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Radio nuclei in elliptical galaxies

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Summary. Observations at 4.9 GHz with the VLA are presented for 36 radio galaxies of the B2 and 3C catalogue, with no previous core flux measurement; 24 cores were detected, while for the others stringent upper limits are given.

The statistical properties of the radio cores in elliptical galaxies are then analyzed, using a sample of 187 radio galaxies, which cover a power range from 10^{23} to 10^{28} W Hz^{-1}. Correlations are found between the core power and the total power and between the core power and the optical absolute magnitude, in agreement with previous results; no redshift dependence is found of the two correlations. The existence of radio galaxies with upper limits to the core flux well below the value expected from the P_c–P_t correlation suggests that these could be relic radio sources, where the nucleus has ceased its activity.

Key words: galaxies: radio – galaxies: nuclei of – VLA maps

1. Introduction

The nuclear activity in galaxies has different manifestations: at radio wavelengths a small scale structure (core) in the center of elliptical galaxies is a clear evidence of a powerful central engine. Observations of compact radio sources and study of their relation with the extended structures can be used indirectly to constrain models of the energy generator. Therefore radio-selected samples can be used in statistical tests, in particular the possible correlation between the core luminosity and the other physical parameters of the source can be investigated.

The most extensive study in this field so far has been performed on a sample of 138 radio galaxies taken from the B2 and the 3CR catalogues by Feretti et al. (1984). They found a significant correlation between the core (P_c) and the total radio power (P_t); however the large dispersion in the relation shows that the core radio power is not a good indicator of the total radio power. Furthermore a correlation of P_c with the galaxy magnitude (M) is present, meaning that a core of high power is more likely to be found in an optical bright galaxy. For 96 objects the radio core was detected, while for 42 only an upper limit was available. Since upper limits are in many cases due to poor resolution and/or sensitivity of previous data, we observed these sources with the Very Large Array (VLA) at 4.9 GHz in order to investigate if all the objects in the sample (both the detections and the upper limits) belong to the same class of objects and to better estimate the correlation between P_c and P_t.

In Sect. 2 we describe the observations and the data reduction, in Sects. 3 and 4 single interesting sources are discussed and the sample is described. In Sect. 5 statistical comparisons are presented. In Sect. 6 some "relic" radio galaxies are selected and briefly discussed. A table with all the data used in this paper is also given.

The adopted values for the Hubble constant and for the deceleration parameter are $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 1$, respectively.

2. Observations and data reduction

New observations of 36 sources with previously undetected cores, selected from the list of Feretti et al. (1984), are presented. They were made in snap-shot mode with the VLA in the A array. Details of the VLA and its modes of operations are given by Thompson et al. (1980). The observations were carried out in January 1985, using the two correlator pairs at frequencies of 4835 and 4885 MHz, each with a bandwidth of 50 MHz. Each observation lasted ~2–3 min. The synthesized beam is about 0″.4.

3C 286 and 3C 138 were observed as primary flux calibrators. All post-calibration reduction was done using the AIPS software system. The visibility amplitudes of the two data bases at 4835 and 4885 MHz were checked for deviating points, which were deleted. Then, the two data bases were combined, and the visibilities were Fourier transformed. The dirty maps were cleaned using the task MX in AIPS. The clean components were subtracted in the UV plane and the process was repeated on the resulting UV data until convergence was reached. Some sources required a self-calibration cycle of the phase only to improve the dynamic range. The model used was good enough to preserve the position information, since no large instrumental error was present in our data.

In Table 1 we present some source parameters: the positions of the core (denoted c) and of other radio components (called A, B, . . .), the flux density of the components, the largest angular size with the corresponding position angle in parentheses and the actual rms noise determined from the final map. 24 core sources have been detected, for the others 12 galaxies low upper limits are given. Contour maps of some extended sources are shown in Fig. 1. We want to stress that due to the missing short UV

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Table 1. Observational data

Name		R.A.(1950) h m s	DEC.(1950) o ′ ″	S(4.9) mJy	LAS(p.a) ″ (o)	noise mJy/beam
0120+33	c	012050.86	325943.8	1.4	0.4(180)	0.15
3C46.0	c	013234.07	373846.5	2.3	0.5(180)	0.10
0149+35	c	014950.02	355420.5	5.0	-	0.11
3C61.1	c	021036.32	860517.2	2.3	-	0.15
3C171.0	c	065110.92	541248.0	2.2	-	0.30
3C173.1	c	070247.70	745416.6	7.4	-	0.17
0828+32AB	c	082820.10	322936.5	3.3	-	0.16
0836+29	c	083659.02	295941.6	8.2	-	0.12
	A	59.00	41.1	3.2		
	B	58.90	39.0	4.6		
0924+30	c	-	-	<0.4	-	0.08
3C225.0	c	-	-	<1.0	-	0.20
	A	093932.10	135934.2	502	0.5(97)	
	B	.40	32.2	285	0.4(173)	
	TOT			807		
1003+26	c	100349.40	260923.9	0.9	-	0.13
1005+28	c	100506.34	281629.6	1.9	-	0.14
3C244.1	c	-	-	<0.7	-	0.14
1113+24	c	-	-	<0.3	-	0.08
1141+37	c	114149.70	372511.1	4.2	-	0.20
1204+24	c	120434.37	241106.5	8.0	-	0.09
1243+26B	A	124354.65	264339.4	1.8	-	0.09
	B	.67	.8	1.2		
3C284.0	c	130841.38	274402.9	3.2	-	0.23
1347+28	c	134756.37	283135.6	4.8	0.4(33)	0.09
1350+31 3C293	E	135003.07	314132.8	74	1.0(89)	
	AB	.15	.8	277	0.4(92)	
	CD	.27	.7	690	0.5(75)	
	F	.36	.2	58	1.2(136)	0.90
	TOT			1320		
1357+28	c	135745.16	284429.9	6.2	-	0.10
1358+30	c	-	-	<0.4	-	0.08
1430+25	c	-	-	<1.0	-	0.20
1441+26	c	-	-	<0.7	-	0.14
	A	144156.35	261405.3	2.4	1.2(85)	
1450+28	c	145023.84	281006.7	3.5	-	0.12
1512+30	c	-	-	<0.4	-	0.08
3C314.1	c	-	-	<1.0	-	0.19
1525+29	c	152539.69	290527.9	2.5	3.8(180)	0.12
1527+30	c	152743.31	305250.1	3.9	4.7(34)	0.12
	A	.23	49.6	2.8	6.0(90)	
1528+29	c	152805.90	291043.1	4.5	-	0.08
3C341.0	c	162602.50	274814.5	0.9	-	0.17
	A	162602.04	274809.6	3.6	0.4(60)	
1643+27	c	164326.63	272530.1	4.1	-	0.18
1657+32A	c	165708.28	323406.6	2.5	-	0.23
1658+32A	c	165818.71	323937.3	2.4	-	0.20
1726+31 3C357	c	172627.31	314824.6	5.7	-	0.23
3C460.0	c			<15		0.25
	A	231859.72	233020.1	214	0.8(30)	
	B	.95	24.3	77	0.7(43)	

spacings only compact features are visible and that all structures larger than 5″–7″ are missed.

3. Comments on individual sources

Our high resolution and sensitivity data confirm that multiple hot spots are relatively common in powerful radio sources (Valtaoja, 1984). In fact in our sample, besides 3C 244.1 studied also by Laing (1981), two other radio galaxies (0836 + 29 I and 3C 173.1) show double hot spots in one of their lobes (see Fig. 1).

