Flux-stability analysis for the comparison stars for some quasars important to ICRF - GAIA CRF link

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1. Introduction

The ESA space mission Gaia was launched on December 2013. The first Gaia data release (Gaia DR1) was made publicly available on September 2016 [1] and the second (Gaia DR2) on April 2018 [2].
The one of the most important results of the Gaia mission is a new highly-accurate optical Gaia Celestial Reference Frame (Gaia-CRF) at the same level of accuracy as the VLBI International Celestial Reference Frame (ICRF). The basic method to tie the Gaia catalog to the ICRF, is using Gaia observations of compact extragalactic ICRF objects that have accurate radio positions. Only 10% ICRF sources (~ 70) are suitable to establish this link, and because of it this number has increased by 47 sources (out of the ICRF list) with high astrometric quality [3].
Our observations of 47 candidate sources have been carried out since July 2016 using two telescopes at the ASV - Astronomical Station Vidojevica (of the Astronomical Observatory of Belgrade) and one 2m RCC (at the Rozhen Observatory of NAO BAS, Bulgaria) in accordance with the joint Serbian - Bulgarian research project “Study of ICRF radio-sources and fast variable astronomical objects”, 2017-2019).

2. Instruments and results

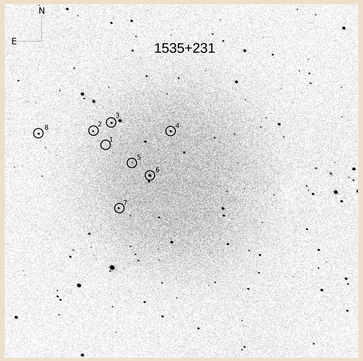
The main information about the instruments are:

1. ASV (AOB) Cassegrain 60cm/600cm — CCD camera - Apogee Alta U42, 2048x2048 pixels, scale=0."46, 13.5x13.5μm pixel size, FoV=15.’8x15.’8
   λ=21.º5E φ=43.º1N h=1140m

2. ASV (AOB) Ritchey-Chrétien 140/1142 — CCD camera - Apogee Alta U42, 2048x2048, 0.24, 13.5x13.5, 8.3x8.3
   λ=21.º5E φ=43.º1N h=1150m

3. Rozhen (NAO BAS) Ritchey-Chrétien 200/1577 — CCD camera - VersArray 1300B, 1340x1300, 0.26, 20x20, 5.6x5.6
   λ=24.º7E φ=41.º7N h=1730m

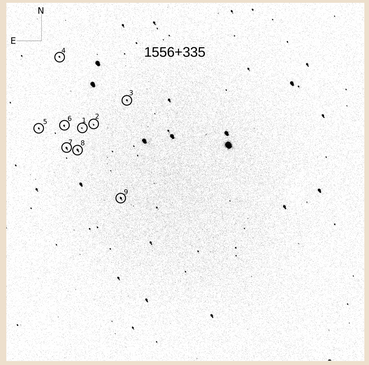
The information in the first column are: site, telescope and D[cm]/F[cm]. In the second column, the geographic coordinates (longitude - λ, latitude - φ) and altitude (h) of site are presented. The FoV is field of view, and NAO BAS means National Astronomical Observatory of Bulgarian Academy of Sciences.
Also, we used the ASV 60 cm and with other CCDs, as it is the SBIG ST-10 XME (scale=0.“23 and FoV=8.’4x5.’7), and Apogee Alta E47 (0.“45 and 7.’6x7.’6). Since April 2018, there is a new CCD, Andor iKon-L, on the 2 m Rozhen (scale=0.“17 and FoV~6’x6’). The Johnson-Cousins BVRcIc filters were available. Usually, we obtained 2 CCD images per filter (V and Rc). The standard bias, dark and flat-fielded corrections (plus hot/dead pixels, cosmic rays, etc.) are done using IRAF scripting language. Objects magnitudes were calculated using differential photometry with Maxim DL software.

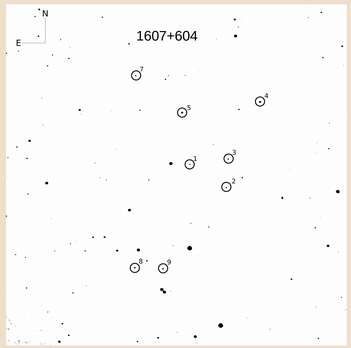


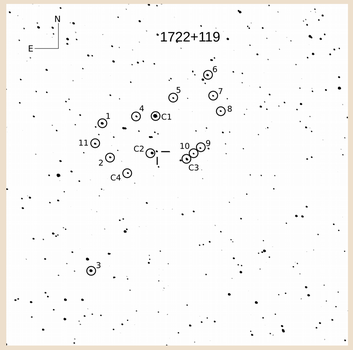
We chose comparison stars from SDSS catalog for objects 1535+231, 1556+335, 1607+604, and 1741+597 following several criteria: not to far from the objects, not so bright or faint stars (with g,r and i magnitudes outside the range 14.5 – 19.5) or not very blue or red (outside the ranges 0.08 < r-i < 0.5 and 0.2 < g-r < 1.4). PSF ugriz magnitudes of the comparison stars were transformed into the Johnson-Cousins BVRcIc [4] using equations:

$$V = g - (0.587 \pm 0.022)(g - r) - (0.011 \pm 0.013)$$
$$R = r - (0.272 \pm 0.092)(r - i) - (0.159 \pm 0.022)$$

For object 172+119 we chose comparison stars from Doroshenko et al. 2014 [5]. Calculated V and R magnitudes were input values as the analysis tool Photometry in MaxIm DL software. With that tool, the magnitudes of selected objects and their comparison stars were calculated for each epoch of observation. The flux-stability analysis for the comparison stars was examined with 3-σ criteria.







