Comparison of photometric results between the Serbian and Bulgarian telescopes and activities in line with Gaia Alerts (Gaia-FUN-TO)

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Abstract. We established the cooperation "Serbian-Bulgarian mini-network telescopes" in 2013, as well as two SANU-BAN joint research projects ("Observations of ICRF radio-sources visible in optical domain" during 2014-2016, and "Study of ICRF radio-sources and fast variable astronomical objects" for the period 2017-2019). Here, some main results of that cooperation are presented, as comparison of Serbian and Bulgarian telescopes/CCD cameras/filters via photometric results. Also, activities in accordance with the Gaia Alerts are shown.
Key words: Gaia Alerts, mini-network telescopes

Introduction

Since mid-2014 the Gaia mission is operating and surveying the full sky: astrometrically, photometrically and spectroscopically. It is a space mission of the European Space Agency (ESA). The main task is to collect the high-precision astrometric data: positions, proper motions, and parallaxes. The G-mag of sources ranges from 3 to 21. The goal of the mission is the Gaia catalogue as an important step in the realization of the Gaia reference frame in future. The second Gaia data release (DR2), with about 1.7 billion sources, has been made publicly available in April 2018. These results are doing revolution in astrometry, our understanding of the Milky Way galaxy, stellar physics and the Solar system bodies. Gaia scans the sky many times, and provides near-real-time photometric data. It is possible to detect some changes in brightness from all over the sky and the appearance of new objects. After that, the Gaia Science Alerts system produces alerts on some interesting objects. The transients are: supernovae, cataclysmic variables, microlensing events, other rare phenomena. The Gaia Photometric Science Alerts published first alerts in October 2014. Nowadays (5 years after that), the Gaia Science Alerts is among the leading transient surveys in the world; ≈ 1000 transients per year are discovered.

During 2013, the cooperation "Serbian-Bulgarian mini-network telescopes" was established; there are 6 telescopes now. It is in line with the SASA-BAS joint research projects "Observations of ICRF radio-sources visible in optical domain" (2014-2016) and actual one "Study of ICRF radio-sources and fast variable astronomical objects" (2017-2019); head is Dr. G.Damljanovic.

1. Instruments

During 2011, the first telescope with $D/F = 60/600$ cm was installed at the Astronomical Station Vidojevica (ASV - Serbian new site) of Astro-

nomical Observatory in Belgrade (AOB). In mid-2016, there was another $D = 1.4$ m ASV telescope obtained via the Belissima project. And, we used 4 instruments in Bulgaria; see Table 1.

Table 1. Instruments in line with the "Serbian-Bulgarian mini-network telescopes"

Station Telescope D/F [cm]	Longitude [deg] Latitude [deg] Altitide [m]	CCD-camera,cheap [pixels],pixel size [microns] Scale [arcsec/pixel] Field of view or FOV [arcmin]
1. ASV (AOB) Cassegrain 60/600	21.5 E 43.1 N 1140	A) Apogee Alta U42, 2048X2048, 13.5X13.5 0.46 15.8X15.8 B) SBIG ST10XME, 2184X1472, 6.8X6.8 0.23 8.4X5.7 C) Apogee Alta E47, 1024X1024, 13X13 0.45 7.6X7.6
2. ASV (AOB) Ritchey-Chrétien 140/1142	21.5 E 43.1 N 1150	A) Apogee Alta U42, 2048X2048, 13.5X13.5 0.243 8.3X8.3 B) Andor iKon-L, 2048X2048, 13.5X13.5 0.244 8.3X8.3
3. Rozhen (NAO BAS) Ritchey-Chrétien 200/1577	24.7 E 41.7 N 1730	A) VersArray 1300B, 1340X1300, 20X20 0.262 5.8X5.7 B) Andor iKon-L, 2048X2048, 13.5X13.5 0.176 6.0X6.0
4. Rozhen (NAO BAS) Cassegrain 60/740	24.7 E 41.7 N 1760	FLI PL09000, 3056X3056, 12X12 0.33 16.8X16.8
5. Rozhen (NAO BAS) Schmidt-camera 50/70 $F = 172$	24.7 E 41.7 N 1759	FLI PL16803, 4096X4096, 9X9 1.08 73.7X73.7
6. Belogradchik AO Cassegrain 60/740	22.7 E 43.6 N 650	FLI PL09000, 3056X3056, 12X12 0.33 16.8X16.8

In Table 1, the first column presents: site, telescope and $D[cm]/F[cm]$. The second one: the geographic coordinates (longitude, latitude), and altitude (h). The NAO BAS means National Astronomical Observatory of Bulgarian Academy of Sciences.

The CCD camera Andor iKon-L is on 2 m Rozhen telescope (see Table 1) since April 2018; F=1581 cm. Also in 2018, the CCD Andor iKon-L was mounted on the 1.4 m ASV, and there is a new dome for that instrument.