3C 61.1: The core radio source coincides with a triplet of galaxies, confirming the identification proposed by Hargrave and McEllin (1975). Each of the 3 galaxies may be the optical counterpart of 3C 61.1; no redshift is available for these galaxies, however recession velocities measures of nearby objects (Miller et al., 1973) reveal a cluster a $z = 0.186$ to which probably the triplet of galaxies belongs.

3C 171.0: The radio structure of this radio galaxy is very peculiar. In our map it consists in a faint core with two lobes in E-W direction with a total extension of $\sim 10''$ plus an extended structure around the eastern hot spot, in N-S direction (Fig. 1). A lower resolution map (Antonucci, 1985) confirms the extended structure visible in our map. Discordant optical positions were given in the literature, we measured the position of the galaxy on the prints of the PSS. Our measure is in agreement with that given by Laing et al. (1983) and coincides, within the errors, with the radio core.

0836 + 29: A detailed radio and optical study has been carried out by van Breugel et al. (1986). In Fig. 1 we show the central region and the two lobes.

3C 244.1: An unresolved radio component at 4 rms level (0.6 mJy) is within 2″ of the optical galaxy.

1243 + 26B: A comparison of our map with the 20 cm data (Fanti et al. 1987) does not allow us to determine which of the two components (A or B) is the core.

1350 + 31 (3C 293): Detailed radio and optical studies have been presented by Bridle et al. (1981) and van Breugel et al. (1984b). In these papers high resolution VLA maps at 2 and 1.3 cm allow to distinguish the flat spectrum core. Our map has not enough resolution to separate the core from the nearby component, but shows in detail the extended regions where the source starts to change its PA (from 90° to $\sim -45°$). The source inner regions are labelled as in Bridle et al. (1981).

1430 + 25: This source is a head-tail source with an unresolved emission at the end of the tail (Fanti et al., 1987 and references therein) which could be a background source. In our observation this source is still unresolved and appears to be an unrelated source.

1441 + 26: The typical morphology of the double radio source (Fanti et al., 1987 and references therein) is completely resolved, except for the knot north-east of the optical position which is considered to be a background source. Only an upper limit can be given for the core source.

1525 + 29: The two sided jet structure (Fanti et al., 1987 and references therein) is resolved and a core with two faint, resolved jets are visible in our map.

1527 + 30: Our high resolution map does not allow us to unambiguously identify the core; however a comparison with the 20 cm map (Fanti et al., 1987 and references therein) seems to indicate an asymmetric core-jet structure, with the eastern component as the core.

3C 341.0: In our map the low brightness structure is resolved (see the map in Bridle and Perley 1984); our map shows a faint core, the south–west hot spot (strongly attenuated) and a compact component (A) that probably is a bright knot.

3C 460.0: The position of the optical counterpart is very near to the component A; higher resolution data are necessary to separate the core emission from the component emission.

4. Sample definition

For a detailed description of the sample we refer to Feretti et al. (1984). In the meantime high resolution WSRT and VLA data have revealed that some B2 radio galaxies are misidentifications (see Fanti et al., 1987). Moreover, in this paper we have added 3CR radio galaxies with $m_v \geq 20$ (see Table 2). In fact, due to

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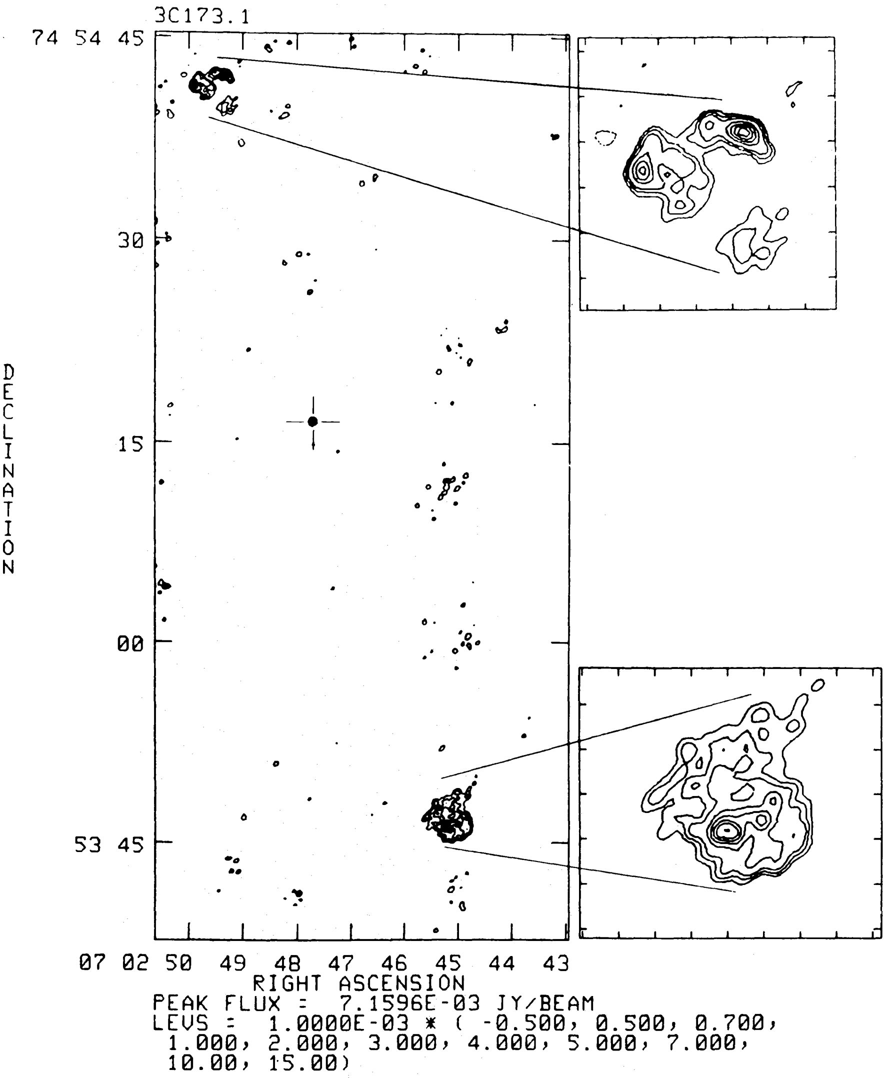

Fig. 1a

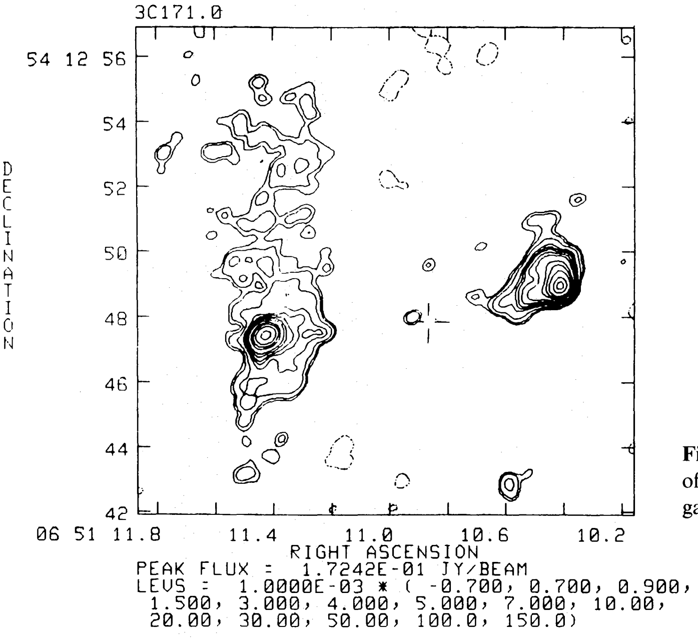

Fig. 1b

Fig. 1a–j. Contour maps at 5 GHz of the interesting sources; the values of contour levels are given below each field. In some cases the optical galaxy is marked by a cross; letters are as in Table 1

