ASTROINFORMATICS

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ASTROINFORMATICS AS A NEW RESEARCH FIELD: UKRVO AND VIRGO RESOURCES

I.B. Vavilova

Main Astronomical Observatory, National Academy of Sciences of Ukraine,
27 Akademika Zabolotnogo, Kyiv, 03143, Ukraine, *irivav@mao.kiev.ua*

ABSTRACT. The data-oriented astronomy has allowed classifying the *Astroinformatics* as a new academic research field, which covers various multi-disciplinary applications of the e-Astronomy. Among them are the data modeling, data mining, metadata standards development, data access, digital astronomical databases, image archives and visualization, machine learning, statistics and other computational methods and software for work with astronomical survey and catalogues with their teta- to peta-scale astroinformation resource.

In this review we describe briefly the astroinformatics applications and software/services performed for different astronomical tasks in frame of the VIrtual Roentgen and Gamma Observatory (VIRGO) and Ukrainian Virtual Observatory (UkrVO). Among them there are projects based on the archival space-born data of X-ray and gamma space observatories and on the Joint Digitized Archive (JDA) database of astroplate network collections. The UkrVO JDA DR1 deals with the star catalogues (FON, Polar zone, open clusters, GRB star fields) as well as the UkrVO JDA DR2 deals with the Solar System bodies (giant and small planets, satellites, astronomical heritage images).

Keywords: Astroinformatics: methods – Star catalogues – Galaxies – High-energy astrophysics

1. Introduction

Astroinformatics is introduced as the new data-oriented approach and advanced methodology for processing astronomical survey and catalogues with their teta- to peta-scale astroinformation resource. Space observatories and ground-based telescopes provide a large volume of data over entire electromagnetic spectrum. Technical architecture (user layer, VO core layer, resource layer) for processing this resource was proposed by the IVOA Executive Committee. Such approach allows easy access to the metadata due to the interoperability between different astronomical archives and data centers.

"Many scientific disciplines are developing formal subdisciplines that are information-rich and data-based, to such an extent that these are now stand-alone research and academic programs recognized on their own merits. In astronomy, peta-scale sky surveys will soon challenge our traditional research approaches and will radically transform how we train the next generation of astronomers, whose experiences with data are now increasingly more virtual (through online databases) than physical (through trips to mountaintop observatories). We describe Astroinformatics as a rigorous approach to these challenges" (cited by "Astroinformatics: A 21st Century Approach to Astronomy", Borne et al., 2009; see, also, Eastman et al., 2005; Gray et al., 2005; Butler, 2007; Cavuoti S., 2012; Vavilova et al., 2012a; Goodman et al., 2012; Borne, 2013; Brescia & Longo, 2013; Norris et al., 2013; Ruiz et al., 2014).

We note the WDC-Ukraine, which is a part of World Data Center System of the International Council of Science (ICSU). Among the basic tasks of WDC-Ukraine there is collection, handling and storage of science data and giving access to it for usage both in science research and study process. That include contemporary tutoring technologies and resources of e-libraries and archives; remote access to own information resources for the wide circle of scientists from the universities and science institutions of Ukraine. The resource of WDS-Ukraine is mainly used for geo-informatics, space weather, and astroinformatics projects.

The crucial role in promulgating new methods and services into the broader astronomy community belongs to the International Virtual Observatory Alliance (IVOA). At the beginning of the era of big data it initiated a creation of the national virtual observatories and development of the infrastructure of astronomical data center. Such centers give to users handy tools for data selection from large astronomical catalogues for a relatively small region of interest in the sky (see, for example, for GOODS: Giavalisco, 2004; for SDSS: D'Abrusco, 2007; "The National Virtual Observatory: Tools and Techniques for Astronomical Research, 2008), data standards and services for image processing (likely to Aladin) and manuals for processing the raw space-born data of various space missions (Chandra, XMM-Newton, Swift, NuStar, WISE, Kepler, GAIA, etc.). Besides the virtual observatories there are other sources for public outreach, for example, the well-known Astrostatistics and Astroinformatics Portal (ASAIP, http://asaip.psu.edu) (Feigelson, 2013; Feigelson, Hilbe (2014)); China Virtual Observatory Portal (Chenzhou et al., 2012), Euro-VO (Buddelmeijer, 2013), Russia VO (Klipio et al., 2003); Data centers and systems as NED, HEASARC, SkyHound, NStED, SIMBAD, Planetary DS, and other (for a brief review on the multi-wave length surveys, see, Michaelian, 2016).

