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LETTER

Letter to the Editor

Detection of WR stars in the metal–poor starburst galaxy IZw 18

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Abstract. Wolf-Rayet stars (WR) have been detected in the NW region of the metal–poor starburst galaxy IZw 18. The integrated luminosity and FWHM of the bumps at 4650 Å and 5808 Å are consistent with the presence of a few individual stars of WC4 or WC5 type. Evolutionary synthesis models predict few WRs in this galaxy, but only of WN type. The presence of WC stars at such low metallicity could however be explained by high mass loss rates, which would constrain the IMF upper mass cut-off in IZw 18 to be higher than 80 $M_\odot$ or alternatively favor a binary channel for WR formation. WC stars could also explain the strong and narrow HeII 4686Å emission line which peaks co–spatially with the WR bump emission, as suggested by Schaerer (1996). This detection shows that WR stars, even of WC type, are formed at metallicities below 1/40th solar.

Key words: Galaxies – Galaxies: IZw 18 – Galaxies: WRs galaxies – Galaxies: star formation – Galaxies: enrichment of ISM – Stars: WR –

1. Introduction

IZw 18 is known to be the most metal deficient object among the blue compact dwarf galaxies (BCDs), with a metallicity of 1/40th of the solar value and undergoing a strong star formation event (Searle & Sargent 1972; Skillman & Kennicutt 1993, hereafter SK93). Moreover, IZw 18 is a close by object with a recession velocity of 740 $\pm$ 10 km/s. This makes this galaxy an excellent laboratory for studying the properties of star formation at low metallicity. It is well known that the spectrum of IZw 18 presents a strong HeII4686Å narrow emission line. As the ionising spectra of ordinary O stars are unable to explain the presence of this feature, Bergeron (1977) originally proposed that this line can directly originate in the atmosphere of hot Of stars.

Broad WR features are often found in the spectra of starburst galaxies (Vacca & Conti 1992). As the WR stage occurs after a few Myrs in the lifetime of massive stars, starburst galaxies are often dominated by a recent burst of star formation undergoing a WR–rich evolutionary phase (Schaerer & Vacca 1996, hereafter SV96).

However, metallicity is a crucial parameter for the evolution of massive stars through the WR phase in a starburst (Maeder & Meynet 1994; Cerviño & Mas-Hesse 1994, hereafter CMH94; Meynet 1995, hereafter M95). Specifically, when the metallicity decreases, the time duration of the WR stage decreases and the lower mass limit for a star to be able to evolve to WR phase increases. This results in a dramatic diminution of the WR/O star ratio with metallicity. Moreover, as the WC star progenitors are supposed to be more massive than the WN ones, the ratio WC/WN should also decrease with metallicity (M95). At low metallicity however, evolutionary models predict that WN stars must dominate the WR population (M95). At the metallicity of IZw 18, no WC should be formed (CMH94).

In Section II, we will present the observations and the measurements. Contrary to expectation, evidence for the presence of few WC stars will be given; the possible excitation of the narrow HeII line by these stars and comparison with the evolutionary models are discussed in the last Section.

2. Observations and data analysis

Seventeen exposures of 3000 seconds each of the blue compact galaxy IZw 18 were obtained with the 3.6m CFH telescope during the three successive nights between 1995 February 1st and 4th using the MOS spectrograph with the 2048x2088 Loral

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Table 1. Relative emission line fluxes in IZw 18 measured in the 7.8" long integrated spectrum.The Balmer line fluxes have been corrected for underlying stellar absorption by 2 Å of equivalent width.

Lines	$I(\lambda)/I(H\beta)$	$I_0(\lambda)/I(H\beta)$	$I_{th}(\lambda)/I(H\beta)$
[OII]λ3727	0.356	0.388	0.845
[NeIII]λ3867	0.181	0.193	0.176
Hδ	0.267	0.283	——
Hγ	0.476	0.497	——
[OIII]λ4363	0.064	0.067	0.049
HeIλ4471	0.022	0.022	0.031
Hβ	1.000	1.000	1.000
[OIII]λ5007	2.002	1.979	1.960
HeIλ5876	0.063	0.058	0.082
Hα	2.978	2.669	2.830
[NII]λ6583	0.008	0.007	0.009
[SII]λ6716	0.021	0.019	0.007
[SII]λ6731	0.016	0.014	0.005
WRbump region			
CIII4650	——	——	2.66E-7
OII4651	——	——	1.8E-4
[FeIII]4658	——	——	1.33E-4
HeII4686	0.040	0.041	1.9E-9
[ArIV]4711	0.01	0.01	9.54E-3
[ArIV]4741	5.7E-3	5.7E-3	6.77E-3

Columns numbers:
2: Measured flux relative to Hβ.
3: Flux corrected for the reddening.
4: Flux predicted from SL96.

