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Linda Mišková, Stanislav Vítek
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Preface

Dear Friends of Astronomy,

you have in your hands the proceedings from the first workshop about glass plate negatives. This proceedings put together selected lectures in the form of articles from the workshop.

The ASTROPLATE workshop held in Prague, Villa Lanna, in March 2014 represented major event in investigation, archiving, and digitization of astronomical photographic archives including all aspects. This volume represents collection of papers related to presentations and posters presented at the confrence.

The photographic emulsion was the only medium for creating and storing images in astronomy for more than 100 years, from the discovery of photography up to the beginning of the era of electronic imaging devices (mostly CCD) in early 1980. And the same was valid for all other areas working with photographs including other sciences, national musea and archives, etc. The astronomers need to save indeed a rich variety of of types of images ranging from direct images of stars and other celestial objects to wide field images covering large sky areas, to various types of spectral images, both wide-field with many spectral images, to just single recorded spectrum. I have got the opportunity to visit and work with more than 50 astronomical photographic archives. In last few years, I have found increasing number of damaged or even very damaged plates in these collections, the two main types of damage being the released emulsion layer and various types of yellow spots known as gold disease. We have established a consortium with specialists working in chemistry and photography restoration, in order to exploit the cause of these damages. It became obvious that if we want to save the large scientific cultural and historical heritage included in these archives, we need both national and international collaboration At the same time, scanning of photographic records started at numerous institutions, with different approaches, technologies, and methods. Again it became evident that wider collaboration is necessary to optimize the digitization procedures in all aspects including metadata treatment. This was the background of the idea to organize an international workshop in Prague, where specialists of all involved disciplines could meet and discuss their results. We were very impressed by the response of the community, and by the high level of the contributions presented at the ASTROPLATE conference. Unfortunately, many of our colleagues were unable to attend this time for various reasons. We plan to organize 2nd ASTROPLATE conference in spring 2016, again in the beautiful Villa Lanna in Prague.

René Hudec

Proceedings are publised without language correcition.
Contents is on the responsibility of author of the separate articles.

Contents

Astronomical Photographic Plate Archives

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Abstract

The world's astronomical photographic archives are presented and discussed. It is obvious that they still represent valuable data source for modern astrophysics, and in addition to that, provide valuable historical and cultural heritage.

Keywords: astronomical photography, digitization

Introduction

The photography was widely used to record images and spectra in astronomy for more than 100 years. As a result, large collections of astronomical photographic records exist at many worlds observatories and astronomical institutes [5]. My estimate based on personal visits and works with many different plate collections (more than 50) is that there are more than 7 million astronomical photographic negatives worldwide [1][2][3].

The data types - substrates

The basic photographic substrates common in astronomical photographic archives are as follows.

(i) Photographic glass negatives.

(ii) Photographic negatives on plastic substrates

The data types – targets

The another division is according to the image/target type recorded on the negative. The basic separation is between direct images and spectral images, where the spectral images can be either single or multiple spectra, or wide field low dispersive spectra with objective prism. The direct images may be single (each star one image) or multiple (each star is recorded several times on the same plate). The negatives were in the past used with large number and rich variety of astronomical telescopes and cameras, and correspondingly, the type variety of archived negatives is also very rich. Many collections represent wide field sky images, but there are also large collections of small negatives, both glass and plastics, taken in the focal plates of medium and large telescopes.

While majority of astronomical negatives worldwide covers sky regions hence with star images, there are also many extended collections with Sun, Moon, and planetary images. In addition to that, on many observatories there are also available additional negatives with buildings, instruments, faces, etc.

Astronomical plates as cultural heritage

The historical astronomical photographic archives represent important part of historical and cultural heritage and, in many cases, reflects and document important epochs of history of science and technology at relevant Institute or Observatory or country. Many collections are related to names famous from the history of astronomy and astrophysics.

The science with plates

The astronomical plates represent important source of valuable data for many areas of recent astronomy and astrophysics. They include huge amount of information as single photographic plate may contains up to 100 000 star images. The astronomical photographic archives represent the only method how to investigate behavior of celestial objects back in history, and in addition to that, represent huge monitoring intervals necessary to detect rare events such as flashes and flares [6]. Most of plates and negatives were never before investigated in full detail, as before computer era this was virtually impossible. The recent wide plate scanning together with dedicated software allows perfect and complex data mining in these archives for the first time.

The non-astronomical photographic collections

The photography served as major recording medium not only in astronomy but also in many other areas of science and technology and in addition to that served as medium to record images in national archives, various museum etc. Before era of Xerox copy machines, the photography was the widely used method to make copies of documents, and these negatives are stored in large museum and cultural collections as well. Many problems related to astronomical plate archives such as suitable storage, digitization, defects, etc., are common for all photographic archives.

Conclusions

The astronomical photographic archives both on glass and plastic substrates count more than 7 million negatives with huge scientific value and cultural and historical heritage. The recent wide digitization together with use of dedicated software and powerful computers allow the extended and complex data mining for the first time.

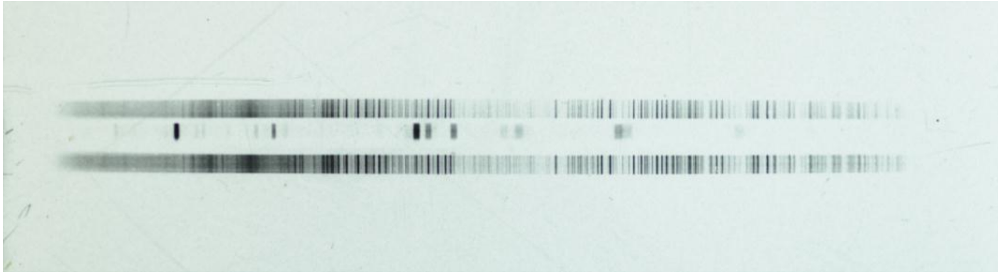

Fig. 1 Example of singe spectrum recorded on glass negative plate, Asiago Observatory, digitized by transportable scanning alternative method [4]..

Acknowledgements

We acknowledge GA CR grant 13-39464J.

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The Astronomical Photographic Data Archive at Pisgah Astronomical Research Institute

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Abstract

The Astronomical Photographic Data Archive (APDA) is dedicated to the collection, restoration, preservation and storage of historical astronomical photographs, films and related documents in a secure and environmentally controlled archival space. A workshop on plate preservation was held in the fall of 2007 at Pisgah Astronomical Research Institute (PARI) and established APDA as a result. APDA, which currently holds 220,000 astronomical images, is located in the $1800m^2$ Research building on the PARI campus. The Research building is a two story concrete structure built on a solid (granite) foundation. In 2012, the National Science Foundation awarded PARI an academic research infrastructure grant that included upgrades to the Research Building's roofing, backup electric power generation, humidity, heating and cooling control systems. APDA intends to digitize and establish a digital database of its photographic collection accessible to the astronomical community via the Internet. Two modified Perkin-Elmer 2020G MicroDensitometers (GAMMA I & II) were acquired from Space Telescope Science Institute. GAMMA II has upgraded with new motion control hardware interfaces and PC-based software. The upgrades are being tested using minor planet plates that were imaged at McDonald Observatory and now reside in the archive at APDA .

Introduction

The Astronomical Photographic Data Archive (APDA) is on the campus of Pisgah Astronomical Research Institute (PARI), is located in western North Carolina, USA, in the Pisgah National Forest (Figure 1). PARI's mission is providing educational and research opportunities for a broad cross-section of users in science, technology, engineering and math (STEM) disciplines.

Figure 1. View from the optical ridge at Pisgah Astronomical Research Institute.

During the early days of the USA space program, NASA recognized the intrinsic value of the location and, in 1962, built the Rosman Research Station to be the primary east coast facility for tracking satellites and monitoring manned space flights. In 1981, the NASA facility was transferred to the Department of Defense (DOD) and used for satellite data collection. At its peak, about 350 people were employed at what is now the PARI campus.

In 1995, the facility was closed and DOD operations were consolidated elsewhere. The government was planning to dismantle the facility, but Greensboro, North Carolina, USA, businessman Don Cline led an effort to save it for public science education and research. A not-for-profit public foundation was established in September 1998. In January 1999, the 200-acre (80-hectare) site was acquired by Don and Jo Cline and gifted to the foundation and the Pisgah Astronomical Research Institute was born.

Astronomical Photographic Data Archive

In 2003, through the efforts of Drs. Michael Castelaz (PARI) and Wayne Osborn (Central Michigan University), APDA received 22,000 slit-sprecta plates and 3,000 Curtis-Schmidt objective prism plates from the University of Michigan. In November, 2007, a three-day workshop was held at PARI and was devoted to developing a national plan for the preservation and future use of astronomy's heritage of historic photographic observations. The outcome of this workshop was the establishment of the Astronomical Photographic Data Archive (APDA) at PARI. Since 2007, APDA has received small and large photographic collections that have increased APDA's collection to over 220,000 plate and film images.

APDA is located in the 1858m^2Research Building (Figure 2.) at PARI. The Research Building houses office space, a Radio Frequency Laboratory, the Aeronomy Program Center, and lab space for short-term projects conducted by PARI Research Faculty Affiliates. Renovation of the Research Building was completed in 2013 with majority funding from the National Science Foundation academic research infrastructure grant (NSF ARI-R2 Award AST-0963300). New roofing, heating, cooling and humidity controls (21C +/- 1 C in temperature and 40% +/- 5% in humidity) and new electrical power backup system (500KW UPS with 500KW diesel power generator) were installed.

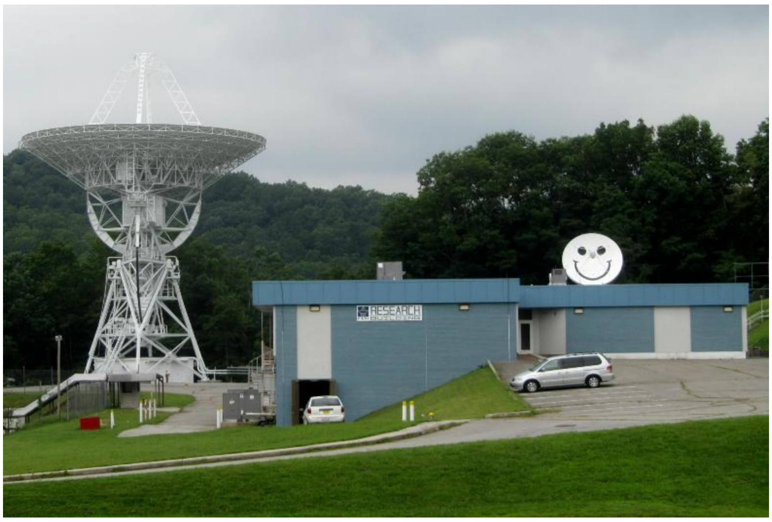

Figure 2. Research Building that house APDA.

To provide the computer storage necessary to hold digitally scanned images, EMC Corporation donated a 400-terabyte storage system. This system is in use in the Research

Building and networked through multiple GigaByte connectivity to the Internet.

Plate Collections

The following lists collections in APDA that have over 1,000 images: University of Michigan (0.95m Reflector – slit spectra), CWRU (Burrell-Schmidt 0.6/0.9m), U.S. Naval Observatory (Washington D.C.), CTIO (Curtis-Schmidt 0.6/0.9m), McDonald Observatory (2.1m), Maria Mitchell Observatory, Harvard/Smithsonian Meteor Photographic Survey (Baker Super-Schmidt 0.32m 55° FoV), Meteorite Recovery Program (Baker-Nunn cameras), and Mauna Loa Solar Observatory disk and limb images (PMON - Hα filter). Numerous photographic surveys found in APDA are listed in Table 1.

Table 1: Photographic Surveys in APDA.

LS1-VI Luminous Stars Survey 1.8-degree prism	UV-Survey 1.8-degree prism
Southern Galactic Hemisphere Survey, 2 or 6 degree prisms	UV-Survey 1.8-degree prism
Henize H-alpha Southern Survey 4-degree prism	Parallax Survey (non-USNO) Direct images
Taurus 6-degree Survey 6-degree prism	HK Survey 4-deg prism
UV-Survey 1.8-degree prism	A-Stars Survey 1.8-deg prism
AntiCenter Survey 4-deg prism	He Survey UV filters
Weak Metalicity Survey 4-deg prism	High Luminosity Survey
6-Degree Survey 6-deg prism	IR Survey 4-deg prism
Low-Z Survey 4-deg prism	Red Survey 4-deg prism
LS1-VI Luminous Stars Survey 1.8-degree prism	OB Survey 4-deg prism
Parallax Survey (non-USNO) Direct images	QSO Survey 1.8-deg prism
Southern Galactic Hemisphere Survey 2 or 6 degree prisms	SGP Survey 1.8-deg prism
Henize H-alpha Southern Survey 4-degree prism	Taurus 6-degree Survey 6-degree prism
NGP Survey 1.8-deg prism	All-Sky Survey 4-deg prism
All-Sky Survey 4-deg prism	Blue Survey 10-deg prism

Digital Scanner Initiative

We are pursuing the acquisition of a high-resolution digital scanner to be used in digitizing APDA's plate collection. To store the Terabytes of digital images, PARI has installed GAMMA II (Guide Star Automatic Measuring Machine) that was relocated from STScI to the Astronomical Photographic Data Archive at the Pisgah Astronomical Research Institute in 2008. GAMMA II is a multi-channel laser-scanning microdensitometer that was used to measure POSS and SERC plates to create the *Guide Star Catalog* and the *Digital Sky Survey*. GAMMA II is designed with submicron accuracy in x and y measurements using a HP 5507 laser interferometer, 15μ sampling, with the capability to measure plates as large as 0.5-m across

GAMMA II is a vital instrument for the success of digitizing the direct, objective prism, and spectra photographic plate collections in APDA for use in research. New motion control interface hardware has been added along with the development of new PC-laptop software for command and data acquisition. Figure 3 shows the GAMMA II machine along with a 12μ pixel scan of a 4mm x 3mm section of a KPNO 4-meter plate of the core of NGC 2207.

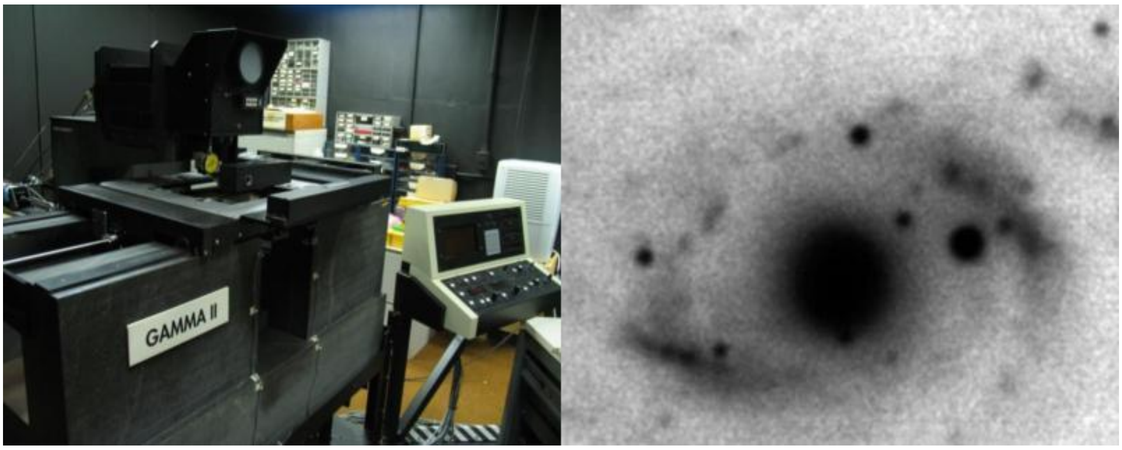

Figure 3. GAMMA II and 4mm x 3mm 12μ pixel image of NGC 2207.

We plan several targeted scanning projects using plates in APDA collection. One is in collaboration with Dr. P.D. Hemenway (University of Texas, professor emeritus) who plans to scan 1400 plates of 34 minor planets to identify systematic errors in the Fundamental System of celestial coordinates. A second collaboration is with Dr. R. Hudec (Astronomical Institute, Academy of Sciences of the Czech Republic) whose work in the Gaia Variability Unit CU7 was to digitize objective prism spectra on the Henize plates and Burrell-Schmidt plates located in APDA. These low dispersion spectral plates provide optical counterparts of celestial high-energy sources and cataclysmic variables enabling the simulation of *Gaia* BP/RP outputs for use in testing computer spectral recognition software.

Summary

The Astronomical Photographic Data Archive has become an important storage facility for historic astronomical photographs. APDA is committed to continue providing secure archival space to institutions, observatories and universities who are facing the possible loss or destruction of astronomical photographs. APDA is testing upgrades to the GAMMA II scanner for use in making digital images of the plate collection at APDA. Currently, digital images of plates in APDA are made using a MicroTek desktop scanner. These images are being used by high school and college students in PARI’s educational programs. Selected objective prism images from the Curtis-Schmidt telescope at CTIO are available through a citizen science project developed at PARI named SCOPE (Spectral Classification Online Public Explorations). SCOPE is online and can be found at scope.pari.edu.

UkrVO: Astroplates and the Joint Digitized Archive

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Abstract

ABSTRACT. The UkrVO (Ukrainian VO) database consists of about 150,000 astronegatives and 50,000 CCD-frames containing the unique astroinformation for formulation of important scientific tasks. This database is compiled from observations conducted in 1898-2011 years at observational sites of 8 Ukrainian observatories with about 50 instruments. The Joint Digital Archive (JDA) of photographic observations has become the UkrVO astroplate's core. Now the UkrVO Joint Digitized Archive covers about 40,000 astroplates, from which 15,000 are digitized. They were performed with a flatbed scanner EpsonExpression 10000XL with 16-bit gray levels, resolution of 1200-1600 dpi. Digitized images are stored in TIFF and FITS formats. Current version of UkrVO site for JDA and other information is placed on http://ukr-vo.org.

Keywords: virtual observatory, UkrVO, database, astroplates

Introduction

The main task of the UkrVO project is the processing and digitizing the all astroplate's archives of astronomical observations, which were saved at the observatories of Ukraine since 1890s [1-6]. At the initial stage, this task involves the creation and development of the Joint Digital Archive (JDA) of photographic observations. The total number of photographic plates in the UkrVO collection exceeds 300 thousands, including not only the positional but also the spectral and photometric observations. The JDA pilot version includes only positional observations (http://ukrvo.org/science/index.php?b1&2). Till the March of 2014, the JDA database contains more than 38 thousands records and more than 6 thousands of the digitized images from glass collections of Main Astronomical Observatory NAS of Ukraine (MAO NASU), Crimean Astrophysical Observatory (CrAO), Nikolaev Astronomical Observatory (RI NAO), and astronomical observatories of the national universities in Kyiv (AO KNU), L'viv (AO LNU), and Odesa (AO ONU). Among them are the following (see, also, Table 1):

− 26 thousand records of astronegatives' metadata and more than 6000 digital images of MAO NASU glass collection (GPA);

− 4 000 records of plates' metadata and more than 1000 digital images (from 4 000 digitized ones) of AO LNU glass collection;

− 8400 records of plates' metadata of SRI MAO glass collection (without images, which are available on the UkrVO web site, the database obtained by the mutual exchange of information between MAO NASU and SRI MAO);

− metadata of 24 partially filled observational archives of AO KNU glass collection with digitized images of more than 1 500 individual plates selected for the solution of current scientific problems;

− 600 records and more than 400 digitized images of selected plates of AO ONU glass collection (out of 120 thousand plates), which are related to the Simeiz collection (CrAO) on the Solar System Small Bodies observations in the 1950s; as well as the JDA of the Crimean AO.

UkrVO Joint Digitized Archive of Astroplates

Now the UkrVO JDA consists of the observational databases of 6 observatories of Ukraine. The number of the digitized archives, astroplates, digitized images etc. are presented in Table 1 (till the end of 2013).

Table 1. Statistical data on the quantitative and qualitative status of the UkrVO Joint Digitized Archive

Observatory	Archives	Number of archives	Number of astro-plates in the main database	Number of astroplates in the processing	Total number of astroplates	Number of the digitized astroplates: Preview and full scans
MAO NASU	ABA020, ABA039B, BYU053, BYU100, EAO035, EAO040B, GUA010A, GUA010B, GUA011A, GUA011B, GUA012A, GUA012B, GUA015, GUA040A,GUA040B, GUA040C, GUA040D, GUA040E, GUA070A, GUA070B, GUA070C, MAJ060, QUI021A, QUI021B, TAS040A, TAS040B, TER060	27	26437	36	26473	7554 +2293
RI “Nikolaev AO”	MYK012, PUL012	2	8405	0	8405	-
**SRI “Crimean AO”	CRI012S, CRI017A, CRI017B, CRI040A, CRI040B, CRI040C, CRI100, CRI120, CRI260	D - 2 S - 6	11000 15000	1750 480		2100 730
AO KNU	9909900A, ABA020C, ABA020D, ABA039K, AMR020A, DAR020A, IND013S, KAO000A, KAO000B, KAO000C, KAO000D, KAO000G, KAO000P, KAO010A, KAO010B, KAO012A, KAO013, KAO013S, KAO014A, KAO020A, KAO040K, KAO040Z, KAO048A, KAO060A, KAO070A	25	589	958	1547	~1500*

AO LNU	LAO010	1	4090	37	4127	3073*
AO ONU	CRI012A, CRI012B	2	600	0	600	289 +216
	Total**(without CrAO data)	57	40121	1031	41152	14889

* Digitized images are partially included into the UkrVO JDA

** By the information from the CrAO VO (D – direct images, S – spectral plates) – now in 2014 these archives are in processing to be added to the UkrVO JDA

Table 2. Ukrainian Plate Archives and telescopes, which are presented in the WFP Database [**7**, 8] till 2013.

			Telescope						
WFPDB Identifier	Archive Location	Observatory	Type	Aperture /mirror (m)	Focal Length (m)	Scale ("/m)	Field Size, (deg)	Years of Operation	Direct Plates
ABA020	Kyiv	Abastumani, Kanobili	Ast	2x 0,20	1,00	206	13,7	1990-1990	30
ABA039	Kyiv	Abastumani, Kanobili	Sch	0,39/0,44	0,62	330	8,2	1987-1987	20
BYU053	Kyiv	Byurakan Obs.	Sch	0,53/0,53	1,83	113	5,0	1985-1985	28
BYU102	Kyiv	Byurakan Obs.	Sch	1,02/1,31	2,13	97	4,0	1983-1983	15
CRI012	Odessa	Crimean Obs. Simeiz	Ast	2x 0,12	0,25	352	35,0	1909-1953	6900
CRI017A	Crimea	Crimean Obs.Simeiz	Cam	0,17	0,75	276	13,0	1948-1965	516
CRI017B	Crimea	Crimean, Nauchny	Cam	0,17	0,75	276	13,0	1951-1953	49
CRI040A	Crimea	Crimean Obs. Simeiz	Ast	0,40	1,60	129	10,0	1947-1948	59
CRI040B	Crimea	Crimean, Nauchny	Ast	2x 0,40	1,60	129	10,0	1951-1965	215
CRI040C	Crimea	Crimean, Nauchny	Ast	2x 0,40	1,60	129	10,0	1963-1998	9781
EAO040B	Kyiv	Engelhardt, Zelench,	Ast	0,40	2,00	103	8,9	1982-1993	142
GUA010A	Kyiv	Main Astron. Obs.	Ast	0,10	0,50	412	20,0	1957-1961	438
GUA010B	Kyiv	Main Astron. Obs.	Ast	0,10	0,50	412	20,0	1957-1961	277
GUA011A	Kyiv	Main Astron. Obs.	Ast	0,11	1,20	172	8,0	1955-1957	35
GUA011B	Kyiv	Main Astron. Obs.	Ast	0,11	1,20	172	8,0	1955-1957	55
GUA012A	Kyiv	Main Astron. Obs.	Ast	2x 0,12	0,70	295	20,0	1949-1990	2041
GUA012B	Kyiv	Main Astron. Obs.	Ast	2x 0,12	0,70	295	20,0	1949-1978	2143
GUA015	Kyiv	Main Astron. Obs.	Ast	0,15	1,70	121	6,0	1955-1961	162
GUA040A	Kyiv	Main Astron. Obs.	Ast	2x 0,40	5,50	38	2,5	1949-1986	8485
GUA040B	Kyiv	Main Astron. Obs.	Ast	2x 0,40	5,50	38	2,5	1949-1986	649
GUA040C	Kyiv	Main Astron. Obs.	Ast	2x 0,40	2,00	103	8,5	1976-1998	4276
GUA040D	Kyiv	Main Astron. Obs.	Ast	2x 0,40	2,00	103	8,5	1976-1997	1834
GUA040E	Kyiv	Main Astron. Obs.	Ast	2x 0,40	2,00	103	6,5	1981-2005	3657
GUA070	Kyiv	Main Astron. Obs.	Rfl	/0,70	3,15	66	1,0	1960-1973	566
KYI020	Kyiv	Kyiv University Obs.	Ast	0,20	4,30			1898-2004	2401
LAO010	L'viv	L'viv University Obs.	Ast	0,10	0,50	412	19,0	1939-1976	8339
MYK012	Mykolayiv	Nikolaev Obs.	Ast	0,12	2,04	101	5,0	1961-1999	8400
ODE006A	Odessa	Odessa Obs.	Ast	0,06	0,12		30,0	1945-1957	2000
ODE006B	Odessa	Odessa Obs.	Ast	0,06	0,12		30,0	1945-1957	2000
ODE007	Odessa	Odessa Obs.	Ast	0,07	0,30		30,0	1945-1957	2000
ODE010A	Odessa	Odessa Obs.	Ast	0,10	0,50		22,0	1945-1957	2000
ODE010B	Odessa	Odessa Obs.	Ast	0,10	0,50		22,0	1945-1957	2000
ODE010C	Odessa	Odessa Obs.	Cam	0,10	0,25	288	35,0	1957-1990	7100
ODE010D	Odessa	Odessa Obs.	Cam	0,10	0,25	288	34,0	1957-1990	7100
ODE010E	Odessa	Odessa Obs.	Cam	0,10	0,25	288	25,0	1957-1990	7100
ODE010F	Odessa	Odessa Obs.	Cam	0,10	0,25	288	12,0	1957-1990	7100
ODE010G	Odessa	Odessa Obs.	Cam	0,10	0,25	288	12,0	1957-1990	7100
ODE010H	Odessa	Odessa Obs.	Cam	0,10	0,25	288	22,0	1957-1990	7100
ODE010I	Odessa	Odessa Obs.	Cam	0,10	0,25	288	18,0	1957-1990	7100
ODE015	Odessa	Odessa Obs.	Ast	0,15	1,00	204	12,0	1945-1957	2000

ODE020	Odessa	Odessa Obs.	Sch	0,20/0,40		474	6,0	1969-1980	2000
PUL012	Mykolayiv	Pulkovo Obs.	Ast	0,12	2,04	101	5,0	1929-1931	196
QUI021A	Kyiv	Quito Astron. Obs.	Cam	0,21	0,74	281	15,6	1986-1986	100
QUI021B	Kyiv	Quito Comet Station	Cam	0,21	0,74	281	15,6	1986-1986	50
TAS040A	Kyiv	Tashkent Obs. Kitab	Ast	2x 0,40	3,00	69	5,5	1981-1989	96
TAS040B	Kyiv	Tashkent Obs. Kitab.	Ast	2x 0,40	3,00	69	5,5	1981-1989	5

A preliminary processing of the digitized images of all the observational archives was done with LINUX/MIDAS/ROMAFOT: registration of objects till 16m, determination of pixel coordinates, instrumental photometric evaluation [3, 4]. The final digitized scans are kept on a server for their following including to the UkrVO JDA (Fig. 1). We give in the Table 2 those statistical data about 125,000 astroplates (Ukrainian Plate Archives), which were included in the Wide-Field Plate Database [7, 8]. One can see a significant difference (see Table 1), which is connected, from our point of view, with a gap in the monitoring during the last years among the observatories on the current status of the digitized astroplates. For example, now the UkrVO JDA give access to the 50,000 digitized astroplates of a good quality.

Instead of the final remarks we would like to point IAU's Commissions attention that the ASTROPLATES project needs the additional financial and scientific support and could be organized, for example, in frame of the HORIZON-2020 program as the cooperation of the European astronomical observatories, which hold this unique astroinformation resource. Due to such support, it seems, such a project will have a success to be finalized till 2020.

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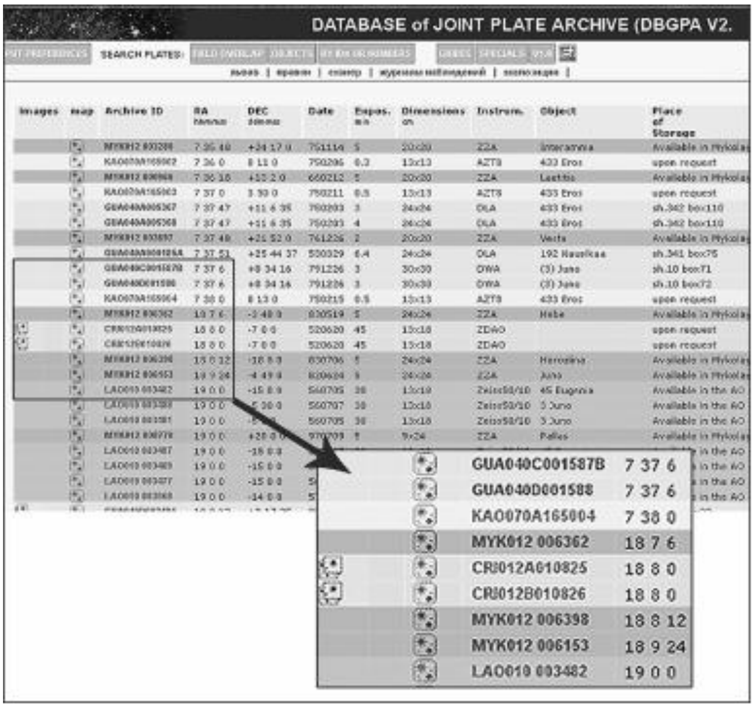

Fig 1: Access to the UkrVO Joint Digitized Archive of astroplates (http://ukr-vo.org).

Photographic collections of observatories as scientific heritage

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Abstract

Photographic collections of observatories in terms of many criteria, of course, are the scientific heritage of humanity. It is important to keep records not only glass collections but also supporting information about them. In historical aspect complete collection has to answer the question: what and when was observed by photographic methods, why items such observations were elected, what tools were used and how they are modernizing, what methods of observation were used, how were treated observations, what results were obtained that, was published, scientists who studied these questions and more. It is therefore necessary to combine photographs from magazines observations, publications, reports observatories, instruments and devices, photographs and other relevant material. In fact, these collections have become museum objects and require further study.

Keywords: academic heritage, astronomical photographic collections.

Introduction

Astronomical observatories photographic collections are research materials which suitable for further study by the latest techniques and technologies. This aspect of the collection is successfully implemented directly in observatories and through digitization and open access becomes available to anyone interested in this information. But the photographic collections of astronomical observations bear mission of scientific heritage, keep information about research methods of his time, materials and tools , scientific paradigms and scientific schools. Along with all ancillary objects (records, equipment, publications, and other special devices), these collections are priceless examples of the cultural heritage of mankind in science [1].

Photographic collections as heritage of science

Cultural heritage - part of material and spiritual culture, created by past generations, endured the test of time and transmitted as something valuable and esteemed. Object of cultural heritage - including that created by the person and, regardless of the state of its preservation, for bringing this is now, value for an anthropological, historical and scientific point of view and retained its authenticity.

In turn, the authentic artefacts of science through which one can "touch the past" have their own characteristics. They are associated with a variety of technical solutions for this branch, the role they played in his time in science and society that created them, their place in the modern scientific context, the information presentation tools.

According to the criteria elaborated by the Working Group of the European network of academic heritage preservation (Universeum) for the so-called recent scientific heritage, objects that are subject to conservation and research should be [2]:

1. to favour the preservation of scientific heritage of local importance,
2. artefacts, which used at the university in teaching, research, making instrument
3. objects, which designed, made or modified at the university
4. it is a rare or unique object.
5. complete and undamaged objects.(But damages and modifications can also give important information)
6. an object is important to the identity of a local or national community
7. presence of the documentation on the object
8. common or not very interesting instruments should be preserved if part of a homogeneous collection
9. the object is a primary source of information for the history of scientific research, scientific practice, the history of teaching or the history of the institution.

Mostly all these criteria astronomical photographic collections are a scientific heritage.

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Utilizing Astronomy's Photographic Heritage: Progress, Problems and Challenges

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Abstract

This paper critically examines the use in modern research of astronomy's rich store of over one hundred years of photographic observations. The necessary steps to permit such use are summarized, and a few success stories mentioned. The problems that presently cause limited use of -- and little interest in -- this material by most researchers are discussed. Opinions are offered on how to best meet the challenge of ensuring that the photographic material becomes recognized as an important observational resource.

Keywords: Photographic astronomical observations

Introduction

Photographic astronomical observations became practical with the invention of the dry gelatin plate technique in 1871; they have been routinely carried out since the 1880s [1]. It is estimated that some four million of these photographic records still exist [2, 3]. Most are located in the files of present or former observatories, but there is an increasing trend toward combining collections in specialized centers. Examples are the Astronomical Photographic Data Archive (APDA) at PARI in North America [4], the Uccle Direct Astronomical Plate Archive Centre (UDPAC) in Western Europe [5], and the Zo-Se plate archive in China [6].

It is well known that the photographic material represents a unique and irreproducible source of astronomical data [7, 8, 9]. It has particular value for research on long-term variability and as a complement to the synoptic surveys now being initiated (e.g., LSST, GAIA). It also provides the only data available for historic events such as, for example, the past outbursts of novae and passages of non-periodic comets. Nevertheless, presently relatively little use is made of this large observational data set. This paper explores the reasons for this and offers some opinions on what might be done to make the photographic data an integral part of modern astronomical research.

Using the Photographic Material

There are two basic approaches to utilizing photographic data sets for science. The first, approach is the survey of a given region of the sky. As many plates of the selected sky region as are available are digitized, and then all objects detected on the plates (above a certain threshold) are compared seeking changes in brightness (or possibly position). This approach has the most potential for scientific return but requires a large investment of both time and funds. The DASCH project at Harvard College Observatory is the archetype for photographic surveys of the time domain [10].

This project will eventually provide time coverage of 100 years (1890 - 1990) for the entire sky with a typical cadence of two weeks. About 60,000 of Harvard's collection of 450,000 direct plates have so far been digitized, with the resulting data being released as given fields are completed. Although less than 15% of the plates have been scanned, the scientific value of this project has already been demonstrated: discoveries of a new class of K giant variables and of new symbiotic novae, to mention two examples. A second survey worth noting is the digitization of plates from Italian observatories which produced the Asiago Photographic Archive (http://dipastro.pd.astro.it/asiago/). This survey has also yielded valuable scientific results, particularly on symbiotic stars and novae (see, for example, [11]).

The second, and most utilized, approach for scientific use of the archival photographic material is the targeted approach: study of one particular object. The most common case is the study of photometric variability. For this, the object's brightness is determined - often by simple eye estimate - on as many plates as can be accessed. A good example of scientific results from a targeted study is the discovery from archival data that the recurrent nova T Pyx shows a steady secular decline in brightness underlying its periodic outbursts [12]. The targeted approach is also that usually employed for scientific study of spectra, but in some cases the targets are not a particular astronomical object but a specific spectral feature (e.g., Hα or Ca II lines).

Increasing the Usage

There is tremendous potential for astronomical discoveries in the archival photographic records. Their scientific value has been demonstrated many times, some examples of which have just been mentioned. It is therefore surprising that relatively little use is made of these data in comparison to other archival data sets. An ADS search for papers published in the five most-read astronomical journals - A&A, ApJ, AJ, MNRAS, PASP - in the past five years (2009 - 2013) yielded only thirty-three papers that utilized unpublished photographic material *for scientific investigations* (papers that describe plate archives, digitization projects, scanner tests and the like were not counted).[1] While some papers certainly have been overlooked, this number can compared to the over 8400 articles in these journals in 2013 alone! Table 1 gives some basic statistics for the 33 papers. One notes (1) the wide variety in the types of objects that were the subject of the study, (2) that in several cases the only photographic data used came from the well-known digitized sky surveys that are on-line and (3) projects that employed direct plates dominate; papers utilizing archival photographic spectra, both slit and objective prism, are few.

The limited use can be attributed to three main factors. The majority of today's astronomers were trained in the CCD era and are not aware that this rich resource exists. Of those that are aware of its existence, many think the old photographic data is not trustworthy (in some cases this had led to plates being discarded). In fact, results from such observations can be just as reliable as those from modern detectors *but only if care is taken to ensure high quality measurement*; on the other hand, careless plate measurement, such as digitization with an unreliable flatbed scanner, can introduce errors that compromise the science as well as tarnish the reputation of photographic data [14, 15, 16, 17]. Finally,

[1] A similar compilation for 2000 - 2008 [13] lists 57 papers, which gives an average of only six papers per year in these journals over the past fourteen years See http://atlas.obs-hp.fr/pdpp/publications/ for more details.

