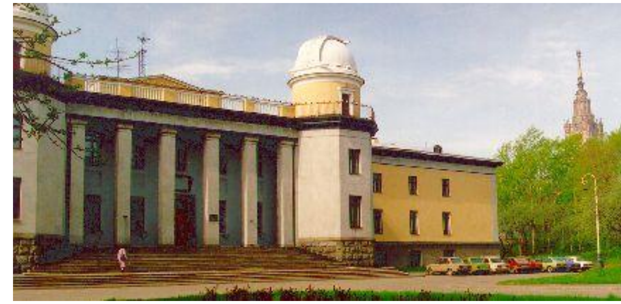


N.N. Samus[1,2,3],

S.V. Antipin[2,1], D.M. Kolesnikova[1], K.V. Sokolovsky[4,2]

[1]Institute of Astronomy, Moscow

[2]Sternberg Astronomical Institute, Moscow University

[3]Eurasian Astronomical Society

[4]Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, Athens

New Variable Stars from Digitized Moscow Plate Collection

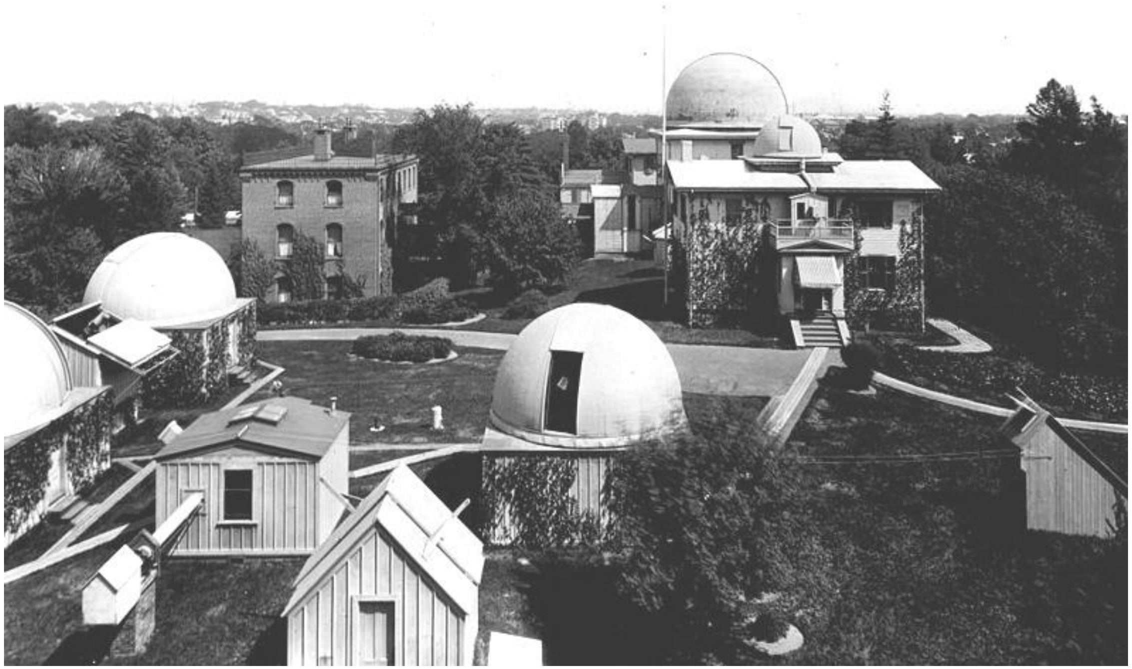
Hamburg, September 18, 2016

The era of analog astronomical photography almost exactly covers the calendar 20th century.

Edward Pickering (1846–1919) initiated sky photographing at Harvard Observatory, with stations in the southern hemisphere. The stacks of half a million direct sky photos is the richest collection in the world.

Pickering's grave at Mt.Auburn cemetery in Cambridge, MA, USA. Photo of 2009.

Plate stacks of Harvard College Observatory cover the time interval from mid-1880s to 1989 (no photos from 1953–1968). Photos of the southern sky are even more numerous.



Harvard College Observatory in 1899

One of those who developed the machine used to digitize Harvard plate stacks, Bob Simcoe, near his machine. April 2009.

Hamburg, September 18, 2016

Digitizing plates will keep them from eventual disasters, like that in Harvard Observatory on January 18, 2016. The Cambridge City water main under the observatory ruptured. 61000 plates were flooded. None of these plates were digitized by that time, some of computers and scanners also suffered. The rescue operation is under way; it is expected that serious losses of information will be avoided.

The basement level of the Harvard Observatory plate stacks (January, 2016)

The era of analog astronomical photography almost exactly covers the calendar 20th century. The number of analog astronomical photographs in the world is estimated to exceed 2 millions. Collecting information on stacks of astronomical photographs kept at observatories of the world is coordinated by M.K. Tsvetkov (Bulgaria) in the WFPDB database,
http://www.wfpdb.org

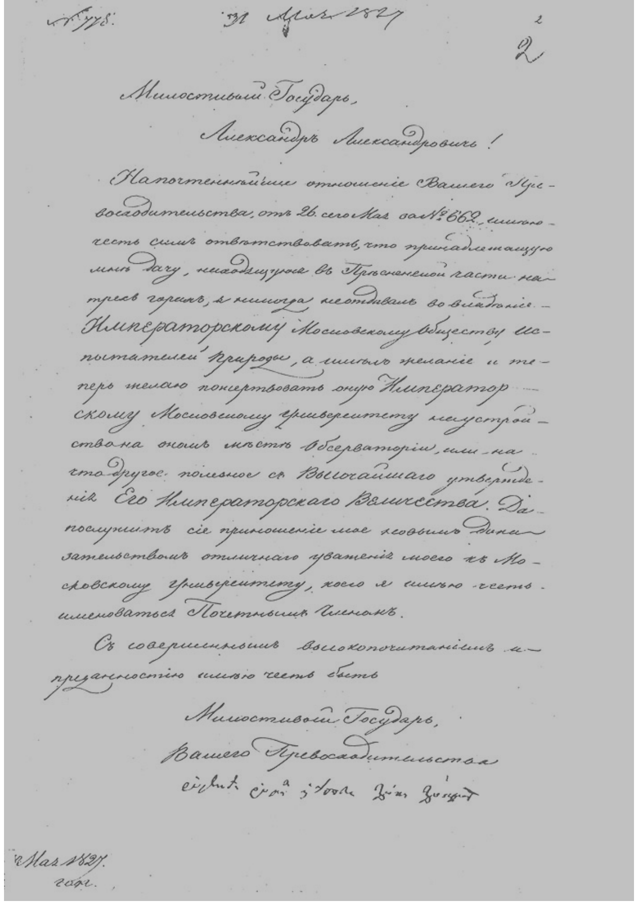
Dr. M. Tsvetkov

Hamburg, September 18, 2016

In 2014, we initiated the “ASTROBASA” project in the frame of cooperation between the Russian and Bulgarian Academies of Sciences: Modern mathematical techniques in astronomical informatics and their application to reductions of wide-field photographic observations; analysis of astronomical images; providing online access to plate catalogs stored at Russian observatories.
Start: 2014
PI (Bulgaria): Prof. O.I. Kunchev (M.K. Tsvetkov among the participants)
PI (Russia): Prof. N.N. Samus

ΖΩΗΣ ΖΩΣΙΜΑΣ, oil painting by Nikiforos Lytras, National Gallery, Athens, Greece

Z.P. Zosima



№ 775. 31 Мая 1827 2

2

Милостивый Государь,

Александръ Александровичь!

