Arcsecond Positions for Milliarcsecond VLBI Nuclei of Extragalactic Radio Sources, Part III: 74 Sources

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VLBI measurements at 2290 MHz and 8420 MHz on baselines of 10^4 km between Deep Space Network stations have been used to determine the positions of the milliarcsecond nuclei in 74 extragalactic radio sources. Estimated accuracies range from 0."1 to 4."3 in both right ascension and declination with typical accuracies of ~0."3. The observed sources are part of an all-sky VLBI catalog of milliarcsecond radio sources. Arcsecond positions have now been determined for 819 sources. These positions are presently being used to identify optical counterparts in the Southern Hemisphere.

I. Introduction

A survey is underway to develop an all-sky catalog of radio sources with milliarcsecond components at 2.29 GHz. This is being accomplished by searching for compact components in known extragalactic sources (Refs. 1, 2, 3) with intercontinental baselines composed of Deep Space Network stations. We have used VLBI measurements of delay and fringe frequency at 2.29 GHz to determine the positions of the milliarcsecond nuclei. Previously we have presented the positions of 747 nuclei (Refs. 4 and 5). In this article, we present the positions of an additional 72 nuclei and include improved positions for P 1237-10 and P 0509+152 (Refs. 4 and 5, respectively). Estimated accuracies for sources in this paper range from 0."1 to 4."3 in both right ascension and declination.

The observations were not performed primarily for position measurements, but were part of the development of an all-sky VLBI catalog of milliarcsecond radio sources at 2290 MHz. The delay observables were derived from single channel 2-MHz bandwidths resulting in arcsecond accuracy. However, these measurements constitute at least an order of magnitude improvement in positional accuracy for most of the sources.

Arcsecond positions serve as a useful starting point in the construction of a high-precision VLBI reference frame as well as allowing unambiguous optical identifications to be made. Based on these positions, more than 100 optical counterparts have already been identified in the Southern Hemisphere (Refs. 6, 7). The positions from this article and Refs. 4 and 5, respectively, are presently being used as a first step in the formation of a precision reference frame of 100–200 sources in which relative radio positions should be determined to milliarcsecond accuracy (Refs. 8, 9).

II. The Observations

The observations were performed with pairs of antennas on either California-Australia, or California-Spain baselines (see Table 1) during 12 separate observing sessions conducted between 1981 and 1983. A list of experiments appears in Table 2. The observations were performed at 2.29 GHz and 8.42 GHz with MK II VLBI recording systems as described in Ref. 4. The total number of sources whose positions were solved for is 157. Of these, there were 72 sources whose positions were not included in Refs. 4 and 5. The length of each observation was a few minutes with 65% of the sources being observed more than once.

III. Method of Position Determination

The details of position determination for this set of sources closely follow the analysis given in Refs. 4 and 5. As in Refs. 4 and 5, observations of sources with well-known positions allowed instrumental delay and frequency offsets to be determined. At least three such calibration sources per experiment were spread in time among the program sources. A list of the 64 calibration sources appears in Table 3. Thirty of the calibration source positions have been determined with VLBI (Ref. 10) and can be referred to the FK4 reference frame (Ref. 11) with an accuracy of $0\overset{''}{.}1$. Other calibration source positions came from Ref. 12 (33 sources, $0\overset{''}{.}1$ accuracy), and Ref. 13 (1 source, $0\overset{''}{.}2$ accuracy).

IV. Results

The calculated positions of 74 sources and the corresponding uncertainties are shown in Table 4. The positions are referred to the equinox of 1950.0 and elliptical aberration terms are included, so as to agree with past astronomical convention. The source positions and position uncertainties for sources which were multiply observed were estimated from a weighted average over several observations. Therefore, individual uncertainties less than $0\overset{''}{.}3$ in Table 4 are due to averaging over multiple observations. Since the uncertainties for the vast majority of observations were dominated by the quadratically added $0\overset{''}{.}3$ error, correlations between right ascension and declination were not tabulated.

