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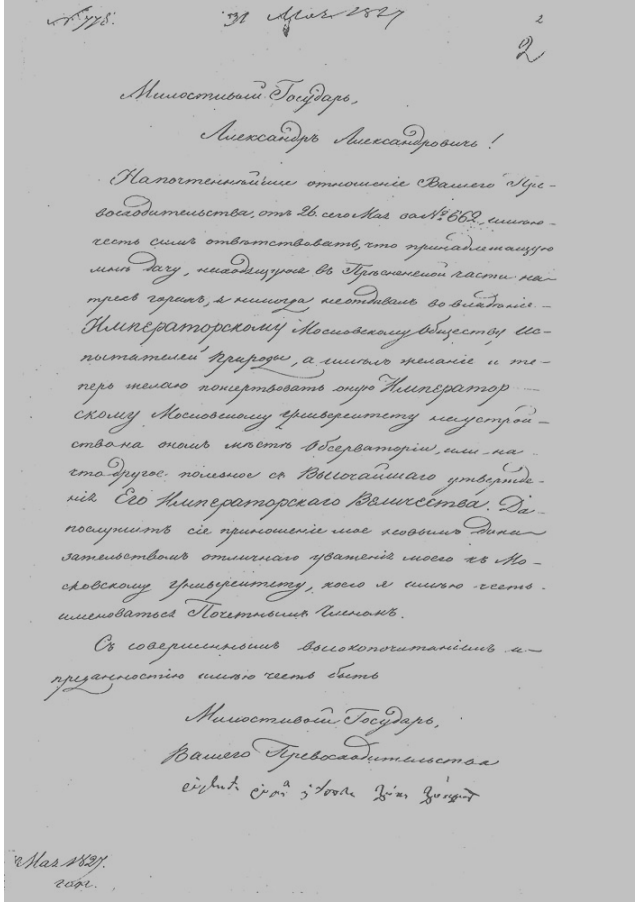
Sternberg Astronomical Institute's plate collection: The present and future of its scientific use

Astroplate III, Bamberg, March 11, 2019

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

Z.P. Zosima



Милостивый Государь,
Александръ Александровичъ!

На почтеннѣйшее отношеніе Вашего Пре-
восходительства, отъ 26. сего Мая за № 662. имѣю-
честь симъ отвѣтствовать, что принадлежащую
мнѣ дачу, находящуюся въ Пресненской части на-
трехъ горшкѣ, я намѣренъ пожертвовать во владѣніе
Императорскому Московскому Обществу ис-
пытателей природы, а именно нынѣ и те-
перь имѣлъ честь пожертвовать оную Император-
скому Московскому университету неустрой-
ства на оной имѣть обсерваторію, или на-
что другое, по мнѣнію съ Высочайшаго утвержде-
нія Его Императорскаго Величества. Да-
позволитъ сіе приношеніе мое моего Дома
засвидѣтельствовать отличное уваженіе мое къ Мо-
сковскому университету, коего я имѣю честь
именоваться Почетнымъ членомъ.

Съ совершеннымъ высокопочитаніемъ и
преданностію имѣю честь быть

Милостивой Государь,
Вашего Превосходительства

27 Мая 1827. года.

Zosima's letter on his present

The old Moscow (Presnya) observatory is on the plot of land donated to Moscow University by the Greek merchant Zoy Zosima in 1827

The first attempts to take sky photographs at Moscow Presnya Observatory were undertaken by Aristarkh Belopolsky (1854–1934) in 1883, before his move to Pulkovo in 1888. He was still using wet colloidal plates.

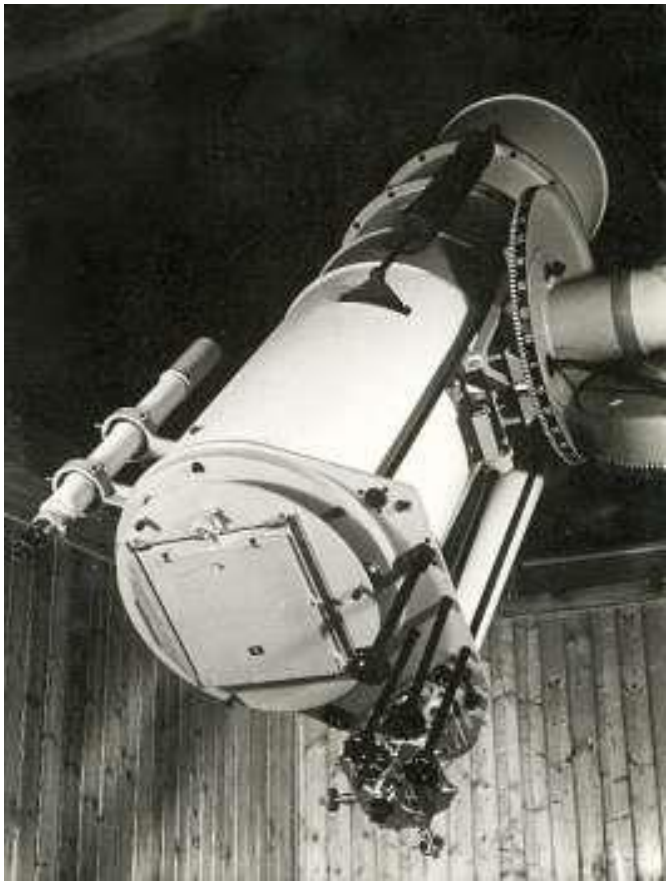
The existing Moscow plate collection was founded by Sergey Blazhko (1870–1956) in 1895.

