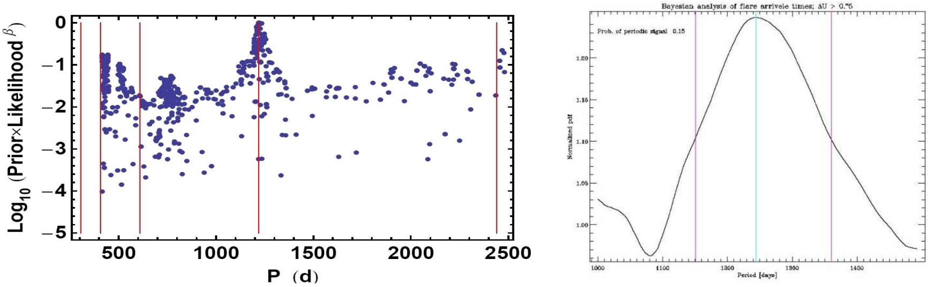

Figure 3. Log of Bayesian posterior probability of density function of period of amplitudes (ΔU left panel) and registered times of flares (right panel) of HCG 377 is shown. The application of the GL method in the case of Gaussian and Poissonian noise revealed a significant period of ~ 1220 days (higher harmonics also are indicated by vertical lines). A Bayesian odds ratio of periodic vs constant model is equal ≈ 100 (for details, see text).

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INVESTIGATIONS OF THE INFLUENCE OF COLLISIONAL PROCESSES ON THE ASTROPHYSICAL PLASMA SPECTRA AT ASTRONOMICAL OBSERVATORY (PERIOD 2008-2009)

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Abstract. The review of activities on the project 146001 "Influence of collisional processes on the astrophysical plasma spectra", supported by the Ministry of Science and Technological development of Serbia, from 1st of January 2008 up to 31st of December 2009 is given, together with the bibliography of published works.

Investigations made within the frame of the Project "Influence of collisional processes on spectra of astrophysical plasma" concern plasma in astrophysics, laboratory and technology. Particular attention has been paid to the investigation of spectral line profiles, of interest for the diagnostics and modelling of stellar plasma, plasma in laboratory and technological plasma, broadened by collisions with charged particles (Stark effect). Semiclasical perturbation and Modified semiempirical methods were used, developed, tested and investigated. They were applied for determination of Stark broadening parameters, and obtained results were used for the investigation of its influence in stellar atmospheres.

Participants of the Project published 8 papers in leading international journals (the upper third of Science Citation Index (SCI) list), namely in (with the number of published papers in the brackets) Astronomy and Astrophysics (1), Astrophysical Journal (3), Astrophysical Journal Supplement Series (1), Monthly Notices of the Royal Astronomical Society (2), Spectrochimica Acta B (1). In the rest of journals from SCI list as New Astronomy (1), New Astronomy Review (5) and European Journal of Physics D (1) were published 7 articles and in international journals which are not on SCI list and in books of international publishers 18 works.

Other results are: Invited lectures on international conferences published in books of international publishers (2) and in conference proceedings (2), monographs published in Serbia (1), articles in national journals and books (16), contributions in proceedings of international conferences (17), published invited lectures at national conferences (2), contributions in proceedings of national conferences (22), abstracts of invited lectures on international conferences (10), abstracts of presentations on international conferences (49), abstracts of invited lectures on national conferences (3), book reviews in international journals (1) abstracts of presentations on national conferences (3). Within the considered period Zoran Simić defended his PhD Thesis.

In total, project participants published 139 bibliographical items, 83 connected with project and 56 not.

Participamts of the Project organized four conferences and one summer school, giving and in this way contribution to the development of scientific collaboration. They are:

1. « DEVELOPMENT OF ASTRONOMY AMONG SERBS V», Belgrade, 18 – 22. April 2008, Chairman of the Scientific Committee M. S. Dimitrijević, members of the Local Organizing Committee M. Dačić, M. S. Dimitrijević.
2. 6th SERBIAN-BULGARIAN ASTRONOMICAL CONFERENCE, Belgrade, 7 – 11. May, 2008, Co-Chairman of the Scientific Committee M. S. Dimitrijević, members M. Dačić, D. Jevremović, Chair of the Local Organizing Committee A. Kovačević, members M. Dačić, M. S. Dimitrijević, N. Milovanović, Z. Simić.
3. 24TH SUMMER SCHOOL AND INTERNATIONAL SYMPOSIUM ON THE PHYSICS OF IONIZED GASES - [SPIG 2008], August 25-29, 2008, Novi Sad, Serbia, Co-Chairman of the Local Organizing Committee M. S. Dimitrijević, members A. Kovačević, M. Dačić, N. Milovanović, Z. Simić.
4. THE SECOND SUMMER SCHOOL IN ASTRONOMY, September 29 – October 1, 2008, Belgrade, Serbia, Co-Chairman of the Scientific Committee M. S. Dimitrijević, Chair of the Local Organizing Committee A. Kovačević, members M. Dačić, Z. Simić (This School is in official program for the celebration of 200 years from the foundation of the University of Belgrade).
5. 7TH SERBIAN CONFERENCE ON SPECTRAL LINE SHAPES IN ASTROPHYSICS, June 15-19, 2009, Zrenjanin, Serbia; Co-Chairman of the Scientific Committee M. S. Dimitrijević, member D. Jevremović, Chairman of the Local Organizing Committee D. Jevremović, members M. Dačić, M. S. Dimitrijević, A. Kovačević, Z. Simić

Project participants also contributed to the organization of the following conferences:

1. «DJORDJE STANOJEVIĆ – LIFE AND WORK - On the occasion of 150 years from his birth“, Novi Sad, 10-11 October 2008, M. S. Dimitriević – Editor of Proceedings and memeber of Scientific Organizing Committee.
2. 1ST WORKSHOP: ASTROPHYSICAL WINDS AND DISKS. SIMILAR PHENOMENA IN STARS AND QUASARS, Platamonas, Greece, September

3-8, 2009, Co-Vice chairman of the Scientific Committee M. S. Dimitrijević, members A. Kovačević, Z. Simić

3. XV NATIONAL CONFERENCE OF ASTRONOMERS OF SERBIA, Belgrade, October 2-5, 2008, member of the Local Organizing Committee A. Kovačević,
4. INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES, 15-20 June 2008, Valladolid, Spain, member of the Scientific Committee M. S. Dimitrijević

From 2008 to 2009, seven researchers were working on this project, six from Belgrade Astronomical Observatory and Andjelka Kovačević from Faculty of Mathematics. The leader of the project during the considered period (1st of January 2008 – 31st of December 2009) was M. S. Dimitrijević, and the participants are:

1. Miodrag Dačić (born 1946) total 20 RM (Research Months)
2. Milan S. Dimitrijević (born 1947) total 24 RM
3. Darko Jevremović (born 1968) total 18 RM
4. Andjelka Kovačević (born 1972) total 16RM
5. Nenad Milovanović (born 1979) total 24 RM
6. Zoran Simić (born 1967) total 24 RM
7. Dragana Tankosić (born 1968) total 8 RM

During two years, seveen participants were engaged for 134 research months, i.e. 11.2 years. The average age was around 46 years (or the average year of birth 1963.9).

The Ministry of Science and Technological Development of Serbia, accepted the project in accordance with the call for projects announced in 2005, and the detailed financial structure of this project during the considered period is shown below.

2009.	
• 1. Salaries for the researchers	8 121 038 RSD
• 2. Expenses of the institution	2 320 320 RSD
• 3. Direct expenses of the Project	596 654 RSD
Sub-Total	11 038 012 RSD
2008.	
• 1. Salaries for the researchers	6 009 281 RSD
• 2. Expenses of the institution	2 001 003 RSD
• 3. Direct expenses of the Project	890 952 RSD
Sub-Total	8 901 236 RSD
Total 2008 - 2009.	**19 939 248 RSD**
(~210 000 EUR – 1 EUR = 95 RSD)	

Decisions on overhead costs were made by director, of Astronomical observatory and they were used for administration and for general expenses of the Institution. While decisions concerning expenses for travels, international collaboration, equipment, and material were made on the Project level.

During 2008. and 2009. years, the investigations of the influence of collisional processes on astrophysical plasma spectra were performed in several directions. The research of the influence of Strak broadening on spectra of chemically peculiar A type stars and white dwarfs have been continuated. The common influence of Stark broadening effect and of hyperfine structure on the lines of ionized manganese has been considered, it was shown when these effects are important and how they can be taken into account. (Popović et al., 2008, New Astronomy, **13,** 85).

It has been investigated the dependence on temperature of Stark broadening in stellar spectra and proposed an improved method to take into account this dependence, for the calculation of stellar atmosphere models and in laboratory plasma diagnostics (Zmerli et al., 2008, European Journal of Physics D **48,** 389).

The influence of Stark broadening at very hot (effective temperature from 40000 to 100000 K) and dense white DO dwarfs was considered, and applying the code for the calculation of atomic structure, were *ab initio* determined Strak broadening parameters for Si VI spectral lines (Hamdi et al., 2008, Monthly Notices of the Royal Astronomical Society, **387,** 871).

The spectrum of the GJ 117 star was observed with 2,7 m telescope on Mc Donalds observatory. Analyzing it by modeling of stellar atmosphere with PHOENIX code was established that ^{6}Li/^{7}Li=0.05+/-0.02. Also was analyzed the mechanism of creation of lithium in this star (Christian et al., 2008, Astrophysical Journal, **686**, 542).

It was worked on the development of the Dartmouth database for investigation of stellar evolution and for this purpose was investigated and calculated the evolutionary history of some types of stars (Dotter et al., 2008, Astrophysical Journal Supplement Series, **178**, 89).

Since the effects of the changement of chemical composition of stellar populations were investigated on the element by element basis on the stellar evolutionary tracks and isochrones to the end of the red giant branch, now are incorporated the fully consistent synthetic stellar spectra with those isochrone models in predicting integrated colors, Lick indices, and synthetic spectra. Older populations display element ratio effects in their spectra at higher amplitude than younger populations (Lee et al., 2009, Astrophysical Journal, 694, 902).

A series of synthetic spectra was elaborated and published and radiative transfer for broad absorption iron lines of low ionization degree was analyzed at active galactic nuclei. Obtained results support the idea that FeLoBALs may be an evolutionary stage in the development of more ``ordinary'' QSOs. (Casebeer et al., 2008, Astrophysical Journal, **676**, 857).

Variability of galaxy optical spectra has been investigated (Shapovalova et al., 2008, Astronomy and Astrophysics, **486** (1), 99-111).

The total and relative contribution to the atmospheric opacity of DB white dwarfs within UV and VUV regions has been determined (Ignjatović et al., 2009, Monthly Notices of the Royal Astronomical Society, **396,** 2201).

A method for the determination of gas temperature in argon – helium microwave plasma on atmospheric pressure, with the help of Van der Waals broadening of spectral lines in optical part of the spectrum, has been elaborated, and the most convenient lines for this purpose have been found (Muñoz et al., 2009, Spectrochimica Acta B **64,** 167).

Furthermore, Stark broadening of spectral lines was analyzed for Serbian Virtual Observatory (Jevremović et al., 2009, New Astronomy Review, **53**, 222), and has been worked on kinematics of broad line region at quasars (Lyratzi et al., 2009, New Astronomy Review, **53**, 179), interpretation of complex profiles of spectral lines in stellar spectra (Danezis et al., 2009, New Astronomy Review, **53**, 214), Stark broadening of spectral lines of chemically peculiar stard (Simić et al., 2009, New Astronomy Review, **53**, 246) and on analyzis of emission lines variability at active galactic nuclei (Shapovalova et al., 2009, New Astronomy Review, **53**, 246).

This are only the most important results and the rest can be seen from bibliography of published papers, presented here.

Certainly the largest success and recognition of Project's results is that, together with our partners from France, England, Austria, Sweden, Italy, Russia and Venezuela we obtained FP7 project "Virtual Atomic and Molecular Data Center.

Additionally, the successful collaboration with Paris Observatory, and UUniversities, Observatories and Institutes in Athens, Cordoba, Paris, Lion, Sankt Petersburg, Moscow, Nizhnyj Arkhiz, London, Belfast, Darthmouth, Groningen, Washington, Oklahoma, Alabama, Wichita, Wisconsin, Georgia, California, Hanover, Göttingen, Sao Paolo, Montreal, Mexico and Tunis, was achieved as well as with the Institute of Astronomy in Sofia (the project SASA-BAS) and with Department of Applied Physics of the Technical university in Sofia, what can be seen from the list of published papers given here.

Also, M. S. Dimitrijević was the supervisor of PhD Thesis of Zoran Simić, defended on 15th of July of 2008.

Within the frame of Project it has been worked and on development of STARK-B database together with Sylvie Sahal-Bréchot and Nicolas Moreau from Paris observatory.

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SPECTROSCOPIC INVESTIGATIONS OF EXTRAGALACTIC OBJECTS AT THE ASTRONOMICAL OBSERVATORY IN BELGRADE (2008 – 2009)

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Abstract. In this paper we present the work and results of the project P146002 (Astrophysical spectroscopy of extragalactic objects) during two-year period (2008-2009). The work on this project is financed by the Ministry of science and technological development of the Republic of Serbia. Here we describe the scientific activities and give a list of published papers in this period.

1. INTRODUCTION

This paper follows two previous reviews (Popović and Ilić, 2006; Popović, Kovačević, Ilić, 2008) where we have reported all activities on the project Astrophysical spectroscopy of extragalactic objects in the period from 2002 to 2007. Astrophysical spectroscopy gives powerful tools for investigation of the emission of extragalactic objects, from which we can learn about the nature and evolution of these objects, and also about the evolution of the Universe. In the period 2008-2009 we have continued the spectroscopic investigation of extragalactic objects started in 2001 at the Astronomical Observatory in Belgrade. These investigations were done in three basic directions: 1. Spectroscopy of active galactic nuclei - AGN; 2. Spectroscopy of quasar gravitational lenses, or the influence of gravitational lenses on quasar spectra; 3. Investigations of the gamma-ray bursts phenomenon.

The most important results from these investigations are: contribution to the research of physical and kinematical properties of central emission regions in AGN, as well as to determining the influence of microlensing effect on quasar spectra (with the aim to scan the inner structure of quasars and lens-galaxy). Also, a model of shock waves for the gamma-ray bursts is developed.

Apart from the scientific research, the project was a base for the education of young researchers (work on several doctoral and master thesis), but also for the

development of wide and successful international collaboration.
In further text we will shortly present the work on this project during 2008 and 2009. We should note here that the participants on this project are closely collaborating with the project led by M. S. Dimitrijević, therefore these two projects (together with the project *Serbian virtual observatory*, led by Darko Jevremović) form an informal group called *Group for astrophysical spectroscopy (GAS)*. Therefore, some activities presented here are actually the activities of the Group for astrophysical spectroscopy.

2. RESEARCHERS ON THE PROJECT

In the period from 2008 to 2009, nine researchers were working on this project from three institutions: Astronomical Observatory in Belgrade (AOB), Faculty of Mathematics in Belgrade (FMB) and Faculty of Sciences in Kragujevac (FSK). The project leader was L. Č. Popović, and the researchers were:

1. Edi Bon (born 1970), PhD student from AOB, total 24 Research Months (RM), category A2 (Note here, that Ministry of Science of Serbia invited a categorization due to score of published papers for each researcher. The catetories are A1, A2, A3, B1, B2, B3, where the best scientists, around 10% of all, are in A1, and B1 is basic category.)
2. Miodrag Dačić (born 1946), research associate professor from AOB, total 4 RM, category A1
3. Nataša Gavrilović (born 1979), Msc student (PhD student from 2009) from AOB, total 24 RM, category A1
4. Dragana Ilić (born 1978), teaching assistant (assistant professor from 2009) from FMB, total 16 RM, category A1
5. Jelena Kovačević (born 1981), MSc student (PhD student from 2009) from AOB, total 20 RM, category A1
6. Predrag Jovanović (born 1968), assistant research professor from AOB, total 24 RM, category A1
7. Luka Č. Popović (born 1964), research professor from AOB, total 24 RM, category A1
8. Saša Simić (born 1971), teaching assistant from FSK, total 16 RM, category B1
9. Marko Stalevski (born 1982), PhD student granted for a young research position from the Ministry

3. SCIENTIFIC AND OTHER ACTIVITIES

The main investigations on the project were related to the activities of galaxies, first of all of to active galactic nuclei (AGNs). These objects are the most powerful sources in the Universe, and they emit energy in a broad range of wavelengths (from gamma to radio emission). The spectroscopy of these objects can give us a lot of information about the innermost part of AGNs, as e.g. mechanisms for producing the energy in the black hole vicinity, the behaviour of plasma in the strong gravitational field, etc. On the other hand, since these objects are the most powerful sources, we can detect them at large cosmological distances, thus they represent objects that carry information important for cosmological investigations. In the mentioned period the investigations were done in the following subjects:

- Physical and kinematical properties of central emission regions in AGN (in different spectral bands, from x-ray to optical emission, as well as the connections between the emissions from these different spectral bands).
- Spectroscopy of quasar gravitational lenses and the influence of gravitational lenses on quasar spectra.
- Connection between the stellar population and the activity in galaxies.
- Gamma ray bursts as the most violent processes in the Universe, i.e. the nature of this phenomenon.

Figure 1. The Local Organizing Committee of the SPIG 2008 (Novi Sad, Serbia, 25.-29. 08. 2008.). From the left to the right: Jelena Kovačević, Nataša Gavrilović, Marko Stalevski, Tanja Milovanov, Edi Bon, Anđelka Kovačević, Branimir Acković, Dragana Ilić, Darko Jevremović, Predrag Jovanović, Nenad Milovanović, Milan Dimitrijević, Zoran Simić i Luka Popović.

In the frame of the listed subjects, the activities of the project participants were the following:

1. Theoretical and experimental investigations, where special attention was given to trainings of young researchers, there were conducted in three directions: a) investigations of physics and kinematics of AGN using the spectral lines shapes and intensities; b) investigations of the influence of gravitational lenses

on the quasar's continuum and spectral lines; c) modelling and explaining the origin of gamma-ray bursts taking into account shock waves;
2. Observations with different telescopes;
3. Research visits to various collaborating institutes and attending scientific conferences interesting to the project;
4. Popularization of science, especially astronomy in the form of giving lectures or organizing exhibition dedicated to astronomy. We should note here that all project participants were actively involved in projects related to the International year of astronomy 2009;
5. Developing of international collaboration through exchange visits of project participants and colleagues from abroad, as well as writing common (bilateral) proposals;
6. Organizing conferences and publishing Proceedings;
7. Systematization and publishing of fulfilled results.

The results that are achieved in the period 2008/2009 are (see Appendix for more detailed description of the achieved results):

– More than 101 bibliography units published, out of which 20 papers in international journals from SSCI list (see the list of references). If we compare the result from this period to the period 2006-2007, we have published two more papers in journals from SSCI list;
– Two PhD theses and two Master theses defended;
– Performed optical observations of gravitational lenses using 6m telescope of Special astrophysical observatory (Caucasus, Russia);
– Became members of the COST action M0905 "Black holes in violent Universe". We should note that this is the first COST action in astronomy. It involves 17 European countries;
– Participated in 14 international and domestic conferences;
– Project participants did 15 research visits to foreign institutes;
– Organized (or participated in organization) six scientific meetings (see Appendix);
– Large international collaboration (Bulgaria, Russia, Germany, Spain, Italy, Mexico, France, Greece, USA). In the frame of this wide collaboration we formed a new Erasmus Mundus master programme in astrophysics "AstroMundus", where participants are four European universities (Innsbruck – Austria, Goettingen – Germany, Padua and Rome – Italy, and Belgrade – Serbia). In this programme three project participants are involved as lecturers, and Dragana Ilić is member of the Consortium Board (deputy L. Č. Popović), and Luka Č. Popović is a member of the Selection Committee for selection of students and scholars (deputy Dragana Ilić).

4. FINANCING OF THE PROJECT

As we have reported in previous papers (Popović, Ilić 2006, Popović, Kovačević, Ilić 2008) the project was mainly financed by the Ministry of science of the republic of Serbia. The Ministry has financed the salaries of the researchers, administrative expenses (run by the Institute) and other expenses (which cover travels, materials, equipment, etc.). In the considered period, the Ministry have allocated to the project in total 22,076,716 RSD (for 2008, in total 9,907,390 RSD and for 2009, in total 12.169.326 RSD), or approx. 220,000 EUR.

We should note that approx. 40% of total funds were spent on researcher's salaries, a significant amount was directed to administrative expenses, while for travels, materials, supplies and equipment, only 2,800,000 RSD (around 28000 eur) were spent in two years. These funds were used for renewing the computer equipment, as well as for financing travels (to meetings), observational missions, etc. Apart from this financial support, some additional fund were obtained from the Alexander von Humboldt Foundation, which is financing a project of collaboration between the Group for astrophysical spectroscopy from the Astronomical observatory and the Group for investigation of active galactic nuclei (led by professor Wolfram Kollatschny) from Institute for astrophysics of the University of Goettingen (Germany). Project is awarded a 40,300 EUR for three years, and in 2009 research visits were done and 6,500 EUR were spent from approved funds.

5. CONCLUSIONS

As in the previous period, we can be satisfied with the achieved results in the period 2008-2009. For sure we will try to work harder and give better results in forthcoming period. When comparing the results from 2001-2005, 2006-2007 and 2008-2009, there is an impression that the last period was slightly more successful than the previous two. Also, we should note that the financial support was larger in the last period.

Finally, we have to mention that in July 2010, new project proposal for 2011-2014 was submitted, under the same title and containing the research subjects mentioned above. Apart from this project, researcher Predrag Jovanović has submitted a new project proposal that will deal in more details and depth the investigations of gravitational lenses phenomenon and its applications in the cosmological research. Considering that this project is a product of spectroscopic investigations of extragalactic objects, this could be treated as another great result of this project.

APPENDIX

A1. Research visits (observational missions)

Nataša Gavrilović, 3-months visits each year to CRAL – L'Observatoire de Lyon, Lyon, France

Luka Č. Popović, Special Astrophysical Observatory, Nizhniy Arkhiz, Russia (2008 observation with the 6m telescope and collaboration, 2009. 10-day visit)

Luka Č. Popović, University of Padua (May 2008, gave a course to PhD students)

Luka Č. Popović, Academy of Science of Finland (May 2008, participating in the Pannel for evaluation of project proposals in astronomy that are supposed to be financed by the Academy of Science of Finland)

Luka Č. Popović, Institute for astrophysics, Canary Islands, Spain (December 2009)

Luka Č. Popović, University of Gent, Belgium (February 2009)

Luka Č. Popović, Special Astrophysical Observatory (August 2009, collaboration with the Laboratory for extragalactic astrophysical spectroscopy)

Luka Č. Popović, Institute for astrophysics, University of Goettingen (one-month visits in November 2008 and in the period 15. 11. – 15. 12. 2009.)

