Astron. Astrophys. 281, 375–387 (1994)

ASTRONOMY AND ASTROPHYSICS

Structures of small-size radio galaxies in clusters

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Received April 7, 1992; accepted June 9, 1993

Abstract. We present high resolution maps of a sample of radio galaxies belonging to Abell clusters, showing linear size $\lesssim 20$ kpc, i.e. completely embedded within the optical galaxy. These radio galaxies were unresolved or only slightly resolved in previous interferometric observations. Most of the sources are resolved at the present resolution. Radio maps of all the resolved sources are given.

The correlation of the linear size versus the total radio power at 1.4 GHz is derived for radio galaxies belonging to clusters and is compared with the results found in a non-cluster sample. The size of cluster sources is slightly smaller on average than that of non-cluster ones, but the difference is not statistically significant.

The tailed structure, typical of cluster radio galaxies of large size, is found in $\sim 24\%$ of the sources of the present sample. This percentage is higher than in a non-cluster sample, but lower than in a cluster sample of radio galaxies with larger size. Tailed radio galaxies are mostly located at the cluster centers, the smallest ones being identified with the brightest cluster members. Stripping of the hot interstellar medium is suggested to be present in these galaxies.

Key words: galaxies: clustering – galaxies: ISM – radio continuum: galaxies

1. Introduction

The extended radio sources associated with cluster galaxies are morphologically different from the isolated ones, due to their interaction with the intergalactic medium. The most striking difference between radio galaxies in and out of Abell cluster is the radio morphology (Fanti 1984). The generally dominant double structure aligned with the parent galaxy, exhibited by most sources in radio catalogues, is in clusters absent or significantly less common. The largest majority of cluster radio sources with dimension > 40 kpc (larger than about a galaxy size) show morphology distorsion from the typical double structure of the type generally called "head-tail" or "wide-angle-tail", which would be determined by a drag action on the radio components due to the galaxy's motion through the intergalactic medium.

The structural behaviour of cluster radio galaxies of small size, i.e. embedded within the optical galaxy, is instead poorly known. Some objects show a classical double structure, which is indication of little or no interaction with the intergalactic medium (see for instance NGC 4472 in Virgo, Wrobel 1990). On the other hand, some radio galaxies have been found to reveal on very small linear scale distorted structures typical of more extended radio sources (NGC 4874 in Coma, Feretti & Giovannini 1987, 1707 + 787 and 1705 + 786 in A 2256, O'Dea & Owen 1985).

It is possible that the morphological difference between cluster and field galaxies, found among the extended sources, is present also in radio galaxies with small size. The existence of tailed radio sources of very small size implies that either the transition between interstellar and intergalactic medium occurs very close to the center of the galaxy, or other mechanisms are responsible for the tail phenomenon.

We present here high resolution maps of a sample of cluster radio galaxies embedded within the optical galaxy boundary. These observations were obtained with the following aims:

— get structural information on the kpc scale, and compare the structures of small radio galaxies in and out of Abell clusters.

— understand the reason of the small size. It could be related either to intrinsic source properties or to the external environment. This is a piece of information necessary to study the evolution of radio galaxies.

We use an Hubble constant $H_0 = 100\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ throughout the paper.

2. Definition of the sample, observations and data reduction

The sample under study was selected from past cluster surveys performed with the Westerbork Synthesis Radio Tele-

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scope (WSRT) at 1.4 or 0.6 GHz (see Table 1 for references) according to the following criteria:

(1) Radio galaxies identified with E or S0 galaxies, belonging to clusters of distance class ≤ 3 with right ascension between 0^h and 16^h10^m and Declination ≥ 15°.

(2) Sources showing a linear extent ≤ 20 kpc, i.e. which were unresolved or only slightly resolved in the previous observations.

For technical reasons, the observations of the radio galaxies in A 2151 were cancelled. The final sample con-

Table 1. List of sources and their properties

Cluster	Name	Other	RA (B 1950)	DEC (B 1950)	z	Opt.	Ref.
A 154	0108 + 173	IC 1634	$01^h08^m23\overset{s}{.}43$	17°23′11″.5	0.0658	cD	1
A 262	0147 + 360	UGC 1308	01 47 55.05	36 01 42.8	0.0161	E	2
	0149 + 359	NGC 703	01 49 43.16	35 55 30.5		S0/E	
	0154 + 361	NGC 759	01 54 52.79	36 05 59.5		E	
A 278	0154 + 317	—	01 54 28.65	31 44 25.7	0.0896	—	1
A 376	0243 + 362	—	02 43 17.92	36 15 46.3	0.0489	—	3
A 407	0256 + 354	—	02 56 40.58	35 28 03.9	0.0470	—	3
	0256 + 357	—	02 56 30.1	35 45 31		—	
	0257 + 361	—	02 57 39.26	36 10 15.5		—	
	0258 + 359	—	02 58 55.7	35 54 09		S0	
	0300 + 355	—	03 00 17.45	35 34 39.5		—	
A 569	0705 + 502	NGC 2332	07 05 43.70	50 15 47.7	0.0196	E	2
A 576	0715 + 555	—	07 15 32.56	55 31 39.2	0.0381	E	2
	0717 + 559	—	07 17 15.24	55 54 19.6		D	
A 1035	1029 + 403	—	10 29 00.75	40 22 09.8	0.0799	—	3
	1029 + 407		10 29 34.1	40 46 34		—	
A 1213	1113 + 295	—	11 13 47.41	29 33 32.4	0.0468	E	2
A 1254	1121 + 713	—	11 21 29.94	71 18 19.7	0.0628	—	1
A 1267	1125 + 270	Zw 156–80	11 25 40.05	27 02 08.2	0.0321	—	1
A 1314	1132 + 493	IC 712	11 32 06.5	49 21 17	0.0341	E	4
A 1367	1141 + 196	—	11 41 09.96	19 40 11.5	0.0215	E	5
	1141 + 202	NGC 3842	11 41 26.57	20 13 38.3		E	
A 1377	1147 + 557	—	11 47 21.57	55 45 01.3	0.0514	—	1
A 1656	1255 + 266	NGC 4849	12 55 47.13	26 39 59.5	0.0232	E	6
	1257 + 282	NGC 4889	12 57 43.43	28 14 46.0		E	7
A 1831	1356 + 282	Zw 162–39	13 56 52.58	28 15 53.5	0.0733	—	1
	1356 + 283	—	13 56 18.13	28 21 42.7		—	
A 1983	1450 + 173	Zw 105–50	14 50 03.12	17 19 32.9	0.0441	S0	1
A 1991	1452 + 188	NGC 5778	14 52 13.28	18 50 41.1	0.0586	E?	1
A 2065	1519 + 275	—	15 19 48.58	27 35 34.2	0.0721	—	1
A 2124	1541 + 360	—	15 41 28.75	36 00 30.8	0.0654	E	8
A 2147	1559 + 161		15 59 56.9	16 09 22	0.0356	E	6
	1600 + 165	—	16 00 58.15	16 32 23.2		E	
	1601 + 160	—	16 01 20.91	16 02 14.1		E?	
A 2162	1610 + 285		16 10 16.11	28 33 23.7	0.0320	E/(S0)	2
	1610 + 297	Zw 167–46	16 10 39.0	29 46 12.9		S0/a	
	1611 + 310	Zw 167–50	16 11 06.90	31 01 40.8		E	

