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MONITORING OF QUASARS IMPORTANT FOR THE LINK BETWEEN ICRF AND THE FUTURE GAIA CRF IN V AND R BAND

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Abstract. The Gaia mission of the European Space Agency (ESA) was launched at the end of 2013. It should provide a catalog of about 600000 quasars (QSOs) and nearly billion stars. Some of these QSOs could be the basis of a new optical reference frame. The current International Celestial Reference Frame (ICRF) is based on the VLBI observations of QSOs at radio wavelengths, but Gaia is doing in optical domain. It is necessary to observe a set of common QSOs at both optical and radio wavelengths to link the future Gaia Celestial Reference Frame - Gaia CRF with the ICRF. Only 10% of the ICRF sources (nearly 70 sources) are suitable to establish that link, and because of that other 47 sources were added which have high astrometric quality, as required for the alignment. Our observations of those 47 sources have been carried out since July 2016 using three telescopes: two of them with D=0.6 m and D=1.4 m are at the Serbian new site the Astronomical Station Vidojevica – ASV, and the third instrument with D=2 m is at the Rozhen Observatory (Bulgaria). In this paper, the main steps of our observations, reduction, and some results (as light curves in V and R bands) of two objects are presented.

1. INTRODUCTION

The European astrometric space mission Gaia was launched on December 2013. The first Gaia Data Release (Gaia DR1) was made publicly available on September 2016 (Mignard et al. 2016, Liu et al. 2017). One of the most important results of the Gaia mission will be a new highly-accurate optical Gaia Celestial Reference Frame (GCRF) at the same level of accuracy as the VLBI International Celestial Reference Frame (ICRF). Because of that, the link between the ICRF and GCRF should be realized at a similar level of accuracy. The basic idea to tie the Gaia catalog to the ICRF is using Gaia observations of compact extragalactic ICRF objects, visible in optical domain, which have accurate radio positions. About 90% of the ICRF sources are not suitable to establish this link. Because of that the remaining 10% of the ICRF sources have been extended by 47 ones, mostly quasars – QSOs (out of the ICRF list), which have high astrometric quality (Bourda et al. 2011).

One of the properties of QSOs is their flux variability, which may have multiple origins: variation in the accretion rate, jet instabilities, gravitational microlensing, etc. There is a correlation between the flux variability and photocentre motion in QSOs (Popović et al. 2012). On the other hand, the stability of QSO photocenter is of importance during optical observations. The QSOs with stable flux should be the base for the link between ICRF and Gaia CRF. Thus, the monitoring of magnitude stability of QSOs over longer period of time is necessary to determine stable QSOs as much as possible and eliminate objects with variable photocenter.

2. OBSERVATIONS AND RESULTS

Our observations of 47 sources have been carried out since July 2016 using two telescopes at the Astronomical Station Vidojevica of the Astronomical Observatory of Belgrade and one at the Rozhen Observatory. The characteristics of the 1.4 m ASV telescope (longitude $\lambda = 21.5^o E$, latitude $\varphi = 43.1^o N$, altitude h=1150 m) and CCD camera are presented in Table 1, and for the other instruments are in paper (Damljanović et al. 2014). The Johnson-Cousins BVRI filters were available.

Table 1: The main information about the 1.4 m telescope and used CCD camera.

Site ASV	CCD camera Apogee Alta U42
Telescope Ritchey-Chrétien	pixel array 2048x2048, scale $0.''24$
D/F = 140/1142 cm	pixel size 13.5x13.5μm and $FoV = 8.'3\text{x}8.'3$

The standard bias, dark and flat-fielded corrections (plus hot/dead pixels, cosmic rays, etc.) are done using IRAF scripting language. The magnitudes of objects were calculated using differential photometry with MaxIm DL software.

We presented two examples, for objects 1556+335 and 1741+597, and chose suitable comparison stars from the Sloan Digital Sky Survey Data Release 14 (SDSS DR14) catalogue following several criteria: not too far from the objects, not so bright or faint stars in accordance with object (with g, r and i magnitudes in the range of $14.5 - 19.5$), not very blue or red stars (in the ranges $0.08 < (r - i) < 0.5$ and $0.2 < (g - r) < 1.4$). We transformed the SDSS point-spread function *ugriz* magnitudes of the comparison stars into the Johnson-Cousins V and R ones (Chonis & Gaskell 2008) using equations:

$$V = g - (0.587 \pm 0.022)(g - r) - (0.011 \pm 0.013) \quad (1)$$

$$R = r - (0.272 \pm 0.092)(r - i) - (0.159 \pm 0.022) \quad (2)$$

Tables 2 shows the number of each comparison star, its equatorial coordinates, V$\pm\sigma_V$ and R$\pm\sigma_R$ magnitudes with suitable errors obtained from equations (1) and (2) for objects 1556+335 and 1741+597.

Table 2: Comparison stars and their V and R magnitudes with errors for objects 1556+335 and 1741+597.

