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ABSTRACT

The young globular clusters of the LMC have ages of 10^7-10^8y. Their masses and structure are similar to those of the smaller galactic globular clusters. Their stellar mass functions (in the mass range 6 $\mathfrak{M}_\odot$ to 1.2 $\mathfrak{M}_\odot$) vary greatly from cluster to cluster, although the clusters are similar in total mass, age, structure and chemical composition. It would be very interesting to know why these clusters are forming now in the LMC and not in the Galaxy.

I will talk about the "young globular" or "blue populous" clusters of the LMC. They were first identified as a family by Hodge (1961). The ages of these objects are 10^7 to 10^8y, and their masses are 10^4 to 10^5 $\mathfrak{M}_\odot$, so they are populous enough to be really useful for studying the evolution of massive stars. I will not discuss this aspect (see the extensive work by Flower and Hodge and Robertson since 1974), but will concentrate on the structure and stellar content of these young clusters.

I. STRUCTURE

These objects have the appearance of globular clusters: see for example the photographs of NGC 1831, 1866 and 2164 in the ESO sky survey. The radial distribution of light and of star counts in the young LMC clusters is fairly well represented by King models (see Freeman 1974, Chun 1978). The King models give tidal radii for the clusters; then, knowing the tidal field of the LMC from its rotation curve, we can estimate the cluster masses. These masses are in the range 10^4 to 10^5 $\mathfrak{M}_\odot$, which is similar to the masses of the smaller halo globular clusters in our Galaxy. The M/L

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ratios are then between about 0.02 and 0.10, depending on the age of the clusters, and this agrees well with the M/L ratios of synthetic young stellar populations (eg Larson and Tinsley 1978).

From the cluster masses, and the lengthscales given by the King models, we can estimate the crossing times (ie the time taken by a star to cross the cluster) and the relaxation times. The Table compares them with the cluster ages:

Ages	10^7 to 10^8 y
Crossing times	$\sim 5.10^6$ y
Relaxation times	$\sim 5.10^8$ y

We see that the crossing times are less than the ages, so it is not surprising that the clusters have settled down to fairly smooth and roughly spherical distributions. But it is interesting that they are so well represented by King models, because these models are associated with relaxed distributions, and these clusters have ages <u>shorter</u> than their relaxation times. This suggests that the clusters may have relaxed by mean field relaxation at the time of their formation.

To emphasise the structural similarity of these young clusters and the old halo clusters of our Galaxy, we can compare the central concentrations of the two classes of systems. The concentrations are well measured by King's parameter c (= tidal radius/core radius). The distributions of c for the young LMC clusters, and for halo clusters in the same mass range, are very similar, with most clusters being in the range $1.0 < c < 1.5$.

Fisher and I have made star counts of several young clusters from AAT plates, to derive their mass functions (see Section II). These counts can also be used to compare the radial distributions of stars, from about 6 $\mathfrak{M}_\odot$ down to 1.2 $\mathfrak{M}_\odot$, to see whether there is any mass segregation. We would not expect to see evidence of mass segregation, because (i) the relaxation times are longer than the cluster ages; (ii) mean field relaxation, which may explain the relaxed appearance of the clusters, does not produce mass segregation; (iii) even if the clusters were fully relaxed, we know from dynamical models that the expected mass segregation would be very difficult to detect for these clusters of relatively low central concentration, despite the large stellar mass range. Fortunately, after all that, we found no evidence whatever for mass segregation. Geyer (1979) makes a similar point.

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To summarise: in appearance and structure, these young clusters are very similar to the halo globular clusters. I believe they deserve to be recognised as young globular clusters (cf Woolley 1960): the halo clusters of our Galaxy must have been very similar, when they were young, to these LMC clusters. There are no young globular clusters known in the Galaxy. It seems very important now to identify the reason why globular clusters are forming now in the LMC but not in the Galaxy. It would give us some valuable insight into the formation of the galactic globular clusters, and this is surely one of our most pressing problems.

II. STELLAR CONTENT

Stellar mass functions for the young clusters can be derived from deep star counts (see Freeman 1977). It turns out that the mass functions differ greatly from cluster to cluster. The slope x of the mass function can take any value between about zero and 3 ($x = 1.35$ for the Salpeter function). This is surprising, because the clusters in the sample have fairly similar ages, masses and central concentrations.

It seemed possible that differences in chemical composition could be responsible for this wide range in the slope of the mass functions. Da Costa's (1977) work on mass functions of galactic globular clusters suggests that their mass functions become steeper (ie more low mass dwarfs) with increasing abundance. However McGregor and I (unpublished) have measured Ca abundances for F supergiants in three young clusters chosen to span the whole observed range in the slope x of the mass function. There is no detectable abundance difference from cluster to cluster (we could detect differences of 0.2 in [Ca/H] if they were present), so we do not know yet why the mass functions are so different from cluster to cluster.

In the galactic disk, star formation appears to proceed with a fairly uniform initial mass function. Here the star formation is usually associated with a high density of gas and dust. In the LMC, many of the young globular clusters lie in the outer parts of the system, where the gas density is fairly low. It seems that their mode of star formation is different from that in the galactic disk. It allows the formation of these large and fairly tightly bound clusters from a low density medium, and the resulting IMF is apparently unpredictable.

When our Galaxy first formed stars, which of these two modes of star formation was the most important ? Was it the high density mode that we see now in the galactic disk, or was it the low density mode that we associate with the LMC clusters ? It could make a significant difference to the subsequent evolution of the Galaxy, particularly if much of the early star formation had a fairly flat IMF: systems with flat IMFs evolve rapidly in luminosity. For example, imagine that, when the Galaxy formed, its outer (low density) regions contained a population of stars whose IMF was deficient in low mass stars. This population would now be mainly nonluminous remnants (white dwarfs, neutron stars, etc). Most galaxies with measured rotation curves appear to have an extended dark population in their outer parts: maybe we can understand it in this way.

