Astronomical and Astrophysical Transactions (*AApTr*), 2018, Vol. 30, Issue 4, pp. 397–402,
ISSN 1055-6796, Photocopying permitted by license only, ©Cambridge Scientific Publishers

Scanning Moscow plate collection: program, electronic catalogs and new variable stars in the field of 104 Her

N.N. Samus[1,2,*], S.V. Antipin[2], D.V. Kolesnikova[1], K.V. Sokolovsky[2,3], M.K. Tsvetkov[4], A.M. Zubareva[1,2]

[1]*Institute of Astronomy, Russian Academy of Sciences, Moscow, Russia*
[2]*Sternberg Astronomical Institute, Lomonosov Moscow State University, Russia*
[3]*Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, Athens, Greece*
[4]*Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Sofia, Bulgaria*

Received 14 March, 2017

We present information on the current status of our program aimed at digitizing the Moscow archive of astronomical direct sky photographs. The scans are used to search for new variable stars. We report the results of this search in one of plate fields in Hercules, with more than 310 new variable stars discovered by us.

Keywords: Variable stars: general

1 Introduction

The history of photographing star fields at Moscow Presnya Observatory starts with rather unsuccessful attempts to use wet colloid emulsions undertaken in 1883 by A.A. Belopolsky (1854–1934), before he moved to Pulkovo in 1888. These photos (about 10 of them), with extremely large distortions making the sky poorly recognizable, are now kept at the Sternberg Institute's museum. Then, in 1895, S.N. Blazhko (1870–1956) started regular photographing using a small 9.7-cm ($F = 64$ cm) wide-field Steinheil camera. Mainly, seven telescopes, installed, at different times, at six observing sites, contributed to the current Sternberg Institute's collection of direct sky plates, estimated to contain some 60000 photographs taken before 1996 (predominantly plates, but also films; cf. Shugarov et al. 1999).

The most important part of our plate collection for studies of variable stars are about 22300 plates taken with the 40-cm astrograph ($F = 160$ cm). This is the so-called GA astrograph purchased in 1930s by C. Hoffmeister for Sonneberg Observatory

*Email: samus@sai.msu.ru

and taken in 1945 as a part of the USSR war reparations. Most of these plates were exposed at the site of the Moscow University's Crimean station, close to the Crimean Astrophysical Observatory. The color system of these 30×30-cm plates, covering $10^\circ \times 10^\circ$ of the sky, is almost exactly Johnson's B, the limiting magnitude of the best plates being about 17.5. For more details on this part of the Moscow plate collection, see Kolesnikova et al. (2008).

The electronic catalog of the main parts of Moscow plate collection has recently been improved (Emelianov et al., 2013) by adding accurate coordinates of each plate's center, instead of traditionally used names of the central objects, sometimes referring to star names from obscure, obsolete lists and catalogs. Now we are ready to present information on our plate archive to the Wide-Field Plate Database (WFPDB). For more information about the WFPDB, see Tsvetkova et al. (2018) in the current issue of the "Astronomical and Astrophysical Transactions". Preparing our plate catalog, we follow the advice of our Bulgarian colleagues, participants of our joint project in the program of cooperation between Bulgarian and Russian Academies of Sciences.

2 Plate scanning and search for variable stars

In 2006, we started digitizing Moscow plates (Kolesnikova et al. 2008). At first, we used two CREO EverSmart Supreme scanners, but they became out of order by 2011 and could not be repaired. Upon advice from one of the authors of the present paper (M.K.T.), we bought a much cheaper Epson Expression 11000XL scanner in the second half of 2013 and resumed scanning with the resolution of 2400 dpi. This high resolution permits us not to deteriorate the limiting magnitude.

Our scanning program proceeds not very quickly because of staff and finance shortages. Actually, there are three independent scanning programs: (1) scanning old historical plates; (2) scanning plates from different telescopes with photographs of the galaxies M31 and M33; (3) scanning plates from the 40-cm astrograph for variable-star research. The present paper presents, in the next sections, some new results from the program (3).

