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RADIO GALAXIES IN THE COMA CLUSTER. II.

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ABSTRACT

Optical data are presented for 50 galaxies in the Coma cluster, including all the known radio sources brighter than $m_p \approx 17$. The redshift distribution of the best radio source sample deviates markedly from that of the cluster as a whole. The correlations of redshift with magnitude and radio flux at 610 MHz are given.

Subject headings: galaxies: clusters of — galaxies: redshifts — radio sources: general

I. INTRODUCTION

This is the second in a series of papers on the optical properties of radio galaxies in nearby rich clusters. In Tifft and Tarenghi 1975 (hereafter RGC1) we reported redshifts for 23 possible radio galaxies, and three non–radio galaxies, with $m_p < 17$ in the field of the Coma cluster. The radio galaxies were from the 5C 4. (Willson 1970) and Westerbork 21 cm (Jaffe and Perola 1975) surveys. Sixteen radio galaxies were found to be cluster members. They appeared to show an anomalous distribution in redshift, with an average redshift significantly greater than the cluster mean. New observations of the Coma cluster at 610 MHz have now been obtained with the Westerbork Synthesis Radio Telescope (WSRT) by Jaffe, Perola, and Valentijn (1976). Optical identifications for the 158 radio sources have been carried out by Jaffe, Perola, and Valentijn (1976) and Valentijn, Perola, and Jaffe (1977). A total of 40 galaxies with $m_p < 17.5$ are detectable at one or more of the three frequencies 408, 610, and 1415 MHz and within 1°6 of the center of the Coma cluster. One or more spectrograms of each of the 40 possible sources have been obtained with the Steward Observatory 90 inch (2.3 m) telescope by using the Cassegrain image-tube spectrograph at a dispersion of 240 Å mm^{-1}.

II. OBSERVATIONS

Table 1 contains the identifications and positions for all galaxies for which we have one or more spectrograms in the radio galaxy program for Coma. Besides the 40 possible radio sources, 10 other galaxies are listed. These are objects included in a first preliminary list of candidates but later discarded. The table contains the following information.

Column (1).—Serial number (TT number). This is the only identification number which covers all the objects. The first 26 objects are from RGC1; however, TT 24–26 are definitely not radio sources and hence are not repeated in this table.

Column (2).—The Westerbork radio source name (Jaffe and Perola 1975; Jaffe, Perola, and Valentijn 1976; Valentijn, Perola, and Jaffe 1977).

Column (3).—The 5C 4. identification (Willson 1970).

Column (4).—The Zwicky catalog number (Zwicky and Herzog 1963), consisting of the catalog field number followed by a running serial number for the galaxies tabulated. Note that 160A is the field designation for the special list of central galaxies in the Coma cluster. If two serial numbers are given, the second refers to the next-higher field number where the galaxy also appears.

Column (5).—Other designations or distinctions in pairs of galaxies. N = NGC, I = IC, RB = Rood and Baum (1967), Mrk = Markarian (1967).

Columns (6) and (7).—1950 positions.

Column (8).—The value of the function

$$\kappa = \left(\frac{(\Delta\alpha)^2}{\sigma_\alpha^2 + \sigma_0^2} + \frac{(\Delta\delta)^2}{\sigma_\delta^2 + \sigma_0^2}\right)^{1/2}, \qquad (1)$$

where $\Delta\alpha$ and $\Delta\delta$ are the differences between the most probable radio position and the center of the optical image of the galaxy. The quantities σ_α and σ_δ are the rms uncertainties in the radio positions; σ_0 is the uncertainty in the position of the center of the optical image. We have used $\sigma_0 = 3''.5$ for the galaxies in the 5C 4. survey (Barbieri and Bertola 1972) and $\sigma_0 = 2''$ for Westerbork galaxies. "Ext" means that the radio source is extended; hence the value of κ is less specific. Galaxies for which $\kappa > 4$ are not considered radio sources and the column is left blank. Rough κ values are given for some of these galaxies in the comments.

Column (9).—References to notes following the table.