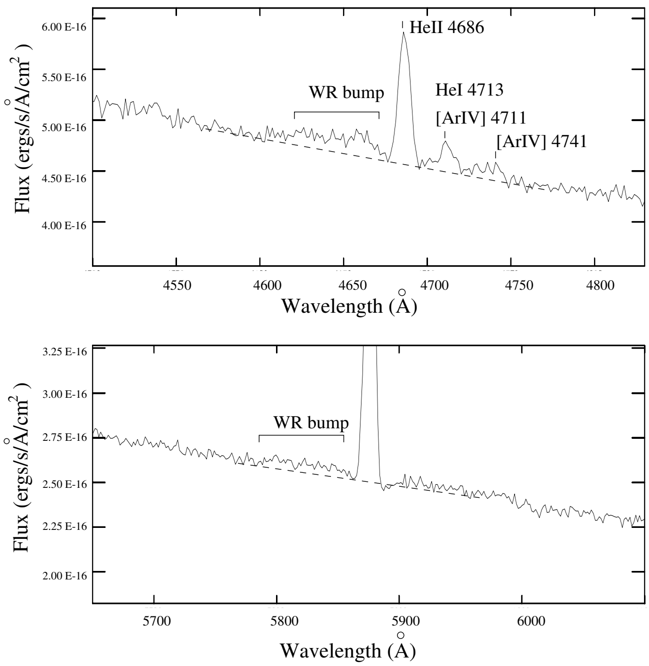

Fig. 1. Regions of the spectrum of IZw 18 around the HeII4686Å (upper) line and the HeI5876Å (lower). The spectrum is integrated over 7.8" centered on the maximum continuum emission. The broken line shows the position of the fitted continuum.

3 CCD detector. A long slit (1.52 arcsec wide) was used with a position angle of 45°, covering a spectral range from 3700 to 6900 Å. The slit was centered on the central HII knot of the NW region of IZw 18. The spatial resolution was 0.3145 arcsec/pix and the dispersion 1.58 Å/pix giving a spectral resolution of about 8.2 Å. The seeing was between 1 and 1.5 arcsec. The spectra were reduced using IRAF. Due to a slight offset between the first night and the following (less than 1"), the sampled spatial region is slightly increased with respect to the slit width.

The strong emission lines in the integrated spectrum were measured over 25 pix (7.8") centered on the continuum maximum emission. This allowed us to determine a reddening of E(B-V)=0.1, in agreement with SK93, assuming an underlying Balmer stellar absorption of 2 Å EW. We have used this value to correct the measured flux from the reddening effect. The EW of $H\beta$ is measured to be 70 $\pm$ 5 Å. The line measurements are given in table 1.

The most striking aspect of this spectrum, integrated over 25 pix (7.8"), are two faint broad emission features around 4650 Å and near 5812 Å (Fig.1).

Such features are typical of WC stars (Smith 1968; Conti & Massey 1989). Nevertheless, narrow nebular emission lines can give non negligible contributions around 4650 Å, such as CIII4650Å; OII4651Å; [FeIII]4658Å; HeII4686Å; [ArIV]4711 4740Å and NIII4634,4640Å. In order to evaluate their contribution to the bump around 4650 Å hence the significance of this bump, we have used the photoionization models produced by Stasiñska & Leitherer (1996 hereafter SL96) for evolving starbursts. No model can exactly match the observed strong emission features [OIII]5007Å, [OIII]4363Å, [NeIII]3869Å and [OII]3727Å. We then used a model giving a reasonable agreement with our data, using parameters as close as possible to that of IZw 18. The model we used (named "iiicikii" in SL96) corresponds to 4 Myrs for the burst in agreement with evolutionary models predictions of CMH94 using the $H\beta$ equivalent width. The results from the model are given in column 4 of Table 1. The NIII4634,4640Å lines are not given by the models. However, this doublet is absent in the spectrum of SBS 0335-052 (Izotov et al., 1997), a starburst galaxy with an abundance and an electronic temperature very similar to those of IZw 18, and so the doublet was neglected.

We then measured the flux in the WR bump at 4650 Å and subtracted the expected nebular lines given by the model. We find that the remaining flux in the bump at 4650 Å is centered at around 4646 Å, has a FWHM of 55 $\pm$ 5 Å leading to a ratio WR(bump)/Hβ=0.029. Finally, we have converted the measurements to absolute flux, assuming a distance of 10 Mpc for IZw 18. The flux in the bump at 4645 Å is (1.0 $\pm$0.3) 10^{37} ergs/s and, after subtraction of the nebular lines, (9.90 $\pm$ 3) 10^{36} ergs/s.

