

A continuous low star formation rate in IZw 18?^{*}

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Abstract. Deep long-slit spectroscopic observations of the blue compact galaxy IZw 18 obtained with the CFH 3.6 m Telescope are presented. The very low value of oxygen abundance previously reported is confirmed and a very homogeneous abundance distribution is found (no variation larger than 0.05 dex) over the whole ionized region. We concur with Tenorio-Tagle (1996) and Devost et al. (1997) that the observed abundance level cannot result from the material ejected by the stars formed in the current burst, and propose that the observed metals were formed in a previous star formation episode. Metals ejected in the current burst of star formation remain most probably hidden in a hot phase and are undetectable using optical spectroscopy. We discuss different scenarios of star formation in IZw 18. Combining various observational facts, for instance the faint star formation rate observed in low surface brightness galaxies (Van Zee et al. 1997c), it is proposed that a low and continuous rate of star formation occurring during quiescent phases between bursts could be a significant source of metal enrichment of the interstellar medium.

Key words: galaxies: dwarf – galaxies: individual: IZw 18 – galaxies: ISM

1. Introduction

The blue compact galaxy IZw 18 is a fiducial object - it has a very low metallicity and is currently experiencing an intense star formation episode. Its metallicity (Searle & Sargent 1972, Skillman & Kennicutt 1993) is the lowest ($1/50 Z_{\odot}$) observed in this kind of objects and more metal-deficient blue compact dwarf galaxies have not been found despite extensive searches

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(Terlevich 1982, Terlevich et al. 1991, Masegosa et al. 1994, Izotov et al. 1994, Terlevich et al. 1996), with the possible exception of SBSG 0335-052W (Lipovetsky et al. 1999). This led Kunth & Sargent (1986) to suggest that during a single starburst event, the metals ejected by the massive ionizing stars are mixed within a short time scale in the HII region and lead, in few Myr, to a metallicity level comparable to that of IZw 18. Other studies have also shown that only one burst is sufficient to account for the oxygen abundance in IZw 18 (Alloin et al. 1978, Lequeux et al. 1981, Kunth et al. 1995). Thus if the metallicity measured in IZw 18 is solely the result of the metals produced in the current burst, a discontinuity in the spatial abundance distribution would be expected corresponding to the edge of the recently enriched region, typically a few hundred parsecs away from the young stellar core (Roy & Kunth 1995).

Early measurements of the abundance in the HI halo of IZw 18 by Kunth et al. (1994) indicated that the metallicity of the very massive neutral cloud in front of the ionizing cluster might be a factor of about 20 lower than in the HII region, strengthening the possibility of a sharp abundance drop. However the UV absorption lines they used were saturated, and this result remains very uncertain (Pettini & Lipman 1995). Moreover, recent HI observations by Van Zee et al. (1998) displayed lower velocity dispersion in the HI halo than those assumed by Kunth et al. (1994), leading to a metallicity comparable to the abundance in the central ionized region.

On the other hand, several observations of starburst galaxies (Kobulnicky & Skillman 1997, and references therein) have shown no significant gradient or discontinuity in the oxygen abundance distributions within the HII regions, except for the well established local overabundance of nitrogen in NGC5253 (Welch 1970, Walsh & Roy 1987, 1989, Kobulnicky et al. 1996, 1997). This corroborates models which predict that during a starburst, the heavy elements produced by the massive stars are ejected with high velocities into a hot phase, leaving the starburst region without immediate contribution to the enrichment of the interstellar medium (Pantelaki & Clayton 1987, Tenorio-Tagle 1996, Devost et al. 1997, Kobulnicky & Skillman 1997, Pilyugin 1999). In this scenario, the metals observed now would have their origin in a previous star formation event, and an underlying

old stellar population would be expected. Early observations of IZw 18 did not reveal clearly such an old population (Thuan 1983, Hunter & Thronson 1995), but recent reanalysis of HST archive data (Aloisi et al. 1999) has shown that stars older than 1 Gyr must be present. Moreover, Ostlin (1999) studied the resolved stellar population in the near infrared with NICMOS onboard HTS and found also that while the NIR colour magnitude diagram was dominated by stars 10-20 Myr old, numerous red AGB stars require a much higher age, in agreement with Aloisi et al. (1999). NICMOS data require stars older than 1 Gyr to be present and an age as high as 5 Gyr is favoured. This holds even if a distance slightly higher than the conventional 10 Mpc is adopted. This suggests that the present star formation episode in IZw 18 is not the first one. The rather high C/O ratio observed in IZw 18 (Garnett et al. 1997) could also suggest a carbon enrichment by an evolved population of intermediate mass stars. However, other starburst galaxies show quite lower C/O ratio (Garnett et al. 1995, Kobulnicky & Skillman 1998, Izotov & Thuan 1999), so this fact remains puzzling and controversial (Izotov & Thuan 1999). Considering the large uncertainties on the determinations of the stellar yields (Prantzos 1998, 1999) and on the determination of the C/O ratio (Izotov et al. 1997, Izotov & Thuan 1999), this may not be used as a strong evidence for an enrichment by an old stellar population.