Luka Č. Popović, Max Planck Institute for Radioastronomy, Bonn (February 2008. Visit financed from the special program of the Alexander von Humboldt Foundation)

Dragana Ilić; Max Planck Institute for Radioastronomy, Bonn (January - February 2008. Visit financed from the special program of the Alexander von Humboldt Foundation)

Dragana Ilić, University of Padua (one-week visits in May 2008, gave an Invited lecture, and September 2008, collaboration)

Dragana Ilić and Jelena Kovačević, Special Astrophysical Observatory, Nizhniy Arkhiz, Russia (November 2008, observation with the 6m telescope and collaboration, two-week visit)

Dragana Ilić and Jelena Kovačević, Institute for astrophysics, University of Goettingne (one-month visit in the period 15. 11. – 15. 12. 2009. Visit financed from the special program of the Alexander von Humboldt Foundation)

Marko Stalevski, The Astronomical Observatory of the University of Ghent, Belgium (February 2 – December 16 2009, collaboration in the frame of the program Erasmus Mundus External Cooperation Window, BASILEUS)

A2. Conferences

A2.1 Organized conferences

1. 7th Serbian Conference of Spectral Line Shapes in Astrophysics, Zrenjanin, 15-19. June 2009 (Co-chairman Luka Č. Popović, everyone from the project were in the Local Organizing Committee)

2. 25st Symposium and Summer School on Physics of Ionized Gases (SPIG), August 25-29, 2008. (Co-chairmans of the Local Organizing Committee: Milan S. Dimitrijević and Luka Č. Popović, everyone from the project were in the Local Organizing Committee)
3. 6th Bulgarian-Serbian Conference on Astronomy and Space Science, Belgrade 7 - 11 May 2008 (organized together with Bulgarian colleagues)
4. XV National Conferences of Astronomers of Serbia, Belgrade 2-5. October, 2008 (Dragana Ilić, chairperson of the Local Organizing Committee)
5. Conference dedicated to the IYA 2009: „Како разумјети Универзум: допринос астрономских и физичких истраживања“ (How to uneerstand the Universe: Contribution of investigation in Astronomy and Physics), Banja Luka, 28-29. May 2009. (Luka Č. Popović co-chairman of the Scientific committee)
6. 1st Workshop on astrophysical winds and disks, Platamonas, Greece, September 3-8, 2009. (vice-chairmans: Luka Č. Popović and Milan S. Dimitrijević)

A2.2 Participations in conferences

1. 6th Serbian-Bulgarian regional astronomical meeting, Belgrade, Serbia, June 2008 (participants: everyone from the project).
2. 24th Summer School and International Symposium on the Physics of Ionized Gases, August 2008, Novi Sad, Serbia (participants: everyone from the project)
3. School and Workshop on Space Plasma Physics, September 2008, Sozopol, Bulgaria (participants: L. Č. Popović, D. Ilić, N. Gavrilović, J. Kovačević)
4. XV National Conferences of Astronomers of Serbia, October 2008, Београд, Serbia (participants: everyone from the project)
5. 7th Serbian Conference on Spectral line shapes in Astrophysics, June 2009, Zrenjanin, Serbia (participants: everyone from the project)
6. 1st International Workshop: "Astrophysical winds and disks - Similar phenomena in stars and quasars", September 2009, Platamonas, Greece (participants: everyone from the project)
7. Quantum of Quasars, December 2009, Grenoble, France (participants: Nataša Gavrilović)
8. Развој астрономије код Срба V (development of Astronomy among Serbs V), 18.04 - 22. 04.2008, Belgrade, Serbia (participants: Miodrag Dačić, Luka Č. Popović, Dragana Ilić, Edi Bon)
9. Conference dedicated to the IYA 2009: „Како разумјети Универзум: допринос астрономских и физичких истраживања“ (How to understand the Universe: Contribution of investigations in Astronomy and Physics), Banja Luka, 28-29. May 2009 (participants: Luka Č. Popović, Dragana Ilić)

10. The Fifth RadioNet Science Workshop "The Central Kiloparsec: Active Galactic Nuclei and Their Hosts", June 4-6, 2008, Crete, Greece (participants: Dragana Ilić)
11. „Accretion and Ejection in AGN: a global view“, June 21-27, 2009, Como, Italy (participants: Dragana Ilić)
12. XXVIIth General Assembly of the IAU, IAU Symposium 267 on "Evolution of Galaxies and Black Holes: Feeding and Feedback", August 2009, Rio de Janeiro, Brasil (participants: Dragana Ilić)
13. 1st School on Multiwavelength Astronomy", Paris, France, 29. June-10 July, 2009 (participants: Marko Stalevski).
14. XXI Canary Island Winter School on Astrophysics", Puerto de La Cruz, Tenerife, Spain, 2-13 November 2009 (participants: Marko Stalevski).

A3. Publications

A3.1 Chapters in international books

1. Jovanović, P., Popović, L.Č., 2009., *X-ray Emission From Accretion Disks of AGN: Signatures of Supermassive Black Holes,* chapter in the book *"Black Holes and Galaxy Formation",* Eds. A. D. Wachter and R. J. Propst, Nova Science Publishers, Inc, Hauppauge NY, USA, ISBN: 978-1-60741-703-3 (62 page)

A3.2 Papers in international journals from SSCI list

1. Shapovalova, A. I.; Popović, L. Č.; Collin, S.; Burenkov, A. N.; Chavushyan, V. H.; Bochkarev, N. G.; Benítez, E.; Dultzin, D.; Kovačević, A.; Borisov, N.; Carrasco, L.; León-Tavares, J.; Mercado, A.; Valdes, J. R.; Vlasuyk, V. V.; Zhdanova, V. E., 2008, *Long-term variability of the optical spectra of ngc 4151. I. Light curves and flux correlations*, Astronomy and Astrophysics, Volume 486, Issue 1, pp.99-111
2. Hamdi, R.; Ben Nessib, N.; Milovanović, N.; Popović, L. Č.; Dimitrijević, M. S.; Sahal-Bréchot, S., 2008, *Atomic data and electron-impact broadening effect in do white dwarf atmospheres: Si VI*, Monthly Notices of the Royal Astronomical Society, Volume 387, Issue 2, pp. 871-882
3. Jovanović, P.; Zakharov, A. F.; Popović, L. Č.; Petrović, T., 2008, *Microlensing of the X-ray, UV and optical emission regions of quasars: simulations of the time-scales and amplitude variations of microlensing events*, Monthly Notices of the Royal Astronomical Society, Volume 386, Issue 1, pp. 397-406.
4. Popović, L. Č.; Shapovalova, A. I.; Chavushyan, V.m H.; Ilić, D.; Burenkov, A. N.; Mercado, A.; Bochkarev, N. G., 2008, *Probing the Physical Properties of the NGC 5548 Broad Line Region Using Balmer Lines,* Publications of the Astronomical Society of Japan, Vol.60, No.1, pp.1-9

5. Popović, L. Č.; Dimitrijević, M. S.; Simić, Z.; Dačić, M.; Kovačević, A.; Sahal-Bréchot, S., 2008, *Stark broadening and hfs of Mn II*, New Astronomy, Volume 13, Issue 2, p. 85-92.
6. P. Jovanović, L. Č. Popović, *Observational effects of strong gravity in vicinity of supermassive black holes*, Fortschritte der Physik, Volume 56, Issue 4-5, Date: April 2008, Pages: 456-461
7. Simić, S.; Popović, L. Č., 2008, *Investigation of Element Abundances in the Surroundings of GRB Afterglows*, International Journal of Modern Physics D, Volume 17, Issue 09, pp. 1377-1382 (2008).
8. Bon, E., Popović, L.Č., Gavrilović, N., La Mura, G., Mediavilla, E., 2009, Contribution of a disc component to single-peaked broad lines of active galactic nuclei. Monthly Notices of the Royal Astronomical Society 400, 924-936.
9. La Mura, G., Di Mille, F., Ciroi, S., Popović, L.Č., Rafanelli, P., 2009., Balmer Emission Line Profiles and Complex Properties of Broad-Line Regions in Active Galactic Nuclei, Astrophysical Journal 693, 1437-1448.
10. Popović, L.Č., Smirnova, A. A., Kovačević, J., Moiseev, A.V., Afanasiev, V.L.\ 2009.\ Three-Dimensional Spectroscopic Study of the Line-Emitting Regions of Mrk 493., Astronomical Journal 137, 3548-3557.
11. Ilić, D. 2009., Plasma Diagnostics in the Broad Line Region of Active Galactic Nuclei Using Emission Lines, Publications of the Astronomical Society of the Pacific, Volume 121, issue 886, pp.1440-1441
12. Urošević, D., Vukotić, B., Arbutina, B., Ilić, D., Filipović, M., Bojičić, I,; Segan, S.,; Vidojević, S. 2009. The sigma-D relation for planetary nebulae, Astronomy and Astrophysics, Volume 495, Issue 2, 2009, pp.537-546.
13. Jevremović, D., and 14 colleagues 2009., The project of Serbian Virtual Observatory and data for stellar atmosphere modeling. New Astronomy Review 53, 222-226.
14. Danezis, E., Lyratzi E., Popović, L.Ć., Dimitrijević, M.S., Antoniou, A., 2009, Interpreting the complex line profiles in the stellar spectra, New Astronomy Review 53, 214-221.
15. Shapovalova, A.I., Popović, L.Č., Bochkarev, N.G., Burenkov, A.N., Chavushyan, V.H., Collin, S., Doroshenko, V.T., Ilić, D., Kovačević, A., 2009, Long-term variability of the Broad Emission Line profiles in AGN, New Astronomy Review 53, 191-197.
16. Lyratzi, E. Popović, L.Č., Danezis, E., Dimitrijević, M.S., Antoniou, A., 2009, Kinematics of the broad absorption line region in QSOs: Rotation and random motion, New Astronomy Review 53, 179-185.
17. La Mura, G., di Mille, F., Popović, L.Č., Ciroi, S., Rafanelli, P., Ilić, D., 2009, Hydrogen Balmer emission lines and the complex broad line region structure, New Astronomy Review 53, 162-168.
18. Jovanović P., Popović, L.Č., Simić, S., 2009, Influence of gravitational microlensing on broad absorption lines of QSOs: The case of the Fe Kalphaline, New Astronomy Review 53, 156-161.

19. Ilić, D., Kovačević, J., Popović, L.Č.,2009,The line parameters and ratios as the physical probe of the line emitting regions in AGN, New Astronomy Review 53, 149-155.
20. Bon, E., Gavrilović, N., La Mura, G., Popović, L.Č., 2009, Complex broad emission line profiles of AGN: Geometry of the broad line region, New Astronomy Review 53, 121-127.

A3.3 Paperes in domestic refereed journals

1. Bon, E., 2009, The Disk Emission in Single Peaked Lines for 12 AGNs, Serbian Astronomical Journal, vol. 177, pp. 9- 13
2. D. Jevremović, M. S. Dimitrijević, L. Č. Popović, M. Dačić, V. Protić Benišek, E. Bon, V. Benišek, D. Ilić, A. Kovačević, M. Malović: 2009, *SERBIAN VIRTUAL OBSERVATORY, Pregled NCD,* 15, 52-58.
3. Arbutina, B., Ilić, D., Stavrev, K., Urošević, D., Vukotić, B., Onić, D. 2009, Optical Observations of M81 Galaxy Group in Narrow Band [SII] and Halpha Filters: Holmberg IX, Serbian Astronomical Journal, 179, 87-94

A3.4 Invited lectures on international conferences published in the Proceedings

1. A. Antoniou, E. Danezis, E. Lyratzi, L. Č. Popović, M. S. Dimitrijević: 2008, *KINEMATICAL PARAMETERS IN THE CORONAL AND POST-CORONAL REGIONS OF THE Oe STARS*, 24th Summer School and International Symposium on the Physics of Ionized Gases, Journal of Physics: Conference Series 133, 012028 (1-8).
2. Vauglin, I.; Gavrilović, N.; Prugniel, P., *Thermal InfraRed surveys from Antarctica for extragalactic astronomy*, EAS Publications Series, Volume 33, 2008, pp.293-295
3. Simić, Saša; Popović, Luka Č., *Variability of GRB light curve: Shock wave model modification*, Journal of Physics: Conference Series, Volume 133, Issue 1, pp. 012030 (2008)

A3.5 Papers in non-international journals

1. Z. Simić, M. S. Dimitrijević, L. Č. Popović, M. Dačić, A. Kovačević, S. Sahal-Bréchot: *ON STARK BROADENING OF Mn II LINES IN Ap-STAR CONDITIONS*, Contributions to the Astronomical Observatory Skalnate Pleso 38, (2008), 451-452.
2. M. S. Dimitrijević, Z. Simić, A. Kovačević, M. Dačić, S. Sahal-Bréchot: *ON STARK BROADENING OF Te I SPECTRAL LINES FOR CP STAR PLASMA ANALYSIS*, Contributions to the Astronomical Observatory Skalnate Pleso 38, (2008), 403-404.

3. M. S. Dimitrijević, T. Ryabchikova, Z. Simić, L. Č. Popović, M. Dačić: *ELECTRON-IMPACT BROADENING OF IONIZED CHROMIUM LINES FOR Ap STAR ATMOSPHERES ANALYSIS*, Contributions to the Astronomical Observatory Skalnate Pleso 38, (2008), 401-402.

A3.6 Papers presented on international conferences published in the Proceedings

1. M. S. Dimitrijević, A. Kovačević, Z. Simić, M. Dačić: 2008, *STARK BROADENING OF O V 1371 A LINE IN STELLAR ATMOSPHERES*, in "Exploring the Solar System and the Universe", Eds. V. Mioc, C. Dumitrache, N. Popescu, American Institute of Physics Conference Proceedings 1043, 410-411.
2. Lyratzi, E. Danezis, L. Č. Popović, M. S. Dimitrijević, A. Antoniou: 2008,A.*DACs AND SACs IN THE UV SPECTRUM OF THE QUASAR PG 0946+301*, in Spectral Line Shapes 15, 19th International Conference on Spectral Line Shapes, AIP Conference Proceedings 1058, 323-325.
3. E. Lyratzi, E. Danezis, L. Č. Popović, M. S. Dimitrijević, A. Antoniou: 2008, A.*KINEMATICS OF BROAD ABSORPTION LINE REGIONS OF PG 1254+047*, in Spectral Line Shapes 15, 19th International Conference on Spectral Line Shapes, AIP Conference Proceedings 1058, 320-322.
4. A. Antoniou, E. Danezis, E. Lyratzi, L. Č. Popović, M. S. Dimitrijević, E. Theodosiou, G. Katsavrias: 2008, *A STUDY OF THE STRUCTURE OF DIFFERENT IONIZATION POTENTIAL REGIONS IN THE ATMOSPHERE OF AX MON (HD 45910)*, in Spectral Line Shapes 15, 19th International Conference on Spectral Line Shapes, AIP Conference Proceedings 1058, 317-319.
5. A. Antoniou, E. Danezis, E. Lyratzi, L. Č. Popović, M. S. Dimitrijević, E. Theodosiou, D. Stathopoulos: 2008, *AX Mon (HD 45910) KINEMATICAL PARAMETERS IN THE Fe II SPECTRAL LINES AS A FUNCTION OF THE EXCITATION POTENTIAL*, in Spectral Line Shapes 15, 19th International Conference on Spectral Line Shapes, AIP Conference Proceedings **1058**, 314-316.
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A3.14 Defended PhD Thesis

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REGULARLY VARYING SOLUTIONS OF FRIEDMAN EQUATION

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Abstract. We discuss solutions of the acceleration equation, the equation associated to the Friedman equation, in the light of the theory of regularly varying functions, also known as Karamata functions. As a result we obtain that the solutions of the acceleration equation might have a multiplicative term which is a slowly varying function. Under usual assumptions for the scale factor $a(t)$, such as $a(t) = t^\alpha$, it appears that this slowly varying term exists. Slowly varying term may explain some phenomena in the standard models of the evolution of the Universe. This paper is an announcement of the more detailed research in this area.

1. INTRODUCTION

The Friedman acceleration equation

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) \tag{1}$$

together with the fluid equation

$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) = 0 \tag{2}$$

and the Friedman equation

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} \tag{3}$$

determines the expansion scale factor $a(t)$ of the Universe. Here ρ is the mass density while p is the pressure of the material in the Universe. The nature of the solution of (1) strongly depends on the energy density term

$$\mathbf{E} = \rho + 3p/c^2, \tag{4}$$

particularly of the sign of $\mathbf{E}$. In order to explain the acceleration of the expansion of the Universe the cosmological constant Λ is added in (1):

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda}{3}. \tag{5}$$

The modified energy density term for $\Lambda \neq 0$

$$\mathbf{E}_\Lambda = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda}{3}. \tag{6}$$

admits negative values, giving more possibilities in modelling of possible scenarios of the past and the evolution of the Universe (e.g. Coles, et al., 2002; Hogan 2007, Lidle, et al., 2000; Narlikar, 2002; Peacock, 1999; Vikman 2005). We note the following two remarks in regards to Λ. First, under the transformations

$$\rho' = \rho + \Lambda/(8\pi G), p' = p - \Lambda/(8\pi G) \tag{7}$$

the equation (5) transforms into (1), but now referring it to the terms ρ' and p'. Therefore, our discussion will be concentrated further on the mathematical solutions of the equation (1). However, we shall abandon in certain situations the strong energy condition $\mathbf{E} > 0$. Secondly, it is well known that there are significant discrepancies in the predictions of what order should be the value of Λ. The reason may lay in the course tuned asymptotic description of the scale factor $a(t)$. In order to avoid this situation a better asymptotic analysis is needed. The theory of regularly varying function in the Karamata sense provides the means for such an analysis, particularly for solutions of the second order differential equations as it is (1). This theory is quite well developed (Bingham at al., 1987; Hille, 1948; Howard, et al., 1990; Marić, 2000; Marić et al, 1990; Omey, 1981; Seneta, 1976; Swanson, 1968), but it seems it has not been much applied in cosmology and in astrophysics in general. Yet, there are few to mention (Mijajlović et al., 2007; Molchanov, et al., 1997; Stern, 1997).

2. REGULAR VARIATION

In this section we shall briefly review the basic notions related to the regularly varying functions. We shall discuss also some properties of solutions of the second order differential equation of the form

$$y'' + f(x)y = 0 \tag{8}$$

related to the regularly varying functions. Observe that the acceleration equation has the form (8).

2.1. Regularly varying functions

A regular variation is related to the power-law distributions, a kind of polynomial relationship between two quantities. It exhibits the property of scale invariance represented by

$$f(x) = ax^k + o(x^k) \tag{9}$$

where a and k are constants, and $o(x^k)$ is an asymptotically small function of x^k. Here, k is the scaling exponent, i.e. a power-law function satisfies $f(\lambda x) \propto f(x)$ where λ is a constant. So, a rescaling of the function's argument changes the constant of proportionality but preserves the shape of the function itself. Power-law relations characterize a large number of natural phenomena, particularly in physics and astronomy. Examples are the Stefan-Boltzman law, gravitational potential and the scale factor $a(t)$ in various cosmological models. A particular interest in a power law can be found in the study of probability distribution and the large fluctuations that occur in the tail of the distribution – the part of the distribution representing large but rare events.

The most general form of a power law is given by

$$f(x) = L(x)x^{\alpha}, \quad \text{or} \quad f(x) \propto x^{\alpha} \tag{10}$$

where $L(x)$ is a slowly varying function i.e. $L(x)$ is positive continuous function (more generally measurable function, but in this article we are dealing anyway only with continuous functions) defined on some neighborhood $[a, \infty]$ of the infinity which satisfies

$$\lim_{x\to\infty} \frac{L(\lambda x)}{L(x)} = 1, \quad \text{for each } \lambda > 0 \tag{11}$$

The real number α is called the index of regular variation.

A positive continuous function R defined on some neighborhood $[a, \infty]$ is the regularly varying of index α if and only if it satisfies

$$\lim_{x\to\infty} \frac{R(\lambda x)}{R(x)} = \lambda^{\alpha}, \quad \text{for each } \lambda > 0 \tag{12}$$

It immediately follows that the regularly varying function $R(x)$ has the form

$$R(x) = L(x)x^{\alpha} \tag{13}$$

where $L(x)$ is slowly regular.

Jovan Karamata (Karamata, 1930) introduced the conceptions of slowly varying function and regularly varying functions. He also proved the following two fundamental theorems.

Examples of slowly varying functions includes iterated logarithms, but there are more complicated examples e.g.

$$L_1(x) = \frac{1}{x}\int_a^x \frac{dt}{\ln(t)}, \tag{14}$$

$$L_2(x) = \exp\left((\ln(x)^{\frac{1}{3}} \cos(\ln(x))^{\frac{1}{3}}\right) \tag{15}$$

The second example is interesting since $L_2(X)$ oscillates infinitely many times between 0 and infinity.

3. REGULARLY VARIATION AND ACCELERATION EQUATION

We shall represent the acceleration equation (5) in the form

$$\ddot{a} + \frac{\mu(t)}{t^2} a = 0. \tag{16}$$

The Hubble parameter $H(t)$ and the deceleration parameter $q(t)$ are defined by

$$H(t) = \frac{\dot{a}(t)}{a(t)}, \quad q(t) = -\frac{\ddot{a}(t)}{a(t)} \frac{1}{H(t)^2} \tag{17}$$

where $a(t)$ is the expansion scale factor of the Universe. Therefore, the equation (16) can be written as

$$\ddot{a} + \frac{q(t)(H(t)t)^2}{t^2} a = 0, \tag{18}$$

hence

$$\mu(t) = q(t)(H(t)t)^2. \tag{19}$$

Observe that $\mu(t)$ is a dimensionless parameter. Let us remind that the density parameter $\Omega(t)$ and the density parameter for the cosmological constant Λ are defined by

$$\Omega = \frac{\rho}{\rho_c}, \quad \Omega_\Lambda = \frac{\Lambda}{3H^2}$$

where ρ_c is the critical density.

The Friedman acceleration equation (1) has two different fundamental solutions that satisfy a power law if and only if the limit

$$\gamma = \lim_{x\to\infty} x \int_x^\infty \frac{\mu(t)}{t^2} dt \tag{20}$$

exists and $\gamma < \frac{1}{4}$. According to the theory of of regularly varying functions and differential equations, if $-\infty < \gamma < 1/4$ and $\alpha_1 < \alpha_2$ are two roots of the equation

$$\alpha^2 - \alpha + \gamma = 0. \tag{21}$$

then there exist two linearly independent regularly varying solutions of the equation $y'' + f(x)y = 0$ of the form

$$y_i(x) = x^{\alpha_i} L_i(x), i = 1, 2, \tag{22}$$

if and only if $\lim\limits_{x\to\infty} x \int_x^\infty f(t)dt = \gamma$. Here, L_i, i=1,2 denote two normalized slowly varying functions. We see that this observation directly applies to the Friedman acceleration equation (16). Thus, the expansion scale factor $a(t)$ satisfies the power law if and only if $\gamma < \frac{1}{4}$.

We discuss only the existence and the possible values of the limit $\lim\limits_{t\to\infty} \mu(t)$. The existence of this limit is the sufficient condition for the existence of (20) and in this case

$\gamma = \lim_{t\to\infty} \mu(t)$. It appears that the values of the constant γ determine the asymptotical behavior at the infinity of the solutions of the acceleration equation, i.e. of the expansion scale factor $a(t)$ of the Universe. If the matter-dominated evolution of the Universe is assumed, that is, dominated by some form of pressureless material since the certain time moment t_0 then the expression $H(t)t$ depends solely on the parameter Ω. In this case we will be able to estimate the possible values of γ. We discuss also the status of the constant γ and the related asymptotic behavior of $a(t)$ for the flat Universe including the cosmological constant Λ and the open Universe with $\Lambda = 0$. Detailed proofs of will be published somewhere else.

4. CONCLUSION

A new constant γ is introduced by (20) related to the Friedman acceleration equation (1). The values of the constant γ determine the asymptotical behavior at the infinity of the solutions of the acceleration equation, i.e. of the expansion scale factor $a(t)$ of the Universe. The instance $\gamma < \frac{1}{4}$ is appropriate for the both cases, the flat and open Universe, and gives the sufficient and necessary condition that the solutions of the acceleration equation are in the Karamata class of functions; more specifically that they satisfy a power law. This property of the acceleration equation is formulated as the *power law conclusion* in the subsection 3.3. As power law functions are the most frequently occurring type of the solutions of the Friedman equation, the study of the constant γ and the related function $\mu(t)$ defined by (19) might be of a particular interest.

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Publ. Astron. Soc. "Rudjer Bošković" No 11, 2012, 311-323

SERBIAN ASTRONOMICAL WORKS IN THE VIRTUAL LIBRARY OF THE FACULTY OF MATHEMATICS IN BELGRADE

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Abstract. The Virtual Library of the Faculty of Mathematics, http://elibrary.matf.bg.ac.rs, contains more than 50 digitized books on astronomy written by Serbian scientists. This article presents a selection of books written in the 18th and 19th century by the authors: Ruđer Bošković, Zaharije Orfelin, Atanasije Stojković, Đorđe Stanojević, Milan Andonović and Kosta Stojanović. For each of these authors a short biography is included.

INTRODUCTION

The Virtual Library of the Faculty of Mathematics is the largest database of digitized texts in Serbia which is open for public use. At the time of writing this article, it contains nearly 1500 books mostly in mathematical sciences of old Serbian scientists (e.g. N. Pejović, 2009). Important collections in this library are a collection of 360 doctoral dissertations in mathematical science, most of them defended at the Faculty of Mathematics of the University of Belgrade and rare books from the 18th and 19th century. Most of these books are rather rare; some of them exist only in one copy and in fact are unavailable to the general public. First steps in building of the Virtual Library were done in 2004 (see Mijajlović at al., 2004).

