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The Radiospectra of a Homogeneous Sample of 4C Radiosources

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Using observations at 178, 408, 1420 MHz the radiospectra of 136 sources in the declination range 29° 30′ — — 34° 30′ of the 4 C catalogue have been determined. From observations at 1420 MHz it is clear that the spectra of many sources flatten at frequencies below 408 MHz. There is evidence that this effect is more marked for sources with small angular diameter.

Key words: radiosources: accurate positions — radiospectra — 4 C radiosources — radiospectra: diameter correlations

In this paper we present a set of ratio data concerning a sample of 136 radiosources of the 4C catalogue (Pilkington and Scott, 1965) which are all the 4C sources in the region $07^h00^m00-18^h30^m00$ and 29°30′–34°30′. They have been observed at 408 MHz with the "Northern Cross Radiotelescope" and at 1420 MHz with the "Owens Valley Radio-interferometer".

The purpose of this work was to obtain the radio spectra of a homogeneous sample of relatively faint radiosources and information about their radio-structure.

Observations and Data Reductions

The observations at 21 cm were made using the Owens Valley radio-interferometer, in the period October 1967 – April 1968.

The radiosources were observed at spacings of 200 ft. N.S. and E.W., in different position angles (usually within 20 minutes of transit and 3 hours before and/or after the transit).

Afterwards about 30% of them was observed at 400 ft. E.W. and about 80% at 800 ft. E.W.

The integration time for each observation was 15 m, giving an effective noise r.m.s. flux density error of 0.05 F.U.

By using short baselines in different position angles we avoided large flux errors due to resolution effects and the possibility of lobe-shifts both in right ascension and declination.

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The technique of observation, calibration and data reduction is described by Fomalont (1967).

For 78 of the radiosources of our sample accurate positions and fluxes at 21 cm were reported by E.T. Olsen (1957).

New measurements on these radiosources confirmed essentially the previous data, except for 8 radiosources which were lobe-shifted or a blend of two radiosources. They are 4C 34.28, 32.32, 33.27, 33.37 (lobe-shifted in declination), 4C 30.31 (lobe-shifted in right ascension), 4C 32.37, 32.44, 32.52 (all blends of two radiosources).

The data at 408 MHz were obtained in the summer 1968, during a continuous sky survey program made with the Northern Cross radiotelescope in Bologna. The description of the instrument and of the observing procedure is given by Grueff and Vigotti (1968).

The flux scale calibration we have assumed is the one suggested by Kellerman (1964), which is almost coincident with that given by Conway, Kellerman and Long (1963) at 1420 MHz and is 8% higher at frequencies lower than 408 MHz. To compute the radiospectra, the fluxes of the 4C catalogue were increased by this factor.

We believe that our flux scale agrees with that of Kellerman within 5%.

The inaccuracy of the 21 cm fluxes, as derived from a comparison between the various measurements at short spacings, is of the order of 0.10 F.U. or better and is essentially due to confusion.

The errors in flux at 408 MHz are of the order of 5% of the total flux.

The position accuracy may be estimated by a comparison between the data at 21 cm and those at 408 MHz. It turns out that the r.m.s. errors are 0.5 s in R.A. and 0.4′ in δ, for both groups of measurements. Presently the optical fields of these radiosources are being studied and the identifications will be published in a forthcoming paper.

In the Table are reported the radio data of the whole sample. The following symbols are employed to indicate the accuracy of the radio position:

a) the difference between the interferometer and the cross R.A. (or δ) is less than 0.5^s (0.5′);

b) the difference between the interferometer and the cross R.A. (or δ) is $>0.5^s$ and $\leqq 1.0^s$ ($>0.5'$ and $\geqq 1.0'$);

c) the difference between the interferometer and the cross R.A. (or δ) is larger than 1.0^s (1.0′).

The reported right ascensions are those measured by the cross. Declinations are the average of the two values obtained with the cross and the interferometer except for the radiosources of class c, for which the declination of the cross was assumed.

The 21 cm flux of the radiosources observed by Olsen is taken from his paper. These radiosources are marked with *.

The last column gives information about the structure and the confusion situation at 21 cm for the strongest radiosources.

