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GLOBULAR CLUSTERS IN GALAXIES BEYOND THE LOCAL GROUP. VIII. ELLIPTICAL GALAXIES IN THE FORNAX CLUSTER

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ABSTRACT

We have confirmed the existence of globular cluster populations associated with five of the elliptical galaxies in the Fornax Cluster. The dominant central elliptical, NGC 1399, is relatively overabundant in globular clusters; its specific frequency is $S \approx 17$, while $\langle S \rangle \approx 5$ for three of the other more normal elliptical galaxies in the cluster. This finding confirms an effect previously noted in the Virgo Cluster and the Hydra Cluster. Moreover, the NGC 1399 globular cluster system structurally resembles that in M87, the dominant central giant elliptical galaxy in the Virgo Cluster. Such galaxies seem to be preferred locations for the formation of large globular cluster systems.

Subject headings: clusters: globular — galaxies: clustering — galaxies: individual — galaxies: stellar content

I. INTRODUCTION

Extragalactic globular cluster systems have gained increasing interest partly because of their potential as beacons in the construction of the extragalactic distance scale but also because of their importance as indicators of the distribution of the oldest stellar components of galaxies. Their observed distributions may have arisen in the galaxy formation process itself but may also be sensitive to the subsequent evolutionary history such as the perturbing effects of galaxy-galaxy interactions. For these reasons, it is important to study the globular cluster populations associated with galaxies of various types and in a variety of environments.

In previous papers in the series we and our co-workers have studied spiral (van den Bergh and Harris 1982, hereafter Paper II; Harris, Harris, and Harris 1984, hereafter Paper III; Harris, *et al.* 1985, hereafter Paper VI), lenticular (Hanes and Harris 1986, hereafter Paper VII), and elliptical (Harris and van den Bergh 1981, hereafter Paper I; Harris, Smith, and Myra 1983; Harris and Hanes 1985, hereafter Paper IV; Pritchet and van den Bergh 1985; Harris 1986, hereafter Paper V) galaxies. Globular cluster systems are most easily recognized and analyzed in the last of these and should eventually be plainly detectable to distances of ~100 Mpc in giant elliptical galaxies (Harris 1983).

Two large-scale properties of such systems are becoming increasingly evident as the sample surveyed increases. The first of these is the importance of environment: giant elliptical galaxies in rich environments, such as NGC 4486 in the heart of the Virgo Cluster, have more globular clusters per unit galaxy luminosity than do their counterparts in less privileged surroundings, although occasional exceptions to this general rule may exist (such as NGC 524; see Paper IV). Second, the globular cluster systems seem to be generally less centrally concentrated than the underlying galaxian luminosity, an effect which seems to be more pronounced in the more luminous galaxies (Lauer and Kormendy 1986; Grillmair, Pritchet, and van den Bergh 1986), although again there are exceptions such as NGC 3311, the central galaxy in the Hydra Cluster (see Paper V for more extensive discussion of these issues).

In the present paper we consider the globular cluster systems in five of the largest E galaxies in the Fornax cluster. Data on the program galaxies are listed in Table 1. Dawe and Dickens (1976) first detected globular clusters in three Fornax ellipticals by carrying out starcounts on a single prime focus plate (unsensitized IIa-O, 20 minutes' exposure) taken at the Anglo-Australian Telescope (AAT). To our knowledge, these interesting systems have not been further explored. Yet the Fornax group is an important one in a number of ways. It lies in the Local Supercluster anticenter direction (~150° from the Virgo Cluster center), and thus an independent distance estimate for Fornax would help to refine the determination of the Local Group peculiar motion. Moreover, much of the basis for the idea (Paper I; Paper V) that E galaxies in rich groups have systematically larger globular cluster systems than those in small or sparse groups rests on the Virgo system alone, which has to date been the only well-surveyed rich group. Next to Virgo itself, Fornax represents the nearest large collection of E galaxies within which the globular cluster luminosity functions, spatial distributions, and total populations can be carefully studied. Last, Fornax has a relatively dominant central giant elliptical (NGC 1399), which is at least roughly analogous to M87 in the Virgo cluster, and there is considerable special interest in such systems.

In § II we describe our starcounts in the fields of the five galaxies discussed there. In § III we derive the local surface density of field objects and the density profile of the globular cluster population, the limiting magnitude of the counts, and the distance-dependent globular cluster specific frequency S. In § IV we discuss the numerical results, finally summarizing our principal conclusions in § V.

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TABLE 1

PROGRAM GALAXIES

Parameter	NGC 1374	NGC 1379	NGC 1387	NGC 1399	NGC 1404
α(1950)	$3^h33^m.4$	$3^h34^m.1$	$3^h35^m.0$	$3^h36^m.6$	$3^h37^m.0$
δ(1950)	−35°24′	−35°36′	−35°40′	−35°37′	−35°45′
Classification	E0	E0	SB0(pec)	E1	E2
B_T (mag)	12.30	12.07	11.83	10.79	11.06
B(HG)[a]	12.70	12.60	12.30	11.15	11.34
$(B-V)$[b]	...	...	...	0.95	0.95
v_0 (km s^{-1})	1201	1368	1184	1375	1903
CFHT plate number	3014	3014	3014	3013	3013
Offset (from plate center)	16′.1	0′.0	11′.6	0′.0	9′.8

NOTE.—Data from Sandage and Tammann 1981 except as noted.
[a] Magnitude quoted by Huchra and Geller 1982.
[b] $(B-V)$ colors from RC2.

II. STARCOUNT DATA

We carried out starcounts upon two plates obtained at the prime focus of the Canada-France-Hawaii Telescope (CFHT); see Table 2. Five bright galaxies (NGC 1374, 1379, 1387, 1399, and 1404) were well placed for starcount analysis. Inspection under low-power magnification of the five program galaxies revealed the existence of a globular cluster system around each; Figure 1 (Plate 7) shows the biggest of these, around NGC 1399. Our initial impression, subsequently borne out quantitatively, was that the globular cluster system associated with the central giant elliptical galaxy NGC 1399 was vastly richer than those associated with the other program galaxies, an important point to which we return in § IV.

