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OBSERVATIONS AT THE 60 cm ASV TELESCOPE AND THE LINK GAIA CRF - ICRF

GORAN DAMLJANOVIĆ[1], FRANCOIS TARIS[2], GEORGI LATEV[3] and MILAN STOJANOVIĆ[1]

[1]*Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia*
[2]*SYRTE, Observatoire de Paris, 61 avenue de l'Observatoire, 75014 Paris, France*
[3]*Institute of Astronomy and NAO Rozhen, Bulgarian Academy of Sciences, 72 Tsarigradsko shosse, BG-1784 Sofia, Bulgaria*
E-mail: gdamljanovic@aob.rs

Abstract. The Gaia mission is a cornerstone of European Space Agency (ESA). It was launched at the end of 2013. The Gaia is the next step (after HIPPARCOS) in development of European pioneering high accuracy astrometry; the main goal is to make a dense QSO-based Gaia Celestial Reference Frame (Gaia CRF). Because of it, it is necessary to link future Gaia CRF and International Celestial Reference Frame (ICRF) with high accuracy. Also, to compare QSOs (or the extragalactic radio sources - ERS) optical and radio positions (VLBI ones), and to search for a relation between optical and radio reference frames. At the other hand, in 2014 one of us (GD) started joint research project "Observations of ICRF radio-sources visible in optical domain", in the frame of bilateral cooperation between Serbian Academy of Sciences and Arts and Bulgarian Academy of Sciences (BAS), which partly deals with Gaia CRF - ICRF link investigation. In mentioned collaboration, we are using the 2 m telescope of NAO Rozhen (Bulgaria) for investigation of morphology of ICRF objects interesting to Gaia astrometry, and the 60 cm telescope of Astronomical Station Vidojevica - ASV (Serbia) for photometry investigation of QSOs. The displacements of the optical photocenter of QSOs could be the result of its astrophysical processes and in line with their positions (astrometry); it is of importance for mentioned link. Some preliminary photometric results of QSOs using the 60 cm ASV are presented here.

1. INTRODUCTION

As a cornerstone of the European Space Agency (ESA), the Gaia space-based mission is the next step of the European pioneering high accuracy astrometry, after the HIPPARCOS one (Kovalevsky et al. 1997). It was launched at December 2013. During its 5-year lifetime, the Gaia is going to map repeatedly over one billion stars. It means, the objects of entire Galaxy with apparent V magnitude between 5.6 and 20, and about 500000 quasars (QSOs) or extragalactic radio sources (ERS); a large amount of astronomical data. So, the Gaia is going to revolutionize our knowledge of the Milky Way.

The main goal of that mission is to make a dense QSO-based Gaia Celestial Reference Frame (Gaia CRF). And it is of importance the relation between optical and radio reference frames via the observations of some ICRF objects (Fey et al. 2009) which are visible in the optical domain. Also, to compare their optical and radio positions (VLBI ones). The other important task is to establish the link between future Gaia CRF and International Celestial Reference Frame (ICRF) with high accuracy (Bourda et al. 2010, 2011; Petrov 2011, 2013; Taris et al. 2013), but for now only about 10% of the ICRF objects are good enough for mentioned link: some sources are not bright enough in optical domain of wavelengths, some objects have significant extended radio emission, etc. So, it is of importance to find and check other sources; they are weak ERS with bright optical counterparts and it is necessary to observe and investigate these objects. At the other hand, the coordinates of sources (it means, astrometry) are in line with the displacements of their optical photocenter as a result of astrophysical processes of objects. And it is necessary to investigate the variations of the light curves of mentioned objects.

For morphology investigation of QSOs we use the CCD observations of ERS made at the RCC telescope[1] of Rozhen National Astronomical Observatory - NAO (Bulgarian Academy of Sciences). For photometry investigation we make the observations of QSOs using the 60 cm telescope at Astronomical Station Vidojevica - ASV (in Fig. 1) of the Astronomical Observatory in Belgrade (AOB), Serbia.

From mid 2013, we did the photometry observations of 47 objects using the 60 cm ASV telescope, and some preliminary photometry results are presented here.

