AN ELLIPTICITY-AGE RELATION FOR GLOBULAR CLUSTERS IN THE LARGE MAGELLANIC CLOUD

S. Michael Fall
Institute of Astronomy, Cambridge, England

Carlos S. Frenk
Astronomy Department, Berkeley, California

We have measured the ellipticities of 52 globular clusters in the LMC and 93 in the Galaxy by eye from polaroid enlargements of the sky surveys (Frenk & Fall 1982). In most cases, the measurements pertain to regions between $(1-2)r_h$ where r_h is the median radius of a cluster; i.e. the radius containing half of the light in three dimensions. These were compared with determinations based on star counts for 12 members of the LMC sample and 19 members of the Galactic sample. We found no systematic difference between the ellipticities from the two methods and concluded that the eye-measurements are free of any major bias. They are also in reasonable agreement with the measurements by Geyer & Richtler (1981) and Geyer, Hopp & Nelles (1983), who used the Agfa contourfilm technique. The ellipticities measured by Geisler & Hodge (1980) from microdensitometer scans are systematically large in comparison with our results and those of Geyer and his associates. Since the scans cover only a small part of each cluster, a few bright stars can cause spurious elongations in the fitted contours.

Our measurements show that the globular clusters in the LMC are stochastically flatter than the globular clusters in the Galaxy. We also found a correlation between the shapes of the LMC clusters and their classification in the scheme devised by Searle, Wilkinson & Bagnuolo (1980). An approximate dating of this sequence, based partly on Hodge's (1983) compilation of turnoff photometry, gives $\log(\mathrm{age/yr}) \approx 0.5(\mathrm{SWB\ type}) + 6.6$. Young clusters are flatter on average than old clusters with most of the change between SWB types III and IV and therefore at ages of a few times 10^8 yr. This relation has much scatter but the general trend is significant at the 97 per cent level. Another indication that the effect is real comes from the correlation between the ellipticities and luminosities of clusters in the LMC (van den Bergh 1983). Since the clusters fade with time, the dependence of their shapes on age probably explains why they appear flattest when brightest and roundest when faintest.

One process that can change the shape of a rotating cluster is evaporation by two-body diffusion. As Agekian (1958) pointed out, stars that escape in the direction of rotation carry away more angular momentum per unit mass than stars that escape in the opposite direction. He

S. van den Bergh and K. S. de Boer (eds.), Structure and Evolution of the Magellanic Clouds, 27–28.

https://doi.org/10.1017/S0074180900039784 Published online by Cambridge University Press

computed this effect for a Maclaurin spheroid with an isotropic velocity distribution and found that its ellipticity decreased on a timescale of order $10^2\tau_r$ where τ_r is the local relaxation time. Shapiro & Marchant (1976) applied this formalism to Galactic globular clusters, using central values of τ_r, and suggested that evaporation alone could explain why they are so round in comparison with elliptical galaxies. In the regions where ellipticities are measured, however, two-body diffusion is characterized better by the reference relaxation time τ_{rh} which is defined as the value of τ_r at the mean density within r_h (Spitzer 1975). Almost all of the globular clusters in the Galaxy have 10^8 yr $\lesssim \tau_{rh} \lesssim 10^{10}$ yr and those in the LMC have slightly smaller values of τ_{rh}. Since the time-scale $10^2\tau_{rh}$ is greater than the ages of these clusters, evaporation probably plays only a minor role in the evolution of their shapes.

A more promising explanation for the relation between ellipticity and age also involves two-body diffusion but operates on faster time-scales. If the clusters form by aspherical collapse and violent relaxation, they will generally be distorted by anisotropic velocity distributions when they first reach dynamical equilibrium. Two-body diffusion will then isotropize the stresses within r_h on small multiples of the reference relaxation time τ_{rh} before evaporation is important. The clusters will then become rounder until they reach a state that is consistent with their total angular momenta and isotropic velocity distributions. We have studied this process in some detail by means of N-body simulations and find that the changes in shape can be quite dramatic (Fall & Frenk, in preparation). For example, the true ellipticities in one series of models evolved from 0.4 to 0.1 on a time-scale of a few τ_{rh} with no evaporation. A detailed comparison with the empirical relation between ellipticity and age is difficult because the data needed to estimate τ_{rh} are available for only a few globular clusters in the LMC. Nevertheless, the agreement is as good as could be expected and strongly suggests that changes in the velocity distributions of the clusters are responsible for much of the observed changes in their shapes.

REFERENCES

Agekian, T.A. (1958) Sov. Astron - AJ, 2, 22.
Frenk, C.S. & Fall, S.M. (1982) Mon.Not.Roy.Astr.Soc., 199, 565.
Geisler, D. & Hodge, P.W. (1980) Astrophys. J., 242, 66.
Geyer, E.H., Hopp, U. & Nelles, B. (1983) preprint.
Geyer, E.H. & Richtler, T. (1981) in "Astrophysical Parameters for Globular Clusters", eds. Davis Philip, A.G. & Hayes, D.S. (L. Davis Press, Schenectady) p.239.
Hodge, P.W. (1983) Astrophys. J., 264, 470.
Searle, L., Wilkinson, A. & Bagnuolo, W.G. (1980) Astrophys.J., 239,803.
Shapiro, S.L. & Marchant, A.B. (1976) Astrophys. J., 210, 757.
Spitzer, L. (1975) in "Dynamics of Stellar Systems", ed. Hayli, A. (Reidel, Dordrecht) p.3.
van den Bergh, S. (1983) preprint.