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Very metal poor classical cepheids: the distance of IZw18

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Abstract. We have obtained deep multi-band (V, I) HST/ACS time-series photometry of the very metal-poor Blue Compact dwarf galaxy IZw18, with the aim of constraining the distance and the Star Formation History of this galaxy (see Aloisi et al. 2007). The time-series sequences allowed us to identify about thirty candidate variables in the galaxy, and to obtain well sampled light curves and reliable periods for three Classical Cepheids, with periods of 8.63, 124 and 130 days, respectively, and a long period variable, with possible period of 139 days. These data provide new insight into the properties of the Classical Cepheids at very low metallicity regime. We have applied to the IZw18 Cepheids theoretical Wesenheit (V, I) relations based on new pulsation models of Classical Cepheids specifically computed for the extremely low metallicity of this primordial galaxy (Z=0.0004, Y=0.24, Marconi et al. 2007 in preparation). As a result we obtain an estimate for the IZw18 mean distance modulus of 31.35 ± 0.26 mag, with canonical models, and of 31.09 ± 0.26 mag, with overluminous models. These distances, and the former in particular, are in very good agreement with the distance we infer from the galaxy Red Giant Branch Tip.

Key words. Blue Dwarf Galaxy: IZw18 — Distance Indicators: Classical Cepheids

1. Introduction

The Blue Compact Dwarf galaxy IZw18 has been a very intriguing object since the discovery by Searle, Sargent & Bagnuolo (1973, and references therein) more than thirty years ago of extremely low metallicity (1/50 $Z_{\odot}$), high gas content and very blue color, that both indicate the existence of gas and recent star formation. These two features suggested that IZw18 might be experiencing its first episode of star formation and thus represents the best local analogue of primordial galaxies in the distant Universe. Several HST studies by different authors have aimed to the com-

Send offprint requests to: G. Fiorentino prehension of the evolutionary state of IZw18, with rather discordant results. People from our team were the first to detected Asymptotic Giant Branch (AGB) stars in IZw18 (Aloisi, Greggio, Tosi 1999) and to demonstrate that the galaxy was as old as several hundreds Myr, at least, using WFPC2@HST data. Izotov & Thuan (2004) reached the conclusion that no red giant branch (RGB) stars are present in IZw18 based on ACS@HST observations of the galaxy. However, Momany et al (2005) and Tosi et al. (2006) re-reducing the same ACS data found different results, in particular they found evidence for the galaxy RGB tip, in their color magnitude diagrams (CMD) of IZw18, and thus suggested that the age of IZw18 is not so young as previously believed. Our new time-series ACS@HST data (HST program # 10586, PI: Aloisi) have permitted us to solve definitively the mystery on the age of IZw18, because we have been able for the first time to identify Classical Cepheids in IZw18, and thus constrain the galaxy distance. This distance turns out to be in very good agreement with an independent estimate based on the galaxy RGB Tip.

2. Observations and data reductions

F606W and F814W imaging of IZw18 was collected with the ACS/WFC on board of the HST in 12 different epochs properly spread over a 120 days time interval, from 2005 October to 2006 January (see Aloisi et al. 2007). One of the 12 visits failed for the F814W exposure and was subsequently repeated, thus providing us also an additional epoch for the F606W filter. The four exposures per filter of each epoch were corrected for geometric distortion and co-added by using the MultiDrizzle software, to produce single images per epoch per filter. The same procedure was applied to the archive F555W and F814W ACS/WFC images of the HST program # 9400 (PI Thuan), that had been taken in 2003 May-June, thus obtaining three and five additional images in the F814W and F555W filters, respectively. These additional data allowed us to enlarge the time interval spanned by our observations up to about three years,

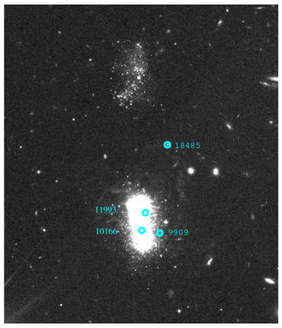

Fig. 1. Map of the four confirmed variable stars in IZw18.

and were particularly useful to pin down periods and to search for long period variability. The severe crowding of the IZw18 images, the demand of achieving the maximum possible depth in the color magnitude diagram (CMD), and the need of processing single epoch data to generate light curves for the candidate variables, made the photometric reduction very challenging and time-consuming, and the use of PSF-fitting photometry mandatory. To produce the galaxy CMD we have performed the photometry with the DAOPHOT/ALLSTAR package (Stetson 1987) on the master images of both new and archive photometry. To produce the single epoch photometry we used DAOPHOT/ALLSTAR/ALLFRAME (Stetson 1987, 1994). Calibration of all the photometry to the Johnson-Cousins V and I magnitudes was obtained using the procedure described in Sirianni et al. (2005, see Aloisi et al. 2007 for details).

