

Table 3. Comparison with results of other authors.

Name	(1) (")	(2) (")	(3) (")	(4) (")	(5) (")	(6) (")	(7) (")	(8) (")
0113-118				0.27, 0.35	0.00, 0.22	0.04, 0.35		
0118-272				-0.42, +0.03	-0.20, +0.37	-0.55, +0.09		+0.13, -0.11
0135-247				+0.04, -0.11	+0.10, +0.01	-0.00, +0.01	+0.05, -0.08	+0.06, -0.11
0138-097				+0.03, +0.02	+0.33, +0.22	+0.12, +0.03		
0237-233				+0.19, +0.33	-0.03, +0.46	-0.10, +0.23	+0.07, -0.04	+0.17, -0.02
0338-214	+0.18, +0.19	-0.11, +0.19	+0.09, +0.29	+0.16, +0.07	+0.01, +0.41	+0.17, +0.16		-0.05, -0.10
0402-362				-0.01, +0.01	+0.20, +0.08	+0.04, +0.04		+0.24, +0.09
0521-365				+0.00, +0.25	+0.00, +0.45	-0.04, +0.36		
0528 250				0.14,   0.10	0.09, 0.05	0.13,   0.01		0.06, 0.09
1954-388				-0.18, -0.05	-0.10, -0.09			-0.04, -0.15
1958-179	+0.14, -0.02	+0.01, -0.19	+0.15, -0.03	+0.39, +0.07	+0.44, +0.07	+0.19, +0.06		+0.08, -0.03
2000-330				-0.04, -0.01	+0.01, +0.08	+0.08, +0.01		+0.03, -0.04
2008-159	+0.17, -0.10	+0.07, +0.15	+0.23, +0.25	+0.14, -0.25	-0.11, +0.10	+0.23, +0.16		+0.20, +0.04
2126-158				+0.05, +0.12	+0.31, -0.10	+0.15, +0.31		-0.05, -0.15
2155-304				-0.06, +0.05	-0.09, +0.18	+0.05, +0.09		+0.20, -0.03
2227-399								+0.02, -0.08
2243-123				-0.18, +0.24	+0.56, -0.01	-0.09, +0.22	-0.14, +0.05	-0.03, +0.06
2255-282	+0.11, +0.11	+0.02, +0.15	+0.09, +0.13	-0.25, -0.09	+0.04, -0.17	-0.14, -0.15		+0.15, -0.20
2331-240				-0.15, +0.42	-0.15, +0.55	-0.14, +0.55	+0.25, +0.05	
2355-106				0.17, 0.07	0.10,   0.41	0.17,   0.00		

Note.

- (1): Comparison with Assafin et al. (1997), PPM;
- (2): Comparison with Assafin et al. (1997), CAMC;
- (3): Comparison with Assafin et al. (1997), ACRS;
- (4): Comparison with Neto, Andrei, & Martins (2000), ACT;
- (5): Comparison with Neto, Andrei, & Martins (2000), Hipparcos;
- (6): Comparison with Neto, Andrei, & Martins (2000), Tycho;
- (7): Comparison with Stone (1994);
- (8): Comparison with Zacharias et al. (1999).

## DETERMINATION OF OPTICAL POSITIONS FOR 38 EXTRAGALACTIC RADIO SOURCES

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In the paper optical positions for 38 counterparts of extragalactic radio sources relative to the intermediate 4th version of AMC catalogue (AMC1B) are presented.

The internal accuracy of the positions is of the order of  $0.''063$ . A list with information of 38 ERS is available. Differences between catalogues AMC1B, TC2 and SAMC for previous evaluation of systematic accuracy are given.

ДОСЛІДЖЕННЯ ОПТИЧНИХ ПОЛОЖЕНЬ 38 ПОЗАГАЛАТИЧНИХ РАДІОДЖЕРЕЛ, Z. Tang, S.Wang, W. Jin, Н.Майгурова, Ю.Процюк, Г.Пінігін, О.Шульга, О. Ковальчук – В статті приведені оптичні положення 38 оптичних аналогів позагалактичних радіоджерел (ПРД) відносно проміжної 4-ї версії каталога АМК (АМСІВ). Внутрішня точність положень ПРД близько  $0.''063$ . Надана таблиця з 38 ПРД. Приведені різниці між каталогами АМСІВ, ТС2 і САМС для попередньої оцінки систематичної точності каталога АМСІВ.