Our procedures for carrying out and analyzing the starcounts were as described in previous papers in the series; see, for example, Paper I. For each program galaxy, we superposed onto the plate a reseau which subdivided the field into 20° sectors and 20 annuli of width 3.23 ± 0.02 mm. We then each independently counted all visible images, making no effort to discriminate between those of stellar and those of nonstellar appearance. We corrected for the known radial plate scale distortion of the CFHT prime focus plates just as described in Paper IV, except that here several of the galaxies lay significantly off-axis. For such galaxies, the superposed circular reseau is slightly deformed to an oval by the radially dependent differential plate-scale distortion. However, this second-order distortion is negligibly small and was ignored.

Except as noted in the discussion which follows, we counted objects in every cell of the reseau except the central circle, which was obscured by the overexposed galaxy nucleus. Intercomparisons of our starcounts revealed that there were no statistically significant radial or azimuthal trends in the ratios of our separate sets of data, implying that we each counted to a uniform level within each field. The ratios of total counts, field by field, ranged from 0.87 (in the sense DAH/WEH) for NGC 1379 to 1.23 for NGC 1387. That is, our personal limiting magnitudes differed slightly from one field to another. However, the absence of any trends within each field justified a simple averaging, cell by cell, in the derivation of the final counts.

Those counts are summarized in Table 3. Successive columns give the following information: (1) the ring number, n; note that ring number n extends from annulus marking $(n-1)$ to n, so that ring 1 is actually the innermost circle containing the galaxy itself; (2) the effective ring radius, defined by $r = (r_i r_o)^{1/2}$, where r_i and r_o are the inner and outer radii of the annulus; (3) the area of the annulus bounded by radii r_i and r_o; (4) the number of objects counted in the rings, and the associated size-of-sample error; (5) the fractional completeness of the counts in the ring; (6) the surface density of counts; (7) the surface density of globular clusters, after the subtraction of a uniform surface density of field objects (derived as described in § III*a* and tabulated at the foot of each subsection of Table 3); and (8) the total globular cluster content of a given ring (i.e., col. [3] multiplied by col. [7]).

We now comment upon the individual fields in turn.

NGC 1374.—Counts in this field covered a restricted range in azimuth because of interference from the penumbra of the guide probe on Plate 3014. Moreover, several other cells were omitted because of the presence of the lenticular galaxy NGC 1375, which lies ~3′ south of NGC 1374. NGC 1375 itself showed no detectable cluster population.

NGC 1379.—Counts were straightforward for this galaxy, which is uncrowded and lies centrally on Plate 3014. (Toward the edge of the field of this plate is the lenticular NGC 1380,

TABLE 2

PRIME FOCUS PLATE MATERIAL

Parameter	CFHT Plate 3013	CFHT Plate 3014
Telescope	3.4 m CFHT	3.4 m CFHT
Focus/corrector	f4.2 prime/wide field	f4.2 prime/wide field
Emulsion/filter	IIIa-J + GG 385	IIIa-J + GG 385
Plate center:		
α (1950)	$03^h36^m36^s$	$03^h34^m06^s$
δ (1950)	−35°37′00″	−35°36′00″
Exposure (minutes)	90	90
Seeing	1″	1″
Galaxies studied	NGC 1399, NGC 1404	NGC 1374, NGC 1379, NGC 1387

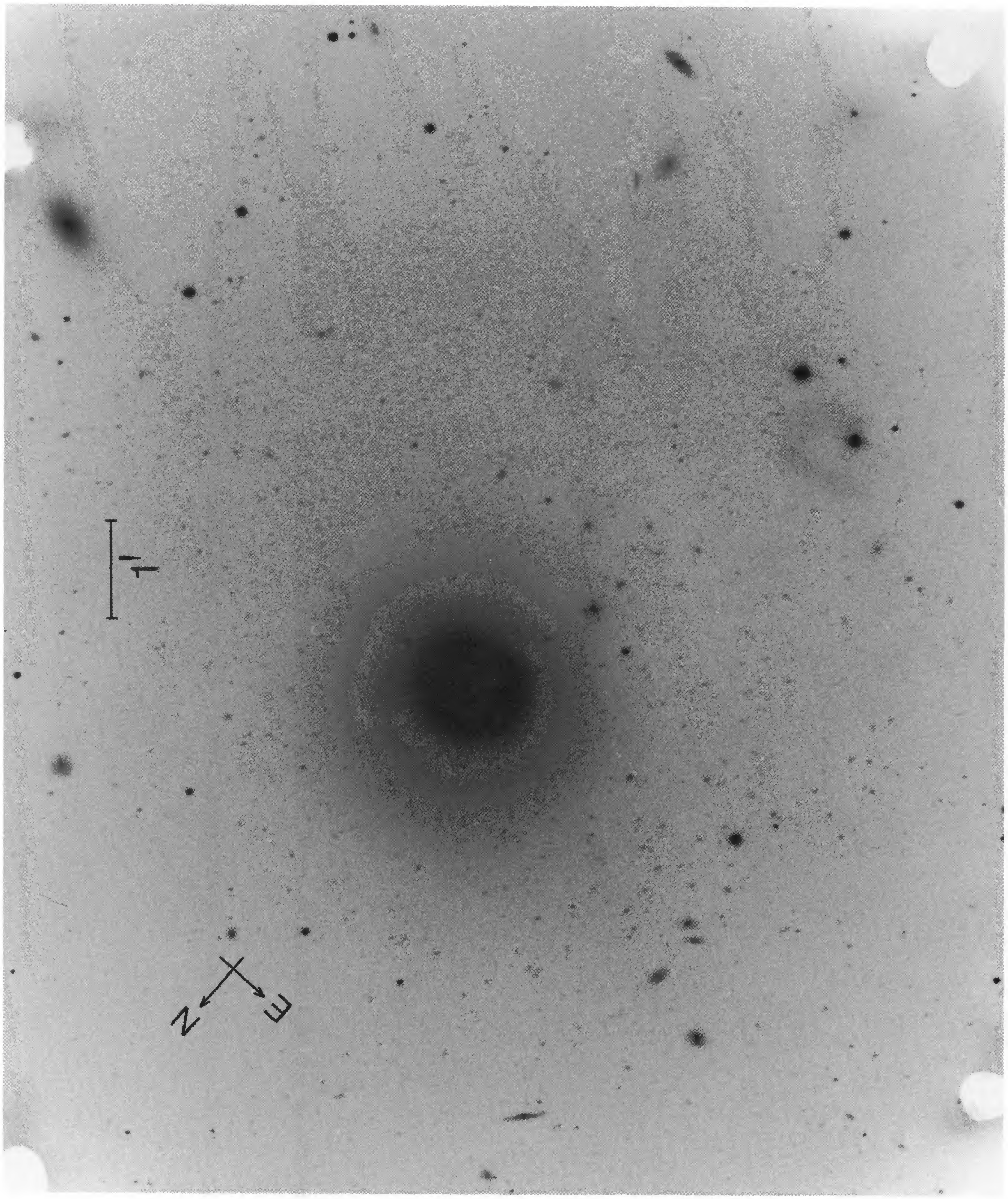

FIG. 1.—Direct photograph of the largest Fornax cluster elliptical galaxy NGC 1399 and its globular cluster system. The scale and orientation are indicated on the reproduction, which is from the CFHT plate described in Table 2.

