Mem. S.A.It. Suppl. Vol. 15, 192

Memorie della
Supplementi

Wide-field plate archives in Rozhen and Belgrade observatories

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Abstract. The wide-field plate archives at disposal in Rozhen Observatory (9332 plates obtained in the period 1979 – 1994) and Belgrade Observatory (14500 plates obtained in the period 1936 - 1996) are presented. The plate archives, made in the frames of different observing programmes, reflect the tendencies in the development of astronomy in these countries. The results from the joint collaboration concerning the plate cataloguing and digitization with EPSON flatbed scanners providing good speed of scanning and good astrometric and photometric accuracy while generating digital data, as well as the inclusion of the images of the scanned plates in WFPDB and BELDATA and their online access in the frames of the Virtual Observatory, are presented too.

Key words. Astronomical Databases: miscellaneous – Catalogs – History and philosophy of astronomy

1. Introduction

In 1872 B. Gould began the first systematic astronomical observations of stellar clusters using photographic plates. The advantages of the photographic observations with plates (or films) as detectors and information storage in comparison with the visual observations soon prepared the coming of photographic era in astronomy which lasted about 130 years and was replaced by the CCD one. Today the plates are on one hand - unique source of information for the past of the different astronomical objects, and on the other hand - scientific heritage representing the previous stage of the present astronomical knowledge. A compiled list of astronomical tasks based on the present exploitation of the archival plates can be found in Tsvetkova (2009).

Since 1991 thanks to the development of information and communication technologies we undertook large-scale work on expanding the use of the stored astronomical plate collections with establishment and development of a database for wide-field ($> 1^0$) plates - Wide-Field Plate Database (WFPDB, http://www.skyarchive.org, (Tsvetkov 1991).

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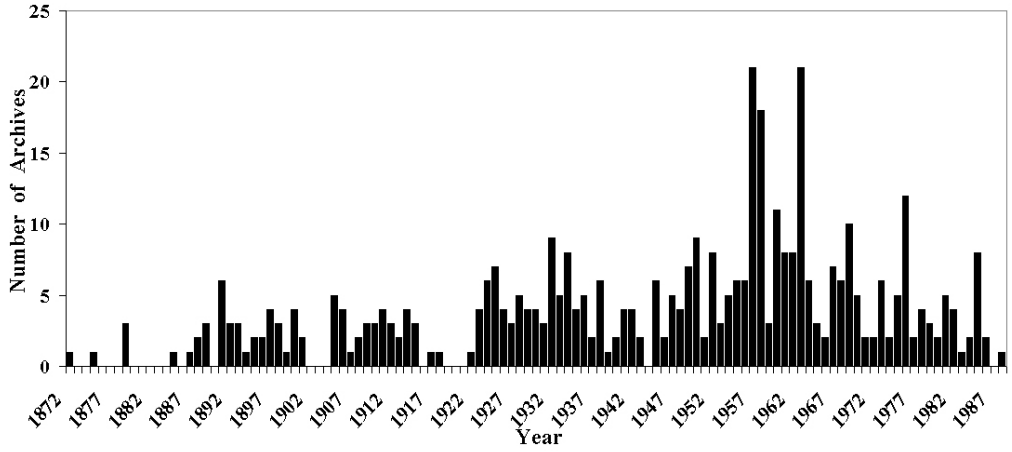
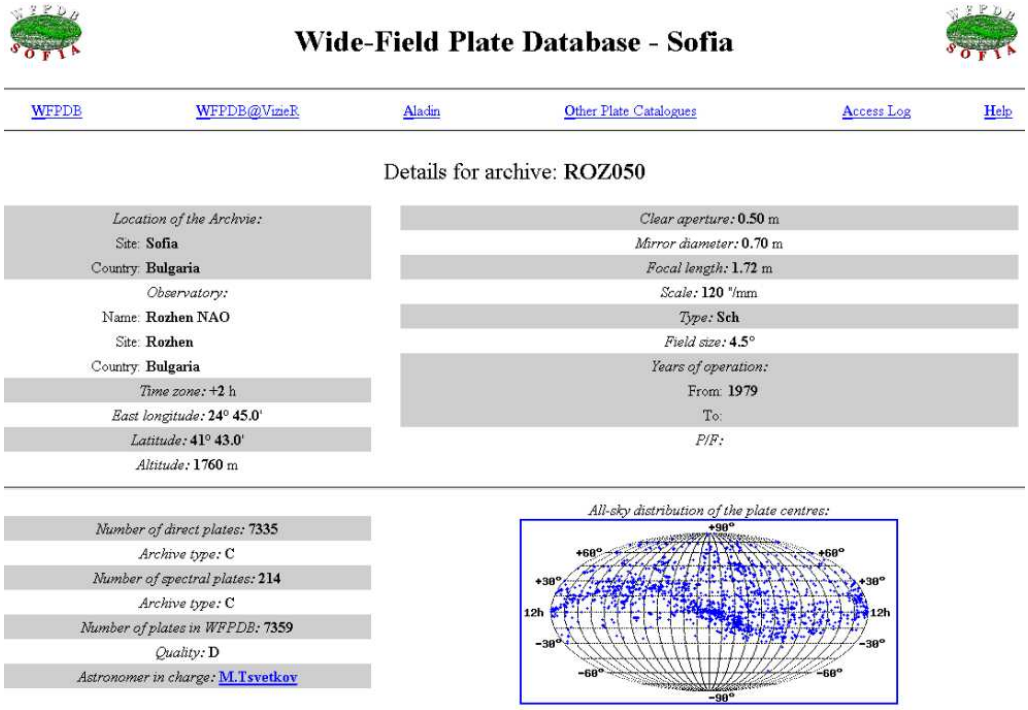


