GMOS–IFU spectroscopy of the compact H II galaxies Tol 0104–388 and Tol 2146–391: the dependence on the properties of the interstellar medium

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Accepted 2012 August 15. Received 2012 July 26; in original form 2012 March 14

ABSTRACT

Using GMOS–IFU spectroscopic observations of the compact H II/blue compact dwarf galaxies Tol 0104–388 and Tol 2146–391, we study the spatial distribution of emission lines, equivalent width EW(Hβ), extinction c(Hβ), ionization ratios ([O III] λ5007/Hβ, [S II] λλ6717, 6731/Hα and [N II] λ6584/Hα), kinematics and the chemical pattern (O/H, N/H and N/O) of the warm interstellar medium in these galaxies. We also investigate a possible dependence of these properties on the I(He II λ4686)/I(Hβ) ratio and find no significant correlation between these variables. In fact, the oxygen abundances appear to be uniform in the regions where the He II λ4686 emission line was measured. It can be interpreted in the sense that these correlations are related to global properties of the galaxies and not with small patches of the interstellar medium. Although a possible weak N/H gradient is observed in Tol 2146–391, the available data suggest that the metals from previous star formation events are well mixed and homogeneously distributed through the optical extent of these galaxies. The spatial constancy of the N/O ratio might be attributed to efficient transport and mixing of metals by starburst-driven supershells, powered by a plethora of unresolved star cluster in the inner part of the galaxies. This scenario agrees with the idea that most of the observed He II λ4686 emission line is produced by radiative shocks, although other sources such as Wolf Rayet stars, high mass X-ray Binaries and O stars cannot be excluded.

Key words: galaxies: abundances – galaxies: dwarf – galaxies: individual: Tol 0104–388 – galaxies: individual: Tol 2146–391 – galaxies: ISM.

1 INTRODUCTION

The ionizing radiation from newly formed stars and its interaction with the surrounding gas generate collisionally excited and recombination emission lines, which are commonly observed in starburst and low-metallicity (1/50–1/3 Z⊙; Kunth & Sargent 1983) dwarf galaxies, such as H II or blue compact dwarf (BCD) galaxies. From recent studies, it was concluded that the hardness of the ionizing radiation from the current star formation (SF) activity increases with decreasing metallicity (e.g. Guseva, Izotov & Thuan 2000; Schaerer 2002; Thuan & Izotov 2005) as is expected in primeval galaxies in the early Universe. These first stars (Population III stars) should be very massive and hot (e.g. Abel, Bryan & Norman 2002), emitting very hard ionizing radiation and thus very effective in ionizing hydrogen and helium; therefore, strong He II emission lines are likely present in the spectra of these galaxies (e.g. Schaerer 2002, 2003). Originally, the low abundances of heavy elements in H II/BCD galaxies and the non-detection of an old stellar population have given rise to the question of whether they may be presently forming their first generation of stars (Sargent & Searle 1970). Recent works, however, have shown that most H II galaxies seem to present an underlying population of old stars from previous episodes of SF (e.g. Papaderos et al. 1996; Telles & Terlevich 1997; Cairós et al. 2003), suggesting an intermittent SF history with short intense SF episodes followed by long quiescent phases.

To date, a small but an increasing number of H II/BCD galaxies has been observed using Integral Field Unit (IFU) spectroscopy (e.g. Izotov et al. 2006a; Cairós et al. 2009a,b, 2010; Lagos et al. 2009; Monreal-Ibero et al. 2010) in order to study the spatial distribution of their properties (i.e. emission lines, extinction, kinematics and abundances). In particular, some of these studies have shown a remarkable chemical homogeneity of oxygen abundance in BCD galaxies. This implies that oxygen and all...
α-elements are primary, produced by massive stars (\(> 8 \times 10^4 \text{M}_\odot\)) and released into the interstellar medium (ISM) during their supernova (SN) phase. These newly synthesized metals will be dispersed in the whole galaxy and mixed via hydrodynamic mechanisms in time-scales of few \(\times 10^4\) yr. On the other hand, the ratio N/O was also found to be rather constant for BCD galaxies \([\log (N/O) \simeq -1.6]\;\text{(Edmunds & Pagel 1978; Alloin et al. 1979; Izotov & Thuan 1999)},\) implying mainly primary production of nitrogen at low metallicity \([12 + \log (\text{O/H}) \lesssim 7.6]\), although the amount coming from each source, primary or secondary, is still debated because of the lack of a clear mechanism that produces N in massive stars besides the effect of the stellar rotation (Meynet & Maeder 2005). The observed spread of N/O at \(6.7 \leq 12 + \log (\text{O/H}) \leq 8.3\) is seen to be large and has been attributed to observational uncertainties, a loss of heavy elements via galactic winds (van Zee, Salzer & Haynes 1998) and/or to the time delays (delayed-release hypothesis) between the production of oxygen by massive stars and that of nitrogen by intermediate and/or massive stars. In this scenario, the SF is an intermittent process in \(\text{H}_\alpha/\text{BCD}\) galaxies (Garnett 1990) with several SF bursts. However, the delayed-release scenario cannot explain the presence of \(\text{H}_\alpha/\text{BCD}\) galaxies with high N/O ratio in comparison to the expected value for their O content. The most plausible explanation of the high N/O ratio observed in these objects is the chemical pollution of N due to the presence of Wolf–Rayet (WR) stars (e.g. López-Sánchez & Esteban 2010a). Localized nitrogen self-enrichment has been measured in a few cases (e.g. Kobulnicky et al. 1997, in NGC 5253) and attributed to the release of N into the ISM by the action of strong winds produced by these stars. Although, there are a few BCD galaxies with significant variations of oxygen abundance, such as in two \(\text{H}_\alpha\) regions of Haro 11 \([12 + \log (\text{O/H}) = 8.33 \pm 0.01\) in Haro B and \(12 + \log (\text{O/H}) = 8.10 \pm 0.04\) in Haro C; Guseva et al. 2012], no localized oxygen enrichment systems have been confirmed (Lagos et al. 2009). Finally, at high metallicity \([12 + \log (\text{O/H}) \gtrsim 8.3]\), the N/O ratio clearly increases with increasing oxygen abundance. Hence, nitrogen is essentially a secondary element in this metallicity regime.

