AN ATTEMPT TO COMPARE THE RADIO ASTRONOMICAL SYSTEM OF COORDINATES OF QUASARS WITH FK4

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ABSTRACT

A method of comparison of the FK4 system to a system based on extragalactic sources is tested on actual data for 140 sources observed by radio-interferometric and whose optical counterparts have positions referred to FK4. The difference of coordinates is analyzed in spherical harmonics series. The computation show that the method gives satisfactory results. However, the precision of the data prevents from any interpretation in terms of systematic errors of the FK4.

Positional observations of compact extragalactic radio sources by radio interferometers have achieved high accuracy. There exist more than two hundred sources with 0"02-0"05 coordinate accuracy and their number increases continuously (1,2,3). This permits the hope that a high accuracy inertial coordinate system depending upon a large number of extragalactic radio sources will be established in the future.

The investigation of using such a system for improvement of a fundamental system is also of interest. One of the possible ways is to compare precise positions of radio sources derived from radio interferometric observations with corresponding optical data. The evaluation of this method was described by Gubanov and Kumkova (1978). In the present paper, the suggested technique is applied to real data. So, for this purpose, 140 identified radio sources, mostly quasars, which have known precise radio and optical positions were chosen. A list of above sources is given in Table I. Unfortunately radio measurements deal mainly with objects on the north hemisphere which is caused by the location of radio antennae.

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TABLE I

0106+013	0953+254	2005+403	0836+711	1705+456	1143-245
0123+257	0954+253	2134+004	0859+470	1730-130	1335-127
0133+476	0955+328	2200+420	0859-140	1738+447	1349-439
0134+329	0959-443	2201+315	0952+179	1743+173	145 -375
0229+132	1148-001	2251+158	0954+658	1749+096	1519-273
0235+164	1155+251	0056-002	0954+554	1928+738	1555+001
0237-233	1215+303	0115+027	1034-293	1933-400	1629+680
0300+471	1219+285	0122-004	1055+018	1954+513	1636+680
0316+413	1226+023	0153+744	1104-445	2021+614	1749+700
0332-403	1253-055	0202+319	1127-145	2134+141	1823+568
0333+321	1313-334	0212+735	1144-379	2227-399	1849+670
0338-214	1328+307	0237-027	1245-197	2230+114	1909+309
0420-015	1328+254	0336-019	1252+119	2345-168	2008-158
0518+165	1404+286	0430+052	1430-178	2352+495	2223-052
0642+449	1442+101	0438-436	1430+052	0016+731	2254+074
0735+178	1458+718	0440-004	1510-089	0200+045	
0736+017	1502+106	0454+844	1517+204	0224+671	
0738+318	1514+197	0454-234	1611+343	0402-362	
0827+243	1641+399	0537-441	1616+063	0422-380	
0831+557	1645+174	0538+498	1634+628	0531+194	
0839+187	1716+686	0552+398	1637+626	0607-157	
0851+202	1739+522	0605-085	1638+398	0615+820	
0912+297	1741-038	0749+096	1642+690	0636+680	
0923+392	1807+698	0814+425	1656+571	0829+187	
0945+408	1821+107	0828+494	1656+571	1030+415	

Radio coordinates of the sources are considered to have accuracy of about 0"1 (2,3,5,6). It is suggested that the list of radio sources may be considered as a catalogue with its system. The base of this assumption is a uniform technique of observations and reductions of data. Corresponding optical coordinates have inherent accuracy 0"1-0"3 (7,8,9,10,11,12). Photographic coordinate of northern objects were determined with reference to stars of AGK3 by means of intermediate stars. The system of AGK3 is FK4 system. For the southern objects, the catalogues SAO and Perth-70 were used, their systems being FK4 too, but to a less extent. Thus, the comparison of radio and optical coordinates of the sources under consideration may be regarded as the comparison of FK4 with the radio system.

As shown (4), the simultaneous determination of mutual orientation and of systematic errors of these systems does not give a satisfactory result and, therefore, the calculations of the parameters have been made independently. The mutual orientation was determined according to the formulae:

$$\Delta\alpha \; \mathrm{Cos}\delta = \Delta w \; \mathrm{Cos}\delta + \Delta i \; \mathrm{Sin}\delta \; \mathrm{Cos}(w-\alpha) - \Delta\Omega\left[\mathrm{Cos}\delta \; \mathrm{Cos}i + \mathrm{Sin}\delta \; \mathrm{Sin}i \; \mathrm{Sin}(w-\alpha)\right] \quad (1)$$

$$\Delta\delta = \Delta i \; \mathrm{Sin}(w-\alpha) + \Delta\Omega \; \mathrm{Sin}i \; \mathrm{Cos}(w-\alpha)$$

where α,δ - equatorial coordinates of radio sources;
i,Ω,w - Eulerian angles of mutual orientation of the coordinate systems;
i - angle of mutual inclination of the main planes of the systems;
Ω - longitude of ascending node in radio coordinate system;

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w - right ascension of ascending node in radio system;
$\Delta\alpha, \alpha\delta$ - differences of radio and photographic positions which include inherent measuring errors in photographic reference process, possible discrepancy of radio and optical emission centroids, star coordinate errors in fundamental catalogue.

