Mem. S.A.It. Vol. 86, 294

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The star formation history of the BCD I Zw 18

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Abstract. With its extremely low metallicity (∼1/50 solar), blue colors, and high gas content, the blue compact dwarf (BCD) I Zw 18 has often been indicated as the best candidate for a truly "primordial" galaxy in the nearby Universe. Nevertheless, recent studies from our group based on deep HST/ACS data have demonstrated the presence of red giant branch stars in this system, implying that star formation was active at least 1 Gyr ago, and possibly back to a Hubble time. At the light of these results, two possibilities remain open to explain the low metallicity observed in this system, i.e. a) for the majority of the galaxy' s life the star formation rate was very low and thus the chemical enrichment was inefficient, or b) strong galactic winds were able to remove the metals. Deriving the star formation history (SFH) of IZw18 is a fundamental step to answer these questions and to provide constraints on chemical evolution and hydrodynamical models of metal-poor galaxies. Here we present our new results on the SFH of I Zw 18 based on the method of the synthetic color magnitude diagrams.

Key words. galaxies: dwarf — galaxies: individual (I Zw 18) —galaxies: irregular — galaxies: resolved stellar populations —galaxies: starburst

1. Introduction

The blue compact dwarf (BCD) galaxy I Zw 18 is one of the most intriguing objects in the local Universe and has fascinated generations of astronomers since its discovery (Zwicky 1966). With a metallicity between 1/30 and 1/50 $Z_{\odot}$ (e.g., Pagel et al. 1992; Skillman & Kennicutt 1993; Izotov & Thuan 1998) it holds the record of the second lowest metallicity and lowest helium content measured in a star-forming galaxy. I Zw 18 is also full of gas (Lequeux & Viallefond 1980; van Zee et al. 1998) and shows very blue colors, $U - B = -0.88$ and $B - V = -0.03$ (van Zee et al. 1998), suggesting the presence of a very young stellar population. All these observational characteristics make I Zw 18 resemble a primeval galaxy in the nearby Universe. In fact, soon after its discovery, the question arose whether I Zw 18 is so metal poor because a) it started forming stars only recently, or b) because its star formation (SF) activity, although occurring over a long period of time, has proceeded at a rate too low for an efficient chemical enrichment, or c) because strong galactic winds have removed from the system most of the metals. The nature of I Zw 18 has important cosmological implications. If indeed some BCDs turned out to be young galaxies, their existence would support the view that SF in low-mass systems has been inhibited till the present epoch (e.g., Babul & Rees 1992). On the other hand, the lack of such primordial systems would provide strong constraints on chemical evolution and hydrodynamical models of metal-poor galaxies, e.g., on their SF regime (continuous or bursting?) or the onset of a galactic wind.

With the advent of the Hubble Space Telescope (HST), it has been possible to resolve the individual stars in I Zw 18 and thus to characterize its evolutionary status. Using deep Advanced Camera for Surveys (ACS) data, Izotov & Thuan (2004) concluded that the galaxy is at most 500 Myr old because of the lack of red giant branch (RGB) stars. However, both Momany et al. (2005) and Tosi et al. (2007), from independent reanalyses of the same ACS data set, suggested that I Zw 18 should be older than at least 1-2 Gyr, since it does appear to contain also RGB stars. In order to shed light on the situation, we acquired in 2006 new time-series HST/ACS photometry to study Cepheid stars in I Zw 18 and pin down its distance (GO 10586, PI Aloisi). By combining the new data with archival ones, we both identified the RGB tip (TRGB) at I_0 = 27.27 ± 0.14 mag ($D = 18.2 \pm 1.5$ Mpc, Aloisi et al. 2007), and detected for the first time a few Cepheids whose light curves allowed us to independently derive the distance to a couple Mpc accuracy (D= 19.0 ± 0.9 Mpc, Fiorentino et al. 2010; Marconi et al. 2010). The detection of RGB stars in I Zw 18 implies that it has started forming stars at least ~1 Gyr ago, and possibly at epochs as old as a Hubble time. Here we present the entire star formation history (SFH) of I Zw 18 based on the synthetic CMD method.

