REFERENCE STARS COMPILED CATALOGUE AROUND EXTRAGALACTIC RADIO SOURCES. REDUCTION TECHNIQUES AND THE FIRST RESULTS

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Some differential reference stars catalogues around extragalactic radio sources obtained from photographic and CCD-observations at different observatories are considered. Compiled catalogue of star positions in fields of $30' \times 30'$ is intended for reduction of ERS optical observations using the telescopes equipped with CCD-cameras. Photographic observations of the fields around 74 ERS were made at the Pulkovo Observatory, around 115 ERS – at the AO KNU, around 188 ERS – at the AIRA in Bucharest. The 208 fields around ERS at NAO using the telescope equipped with a CCD-camera were obtained. The first results of the creation of uniform compiled catalogue are given. Astrometric positions for stars brighter than 16 magnitude in more than 20 fields around ERS are presented. A comparison of our results with those of other authors is made.

INTRODUCTION

To connect optical and radio astrometrical coordinate systems it is very important to observe common objects both in optic and radio waves. As the most ERS are very faint it is possible to resolve this problem in optical range with ground-based telescopes using CCD-detectors. Currently, many programs are made to establish reference frame around astrometrical extragalactic radio sources (ERS) [1, 4, 5]. This frame is needed to observe ERS in optical range with sufficient accuracy without multistage link from the faint determined objects to the bright reference stars.

We have four original star catalogues. These catalogues were obtained to observe faint ERS in future with a CCD-camera [1]. Three of these catalogues were photographically obtained using the astrographs, and one of them was obtained with the Axial Meridian Circle equipped with a CCD-matrix (see Table 1). Photographic observations have been obtained with the Normal Astrograph (330/3464) at the Pulkovo Astronomical Observatory (MAO RAS) in the 1990s – 74 ERS fields (35 are calculated). 115 ERS fields have been obtained with the Astronomical Observatory, National Taras Shevchenko University of Kyiv (AO KNU) Astrograph (200/4126). 188 ERS fields have been performed with the Double Astrograph (380/600) at the Astronomical Institute of the Romanian Academy (AIRA) in Bucharest. 208 ERS fields have been derived with the Axial Meridian Circle (180/2480) using a CCD-matrix at the Nikolaev Astronomical Observatory.

These four catalogues have been reduced to about the same epoch. In order to increase the star position density and accuracy around ERS it was decided to compile these four catalogues. Since they were obtained with different telescopes and image registration techniques it was needed to link their position to common epoch and to analyze the systematic coordinates differences of the same stars.

Table 1. Catalogues included to the reference stars compiled catalogue

Place of observations	Name of catalogue	Type of observations	Size of fields, min	Number of fields	Number of stars	Observation epoch	Number
Mykolaiv	AMC1B	CCD	60×24	208	14403	1996–1998	12–14
Bucharest	PIRS-B	Photo	60×60	188	4700	1991–2000	12–15
Pulkovo	Pul ERS	Photo	35×35	35	4500	1991–1995	10–16
Kyiv	PIRS-K	Photo	60×60	115	2875	1989–1993	12–15

THE COMPARISON OF CATALOGUES

The proper motions for considerable part of stars were taken from the Catalogue positions and proper motions (UCAC) which consists of 48 millions of stars. It is clearly that the four considering catalogues are differ one from another, *i.e.*, they will be included in compiled catalogue with different weights. The catalogue of the Nikolaev Observatory consist of the most measurements of alone star: up to 6. The catalogue of the Pulkovo Observatory is situated at the second place: from 3 to 5 plates for field. All the others have one measurement of each star of the field. All catalogues have the weights for compiled catalogue which are equals the number of stars measurements.

Therefore, in order to detect the systematic differences some fields from the AMC1B and Pul ERS catalogues have been compared, because the most coincided stars are included into them. The Mykolaiv catalogues and the Pulkovo catalogues have been reduced to equinox J2000.0 and the differences of positions for coincided stars have been calculated. The mean differences and their errors are given in Table 2.