Table 1. Properties of research papers in 2009 - 2013 that utilized photographic plate

Type of plates used	Direct plates of star fields = 30, slit spectra = 2, solar patrol plates = 1
Approach used	Survey approach = 6, targeted approach = 27
Purpose	Photometry = 23, astrometry = 3, spectroscopy = 2, morphology =1, search and discovery = 4
Subject	Star (usually a variable) = 17, nova = 7, extragalactic object = 5, stellar cluster = 2, sun = 1, planetary satellites = 1
Source of plate material	1 plate archive = 13, 2 archives = 6, more than 2 archives = 5, DASCH survey = 4, other survey = 1, on-line digital sky surveys = 4

there is the difficulty in locating and accessing the data desired. The reduced data (magnitudes, calibrated spectra) are usually not available on-line nor are the original images that could be downloaded and measured, as is often the case with CCD observations. Use of photographic records often requires a visit the plate archive and physically handling each plate of interest. This final factor is, however, gradually being addressed by plate digitization programs.

Perhaps more surprising than the low usage of the photographic material is the limited interest in these data by the astronomical community given its known scientific value. This is reflected by the lack of support - by both research groups and funding agencies - for projects intended to make photographic records more accessible; many such projects have been curtailed or eliminated for financial reasons. One can ask what needs to be done to make the photographic observations become recognized as an integral part of modern astronomical research data.[2] Below are four possibilities for discussion.

First, it is common for investigators using photographic data to utilize plates from only one archive. The norm in modern astronomical research is the collaborative effort, usually involving investigators from several institutions. Utilizing plates from several collections would improve the historical data, particularly time coverage in variability studies. I can cite studies where relevant plates in our Yerkes plate collection were not utilized. The use of an institution's plates greatly helps it in justifying the importance of its plate collection and in seeking funding. Shouldn't researchers be encouraged to broaden their nets when using photographic data?

Second, effective use of the targeted approach in using plates, as well to a certain extent of the survey approach, requires catalogs so those plates of interest can be located. There is a critical need for internet-searchable catalogs of the plates held in plate collections. The useful Wide Field Plate Database (http://www.skyarchive.org; [18]) lists where plate collections are located, but the catalogs listing the individual plates are not easily located, if they even exist. I would argue producing detailed catalogs of plates in collections should be a higher priority at this time than digitizing small sets of plates. If a researcher knows the identities of relevant plates, he or she can probably arrange for

[2] This would no doubt occur if paper referees would question, when relevant, whether the authors have examined the historical record in the same was as they often ask them if pertinent theoretical predictions or observations in other wavelength regions were considered.

digitization. Further, these plate catalogs need not only to be on-line, the links must be easily accessible and discoverable. The wide-spread use of the digital sky surveys, 2MASS and Sloan data and the like reflects their well-known and easily-used internet links. Shouldn't the creation of a prominent web page with links to all the existing on-line plate catalogs be a high priority?

Third, more communication and collaborative efforts are needed between the groups involved in cataloguing and digitizing plates. The DASCH project likely will eventually produce the fundamental database for time domain investigations involving the last century. But to optimize the database the Harvard plates need to be supplemented with plates from other collections. The Harvard plates have gaps in their time coverage, most notably the infamous Menzel gap of 1954 - 1965 which resulted from the 1950's decision by then Observatory Director D. Menzel to discarded some plates to create more office space and to suspend Harvard's long-running photographic sky patrol for budgetary reasons. There are several plate collections that can help fill this lack of coverage for the northern sky (e.g., Sonneberg's), but identifying southern-sky plates taken in this period is more challenging and should be a priority. Shouldn't the plate archive community start work now to identify and ensure preserving of those plates that can eventually be used to address this shortcoming of the Harvard data?

Finally, there is presently the tendency for those involved in plate cataloging and digitizing efforts to work fairly independently. At times, groups may even be competing for support. Shouldn't this work be conducted in the modern way - a coordinated, international team approach rather than the independent individual efforts most common at present?

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Air quality measurements for preservation of photographs

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Abstract

The damage to film materials in storage can be reduced by improving their preventive conservation conditions. The preventive conservation conditions are determined by the degradation mechanisms for the films as influence by the climate, light and air quality they are exposed to. Measurement of the single environmental parameters that degrade the films or with dosimeters (e.g. the MEMORI dosimeter) for which the degradation can be compared with that for the films, will indicate the risk situation for the films and be necessary information when determining the mitigation actions best suited to protect the films for the future.

Keywords: Film material, preventive conservation, air quality, dosimeter.

Introduction

For proper storage of photographic negatives and plates it is necessary to understand the sensitivity of the photographic material to the surrounding environment; climate, air pollution and light. Table 1 shows the sensitivity of photographic material [1]:

Photogr. material	Ultra sensitive	Very sensitive	Sensitive
Plastic based	Sulfides	Light > High RH	Oxidising pollutants, Fluctuating RH
Paper based	Sulfides	Light > High RH > Organic pollutants	Fluctuating RH
Glass based	Sulfides	Light > High RH	Oxidising pollutants, Fluctuating RH

Table 1: Priority table for the sensitivity of photographic material to environmental factors.

However, the sensitivity of photographs is not only related to the support, but also to its image forming material [2]. For example, color and B&W images have a very different sensitivity to organic acids and sulphides. An overview of image deterioration and their causes, about environmental standards for photographic materials and other preservation topics related to photographic images can be found on e.g. the Image Permanence Institute web pages [3]. From Table 1 it is clear that low levels of sulphides and light are essential for the preservation of photographic material. Climate control is also important. Photographic material should be kept at as low temperature (T) as possible and at low relative humidity (RH), but avoiding dry conditions that can cause mechanical damage [3]. Lastly, it is important to avoid fluctuating RH and T, which can inflict mechanical damage due to dimensional change, and the presence of pollutants that can oxidize silver, dyes and polymeric materials, causing fading, yellowing and delamination.

Air quality measurements

To assure good storage environments it is essential to do climate and air quality measurements.

1.1 Parameter measurements

Often some measurements of separate parameters that characterize the indoor climate (temperature and humidity) light (visible and UV light) and air quality, i.e. air pollution, are performed. Temperature, relative humidity and light are relatively easy and commonplace to measure in cultural heritage buildings. Air quality should also be measured for a more complete assessment of damage risk. The concentration of most gases in the air can be measured by relatively simple passive methods or with more technically advanced and expensive continuous monitoring [4]. For photographic materials it can be especially relevant to measure the amount of sulphides, organic acids such as formic and acetic acid, inorganic acids such as nitric acid (HNO_3) and oxidizing pollutant gases such as nitrogen dioxide (NO_2), which also forms nitric acid on deposition on surfaces, and ozone (O_3)

1.2 Dosimetry

The term “dosimeter” is often used for devices that measure the effect of a combination of environmental parameters on some sensitive material, rather than sampling one gas. The dosimeter material may resemble or its measured degradation can be compared with the objects of, e.g. film material. Metal coupons or polymer materials have been used [4]. Polymer dosimeters would usually represent damage processes on organic materials better than metal coupons. Such generic dosimeters can give a simpler overall first assessment of environmental quality. A disadvantage is that diagnosis can be more difficult (than from a well selected set of parameter measurements). As the dosimeter material is usually different from the heritage materials of interest, it is important that the results **indicate** risk for damage. The presence of sulphides (Table 1), can be easily measured by exposing silver coupons and observe the amount of blackening. The corrosion rate of a silver coupon can represent the “risk for damage of cultural heritage objects”. Other metal coupons, such as copper, polymer dosimeters are more sensitive to the oxidizing pollutants. Some glass formulas are more sensitive to acids. The MEMORI technology [1] combines a synthetic polymer and a glass dosimeter to widen the sensitivity. The glass reacts to airborne acids, which indoor are usually emitted from building materials. The synthetic polymer reacts to the oxidizing pollutants, which usually have combustion sources and infiltrate from outdoor. Temperature, humidity and UV light also affect the measurement result. The MEMORI system allows simple diagnosis if the indoor (lack of) air quality is likely due to indoor or outdoor sources. The dosimeters are measured by a portable reader. Figure 1 shows MEMORI result from some English Heritage locations.

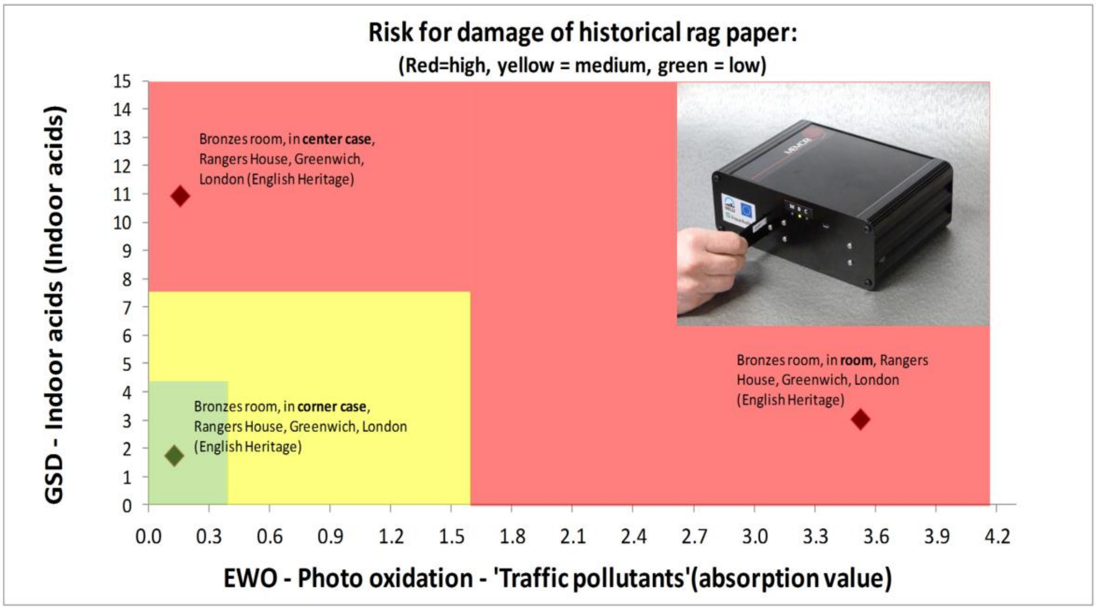

Figure 1: MEMORI results from measurements in English Heritage, Rangers House, bronzes room, Greenwich, London. Inside polluted ('center case') and very clean ('corner case') showcases and in the room.

Discussion and conclusion

The damage to film material in storage can be reduced by improving their preservation conditions. From an understanding of the degradation processes and environmental sensitivity of photographic material and measured values for the indoor climate, light conditions and air quality or their effect on a relevant dosimeter, the degradation risk for the films can be assessed and the most cost effective mitigation measures can be suggested to improve the preservation conditions.

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Harvard Plate Cleaning Machine

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Abstract

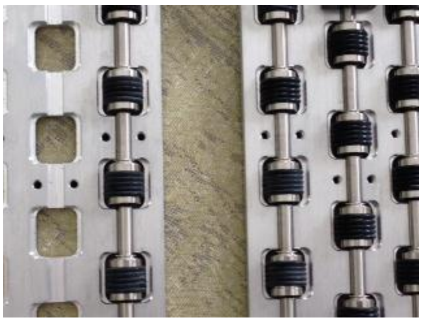
Before digitizing Harvard's glass plates, we need to clean off the non emulsion side of each plate to remove accumulated grime, dust, and sometimes old identifying India ink markings from past research. In pre-production runs to see how many plates could be digitized in a day, we found that it took on average 4-5 times as long to clean a plate as it did to digitize it. This led to a desire to automate, as much as possible, the cleaning process. This paper discusses the approach taken to design and build a machine to clean plates automatically (except for loading and handling) fast enough to keep pace with the digitizer's 400 plates per day throughput potential.

Keywords: photographic plates, automation, digitization, cleaning

Introduction

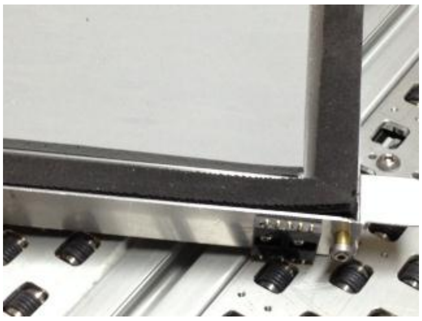
After a few months of trial runs trying to get digitization production up to the DASCH design goal of 400 plates per day, we found that the digitizer could achieve that goal but the people found the pace rather grueling. The preprocessing of the plates, especially the hand cleaning was taking 4-5 times as long as the digitizing. To continue hand cleaning would mean more personnel costs than the project could sustain in the long run. At that point we undertook to design and build a machine to automate, as much as possible, the cleaning process.

Design concept



The design concept for the machine was to have a modular aluminum transport bed that would hold inset ball bearing capstans with EDPM rubber O-rings allowing the plate, held in a fixture, to be moved past a series of rotating brushes and a drying station. The mounting for the bearings would require a plate with complex CNC machining and the CNC milling machines at Harvard had a limit of 8 in x 19 inches. The aluminum plate to be machined was designed to have two sections, each consisting of a 7.5cm (3 in) x 44.5 cm(17.5in) section with rubber roller bearings followed by a 2.8 cm (1+ in) x 45 cm (17 5/8 in) opening for cleaning or drying stations The sections were designed to butt together allowing creation of a standard spacing; or, with some judicious sawing, they could be placed together with no spacing or arbitrary spacing as long as the open distance would support the plate and fixture The working part of the bed is now 47cm (18 in) wide by 145 cm (57 in) long and it consists of 15 2/3 roller sections with 12 open areas. The open areas range from 1 cm to 5.7 cm. There are 564 roller bearings with 2820 EDPM rubber O rings (five on each bearing) forming two completely independent tracks allowing two plates to be moved and cleaned simultaneously. The bed surface is Anisotropic allowing free movement in the direction up and down the track while the friction of the rubber O rings provides resistance to any sideways or rotational movement.

1.1 Plate Fixture



The plate is held by an aluminum fixture that provides protection for the emulsion. The fixture has two types of silicone foam rubber with differing properties. The plate is made of 2.54 cm (1 in) thick solid aluminum that has been machined to have an outer edge where Delrin plastic strips can be placed. The strips are machined to provide an angled substrate (currently 5 degrees) for the very soft silicon rubber replaceable strips used to capture the edge of the plate glass. This soft silicone rubber provides friction to transfer the motion of the fixture to the glass plate and it also provides a seal for the irregular edges of the plate. Just inside this section of the fixture is a shallow air plenum that has 4 through holes at the corners to prevent creating a vacuum seal between the plate and the fixture. In the central part of the fixture is a somewhat harder silicone rubber surface that can support the plate should it sink far enough into the softer foam to touch the inner foam, It also protects the plate by limiting possible bending of the plate. Each long side of the fixture has, on its ends, a Delrin block with a number of brass pins spaced to engage the openings in the stainless steel ladder chain which, moved by a stepper motor transports the fixture on the bed surface or on the upper side rails. When at the capture location, the fixture can be raised or lowered by 4 air cylinders that push on short extensions to the fixture. Adjacent to the chain drive engagers, there are 4 ball bearing cams that allow the plate to run in a raised track above the bed or to limit upward motion by the bottom of the track when the fixture is running along the bed. This provides a strict limit on how far upward pressure from the rotating brushes can lift the glass and fixture.

1.2 Electronics

To run the machine there are two electronic boxes for each track. The first box is the human interface box. It contains a single chip microprocessor board from Pololu.com called the Orangutan SVP 1284. This robotic controller system contains an LCD display and a main processor a ATmega1284P chip with 128 KB flash, 16 KB RAM, 4 KB EEPROM. This chip contains the main control program for the machine in the flash memory. It is packaged in a small aluminum box mounted where it is easy for the operator to select among several possible cleaning cycles in a normal running mode or in a maintenance mode it can be used to test each of the inputs, outputs, and motors used in the machine. The computer talks through a serial communications path (I2C) to a custom designed expansion card that provides the capability to have 11 inputs, 12 open collector outputs for driving pneumatic relays, 4 high power outputs to run pumps and to energize the relay for the air knife used for drying, and 5 stepper motor controllers (one to load the plate, one to move the fixture and one for each brush). The connection between the boxes is through a stereo audio extension cable. The electronics for each track is totally independent including a separate 13.8 Volt 7.5 amp power supply. All of the electrical connections to sensors, relays, and motors are made to the expansion boxes mounted below the working surface.

1.3 Cleaning Brushes

The primary cleaning method is by 2.54 cm (1 in) diameter bristle brushes from Jenkins Brush Company. These are custom made and are constructed in a way that allows the brushes to be refurbished with new bristles. The brushes can be raised and lowered by two zero stiction Air-Pot air cylinders. A cylinder at each end of the brush ensures that the pressure on the glass plate is even across the line of contact of the brush and the plate and the zero stiction property of this type of cylinder makes it a virtually perfect spring with the spring rate controlled by air pressure. We have three brushes on each track, the first brush is very stiff and its purpose is to remove writing and the more difficult to remove grime. The next two bushes are softer. They are to remove the debris from the first brush and finally to provide a final rinse stage.

1.4 Drying

The drying is accomplished by a compressed air knife from AirTx corp. that uses the coanda effect to multiply the volume of air moved by 40-50 X the amount of compressed air used. The knife is divided into two 8.5 inch active sections each supplied with clean, dry compressed air through a relay controlled by the electronics

1.5 The Cleaning Cycle

The entire cleaning cycle consists of the following actions: first the plate is placed on the PCM bed inside some Delrin guides to align the plate to the direction of movement. Then a button push starts the plate automatically moving toward the fixture loading position. As the plate gets close to that position the glass it is sensed by an infrared short distance reflective sensor and then gently brought up against two raised air cylinder shafts to do a precise positioning so that the fixture can be lowered down to capture the plate. After capturing the plate, the fixture is moved to the back of the machine, stopping for a few seconds where it covers the three brush areas to allow wetting the brushes while without any splattering. Then the fixture with the plate is moved beyond the brushes to the very back of the machine the cleaning process starts. As the fixture with the plate is brought forward past each brush position, the brush is raised and rotated to scrub the plate. The process is slightly more complicated because we actually move the plate back and forth when over each brush so that it is only raised when we are sure it will be well inside the edge of the plate and the brushes are always rotated so that the direction of rotation as the brush goes off the plate will be counter to the direction the plate is moving. We do this to make sure the brush will not be pushed up against the silicone rubber foam that is holding the plate wetting it. Once past all three brushes the plate is moved back a short distance and it is run slowly forward across the air knife opening to blow dry it and then sped up to go back to the capture area. There the fixture is raised by air cylinders and is moved back on the rails. The air cylinder shafts are lowered so the plate can be moved out to the very front of the machine where it can be taken off by hand. This whole process takes a little more than a minute.

1.6 The Cleaning fluid

The cleaning fluid we are planning to use is a mixture of water and Ethanol. The exact ratio is yet to be determined and it may be different for each of the three cleaning stations. Using this mixture has raised a number of issues. The first is that all parts used in the machine have to be Ethanol compatible. A second is the need to completely enclose the machine and provide ways to deal with any liquid waste and any vapor levels that might be detrimental to the operator and others in the vicinity. We are continuing to work on all of these issues.

1.7 Acknowledgments

We thank the many people who have contributed to this project directly or indirectly. Of special note are Bianca and Stephen Homberg who as high school students did the original software design and coding. We are also grateful for the partial support from NSF grants AST-0909073, and AST-1313370 that helped make this machine possible.

Glass Plate Negatives – Conservation and Restoration in Practice

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Abstract

This paper focuses on conservation and restoration of glass plate negatives in practice. In the frame of conservation it will mention primarily cleaning both the sensitive gelatine layer and the glass support. The part devoted to restoration will concentrate on the most frequent problems: broken glass support, flaking of the gelatine layer, problems when transferring a gelatine layer etc.

Keywords: glass plate negatives, deterioration, gelatine layer, glass, conservation, photographic materials, restoration.

Introduction

Generally we can say that photographic materials are one of the most sensitive collection items with regard to its physical-chemical nature. These funds are on the other hand most used ones for reproductions, exhibitions etc. Researches in archives and museums show that negative materials with silver-gelatine sensitive layers are represented in our photographic collections in the highest number. And that is why their physical state and conditions of long-term storage should be stressed.

Methods of cleaning glass plate negatives

Negatives on the glass plate were at the time of their origin stored in boxes in vertical or horizontal position. Ways of their storing mostly depended on the size of given negatives. In some cases the negatives were stored in parchment paper envelopes or between interlaying papers of various qualities. The stored negatives, however, often touched one another, without any interlaying material between them.

Glass plate surface is most often stained with grease (i.e. finger prints, food residues) and dust particles. This dirt on the sensitive layer provides suitable conditions for the growth of microorganisms which can irreversibly damage the sensitive layer of the negative.
To remove these solid particles it is possible to use so called mechanical/dry cleaning. Nevertheless, it is impossible to remove different types of grease stains just by mechanical cleaning. This is why it is suitable to combine this way of cleaning and cleaning with suitable solvents (mostly organic). Here presented solvents are suitable mainly for negatives with silver-gelatine sensitive layer. This method is generally regarded less invasive and more effective. Application of these solutions can be performed with help of cotton pads impregnated in the given solvents. Most often used solvents in practice are: medical petrol (hexane), ethanol, isopropyl alcohol, acetone, 1,1,1 - Trichloroethane, distilled water.

Fixation of glass plate negatives fragments

Photographers had problems with mechanically damaged negatives already at the time when glass plate negatives were used. A broken negative was most often regarded to be utterly unusable and destined to be disposed. However, when precious once-in-a-lifetime shots were considered, much

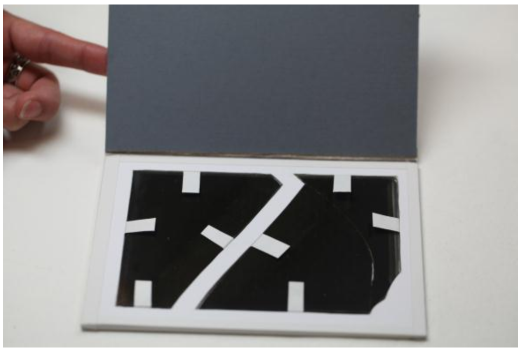
effort was put into preserving it. Some methods describing preservation of these negatives were described in period manuals, e.g. *Hearn´s Practical Printer* from 1878 [1] described two methods of fixing a broken colloid negative.
In today´s restoration practice are used more ways how to approach conservation or possible restoration of glass negatives. Here are descriptions of individual procedures and approaches to this problematic.

Passive restoration

In these procedures the negative is not fixed to the new plate, nor is used any adhesive for gluing individual fragments.

Fixation of fragments with help of cardboard "passe-partout"

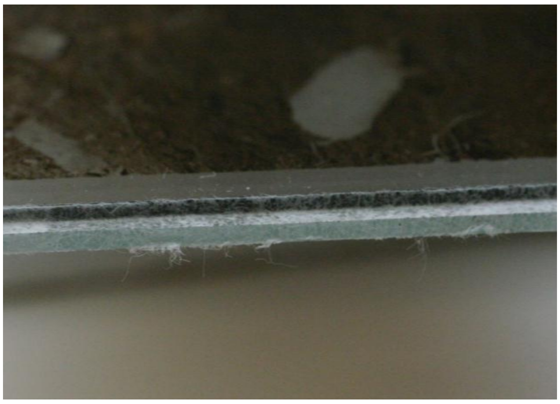
Openings of the size corresponding to negative fragments are cut into the cardboard as thick as the damaged glass plate. Cardboard prepared in this way is backed from the back side with another cardboard of the same size. Individual fragments are afterwards inserted into the openings. This kind of conservation of broken glass plates is most often used in institutions throughout the world. Used paper must contain 87% alfa cellulose and must not contain groundwood pulp and lignin. For gluing it is not possible to use resin glue but only neutral glue (alkyl ketene dimers). It also must not contain any pigments, fillings, optical brightening agents, UV absorbers and other substances. The pH value scale should be from 6 to 7 [2]. Another standard the used packing materials should meet is PAT (Photographic Activity Test).



Negative in the cardboard *"passe-partout"*

Methods of glass plate negative fixation

Ways of fixation on a new glass plate used in the past are used in today´s restoration practice in different modifications. Here is a method proved successful when restoring glass negatives in collections of the National Archives of the Czech Republic, National Museum and other home institutions:
Fragments of the negative are placed on the glass which is 1 to 2 mm bigger than the original negative. The negative is fixed with Japanese paper on sides and does not overlap the picture layer. To fix the Japanese paper we use rice starch [3]. The advantage is easy manipulation with the glued negative and reversibility of this restoration act. The negative is then inserted into four flaps enclosure suitable for photographic material. It is afterwards put into a box or suspension folder (in accordance with the negative size) made of cardboard suitable for photographic materials.



Edge of negative fixed on glass

Gluing of glass negative fragments

Gluing of negatives was to a limited extent used already by glass negatives makers. Especially in the case when only a small part of the negative (e.g. a corner) was damaged and for gluing it back was used Canadian balm or gelatine solution.

These days some restorers prefer gluing negative fragments with synthetic or natural glues before fixing them to the new glass plate. Gluing methods and choice of glues is based on methods of restoring archaeological glass findings. These adhesives can be divided into two categories:

1) Glues on the basis of natural polymers: gelatine, Canadian balm
2) Glues on the basis of synthetic polymers: cellulose esters, epoxies, acrylates, polyesters, silicones

It is necessary to emphasize that used adhesive for restoring photographic material must be chemically and physically stable. It must not succumb to subsequent changes (e.g. change of colour) or react with the sensitive layer of the negative. Studies executed by M. Gillet, N. Kennedy and C. Garnier [4] proved that after application of mainly epoxide resins there were changes in colour of the sensitive layer. Results of this study highlighted danger of penetration of volatile components of these glues when applying them, which brings the danger of irreversible damage to the sensitive layer.

Gelatine layer transfer

This technology can be used only with negatives with silver-gelatine sensitive layer in the case the glass plate was highly degraded and the picture became non-transparent or in the situation when bigger parts of the sensitive layer are separated from the glass plate. The transfer cannot be performed with negatives with lacquer on the sensitive layer.

Gelatine layer separated from the glass

The process consists of the following phases [5]:

Preparing a new glass plate – is important for good adhesion of the sensitive layer. The glass surface must be absolutely clean, for which is used chromium-sulphuric bath, where the glass plate stays for 18 hours. After that the plate is rinsed in water and immersed into water solution of sodium carbonate to neutralize the acid. Then rinsing in water comes again.

Emulsion networking – is important to prevent gelatine from swelling up in water and acid bath. The best results were reached after the plate was immersed in the water diluted formaldehyde solution. Lacquered negatives cannot be treated in the hardening bath since the protective film would become transparent in the formaldehyde solution.

Complete separation of the sensitive layer – is performed by immersing the plate into water solution of hydrofluoric acid. This isolates the picture layer and is followed by rinsing in distilled water at least three times to remove the acid residues. After that the still moist picture layer is transported on a new glass plate.

When transporting the sensitive layer on a new plate (which must be at least 10% larger than the original glass plate) the used adhesive is chrome alum. Afterwards comes drying in the air.

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Digitization as a Method of Protection and Presentation of Glass Plate Negatives

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Abstract

In 2007–2009, the National Archives engaged in a research project dealing with glass negatives in comprehensive manner. The paper presents a part of this project that is digitizing negatives in a careful way by reproduction based on traditional photographic methods using digital camera and light table with an opal glass. It shows that treating plates as 3D objects affects the resulting reproduced image and also allows documenting any damage to the carrier and the light-sensitive layer.

Keywords: photography, glass plate negatives, digitization, preservation.

Introduction

This paper presents one part of a research project called "Preservation of light-sensitive archival documents on glass substrate (plate negatives)" which was undertaken by the National Archives in Prague in the years 2007 to 2009 [1].

Glass negatives which are part of important archival collections and their historical, social, and cultural value is incalculable, got in the center of our attention. Their bad physical state became the main reason to launch this research. Glass plates can be easily mechanically damaged, and handling them is difficult. Due to poor storage and manipulation, glass substrate brittles, changes its crystalline structure; photosensitive layer that is applied to it degrades, shells off, various "veils" are being formed on it, and these gradually cover the image until it becomes unreadable.

Archival records of this type cannot be submitted to researchers for study, and thus the information contained in them has to be mediated to the public in another way – the best as a quality reproduction. We excluded in advance the use of desktop scanners for creating reproductions, as well as capturing analog reproductions, which is expensive and slow, and therefore we have attempted to find a more appropriate way.

1. Main Goals of the Research

We aimed was to present a comprehensive material to experts in memory institutions that would address the issue of long-term storage and making glass negatives available. Our objectives were as follows:

- To determine appropriate climate and suitable materials for long term storage of glass plate negatives;
- To analyze types of damages (mechanical, microbiological, chemical, etc.) and specify appropriate conservation procedures;
- To draft methodology for archival processing of photographic archival records using international general or special standards. (In connection with this, circumstances "made us" to attempt to define some terms so that the guidelines would be understandable not only to archivists, but also to experts in museums, libraries, etc.)

Further, we aimed to propose a suitable method of careful reproduction and an appropriate form of making digital reproductions available.

From what has been said, it follows that the solution of each of the objectives of the project involved experts from various professions, i.e. archivists, conservators, photographers, and IT consultants so that it could be possible to process comprehensively the problems of making archival documents available. Making available includes not only "mediation" of archival documents to the general public (i.e. making records accessible), but the whole set of related activities from acquisition, record keeping, conservation, arranging, inventorying, etc. until the final provision of archival documents to researchers in a suitable form.

2. Digitization of Glass Plate Negatives

2.1 Choosing the Appropriate Method

Our main goal was to find a way of very careful reproduction of fragile glass plates, whose historical value is significant. We were aware that any reproduction (even analog) brings some loss of quality, loss of information, which may not be problematic with archival documents whose physical condition is yet sustainable and their "original" is still available. In the case of glass plates a problem could occur (e.g. breakage), so we chose the method of quality digitization, where the loss of information is largely eliminated by the technology used, and the resulting reproduction contains at least the same amount of information as glass negative itself.

When reproducing, we view a glass plate as a three-dimensional object (and not as a two-dimensional pattern) which features properties that can significantly affect the final (i.e. reproduced) photographic image. In addition to visual information, i.e. the content of the photographic document, the selected technological process allows us to document damage both on the side of the support of the light sensitive layer (glass) and the potential damage to the sensitive layer itself.

At the same time, we believe that when reproducing, it is important to capture and document period interventions by the author and any later interventions (such as retouching or any traces of manipulation with photographic image) – knowledge of these may lead to disclosure of new context of image formation. Thanks to quality reproduction we may also attempt to give researchers an idea of the original document content – the scene as seen by a photographer when he pulled the trigger.

Appropriately chosen reprographic process will allow us to understand better circumstances of creation of the photographic document, which is for us an important historical source, and therefore to assess it more accurately or more precisely.

We came to the conclusion that the method of reproduction may affect the information value of the photographic document, and therefore the effort to capture as much of the original information.

2.2 Main Criteria for Digitization – Sharpness and Resolution

In terms of working practices, the selected method of digitizing glass plates is grounded in the use of traditional photographic (reprographics) procedures, and based on them, the main criteria of digitization were defined. These include contour sharpness – which is secured primarily by using very high quality lens – and the resolution.

Resolution is often overestimated criterion in terms of stating the number of pixels. For the quality of the digital image, this figure is important only in connection with the use of high-quality lens, a suitably chosen light, and the elimination of all kinds of visual noise – without securing these preconditions, together with high-resolution we get an image with running details and therefore with only formal high resolution, but non-functional.

2.3 Color Depth

Color depth of 48 bits is recommended for accurate photo reproduction with high demands on the absence of loss of image halftones (despite the fact that the human eye is far from recognizing as many details).

The quality of a digital image using a low color depth, however, would be comparable to analog photograph made directly on photographic paper, which also leads to considerable loss of information. This is caused by the low sensitivity of photographic paper. Negatives and slides contain much more detailed information (data) than what an enlargement subsequently made is able to provide.

The 48-bit color depth provides wide exposure latitude – i.e. it allows capturing large exposure differences between light and dark areas of the picture. This option offers the advantage of very fine halftones gradation – i.e. the possibility to capture very subtle tonal differences.

Achievement of color depth of 48 bits requires following prerequisites: The absence of image noise especially in dark parts of the image that occurs mainly due to the gradually increasing temperature on the surface of the sensor. (Because of the heat, emitted electrons cause false exposure – mainly in blue image channel. This can be compared to image noise in analog photographs on photographic film, which is manifested as grain.) Noise can be eliminated by the use of active cooling of the sensor (-5 °C). Other prerequisites are elimination of noise caused by long exposure and elimination of overexposure noise (blooming).

2.4 Lights

An important prerequisite for obtaining high-quality digital reproductions is photographic lights. They must meet a number of requirements, such as emission of wide, continuous spectral range of daylight, unwanted (invisible) components excluded. They should operate only at the moment of exposure and allow both modulation of light (i.e. diffused, direct), and variable power regulation.

2.5 Digitization Device

Based on these criteria and parameters, we designed a device that consists of light table (a table with an infinite background) equipped with opal board and glass plate. This solution allows selecting the lower light with varying degrees of light diffusion.

Two to four lights enable variability of settings (various positions) and lightning with stepless power control. Lower light (soft) is used when capturing the visual content of the negative, upper (direct) light is used when capturing physical condition and damage of glass plate and sensitive layer.

For scanning we use technical camera Sinar with digital high-resolution back equipped with active cooling which is connected to a computer with graphic software and software communicating with the digital back.

Result from digitization is a set of three reproductions of which only one (depicting visual content) is provided to the public. The other two are used for the needs of archivists and especially conservators.

3. Workflow, Storage of Reproductions, and Their Publication

For the digitization it was necessary to design workflows that must always be followed exactly – no changes are allowed. Further, it was also necessary to define the responsibility for individual operations. Workflow within the project had seven steps: Work allocation (administrator), digitization (operator), data transfer to a temporary repository for processing (administrator), data integrity check (IT operator), checking, editing, and creation of study copies (graphic designer), saving in a storage (IT operator), and removing processed source files from temporary repository (administrator). Disk arrays and data tapes were used for permanent storage within the project. Technical metadata and descriptive data were edited manually with the use of EXIF and software for describing archival documents (Janus).

For the publication within the project, an application allowing a simple presentation of reproductions was created, which is freely available together with the entire research report on the website of the National Archives [1]. Conservators' part of the report was issued as a separate publication, the segment devoted to archival processing and terminology is intended for a broader discussion.

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Digitizations in the GAIA framework : the NAROO project.

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Abstract

The photographic plate archives are valuable treasories available in many countries. However, what to do, how to extract interesting information from the plates? Is the digitizing of plates necessary? For what purpose? At Paris Observatory, we considered first that the analysis of old observations is very interesting for the moving objects of the Solar system and for variable stars such as Be stars. The dynamics of Solar system objects is a fruitful field of interest, allowing to modelize the formation and the evolution of these objects. However, we need to validate our models through observations. Past observations are necessary since the time sampling is essential. Old photographic plates may bring the information after digitizing and after a new astrometric reduction. Since the Gaia reference star catalogue will allow to make such a reduction, we will be able to observe in the past with today accuracy. We first made tests using the UCAC2 catalogue and digitization made at the Royal Observatory of Belgium. The NAROO project (New Astrometric Reduction of Old Observations) is to select, digitize and reduce photographic plates allowing us to reach our goal.

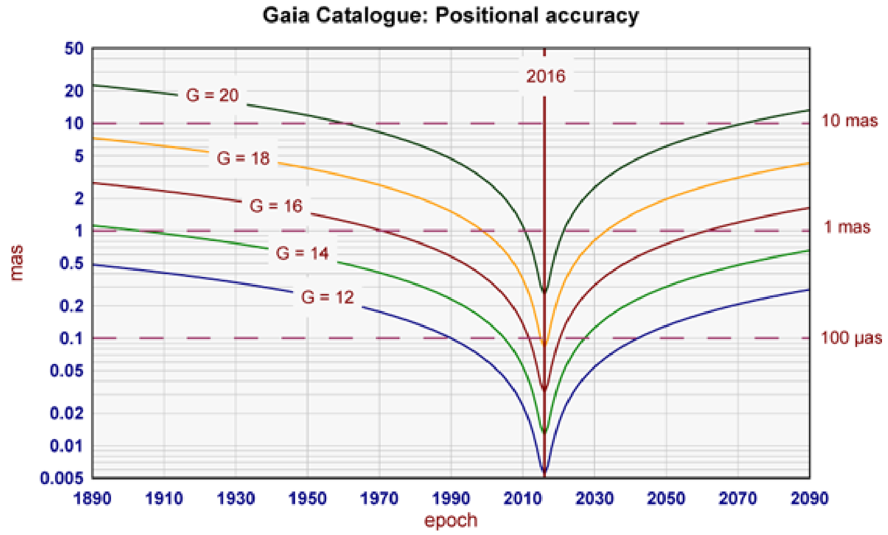
Keywords: solar system – evolution – astrometry – Gaia catalogue.

