

THE DISTRIBUTION OF GALAXIES NEAR THE CENTER OF THE COMA CLUSTER

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ABSTRACT

Statistical tests of distribution identity indicate that there are definite tendencies toward mass segregation in the extreme central portion of the Coma Cluster. The bright ($m_{\text{pk}} \leq 15.7$) galaxies are more centrally concentrated than the dwarf galaxies. The SB0's appear to be distributed about a different center than are the other galaxies. The ellipticals have a radial distribution statistically identical to that of the S0 galaxies. There are no significant differences in the angular distributions of any groups. Closeness of association and subclustering analyses imply that the dwarf galaxies are *not* satellites of more massive galaxies, and the only evidence of subgrouping of similar types of galaxies is the distribution of the SB0's. Quantitative estimates indicate that the anomalously large mass-light ratio for the cluster cannot be reduced significantly by considering subgrouping or mass-segregation effects.

I. INTRODUCTION

The Coma Cluster ($\alpha = 12^{\text{h}}57^{\text{m}}3$, $\delta = 28^{\circ}14'$, 1950) is a large, dense, nearby (70 Mpc), regular cluster of galaxies. It is quite evident even from a visual inspection of photographs that the conspicuous members of the Coma Cluster exhibit a strong central concentration in the region about the cluster's two brightest members, NGC 4874 and NGC 4889. What is not so evident, however, is the detailed distribution of galaxies in the cluster, particularly according to galaxy type.

Making a distinction between bright and faint galaxies, Zwicky (1957) found that there is a pronounced mass segregation in the Coma Cluster, with the fainter galaxies less centrally concentrated. Noonan (1961), however, using Zwicky's counts, found the radial distributions of the bright and faint members to be nearly identical. Abell (1963), using magnitudes derived with an extra-focal photometry technique, arrived at similar conclusions. Reaves (1966), on the other hand, after identifying thirty-two probable dwarf galaxies in the extreme central part of the cluster (total area surveyed: 0.3 square degree), found from a visual inspection that the dwarfs appear *not* to have the extreme central concentration which the bright galaxies exhibit. At its very center, therefore, if Reaves's preliminary conclusion is correct, the Coma Cluster is similar to the Fornax Cluster of galaxies, whose dwarf members were found by Reaves (1964) and Hodge, Pyper, and Webb (1965) not to have a strong central concentration.

The investigations of the Coma Cluster to date have made distinctions only between bright and faint galaxies. We have attempted to make a more exhaustive statistical study of the distribution of galaxies, examining the galaxies by type as well as by luminosity. In addition to seeking information about the large-scale distribution of the cluster members in the central region, we have also looked for evidence of subclustering, which has been found to some extent in other clusters (see, e.g., Zwicky 1957, p. 78; Burbidge and Burbidge 1959) and suggested in the Coma Cluster by several investigators (Shane and Wirtanen 1954; van den Bergh 1961).

The area of the Coma Cluster used in this study is the same as that used by Rood and Baum (1967) to obtain photographic brightness profiles of Coma Cluster galaxies. The classifications by galaxy type were made by Rood. The identification of dwarfs on our plates was made by Reaves (1966). (Although thirty-two dwarfs were classified, two

were excluded from this study because they are just outside the limits of our field.) Aside from the dwarfs, only those galaxies listed in the Rood and Baum (1967) catalogue as S0 (81), E (74), and SB0 (20), along with four other "bright" galaxies (explained below), were used, thus making a total of 209 galaxies studied. Of the E's, S0's, and SB0's, forty-seven are listed in the Zwicky and Herzog (1963) catalogue with $m_{pg} \leq 15.7$. These are designated "bright" galaxies in this study, as are the four galaxies mentioned above, which are in both catalogues but are neither E, S0, nor SB0 type.

II. CLOSENESS OF ASSOCIATION AND SUBCLUSTERING

Reaves (1964) has described a method whereby the degree of association of dwarf galaxies with normal galaxies in a cluster is expressed as a number, a ratio of median projected separations. (The ratio: the median distance measured from each normal galaxy to the nearest normal galaxy divided by the median distance measured from each dwarf to the nearest normal galaxy.)

TABLE 1
POSSIBLE CLOSENESS-OF-ASSOCIATION MEASUREMENTS*

SS	SE	SB	SBr	SD
ES	EE	EB	EBr	ED
BS	BE	BB	BBr	BD
BrS	BrE	BrB	BrBr	BrD
DS	DE	DB	DBr	DD

* Those actually used are the measurements under the step line.

