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31.4-GHz FLUX DENSITY MEASUREMENTS OF A COMPLETE SAMPLE OF SOURCES FROM THE 5-GHz S5 SURVEY

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ABSTRACT

Measurements at 31.4-GHz (9.5-mm) are presented for the complete sample of 66 radio sources with declinations greater than $+70°$ and 5-GHz flux densities greater than 0.5 Jy. About half the sources have the flat radio spectra characteristic of objects with compact components radiating most strongly in the mid-centimeter wavelength range, and about one third show evidence of very compact components ($\theta \lesssim 0\rlap{.}''0001$) radiating at short centimeter wavelengths regardless of morphological type. The median spectral index of all the sources, the quasars alone, and the galaxies alone tends to flatten with increasing frequency for steep spectrum sources, whereas a steepening was found with increasing frequency for the flat spectrum sources.

I. INTRODUCTION

Kühr *et al.* (1981) presented the results of the 5-GHz strong source survey (S5) covering the declination range $+70° \geqslant \delta \geqslant +90°$ and included measured flux densities of the sources, obtained with the Max-Planck Institut für Radioastronomie 100-m antenna, at 2.7, 5, and 10.7 GHz. The present work continues our study of S-survey sources at millimeter wavelengths (Witzel *et al.* 1978; Geldzahler and Witzel 1981—hereafter referred to as GW) and extends the knowledge of the source spectra of the S5 objects to 31.4 GHz for the complete sample of 66 objects with 5-GHz flux densities $S \geqslant 0.5$ Jy, $\delta \geqslant +70°$, $b^{\rm II} \geqslant |10°|$. Objects exhibiting both flat and steep spectra at 5 GHz are represented in the sample in about equal number.

Our principal aims in doing this study were to extend the knowledge of the statistical distribution of 31.4-GHz flux densities and spectral indices for the S-survey sources in general, to learn more about the detailed spectra of the S5 sources in particular, and to help select those S5 objects whose high-frequency spectra indicate that further study is warranted at still higher frequencies and also with other observing techniques such as very long baseline interferometry. The results of this study, presented below, have met all our objectives, and we present here only the 31.4-GHz flux density measurements while awaiting the results of several other studies of the S5 sources.

II. OBSERVATIONS

The data were obtained on the NRAO* 11-m antenna at Kitt Peak between 4–7 October 1981. At the Cassegrain focus of the telescope a two-feed system was used producing two beams, each of which had half-power beamwidths of 3.6 arcmin and which were separated on the sky by 8.08 arcmin. During the observations, one beam continuously pointed at the source position, while the other was used continuously as a reference. At time intervals of 30 s the pattern was reversed by moving the telescope. A waveguide switch oscillating at 2 Hz connected the four incoming signals (each horn giving mutually orthogonal linear polarization) to an uncooled four-channel parametric amplifier centered at 31.4 GHz with noise temperatures of about 600 K and band passes of 1100 MHz each. During the 2-Hz cycle, each of the two feeds was thus alternately connected to each pair of channels which amplified and finally summed the total powers of the two polarizations. The two resulting outputs were synchronously detected and alternately subtracted from each other giving rms noise fluctuations in a 1-s integration equivalent to a 2.3-Jy source, which is roughly equal to a 3σ sensitivity of 150 mJy in a half-hour integration period.

Changes in receiver gain were monitored about every four hours using a noise signal equivalent to 8.4 K of antenna temperature. The pointing was checked and corrected at a similar interval using either 3C84, 3C345, or DR21. The changes in pointing, typically $\lesssim 15$ arcsec, correspond to uncertainties in the measured flux densities of about 0.5%–1.5%. Since these errors are considerably smaller than the measurement errors due to receiver noise, no corrections were applied to the data.

The total time spent observing a source was typically 20 minutes, although only ten minutes were spent on exceptionally strong sources, and 30 minutes on weak sources where the signal-to-noise ratio was $\lesssim 5$. The flux densities were scaled to that of DR21 which was ob-

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TABLE I. 31.4-GHz flux densities $\geq 3\sigma$.