References to Table 1: 1. Fanti et al. (1983); 2. Fanti et al. (1982); 3. Harris & Miley (1978); 4. Wilson and Vallée (1982); 5. Gavazzi (1979); 6. Jaffe & Perola (1975); 7. Birkinshaw & Davies (1985); 8. Hanisch (1984).

sists of 37 objects, belonging to 22 clusters. Four objects of the sample were not detected (see Sect. 3). We give in Table 1 the name of the cluster (col. 1), the IAU name of the radiogalaxy (col. 2), the name of the associated optical galaxy, when available (col. 3), the radio source position (cols. 4 and 5), the cluster redshift (col. 6), the optical morphology, when available (col. 7), the reference of the low resolution data (col. 8). The positions given in the table are obtained from the present maps, except for the undetected sources. Source positions are generally the barycenter of the emission regions, except in the cases where it seems more significant to give the peak position.

Each source was observed in November 1988 for about 15 min, with the VLA in A configuration, at frequencies 1415 and 1465 MHz, with 50 MHz bandwidth. The resolved sources were furthermore observed between July 1990 and November 1991 with the VLA in the A/B and B configurations, at the same frequencies and bandwidth. We give in Table 2 the configuration (col. 3) and the total integration time for each source (col. 4).

The flux-density scale was calibrated relative to 3C 286 or 3C 48, adopting the scale of Baars et al. (1977). The phase calibration was made relative to secondary calibrators located within about 15° of each object.

Each field was mapped with the AIPS package following the standard procedure (Fourier inversion, Clean and Restore). Self-calibration was applied for sources with large enough flux density, to minimise the effects of amplitude and phase uncertainties of atmospheric and instrumental origin. The (u, v) data from different configurations were first reduced separately, for a consistency check, then added together, to produce maps with high resolution and a good sensitivity to the extended structure. The noise on the cleaned maps typically ranges between 0.04 and 0.1 mJy beam^{-1}, while the synthesized beam is generally between 1 and 1.5 arcsec, except for a few cases of maps obtained with the B array alone (see columns 5 and 6, respectively, in Table 2).

3. Results

Out of the 37 sources of the sample, 4 are undetected in the present observations (0256 + 357, 0258 + 359, 1029 + 407, 1559 + 161). This implies that either they are of very low surface brightness, and completely resolved out, or they were mistaken, due to confusion, in the previous observations. Among the detected sources, 12 are still unresolved at the present resolution. The contour maps of the 21 resolved sources are presented in Fig. 1. In Table 3, we give the source parameters as follows:

Columns 1 and 2: cluster and source name,
Column 3: total flux density at 1.4 GHz, obtained by integration over the source brightness distribution for the extended sources, or from a gaussian fit in the pointlike sources,
Column 4: largest angular size of the source. For the simplest structures it was obtained from fitting the brightness distribution by an elliptical gaussian. For the double sources, the separation between the 2 components is given. For well resolved sources, the size was measured from the contour plots, as defined by the lowest reliable brightness contour (generally 2 rms of the noise). The measured diameters were corrected for the effect of the finite observing beam,
Column 5: logarithm of radio monochromatic power at 1.4 GHz,
Column 6: largest linear size, obtained from the angular value of column 4,
Column 7: minimum energy density in the regions of lower brightness,
Column 8: radio structure, with the following meaning: D = double, E = extended-diffuse, J = core–jet, P = point-like, T = tailed.

The distribution of the monochromatic power of the radio galaxies under study ranges from $6\,10^{20}$ to $5\,10^{23}$ W Hz^{-1} at 1.4 GHz. The linear size is generally smaller than 10 kpc, but there are 4 cases where the structure extends to values between 35 and 100 kpc. These objects belong to the present sample since their linear size as obtained in the old WSRT maps was not larger than 20 kpc. With the present highly sensitive observations, we have detected an extended structure of very low brightness, which makes these radio galaxies larger than previously believed.

Values of the minimum energy density in the resolved sources were computed with standard formulae (Pacholczyk 1970) and assumptions (ellipsoidal volume, filling factor = 1, ratio of proton to electron energy = 1, synchrotron spectrum extending from 10^7 to 10^{10} Hz) and refer to the source regions where the brightness is lower, i.e. tails and lobes or, more generally, the source terminations. These values are between $\sim 10^{-12}$ and $\sim 5\,10^{-11}$ erg cm^{-3}.

Among the resolved sources, there is not a really dominant structure. We find the typical morphologies of FRI sources, i.e. jets and lobes with some distorsions. We find 2 doubles, unexpected at this low radio power. We detect 8 tailed radio sources, 4 of them are characterized by small size, i.e. completely embedded within the galaxy. Moreover, we find 3 diffuse sources, which show no evidence of an active nucleus.

4. Notes of individual sources

0108+173. The associated cD galaxy is surrounded by many faint galaxies and has a common optical envelope with IC 1635. This pair of galaxies dominates the cluster A 154. The double radio structure of 0108 + 173 is very peculiar at this radio power and linear size. Future observations at 6 cm will clarify the location of radio core and the shape of the lobes.

0154+317. This source shows a complex morphology with two main peaks and no clear evidence of a compact nucleus.

