

## SERBIAN-BULGARIAN MINI-NETWORK TELESCOPES AND GAIA-FUN-TO FOR THE PERIOD 2014-2017

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**Abstract.** About 3000 Gaia Alerts were done by the Gaia Science Alerts group during the last three years (period October 2014 – October 2017). We have observed about 45 objects (about 1650 CCD images) of Gaia-FUN-TO for that period; it is near 15 objects (or 550 CCD images) per year. The standard Johnson BV and Cousins RcIc filters were used, and bias, dark and flat-fielded corrections were applied (plus hot/dead pixels, shutter effect, etc.). The astrometry solution for individual data frames was done in Astrometry.Net (<http://astrometry.net>), and the Source Extractor was used for the aperture photometry measurements. Finally, the data were sent to the Cambridge Photometry Calibration Server or CPCS (<http://www.ast.cam.ac.uk/iaa/wikis/gsaawgwiki/index.php/Follow-up>) for further calibration. At the end of 2014, the rare object Gaia14aae (GaiaVerif14acp), the deeply eclipsing AM CVn system, was actual and we did our efforts to observe it; as a result, the paper about it (Campbell et al. 2015) was published. In the last two years, another rare object, Gaia16aye – the binary microlensing event, was very interesting and we observed it many times. Also, other rare objects (supernovae, cataclysmic variables, etc.) were observed. To do that, we have used 6 instruments via local cooperation the “Serbian-Bulgarian mini-network telescopes” (established in 2013) and SANU-BAN joint research project “Study of ICRF radio-sources and fast variable astronomical objects” for three-years period (2017-2019, the head is G. Damljanović). In the last two years (2016-2017), the 60 cm Rozhen telescope (Bulgaria) has been under reconstruction, but there is a new one, the 1.4m at ASV (Serbia) from mid-2016 via Belissima project. The first data of the 1.4 m telescope are very good. Some results about the Gaia-FUN-TO are presented, here.

## 1. INTRODUCTION

The Gaia is a space mission of the European Space Agency – ESA. It is operating since 2014 (astrometrically, photometrically and spectroscopically surveying the full sky). The Gaia-based results are useful for all the relevant scientific communities. It is doing revolution in astrometry, our understanding of the Milky Way galaxy, stellar physics and the Solar system bodies. The main goal of Gaia is to collect the high-precision astrometric data (positions, proper motions, and parallaxes) of sources in the G magnitude range 3 to 21. The Gaia catalogue is an important step in the realization of the Gaia reference frame in future. The second Gaia data release - DR2 (~1.7 billion sources) has been made publicly available on April 2018.

The Gaia scans the sky multiple times, and provides near-real-time photometric data. These data are used to detect some changes in brightness from all over the sky (or appearance of new objects), and the Gaia Science Alerts system produces alerts on some interesting objects. The Gaia Photometric Science Alerts published first alerts at October 2014. Three years after that, the Gaia Science Alerts is among the leading transient surveys in the world. The transients are: supernovae, cataclysmic variables, microlensing events, other rare phenomena. During three years, more than 3000 transients were discovered (until October 2017).

The installation of first telescope (the 60 cm one) at Serbian new site, the Astronomical Station Vidojevica - ASV (of Astronomical Observatory in Belgrade – AOB), was in 2011. At mid-2016 there is a new one, 1.4 m telescope at ASV, via the Belissima project (see <http://belissima.aob.rs>). Also, we used 4 instruments in Bulgaria (at Belogradchik and Rozhen sites).

## 2. INSTRUMENTS AND RESULTS

We started the regional cooperation “Serbian-Bulgarian mini-network telescopes” (now, 6 instruments) in 2013. It is in line with the SANU-BAN joint research project “Observations of ICRF radio-sources visible in optical domain” (for the period 2014-2016), and actual one “Study of ICRF radio-sources and fast variable astronomical objects” (2017-2019); head is G.Damljanović. The main information about the instruments is presented in few papers (Damljanović *et al.* 2014; Taris *et al.* 2018). It is possible to see the pictures of Schmidt-camera 50/70 cm (Fig. 1), at NAO Rozhen, and 60 cm of ASV with dome (Fig. 2). The NAO BAS means National Astronomical Observatory of Bulgarian Academy of Sciences, and Serbian Academy of Sciences and Arts is SASA (or SANU in Serbian language).