Thus the mechanism responsible for the dispersal and mixing of newly synthesized elements in a starburst galaxy remains unclear, as well as the chain of star formation events responsible for the observed abundances. IZw 18, as the lowest abundance galaxy among starbursts, is an ideal laboratory to study these processes; its low metallicity is indicative of a rather “simple” star formation history, and one would expect the material ejected by the present massive stars to give high contrast in the abundances between the enriched and the non enriched zones. However, if the small companion galaxy northwest of I Zw18 has had an influence, as suggested by Dufour et al. (1996) through tidal effects or streaming gas resulting from a collision with the main body of I Zw18, the recent history of dispersal and mixing of elements may not be that easy to disentangle.

We conducted deep long slit spectroscopy of IZw 18 in order to measure the O/H abundances as far as possible from the central HII region of the NW knot, and to detect a discontinuity or systematic gradient in the metallicity distribution. Observations and reduction are described in Sect. 2; results are presented in Sect. 3 and 4 and the star formation history of this galaxy is discussed in the last sections.

2. Observations and data reduction

Seventeen exposures of 3000 seconds each of the blue compact galaxy IZw 18 were obtained with the 3.6 m Canada-France-Hawaii Telescope during three successive nights between 1995 February 1 and 4 using the MOS spectrograph with the 2048 × 2088 Loral 3 thick CCD detector. A long slit (1.52 arcsec wide) was used with a position angle of 45° covering the spectral range from 3700 to 6900 Å. The position of the slit is displayed on Fig. 1. The spatial resolution was 0.3145 arcsec/pix

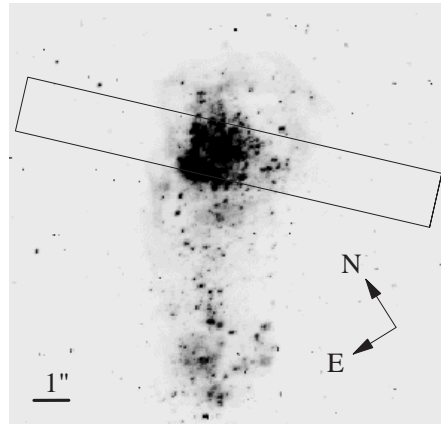


Fig. 1. V-band image of IZw 18 (from Hunter & Thronson 1995) with the slit position overlaid.

and the dispersion 1.58 Å/pix, leading to a spectral resolution of about 8.2 Å. The seeing was between 1 and 1.5 arcsec. The spectra were reduced using IRAF. The bias was removed using the overscan section from each frame. The pixel-to-pixel sensitivity correction and the illumination effects (vignetting) were corrected using dome flat field and sky flat images. The images were calibrated in wavelength using a combination of two exposures made during the second night with a Neon and a Helium lamp respectively. Five 50 seconds exposure images of the standard star Feige 34 were obtained in order to flux calibrate the spectra. To account for wavelength-dependent atmospheric refraction, we fitted a low-order polynomial along the stellar continuum in each frame and then realigned each spectrum before combination. The $H\beta$ spatial profile on the seven frames obtained during the first night was different from those ten obtained during the two other nights. We assumed that the positioning of the slit was slightly different during the first and the two other nights. Nevertheless, as the offset was less than 1” (slit positioning error), we aligned and combined all the nights together in order to increase the S/N ratio.

After reduction, an abnormal “diffuse light” background in the blue part of the long exposure images appeared. The origin of this “light” is probably due to a slight increase in the temperature of the CCD with time or to light diffused in the instrument during long exposures. This feature was removed by the subtraction of the background (task BACKGROUND) and using the task APSCATTER which is especially designed for this kind of purpose. The residuals after correction were less than 0.5 % of the continuum level. Three bad columns (579 to 581 *i.e.*, 4600 and 4602 Å respectively) of the CCD were ignored. We applied a Doppler correction to shift the final spectrum to zero velocity.

Spectra were extracted by summing along the slit. The apertures used were 5 pixels (1.57”) wide with 2 pixels (0.63”) of overlap. In order to increase the signal to noise (especially for the [OIII]4363Å line), large aperture spectrum were extracted summing over 12 pixels (3.78”) every 6 pixels (1.89”) along the slit, but this did not allow extension of the region over which [OIII]4363Å could be measured. We also extracted a large aperture spectrum integrated over the whole galaxy (25 pixels cen-

tered on the maximum of the continuum emission) in order to compare our observations with the spectroscopic measurements (but with different PA) of Skillman & Kennicutt (1993). A small aperture spectrum integrated over 2 pixels ($0.62''$) has also been extracted to match the aperture used by Izotov et al. (1997). The large aperture spectrum is displayed in Fig. 2 and results of line measurements (for both small and large aperture) are shown in Table 1. Their mean FWHM is around 8 \AA , and the lines are unresolved.

