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THE LINK BETWEEN FUTURE GAIA CRF AND ICRF AND THE OBSERVING FACILITIES OF THE 60 cm ASV TELESCOPE

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Abstract. The Gaia satellite was successfully launched at the end of 2013. That astrometrical mission is the cornerstone of the European Space Agency (ESA). The main goal of Gaia, during its 5-year lifetime, is to map all sky, over one billion stars of our Galaxy and about 500,000 quasars (QSOs) and other extragalactic objects. It means, all objects with apparent V magnitude between 5.6 and 20. The results will be a unique time-domain space survey, and a dense optical QSO-based Gaia Celestial Reference Frame (Gaia CRF). For this purpose a high accuracy link between the future Gaia CRF and International CRF (ICRF) is necessary. The Gaia astrometry should include lots of effects, as the displacements of optical photocenter of sources (that effect is a possible consequence of astrophysical processes of QSOs). Nearly 90 % of the ICRF objects are not suitable for that link (the sources are not bright enough in optical band, with significant extended radio emission, etc.). And it is of importance to check other sources (weak extragalactic radio sources with bright optical counterparts, etc.). First of all, we need to investigate the flux stability of objects via their photometry monitoring. So, the photometry investigation of these objects and the analysis of variations of their light curves are of importance for the mentioned link. The part of that investigation is our observation of 47 objects (mostly QSOs, but not in the ICRF list) made in the B, V and R bands using the new telescope at the Astronomical Station Vidojevica (ASV) of Astronomical Observatory in Belgrade (AOB). Some preliminary photometric results for object BL 1722+119 in the frame of this investigation are presented.

1. INTRODUCTION

The Gaia is the first space-based ESA (the European Space Agency) mission after Hipparcos (ESA 1997, van Leeuwen 2007), and the next step of the European pioneering high-accuracy astrometry. The Gaia satellite was launched in December 2013, and it is going to revolutionize our knowledge of the Milky Way with observations of over one billion stars of our Galaxy; also, of about 500,000 quasars (QSOs) and other extragalactic objects. During its 5-year lifetime, it is going to map (repeatedly) all

Table 1: The main information on the ASV 60 cm telescope.

Site	longitude - $\lambda(^o)$	CCD camera
Telescope	latitude - $\varphi(^o)$	pixel array and scale ($''$)
$D(cm)/F(cm)$	altitude - h (m)	pixel size (μm) and field of view - FoV ($'$)
ASV (AOB)	21.5	Apogee Alta U42
Cassegrain	43.1	2048x2048, 0.46
60/600	1150	13.5x13.5, 15.8x15.8

sky as a unique time-domain space survey; all objects are with apparent V magnitude between 5.6 and 20. A dense optical QSO-based Gaia Celestial Reference Frame (Gaia CRF) is the main goal of the mission. The high accuracy link between future Gaia CRF and International CRF (ICRF) is of importance, but up to now nearly 90% objects from ICRF list have not been suitable for that link (Bourda et al. 2010, 2011; Petrov 2011, 2013; Taris et al. 2011, 2013) because: the objects are not bright enough in the optical domain, they have significant extended radio emission, etc. The relationship between morphology, magnitude variability and astrometry for QSOs is described by Popović et al. (2012). It is necessary to include in the link other objects (not from ICRF list), the weak extragalactic radio sources (ERS) with bright optical counterparts, but fist of all to investigate their flux variability via photometry monitoring and analysis of their light curves. Because of this, the observations of 47 objects (mostly QSOs, not from ICRF list) are going on during last few years. We took part in that monitoring (in BVR bands) using the new telescope at the Astronomical Station Vidojevica (ASV) of Astronomical Observatory in Belgrade (AOB). Preliminary photometric results concerning object BL 1722+119 (in Fig. 1) are presented.

2. OBSERVATIONS AND RESULTS

Since a few years ago astrometry with ground-based optical telescopes has become very actual part of astronomical investigation. The reason is the possibilities of ground-based instruments which are in line with the Gaia mission. These telescopes are useful for: the astrometric monitoring of Gaia satellite, the link between radio and optical positions of ERS, the realization of a catalogue of quasars, etc. To align the radio frame and optical frame with high accuracy, the common objects (ERS) are of importance. From mid-2013 we have taken part in the photometric ground – based observations of ERS which are visible in the optical domain and useful for establishing the link between the future Gaia CRF and ICRF. The ASV 60 cm telescope has been used (see Table 1). During 2013 and 2014, 47 sources, which are not in the ICRF list, were observed with that instrument (some of them more than once). Usually, we had three CCD images per filter.

