Photometric properties of young blue compact dwarf galaxy candidates

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A tiny fraction (<1%) of very metal-deficient (12+log(O/H)≤7.6) blue compact dwarf (BCD) galaxies exhibits a nearly galaxy-wide starburst activity and no signatures of an old stellar host galaxy. The evolutionary status and formation history of these most metal-deficient BCDs are still a subject of debate. Various lines of evidence suggest, however, that these systems do not contain a substantial population of stars older than ~1 Gyr and hence qualify as nearby young-galaxy candidates.

Elaborated multiwavelength studies of these rare, young BCD candidates may therefore provide crucial insights into the formation and starburst-driven evolution of low-mass galaxies in the early universe. In order to assess the photometric structure and evolutionary status of these systems it is of critical importance to correct for the effect of extended nebular emission, as the latter may severely affect colors and age estimates obtained therefrom.

One such example is I Zw 18 (Fig. 1), the second most metal-poor BCD galaxy known (≈$Z_\odot/50$). This system is embedded within a filamentary low-surface brightness (LSB) envelope, extending out to 18" (~1.3 kpc, assuming a distance of 15 Mpc). Papaderos et al. (2002), using broad- (BVRI) and narrow-band (Hα, [OIII]) HST data, have shown that the extended LSB envelope of this young BCD candidate is entirely due to nebular line emission: ionized gas accounts for more than 80% of the line-of-sight emission at a galactocentric distance of 8" (~0.65 kpc) and for up to 50% of the total R light of I Zw 18.
Consequently, a twodimensional subtraction of ionized gas emission is indispensable for a meaningful study of the photometric structure of this system. As evident from Figures 2&4, the latter correction leads to the reduction of the exponential scale length α of the LSB component of IZw18 by 50%, moving the BCD into the parameter space typically populated by the most compact dwarf galaxies.

Ionized gas emission also affects colors in the central, high-surface brightness part of IZw18. As shown in Izotov et al. (2001a) and Papaderos et al. (2002) the equivalent width of the Hα line, EW(Hα), exceeds 1300 Å over the whole northwestern half of the BCD and along its western supershell (see Fig. 3b). The reddest V–R colors (0.2–0.5 mag) are observed along the supershell and the extended rim surrounding the NW star-forming region (Fig. 3a).
On the other hand, the V–I color in the corresponding regions (Fig. 3c) shows an opposite trend, being the bluest (–0.5 mag).
Comparison of panels a–c in Fig. 3 reveals that extended regions showing both red V–R and blue V–I colours are spatially correlated with the EW(Hα), but are anticorrelated with the surface density of the stellar background (contours in panels a and b). This again bears witness to the severe contamination of optical colors by nebular line emission on scales of several 100 pc.

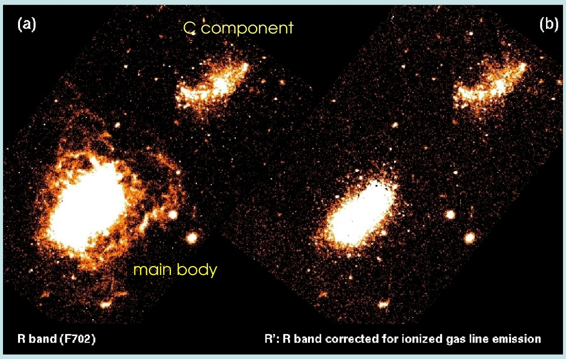


Fig. 1: Archival HST WFPC2 exposure of I Zw 18 (D=15 Mpc) in the R(F702W) band prior to (panel a) and after subtraction of nebular line emission (panel b).

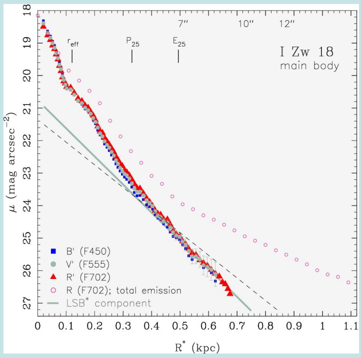


Fig. 2: Surface brightness profiles (SBPs) of I Zw 18 in B (F450), V (F555) and R(F702) computed after removal of nebular line emission (labelled B´, V´ and R´). The R SBP, computed from the total (stellar and ionized gas) emission is included for comparison. A linear fit to the outermost part (R*>0.5 kpc) of the V´ SBP (labelled LSB component) is shown by the thick-grey line.

