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Wide Field Optical Photometry of the Carina Dwarf Spheroidal Galaxy

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Abstract. We present optical photometry of the Carina Dwarf Spheroidal (dSph) Galaxy. Data have been collected with CCD mosaic cameras available at the 2.2m ESO/MPI and at the 4m CTIO Blanco telescopes. Our current (V,B-V) Color-Magnitude diagram (CMD) confirms the occurrence of an old (∼ 11 Gyr) and an intermediate-age (∼ 5 Gyr) population. Furthermore, we found evidence of a well-defined blue plume of young Main Sequence (MS) stars with an age at most of the order of ≃ 1 Gyr. The radial distributions of the stellar populations of different age appear to be different: the intermediate-age population is flatter and more centrally concentrated when compared with the old one. Moreover, star counts of the old stellar component are asimmetric along both the major and the minor axis. This feature might be the signature of a tidal interaction with the Galaxy.

Key words. Galaxies – local Group – Carina

1. Introduction

dSphs are the faintest and smallest galaxies in the Universe, but they are key stellar systems in modern cosmology. In fact, according to Cold Dark Matter (CDM) cosmological models they are the building blocks for larger stellar systems, via merging processes. The Galaxy has nine dSph companions, and the possibility to study these nearby objects offers the unique opportunity to constrain the quoted models. The typical high Mass-to-Light (MŁ) ratios (from a few to $\simeq 300 M_{\odot}/L_{\odot}$, Kleyna et al. 2001) seem to support that these objects are dark matter dominated. Moreover, accord-

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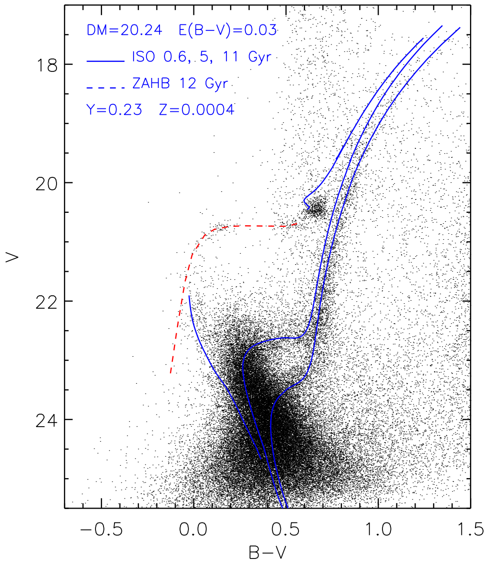

Fig. 1. CMD of the central region of Carina based on the 2.2m ESO/MPI telescope data. We superimposed seleted isochrones and a Zero Age Horizonthal Branch for the labeled distance modulus, chemical composition, and reddening.

ing to CDM models, dSphs should not have experienced any star formation (SF) event in recent epochs. This seems in agreement with the absence of both dust and gas together with the low internal velocity dispersion ($\equiv 10 km/s$, Moore et al. 1999). However, this prediction is at odds with observations, which demonstrate the complex and even recent SF episodes of some dSphs in the Local Group (LG). In this scenario Carina is an ideal laboratory, since it is the prototype of a dSph with a complex and bursting SFH. Moreover, it is not clear (Kuhn et al. 1996) whether it is experiencing a tidal interaction with the Galaxy.

