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BAO Plate Archive Project: Digitization, Electronic Database and Research Programmes

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Abstract. The most important part of the astronomical observational heritage are astronomical plate archives created on the basis of numerous observations at many observatories. Byurakan Astrophysical Observatory (BAO) plate archive consists of 37,000 photographic plates and films, obtained at 2.6m telescope, 1m and 0.5m Schmidt type and other smaller telescopes during 1947–1991. In 2002-2005, the famous Markarian Survey (also called First Byurakan Survey, FBS) 1874 plates were digitized and the Digitized FBS (DFBS) was created. New science projects have been conducted based on these low-dispersion spectroscopic material. A large project on the whole BAO Plate Archive digitization, creation of electronic database and its scientific usage was started in 2015. A Science Program Board is created to evaluate the observing material, to investigate new possibilities and to propose new projects based on the combined usage of these observations together with other world databases. The Executing Team consists of 11 astronomers and 2 computer scientists and will use 2 EPSON Perfection V750 Pro scanners for the digitization, as well as Armenian Virtual Observatory (ArVO) database will be used to accommodate all new data. The project will run during 3 years in 2015–2017 and the final result will be an electronic database and online interactive sky map to be used for further research projects, mainly including high proper motion stars, variable objects and Solar System bodies.

1. Introduction

Astronomical plate archives created on the basis of numerous observations at many observatories are the most important part of the astronomical observational heritage. The necessity of digitization of astronomical plates was emphasized and current progress in various national and international projects was given at Astroplate-2014 workshop (e. g. Osborn 2014; Hudec 2014; Kazantseva 2014; Nesci et al. 2014a; Stupka & Benesova 2014).

Byurakan Astrophysical Observatory (BAO) Plate Archive is one of the largest astronomical archives in the world and is considered to be BAO main observational treasure. It is the results of decades hard work of Armenian astronomers and the work of BAO telescopes and other expensive equipment, as well as the results of their activi-

ties. Today BAO archive holds some 37,000 astronomical plates, films or other carriers of observational data. However, previous observational and informational registration methods currently do not make it available to wide range of scientists, and especially its usage for solution of new research problems.

Digitization of BAO plates will be a significant contribution to the Wide-Field Plate DataBase (WFPDB) developed in Sofia, Bulgaria (Tsvetkov & Tsvetkova 2012).

A project on **Digitization of BAO Plate Archive and creation of BAO Interactive Astronomical Database** (shortly BAO Plate Archive project, BAO PAP) has started in February 2015. It is aimed at preservation of BAO valuable observational material accumulated during 1947-1991, creation of full Database of all BAO observations, creation of BAO Interactive Sky Map with visualization of all observations and quick access to the data, development and accomplishment of new research projects based on the existing observational material, and integration of BAO observations into the international databases. A number of BAO young astronomers are involved in this project and it will last 3 years.

Project objectives are the preservation of BAO observational archive, preservation of scientific information contained in photographic plates and other careers, creation of opportunity of dissemination and wide usage of observational data, putting in correspondence of observational material to modern standards and usage methods, proposing new science projects and creation of possibility of their further accomplishment, and making BAO activities visible.

A short description of BAO Plate Archive was given by Mickaelian (2014).

2. BAO telescopes and observing programmes

BAO observers worked with a number of BAO telescopes during 1947-1991 and obtained several dozens of thousands plates, films and other products. The table gives general understanding on observations of 10 BAO telescopes that worked on photographic photometry, electrophotometry, slit and objective prism spectroscopy, and polarimetry of many thousands astronomical objects. We give in Table 1 an overview of BAO telescopes and produced observational material. Telescope “Sizes" are given for the mirror and focal length for classical telescopes and for the correcting lens, mirror and focal length for Schmidt type telescopes.

Here we list the main observational projects accomplished on the three most important BAO telescopes (2.6m classical reflector, 1m Schmidt and 0.5m Schmidt; Figure 1).

21" (0.5m) Schmidt telescope:

- Polarization of cometary nebula NGC 2261
- Nuclei of nearby Sa and Sb galaxies
- Nuclei of nearby Sc galaxies
- Search for flare stars in Pleiades
- Search for flare stars in Orion

Table 1. Overview of BAO telescopes and produced observational material.