2. Color-magnitude diagrams

Observations and data reduction have been extensively described in previous papers (Aloisi et al. 2007; Fiorentino et al. 2010; Contreras Ramos et al. 2011). We acquired imaging with the ACS/WFC in F606W (~broad V) and F814W (~I), for total integration times of ≈ 27,700 s and ≈ 26,200 s. The single exposures were co-added using the software package MULTIDRIZZLE (Koekemoer et al. 2003), in order to obtain 2 deep images in F606W and F814W, respectively. We also retrieved and combined archival ACS/WFC data in F555W (~V) and F814W (GO program 9400, PI Thuan) into two deep master images with total integration times of ≈ 43,500 s and ≈ 24,300 s, respectively. PSF-fitting photometry was performed with DAOPHOT (Stetson 1987) in IRAF for both the archival and proprietary datasets. Artificial star experiments were performed on the original frames following the same reduction procedure as for the real data.

The I, V−I color-magnitude diagrams (CMDs) are shown in Fig. 1. To account for the highly variable crowding within I Zw 18, we selected five regions (A, B, C in the main body, D and E in the secondary body): region A is the most crowded one while region C and D are the least crowded ones.

3. Star formation history

We derived the SFH of I Zw 18 through comparison of the observed CMDs with synthetic ones. Our procedure consists of two separate steps: 1) the definition of the so called *basis functions* (i.e. simple star formation episodes of fixed duration) from the combination of the adopted stellar evolution models with the photometric properties of the examined region, and 2) the statistical analysis for the identification of the best SFH and relative uncertainties. The basis functions were created following the approach initially described in Tosi et al. (1991), and adopting the last version of the code by Angeretti et al. (2005). We adopted the Padova models with $Z = 0.0004$ (Fagotto et al. 1994), a Salpter' s IMF (Salpeter 1955), and a distance modulus of $(m - M_0) = 31.3$ derived by Aloisi et al. (2007). Photometric errors and incompleteness were implemented into the basis functions using the results of the artificial star experiments. Then, the SFH was derived through a statistical approach with the code SFHMATRIX (Grocholski et al. 2012). In

