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RADIO GALAXIES IN THE COMA CLUSTER

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ABSTRACT

Redshifts for 23 possible radio galaxies with $m_p < 17$ in the field of the Coma cluster are reported and discussed. Of the 16 most likely cluster members, half are nonelliptical galaxies with emission lines in their spectra, and the remainder are non–emission-line E or S0 galaxies. Except for two of the weakest sources, the galaxies have redshifts which average 600 km s^{-1} greater than the cluster mean. The excess redshift does not appear to depend upon emission-line properties or distance from the cluster center. The non–emission-line galaxies are brighter both optically and at radio wavelengths than the emission-line objects. A direct correlation of radio magnitude and redshift appears to exist for the non–emission-line radio sources.

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

I. INTRODUCTION

A radio survey, the 5C4 investigation, in the Coma cluster has been carried out by Willson (1970). It contains 189 radio sources with $S_{408} > 16$ mJy; Twenty-four sources were also detected at 1407 MHz. Sixteen galaxies brighter than $m_p = 17$ appear to be associated with radio radiation (Willson 1970, Table 5).

Recently a deep survey of radio sources in the direction of several rich clusters of galaxies has been carried out by Jaffe and Perola using the Westerbork synthesis radio telescopes. Results on the bright central radio sources have been published (Jaffe and Perola 1974*a*), the catalog of all sources at 1415 MHz is finished (Jaffe and Perola 1974*b*), and analysis at lower frequencies is in progress.

The Westerbork observations at 1415 MHz for the Coma cluster show 38 radio sources, about a factor of 2 increase over the 5C4 program. For 22 sources an identification is suggested, including seven bright galaxies not in the 5C4 list. The Cambridge and Westerbork surveys extend over an area about 1° in radius at 1400 MHz and about 2° in radius at their respective lower frequencies. The radio sensitivity also drops off with radius; hence there is a distinct selection effect with radius.

Using the Steward Observatory 90-inch (2.3 m) telescope with the Cassegrain image-tube spectrograph, we have obtained one or more spectrograms of each of the 23 possible radio galaxies. A more complete survey will be possible when the lower-frequency radio study is finished; however, a preliminary discussion of the present sample is of interest and is the subject of this paper. Similar studies of the other clusters (Hercules cluster and A2197 plus A2199) are in progress.

II. OBSERVATIONS

Table 1 contains a general summary of results on the 23 possible radio sources and three galaxies originally considered as possible sources. The first five columns contain a serial number and identifications from the 5C4 survey (Willson 1970), the Westerbork study (Jaffe and Perola 1974*b*), the *Catalogue of Galaxies and Clusters of Galaxies* (Zwicky and Herzog 1963), and other sources. The Zwicky catalog number is the catalog field number followed by a running serial number for the galaxies tabulated. Note that 160 A 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 object also appears. Other source names include N = NGC, I = IC, RB = Rood and Baum (1967), and W = provisional Westerbork number, which is used for Westerbork sources without designations in other lists. For most of the sources with 5C, Zwicky, or RB designations, the galaxy may be readily identified. For the W objects and 5C4.113 identification, information is provided in the notes following the table.

The column headed "Certainty" indicates the degree of certainty that the radio source is actually associated with the galaxy. I, II, III, and X refer to almost certain, probable, doubtful, and negative Westerbork identifications, while A and Q refer to probable and questionable 5C identifications.

The magnitude given in column (7) is the photographic magnitude from Zwicky and Herzog (1963), or an estimated value if the galaxy is not listed in that source. The redshift in column (8) is the Steward Observatory value as measured by Tifft and corrected for Earth orbital motion and galactic rotation (300 km s^{-1}). The V_0 class in column (9) indicates the nature and number of spectrograms used. The first letter is C if older spectrograms with Fe-Ar comparison were used. These spectra were measured only in the interval 3600–5100 Å, and include no corrections derived from nightsky line measurements. The letter D refers to similar Fe-Ar spectrograms including nightsky calibration corrections, and longer wave-