2. Data and CMD

DSphs are uncrowded stellar systems, characterized by low surface brightness and low central density. Furthermore, nearby LG dSphs cover wide sky regions. Our observational strategy to sample a substantial fraction of the Carina stellar content is based on two wide field CCD cameras ($\simeq 34' \times 34'$). Time series data were collected with the 2.2m ESO/MPI and the 4m CTIO telescopes in January 2000 and January 2003. Standard IRAF NOAO mscred tasks have been applied for bias subtraction and flat field correction. Photometry was performed using DAOPHOTII/ALLSTAR (Stetson 1987,2.2m dataset) and DAOPHOTII/ALLFRAME (Stetson 1995,4m) packages. Figure 1 shows the CMD of the Carina central region according to the 2.2m dataset. We superimposed theoretical isochrones provided by the Pisa evolutionary group (Castellani et al. 2003). We adopted for He and metal abundances $Y = 0.23$, $Z = 0.0004$, a distance modulus DM=20.24, and a reddening E(B-V)=0.03. The bursting star formation history is evident, and we can nicely fit the two most important SF episodes with an old component (11 Gyr) and an intermediate age ($5-8$ Gyr) population. Interestingly enough, the RGB is very thin. This seems to support the idea that the spread in metallicity between the old and the intermediate age population is very small around the mean value of $[Fe/H] \simeq -1.7$. This finding seems in contrast with high resolution spectroscopic measurements. Tolstoy et al. (2003) obtained, on the basis of 5 giant star spectra, a mean value $< [Fe/H] > \simeq -1.6$ with a spread of $\delta[Fe/H] \simeq 0.5$ dex. The other striking feature disclosed by the diagram is the blue plume of relatively bright objects ($B - V \simeq 0, V \simeq 22$) which we interpret as a MS of young stars (≤ 1 Gyr). This conclusion is strenghtened by the detection of 15 Anomalous Cepheids (ACs). Even though the nature of these stars is still debated, one of the most popular interpretation (Fiorentino et al. 2003) suggests that they are evolved single stars with stellar masses of the order of $M \simeq 2M_{\odot}$.

3. Radial Distributions

According to empirical evidence (Mighell et al. 1997; Harbeck et al. 2001) it has been suggested that the old and the intermediate-age populations present different radial distri-

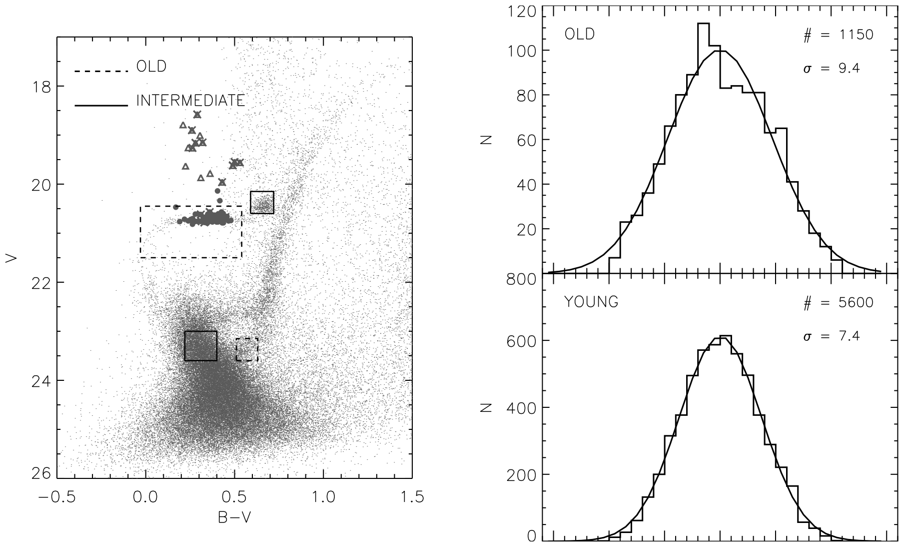

Fig. 2. Left panel: Selected sample of stars representative of both old and intermediate age populations. Right panel: The radial distribution of both sample projected on the major axis of Carina.

butions. To investigate such an occurence we selected two stellar samples representative of these two populations in different evolutionary phases (see Fig. 2, left panel). Thanks to the large database we collected it has been possible to select large samples of old (HB+ subgiant stars $\simeq$ 1000) and intermediate-age (Red Clump+ MS stars $\simeq$ 5000). Figure 2, right panel, shows the distribution of both samples projected onto the major axis of the galaxy. The old population distribution appears broader than the intermediate-age one; the former is also flatter and more centrally concentrated. This occurrence has been found in other dSphs (Stetson et al. 1998; Harbeck et al. 2001) and seems to be a general feature across the LG. Moreover, the distribution of old stars is asymmetric: the presence of a well-defined "shoulder" in the N-E direction may be the fingerprint of the tidal interaction with the Galaxy, according to numerical simulations (Johnston et al. 1999).

