Photographic archives of Ukrainian observatories: digitization of heritage

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Astronomical observatories of Ukraine possess a great informatics potential, encapsulated in their observational archives and databases, collected from late XIX to early XXI. The archives of three astronomical observatories of Ukraine – of Kyiv, Lviv and Odessa universities – are interesting not only by a vast collection of photographic observations from late XX to early XXI, but by historic photographic plates of late XIX – mid XX. A small amount of plates for this period is extant worldwide (without regard for CdC plate archives) since the observational programs were cut down during WWI and WWII and the great part of glass archives was lost. Loss of collections entailed the loss of observational methods connected therewith.

The history of the progress in astronomical observational technique is of the same interest for the society as modern one. Observational technique with the Harthmann diaphragm, hexagonal diaphragm, tubular or wedge photometer, Fesenkov photometer, heliographic photographic observations, an image boost in special chemical solutions and many other have now come into the stage of little-known technique of historic interest. Unfortunately the complete information about the image observational conditions is hardly been restored: records and logs are often lost. But every series of historic photographic observations deserves the attention to be paid and a careful study to be done. Therefore the preservation of historical observational archives in the framework of Ukrainian virtual observatory project is conducted without separation them into scientific and historical counterparts.

Joint Digital Archive of UkrVO national project

The Joint Digital Archive (JDA) of photographic and CCD observations has to form the core of UkrVO project according to the concept of UkrVO (http://ukr-vo.org/conception/index.php?2) and to provide the open access to its digital content. The digitization of Ukrainian photographic archives has started since 2008. Vast collections of stored astronomical images require the development of tools for their fast, robust calibration, vetting, search and retrieval. We intend to collect the image content of at last six astronomical observatories of Ukraine in the joint electronic archive. The time interval of collected plates covers more than 100 years and plates were obtained with more than 20 instruments. That means that every “publisher” of digitized collection have to undertake efforts to bring their data to unified standards in order to take advantages of united astronomical resources.

Recent years many observatories in the world have used flatbed scanners as the digitizers for

their glass collections. And until this moment, the quality of digitization with commercial scanners causes many questions. Nevertheless, flatbed scanners remain the most available appliances for relatively rapid archive digitization and application of the proper scan procedure and proper algorithms of digitized image treatment provide the best accuracy, which could be achieved for given appliance and given observational material.

So far as in Ukraine some university observatories – owners of photographic glass collections suffer from lack of computer facilities the deployment of their digital archives is carried out on the computer resources of Main Astronomical Observatory NAS of Ukraine. Here the database of Golosiiv plate archive with open access (DBGPA, http://www.gua.db.ukr-vo.org) has run since 2003, which besides its direct tasks performs the function of the test area for JDA development and its administration and data access software adjusting. To date the prototype of JDA embraces data of four glass collections, including their historical parts.

The digitization of three archives, MAO NASU, AO of Lviv National university and AO of Kyiv National university, is carried out using two models of flatbed scanners. It started with Microtek ScanMaker 9800XL TMA and now has been continued with Epson Expression 10000XL. The database with metadata of plates is allocated on the computational resources of MAO. Currently the digitization procedure is carried out in two variations. We obtain images with high level of resolution for the currently running investigations. Plates have been scanned at 16-bits gray dynamic range, with a resolution of 1200 dpi, and saved in TIFF format. Maximum linear dimensions of the image are of 13 thousand pixels (30x30 cm plates) for both sides. A volume of the scanned file is near 380 Mb.

Another type of scanned images is a sort of fast visualization. Wide-field plates, included into WFPDB (Tsvetkova,Tsvetkov, 2005), have been scanned in a preview format. Previews are the images, obtained for the visualization through the browser with the aim of preliminary estimation of the quality of photographic material and the possibility of its further involvement into investigations. On the preview image all the ink marks and scripts are preserved from wiping, being historically valuable. The preview-images have been scanned at 8-bits gray levels or 24-bits rgb, with a resolution of 300-1200 dpi, and saved in JPG format. Linear dimensions of the image are near 1.2 thousands pixels for both sides for plates of any dimensions. A volume of the scanned file is 30 to 250 Kb. For the plates, previously scanned with the full resolution, the preview images are created “on the fly” – when the plate finds itself in the results of search and the image is detected in the server storage, it is resized, converted from TIFF into JPEG and display on the preview page.

As a rule, plates of a high quality are digitized with high resolution without regard if they are involved into current scientific tasks or no.

Accuracy estimation of scanners.

Both types of scanners, Epson Expression 10000XL and Microtek ScanMaker 9800XL TMA, can be used for digitization of plates up to 30x30 cm. In order to estimate photometric and positional errors of both scanners set of six sequentially made scans of the same plate (Double Wide-Angle Astrograph of MAO NASU, F=2000, Ø=400, scale 102 arcsec per mm, ORWO ZU-21, field - 8˚x8˚) with the resolution 1200 dpi (or 21.17 μm/pixel) have been processed.

The total amount of registered objects is about 100 thousands. For each scanner and every object the average values of six scans have been obtained: coordinates X, Y and instrumental photometric values. As the plate was obtained with two expositions of different duration (16 minutes and 35 seconds), so only the objects with both expositions have been included into analysis. The total number of analyzed objects has been reduced down to 6000 with star magnitude interval 6^m - 13^m from TYCHO-2. Trends of individual deviations of coordinates ΔX, ΔY from the average value are given on the Fig. 1: Epson is on the left panel and Microtek on the right one.