In the region around the HeI5876Å line, a faint large bump centered at 5820 Å is observed (fig. 1) with a FWHM of 50 $\pm$ 10 Å. The flux emitted in this bump is found to be (4 $\pm$ 1.5) 10^{36} erg/s.

We also investigated the spatial location of the emission features. The nebular emission is shifted by 1" in the NE direction with respect to the continuum emission. By binning the spectrum over 1.6" at all the positions along the slit, we find that the bumps at 4645 Å and 5820 Å are correlated in position and occur in a region situated between 1" and and 2" SW from the central star cluster. Moreover, this corresponds to the position of the maximum emission of the narrow HeII4686Å relative to Hβ (Fig. 2).

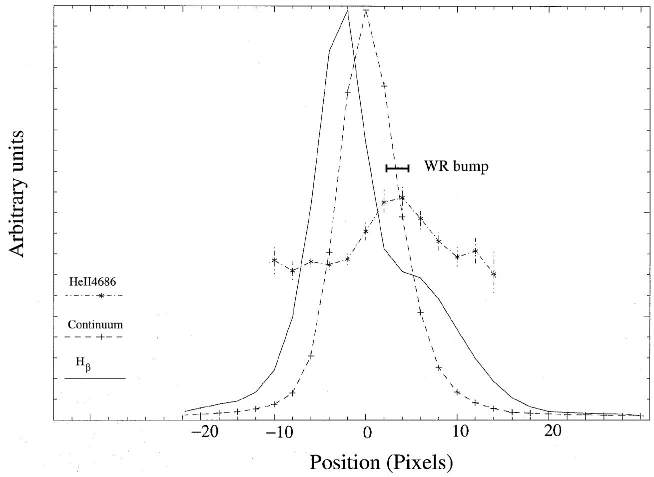

Fig. 2. Spatial location of the different spectral emission features along the slit (1 pixel=0.3145 arcsec). Position of the maximum emission in the WRbump is indicated with bold line.

3. Discussion

3.1. WR population

Generally WR stars are classified in two groups, WN and WC. Stars with type ranging from 2 to 5 and from 4 to 6 respectively are called early (and noted WNE and WCE) while WR with type ranging from 6 to 9 for WN and from 8 to 9 for WC are called late (Conti et al., 1990) and noted WNL, WCL. It is commonly accepted that early type stars are hotter than late type ones, even if no direct relationship between type and temperature has been determined (Vacca & Conti, 1992). WN stars are mainly characterized by the NIII4634,4640Å blend, NIV4057Å NV4604,4620Å blend and HeII4686Å emission lines, while WC stars are betrayed by CIII4645Å, CIII5696Å and CIV5801,5812Å emission features (Conti et al., 1990).

Our spectra show unambiguously a broad bump centered at 4645 Å which cannot be nebular in origin. No underlying contribution under the narrow 4686 Å line is detected, which rules out WN stars for which a strong broad contribution at 4686 Å is expected, but not WCE in which the contribution at 4686 Å can be negligible (Schaerer 1996). The bump at 4645 Å appears to be correlated with another bump around 5820 Å which we interpret as the CIV5801,5812Å blend. Smith (1991) gives an average luminosity of 5 10^{36} ergs s^{-1} in the 4650 Å bump and 3 10^{36} ergs s^{-1} in the 5808 Å bump for WCs. The measured fluxes in the two bumps, taking the uncertainties into account, agree well with the presence of one or two WC stars in IZw 18. Note that Hunter & Thronson (1995) report the possible detection of two WR stars with the HST using a 4695 Å filter. Finally, the comparison between the FWHM of the bumps given by Smith et al. (1990) with our measured values (55 ± 5 Å at 4645 Å and 50 ± 10 Å at 5820 Å) supports the presence of WCEs and indicates that the most probable types for these stars are WC4 or WC5. According to CMH94, and M95, the progenitors of WR stars at $Z = 0.001$ are stars at least more massive than 80 $M_{\odot}$. This constrains the IMF upper mass cutoff in IZw 18 to be higher than 80 $M_{\odot}$. Moreover, at metallicity lower than 1/20th solar, CMH94 do not predict the formation of WC. However these types are predicted if WR binary stars are taken into account (SV96; Cerviño et al. 1996) as will be discussed below.

