GLOBULAR CLUSTER SYSTEMS IN GALAXIES

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1. INTRODUCTION

The study of globular cluster systems is very important. Because these systems are so old, their investigation is a form of archeo-astronomy whereby a slow and, at times, tedious gathering of fragmentary data laboriously uncovers the skeleton of early galactic structures. Our theories and our imagination can then try to put some flesh on these bones in attempts to visualize what these early inhabitants of the Universe might have looked like.

It is clearly desirable, before we can embark with some confidence in these paleoastronomical reconstructions, that as large as possible a body of observational data be collected. Only then can we hope to identify what is fundamental or universal in these structures and what is merely an accidental result of peculiar local conditions or evolution. There is, for instance, a finite possibility that the system of globular clusters associated with our own Galaxy is peculiar. Thus, to achieve our goals, we must investigate globular clusters in a sizeable sample of different galaxies.

This work has really just begun. Reasonably detailed information is currently available for only three systems: those associated with the Galaxy, with the large Magellanic Cloud and with the Andromeda nebula. Fragmentary data, usually restricted to count statistics or broad-band photometry, have been published for clusters associated with six other dwarf members of the Local Group and for fifteen Virgo cluster members. Preliminary reports on the cluster systems of intermediate-distance galaxies are available for NGC 3115 (Strom et al. 1977), for M81 (Racine et al. 1979) and for NGC 5218 (van den Bergh 1979, de Vaucouleurs 1979). At distances beyond Virgo globular clusters have been detected in the three largest elliptical galaxies of the Fornax I cluster (Dawe and Dickens, 1976) and around NGC 3311 in the Hydra I cluster (Smith and Weedman 1976), where the brightest clusters appear at the current limit of telescopic detection, $B \simeq 23.5$.

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Distant globular clusters are difficult to study. The discovery of their small, diffuse images around galaxies in the $0.5 < d$ (Mpc) < 5 range is hampered by confusion with very distant background galaxies and, across the faces of spiral and irregular galaxies, with the images of open clusters and knots of nebulosities. For d > 5 Mpc the globular clusters have images which are typically smaller than 2" and can only be separated from foreground stars by statistical subtraction of count densities or by a very exacting combination of photometric and proper motion studies. Except for exceedingly rich systems, such as the one around M87, the results are bound to be plagued by considerable residual noise and contamination.

The first-ranked clusters in rich systems reach luminosities of $M \simeq -12$ and can be seen at distances of 100 Mpc. But the peak of the cluster luminosity distribution, at $M \simeq -7.4$, fades below the limit of our telescopes ($V \simeq 23$) at distances beyond the Virgo cluster. Somewhat detailed spectrophotometric data can realistically be obtained only for systems whose velocity of recession is less than 1000 km s^{-1}. The best strategy in future studies of globular cluster systems would thus be to search and investigate field and small-group galaxies in the 2 to 10 Mpc range. We should also, of course, try to clean up the somewhat sad state of affairs in such obvious Local Group members as the Magellanic Clouds and the Triangulum galaxy.

In what follows I shall summarize the main features of globular cluster systems as they seem to emerge from the currently available data. Much of this material has already been presented and discussed elsewhere (Harris and Racine 1979) and the reader is referred to that paper for a detailed bibliography. Here I should like to give a rather concise outline of the systems' properties and to express some, probably premature, speculations and opinions on the cosmological significance of globular cluster systems. I trust that some brilliant minds who will follow me at this podium will shortly be able to set the theoretical interpretation of the data in a straighter or, at least, more convincing fashion.

2. SPATIAL DISTRIBUTION OF GLOBULAR CLUSTERS

Rich ($n > 100$) systems of globular clusters span enormous distances. In our Galaxy the most remote cluster, NGC 2419, is found at a galactocentric distance of 100 kpc, twice as far as the Large Magellanic Cloud. Cluster systems around giant elliptical galaxies like M49 (NGC 4472) or M87 (NGC 4486) have, in projection, effective radii of 40 kpc and 100 kpc respectively. They may possibly stretch over diameters approaching 1 Mpc. Globular cluster systems thus extend around their parent galaxies to distances which are comparable to the intergalactic separations themselves.

