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OBSERVATIONS OF DISCRETE SOURCES AT 10 CM AND 40 CM WAVELENGTHS

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Abstract

Results are given of observations of 44 discrete sources at 10 and 40 cm wavelengths. The results are given as ratios of source flux density to Cassiopeia A flux density. Most of the sources observed are associated with extragalactic objects.

I. INTRODUCTION

The work reported here is part of a program begun two years ago to provide a homogeneous set of observational data for studying the spectra of discrete radio sources. In order to avoid many of the problems of absolute flux measurements and to achieve as high internal consistency as possible, all observations are obtained in the form of ratios of source flux density to standard source flux density. No attempt is made to determine flux densities on an absolute basis.

The intense galactic source Cassiopeia A has been adopted as the primary standard, because it has the best determined absolute spectrum of any radio source. It has, however, several serious disadvantages as a standard source. There is now evidence (Högbom and Shakeshaft 1961; Heeschen and Meredith 1961) that its intensity is decreasing at a fairly rapid rate, as was predicted by Shklovsky (1960). As the accuracy of observations is increased and as the time interval spanned by usable observations becomes greater, it will become necessary to take this secular decrease into account. In addition, because Cas A is several orders of magnitude more intense than most sources with which we are dealing, accurate comparisons are difficult. Finally, the fact that it is not visible to observers in the southern hemisphere is a considerable disadvantage. For these reasons it is desirable that, as soon as possible, some other sources be calibrated on an absolute basis and adopted as standards for further measurements.

Except for a few bright galactic sources, the observing list was chosen from sources which have been identified with extragalactic objects, or which are thought to be probably extragalactic on the basis of tentative identifications, small angular diameter, or high galactic latitude. Results of observations of some of these sources at other wavelengths have been previously published (Heeschen 1961; hereafter referred to as Paper I). The data at different wavelengths should be relatively free of systematic errors, since the same techniques were used in each case.

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II. OBSERVATIONS

The observations at 10 cm wavelength were made during the period October, 1960, to April, 1961; those at 40 cm were made during February - April, 1961. All observations were made with the 85-foot diameter Tatel telescope. The telescope beamwidths at the two observing wavelengths are given in Table 1.

TABLE 1

TELESCOPE BEAMWIDTHS

λ (cm)	Beamwidth (minutes of arc)	
	in α	in δ
10	16	16
40	69	68

The pointing accuracy of the telescope was, for these observations, about ± 1 minute of arc. In general, published positions of the sources were used; where serious discrepancies existed in the published position of a given source, the position was measured in the coordinate system of the telescope prior to measuring its source/Cas A intensity ratio. These position measurements were not put on an absolute basis and are not given here since an extensive program of accurate position measurements is in progress (Drake, in preparation). Errors due to telescope positioning are, in general, not significant, although the possibility of gross errors resulting from the use of inaccurate positions cannot be completely ruled out in the case of some of the 10 cm observations.

Both the 10 and 40 cm receivers used were Dicke-type radiometers, switching between the antenna and a dummy load. The 10 cm receiver, built by the Ewen-Dae Corporation, employed traveling wave tube amplifiers. As used for these observations, it had a 200 mc bandwidth centered at 3000 mc, and an overall system noise temperature of about 1200 °K. The 40 cm receiver was built at the Observatory by W. Waltman. It had an IF bandwidth of 2.7 mc and a system noise temperature of 500 °K. The receiver was operated without image rejection, at a local oscillator frequency of 750 mc/sec. Digital outputs were used with both receivers, and both had internal calibration signals obtained from argon noise sources inserted between the antennas and the receivers. Details of these features were described in Paper I.

The observing procedure and reductions were similar to those described in Paper I. Observations were made of the peak intensity of a source, relative to the internal calibration signal. These source/calibration ratios were then converted to source/standard source ratios by using observations of the standard source obtained the same day. At 40 cm, two secondary standards - 3C 123 and 3C 274 (M87) - were used in addition to the primary standard, Cassiopeia A. Only 3C 274 and Cas A were used as standards at 10 cm. The secondary standards were calibrated against Cas A, and all observations were finally reduced to source/Cas A ratios.

In order to minimize receiver linearity problems, approximately 10 db attenuation was inserted between the antenna and receiver during 40 cm observations of the stronger sources. This was done to establish the ratios Cyg A/Cas A, and M87/Cas A. The signal from M87 without attenuation is sufficiently weak that the receiver response is linear. It was therefore used as the secondary standard for unattenuated observations of all other sources at 40 cm wavelength. Linearity corrections were not required for the 10 cm observations.