Fig. 1. Time distribution of the number of worldwide plate archives.

Today the WFPDB comprises the information for 442 plate archives containing about 2200000 plates (in the Catalogue of Wide-Field Plate Archives, (Tsvetkova and Tsvetkov 2008) and the descriptive information for 546000 plates (in the Catalogue of Plate Indexes). Combining the information from the both catalogues one can be completely informed about the archives and its contents.

As "plate archive" we denote a collection of plates obtained with a definite telescope at a definite observational site and stored at a definite place. This means that one telescope may have more than one archive, if the telescope was moved or if its plates are stored at different observatories or institutions. The most of the wide-field plate archives are established with small apertures telescopes up to 50-60 cm, mostly refractors, astrographs and cameras. The number of plates in the individual archives ranges between several tenths to more than 100000. Only a small number of archives have more than 10000 plates. The establishment of the plate archives in the different observatories is shown in Fig. 1 using the data from the Catalogue of the Wide-Field Plate Archives (Tsvetkova and Tsvetkov 2006, 2008).

This distribution reveals the history and tendency of development of astronomy. For instance, one can notice a peak around 1892 when the photographic observations in astronomy began to be widely used, and quickly increased number since 1960, when was the "Golden Age" of wide-field photography, as well as the both depressions because of the two world wars. The maximum in the appearance of new archives is after 1955 up to the beginning of 1970, when the plate observations comprised in more than 130 archives started. It is interesting fact that while in the observatories in Bulgaria, Romania and Serbia there are plate collections with total number of plates respectively 9332, 16403 and 14500, in the observatories of the both neighbouring countries Greece and Turkey no any plate observations were conducted, due obviously to the specific development of astronomy in these countries. Analysing the content of the plate archives, namely the number of plates and its time distribution, the observing programmes in the frames of which the plates were obtained, observed object type, used method of observation, exposure multiplicity and duration, emulsions and filters for realization of given photometric system, one can have a look to history and development of astronomy in the respective country. Very often the time distribution of the plates reveals a coincidence between the maximums of the observational activity and the periods of some observational campaigns executed in the respective observatory: sky sur-



Wide-Field Plate Database - Sofia

WFPDB | WFPDB@VizieR | Aladin | Other Plate Catalogues | Access Log | Help

Details for archive: **ROZ050**

Location of the Archvie:	*Clear aperture:* **0.50** m
Site: **Sofia**	*Mirror diameter:* **0.70** m
Country: **Bulgaria**	*Focal length:* **1.72** m
Observatory:	*Scale:* **120** "/mm
Name: **Rozhen NAO**	*Type:* **Sch**
Site: **Rozhen**	*Field size:* **4.5°**
Country: **Bulgaria**	*Years of operation:*
Time zone: **+2** h	From: **1979**
East longitude: **24° 45.0'**	To:
Latitude: **41° 43.0'**	*P/F:*
Altitude: **1760** m	

Number of direct plates: **7335**	*All-sky distribution of the plate centres:*
Archive type: **C**	
Number of spectral plates: **214**	
Archive type: **C**	
Number of plates in WFPDB: **7359**	
Quality: **D**	
Astronomer in charge: M.Tsvetkov	

Fig. 2. WFPDB search result with instrument identifier ROZ050.

vey, supernova search, investigations of flare stars in stellar associations and clusters.

2. Rozhen Observatory wide-field plate archives

The plate observations in Rozhen Observatory began immediately after the installation and test observations of the both wide-field telescopes - 2m Ritchey-Chretien-Coude (RCC, in 1980) and Schmidt (in 1979) telescopes, and when in 1981 the observatory was officially opened, already there were a lot of plates obtained. In Tables 1 and 2 the essencial information for the Rozhen telescopes and plate archives respectively, as an excerpt of the Catalogue of Wide-Field Plate Archives (version 5.2 August 2009) is present.

