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NEW CANDIDATE EHB STARS IN THE OPEN CLUSTER NGC 6791: LOOKING LOCALLY INTO THE UV-UPTURN PHENOMENON

L.M. Buson[1] E. Bertone[2] A. Buzzoni[3] and G. Carraro[4,5,6]

[1] *INAF - Osservatorio di Padova, Italy*

[2] *INAOE, Puebla, Mexico*

[3] *INAF - Osservatorio di Bologna, Italy*

[4] *Dept. de Astron. Univ. de Chile, Santiago. Chile*

[5] *Astronomy Dept., Yale Univ., USA*

[6] *Dip. di Astronomia, Univ. di Padova, Italy*

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Abstract. Relying on U,B imagery at the Italian Telescopio Nazionale Galileo (TNG), we report here the discovery of a sample of 13 new UV-bright post-HB candidate stars in the field of the galactic open cluster NGC 6791. Owing to its super-solar metal content ([Fe/H] $\gtrsim 0.2$ dex) and estimated age ($t \gtrsim 8$ Gyr), this cluster represents the nearest and ideal stellar aggregate to match the distinctive properties of the evolved stellar populations possibly ruling the UV-upturn phenomenon in elliptical galaxies and bulges of spirals.

Our ongoing spectroscopic follow-up of this unique UV-bright sample will allow us to assess – once cluster membership of the candidates is properly checked– the real nature (e.g. SdB, SdO, AGB-manqué or EHB stars) of these hot sources, and their link with the ultraviolet excess emerging from low-mass, metal-rich evolutionary environments of external galaxies.

Key words: stars: sudwarfs, stars: horizontal-branch, ultraviolet: stars

1. INTRODUCTION

Since its early discovery (Code 1969), the so-called UV-upturn phenomenon in old stellar populations of ellipticals and spiral bulges (namely the abrupt rise in the UV continuum emission shortward of $\lambda \sim 2,000$ Å) has been the subject of growing theoretical analyses intended to establish its origin and evolution (see e.g. Greggio & Renzini 1990 and O'Connell 1999, for a review).

Both theory and observations currently seem to converge towards the "Extreme Horizontal Branch" (EHB) scenario as the main responsible for the phenomenon (Dorman et al. 1995; Brown 2004). If this is the case, models show that hot HB stars with Helium core mass $M_{\rm core} \lesssim 0.52\ M_\odot$ can escape the standard Post-HB evolution (that would culminate with the planetary-nebula event at the end of the asymptotic giant branch evolution), and directly reach the high-temperature region of the H-R diagram ($T_{\rm eff} \gtrsim 30\,000$ K) to fade then along the white-dwarf cooling sequence (Dorman et al. 1993).

In this framework, the role of metallicity cannot yet be confidently assessed, however, as we face two conflicting scenarios relying either on a metal-poor evolution (naturally giving rise to a blue HB morphology, see Park & Lee 1997) or a metal-rich case, where the onset of UV emission needs at least a fraction of stars to exceed some critical threshold in [Fe/H] (Greggio & Renzini 1990; Bressan et al. 1994; Buzzoni 1995; Dorman et al. 1995). In this regard, one should be aware that even the high-resolution UV spectroscopy provided by FUSE for the UV-brightest elliptical NGC 1399 turned out to be inadequate to solve the problem, as it mainly probes the photospheric abundance of hot stars, likely perturbed by diffusion effects and therefore not fully indicative of the true metallicity of the whole galaxy stellar population (Brown et al. 2002).

2. NGC 6791: THE UNEXPECTED SHORTCUT

Photometric observations of evolved UV-bright stars in external galaxies are still confined to the relevant case of M31 and its satellite system (e.g. Bertola et al. 1995; Brown et al. 1998, 2000), and no suitable spectroscopy for single stars is available to date.

Surprisingly enough, the closeby Galactic open cluster NGC 6791, less than 5 kpc away (Friel 1995; Carraro et al. 1999), turned out to be a highly valuable candidate to address the issue of the EHB UV-bright stars, standing out as a sort of backyard "Rosetta Stone" to assess the UV emission of spheroids much farther away. This cluster is actually one of the brightest ($L_V \sim 6.3\,10^3\ L_\odot$), oldest ($t \gtrsim 8$ Gyr) and metal-rich ([Fe/H]$\gtrsim +0.2$) ones (King et al. 2005; Stetson et al. 2003; Carraro et al. 1999), and hosts a significant fraction of sdB/O stars (Kaluzny & Rucinski 1995; Kaluzny & Udalski 1992, see Fig. 1) interpreted by Yong et al. (2000) as EHB stars with $T_{\rm eff}$ in the range 24–32 000 K, as confirmed by ground and space-borne (UIT and HST) observations (Liebert et al. 1994; Landsman et al. 1998).