ОПРЕДЕЛЕНИЕ ОПТИЧЕСКИХ ПОЛОЖЕНИЙ 38 ВНЕГАЛАКТИЧЕСКИХ РАДИОИСТОЧНИКОВ, Z. Tang, S.Wang, W. Jin, Н.Майгурова, Ю.Процюк, Г.Пинигин, А.Шульга, А. Ковальчук - В статье представлены оптические положения 38 оптических аналогов внегалактических радиоисточников (ВРИ) относительно промежуточной 4-й версии каталога АМК (АМСІВ). Внутренняя точность положений ВРИ около  $0.''063$ . Показана таблица, включающая 38 ВРИ. Приведены разности между каталогами АМСІВ, ТС2 и САМС, для предварительной оценки систематической точности каталога АМСІВ.

## 1. INTRODUCTION

We are carrying out a project with the purpose of establishing and improving the link between the radio and optical reference frames by means of ground-based, optical observations of counterparts of compact, extragalactic radio sources. The number of sources to be observed in our project was about 200 and after adding of southern ERS is about 300. There is a collaboration between Shanghai Astronomical Observatory (SHAO) and Nikolaev Astronomical Observatory (NAO) which had been carried out since Jan. 1996, with the main purpose of determining optical positions of ERS and second reference stars around them by using telescopes with CCD at SHAO and automatic Axial Meridian Circle (AMC) at NAO. This paper presents parts of the result. Section 2 talks about the information of observation and reduction. Section 3 presents the results of the optical positions of 38 ERS, and a comparison of our results with that of other authors is provided. A discussion is presented in section 4.

## 2. OBSERVATION AND REDUCTION

The observations of 38 sources were carried out with CCD equipped at the 1m telescope of Yunnan Observatory during 2001. During Drs Shulga and Protsyuk to China from February 27 to March 2, 2001 the AMC1B was taken

as the reference catalogue (AMC1B,2001). It contains about 15000 stars with internal catalogue accuracy on both coordinates with epoch 1997.09:

$$\epsilon_{\alpha} \cos \delta = \pm 0''.07 \cdot (\sec Z)^{0.20} \cdot (\text{mag} - 7)^{0.43};$$

$$\epsilon_{\delta} = \pm 0''.09 \cdot (\sec Z)^{0.10} \cdot (\text{mag} - 7)^{0.31}$$

The range of AMC1B magnitude is 12-14.

Parameters of the 1m telescope and the AMC are listed in Table 1:

**Table 1.** Parameters of the telescopes

	1 m telescope	AMC
diameter	1 m	180 mm
focal length	13m	2480 mm
scale	15."6/mm	12."02/mm
field of view	6'.5×6'.5	23'×26'
CCD	1024×1024	1040×1160

Table 2 gives the information of the 38 sources. In the table (left side), the first column is the object name (IERS Designation); the second column is the category of the source: D=Defining, C=Candidate, O=Other; the third and fourth column are the right ascension and declination of the source taken from ICRF (MaxFessel, 2002); the fifth column is the type of the source: Q=Quasar, L=BL Lac, G=Galaxy; the sixth column is the visual magnitude of the source; and the last column is the number of observations for each source.

As recommended in paper of Tang et al., 2001, Gauss method was adopted to compute the centers of star images of sources and reference stars with Cbox value of 8 pixel. Four constants model was applied to relate the measured and standard coordinates.

Since the difference in magnitude between ERS and the reference stars sometimes exceeds the linear response range of the CCD, it is difficult to get good images of ERS and reference stars in one CCD frame. A two-step procedure was carried out during the observation, with the field stars whose magnitudes are intermediate between ERS and reference stars as the bridge. First, observing with short exposure to make good images of AMC reference stars and bridge stars, and the positions of the bridge stars were obtained with the reference of AMC stars; then observing long exposure to get enough signal-to-noise ratio for ERS and bridge stars, and the positions of ERS were reduced with the reference of the bridge stars.