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TABLE 1

Coma Radio Galaxies

Number	5C4.	Westerbork	Zwicky	Other	Certainty	m_p	V_o	V_o Class	Emission	Absorption
				Members						
1.......	007	...	159–102	...	...	14.5	7010	T1β	mild	present
2.......	020	...	159–113/008	N4789	...	13.3	8224	T1	...	...
3.......	043	...	160–028	N4727	...	14.1	7455	T1	...	...
4.......	051	1254+27W1	160–039	N4839	I	13.6	7376	T1	...	...
5.......	...	1255+28W3	...	W18	II	(16.0)	8151	T2$\alpha\beta$	mild	present
6.......	058	1255+28W6	160–055	N4848	I	14.2	7271	T1β	mild	present
7.......	...	1256+28W4$_{a,b}$	...	RB214	III	(16.5)	6975	C1	...	...
8.......	...	1256+27W4	160–073	RB219	I	15.1	5354	D1β	moderate	yes
9.......	...	1256+28W7	160A–04	N4858	I	15.5	9491	T1β	moderate	possible
10.......	...	1256+28W8	160A–15	N4865	I	14.6	4588	C2	...	...
11.......	081	1256+28W9	160A–16	N4869	I	14.9	6801	C3	...	...
12.......	085	1257+28W1	160A–22	N4874	I	13.7	7180	C3	...	...
13.......	...	1257+28W2	160A–31	...	III	15.7	6636	C1	...	...
14.......	108	1258+28W3	160A–43	I4040	(I)	15.1	7644	T2β	moderate	present
15.......	109	...	...	...	...	(16.0)	8970	T1β	strong	possible
16.......	113	...	...	...	...	(17.8)	6314	T1	...	...
17.......	117	1258+28W6	160A–51	N4911	...	13.7	7898	D1	...	...
18.......	130	...	160–096N	N4922N	A	(15.5)	7027	T1β	strong	present
19.......	161	...	...	...	...	(16.0)	7787	T1	...	...
				Foreground						
20.......	022	...	159–116/011	N4793	A	12.3	2388	T1A	weak	yes
21.......	175	...	160–134	N4961	Q	13.5	2588	T1β	mild	yes
				Background						
22.......	019	...	...	3C 277.3	A	(16.3)	25732	T1A	weak	yes
23.......	...	1255+27W1	...	W17	I	(16.5)	20256	T1	...	...
				Non-Radio Galaxies						
24.......	...	...	160A–06	N4860	X	14.7	7905	T1	...	...
25.......	...	...	...	W10	X	(16.0)	7259	T1	...	...
26.......	...	...	160–096S	N4922S	X	...	7232	T1	...	...

Notes.—1) 5C4.007 is a spiral galaxy with a previous redshift determination by Kintner (1971) at 7112 ± 150. Kintner makes no note of emission lines. The galaxy is A7 in the list of Mayall (1960). The $V_o = 7010$ given here is based upon Hβ emission in one good spectrogram and refers to the nucleus. Hα and λ3727 emission agree (6996/6983), but are not as reliable as Hβ. An absorption-line redshift based primarily upon H, K, G, and Mg I was found to be 6999. The K$-$H residual is large (+272), but G and Mg I fall between. The southern portion of the galaxy ($\sim 8''$ south of the nucleus) shows a V_o about 100 km s^{-1} greater, and although the northern region does not confirm the line tilt, some rotation is probable. A second spectrogram could be measured only for λ3727 and absorption, but agrees within about 20 km s^{-1} of values from the better spectrogram.

2) 5C4.020 = N4789 is a bright E/S0 galaxy with a previous redshift determination of 8377 as listed in the *Reference Catalogue of Bright Galaxies* (RC) (de Vaucouleurs and de Vaucouleurs 1964). $V_o = 8224$ given here is well determined from H and K ($K - H = +10$). There is no emission detectable, and the continuum appears normal.

3) 5C4.043 = N4727 is an E galaxy with a previous redshift determination of 7657 (RC). The value given here, $V_o = 7455$, is based upon H, K, and D, with good internal agreement ($K - H = +23$). There is no detectable emission and a normal continuum.

4) 5C4.051 = N4839 is an E galaxy included in the Westerbork list. A previous redshift determination exists, $V_o = 7455$ (RC). $V_o = 7376$ given here is from H and K ($K - H = +43$), with close agreement from Ca I. No emission is present, and the continuum is normal.

5) W18 is an apparently disturbed E or S0 galaxy located at $\alpha = 12^{h}55^{m}.5$, $\delta = +28°20'$ (1950). It lies $10'.8$ S and $1'.9$ W of N4848. $V_o = 8151$ given here is based upon Hα + Hβ emission. Two spectrograms agree well (8182/8120). Emission in [O II] and [O III] is seen, but is not as reliable for redshift (λ3727 gives $V_o = 8094$, N2 gives $V_o = 8162$). Weak (veiled?) H and K absorption is present and shows a wide scatter about the same redshift, as well as can be determined. The continuum is relatively blue.