4. Outer Regions

The possibility of tidal interaction has been further investigated with the 4m CTIO telescope dataset. We selected an external field, offcentered by $\simeq 25'$ along tha major axis to investigate a region external to the tidal radius. The individal CMDs for each chip of the camera are shown in Fig. 3. The features of the diagram are similar among all the chips. There is evidence of the presence of old MS stars in all the panels. Nevertheless, the upper right one shows the farthest region from the center and it is beyond the Carina tidal radius. The blue faint stars are bona fide old MS stars of the galaxy, since the field contamination is negligible in this color range ($B-V \leq 0.4$) and these objects are too many to be background blue galaxies.

5. Conclusions

We investigated the stellar content of the Carina dSph galaxy. The wide field imager data allowed us to to confirm the presence of old and intermediate-age stars and to disclose a population ($\simeq$ 1 Gyr) of young objects. We found that stellar population of different ages show different radial distributions. There is evidence of tidal interaction with the Galaxy.

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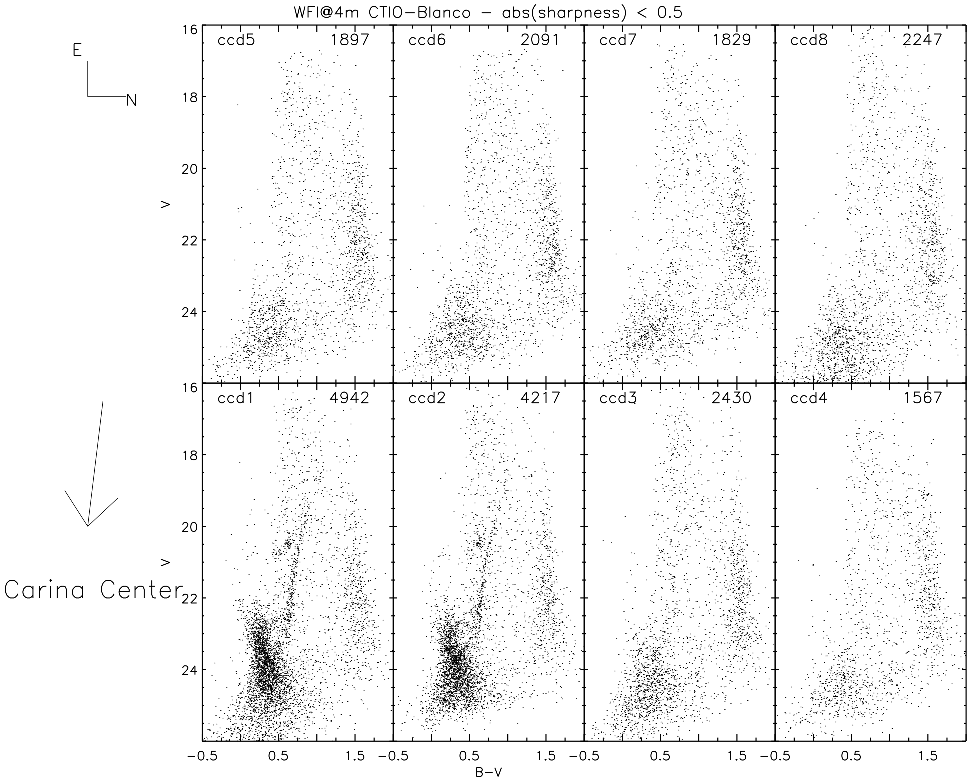

Fig. 3. CMD of the external field (25′ off-center). The panel labeled as ccd8 is beyond the Carina tidal radius. Data plotted in this panel show the occurrence of stars belonging to Carina. This supports the idea that Carina might be in tidal interaction with the Galaxy.

References

Castellani et al. 2003, in preparation
Fiorentino et al. 2003, this conference
Johnston, K. V. et al. 1999, MNRAS, 302, 771
Harbeck, D., et al. 2001, AJ, 122, 3092
Kleyna et al., 2001, ApJ, 563, 115
Kuhn, J. R. et al. 1996, ApJ, 469, 93
Mighell, K. J. 1997, AJ, 114, 1458
Moore, B. et al. P. 1999, ApJ, 524, L19
Stetson 1987, 99, 191
Stetson 1994, 106, 250
Stetson et al. 1998, PASP, 110, 533
Tolstoy et al. 2003, AJ, 125, 707