Table 2. The comparison of coincided stars of the AMC1B (Mykolaiv) and Pul ERS (Pulkovo) catalogues

N	Name	Number of stars in field			Mean (O–C)			
	of field	Mykolaiv	Pulkovo	Coincided	RA	Err	DEC	Err
1	0026+346	106	148	57	−0.006	0.047	−0.41	0.43
2	0133+476	206	159	76	0.024	0.047	−0.27	0.35
3	0355+508	82	117	45	0.010	0.034	−0.21	0.31
4	0420+417	76	112	28	0.017	0.045	−0.34	0.44
5	0552+398	235	148	57	0.009	0.033	−0.13	0.36
6	0923+392	21	56	11	−0.060	0.026	−0.50	0.76
7	2200+420	278	92	53	0.007	0.041	−0.19	0.38
8	2337+264	98	92	44	0.018	0.036	−0.23	0.55
9	2351+456	78	110	25	−0.040	0.047	0.03	0.38

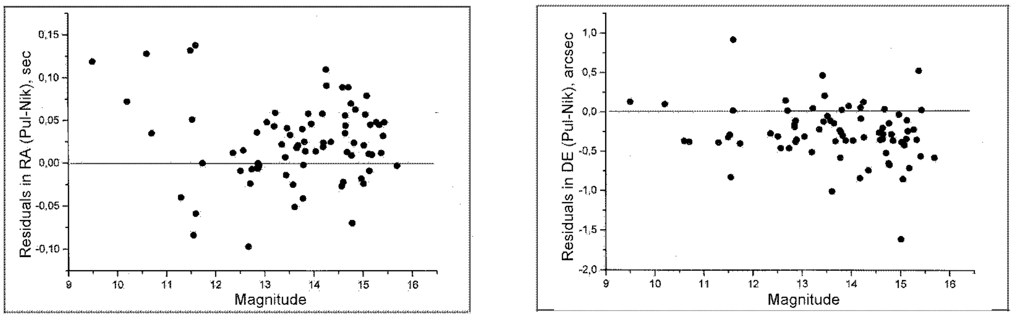
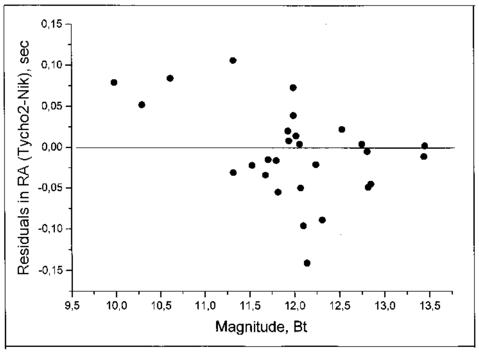


Figure 1. The residuals in RA and DEC for 76 coincided stars in ERS 0133+476 field

We can practically see obvious negative component in declination for all nine fields. The lesser positive component take place in right ascension. If stars of this field from AMC1B to compare with coincided stars from Tycho-2, then mean difference is $-0.006^s \pm 0.055^s$ in RA and systematic AMC1B coordinate overstating is keeping: $-0.22'' \pm 0.29''$. This fact needs in additional investigations for all stars fields.



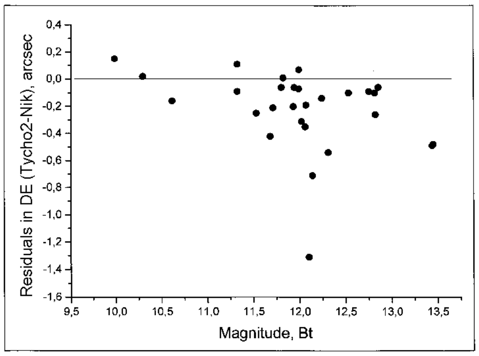


Figure 2. The residuals in RA and DEC for 28 coincided stars in ERS 0133+476 field

THE COMPILED CATALOGUE

2503 stars of the main catalogue have been included in the former version of compiled catalogue for 25 reference stars fields around ERS by means of mutual identifications coincided stars. These stars have proper motions in UCAC. Their positions have been obtained from other compiled catalogues not coincided with main catalogue. Coordinates of all stars are referred to J2000.0. Initial data for each included catalogue and the first results of former version compiled catalogue for 25 fields are given in Table 3.