Using the data retrieval from the WFPDB with instrument identifier ROZ200 and ROZ050 respectively, a statistics concerning the all-sky distribution of the plate centres, the distribution of the number of plates according to the type of the observed objects (asteroids, planets, comets, variable stars, open or globular clusters, galaxies, etc.), the exposure duration influencing the plate limit, as well as the exposure multiplicity as a method of observation required by different programmes (for asteroids, search for flare stars, etc.), the used emulsions, the plate size when it concerns the plate digitization, is presented here. In the Wide-Field Plate Database - Sofia Search Page (http://draco.skyarchive.org/search/) can be obtained details for the both archives of the Rozhen Observatory (see Fig. 2 for the details of the archive of the 50/70 cm Schmidt telescope under the WFPDB identifier ROZ050), as well as the all-sky distribution of the plate centres. The distribution of the number of the obtained 1984 plates with the 2m RCC telescope within the period 1980 – 1992 (Fig. 3) is influenced not only by the astroclimatic conditions, but also by such facts in the history of the observatory as the realuminization of the primary mirror of the telescope in 1987.

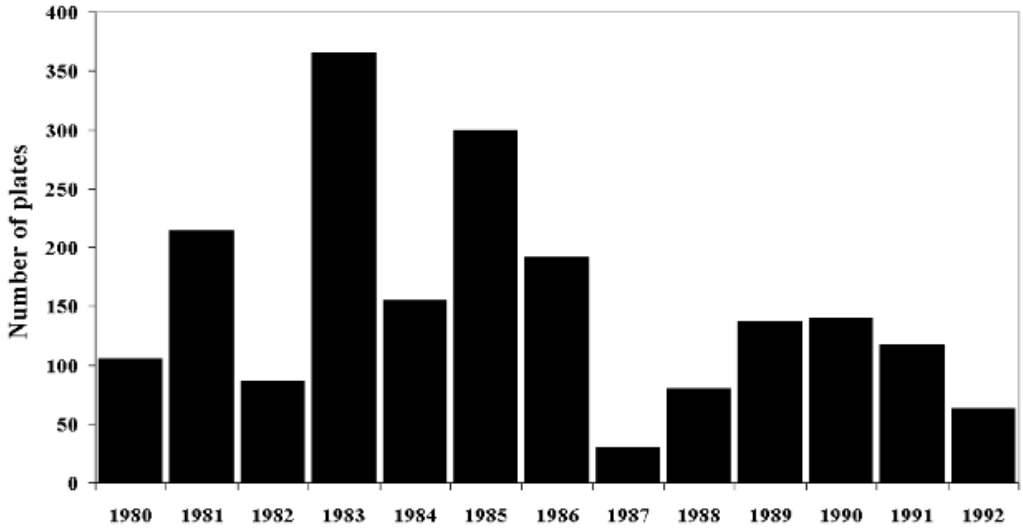


Fig. 3. Time distribution of the number of plates of the Rozhen 2m RCC telescope.

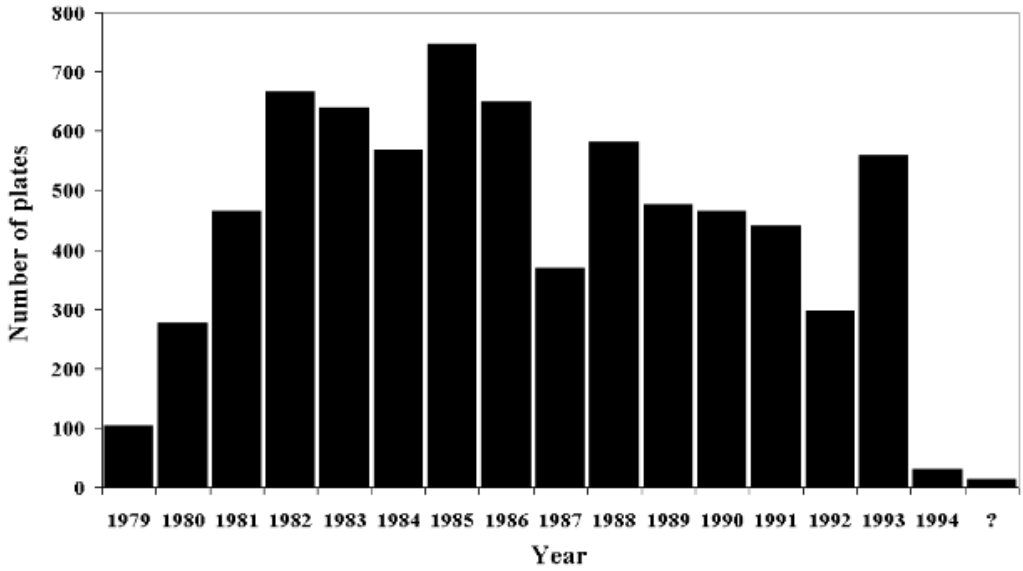


Fig. 4. Time distribution of the number of plates of the Rozhen 50/70 cm Schmidt telescope.

The time distribution of all 7348 plates (170 of them with objective prism) obtained with the Rozhen Schmidt telescope in the period 1979 – 1994 is shown in Fig. 4. The distribution of the number of the ROZ200 and ROZ050 plates by month reflects the better conditions for observations in July, August, September and October in Rozhen Observatory.

