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PHOTOGRAPHIC PLATE LIBRARIES AT EUROPEAN ASTRONOMICAL OBSERVATORIES*

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Abstract. This paper presents the efforts to organize photographic plate libraries at European astronomical observatories and institutions. The Wide-Field Plate Database project, launched in 1991, has been collecting data about the plates, including plate archives, plate index catalogue data extracted from the logbooks, and digitized plate images. Developing further the WFPDB project, we intend to complete the high-resolution digitization of the plates (in standardized FITS file format) and a suitable digitalization of the catalogues and logbooks (in JPEG and TIFF), with flatbed scanners, and also to organize links to the relevant scientific research papers. At present about 250000 plates have been digitized and await implementation of online access. The main idea is to build an Astro-Multimedia Library, based on the latest methods of Computer Science, in particular on Multiresolution Analysis techniques, which allow for efficient representation of image scans at different resolutions.

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1. Introduction. During the last decade at the Institute of Mathematics and Informatics of the Bulgarian Academy of Sciences a process of digitalization of mathematical and other related scientific monographs, journals, conference proceedings and books (recent or older ones) has been running. Living in a digital data world this process is a part of a Digital Mathematics Library for digitalization of the mathematical heritage.

For more than 130 years, the astronomical photographic plates used as detectors and information storage since the first application of photography as a method for astronomical observations have also constituted an important contribution to the scientific heritage. These plates represent the first stage of the modern astronomical knowledge, and are now considered a unique source of information on the past of various astronomical objects. In the framework of the modern project on Astroinformatics as Data-Oriented Astronomy we set aims and objectives to organize the collected data for old astronomical photographic archives of plates (representing direct or objective prism spectral images of astronomical objects), obtained since 1872 (the first systematic observations of stellar clusters by B. Gould in Cordoba Observatory) up to the beginning of the 21 century when the last photographic plates were obtained and totally replaced by charge-coupled devices (CCD)—the major technology today for astronomical digital imaging.

The astronomical photographic plate consists of glass coated on one side by dry emulsion of silver bromide. Such observing material has to be handled with care, not only because the glass is fragile, but also because of the aging of the emulsion—chemical (e.g., yellow spots appear) and physical (e.g., the emulsion begins to peel) deterioration. Many of the astronomical observatories try to collect this valuable plate material considered to be a property of the observatory where the plate had been obtained. The observatories provide appropriate storage for the plates and offer possibilities for working with them; also they collect plates from observatories which are no longer in operation, transferring some of the plates to another observatory, or from individual observers who still keep them but no longer use them. Thus the USA National Science Foundation supports an idea of preserving the photographic plate observations in North America by collecting them in a National Astronomical Plate Archive in the Pisgah Astronomical Research Institute (PARI) in Rosman, North Carolina. In this paper we present the efforts undertaken in Europe.

The astronomical photographic plates obtained with a particular telescope at a particular observational site and stored at a definite place constitute the so-called plate archive. One telescope may have more than one archive, if the

telescope was moved or if its plates are stored at different observatories or institutions. Analysing the information about all known plate archives one can see that most wide-field plate archives are produced with small-aperture telescopes (up to 50–60 cm), mostly refractors, astrographs and cameras. The number of plates in the individual archives ranges between several dozen to more than 100 000. Only a small number of archives have more than 10 000 plates.

2. Astronomical photographic plate libraries. The astronomical photographic plate libraries (Fig. 1) as a part of the Astro-Multimedia libraries include such components as plate archives; computer-readable catalogues, giving access to the descriptive data; plates (an example given in Fig. 2); logbooks and sheets with observer's notes (Figs 3–4); and desirable links between the archival plates and the papers based on them. In order to assure good storage, access, effective search possibilities, improvement of the data and services, the plate libraries have to unify the efforts not only of the librarians, but also of the astronomers, networking and information technology specialists.

