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HST multiband photometry of the globular cluster NGC 6388

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Abstract. We present color-magnitude diagrams (CMD) of the globular cluster NGC6388 based on HST multiband photometry (F255W, F335W, F439W, F555W). In this paper we focus our attention on the peculiar horizontal branch of this cluster. After a careful reddening correction, we fitted the observed CMD with theoretical models. For the first time we demonstrated that the HB of this very metal rich globular cluster extends beyond $T_e > 30.000$K, showing clear evidence of a population of blue hook (D'Cruz et al., 2000, Brown et al. 2001) stars. Moreover, we could demonstrate that the HB tilt (slope) is not a reddening effect, and is present in all the photometric bands.

Key words. color-magnitude diagram – HB stars

1. Introduction

In this work we present preliminary results of an HST project (GO8718, PI Piotto) aimed at the investigation of the properties of hot horizontal branch (HB) stars in a number of Galactic globular clusters (GGC), based on HST WFPC2 multiband photometry. Our first target was NGC 6388, a metal rich ([Fe/H]=-0.6) cluster with an anomalous HB. Despite its high metal content, this GGC has an extended blue HB (Rich et al. 1997), with a significant tilt in the V vs. B-V bands (Raimondo et al. 2002). The origin of both anomalies is not yet understood. In the present paper, we will show that the HB tilt is visible in all the photometric bands, and that it cannot be due to the strong reddening affecting this cluster. We will also show that the HB of NGC 6388 extends well beyond $T_e > 30.000$K, with a broad tail, likely populated by late-helium flashers.

2. Reduction and data analysis

The new NGC 6388 data presented in this paper represents an extension of the original F555W vs F439W-F555W color magnitude diagram (CMD) published by Piotto et al. (2002). In particular, within GO8718 we collected ultraviolet images for a total exposure of 1060s in the F336W and of 9200s in the F255W bands. Cosmic rays made difficult the analysis of F255W data, in particular the identification of the stars and the PSF profile computation. The data were reduced

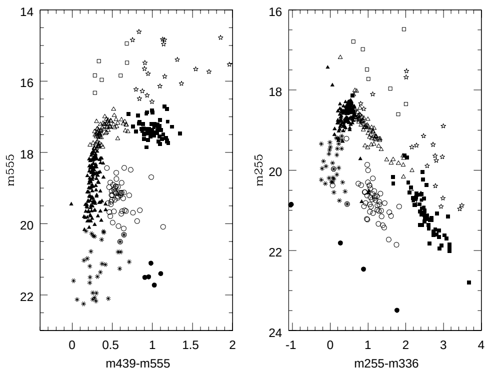

Fig. 1. Optical and far-UV CMDs of the HB of NGC 6388

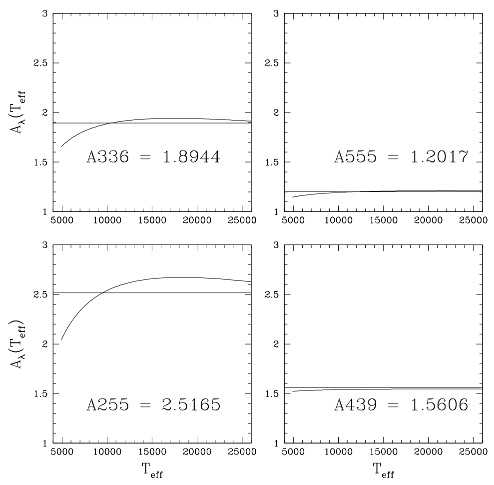

Fig. 2. The four panels shows the extinction coefficients as a function of the temperature for the 4 photometric bands used in the present work. The constant line shows the average Holtzman et al.(1995) coefficients for the same bands.

with DAOPHOT and ALLFRAMEII (Stetson, 1987, Stetson, 1994). The PSF fitting photometry was then calibrated to the WFPC2 flight photometric system following Dolphin (2000). The UV star list was finally cross-correlated with the F439W and F555W list of stars, and only the stars identified in all of the four bands have been used to construct the CMDs. An example of the CMDs using different bands is shown in Fig. 1, where different symbols show the same stars in the two panels. The CMD from the UV bands shows the entire HB plus the brightest blue stragglers (stars plotted as open circles).

Before comparing the observed CMDs with stellar evolutionary models, we need to apply the appropriate reddening correction. As it is well known, the reddening correction depends on the stellar temperature and the effect is more relevant for objects heavily reddened, and larger for bluer photometric bands. Therefore, we have determined the dependence of the reddening correction on the temperature by convolving the appropriate atmospheric models of Bessel et al. (1998) with the filter bandpass, and applying the extinction law of Scuderi et al.(1996). Fig.2 shows the size of the effect. For the filters F555W and F439W there is almost no difference with a constant reddening correction (we used the reddening values tabulated by Holtzman et al.(1995) for these bands); whereas for the bluer filters the difference is large, and becomes rather significant for the F255W band.

After the reddening correction, we tried to match the observational data with stellar evolutionary models for HB structures. In the present work, we adopt the models computed for a metallicity Z=0.006 and an initial He content equal to Y=0.23 (for more details on these models we refer to Zoccali et al. (1999)). Bolometric magnitudes and effective temperatures have been transformed into HST magnitudes according to the transformations provided by Origlia & Leitherer (2000), based on the atmosphere models computed by Bessel et al. (1998). From Harris (1996), we adopted [Fe/H]=-0.6, a distance modulus $(m-M)_{F555W}$=16.54, and a reddening E(F439W-F555W)=0.37.