Table 2 contains the detailed properties of each

TABLE 1

RADIO SOURCE CANDIDATES

TT (1)	Westerbork (2)	5C 4. (3)	Zwicky (4)	Other (5)	α (1950) (6)	δ (7)	κ (8)	Notes (9)
27..........	...	6	...	...	$12^{\rm h}50^{\rm m}.2$	29°08′	2.6	
1..........	...	7	159–102	...	50.5	28 39	1.1	
22..........	1251+27 W2	19	...	3C 377.3 Com A	51.8	27 54	2.3	
2..........	1251+27 W3	20	159–113/008	N4789	51.9	27 21	3.5	
20..........	1252+29 W1	22	159–116/011	N4793	52.3	29 12	1.9	
28..........	...	...	...	...	52.4	27 37		1
29..........	1252+28 W7	...	160–015	...	53.0	28 04	3.2	
30..........	1253+27 W6	...	160–020 N	Mrk 53	53.7	27 57	1.7	
3..........	1254+27 W4	43	160–028	N4827	54.3	27 27	4.9 Ext	2
31..........	...	44	...	...	54.5	26 49	2.0	
4..........	1254+27 W1	51	160–039	N4839	55.0	27 46	1.5 Ext	
23..........	1255+27 W1	...	...	...	55.5	27 53	< 1	
5..........	1255+28 W3	...	...	...	55.5	28 20	2.8	
6..........	1255+28 W6	58	160–055	N4848	55.7	28 31	2.0	
32..........	1255+28 W11	...	160–058	...	55.7	28 59	1.6	
33..........	1255+27 W6	...	...	...	55.9	27 35	< 1	
34..........	1256+27 W5	...	160–064	Mrk 56	56.2	27 32	1.4	
7..........	1256+28 W4ab	...	...	RB 214	56.5	28 04	Double	3
9..........	1256+28 W7	...	160A–04	N4858	56.6	28 23	2.0	
8..........	1256+27 W4	...	160–073	RB 219, Mrk 58	56.7	27 55	1.0	
10..........	1256+28 W8	...	160A–15	N4865	56.9	28 21	< 1	
11..........	1256+28 W9	81	160A–16	N4869	56.9	28 11	< 1 Ext	4
12..........	1257+28 W1	85	160A–22	N4874	57.2	28 14	< 1 Ext	5
52..........	1257+28 W8	...	...	RB 144	57.2	28 16	Uncertain	6
53..........	1257+28 W5	...	...	RB 44	57.3	28 08	< 1	7
35..........	1257+28 W7	...	...	RB 60	57.5	28 06	3.1 Ext	8
36..........	...	...	160A–28	N4883	57.5	28 18		9
13..........	1257+28 W2	...	160A–31	...	57.6	28 05	3.6	
37..........	...	...	...	RB 71	57.6	28 13		10
38..........	...	...	...	RB 68	57.6	28 13		10
39..........	...	...	...	...	57.7	27 07		11
40..........	1257+27 W8	...	160–082	...	57.9	27 40	2.4	
41..........	...	...	...	W of pair	58.0	27 47		12
42..........	...	...	...	E of pair	58.0	27 47		12
43..........	1258+27 W6	...	160–086	...	58.1	27 55	1.3	
14..........	1258+28 W3	108	160A–43	I4040	58.2	28 20	< 1	
15..........	1258+28 W11	109	...	...	58.3	28 47	1.1	
16..........	1258+28 W12	113	...	...	58.3	28 41	2.0	
17..........	1258+28 W6	117	160A–51	N4911	58.5	28 04	1.7	
44..........	...	...	...	RB 129	58.8	28 11		13
45..........	1259+28 W1	...	160–095	N4921	59.0	28 09	3.8	
18..........	...	130	160–096 N	N4922 N	59.0	29 35	< 2	14
46..........	1258+28 W20	...	160–098	...	59.0	28 57	3.3	
47..........	...	...	...	SW of pair	59.2	28 25		15
48..........	...	...	...	NE of pair	59.2	28 25		15
49..........	1259+28 W5	...	160–105	N4927	59.5	28 17	1.0	
50..........	1300+28 W1	...	...	...	13 00.3	28 24	1.4	
51..........	...	157	...	...	01.4	29 29	< 1	
19..........	...	161	...	...	01.9	28 44	2.0	
21..........	...	175	160–134	N4961	03.3	28 00	Off nucl.	