U.: the flux measured at the 800 ft. spacing agrees with that measured at 200 ft. (NS and EW) within 20%;

P.R.: the flux measured at the spacing of 800 ft. is 20–40% lower than that measured at 200 ft. (NS and EW);

R.: the flux measured at 800 ft. is less than 60% of the flux measured at 200 ft.;

C: slightly confused at 21 cm. This means that in the main beam of the interferometer there is another radiosource which has at 408 MHz a flux, at least 1/3 of the flux of the observed radiosource.

Radiostructures

In Figs. 1 and 2 are the distributions of the ratios of fluxes respectively at 400 ft. E.W. (575 λ) and 800 ft. E.W. (1150 λ) to the flux at 200 ft. N.S. (288 λ). If the resolution at this last spacing is small, those ratios are close to the fringe visibility amplitude at 575 λ and 1150 λ. So we shall call these two ratios simply "fr. vis. ampl." at the two mentioned spacings.

We can see that at 575 λ the mean "fr. vis. ampl." is about 6% lower than unit.

At 1150 λ the "fr. vis. ampl." distribution shows a higher resolution, its mean value being about 89% of unit.

At least three radiosource show clearly a double structure, their flux measured at the spacing of 400 ft. being significantly less than that measured at 800 ft. They are 4C 32.25, 32.29, 33.35. The E–W separation between the two components is of the order of 2.0′. For the remaining radiosources our data do not allow any individual interpretation. They will be used only for statistical purposes.

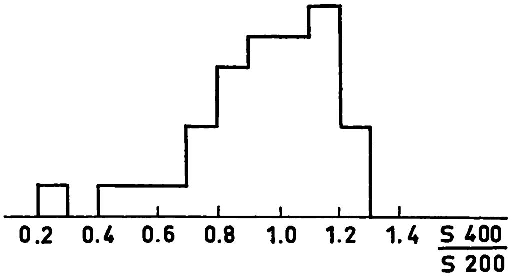

Fig. 1. Distribution of the ratios of the flux at 400 ft. E.W. to the flux at 200 ft. N.S.

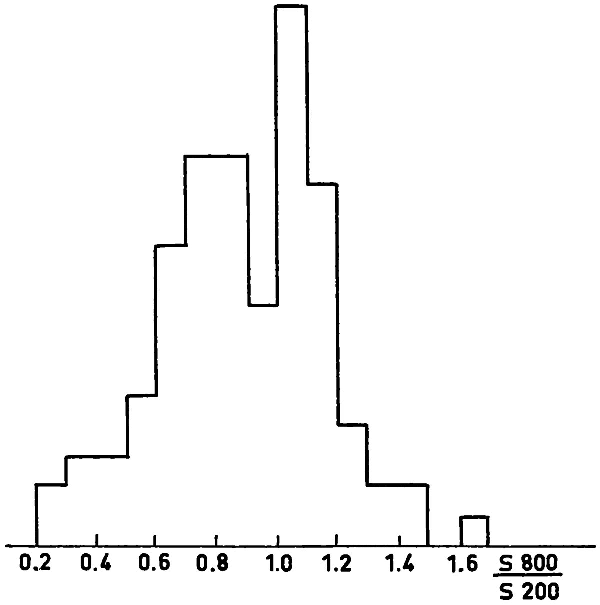

Fig. 2. Distribution of the ratios of the flux at 800 ft. E.W. to the flux at 200 ft. N.S.

Radio Spectra

We have computed the radio spectra for those 132 4C sources which are not strongly confused or not a blend of two radio sources.

A first search for a correlation between the mean spectral index and the flux density did not give any result. The mean value of the spectral indices for different classes of flux was found to be not significantly different.

In Fig. 3 and Fig. 4 are shown the distributions, for the complete sample, of the spectral indices α_1 and α_2 in the two frequency intervals of 178–408 and 408–1420 MHz.