2. DATA AND RESULTS

At the beginning of 2014, GD started joint research project "Observations of ICRF radio-sources visible in optical domain", in the frame of bilateral cooperation between Serbian Academy of Sciences and Arts and Bulgarian Academy of Sciences. That project partly deals with Gaia CRF - ICRF link investigation. And in collaboration with Bulgarian colleagues, we are doing our observations at the Rozhen telescope (D/F=2m/16m) of National Astronomical Observatory, Bulgarian Academy of Sciences (BAS), for investigation of morphology of ICRF objects interested for Gaia astrometry. For photometry investigation, the ASV (in Fig. 1) of AOB telescope (D/F=60cm/600cm) is useful. These telescopes are between other instruments for mentioned subjects; the main information of the 2 m Rozhen and 60 cm ASV telescopes are in Table 1. The information of the first column of Table 1 are: site, telescope and D(cm)/F(cm). In the second column, the geographic coordinates (longitude - λ, latitude - φ) and altitude (h) of site are presented. The field of view (FoV) and some details of CCD cameras are in the third column. In the near future (during next year), a new $D = 1.4$ m telescope will be installed at ASV in the frame of Belissima project (http://belissima.aob.rs).

The 60 cm ASV telescope was used for optical observations of 47 objects, mostly QSOs, and photometry investigation (for the link Gaia CRF - ICRF) since mid-2013. Until now, near all objects were observed, some of them few times. We did it in the

[1]Based on observations with the 2 m RCC telescope of the Rozhen National Astronomical Observatory operated by the Institute of Astronomy, Bulgarian Academy of Sciences.

Figure 1: Telescope Cassegrain 60 cm, ASV.

B, V and R bends (three CCD images per filter). Here, we present some preliminary photometric results of objects QSO 1212+467 (in Fig. 2, the observations were done at June 27^{th} 2014) and BL 1722+119 (in Fig. 3, July 9^{th} 2013). One of our observations with 60 cm ASV is presented in Fig. 2; the exposure time $exp. = 300^s$ in R filter. All exposures were guided.

The standard bias, dark and flat-fielded corrections were done (Berry and Burnell 2002); also, hot/bad pixels were removed. For 1722+119, the comparison stars were used via http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/; C1, C2,

Table 1: The main information of the ASV 60 cm and Rozhen 2 m telescopes.

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) Cassegrain 60/600	21.5 43.1 1150	Apogee Alta U42 2048x2048, 0.46 13.5x13.5, 15.8x15.8
Rozhen (NAO BAS) Ritchey-Chretien 200/1600	24.7 41.7 1730	VersArray 1300B 1340x1300, 0.26 20x20, 5.6x5.6

Table 2: Our photometry results of QSO 1212+467 and BL 1722+119 with st. errors.

type&name of object, filter	catalogue or t	mag. of object	magnitude of star 2,3,4,5
B	SDSS		16.40(0.05);16.56(0.05);17.02(0.05);17.94(0.06)
V	SDSS		15.80(0.03);16.07(0.03);16.43(0.03);17.18(0.04)
R	SDSS		15.45(0.04);15.78(0.04);16.08(0.04);16.73(0.05)
Q1212+467B	836.38924	18.15(0.03)	16.46(0.01);16.54(0.01);16.98(0.02);17.84(0.01)
Q1212+467V	836.39287	17.94(0.03)	15.87(0.01);16.05(0.01);16.36(0.01);17.13(0.01)
Q1212+467R	836.39652	17.78(0.01)	15.54(0.01);15.75(0.01);15.99(0.01);16.66(0.01)
			magnitude of C1,C2,C3,C4
B	SDSS		-;-;-;-
V	SDSS		11.98(0.05);13.21(0.05);14.10(0.05);15.74(0.08)
R	SDSS		10.93(0.05);12.62(0.05);13.64(0.50);15.14(0.08)
L1722+119B	483.48651	-	-;-;-;-
L1722+119V	483.48129	15.32(0.02)	-;13.22(0.01);14.10(0.01);15.67(0.01)
L1722+119B	483.49204	14.87(0.01)	-;12.63(0.01);13.62(0.01);15.15(0.01)

C3 and C4 (see Fig. 3), but C1 was saturated in V and R filters (at our data), and in B filter there is not input magnitude data from mentioned site. We need the calibrated stars around the object or precise (as much as possible) photometric input data during determining the calibrated stars (from some photometric catalogue). And for the object 1212+467, we determined the calibrated stars, which are indicated from 2 to 5 in Fig. 2 (the QSO is indicated as 1), by using SDSS catalogue and transformations (Chonis and Gaskell 2008) to calculate B, V, R magnitudes from u, g, r, i, z ones. The relative photometric method was used. The MaxIm DL Pro 5 image processing package was applied for CCD observations, and all frames were reduced individually. We took into account the calibrated stars with the signal to noise ratio (SNR) which is similar to or better than QSO one. The calculated magnitude (of object or output data for calibrated star) is the average value, from three CCD images, with standard error. Our preliminary photometry data of 1212+467 and 1722+19 are presented in Table 2.