Also, we used the 60 cm and 1.4 m at ASV with other CCDs: the SBIG ST-10 XME (scale=0.23 arcsec and field of view or FoV=8.4x5.7 arcmin using 60 cm at ASV), Apogee Alta E47 (0.45 arcsec and 7.6x7.6 arcmin using 60 cm at ASV), etc.



**Figure 1:** The Schmidt-camera 50/70 cm (NAO Rozhen, Bulgaria).

Before October 2017, a new aluminization of 2 m Rozhen telescope was finished.

Usually, we did 3 CCD images per filter. The standard bias, dark and flat-fielded corrections are done (also, hot/dead pixels are removed). The Astrometry.Net and Source Extractor are used. The output is supposed to be submitted to the Cambridge Photometric Calibration Server (CPCS) for further calibration. The Johnson-Cousins BVRcIc filters were available.

We collected about 1650 CCD images of the Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO, or Gaia Alerts) during about three years (October 2014 – October 2017); or ~550 images per year. It is about 45 objects (near 15 objects per year).

In 2017, we observed 14 objects (about 56% of all objects which we observed) using just the **60 cm telescope at ASV**: Gaia16aye (11 times), Gaia16bnz (2), Gaia17bsu (1), Gaia17bsp (1), Gaia17bsr (1), Gaia17bts (7), Gaia17bxh (1), Gaia17chf (1), Gaia17cgo (1), Gaia17che (1), Gaia17cpa (1), Gaia17cup (2), Gaia17cut (1), and Kojimaevent (1).

With the **1.4 m one at ASV**, we did 5 objects (18%): Gaia16aye (11), Gaia17arv (1), Gaia17asa (1), Gaia17asc (1), and Gaia17aru (1).

With the **60 cm instrument at Belogradchik**, just one object (4%) and it is Gaia17ade (2).

Also, one object (4%) using the **2 m telescope at NAO Rozhen**; it is Gaia16aye (4).

And 5 objects (18%) with **Schmidt-camera 50/70 cm at NAO Rozhen**: Gaia17asc (1), Gaia17arv (1), Gaia17asa (1), Gaia17chf (1), and Gaia17bts (1).

The **60 cm telescope of NAO Rozhen** (0%) was under reconstruction from 2016 until mid-2018, and we expect some data using that instrument.

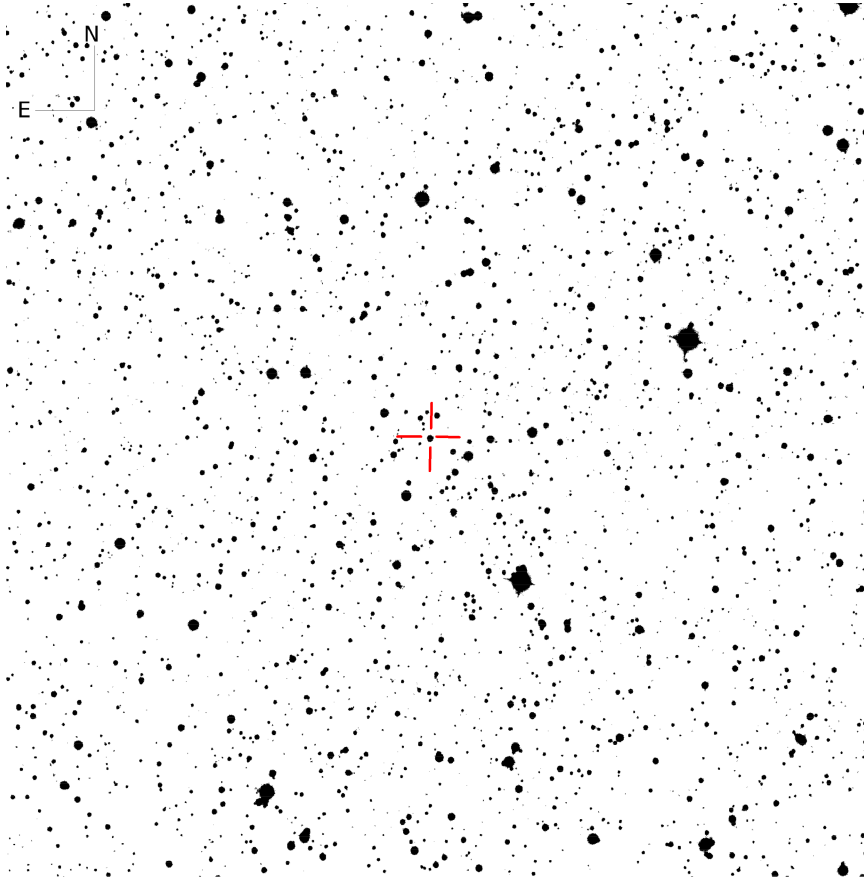
About some results, the CCD image of **Gaia16aye**, after standard reduction (bias/dark/flat, hot/dead pixels, etc.), is presented (see Fig. 3). The object is marked with cross. That image was made at 19th June 2017 using the 1.4 m ASV telescope with CCD Apogee Alta U42: R-filter, Exp.=40sec, FoV=8.3x8.3 arcmin, binning=1x1, scale=0.243 arcsec. The Gaia16aye was published on Gaia Science Alerts webpage on 9 Aug 2016. The star has a counterpart in the 2MASS as 2MASS 19400112+3007533 towards the Cygnus constellation. That object is the binary microlensing event, and the first discovered in the Northern Galactic Disk. Lot of points (see Fig. 4, light curve of Gaia16aye) are the results of our Serbian-Bulgarian observations. We observed the Gaia16aye 18 times (epochs) during second half of 2016 and 26 times during 2017. At 25th October 2016 we did it using 3 instruments: 50/70 cm Schmidt-camera and 2 m telescope of NAO Rozhen, and 1.4 m instrument of ASV. Together paper about that object is under preparation in the A&A journal (with other co-authors); we hope it will be done, soon.