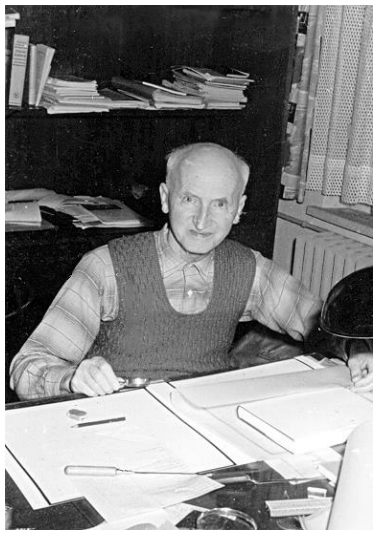
Группа московских астрономов в 1901 году.
Слева направо:
сидят - Павел Карлович Штернберг, Лидия Петровна Цераская,
Фёдор Александрович Бредихин, Витольд Карлович Цераский;
стоят - Сергей Николаевич Блажко, Сергей Алексеевич Казаков
и Борис Петрович Модестов

Moscow plate archive

1950s: new observing site in Crimea. Its first telescope was a 40-cm astrograph (Cuno Hoffmeister's GA astrograph, taken from Sonneberg as an item of war reparations)

The Sternberg Institute's Crimean Laboratory





Cuno Hoffmeister (1892–1968)

Boris Kukarkin (1909–1977)

The Crimean 40-cm astrograph (photos taken in Sonneberg before 1945 and in Crimea in 1980s)

THE MOSCOW (SAI) ASTRONOMICAL PLATE COLLECTION

D, cm	*F*, cm	Field, degrees	m_{lim}	Years	*N*	Site (sites)
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	Simeiz, Kuchino, Nauchny
50	200	3.5×3.5	18–19	1958–2004	10000	Moscow, Uzbekistan
50	200	Spectra		1959–2004	2300	Nauchny
70	1050	0.6×0.6	13–18	1961–1995	9500	Moscow

Plus other, less important series of plates and films (after Shugarov, Antipin, Samus and Danilkina, 1999, corrected and appended).

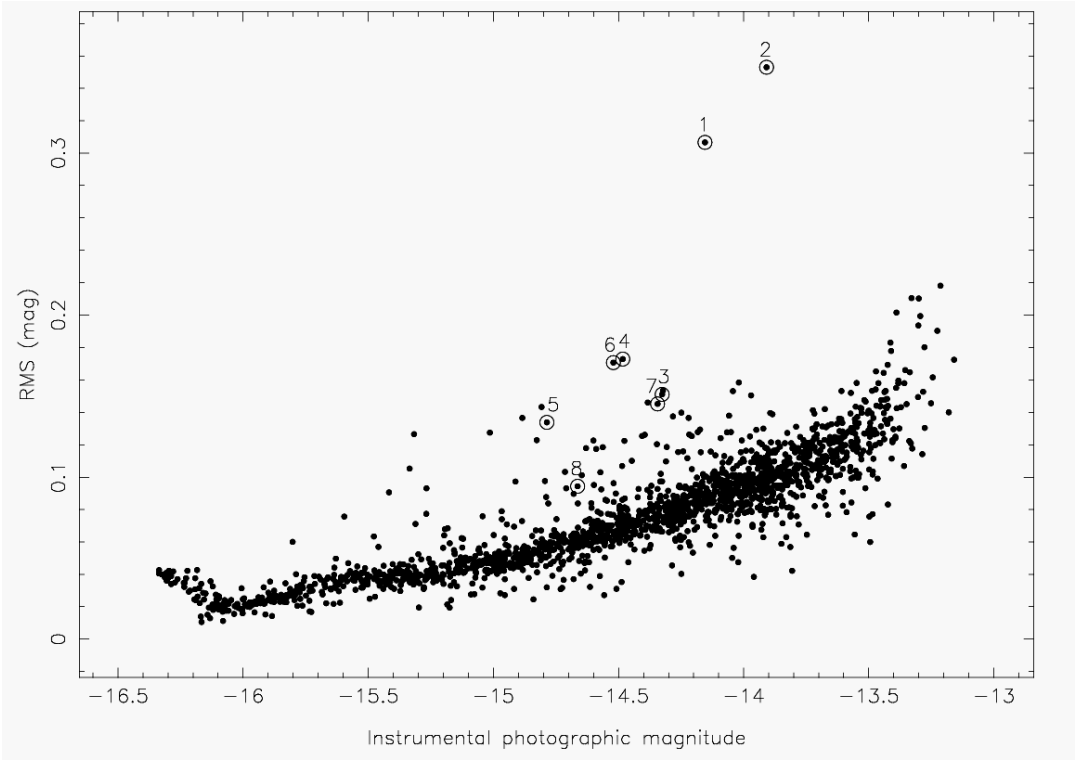
Science using most plates of the SAI stacks: mostly *variable stars*. Different plate series have their own features.

The 40-cm astrograph. Fields of variable stars from the North Pole approximately to –30^{o} declination, some of the fields very rich (up to 500 plates; sometimes it is possible to get up to 1000 estimates for a star found in several adjacent fields). Typical exposure time: 45 minutes. Besides variable-star fields, selected globular clusters for studies of their variable stars (usually 30-minute exposure time or even shorter exposures, e.g. for bright Cepheids near cluster centers), supernova patrol. Excellent quality of the majority of plates.

An electronic catalog was compiled for plates of the old series and for those from the 40-cm astrograph. Old catalogs (paper log books) often contained, instead of coordinates of plate centers, names of their central objects, sometimes in obsolete, exotic naming systems. Now the electronic plate catalogs presents center coordinates for each plate. Publication: N.V. Emelianov, K.V. Kuimov, N.N. Samus, Proceedings of NAROO-GAIA Workshop "A new reduction of old observations in the Gaia era", Paris, June 20–22, 2012; Paris, 2013, p. 137–140.

