# New Clues to the Nature of Blue Compact Dwarf Galaxies*

M. M. Crone[1], R. E. Schulte-Ladbeck[2], U. Hopp[3], L. Greggio[3,4]

[1] Skidmore College, Saratoga Springs, NY 12866, USA
[2] University of Pittsburgh, PA 15260, USA
[3] Universitätssternwarte München, München, FRG
[4] Osservatorio Astronomico di Bologna, Bologna, Italy

**Abstract**

Deep HST photometry of the Blue Compact Dwarf Galaxy UGCA 290 provides two clues to the nature of BCDs: an unusually small, compact population of red giants; and a recent star formation history which is remarkably similar to that of the classic, well-studied BCD VII Zw 403. Here we compare WFPC2 photometry of these two galaxies in $U$, $V$, $I$, and H$\alpha$, and discuss the implications of their similarities and differences.

## 1 Introduction

Blue Compact Dwarf Galaxies (BCDs) are unusual in that they demonstrate vigorous star formation in a low-metallicity system. Issues surrounding them include their candidacy for nearby "primeval" galaxies, their relationships to other nearby dwarfs and to the faint blue excess at intermediate redshift, and their use as laboratories for observing star formation in a low-metallicity, low-mass system.

Thus far, all BCDs resolved as deeply as the red giant branch (RGB) show star formation extending back to more than 1 Gyr ago, and a "gasping" mode of star formation (see the contribution by Schulte-Ladbeck in this volume). However, until recently all such galaxies were of one particular BCD subtype: type iE, in which an irregular star-forming region is embedded in a large, red elliptical background sheet.

The galaxy UGCA 290, which was identified as a BCD based on its compact, bright HII emission (Karachentsev & Makarov 1998), provides a nearby example of a BCD outside the iE subtype: its star forming region forms two large lobes which stretch across most of the visible galaxy. UGCA 290 is a fairly isolated member of the Canes Venatici Cloud. We observed this galaxy with the HST/WFPC2 as part of GO Program 8122, in the filters F336W, F555W, F814W, and F656N, which approximate $U$, $V$, $I$, and H$\alpha$. The first results of our photometry in $V$ and $I$ are described in Crone et al. 2000. Briefly, the color-magnitude diagram (CMD) in $V$ and $I$ reveals well-defined red and blue plumes and a low-metallicity red giant branch, indicating stars with a variety of ages, back to at least 1-2 Gyr. From the tip of the red giant branch we determine a distance of 6.7 Mpc; the absolute magnitudes we quote in these proceedings are based on that distance. Our primary discovery besides the existence of red giants was the similarity between the

*Based on observations made with the NASA/ESA Hubble Space Telescope obtained from the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA contract NAS 5-26555. We acknowledge financial support from NASA grant GO-08122.02-97A.

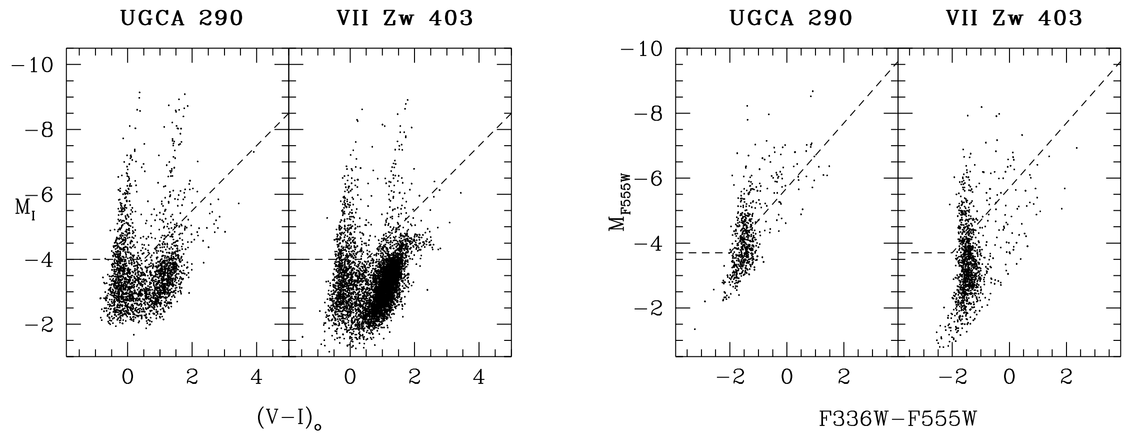


Figure 1: Comparison of the $V, I$ and F336W, F555W color-magnitude diagrams for the two galaxies UGCA 290 and VII Zw 403. We quantitatively compare the regions above the dashed lines.

$V - I, I$ CMD of UGCA 290 and that of the well-studied type-iE BCD VII Zw 403 (e.g. Lynds et al. 1998, Schulte-Ladbeck et al. 1999). Here, we follow up on this work with a more complete comparison of these two galaxies, including our observations in $U$ and H$\alpha$.

