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THE STELLAR CONTENT AND METALLICITY OF THE NGC 5128 GLOBULAR CLUSTERS

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ABSTRACT

Infrared data are presented for 12 star clusters around the galaxy NGC 5128 (Centaurus A). These clusters are not like the intermediate age clusters in the Magellanic Clouds since no evidence is found for carbon stars. They are most likely old globular clusters. Their infrared colors are quite similar to those of giant elliptical galaxies. Five of the clusters are shown to have metallicities considerably greater than solar. These five are also quite luminous. They have no counterparts in either M31 or the Milky Way but may be similar to the brightest clusters in M87.

Consideration of recent photographic data for globular clusters around the Virgo ellipticals shows these data to be inconsistent with the claim that the mean metallicity of a cluster system is a function of the parent galaxy's mass or luminosity.

Subject headings: clusters: globular — galaxies: individual — galaxies: stellar content — stars: abundances

I. INTRODUCTION

Subsequent to the discovery of the first globular cluster to be associated with NGC 5128 by Graham and Phillips (1980), van den Bergh, Hesser, and Harris (1981), and Hesser *et al.* (1984, hereafter HHBH) showed that the cluster system associated with this peculiar galaxy may consist of as many as 600 members. Nineteen clusters have been positively identified on the basis of their radial velocities (Graham and Phillips 1980; HHBH). A number of these appear to be at least as metal rich as 47 Tuc (HHBH; Frogel 1980).

This paper presents new infrared data for 12 of the NGC 5128 clusters. From these data information is derived which relates to their stellar content, age, metallicity, and luminosity. The approach taken is firmly grounded on well-studied nearby clusters for which infrared observations are available of both the integrated light and individual stars (Aaronson *et al.* 1978; Frogel, Persson, and Cohen 1980, hereafter FPC; Persson *et al.* 1983; Frogel, Cohen, and Persson 1983). The results are compared with similar studies of clusters around the Milky Way, M31, and the Magellanic Clouds in the reference just cited.

II. THE OBSERVATIONS

The data are presented in Table 1. They were obtained at CTIO with the InSb system D3 on the 4 m reflector between 1980 and 1983. An $f/30$ chopping secondary was used together with on-axis TV systems for acquisition and guiding.

The standard stars used are those of Elias *et al.* (1982). Hence the observations in Table 1 are on the same system (CTIO/CIT) as all other cluster data published by my colleagues and myself. Photographic values for V and $B-V$ are from HHBH. These are based on observations with a Pickering-Racine wedge and according to HHBH have an uncertainty of less than 0.1 mag. $U-V$ is predicted from $B-V$ as discussed later. Observations of the same cluster made on more than one night agree to within the accuracy quoted in Table 1.

Twelve of the objects listed in Table 3 of HHBH were observed in the infrared. These include the eight brightest objects in both B and V and the three reddest of the next seven, all of which have radial velocities consistent with their being members of the NGC 5128 cluster system. Object 21 was also observed as it is the brightest of those in HHBH's table with no velocity measurement. Since its optical and infrared colors and magnitudes are quite similar to those of the others observed, it will be considered to be a cluster for the purposes of this paper unless otherwise stated.

III. THE RESULTS

a) The Nature of the NGC 5128 Clusters

From $B-V$ alone it is not possible to establish whether a cluster is a true, old globular or similar to intermediate age clusters in the Magellanic Clouds. That this is a problem may be seen by considering the work of Searle, Wilkinson, and Bagnuolo (1980) and of Frenk and Fall (1982). Searle *et al.* demonstrated that Magellanic Cloud clusters can be ordered in a one-dimensional "candy cane" sequence. They concluded that a cluster's position along this sequence is determined by age and metallicity and that these two parameters varied in a closely linked, monotonic fashion. Frenk and Fall showed that Searle *et al.*'s cluster sequence and ranking scheme are derivable from $U-B$, $B-V$ colors as well. However, for $B-V$'s between 0.6 and 0.9, $U-B$ is double valued; clusters in SWB groups V, VI, and VII, and to a lesser extent group IV, cannot be distinguished from one another on the basis of $B-V$ alone. It is in clusters belonging to groups IV, V, and VI that luminous asymptotic giant branch stars, both of C and M type, are found. These clusters are believed to be of intermediate age, i.e., not more than about half of the age assigned to Galactic globular clusters (Mould and Aaronson 1982; Frogel and Cohen 1982; Frogel and Blanco 1983; Persson *et al.* 1983; Frenk and Fall 1982; Hodge 1983).