It is convenient to represent the density distribution of clusters around a galaxy by some analytical function of the projected galactocentric distance. De Vaucouleurs (1977) has shown that the $r^{1/4}$-law gives an excellent representation of the cluster system around our Galaxy. This same empirical relation also applies to cluster systems in M31 (de Vaucouleurs and Buta 1978), M49 and M87 (Harris and Racine 1979). Thus the same type of functional relationship which applies to the light distribution of the simplest elliptical and spheroidal systems seems to hold for those systems of clusters studied so far.

One could in fact expect that the projected density profiles of globular cluster systems would parallel the luminosity profiles of the spheroidal components of the parent galaxies. Discrepancies noted in recent discussions of this subject (Harris and Smith 1976; Harris and Petrie 1978) were usually attributed to uncertainties in the background counts or, photometric levels, or to incompleteness of the cluster catalogs for the inner regions of the galaxies. However, a critical reanalysis of the available data shows rather conclusively that the globular systems have significantly larger effective radii than do the light distributions of the spheroidal components.

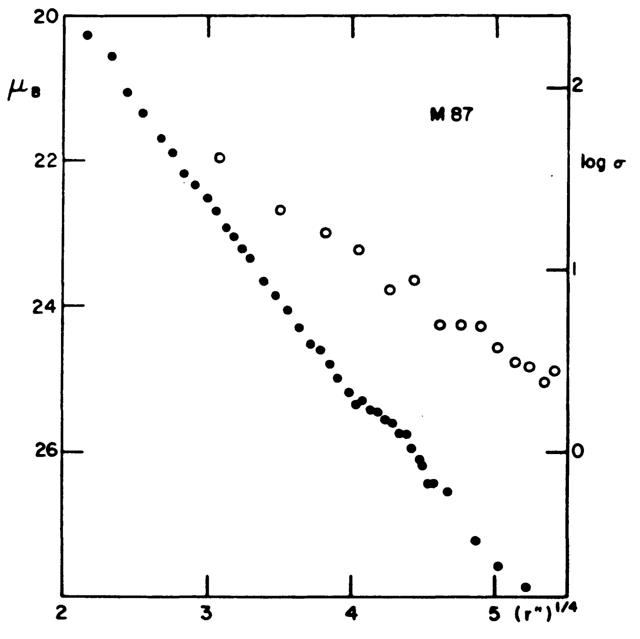

Figure 1. Comparison of the density profile of globular clusters around M87 (open circles, right-hand scale) with the luminosity profile of the galaxy (dots, left-hand scale). This shows that the globular cluster system has a larger effective radius than the galaxy.

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Figure 1 compares the photometric profile of M87 discussed by de Vaucouleurs and Nieto (1978) with the Harris and Smith's (1979) counts of globular clusters. Here a revised field count level of 5 objects per square minute of arc is adopted (rather than 6/□' as in Harris and Smith) but this does not substantially affect the conclusion. The broader profile of the globular cluster system is obvious. As pointed out by Harris and Racine (1979) similar divergences appear in the data for M49 and for the Andromeda galaxy.

These observations suggest that globular clusters became differentiated structures at an epoch which preceeded the formation of the stars in the present spheroidal component, i.e. when the protogalactic material had a less concentrated distribution.

In our Galaxy, Harris (1976) has indicated that clusters of different metallicity show the same degree of concentration to the galactic center at those galactocentric distances where they co-exist; but for a given metallicity class one finds a limiting distance beyond which the population disappears, until, in the outer halo, only the lowest metallicity objects are found. Unfortunatly the small number of available data points (~ 70) and the unavoidable selection effects at small galactocentric distances make it impossible to perform a conclusive analysis of these metallicity dependent gradients. This would have added considerable information on the run of metallicity with central concentration in the protogalaxy. And as we shall see in Sec. 4 the behavior of clusters in external galaxies confuses rather than clarifies the issue.

3. TOTAL POPULATION AND DIMENSION OF PARENT GALAXY

Brighter, larger galaxies possess more globular clusters. This nearly trivial statement is supported by observation discussed by Jaschek (1957), Wakamatsu (1977 a, b) Hanes (1977) and by Harris and Racine (1979). The main trend that emerges is that the total number of clusters, N_t, is closely correlated to the luminosity L of the spheroidal component of the galaxy. Although a direct proportionality cannot yet be affirmed, the data show that $N_t \propto L^{1.0 \pm 0.3}$.