The plate observations were performed in the Johnson wide band photographic system – UBVRI, or in pg, for the ROZ200 plates with about 57% of all obtained in B colour,

Table 1. Rozhen Observatory wide-field telescopes

WFPDB identifier	Aperture (m)	Focal length (m)	Scale "/mm	Tel. type	Field size (deg)
ROZ050	0.50/0.70	1.72	120	Schmidt	4.5
ROZ200	2.00	16	13	Ritchey-Chretien	1.0

Table 2. Rozhen Observatory wide-field plate archives

WFPDB instr. identifier	Years of operation	Number of plates	Size of plates (cm)	Archive type	Astronomer in duty
ROZ050	1979-1994	7348	13x13, 16x16	C	M. Tsvetkov
ROZ200	1980-1992	1984	30x30	C	N. Petrov

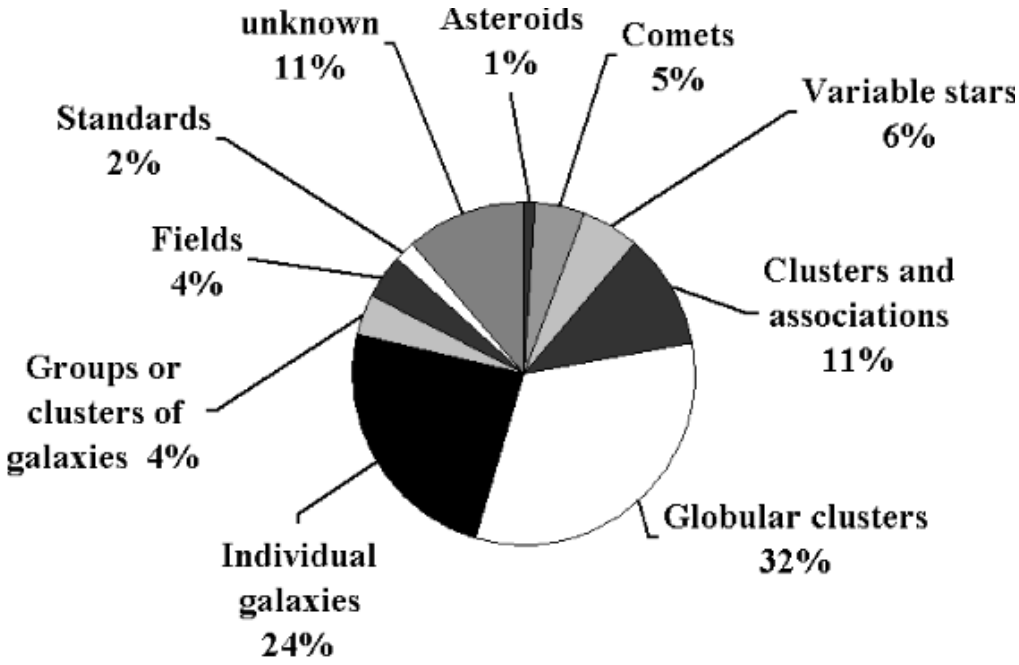


Fig. 5. Observing programmes carried out with the Rozhen 2m RCC telescope.

while for ROZ050 plates 52% are pg plates. From the distribution of the duration of exposures used for observations carried out with the 2m RCC telescope it is seen that 44% of all plates were obtained with exposure duration less and equal of 30 min. In the distribution the very short exposures less than 5 min constitute about one third - 28% of them, present by an observed maximum. The plates with exposure duration equal of 30 min are another third – 29%. Half of the plates with exposure duration bigger than 30 min and less than 100 min were obtained with exposure equal of 60 min which give another maximum in this distribution. The plates with exposure duration bigger than 100 min up to the maximum exposure

