INTRODUCTION

One of the prime objectives of radio interferometry as applied to geophysics is establishing a grid of extragalactic radio sources against which to measure motions of the earth. The stability of this grid is of prime importance as this directly affects the accuracy of the geodetic measurements. Using radio interferometric techniques, the positions of these objects may be measured quite precisely. In this paper, the use of connected element interferometry will be emphasized. The very long baseline (VLBI) techniques are the subject of many other papers at this meeting and therefore will be mentioned only as they are relevant to establishing a reference frame of radio sources.

Connected Element Interferometry

In connected element interferometry, a common local oscillator is fed to all the antennas comprising the interferometer. This naturally limits the spacing of the antennas to several tens of kilometers. Antennas are linked together by cable as in the Cambridge interferometer, by radio link as in the Green Bank interferometer, or via waveguide as in the very large array (VLA) in Socorro, New Mexico. At present, experiments are being carried out to link antennas separated by thousands of kilometers via satellites. Since the antennas have a common local oscillator, the interferometer phase and amplitude are the prime observables. This differs from VLB, in which the prime observables are delay or fringe rate and amplitude. As you probably know, the delay and fringe rate are simply the frequency and time derivatives, respectively, of phase. This is the reason connected element interferometry has been able in the past to achieve similar accuracies in the measurement of the positions of celestial sources as VLB despite the shorter baselines used. We shall hear several talks at this meeting concerning the use of phase by VLB observers.

Highly accurate astrometric work in connected element interferometry was done by Elsmore and Ryle (1976) at Cambridge using an east-west interferometer of length 5 km at a frequency of 5 GHz. They achieved an accuracy of $\sim 0\overset{''}{.}03$ for a source at declination 45°. This celestial position accuracy roughly corresponds to measuring the baseline length to an accuracy of 0.3 mm. This was followed by the work of Wade and Johnston (1977) who used the Green Bank interferometer with a baseline of 35 km at a frequency of 2.7 GHz to measure the positions of celestial sources to $0\overset{''}{.}03$ at a declination of 40°. Since this instrument has a baseline which is along an azimuth of ~205°, it has a considerable north-south component. This allowed the positions of sources south of the equator to be measured with high accuracy. Here again, the 35-km baseline must be measured to an accuracy of a millimeter.

The chief cause of inaccuracy in these catalogs is believed to be caused by inhomogeneities in the water vapor content of the troposphere which give rise to irregularities in the instrumental phase. The time scale of these irregularities is a few minutes to many hours and of amplitude, a few millimeters in differential phase path between the antennas (Hinder 1970; Johnston 1979a). Repeated observations are used to smooth out these irregularities. Elsmore and Ryle (1976) calibrate their interferometer and then observe a single source, horizon to horizon. Wade and Johnston (1977) observe all sources (~25) every day at ~5 hour angles distributed over the sky. In this way, they calibrate their instrument as they observe.

Radio Source Catalogs

The quoted catalog errors versus declination are shown as a function of declination in figure 1. Here, one can easily see the accuracy of source position in declination decrease as one approaches the equator. Also shown in this figure are the VLB catalogs of Clark et al. (1976) and Fanslow (1978). One can easily see a trend towards increasing accuracy as a function of time.

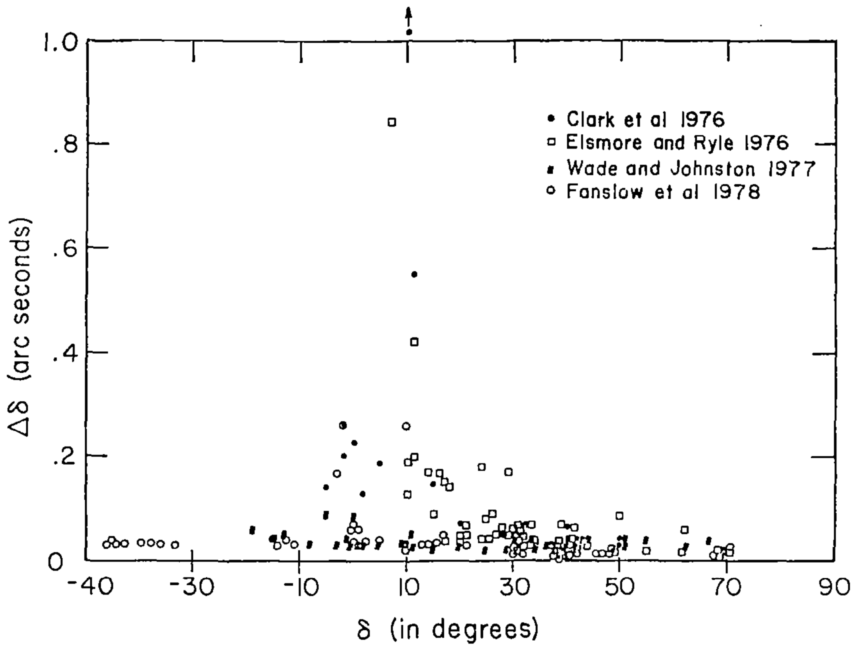


Figure 1. Error in source declination as a function of declination. Note the errors in the earlier observations increase substantially near the equator.