Object	No.	$\alpha_{J2000.0}[^o]$	$\delta_{J2000.0}[^o]$	V$\pm\sigma_V$[mag]	R$\pm\sigma_R$[mag]
1556+335					
	2	239.719511	33.39111	17.336 ±0.066	16.850 ±0.073
	3	239.690368	33.40961	16.381 ±0.057	16.095 ±0.056
	5	239.767998	33.38780	16.271 ±0.063	15.916 ±0.060
	6	239.745631	33.39005	16.198 ±0.064	15.825 ±0.061
	7	239.743191	33.37371	15.552 ±0.063	15.188 ±0.060
	8	239.733993	33.37219	15.743 ±0.082	14.897 ±0.104
1741+597					
	2	265.623308	59.75173	15.565 ±0.062	15.204 ±0.063
	3	265.570839	59.75384	16.673 ±0.063	16.314 ±0.062
	4	265.684139	59.76858	16.376 ±0.073	15.795 ±0.073
	5	265.614598	59.79544	16.154 ±0.067	15.704 ±0.064
	6	265.682834	59.71898	16.126 ±0.082	15.684 ±0.085
	7	265.597679	59.71684	16.633 ±0.085	16.124 ±0.091

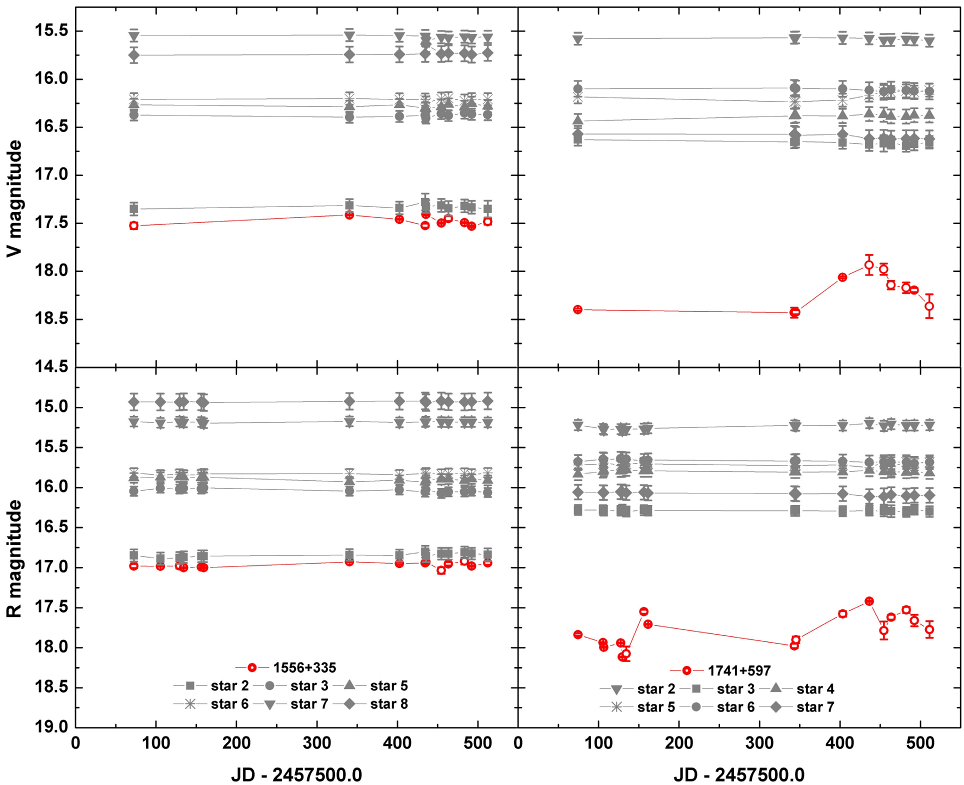

Figure 1: The light curves of V and R magnitudes of the objects 1556+335 (left) and 1741+597 (right) with light curves of the comparison stars, since July 2016 until September 2017.

Calculated V and R magnitudes were input values as the analysis tool Photometry in MaxIm DL software. With that tool, useful for the differential photometry, the magnitudes of selected objects and their comparison stars were calculated for each epoch of observation. Usually, we obtained two CCD images per filter, and calculated V and R magnitudes are average values with suitable standard deviation (σ_{cV}, σ_{cR}). The obtained magnitudes of comparison stars should be in good agreement with the input ones. Here, it was the case. The light curves of objects 1556+335 and 1741+597 together with their comparison stars are shown in Fig. . The error bars of V represent the root sum squared of input error σ_V and st.dev. σ_{cV}. The same is for R magnitude.

3. CONCLUSION

For the period mid-2016 - Sept. 2017, it seems that comparison stars have no changes in the brightness. The same could be said for object 1556+335. Unlike them object 1741+597 has had some changes. We plan to check the V and R magnitudes of the comparison stars and objects using a suitable statistical criterion. After that, our next step is to examine magnitude stability of stars and objects, and quasiperiodicity of object 1741+597. The mentioned procedure will be applied to the other objects.

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