Source	ID	Flux Density at 31.4 GHz	$\alpha(5,31.4)$	Spectral Index $\alpha(2.7,10.7)$	$\alpha(10.7,31.4)$	Other Catalogues
0013+790	E	0.42±0.10	−0.49±0.13	−1.07±0.02	−0.08±0.26	3C6.1, 4C+78.01
0014+813	Q	1.37 0.15	+0.50 0.06	+0.13 0.02	+0.58 0.10	
0016+732	Q	1.13 0.10	−0.21 0.05	+0.15 0.01	−0.45 0.08	
0048+892	E	0.33 0.08	−0.28 0.13	−1.01 0.04	+0.19 0.22	
0153+745	Q	0.62 0.09	−0.48 0.08	−0.32 0.01	−0.61 0.13	
0205+723	G	0.26 0.06	−0.41 0.12	+0.04 0.01	−0.97 0.21	4C+72.03
0210+861	G	0.71 0.10	−0.48 0.08	−1.56 0.04	+0.56 0.14	3C61.1
0212+736	BL	1.55 0.12	−0.19 0.04	−0.03 0.01	−0.36 0.07	
0403+768	E	0.86 0.13	−0.64 0.08	−0.58 0.01	−0.69 0.14	4C+76.03
0454+845	BL	1.22 0.11	−0.07 0.05	+0.24 0.02	−0.22 0.08	
0604+728	G	0.29 0.06	−0.36 0.11	−0.54 0.03	−0.23 0.20	4C+72.10
0615+821	Q	0.69 0.10	−0.20 0.09	−0.12 0.02	−0.20 0.13	
0633+734	Q	0.55 0.11	−0.11 0.11	−0.37 0.02	+0.11 0.19	
0716+714	BL	1.46 0.17	+0.14 0.06	+0.53 0.02	−0.29 0.09	
0718+793	E	0.51 0.10	−0.11 0.11	−0.19 0.02	+0.06 0.18	
0740+768	E	0.41 0.10	−0.19 0.13	+0.34 0.02	−0.29 0.23	
0740+828	E	1.01 0.11	+0.04 0.06	−0.50 0.02	+0.41 0.10	
0836+711	Q	1.26 0.08	−0.39 0.03	−0.43 0.01	−0.30 0.06	4C+71.07
0931+835	E	0.53 0.11	+0.01 0.09	−1.41 0.04	+1.00 0.09	3C220.3
0950+748	E	0.34 0.07	−0.39 0.11	−0.77 0.03	+0.00 0.19	
1003+831	G	0.99 0.08	+0.17 0.04	−0.12 0.02	+0.38 0.07	
1007+716	Q	0.19 0.05	−0.63 0.14	−0.97 0.03	−0.36 0.24	4C+71.09
1009+748	E	0.22 0.03	−0.56 0.07	−1.06 0.03	−0.22 0.13	4C+74.16
1039+812	Q	0.75 0.09	−0.23 0.06	−0.10 0.02	−0.04 0.11	
1044+719	E	0.47 0.08	−0.22 0.09	+0.19 0.02	−0.66 0.16	
1053+704	Q	0.55 0.08	−0.14 0.08	+0.28 0.02	−0.52 0.13	
1053+815	G	0.77 0.09	−0.00 0.06	+0.16 0.02	−0.41 0.11	
1058+727	Q	0.25 0.07	−0.63 0.15	−0.47 0.02	−0.75 0.26	4C+72.16
1150+813	Q	1.24 0.06	+0.03 0.03	−0.09 0.02	+0.11 0.05	
1157+733	E	0.67 0.09	−0.75 0.07	−0.82 0.01	−0.62 0.12	3C268.1, 4C+73.11
1221+809	Q	0.32 0.06	−0.25 0.10	+0.29 0.02	−0.58 0.17	
1322+835	E	1.22 0.08	+0.48 0.04	−0.11 0.03	+1.08 0.07	
1357+769	Q	0.57 0.09	−0.20 0.09	+0.02 0.02	−0.05 0.15	
1436+763	E	0.21 0.07	−0.56 0.19	−0.63 0.03	−0.50 0.31	4C+76.08
1448+762	E	0.74 0.07	+0.05 0.19	+0.29 0.02	−0.11 0.09	
1458+718	Q	0.56 0.06	−0.98 0.06	−0.69 0.01	−1.16 0.10	3C309.1, 4C+71.15
1612+798	E	0.39 0.08	−0.22 0.11	−0.67 0.03	+0.16 0.19	4C+79.15
1631+859	E	0.70 0.18	+0.10 0.14	−0.84 0.03	+0.78 0.24	
1637+826	G	1.06 0.12[a]	+0.04 0.06	−0.46 0.03	+0.35 0.11	
1749+701	BL	1.65 0.07[a]	+0.23 0.02	−0.35 0.02	+0.45 0.04	
1803+785	BL	2.43 0.08	−0.04 0.02	+0.08 0.01	−0.03 0.03	
1826+796	G	0.23 0.06	−0.49 0.14	+0.02 0.03	−0.64 0.24	
1845+795	G	0.78 0.06	−0.94 0.04	−0.86 0.05	−0.88 0.10	
1928+738	Q	1.17 0.09	−0.57 0.04	−0.09 0.01	−0.86 0.07	4C+73.18
2007+777	BL	1.20 0.07	−0.03 0.03	+0.21 0.01	+0.08 0.05	
2342+821	E	0.75 0.11	−0.31 0.08	−0.92 0.01	+0.13 0.13	