Comparison of these catalogs was also encouraging. Table 1 shows the weighted mean differences for sources common to various catalogs for comparison. The zero point in right ascension is not significant since each catalog uses a different zero point. Clark et al. (1976), Wade and Johnston (1977), and Spencer et al. (1979) use 3C273B; Elsmore and Ryle (1976) use β Persei; and Fanslow (1978)* uses NRAO140.

*J. Fanslow, private communication, 1978.

Table 1
Weighted Mean Differences
Wade and Johnston (1977) - Other Catalogs

Catalog	Sources in Common	$\Delta\alpha$	$\Delta\delta$
Clark et al. (1976)	17	$-0\overset{s}{.}0001\pm0.0006$	$0\overset{''}{.}002\pm0.009$
Elsmore & Ryle (1976)	17	-0.0060 ± 0.0015	0.049 ± 0.016
Fanslow (1978)	10	-0.0032 ± 0.0026	0.012 ± 0.017
This paper	10	0.0002 ± 0.0020	0.000 ± 0.016

Sources of Disagreement

There are discrepancies in position in these catalogs which exceed the quoted errors. These discrepancies are due to source structure, baseline geometry, and the use of different astronomical constants employed in the data reduction process. The last difficulty can be easily removed if future catalogs are made using the adopted astronomical constants and stating this explicitly in the catalog.

The beams of the connected element interferometer are quite large by VLB standards; i.e., $\sim 3''$ for the Cambridge telescope and $0\overset{''}{.}6$ for the Green Bank telescope. This can and will cause problems. The maps of 3C345 made by Readhead et al. (1978), displayed in figure 2, show how source structure changes versus frequency. Since these are VLB maps in which the same antennas are usually employed at all frequencies, the resolution varies with frequency. We are faced with the problem that at different frequencies the source structure may appear quite different. The extended structure ranges in position angle from $-76°$ to $-57°$ going from highest to lowest resolution (~ 1 to 10 milliarcseconds). A VLA map (Perley and Johnston, 1979) of 3C345 is displayed in figure 3 along with the spectra of the two major components. There is a resolved extended component at a position angle of $-31°$ apparent with a resolution of 1 arcsecond.

Radio catalogs have been made with a large number of beamwidths and at frequencies varying from 2-8 GHz. The sensitivity to structure is of the order of a synthesized beamwidth. This can be seen to be a problem for the larger beamwidth, low frequency operation of connected element interferometry.

All of the catalogs published at present are from observations made at a single frequency, and some effectively made over a single baseline such as the catalog of Wade and Johnston (1977). There was an increase in accuracy in the published work about 1976, for which most of the data was obtained