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TABLE 3

STARCOUNTS

Ring (1)	r (arcmin) (2)	Ring Area ($arcmin^2$) (3)	n (4)	f (5)	σ ($arcmin^{-2}$) (6)	σ_{cl} ($arcmin^{-2}$) (7)	N_{cl} (8)
			A. NGC 1374 from CFHT Plate 3014				
2..........	1.03	4.98	36.0 ± 6.0	1.00	7.23 ± 1.20	3.73 ± 1.35	18.6 ± 6.7
3..........	1.78	8.30	23.5 ± 4.8	0.50	5.66 ± 1.17	2.16 ± 1.31	17.9 ± 10.9
4..........	2.52	11.62	26.0 ± 5.1	0.50	4.47 ± 0.88	0.97 ± 1.07	11.3 ± 12.4
5..........	3.25	14.94	45.0 ± 6.7	0.61	4.93 ± 0.74	1.43 ± 0.95	21.3 ± 14.2
6..........	3.98	18.27	50.0 ± 7.1	0.61	4.48 ± 0.64	0.98 ± 0.88	17.9 ± 16.0
7..........	4.71	21.59	46.5 ± 6.8	0.61	3.53 ± 0.52	0.03 ± 0.79	0.6 ± 19.1
8..........	5.44	24.91	55.5 ± 7.4	0.61	3.65 ± 0.49	0.15 ± 0.78	3.6 ± 19.3
9..........	6.17	28.23	86.0 ± 9.3	0.61	4.98 ± 0.54	1.48 ± 0.81	41.9 ± 22.8
10..........	6.90	31.55	69.0 ± 8.3	0.61	3.58 ± 0.43	0.08 ± 0.74	2.5 ± 23.3
11..........	7.63	34.87	75.0 ± 8.6	0.61	3.52 ± 0.41	0.02 ± 0.73	0.7 ± 25.3
$\sigma_b = 3.50 \pm 0.59$							
			B. NGC 1379 from CFHT Plate 3014				
2..........	1.04	5.13	57.5 ± 7.6	1.00	11.22 ± 1.48	7.06 ± 1.50	36.2 ± 7.7
3..........	1.81	8.54	51.5 ± 7.2	1.00	6.03 ± 0.84	1.87 ± 0.88	16.0 ± 7.5
4..........	2.55	11.96	67.0 ± 8.2	1.00	5.60 ± 0.69	1.45 ± 1.00	17.3 ± 12.0
5..........	3.30	15.37	81.5 ± 9.0	1.00	5.30 ± 0.59	1.15 ± 0.64	17.6 ± 9.8
6..........	4.04	18.78	75.5 ± 8.7	1.00	4.02 ± 0.46	−0.13 ± 0.53	−2.4 ± 9.9
7..........	4.78	22.18	97.5 ± 9.9	1.00	4.40 ± 0.45	0.23 ± 0.51	5.2 ± 11.3
8..........	5.52	25.58	105.0 ± 10.2	1.00	4.11 ± 0.40	−0.05 ± 0.47	−1.4 ± 12.0
9..........	6.25	28.97	136.5 ± 11.7	1.00	4.71 ± 0.40	0.55 ± 0.47	16.0 ± 13.7
10..........	6.99	32.36	124.5 ± 11.2	1.00	3.85 ± 0.35	−0.31 ± 0.43	−10.1 ± 13.8
11..........	7.73	35.74	159.0 ± 12.6	1.00	4.45 ± 0.35	0.29 ± 0.43	10.3 ± 15.4
$\sigma_b = 4.16 \pm 0.25$							
			C. NGC 1387 from CFHT Plate 3014				
2..........	1.04	5.05	71.0 ± 8.4	1.00	14.06 ± 1.66	8.73 ± 1.68	44.1 ± 8.5
3..........	1.79	8.42	67.0 ± 8.2	1.00	7.96 ± 0.97	2.63 ± 1.00	22.1 ± 8.4
4..........	2.54	11.78	83.0 ± 9.1	1.00	7.05 ± 0.77	1.71 ± 0.81	20.2 ± 9.5
5..........	3.27	15.15	104.0 ± 10.2	1.00	6.87 ± 0.67	1.54 ± 0.71	23.3 ± 10.7
6..........	4.01	18.51	108.0 ± 10.4	1.00	5.83 ± 0.56	0.50 ± 0.60	9.3 ± 11.2
7..........	4.74	21.88	124.0 ± 11.1	1.00	5.67 ± 0.51	0.34 ± 0.55	7.4 ± 12.1
8..........	5.48	25.25	124.0 ± 11.1	1.00	4.91 ± 0.44	−0.42 ± 0.50	−10.6 ± 12.5
9..........	6.21	28.61	155.0 ± 12.4	1.00	5.42 ± 0.43	0.09 ± 0.49	2.5 ± 14.0
10..........	6.94	31.98	171.0 ± 13.1	1.00	5.35 ± 0.41	0.02 ± 0.46	0.6 ± 14.8
$\sigma_b = 5.33 \pm 0.22$							
			D. NGC 1399 from CFHT Plate 3013				
2..........	1.04	5.13	177.5 ± 13.3	1.00	34.63 ± 2.60	29.22 ± 2.63	149.8 ± 13.5
3..........	1.81	8.54	212.0 ± 14.6	1.00	24.82 ± 1.71	19.42 ± 1.77	165.9 ± 15.1
4..........	2.55	11.96	212.0 ± 14.6	1.00	17.73 ± 1.22	12.33 ± 1.31	147.4 ± 15.6
5..........	3.30	15.37	172.5 ± 13.1	1.00	11.23 ± 0.85	5.82 ± 0.96	89.5 ± 14.8
6..........	4.04	18.78	223.5 ± 14.9	1.00	11.90 ± 0.79	6.50 ± 0.91	122.1 ± 17.1
7..........	4.78	22.18	218.5 ± 14.8	1.00	9.85 ± 0.67	4.45 ± 0.81	98.7 ± 17.9
8..........	5.52	25.58	233.0 ± 15.3	1.00	9.11 ± 0.60	3.71 ± 0.75	94.9 ± 19.1
9..........	6.25	28.97	224.0 ± 15.0	1.00	7.73 ± 0.52	2.33 ± 0.69	67.6 ± 19.9
10..........	6.99	32.36	262.0 ± 16.2	1.00	8.10 ± 0.50	2.70 ± 0.67	87.3 ± 21.8
11..........	7.23	35.74	239.0 ± 15.5	0.94	7.08 ± 0.46	1.68 ± 0.64	60.1 ± 23.0
12..........	8.46	39.11	252.0 ± 15.9	0.89	7.25 ± 0.46	1.85 ± 0.64	72.3 ± 25.1
13..........	9.20	42.47	215.5 ± 14.7	0.78	6.53 ± 0.45	1.13 ± 0.63	47.8 ± 26.9
14..........	9.93	45.82	211.5 ± 14.5	0.78	5.93 ± 0.41	0.54 ± 0.61	24.5 ± 27.8
15..........	10.67	49.16	252.5 ± 15.9	0.78	6.60 ± 0.41	1.20 ± 0.61	59.1 ± 30.1
16..........	11.40	52.49	281.0 ± 16.8	0.83	6.42 ± 0.38	1.03 ± 0.59	53.8 ± 31.0
17..........	12.13	55.81	300.5 ± 17.3	0.89	6.06 ± 0.35	0.66 ± 0.57	36.8 ± 31.8
18..........	12.86	59.11	291.0 ± 17.1	0.89	5.54 ± 0.32	0.14 ± 0.56	8.2 ± 32.8
19..........	13.60	62.40	315.5 ± 17.8	0.83	6.07 ± 0.34	0.67 ± 0.56	41.6 ± 35.2
20..........	14.33	65.68	279.5 ± 16.7	0.83	5.11 ± 0.31	−0.29 ± 0.54	−19.3 ± 35.7
$\sigma_b = 5.40 \pm 0.45$							
			E. NGC 1404 from CFHT Plate 3013				
2..........	1.04	5.13	71.5 ± 8.5	1.00	13.93 ± 0.66	7.64 ± 1.70	39.2 ± 8.7
3..........	1.81	8.56	83.5 ± 9.1	1.00	9.76 ± 1.06	3.46 ± 1.12	29.6 ± 9.6
4..........	2.56	11.98	85.5 ± 9.2	1.00	7.14 ± 0.77	0.84 ± 0.84	10.0 ± 10.1
5..........	3.30	15.40	99.5 ± 10.0	1.00	6.46 ± 0.65	0.16 ± 0.74	2.5 ± 11.4
6..........	4.04	18.82	136.0 ± 11.7	1.00	7.23 ± 0.62	0.92 ± 0.71	17.4 ± 13.4
7..........	4.78	22.24	177.5 ± 13.3	1.00	7.98 ± 0.60	1.68 ± 0.69	37.4 ± 15.4
$\sigma_b = 6.30 \pm 0.35$							