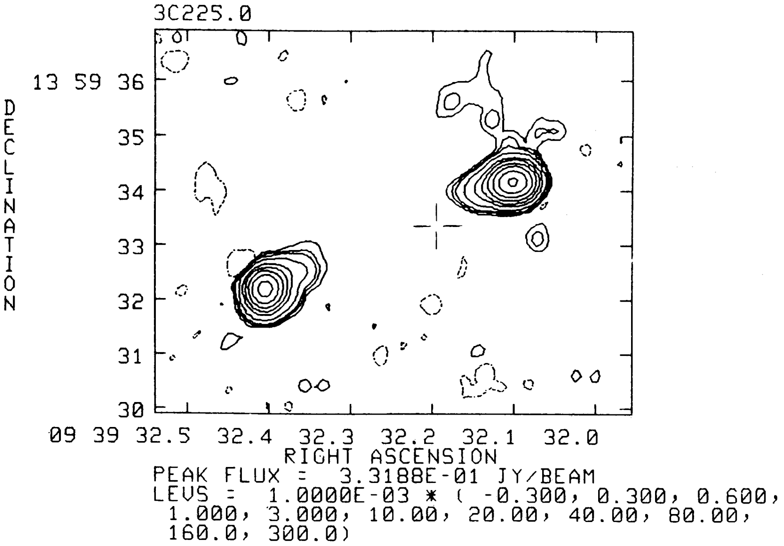
3C225.0
DECLINATION
13 59 36
35
34
33
32
31
30
09 39 32.5
32.4
32.3
32.2
32.1
32.0
RIGHT ASCENSION
PEAK FLUX = 3.3188E-01 JY/BEAM
LEVS = 1.0000E-03 * (-0.300, 0.300, 0.600, 1.000, 3.000, 10.00, 20.00, 40.00, 80.00, 160.0, 300.0)

Fig. 1c

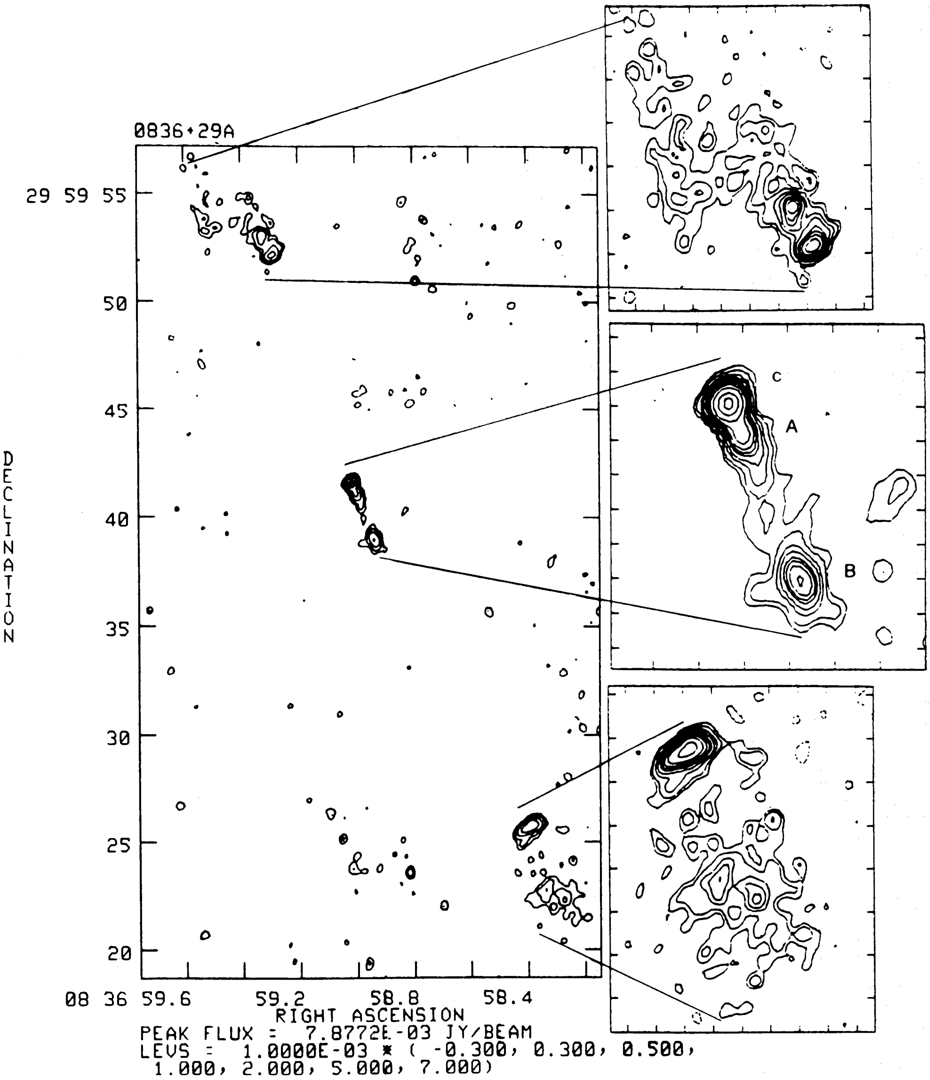
0836+29A
DECLINATION
29 59 55
50
45
40
35
30
25
20
08 36 59.6
59.2
58.8
58.4
RIGHT ASCENSION
PEAK FLUX = 7.8772E-03 JY/BEAM
LEVS = 1.0000E-03 * (-0.300, 0.300, 0.500, 1.000, 2.000, 5.000, 7.000)
C
A
B

Fig. 1d

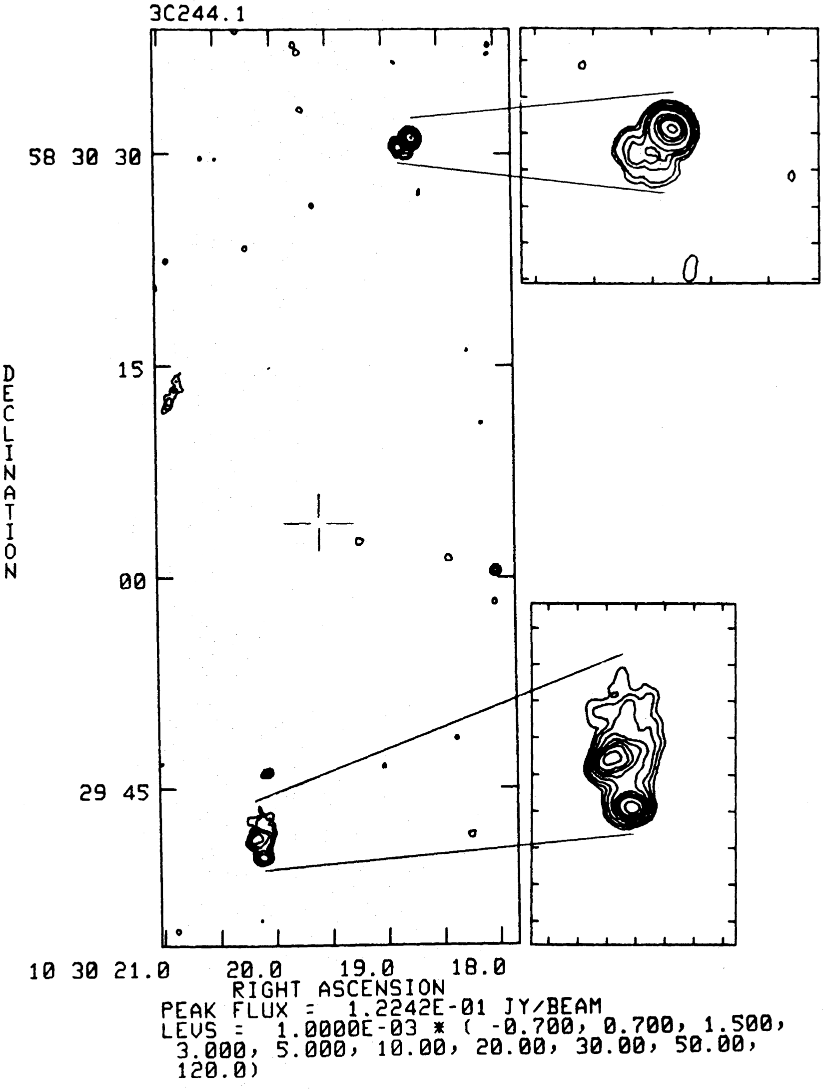
3C244.1
58 30 30
15
00
29 45
DECLINATION
10 30 21.0
20.0
19.0
18.0
RIGHT ASCENSION
PEAK FLUX = 1.2242E-01 JY/BEAM
LEVS = 1.0000E-03 * (-0.700, 0.700, 1.500, 3.000, 5.000, 10.00, 20.00, 30.00, 50.00, 120.0)

