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Blue straggler stars in the unusual globular cluster NGC 6388

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Abstract. We have used multi-band high resolution *HST* WFPC2 and ACS observations combined with wide field ground-based observations to study the blue straggler star (BSS) population in the galactic globular cluster NGC 6388. As in several other clusters we have studied, the BSS distribution is found to be bimodal: highly peaked in the cluster center, rapidly decreasing at intermediate radii, and rising again at larger radii. In other clusters the sparsely populated intermediate region (or "zone of avoidance") corresponds well to that part of the cluster where dynamical friction would have caused the BSS or their binary progenitors to sunk to the cluster center. Instead, in NGC 6388, BSS still populate a region that have been cleaned out by dynamical friction effects, thus suggesting that dynamical friction is somehow less efficient than expected.

1. Introduction

NGC 6388 is one of the most peculiar Galactic Globular Clusters (GGCs). As shown for the first time by Rich et al. (1997), this bulge cluster has an extended blue Horizontal-Branch (HB), despite its high metal content ([Fe/H] = −0.44; Carretta et al. 2007). Such an HB morphology is contrary to expectations: metal-rich clusters have stubby red HBs, while metal-poor clusters usually have predominantly blue HBs. Moreover, hints for the presence of an intermediate mass black hole (IMBH) at the center of NGC 6388 have been recently inferred from the observed surface brightness profile (which shows a deviation from a flat core behavior in the inner $\sim 1''$) and from detailed dynamical modeling (Miocchi 2007; Lanzoni et al. 2007).

In the present work we study the Blue Straggler Star (BSS) population of this peculiar cluster by using a proper combination of multi-band high resolution WFPC2 and ACS observations. This is part of a general project devoted to explore the interplay between dynamic and stellar evolution in the dense stellar systems.

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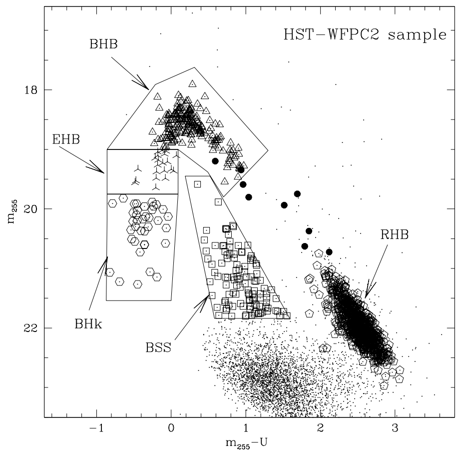

Fig. 1. UV CMD of the HST-WFPC2 sample. The empty squares are the selected BSS while the empty pentagons are the red HB stars used as reference population.

2. The BSS selection

Hot populations like BSS and blue HB (BHB) stars are the brightest objects in UV CMDs, while the RGB stars, that dominate the emission of GCs in the optical bands, are faint at these wavelengths. In addition, the high spatial resolution of *HST* minimizes problems associated with photometric blends and crowding in the high density cluster central regions. Thus *HST* UV CMDs are ideal for selecting BSS in GCs.

Given this, our main criterion for the selection of the BSS population is the position of stars in the (m_{255}, $m_{255} - U$) CMD (see Fig.1). To avoid incompleteness biases and contamination from TO and sub-giant stars, we adopt a magnitude threshold that is about one magnitude brighter than the TO point: m_{255} = 21.85. Using the BSS in common between the WFPC2 and the ACS Fronts of View (FoVs), we have transformed the BSS selection box from the UV plane into the optical plane. To avoid regions with very high risk of Galactic contamination, we have considered only stars with $(B - V) < 0.7$.

The final sample is of 153 BSS at $r < 110$": 114 are found in the WFPC2 dataset, and 39 in the complementary ACS sample.