Table 1 gives representative statistics and illustrates the general trend and some outstanding peculiarities.

The abnormally large cluster population associated with M87 is strikingly evident. This giant elliptical galaxy at the center of the Virgo cluster may contain a total cluster population exceeding the average for its luminosity by an order of magnitude. The figure of N_t = 30,000 given in Table 1 is an upward revision (by a factor of two) of the Harris and Racine's (1979) estimate, taking into account the unsurveyed area at large (> 30') radii. It is generally believed that the central position of M87 in the Virgo cluster might have favored its accreting such a large number of clusters. Alternatively the total mass, hence mass-to-light ratio of M87 may be abnormally large and its cluster population could then be in agreement with a universal relation between N_t and M.

TABLE 1. Total Population of Globular Clusters in Selected Galaxies

Galaxies	Type	M_v	$N_{observed}$	N_t
NGC 4472 (M49)	gE	-22.5	1700	4200
NGC 4486 (M87)	gE	-22.3	6000	30,000
NGC 5128	Ep	-21.3	~ 0	~ 0
NGC 224 (M31)	S	-21.1	300	320
Galaxy	S	-20.:	131	180
LMC	Irr	-18.5	17	23
NGC 205	dE	-16.4	8	8
NGC 147	dE	-14.9	4	4
Fornax	dSph	-13.6	6	6

The peculiar field elliptical NGC 5128 (CenA) has been noted to lack any appreciable cluster population (van den Bergh 1979, de Vaucouleurs 1979), despite its high luminosity. Although this anomaly may be related to the peculiar nature of this system, it could be due to a genuine difference between galaxies in the field and in clusters. However the SO galaxy NGC 3115, which is not in a rich cluster, does contain a large number of globular clusters (Strom et al. 1977).

In the Fornax I cluster Dawe and Dickens (1976) have detected cluster systems in three large ellipticals (NGC 1374, 1379 and 1399) but failed to find them around several other galaxies of comparable luminosity. It is becoming apparent that the general relation between the total population of clusters and the size of the parent galaxies does suffer significant exceptions. Further studies of this question should shed some light on the effect of a galaxy's environment on the characteristics of its outermost regions.

Finally it should be noted that the present estimate of N_t = 320 for the M31 clusters is smaller than the one given by Harris and Racine (1979) [N_t = 450] due to a revision to fainter magnitudes of the estimated limit of the survey (Sargent et al. 1977; Racine and Shara 1979). It appears that the relative populations of globular clusters in M31 and in the Galaxy are in reasonable agreement with the relative masses of these large Local Group spirals.

4. CLUSTER METALLICITY AND MASSES OF GALAXIES

Table 2 summarizes the available data on the mean intrinsic (B-V) colors of globular clusters associated with galaxies ranging from giant ellipticals (M87) to dwarf spheroidals (Fornax). The results suggest that more massive galaxies tend to produce redder, higher metallicity clusters. This is confirmed by spectroscopic and spectrophotometric

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studies of clusters in M31, NGC 205 and Fornax (van den Bergh, 1969: Searle and Zinn, in prep.) and in M87 (Racine et al. 1978; Hanes, 1979).

TABLE 2. Mean Intrinsic Colors of Globular Clusters

System	$\overline{(B-V)}_o$	n	E(B-V)
M87 (B<21)	0.73 ±0.03	33	0.02
M31 (halo)	0.74 ±0.03	14	0.11
Galaxy (r < 3kpc)	0.72 ±0.02	45	-
Galaxy (r > 3kpc)	0.66 ±0.02	33	-
LMC/SMC	0.64 ±0.02	16	0.10
dE, dSph	0.56 ±0.02	17	*

* adopted E(B-V) for dE and dSph galaxies: Fornax: 0.02; NGC 147, 185: 0.15; NGC 205: 0.11.

The details of the metallicity correlations are by no mean obvious. The outer halo clusters of our Galaxy, which are commonly thought of as standards are exclusively low metallicity objects whereas those of M31, a galaxy of similar mass, have moderately high metallicity on the average. In the giant galaxy M87 Racine et al. (1978) find, from spectrophotometric data on three clusters, metallicities similar to those in the M31 sample; and Hanes (1979) has measured nearly solar metallicity in a few M87 clusters. The most that can be said at the present time is that the smallest galaxies [$M_V > -17$] have globular clusters all of the low metallicity variety whereas in the haloes of large [$M_V < -20$] systems metallicity does not uniquely correlate with the size of the galaxy.