2.1. Variable star identification and period search

We have used four different approaches to identify variable sources in IZw18 and to distinguish bona-fide variable objects from false detections. In the following, we describe briefly these various techniques, their results, and the period search procedures we used to establish periodicities for the confirmed variable stars.

In a first attempt we applied to our dataset the Optical Image Subtraction Technique and

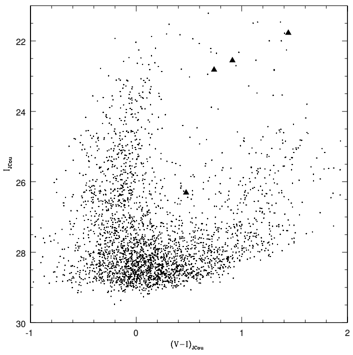

Fig. 2. CMD of IZw18 in the Johnson-Cousin photometric system, *V* and *I* are dereddened magnitudes, usually named V_0 and I_0. Dots represent the mean magnitudes obtained by weighting over the star pulsation cycle.

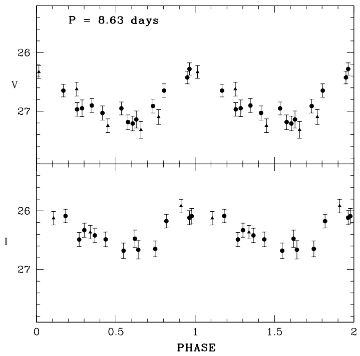

Fig. 3. *V* and *I* light curves for the P=8.63 days Cepheid.

the package ISIS 2.2 (Alard, 2000). This method identifies variable sources by direct comparison of the time-sequence of images, and is very powerful to detect variables in very crowded stellar systems such as the main body of IZw18. With this approach we obtained a map of candidate variables and the differential fluxes per individual epoch produced by the ISIS PSF-fitting algorithm, on which to perform the period search. However, the undersampling of the ACS/WFC images revealed a very challenging issue for ISIS. The number of sources flagged as candidate variables was extraordinary large, making the check of the individual time-series extremely time-consuming and difficult working in differential flux. Moreover, inspection of the images revealed that ISIS had very often failed to distinguish real stars from spurious sources, blended objects, galaxies and background noise.

We then performed PSF-fitting photometry of the image sequence with DAOPHOT/ALLSTAR/ALLFRAME. With the help of the Stetson (see Turner, A. 1997) manual for ACS data reduction, and choosing with great care the PSF reference stars, we were able to obtain reliable single epoch photometry for more than 2000 sources resolving stars down to a limiting magnitude of about $V \sim 29.5$ mag. We then used an output of ALLFRAME, the Welch-Stetson index (Welch & Stetson 1993), to flag the candidate variable stars in the catalogue of measured sources returned by ALLFRAME. They were definitely less in number than found with ISIS. This second approach, allowing to build light curves for the candidate variables in magnitude scale, made also the check of the candidates much more easy and straightforward than working with the differential flux light curves of ISIS, where we lack instead information on the actual amplitude of the light variation. The match between lists obtained with the two different approaches returned only a few candidates in common. Several of the candidate variables found only by the Image Subtraction Technique were also re-analyzed using their appropriate luminosities in magnitude scale.

As a third approach PSF-fitting photometry of the single epoch data was performed with DoPHOT (Schechter, Mateo & Saha 1993) and we used the package procedures, as discussed in Saha & Hoessel (1990), to search for periodic variables.

Finally, identification of candidate sources was also performed by visual inspection of the χ^2 image by one of us (A.S.). In this approach each pixel is the χ^2 value calculated from the corresponding pixels in the co-registered target images at all epochs. The four procedures returned a catalogue of about 30 bona-fide candidate variable sources. Period search for the candidate variables was performed using two

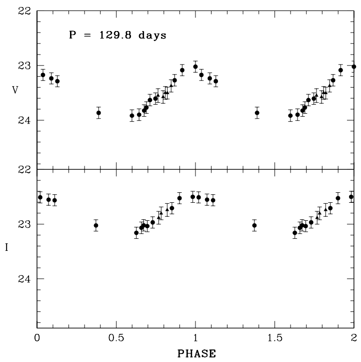

Fig. 4. Same as in Fig. 3 for the P=125 days Cepheid.

independent programs. The Period Dispersion Minimization (PDM) algorithm within IRAF, was used to derive a first guess of the period, by making a quick search over a large interval ranging from 2-3 days to about 200 days. Period refinement was then obtained with GRaTiS (Graphical Analyzer of Time Series) a private software developed at the Bologna Observatory (see e.g. Clementini et al. 2000) which also allowed us to work on the combined F606W and the F555W dataset. We obtained well sampled light curves and were able to derive reliable periodicities for 4 variable stars, three Classical Cepheids, with periods of 8.63 (Fig. 3), 124 (Fig. 4) and 130 days, respectively, and a long period variable with possible period of 139 days.