In this paper we present a collection of books on astronomy written by Serbian authors and printed in the 18th and 19th century that are digitized and uploaded into the Virtual library. These books are the first Serbian astronomical books, and we can also say that they are the first scientific works of Serbian writers. Let us note here a general feature of these first Serbian scientists. They were universal in their research interest and in other respects as well, so astronomy was not their only specialty. They were successful in other sciences, too: in mathematics, physics or philosophy, for example. For them, science mostly was the view of a unique being - Nature. The language of science was used by them to describe the nature of this being. Besides, they were often successful politicians, artists, travelers and writers of novels and poems. Their importance for the development of Serbian culture, language and science is enormous. Therefore, in addition to their manuscripts from astronomy we present here their brief biographies and other works as well. The good source for the history of astronomy in Serbia is Simovljević's (1980) article *Astronomy*.

BOOKS IN ASTRONOMY FROM THE EIGHTEENTH AND NINETEENTH CENTURIES.

In the Virtual Library there are 15 digitized books from this period by the following authors:

Ruđer Bošković (1711-1787), *Elementorum Universal Matheseos*, T. I-III, 1757, Venetis.

Zechariah Orfelin Stefanović (1726-1785), *Perpetual Calendar*, 1783, Vienna.

Atanasije Stojković (1773 -1832), *Physics*, 1810, Buda.

Đorđe Stanojevic (1858 -1921), most of his works (8) is digitized, including: *The* s*tarry sky of independent of Serbia*, 1882, Belgrade.

Milan Andonović (1849 -1926), *Cosmography* (1888), *On the Cosmos* (1889), Belgrade.

Kosta Stojanović (1867 - 1921), *Atomistics by Ruđer Bošković*, 1892, Niš.

Ruđer Bošković

Ruđer Bošković (1711-1787) is a famous mathematician and astronomer of Dubrovnik and one of the most important scientists of his time. He is included among one hundred most prominent Serbs of all time. He was a university professor, founder of the Milano Observatory and the director of the French Navy Optical Institute. He was an universal creator: philosopher, mathematician, astronomer, scolar, geologist, architect, archaeologist, diplomat, writer, professor, poet and polyglot.

He was born on 18^{th} May 1711 as the seventh child of Nikola Bošković (a Serb from Orahov Do, a village near Trebinje in Herzegovina) and mother Paola (of

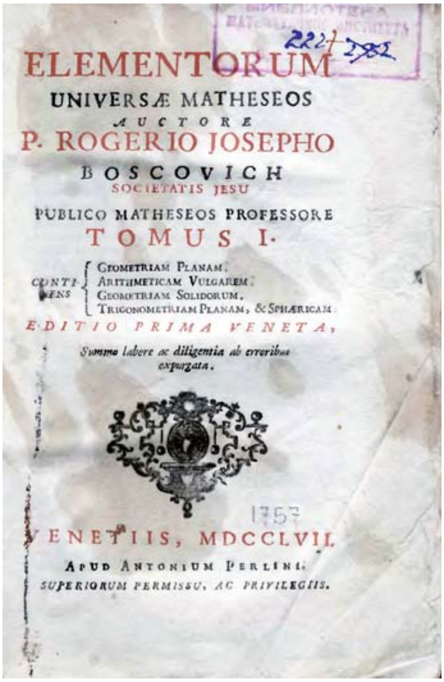
Italian descent, from the family of Baro Bettera, a notable poet from Dubrovnik). He lived mostly in Italy, where he gained world fame. Bošković died on February 13, 1787.

Bošković formulated the Unified Law of Forces, assuming that there is not only an attracting force (as Newton's law states), but that there is also repulsion which alternately changes with attraction at small distances between bodies. According to him, an elementary dimensionless particle is the source of the force, and time and space are relative, unlike in Newtonian theory. Hence, he is often considered as the forerunner of Albert Einstein.

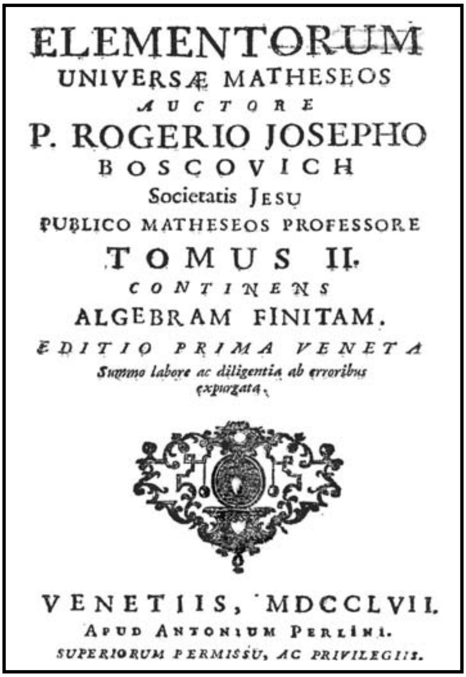
Ruđer Bošković had numerous contributions to astronomy, among others: he introduced two geometric methods for determining the elements of the rotation of the Sun by observing the positions of three bodies, calculated the dimensions and the flatness of the Earth and discovered the comets. He was the first (1782) who accurately determined the trajectory of Uranus based on the measurement of coordinates of Uranus obtained by Messier and Méchain. It should be said that at the time of discovery it was thought that Uranus was a comet. By calculating the trajectory of Uranus, he perfected the method for determining the orbits of comets on the basis of four measured positions. In the 1800th it was one of the most accurate methods. He also studied the atmosphere of Jupiter and the nature of the Aurora.

Ruđer Bošković published numerous numbers of paper sheets in mathematics, astronomy and physics. His well-known books are *Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium*, *Opera pertinentia ad opticam et astronomia* and *Elementorum universae matheseos*.

In the Virtual library there are the following books by him: *Elements of Mathematics* (*Elementorum Universal Matheseos* - Tomus I-III, 1757, Venetis), *Diary on the Journey from Constantinople to Poland* (1762), translated by D. Neljeković, 1937, Belgrade, *On the law of continuity and its consequences in respect to the basic elements of matter and their forces*, printed in 1754, translated into Serbian by E. Stipanić, 1975, Belgrade.



ELEMENTORUM
UNIVERSÆ MATHESEOS
AUCTORE
P. ROGERIO JOSEPHO
BOSCOVICH
SOCIETATIS JESU
PUBLICO MATHESEOS PROFESSORE
TOMUS I.
CONTINENS
Geometriam Planam,
Arithmeticam Vulgarem,
Geometriam Solidorum,
Trigonometriam Planam, & Sphæricam.
EDITIO PRIMA VENETA,
Summo labore ac diligentia ab erroribus expurgata.
VENETIIS, MDCCLVII.
Apud Antonium Perlini.
SUPERIORUM PERMISSU, AC PRIVILEGIIS.



ELEMENTORUM
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Societatis Jesu
PUBLICO MATHESEOS PROFESSORE
TOMUS II.
CONTINENS
ALGEBRAM FINITAM.
EDITIO PRIMA VENETA
Summo labore ac diligentia ab erroribus expurgata.
VENETIIS, MDCCLVII.
Apud Antonium Perlini.
SUPERIORUM PERMISSU, AC PRIVILEGIIS.

Zechariah Stefanović Orfelin

Zechariah Stefanović Orfelin (1726 - 1785) was a prominent Serbian poet, historian, engraver, baroque educator, calligrapher and writer of textbooks. He was born into a Serbian family in Vukovar (Slavonia).

Among his most important works is *Slavenoserbski magazine* printed in Venice in 1768. This is the first South Slavic magazine. Although it was printed just in one volume, its importance is great. In the preface he presented the idea of civil enlightenment, and he aslo said that science, literature and philosophy should leave the narrow circle of educated people and that it must become available to everyone. In 1768 Zechariah Orfelin introduced into Serbian literature a language which was a mixture of Church and common language. He also included many Russian words. In this way he practically founded the Slavoserbian language. Because of his artistic works, primarily in the copper plate, he was elected a member of the Art Academy in Vienna.

Orfelin is the author of the first Serbian primer (*bukvar*) which was used since 1767 in teaching many generations of students in writing and reading. He is also the author of the first Serbian-Latin textbook. His most comprehensive work was *The Life of Peter the Great* (Venice, 1772), which he had seen as the enlightened monarch. He also wrote *Perpetual* (eternal) *calendar.* This book includes a comprehensive chapter on astronomy.

Orfelin's *Perpetual Calendar* was printed in Vienna in 1783. The book has 366 pages and 9 astronomical drawings at the end of the book. Its content concerns mainly natural sciences and astronomical phenomena and contains, as well, description of historical events since the creation of the World in a chronological order. Chapters on astronomy bear the names: *Space, The Moon and the Planets,Comets,Solar Eclipse and Moon Eclipse*. It includes information on weather cycles, tables with information about the Sun and the Moon (needed for the calculation of the date of Easter according to the Big indicium), tables on the length of day and night, moon phase tables, and more. Therefore *Perpetual calendar* is the first book on astronomy written in the Slavic language, how Orfelin said "to the benefit of the Slavic-Serbian (*slovenoserbskim*) people". More details about Orfelin's Calendar, the reader can find in Milovanović (2007).

ВѢЧНЫЙ
то есть
ѿ начала да конца міра трающій
КАЛЕНДАРЬ,
содержащій въ себѣ
Святцеловъ и краткая, по Восточныя Церкве исчисленію, ѡ кругахъ годовыхъ, и прочихъ принадлежащихъ вещей изясненія; къ тому фузіческая ѡ тѣлахъ міра, и ѡ воданыхъ и воздушныхъ приключеніяхъ разсужденія; съ прибавленіемъ свѧщенныя и свѣтскія Хронологіи нынѣ первѣе на славенскомъ языкѣ въ пользу славеносербскихъ народовъ.
НАПИСАНЪ
ЗАХАРІЕМЪ ОРФЕЛІНОМЪ
Цес. Крал. Віенскія Академіи художествъ членомъ.

съ фигурами.

Напечатанъ въ Царствующемъ Градѣ Віеннѣ, При Іѡсифѣ благородномъ ѿ Курцбекъ, Иллурическомъ Восточномъ Дворномъ Тупографѣ, въ лѣто 1783.

The cover pages from the Orfelin's *Perpetual Calendar*

Atanasije Stojković

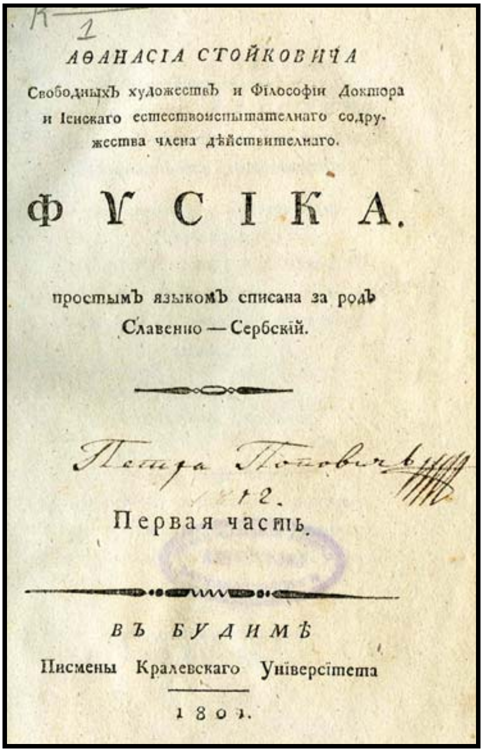
Atanasije Stojković was born in 1773 in Ruma, Vojvodina. In this town he finished Ascension school (Serbian Grammar school). He went soon to Šopron where in 1794 completed the first six grades of high school and then enrolled in a secondary school in Szeged, where in 1796 graduated philosophy. In Vienna, in July 1797th, he met Dositej Obradović and introduces himself with Dositej's enlightenment ideas. In the fall of this year he managed to obtain support from Metropolitan Stratimirović for studies in Göttingen, at that time one of the most famous universities. There he obtained PhD degree in philosophy (1799), and began intensive studies in various sciences (physics, mathematics, astronomy, history). After a brief stay in Ruma (1799) he moved to Budapest, where he published his main work *Physics* (1801-1803), printed in 3 volumes.

In the Habsburg monarchy it was difficult to obtain a civil job, so after the call of Severin Osipovič Potocki, the future Minister of Education of Russia, Atanasije accepted the position of regular professor of physics at newly established Kharkov University. He soon became the dean of the Department of Physics and Mathematics and on two occasions (1807-1808 and 1811-1813) he was the Rector of the University of Kharkov. He is the founder of the Kharkov Learned Society and he also received many honors and decorations. He became a member of the Imperial Academy of Sciences, obtained many material privileges, became a national consultant and Tsar Alexander I gave him the Medal of St. Vladimir of the third degree.

Atanasije Stojković was a hardworking and capable man, of wild spirit, very successful and was appreciated in his surroundings. He spoke several languages: German, Latin, French, Italian, English, Greek, Hungarian, and almost all Slavic languages. He had interesting and exciting life that next to science was marked by an affair that ended his professorial career. He was also engaged in a secret mission and diplomacy. He died in Kharkov in 1832.

With his versatility, ambition and intelligence, probably under the influence of enlightenment ideas of Dositej Obradović, Stojković was trying to educate his people, to improve their science and culture, at a time when barely was foreseen the emergence of a new Serbian state.

The Stojkvić's book *Фисика* (Physics) was printed in 3 volumes. The first two volumes have 320 pages while the third was written in 284 pages. The book presents an overview of the knowledge at that time of nature and natural phenomena. At the beginning of the first volume there is a chapter on mechanics (the properties and movements of the body). The most of the first volume (the second and the third chapter) is devoted to astronomy. There are described celestial bodies, apparently moving spheres of the sky, stars, solar system, the Sun, planets, comets, the Moon, the eclipses. The third chapter describes our planet Earth. Also, the concepts of celestial equator, horizon, zenith, and nadir are introduced. He also explains the geographical coordinates, the size of Earth, the Earth's movement, the change of the day and night on the Earth and the Earth's interior. The rest of the book is devoted to the description of geographical notions and meteorological phenomena.


АѲАНАСІА СТОЙКОВИЧА

Свободныхъ художествъ и Філософіи Доктора и Іенскаго естествоиспытателнаго содружества члена дѣйствителнаго.

ФѴСІКА.

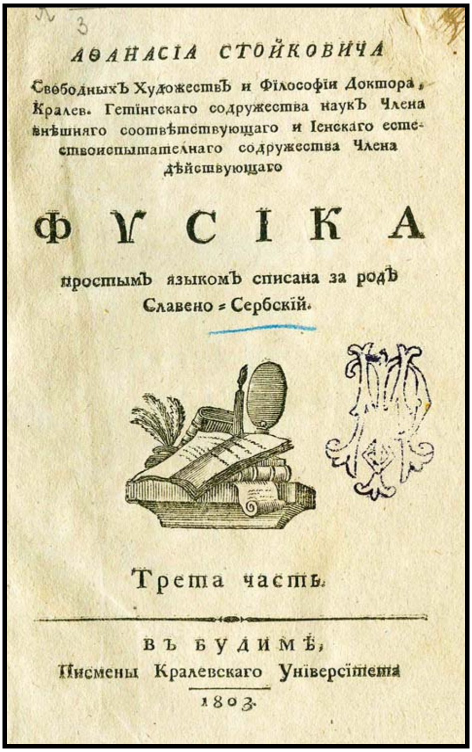
простымъ языкомъ списана за родъ Славенно — Сербскій.

Первая часть.

ВЪ БУДИМѢ

Писмены Кралевскаго Университета

1801.


АѲАНАСІА СТОЙКОВИЧА

Свободныхъ Художествъ и Філософіи Доктора, Кралев. Гетінгскаго содружества наукъ Члена внѣшняго соотвѣтствующаго и Іенскаго естествоиспытателнаго содружества Члена дѣйствующаго

ФѴСІКА

простымъ языкомъ списана за родъ Славено = Сербскій.

Трета часть.

ВЪ БУДИМѢ,

Писмены Кралевскаго Університета

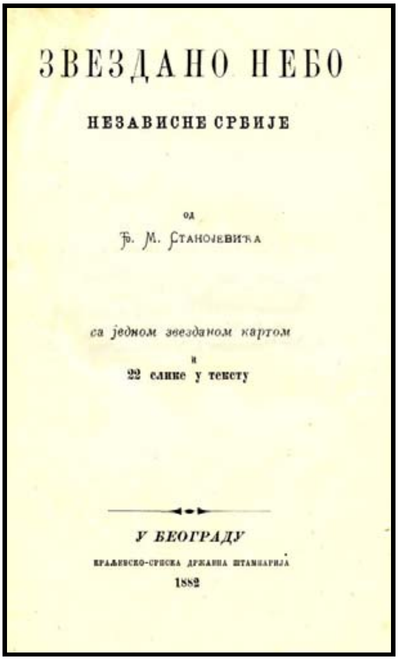
1803.

The book is written in the common language, without complex mathematical formulas and equations, having the aim to present knowledge about astronomy and nature to ordinary people.

Đorđe Stanojević

Đorđe Stanojević (1858-1921) was born in Negotin. He completed the Grand School in Belgrade. After that he became an assistant at High School, working with his teacher Kosta Alkovića (1836-1909) and then as the professor at the First Belgrade Gymnasium (1883). Having the scholarship of the Ministry of Defense (1883-1887), he studied in the most famous astronomical and meteorological observatories in Europe (Potsdam, Hamburg, Meudon, Greenwich, Pulkovo).

On behalf of his results he received a call from the Paris Observatory to participate in scientific research expedition to study the Sun and in the Petrovsk where he participated in the study of the full eclipse of the Sun. Two years later he joined another scientific-research expedition to the Sahara to study the thermal spectrum of the Sun. At that time and later, he published several research papers in astronomy in the publications of the Paris Academy of Sciences. These are the first scientific works in astronomy among the Serbs.



ЗВЕЗДАНО НЕБО

НЕЗАВИСНЕ СРБИЈЕ

од

Ђ. М. Станојевића

са једном звезданом картом

и

22 слике у тексту

У БЕОГРАДУ

КРАЉЕВСКО-СРПСКА ДРЖАВНА ШТАМПАРИЈА

1882

Stanojević was a versatile, knowledgeable man with a lot of active interest in many fields of science and technology. His interest in physics was great. Upon his return to Serbia he devoted himself to the study of modern physics. In the same time, he became the lecturer in physics and mechanics at the Military Academy. Also, he taught applied physics and mechanics at the High School and at the Belgrade University after establishing it in 1905. He was responsible for the construction of hydroelectric power plants in Serbia (Vučje, Negotin, Užice, Ivanjica and other places) and for the electrification of Belgrade. This put Belgrade among the first European capitals with full electric lighting. He died in Paris in 1921.

In Negotin there is "Đorđe Stanojević" Square and the museum is dedicated to him. In New Belgrade there is "Đorđe Stanojević" street. The Electric Power Industry of Serbia on the occasion of its day, 6th October, gives recognition "Đorđe Stanojević" for contributions to the development of Serbian electric power industry.

The Virtual Library contains eight digitized books of Đorđe Stanojević: *The starry sky of independent of Serbia*, 1882, Belgrade; *A walk across the clouds*, 1884, Belgrade; *Cosmic energy of modern physics* (introductory lecture, 22nd September, 1887, Department of Physics at the Military Academy in Belgrade); *Nikola Tesla and his discoveries*, 1894, Belgrade; *Science of light*, 1895, Belgrade; *Central forces in nature*, 1906, Belgrade; *Industry of coldness*, 1909, Belgrade; *Inaccurate celebration of the Easter in the Orthodox Church and the reform of the calendar*, 1908, Belgrade.

Stanojević works are characterized by the simplicity and easiness of writing when exposed to often complex astronomical phenomena. These phenomena, however complex, are mostly descriptively presented, without mathematical expressions and using very fine drawings. Therefore, this book is primarily intended for general education and general readers. In this regard, Stanojević scored his goal, to bring the basic knowledge of astronomy to the general reader. It is our great pleasure to have this precious book out of the darkness of library storage into the light through the Virtual Library and made it easily accessible to the future readers.

More details about Stanojević life and works the reader can find in Pejović (2008ab, 2009).

Milan Andonović

Milan Andonović (1849-1926) was born in Požarevac where he finished high school. He was educated in Belgrade at the engineering departments of the Great School in Belgrade and at the German Universities in Karlsruhe, Aachen and Munich under the supervision of famous professors Ritter, Jordan, and Helmert. There he specialized in mechanics, geodesy and astronomy. Upon his return to Serbia in 1880, he was appointed as the professor of geodesy at the Great School in Belgrade. He was responsible for the introduction and enforcement of the cadastre in Serbia in the late 19th century. He founded the Geodetic Institute under whose auspices were surveyed many towns in Serbia. In 1907 he founded the Surveying and Building Academy where many Serbian surveyors and civil engineers were trained. Together with John Dragašević, Milan Nedeljković and Djordje Stanojević he is bearing the credit for introducing the teaching of astronomy in Serbian schools and promotion of science in Serbia. He died in Vienna in 1926.

МИЛАН J. АНДОНОВИЋ

Andonović had published a number of scientific papers, books (all printed in Belgrade), and discussions related to surveying, astronomy, shape and size of the Earth, the theory of least squares, survey and cadastre:

Basics probability and the theory of least squares, 1886; *The shape and size of the Earth*, 1886; *Cosmography with basic astronomical notes for high school teachers*, 1888; *The volume and size of our Earth*, 1889; *The Universe*, 1889; *Basic geodesy with distinctive view of the cadastral question*, 1890-1897 (1st part 1890, p.368, 2nd part 1897 vol. 1, p. 369-1390; vol. 2, p.1391-1641); *The cadastre*, 1889.

He also wrote during the First World War, political discussions and articles (in German and French) in favor of Serbia. There are the following digital copies of his books in the Virtual Library: *Cosmography*, 1888, and *The Universe*, 1889, both printed in Belgrade

Hard copies of both books are in the Library of Astronomical Observatory of Belgrade. Books are digitized by the courtesy of Vojislava Protić-Benišek.

Cosmography was intended for high school students and students of other secondary schools. Probably, it was used as a secondary textbook at the Military Academy and the Grand School, the forerunner of the Belgrade University. In addition to the foreign literature, Andonović mentioned in the bibliography two Serbian authors: *Trigonometry* of Dimitrije Nešić and *Cosmometry* by Jovan Dragašević. The book has many illustrations: 141 photos and drawings, 17 tables and a large star map. He took most of these drawings, with permission, from a book of E. Weiss, then the director of the Vienna Observatory.

Cosmography is an extensive (533 pages) and quite comprehensive book. It describes celestial sphere, constellations, the shape and size of the Earth, the Earth's rotation and revolution, the apparent movement of the Sun, coordinate systems, time, calendars, Solar system, stars, tides, precession, Cosmogony and among other things, Kant-Laplace's theory about the origin of the World (i.e. the Solar system). Besides all that, there are twenty fully solved astronomical problems with detailed explanations.

The book is written in a very beautiful style, almost as a literary work, and is worth reading also from that point of view. There we find many forgotten words and terms whose meaning were forgotten or had changed since today. For example, the cluster (Serb. *zvezdano jato*) there means constellation, stardust

(Serb. *ozvezdina*) - meteorite, comet star (Serb. *zvezda repatica*) - comet, the inflow and outflow (Serb. *priliv i odliv*) – the tide. Also, for each constellation he introduces the *alinjman* – having the meaning similar to asterism.

КОСМОГРАФИЈА

СА

ОСНОВНИМ АСТРОНОМСКИМ НАПОМЕНАМА

ЗА

ВИШЕ РАЗРЕДЕ СРЕДЊИХ И УЧИТЕЉСКИХ ШКОЛА

ОД

М. Ј. Андоновића

ПРОФЕСОРА ВЕЛИКЕ ШКОЛЕ

СА 141. СЛИКОМ У ТЕКСТУ И 25 ТАБЛИЦА

У БЕОГРАДУ

ИЗДАЊЕ И ШТАМПА КРАЉЕВСКО-СРПСКЕ ДРЖАВНЕ ШТАМПАРИЈЕ

— 277 —

је око средине збијена. Близо до ове маглине налазе се и неколико прилично светлих звезда.

Звездана гомила у Херкулу.
Сл. 59.

Маглина у Ртовима.
Сл. 60.

