Mem. S.A.It. Suppl. Vol. 19, 146

Memorie della
Supplementi

The Blue Compact Dwarf Galaxy IZw18

I. Musella[1], M. Marconi[1], G. Fiorentino[2,3], G. Clementini[2], A. Aloisi[4], F. Annibali[5], R. Contreras[2], A. Saha[6], M. Tosi[2], and R. P. van der Marel[4]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Capodimonte, Vicolo Moiariello 11, I-80131 Napoli, Italy
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Bologna, Via Ranzani 1, I-40127 Bologna, Italy
[3] Kapteyn Astronomical Institute, University of Groningen, Postbus 800, 9700 AV Groningen, The Netherlands
[4] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; aloisi@stsci.edu
[5] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Padova, Vicolo dellOsservatorio 5, I-35122 Padova, Italy
[6] National Optical Astronomy Observatory, P.O. Box 26732, Tucson, AZ 85726 e-mail: ilaria.musella@oacn.inaf.it

Abstract. We present the results obtained for the Blue compact galaxy IZw18 on the basis of ACS HST data obtained from our group. In particular, we discuss the stellar population and the variable stars content of this galaxy to get information about its star formation history and distance.

Key words. galaxies: dwarf — galaxies: individual (IZw18) — galaxies: stellar content — stars: distances — stars:variables: Cepheids

1. Introduction

Nearby very metal poor galaxies are challenging objects because they can be regarded as chemically unevolved stellar systems and hence a local analog to primordial galaxies in the distant universe.

In this context, we have studied the Blue Compact Dwarf (BCD) galaxy IZw18, that is one of the most intriguing object in the nearby universe because its metallicity of $Z = 1/30 - 1/50\ Z_{\odot}$ (Skillman & Kennicutt 1993) that is one of the lowest nebular metallicity of all known star forming galaxies. It has an high gas fraction (e. g. van Zee et al. 1998) and an high star formation rate (Searle & Sargent 1972), producing a blue young stellar population that dominates the integrated luminosity and color. These two features both suggested that IZw18 might be undergoing its first episode of star formation. The detection of AGB stars in HST/WFPC2 photometry (Aloisi et al. 1999) showed that star formation must have started at least several hundred Myr ago, but the claimed absence of RGB stars in HST/ACS images (Izotov & Thuan 2004) seemed to put this value as an upper limit to the age of IZw18's stars. However, a better analysis of these HST ACS data by Momany et al.

Send offprint requests to: I. Musella

(2005) and Tosi et al. (2007) has shown, even if with large photometric errors, the evidence of an RGB and the possibility that the adopted distance was wrong.

On this basis, we carried out a new project (HST Cycle 14 - Program 10586, PI A. Aloisi) to obtain new V and I time-series photometry with HST ACS to allow the first detection and study of the IZw18's Cepheids stars to get an accurate determination of the distance of this galaxy. Moreover, by using this new data combined with the archival ones we have obtained a new deeper CMD.

As well known, Classical Cepheids are primary distance indicators playing a fundamental role in the calibration of the extragalactic distance scale. An important issue still under debate is the universality of the Cepheid Period-Luminosity (PL) relations, and, in turn, the possibility of applying a PL calibrated on the the Large Magellanic Cloud (LMC) sample to infer the distance of any galaxy containing Cepheids, independently of its chemical composition. In the last decade, many efforts have been devoted to investigate the dependence of the Cepheid properties on metallicity, since a metallicity effect could produce significant systematic errors in the evaluation of the extragalactic distance scale and in turn of H_0. However, no general consensus has been reached yet. On the theoretical side, linear non adiabatic models mostly suggest that a variation in chemical composition produces negligible effects on the PL relations (Chiosi, Wood, & Capitanio 1993; Alibert et al. 1999; Saio & Gautschy 1998; Sandage, Bell, & Tripicco 1999), while nonlinear convective pulsation models (Bono et al. 1999; Fiorentino et al. 2002; Marconi, Musella & Fiorentino 2005) predict a significant metallicity effect on the Cepheid instability strip (IS) topology and on the PL relation. In particular, metal-rich pulsators with periods longer than five days have fainter optical magnitudes than the metal-poor pulsators.

