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Optical astrometry of Benchmark radio sources

IV. New results in the southern hemisphere

E. Costa and P. Loyola

Departamento de Astronomía, Universidad de Chile. Casilla 36−D Santiago, Chile

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Abstract. Optical positions relative to the International Reference Stars Catalogue (IRS), and therefore in the system of the FK5, have been obtained for the optical counterparts of 40 compact extragalactic radio sources south of $\delta \sim +6^\circ$. Many of these sources are being considered as possible Benchmark objects for the establishment of a quasi−inertial unified radio/optical reference frame. Precision levels as good as $0.1''$ in both coordinates were achieved. A comparison with VLBI radio positions available for these sources is presented. We give new evidence for the existence of an offset in the origin of right ascension between the radio and optical reference frames as defined at present.

Key words: astrometry — reference systems

1. Introduction

In this paper we give new results of a decade−old program to determine precise optical positions for the optical counterparts of compact extragalactic radio sources (CERS) being considered as possible Benchmark objects to link the new high−precision VLBI radio reference frame (see e.g. Johnston et al. 1995, hereafter Johnston), with the optical reference frame. Of the roughly 600 objects that have been or are present being considered as possible link sources (Fey 1994), we have obtained homogeneous optical positions at a precision level as good as $0.1''$ in both coordinates for about 250 of them by means of routine observations carried out with a flat−field 70/100/210 cm Maksutov astrograph. Comparison of our optical data with available VLBI radio positions has allowed us to uncover misidentifications and unsuitable link objects −thus contributing to the basic goal of selecting the most adequate Benchmark sources− and to evaluate the existence of offsets between the radio and the optical frames as defined at present (see e.g. Costa & Loyola 1996, and references therein).

Here we present new optical observations of 40 southern CERS selected mainly from the list of Jauncey et al. (1989), hereafter Jauncey. The optical positions were measured with respect to the stars of the IRS catalogue (Corbin 1991), and therefore are given in the system of the FK5.

2. Observations and reductions

References to the optical identifications, finding charts and other relevant data for the sources observed can be found in Jauncey et al. (1993). Notes on individual objects are given in Sect. 4.

The observations were carried out with the Maksutov astrograph (field: $5^\circ \times 5^\circ$, scale: $100''$/mm) at the Estación Astronómica de Cerro el Roble, operated by the University of Chile. Details on the observational and reduction procedure can be found in Costa & Loyola (1992, 1994 and 1996; hereafter Papers I, II and III, respectively).

3. Results and errors

The results, in the FK5(J2000) system, are presented in Table 1. The first column gives the IAU designation of the sources, the second and fourth columns the resulting optical positions and the third and fifth columns their corresponding total internal errors. Finally, Col. (6) gives the epochs of the observations.

The errors of the measurements were determined as described in Sect. 4.2 of Paper I. The total internal errors of the positions presented in Table 1 were determined using the same relations given in Sect. 4.1 of Paper I. The total error contributed by the IRS catalogue was estimated on a zonal basis, as explained in Paper II.

4. Notes on individual objects

1236−684: The optical counterpart proposed by Jauncey −for which we give optical coordinates in Table 1− is incorrect. This conclusion is sustained by the high (radio−optical) residuals obtained when comparing our

