Contrib. Astron. Obs. Skalnaté Pleso **49**, 358 – 362, (2019)

Follow-up observations of variable stars at the Terskol Observatory within the Gaia project

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Received: November 7, 2018; Accepted: February 6, 2019

Abstract. We report on optical observations of stellar objects (SNe, CVs, YSOs, etc.), which were detected within the framework of the Gaia mission. The telescopes Zeiss-2000 and Zeiss-600 at the Terskol Observatory provide good enough opportunities especially for follow-up studies of these objects. Photometric observations have been used to perform a quick analysis of the imaging data in order to reveal short- or long-term variability in the brightness of Gaia transients. Appropriate software developed has been applied for processing and analysis of datasets gathered in 2016-2018 for more than 40 objects; a lot of them have been continuously observed over the years. In this paper, we present some results obtained for transients Gaia17dce, Gaia18aen, and Gaia18cct.

Key words: variable stars – photometry – light curves – transients – Gaia

1. Introduction

Nowadays, analysis of observational datasets gathered by the Gaia satellite is worldwide well advanced. Research groups in many countries work together to achieve the best possible results by investigating a wide variety of transient events and stellar activity, which have been detected by the space telescope. However, interpretations and theoretical models which are based on space data require verification and additional observations to be performed using ground-based instruments.

During the last three years, the facilities of the Terskol Observatory in the Northern Caucasus (43° 16′ 29″ N, 42° 30′ 03″ E, 3143 m asl) have been heavily used for follow-up photometry of Gaia transients. The available optical telescopes with diameters up to 2 m open up good opportunities for long-term monitoring of asteroids and stellar objects (Tarady et al., 2010). By providing observations of newly detected transients (SNe, CVs, YSOs, etc.), the Terskol Observatory contributes significantly to their classification and a better understanding of star formation and evolution.

2. Observations and results

Research activities at the Terskol Observatory (IAU code B18) are now highly focused on BVRI photometry (including long-term monitoring) of transients detected by ESA Gaia, DPAC and the Photometric Science Alerts Team *(gsaweb.ast.cam.ac.uk/alerts)*. As for the objects to be of the most importance, the following selection criteria are applied:

- (very) recently detected transients (G mag down to 18.8);
- a high emphasis on unclassified objects;
- objects that show unusual (intriguing) light curves.

Since 2016, a lot of Gaia transients have been observed at the Terskol Observatory: Gaia16asm, Gaia16bkf, Gaia16bkn, Gaia16blg, Gaia16bnz, Gaia16bvs, Gaia16bvt, Gaia17akp, Gaia17agr, Gaia17agj, Gaia17aqm, Gaia17asz, Gaia17bqo, Gaia17ctl, Gaia17cty, Gaia17cuh, Gaia17cvx, Gaia17cxa, Gaia17dev, Gaia17dcx, Gaia17ddg, Gaia17dce, Gaia17ddi, Gaia17ddp, Gaia18aak, Gaia18aen, Gaia18aes, Gaia18afb, Gaia18akt, Gaia18aip, Gaia18ajz, Gaia18arm, Gaia18arn, Gaia18axl, Gaia18azl, Gaia18avw, Gaia18cct, Gaia18cfs, Gaia18chm, etc.

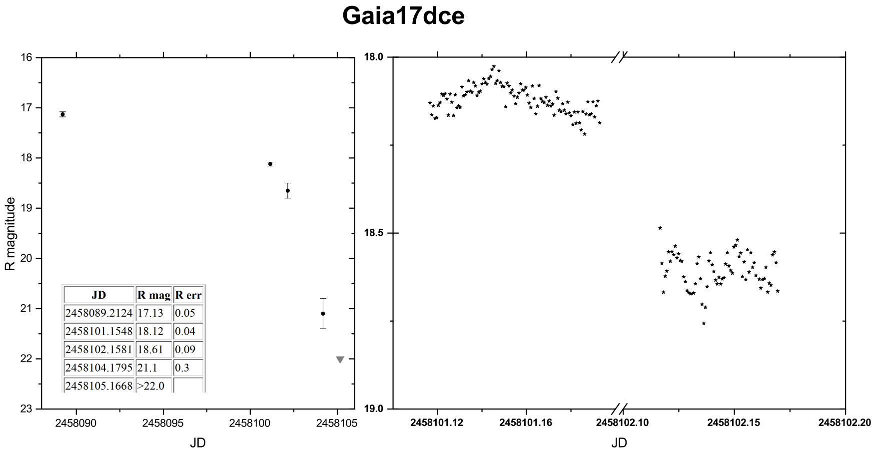
More than 8000 photometric measurements of these objects were recorded; images were taken mainly with the Zeiss-600 telescope. For sources of magnitude G$\sim$16, a photometric accuracy of better than 0.05 mag was achieved for V, R, I passbands, while the errors in B values are somewhat larger. The follow-up data points obtained have been uploaded to the Cambridge Photometric Calibration Server *(http://gsaweb.ast.cam.ac.uk/followup)*. The co-processing of photometric data from many observing sites results in a detailed light curve coverage that allows one to investigate the object′s distinctive features (Wyrzykowski et al., 2018).