which is comparable in size with our program ellipticals and one of the most luminous Fornax members. Interestingly, it showed no obvious indication of a globular cluster system.)

NGC 1387.—Our separate sets of counts were in good agreement but did not extend initially to large enough radii to delineate the background level adequately. One of us (W. E. H.) repeated the counts over a larger area; those are the values presented in Table 3C.

NGC 1399.—This galaxy is centrally placed on Plate 3013 and lies fully 13′ NNW of its nearest neighbor NGC 1404. However, its extensive rich cluster population necessitated counts out to large radii, which led to the omission of some cells affected by the guide probe penumbra or the presence of NGC 1404.

NGC 1404.—As noted, this galaxy lies within the outskirts of the detected cluster population of NGC 1399, so that the local "background" displays a gradient in surface density. The analysis of its globular cluster population was complicated by this fact, as we describe in § III*a*, so our inferred total cluster population may have systematic uncertainties.

III. ANALYSIS

a) Background Density and the Distribution of Globular Clusters

For each galaxy in turn, we followed the procedures described in detail by Harris (Paper V) in simultaneously determining the background density σ_b of field objects and the parameters characterizing the globular cluster distribution. Our adopted σ_b values for each field are listed in Table 3. For three of the fields (NGC 1374, NGC 1379, NGC 1387), simple averaging of the counts in the outermost few annuli serves to define the local background; however, for NGC 1399 the surface density is still falling slightly through the outermost annuli, while NGC 1404 is projected upon that nonuniform distribution. The iterative methods of Paper V are designed to accommodate such cases.

In Table 4 we present the results of our calculations for the structural profiles of the cluster systems in our five Fornax ellipticals. Parts (A) and (B) of Table 4 refer to two different model descriptions of the projected cluster distribution: Table 4A refers to a simple power law, where $\sigma_{cl} = a_1 r^{a_2}$; and Table 4B refers to a "de Vaucouleurs" law, with $\log \sigma_{cl} = a_1 + a_2 r^{1/4}$. In the second interpolation model, the data for all the galaxies except NGC 1399 were a bit too noisy and covered too small a range in r to allow good convergence in the zero point; in these cases the formal fitting errors in a_1 are not useful and we simply list a_1 in parentheses in the table. For both models, the *slope* a_2 is much more reliably determined and is not particularly sensitive to the exact radial range chosen for the fit.