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

The new Epson Expression 11000XL scanner with a unit for scanning transparent large-format objects with the 2400 dpi resolution was purchased, following an advice from Milcho Tsvetkov, and installed on October 28, 2013. The work on digitizing Moscow plate stacks could be resumed.



Cross-identification of stars on different plates, zero point corrections, initial selection of variable-star candidates: the VaST software developed by K. Sokolovsky and A. Lebedev. The selected candidates are then checked one after another and a search for periods is performed.

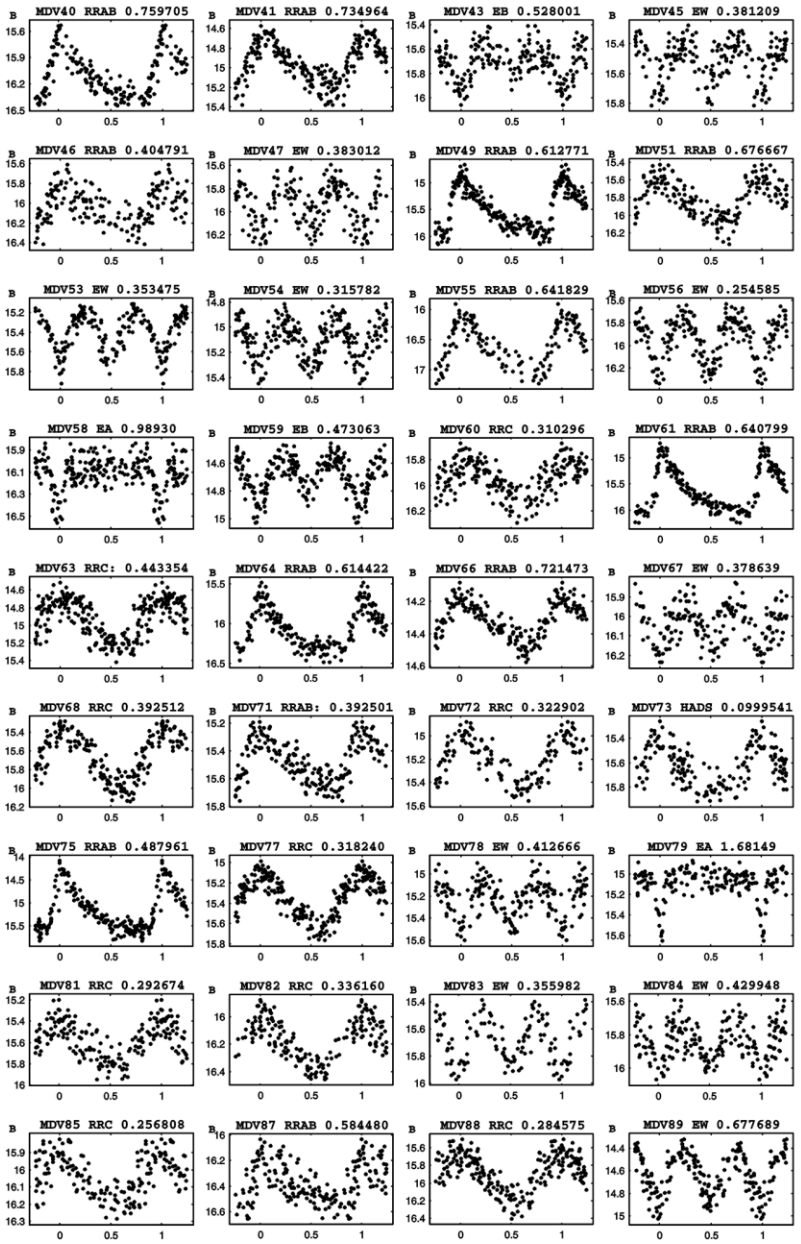
“Pilot projects”

4 partial fields of the 40-cm astrograph were studied.

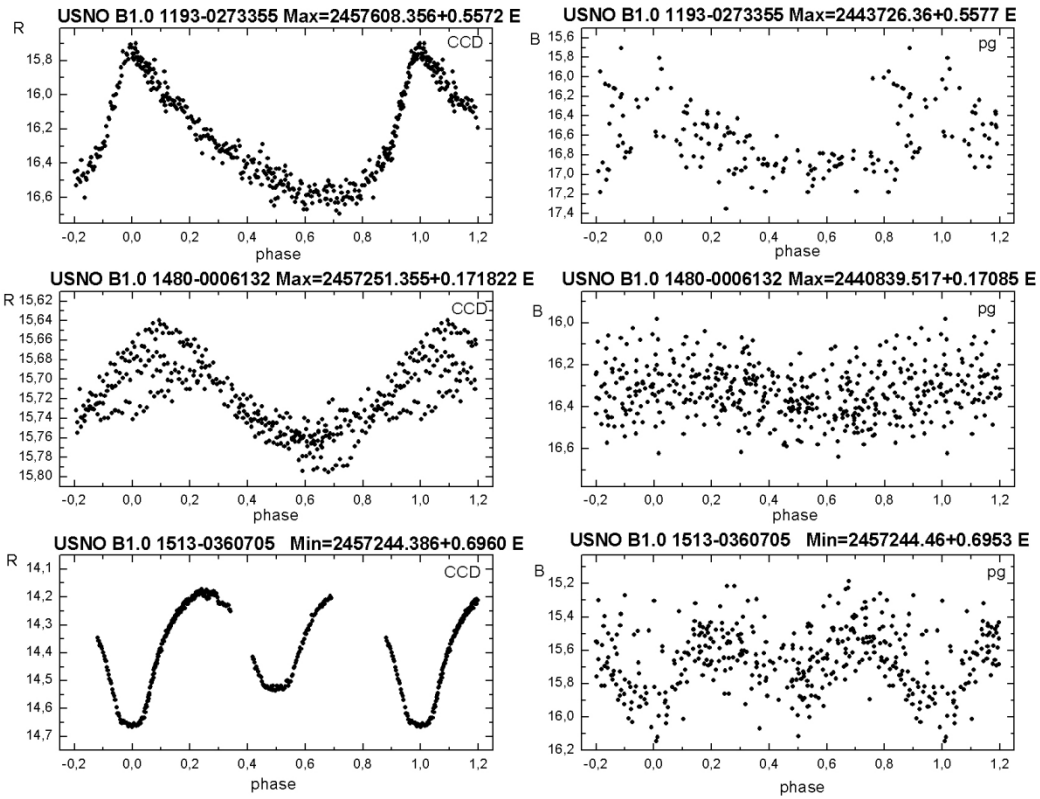
Subfield coordinates (2000)	Subfield size	No. of plates	Results
16 06 12 +33 22 16	1.2°×1.2°	80	1 new variable
13 16 27 +17 41 52	4°× 4°	247	15 new variables
20 54 24 +41 05 38	1.5°×1.5°	175	22 new variables
21 24 44 +36 21 51	1.5°×1.5°	175	