Because globular clusters can be traced much further out than the light of the underlying galaxies they can provide information on the chemical abundances in the outermost, oldest regions of a galaxy. It is thus tremendously important to obtain a clearer picture of this aspect of globular cluster systems. The ongoing studies of clusters in the Magellanic Clouds should yield very significant clues in this respect. The M33 clusters should be "revisited" and investigated in details. And clusters in moderately distant galaxies, like the members of the M81 group, will also have to be studied before a large enough data base is available to disentangle the relevant parameters affecting cluster metallicity.

A color (metallicity) gradient has long been known to exist in the cluster system of our galaxy, the higher metallicity objects being only found at smaller [$R_g < 10$ kpc] distances. The extension of this gradient to the outer halo is suggested by the currently available data (Harris and Racine (1979). No such gradient is apparent for the Andromeda galaxy. Preliminary UBVR photometry of clusters in M87 (Harris, priv. comm.)

confirms the earlier findings of Hanes (1971) that the mean colors decrease at larger radii, thus suggesting a metallicity gradient for this system. Here again a considerable amount of quite difficult observational work is still needed before we can draw more definite conclusions about the nature and the origin of metallicity gradients in galactic haloes.

5. LUMINOSITY DISTRIBUTION OF GLOBULAR CLUSTERS

Figure 2 shows the luminosity distribution of samples of globular clusters in the Galaxy and in M31, as compiled by Racine and Shara (1979). No significant magnitude dependent selection effects should be present in these data. For the first time two sizeable samples can be compared over their full luminosity range. It is clear that both distributions have essentially the same shape, a view confirmed by statistical tests on the data. The peaks of the distribution, at M = -7.4 corresponds to very sizeable stellar systems (like M12, or half as luminous as M13). This is within comfortable reach of observing techniques in all Local Group galaxies (V<17) and could be detected to distances as large as 10 Mpc.

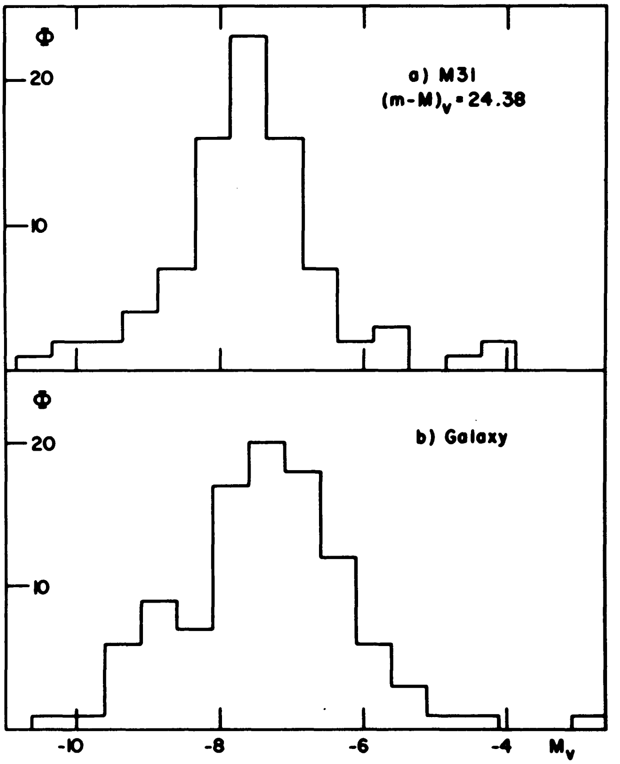

Figure 2. The luminosity distribution of globular clusters in M31 and in the Galaxy.

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A more extensive comparison of somewhat less reliable luminosity distributions is given in Table 3. Here the mean absolute magnitudes $\overline{M}_v$, are listed for all nine galaxies for which some confidence can be had that the available data justify the exercise - although M33 is included with considerable trepidation. The quoted uncertainties (m.e.) result from the cosmic scatter of the individual cluster luminosities and from uncertainties in the adopted distance moduli.