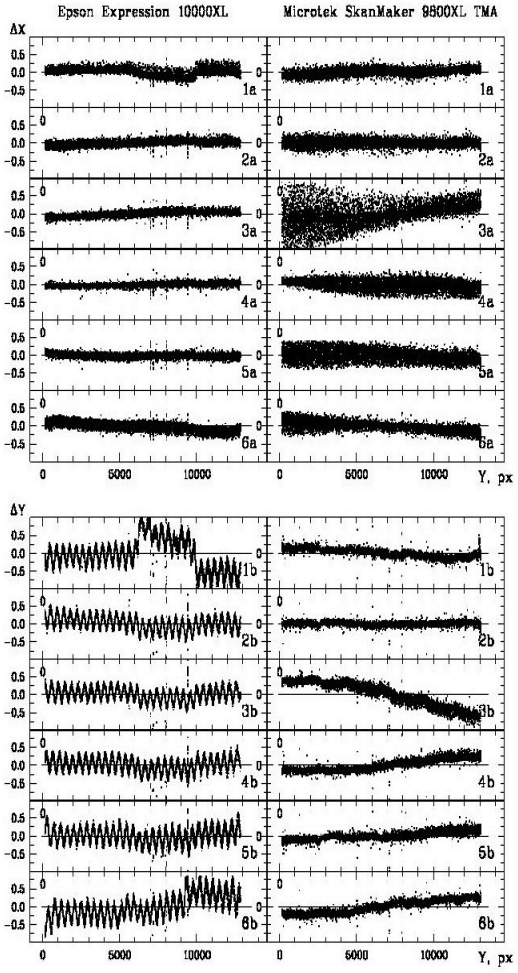
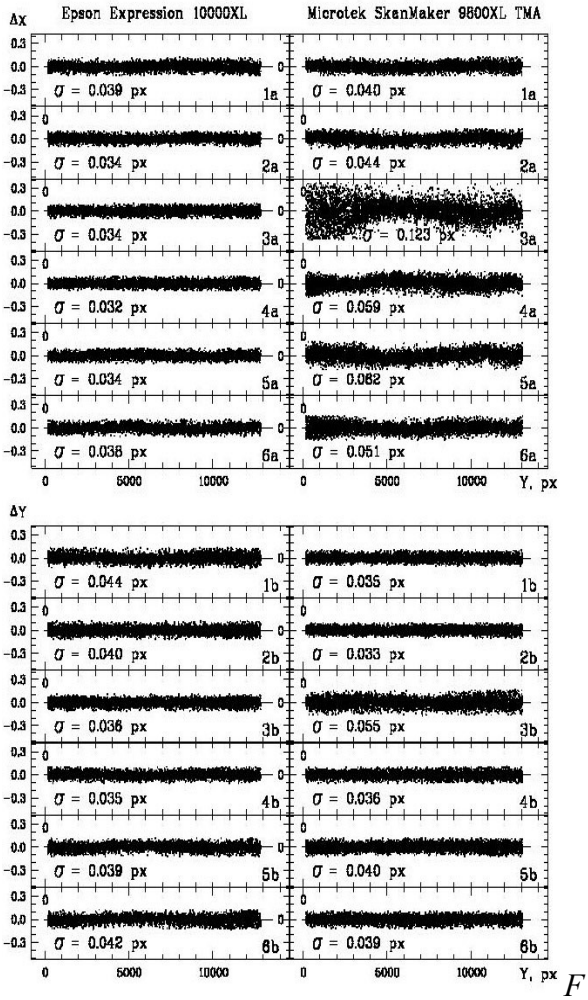


Fig. 1. Individual deviations ΔX, ΔY of coordinates from the average value, obtained from six sequential scans before the instrumental errors elimination.



iFig. 2: The same data as for Fig.1, but after the systematic errors elimination.

Fig.2 shows the same panels after the removal of systematic trends and r.m.s. errors are: $\sigma_{X,Y} = \pm 0.03$ - 0.06 pixels that means $\sigma_{\alpha,\delta} \leq \pm 0.1''$ for both scanners. R.m.s. errors of instrumental magnitudes σ_m are $\leq \pm 0.015^m$, it follows that $\sigma_B \leq \pm 0.03^m$ for both digitizers also.

Different resolution effects. Double exposition separation.

A vast part of archive plates in three observational archives were obtained with multiple expositions: double, triple or even more. The test plates of DWA have double exposition: duration of the short m_2 is 30 - 60 sec and the long one m_1 is 16 - 27 min. It causes the necessity of correct separation of two expositions images in the procedure of plate calibration. Criteria of separation are the astrometric (distance and coordinate frame rotation parameters) and photometric one (difference of the instrumental magnitudes $\Delta m = m_1 - m_2$). The photometric dependence of two expositions is shown on the Fig.3 for images digitized with different resolution: 300, 600, 900, 1200 and 1600 dpi (left to the right). In any case, the relation between two expositions m_1 and m_2 is non-linear and for

Microtek ScanMaker the long exposition curve on the bright star end has the regions of saturation and solarization (the right branch).

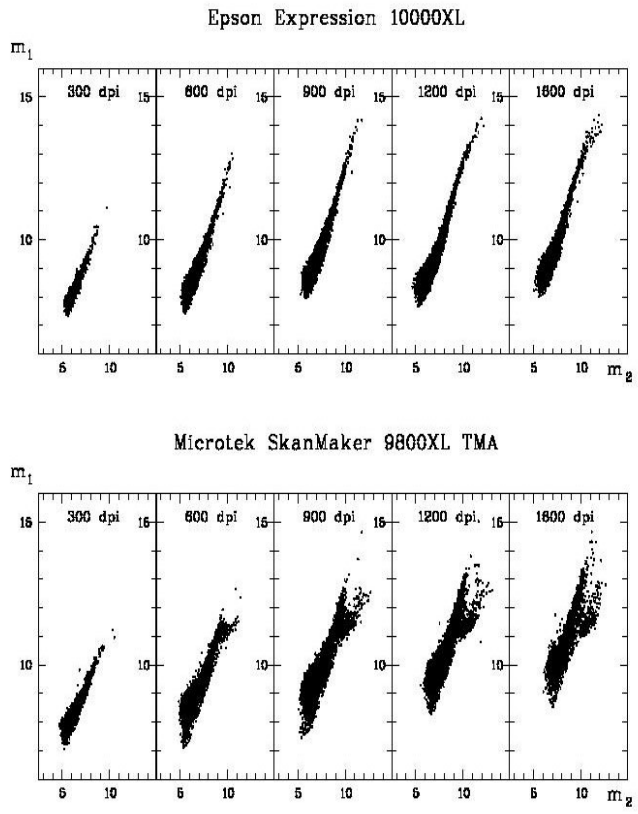


Fig. 3.The relation between two expositions (instrumental values) for different resolutions.

