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CCD OBSERVATIONS OF ERS WITH THE 60 cm TELESCOPE AT ASV

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Abstract. We present the observations of extragalactic radio sources (ERS) which are possible in the optical domain and can be used to establish the link between the ICRF2 and the future Gaia Celestial Reference Frame (GCRF). Our telescope of small aperture size (<1 m) is located in the south of Serbia, near the town of Prokuplje, at the Astronomical Station Vidojevica (ASV) which belongs to the Astronomical Observatory of Belgrade (AOB). It is a Cassegrain-type optical system (D=60 cm, F=600 cm) of equatorial mount. About 40 ERS, from ICRF2 list, were observed at ASV during 2011 and 2012. These observations are of importance to compare the ERS optical and radio positions (VLBI ones), and to investigate the relation between optical and radio reference frames. Also, they are useful to check the possibilities of the instrument. We observed ERS with the CCD Apogeee Alta U42. The observations, reduction and preliminary results of some ERS are presented here.

1. INTRODUCTION

During last few years, astrometry with ground based optical telescopes has become a modern topic, and it is in line with the GAIA mission for: the future astrometric monitoring of GAIA, the link between radio and optical positions of ERS, the realization of a catalogue of quasars, etc.

The International Celestial Reference Frame (ICRF1) was adopted by the IAU in 1997 (the IAU XXIII GA, Kyoto). It is defined by the measured positions of 212 extragalactic radio sources, mainly quasars, by using VLBI. The ERS are assumed to provide fixed (quasi-inertial) directions in space. The ICRF1 replaced the optical FK5 reference frame on January 1, 1998. The second realization, ICRF2, was adopted at the IAU XXVII GA (2009, Rio de Janeiro); there are the precise positions for 3414 radio sources (295 "defining" and 3119 additional ones). The two largest weaknesses of ICRF1 were eliminated: more uniform sky distribution of ERS and the position stability of the 295 ICRF2 defining sources. On the other hand, the Hipparcos Celestial Reference Frame (HCRF) is an optical one. It was linked to the ICRF (radio one), but the accuracy decreases over time because of the error in the proper motions of stars, and it is necessary to verify and refine the relation between the HCRF and ICRF2 by using different telescopes and methods. To align the radio frame (ICRF2) and optical frame (HCRF) with high accuracy, we need to observe the common objects, ERS, and to calculate their accurate optical positions.

The task of ICRF2 is obtaining the coordinates of quasars as accurately as possible, and to determine the precise coordinates of moving objects (stars, planets, etc.). The ICRF2 consists of the precise coordinates of compact ERS, mostly quasars; their current positions are known to be better than 1 mas. From time to time, it is necessary to analyze the accurate observational VLBI data concerning ERS at radio wavelengths and the CCD ones obtained by telescopes in the optical domain.

The frame stability is based upon the assumption that the proper motions of ERS are negligible. But, due to their active nuclei, there is a structural instability of the sources at radio and optical wavelengths. On the other hand, a regular maintenance of the system and improvement of the frame are necessary. Because of it, the optical telescopes are useful to monitor the magnitude and morphology of some ERS. The morphology of ERS is studied using the data obtained with medium size aperture (1 m to 2 m) telescopes, but in photometrical studies we can use the data from small aperture size (< 1 m) telescopes, such as our telescope at ASV.

The telescope position is: longitude $\lambda = 21^\circ 33' 20''\!.4$, latitude $\varphi = 43^\circ 8' 24''\!.6$ and altitude $h = 1150$ m. It has a German equatorial mount and a Cassegrain optical system with optical elements produced by LOMO company (St. Petersburg, Russia). The primary mirror is parabolic with a diameter $D = 60$ cm and the secondary one is hyperbolic with $D = 20$ cm; it is a classical Cassegrain optical system. The telescope focal length is 600 cm. The main characteristics of CCD camera Apogee Alta U42 are: the size of CCD chip is 2048×2048 pixels, pixel size is $13.5 \times 13.5 \mu m$ and field of view (FOV) is about $15.'8 \times 15.'8$. The angle corresponding to one pixel is $0''\!.46$.

2. OBSERVATIONS AND RESULTS

It is possible to investigate the relationship between optical and radio frames using the differences between optical and radio coordinates ((O-R)$_\alpha$, (O-R)$_\delta$) of ERS. We observed ERS with the CCD camera Apogeee Alta U42 attached to 60 cm telescope at ASV during 2011 and 2012. About 40 ERS were observed from the ICRF2 list (Fey at al. 2009).

Here, the positions (α, δ) of the optical counterparts to ERS were determined and the relative method was applied by using the coordinates and proper motions of stars from the XPM catalogue compiled by Fedorov et al. (2010). XPM contains data for 314 million stars distributed all over the sky for the epoch J2000.0. It contains much more stars than the Hipparcos Catalogue which makes it possible to have enough stars within a small field of view.

Here, we present results for 6 optical counterparts of ERS from the ICRF2 list (Table 1): L 0109+224 (J011205.8+224438), A 0059+581 (J010245.7+ 582411), Q 2250+190 (J225307.3+194234), G 0007+106 (J001031.0+105829), L 2254+074 (J225717.3+074312) and G 0309+441 (J031301.9+412001). The designations outside the parentheses are ICRF ones, within them the IERS[1] designations are used. We made 6 frames per ERS (3 at R filter and 3 at V one), and $14.2 \leq m_V \leq 17.0$. For each frame, the exposure time was 60^s and all exposures were guided. The corrections for apparent displacements, as differential refraction (Aslan et al. 2010, Kiselev 1989), and the reduction on bias, dark and flat-field were not applied. Designations of the

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[1] International Earth Rotation Service

Table 1: Observed ERS: L - BL Lac, A - active galactic nuclei or quasar, Q - quasar, G - galaxy.