[a]Flux density taken from Witzel et al. (1978).

served several times each day and for which we assumed a flux density of 18.29 Jy (Ulich 1981). This flux density scale is consistent with the scale of Baars *et al.* (1977). The data were analyzed using the on-line data reduction system at the telescope site.

III. RESULTS

Our data for the 46 sources with measured flux densities $\gtrsim 3\sigma$ are presented in Table I which lists the IAU source designation in column 1, the optical identification in column 2, and the measured 31.4-GHz flux densities (Jy) and associated rms errors in column 3. Columns 4, 5, and 6 present two-point spectral indices ($S \propto \nu^{\alpha}$) and their errors for the range 5–31.4 GHz to make easy comparison with the results of Witzel *et al.* (1978) and GW, 2.7–10.7 GHz, and 10.7–31.4 GHz. The first index provides a broad composite spectral shape, the second is sensitive to sources radiating strongly at mid-centimeter wavelengths, and the third, although subject to large uncertainties due to the narrower frequency range, is more sensitive to the presence of young compact opaque source components.

The optical identifications generally are based solely on positional coincidence between VLA positions and accurate optical positions (Kühr 1983). A glass copy of the Palomar Sky Survey was inspected to determine whether the radio source was lying in an empty field (*E*, identifications from deeper plates were ignored in this paper so as not to introduce a bias in favor of the well-known sources, e.g., 3CR sources), near a blue, neutral, or slightly red and stellar object designated (*Q*), or near a very red or extended object, designated (*G*). This identification scheme was chosen for consistency with previous S surveys; e.g., Kühr 1977. Six confirmed BL Lac-type objects are given as BL.

For statistical studies of the complete S5 sample, two other sources not given in the S5 paper should be included; namely, 1557 + 70 and 1749 + 70, which were originally found in the S4 survey in a small region of overlap with the S5 (Pauliny-Toth *et al.* 1978). Neither source was measured during our observing run in October 1981. 1749 + 70, a BL Lac object, was nevertheless included in Table I and in our analysis using the flux density measurement at 31.4-GHz from Witzel *et al.* (1978). 1557 + 70 was not included since the flux density of the source is not known at either 10.7-or at 31.4-GHz. Table II presents the same information as Table I for those 20 sources with measured 31.4-GHz flux densities $< 3\sigma$. The spectral indices, however, between 31.4- and 10.7-, as well as those between 31.4- and 5-GHz, were derived by using our upper limit of 150 mJy at 31.4-GHz. Table III presents our 31.4-GHz measurements for ten sources in the S5 region which were not among the complete sample as defined in Sec. I.

IV. DISCUSSION

In order to study the frequency dependence of the flux densities on the widest possible scale for which essentially complete measurements are available at present, we examine in the following the two-point spectral indices between 2.7- and 10.7-, and between 10.7- and 31.4-GHz, respectively. The middle frequency of 10.7-GHz was chosen to give a roughly equal range in frequency space, rather than using the survey frequency of 5-GHz.

In Fig. 1 we present the distribution of spectral indices in the frequency range 2.7–10.7 GHz for our complete sample, as well as separately for those sources identified as quasars, galaxies, and lying in empty fields. The spectra were derived from Kühr *et al.* (1981). The

TABLE II. 31.4-GHz flux densities $< 3\sigma$.