The origin of hard-ionization emission lines such as \(\text{He}^+ \lambda 4686\) in BCD galaxies has been a subject of study in recent years given that photoionized models of \(\text{H}_\alpha\) regions fail to reproduce the observed high-ionization line ratios. In particular, the observed intensity of \(\text{He}^+ \lambda 4686\) with respect to \(\text{H}^\beta\) is several orders of magnitude larger than model predictions for photoionized regions (Stasińska 1990). Several mechanisms for producing hard ionizing radiation have been proposed, such as massive main-sequence stars (Schaerer & de Koter 1997), WR stars (Schaerer 1996), primordial zero-metallicity stars (Schaerer 2002, 2003), high-mass X-ray binaries (HMXBs; Garnett et al. 1991) and radiative shocks (Dopita & Sutherland 1996), and O stars at low metallicity may also contribute to the \(\text{He}^+\) ionizing flux (Brinchmann, Kunth & Durret 2008). Fricke et al. (2001), Izotov, Chaffee & Schaerer (2001) and Izotov et al. (2004) have explored these different mechanisms which can produce the hard radiation in SBS 0335−052, Tol 1214−277 and Tol 65. They concluded that the ionization produced by main-sequence stars cannot explain the strong \([\text{Fe}^+\lambda 4227\) and \(\text{He}^+ \lambda 4686\) emission lines, but other ionization sources such as WR stars, HMXB systems and fast shocks can be considered.

We focus here on two compact \(\text{H}_\alpha\) galaxies, Tol 0104−388 and Tol 2146−391, in order to study the relationship between the physical, chemical and kinematics properties, the nature of their hard-ionization radiation pattern (\(\text{He}^+ \lambda 4686\) emission lines) in the ISM of these galaxies based on IFU spectroscopic observations on the Gemini-South telescope. We selected these galaxies because both objects belong to a subset sample of \(\text{H}_\alpha\) galaxies with compact morphology and relative low metallicity \([12 + \log (\text{O/H}) \lesssim 7.8−7.9\) dex), possibly mimicking the properties one expects for young galaxies at high redshift. In Fig. 1, we show \(g\)-band acquisition images of the galaxies Tol 0104−388 and Tol 2146−391 in logarithmic scale. The rectangle indicates the GMOS–IFU FoV of \(3.5 \times 5\) arcsec\(^2\).

![Figure 1](https://example.com/figure1.png)

Figure 1. \(g\)-band acquisition image of the galaxies Tol 0104−388 and Tol 2146−391 in logarithmic scale. The rectangle indicates the GMOS–IFU FoV of \(3.5 \times 5\) arcsec\(^2\).

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Monthly Notices of the Royal Astronomical Society © 2012 RAS
Table 1. General parameters of the galaxies.

| Name       | Coordinates (J2000) | \(D\) (3K CMB)\(^a\) | \(1\) arcsec (3K CMB) | 12+\(\log(O/H)\)\(^b\) | Other names |
|------------|---------------------|------------------------|------------------------|--------------------------|-------------|
| Tol 0104−388 | 01:07:02.1           | −38:31:52              | 88.4                   | 429                      | 8.02        | CTS 1001   |
| Tol 2146−391 | 21:49:48.2           | −38:54:09              | 117.3                  | 569                      | 7.82        |             |

\(^a\)Obtained from NED.  
\(^b\)Derived from the present observations.

2 OBSERVATIONS AND DATA REDUCTION

The observations were performed with the Gemini Multi-Object Spectrograph (GMOS; Hook et al. 2004) and the IFU unit (hereafter GMOS–IFU; Allington-Smith et al. 2002) at Gemini-South telescope in Chile, using the gratings B600+G5323 (B600) and grating R600+G5324 (R600) in one-slit mode. The GMOS–IFU in one-slit mode comprises a pattern of 750 hexagonal elements with a projected diameter of 0.2 arcsec, covering a total 3.5 \(\times\) 5 arcsec\(^2\) field of view (FoV), where 250 of these elements are dedicated to sky observation. The CCD detector is assembled by three chips with 2500 of these elements dedicated to sky observation. The 2D data images were transformed into 3D data cubes, resampled as square pixels with 0.2 arcsec spatial resolution and corrected for differential atmospheric refraction using the gcube routine. Finally, the data cubes obtained using the gratings B600 and R600 were combined, forming a final data cube covering a total spectral range from \(\sim\)3021 to 7225 \(\AA\). More details about the reduction procedure applied to our data can be found in Lagos et al. (2009).