Telescope	Sizes [cm]	Years	Observing methods	Plates
5" double–astrograph	13	1947–1950	photometry	3000
6"	15	1947–1950	photometry	3000
8" Schmidt	20/20/31	1949–1968	photometry	4500
20" Cassegrain	51/800	1952–1991	electrophotometry	
10" telescope–spectrograph	25	1953–19??	spectra	
Nebular spectrograph		1954–19??	spectra	
16" Cassegrain	41/400	1955–1991	electrophotometry	
21" Schmidt	53/53/183	1955–1991	photometry	12000
40" Schmidt (AZT–10)	102/132/213	1960–1991	photometry, spectra	7500
ZTA–2.6m	264/1016	1975–1991	photometry, spectra	7000
All telescopes		**1947–1991**		**37000**

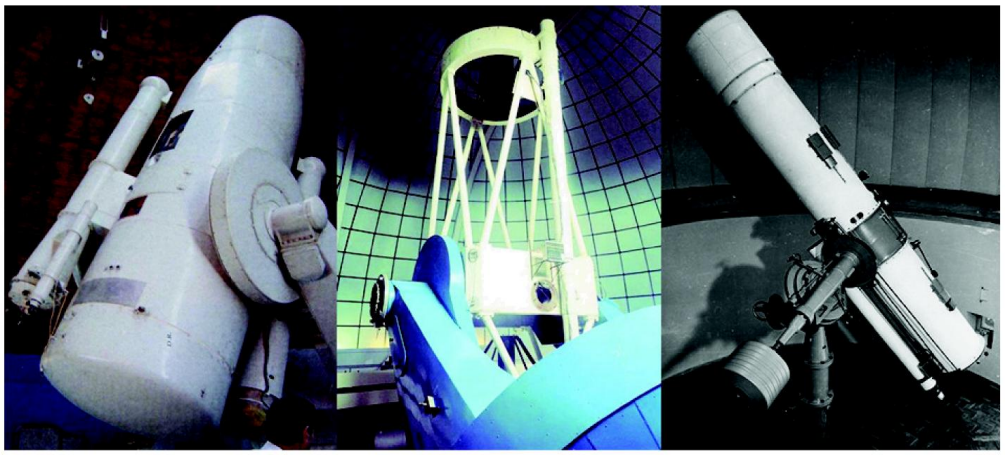

Figure 1. BAO most important telescopes: 2.6m classical reflector, 1m Schmidt and 0.5m Schmidt.

- Search for flare stars in NGC 7000 (Cygnus)
- Search for flare stars in Praesepe
- Search for flare stars in Taurus Dark Clouds (TDC)
- Variability of Markarian galaxies
- Monitoring of extragalactic supernovae in certain areas

40" (1m) Schmidt telescope:

- Detailed colorimetry of bright galaxies
- First Byurakan Survey (FBS, Markarian survey; Markarian 1989)

- Search for flare stars in Pleiades
- Search for flare stars in Orion
- Search for flare stars in NGC 7000 (Cygnus)
- Search for flare stars in Praesepe
- Search for flare stars in Taurus Dark Clouds (TDC)
- Second Byurakan Survey (SBS; Stepanian 2005)
- Extension of the FBS in the Galactic Plane

ZTA-2.6m telescope:

- Morphological study of Markarian galaxies
- Investigation of star clusters
- Investigation of groups and clusters of galaxies
- Spectroscopy FBS blue stellar objects
- Spectroscopy FBS late–type stars
- Spectroscopy SBS galaxies and stellar objects (BAO/SAO)
- Direct images of the central regions of Markarian galaxies
- Spectroscopy of T Tauri and flare stars
- Spectroscopy of Byurakan-IRAS Galaxies (BIG objects)
- Spectroscopy of ROSAT AGN candidates (BAO/HS/OHP/INAOE)