The integrated infrared colors of Magellanic Cloud clusters

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TABLE 1

NGC 5128 Globular Cluster Photometry

Cluster[a]	Observed[b]			Reddening Corrected[c]							
	K	$J-K$	$H-K$	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	$[\mathrm{Fe/H}]_Z$	Notes[d]
1	14.80 (3)	0.66 (4)	0.14 (3)	14.77	(0.80)	0.69	2.49	0.61	0.12	−1.09	
3	14.28	0.96 (3)	0.19	14.25	(1.36)	0.91	3.11	0.91	0.17	+0.35	1
5	15.06 (3)	0.62 (4)	0.11 (3)	15.03	(0.65)	0.63	2.23	0.57	0.09	−1.70	1
6	14.06 (3)	0.86 (4)	0.16 (3)	14.03	(1.41)	0.93	2.66	0.81	0.14	−0.70	
7	14.24 (3)	0.77 (3)	0.18 (3)	14.21	(1.01)	0.77	2.54	0.72	0.16	−0.98	2
11	14.41 (3)	0.96 (3)	0.24 (3)	14.38	(1.62)	1.01	3.18	0.91	0.22	+0.51	
12	14.36 (3)	0.96 (3)	0.22 (3)	14.33	(1.46)	0.95	3.31	0.91	0.20	+0.81	
17	14.87 (3)	0.76 (4)	0.12 (3)	14.84	(0.80)	0.69	2.52	0.71	0.10	−1.02	
18	14.66 (3)	0.79 (3)	0.20 (3)	14.63	(1.13)	0.82	2.50	0.74	0.18	−1.07	
21	14.75 (4)	0.81 (5)	0.25 (4)	14.72	(1.54)	0.98	2.66	0.76	0.23	−0.77	3
23	13.88	0.89	0.23	13.85	(1.62)	1.01	3.06	0.84	0.21	+0.23	1
26	14.46 (3)	0.99 (4)	0.27 (3)	14.43	(1.72)	1.05	3.35	0.94	0.25	+0.91	

[a] Identification numbers are from Hesser *et al.* (1983).

[b] Numbers in parentheses are uncertainties in units of hundredths of a magnitude when greater than 2. All IR measurements are through a 7".1 aperture.

[c] Extinction and reddening values for $E(B-V) = 0.11$ are as given in Frogel (1980). The $(U-V)_0$ values were predicted from $(B-V)_0$ as discussed in the text. Optical photometry is from Hesser *et al.* (1983).

[d] Notes.—(1) Observed on two nights. (2) This is the Graham and Phillips (1980) cluster. The IR data for it are from Frogel (1980). (3) This object has no radial velocity as yet.

behave in a very different manner from the nearly dispersionless candy cane diagrams (Persson *et al.* 1983). $(J-K)$ and $(H-K)$ have a range of about a magnitude for clusters at closely adjacent locations in the Searle *et al.* sequence. For the very young clusters in groups I–III this range in color can be accounted for by the presence of red supergiants or luminous asymptotic branch M giants; for clusters in groups IV–VI it is due to the presence of C and M type asymptotic branch giants (Persson *et al.* 1983; Frogel and Blanco 1983).

Figure 1 displays the $(J-K)$, $(B-V)$ colors for clusters from a number of galaxies. The very large range in $(J-K)$ for the Magellanic Cloud clusters at constant $(B-V)$ is obvious. The red stars which so dominate the infrared light, and the bolometric luminosity as well (Persson *et al.* 1983; Frogel and Blanco 1983), contribute only a relatively small amount to the B and V passbands. The colors of the NGC 5128 clusters overlap the sequence for old globular clusters and extend it to redder colors into the region occupied by early-type galaxies. In particular, the NGC 5128 clusters have significantly different colors from those Magellanic Cloud clusters known to possess luminous asymptotic branch giants. HHBH's photographic $B-V$ values would have to be systematically too red by 0.2–0.4 mag to alter this conclusion.

Figure 1 also rules out a young age for the clusters, i.e., of order 1 Gyr or younger, which would be the case if the clusters resulted from a recent merger between a spheroidal system and a dust-laden disk system (e.g., Malin, Quinn, and Graham 1983).