We have applied this method to the galaxies in our study, using various combinations of measurements. The measurements were made on a print of a plate taken in 1943 by Baade using a 60-min exposure on IIaO emulsion with the Hooker 100-inch reflector stopped down to 84 inches. (See Plate II, Rood and Baum 1967.) Table 1 shows the twenty-five possible median separations that may be used in forming the ratios. In each case the first letter(s) indicate the type of galaxy *from* which measurement is made, and the second letter(s) indicates the type of galaxy *to* which measurement is made. S represents the S0's, E the ellipticals, B the SB0's, D the dwarfs, and Br the bright galaxies.

Of the three hundred ratios (ignoring reciprocals) that may be formed from these measurements, many are redundant. For example, BB/SB tells whether the S0's are closely associated with the SB0's, and SS/BS tells whether the SB0's are closely associated with the S0's, which is really the same thing. Furthermore, for the case of non-association, only those ratios which are of the form XX/YX (again ignoring reciprocals) are conveniently sample-independent, requiring no normalizing factors for different sample sizes, so we have considered only ratios of this form. There are ten such independent ratios of this type which we have calculated, and the fourteen measurements from which they were obtained are those below the step line in Table 1. The ratios themselves are given in Table 2 with probable errors determined from 50 per cent confidence intervals for the median distances, as outlined by Brunk (1965, p. 348). The results will be discussed in § IVa.

In an effort to determine whether there is any significant evidence of subclustering

according to nebular type, the type of the galaxy nearest to each of the 205 typed galaxies was noted. The results of this count are given in Table 3, where, for example, we note how many times an S0 was the closest galaxy to an S0, how many times an E was the closest galaxy to an S0, how many times an S0 was the closest galaxy to an SB0, etc. The observed numbers are compared with the number of each type that is predicted if the choice of nearest galaxy were independent of galaxy type, assuming a Poisson distribution with mean error $\sqrt{n}$ rounded to the nearest integer. Above the predicted value in each case is the actual observed count.

The conclusions from this subclustering analysis will also be considered in § IVa.

TABLE 2
CLOSENESS-OF-ASSOCIATION RATIOS

SS/ES = 1 13 ± 0 09	EE/BE = 1 11 ± 0 12	BB/BrB = 0 60 ± 0 04	BrBr/DBr = 0 82 ± 0 13
SS/BS = 0 83 ± 0 08	EE/BrE = 1 13 ± 0 13	BB/DB = 0 35 ± 0 10	
SS/BrS = 1 05 ± 0 09	EE/DE = 0 75 ± 0 10		
SS/DS = 0 95 ± 0 14			

TABLE 3
COMPARISON OF OBSERVED AND PREDICTED FREQUENCY OF EACH
GALAXY TYPE BEING THE NEAREST TO EACH TYPE GROUP

Type Group	Total No in Group	No S0's Closest	No E's Closest	No SB0's Closest	No D's Closest
S0	81	30 32 ± 6	35 29 ± 5	7 8 ± 3	9 12 ± 3
E	74	38 30 ± 5	25 26 ± 5	4 7 ± 3	7 11 ± 3
SB0 ..	20	6 8 ± 3	5 7 ± 3	4 2 ± 1	5 3 ± 2
D .	30	14 12 ± 3	7 11 ± 3	5 3 ± 2	4 4 ± 2

III. IDENTITY-OF-DISTRIBUTION TESTS

This portion of our analysis was aimed at determining by the use of various statistical tests whether the distributions, radial and angular, of the different types of galaxies are the same or different. For these analyses it was necessary to have accurate positional coordinates of all the galaxies involved. For those galaxies in the Rood-Baum survey, rectangular x - y coordinates (y running south to north) on an arbitrary centimeter plate scale were found by Rood using a 48-inch Schmidt plate taken by Baum in 1958 with a 10^m48^s exposure on 103aD emulsion. For those galaxies not in the Rood-Baum survey (twenty-one dwarfs), the x - y coordinates had to be determined separately. This was done using the *Palomar Sky Survey* print of the Coma Cluster region. (All dwarfs were visible there, once their locations were known from the 100-inch plates.) The positions of all thirty dwarfs were found, so that there were nine dwarfs whose positions were measured in both ways. The two sets of coordinates for these dwarfs were in excellent agreement (maximum difference ≈ 0.1 mm), so we are reasonably certain of hav-

ing a consistent set of positions for all 209 galaxies. The complete set of positions for all galaxies in the Rood-Baum catalogue (including 109 untyped, barred spiral, and spiral galaxies not used in this study) and for the dwarfs is given in the Appendix for reference. For types, the reader is referred to Table I in the study by Rood and Baum (1967).