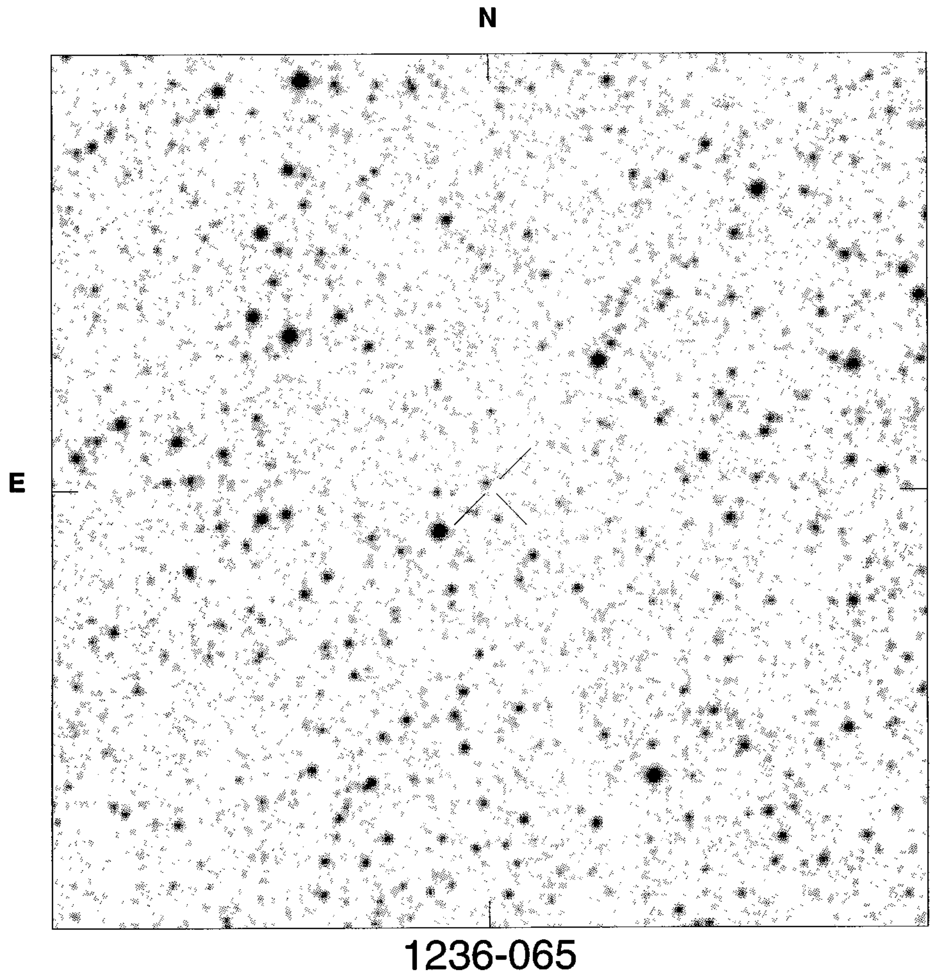

Fig. 1. Finding chart for 1236 − 684. Chart is 9 arcmin on a side. See Sect. 4 for details

optical position for this object with the VLBI radio position given by Johnston (see Table 2). As illustrated by Fig. 1, which shows more or less precisely the position of the radio source, the object proposed by Jauncey lies well offset to the NE of the radio source. At the limit of our plates ($B \approx 20.5$), no faint alternative counterpart is seen. The finding chart and the radio source position identification were obtained using standard IRAF procedures from a digitized image extracted from the Digitized Sky Survey (DSS), produced by the Space Telescope Science Institute. The scan used is based on a 4 min. exposure visual plate taken with the UK Schmidt telescope. The unfortunate fact that this scan is based on a shallow "supplemental" plate of the UK Schmidt southern sky survey plate collection, prevented us from examining the possible existence of a very faint alternative optical counterpart, at a magnitude level of $B \approx 22.5$ (which is the approximate limiting magnitude of the "standard" deep blue UK Schmidt survey plates).

2052−474: The finding chart for this object published by Jauncey is incorrect. A correct identification for the optical counterpart of this source can be found in Murdoch et al. (1984).

2314−409: Identification of the optical counterpart of this source is claimed by Jauncey, but no finding chart has been published. In Fig. 2 we present a tentative optical counterpart for this source, whose coordinates are given in Table 1. The finding chart and the optical identification were obtained, as explained for Fig. 1, from a DSS scan based on a 60 min. exposure UK Schmidt blue plate.

