The Stellar Content of Local Group Galaxies
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Comparative Morphology of the HST[1] Color-Magnitude Diagram of the Nearby Blue Compact Dwarf Galaxy VII Zw 403 with that of Local Group Dwarfs

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Abstract. There are no examples of Blue Compact Dwarf (BCD) galaxies known within the Local Group (LG). Multicolor HST/WFPC2 observations of the nearby BCD VII Zw 403 (= UGC 6456) now resolve single stars with the quality (in terms of limiting magnitude and completeness) previously achieved for LG dwarfs from the ground. We use the M_I, $V-I$ color-magnitude diagrams (CMDs) of several LG dwarfs as templates to assess the stellar content and star-formation history (SFH) of the BCD VII Zw 403. This is the first BCD for which a clear spatial segregation of the resolved stellar content into a "core-halo" structure is detected: active star formation is observed in the central region of VII Zw 403, while in "Baade's red sheet", this young population is strikingly absent. If BCD halos are home to dominant ancient stellar populations, then the fossil record conflicts with delayed-formation scenarios for dwarfs. We present a sketch of the SFH in the core and halo of VII Zw 403.

1. Introduction

Blue Compact Dwarf galaxies are selected based on low luminosity ($M_B \geq -18$), a blue spectrum with narrow emission lines, and a small diameter ($\leq$1kpc) or small angular size (Thuan & Martin 1981). The stellar content and evolutionary history of BCDs have been a puzzle for some time. Searle & Sargent (1972), investigating two prototypical BCDs, posed the question of whether BCDs are young galaxies in the sense that most of their star-forming activity has taken place in recent times, or old galaxies in which star formation occurs in intense bursts separated by long quiescent intervals. A census of the intermediate-age

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and old stellar populations of BCDs bears not only on the question of the nature of BCDs, but also on the star formation histories of dwarf galaxies over a Hubble time.

VII Zw 403 is a type "iE" BCD in the classification of Loose & Thuan (1986). This is by far their most common type of BCD and considered characteristic of the BCD phenomenon. In iEs, the outer isophotes are elliptical, whereas the brightest star-forming regions are distributed somewhat irregularly in the vicinity of the center — although not at the exact center. This description is similar to that of the structural properties of early-type (dSph, dIrr/dSph) galaxies in the LG (see Mateo 1998). While VII Zw 403 exhibits a smooth, elliptical background sheet (see the *R*-band image of Hopp & Schulte-Ladbeck 1995) with an integrated color that fits well to that of an old, metal poor population (Schulte-Ladbeck & Hopp 1998), it also displays an H I mass ($\approx 8.5 \times 10^8$ $M_\odot$) and a present-day SFR ($\approx 6.4 \times 10^{-3}$ $M_\odot yr^{-1}$) that are typical of dIrrs (based on the distance of 4.8 Mpc derived from the tip-of-the-red-giant-branch (TRGB) method by Schulte-Ladbeck et al. 1998). The H II-region oxygen abundance of about 1/20 of solar (Martin 1997) is on the low side even for BCDs. A large-scale outflow of hot gas was detected in X-rays (Papaderos et al. 1994). VII Zw 403 is spatially very isolated, with no nearby massive neighbors that could act as obvious triggers of its present day star formation (Schulte-Ladbeck & Hopp 1998).

2. Results

The HST observations of VII Zw 403 and results for the star-forming center located in the PC chip are discussed in Schulte-Ladbeck et al. (1998). The combined CMD of all four WFPC2 chips was modeled by Lynds et al. (1998), who argue that star formation took place in the last 1 Gyr, with a strong burst at around 600 to 800 Myr.

In Fig. 1, we display the M_I, $V-I$ CMD of VII Zw 403. To derive the spatial variations in the stellar populations of this BCD, we first overplotted the WFPC2 footprint onto a digitized sky survey (DSS) image. The high-surface-brightness, inner regions of VII Zw 403 are encompassed almost entirely by the PC chip, whose dimension is $35'' \times 35''$, corresponding to an area of about 815×815 pc at the distance of this galaxy. The CMD of this area is shown in the left part of Fig. 1 and labeled "inner". The Holmberg diameter of VII Zw 403, $2a_H = 146''$ (Schulte-Ladbeck & Hopp 1998), translates into a linear diameter of 3.4 kpc. The WF chips, in their L-shaped configuration around the PC chip, were aligned such that the WF2 and WF4 chips fell along the galaxy's major axis. Some portions of these chips contained bright areas of the galaxy as seen on the DSS (but no obvious star-forming regions). Nevertheless, these parts were avoided in order to derive the CMD of the "outer" regions of VII Zw 403 in Fig. 1. The area included in the "outer" CMD is about 12.6 times that of the "inner" CMD.

The CMDs of the BCD VII Zw 403 show a stunning dichotomy similar to the "core-halo" structure observed in several dSph, dIrr, and "transition" dIrr/dSph galaxies of the LG (cf. Mateo 1998).