The plate libraries were established with the aims to propose long-term storage of the plates, to provide plate digitization and digital curation as well

Fig. 1. The largest European photographic plate library in Sonneberg Observatory with 250 000 plates (left), and in Rozhen Observatory with 10 000 plates (right)

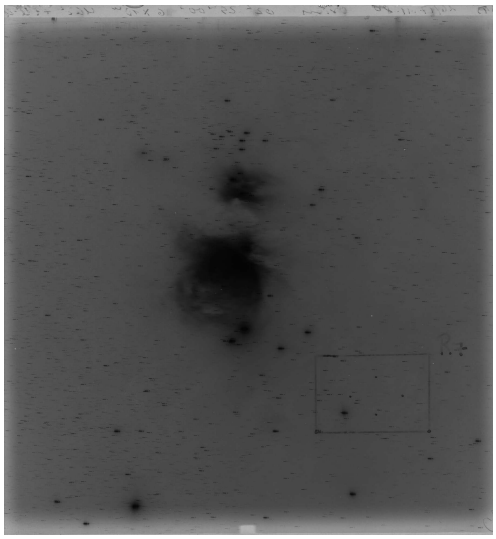

Fig. 2. Preview image of the ROZ050 000345 plate with the discovered third flare-up of the flare star V896 Ori (Rozhen Observatory designation R7) in M42/M43 nebulae (Orion region) with the observer's marks

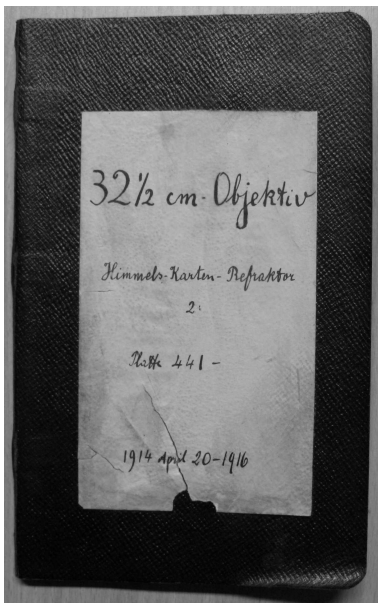

Fig. 3. Logbooks of the Potsdam Carte du Ciel telescope from April 20, 1914

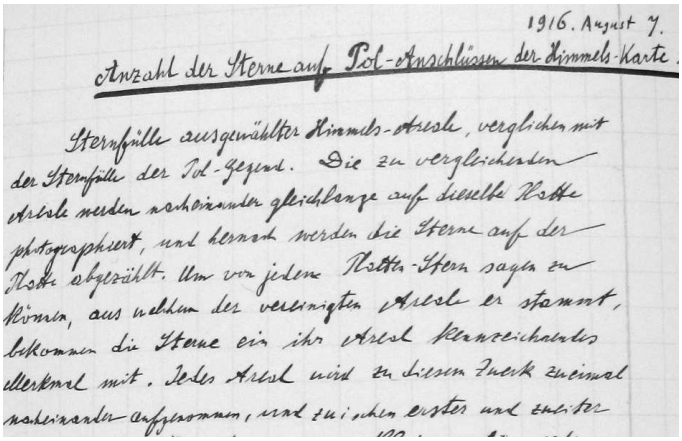

Fig. 4. A part of the observer's notes made in 1916 from the Potsdam Observatory Carte du Ciel archive

as access to the plate material for scientists, who would re-use the plates for research, as well as amateur astronomers, students, educators and the public, i.e. as outreach and education resources.

This information can be accessed through an appropriate web-based search interface. What can be an object of searching: plate metadata, quick visualization scan of a plate, large resolution plate scans (full plate or partial plate around the astronomical object of interest), image metadata characteristics, other plates in the same field, links to published papers based on this material and their bibliographic data (bibcode). As a rule the plate libraries established in astronomical observatories provide good storage and maintenance for the plates as:

- Building and environmental control (for suitable temperature, humidity or mould-free conditions, non-professional access, etc.);
- Inventory of the plate collection;
- Web-based searchable catalogues, giving descriptive plate data;
- Access to the information on plates and plate archive locations and contents, as well as from the plate envelopes, observing logbooks, card catalogue or other paper files;
- Plate accessibility (excluding the Royal Greenwich Observatory plate collection stored temporary in a London warehouse with slow and difficult access);
- Plate digitization giving digital preservation, not only because of the fragile glass holder of the emulsion, making any plate movement – to lend or borrow the plates – dangerous, but also for enabling their re-use. The digitized plate images can be obtained upon request, so the copyrights of the owner (observatory or other institution) are protected;
- Digital curation providing the digital material collection, maintenance, selection and retrieval, as well as preservation in standard data file format and archiving already digitized plates using various techniques.