On the empirical side, several authors suggest that metal-rich Cepheids are, at fixed period, brighter than metal-poor ones (Kennicutt et al. 1998; Kanbur et al. 2003; Storm et al. 2004; Groenewegen et al. 2004; Sakai et al. 2004; Macri et al. 2006). Other empirical results that seem to support the nonlinear theoretical scenario were obtained by Romaniello et al. (2005, 2008), on the basis of spectroscopic [Fe/H] measurements for Galactic and Magellanic Cloud Cepheids. Using only their spectroscopic abundances for Galactic Cepheids with published distances, Romaniello et al. (2005) found that the metallicity correction is in qualitative agreement with our theoretical results.

However, very few investigations were devoted to Cepheids in the metal poor regime and the sample identified in IZw18 has offered a unique opportunity to perform a theoretical study of the properties of the most metal poor Cepheids known (Marconi et al. 2010).

In Sect. 2 we present the theoretical scenario we have developed to interpret the properties of IZw18 Cepheids. The CMD and its features are discussed in Sect. 3. The different independent methods used to determine the distance of the galaxy are discussed in Sect. 4 whereas in Sect. 5 we discuss the discovery of Ultra Long Period Cepheids in IZw18. Conclusions are summarized in Sect. 6

2. Pulsation models

We computed the nonlinear convective pulsational models for Z=0.0004, Y=0.24 and a mass range from 5 to 13 $M_\odot$ (Marconi et al. 2010), using the same pulsation code (see Bono et al. 1999, for details) adopted in our previous investigations of more metallic Cepheids (Bono et al. 1999; Fiorentino et al. 2002; Marconi, Musella & Fiorentino 2005). In Figs. 1 and 2 we report the IS and the theoretical PL relations, in the V and I bands, obtained for this chemical composition compared with previous predictions at higher metallicity for Magellanic and Galactic Cepheids. We found that the metallicity dependence of the IS and of the PL, PLC and Wesenheit relations of Classical Cepheids in the metal poor range ($Z \leq 0.004$) is negligible especially for periods longer than 10 days. On this basis, we can hypothesize a universality of the PL for metallicity lower than the LMC one. This is an im-

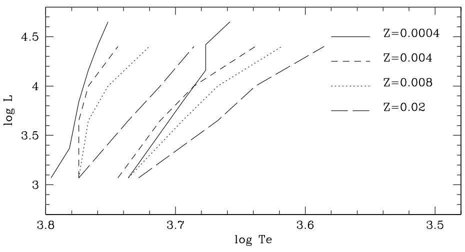

Fig. 1. Comparison between the theoretical IS obtained for $Z = 0.0004$ and results obtained by Bono et al. (1999) for $Z = 0.004$, $Z = 0.008$ and $Z = 0.02$.

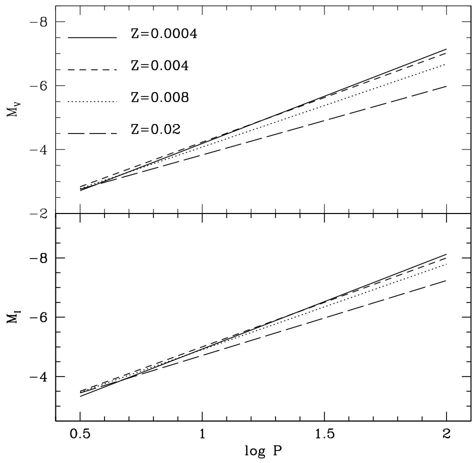

Fig. 2. Comparison between the theoretical PL relations in the V and I bands, and the relations corresponding to the chemical composition of Cepheids in the Magellanic Clouds, and in the Milky Way.

portant result because, at present, the Cepheid extragalactic distance scale is calibrated on the basis of metal rich ($Z > 0.02$) spiral galaxies with a non negligible and not well established metallicity effect.

3. Variable stars in the Color-Magnitude Diagram

Fig. 3 shows a CMD based on an accurate photometric investigation reaching about 1.5 mag below the Tip of the red giant branch (TRGB) that is another accurate distance indicator, independent of Cepheids.

Furthermore, the detection of the RGB indicates a much older stellar population (at least ∼2 Gyr old) than previously believed.