Напочтеннѣйшее отношение Вашего Превосходительства, отъ 26. сего Мая за № 662, имѣю честь симъ отвѣтствовать, что принадлежащую мнѣ дачу, находящуюся въ Прѣсненской части на трехъ горахъ, я никогда неотдавалъ во владѣніе Императорскому Московскому обществу Испытателей природы, а имѣлъ желаніе и теперь желаю пожертвовать оную Императорскому Московскому Университету на устройство на оном мѣстѣ Обсерваторіи, или на что другое полезное съ Высочайшаго утвержденія Его Императорскаго Величества. Да послужитъ сіе приношеніе мое новымъ доказательствомъ отличнаго уваженія моего къ Московскому Университету, коего я имѣю честь именоваться Почетнымъ Членомъ.

Съ совершеннымъ высокопочитаніемъ и преданностію имѣю честь быть

Милостивой Государь,

Вашего Превосходительства

Мая 1827.

Zosima’s letter on his present

The old Moscow (Presnya) Observatroy was build at the plot given by the Greek merchant Zoy Zosima as a present to Moscow University in 1827.

Hamburg, September 18, 2016

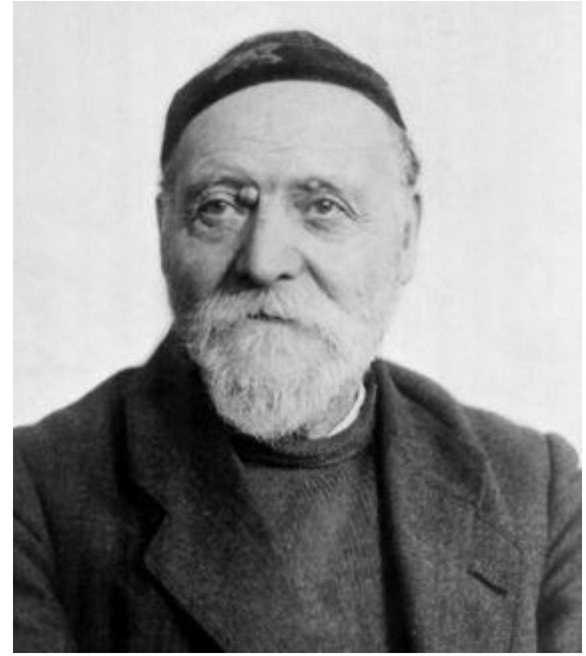
Presnya Observatory still exists. 1954: the new SAI building at Lenin Hills. 1950s: the new observing station in Crimea. 2014: the first light of the 2.5-m telescope at a new SAI's observatory near Kislovodsk.

Crimean laboratory of the Moscow University with its 125-cm reflector

The dome of the new 2.5-m reflector near Kislovodsk

SAI's 2.5-m telescope

Hamburg, September 18, 2016



First attempts to take sky photos at Moscow's Presnya Observatory: Prof. Aristarch Belopolsky (1854–1934) in 1883, before his move to Pulkovo (1888), using wet colloid emulsions.

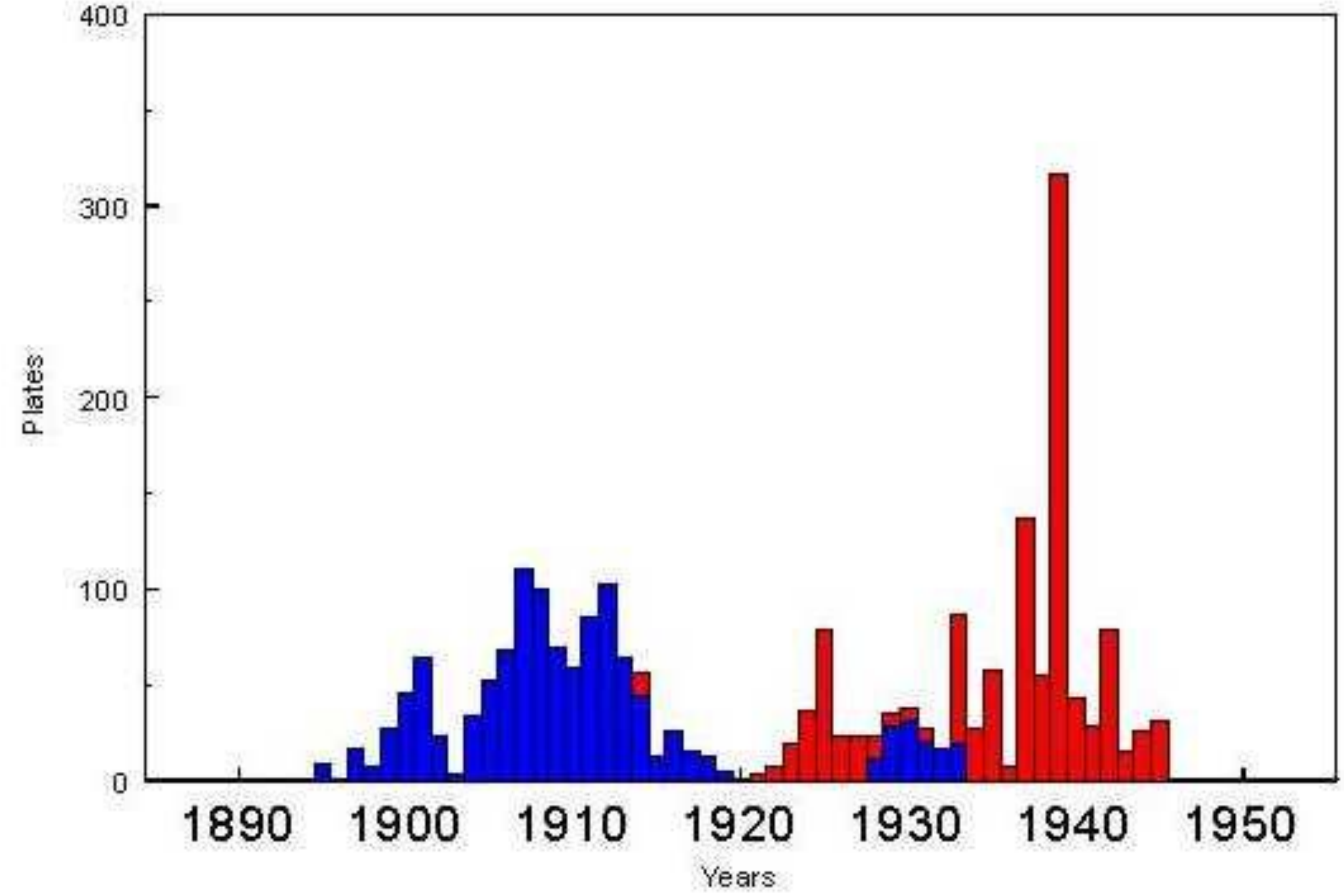
The present Moscow plate stacks were founded by S.N. Blazhko (1870–1956) in 1895.