2. Gaia Alerts and mini-network telescopes

At all three sites, the BVRcIc Johnson - Cousins filters are available. Usually, we do 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 of Gaia Alerts. We collected ≈ 3000 CCD images of the Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO, or Gaia Alerts) during 5 years (Oct.2014 – Oct.2019); or ≈ 600 images per year. There are ≈ 75 objects, or ≈ 15 per year.

During 1 October 2017 - 1 October 2018, we observed 11 objects, of which 10 using the 60 cm ASV: Gaia16aye (3 times), Gaia16bnz (2), Gaia17bts (3), Gaia17cpa (1), Gaia17cut (1), Gaia17cup (1), Gaia18arn (1), Gaia18axl (2), Gaia18bqa (7) - ATLAS18qqn - AT2018cow, Kojimaevent (1). With the 1.4 m ASV we collected no data during May - September 2018 (because of aluminization, and after that it was removed to new dome). With the 60 cm Belogradchik we collected no data (bad weather for observations). There is just 1 object using the 2 m Rozhen – FoReRo; it is AT2018cow (1). And 2 objects with Schmidt-camera 50/70 cm at Rozhen: AT2018cow (1) and AT2018gep (2). No data was obtained using the 60 cm Rozhen telescope because it was under reconstruction from 2016 to mid-2018. More results are presented in few papers (Damljanovic et al., 2014; Campbell et al., 2015; Wyrzykowski et al., 2019) and at few conferences.

Table 2. Comparison of photometric results using the Schmidt-camera 50/70 cm - A (Rozhen, 28^{th} March) and 1.4 m ASV - B (Vidojevica, 29^{th} March 2019); comparison stars from the paper (Fiorucci et al., 1998) - C

Band	JD 2458000+ [days]	Object(st.dev.) [mag]	Comparison stars C1, C2, C3 and C5 [mag]			
A						
V	571.42334	15.555(0.005)	13.028(0.005)	14.643(0.005)	14.768(0.005)	15.672(0.006)
R	571.42436	15.175(0.005)	12.553(0.005)	14.256(0.005)	14.388(0.005)	15.320(0.006)
B						
V	572.51699	15.570(0.005)	13.003(0.005)	14.666(0.005)	14.771(0.005)	15.669(0.006)
R	572.52400	15.210(0.005)	12.550(0.005)	14.264(0.005)	14.389(0.005)	15.334(0.006)
C						
V			13.04(0.05)	14.61(0.05)	14.77(0.05)	15.62(0.06)
R			12.56(0.05)	14.22(0.04)	14.39(0.05)	15.32(0.05)

3. Comparison of photometric results

To compare photometric results between the Serbian and the Bulgarian telescopes, we did observations of the same objects during the same period

of time using several telescopes. For example, the object 0806+524 (QSO, BL Lac type) was observed with its comparison stars using the Schmidt-camera 50/70 cm (Rozhen, with Dr. G.Latev) on 28 March and 1.4 m ASV (Vidojevica) on 29 March 2019; see Table 2. The V and R magnitudes from Fiorucci et al. (1998) and our telescopes are in good agreement with each other. The photometric results using these telescopes (with there CCDs and filters) are in line with each other, and produce good results. Good photometric agreement was shown using these telescopes for the object 1553+113 (QSO, BL Lac type) at the same dates. We did similar tests (via QSOs 1212+467, 1242+574 and 1345+735) using the 2 m Rozhen (on 31 March with S.Boeva) and 1.4 m ASV telescopes (on 30 March 2019); the results were in line with each other. The same was shown using 60 cm Belogradchik (S.Boeva) and 60 cm ASV during Oct.2014.

Conclusion

Via our cooperation "Serbian-Bulgarian mini-network telescopes", we are using 6 telescopes at 3 sites. A few objects were observed during the test phase in 2013 and 2014 (Damljanovic et al., 2014). From the end of 2014 we continued with the Gaia Alerts or Gaia-Follow-Up Network for Transients Objects (Gaia-FUN-TO). During five years (Oct.2014 – Oct.2019), we observed $\approx$ 75 Gaia Alerts ($\approx$ 15 ones per year); $\approx$ 3000 CCD images were collected ($\approx$ 600 ones per year). It was done in Johnson BV and Cousins RcIc filters; usually we did 3 images per filter. Also, we did some objects more frequently during few years interval. The paper about the rare object, the eclipsing AM CVn Gaia14aae was published by Campbell et al. (2015). Some results were presented at few conferences. We took part in the few years long observations of the Gaia16aye (Ayers Rock), the binary microlensing event (the first discovered in the Northern Galactic Disk) starting from mid-2016. The paper about this object is submitted to *A&A* (Wyrzykowski et al., 2019). We compared photometric results using the observations of same objects during same period, but made at different Serbian and Bulgarian telescopes, and they are in line with each other.

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