We have found a list of 34 candidate variables. Only for 5 of these (red triangles in Fig. 3) we obtain reliable light curves shown in Fig. 4. The first two pulsators (V4 and V7) are long period red variables, V6 (at $< I >= 26.38$ mag and $V - I = 0.63$ in the CMD) is a Classical Cepheid with P=8.71 d and the last two, V1 and V15 (P=130.3 and P=125 days, respectively), fall in the extension of the computed theoretical IS (red and blue lines in Fig. 3) to longer periods. We notice that the shape of the light curves of V1 and V15 is that of Classical Cepheid one, but at this low metallicity, evolution and pulsation models do not predict the existence of such ultra long period Cepheids.

We also note the lack of Cepheids with periods in the range 10-100 d. This is probably due to the starbursting nature of this galaxy that is very active in recent epochs but without a significant star formation in the epoch in which the "missing" Cepheids (stars with a mass from 6 to 20 $M_\odot$) should have formed (Aloisi et al. 2007).

Moreover, by using the evolutionary tracks by Fagotto et al. (1994) at $Z = 0.0004$ for a mass range from 4 to 60 $M_\odot$, we have found that V6 is best reproduced by a 6 $M_\odot$ model (green line in Fig. 3).

4. Distance of IZw18

To determine the distance of IZw18 we use two different independent methods. One based on the TRGB (Aloisi et al. 2007) and the other on the Classical Cepheids (Fiorentino et al. 2010; Marconi et al. 2010).

We obtain for the TRGB of our CMD a magnitude $< I >= 27.27 \pm 0.14$ mag, that compared with the TRGB absolute magnitude at the metallicity of IZw18 $M_{I,TRGB} = -4.03 \pm 0.10$ mag (Bellazzini et al. 2004), implies a distance modulus $(m-M)_0 = 31.30 \pm 0.17$ mag, i.e., $D = 18.2 \pm 1.5$ Mpc.

To determine the distance on the basis of Cepheids, we take into account the only

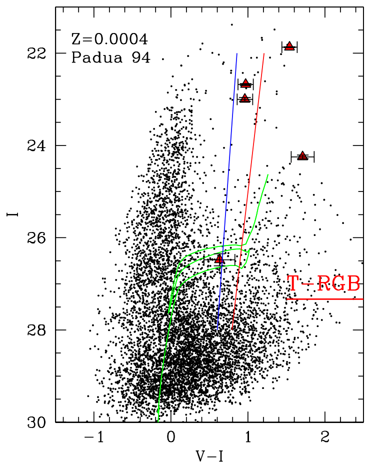

Fig. 3. $I, V - I$ CMD of IZw18 obtained in this project. Filled red triangles show the five confirmed variable stars detected in IZw18, which are plotted according to their intensity-averaged mean magnitudes and colors. The solid green line is the evolutionary tracks by Fagotto et al. (1994) that best fits the variable at $\langle I \rangle = 26.48$ mag and $\langle V - I \rangle = 0.63$ mag (star V6), and corresponds to a 6 $M_{\odot}$. Solid and dashed lines represent the theoretical boundaries of the Instability Strip (IS). The horizontal red line at $I = 27.33$ mag shows the location of IZw18 RGB Tip (TRGB), according to Aloisi et al. (2007) reddened value.

confirmed Classical Cepheid V6. As the PL is a statistical relation, to obtain a reliable distance, we prefer to rely on other methods. In particular we use the pulsational models obtained by our group and apply the theoretical Wesenheit relation and the light curve model fitting technique, already applied with success to both Galactic (Natale et al. 2008) and Magellanic Cepheids (Wood, Arnold & Sebo 1997; Bono, Catsellani & Marconi 2002; Keller & Wood 2002, 2006).

The application of the theoretical Wesenheit $W(V, I) = V - 2.54(V - I)$ to V6 (filled circle) is shown in Fig. 5 and provides a distance modulus $\mu_o = 31.4 \pm 0.4$ mag.