Fig. 2 shows the integrated spectrum of the galaxies summing over all spaxels in the FoV. In this figure, we identified the main emission lines detected and used in our study. The spectral resolution \(R_{B600} = 1688\) and \(R_{R600} = 3744\) of the GMOS–IFU using gratings B600 and R600 allows us to resolve the [O II] \(\lambda\lambda 3726, 3729\) doublet, [O III] \(\lambda 4363\) and other weak emission lines. The most remarkable feature in the spectrum of these galaxies is the detection of He II \(\lambda 4686\) that are associated with a high-ionization radiation. We detect, for the first time, very weak He II \(\lambda 4686\) emission line in the spectrum of Tol 0104−388, while in Tol 2146−391 the presence of this high-ionization emission line has been measured previously in the literature (e.g. Papaderos et al. 2006; Guseva et al. 2007, 2011).

Finally, the emission-line fluxes were measured using the IRAF task fitfilepsf by fitting Gaussian profiles. Since most of the emission lines were measured using an automatic procedure, we filtered the maps assigning the value \(0 \text{erg cm}^{-2} \text{s}^{-1}\) to all spaxels with signal-to-noise ratio \((S/N) < 3\). The error associated with each emission line \((\sigma)\) was calculated using \(\sigma = \sigma_c \sqrt{1 + \text{EW}/N\Delta}\), where \(\sigma_c\) is the standard deviation in the local continuum associated with each emission line, \(N\) is the number of pixels, EW is the equivalent width of the line and \(\Delta\) is the instrumental dispersion in \(\AA\) (see Lagos et al. 2009).

3 PROPERTIES OF THE IONIZED GAS

3.1 Emission lines, EW(H\(\beta\)) and extinction

We used the flux measurement procedure described previously in Section 2 to construct emission-line maps (e.g. [S II] \(\lambda\lambda 6731, [S II] \lambda 6717, [N II] \lambda 6548, [N II] \lambda 6584, H\alpha, [O III] \lambda 5007, [O III] \lambda 4959, H\beta, He II \(\lambda 4686, [O III] \lambda 4363, H\gamma, [O II] \lambda 3726, 3729\) continuum) in an FoV of \(3.2 \times 5\) arcsec\(^2\), equivalent to \(\sim 1372 \times 2058\) pc\(^2\) for Tol 0104−388 and \(\sim 1820 \times 2730\) pc\(^2\) for Tol 2146−391. In Fig. 3, we show the [OII] \(\lambda 4363\), H\beta and [N II] \(\lambda 6586\) emission-line maps and continuum near H\alpha of Tol 0104−388 (upper maps) and Tol 2146−391 (lower maps), respectively. The map of emission lines displays a single peak in Tol 0104−388 but the elongated shape of Tol 2146−391 suggests a double peak as is noted in the acquisition image of Fig. 1. Unfortunately, we did not resolve spatially these two GH\alpha RRs in our monochromatic maps from the data cube of Tol 2146−391.

The observed emission-line fluxes, for all the spaxels in our FoV, have been corrected for extinction using the observed Balmer decrement as \(I(\lambda)/I(H\beta) = F(\lambda)/F(H\beta) \times 10^{-(H\beta)/f(\lambda)}\), using the Cardelli, Clayton & Mathis (1989) reddening curve, \(f(\lambda)\). The observed \(F(\lambda)\) and corrected emission-line fluxes \(I(\lambda)\) relative to the H\beta multiplied by a factor of 100 and their error, the observed flux of the H\beta emission line, the H\beta equivalent widths EW(H\beta) and the extinction coefficient \(c(H\beta)\) for the integrated galaxy are given in Table 3.

In Fig. 4, we show the spatial distribution of EW(H\beta) and extinction \(c(H\beta)\) for our sample galaxies. The EW(H\beta) in Tol 0104–388 varies from \(\sim 0\) to 200 \AA\ and in Tol 2146–391 it varies from \(\sim 0\) to 386 \AA, while the \(c(H\beta)\) extinction varies from 0 to \(\sim 0.66\) in Tol 0104–388 and from 0 to \(\sim 1.33\) in Tol 2146–391. The EW(H\beta) and extinction distribution \(c(H\beta)\) in these galaxies show an inhomogeneous pattern, where the peak of these values is displaced from the maximum of H\alpha emission. In particular, the extinction map of Tol 2146–391 shows a hole-like structure in the right part of the FoV, where several spaxels located in this region show values close to 0 or \(F(\alpha)/F(H\beta) \sim 2.87\). These structures appear to be real given that they are not produced by misalignment between the maps.

We found an integrated extinction value of \(c(H\beta) = 0.32\) for Tol 0104–388, which is in reasonable agreement with those...
Figure 2. Integrated spectra (summing over all spaxels in the FoV) of Tol 0104–388 and Tol 2146–391. Top panels: blue spectrum (B600 grating). Bottom panels: red spectrum (R600 grating). The gaps between the detectors are shown in the figure.