1. TT 28 is not a radio source. A preliminary report suggesting a source was not confirmed. This galaxy is located 4′ S, 1′.5 W of Z159–118.
2. TT 3. Although $\kappa = 4.9$, the identification is considered probable because of the extended nature (Jaffe *et al.* 1976).
3. TT 7 is not a likely radio source (Jaffe and Perola 1975).
4. TT 11 is the well-known radio tail galaxy N4869. There is no question of its identity.
5. TT 12 is the well-known complex radio source associated with the supergiant galaxy N4874. There is no question of identity.
6. TT 52. Radio positional errors are large due to contamination from the Coma C extended radio source (Valentijn *et al.* 1977). There is also a second radio source, 1257+28 W6, which forms a double with this source. Overall, the identification is very uncertain.
7. TT 53. Radio positional errors are large due to contamination from the Coma C extended radio source (Valentijn *et al.* 1977). The faint galaxies RB 41 and 39 are also close to the radio position ($\kappa = 1.8, 2.0$); however, the high-redshift Coma background galaxy RB 44 is closest ($\kappa = 0.9$) and is considered the most likely identification in view of its emission-line spectrum. Without higher-resolution data, the final identification remains somewhat uncertain.
8. TT 35. This is an unlikely identification. A 19 mag galaxy is closer to the radio position ($\kappa < 2$).
9. TT 36. This galaxy has $\kappa = 5.2$ with respect to the radio source 1257+28 W10; hence is virtually certainly not related to the source.
10. TT 37 and 38. These faint galaxies are near a possible radio source later dropped from the identification lists. They are included here for completeness.
11. TT 39. This faint galaxy is located 3′ S of Z160–081. It has $\kappa = 5.2$ with respect to the radio source 1257+27 W6, which is identified with a 20 mag object (Valentijn *et al.* 1977).
12. TT 41 and 42. Two galaxies near 5C 4.106 = 1258+27 W3 identified with a faint starlike object (Valentijn *et al.* 1977). The quantity κ is greater than 5 for both galaxies; hence they are not associated with the radio source.
13. TT 44. The galaxy has $\kappa = 4.3$ with respect to the radio source 1258+28 W18; hence is not a likely identification.
14. TT 18. No accurate position of the galaxy is available; however, the source identification appears good and κ is estimated from Willson (1970).
15. TT 47 and 48. This faint pair of galaxies is located 3′ N and 2′ W of Z160–101. The galaxies have $\kappa = 6.8$ and 4.1, respectively, with respect to the radio source 1259+28 W2 (Valentijn *et al.* 1977).