Emission lines were measured automatically using the routine TWOFITLINES¹. We compared the measurements with those made interactively with Gaussian fits through the IRAF task SPLOT and found no differences larger than two percent. A few weak lines in regions of low S/N high, for which no Gaussian could be fitted, were measured by direct integration. The errors bars were computed by summing in quadrature the effective photon noise on the line flux and the rms noise in the local continuum. An additional two percent error accounts for uncertainties in the flat-fielding and sky+diffuse light subtraction process.

3. Dust extinction

The interstellar dust extinction, or reddening, was first evaluated using the $H\alpha/H\beta$, $H\gamma/H\beta$ and $H\delta/H\beta$ ratios, assuming their intrinsic values to be 2.75, 0.475, 0.264 respectively for an electron temperature of 20000 K and a density of 100 cm^{-3} (Osterbrock 1989). We used the extinction function

$$\frac{I(\lambda)}{I(H\beta)} = \frac{F(\lambda)}{F(H\beta)} 10^{K(\lambda) \cdot E(B-V)} \quad (1)$$

where $I(\lambda)$ is the intrinsic line intensity, $F(\lambda)$ is the observed flux at each wavelength and $K(\lambda)$ is the extinction function according to the galactic reddening law of Seaton (1979).

In order to correct from the effect of stellar absorption in the Balmer lines, we first assumed that their strength was the same for all the lines. We derived then the value for which consistent results for $E(B-V)$ were obtained using the three different Balmer ratios. As the extent over which the flux was integrated is larger than the size of the ionizing star cluster, we corrected for the underlying stellar absorption only in the central area, *i.e.*, over $3.8''$ (185 pc) centered on the maximum continuum emission, according to the images of Hunter & Thronson (1995). We found the underlying stellar absorption to be around 1.8 \AA , close to the value of 2 \AA used by Skillman & Kennicutt (1993) and Roy & Walsh (1987) and adopted this value (1.8 \AA) for correction.

The variation of the extinction parameter $E(B-V)$ along the slit is shown in Fig. 3.a. It can be seen that a good agreement between the three computed values is obtained only in the central region (we have indeed forced this agreement by defining the strength of the absorption lines). Outside the central area, values obtained using $H\gamma/H\beta$ and $H\delta/H\beta$ ratios are systematically lower than values obtained with $H\alpha/H\beta$, and fall most of

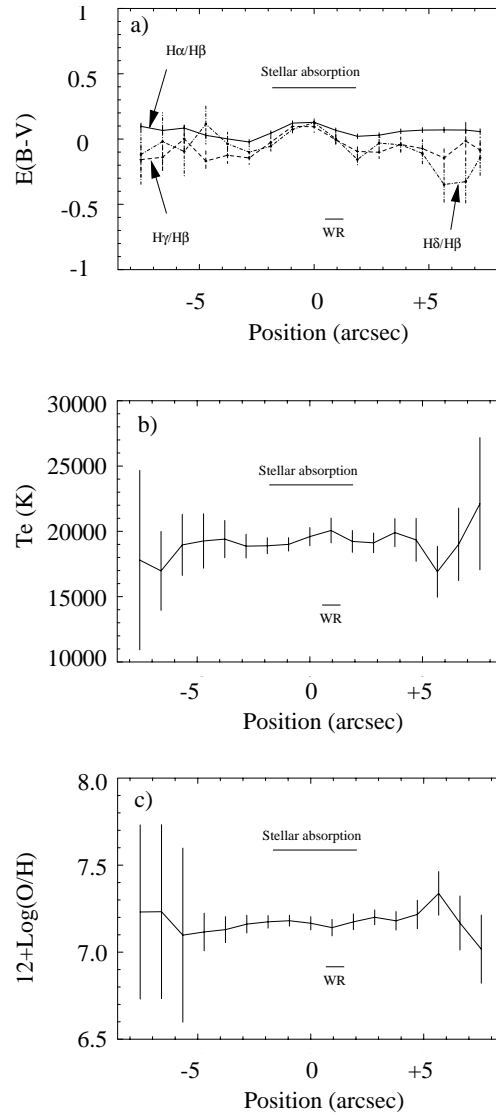


Fig. 3a – c. Spatial profile of $E(B-V)$, T_e and oxygen abundance in IZw 18. Positions are given in arcsec from the maximum of the continuum emission, with values negative and positive in the NE and SW directions respectively. The region where the stellar absorption has been subtracted is indicated, as well as the region where the WR stars have been found.

the time below zero. Artificially increasing the $H\beta$ flux by less than four percent erases this discrepancy, suggesting it could be (partially) related to small calibration errors due to the Balmer absorption lines in the Feige 34 spectra.