**Table 2.** Information of 38 extragalactic radio sources.

0735+178 O	07 38	07.39375	17 42	18.9983	L	16.2	8	7 38	7.4110	17 42	19.114	0.009	0.010	4	0.246	0.116
0745+241 D	07 48	36.10928	24 00	24.1102	Q	19.0	6	7 48	36.1125	24 00	24.857	0.088	0.126	3	0.044	0.747
0804+499 D	08 08	39.66627	49 50	36.5305	Q	18.9	5	8 8	39.6681	49 50	37.153	0.079	0.065	4	0.017	0.622
0805+410 D	08 08	56.65204	40 52	44.8889	Q	19.0	4	8 8	56.6434	40 52	45.157	0.042	0.031	4	-0.098	0.268
0820+560 D	08 24	47.23635	55 52	42.6694	Q	18.0	3	8 24	47.2840	55 52	43.233	0.260	0.072	3	0.401	0.564
0833+585 D	08 37	22.40973	58 25	01.8452	Q	18.0	5	8 37	22.3612	58 25	2.698	0.067	0.085	2	-0.381	0.853
0836+710 C	08 41	24.36524	70 53	42.1733	Q	16.5	6	8 41	24.3710	70 53	41.462	0.042	0.030	3	0.028	-0.711
0851+202 C	08 54	48.87492	20 06	30.6409	L	15.4	6	8 54	48.9099	20 06	30.823	0.011	0.013	2	0.493	0.182
0906+015 C	09 09	10.09160	01 21	35.6177	Q	17.8	5	9 9	10.1170	1 21	35.824	0.031	0.023	3	0.381	0.206
0912+029 C	09 14	37.91344	02 45	59.2463	Q	18.5	6	9 14	37.9146	2 45	59.525	0.185	0.071	3	0.018	0.279
0923+392 Q	09 27	03.01391	39 02	20.8520	Q	17.9	8	9 27	3.0698	39 20	20.624	0.008	0.012	2	0.651	-0.228
0945+408 D	09 48	55.33814	40 39	44.5872	Q	17.5	9	9 48	55.2979	40 39	43.958	0.109	0.044	3	-0.457	-0.629
0953+254 O	09 56	49.87536	25 15	16.0496	Q	17.2	6	9 56	49.9966	25 15	17.624	0.023	0.039	2	1.644	1.574
1011+250 C	10 13	53.42873	24 49	16.4413	Q	16.6	4	10 13	53.4143	24 49	18.711	0.023	0.013	3	-0.196	2.270
1020+400 D	10 23	11.56562	39 48	15.3854	Q	17.5	6	10 23	11.7697	39 48	14.835	0.111	0.079	3	2.352	-0.550
1053+704 C	10 56	53.61750	70 11	45.9159	Q	18.5	4	10 56	53.8418	70 11	46.832	0.166	0.113	3	1.141	0.916
1111+149 D	11 13	58.69510	14 42	26.9526	Q	18.0	3	11 13	58.7381	14 42	28.118	0.036	0.039	3	0.624	1.165
1128+385 D	11 30	53.28261	38 15	18.5471	Q	16.0	7	11 30	53.2808	38 15	18.397	0.033	0.044	3	-0.021	-0.150
1236+077 D	12 39	24.58831	07 30	17.1891	Q	18.5	4	12 39	24.5544	7 30	20.522	0.040	0.108	3	-0.504	3.333
1257+145 D	13 00	20.91880	14 17	18.5311	A	18.0	6	13 00	20.8113	14 17	16.468	0.048	0.049	3	-1.563	-2.063
1302+102 C	13 05	33.01502	-10 33	19.4280	G	15.2	7	13 5	33.0385	-10 33	18.567	0.009	0.018	2	0.347	0.861
1307+121 C	13 09	33.93242	11 54	24.5520	L	18.5	6	13 9	33.9130	11 54	24.148	0.027	0.017	3	-0.285	-0.404
1308+326 D	13 10	28.66384	32 20	43.7829	Q	15.2	4	13 10	28.5097	32 20	46.689	0.011	0.007	2	-1.953	2.906
1315+346 C	13 17	36.49418	34 25	15.9326	Q	19.0	10	13 17	36.6094	34 25	15.944	0.069	0.042	2	1.426	0.011
1338+381 C	13 40	22.95176	37 54	18.8347	Q	17.9	4	13 40	23.0221	37 54	45.667	0.061	0.080	3	0.832	1.832
1342+663 D	13 44	08.67967	66 06	11.6438	Q	18.6	4	13 44	8.7171	66 6	11.871	0.298	0.175	3	0.227	0.227
1354+195 O	13 57	04.43666	19 19	07.3723	Q	16.0	6	13 57	4.4261	19 19	9.465	0.030	0.050	4	-0.150	2.093
1402+012 C	14 04	45.89549	-01 30	21.9494	Q	18.2	5	14 4	45.8890	-1 30	22.841	0.077	0.088	2	-0.097	-0.892
1416+067 D	14 19	08.18017	06 28	34.8035	Q	16.8	5	14 19	7.8519	6 28	37.306	0.044	0.022	2	-4.893	2.502
1418+546 D	14 19	46.59740	54 23	14.7872	L	15.7	6	14 19	46.6028	54 23	16.227	0.025	0.021	2	0.047	1.440
1424+240 C	14 27	00.39184	23 48	00.0349	L	15.0	5	14 27	0.4127	23 48	0.171	0.017	0.023	3	0.287	0.136
1435+638 D	14 36	45.80214	63 36	37.8666	Q	16.6	5	14 36	45.8202	63 36	38.130	0.032	0.020	3	0.121	0.263
1442+101 D	14 45	16.46521	09 58	36.0724	Q	17.8	6	14 45	16.6319	9 58	42.029	0.021	0.018	3	2.463	5.957
1458+718 O	14 59	07.58395	71 40	19.8680	Q	16.8	6	14 59	7.5953	71 40	19.832	0.046	0.049	5	0.053	-0.036
1459+480 D	15 00	48.65420	47 51	15.5383	17.1	6	6	15 0	48.8007	47 51	13.880	0.275	0.208	3	1.475	-1.658
1532+016 D	15 34	52.45367	01 31	04.2066	Q	18.0	5	15 34	52.5385	1 31	4.463	0.155	0.050	2	1.272	0.256
1538+149 D	15 40	49.49151	14 47	45.8849	L	17.3	8	15 40	49.5046	14 47	46.727	0.084	0.047	5	0.190	0.842
1547+507 D	15 49	17.46853	50 38	05.7882	Q	18.5	8	15 49	17.4356	50 38	5.529	0.063	0.060	4	-0.313	-0.259