Cases of Moscow plate stacks

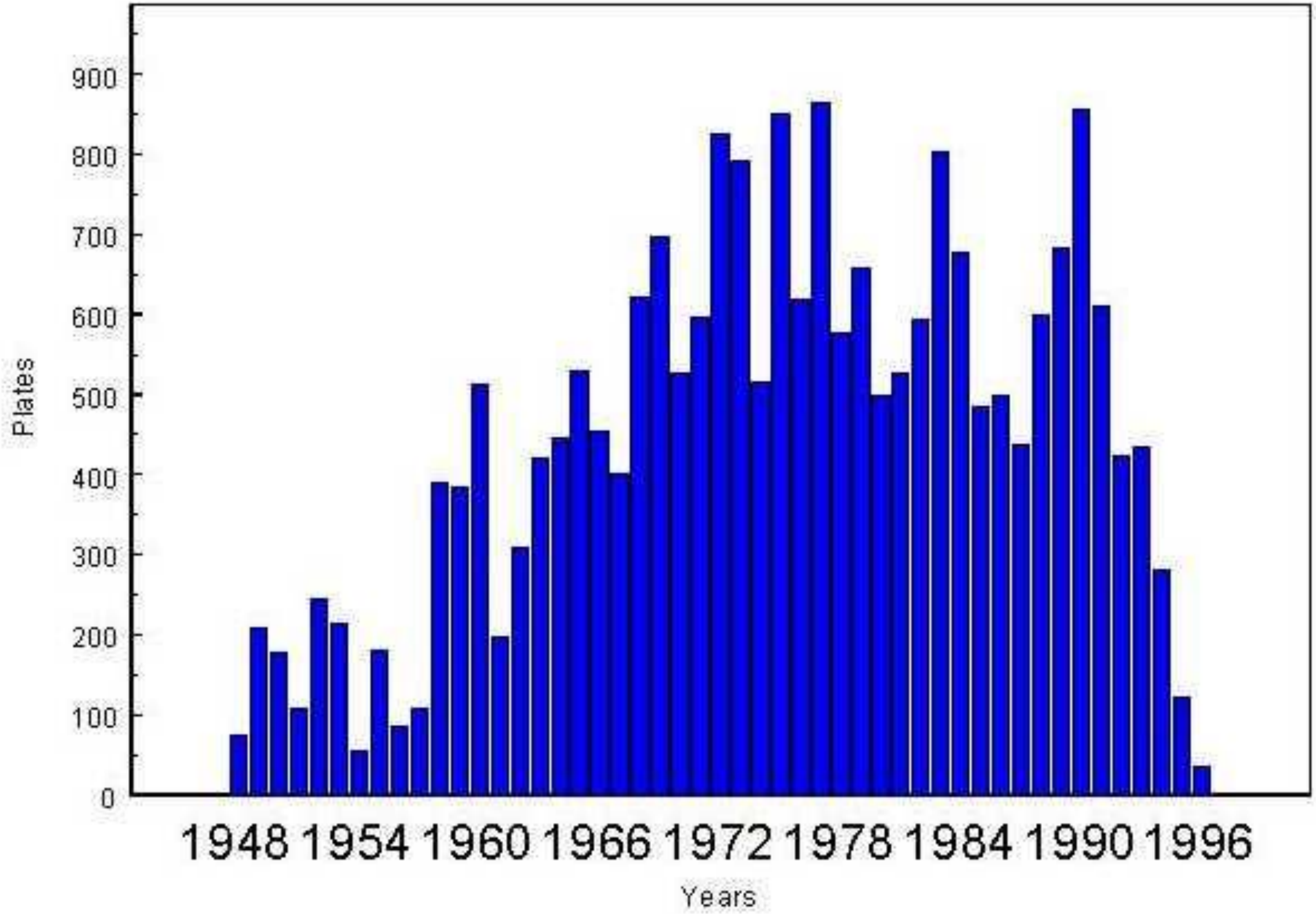
MOSCOW PLATE STACKS (SAI)

D, cm	*F*, cm	Field, degrees	m_{lim}	Years	*N*	Site(s)
10	64	20×28	13–14	1895–1933	1100	Moscow
16	82	16×22	14	1933–1956	2700	Moscow
23	230	6×6		1955–1991	10000	Moscow etc.
38	640	1.4×1.4	14	1902–1972	6400	Moscow
40	160	10×10	17–18	1948–1996	22300	Kuchino, Crimea
50	200	3.5×3.5	18–19	1958–2004	10000	Moscow, Uzbekistan
50	200	Spectra		1959–2004	2300	Crimea
70	1050	0.6×0.6	13–18	1961–1995	9500	Moscow

Plus other plates and films of inferior importance (from Shugarov, Antipin, Samus, and Danilkina 1999, with corrections and additions). On May 18, 2016, several boxes of plates taken in 1895 with an unknown telescope were found!

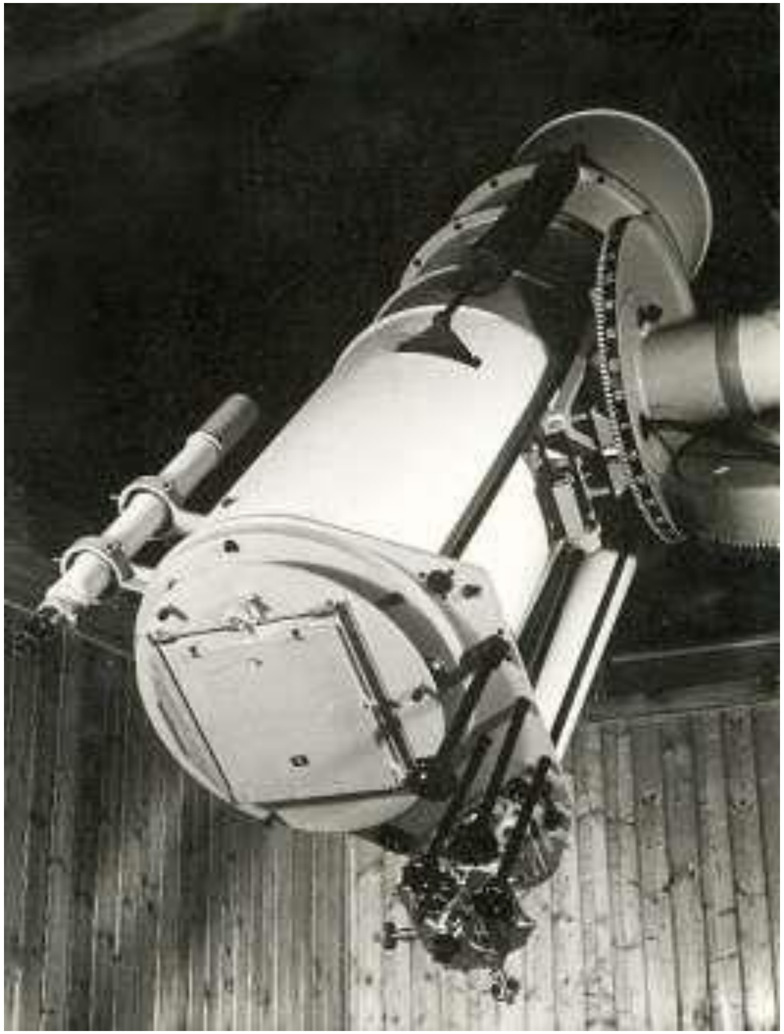


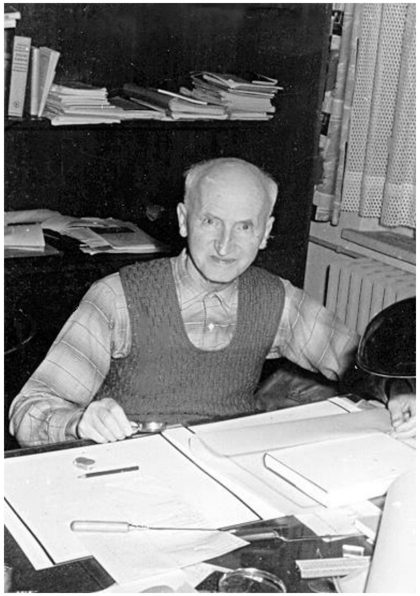
Time distribution of old plate series of Moscow stacks