Introduction

The large archives of photographic plates available worldwide in many observatories were no more used since their first reduction at the time of the observation. A question occurred about these plates: is it necessary to digitize them in order to have files of digitized images available? Several answers were provided considering that saving those old data was essential for the future generation. In Paris Observatory, we started a scientific project of digitization of old plates of either moving objects or transient phenomena such as variable stars. The time factor was so important for these studies that a new reduction of old data would bring valuable new information

A new reduction

Old data are still used for the validation of models based upon the evolution of bodies with time. The reductions made at the time of the observation were of poor quality because of the difficulty of the calibration with the reference catalogues of that time. After digitization, using new reference catalogues, a new reduction is possible [3]. The Gaia reference star catalogues will not only provide reference stars until magnitude 20 but also will provide proper motions of stars with an accuracy of about 5 mas for stars until magnitude 17 as shown on the figure below.



The accuracy of the proper motions of the stars of the Gaia catalogue [1]
would bring valuable new information

Some examples

Below one will find the interest of old data for some scientific studies

1.1 Dissipation of energy in the icy satellites

The dynamics of the solar system bodies is well known thanks to celestial mechanics. However, a question arises for the satellites of the giant planets, the icy satellites: are the tides between the planet and the satellites sufficiently strong to heat the internal structure of the satellites? How is their evolution with time? This is measurable thanks to the observation of an acceleration in the motion of the satellites, signature of dissipation of energy. Such an acceleration is visible on the longitude of the satellites in their orbits which is observable only through a long interval of time, the effect being cumulative. The old data have then a specific interest.

1.2 The Near Earth Objects

The Near Earth objects (asteroids and comets) are now extensively studied in order to know the evolution of their orbits and a possible collision with Earth. Even they were not known during the first half of the XXth century, they were observed! They appear fortuitously on plates, especially on Schmidt plates and may be found nowadays thanks to recent softwares computing the presence of all solar system bodies for any field at any time. Having positions of these objects on an interval of time of several decades will help to understand their dynamical evolution and to know more on the evolution of the Solar system

1.3 The Be stars

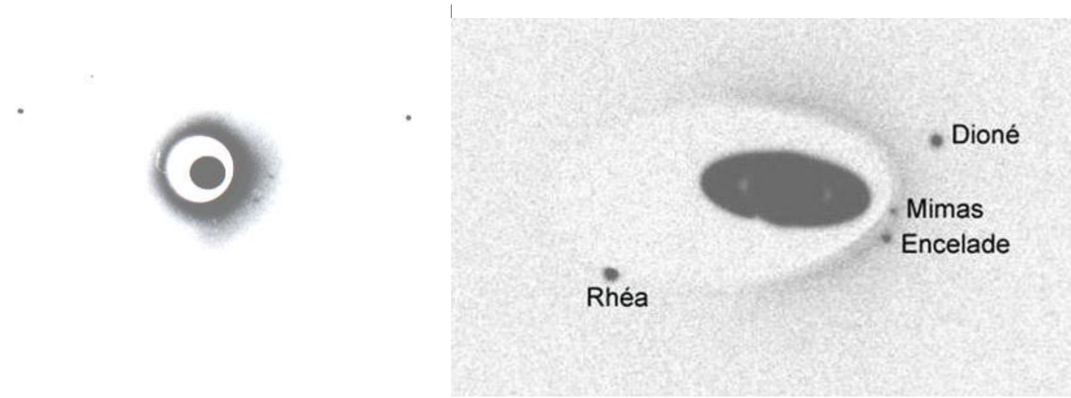
The Be stars are massive stars ejecting material. They are variable stars at several time scales : hours, days, months, years, decades. So, the study of the photometric and spectroscopic variation of these stars is an important task in their study. The present data bases have no observations before the 1990's. Observations must be accumulated and the data bases will be feeded with old data extracted from photographic plates.

The NAROO project: preliminary results

Our project is to build a digitizing machine at Paris Observatory and to start digitizing plates of interest for our scientific purpose. We made tests using the Damian machine of the Royal Observatory of Belgium. Thanks to the help of the ROB and to the European Project ESPaCE we were able to digitize plates from the U.S. Naval Observatory of the satellites of Mars, Jupiter and Saturn (below an example of a plate of the Martian satellites). The accuracy was not only better than the one of the reduction made at the time of the observations, but also was able to provide right ascensions and declinations of the objects when we got only relative positions to the planet in the past. This was made possible by the extraction of reference stars on the plates not visible at the time of the first reduction, needing a computer for image analysis to find more stars. We provide below results from the position of the planet Jupiter from the position of the Galilean satellites. We are able to validate the planetary ephemerides on longer periods than previously.

	$\overline{(O-C)}_{\alpha\cos\delta}$	$\sigma_{\alpha\cos\delta}$	$\overline{(O-C)}_{\delta}$	σ_{δ}
DE421	-1.7	63.0	40.0	73.1
DE423	-1.8	62.8	38.1	71.5
INPOP06	-6.1	63.0	37.4	71.6
INPOP08	44.1	69.3	47.8	91.6
INPOP10	3.0	62.8	37.4	71.1
EPM08	-2.3	63.1	37.6	71.3

Residuals Observations minus ephemerides for the planet Jupiter for the USNO photographic plates and standard deviation of the residuals [2]



Left : the planet Mars (under a metallic filter) surrounded by light diffusion in which the satellites are visible. Farther are the stars referenced in the UCAC2 catalogue. [4] At right, the Saturnian system with the planet Saturn under a metallic filter.

Conclusion

The first results obtained on the natural planetary satellites have shown that a new reduction of photographic plates will provide not only more accurate results but also new information due to the possibility of image analysis showing unsuspected objects or features.

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Absolute Proper Motions from the Digitized Sky Surveys

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Abstract

The astrometric task of calibrating and removing systematic errors in the derivation of absolute proper motions from the Schmidt Sky Surveys is successfully tackled when background galaxies are used as fiducial reference points. We present the results of this approach as applied to the Guide Star Catalog plate material, touching on its relevance in the GAIA era.

Keywords: Digitized sky surveys, Schmidt plate astrometry, Galactic astrophysics

1 Introduction

We have tested and applied a novel method for the derivation of absolute proper motions from the Catalogue of Objects and Measured Parameters from All-Sky Surveys (COMPASS, [2]). This is an object-oriented database built for the realization of the Guide Star Catalogue II series (GSC2.3, [6] and references therein), which contains astrometric, photometric, classification parameters and image centroidings of all objects detected on more than 7000 Schmidt plates. The plates had been digitized at the Space Telescope Science Istitute (STScI, Baltimore MD, USA) on two PDS machines that were refurbished to cope with the increased accuracy and throughput requirements imposed by the GSC and DSS projects (http://archive.stsci.edu/gsc/; https://archive.stsci.edu/dss/). The adopted sampling was 15 micrometers, corresponding to a pixel scale of ~ 1 arcsecond, with only a minor number of plates sampled at 25 micrometers ($1.7''$/pixel). We retained the results of the GSC2.3 centroiding algorithm, i.e., an iterative elliptical gaussian fit of previously deblended image cutouts. The average r.m.s. error of the fit is of the order of 0.12-0.13 pixels [7], with individual errors varying as function of plate quality, object brightness, and PSF characteristics. Though a margin of improvement seems to exist in the case of saturated and stretched images [4], we made no attempt in this area - as we lacked the resources to handle the raw images - and rather concentrated our efforts on the plate-to-sky transformation.

2 The Astrometric Problem (and Solution)

The astrometric calibration of GSC2.3 was based on the application of the original Mask Method [8] and the use of the ACT and Tycho-2 reference catalogues. This strategy allowed to link directly the GSC to the International Celestial Reference System (ICRS) defined by extragalactic sources and to get rid of the bulk of plate-dependent residual errors reflecting the inability of finding a suitable analytical transformation from plate measurements to celestial coordinates. Although this solution represented a significant improvement over the previous GSC version, extensive tests evidentiated that it was still suffering from some deficiencies known to have plagued Schmidt plate astrometry for decades. A relatively recent paper by Kuimov et al. [3] suggested that Schmidt systematics be dominated by the effect of plate deformations due to its bending onto the focal plane, demonstrating that a seventh-order polynomial model deduced from the Kirkhhoff-Love plate theory could give optimal results. Their somewhat promising analysis, however, ignored the existence of a completely different issue called in jargon 'magnitude equation'. As shown by Morrison et al. [5], the astrometric residuals suffer from a component depending on the star's magnitude, which increases with distance from the plate center, therefore mimicking a coma aberration that correlates with the pure geometric distorsions. A pure magnitude term also exists when the exposure is poorly guided, and the colour of the stars is likely to affect the centroider estimator. Ultimately, the complex structure of plate-to-plate variations of the systematics needed to be fully investigated. Therefore, the lack of dense astrometric reference catalogues covering the same broad magnitude range as the plates remained the major drawback in the successful use of Schmidt plates for accurate astrometric works. Lately, the USNO CCD Astrograph Catalog series, in its 4th version (UCAC4, [9]) listing accurate positions, proper motions, and colours for over 10^6 stars down to photographic mag $\simeq 16$, seemed mostly adequate, though still not ideal, to unraveling such intricacies and finally exploiting the true astrometric potential of Schmidt plates.

2.1 Schmidt Plate Astrometry for the Galaxy

The ability of deriving unbiased absolute proper motions over large sky areas is a fundamental task for Galactic studies. Since we can shed light on the evolution history of our Galaxy by investigating the kinematic properties of different stellar populations, characterized by different absolute magnitudes and colour distributions, it is of utmost importance not to undermine the astrophysical nature of stellar motions by trying to eliminate the sources of systematic errors described above. For this reason, instead of using UCAC4 stars for the removal of magnitude- and colour-dependent errors, we investigated the potential usefulness of non-stellar objects (i.e., galaxies) detected on each plate. The advantage of using galaxies is, in principle, doublefold: on one side, they have no measurable proper motions on the plate and thence, any shift they display in the intercomparison of different exposures must be imputed to a deficiency of the plate-to-plate transformation, which can in such way be detected and corrected for; furthermore, they constitute an ideal reference frame that, being fixed in space and time, can deliver genuine proper motions. On the other hand, the hypothesis that all objects (stellar and non-) physically close on a photographic plate and with similar magnitude/colour will be affected by similar systematics is crucial; also, an adequate number of galaxies must be present on a single exposure in order to perform a good modelling. The first requirement was checked on several plates, bringing to the conclusion that, in spite of the different density profiles on the photographic emulsion, the centroiding properties of galaxy images are, in fact, comparable to those of point-like objects and can be successfully used to investigate magnitude- and color-dependent errors. Unfortunately though, one can rely on galaxies at relatively high galactic latitudes, as only galactic objects are visible towards the plane because of high interstellar extinction. Based on these principles, we have worked out a robust method for the computation of absolute stellar proper motions from Schmidt plates and applied it to all plates at galactic latitudes $|b| \geq 27^o$, covering a sky area of 22,525 square degrees. In the following, we brefly present the main calibration steps and give some results, while referring to Zhaoxiang et al. (2014, [10]) for a detailed account of this work.

3 Derivation of Proper Motions

The calibration problem comes down to two major steps: a) *rectification* of mutual overlapping plate areas, which delivers *pseudo* absolute proper motions in the system defined by the plate designed as reference; b) *absolutization* of proper motions, which means to express their coordinate components in the reference frame of the ICRS. Step a) involves some logical passages implementing what we have learned in many years of experience with Schmidt plate reductions: it is possible to treat the pattern of systematic errors as the superposition of a purely geometric function and another one depending on the object's magnitude/colour. Moreover, the geometric term is characterized by small-scale variations - of the order of few arcminutes - whereas the magnitude/color one can be safely accounted for by a second-order polynomial, retaining only linear terms in the plate coordinates. These considerations allowed us to model the difference between the coordinates of a stellar object measured on the reference plate (x_r, y_r) and on the overlapping one (x_o, y_o), as:

$$\Delta x_s = \mu_x \Delta t + D(x_o, y_o) + E(m, C, x_o, y_o) \quad (1)$$

where m and C are the magnitude and colour of the star (with respect to a suitable zero-point), and μ_x the measured proper motion. Functions D and E represent the geometric distorsion and magnitude/color terms, respectively. For a galaxy detected on two plates, one can write an analogous equation:

$$\Delta x_g = D(x_o, y_o) + E(m, C, x_o, y_o) \quad (2)$$

which resembles the previous one apart from the proper motion term that vanishes in the case of galaxies. Equivalent expressions hold for the y coordinate. For the estimation of D we used stars instead of galaxies; this choice gave us a better leverage in term of number density and allowed us to restrict the range of stars to the middle of the unsaturated magnitude range, viz. $(m_{lim} - 4.5) \leq m \leq (m_{lim} - 2.0)$, where the image profile is well sampled and the centroiding algorithm delivers the best results. The procedure includes a global fit of a third-degree polynomial followed by a local moving mean with a self-adjusting scale, in all circumstances smaller than 20 arcminutes. Once D is estimated and removed from all objects, the updated difference for stellar objects would read:

$$\Delta x_s = (\mu_x - \bar{\mu}_x)\Delta t + E(m, C, x_o, y_o) \quad (3)$$

while for galaxies it would become

$$\Delta x_g = -\bar{\mu}_x \Delta t + E(m, C, x_o, y_o) \quad (4)$$

where $\bar{\mu}_x$ stands for the average proper motion of the reference stars, artificially injected into Eq. (4) by the procedure. This does not represent a problem, for now the average proper motion term can be fitted along with the E function by applying Eq. (4) to all the galaxy measurements on each plate couple (reference + overlapping). Once the estimated $\bar{\mu}_x$ and E are removed from the stellar differences in Eq. (3), one ends up with

$$\Delta x_s = \mu_x \Delta t \quad (5)$$

showing that the stellar displacement assumes now the meaning of a true proper motion, though still expressed in *plate* coordinates. At this point we need to convert the proper motion components onto the equatorial system, which entails, practically, finding the scale and rotation parameters of the transformation $(\mu_x, \mu_y) \to (\mu_\alpha, \mu_\delta)$. This task is accomplished using UCAC4, and a relatively low-degree polynomial is adequate in this case.

4 Errors estimation and Control

Assuming that all the observations of a star are evenly distributed about the reference mid-epoch, the *formal* proper motion error takes the following simple form

$$\sigma_\mu = \frac{\sigma_s}{< \Delta t > \sqrt{N_{obs}}}$$

where σ_s is the error on the single coordinate measurement, N_{obs} the number of observations and $< \Delta t >$ the average time difference between the various observations. From the plate statistics we derive an overall error range of $1.1 < \sigma_\mu < 14.4$ mas. This does not take into account a possible *zero-point* offset, which would affect all proper motions obtained with the same galaxies as fiducial references; such an estimation can be inferred from the covariance matrix of the system of equations (4). Again, from our data we worked out a range of $0.1 < \sigma_{zero} < 1.5$ mas. In order give an objective evaluation of the quality of our proper motions, we cross-matched the Gaia Initial QSO catalogue (GIQC, [1]) with the plate images. Since these are compact extragalactic objects, they are ideal targets for a null test as their motions should be exactly zero. We have examined the distribution of computed proper motions as function of magnitude and colour for more than 370,000 GIQC objects down to photographic R mag ≈ 20 , and found a very good agreement with our theoretical error estimates, as shown in the graphs of Figure 1. Of course, such global analysis must be complemented with local checks of the residuals via plate-to-plate comparisons and against additional external catalogues. Also, the lack of galaxies at low Galactic latitudes must be tackled if we aim at accurate proper motions over the full sky. Most of these issues are discussed in our journal paper [10]. In conclusion, we feel confident that these absolute proper motions can be successfully used for Galactic astrophysics and that they can help gauge the quality of proper motions delivered by the Gaia mission, especially for magnitudes ~ 19 where our random errors do not swamp Gaia's expectations in this magnitude range.

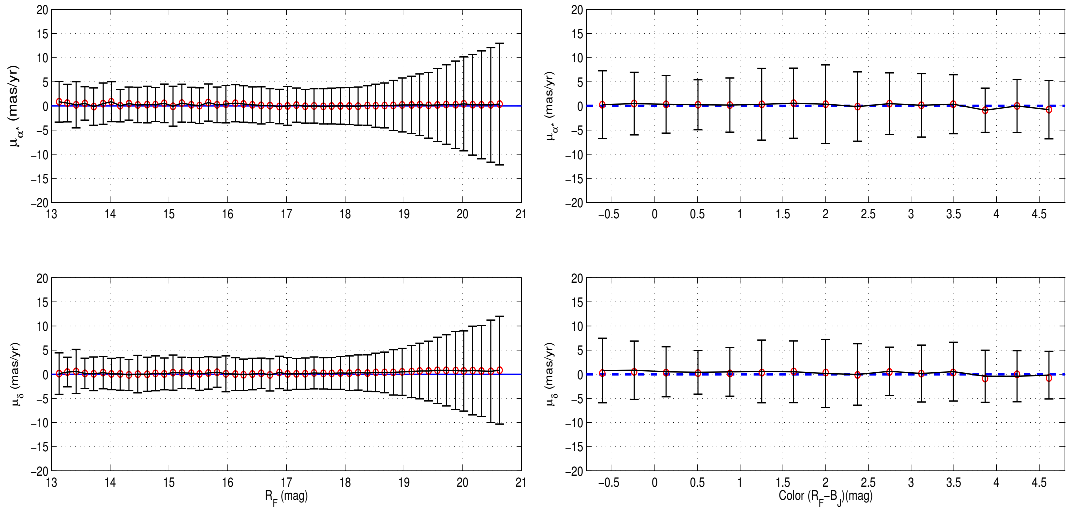

Figure 1: Distribution of computed proper motions ($\mu_{\alpha*}, \mu_\delta$) for the 376,490 GIQC QSOs matched with Schmidt plate data. Red circles are averages over the corresponding bin of magnitudes (left panels) and colours (right panels), with vertical bars indicating the dispersion around mean values

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Publishing Scanned Plates Using DaCHS

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Abstract

Scanning plates is only the first step in preserving photographic plates. Publishing the scans is just as important. A comparatively easy way for proper, VO-compliant publication of a digitized plate archive is GAVO's Data Center Helper Suite (DaCHS). It implements all relevant VO protocols, in particular the Simple Image Access Protocol (SIAP), the Table Access Protocol (TAP), and the Observation Core data model.

Using the example of the Heidelberg Königstuhl Archives, we illustrate the publication of a large data set to the Virtual Observatory and the web with DaCHS and show how easily our software can be installed and used by other data providers to archive and publish their data collections.

Keywords: Astronomical databases, Digital plate archive, Astrometry, Virtual Observatory

1 Introduction

Since 2005, in cooperation with the German Astrophysical Virtual Observatory (GAVO), the unique collection of the Heidelberg Königstuhl Archives that encompasses more than 25,000 photographic plates dating from the late 19th century to our days has been digitized with funding provided by the Klaus Tschira Foundation.

The preservation of our photographic archives may be considered a two-step process. While the scanning of the plates ensures preservation of information despite ongoing oxidative deterioration of the photo emulsions, the subsequent archiving of the plate data in the GAVO Data Center [1] and its publication to the Virtual Observatory (VO) and the web ensure the persistence of the archives and the standardized access to them.

Data published following VO standards can be discovered by in-client standard interfaces, can be used with standard clients and without being forced to learn how to operate custom web services, and has standard metadata helping later scientific exploitation.

This contribution introduces the central components of the Data Center Helper Suite (DaCHS) and illustrates – by using the example of the Heidelberg Königstuhl archives – how this piece of software can help data providers to publish their data sets in a VO-compliant manner.

2 The DaCHS Multi-Protocol VO Server

In the course of the development of the Virtual Observatory, several key technologies have been defined aiding the dissemination of scanned plates, including the Simple Image Access Protocol (SIAP) [2] that allows image discoveries based on spatial (and serveral other) constraints, and the Table Access Protocol (TAP) [3], a service protocol for accessing general table data. For observational data, TAP is combined with a data model describing generic observations called ObsCore, yielding a powerful system letting users formulate very expressive search constraints and execute them on all compliant systems with one operation. The combination of TAP and ObsCore is referred to as ObsTAP [4].

Moreover, as a crucial part of the publication infrastructure DaCHS' ingestion component is equipped with a great number of different grammar modules ready to parse FITS images and VOTables, different types of text files and many other sources.

Finally, DaCHS contains the Stan templating system of Python's web development framework Nevow [5] allowing for the publication of HTML form-based services and documentation pages.

2.1 Resource Descriptor

The central concept of DaCHS' publication infrastructure is an XML file referred to as a Resource Descriptor (RD). Typically, all information on a data collection and the related services is collected in a single RD which imports procedures, informational and administrative web pages, and generates the actual services together with their metadata documents.

3 Steps to Publishing a Scanned Plate Archive

As a fairly typical example of a scanning project, we take the Heidelberg Königstuhl archives to illustrate the individual steps to take to get a data collection published. The finished service is called HDAP (Heidelberg Digitized Astronomical Plates).

3.1 Installing DaCHS

The preferred way to run DaCHS is on Debian or compatible systems on which the software can be easily installed from an APT repository. To use GAVO's repository, the line

```
deb http://vo.ari.uni-heidelberg.de/debian stable main
```

has to be added to the file */etc/apt/sources.list*. After updating the package cache, e.g., on the command-line via `sudo apt-get update`, DaCHS can be installed by saying `sudo apt-get install gavodachs`. All the package dependencies will be handled in an automatic way.

3.2 Metadata Handling

Our starting point is defined by a set of digitized photographic plates stored in the commonly used FITS (Flexible Image Transport System) format with minimal headers (basically, NAXISn and BITPIX).

The observation journals are digitized into a plate database containing, e.g., the observer, the observation time and so on. Additional metadata, in particular information about the instrument at which the image was taken or the photo emulsion used, are inferred based on the plate identifier. This metadata set is supplemented by the astrometric plate solution as obtained by the program SExtractor [6] that writes the objects found on a photo plate in (x, y) to a catalogue, and by the Astrometry.net tool [7] which tries to do the assignment $(x, y) \to (\alpha, \delta)$.

This process is governed by about 500 lines of python building on the processing subsystem of DaCHS, which includes code for traversing the source collection, maintaining state, and manipulating FITS headers. Most of the custom code is encoding rules for handling metadata inference for the ten different instruments that went into HDAP.

3.3 Writing an RD

In DaCHS, publishing a data collection to one or several VO protocols or a web page means writing a Resource Descriptor. In the following, we give excerpts that contain the principal elements of the HDAP Resource Descriptor. A more detailed explanation how to write such an XML file can be found in [8].

An RD starts with the root element `<resource>` followed by some pieces of meta information on the data collection, here:

```
<resource resdir="lswscans" schema="lsw">
    <meta name="creationDate">2007-11-10T12:00:00Z</meta>
    <meta name="description">Scans of plates obtained at Landessternwarte
        Heidelberg-Königstuhl, its predecessors, as well as the
        German-Spanish Astronomical Center (Calar  Alto Observatory), Spain,
        1880 through 1999.</meta>
    <meta name="title">HDAP -- Heidelberg Digitized Astronomical Plates</meta>
```

```
    ...
</resource>
```

Declaring metadata is essential for later registration of services and data. Furthermore, it is also required to generate informational pages.

Conventionally, the next items in the RD are the table definitions:

```
<table id="plates" onDisk="True" adql="True" mixin="//siap#pgs">
    <mixin collectionName="'HDAP'"
        targetName="object"
        expTime="exposure"
        tMin="(to_char(startTime, 'J')::double precision-2400000.5)"
        tMax="(to_char(endTime, 'J')::double precision-2400000.5)"
    >//obscore#publishSIAP</mixin>
    <column name="exposure"
        tablehead="Exp. time" unit="s" ucd="time.duration;obs.exposure"
        description="Effective exposure time" verbLevel="15"/>
    ...
</table>
```

The `<column>` elements set the fields of the database table. A more complicated feature are the `<mixin>` elements, a technique used by DaCHS to ensure a certain functionality on a table. In this case, there are two mixins, the first one to support the requirements for an SIAP service, the second one to endow the table with everything needed for ObsTAP. While SIAP allows to search HDAP for images matching a certain region of the sky, ObsTAP also enables a user to browse the archive for uncalibrated plates or non-stationary objects like comets.

The ingestion component of DaCHS is controlled using data elements:

```
<data id="import" updating="True">
    <sources recurse="True">
        <pattern>data/part1/*.fits</pattern>
        <pattern>data/part2/*.fits</pattern>
    </sources>
    <fitsProdGrammar qnd="True" id="impGrammar">
        ...
    </fitsProdGrammar>
    <make table="plates" rowmaker="make_plates"/>
</data>
```

The input data sets are declared within the `<sources>` elements. The grammar chosen here returns FITS headers as dictionaries, i.e., a sequence of string-to-string mappings. These are then turned into proper database rows in `<rowmaker>` elements.

Finally, our RD has to define the services exposing the data:

```
<service id="siap" core="qhsiap" allowed="siap.xml">
    <publish render="siap.xml" sets="ivo_managed"/>
    <publish render="form" sets="ivo_managed" service="q"/>
    <meta name="shortName">hdap_siap</meta>
    ...
</service>
```

A service is a combination of a core, the element which performs the actual computations for the service, and one or more renderers setting the interface, in this case a web form or an SIAP interface. Service-specific metadata may override any piece of global metadata given in the beginning of the Resource Descriptor.

3.4 Data Access

In addition to the VO protocols, HDAP is also available through two form-based web services, also driven by DaCHS. While[9] allows for retrieving images based on positions and thus can only be used to find astrometrically calibrated plates, [10] also gives access to uncalibrated images and is the appropriate tool for object name-based searches.

The popular Virtual Observatory application TOPCAT [11] has both a built-in SIAP and a TAP client. Our archives can be accessed via SIAP by the URL

```
http://dc.zah.uni-heidelberg.de/lswscans/res/positions/siap/siap.xml?
```

and by TAP giving the URL

```
http://dc.zah.uni-heidelberg.de/tap
```

to TOPCAT's TAP client. The table name is `lsw.plates`.

Like any tool speaking SIAP, Aladin 12 can be used to visualize the Königstuhl archives. Catalog data or images from other sources can be overlaid on the photographic plates endowed with an astrometric calibration.

4 Conclusion

DaCHS is in operation in various data centers all over the world, with services serving everything from giga-record-size catalogs to collections of historical astrophotographic plates. Due to its easy installability and its powerful publication infrastructure supporting to Virtual Observatory standards, DaCHS provides a reasonably smooth path for publishing scanned plates. Technical support for doing so is – within reasonable limits – available from the authors.

5 Acknowledgements

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Preservation of Polish astronomical plates - digitization, callibration, publishing

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Streszczenie

There are large reserves of different astronomical plates in Poland. We plan to digitize them, convert to FITS format, supply with metadata and calibrate with positioning software providing a coordinate grid. Then the digitized data will be published as the part of the project of Virtual Observatory for the wider astronomical community.

Keywords: astronomical plates, astronomical data, archives, digitalization

1 Introduction

Polish archives of old astronomical data are composed of a wide variety of data carriers, including photographic plates of different sizes, magnetic tapes, DDS tapes with radio observations, and drives with data from photoelectric photometer, X-ray spectra of the Sun and sun-like stars, particle simulations (Geant4) and hydrodynamic modeling. Large archives of astronomical plates are situated in: Astronomical Observatory of the Jagiellonian University in Cracow, Nicolaus Copernicus University in Toruń, Adam Mickiewicz Universiy in Poznań, and Nicolaus Copernicus Astronomical Center in Warsaw.

The main goal of this work is to complete and publish a complete digitized archive of Polish astronomical plates. The scientific motivation includes possible comparison of old and new astronomical data based on these plates, their use in some projects requiring long-term observations, as well as searches for variable and transient events. Digitized plates can be also used for teaching. Finally, the archives should also be preserved due to their historical value. This work is partially funded by PLGrid Plus project (*Domain-oriented services and resources of the Polish Infrastructure for Supporting Computational Science in the European Research Space – PLGrid Plus*)[1].

In this paper we report only on the plate archive located in Cracow and we describe the development of preliminary procedures of its preservation, digitalization and providing to the astronomical society.

2 Data overview

Astronomical Observatory of Jagiellonian University in Cracow owns a collection of a few thousand astronomical photographic plates made using the Maksutov 30 cm telescope, the Cassegrain 50 cm telescope, and an astrograph between 1960 – 1980. It is estimated that originally about 4 000 plates were made with the Maksutov and Cassegrain telescopes, however only about 1 200 so-called "small" (6 × 9 cm) plates have been preserved to this day. There are also about 400 13 × 18 cm plates taken with the astrograph. The degradation of these archives is progressing very quickly and there is an urgent need to perform their digitization. This operation is currently in progress and initial, simple scanning of the entire collection was completed in 2013.

The astronomical plates archive of the Jagiellonian University preserves both direct imaging plates and spectra. The main targets are variable star, quasars and comets. The original observing logs for these plates are also available, but they are handwritten so it is not possible to run automatic text reading using an OCR program, and for this reason there is a necessity to scan and preserve the logs individually. In many cases the object names have to be read directly from the plate because there is no log entry at all, or the plate box/envelope is not labeled correctly.

The plates are very often damaged due to deterioration of the emulsion, including yellowing of the photosensitive material, glass corrosion, mechanical wiping, scratches or cracks. Only about 80% of the archive comprises well-preserved, valuable astronomical data.

Rysunek 1: Example of good-preserved 6 × 9 cm astro plate from Cracow archive.

3 Digitalization

3.1 Scanning

We developed algorithms[1] for scanning astronomical plates using an Epson 10000 XL Scanner with special adapter for scanning transparent materials. The same method had been applied to small and medium photographic images. Both 6 × 9 cm and 13 × 18 cm plates easily fit on the scanner working plate. Due to the large resulting files every plate is scanned individually.

In the first approach, the plates were scanned once and only after pre-vacuuming. Only when the initial scans are performed and available, more sophisticated cleaning will be performed, including removal of the observers tags. After this the plates will be also scanned again in two perpendicular directions. To avoid underexposure of images or damage of the emulsion layer we assumed that the plates should be placed on the scanner with the emulsion facing the photosensitive element (uppermost in the case of the Epson 10000 XL).

Each time before performing the proper scan it was necessary to focus the scanner manually. Suitable focusing is crucial to preserve the quality of image obtained during scanning, and because final digitization is supposed to be done only once, any errors or inaccuracies committed in this process cannot be repaired. It was found that the optimal focusing in the case of most plates is from the range of 0.7 to 1.4. Additionally, plates are based on thick or thin glass. Experimentally determined amplitude of the focusing between different thicknesses closes in 0.3. In the case of 13×18 cm plates we also specified the levels of brightness. The brightness thresholds were manually determined after focusing the scanner and before each proper scan, based on the preview image.

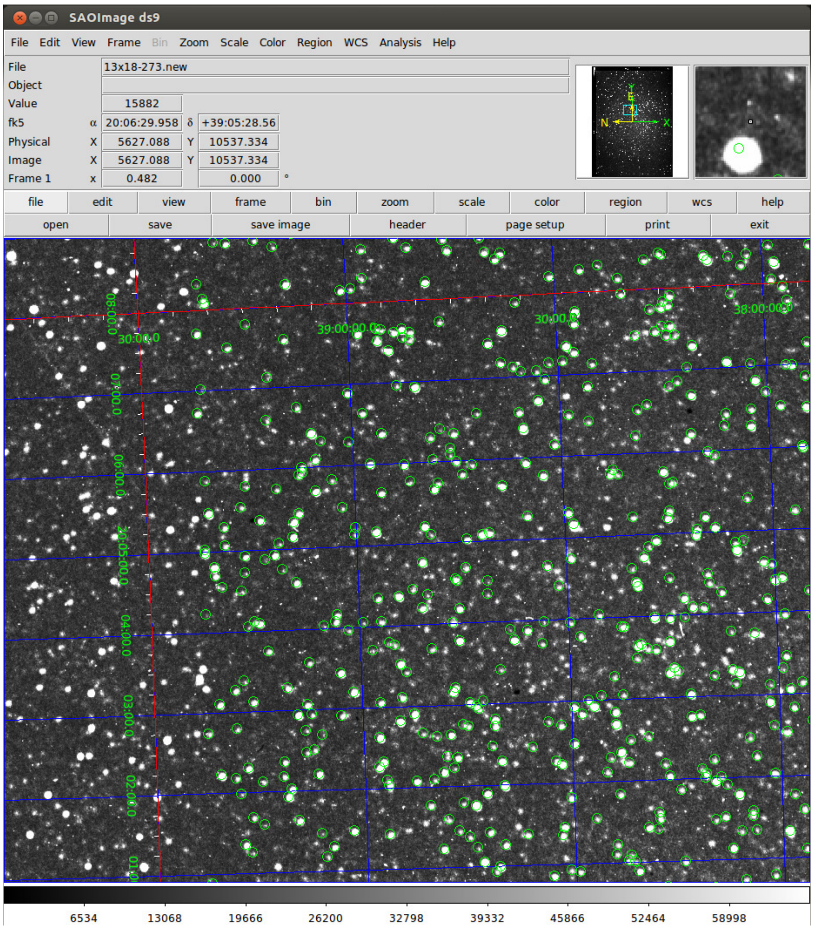
The total scan results includes 379 scanned 13×18 cm plates (149 GB of disk space) and scanned 1166 6 × 9 cm plates (118 GB). Due to the long time needed to scan one plate (15-20 minutes), so far we were able to scan plates in one direction only and without pre-cleaning. However, even these first scans will preserve data in the case of plate damage.

3.2 Calibration

Data in digital form should be calibrated astrometrically and, if available, also photometrically. Astrometric calibration consists in determining the coordinates of the sky covered by the image on the plate in the equatorial system, the scale of the digitized image in arcseconds per pixel, and the parameters defining the field curvature resulting from the projection of the celestial sphere on a flat plate by an optical telescope. Photometric calibration is the designation of the transformation between the brightness of the stars in the image (manifested as shades of gray or in the form of the size of the star image – on photographic emulsion a brighter star creates a larger image).

For the astrometric calibration we use astrometry.net v. 0.46 software[7]. Astrometry.net is a project that aims to provide an open source Astrometry calibration astronomical images of all kinds regardless of the scale, the type or the quality. Apart from the project PLGrid Plus, astrometry.net is also used by the plate digitization project of the Harvard Observatory, DASCH. The basis of astrometric calibration is automatic identification of objects (most often: stars) on the plate. This is done by (a) finding the position of the stars in the image, then (b) determination of a triangle mesh between these items and (c) comparing the grid with catalogs of stars. Triangle mesh is used because of the fact that the relative angles and lengths of the sides are independent of the scale.

Preliminary photometry of objects imaged on the plate is performed by using the Source Extractor[4], which identify objects using an algorithm based on a simulated neural network. After finding the object program also performs photometry and print catalog.



Rysunek 2: Digitized plate supplied with coordinate grid.

3.3 Supplying with metadata

Our recommended workflow is composed of image conversion from TIFF[3] to the FITS format[2], supplying FITS headers with metadata, source extraction from digitized plates and astrometric and photometric calibration. FITS is the standard astronomical format for storing images, and after the pre-treatment the scans should be converted to this format. For this purpose we use public programs such as Fits Viewer. FITS format allows also for recording additional information in the headers. The typical entries for optical data are:

- The name of the object (keyword: OBJECT);
- Date of observation (keyword: DATE-OBS);
- Start time of the observation (keyword: TIME-OBS);
- End time of observation (keyword: TIME-END);
- The name of the telescope (keyword: TELESCOPE);
- The name of the observer (keyword: OBSERVER);
- Comments of the observer (keyword: COMMENT);
- All the information available for the plate in the daily observation log.

The first aim of the procedures (or automatic system) preparing digitized plates for publication in the Virtual Observatory should be compiling the obtained scans and their additional information (from the logs) into stand-alone FITS files containing all relevant metadata, comments, and other related data. This type of file can then be easily published using the existing tools of the Virtual Observatory.

4 Publishing

The International Virtual Observatory Alliance define the standards for the framework called the Virtual Observatory (VO)[6]. Publication of digitized scans in the VO requires their conversion into electronic form, describing their respective metadata, introducing them to the database description (register), and making available the digitized images by appropriate protocols of the Virtual Observatory such as Cone Search or VOQuery.

To satisfy this recommendation we developed special tools for quick calibration of scanned data and their transfer to the VO servers, handled by scripts run from the command line in Linux shell. For the final version we plan the implementation of the graphical tools for automatic preparation of FITS files that can be edited in order to supply them with the header metadata. The best solution may be a web appliation providing to the user a form for retrieving the necessary data, enabling the transfer of scans as TIFF files, and performing the appropriate operations on these files by calling suitable existing tools like SExtractor, Wcstools[5] or IRAF.

5 Summary

In this paper we reported on investigation in the plate archives preserved in Astronomical Observatory of Jagiellonian University in Cracow, Poland. The primary, test scanning had been performed and we presented the procedure of digitizing and further calibration of the plates, as well as their conversion to the astronomical FITS format. We also recognized several problems and additional questions.