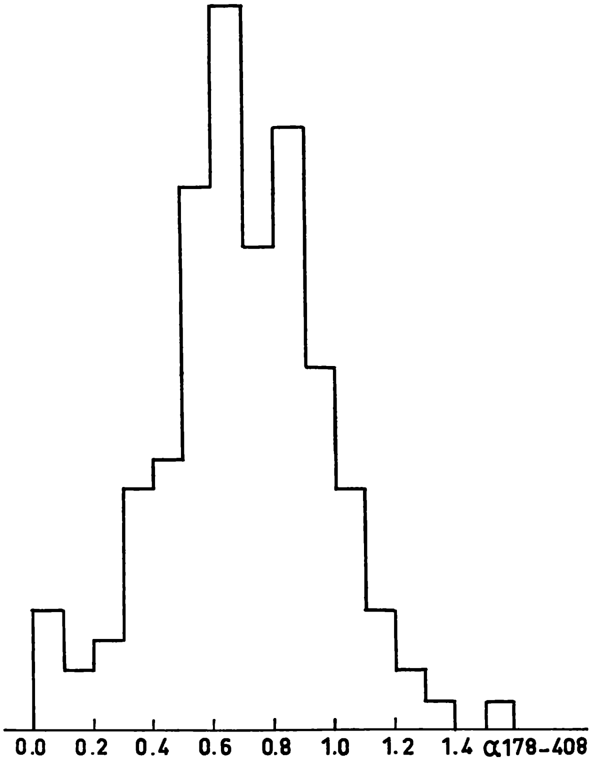

Fig. 3. Distribution of the spectral indices in the frequency interval 178-408 MHz

We have:

178– 408 MHz, $\alpha_1 = 0.70 \pm 0.02$, $\sigma_1 = 0.27$,

408–1420 MHz, $\alpha_2 = 0.81 \pm 0.015$, $\sigma_2 = 0.18$.

The two spectral distributions are peaked around two different mean values, with a mean difference of about 0.11.

Such a difference may be partially due to systematic errors in the calibration of the flux scales, but this is unlikely to account for the observed degree of curvature.

It seems to us that this curvature effect is due more likely to a flattening of the radio spectrum at low frequencies rather than to a steepening at high frequencies. It effects the distribution of the spectral indices for those radiosources with higher curvature

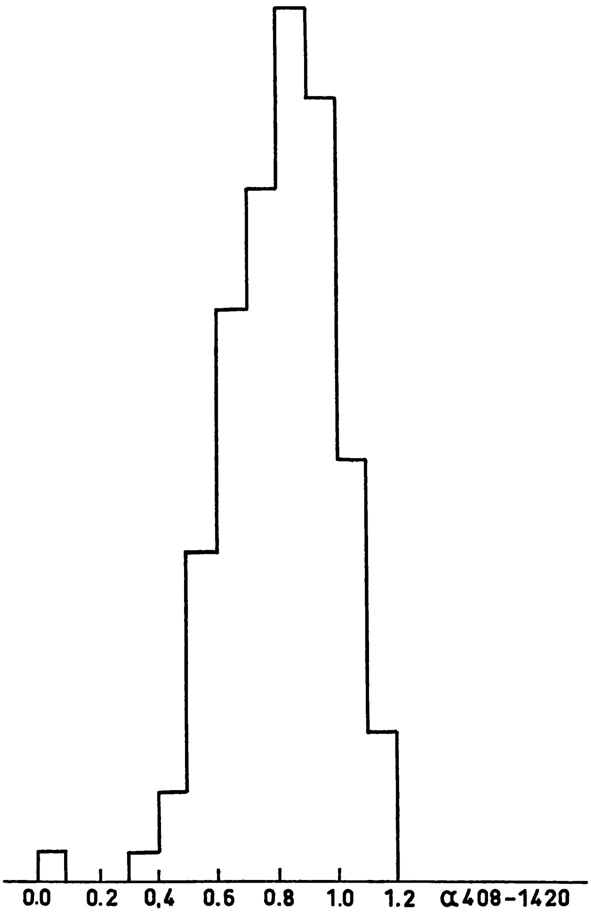

Fig. 4. Distribution of the spectral indices in the frequency interval 408-1420 MHz

($\alpha_2 - \alpha_1 > 0.35$), shows a mean value of 0.88 between 408 and 1420 MHz, while in the range 178–408 MHz it is considerably flatter ($\bar{\alpha}_1 = 0.43$) than the spectral distribution of the whole sample.

Furthermore there is clear evidence of a correlation between the radiodiameter and the curvature of the spectrum (defined as $\alpha_2 - \alpha_1$). This correlation is shown in Fig. 5, where it is reported the distribution of the curvatures respectively for those radiosources with 0.8 < "fr. vis. ampl. at 1150" (diameter smaller than 30″) and for those with "fr. vis. ampl. at 1150″ < 0.8 (diameter larger than 30″).

