Determination of Optical Positions for Extragalactic Radio Sources under the Collaboration Between SHAO and NAO

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Abstract. The optical positions of 9 compact extragalactic radio sources have been determined by using the 1.56m, 1m and 60/90cm telescopes with CCDs in China and the Axial Meridian Circle at Nikolaev Astronomical Observatory since Jan. 1996 in a cooperative project between the two observatories. The instrumentation, observations and reduction are briefly described, and the preliminary results are presented. The comparison between the optical and radio positions for 9 sources are also given. More optical positions of radio sources are being processed.

1. Introduction

With the compact extragalactic radio sources (CERS) as the fiducial points, the radio reference frame may be said to be a quasi-inertial reference frame (Ma *et al.*, 1998). Because the sources are very remote, their proper motions (approximately a few $\mu as/yr$) are negligible as compared with observational accuracy. Since January 1998, the International Celestial Reference System (ICRS) has been adopted by the 23rd IAU General Assembly, and is realized by the International Celestial Reference Frame (ICRF), which is combined from various radio catalogs by the International Earth Rotation Service (IERS). The ICRS is realized by the Hipparcos Catalog in optical wavelengths. The Working Group (WG) on the ICRS was set up at 23rd IAU General Assembly. The WG is concerned with all aspects connected with the approved International Celestial Reference System: its use, extension and its promotion to the astronomical community (Mignard, 1998). The main tasks of the WG are maintenance and extension of the ICRS, densification, and linkage to the dynamical system.

A joint project between Shanghai Astronomical Observatory (SHAO) and Nikolaev Astronomical Observatory (NAO) has been carried out since Jan. 1996 to determine the optical positions of the CERS using the 1.56m telescope with CCD at SHAO and the positions of secondary reference stars around the CERS determined with the fully automatic Axial Meridian Circle (AMC) at NAO. The preliminary results are presented and the comparison between the optical and radio positions are given in this paper.

2. Instrumentation

The 1.56m reflector is a R-C type telescope and the AMC is a horizontal telescope. In order to observe the faint stars the CCD cameras were installed on two telescopes. The optical parameters of the two telescopes are listed in Table 1. Sometimes a corrector for reducing the focal length was used on the 1.56m telescope, which makes the focal length three times shorter.

Table 1. Optical parameters of the telescopes.

parameter	1.56m telescope	AMC
diameter	1.56m	180 mm
focal length	15.6m	2480 mm
scale	$13''.25$/mm	$83''.19$/mm
field of view	$4'.4 \times 4'.4$	$23' \times 26'$
CCD	1024×1024	1040×1160

Some other principal components of the AMC follow. The prizm unit was made from a cital cylinder with a central hole diameter 40 mm truncated at 45 degrees and a diameter of 180 mm. The divided glass circle with the reading system has 4 parameters: diameter of 420 mm, division interval of $5'$, four reading microscopes with mean error $0''.02$ and reading time 16sec. The autocollimator with CCD micrometer in the prime vertical has parameters: objective aperture of 180 mm, focal length of 12360 mm, scale reading in the image plane $1'' = 59.92\mu$m. The tube is evacuated to eliminate the refraction anomalies in the horizontal light path. The CCD autocollimator micrometer has an error reading an artificial mark of $0''.02$.

In addition, because the weather at the Sheshan station of SHAO is not good enough, other telescopes were also used for this purpose. A 1m reflector with a 1024×1024 CCD was used at Yunnan Astronomical Observatory (YNAO). The field of view is $6'.5 \times 6'.5$ and the focal length is about 13m. A 60cm reflector with a 1024×1024 CCD was used at Xing-Long Station of the Beijing Astronomical Observatory (Wang *et al.*, 1998). The field of view is $16'.6 \times 16'.6$ and the focal length about 2.5m. A 60/90cm Schmidt telescope with a 2048×2048 CCD was used at Xing-Long Station of the Beijing Astronomical Observatory. The field of view is $1° \times 1°$ and the focal length is 1.8m (Tang *et al.*, 1998).

3. Observations and reductions

The optical counterparts of 86 compact extragalactic radio sources have been observed in China since Jan. 1996 (see Table 2). There are 36 CERS also observed by the AMC (with the mark *).

The field of view of the CCD is so small that almost all distortions may be ignored. In using the 60/90 cm telescope, only the center area of the $1° \times 1°$ field of view was used. Therefore the relationship between the measured and the standard coordinates may be expressed by orthogonal linear equations (Murray 1983).

There are three methods: centroid, gaussian and optimum filter in the centering task of the IRAF software used to determine the centers of star images.

Table 2. 86 compact extragalactic radio sources.