The main columns of Table 2 are: the source type, name of ERS and filter are in the first column (Q – quasar L – BL Lac, A – active galactic nuclei or quasar, G – galaxy), the date t (or the catalogue SDSS which was used for calculation of B,V,R magnitudes of comparison stars via u,g,r,i,z magnitudes) in next column, and then the magnitudes for object and comparison stars (or input B,V,R magnitudes of comparison stars) in next two columns; $t = JD - 2456000$, the JD is Julian Date. The calibrated stars, around the object 1212+467, are marked with circles from 2 to 5, and the QSO with 1. Usually, the ERS is near the central part of the images.

The input photometric data and our photometry results (output) for calibrated stars are in accordance with each other. It means, the input data (of stars C1,C2,C3,C4 for object 1722+119, and stars 2,3,4,5 for object 1212+467) are good enough to calculate the magnitudes of our objects with small standard errors; the standard errors are of the order 0.01 magnitude. Also, the CCD observations using the 60 cm ASV

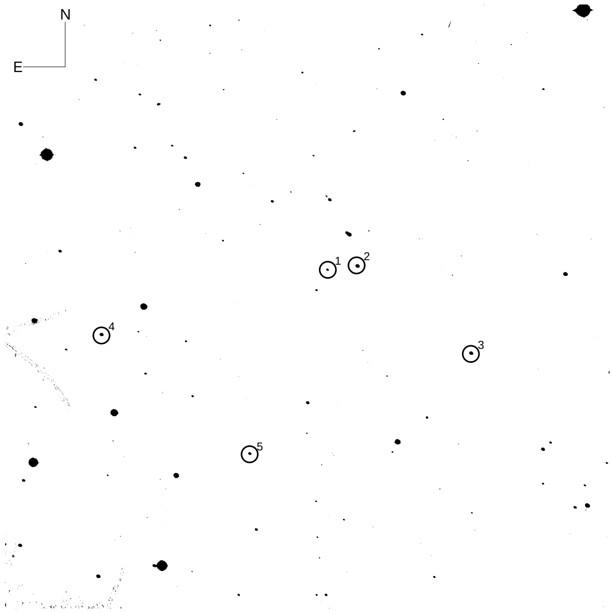

Figure 2: The QSO 1212+467 (1) with calibrated stars (2-5); FoV is 15.′8x15.′8.

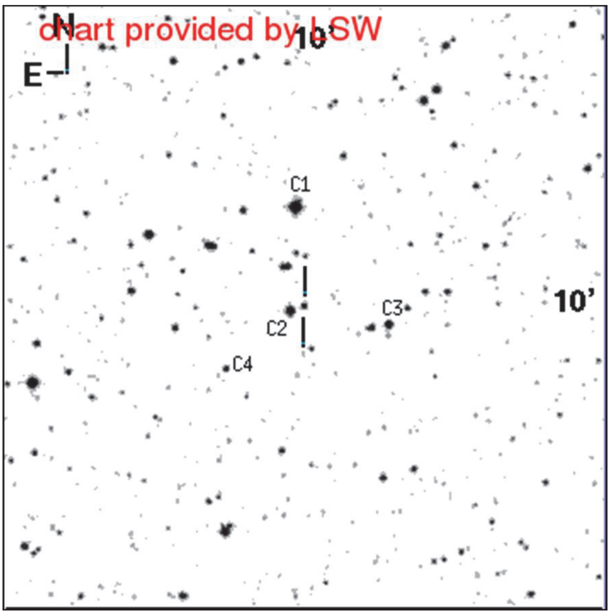

Figure 3: The BL 1722+119 with calibrated stars (C1,C2,C3,C4).

telescope are qualified for precise photometry of QSOs, and mentioned astrometry investigation of QSOs. The standard bias, dark and flat-fielded corrections (with removal of hot/bad pixels) were done to improve photometry results. So, the observations of QSOs using the 60 cm ASV are useful for mentioned link.

3. CONCLUSIONS

Here, we presente our preliminary photometry results of QSOs observations (objects 1212+467 and 1722+119) using the 60 cm ASV telescope. For the object 1722+119, we used the input photometry data of calibrated stars (C1,C2,C3,C4) via site http://www.lsw.uni-heidelberg.de/projects/extragalactic/charts/. For the object 1212+467, we determined calibrated stars around the QSO, and calculated their magnitudes in B,V,R filters using u,g,r,i,z ones (from SDSS catalogue DR7) and 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 importance for quality data that the average seeing at ASV site is near 1.2 arcsec. So, we can get the magnitudes of our objects (QSOs) with small standard errors which are of the order 0.01 magnitude.

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

We conclude that this kind of observations (of QSOs with magnitudes less than about $V = 18.5$) and mentioned investigations are possible with the 60 cm ASV instrument.

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