Stasinska & Schaerer (1999) have shown that $H\alpha$ is partially excited by collisions in IZw 18, so that the $H\alpha/H\beta$ ratio should be between 2.95 and 3.00 for at least the main body of the nebula, higher than for case B recombination. This effect would explain the discrepancy between the reddening values estimated using different line ratios. These authors conclude that the reddening affecting this ionized nebula should be practically equal to zero. Therefore, we have assumed no reddening at all along the slit in our calculations.

¹ Twofitlines, Version 1.4 package for IRAF provided by Jose Acosta, Instituto de Astrofísica de Canarias - SPAIN

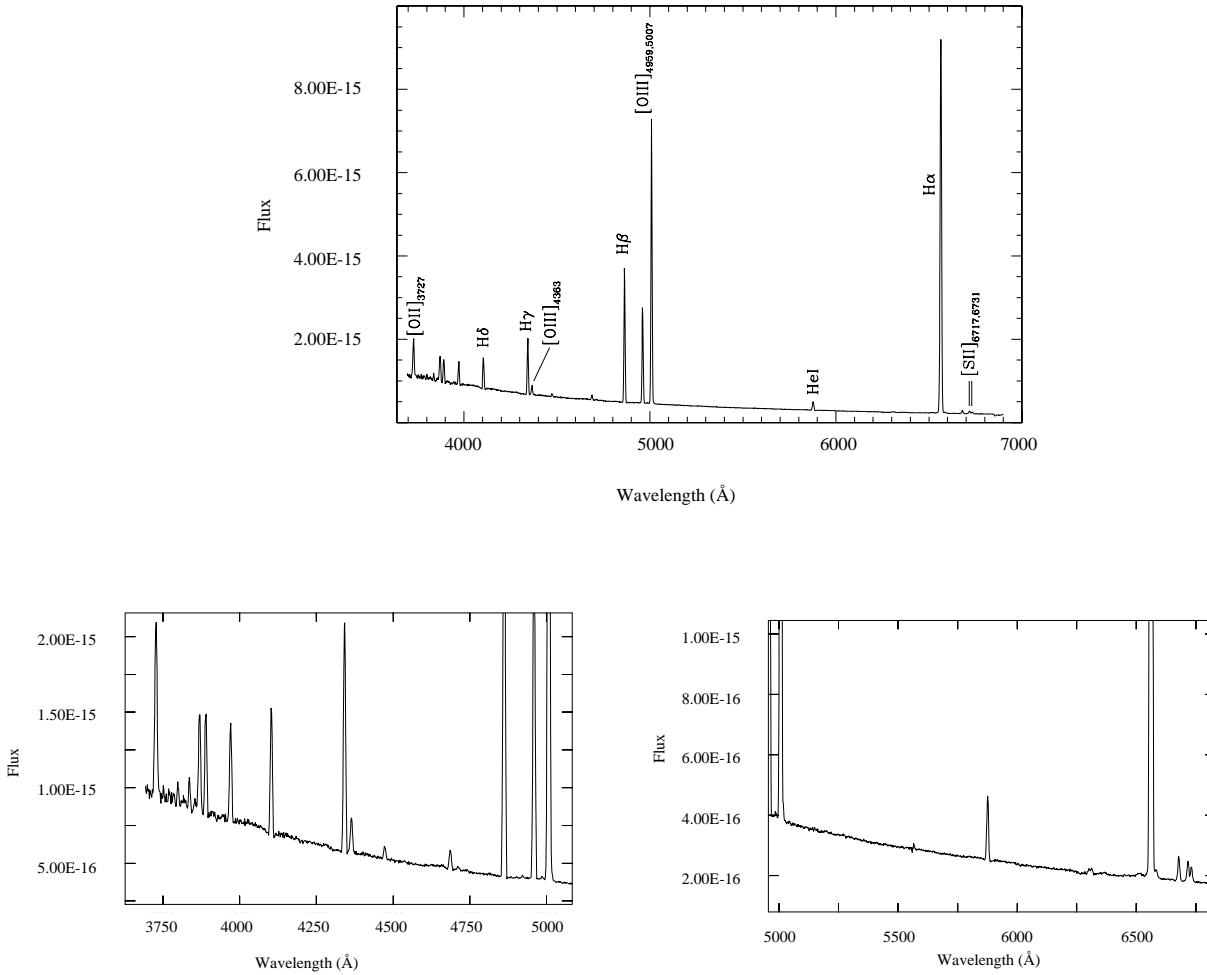


Fig. 2. Large aperture spectrum (over 25 pix *i.e.*, 7.85") of IZw 18, with zooms on the blue and red part to show the faintest lines. The most important lines are labelled.

