

YOUNG STAR-FORMING DWARF GALAXIES: LABORATORIES FOR GALAXY FORMATION AND EVOLUTION STUDIES

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Abstract

The study of extremely metal-deficient Blue Compact Dwarf (BCD) galaxies is crucial for understanding galaxy formation and evolution. We discuss in detail two BCDs with a metallicity less than 1/20 that of the sun, SBS 0335-052 ($Z_{\odot}/41$) and SBS 1415+437 ($Z_{\odot}/21$). We show that the two BCDs do not contain stars older than 100 Myr and thus appear to be truly young galaxies, undergoing now their first burst of star formation. The HI envelope in which SBS 0335-052 is embedded appears to be primordial, devoid of any heavy element. We then show how the study of the escape of Ly α photons in BCDs can shed light on the long-standing problem of the weakness or absence of Ly α emission in high-redshift star-forming galaxies. We also discuss the P Cygni profile phenomenon in extremely metal-deficient environments.

1 Introduction

The study of dwarf galaxies is most important for cosmology because of two main reasons. First, Hubble Space Telescope (HST) images have shown that more than 40 % of high-redshift galaxies appear to be the product of mergers of smaller galaxies (e.g. van den Bergh et al. 1996), suggesting that dwarf galaxies are the building blocks of normal galaxies and supporting the paradigm of the hierarchical growth of structures in the Universe from small units to larger ones. Second, extremely metal-deficient blue dwarfs appear to be forming stars for the first time within the last 100 Myr, and thus are truly young galaxies which constitute excellent laboratories for studying galaxy formation processes.

The formation of galaxies is one of the most fundamental problems in astrophysics, and much effort has gone into the search for primeval galaxies (PG). A possible definition of a

primeval galaxy is a young system undergoing its first major burst of star formation. It is now widely believed that the vast majority of galaxies underwent such a phase at redshifts ~ 2 or greater. In most galaxy formation scenarios, young galaxies are predicted to show strong Ly α emission, associated with the cooling of the primordial gas and the subsequent formation of a large number of massive ionizing stars (Partridge & Peebles 1967; Charlot & Fall 1993). Yet, despite intensive searches, the predicted widespread population of Ly α primeval galaxies has remained elusive (Pritchet 1994).

Several objects have been put forward as possible PG candidates, ranging from high-redshift radio galaxies to Ly α emitters found around quasars and damped Ly α systems, mainly on the basis of very high luminosity and star formation activity. However, most of these candidate PGs already contain a substantial amount of heavy elements, as evidenced by the presence of strong P Cygni profiles and interstellar absorption in their spectra (Steidel et al. 1996; Yee et al. 1996). These spectra are very similar to those of nearby starburst galaxies known to contain old stellar populations (Leitherer et al. 1996). Thus high-redshift galaxies discovered thus far are not truly primeval. Moreover, even if true PGs are discovered at high-redshift, it is difficult to study them in detail, even with the largest existing telescopes, because of their extreme faintness and very compact angular size. We propose here to take a different approach to the PG problem. Instead of searching for very high-redshift galaxies in the process of forming, we look for nearby galaxies undergoing their first burst of star formation, and hence satisfying the above definition of a PG. The best candidates for such a search are blue compact dwarf galaxies (BCD).

BCDs are low-luminosity extragalactic objects with $M_B \geq -18$ where intense star formation is presently occurring, as evidenced by their blue UVB colors, and their optical spectra which show strong narrow emission lines superposed on a stellar continuum which is rising toward the blue, similar to spectra of HII regions. Star formation in BCDs cannot be continuous but must proceed by bursts because of several observational constraints: 1) Gas is transformed into stars at the rate of approximately $1 M_{\odot} \text{yr}^{-1}$, so that the current burst cannot last more than about 10^8 yr before depleting the neutral gas supply of $\sim 10^8 M_{\odot}$; 2) Optical-infrared colors of BCDs give ages of about 10^7 yr; and 3) Population synthesis of UV spectra of BCDs give invariably jumps in the stellar luminosity function, indicative of starbursts (see Thuan 1991 for a review).

Ever since their discovery, the question has arisen whether BCDs are truly young systems where star formation is occurring for the first time, or old galaxies with an old underlying stellar population on which the current starburst is superposed (Searle, Sargent & Bagnuolo 1973). Thuan (1983) carried out a near-infrared JHK survey of BCDs and concluded that all the objects in his sample possessed an old underlying stellar population of K and M giants. That result was not unambiguous as the JHK observations were centered on the star-forming regions and the near-infrared emission could be contaminated by light from young supergiant stars. The advent of CCD detectors allowed to look for the low-surface-brightness underlying component directly. Loose & Thuan (1985) undertook a CCD imaging survey of a large BCD sample and found that nearly all galaxies ($\geq 95\%$) in their sample show an underlying extended low-surface-brightness component, on which are superposed the high-surface-brightness star-forming regions. Subsequent CCD surveys of BCDs have confirmed this initial result (Papaderos et al. 1996, Telles & Terlevich 1997). Thus, most BCDs are not necessarily young galaxies. However, there was a hint that extremely metal-deficient BCDs do not contain an old stellar population and can be primordial. *Hubble Space Telescope (HST)* imaging of I Zw 18, the most metal-deficient BCD known ($Z_{\odot}/50$, Searle & Sargent 1972), to $V \sim 26$ by Hunter & Thronson (1995) suggests that the stellar population is dominated by young stars and that the colors of the underlying diffuse component are consistent with those from a sea of unresolved B or early A stars, with no evidence for stars older than $\sim 10^7$ yr.