Ukraine Virtual Observatory (UkrVO) has been an IVOA member since 2011 (http://ukr-vo.org/). The current UkrVO concept supports development of astro photo plate archives in the form of direct images of certain sky areas and celestial objects, as well as the spectra of celestial objects for multi-wave length studies of their properties (Vavilova et al., 2012b, 2014).

Virtual observatory VIRGO.UA for cosmology and high-energy astrophysics is a segment of VO "Infrastructure", which deals with ensuring the provision of standards for Grid Services for virtual organizations (http://virgoua.org/).

In this review we describe briefly the astroinformatics applications and software/services performed for different astronomical tasks in frame of the Ukrainian virtual observatories – VIRGO and UkrVO.

2. Virtual Roentgen and Gamma Observatory (VIRGO) data center and services

Despite the overall success of the project VIRGO, number of Ukrainian astronomers who use the data of X-ray and gamma-ray observatories is still small. To overcome this problem, a web-based virtual observatory VIRGO (http://skyview.virgoua.org) as a "sky map" was developed (Figure 1). It allows visualizing the distribution parameter (intensity of signal, etc.) in space and the range energies setting by the user. From the analysis of such a large number of web interfaces it can be noted that the main progress in their development is associated with easier access to data and improve their visualization. Besides these two aspects, it was introduced a new approach to the quality of data provided by the user. In our opinion, one of the main reasons that an obstacle to the use of data in scientific studies, there is uncertainty value bias, which is usually not considered by the available standardized software. One of the examples of using these sky maps in 2–5 and 5–10 keV range with a public database of X-ray observations by XMM-Newton is a search of the dark matter decay line (Boyarsky et al., 2014; Savchenko, 2014: Yakubovsky et al., 2015).

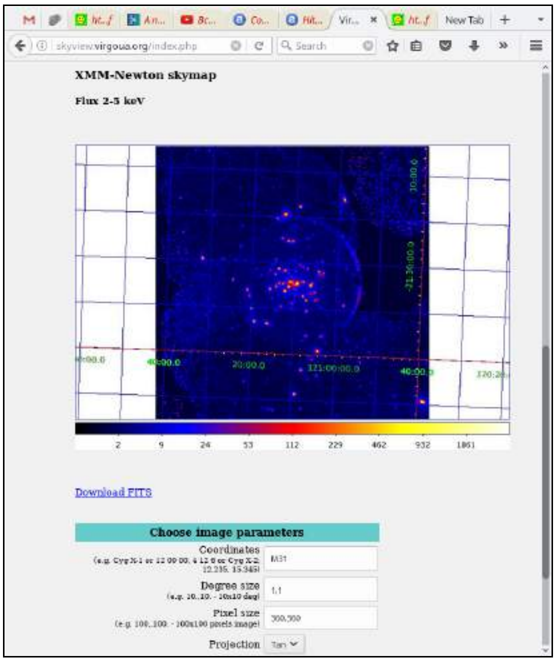

Figure 1: Screenshot of the interface "XMM-Newton sky map" (http://skyview.virgoua.org) from the VIRGO web-site.

The possibility of combining observational data obtained by ground-based telescopes and space observatories allows analyzing multi-wave physical properties of celestial bodies in more holistic measure. With this aim we prepared the new specially-oriented astro-space databases obtained with ground-based telescopes and space observatories. As a result, multi-wavelength spectral and physical properties of galaxies and galaxy clusters were analyzed in more details. These samples are as follows:

1) to study the spectral properties of quasars and the distribution of matter in intergalactic scales using Lyα forest (Ivashchenko et al., 2014; Torbaniuk O., :2015,:2016):

• sample of 3535 quasars from the SDSS DR7, redshift $2.3<z<4.6$; spectrum of a good quality (high signal to noise ratio), available in the spectral view of the sky;

• sample of 33 quasars with $z>2$, with high resolution spectra in publicly accessible ESO base;

• sample of 102643 quasars from the SDSS DR10 (including the sample "for composites" – 65976). Other objects: 11192 quasars with broad absorption lines (BAL); 6804 quasars with DLA- systems; 1248 quasars with absorption lines in Lyα; 493 quasars in line with the absorption Lyβ; 20 "normal" galaxies or galaxies with star-formation; 617 quasars with properly defined redshift; 1507 objects, whose spectra have low signal-to-noise (impossible to identification); 417 incomplete spectrum (for example, there is only part of the spectrum); 191 blazar's candidate;

2) to study galaxies (including with active nuclei) in spite of their evolution and formation of large-scale structures in the Universe as well as the influence of the environment on the internal parameters of galaxies:

• sample of about 260,000 galaxies from SDSS DR9 up to $z<0.1$ to study their properties depending on environment, star-formation etc. (Dobrycheva, 2013; Dobrycheva et al., 2012, 2014, 2015);

• sample of 1429 active galactic nuclei (AGN) type I, 123 AGNs of type II, 10 BLRGs from SDSS DR7 with $0.1<z<1.1$ in the field of view WiggleZ (Ivashchenko et al., 2015); and blazars (Vol'vach et al., 2011);

• sample of 95 AGNs selected from the 22-month Swift/BAT all-sky survey and spectra for these objects from XMM-Newton and INTEGRAL/IBIS in 0.5-250 keV (Vasylenko et al., 2015);

• sample of 62 2MIG isolated galaxies with active nuclei to $z<0.05$ (Chesnok et al., 2009; Chesnok, 2010; Pulatova et al., 2015), which is considering as unique for recognizing their internal multiwavelength properties and physical parameters of accretion on the supermassive black holes outside of the environment.

3) to test cosmological parameters and the evolution of matter in a wide range of age of the Universe. The nature of dark components Universe – dark matter and dark energy – is one of the major challenges of modern cosmology. For this purpose, the key is the data on the CMB anisotropy obtained by WMAP and Planck, and data on the large-scale structure of the universe. Last baryon acoustic oscillations (BAO) include power spectra of galaxies, galaxy clusters, and Lyα-forest. However, information on the optimum cosmological model is important for data analysis of extragalactic observations.

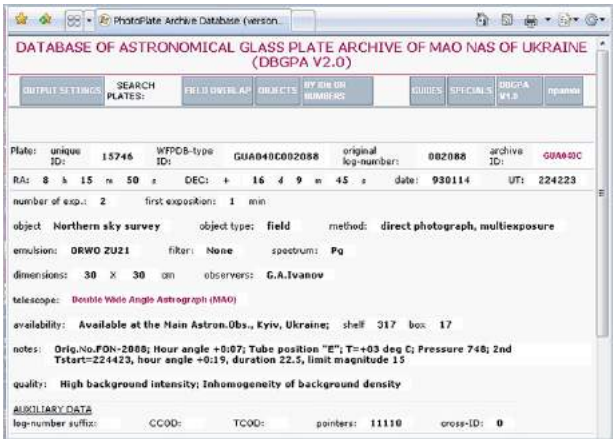

Figure 2: Screenshot of the interface of the UkrVO Joint Digitized Archive of astroplates, N=46 607 up to the current date (http://gua.db.ukr-vo.org/archivespecial.php; see, also, http://www.skyarchive.org for the wide-field astroplate database).

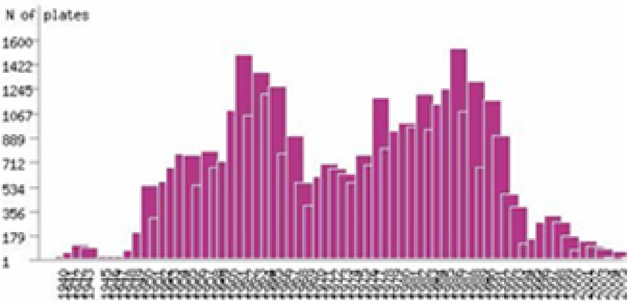

Figure 3: UkrVO Joint Digitized Archive of astroplates: distribution by years of observations.

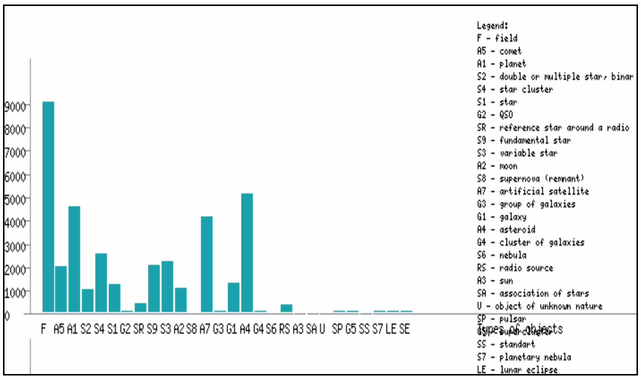

Figure 4: UkrVO Joint Digitized Archive of astroplates: distribution by research fields.