3. Wide-Field Plate Database. The information concerning all wide-field photographic astronomical plate archives, as well as plates proper, is collected in the Wide-Field Plate Database (WFPDB) [1]. From all existing and stored 2475600 wide-field ($> 1^\circ$) plates in professional astronomical observatories and institutions all over the world, at this moment (January 2012) the database contains online information on 563612 plates, i.e., about 23% of the total.

Based and developed at the Institute of Astronomy (Bulgarian Academy of Sciences) since 1991, and with mirror sites in the Astrophysical Institute Potsdam since 2007 and in the Institute of Mathematics and Informatics (Bulgarian Academy of Sciences) since 2010, the WFPDB aims to store the valuable scientific heritage accumulated in the frames of the following observing programmes: Observations of the major planets and their satellites; Observations of small solar system bodies; Photographic sky surveys; Selection of reference stars; Artificial satellites observations; Observations of stellar occultation; Discoveries and patrol of variable stars; Determination of parallaxes and proper motions of stars; Observations of binaries; Studies of the Galaxy's structure and kinematics; Searches and monitoring of active galaxies, quasars, novae and supernovae, etc. Another aim of the WFPDB is to quickly offer an opportunity to look back in time to records of astronomical phenomena of interest to professional astronomers as well as amateurs, students and educators.

What can be done with archival plates? According to the compiled list of astronomical tasks and results [2] achievable through access to digitized archival plates from at least two plate archives stored in different astronomical observatories or institutions, the archival plates have already been used for:

- Composed light curves of variable stars for a maximally long time period;
- Search for long-term variations in brightness in young solar-type stars, RS CVn, active red dwarf stars, the Pleiades red dwarf stars;
- Search for past eruptions of pre-main sequence stars;
- Observations of small solar system bodies;
- Search for optical analogues of Gamma Ray Bursts;
- Search for photometric variability of quasars;
- Supernovae search in digitized archives;
- Use of Carte du Ciel plates—for determinations of proper motions, for discoveries of quick brightness changes, for investigations of the differential rotation in the galactic plane up to 500 pc from the Sun.

The WFPDB integrates:

- **Catalogue of Wide-Field Plate Archives** (CWFPAs, [3, 4]), whose current version as of January 2011 gives in table form the information on all known plate archives (with total number 476 to date) with 2475600 plates stored in the observatories mainly in Europe, North and South America and in South Africa.

- **Catalogue of Wide-Field Plate Indexes** (CWFPIs), with two versions:
  - Static version installed since 1997 at Strasbourg with online search via VizieR (see Search in the WFPDB—catalogue number VI/90) for information on 323 000 plates [5];
  - Enlarged, regularly updated and developed version installed since 2001 in Sofia [1], containing, as of January 2012, the parameters of 563612 plates from 131 archives with provided possibilities for data search, quick plate preview as low-resolution JPEG files of some of the plates and complete plate image as high-resolution FITS files upon request.
- **Data Bank of digitized plate images**—plate previews for quick plate visualization and easy online access, and working scans for photometric and astrometric investigations with implementation of Wavelet transformation methods for compression;
- **Links to online services and cross-correlation with existing catalogues or journals** (e.g. plate images in the WFPDB and published papers in the Information Bulletin on Variable Stars (IBVS) as scientific output of the use of plates [6].

The WFPDB has a search engine, i.e., a possibility to select plates among all included plate catalogues. In the WFPDB search page every plate catalogue can be found with the WFPDB observatory identifier, instrument aperture, instrument aperture suffix plus the original plate number. For every catalogue more details on the location of the archives, the observatory, the parameters of the telescope and the period of its operation, the coordinates of the plate center in epoch 2000.0, the date and beginning of the observation in UT, object name and type, method of observation, number of exposures and their duration, type of emulsion, filter and spectral band, the size of the plate, the quality of the plate, some notes with specific contents, the name of the observer, the place of plate storage (availability) and the status of plate digitization, as well as the name of astronomer in charge for the archive can be found (Fig. 5).