3. The BSS Projected Radial Distribution

In order to study the radial distribution of BSS (or any other population) for detecting possible peculiarities, a reference population representative of normal cluster stars must be defined. In NGC 6388 the RGB population is affected by a significantly larger field contamination, with respect to the HB. On the other hand, the HB morphology is quite complex, the presence of a Blue Tail in such a metal-rich cluster is unusual, and the nature of Extreme HB (EHB) and Blue Hook stars (BHk) is still unclear. Instead, the HB red clump (RHB) is a common feature of similar metallicity GCs, it is bright and well defined both in the UV and in the optical CMDs, and it comprises the majority (80%) of the HB population. Moreover we have verified that RHB and RGB stars share the same radial distribution, suggesting that RHB stars are indeed representative of normal cluster populations. For all these reasons, we have chosen the RHB as the reference population for NGC 6388. In order to study the radial distribution of BSS, we counted the number of BSS and HB stars (N_{BSS} and N_{HB} respectively) in 6 concentric annuli and we have computed the normalized ratio (Ferraro et al 1993):

$$R_{\rm pop} = \frac{N_{\rm pop}/N_{\rm pop}^{\rm tot}}{L^{\rm samp}/L_{\rm tot}^{\rm samp}},$$

where pop=BSS, RHB, $N_{\rm pop}$ refers to statistically decontaminated number counts, and the luminosity in each annulus has been calculated by integrating the King model that best fits the observed surface density profile and by properly taking into account the incomplete spatial coverage of the outermost annulus. As expected from stellar evolution theory (Renzini & Fusi Pecci 1988), the radial trend of $R_{\rm RHB}$ is essentially constant with a value close to unity. On the contrary, the BSS radial distribution is clearly bimodal: as shown in Fig.2, $R_{\rm BSS}$ reaches a value of almost 2 at the center

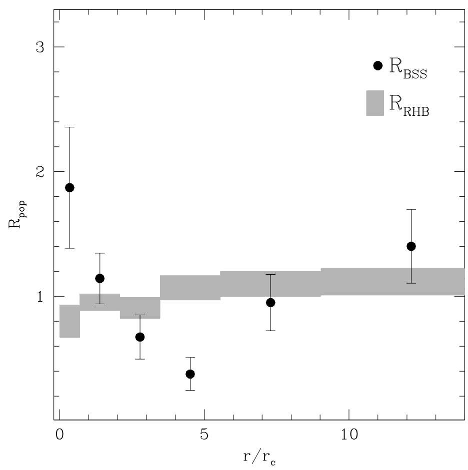

Fig. 2. Radial distribution of the BSS and the red HB double normalized ratios

$R_{\rm BSS}$ decreases to a minimun near $r = 5\,r_c$, and rises again at $r = 11\,r_c$. Such a bimodality is also shown by the BSS specific frequency F= N_{BSS}/N_{RHB}.

4. Discussion

We have compared the BSS specific frequency of NGC 6388, with that obtained for other GCs showing bimodal distributions. The observed minimum is closer (in physical units) to the cluster center than in any previously observed cluster. By equating the dynamical friction timescale ($t_{df} \propto \sigma^3/\rho$; e.g. also Mapelli et al. 2006) to the cluster age (assumed to be t = 12 Gyr), one can estimate the value of the radius of avoidance ($r_{\rm avoid}$). This is defined as the radius within which all the stars of $\sim 1.2\,M_{\odot}$ (the expected average mass for BSS) have already sunk to the core because of dynamical friction effects. By adopting $\sigma_0 = 18.9\,{\rm km\,s^{-1}}$ and $n_0 = 10^6$ stars ${\rm pc^{-3}}$ as central velocity dispersion and stellar density (Pryor & Meylan 1993), and by assuming the cluster structural parameters derived from the best-fit King model by Lanzoni et al. (2007), we have obtained $r_{\rm avoid} \simeq 15\,r_c$ for NGC 6388. This is about 3 times larger than the location of observed minimum ($\sim 5r_c$), thus suggesting that the dynamical friction has been less effective than expected in segregating the BSS in the core of this cluster.

For comparison in all the other ”bimodal” GCs studied in a similar way the position of $r_{\rm avoid}$ well corresponds to that of the observed minimum. NGC 6388 is thus the first case where the two distances do not coincide.

This result is quite puzzling and somehow suggests that NGC6388 appears “dynamically younger” than expected on the basis of its structural properties. In fact, our observations suggest that the dynamical friction in this cluster has been effective in segregating BSS (and similar massive objects) out to only 4–5 r_c, whereas the theoretical expectation indicates that, within 15 r_c, all stars with the mass of BSS or their binary progenitors should have already sunk to the center. Note that significantly larger (by a factor of 2) velocity dispersion, or lower (by a factor of 7) central density would be necessary to reconcile the expected and the observed minima. Why is dynamical friction less efficient in this cluster? Could the presence of an IMBH in the cluster center be important?

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