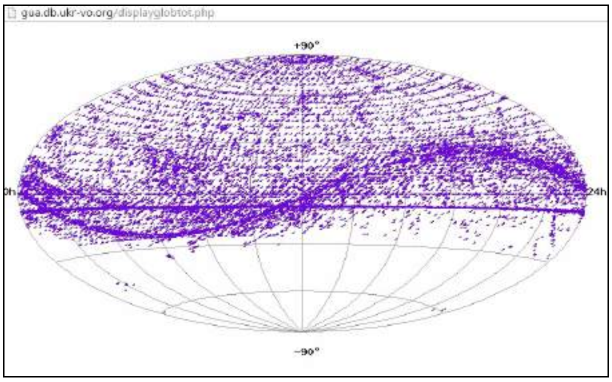

Figure 5: UkrVO Joint Digitized Archive of astroplates: distribution of astroplates over the sky (41,000 observations conducted with 32 telescopes of 20 to 412"/mm; exposure time is from 1 s to 1.5 h).

• sample of about 130 galaxy clusters at z<2 observed by "Chandra" and other X-ray observatories (Babyk et al., 2014; Babyk, 2016) for determining a visible and dark matter content in galaxy clusters;

• sample of the power spectra of CMB temperature fluctuations obtained in space experiments WMAP (WMAP9) and Planck, supplemented by data on the CMB polarization; sample for measuring the Hubble constant with HST; sample for BAO from SDSS DR7, DR9 and 6dF [12]; the power spectra of galaxies from WiggleZ Dark Energy Survey; the distance to SN Ia from compilations of SNLS3 and Union2.1. It was obtained that a combination of data sets, which include BAO data, – Data Planck2013 +HST+BAO+SNLS3 – gives the most accurate determination of cosmological parameters from the narrowest confidence intervals (Novosyadlyj et al., 2014; Sergijenko et al., 2015).

3. UkrVO Joint Digitized Archive of Astroplates

The UkrVO's development allows us 1) to save the unique astronomical observational heritage accumulated in observatories of Ukraine from the 1890-ies; 2) to open the wide on-line access to the joint database of digitized astronomic negatives and spectra for the national/foreign scientific community. The current state is available at the UkrVO web-site. At the initial stage, this task concluded in the creation and development of the Joint Digital Archive (JDA) of photographic observations. The total number of photographic plates in the UkrVO collection exceeds 300 thousands, including not only the positional but also the spectral and photometric observations. The current JDA version includes, at mainly, the positional observations of various celestial bodies. About 125,000 astroplates (Ukrainian Plate Archives) are included in the Wide-Field Plate Database by Tsvetkov M. (Kolev et al., 2012) (http://www.wfpdb.org/catalogue.html).

A preliminary processing of the digitized images of astroplates was done with a MIDAS/ ROMAFOT special software: registration of objects till 16^m, determination of pixel coordinates and photometric values (Protsyuk et al., 2014a, 2016). The errors of Epson scanners arising during processing the astroplates were tested in works by Golovnya et al. (2010), Protsyuk et al. (2014b, 2014c). They are equal to $\sigma_{x,y} = \pm$ 0.02-0.06 px and $\sigma_m = \pm$ 0.015-0.024 mag for astrometry and photometry, respectively. Another soft ware was developed for obtaining the equatorial coordinates and magnitudes of objects on the digitized astroplates (see, in detail, Andruk et al., 2015b).

Now the UkrVO JDA gives access to ~50,000 digitized astroplates of a good quality (its interface is illustrated in Figure 2). The UkrVO JDA Data releases, which were performed by scientists from Kyiv, Mykolaiv, Odesa, L'viv and Crimea including those in a tight international cooperation, are in a final stage for issuing. UkrVO Data Release 1 deals with the star catalogues (FON, Polar zone, open clusters, GRB star fields). UkrVO Data Release 2 deals with the Solar System bodies (giant and small planets, astronomical heritage images). Source of these data: the digitized astroplates, which were organized as the UkrVO JDA database of astroplate network collections of different institutions as owners of these collections.

The histograms of a number of the digitized astroplates by years and by research fields, as well as distribution of objects over the sky are given in Figures 3-5, respectively.

3.1. UkrVO JDA Data Release 1: Star catalogues

Aforementioned software was tested many times and applied for creation of new catalogues and samples with different purposes (Andruk et al, 2015a, 2015b;. Kazantseva et al, 2015;. Muminov et al, 2016;. Muminov et al,. 2017; Protsyuk et al, 2014d;. Yatsenko et al, 2011; Yizhakevych et al, 2014, 2015).