TABLE 2

Properties of the Radio Source Sample

TT	κ	V_0	Source	m_p	S_{610}	R^0	Type	Other V_0
				Coma Sources				
1	1.1	7012E	E1β	14.5	...	1.6	S	7112 K
6	2.0	7272E	E1β	14.2	36.4	0.5	S	7221 RC
8	1.0	5354E	C1β	15.1	< 4	0.4	SBa	5366 K
9	2.0	9500E	E1β	15.5	16.3	0.2	SBb	9398 RC, 9405 U
14	< 1	7613E	CE2β	15.1	27.5	0.2	I/Sc	7528 RC, 7759 CR
15	1.1	8907E	E1β	(16.0)	6.5	0.6	pec	
18	< 2	7029E	H1β	(15.5)	...	1.4	pec	
30	1.7	4982E	E1$\alpha\beta$	15.5	6.0	0.9	pec	4887 GN
32	1.6	7674E	E1α	15.5	4.7	0.8	Sc	(7692) G, 7623 GN
33	< 1	7478E	E1$\alpha\beta$	(16.0)	6.9	0.8	pec	
34	1.4	7423E	E1$\alpha\beta$	15.4	4.4	0.8	Spec	7425 CR
43	1.3	7481E	C1$\alpha\beta$	15.4	4.3	0.4	Spec	7508 CR
3	(?) Ext	7498	E1	14.1	26.3	1.1	E	7657 RC
4	1.2 Ext	7449	E1	13.6	115.9	0.7	E	7455 RC
10	< 1	4588	C2	14.6	< 4	0.2	E	4655 RC
11	< 1 Ext	6801	C3	14.9	1173.0	0.1	E	6715 RC
12	< 1 Ext	7180	C3	13.7	396.0	0.1	S0	7183 RC, 7131 K
16	2.0	6392	E1	(17.8)	8.6	0.5	E	
17	1.7	7831	C1	13.7	26.1	0.3	S	8018 RC
19	2.0	7832	E2	(16.0)	...	1.1	E	
49	1.0	7573	E2	14.8	5.1	0.5	E	7572 K
				Possible Coma Sources				
5	2.8	8180	CE2$\alpha\beta$	(16.0)		0.4	E/S0	8175 U
35	3.0 Ext	7895	E1	(17.5)		0.1	S0	
52	Uncertain	5437	C1	(17.5)		0.2	E	
				Improbable Coma Sources				
2	3.5	8224	E1	13.3		1.5	E/S0	8377 RC
7	Double	6975	C1	(17.0)		0.3	E	6865 U
13	3.6	6636	C1	15.7		0.2	S0	6640 U
29	3.2	7498	E1	15.5		1.0	S0	7443 G
45	3.8	5331	C1	13.7		0.4	SBb	5472 RC, 5486 GT
46	3.3	8772E	E1$\alpha\beta$	15.3		0.8	Sc	(8922) G
				Foreground Sources				
20	1.9	2464E	E1A	12.3		1.5	Sc	2544 RC
21	Off nucl.	2591E	E1β	13.5		1.3	Sc	2574 RC
				Background Sources				
22	2.3	25732E	E1A	(16.3)		...	...	25710 S
23	< 1	20304	E1	(16.5)		...	E	
27	2.6	58813	E1	...		...	E	
31	2.0	36624	E1	...		...	E	
40	2.4	11183E	E1β	15.6		0.6	Sc	10871 G
50	1.4	49250	Est	...		...	E	
51	< 1	50013	E1	...		...	...	
53	< 1	17470E	E1α	(18.0)		0.1	S0	
				Nonsources				
28	> 4	12051	E1	...		...	E	
36	...	8051	C3	15.5		0.1	SB0	7949 K
37	...	5994	E1	(18.0)		0.0	S0	
38	> 4	6949	E1	(18.5)		0.0	S0	
39	> 5	23750	E1	...		...	SBb	
41	> 6	7849	C1	(16.0)		...	E	
42	> 5	7467	C1	(16.0)		...	pec	
44	> 4	6015	C1	(16.5)		0.3	E	
47	> 6	5387	E1	(17.0)		0.4	S0	
48	> 4	6032	E1	(18.0)		0.4	E	

Descriptions of objects and spectra have been given in RGC1 for all galaxies up to TT 26. These notes describe higher-numbered objects.

27. 5C 4.006 is a very faint background galaxy. It appears as a starlike spot on the Sky Survey prints. The spectrogram shows a normal absorption spectrum with H, K, and G. The K − H residual is large and the overall estimated redshift accuracy is $\pm 300\ \mathrm{km\ s^{-1}}$.

28. This non–radio source appears to be about an E2 galaxy from KPNO 4 m negatives. The spectrogram shows clear sharp H, K, and G absorption and no emission in a normal continuum.

29. This unlikely radio source shows a distinct nucleus, faint disk, and a faint outer ring on KPNO 4 m negatives; hence it is classified S0. The spectrum is a normal absorption spectrum with strong H and K.

30. Z160–020 N = Mrk 53 is peculiar morphologically, appearing as two dense superposed elliptical blobs on KPNO 4 m negatives. The spectrum shows strong emission. Hα–Hγ are in emission with higher H-lines in absorption. [S II], [O II], [N II], and [O III] emission is clear. The redshifts from Hα, Hβ, and [O III] agree within 10 km s^{-1}. H absorption redshifts also agree within the internal scatter.

31. 5C 4.044 is a faint background galaxy. It appears as a faint fuzzy spot with an extremely faint companion on Sky Survey prints. Probable type is E. The spectrum shows a normal absorption spectrum. Well-defined H- and K-lines show good internal redshift agreement.