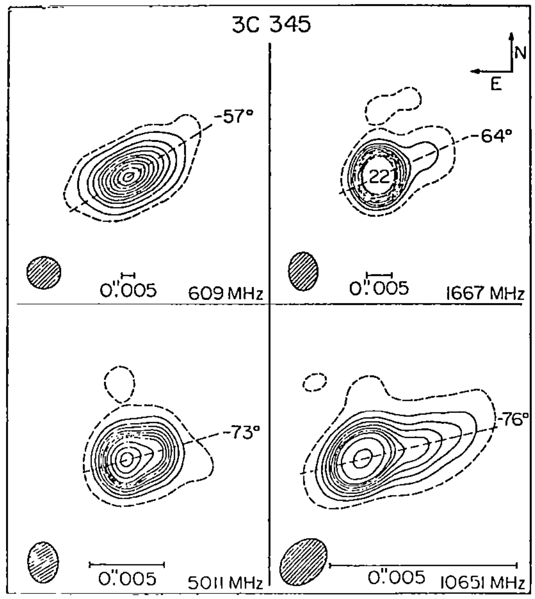
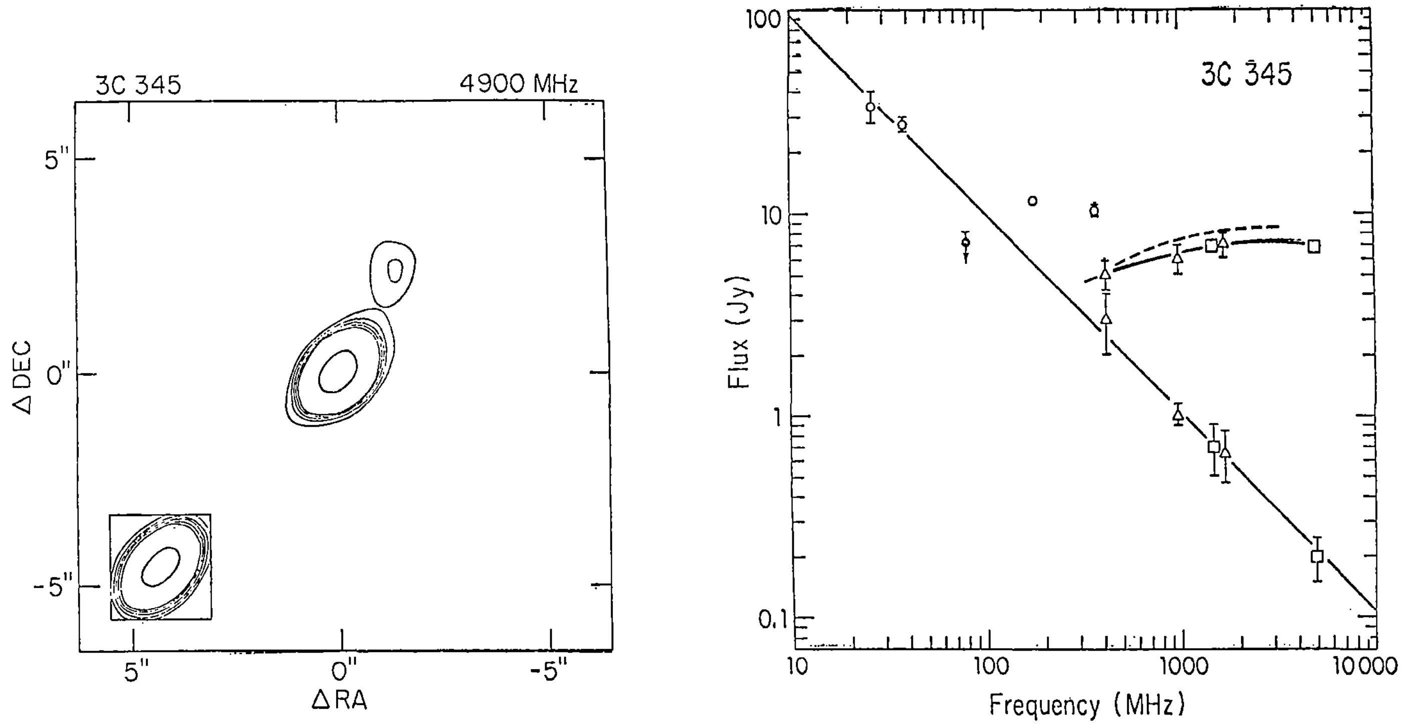


Figure 2. Hybrid radio maps of 3C345 at 609, 1667, 5011, and 10651 MHz. Note the systematic rotation of the source structure at the different frequencies. The dashed ellipses show the size (FWHM) of the restoring beams (after Readhead et al., 1978).

at solar minimum. Now that solar maximum is here (October 1979), the effects of the ionosphere will be ~100 times greater. For example, in the 1974 to 1976 data of Wade and Johnston (1977), who used a 35-km baseline, there was no need for a differential phase pathlength correction because this effect did not exceed 0.1 cm at a wavelength of 11.1 cm. However, in the present operation of the Green Bank interferometer by the United States Naval Observatory, ionospheric effects have been observed to contribute a differential phase pathlength of over 10 cm. Therefore, at times of high solar activity, dual frequency observations are necessary for accurate astrometric work (i.e., 0.″01) especially at low radio frequencies and intermediate range baselines (~100 km). One other aspect concerns ionospheric effects on observations over a single baseline. The effects of the ionosphere cannot be removed from the data without some a priori knowledge of the radio source structure. Observations over several baselines at two frequencies are necessary to separate these effects since the effects of source structure will be displayed in the lack of phase closure among three or more baselines.



(a) (b)

Figure 3. (a) Radio maps of 3C345 at 4990 MHz made with the VLA. The contour intervals are 1% of the peak brightness to the 5% level, with the 50% contour added to show the half-power beamwidth. The clean beam is displayed in the lower left corner (after Perley and Johnston, 1979). (b) The radio spectrum of 3C345 (after Perley and Johnston, 1979). The spectrum of the compact "astrometric" source (- - -) is flat while that of the extended component (——) is very steep.