Catalogue of the equatorial coordinates and the B-values of stars of a Kyiv part of the FON program. This catalogue contains 19,568,347 stars and galaxies to $B \leq 16.5^m$ for the 1988.1 epoch (Andruk et al., 2016a, 2016b; Pakuliak et al., 2016). Number of processed astroplates is 2260. Their digitization was carried out by Microtek Scan Maker 9800XL TMA and Epson Expression 10000XL, scanning mode – 1200 dpi, the size of most plates is 30x30 cm or 13000x13000 pixels. Coordinates of the stars and galaxies were obtained in the Tycho-2 catalog system, B-magnitudes in photomeric standards system (Andruk et al, 1995;. Kornilov et al., 1991; Mermilliod, 1991; Relke et al., 2015). Intrinsic accuracy for all objects is $\sigma_{\alpha\delta} = \pm 0.23''$ and $\sigma_B = \pm 0.14^m$ (for stars in the range of $B = 7^m - 14^m$, errors are $\sigma_{\alpha\delta} = \pm 0.10''$ and $\sigma_B = \pm 0.07^m$) for the equatorial coordinates and B-magnitudes, respectively. Convergence between the determined and referenced positions is $\sigma_{\alpha\delta} = \pm 0.06''$, and the convergence with photoelectric star B-magnitudes is $\sigma_B = \pm 0.15^m$. Coordinate's errors related to the UCAC-4 are $\sigma_{\alpha\delta} = \pm 0.30''$ (18,742,932 or 96.36% of objects were identified) (Zacharias et al., 2013).

Catalogue of the equatorial coordinates and the B-magnitudes of the Kitab's part of the FON program. Observations in frame of the FON program were conducted also at the Kitab Observatory (Academy of Sciences of Uzbekistan) from 1981 to 1996 with telescope DAZ telescope (F/D = 40/200). In 2015, about of 2600 astroplates were transported to the Institute of Astronomy in Tashkent (Uzbekistan), where their digitizing has started (Muminov et al., 2013). The digitized astroplates are being processed till now at this institute and also at the Walter Hohmann Observatory (Essen, Germany), Nikolaev Astronomical Observatory (Ukraine), and at the Main Astronomical Observatory NAS of Ukraine in Kyiv (1250 astronegatives up to current date). A preliminary estimation of intrinsic errors of this catalogue is based on the results of astronegatives for region α [21^h, 3^h], δ [-2^o, -6^o]: the averaged errors are $\sigma_{\alpha\delta} = \pm 0.2''$ and $\sigma_B = \pm 0.18^m$ (for stars with $B<14^m$ they are equal to $0.1''$ and 0.1^m) for the equatorial coordinates and B-magnitudes, respectively (Yuldoshev et al., 2016a, 2016b).

U-magnitudes of stars and galaxies from the digitized astroplates of 1.2m Schmidt telescope in Baldone Observatory (Latvia). Archives of the Schmidt telescope contains 734 astroplates in 253 regions of the sky captured in U-band close to the U-Johnson (Eglitis et al. 2016a, 2016b). At the moment, it is scanned about 300. The coordinates of stars and galaxies are obtained in Tycho-2 system, the U-values in the photoelectric standards.

Intrinsic accuracy for all objects is $\sigma_{\alpha\delta} = \pm 0.28''$ and $\sigma_B = \pm 0.20^m$ (for stars in the range of $B = 8^m - 14^m$, errors are $\sigma_{\alpha\delta} = \pm 0.11''$ and $\sigma_B = \pm 0.09^m$) for the equatorial coordinates and B-values, respectively. Systematic difference between common stars of this catalogue and Tycho-2 is $\sigma_{\alpha,\delta} = \pm 0.06''$(for 5814 stars); for U-magnitudes $\sigma_B = \pm 0.13^m$ (for 876 stars). These estimations have a preliminary character and based on the data of catalogue of positions and U-magnitudes for 68,784 stars and galaxies for 12 regions of the MEGA program (Andruk et al., 1995).

Catalogues of position and proper motions of stars (Protsyuk et al., 2014a, 2015a). In 2016, the catalogue of position and proper motions of stars in the areas around the Galactic open clusters was created by using photographic and CCD observations obtained with different telescopes in the 20-21 century.

Near 290 plates (20x20cm, 5ºx5º), which have been obtained with the Zonal Astrograph of Nikolaev Astronomical Observatory (NAO) (D = 116 mm, F = 2040 mm, scale =101"/mm) in 1962-1993, were scanned. In 2011-2015, more than 20,000 CCD frames were obtained with KT-50 telescope (D = 500 mm, F = 3000 mm, 43'x38', scale = 0.8"/pix) (Shulga et al., 2012). Totally more than 270 thousands FITS files from MAVO image archives with observational epoch from 1953 to 2010 were downloaded. All the data was processed and coordinates of all objects on the images were obtained.