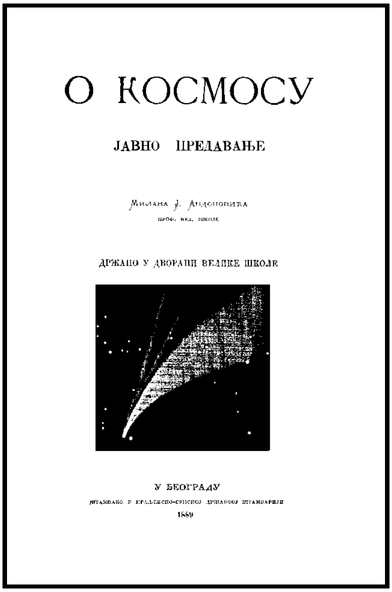
Слика 61. показује прстенасту Маглину у јату Лире, између звезда β и γ. Близо до ове Маглине стоје две звезде врло слабо светле.

Слика 62. показује Маглину у Еридану, која се састоји из једне подуже маглине, која је у средини и ка

Маглина у Лири.
Сл. 61.

Маглина у Еридану.
Сл. 62.

крајевима прилично збијена, а осем тога има поред себе и једну малу округлу маглину.



О КОСМОСУ

ЈАВНО ПРЕДАВАЊЕ

Милана Ј. Андоновића

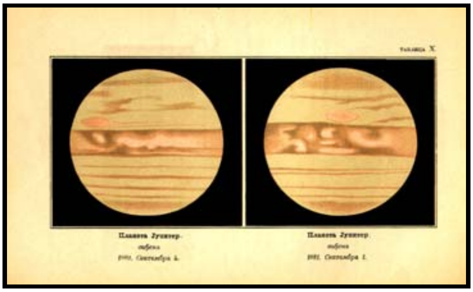
проф. вел. школе

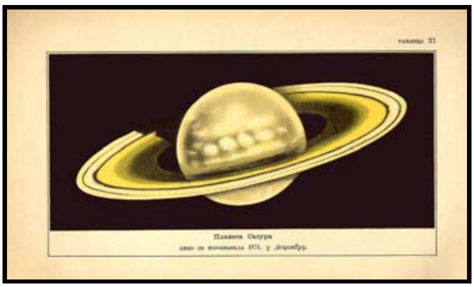
ДРЖАНО У ДВОРАНИ ВЕЛИКЕ ШКОЛЕ

У БЕОГРАДУ

ШТАМПАНО У КРАЉЕВСКО-СРПСКОЈ ДРЖАВНОЈ ШТАМПАРИЈИ

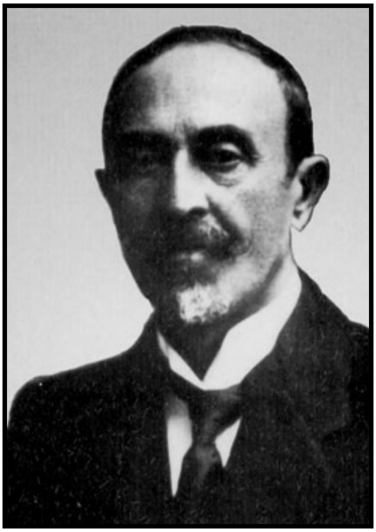
1889





For example the *alinjman* of Big Bear (in Serbian also called *Velika kola* - Big Chariot) has four stars – the asterism trapeze of the constellation Big Bear, while the *alinjman* of North Star is the line that passes through the rear wheels of the Big Chariot towards to the North Star. The Virtual Library contains digital copies of his books: *Cosmography* (1888) and *The Universe* (1889), both published in Belgrade.

Kosta Stojanović



Kosta Stojanović (1867-1921) was born in Aleksinac. There he finished elementary school and lower secondary school, while the high school he completed in Niš. He graduated in mathematical sciences at the Grand School in Belgrade. For some time he was working as a high school teacher in Niš and Belgrade. He went to Paris in 1893 where he studied mathematics, astronomy, mechanics and physics under the supervision of famous professors Poincaré, Picard and Appeal. There he became a member of the Historical Society of France and the French Astronomical Society. He went to Leipzig in 1897 where he entered doctoral studies in mathematics. Unfortunately, he returned to Serbia after three months because of his illness.

КОСТА СТОЈАНОВИЋ

ПРЕДАВАЊА НА УНИВЕРЗИТЕТУ
ИЗ
ПРИМЕЊЕНЕ МАТЕМАТИКЕ

МЕХАНИКА

БЕОГРАД
ШТАМПАНО У ДРЖАВНОЈ ШТАМПАРИЈИ КРАЉЕВИНЕ СРБИЈЕ
1912.

Kosta Stojanović was a university professor, but he had a very rich political career, too. At the beginning of 1900th he became a deputy as the representative of the Niš district.

Since the 1903rd he taught applied mathematics at the Grand School and at the Belgrade University after it was established in 1905. Whereupon he abruptly interrupted academic career and 1906 he became the Minister of Commerce, at the time of the custom war between Belgrade and Vienna.

Around that time, Kosta Stojanović wrote the book *Fundamentals of economy value*. This book is a work in mathematical economics and Stojanović there used very advanced mathematical apparatus, for example, the theory of partial differential equations to describe economic models. Even today there is an interest for this book, not only in Serbia but also in the other parts of former Yugoslavia. This is probably the most advanced book in economics ever printed in Serbia due to the mathematical tools that were used in.

He was the Minister of Agriculture (1919-1920) and the Minister of Finance in 1921 in the government of Nikola Pašić. A few days after the appointment as the minister of finance, he suddenly died.

The book *Mechanics* is actually a university textbook in applied mathematics. Let us mention that at this time, under the term applied mathematics it was assumed mechanics, mathematical physics and celestial mechanics. The most of the book is related to the vector calculus, then the kinematics, statics, dynamics, analytical mechanics and the theory of differential equations. Chapter Ten of this book is dedicated to astronomy. There he gave the basics of celestial mechanics and the theory of differential equations of the motion of planets, comets and satellites. Also, the theory of elliptical movement, the method of variation of constants and parabolic motion of comets are presented.

CONCLUSION

The Virtual Library of the Faculty of Mathematics has a significant place in the presentation of old and rare books to the Serb scientific and professional community and general public wide-world. This fact we can convince, for example, by the choice of books from the collection of astronomical works of the Serbian scholars presented in this article.

Acknowledgements

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Chepelare, Bulgaria, June 1-4, 2010,
Editors: M. K. Tsvetkov, M. S. Dimitrijević, K. Tsvetkova, O. Kounchev, Ž. Mijajlović
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METHOD FOR TRACKING AND MAPPING A MOTION BASED ON IMAGES OF THE SOLAR CORONA

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Abstract. This work continues our investigations on possibilities of presentation the time development of eruptive solar protuberance and related magnetic field. The aim of this work is mapping the direction of movement of different layers of protuberance. The map construction is based on compass directions dividing them to 8 possible – North, South, West, East, North-West, North-East, South-West, South-East. The tests in this investigation are carried on sequences of images obtained from 15 cm Lio coronagraph-telescope of NAO Rozhen, used for observation of protuberance of low solar corona.

1. INTRODUCTION

This work continues the investigations on possibilities of presentation the time development of eruptive solar prominence and related magnetic field described in "Technique for tracking and visualization of motion in sequence of images of the solar corona".

The aim of the work is mapping the direction of movement of different layers of prominence and tracking its positions in the sequence of images.

The movement produces any displacement that follows some direction. The direction shows possible changes in different layers of prominence and its estimation gives information about the magnetic field behavior. There are two questions of interest:

- Available inhomogeneous is the whole prominence from the point of view of dynamics of eruption?
- What are directions of movement available in prominence?

A simple technique that uses spatial gradients, gives a possibility to estimate the directions in angular interval. The differences between positions of layers could be obtained using sequences of computer images of prominence. Pixel based image processing [3] calculates the time-spatial gradient on the area of four neighbor pixels with same positions into sequenced frames [1]. The ratio between y and x gradient gives degree of deviation - Q of the lightness of each pixel and is easy imaged by corresponding color hue derived from RGB reproducing signals (models HSV, HLS, HSI). Giving limits of deviation, all possible directions of movement could be reduced to 8 possible – North, South, West, East, North-West, North-East, South-West, South-East. Using them, a time-dependent map of layers following one direction is possible to be constructed. In addition, rapid changes of directions in sequenced frames that respond to effect of turbulence fix a possible collision.

2. TEST EXPERIMENT

The tests in this investigation is carried on sequences of images obtained from 15 cm Lio coronagraph of NAO Rozhen, used for observation of prominence of low solar corona. The images are registered by 8-Mb digital camera CANON 350D and saved in jpg file format.

Specially developed software is used for preliminary processing, coinciding the frames in sequences, and obtaining images describing compass directions. The processing includes as follow:

- initial analysis and extraction of photo-spherical shining by statistical estimation of the pixels values,
- improvement of the images quality applying gauss-filter and sharpen edges,
- coinciding the frames into each sequence,
- producing gradient images,
- extraction of the images in correspondence with the compass directions.

The data about changes of directions are incorporated by values of angle θ calculated for each pixel. Possible directions are limited between 0 and 360 degrees with 1-degree step of separation.

Table 1 describes relations between compass-directions and interval of values in hue used in this image processing.

Table 1: Hue limits and compass direction relations

$[H_1$-$H_2]$	Compas
339 – 0 :	E
23 - 67	NE
68 - 112	N
113 - 157	NW
158 - 202	W
203 - 248	SW
249- 294	S
295 - 338	SE

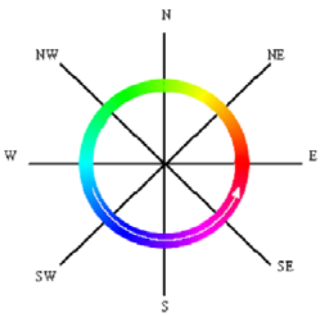

Figure 1. Compass directions.

The directions are imaged by pixels with color attributes corresponding to particular color hue. As a result, each gradient image is separated to eight images composed from pixels marked by one compass direction.

The test uses a sequence of 36 images of solar corona.

3. RESULTS AND DISCUSSION

An image of colored gradient directions is given in Fig. 2. Different layers are separated in dependence on defined hue limits. Fig. 3 demonstrates images of the all-compass directions presented in the image mentioned above.

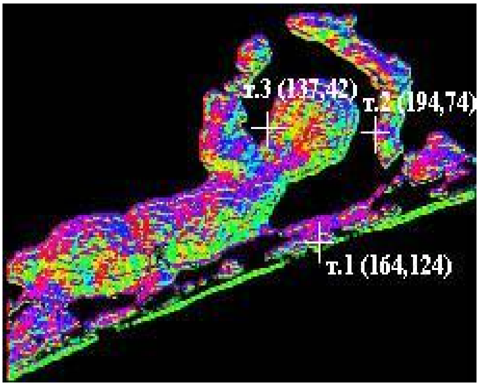

Figure2. Compass gradient image.

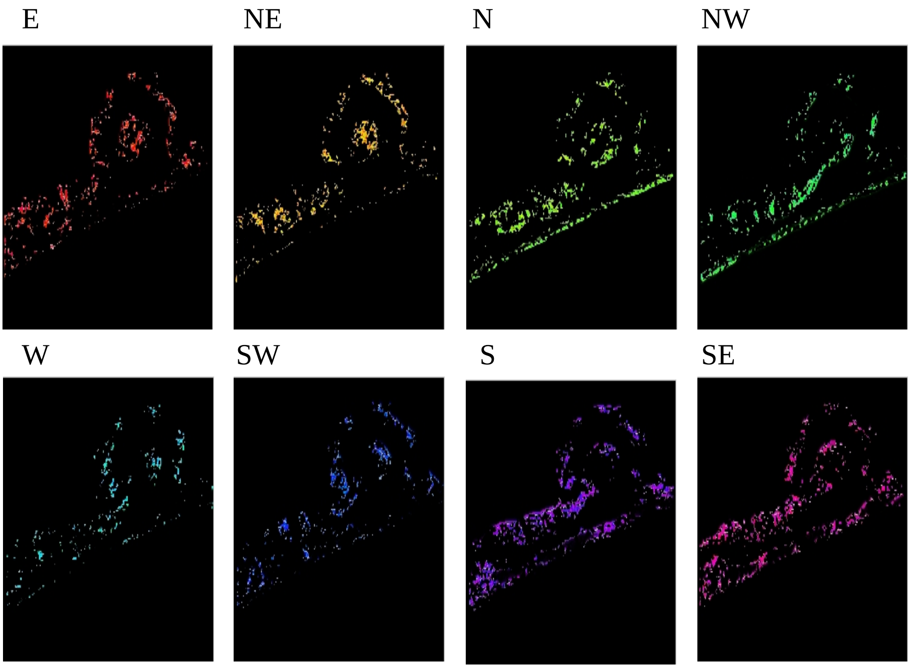

Figure 3. Images of layers with pixels with given direction.

Three point in the top, middle and bottom position of the prominence (mentioned at the gradient picture) are traced into the period of 25,4 min. Their compass directions are given in Table 2. Time is mentioned as duration between the first and the subsequent image. The “collision” of opposite directions is marked by red color.

Table 2: Directions of movement at the three mentioned points.

t	0	0.3	1.9	2.1	2.5	2.8	3.1	3.2	3.7	4.1	4.3	5.2
p.1	↑	→	↖	↓	↓	←	↖	↖	↙	←	↖	↖
p.2	→	↙	→	↘	↗	↑	↑	↑	↑	→	→	↖
p.3	↖	↖	←	↖	←	↙	↙	↘	↘	↖	↖	→
t	5.9	7.2	7.4	8.4	9.1	11.	12.	13.	14.	15.	15.	16.
p.1	↖	↖	↖	↖	↖	↖	↑	↑	↙	↖	↖	↑
p.2	←	↓	↑	←	←	→	↖	↖	→	←	↓	↓
p.3	→	↖	↗	↖	←	→	↙	↙	→	→	→	→
t	16.	17.	18.	18.	19.	19.	19.	20.	20.	23	25.	
p.1	↑	↖	←	←	→	↓	→	↗	↗	↓	↓	
p.2	→	↙	↙	↙	↙	↙	↓	↙	↗	→	↙	
p.3	→	↓	↓	↙	↓	↓	↘	↘	→	→	→	

The results show maximal time of saving direction of movement available at the bottom point. In the test sequence it is between t=4,3 and t=11,9 min and follows NW direction. Maximal number of collisions is presented for the middle point.The first twelve images of map of movement to the right (NE) direction are given in Fig. 4.

4. CONCLUSIONS

Special software is developed to separate the part of different motion direction in frames. The separated images form moving maps of different directions in dependence on the time. The results of the test demonstrate possibilities to define the time of saving direction of movement in arbitrary points and eliminate flickering. The method also gives a possibility to trace the direction of internal motions in the prominence body.

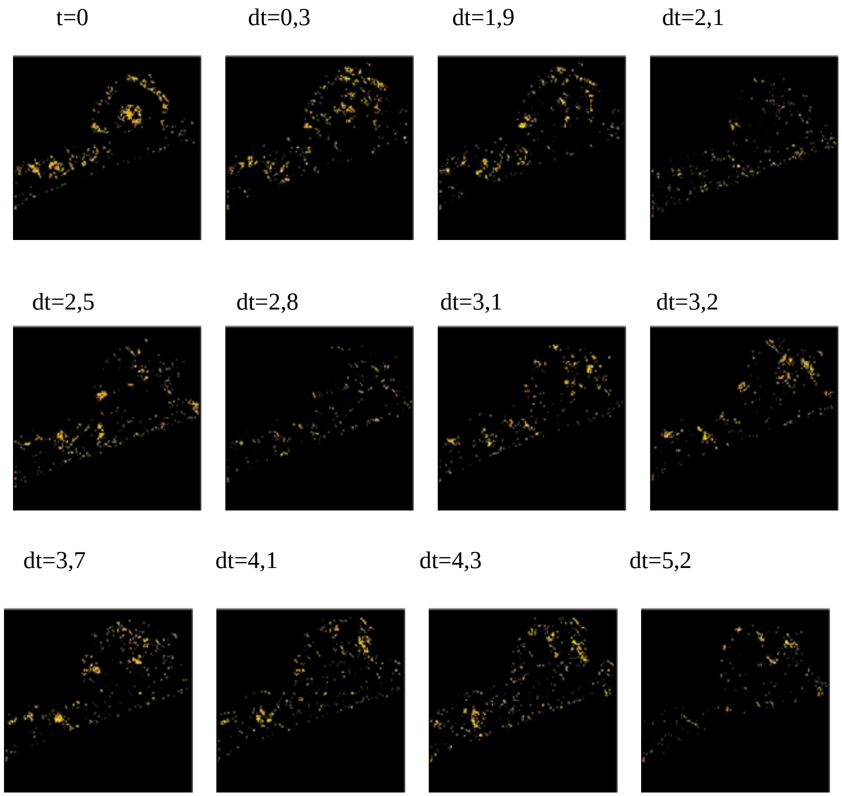

Figure 4. Images of pixels for the first twelve time samples of the NE compass direction.

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ELECTRICAL CONDUCTIVITY OF PLASMAS OF DB WHITE DWARFS ATMOSPHERES

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Abstract. The static electrical conductivity of plasma was calculated by using the modified random phase approximation and semiclassical method, adapted for the case of dense, partially ionized plasma of DB white dwarf atmospheres. were performed for the range of plasma parameters of interest for DB white dwarf atmospheres with effective temperatures $1 \cdot 10^4\mathrm{K} \lesssim T_{eff} \lesssim 3 \cdot 10^4\mathrm{K}$.

1. INTRODUCTION

The data on electrical conductivity of plasma of stars with a magnetic field or moving in the magnetic field of other component in a binary system (see e.g. Zhang et. al., 2009; Potter and Tout, 2010; Rodriguez-Gill et al., 2009) 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. Electrical conductivity was particularly investigated for solar plasma, since it is of interest for the consideration of various processes in the observed atmospheric layers, like the relation between magnetic field and convection, the question of magnetic field dissipation and the energy released by such processes (see e.g. Kopecký 1970 and references therein).

An additional interest for data on electrical conductivity in white dwarf atmospheres may be stimulated by the search for extra-solar planets. Namely Jianke et al. (1998) have shown that a planetary core in orbit around a white dwarf may reveal its presence through its interaction with the magnetosphere of the white dwarf. Such an interaction will generate electrical currents that will directly heat the atmosphere near its magnetic poles. Jianke et al. (1998) emphasize that this heating may be detected within the optical wavelength range as H_α emission. For investigation and modelling of mentioned electrical currents, the data on electrical conductivity in white dwarf atmospheres will be useful.

One of the most frequently used approximations for the consideration of transport proprieties of different plasmas is the approximation of "fully ionized plasma" (Spitzer 1962, Radke et al. 1976, Adamyan et al. 1980, Kurilenkov and Valuev 1984, Ropke and Redmer 1989, Djurić et al. 1991, Nurekenov et al. 1997, Zaika et al. 2000, Esser et al. 2003). It was shown that the electrical conductivity of fully ionized plasmas can be successfully calculated using the modified random-phase approximation (RPA) (Djurić et al. 1991, Adamyan et al. 1994a,b) in the region of strong and moderate non-ideality, while the weakly non-ideal plasmas were successfully treated within semiclassical approximation (SC) (Mihajlov et al. 1993, Vitel et al. 2001). In practice, even the plasmas with the significant neutral component are treated as fully ionized ones because of simplification of the considered problems, (Ropke and Redmer 1989, Esser and Ropke 1998, Zaika et al. 2000, Esser et al. 2003). However, our preliminary estimations have shown that such an approach is not applicable for the helium plasmas of DB white dwarf atmospheres described in Koester (1980) where the influence of neutral component can not be neglected.

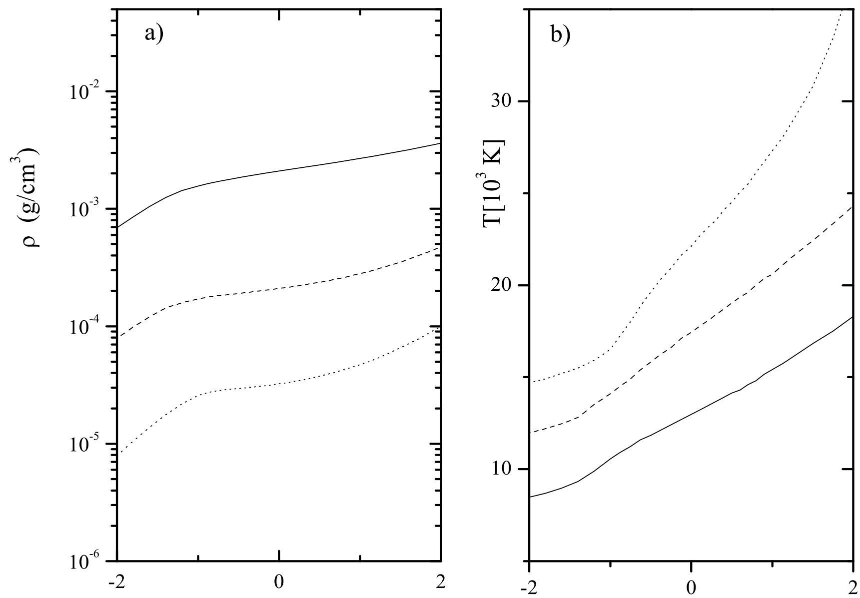

Figure 1. DB white dwarf atmosphere models with log $g = 8$ and T_{eff}=12000K (full curve), T_{eff}=16000K (dashed curve) and T_{eff}=20000K (dotted curve) from Koester (1980): (a) The mass densities; (b) The temperatures, as functions of Rosseland opacity τ.

Consequently, an adequate method for calculations of electrical conductivity of dense, partially ionized helium plasmas is developed here and all details are published in Srećković et al. (2010). This method represents a generalization of methods developed in Djurić et al. (1991) and Mihajlov et al. (1993), namely modified RPA and SC methods, and gives a possibility to estimate the real contribution of the neutral component to the static electrical conductivity of the considered helium plasmas in wide ranges of the mass densities (ρ) and temperatures (T).

The calculations were performed for the helium plasma in the state of local thermodynamical equilibrium with given ρ and T in regions $1 \cdot 10^4\mathrm{K} \lesssim T \lesssim 1 \cdot 10^5\mathrm{K}$ and $1 \times 10^{-6}\mathrm{g/cm^3} \lesssim \rho \lesssim 2\mathrm{g/cm^3}$. For the calculations of plasma characteristics of DB white dwarf atmospheres the data from Koester (1980) were used. All results are given in Srećković et al. (2010) and here only the application to DB white dwarf atmospheres will be shown.

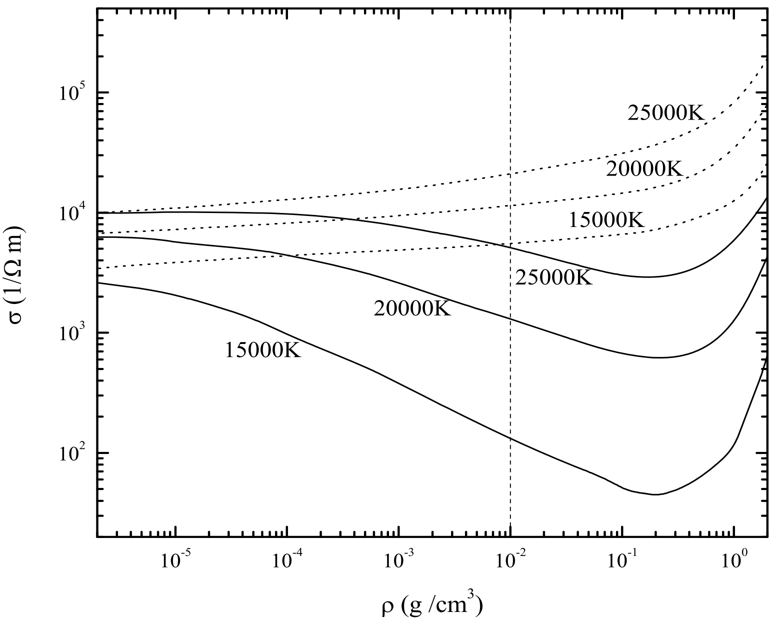

Figure 2. Static electrical conductivity σ of dense He plasmas as a function of mass density ρ (full curves), compared to the Coulomb part of conductivity (dashed curves). The area between the two vertical dashed lines marks the region which is of interest for DB white dwarfs.