5. Comparison with other data and discussion

Table 2 gives the differences in the FK5(J2000) system with the VLBI radio positions published by Johnston, in the sense radio minus this work (CL). With the exception of the source 1236 − 684 (see previous section), the comparison shows a good overall agreement, consistent with the declared precision of the results being compared. Two other sources (0454−463 and 2314+038) for which we give an optical position in Table 1, have been declared unsuccessfully observed by Johnston. As might be expected, a

Table 1. Optical positions in the FK5 system of 40 compact extragalactic radio sources

(1) IAU Designation	(2) α(J2000.0) h m s	(3) $\epsilon_\alpha \cos\delta$ $\pm''$	(4) δ(J2000.0) ° ′ ″	(5) ϵ_δ $\pm''$	(6) Plate Epoch
0019+058	00 22 32.402	0.11	+06 08 03.93	0.10	89.11.23
0034−014	00 37 04.151	0.16	−01 09 08.11	0.11	93.11.08
0035−024	00 38 20.516	0.09	−02 07 40.72	0.10	93.10.07
0131−522	01 33 05.800	0.13	−52 00 03.93	0.10	92.11.17
0219−637	02 20 54.202	0.17	−63 30 19.07	0.10	93.11.09
0332−403	03 34 13.638	0.12	−40 08 25.44	0.11	94.01.04
0355−483	03 57 21.936	0.28	−48 12 15.13	0.09	93.01.17
0454+039	04 58 47.167	0.11	+03 47 52.43	0.09	93.01.15
0454−463	04 55 50.799	0.13	−46 15 59.00	0.13	93.01.16
0521−262	05 23 18.470	0.15	−26 14 09.52	0.09	93.01.18
0537−158	05 39 32.018	0.08	−15 50 30.23	0.13	93.01.16
0622−441	06 23 31.791	0.10	−44 13 02.62	0.13	93.01.15
1202−262	12 05 33.254	0.13	−26 34 04.15	0.12	93.06.18
1206−399	12 09 35.247	0.13	−40 16 13.31	0.12	92.05.02
1236−684	12 39 47.047	0.20	−68 45 29.28	0.12	93.06.15
1351+021	13 53 51.590	0.09	+01 51 53.27	0.09	93.06.18
1509+022	15 12 15.745	0.08	+02 03 17.01	0.11	93.06.15
1549−790	15 56 58.983	0.30	−79 14 04.14	0.11	93.06.16
1602−001	16 04 56.142	0.12	−00 19 06.85	0.12	93.06.14
1603+001	16 06 12.702	0.13	+00 00 26.99	0.11	93.06.15
1718−649	17 23 40.937	0.18	−65 00 36.47	0.17	93.06.14
1733−565	17 37 35.773	0.15	−56 34 03.27	0.13	93.06.17
1823−455	18 27 10.246	0.13	−45 33 09.50	0.16	93.06.17
1831−711	18 37 28.706	0.29	−71 08 43.36	0.10	93.07.12
1852−534	18 57 00.441	0.14	−53 25 00.40	0.12	93.07.12
1929−457	19 32 44.885	0.12	−45 36 37.94	0.09	93.07.20
2004−447	20 07 57.084	0.13	−44 34 46.85	0.16	93.07.12
2022−702	20 27 24.608	0.20	−70 07 17.15	0.09	92.09.24
2052−474	20 56 16.376	0.15	−47 14 47.52	0.13	92.09.25
2058−425	21 01 59.127	0.11	−42 19 16.66	0.10	93.09.11
2105−489	21 08 50.768	0.12	−48 46 21.57	0.09	93.09.12
2205−636	22 08 47.322	0.13	−63 25 47.16	0.10	92.09.25
2217+018	22 20 30.771	0.09	+02 04 53.34	0.11	93.09.11
2314−409	23 16 46.937	0.15	−40 41 21.27	0.16	92.09.26
2324+038	23 16 35.232	0.10	+04 05 18.06	0.09	93.09.12
2324−023	23 26 53.804	0.10	−02 02 14.14	0.09	93.09.11
2327−459	23 30 37.665	0.09	−45 39 58.01	0.08	93.11.09
2332−017	23 35 20.386	0.11	−01 31 10.04	0.11	93.11.10
2351−006	23 54 09.180	0.08	−00 19 48.11	0.11	93.10.07
2352−455	23 55 28.785	0.11	−45 13 25.49	0.11	93.10.06

comparison of their a−priori radio positions given in the NRL/USNO radio/optical survey working list (Fey 1994) with our optical data gives very high residuals, and therefore were not included in Table 2. For both objects optical positions have been obtained by Jauncey, in the FK4 system. In the case of 0454 − 463 the optical position given by Jauncey (transformed to the FK5, J2000 system) is in good agreement with ours. As pointed out by Johnston, the radio counterpart was apparently correlated at the wrong position. As for 2314+038, our optical position is not consistent with Jauncey's.