All observations were made near the meridian, and were corrected for atmospheric absorption by the relation

$$I(z) = I(0)p^{(\sec z - 1)},$$

where I(z) is the intensity observed at zenith distance z. The values of log p used were -0.0028 at 40 cm and -0.0050 at 10 cm. They were obtained by interpolation from the values given in Paper I for other wavelengths. Corrections usually amounted to less than 0.5 per cent.

The results are shown in Table 2. Column 1 gives the source designation in the Cambridge 3C catalog (Edge et al. 1959), and column 2 the NGC number or common name. Columns 3 and 5 give the measured source/Cas A ratios, corrected for extinction. The corresponding internal probable errors are shown in columns 4 and 6. The parentheses in column 5 indicate values which may be subject to confusion errors, as described in section III. These source/Cas A ratios are peak intensity ratios. They are measures of the total flux density ratios only if both the source and standard source have angular diameters negligibly small compared to the antenna beamwidth. All of the sources are small compared to the antenna beamwidth at 40 cm, and for observations at this wavelength the ratios given in Table 2 are measures of the total flux density ratio. This is not the case at 10 cm, however, where many of the sources are not small compared to the beamwidth. In particular, the standard source, Cas A, has an angular diameter of about 4 minutes of arc, which necessitates applying corrections to all the 10 cm observations.

Corrections for source size were applied to the 10 cm results, using the method described in Paper I. The adopted diameters, shown in column 3 of Table 3, were taken from the 3C catalog or from Moffet (1960). A different method was used for eight sources having complex brightness distributions. Source models based on Moffet's measurements were integrated over the antenna beam pattern to obtain corrected values of flux density. These sources are denoted by asterisks in column 3 of the table. The few sources for which no diameter estimates were available were taken to be point sources. The corrected source/Cas A ratios are given in column 4 of Table 3. In no case did a correction amount to more than a few percent. Even if the corrections are uncertain by 50 per cent, their contribution to uncertainties in the final source/Cas A ratios is negligible except for the few strongest sources.

III. DISCUSSION

The principal uncertainty in the 40 cm results, which is not reflected in the internal probable errors given in Table 2, arises from the relatively poor angular resolution of the 85-foot telescope at this wavelength. According to von Hoerner's (1961) criterion, an 85-foot telescope operating at 40 cm wavelength becomes resolution limited at a flux density of about 3×10^{-26} w $m^{-2}(c/s)^{-1}$. The corresponding source/Cas A ratio is about 0.0007. At this flux level, there is a statistical uncertainty in any measurement of 20 per cent, due to the confusion or background "noise" from unresolved sources. The measurement of any particular source may of course be affected to a greater or lesser

TABLE 2

OBSERVED SOURCE/CAS A RATIOS

3 C No.	Name or NGC	λ = 10 cm		λ = 40 cm	
		Source/Cas A	p.e.	Source/Cas A	p.e.
26		0.0005	0.0001	0.0016	0.0003
28		.0005	.0001	(.0011)	.0006
29		.0017	.0003	—	—
33		.0051	.0001	.0052	.0003
40		<.0002	—	—	—
48		.0056	.0003	.0050	.0003
66		.0018	.0002	.0043	.0003
71	1068	.0022	.0001	.0020	.0002
75		.0023	.0001	(.0026)	.0003
78		≤.0002	—	(.0026)	.0001
84	1275	.0060	.0002	.0085	.0003
	1316	—	—	.0458	.0007
98		.0045	.0002	(.0043)	.0005
123		.0174	.0002	.0195	.0001
135		—	—	.0010	.0002
144	Tau A	.514	.005	—	—
161		.00784	.00004	.0067	.0001
171		.0013	.0001	(.0022)	.0001
191		.0007	.0001	.0011	.0001
196		.0051	.0001	(.0065)	.0001
218	Hyd A	.01533	.00004	.0194	.0001
219		.0029	.0001	.0040	.0001
234		.0017	.0001	(.0024)	.0001
	4038/9	.0005	.0001	(.0006)	.0001

TABLE 2 (continued)