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

A search for new variables in the 10º×10º field of the 40-cm astrograph (30×30 cm plates) centered at 66 Oph. 254 plates, 1976 –1995 . We found 480 new variables in a comparatively well-studied field, mainly 13.5^{m}–16.5^{m}*B* (below the limits of the ASAS-3 and ROTSE-I/NSVS surveys).



The field centered at the SA9 Kapteyn area, field of β Cassiopeiae (still being analyzed, high star density), 104 Her followed. About 1500 new discoveries added. CCD observations arranged for stars with variations not beyond doubt. MDV numbers up to MDV 595 (field SA 9) given.



CCD confirmations of newly discovered variable stars in the fields of 104 Her (top) and β Cas

The results published in 2018: the field of 104 Herculis (18^h12^m +31.4°, J2000.0). Scans of 167 plates were available.
We announced 275 new variables (MDV 596 – 870):
8 high-amplitude Delta Scuti (HADS) stars; the trend of too many HADS stars we discover from scans compared to the earlier statistics is continued;
An RV Tauri (RVA) star with a nice light curve;
3 type II (CW) Cepheids;
70 RR Lyrae stars of different subtypes;
150 eclipsing variables;
22 red variable stars (9 LB stars and13 SR stars).

Karim Pichara's team (Chile, USA) works on machine-learning algorithms of automatic variable-star classification from the light curve parameters and other charactersitics. In 2016 – 2017, an attempt was made to apply techniques based on Random Forest algorithms to our photographic data for new variables in the 104 Her field. Raw, noisy photographic data were used, without any preliminary cleaning that would eliminate erroneous data points.

In total, we analyzed observations of 273 stars. Three versions of variability types were suggested for each of them, with probability of each type indicated. We also suggested types for the same stars using traditional human approach.

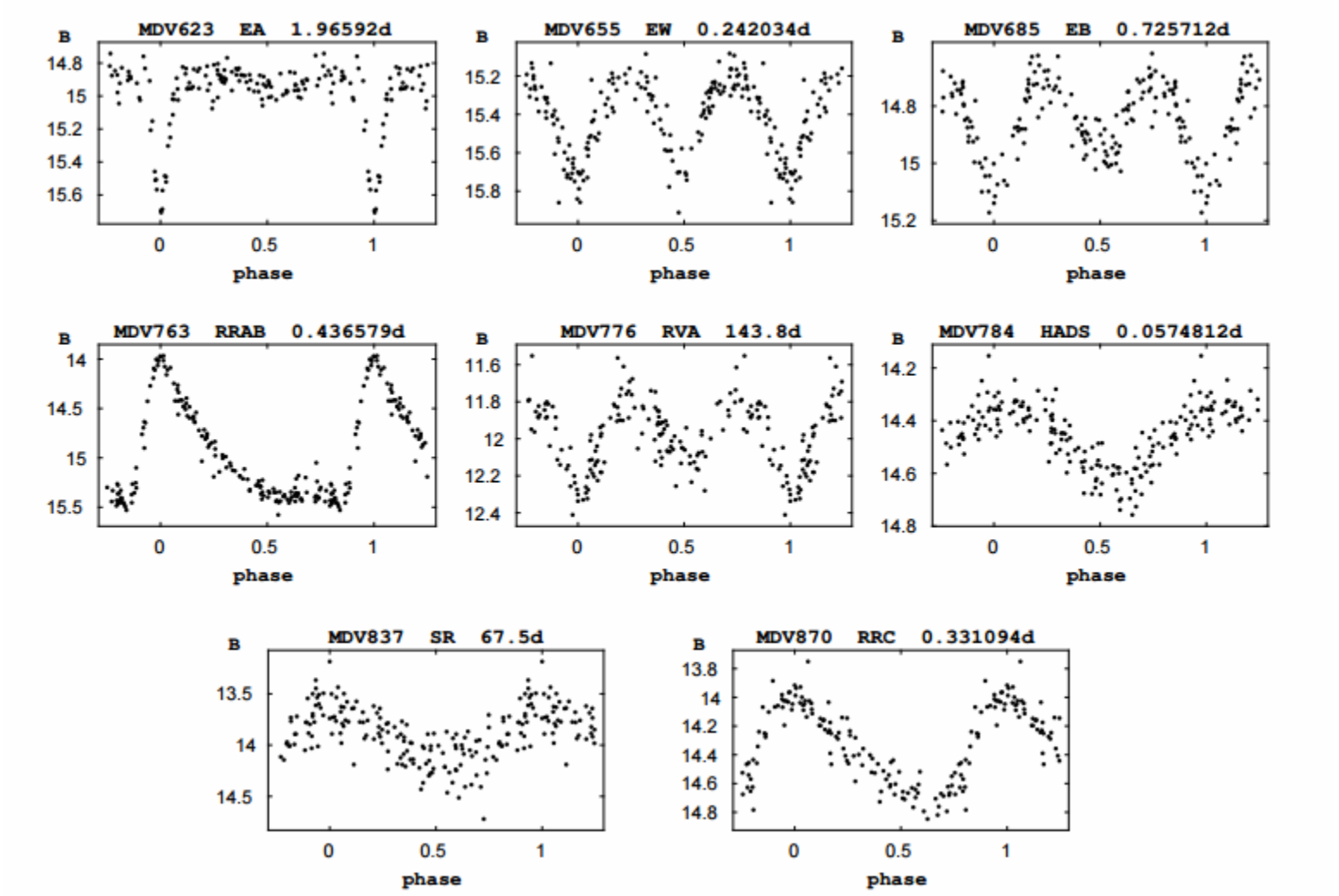
Agreement with the automatic classification suggested as the most probable one: 155 stars (57%)