Table 2. Observational data

Cluster	Name	Array	Obs. time (min)	Noise (mJy beam^{-1})	Beam ($'' \times ''$)	PA ($\circ$)
A 154	0108 + 173	A	12	0.08	1.1 × 1.1	
A 262	0147 + 360	A	16	0.13	1.1 × 1.0	(−27)
	0149 + 359	A	11	0.13	1.1 × 1.0	(−24)
	0154 + 361	A, B	33	0.05	1.1 × 1.1	
A 278	0154 + 317	A, B	33	0.19	1.2 × 1.2	
A 376	0243 + 362	A, B	34	0.07	1.3 × 1.1	(−22)
A 407	0256 + 354	A, B	32	0.06	1.2 × 1.2	
	0256 + 357	A	24	0.10	1.0 × 1.0	
	0257 + 361	A	24	0.11	1.0 × 1.0	
	0258 + 359	A	16	0.09	1.2 × 1.2	
	0300 + 355	A, B	28	0.07	1.4 × 1.4	
A 569	0705 + 502	A	24	0.09	1.1 × 1.0	(29)
A 576	0715 + 555	A, B	68	0.04	1.4 × 1.4	
	0717 + 559	A, B	34	0.04	1.5 × 1.5	
A 1035	1029 + 403	A	16	0.12	1.4 × 1.0	(74)
	1029 + 407	A	16	0.11	1.4 × 1.2	(70)
A 1213	1113 + 295	A, B	25	0.07	2 × 2	
A 1254	1121 + 713	A	16	0.10	1.7 × 1.3	(53)
A 1267	1125 + 270	A, B	30	0.04	1.5 × 1.5	
A 1314	1132 + 493	A, A/B, B	42	0.05	1.3 × 1.3	
A 1367	1141 + 196	A, A/B, B	45	0.04	1.5 × 1.5	
	1141 + 202	B	20	0.05	5 × 5	
A 1377	1147 + 557	A	16	0.12	1.5 × 1.2	(60)
A 1656	1255 + 266	A, A/B, B	75	0.06	1.5 × 1.5	
	1257 + 282	A	16	0.09	1.3 × 1.1	(77)
A 1831	1356 + 282	A	16	0.10	1.4 × 1.1	(80)
	1356 + 283	A, A/B, B	44	0.05	1.5 × 1.5	
A 1983	1450 + 173	A, A/B, B	81	0.05	2 × 2	
A 1991	1452 + 188	A, A/B, B	44	0.04	1.7 × 1.2	(−77)
A 2065	1519 + 275	A, B	62	0.03	1.6 × 1.4	(−86)
A 2124	1541 + 360	A	16	0.10	1.3 × 1.1	(75)
A 2147	1559 + 161	A	15	0.06	1.3 × 1.3	
	1600 + 165	A, A/B, B	56	0.04	1.3 × 1.2	(74)
	1601 + 160	B	18	0.06	5.9 × 5.3	(−51)
A 2162	1610 + 285	A	16	0.14	1.4 × 1.1	(81)
	1610 + 297	A	16	0.09	1.3 × 1.1	(72)
	1611 + 310	A, A/B, B	51	0.08	1.4 × 1.1	(73)

0154+361. Its structure is characterized by a diffuse emission, with a central peak, but no compact core. This source is reminiscent of objects presented by Wrobel & Heeschen (1988), who suggest that the radio emission could originate from star formation, rather than from an active nucleus. This possibility is supported in the present source by its identification with the IRAS source 01548 + 3605, which has a flux of 0.8 Jy at 60 μm. The ratio between radio and infrared flux is in agreement with that of star forming galaxies (Wrobel & Heeschen 1988).