A total of 102 sources were observed two or more times, and the scatter in their position estimates is consistent with the estimated uncertainties. Figure 1 is a histogram of the ratio of the weighted rms scatter of the measurements to the weighted rms estimate of position coordinate uncertainty for both the right ascension and declination of each multiply observed source. For the 102 multiply observed sources, the rms value of this ratio is 0.7 for right ascension and 0.9 for declination.

In addition to the 74 sources listed in Table 4, we also reobserved 83 sources whose positions were reported in Refs. 4 and 5. For these 83 sources, Fig. 2 shows a histogram of the difference between the two measurements of each coordinate divided by the RSS error of the position coordinate uncertainties. For 85 sources including P 1237–10 and P 0509+152, this calculated ratio has a rms value of 1.5 for right ascension and 1.3 for declination. If we delete these two sources from this calculation, the rms value for right ascension becomes 1.0 and for declination becomes 0.9. For those two sources, P 1237–10, and P 0509+152, positions are given here which are improved from those cited in Refs. 4 and 5.

For 32 sources, we could compare our position estimates with other position estimates of better or similar accuracy (Refs. 10, 12, 14). Figure 3 displays a histogram of the ratio of the value of the difference between our source position estimate and the other catalog value to the RSS of the position uncertainties of both catalogs. For these 32 sources, the rms value of this ratio is 1.2 for right ascension and 1.2 for declination. For both right ascension and declination, the value of the ratio never exceeds 3.3. The bias offsets between our position estimates relative to those of the other catalogs for these 32 sources are $-0\overset{''}{.}05 \pm 0\overset{''}{.}05$ in right ascension and $-0\overset{''}{.}03 \pm 0\overset{''}{.}05$ in declination. Hence, these position estimate comparisons, along with the multiple observation comparisons, indicate our position uncertainty estimates are realistic.

Figures 4(a) and 4(b) show histograms of the number of sources versus estimated position uncertainty for declination and right ascension, respectively, for the 157 observed sources. Estimated accuracies range from $0\overset{''}{.}1$ to $4\overset{''}{.}3$ in both right ascension and declination.

V. Summary

Positions for the milliarcsecond nuclei of 74 extragalactic sources have been determined to an accuracy of $\sim 0\overset{''}{.}1$ to $4\overset{''}{.}3$ in both right ascension and declination. The reliability of the determined positions has been demonstrated by testing the repeatability of multiple observations on the same source and by comparing the results with other radio catalogs. Arcsecond positions have now been determined for 819 milliarcsecond nuclei.

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Table 1. Participating observatories

Location	Designation	Diameter, m	Baseline Length: Kilometers	Baseline Length: Wavelengths
Tidbinbilla, Australia	DSS 43	64	10.6×10^3	8.1×10^7
Goldstone, California	DSS 13	26		
			8.4×10^3	6.4×10^7
Madrid, Spain	DSS 63	64		

Table 2. Experiment list

Experiment: Yr	Mo	Dy	DSS's Observing	
81	01	31	13	43
81	10	23	13	43
81	10	24	13	43
81	10	26	13	43
81	11	01	13	43
82	05	18	13	43
82	05	30	13	43
82	06	05	13	43
82	09	03	13	43
82	09	08	13	43
83	06	21	13	43
83	11	25	13	63

