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OBSERVATIONS OF GAIA-FUN-TO FROM 2014 USING SERBIAN AND BULGARIAN TELESCOPES

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Abstract. The Gaia mission is the cornerstone of the European Space Agency – ESA. It is astrometrically, photometrically and spectroscopically surveying the full sky. The satellite was launched at the end of 2013 and the observations were started in July 2014. In October 2014, the Gaia Photometric Science Alerts published first alerts. Three years after that (October 2017), the Gaia Science Alerts is among the leading transient surveys in the world; about 3000 transients were discovered. The transients are: supernovae, cataclysmic variables, microlensing events, other rare phenomena. On the other hand, the installation of the first instrument, the 60 cm telescope, at the Serbian new site, the Astronomical Station Vidojevica (ASV) of Astronomical Observatory in Belgrade (AOB), was in 2010. Since mid-2016, we started to use the new 1.4 m ASV (via Belissima project). Also, two Bulgarian sites (Belogradchik and Rozhen), with 4 instruments, are of our interest. Using these 6 instruments, in line with "Serbian – Bulgarian mini-network telescopes", astronomical cooperation in our region (the head is G. Damljanović), we observed about 45 Gaia Alerts objects or Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO) until October 2017.

1. INTRODUCTION

After the Hipparcos (ESA 1997, van Leeuwen 2007), the Gaia is another big mission of the European Space Agency – ESA and the next step of the European pioneering high-accuracy astrometry. During its 5-year lifetime, it is going to repeatedly map all sky. As result, it will be a unique time-domain space survey. The first Gaia data release (DR1) was publicly available on September 14^{th}, 2016. That Gaia catalogue is an important step in the realisation of the Gaia reference frame in the future. The Gaia is doing revolution in astronomy, our understanding of the Milky Way galaxy, stellar physics and the Solar System bodies. The Gaia has got an interdisciplinary character, and Gaia-based results are useful for all the relevant scientific communities. This survey will be complete to $V = 20$ mag in astronomy and photometry ($\approx$ 1 billion sources) and to 16 mag in spectroscopy ($\approx$ 150 million ones).

Since October 2014 the Gaia Photometric Science Alerts started to publish alerts. Three years after that (until October 2017), about 3000 alerts were published: cataclysmic variables, supernovae, candidate microlensing events, etc. At 2013, we es-

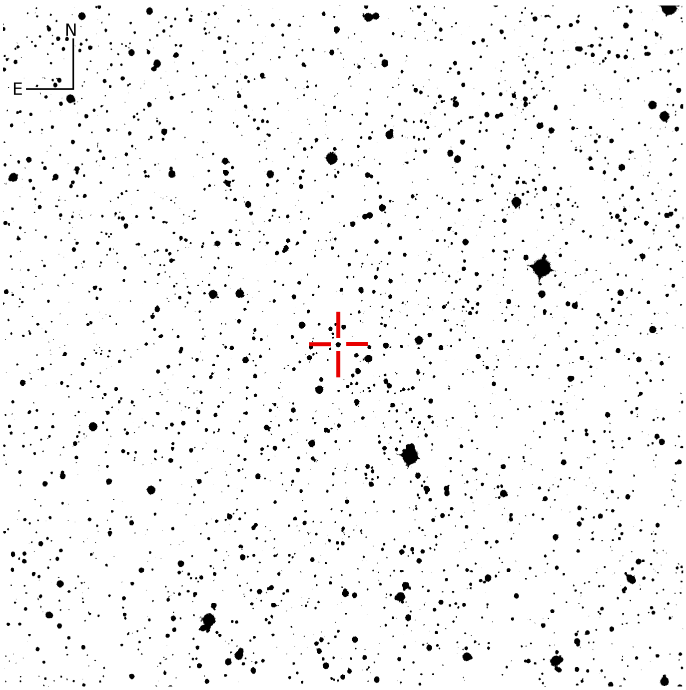

Figure 1: The Gaia16aye using the 1.4 m ASV telescope.

tablished the "Serbian – Bulgarian mini-network telescopes" (now, there are 6 instruments) to do observations of a few objects during the test phase (in 2013 and 2014) of the Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO). And we continued the observations of Gaia Alerts (Gaia-FUN-TO) objects from the end of 2014. The main information about the instruments has been published (Damljanović et al. 2014), and is presented in Table 1 (for the 1.4 m ASV telescope). Our activities about Gaia-FUN-TO are in line with the bilateral Serbian-Bulgarian joint research projects "Observations of ICRF radio-sources visible in optical domain" (during three years period 2014-2016) and "Study of ICRF radio-sources and fast variable astronomical objects" (for the period 2017-2019); the head is G.Damljanović. Until October 2017, we observed about 45 Gaia Alerts objects (nearly 1700 CCD images).

2. OBSERVATIONS AND RESULTS

There are a few years, the astrometry with ground-based optical telescopes (of small and medium size) has become very actual part of astronomical investigation. The main reason is the Gaia satellite and the possibilities of ground-based instruments which are in accordance with the ESA mission: the astrometric monitoring of Gaia satellite, the photometry of Gaia Alerts objects, the link between radio and optical positions of quasars (QSOs), the realisation of a catalogue of QSOs, etc. Also, new sensitive CCD cameras are of importance for good results of ground-based astronomy.

In Table 1, there is the main information about the ASV 1.4 m telescope: the Ritchey-Chrétien $D = 140$ cm instrument at ASV site with its geographic coordinates

Table 1: The main information on the ASV 1.4 m telescope.