A Source Catalog

With these problems in mind, the ideal radio source for astrometry is one with little or no structure in its radiation. To establish a reference frame, a large number of sources are needed. Optical catalogs contain over a thousand stars; i.e., the FK4 contains 1535 fundamental stars. Johnston (1979b) estimates from the number of radio sources with flat spectra found in radio surveys that there will be approximately 1500 sources of intensity $\geq$0.6 Jy distributed over the celestial sphere containing compact components. Many of these sources may contain complex structure. Optical astronomers would like to identify compact radio sources which have optical counterparts in order to use the superior accuracy of the radio source position to reduce the zonal systematic errors in the optical catalogs.

With these views in mind, a working group for the Identification of Radio/Optical Sources was established at IAU Colloquium No. 48. This report was presented at the IAU General Assembly in August 1979. Since this report has a very limited distribution among the geophysical community, it has been added as Appendix A to this paper. It contains a primary list of sources having positions exceeding $0\rlap{.}''1$ in accuracy. The secondary list contains sources that are not useful because of radio structure or they have a poor position. This list is a first attempt at establishing, through a coordinated effort, an extragalactic reference frame from QSO's and other radio sources. These lists should be viewed as changeable as more information becomes known about individual sources. Anyone suggesting changes in this source catalog should inform a member of this working group.

At present, the accuracy of radio source catalogs from papers presented at this meeting is approaching $0\rlap{.}''01$. For improved accuracy beyond this figure, the structure of radio sources on the milliarcsecond scale must be taken into account. This structure is frequently complex as in 3C84 or may have a simple, two-component structure as in BL Lacetae. Since these sources radiate via the synchrotron mechanism, a lower limit of about a milliarcsecond on the angular size is set by energy losses due to inverse Compton scattering. Therefore, it is very important to identify those radio sources with the simplest structure. No mention has been made of the variability of this structure. This will also have to be evaluated, as the most compact sources are the most time variable.

Conclusion

The establishment of a reference frame based upon extragalactic radio sources is fast approaching. Connected element interferometry has not produced a new catalog of source positions since 1977. However in the near future, work presently being done on the VLA and the Green Bank interferometer should result in new catalogs. The VLBI work reported in this meeting by G. Purcell (JPL) and T. Clark (Goddard) shows that the accuracy in source position is approaching $0\rlap{.}''01$. The number of sources with precise position exceeds one hundred. There only remains to refine this data, as well as is possible, to define a reference frame and make it available to those interested in geodetic applications.

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APPENDIX A

Report of IAU Commission 24, Working Group on the Identification of Radio/Optical Astrometric Sources

The primary objective of this working group is to select a preliminary list of suitable celestial sources that may be employed as a benchmark in establishing an inertial reference frame based upon extragalactic sources. Space astrometry programs in the next decade should have a precision capability in the milliarcsecond range; therefore the reference frame needs to be established to that accuracy. Advances in astrometry at radio frequencies make objects that radiate at these frequencies the best candidates at present for establishing this reference frame. Therefore, the working group has first attempted to identify suitable radio sources. In order to use this reference frame of extragalactic radio sources to improve already established optical and dynamical reference frames, as well as to determine the origin of the improved frame, suitable radio sources with optical counterparts are required.

Radio sources should be chosen that do not have significant large scale (greater than 1″) structure in the radio range above 1.4 GHz. This criterion would eliminate almost all sources which have precise published positions. However the radio structure of a large number of sources is not yet known, so this criterion cannot now be strictly applied. Extensive additional observations are required to definitely establish these sources, and it is hoped that the list presented with this report can serve as a starting point in the search for these sources.

Not all sources listed have known optical counterparts, but these are listed in the hope that these counterparts may yet be identified. Ideally the optical magnitude of the sources should be brighter than 18, and it should be constant to 0.5 magnitude. The object should be stellar-like, free of nebulosity, and have no nearby companion (less than 1″). The sky coverage should be as uniform as possible, although it is recognized that at present the lack of observatories in the southern hemisphere restricts the coverage at high negative declinations, and the zone of avoidance restricts primarily the right ascension coverage.

At present, because it is impossible to definitely identify the best sources, the list of candidate sources has been divided into a primary and a secondary list. The primary list contains those sources which at this time are known to be good sources that should be used in establishing the reference frame. The secondary sources are those for which there is inadequate knowledge, i.e. poor radio or optical position, uncertain identification, lack of knowledge of radio or optical structure, etc. In addition to these lists, there is a third list of galactic objects which display radio emissions and are bright optically. These objects include binary stars, infrared objects, masers, etc.

Unfortunately, the optical astrometry contains possible systematic errors, perhaps as large as 0.″1. For instance, among the sources on the USNO optical program that are on the above primary list and have more than one position published in the recent, high-precision radio and optical lists, a radio mean point has both an internal and an external error of about 0.″05, indicating no systematic radio errors at that level. However, whereas an optical mean point has an internal mean error also around 0.″05, it has an external error of about 0.″08, indicating a formal systematic error of about 0.″06. This could be due, for instance, to catalog errors in one or more of the catalogs to which the positions are ultimately referred, or it could be due to a magnitude error in one or more of the telescopes used in the cascading process, or it could be due to one or more other, unforeseen, causes. Before the optical reference frame can be adequately referred to the radio frame, at the precisions now possible, these systematic errors must be identified and eliminated.