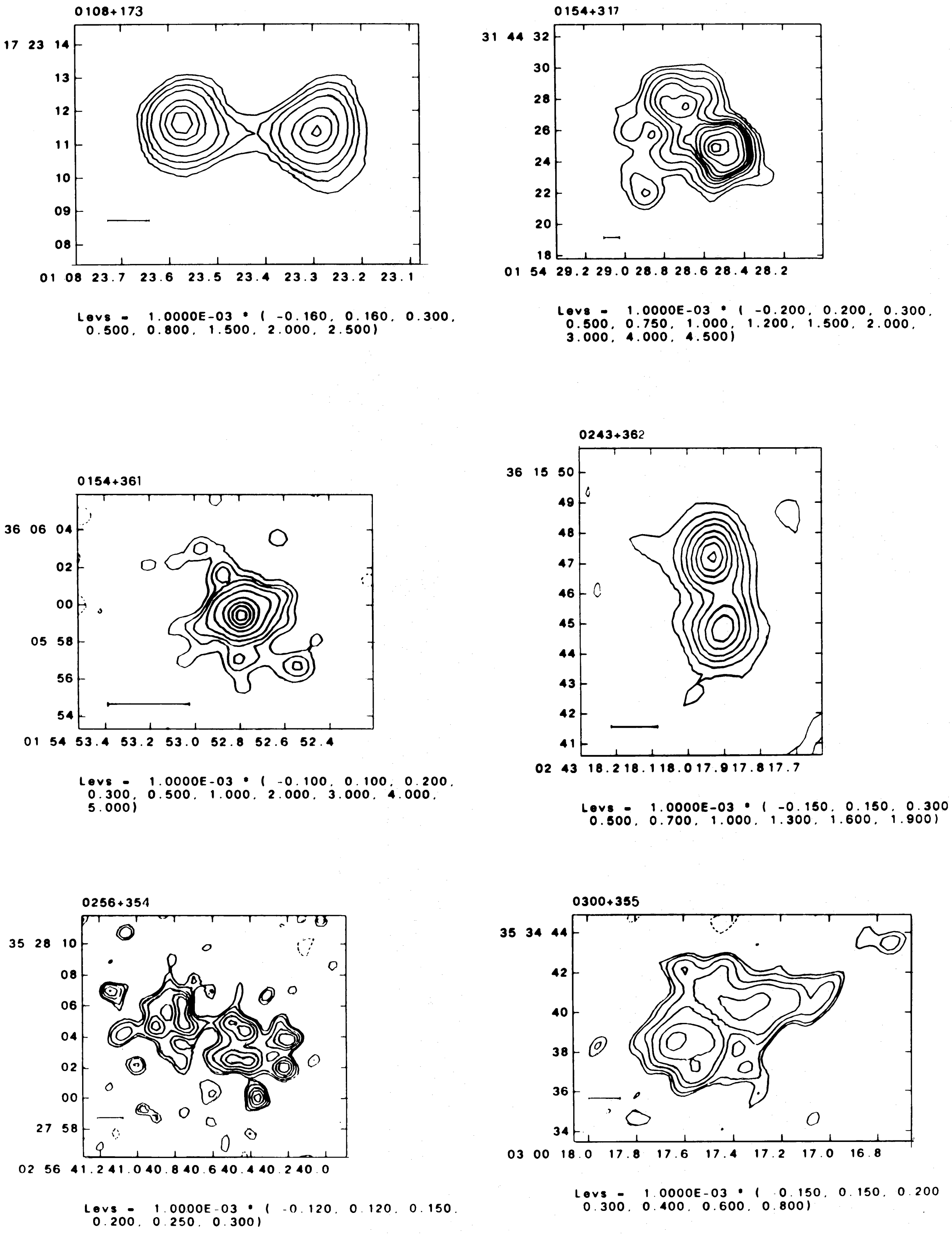


Fig. 1. Contour maps of the resolved sources. Coordinates are Right Ascension and Declination at epoch B 1950. Values of the contour levels in mJy beam^{-1} are given at the bottom of each map. For each source, full resolution maps are presented (HPBW in the last column of Table 2). Additional maps with lower resolution are given for the sources 0715 + 555 (HPBW = 2 ″), 1450 + 173 (HPBW = 5.7″ × 4.5″@ − 62°), 1519 + 275 (HPBW = 5.7″ × 4.4″@ − 55°) and 1600 + 165 (HPBW = 6.2 ″ × 3.8″@ − 68°), to show the low brightness structures. The line in the left bottom corner of each map represents 1 kpc. The position of the optical galaxy is marked by a cross for the most extended sources, while the other radio sources are imbedded in the optical galaxy

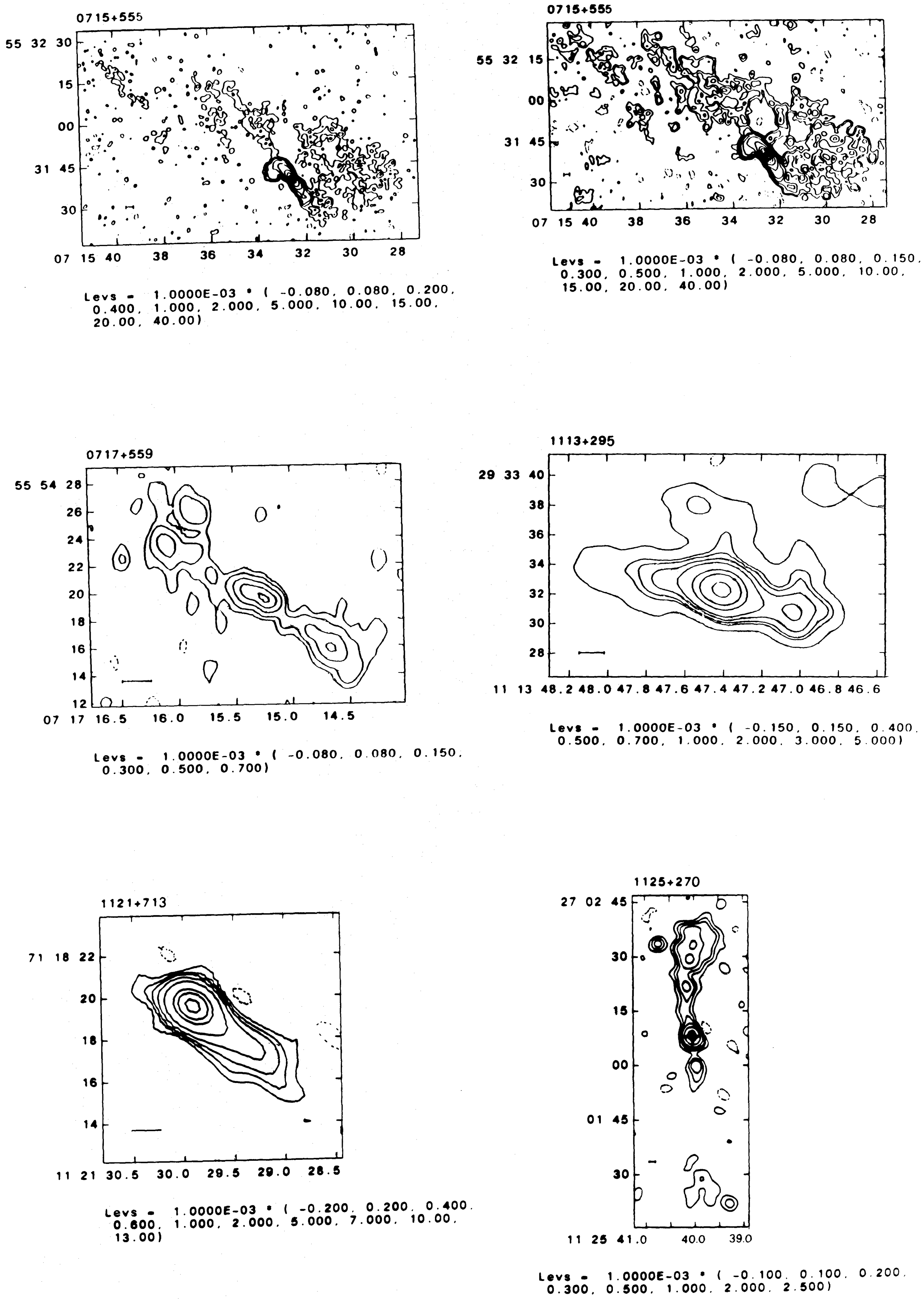
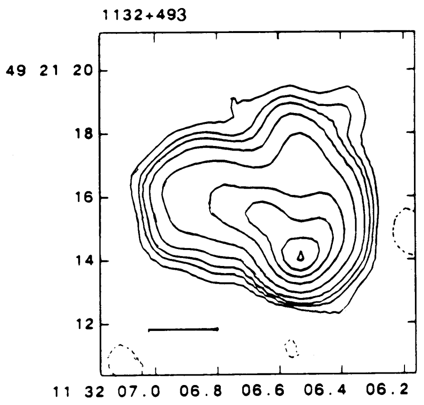


Fig. 1 (continued)



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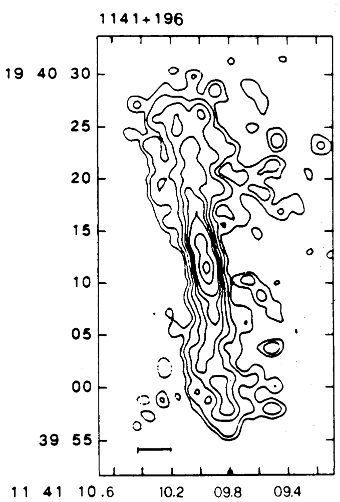

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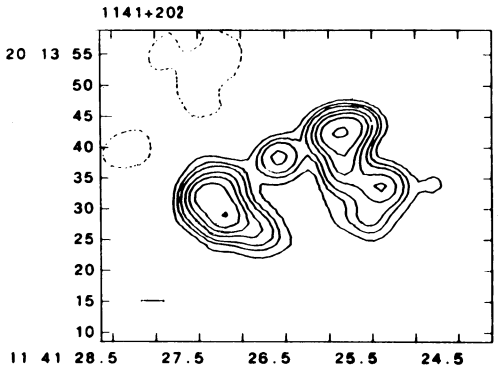