The data about the accuracy of photometric values σ_m, coordinates σ_X, σ_Y (in pixels per arcsec) and number of short exposition images N for different resolutions are given in Table 1.

For the efficient digitization of university archives the mobile laboratory for digitization has been created on the basis of MAO NASU thanks to support of Ukrainian Astronomical Association (UAA http://194.44.35.19/uaa/). It provides other observatories with scanning facilities for free of charge rent.

Currently the active digitization of Lviv Franko university photographic archive is carrying out and process of Kyiv Shevchenko university photographic archive digitization has recently been started. The results of digitization are stored in the central DBGPA database with the open access to them and are backed up in MAO NASU computer cluster archival store places and on the pages of UkrVO web-portal (http: / / ukr-vo.org / history / index.php ? b2 & 4 & 1, http: / / ukr-vo.org / history / index.php ? b 1 & 4).

The structure and representation methods of the digitized archives' historical components are developed taking into account the possibility of its application in the educational process and for the museum activity in the field of the history of the astronomical science in Ukraine.

Table1: The accuracy of astrometric and photometric calibration for two scanners and different resolutions.

	300 dpi	600 dpi	900 dpi	1200 dpi	`1600 dpi
Epson Expression 10000XL					
N	919	4793	6056	8235	6134
σm	±0.18	±0.22	±0.24	±0.22	±0.22
σx /σα	±0.17/±1.12	±0.21/±0.69	±0.21/±0.62	±0.23/±0.49	±0.26/±0.41
σy /σδ	±0.18/±1.17	±0.22/±0.73	±0.22/±0.63	±0.25/±0.54	±0.28/±0.46
Microtek ScanMaker 9800XL TMA.					
N	1933	7642	10421	9717	6473
σm	±0.22	±0.34	±0.40	±0.35	±0.36
σx /σα	±0.21/±1.84	±0.29/±1.27	±0.34/±0.90	±0.36/±0.78	±0.39/±0.63
σy /σδ	±0.23/±2.04	±0.35/±1.52	±0.45/±1.18	±0.49/±1.07	±0.60/±0.98

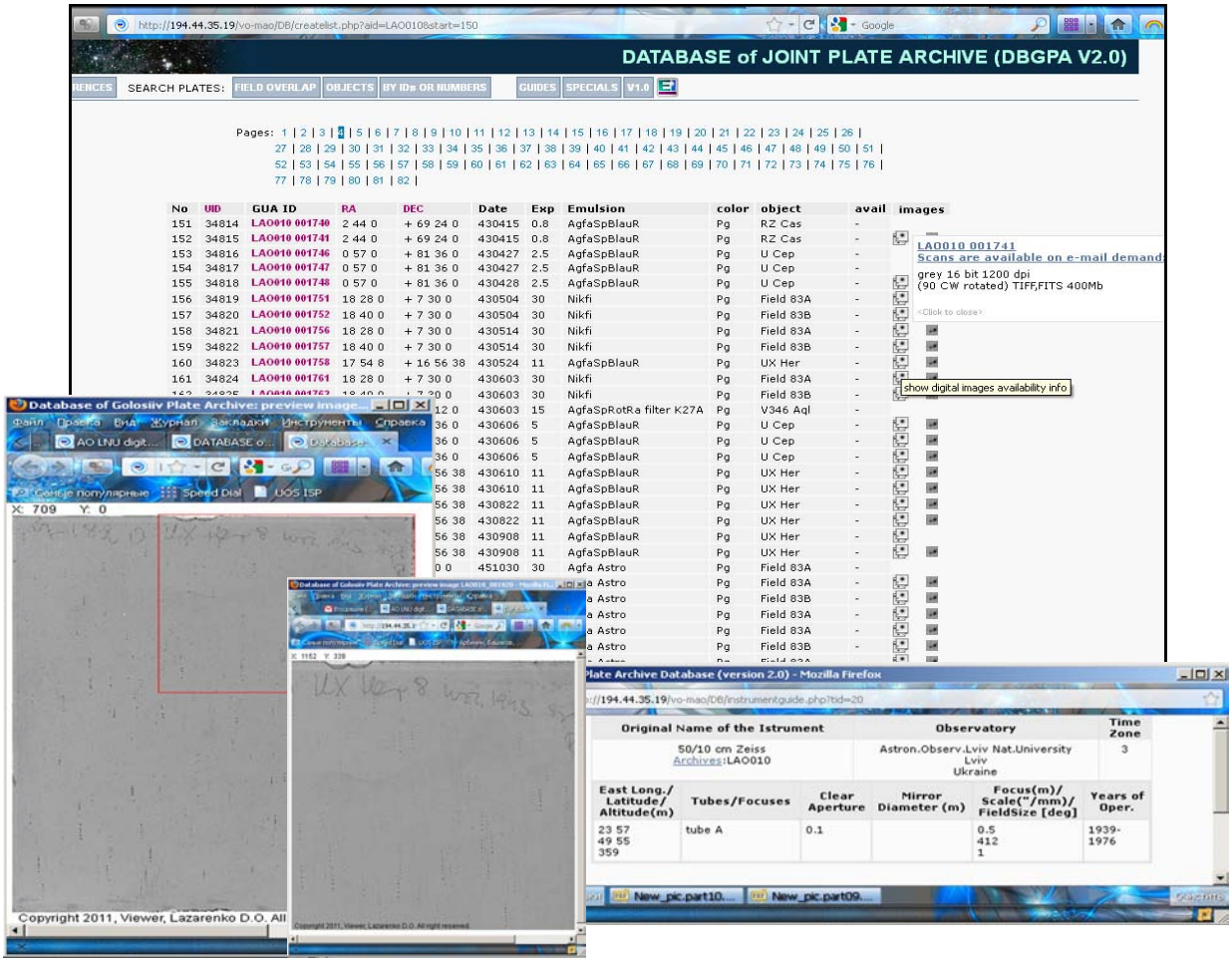


Fig 4. AO LNU digital archive deployed on the computational facilities of MAO NASU

