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PROBING THE CORES OF DENSE GLOBULAR CLUSTERS WITH THE HUBBLE SPACE TELESCOPE

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I. SUMMARY

Images obtained with the pre-repair and post-repair *Hubble Space Telescope* (WF/PC-I and WFPC2, respectively) have been used to study the central regions of a few nearby dense Galactic globular clusters. In this paper, I draw on results from recent and ongoing studies of the "post core collapse" clusters M15 [NGC 7078] (Yanny et al. 1994a; Guhathakurta et al. 1996, 1997b), M30 [NGC 7099] (Yanny et al. 1994b; Webster et al. 1997), and NGC 6624 (Yanny et al. 1997), and the dense "King model" clusters 47 Tucanae [NGC 104] (Guhathakurta et al. 1992, 1997a; Edmonds et al. 1996), M3 [NGC 5272] (Guhathakurta et al. 1994), and M13 [NGC 6205] (Cohen et al. 1997). These studies rely primarily on short exposures in two or three of the following bands: F336W (U), F439W (B), F555W (V), and F785LP (I). The one exception is the study of 47 Tucanae for which very long WF/PC-I exposures in UBV have been analyzed.

Near the dense centres of clusters, the effects of crowding limit detection and photometry of individual stars to stars around the main sequence turnoff or brighter—i.e., those with $V_{\rm lim} \lesssim V_{\rm MSTO} + 2$. Detailed simulations have been carried out tailored to the parameters of specific clusters mimicking the instrumental characteristics of WF/PC-I and WFPC2; these provide realistic estimates of the completeness fraction and photometric error as a function of stellar brightness and projected distance from the cluster centre. The two main areas discussed in this paper are: (1) stellar density distribution near the centres of dense clusters, and (2) post main sequence stellar populations and radial population gradients in these regions. Particular emphasis is given to the following issues:

(a) M15's Density Cusp

The surface density distribution of evolved stars in M15's inner 5″, after correcting for the effects of incompleteness and photometric error, is well fit by an $\alpha = -0.8$ power law profile. The 95% upper limit to the core radius is $r_{\rm core} < 2''$ (0.1 pc); the density profile shows no hint of flattening towards smaller radii. Cusps similar to that seen in M15 are also evident in the clusters M30 and NGC 6624, and comparable upper limits are placed on the size of a possible core. The ellipticity in the projected star count distribution in M15's central 10″ is $e \approx 0.05$; this is consistent with the amplitude and orientation of the mild rotation observed in this region (Gebhardt et al. 1995).

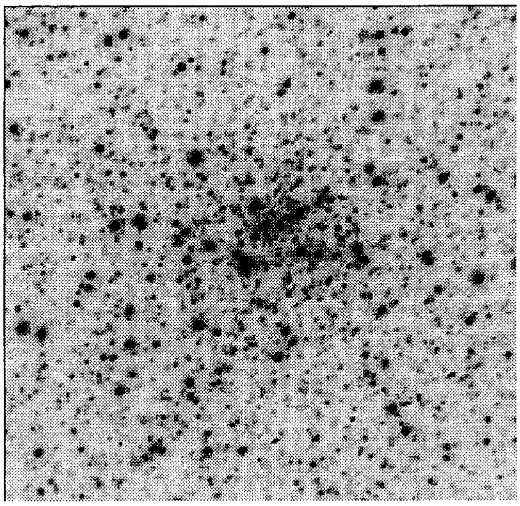

Fig. 1.— The central 9″×9″ of $M15$ imaged with the Hubble Space Telescope's $WFPC2$ in the $F336W$ (U) band. The size ($FWHM$) of a stellar image on $WFPC2$ is $\leq 0.1''$ and this makes it possible to study brightnesses and colors of individual stars despite the high stellar (surface) density. Nearly 100 stars are detected within $r < 1''$ of the cluster center!.