Apart from speculations, the young globular clusters of the LMC provide us with two immediate and very significant problems. Why do they form in the LMC and not in the Galaxy, and why are their mass functions so unpredictable ?

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DISCUSSION

FROGEL: I must make a comment about the discussion that followed the last paper. I have now the infrared observations of a number of carbon stars in the so-called intermediate age clusters in the LMC. The bolometric luminosities that Mould and Aaronson got are incorrect by two magnitudes. The mean M_{bol} for these carbon stars are -4.9 and that corresponds to the mean of the M_{bol} of about eight carbon stars that have been observed in the field of the LMC. Thus any age arguments that they make on the basis of the luminosities of their carbon stars are incorrect.

KRAFT: But do those luminosities go above the first giant branch?

FROGEL: They are now 0.6 or 0.8 mag above the 47 Tuc giant branch tip.

KRAFT: That still means that its qualitiatively very good.

FROGEL: Correct, correct. But it's not three magnitudes farther down.

HODGE: Before he sits down, are there any questions for Ken? (Laughter).

RENZINI: I want to establish what is the upper limit for the mass of these young globulars, these $10^5 M_\odot$ to which you referred?

FREEMAN: Well, just the brightest ones that we know are $\sim 10^5 M_\odot$.

RENZINI: How well established is that? What is the uncertainty in the mass determination?

FREEMAN: Probably it wouldn't exceed a factor of two.

NISSEN: You said we had no such clusters in our galaxy, but how about h and χ Persei - it has a high mass and spherical appearance.

FREEMAN: I don't think it's mass gets into this sort of range, does it?

NISSEN: $10^4 M_\odot$.

FLOWER: Permit me to comment on the potential of young Magellanic Cloud clusters for calibrating, at least in part, stellar evolutionary models. As Ken has pointed out, it is now possible to obtain photometric metal abundance for these clusters. For instance, a number of young Magellanic Cloud clusters like NGC 1866 and NGC 2164 seem to have metallicities in the range of -1.0 to -0.5. Interestingly, synthetic cluster fits to the color-magnitude diagrams of young cloud clusters, like NGC 1866, strongly suggest a solar metallicity interpretation. Hence, the rather low metallicities observed represent an apparently real problem with stellar evolutionary models. So I'd like to stress the importance of obtaining more secure metallicity measures for the Magellanic Cloud clusters.

JANES: How do you get your luminosity from such crowded clusters?

FREEMAN: You make up a number-radius profile for each mass group, and then you can take those in a certain direction before

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crowding gets you. And it's quite far enough to define the number up to each magnitude. There are no technical problems.

BOK: Will Ken Freeman summarize in one sentence how he thinks that these things will develop in the future evolutionary picture? Just a brief statement - here is their future 10^8 y from now.

FREEMAN: In one sentence: the ones with x $\approx$ 0 by 10^8 y time they will have dropped in integrated luminosity by between four or five magnitudes and you won't even know they're there. The ones with x = 2.5 will be obvious for quite a long time.

BLAAUW: Would you say that these objects are the most massive ones for the whole spectrum of masses from which these objects are detailed? Or would you think that these things are in a class by themselves, and that at lower masses, they really occur in lower frequencies?

FREEMAN: I can't give you a good answer for that. I think they're something that will continue, but I'm not sure.

BLAAUW: Then there should be a very large number of clusters in the general field, this large halo around the clouds, isn't that right?

FREEMAN: Well, these are objects in the disc of the LMC and they have extreme Population I kinematics; I know this from my velocities. They shouldn't be thought of as halo objects. They really are extreme Population I objects.

CHRISTIAN: Then how do the positions of the clusters differ relative to the HI background? Is the density of the HI different in the three clusters that you cited?

FREEMAN: For the three that I showed the density is very low in each case. It seems to me that the brightest giants in these clusters are found predominantly in regions far out, but I can't really quantify that statement.

KING: With regard to how the Large Magellanic Cloud is able to make such clusters, I think we have to remember that it's a very different type of galaxy from the Milky Way and that late type galaxies do show this tendency. There are bright blue clusters - I don't think Paul has got a name for them-in M33. They've been very little investigated, because it is near the right ascension of M31 - nobody ever looks at it. It always comes in second. But it would be very interesting to look at the bright blue clusters in Sc spirals and see if they're a bridge between the nonexistent ones and the Milky Way and the ones in the LMC.

FROGEL: The luminosity functions you derived, can they be dependent in any way on mass segregation? Secondly, we can't be living in a special age when we just see these clusters, because of their short life spans. From HI studies, or whatever, is there any evidence we can get enough mass pumping to form one of these clusters out of the interstellar median?

FREEMAN: I asked a loaded question yesterday about what the tidal radius of a local aggregation due to its formation is.

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The point is that if you want these things forming out there in low density regions, you've got to use up almost everything that's inside the tidal radius locally to make one of these things. And the tidal field of the LMC just lets you make one of these things, and no more. As far as the mass segregation goes, the answer is a loud NO, because we can actually see that there is no mass segregation for about 3/4's of the cluster radius, anyway.

FROGEL: Well, is it reasonable physically to expect that everything inside the tidal radius will coalesce?

RACINE: I think it should be pointed out that in comparing the masses of these objects to the galactic globular clusters that the more massive of these are $10^5 M_\odot$, whereas the most frequent mass in the galaxy is a (few) x 10^5, so on the average they are significantly less massive.

FREEMAN: Oh, yes.

RACINE: I have a question. Is there any indication in the data that there is a correlation betwen "x" and the actual total mass of the system?

FREEMAN: None at all.

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