**Figure 2:** The 60 cm telescope in its dome (ASV, Serbia).

In line with our cooperation with Dr. Alok Gupta (India) that object was observed 5 nights (21<sup>st</sup> – 25<sup>th</sup> November 2016) with the 1.31 m ARIES telescope (Aryabhata Research Institute of observational sciences, Manora Peak, Nainital) in the central Himalayan region:  $\lambda=79.7E$  deg,  $\varphi=29.4N$  deg,  $h=2420$  m. The CCD Andor DZ436 was used: 2048x2048 pixels, 13.5x13.5  $\mu\text{m}$  pixel size, the scale is

0.54 arcsec per pixel, FoV=18.5x18.5 arcmin. That instrument is modified R.-C. system Cassegrain; it is Devasthal Fast Optical telescope (DFOT).



**Figure 3:** The Gaia16aye using the 1.4 m telescope (ASV, Serbia).

Some results of Gaia16aye, in line with observations done at 25<sup>th</sup> October 2016 (JD=2457687.5), are:

- using **1.4 m telescope at ASV**

MJD=57686.89422, V=14.949 st.dev.=0.010,

-\\-.88938, V=14.806 st.dev.=0.010,

-\\-.89486, r=14.167 st.dev.=0.010,

-\\-.89241, r=14.108 st.dev.=0.010,

-\\-.89042, i=13.341 st.dev.=0.010,

-\\-.89175, V=14.873 st.dev.=0.010,

-\\-.88990, r=14.116 st.dev.=0.010,

-\\-.89300, i=13.409 st.dev.=0.010,

-\\-.89580, i=13.372 st.dev.=0.010,

- using **2 m telescope at NAO Rozhen**
  - \\-.73236,  $r=14.175$  st.dev.=0.005,
  - \\-.72706,  $B=16.478$  st.dev.=0.010,
  - \\-.73198,  $r=14.177$  st.dev.=0.005,
  - \\-.73153,  $V=14.944$  st.dev.=0.005,
  - \\-.73325,  $i=13.450$  st.dev.=0.005,
  - \\-.72902,  $B=16.451$  st.dev.=0.005,
  - \\-.73094,  $V=14.944$  st.dev.=0.005,
  - \\-.73289,  $i=13.437$  st.dev.=0.005,
  - \\-.72531,  $V=14.965$  st.dev.=0.005,
- using **Schmidt-camera 50/70 cm at NAO Rozhen**
  - \\-.81028,  $r=14.269$  st.dev.=0.020,
  - \\-.80504,  $B=16.538$  st.dev.=0.050,
  - \\-.80978,  $r=14.272$  st.dev.=0.020,
  - \\-.80928,  $V=15.001$  st.dev.=0.040,
  - \\-.80347,  $i=13.457$  st.dev.=0.020,
  - \\-.80690,  $B=16.575$  st.dev.=0.060,
  - \\-.80205,  $r=14.287$  st.dev.=0.020,
  - \\-.80599,  $B=16.567$  st.dev.=0.050 .