Our preliminary photometric results, using the relative method, of the object BL 1722+119 (see Fig. 1) are presented in Table 2 (for July 9^{th} 2013). The comparison stars (C1, C2, C3 and C4, see Fig. 1, and the first part of Table 2) were found and used via http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/. For processing the CCD images, the first step is to detect the star-like object (ERS) and

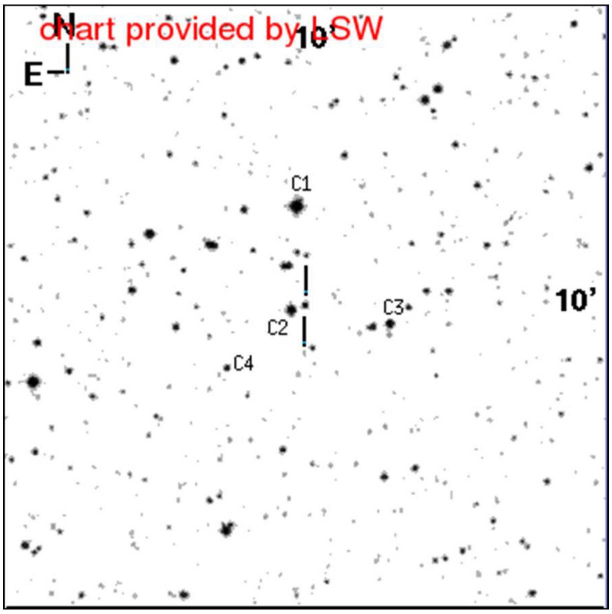

Figure 1: Object BL 1722+119 with calibrated stars (C1,C2,C3,C4).

comparison stars. The standard bias, dark and flat-fielded corrections were done. Also, hot/bad pixels were removed. All CCD exposures were guided. In our data (for July 9th 2013), C1 was saturated in the V and R bands. In the B band there are no input magnitude data (see the first part of Table 2). The calculated magnitude (presented in the second part of Table 2, for V and R filters) is an average value with standard error using 3 images per filter. The output magnitudes of C2, C3 and C4 are close to their input values (from mentioned site); it means the photometric calculation is correct. The MaxIm DL image processing package was applied to the CCD data for calibration and photometric calculation.

For the objects without charts and determined calibration stars we need to do it by ourself. This means to determine a set of calibration stars and to use the input magnitudes from a catalogue; it could be the SDSS catalogue with transformations (Chonis and Gaskell 2008) to calculate BVRI magnitudes from *ugriz* ones.

3. CONCLUSIONS

We present our preliminary photometric results for object BL 1722+119 using observations made with the 60 cm ASV telescope. The input photometry data of calibrated stars (C1,C2,C3,C4) were obtained via site

http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/, and close to calculated values. For other objects we need to determine a set of calibrated stars around each QSO, and to calculate the magnitudes in the B,V,R bands (of these stars) using *ugriz* ones from the SDSS catalogue and the transformations (Chonis and Gaskell 2008). All necessary steps for reduction of CCD data (the standard bias, dark and flat-fielded corrections, and removal of hot/bad pixels) were applied. Also, it is of

Table 2: Our photometry results of BL 1722+119 with standard errors.

type&name of object, filter	JD-2456000	mag.of object	mag.of star C1	mag.of star C2	mag.of star C3	mag.of star C4
B			-	-	-	-
			-	-	-	-
V			11.98	13.21	14.10	15.74
			(0.05)	(0.05)	(0.05)	(0.08)
R			10.93	12.62	13.64	15.14
			(0.05)	(0.05)	(0.50)	(0.08)
BL 1722+119 B	483.48651	-	-	-	-	-
		-	-	-	-	-
BL 1722+119 V	483.48129	15.32	-	13.22	14.10	15.67
		(0.02)	-	(0.01)	(0.01)	(0.01)
BL 1722+119 R	483.49204	14.87	-	12.63	13.62	15.15
		(0.01)	-	(0.01)	(0.01)	(0.01)

importance for high-quality data that the average seeing at the ASV site is nearly $1.''2$ and to observe during a moonless night. So, we could get the magnitudes of our objects (QSOs) with small standard errors which are of the order of 0.01 mag.

Some problems during the calculation of B,V,R magnitudes of QSOs can be due to: faintness of the optical counterparts to QSOs, atmospheric influences, technical problems, etc. For example, we could improve the quality of the ASV data by using a star guider (to use the exposures longer than 5 minutes for faint objects).

We conclude that this kind of observations (of QSOs with magnitudes less than about $V = 19.0$) and mentioned investigations are possible with data obtained with the 60 cm ASV instrument.

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References

Bourda, G. et al.: 2010, *A&A*, **520**, A113.
Bourda, G. et al.: 2011, *A&A*, **526**, A102.
Chonis, T.S., Gaskell, C.M.: 2008, *Astron. J.*, 135:264-267.
ESA: 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200.
Petrov, L.: 2011, *Astron. J.*, 142:105(6pp).
Petrov, L.: 2013, *Astron. J.*, 146:5(8pp).
Popović, L. et al.: 2012, *A&A*, **538**, A107.
Taris, F. et al.: 2011, *A&A*, **526**, A25.
Taris, F. et al.: 2013, *A&A*, **552**, A198.
van Leeuwen, F.: 2007, Hipparcos, the New Reduction of the Raw Data, Springer, Dordrecht.