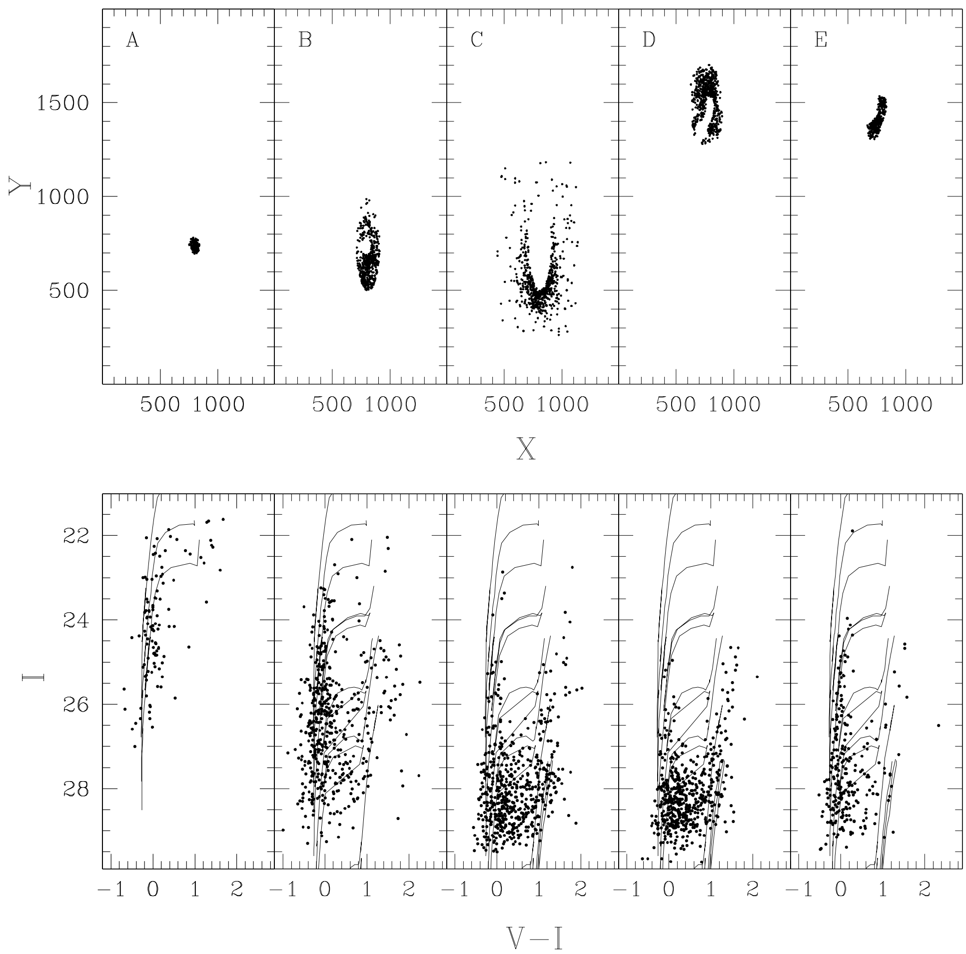

Fig. 1. Upper panels: spatial distribution of the stars in regions A, B, C, D and E in I Zw 18. Bottom panels: corresponding CMDs. Superimposed are the Padova 94 stellar tracks for the masses: 60, 30, 20, 12, 8, 7, 5, 2, 1, 0.8, and 0.6 $M_{\odot}$. For regions A and B, the smallest plotted masses are 20 and 2 $M_{\odot}$, respectively.

brief, the SFH is inferred finding the weighted combination of basis functions that best reproduce the observed CMD in a χ^2 sense. Our results for the different regions are summarized in Table 1.

4. Conclusions

We have inferred the SFH of I Zw 18 from our HST/ACS data using the method of synthetic CMDs (see Table 1). We conclude the following:

- We confirm that I Zw 18 has started forming stars earlier than ~1 Gyr ago, and possibly at epochs as old as a Hubble time. Thus it is not a truly young galaxy at its first bursts of star formation, as argued in previous studies (e.g., Izotov & Thuan 2004).
- Although old stars are present in I Zw 18, the mean SFR at epochs older than ~1

Table 1. Stellar mass (in $10^6 M_\odot$) formed in I Zw 18 at different epochs

Region	0-10 Myr	10-100 Myr	100-1000 Myr	>1000 Myr	Total
A	11.07	>2.22	-	-	>13.29
B	0.20	1.14	>0.61	-	>1.95
C	0.025	0.137	0.696	1.45	2.31
Main Body	11.29	>3.50	>1.31	>1.45	> 17.55
D	0.003	0.12	0.976	0.37	1.47
E	0.005	0.34	0.40	0.279	1.02
Sec Body	0.008	0.46	1.38	0.65	2.50

Gyr turns out significantly lower than the current rate. In the most external regions of I Zw18' s main body, where old stars are detected, the average rate over the last $\sim$100 Myr is $\approx$10 times as large as the mean rate in the 1-10 Gyr age interval.
- The main body has been forming stars at a very high rate in recent epochs. In the most crowded region A, a burst occurred 6-10 Myr ago at a rate as high as $1.6 M_\odot/yr$ (specific SFR $\sim 3 \times 10^{-5} M_\odot yr^{-1} pc^{-2}$).
- Both the main and the secondary bodies have been actively forming stars over the last $\sim$300 Myr. However, while in the main body the peak of the SF occurred during the last $\sim$10 Myr, in the secondary body the SF was more active before 10 Myr ago, with negligible SF during the last 10 Myr.
- The high current SFR in I Zw 18 and the low mass fraction locked in old stars explains why this galaxy is so blue and (probably) why it is so metal poor, resembling primeval galaxies in the early Universe.

Acknowledgements. FA and MT have received partial financial support from ASI, through contract COFIS ASI-INAF I/016/07/0 and contract ASI-INAF I/009/10/0.

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