From the search page the user can get information using different constraints on the observation parameters. There are additional pages—with details on the plate archive with a map of the all-sky distribution of the plate centers, and with details on the selected plate, including notes, observer's name and information on the plate availability and plate digitization (if such information exists). The search page may also contain the plate preview (if the plate is digitized), as well as a link to the respective logbook where the plate is described (if the

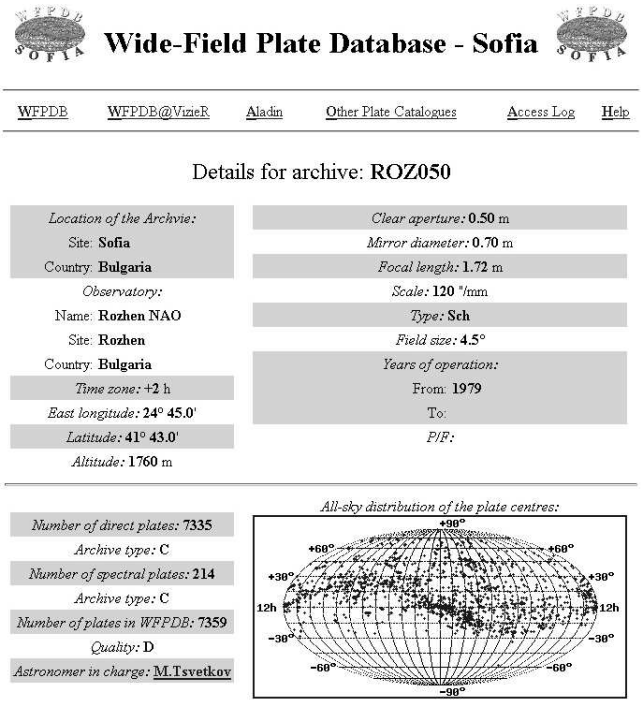

Fig. 5. WFPDB-Sofia Search Page giving details on plate archive with database identifier ROZ050

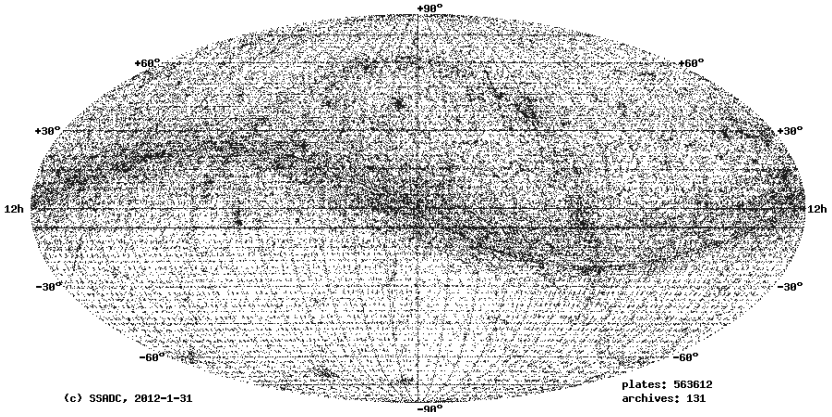

Fig. 6. All-sky distribution of the centers of plates included in CWFPIs in equatorial coordinates (J2000)

logbook exists).

The all-sky distribution of the plate centers included in CWFPIs as of January 2012 in equatorial coordinates is presented in Fig. 6. This distribution is updated daily. One can note the larger density of observations in the regions near the ecliptic and the galactic equator due to the large number of observations of solar system bodies and of objects in the Galaxy. There are also smaller regions of high concentration of plates such as the regions of the Andromeda galaxy (M 31), the Pleiades stellar cluster, the closest neighboring galaxies Magellanic Clouds, etc.