Fig. 1e

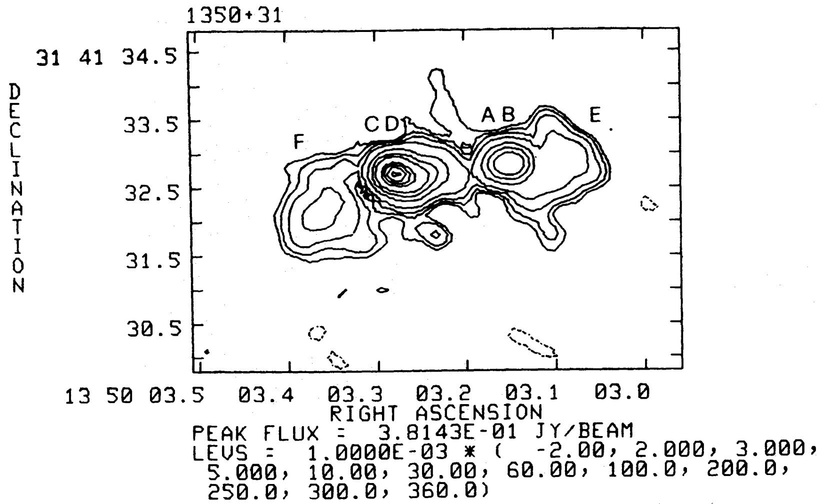
1350+31
31 41 34.5
33.5
32.5
31.5
30.5
DECLINATION
F
C D
A B
E
13 50 03.5
03.4
03.3
03.2
03.1
03.0
RIGHT ASCENSION
PEAK FLUX = 3.8143E-01 JY/BEAM
LEVS = 1.0000E-03 * (-2.00, 2.000, 3.000, 5.000, 10.00, 30.00, 60.00, 100.0, 200.0, 250.0, 300.0, 360.0)

Fig. 1f

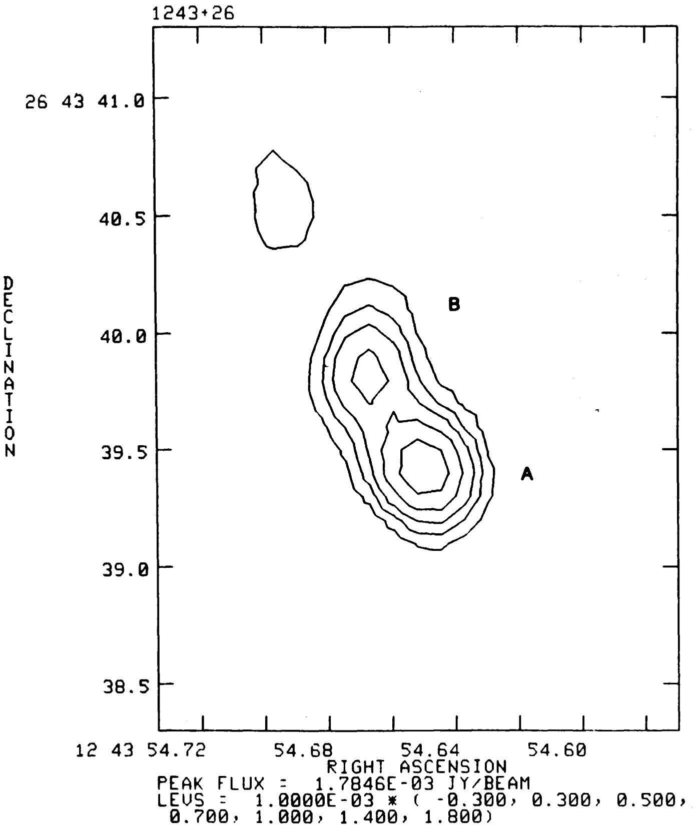

Fig. 1g

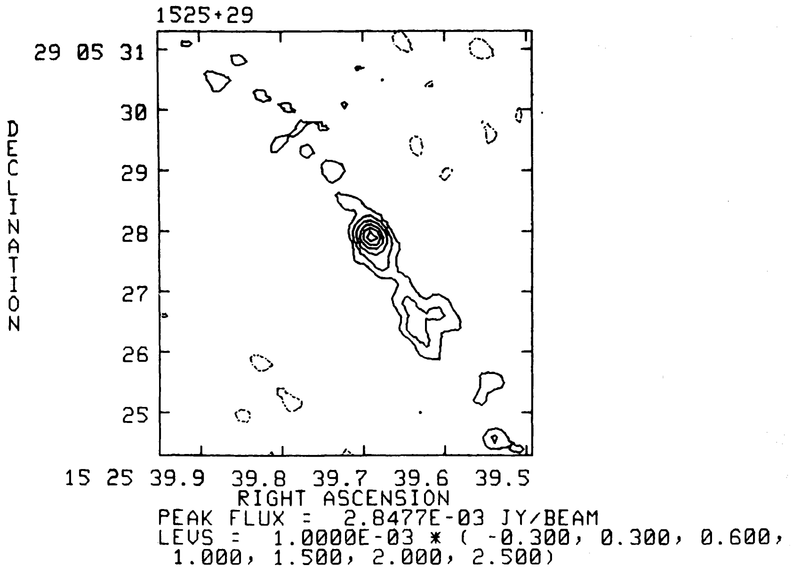

Fig. 1h

recent studies of the 3CR catalogue (Spinrad et al., 1985 and references therein) all 3CR sources matching our constraints (Feretti et al., 1984) have been identified and can be added without introducing an optical bias. Also, the radio data have been updated according to recent works up to the beginning of 1987. The absolute visual magnitude of distant galaxies has a large uncertainty due to the *K*-correction. We adopted the *K*-correction estimated by Pence (1976).