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Building up APPLAUSE:
Digitization and web presentation of
Hamburger Sternwarte plate archives

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Abstract

Photographic plates have been digitized at Hamburger Sternwarte already since the 1980's using a PDS machine. A new digitization project was started to make most of the 35000 plates observed in 85 years accessible for everyone, but particularly for modern computer based research. A dedicated web site with an integrated search engine was developed to bring together all accessible information for each plate. To date, the data base contains scans from about 22000 plates and related hand written material. A tight cooperation with Potsdam and Bamberg observatories aims at a combined data base called APPLAUSE which will comprise about 80000 astronomical photographic plates accessible by virtual observatory tools.

Keywords: Digitization of heritage, research options, web presentation.

Introduction

Hamburger Sternwarte in Bergedorf was built between 1906 and 1912. Beside dome buildings with new telescopes and offices, also apartment buildings for resident astronomers were constructed. Beside others, three new telescopes were erected. They were designed, both, for object discoveries and for astrophysical research and are therefore equipped with objective prisms and filters. A 60 cm refractor-telescope, a 1m mirror-telescope, at that time the 4th largest telescope in the world, and a “three astrographs on one mounting”- telescope, one of them designed as a 'Carte du Ciel'-telescope. The approximately 35000 photographic plates of Hamburger Sternwarte plate archives exposed in approximately 85 years of observations are not only a treasure for astronomical research but also a cultural heritage as they reflect the development of astronomical instruments and observation technique in the 20th century. In 2010 a pilot project was started to explore if a complete digitization and Internet publication deems possible. In December 2011, 100 years after the exposure of the first plate, already 3700 plates were scanned and a new web site which gives access to the data was presented to the public. In the same year the cooperation with Bamberg and

Potsdam observatories was started. In 2013 Hamburg proposed Hamburger Sternwarte as world heritage candidate.

1.1 Plate archives

The plate archives comprise not only astronomical plates but also photographic plates documenting the construction of Hamburger Sternwarte and people living and working there. Additionally, large amounts of hand written material as log books and observer notes still exist. Together with the astronomical plates they document the development of modern astrophysics from observations of minor planets and comets to the exploration of extragalactic objects. Beside large sky survey projects as the Bergedorfer Durchmusterung, the AGK-projects and the Quasar-surveys (HQS and HES), plates were taken for experiments with emulsions or instrumentation, and observations of newly detected unknown objects. The latest observations on photographic plates were made at the end of the last century using the Hamburger Schmidt-Spiegel (former Großer Schmidt-Spiegel of Hamburger Sternwarte) now at Calar Alto Observatory in Spain. Only plates taken after 1980, so far, had been digitized completely using a PDS machine. Together with the hand written material the plate archives are also a treasure chest for historians.

1.2 Digitization project

In January 2010 a pilot project was started to explore if a complete digitization of all plates will be possible. The degradation of plate emulsions with time and the steeply decreasing number of astronomers who worked with such plates, on one hand, and the fast increase of storage capacity, computer memory, and Internet band width plus the availability of fast scanners, on the other hand, gave the impression that the time now was ripe for such a project. First estimations yield about 15 men years of plate scan time for a complete digitization but with more scanners and people serving them, the project should be feasible in a couple of years. In 2011 the Deutsche Forschungsgemeinschaft issued a call for proposals concerning digitization projects. The application by Potsdam, Bamberg and Hamburg observatories was successful and thanks to funding by the DFG about two thirds of the Hamburg project could be finished already.

1.3 Scanning process

The plates, envelopes and books are scanned using Epson Expression 10000 XL scanners which are about 75 times faster than the PDS-machine, which was state of the art in the 1980s. The loss in image quality, compared to the PDS-machine, seems acceptable (Dmax=3.8, pixelsize ~ 10.8 μ). A larger problem is the loss in accuracy concerning stellar positions along the scan direction (a common problem of all flat bed scanners). Two high resolution scans are made, one with the plate rotated by 90°, to overcome this problem. The hand written material is scanned at 150 dpi (JPEG), while the plates are scanned at 300 dpi (JPEG) for an overview scan (in case there are marks on the glass side) before plates are cleaned and scanned at high resolution at 2400 dpi (16 bit PNG).

1.4 Data processing

The large amount of data (~25 TB for the Hamburg plates) and the large amount of data sets (4 to 20 belonging to one plate) make an automatic processing essential. At night scripts are started which search for newly scanned files, converting them to the final file format. For all high resolution scans FITS-format is used while all other scans are stored in JPEG-format. As a last step the new files will be copied to the storage device, a 32 TB RAID6-system. In the following night these data are additionally transferred to the tape robot in the 20 km distant University, where they are kept as a backup. Scripts identifying all scanned images belonging to a single plate, select the pages of the observer notes, written during the observation night, the logbook entry, the envelope scan and the overview plate image to form a HTML-web-page with the appropriate links. Additionally, these data are entries of a SQL-database which can be used with search function tools and in combination with a book reader. The search engine offers filtering, using the meta-data. It is e.g. possible to extract all plates exposed with a certain emulsion and/or filter, with exposure times larger than a given value, and other ex- or inclusions as objective prism or multi exposure plates.

1.5 Accessibility

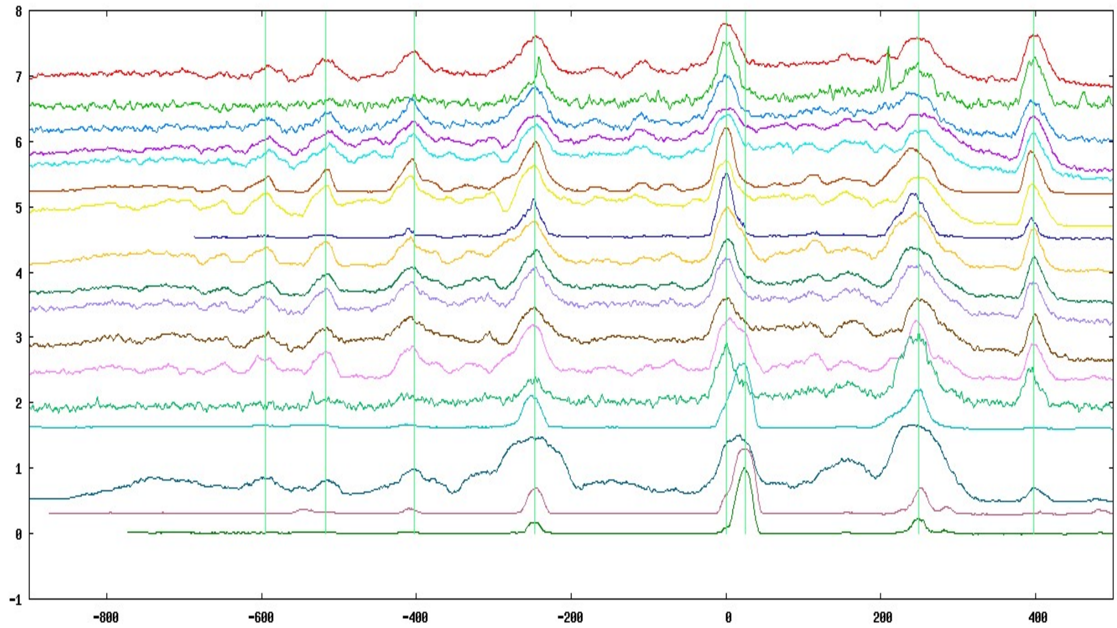
All data are immediately available the next day and can be accessed free for all non-commercial use(open access). The meta-data are displayed together with all low resolution images on a single web page and the link to the book reader opens the possibility to inspect the observer notes around the observation and the days before and after it. All functions are optimized to serve researchers as well as historians, amateur astronomers, pupils or other interested people. On all web pages there are links leading to the high resolution scans with sizes up to 1.5 GB for a 30x30 [cm] plate.

The plate archives can be accessed following the link http://plate-archive.hs.uni-hamburg.de .

1.6 Status of the project

The oldest plates for each telescope were scanned first, and about 22 000 plates are already scanned and available through the web site. Additionally, this database will be part of a common database of the three observatories called **APPLAUSE** (**A**rchive of **P**hotographic **PL**ates for **A**stronomical **USE**) which will be maintained at the AIP in Potsdam and which should contain about 85 000 digitized photographic plates. The implementation into GAVO, the German virtual observatory project, will simplify the use, as standard search tools will list e.g. all plates on which a given object can be found.

1.7 Research perspectives



To use the database scientifically it will be necessary to do a brightness calibration and to convert object positions into sky coordinates precisely. First results and the reachable accuracy are already given by U. Heber and T. Tuvikene (these proceedings). Beside the search for variable objects or proper motions, the information from objective prism plates can also be of interest. As an example the diagram shows the consecutive normalized emission line spectra of the expanding shell of Nova Gem 1912 in a time span of 12 months (x-axis in Pixels, blue left hand side). In 1912 the origin of a nova (nuclear explosion on the surface of a white dwarf in a binary system with Roche lobe overflow from the primary star) was still unknown. On one of the first exposed plates the spectrum was compared to the spectrum of a bright cool star, exposed twice near to the nova spectrum, but from then on it was compared with an absorption line spectrum of a bright hot star showing the Balmer line series, which is well comparable to the Balmer emission line spectrum of the shell. The shell spectra (from top to bottom) display the evolution of the expanding shell. Interesting e.g. is the sudden reappearance (third spectrum from bottom) of the at that time much broader Balmer lines, pointing to a new heating process in the already distant shell. Today such spectra can be modeled and a comparison with theoretic calculations seems possible.

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Kyiv UkrVO glass archives: new life

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Abstract

In the framework of UkrVO national project the new methods of plate digital image processing are developed. The photographic material of the UkrVO Joint Digital Archive (JDA) is used for the solution of classic astrometric problem - positional and photometric determinations of objects registered on the plates. The results of tested methods show that the positional rms errors are better than ±150 mas for both coordinates and photometric ones are better than $\pm 0.20^m$ with the Tycho-2 catalogue as reference.

Keywords: UkrVO, JDA, LINUX-MIDAS-ROMAFOT

Introduction

The national project of the Ukrainian Virtual Observatory (UkrVO) has breathed new life into the old observational archives. The Joint Digital Archive (JDA) of photographic observations has become the core of the UkrVO. JDA includes observational archives of five Ukrainian observatories covered the period of around 100 years (http://gua.db.ukr-vo.org/archivespecial.php) [1-5]. The great part of JDA (about 70%) embraces archives of two Kyiv observatories: MAO NAS of Ukraine and AO of Kyiv national university. In the UkrVO framework, the digitizing of glass collections has started. To the moment JDA controls 50 Kyiv observational archives with 40 thousand of metadata records and near 14 thousand of digital images. The JDA is supplemented by 14.5 thousand digital images of observational logging records, identified with 23 thousand photographic plates, included into the database, as well as about 6 thousand arrays of coordinates and photometric data of objects, registered on the plates and derived in pre-processing procedures.

In addition to the direct images the photographic archive of MAO NASU contains about 50 thousand photographic plates with spectra. This archive includes the material of a large number of observational projects and can be partly classified and digitized. We started the process of digitizing some collections of spectra, which are well documented and can be included into the spectral library (UkrVO SDL, http://ukr-vo.org/spectra).

Astrometric solutions with the Joint Digital Archive.

Plate digitizing is carried out using a flatbed scanner EpsonExpression 10000XL with 16-bit gray levels, resolution of 1200-1600 dpi. Digitized images are stored in TIFF and FITS formats. The results of digitizing are used in the next research directions: - enrichment of FONAK astrometric catalog (the photographic review of the northern sky) with data of objects, registered on the digitized images down to 16 magnitude (B band) [6]; search of optical analogs of GRB and creation of catalogs of objects in the areas around GRBs; creation of astrometric catalogs of coordinates of Pluto and outer faint satellites of Jupiter and Saturn; elaboration of proper methods of treatment and obtaining of astrometric coordinates for "moving" objects - asteroids, comets – by digitized images. The astrometric and photometric calibration procedures were developed on the basis of LINUX-MIDAS-ROMAFOT software [7, 8]. These applications previously were oriented to processing of plates with the point images of objects and lately were modified in order to process images with tracks of moving objects such as external satellites of Jupiter and Saturn, minor planets and comets. The improvements concern the derivation of topocentric coordinates, their correction for scanner instrumental errors and the specific form of object image (Fig.1) and application of different models for the final reduction in the Tycho-2 frame as reference. The comparison of obtained positions with ephemerides was made using Natural Satellites Ephemeride (IMCCE.Paris): http://www.imcce.fr/langues/en/ephemerides/.

1.1 The catalogs of objects in the areas around GRBs.

The results of continuous GRB observations onboard spacecrafts are published in GCN Circulars and handed over to observatories for investigation of any objects in the sky areas around the GRB. The last task in addition can be solved using data of JDA. Objects, which potentially could appear on archive plates were selected in GCN Circulars published data. The positional accuracy of selected objects is between ±0.3 as and ±7.0 as and the range of magnitudes is 14^m-19^m. GRB and all the objects are sought and identified on the digitized within the circle with the radius of dozens of arcminutes. Up to date the analysis of coordinates for 108 GRB, taken place in 2003, 2009 – 2013, has been carried out. The bright objects with coordinates different from those of given to GRB but absent in vast stellar catalogues where found in several areas. Studying of these objects is going on with attraction of another observational facility. The data of 25 areas are published in GCN Circulars (№ 2170, 11385, 11393, 11435, 11596, 11751, 11832, 12113, 12306, 12586, 12680, 12786 - 12808, 12827, 12875, 12906, 12918, 12919, 12979, 12987, 13014, 13063, 13066, 13086). Faint objects were found in the vicinity of two GRB non-identified by the program by their positional data [9]. We obtain catalogues of stars in the vicinity of GRB110213A (4am x 4am) and GRB101224A (10am x 10am). Catalogues are available on the web site of MAO NASU.

1.2 The positional accuracy of minor planets determinations.

The methods of minor planets search has been discussed previously [10]. We found the plate GUA040C002088 with possible image of Potentially Hazardous Asteroids 4179 Toutatis and also possible images eight asteroids from Main Belt. Next step of our work was the derivation of minor planet topocentric coordinates for the moments of middle of second exposure. Figure 1 shows the trend of systematic differences between measured and catalog coordinates for right ascensions and declinations the correction for the instrumental errors of the scanner (left) and the trend of random differences after the correction for instrumental errors of the scanner (right). Differences in arcsec on 1a), 1b), 1d) and 1e) panels are given vs pixel coordinate axes of images X,Y and on 1c) and 1f) panels vs B-magnitudes of Tycho-2. The rms unit errors $\Delta\alpha$, $\Delta\delta$ decrease from σ=0,306″ to σ=0,104″ and from σ=1,928″ to σ=0,113″ correspondingly after the scanner errors removing. N on 1a) - reference stars of Tycho-2. The top ticks on 1a), 1e) panels fix the positions of minor planets on the plate; numbers are given according the MP column in Tab.1. Table 2 gives the calculated B magnitudes in Tycho-2 photometric system with the above said residuals $(O\text{-}C)_\alpha$ and $(O\text{-}C)_\delta$ [11].

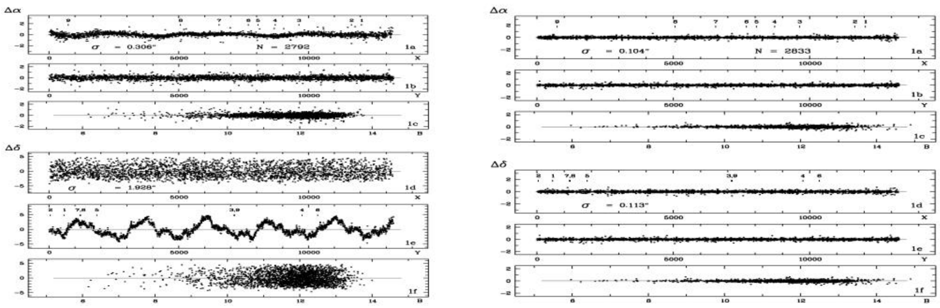

Fig. 1: The trend of systematic differences between the measured values and catalog coordinates of stars before (left) end after (right) the correction for the instrumental errors of the scanner

Table2: Calculated B-magnitudes and residuals $(O\text{-}C)_\alpha$, $(O\text{-}C)_\delta$ for minor planets.

Name	V_{JPL}	R.A.(J2000)DEC $_{JPL}$	B	$(O\text{-}C)_\alpha$, $(O\text{-}C)_\delta$.
1 2854 Rawson	15.55	$08^h02^m18.739^s$ +19°40′22.168″	-	-
2 4179 Toutatis	13.21	08 03 15.448 +19 59 30.590	13.58	$+0.050^s$ +1.150″
3 1401 Lavonne	15.31	08 08 27.771 +15 45 36.553	16.46	+0.064 +0.144
4 232 Russia	13.31	08 10 44.601 +14 12 10.399	13.60	-0.030 +0.374
5 1689 Floris-Jan	14.66	08 12 24.308 +18 56 10.082	14.86	-0.042 +0.629
6 1249 Rutherfordia	13.66	08 13 17.978 +13 50 38.643	13.83	-0.079 +1.306
7 1457 Ankara	14.40	08 16 12.243 +19 18 47.036	14.61	-0.032 +0.868
8 21023 1989 DK	15.45	08 19 50.967 +19 17 03.600	-	-
9 807 Ceraskia	14.55	08 30 33.604 +15 42 12.304	14.95	+0.127 -0.510

1.3 Astrometric solutions for Jupiter and Saturn satellites.

The image processing was made for the set of digital images of plates with Saturn satellites (S4-S8) and external satellites of Jupiter (J6-J7) [12].

Table 3: The comparison of obtained positions with the ephemerides in IMCCE.

Name	Instrument	mg	N	$(O\text{-}C)_{\alpha}$,″	$(O\text{-}C)_{\delta}$,″	RMS_{α},″	RMS_{δ},″
Dione S4	DLA	10.4	28	-0.12	-0.07	0.36	0.26
Rhea S5	DLA	9.7	40	0.02	-0.03	0.31	0.27
Titan S6	DLA	8.4	35	-0.01	-0.12	0.29	0.29
Japetus S8	DLA	10.2-11.9	40	0.06	0.03	0.28	0.33
Himalia J6	DWA	~14.8	5	0.11	-0.26	0.54	0.35
Himalia J6	Z600	~14.8	6	0.22	0.09	0.36	0.53
Elara J7	Z600	~17.1	2	1.42	-0.24	1.45	0.86
Himalia J6	DAZ	~14.8	2	0.48	0.23	0.52	0.24

Table 3 contains photographic stellar magnitudes of satellites averaged over the number of images, mean values of (O-C) in arcsec for both coordinates and their rms errors. Data are grouped by specific instruments.

1.4 Catalogues of Pluto astrometric data.

Kyiv archives in JDA contain 67 digital images of plates with Pluto related to 1961-1990 years of observations. The main goals of their treatment were to determine whether the better positional accuracy could be achieved with those photographic materials due to new methodic of image processing and could the scanned images in general be used for the astrometric solutions with the high positional accuracy in applications for moving objects. The part of plate set was earlier used for positional determinations and the compilation of the Pluto positional catalogue. Using the current results we obtain the joint catalog of Pluto positions. For current data rms errors of unit weight are 2 to 3 times better than that of classic methodic [13, 14].

The comparison of results for plates of different linear dimensions (13x13 cm to 30x30 cm), scales (38 to 103 ″/mm) and expositions (5 to 60 minutes of time) permits to obtain the reliable material concerning the regularity of (O-C) in the system of planet coordinates in relation to appropriate values of different ephemerides in the specified time period. Digital images of plates and state-of-art stellar catalogues allow to improve the accuracy of positional determinations, use the earlier unusable photographic material for the enhancement of observational series with reliable results and to involve more faint stars omitted previously into the processing of plates.

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Present status of the "Carte du Ciel" and "Astrographic Catalogue" glass plates of the Real Instituto y Observatorio de la Armada

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Abstract

The Real Instituto y Observatorio de la Armada of Spain (ROA) was one of the 18 observatories that have collaborated in the observations and calculus to elaborate the "Carte du Ciel" and the "Astrographic Catalogue". The ROA observe the zone from -3º to -9º in declination. Currently the complete collection of plates is stored in the ROA library in moderately good conditions. A few years ago a digitization of all the plates was carried out using a commercial flatbed scanner machine. Every plate was scanned in to positions rotated 90º in order to be able to remove the systematic errors introduced by the movement of the reading head of the scanner machine.

In this paper we present the status of the collections and the possibility to get copies of the plates in FITS format by means of a formal to the ROA.

Introduction

In 1887 admiral Mouchez director of the Paris Observatory organized the "International Congress Astrophotographic". Fifty six astronomers of all the world participated in the meeting and agreed to proceed to take photographic plates of the whole celestial sphere thrice, two to produce the "Carte du Ciel" with a limit magnitude of about 14.0 and another one to produce the "Astrographic Catalogue" reaching up to magnitude 11.0.

18 observatories spreaded over the world agreed to divide the celestial sphere in declination zones and to observe one zone each. These observatories were from north to south: Greenwich, Rome, Catania, Helsingfors, Potsdam, Oxford, Paris, Bordeaux, Toulouse, Alger, San Fernando, Tacubaya, Santiago, Cordoba, Perth, The Cape, Sidney and Melbourne [2].

The main object of the project of the "Carte du Ciel" was to get a photographic map of the whole celestial sphere with similar telescopes of 33cm of aperture and 343 cm of focal length, using glass plates. So the scale was 1 arcmin/mm. Each plate covers 2º x 2º of sky and its centre was separated 1º in right ascension and declination of the centre of the 4 plates surrounding it. This way, each sky region was photographed twice.

In order to get a correct identification of the stars and reject spurious spots, the plates with centre in odd degree declinations have three 30 minutes exposures with a small separation of 7" in order to get a equilateral triangle with the three exposures, the plates with centre in even degree declinations only have one exposure of 1 hour getting a limit magnitude of 14.5.

The plates for the "Astrographic Catalogue" were observed in a similar way to those of the "Carte du Ciel" but with exposures of 6 minutes for those with centre in even degree declination and three exposures of 6 minutes, 3 minutes and 20 seconds forming also a equilateral triangle for those plates with centre in odd degree declinations. The limit magnitude for the 6 minutes exposures was 11.

To to facilitate the measurement of the coordinates of the stars photocentre a grid of lines separated 5mm (5’) was superimposed to the plates before the developing [1].

Once developed the “Carte du Ciel” plates were enlarged to double size in a cliche and then copper printing plates were elaborated to produce the “Cartes du Ciel”.

The San Fernando Observatory observed the zone of declination -3º to -9º. A total of 1260 plates were exposed since 1892 to 1930 for every catalogue. The six volumes of the “Catálogo Astrofotográfico de San Fernando” with more than 400000 star positions were published between 1921 and 1929.

Present status of the San Fernando sets of plates

Currently the two set of plates are stored in the library of the observatory inside metal boxes. Each box contains 24 plates and they are stored in a wood cabinet with good air circulation in one of the north halls of the main building, provided with a dehumidifier machine, so there are not big seasonal temperature changes nor high humidity in the hall.

As well in the library are stored the six volumes of the “San Fernando Astrophotographic Catalogue” and the sets of the printed version of the all the zones of the “Carte du Ciel” pictures.

The copper printing plates used to print the “Carte du Ciel” catalogue of the San Fernando zone are also preserved in wood boxes at the ROA.

Digitization of the San Fernando sets of plates

During the years 2003 and 2004 the two sets of glass plates were digitized using a commercial scanner AGFA type DuoScan F40. This scanner has an optical resolution of 1200 x 2400 ppi, a dynamical range of 3.0 in density and a digital resolution of 16 bits. The reading head uses a trilinear CCD array of 10000 elements. The main performance of this scanner is its built-in scanning bed for transparencies which permits the images captured from to be scanned directly, not through a glass plate as used for opaque materials. We have used the maximum resolution of the scanner which give a scale of 0”.60 per pixel and an area of 13000 x 13000 pixels that covers 2º.3x2º.3, a little more that the 2ºx2º area of the plate.

Each plate was scanned twice, identified as A and B, with a rotation of 90º between both positions, in order to be available to remove the effect of the non uniform motion of the system drive of the scanner reading head and a systematic effect in the linear CCD array. This last effect is more or less regular, but the motion of the drive varies from one scan to another. The two images of every glass plate are recorded in standard FITS format in one CDRom.

Dr. Vicente [4] in her doctoral thesis and in two articles in A&A [4] y [5] showed that it is possible to get a precision in the measures of the star positions of 3 μm equivalent to 0”.20 based from the plates images with a software developed by her. This precision is similar to that of other measuring machines digitizing this kind of old plates. The software is based in comparisons of the stars coordinates measured in the two 90º rotated positions of each plate and also in the four overlapping plates and its corresponding rotated.

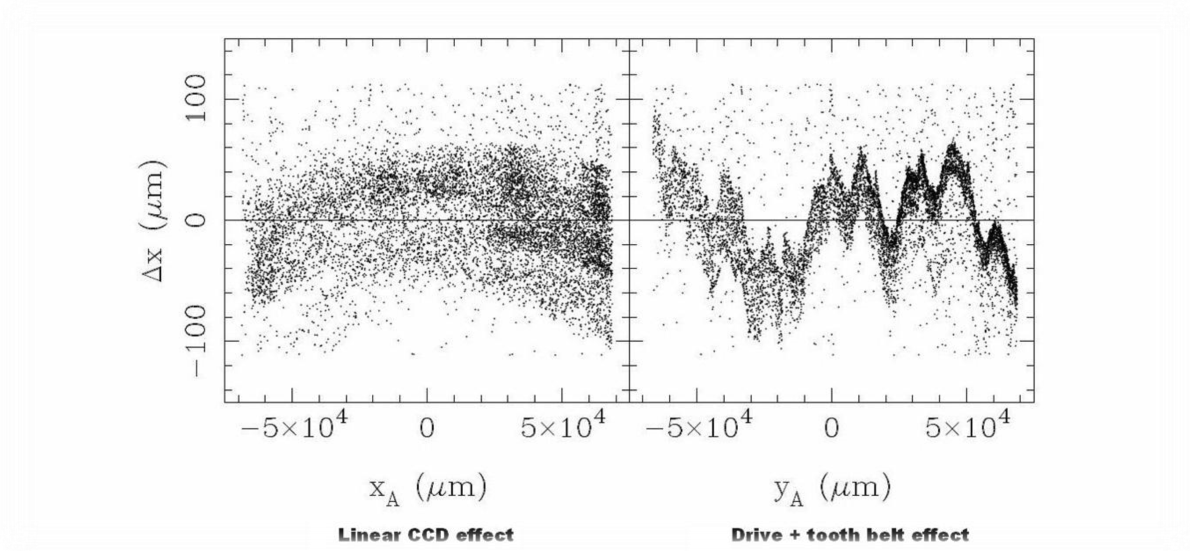

Figure1.- Typical systematic effects of the linear CCD (X) and the drive (Y) of the AGFA scanner (Figure by courtesy of Vicente et al.).

Conclusions

The ROA preserves the two set of 1260 glass plates corresponding to the “Carte du Ciel” and “Astrographic Catalogue” in moderately good conditions taking into account that the plates were exposed more than a century ago.

As well the ROA preserves the copies of the pictures in scale 2:1 of all the zones of the “Carte du Ciel” and the copper printing plates of the San Fernando zone.

In 2003 all the glass plates of the both sets were scanned twice with a commercial flatbed scanner in positions rotated 90º. The two scans of each plate were recorded in format FITS in one CDRom.

Using the convenient software it is possible to measure the positions of the stars with a precision of approximately 0”.2 from the FITS images of the CDRoms.

It is possible to get from the ROA copies of the CDRoms upon request.

At this moment the ROA projects to copy the two set of 1260 FITS images in one USB disk of 2 terabytes in order to preserve them in a more modern and quick accessible format.

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Alternative technique for astronomical plate scanning

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Abstract

Alternative plate scanning technique is described and compared to the other methods. The technique is fast and hence inexpensive still providing scientific grade results.

Keywords: astronomical photography, digitization

Introduction

In the years 2008 to 2012 we participated in the US-Czech collaborative AMVIS project with emphasis on analyses in US astronomical photographic glass plate archives. Very soon it became evident that there are very numerous and large photographic plate collections in the USA most of them with very high quality and scientifically valuable data, but at the same time, that there is lack on equipment for plate analyses including plate scanning devices.

This is why we have developed and tested the alternative plate scanning method based on transportable device. This device was then further improved and upgraded including special software for automated image treatment and lens distorsion correction etc. The astrometric and photometric accuracy of the method was tested and compared, where possible, with other plate scanning methods. Below we give a short description of the three plate scanning techniques recently in use for astronomical photographic archives.

Photographic plate scanning methods

The three basic plate scanning techniques are as follows.

1. Custom made high quality scanner, mostly with granite table. Preference: very high astrometric accuracy 0.1 microns or less, drawbacks: very expensive device, expensive operation, plate scanning cost 100 Euro per plate or more.

2. Commercial high quality flatbed scanner. Most used instrumentation in plate scanning. Moderately expensive investment and operation, one plate scan typically of order of 10 Euro. Usually good accuracy in one direction but worse in the direction of CCD line movement where typically waves are detectable.

3. High quality digital camera with homogeneous light table and high quality lens. Moderate expensive equipment but operation is extremely fast typically one plate just very few seconds and hence very inexpensive. Typical cost of digitization is just 0.5 Euro or even less. Suitable of medium sized up to small and very small plates where the method provides very good resolution and accuracy.

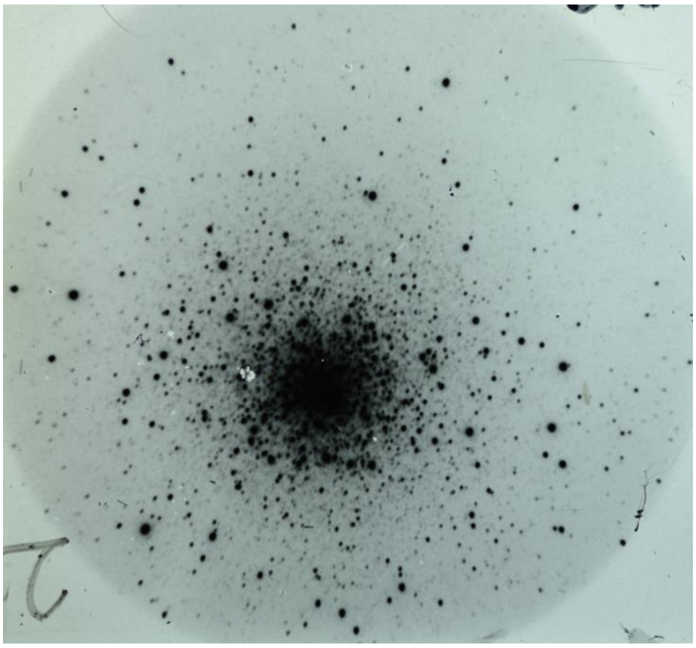

Fig. 1 Loiano Observatory direct image digitized by digital camera.

Transportable digitizing device

Most of the plate archives that we visited have no plate scanners and lack modern instrumentation in general. As our study includes plate digitization, it was necessary to find a solution. Since we were going to travel from Europe to the US by air, the obvious option was a transportable digitization device based on a digital camera with a high-quality lens and a stable tripod.

This solution has the following advantages over other techniques: the device is easily transportable, and offers much faster scanning and higher repeatability than commercial flatbed scanners, because there are no moving scanner parts. The equipment that we used was as follows: Camera: 21 MPx Canon EOS 5D Mark II (later replaced by 39 Mpx Nikon), Lenses: Canon EF 24–70 f/2.8 L USM and Canon 70–200mm F4, a stable tripod, and a Fomei LP-310 professional photographic light table and custom made table. More recently, we have been working on the design and development of a better custom-made light table based on highly homogeneous LED illumination, and also a further improved camera and lens. The recorded images are then corrected for lens image distortions and for other effects, in order to store research-grade.

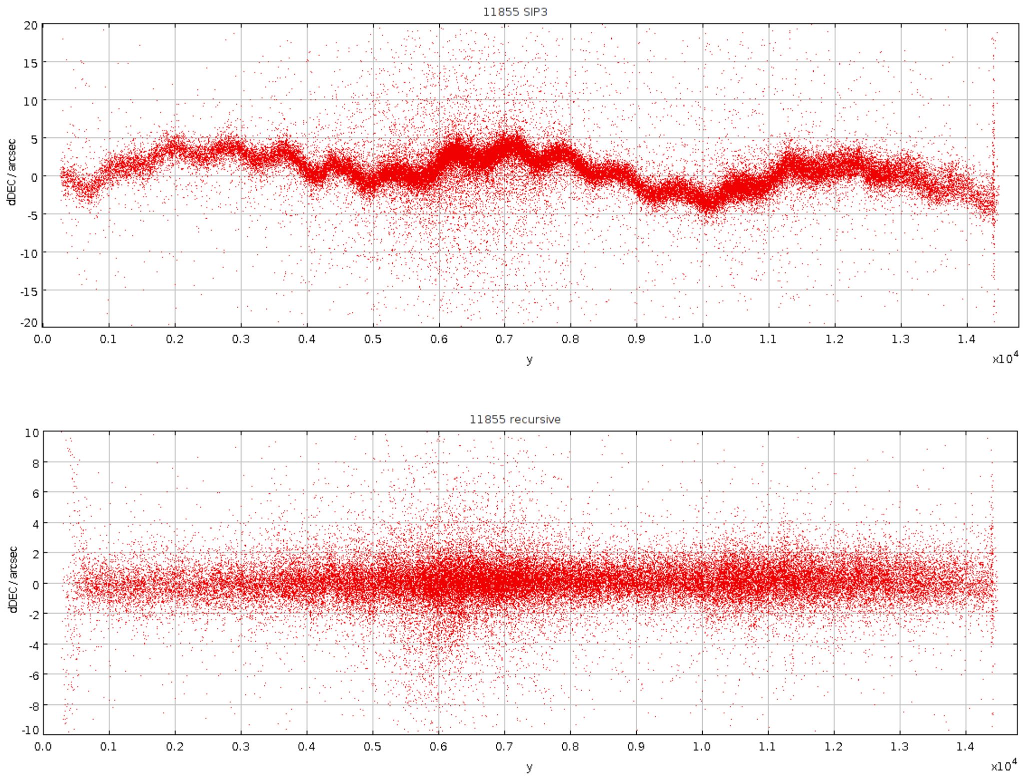

Fig. 1 The residual plots in declination in plate scan of Bamberg SUD plate SUD11855 with plate scanner (top) and with our technique (digital camera, bottom). The waves caused by the irregular CCD line movement in the plate scanner are clearly visible.

The inventory of astronomical plate collections

There is no complete inventory of all astronomical photographic records available. The wide field astronomical plate database WFPDB includes only collections wide field sky images end even that's is incomplete. In the USA, the inventory of north American plates was compiled by Robbins and Osborn [4], but the list is again far from complete.

Our experience shows that there are numerous astronomical plate collections, some of them large, at places and Institutions unknown to the community before. Some of them were visited by us with test plate scanning using our transportable device.

Selected plate and/or negative collections

Below we give very few examples of plate archives recently visited and exploited.

Lowell Observatory AZ USA

Unique collection of planetary images on 35 mm wide film obtained during the NASA program around 1970. The archive may contain up to 1 million frames.

University of New Mexico at Santa Cruz

Unique collection of about 10000 photographic plates with multiple planetary images

CHFT Telescope Hawaii USA

Collection of large and deep plates taken with very large CFHT with mirror aperture of 3,6 m. Many of these plates are with observers but the Institute started successfully to collect them back.

Loiano Observtory Italy

Collection of about 15000 astronomical glass plates many of them taken with large Loiano telescope i.e. narrow field images and many spectra.

Bologna observatory Italy

Unique plate collection taken by Bologna specola tower telescope with multi mirror optics manually adjusted. About 10 000 plates all the same declination mostly of historical and cultural value. Recently improperly stored with limited access.

Conclusions

The alternative plate scanning method based on transportable device was developed and tested. This device was then further improved and upgraded including special software for automated image treatment and lens distorsion correction etc. The astrometric and photometric accuracy of the method was tested and compared, where possible, with other plate scanning methods. The method is fast and inexpensive still yielding scientific grade results.

Acknowledgements

We acknowledge GA CR grant 13-39464J. We thanks Dr. Taavi Tuvikene for his help with astrometry accuracy analysis.

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Accuracy of DSLR cameras

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Abstract

This paper deals with problematic whether is possible to use DSLR (digital single-lens reflex) cameras for precise measurement. Digital cameras have good cost to performance ratio thus they are good candidates as tools for digitalization of astronomy glass plates and photometric measurement. This paper show what affect output data accuracy of such devices.

Keywords: Digital camera, digitalization, accuracy, noise, measurement, Canon, Nikon.