4. Abundance determinations

4.1. Electron temperature

The temperature sensitive [OIII]4363Å line was measured over a slit length of 12 arcsec. This extent is comparable with that reported by Martin (1996) despite the large difference in exposure times (51000 s for this observation and 12000 s for that of Martin), but with a different orientation of the slit (PA = 45° against 7.6° of Martin). Nevertheless, the [OIII]5007 line was observed over a length of 49 arcsec (2.5 kpc) against 23 arcsec in Martin's observations. We then computed the ratio of [OIII]4959+[OIII]5007 line strength to [OIII]4363Å to evaluate the electron temperature $T_e(\text{OIII})$ with a program based on the 3-level atom formulae from McCall (1984) using atomic data from Mendoza (1983). Uncertainties were propagated through all steps to derive the error bars. Fig. 3.b shows the variation of the derived electron temperature as a function of position along the slit. The electron temperature can be considered constant across the HII region. Using the large and small aperture spectra, we also obtain a mean electron temperature of 19300 ± 600 K and 19700 ± 1000 K in agreement with

the previous determinations of Skillman & Kennicutt (1993) and Izotov & Thuan (1999) respectively. However, our measurement in the small aperture appears somewhat smaller (but still compatible within the error bars) than the value of Izotov & Thuan (1999).

4.2. The oxygen abundance

Oxygen abundances were derived for the regions where the electron temperature was measured using [OIII]λ4363. They were obtained by summing over ionization states using the expression:

$$\frac{\text{O}}{\text{H}} = \frac{\text{O}^+}{\text{H}^+} + \frac{\text{O}^{++}}{\text{H}^+} \quad (2)$$

The presence of HeII 4686 suggests that O^{+++} should also be present. Generally, HeII 4686 is used to evaluate the abundance of $\frac{\text{O}^{+++}}{\text{H}^+}$ but the origin, nebular or circumstellar, of HeII 4686 in IZw 18 is not well established. However it has been shown Legrand et al. (1997) that this line peaks at the position of the WR feature, suggesting that these stars could be responsible for a higher excitation locally, and that O^{+++} is not an abundant

Table 1. Observed line fluxes (without reddening correction) of the NW component of IZw 18 for the large aperture (LA) and the small aperture (SA) spectra.

Line Id	Rest λ (Å)	Flux (LA)	Error on Flux (LA)	EW (LA)	Flux (SA)	Error on Flux (SA)	EW (SA)
[SII]	6731.4	1.6	0.1	-2.5	1.4	0.2	-1.1
[SII]	6716.8	2.2	0.1	-3.5	1.8	0.2	-1.5
HeI	6678.4	2.5	0.1	-3.9	2.7	0.2	-2.1
H α	6563.0	306.4	0.9	-450	329.8	0.2	-251.8
[NII]	6584.2	0.8	0.1	-1.2	0.7	0.2	-0.6
[SIII]	6312.9	0.5	0.1	-0.7	detected	—	—
[OI]	6301.6	0.5	0.1	-0.7	—	—	—
HeI	5876.1	6.5	0.1	-7.3	6.3	0.2	-3.6
[OIII]	5007.2	205.4	0.6	-152	223.5	0.3	-86.2
[OIII]	4959.3	68.8	0.6	-49.4	74.9	0.3	-28.2
HeI	4922.4	0.6	0.1	-0.5	—	—	—
H β	4861.9	100	0.2	-68.7	100	0.3	-35.8
HeI + [AIV]	4712.0	0.9	0.1	-0.6	0.3	0.2	-0.1
HeII	4686.4	3.6	0.2	-2.2	4.3	0.4	-1.4
HeI	4472.8	2.3	0.2	-1.2	1.2	0.5	-0.3
[OIII]	4364.4	6.6	0.3	-3.3	7.5	0.7	-2.0
H γ	4341.8	44.8	0.2	-21.9	41.3	0.5	-10.7
H δ	4103.3	22.2	0.3	-8.9	17.0	0.7	-3.6
H ϵ	3970.7	17.6	0.5	-6.4	12.2	0.8	-2.3
[NeIII]	3869.5	18.3	0.7	-6.1	19.4	1.3	-3.4
HI + NeIII	3889.9	17.4	0.6	-5.9	12.0	1.1	-2.1
SiII	3854.9	2.7	0.1	-0.9	detected	—	—
HI	3836.2	3.5	0.5	-1.1	1.3	0.7	-0.2
HI	3798.9	3.4	0.1	-1.1	1.7	0.7	-0.3
HI	3769.1	detected	—	—	—	—	—
HI	3751.8	detected	—	—	—	—	—
[OII]	3727.4	35.6	0.9	-10.9	30.1	1.8	-4.8
H β flux (ergs cm ⁻² s ⁻¹)		2.9E-14			3.5E-15		
E(B-V) _{Hα/Hβ}		0.075			0.121		
E(B-V) _{Hγ/Hβ}		0.008			0.077		
E(B-V) _{Hδ/Hβ}		0.008			0.136		

ion. Skillman & Kennicutt (1993) and Izotov & Thuan (1998) have estimated that this stage contribute less than 4 percent to the total oxygen abundance. In term of a possible abundance gradient in IZw 18, neglecting O⁺⁺⁺ will not change the general trend of the abundance profile and would, at worst, slightly underestimate, by a few percent, the oxygen abundance in the region around WR stars. So the contribution of $\frac{O^{+++}}{H^{+}}$ was not included. The contribution of the ionization states O⁺ and O⁺⁺ was computed using a program based on the 3-level atom formulae from McCall (1984) with atomic data from Mendoza (1983) using the [OII] 3727 and [OIII] 4959 lines. We compared the abundances delivered by our program with abundances calculated by IRAF using the 5-level atom approximation from Shaw & Dufour (1995) and found no significant differences. The spatial profile of the oxygen abundance is given in Fig. 3.c.

