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OBSERVATIONS OF ERS FROM ICRF2 LIST USING ASV 60 cm AND ROZHEN 2 m TELESCOPES

IVANA S. MILIĆ and GORAN DAMLJANOVIĆ

Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia
E-mail: ivana@aob.rs, gdamljanovic@aob.rs

Abstract. During 2011 we observed the extragalactic radio sources (ERS, which are visible in the optical domain) from ICRF2 list using the ASV $D = 60$ cm (Serbia) and Rozhen $D = 2$ m (Bulgaria) telescopes with CCD camera. It is of importance to compare the ERS optical and radio positions (VLBI ones) and to search for a relation between optical and radio reference frames. A few ERS were observed with both telescopes, and it is usefull to check the possibilities of ASV 60 cm instrument via the Rozhen 2 m results. At the ASV 60 cm we used the CCD camera Apogee U42 (2048x2048 pixels, the pixel size is 13.5x13.5 μm, and at the Rozhen 2 m it is the CCD VersArray 1300B (1340x1300 pixels, the pixel size is 20x20 μm). The observations, reduction and preliminary results of common ERS are presented here.

1. INTRODUCTION

The reference systems are based on the resolutions of international scientific unions. So, the celestial system is based on IAU (International Astronomical Union) Resolution A4 (1991). It was officially initiated and named International Celestial Reference System (ICRS) by IAU Resolution B2 (1997). The fundamental celestial reference frame (International Celestial Reference Frame – ICRF) was adopted by the IAU (1997). There were the original list of radio objects and two extensions (ICRF-ext1 and ICRF-ext2). Now, they are referred to as ICRF1: all in all 717 sources, 212 defining ones, 109 new ones, 294 candidate ones, and 102 additional sources. At the IAU XXVII GA (2009), the second realization of the ICRF (the ICRF2) was adopted with the list of precise positions for 3414 compact radio astronomical sources. The investigation of a relation between optical and radio reference frames is of importance. For that subject, we need to make the observations of some ICRF2 ERS which are visible in the optical domain, and to compare their optical and radio positions (VLBI ones). The optical positions (α and δ) could be calculated using reference stars from some of nowadays big star catalogues. To do that comparison we can use our CCD observations of ERS made at the RCC telescope[1] of Rozhen National Astronomical Observatory (Bulgarian Academy of Sciences) and at the Astronomical Station

[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.

Vidojevica – ASV of the Astronomical Observatory in Belgrade (Serbia). Here, we presented the possibilities of ASV telescope comparing our ASV 60 cm and Rozhen 2 m results for 6 ERS objects observed with both instruments.

2. DATA

The Hipparcos reference frame was realizing the ICRS in optical wavelengths, and the accuracy is significantly better than in the case of FK5. So, the HCRF, Hipparcos Celestial Reference Frame, is the optical one. It was linked to the ICRF1 (radio one) with an accuracy of ±0.6 mas in position (for the epoch 1991.25) and ±0.25 mas per year in rotation (Kovalevsky et al. 1997). That accuracy degrades over time because of the error in 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. We can investigate the relation between optical and radio reference frames via ERS visible in the optical domain. To do that we made the observations of ERS using the Rozhen 2 m ($D = 2$ m, $F = 15.77$ m) and ASV 60 cm ($D = 60$ cm, $F = 6$ m) telescopes. The CCD fields around ERS were observed using CCD camera VersArray 1300B (1340x1300 pixels, the pixel size is 20x20 μm, the scale is 0.26 arcsec/pix, the field of view – FOV is about 5.5x5.5 arcmin) with 2 m Rozhen telescope, and using CCD Apogee U42 (2048x2048 pixels, the pixel size is 13.5x13.5 μm, 0.46 arcsec/pixel, the FOV is about 15.8x15.8 arcmin) with 60 cm ASV one (Fig. 1).

Table 1: Observed ERS using ASV 60 cm and Rozhen 2 m telescopes.

ERS	RA (VLBI) (h,m,s)	DEC (VLBI) (°,′,″)	Mag	Exp V Rozh (s)	Exp R Rozh (s)	Exp V ASV (s)	Exp R ASV (s)
L0109+224	01 12 05.8247	22 44 38.786	16.4	10	15,10	60	60
A0059+581	01 02 45.7624	58 24 11.137	16.1	15	10	60	60
Q2250+190	22 53 07.3692	19 42 34.629	16.7	20	20	60	60
G0007+106	00 10 31.0059	10 58 29.504	14.2	5	5	60	60
L2254+074	22 57 17.3031	07 43 12.302	17.0	20	20	60	60
G0309+411	30 13 01.9621	41 20 01.183	16.5	15	15	60	60

The ERS (extragalactic radio sources) are compact extragalactic objects, mostly quasars (quasi stellar objects, QSO), BL Lacertae (BL Lac) sources and a few active galactic nuclei (AGNs). The ERS are far away and their proper motions should be negligibly small. The current VLBI positions are known to better than 1 mas. The total number of objects is 3414 in ICRF2: 295 'defining', and additional 3119 ones. Alignment of ICRF2 with the ICRS was made using common ICRF2/ICRF-Ext. 2 138 stable ERS. From 1 January 2010, the realization of the ICRS is the ICRF2, and the two largest weaknesses of ICRF1 were eliminated: more uniform sky distribution of ERS and the position stability of the 295 ICRF2 defining sources.