3.2. Narrow HeII4686Å line and evolutionary models

It is well known that IZw 18 presents a strong HeII4686Å line in emission (SK93). The production of this line requires very energetic photons (E $\geq$ 54 eV) of which too few are produced by ionizing sources with effective temperature $T_{eff} \leq 70000$ K (Garnett et al. 1991 hereafter G91). Since its intensity is several times larger than predicted by photoionization models of HII regions ionised by O stars, Bergeron (1977) suggested that this line can arise directly in the atmosphere of hot Of stars. However, as asserted by Conti (1991), Of stars typically have both NIII4640Å and HeII4686Å with roughly the same intensity, and in IZw 18 no NIII4640Å as strong as the HeII4686Å line is observed. Campbell et al. (1986) have suggested that the low abundance in IZw 18 may suppress the NIII lines (see also Walborn et al 1995). On the other hand, G91 have proposed an excitation of the HeII4686Å by X-ray sources, but Motch et al. (1994) using ROSAT data, have shown that this mechanism cannot explain the observed emission in IZw 18. Pakull & Motch (1989) have also suggested that hot WN stars could be at the origin of this line. Finally, ionization by WC stars has been suggested by Schaerer (1996).

Some association between HeII4686Å and WO stars has been reported by G91 while nebular HeII4686Å associated with the presence of WC stars have been reported by Gonzalez-Delgado et al. (1994). The correlation observed between the maximum emission of the narrow nebular HeII4686Å and the supposed location of the detected WC in IZw 18 (Fig. 2) favour this later hypothesis. G91 however find no offset between the peaks of Hβ and HeII4686Å for a different orientation of the slit. Izotov & Thuan (1997, ApJ submitted) also report a shift and attribute the difference between their results and the ones of G91 to a poorer S/N and resolution of the G91 data.

Schaerer (1996), using non-LTE, line blanketed model atmospheres accounting for stellar winds, synthesized the nebular and WR HeII4686Å emission in young starbursts. He finds that after 3 Myrs, the $HeII_{nebular}/H\beta$ ratio increases due to the appearance of WC stars. For metallicities between solar and 1/5th solar, the ratio is the strongest with typical values between 0.01 and 0.03. At low metallicity ($1/20 Z_{\odot}$), this ratio peaks after 3.4 Myrs at 4 10^{-3}, already ten times lower than what is observed in IZw 18. Moreover, at low Z, due to the low mass loss, the WC population becomes negligible (M95, CMH94, Maeder & Meynet 1994) explaining the faintness of the expected nebular HeII4686Å line.

However, M95 has shown that models using mass loss rates twice the standard ones, although in good agreement with the overall results obtained by CMH94, predicts more WCs. Observational evidence for larger values of mass loss rates are given in Heap et al. (1994) for R136a. Still, some objects with relatively low metallicity exhibit large numbers of WC stars like IC 10 which have a ratio WC/WN of 2 (Massey 1996) while Massey & Armandroff (1995) suggest that the star formation "vigor" affects the IMF and thus the number of WC to WN stars (see eg M95). Another way to form WR stars is the binary channel, but as mentioned by SV96 and Cerviño et al. (1996), the WRs formed in binary systems start to appear at 5 Myrs which may be longer than the burst age in IZw 18. Our new observations show that WC stars can form in a very metal deficient environment and tend to corroborate the high mass loss rate hypothesis of M95, possibly with rates even higher than twice the standard one at very low metallicities. Although our result has little statistical bearing, the absence of WN stars comes as a surprise as evolutionary models (CMH94, M95) predict more WN stars than WC stars at low metallicity and even no WC at $Z \leq \frac{1}{20} Z_{\odot}$ (CMH94). This detection of WC in a environment with metallicity as low as 1/40th solar may indicate that a binary channel for WR star formation and/or higher mass loss rates have to be accounted for.

4. Conclusion

Two broad bumps have been detected in the spectra of IZw 18, centered respectively at 4645 Å and 5820 Å. We interpret these features as evidences for the presence of WR stars of WC type. The flux and FWHM of these bumps affirm that we are in presence of one or two WC4 or WC5 stars. The strong narrow HeII4686Å line peaks co-spatially with the WR bumps indicating that this line is nebular in origin and due to the presence of these detected WC stars. No evidence for the presence of WN stars is found contrary to evolutionary models at very low metallicity. This favours the hypothesis that mass loss rates may be higher than twice the standard one at very low metallicities or that the binary channel is an important process of WR stars formation. Finally, the implication on the IMF of IZw 18 is that stars more massive than 80 $M_{\odot}$ have been formed in this galaxy.

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