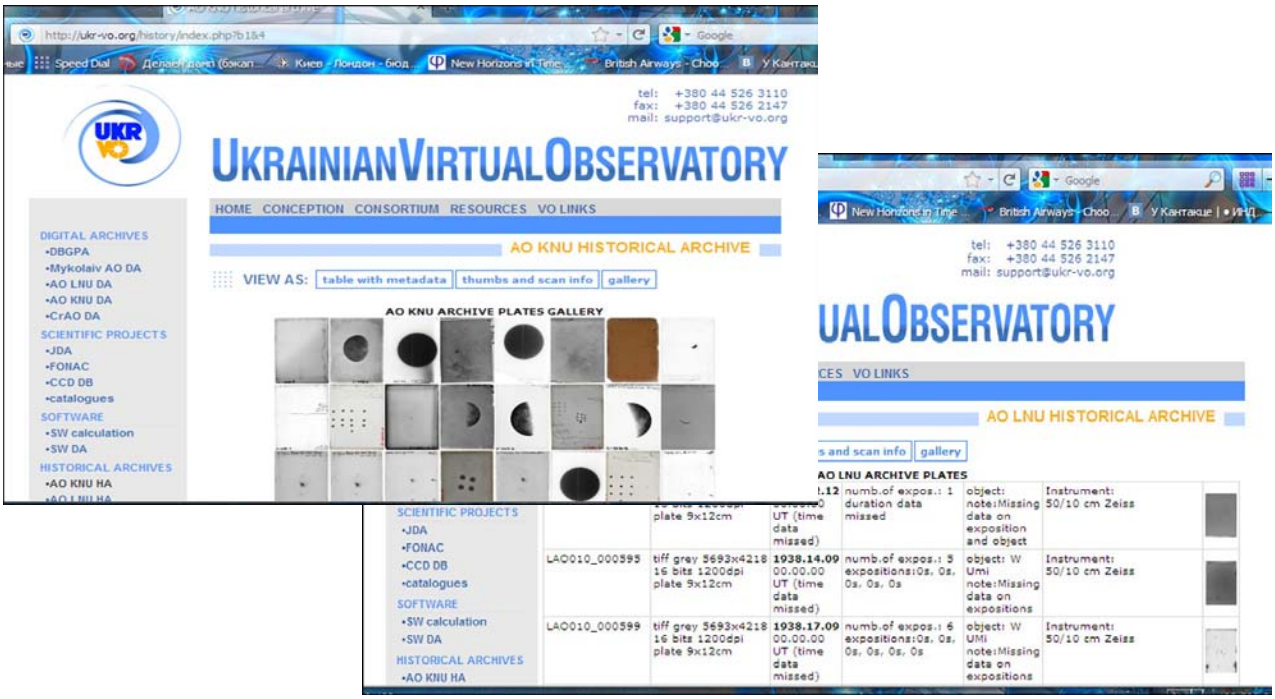


Fig.5. UkrVO portal pages devoted to the historical parts of glass collection of two observatories

Digital archive of the Astronomical Observatory of Lviv National University

Since 1934, in Astronomical Observatory of Lviv National University (AO LNU, LAO) photographic observation of sky to search for and study variable stars and photographic photometry of photovisual magnitudes for catalog of circumpolar stars were conducted. Along the way, observations of selected variable stars of various types, novae stars, occultations of stars by the moon were made. The observations were carried out with instruments: the camera with Zeiss lens triplet (D = 100 mm, F = 500 mm), Mertz refractor, astrocamera (D = 140 mm, F = 700 mm) and the Zeiss refractor (D = 130 mm, F = 2400 mm). For photovisual photometry of stars plates were measured by the aid of the Schilt photometer (until 1950th). About 180 archive plates were obtained during the Second World War, unfortunately, not all observational logs were kept during that period of observations.