The densification catalogues derived from the HCRF because the HCRF was primary realization of the ICRS at optical wavelengths. Some of these catalogues are: Tycho-2, UCAC3, 2MASS (near-IR), PPMXL, XPM, etc. We used here XPM catalogue (Fedorov et al., 2010). And we assume that the centers of emission of radio/optical sources coincide between each other in line with the accuracy level of the optical observations.

We need to observe the common radio/optical objects to align radio frame (ICRF2) and optical one (HCRF) with high accuracy. To do that, we calculated the accurate optical positions of ERS. So, the ground based astrometric observations of ERS are very important. During autumn 2011, we made the observations with the Rozhen 2 m and ASV 60 cm telescopes. Some of ERS were observed at both sites. And it is a good opportunity to check the ASV results via the Rozhen ones.

A total of 6 optical counterparts of ERS were observed on both sites (see Table 1): L 0109+224, A 0059+581, Q 2250+190, G 0007+106, L 2254+ 074 and G 0309+411. We made 6 frames per ERS (3 at R filter and 3 at V one). The magnitudes ranged from 14.2 to 17.0 (ICRF, V domain). All exposures were guided. The exposure time ranged from 5^s to 20^s for the Rozhen 2 m telescope and 60^s for ASV 60 cm (see Table 1). The main columns of Table 1 are: the source name and type of ERS is in the first column (Q – quasar L – BL Lac, A – active galactic nuclei or quasar, G – galaxy), the next two columns are α and δ (from ICRF2 list) of ERS, then the magnitude which is obtained for V domain, and our exposure time is presented for V and R domains (last four columns).

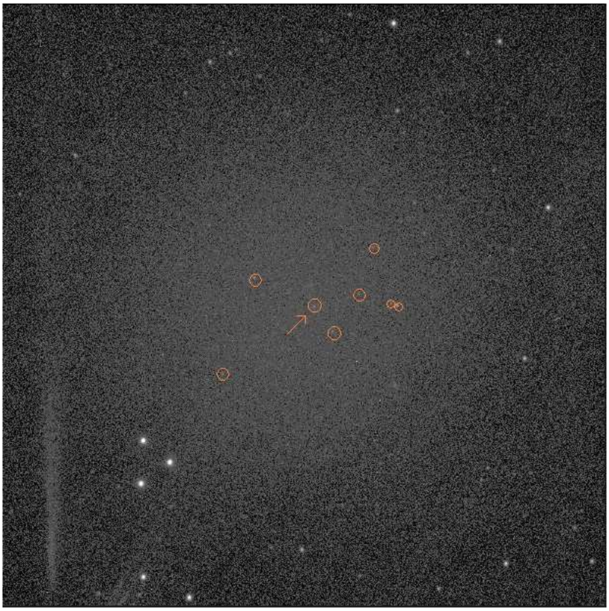

Figure 2: The ERS G 0007+106 with magnitude of 14.2 observed with ASV 60 cm.

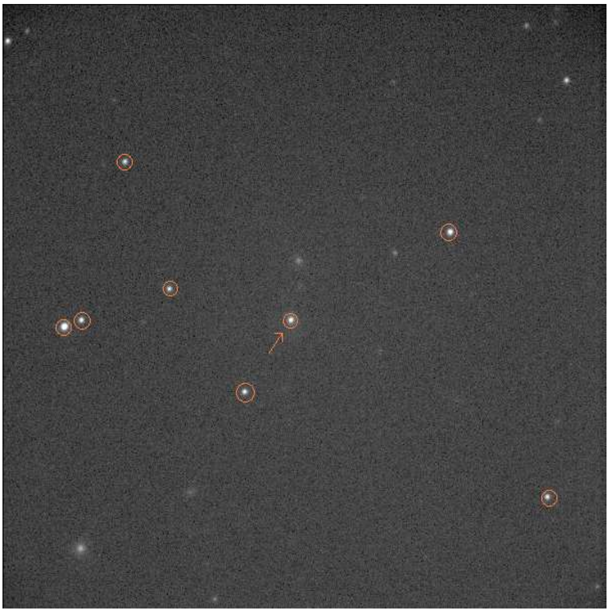

Figure 3: The ERS G 0007+106 with magnitude of 14.2 observed with Rozhen 2 m.