The plate collection of the 40-cm astrograph can contain as many as 100–500 plates per field. We decided to arrange scanning so that all plates of a field are scanned within a short time interval, and then the result is used to search for new variable stars and to study the newly discovered objects.

Our semi-automated search for new variables makes use of the VaST software (Sokolovsky and Lebedev 2005; http://scan.sai.msu.ru/vast) that relies on SExtractor (Bertin and Arnouts 1996) for star detection and aperture photometry. A detailed description of the VaST software has been recently published (Sokolovsky and Lebedev 2018).

After several tests we called "pilot projects" we searched for variable stars in the fields centered at 66 Oph ($18^{\rm h}00^{\rm m} + 04.4^\circ$, 2000; Kolesnikova et al. 2008, 2010), Kapteyn's field SA9 ($03^{\rm h}12^{\rm m} + 60.6^\circ$, 2000; Sokolovsky et al. 2014). The procedure is that we identify candidate variables semi-automatically and then rely upon judgment of human experts concerning reliability of variations and probable classification.

3 Recent results for the field around 104 Her

The field most recently studied using Moscow plate scans is that centered at the star 104 Her ($18^h12^m + 31.4°$, 2000). For this field, we have scans of 167 plates taken with the 40-cm astrograph in 1976–1994. This field is at a moderately high galactic latitude (+21.6° at its center). From the scans, we currently have more than 310 new discoveries of variable stars (Kolesnikova et al. 2017).

As usual, eclipsing variables dominate among the newly discovered variable stars (206 stars; 118 of them, EW variables). It was quite expected, because of the galactic latitude, that there were also 54 new RR Lyrae stars of different subtypes. Also numerous are pulsating red variables (we tentatively consider 25 of them LB stars and 15, SR variables).

We discovered four reliable high-amplitude δ Scuti (HADS) stars in the field. This result is in agreement with the previously noticed unexpectedly high number of HADS stars in our automatic discoveries compared to the earlier GCVS statistics (Kolesnikova et al. 2010). Besides, we detected (not very certainly) four possible Cepheids (two of them are expected to be Type II Cepheids).

Figure 1 is the light curve of the RV Tauri variable ($18^h23^m46.2^s + 28°52'14''$, 2000.0) discovered in the field of 104 Her. The presence of the star in the field was known to us (it was found several years ago by one of the authors, S.V.A., but remained unpublished). Since we are still gathering experience with automatic discoveries, it was of interest for us that our "blind" search for new variable stars has recovered the star.

Another discovery is presented in Fig. 2. This variable ($18^h24^m39.3^s +30°32'19''$, 2000.0) has a very short period (0.0575^d) and, by its light curve, is a HADS variable. Its apparent association with a ROSAT X-ray source 1RXS J182439.3+303213 is most

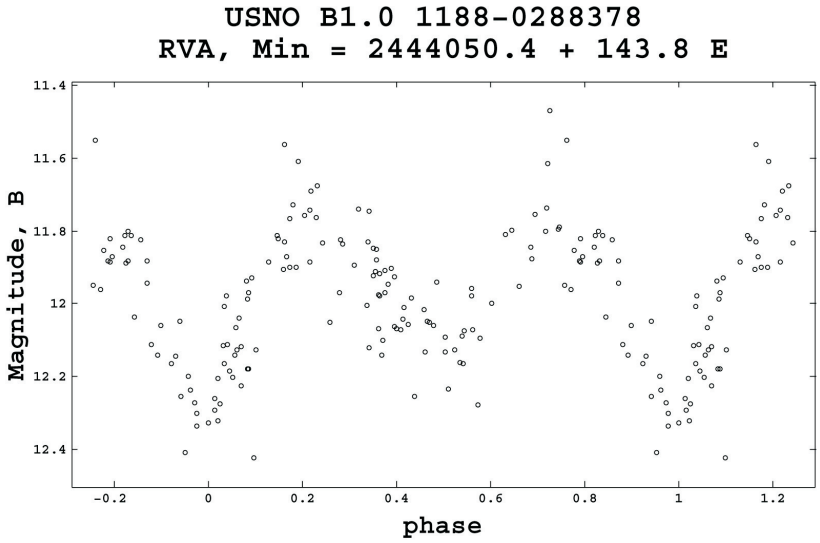


Figure 1 The photographic light curve of the RV Tau variable in the field of 104 Her.