One M31 cluster, V29, is as red as the reddest NGC 5128 clusters. Values of $Q(ugr)$ and $Q(vgr)$ for V29 of 0.33 and 0.35, respectively (Searle 1981), place it right on the Zinn (1980) sequence for Milky Way globular clusters at the metal-rich end. One of the main conclusions of this paper, then, is that *photometrically, the NGC 5128 globular clusters are most like old globular clusters and are distinct from the intermediate age Magellanic Cloud clusters.*

Figure 2 is adapted from Figure 1 of FPC. The only two globular clusters which lie outside of the region enclosed by the dashed line, both from M31, are shown. The $(U-V)$ colors for the NGC 5128 clusters were predicted from their $B-V$ colors via the mean relationships between $(U-B)$ and

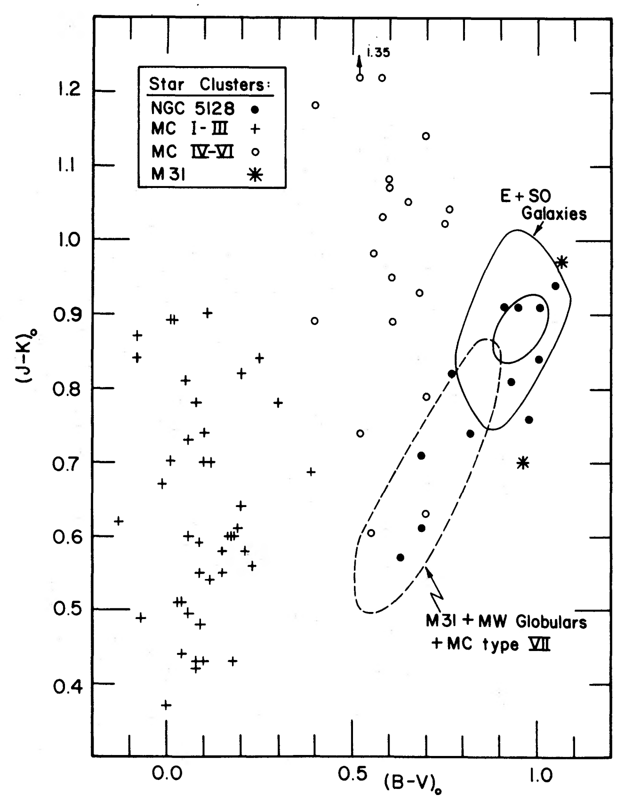

Fig. 1.—A color-color plot for globular clusters from a number of galaxies. Young (I–III) and intermediate (IV–VI) age Magellanic Cloud (MC) clusters are distinguished from one another. The dashed line shows the location of old globular clusters (Aaronson *et al.* 1978, Persson *et al.* 1983, and FPC). Colors from E and S0 galaxies are from Frogel *et al.* (1978), Persson, Frogel, and Aaronson (1979), and unpublished data. More than half of the galaxies are contained within the inner contour.

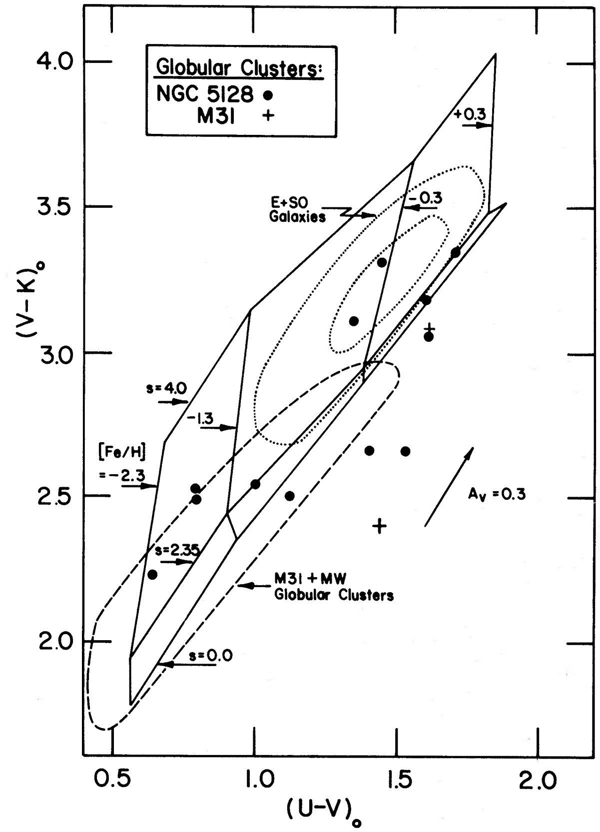

FIG. 2.—Similar to Fig. 1. Population synthesis models are from FPC. $U-V$ colors for the NGC 5128 globulars are predicted from $B-V$ as discussed in the text. A Salpeter (1955) mass function for the main sequence would have a slope of $s = 2.35$.