Summarizing, the main observational projects run on these telescopes were: **21" (0.5m) Schmidt:** Polarization of cometary nebula NGC 2261, Nuclei of nearby Sa and Sb galaxies, Nuclei of nearby Sc galaxies, Search for flare stars in Pleiades, Orion, NGC 7000 (Cygnus), Praesepe and Taurus Dark Clouds (TDC), Variability of Markarian galaxies, Monitoring of extragalactic supernovae in certain areas, etc.; **40" (1m) Schmidt:** First Byurakan Survey (FBS, Markarian survey; Markarian 1989), Second Byurakan Survey (SBS; Stepanian 2005), Extension of the FBS in the Galactic Plane, Detailed colorimetry of bright galaxies, Search for flare stars in Pleiades, Orion, NGC 7000 (Cygnus), Praesepe and Taurus Dark Clouds (TDC), etc.; and **ZTA-2.6m telescope:** Morphological study of Markarian galaxies, Investigation of star clusters, Investigation of groups and clusters of galaxies, Spectroscopy of FBS blue stellar objects, FBS late–type stars, SBS galaxies and stellar objects (BAO/SAO), T Tauri and flare stars, Byurakan-IRAS Galaxies (BIG objects) and ROSAT AGN candidates (BAO/HS/OHP/INAOE), and Direct images of the central regions of Markarian galaxies.

Especially efficient were Byurakan surveys accomplished by Markarian and colleagues: FBS and SBS.

3. BAO Plate Archive Project

The digitization of astronomical plates and films pursues not only the maintenance task, but also it will serve as a source for new scientific research and discoveries, if only the digitized material runs according to modern standards and, due to its accessibility, it will become an active archive. The project is aimed at compilation, accounting, digitization of BAO observational archive photographic plates and films, as well as their incorporation in databases with modern standards and methods, providing access for all observational material and development of new scientific programs based on this material.

Scientific Programs Board (SPB) is created to evaluate the existing observational material, to select sets of priorities to be scanned first and to propose new research projects. It consists of BAO Director Haik Harutyunian (Chair), DFBS Principal Investigator and ArVO Project Manager Areg Mickaelian (Coordinator) and most experienced BAO observers (Kamo Gigoyan, Tigran Magakian, Norair Melikian, Tigran Movsessian, Elena Nikogosian, Elma Parsamian, and Artashes Petrosian), as well as researchers from NAS RA Institute of Informatics and Automation Problems (IIAP) Vladimir Sahakian and Hrachya Astsatryan are involved for their experience in computer science related to databases and computational methods.

Project Executing Team (PET) consists of 14 members: Areg Mickaelian (Project Manager, SPB Coordinator), Elena Nikoghosian (Deputy Manager on Administrative Issues, SPB member), Kamo Gigoyan (Deputy Manager on Technical Issues, SPB member), Gurgen Paronyan (Person in charge for BAO Plate Archive, PET member), Hayk Abrahamyan, Naira Azatyan, Hasmik Andreasyan, Marietta Gyulzadyan, Knarik Khachatryan, Gayane Kostandyan, Ani Vardanyan (PET members), Gor Mikayelyan (Database Manager, Web Designer), Sona Farmanyan (Webpage content, dissemination, outreach, and organizational issues) and Aram Knyazyan (NAS RA IIAP, Database Manager).

The project consists of the following tasks:

- Development of technical principles of the Project, necessary Equipment, Timeline and the Budget,
- Collection of all photographic plates (until recently only plates obtained before 1974 had been collected in BAO Plate Archive),
- Revision and accounting of the plates and observing journals in BAO Plate Archive,
- Scanning of a few dozens of plates for test and educational reasons to set up the necessary parameters for the scanning in frame of the main Project,
- Input of data from observing journals,
- Creation of the Project Database and development of the principles of organization of data in it,
- Creation of the Project Webpage and User Interface.
- Scanning of photographic plates and films
- Astrometric solution

- Extraction of images and spectra
- Wavelength calibration
- Density and flux calibration
- Multiband (UBVR) photometry
- Making up template low-dispersion spectra
- Numerical classification of low-dispersion spectra
- Visualization of BAO observations on sky map
- Creation of electronic interactive sky map and search system
- Scientific analysis of existing observational material and providing new research possibilities
- Proposing and discussing new research projects

Figure 2. BAO Plate Archive Project webpage.