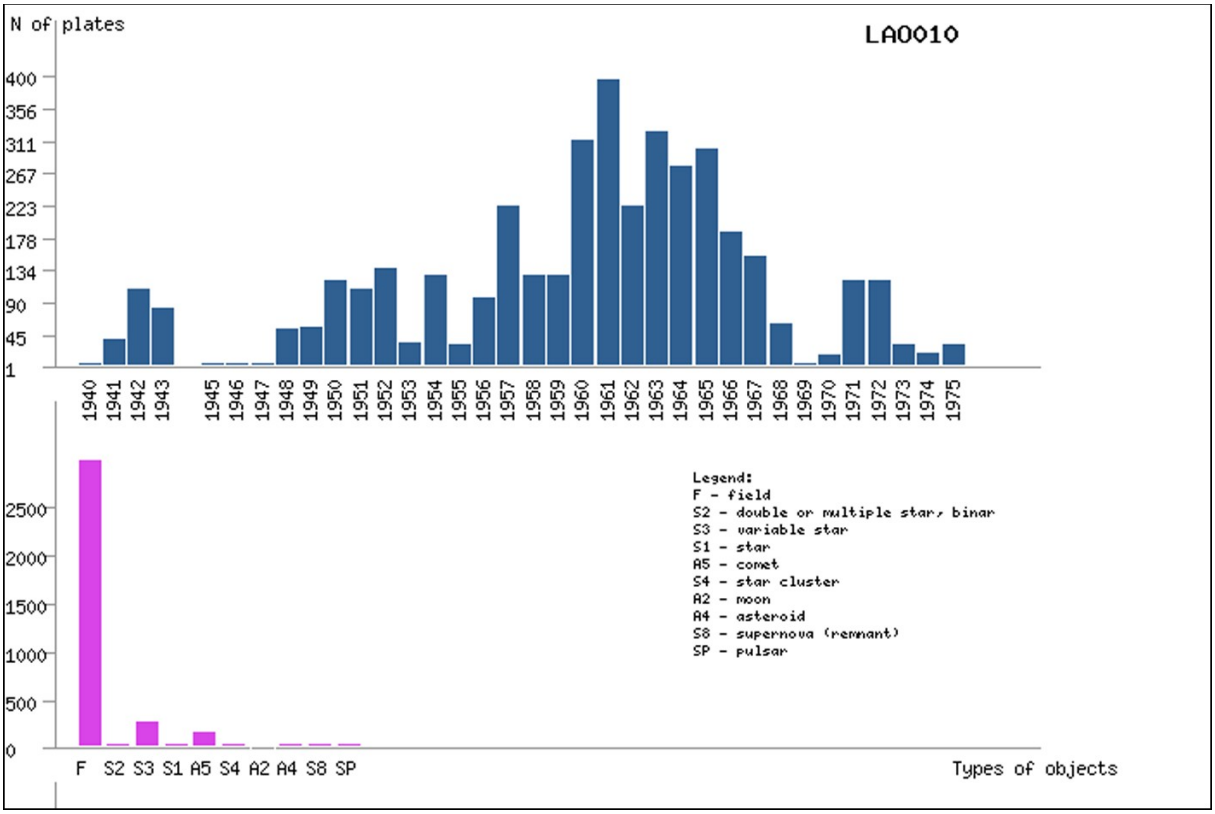
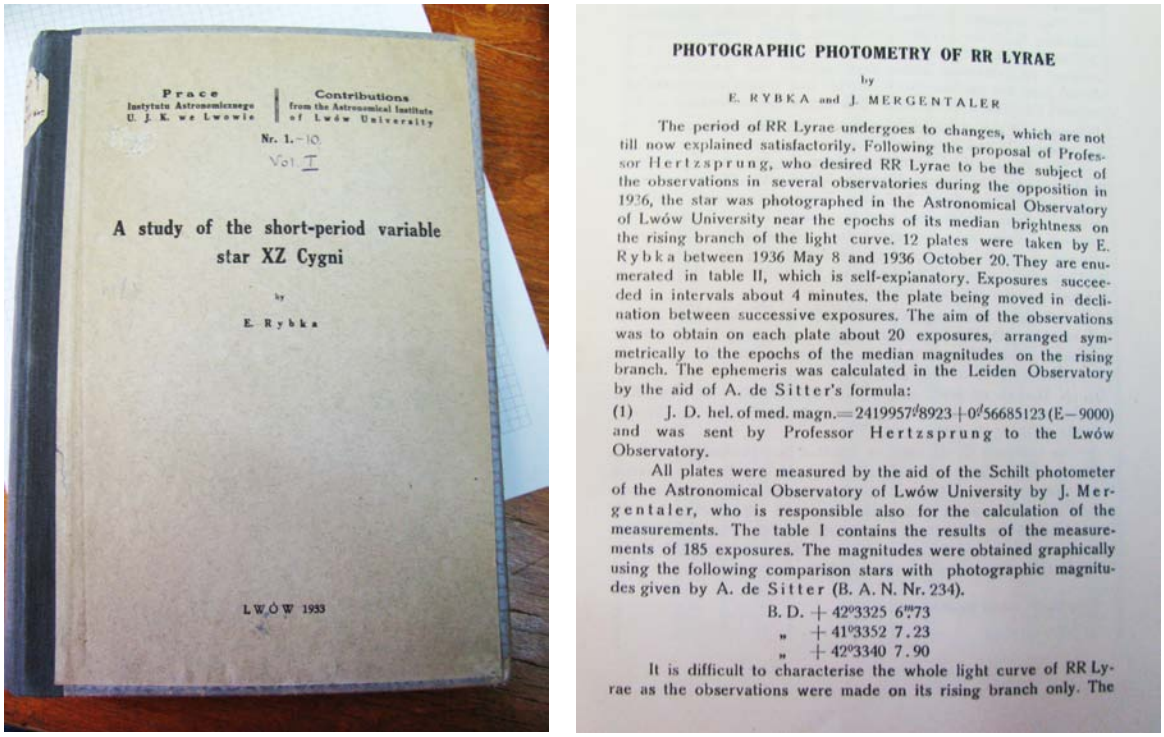


Fig.6. Statistical representation of AO LNU glass collection (listed part)

In 1945-1950 years photographic observations of variable stars, novae, comets, lunar eclipses were carried out. On Zeiss astrocamera (D = 100 mm, F = 500 mm) photographic observations of selected regions of the sky to study variable stars, located on the south from the North Pole to the DEC = 10 degr were continued. Today, AO LNU is the owner of valuable archive that stores the photographic plates from 1939. Formats of plates are 90x120 mm, 130x180 mm. Plates are not always treated or processed partially in accordance with the tasks. The time interval of archive covers 37 years(1939-1976). Single plates are attributed to 1936-1938 observational moments.

The total number of plates in Lviv collection numbers about 8 000, including nearly 6 000 plates, which are the direct images of the northern sky. Besides variable stars and novae, observations of comets (Whipple, Tuttle, Giacobini, Mrkos, Burnham, Roland, Alcock, Swift,Honda, De Vico Swift, van den Bergh, Hyakutake, Kilstona, Ikeya-Seki, Arend, Everhart and others) and minor planets were made.



Prace
Instytutu Astronomicznego
U. J. K. we Lwowie

Contributions
from the Astronomical Institute
of Lwów University

Nr. 1.–10.

Vol. I

A study of the short-period variable star XZ Cygni

by

E. Rybka

LWÓW 1933

PHOTOGRAPHIC PHOTOMETRY OF RR LYRAE

by

E. RYBKA and J. MERGENTALER

The period of RR Lyrae undergoes to changes, which are not till now explained satisfactorily. Following the proposal of Professor Hertzsprung, who desired RR Lyrae to be the subject of the observations in several observatories during the opposition in 1936, the star was photographed in the Astronomical Observatory of Lwów University near the epochs of its median brightness on the rising branch of the light curve. 12 plates were taken by E. Rybka between 1936 May 8 and 1936 October 20. They are enumerated in table II, which is self-expianatory. Exposures succeeded in intervals about 4 minutes, the plate being moved in declination between successive exposures. The aim of the observations was to obtain on each plate about 20 exposures, arranged symmetrically to the epochs of the median magnitudes on the rising branch. The ephemeris was calculated in the Leiden Observatory by the aid of A. de Sitter's formula:

(1) J. D. hel. of med. magn. = 2419957^{d}8923 + 0^{d}56685123 (E − 9000)

and was sent by Professor Hertzsprung to the Lwów Observatory.