Using the data from the present version of the CWFPAs (January 2011) in Fig. 7 the distribution of European plate archives according to the initial year of telescope operation is presented. The peak of the appearance of new archives was between 1955 and 1970, when new 120 archives were established. An interesting fact is that this distribution (of 311 European archives) resembles the similar distribution of all known plate archives worldwide (476 archives), obviously due to the identical development of photographic astronomy in Europe as well as worldwide. This fact is supported by the similar time distribution of the number of established astronomical observatories—optical, ultraviolet, infrared, radio, solar space observatories (operating or no longer operating) according to the data from the Astronomical Almanac 2009. In the three distributions one can notice depressions due to the two world wars, an increasing number around 1900 when the photographic observations in astronomy began to be widely used and a quick

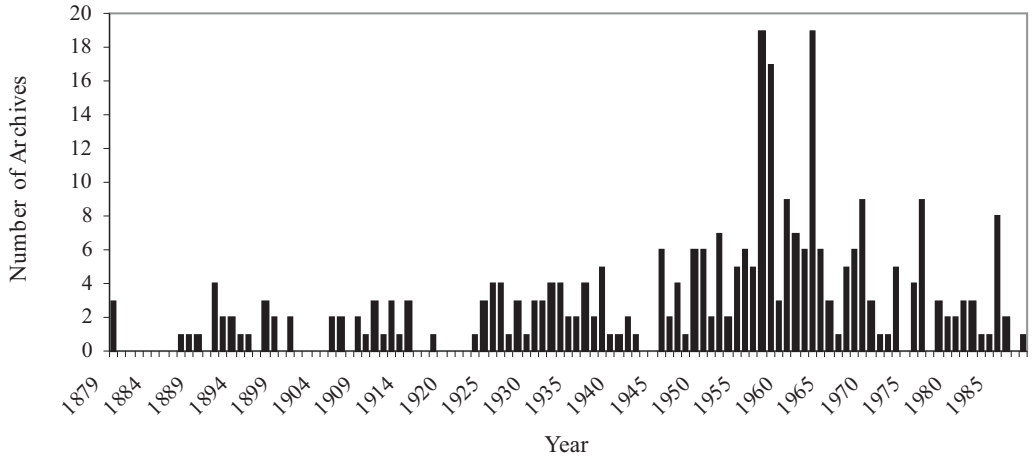

Fig. 7. Distribution of the number of all known European plate archives according to the year when the archives were established

increase number since 1955, when the "Golden Age" of wide-field photography came, subsequently replaced after 1975 by the CCD devices as detectors and storage of information. The reason for the decreasing number of established observatories after 2000 is that now only big corporations can afford the money needed to build and maintain an observatory.

Fig. 8 presents the distribution of all known 2475600 wide-field plates by continents—Africa, North America, South America, Asia, Australia and Europe. About 1195600 wide-field plates obtained both in the Northern and in the Southern hemisphere are stored in Europe (approx. 48.3% of all plates).

The distribution of the plates stored in 26 European countries, possessing 1195600 wide-field plates (1139800 direct and 55800 spectral ones), is shown in Fig. 9. The division of the countries into regions (Western Europe and Eastern Europe) refers not only to the geographic meaning, but also to economic, political and cultural aspects, is shown in Fig. 10. Thus "Western Europe", having 54% of all plates, comprises the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, United Kingdom, and the Vatican. For the group of "Eastern Europe" the large plate collections of Russia and Ukraine are given separately, containing respectively 12% and 11% of all European plates. The remaining countries of "Eastern Europe", with 23% of all plates, include Czech Republic, Hungary, Bulgaria, Slovakia, Serbia, Romania, Armenia, Estonia, Georgia, Latvia, and Poland.

4. Plate digitization. Plate digitization is a necessary initiative, being the only way to ensure preservation against careless manipulation and emulsion aging. It enables quick access to the plate image information through online preview, as well as re-use of this astronomical data through high-resolution plate image scan.

The plate preview scans made at low resolution (600 or 1200 dpi, even with a digital camera and light table) in JPEG file format aim at quick visualization, offering the possibility to examine visually the appearance of the plate and to make a preliminary judgment on the usefulness of a certain archived observation for some intended purposes, as well as easier web accessibility. Another purpose of the plate previews is to store the important marks made on the plates by the observer—of the observed minor planets, variable stars, comets, standard stars, etc. In the WFPDB the plate previews are a part of the database and constitute the bank of digitized plate images.