3. Confirmed variable stars

Results from the analysis of the 4 confirmed variables are summarized in Table 1, where we provide for each star the ALLFRAME identification number, the period, and the intensity-averaged mean magnitudes and colors in the *V* and *I* bands of the Johnson-Cousin photometric system. Fig. 1 and 2 show the location of the four confirmed variable stars over the map and the CMD of IZw18. The filled circles in Fig. 2 represent the intensity-averaged mean magnitudes obtained by weighting over the star pulsation cycle and, with the only exception of the red variable with the longer period, suggest the existence of a narrow Instability Strip (Fiorentino et al. 2007, in preparation).

4. Theoretical models vs observations

Using the nonlinear, nonlocal, time dependent convective pulsation code, described in Bono, Marconi & Stellingwerf (1999 and references therein), we have computed new theoretical models for the low metal abundance of IZw18: Z=0.0004 (Y=0.24). The new models are extensively discussed in a forthcoming paper (Marconi et al. 2007, in preparation) and will allow us to constrain the metallicity dependence of the Cepheid period luminosity (PL) relation in the low metallicity regime (Z from 0.0004 to 0.008). By applying the theoretical PL, Period-Luminosity-Color (PLC), and Wesenheit (WPL) relations, based on these models, to the Classical Cepheids in IZw18, we should be able to constrain the galaxy distance modulus. However, the small number of Cepheids identified in IZw18, does not allow us to use PL relations, which are known to provide reliable results only when applied to statistically significant samples of Cepheids, while we can rely on pulsation relations that can be applied to individual Cepheids, such as the PLC and the WPL (Madore 1982). In particular the latter has the advantage of being reddening-free by definition (see Madore 1982, Caputo, Marconi, Musella 2000 for details).

By applying to the three bona-fide Classical Cepheids the new reddening free theoretical WPL relations (see Table 2) obtained using both canonical and non-canonical (overluminous by about 0.25 dex) assumptions on the evolutionary Mass-Luminosity relations (see Bono, Marconi & Stellingwerf 1999, Caputo et al. 2005 for details) and reported in Table 2, we obtain two estimates for the mean distance modulus: $<\mu_0>_C$=31.35±0.26 derived with canonical models, and $<\mu_0>_{NC}$=31.09±0.26 derived with non canonical models.

Table 1. Cepheid candidates.

ID	P (day)	V_{JC}(mag) (mag)	I_{JC}(mag) (mag)	$(V-I)_{JC}$(mag) (mag)
9909	8.63	26.78	26.31	0.47
18485	125.0	23.47	22.56	0.91
11993	130.0	23.56	22.81	0.74
10166	139.0	23.21	21.77	1.44

Table 2. Canonical and non canonical Weseheneit relations derived from the new theoretical models for Z=0.0004 and Y=0.24. M_I-1.54(M_V-M_I)=$\alpha + \beta$ logP.

models	α	β	σ
canonical	-2.64±0.12	-3.44±0.06	0.12
non canonical	-2.62±0.13	-3.30±0.09	0.13

5. Summary and conclusions

We have identified and derived periods for four variable stars in the blue compact dwarf galaxy IZw18, based on time series images of the galaxy obtained with the ACS@HST. With the only exception of the reddest and brightest object, we classified the identified variable sources as Classical Cepheids and estimated the distance to IZw18 using theoretical W(V, I) relations specifically computed for the very low metal abundance of the galaxy. These relations provide an average distance modulus of 31.35 ±0.26 mag adopting a canonical ML relation and of 31.09 ±0.26 mag when an increase in the luminosity of 0.25 dex is assumed for each mass.

These results indicate that IZw18 is much further away than previously thought, thus supporting the early suggestion by Aloisi et al. (1999) that IZw18 is at least 2 Gyrs old. Moreover our distance estimates are consistent within the errors (almost coincident in the case of canonical models) with the value (31.39 ± 0.20 mag.) obtained by means of a totally independent distance indicator, namely the RGB tip (see Aloisi et al. 2007).

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