All plates were measured by the aid of the Schilt photometer of the Astronomical Observatory of Lwów University by J. Mergentaler, who is responsible also for the calculation of the measurements. The table I contains the results of the measurements of 185 exposures. The magnitudes were obtained graphically using the following comparison stars with photographic magnitudes given by A. de Sitter (B. A. N. Nr. 234).

B. D. + 42°3325 6^m.73
„ + 41°3352 7.23
„ + 42°3340 7.90

It is difficult to characterise the whole light curve of RR Lyrae as the observations were made on its rising branch only. The

Fig.7. “Contributions from Astronomical Institute of Lwow University”, v.I,1933

Observations of variable stars were done with the method of multicolor photometry to determine the physical parameters of their variability and to build a physical model (EP Lyr, CX Lyr, BD Her, RZ Lyr, V342 Her, V733 Agl, CU Cyg, etc.). Part of the plates was obtained with multiple exposures, plates with emulsions of 15 sorts were used.

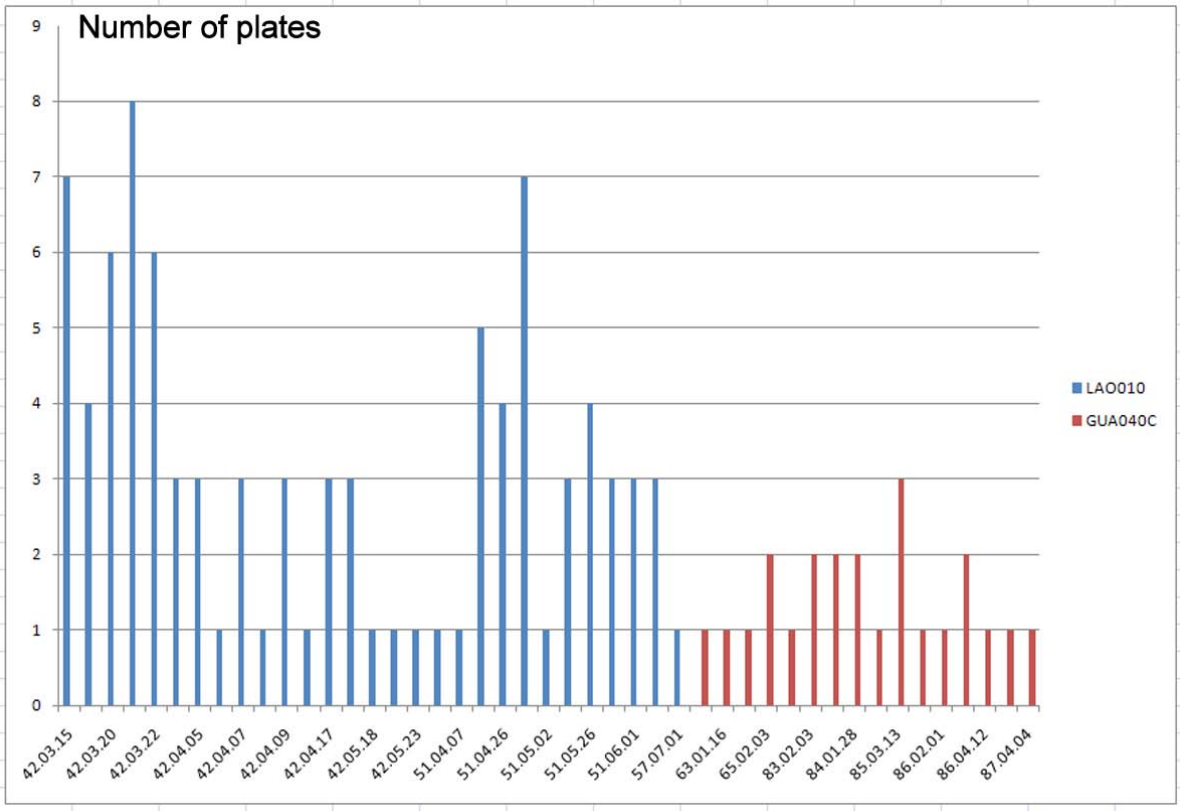
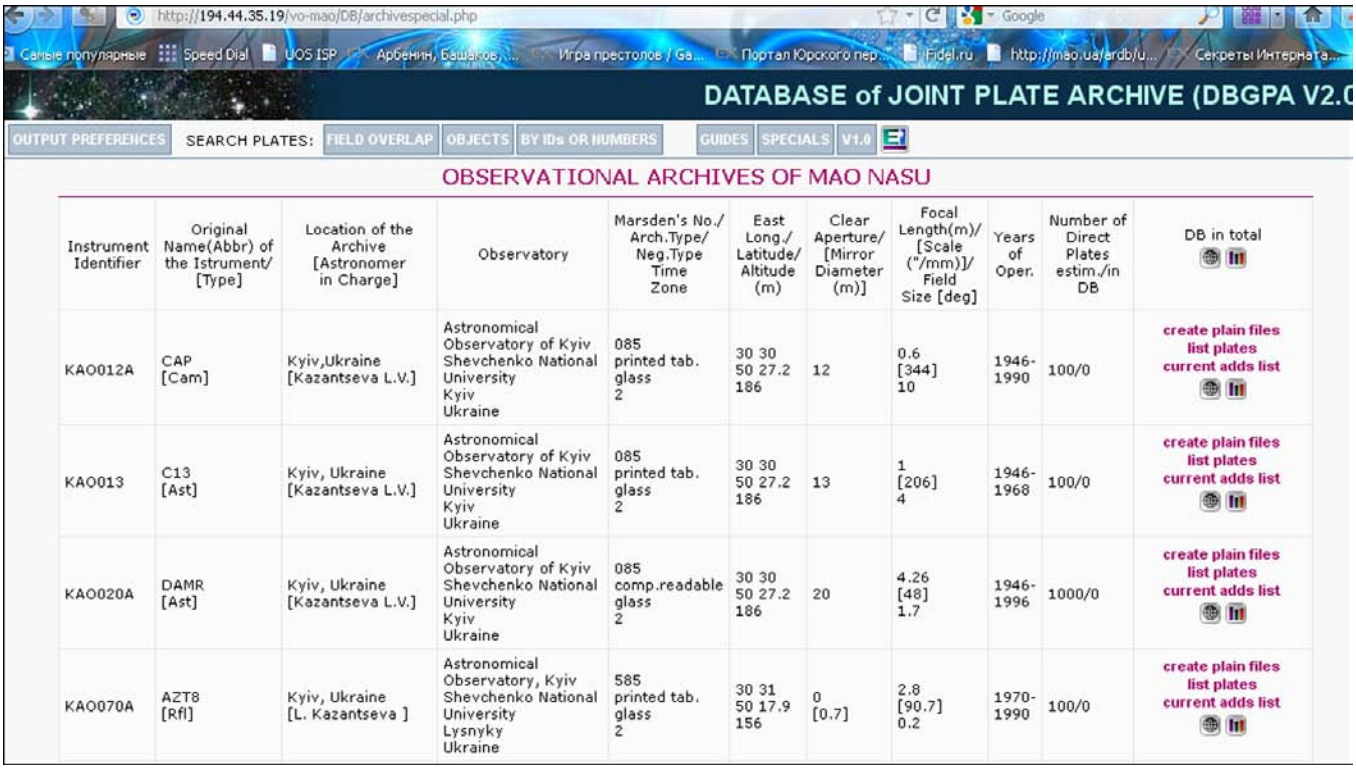