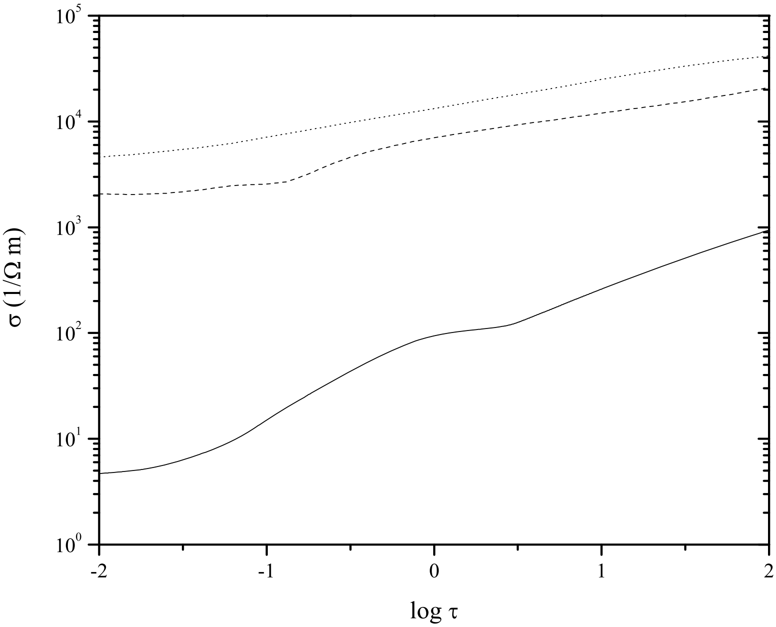

Figure 3. Electrical conductivity σ as a function of the logarithm of Rosseland opacity τ for DB white dwarf atmosphere models with log g = 8 and T_{eff}=12000K (full curve), T_{eff}=16000K (dashed curve) and T_{eff}=20000K (dotted curve).

2. RESULTS AND DISCUSSION

In order to apply our results to the study of DB white dwarf atmosphere plasma properties, helium plasmas with electron (N_e) and atom (N_a) densities and temperatures (T), characteristic for atmosphere models presented in the literature (Koester 1980), are considered here. So, the behaviour of ρ and T for models with the logarithm of surface gravity log g =8 and the effective temperature T_{eff} =12000K, 16000K and 20000K is shown in Fig. as a function of Rosseland opacity τ. As one can see, these atmospheres contain layers of dense helium plasma. In order to cover reliably the considered plasma parameter range, we tested our method for the calculation of the plasma electrical conductivity within a wider range of mass density $1 \times 10^{-6}\mathrm{g/cm}^3 \lesssim \rho \lesssim 2\mathrm{g/cm}^3$ and temperature $10000K \lesssim T \lesssim 30000K$.

The influence of neutral atoms on the electrical conductivity of helium plasma is shown in Fig. . In this figure the electrical conductivities for T = 15000, 20000 and 25000K are given as functions of mass density ρ. The range between the two vertical dashed lines corresponds to the conditions in the considered DB white dwarf atmospheres. Two groups of curves are presented in this figure: a) the dashed ones, obtained neglecting the influence of atoms, i.e. with $\nu_{ea} = 0$; b) the full line curves calculated including the influence of atoms. First, one should note that the behaviour of these two groups of curves is qualitatively different: the first one increases constantly with increasing ρ, while the other group of curves decreases, reaches a minimum, and then starts to increase with increasing ρ. One could explain such behaviour of the electrical conductivity by the pressure ionization. This figure also clearly shows when the considered plasma can be treated as "fully ionized".

The developed method was applied to the calculation of plasma electrical conductivity for the models of DB white dwarf atmospheres presented in Fig. . The results of the calculations are shown in Fig. . Let us note a regular behaviour of the static electrical conductivity which one should expect regarding the characteristics of DB white dwarf atmospheres.

The method developed and published in Srećković et al. (2010) represents a powerful tool for research into white dwarfs with different atmospheric compositions (DA, DC etc.), and for the investigation of some other stars (M type red dwarfs, Sun etc.). Finally, this method provides a basis for the development of methods to describe the other transport characteristics which are important for the study of all the mentioned astrophysical objects, such as the electronic thermo-conductivity in the star atmosphere layers with large electron density, electrical conductivity in the presence of strong magnetic fields and dynamic (high frequency) electrical conductivity.

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SOFTWARE APPROACH FOR PARAMETRIZATION OF FITS DATA

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Abstract. Using ordinary software tools including tiff-fits converting, astroinformatics users need editing or repeating table information, named fits-header. In this paper the approach and software realization of the usable software tool for the astroinformatics purposes are described.

1. INTRODUCTION

Some of the tasks of the project Astroinformatics directly linked to the need for adding or editing a text-tabular astroinformatics data, called fits-header. One such case is the conversion of astronomical images scanned as TIFF graphics file format to that adopted in specialized astroinformatics FITS (2010) file format. The content of the fits-header is essential for proper interpretation of the contained graphics and also has useful information about the observatory, made graphically documented observation, astronomical instruments, which is made, the observation date and duration of monitoring and others.

There are software solutions that allow editing of the fits-header directly entered by the user: name for the key, value and comment. Experience of using these software tools shows that the introduction of direct indication of the key values and is not sufficiently effective. Alphanumeric identification key of the sense defined constant, or speaking a second domain name and be spelled exactly the use of certain symbols and format. Similarly, the value of the corresponded value is of a particular type has a physical dimension, range of values and in some cases default.

During the research project "Astroinformatics" and being able to create new software tools and processes for the conversion of tabular and graphical content astroinformatics widely used FITS file format, here a programming model with which to implement menu oriented interactive subsystem for adding and editing of fits-header data and parameterized views of partial images is offered.

2. PROGRAMMING MODEL OF THE PARAMETERIZED FITS-HEADER DATA

Fig. 1 displays the development of the project Astroinformatics software application, "TIFF to FITS converter".

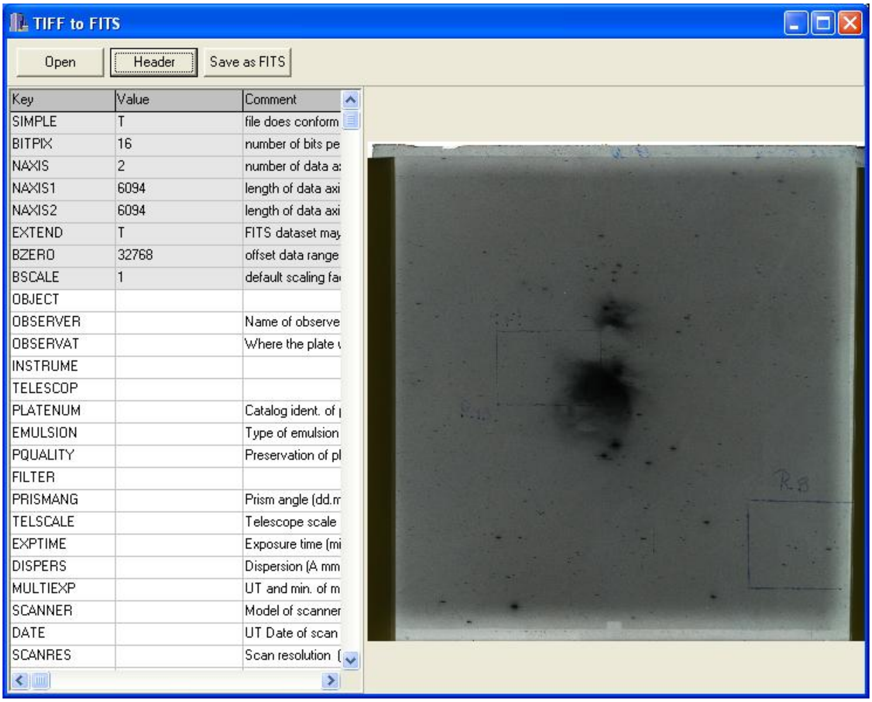

Figure 1. Astronomical image with fits-header table.

On the left in Fig. 1 tabular fits-header data specific to the output TIFF file of the astronomical image and automatically filled in, and some other keys, values that need to be manually entered are shown. For large groups of output TIFF files manually input fits-header data have some repetition, therefore parametrization by creating templates is suggested.

Fig. 2 presents schematically the essence and logical links used for description of complex patterns of fits-header data.

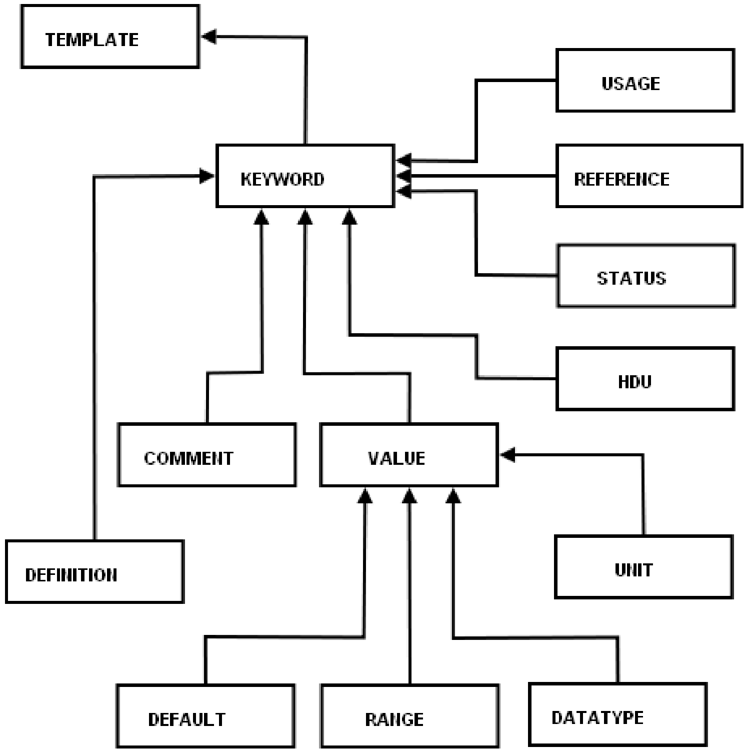

Figure 2. Logical scheme fits-header template.

A brief explanation of the entities of the logical scheme in Fig. 2 is presented in Table 1.

Table 1:

Entity	Description
TEMPLATE	Defined list of templates available to users by their names
KEYWORD	Alphanumeric identification key
USAGE	Scope of the key - standard, or conventional
REFERENCE	Reference to the document governing the use of key
STATUS	Mandatory or reserved for possible use
HDU	Specify the data block to which can be used
COMMENT	User comments
DEFINITION	Substantive definition of the key governing document
VALUE	Key value
UNIT	Units of value
DATATYPE	Type of value
RANGE	Range of values for that key
DEFAULT	Default value, if any

3. PROGRAMMING MODEL FOR USER-DEFINED VIEWS

The study of application software custom designed for astroinformatics shows the need to build tools for astroimages navigation in order to detect the image details. Most of the examples mentioned have similar software features zoom and select the current center of the image and applying different methods of filtering and visual correction. In practice, if a specialized user is interested in details of the image, which referred to a specific FITS file, this file may be accessed through a set of parameters. A similar example is a Linux version of the test program, developed for the needs of project Astroinformatics and shown in Fig. 3. Here a relatively simple but effective software tool helps the user to access a total picture of the region and to receive in a new window image in the partial set zoom and filters applied.

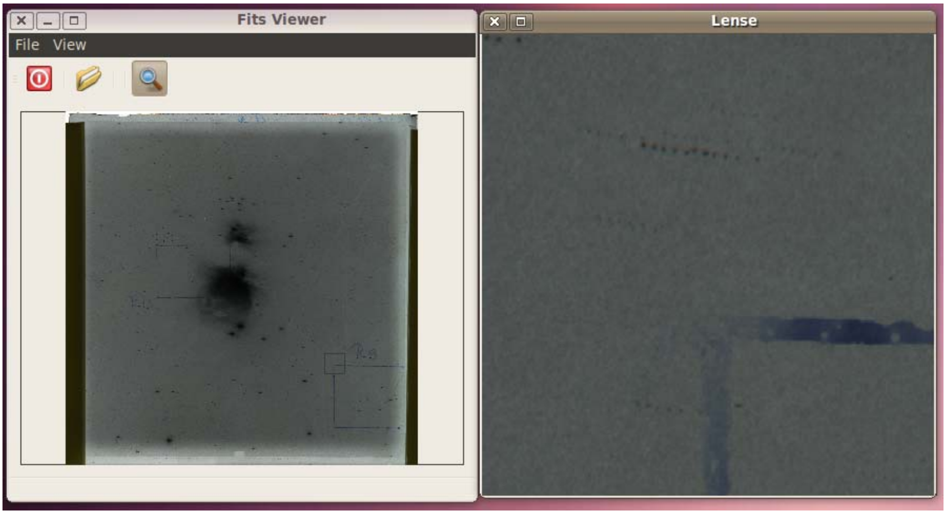

Figure 3. Astroimage defined view.

Is it possible an once defined view to be parameterized in such a way that at the next entry in the program to be restored and why not the user to get a list of all defined views to that image?

This opportunity provides a flexible structure of the FITS file format, namely the creation of an extension of type ASCII table. Each user is described in view of information structure, preservation and access program. The data structure designed to maintain user views at FITS astro-image is presented in Fig. 4.

Software and technological approach for storing user parameterized views is likely to be as tabular relational scheme or XML structure (Thomas et al., 2001). FITS an interesting solution based on SQL (Structured Query language) was submitted by Amy Shelton (FITS Query Language, 2008).

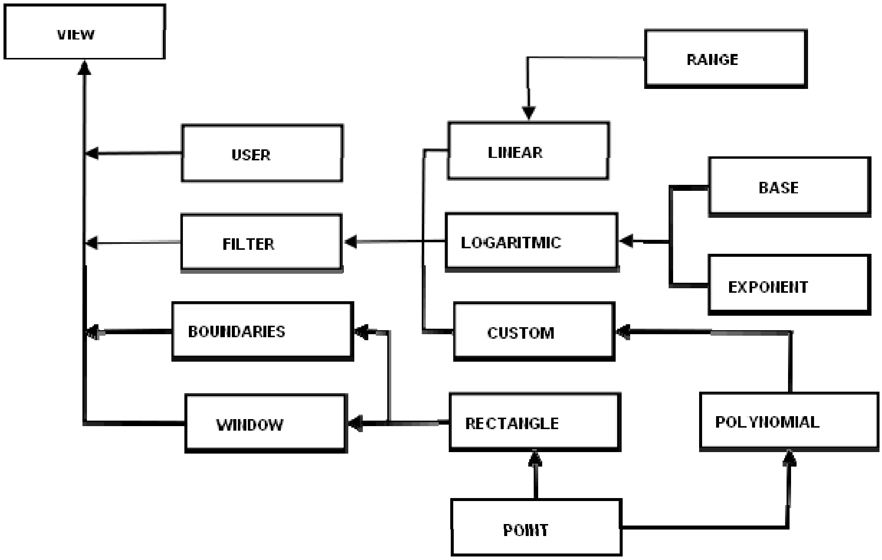

Figure 4. Parameterization of user views.

In Fig. 4 naming views consist of user data, data on the attached filter which could be linear, logarithmic, or arbitrarily defined. In the latter case the filter is presented as functional interpolation curve. Geometric positioning and screen size of the view defined by boundaries on a rectangular area in the main image window and the borders of the resulting view.

4. CONCLUSIONS

Models of software programming tool to serve astroinformatics users based on pilot testing of software within the project Astroinformatics is provided. Final development of a similar type of software would increase efficiency of the work of specialists dealing with converting graphics file formats to specialized for astroinformatics FITS file format. Also, beyond the project, the proposed publication of software so far in "custom parameterized views" is in the service of numerous professionals and amateur astronomers, as well as astroinformatics specialists. In the latter case a further development of the idea of parameterized FITS tabular data could grow to the construction and maintenance of WEB-based database with possibilities for centralized updating of fits-header versions and increase mobility in the definition and use of user defined views FITS .

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STATISTICAL ANALYSIS OF LANGMUIR WAVES ASSOCIATED WITH TYPE III RADIO BURSTS

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Abstract. Interplanetary electron beams, produced by CMEs and flares, are unstable in the solar wind and generate Langmuir waves at the local plasma frequency (f_p) or its harmonic ($2f_p$). Radio observations of the waves in the range 4 - 256 kHz from the WAVES experiment onboard the WIND spacecraft have been statistically analyzed. A subset of 36 events has been selected for this study. The background consisting of thermal noise, type III bursts and Galactic background has been removed and the remaining power spectral density has been fitted by Pearson's system of probability distributions. The coefficients of the probability distributions have been calculated by using two methods: method of moments and maximum likelihood estimation method. We have shown that the probability distributions of the power spectral density of the Langmuir waves belong to three different types of Pearson's probability distributions: type I, type IV and type VI. In order to compare the goodness of the fits, a few statistical tests have been applied, showing for all of the considered events that the Pearson's probability distributions fit the data better than the Gaussian ones. This is in contradiction with the Stochastic Growth Theory which predicts log-normal distribution for the power spectral density of the Langmuir waves. The uncertainty analysis that has been performed also goes in favor of the use of Pearson's system of distributions to fit the data.

1. OBSERVATIONS AND SAMPLE EVENTS SELECTION

We used the measurements obtained by four different experiments on-boarded Wind spacecraft - a laboratory for long-term solar wind measurements, launched on November 1, 1994. We have focused on radio observations obtained by the WAVES experiment (Bougeret et al., 1995). In our study of locally generated Langmuir waves we use data of two multi-channel thermal noise receivers (TNR), which cover 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 plasma electric field (every 1.5 s or half spacecraft spin). The Langmuir waves that are converted into electromagnetic waves – type III bursts, can then be observed with two radio receivers, RAD1 and RAD2. The RAD1 frequency range, from 20 to 1040 kHz, is divided into 256 linearly spaced channels of 3 kHz bandwidth each. Frequency range of the RAD2 radio receiver, from 1075 to 13825 kHz, is divided in the same number of channels as RAD1, but with 20 kHz bandwidth.

For the selection of a sample events we used: (1) one minute averaged measurements of interplanetary magnetic field vector in Geocentric Solar Ecliptic (GSE) cartesian coordinates from Magnetic field investigation (MFI), (Lepping et al., 1995); (2) for the particles measurements, i.e. for the full three-dimensional distribution of suprathermal electrons and ions, we used 3-D Plasma and Energetic Particle Investigation (3DP) experiment (Lin et al., 1995); (3) for the solar wind velocity we used data from the Solar Wind Experiment (SWE) (Ogilvie, 1995) which provides three-dimensional velocity, density and temperature of the solar wind ions. As the solar wind velocity we used proton velocity averaged over the time interval when our event occurred.

The measurements, taken simultaneously by the four experiments, allow qualitative analysis of the events.

2. ANALYSIS

The stochastic growth theory (SGT) describes situations in which an unstable distribution of particles interacts self-consistently with its driven waves in an inhomogeneous plasma environment and evolves to a state in which the particle distribution fluctuates stochastically about a state close to time and volume averaged marginal stability. These fluctuations drive waves so that the wave gain, $G = 2\ln(E/E_0)$, is a stochastic variable. The wave gain is the time integral of the wave energy density growth rate and it is related to the wave electric field, $E(t)$, by $E^2(t) = E_0^2 \exp[G(t)]$ where E_0 is a constant field. The observed electric field, E, is a consequence of a large number of amplifications and damping: $E = E_0 \prod_{i=1}^{N} e^{G_i}$, $(N \gg 1)$, where gain, G_i, is a stochastic variable. Taking the logarithm of this equation one obtains: $\log E = \log E_0 + \sum_{i=1}^{N} G_i$. The central limit theorem can then be applied to the probability distribution of $\log E$ which is thus a normal distribution (e.g. Robinson, 1992).

In order to see if the Langmuir waves associated with type III solar bursts satisfy predictions of the SGT, we have undertaken the following steps. We have integrated the power spectral density (S_t, index t denotes a certain moment of time) of Langmuir waves through a narrow interval of frequencies (f_1, f_2) around the local plasma frequency (f_p): $P_{LW,t} = \int_{f_1}^{f_2} S_t \,\mathrm{d}f$, $(f_1 < f_p < f_2)$. The integration is done numerically by a trapezium method. In that way we obtain the total power of the Langmuir waves at a given moment of time ($P_{LW,t}$).

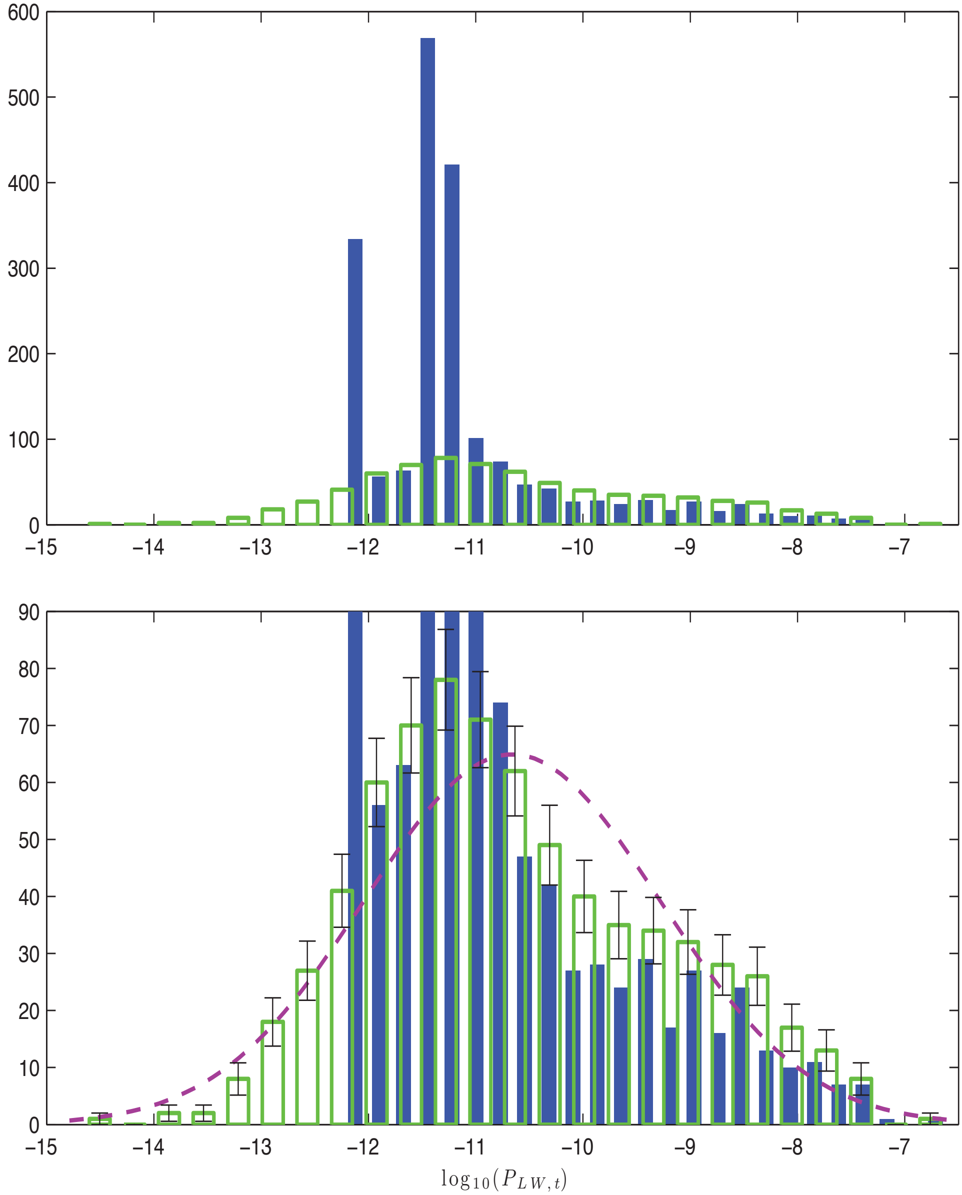

Figure 1. Histograms of Langmuir waves power (2002 October 21st event). Upper panel: Before (filled blue bars) and after (empty green bars) background removing. Lower panel: part of upper panel, dashed line represents Gaussian fit of Langmuir waves power histogram after background removing.

To remove the background consisting of the thermal noise, the type III radio burst and the galactic background, we have developed a heuristic algorithm based on numerical techniques (interpolation and smoothing) with a few parameters. From the remaining data we made new histogram, displayed in Fig. 1 (green empty bars), and fit it with a normal distribution shape function (dashed line in Fig. 1, lower panel). The error bars on the histogram are calculated as standard deviation of counting statistics, i.e. the Poisson distribution.