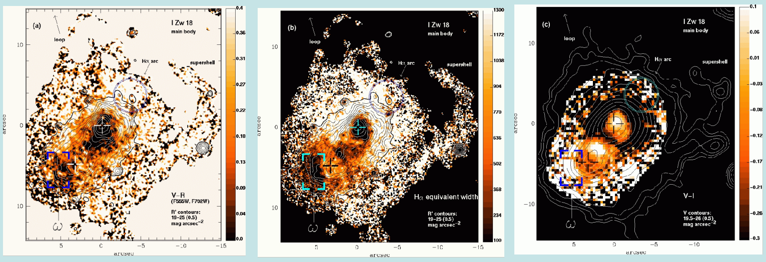


Fig. 3: a) V-R map of I Zw 18, computed from HST WFPC2 data. Crosses mark the positions of the NW and SE star-forming regions. The region labelled „*Hα arc*“ and „*loop*“ (Izotov et al. 2001a) are indicated. Contours, computed from the **R´** image (cf. Fig. 1b) illustrate the morphology of the stellar component of IZw18. **b)** Hα equivalent width map of IZw18, displayed in the range between 100 Å and 1300 Å. Contours have the same meaning as in panel **a**.
c) V-I map of IZw18, as derived from ground-based data. The color map is displayed in the range -0.3-0.1 mag and overlaid with 19.5 to 26 mag arcsec^{-2} V contours.

Fig. 4: Comparison of the structural properties of the stellar host galaxy of IZw18 with those of other types of dwarf galaxies: **a)** extrapolated central surface brightness $\mu_{E,0}$ vs. absolute B magnitude M_{host} of the stellar host galaxy; **b)** exponential scale length α vs. M_{host}. Subtraction of ionized gas emission shifts IZw18 by -1.6 mag and -0.31 dex in panels **a** and **b**, respectively, moving it into the locus populated by the most compact (α~100 pc) dwarf galaxies. The position of the young BCD candidates from Fig. 5 is indicated.

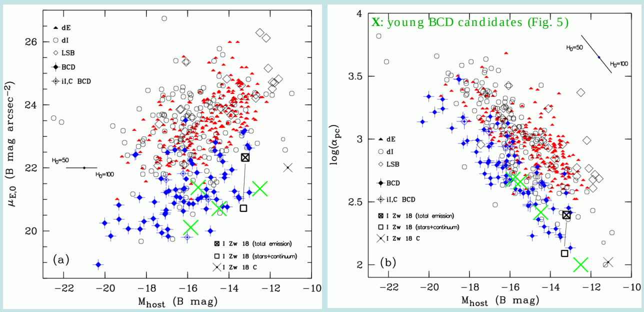
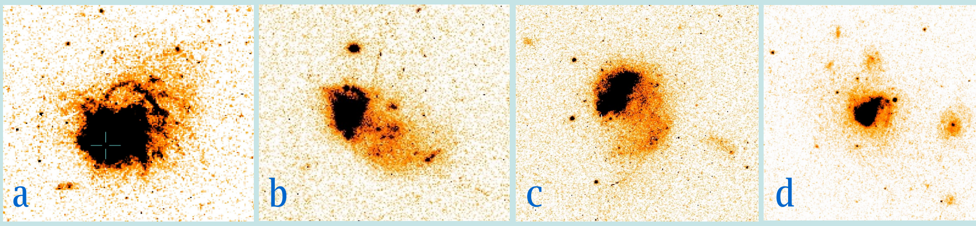


Fig. 5: HST WFPC2 exposures of the young BCD candidates **a)** SBS 0335-052E (D=54.3 Mpc), **b)** Tol 1214-277 (D=104 Mpc), **c)** Tol 65 (D=36 Mpc) and **d)** Pox 186 (D=18.5 Mpc).