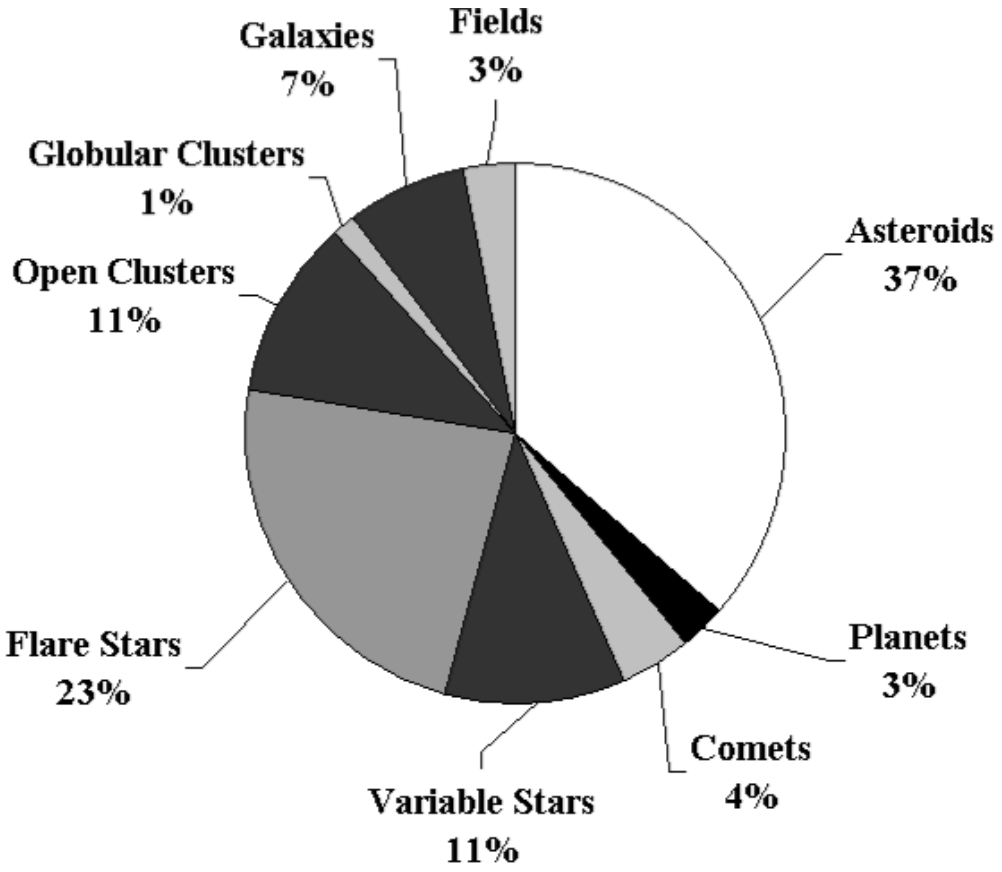


Fig. 6. Observing programmes carried out with the Rozhen 50/70 cm Schmidt telescope.

used (300 min) constitute about 16% of all 2m RCC plates. Predominantly such long exposure plates were used for observations of M31 and other galaxies. 93% of all ROZ050 plates are with exposures less than 40 min. The predominant exposures are 20 min (29%) and 30 min (18%).

The observing programmes of the Rozhen 2m RCC telescope include the observations of globular clusters (639 plates), active galaxies (Starburst, Seyfert, quasars, Markarian's, Arakelian's), and interacting galaxies (475 plates), stellar clusters and associations (217 plates), variable stars (112 plates), comets (90 plates), as well as groups or clusters of galaxies, different fields, asteroids, standards, etc. The used emulsions were Kodak (103aO, 103a D, 103aF, IIaO, IIaD, IIaF, IIIaF, IIIaJ, etc.) and ORWO (ZU 21, ZP3, RP1, etc).

In the observing programmes of the Rozhen 50/70 cm Schmidt telescope the most observed objects were the asteroids (2450 plates), followed by the search for flare-ups of flare stars in stellar clusters and associations as the Pleiades, Gamma Cygni region, M42/43 in Orion, Praesepe, Alpha Per, Tauri Dark Clouds, the open cluster NGC 2264, the emission nebula NGC 7000 (with totally 1564 plates). Another observed objects were open stellar clusters - among them IC 4665 with 263 plates available, IC 5146 with 80 plates available; different type variable stars (e.g. for the unusual nova-like star KR Aur there are 177 plates); different type galaxies; comets: Halley, Shoemaker-Levy 9 (1993e),

Giacobini-Zinner (21P), Tempel 1, Tempel 2, Schaumasse, Panther, Metcalf-Brewington (1991a), Tanaka-Machholz (1992d), Austin, Bradfield (C/2004 F4), Encke, Helin (1977e), Kopff, Levy (1990 XX), Machholz (C/2004 Q2); different fields; major planets; globular clusters, etc.

3. Belgrade Observatory wide-field plate archives

At the time of the establishment in 1887 the Belgrade Observatory was located in the center of the city of Belgrade. The photographic plate observations began after moving the observatory in 1932 on the Veliki Vračar Hill (today Zvezdara) with better conditions with the supplied wide-field telescopes 16 cm Zeiss Astrograph, Zeiss Refractor with 16 cm photographic camera and Askania Equatorial Refractor with 12.5 cm photographic camera. The systematic observations started in 1936 with the Zeiss astrograph when with exposure duration of 3 hours the most productive observer M. Protić reached 14-15th stellar magnitude while observed minor planets. The observing programmes executed with the Belgrade wide-field telescopes include search for new minor planets (33 new discovered) and investigations of known minor planets, observations of comets, Sun, major planets, stellar regions, stars and stellar clusters, zone observations, nebulae, etc. (Protić-Benišek 2006). Details for the inventory of the Belgrade plate collection, cataloguing and plate digitization can be found in (Tsvetkova et al. 2009).