### 3. RESULTS AND COMPARISON

Results of optical positions for 38 southern radio sources are listed in Table 2 (right side). The first and second column of the table are right ascensions and declinations; the third and fourth column are their standard errors; the fifth column is the number of stars used as reference, the sixth column is and seventh column are the differences between our results and ICRF.

Since there is no proper motions given by AMC1B, the positions presented in this paper are just the observational positions at the epoch of the AMC1B.

The standard error of the position for a source should consists of three parts: the centering error of the source, which represents the quality of image in the CCD and is decided by the seeing and sky background; the standard error of the model, which reflects the precision of the reference catalogue in the area around the source; and the rms of the mean positions of all observations, which reveals the repeatability of the observations, it is influenced by the stability of the whole

telescope system and the meteorological situation. The standard error of the available position is just the last one, not including the first two, so their real values are larger, which should be noted.

Since the formal error of the positions ICRF and that of the CCD reductions are relative small, the possible reasons of the big differences between our results and ICRF maybe caused by the systematic errors of the AMC in the fields around these sources. The precision of the optical positions of radio sources is influenced by the local characteristic of the reference catalogue. The local systematic error caused by imprecise proper motions and positions will affect the positions of radio sources.

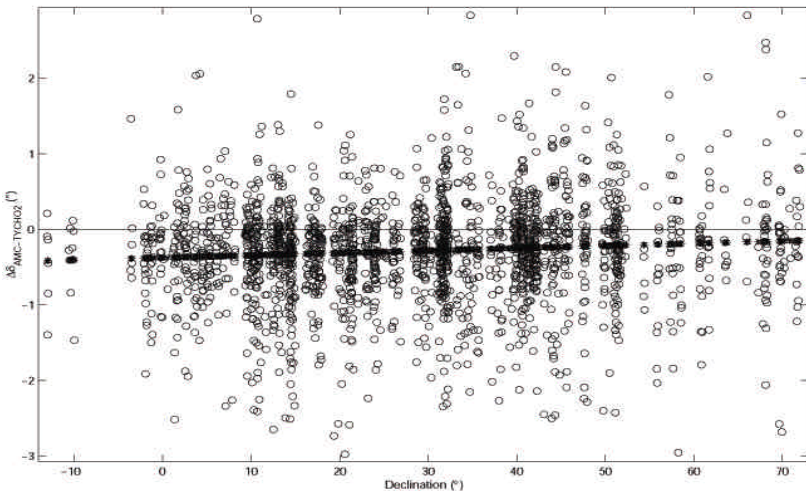
This version AMC1B with good and stable internal accuracy was used as reference catalogue by previous evaluation of comparison between optical and radio positions ERS. However for more exact reduction this catalogue showed marked systematic differences between AMC1B and ICRF. By this reason of AMC1B correction it was decided to use another catalogues as reference one.

