THE DIRECT DETECTION OF INDIVIDUAL OLD STARS IN THE MOST NEARBY BCD

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Abstract

We present HST/WFPC2 observations of the most nearby known BCD, VII ZW 403. The high spatial resolution of the data allow, for the first time, the direct detection of individual, old red giant stars in a BCD. VII Zw 403 is not a young galaxy.

1 Old stars in young galaxies?!

In 1972, Searle & Sargent [21] announced that two prototypical Blue Compact Dwarf Galaxies (BCDs), I Zw 18 and II Zw 40, were "the first metal-poor systems of Population I to be discovered". They posed the question whether or not BCDs are truly young galaxies, forming their first generation of stars at the current epoch, or old galaxies experiencing episodes of enhanced star-formation separated by long quiescent periods.

BCDs challenge models of galaxy formation to explain the presence of small, low-metallicity galaxies undergoing vigorous star formation. Are BCDs the result of primordial gas falling into small dark matter halos after the inter-galactic medium cooled sufficiently for the gas to collapse and form stars [1]? Are they rapidly evolving for $z < 1$, in which case they could account for the rapid evolution in the galaxy luminosity function necessary to explain the faint blue excess [22]? Are they by-products of interactions between massive galaxies [13]?

The unambiguous detection of old stellar populations in BCDs will provide insight into both the nature of these galaxies and their rôle in models of galaxy formation and evolution.

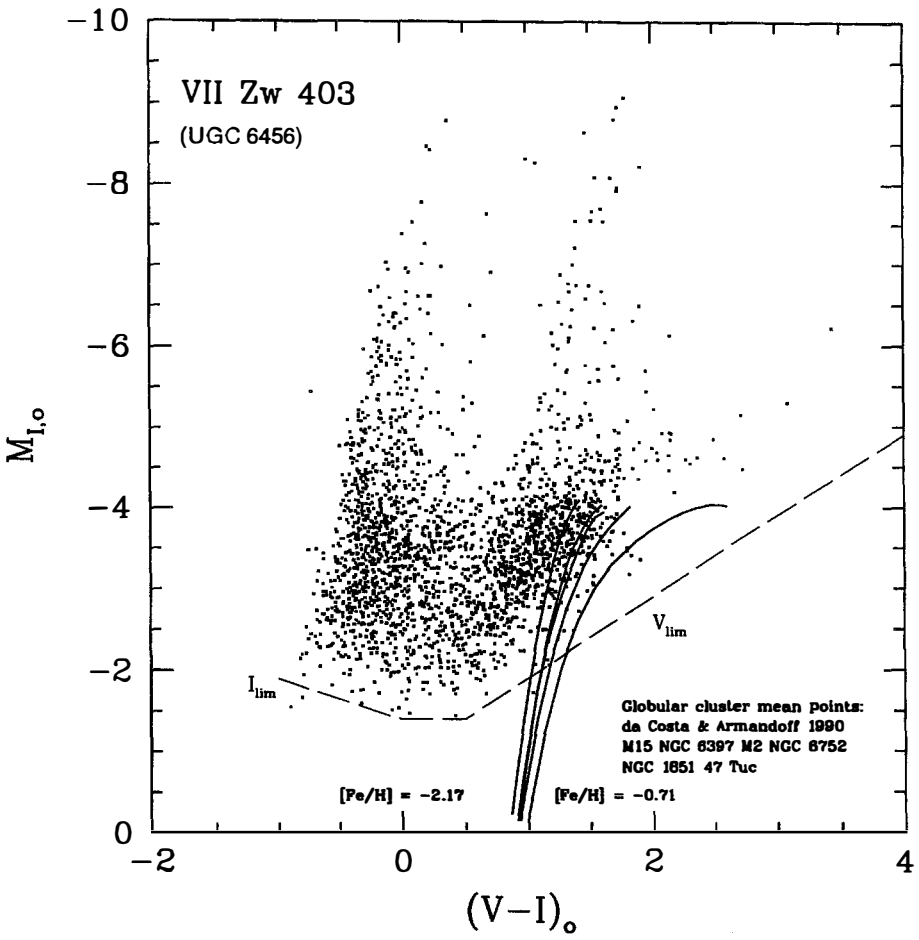

Figure 1: CMD of VII Zw 403, with empirical galactic globular cluster loci overlayed.