The rectangular coordinates for each galaxy were converted to a polar system for each of three polar centers. NGC 4874 and NGC 4889 were each taken as a polar origin, and the mid-point between these two was used as the third origin (hereinafter called "Field 1 center"). This is the center of Field 1 of the Rood-Baum survey area. Zwicky (1957) and Abell (1965) regard it as the approximate cluster center. We adopt the same convention in this paper, although to our knowledge no firm quantitative empirical or theoretical justification exists. Figure 1 (Plate 12) shows the area studied and the distribution of the various galaxy types. Note the apparent lack of central concentration for the dwarfs which Reaves (1966) refers to. The approximate locations of the x - y grids used in position measurements are indicated by the graduations.

The distribution-identity tests used were: χ^2 test, runs test, median test (Brunk 1965, pp. 278, 361), Kolmogorov-Smirnov test (von Mises 1964, p. 492), and the "ratio test," another extension of the Reaves closeness-of-association test. The χ^2 test is the one

TABLE 4
MEDIAN SAMPLE-TO-CENTER DISTANCES* FOR EACH GALAXY GROUP

Center	E	S0	SB0	Br	D
Field 1	0 93 $\pm$ 0 08	1 02 $\pm$ 0 09	0 70 $\pm$ 0 01	0 89 $\pm$ 0 10	1 32 $\pm$ 0 14
NGC 4874	0 89 $\pm$ 06	1 03 $\pm$ 07	82 $\pm$ 12	84 $\pm$ 05	1 21 $\pm$ 05
NGC 4889	1 03 $\pm$ 0 03	1 07 $\pm$ 0 10	0 57 $\pm$ 0 06	0 93 $\pm$ 0 07	1 45 $\pm$ 0 08

* In units of the x - y plate scale used for position measurement

standardly used in many astronomical applications, but it is not distribution-free for a finite sample. The runs, median, and Kolmogorov-Smirnov tests, however, are distribution-free, the only necessary assumption being that the probability distribution of the population is continuous. The runs tests is more sensitive to differences in the shape of the distribution function than is the median test, which, however, is more sensitive to differences in the median. The Kolmogorov-Smirnov test is reputedly very powerful for small samples. The ratio test compares the median distance from center for two distributions—it is the simple ratio of the median sample-to-center distances. (The distances from which these ratios are formed are given with probable errors in Table 4.)

The populations compared were E-S0, SB0-S0, and bright-dwarf. The null hypothesis was identity of distributions, and Table 5 indicates acceptance or rejection of this hypothesis, at the 5 per cent significance level, for each case. (The angular-distribution results are not tabularized, since, for all but the ratio test, which is biased in the angular case by the asymmetry of the area surveyed, there is complete acceptance of identity except in one case, the bright-dwarf angular distribution about the Field 1 center.) The results for the ratio test are given numerically with probable errors determined exactly as in the closeness-of-association ratios. The numerators and denominators of the ratios are suggested by the notation in the population column.

Figure 2 compares the B/S populations for the Field 1 center, showing the number of each type in concentric rings of equal width (except for the last ring) centered at the origin. Here a difference in the distributions of the SB0's and S0's is evident. Figure 3 compares the Br/D populations in the same way and illustrates that the dwarfs appear more spread out. In Figures 2 and 3 the last ring reaches the limits of the survey.