For more than 20 years, I Zw 18 stood in a class by itself. The BCD metallicity distribution ranges from $\sim Z_{\odot}/3$ to $\sim Z_{\odot}/50$, peaking at $\sim Z_{\odot}/10$, and dropping off sharply for $Z \leq Z_{\odot}/10$. Intensive searches have been carried out to look for low-metallicity BCDs but they have met until recently with limited success. For example, the majority of the BCDs in the Salzer (1989) and Terlevich et al. (1991) surveys have metallicities larger than $Z_{\odot}/10$. Several years ago, a new BCD sample has been assembled by Izotov et al. (1993) from objective prism survey plates obtained with the 1m Schmidt telescope at the Byurakan Observatory of the Armenian Academy of Sciences during the Second Byurakan Survey (SBS). The most interesting feature of the SBS is its metallicity distribution (Izotov et al. 1992, Thuan et al. 1994): it contains significantly more low-metallicity BCDs than previous surveys. It has uncovered about a dozen BCDs with $Z \leq Z_{\odot}/15$, more than doubling the number of such known low-metallicity BCDs and filling in the metallicity gap between I Zw 18 and previously known BCDs. We shall discuss here two examples of extremely metal-deficient SBS BCDs and the observational evidence that they may be young galaxies. In section 2, we describe the properties of SBS 0335-052 which is the second most metal-deficient BCD known with a metallicity of only $Z_{\odot}/41$ (Izotov et al. 1990, Melnick et al. 1992). Section 3 discusses the properties of SBS 1415+437 (Thuan et al. 1998) which has a metallicity of $Z_{\odot}/21$. The study of nearby young dwarf galaxies can also shed light on the long-standing problem of the weakness of $\text{Ly}\alpha$ emission of high-redshift star-forming galaxies. We discuss $\text{Ly}\alpha$ emission and absorption in BCDs and P Cygni profiles in extremely metal-deficient environments in section 4.

2 The young dwarf galaxy SBS 0335-052

2.1 Age of the stellar component

HST WFPC2 images of the BCD show that most of the star formation in SBS 0335-052 ($M_B = -16.7$, $v = 4076 \text{ km s}^{-1}$) occurs in 6 super-star clusters (SSCs) with $-14.1 \leq M_V \leq -11.9$, within a region $\sim 520 \text{ pc}$ in size (Figure 1, Thuan et al. 1997). Later processing by Papaderos et al. (1998) of the same HST images reveals several fainter clusters (not SSCs). The SSCs are roughly aligned in the SE-NW direction, and there is a systematic reddening of the V-I color of the SSCs away from the brightest one, with a flattening of the color of the clusters beyond 520 pc (Figure 2).

Some of the reddening may be due to dust which is clearly seen as white patches in the V-I color map (Figure 3) and which is mixed spatially with the SSCs. It is interesting that even in a very metal-deficient interstellar medium (ISM) with only 1/40 of the Sun's metallicity, dust is clearly present. Thuan & Sauvage (1998) have obtained mid-infrared (between 5 and 17 microns) observations of the BCD. With an $L_{12\mu\text{m}}/L_B$ of 2.15, the galaxy is unexpectedly bright in the mid-infrared for such a low-metallicity object. The mid-infrared spectrum (Figure 4) shows no sign of carbon-based dust, i.e. the Unidentified Infrared Bands are absent, which can be interpreted either as an effect of dust destruction by the very large number of young stars present in the galaxy or an effect of its very low metallicity. The spectral energy distribution is dominated by a very strong continuum which makes the ionic lines of [SIV] and [NeIII] very weak and just above the detectability limit. The spectral energy distribution from 5 to 17 microns can be reproduced by a grey-body spectrum modified by extinction. The required extinction law is similar to that observed toward the Galactic Center and the optical depth is $A_V \sim 18-20$. Such a large optical depth implies that much of the current star-formation activity in SBS 0335-052 is hidden by silicate dust whose mass is in the range $10^4-10^5 M_{\odot}$. Thuan & Sauvage (1998) found that the total MIR luminosity is of the same order as the blue luminosity