TABLE 3. Mean Luminosity of Globular Clusters in Local Group Galaxies

System	M_v (gal.)	$\overline{M}_v$ (cl.)	n	$(m-M)_v$
M31	-21.1	-7.59 ±0.25	86	24.38
Galaxy	-20.:	-7.34 ±0.18	103	-
M33	-18.9	-7.87 ±0.40	6	24.38
LMC	-18.5	-7.43 ±0.34	17	18.64
SMC	-16.9	-7.03 ±0.37	13	18.95
NGC 147, 185, 205	-15.5	-6.87 ±0.34	15	24.38
Fornax	-13.6	-7.26 ±0.53	5	20.90
		-7.38 ±0.12	245	

For galaxies whose luminosities and, probably, masses differ by a factor of 1000 globular clusters are seen to have essentially the same mean absolute magnitude, $\overline{M}_v = -7.4$. It is quite clear that the formation and evolution processes which have determined the characteristic size of individual clusters were not controlled by the dimensions of their parent galaxies. This property confirms the hope -which has long been an energetic spur for these investigations- that globular clusters can be useful standard candles in the calibration of extragalactic distances. It must also tell us something fundamental about the way globular clusters and galaxies have formed. It suggests that the smaller-scale inhomogeneities or fragments which developped in the early proto-galactic material had a universal mass spectrum whose relics are found in today's globular clusters.

The actual <u>shape</u> of the luminosity, or mass, distribution must contain additional clues about their formation process. It has so far been customary to fit their luminosity distribution by a Gaussian profile, an adequate representation, with $\sigma = 1^m.1$, given the statistical uncertainties of the counts. There are, of course, no reason to expect that the luminosities should be normally distributed with respect to the logarithm of their values. Marginal evidence is now available to suggest that the luminosity distribution Φ (M) may not be Gaussian.

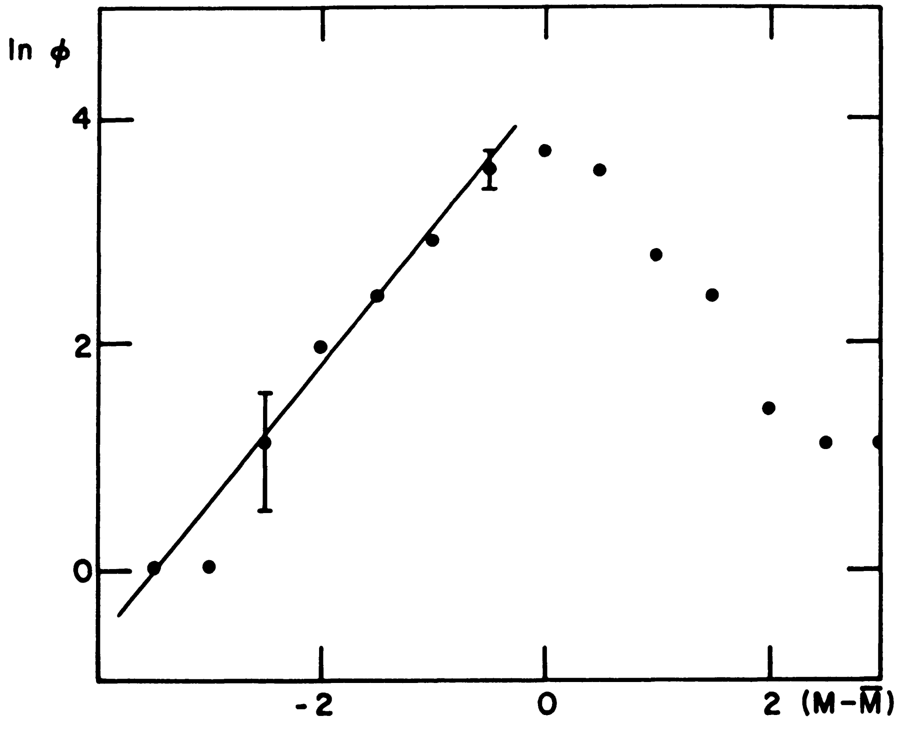

Figure 3. The bright end of the composite (Galaxy plus M31) luminosity distribution is adequately represented by a power law, within the current statistical uncertainties.