On the other hand, using the light curve model fitting techniques (Fig. 6), we obtain the best fit adopting a model with $M/M_{\odot} = 6.5$

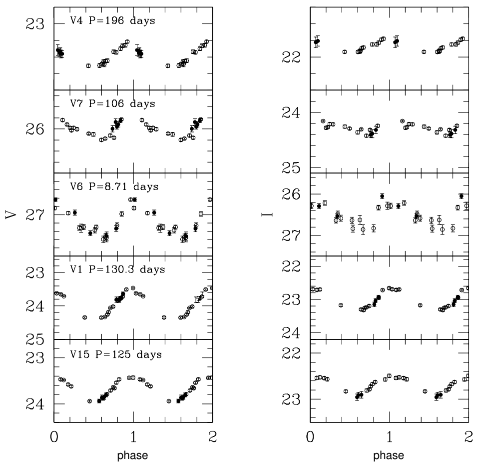

Fig. 4. V (left) and I (right) light curves of the confirmed variable stars in IZw18. The star's periods are indicated. Open and filled circles correspond to our 2007 proprietary data, and to the archival data, respectively.

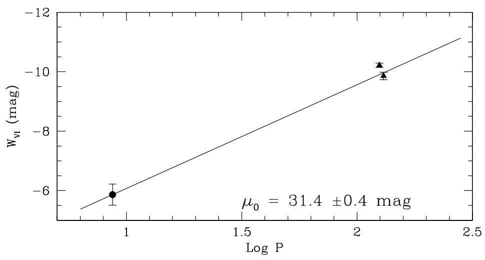

Fig. 5. Comparison between theoretical canonical Period-Wesenheit relations in the VI bands and data of the three Cepheids in IZw18. The distance moduli obtained from the application of this relation to the bona fide Classical Cepheid V6 (filled circle) is labelled.

and $logL/L_{\odot} = 3.68$ and using a distance modulus of 31.4 ± 0.1 mag.

Therefore, both distance determinations obtained by using the Classical Cepheid V6 are in very good agreement with the result obtained from the TRGB method and confirm that IZw18 is much further away than previously thought, and it is at least as old as about 2 Gyrs.

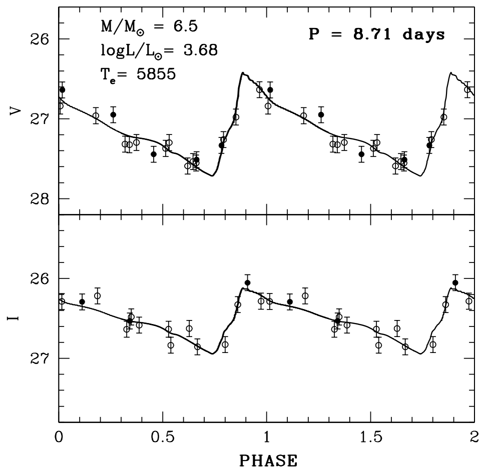

Fig. 6. Application of the theoretical model fitting to the *V, I* light curves of the Classical Cepheid V6. The black line represents the pulsational model best reproducing the observed light curves corresponding to the labelled stellar parameters. Symbols are the same as in Fig. 4

5. The Ultra long period Cepheids

To conclude, we discuss the properties of the two pulsators in IZw18 resembling the characteristics of the so called ultra long Cepheids (ULPs; see Bird et al. 2009, for details). ULPs have been recently identified in nearby star forming galaxies: LMC, SMC, NGC 6822, NGC 55, NGC 300 (see Figs. 3, 4 and 5 in Bird et al. 2009). Candidate ULPs in IZw18 are the most metal poor known so far. Their period is too long with respect to those predicted by evolution and pulsation models, but the shape of their light curve is the typical one of Classical Cepheids. As we can see in Bird et al. (2009) and in our Fig. 5, they lie on the extrapolation of the Classical Cepheid PL and Wesenheit relations to longer periods. We need to understand the nature of these pulsators because they could represent the "best standard candles" to extend the cosmic distance ladder to the 100Mpc and beyond (Bird et al. 2009). To this purpose, new observing time to TNG to follow-up these very long period variables has been awarded.

6. Conclusions

The new deeper HST photometry used in this work has revealed that the age of IZw18 is higher than previously believed. The CMD shows a well defined RGB and indicates that this galaxy has a stellar population older than 1 Gyr. Five pulsators, 2 red long period variables, 1 Classical Cepheid and 2 ULPs, have been detected.

We obtain several very accurate independent distance determinations using the TRGB and Classical Cepheids that are in very good agreement and give a mean distance of $\sim 18 \pm 1$ Mpc, longer than previously believed ($\sim$ 15 Mpc).