Introduction

Today's DSLR cameras offer reasonable good image quality and high resolution for appropriate cost. Manufacturers deliver new model, which brings better performance almost every year. Manufacturers tend to improve resolution as well as noise parameters. But this product is mentioned for professional photographs, which means for daylight documentation and aesthetic use, where is not important precise data handling. Still DSLR cameras have big CMOS chip with mostly 14bit A/D converter which in theory can be used for precise measurement.

There are several studies about use of DSLR for luminance measurement [1] or astrometry and photometry [2]. Unfortunately it is impossible to obtain information about camera functions and performance from manufacturers, because it is subject of technological know-how. This paper offers some preliminary results of main linearity and noise properties of some lately introduced DSLRs.

1. Linearity

Linearity is one of the most important characteristics in A/D conversion. Linearization noise is limiting for resulting accuracy. Also both tested brands of cameras (Canon and Nikon) have different approach to linearity and histogram corrections. Test was conducted by taking images of test patch ISO 14524 [3], [4] with variable exposure values. Exposure to full saturation was estimated, and three sequences to minimal exposure were taken, and resulting values were averaged. Both cases are illustrated in Fig.1. Linearity looks good, but closer investigation show some troubles in data handling by Nikon. After linear model subtraction and plot of residual relative values as function of digital output it is possible see that Nikon behaves clearly oddly. It real world it is impossible to obtain linear response from start to end of characteristic and even without any offset. That point on some data preprocessing and offset subtraction. There is a big improvement in accuracy approximately at output value 100, where supposed offset value should be. Also residual values vary in wide range from -7 % to +6 %. Canon have offset around output value 1024. After subtraction of this value for better readability it is clearly visible that residuals are smaller from -5 % to 4 %. Both brands have 14bit A/D converter so useable range is about 13000 ADU in case of Canon and 14000 ADU in case of Nikon.

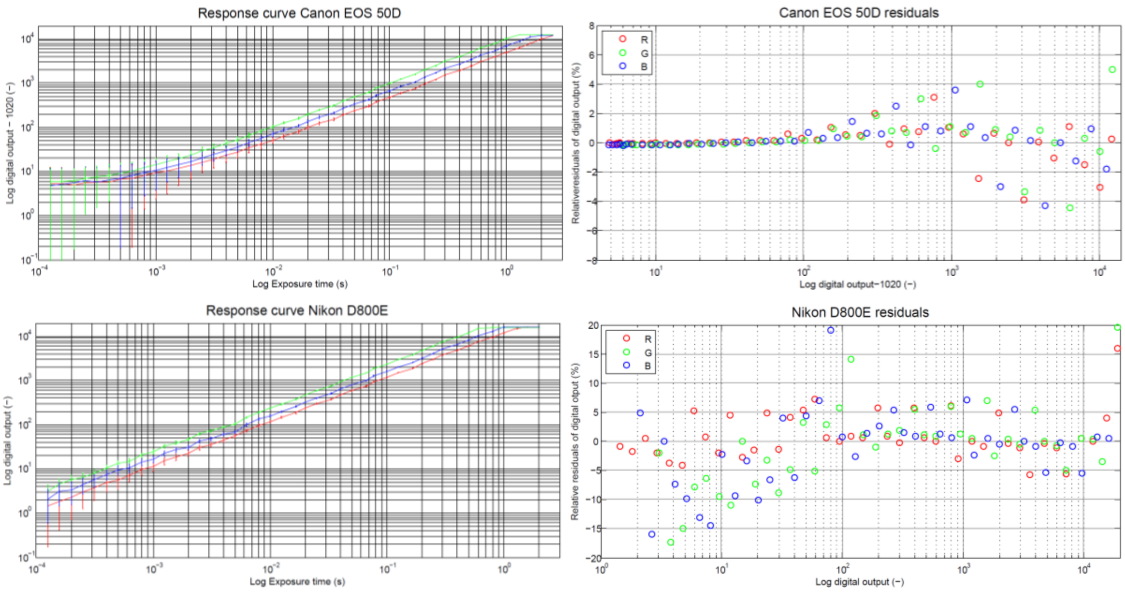

Fig.1. Response curves and residuals of Nikon D800E and Canon 50D

2 Temperature stability

Temperature affect noise level, unfortunately there is no temperature control in DSLRs. On the contrary, camera could heat itself very significantly. There is big difference between approach to noise handling in image taken by Nikon and Canon cameras. Canon cameras have temperature sensor which measure temperature of chip and these information can be accessed by specialized software. Sadly there is no similar option available for Nikon cameras so we can only see how noise is changing during the time.

Canon camera heats from room temperature up to 40°C and in matter of one hour there is not reached temperature stability. Noise is increasing with linear trend but mean values on opposite side descending. So after sum of these values, it is possible to see, that there is some processing in background. There is some data processing that subtracting mean values, so noise remains still in same position around 1030ADU. But situation with Nikon cameras is even worse. If we compare progression mean and sigma values over time, we can clearly see that there is strong dependence. This graph confirms data from linearity measurement that there is offset subtraction going on, that cut off previous values and leaves only noise. Further investigation in next chapter show, that this is the biggest problem. All data are illustrated at Fig. 2. for Canon 50D and at Fig. 3. for Nikon D700.

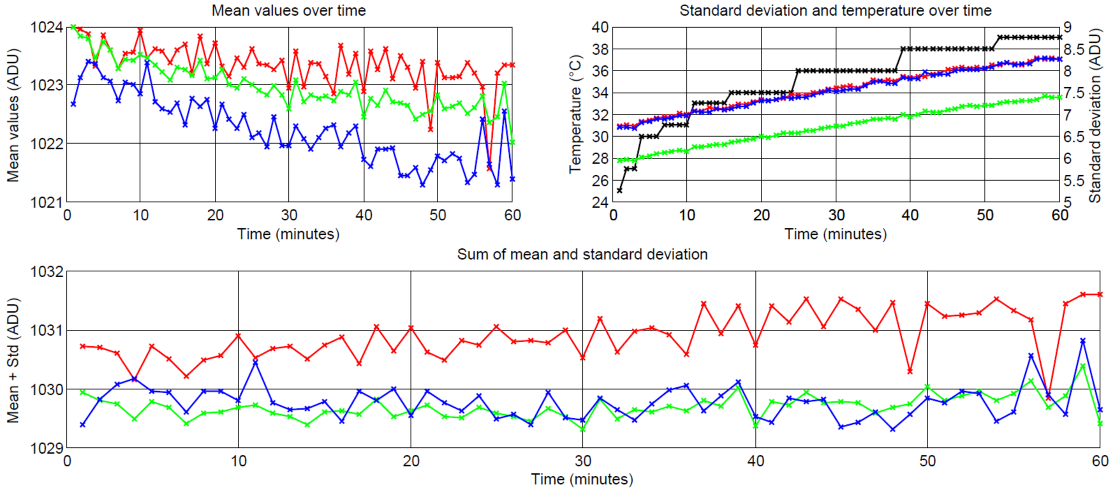

Fig. 2. Temperature noise stability over time Canon 50D

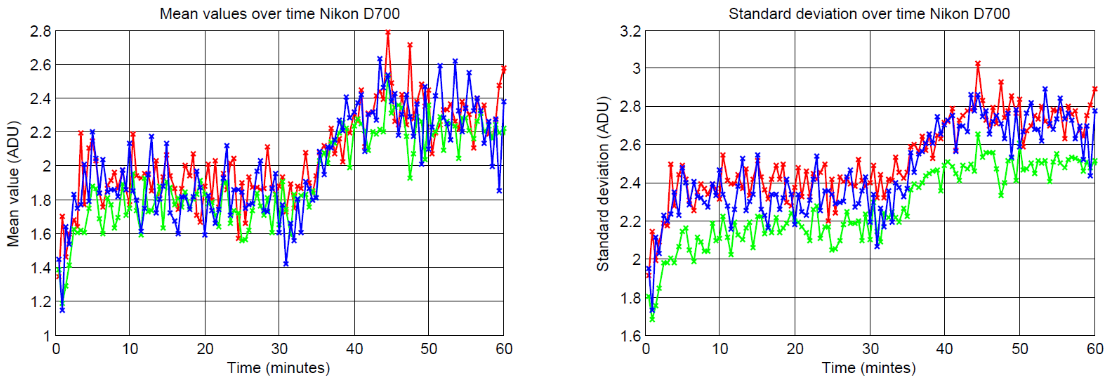

Fig. 3. Noise stability over time Nikon D700

3 Bias appearance

Bias consists of offset and noise of A/D converter [5]. In previous chapter was shown that Canon and Nikon have different approaches to offset handling. Canon uses some algorithm to maintain bias constant as much as possible. In process they subtract corresponding standard deviation from mean values. But they preserve data in noise levels. This is the biggest problem of Nikon. It is obvious that they find peak at A/D converter noise and set this to zero. This totally excludes any reasonable attempt for precise noise calibration. This leads to totally black areas in bias and dark frame images, with no information as Fig. 4. shows.

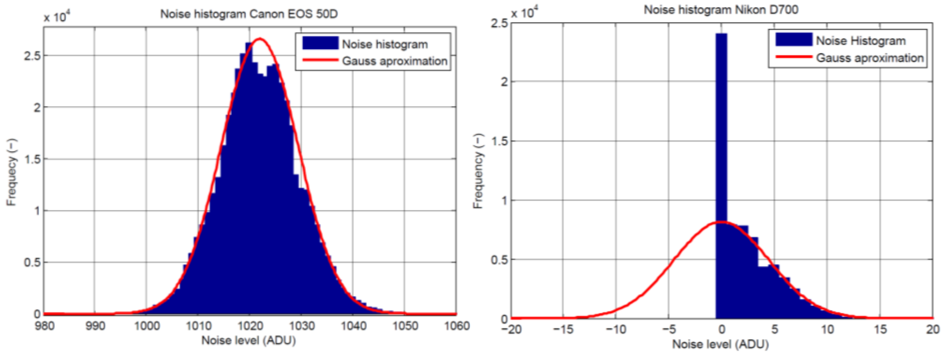

Fig. 4. Bias noise for Canon 50D and Nikon D700

Conclusion

It is clearly visible that digital cameras have good linearity within wide range of dynamic range of A/D converter. Linearity could be affected by imprecise time measurement and by some mechanical issues on shutter. From linearity comparison results that better accuracy have Canon 50D. Shape of response curve of Nikon D800E suggests that some data processing going on before storage to memory. Nikon subtracts offset and half of bias noise in purpose to keep photographs black. This suit professional photographers but precise measurement ruled out. Canon seem to do same but with more careful way. Canon adjusts mean values according to noise from given offset. So noise data are preserved. It is important to realize that this bias issue is not so important for digitalization of glass plates because there is not crucial to measure intensity of stars but their diameter. If plates are backlighted accordingly, the noise issue does not affect information about stars on plate.

Acknowledgments

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Scientific use of digitized plates

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Abstract

We review some recent papers based on old digitized plates from the Asiago and Byurakan Observatories, both direct and spectroscopic. Finally a brief report is made of the just completed digitization of long time series of four Schmidt fields on the galactic plane (M16, Cygnus, Cassiopea, IC1805), which may be relevant for the GAIA mission.
Keywords: surveys; photographic plates.

1 Introduction

Photographic plates has been by far the basic detector for astronomy for more than a century. Most plates used for sky patrol were blue sensitive, so this is the most covered band in plate archives. Many astronomical sources have evolutionary time scales much longer than the human life, so archive data are the only means to follow such phenomena in the past. Furthermore, plate archives are the only way to recover informations on the past behaviour of objects whose astrophysical interest appeared only after their detection in high-energy or infrared bands by space born instruments. Examples of such sources are: AGN, Long Period variables, cataclismic variables, Young Stellar Objects. In the following, some cases are shortly illustrated with recently published papers based on plate archives.

2 AGN

After the discovery of the first Quasars, extensive monitoring of the optical variability of many of them has been performed. However, many of these objects, belongin to the more general class of Active Galactic Nuclei, were not found by optical search but rather by Radio and X-rays surveys. Several AGN were therefore identified as such only some years after their inclusion in catalogs of Radio or X-ray sources and detailed optical light curves are still missing for many of them. Searches for AGN in plate archives of different Observatories, taken for different purposes much before their discovery, may help in describing their past behaviour. Here we report some recent studies on this topic, showing fruitful results.

Long term light curve of S5 0716+714.

This bright (B=14 in the POSS I) and strongly variable BL Lacertae object was discovered as a radio source in 1981. I made a search in the Asiago plate archive finding 53 useful plates: the light curve showed a large long-term trend with time scale of about 50 years (Fig. 1), which could be due to a precessing jet approaching and receding from our line of sight (Nesci et al. 2005). An archive search for epochs prior to the first POSS could help to check the periodic nature of this trend and strengthen the physical interpretation.

GB6 1058+5628: a quasi periodic BL Lac object the from Asiago plate archive.

Also this BL Lac is rather bright (B=16.2 on the POSS I), but again was discovered only with radio surveys (6C catalog, 1965). A search in the Asiago archive allowed to build a well sampled light curve since 1962 characterized by an oscillating behaviour on time scale of $\sim$7 years overposed to a monotonic decreasing trend. This trend inverted after year 1996, according to sparse CCD observations (Nesci 2010). The Asiago Supenova patrol was discontinued after the end of the photographic plates era, so one should look in modern CCD sky patrol projects, like those for GRBs or NEOs, to trace the recent behaviour of the source.

Optical variability of 1WGA J0447-0322

This Flat Spectrum Radio Quasar (B=16.1 on the POSS I) was discovered as a radio and X-ray source in 1990 (PMN catalog and ROSAT all sky survey), but its nature was recognized only in the year 2000 (Caccianiga et al. 2000). Its historic light curve was built from the Asiago plate archive

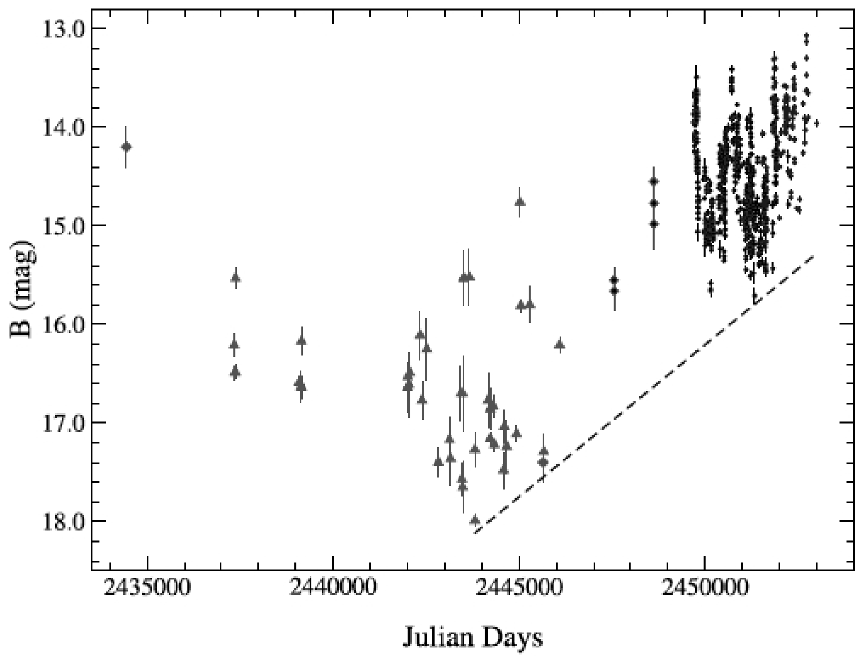

Figure 1: Historic light curve of S5 0716+714 from Asiago 40/50/120 cm Schmidt plates up to 1983 and CCD data afterwards.

from 1961 to 1991 (Nesci et al. 2007) and showed a bistable behaviour, with erratic oscillations of 0.3 mag amplitude around a mean level which decreased abruptly by 0.5 mag in 1987. Figure 2, left panel, shows the calibration curve of a plate: rms deviation from the linear fit was 0.09 mag.

3C 345: the historical light curve (1967-1990) from the digitized plates of the Asiago Observatory.

This QSO was discovered by its radio emission in 1965 as a 3C catalog source. A comprehensive light curve form the Asiago archive was made by Omizzolo et al. (2005), including a reanalysis of the first 10 years of data already published, derived with traditional methods of photographic photometry. The curve showed an overall stable mean flux level, with fast and large variations. Furthermore, several other QSOs present in the field were studied for their optical variability for the first time, including the nearby Seyfert galaxy NGC 6212. The photometric accuracy achieved was 0.1 mag.

J004457+4123 (Sharov 21): not a remarkable nova in M31 but a background quasar with a spectacular UV flare.

Sharov 21 is a source inside the image of the Andromeda galaxy, and was initially considered to be a Nova belonging to it. An extensive search on several archive plates, besides those used in the original paper by Sharov (Meusinger et al. 2012), allowed to establish a light curve more than 50 years long, supporting the evidence that the large flare at B=17 in 1992 was a unique event in the recorded history of the source. Follow-up spectroscopy proved that it was a background radio-quiet QSO at z=2.1. The most likely interpretations of the flare were a Tidal Disruption Event or a microlensing by a star of the foreground M31 galaxy .

3 Variable Stars

Also in the case of variable stars some surprise may come from the analysis of old plates taken before their discovery. Here are a few examples of very different objects.

Historic outbursts of MASTER OT J023406.06+384142.4.

This variable was discovered by the MASTER network of robotic telescopes. The field was among those covered by the Asiago Supernova patrol in the years 1960-1990. Overall I checked 565

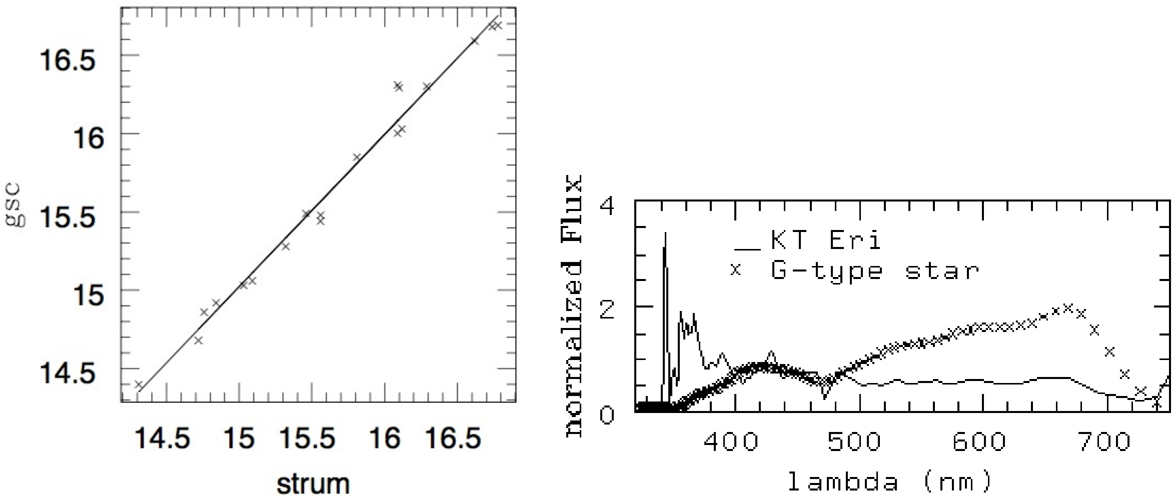

Figure 2: Left panel: calibration plot of the instrumental magnitudes vs the CCD ones of reference stars in the field of WGA 0447-0332; Asiago 67/92/215 cm Schmidt telescope. Right panel: spectrum of KT Eri from plate 0350 of the FBS taken on 1971-01-25 (line). Crosses are the average spectrum of G-type stars on the same plate, for comparison.

plates of the 50/40/100 cm Schmidt telescope (S50) and 86 plates of the 92/67/215 cm Schmidt telescope (S90), covering about 24 years: the number of nights with useful observations was 384. Seven outbursts were detected (Nesci 2013), recorded in 31 plates. A recurrence around 320 days was inferred, which is within the range for Cataclysmic Variables of the SU UMa type, supporting the tentative classification of this star.

A prediscovery spectrum of KT Eri (Nova Eridani 2009).
No previous outbursts of this Nova were known at the epoch of its discovery in 2009. A spectrum of this star was recorded in an objective-prism plate of the First Byurakan Survey. Its spectrum (Fig. 2, right panel), extracted with IRAF/apall (Nesci 2009), showed the presence of several strong emission lines up to the near UV, typical of the post-outburst nebular phase of the Novae. It was therefore possible to discover the nature of recurrent Nova for this interesting star.

The case of the pre-main-sequence star V582 Mon (KH 15D).
Another example of the usefulness of long time monitoring, for scopes rather different from the original one, is the strange case of a Pre Main Sequence star, V 582 Mon, in the field of NGC 2264. This star was found to have regular eclipses with a period of 48.3 days (Kearns and Herbst 1998) with modern CCD photometry. A reanalysis of old plates in B and I bands from the Asiago Observatory of this open cluster, much observed as reference field for comparison stars, by Maffei et al. (2005), showed that the star was stable from 1955 to 1958, the eclipses first appeared in the B band, in 1958, with the same period of the modern observations, and only after four years they started to be visible also in the I-band. This finding allowed to derive some hints on the process of dust formation in the surroundings of this star.

4 The Perugia University scan project

Long period variables, like the Mira's, have been studied for decades with photographic plates. A long term project, never fully completed, was started in the 1960's by P.Maffei (1975) at the Asiago Observatory. His plates covered four fields on the galactic plane centered on M16-M17 (l=16), γ Cyg (l=78), γ Cas (l=123), IC 1805 (l=134) for a statistical search of Mira variables and covered the period from 1963 to 1983. Couples of plates were taken in the same night in the B and I bands (103aO+GG13, IN+RG5) with the Asiago 67/92/215 cm and 40/50/120 cm Schmidt telescopes; since 1980 plates were also taken with the 40/60/121 cm Schmidt telescope of the Catania Observatory. The limit of these plates is about I=16 mag.

Only for the field of M16-M17 the light curves of the discovered variable stars have been published (Vizier on-line Data Catalog II/320 at CDS). For the other three fields, simple lists of detected variables have been published on the IBVS, just with the indication of Period, variability range, epoch of maximum. Up to now, very few detailed studies, or correlations with infrared space observations, has been made for these Mira and Semiregular variables.

At the Perugia University, we have scanned the plates of this large survey with an EPSON 1680 Pro in transparency mode, at 1600 dpi (15.88 μm) resolution. This provides a sampling of 1.52 arcsec/pixel for the large Schmidt, and 2.72 arcsec/pixel for the small ones. The output levels of the scans were selected manually in order to assure the full recording of the dynamical range of each plate. In total we scanned 306 plates of M16 (of which 149 from the Catania Observatory), 45 plates of Gamma Cyg, 199 plates of Gamma Cas, 160 plates of IC 1805. Furthermore, we digitized also 45 images of NGC 2264 (l=203), which were taken for calibration purposes, and 9 images of the Baade window near the globular cluster NGC 6522 towards the galactic center (l=1). Three other plates, centered on SN 1971 I (nearly overlapping the γ Cas field) were also scanned.

We plan to perform the astrometric solutions of these plates and to make them available on line in a near future. This will allow an easy check of the light curves, identification of possible blended sources with nearby IR stars, and comparison with recent Mid Infra Red catalogs (e.g. AKARI, WISE). Overall more than 400 known variable stars are present in the digitized fields, and likely a number of others wait to be discovered.

We hope that for most of these stars geometric parallaxes from the GAIA mission will be available, allowing a study of their 3D distribution on the galactic plane.

5 Conclusions

We have shown a few examples, mainly from my direct experience, where the access to plate archives has been the key tool for astronomical research. Keeping this treasure of past observations available to the future generations of astronomers is in my opinion a duty for our community, not only for respect of the hard work of our forerunners, but to allow unsuspected discoveries to be made at a very low cost.

Acknowledgements M. Bagaglia thanks the Fondazione Cassa di Risparmio di Foligno for financial support.

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A search for new variable stars using digitized Moscow collection plates

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Abstract

By digitizing astronomical photographic plates one may extract full information stored on them, something that could not be practically achieved with classical analogue methods. We are developing algorithms for variable objects search using digitized photographic images and apply them to 30 cm ($10^\circ \times 10^\circ$ field of view) plates obtained with the 40 cm astrograph in 1940–90s and digitized with a flatbed scanner. Having more than 100 such plates per field, we conduct a census of high-amplitude ($> 0.3m$) variable stars changing their brightness in the range $13 < m < 17$ on timescales from hours to years in selected sky regions. This effort led to discovery of ~ 1000 new variable stars. We estimate that 1.2 ± 0.1 % of all stars show easily-detectable light variations; 0.7 ± 0.1 % of the stars are eclipsing binaries (64 ± 4 % of them are EA type, 22 ± 2 % are EW type and 14 ± 2 % are EB type); 0.3 ± 0.1 % of the stars are red variable giants and supergiants of M, SR and L types.

Keywords: variable stars, photographic photometry

1 Introduction

Historical sky photographs present a record of positions and brightness of astronomical objects. They are used to study behaviour of objects as diverse as Solar system bodies [1, 2], binary stars [3, 4], and active galactic nuclei [5, 6] on timescales not accessible with CCD imaging data. A few authors used digitized photographic plates to identify previously unknown variable objects [7, 8, 9, 10].

The Moscow collection contains about 60000 photographic plates (mostly direct sky images) dating back to 1895. The most important part of the collection, known as the “A” series, are 22300 plates taken in 1948–1996 with the 40 cm astrograph [11]. These are blue-sensitive 30 cm by 30 cm plates covering $10^\circ \times 10^\circ$ field on the sky down to the limiting magnitude of $B \sim 17.5$. The typical exposure time is 45 min.

The original aim of obtaining the “A” series plates was to study variable stars. We decided to extend this work using modern image analysis techniques. The first tests confirmed that it is possible to find variable objects using small sections of plates digitized with a flatbed scanner [12, 13, 14, 15] and we went ahead to process a series of full-sized $10^\circ \times 10^\circ$ plates [16, 17]. Below we describe the current state of the project.

For the original tests we used a pair of CREO/Kodak EverSmart Supreme II scanners operating at 2540 dpi resolution ($1.''2$/pix). While showing good photometric performance (typically $< 0.1m$ accuracy of an individual measurement), the scanners were suffering from problems common to many flatbed scanners including poor out-of-the-box astrometric performance caused by irregular motion of the scanner drive (Fig. 1) and stitches between image parts digitized during different passes of the scanning array over a photographic plate. It takes about 40 minutes to digitize a half of the 30 cm plate with the Supreme II scanner. The time it takes to clean a plate and manually place it into a scanner is small compared to the scanning time. The original Supreme II scanners were recently replaced by the new Epson Expression 11000XL which provides a factor of two increase in scanning speed operating at 2400 dpi resolution ($1.''4$/pix). The Supreme II and Expression 11000XL scanners provide comparable results in terms of photometric and astrometric accuracy. Still, because the scanning process is so slow, we consider it to be more of a technology development tool and an opportunity to investigate a few individual fields rather than a practical way to digitize all the Moscow plate collection in reasonable time.

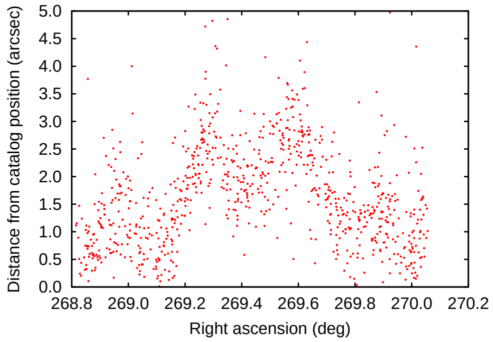

Figure 1: Deviation from the catalog position as a function of R.A. Plate solution with the 2nd order polynomial correction is applied for this 1°.3 × 1°.3 field digitized with the Expression 11000XL scanner.

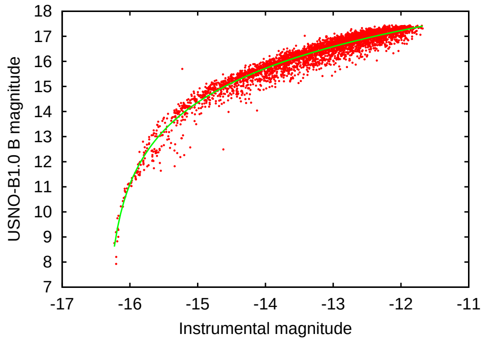

Figure 2: The magnitude calibration curve for the same field as Fig. 1. Points represent stars matched with the USNO-B1.0 catalog.

2 Plate digitization and data reduction

The plates are digitized with 48 bit color depth (16 bit/color channel) and saved into a TIFF format using a control software supplied with a scanner. TIFF is the only format capable of preserving such color depth that is supported by the control software of both scanner types. This format has a built-in limitation that a file cannot be larger than 2^{32} bytes (4 Gb) corresponding to a $\sim 9400 \times 9400$ pix image at 48 bit color depth. This means that a 30 cm plate cannot be scanned into a single file, so in practice a plate is scanned into two files with a small overlap between the two images. This does not pose a problem for the subsequent analysis.

The TIFF images are converted into FITS format using the `tiff2fits`[1] code. Data from only the green channel are used to write a monochrome FITS image. The negative images are inverted at this stage to have white stars on dark background. Large images are cut into pieces of about $1° \times 1°$ so sensitivity variation caused by vignetting and other aberrations in the astrograph's optics as well as atmospheric transparency variations can be approximated as a linear function of an object's position on a small image. Since plates that belong to the same "field" may have offsets of more than 1° between their centers, a star is used as a reference point for cutting to ensure that the same sky area is covered by small images resulting from cutting scans of different plates.

Each series of small images is processed independently using the `VaST`[2] variability search software [18]. `VaST` is using `SExtractor`[3] [19] to perform object detection and aperture photometry (the aperture size is determined individually for each image to compensate for seeing variations) and performs cross-identification of stars detected on the images producing lightcurves of all detected stars as an output. The circular aperture size is optimized for measuring stars with $B > 13$. The images are plate-solved using the `Astrometry.net`[4] software [20, 21] and the internal magnitude scale is calibrated by matching the detected stars to the USNO-B1.0 catalog [22]. Following [23] we use the relation of the form $m_1 = a_0 \times \log_{10}\left(10^{a_1 \times (m_2 - a_2)} + 1\right) + a_3$ proposed by [24] to match catalog B (m_2) magnitudes to the measured aperture magnitudes (m_1) through the fitted coefficients a_0, a_1, a_2, and a_3 (Fig. 2). This relation is also utilized to match instrumental magnitude scales of individual frames before performing absolute calibration. The obtained lightcurves are used to search for variable stars using an RMS–magnitude plot and period search techniques [17].

[1] `ftp://scan.sai.msu.ru/pub/software/tiff2fits/`
[2] `http://scan.sai.msu.ru/vast/`
[3] `http://www.astromatic.net/software/sextractor`
[4] `http://astrometry.net/`

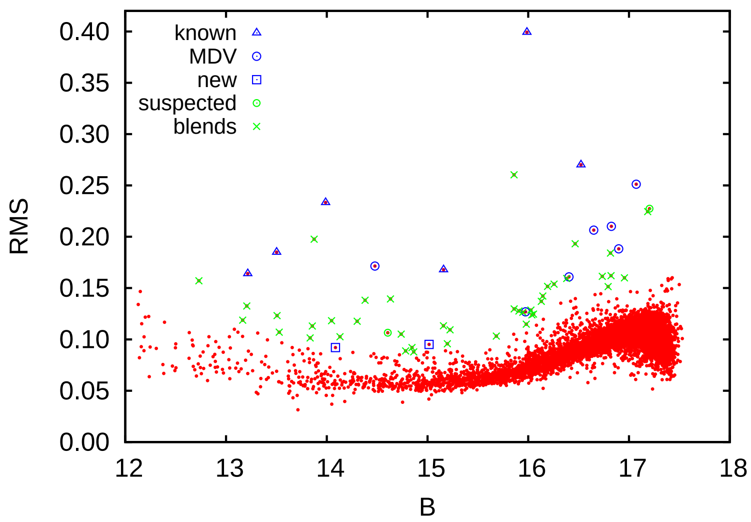

Figure 3: Lightcurve RMS as a function of mean magnitude.

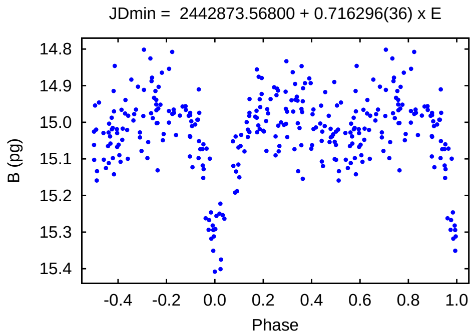

Figure 4: Lightcurve of B1.0 0953-0319502.

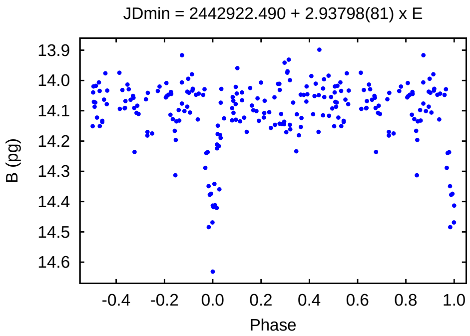

Figure 5: Lightcurve of B1.0 0944-0313124.

3 Results

Fig. 3 presents the RMS–magnitude plot for the test field digitized with our new Expression 11000XL scanner. The plot marks previously known variable stars in this field ("known"), variables identified by [16] ("MDV"), "suspected" variables, and constant stars with photometry corrupted by a close neighbor ("blends"). Two new Algol-type binaries were identified while processing the test data (marked as "new"), their lightcurves are presented in Fig. 4 and 5.

We applied this variable stars search technique to three $10° \times 10°$ fields centered at 66 Oph (254 plates exposed in 1976–1995), BD+60°636 (182 plates, 1949–1989), and β Cas (391 plates, 1964–1994). Processing of 66 Oph and BD+60°636 fields resulted in discovery of 557 previously unknown variable stars including 6 Cepheids (Type I and II), 147 RR Lyrae type variables, 12 High-amplitude δ Scuti stars (HADS), 168 red semiregular and irregular (types SR and L) variables, 222 eclipsing binaries, 2 BY Dra type stars. Preliminary processing of 50 % of the β Cas field (the most well-sampled of the three studied fields) resulted in detection of 604 variable stars (454 of them new) among ~ 51000 stars in the magnitude range accessible for our variability search. We estimate that 1.2 ± 0.1 % of the stars show easily-detectable (amplitude $> 0.3m$) light variations; 0.7 ± 0.1 % of the stars are eclipsing binaries (64 ± 4 % of them are EA type, 22 ± 2 % are EW type and 14 ± 2 % are EB type); 0.3 ± 0.1 % of the stars are red variable giants and supergiants of M, SR and L types. The fraction of pulsating variable stars of all types is expected to be a strong function of the Galactic latitude and deserves a more detailed investigation. The errors are estimated from the Poisson statistics and cannot account for any systematic effects remaining in our search.

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The Asiago plate archive

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Abstract

About 52 000 deep imaging plates (most in B band or unfiltered blue-sensitive 103a-O, with B∼18 or fainter limiting magnitude) and 26 000 plate spectra are stored in the Asiago plate archive. They were obtained between 1942 and 1998 with the Asiago 1.22m and 1.82m reflectors, and the 40/50cm and 67/92cm Schmidt telescopes. The plates are well documented and accurately preserved at nearly constant temperature and controlled humidity. We provide a description of the archive, paper and electronic metadata, plate access, scanning status, web interrogation and an overview of the scientific use, that sees a nearly constant flow of about ∼2.5 refereed papers per year using data extracted from Asiago plates.

Keywords: astronomical photographic plates - spectroscopy - photometry

1 The instruments

Four different telescopes contributed over the years to the plate collection currently maintained at the Asiago observatory (1060m a.s.l., on north-east Italian pre-Alps, jointly operated by INAF National Institute of Astrophysics and the Dept. of Physics and Astronomy of the University of Padova): the 1.22m reflector which begun operation in 1942, the Schmidt 40/50cm in 1958, the Schmidt 67/92cm in 1965, and finally the 1.82m reflector that joined in 1973.

The 1.22m exposed 9 720 imaging plates (9x12cm) at the Newton focus (6m focal length) during 1942-1997, and recorded 18 584 plate spectra (cf. Fig. 1 left) with the Cassegrain double-prism spectrograph during 1951-1994 and other 3 220 plate spectra with the Newtonian spectrograph during 1958-1991. Since 1994 the detectors have been exclusively of the CCD type, and since ∼2000 the telescope is used exclusively for low and medium resolution spectroscopy with a B&C spectrograph at the Cassegrain focus.

The 1.82m obtained 3870 direct imaging (12x20cm) plates at the Cassegrain focus (f/9) and 4301 plate spectra with the B&C and Echelle spectrographs (cf. Fig 1 right). Since 1988 it has been equipped exclusively with CCD detectors. Current main instruments are the spectrograph+imager AFOSC, the high resolution Echelle spectrograph and the ultra-fast AquEYE 2D imaging system.