Catalogue of position and proper motions of about 2.7 million stars $(7–16)^m$ in Tycho-2 system (NAO2015pm) was created. The accuracy of positions on both coordinates is ranged from 0.02–0.04" for the stars of $(7–12)^m$ to 0.08–0.11" for the stars of $(14–16)^m$. Intrinsic accuracy of proper motions is near 0.04"/year. Systematic difference between common stars of NAO2015pm and XPM catalogues (Fedorov et al., 2009) is less than 0.005"/year on both coordinates.

Catalogues of stars in fields of Gamma-Ray Bursts. GRBs are registered first by space observatories and transmit this information immediately for ground-based observatories, which, in own turn, may detect optical afterglow emitted during the next hours and days. Results on GRBs are published in the circulars GRB Coordinate Network (GCN Circulars). GRBs are occurring about once a day and have a uniform distribution on the celestial sphere.

Catalogues of stars in fields of GRBs allowed searching for optical counterparts of GRB in the past. With this aim we use astroplates from UkrVO JDA database (Sergeeva et al., 2004, Vavilova et al., 2012a,b,, 2014a,b). The positional accuracy of selected objects is between ±0.3″ and ±4.5″ and the range of magnitudes is $14^m - 19^m$. GRBs and all the objects are sought and identified on the digitized plates within the circle with a radius of dozens of arc minutes. The data on the equatorial coordinates and B-magnitudes of stars in GRB fields are obtained with LINUX/MIDAS/ROMA FOT software in Tycho-2 system (Andruk et al., 2010, 2016a; Yatsenko et al., 2011; Golovnya et al., 2010). They are as follows: $\sigma_\alpha=\pm0.17''$, $\sigma_\delta=\pm0.3''$ for coordinates and $\sigma_m=\pm0.3$ for B-magnitudes. Because of the expected optical image analogs of GRBs are very weak, we use only astroplates with exposure time more than 10 minutes (practically, they are all from the FON program collection). To clarify the parameters of stars and sizes of fields around GRBs, the maps of Digitized Sky Survey II (DSS2) and service Aladin v8.0 have being applied. The results of this work are published in GSN Circulars (see, for example, Golovnya, 2016). We note that the probability to find optical analogs of GRBs is small, especially when searching for them in the past.

3.2. UkrVO JDA Data Release 1: Software and web-services

The VizieR web service (Strasbourg, France) contains more than 15400 published astronomical catalogues. The **astronomical web-services** (AWS) of UkrVO (Mazhaev & Protsyuk, 2013) provide the automated search and selection of required data in accordance with the SCS standard for three catalogues compiled in Ukraine, namely, All-Sky Compiled Catalogue of 2.5 million stars (ASCC) by Kharchenko (2001), FONAC (Kislyuk and Yatsenko, 2005), XPM (Fedorov et al., 2009). The structure of AWS web address consists of path to script and search options after the question mark. The user can search in different areas of the sky and retrieve data from the astrometric catalogues. These AWS were inscribed into a register of the USA Virtual Astronomical Observatory (VAO). The register contains more than 17000 services.

“The high energy astrophysics science archive research center (HEASARC) validates each web service at least once per month. Using Data Discovery Tool (DDT) developed by the VAO, it is possible to retrieve data from all archives, which are inscribed in the VAO register. Illustration of the access with AWS by using Aladin GUI to XPM catalogue is given in Figure 6. It’s also possible with

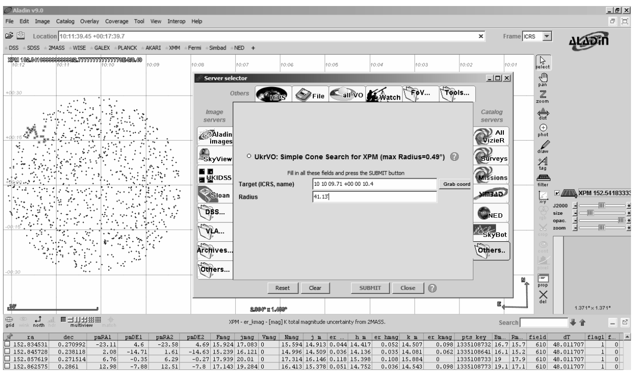

Figure 6: Screenshot of the GUI and search results for XPM catalogue (Fedorov et al,. 2009) obtained with Aladin (AWS is developed by Mazhaev & Protsyuk, 2013).

this GUI to obtain access to two UkrVO JDA databases of observations conducted with astro photo plates and CCDs in the 20th and 21st centuries, respectively. Using the search results within metadata window of Aladin, one can download and visualize a preview image of a found photo plate” (cited by Mazhaev (2017)).