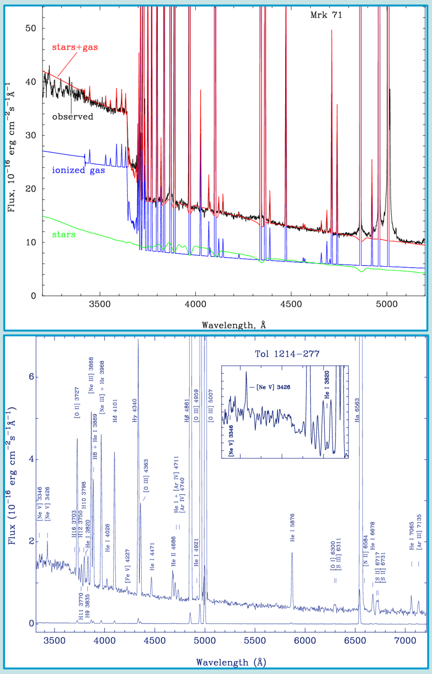


Fig. 6: a) Modelling of the optical spectrum of the brightest HII region the BCD Mkn71 as due to the superposition of stellar and ionized gas emission (from Guseva et al. 2005). The appreciable contribution of ionized gas emission to the observed spectrum is evident.
b) The redshift-corrected spectrum of the brightest HII region in the low-metallicity (12+log(O/H)=7.51) BCD Tol 1214–277 with labelled emission lines (from Izotov et al. 2004). The lower spectrum is the observed spectrum downscaled by a factor of 50. The inset shows a close-up view of the blue part of the spectrum with the two high-ionization [Fe V]λ4227 and [Ne V]λ3425 lines.

Other examples of young BCD candidates with colors significantly affected by intense, spatially extended nebular line emission are SBS 0335–052E (Fig. 5a; Thuan et al. 1997, Papaderos et al. 1998, Izotov et al. 2001b, Pustilnik et al. 2004), Tol 1214–277 (Fig. 5b; Fricke et al. 2001, Izotov et al. 2004) and Pox 186 (Fig. 5d; Guseva et al. 2004).

Studies of the hard ionizing radiation in low-metallicity BCDs

If we wish to understand the spectra of primeval galaxies, it is highly important to understand how the UV radiation field of these systems changes as metallicity decreases. BCDs constitute ideal and unique sites for studying the properties of the hard ionizing radiation in environments intermediate between local galaxies and high-redshift primordial galaxies.

It is well established that the lower the metallicity, the harder is the radiation from massive stars. As a consequence, strong He II emission lines are expected in the spectra of metal-deficient galaxies. Indeed strong nebular HeIIλ4686 emission has been detected in many low-metallicity BCDs (e.g., Guseva et al. 2000), implying the presence of large fluxes of hard UV radiation with energies >4 Ryd. The intensity of this line in some of the most metal-deficient BCDs can be as high as 5% of the Hβ intensity, comparable to that predicted for zero-metallicity stellar populations (Panagia 2003; Schaerer 2003), and suggesting that some properties of the massive stars in BCDs and those in primordial galaxies may be similar.

Furthermore, several other high-ionization emission lines have been discovered in metal-deficient BCDs using high S/N spectroscopic data. [Fe V]λ4227 and [Ne V]λ3425 emission is detected in Tol 1214–277 (4% of solar metallicity, Fricke et al. 2001, Izotov et al. 2004, see Fig. 6) and SBS 0335–052 (2.5% of solar metallicity, Izotov et al. 2001, Thuan & Izotov 2004). The presence of [Fe V]λ4227 requires radiation with energy greater than 4 Ryd and that of [Ne V]λ3425, with energy greater than 7.8 Ryd.
The high-ionization [Fe V]λ4227 and [Ne V]λ3425 lines have never been detected in normal nearby solar-metallicity starburst galaxies. Except for metal-deficient BCDs, they are only seen in AGNs.

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