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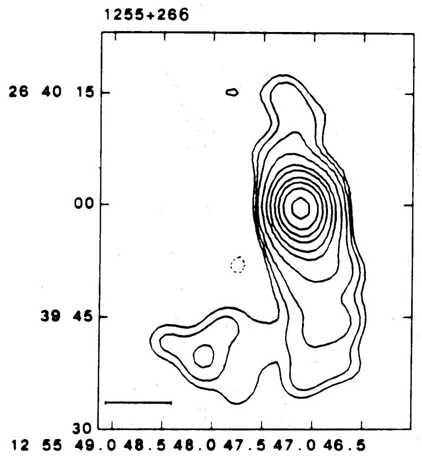

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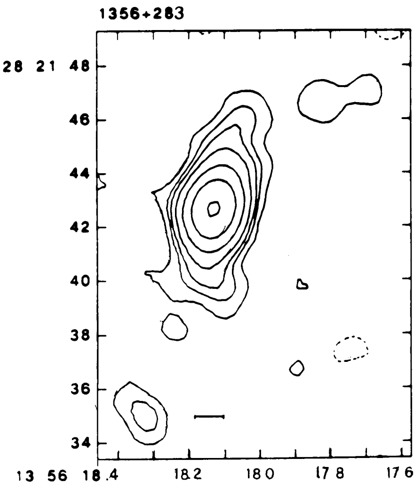

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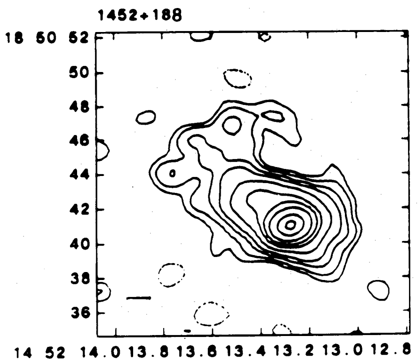
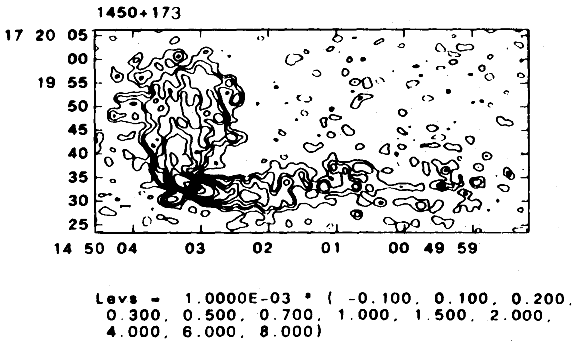
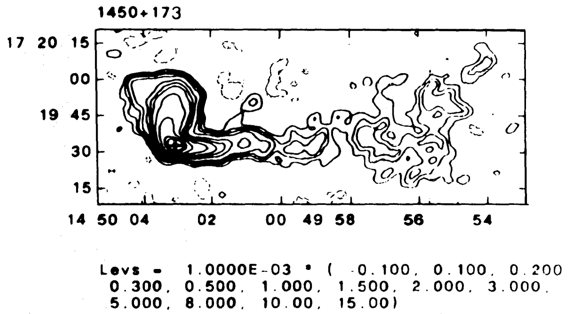
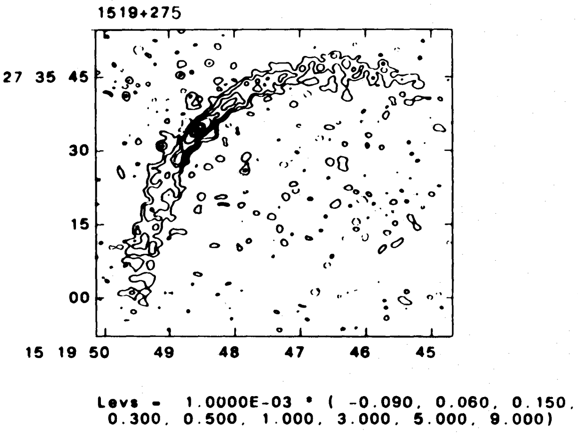


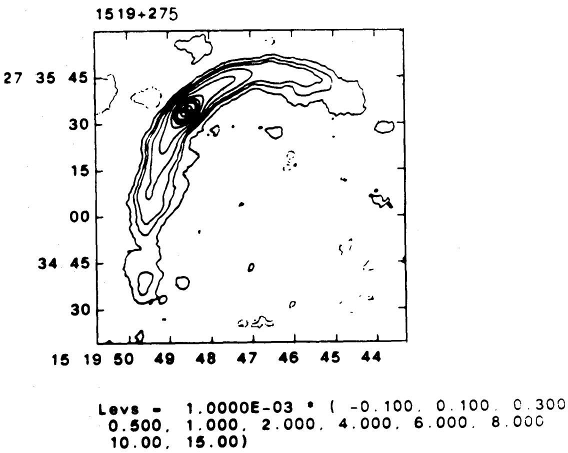
Levs = 1.0000E-03 * (-0.080, 0.080, 0.150, 0.300, 0.500, 1.000, 2.000, 3.000, 5.000, 10.00, 15.00)

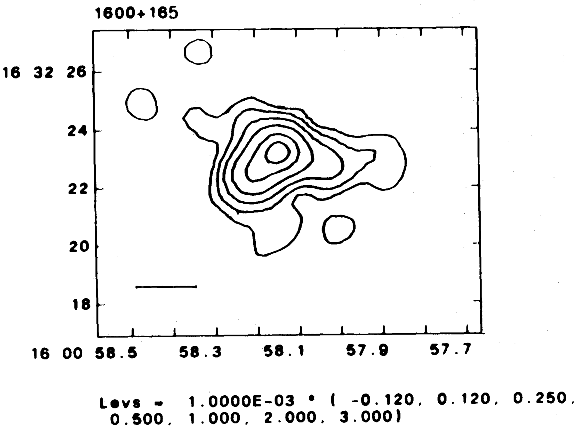
Fig. 1 (continued)