As we are comparing equatorial coordinates, we have to consider the case i = 0; then equations of errors (1) take from:

$$\Delta\alpha \; \mathrm{Cos}\delta = \Delta i \; \mathrm{Sin}\delta \; \mathrm{Cos}(w-\alpha) + (\Delta w - \Delta\Omega) \; \mathrm{Cos}\delta$$
$$\Delta\delta = \Delta i \; \mathrm{Sin}(w-\alpha) \qquad (2)$$

The systematic errors are expanded in normalized spherical functions:

$$\Delta\alpha \; \mathrm{Cos}\delta = \sum_{m=o} \sum_{k=o} (A_{mk} \; \mathrm{Cosk}\alpha + C_{mk} \; \mathrm{Sink}\alpha) \; P_{mk} \; (\mathrm{Sin}\delta)$$
$$\Delta\delta = \sum_{m=o} \sum_{k=o} (C_{mk} \; \mathrm{Cosk}\alpha + d_{mk} \; \mathrm{Sink}\alpha) \; P_{mk} \; (\mathrm{Sin}\delta) \qquad (3)$$

Two lists were chosen from the initial list of 140 objects for computation of the corrections to the orientation parameters. The first one consisted of 55 objects (which are contained in Table I) with differences of radio and optical coordinates less 0".6. The calculations were fulfilled for the initial list and two variants. The results of the calculations of corrections Δi, $(\Delta\omega-\Delta\Omega)$ in the case i = 0, ω = 0 are presented in Table 2. Analysis of the results of Table 2 shows that the evaluations of the same corrections are satisfactorily close and values of the correction Δi derived from right ascensions and from declinations essentially differ. The above results shows us that the systematic part of the differences $\Delta\alpha$ Cosδ, $\Delta\delta$ are stable and differ from each other. As it was shown earlier, the correction Δi_{α} correlates with member of expansions (3) A_{20}, the correction $(\Delta\omega-\Delta\Omega)$ correlates with A_{00}, A_{20}, B_{21} and $\Delta i\delta$ correlates with A_{11}. Thus the corrections presented in Table 2 are linear combinations of the corrections themselves and of the mentioned members of the expansions. The correlations between Δi_{α} and $(\Delta\omega-\Delta\Omega)_{\alpha}$ do not exceed 0.07 in all cases.

TABLE 2

Corrections	For 55 objects	For 115 objects	For 140 objects
Δi_{α}	-0".03 ± 0".04	-0".07 ± 0".05	-0".06 ± 0".06
$(\Delta\omega-\Delta\Omega)_{\alpha}$	-0".03 ± 2	-0".05 ± 2	-0".03 ± 3
$\Delta i\delta$	+0".04 ± 3	+0".3 ± 3	+0".01 ± 5

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The evaluation of systematic errors by formulae (3) has been made for α and δ separately because their expansions are identical. Sixteen members of expansions (3) were calculated, which corresponds to m,k $\leq$ 3. The calculations were fulfilled for three lists of objects as it was done during the calculations of the orientation. The values of factors of expansions (3) A_{mk},B_{mk} for $\Delta\alpha$ Cosδ and for $\Delta\delta$ for variant of 115 objects are given in Table 3. In the same Table 3, the rms errors of coefficients are presented. The system of coefficients is not complete, the factor A_{20} includes, in fact, A_{00} because these members do not separate for this case of distribution of the objects on the sphere. The systematic differences $\Delta\alpha$ Cosδ in terms of $0^s.001$ and $\Delta\delta$ in terms of 0".01 computed in accordance with data of the Table 3 are given in Tables 4 and 5, respectively. The values for $\delta < -45^0$ and $\delta > 60^0$ are not presented for the lack of sources in these areas. The system of conditional equations for 55 objects is difficult to solve because of high correlations between the members of expansions (3). The results for the list of 140 objects are practically in accordance with the results presented in Tables 4 and 5, but the corresponding errors are larger. In addition, the list of 115 objects was subdivided in an arbitrary way in two lists of equal volume. The systematic errors have been computed for both lists and calculations and gave the same results for both variants. It proves the nonrandom nature of the results of the Tables 4 and 5. Though the final purpose of these calculations is to estimate the systematic errors of FK4, the quality of initial data does not yet allow us to interpret the results in this way. The data of the Tables 4 and 5 should be regarded as systematic differences of the two coordinates systems, viz., radio and optical.