Agreement with the second or third option: 85 stars (31%)

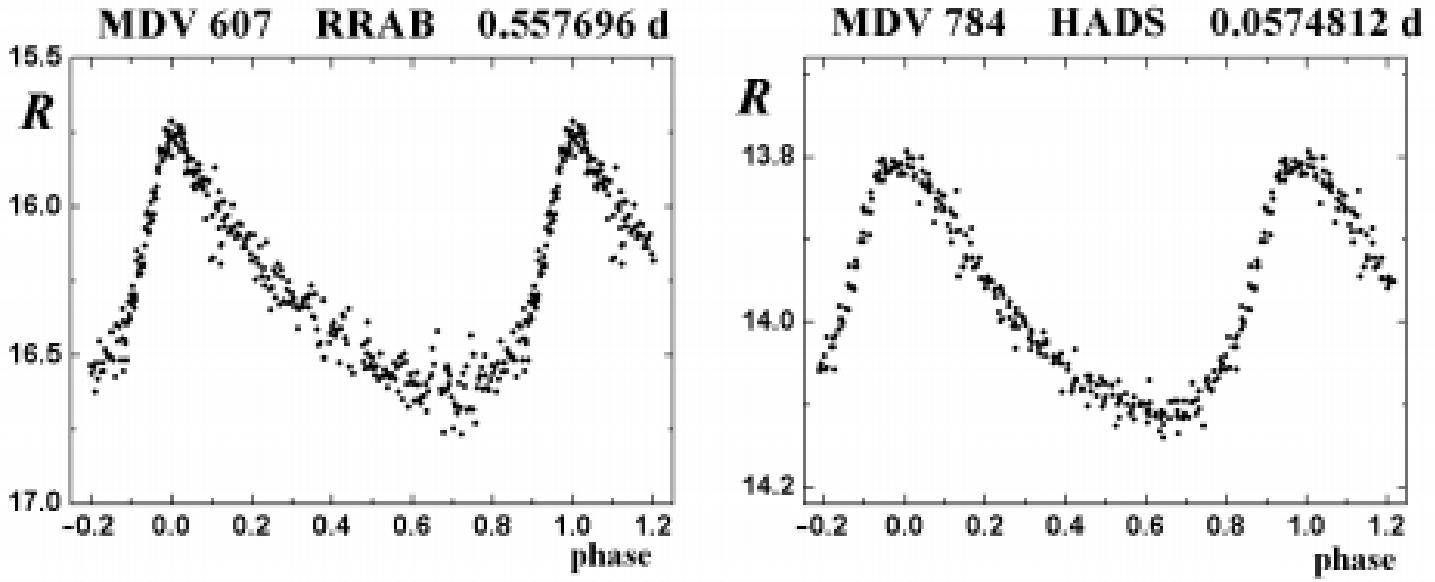
Complete disagreement of our types with the automatic classification: 33 stars (12%); nine of these stars belong to types not represented in the machine-learning sample.

In particular, the algorithm missed interesting variables: three of the HADS stars and the RVA star.

1. **The automatic classification is usually successful.**
2. **Our noisy data cause noticeable difficulties for the algorithm, compared to “pre-cleared” data, also used in our experiments.**
3. **Though the economy of time is very large, we cannot yet completely rely upon the automated classification in the case of noisy data; further improvement of the algotithm is needed.**



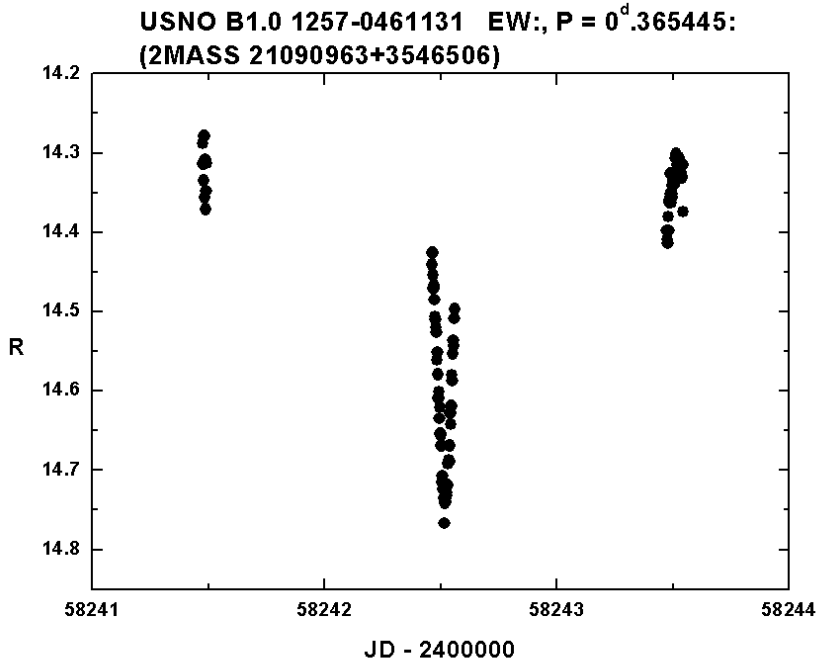
Light curves of variables of different types in the recent bunch of MDV stars