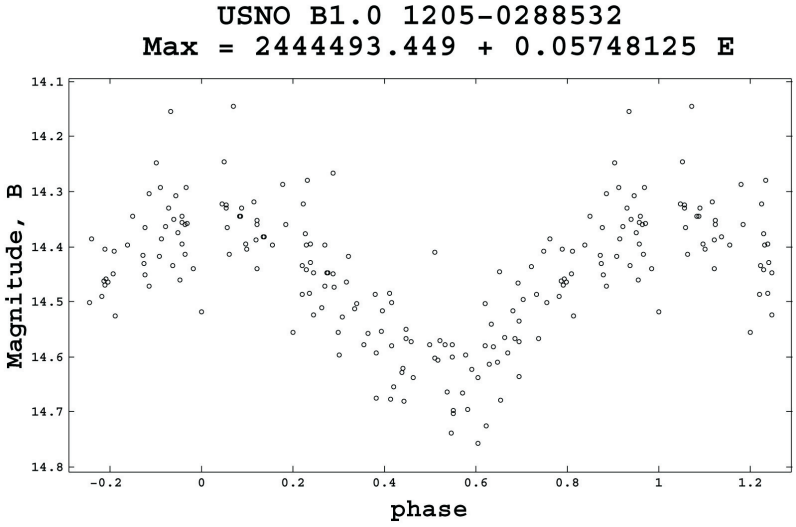


Figure 2 The photographic light curve of the new HADS variable in the field of 104 Her.

probably due to low accuracy of the X-ray coordinates. We have now improved its light curve and confirmed its HADS classification from CCD observations (Fig. 3).

As usual, searching variable stars from photographic plates, we found several stars that vary, with a certain amount of probability, but cannot be reliably confirmed and attributed to one of the variability type. For such stars, we organize CCD observations using telescopes of the Moscow University's Crimean laboratory. Figure 4 shows the result for one of suspected variables in the field of 104 Her ($17^{\rm h}55^{\rm m}03.1^{\rm s}$ $+29°19'11''$,

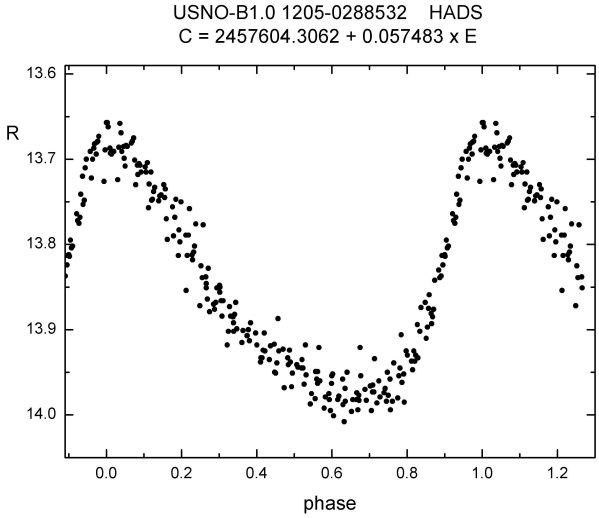


Figure 3 The CCD light curve of the same HADS variable.

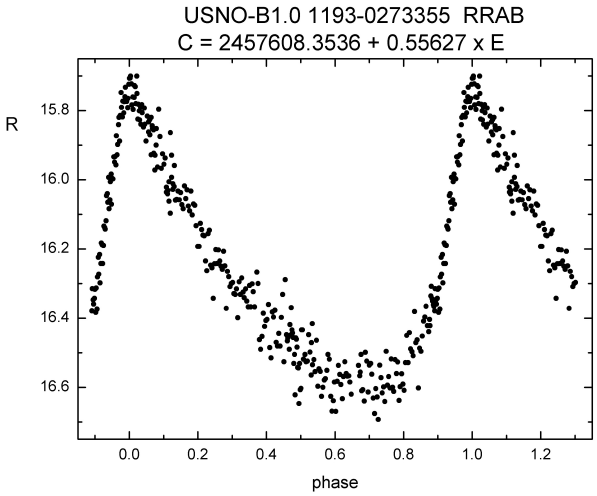


Figure 4 The CCD light curve of the new RR Lyrae (RRAB) variable in the field of 104 Her.