Figure 3. Observed emission-line maps (from left to right): [O III] λ4363, Hα, [N II] λ6584 and Hα continuum of Tol 0104–388 (upper panels; 1 arcsec = 429 pc) and Tol 2146–391 (lower panels; 1 arcsec = 569 pc) in the original 0.2 arcsec pixel size. Fluxes in units of $10^{-18}$ erg cm$^{-2}$ s$^{-1}$ and continuum in units of $10^{-18}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$. The maximum Hα emission is indicated in the maps by an X symbol.
Table 3. Observed and extinction-corrected emission lines for Tol 0104–388 and Tol 2146–391. The fluxes are relative to $F(H\beta) = 100$.

| Emission Line | Tol 0104–388 | Tol 2146–391 |
|---------------|--------------|--------------|
| \([\text{O} \text{II}] \lambda 3726\) | 76.00 ± 2.08 | 18.84 ± 2.31 |
| \([\text{O} \text{II}] \lambda 3729\) | 105.30 ± 3.30 | 25.72 ± 0.23 |
| \([\text{Ne} \text{II}] \lambda 3868\) | 23.80 ± 0.99 | 28.98 ± 1.28 |
| \([\text{He} \text{I} + \text{He} \text{II}] \lambda 3889\) | 13.20 ± 0.51 | 13.00 ± 0.40 |
| \([\text{Ne} \text{II}] \lambda 3968\) | 6.80 ± 0.53 | 9.46 ± 0.16 |
| \([\text{He} \text{I}] \lambda 4026\) | 1.37 ± 0.30 | 1.18 ± 0.07 |
| \([\text{S} \text{II}] \lambda 4069\) | 2.09 ± 0.25 | 2.49 ± 0.59 |
| \([\text{H}\delta] \lambda 4101\) | 19.80 ± 2.90 | 19.02 ± 1.04 |
| \([\text{He} \text{I}] \lambda 4340\) | 42.60 ± 2.13 | 40.76 ± 2.07 |
| \([\text{O} \text{II}] \lambda 4363\) | 3.60 ± 0.20 | 10.78 ± 0.63 |
| \([\text{Fe} \text{II}] \lambda 4658\) | 1.38 ± 0.05 | 0.67 ± 0.04 |
| \([\text{He} \text{I}] \lambda 4868\) | 0.80 ± 0.09 | 1.56 ± 0.52 |
| \([\text{H}\beta] \lambda 4861\) | 100.00 ± 3.70 | 100.00 ± 2.38 |
| \([\text{O} \text{I}] \lambda 4959\) | 119.33 ± 5.23 | 202.90 ± 4.09 |
| \([\text{O} \text{I}] \lambda 5007\) | 353.33 ± 17.69 | 610.51 ± 10.47 |
| \([\text{He} \text{I}] \lambda 5876\) | 12.27 ± 0.36 | 10.56 ± 0.62 |
| \([\text{[O} \text{I}] \lambda 6300\) | – | 2.36 ± 0.67 |
| \([\text{[S} \text{II}] \lambda 6312\) | – | 1.62 ± 0.06 |
| \([\text{[O} \text{I}] \lambda 6363\) | 2.72 ± 0.24 | 0.95 ± 0.03 |
| \([\text{[N} \text{II}] \lambda 6584\) | 7.93 ± 1.05 | 1.18 ± 0.25 |
| \([\text{He} \text{I}] \lambda 6563\) | 370.00 ± 10.06 | 326.32 ± 7.22 |
| \([\text{[O} \text{I}] \lambda 6584\) | 25.20 ± 1.60 | 3.86 ± 0.42 |
| \([\text{He} \text{I}] \lambda 6678\) | 3.59 ± 0.16 | 2.06 ± 0.16 |
| \([\text{[S} \text{II}] \lambda 6717\) | 25.20 ± 1.68 | 7.06 ± 0.91 |
| \([\text{[S} \text{II}] \lambda 6731\) | 24.86 ± 1.64 | 5.22 ± 0.81 |
| $F(\text{H}\beta)^a$ | 15.00 ± 0.28 | 55.20 ± 0.61 |
| $\text{EW}(\text{H}\beta)^b$ | 109 ± 22 | 229 ± 30 |
| $c(\text{H}\beta)$ | 0.32 | 0.30 |

\(^a\)In units of $10^{-15}$ erg cm$^{-2}$ s$^{-1}$.

\(^b\)In units of Å.

3.2 Velocity field

We have obtained the spatial distribution of radial velocity $v_r$ by fitting a single Gaussian to the H$\alpha$ emission-line profiles. In order to better examine the variations in the FoV, in Fig. 5 we show the smoothed radial velocity derived from the shifts of the H$\alpha$ line peak.

The velocity field $v_r$ of Tol 0104–388 in the left-hand panel of Fig. 5 shows an apparent systemic motion where the upper part of the galaxy is redshifted, while the lower part is blueshifted, with a relative motion of $\sim 50$ km s$^{-1}$ with respect to the systemic velocity (black contour in the radial velocity map). This velocity map indicates the presence of a clear rotation pattern in this galaxy. On the other hand, the radial velocity map of Tol 2146–391 (right-hand panel of Fig. 5) is rather complex, indicating asymmetric gas motions without any clear rotational pattern. The whole range of radial velocities displayed in the map is about 60 km s$^{-1}$. No significant differences were found from the map derived using H$\beta$ and [O II] $\lambda 5007$ in both galaxies.

The systemic velocity obtained from the fit to the emission maxima (located on the cross in the velocity maps) is 6803 km s$^{-1}$ for Tol 0104–388 and 8854 km s$^{-1}$ for Tol 2146–391. For the integrated spectrum of the galaxies, we obtained values of 6815 km s$^{-1}$ for Tol 0104–388 and 8854 km s$^{-1}$ for Tol 2146–391, respectively. Although our GMOS–IFU observations were performed using the medium-resolution grating, we found a velocity...
3.3 Emission-line diagnostic diagrams

The standard BPT diagnostic diagrams (Baldwin, Phillips & Terlevich 1981) have been used to analyse the possible excitation mechanisms present in Tol 0104−388 and Tol 2146−391. Fig. 6 considers [O III] λ5007/Hβ versus [S II] λλ6717,6731/Hα and [O III] λ5007/Hβ versus [N II] λ6584/Hα for both galaxies in our sample. The solid lines (adapted from Osterbrock & Ferland 2006) show the locus of separation between regions dominated solely by photoionization (H II-like regions) and regions dominated by shocks (e.g. active galactic nuclei). The dotted lines represent the same as the solid lines but using the models given by Kewley et al. (2001). This figure shows that the positions of all individual spaxels, in these diagrams, suggest that photoionization from stellar sources is the dominant excitation mechanism in our two galaxies.