32. Z160–058 is a moderately well inclined Sc spiral showing a clear nucleus and disk with spiral arms and H II knots on KPNO 4 m negatives. The spectrogram, set at P.A. 80° E of N along the major axis, shows weak emission in λ3727, Hα, and very weak Hβ. The λ3727 emission extends across the disk and shows some tilt. Absorption in H and K is present.

33. This radio source appears as an irregular distorted blob on KPNO 4 m plates. It shows a strong center with fainter wings extending NW–SE, the SE wing being stronger and longer. A north-south spectrogram shows strong emission centered slightly off the nucleus. Hα, β, γ [O II], and [N II] are seen, also possible [S II]. A weak K-line is seen, mostly in the halo. The stronger emission lines agree closely in redshift, as does the K-line.

34. Z160–064 = Mrk 56 is an irregular spiral with distorted arms and strong nucleus on KPNO 4 m plates. The broad nuclear area shows emission with no detectable absorption. Hydrogen emission extends to Hγ, possibly Hδ. [O III], broad λ3727 [O II], and possible [N II] emission is present. The continuum is blue.

35. RB 60 is a small S0 galaxy in the central region of the cluster. It shows a distinct disk with a strong nucleus and what could be a trace of a spiral arm or superposed galaxy on KPNO 4 m plates. The spectrum is a normal absorption spectrum with distinct H and K and little else.

36. NGC 4883 is a well-known SB0 galaxy in the central region of the cluster. The spectrum is a normal absorption spectrum.

37. RB 71 is a small compact S0 just north of RB 68 which was observed simultaneously. KPNO 4 m negatives show a jet or superposed galaxy extending to the NW. The spectrum is a normal absorption spectrum with H and K absorption.

38. RB 68 is a small round S0 showing a compact nucleus and halo on KPNO 4 m negatives. The spectrum of this faint galaxy is normal but very weak; only the G-band was measurable, thus the redshift is somewhat uncertain.

39. This background galaxy is SBb with a sharp nucleus and well-developed arms according to KPNO 4 m negatives. The galaxy has a normal absorption spectrum with sharp H and K.

40. Z160–082 is a background which should probably be classified Sc. KPNO 4 m negatives show a sharp nucleus and a well developed partial ring of strong H II knots, especially strong in the SE. The ring is broken in the NW. The sharp nucleus shows weak Hβ and λ3727. Much stronger emission is present in the H II ring both north and south of the nucleus. Absorption—H, K, and G—is seen in the nucleus. The emission ring shows rotation; the N-S differential is +250 km s^{-1} across the ring.

41. This galaxy, which forms a 30″ pair with TT 42, is an elliptical of subclass about E4 according to KPNO 4 m negatives. The spectrum is a normal absorption spectrum with H and K.

42. This galaxy is a rather irregular lumpy object with a weak flare to the south and a stronger irregular one north. The spectrum is very blue compared with TT 41 but shows no emission. Hydrogen absorption is present to H9, along with H and K.

43. Z160–086 is a lumpy irregular spiral with strong blocky arms and faint outer wisps. The inner structure is not regular as seen on KPNO 4 m negatives. The spectrum shows strong emission in λ3727 and Hα, β. [O III] 5007 is weak and doubled. The lower component matches other emission line in redshift, but the second component is 1028 km s^{-1} greater. The splitting has been confirmed on a second spectrogram. Broad H absorption underlies the H emission and can be seen to about H10. Emission is strong in the nucleus and extends into the disk. Emission and absorption redshifts do not differ detectably except for the [O III] second component. The [O III] components are equal in intensity.

44. RB 129 is a small E galaxy with a normal absorption spectrum.

45. NGC 4921 is a large face-on SBb galaxy. Distinct H II knots appear in the arms on the W and S. No emission is seen in the central regions where a normal absorption spectrum is present.

46. Z160–098 is an irregular face-on Sc with heavy arms on KPNO 4 m negatives. The W arm shows a strong knot. Strong H emission is present but fades rapidly into absorption by Hδ and concentrates in the nucleus; λ3727 is more extended; λ5007, [O III] is not certainly present, but [N II] is seen. The color is relatively normal, not excessively blue; however, the only absorption measurable with certainty was H + Hε.

47. This faint galaxy is the SW object in a pair; KPNO 4 m negatives show it to be a small S0–Sa elongated in the NNE–SSW direction. The galaxy shows a normal absorption spectrum.