To find a better approximation for the probability functions we have applied a family of distributions proposed by Pearson (1895).

3. APPLYING pEARSON'S SYSTEM OF DISTRIBUTIONS

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 (see Fig. 2 for an example). 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.).

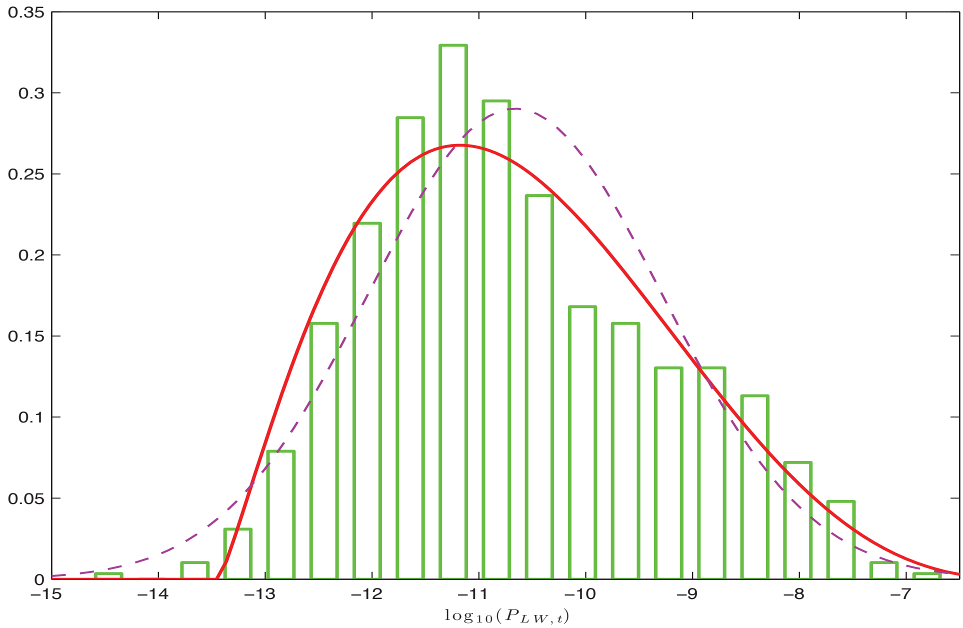

Figure 2. Pearson type I (solid red line) and normal (dashed line) probability density distribution of Langmuir waves power (2002 October 21st event).

In 1895 Pearson (1895) defined this distribution system by the following ordinary first order differential equation for the probability density function $p(x)$:

$$-\frac{p'(x)}{p(x)} = \frac{b_0 + b_1 x}{c_0 + c_1 x + c_2 x},$$

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 parameter values, 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 (μ_2, μ_3 and μ_4). Pearson proposed two dimensionless parameters, i.e. the two moment ratios square of skewness ($\beta_1 = \mathrm{Sk}^2$) and kurtosis (β_2):

$$\beta_1 = \frac{\mu_3^2}{\mu_2^3}, \quad \beta_2 = \frac{\mu_4}{\mu_2^2}.$$

These two parameters characterize the peakedness and the asymmetry of the distribution and it turns out that the distribution type depends only on two of them. Their values can be estimated from observations (Johnson et al., 1994). The other way of parameter estimation is the Maximal Likelihood Estimation method. For each Pearson distribution type its parameters are determined to maximize the likelihood function of the sample data. The best result over all types is chosen. For optimization we used standard Nelder-Mead and Levenberg-Marquardt methods (Press et al., 2007). Both methods gave very similar results.

We find that our 36 events belong to only 3 types of Pearson's distributions: type I (beta), type IV (not related to any standard distribution) and type VI (beta prime). The positions of all 36 events in the $\beta_1 - \beta_2$ plane are shown in Fig. 3.

Most of the events are close to normal distribution, which is represented by the point $(\beta_1, \beta_2) = (0, 3)$. To see whether they are really different from a normal distribution, i.e. if the point $(0, 3)$ lies within the uncertainty limits of the events, we used two methods to evaluate the error-bars in β_1 and β_2: a Monte Carlo simulation and a method of moments proposed by Karl Pearson (1895). Error bars shown in Fig. 3 are calculated by the method of moments. It is found that the point $(0, 3)$ belongs to only four of the uncertainty ellipses (blue points). Out of 36 events, 32 have no intersection with the normal distribution point, opposite to the predictions of the SGT.

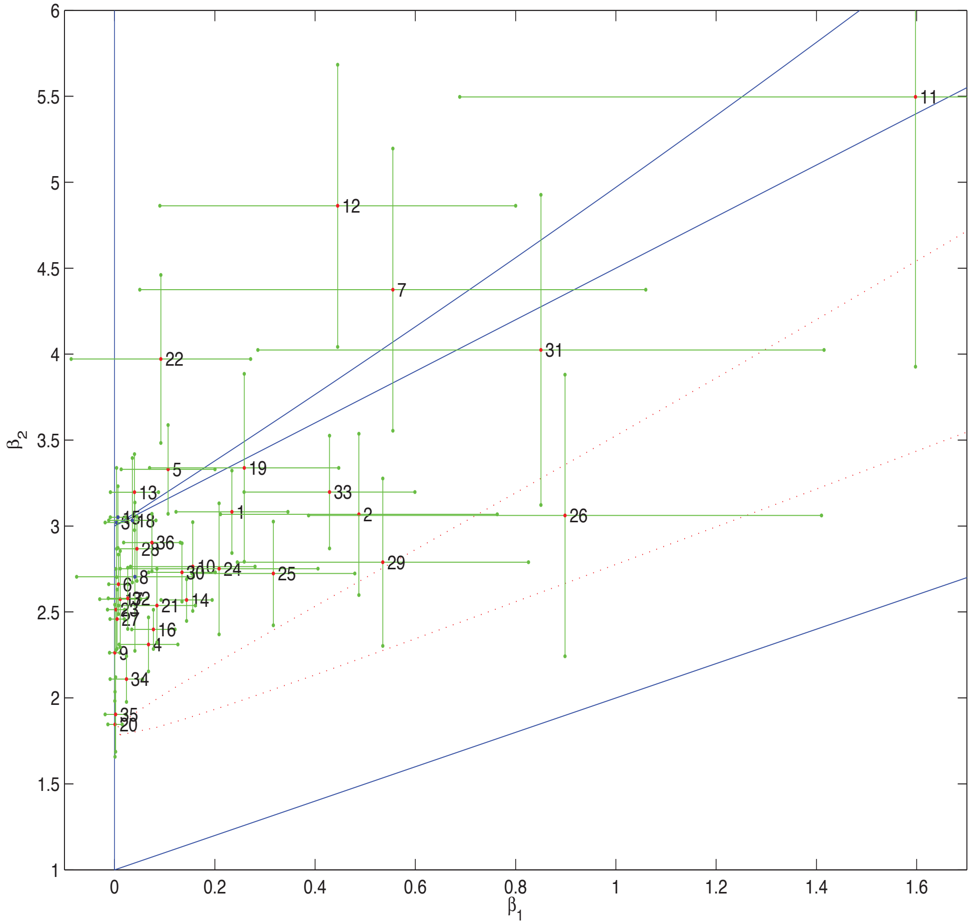

Figure 3. Beta plane. Out of the 36 events: 28 belong to Pearson's type I, 1 to type VI and 7 to type IV probability distribution.

4. CONCLUSIONS

We have examined 36 time intervals containing intense locally formed Langmuir waves that are associated with type III radio bursts. We have shown that the probability distributions of the power of these waves belong to three different types of Pearson's probability distributions: type I, type IV and type VI. The goodness of the fits test (e.g. χ^2) shows that the Pearson's probability distributions fit the data better than Gaussian ones for all of the considered events. This is in contradiction with the SGT which predicts Log-normal distributions for the power of the Langmuir waves. The uncertainty analysis of β_1 and β_2 parameters also goes in favor of the use of Pearson's system of distributions to fit the data.

This result indicates that the SGT possibly requires additional verifications and examinations.

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SECULAR PLATE DRIFT IN NORTH DIRECTION DETERMINED BY ASTROMETRICAL LATITUDE OBSERVATIONS AT OBSERVATORY PLANA

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Abstract. The secular plate drift at observatory Plana in North direction is determined by means of astrometrical latitude observations from zenith tube Zeiss 135/1750. The latitude variations due to the polar motion are determined from the solution C04 of the IERS for the pole coordinates. The time series of the mean latitude variations and mean polar changes of the latitude are determined by averaging in running 6-year window. The mean nonpolar latitude variations are determined as difference between these time series. The secular plate drift in North direction is estimated by the linear trend of the mean nonpolar latitude variations. The results are compared with the values from GPS measurements, provided by a permanent station, located nearby the observatory Plana.

1. INTRODUCTION

The geodynamical phenomena, related to the variations of the Earth shape, rotation and gravity field, are complex and often nonpredictable effects, determined by the structure and dynamical properties of the Earth. These phenomena are of special interest to the geosciencies, and particular to the geodynamics, the geophysics and the geodesy. These geophenomena are so complex, that it universal investigation is possibly only on the base of the utilization of various methods of observations. Such methods are the classical astronomical geodetic methods of determination of astronomical time - geographic longitude and geographic latitude. The latitude observations are connected directly to the vertical in the observation station, and due to it's high precision and long duration can be used to investigation of the permanent changes of the vertical in time.

The nonpolar latitude changes are connected to the changes of position of the vertical at the observation station. The last changes are within the nonpolar changes of the geographic latitude at the point, and that is the reason to derive the changes of the vertical from the latitude changes. Thus, investigation and determination of the nontidal changes of the vertical at a given point of earth surface is connected to investigation and determination of the changes of the geographic latitude of the observation station.

A part of nontidal changes of the vertical can be provoked by the deformations and motions of the earth plates. The nonpolar changes of the geographic latitude can be used as indicator of the horizontal and vertical changes at the observation station and for investigation of the local gravity field variations.

2. LATITUDE VARIATIONS AT OBSERVATORY PLANA AND ITS HOMOGENEITY

The latitude observation by zenith telescope Zeiss 1750/135 at observatory Plana are provided permanently since 1987.5. More than 20 000 observations of 72 star pairs in 12 groups are available (Fig. 1). For processing of the latitude observations and investigation of the oscillations of the vertical in the Central Laboratory for Geodesy are developed several methods for determination of some instrumental constants and specific systematic errors (Darakchiev and Chapanov, 2003; Chapanov and Darakchiev, 2005).

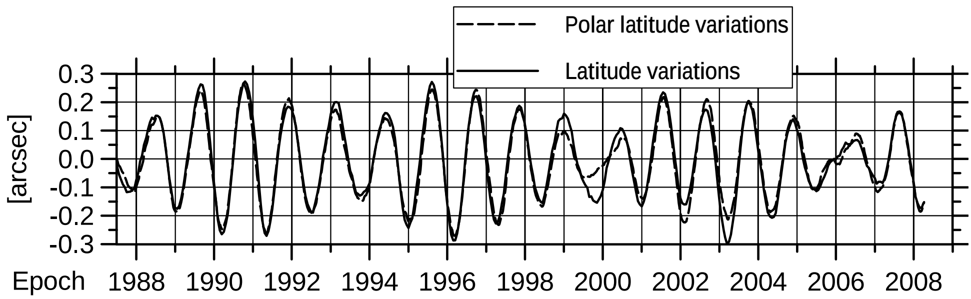

Figure 1. Smoothed time series of the latitude variations at observatory Plana, determined from observations with zenith telescope Zeiss 135/1750 and the polar latitude changes, determined from solution C04 of the IERS for the pole coordinates.

The nonpolar latitude changes are determined as differences between the observed latitude values and polar latitude variations, computed by the solution C04 for pole coordinates of the International Earth Rotation Service (IERS). The time series of the nonpolar latitude change are determined by normal points at 0.05a (Fig.2). The normal points are computed by means of the robust Danish method (Kubik, 1982; Juhl, 1984; Kegel, 1987). This method allows to detect and isolate outliers and to obtain very accurate and reliable solution for the nonpolar latitude changes and the oscillations of the local vertical in the meridian plane. The smoothed time series of the latitude variations at observatory Plana and the polar latitude changes, determined from solution C04 of the IERS for the pole coordinates are shown in Fig. 1. The comparison between the curves points out excellent agreement of the amplitudes and phases of the annual and Chandler oscillations due to the polar motion. Visible disturbances of Plana latitude variations after 1999 are due to the oscillations of the vertical, dominated by 3-year oscillations (Fig. 2).

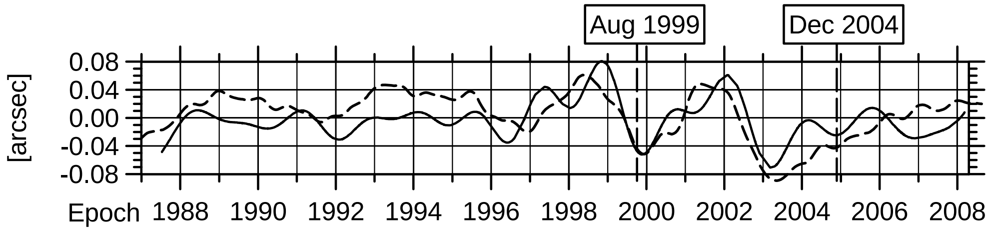

Figure 2. Interannual (with solid line) and long-term (with dashed line) variations of the vertical in observatory Plana and disaster earthquakes in Turkey in 1999 and Sumatra in 2004. The interannual curve is composed by oscillations with periods below 3.5a. The long-term curve is determined by running average in 1-year window.

The interannual oscillations of the vertical at observatory Plana consist of 3.5-year and 5.5-year cycles. The 5.5-year cycles are visible till 1997 and 3.5-year cycles – after that. Correlation relationships between 3.5-year oscillations of the vertical at observatory Plana and disaster earthquakes in Turkey in 1999 and Sumatra in 2004 exist (Chapanov and Darakchiev, 2008). These earthquakes occurred after the end of the 3.5-year cycles of the local gravity, so they are probably connected with some strong geodynamical disturbances after 1999. These geodynamical events disturbs interannual oscillations of the gravity and it long-term behavior. We determine the long-term behavior of the local gravity and corresponding trends of the variations of the vertical by means of Vondrák-Whitaker filtration (Vondrák, 1969, 1977) of the latitude variations of Plana observatory and polar variations of Plana latitude determined with different smoothing factors (ε=0.01, 0.1, 1.0, Figures 3-5). The difference between the filtered time series of the variations of Plana observatory and polar variations of Plana latitude is positive for the first part of the observed time span and negative for the second part. The positive values of the nonpolar latitude variations at Plana observatory occurred before 1999.7 – 2001.4, so the quite period of vertical oscillations is approximately before 2001.5 and disturbed period, due to significant 3-year gravity oscillations – after 2001.5. According this, the trend of the vertical changes at observatory Plana for the period 1987.5-2001.5 represents the secular plate drift in North direction, while the vertical changes after 2001 are dominated by strong geodynamical disturbances.

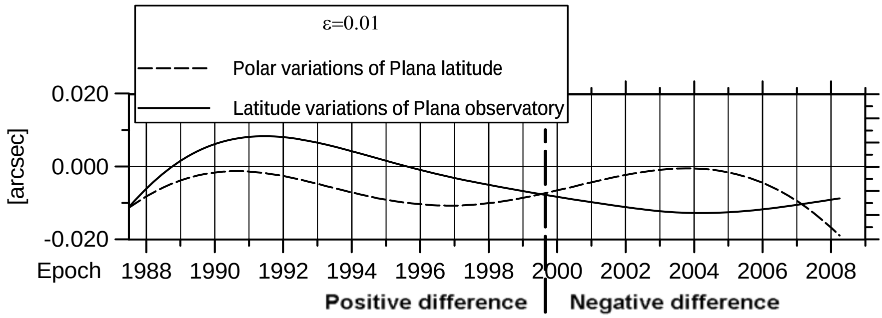

Figure 3. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=0.01. The nonpolar latitude changes are positive before 1999.6 and dominating negative after.

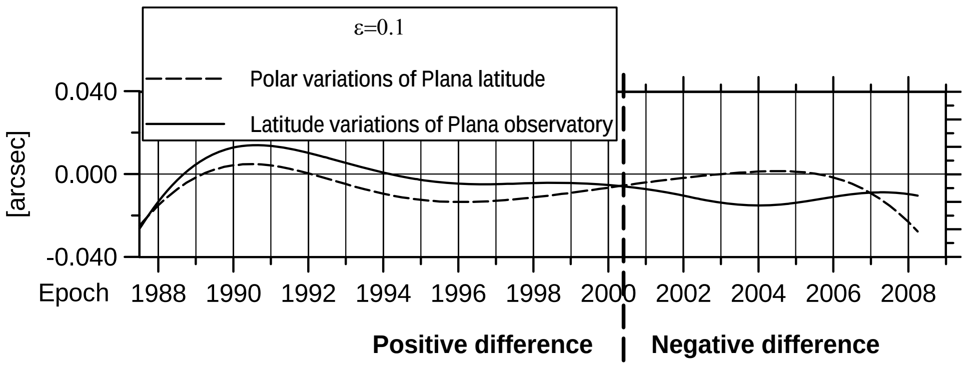

Figure 4. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=0.1. The nonpolar latitude changes are positive before 2000.4 and dominating negative after.

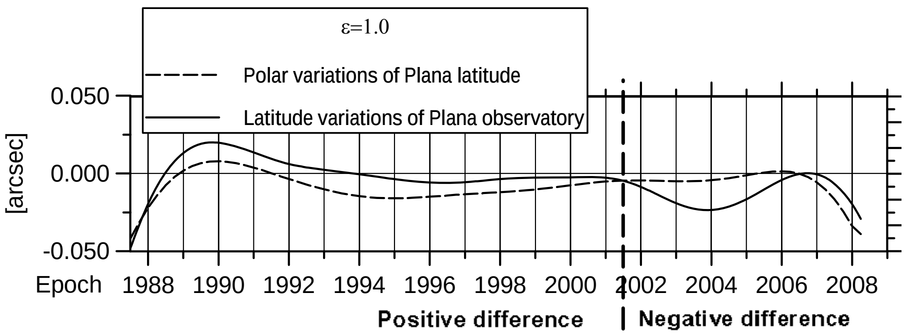

Figure 5. Vondrák-Whitaker filtration of the latitude variations of Plana observatory and polar variations of Plana latitude determined with smoothing factor ε=1.0. The nonpolar latitude changes are positive before 2001.3 and dominating negative after.

3. IMPROVED METHOD OF 6-YEAR AVERAGING

The method is similar to the method for determination of the polar motion components (Chapanov, 2004). The first step of the method includes solving the system

$$x = x_0 + \frac{dx}{dt}t + \sum_{i=1}^{n} a_{yi} \sin i\omega_y t + b_{yi} \cos i\omega_y t + \sum_{i=1}^{m} a_{ci} \sin i\omega_c t + b_{ci} \cos i\omega_c t, \quad (1)$$

for the following unknowns – the mean coordinates of the current six-year span $\hat{x}_0$, the velocities of the linear trend $d\hat{x}/dt$, the harmonic coefficients of the seasonal component $\hat{a}_{yi}, \hat{b}_{yi}$, $i = 1,\ldots,n$ and the harmonic coefficients of the Chandler component $\hat{a}_{cj}, \hat{b}_{cj}$, $j = 1,\ldots,m$. The observations for the first step are the coordinates x from the current six-year span.

The initial values of the seasonal (annual) frequency ω_y^0 and Chandler frequency ω_c^0 are determined by

$$T_y^0 = 365.2422\,d,\ T_c^0 = 1.2\,T_y^0,\ \omega_y^0 = \frac{2\pi}{T_y^0},\ \omega_c^0 = \frac{2\pi}{T_c^0}, \quad (2)$$

where T_y^0 and T_c^0 are the initial values of the annual and Chandler periods. The estimates are obtained from (1) by the Least-squares method. In the second step the unknowns from the first step are improved and corrections of the seasonal and Chandler periods are determined. The coordinates x^c are computed by (1) with aid of the observation time and the obtained estimates. The linear system is solved

$$\begin{aligned} x - x^c = {} & \delta x_0 + \delta\dot{x}t + \sum_{i=1}^{n} \delta a_{yi} \sin i\omega_y^0 t + \delta b_{yi} \cos i\omega_y^0 t \\ & + 2\pi i t \left(T_y^0\right)^{-2} \delta T_y^x \left(\hat{b}_{yi} \sin i\omega_y^0 t - \hat{a}_{yi} \cos i\omega_y^0 t\right) \\ & + \sum_{i=1}^{m} \delta a_{ci} \sin i\omega_c^0 t + \delta b_{ci} \cos i\omega_c^0 t \\ & + 2\pi i t \left(T_c^0\right)^{-2} \delta T_c^x \left(\hat{b}_{ci} \sin i\omega_c^0 t - \hat{a}_{ci} \cos i\omega_c^0 t\right), \end{aligned} \quad (3)$$

for unknowns δx_0, $\delta\dot{x}$, δa_{yi}, δb_{yi}, i=1,…, n; δa_{cj}, δb_{cj}, j=1,…, m, which are the corrections of the estimates from the first step; $\delta \mathbf{T_y}^{\mathbf{x}}$, $\delta \mathbf{T_c}^{\mathbf{x}}$ are the corrections of the annual and Chandler periods for the coordinate **x;** and $\delta \mathbf{T_y}^{\mathbf{y}}$, $\delta \mathbf{T_c}^{\mathbf{y}}$ - for the coordinate **y** of the pole. Next iterations with the corrected values of the unknowns can be made, if it is necessary.

4. MEAN VARIATIONS OF THE LATITUDE AT OBSERVATORY PLANA.

The mean variations of the latitude and polar latitude of observatory Plana are determined by the improved method of 6-year averaging (Fig.6 - 7).

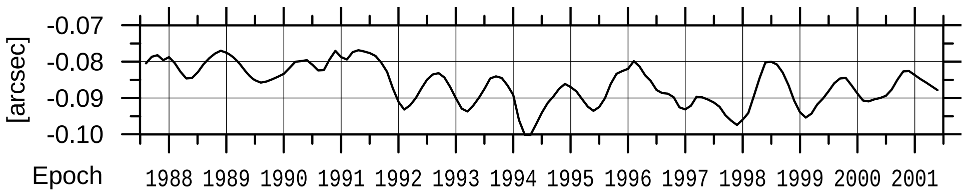

Figure 6. Mean latitude variations determined by the improved method of 6-year averaging. The rms errors are below 5mas.

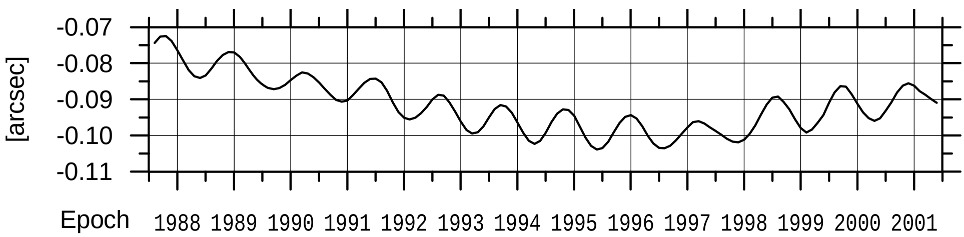

Figure 7. Mean polar latitude variations, determined by the improved method of 6-year averaging. The rms errors are below 3mas.

5. LINEAR TREND OF THE MEAN VARIATIONS OF THE VERTICAL IN NORTH DIRECTION

The linear trend of the mean variations of the vertical in North direction at observatory Plana are determined as a difference between the time series of the latitude and polar latitude variations (Fig.8). The secular plate drift in North direction is estimated by the linear trend from the Fig.8. This estimate is compared with the result obtained by the GPS data for the period 1997.5-2009 from station Sofi, located near the observatory Plana (Fig.9, Table1).

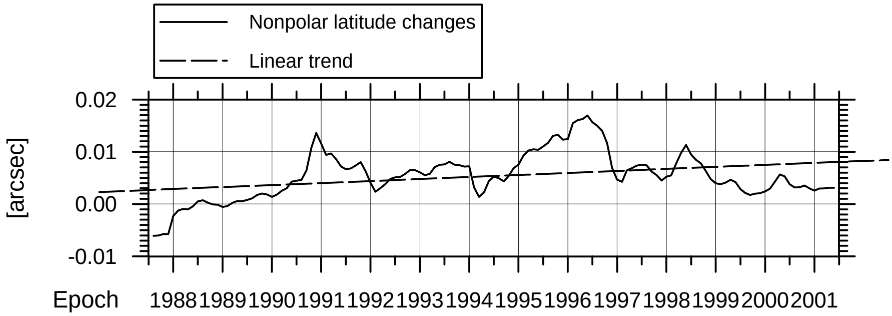

Figure 8. Mean variations of the vertical in North direction at observatory Plana. The linear trend is an estimate of the secular plate drift in North direction.