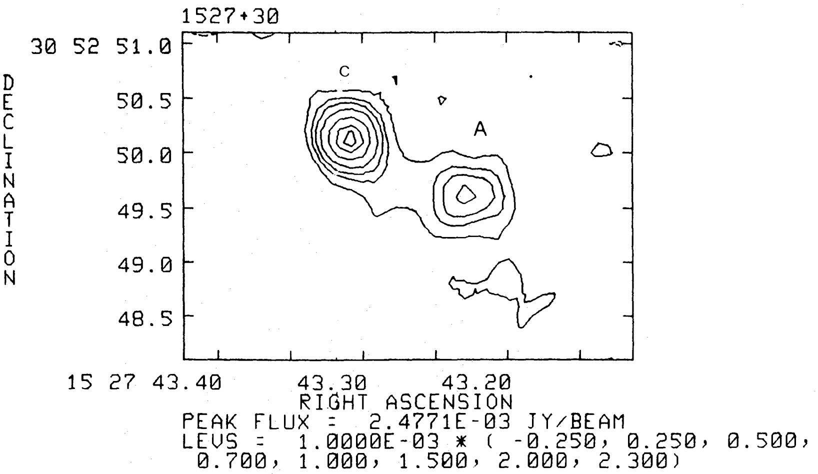

Fig. 1i

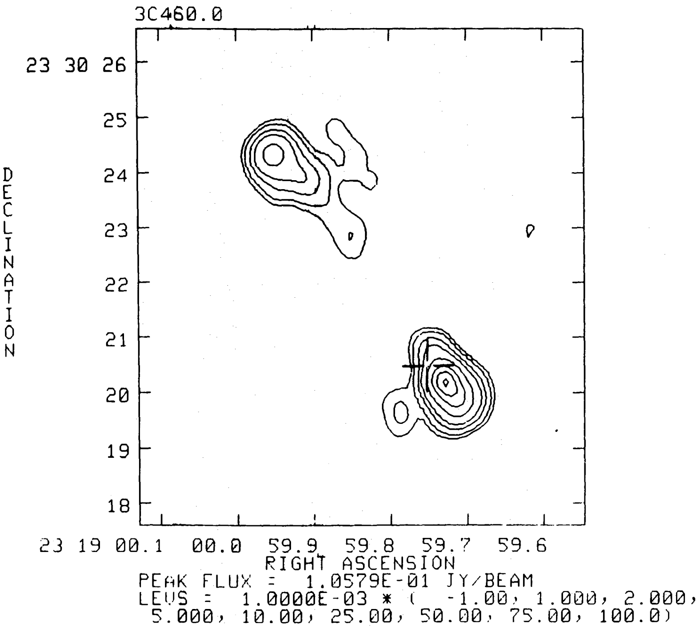

Fig. 1j

The final sample consists of:

a) 91 radio galaxies that form the two complete B2 samples,
b) 96 radio galaxies taken from the 3CR catalogue.

The distribution of the total radio power at 408 MHz is shown in Fig. 2 for the 187 radio galaxies of the present work. It covers with good statistics about 5 orders of magnitude from 10^{23} to 10^{28} W Hz^{-1}. The present sample has a larger number of galaxies with $P_t > 10^{27}$ with respect to the one analyzed in Feretti et al. (1984).

5. Statistical analysis

5.1. The correlation between core and total radio powers

We used the statistical procedure described in Feretti et al. (1984), to which we refer for a detailed description and discussion of the method used. The mathematical formalism is the same as that developed for deriving luminosity functions from samples containing detections and limits (Avni et al., 1980; Avni and Tananbaum, 1982). This method is essentially the same as the one discussed in Isobe et al. (1986).

Figure 3 shows P_c versus P_t for all the objects. For 135 objects we have a core flux measurement, while for 52 we can give only an upper limit for the core flux density. The best fit linear regression of log P_c versus $\log P_t$ gives:

$$\log P_c = 11.01 + 0.47 \log P_t . \quad (1)$$

The formal error on the slope (treated as a single interesting parameter) is 0.04. This fit was obtained using a Maximum Likelihood Method which makes full use of all the available data, including the upper limits. The slope is lower than the value given in Feretti et al. (1984) but the two values are well in agreement

Table 2a and b. The columns are: 1: B2 and/or 3C name; 2: Redshift, taken from Ref. 1 or 36; 3: Absolute visual magnitude corrected for the galactic absorption and the K effect, taken from Ref. 1 or 36; 4: Core flux density in mJy at 5.0 GHz; 5: Total flux density in mJy at 0.408 GHz, taken from Ref. 1 or 37; 6: Logarithm of the core radio power in W Hz^{-1}; 7: Logarithm of the total radio power in W Hz^{-1}; 8: Reference number for the core flux density