48. This faint galaxy is the NE object in the pair with TT 47 above. KPNO 4 m negatives show it to be about an E3 galaxy. It shows a normal absorption spectrum.

49. Z160–105 = NGC 4927. This radio source is a simple smooth E3–E4 galaxy on KPNO 4 m negatives. The spectrum is a normal absorption spectrum with broad fuzzy lines. No emission is detectable.

50. This faint background galaxy is a small E0–E1 according to KPNO 4 m negatives. The spectrum shows no emission and is too weak to measure; however, the H, K, and G breaks can be recognized, and the redshift, which has been visually estimated, should be reliable within ±1000 km s^{-1}.

51. 5C 4.157 is a faint background galaxy. No classification is available, since it is off the 4 m plates available to the authors. The spectrum is weak but shows H and K clearly in a normal absorption spectrum. No emission is present.

52. RB 144 is a small E galaxy with a normal absorption spectrum.

53. RB 44 is a background galaxy. From KPNO 4 m negatives it appears to be an S0 or SB0, slightly asymmetrical. The spectrum shows distinct λ3727 and moderate Hα + [N II]. No other emission is detectable. H + Hε absorption is probably present but no other lines are seen for sure. The continuum is fairly normal in color, not blue.

object in Table 1. The table is in six parts: Coma radio sources (generally $\kappa \leq 2$), possible sources (generally $2.0 < \kappa < 3.0$), improbable sources (generally $3.0 \leq \kappa < 4.0$), foreground sources, background sources, and nonsources ($\kappa > 4$). Within each category, the galaxies are in order by TT identification number. The best radio sources are further grouped into emission and non-emission-line galaxies. The table contains the κ value, the Steward Observatory redshift; all measures were made by Tifft using a single-screw Gaertner measuring machine with hand reductions. All redshifts include corrections for Earth orbital and galactic rotation (300 km s^{-1}) motions. An E following the redshift means emission is present. The "source" column gives the number and type of spectra and basis of the redshift value given. The notation is described by Tifft and Gregory (1976). The remaining columns of Table 2 give the photographic magnitude with estimates in parentheses; the 610 MHz radio flux (best sources only) from Valentijn, Perola, and Jaffe (1977);

the distance from the cluster center in degrees; the morphological type; and redshifts from other sources as follows: K = Kintner (1971), RC = de Vaucouleurs and de Vaucouleurs (1964), U = Ulrich (1976), CR = Chincarini and Rood (1972*a*, *b*), G = Gregory (1975*a*), GN = Gregory (1975*b*), GT = Gregory (1975*a*) with spectrograms from Tifft for intercomparison, and S = Schmidt (1965). The table is followed by descriptive notes on each galaxy and its spectrum, if it was not included in RGC1.

Overall comparison of the Tifft-Steward redshifts with the 31 determinations from other observers and sources gives a mean difference -8 ± 20 (mean error of mean) and an internal rms scatter of 108 (95, omitting one large residual). Assuming equal distribution of errors, the typical redshift uncertainty for the brighter galaxies overall is ± 70 km s^{-1}. Eighteen of the 31 comparison galaxies contain emission lines, and the improved accuracy in measuring emission features is reflected in this favorable intercomparison. If the one large residual is omitted, the 17 best emission-line galaxies alone have an internal rms scatter of 78 km s^{-1}. Assuming, again, equal distribution of error, the typical emission-line redshift uncertainty is ± 55 km s^{-1}.

III. DISCUSSION

In RGC1 a number of correlations among the Coma radio galaxies were discussed. No careful distinctions were drawn according to the certainty of the identity, however; and the sample has now been further enlarged. Twenty-one galaxies in the first part of Table 2 have a good probability of being genuine radio sources. Note that, with the exception of TT 16, none are fainter than slightly below the Zwicky catalog limit of $m_p = 15.7$. For a normal distribution, with 20 points within 2 σ, the expected number of points between 2 and 3 σ is 1 and that greater than 3 σ is only 0.1. Thus only one source in the second part of Table 2 is probably a genuine radio source, and probably none in the third section. Note that all the candidates in the 2–3 σ class are faint galaxies. From both the statistical expected numbers and the change in the magnitudes of the sample, it is considered unlikely that more than one or two real radio sources lie outside the first section of the table. A good case can be made that one or two of the galaxies in the first list are also spurious, in particular the galaxy TT 16, which is the faintest galaxy in the entire sample of possible sources. Emission-line galaxies outnumber nonemission objects 12:9 in the first list but are outnumbered 4:1 on the next two lists. In the subsequent discussion of properties of Coma radio sources, we shall therefore limit ourselves to the 20 galaxies on the first list with $m_p \leq 16.0$.