The new theoretical pulsational scenario presented for the Cepheids in IZw18 shows that the dependence on the chemical composition of Cepheid relations is negligible at metallicity lower than the LMC one.

The lack of Cepheids with periods from 10 to 100 days and the identification of only one pulsator at 8.71 days gives important information about the star formation history and about the starbursting nature of IZw18.

Finally, we have discussed the observational properties of the two detected ULPs and their role as possible distance indicators.

Acknowledgements. Financial support for this study was provided by COFIS ASI-INAF I/016/07/0. Support was also provided by NASA through grants associated with program GO-10586 from the Space Telescope Science Institute (STScI), which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555.

References

Alibert, Y., Baraffe, I., Hauschildt, P., Allard, F. 1999, A&A, 344, 551

Aloisi, A. Tosi, M, Greggio, L., 1999 AJ 118, 302

Aloisi, A., Clementini, G., Tosi, M. et al., 2007, ApJ 667, L151

Bellazzini, M., Ferraro, F. R., Sollima, A., Pancino, E., & Origlia, L., 2004, A&A, 424, 199

Bird, J.C., Stanek, K.Z., & Prieto, J.L., 2009, ApJ, 695, 874

Bono, G., Caputo, F., Castellani, V., Marconi, M. 1999, ApJ, 512, 711
Bono, G., Castellani, V., & Marconi, M. 2002, ApJ Letters, 565, 83
Chiosi, C., Wood, P. R., Capitanio, N. 1993, ApJS, 86, 541
Fagotto, F., Bressan, A., Bertelli, G., Chiosi, C., 1994, A&AS, 104, 365
Fiorentino, G., Caputo, F., Marconi, M., Musella, I. 2002, ApJ, 576, 402
Fiorentino, G., Contreras Ramos, R., Clementini, G. et al. 2010, ApJ, 711, 808
Groenewegen, M. A. T., Romaniello, M., Primas, F., Mottini, M. 2004, A&A, 420, 655
Kanbur, S. M., Ngeow, C., Nikolaev, S., Tanvir, N. R., Hendry, M. A. 2003, A&A, 411, 361
Keller, S.C., & Wood, P.R. 2002, ApJ, 642, 834
Keller, S.C., & Wood, P.R. 2006, ApJ, 578, 144
Kennicutt, R. C. Jr, et al. 1998, ApJ, 498, 181
Izotov,Y. I., & Thuan T. X., 2004, ApJ, 616, 768
Macri, L. M., Stanek, K. Z., Bersier, D., Greenhill, L. J., Reid, M. J. 2006, ApJ, 652, 1133
Marconi, M., Musella, I., Fiorentino, G. 2005, ApJ, 632, 590
Marconi, M., Musella, I., Fiorentino, G. et al., 2010, ApJ, 713, 615
Momany, Y., Held, E. V., Saviane, I. et al. 2005, A&A, 438, 111
Natale, G., Marconi, M., Bono, G., 2008, ApJ Letters 674, 93
Romaniello, M., Primas, F., Mottini, M. et al., 2005, A&A, 429, 37
Romaniello, M., Primas, F., Mottini, M. et al. 2008, A&A, 488, 731
Saio, H., Gautschy, A. 1998, ApJ, 498, 360
Sakai, S., Ferrarese, L., Kennicutt, R. C., Jr., Saha, A. 2004, ApJ, 608, 42
Sandage, A., Bell, R. A., Tripicco, M. J. 1999, ApJ, 522, 250
Searle, L., & Sargent, W. L. W., 1972, ApJ, 173, 25
Skillman, E. D., Kennicutt, R. C., 1993, ApJ, 411, 655
Storm, J., Carney, B. W., Gieren, W. P. et al., 2004, A&A, 415, 531
Tosi, M., Aloisi, A., Mack, J., & Maio, M., 2007, Proc. IAU Symp. 235, eds F. Combes & J. Palous, (Cambridge: Cambridge Univ. Press), 65
van Zee, L., Westpfahl, D., Haynes, M. P., & Salzer, J. J. 1998, AJ, 115, 1000
Wood, P. R., Arnold, A., Sebo, K. M., 1997, ApJ, 485, 25