Special-oriented software has been developed for variable star research in the Odessa National Maritime University. We note MCV and VSCalc and describe ILA project.

The program **MCV ("Multi-Column View")** allows to make time series analysis of irregularly spaced data, particularly, having unique features: the approximation using combinations of algebraic and trigonometric polynomials simultaneously for up to 3 main periods (and harmonics); the periodogram analysis using the trigonometric polynomial of an user-defined degree superimposed on to an algebraic polynomial trend without a "pre-whitening"; the reduction of the CCD measurements using many stars in the field (the algorithm of the "artificial comparison star") and dozens of other features. At minimum, the program may be used for an automatic visualization of the (multi-) or one-column time series and preparation of graphs in the raster format. The description of the first version was published by Andronov and Baklanov (2004), but the program is regularly upgraded and new versions available at http://soft.softodrom.ru/ap/Bred2i-p4726.

Breus (2007a, b) proposed the **"Variable Stars Calculator" (VSCalc)** software, where 1) there is a possibility for reduction of visual observations and conversion of the photographic plate numbers in HJD (currently the database of the Odessa plate collection is available, but other files may be used as well); 2) the periodogram analysis may be carried out using the method by Lafler-Kinman-Kholopov; 3) the extrema may be determined using an algebraic polynomial of statistically optimal order.

Additional algorithms were realized in the programs **for vicinities of the extrema** by Andrych et al. (2015) and **for complete light curves** by Andronov et al. (2016). This method was improved for the multi-color observations by Andronov et al. (2015). The reduction of the photo-polarimetric observations obtained at the 2.6m Shain telescope at the Crimean Astrophysical Observatory is carried out using the program "ZTSh-Server" (Breus et al., 2007b; Kolesnikov et al., 2016).

New programs are developed for automatic search for variable stars using measurements of all stars in the field and for the photometry of stars using overlapping images, The programs may be revised upon request.

Variability of stars was studied based on mathematical modeling of the observations from the following sources: own observations obtained in Poland, Slovakia (multi-color CCD photometry) and at the 2.6m Shain telescope of the Crimean Astrophysical observatory (photo-polarimetry); CCD observations within temporarily observational projects on the selected stars within an international project ***"Inter-Longitude Astronomy"* (ILA)** with participants from USA, Korea, Germany, Greece, Poland, Slovakia, Finland, Italy, Czechia, Hungary, France; observations with the ground-based CCD (Catalyna, ASAS, NSVS, WASP), visual (AAVSO, AFOEV, VSOLJ) and space (Hipparcos-Tycho, CHANDRA, UHURU, ROSAT) photometrical surveys (see, a brief report, Andronov et al. (2010)). Highlights of the studies of the statistically optimal approximations of mean phase and individual light curves of pulsating and symbiotic variable stars were briefly reviewed by Andronov et al. (2014). Statistically optimal approximations of astronomical signals and their implications to classification and advanced study of eclipsing binaries were discussed by Andronov et al. (2016 b,c).

The main variable star research upon the "ILA" project is as follows (studies of selected objects, more than 1900):

* ***"Polar"*** ("Magnetic cataclysmic variables") – classical, eclipsing, asynchronous and intermediate polars, as well as the magnetic Dwarf Nova DO Dra; particularly, the spin evolution of white dwarfs in these objects; behavior in different luminosity states);

* ***"Superhumper"*** – "Non-magnetic cataclysmic variables" – superhumps, quasi-periodic and transient periodic oscillations in Nova-like stars and/or UGSU-type dwarf Novae;

* ***"Eclipser"*** – "Eclipsing Binary stars" – phenomenological modeling of the light curve using special patterns (shapes, profiles) of the phase-limited eclipses), determination of characteristics, studies of stability or variability of the period and shape of the light curve;

* ***"Impactor"*** – "Extreme direct impactors" – in interacting binary stars, a new subclass with a prototype star V361 Lyr;

* ***"Symbiosis"*** – "Symbiotic variable stars" – multicomponent variability from minutes to decades;

* ***"Stellar Bell"*** – "Pulsating variable stars", currently of M, SR, RV, RR, DSct types;

* ***"New Star"*** – discovery, classification and determination of the phenomenological parameters of new variable stars.