6) 5C4.058 = N4848 is a spiral galaxy included in the Westerbork list. A previous redshift value of 7221 (RC) agrees well with the $V_o = 7271$ given here. The galaxy shows a complex V_o field. The adopted nuclear region redshift is based upon Hβ in one good spectrogram. Two main emission knots fall on the N–S slit, the nucleus being the more northern and stronger. Nuclear λ3727 and Hα give concordant redshifts of 7233 and 7249, but are not as reliable as Hβ. Weak N2 [O III] emission appears to be present, but at a distinctly higher redshift (7501). The southern knot gives V_o from Hβ at 7462, with λ3727 in agreement at 7409; thus this knot is at a distinctly higher redshift. Weak absorption (veiled?) of H, K, and other common lines is present, and scatters about the emission-line redshift with no indication that it differs systematically. The continuum is relatively blue. A second, weaker spectrogram gives single blended V_o values for Hα, Hβ, λ3727, and absorption which tend to lie between the values of the two knots in good agreement (Hα + Hβ $V_o = 7341$, λ3727 $V_o = 7280$), and also shows a high N2 V_o (7514), with indications that it arises from a different spatial region. The second spectrogram gives H and K $V_o = 7194$, with good internal agreement.

7) RB 214 is a doubtful radio source in the Westerbork list. V_o for this faint S0 galaxy is based upon a previous study by Tifft (1973). $V_o = 6975$ given here differs slightly (33 km s^{-1}) from the original value which included some weaker lines in addition to H and K, and which have now been omitted. $K - H = -55$. No emission is present and the continuum appears normal.

8) RB 219, classified as SBa by Rood and Baum (1967), has a redshift previously determined as 5366 by Kintner (1971), who noted the presence of emission. The galaxy is number 13 in the list by Mayall (1960). $V_o = 5354$ derived here is based upon Hβ

emission. Emission at Hα and [N II] gives good agreement (Hα + Hβ + [N II] gives V_o = 5390), while λ3727 is somewhat lower but uncertain. Hydrogen absorption is seen to H9. At Hβ, emission dominates; at Hδ, absorption, with near perfect cancellation of Hγ. The mean redshift of absorption agrees well with emission, although Hβ appears asymmetric. (H8 + H9 + K + G gives V_o = 5322.) The continuum is blue.

9) N4858 is an SBb galaxy, according to Rood and Baum (1967), with a previously determined redshift of 9398 (RC). The redshift of 9491 given here is based upon Hβ; however, the measures overall suggest a complex mixed V_o field. A N–S slit shows emission of hydrogen and λ3727 concentrated in two knots. [O III] is seen primarily between the knots, and absorption appears in the outer portion of the galaxy. Within the knots, which do not differ noticeably in V_o, Hβ is in reasonable agreement with λ3727, Hα, and [N II], but the line may be structured-multiple or asymmetric. [O III] between the knots has a distinctly higher V_o (9747). Absorption, based on the H line, gives a poorly determined redshift between the emission extremes.

10) N4865 is an apparently normal E galaxy with a previous redshift determination of 4655 (RC). The galaxy shows a normal continuum and absorption spectrum. The new V_o = 4588 is based upon H, K, and G, and is the mean of two determinations (4622 and 4534).

11) 5C4.081 = N4869 is a normal E galaxy morphologically, but shows an unusual radio tail structure. The galaxy lies near the center of the cluster. A normal continuum and absorption spectrum is present, with no emission. The previous redshift of 6715 (RC) compares satisfactorily with the new value of 6801, which is a mean of three spectrograms (6815, 6811, and 6778) measured at H, K or H, K, G.

12) 5C4.085 = NGC 4874 is one of the two central supergiant galaxies in the cluster, and is classified S0. A normal continuum and absorption spectrum is present without detectable emission. Published redshifts are 7183 (RC) and 7131 (Kintner 1971). V_o = 7180 in this investigation is a mean of three spectrograms (7153, 7255, and 7133) measured at H, K or H, K, G.

13) Z160A–31 is a doubtful Westerbork radio source with S0 morphology. A normal continuum and absorption spectrum is present without emission. V_o is a mean of H, K, and G. The K − H residual is −60, with G falling between.