TABLE 4

BACKGROUND-CORRECTED FITS

Galaxy	Region	$\log a_1$	a_2	σ_b
A. Power Law: $\sigma_{cl} = a_1 r^{a_2}$				
NGC 1374....	Rings 2–11	0.60 ± 0.15	−1.23 ± 0.42	3.50 ± 0.59
	3–11	0.70 ± 0.59	−1.36 ± 0.83	...
NGC 1379....	Rings 2–11	0.89 ± 0.10	−2.16 ± 0.43	4.16 ± 0.25
	3–11	0.87 ± 0.50	−2.13 ± 0.90	...
NGC 1387....	Rings 2– 7	0.87 ± 0.38	−1.67 ± 0.75	5.33 ± 0.22
	2–10	1.04 ± 0.37	−2.23 ± 0.79	...
NGC 1399....	Rings 3–19	1.72 ± 0.05	−1.64 ± 0.09	5.40 ± 0.45
	5–20	1.74 ± 0.14	−1.68 ± 0.18	...
NGC 1404....	Rings 2– 5	0.94 ± 0.10	−2.18 ± 0.56	6.31 ± 0.35
	2– 6	0.94 ± 0.10	−2.06 ± 0.49	...
B. "de Vaucouleurs" Law: $\sigma_{cl} = \log a_1 + a_2 r^{1/4}$				
NGC 1374....	Rings 2–11	(213)	−1.74 ± 0.59	3.50 ± 0.59
	3–11	(225)	−1.76 ± 1.02	...
NGC 1379[a] ...	Rings 2– 9	(9900)	−3.13 ± 0.63	4.16 ± 0.25
	2–11	(10500)	−3.16 ± 0.61	...
NGC 1387[a] ...	Rings 2–10	(10000)	−3.05 ± 0.51	5.33 ± 0.22
	3–10	(8221)	−2.97 ± 0.95	...
NGC 1399....	Rings 3–20	(4551)	−2.05 ± 0.12	5.40 ± 0.45
NGC 1404[a] ...	Rings 2– 5	?	(−2.14)	6.31 ± 0.35

[a] Did not converge well.

TABLE 5

LIMITING MAGNITUDES

Galaxy	B_J (lim)
NGC 1374......................	23.4 ± 0.2
NGC 1379......................	23.6 ± 0.1
NGC 1387......................	23.95 ± 0.1
NGC 1399......................	23.95 ± 0.1
NGC 1404......................	24.2 ± 0.1

In Figures 2*a*–2*e* we present the background-subtracted surface density of globular clusters $\sigma_{cl}(r)$ as a function of radius for the five program galaxies, in a power-law representation. Also shown for reference are lines of slope $\Delta \log \sigma / \Delta \log r = -2$. Inspection of the figures and of the entries of Table 4A reveals that, as for elliptical galaxies studied previously (Papers I, IV, V), the globular clusters are distributed in projection with power laws of index near -2.

b) Limiting Magnitudes of the Studies

In previous papers in the series we have estimated the effective limiting magnitudes of our starcounts by a comparison of the observed surface density of field objects to the predictions of a model which includes foreground stars (Bahcall and Soneira 1981) and remote background galaxies (Jarvis and Tyson 1981). The method is fully described in Paper I; its application to the Fornax galaxies studied here yields the results given in Table 5, results which are consistent in our experience with IIIa-J plate material of similar quality. In most cases the count limit (not a *photometric* limit) is near $B_J \approx 24$, with the plate-to-plate differences being due to slightly different seeing quality and "personal equations" during the star counting.

c) Globular Cluster Specific Frequency

The specific frequency S of a globular cluster population is defined (Paper I) as the number of globular clusters per unit ($M_v = -15$) luminosity of the parent galaxy. For the Fornax Cluster, the distance is not well known, so the absolute magnitudes of the galaxies are uncertain. Moreover, the globular cluster systems are not fully seen: the fainter clusters lie below our count limits, and there is a degree of geometrical incompleteness in the counts because of the obscuration of the central regions by the galaxy itself (and, for NGC 1399 alone, because of the extension of the globular cluster cloud beyond the largest annulus).

We first consider the question of the distance of the Fornax Cluster of galaxies. Twenty-three members of the cluster constitute Huchra and Geller's (1982) group 17. Their data imply a mean recession velocity of 1087 ± 64 km s^{-1}. Note that their