BAO PAP webpage [1] (Figure 2) was recently open and contains a lot of information on BAO observations, previous digitization projects, present Project details, teams, follow-up research projects, deliverables and related links (many items will be filled in during the next months). **"BAO Observations"** contain data on BAO telescopes, observers, observing programs accomplished during 1947-1991, publications based on

[1] http://www.aras.am/PlateArchive/

BAO observations, and presents BAO Plate Archive organized in 1986. **"Digitization Projects"** present previous digitization projects, including DFBS (digitized Markarian Survey), Second Byurakan Survey (SBS), FBS Blue Stellar Objects spectroscopy and Variability of ON 231. **"Project Description"** gives Project Tasks, Instruments and Methods, and Timeline. **"Project Teams"** presents SPB and PET with links to their personal webpages. **"Follow-Up Projects"** is the list of possible follow-up research projects that may be carried out based on the digitized data. **"Deliverables"** will be regularly updated with publications, presentations, reports, project related meetings, press-releases and mass media news concerning BAO PAP. **"Related Links"** give links to BAO, Wide-Field Plate Data Base (WFPDB), IAU Working Group on Preservation and Digitization of Photographic Plates (PDPP), DFBS, Armenian Virtual Observatory (ArVO), International Virtual Observatory Alliance (IVOA), digitization projects in other countries and observatories, related software, etc.

However, the main products will be **"Data Access"** and **"Interactive Sky Map"**. The first one will contain BAO Observational Database, Search by any parameter (Dates / Julian dates, Telescope, Observing modes/methods, Instrument, Receiver, Emulsion, Filters, Seeing, Project name, Project PI, Observers, Targets / coordinates, Sky area, Surface, Scale, Spatial resolution, Spectral range, Spectral resolution, Limiting magnitude, Number of nights, Number of exposures, Links), Data Visualization and Download of the digitized plates, films, part of them or individual objects images or spectra. "Interactive Sky Map" will visualize the observed by BAO telescopes sky and will give possibility to check observed areas for a given observational project, given telescope, observer, observing method, limiting magnitude, etc. There will be possibility to check individual fields for presence and number of plates to propose further research projects. Main expected projects are supposed to be those on variability and proper motions, as well as studies of the Solar System objects.

4. Previous digitization programmes at BAO and research projects

A number of digitization projects have been accomplished at BAO, including the most important one, **Digitized First Byurakan Survey (DFBS** [2]; Mickaelian et al. 2007; Massaro et al. 2008) based on the digitization of the famous Markarian Survey (Markarian et al. 1989). Its main features are:

- Pixel size is 15.875μm or 1.542"
- Each plate is 9601×9601 pixels
- Each plate is 180 MB file
- Each low-dispersion spectrum is 107×5 pixels (1700μm length)
- Astrometric solution has ∼1" rms
- Average dispersion is 33Å/pix (22–60 from blue to red part)
- Photometric accuracy is ∼0.3^m

[2]http://www.aras.am/Dfbs/dfbs.html

- In total there are 1874 digitized plates
- The database is ~400GB
- There are 40,000,000 spectra for 20,000,000 objects

We give in Figure 3 a piece of visualized DFBS field together with its corresponding DSS2 area. Some 40,000,000 DFBS low-dispersion spectra have been extracted from 1874 plates, measured and analyzed by means of the dedicated software bSpec (Figure 4), written by Giuseppe Cirimele.

The spectra extraction and analysis software is described in Mickaelian et al. (2010) and Knyazyan et al. (2011). In Figure 5 we give an example of extraction of an asteroid spectrum from DFBS using VO software SkyBot proving how useful the DFBS plates can be for follow-up studies (Thuillot et al. 2007; Berthier et al. 2009; Sarkissian et al. 2012). The efficiency of studies of AGB stars based on DFBS low-dispersion spectra and follow-up spectroscopy was shown by Nesci et al. (2014b). Gigoyan & Mickaelian (2007) have found a very high proper motion (PM) M7 type dwarf star, lying about 3 pc from the Sun, FBS 0250+167. Its PM is 5.050″/yr and it is in the list of the 10 known highest PM stars. Figure 6 shows that only existence of additional observational material, namely DFBS plates from 1969, linked measurements between DSS1 and DSS2 and helped identifying this object and measuring its PM.