Table 3. List of calibrator sources

Source	Position Reference	Source	Position Reference[a]
NRAO 5	2	B2 0745+24	2
P 0019+058	2	B2 0742+31	2
P 0038–020	2	DW 0742+10	2
P 0048–09	2	GC 0748+33	2
0056–001	2	GC 0759+18	2
P 0106+01	1	B2 0827+24	1
P 0111+021	2	GC 0839+18	1
P 0112–017	2	OJ 287	1
P 0119+11	2	AO 0952+17	1
GC 0119+04	2	0953+25	2
OC 079	2	P 1055+01	1
3C 48	1	P 1127–14	1
P 0201+113	2	P 1148–00	1
P 0202+14	2	3C 273	1
GC 0221+06	2	3C 274	1
CTD 20	2	DW 1335–12	1
		P 1351–018	2
GC 0235+16	1	OP–192	2
0316+162	2	P 1510–08	1
P 0317+188	2	NRAO 530	1
P 0332–403	1	P 1741–038	1
GC 0406+12	2	1803+73	3
P 0409+22	2	OV–236	1
P 0428+20	1	OV–198	1
3C 120	1	P 1936–15	2
P 0446+11	2	P 2008–159	2
P 0454+06	2	P 2134+004	1
3C 138	1	OX–192	1
DA 193	1	OY–172.6	1
OI 318	2	3C 454.3	1
P 0735+17	1	GC 2318+04	2
OI 363	1	P 2345–16	1
B2 0738+27	2		

[a]Position Reference Key:
1 Fanselow et al. 1981 (Ref. 10)
2 Perley 1982 (Ref. 12)
3 Waltman et al. 1981 (Ref. 13)

Table 4. B1950.0 source positions

Source Name	Right Ascension				Declination			
	Hr	Min	Sec	Error	Deg	Min	Sec	Error
P 0013–00	0	13	37.359	0.014	– 0	31	52.55	0.23
0032+276	0	32	4.590	0.028	+27	37	54.27	0.30
0047–051	0	47	49.001	0.011	– 5	8	39.63	0.24
P 0054–006	0	54	43.396	0.012	– 0	40	45.73	0.21
P 0114+07	1	14	49.523	0.016	+ 7	26	30.63	0.32
P 0127+145	1	27	15.025	0.016	+14	31	20.09	0.27
0131–001	1	31	38.936	0.028	– 0	11	35.27	0.48
P 0137+012	1	37	22.890	0.015	+ 1	16	35.74	0.51
GC 0147+18	1	47	5.622	0.024	+18	42	27.65	0.32
P 0149+21	1	49	31.739	0.017	+21	52	20.68	0.21
P 0158+031	1	58	5.156	0.012	+ 3	8	20.49	0.18
P 0159+034	1	59	15.644	0.016	+ 3	28	42.56	0.27
0229+262	2	29	33.586	0.029	+26	15	26.13	0.30
0242+238	2	42	23.589	0.027	+23	52	58.21	0.22
P 0253+13	2	53	50.168	0.015	+13	22	32.31	0.22
0305+039	3	5	49.193	0.048	+ 3	55	11.28	0.62
0322+222	3	22	40.840	0.023	+22	13	42.12	0.31
NRAO 140	3	33	22.405	0.024	+32	8	36.87	0.30
0338+074	3	38	12.716	0.046	+ 7	25	48.92	0.51
P 0338–214	3	38	23.260	0.017	–21	29	7.86	0.21
0344+199	3	44	36.530	0.029	+19	55	25.59	0.35
0423+233	4	23	54.706	0.029	+23	21	6.49	0.45
0426+273	4	26	47.384	0.029	+27	18	7.34	0.30
P 0458+138	4	58	55.545	0.032	+13	51	49.79	0.36
0459+252	4	59	54.256	0.018	+25	12	12.17	0.26
0502+049	5	2	43.802	0.011	+ 4	55	40.04	0.21
0506+056	5	6	45.747	0.021	+ 5	37	50.44	0.42
0507+179	5	7	7.483	0.011	+17	56	58.63	0.16
P 0509+152	5	9	49.447	0.010	+15	13	51.91	0.15
0518+165	5	18	16.513	0.022	+16	35	26.86	0.31
0620+389	6	20	51.521	0.015	+38	58	27.24	0.16
3C 166	6	42	24.662	0.014	+21	25	1.94	0.18
0743+25	7	43	23.055	0.010	+25	56	24.88	0.13
GC 0805+26	8	5	34.293	0.034	+26	55	24.20	0.33
0952+179	9	52	11.799	0.012	+17	57	44.49	0.21
GC 1004+14	10	4	59.769	0.010	+14	11	11.08	0.16
1011+250	10	11	5.647	0.020	+25	4	10.12	0.22
P 1012+232	10	12	0.513	0.016	+23	16	11.91	0.21
GC 1022+19	10	22	1.461	0.009	+19	27	34.72	0.14
P 1036–154	10	36	39.481	0.019	–15	25	28.24	0.22
1039+300	10	39	49.760	0.030	+30	5	28.29	0.31
P 1042+071	10	42	19.454	0.010	+ 7	11	25.10	0.19
P 1045–18	10	45	40.100	0.015	–18	53	44.08	0.21
P 1045+019	10	45	46.829	0.022	+ 1	58	5.49	0.33
P 1130+10C	11	30	25.131	0.023	+10	40	4.71	0.55
P 1142+052	11	42	47.069	0.036	+ 5	12	7.28	0.86
1144+352	11	44	45.505	0.026	+35	17	47.36	0.30
P 1149–084	11	49	43.831	0.018	– 8	24	21.92	0.23
P 1158+007	11	58	49.619	0.032	+ 0	45	8.78	0.50
P 1203+011	12	3	15.079	0.025	+ 1	10	21.02	0.40
1215–002	12	15	24.920	0.014	– 0	13	6.41	0.35
P 1228–113	12	28	20.042	0.021	–11	22	36.16	0.31
P 1237–10	12	37	7.280	0.017	–10	7	0.63	0.26
P 1310–041	13	10	15.621	0.010	– 4	8	56.47	0.16
P 1333–049	13	33	20.257	0.044	– 4	56	22.39	0.34
P 1340–17	13	40	54.456	0.024	–17	32	51.35	0.37