TABLE 3

mk	Expansion $\Delta\alpha$ Cos δ A_{mk}, B_{mk} $0^s.001$		Expansion $\Delta\delta$ C_{mk}, d_{mk} 0".01	
10	-8	± 6	-22	± 13
11	4	6	-9	11
11	3	5	0	10
20	12	7	22	13
21	4	4	5	7
21	-4	3	-9	7
22	14	5	5	10
22	2	4	6	9
30	5	7	8	14
31	-11	5	-17	11
31	6	5	1	10
32	3	5	-1	10
32	3	6	6	11
33	-2	4	5	7
33	-12	4	0	9

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TABLE 4

δ \ α	0^h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
60°	4	3	2	2	1	1	1	1	1	0	-1	-0	0	2	4	5	6	6	5	4	4	4	4	4
45°	0	0	-1	-2	-2	-1	-0	1	0	-2	-4	-5	-4	-2	0	3	3	2	-1	-4	-6	-5	-3	-1
30°	-2	-1	-2	-3	-3	-1	1	2	-2	-1	-5	-8	-8	-5	-1	2	1	-3	-9	-15	-17	-15	-11	-6
15°	-1	1	-0	-2	-2	-0	3	4	4	-0	-6	-9	-9	-5	-0	3	1	-5	-14	-22	-25	-22	-15	-7
0°	-3	6	4	1	-0	1	3	4	3	-0	-6	-10	-9	-4	2	6	4	-3	-13	-22	-25	-21	-13	-4
-15°	-9	11	9	5	2	1	1	1	-1	-4	-8	-10	-7	-1	6	10	8	2	-7	-15	-16	-14	-6	3
-30°	15	16	13	8	3	-0	-2	-4	-6	-8	-10	-10	-6	1	8	12	12	8	2	-3	-4	-1	5	11
-45°	18	18	14	9	4	-1	-4	-7	-9	-10	-10	-8	-4	2	8	13	14	13	11	9	8	-10	14	17

TABLE 5

δ \ α	0^h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
60°	-3	-5	-7	-9	-11	-12	-11	-8	-5	-0	4	8	11	13	14	13	12	10	8	6	4	2	0	-1
45°	-9	-10	-12	-14	-17	-18	-18	-15	-10	-3	1	5	8	8	8	6	4	1	-2	-4	-6	-8	-9	-9
30°	-12	-11	-11	-13	-16	-19	-19	-17	-12	-6	-1	2	3	2	-0	-3	-6	-9	-12	-14	-16	-17	-16	-14
15°	-10	-7	-6	-8	-11	-14	-15	-14	-10	-6	-2	-0	-1	-3	-6	-9	-12	14	-16	-18	-20	-20	-18	-15
0°	-5	-1	1	-0	-3	-7	-10	-10	-8	-5	-3	-2	-3	-5	-7	-9	-9	-10	-11	-12	-14	-14	-13	-9
-15°	4	6	7	6	2	-3	-6	-7	-7	-6	-4	-4	-4	-4	-3	-2	0	2	3	2	0	-1	-1	1
30°	12	12	11	8	4	-0	-4	-7	-7	-7	-5	-4	-2	1	5	9	14	17	19	18	17	15	13	12
45°	19	17	13	9	5	0	-3	-6	-7	-6	-4	-1	3	7	13	19	24	29	31	31	30	27	25	22

The results obtained for the chosen list show obviously that the improvement of the fundamental system of star coordinates by means of precise positional radio observations may be obtained satisfactorily, if highly accurate uniform catalogue of not less than 200 extragalactic radio sources uniformly distributed on whole sphere and surely identified optically will be established by radio interferometric observations in future.

REFERENCES

Arque, A. N., et al.: 1978, IAU Col. N 48, Vienne, 155.

Bridle, A. H., Goodson, R. E.: 1977, I. Roy. Astron. Soc. Can 71, N 3, 240.

Clark, I. A., et al.: 1978, Astron. J. 81, 599.

Couper, H. A.: 1972, Astrophys. Lett. 10, 121.

de Vegt, C., Gehlich, E. D.: 1978, Astron. Astrophys. 67, 65.

Elsmore, B.: 1978, IAU Col. N 48, Vienne, 93.

Gubanov, V. S., Kumkova, I. I.: 1978, IAU Col. N 48, Vienne, 135.

Johnston, K. J.: 1978, IAU Col. N 48, Vienne 175.

Wade, C. M.: 1974, IAU Col. N 61, 133.

Wade, C. M., Johnston, K. J.: 1977, Astron. J. 82, 791.

Walter, H. A., West, R. S.: 1979, ESO Messenger, 18.

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