Site Telescope $D(cm)/F(cm)$	longitude - $\lambda(^o)$ latitude - $\varphi(^o)$ altitude - h (m)	CCD camera pixel array and scale $('')$ pixel size (μm) and field of view - FoV $(')$
ASV (AOB)	21.5	Apogee Alta U42
Ritchey-Chrétien	43.1	2048x2048, 0.24
140/1142	1150	13.5x13.5, 8.3x8.3

is presented in the left part, and the CCD camera Apogee Alta U42 (with its pixel size, pixel array, etc.) on the right side. The other Serbian – Bulgarian instruments, as well as another Serbian the 60 cm ASV telescope and Bulgarian ones (at Belogradchik and Rozhen sites) are presented in published paper (Damljanović et al. 2014).

In Fig. 1, the CCD image of Gaia16aye (Ayers Rock), after standard reduction, using the 1.4 m ASV telescope is presented. The object is marked with a cross. That image was done with the CCD Apogee Alta U42 at June 19^{th} 2017: R – filter, Exp.=40^s, benning=1x1. The coordinates of that object are $RA = 295.^o00474$ (19^h:40^m:$01.^s14$) and $Dec. = 30.^o13149$ (30^o:$07'$:$53.''36$); the Galactic ones are $64.^o99988$ and $3.^o83903$. The alerting date is August 8^{th} 2016. That object is the binary microlensing event and the first discovered towards the Galactic Plane. We observed the Gaia16aye 41 times (epochs): 18 times in 2016 and 23 times during 2017 (until 9^{th} October); about 490 CCD images. On 25^{th} October 2016 we did it using three instruments: a 2 m Rozhen, 50/70 cm Schmidt – camera (Rozhen) and 1.4 m ASV; it was good coordination of the "Serbian – Bulgarian mini-network telescopes". Also, in line with our cooperation with Dr. Alok Gupta (India) that object was observed for 5 nights (21^{st}-25^{th} November 2016) using the 1.31 m ARIES telescope (Aryabhatta Research Institute of observational sciencES, Manora Peak, Nainital) in the central Himalayan region: $\lambda = 79.^o7E$, $\varphi = 29.^o4N$, $h = 2420$ m. The CCD Andor DZ436 was used: 2048x2048 pixels, 13.5x13.5 μm, FoV=$18.'5$x$18.'5$, scale=$0.''54$ per pixel. In Table 2, the photometry results of Gaia16aye (at June 19^{th} 2017) are done. The Jhonson – Cousins BVRI filters were available, and usually we did 3 images per filter.

We did about 1700 images for about 45 Gaia-FAN-TO objects during three years period (October 2014 – October 2017). After the standard bias, dark and flat-fielded corrections (also, hot/dead pixels were removed), the Astrometry.Net[1] and Source Extractor were applied. The output is supposed to be submitted to the Cambridge Photometric Calibration Server (CPCS)[2] for further calibration. In Table 2, the Modified Julian Date (MJD=JD-2400000.5) and magnitude of Gaia16aye (1^{st} and 2^{nd} columns) were calculated after the CPCS step, and we took them from the mentioned server after all steps of calibration and computation procedures. The CPCS matches instrumental magnitudes of all stars (3^{rd} column) in the CCD field with known data from other catalogue, as the APASS catalogue in Table 2 (4^{th} column).

As a result, during 2017 (until October) we observed about 15 Gaia-FUN-TO objects. Mostly, using the 60 cm ASV (9 objects): Gaia16aye (8 times), Gaia17bsu(1), Gaia17bsp(1), Gaia17bsr(1), Gaia17bts(4), Gaia17bxh(1), Gaia17chf(1), Gaia17cgo(1)

[1] http://astrometry.net
[2] http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/Follow-up

Table 2: Photometry results of Gaia16aye, June 19^{th} 2017.

MJD	Magnitude (mag_{err})	n points	Catalogue
57924.00453	V=15.71 (0.01)	29	APASS
57924.00778	r=14.99 (0.01)	29	APASS
57924.00977	V=15.72 (0.01)	29	APASS
57924.01104	i=14.21 (0.01)	29	APASS
57924.00389	B=17.27 (0.04)	27	APASS
57924.01041	r=14.99 (0.01)	30	APASS
57924.00712	V=15.72 (0.01)	29	APASS
57924.00579	i=14.21 (0.01)	28	APASS
57924.00847	i=14.19 (0.01)	29	APASS
57924.00914	B=17.25 (0.04)	28	APASS
57924.00515	r=14.97 (0.01)	29	APASS
57924.00645	B=17.19 (0.05)	27	APASS

and Gaia17che(1). With the 1.4 m ASV, we did 5 objects: Gaia16aye(11), Gaia17arv(1), Gaia17asa(1), Gaia17asc(1) and Gaia17aru(1). With the 60 cm Belograchik, just Gaia17ade(2). Also, 1 object using the 2 m Rozhen (it is Gaia16aye(4)), but 5 objects with the Schmidt – camera 50/70 cm: Gaia17asc(1), Gaia17arv(1), Gaia17asa(1), Gaia17chf(1) and Gaia17bts(1). No data from the 60 cm Rozhen.

3. CONCLUSIONS

About 3000 alerts have been issued by the Gaia Science Alerts group during 3 years (until October 2017), and we observed about 45 objects (near 1700 CCD images) using 6 instruments of the "Serbian – Bulgarian mini-network telescopes". We could get the magnitudes of the Gaia Alerts objects with small errors (of the order of 0.01 mag, see in Table 2). Our paper (Campbell et al. 2015) about rare object, the eclipsing AM CVn Gaia14aae, was published and some of our results were presented at a few conferences. From mid-2016, we took part in the big campaign about the Gaia16aye.

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