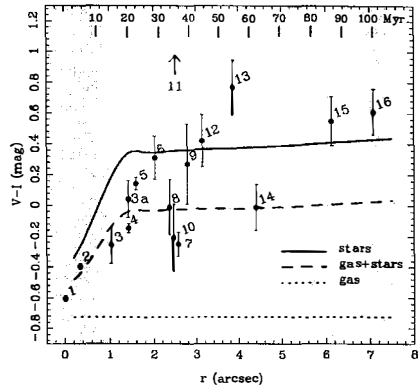
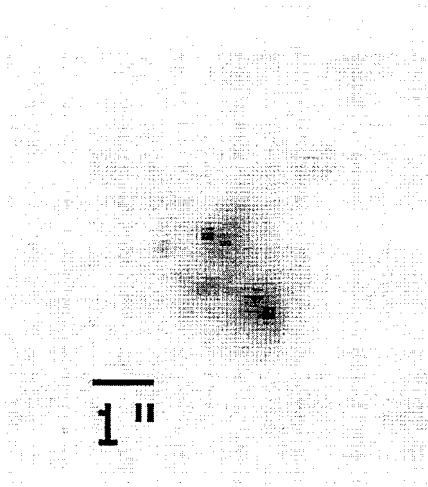


Fig. 1 (left): HST WFPC2 V image of SBS 0335–052 showing the high surface brightness super-star clusters. At a distance of 54.3 Mpc, 1 arcsec corresponds to a linear size of 263 pc. **Fig. 2 (right):** (V–I) color vs. distance from the brightest super-star cluster at the SE tip of SBS 0335–052. The color gets redder with increasing distance.

of the BCD, implying that the total star formation rate (SFR) as derived from the optical or UV luminosities must underestimate the true star formation rate by a factor of at least 2. These results have interesting cosmological implications. If a significant fraction of the star formation is hidden by dust in higher redshift starburst galaxies as in SBS 0335–052, then the cosmic star formation rate will be systematically underestimated if only UV and optical fluxes are taken into account. This is in fact the result found by Flores et al. (1998) who carried out deep 15 micron ISO surveys of distant galaxies with a median redshift of ~ 0.76 . Those authors found that the cosmic SFR derived from FIR luminosities, from 43 to 123 microns, assuming that the FIR luminosity comes mostly from dust heating by young stars, is ~ 2.3 times higher than the SFR estimated previously from UV fluxes (Madau et al. 1996), and comparable to the underestimate factor of ~ 2 found for SBS 0335–052.

Thuan et al. (1997) and Papaderos et al. (1998) attribute however most of the color variation of the SSCs not to dust, but to an age variation resulting from sequential propagating star formation. The V–I colors are consistent with the picture that star formation started at the location of the most distant cluster, some 1.8 kpc away from the location of the brightest and bluest cluster at the South East end of the galaxy, at about 100 Myr ago and propagated through the ISM to the latter, whose age is only ~ 4 Myr, with an average speed of ~ 18 km s $^{-1}$ (Thuan et al. 1997, Papaderos et al. 1998). Thus the star-forming clusters have ages between 4 and 100 Myr. Does SBS 0335–052 possess an underlying older stellar population? The extended underlying component is shown in figure 5 where the contrast has been adjusted to display very low surface-brightness features. The unusually blue colors of this underlying component (see the U–B color profile labeled E in Figure 6) and its irregular, blotchy and filamentary structure suggest that a significant fraction of the light is of gaseous rather than stellar origin. A supershell of 380 pc radius can be seen delineating a large supernova cavity. However Izotov et al. (1997) found that the H β equivalent width in the underlying component is ~ 3 times lower than the value expected for pure gaseous emission, implying that two-thirds of the light comes from an underlying stellar population. Papaderos et al. (1998) have modeled

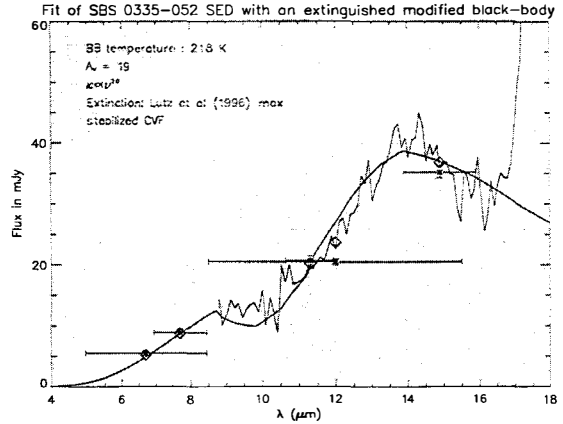
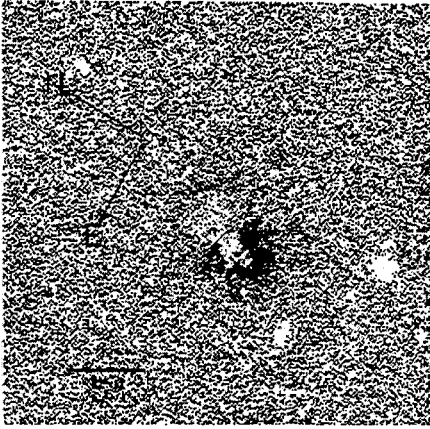


Fig.3 (left): (V-I) color map of SBS 0335-052. Blue is dark, red is light. The dust patches on top of the super-star clusters are clearly seen.