Table 2a. B2 radio galaxies

NAME	Z	M vis	Sc 5.0 mJy	St 0.408 mJy	Log P core W/Hz	Log P total W/Hz	Ref
003425	0.0321	-21.4	10.0	270	22.04	23.50	2
005526 N326	0.0472	-22.2	8.0	4900	22.29	25.10	41
005530	0.0167	-22.4	546.0	2800	23.24	23.95	49
010432 3C31	0.0169	-21.3	92.0	9900	22.45	24.50	41
011631	0.0592	-22.0	<1460.0	3490	<24.74	25.10	5
012033 N507	0.0164	-21.9	1.4	690	20.61	23.30	59
014935	0.0160	-20.3	5.0	360	21.16	23.00	59
020635	0.0375	-21.9	106.0	4560	23.22	24.85	56
022236	0.0327	-21.5	140.0	340	23.20	23.59	55
025835	0.0160	-21.0	<243.0	3900	<22.83	24.05	55
032639	0.0243	-21.2	70.0	1900	22.65	24.05	2
033139	0.0202	-21.7	149.0	1720	22.82	23.88	55
064827	0.0409	-22.5	213.0	270	23.58	23.70	40
070832	0.0672	-21.2	15.0	290	22.86	24.15	39
072230	0.0191	-19.8	51.0	380	22.30	23.15	44
075537	0.0413	-21.9	195.0	5900	23.55	25.04	5
080024	0.0433	-21.3	3.0	320	21.78	23.80	58
082832AB	0.0507	-21.0	3.3	4370	21.96	25.08	59
083629(II)	0.0790	-22.4	131.0	1800	23.94	25.08	3
083629(I)	0.0650	-22.1	8.2	1560	22.57	24.85	59
083832	0.0680	-22.0	<109.0	1920	<23.73	24.98	39
084431	0.0675	-22.3	58.0	3750	23.45	25.25	47
090837	0.1040	-22.2	24.0	1190	23.44	25.14	44
091338	0.0711	-21.1	<1.0	820	<21.74	24.65	39
091532	0.0620	-22.1	8.0	470	22.52	24.29	12
092236B	0.1125	-22.2	15.0	1820	23.31	25.40	39
092430	0.0266	-21.2	<0.4	1750	<20.48	24.10	59
100326	0.1165	-21.3	0.9	300	22.11	24.64	59
100335 3C236	0.0989	-21.2	84.0	6140	23.95	25.81	33
100528	0.1476	-22.0	1.9	250	22.65	24.77	59
103730	0.0909	-20.9	<84.0	1150	<23.88	25.01	44
104031	0.0360	-20.8	55.0	1690	22.88	24.40	6
110138	0.0300	-21.6	640.0	1150	23.79	24.05	5
110230	0.0720	-22.1	26.0	960	23.16	24.70	6
111324	0.1021	-22.5	<0.3	260	<22.53	24.46	59
111329	0.0489	-21.9	41.0	4950	22.94	25.10	56
111628	0.0667	-22.3	30.0	1070	23.17	24.71	45
112239	0.0067	-22.1	6.0	4950	20.46	22.15	41
114137	0.1150	-21.2	4.2	5140	22.78	25.86	59
114435	0.0630	-21.9	250.0	330	24.03	24.15	44
120424	0.0769	-21.7	8.0	270	22.70	24.24	59
120434	0.0788	-21.2	23.0	1010	23.18	24.83	39
121729	0.0021	-19.5	350.0	580	21.22	21.44	5
124326B	0.0891	-22.1	<1.8	890	<22.19	24.88	59
125127 3C277.3	0.0857	-20.9	12.0	6300	22.98	25.69	41
125628	0.0224	-20.5	2.0	1460	21.08	23.90	41
125728	0.0239	-21.4	1.1	500	20.83	23.50	46
131629	0.0728	-21.8	31.0	3150	23.25	25.26	41
132131	0.0161	-20.8	21.0	3600	21.77	24.00	19
132236	0.0175	-20.8	150.0	1710	22.69	23.75	5
133926	0.0722	-22.6	55.0	1260	23.49	24.85	3
134626	0.0633	-22.1	53.0	3150	23.35	25.13	42
134728	0.0724	-21.6	4.8	520	22.44	24.47	59
135031 3C293	0.0452	-21.2	100.0	10150	23.34	25.35	43
135728	0.0629	-21.9	6.2	690	22.42	24.47	59
135830	0.1104	-22.0	<0.4	880	<21.73	25.06	59
142226	0.0370	-20.8	25.0	2020	22.57	24.50	6
143025	0.0183	-21.3	<1.0	1390	<21.85	24.99	59
144126	0.0621	-22.2	<0.7	660	<21.46	24.44	59
144727	0.0306	-20.7	33.0	340	22.52	23.53	3
145028	0.1265	-21.6	3.5	380	22.77	24.81	59
150226 3C310	0.0540	-21.3	80.0	23400	23.40	25.86	20
151230	0.0931	-21.9	<0.4	270	<21.57	24.40	59
152128	0.0825	-21.7	70.0	1570	23.71	25.06	6
152529	0.0653	-22.3	2.5	430	22.06	24.30	59
152730	0.1143	-22.8	3.9	450	22.74	24.80	59
152829	0.0843	-22.0	4.5	730	22.54	24.75	59
155726	0.0442	-21.4	31.0	250	22.81	23.72	3
161029	0.0313	-21.3	<6.0	320	<21.80	23.50	5
161327	0.0647	-21.7	25.0	450	23.05	24.30	3
161532 3C332	0.1515	-22.3	10.0	5100	23.41	26.23	47
161535	0.0296	-20.9	28.0	5400	22.42	24.72	50
162138	0.0310	-22.0	50.0	930	22.72	24.00	6
162639 3C338	0.0303	-22.3	105.0	18120	23.02	25.25	8
163729	0.0875	-22.5	13.0	810	23.03	24.82	6
163832	0.1398	-22.6	64.0	600	24.13	25.10	3
164327	0.1017	-21.8	4.1	290	22.66	24.51	59
165239	0.0337	-22.6	1250.0	1770	24.18	24.35	40
165732A	0.0631	-21.0	2.5	1250	22.03	24.36	59
165830	0.0351	-20.2	84.0	1550	23.05	24.31	6
165832A	0.1024	-21.6	2.4	600	22.43	24.83	59
172631 3C357	0.1670	-22.4	5.7	6150	23.23	26.26	59
173632	0.0741	-21.8	8.0	600	22.70	24.55	39
175232B	0.0449	-21.6	12.0	320	22.42	23.84	39
182732A	0.0659	-21.9	26.0	740	23.08	24.54	3
183332 3C382	0.0586	-22.2	188.0	13700	23.84	25.70	47
185537	0.0552	-23.0	<100.0	800	<23.51	24.40	55
211626	0.0164	-21.2	47.0	320	22.13	23.00	56
222939 3C449	0.0181	-20.9	37.0	6450	22.11	24.35	9
223635	0.0277	-21.1	8.0	770	21.74	23.80	56
233526 3C465	0.0301	-22.2	270.0	20200	23.41	25.30	10