A secondary objective of this working group, therefore, is to prepare a core list of objects that would be suitable for use in trying to solve the systematic error problem. The objects on this list must be from the above primary list, in order that we can be sure the radio positions are suitable standards. They must meet all of the above optical characteristics, particularly as to magnitude, in order that they will be bright enough to be observed on all participating programs. (NRAO 512 *does not meet this criterion, but it is in the same field as 3C345 and therefore is of special interest.)* The list must be short enough but have adequate coverage to permit all observatories to observe all objects a sufficient number of times. Therefore, we present a fourth list of objects which, for the most part, have a significant observational history, but which should continue to be observed routinely for calibration purposes. These objects are denoted by an * on the primary list.

The working group makes the following specific recommendations:

(1) The objects on the primary list should receive the maximum possible optical and radio attention, to insure the highest-quality positions and information on structure, which will therefore make these objects suitable as an inertial reference frame at the milliarcsecond level for space astrometry.

(2) That the publication of radio catalogs contain clear references to the radio frequency, epoch of observation, the equator and equinox and the values of the principal astronomical constants used in the reduction process.

(3) The objects on the secondary list should continue to be surveyed, both to improve knowledge of structure and to improve positional, and therefore identification, information. These objects may become of quality to be on the primary list.

(4) Additional objects should be observed for radio structure and optical counterparts as facilities permit, for possible later inclusion on either of the above lists.

(5) The core list should be observed as intensively as possible by all groups carrying out either optical or radio astrometry of these sources, to make possible a complete analysis of the systematic errors present before the space astrometry programs go into operation.

Members of the Working Group

	A. N. Argue	University of Cambridge
	B. Elsmore	Cavandish Laboratory
	R. S. Harrington	U.S. Naval Observatory
Chairman:	K. J. Johnston	Naval Research Laboratory
	I. Kumkova	Pulkova Observatory
	C. DeVegt	Hamburger Sternwarte
	H. Walter	Astronomisches Rechen-Institut
	A. Witzel	Max-Planck Institut für Radioastronomie

The lists of primary and secondary sources are displayed in Table Ia and Ib. The columns are:

Column 1	Source	Source designation in IAU coordinates. * denotes core list of objects
Column 2	$\alpha_{(1950)}$	Right ascension based upon epoch 1950.
Column 3	$\delta_{(1950)}$	Declination based upon 1950 epoch.
Column 4	S(5 GHz)	Radio flux at a frequency of 5 GHz in Janskys. Thus flux for most sources is variable, and this flux should be taken as a very imprecise source flux for measurements at any particular epoch.
Column 5	I.D.	Source identification: Q-quasar G-galaxy BSO-blue stellar object Lac-BL Lacertae object
Column 6	m_v	Visual magnitude. Again since these sources are quite variable in their visual luminosity, this number should be taken as a very imprecise indication of the visual magnitude at any epoch.
Column 7	Z	Redshift.