Fig.4 (right): The best-fit model (thick continuous line) for the mid-infrared spectral energy distribution of SBS 0335-052 obtained by ISO (Thuan & Sauvage 1998). It is composed of a 244 K blackbody spectrum modified by an emissivity law proportional to $\nu^{2.0}$ and extinguished by a screen of dust of optical thickness $A_V = 19$, with an extinction curve similar to that observed toward the Galactic center (Lutz et al. 1996). Note that changing the exponent of the emissivity law from 2.0 to 1.5 only affects the temperature, leaving the optical depth nearly unchanged. Open symbols represent simulations of broad-band observations derived from the best-fit spectrum. There is excellent agreement with the real broad-band observations (crosses)

the UBVR colors of this stellar component, after removal of the ionized gas contamination. They found that the colors are consistent with an underlying stellar population not older than 100 Myr.

2.2 Age of the neutral gas component

Thus the stellar component in SBS 0335-052 is extremely young and the BCD is likely undergoing star formation for the first time. If this is the case, the neutral gas envelope surrounding the BCD must also be very metal-deficient. A 21 cm VLA map of the BCD (Pustilnik et al. 1998) has shown it to be embedded in an extraordinarily large HI cloud seen nearly edge-on, with dimensions some 64 by 24 kpc. This is to be compared with the typical size of HI envelopes around BCDs which is more like a few kiloparsecs in each dimension. We can use the BCD as a background light source shining through the HI envelope to probe the physical conditions of the neutral gas. The Ly α line seen in absorption would give the column density of atomic hydrogen, while the OI λ 1302 line would give the column density of the most abundant heavy element that remains neutral in the HI cloud. This would allow us to set limits on the O/H abundance ratio in the neutral gas. Figure 7 shows the ultraviolet spectrum of SBS 0335-052 around the Ly α line obtained by Thuan & Izotov (1997) with the Goddard High Resolution Spectrograph aboard the Hubble Space Telescope (HST). A strong damped Ly α absorption line is seen along with several heavy element interstellar absorption lines such as OI λ 1302, SiII λ 1304 and SII λ 1251, λ 1254, and λ 1259. The HI column derived by fitting the Ly α absorption

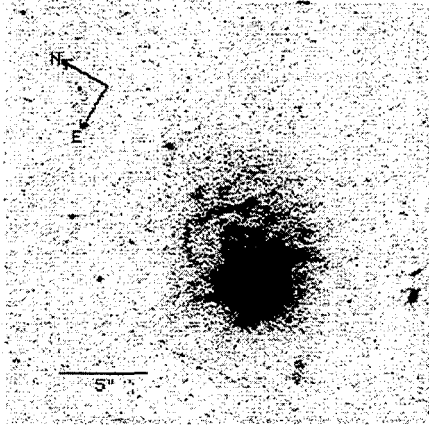


Fig.5 (left): Same V image as in Fig.1, with the contrast adjusted to show the low surface brightness underlying component of SBS 0335–052. The supershell delineating the large supernova cavity is clearly seen.

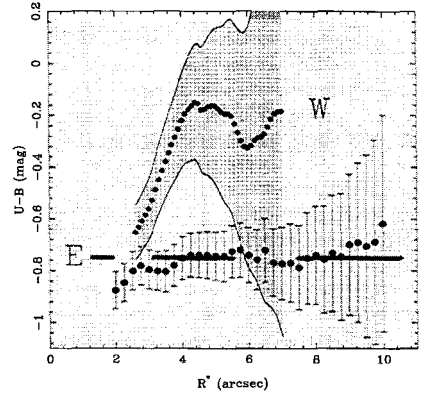


Fig.6 (right): (U-B) color profile (labeled E) of SBS 0335–052. The color is very blue and the profile flat.

profile is $N(\text{H I}) = (7.0 \pm 0.5) \times 10^{21} \text{ cm}^{-2}$, the highest derived thus far for a BCD, and ~ 2 times larger than in I Zw 18 (Kunth et al. 1994). Comparison with high-resolution quasar spectra implies that the O I $\lambda 1302$ line along with other heavy element interstellar absorption lines such as Si II $\lambda 1304$ and S II $\lambda 1251$, $\lambda 1254$, $\lambda 1259$ are not saturated, which allow us to derive abundances. Assuming that these lines originate in the H I gas, we derive extremely low abundances of oxygen, silicon and sulfur, respectively 37000, 4000 and 116 times lower than the solar values. The oxygen abundance is a whole 37 times lower than in the neutral gas of I Zw 18. However, these highly discrepant deficiency factors between different elements suggest that the absorption lines are produced, not in the H I, but in the H II gas. Adopting that hypothesis, the derived abundance from the *UV* absorption lines are then consistent with that derived from the optical emission lines ($Z \sim Z_{\odot}/40$). The conclusion that the heavy element absorption lines originate in the H II region is supported by the detection of several systems of blueshifted S II $\lambda 1259$, Si II $\lambda 1260$, O I $\lambda 1302$, Si II $\lambda 1304$, C II $\lambda 1335$ absorption lines originating in fast-moving clouds with velocities up to $\sim 1500 \text{ km s}^{-1}$, and also by the presence of heavy element absorption lines with excited lower levels. If this conclusion holds, then the H I cloud in SBS 0335–052 is truly primordial, unpolluted by heavy elements (Thuan & Izotov 1997).