DFBS plate database is available in Vizier, Strasbourg (Mickaelian et al. 2005).

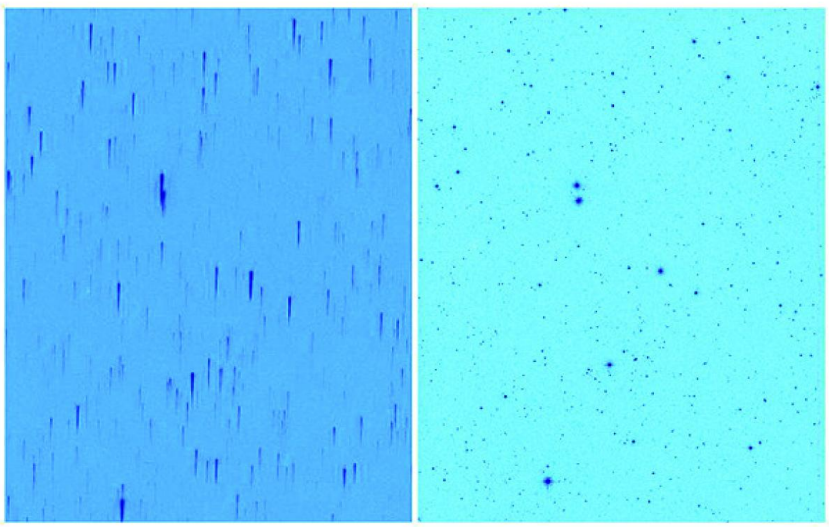

Figure 3. DFBS data visualization with comparison of similar DSS2 field.

The Second Byurakan Survey (SBS; Stepanian 2005) plates are also subject for digitization, as they are hypersensitized and their emulsion is more sensitive for deterioration. 180 plates have been digitized so far. Due to SBS smaller photographic grains, 2400 dpi (10μm pixel size) is being used and 512 MB files are being obtained for each plate.

Photographic spectra of the FBS blue stellar objects (BSOs) have been obtained using 2.6m telescope and UAGS spectrograph on photographic films. ~700 such spectra have been scanned with 1600 dpi, 16 bit and 650×21 pix sizes images were obtained (FBS BSOs; Mickaelian 2008 & late-type stars; Gigoyan & Mickaelian 2012).

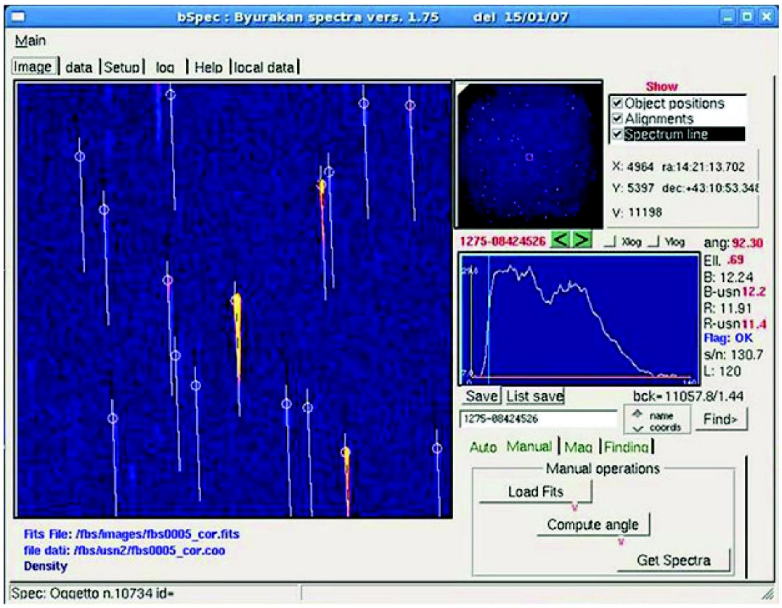

Figure 4. DFBS spectra extraction and analysis software bSpec.