PLATE 12

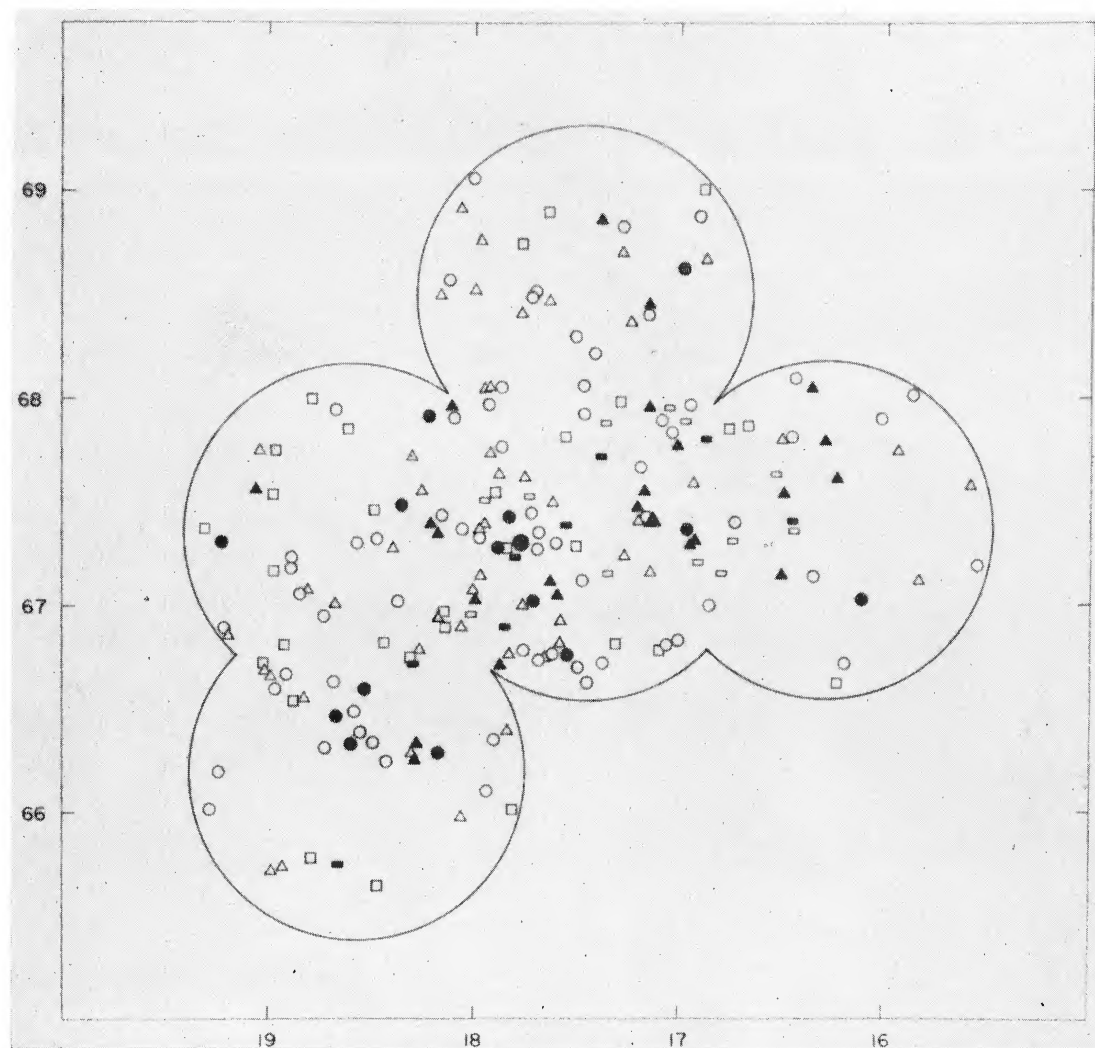


FIG. 1.—Surveyed galaxies in the central portion of the Coma Cluster. Squares represent the dwarfs, circles the S0's, triangles the ellipticals, and bars the SB0's. NGC 4874 and NGC 4889 are the slightly larger circle and triangle, respectively, in the center. Filled-in symbols indicate the bright galaxies ($m_{\text{pe}} \leq 15.7$). North is up, east is to the right.

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TABLE 5
RESULTS OF TESTS OF IDENTITY OF RADIAL DISTRIBUTION, WITH NULL
HYPOTHESIS THAT POPULATIONS ARE IDENTICAL

Center	Populations Compared	χ^2 Test	Runs Test	Median Test	Kolmogorov-Smirnov Test	Ratio Test
Field 1	{E/S	Acc	Acc.	Acc	Acc.	0.91 ± 0.11
	{B/S	Rej	Rej	Rej	Rej	.68 ± 0.06
	{Br/D	Rej	Acc	Rej	Rej	.67 ± 0.10
NGC 4874	{E/S	Acc	Acc	Acc.	Acc	.87 ± 0.08
	{B/S	Acc	Rej	Acc	Acc	.80 ± 0.13
	{Br/D	Acc	Acc	Acc.	Acc	.69 ± 0.05
NGC 4889	{E/S	Acc.	Acc	Acc	Acc	.97 ± 0.09
	{B/S	Rej	Rej	Rej	Rej	.54 ± 0.08
	{Br/D	Acc.	Acc.	Rej	Rej	0.64 ± 0.06