In summary, all the known observational evidence suggests that SBS 0335–052 is truly a young galaxy.

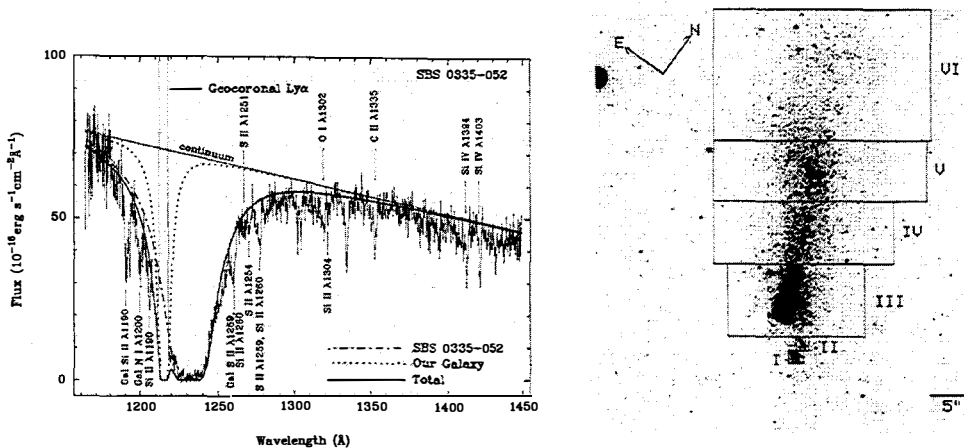


Fig.7 (left): HST GHRS spectrum of SBS 0335–052 around the Ly α line. A strong damped Ly α absorption is seen along with several heavy element interstellar absorption lines.
Fig.8 (right): HST WFPC2 *I* image of SBS 1415+437. The shape is cometary-like. A bright supergiant HII region at the SW end, resolved stars in the body of the galaxy and unresolved diffuse stellar emission can be seen. The different regions used for stellar population color-magnitude diagram analysis are marked.

3 Another young galaxy: SBS 1415+437

3.1 Age from color-magnitude diagrams

Figure 8 shows the HST WFPC2 *I* image of SBS 1415+437 ($M_B = -14.0$, $v = 607 \text{ km s}^{-1}$) with the contrast level adjusted so as to show the low surface-brightness underlying extended component (Thuan et al. 1998). The galaxy has an elongated, comet-like shape with a bright H II region on its SW tip. Many point sources identified as luminous stars can be seen. To the SW of the brightest H II region, two stellar clusters with resolved stars are present. The luminous stars and the HII regions are aligned suggesting, just as in SBS 0335–052, propagating star formation (from the NE to the SW). The mode of star formation in the two BCDs is different however. While SBS 0335–052 makes stars in luminous super-star clusters, star-formation in SBS 1415+437 appears to be less extreme and is more similar to that in I Zw 18 (Hunter & Thronson 1995). The superior spatial resolution of the HST allows to resolve individual stars and construct color-magnitude diagrams to study the stellar populations in the BCD. To check the hypothesis of propagating star formation, we have derived stellar ages for 6 separate regions in the BCD, labeled from I to VI as shown in Figure 8.

The ($V-I$) vs. I diagrams (uncorrected for extinction) for each region are shown in Figure 9 together with stellar isochrones by Bertelli et al. (1994) for a heavy element abundance equal to 1/20 the solar value. Each isochrone is marked by the logarithm of the age in years. The region of the asymptotic giant branch (AGB) stars is shown by a dashed line while the observational limits are shown by dotted lines. We adopt $V = 27.5 \text{ mag}$ and $I = 27 \text{ mag}$ as completeness limits. Since we do not correct for extinction, the stars are really brighter and bluer so that the ages given by the isochrones are only upper limits. Inspection of Figure 9 shows that there