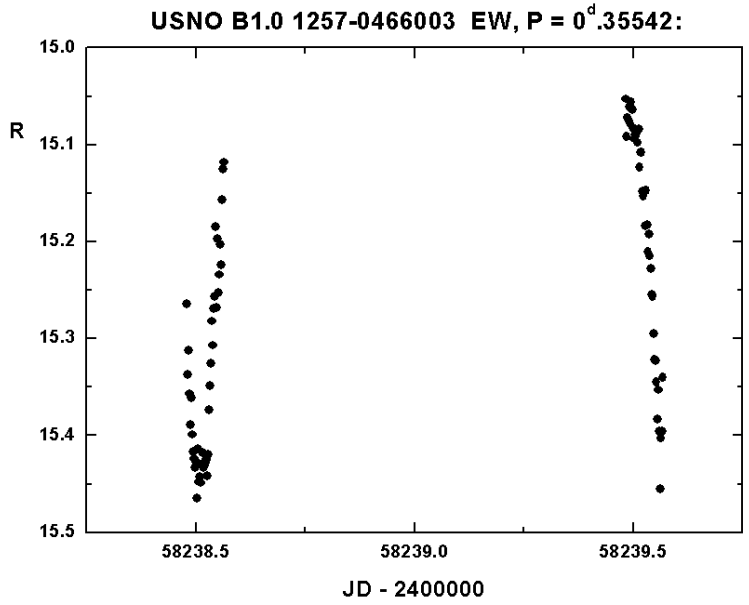


CCD light curves for two of the new variables

We are currently continuing our work in the field centered at 61 Cygni. The situation is now very different after the Gaia DR2 appeared in April, 2018, with more than half a million discoveries of pulsating variables. Their discoveries of eclipsing variables are not yet announced, leaving some space for our work. Also, projects like WISE space telescope (NASA), ASAS-SN (Ohio University) discovered many new variables (their interpretation for some of them can be improved) and, most important, provided *V*-band observations for many stars just in our working range of magnitudes.

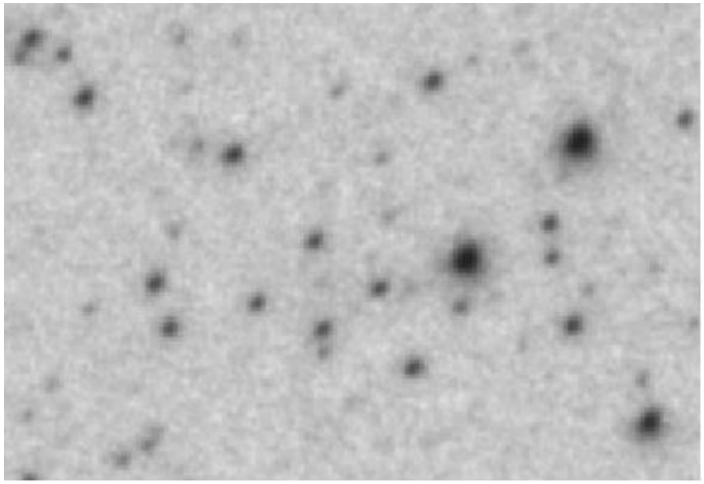
New field's statistics: 227 discoveries, 43 of them already discovered by WISE; 20, already announced by GAIA; 3, discovered by ASAS-SN; 16, discovered by different authors. Thus, 148 discoveries seem "new".

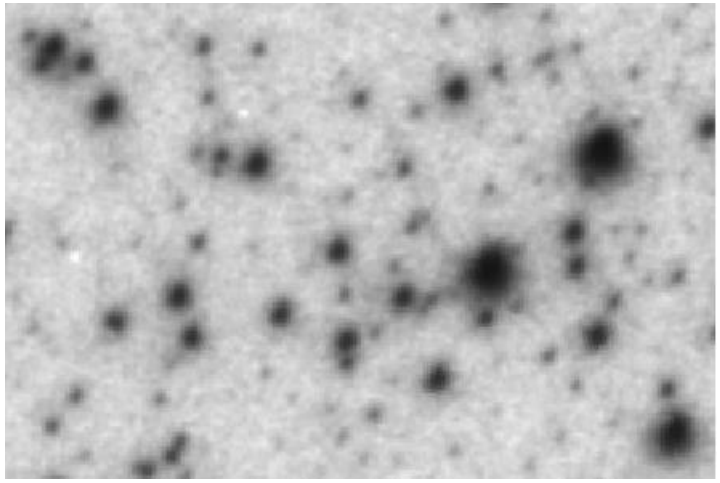




CCD observations of doubtful stars in the new field are still under way

Our software is inefficient for detecting transient phenomena. The star to be identified as a variable should be visible in most images. Only recently, we were able to detected our first dwarf nova due to its being close to an always visible star. We are looking for a better solution.