2000.0) that is now confirmed to be a reliable RRAB star.

4 Cooperation aimed at automated classification

As noted above, our final decisions concerning variability type are taken by human experts. Currently, the flow of variable-star discoveries makes it more and more important to develop systems permitting automated classification of variable stars based on photometric series. The first attempts to do this were not very successful, but recent progress is impressive (e.g., Pichara et al. 2016; Mackenzie et al. 2016).

In most cases, automated classification algorithms are applied to high-quality CCD photometry of variable stars. Noisy photographic data can be much trickier. However, attempting to develop an automatic pipeline for large-scale photographic discovery projects like ours is worthwhile, opening prospects of quick processing of large amounts of data.

Since the second half of 2016, we have been cooperating with K. Pichara (Catholic University of Chile and Harvard University, USA) and I. Becker (Catholic University of Chile), studying possibilities of applying their classification algorithms to our photographic data for the field of 104 Her. The first results are quite encouraging, though it is still necessary to increase the percentage of correct identifications in order to avoid mixing up variability types with rather similar light curves (like EW eclipsing stars and RRC pulsating variables).

Conclusions

The plate collection of the Sternberg Astronomical Institute, one of the richest ones in Eastern Europe, provides interesting possibilities for new astronomical research. To take complete advantage of these possibilities, the plate archive should be digitized. With the progress of this work, we will be able to obtain new results in searching for variable stars and studying them, opening prospects of improving variable-star statistics for our Galaxy.

Acknowledgements We acknowledge support from the Presidium of the Russian Academy of Sciences (program P-7).

References

Bertin, E., Arnouts, S., 1996, Astron. & Astrophys. Suppl., 117, 393

Emelianov, N.V., Kuimov, K.V., Samus, N.N. 2013, Proceedings of NAROO-GAIA Workshop "A new reduction of old observations in the Gaia era", Paris, June 20–22, p. 137

Kolesnikova, D.M., Sat, L.A., Sokolovsky, K.V., Antipin, S.V., Samus, N.N. 2008, Acta Astronomica, V. 58, p. 279

Kolesnikova, D.M., Sat, L.A., Sokolovsky, K.V., Antipin, S.V., Belinsky, A.A., Samus, N.N. 2010, Astronomy Reports, V. 54, p. 1000

Kolesnikova, D.M., Antipin, S.V., Sokolovsky, K.V., Samus, N.N., Zubareva, A.M., 2017, in preparation

Mackenzie, C., Pichara, K., Protopapas, P., 2016, Astrophys. J., 820, 138

Pichara, K., Protopapas, P., León, D., 2016, Astrophys. J., 819, 18

Shugarov, S., Antipin, S., Samus, N., Danilkina, T., 1999, Acta Historica Astronomiae, V. 6, p. 81

Sokolovsky, K.V., Antipin, S.V., Zubareva, A.M., Kolesnikova, D.M., Lebedev, A.A., Samus, N.N., Sat, L.A., 2014, Astronomy Reports, V. 58, p. 319

Sokolovsky, K.V., Lebedev, A., 2005, in "12th Young Scientists' Conference on Astronomy and Space Physics", Kyiv, Ukraine, April 19–23, 2005, eds. A. Simon and A. Golovin, p. 79

Sokolovsky, K.V., Lebedev, A.A., 2018, Astronomy and Computing, 22, 47

Tsvetkova, K., Tsvetkov, M., Kirov, N., Kaglarsky, D., Edelmann, H., 2018, Astronomical and Astrophysical Transactions (this issue)