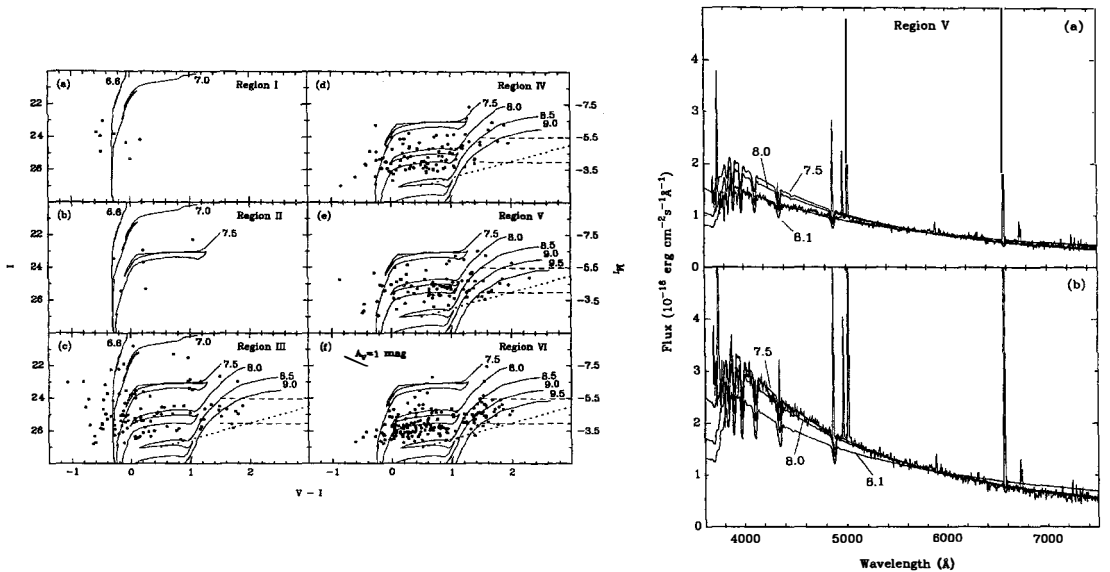


Fig.9 (left): Color-magnitude diagrams of stellar populations in the different regions of SBS 1415+437 as defined in Fig.8. There is a systematic age increase from region I to region VI, implying propagating star formation from the NE to the SW.

Fig.10 (right): MMT spectrum of region V (see Fig.7) of SBS 1415+437. The upper panel shows the spectrum uncorrected for extinction, while the lower panel shows the same spectrum corrected for extinction. The best-fit model gives an age between 30 and 100 Myr.

is a clear age gradient from region I to region VI. Region I is the youngest (about 5 Myr), containing only main-sequence stars. Region II is more evolved. It contains red supergiants and has an age of ≥ 10 Myr. Region III includes the brightest H II region and shows a mixture of stellar populations. The bulk of the stars in region III have ages ranging between ≤ 10 Myr and 100 Myr. The red stars with (V-I) between 1.0 and 1.8 are likely to be red supergiants rather than AGB stars. The stellar populations in regions IV - VI are similar to those in region III except for the fact that very young populations with age less 10 Myr are no more present. We emphasize that the properties of the stellar populations in SBS 1415+437 are quite different from those in other nearby low-metallicity dwarf galaxies with HST color-magnitude diagrams. In those dwarfs, very red AGB stars are present indicating a larger age (e.g. Dohm-Palmer et al. 1997, this volume; Schulte-Ladbeck et al. 1998, this volume). Two general conclusions can be obtained from the above color-magnitude analysis: 1) star formation in SBS 1415+437 is propagating from the NE to the SW; 2) there is no evidence for stars older than ~ 100 Myr in the BCD.

3.2 Age from spectral evolutionary synthesis models

The second conclusion is supported by evolutionary synthesis modeling of the spectrophotometric data of regions III to VI. As an example, we show in Figure 10 the spectrum of region V. To illustrate the effect of extinction, we show in the upper panel the spectrum uncorrected for extinction, and in the lower panel the spectrum corrected for extinction as derived from the Balmer decrement ($C(H\beta) = 0.26$ which corresponds to $A_V = 0.57$ mag and $A_I = 0.35$ mag).

To estimate quantitatively the age of each region, we calculate a grid of spectral energy distributions (SED) for stellar populations with ages varying between 10 Myr and 20 Gyr and heavy element abundance $Z_{\odot}/20$, using isochrones from Bertelli et al. (1994) and the compilation of stellar atmosphere models from Lejeune et al. (1998). A Salpeter IMF with slope -2.35 , an upper mass limit of $120 M_{\odot}$ and a lower mass limit of $0.6 M_{\odot}$ were adopted. For stellar populations with age less than 10 Myr we use theoretical spectral energy distributions by Schaerer & Vacca (1998) for a heavy element abundance $Z_{\odot}/20$ and a Salpeter IMF. The stellar emission in SBS 1415+437 is contaminated by emission of ionized gas from supergiant H II regions. Therefore, to study the stellar composition in the BCD, it is necessary to produce a synthetic SED which includes both stellar and ionized gaseous emission. We have chosen not to calculate the contribution of ionized gas emission from the model value for the Lyman continuum luminosity. Rather, we add the gaseous spectral energy distribution calculated from the observed line fluxes and equivalent widths to the calculated stellar spectral energy distribution. The contribution of the gaseous emission is scaled to the stellar emission by the ratio of the observed equivalent width of the $H\beta$ emission line to the equivalent width of $H\beta$ expected for pure gaseous emission. The contribution of bound-free, free-free, two-photon continuum emission has been taken into account for the spectral range from 0 to 5 μm . Emission lines with intensities derived from the spectra in the range $\lambda\lambda 3700 - 7500\text{\AA}$ are then added. The effect of gaseous emission is important for region III but it has a minor influence in other regions as indicated by the small $H\beta$ emission line equivalent width ($EW(H\beta) = 18 \text{\AA}$ in region V). Therefore, we do not take into account gaseous emission in regions IV to VI. It is clear from Figure 10, the best fit to the spectrum corrected for extinction (lower panel) gives an age between 30 and 100 Myr for region V (the models are labelled by the logarithm of the age in years). A similar analysis for the other regions give the same answer: none contains stellar populations older than 100 Myr. Thus SBS 1415+437, just like SBS 0335-052, is also a young galaxy.