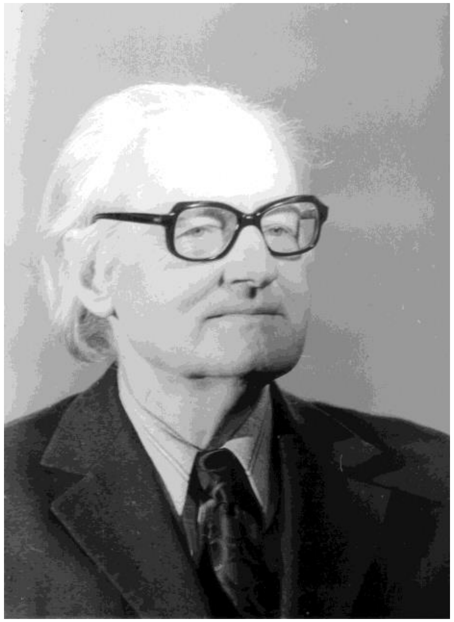
Time distribution of plates from the 40-cm astrograph, the main part of the Sternberg Institute's stacks.

Hamburg, September 18, 2016





Cuno Hoffmeister
(1892–1968)



Boris Kukarkin
(1909–1977)

The Crimean 40-cm astrograph (in Sonneberg till 1945)

Hamburg, September 18, 2016

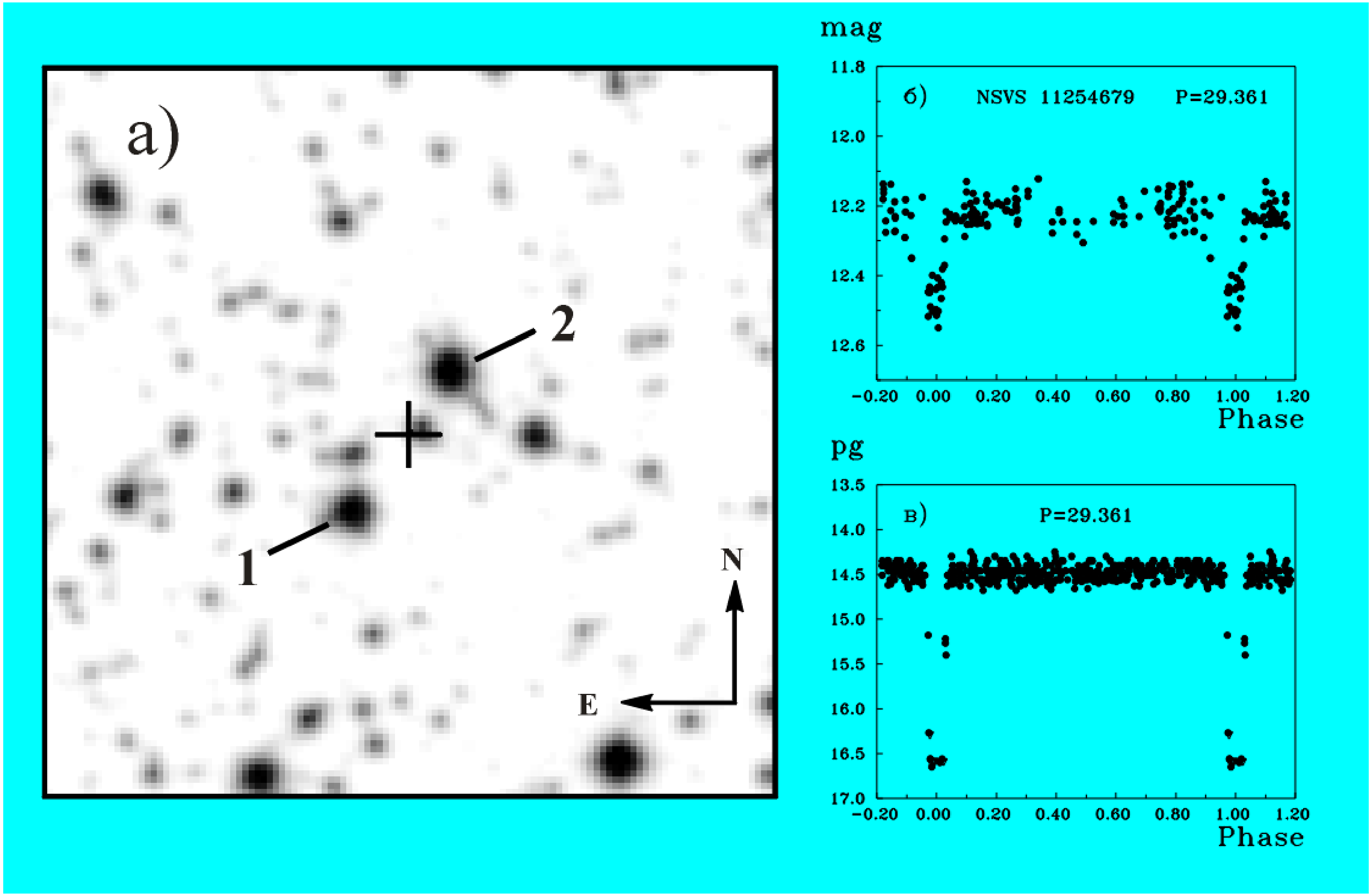
Science based on the major part of the SAI plate stacks: first of all, *variable stars*. Different plate series have their specific features.

Old series (1895–1956, 10-cm and 16-cm cameras): overlapping northern fields, few plates per each field. Individual variables.

40-cm astrograph. Fields of variable stars from the north pole down to declination about –30^{o}, very many plates in some fields (up to 500; for a star entering several adjacent fields, it is possible to get up to 1000 estimates). Typical exposure time: 45 minutes. Besides variable-star fields, selected globular clusters for studies of their variables (usually 30-minute exposures or even shorter exposure times, e.g. for bright Cepheids near cluster centers), Supernova patrol. Most plates are of excellent quality.

70-cm reflector. The limiting magnitude and angular resolution strongly depend on the seeing on the particular night. Poor seeing: individual variables. Good seeing: variables in double stars, open and globular clusters. Photographs using *UBVRI* filters. Exposure times: from 1 minute to several hours.

50-cm Maksutov camera. Photos with filters. Not only for variable stars but also for color-magnitude diagrams of open and globular clusters. Many plates of the M31 and M33 galaxies (search for novae and other programs). Objective-prism spectra.



Archive plates can supplement automatic CCD surveys. It is star 1 that really varies.