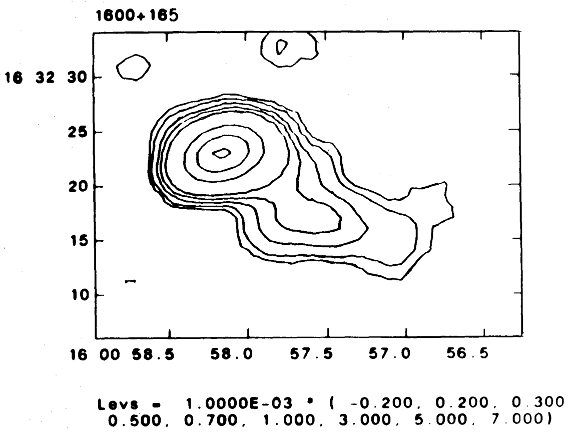












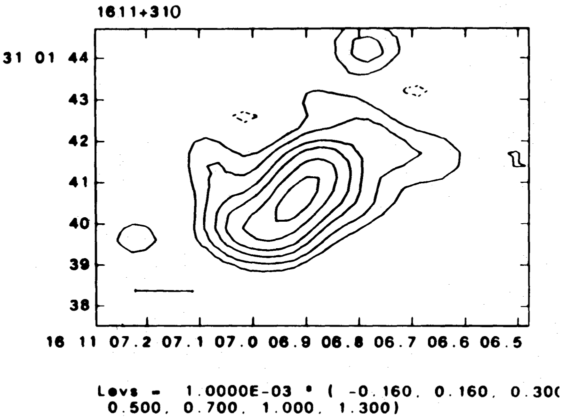


Fig. 1 (continued)

0256+354. The structure of this source is very diffuse and of very low brightness, showing no active nucleus. This source is coincident within the errors with the IRAS source 02566 + 3528, which has a flux of 0.98 Jy at 60 μm. Therefore, it is likely that also in this case, as in the previous one, the radio emission originates from star formation. The optical identification is with 2 galaxies which are almost touching each other (Harris & Miley 1978).

Table 3. Radio parameters of the galaxies

Cluster	Name	Flux (mJy)	AS ($''$)	log $P_{1.4}$ (W Hz^{-1})	$LS_{1.4}$ (kpc)	u_{min} (10^{-11} erg cm^{-3})	Radio structure
A 154	0108 + 173	9.6	4.0	22.65	3.4	5.2	D
A 262	0147 + 360	19.4	—	21.73	<0.25	—	P
	0149 + 359	12.3	—	21.54	<0.25	—	P
	0154 + 361	16.4	6.4	21.66	1.5	5.3	E
A 278	0154 + 317	32.5	8.5	23.45	9.3	2.0	E
A 376	0243 + 362	6.9	2.5	22.25	1.6	2.9	D
A 407	0256 + 354	8.8	10.6	22.32	6.6	0.7	E
	0256 + 357	<0.3[a]					
	0257 + 361	88.2	—	23.32	<0.6	—	P
	0258 + 359	<0.3					
	0300 + 355	9.3	9.5	22.34	5.9	0.9	E
A 569	0705 + 502	115	—	22.68	<0.3	—	P
A 576	0715 + 555	226	100	23.55	51.4	0.2	T
	0717 + 559	6.7	21	22.02	10.8	1.6	T
A 1035	1029 + 403	11.6	—	22.90	<1.4	—	P
	1029 + 407	<0.3					
A 1213	1113 + 295	16.7	17	22.59	10.6	0.7	J
A 1254	1121 + 713	25	6.5	23.03	5.3	1.5	J
A 1267	1125 + 270	18.6	80	22.31	35.0	0.3	J
A 1314	1132 + 493	26.3	10	22.52	4.6	1.3	T
A 1367	1141 + 196	39.4	30	22.29	9.0	1.8	J
	1141 + 202	10.5	55	21.72	16.5	0.2	T
A 1377	1147 + 557	146.3	—	23.62	<1.0	—	P
A 1656	1255 + 266	31.3	25	22.26	8.1	1.3	T
	1257 + 282	1.0	—	20.76	<0.4	—	P
A 1831	1356 + 282	37.9	1.4	23.34	<1.3	—	P
	1356 + 283	7.9	8	22.66	7.4	0.8	J
A 1983	1450 + 173	110	130	23.36	76.6	0.3	T
A 1991	1452 + 188	35.7	10.5	23.12	8.0	0.7	J
A 2065	1519 + 275	56.5	110	23.50	100.4	0.1	T
A 2124	1541 + 360	11.9	—	22.74	<1.1	—	P
A 2147	1559 + 161	<0.2					
	1600 + 165	12.3	25	22.22	12.1	0.3	T
	1601 + 160	88.5	—	23.08	<2.8	—	P
A 2162	1610 + 285	81.5	—	22.95	<0.6	—	P
	1610 + 297	30.4	—	22.52	<0.6	—	P
	1611 + 310	5.3	5.0	21.77	2.2	2.5	J

[a] This undetected galaxy is projected by chance on an extended radiogalaxy (see the notes on individual sources in the text).

0256+357. This source is the bright, apparently compact eastermost component of the extended source n.75, given by Harris & Miley (1978). Those authors indicate 3 cluster galaxies present in the emitting region (see their Fig. 2) and possibly responsible of it. In the present observations, this source is undetected, while a core-jet source is found to be coincident with the central of the 3 galaxies, at the position RA=$02^h56^m24\overset{s}{.}1$, DEC = 35°44′38″ (figure not given). Therefore, 0256 + 357 is likely to be the lobe, completely resolved out, of a complex, very extended radio galaxy.

0300+355. This is another case of diffuse source, without compact nucleus. No infrared source is found in the IRAS catalogue coinciding with this galaxy, thus there is no support to the possibility that the radio emission originates from star formation. We tentatively suggest that this is a relic radio source, where the active nucleus has turned off. Spectral information will be helpful to clarify the nature of this object.

0715+555. The low surface brightness tails of this radiogalaxy are better visible in the low resolution map. The radio structure is strongly affected by projection effects.

0717+559. This source consists of a core and two opposite jets, the eastern one bent by ~ 90° at about 7″ from the core. A similar bend seems to occur in the western jet, but the radio brightness here is very low. The total flux density in the present map is only ~ 50% of the total flux density detected with the WSRT at 1.4 GHz (Fanti et al. 1982). This implies the existence of additional low surface brightness structure.

1113+295. The total flux density detected for this source is 70% of the total flux density in the previous WSRT observations at 1.4 GHz by Fanti et al. (1982).

1125+270. The southern lobe in this radio galaxy is of very low brightness, therefore undetected in the previous WSRT observations (Fanti et al. 1983). Owing to the existence of this component, the radio source turns out to have a total linear size larger than 20 kpc.

1132+493. Owing to its size of 4.6 kpc, this is the smallest known radio galaxy with tailed structure. It is identified with the brightest member of the cluster A 1314, which also is characterized by the presence of two extended tailed radiogalaxies, IC 711 (Wilson & Vallée 1977) and IC 708 (Vallée et al. 1981). The tails of these 3 cluster radiogalaxies point in different directions with respect to the cluster center.