3.3 Are all galaxies with $12 + \log O/H < 7.6$ young?

The BCDs I Zw 18, SBS 0335-052 and SBS 1415+437 are all extremely metal-deficient and all appear to be young, with stars not older than ~ 100 Myr. Can this correlation between metallicity and age be generalized? We (Izotov & Thuan 1998, this volume) have argued on the basis of the behavior of the C/O and N/O ratios as a function of O abundance, that all galaxies with $12 + \log O/H < 7.6$ began to form stars less than ~ 100 Myr ago.

4 The escape of $Ly\alpha$ photons and P Cygni profiles in BCDs

4.1 $Ly\alpha$ emission and absorption

The study of nearby young galaxies can also shed light on a long standing problem concerning the Lyman-alpha emission of primeval galaxies. In any galaxy formation scenario, young galaxies are predicted to show strong $Ly\alpha$ emission (rest frame equivalent width of $\sim 100\text{\AA}$) associated with the formation of a large number of massive ionizing stars (e.g. Charlot & Fall 1993). Yet, despite intensive searches, the predicted population of $Ly\alpha$ primeval galaxies remained elusive (Pritchet 1994). The absence of $Ly\alpha$ emission in high-redshift galaxies is reminiscent of the behavior of $Ly\alpha$ emission in nearby starburst and BCD galaxies, which is either absent or greatly diminished. The $Ly\alpha/H\beta$ line intensity ratio in those galaxies with detected $Ly\alpha$ emission does not exceed 10, significantly lower than the theoretical recombination ratio of 33. Some galaxies show strong $Ly\alpha$ absorption rather than emission. The favored

explanation for such a reduction in Ly α emission from recombination values is redistribution of Ly α photons by multiple scattering in the H I envelope or absorption of these Ly α photons by dust in the star-forming region. The latter mechanism would imply increasing Ly α /H β line intensity ratios with decreasing metallicities, since presumably low-metallicity objects contain less dust, and hence suffer less destruction of Ly α photons (Terlevich et al. 1993). *HST* observations of the two most metal-deficient BCDs known, I Zw 18 (Kunth et al. 1994) and SBS 0335-052 (Thuan et al. 1997, section 2), show Ly α not in emission but absorption, which goes against a Ly α strength-metallicity anticorrelation. Lequeux et al. (1995), in their study of the BCD Haro 2 ($Z_{\odot}/3$) which shows Ly α in emission, have argued that Ly α photons can escape when the neutral material where the absorption occurs is outflowing with a velocity of ≤ 200 km s $^{-1}$ with respect to the star-forming region. The Ly α emission is redshifted with respect to both the H II region and the expanding absorbing shell, the motion of which is probably powered by stellar winds and supernovae. This explanation does not apply to the case of the BCD T1214-277 ($Z_{\odot}/23$) whose HST GHRS UV spectrum is shown in Figure 11. It clearly shows Ly α in emission which makes it the lowest metallicity galaxy known with detected Ly α emission. Its Ly α -to-H β intensity ratio is ~ 4 , while its equivalent width is $\sim 70\text{\AA}$, the highest found in a star-forming galaxy. Contrary to the case of Haro 2, Ly α emission is not redshifted with respect to the H II gas velocity. Thus the escape of Ly α photons in T1214-277 is not a consequence of the motions of the neutral H I envelope.

As for SBS 0335-052, dust extinction may play some role as it is directly seen in *HST* WFPC2 images (Thuan et al. 1997, Figure 3). While there is evidence for fast gas motions in SBS 0335-052 with velocities up to ~ 1500 km s $^{-1}$, the H I gaseous envelope appears to be static with respect to the H II region, as the 21 cm and emission-line velocities are in good agreement. Thus, with its extremely large H I column density, the redistribution of Ly α photons in SBS 0335-052 by multiple scattering over the large volume of the H I cloud probably plays also an important role in diminishing the intensity of the Ly α line. The orientation of the HI cloud may also play a role. In the case of SBS 0335-052, the HI envelope is reasonably flattened (Pustilnik et al. 1998) suggesting it is seen nearly edge-on. In that case, Ly α photons escape more easily along directions perpendicular to the line of sight than along it. Moreover, as discussed by Gialvalisco et al. (1996), the escape of Ly α photons may be controlled not only by the geometry but also by the porosity of the neutral gas.