14) 5C4.108 = I4040 is an Irr/Sc type galaxy. V_o = 7644 in this study is based upon Hβ in two spectra (7634 and 7654). Weak Hα is in general agreement. Weak λ3727 and [O III] N2 is present, but unreliable for redshift. Weak (veiled?) absorption is present at the same V_o, as well as can be determined. The continuum is somewhat blue. Published redshifts for this object are 7528 (RC) and 7759 (Chincarini and Rood 1972).

15) 5C4.109 presents a very elongated lenticular image in a N–S alignment. The spectrum shows a faint blue continuum and very strong high-excitation emission. Weak H and K absorption is possibly present. Emission present includes Hα, Hβ, Hγ, λ3727, N1 and N2, and [Ne III]. Two main emission knots are present, with weaker emission between. The redshift adopted is an overall mean for Hβ; however, all the stronger lines agree within 50 km s^{-1} when taken overall across the spectrum. There is no general indication of rotation along the elongated image, although there is some deviation in the [O III] redshift between the two knots, one tending low and the other high by nearly 100 km s^{-1}. Hβ, however, shows a much smaller difference, and it is uncertain whether the [O III] difference should be ascribed to rotation. Higher dispersion will probably show a more complex V_o field. Absorption appears most prominently between the two main knots, and if real, indicates a somewhat higher redshift (9156).

16) 5C4.113 is the faintest galaxy in this survey of radio sources, and could very easily be a chance identification. Willson (1970) gives the galaxy an m_{pg} = 17.8. The object is located 3.′1 E and 4.′1 N of N4896, and appears morphologically to be a small elliptical. The spectrum shows a normal continuum with absorption. Five lines give a relatively low-weight V_o = 6314, with an uncertainty of about ±150.

17) 5C4.117 = N4911 is a spiral galaxy with a published redshift of 8018 (RC). The galaxy has a normal absorption spectrum showing no emission. The new redshift V_o = 7898 is based upon H + K, with K − H = −34.

18) 5C4.130 = N4922N is the NE component of a multiple galaxy system. A complex plume and wispy interactive structure is associated with the pair. The previous redshift published for N4922 apparently refers to the brighter SW component only. The NE component shows a blue continuum and a high excitation emission spectrum in the nucleus, including emission in [O II], [O III], [Ne III], [N II], [S II], and Hα, Hβ, and Hγ. Absorption in H and K is seen in the halo. Absorption and [O II], [N II], and hydrogen emission are consistent with the Hβ V_o = 7027 given in Table 1. [O III] and [Ne III] are higher in V_o and structured. [O III] has V_o = 4216. High-dispersion spectra have confirmed the presence of [O III] structure, but have not been studied in detail. It is of interest that the [O III] V_o is close to V_o of the SW component in the pair. (See No. 26, below.)

19) 5C4.161 appears to be a small elliptical galaxy. The galaxy shows a normal continuum and absorption spectrum without emission. The redshift is based upon H and K with K − H = −60.

20) 5C4.022 = N4793 is a bright foreground Sc galaxy with a previous redshift (RC) of 2544. V_o = 2388 in this paper is based upon H and K (K − H = −19). Emission in 3727 and possibly Hα is present; 3727 gives V_o = 2372.

21) 5C4.175 = N4961 is a bright foreground Sc galaxy with a previous redshift (RC) of 2574. There is some uncertainty in association of this galaxy with the radio source. V_o = 2588 in this study is based upon a weak Hβ emission line showing absorption wings. The line at λ3727 is clear and moderately broad, and broad N2 emission is weakly seen. Although not reliable for V_o, 3727 and N2 agree well at 2648 and 2620, respectively. The galaxy shows structure along the N–S slit orientation, and possibly some slight rotation. Broad diffuse hydrogen absorption is seen to H9. V_o based upon Hβ, Hδ, H8, H9, and K gives 2547.

22) 5C4.019 = Coma A is a mag 17 background source. Schmidt (1965) gives z = 0.0857, which corresponds to V_o = 25700, and indicates that both λ3727 and [O III] were seen. The redshift V_o = 25732 given in Table 1 is from H and K only. The line at λ3727 is present and gives V_o = 25800, but is unreliable since it is superposed precisely on the Hg 4047 nightsky line.