Source	ID	Flux density at 31.4-GHz		$\alpha(5, 31.4)$[a]	Spectral index $\alpha(2.7, 10.7)$		$\alpha(10.7, 31.4)$[a]	Other catalogs
0010 + 775	*Q*	0.09 ±	0.07	− 0.90	− 0.73 ±	0.02	− 1.08	
0106 + 729	*G*	− 0.21	0.08	− 0.97	—		—	3C33.1, 4C72.01
0219 + 767	*G*	0.13	0.13	− 0.71	− 1.06	0.02	− 0.44	4C + 76.01
0223 + 775	*G*	0.07	0.07	− 0.82	− 1.18	0.02	− 0.55	4C + 77.03
0236 + 718	*E*	− 0.06	0.07	− 0.71	− 0.95	0.02	− 0.51	4C + 71.03
0407 + 747	*G*	0.14	0.06	− 1.01	− 0.88	0.02	− 1.10	4C + 74.08
0702 + 749	*G*	0.19	0.09	− 0.90	− 1.11	0.05	− 0.70	3C173.1, 4C + 74.12
0734 + 705	*E*	0.00	0.06	− 0.74	− 1.29	0.04	− 0.31	3C184.0
0734 + 805	*G*	0.04	0.08	− 1.10	− 1.42	0.08	− 0.55	3C184.1
0926 + 793	*G*	0.21	0.09	− 0.68	− 1.12	0.03	− 0.40	3C220.1, 4C + 79.06
0944 + 734	*G*	0.06	0.06	− 0.81	—		—	
1018 + 808	*G*	0.13	0.06	− 0.68	− 1.08	0.07	− 0.36	
1100 + 773	*Q*	0.33	0.13	− 0.89	− 0.81	0.02	− 1.02	3C249.1, 4C + 77.09
1650 + 758	*E*	− 0.15	0.07	− 0.80	− 1.08	0.04	− 0.51	4C + 75.06
1825 + 743	*G*	0.04	0.07	− 0.87	− 0.82	0.04	− 0.79	3C379.1, 4C + 74.23
1946 + 708	*G*	− 0.01	0.06	− 0.79	− 0.43	0.02	− 0.96	
2010 + 723	*Q*	− 0.23	0.05	− 0.99	− 0.26	0.02	− 1.49	4C + 72.28
2051 + 745	*G*	0.13	0.08	− 0.68	− 0.11	0.03	− 0.84	
2133 + 837	*E*	− 0.12	0.06	− 0.72	− 0.92	0.03	− 0.58	
2136 + 824	*Q*	0.00	0.09	− 0.66	− 0.40	0.02	− 0.89	

[a] Upper limit of 150 mJy at 31.4-GHz used.

TABLE III. S5 sources not included in the complete sample.

Source	ID	Flux Density at 31.4 cm	$\alpha(5,31.4)^a$	Spectral Index $\alpha(2.7,10.7)$	$\alpha(10.7,31.4)^a$	Other Catalogues
0027+703	E	0.06±0.07	-0.70	+0.21±0.02	-1.08	
0149+710	G	0.00 0.08	-0.78	-0.43 0.03	-1.10	
0802+734	E	0.31 0.08	-0.15±0.14	-0.28 0.03	+0.00±0.24	
0847+808	Q	0.39 0.10	+0.48 0.14	+0.00 0.07	+0.95 0.25	
0859+839	E	0.47 0.10	+0.59 0.12	--	--	
0903+685	Q	0.02 0.07	-0.38	-0.50 0.05	-0.06	
0916+864	Q	1.16 0.09	+0.83 0.05	-0.07 0.05	+1.63 0.09	
0925+754	E	0.26 0.08	-0.08 0.17	-0.11 0.04	+0.04 0.29	
1323+799	E	0.83 0.12	+0.32 0.08	+0.18 0.02	+0.45 0.14	
2255+702	Q	-0.10 0.06	-0.81	-0.98 0.03	-0.61	4C+70.24

[a]Upper limit of 150 mJy at 31.4 GHz used only for 0027+703, 0149+710, 0903+685, and 2255+702.

overall distribution is in agreement with the double-peaked shape characteristic for the 5-GHz Strong Source Survey sources (Pauliny-Toth *et al.* 1978) having maxima near $\alpha \approx 0$ and $\alpha \approx -0.8$. The median spectral indices, given in Table IV, indicate the expected significant differences for the three identification classes in the sense that among the flat spectrum sources quasars are more frequently found than galaxies, whereas the reverse holds for steep spectrum sources. This is a well-known phenomenon in high-frequency surveys for sources stronger than about 500 mJy (e.g., Pauliny-Toth *et al.* 1978; Kühr 1980; Peacock and Wall 1980).