The first correlation, pointed out in RGC1 and here clearly confirmed, is that the emission-line radio galaxies are entirely nonelliptical in morphology. Likewise, the non-emission-line galaxies are nearly exclusively of E and, occasionally, S0 morphology. The sole exception is TT 17, a nonemission spiral. In RGC1, it was not possible to categorize radio sources by radius from the cluster center. It is now possible to suggest, but not prove, that the non-emission-line sources concentrate more strongly to the center. The eight non-emission-line galaxies (TT 16 excluded) have $\langle R \rangle = 0^\circ.51 \pm 0^\circ.15$, $\sigma = 0.39$, while the 12 emission-line galaxies have $\langle R \rangle = 0^\circ.72 \pm 0^\circ.13$, $\sigma = 0.42$. These two means have only about a 15% chance of being derived from the same population according to the standard t-test. Because of the progressive incompleteness of the radio survey with distance from the cluster center, it is still not possible to accurately compare the concentration of radio sources with the total cluster population. The sources clearly concentrate toward the center, with eight at $R \leq 0^\circ.45$ and eight more in the much larger volume $0^\circ.45 \leq R \leq 0^\circ.9$. This is slightly less concentration than the galaxies as a whole. From Tifft and Gregory (1976), the number of Zwicky galaxies within $0^\circ.45$ of the center is 1.6 times the number between $0^\circ.45$ and $0^\circ.90$. Since the radio incompleteness will work to make the radio galaxy concentration still less, we tentatively conclude that at least the emission-line radio galaxies, already shown above as apparently preferring larger radii, decrease in relative population toward the cluster center. It will be of interest to compare the radio concentrations with the separate distributions of E and non-E galaxies when suitable classification data become available.

Let us turn now to the redshift distribution; it was shown in RGC1 that the redshift distribution of radio galaxies deviates strongly from the overall distribution of all redshifts in the cluster. The enlarged and refined sample given here permits a further look at this correlation. Figure 1 is the redshift-magnitude diagram for the 20 best sources. The dashed line is the mean redshift of the cluster, 6952 km s^{-1}, from Tifft and Gregory (1976). The original RGC1 study suggested a high-redshift group and a low-redshift group. This refined sample confirms the pattern and suggests the splitting of the high-redshift group into the high- and very high-redshift categories. Table 3 shows that each

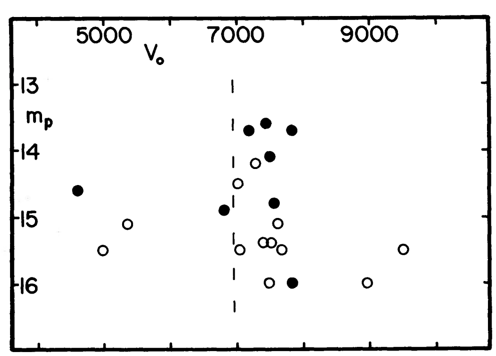

FIG. 1.—Redshift-magnitude diagram for the 20 most certain radio galaxies in the Coma cluster with $m_p \leq 16.0$. *Filled circles*, non-emission-line galaxies. The two galaxies closest to 7000 km s^{-1} are outlying, $R > 1^\circ.4$. Three redshift groups are apparent.