23) W17 is a faint, apparently E type galaxy located 6.′7 N and 6.′7 E of N4839. The spectrum is normal, without emission. V_o is based upon H, K, and G, and has an uncertainty of about ±100.

24) N4860 lies close to N4858, and was initially associated with that radio source. This E galaxy has a published V_o = 7874 (RC). The value V_o = 7905 derived here is based upon four absorption lines in close agreement. No emission is present.

25) W10 was originally suggested as an identification for the Westerbork source 1254+28W1a, b which is now associated instead with a faint blue object. W10 lies 2′ N and 20′ W of N4848, and appears to be a faint E galaxy. The spectrum is a normal absorption spectrum without emission. V_o is based upon four lines, and has an uncertainty of about ±100.

26) N4922S is the SW component of the double galaxy containing 5C4.130. The previously published V_o = 7376 (RC) of N4922 presumably refers to this galaxy, which is the bright member of the pair. The value of V_o = 7232 found here is based upon H, K, and G. A normal continuum and absorption spectrum is present.

length measurements where useful. T refers to newer spectrograms with He-Ar comparisons measured over the full range from 3500 to 7700 Å, and including nightsky calibration corrections. A comprehensive discussion of the Steward Observatory galaxy redshift program will be published at a later date.

The numeral in the V_o class designation indicates the number of spectrograms used to determine V_o. If a designation follows the number, it indicates that emission is present in the spectrum. If β or $\alpha\beta$ appears, it means Hβ or Hα + Hβ have been used exclusively to determine the tabulated V_o. The clear, sharp character of these lines in many cases provides superior V_o values. An A following the number means that emission was present but that the absorption redshift is more reliable and is given instead. This often means that only 3727 Å emission was seen, and since the 3727 Å wavelength is unstable and the line falls near the end of the comparison calibration, it is often not reliable for V_o.

The final two columns of the table indicate the strength of emission on a subjective scale (weak–mild–moderate–strong), and indicate whether absorption lines were also seen, on a subjective scale (possible–present–yes). Following the table, each galaxy is discussed in turn to give details of the spectrograms and to discuss other features of the galaxy.

III. DISCUSSION

Of the 23 radio identifications, two are probably foreground and two background. Among the remaining 19, two Westerbork sources are doubtful identifications and the one faint 5C4 source, 5C4.113, also seems questionable. These three galaxies will be considered separately. Table 2 summarizes various properties of the 19 radio galaxies falling in the redshift range of the Coma cluster. The identification number is the same as given in Table 1. Except for the three doubtful cases listed separately, the galaxies are grouped by emission-line properties for comparison with morphology, distance from cluster center, radio flux density at 408 MHz (Willson 1970) and 1415 MHz (Jaffe and Perola 1974*b*, preliminary personal communication), redshift, and magnitude. It should be noted that the 5C4 and Westerbork flux densities are not completely compatible, as pointed out by Jaffe and Perola (1974*a*).

Among the 16 best identifications, five are not in the region surveyed at frequencies around 1400 MHz at either Cambridge or Westerbork. The 11 objects within 1° of the cluster core contain six objects present in both surveys, four present only in the Westerbork study, and one which has been detected only at 408 MHz in the 5C4 survey and is probably too faint at 1415 MHz to be detectable with the Westerbork radio telescope. The objects not in common are invariably the weakest sources on the respective lists.

Of the 16 most likely cluster member identifications, eight show some degree of optical emission-line activity. All but one of the optically active galaxies are morphologically nonelliptical, and the one is doubtful. Of the eight objects that are not optically active, all but one are classified E or S0. Thus the presence of emission is closely correlated with morphology, but not directly correlated with radio emission. The presence of activity which excites radio radiation probably also results in the excitation of optical emission *if* the morphology is such that a suitable interstellar medium is present. A large amount of interstellar material is obviously not essential to the radio process itself. It is not known how many emission-line objects in Coma are not radio emitters; however, a fairly complete survey of emission-line galaxies in Coma is underway, and it should soon be possible to address this question. It should be added that there are a number of spiral galaxies in Coma which neither are radio sources nor show optical emission lines.