Here we provide some findings for the three unclassified transients.

Gaia17dce

This bright blue hostless transient was discovered by Gaia on 2017-11-27 at magnitude G = 16.67. There was no progenitor object on archival images. We detected Gaia17dce on the images taken on 2017-12-01 with the 2-m telescope. Using the AAVSO catalogue for photometric calibration we obtained the following magnitudes of the source (not corrected for the Galactic foreground extinction): B = 17.41 $\pm$ 0.07, V = 17.12 $\pm$ 0.08, R = 17.13 $\pm$ 0.05 (MJD 58088.71).

Additional observations of this unclassified object, which were performed at Terskol from 2017-12-13 to 2017-12-17, showed that its R-band brightness has fallen down by more than 4 mags within the four days; the light curve depicted small variations within 0.2 mag on a time scale of hours (Fig. 1). Taking into account a sudden increase in brightness by at least 5 mags and a rapid decay 20 days later, we suggest that Gaia 17dce is a cataclysmic variable star. It is significant to note that we did not detect Gaia17dce in CCD images taken on 2017-12-17 (limiting R mag > 22.0), on 2018-04-25 (limiting R mag > 21.0), and on 2018-07-17 (limiting R mag $\sim$ 21.0).



JD	R mag	R err
2458089.2124	17.13	0.05
2458101.1548	18.12	0.04
2458102.1581	18.61	0.09
2458104.1795	21.1	0.3
2458105.1668	>22.0	

Figure 1. *Left*: R-band photometry for Gaia17dce performed in December 2017 with the 2-m telescope at the Terskol Observatory. *Right*: R-band observations of Gaia17dce on December 13 and 14, 2017. Notes: 1) due to the instrumental errors, measurements of December 14 were smoothed using the boxcar averaging (of three points); 2) the grey triangle indicates the limiting R magnitude of about 22.0; 3) the NOMAD catalog was used for photometric calibration.

<u>*Gaia18aen*</u>

A $\sim$ 1 mag increase in brightness of this object was detected by Gaia on 2018-01-17, when its G magnitude reached 11.33. This bright emission line star in the Galactic plane apparently did not show any significant variability until December 2017. Moreover, it was noticed by Wray (1966) and indicated as WRAY15-136.

BVRI photometry of Gaia18aen was performed at Terskol with the 0.6-m telescope in February-March 2018. All the follow-up data points were uploaded to the Cambridge Photometric Calibration Server. Fig. 2 shows multi-band observations of Gaia18aen, which were acquired in 2018 by Gaia and by the three ground-based observers. The light curve demonstrates the decaying oscillations on a time scale of months, with the general decline of the object's brightness to the baseline. So far, the revealed variability does not allow the unambiguous classification of Gaia18aen; it is assumed to be an YSO or a nova.