Table 4. (contd)

Source Name	Right Ascension				Declination			
	Hr	Min	Sec	Error	Deg	Min	Sec	Error
P 1418–064	14	18	29.578	0.073	– 6	30	14.83	0.68
1434+235	14	34	25.397	0.018	+23	34	3.14	0.22
P 1443–162	14	43	6.682	0.015	–16	16	26.65	0.23
1511+238	15	11	28.293	0.030	+23	49	43.69	0.32
P 1514–24	15	14	45.278	0.016	–24	11	22.56	0.22
OS–268	16	40	32.583	0.015	–23	10	33.50	0.22
1640+254	16	40	36.539	0.023	+25	28	43.63	0.22
1909+269	19	9	33.631	0.024	+26	53	10.01	0.33
OV–235	19	20	34.242	0.015	–21	10	24.72	0.21
P 1942–313	19	42	49.158	0.024	–31	18	59.05	0.23
P 2002–185	20	2	24.408	0.022	–18	30	38.76	0.33
2107–105	21	7	18.809	0.017	–10	33	12.52	0.23
P 2220–163	22	20	59.335	0.033	–16	22	17.68	0.32
P 2223–114	22	23	4.500	0.017	–11	28	56.52	0.27
P 2314–116	23	14	45.938	0.054	–11	38	46.90	0.40
P 2318–087	23	18	43.100	0.291	– 8	43	54.06	4.24
P 2338+000	23	38	33.144	0.020	+ 0	1	54.87	0.54
P 2340–036	23	40	22.498	0.016	– 3	39	4.88	0.38

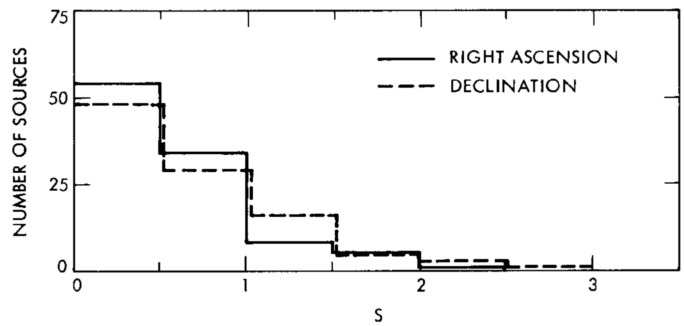

Fig. 1. Comparison of position estimates for 102 multiply observed sources. *S* is the ratio of the weighted rms scatter of the measurements to the weighted rms estimate of the uncertainty in that position coordinate.