In Tables 3 and 4 the main characteristics of the Belgrade Observatory wide-field telescopes (with respective WFPDB identifiers and the names under which the telescopes are known in the observatory), as well as the characteristics of their plate archives are respectively given as an excerpt of the Catalogue of Wide-Field Plate Archives (version 5.2 August 2009). In Fig. 7 the time distribution of 3000 scanned Belgrade plates is given. Fig. 8 presents the observing programmes carried out with the Belgrade wide-field telescopes.

The preparation of the computer-readable versions of the Belgrade Observatory wide-field plate archives from the stored logbooks is running simultaneously with the plate scanning. The used emulsions were Kodak 103aO, IIaO, 103aJ, 103aF, etc., Ferrania Panchro anti-halo, Agfa Astro, Perutz, Gevaert Super Chromosa, ORWO ZU2, ZU21, Ilford.

4. Plate digitization

The main requirements to the scanners, suitable for plate digitization, are good astrometric and photometric accuracies while generating archival quality digital data with fast scanning speeds. The available PDS1010plus microdensitometer in Sofia Sky Archive Data Center (SSADC), giving possibility for high precision, is too slow for systematic plate scanning. The improved flatbed scanners fulfill the requirements and facilitate large-scale digitization making it more cost-effective. In Table 5 the flatbed scanners EPSON at disposal in Rozhen Observatory, SSADC and Belgrade Observatory, and their scanning platforms as far as they are dependent on the plate size, are present.

In Table 6 the main parameters of the available flatbed scanners are present: Optical density (Dmax), Color depth (bit internal/bit external), Grayscale depth (bit internal/bit external), Maximum hardware resolution.

The used software for scanning is the standard one for making preview images - Adobe Photoshop, and the programme Scanfits developed by S. Mottola (Barbieri et al. 2003) for the real scans in FITS format.

The plate scanning was done with whole density range (0 – 255) and Gamma = 1.00. The chosen resolution is a compromise between the outcome file size and the astronomical task. The chosen color depth is dependent also from the task: for preview images in order to save the observer's marks on the plate, the image type is 8-bit 24 bit Color, for the real scans – 16-bit Grayscale.

Concerning the easier web accessibility and to store the information from the observer's marks on the plate a system for quick plate visualization – plate previews, was developed. The preview images are done with 600 (or 1200) dpi in TIFF format and compressed

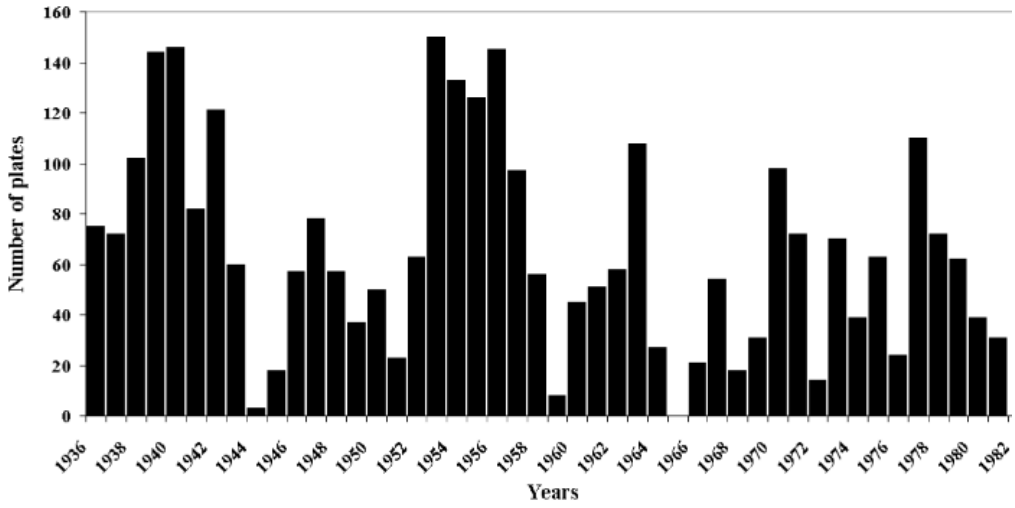


Fig. 7. Time distribution of 3000 scanned Belgrade plates.