TABLE 3

MEAN REDSHIFT DEVIATIONS

Group	N	$\langle V_0 \rangle \pm$ m.e.	Disp.	$\Delta\langle V_0 \rangle$	t	p
Total Coma	226	6952 ± 61	909	. . .	. . .	. . .
Low-z group	3	4975 ± 221	313	−1977	3.7	< 0.001
High-z group	15	7410 ± 77	290	+458	1.94	0.02
Very high-z group	2	9235 ± 265	265	+2283	3.5	< 0.001

of the three groups alone deviates significantly from the mean. The separation of the very high-redshift galaxies may not be correct, in view of the fact that a number of additional strong emission-line galaxies are known to fall in between. It is, however, useful to show that the high-redshift radio galaxies, even without the extreme objects near 9000 km s^{-1}, clearly do not fit the cluster mean. The relationship of the redshift groupings to the redshift-magnitude bands in Coma (Tifft 1972, 1973, 1974) is discussed elsewhere (Tifft 1977).

A second interesting correlation in RGC1 is the apparent relationship of radio flux and redshift. Using the new 610 MHz data from Valentijn, Perola, and Jaffe (1977), we can examine this correlation for nearly all the best radio sources together. Three galaxies lie outside the Westerbork region and two have only upper limits for detection. Figure 2 shows the relationship of log S to redshift. The separation of the two very high-redshift galaxies as well as the low-redshift galaxies is now especially clear. The suggested correlation appears within the main concentration of high-redshift galaxies. Although the correlation depends primarily upon the two highest flux points, it appears to be significant by the following argument. The nine low flux points in the high-redshift group show no detectable trend in redshift. They define a narrow redshift distribution with mean $V_0 = 7538$ km s^{-1} and dispersion 150 km s^{-1}. The redshifts of the two highest flux points lie 2.4 σ and 4.9 σ below the mean of the low flux distribution. This is quite improbable if they belong to the same distribution. It may, of course, be argued that the two high flux galaxies are a completely unrelated class of objects. This is a rather ad hoc assumption, however, especially in view of the fact that the one galaxy at intermediate flux begins to show the same trend. The high-redshift group bears an intriguing relationship to the brightest major redshift-magnitude bend in Coma (Tifft 1972). The high flux end corresponds with the upper end of the band, while the low flux end occurs at the redshift boundary between E and non-E galaxies.

A final correlation discussed in RGC1 was the tendency for optical and radio luminosities to vary together for the weaker sources. This is illustrated in Figure 3, where log S_{610} is plotted against m_p. The solid line represents a constant flux ratio and represents the points well up to log $S = 1.5$. At higher flux levels, the points suggest a turnover returning to fainter m_p. Because of the redshift–radio flux relationship suggested in Figure 2, redshift increases to the right in Figure 3. It appears that the data in the center of the Coma cluster suggest a correlation, for radio sources, of both optical and radio flux with redshift. The correlation peaks at a higher redshift for optical flux.

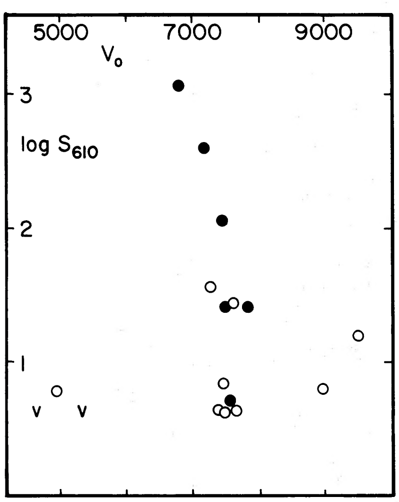

FIG. 2.—Redshift–radio flux relationship for the most certain radio galaxies in the Coma cluster for which 610 MHz flux data are available. *Filled circles*, non-emission-line galaxies. Three redshift groups are distinct.

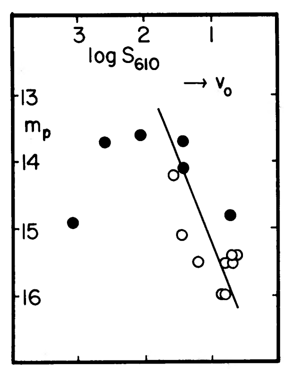

FIG. 3.—Photographic magnitude–radio flux relationship for the most certain radio galaxies in the Coma cluster for which 610 MHz flux data are available. *Filled circles*, non-emission-line galaxies. The solid line represents a constant ratio of optical to radio flux. Note that no distinction between redshift groups is now made. For the main group of radio galaxies, redshift relates to log S (Fig. 2) according to the arrow.

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