In Fig. 7, we show the maps for the three available line ratios involved in these diagrams: [O III] λ5007/Hβ, [S II] λλ6717,6731/Hα and [N II] λ6584/Hα. This figure shows that the ionization structure in the central region of Tol 0104−388 is rather constant for [N II]

\[ \frac{\text{O}}{\text{H}} = \frac{\text{O}^+}{\text{H}^+} + \frac{\text{O}^{+2}}{\text{H}^+}, \quad (1) \]

\[ \frac{\text{N}}{\text{H}} = \text{ICF(N)} \frac{\text{N}^+}{\text{H}^+}, \quad (2) \]

\[ \frac{\text{Ne}}{\text{H}} = \text{ICF(Ne)} \frac{\text{Ne}^{+2}}{\text{H}^+}, \quad (3) \]

\[ \frac{\text{S}}{\text{H}} = \text{ICF(S)} \left( \frac{\text{S}^+}{\text{H}^+} + \frac{\text{S}^{+2}}{\text{H}^+} \right), \quad (4) \]

where \( \text{O}^+ \), \( \text{O}^{+2} \), \( \text{N}^+ \), \( \text{Ne}^{+2} \) and \( \text{S}^+ \) ions are obtained from the nebular output file. Nitrogen, neon and sulphur abundances were calculated using ionization correlation factors (ICFs) and the relationship between \( \text{S}^+ \) and \( \text{S}^{+2} \) given by Kingsburgh & Barlow (1994). We assumed that \( T_e(\text{O} \text{iii}) \) temperature is given by \( T_e(\text{O} \text{iii}) = 2/[T_e^{-1}(\text{O} \text{iii})+0.8] \) (Pagel et al. 1992), \( T_e(\text{S} \text{ii}) = 0.83 \times T_e(\text{O} \text{iii})+0.17 \) (Garnett 1992) and \( T_e(\text{O} \text{ii}) = T_e(\text{S} \text{ii}) = T_e(\text{N} \text{ii}) \).

In Table 4, we show the electron density, temperature and abundances calculated for each of the integrated apertures considered in this study. Fig. 10 (left-hand panel) shows the spatial distribution of the oxygen abundances in the spaxels where the emission lines \([\text{O} \text{iii}] \lambda\lambda 4959,5007/[\text{O} \text{ii}] \lambda 4363 \) and \([\text{S} \text{ii}] \lambda 6717/[\text{S} \text{ii}] \lambda 6731 \) were detected, and in the right-hand panel of the same figure we show the spatial distribution of \( \text{N}^+ \) in the spaxels where \([\text{N} \text{ii}] \lambda 6584 \) was detected. Finally, in Fig. 11 we show the spatial distribution of \( \log(\text{N}/\text{O}) \).

Tol 0104–388. In this galaxy, the electron density is relatively high (upper panel of Fig. 8), varying from \( \sim 100 \) to \( 1033 \text{ cm}^{-3} \), while the temperature varies from \( 10 \text{ 502} \) to \( 13 \text{ 700} \text{ K} \). The highest values of density are placed near the peak of He\( \text{II} \) emission. We obtained an integrated electron temperature of \( T_e(\text{O} \text{iii}) = 12 \text{ 199} \pm \text{ 412} \text{ K} \), which agrees with the value \( 1.25 \pm 0.15 \times 10^4 \text{ K} \) reported by

Figure 7. Emission-line ratios: \( \log [\text{O} \text{iii}] \lambda 5007/\text{H}\beta \), \( \log [\text{S} \text{ii}] \lambda\lambda 6717,6731/\text{H}\alpha \) and \( \log [\text{N} \text{ii}] \lambda 6584/\text{H}\alpha \) for both galaxies in our sample (Tol 0104–388: upper panels; Tol 2146–391: lower panels). The maximum He\( \text{II} \) emission is placed over region A and is indicated in the maps by an X symbol.
The electron temperature varies from $1.25 \times 10^3$ to $2.55 \times 10^3$ K. In this galaxy, we obtained an integrated temperature of $T_e(\text{O} \text{m}) = 15.277 \pm 584$ K and a density of $n_e(\text{S} \text{II}) < 100$ cm$^{-3}$. The electron temperature varies from 12 to 22 K. The density in the outer part of the galaxy is practically constant with $n_e(\text{S} \text{II}) < 100$ cm$^{-3}$, given that the ratio $[\text{S} \text{II}] / \text{O} \text{m}$ is typically greater than 1 (see Fig. 8), which indicates a low-density regime (Osterbrock & Ferland 2006); hence, we assumed an electron density of $n_e \sim 100$ cm$^{-3}$ in most apertures in Tol 2146–391. Our $n_e$ values found in the inner part of the galaxy are consistent with the values 162 and 147 cm$^{-3}$ found by Guseva et al. (2011), corresponding with the two GH i Rs (Fig. 1) found in this work. The oxygen abundance of 12+log(O/H) ranges from 7.69 to 7.96, with a mean value of 7.84 and a standard deviation of 0.06. The integrated oxygen abundance of 12+log(O/H) = 7.82 ± 0.09 agrees with the values 7.80 ± 0.01 and 7.78 ± 0.01 obtained by Papaderos et al. (2006), Guseva et al. (2007) and Guseva et al. (2011), respectively, and with the values found by Guseva et al. (2011) of 7.82 ± 0.01 and 7.79 ± 0.01 for the two GH i Rs resolved in this galaxy. But in disagreement with the reported value of 7.62 ± 0.08 given by Kehrig et al. (2006). The $N^+ / H^+$ distribution values range from 0.19 × 10$^{-6}$ to 0.44 × 10$^{-6}$ with a mean value of 0.29 × 10$^{-6}$ and a standard deviation of 0.06 × 10$^{-6}$. Given that we calculated