1141+202. This is another small tailed source. As in the case of 1132 + 493, it is associated with the brightest cluster member in A 1367. This cluster is peculiar for the existence of extended trails of radio emission behind three irregular galaxies in its periphery (Gavazzi & Jaffe 1987). We note that the present radio galaxy is very similar to NGC 4874, the brightest member of the Coma cluster.

1255+266. Highly sensitive WSRT observations at 327 MHz frequency (Venturi et al. 1990) have revealed that this is a tailed radio galaxy with a very low surface brightness tail, of a few arcmin in size. The statistical analysis in this paper is performed with the size at 1.4 GHz, given in Table 3.

1450+173. This source is resolved as a tailed radio galaxy, with very asymmetric jets and lobes. The asymmetry may arise from projection effects. The eastern jet is very short, and suddenly bends to the north and spreads into the lobe. The western jet is longer and more collimated, with no prominent bend. In the low resolution map, an extremely low surface brightness lobe is detected, at ~ 1.5′ from the core, where the western jet points at. The existence of the very low brightness lobes implies for this radio galaxy a much larger size than previously believed (Fanti et al. 1983) and a total extension well outside the optical galaxy boundary.

1519+275. This is a tailed radio source, characterized by two opposite very symmetric jets, well collimated and continuously bent. The same feature is visible in the low resolution map, where no lobes are seen at the jet terminations. The symmetric structure implies that projection effects are probably negligible, i.e. that the radio source lies close to the plane of the sky. The WSRT observations of Fanti et al. (1983) detected a radio source of 20″ in size, in position angle 120°, i.e. approximately in the direction of the inner jets. The outer jets were then missed, because of the sensitivity. The total size of the radio galaxy is about 70″, corresponding to 64 kpc, i.e. it extends out of the bounds of the optical galaxy. The total flux density detected in the present observation is much larger than that obtained from the old WSRT data.

1541+360. The total flux density detected for this source is only 60% of that previously measured with the WSRT. Since the source is pointlike, either a very low brightness halo is missed, or the source is variable.

1600+165. In this small tailed radio galaxy, the jets are sharply bent to the south-west. In the low resolution map, the tail is found to extend up to 10–12″ from the core.

5. Discussion

5.1. Radio galaxy size

To analyze the properties of small-size cluster galaxies, we have examined their behaviour in a size-power diagram. Figure 2 shows the plot of maximum linear size D vs. the radio power P, both at 1.4 GHz, for cluster radio sources. To the present data (dots) we have added the data relative to the extended radio galaxies taken from the literature and belonging to clusters which match the selection criteria of the present sample (triangles). The global trend indicates an increase of the size at increasing radio power, as already found by Fanti et al. (1982). The best fit linear regression

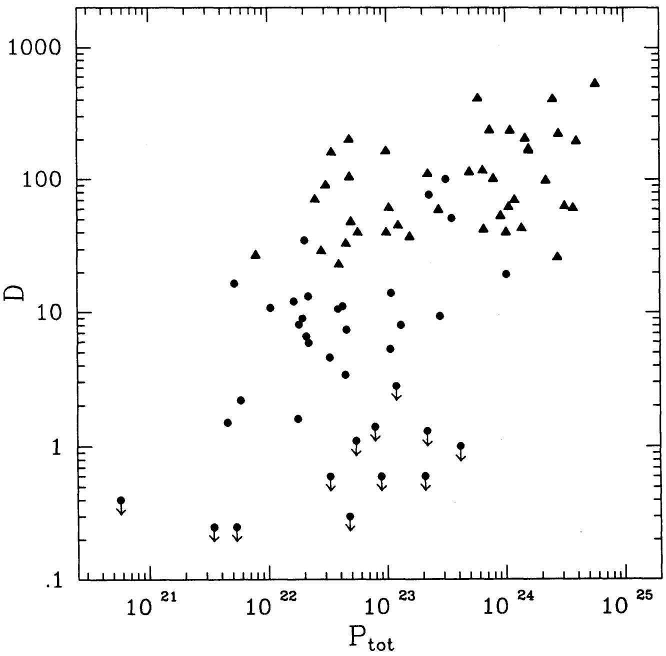


Fig. 2. Plot of the linear size versus the radio power at 1.4 GHz, for radio galaxies in clusters: the dots refer to the present sample, the triangles to more extended radio galaxies taken from the literature

of the data, including the upper limits is $\log D = 0.65 \pm 0.10 \log P$. The radio galaxies in our sample are therefore smaller in size simply because they are fainter.

The dependence of linear size from radio power for B2 and 3C radio galaxies at low redshift has been recently analyzed by De Ruiter et al. (1990). Their sample essentially consists of radio galaxies outside clusters, in a redshift range similar to ours. They find that below a radio power of $10^{24.5}$ W Hz^{-1}, i.e. essentially in the B2 sample, the size increases with the power at $\log D \approx 0.52 \log P$, which is fully consistent with our result.

There seems to be, however, an excess of pointlike sources in the cluster sample with respect to the B2 sample, so we have checked whether the size of cluster radio galaxies is smaller than that of the non-cluster ones, besides the similarity of the size-power correlation. The median value of the size in the cluster and non-cluster galaxies in the same power range ($\leq 10^{24.5}$ W Hz^{-1}) is 33 and 53 kpc, respectively. This difference, checked with the median test (see e.g. Siegel & Castellan 1988), was found to be not statistically significant. No significant difference was found even comparing the median size of radio galaxies grouped according to their power, although the size of cluster sources is systematically lower than that of non-cluster ones. Our conclusion is, therefore, that the cluster environmental effect is not dominant in determining the total extension of radio galaxies. A weak effect might be present, in the sense that cluster sources are slightly smaller. This effect is in the same direction, but not as strong as that found by De Ruiter et al. (1990).

The values of minimum energy density in the radio galaxies of our sample are fully consistent with those found by De Ruiter et al. (1990), thus reinforcing the suggestion that these small galaxies are not different from the larger galaxies. The existence of weak pointlike sources is consistent with the findings of Sadler et al. (1989), who suggest that these faint sources arise from the same non-thermal emission mechanism which operates in more powerful radio galaxies. Spectral information will be helpful in deriving some constraint on the nature of these sources, and get information on their age. This point will be discussed in better detail in a future paper, where we will present observations at 6 cm.