Type of ERS and name	α_{ICRF2} [h m s]	δ_{ICRF2} [° ′ ″]	V mag	Exp [s]
L 0109+224	01 12 05.825	22 44 38.786	16.4	60
A 0059+581	01 02 45.762	58 24 11.137	16.1	60
Q 2250+190	22 53 07.369	19 42 34.629	16.7	60
G 0007+106	00 10 31.006	10 58 29.504	14.2	60
L 2254+074	22 57 17.303	07 43 12.302	17.0	60
G 0309+441	03 13 01.962	41 20 01.184	16.5	60

columns in Table 1 are: the source name and type of object, the ICRF2 coordinates (α, δ) of ERS, the V magnitude and the exposure time.

For processing the CCD images, the first step is to detect the star-like object (ERS) and reference stars. The Fortran program for reduction of stellar apparent coordinates is written with some procedures from SOFA packages (Standards of Fundamental Astronomy). The next step is the measuring the CCD positions (x, y) of ERS and stars. The linear model was used, as a standard astrometric "plate" reduction, with the available reference stars, $\xi = ax + by + c$ and $\eta = dx + ey + f$ (Kiselev 1989), to transform the measured CCD coordinates (x, y) to tangential ones (ξ, η). Because of small FOV, the tangential coordinates of reference stars and ERS are equal to the equatorial ones (Aslan et al. 2010). The unweighted Least – Squares Method (LSM) was used to calculate the unknown values of parameters a, b, c to get α, and d, e, f to get δ. To do that we need at least 3 reference stars. The AIP4WIN (Berry & Burnell 2002) image processing package was applied to the CCD data. Thus, the optical coordinates of 6 mentioned ERS objects were determined. Finally, we compared our optical (O) positions of ERS with the radio (R) ones to determine the values (O-R) in α and δ (see the results in Table 2). We used the VLBI radio coordinates from IERS Technical Note No. 35 (Fey at al. 2009).

Our results have been compared with those of Maigurova and Damljanović (2011) and a good agreement has been found.

The same objects were observed also at Rozhen with the 2 m telescope (Damljanović and Milić 2012) and the resulting coordinate differences are comparable.

3. CONCLUSIONS

The presented preliminary results (in α and δ) and their standard errors for the 6 observed ERS objects obtained with the 60 cm telescope at ASV agree well with the results obtained with the larger Rozhen telescope. Also, these results are useful for improving the coordinates and proper motions of reference stars contained in the XPM catalogue and to calculate the unknown position of every star in the neighborhood of ERS. Using dark, bias, flat frames and stacking during the reduction of CCD images, we expect better results of (O-R) in positions of ERS. Also, the ASV results could be improved with star guider (to use the exposures longer than 90 sec). The small

Table 2: Differences between optical and radio coordinates $(O-R)_\alpha$ and $(O-R)_\delta$ for ERS and their standard errors

Name of ERS	(O-R)$_\alpha$ [$''$]	(O-R)$_\delta$ [$''$]	σ_α [$''$]	σ_δ [$''$]
L 0109+224	–0.049	–0.036	0.138	0.158
A 0059+581	0.026	0.317	0.226	0.495
Q 2250+190	–0.181	0.224	0.400	0.120
G 0007+106	–0.115	0.053	0.038	0.076
L 2254+074	0.145	0.180	0.381	0.556
G 0309+441	0.064	–0.353	0.315	0.263

telescope at ASV practically does not allow observations of faint objects (fainter than about $m_V = 18$).

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References

Aslan, Z., Gumerov, R., Jin, W., Khamitov, I., Maigurova, N., Pinigin, G., Tang, Z., Wang, S.: 2010, Optical counterpart positions of extragalactic radio sources and connecting optical and radio reference frame, A&A, **510**, A10.

Berry, R., Burnell, J.: 2002, The Handbook of Astronomical Image Processing, Includes AIP4WIN Software, Willmann-Bell, Inc., Richmond, USA.

Damljanović, G., Milić, I. S.: 2012, CCD measurements in optical domain and astrometric positions of ICRF2 radio sources, Proc. of the Journées 2011, Systèmes de Référence Spatio - Temporels "Earth rotation, reference systems, and celestial mechanics: Synergies of geodesy and astronomy", eds. H.Schuh, S.Böhm, T.Nilsson and N.Capitaine, Vienna University of Technology and l'Observatoire de Paris, 92-93.

Fedorov, P. N., Akhmetov, V. S., Bobylev, V. V., Bajkova, A. T.: 2010, An investigation of the absolute proper motions of the XPM catalogue, MNRAS, **406**, 1734-1744.

Fey, A. L., Gordon, D., Jacobs, C.S.: 2009, IERS Technical Note, No. **35**.

Kiselev, A.A.: 1989, Theoretical foundations of photographic astrometry, Nauka, Moskva.

Maigurova, N., Damljanović, G.: 2011, Some problems of the ERS astrometric reductions, Abstract Book of the International Conf. "Astronomical Research: from Near–Earth Space to the Galaxy", Mykolaiv: Atoll, Ukraine, 40.