Peña et al. (1991), and a density of $n_e(\text{S} \text{II}) = 614$ cm$^{-3}$. The oxygen abundance values in units of 12+log(O/H) in Tol 0104–388 range from 7.96 to 8.24, with a mean value of 8.06 and a standard deviation of 0.06. We obtained an integrated value of 12+log(O/H) = 8.02 ± 0.04 that agrees with the mean value of the spaxels within the errors. This integrated 12+log(O/H) abundance is consistent with the value of 12+log(O/H) = 8.19 ± 0.15 derived by Peña et al. (1991). The N$^+ / H^+$ distribution values range from $1.85 \times 10^{-6}$ to $2.72 \times 10^{-6}$ with a mean value of $2.21 \times 10^{-6}$. With this information, we found that the 12+log(N/H) values range from 6.60 to 6.92, a mean value of 6.74, a standard deviation of 0.07 and an integrated value of 12+log(N/H) = 6.77 ± 0.08. Finally, the log(N/O) ratio values range from −1.43 to −1.20 with a mean value of −1.33 and a standard deviation of 0.05. We found an integrated value of log(N/O) = −1.25 ± 0.12, log(He/O) = −0.62 ± 0.23 and log(S/O) = −1.70 ± 0.08. These values appear normal for BCD galaxies at this metallicity (Izotov & Thuan 1999; López-Sánchez & Esteban 2010a; Guseva et al. 2011).

Tol 2146–391. In this galaxy, we obtained an integrated temperature of $T_e(\text{O} \text{m}) = 15.277 \pm 584$ K and a density of $n_e(\text{S} \text{II}) < 100$ cm$^{-3}$. The electron temperature varies from 12 to 22 K. The density in the outer part of the galaxy is practically constant with $n_e(\text{S} \text{II}) < 100$ cm$^{-3}$, given that the ratio $[\text{S} \text{II}] / \text{O} \text{m}$ is typically greater than 1 (see Fig. 8), which indicates a low-density regime (Osterbrock & Ferland 2006); hence, we assumed an electron density of $n_e \sim 100$ cm$^{-3}$ in most apertures in Tol 2146–391. Our $n_e$ values found in the inner part of the galaxy are consistent with the values 162 and 147 cm$^{-3}$ found by Guseva et al. (2011), corresponding with the two GH i Rs (Fig. 1) found in this work. The oxygen abundance of 12+log(O/H) ranges from 7.69 to 7.96, with a mean value of 7.84 and a standard deviation of 0.06. The integrated oxygen abundance of 12+log(O/H) = 7.82 ± 0.09 agrees with the values 7.80 ± 0.01 and 7.78 ± 0.01 obtained by Papaderos et al. (2006), Guseva et al. (2007) and Guseva et al. (2011), respectively, and with the values found by Guseva et al. (2011) of 7.82 ± 0.01 and 7.79 ± 0.01 for the two GH i Rs resolved in this galaxy. But in disagreement with the reported value of 7.62 ± 0.08 given by Kehrig et al. (2006). The $N^+ / H^+$ distribution values range from $0.19 \times 10^{-6}$ to $0.44 \times 10^{-6}$ with a mean value of $0.29 \times 10^{-6}$ and a standard deviation of $0.06 \times 10^{-6}$. Given that we calculated
ICF(N) values, over the majority of the spaxels in the FoV, are typically $\sim 10$, we found a variation of $12+\log(N/H)$ from 6.27 to 6.83, an average value of 6.52 dex and a standard deviation of 0.16. An integrated value of $12+\log(N/H) = 6.54 \pm 0.07$ is found in Tol 2146–391. The log(N/O) ratio values range from $-1.55$ to $-1.05$ with an average value of $-1.32$ and a standard deviation of 0.12. We found a value of $\log(N/O) = -1.28 \pm 0.29$ summing over all spaxels in the FoV. This integrated value appears to be in agreement, within the errors, with the ones obtained by Guseva et al. (2011) for the two GH II Rs: $\log(N/O) = -1.57 \pm 0.03$ and $-1.63 \pm 0.03$. Finally, our integrated $\log(N/O) = -0.82 \pm 0.41$ appears to be consistent with values obtained by Guseva et al. (2011).