Combining the results presented in Table 2 with analogous results published in Papers II and III of our series, a comparison subset of 45 objects with the VLBI positions given by Johnston is obtained. After the omission of the

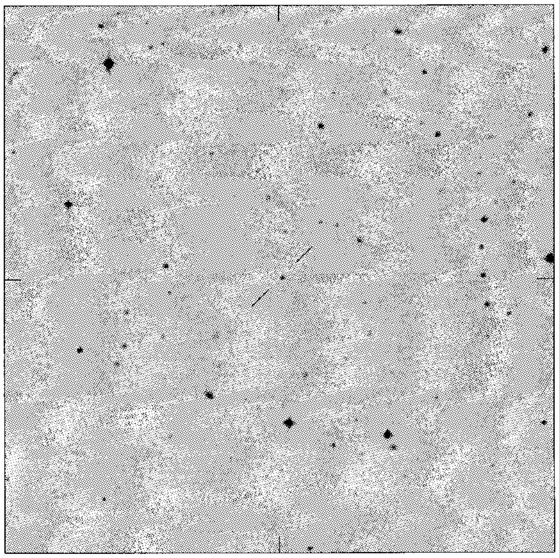

Fig. 2. Finding chart for 2314 − 409. Chart is 9 arcmin on a side. See Sect. 4 for details

Table 2. Comparison in the FK5 system with the VLBI radio positions given by Johnston et al. (1996)

IAU Designation	(Radio − CL) $\Delta\alpha\cos\delta$ ″	$\Delta\delta$ ″
0019+058	+0.58	+0.34
0131−522	−0.35	−0.02
0332−403	+0.19	+0.04
0355−483	−0.18	−0.03
0537−158	−0.11	−0.09
0622−441	−0.05	+0.08
1206−399	−0.04	+0.21
1236−684	−2.15	−1.61
1549−790	−0.32	−0.14
1718−649	+0.59	−0.15
1733−565	−0.02	+0.11
1831−711	+0.04	−0.19
2052−474	−0.16	−0.11
2058−425	−0.14	+0.50
Mean residual	+0.002	+0.04
Sigma	0.29	0.21
Standard error	0.08	0.06
N° of common objects	13	

sources 1116+128 and 1236 − 684, which have (radio − CL) residuals more than 3 times the standard deviation of the average residuals of the subset, the following statistics are obtained:

$$\overline{\Delta\alpha\cos\delta} = -0.11'' \qquad \overline{\Delta\delta} = 0.02''$$

$$\sigma(\overline{\Delta\alpha\cos\delta}) = 0.34'' \qquad \sigma(\overline{\Delta\delta}) = 0.27'' \qquad n = 43$$

$$\epsilon(\overline{\Delta\alpha\cos\delta}) = 0.05'' \qquad \epsilon(\overline{\Delta\delta}) = 0.04''.$$

The $\Delta\alpha\cos\delta$ and $\Delta\delta$ (radio − CL) residuals for the 43 sources are plotted as a function of the coordinates in Figs. 3a-d. Quick inspection of Figs. 3a and 3b, which illustrate the dependence of $\Delta\alpha\cos\delta$ on both coordinates, shows the existence of a general deviation in RA between the radio reference frame, represented by the VLBI radio system established by Johnston, and the optical reference frame represented by our optical positions of CERS referred to the FK5 system through the intermediary of the IRS catalogue. This result confirms what was reported in Paper III on the basis of a smaller subset of comparison objects.

Our result is consistent with recent results by Argyle et al. (1996), hereafter Argyle who, based on optical observations of CERS and radio stars measured in the system defined by the annual series of Carlsberg Meridian Catalogues, also report the existence of a similar deviation in RA ($\sim 0.1''$ south of the equator) between the VLBI frame and the optical frame of the FK5 implicit in the Carlsberg system.