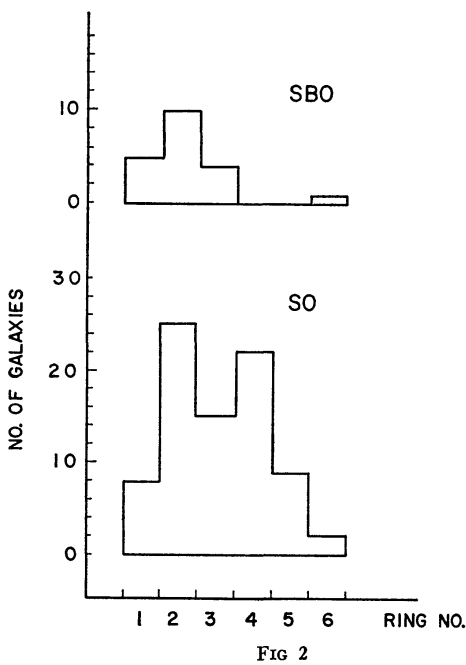
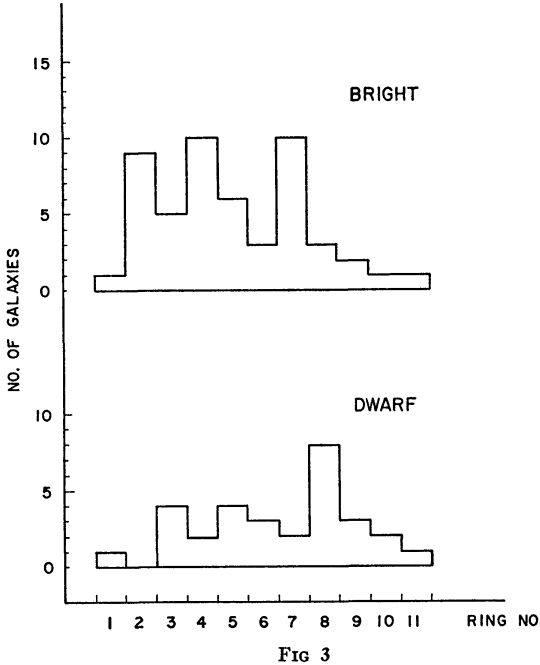


FIG. 2.—SBO-SO radial distributions about the Field 1 center
FIG. 3.—Bright-dwarf radial distributions about the Field 1 center



IV. DISCUSSION

a) Closeness of Association and Subclustering

In examining the closeness-of-association ratios (Table 2), we note with Reaves (1964) that a ratio of the type we have computed, if >1 , generally implies a close association between the two types of galaxies involved, perhaps even a satellite relationship. For example, if the majority of dwarfs were satellites of the bright galaxies, we would expect the ratio BrBr/DBr to be >1 . On this basis, the ratios suggest *slight* associations of the ellipticals with the S0's, the SB0's with the ellipticals, and the bright galaxies with the ellipticals, but these inferences are quite marginal. Note, however, that our BrBr/DBr ratio is 0.82 ± 0.13 , certainly <1 , indicating that most dwarfs are most likely *not* satellites of the bright, more massive galaxies. This is exactly what Reaves (1964) has found for the Fornax and Virgo clusters. Furthermore, the ratios indicate that the dwarfs are not strikingly associated with any particular type of galaxy, E, S0, or SB0, and that they seem especially to shun the ellipticals and SB0's. Also, the bright galaxies and the SB0's appear not to be closely associated with each other. There are thus no significant satellite systems observed. (The more detailed reasons for some ratios being <1 are mentioned in § IVb.)

The subclustering analysis indicates that there is no significant subclustering of similar types of galaxies, since the observed frequencies in Table 3 agree well with the frequencies expected if this were the case. The only indications at all of any groupings are the slight association of the ellipticals with the S0's, which the closeness-of-association test indicates also, and an SB0-SB0 association. The absence of any significantly strong clumping within the extreme center of the cluster, however, would seem to indicate, if we are willing to extrapolate to larger areas of the cluster, that the apparent secondary concentration (which was beyond our fields) noted by several investigators (Shane and Wirtanen 1954; van den Bergh 1961; Omer, Page, and Wilson 1965) is indeed caused by a background cluster as Omer, Page, and Wilson have decided.

It is well known that anomalously large mass-to-light ratios are found for large clusters of galaxies such as the Coma Cluster when the virial theorem is applied. Among the possible explanations for such results is that perhaps clumping is underestimated, causing the mass to be overestimated. Holmberg (1961) finds this effect important in the Virgo Cluster. Abell (1965) maintains that for clusters such as Coma, however, the effect of subclustering on the mass-light ratio is probably negligible, and, on the basis of our not finding significant clumping within the central regions of Coma, we would have to agree with regard to this cluster.

b) Identity of Distribution

The identity-of-distribution tests clearly indicate that, to the 5 per cent significance level, the elliptical and S0 galaxies have identical radial distributions and that the SB0's and S0's have different radial distributions, as do the bright and dwarf galaxies. The SB0-S0 distributions differ (and their closeness-of-association ratio is <1) because the SB0's are associated with their own separate center of distribution. Table 4 shows that the SB0's appear to have a center of distribution near NGC 4889, whereas the other types do not exhibit this. The SB0's, therefore, do show some subgrouping—in the sense of being associated with their own center of distribution. This conclusion is also suggested by Figure 1 and indicates that the situation is somewhat similar to that in the Virgo Cluster, in which subclustering tendencies are found (Burbidge and Burbidge 1959). The reason for the difference in the bright and dwarf distributions is that the bright galaxies are more centrally concentrated than the dwarfs.