The actual plate images used for astronomical tasks are made at an optimal high resolution of 1600 (or 2400) dpi in FITS format. The actual scans

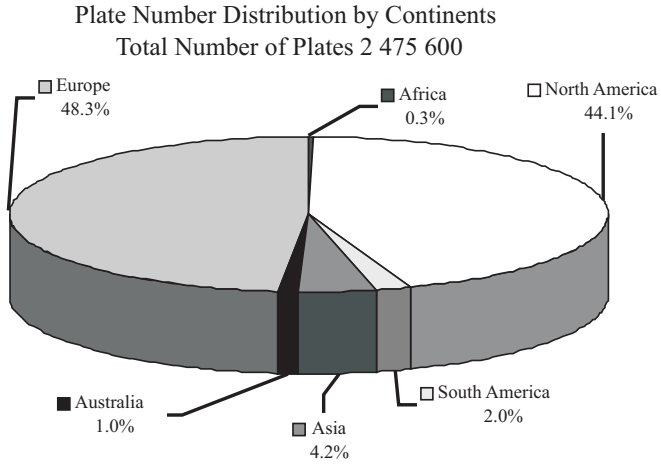

Fig. 8. Distribution of all known wide-field plates by continents

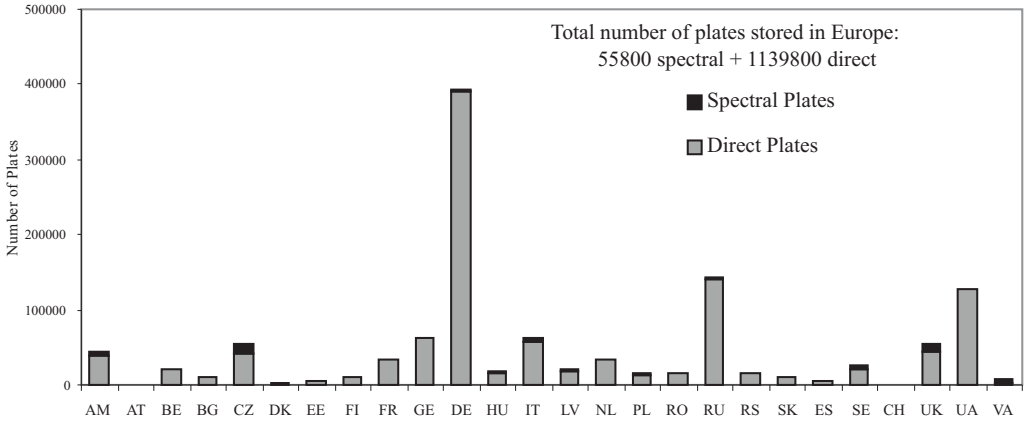

Fig. 9. Distribution of the astronomical photographic plates of 26 european countries

are usually available upon request, thus the copyright of the observatories is protected. For bad quality plates only previews are needed. The systematic plate scanning takes considerable funds and gives a huge volume of scan data, which have to be stored. One possible solution of this problem is to perform the plate digitization making digital collections of plates obtained in the frames of a given observing programme [7]. The preparation of digitized collections of selected plates (e.g., containing images of the Pleiades stellar cluster [8], of minor planets and comets, etc.) aims at assembling and exploring massive data sets in order to