Table. *List of the observed* 4 C *sources*

Name	R.A.		Flux at 178 MHz	Flux at 408 MHz	Flux at 1420 MHz	
4 C 31.27*	072117.9 a	31°37.8 a	4.8	2.95	1.01	P.R.
4 C 31.28	072414.3 a	31°15.7 a	2.3	1.0	0.38	C
4 C 31.29	073100.3 c	31°45.5 b	2.3	1.25	0.36	
4 C 33.21	073241.9 a	33°14.0 a	7.4	5.65	2.40	U.
4 C 31.30	074230.8 b	31°50.3 b	4.4	2.75	1.27	R.
4 C 31.31*	074702.6 a	31°27.5 a	2.7	2.40	1.27	P.R.
4 C 34.26	074818.6 a	34°17.2 a	2.4	1.50	0.45	
4 C 29.26*	074941.4 a	29°54.5 a	2.9	1.60	0.55	
4 C 29.27	075151.1 a	29°49.8 a	2.4	1.15	0.37	
4 C 30.13*	080135.7 b	30°20.8 a	4.7	3.50	1.45	P.R.
4 C 30.14	080511.7 a	30°55.5 a	2.1	1.30	0.53	R.
4 C 32.24*	080950.2 a	32°52.4 a	5.1	3.60	1.26	
4 C 30.15*	081726.3 a	30°44.5 c	2.5	1.55	0.41	
4 C 34.28*	082203.8 c	34°16.5 c	3.8	1.65	1.16	R.
4 C 32.25	082819.0 c	32°29.8 c	2.4	4.00	1.60	P.R.
4 C 29.30	083658.4 a	29°59.9 a	2.0	1.60	0.70	U.
4 C 32.26	083805.7 a	32°35.5 a	2.0	1.60	0.79	R.
4 C 29.31*	084007.1 a	29°54.9 a	4.7	2.85	0.93	
4 C 31.32*	084454.9 c	31°58.7 a	5.7	3.05	1.00	
4 C 33.22	085016.2 c	33°06.2 a	2.0	1.15	0.60	U.
4 C 34.29*	085034.8 b	34°17.4 b	2.8	2.15	0.85	
4 C 30.16	085132.1 b	30°21.2 a	2.1	1.40	0.40	
4 C 34.30*	085433.1 c	34°15.7 a	8.5	5.45	1.83	
4 C 29.34	085810.7 b	29°57.7 c	2.4	1.25	0.53	
4 C 33.23	085930.9 a	33°22.0 b	2.7	1.25	0.50	
4 C 30.17	090331.4 b	30°23.6 a	2.4	2.00	0.75	U.
4 C 32.27*	090449.3 a	32°01.4 a	3.5	2.50	0.99	P.R.
4 C 31.33*	091910.9 a	31°24.0 a	6.0	3.35	0.88	
4 C 32.28*	092233.2 b	32°12.9 a	2.9	1.60	0.58	
4 C 32.29	092312.5 a	33°00.5 b	2.6	1.20	0.31	
4 C 31.34*	092734.4 a	31°25.1 a	3.3	1.35	0.42	
4 C 32.30*	092935.4 a	32°45.3 a	2.9	2.00	0.78	
4 C 32.31	093807.7 b	32°35.3 b	2.4	1.20	0.35	
4 C 32.32*	095501.8 c	32°05.1 c	4.0	1.75	0.74	R.
4 C 32.33*	095525.8 a	32°38.4 a	4.0	3.4	1.59	U.
4 C 32.34*	100139.6 b	32°06.3 a	6.4	3.9	1.45	
4 C 32.35	101626.9 a	32°57.0 b	2.4	1.65	0.58	U.
4 C 31.35*	101747.8 b	31°53.6 a	5.4	2.95	0.95	
4 C 30.18	102835.0 c	30°02.5 a	2.0	1.35	0.55	U.
4 C 34.32	103144.7 a	34°04.9 a	2.3	1.40	0.39	
4 C 32.36*	103602.7 b	32°21.8 a	3.5	2.10	0.74	
4 C 30.19	103743.4 b	30°13.5 a	2.0	1.15	0.35	
	103802.6 b	33°23.7 c		1.00	0.37	
4 C 33.24	103900.2 c	33°24.8 a	2.4	1.10	0.35	
4 C 29.39*	104440.4 c	29°44.0 a	2.5	1.75	0.62	
4 C 34.33*	104911.7 b	34°29.1 a	3.7	2.35	0.71	
4 C 30.20*	105721.2 a	30°42.9 a	6.1	3.40	0.86	
4 C 31.36	110558.7 c	31°29.0 b	2.1	1.20	0.42	
4 C 33.25	111159.6 a	33°18.6 a	2.4	1.60	0.66	C
4 C 29.41*	111354.5 b	29°31.7 a	5.5	4.35	1.99	
4 C 30.21*	112329.6 b	30°19.8 b	4.9	3.10	1.01	U.
4 C 33.26	112343.1 a	34°02.0 a	2.8	3.20	1.26	U.
4 C 32.37*	112522.5	32°47.7	3.5	1.60	0.70	
	112531.4	32°32.8		1.90	0.70	
4 C 32.38	112754.6 a	32°38.0 b	2.0	1.35	0.36	
4 C 33.27*	113030.1 c	33°59.3 c	4.1	2.20	1.08	
4 C 33.28*	113053.1 a	33°34.6 a	4.8	2.55	0.97	P.R.