### 3.1 Comparison between AMC1B and Tycho-2 catalogue.

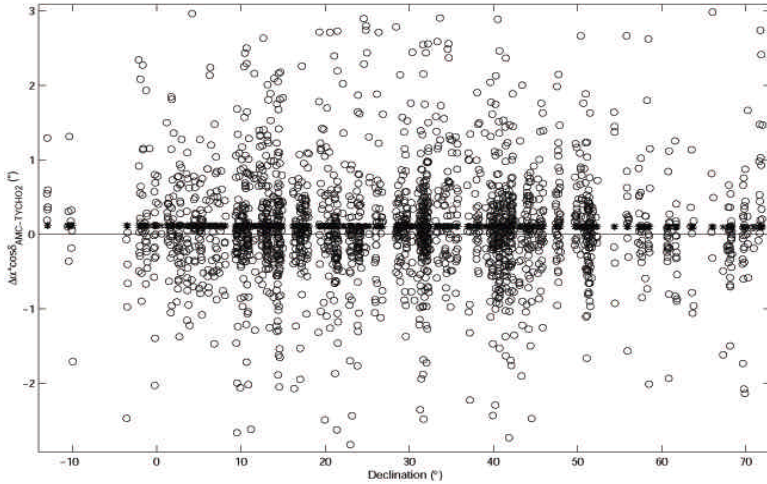
Procedure: the positions of Tycho-2 were first transferred to the observational epoch of the AMC1B; search the common stars between AMC1B and Tycho-2: 2311 common stars; compute the difference of the positions of common stars in the two catalogues; the rest of stars after excluding when their differences are bigger than  $3\sigma$ : 2221 common stars.

RE-compute the difference of the positions of common stars in the two catalogues:  $\Delta\alpha\cos\delta = 0.''11 \pm 0.''74$  and  $\Delta\delta = -0.''28 \pm 0.''68$

It can see on the Figure 1, a) relationship between  $\Delta\alpha\cos\delta$  and  $\delta$ , b) relationship between  $\Delta\delta$  by  $\delta$ .



a)



b)

Figure 1. Comparison between AMC1B and Tycho-2 catalogue.

### 3.2 Comparison between AMC1B and CAMC catalogue.

Procedure: search the common stars between AMC1B and CAMC-9: 643 common stars; compute the difference of the positions of common stars in the two catalogues; the rest of stars after excluding when their differences are bigger than  $2\sigma$ : 597 ( $\alpha$ ) and 608 ( $\delta$ ) common stars.

RE-compute the difference of the positions of all common stars in the two catalogues:  $\Delta\alpha\cos\delta = -0.''03 \pm 0.''01$  and  $\Delta\delta = -0.''16 \pm 0.''01$

It can see on the Figure 2,a) relationship between  $\Delta\alpha\cos\delta$  by  $\delta$  b) relationship between  $\Delta\delta$  by  $\delta$ .

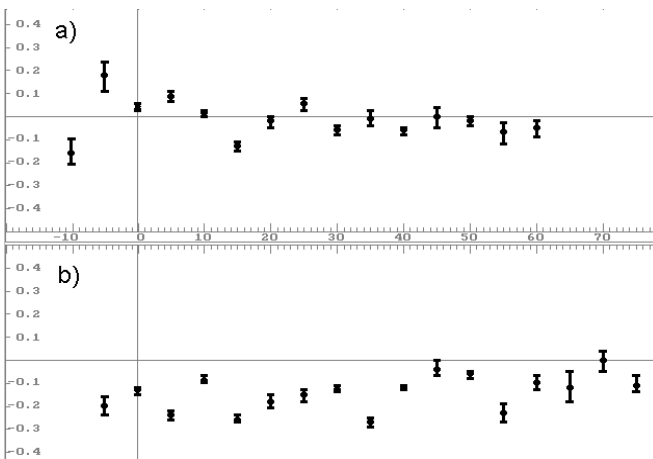


Figure 2. Comparison between AMC1B and CAMC-9 catalogue.

#### 4. DISCUSSION

- obtained accuracy of ERS differences like (O-R) about 63 mas showed about satisfactory internal accuracy of ERS observations and catalogue AMC1B;
- a simple external comparison between AMC1B and Tycho-2 and CAMC catalogues showed about existence of marked and similar differences between AMC1B and two different catalogues;
- it is necessary to reduce AMC1B to the ICRF system and compile a combined catalogue of reference stars positions from the northern hemisphere (including AMC1B and other) in a short time with better accuracy and density.

The establishment of the linkage between optical and radio reference frame is a long-term task. Observations of the optical counterparts of the radio sources should be carried out for a long time, and the results of the linkage with higher precision will be obtained.

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