3. OBSERVATIONS AND REDUCTIONS

In 2003 we started a specific observing programme aiming at imaging a large field of NGC 6791 in the Johnson U,B wavebands with the LRS FOSC camera at the 3.5 m Italian Telescopio Nazionale Galileo (TNG) at La Palma. Taking advantage of its 0.275 arcsec/px scale and its wide (9.4×9.4 arcmin) field of view, this imager allowed us to carry out a suitable (16×16 arcmin) and accurate (± 0.01 mag) survey of the cluster region. Resulting CMDs, based on 330 sec B and 1200 sec U exposures, are shown in Fig. 2. Data have been reduced with IRAF packages CCDRED, DAOPHOT, ALLSTAR and PHOTCAL, making use of the point spread function method (Stetson 1987).

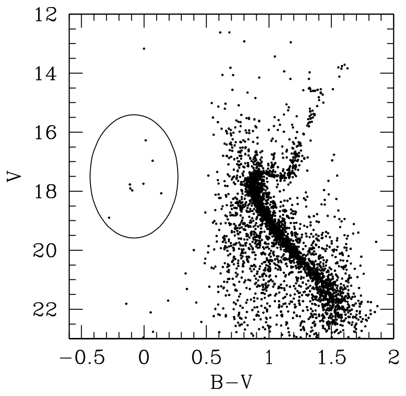

Fig. 1. The Kaluzny & Rucinski (1995) c-m diagram of NGC 6791, based on CCD photometry at the ESO 2.1m telescope (only best photometric sample plotted here). Yong et al. (2000) provided a good fit to these data with a ([Fe/H], t) = (0.33 dex, 8 Gyr) model, predicting however a red HB morphology clumped about $(B-V) \simeq 1.3$, and clearly missing the eight hot (supposedly EHB) stars singled out in the plot.

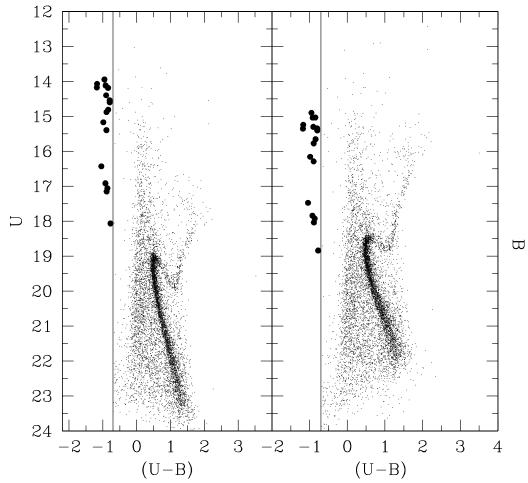

Fig. 2. Combined U vs. U–B and B vs. U–B diagrams of the field of NGC 6791 explored with TNG LRS. Big solid dots mark our 13 newly discovered UV-bright sources with (U–B) < −0.7 (vertical line) together with four objects (the clump about U∼ 17) including three member sdB and one sdO from the sample of faint blue stars by Kaluzny & Udalski (1992).

4. TOWARDS THE FUTURE

The analysis of Fig. 2 shows a cleanly detected sample of 13 new UV-bright objects, bluer than (U–B) < −0.7, and consistent with sdB/O stars, that sums up to the four EHB candidates (the clump of stars around $U \sim 17$) previously found in this color range by Kaluzny & Udalski (1992).*

Our current observational campaign, making use of several spectroscopic facilities at TNG and other telescopes, will provide us with both low- (∼ 10 Å FWHM) and mid- (∼ 6 Å) resolution spectra along the full optical range ($\lambda\lambda$ 3500—8000 Å) for these newly identified targets, assessing their cluster membership and, for those positive cases, allowing us to settle the effective temperature and surface gravity of each star by fitting the observed spectral energy distribution with the new

*Although about 2 mag brighter than the Kaluzny & Udalski (1992) candidates, our targets might still be consistent with an sdB/O classification, recalling the large spread in the bolometric correction to U and B magnitudes and the allowed temperature range compatible with the observed scatter in the (U–B) color (cf. e.g. Johnson 1966).

UVBLUE and BLUERED synthetic spectral libraries (Rodriguez-Merino et al. 2005; Bertone et al. 2003) of appropriate metallicity. Among others, such a complete sample of *bona fide* EHB stars will also provide a first reliable estimate of the lifetime and global UV energetic budget associated to the EHB evolution relying on the so-called "Fuel Consumption Theorem" of Renzini & Buzzoni (1986).

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