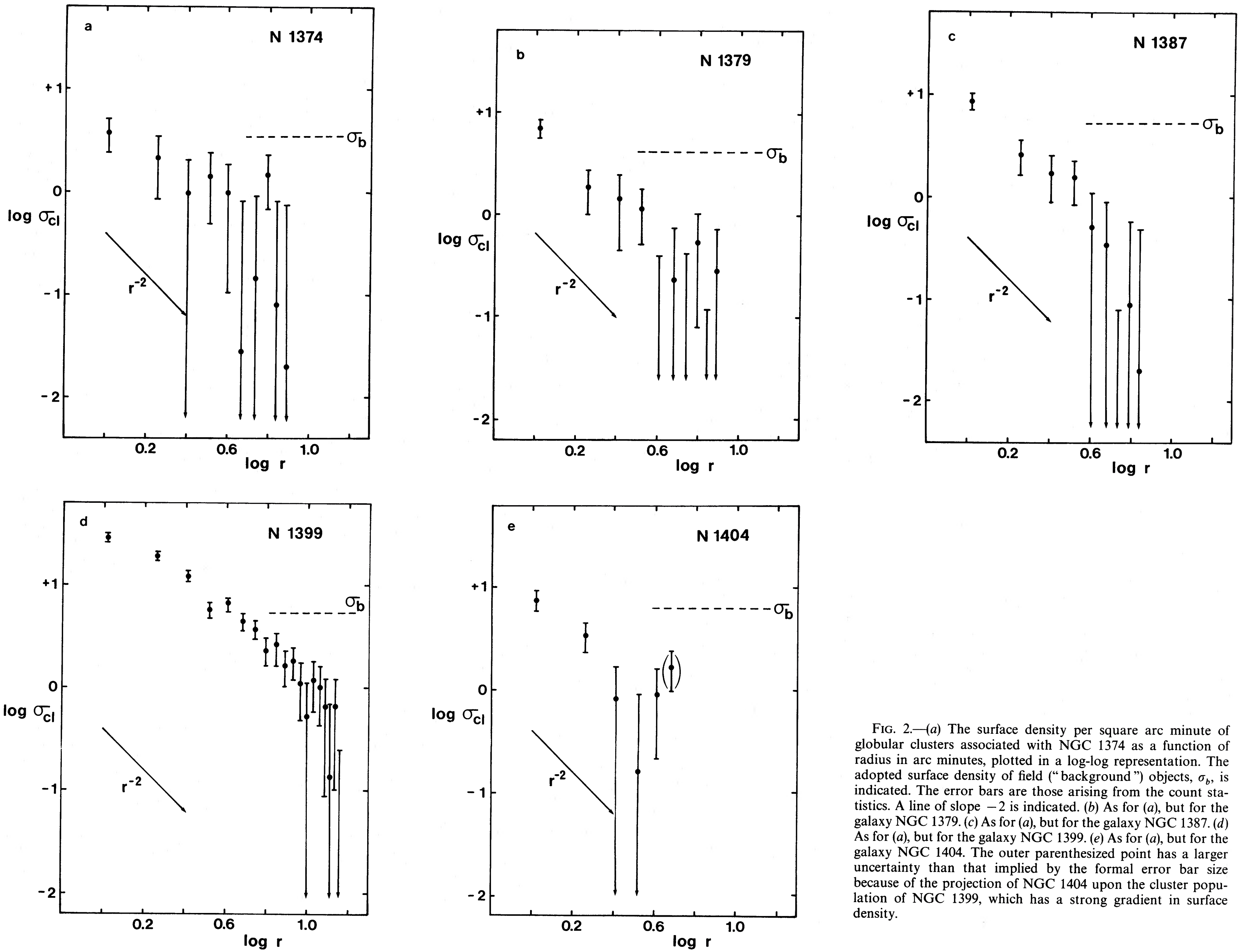

FIG. 2.—(*a*) The surface density per square arc minute of globular clusters associated with NGC 1374 as a function of radius in arc minutes, plotted in a log-log representation. The adopted surface density of field ("background") objects, σ_b, is indicated. The error bars are those arising from the count statistics. A line of slope -2 is indicated. (*b*) As for (*a*), but for the galaxy NGC 1379. (*c*) As for (*a*), but for the galaxy NGC 1387. (*d*) As for (*a*), but for the galaxy NGC 1399. (*e*) As for (*a*), but for the galaxy NGC 1404. The outer parenthesized point has a larger uncertainty than that implied by the formal error bar size because of the projection of NGC 1404 upon the cluster population of NGC 1399, which has a strong gradient in surface density.

quoted velocities have been twice corrected: once for reduction to the centroid of the Local Group, and secondly for an assumed Virgocentric infall of 300 km s^{-1} for the Local Group (with a consequent $\sim$200 km s^{-1} reduction in the recession velocities of the Fornax galaxies). Aaronson *et al.* (1981) derived a mean recession velocity corrected to the Local Group centroid (but uncorrected for local infall) of $v_0 = 1340$ km s^{-1}. Since the precise amplitude and direction of the local peculiar motion is still under debate, we adopt a corrected recession velocity of 1100 km s^{-1} for the Fornax Cluster and absorb the uncertainties in this value into the range of Hubble parameters which we explore. Then the true distance modulus is $(m - M)_0 = 30.2 - 5 \log h$, where h is the present value of H_0 in units of 100 km s^{-1} Mpc^{-1}. In what follows, we consider two values of h which represent the likely extremes acceptable to most astronomers: $h = 0.5$ and $h = 1.0$.

For purposes of example, we now consider one galaxy (NGC 1387) in detail. (The results of these calculations and those for the other galaxies are summarized in Table 6.) The foreground absorption at the latitude of the Fornax Cluster is $A_J\,(\sim A_B) = 0.25$ mag according to de Vaucoluleurs, de Vaucouleurs, and Corwin (1976, hereafter RC2). Inspection of the Burstein and Heiles (1982) map for the southern galactic hemisphere suggests a reddening in the range 0.00 mag $\leq E_{B-V} \leq$ 0.03 mag (whence 0.00 mag $\leq A_B \leq$ 0.12 mag), although they note that the regions of the map corresponding to declinations less than $-23°$ are of lower accuracy. We adopt $A_J = 0.10$ mag in what follows. The limiting magnitude of the starcounts, $B_J = 23.95 \pm 0.1$, yields detection limits of $M_J = -7.85$ mag ($h = 0.5$) or $M_J = -6.35$ mag ($h = 1.0$) for globular clusters in this galaxy. The mean absolute magnitude for the globular clusters in our own Galaxy and in M31 (Harris and Racine 1979; Racine and Shara 1979; van den Bergh 1985) is $\langle M_J \rangle = -6.8 \pm 0.1$. Our working assumption that the globular cluster luminosity function in NGC 1387 has the same mean as in the Local Group implies that our detection limit falls 1.05 ± 0.1 mag short of the peak (for $h = 0.5$) or reaches 0.45 ± 0.1 mag beyond it (for $h = 1.0$).

We next assume that the globular cluster luminosity function is approximately Gaussian in a number-magnitude relationship (Hanes 1977, 1980; Harris and Racine 1979). For completeness, we consider three possible values for the intrinsic dispersion of the function: $\sigma = 1.00$, 1.25, and 1.50. For $h = 0.50$, the implication is that our counts reach to within 1.05, 0.84, or 0.70 σ of the peak, and that we have detected 15%, 20%, or 30% of the total. For $h = 1.0$, the counts would instead reach 0.45, 0.36, and 0.30 σ beyond the peak, detecting 67%, 64%, or 62% of the total. Summation of the counts in annuli 2–7 for NGC 1387 yields a net cluster count of 126 ± 25, which total is amended to $N_0 = 150 \pm 30$ when corrected for incompleteness in the innermost circle, as judged by an inward extrapolation of the surface density profile. Finally, the inferred total cluster populations N_T, corrected for the magnitude-limited incompleteness, are given in Table 6.

The absolute magnitude of the parent galaxy NGC 1387 is the last ingredient. The *Second Reference Catalogue of Bright Galaxies* (RC2) contain B_T magnitudes for only two of our program galaxies, but more complete photometry is to be found in the *Revised Shapley-Ames Catalogue* (Sandage and Tammann 1981, hereafter RSA); the available photometry is summarized in Table 1. We assume that all five of our galaxies have $(B-V)_T = 0.95$, as is the case for NGC 1399 and NGC 1404 (the only two with direct measurements). Then the integrated V magnitude for NGC 1387 is $M_v = -20.92$ (for $h = 0.5$) or -19.42 (for $h = 1.0$). The exercise is complete, except for the straightforward calculations of the specific frequency S, with results which are summarized in Table 6.