As we can see from presented values for same filter, the suitable results are close to each other (in accordance with ground-based possibilities) even using different instruments. These magnitudes are transferred from our set of filters (Johnson BV and Cousins RcIc) into another one via the Cambridge Server.

### 3. CONCLUSIONS

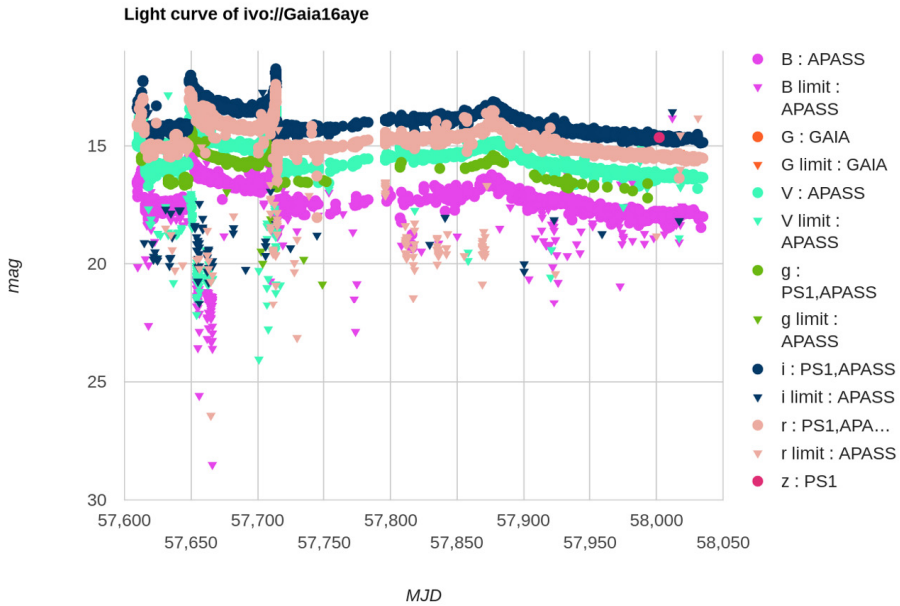
The Gaia satellite (ESA mission) was launched at the end of 2013, and the first astronomical observations were in mid-2014. Since October 2014, the Gaia Photometric Science Alerts (group of Gaia mission) started to publish alerts. Until October 2017 about 3000 alerts (cataclysmic variables, supernovae, candidate microlensing events, etc.) have been issued by the Gaia Science Alerts group.

Using 6 telescopes (via our regional cooperation “Serbian-Bulgarian mini-network telescopes”) we observed few objects during the test phase in 2013 and 2014 (Damljanović et al. 2014). Then, we continued the observations of the Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO, or Gaia Alerts) from the end of 2014.

As result, we observed about 45 objects until the end of October 2017 (three years of observations); it is near 15 objects per year. About 1650 CCD images were collected (or about 550 ones per year). It was done in Johnson BV and Cousins RcIc filters; usually we did 3 images per filter. The paper (Campbell et al. 2015) about rare object, the eclipsing AM CVn Gaia14aae one, was published. Also, some our results were presented at few conferences.

From mid-2016, we took part in observations of the Gaia16aye (Ayers Rock), binary microlensing event, the first discovered in the Northern Galactic Disk; we

hope it will be a published paper about that object, soon. Presented results of the object, using observations of three instruments (2 m instrument of NAO Rozhen, 1.4 m telescope at ASV, and Schmidt-camera 50/70 cm of NAO Rozhen), are close to each other. That object is just one of Gaia Alerts objects which we observed as very interesting ones. Our plan is to continue with our activities about the Gaia-FUN-TO.



**Figure 4:** The light curve of Gaia16aye or Ayers Rock (mid-2016 – 9<sup>th</sup> Oct. 2017).

### Acknowledgements

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