Table (continued)

Name	R.A.		Flux at 178 MHz	Flux at 408 MHz	Flux at 1420 MHz	
4 C 30.22*	113217.0 b	30°21.5 b	6.5	3.90	1.12	
4 C 30.23*	114145.3 a	30°14.7 a	3.6	2.85	1.03	
4 C 31.37	114253.2 a	31°50.5 a	18.3	10.00	2.90	
4 C 28.44*	115138.7 b	29°32.7 a	6.7	5.35	1.72	
4 C 31.38*	115344.5 a	31°44.8 a	7.5	6.70	3.24	U.
4 C 29.45*	115658.2 a	29°31.5 a	2.8	2.95	1.98	U.
4 C 34.36	115818.5 c	34°33.4 b	2.4	1.25	0.41	
4 C 31.39	115825.2 a	31°50.5 a	9.7	4.10	1.10	
4 C 30.24	120109.1 a	30°54.0 a	2.4	1.30	0.47	
4 C 29.46*	120220.0 a	29°46.6 a	6.0	3.70	1.14	
4 C 32.39	121601.1 b	32°00.2 a	2.1	1.25	0.32	
4 C 33.29	121803.9 a	33°59.5 a	12.7	8.30	2.70	
4 C 31.40*	121923.4 b	31°47.7 a	5.1	2.9	0.73	
4 C 31.41	122638.0 a	31°54.1 c	2.2	0.7	—	C
4 C 32.40*	123642.9 a	32°47.0 a	2.9	2.1	0.86	U.
4 C 32.41*	124455.8 a	32°25.4 a	2.5	1.6	0.44	
4 C 33.30*	124727.0 a	33°39.9 a	3.6	2.7	1.42	R.
4 C 30.25*	124800.4 a	30°32.5 a	2.6	1.35	0.50	
4 C 33.31	125638.0 b	33°22.2 a	2.0	1.05	0.47	
4 C 32.42*	130929.2 c	32°43.7 c	3.9	2.35	0.69	C
4 C 29.47*	131643.0 b	29°54.2 a	3.2	2.55	1.11	U.
4 C 32.43*	132028.4 a	32°31.9 a	4.2	2.90	0.98	U.
4 C 29.48*	132041.8 a	29°57.2 a	4.0	3.35	1.50	U.
4 C 32.44*	132358.4 a	32°09.8 a		6.70	4.37	U.
	132513.6 a	32°07.0 a	5.8	2.50	1.22	U.
4 C 31.42*	132605.6 a	31°00.1 a	4.1	2.50	0.74	
4 C 33.32	132818.4 a	33°14.3 a	2.2	1.50	0.48	
4 C 30.26	132849.9	30°45.6	24.0	24.8	15.3	
4 C 32.45*	134046.9 a	31°59.1 b	2.7	1.8	0.99	
4 C 29.49*	134632.2 a	29°54.5 a	3.4	2.0	0.79	
4 C 31.43	135003.0	31°41.7	12.7	10.1	4.70	
4 C 32.46*	135432.0 b	32°34.6 a	4.3	2.55	0.73	
4 C 34.38	140433.2	34°26.0	10.3	5.35	1.30	
4 C 31.44*	140750.6 c	31°39.2 a	4.3	2.25	1.19	
4 C 31.45	141919.7 b	31°32.6 c	2.2	1.1	0.51	
4 C 30.27*	142251.0 b	30°40.5 c	2.6	1.25	0.69	C
4 C 31.46*	143306.7 a	31°54.0 b	4.5	2.45	0.70	U.
4 C 34.39*	143644.5 b	34°03.7 a	3.4	1.60	0.70	
4 C 33.33	145058.1 a	33°21.5 a	2.0	1.15	0.45	
4 C 33.34*	150228.2 a	33°55.6 a	3.5	2.0	0.63	U.
4 C 32.47	150404.0 a	32°20.0 a	2.3	1.7	0.50	
4 C 30.28	150538.3 c	30°24.3 c	2.0	0.90	0.35	
4 C 32.48*	151012.4 b	32°09.3 a	2.9	2.55	0.96	
4 C 33.35	151400.1 c	33°58.7 c	2.2	0.91	0.35	
4 C 34.41*	152842.2 c	34°04.3 c	3.3	1.00	0.37	
4 C 34.42*	153932.2 b	34°20.4 a	3.7	2.35	0.86	U.
4 C 30.29*	154712.1 b	30°56.2	6.8	4.30	1.30	
4 C 33.36*	154853.3 a	33°29.1 a	4.5	2.1	0.78	U.
4 C 33.37*	154930.3 c	34°04.5 c	3.9	1.50	0.56	
4 C 34.43*	155937.0 a	34°31.9 a	4.6	2.80	0.96	
4 C 33.38	160012.3 a	33°35.2 a	2.4	2.40	2.65	U.
4 C 32.50	160216.5 a	32°29.3 a	2.9	1.95	0.70	U.
4 C 33.39*	160810.1 a	33°06.4 a	7.2	5.25	2.11	U.
4 C 32.51	161546.6	32°30.1	9.5	7.00	2.50	
4 C 33.40*	161626.8 a	33°55.7 a	3.0	1.75	0.86	
4 C 30.30*	164043.6 a	30°01.6 a	3.9	2.10	0.62	
4 C 32.52	165709.0 a	32°33.5 b		1.25	0.29	

