Letter to the Editor

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

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Abstract. Wolf-Rayet stars (WR) have been detected in the NW region of the metal–poor starburst galaxy I Zw 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 I Zw 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 4686 Å 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: I Zw 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, I Zw 18 is a close by object with a recension velocity of 740 ± 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 I Zw 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 I Zw 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 I Zw 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
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 central HII knot of the NW region of IZw 18. The flux emitted in this bump is found to be 4.00E-16 ergs/s/Å/cm² at 4650 Å. The flux in the bump at 4645 Å is 2.00E-16 ergs/s/Å/cm², and at 5820 Å, it is 2.97E-16 ergs/s/Å/cm², leading to a ratio WR(bump)/Hβ = 0.029. Finally, we have converted the measured flux from the reddening effect. The EW of Hβ is measured to be 70 ± 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). In the region around the HeI5876 Å line, a faint large bump is observed (Fig. 1) with a FWHM of 50 ± 90 Å. The flux in the bump at 4645 Å is (1.0 ± 0.3) × 10^37 ergs/s, and, after subtraction of the nebular lines, (9.90 ± 3) × 10^36 ergs/s.

In the region around the HeI5876 Å line, a faint large bump centered at 5820 Å is observed (Fig. 1) with a FWHM of 50 ± 10 Å. The flux emitted in this bump is found to be (4 ± 1.5) × 10^36 ergs/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 2" SW from the central star cluster. Moreover, this corresponds to the position of the maximum emission of the narrow HeII4686 Å relative to Hβ (Fig. 2).
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 $T_{\text{eff}} \leq 70000$ 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 III4640Å and HeII4686Å with roughly the same intensity, and in IZw 18 no III4640Å as strong as the HeII4686Å line is observed. Campbell et al. (1986) have suggested that the low abundance in IZw 18 may suppress the III 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 González-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) favours this later hypothesis. G91 however find no offset between the peaks of H$\beta$ 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 HeI/nbular/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 IZw18. 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 at low metallicity and even no WC at \( Z \leq \frac{1}{20} Z_\odot \) (CMH94). This detection of WC in an 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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References

Bergeron J., 1977, ApJ, 211, 62
Campbell A.W., Terlevich R., Melnick J., 1986, MNRAS, 223, 811
Cerviño M. & Mas-Hesse JM. (CMH94), 1994, A&A, 284, 749
Cerviño M., Mas-Hesse J.M., Kunth D., 1996, “WR stars in the framework of stellar evolution” 33rd Liege int. Ast. Coll.
Conti P.S., Massey P., 1989, ApJ, 337, 251
Conti P.S., Massey P., Vreux JM., 1990, ApJ, 354, 359
Conti P.S., 1991, ApJ, 377, 115
Garnett D.R., Kennicutt R.C., Chu Y., Skillman E.D. (G91), 1991, ApJ, 373, 458
Gonzalez-Delgado R.M. et al., 1994, ApJ, 437, 239
Heap et al., 1994, ApJ 435, L39
Hunter D.A., Thronson HA., 1995, ApJ, 452, 238
Izotov et al., 1997, ApJ 476, 698
Maeder A., Meynet G., 1994, A&A, 287, 803
Massey P., 1996, in “WR stars in the framework of stellar evolution”, 33rd Liege int. Ast. Coll.
Massey P., Armandroff T.E., 1995, AJ, 109, 2470
Meynet G. (M95), 1995, A&A, 298, 767
Motch C., Pakull M.W., Pietsch W., 1994, in “violent star formation, from 30 Doradus to QSO”, Ed. G. Tenorio Tagle, Cambridge University press
Pakull M.W., Motch C., 1989, Extranuclear activity in galaxies, Ed E. Meurs & B. Fosbury
Schaerer D., 1996, ApJ, 467, L17
Schaerer D., Vacca W. (SV96), 1996, in “WR stars in the framework of stellar evolution”, 33rd Liege int. Ast. Coll.
Searle L., Sargent W.L.W., 1972, ApJ, 173, 25
Skillman E.D. & Kennicutt R.C.(SK93), 1993, ApJ, 411, 655
Smith L., 1968, MNRAS, 138, 109
Smith L., 1991, in “Wolf-Rayet Stars and interrelations with other stars in galaxies”, IAU sym., 143
Smith, LF., Shara M, M., Moffat A.F.J., 1990, ApJ, 358, 239
Stasinska G., & Leitherer C. (SL96), 1996, ApJSup, 107, 661
Izotov Y.I., Thuan T.X., Lipovetsky V.A., 1997, ApJS, 108, 1
Vacca W., Conti P.S., 1992, ApJ 401, 543
Walborn et al., 1995, PASP, 107, 104

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