2 Detecting the old stellar population

An old galaxy must show evidence for the presence of an old stellar population. Because BCDs are generally too small and too distant to resolve into stars from the ground, studies of their stellar populations have been based on global galaxy colors and spectra. Thuan [25] reviewed several observations which, taken together, made him favor the old-galaxy hypothesis for BCDs. Spectral synthesis modeling of IUE spectra [8] indicates that the star-formation history of BCDs is best characterized by multiple, discrete star-forming episodes. Near-infrared photometry of BCDs may indicate an old population of red giants [24], however, CO indices suggest that the population detected in the infrared is frequently primarily composed of red supergiants from the current starburst [3]. [14], [10], [12] [18], and [23] studied the optical morphology of BCDs. The results suggest that many BCDs show more extended morphologies in red images than in blue images, with colors becoming redder with increasing distance from the starburst centers. These observations have been interpreted to indicate the presence "Baade's red sheet". However, recovering the mixture of stars in a galaxy from integrated light alone via evolutionary population synthesis modelling is subject to ambiguity and, at best, large uncertainties [5],[17].

Direct observations of old stellar populations in galaxies require them to be resolved into individual stars. Following Da Costa [6], there are three indicators for the presence of a Pop. II component in a galaxy: 1) The observation of a main-sequence turnoff whose absolute magnitude is comparable to that in a galactic globular cluster, 2) Presence of RR Lyr variables, 3) Observation of a well-defined horizontal branch of core-helium burning stars in a color-magnitude diagram (CMD). *All of the above Pop. II indicators are below the detection limit for even the most nearby known BCD.* There are two less definitive indicators, namely 4) The existence of star clusters which in all properties are comparable to those of galactic globular clusters and 5) The presence in the CMD of a red giant branch (RGB) with a well-defined tip.

We [20] have analyzed the CMD of the most nearby BCD catalogued [11], VII Zw 403. Only the superior spatial resolution of the HST made it possible to obtain the data displayed in Figure 1. Here, we use the data to infer the presence of an old stellar population in VII Zw 403, an isolated BCD with an HII-region metallicity of log(O/H)=-4.2 or about 1/20 of solar [15].

Previous indications that this nearby BCD might contain an old, underlying stellar population have come from its spectrum, integrated colors and morphology. We [9] published a ground-based CCD image of VII Zw 403 in the R-band. The galaxy clearly shows an elliptical background-light distribution; in the classification of [14], its morphology is that of the common, iE type BCD. The integrated color of the disk, B-R=1.16, fits well to the color of an old, metal-poor population in the population synthesis models of [19]. [4] presented a low-quality, optical spectrum of VII Zw 403, which nevertheless shows a continuum break in the area of the Ca H and K and the G-band absorption features, which they attributed to an old stellar population. We obtained a CCD, long-slit spectrum of VII Zw 403 and confirm the presence of Ca H & K, the G band, Hβ and possibly Mg I in absorption.

The CMD displayed in Fig. 1 very clearly shows that the resolved stars in VII Zw 403 contain a population of old, red giants. In [20], plate 1, this sheet of red giants is seen to permeate the entire PC image of the galaxy. The RGB of VII Zw 403 (the densely populated strip at V-I of about 1 in Fig. 1) has a well defined tip (near $M_{I,o}$=-4). This allows us to apply criterion 5) from Da Costa's list to infer the presence of an old stellar population. We overplot on Fig. 1 empirial, galactic globular cluster giant branches from [7]. They set a limit on the metallicity of the red giants in VII Zw 403, of [Fe/H] below -1.3 or Z<1/20 of solar. We also find that the distribution of faint, red stars on our CMD can best be described with the oldest (> 1 Gyr) and metal poorest of the Padua isochrones [2].

We can therefore derive the distance to this galaxy using the tip-of-the-red-giant-branch method, and we obtain d = 4.8 ($\pm$ 0.5) Mpc, and, together with the ground-based data of [9], a Holmberg diameter of about 3400 pc; the new H I mass becomes $8.5x10^8$ $M_\odot$.

A discussion of the young (main-sequence, blue and red supergiant) and the intermediate-age (asymptotic giant branch) stars was given in [20]. We add here the absence of Wolf-Rayet features in our long-slit spectrum indicating the absence of very young, Wolf-Rayet stars in VII Zw 403; this was confirmed independently during the workshop in private communication with both Martin and Izotov, who have unpublished, high signal-to-noise, optical spectra of HII regions in VII Zw 403. We also used an HST image in the Hα filter to estimate the present-day star-formation rate and derive a value of a few times 10^{-3} $M_\odot$/yr, in agreement with the value found by [16]. The star-formation rate per unit area in VII Zw 403 is typical of that of many dwarf Irregular galaxies. At this rate, VII Zw 403 has ample time before it exhausts its current gas supply. Future work will include a more detailed comparison of the single-star photometry of VII Zw 403 with its integrated colors. We are also in the process of obtaining near-IR CMDs with HST/NICMOS of another four nearby BCD from the list of [11].

3 Conclusions

We presented the direct detection of old stars in a BCD; HST single-star photometry of VII Zw 403 shows a red giant branch with a well defined tip that fits to a metal-poor, galactic globular cluster giant branch. We conclude that the metal-poor, gas-rich, star-forming dwarf VII Zw 403 is not a young galaxy.

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