$(B-V)$ for galactic globular clusters from Racine (1973) and that for the reddening corrected colors for the M31 clusters given in FPC. This procedure was followed since the models in FPC do not predict $B-V$ colors. Independent of the predicted colors, Figure 2 shows that the NGC 5128 clusters overlap the M31 and Galactic globulars in $V-K$ as well as in $J-K$ and $B-V$ as seen from Figure 1. The slope of the initial mass function for the models is $x = s - 1$ where the Salpeter (1955) value is $s = 2.35$. The mean dispersion of the NGC 5128 globular clusters perpendicular to a line drawn between the $s = 2.35$ and 0.0 ones is 0.13 mag—no greater than that expected from the uncertainties in the colors alone. Hence, the main-sequence luminosity function of the NGC 5128 globular clusters is well represented by the Salpeter (1955) function—the same result as has been found for all other globular cluster systems studied to date.[2]

[2] This result depends on the similarity of the $BVJHK$ colors of the clusters in the systems under discussion and not on the fact that it was necessary to predict $U-B$ values. However, it is clear that if the true $U-B$ colors of the NGC 5128 clusters turn out to be significantly different from those predicted, the conclusion will be affected.

The metallicities implied by matching the observed colors to those of the models in Figure 2 are significant underestimates since the FPC model colors are calibrated with the assumption that the value of [Fe/H] for 47 Tuc is -1.2.

b) *Metallicity and Luminosity*

HHBH noted that a number of the NGC 5128 clusters may have metallicities greater than that of 47 Tuc. The $V-K$ color of a globular cluster is a sensitive indicator of its metallicity (Aaronson *et al.* 1978; FPC). Equation (1) of FPC relates the two quantities, on Zinn's (1980) metallicity scale, and is used here to get the [Fe/H] values given in the penultimate column of Table 1. While one may quibble over the numerical values since Zinn's data do not include clusters with greater than solar metallicity, the important point is that the $J-K$ and $V-K$ colors for five clusters are significantly greater than the observed values for Galactic globulars with solar or near-solar metallicity (Aaronson *et al.* 1978).[3]

Figure 3 is an infrared color-magnitude diagram for the NGC 5128 clusters from Table 1 and for the M31 clusters from FPC. In order to have a complete magnitude-limited sample, the $(V-K)$ colors for four of the NGC 5128 clusters were predicted from their $B-V$'s given by HHBH. Object 21 has been excluded. Hence Figure 3 shows the 15 brightest, in V and B, confirmed globular clusters in NGC 5128. A distance of 3 Mpc was chosen. This is at the low end of the range of distances to NGC 5128 which may be found in the current literature (cf. HHBH and references therein). The upward sloping lower bound to the distribution of the

[3] Examination of the infrared colors of the spheroidal component of NGC 5128 (Becklin *et al.* 1971; Harding, Jones, and Rodgers 1981; Adams, Adamson, and Giles 1983) gives no indication that these objects are affected by obscuring material internal to NGC 5128 itself. Similarly, the contrast-enhanced photograph of Malin, Quinn, and Graham (1983) does not reveal any dust clouds away from the central dust lane which could affect the colors of the clusters in question. HHBH have reached the same conclusion.