TABLE 6

SPECIFIC FREQUENCIES

h	M_v	σ	N_T	S
A. NGC 1374: $N_0 = 104 \pm 47$				
0.5	−20.45	1.00	1898 ± 858	12.5 ± 5.7
		1.25	1037 ± 469	6.9 ± 3.1
		1.50	727 ± 328	4.8 ± 2.2
1.0	−18.95	1.00	226 ± 102	5.9 ± 2.7
		1.25	222 ± 100	5.8 ± 2.6
		1.50	220 ± 99	5.8 ± 2.6
B. NGC 1379: $N_0 = 108 \pm 29$				
0.5	−20.68	1.00	1337 ± 359	7.2 ± 1.9
		1.25	822 ± 221	4.4 ± 1.2
		1.50	616 ± 165	3.3 ± 0.9
1.0	−19.18	1.00	200 ± 54	4.3 ± 1.2
		1.25	203 ± 55	4.3 ± 1.2
		1.50	205 ± 55	4.4 ± 1.2
C. NGC 1387: $N_0 = 150 \pm 30$				
0.5	−20.92	1.00	1021 ± 204	4.4 ± 0.9
		1.25	748 ± 150	3.2 ± 0.6
		1.50	620 ± 124	2.7 ± 0.5
1.0	−19.42	1.00	223 ± 45	3.9 ± 0.8
		1.25	234 ± 47	4.1 ± 0.8
		1.50	243 ± 49	4.2 ± 0.9
D. NGC 1399: $N_0 = 1690 \pm 377$				
0.5	−21.96	1.00	11504 ± 2566	18.9 ± 4.2
		1.25	8429 ± 1880	13.9 ± 3.1
		1.50	6983 ± 1558	11.5 ± 2.6
1.0	−20.46	1.00	2509 ± 560	16.4 ± 3.7
		1.25	2638 ± 589	17.3 ± 3.9
		1.50	2735 ± 610	17.9 ± 4.0
E. NGC 1404: $N_0 = 97 \pm 28$				
0.5	−21.69	1.00	458 ± 132	1.0 ± 0.3
		1.25	372 ± 107	0.8 ± 0.2
		1.50	327 ± 94	0.7 ± 0.2
1.0	−20.19	1.00	128 ± 37	1.1 ± 0.3
		1.25	136 ± 39	1.1 ± 0.3
		1.50	143 ± 41	1.2 ± 0.3

IV. DISCUSSION

a) Previous Detections

On the basis of starcounts to somewhat brighter limits than ours, Dawe and Dickens (1976) inferred the presence of globular clusters in three of the Fornax Cluster galaxies: NGC 1374, 1379, and 1399. They did not detect excess numbers of objects around six other galaxies, including NGC 1387 and 1404. These results are consistent with the implications of our Table 6, where we see that NGC 1387 and 1404 have the smallest total cluster content (N_T) among the five galaxies studied here for various adopted values of intrinsic dispersion (σ) and distance scale (h).

Dawe and Dickens found a slight elongation in the surface density distribution of excess objects about NGC 1399, coupled with an apparent offset of the centroid of such objects

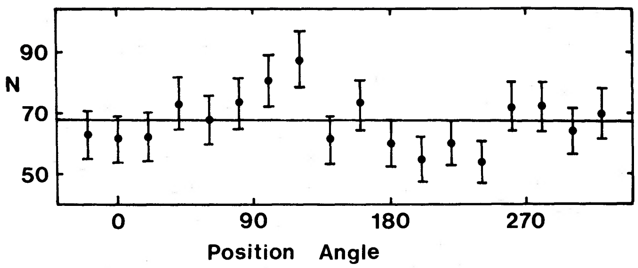

FIG. 3.—The dependence of starcount surface density upon position angle in the field of NGC 1399. The counts were summed over sectors of width 20° over annuli 2–7. The error bars are those arising from size-of-sample effects, and the horizontal line represents the mean of the eighteen separate values. Note the zero-point offset in the ordinate scale.

from the galaxy itself. (No such effects were seen in NGC 1374, while too few objects were found in NGC 1379 to permit the test.) They expressed the reservation that the excess might be due to a Coma-like cluster of galaxies (at ~ 40 times the Fornax distance) against which NGC 1399 was seen in near-central projection. However, no obvious clustering of nonstellar images in the region concerned could be seen on our plate; and our much deeper counts reveal no significant asymmetry, as is shown by our Figure 3. There we plot the surface density of our counts, in 20° sectors summed over annuli 2–7, as a function of position angle. There is no statistically significant departure from a uniform distribution, although we do confirm the presence of a slight excess at position angle 115°, as noted by Dawe and Dickens. They also noted a slight paucity in the NE quadrant (at p.a. $\approx$ 40°–50°), a feature not apparent in our counts. In short, our deeper counts suggest to us that these various local excesses or deficiencies are most likely to be due to statistical fluctuations in the cluster population around NGC 1399. The deeper the counts reach and the more clusters are seen, the less evident these fluctuations should become.

b) *The Surface Density of Globular Clusters*

As noted in § III and reflected in the entries of Table 4, the globular cluster surface density distributions are broadly consistent with power laws of index α ($= \Delta \log \sigma / \Delta \log r$) near -2; the value is most precisely known for NGC 1399, where $\alpha = -1.64 \pm 0.09$. We know of no large-scale surface photometry for the Fornax galaxies studied here; therefore, we unfortunately cannot test the suggestion (Paper V) that the structure of the globular cluster population is less centrally concentrated than the underlying galaxian light. Large-scale surface photometry for these systems is badly needed.

An additional suggestion from Paper V is that a rough correlation exists between $\alpha = \Delta \log \sigma / \Delta \log r$ (giving the structural shape of the projected cluster distribution) and the integrated luminosity of the parent galaxy. The observed correlation is that, with a significant amount of scatter, more luminous galaxies tend to have more extended (flatter α) cluster systems. Our data for the Fornax members are summarized in Figure 4, which shows α versus M_v^T on a scale where $h = 0.75$ (compare this with Figure 10 of Paper V). The plot contains only E galaxies, with the Fornax members represented by open symbols. The Fornax data do not strongly support the correlation but are also not inconsistent with it, given the significant uncertainties in the adopted galaxy luminosities and the formal errors on α. It should also be noted that much of the scatter about the line in the figure could be due to simple distance errors (which would move points horizontally in the figure). If Fornax is as distant as ~ 20 Mpc (or alternatively if it is at least as remote as the Virgo Cluster), then it would fall much more closely in line with the mean relationship shown.

c) *Specific Frequencies*

The entries of Table 6 reveal that the specific frequencies of the globular clusters associated with the Fornax galaxies range from $S \approx 1$ for NGC 1404 to $S \approx 17$ for NGC 1399, depending upon the adopted intrinsic dispersion σ of the hypothesized globular cluster luminosity function and the distance scale h.