Between 1958-1992 the Schmidt 40/50cm exposed 18 411 imaging film plates (1.0m focal length 1.0m, correcting plate in UBK7 Schott glass, circular field 10cm in diameter, usual limiting mag B∼18.0) and 2 006 objective prism film plates (prism in UBK7 glass, 40cm in diameter, 12° angle, 450 Å/mm dispersion at Hγ, excellent transmission down to the UV atmospheric cut-off; see Fig. 2 top). The telescope is preserved in good conditions, but it is not currently operative.

The Schmidt 67/92cm (correcting plate in UBK7 glass, 215cm focal length, 20x20cm square plates, their diagonals oriented along North-South and East-West directions) operated with glass plates over 1965-1993 and with TP 4415 film plates (treated in forming gas) over 1993-1998. Since then it is equipped with a large format CCD observing through $UBVR_{C}I_{C}$ photometric filters. It obtained 16 729 direct plates (usual limiting mag B∼18.6) and 1 087 objective prism plates (two UBK7 glass prisms, 4.5° and 1.0° angles, that can be mounted individually or in combinations, providing a total of four different dispersions: 398, 650, 1000 and 1250 Å/mm at Hγ).

All together, about 52 000 deep imaging plates (most in B band or unfiltered blue-sensitive 103a-O) and 26 000 plate spectra are preserved in the archive.

2 The archive

The archive is located in a dedicated room at the Asiago observatory, where plates are contained in soft, non-abrasive paper envelopes stored vertically in metallic cabinets that allow air to circulate (cf. Fig 3). The envelopes are machine printed, copying the metadata from the hand-written logbooks plus sometimes later annotation by users. Given the massive walls and its location at the center of a large heated building, the temperature in the archive slowly drifts from ∼19° in winter to ∼23° in summer. The humidity is controlled and kept stable.

Various binocular Zeiss microscopes are available for plate inspection and two flatbed scanners for digital scanning (back illuminated, A3-size EPSON Expression 1640XL and 10000XL).

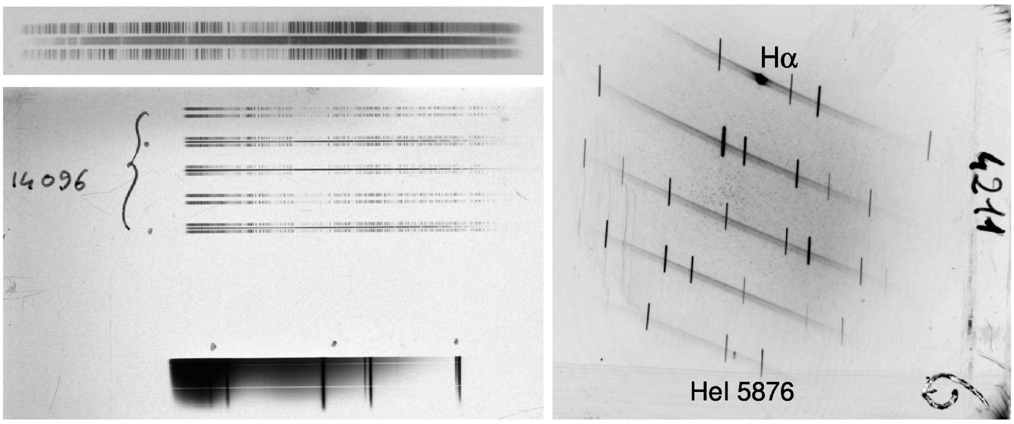

Figure 1: Examples of plate spectra stored in the Asiago plate archive. *Top left:* 1.22m + Double Prism Spectrograph + S20 image intensifier + 103a-D, covering from Hα to H10 (3798 Å). *Bottom left:* 1.22m + Double Prism Spectrograph + 103a-F direct (λ-range according to emulsion type) with spetro-densitometer calibration recorded at the bottom. *Right :* 1.82m + Echelle spectrograph + 1200 ln/mm cross-disperser + two stages S20 image intensifier + IIIa-F.

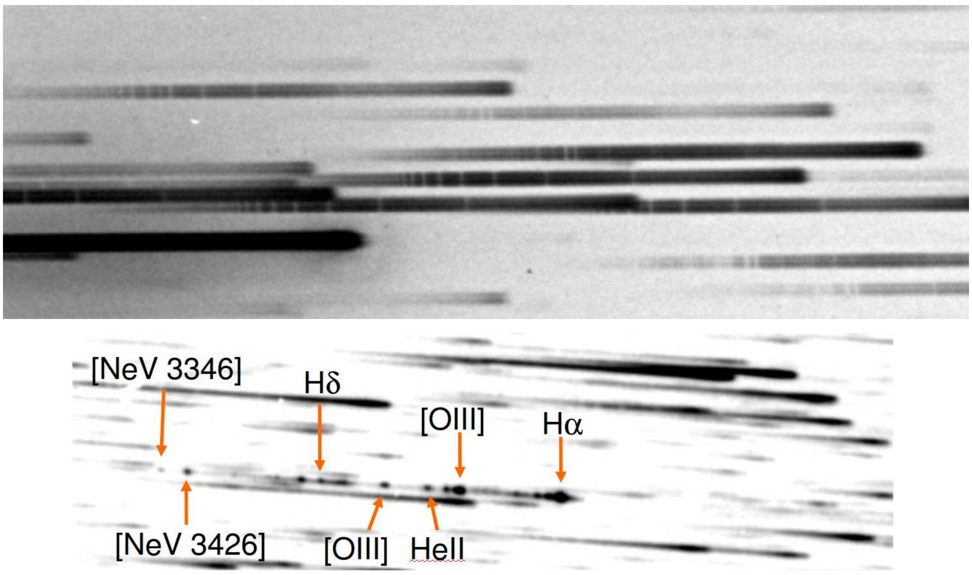

Figure 2: Small areas from objective prism plates stored in the Asiago plate archive. *Top:* Schmidt 40/50cm + UBK7 12° objective prism + IIIa-F, trailed (450 Å/mm dispersion at Hγ). *Bottom:* Schmidt 67/92cm + UBK7 4.5° objective prism + Tech-Pan 4415 (treated in forming gas), untrailed (650 Å/mm dispersion at Hγ).

3 Metadata, plate access and scanning, web interrogation

The metadata are digitally available for all imaging plates and for the plate spectra obtained at the 1.82m telescope, but not (yet ?) for the plate spectra obtained at the 1.22m telescope. The metadata can be accessed and searched for via the web page of the INAF Astronomical Observatory of Padova (http://archive.oapd.inaf.it/asiago/7000/7040.html) and the Wide-Field Plate Database (http://wfpdb.org/search/). No preview is available on-line. The coordinates listed for the plates are usually those of the objects for which the plates were originally exposed. While the main targets are well placed within the area of the sky imaged by the plates, the actual plate center usually coincides with a nearby and suitably bright star used for guiding. Thus, while an expert guess is usually correct for objects away from plate borders, only visual inspection of the plates can provide solid proof of actual presence within the imaged field.

All original hand written logbooks are preserved with the plates and can be easily accessed and consulted. They usually report a good deal of ancillary informations, including sky conditions, guiding, developing and fixing bath etc.

Only a small fraction of the plates (2500 in all) has been scanned (at 1600 dpi and 14 bits), and the scans are stored on DVDs. A list of the scanned plates is available on-line. The scanning effort focused on plates imaging mainly M31, M33, M42, M45, NGC 2264 and zeta Ori. For lack of man power, no further systematic plate scanning (or digital preview) is currently foreseen.

To use the plates, the visiting astronomer needs to physically access the Archive in Asiago (equipped with a modern, fully featured guest house) or to seek a collaboration with a resident astronomer. Most of the studies currently carried out on the Asiago plates (see next section for further details) involve searching for some faint optical counterparts or reconstructing the photometric history of variable objects, which are usually done visually at the microscope (using calibrated local photometric sequences) and quite less frequently involve digital scanning of the plates.

Figure 3: The Asiago plate archive. The temperature is stable through the year and the humidity is controlled. Plates are store vertically in soft, non-abrasive paper envelopes. Three binocular Zeiss microscopes and two large area flat-bed scanners are available to assist.

4 Scientific use

The Asiago plate archive regularly contributes to a steady flow of refereed paper (∼2.5 per year on average). They basically aim to reconstruct the photometric history of peculiar objects or investigate the pre-outburst behavior of objects recently erupted. Among the most recent topics there are progenitors of novae (Munari & Henden 2013, Jurdana-Šepić et al. 2012), pre-ZAMS objects (Poljančić et al. 2014, Semkov et al. 2014, 2013, 2012, Nesci et al. 2013), AGNs (Nesci et al. 2014, 2010, eusinger et al. 2010), interacting binaries (Jurdana-Šepić & unari 2010), and RR Lyr variables (Szeidl et al. 2011). Only the direct images plates contribute to this statistics, because their metadata are available in digital form and are easily searchable via a web interface. The huge archive of spectroscopic plates remains essentially unexplored for lack of digital metadata. All the spectroscopic material is diligently documented on the logbooks of the various spectrographs, but they are all hand written. So, long term spectral monitoring of hundreds of novae, supernovae, emission line objects, pre-ZAMS and flare stars, single and double-lined binaries, and a lot more, is still waiting for digital transcription of hand written metadata to be re-discovered and re-used.

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Investigation of binary X-ray sources with photographic plates

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Abstract

We summarize how the archival photographic plates can be used for a study of the long-term activity of various types of X-ray binaries in the optical band. We show examples of the unpredictable phenomena (flares, outbursts, transitions between the states) which are easily recognizable on the plates. Such plates are very helpful in extending the investigated time intervals into the past, especially because some of these systems underwent dramatic changes of their activity during the last decades, sometimes even before they were discovered as the variable objects and/or the X-ray sources.

Keywords: Instrumentation: miscellaneous. Methods: data analysis. Methods: observational. Radiation mechanisms: general. Accretion, accretion disks.

1 Introduction

Monitoring of the sky is important for obtaining data which enable to study the long-term activity of various objects. Binary X-ray sources are important in this regard because they emit radiation also in the optical band and are often highly variable on various timescales. For the photographic observations, the activity of such objects on the timescales of days, weeks, even years and decades is very interesting. Transitions between the activity states (e.g. outbursts, high/low states) of such sources are often fast and unpredictable. Monitors of any type are therefore needed. It is also desirable to monitor a large part of the sky (not only a single, already known object) because most transients (objects with outbursts) were discovered only in outburst, not in quiescence before this event. A lot of 'sleeping' transients exist. Monitoring is also inevitable for a search for rare, unexpected and unique phenomena even in the already known objects. The very numerous archival photographic observations mapping the sky for many years are very important for this study.

Binary X-ray sources consist of the compact object (white dwarf (WD), neutron star (NS), black hole (BH)) accreting matter from its companion star (donor). Their typical orbital period is of the order of hours. The systems with the WD are called cataclysmic variables (CVs), those with the NS or BH are called X-ray binaries (Lewin et al. 1995).

2 Types of the long-term activity

Classical novae: The very strong brightenings of classical novae are caused by the episodic thermonuclear explosions of the accreted matter on the WD in various CV types (e.g. Warner 1995). The typical duration of this explosion in the optical band is between weeks and months. The typical amplitude is 12–15 mag. The recurrence time (cycle-length) of the explosion is very long, usually about 10^4 years, only in very few systems called recurrent novae it is of the order of decades. The rise of the optical brightness to the peak of the explosion is usually very fast (a few days), so it is often badly covered by the data. Because of the above-mentioned properties, the classical nova is often discovered as a new object in an "empty" position. Because classical novae are usually faint in quiescence, they are discovered by the explosion. Also the pre-explosion activity of a given classical nova (and search for the previous explosions) can be studied on the archival plates.

Dwarf novae: This type of CVs displays strong brightenings by several mag which typically last for about a week and recur on the timescales of weeks or even years (e.g. Smak 1984; Warner 1995). Such an activity, attributed to a thermal-viscous instability of the accretion disk, is easily detectable on the photographic plates.

GK Per/1A 0327+43, now behaving as a dwarf nova, is a CV which underwent dramatic variations of the type of its activity during less than a century. It exploded as a classical nova in 1901. After returning to quiescence, it behaved as the novalike type, and finally it became a dwarf nova with the outbursts with the typical amplitude of about 3 mag, as documented by the archival photographic plates (Hudec 1981; Sabbadin & Bianchini 1983). The annular means of brightness (averaged over dwarf-nova outbursts and quiescence in a series of plates) showed that these events started when the mean level of the optical luminosity decreased below some level (Hudec 1981). In the framework of the model by Schreiber et al. (2000), the main common cause of this evolution is a strongly enhanced mass outflow from the donor invoked by strong irradiation during classical nova explosion in 1901. The thermal-viscous instability of the disk can be thus influenced or even temporarily stopped by the changing conditions caused e.g. by the nova explosion. Evolution of the past novae therefore deserves a careful investigation and the archival plates can be very helpful in this matter.

Novalike CVs: These systems contain the accretion disks which do not show a thermal-viscous instability (hence no outbursts). Their long-term activity is attributed to the variations of the mass transfer rate between the components of the binary (e.g. Warner 1995).

V1223 Sgr displays strong long-term activity with episodes of low states, when the brightness can fade from ∼13 mag down to the level deeper than 16 mag (Harvard photographic plates (Garnavich & Szkody 1988)). A series of Bamberg photographic plates (one plate per night) represents a relatively dense mapping of activity in a time segment rather scarcely mapped by the Harvard data. It shows that the brightness of V1223 Sgr is far from being stable on the timescales of months and years even in the high state (Fig. 1a). Comparing the data obtained by various methods (e.g. photographic and CCD) also enables to investigate its activity on the timescale of several decades (Fig. 1b). The differences caused by the spectral sensitivities of the individual detectors can be diminished by transforming the measurements to a single band (e.g. B) if the typical color indices of the CV are known.

The statistical distribution of brightness is helpful for describing the properties of the long-term activity of CVs. These histograms and their parameters (the standard deviation, skewness, excess) are useful even when the data are sampled. Figs. 1cde bring some examples for V1223 Sgr. The profile of this statistical distribution is dominated by a broad bump with the peak-to-peak amplitude of more than 1 mag(B). This is the result of co-adding various episodes of the high states, sometimes with the brightness varying on a timescale of months even during a single episode. Groups of the low states represent tails from such bumps rather than forming specific levels of brightness. The fuzzy boundaries of the bright side of the statistical distributions of brightness show that the system cannot find equilibrium of the mass transfer even in the high state.

Polars: This CV type contains so strongly magnetized WD that no accretion disk can be formed. The matter is channeled directly toward the magnetic pole(s) of the WD (e.g. Warner 1995). AM Her/4U 1814+50 is the prototype of this group. Analysis of 700 Sonneberg archival photographic plates mapping the activity in the years 1928–1976 (Hudec & Meinunger 1976) showed that it is dominated by the alternating high and low states on the timescale of months. Transitions between the states are shorter than the durations of the states (the plates often catch the system in a given state). Study of this optical activity even mapped the epoch preceding the discovery of this object and its classification as the X-ray source.

Low-mass X-ray binaries (LMXBs): These systems are similar to CVs but they contain a NS or a BH as the accretor (Lewin et al. 1995). Dominant part of their optical emission comes from the accretion disk and the irradiated part of the donor.

Her X-1/HZ Her with its orbital period of 1.7 d (Tananbaum et al. 1972) displays unique optical activity because the dominant part of the optical emission is caused by reprocessing off X-rays on the donor (e.g. Gerend & Boynton 1976). This leads to a very prominent orbital modulation with the peak-to-peak amplitude of more than 1 mag if the system is in the active state. Sonneberg photographic data (one plate per night) enabled to investigate the long-term activity of Her X-1 in the optical band even before the era of X-ray astronomy (Hudec & Wenzel 1976; Šimon et al. 2002). The active states were sometimes interrupted by episodes of inactive states. The mostly flat profile of the optical modulation in such an inactive state, rising only slightly above the level of the center of the shallow primary eclipse, suggests a reduction of irradiation of the donor. All episodes

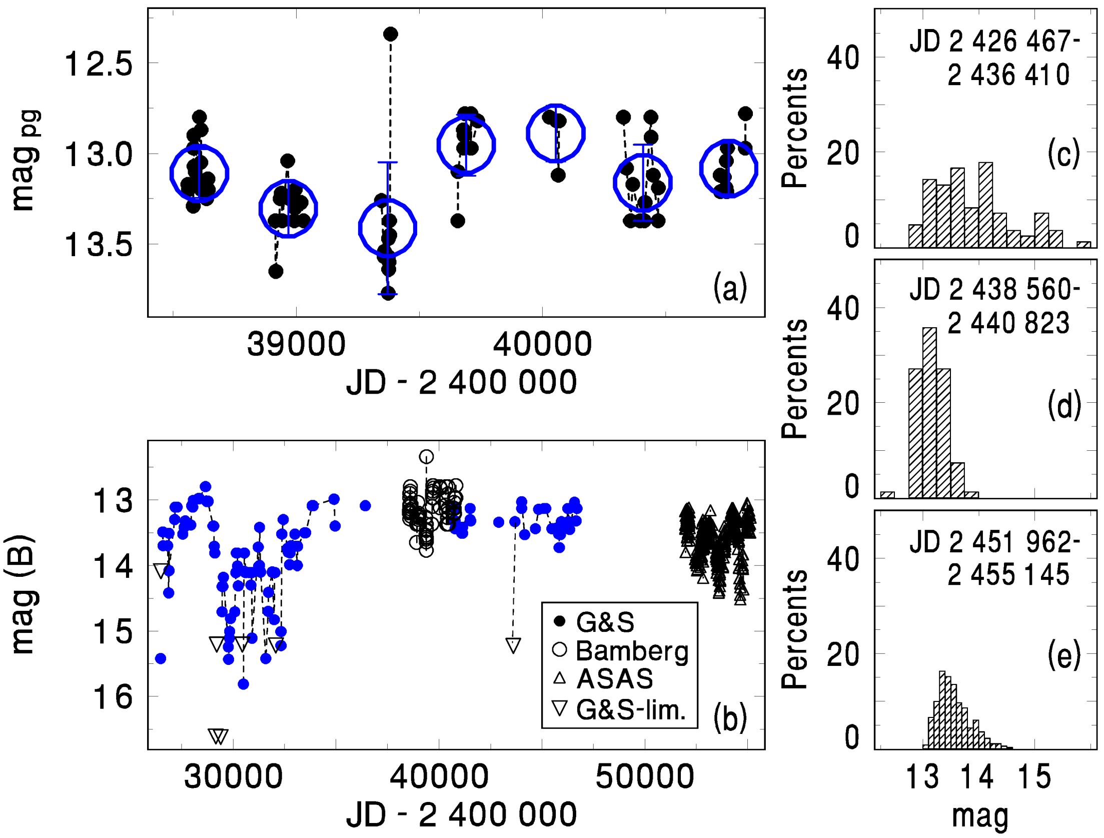

Figure 1: **a)** The light curve of V1223 Sgr made of Bamberg photographic data. Open circles denote the annular means (their error bars represent the annular value of the standard deviation of magnitude; the flare in JD 2 439 383 is not included in the mean). The level of brightness is not stable on the timescales of months even in the high state. **b)** The activity of V1223 Sgr from the photographic and CCD observations (ASAS data (Pojmanski 1997)). The data points are connected by the lines to guide the eye. **c)**, **d)**, **e)** Statistical distribution of brightness of V1223 Sgr. Adapted from Šimon (2014).

of the inactive state were discovered just on the archival plates and occurred only before the era of X-ray astronomy. The orbital modulation had a smaller amplitude during the short active states (1934–1937 and 1941–1949) than in the subsequent long active state (on the photographic plates obtained in the years 1959–1993). This behavior was attributed to a lower degree of heating of the donor star.

High-mass X-ray binaries (HMXBs): Although the luminosity of the donor component is often dominant in the optical, episodes of strong mass accretion onto the compact object can give rise to the large-amplitude optical variations in some of these systems (e.g. Lewin et al. 1995).

CI Cam/XTE J0421+560 is a remarkable system which underwent a large outburst (in the X-ray, optical and radio bands), during which it brightened by about 2 mag (Frontera et al. 1998). Bamberg archival photographic plates in blue light (similar to the B band) (1928–1939) along with the photoelectric multiband (1985–2004) (Bergner et al. 1995) and CCD data (1999–2004) (Šimon et al. 2007) show the striking difference in activity before and after the outburst (fluctuations on the timescale of days or weeks versus smooth waves on the timescale of years) (Šimon et al. 2008). In this scenario, even the optical activity itself can indicate the influence of the X-ray outburst on the character of the long-term activity of the binary system. This change of activity suggests that the outbursts of CI Cam appear to be quite rare (once per several decades?).

V4641 Sgr/SAX J1819.3–2525 underwent a major outburst in 1999 (in X-rays, optical, and radio) (Orosz et al. 2001). Several smaller outbursts with their recurrence time of several hundreds days followed this main event (e.g. Uemura et al. 2002). The observations on the Bamberg photographic plates (1964–1967) show that the system was active also before this big outburst. Its brightness displayed fluctuations with the amplitude of less than 1 mag on the timescale of several weeks and a possible small outburst (Šimon & Henden 2008).

2.1 Conclusions

The data on the archival photographic plates enable to study the activity of various types of X-ray binaries and they can significantly extend the mapped time interval into the past, including the time intervals preceding the discovery of such objects and/or their type. Unpredictable and rare events (flares, outbursts, transitions between the states) can be discovered on the archival plates. The large-amplitude activity of some objects can be studied even on the non-digitized photographic plates (e.g. by Argelander method and a microscope). It is also possible to combine the photographic archival data with the newer CCD observations.

Acknowledgements: This study was supported by grants 13-394643 and 13-33324S provided by the Grant Agency of the Czech Republic. Also support by D-25-CZ4/08-09 DAAD is acknowledged. This research has made use of the Dr. Remeis Observatory Bamberg Southern Patrol Photographic Sky Survey, and the All Sky Automated Survey (ASAS) database, the observations provided by the ASM/RXTE team, the data from the AAVSO International database (Massachusetts, USA) and the AFOEV database operated in Strasbourg, France. We thank the variable star observers worldwide whose observations contributed to this analysis.

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AGB stars and the plate archives heritage.

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Abstract

We report on the characterization of a number of AGB candidate stars identified with objective-prism plates of the Byurakan Observatory. Digitized photographic sky survey plates and recent CCD photometry have been used to improve the selection and distinguish variable and non-variable stars. Some comparisons among published catalog magnitudes are also made. Slit spectroscopy from the Asiago and Loiano Observatories allowed a firm spectral classification, separating C-Type, N-Type and normal M giants. Color-color plots using WISE, AKARI and 2MASS J-band data allow an efficient discrimination of spectral types, which can be used for the definition of larger statistical samples.
Keywords: surveys; photographic plates; late type stars.

1 Introduction

The large Schmidt telescope of the Byurakan Observatory (102/132/213 cm) with the 1.5 degree prism and 103aF emulsion made a successful survey of the northern sky in the 1970's. On these plates late type stars are easily recognized by their strong, nearly point-like, red emission while the blue part of the spectrum is very faint or even absent. This allows to build sample of AGB stars candidates, and/or to check the nature of infrared (IR) objects detected by space-based IR instruments like WISE, IRAS, AKARI or of ground-based surveys like 2MASS.

The first Byurakan Survey plates and automatically extracted spectra are freely accessible at http://byurakan.phys.uniroma1.it/index.php (Mickaelian et. al. 2007).

The AGB stars, due to their large luminosity, can be traced up to the limit of our Milky Way halo and therefore serve as tracers of its gravitational field and of dark matter distribution (see e.g. Mauron et al. 2013 and references therein). In this paper we report on an on-going survey program of AGB candidates in the northern hemisphere, aimed at obtaining a better spectral classification and exploring the possibilities of a classification from recent photometric infrared data from satellite surveys. Candidate stars were taken from the "Revised and Updated Catalogue of FBS Late-Type Stars"(Gigoyan and Mickaelian, 2012).

2 Spectroscopic data

Each star has been spectroscopically classified using the BFOSC instrument at the Loiano 1.5m telescope, and the AFOSC instrument at the Asiago 1.8m telescope, with resolution of 12 Åand in many cases of 6 Å[1]. We are therefore able to establish a firm spectral subtype, distinguish Early- and Late- types of Carbon stars, normal Oxigen stars, and discriminate giants from dwarfs. Actually very few dwarfs were found.

In Fig. 1 left panel, the appearance of a Carbon star (FBS2213+421) on a Byurakan plate is shown.

3 Variability

Among the stars of our sample, several are variable. As an example, from the data available in literature, V381 Lac was very bright at the epoch of POSS1 (1952); invisible in the red plates of POSS2 (1989); bright between 1999 and 2000, from NSVS; undetected by the SDSS in 2006. From

[1] Partially based on observations taken at the Asiago and Loiano Observatories

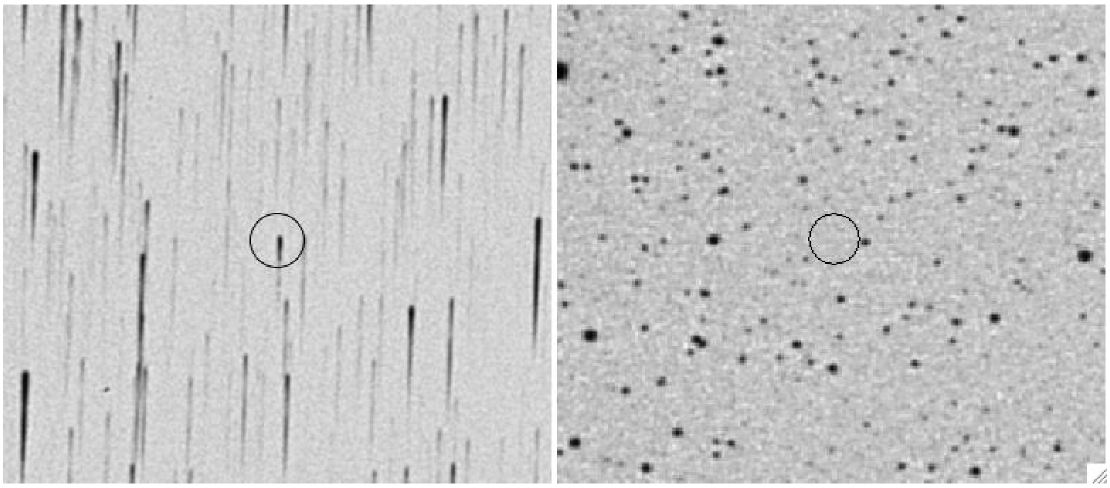

Figure 1: Left panel: Byurakan objective-prism plate n.936 taken in 1973 showing the C-type star FBS2213+421 (V 381 Lac) at B=15.6. Right panel: Asiago plate n.6394, taken in 1967 showing the field of the star, which was below the plate limit B=17.7 .

our archives we see that the star shows a well exposed spectrum in the Byurakan plate (1973) while it is not detectable in the Asiago direct image of 1967 shown in right panel of Fig 1.

We started checking the variability of our stars using the USNO-B1 catalog, based on the POSS I and POSS II surveys, in the B and R bands. The photometric accuracy of this catalog is not high, especially for stars partially saturated: form our experience a difference of at least 0.5 magnitudes is required to be sure of the star variability.

A few other digitized plates taken with the Palomar 120/180/307 cm Schmidt, besides those used for the Digital Sky Survey, can be retrieved from the Space Telescope Science Institute website (http://archive.stsci.edu/cgi-bin/dss-plate-finder/). To derive magnitudes also from these plates, we re-made the aperture photometry of our stars with IRAF/apphot on all the POSS plates, using some nearby (radius 4 arcmin) reference stars taken from the GSC2.3.2 catalog: for consistency, the same sequences were used also for the CCD photometry of our images from the Asiago and Loiano telescopes.

It is useful to have an estimate of the photometric reliability of the most used all sky catalogs. In our search we tested the USNO-A2, the USNO-B1 and the GSC2.3.2. The new APASS (UCAC 4), still not covering the whole sky, may become a valid alternative in the near future, given that it is not based on photographic photometry but is entirely based on CCD images.

The photometric calibration of the DSS plates for the aforementioned catalogs was made on a plate-by-plate basis. Differences between catalogs are therefore expected to vary somehow from plate to plate: we report here the relations between catalogs for the field of V 381 Lac.
R(USNO-A2)=B(GSC)*0.86+2.63 (rms=0.27)
B(USNO-A2)=B(GSC)*0.80+2.71 (rms=0.43).

The correlation is very good, but for the R magnitudes there is a small deviation from a straight line for the bright (R<13) stars. Indeed using only GSC2 stars with R<15 (35) the slopes become more near to the ideal slope 1.
R(USNO-A2)=R(GSC)*0.99+1.77 (rms=0.26)
B(USNO-A2)=B(GSC)*0.83+2.34 (rms=0.36)

The comparison with USNO-B1 is the following:
R1(usno)=R(gsc)*1.03-0.49 (rms=0.23)
R2(usno)=R(gsc)*1.02-0.12 (rms=0.27)
B1(usno)=B(gsc)*0.99+0.08 (rms=0.28)
B2(usno)=B(gsc)*0.96+0.94 (rms=0.42)

Comparison between the USNO-A2 and USNO-B1 is good, with systematic deviation for bright stars (B<15).

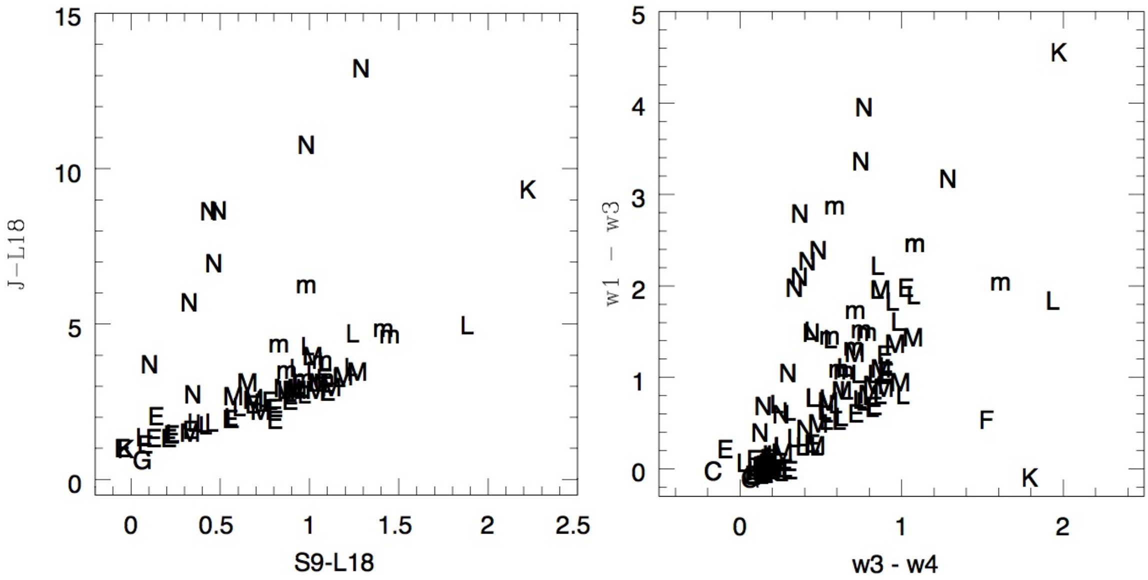

Figure 2: Left panel: AKARI-Jband color-color plot of the sample stars. L=M5 and later; E=Earlier than M5; N=N-type stars; C= CH stars; M=generic M-type stars; m=Mira variable; K and F mark peculiar stars. Abscissa AKARI S9-L18 magnitude difference; ordinate J-AKARI L18 magnitude difference. Right panel: WISE color-color plot; abscissa W3-W4, ordinate W1-W3.

B1(usno)=B(a2)*1.23-3.18 (rms=0.33)
B2(usno)=B(a2)*1.16-1.90 (rms=0.38)

Further sources of photometric data are the recent sky surveys for NEO or GRB, like the Catalina Sky Survey at Caltech (Drake et al. 2009; http://nesssi.cacr.caltech.edu/DataRelease/) or the NSVS (Wozniack et al. 2004; http://skydot.lanl.gov/nsvs/nsvs.php).

We checked the zero-point consistency of the magnitude scales of these Surveys with the GSC2.3.2 catalog, using some stars which appeared to be nearly constant in the Surveys. It is worth to remember that the NSVS data were obtained with an unfiltered CCD, so that the quantum efficiency of the sensor makes the effective band most comparable to the Johnson R band (Wozniak et al. (2004)), or better a mix of V and R colors, which is a function of the spectral type of the star. To inter-calibrate the NSVS and our magnitudes we used the stars in our sample with a very stable NSVS light curve. We found that a reliable calibration would require a bigger set of non variable stars in the M0-M8 spectral types range to define a better color correction. In fact, we verified that for M8 stars, which emit most the photons in the IR tail of the unfiltered detector, the ROTSE instrumental magnitude are generally brighter than for M1-type stars of similar R magnitude. In any case, even with this caveat, our data have been useful to confirm the variability/stability of the stars of our sample.

4 Color selection

As supplementary diagnostic for stellar classification we used IR photometry by applying the color–magnitude and color–color diagrams to data downloaded from several ground based and satellite surveys.

We checked among the different color-color plots which can be made using the AKARI, WISE, 2MASS fluxes of our sample stars if there are good photometric discriminants between Carbon rich and Oxygen rich objects. Extensive work on these tools has been made by Ishihara et al. (2011) and Xun Tu & Zhong-Xian Wang (2013). Here we present preliminary results using different color choices. Two examples are reported in Fig. 2. The left panel shows that the J-L18 color index, coupled with the AKARI S9-L18 index provides a very good selection between Carbon stars, Nitrogen stars and normal M-type stars.

Several useful diagrams can be obtained from the combination of the WISE colors: in this paper we selected the 3.4-12 μm (w1-w3) *vs* 12-22μm (w3-w4). This diagram is the best among the WISE ones to discriminate the different types of stars, establishing a well defined sequence of locations for variability class and separating all the Carbon from the M stars. The right panel of Fig. 2 shows how our sample stars are located in this color–color plot.

As a further check we looked also at the IRAS catalog to locate our sources in the classical [25]-[60] vs [12]-[25] color–color plot. The agreement with the work by van der Veen and Habing (1988) is poorer than expected. The most probable reason of some strong discrepancies might be the large uncertainties of the fluxes reported in the IRAS catalog for several of our stars, suggesting to use great caution in the application of this plot.

5 Conclusions

Photographic archives can still contribute to high quality science, provided that they can be easily accessed from the web. A fast consultation of images, even if of not high quality, may indeed help the researcher to have a quick response and decide if further investigation is worth to be made.

The technology of plate scanners is rapidly evolving, as well as the availability of very massive electronic storage at low price, so the task of digitization is easier than just 10 years ago. A good storage of the original photographic material is therefore important, because in few years better scanners may be available allowing more accurate data retrieval.

Putting on line at least the logbooks of the plate archives is mandatory making the old photographic data accessible and efficiently used.

Acknowledgements This publication makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration.

We thank the Directorate of the Loiano and Asiago Observatories for telescope time allocation

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Unveiling the nature of red novae cool explosions using archive plate photometry

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Abstract

Based on archive photographic photometry and recent CCD photometric data for red novae V4332 Sgr and V838 Mon, we established their stellar composition, exploded components, and the nature of explosions. Low temperature in the outburst maximum is due to quasi-adiabatic expansion of a massive stellar envelope after the central energy surge preceded the outburst.

Keywords: binary systems, mergers, red novae stars; individual: V4332 Sgr, V838 Mon

Red novae are the stars erupting into cool supergiants [1]. There are images of progenitors for red novae V4332 Sgr and V838 Mon in Moscow and Sonneberg plate collections. The first star is an age-old object seen at the latitude of –9.4° and located in the Galactic bulge or in the thick disk, the second one is a young object associated with the cluster of B type stars and the dust environment located at the distance of 6.1±0.6 kpc.

Three pairs of deep one-hour exposures in *B* and *V* bands of V4332 Sgr were taken with the meniscus 50 cm Maksutov telescope AZT-5 of the SAI Crimean Station between 1977 June and 1986 June. For V838 Mon we have 148 *B*-band plates suitable for eye estimates, dated between 1928 and 1994 and taken with identical 40 cm astrographs in Sonneberg and Crimea. 57 of them are good for digitization and accurate measurements. In addition, there are 50 *V*-band plates obtained with AZT-5, all are good for measurements. Emulsions of AGFA and ORWO ZU-21 (Germany) were used to reproduce the *B* band with the 40-cm astrographs, the ORWO ZU-21 was used with the BS-8 filter at AZT-5 to cut the ultraviolet part of a spectrum. The Kodak 103aD emulsion (USA) with the GS-17 filter was used to fit *V* band at the AZT-5. So, the observations were performed in the standard bands of Johnson *UBV* system.