3. CALCULATION AND RESULTS

The detection of star-like objects (ERS) and reference stars is the first step for processing the CCD images. The next step is measuring the positions of centers (x, y) of ERS and stars. And the reduction, to get tangential and equatorial coordinates. The linear model was used, it is a standard astrometric "plate" reduction with the available reference stars,

$$\xi = ax + by + c$$

$$\eta = dx + ey + f$$

to transform the measured CCD coordinates (x, y) to tangential ones (ξ, η). The unweighted Least – Squares Method (LSM) was applied to calculate the unknown values of parameters a, b and c to get α. And d, e, and f ones to get δ. The FOV of CCD frames was small and we did not apply the corrections for apparent displacements, as differential refraction (Aslan at al. 2010, Kiselev 1989). So, we need at least 3 reference stars, but sometime in small FOV there are not enough reference stars with precise coordinates and proper motions to calculate the values of α and δ of ERS. On the other side, we need the good precision of astrometric data of reference stars (from some catalogue) to determine precise link between the radio and optical frames.

The bias and flat-field frames were not applied to our raw frames. The dark correction is not significant at Rozhen site because the CCD chip was cooled to -110^o C (good for ERS fainter objects). The AIP4WIN image processing package (Berry and Burnell 2002) was applied for CCD observations. All frames were reduced individually. The XPM catalogue which was used for reduction contains the positions and proper motions for 314 million stars distributed all over the sky for the epoch 2000.0. To calculate the stellar apparent positions, some programmes from SOFA package were used. So, the positions of ERS were calibrated with respect to the XPM catalogue by using CCD observations. In this way, we determined the optical coordinates of mentioned 6 ERS objects. The ERS radio ones are from the ICRF2 list (Fey et al. 2009). Some of XPM stars did not taken into account because of their very low signal to noise ratio.

In Fig. 2, as an example of ASV observation, the CCD frame of ERS G 0007+106 is presented, and in the Fig. 3 it is the same ERS but observed with 2 m Rozhen telescope. All 7 stars are marked with circles. The ERS is near the central part of the images and marked with the direction arrow and a circle.

We compared the optical positions of ERS with the radio ones to determine the values (O-R)$_\alpha$ and (O-R)$_\delta$ (see Table 2). There are the unweighted mean offsets of (O-R)$_\alpha$ (the second column for the Rozhen side and the sixth one for the ASV side) and (O-R)$_\delta$ (the third column for the Rozhen side and the seventh one for the ASV side) values with their standard errors.

From both telescopes, these offsets in α are close to each other for bright ERS G 0007+106 with magnitude 14.2 (also, in δ); see Table 2. The errors of ASV offsets are small and close to suitable Rozhen ones. The similar situation is for the ERS L 0109+224 with magnitude of 16.4. The errors of ASV offsets of other ERS objects are

Table 2: Differences between optical (our results) and radio (VLBI) positions of ERS observed with ASV 60 cm and Rozhen 2 m telescopes.

ERS	Rozh				ASV			
	$(O\text{-}R)_\alpha$ ($''$)	$(O\text{-}R)_\delta$ ($''$)	σ_α ($''$)	σ_δ ($''$)	$(O\text{-}R)_\alpha$ ($''$)	$(O\text{-}R)_\delta$ ($''$)	σ_α ($''$)	σ_δ ($''$)
L0109+224	-0.111	0.001	0.015	0.019	-0.049	-0.036	0.138	0.158
A0059+581	0.138	-0.028	0.050	0.098	0.026	0.317	0.226	0.495
Q2250+190	0.131	0.159	0.166	0.040	-0.181	0.224	0.400	0.120
G0007+106	-0.151	0.089	0.042	0.055	-0.115	0.053	0.038	0.076
L2254+074	0.074	0.007	0.095	0.040	0.145	0.180	0.381	0.556
G0309+411	-0.347	-0.250	0.133	0.271	0.064	-0.353	0.315	0.263

remarkably bigger than the corresponding Rozhen ones. Also, some of ASV offsets are different from the corresponding Rozhen ones.

4. CONCLUSIONS

In the paper by Damljanović and Milić (2012) we presented our fist results of ERS observations using 2 m Rozhen telescope, and concluded that this kind of observations and investigations is possible with that instrument.

From just 6 ERS objects observed at both sites (with Rozhen 2 m and ASV 60 cm telescopes), we can conclude that the optical observations of ERS are possible by using 60 cm ASV telescope and a good CCD camera, but at present it is better to observe ERS with magnitudes less than about 16.5. The corresponding offsets (in α and in δ), as the results of 2 m Rozhen and 60 cm ASV observations, are very similar for bright ERS objects (for example G 0007+106 and L 0109+224). Moreover, from ASV observations and in the case of G 0007+106 (with magnitude 14.2) the errors of offsets are small and close to the corresponding Rozhen ones. Some problems during the calculation of ERS optical positions can be caused by: faintness of the optical counterparts to ERS, atmospheric influences and technical problems. We could improve the ASV results by using: star guider (to use the exposures longer than 1.5 minutes), dark, bias and flat during reduction of data, and stacking of data. Anyway, it is better to use the Rozhen 2 m telescope for observations of faint ERS objects; it means with magnitude exceeding 17.

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