(b) Blue Stragglers

Several blue straggler stars are identified in each of the six clusters studied so far; many of these stars are previously unidentified and/or uncatalogued as blue stragglers. The specific frequency of blue straggler stars, $F_{\rm BSS} \equiv N({\rm BSS})/N(V < V_{\rm HB} + 2)$, appears to be largely independent of stellar density (and within a relatively narrow range of ± 0.5 dex) across a variety of cluster environments spanning 4–5 orders of magnitude in stellar density. Blue stragglers are centrally concentrated relative to other post main sequence stars, presumably as a result of mass segregation: this is a particularly strong effect in M30; in 47 Tucanae, the radial distribution is consistent with the stragglers having a mass of $M_{\rm BSS} \sim 2\,M_{\rm TO}$.

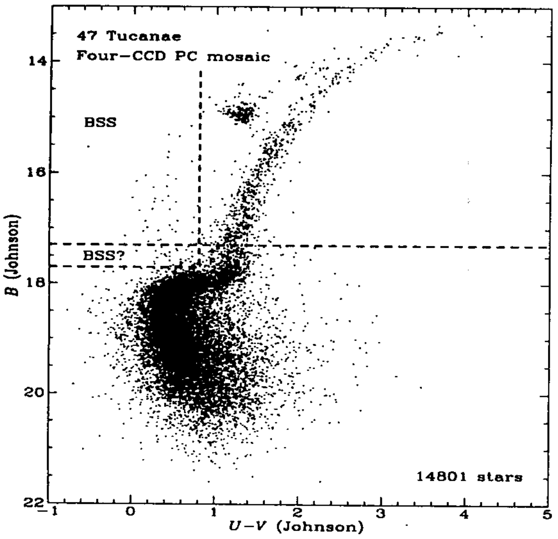

Fig. 2.— A color-magnitude diagram of stars in the core of 47 Tucanae derived from very deep pre-repair WF/PC-I images in the UBV bands. The blue straggler sequence is clearly visible.

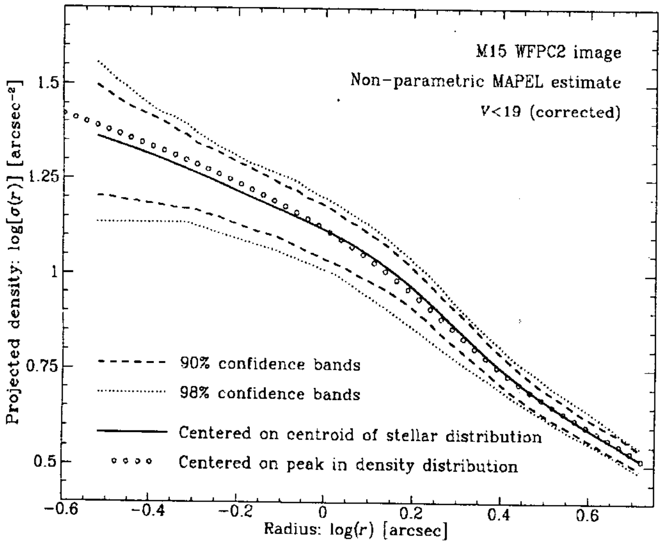

Fig. 3.— Non-parametric (MAPEL) estimate of the surface density profile of post main sequence stars in the central part of M15 corrected for the effects of incompleteness and photometric error. The data are consistent with a simple power law cusp of index $\alpha \sim -0.8$, with no evidence of a constant density core.

(c) Radial Population Gradients

There is a deficiency of the brightest red giant branch stars (relative to the number of faint giants, subgiants, and turnoff stars) near the centers of the post core collapse clusters M15 and M30. It is interesting to note that horizontal branch stars (the evolutionary products of red giants) also seem to be very slightly depleted near the centres of clusters; the degree of central depletion of horizontal branch stars, however, appears to be much weaker than that of bright red giants. This suggests that the bright red giant phase is short circuited, rather than terminated, in these regions of very high stellar density.

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