Figure 3 shows ln Φ plotted against absolute magnitudes for the composite data from M31 and the Galaxy. A Gaussian curve would be a parabola in these coordinates. The error bars are still sufficiently large to allow such a fit but a straight line is an equally good representation for the bright end of the distribution. The line drawn in Fig. 3 has the equation

$$\ln \Phi(M) = 1.2\ (\pm 0.2)\ (M-\overline{M}) + \text{constant.} \qquad (1)$$

That such a representation is still allowed by the available data should be kept in mind when attempting to use the bright end of Φ(M) to determine extragalactic distances. If Φ(M) is indeed exponential, the procedure becomes invalid unless the total cluster population is independently known. Until this possibility can be eliminated one should only use the peak of the distribution which, as seen above, is a stable statistic as a distance indicator.

For the observed bright end of the distribution of clusters associated with M87 and with five other giant ellipticals in Virgo, one similarly finds

$$\ln \Phi(M) = 0.8\ (\pm 0.2)\ (M-\overline{M}) + \text{constant.} \qquad (2)$$

The coefficients in eq. (1) and (2) are closely similar and, together with the reasonable hypothesis that the M/L ratio does not strongly depend on L, would imply that the mass spectrum of the brighter clusters follows the very simple law

$$n(M).M^{-2} = \text{constant.} \qquad (3)$$

In the Galaxy the total population of ~180 clusters contains ~300 times as much mass as a "typical" cluster of $M_v = -7.4$ ($L \simeq 7\times10^4\ L_\odot$). Most of this mass comes from clusters more massive than the present mode of the distribution. For $M/L \sim 2$ a "typical" cluster has a mass of $\sim 1.5\times10^5 M_\odot$ and the whole cluster system contains $\sim 4\times10^7$ solar masses. This represents only $\sim 10^{-4}$ of the total galactic mass. It would be interesting to know what fraction of the galactic mass was initially locked up in globular clusters. Surely, dynamical evolution of individual clusters will result in their present sizes being significantly smaller than they were 10^{10} years ago. Their mass spectrum itself might have evolved, possibly in the sense that smaller, looser clusters have been preferentially destroyed. By making the "ad hoc" hypothesis that the initial mass spectrum followed eq. (3) for all $M > 1M_\odot$--the current break at $M_v = -7.4$ being due to evolution--then one finds that the original system would have been ~10 times more massive than it now is. Even if the M/L ratio were further increased by an order of magnitude, the globular cluster system would have initially represented only one percent of the mass of the Galaxy. It is thus hardly conceivable that most of the bulk of the Galaxy results from the coalescence of objects related to the current globular cluster system. Furthermore the similarities of the various systems make it improbable that their current statistics were shaped by strong evolutionary effects.

6. CONCLUSION

We have surveyed the main features of globular cluster systems as revealed by currently available data. The emerging picture is one of rather dull uniformities, interspersed with a few mavericks. But this very uniformity or universality may be the most significant aspect of these systems and the one which, in time, will provide a key to our understanding of globular clusters and galaxies.

The main characteristics of the cluster systems seems to be as follows.

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The projected space distributions of clusters all closely follow the $r^{1/4}$-law and tend to have larger effective radii than the underlying spheroidal components of the parent galaxies.

The total number of clusters associated with a galaxy is completely determined by, and may be proportional to the mass of the galaxy. Some exceptional deviations to this rule are however coming to light (M87, NGC 5128). The study of more field galaxies is urgently needed in this respect.

The luminosity distribution of globular clusters is everywhere the same with a well defined peak at $M_V = -7.4$ and is independent of the size or type of the parent galaxy.

Low-mass galaxies are apparently unable to generate high-metallicity globular clusters. Metallicity gradients, when they exist, are in the sense that the metal-poorest objects are found at large distances.

It is still premature to draw hard and fast rules and inferences from these characteristics whose universality still has to be confirmed. Only a handful of systems have been studied so far and the trends are just beginning to emerge. But we can be confident that the work being actively pursued on these systems of globular clusters will be of pivotal importance to our understanding of the formation and evolution of galaxies.