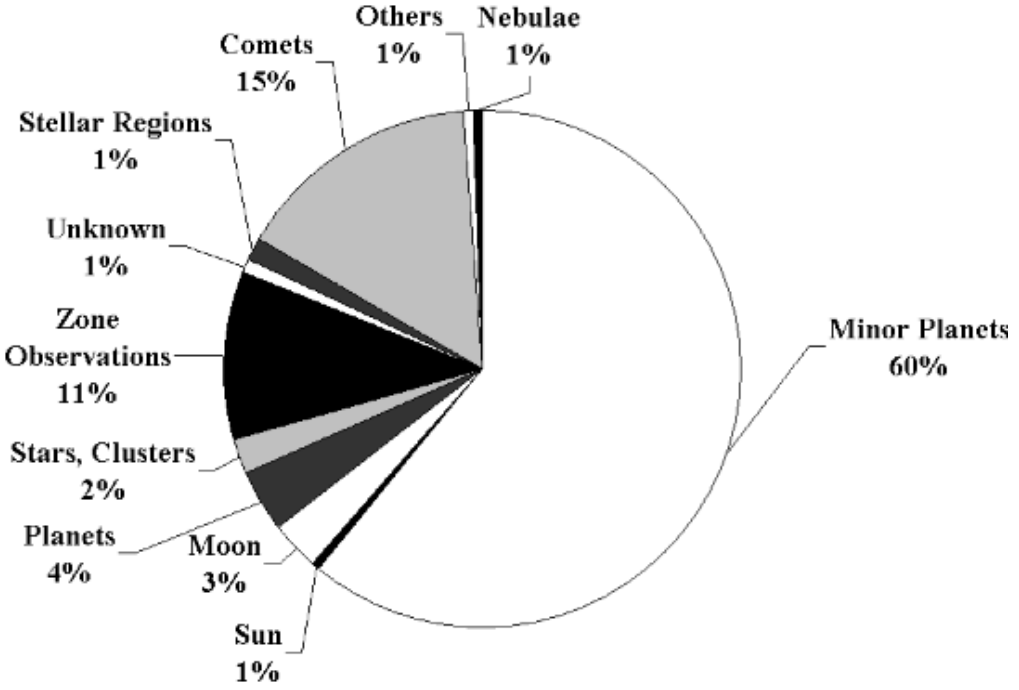


Fig. 8. Observing programmes carried out with the Belgrade Observatory wide-field telescopes.

Table 3. Belgrade Observatory wide-field telescopes

WFPDB identifier	Aperture (m)	Focal length (m)	Scale "/mm	Tel. type	Field size (deg)
BEL012	0.12	1.00	206	Askania Rfr	7.0
BEL016A	0.16	0.80	258	Zeiss Ast	11.5
BEL016B	0.16	0.80	258	Zeiss Rfr	11.5

Table 4. Belgrade Observatory wide-field plate archives

WFPDB instr. identifier	Years of operation	Number of plates	Size of plates (cm)	Archive type	Astronomer in duty
BEL012	1970-1996	4000	9x12, 13x18	TC	V. Protić-Benišek
BEL016A	1936-1985	10000	9x12, 13x18	TC	V. Protić-Benišek
BEL016B	1936-1941	500	6x9	T	V. Protić-Benišek

Table 5. Flatbed scanners at disposal

Institution	EPSON flatbed scanner type	Transparency scanning area (mm)
Rozhen Obs.	EXPRESSION 10000XL	310x419
SSADC	EXPRESSION 1640XL	290x419
	PERFECTION V700 PHOTO	203x254
Belgrade Obs.	PERFECTION V700 PHOTO	203x254

2000x2000 pxl JPEG format. The real scans for photometric or astrometric tasks are done with optimal big resolution 1600 (or 2400) dpi. In order to have adequate web archiving among the variety of file formats we keep within FITS format for digitized plate images as requirements of Virtual Observatory.

The standards and metadata for digitized photographic plates in order to provide indexing, accessing, preserving, and searching for plate images are similar to the developed ones in AIP for the Potsdam CdC plates included in the German Astrophysical Virtual Observatory (GAVO, http://vo.aip.de/plates/, (Tsvetkov et al. 2009). The search interface for the scanned plates give information for the plate identifier, coordinates, date, file type (compressed JPEG, TIFF, FITS format), header of the FITS file, file size, and the scan.

What concerns the preservation of digital content, stored on the servers of WFPDB and Serbian VO (Jevremović et al. 2009), using the advanced information technologies we are in process of application of wavelet based approaches to more effective compression of the huge volume of scanned plate data.

A preview image of the ROZ050 000382 plate in M42/M43 in the Orion region with the marks of the observer is shown in Fig. 9. In Fig. 10 a part of scanned BEL016A480007 plate with image of comet 1948a (Mrkos), and with the marks of Milorad Protić is shown. The history of the discovery of this comet is that on 1947 Dec 20, A. Mrkos discovered the comet on his plate obtained in the Skalnate Pleso Observatory, but because bad weather next days he could not confirm it. Again he observed on 1948 Jan 18 and anounced the

Table 6. Main parameters of the available flatbed scanners

Scanner	Dmax	Color depth	Grayscale depth	Resolution (dpi)
1640XL	3.6	42/42	14/14	1600
10000XL	3.8	42/42	16/16	2400x4800
V700 PHOTO	4	42/42	16/16	4800x9600

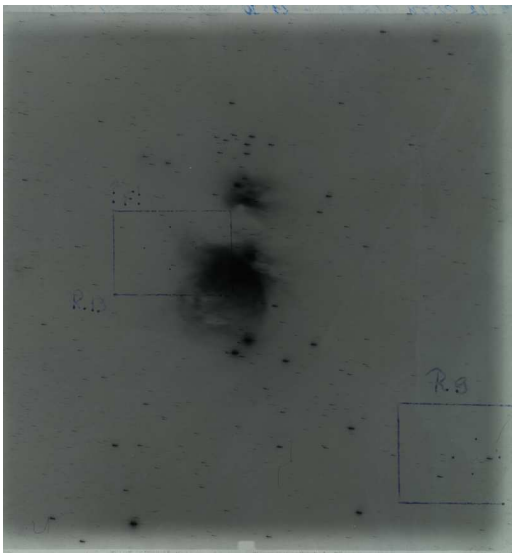


Fig. 9. The scanned ROZ050 000382 plate in the Orion region.