In the case of the SB0-S0 and bright-dwarf distributions, it was the ratio test which allowed us to choose between the two most likely alternative reasons for the other tests

rejecting distribution identity: different distribution centers entirely, or simply different distributions about the same center.

We thus have the more massive galaxies clustering closer to the center than do the dwarf galaxies. (Note that Noonan 1961, while finding that the over-all bright-faint radial distributions in Coma were *nearly* identical, observed slight effects, particularly in the extreme central portions, which if "real" would indicate that the bright galaxies are more centrally concentrated. Our findings show that the effects he noted are indeed genuine.)

It is worthwhile discussing here another possible explanation for the mass-light anomaly in virial-theorem computations for the Coma Cluster. In one form the virial theorem can be expressed as $M \propto \langle v^2 \rangle_{Av} R_h / G$, where M is the total cluster mass, G the gravitational constant, $\langle v^2 \rangle_{Av}$ the mass-weighted average velocity squared, and R_h the harmonic mean separation weighted according to the product of the masses of each mass pair in the cluster. The estimate that is derived for M is thus dependent upon the value taken for R_h . In the case of the Coma Cluster, we estimate from the results given in Table 5 that an R_h based on the distribution of faint galaxies alone would differ at most by a factor of 1.7 (i.e., 1/0.6) from an R_h based on the distribution of bright galaxies alone. Since in a real application, the mass distribution (and thus the value for R_h) used would be based on some *composite* of the bright and faint distributions, the error in the total mass caused by unrecognized mass segregation would have an extreme upper limit of a factor of about 2 (the actual error is probably much less). The anomalous mass-light ratio of the Coma Cluster, therefore, cannot be satisfactorily explained by underestimation or unrecognized mass segregation.

V. SUMMARY

We now summarize several conclusions of the analysis. The dwarf galaxies in the Coma center cannot be regarded as satellites of more massive galaxies. In this respect, the Coma Cluster is similar to the Virgo and Fornax clusters. It is interesting to note that Reaves (1964) has found the median projected distance between a dwarf galaxy and the nearest bright galaxy in the Virgo and Fornax clusters to be ≈ 140 kpc (based on a Hubble constant $H = 100 \text{ km sec}^{-1} \text{ Mpc}^{-1}$). In the Coma Cluster, the median distance is ≈ 42 kpc, reflecting the denser character of Coma. The median distance from a bright galaxy to the next nearest bright galaxy is ≈ 35 kpc. In addition, we conclude that there are no strong close associations or satellite systems among other galaxy types in Coma—only a slight indication of mild E-S0 association; and subclustering of similar types of galaxies is observed only in the case of the SB0's.

The identity-of-distribution tests indicate that the dwarf population is radially more spread out than the bright galaxies. We therefore have definite tendencies toward mass segregation in the Coma Cluster, as there are in the Fornax Cluster, another regular cluster (Reaves 1964; Hodge, Pyper, and Webb 1965), but not in the Virgo Cluster (Reaves 1956) or in the Canes Venatici Cluster (van den Bergh 1960; Reaves 1965), two irregular clusters. The SB0 and S0 distributions differ (SB0's have their own separate center of distribution). The E and S0 radial distributions are the same, as are practically *all* angular distributions.

The fact that there is evidence of some degree of mass segregation may indicate that we are seeing the effects of partial or incipient dynamical relaxation in the Coma Cluster. The segregation observed, however, is not enough to be the cause, by going unnoticed, of the anomalously large mass-light ratio obtained for the Coma Cluster, and likewise the absence of clumping indicates that subgrouping effects are also insufficient to cause such a high M/L .