Table 3. The number of stars of reference stars compiled catalogue for ERS

N	Name of field	Pulkovo	Mykolaiv	Bucharest	Kyiv	Main catalogue	Number of stars	Stars all*
1	0026+346	164	116	55	25	P	148	201
2	0133+476	174	228	66	24	M	206	286
3	0355+508	165	146	63	25	P	117	187
4	0420+417	159	87	51	25	P	112	160
5	0552+398	165	260	66	25	M	235	325
6	0923+392	61	23	63	26	P	56	64
7	1641+399	145	133	55	24	P	131	156
8	1652+398	120	133	54	25	M	101	149
9	2200+420	107	309	68	25	M	278	327
10	2319+272	72	112	72	25	M	65	115
11	2337+264	104	112	47	25	M	98	146
12	2351+456	119	91	62	25	P	110	163
13	0234+285	–	93	74	25	M	90	136
14	0400+258	–	80	65	25	M	73	107
15	0420–014	–	123	71	22	M	55	61
16	0440–003	–	44	59	25	M	39	42
17	0457+024	–	81	66	(25)	M	71	111
18	0458–020	–	86	25	24	M	34	62
19	0500+019	–	81	66	(25)	B	53	74
20	0528+134	–	11	68	25	K	23	33
21	0711+356	–	106	54	24	M	95	130
22	0735+178	–	89	55	25	M	80	107
23	0738+313	–	96	54	24	M	88	111
24	0748+126	–	97	45	25	M	91	109
25	0906+015	–	62	64	22	M	54	91

The table consists of the number of stars in working catalogues, the initial catalogue (P – Pulkovo, M – Mykolaiv, B – Bucharest, K – Kyiv), and the number of stars in compiled catalogue – common at working catalogues and with the addition of stars from separate catalogues.

The equatorial coordinates of more than 3400 stars have been calculated for 25 fields around extragalactic radio sources. They were reduced to epoch J2000.0 in the ICRS frame. Practically, all the fields included more than 100 stars around ERS by diameter 35–40 arcminutes.

THE FARTHER WORK

All the processes of compiled catalogue creation will be carried out by three stages.

Stage 1. Obtaining compiled catalogue of reference stars to epoch J2000.0 by using the data from four above-mentioned catalogues. Other catalogues (UCAC, CaMC, PPM) are used for proper motions. The problem has been solved to take into account the catalogues weights equaled to number of measurements. The first results of this stage for 25 catalogues are given in Table 3. For this stage it is supposed to obtain 35 fields for Pul ERS calculated catalogues.

Stage 2. Stars without proper motions will be added to 35 catalogues. It is the stars that are absent in famous catalogues. Positions for epochs of star observations will be appeared in the compiled catalogue. So, if epoch differences for faint stars are not more than three years, the mean coordinates may be obtain.

Stage 3. The same investigations will be made for another three catalogues. In order to take into account the AMC1B catalogue based on CCD-observations, as a main catalogue, it is necessary to analyze accurately its systematic deviations. The analysis might be made using the stars with proper motions from other catalogues. Coordinates of these stars will be compared with these ones from the Tycho-2, CaMC, UCAC [6] or USNO-B [3]. Taking into account that more than billion stars are included in the USNO-B catalogue, the importance of our catalogues to be increased, the accuracy of reference star positions is invaluable.