Table (continued)

Name	R.A.		Flux at 178 MHz	Flux at 408 MHz	Flux at 1420 MHz	
4 C 32.52	165831.8 a	32°37.9 c	3.3	1.30	0.49	
4 C 30.31*	165849.6 c	30°12.2 b	2.8	1.25	0.44	
4 C 29.50*	170210.7 a	29°51.2 a	6.6	3.35	1.49	
4 C 34.45*	170749.6 a	34°29.7 a	4.2	2.30	0.59	
4 C 29.51*	171135.9 a	29°52.0 a	2.7	1.30	0.57	
4 C 34.46*	171346.5 b	34°38.7 a	2.8	1.45	0.52	
4 C 34.47*	172131.5 c	34°19.8 b	5.0	2.60	1.11	
4 C 31.47	172627.4	31°48.8	9.7	6.15	2.50	
4 C 32.53*	172922.1 a	32°35.2 a	2.7	1.90	0.66	C
4 C 34.48	173522.8 a	34°09.5 c	2.3	1.05	0.50	
4 C 31.48*	173702.0 a	31°29.2 c	2.7	1.40	0.52	
4 C 33.41	173920.0 a	33°07.6 a	2.1	1.60	0.50	
4 C 31.49*	173907.5 a	31°06.6 a	3.3	2.05	0.86	C
4 C 33.42	173932.2 b	33°34.0 a	2.0	1.35	0.41	
4 C 29.52*	174002.4 c	29°29. 5c	2.9	1.20	0.63	C
4 C 29.53*	174950.8 a	29°51.5 b	5.1	2.60	1.09	R.
4 C 29.54	175911.9 c	29°51.0 b	2.3	1.25	0.52	
4 C 32.54*	180649.5 b	32°34.2 a	2.5	1.55	0.42	C
4 C 30.32	180820.0 a	30°47.7 a	3.5	2.00	0.67	
4 C 33.43	181103.3 a	33°36.4 a	2.2	1.50	0.55	
4 C 33.44*	181410.0 c	33°26.4 a	2.9	1.75	0.62	
4 C 29.55	182051.9 a	29°29.9 b	3.5	2.35	0.70	
4 C 34.49	182158.3	34°07.5	2.1	1.40	0.60	
4 C 33.45	182748.8 b	33°25.5 b	2.3	1.20	0.33	
4 C 31.50	182947.2 a	31°06.6 a	2.3	1.15	0.40	

Notes

4 C 32.25 Two components of about the same intensity. The separation in p = 90° is 2.2′ ± 0.5; in p = 0° is 3.5′ ± 1.0′.
Identified with a galaxy of $m_v \sim 15.5$.