In summary, there is no unique mechanism which controls the appearance of Ly α emission in nearby young dwarf galaxies. Dust extinction may play a role, but the velocity structure of the H I gas, the orientation of the H I cloud and its porosity may also play determining functions. The fact that some BCDs do not show Ly α in emission implies that Ly α searches for high-redshift galaxies will always be incomplete.

4.2 P Cygni profiles

A most interesting result concerning young galaxies is the detection in the spectrum of some of them of strong Si IV $\lambda 1394$, $\lambda 1403$ lines with P Cygni profiles. Figure 12 shows these profiles for SBS 0335-052 (section 2). A P Cygni profile can also be seen in the spectrum of T1214-277 for the N V $\lambda 1240$ line (Figure 11). This makes these two BCDs the two most metal-deficient galaxies known with P Cygni profiles. These results are somewhat surprising because we do not expect to see P Cygni in such very low metallicity environments. A minimum amount of metals is needed to provide the necessary opacity to drive the stellar winds originating from massive O stars and responsible for the P Cygni profiles. A possible way out comes from the *HST* WFPC2 observation of SBS 0335-052 by Thuan et al. (1997) which shows that star formation in the BCD is self-propagating, resulting in a chain of 6 main super-star clusters roughly aligned in

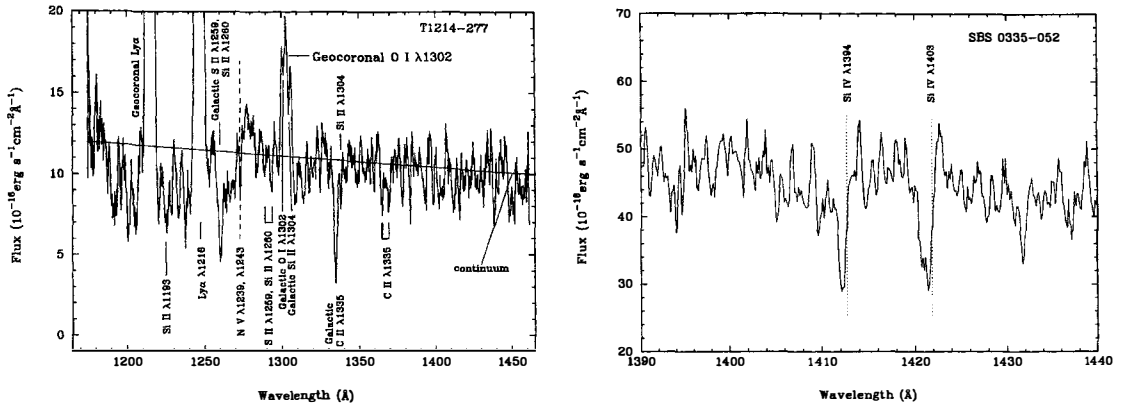


Fig.11 (left): HST GHRS spectrum of T1214–277 around the Ly α line. There is Ly α emission and a NV λ 1240 line with a conspicuous P Cygni profile.

Fig.12 (right): Spectrum of SBS 0335–052 showing the P Cygni profiles of the Si λ 1394 and λ 1403 interstellar absorption lines.

a northwest - southeast direction, and with age decreasing from ~ 30 Myr to ~ 4 Myr. Thus star formation in SBS 0335–052 has proceeded in 6 separate bursts of duration less than a few Myr. We can imagine a scenario where the stars born in the later bursts and responsible for the stellar winds, formed from gas already enriched in heavy elements by supernovae resulting from the previous bursts, although it is not clear whether the metals produced in supernovae have had enough time to mix with the pristine gas. Another possibility is to postulate that somehow the evolution of massive stars leads to an increase of their surface metallicity and hence to the onset of a stellar wind.

The terminal wind velocity as measured from the blue absorption edge of the P Cygni profiles is ~ 2000 km s $^{-1}$ for T1214–277, at the lower range of velocities (2000 – 4000 km s $^{-1}$) obtained for the BCDs studied by Fanelli et al. (1988) and for massive stars in the Galaxy (Z_{\odot}) and the LMC ($Z_{\odot}/3$) (Prinja et al. 1990). As for SBS 0335–052, it has a substantially lower terminal velocity of ~ 500 km s $^{-1}$, below the velocity range (1200 – 1500 km s $^{-1}$) observed for SMC stars ($Z_{\odot}/8$) (Puls et al. 1996). These results suggest a decrease of terminal wind velocities with decreasing metallicities.

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