3 C No.	Name or NGC	$\lambda = 10$ cm		$\lambda = 40$ cm	
		Source/Cas A	p.e.	Source/Cas A	p.e.
270	4261	0.0075	0.0001	0.0066	0.0002
	4374	.0029	.0001	.0019	.0001
274	4486	.077	.001	.0863	.0002
278	4782/3	.0034	.0002	(.0028)	.0001
295		.0080	.0001	.0094	.0001
298		.0018	.0001	.0038	.0002
310		.0023	.0003	(.0025)	.0001
315		.0017	.0001	(.0012)	.0002
317		.0014	.0002	.0014	.0001
327		.0038	.0002	.0048	.0001
338	6166	.0014	.0001	.0020	.0007
348	Her A	.0142	.0004	.0208	.0001
353		.0222	.0003	.0233	.0001
386		.0029	.0002	(.0022)	.0001
405	Cyg A	.489	.003	.727	.003
430		.0035	.0001	.0037	.0002
433		.0041	.0001	(.0037)	.0002
445		.0026	.0002	.0027	.0002
456		<.0002	———	<.0005	———
465		.0019	.0001	.0037	.0001

TABLE 3

10 CM OBSERVATIONS CORRECTED FOR SOURCE SIZE

3 C No.	NGC or Name	adopted diameter	corrected Source/Cas A	3 C	NGC or Name	adopted diameter	corrected Source/Cas A
26		P	0.0005	270	4261	*	0.0077
28		P	.0005		4374	P	.0029
29		P	.0017	274	4486	*	.078
33		P	.0050	278	4782/3	2.5	.0034
48		P	.0055	295		P	.0078
66		4'.0	.0018	298		P	.0018
71	1068	P	.0021	310		1.8	.0022
75		*	.0023	315		1.0	.0017
84	1275	*	.0060	317		P	.0013
98		3.0	.0045	327		2.0	.0037
123		P	.0171	338	6166	1.2	.0014
144	Tau A	3.3	.510	348	Her A	*	.0140
161		P	.0077	353		*	.0222
171		P	.0013	386		1.9	.0028
191		P	.0007	405	Cyg A	*	.481
196		P	.0050	430		P	.0035
218	Hyd A	P	.0150	433		P	.0040
219		*	.0029	445		1.6	.0026
234		P	.0017	465		5.0	0.0019
	4038/9	P	0.0005				

degree, but the extent of the uncertainty arising from confusion cannot be evaluated for a particular case. In column 5 of Table 2 results in parentheses indicate that a "bumpy" background was definitely present. These results perhaps have a higher probability of large uncertainty due to confusion than do the others.

At 10 cm wavelength the confusion limit is reached at a source/Cas A ratio of about .0001. Confusion is therefore probably not serious for any of the sources measured.

Some idea of the reliability of the 10 cm observations can be obtained by comparing them with recent observations at 9.6 cm, made with the 22 meter parabola of the Lebedev Physical Institute (Kuzmin, Levchenko, Noskova and Salomonovich 1960). Results for the eight sources common to the two lists are compared in Table 4. Here the Lebedev flux density measurements have been converted to source/Cas A ratios using their measured flux density of Cas A.

TABLE 4

Source	Kuzmin et al. 9.6 cm	NRAO 10 cm
3C 84	0.0096	.0060
123	.0193	.0171
144	.545	.510
218	.014	.0150
274	.076	.078
348	.014	.0140
353	.021	.0222
405	.441	.481

Except in the case of 3C 84 the agreement is generally good. The very large discrepancy for 3C 84 suggests a gross error in one of the two measurements.

It is also of interest to compare the results obtained by various observers for the two strongest sources, Cyg A and Tau A. In Table 5 our results for these two sources are compared with those of Kuzmin et al. (1960), Haddock, Mayer and Sloanaker (1954), and Broten and Medd (1960).

TABLE 5

Source	NRAO 10 cm	Kuzmin et al. 9.6 cm	Haddock et al. 9.4 cm	Broten and Medd 9.4 cm
Cyg A	.481	.441	.467	.507
Tau A	.510	.545	.533	.530

Although the agreement is fair, it is perhaps somewhat surprising that the source/Cas A ratios for these strong sources are not determined more accurately than is apparently the case. Since the internal uncertainties are generally smaller than the differences between results of different observers, there may be systematic effects arising from different observing and reduction techniques and different equipment.

Judging from Tables 4 and 5, systematic differences between our results and those of other observers are probably not greater than 10 per cent. We believe that the systematic effects between observations at different wavelengths presented here and in Paper I must be still smaller.

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