Table 2b. 3CR radio galaxies

NAME	Z	M vis	Sc 5.0 mJy	St 0.408 mJy	Log P core W/Hz	Log P total W/Hz	REF
3C6.1	0.840	-23.0	20.0	8700	25.18	27.82	17
3C13.0	1.351	-24.7	<0.4	6720	<23.89	28.12	15
3C16	0.405	-21.1	<0.8	5400	<23.15	26.98	53
3C19.0	0.482	-22.6	<200.0	9220	<25.70	27.36	29
3C28	0.1952	-21.8	<0.2	7300	<21.91	26.47	51
3C33	0.0595	-21.2	24.0	31600	22.96	26.08	23
3C34.0	0.689	-22.8	<8.0	5700	<24.61	27.46	29
3C41.0	0.794	-23.5	<30.0	9220	<25.31	27.79	14
3C42.0	0.395	-21.7	<25.0	9650	<24.62	27.21	29
3C46.0	0.4373	-22.8	2.3	4000	23.57	26.91	59
3C49.0	0.621	-22.3	10.0	6500	24.62	27.43	57
3C55.0	0.240	-19.1	<2.5	10100	<23.19	26.80	13
3C61.1	0.1840	-20.3	2.3	17600	22.92	26.81	59
3C65.0	1.176	-23.8	0.6	10170	23.95	28.18	15
3C66B	0.0215	-21.7	182.0	19230	22.96	24.98	18
3C67.0	0.3102	-22.8	<400.0	7000	<25.62	26.86	38
3C68.2	1.575	-24.5	<7.0	4000	<25.27	28.03	17
3C76.1	0.0328	-20.3	10.0	5100	22.06	24.77	10
3C79.0	0.2559	-21.5	10.0	14000	23.87	26.99	48
3C98	0.0306	-20.6	9.0	25300	21.96	25.40	22
3C109.0	0.3056	-22.9	263.0	13300	25.12	27.12	40
3C123.0	0.218	-18.5	6600.0	134260	26.53	27.84	17
3C171.0	0.2384	-21.2	2.2	8400	23.12	26.71	59
3C173.1	0.2920	-22.1	7.4	6000	23.83	26.74	59
3C184.0	0.994	-24.2	<10.0	7000	<25.03	27.87	29
3C184.1	0.1182	-21.1	6.0	7600	22.95	26.06	21
3C192	0.0597	-21.2	8.0	12200	22.49	25.67	24
3C200.0	0.458	-22.3	35.1	7310	24.90	27.22	11
3C217.0	0.8975	-23.0	<25.0	7940	<25.33	27.84	29
3C219.0	0.1744	-21.8	51.0	21600	24.22	26.85	16
3C220.1	0.61	-22.9	25.0	7200	25.00	27.46	29
3C220.3	0.68	-23.3	<20.0	10400	<25.00	27.71	29
3C223.0	0.1368	-21.3	9.0	5300	23.26	26.03	21
3C225.0B	0.58	0000	<1.0	11400	<23.56	27.61	59
3C226.0	0.823	-25.0	7.5	6700	24.74	27.69	7
3C228.0	0.5524	-22.0	13.3	9200	24.65	27.48	7
3C234.0	0.1848	-21.7	90.0	19800	24.52	26.86	21
3C239.0	1.781	-26.1	0.5	7600	24.23	28.41	15
3C241.0	1.617	-24.5	3.0	6300	24.93	28.25	57
3C244.1	0.4280	-22.8	<0.6	14600	<23.07	27.46	59
3C247.0	0.7489	-22.6	3.5	6920	24.32	27.62	7
3C252.0	1.10	-24.0	1.1	6600	24.15	27.93	7
3C263.1	0.366	-21.3	<300.0	9900	<25.63	27.15	29
3C264	0.0206	-21.3	200.0	15500	22.96	24.85	25
3C265.0	0.811	-23.5	<15.0	11240	<25.02	27.90	29
3C266.0	1.275	-24.8	<0.6	7300	<24.02	28.10	15
3C267.0	1.140	-23.7	3.0	6100	24.62	27.93	15
3C268.1	0.97	-23.4	2.0	13000	24.31	28.12	15
3C268.3	0.371	-21.4	<130.0	9300	<25.28	27.14	7
3C272.1	0.0037	-21.4	180.0	12800	21.42	23.27	10
3C274	0.0037	-21.7	4000.0	800000	22.77	25.07	26
3C274.1	0.422	-21.8	<6.0	8200	<24.06	27.19	29
3C277.2	0.766	-22.7	<15.0	6000	<24.98	27.58	29
3C280.0	0.996	-23.5	1.0	12200	24.03	28.11	15
3C284.0	0.2394	-21.8	3.2	5030	23.29	26.49	59
3C285	0.0797	-21.0	6.0	5600	22.61	25.58	10
3C288.0	0.2460	-22.8	30.0	9400	24.29	26.79	17
3C289.0	0.9674	-22.3	<0.5	7700	<23.70	27.89	7
3C292.0	0.71	-23.1	<4.0	5700	<24.34	27.49	4
3C295.0	0.4614	-22.0	<300.0	68800	<25.84	28.20	29
3C296	0.0237	-22.1	77.0	6800	22.67	24.61	27
3C299.0	0.3670	-21.9	50.0	7700	24.86	27.05	57
3C300.0	0.2700	-22.1	9.0	10000	23.85	26.89	21
3C303	0.1410	-21.4	150.0	6000	24.51	26.11	17
3C303.1	0.2670	-21.2	<5.0	7000	<23.58	26.73	57
3C305	0.0410	-21.8	29.0	7200	22.72	25.10	28
3C314.1	0.1197	-20.8	<1.0	5500	<22.19	25.93	59
3C315.0	0.1083	-20.9	<150.0	9800	<24.28	26.09	24
3C318.0	0.752	-23.8	<90.0	8000	<25.74	27.69	57
3C319.0	0.1920	-20.8	<1.0	8200	<22.60	26.51	34
3C321.0	0.0960	-21.4	30.0	7100	23.47	25.85	29
3C324.0	1.2063	-25.1	<0.5	7400	<23.89	28.06	7
3C325.0	0.86	-23.8	1.2	10000	23.98	27.90	7
3C326.0	0.0895	-20.2	13.0	9640	23.05	25.92	35
3C330.0	0.55	-22.6	<15.0	15500	<24.69	27.70	13
3C337.0	0.635	-22.5	<0.5	6700	<23.34	27.46	7
3C340.0	0.7754	-22.3	<0.5	6700	<23.51	27.64	7
3C341.0	0.4480	-22.6	1.0	5600	23.49	27.08	41
3C343.1	0.75	-23.5	<200.0	13500	<26.08	27.91	57
3C346	0.1620	-22.4	220.0	7600	24.79	26.33	10
3C349.0	0.2050	-20.4	25.0	8600	24.05	26.59	29
3C356.0	1.079	-24.6	0.9	6200	24.05	27.89	15
3C368.0	1.132	-25.1	<0.6	5300	<23.92	27.86	15
3C381.0	0.1605	-21.7	5.0	10000	23.14	26.44	10
3C388	0.0917	-22.2	62.0	14600	23.75	26.10	30
3C390.3	0.0569	-21.6	330.0	26900	24.06	25.97	31
3C401.0	0.2010	-21.7	32.0	11000	24.14	26.68	41
3C427.1	0.572	-20.0	0.8	11300	23.45	27.60	7
3C433	0.1016	-21.7	5.0	28000	22.74	26.49	32
3C436.0	0.2145	-21.6	19.0	11800	23.97	26.77	21
3C441.0	0.707	-23.1	<20.0	7740	<25.03	27.62	29
3C442	0.0262	-21.1	2.0	10600	21.17	24.89	10
3C452.0	0.0811	-21.4	130.0	28200	23.96	26.30	21
3C460.0	0.2680	-21.4	<15.0	4600	<24.06	26.55	59
3C469.1	1.336	-24.9	2.6	6000	24.70	28.10	7
3C470.0	1.653	00.0	<25.0	5360	<25.87	28.20	29

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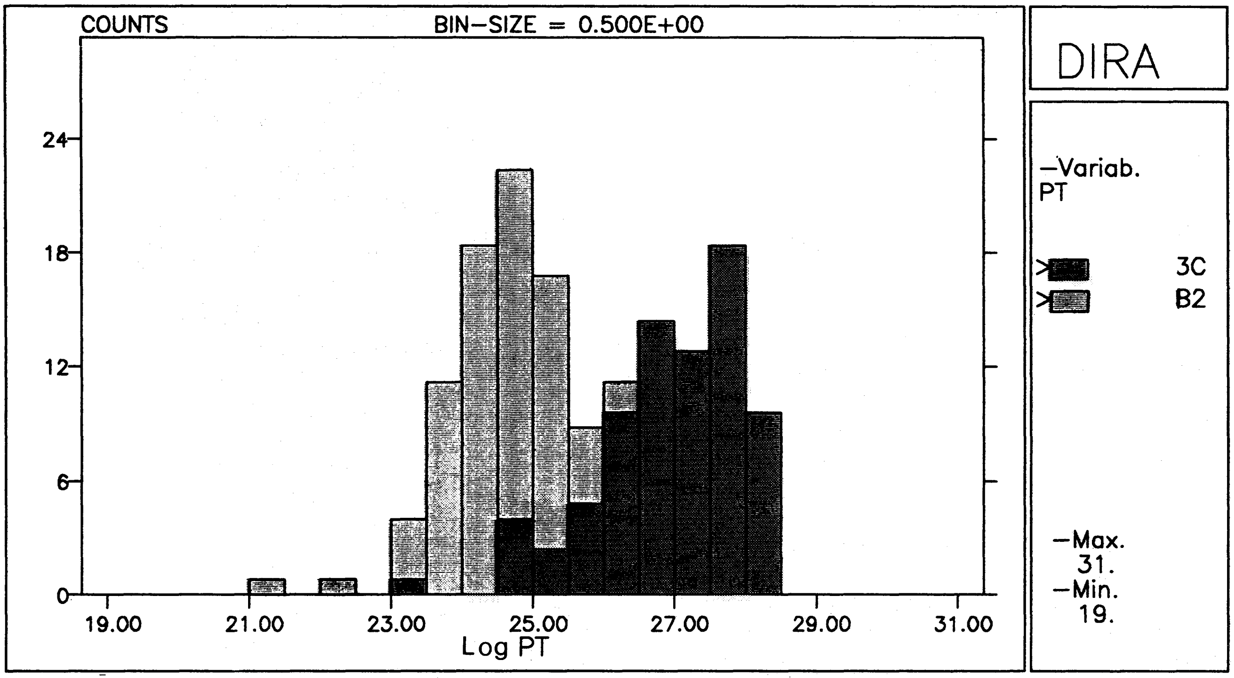

Fig. 2. Distribution of the total radio power at 408 MHz for the sources used in the present paper

within the errors. The better statistics reduce the dispersion around the best fit regression line, even if the large number of faint 3C galaxies ($m > 20$) with high upper limits for the core radio emission still introduces relatively large uncertainties. The result of Eq. (1) confirms that in a statistical sense the core radio luminosity of elliptical radio galaxies increases less rapidly than the total radio luminosity. At present the physical reason of the correlation between P_c and P_t is not clear. We can suppose that the core emission, as the jet emission, is due to dispersions in the energy transport and/or production. In this case we expect that a high power radio source has a more efficient engine than a low power radio galaxy, therefore the fraction of emission that we see in the core decreases when P_t increases.