We consider first the case $h = 1.0$. For this adopted distance scale, the counts reach to just about the turnover in the assumed normally distributed globular cluster luminosity function, and the inferred total cluster population is therefore almost independent of the adopted intrinsic dispersion σ, as can readily be seen. For this distance, NGC 1399 (at $S \approx 17$) is vastly overabundant in globular clusters relative to the other galaxies studied (for NGC 1374, 1379, and 1387, $\langle S \rangle \approx 5$). In this respect the Fornax Cluster is similar to Virgo and to

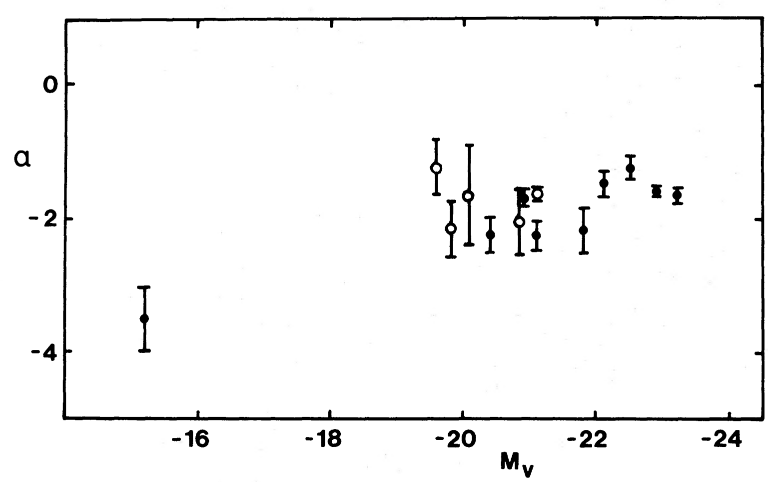

FIG. 4.—The dependence of α, the index of a power-law representation of globular cluster distribution, upon the integrated absolute magnitude M_v of the parent galaxy for the elliptical galaxies in the Fornax cluster (*open symbols*). The absolute magnitudes were derived assuming $h = 0.75$, as in Paper V, and the error bars represent the formal uncertainties in the determinations of α.

Hydra: in Virgo, the central giant elliptical galaxy NGC 4486 (M87) has $S \approx 15$ (Paper V), while the mean for the other Virgo ellipticals lies near $\langle S \rangle \approx 6$; and in the Hydra cluster, the dominant central galaxy, NGC 3311, has $S \approx 20$ (Harris, Smith, and Myra 1983). The fifth Fornax galaxy studied, NGC 1404, has $S \approx 1$, the lowest value yet seen in a bright elliptical galaxy. The reason for this is unclear but may simply be an artifact of the difficult field correction (see § II above). If the small value of S is in fact correct for NGC 1404, it may suggest that the presence of NGC 1399 itself has led to the stripping of clusters from NGC 1404 or even inhibition of their original formation in more normal numbers. This pair of galaxies may represent an interesting region in which to test theories of such processes.

The analysis is not quite so straightforward for an adopted distance scale corresponding to $h = 0.5$. In this case, the starcounts reach only shallowly into the assumed intrinsic luminosity functions, and different assumptions about the intrinsic dispersion of the function can yield very different estimates of the total cluster population, as the entries of Table 6 indicate. For example, if $h = 0.5$ and an intrinsic dispersion of $\sigma = 1.00$ is adopted, NGC 1374 has nearly as high a specific frequency as does NGC 1399 (but with a far larger uncertainty!). However, if we assume that σ has a most likely value of ~ 1.3 (van den Bergh, Pritchet, and Grillmair 1985; van den Bergh 1985) and that it does not differ significantly from one galaxy to another, then NGC 1399 is clearly the dominant system. It has a larger specific frequency by a factor of 2 or 3 than in three other galaxies studied here, with NGC 1404 underabundant in globular clusters by another factor of 5.

Independent of distance scale, then, and with but little dependence upon the adopted form of the globular cluster luminosity function, we conclude that in the Fornax Cluster the central dominant galaxy is overabundant in globular clusters by a factor near 3 when compared with similar galaxies within the cluster. NGC 1399 therefore contains the third known "supergiant" globular cluster system, in the sense discussed in Paper V (after M87 and NGC 3311). It is also worth noting that the spatial distribution of the NGC 1399 system is virtually identical to those in M87 and the other Virgo supergiant galaxy NGC 4472; all three have $\alpha \approx -1.6 \pm 0.2$. The family resemblance among these big systems of halo clusters continues to grow more striking as further galaxies are added to the sample.

V. SUMMARY

We have confirmed the existence of globular cluster systems associated with five of the elliptical galaxies in the Fornax Cluster. Conclusions regarding their specific frequency are slightly subject to uncertainties in the distance scale adopted; nevertheless, the following features seem to be well established:

1. NGC 1399 is similar to M87, the central giant elliptical galaxy in the Virgo Cluster, both in the specific frequency ($S \approx 17$) and the spatial structure ($\alpha \approx -1.6$) of its globular cluster population.
2. The less dominant elliptical galaxies in Fornax (NGC 1374, 1379, 1387) are similar in specific frequency ($S \approx 5$) to their counterparts in the Virgo Cluster. This confirms the trend that E/S0 galaxies in small groups tend to have lower specific frequencies than those in big groups (Paper I).
3. These features strongly confirm a trend already suggested by Virgo and Hydra: namely, a pronounced overabundance of globular clusters in the central giant elliptical galaxy, with the other cluster members having more average numbers of globulars. The reason for this is still a matter of conjecture, but it is most likely to be a result of special initial conditions during the globular cluster formation epoch (as first pointed out by van den Bergh 1984; and see Paper V).

The large cluster population in Fornax (and in NGC 1399 in particular) offers the prospect of a single-step distance measurement for the Fornax cluster, through a photometric determination, via CCD direct imaging, of the globular cluster luminosity function. Indeed, such measurements will permit an immediate determination of the relative distances of Fornax and Virgo, as long as the intrinsic globular cluster luminosity function is similar from one giant elliptical to another. Since Virgo and Fornax are nearly antipodal, the relative distances will yield a straightforward measurement of the pecular velocity of the Local Group relative to the cosmic microwave background.

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