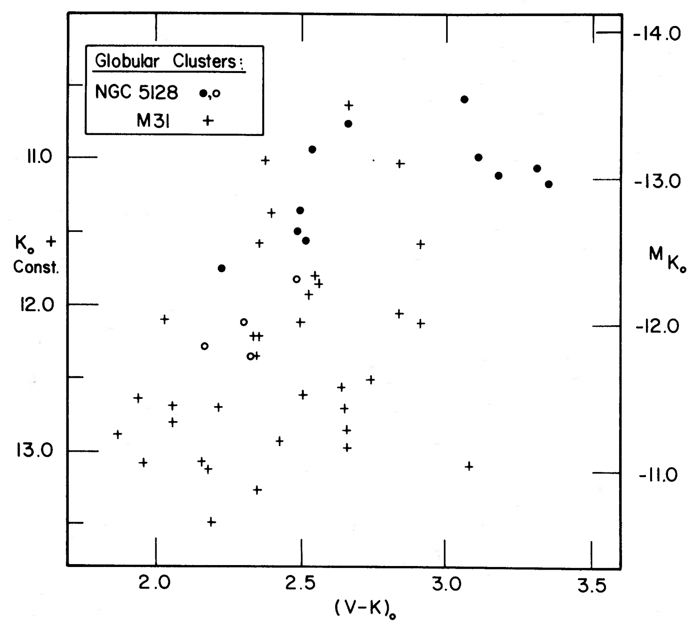

FIG. 3.—A color-magnitude diagram for the globular cluster from M31 (FPC) and NGC 5128. Clusters with open circles had their $V-K$'s predicted from $B-V$ as described in the text. The NGC 5128 points were plotted for a distance corresponding to 3 Mpc. The vertical axis corresponds to K_0 for the M31 clusters. The slope of the lower bound to the distribution of the NGC 5128 clusters is due to the V magnitude limited nature of the sample.

NGC 5128 clusters is due to the magnitude limit of the sample in V since such a limit implies a K magnitude limit which brightens by 1.5 mag between $V-K = 2.0$ and 3.5. The five reddest, most metal-rich clusters are among the brightest in the sample. They have no counterparts in M31 or the Milky Way. V29, the reddest observed cluster in M31, is 2 mag fainter than these five clusters.[4]

The second main result of this paper, then, is that *in a magnitude-limited sample of the NGC 5128 globular clusters, one-third, or five of the clusters, have metallicities greater than solar and are quite luminous*; they have no known counterparts in either M31 or the Milky Way. If the distance of NGC 5128 is greater than 3 Mpc, these five clusters become even more outstanding.[5]

IV. DISCUSSION

A potential problem with the conclusion that the NGC 5128 clusters are old globular clusters is that the appearance of an intermediate age but metal-rich cluster is not known. Qualitatively, one may predict that such a cluster will contain fewer carbon stars relative to a metal-poor cluster of the same age (e.g., Renzini and Voli 1981; Iben and Renzini 1983; Miller and Scalo 1983) and hence should not have as red infrared colors as the Magellanic Cloud clusters. $B-V$ will become only marginally bluer by the removal of the C stars but will be pushed to the red because of the higher metallicity. The presently available data cannot provide resolution of this problem.

The similarity of the colors of the metal-rich NGC 5128 globular clusters to those of early-type galaxies supports the metal-rich, old age interpretation (see Figs. 1 and 2). Whitford (1978) has demonstrated that the integrated light of the Galactic nuclear bulge in Baade's Window is indistinguishable from that of early-type galaxies. Whitford and Rich (1983) find that a major fraction of the K giants in the Window are super–metal rich. Their values for [Fe/H] are comparable to the values given here in Table 1. Furthermore, Frogel and Whitford (1982) argue that the presence of luminous M giants in Baade's Window, which presumably accounts for the red colors, is not inconsistent with an old age.

It is interesting to consider the fact that one-third of a magnitude-limited sample of clusters appears to be super–metal rich and luminous. From Figure 3 here and from consideration of color-magnitude diagrams for galactic globular clusters, it is apparent that a similarly magnitude-limited sample for either M31 or the Milky Way would have a mean [Fe/H] significantly less than that of the 15 brightest NGC 5128 clusters. Data for the cluster systems of M87, M31, and the Milky Way give no evidence for the existence of a color-magnitude relation for the clusters' integrated light (van den Bergh 1969; Harris and Racine 1979; Strom *et al.* 1981; FPC). Hence, the selection process *per se* should not have produced this result.

The data of Strom *et al.* (1981) and of Forte, Strom, and Strom (1981) contain sufficient information to test the hypothesis that the mean metallicity of a globular cluster system is a function of parent galaxy mass or luminosity as has been made by van den Bergh (1969) and Racine (1980), but disputed by Hanes (1977). From Table 12 of Strom *et al.*, the weighted mean $U-R$ color for the M87 globulars is 1.53 with a dispersion of 0.4. From the data in Table 1 of Forte *et al.* (with the transformations garnered from the latter two papers) the mean $U-R$ colors for the cluster systems of NGC 4374, 4406, and 4621 are 1.61, 1.62, and 1.76, respectively.