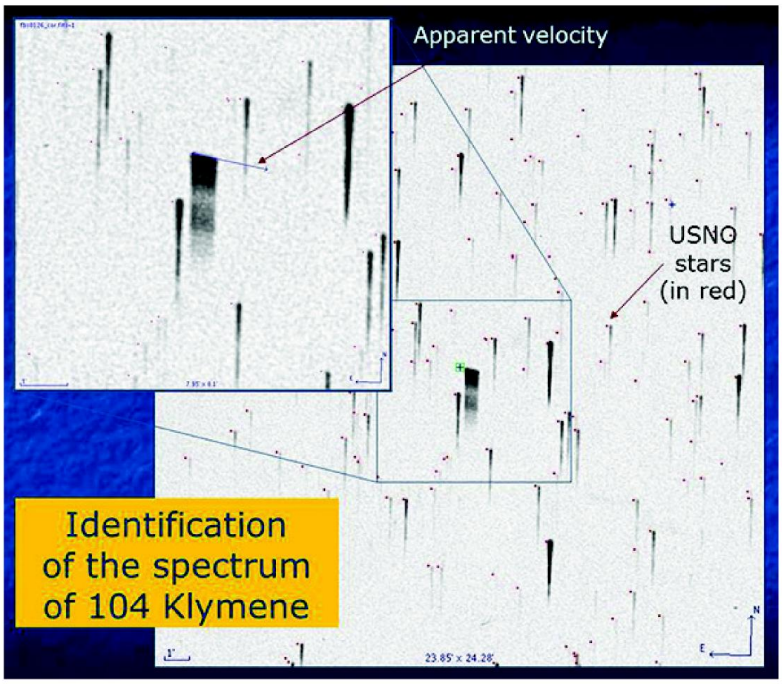

Figure 5. Extraction of an asteroid spectrum from DFBS using VO software SkyBote.

All spectra were put in a standard format, so that automatic reduction was possible (Figure 7). 101 FBS blue stellar objects were published and a number of planetary nebulae, white dwarfs, hot subdwarfs and HBB stars have been revealed (Sinamyan & Mickaelian 2009).

Another project was the study of long-term variability of ON 231, which appeared in the Coma field, where photographic chains for discovery of flare stars were carried

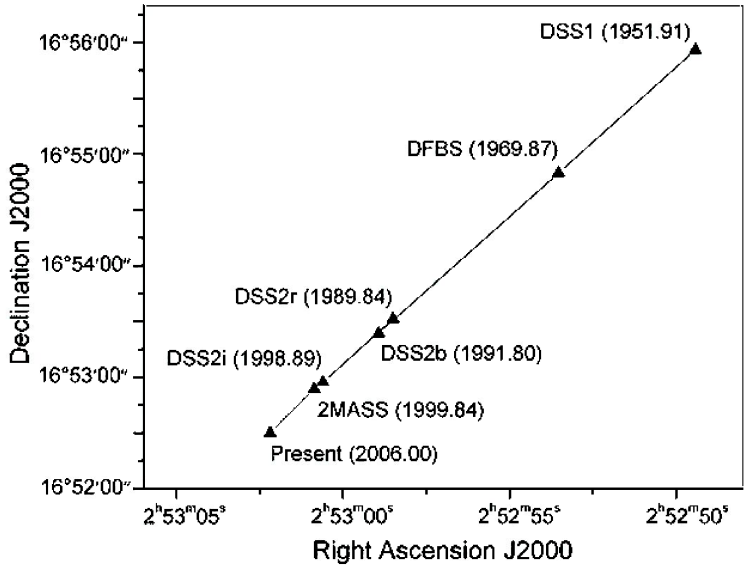

Figure 6. Direction of the motion of the high proper motion (PM=5.050″/yr) star FBS 0250+167, which was found due to DFBS plates.