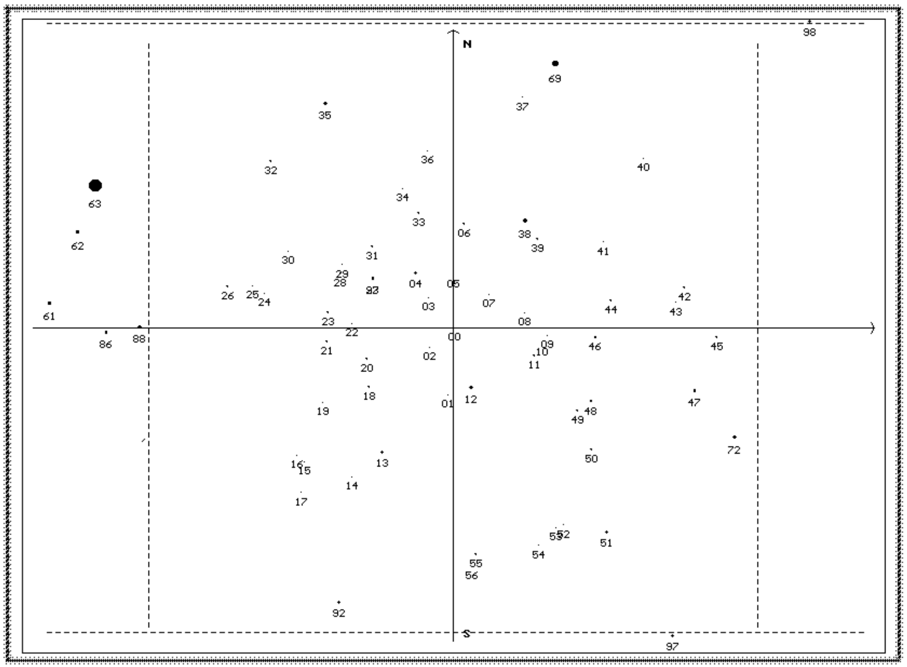


Figure 3. The map of the stars field around ERS 1418+546. Size of the interior field is $30' \times 30'$. The star number is corresponded to star number in catalogue

FORMAT OF THE FORMER VERSION OF THE CATALOGUE

Preliminary compiled catalogue are given in the next format – 110 positions are given for each star. The coordinates are in radians and in integer format without blank. All star positions recalculated to epoch J2000.0 using the proper motions from UCAC.

Positions

1 – 4	the star number by given catalogue;
5 – 11	the magnitude (from UCAC or obtained by observer);
12 – 28	RA in radian at observation epoch to ICRS system for J2000.0 equinox;
29 – 34	the error of mean RA, 0.001^s;
35 – 37	the number of RA observations;
38 – 53	DEC in radian at observation epoch to ICRS system for J2000.0 equinox;
54 – 59	the error of mean DEC, $0.001''$;

60 – 62	the number of measurements that are used to obtained declination;
63 – 65	the inclusion index (0 or 1) of the AMC1B catalogue;
66 – 67	the inclusion index (0 or 1) of the PIRS-B catalogue;
68 – 69	the inclusion index (0 or 1) of the PIRS-K catalogue;
70 – 71	the inclusion index (0 or 1) of the Pul ERS catalogue;
72 – 83	RA of star in integer format HHMMSSDDD;
84 – 94	DEC of star in integer format ±GGMMSSDD;
95 – 102	the proper motion RA, mas/yr (without $\cos\delta$);
103 – 110	the proper motion DEC, mas/yr.

THE MAP OF THE STARS FIELD AROUND ERS

In order to comfort detected stars field, when observations are made with a CCD-detector, every stars field has a map in *pcx*-format. In Fig. 3 the example of such map is given.

The positions of detected stars will be assumed to compare with selective stars from the ERL398 [5] and UCAC catalogues. All versions of the catalogues for ERS are kept in magnetic tapes at the Laboratory of Astrometry and Star Astronomy of the MAO RAS. These fields will be good standards to following observations of the faint stars.

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