To digitize plates, the Eastman Kodak CREO scanner of the Sternberg Institute was used. Scanner output images in TIFF format were transformed to BITMAP by MaxIm DL software with changing cuts. Additionally we used the FinePix F10 FujiFilm camera in gray mode with an ordinary convex lens, and transformed its JPEG images to BITMAP with MS Paint. The last method of digitization can't be used for wide fields due to lens distortion, but it is as good for a single star with outskirts as CREO scanner. Self-focusing and very short exposures of the FinePix

F10 camera allow shooting without support stands. So, this method may be widely used by students and amateurs. Digital BITMAP images were reduced with Goranskij's software WinPG, the characteristic curves were plotted with 17 to 23 comparison stars and approximated with the 1st or 2nd order polynomial. The mean squire residuals are in average of $0^m.08 - 0^m.12$, but vary in the range of $0^m.04 - 0^m.23$ depending on the size of emulsion grains that is typical for photography.

The historical light curve of V4332 Sgr in the *B* band based on DSS and AZT-5 plates, and modern CCD data is shown in Fig. 1. The outburst is not plotted. The progenitor was a binary of a blue and a red star. The *B*-band data along with other filters shows pre-outburst brightening similar to that one detected in V1309 Sco by OGLE [2]. After the outburst, the brightness level fell down due to disappearance of an exploded blue companion. The second brightness decay happened between 2006 and 2008, and accompanied by the temperature drop of a red M-type star by 1000 K.

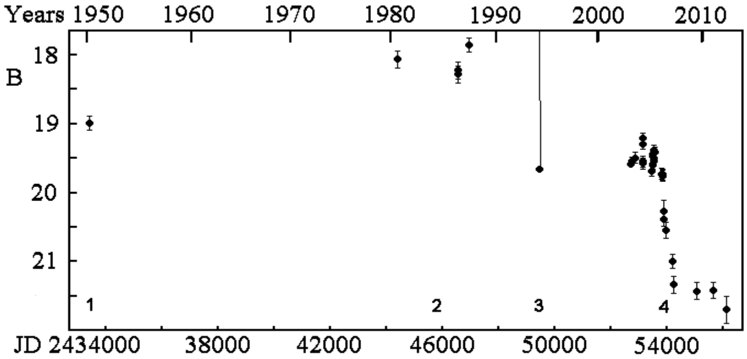

Figure 1. Historical light curve of V4332 Sgr in the *B* band. The main points of the evolution are marked. 1 – POSS I. 2 – AZT-5 + POSS II; brightening before the outburst. 3 – The outburst. 4 – The light and temperature decay of an M-type star after the outburst.

The historical light curve of V838 Mon in the *B* band based on archival plates, and on modern CCD data is given in Fig. 2. The outburst is not presented in this Figure, too. Our photometry does not show any significant variability of the progenitor but reveals that it was a binary of B-type stars. It weakened by $0^m.461$ *R* in 1998, 4 years before the outburst [3]. In October 2002 the explosion remnant became so cool (1200 K) that its radiation was not visible in *UBV* bands, where the light of the B3V star, survivor of the explosion was dominating. Having known magnitudes of the companion and the progenitor, we determined magnitudes of the exploded star. It was a B3V star, too, and it was brighter than its companion by 36 per cent. In December 2006 the explosion remnant evolved to M-type giant, and in its approach, the B3V companion disappeared totally for 70 days in all the photometric bands, what allowed us to measure its *UBVRI* magnitudes. In 2007 we observed a submergence of the companion into the remnant. During 200 days the hot companion moved in the void under an exterior shell of the remnant, and the radiation of the companion was absorbed by a factor of five. Then in 2008 it disappeared, and was not visible up to present time.

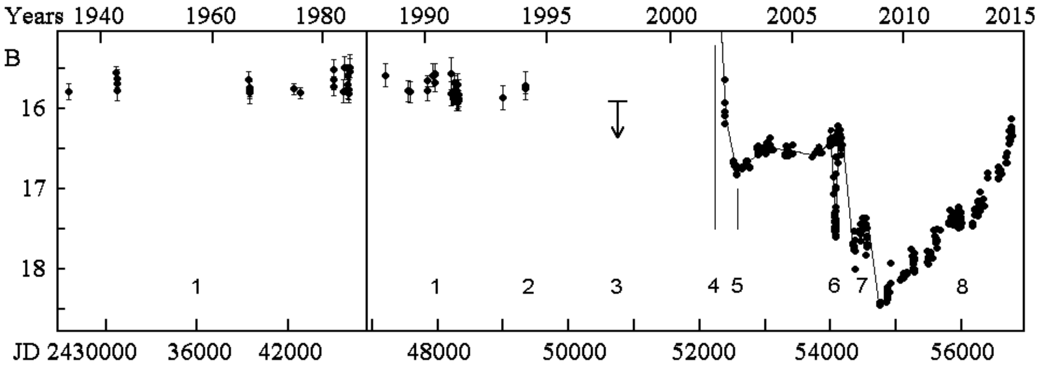

Figure 2. Historical light curve of V838 Mon in the *B* band. Main phases of the evolution are noted. 1– Progenitor, the pair of B3V stars. 2 – Stop the astro-plate production. 3 – Kimeswenger & Eires found a decay in the *R* band. 4 – Outburst of the brighter B3V star in the binary. 5 – B3V companion is only visible in the *B* band. 6 – The eclipse. The B3V companion vanished for 70 days. 7 – The B3V companion moving in the void is visible through the shell. 8 – The B3V companion plunged into the M-type remnant.

Finally, we were able to determine the spectral energy distributions (SED) of progenitors and remnants of both red novae (Fig. 3). We found that in V4332 Sgr SEDs (Fig. 3, left), the continuum of the M giant was visible both before and after the outburst, and it was stronger and hotter when it was closer to the outburst in time. We inclined to treat the explosion in V4332 Sgr as a merger event in a blue straggler which might be a contact binary in a system with the M giant. We think that brightening of M star is connected with the accretion of matter onto its surface in the stages of forming common envelope of the binary and of a dynamical destruction of the merger remnant.

To extract SEDs of V838 Mon components from the common light of the binary, we measured the light of each component lost in the eclipse or after the explosion. The SED of the exploded star (central one of the three in Fig. 3, right) was determined as a difference of the progenitor's SED and the survived B3V companion's SED. The SED of exploded star is compared with the SED of HD 29763 (B3V). With the known distance, it is found to be located in the zero-age main sequence of the Temperature – Luminosity diagram. The exploded component of the system was a young star with $R = 2.9\ R_{\odot}$, $L = 1020\ L_{\odot}$, $\log T_e = 4.29$. Its companion is a lower luminosity star having $R = 2.5\ R_{\odot}$, $L = 740\ L_{\odot}$ and the same temperature. There is no evidence of binary nature or merger for the exploded star in V838 Mon. In addition, we established that the radius of the remnant at the first appearance in the outburst with K0 I spectrum was equal to 327 $R_{\odot}$, and that the exploded star's envelope had undergone pre-outburst expansion in the conditions close to adiabatic which continued at least four years. The central energy surge causing a slow shock to massive star envelope is a reason of cool explosions of red novae [4].

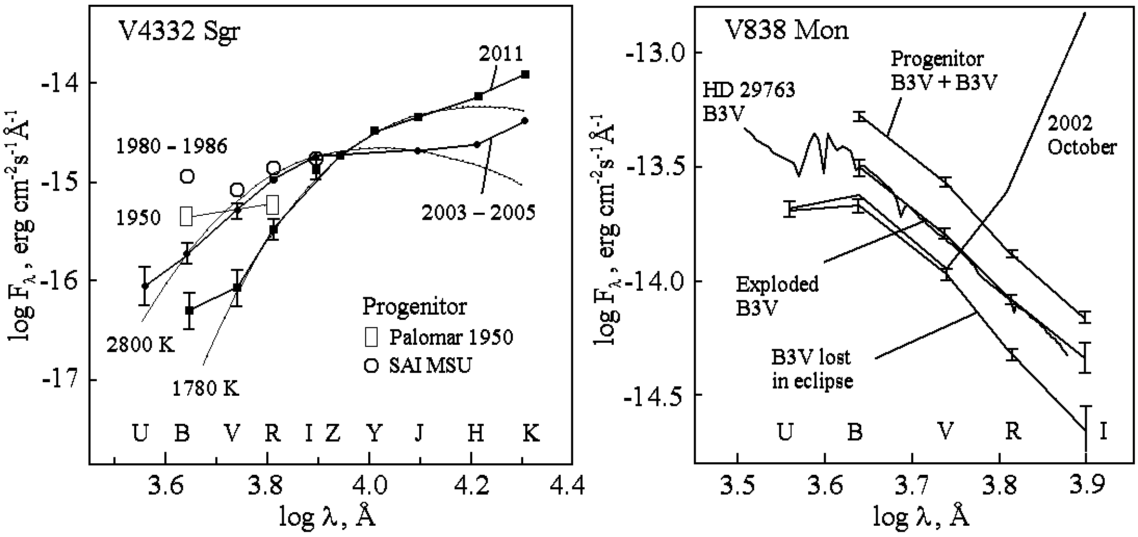

Figure 3. Spectral energy distributions (SED) of V4332 Sgr (left) and V838 Mon (right). All SEDs are corrected for interstellar reddening. Empty signs in V4332 Sgr SED are photographic observations of the progenitor, black signs and lines mark M-type star continuum without emission-line contribution. Blackbody fitting is also shown. SEDs extracted from the common light of V838 Mon (right). The following SEDs are given: the progenitor binary (top), the exploded component before its explosion compared with the SED of HD 29763 (B3V) (middle), and the B3V companion (bottom). The two-component SED of the binary with the cool remnant in 2002 October is also shown.

In a massive star experienced such an energy surge, the radiation transfer time exceeds its dynamic expansion time by many orders of value, so the explosion energy is concentrated in the bottom of the expanding envelope. The surface area of the envelope becomes very large when the radiation reaches it, and the explosion energy is insufficient to heat the star surface to a high temperature. Reasons of such energy surges may be both the merger of stellar nuclei after forming a massive common envelope in a contact binary, and the instability in the nucleus of a massive young star. So, the red nova phenomenon is representative of both old and young stellar populations.

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Historical light curve of the black hole binary V4641 Sgr based on the Moscow and Sonneberg plate archives

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Abstract

We performed digital processing of a large set of photographic plates for the X-ray binary system V4641 Sgr containing a black hole. A total of 277 plates were found in archives dated between 1960 and 1992. Photographic observations revealed lower level of outburst activity if to compare with CCD data after the large 1999 outburst. Only single outburst which happened in 1978 was confirmed. If archive photographic data are used along with contemporary CCD observations, the orbital period may be improved, and its value is 2.81728 ±0.00004 day.

Keywords: photometry, X-ray binaries, black holes; individual: V4641 Sgr

Introduction

V4641 Sgr is a system containing a B9–A0 III star with the mass of 2.9 ± 0.4 $M_{\odot}$ and a black hole of 6.2 ± 0.7 $M_{\odot}$ [1]. The orbital period of the system is P = 2.81678 day [2]. Its distance is 6.2 ±0.7 kpc [1]. The star was discovered by Goranskij [3] during the 1978 outburst but at first it was misidentified with Luyten's variable GM Sgr, a Mira type star [4]. At the beginning of 1999, V4641 Sgr was detected in X-rays as SAX 1819.3–2525, and later, in 1999 September it experienced a large outburst in all ranges of electromagnetic wavelengths and reached magnitude of $8^{m}.9$ in *V* band. In this event, relativistic jets were detected with the VLA radio interferometer [5]. The orbital period was improved in [6] by using photometry. Photometric observations show active states and outbursts, short-time flaring in the scale of seconds, a temporal appearance of the reflection effect [7,8,9]. Spectroscopy reveals changes in the profiles of Balmer lines and other manifestation of the black hole activity.

Archive search

We found 266 plates of V4641 Sgr in the Moscow plate collection of the Sternberg Astronomical Institute taken with 40 cm astrograph of SAI Crimean Station which are dated between 1960 and 1992. Typical exposures were of 45 minutes. The photographic observations were ended in 1992 as the production of astronomical plates was stopped. Partially, the star was estimated by eye on the basis of this set [4]. Additionally, 11 plates were found in the Sonneberg collection. Plates were taken between 1984 and 1988 with the similar astrograph. The exposure time of these plates were 30 minutes. All the plates were produced by AGFA/ORWO factory in Germany. Plates are sensible to blue light and realize Johnson *B* band well. The region of the variable star in these plates including close outskirts with comparison stars was digitized using a simple convex lens and FinePix-10 FujiFilm camera in the grey mode. This camera is self-focused on each frame, and it is sensible enough to take sharp and clear images with small exposures without any support stand. The frames in JPEG format given by the camera were transformed to BITMAP files, and reduced with the WinPG software developed by V. Goranskij. We used 17 comparison stars. Characteristic curves were fitted with the first or second order polynomial. The accuracy of the fit calculated as mean-squire residual from the polinomial varies between $0^m.03$ and $0^m.20$, mean value is $0^m.08$. Since 1994, we continued photoelectric and CCD observations with different telescopes and devices. CCD observations are performed up to now. So, our time set of V4641 Sgr continues about half century.

Results

The total light curve of V4641 Sgr in the *B* band is presented in Fig. 1. In the period between 1972 and 1992, only single 1978 outburst was detected, this is the outburst which led to the discovery of the star. In the peak of the 1978 outburst, the star reached $12^m.12$ *B*, and subsequent decay continued about 2 days. Additionally, a short-time outburst of V4641 Sgr with the 5.87 day decay in 1901 is found by J. Grindley and colleagues based on the Harvard collection, and an episode of bright state on June 28, 1965 is caught by R. Hudec and his colleagues using the Bamberg archive. The last two events were reported at this workshop. It is necessary to notice that the object was not detected in X-rays before the outburst in 1999. After the strong 1999 outburst, the optical outbursts became frequent. They repeated in 2002, 2003, and 2004. Object appeared in X-rays also in 2008, 2010, and in 2014.

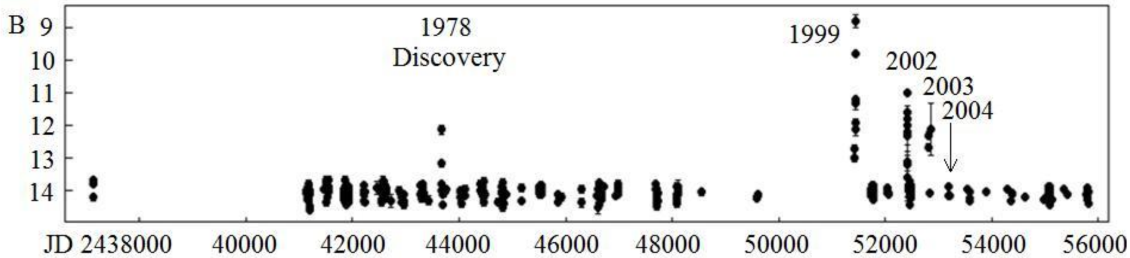

Figure 1. Historical half-century light curve of V4641 Sgr

Frequency analysis with the phase-dispersion minimization method [10] gives the best period $2^d.81728 \pm 0^d.00004$, and the double-wave light curve with unequal minima depths. The deepest minimum coincides with the black hole inferior conjunction. The date of conjunction is JD Hel. 2451764.337 ±0.005. The light curve plotted versus phase of this period is given in Fig. 2. The averaged orbital light curve with the amplitude of $0^m.45$ in the primary minimum demonstrates the greatest observed ellipsoidal effect of stellar component. The depth of the secondary minimum is $0^m.28$.

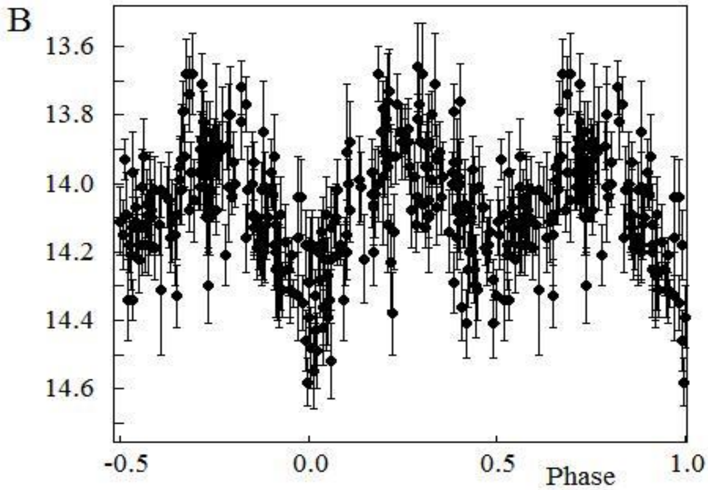

Figure 2. Photographic light curve of V4641 Sgr plotted versus the orbital phase. A primary minimum corresponds with the inferior conjunction of the black hole.

We performed CCD *B*, *V* and R_C monitoring of V4641 Sgr in 16 nights between June 5 and 25, 2007 using SAI Crimean Station 60-cm telescope and SAO 1-m telescope [9]. These observations (Fig. 3) show essential light excess over the quiet light level, visible only in the orbital phases between –0.25 and +0.25 with the maximum value of 0.15 mag in the *V* band at the black hole inferior conjunction. The excess is absent in other orbital phases. This phenomenon has not been observed previously. We explain it as an irradiation of the area of A0 type star facing to the black hole. The area re-emits weak X-ray radiation of the black hole to optical bands. At the same time with the reflection effect the radiation at 0.5–10 keV was detected by Swift XRT at the level of $(1.2–2.1) \cdot 10^{-11}$ ergs/cm^2/s [11].

On July 11, 2001, near the inferior conjunction of the black hole, we carried out the spectroscopic observations of V4641 Sgr with the Russian 6-m telescope in order to view the black-hole surroundings against the stellar disk of the normal component. A depression with equivalent width EW = 0.5 A was observed in the red wing of the Hα profile with the maximum absorption at the heliocentric velocity of 642 km/s [8]. We suggested that this gas stream could be a part of a rarefied gaseous disk around the black hole, in the system's orbital plane. Assuming that the flow is moving through the circular Keplerian orbit around the black hole, the mass of the black hole is determined as M_{BH} =7.1− 9.5 $M_{\odot}$, what overlaps the mass range given by Orosz et al. [2].

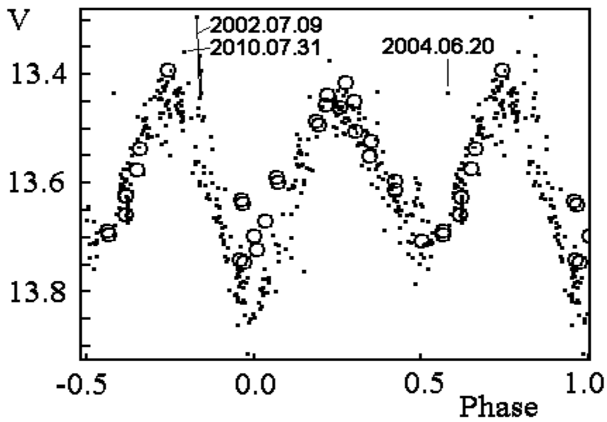

Figure 3. Appearance of the reflection effect in May 2007 (blank circles) in the *V* band. Swift detected a weak and variable X-ray radiation. Short solid lines mark splashes of an optical radiation.

We explain the deeper minimum in the light curve at the phase of the black-hole inferior conjunction as an extreme case of fon Zeipel effect at the surface of the optical companion faced to the black hole due to very low gravity at this area of the star. This effect is clearly recorded with our photographic observations. Photographic observations revealed lower level of outburst activity compared with CCD data after the large 1999 outburst. Unfortunately, such low-amplitude effects as X-ray irradiation and rapid flaring in the scale of seconds are lost due to errors of photographic observations and long-time exposures.

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Astronomical plates at the Observatoire de la Côte d'Azur

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Abstract

The *Observatoire de la Cote d'Azur*, formerly *Observatoire de Nice*, owns a collection of 8 200 astronomical photographic plates taken with a double Zeiss astrograph (1935 to 1978), and 3 600 plates from the Calern observatory Schmidt telescope (1978 to 1996). A general referencing operation for these plates is currently in progress, which includes archiving, preservation and documentation.

Keywords : preservation, Schmidt telescope, astrograph, asteroids, astrometry

1 Introduction

The *Observatoire de la Côte d'Azur*, formerly *Observatoire de Nice*, founded in 1879 has from the beginning dedicated an important part of its research to astrometry, in particular with the installation of a large meridian circle made by the Brunner brothers (1887) and then a Zeiss binocular astrograph (1931). In the 1970s, astrometry observations were enriched by the construction of a Schmidt telescope at the Calern observatory (some 60 km from the *Observatoire de Nice*). This observing site was administrated since 1974 by the CERGA (*Centre d'Etudes et de Recherches en Géodynamique et en Astrométrie*). In 1988, the CERGA and the *Observatoire de Nice* merged into the *Observatoire de la Côte d'Azur* (hereafter OCA). Nowadays, OCA owns collections of plates taken with its Zeiss astrograph and its Schmidt telescope, and also collections from other observing sites.

2 More than 11 000 plates over more than 60 years (1935-1996)

2.1 The binocular Zeiss astrograph

This instrument has been provided as war damages by the German optical manufacturer C. Zeiss. This twin refractive astrograph (see Figure 1) was installed at the *Observatoire de Nice* in 1935, on a massive German-style equatorial mount. Both optics have a focal length of 2 m and a diameter of 40 cm (aperture ratio: F/5). Since its first light in 1935, some 8 200 astronomical images have been taken on glass plates with various formats (9 x 12 cm, 13 x 18 cm, 16 x 16 cm, 18 x 24 cm, 24 x 30 cm, and 30 x 30 cm). The estimated limiting magnitude for these plates is Mv = 15 (V photographic magnitude). Mostly, two observing teams were involved: A. Patry (1902-1960) and M. Laugier (1896-1976), who produced some 2 700 plates from 1935 to 1961, and B. Milet, who produced 5 500 plates from 1965 to 1978. Most of these plates were done on Solar System minor objects. A Zeiss measuring machine was used for plate metrology.

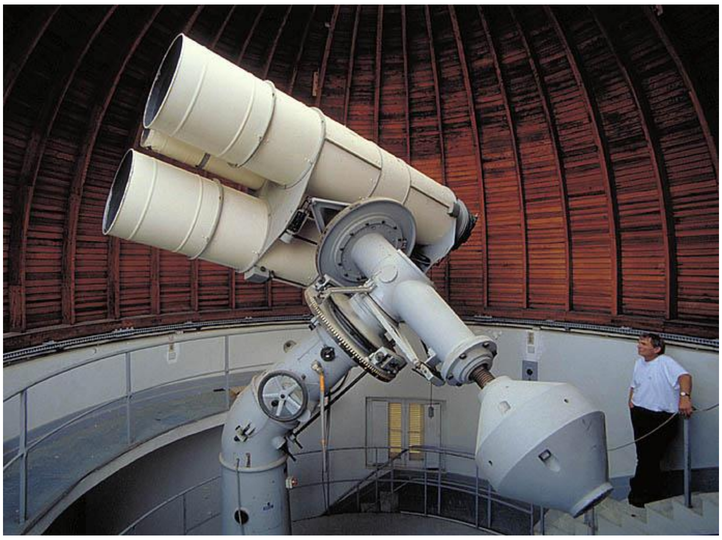

Figure 1: The Zeiss binocular astrograph at *Observatoire de Nice*. (Marc Heller © OCA).

2.2 The Calern observatory Schmidt telescope

This instrument, also known as "TESCA" (*TElescope de SChmidt de CAlern*), is a pure Schmidt camera with a 1.52 m spherical primary mirror with a focal length of 3.16 m [1]. The Schmidt lens is in fused silica and has a diameter of 90 cm. Both were polished by J. Texereau (1919-2014). The mount is a fork equatorial with oil film bearings. Between 1978 and 1996, the observing team (J.-L. Heudier, Ch. Pollas, A. Maury *et al.)* produced some 3 600 astronomical images on glass plates and soft film (30 x 30 cm). The estimated limiting magnitude for these plates is Mb = 20.1 (B photographic magnitude).

During those 18 years, several science topics were addressed:

- Solar System objects (search and characterization of asteroids and comets, satellites of major planets, construction of secondary catalogues for occultation programs, astrometry of minor objects).
- Stellar dynamics in clusters.
- Optical counterparts for gamma, UV, IR and radio objects detected by space-borne instruments.
- Supernovae and variable stars.
- Quasars, nebulas.
- Space debris location.

Figure 2: TESCA, the Calern observatory Schmidt telescope. (© OCA).

3 Astronomical images from other observing sites

The OCA historical plate collection has been enriched by several astronomical images (glass plates and soft films) from other institutes:

- 3 293 images on soft film (diameter: 17.5 cm) taken by the Schmidt telescope at Meudon observatory from 1961 to 1975 [1]. Estimated limiting magnitude: M = 16 (photographic magnitude).
- Few plates from the "*Carte du Ciel"* program taken at various observatories (Algiers and non- identified observatories). See *e.g.* Figure 3.
- Some 50 glass plates (meridian plates and solar images) taken by O. Calame in the 1960s at the Pic du Midi observatory.
- Some 450 plates with various formats (9 x 12 cm, 16 x 16 cm, 18 x 18 cm, 25,5 x 25,5 cm, and 30 x 30 cm), mostly from Ch. Veillet, taken at La Silla, CFHT, *Observatoire de Haute Provence*, *Observatoire du Pic du Midi*, and Chiran observing station. Studied objects: mostly Solar System planets (in particular Jupiter, Saturn, Uranus, Neptune, Pluto), nebulas, clusters, galaxies.

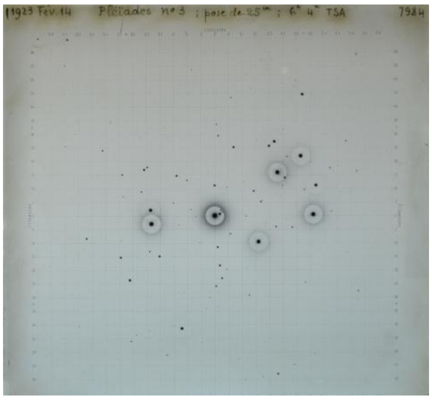

Figure 3: The M45 open cluster on a plate from the *"Carte du Ciel"* program, taken on February 14th, 1923 at Algiers Observatory. Firmed FG. Format: 16x16 cm. (© OCA)

4 A strong will to preserve this collection

In autumn 2012, an important protection operation was undertaken by the OCA through its Heritage service for the 16 000 photographic plates and films which were stored for several years in precarious conditions of preservation - very high and fluctuating relative humidity, unstable temperature, presence of dust - at the Calern observatory (the Nice astrograph plates had already been moved there during the 1990s). This operation involved two distinct phases:

- **Secured storage**. All the plates have been moved and stored in one single room (see Figure 4). An air-drying facility has been set up in this room and in the original places, to gradually change the air temperature and relative humidity, in order to avoid thermal shocks, and then, to maintain correct and stable preserving conditions. This operation involved tedious and delicate handling operations for more than 11 000 fragile plates. Specially designed containers have been constructed, to ease and secure the moving operations.
- **Classification and inventory of the plates** which were not inventoried (more than 8 000) before moving.
- **Plate preservation.** A quality control has been performed on sample plates randomly selected in each series of our collection. Most of the selected plates have revealed to be still well

preserved. These plates have been dry-cleaned to remove dust. Then, they have been inserted in neutral paper folders.

By now, all the 16 000 plates and films are stored in a controlled atmosphere in conformity with the standards given by the French National Archives and the CRCC – *Centre de Recherche sur la Conservation des Collections* [2] [3].

Figure 4: A new secured storage facility for astronomical plates at the Calern observatory. The complete OCA's plate collection has been moved there in February 2013. (© OCA)

5 General referencing operation

Such a collection of astronomical images would be of anecdotic interest without a thorough, accurate and accessible referencing system. For this sake, a general referencing operation has been launched in 2013 and is currently in progress. This important yet difficult and tedious task involves collaborations with several researchers to gather as much information as possible on these plates. A flexible and complete classification scheme has been designed and is under implementation in a database.

For the Zeiss astrograph collection, no inventory existed before 2013. All available observer's logs have been digitized and linked with plates. This concerns some 2 500 observing logs, about 1 500 celestial objects (asteroids, comets) on some 6 000 plates. See *e.g;* Figures 5 and 6 for a sample plate from the Zeiss astrograph, an its file in the database.

Plates from the Calern Schmidt telescope (Figure 7) have already been inventoried by Ch. Pollas (TESCA team). These data have to be integrated in the database.

Plates from other collections are currently been inventoried, in order to ease their future integration in our plate database.

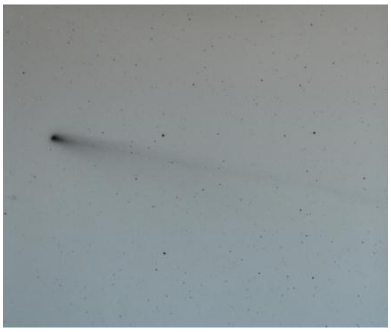

Figure 5: West Comet. Plate n° 4406 taken by B. Milet on March 25.16724, 1976. Format: 16x16 cm. (© OCA)

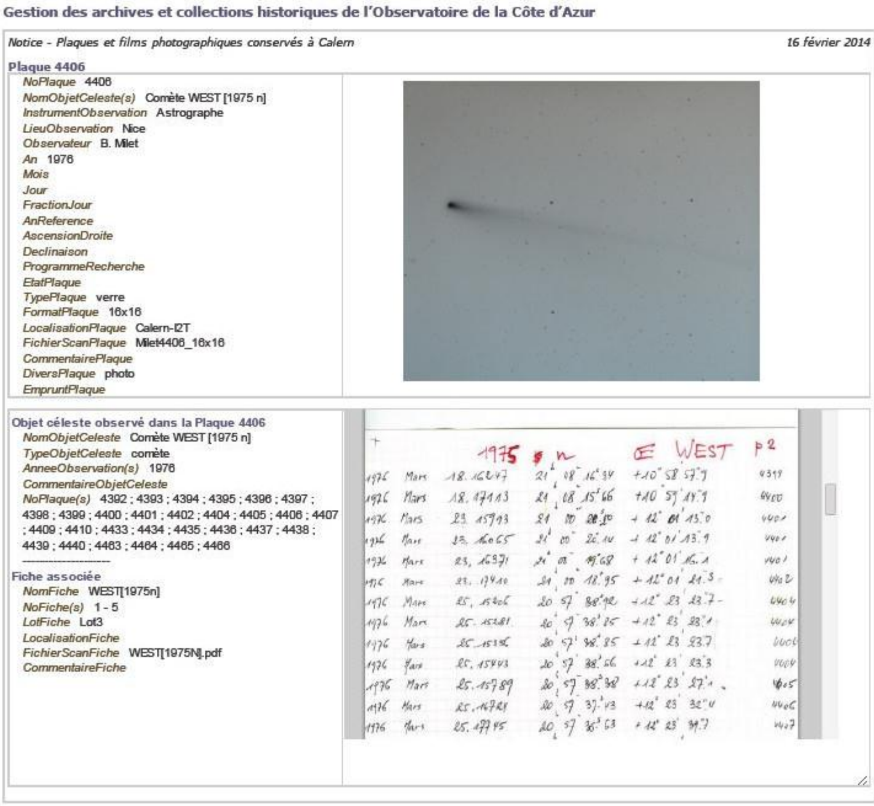

Figure 6: Database issue corresponding to the plate in Figure 5. (© OCA)

Figure 7: Film n°3400 taken by TESCA team with the Calern Schmidt telescope. On May 28th, 1995. Format: 30x30 cm. (© OCA)

6 Prospective

Preserving and referencing astronomical plates in such a collection is only the first step in a long process that we expect to end by some scientific exploitation. The preserving effort has to be continued (end of reconditioning, the quality of the plate needs to be checked frequently). The referencing effort has to be pursued and refined. The next step will be a long-term operation of high resolution digitization of the most valuable plates (if not all), to make this scientific information easily and flexibly accessible to researchers. The last step will be the scientific exploitation itself by astronomers from OCA (some of them are deeply involved in the GAIA program, and thus interested in astrometry and proper motion determination, for example) or from other institutes (IMCCE, *Observatoire de Paris*,…).

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Byurakan Astrophysical Observatory plate archive and its scientific usage

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Abstract

The Byurakan Astrophysical Observatory (BAO) has one of the richest collections of observational data. Several telescopes have worked in photographic mode for dozens of years during 1947-1991 and left dozens of thousands direct images, thousands of objective prism plates and thousands of spectra on films. BAO is especially known for its famous surveys; the First Byurakan Survey (FBS, Markarian survey) is a unique material, some 2000 objective prism plates, each containing some 15,000-20,000 low-dispersion spectra, as well as Second Byurakan Survey (SBS) and some other surveys are available. BAO Plate Archive was organized in 1986 and since then most of the plates have been collected, altogether 37,500 plates. The FBS was digitized and the DFBS spectroscopic database was created, as well as several other sets of plates and films were scanned. A number of science projects have been and are being accomplished using the archival data, such as optical identifications of IR sources, study of Solar System objects (comets, asteroids), spectral classification of objects using film spectra, search and study of variable objects (stars, blazars), high proper motion stars, etc.

Keywords: surveys, plate archives, digitization, asteroids, blue stellar objects, blazars.

Introduction

The Byurakan Astrophysical Observatory (BAO) is the largest one in the Middle East region. It was founded in 1946 by the outstanding scientist V.A. Ambartsumian (1908-1996). Optical telescopes were installed and operated at BAO in several modes since 1947, and radio telescopes, since 1951. BAO possesses one of the biggest Schmidt telescopes in the world, 40″ Schmidt and at present a medium-size, but at the moment of its installations one of the largest optical reflectors, ZTA-2.6m. There are several other historical telescopes as well, including 21″ and 8″ Schmidt telescopes, 51 cm and 41 cm reflectors, etc. BAO has one of the richest collections of observational data. Several telescopes have worked in photographic mode for dozens of years during 1947-1991 and left dozens of thousands direct images, thousands of objective prism plates and thousands of spectra on films. BAO is especially known for its famous sky surveys and objects discovered from them (Markarian, Arakelian and Kazarian galaxies, Shahbazian groups of galaxies, Parsamian cometary nebulae, flare and T Tauri stars, Byurakan-IRAS Galaxies and Stars, etc.). The First Byurakan Survey (FBS, Markarian survey) is a unique material, some 2000 objective prism plates taken during 1965-1980 at high galactic latitudes ($|b|>15°$) of the Northern sky and part of the Southern sky ($\delta>-15°$), each containing some 15,000-20,000 low-dispersion spectra, as well as Second Byurakan Survey (SBS) and some other surveys are available.

BAO Plate Archive

BAO Plate Archive was organized in 1986 and since then most of the plates have been collected, altogether some 20,000 plates. In addition, there are many photographic spectra taken on films (2.6m telescope, UAGS), electrophotometric and polarimetric observations registered on papers, etc. Table 1 shows all BAO telescopes with their main characteristics, years of work in photographic mode, main methods of observations and total number of obtained plates. Altogether there should be 37,500 plates, however, some were taken in frame of collaborative programs and were taken to other observatories, and many still are at observers' personal archives.

Table 1. BAO telescopes and their observational material.

Telescope name	**Size** (cm)	**Years**	**Observ. methods**	**Plates**
5" double-astrograph	13	1947-1950	Photometry	3000
6" telescope	15	1947-1950	Photometry	3000
8" Schmidt	20/20/31	1949-1968	photometry	4500
20" Cassegrain	51/800	1952-1991	electrophotometry	–
10" tel.-spectrograph	25	1953-1960s	spectra	–
nebular spectrograph		1954-1960s	spectra	–
16" Cassegrain	41/400	1955-1991	electropolarimetry	–
21" Schmidt	53/53/183	1955-1991	photometry	12500
40" Schmidt (AZT-10)	102/132/213	1960-1991	photom., spectra	7500
ZTA-2.6m	264/1016	1975-1991	photom., spectra	7000
All telescopes		**1947-1991**		**37500**

Digitization projects

We have created a digital database for all BAO observing journals so that there is an access to any observation by dates, telescopes, observing methods, instruments (prism, spectrograph, etc.), project names, project PI and observers, targets and coordinates. For all plates, also receivers, emulsions, filters, seeing, scales, spectral ranges, spatial and spectral resolutions, limiting magnitudes are given, as well as a list of all observational programs has been compiled providing information on the PI, project name, years, number of nights, number of obtained plates, and links.

The FBS is the largest project by its scientific importance and was digitized in 2002-2005 using Epson Expression 1680 Pro scanner. Altogether 1874 plates were scanned with 1.542″ sampling (pixel size 15.875μ), astrometric solution software was run for all of them and 1″ rms accuracy was obtained. Each spectrum is 107×5 pixels, each plate is 9601×9601 pixels and the corresponding file is 176 MB large. A dedicated software bSpec was written by G. Cirimele, allowing extraction and analysis for all DFBS spectra (Mickaelian et al. 2007; 2010; Massaro et al. 2008).

We have used the same scanner for digitization of BAO-2.6m telescope spectra obtained with UAGS. These are some 700 spectra for FBS blue stellar objects for their spectroscopic classification and study. Some more 400 spectra for FBS late-type stars have also been scanned. Fig. 1 shows how the photographic film spectra have been digitized and put in a standard format, so that automatic software allows find their positions for reduction.