## 2 The Color-Magnitude Diagrams and Luminosity Functions

We quantitatively compare the stellar contents of UGCA 290 and VII Zw 403 using the two-dimensional Kolmogorov-Smirnov statistic (Peacock 1983) and their $I$-band luminosity functions.

Figure 1 shows the $(V - I)_o$, $M_I$ and F336W-F555W, $M_{F555W}$ CMDs. (We did not transform the F336W magnitudes to $U$ or attempt to correct for internal extinction because of the relatively large uncertainties involved.) We quantitatively compare the two galaxies by using the K-S test on the regions above the dashed lines. Within these regions completeness is $> 95\%$ and photometric errors are small ($< 0.09$ for $V$ and $I$, and $< 0.2$ for F336W). We normalized the K-S test results using bootstrap realizations of each observed CMD, and found that the K-S statistic varied slightly more for these distributions than expected from their x-y correlations (see Fasano & Franceschini 1987). We find that these regions of the $V, I$ CMDs, which stretch over nearly five magnitudes, are indistinguishable using the K-S test. Note that the fainter and redder section of the CMD for VII Zw 403 ($M_I > -5$, $(V - I)_o > 0.7$) is much more populated than for UGCA 290, because it includes the red giants and asymptotic giant branch stars which form its large elliptical background sheet. In contrast with the results for $V$ and $I$, the K-S test distinguishes the selected regions of the F336W, F555W CMDs at the 99% level, indicating different very young stellar populations, or at least, different degrees of completeness for the very young stars.

Figure 2 shows the $I$-band luminosity functions of the two galaxies, plotted as histograms in 0.5 magnitude bins in $M_I$. We fit each histogram to the function $\log N = \log N_o + \alpha M_I$, again limiting ourselves to magnitudes where our photometry is $> 95\%$ complete ($M_I < -4$ for the blue plume and $M_I < -5.5$ for the red plume). In all cases, this function provides a good fit, with a reduced chi-squared of less than 1.5. Note that, as expected from the K-S test results, the slopes for the two galaxies are consistent with each other.

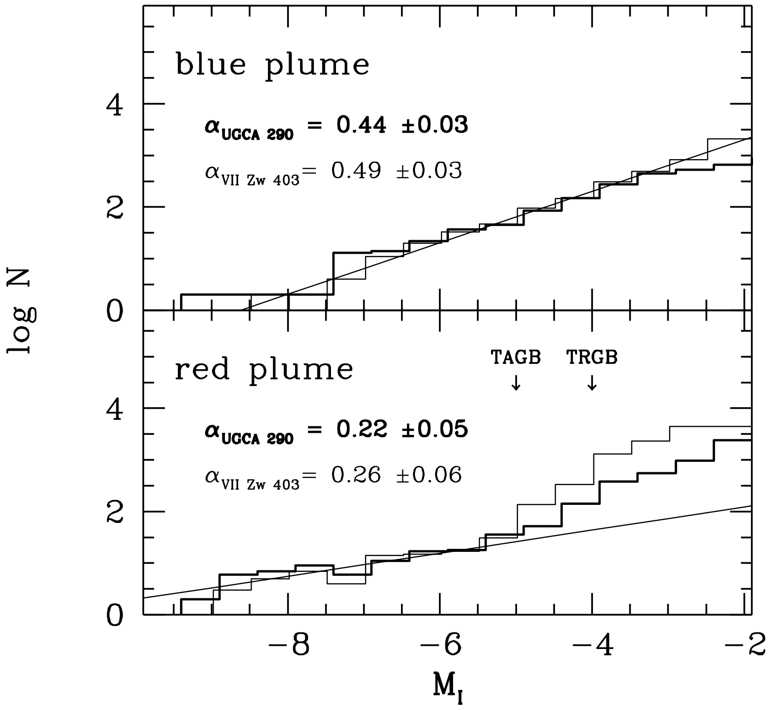


Figure 2: Comparison of the luminosity functions for UGCA 290 (bold lines) and VII Zw 403 (fine lines), including the results of power-law fits to the data. The color used to separate the "blue plume" from the "red plume" is $(V-I)_{\mathrm{o}}=0.7$. In the lower panel, downward arrows indicate the locations of the tip of the asymptotic giant branch (TAGB) and the tip of the red giant branch (TRGB). The histograms have been corrected for incompleteness.

## 3 H$\alpha$ Emission and Global Properties

In Crone et al. 2000, we showed that the spatial distributions of the resolved stars in these two galaxies are quite different: the young stars in VII Zw 403 concentrate near the center of an extended distribution of older stars, while the young stars in UGCA 290 scatter over nearly the entire visible galaxy. Here, we look at the spatial distribution of H$\alpha$ emission (Figure 3). It is clear that the emission for UGCA 290 is more diffuse and lacking in intense knots. The relative concentration of the H$\alpha$ emission in VII Zw 403 is even more obvious when one remembers that it is embedded in a distribution of older stars several times as large. The total H$\alpha$ luminosity for UGCA 290, assuming 1 mag of foreground extinction, is $L_\alpha = 1.2\text{x}10^{39}$ erg/s, about 60% of the value for VII Zw 403. These results support the picture that there is more current star formation in VII Zw 403, and that it is much more concentrated.

