REFINEMENT OF LINKING OPTICAL-RADIO REFERENCE FRAMES ON THE BASIS OF THE INTERNATIONAL JOINT PROJECT BETWEEN COLLABORATIVE OBSERVATORIES

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ABSTRACT. Results of the Joint Project between observatories from China, Turkey, Russia and Ukraine on improvement of linking optical and radio reference systems are discussed. The 300 extragalactic radio sources (ERS) observation program is extended at the expense owing to the increase of observation in a southern hemisphere up to -40^0 declinations. The stars from catalogues USNO-A2.0 and UCAC1 were used as reference one. The analysis of ERS position (optical – radio) differences in observations with different telescopes showed about ±40mas accuracy. The observations of more than 100 ERS made with 1.5m RTT150 in Turkey and two telescopes in China were used. The intermediate internal estimation of angles between optical and radio systems on the base of ERS coordinates selected in the -40^0 +75^0 declinations zone was made: ω_x =7±24, ω_y =-3±24, ω_{zy} = -12 ± 21 (s.e.) mas.

1. INTRODUCTION

- Due to the epoch difference between optical and radio reference frames it is very important for modern astrometry to refine frame's link by different methods and instruments [1].
- The task of collaborated programme (Joint Project) between astronomical observatories from China, Turkey, Russia and Ukraine is the refinement of optical / radio linking [2,3].
- It will be appropriate for enhancing of optical-radio link accuracy. It can be shown that rotation parameter's precision of about 5 mas will be reached by using of 300 extragalactic radio sources (ERS) with positional precision not worse than 20 mas [3].

2. PROGRAM AND INSTRUMENTATION

The final collaborated program list includes about 300 ERS for declination zone from -40^o to $+90^o$. There are about 200 ERS optical counterparts in the northern sky and 100 ERS in the southern sky. At present several CCD telescopes are used by collaborated observatories for the Joint Project:

- Nikolaev astronomical observatory (Ukraine): AMC - Axial meridian circle (180,2480) and Zone astrograph (160,2044) of the Nikolaev astronomical observatory equipped with the similar CCDs ISD017A (1040x1160, 16 x 16 mkm, $1.''6$/pix);
- Kazan state university (Russia) and Turkish national observatory (Turkey): RTT150 – Russian-Turkish Telescope (1500,11600) of the Kazan state university installed in Turkey (TUG) for joint using. Right now it is equipped with the CCD ST-8 (1530 x 1020, 9 x 9 mkm, $0.''16$/pix);
- Shanghai astronomical observatory (China): Yunnan observatory 1m telescope (FOV $6'.5\mathrm{x}6'.5$, focal length 13m, scale 0.024mm/pixel and $0.''3737$/pixel); Beijing astronomical observatory 2.16m telescope (FOV $10'\mathrm{x}10'$, focal length 13m, scale 0.015mm/pixel and $0.''3$/pixel).

3. OBSERVATION AND REDUCTION

3.1. *Reduction Methods*

Reduction of the CCD images with software including flat field correction, digital image filtration, identification of star-like objects, display of the images and calculation of star-like objects' CCD coordinates was made. It is possible to operate with CCD fields made in stare and drift-scan modes [4].

Positions of the ERS optical counterparts were obtained by CCD direct imaging on the collaborated telescopes, using the secondary reference star positions from the catalogues USNO-A2.0 and UCAC1.

For an accurate reduction by small CCD fields with enough number of secondary reference stars it was decided to use the compiled catalogue as a reference one that was made of some new CCD catalogues [5]. Creation of compiled catalogue with stars of $12\text{-}15^m$ for about 300 ERS fields in declination zone -20^0 $+90^0$ is in progress from 2001. Seven separate catalogues made by observatories in Kiev (PIRS and MAC1), Bucharest, La Palma (CAMC1-11), USNO and Hamburg observatories (ERL), Pulkovo, Nikolaev (AMCIB) with CCD and photographic telescopes are used.

3.2 *Observation in Chinese observatories*

The observations of 22 ERS in the southern hemisphere and optical positions determination relative to the UCAC1 were carried out [6]. The internal accuracy of comparison between optical and radio ERS positions is on the level of 60mas and 45 mas in right ascension and declination, respectively. UCAC1 is good connected with the ICRF. Additionally, there were obtained 65 ERS observed in Yunnan and Beijing observatories on the level of a good quality of about 30mas in both coordinates. Preliminary calculation has shown a possibility to use them for angles data processing.