For 95 Galactic globulars with $U-V$ colors from Harris and van den Bergh (1974) or the compilation of Harris and Racine (1979), color excesses from Zinn (1980) or Harris and Racine (1979), and the transformation between $U-V$ and $U-R$ given by Strom *et al.*, a mean $(U-R)_0$ is derived of 1.55 with a dispersion of 0.3. Strom *et al.* get 1.62 for this value, the difference being an indication of the uncertainties involved. For the magnitude-limited sample of 35 M31 clusters with individual reddening determinations by Searle (as given in FPC), the mean $(U-R)_0$ is 1.69 with a dispersion of 0.37. Thus, while the redness of the M31 cluster system with respect to that of the Milky Way is confirmed, data for the Virgo elliptical galaxies are not consistent with the claim that the mean metallicity of a globular cluster system depends on the mass or luminosity of the parent galaxy.

To illustrate the above results, Figure 4 shows a histogram of $U-R$ values for all M87 cluster candidates (Strom *et al.* 1981) together with the generalized distributions for the M31 and Milky Way globular clusters derived here. The data of Strom *et al.* and Forte *et al.* are based on photographic measurements against a strong, sloping background. It would be valuable to confirm their colors by some other means.

So it appears that if the high percentage of super–metal-rich clusters in the NGC 5128 sample is not a statistical fluke, there is no precedent for understanding it on the basis of either a color-magnitude relation for clusters or an exceptionally high mass for the galaxy. The M87 cluster system may hold a clue to this problem. Figure 4 of Harris

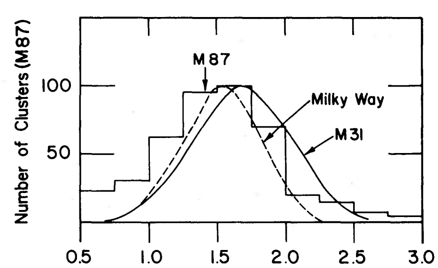

FIG. 4.—The histogram shows the distribution of all objects in the vicinity of M87 for which Strom *et al.* (1981) give $U-R$ colors. Most of these are globular clusters, but the blue side in particular will be contaminated by foreground stars. For the other two systems the reddening corrected colors were used to construct the generalized distributions as discussed in the text. If Strom *et al.*'s values were used for the Milky Way clusters, the Gaussian curves for it and M31 would be more nearly identical.

[4] There are 17 M31 clusters in the lists of Vetesnik (1962) and van den Bergh (1969) with V brighter than 16.3 but with no infrared data. $(V-K)$ colors for these clusters were predicted from their $U-V$'s. The predicted K magnitudes for these 17 clusters are all fainter than 12.2. Furthermore, inspection of their locations on a large scale photograph of M31 indicate that nearly all are red because of internal obscuration in M31. These clusters would tend to fill in the lower right of the figure.

[5] Although adoption of a distance of 3 Mpc to NGC 5128 brings the luminosities of the brightest NGC 5128 clusters into agreement with the brightest in M31 (Fig. 3), it would be more informative to independently determine the distance to the galaxy and *then* study the luminosity of the clusters. Racine (1980) has cautioned against the use of the bright wing of cluster luminosity functions to derive distances.

and Racine (1979) shows that, with one exception, the eight brightest clusters in M87 which have been confirmed by proper motion studies have $B-V$ colors significantly redder than the mean $B-V$ for all 201 clusters in the sample. Also, Brodie's (1980) spectra for four bright M87 clusters, though noisy, suggest that three of them have abundances near or greater than solar, whereas three fainter clusters studied by Racine, Oke, and Searle (1978) have a mean [Fe/H] of only -0.7.

Finally, consider Tremaine, Ostriker, and Spitzer's (1975) proposal that the nuclei of some galaxies are formed by the accretion of globular clusters. Proponents of this view can take heart from the fact that there is now one galaxy which has globular clusters with infrared colors red enough to match those of the central regions of elliptical galaxies (Frogel *et al.* 1978; FPC).

At this point it is necessary to obtain a significantly larger sample of confirmed clusters for NGC 5128 and to improve the accuracy of the *UBV* colors. In principle, the latter should be obtainable from the spectrophotometric scans. The brightest clusters in M87 should also be reobserved.