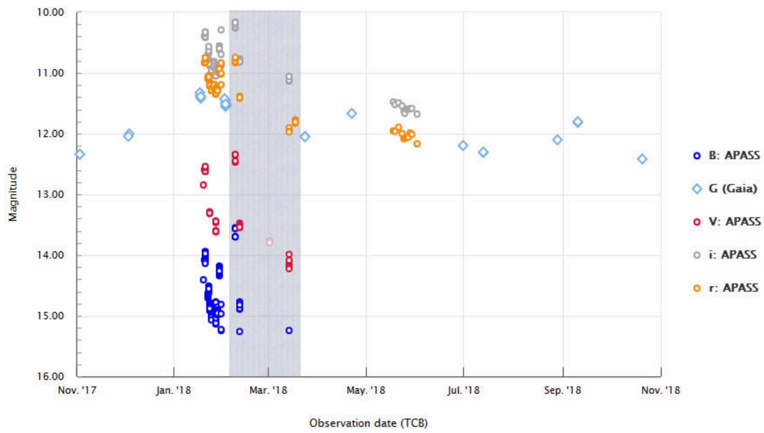


Figure 2. Multi-band follow-up observations of Gaia18aen in 2018. The shaded area depicts the time span containing observations from Terskol. *(Image from http://gsaweb.ast.cam.ac.uk/alerts)*.

Gaia18cct

A long-term rise of 0.4 mag in brightness of this Gaia source was announced on 2018-08-10. Based on the Gaia′s photometry (Fig. 3, the inset), which showed a slow falling (over more than one year) and than a slow rising (over the period of about one year) of the brightness of the object, Gaia18cct was primarily assumed to be a microlensing event or a Mira. In this case, however, one should take into account that Gaia18cct appears near the direction of the Galactic anticenter and is apparently located at the outer edge of the Milky Way.

Since 2018-08-14, Gaia18cct has been continuously observed at Terskol; data processing has been made using the Cambridge Photometric Calibration Server. Fig. 3 demonstrates that the source brightness remained approximately constant over the observed four-month period, with insignificant changing colors. Thus, the results obtained show clearly that further observations of Gaia18cct are needed in order to classify its variability.

3. Conclusions

Three-year observations of Gaia transients at the Terskol Observatory have yielded new data and findings. Photometric observations acquired with the aid of the 0.6-m and 2-m telescopes have been continuously uploaded on the Cambridge Photometric Calibration Server. Being collected along with datasets gathered worldwide, they can be used by the astronomical community for a further analysis. This is an outstanding example how a more systematic, integrated use of small and medium-aperture telescopes leads to better information about transient events in the Universe.

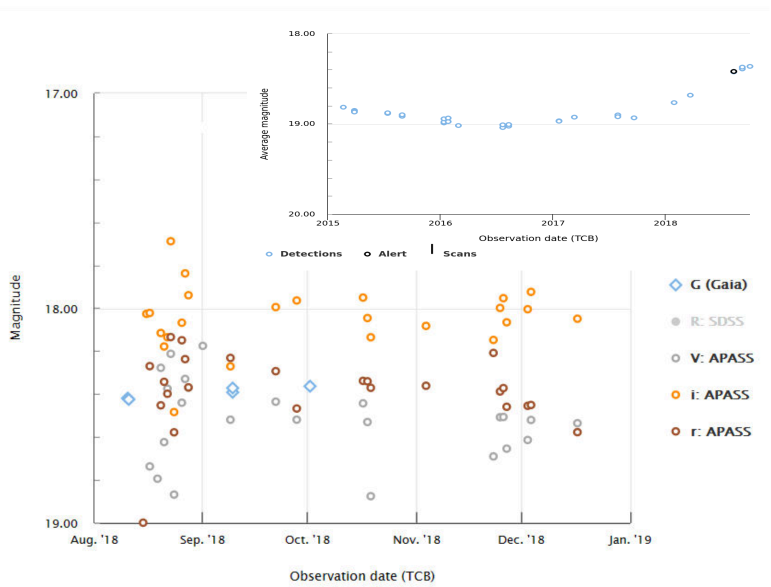


Figure 3. Multi-band follow-observations of Gaia18cct in August-December 2018 at Terskol with the 0.6-m telescope. *The inset*: Lightcurve of Gaia18cct from Gaia's observations. *(Images from http://gsaweb.ast.cam.ac.uk/alerts).*

Acknowledgements. We acknowledge the use of the Cambridge Photometric Calibration Server *(http://gsaweb.ast.cam.ac.uk/followup)* developed and maintained by Lukasz Wyrzykowski, Sergey Koposov, Arancha Delgado, and Pawel Zielinski, funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 730890 (OPTICON).

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