Table Ia
Primary Sources

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) Z
0016+731	$00^h 16^m 54^s.14$	+73° 10′ 51″.6	1.72	Q?	18.0	
0106+013	01 06 04.523	+01 19 01.06	3.7	Q	18.4	2.107
0133+476	01 33 55.11	+47 36 13.0	2.0	Q?	19.0	
0153	01 53 04.25	+74 28 05.5	1.09	Q?	16.0	
0212+735	02 12 49.87	+73 35 40.2	2.24	Q?	19.0	
0237–027	02 37 13.71	–02 47 32.5	0.88	Q	19.5	
0237–233*	02 37 52.8	–23 22 06.4	3.33	Q	16.6	2.224
0300+471	03 00 10.12	+47 04 33.7	2.20	Q		
0316+413*	03 16 29.566	+41 19 51.90	50.0	G	12.7	0.018
0331–403	03 32 25.23	–40 18 23.4	1.47	Q	18.5	1.445
0333+321*	03 33 22.406	+32 08 36.65	2.4	Q	17.0	1.263
0336–019*	03 36 58.954	–01 56 16.86	2.2	Q	17.5	0.852
0338–214	03 38 23.27	–21 29 07.5	1.28	G	18.0	0.048
0402–362	04 02 02.59	–36 13 11.8	1.0	Q	16.0	1.417
0420–015	04 20 43.55	–01 27 28.7	2.0	Q	18.0	0.915
0422–380	04 22 56.16	–38 03 09.0	1.08	Q	50.78	
0438–436	04 38 43.18	–43 38 53.5	5.0	Q	19.8	2.852
0454+844*	04 54 57.02	+84 27 53.1	1.57	G?	16.5	
0518+165	05 18 16.526	+16 35 26.85	4.0	Q	19.0	
0537–441	05 37 21.07	–44 06 45.0	4.20	Q	15.5	0.894
0552+398	05 52 01.408	+39 48 21.93	5.0	Q	18.0	2.365
0615+820	06 15 32.80	+82 03 56.5	0.99	Q	17.5	
0636+680	06 36 47.64	+68 01 27.2	0.52	Q	19.0	
0642+449	06 42 53.020	+44 54 30.85	0.9	Q	18.0	
0736+017	07 36 42.51	+01 44 00.1	2.13	Q	18.0	0.191
0738+313	07 38 00.18	+31 19 02.1	2.0	Q	17.5	0.630
0814+425	08 14 51.672	+42 32 07.68	1.7	Q	18.5	
0828+494	08 28 47.94	+49 23 33.4	1.4	Q	18.5	
0831+557*	08 31 04.379	+55 44 41.36	5.6	G	17.5	
0839+187	08 39 14.076	+18 46 27.20	1.4	BSO	16.5	
0859+470	08 59 39.99	+47 02 56.9	1.9	Q	18.7	
0923+392*	09 23 55.318	+39 15 23.57	7.4	Q	17.0	0.698
0954+253	09 53 59.742	+25 29 33.55	1.6	Q	17.5	0.712
0954+556	09 54 14.34	+55 37 16.6	2.3	Q	17.5	
0954+658	09 54 27.86	+65 48 15.5	0.8	Q	18.7	
0955+326	09 55 25.403	+32 38 23.05	1.0	Q	16.0	

Table Ia (continued)

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) Z
1030+415	$10^h 30^m 07^s.79$	$+41° 31' 34''.9$	0.9	Q/Lac	18.2	
1034–293	10 34 55.82	–29 18 26.9	1.78	Q	18.0	
1104–445	11 04 50.37	–44 32 52.7	2.54	Q	18.0	
1127–145*	11 27 35.68	–14 32 54.8	5.39	Q	16.9	1.187
1143–245	11 43 36.37	–24 30 52.7	1.16	Q	18.5	1.95
1148–001	11 48 10.13	–00 07 13.2	2.5	Q	17.6	1.982
1155+251	11 55 51.641	+25 06 59.86	0.9	G	17.5	
1219+285	12 19 01.102	+28 30 36.49	1.6	Q	14.5	
1226+023*	12 26 33.246	+02 19 43.38	33.5	Q	13.0	0.158
1252+119	12 52 07.70	+11 57 21.3	0.97	Q	16.6	0.87
1253–055*	12 53 35.832	–05 31 08.01	14.0	Q	16.8	0.536
1328+254	13 28 15.924	+25 24 37.58	3.3	Q	18.0	1.055
1328+307	13 28 49.660	+30 45 58.70	7.4	Q	17.0	0.846
1404+286*	14 04 45.615	+28 41 29.23	3.0	G	14.0	0.077
1442+101	14 42 50.476	+10 11 11.89	1.2	ST	18.5	
1502+106	15 02 00.159	+10 41 17.71	2.2	Q	19.4	1.833
1510–089*	15 10 08.92	–08 54 48.0	1.2	Q	17.8	0.361
1519–273	15 19 37.23	–27 19 29.6	2.0	Q	18.5	
1555+001	15 55 17.688	+00 06 43.54	2.1	Q	19.0	
1611+343	16 11 47.912	+34 20 19.83	2.3	Q	18.0	1.404
1616+063	16 16 36.55	+06 20 13.9	0.9	Q	19.0	
1634+628	16 34 01.057	+62 51 41.83	1.6	Q		
1638+398*	16 38 48.173	+39 52 30.09	0.6	Q	17.0	
1641+399*	16 41 17.608	+39 54 10.82	7.2	Q	16.3	
1642+690	16 42 18.03	+69 02 13.2	1.6	Lac	19.2	
1656+571	16 56 26.48	+57 10 26.0	0.6	Q	17.4	
1705+456	17 05 50.42	+45 40 01.9	0.4	Q	17.4	0.646
1726+455	17 26 01.03	+45 33 05.4	0.9	Q	18.5	
1730–130	17 30 13.536	–13 02 45.93	5.2	Q	18.5	
1741–038	17 41 20.619	–03 48 49.02	2.2	Q	18.5	
1749+701	17 49 03.38	+70 06 39.5	2.1	Q	17.5	
1807+698*	18 07 18.547	+69 48 57.07	1.9	Lac	14.2	0.051
1921–293	19 21 42.18	–29 20 24.9	6.1	Q?	17.5	
1928+738*	19 28 49.34	+73 51 44.7	3.11	Q	15.5	
1954+513	19 54 22.44	+51 23 46.6	1.3	Q	18.5	1.230
2005+403	20 05 59.560	+40 21 02.80	4.5	Q	19.5	1.736
2008–159	20 08 25.90	–15 55 37.6	1.0	Q	18.0	