Fig.8. Timeline of W Uma photographic observations**.** Blue bars – glass archive of AO LNU (1942-1957), red bars – archive of MAO NASU (1965-1987).

Digital archive of the Astronomical Observatory of Kyiv National University

According to preliminary estimates, a collection of astronomical photographic images of the Astronomical Observatory of Kyiv National Taras Shevchenko University has over 20,000 images of the period 1898-1996. To date about 4.5 thousand plates are systematized, identified and partly cataloged and digitized. 65% of them are the glass plates, others are the large-format films. For the convenience of organizing photos a long time period is divided into over 200 series, each one is separately examined and digitized.

Most of the series include pictures of the photometric standards obtained on the same date. In the case of comets, exhibited by different methods, calibration images were obtained. Most plates have dimensions of 13 x 18, 13 x 13 and 16 x 16 cm, the maximum size of plates - 30 x 30 cm, the minimum (calibration ones)- 9 x 6 cm. The collection includes also some secondary images, achieved by the contact method, but their accuracy needs to be investigated as well as the accuracy of slides, obtained from plates of large size. On plates emulsions of more than 40 types were identified.



Instrument Identifier	Original Name(Abbr) of the Istrument/ [Type]	Location of the Archive [Astronomer in Charge]	Observatory	Marsden's No./ Arch.Type/ Neg.Type Time Zone	East Long./ Latitude/ Altitude (m)	Clear Aperture/ [Mirror Diameter (m)]	Focal Length(m)/ [Scale ("/mm)]/ Field Size [deg]	Years of Oper.	Number of Direct Plates estim./in DB	DB in total
KAO012A	CAP [Cam]	Kyiv,Ukraine [Kazantseva L.V.]	Astronomical Observatory of Kyiv Shevchenko National University Kyiv Ukraine	085 printed tab. glass 2	30 30 50 27.2 186	12	0.6 [344] 10	1946-1990	100/0	create plain files list plates current adds list
KAO013	C13 [Ast]	Kyiv, Ukraine [Kazantseva L.V.]	Astronomical Observatory of Kyiv Shevchenko National University Kyiv Ukraine	085 printed tab. glass 2	30 30 50 27.2 186	13	1 [206] 4	1946-1968	100/0	create plain files list plates current adds list
KAO020A	DAMR [Ast]	Kyiv, Ukraine [Kazantseva L.V.]	Astronomical Observatory of Kyiv Shevchenko National University Kyiv Ukraine	085 comp.readable glass 2	30 30 50 27.2 186	20	4.26 [48] 1.7	1946-1996	1000/0	create plain files list plates current adds list
KAO070A	AZT8 [Rfl]	Kyiv, Ukraine [L. Kazantseva]	Astronomical Observatory, Kyiv Shevchenko National University Lysnyky Ukraine	585 printed tab. glass 2	30 31 50 17.9 156	0 [0.7]	2.8 [90.7] 0.2	1970-1990	100/0	create plain files list plates current adds list

Fig.9. Some KAO archives in the JDA.

A significant part of early glass collection consists of photographic plates, had been used for photometric calibration and presenting the methods of calibration. Calibration images were obtained out of instrument focus. In order to estimate luminous flux of object on its photographic image the methods based on the principles of sources equalization were used. Magnitudes of stars are derived from logarithm of luminosity in the every place of the plate due to homogeneous brightness and equal dimensions of out-of-focus stars images. For comparison of star magnitudes and photometric instrumental data, calibration of plate was made twice immediately during observations before and after the main image. Calibration was made by the aid of tube photometer, which generates its own photometric system and being calibrated in laboratory gives the tools for star magnitude estimation.

Fig.10. Photometric standard for photographic session of 1975h comet. Out-of-focus image of α Draconis, AZT-8 telescope.

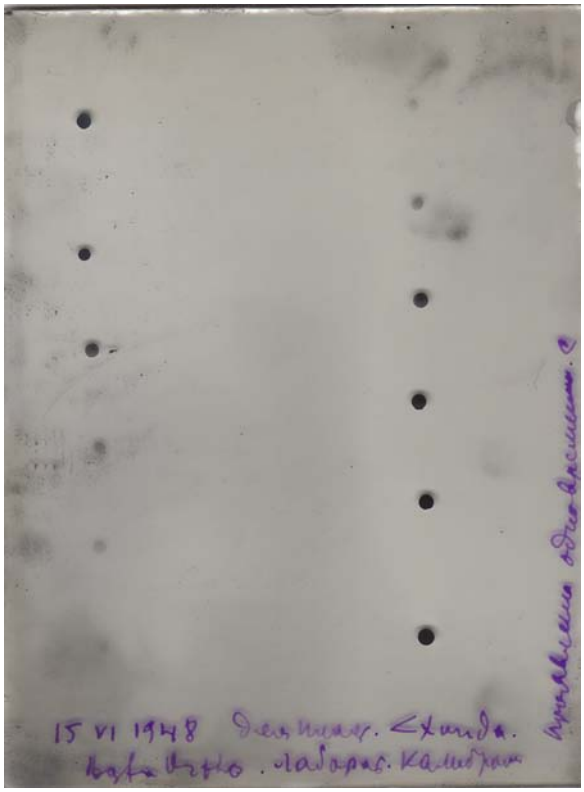


Fig.11. Calibrating images obtained with the tube photometer in laboratory for estimation of emulsion sensibility