For our distance of 6.7 Mpc, the integrated apparent magnitude found by Makarova et al. (1998) corresponds to an absolute magnitude of $M_{\mathrm{B}} = -13.4$. At this magnitude, the effective surface brightnesses and scale lengths for different kinds of star-forming dwarfs overlap considerably, confounding an effort to classify UGCA 290 based on these quantities. The H$\alpha$ luminosity quoted above is slightly higher than typical for dIrrs at this $M_{\mathrm{B}}$ (Hopp 1999).

## 4 Conclusions and Implications

UGCA 290 is the first BCD outside of the iE subtype to be resolved into red giants, showing the presence of stars more than 1 Gyr old. In addition, its $V$, $I$ CMD is indistinguishable from that of the classic iE BCD VII Zw 403 over nearly five magnitudes, according to the two-dimensional

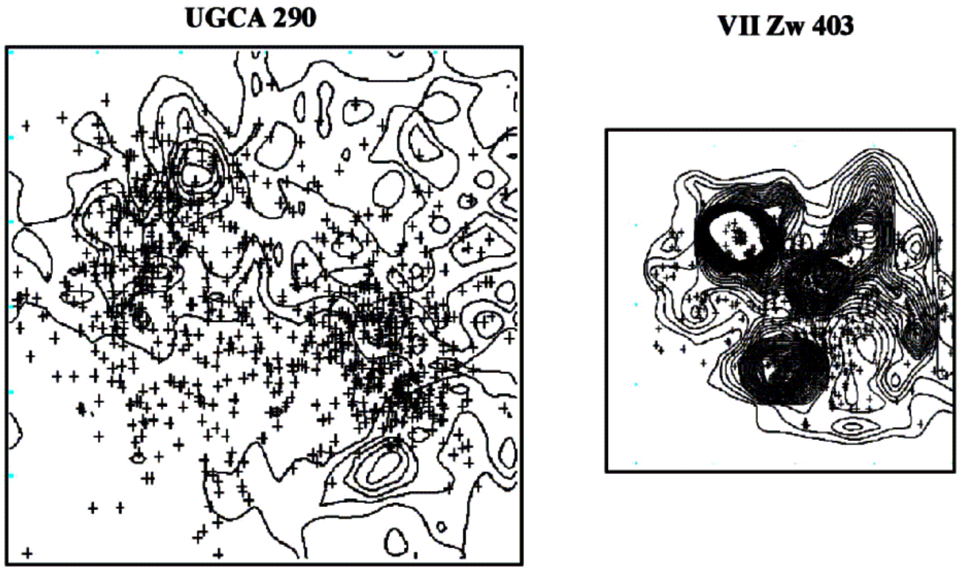


Figure 3: H$\alpha$ morphology from Planetary Camera data. The two images are set to the same physical scale; the field of view for UGCA 290 is about 1 kpc across. Isophotes are calculated from the H$\alpha$ images with point sources and background subtracted, smoothed on a scale of 50 pc. The faintest contour is 21 mag/arcsec$^2$. The brightest contour is 19.5 mag/arcsec$^2$ for UGCA 290 and 17.5 mag/arcsec$^2$ for VII Zw 403. Crosses indicate young stars, defined as having $M_{\rm F336W} < -4.5$.

K-S test and fits to its luminosity functions. At the same time, however, these two galaxies differ in terms of old stellar content, very young stellar content, and morphology.

We note that the scattered distribution of star formation in UGCA 290, together with its integrated values for $L_\alpha$ and $M_{\rm B}$, place its properties between BCDs and DIrrs, suggesting a continuum between these two types of galaxies.

The fact that such similar recent global SFHs are seen in UGCA 290 and VII Zw 403 despite obvious differences in stucture and earlier history, suggests the question: To what extent are their similarities caused by accidentally similar phases of a stochastic internal process, and to what extent are they caused by universal events? The answer to this question is fundamental to understanding the nature of the classification "Blue Compact Dwarf."

**References**

Crone, M.M., Schulte-Ladbeck, R.E., Hopp, U., & Greggio, L. 2000, ApJ, 545, L31
Fasano, G., & Franceschini, A., 1987, MNRAS, 225, 155
Hopp, U. 1999, A&AS, 134, 317
Karachentsev, I.D., & Makarov, D.I. 1998, A&A, 331, 891
Lynds, R., Tolstoy, E., O'Neil Jr., E.J., & Hunter, D.A. 1998, AJ, 116, 146
Makarova, L. Karachentsev, I., Takalo, L.O., Heinamaki, P., & Valtonen, M. 1998, A&AS, 128, 459
Peacock, J.A. 1983, MNRAS, 202, 615
Schulte-Ladbeck, R.E., Hopp, U., Crone, M.M., & Greggio, L. 1999, AJ, 525, 709