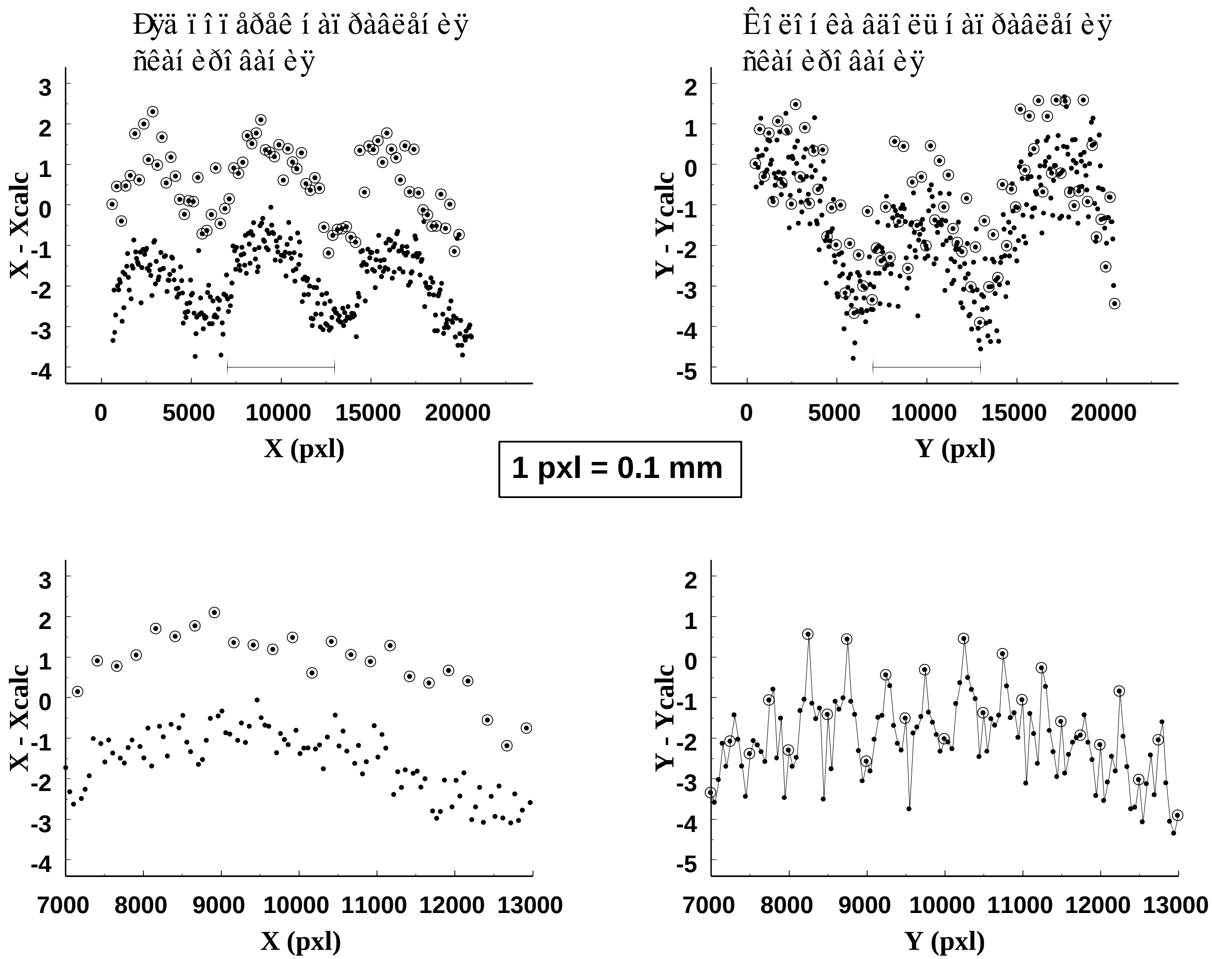
Hamburg, September 18, 2016

CREO EverSmart Supreme scanners in SAI
(were used in 2006–2011)

Hamburg, September 18, 2016

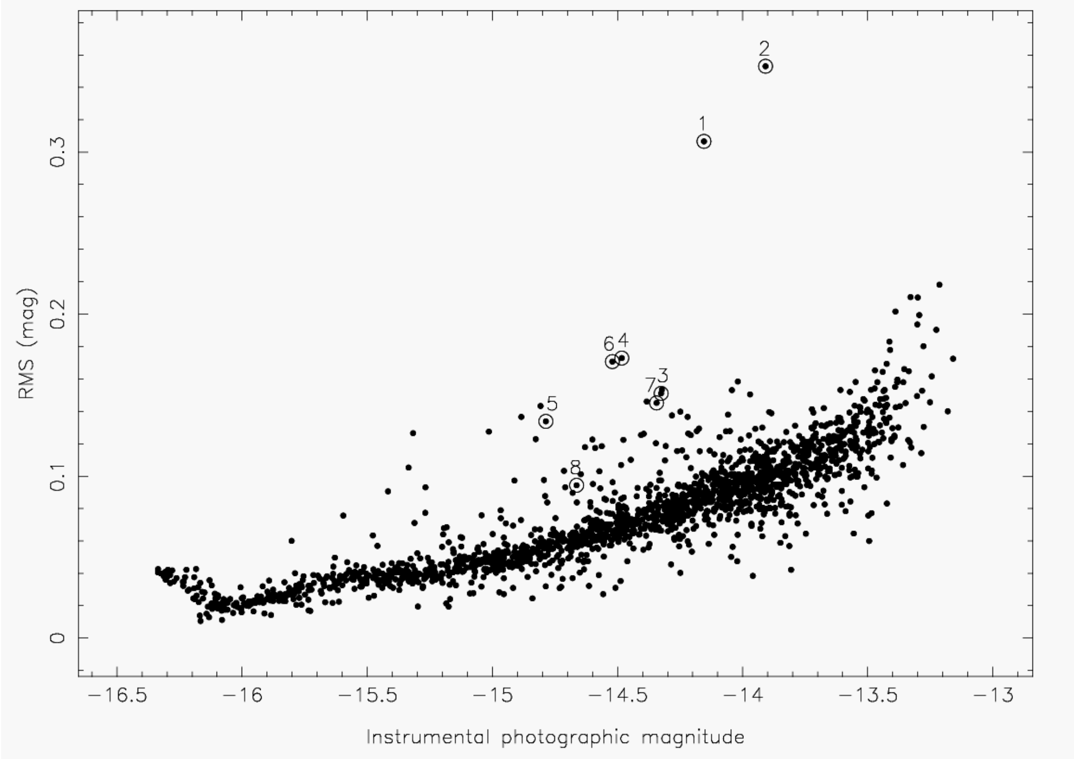
The new Epson Expression 11000XL scanner, with a unit for scanning transparent large-size material (resolution 2400 dpi), was ordered upon advice from M.K. Tsvetkov and obtained on October 28, 2013. After that, we resumed scanning Moscow plate stacks.

Hamburg, September 18, 2016



CREO scanners had complex astrometric properties. For plates of the 40-cm astrograph, deviations reached 2´.

Hamburg, September 18, 2016



Cross-identifications of stars from different plates, zero-point corrections, initial selection of candidate variable stars: the VaST code developed in our team by K. Sokolovsky and A. Lebedev. After the selection of candidates, they are checked one after another, and the search for periods is performed.