5.2. Radio structures

For the discussion of radio morphologies, we concentrate only on the 29 objects with linear size actually < 20 kpc, omitting the 4 radio galaxies, which turned out to be larger than the original size threshold (0715 + 555, tailed; 1125 + 270, core–jet; 1450 + 173, tailed; 1519 + 275, tailed). In addition to these, we also use the radio galaxies smaller than 20 kpc, that match the selection criteria of the present sample, but were not included because observed by other authors (see Table 4). The final sample of small cluster sources consists of 33 radio galaxies. Among them, 8 sources, corresponding to a percentage of ~24%, show the tailed structure typical of extended cluster radio galaxies, and only 2 (6%) are double. As a comparison non-cluster sample we use the B2 radio galaxies, selecting those with size $\lesssim$ 20 kpc, and excluding the few objects belonging to Abell clusters. There are 22 B2 radio galaxies matching this criterion. Although distorsions on small scale are common (De Ruiter & Parma 1984; De Ruiter et al. 1990), only 2 radio galaxies (0258 + 35 and 1621 + 38) show a tailed morphology (9%), while 5 are double (23%).

Therefore, there is in the cluster sample a higher percentage of tailed radio galaxies and a lower percentage of double sources. It is evident that the cluster environment plays a role in the morphology of radio sources, also within very small scales, i.e. within the optical galaxy boundary.

We now compare the morphological properties of our sample with those of cluster radio galaxies of larger size. According to Fanti (1984), the percentage of tailed sources among radio galaxies of size > 40 kpc and power $P > 10^{23}$ W Hz^{-1} is rather independent on the luminosity range, and is ~45–60%. The percentage of tailed radio galaxies in our sample is, therefore, significantly lower than that of tailed sources in a sample of large cluster radio galaxies. This indicates that the ram pressure exerted by the intergalactic medium is less effective on the small sources than on the large ones.

Our suggestion is that the structure of cluster galaxies is related to the content of hot interstellar medium. Tailed

Table 4. Radio galaxies belonging to the present sample, observed by other authors

Cluster	Name	Other	Flux (mJy)	AS (″)	log $P_{1.4}$ (W Hz^{-1})	$LS_{1.4}$ (kpc)	Radio structure	Ref.
A 262	0149 + 35	NGC 708	78	58	22.34	13.2	J	1
A 2079	1525 + 29	UGC 9861	220	23	24.01	19.3	T	1
A 1656	1254 + 27	NGC 4839	65	34	22.63	11.1	T	2
	1257 + 282	NGC 4874	190	43	23.04	14.0	T	3

References to Table 4: 1. Fanti et al. (1986); 2. Fanti et al. (1987); 3. Feretti & Giovannini (1987).

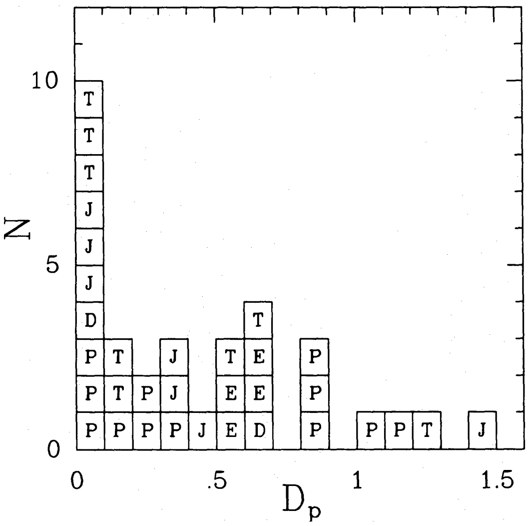


Fig. 3. Distribution of the cluster galaxies of size ≤ 20 kpc, as a function of the projected distance from the cluster center in units of the Abell radius. The radio morphology is indicated as follows: D = double, E = extended-diffuse, J = core–jet, P = pointlike, T = tailed

radio galaxies of very small total size can form when the content of hot gas in the parent galaxy is low. In this case, the radio jets can be bent by ram pressure, while the presence of significant gas in the galaxy protects the radio jets and prevents them from the bending. The hot interstellar medium may be significantly stripped in cluster galaxies, owing to the effect of intergalactic medium pressure. This is consistent with the evidence of ram pressure stripping of the gaseous halos found by White & Sarazin (1991).

In this context, the formation of small tailed structures is obviously related to the efficiency of ram pressure stripping. Figure 3 shows the distribution of morphologies as a function of the projected distance from the cluster center, in units of the Abell radius. All structures, included the pointlike sources, seem to be located at all possible distances. We note, however, that 5 tailed radio galaxies, out of 8, are located at the cluster centers, where the intergalactic medium density is highest, and the stripping effect most efficient. Moreover, the smallest tailed sources in the sample are identified with the brightest cluster members (A 1314, Coma, A 1367). X-ray information on these individual objects would be needed to confirm this interpretation. Actually, no X-ray halo was found to be associated with the dominant galaxy in A 1367 (Bechtold et al. 1983), while NGC 4874 in Coma appears to have its own extended gaseous atmosphere in the recent Rosat data (White et al. 1993), but the X-ray luminosity is somewhat low for its optical luminosity. The existence of first ranked galaxies showing tailed radio structure, related to the stripping of hot interstellar medium, implies that these first ranked galaxies are not stationary at the cluster centers.

6. Conclusions

We have presented high resolution maps of a sample of cluster radio galaxies of size smaller than 20 kpc. The conclusions of the present paper are the following:

(1) The radio morphology of resolved sources is very similar to that of large scale FRI radio galaxies (jets, lobes, distorted structures, etc.), but the linear size and radio power are scaled down.

(2) By adding to the present sample the extended radio galaxies in clusters, we find that the size-power relation for cluster radio galaxies is similar to that holding for non-cluster ones. We find no statistically significant difference between the average size of cluster and non-cluster objects, although the cluster sources are slightly smaller on average than the non-cluster ones. Therefore, any effect of the cluster environment on the total size of a radio galaxy seems to be very weak.

(3) The percentage of tailed structures in the present sample is significantly higher than in a non-cluster sample of similar size, indicating that the cluster environment plays a role in shaping the radio source morphology even on very small scales. Our suggestion is that these small tailed radio sources originate in galaxies with little hot interstellar medium. We note that most of these galaxies are located at the cluster center, where the gas density is higher, and the stripping effect more efficient.

(4) The tailed structures in small cluster radio galaxies are less frequent than in radio galaxies larger than 40 kpc. This is related with the efficiency of gas stripping in the parent galaxy.

Acknowledgements. We wish to thank Frazer Owen for stimulating discussions and Roberto Fanti and Paola Parma for helpful suggestions. Thanks are due to Nando Primavera for drawing the figures. The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation.

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