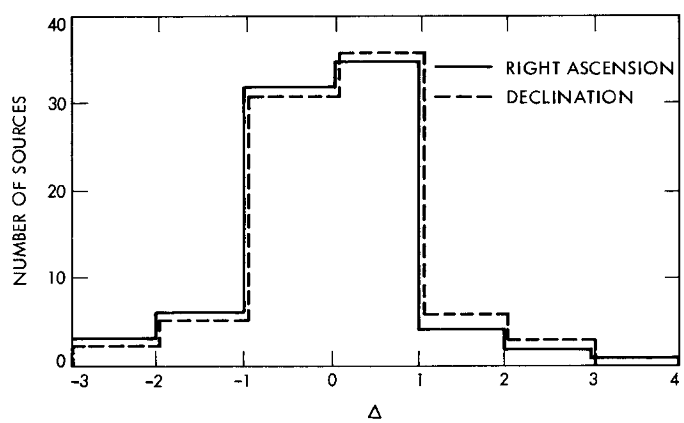

Fig. 2. Comparison of position estimates of 83 sources in common with Refs. 4 and 5. For each source, Δ is the ratio of the difference between the source coordinate estimates to the weighted rms estimate of the uncertainty in that position coordinate.

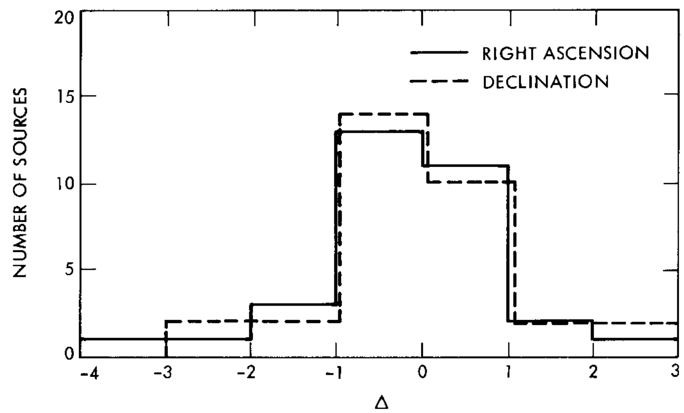

Fig. 3. Comparison of position estimates with other radio positional catalogs. For each source, Δ is the ratio of the difference between our source coordinate estimate and the other catalog value to the RSS of the uncertainties of both catalogs.

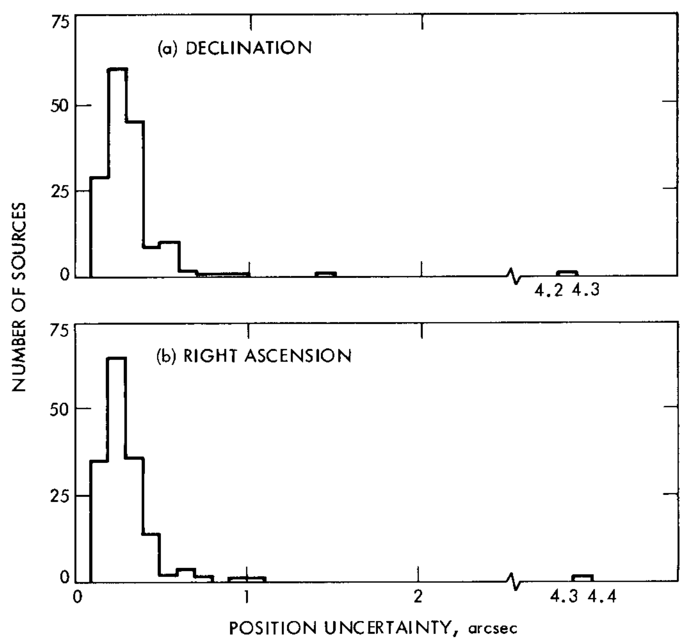

Fig. 4. Histogram of number of sources vs estimated position uncertainty