“PILOT PROJECTS”

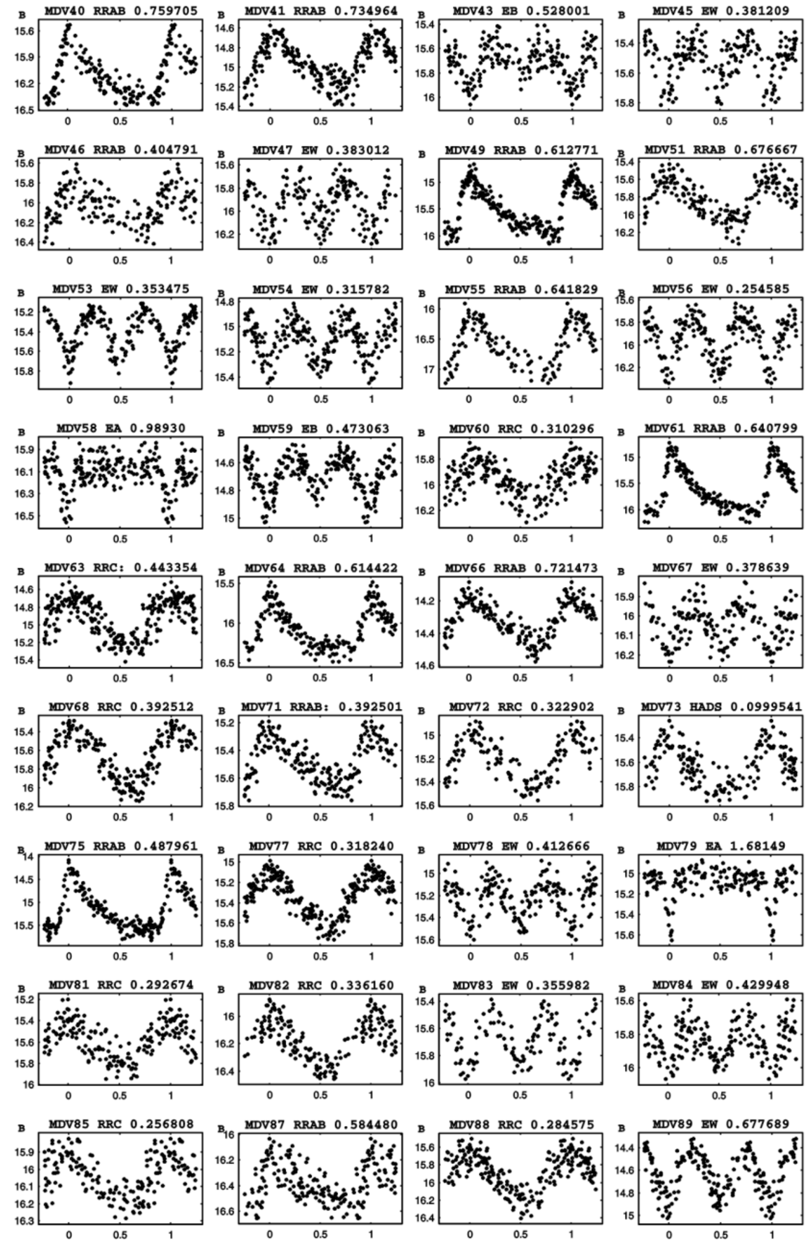
Four fragments of fields of the 40-cm astrograph were studied.

<table>
<tr><th>Fragment’s coordinates (2000)</th><th>Fragment’s size</th><th>No. of plates</th><th>Results</th></tr>
<tr><td>16 06 12
+33 22 16</td><td>1.2°×1.2°</td><td>80</td><td>1 new variable star</td></tr>
<tr><td>13 16 27
+17 41 52</td><td>4°× 4°</td><td>247</td><td>15 new variable stars</td></tr>
<tr><td>20 54 24
+41 05 38</td><td>1.5°×1.5°</td><td>175</td><td rowspan="2">22 new variable stars</td></tr>
<tr><td>21 24 44
+36 21 51</td><td>1.5°×1.5°</td><td>175</td></tr>
</table>

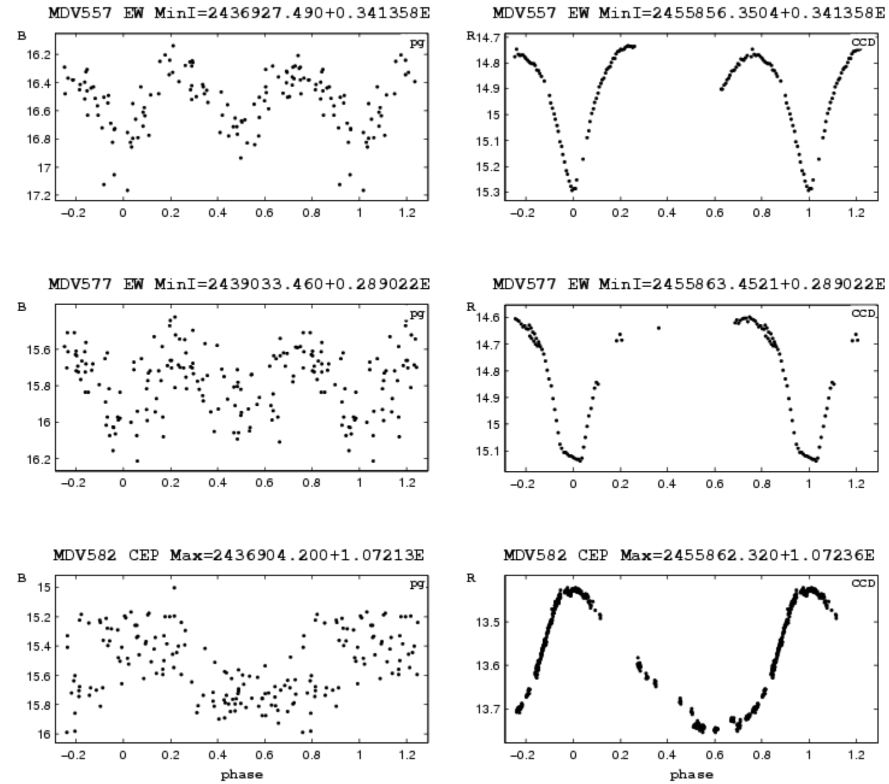
The MDV (“Moscow Digital Variables”) series: MDV 1–38 in the pilot projects.

Hamburg, September 18, 2016

Search for new variables in the $10^{o}\times10^{o}$ field of the 40-cm astrograph (30×30 cm plates) centered at 66 Oph. 254 plates of 1976 –1995 . We found 480 new variables in the relatively well-studied field, mainly at magnitudes 13.5^{m}–16.5^{m}*B* (fainter than the survey limit of the ASAS-3 and ROTSE-I/NSVS projects).



We continued our searches in a field around the Kapteyn area SA9 and in the field of β Cassiopeiae. About 1000 new variable stars were discovered, in addition to those we found earlier. If variations appeared doubtful, we performed CCD observations for confirmation.