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REFERENCES

Aaronson, M., Cohen, J. G., Mould, J., and Malkan, M. 1978, *Ap. J.*, **223**, 823.
Adams, D. J., Adamson, A. J., and Giles, A. B. 1983, *M.N.R.A.S.*, **202**, 241.
Becklin, E. E., Frogel, J. A., Kleinmann, D. E., Neugebauer, G., Ney, E. P., and Strecker, D. W. 1971, *Ap. J.* (*Letters*), **170**, L15.
Brodie, J. P. 1980, Ph.D. thesis, University of Cambridge.
Elias, J. H., Frogel, J. A., Matthews, K., and Neugebauer, G. 1982, *A.J.*, **87**, 1029.
Forte, J. C., Strom, S. E., and Strom, K. M. 1981, *Ap. J.* (*Letters*), **245**, L9.
Frenk, C. S., and Fall, S. M. 1982, *M.N.R.A.S.*, **199**, 565.
Frogel, J. A. 1980, *Ap. J.* (*Letters*), **241**, L41.
Frogel, J. A., and Blanco, V. M. 1983, *Ap. J.*, to be submitted.
Frogel, J. A., and Cohen, J. G. 1982, *Ap. J.*, **253**, 580.
Frogel, J. A., Cohen, J. G., and Persson, S. E. 1983, *Ap. J.*, **275**, 773.
Frogel, J. A., Persson, S. E., Aaronson, M., and Matthews, K. 1978, *Ap. J.*, **220**, 75.
Frogel, J. A., Persson, S. E., and Cohen, J. G. 1980, *Ap. J.*, **240**, 785 (FPC).
Frogel, J. A., and Whitford, A. E. 1982, *Ap. J.* (*Letters*), **259**, L7.
Graham, J. A., and Phillips, M. M. 1980, *Ap. J.* (*Letters*), **239**, L97.
Hanes, D. A. 1977, *M.N.R.A.S.*, **179**, 331.
Harding, P., Jones, T. J., and Rodgers, A. W. 1981, *Ap. J.*, **251**, 530.
Harris, W. E., and Racine, R. 1979, *Ann. Rev. Astr. Ap.*, **17**, 241.
Harris, W. E., and van den Bergh, S. 1974, *A.J.*, **79**, 31.
Hesser, J. E., Harris, H. C., van den Bergh, S., and Harris, G. L. H. 1984, *Ap. J.*, **276**, 491 (HHBH).
Hodge, P. 1983, *Ap. J.*, **264**, 470.
Iben, I., Jr., and Renzini, A. 1983, *Ann. Rev. Astr. Ap.*, in press.
Malin, D. F., Quinn, P. J., and Graham, J. A. 1983, *Ap. J.* (*Letters*), **271**, L5.
Miller, G. E., and Scalo, J. M. 1982, *Ap. J.*, **263**, 259.
Mould, J., and Aaronson, M. 1982, *Ap. J.*, **263**, 629.
Persson, S. E., Aaronson, M., Cohen, J. G., Frogel, J. A., and Matthews, K. 1983, *Ap. J.*, **266**, 105.
Persson, S. E., Frogel, J. A., and Aaronson, M. 1979, *Ap. J. Suppl.*, **39**, 61.
Racine, R. 1973, *A.J.*, **78**, 180.
———. 1980, in *IAU Symposium 85, Star Clusters*, ed. J. E. Hesser (Dordrecht: Reidel), p. 369.
Racine, R., Oke, J. B., and Searle, L. 1978, *Ap. J.*, **223**, 82.
Renzini, A., and Voli, M. 1981, *Astr. Ap.*, **94**, 175.
Salpeter, E. E. 1955, *Ap. J.*, **121**, 161.
Searle, L. 1981, private communication.
Searle, L., Wilkinson, A., and Bagnuolo, W. G. 1980, *Ap. J.*, **239**, 803.
Strom, S. E., Forte, J. C., Harris, W. E., Strom, K. M., Wells, D. C., and Smith, M. G. 1981, *Ap. J.*, **245**, 416.
Tremaine, S. D., Ostriker, J. P., and Spitzer, L., Jr. 1975, *Ap. J.*, **196**, 407.
van den Bergh, S. 1969, *Ap. J. Suppl.*, **19**, 145.
van den Bergh, S., Hesser, J. E., and Harris, G. L. H. 1981, *A.J.*, **86**, 24.
Vetesnik, M. 1962, *Bull. Astr. Inst. Czechoslovakia*, **13**, 180.
Whitford, A. E. 1978, *Ap. J.*, **226**, 777.
Whitford, A. E., and Rich, R. M. 1983, *Ap. J.*, **274**, 723.
Zinn, R. 1980, *Ap. J. Suppl.*, **42**, 19.

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