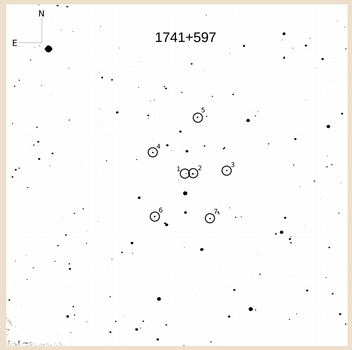


Fig.1. Field of view of objects 1535+231, 1556+335, 1607+604, 1722+119, and 1741+597 with Apogee Alta U42, ASV1.4m

Object

Calculated V and R magnitudes for comparison stars

1535+231

Comparison star	Ra	Dec	V	R
2	234.314908	23.01830	17.200 (±0.050)	16.658 (±0.073)
3	234.300042	23.02485	15.983 (±0.068)	15.633 (±0.071)
4	234.251775	23.01917	16.232 (±0.065)	15.867 (±0.060)
7	234.293122	22.96096	16.470 (±0.058)	15.973 (±0.067)
8	234.359172	23.01592	15.860 (±0.074)	15.149 (±0.086)

1556+335

2	239.719511	33.39111	17.336 (±0.066)	16.85 (±0.073)
3	239.690368	33.40961	16.381 (±0.057)	16.095 (±0.056)
5	239.767998	33.3878	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)

1607+604

2	242.028820	60.28951	17.068 (±0.059)	16.619 (±0.058)
3	242.025260	60.31162	16.864 (±0.055)	16.423 (±0.061)
4	241.973520	60.35552	15.195 (±0.054)	14.781 (±0.059)
5	242.096377	60.34816	15.630 (±0.064)	14.965 (±0.078)
7	242.168538	60.37746	16.856 (±0.053)	16.467 (±0.060)

1722+119

C2	261.27142	11.86956	13.173 (±0.005)	12.570 (±0.006)
C3	261.27142	11.86596	14.078 (±0.012)	13.600 (±0.008)
1	261.31233	11.89069	13.445 (±0.009)	12.848 (±0.010)
2	261.30477	11.86477	14.823 (±0.008)	14.691 (±0.012)
5	261.25696	11.91283	15.873 (±0.010)	15.385 (±0.016)
9	261.23344	11.875115	15.809 (±0.008)	15.332 (±0.014)
10	261.23871	11.87052	16.142 (±0.011)	15.699 (±0.019)
C4	261.29002	11.85310	15.665 (±0.009)	15.164 (±0.013)

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)

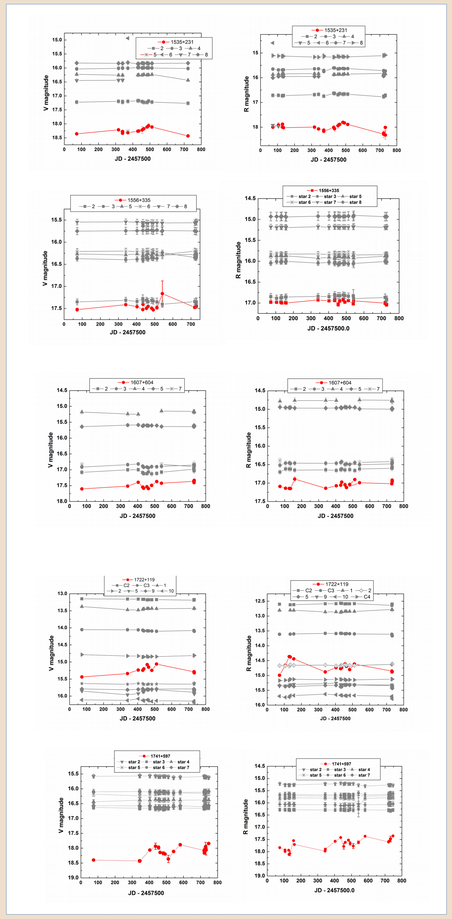


Fig.2. The light curves of V and R magnitudes of the objects 1535+231, 1556+335, 1607+604, 1722+119, and 1741+597 with light curves of theirs comparison stars, since July 2016

3. Conclusion

In Fig.2. are shown the light curves of the objects (QSOs) with light curves of their comparison stars. For the period ~ 2year using 3-σ rule we can say that in measurements of the brightness of the comparison stars (2, 3, 4, 7, 8 – 1535+231; 5, 6, 7 – 1556+335; 2, 3, 4, 5, 7 – 1607+604; C2, C2, 1, 2, 5, 9, 10, C4 – 1722+119; 2, 3, 5, 6, 7 - 1741+597) are not present systematic but only random errors. Our next step is to examine magnitudes stability of the objects with some statistical methods and quasiperiodicity where necessary.

Acknowledgements

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