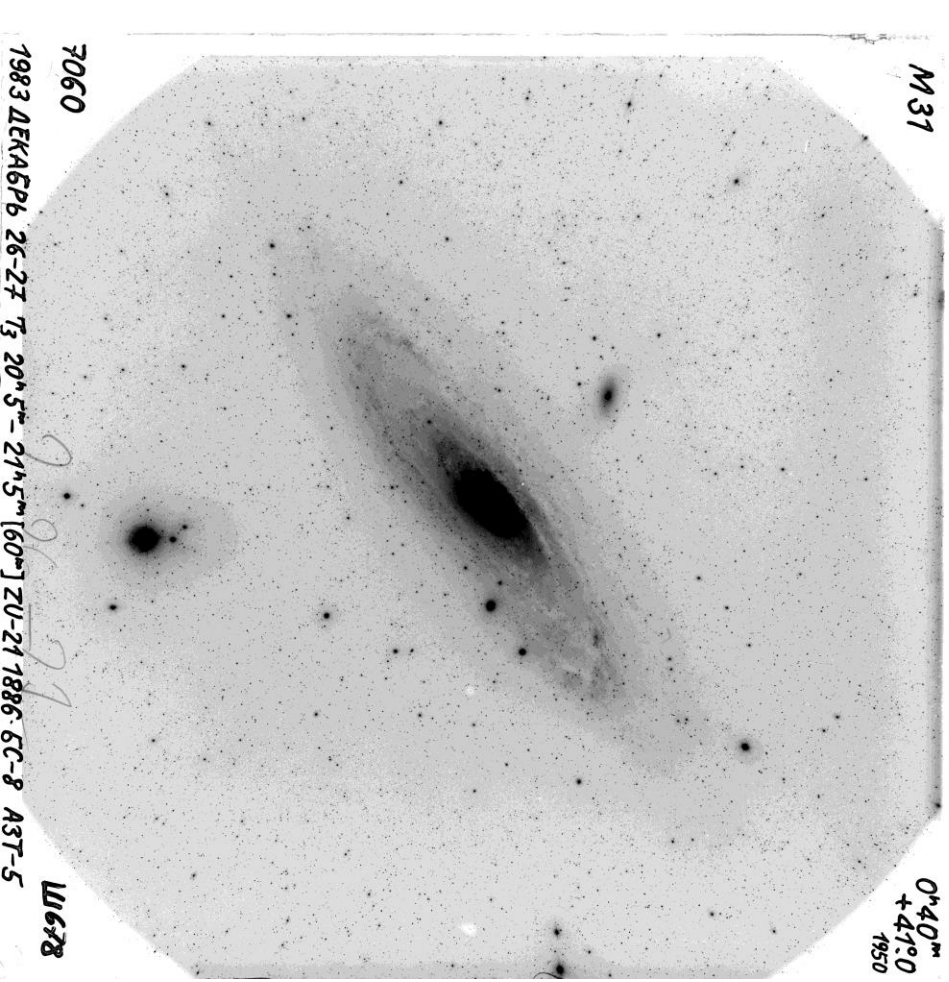


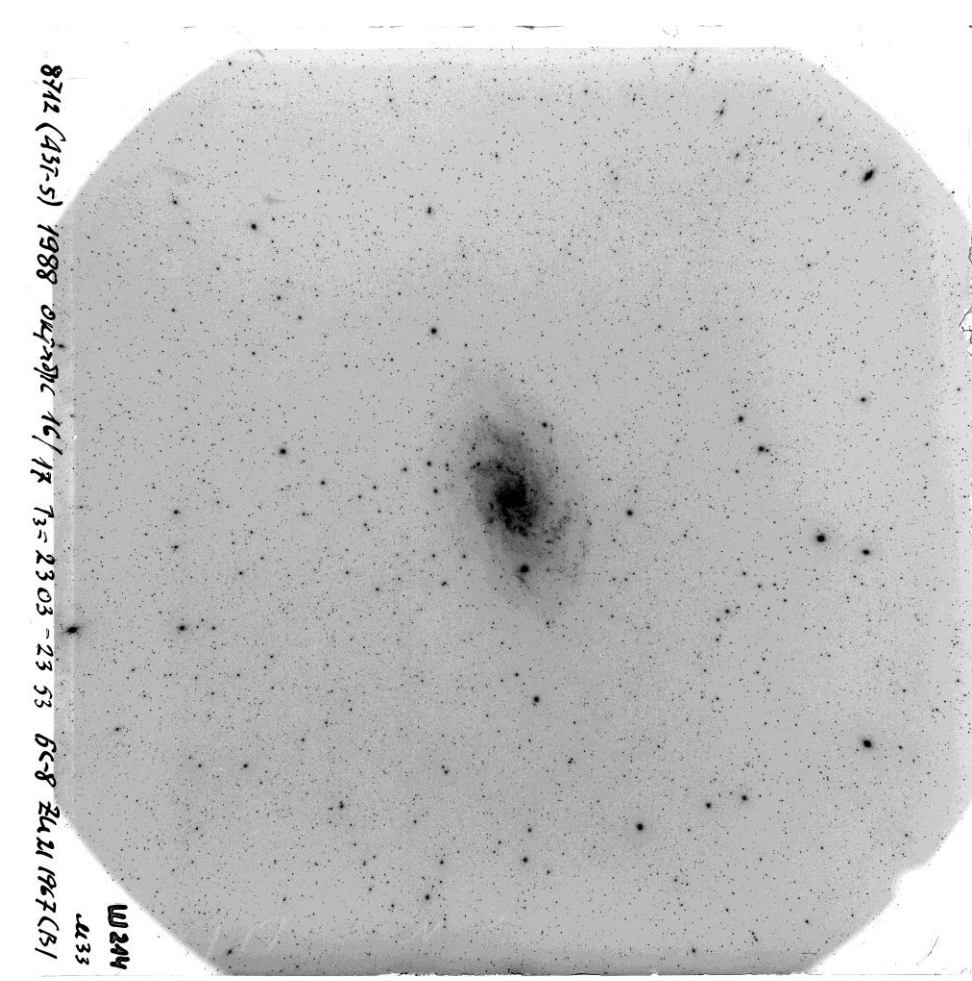


The new U Gem star in its high and low states

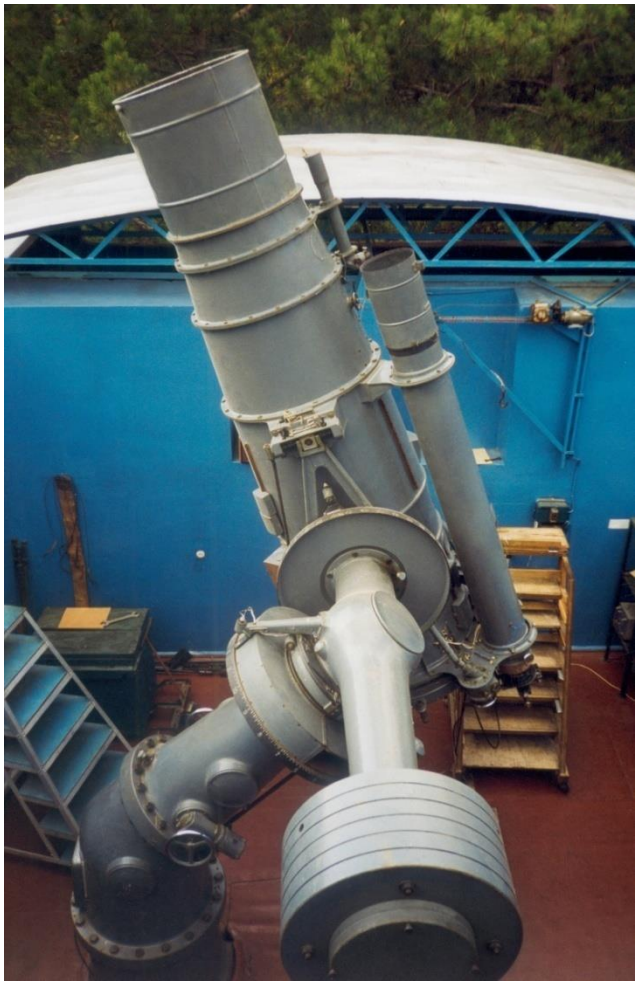
Probable tasks for our future work on plate scans:

- Studying secular behavior of variable stars (period variations);
- studying secular behavior of variable stars (changes of mean brightness);
- studying apsidal motion of eclipsing stars.





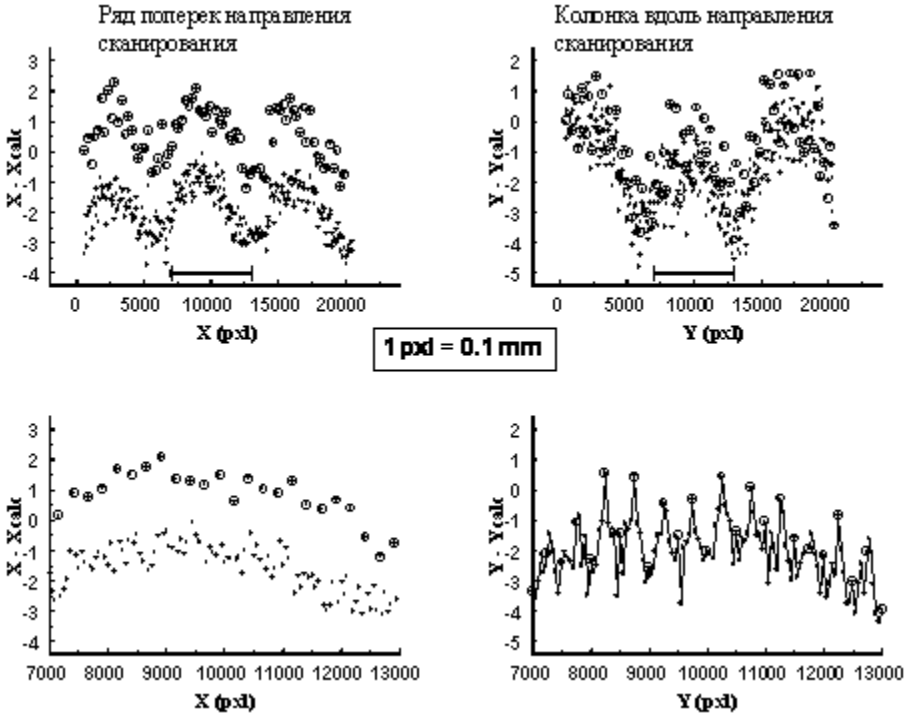
50-cm Maksutov plates of M31 and M33. All M31 plates (about 2000) have been digitized, similar work on M33 (about 700 plates) will be finished this year. Access to scans is at http://vast.sai.msu.ru/~alla/ (for questions, contact us)



The Crimean 50-cm Maksutov

The search for M31 novae on our AZT-5 plates: more than 70 discovered so far.

Astrometry using our scans:
Periodic errors of rectangular coordinates measured from scans;
Recent experiments performed by the head of SAI astrometry team, Prof. A.K. Dambis, evoke new hopes for astrometric use of our scans.



Periodic errors for CREO scanners (sorry for Cyrillics…)

THANK YOU!
DANKE SCHÖN!