Table 1: Estimates of the secular plate drift in North direction, determined by latitude and GPS data.

	Linear trend of the vertical [mas/a]	Secular plate drift [mm/a]
ZT Plana	+0.39 ±0.09	+11.6 ±2.8
GPS Sofi		+11.97 ±0.01

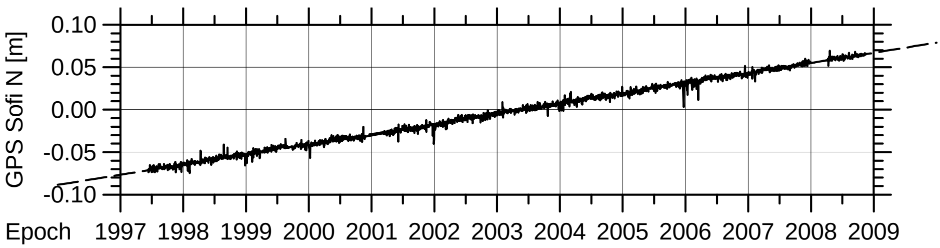

Figure 9. The time series of variations in North direction of the GPS station Sofia, located nearest to observatory Plana.

6. CONCLUSIONS

The trend of the vertical changes at observatory Plana for the period 1987.5-2001.5 represents the secular plate drift in North direction, while the vertical changes after 2001 are dominated by strong geodynamical disturbances.

The secular plate drift in North direction, determined by linear trend to the mean non-polar latitude observation at observatory Plana for the period 1987.5-2001.5, is +11.6 ±2.8mm/a, which is with excellent agreement with the value of

+11.97 ±0.01mm/a, determined by GPS measurements for the period 1997.5-2009 from station Sofi, located near the Sofia.

Acknowledgments

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THE INASAN ZVENIGOROD OBSERVATORY PLATE COLLECTION

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Abstract. Description of the astronomical wide-field plate- and film-collection of the Zvenigorod Observatory of the Institute of Astronomy of the Russian Academy of Sciences is presented. The archives of the collection are the result of photographic observations conducted for more than thirty years from 1972 to 2005. They included:
1) photographic plates obtained with the 40 cm Carl Zeiss astrograph (the half of the plates are included in the Sofia WFPDB). The plates are now in process of digitization in FITS-formats, 700 MB each scan. Two EPSON 1640XL scanners are used. The observational programs include the FON photographic north sky survey, small bodies in the Solar system - asteroids and comets;
2) film archive from the AFU-75 camera;
3) archive of artificial satellites monitoring observations with wide-field camera VAU.

1. INTRODUCTION

In 1958 near Zvenigorod (in Moscow region) the experimental station of Astronomical Council of the USSR Academy of Sciences (nowadays the Zvenigorod Observatory) was created with the order of the Presidium of the Academy of Sciences of the USSR. Throughout many years it was the main scientific base for working out of new techniques, equipment and observers for the Earth artificial satellites observations. Later on traditional telescopes for observations of common astronomical objects: stars, planets, comets and asteroids, were installed too.

We describe the astronomical wide-field plate- and film-collection of the Zvenigorod Observatory of the Institute of Astronomy of the Russian Academy of Sciences, as well as the digitization projects.

2. AVAILABLE ARCHIVES OF THE ZVENIGOROD OBSERVATORY

The plate archives are results of the photographic observations carried out at the Zvenigirod Observatory for more than thirty years from 1972-2005. The parameters of the instruments and characteristics of the archives are presented in Table 1.

Brief information on archives is given below:

1) Photographic plates taken with the 40 cm **Carl Zeiss astrograph**, totally about 4500 plates, plate size is 30x30 cm. For the majority of the plates the used exposures allow stars up to 16.5 magnitudes to be well visible. The half of the plates is included into the Sofia WFPDB (Tsvetkov, 2006). The plates are in process of digitization in FITS-format, each scan has size of 700 MB. Two EPSON 1640XL scanners are used.

Table 1: Plate collections and the used instrument parameters of the Zvenigorod Observatory.

Instrument	D cm	F cm	Field deg	Plate/film size, cm	Years	Plate number
Astrograph Zeiss-400	40	206	8 x 8	30 x 30	1972 - 2005	4500
AFU camera	21.2	73.6	10 x 15	20 x 14	1973 - 1985	2800
VAU camera	107	70	5 x 30	6 x 36	1971 - 2005	10000

2) **AFU-75 camera** with about 2800 films. All films are obtained during the satellites observations. The film is displaced during the exposure with speed of movement of the satellite, but with periodic stops through 3 or 6 mm. The full image of a star represents a chain from 13 or 7 images with 1 arcsec exposures. Usually limiting magnitude was 8 magnitudes. This archive is catalogued. It scanning is not provided.

3) Monitoring observations with very wide-field 107 cm **VAU camera**. On the whole field the images are not distorted by aberrations due to the location of the film on a spherical focal surface. The archive has nearly 10000 films. It is not catalogued. The scanning is not supposed.

4) **FZT** photographic plates – the geodynamics observations were carried out in 1980. The catalogue of stars of the Moscow zenith zone is a result of these observations. It has been decided to keep only the archive.

Figure 1. The Zvenigorod astrograph Carl Zeiss-400.[2]

Figure 2. The camera VAU.[1]

Figure 3. The camera AFU-75 and the FZT in the background.

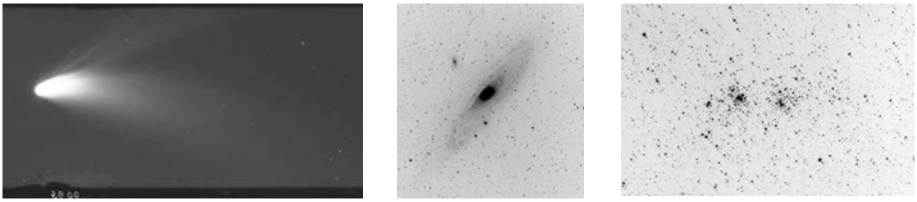

Figure 4. Picture of Hale-Bopp comet taken in the beginning of April 1997 with a length of a tail of 15 degrees, the observer is N.S.Bahtigaraev (left); The Andromeda galaxy (in the middle) and h and hi Persei open cluster (right) received by the astrograph.

[1] Nauchnye Informacii Astrosoveta, Moscow, 1986, **60**, 84.
[2] Zvenigorod Observatory Instruments (http://www.inasan.ru/rus/zvenigorod/instr.html).

3. DIGITIZATION OF THE PHOTOGRAPHIC PLATES

The basic result from the plate digitization will be a digital plate archive including about 4000 scans of the plates received by the astrograph.

The image archive structure includes:

1. Scans in FITS-format, approximately 700Mb each one as a main part of the digital arcive;
2. Preview scans archive with images in JPG and TIF file formats with the size of 3MB and 600MB correspondingly;
3. Original page scans of the observational logs in JPG and TIF file formats;
4. Catalogue of the plates in the WFPDB format (in ASCII file format given in http://cdsarc.u-strasbg.fr/viz-bin/Cat?VI/90).

The equipment for the project includes the two EPSON EXPRESSION 1640 XL scanners with the scanning parameters given in Table 2. The scanning plate was put with the emulsion downwards on the glass plane of the scanner.

Table 2: Scanning parameters

Parameter	**Work scan**	**Small preview**	**Large preview**
Image Type:	16-bit Grey	24-bit color	24-bit color
Resolution	1600 dpi	300 dpi	1200 dpi
Format of the image	fits	jpg	tiff
Scale	100%		
Document Type	Transparency		
Film Type	Positive film		
Trimming	Off		
Auto Exposure	On		

The accuracy of the coordinate measurements was checked in the Byurakan observatory. For Schmidt plates the root-mean-square deviation is equal of 0.33 arcsec. The photometric scan accuracy is 0.14mag (Nesci et al., 2003).

Acknowledgements

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COMPUTER MODELS FOR SKY IMAGE ANALYSIS OF THE INASAN ZVENIGOROD OBSERVATORY

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Abstract. The information systems including archives of digital copies of the Astrograph plate collection obtained in the Zvenigorod Observatory of the Institute of Astronomy, RAS, and means for access to those copies are developed. There are possibilities to have a look at preview photos in JPG, to view any part of the image from the primary file in FITS format with the ability to save and print the fragment. A remote access system is implemented on cross-platform SQL Server FireBird v.2.1.

1. INTRODUCTION

The Zvenigorod Astrograph plate collection includes more than 4.5 thousand plates. At the present time digitized plate records in FITS file format by mean of EPSON 1640 XL scanner are produced (for more information see in Chupina and Vereshchagin; Tsvetkov, 2005).

The need for automated processing of plates, digitized in FITS format and the necessary plate information is long overdue.

In this report we present the preliminary results from the attempt to transfer FITS format into the database and create software to obtain the necessary information from the database. This software should work both for the user located on the territory of the observatory (LAN), as well as outside the territory (WEB).

2. THE TASK OF CONSTRUCTING MODELS

The task of constructing models is to create a user-friendly software interface for viewing, copying and analyzing archival photographs of the sky. The main properties software interface includes:

1. Viewing files of low resolution scans in JPG format with the provision of information about the time of the observations, the coordinates of the center of the plate, etc.

2. Saving an external file and printing information.

3. Viewing any part of the scan with high resolution in BMP format providing information on the time of observations coordinates of the center of the plate, and information about the objects file (list of stars with known parameters, including name of stars and other important parameters). The query to the database can be used for variety of user's tasks: for example, to select plates for a certain star, to show the image of this star with the ability to print and copy it, and so on.

This problem is actually not trivial and requires a systematic approach. For example: as the program shell is created, then it should be provided to convert FITS format to BMP format – as the average size of the FITS file is 700 MB. Because of the need to obtain various information, this information should be stored in a database. It is necessary to select the appropriate database server, and, therefore, have the necessary means to access the server. Below is a list sequence of items that should have been resolved.

2.1. Development of a database

FireBird v.2.1. was chosen for the database SQL-server. It has the following advantages:
Cross-platform;
It consumes very little system resources;
SQL dialect is strongly developed;
There are powerful tools for administration and development;
Free.

2.2. Choice of software

A high-level language DELPHI was chosen to develop software shell. The main advantages are: fast speed of development, large selection of visual components for both the choice of the user interface and access to SQL server, object-oriented programming.

2.3. Development of control programs

This is the main and most time-consuming process of constructing the model. This item includes both the development of test programs and program development for the end user. To work with the files was necessary to develop several testing programs for the following tasks:

- Choice of coordinates of the center of the star and the image area:

1. Working with the file: Image of the file, copying and saving.
2. Analysis of error coordinates transformation of the plate in the stellar coordinates.

3. Analysis of errors converting the image area in magnitudes.
4. Automatic data processing and recording the basic parameters of the file in the database.

- User program:

1. To develop a program to view the database (local version) - available only to users connected to the LAN.
2. To develop a program to convert FITS in JPEG, including sample information from FITS, in view of transfer to a remote server.
3. Development of a selection of FITS without loss of resolution.
4. Development of queries in a database for retrieval of information, taking into accounts the transfer to a remote server.

3. THE MAIN RESULTS OBTAINED

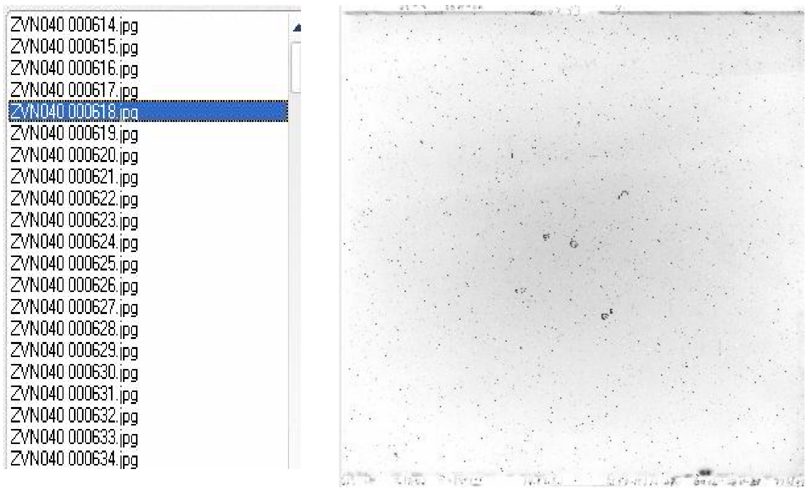

Figure 1. View of the list of files with low resolution.

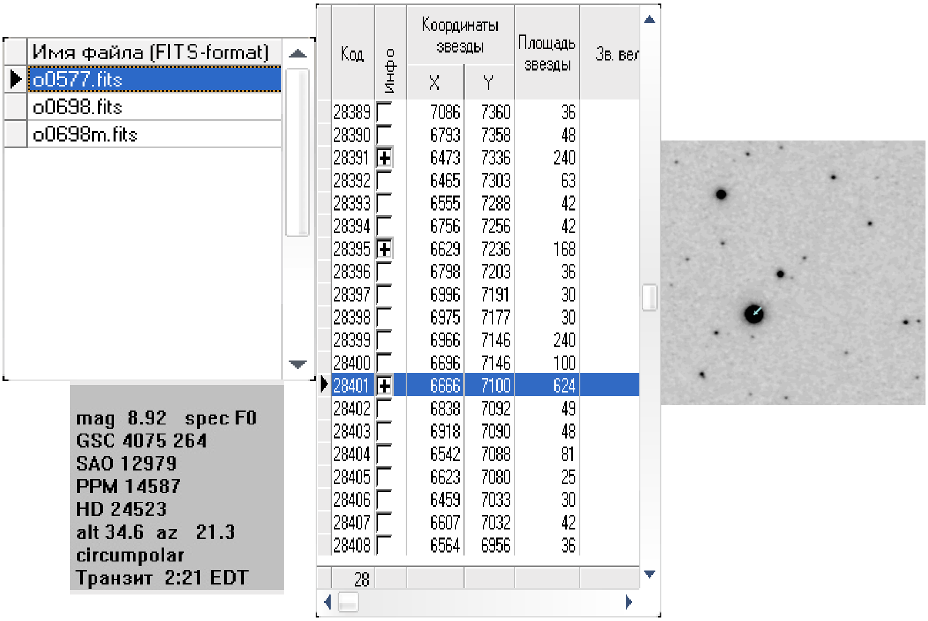

Figure 2. Selected FITS file and received information from the database.

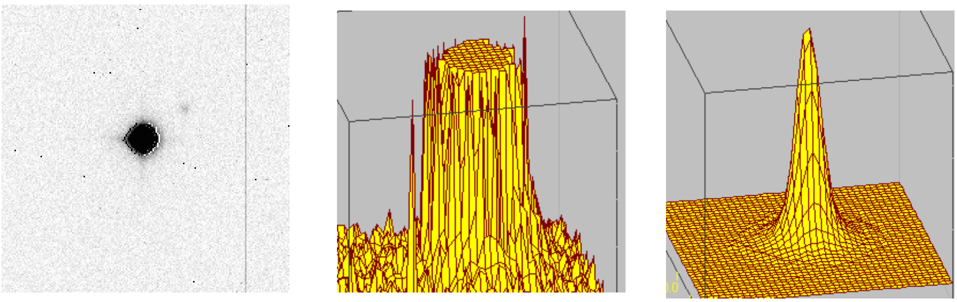

Figure 3. Distortion is the true spatial distribution of brightness caused by the nonlinearity of the transformation of FITS to BMP.

In Fig. 1 a list of plates that were converted to low-resolution preview files is shown. Information about files can be found in the database, as well as in (Tsvetkov, 2005).

Fig. 2 shows the process of selecting the necessary information on file 00577 (plate ZVN040 00,577). For this plate in the database there is a list of objects (stars, etc.) and information on each object. For example, an object with a unique code in the database 28401 is marked with a cross. This means that it is identified from the listed catalogs. This object is shown with arrow in Fig. 2 (bmp-format 700x700 pixel).

4. CONCLUSIONS

The work on this project continues today. Several problems have to be solved, namely:

- Getting the distribution volume of the brightness of the objects;
- Connection of the objects in the database with the catalogs of stars (Name of star, and so on).

After solving these problems the solution given in the paragraph 1 «The task of constructing models» seems a trivial task.

The author would be pleased to accept criticisms and suggestions for the development of this project.

It should be noted that the algorithms to automate the processing of plates of the Zvenigorod observatory are also applicable to other plates transferred to FITS-format.

Acknowledgements

I thank professor M. Tsvetkov for critical comments on the work.

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LOW STATE OF KR AURIGAE (2008 – 2010)

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Abstract. We report data from the present deep minimum of cataclysmic variable KR Aur, lasted more than 2 years. We present multicolor (UBV) simultaneous light curves obtained with the telescopes available at NAO Rozhen and AO Belogradchik. We detected strong flickering activity in the faint state during all observations.

1. INTRODUCTION

KR Aur is well known cataclysmic variable star, discovered by M. Popova in 1960 (Popova, 1960). It is interacting binary system, consisting of a white dwarf and a secondary red dwarf with orbital period 3.907 hour (Shafter, 1983). This object is classified as anti-dwarf novae or VY Scl type star: usually the brightness of KR Aur is about 13 mag (with variations of 1 mag), but occasionally mass transfer from the late-type star to the white dwarf fades and magnitude drops to 15–16 mag (intermediate state) or rarely to 18 -19 mag (low state). The previous minimum of KR Aur was too long and too deep: it continued from 1994 (Antov et al., 1996) to 2001 (Boeva et al., 2006). The behavior of its light-curve was very unsteady: the brightness varied between intermediate and weak values. In 2008 started another one deep state of KR Aur. Our data are from this new minimum lasting until now.

2. OBSERVATIONS

The observational data is received with the following telescopes at NAO-Rozhen and AO-Belogradchik:

- 2m reflector with optical system Ritchey-Chretien-Coude at NAO-Rozhen with corresponding equipment:

1. A dual channel focal reducer FoReRo2 (Jockers et al., 2000) with a CCD camera Photometrics (1024x1024) for the blue channel and a camera VersArray (512x512) for the red channel.
2. A CCD camera VersArray 1300B – 1340x1300, px size 20 µm at the direct telescope's focus.

- 50/70 Schmidt telescope at NAO-Rozhen with a CCD camera SBIG STL-11000M, 4008x2672 px, 9 µm and FLI PL 16803, 4096x4096 px, 9 µm.
- 60 cm telescope Cassegrain at NAO- Rozhen with FLI PL 9000, 3056x3056 px, 12µm.
- 60 cm telescope Cassegrain at AO-Belogradchik with CCD cameras SBIG ST8, 510x340px, 27 µm and FLI PL 9000, 3056x3056 px, 12µm.

We present observations from 24 nights in the period from January 5, 2008 to April 4, 2010. We obtained estimates of the brightness of KR Aur in V band as well as light curves in one or more bands lasted from 1 to 6 hours.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the long-term light curve of KR Aur between January 2008 (when the system was in high state) and April 2010 in V- filter.

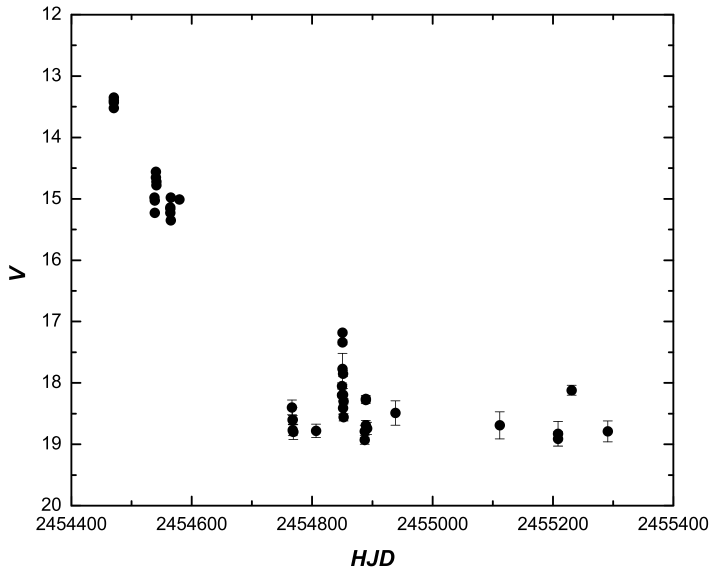

Figure 1. The light curve of KR Aur in V from January 2008 to April 2010.

In March - April 2008 we registered a decrease of the brightness – V magnitude was about 15. The V magnitude dropped down in the next month when the variable was not visible for observations. In October KR Aur was in low state with a typical magnitude 18-19. In January 2009 we registered a weak increase in the brightness up to 17 mag and until now we obtained V magnitudes in the range 18-19 mag with strong fast changes.

Fig. 2 presents the short-term variations (flickering) in April 2008. It is about 1 hour lasting light curve with brightness variations of about 0.5 mag in V band.

In Fig. 3 and Fig.4 we present UBV simultaneous observations obtained with 2 telescopes – 2 m at NAO Rozhen using dual channel focal reducer FoReRo2 for U and V bands and 50/70 cm Schmidt telescope at NAO-Rozhen for B band. The behavior of the brightness in these 3 different bands is similar with flickering amplitudes for U of about 1.5 and 0.9 mag respectively for January 20, 2009 and February 26, 2009, for B – 1.3 and 0.6 mag, and for V – 1.3 and 0.7 mag. The color indices are U-B ~ 1.0, B-V ~ 0.0. According to our observations the flickering activity of KR Aur never stopped completely as it has been observed for the similar variable MV Lyr (Robinson et al., 1981 and our observations) at low state. Thus KR Aur seems to be one of most active members of VY Scl sub-class variables.

KR Aur is unique object because only for these two VY Scl stars have been observed deep minima with duration of years. Additional observations of this variable are necessary to study the rare deep states.

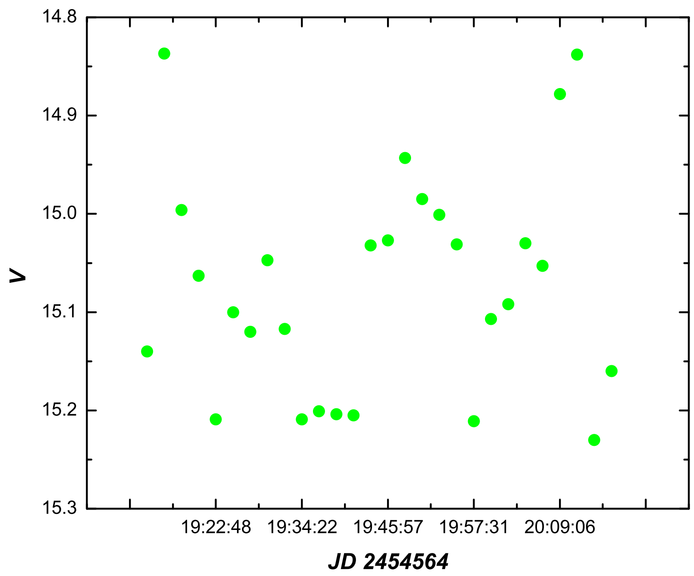

Figure 2. The fast variations of KR Aur on April 7, 2008 when the brightness decrease (intermediate state).

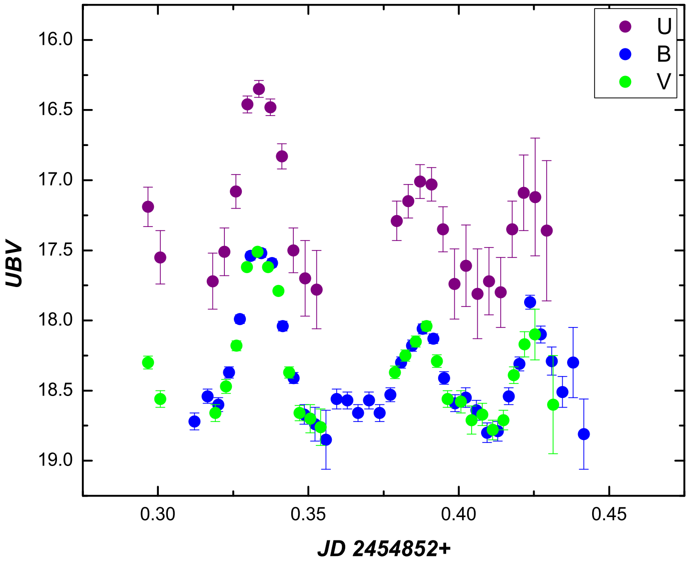

Figure 3. The simultaneous 3:15 hours lasting observations of KR Aur on January 20, 2009 in UBV.