4 C 29.30 Identified with galaxy $m_p = 15.7$ (Zwicky, 1963)

4 C 31.32 Identified with galaxy $m_p = 15.5$ (Zwicky, 1963)

4 C 29.41 Identified with galaxy $m_p = 15.1$ (Zwicky, 1963)

4 C 31.41 Strongly confused by a nearby radiosource of the same intensity. The 21 cm flux of the two sources is 0.4 F.U.

We can see that the radiosources with curved spectra belong essentially to the first class.

A possible explanation for this shape of spectra may be synchrotron self-absorption occurring at frequencies at which the brightness temperature becomes comparable with the kinetic temperature of the relativistic electrons.

This explanation should also imply that the radiosources which show curved spectra have angular structures much smaller than the limit of 30″ we could set for them.

If in these radiosources the brightness distribution is not uniform, synchrotron self absorption will occur at different frequencies for each emitting region producing a flattening of the radio spectrum at meter wavelength instead of a cut-off.

This may well be the situation of our radiosources, since only in three cases (4C 33.26, 29.45, 33.38) the flux at 408 MHz is not lower than that at 178 MHz, suggesting a low frequency cut-off in the spectrum.

We cannot be sure, on the basis of our data, that the explanation given above is correct and that we are not dealing with the bending of the spectrum due to synchrotron losses (Kellerman, 1964). However we point out the similarity of the spectral shape of the radiosources reported here with that of the 3C R radiosources (Kellerman, Pauliny-Toth, and Williams, 1968).

For these last radiosources there is now a large amount of information on their small scale radiostructure, and it is possible for them, to affirm that the shape of the radiospectrum is determined not only by the energy distribution of relativistic electrons but partly by synchrotron self absorption.

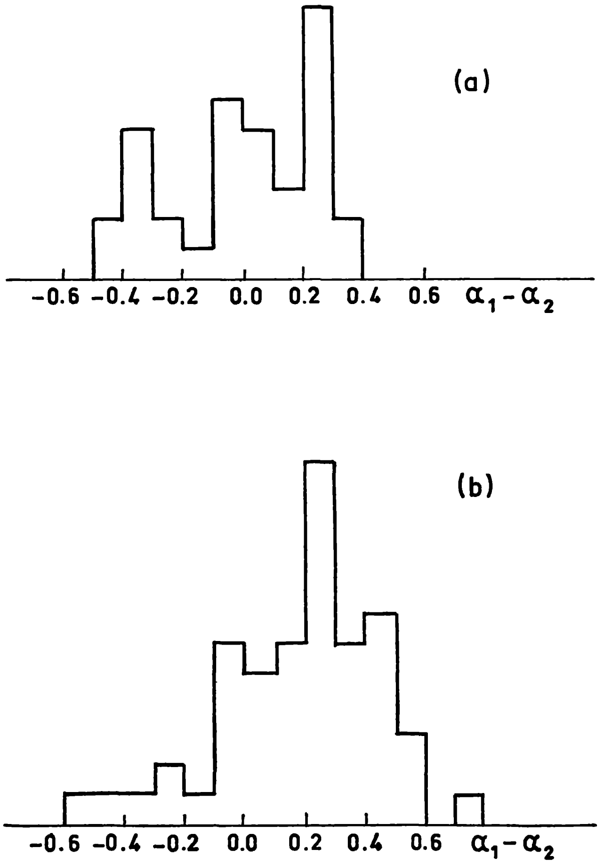

Fig. 5 a and b. Distribution of the curvatures. a) for radiosources with 0.8 < "fr. vis. ampl. at 1150 λ" < 1.2. b) for radiosources with "fr. vis. ampl. at 1150 λ" < 0.8

We suggest therefore that the same process is responsible for the spectral shape of the radiosources reported here.

Interplanetary scintillations will be useful to test this interpretation.

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