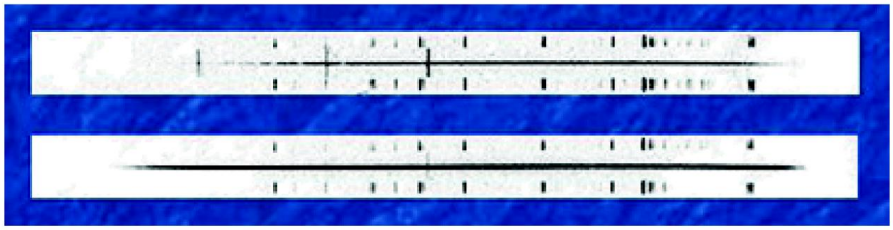

Figure 7. Standard format of FBS spectra with 650×21 pix sizes images for automatic reduction.

out. In total 189 plates with a total number of more than 1200 exposures in 1969–1976 with the Byurakan 21" and 40" Schmidt telescopes were obtained. This was a valuable material for study of ON231 long-term variability (Figure 8; Erastova 2004).

5. Summary

BAO Plate Archive Project will lead to preservation of BAO valuable observational material obtained during 1947-1991. However, our goal is not only to create a passive archive of scanned plates and films, but also to make use of especially those fields, where more studies are possible. Proper motion and variability studies are most important, as time domain material is contained in historical plates. Such possibilities based on DFBS were shown by Mickaelian et al. (2006); DFBS as a unique database for proper motion, variability studies, and object classification. New variable stars discovered on digitized plates of Moscow collection was reported by Sokolovsky et al. (2014).

There are a number of further possible research projects that will be conducted having the plates digitized:

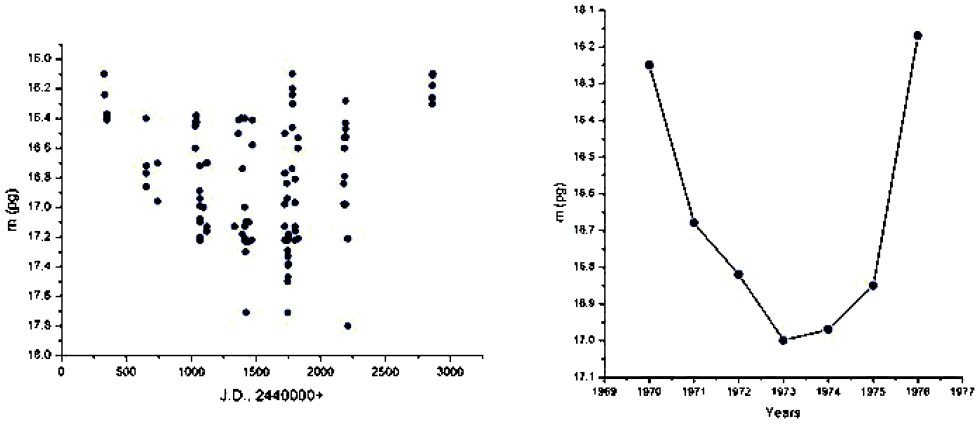

Figure 8. Photometric measurements and variability study of the blazar ON 231 observed in the Coma field.

- Correction of ephemerides of known asteroids and search for new asteroids (Thuillot et al. 2007; Berthier et al. 2009)
- Discovery and study of variable stars (Mickaelian et al. 2011; Nesci et al. 2009)
- Revealing high proper motion stars (Mickaelian & Sinamyan 2010)
- Study of variability of known blazars and discovery of new blazars
- Revealing Novae and Supernovae progenitors
- Discovery of new QSOs
- Discovery of new white dwarfs (Sinamyan & Mickaelian 2011)
- Discovery of new late-type stars (Gigoyan et al. 2010)
- Discovery of optical sources of gamma-ray bursts
- Optical identifications of X-ray, IR and radio sources (Mickaelian & Sargsyan 2004; Mickaelian & Gigoyan 2006; Mickaelian et al. 2006; Hovhannisyan et al. 2009).

Armenian Virtual Observatory [3] (ArVO; Mickaelian 2006) was created in 2005 to maintain and actively use DFBS database. ArVO based science cases have been shown by Mickaelian (2007). BAO Plate Archive Project will enrich ArVO with many more images and spectra that are subject for further studies together with other available multi-wavelength and multi-time-domain data (Mickaelian et al. 2010).