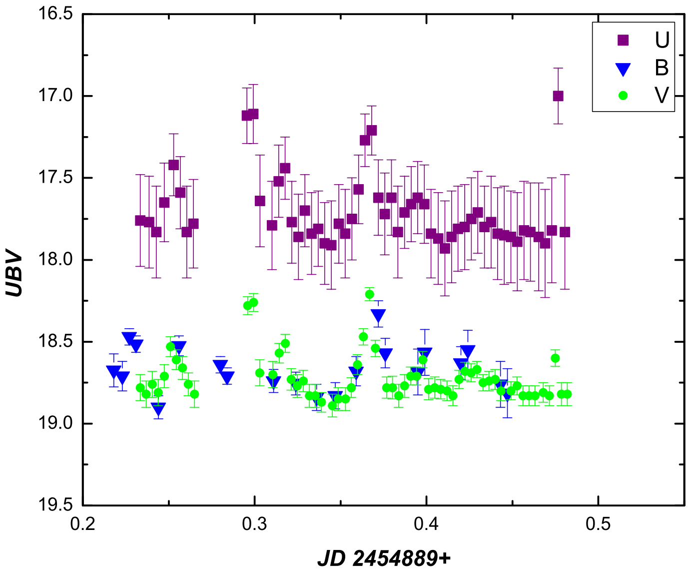

Figure 4. The simultaneous about 6 hours lasting observations of KR Aur on February 26, 2009 in UBV.

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STRUCTURE OF ACCRETION DISK IN THE PRESENCE OF MAGNETIC FIELD

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Abstract. This paper presents our results on the problem of the evolution of the disc. We investigate the development of accretion flow in its interaction with the magnetic field. We analyze the restructuring of the flow under the action of the ongoing processes and activity of instabilities. We consider distribution of entropy and locally heating and how it is tied to the emergence of a crown. We discuss influence of the magnetic fields over viscosity parameter. We investigate distribution coefficients k_φ (r, z) and ω (r, z) and connection with behavior of wave numbers k_φ (K), k_r (K) and ω (K).

1. INTRODUCTION

Accretion processes effective converts mass of a substance into energy. This energy is transformed into radiation and emitted by the disc surfaces. Such objects can process up to 50% of rest mass of matter into energy. They are learned especially actual in the world because they are powerful energy sources in outer space. Accretion discs are among the most widely used objects in the universe, not only in time and space, but also in evolutionary terms. As an example, the quasars are objects with large red displacement and most of them belong to the early universe. On the other hand accretion discs present in almost all stages of evolution of stars and their subsystems- from protostellar, proto-planetary discs through relatively cold discs residues, asteroid belts and rings of planets to accretion discs of compact objects in the ended life of the stars.

In the accretion discs various instabilities and structures are developing, that govern the distribution of energy there. They are expressing into huge numbers of non-stationary phenomena that we observe.

Accretion is qualitatively and quantitatively more effective when the picture include the presence of a magnetic field. In the processes of interaction are formed three main streams: disk corona and jet (Balbus and Hawley, 1998), which are genetically related. Each of these mega-structures has its own energetic, which is part of the total, but some objects may be autonomous subsystem.

For us here is the important role of the principal components - Accretion disk because the process of its evolution to create the conditions for the emergence of other major components of the system. This article will trace in the evolution of the disc, the reasons the birth of its corona. We would like to find out how the interactions of plasma flow and magnetic field in the disc, allowing for the development of a crown.

2. BASIC EQUATIONS

We investigate the basic equations of magneto-hydrodynamics for non-stationary and non-axis-symmetrical accretion flows. We construct model of the disc:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \boldsymbol{v}) = 0$$

$$\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}.\nabla \boldsymbol{v} = -\frac{1}{\rho}\nabla p - \nabla \Phi + \left(\frac{\boldsymbol{B}}{4\pi\rho}.\nabla\right)\boldsymbol{B} + \vartheta \nabla^2 \boldsymbol{v} \qquad \Phi = \frac{GM}{\boldsymbol{r} - r_{\mathrm{g}}}$$

$$\frac{\partial \boldsymbol{B}}{\partial t} = \nabla \times (\boldsymbol{v} \times \boldsymbol{B}) + \eta \nabla^2 \boldsymbol{B} \qquad \eta = \frac{c^2}{4\pi\sigma}$$

$$\rho T \frac{\partial S}{\partial t} - \frac{\dot{\boldsymbol{M}}}{2\pi \boldsymbol{r}} T \frac{\partial S}{\partial \boldsymbol{r}} = Q^+ - Q^- + Q_{\mathrm{mag}}$$

$$p = p_{\mathrm{r}} + p_{\mathrm{g}} + p_{\mathrm{m}}$$

It is one-temperature, geometric thin, optical thick Keplerian disc with advection in the normal magnetic field. The fluid is incompressible the disc is without self-gravitation. Different instabilities create the irregular periodicities in changeability of material features, which should not be neglect and can be used. Where $r_0 = 10^n R_g$, F_{i0} are the values of the outer edge of the disc.

$$\boldsymbol{F}_{\mathrm{i}} = \boldsymbol{F}_{\mathrm{i}0} \Re_{\mathrm{i}}(x = \boldsymbol{r}/r_0, Z = \boldsymbol{z}/r_0) exp[k_\varphi(x,Z)\varphi + \omega(x,Z)t] = \boldsymbol{F}_{\mathrm{i}0} f_{\mathrm{i}}(x,Z)$$

The coefficient *ω(r, z)* indicates how often the flow deflects, because of meeting structure or a spontaneous disturbance on its way. The coefficient $k_\varphi(r, z)$ is sinus of the central angle (in radians) between such disturbances of one orbit. We are called *ω(r, z)* and $k_\varphi(r, z)$ meeting coefficients. Chose of periodic function is not random. It is prompted by analogy with the Poisson distribution in statistics, for encounter the flow with structure or spontaneous disturbance and is associated to the advective nature of the disc. In this way accepting periodicities by t and φ are dependable on the distance from the centre r and height on the equatorial plane z. Such presenting allows keeping non-obvious dependence of leading parameters by time and angle, searching solution only according variables x and Z. Coefficients presents feedback (not-obvious) between flow characteristics and its instabilities, which exist as shown (Balbus and Hawley, 1998) (they do not define it).

Registered in the 2D-solution rings with higher density are short living formations with constant entropy in time and they can be considered locally. It could be assumed in first approximation that angular momentum, sonic and magneto-sonic velocities of such ring are constant. Basic equations are averaged by z. We bring in the physical quantity: local warming with which can express the three wave numbers and we obtained the local dependence of instabilities from warming – wave numbers depending on the disc features. Now is necessary to include global distributions of the flow characteristics, to show dependencies $\omega(K)$, $k_{\varphi}(K)$ and $k_r(K)$ in fixed orbit. Also we obtained the distribution of the average local warming on the disc (feeding up of instabilities) (Yankova and Filipov, 2003).

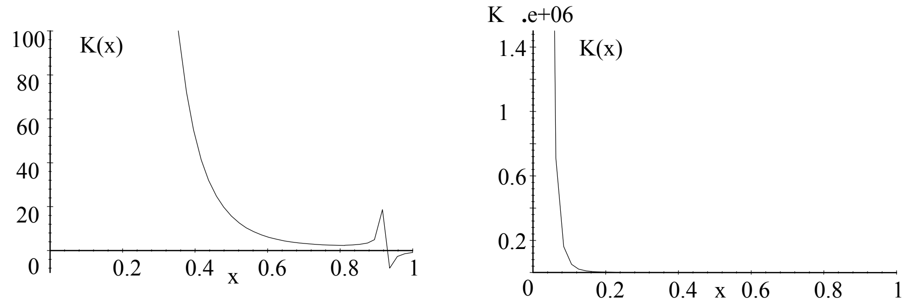


Figure 1. Distribution of average local heating in the disc at the moment t ~ 1P, in small (a) and large increases (b).

3. RESULTS

The results obtained from (Yankova and Filipov, 2003) local solution shown disc as a self-structuring system. Describe the influence of magnetic viscosity over the full vertical structure and advection as a precondition to reorder the disk.

Here are shown the results of two real objects:

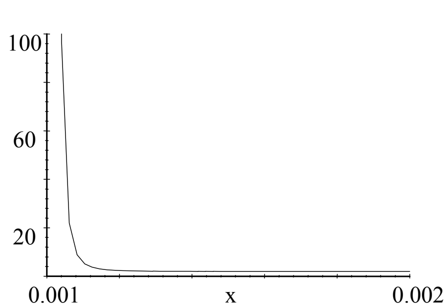
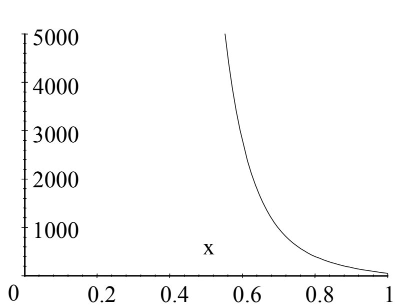


Figure 2a. Distribution of the dimensionless gradient function of entropy in the disc for t = 1P.



Distribution of the dimensionless gradient function of entropy in the disc for t ≈ 0.

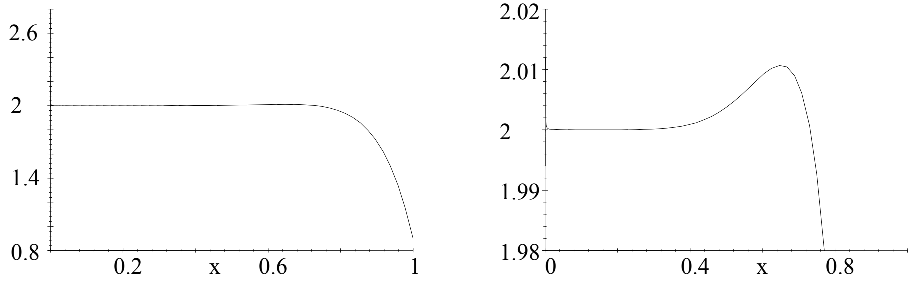


Figure 2b. Maximum at x~0.65(650R_g). Minimum at x ~ 0.16 (160R_g).

In Fig. 2 we see the distributions of the Cyg X-1 have weak negative gradient of entropy in the range x ~ 0.16 ÷ 0.65, from which it follows that a significant proportion of the energy remains in the disk and supplies instability. Its local disk warming (Fig. 3) reflects the areas in which the disk cools efficiently (x> 0.2) or low (x <0.2).

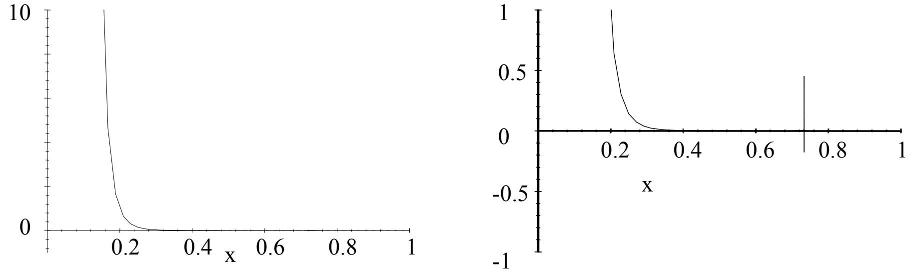


Figure 3. Distribution of the function of local warming K (x) when t = 1P~ Ω_0^{-1}. Disturbance of the inflow reaches ~ 731-732R_g.

Distribution K (x) of SgrA* (Figure 4) can be concluded that almost all disk is cooling successfully on behalf of advection and increase the amount of instability. This has all the wave numbers decreased with increased warming in the ring (we showed it in), which strengthens the argument for the belief that this disc MRI increased size. Number born instability essentially is not reduced, decreasing the number of existing item k in time. For mutual growth, they are swallowed. So fall ω (K).

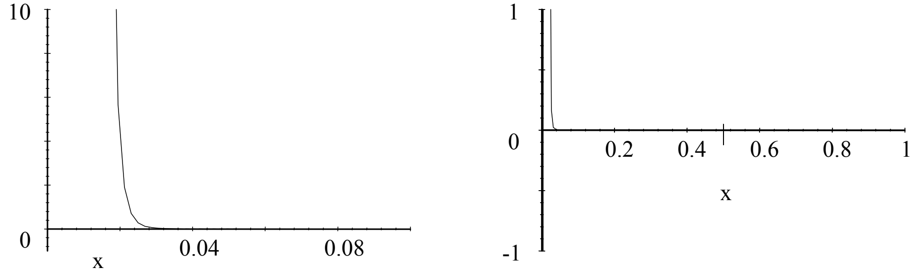


Figure 4. Distribution of the function of local warming to the point of inflow ($\varphi_0 = 0$) when $t=1P\sim\Omega_0^{-1}$.

Disturbance in the spiral reaches ~ $50R_g$ the disk and is even less than Cyg X-1.

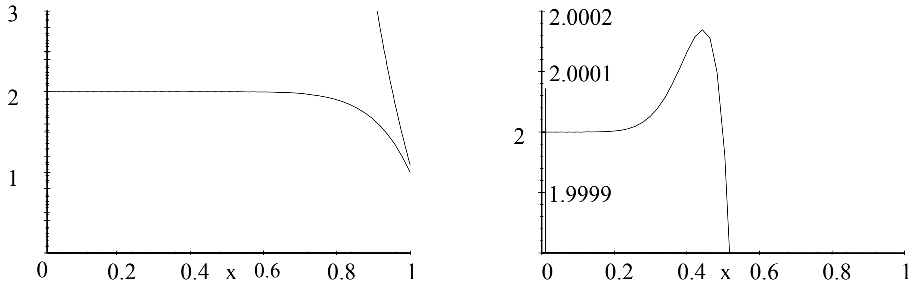


Figure 5a. Distribution of the dimensionless gradient function of entropy in the disc for $t=1P\sim\Omega_0^{-1}$.

Maximum at x ~ 0.44 ÷ 0.45 (44 ÷ $45R_g$)

No minimum.

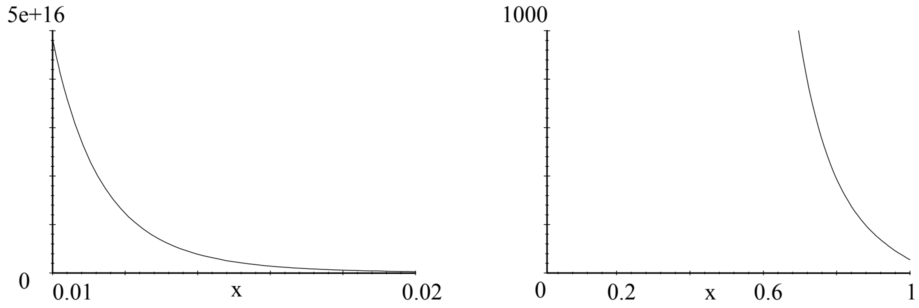


Figure 5b. Distribution of the dimensionless gradient function of entropy in the disc for $t \approx 0$.

4. DISCUSSION

With a sufficiently weak magnetic field members of turbulent viscosity in the disk as a result of SFI + MRI, both factors leading to linear instability can be ignored: 1) in the kinetic viscosity the relay criterion is met because on the disc for a smooth profile Ω(r); 2) in a differential system with a rotating magnetic field always leads to displacement dynamo, but not to the dynamo action. After an initial increase magnetic energy decreases due to dissipation of the field and the dynamo establish in state, where only offset losses. Oscillating field is obtained if α is negative in one hemisphere, than the energy transferring periodically from toroidal to radial component of the field and vice versa. While the dynamo number $D < D_{cr}$, (as for $D > 0$ there is stability, but for $D < 0$ – oscillation) and $D \approx D_{cr}$. That is reason for self-excitation dynamo and MRI appearing. Thay works for a small scale, when there is no stratification and for a big one, when there $v_{ms} < v_s$. The negative α-effect is caused by the fluctuations of v_z, which control the magnetic buoyancy due to shifting. If shifting in the disc is negative, the buoyancy dominates and the α-effect is negative, however, the advection leads to a positive α-effect. Consequently, the effect changes its sign for small shifting (weak field). The negative α-effect could generate a dipole field. 3D-simulations indicate that MRI could support such field even in a global model (Brandenburg and Subramanian, 2004).

Then the disc non-linear effects provide reallocation of the energy, the field and the angular moment. Coefficient $\alpha_t = \alpha + \alpha_m$

$$\alpha_t = \frac{v_t^2 + v_{ms}^2}{v_s^2}, \quad \text{where} \quad \alpha = \frac{\left\langle \overline{v_r}\,\overline{v_\varphi} \right\rangle}{v_s^2} \sim v_t^2 \tau_t \quad \text{and} \quad \alpha_m = \frac{\left\langle \overline{b_r}\,\overline{b_\varphi} \right\rangle}{4\pi \rho v_s^2}.$$

Most energy has found itself in long wave modes; the main transport of moment also comes from them. MRI is fast growing. Non-linear saturation is the increasing range of their modes (E_k and E_m are increasing exponentially). The growing strongly depends on the configuration of main field. From toroidal field where they are missing to vertical - uniform where are best expressed while $v_a < v_s$. Approximation of the main field in our case strongly recalls the last. For the vertical field (may be not uniform), the asymmetric MR- mode grows the fastest. Saturation from reconnection and dissipation of magnetic field created a powerful magnetic pressure, which with the help of the instabilities of Parker and RTI is transporting and formed strongly magnetize corona. This preserves the equilibrium of energies $E_m \sim E_k$ in the disk and magnetic field cannot inhibit rotation effects and to quench magnet-rotation instability (Brandenburg and Subramanian, 2004).[1]

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[1] Biskamp D., MHD Turbulence, Cambridge University Press.

Reconnections of the magnetic lines are reducing and the distance between the loops increases, so the surplus magnetic energy is released in the new configuration. Back in the presence of negative entropy gradient (figures 2 and 5) of creating conditions for increased instability in energy absorption. Stabilize them as structures and leads to a new disk (using an irreversible transition) state.

As shown in (Yankova, 2009) the coefficients of meeting correlate to the wave numbers of the local model, but in the outer regions there is no mechanism to distinguish functions. In inland areas, the prohibiting the existence of MRI distinguishes them quite clearly and could see the functions separately. The same is shown here, but for each object (figures 6÷10). This is a convenient indicator to assess what is happening. Finally, as shown and referred to summarize the results may predict that MRI leave internal regions of the disk before they are ruined, as entities.

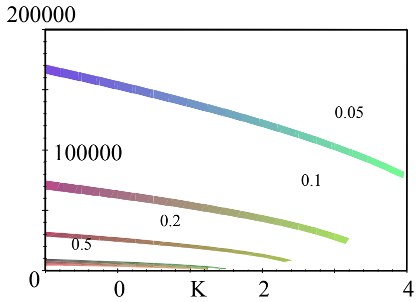
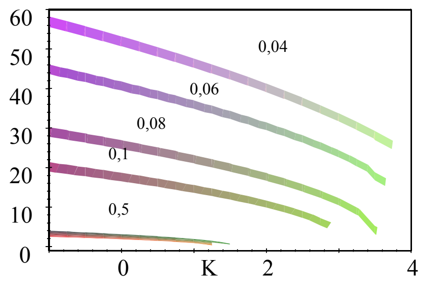


Figure 6. Contours $\kappa_r(K)$ for x~const. Cyg X-1



Contours $\kappa_r(K)$ for x~const. SgrA*

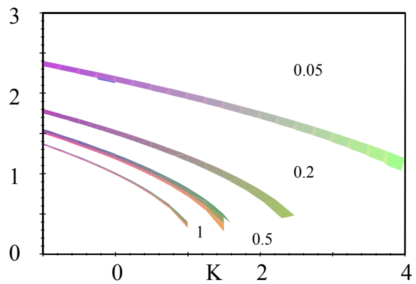
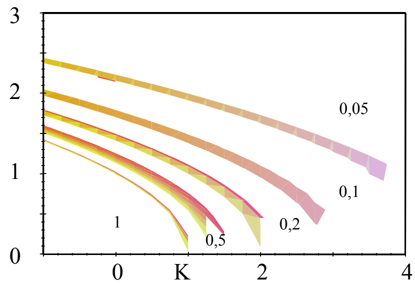


Figure 7. Contours $\kappa_\varphi(K)$ for x~const. Cyg X-1



Contours $\kappa_\varphi(K)$ for x~const. SgrA*

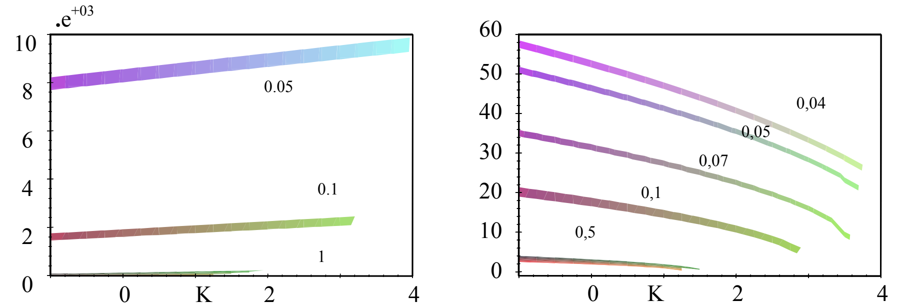


Figure 8. Contours ω(K) for x~const. Cyg X-1

Contours ω(K) for x~const. SgrA*

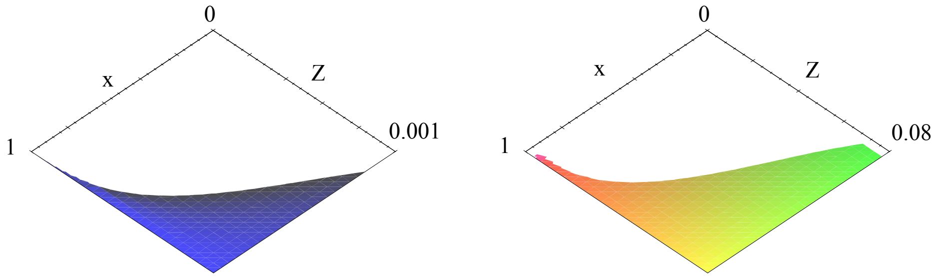


Figure 9. $f_7(x, Z)$ – dimensionless function of distribution coefficient ω (r, z) for Cyg X-1 at the moment $t \approx 1P \sim \Omega_0^{-1}$.

$f_7(x, Z)$ – dimensionless function of distribution coefficient ω (r, z) for SgrA* at the moment $t \approx 1P \sim \Omega_0^{-1}$.

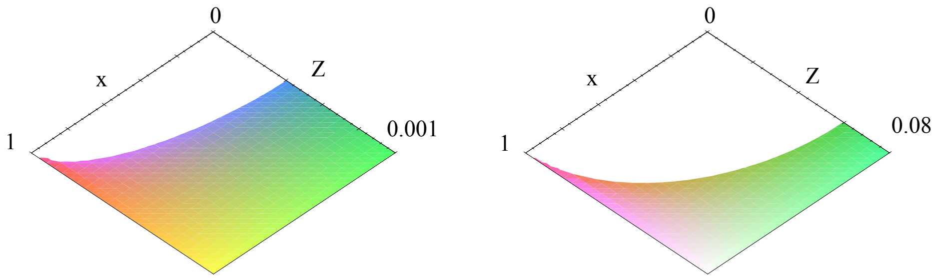


Figure 10. $f_8(x, Z)$ – dimensionless function of distribution coefficient $k_\varphi(r, z)$ for Cyg X-1 at the moment $t \approx 1P$.

$f_8(x, Z)$ – dimensionless function of distribution coefficient $k_\varphi(r, z)$ for SgrA* at the moment $t \approx 1P$.

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AUTHORS' INDEX

Conference photo.
First row: Valery Hambaryan, Milcho Tsvetkov, Milan S. Dimitrijević, Katya Tsvetkova, Luka Č. Popović.

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