We also used the large and small aperture spectra to derive the mean oxygen abundance $12 + \log(\frac{O}{H}) = 7.18 \pm 0.03$ in both cases, in excellent agreement with Skillman & Kennicutt (1993). This value appears different from

that reported by Izotov & Thuan (1999), mainly due to the differences in the electronic temperatures adopted.

Our results (Fig. 3.c) show unambiguously that there is no significant abundance gradient nor discontinuity in the NW-HII region of IZw 18 at scales smaller than 600 pc (using $H_0 = 75 \text{ km.s}^{-1}.\text{Mpc}^{-1}$). Martin (1996) suggested a possible, but weak, gradient in an orthogonal direction. The spatial resolution of our observations is 50 pc, and smaller scale inhomogeneities cannot be excluded. Moreover, the spatial profile of the oxygen lines does not indicate any abrupt change in metallicity at larger distances. Combined with the results of Van Zee et al. (1998), who found for the HI halo an abundance comparable with that of the HII gas, our results strongly favour a homogeneous metallicity distribution over the whole galaxy. This is fully consistent with related studies which have found very homogeneous spatial abundance distributions in several other giant HII regions (Diaz et al. 1987, Gonzalez-Delgado et al. 1994, Skillman 1985), as in 30 Doradus (Rosa & Mathis 1987), LMC-SMC (Dufour & Harlow 1977, Pagel et al. 1978,

Russell & Dopita 1990), or dwarf and irregular galaxies (Devost et al. 1997, Kobulnicky & Skillman 1997, 1996, Roy et al. 1996, Pagel et al. 1980, Masegosa et al. 1991), again with the exception of NGC 5253 already referred to in the Introduction.

5. Toward a new star formation history for IZw 18

5.1. A previous star formation event

The oxygen abundance distribution in IZw 18 appears extremely homogeneous throughout the galaxy, indicating a thoroughly mixed interstellar medium. If the measured abundances result from the metals ejected by the massive stars involved in the current burst, as suggested by Kunth & Sargent (1986), this would imply efficient mixing of the ejecta on scales of at least 600 pc within a timescale comparable to the age of the present burst *i.e.*, a few Myr (Hunter & Thronson 1995). However, dispersal of the heavy elements ejected by the massive stars can hardly be accomplished in less than 10^8 yr on scales between 100 and 1000 pc (Roy & Kunth 1995); the timescale required for complete mixing is even longer (Tenorio-Tagle 1996). Thus the observed metals cannot arise from the material ejected by the stars formed in the current burst. It follows that *the presently observed metals should have been formed in a previous star formation episode*. The metals ejected in the current burst of star formation remain most probably hidden in a hot phase as suggested by Pantelaki & Clayton (1987) and more recently by Tenorio-Tagle (1996), Devost et al. (1997), Kobulnicky & Skillman (1997) and Pilyugin (1999). Bomans (1999) has shown on a deep pointing with the ROSAT HRI instrument that there is extended X-ray emission to the SW and maybe to the NE from the central bubble of IZw 18. This extended emission seems to trace the expanding H_α loops, leading the author to conclude that it supports the picture of hot, metal-enriched gas streaming out of IZw 18. This gas would have been ejected into the halo where it would take long excursions while cooling and returning to the central galactic region to become available for future processing into stars (Tenorio-Tagle 1996). X-ray observations of the BCD VII Zw 403 (Papaderos et al. 1994) are also interpreted as hot material ejected by the present starburst. The availability of powerful X-ray observatories in the near future will allow the metallicity of this hot gas to be derived, allowing this scenario to be confirmed.

If the observed metals in IZw 18 were formed in a previous star formation episode, this would imply that the object is not a “young” galaxy undergoing its first star formation as suggested by Searle & Sargent (1972). Such a view is also supported by other studies, which independently lead to another scenario (Dufour et al. 1988, Dufour & Hester 1990, Hunter & Thronson 1995, Kunth et al. 1995, Garnett et al. 1996, Aloisi et al. 1999).