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APPENDIX

x - y POSITIONS FOR ALL GALAXIES IN THE EXTREME CENTRAL
REGION OF THE COMA CLUSTER

GALAXIES IN THE ROOD-BAUM (1967) SURVEY

No *	x	y	No	x	y	No	x	y
134	15 595	67 145	172	16 960	68 180	66	17 390	67 870
133	15 625	67 540	94	16 970	67 190	65	17 390	67 160
N4921	15 635	66 930	102	16 975	67 580	N4881	17 390	68 840
132	15 770	67 330	93	16 980	67 845	64	17 400	67 140
131	15 780	66 800	N4898	16 980	67 290	N4883	17 420	67 705
130	15 890	67 985	171	16 980	68 040	63	17 420	67 080
129	15 890	67 080	92	16 990	67 955	156	17 425	68 915
128	15 980	67 715	N4898	16 990	67 280	155	17 435	68 210
127	16 055	67 870	101	16 995	67 460	62	17 440	66 715
126	16 065	66 960	N4895	16 995	68 610	61	17 465	67 360
125	16 135	67 030	91	17 000	67 870	58	17 510	68 050
124	16 170	67 000	N4894	17 010	67 355	59	17 510	67 915
123	16 230	66 990	170	17 030	68 440	60	17 510	66 620
122	16 260	66 690	I4021	17 045	67 750	154	17 520	69 100
I4051	16 270	67 580	90	17 065	66 815	57	17 525	67 050
121	16 285	67 370	89	17 080	67 810	55	17 530	67 115
120	16 325	67 785	169	17 080	68 770	56	17 530	67 035
N4908	16 325	67 760	88	17 085	68 010	153	17 530	68 300
I4045	16 390	68 020	87	17 090	67 930	53	17 570	66 700
119	16 405	67 115	85	17 120	67 875	54	17 570	67 430
118	16 435	66 650	86	17 120	67 470	52	17 590	68 040
116	16 470	68 070	83	17 130	66 795	51	17 600	67 480
117	16 470	67 225	84	17 130	67 300	I3998	17 605	67 380
115	16 480	67 405	81	17 160	66 780	49	17 610	66 750
114	16 490	67 795	82	17 160	66 805	50	17 610	67 520
I4042	16 500	67 380	168	17 170	68 350	151	17 615	68 995
113	16 500	67 330	167	17 175	68 440	152	17 615	68 965
112	16 515	66 970	N4889	17 180	67 400	48	17 630	66 930
111	16 525	67 770	80	17 180	67 280	N4876	17 640	67 040
I4041	16 530	67 510	166	17 180	68 380	47	17 645	66 805
N4906	16 555	67 120	I4012	17 190	67 950	46	17 655	67 295
109	16 585	67 620	79	17 190	67 300	150	17 655	68 895
110	16 585	67 610	78	17 200	67 150	45	17 665	67 495
108	16 590	67 470	I4011	17 215	67 540	149	17 665	68 460
I4040	16 600	67 830	77	17 220	67 410	43	17 690	67 115
107	16 625	67 615	165	17 220	68 865	44	17 690	66 760
106	16 635	67 225	76	17 225	67 130	147	17 715	68 295
105	16 640	66 625	74	17 230	67 655	148	17 715	68 510
104	16 665	67 180	75	17 230	67 400	41	17 725	66 740
180	16 740	68 400	164	17 230	68 270	42	17 725	67 350
179	16 755	68 390	N4886	17 260	67 460	146	17 725	68 480
100	16 780	67 385	73	17 270	67 330	39	17 735	66 735
178	16 785	68 390	162	17 270	68 365	40	17 735	67 270
99	16 790	67 295	163	17 270	68 350	38	17 770	67 440
103	16 810	67 870	161	17 275	68 915	N4875	17 780	67 015
98	16 820	67 580	72	17 280	67 645	37	17 780	67 520
97	16 835	67 195	160	17 290	68 810	145	17 785	68 740
96	16 840	67 135	159	17 300	68 690	36	17 790	66 825
177	16 840	68 450	158	17 305	68 460	144	17 790	68 410
176	16 850	68 760	157	17 310	69 220	35	17 795	67 615
175	16 895	68 635	70	17 315	67 475	34	17 810	67 010
I4026	16 905	67 780	71	17 315	67 230	33	17 815	67 005
95	16 910	66 980	69	17 320	67 960	N4874	17 815	67 300
174	16 910	68 850	68	17 355	67 200	31	17 820	66 785
173	16 950	68 930	67	17 365	68 045	32	17 820	67 160