CCD confirmations of new variable stars in the SA9 field

Interesting selection effects:
With our software, we cannot discover transient phenomena (among them, Mira stars faint at minimum brightness).
HADS stars are rare in the GCVS (121 with amplitudes of at least 0.2 mag in the whole catalog), but our sample contains many such stars (11). This is from studies of 0.24% of the whole sky area!
The period distribution of eclipsing variables is strongly biased towards shorter periods (GCVS percentage in brackets):

P	EA	EB	EW
0.2–0.4 d		13% (1.7%)	50% (47.8%)
0.4–0.6 d		47% (15.4%)	42% (30.9%)
0.6–0.8 d	22% (3.7%)	22% (17.8%)	6% (14.0%)
0.8–1.0 d	17% (5.0%)	9% (13.4%)	2% (5.5%)
>1 d	61% (89.2%)	9% (51.7%)	

We use the β Cas field for tests of a more automatic technique of our search. In our earlier studies, we continued the initial selection of candidates by checking each star's light curve mostly by eye, while our new codes start searching for periodicity already during the candidate selection, resulting in a more promising list of candidates.

We compiled an electronic catalog of all plates of the main Moscow series. The paper version of this catalog presented names of central objects instead of their coordinates. For the electronic catalog, the central objects were identified and their coordinates added. This catalog will be incorporated into WFPDB in the near future.

The most recent results from our program (2016, in preparation) – field 104 Herculis (18^h12^m +31.4°, J2000.0). 167 plates scanned. More than 310 discoveries:

3 reliable high-amplitude Delta Scuti stars (HADSs); continues the tendency for too many HADSs from our scans compared to earlier statistics;

1 very nice RV Tauri (RVA) star;

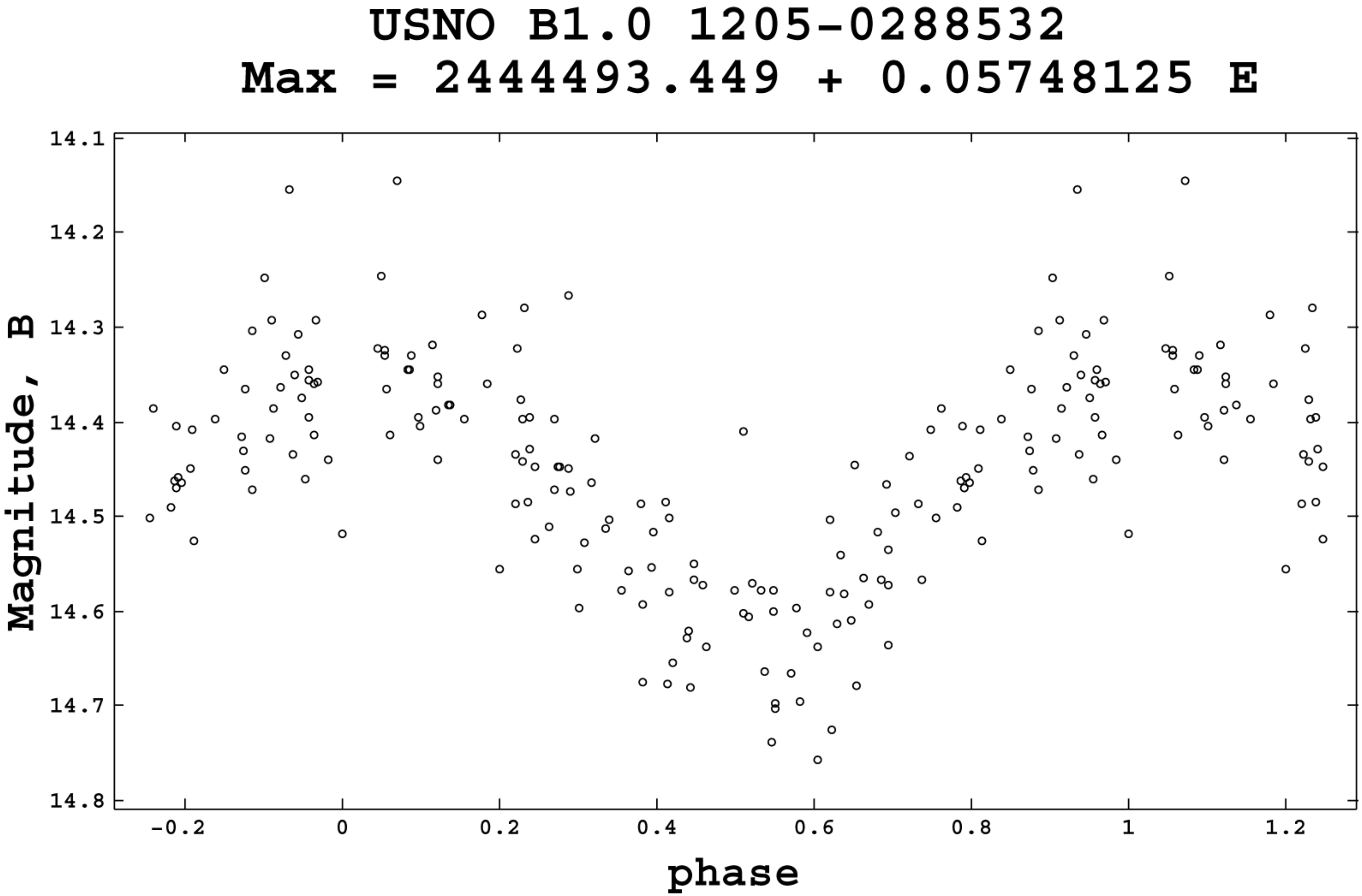
4 uncertain Cepheids (2 of them, probably CW);

54 RR Lyrae stars of different subtypes;

206 eclipsing variables (118 of them, EW);

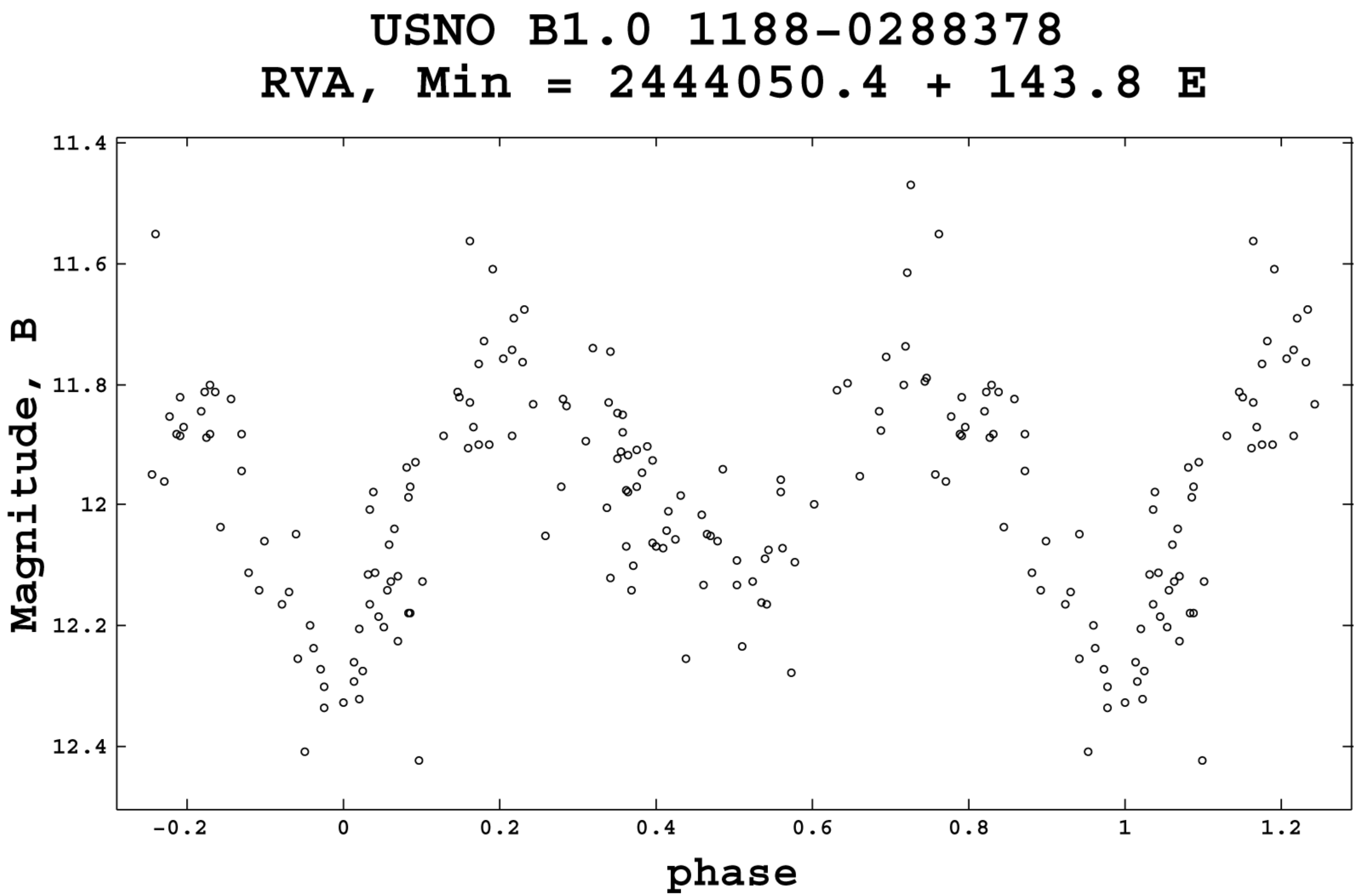
40 red variables (25 LB and 15 SR stars);