Table Ia (continued)

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) Z
2134+004	$21^h34^m05^s.19$	+00° 28′ 25″.3	10.6	BSO	18.0	
2200+420*	22 00 39.363	+42 02 08.58	3.0	Lac	14.0	0.07
2201+315	22 01 01.432	+31 31 05.87	1.5	Q	14.5	
2223–052	22 23 11.08	–05 12 17.8	3.6	Q	18.4	1.404
2230+114*	22 30 07.810	+11 28 22.76	4.0	Q	17.3	1.037
2251+158*	22 51 29.522	+15 52 54.31	9.0	Q	16.1	0.859
2345–167	23 45 29.691	–16 47 52.79	2.3	Q	15.0	0.6
2352+495	23 52 37.790	+49 33 26.76	1.8	G	19.0	0.237

Table Ib
Secondary Sources

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) Z
0116–219	$01^h16^m32^s.48$	–21° 57′ 17″.5	0.49	Q?	19.0	
0134+329	01 34 49.826	+32 54 20.52	5.6	Q	16.5	
0150–334	01 50 56.95	–33 25 09.6	0.74	Q	16.5	0.610
0224+671	02 24 41.164	+67 07 39.70	2.0	EF		
0229+132	02 29 02.52	+13 09 40.4	2.0	Q	18.0	2.065
0430+052	04 30 31.602	+05 14 59.58	6.0	S	15.0	0.032
0529+075	05 29 56.39	+07 30 40.5	1.53	Q	19.0	
0607–157	06 07 25.98	–15 42 03.4	2.35	Q	17.0	
0735+178	07 35 14.13	+17 49 09.3	2.0	Lac	16.0	
0945+408	09 45 50.08	+40 53 43.5	1.6	Q	17.5	1.252
0952+179	09 52 11.795	+17 57 44.47	0.9	Q	18.0	
0959–443	09 59 58.76	–44 23 30.0	0.44	Q	17.0	0.840
1055+018	10 55 55.31	+01 50 03.7	2.79	Q	18.0	0.888
1215+303	12 15 21.141	+30 23 39.93	0.4	Q	14.5	
1311+678	13 11 45.06	+67 51 42.2	0.92	BF		
1430–178	14 30 10.65	–17 48 24.1	0.9	Q	19.0	
1451–375	14 51 18.28	–37 35 22.6	1.0	Q	17.0	0.314
1514+197	15 14 40.981	+19 43 10.80	0.5	G	19.5	
1517+204	15 17 50.614	+20 26 53.03	0.8	G	19.5	
1629+680	16 29 50.82	+68 03 38.7	0.4	Q	18.7	
1637+626	16 37 55.286	+62 40 34.24	1.4	G	22.5	

Table Ib (continued)

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) Z
1716+686	$17^h16^m27\overset{s}{.}82$	$+68°39'48\overset{''}{.}3$	0.7	Q	18.5	
1739+522	17 39 29.00	+52 13 10.4	1.5	Q	18.5	
1749+096	17 49 10.39	+09 39 42.7	1.6	Lac	18.0	
1821+107	18 21 41.65	+10 42 44.0	1.4	Q	16.0	
1823+568	18 23 14.99	+56 49 18.0	1.5	Q	18.4	
1849+670	18 49 16.48	+67 02 07.8	0.5	Q	18.0	
1901+319	19 01 02.313	+31 55 13.81	1.8	Q	17.5	
1933–400	19 33 51.11	–40 04 47.1	1.0	Q	19.0	
2227–399	22 27 44.99	–39 58 16.9	0.7	Q	18.0	0.323
2254+074	22 54 45.965	+07 27 08.40	0.5	BSO	15	
2331–240	23 31 17.85	–24 00 13.3	1.0	G	16.5	0.048

The list of galactic objects is displayed in Table II. The columns are:

Column 1	Source	Source name – usually variable star designation.
Column 2	$\alpha_{(1950)}$	Right ascension at epoch 1950 in hours, minutes, and seconds.
Column 3	$\delta_{(1950)}$	Declination at epoch 1950 in degrees, minutes, and seconds.
Column 4	S (5 GHz)	Flux at a radio frequency of 5 GHz in Janskys. The fluxes reported in the literature for most of these stars is usually the maximum radio flux emitted by this object. Note again most of these stars are extremely variable in their radio flux.
Column 5	I.D.	Source identification: 1 = Flare star 2 = Normal single star 3 = Double or multiple stars 5 = X-ray stars 6 = peculiar stars (dwarfs, magnetic stars) 7 = shell stars or other emission line stars
Column 6	m_v	Visual magnitude
Column 7	d_{pc}	Distance in parsecs
Column 8	Comments	