0014 + 813	0036 + 030	0055 + 300	0111 + 021	0116 + 319
0135 − 247	0153 + 744	0215 + 015	0241 + 622	0309 + 411*
0316 + 413	0355 + 508	0405 − 123	0420 − 014*	0430 + 052*
0528 − 250	0538 + 498*	0552 + 398*	0607 − 157	0636 + 680*
0642 + 449	0707 + 476*	0716 + 714	0718 + 792	0723 − 008
0735 + 178*	0736 + 017	0738 + 313*	0814 + 425	0818 − 128*
0820 + 560*	0827 + 243*	0836 + 710*	0839 + 187	0839 + 200
0850 + 561	0851 + 202*	0859 − 140	0917 + 449*	0955 + 326
1034 − 293	1038 + 064	1039 + 811	1040 + 123	1044 + 719
1045 − 188	1127 − 145	1128 + 385*	1144 + 402*	1145 − 071
1148 − 001*	1150 + 497	1216 + 487	1219 + 285	1226 + 023
1228 + 126*	1237 − 101	1257 + 145*	1302 − 102*	1354 + 195*
1404 + 286*	1418 + 546*	1419 + 536	1420 + 326	1442 + 101
1510 − 089	1538 + 149*	.1641 + 399	1652 + 398*	1658 + 053
1705 + 456*	1727 + 502*	1749 + 096*	1749 + 701	1803 + 184
1821 + 107*	1838 + 052	1845 + 797	1901 + 319*	1937 − 101*
2007 + 777	2128 − 123	2145 + 067*	2200 + 420*	2251 + 158*
2344 + 092*				

The results of test comparisons show that the centroid method is a little better than the other two methods. It should be better to choose the appropriate sampling range to compute the centers of star images, which is based on the magnitude. The reduction method of the AMC in right ascension and declination is the general procedure for a meridian circle.

4. AMC 1.0

In 1996, the observation program of intermediate reference stars in the fields around 250 northern CERS in the declination zone from +70° to −20° and in the 12–14 magnitude range was started. The positions of the reference stars, selected from the GSC, were provided in the Hipparcos system to improve the optical/radio reference frames linkage (ESA, 1997). AMC 1.0 was completed in August 1999, in which more than 10000 secondary reference stars around 220 CERS were observed.

The comparison between the results of the AMC and the Hipparcos catalogs and other instruments are shown in Figures 1 and 2 (Kovalchuk *et al.*, 1997). The figures show the variation of the mean systematic differences of $(O-C)_\alpha \cos\delta$ and $(O-C)_\delta$ for each declination zone in steps of 5 degrees. The errors of the mean systematic differences $(O-C)$ ranges from $0''\!.03$ to $0''\!.05$, Results for the AMC show that 1) the internal accuracy of mean systematic differences is about $0''\!.01 - 0''\!.02$, 2) accuracy of one observation for HC stars $0''\!.11 \sec 0.65(Z)$ for both coordinates and about $0''\!.13$ – $0''\!.20$ for GSC stars, 3) the position accuracy of the AMC catalog is $0''\!.05$. Of course, to improve the precision of the AMC more observations will be needed because some stars have only a single observation. The second version of the AMC will be released soon.

https://doi.org/10.1017/S0252921100000105 Published online by Cambridge University Press

5. Results and comparison

The 9 optical positions of CERS using the second reference stars of AMC are listed in Table 3 in which the name and magnitude of CERS, α and δ at J2000.0 are listed in columns 1 to 4, and the observing epoch is listed in column 5. Though the AMC has no proper motions, the epoch of observations of SHAO and that of the AMC is not more than 3 years, so the influence of proper motions is small. The number of reference stars is about 4 to 9. The comparisons between optical and radio positions published in IERS Technical Note 23 are listed in columns 6 and 7 of Table 3. The mean absolute difference of optical-radio positions for 9 CERS is $0\farcs25$ and $0\farcs40$ in right ascension and declination respectively. More optical positions of CERS are being processed.

Table 3. Positions of nine sources.

Name	mag	α	δ	$\Delta\alpha$	$\Delta\delta$	T
		h m s	° ′ ″	″	″	
0552+398	18.0	05 55 30.797	+39 48 49.20	−0.10	= +0.03	1996.16
0735+178	16.2	07 38 07.358	+17 42 19.29	−0.50	= +0.29	1999.11
0818-128	15.0	08 20 57.462	−125859.32	+0.20	= −0.16	1999.11
0827+243	17.3	08 30 52.029	+24 11 00.80	−0.78	= +0.98	1999.14
0851+202	15.4	08 54 48.874	+20 06 30.24	−0.01	= −0.40	1996.06
1652+398	13.9	16 53 52.210	+39 45 37.33	−0.08	= +0.72	1999.37
1727+502	16.0	17 28 18.635	+50 13 10.71	+0.11	= +0.24	1999.37
2145+067	16.5	21 48 05.487	+06 57 39.37	+0.42	= +0.77	1996.64
2200+420	14.7	22 02 43.292	+42 16 40.03	+0.01	= +0.05	1998.18

Acknowledgments. We are indebted to the Department of International Scientific and Technical Cooperation, Ministry of Ukraine for Science and Technology and the Chinese Natural Science Foundation for their financial support this research work.

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