In Fig. 2 we give the spectral index distribution of the same sources in the frequency range 10.7–31.4 GHz. For the sources from Table II not detected at 31.4-GHz, we used our approximate detection limit of 150 mJy at 31.4-GHz to calculate the spectral indices and included them in the distribution in order to avoid a bias against the weak and steep spectrum sources (these sources are marked by arrows in Fig. 2). For the complete sample, as given in Table IV, the distribution has a median value of $<\alpha(31.4/10.7)> = -0.37 \pm 0.07$. This median value is not affected by using the upper limits, but its dispersion is expected to grow with a growing detection rate at 31.4-GHz.

Comparing Figs. 1 and 2 and median values in Table IV we note that in a statistical sense there is a tendency for the spectra in this sample to flatten towards higher observing frequency; this effect is primarily observed in the empty field sources.

Figure 3 shows the spectral curvature of the individual sources in a two (radio-) color diagram where we used the same sample and the sample frequency ranges as in Figs. 1 and 2. Identified sources are given as par-

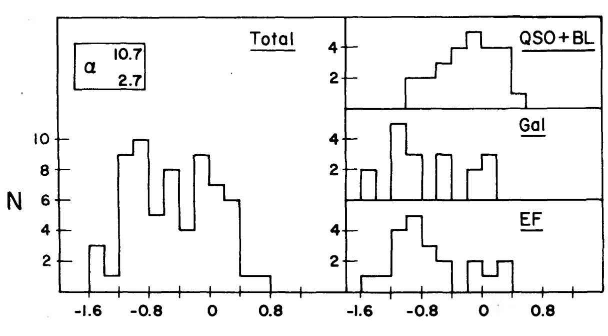

FIG. 1. Distribution of spectral indices between 2.7- and 10.7-GHz for all S5 survey sources of the complete sample (with the exception of 0106 + 729 and 0944 + 734 for which no flux densities at 10.7-GHz are available).

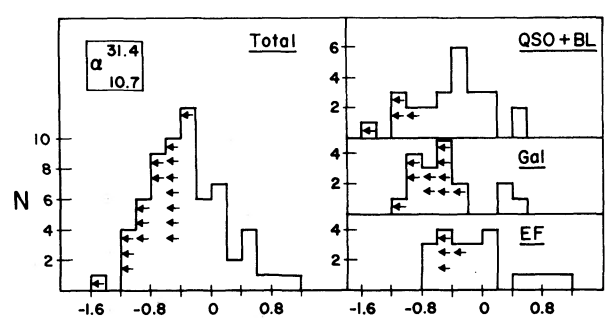

FIG. 2. Distribution of spectral indices between 10.7- and 31.4-GHz for same sample as in Fig. 1. Arrows indicate sources for which only upper limits were obtained.

TABLE IV. Median values of the spectral indices of sources presented in Tables I and II. The median values are presented since they are less sensitive than the means to a small number of extreme values of α. The error in α is estimated as the mean of the ranges, on each side of the median, which contain $\sqrt{N/2}$ sources.

	N	Median $\alpha_{2.7}^{10.7}$	Median $\alpha_{10.7}^{31.4}$
Total Sample	64	-0.50±0.10	-0.37±<u>0.07</u>[a]
Quasars & BL Lac's	25	-0.14 0.09	-0.35 0.10
Galaxies	18	-0.87 0.23	<u>-0.56 0.09</u>[a]
Empty Fields	21	-0.82 0.13	-0.17 0.15
Sources with flat spectra between 2.7 and 10.7 GHz			
	N	Median $\alpha_{2.7}^{10.7}$	Median $\alpha_{10.7}^{31.4}$
Complete Subsample	34	-0.04±0.06	-0.30±0.10
Quasars & BL Lac's	21	-0.06 0.09	-0.30 0.08
Galaxies	7	-0.05 0.11	-0.70 0.20[b]
Empty Fields	6	0.0 0.17	0.0 0.34
Sources with flat spectra, GW sample			
	N	Median $\alpha_{2.7}^{5}$	Median $\alpha_{5}^{31.4}$
Complete Subsample	180	+0.10±0.03	-0.31±0.03
Quasars	126	+0.10 0.03	-0.20 0.03
Galaxies	23	+0.01 0.04	-0.38 0.04

[a]Underlined values are subject to changes due to the upper limits used.