In Fig. 3 we show the comparison between the observed CMDs and the models, adopting the quoted distance modulus. Despite the fact that we apply a temperature dependent absorption correction, it is not possible to fit the entire HB. In particular, while the models properly reproduce the lower envelope of the red part of the HB, it is not possible to fit the hot stars, which are always brighter than the theoretical track. This is a different way to see the well known problem of the tilted HB (Raimondo et al. 2002): as shown by Fig. 3, the HB presents a slope which cannot be reproduced by standard models. This anomalous tilt of the HB is present in all the bands, and cannot be an artifact of the reddening. Also the differential reddening can not account for it (see also the discussion in Raimondo et al. 2002. If we try to fit the hottest HB stars, the red HB would be fainter than predicted by the models. A slight HB slope is predicted by the canonical models (Raimondo et al. 2002), but it is much shallower than the observed one. Sweigart & Catelan (1998) showed that the observed slope could be reproduced assuming a large He abundance (Y=0.43). However, such an high helium content is not consistent with other cluster observable, like the position of the bump along the RGB (Riello et al., 2003) and also with the He abundance estimates based on the R parameter obtained by Zoccali et al. (1999). A comparison between the UV CMD and the models shows that the extended blue tail (EBT) of NGC 6388 reaches temperatures as high as $T_e = 31.500$ K (the hottest point in the models plotted in Fig. 4).

The far-UV diagram shows another interesting feature. Even if we force the models to fit the blue portion of the HB, the hottest stars appear significantly fainter than predicted by the models, and show a larger dispersion in temperature and/or luminosity.

A similar feature, called "blue hook", has been already observed in ω Cen (Moehler et al. 2002) and NGC 2808 (Brown et al. 2001). Brown et al. (2001) suggest that these stars in the final part of the HB tail might be late helium-flashers. The late helium flashers (D'Cruz et al., 2000 and

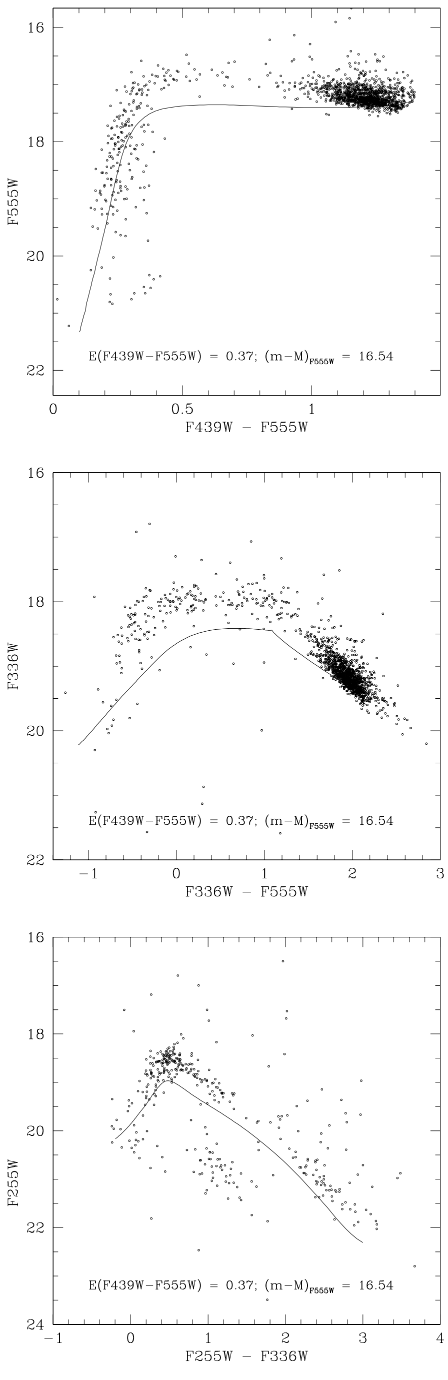

Fig. 3. Comparison of the observed CMDs with the models.

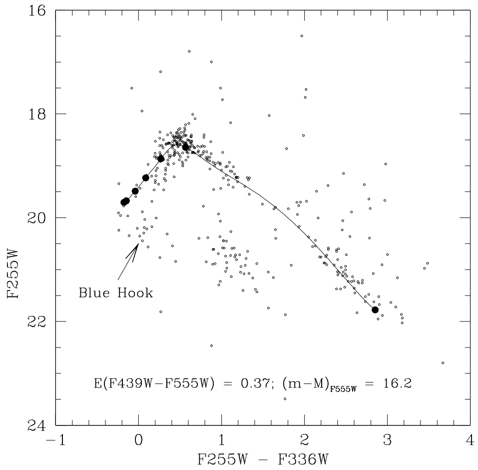

Fig. 4. (F255W vs. F255W-F336W CMD: the full circles represent different temperatures, with a step of 5000 K, from ~5000 to ~31500 K; the arrow shows the *Blue Hook* candidate stars.

Brown et al. 2001) are stars that experience the He Flash while descending the white dwarf cooling sequence and then undergo He-mixing, and may have surface abundance anomalies (Cassisi et al. 2003). This is the first time that late helium flashers are identified in such a metal-rich GGC.

3. Conclusions

The results of our analysis of HST multi-band photometry of NGC 6388 can be summarized as follows:

1. The HB tilt is not a reddening effect (at least not completely), and it is observed in all bands;
2. The Extended Blue Tail of this cluster reaches effective temperature greater than $T_e = 30000K$;
3. *Blue Hook* stars are observed also in a metal-rich GGC like NGC 6388.

Preliminary results of NGC 6441, the globular cluster *twin* of NGC 6388 (they have very similar reddening and metallicity) show that the two clusters present analogous features (both present the tilt and the Blue Hook stars). A more detailed investigation and a thoughtful comparison with theoretical models is still in progress.

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