The powerful **CoLiTec (Collection Light Technology)** software for the automated search for small celestial objects on a series of CCD frames has been developed within the UkrVO (http://www.neoastrosoft.com/). The core of this software is a new iteration method based on a subpixel Gaussian model of the discrete object image to estimate coordinates of celestial body. The method operates by continuous parameters (object's coordinates) in a discrete observational space (the set of pixel potentials) of the CCD frame. In this model, the kind of coordinate distribution of the photons hitting a pixel of the CCD frame is known a priori, while the associated parameters are determined from a real digital object image. The method is flexible in adapting to any form of object image, has high measurement accuracy along with a low calculating complexity (Savanevych et al., 2015a).

The comparative analysis of the processing of the same frames using CoLiTec and Astrometrica software says that in the case of low signal to noise ratios, the standard deviation of positional CCD measurements using the Astrometrica software is 30-50% greater than that of the CoLiTec software (Savanevych et al., 2015b). In 2014, the COLITEC software was recommended to all members of the *Gaia-FUN-SSO network* for analyzing observations as a tool to detect faint moving objects in frames.

The CoLiTex group developed also a new tool for the calibration of astronomical images – **FrameSmooth** – as a cross-platform module for brightness equalization of CoLiTec software. It allows processing images with any formats. Module is based on using the filter for brightness equalization, inverse median, and nonlinear high-frequ ency filters. It supports additional astronomical masterframes (Bias, Dark, DarkFlat and Flat) as well as OLDAS mode and feature for converting images in fits format were added (Dubovský et al., 2016). Figure 7 illustrates advantages of this method as comparing with traditional Muniwin method of calibration of the field of V1323 Her.

Star catalogues, software and services of the Crimean Astronomical VO (CrAVO). Information about archives of astronegatives obtained at the Crimean Astrophysical Observatory (CrAO) is located at the International Center in Sofia (http://www.skyarchive.org/); the data are available through a data base in the VizieR catalog VI/ 90 or with «CRI» key at: http://draco.skyarchive.org/ search/. CrAVO data archives and catalogues are the part of the UkrVO astroinformatics resource (Shlyapnikov, 2007; Vavilova et al., 2012a).

The editable version of database consists of 39 catalogues prepared at the CrAO: some of them are digitized, 16 catalogues with the data on magnitudes and spectral classes of 34154 stars **("Shajn Plan")** are in processing (Gershberg et al., 2011; Fursiak, 2012; Shlyapnikov, 2013; Slyapnikov et al., 2015).

Starting from 2013, a new database of spectral observations of celestial bodies has been forming (Gorbunov, Shlyapnikov, 2013; Pakuliak et al., 2014). They include spectroscopic observations conducted at the wide-angle astrographs with objective prism and reflectors (D = 1000,1220 and 2600 mm). The collection of spectroscopic

Figure 7: Field of variable star V1323 Her. From left to right: raw image, calibrated in usual way with the Muniwin, calibrated with FrameSmooth (see, in detail, presentation by Dubovský P.A., Savanevych V.E., Kudzej I. et al., http://www.neoastrosoft.comprague_ 2016_en/#more-3772 at the 48th Conference on variable stars research, Prague, 2016).

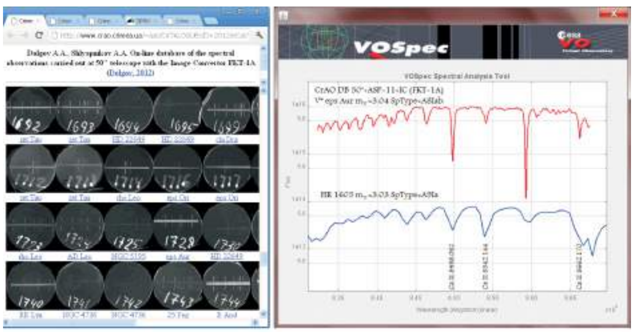

Figure 8: Example of the digitized spectrum with VOSpec from the database of spectral observations with 50-inch telescope at the CrAO.

observations with the objective prism consists of three parts in dependence on type of astrograph where this collection was obtained (Dolgov, Shlyapnikov, 2013). Parameters of astrographs (D/F in mm) and dispersion σ of digitized spectra in Hγ line (Å/pix) are as follows: Unar (D/F = 117/600, σ = 1.5), Dogmar (D/F = 167/750, σ = 1.4), 400-mm (D/F = 400/1600, σ = 1.5). Figure 8 gives an example of the digitized spectrum from the database of spectral observations with 50-inch telescope of the Crimean Astrophysical Observatory.

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