[b]Leaving out the undetected sources, as was done with the GW sample, would yield -0.50±0.35.

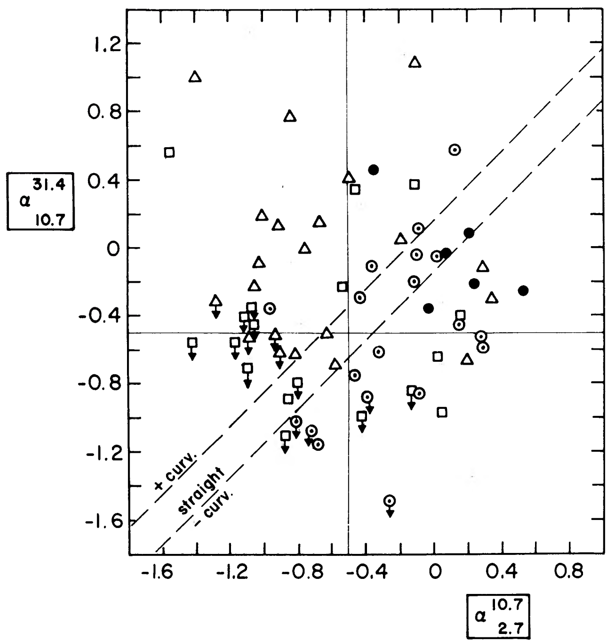

FIG. 3. Two (radio-) color diagram for same sample as in Fig. 1. Those sources lying between the dashed lines exhibit straight, power law spectra from at least 2.7- to 31.4-GHz; those above the dashed lines show positively curved spectra and those below negatively curved spectra. Arrows indicate sources for which only upper limits were obtained.

tially closed circles for the quasars, closed circles for the BL Lac objects, and squares for galaxies; the empty field sources are marked as triangles. The two diagonal parallel lines roughly indicate the boundaries between which a source would be found if it had a pure power law spectrum and typical errors of flux density as determined at the three different frequencies. It is interesting to note the following:

(i) The S5 sources of the complete sample are distributed roughly equally about the diagram indicating nearly equal numbers of steep ($\alpha < -0.5$) and flat, positively [$\alpha\,(10.7/2.7) - \alpha\,(31.4/10.7) < 0$] and negatively curved spectra.

(ii) Referring to those sources which exhibit steep spectra at 5 GHz, only three (0403 + 768, 1436 + 763, 1845 + 795, and possibly a few more of the sources, where only the upper limits of the higher frequency spectral indices were used) out of the 66 sources still show a steep and straight spectrum over the entire frequency range; the spectrum of one source (1458 + 718 = 3C309.1) only slightly indicates a high frequency cutoff expected from synchrotron radiation losses.

(iii) An extreme case of nuclear activity might have been detected in the galaxy 3C61.1 (in the upper left corner of the diagram) which is known to be a "classical" steep and straight spectrum source longward of 5 GHz; the flux density at 10.7-GHz, however, used to calculate the spectral indices, could have been significantly underestimated due to resolution effects—as recent observations at the VLA of this very extended radio source indicate (Kühr and Johnston, in preparation). Correcting for this effect would yield $\alpha\,(2.7, 10.7) = -0.088 \pm 0.02$ and $\alpha(10.7, 31.4) = -0.32 \pm 0.10$. There are two more sources for which a similar resolution effect might have changed their spectra, namely 0931 + 835 and 1009 + 74; corrected values for α (2.7, 10.7)/α (10.7, 31.4) would be $-1.04 \pm 0.03/0.53 \pm 0.10$ and $-0.80 \pm 0.04/-0.56 \pm 0.12$, respectively.

(iv) The spectra of the lower frequency flat spectrum sources comprise two different classes: First, those which originate from a single dominating quasi-compact component producing a typical synchrotron spectrum which peaks between 1 and 5 GHz (this type is typically found in the lower right quadrant of the diagram), and secondly, those where a superposition of several spectra, produced by about equally strong components of differing compactness, results in a flat undulating spectrum throughout the centimeter and millimeter wavelengths also showing variability (typically found in the upper right quadrant of the diagram).