Among the eight galaxies with optical emission, there is no apparent relationship between emission strength and radio flux. There is a tendency for the non–optically active galaxies to be stronger radio emitters than the emission-line galaxies. This is true even if one discounts the two major sources in the cluster center. The emission-line radio galaxies have an average flux density $\bar{S}_{408} = 50$ mJy and $\bar{S}_{1415} = 14$ mJy, whereas the radio sources without emission lines have $\bar{S}_{408} = 109$ mJy and $\bar{S}_{1415} = 30$ mJy, with

TABLE 2

Properties of Coma Radio Galaxies

Number	Emission	Morphology	R^0	S_{408}(5C)	S_{1415}(W) Prelim.	V_o	m_p
1............	mild	S	1.6	76	...	7010	14.5
5............	mild	E/S0?	0.4	...	4	8151	(16.0)
6............	mild	S	0.5	55	23	7271	14.2
8............	moderate	SBa	0.4	...	8	5354	15.1
9............	moderate	SBb	0.2	...	12	9491	15.5
14............	moderate	I/Sc	0.2	68	22	7644	15.1
15............	strong	pec	0.6	21	...	8970	(16.0)
18............	strong	pec	1.4	60	...	7027	(15.5)
2............	...	E/S0	1.5	108	...	8224	13.3
3............	...	E	1.1	114	...	7455	14.1
4............	...	E	0.7	217	67	7376	13.6
10............	...	E	0.2	...	6	4588	14.6
11............	...	E	0.1	1660	650	6801	14.9
12............	...	S0	0.1	406	220	7180	13.7
17............	...	S	0.3	50	17	7898	13.7
19............	...	E	1.1	55	...	7787	(16.0)
7............	...	E	0.3	...	69(d)	6975	(16.5)
13............	...	S0	0.2	...	4	6636	15.7
16............	...	E	0.5	23	...	6314	(17.8)

(d) Radio double structure. The flux is total flux.

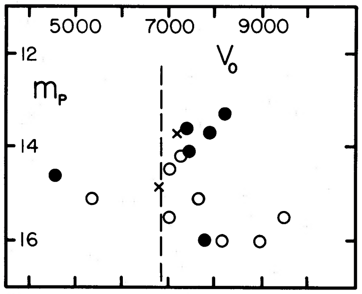

FIG. 1.—The m_P-redshift diagram for the 16 best identified radio galaxies in the Coma cluster. The mean cluster redshift is shown with a dashed line. Filled circles refer to non-emission-line galaxies, open circles to emission-line galaxies, and crosses to NGC 4874 and NGC 4869.

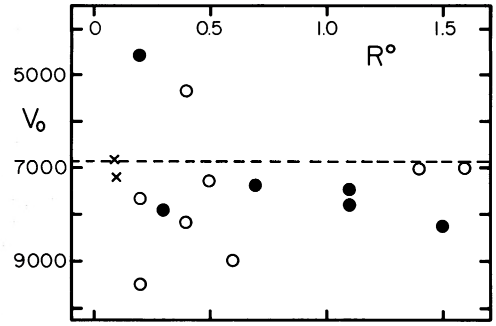

FIG. 2.—Observed redshift versus distance from the center of the Coma cluster. The symbols are the same as in Fig. 1.

N4869 and N4874 omitted. It is also true, however, that the emission-line galaxies are fainter in optical luminosity than the nonemission types. The same samples noted above have a $\langle \Delta m \rangle = 1.0$. Thus the radio flux per unit optical luminosity is very nearly the same in both samples when N4869 and N4874 are omitted. The flux per unit mass will, of course, depend upon the M/L ratios assumed, and whether different values are used for E and non-E galaxies.

One further interesting feature of the emission-line objects is a tendency for many of them to show either dual emission knots or dual optical structure, sometimes with a complex V_o field. Violent activity certainly appears to be present in these galaxies. The nonemission objects, on the other hand, appear to show little or no structural distortion.

There is no obvious relationship between radial distance from the cluster center and either morphological or emission-line properties within the radio galaxy sample. The limited radial coverage of the radio surveys, especially until the 50 cm Westerbork observations are available, make any careful study of this question impossible at this time. It is likewise difficult to determine whether the radio galaxy radial frequency distribution differs from that of the cluster as a whole.