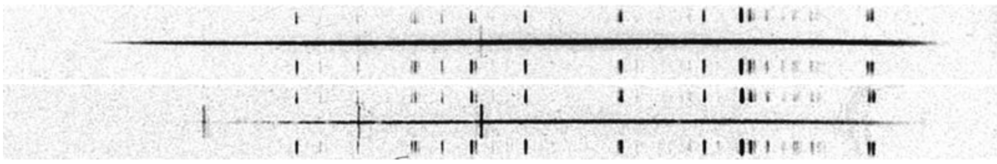

Fig. 1. Photographic film spectra of the FBS blue stellar objects taken by UAGS spectrograph at 2.6m telescope and digitized in a standard format.

Another digitization project was the scanning of 189 plates obtained with BAO 0.5m and 1m Schmidt telescopes by "chain images" method, when the position is slightly shifted after each exposure to obtain a chain of images for each objects for further comparison and discovery of variability. These plates were obtained in Coma field for search for flare stars. Some 1200 exposures are present and the scanned images allow comparing the brightnesses (Fig. 2).

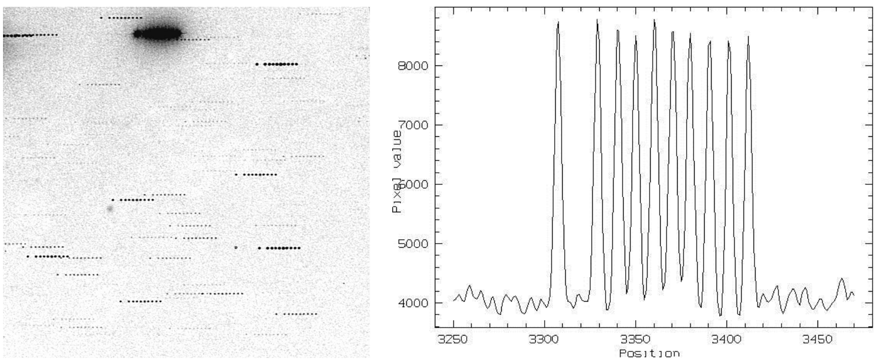

Fig. 2. Photographic plate taken with BAO 0.5m Schmidt telescope by method of "chain images" and a scan of such chain showing the changes of brightness of a given object.

Science projects based on BAO Plate Archive

A number of science projects are especially useful based on archival data, typically related to variability or motions of objects, i. e. using advantages of having observations in various epochs:

- optical identifications of X-ray, IR, and radio sources (Hamburg-ROSAT Catalogue, Zickgraf et al. 2003; Byurakan-Hamburg-ROSAT Catalogue, Mickaelian et al. 2006; Byurakan-IRAS Galaxies (BIG), Mickaelian & Sargsyan 2004, Byurakan-IRAS Stars

(BIS), Mickaelian & Gigoyan 2006; Spitzer 24μ excess bright stars in Boötes and FLS areas, Hovhannisyan et al. 2009, etc.),

- study of small bodies of the Solar System (comets, asteroids; e. g. revision of ephemeris of asteroids using various observations, search for new asteroids using objective prism spectra, etc.; Berthier et al. 2009),
- spectroscopy of objects using film spectra (Sinamyan & Mickaelian 2009),
- variable objects (variable stars, blazars, e. g. Erastova 2004),
- high proper motion stars (e. g. Gigoyan & Mickaelian 2007).

Several similar science projects have been conducted based on BAO Plate Archive. Optical identifications of 1278 IRAS point sources have been carried out using the FBS/DFBS spectra, as well as DSS1/DDS2 images and available data in other catalogues. While direct images only give an understanding about the position, brightness and extension of objects, the spectra indicate the nature of objects based on the spectral energy distribution, colour, broad absorption and emission lines, etc. Byurakan-IRAS Galaxies (BIG, Mickaelian & Sargsyan 2004) and Byurakan-IRAS Stars (BIS, Mickaelian & Gigoyan 2006) samples have been created. BIG objects contain many active galaxies (both AGN and starbursts) and high-luminosity IR galaxies (ULIRGs) and BIS objects contain Mira and semi-regular variables, late-type (K, M, C) and other interesting stars.

We have carried out search for asteroids spectra in the DFBS. In our project, asteroids were divided into two groups: 1) fast asteroids, which have been moved during the exposure time (20 min) and which have extended spectra showing the direction of motion and 2) slow asteroids, which have star-like (Solar) spectra and may be only found if previously known. VO software SkyBOT (Berthier et al. 2006) was used to detect the positions of asteroids for the given epoch for each plate. Both revision of ephemeris of known asteroids using the DFBS observations and search for new ones using extended spectra were accomplished (Berthier et al. 2009). Fig. 3 shows two cases of asteroids spectra in the DFBS: 104 Klymene and 288 Glauke, both showing extended spectra.

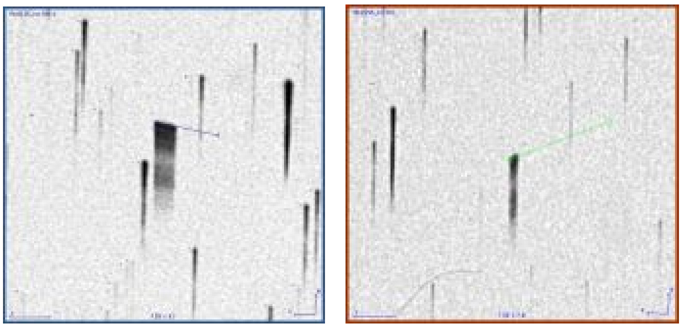

Fig. 3. DFBS spectra of two asteroids (left: 104 Klymene, right: 288 Glauke) showing their motion during the exposure time (20 min) and distinguishing them among the stellar spectra.

FBS blue stellar objects (BSOs) were observed with the 2.6m telescope and UAGS spectrograph to reveal their physical types and study them in detail. Some 700 medium resolution spectra were obtained. These spectra were digitized and classified (Sinamyan & Mickaelian 2009). Many new white dwarfs (WD), hot subdwarfs (sd), cataclysmic variables (CV), planetary nebulae nuclei (PNN), horizontal branch B stars (HBB), as well as QSOs and Seyferts have been found. Fig. 4 shows the digitized UAGS spectra extractions for FBS BSOs.

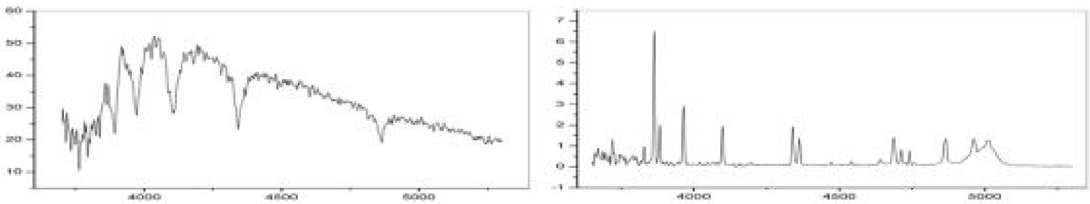

Fig. 4. Photographic film spectra of the FBS blue stellar objects taken by UAGS spectrograph at 2.6m telescope and extracted from 2D scans (WD and PN).

A project to study the long-term variability of the blazar ON 231 was conducted. It appeared that in BAO Plate Archive there were 189 plates taken by L.K. Erastova during 1969-1976 in the Coma field to search for flare stars using the “chain images” method, so that some 1200 photometric measurements were taken for each object in the field. ON 231 is in this field and a unique opportunity appeared to follow its long-term variability (Erastova 2004). Fig. 5 shows the magnitude changes and mean magnitudes for each year of observations.

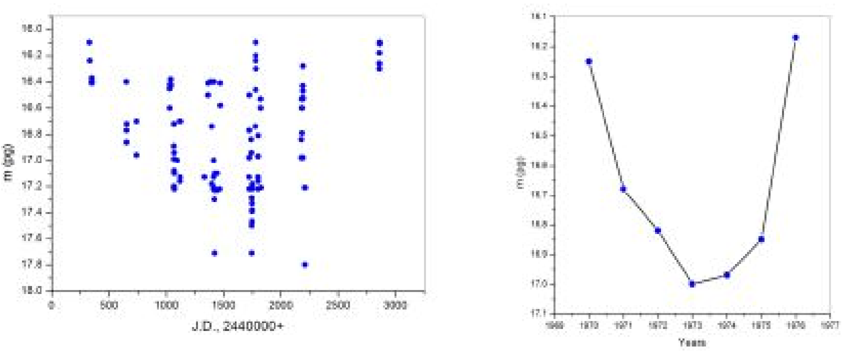

Fig. 5. Long-term variability of ON 231: mean data for each JD (left) and mean magnitudes for each year (right).

At present a project of further digitization of BAO Plate Archive is being undertaken following the priorities according to important science projects. A sky map will be created showing all Byurakan observations and projects carried out in various areas. The combination of various observing methods, areas, epochs and wavelengths may still lead to new science projects and discoveries.

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Improvement of the orbital period of the symbiotic binary FG Ser by using archival photographic and new photoelectric observations

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Abstract

The archival photographic and new photoelectric observations of the symbiotic star FG Ser were used to find a more precise value of the orbital period, $P = 629.4 \pm 1.0$ days. This study is an example of how the archival data can provide a valuable contribution to the long-term light curve analysis

Keywords: photometry, symbiotic star, orbital period

1 Introduction

The photographic archive of the Sternberg Astronomical Institute of the Moscow State University (SAI MSU) contains more than 50,000 photographic plates obtained by telescopes with a diameter of the lens or mirror from 10 to 70 cm. The first plate was obtained in 1894. The archive is suitable for refining the light curves of variable stars and rectification of their periods using observations over a large time interval. The symbiotic star FG Ser is an example.

Variability of FG Ser (= AS296 = S10363) was discovered by C. Hoffmeister (1968) on the photoplates of the Sonneberg observatory, the largest European astronomical plate collection. He classified the object as a variable star with brightness variations in the range 13.5 - 14.5 mag. The outburst of FG Ser was detected by Munari & Iijima (1988) in June 30, 1988, when the object brightened to 10 mag. Munari & Iijima (1988) and Gutierrez-Moreno et al. (1990) discussed the spectroscopy of FG Ser symbiotic variable during the outburst and in quiescence and derived some physical parameters of this object. Munari et al. (1992) used the photographic plates archive of the Asiago Observatory as well as new photoelectric and visual observations to show that the object is an eclipsing binary with the orbital period of 650 days. Later Munari et al. (1995) used the new photometric observations to refine the value of the period to P = 658 days. Kurochkin (1993) investigated the object on archival photographic plates of the SAI taken in 1949 – 1987 and determined its orbital period to be 630 days. Mürset et al. (2000) combined the measured radial velocity variations for the red giant secondary with published eclipse photometry, confirmed the binary orbital period of 650 days and presented the first reliable model of the system.

2 New results

We remeasured the brightness of FG Ser on photoplates of the SAI archive, using the new photometric standard sequence published by Henden and Munari (2000). We measured also earlier photoplates taken in 1901 – 1904. The photographic observations of FG Ser were taken by 10-cm, 16-cm and 40-cm telescopes at the time intervals 1901 – 1904 (2415612 – 2416699) and 1949 – 1995 (JD 2435362 – 2449949). The photographic magnitudes are close to the B passband of Johnson.

The majority of the SAI plates covering the field of FG Ser correspond to the 66 Oph field of the "A" series observed with the 40 cm astrograph in Crimea. These plates were digitized with a flatbed scanner (2540 dpi resolution, 16 bit grayscale depth) to be used for variable star search by Kolesnikova et al. (2008, 2010). We reprocessed the original scans with the latest version of the VaST[1] software featuring the improved photographic aperture photometry calibration technique (Bacher et al. 2005; see Sokolovsky et al., 2014 in these proceedings) to extract the lightcurve of

[1]`http://scan.sai.msu.ru/vast/`

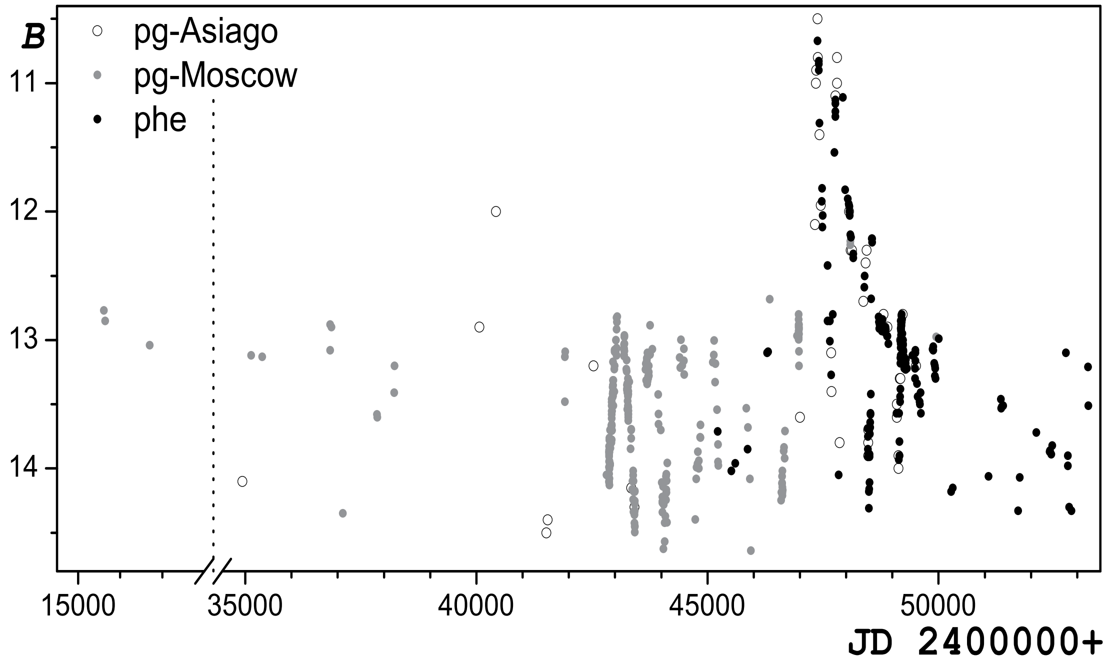

Figure 1: The historical light curve of FG Ser.

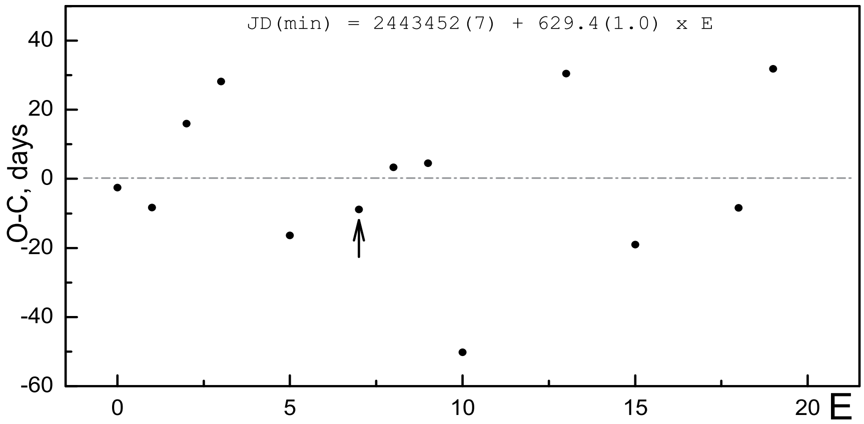

Figure 2: The graph of the O − C residuals for FG Ser. The moment of the eclipse during the outburst is indicated by an arrow.

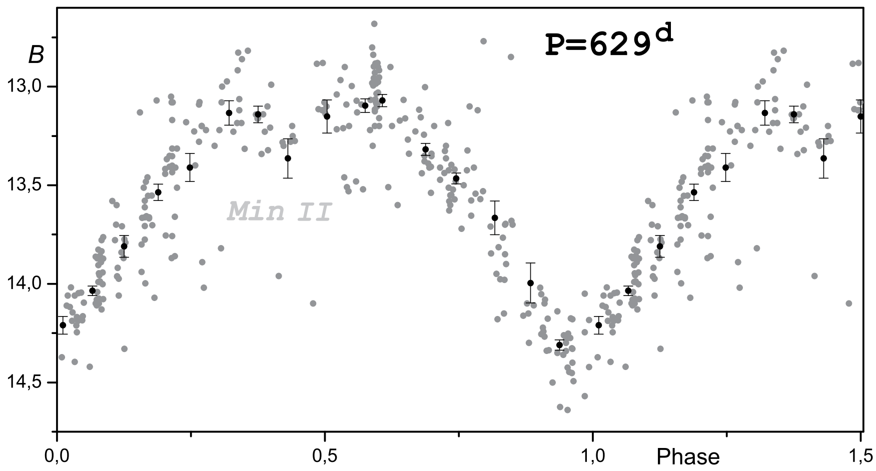

Figure 3: The phase light curve of FG Ser.

FG Ser. The plates of other, mostly older, series are not yet available in the digital form. The brightness of FG Ser on these plates was measured by using an iris-microphotometer of the SAI.

We obtained 259 measurements by using the SAI archive. For the light curve analysis, we added photoelectric and archive photographic observations by Munari et al. (1992, 1995) at the Observatory of Asiago. We also utilized our previously unreported photoelectric observations, obtained in 1995 – 2004 with the 60-cm Zeiss-telescope located in the Crimean Laboratory of the SAI MSU.

The light curve of all observations of FG Ser is presented in Fig. 1. Our and Munari et al. (1992, 1995) photoelectric observations in the B passband are marked by black circles. The agreement of photographic observations of the Moscow and Asiago archives with photoelectric data is about 0.1 mag. Therefore, we could refine the orbital period using all observations, without separation into photoelectric and photographic ones. As a result, we found the new ephemeris for the time of eclipses:

$$JD_{min} = 2443452(7) + 629.4(1.0) \times E$$

The graph of the O – C residuals, including the outburst in 1988, is shown in Fig. 2. The moment of the eclipse during the outburst is indicated by an arrow. There is no detectable time shift for this eclipse relatively to other eclipses. The phase light curve of the data, except the outburst in 1988-89, constructed with this ephemeris, is shown in Fig. 3.

3 Final remarks

It is interesting to mention some results of our investigation of other symbiotic stars using archival photoplates. In particular, we constructed detailed light curves or refined periods of HM Sge (Dokuchaeva, 1977; Chochol et al., 2004), TX CVn (Skopal et al., 2000), V1329 Cyg (Chochol et al., 1999), V1016 Cyg (Parimucha et al., 2000), YY Her (Munari et al., 1997), RT Ser (Shugarov et al., 1997, 2003), PU Vul (Shugarov et al., 2012). The precursors of classical Novae: HR Del (Shugarov, 1967), V1680 Aql (Antipin, 2005), V1500 Cyg (Harevich et al., 1975) and peculiar Nova V838 Mon (Goranskij et al., 2004) were detected on archive photoplates, obtained before the outbursts of these stars. The detailed photometric study of several cataclysmic variables was made using photo archives of some observatories: novalike MV Lyr (Andronov and Shugarov, 1982, 1983; Pavlenko and Shugarov, 1998), the WZ Sge-type systems V455 And (Katysheva and Shugarov, 2009) and EZ Lyn (Pavlenko et al., 2007), dwarf nova HS 0218+3229 (Golysheva et al., 2012, 2013). Archival photographic data were successfully combined with CCD observations to improve period accuracy of Algol-type binaries (Sokolovsky et al., 2011). A brief history of variable stars studies with the SAI archive was given by Shugarov et al (1999).

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Photo plates digital archives of the INASAN Zvenigorod Astronomical Observatory

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Abstract

We present the electronic library of the astronomical plates, which were created by telescopes of Zvenigorod observatory (near Moscow). Zvenigorod's Observatory stores large archive of the photos, accumulated from 1972 to 2005. The observatory team is working on create a digital archive of the plate images, a scanning, cataloging and safekeeping. Telescopes: AFU – 75 Camera, Astrograph Carl Zeiss, VAU Camera. Our plates have the field stars of different types up to 16 magnitude, comets and asteroids, Mars and Pluto, and the galaxy images of different sizes. The plate parameters are on-line available both with INASAN website and with Bulgarian WFPDB. The image in FITS-format (700 Mb) can be ordered by e-mail. Both professionals and amateurs will be use the scans archive for study of variable stars, asteroids, comets and other sky objects.

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Keywords: astronomical data bases; techniques: digitizing, asteroids, comets.

Introduction

Zvenigorod Astronomical Observatory is a department of Institute of Astronomy of the Russian Academy of Sciences. Observatory longitude: 36° 45.5' 10, latitude: 55° 41.9'11, altitude: 198 m. During photographic observations we have accumulated much material derived with telescopes, whose characteristics are given in the Table 1.

Table 1. The Zvenigorod telescopes parameters

Telescope	D, cm	Focus, cm	Detector	scale
Carl Zeiss Astrograph	40	206	photographic plate 30 x 30 cm, 8 x 8 degree	103“/mm
AFU – 75 Camera	21.2	73.6	film 14 x 20 cm, 10 x 15 degree	208“/mm
VAU Camera	in. mirr. = 50 prim.mirr. = 107	70	film 6 x 36 cm, 5 x 30 degree	

We have a various targets at working with this material. VAU Camera Film Archive has nearby 10000 films. It is not catalogued. Scanning is not supposed. AFU Camera has produced 2683 films. All films are made during observation of the satellites. On film the full image of a star is a chain from 13 or 7 points with 1 arcsec exposures. Usually limiting magnitude is 8 magnitude. The archive is catalogued and placed in WFPDB, see paragraph 1.3 below . Scanning is not planned. Carl Zeiss Astrograph: the 3703 negatives were produced and fixed in log since 1972 to 2005. The archive is catalogued and placed in WFPDB too. Various information on our archive in [1-5], and the main features are given below.

The Astrograph archive

1.1 The observational programs

During the operation of this instrument several programs was carried out:

1) «Photographic review of the sky» (FON) program. Observation was carried out from 1980 to 1992 for Photographic catalog of proper motions (FOKAT) catalog creation. Sky area from -2° on +90°. Magnitude limit is 16 magnitude. The plates are about 50% of whole archive.

2) Asteroids program, about 30% of archive. The program purpose is the refinement of the position of the vernal equinox.

3) Comets program, 8% of all archive. There were two tasks: determination of exact coordinates (exposition of 5 - 6 minutes) and studying of a tail of a comet (length of the image is up to 7° (25 cm)) with expositions 1 hour and more.

4) The catalog of basic stars round 190 radio sources (8%);

5) Pluto observation (3%). It is carried out by V.P. Osipenko for specification of its orbit;

6) Mars observation (3%) was in 1988 for the needs of two interplanetary stations "Fobos" voyage to Mars.

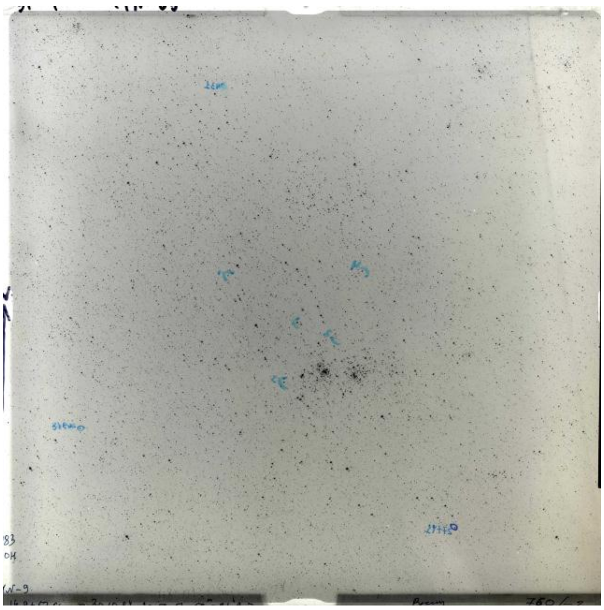

Fig.1. The typical scan: plate number ZVN040_000983 with a star field and h and hi Persei open

cluster near the center. Photographic plate produced by astrograph.

1.2 The electronic library

Since 2006 we have started to create an electronic library of this material. For each plate, we create a black-white working scan (FITS, 1600 dpi, 700 Mb) and two color preview images (for Internet – JPEG, 300 dpi, 3 Mb and for Press – TIFF, 1200 dpi, 600 Mb). Requirements when scanning working scans: resolution as close as possible to the grain size of the negative, but without interpolations. All characteristics of the plate are given in the FITS-file header. Now about 2000 scans are accessible. The scan's files are kept on DVD, SATA and USB disks.

Observational log page scanned too (JPEG, 300 dpi and TIFF, 600 dpi, color). The Astrograph and AFU archives are cataloged. The catalogs are ASCII-files in the WFPDB format.

1.3 The on-line access

The online information about our work, science groups, tools, volumes and characteristic of the plate and film libraries is presented on:

1) the INASAN site http://www.inasan.ru/rus/scan/;

2) the Wide Field Plate Data Base **WFPDB** in Bulgaria: http://wfpdb.org /search/search.cgi

(Getting data about archive and each plate, viewing of the plate images, selection plates by the parameters. In the search to use: IDobs - “ZVN”, IDins - “040” for Astrograph, IDins - “021” for AFU.);

3) About the Zvenigorod Observatory Telescopes:
http://www.inasan.ru/eng/zvenigorod/instr.html.

The service group

The project: "The service of the electronic library of the astro negatives produced on Zvenigorod Observatory” is in the plan of the Russian Virtual Observatory (RVO, http://www.inasan.rssi.ru/eng/rvo/). Equipment: A3 EPSON Expression 1640XL professional scanner. Service group: Sergei V. Vereshchagin, Natalia V. Chupina, Valentina I. Panferova, Valeri P. Osipenko. To date, basic work on archiving completed. Now our responsibilities are service and support in working order the digital archives, film and glass plate libraries; a scanning and cataloging the plate images for some plates in needed cases. Data reduction to a standard format and it inclusion into WFPDB continue to be in compliance with all requirements of the Data Center in Sofia (WFPDB).

The modern work

At present, the positional observation of near-earth satellites is reopened to solve some fundamental and applied problems. The corresponding software is constructed.

The photometric observation of near-earth satellites using CCD detectors is starting. The location of the Zvenigorod observatory is favorable for observations of sun-synchronous satellites, http://www.inasan.ru/eng/zvenigorod/tasks.html

The archive materials are also used for the modern main Observatory goals (observation of asteroids, space debris and national education programs).

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Correction of lens distortion for astronomical plates digitized by SLR camera

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Abstract

It is necessary to carry out precise measurement of detected stellar objects in astronomy. In case of astronomical plates digitization by digital SLR (Single Lens Reflection) camera, they could be trans-illuminated and taken by the camera equipped with a suitable lens. The condition is a 100% match of an object (astronomical plate) and its image. Nevertheless, mentioned imaging system is not ideal. Various optical aberrations occur during acquisition. They introduce errors as are e.g. distortion, coma, astigmatism or chromatic aberration. Distortion influences correct positions of stellar objects and causes incorrect interpretation of taken data whether they were correct acquired using astronomical plate. Therefore, it is necessary to modify existing methods for astronomical image processing in the case of input lens with wider field of view or to remove lens distortion and apply existing algorithms. In this paper we describe a principle of image system distortion elimination using OpenCV software library.

Keywords: astronomy, correction of image distortion, astronomical plates, digitization, OpenCV.

1 Introduction

Optical aberrations occur during image acquisition using a real imaging system. Source of aberrations is mostly an optical part consisting of a real input lens, which cannot be modeled by pinhole camera model [1]. There are many kinds of optical aberrations, e.g. spherical, coma, astigmatism, chromatic, distortion etc. Images of real cameras suffer from more or less lens distortion, which is a nonlinear and generally radial distortion. The most prevalent form of this effect is the barrel and the pincushion distortion (see Fig. 1). The first is due to the fact that many wide angle lenses have higher magnification in the image center than at the periphery. This causes the image edges to shrink around the center and form a shape of a barrel. The pincushion distortion is the inverse effect, when the edges are magnified stronger [2]. In case of astronomical imaging, barrel distortion can be mainly met. It causes inaccuracy of stellar object measuring usin g astrometry and photometry algorithms. Thus it is necessary to modify existing methods for astronomical image processing in the case of input lens with wider field of view or to remove lens distortion and apply existing algorithms.

In our case, we have a deal with a digitization of astronomical plates using digital SLR (Single Lens Reflection) camera Nikon with properly lens. Information about camera and lens model is confidential jet. The whole process consists of 4 stages: image acquisition, correction of barrel distortion, image cropping and meta-data inserting. This paper deals with correction of image distortion.

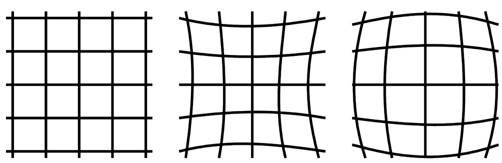

Figure 1: Examples of the pincushion (middle) and the barrel (right) distortion of the grid (left).

2 Correction of barrel distortion

Correction of barrel distortion is in our case performed in C++ language using open source OpenCV library [3] containing properly software packages. The whole process consists of few steps described below.

2.1 Theoretical background

For the distortion, OpenCV takes into account the radial and tangential factors. For the radial factor, the following equations are used [6]:

$$x_{corrected} = x\,(1 + k_1 r^2 + k_2 r^4 + k_3 r^6), \tag{1}$$

$$y_{corrected} = y\,(1 + k_1 r^2 + k_2 r^4 + k_3 r^6). \tag{2}$$

It means, that for an old pixel point at (x, y) coordinates in the input image, its position on the corrected output image will be $(x_{corrected}, y_{corrected})$. The presence of the radial distortion manifests in form of the "barrel" or "fish-eye" effect. Tangential distortion occurs because the image taking lenses are not perfectly parallel to the imaging plane. It can be corrected via the equations (3, 4).

$$x_{corrected} = x + [2p_1xy + p_2(r^2 + 2x^2)] \tag{3}$$

$$y_{corrected} = y + [p_1(r^2 + 2y^2) + 2p_2xy] \tag{4}$$

There are five distortion parameters which are presented as a vector $Dist_{koef} = (k_1, k_2, p_1, p_2, k_3)$ in OpenCV. Sometimes, it can be extended by further coefficients; it depends however on a distortion rate and capabilities of OpenCV. Vector of distortion coefficients is also called extrinsic camera parameters [6].

For the unit conversion, the following formula is used:

$$\begin{bmatrix} x \\ y \\ w \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}, \tag{5}$$

where $[X, Y, Z]$ are the coordinates of a 3D point in the world coordinate space and $[x, y, w]$ are projection coordinates. Presence of w is explained by the use of homography coordinate system (and $w = Z$). The unknown parameters are f_x and f_y (camera focal lengths) and (c_x, c_y) which are the optical centers all expressed in pixels. If for both axes a common focal length is used with a given aspect ratio a(usually 1), then $f_y = f_x * a$ and in the formula 5 will be just a single focal length f. The matrix containing these four parameters is referred to as the camera matrix or the matrix of intrinsic parameters. While the distortion coefficients are the same regardless of the camera resolutions used, these should be scaled along with the current resolution from the calibrated resolution [6].

2.2 Camera calibration

The process of determining intrinsic and extrinsic parameters is called calibration. Calculation of these parameters is done through basic geometrical equations. The equations used depend on the chosen calibrating objects. Currently OpenCV supports three types of objects for calibration:

- Classical black-white chessboard
- Symmetrical circle pattern
- Asymmetrical circle pattern

Image of black-white chessboard was selected for our purpose. It is loaded to a program and a suitable function with two input parameters (the chessboard pattern and number of internal corners inside the pattern) is used for internal corners searching, which analyzes input image and considers whether it is a view of the chessboard pattern. For example, a chessboard has 8 x 8 squares and 7 x 7 internal corners, that is, points where the black squares touch each other. Fig. 2 shows an example of internal corners detection inside chessboard pattern.

As was mentioned above, camera calibration consists of intrinsic (camera matrix) and extrinsic (distortion coefficients) camera parameters estimation. The algorithm is based on [4] and [5]. Taken chessboard pattern is used as an input image with additional information about number of detected internal corners. The algorithm is as follows:

- Compute the initial intrinsic parameters or read them from the input parameters. The distortion coefficients are all set to zeros initially.
- Estimate the initial camera pose as if the intrinsic parameters have been already known.
- Run the global Levenberg-Marquardt optimization algorithm [8] to minimize the reprojection error, that is, the total sum of squared distances between the observed feature points and the projected (using the current estimates for camera parameters and the poses) object points.

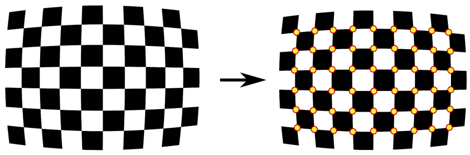

Figure 2: Example of internal corners detection inside chessboard pattern with 10 x 10 white and black squares.

2.3 Correction of distortion

Function for correction of distortion consists of two steps. First, it is necessary to find out transformation matrices and then to perform transformation using remapping function. First step computes the joint undistortion and rectification transformation and represents the result in the form of maps for the next stage. The undistorted image looks like original, as if it is captured with a camera using the input or calculated camera matrix and zero distortion coefficients. The function actually builds the maps for the inverse mapping algorithm that is used by following remapping function. That is, for each pixel ($x_{corrected}$, $y_{corrected}$) in the destination (corrected and rectified) image, the function computes the corresponding coordinates in the source image (that is, in the original image from camera) using distortion parameters. Then, values of pixels with non-integer coordinates are computed using one of available interpolation methods: nearest-neighbor, bilinear, bicub ic and Lanczos [7] interpolation. In our case, bilinear interpolation is used. More in detail description can be found in [6]. Fig. 3 shows results of barrel and pincushion distortion correction using described procedures.

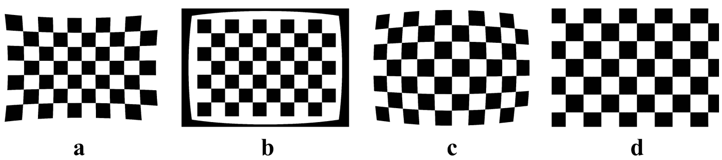

Figure 3: Correction of barrel (a,b) and pincushion (c,d) distortion using OpenCV library.

Also it is important to show how do the input coordinates change depending on distortion rate. Fig. 4 contains graphs showing dependence of $x_{corrected}$ and $y_{corrected}$ on input coordinates (x, y) of detected internal corners inside chessboard pattern taken by our system and simulated one. Distortion rate is expressed by distortion coefficients in format $Dist_{koef} = [k_1, k_2, p_1, p_2, k_3]$, which are [2.89963, -5.08158, -0.0368887, 0.0768382, -0.00158777] for used imaging system and [0.534283, -0.000411199, 0.00138055, 0.00210434, -3.03593e-08] for simulated pattern. Mean Square Error (MSE) represents an objective criterion for comparison of coordinates change. The highest it is, the biggest is the difference and thus the biggest is the distortion rate.

3 Conclusion

This article had to acquaint the reader with the problematic of image distortion and the software method for its reduction based on OpenCV. According to Fig. 4 and differences between input and corrected coordinates of detected internal corners of chessboard patterns expressed by MSE, we can conclude that distortion ration of taken images is very low. Therefore, it is necessary to think about necessity of this step during image processing.

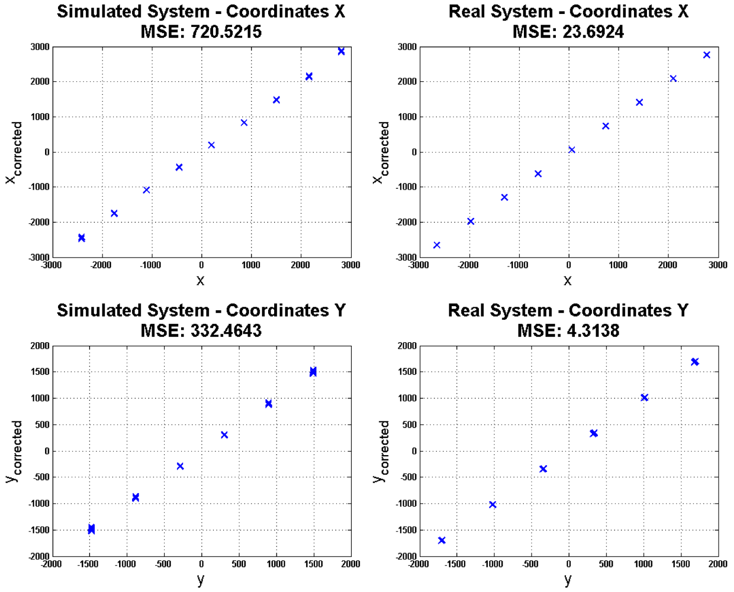

Figure 4: Dependence of $x_{corrected}$ and $y_{corrected}$ on input coordinates (x,y) of detected internal corners inside chessboard pattern taken by our system (right) and simulated one (left).

4 Acknowledgments

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