Fig.12. Different photometric wedges

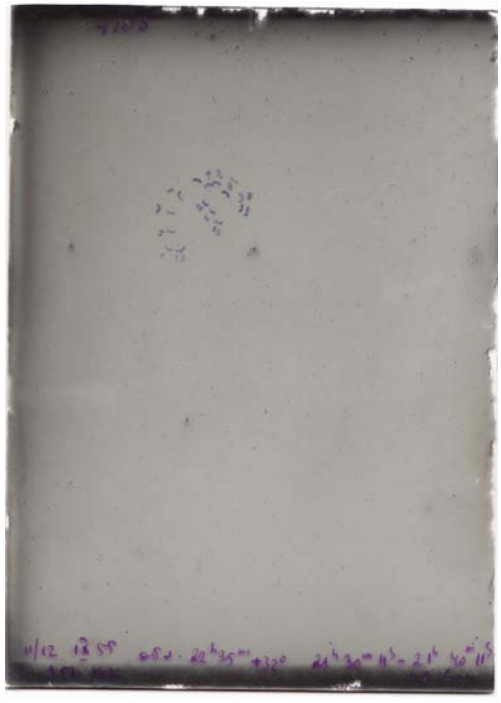


Fig.13. Photometric standard for calibration of observations

Another method of photometric estimations consists in application of photometric wedge for film exposure through it. Then the obtained scale of densities was used for reckoning of star magnitude by grade of emulsion darkening. More often photometric estimations were provided with expositions of photometric standard fields, obtained several times during the observational session.

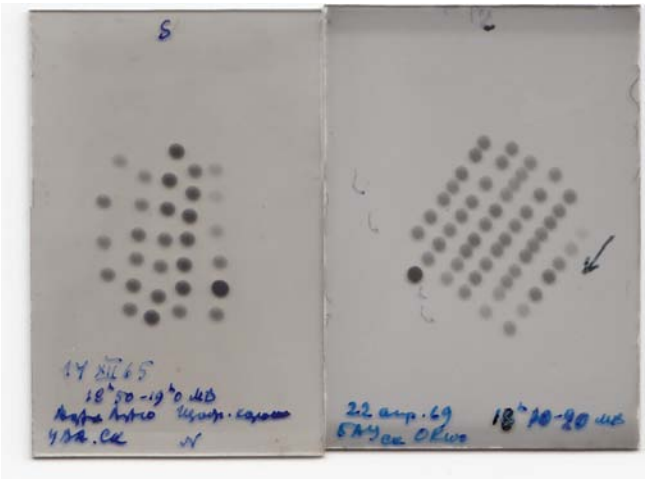


Fig.14. Out-of-focus calibration images

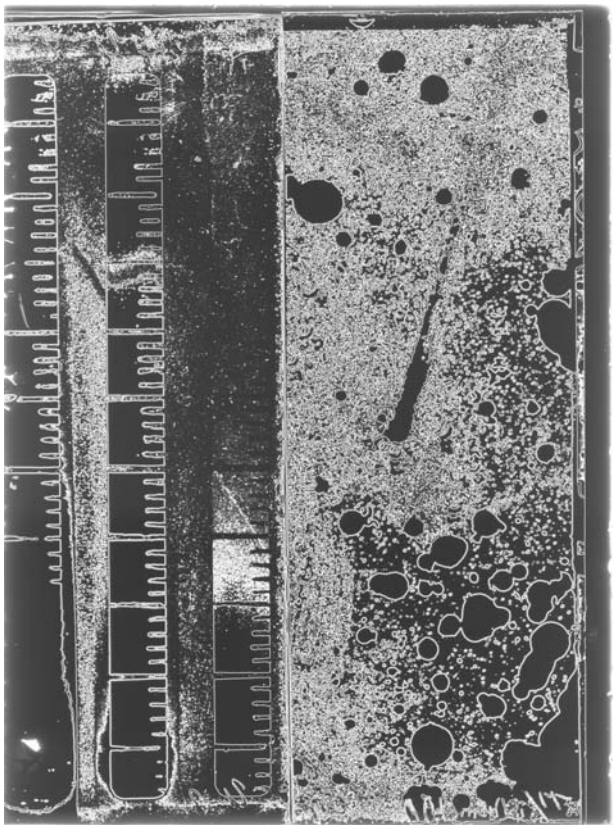


Fig.15. Equidensites

For photometric estimations of stretched objects the so called Sabattier *effect* or equidensites method was used. If the plate is exposured several times during the development, details of image with different grade of darkening could be separated, exposing thereby different structures of object.

The special feature of the collection is that the images were obtained on 40 different instruments as in stationary so in expeditionary conditions. Solar system bodies, especially comets, solar and lunar eclipse, the passage of Mercury and Venus on the solar disk, stellar fields around the radio sources, meteors and satellites were among the objects of observations. Problems with collection organization and classification are caused not only by a long timeframe, but also by the fact that during this period observatory collection survived two evacuations, that did not facilitate to keep the entire collection and all the observational logs. In 2010, the first attempts have been undertaken to implement the standards of the IVOA to the historical part of the archive, received during 1898-1946, and to provide the open access to its data.

In 2010 the efforts in KAO plate collection including into Joint Database of Ukrainian glass archives on the basis of MAO NASU computational facilities have been undertaken. Test digital images of near 100 historical plates were obtained with Microtek 9800 flatbed scanner and estimation of possible positional and photometric accuracies which could be reached from digital images of KAO plate collection has been conducted. The accuracy studying gives the very encouraging results of 100 mas in positions and 0.07 in magnitudes.