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Resolving Globular Clusters in the Fornax Cluster and Beyond

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Abstract. We describe an ongoing program to measure structural parameters for globular clusters with a range of ages in early-type galaxies. Using deep, optimally-dithered HST WFPC2 observations of NGC 3597, NGC 1316, and NGC 1399, we apply a χ^2 minimization method to the determination of cluster sizes. The goals include studying the structure spectrum of stellar clusters at birth, and determining the rate at which tidal and evaporative destruction mechanisms operate to alter luminosity functions and specific frequencies to what we see in ellipticals today.

1. Introduction

Recent numerical experiments have demonstrated that observed, log-normal globular cluster luminosity functions (GCLFs) may be a natural consequence of globular cluster disruption processes which include evaporation, bulge and disk shocking, and dynamical friction (Gnedin & Ostriker 1997; Vesperini 2001). Several cluster systems have now been found which have power-law luminosity functions and whose members are generally brighter and bluer than most old globular clusters, suggesting that the clusters are significantly younger. Thus both theory and observation indicate that clusters are not born in accordance with some universal, steady-state mass function, but rather that natural selection acts to destroy feeble or loosely-bound clusters which cannot long survive their host environment. The usefulness of GCLFs as distance indicators must therefore be viewed with some suspicion until we can determine how rapidly the LF of young clusters evolves towards a stable, universal form. The relatively high specific frequencies of globulars in ellipticals may similarly be as much a function of destruction time scales as of selective cannibalism or gas-rich mergers.

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2. The Method

Disruption of clusters can occur for a number of reasons including two-body relaxation (evaporation), perigalactic shocking, disk shocking, encounters with molecular clouds, and dynamical friction. For clusters in early-type galaxies only the first two processes are important. Evaporation operates on a time scale given by

$$t_{ev} = f(c)\frac{M^{1/2}R_h^{3/2}}{G^{1/2}m\ln\Lambda} \quad (1)$$

where the concentration parameter $c = \log r_t/r_c$, r_c and r_t are the core and tidal radius, M is the cluster mass, r_h is the half-mass radius, m is the average stellar mass, and $\ln\Lambda = \ln 0.4N$, where N is the number of stars in the cluster.

By measuring c and R_h for individual clusters we can determine the relative evaporation time scales. The accelerating effects of perigalactic shocking can then be estimated by making reasonable and consistent assumptions about orbit shapes and galactic potentials, and by comparing GCLFs of different ages but similar environments to one another.

3. The Sample

Using the Hubble Space Telescope, we have obtained deep, dithered WFPC2 images of the early-type galaxies NGC 3597, NGC 1316, and NGC 1399. Eight F606W exposures of each galaxy allows us to probe the cluster population to V $\gtrsim$ 24, or masses well below the turnover magnitude in old GCLFs.

NGC 3597: Though the surface brightness profile of NGC 3597 is that of an elliptical galaxy, there are plumes of material and intense star formation going on in the central regions, indicating a merger $<$ 1 Gyr ago (Lutz 1991). Carlson et al. (1999) found the cluster system to have a power-law LF and be between 300 and 700 Gyr old.

NGC 1316: This is the nearest big elliptical containing a sizable population of clusters with an exponential LF. Grillmair et al. (1999) found a power-law LF and an age of $\approx$ 1 Gyr.

NGC 1399: Grillmair et al. (1999) determined that NGC 1399's GCLF is log-normal over almost its entire extent and is statistically indistinguishable from the LF of globular clusters in M 87 and our own Galaxy. NGC 1399's cluster system is taken to be "evolved" and serves as a standard to which the younger systems may be compared.

4. Preliminary Results

The core radii and concentrations are determined by simultaneously fitting two-dimensional King models, convolved with the TinyTim HST/WFPC2 point-spread function, to the uncombined set of dithered observations. A downhill simplex method is used to minimize χ^2, allowing center position, r_c, r_t, and uniform flux scaling to be free parameters. The relative positions on each set of eight dithered frames are constrained beforehand. Figure 1 shows values of r_c

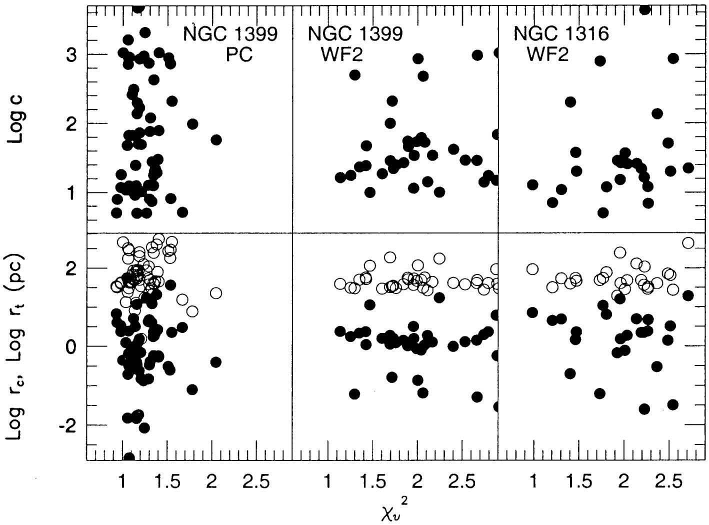

Figure 1. Measured core and tidal radii, and the concentration parameter $c = r_t/r_c$, as a function of reduced χ^2. The filled circles show measured core radii, while the open circles indicate best fit tidal radii.

and r_t determined for the brighter clusters in NGC 1399 and NGC 1316. The results are broadly consistent with the lower resolution work of Grillmair et al. (1999) in that the clusters of NGC 1316 show a broader range of core radii than do those of NGC 1399.

We have carried out simulations by placing King model realizations with known parameters onto each of the eight images of NGC 1399. Though preliminary, the simulations indicate that we are able to constrain both core and tidal radii very well in the PC images, but that there may be a "floor" in the measured core radii at lower signal-to-noise ratios in the WF images. More work remains to be done to understand our uncertainties before we can extend our analysis to the fainter clusters where we expect structural variations to be important.

References

Carlson, M. N., Holtzman, J. A., Grillmair, C. J., & the WFPC2 IDT 1999, AJ, 117, 1700

Gnedin, O. Y., & Ostriker, J. P. 1997, ApJ, 474, 223

Grillmair, C. J., Forbes, D. A., Brodie, J. P., & Elson, R. 1999, AJ, 117, 167

Lutz, D. 1991, A&A, 245, 31

Vesperini, E. 2001, MNRAS, 322, 247