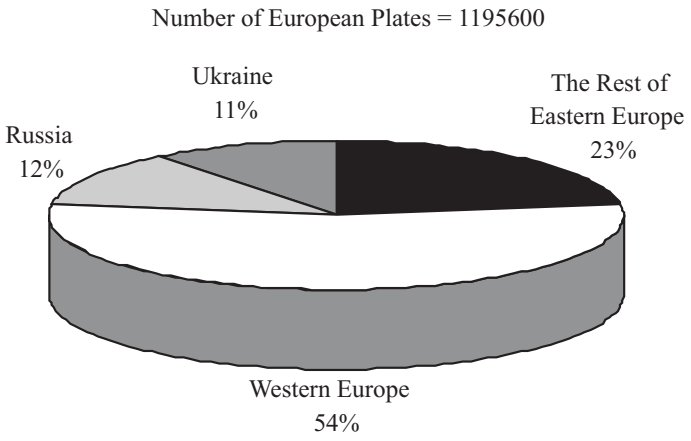

Fig. 10. Distribution of the stored european wide-field plates by regions

reveal new knowledge existing in the data, but still not recognized in any individual data set. The preparation of digital plate archives according to the main observing programmes is an already running process. In Konkoly Observatory such a digital archive was made for plates obtained within the supernova search programme (Konkoly Supernova Digital Plate Archive [9, 10]). The plate visualization scans can be accessed online in the WFPDB. The high-resolution scans for scientific investigations and educational use are stored in Sofia and Budapest. In Rozhen Observatory some of the representative plates obtained with the Schmidt telescope of the observatory during the observation campaign for search and investigations of flare stars in stellar clusters and associations in 1970–1990 have already been scanned. Besides the primary aim of this digital plate archive – to serve for automatic flare star search – another result is the implementation of an interlinking of IBVS where the discovered flare stars are published with WFPDB, where one can find the scanned plates containing the images of the respective flare stars [6]. There are Variable Stars Digital Plate Archives because the light curves of the variable stars with a larger statistical basis due to involving archival plates can better classify the type of variability. Other examples are the Carte du Ciel Digital Plate Archives with digital plates of the first photographic all-sky survey with charts to 14^{th} magnitude and measured positions for stars to 11^{th} magnitude. For example 977 stored Potsdam CdC plates [11, 12] had been scanned with an EPSON EXPRESSION 10000 XL flatbed scanner at a resolution of 1200 dpi for the preview scans and at 2400 dpi for the working scans stored in JPEG and FITS format files. They are installed on the German Astrophysical Virtual Observatory (GAVO) Potsdam server [13].

After the technical scanning the process of plate digitization includes estimation of the quality of the digitization data, linkage of the scanned plate images (e.g., to WFPDB) for online access, as well as digitization of the related logbooks and observer's notes in order to establish a link between the required plate in WFPDB to the page in the logbook describing this plate through the methods and technologies for logbooks data extraction.

In Table 1 the main parameters of the most-used EPSON flatbed scanners are presented: Optical density (Dmax), Color depth (bit internal/bit external), Grayscale depth (bit internal/bit external), Maximum hardware resolution (dpi).

Table 1. Main parameters of the employed EPSON flatbed scanners

Scanner	Dmax	Color depth	Grayscale depth	Resolution (dpi)
EXPRESSION 1640XL	3.6	42/42	14/14	1600
EXPRESSION 10000XL	3.8	42/42	16/16	2400×4800
PERFECTION V700 PHOTO	4	42/42	16/16	4800×9600

The software used for scanning is the standard one for making preview images—Adobe Photoshop, and the *ad hoc* developed software Scanfits [14] for the real scans in FITS format.

The volumes of the plate image files depend on the resolution chosen for scanning as well as on the plate size. For the output JPG files produced through compression 2000×2000 pxl of the initially produced output TIFF files for plate previews with resolutions from 600 up to 1200 dpi the volumes are between 1–3 MB for plate sizes from 13×13 cm to 30×30 cm. For the same plate sizes the volumes of the FITS files of the scanned plates with resolutions of 1600–2400 dpi the output file volumes range within 100–700 MB.

As an example of the standards and metadata for digitized photographic plates, providing indexing, accessing, preserving, and searching for plate images, the ones developed for the Potsdam CdC plates included in the German Astrophysical Virtual Observatory (`http://vo.aip.de/plates/`) served. The search interface for the scanned plates gives information about the plate identifier, coordinates, date, file type (compressed JPEG, TIFF, FITS format), header of the FITS file, file size, and the scan.

An important point of the project is the analysis and processing of the digital content stored on the servers of WFPDB. The methods which we use are

based on Multiresolution Analysis Techniques and rely upon Wavelet Analysis, which has been developed to a big extent by participants in the Astroinformatics project. The detailed explanation of the polyharmonic wavelets and their application to analysis of astronomical images of WFPDB is provided in [15, 16]. Further applications of wavelet-based approaches to more effective compression of huge volume of the scanned plate data is in progress (see [17]).

The main objectives of a future project in the area will be to further the organization of the plate scans in a global image database and the development of a Web-based software system for object plate identifications and search in the database.

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