In Fig. 12, we show the distribution of $\log(N/O)$ in Tol 0104–388 and Tol 2146–391. For each of these two galaxies, we show the integrated log (N/O) values (solid lines) and the mean log (N/O) values (dotted lines) of the data points. Table 5 summarizes the statistical properties of the spaxels in our sample galaxies. We note an agreement, within the errors, between the mean value of the spaxels and the properties derived from the integrated spectrum. In the case of the oxygen abundance, we found a variation of $\Delta(O/H) \sim 0.28$ between the minimum and maximum values, for both galaxies, with a low standard deviation. This result indicates that these variations are not statistically significant across the galaxies. The log (N/O) variation in Tol 0104–388 shows a value of 0.22 with a low standard deviation, while in Tol 2146–391 we found a variation of $\Delta(N/O) = 0.50$, with a higher standard deviation with respect to the oxygen abundance. Although the mean value of log(N/O) is consistent with the integrated value, this result indicates that a slight variation is observed in Tol 2146–391. In fact, Figs 10 and

4 DISCUSSION

4.1 Spatial distribution and dependence of the He II $\lambda 4686$ emission line on the EW(He$\beta$) and metallicity of the ISM

In Fig. 13, we show the spatial distribution of He II $\lambda 4686$ in Tol 2146–391. In Fig. 14 we show the spatial distribution of H$\beta$ emission line and superimposed the resampled 0.8 arcsec spaxels in the region (from 4640 to 4725 Å) that contains the He II $\lambda 4686$ emission line for Tol 0104–388 and Tol 2146–391. To do this, we summed the spectra, in the data cubes, in a region of $4 \times 4$ spaxels in order to increase the S/N. From this figure, we find a weak He II $\lambda 4686$ emission line in the core of Tol 0104–388, previously not detected in this galaxy, so we see that in both galaxies the He II $\lambda 4686$ emission line is concentrated in the core.
Figure 12. Distribution of log(N/O) in Tol 0104−388 (upper panel) and Tol 2146−391 (lower panel). For each of these two galaxies, we show the integrated log (N/O) values (solid lines) and the mean log (N/O) values (dotted lines).

Table 5. Statistical properties of the galaxies.

|                | Tol 0104−388 | Tol 2146−391 |
|----------------|--------------|--------------|
|                | Mean | SDEV\(^a\) | \(\Delta^b\) | Mean | SDEV | \(\Delta\) |
| \(O^+/H^+\) \((\times 10^5)\) | 4.73  | 0.63   | 2.91  | 0.60  | 0.11  | 0.39 |
| \(O^{++}/H^+\) \((\times 10^5)\) | 7.12  | 1.24   | 5.68  | 6.34  | 0.99  | 4.37 |
| 12+log (O/H)   | 8.06  | 0.06   | 0.28  | 7.84  | 0.06  | 0.27 |
| \(N^+/H^+\) \((\times 10^5)\) | 2.21  | 0.00   | 0.87  | 0.29  | 0.06  | 0.25 |
| 12+log (N/H)   | 6.74  | 0.07   | 0.31  | 6.52  | 0.16  | 0.56 |
| log (N/O)      | −1.33 | 0.05   | 0.22  | −1.32 | 0.12  | 0.50 |

\(^a\)Standard deviation of the spaxels.

\(^b\)Difference between minimum and maximum values.

Figure 13. Spatial distribution of the He II \(\lambda 4686\) emission line in the galaxy Tol 2146−391. Fluxes in units of \(10^{-18}\) erg cm\(^{-2}\) s\(^{-1}\) Å\(^{-1}\). The maximum H\(\alpha\) emission is indicated in the map by an X symbol.

Thuan & Izotov (2005) found, studying a sample of galaxies where the He II \(\lambda 4686\) emission line was detected, that the hardness of the ionizing radiation does not appear to depend on starburst age or EW(H\(\beta\)), when the integrated properties of the galaxies are considered. On the other hand, as mentioned by previous spectroscopic studies (e.g. Campbell, Terlevich & Melnick 1986; Guseva et al. 2000; Thuan & Izotov 2005), the hardness of this ionizing radiation in BCDs increases with decreasing metallicity. This implies that these ionization emission lines are stronger in galaxies with lower metallicities. This correlation was determined from the integrated spectra of galaxies. But what is the relationship between the spatial distribution of abundances and EW(H\(\beta\)) with the hardness of high-ionizing radiation across the spaxels in our sample galaxies?

In Fig. 15, we show the intensity of the He II \(\lambda 4686\) emission line relative to H\(\beta\) of each spaxel of 0.2 arcsec as a function of (a) EW(H\(\beta\)), (b) oxygen abundance 12+log (O/H) and (c) log (N/O) ratio for the galaxy Tol 2146−391. We performed a Spearman’s rank correlation test on our data in order to assess how well the relationship between He II \(\lambda 4686\) emission lines can be described as a function of the other properties. From this procedure, we did not find a significant correlation between these variables using this correlation technique. In fact, the oxygen abundances appear to be uniform in the regions where the He II \(\lambda 4686\) emission line was measured. It can be interpreted that there are no correlations with small patches of the ISM.