5.2. The dearth of low metallicity galaxies

The metal abundances measured in IZw 18 are the lowest known in the interstellar matter (but not in stars) of the local universe; this remains so despite extensive metallicity measure-

ments in emission line galaxies (Terlevich 1982, Terlevich et al. 1991, Masegosa et al. 1994, Izotov et al. 1994, Terlevich et al. 1996). Because of the correlation between size, luminosity and metallicity in dwarf galaxies (Skillman et al. 1989), Masegosa et al. (1994) proposed that galaxies with very low metallicity are too faint to be “caught” in their sample. This raises the possibility that extremely metal deficient objects may be very faint. IZw 18 and other starburst galaxies (Roennback & Bergvall 1995) lie quite far away from the correlation established by Skillman et al. (1989) for dwarf irregular galaxies. This may reflect the fact that they are presently undergoing a strong star formation event which increases their luminosity. However, the galaxies used by Skillman et al. (1989) were selected from the H_α catalog of Kennicutt et al. (1989), thus the sample allows for current star formation! The origin of the correlation remains unclear (see also Skillman 1999).

It is easy to show that the present star formation rate in IZw 18 or in other starbursts cannot be sustained for a Hubble time without producing excessive chemical enrichment and a numerous stellar population. It is generally admitted that blue compact galaxies experience violent star formation events separated by long quiescent phases (Searle & Sargent 1972) during which they would appear as Low Surface Brightness Galaxies (LSBG) or quiescent dwarfs. However this population does not contain any objects more metal poor than IZw 18 (McGaugh & Bothun 1993, McGaugh 1994, Roennback & Bergvall 1995, Van Zee et al. 1997a,b). *Does the metallicity of IZw 18 represent a lower limit for the abundance in the gas of local galaxies? If so, why?*

5.3. The lack of HI clouds without optical counterpart

Different observing programs have been carried out to search for isolated intergalactic HI cloud, but without success so far (Briggs 1997). Most local so-called primeval HI clouds candidates turned out to be associated with stars (see for example Djorgovski 1990; Impey et al. 1990; McMahon et al. 1990; Salzer et al. 1991; Chengalur et al. 1995, for HI1225+01). *Does this mean that such entities do not exist?* If so, this would imply that *all gas clouds (with a mass comparable to that of a dwarf galaxy) have formed stars*. However, the detection limits for HI surveys remain quite high ($N_{HI} \sim 10^{18} \text{ cm}^{-2}$), and the existence of very small primeval HI clouds cannot be ruled out. Nevertheless, if isolated dwarf galaxy progenitor HI clouds existed, they would have sizes and masses comparable to small galaxies, and they would present sufficient column densities to be detected by radio techniques. So far, non-detection indicates that if such clouds exist, they are very rare. This idea is reinforced by the presence of absorption line systems of high column densities in the spectra of quasars which seems to arise mainly from halos of bright galaxies and not from small HI clouds (Lanzetta et al. 1995, Tripp et al. 1997), indicating again that the latter are sparse. Furthermore, it has been shown that the diffuse cosmic UV background can ionize the extreme outer HI disks of spiral galaxies (Van Gorkom 1991, Corbelli et al. 1989, Maloney 1990, Corbelli & Salpeter 1993a,b), producing

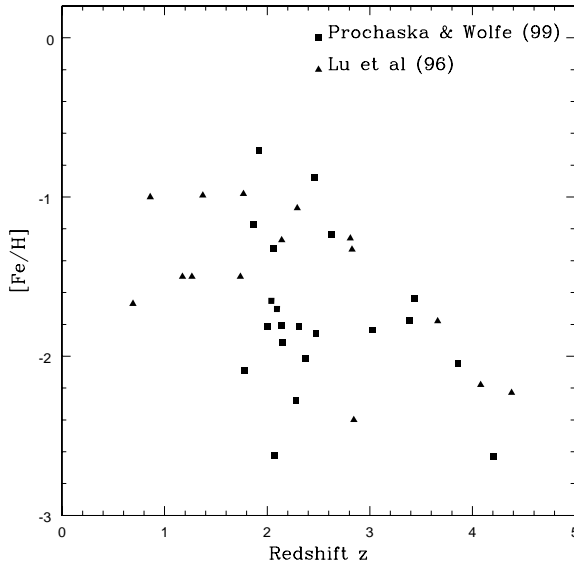


Fig. 4. DLA [Fe/H] abundance as a function of redshift. Data from Lu et al. (1996) and Prochaska & Wolfe (1999)

an abrupt fall in their HI column density. This effect could contribute to hide some primeval HI gas from the current surveys.

5.4. The temporal evolution of the metallicity

Absorption lines in Damped Lyman Alpha (DLA) systems are used to study the temporal evolution of the metallicity of the interstellar gas. Although the nature of the absorbing systems is still controversial (Tripp et al. 1997), it is generally admitted that the metallic lines are associated in some way with galaxies. The temporal evolution of the metallicity in the DLA systems reported by Lu et al. (1996) and more recently by Lu et al. (1998) and Prochaska & Wolfe (1999) is reproduced in Fig. 4.