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[3] http://www.aras.am/Arvo/arvo.htm

References

Berthier J., Sarkissian A., Mickaelian A., Thuillot W. 2009, European Planetary Science Congress 4, 526
Erastova, L. K. 2004, A&AT 23, 209
Gigoyan K. S., Mickaelian A. M. 2007, Astrophysics 50, 54
Gigoyan K. S., Mickaelian A. M. 2012, MNRAS 419, 3346
Gigoyan K. S., Sinamyan P. K., Engels D., Mickaelian A. M. 2010, Astrophysics 53, 123
Hovhannisyan L. R., Weedman D. W., Mickaelian A. M., et al. 2009, AJ 138, 251
Hudec R. 2014, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 1
Kazantseva L. 2014, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 13
Knyazyan A., Mickaelian A. M., Astsatryan H. 2011, International Journal "Information Theories and Applications" 18, 243
Markarian, B. E.; Lipovetsky, V. A.; Stepanian, J. A.; et al. 1989, Comm. SAO 62, 5
Massaro E., Mickaelian A.M., Nesci R., Weedman D. (Eds.) 2008, The Digitized First Byurakan Survey, ARACNE Editrice, Rome, 78p.
Mickaelian A.M. 2006, Rom. Astron. J. 16S, 23
Mickaelian A.M. 2007, Highlights of Astronomy 14, 594
Mickaelian A. M. 2008, AJ 136, 946
Mickaelian A. M. 2014, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 109
Mickaelian A. M., Gigoyan K. S. 2006, A&A 455, 765
Mickaelian A. M., Gigoyan K. S., Nesci, R., Rossi C. 2006, Mem.S.A.It. 77, 1159
Mickaelian A. M., Hagen H.-J., Sargsyan L. A., Mikayelyan G. A. 2005, Catalog No. VI/116 at CDS, Strasbourg
Mickaelian A. M., Hovhannisyan L. R., Engels D., et al. 2006, A&A 449, 425
Mickaelian A.M., Mikayelyan G.A., Sinamyan P.K. 2011, MNRAS 415, 1061
Mickaelian A. M., Nesci R., Rossi C., et al. 2007, A&A 464, 1177
Mickaelian A. M., Sargsyan L. A. 2004, Astrophysics 47, 213
Mickaelian A. M., Sargsyan L. A., Mikayelyan G. A. 2010, Proc. of Science, 30
Mickaelian A. M., Sargsyan L. A., Nesci R., et al. 2010, ASP Conf. Ser., Vol. 434: Astronomical Data Analysis Software and Systems XIX, p. 325
Mickaelian A., Sinamyan P. 2010, MNRAS 407, 681
Nesci R., Mickaelian A. M., Rossi C. 2009, Astron. Tel. #2338
Nesci R., Bagaglia M., Nucciarelli G. 2014a, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 75
Nesci R., Gaudenzi S., Rossi C., Pezzotti C., Gigoyan K., Mauron N. 2014b, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 91
Osborn W. 2014, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 15
Sarkissian A., Arzoumanian E., Mickaelian A. M., Berthier J., Thuillot W., Vachier, F. 2012, Proc. Conf. Young Scientists, Yerevan, NAS RA, p. 56
Sinamyan P. K., Mickaelian A. M. 2009, Astrophysics 52, 76
Sinamyan P. K., Mickaelian A. M. 2011, Astrophysics 54, 403
Sokolovsky K. V., Antipin S. V., Zubareva A. M., Kolesnikova D. M., Lebedev A. A., Samus' N. N., Sat L. A. 2014, ARep 58, 319
Stepanian, J.A. 2005, RMxAA 41, 155
Stupka J., Benesova E. 2014, Proc. Astroplate-2014 Conf., Eds. L. Mišková & S. Vítek. Prague, p. 31
Thuillot W., Berthier J., Sarkissian A., et al. 2007, Highlights of Astronomy 14, 616
Tsvetkov, M.; Tsvetkova, K. 2012, Proc. IAU S285: New Horizons in Time-Domain Astronomy, Cambridge Univ. Press, p. 417