REFERENCES

Dawe, J.A., Dickens, R.J.: 1976 *Nature* 263, 395.
de Vaucouleurs, G.: 1977, *Astron. J.* 82, 456.
de Vaucouleurs, G.: 1979, private communication.
de Vaucouleurs, G., Buta, R.: 1978, *Astron. J.* 83, 1383.
de Vaucouleurs, G., Neito, J.L.: 1978 *Astrophys. J.* 220, 449.
Hanes, D.A.: 1971, M. Sc. thesis, Univ. of Toronto.
Hanes, D.A.: 1977, *Monthly Notices Roy. Astron. Soc.* 179, 331.
Hanes, D.A.: 1979, (see this volume)
Harris, W.E.: 1976, *Astron. J.* 81, 1095.
Harris, W.E., Petrie, P.L.: 1978, *Astrophys. J.* 223, 88.
Harris, W.E., Racine, R.: 1979, *Ann. Rev. Astron. Astrophys.* Vol. 17.
Harris, W.E., Smith, M.G.: 1976, *Astrophys. J.* 207, 1036.
Jaschek, C.O.R.: 1957, *Z. Astrophys.* 44, 33.
Racine, R., Oke, J.B., and Searle, L.: 1978, *Astrophys. J.* 223, 82.
Racine, R., Shara, M.: 1979, *Astron. J.* (in press).
Racine, R., Shara, M., and Ménard, G.: 1979, paper read at the Vancouver meeting of the Can. Astron. Soc.
Sargent, W.L.W., Kowal, S.T., Hartwick, F.D.A., and van den Bergh, S.: 1977, *Astron. J.*
Smith M.G., Weedman, D.W.: 1976, *Astrophys. J.* 205, 709.
Strom, K.M., Strom, S.E., Jensen, E.B., Moller, J., Thompson, L.A., and Thuan, T.D.: 1977, *Astrophys. J.* 212, 335.
Van den Bergh, S.: 1969, *Astrophys. J. Supp.* 19, 145.

van den Bergh, S.: 1979, DAO *Preprint*.
Wakamatsu, K.I.: 1977a, *Publ. Astron. Soc. Pacific*, 89, 267.
Wakamatsu, K.I.: 1977b, *Publ. Astron. Soc. Pacific*, 89, 504.

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DISCUSSION

KING: Thank you very much for a stimulating review, René. I'm glad to see that at some point you identified M49 as NGC 4472; because, although you are a man of the 18th century, I live in the 19th century, myself, and prefer NGC numbers. Before asking for questions, I'm just going to make a remark about IAU Commission 37 and cluster nomenclature. Could you perhaps give me the number of M13, on the proposed new system?

RACINE: As a matter of fact, I don't know what it is.

ANON: 1636+32.9.

KING: Something like that. This is what is called the Parke's system. It's been adopted by Commission 37 as the proper way of designating clusters, but one should have a "C" in front to indicate it's a cluster. One is not prejudiced whether or not it's a globular or open, as that might change. It's just to make it clear that we're not talking about a galaxy or a quasar. And Commission 37 suggests very strongly that one also puts all other familiar designations in parentheses, so that somebody knows what you're talking about: C1636+32.9(M13,NGC 6205). (Laughter).

NEMEC: In regards to nomenclature, as well, by the same token I hope that will not also be the case for individual stars in globular clusters. If one were to do that, a particular star in M13 which was first designated 47 by Scheiner in 1892 would also have to be designated Ludendorff "70", Barnard "2", Baum "4", Johnson "59", Arp "II-67", Savedoff "B786", Kadla "309", and, finally, Hesser, Hartwick and McClure "e". (Laughter).

KING: You unfortunately left out one piece of nomenclature - your name!

KRAFT TO KING: The only important point is, don't let Helmut know! (Laughter).

HANES: I have a comment and a question. The comment is about this business of the surface density profiles. Like you, I also believed that they fell off like the underlying light and believed that the slight drop in globular cluster number near the center was an incompleteness effect. When I sat down to calculate it, I found, in fact, that is not so. They do have a slope that is different from the underlying light. In a log-log plot the cluster distribution is shallower by about one power.

RACINE: Bill Harris and I used the $r^{1/4}$ law and it gives a straight line.

HANES: Yes, yes, but it's exactly the same thing.

KING: I'd like to interject a comment. Dave says he got a different power law. René says he used the $r^{1/4}$ law. If something fits the $r^{1/4}$ law it's got a specific power law, namely r^{-2} and I

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do not understand how to reconcile your two statements.

RACINE: Given the statistical noise in the counts I would guess that the difference in shape between the two isn't that significant. (Laughter).