* The numbers are those used in the Rood-Baum survey

APPENDIX—*Continued*
Rood-Baum Survey—*Continued*

No	x	y	No	x	y	No	x	y
N4872	17 855	67 230	271	18 120	67 910	I3947	18 675	66 355
N4873	17 885	67 430	4	18 130	67 340	255	18 680	67 900
29	17 890	66 770	5	18 130	67 370	207.	18 690	66 995
30	17 890	67 095	N4865	18 130	67 970	254	18 705	67 545
237	17 890	66 010	226	18 160	65 990	253	18 705	67 480
236	17 895	65 995	270	18 180	68 000	206	18 710	66 530
28	17 900	68 055	135	18 185	68 500	252	18 710	67 960
235	17 900	65 950	3	18 190	66 955	251	18 720	67 795
I3973	17 910	66 895	225	18 195	66 290	250	18 725	67 030
25	17 910	67 275	2	18 205	67 440	I3946	18 735	66 490
26	17 910	67 765	N4867	18 220	67 355	205	18 750	66 650
27	17 910	67 740	269	18 225	66 950	249	18 760	67 610
234	17 910	66 400	1	18 230	67 150	N4854	18 770	65 765
N4871	17 930	67 280	268	18 240	67 920	204.	18 790	66 980
24	17 930	67 630	I3963	18 250	66 300	203	18 790	66 765
233	17 935	66 475	N4864	18 270	67 390	202	18 800	66 185
I3976	17 940	66 710	267	18 295	67 560	201	18 805	66 870
23	17 940	67 205	223	18 320	66 800	200	18 810	66 335
142	17 940	68 045	266	18 330	67 730	248	18 830	67 770
143	17 940	68 045	265	18 335	66 960	199	18 865	66 220
232	17 945	66 040	I3959	18 350	66 350	247	18 880	67 090
22	17 960	67 730	222	18 360	66 500	197	18 900	65 710
20	17 970	67 615	I3960	18 365	66 730	198	18 900	66 575
21	17 970	67 975	I3957	18 370	66 265	246	18 900	67 080
231	17 980	66 360	221	18 380	66 290	245	18 930	67 260
141	17 985	68 750	220	18 400	66 705	244	18 940	67 200
17	18 000	66 750	I3955	18 400	67 490	196	18 950	66 550
18	18 000	67 500	219	18 405	65 600	195	18 985	66 700
19	18 000	67 450	218	18 410	66 700	193	18 990	65 500
16	18 005	67 380	264	18 410	67 890	194	18 990	66 830
139	18 010	69 050	217	18 420	66 395	191	19 025	65 760
140	18 010	68 510	263	18 420	67 780	192	19 025	66 630
14	18 015	67 370	262.	18 420	67 035	190	19 060	66 700
15	18 015	67 955	261	18 435	67 290	188	19 080	65 755
11	18 020	67 165	N4858	18 490	68 130	189	19 080	66 715
12	18 020	67 500	216	18 510	66 265	243	19 080	67 770
13	18 020	67 340	260	18 515	67 335	187	19 090	66 410
230	18 020	66 115	215	18 520	66 980	242	19 090	66 940
10	18 040	66 970	259	18 530	67 160	241	19 110	67 590
229	18 040	65 955	214	18 565	66 360	185	19 120	66 400
N4869	18 060	67 040	213	18 585	66 550	186	19 120	66 505
9	18 060	67 080	I3949	18 590	66 610	184	19 170	65 930
138	18 075	68 900	212	18 590	66 450	240	19 270	66 890
8	18 080	66 960	258	18 590	67 010	239	19 275	66 930
137	18 090	68 210	211	18 610	66 570	N4850	19 280	67 330
228	18 090	66 535	257	18 610	67 320	183	19 320	66 225
7	18 100	67 370	210	18 620	66 410	238	19 365	67 720
6	18 115	66 900	256	18 640	67 870	182	19 375	66 050
136	18 120	68 575	209	18 645	66 505	181	19 380	66 440
227	18 120	66 075	208	18 660	66 900			

All Thirty-two Identified Dwarfs

No.*	x	y	No	x	y	No	x	y
32	16 290	66 615	18	17 870	66 025	10	18 650	67 860
31	16 720	67 870	21	17 900	67 280	9	18 820	68 000
30	16 810	67 830	19†	17 915	66 600	8	18 865	65 800
29	16 930	68 990	20	17 960	67 550	7	18 940	66 550
28	17 170	66 790	17†	18 170	68 980	6	18 990	66 820
27	17 350	67 970	16	18 200	66 900	5	19 005	67 770
26	17 385	66 810	15	18 210	66 985	4	19 010	67 180
25	17 565	67 285	14	18 345	66 760	3	19 015	67 550
24	17 605	67 810	13	18 495	66 825	2	19 090	66 720
23	17 680	68 895	11	18 530	65 670	1	19 355	67 395
22	17 800	68 730	12	18 550	67 480			

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