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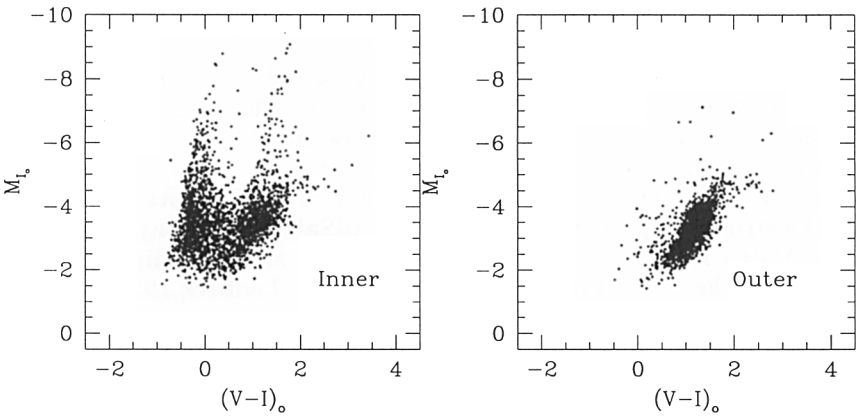

Figure 1. CMDs of different regions within the BCD VII Zw 403.

3. Discussion

VII Zw 403 is the first BCD resolved to faint enough limiting magnitudes to allow observation of the "red tangle", that feature in a CMD which potentially harbors the truly ancient population of a galaxy (Aparicio & Gallart 1994). We here proceed to use the M_I, $V-I$ CMDs of LG dwarfs as benchmarks against which we compare the CMD of VII Zw 403. In this way, we derive a sketch of the SFR vs. time for the inner and the outer regions of VII Zw 403, that may be compared with the SFHs of LG dwarfs depicted in Fig. 8 of Mateo (1998).

In its inner region, VII Zw 403 displays no Wolf-Rayet stars, but an abundance of main-sequence (MS) stars, blue supergiants and red supergiants, all stars of young age. A prominent asymptotic-giant branch (AGB) tail is very reminiscent of that which is observed in the CMD of the LG dIrr NGC 6822 (Gallart et al. 1994), heralding an intermediate-age population. There is a red giant branch (RGB) with a well defined tip, and the aforementioned red tangle, both indicators (but not proof) of an old stellar population. The only LG dIrr known to show a core-halo structure is WLM (Minitti & Zijlstra 1996).

In its outer region, the strong young stellar population is clearly absent. We do not see any MS stars down to a limiting magnitude of $V \approx 27$ or $M_V \approx -1.4$. This allows us to set a lower limit of about 1 Gyr on the age of this population, since stars younger than that would not have turned-off the main sequence. AGB stars and a prominent red tangle are instead the only features of this CMD, a situation very reminiscent of the outer regions of the LG dIrr/dSph Antlia (Aparicio et al. 1997). The metallicity of the halo derived from the RGB is [Fe/H]≈ -2. The RGB is fairly wide as compared to some dSphs and indicates a range of metallicities.

In Fig. 2, we summarize the comparison of the CMDs of VII Zw 403 with those of LG dwarfs in the form of a SFH vs. time cartoon. This is a preliminary sketch since we have not tried to calculate a normalization of the different stellar

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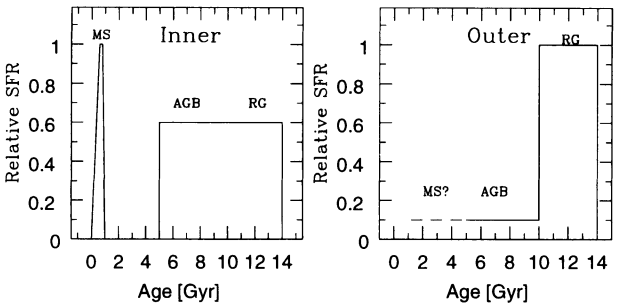

Figure 2. A cartoon of the SFH of VII Zw 403.

indicators with respect to one another, but rather follow the spirit of Mateo's (1998) Fig. 8.

4. Conclusions

VII Zw 403 is the first BCD with a pronounced core-halo structure in its resolved stellar populations. Since it belongs to the abundant iE structural type and since such BCDs are suspected to contain an old population in their red halos, we may speculate that star formation in many BCDs started at quite an early epoch. Hence most BCDs are likely to be old galaxies experiencing episodic star bursts over a Hubble time. The presence of an intermediate-age population in VII Zw 403 together with the extended outflow of hot gas detected in X-rays is of particular interest for models of dwarf-galaxy evolution. The faint-blue-excess galaxies or "boojums" (e.g. Babul & Ferguson 1996) formed stars at an epoch that corresponds to the intermediate-age population in our local, fossil record. However, in the case of VII Zw 403, evidence is accumulating for a much earlier, dominant star-forming event, in addition to star formation at the current epoch.

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