One notices that the mean metallicity of the interstellar gas increases as one gets closer to local time. This is generally interpreted as the effect of cumulative enrichment by strong star formation events. However, a more intriguing feature is that the metallicity of the most underabundant systems seems also to increase with time! No extremely underabundant system has been found at low redshift. If the enrichment is solely the result of starburst events, we should find, locally, objects which have not undergone any burst (or very few of them); these objects would have a very low metallicity (comparable to what is observed at high redshift). *Does the apparent increase in metallicity of the most underabundant systems indicate the existence of a minimal and continuous enrichment of the interstellar medium?* The number of systems observed at low redshift is small (Meyer & York 1992, Steidel et al. 1995, Pettini & Bowen 1997, de la Varga & Reimers 1997, Boisse et al. 1998, Shull et al. 1998); if some unevolved systems exist, they must be very few. The non detection of such systems could arise from a selection effect rather than from their inexistence.

5.5. A new star formation regime

It is generally accepted that the metal enrichment of the ISM builds up mainly in bursts. Different studies have been carried out to model these bursts to reproduce the global properties of galaxies. In the case of IZw 18, Kunth et al. (1995) have shown that only one burst, with an intensity comparable to the present one, is enough to produce the observed abundances. As we have shown, this single burst cannot be the present one. Previous massive star formation has occurred. We cannot eliminate the possibility that this previous star formation event was a starburst.

However, starburst episodes must be separated by quiescent phases, during which these systems appear as quiescent dwarfs or Low Surface Brightness Galaxies (LSBG). Studies of the latter objects (Van Zee et al. 1997c) have revealed that, despite their low gas density, star formation occurs (with a weak efficiency), probably as a local process instead of a global event. *The SFR between bursts is very low, but not zero, so the metallicity would increase slowly during these quiescent phases.* Because these star formation rates are very weak, they are generally neglected in studies of star formation history of galaxies. However, in dealing with very low metallicity galaxies, they are capable of raising the metallicity levels up to values comparable to that of IZw 18 in less than a Hubble time.

For example the galaxy UGC 9128, studied by Van Zee et al. (1997b) presents a SFR of about $1.7 \cdot 10^{-4} M_{\odot} \text{ yr}^{-1}$ for a HI mass of $3.55 \cdot 10^7 M_{\odot}$. If such a low SFR lasts 10 Gyr, it will form $1.7 \cdot 10^6 M_{\odot}$ in stars, and no more than 5% of the initial mass of gas will have been transformed into stars. At this low continuous star formation rate, sustained during even a Hubble time, the fraction of gas still available at present epoch remains high (about 95%). Thus the existence of a continuous low star formation rate in dwarf galaxies is consistent with the large HI reservoirs generally observed in these objects.

The current metallicity of the gas Z_{gas} assuming the simple closed box model Pagel (1998) can be expressed by (Searle & Sargent 1972)

$$Z_{gas} \sim -y \ln(G) \quad (3)$$

where G is the fraction of gas presently available and y the yield in heavy elements. The uncertainties on this last parameter are large, but y is likely to be in the range 0.01 to 0.036 (Maeder (1992)). Using a mean value $y \sim 0.02$, and for the example above with $G = 0.95$, we estimate the metallicity of the gas resulting from this low SFR enrichment to be close to 10^{-3} , that is 1/20th solar!

Consequently, a low continuous star formation rate cannot be neglected, especially when dealing with low metallicity galaxies; this may be the dominant star forming and metal enrichment process in dwarf galaxies.

We propose that in the most extreme objects, like IZw 18, a continuous low star formation regime can account for the observed abundances. We surmise that the present starburst is the first major one in the history of IZw 18, and that a mild star formation rate has been going on for several Gyr. Preliminary cal-

culations strengthen this hypothesis (Legrand & Kunth 1998). If such a low regime is universal, we expect that all small systems have been forming stars and that their metallicity has increased slowly but steadily with time. This scenario explains the lack of local objects more underabundant than IZw 18, the absence of HI clouds without an optical counterpart and the evolution as a function of redshift of the most metal poor quasars absorption systems. Detailed modelling of this low star formation regime is presented in Legrand (2000).

6. Conclusion

We have acquired deep long slit spectroscopy of the metal poor dwarf star forming galaxy IZw 18. We confirm the very low metal content of the galaxy, and show that no significant abundance gradient nor inhomogeneities larger than ± 0.05 dex are present in IZw 18 on scales of 50 pc to 600 pc. This is in apparent contradiction with the hypothesis of instantaneous local pollution proposed by Kunth & Sargent (1986). Instead, this supports a picture where metals ejected in the current burst of star formation escape into a hot halo hidden phase in the halo, follow a long excursion while cooling and come back much later into the central galactic region (or escape into the intergalactic medium). This also implies that star formation has been occurring previous to the current burst. Based on different observational facts, we propose that the metals in IZw 18 are the result of a mild *continuous* star formation rate. The generalization of this model to all gas clouds can account for the scarcity of local galaxies with a metallicity lower than IZw 18, for the increase with time of the metallicity of the most underabundant DLA systems, and for the apparent absence of HI clouds without optical counterparts. If starbursts appear as important episodes in the history of galaxies, the low continuous star formation regime, dominant during the quiescent inter-burst periods, cannot be neglected.

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