We have also tested the possibility of a change of the slope for low and high luminosity radio galaxies by analyzing separately the galaxies with P_t higher and lower than 10^{25} W Hz^{-1} and also higher and lower than 10^{26} W Hz^{-1}. The best fit slopes are always perfectly consistent showing that the correlation between P_c and P_t can be represented by a single law for our entire data set covering a range larger than 10^5 in total radio luminosity. This result confirms that no difference seems to exist in the correlation P_c–P_t between the high luminosity edge-brightened double sources and the low luminosity relaxed sources.

We have computed a linear regression of P_c as a function of both P_t and M_v simultaneously of the form:

$$\log P_c = A_m \times |M_v| + A_t \times \log P_t + \text{const} \tag{2}$$

The 3C radio galaxies with $m > 20$ have been excluded since introduce a very large dispersion because of the very uncertain absolute magnitude due to the large K-correction.

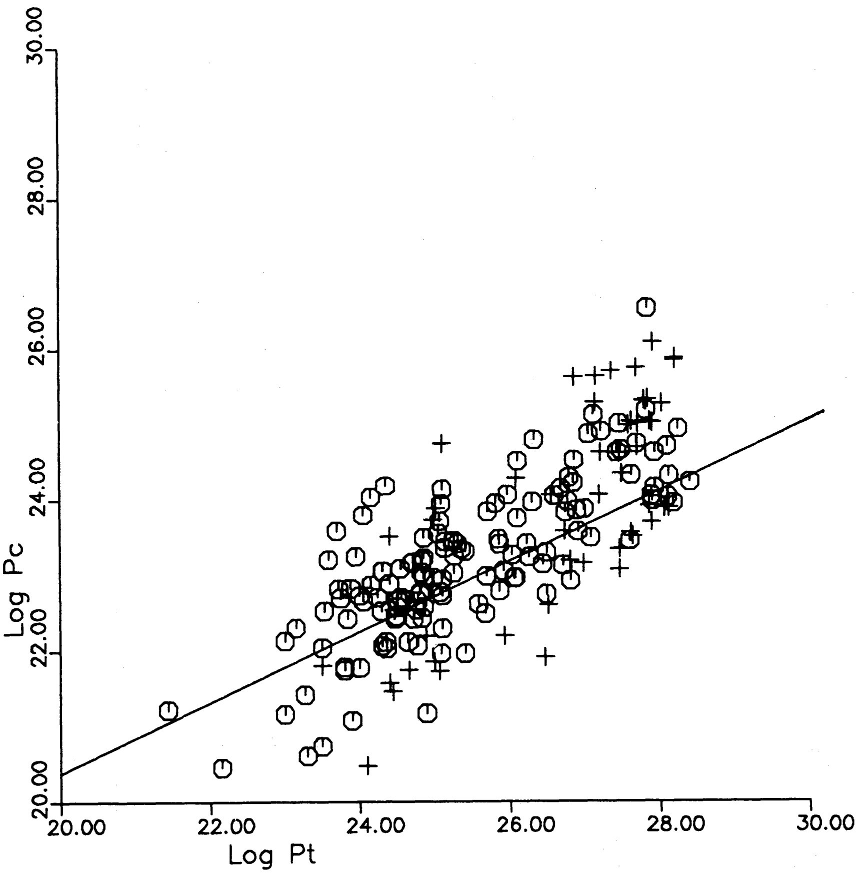

Fig. 3. Plot of the core power at 5 GHz versus the total power at 0.4 GHz, in W Hz^{-1}; circles represent the detections, while the crosses represent the upper limits for the core radio powers; the solid line is the best fit linear regression of log P_c versus log P_t

We find that the best estimates for the regression parameters are: $A_m=0.31$; $A_t=0.42$; $\sigma_g=0.73$, where σ_g is the standard deviation of the distribution of the residuals, in good agreement with the previous estimates (see Feretti et al., 1984 and references therein).

A study of the P_c-P_t correlation for a large complete sample of quasars is not presently available in the literature. However Fanti et al. (1979) suggested that a correlation $L_c \propto L_{\mathrm{ext}}^k$ with $k \leqslant 0.5$, where L_c is the core luminosity and L_{ext} is the luminosity of the extended region, may exist for quasars. Therefore it is possible that the correlation P_c–P_t found for galaxies is also valid for quasars; this point must be investigated with better data.

5.2. Correlation between core radio power and redshift

The present sample is more populated at high redshift than the previous sample of Feretti et al. (1984), therefore we checked the presence of a correlation between the core radio power and z. The radio galaxies with $z>0.1$ are 93 (50%) and 66 (35%) have $z>0.2$. After the correction of P_c for the dependence on P_t, to avoid selection effects, we do not find any correlation between the core radio power and z. Therefore no redshift evolution of radio cores is present in our data, but a large dispersion is present since ~50% of the radio galaxies with $z>0.2$ have an undetected core.

6. Relic radio sources

All the sources with an undetected core could represent "dying" sources, i.e. sources in which the supply of energy from the nucleus has ceased. In fact, in such a phase a source is supposed not to disappear immediately, but to gradually fade away and to remain detectable for a long period. Although many sources do not show the presence of the core, often the non detection of it is due to a lack of adequate instrumental resolution or sensitivity; this is true for some of the objects of our sample for which the high limits on the core radio emission result from the poor sensitivity of the old observations.

Of all the sources with a limit to the core radio emission we have considered those with P_c at least 1 σ lower than the value expected from the P_c–P_t correlation. There are 10 such sources, of which only two, 0924+30 and 3C 28 are more than 2σ below the mean P_c–P_t relation, while the others are at between 1–2 sigma.

Sources without energy supply from the nucleus are expected to have a relaxed structure with a low surface brightness and also a lack of hot spots and jets which are commonly interpreted as indicators of continuing activity. They also should have a steep spectrum. We therefore examined the 10 sources individually, to check the radio structure and the value of the spectral index, when available, due to the high dispersion of the correlation between P_c and P_t.

For the B2 sources maps with high resolution and sensitivity exist (Fanti et al., 1987 and references therein) while for the 3C sources we have used whatever is available in the literature. As a result of this analysis, we can consider 0924+30 and 3C 28 as relic sources, both having all the characteristics we expect for such a source, i.e. a relaxed structure and a very steep spectral index (see Cordey, 1987, and Giovannini et al., 1987 for a detailed study of these sources). The sources 0913+38, 3C 319 and 3C

244.1 should be excluded because of the presence of jets (0913 +38) and hot spots, while for 1512+30 the resolution is not good enough to have detailed information on the radio structure. The remaining 4 sources (1358+30, 1430+25, 1441+26, 3C 314.1) can be considered probable relics since they do not show any definite sign of activity in their radio structure, and have a steep spectral index ($\alpha > 1$). Thus only 2 out of 187 sources can be considered relics, which, together with the 4 probable relics represent ~3% of the sample.

We have also checked the radio structure and spectrum of the other radio galaxies with a high limit in the core radio emission. Very few of them (1–2) show a radio structure similar to relic radio sources, therefore we are confident that also with better data the number of relic radio sources still represent ~3–4% of our sample. This result is in agreement with Cordey (1986) and implies that the remnant phase of a radio source must be short compared with the average lifetime of the radio activity.

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