HANES: I'll talk to you after and show you what I mean, but if you consider the ultimate case of a horizontal line you will see that *any* straight line in the $r^{1/4}$ plane does not correspond to an r^{-2} line in the log-log plot.

FREEMAN: If I could just ask one question on this same topic. This is terribly important, as everybody realizes, whether the clusters follow the light or not. Why do they change? What has changed since last year, when we were told in Cambridge that they follow fairly well? It's so important that it would be worthwhile if you could just say a couple of words about the change.

RACINE: I think that the main new input is that we feel now that we have much better background counts for M87 in Virgo; we have more fields which have been studied on 4-m plates. Although this doesn't change the overall conclusion, the trend is now stronger. There is also, I think, a psychological reason. We all wanted them to follow the same thing, but I think that the data are good enough that we can now state that they do not.

COHEN: Can you say anything about the distance modulus to the Virgo cluster yet?

RACINE: Not as much as I would have a year ago. (Laughter). This is just because of that power law in the luminosity function. The deepest counts, which go to about magnitude 24 from Bill Harris and Malcolm Smith's plates, clearly do show in the integrated N(m) the turnover, so the peak must be reached there. I think now that the accuracy is certainly on the order of 0.75 mag; 30.5 to 31.3 - that's the ballpark estimate.

SCHOMMER: Concerning insignificant objects like Pal 13, with $M_V \sim -2$ and it's only about 25 kpc away: would you or any of the Schmidt surveyors care to comment on the completeness of such objects, even in our own galaxy at fairly large distances?

RACINE: There have been about half a dozen similar objects found in the southern sky surveys, so possibly there may be another dozen or so missing objects. I don't think it's likely to change the overall picture of the distribution.

CARNEY: All the globular clusters survey searches have always concentrated on galaxies. Have there ever been any searches between galaxies in, say, Virgo?

RACINE: This would be absolutely impossible now, I think. Certainly in Virgo we cannot tell the clusters from the stars and you would have no control whatsoever on what the background is. It would also be very difficult if you were to find them, to know to which galaxy they belong. Apparently among the faint clusters discovered by Arp and Madore, one of them may be an extragalactic cluster.

HANES: In answer to Judy Cohen's question, I can tell her that I have a paper which I think will be out this month in *Monthly Notices*, in which I use the Harris and Smith and Harris and Petrie

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counts of globular clusters around a couple of Virgo galaxies to pin down what I think is a good Virgo cluster distance modulus of 30.7 ± 0.3. I have a bit more faith in that than René seems to. I'm not too concerned about this business of a power law, because if you take a small portion of any kind of representation you can always fit a power law to it and, as René says, the Harris counts really do show that the turnover is there.

HARRIS, W.: A comment on Bruce Carney's question. Malcolm Smith and I do have a plate pair which is half way between M87 and M49 (NGC4492) which might cast some light on whether or not there are any clusters between those two large galaxies, but the problem there is that we now need another background field which is outside the Virgo cluster and we don't have that.

KING: I have a couple of comments myself. With regard to mean eccentricities, I think one has to treat them with caution because you are comparing the tidal radius with a force field and we are in process of revising our notions on what the force field really is. I think those have to be handled cuatiously.

RACINE: Which way would that go?

KING: I don't think fast on my feet, I'm sorry.

FREEMAN: It will tend to reduce the eccentricities in the outer parts.

KING: My other comment; there was a paper submitted to this meeting and that was withdrawn because the authors didn't come, but they were talking about it fairly freely at Montreal and said I could mention it here. Faber and Burstein have been observing line strengths in M31 and the Milky Way and they look at Hβ and at the Mg"b" line and find a kind of anti-correlation as one might expect for a number of globulars in the Milky Way. Somehow, and I'm just reproducing in a graph what they told me in words, they get this sort of effect, that both Hβ and Mg are simultaneously stronger in M31 compared with the Milky Way. I can't answer any questions about that, because I've told you at least as much as I know already. (Laughter).

ALCAINO: I just want to remark that the two edge on galaxies of the Sculptor group, NGC55 and NGC 253, are appropriate candidates for globular searches. The distance modulus is ∿28, or 3 mpcs, so you would have to see the brightest globulars sitting around 19th which is feasible with the larger telescopes.

RACINE: I think we do. We do have plates of these that are being looked at right now.