Figure 1 shows the magnitude-redshift diagram for the 16 most certain radio-source identifications. For the faintest objects the magnitudes are estimated. As first pointed out by Tifft (1974) using 5C4 data, and here confirmed and extended with the Westerbork data, the galaxies concentrate distinctly in the range of redshift greater than the average of the cluster. Table 2 and Figure 1 indicate that although the emission-line nonelliptical galaxies include the most extreme high-redshift objects, there is no clear optical distinction between the groups by redshift. It is of interest to note that the three doubtful identifications (not plotted in Fig. 1) show redshifts which are in accord with the cluster mean near 6865 km s^{-1} (6888, Rood *et al.* 1972; 6839, Tifft 1972). This is also true of the two strong radio sources N4869 and N4874. It may be, therefore, that only the relatively low-flux, "common" radio galaxies show the unusual redshift pattern.

Figure 2 shows the dependence of redshift on radius from the cluster center. The four most extreme redshifts in Table 2 (two high, two low) are associated with galaxies less than 1° from the cluster center; otherwise there is no obvious relationship of the deviation to radius. The nine inner low-flux radio galaxies give $\langle V_o \rangle = 7416$ and the outer five give $\langle V_o \rangle = 7501$, both on the order of 600 km s^{-1} greater than the cluster mean. The average absolute deviation from the mean is even more extreme, 1100.

The two very-low-redshift sources are not at all similar optically, nor are they optically distinct from the other galaxies. They are, however, distinctly set aside from the other sources in radio flux. They are two of the three weakest sources.

The redshift–optical magnitude diagram in Figure 1 shows no obvious structure other than the high-redshift segregation. The redshift–radio magnitude diagram, however, does suggest a correlation. Figure 3 shows redshift–log S diagrams for non–emission and emission-line galaxies separately. The non–emission-line galaxies, except for the one low-redshift, low-flux galaxy, show a well defined correlation. The emission-line galaxies are more scattered or perhaps follow a flatter, fainter extension of the non–emission-line correlation. Again the low-redshift, low-flux density is set clearly apart from the others.

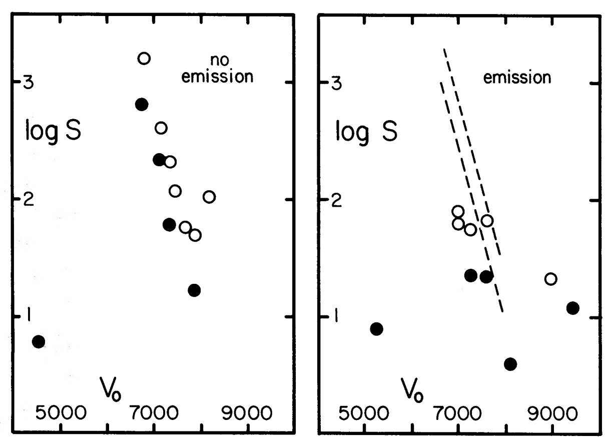

FIG. 3.—The log S–redshift diagram for non–emission-line galaxies (*left*) and emission-line galaxies (*right*). Open circles refer to 408 MHz flux densities and filled circles to preliminary 1415 MHz flux densities. The dashed lines in the right figure represent the mean correlation for non–emission-line galaxies.

In general summary, three classes of radio sources are indicated in the Coma cluster: (1) Optically bright, radio strong, non–emission-line E/S0 galaxies of $V_o > \langle V_o \rangle$ which appear to follow a log S–V_o correlation. (2) Optically faint, radio weaker, emission-line non-E galaxies of $V_o > \langle V_o \rangle$. (3) Radio weak galaxies of mixed types and $V_o < \langle V_o \rangle$.

One possible explanation of the redshift pattern (Fig. 1) in terms of intrinsic redshifts and time evolution in matter and galaxies has been given by Tifft (1974). Another intrinsic redshift suggestion, the "excess redshift" effect, is also possible, although the two low-redshift objects are somewhat inconsistent. A conventional dynamical explanation would seem to require that the radio galaxies be rapidly infalling or "ejected" galaxies, perhaps interacting with an intergalactic medium. It is interesting to note in this regard that the one galaxy with a radio tail, suggesting such an interaction, is the one closest to the mean cluster redshift. This object could, of course, have a large transverse velocity. The asymmetry in the peculiar redshift distribution is difficult to explain dynamically. Since infall or ejection presumably involves nearly radial motion, the dependence of the redshift deviation on distance from the cluster center is a critical test of the concepts. Further radio identifications to at least 3° radius would be highly desirable, since the present data (Fig. 2) show no clear support for radial motion. The apparent physical disruption and localized concentrated emission in the optically active galaxies also argue in favor of an internal mechanism for source origin rather than interaction with a tenuous intergalactic medium.

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