Observation with the RTT150 in Antalya: The observations of 26 ERS in the southern hemisphere and optical positions determination relative to the USNOA2.0 were carried out in Antalia in accordance with the Joint Project. The internal accuracy of comparison between optical and radio ERS positions is on the level of 43mas and 34 mas in right ascension and declination, respectively. USNOA2.0 is not so accurate catalogue as UCAC1 and its connection with the ICRF is of the same order. The observations of 44 ERS in northern hemisphere and optical positions relative to USNOA2 were carried out in Antalia. The internal accuracy of comparison between optical and radio positions is 31 mas and 38 mas in right ascension and declination, respectively.

4. DETERMINATION OF PRELIMINARY ANGLES BETWEEN OPTICAL AND RADIO REFERENCES FRAMES

The values of angles between optical and radio reference frames in accordance with the data of observation with RTT150 in Turkey and 1-m telescope in China were also calculated by common formulas:

$\Delta\alpha_{\ O-R}$ Cosδ = ω_x Sinδ Cosα + ω_y Sinδ Sinα - ω_z Cosδ , (1)

$\Delta\delta_{\ O-R}$ = - ω_x Sinα + ω_y Cosα ,

where: $\Delta\alpha_{O-R} = \alpha_O$ - α_R and $\Delta\delta_{\ O-R} = \delta_O$ - δ_R are ERS coordinate differences in optical and radio reference frames; ω_x,ω_y,ω_z - rotation angles about the x,y,z axes, respectively.

It is to be noted that some differences in position between USNO-A2.0 and ICRF are available due to systematic errors: position errors depending from star brighness and declination, unknown proper motion of secondary reference stars, regional differences in positions between ICRF and USNO-A2.0; also, distorsion of drift scanning CCD fields, some reduction errors of the CCD images made by stare and drift-scan modes, by operation with pointlike and extended objects from the ERS counterparts.

As a first analysis free terms $\Delta\alpha_0$Cosδ and $\Delta\delta_0$ were determined in two equations (1) for consideration of differences between USNO-A2.0 and ICRF. Resulting values of these terms made $\Delta\alpha_0$Cosδ = $+0.''11 \pm 0.''04$ and $\Delta\delta_0$= $+0.''14 \pm 0.''02$ and are similar to those discussed in [7-8]. After taking it into accout the unknown angles values from available observations in the ICRF were determined.

The second estimation of obtained angles are given in the Tabl.1 in comparison with the angles determined by different authors [9-19].

Table 1. Optical-radio rotational parameters

Source	ω_x (mas)	ω_y (mas)	ω_z (mas)	N	σ_1 (mas)	$\sigma_{(O-R)}$ mas
Hamburg(1990), [13]	30±20	53±20	23±20	28	±86	
CAMC+Bord (1990), [14]	32±18	10±19	13±18	20	66	±66
Kiev(1992), [16]	0±30	70±30	20±20	251	365	
Jonston et al (1994), [17]	43±19	31±19	-29±18	43		
FASTT(1994), [10]	-20±17	28±16	11±13	99	122	42
Kumkova et al (1995), [18]	38±18	22±16	-17±16	78		146
Andrei et al(1995), [15]	-30±20	30±30	20±20	29	170	
FASTT(1997), [11,12]	-2.2±3.3	-2.2±3.4	3.4±2.9	689		
Zacharias et al (1999), [19]	-0.2±3.9	-5.4±3.9	-2.5±3.9	318	58	50
Joint Project (2002), [9]	**7± 24**	**-3± 24**	**-12± 21**	**92**	**175**	**40**

The column N gives the number of ERS sources in the solution, $\omega_{x,y,z}$ - rotation angles with their standard errors; σ_1 – error of unit weight; $\sigma_{(O-R)}$ – accuracy of the ERS optical position with respect to the radio reference frame.

Comparing the data from different observatories it should be noted the internal accuracy of obtained angles in Tabl.1 is dependent mainly from the position accuracy of USNOA2.0 stars. It is possible to obtain good accuracy results with help of the best secondary reference stars position by using the future compiled catalog , new UCAC in the northern hemisphere, also by increasing the ERS number.

At present, there are additional available observations (about 100 ERS) made by collaborated telescopes. Also, we intend to obtain enough number of ERS observations in the next year accordingly the final program list (about 300 ERS).

5. CONCLUSION

Current processing of the optical/radio differences of 92 ERS with the average position accuracy of 40 mas by using the secondary reference stars from the USNO-A2.0 permits to determine rotation parameters with accuracy of 21-24 mas.

The expected accuracy of the optical/radio linking could be of about 5 mas by using the collaborated telescopes that will provide sufficient number of ERS (about 300) with their position accuracy of 20 mas and accuracy of secondary reference stars on the level of 40-50 mas.

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