1 interesting, probably cataclysmic, variable with P~80 minutes.



This short-period new variable (18h24m39.3s, +30°32′19″ , 2000.0), initially believed by us to be a HADS, is a ROSAT X-ray source; a cataclysmic variable?

Hamburg, September 18, 2016

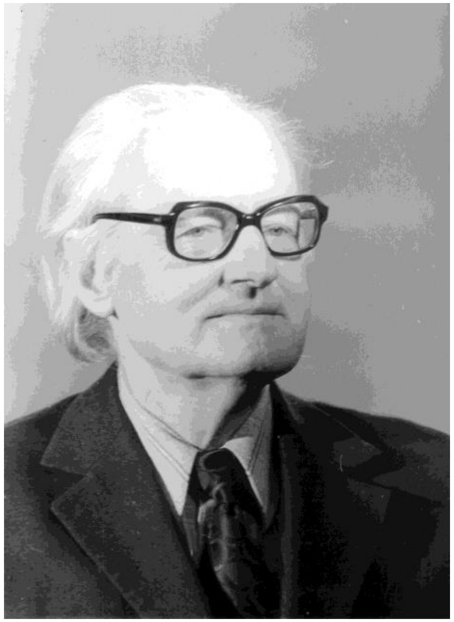


The new RV Tauri variable in the 104 Her field

Hamburg, September 18, 2016

GENERAL CATALOG OF VARIABLE STARS (GCVS): SINCE 1946, ON BEHALF OF THE IAU

P.P. Parenago
(1906–1960)



B.V. Kukarkin
(1909–1977)

P.N. Kholopov
(1922–1988)

Hamburg, September 18, 2016

The GCVS team (photo of 2009)

Hamburg, September 18, 2016

VARIABLE STAR CATALOGS

E. Pigott 1786 12 stars (2 SNe, 1 Nova, 4 Miras, 2 Cepheids, 2 eclipsing stars, and the unique star P Cyg)

F. Argelander 1844 18 stars (1 still not confirmed)

E. Schoenfeld 1875 143

"Astronomische Gesellschaft" (issued yearly):

R. Prager 1926 2906

H. Schneller 1942 9476

Moscow compilers:

GCVS I 1948 Single volume, 10930

GCVS II 1958 Two volumes, 14708, cross-id tables

GCVS III 1969–1971 Three volumes, 20437

GCVS IV 1985–1995 Five volumes, 28435 plus about 12000 extragalactic variable stars, cross-id tables

By August, 2016 51853

The GCVS is traditionally restricted to sufficiently well-studied variable stars (with at least variability type known) of our Galaxy (with the exception of those in globular star clusters). Special catalogs of variable stars in globular clusters are being compiled in Canada. The number of their objects can be roughly estimated as 6000.

Helene Sawyer Hogg (1905 – 1993), founder of the catalog of variable stars in globular clusters. Her work is continued by Christine Coutts Clement.

Extragalactic variable stars are normally outside the scope of the GCVS. The only GCVS attempt to cover them was made in the 4th edition (Volume V, 1995): 10979 variable stars (with the exception of supernovae) in 35 galaxies plus 984 supernovae. After that, the number of known extragalactic variables began to increase exponentially, and the GCVS team stopped to follow their discoveries.
SAI catalog of supernovae: D.Yu. Tsvetkov, N.N. Pavlyuk, O.S.Bartunov. More than 5000 entries. Its authors also write that the number of objects becomes too large to be managed on a star-by-star basis.

If catalogs like GCVS include only confirmed and sufficiently well-studied stars, we need so-called catalogs of suspected variable stars.

Astronomische Gesellschaft:

A catalog by E. Zinner and two catalogs by R. Prager (1929 – 1937), not replacing but appending each other (8020 stars)

GCVS team:

Replacement

CSV I (1951) 5835 + 2299 (1–5835, 100001–102999)

Continuation

CSV II (1965) 3079 + 838 (5836–8904, 103000–103137)

Replacement

NSV (New Suspected Variables) catalog (1981), 14811

Continuation (1998)

Numbers from 15001, 11206 stars

Principles of GCVS compiling, with human star-by-star analysis of information, are time-consuming, and thus GCVS is lagging behind the exponential growth of discoveries.
The American Association of Variable Star Observers (AAVSO) established the AAVSO Variable Star Index with excellent coverage. On August 15, 2016, it contained 398161 stars. The compilers also begin to feel overloaded with work.

Sebastian Otero (AAVSO), Argentina, VSX coordinator

Hamburg, September 18, 2016

KEPLER mission

Preliminary results:

Among ~ 150 000 program stars:

~ 60 000 are periodic variables;

~ 34 000 stars vary with poorly pronounced periodicity or aperiodically (G. Basri et al., 2011)

Given the KEPLER photometric accuracy, two thirds of all stars are variable.

USNO-B1.0 catalog (2003):

1 042 618 261 objects (stars and galaxies), ~ 1 billion stars to 20–21^{m} , about 700 million variables detectable with Kepler accuracy

Specialized variable-star catalogs (like GCVS) and variable-star databases (like VSX) based on star-by-star analysis will become impossible very soon. However, if we do not keep reliable knowledge on variable stars, we will discover the same things again and again.

My view of the possible way out is to include a section on variability characteristics into major catalogs, like USNO-B1.0. So far, this was done only in the HIPPARCOS catalog (about 100000 stars).

СПАСИБО!
DANKE SCHÖN!
THANK YOU!

Hamburg, September 18, 2016