In the present sample there are six known BL Lac-type objects (see Biermann *et al.* 1981 for five of them); they all belong to the second class of spectra described above. The data for those five objects given in this paper, together with mm/sub-mm measurements (Biermann, private communication), indicate flat or inverted radio spectra up to 300 GHz.

In the following we want to compare our results in Table IV with those given by GW for a similar complete sample of sources stronger than 1 Jy at 5 GHz (their use of α (5/2.7) and α (31.4/5), rather than α (10.7/2.7) and α (31.4/10.7) in this paper, was found to be of little influence). GW claim to observe steepening spectra with increasing frequency, an effect which should be even more pronounced had they included the undetected sources at 31.4-GHz and used upper limits in the distribution of α 31.4/5. This effect cannot be found in our S5 sample as a whole (there is actually a tendency for flattening spectra with increasing frequency with the empty field sources being more extreme than the others; see Figs. 1 and 2). Considering the fact, however, that the GW sample contains only 22% steep spectrum sources vs 48% in the S5 sample, it is only meaningful to compare the flat spectrum sources of each sample. The results of this comparison are given in Table IV. We find similar medians for the spectral index distributions studied in this paper and the GW sample, which are also in agreement with an earlier paper by Witzel *et al.* (1978).

This leads us to the conclusion that within our complete sample of high-frequency survey sources the tendency of steepening spectra with increasing frequency, found primarily in flat spectrum sources, is roughly compensated by the tendency of flattening spectra with increasing frequency, found primarily in steep spectrum sources. This effect is readily explained by studies of radio galaxies with very long baseline interferometry (Schilizzi 1976) and the VLA (Geldzahler and Fomalont 1978) which strongly suggest that most if not all radio galaxies, which constitute the bulk of the steep spectrum radio sources, encompass centrally located compact radio sources detectable with sufficient sensitivity. Thus, in general at high frequencies, the steep spectrum components contribute equally or less prominently than do the compact objects, so the spectra of steep spectrum sources will tend to flatten. On the other hand, at high frequencies, the spectra of the compact sources will tend to steepen since for both uniform and nonuniform models of such objects the size of the emitting region decreases with increasing frequency, while the flux density varies directly with size. This effect can be clearly seen in Fig. 3. Among the steep spectrum sources positive and negative curvature can be found in a ratio of about 5.5 to 1 (this ratio will probably decrease with a higher detection rate at 31.4-GHz), whereas the comparable ratio among the flat spectrum sources is about 1 to 2.5.

Finally, we note that the relative number of flat spectrum sources in complete samples of sources found at high radio frequencies decreases with lower flux density limits (Kühr 1980). It is, therefore, not meaningful to compare samples which are complete above different flux density limits.

V. CONCLUSIONS

Those sources with steep spectra between 2.7- and 10.7-GHz and inverted spectra between 10.7- and 31.4-GHz surely will be useful as high-frequency calibrators for the VLA and baseline amplitude calibrators for VLBI observations. They warrant further study at 31.4 GHz, 90 GHz, and infrared frequencies to determine whether their rising spectra are due to nonthermal emission arising from very young source components or are part of the transition region between the thermal and nonthermal emission as seen for example in the spectrum of M82 (cf. Kellermann and Pauliny-Toth 1971). Further studies of those nine empty field sources with rapidly rising high-frequency spectra should be pursued. In particular, accurate optical identifications and accompanying redshifts are highly desirable to discern just what kind of objects these are. Additionally, very long baseline interferometry at 1.3 cm of the three strongest should be initiated as soon as possible to follow the evolution of the (presumably) extremely young source components in these objects. This would be of great value since, with the exception of the superluminal sources, only the source 4C39.25 has been studied systematically over a long time base, ~ten years, and it is this source which is challenging current interpretations of apparent source morphology regarding the site of energy generation (Shaffer *et al.* 1977; Shaffer private communication). Clearly, however, more than one example of such an object is necessary to make any definitive statement regarding this point. The suggested VLBI observations will surely be helpful in discerning the appearance and changes in appearance of the energy generation site which in turn should lead to a better understanding of the nature of such sources.

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