Table II
Galactic Objects

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) d pc	(8) Comments
UU Psc	$00^h12^m24^s.12$	$08°32'36''.6$	0.01	3	5.9	71	
UV Psc	01 14 18.59	06 32 53.6	0.0	3	9.1	125	
HR 407	01 22 51.41	23 15 07.6	0.005	3	6.0	90	
Ls+61°303	02 36 40.60	61 00 54.0		5	11.4*	>1,000	*m_b
β Per	03 04 54.36	40 45 52.5	1.0-0.01	3	2.2	25	FK4-111
CC Cas	03 10 07.40	59 22 38.5	0.01	3	7.1	1,000	
UX Ari	03 23 33.15	28 32 31.7	0.10-0.01	3	6.5	50	
HR 1099	03 34 13.13	00 25 31.0	1.0-0.05	3	5.9	35	
T53B	03 46 15.00	24 08 20		1	15.5	126	
DM+09°549	04 10 50.08	10 05 11.9		2	6.2	126	
b Per	04 14 28.44	50 10 28.6	0.01	3	4.6	56	
DM+18°734	04 45 46.28	18 37 40.3	<0.0005	3	6.8	83	
V371 Ori	05 31 10.00	01 54 53.0		1	11.7	15	
α Ori	05 52 27.78	07 23 57.7	0.005	2	1.9	200	FK4-224
π Aur	05 56 13.36	45 56 04.2	0.01	7	4.5	167	
σ Gem	07 40 11.39	29 00 22.3	0.01	3	4.3	59	
Ross 882	07 42 04.00	03 40 48.0	0.05	1	11.8	5	
54 Cam	07 58 32.15	57 24 51.2	0.01	3	6.4	38	
ζ Pup	08 01 49.55	-39 51 41.0		2	2.3	450	
γ Vel	08 07 59.45	-47 11 18.3	0.036	3	1.8	350	
RU Cnc	08 34 33.73	23 44 12.8	0.006	3	11.6	190	
TY Pyx	08 57 34.04	-27 37 10.5		3	7.5	55	
κ Dra	12 31 21.43	70 03 48.7	0.02	6	3.8	100	FK4-472
HR 5110	$13^h32^m33^s.92$	$37°26'16''.6$		3	5.0	46	FK4-502
ZZ Boo	13 53 51.82	26 09 46.1	0.009	3	6.8	116	
Cir X-1	15 16 48.30	-56 59 14.0		5	~16	>10,000	
σ CrB-A	16 12 48.27	33 59 02.2	0.016	3	5.8	23	
Sco X-1	16 17 04.47	-15 31 15.8	0.033	5	12.5	500	
α Sco	16 26 20.21	-26 19 22.0	0.01	3	1.1	130	FK4-616
Ry Sct	18 22 42.71	-12 43 09.2	0.1	3	9.7	2,100	
β Lyr	18 48 13.96	33 18 12.2	0.01	3	3.4	260	FK4-705
SS 43319	19 09 21.32	04 53 52.9	0.5	1	14.2	3,500	
Cyg X-1	19 56 28.87	35 03 55.0	0.02	5	8.9	2,000	
HD 192163	20 10 17.30	38 12 14.9	0.003	7	7.2		
P Cyg	20 15 56.54	37 52 35.2		7	4.7	1,800	
DM+43°3571	20 18 46.71	43 41 42.9		3	7.7	1,600	

Table II (continued)

(1) Source	(2) $\alpha_{(1950)}$	(3) $\delta_{(1950)}$	(4) S (5 GHz)	(5) I.D.	(6) m_v	(7) d pc	(8) Comments
Cyg X-2	21 42 36.50	38 00 21.9	0.003	5	14.0		
RT Lac	21 59 28.63	43 38 56.0	0.02	3	8.8	200	
AR Lac	22 06 39.41	45 29 46.2	0.01	3	6.1	50	
DM+54°2846	22 42 05.68	55 19 35.1		6	8.8		
EV Lac	22 44 39.98	44 04 35.5		1	10.2	5	
HD 216489	22 50 34.48	16 34 31.9	0.033	3	5.7	112	
HR 8752	22 57 58.20	56 40 36.8	0.01	7	5.0	1,700	
SZ Psc	23 10 50.54	02 24 08.9		3	7.7	100	
λ And	23 35 06.61	46 11 10.9	0.065	3	3.9	23	
HD 224085	23 52 29.08	28 21 17.9	0.08	3	7.5	29	