As shown by Argyle, roughly half of this deviation is attributable to an offset in the origin of RA between the radio and optical reference frames, the remnant probably being intrinsec to the Carlsberg system itself. Although with the precision of our data, and the small subset of comparison sources available, it is not possible in our case to disentangle the contributions to the general deviation in RA found by us, it is reasonable to suppose that it is also due in part to the existence of an offset in the origin of RA between the radio and optical frames as defined at present.

On the contrary to what is reported by Argyle, we do not find evidence for a general deviation in declination between the radio and optical frames. As shown by Figs. 3c and 3d, which ilustrate the dependence of δ on both coordinates, the only obvious effect is a local deviation in the $-45°$ to $-80°$ zone seen in the relation $\Delta\delta$ vs. δ.

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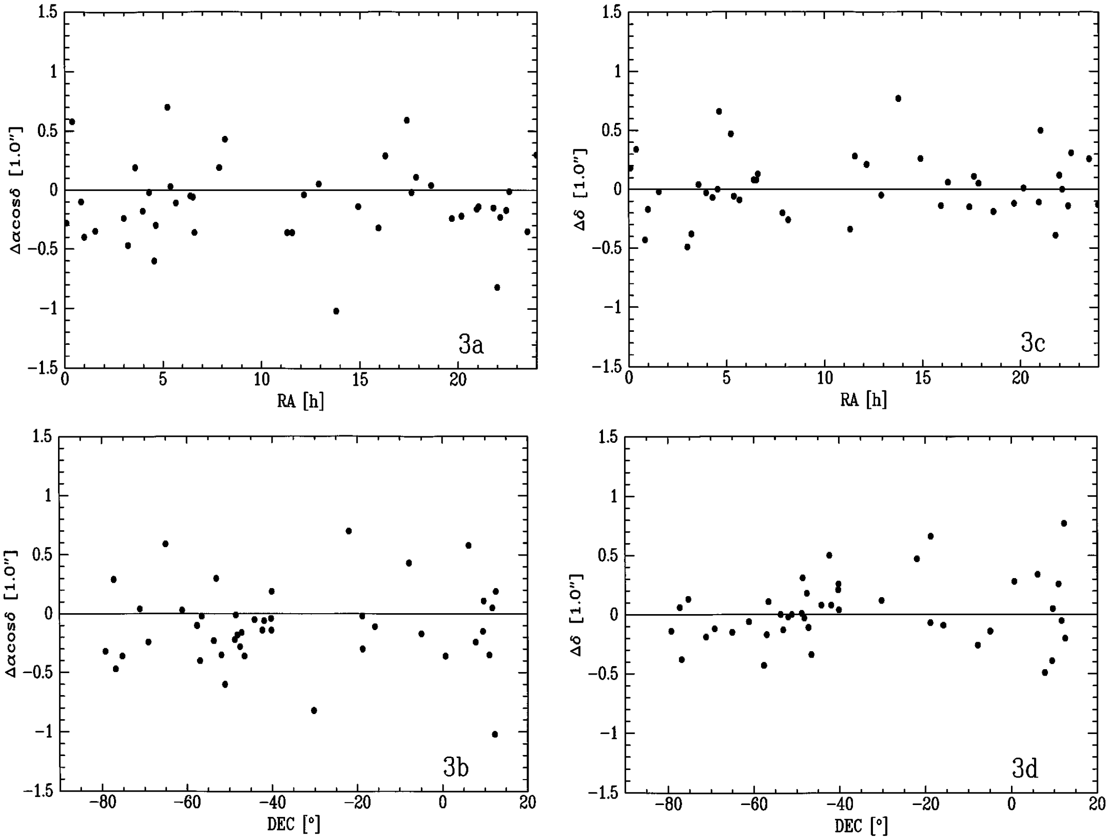

Fig. 3. a-d) Residuals in the sense (radio − CL), plotted as a function of the coordinates, for the 43 sources in common between the VLBI survey of Johnston et al. (1995) and the optical survey of Costa & Loyola (Papers II, III and IV). See Sect. 5 for details

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