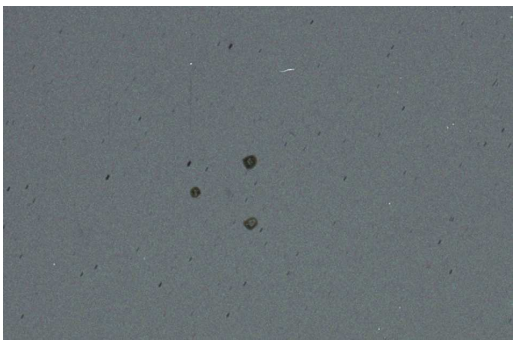


Fig. 10. A part of scanned BEL016A480007 plate with image of 1948a comet.

discovery of a new comet named 1948a. In Belgrade Milorad Protic observed the same comet on 1948 Jan 10, i.e. before the announced discovery. Thus this plate was used for improving the comet coordinates.

5. Collaboration results

The collaboration in the wide-field plate archiving was in the frames of joint bilateral projects between the Astronomical Observatory of Belgrade and Space Research Institute, Bulgarian Academy of Sciences (2004-2006) and the Astronomical Observatory of Belgrade and Institute of Astronomy, Bulgarian Academy of Sciences (2007-2009). The topics were Cataloguing the wide-field photographic observations, Digitization of selected plates, Plate processing (with the routines supplied by IRAF software packages and IDL astronomy users library), Application of archived observations, Exchange of experience in development and application of astronomical databases (WFPDB and BELDATA) and organization of mirror sites of the databases.

The working programme included: Preparation of plate catalogues for the wide-field photographic observations at Belgrade Observatory in the WFPDB format; Digitization of Belgrade plates; Inclusion of the plate catalogues in the WFPDB and in BELDATA; Estimation of the quality of the digitization data; Inclusion of the images of the scanned plates in WFPDB and BELDATA and online access; Organization of mirror sites.

As results the information for the Belgrade plate archives is already included in the WFPDB, there is an online access to this information for all the astronomical community through the WFPDB updated version in SSADC. The plate archiving is included

as a topic in the project Serbian Virtual Observatory (Jevremović et al. 2009), running since February 2008. The Belgrade plates in the region of the Pleiades have been scanned and added to the Pleiades Plate Database (PPDB) aiming to reveal the long-term behaviour of some Pleiades stars. Already there is a systematic plate scanning and as a result up to August 2009 about 3000 plates have been scanned.

6. Future plans

The further work aims an acceleration of the plate cataloguing in Belgrade Observatory in the WFPDB format. The next step will be analysis of the Belgrade plate catalogues based on the data retrieval from the WFPDB. The pipeline of the systematic scanning of Belgrade Observatory includes procreation of archives of digitized Belgrade plates with low resolution for quick plate visualisation and their online access as a main priority, making the preview images in TIFF and JPEG file format and linkage of the preview images to the WFPDB, preparation for including the plate scans data into Virtual Observatory - putting the data on the local servers in Belgrade Observatory. As priority tasks are scanning selected Belgrade plates containing images of minor planets and comets, and scanning plate envelopes (with flatbed scanner or even with digital camera), for saving the information written on them, not put in the catalogue format.

The last step before the systematic astronomical research is an 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 as current tasks. The preparation of digital plate archives according to the main observing programmes is already running process in Rozhen Observatory. The aims are to assemble and explore massive data sets in order to reveal a new knowledge existing in the data, but still not recognized in any individual data set. Some of the representative plates obtained with the Schmidt telescope of Rozhen Observatory during the observation campaign for search and investigations of the flare stars in stellar clusters and associations in 1970 – 1990 are already scanned. Besides the primary aim to serve for investigations of the flare stars another result is the realization of an interlinking the electronic Information Bulletin on Variable Stars (IBVS) where the discovered flare stars are published with the Wide-Field Plate Database (WFPDB) where one can find the scanned plates containing the images of the respective flare stars.

Acknowledgements. K.T., M.T. and M.S.D. thank Dr. E. Lyratzi and Prof. E. Danezis for the invitation and excellent organization of the workshop. The work on the archives is supported by the bilateral project between Bulgarian Academy of Sciences and Serbian Academy of Sciences and Art and partially supported by the BG NSF DO-02-273 grant. It is also supported by Ministry of Science and Technological Development of Republic of Serbia through projects TR13022 Serbian Virtual Observatory, and 146001 Influence of collisional processes on astrophysical plasma spectra.

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