4.2 Sources of the nebular He II \(\lambda 4686\) emission line and their spatial distribution

Studying a sample of GH II Rs, Guseva et al. (2000) found that galaxies with detected and non-detected WR features have the same distribution dependences of I(He II \(\lambda 4686\))/I(H\(\beta\)) versus EW(H\(\beta\)). This implies that WR stars are not the sole origin of He II \(\lambda 4686\) in star-forming regions. On the other hand, de Mello et al. (1998) found a spatial correlation between the nebular He II \(\lambda 4686\) emission between the star clusters and the position of WR stars in the galaxy IZw 18, supporting the hypothesis that WR stars are responsible for nebular He II emission in this galaxy, while Izotov et al. (2006a) found that the hard ionizing radiation responsible for the He II \(\lambda 4686\) emission, in the galaxy SBS 0335−052, is not likely related with the position of the most massive and young star clusters, but rather is related to fast radiative shocks. Another possibility is that the...
high-ionizing radiation is produced by the accretion of gas by HMXBs (Garnett et al. 1991) located in the star cluster population in the core of the galaxies. As suggested by Thuan et al. (2004), the high X-ray luminosities of these sources may be due to a metallicity effect, resulting in a larger X-ray luminosity, so producing an additional photoionization of the gas in low-metallicity systems, as is the case of H\alpha/BCD galaxies. Finally, Brinchmann et al. (2008) suggest that at low metallicity the main source of He\alpha\beta 4686 ionizing photons appears to be O stars.

The action of stellar winds and SN explosions from the star clusters generates expanding shells (e.g. Hodge 1974; Martin 1998) that eventually will be able to produce on large scales collisionally excited emission lines. Garnett et al. (1991) have suggested that fast radiative shocks in GH\beta\alpha Rs can produce relatively strong He\alpha emission under certain conditions. Hydrodynamical models by Dopita & Sutherland (1996) have shown that fast shocks, with shock velocities of 400–500 km s\(^{-1}\), are an efficient means to produce a strong local UV photon field in the ISM of galaxies. Therefore, such shocks can be responsible for the observed fluxes of He\alpha\beta 4686 and other high-ionization emission lines. The existence of these fast motions is supported by the presence of broad components, with velocities of hundreds of km s\(^{-1}\) (e.g. Izotov et al. 1996; Westmoquette et al. 2007), in the line profiles of the strongest emission lines in some H\alpha/BCD galaxies and GH\beta\alpha Rs. We checked for the presence of broad components in the H\alpha line profile of our sample galaxies. In Tol 0104–388, this emission-line profile is symmetric and well represented by a single Gaussian, and does not show prominent low-intensity broad components in the integrated spectrum. In the case of Tol 2146–391, the base of the H\alpha (and other such as [O\textsc{iii}] \(\lambda 5007\)) profile appears to be very broad, with a component similar to the ones observed in other BCD galaxies (e.g. Izotov et al. 1996). Fig. 16 shows the spatial distribution of H\alpha emission-line profiles in the 0.8 \(\times\) 0.8 arcsec\(^2\) spaxel size, as indicated in Section 4.1, for the galaxies Tol 0104–388 and Tol 2146–391. Again, we observe that the profile in the spaxels in Tol 0104–388 is well represented by a Gaussian, while in Tol 2146–391 we observe a broad base in the emission lines in the spaxels in the inner part of the map (see Fig. 16). In order to detect the presence of a broad component in these spaxels, we used the PAN\(^3\) routine (Peak ANalysis) in IDL to fit two components to these profiles. Using this software, we found that these spaxels are well represented by a single Gaussian,

\[^{3}\text{http://www.ncnr.nist.gov/staff/dimeo/panweb/pan.html}\]

\[\text{Figure 15.} \quad \text{Intensity of the He\alpha\beta 4686 emission line relative to H\beta as a function of the equivalent width of H\beta, oxygen abundance 12+log(O/H) and log(N/O) ratio for the galaxy Tol 2146–391.}\]

\[\text{Figure 16.} \quad \text{Spatial distribution of H\alpha profiles in the galaxies Tol 0104–388 and Tol 2146–391.}\]
Finally, as we mentioned previously in this work, only Tol 2146–391 was reported in the literature as a WR galaxy by previous studies (e.g. Masegosa, Moles & del Olmo 1991). The examination of each individual 0.2 arcsec spaxel and in the binned maps (see Fig. 14) and also in the integrated spectra (see Fig. 2), in both galaxies in our sample, does not reveal any clear stellar WR features. Given the spatial distribution of the nebular He ii λ4686 emission in our two analysed galaxies, this high-ionizing radiation is likely associated with a mix of sources, where WR stars, HMXB and O stars cannot be excluded. Expanding shells powered by these unresolved star cluster/complexes (Lagos et al. 2011) can also likely be added as a source of ionizing radiation, at least in the case of Tol 2146–391.

4.3 Spatial and radial correlation of properties in the ISM

In Fig. 17, we show the log (N/O) versus EW(Hβ) and 12+log(O/H) versus log (N/O) for all 0.2 arcsec spaxels of our two galaxies. In this figure, triangles correspond to the data points of Tol 0104–388 and circles correspond to the data points of Tol 2146–391. Izotov et al. (2006b) suggest that there is a dependence between the N/O ratio and the EW(Hβ), for the entire galaxies, in the sense that the N/O ratio should increase with decreasing EW(Hβ). Their conclusion is based on integrated spectra of a large sample of emission-line galaxies with EW(Hβ) ranging from ~20 to ~350 Å. This trend was also observed recently by Brinchmann et al. (2008) and López-Sánchez & Esteban (2010a). However, no correlation between N/O and EW(Hβ) is found by Buckalew, Kobulnicky & Dufour (2005) using a smaller sample of galaxies. Izotov et al. (2006b) argue that the observed trend of N/O increasing as EW(Hβ) decreases is naturally explained by the expected ejection from WR stars. We observed in the upper panel of Fig. 17 that the EW(Hβ) values are rather constant, with a very small range of equivalent widths ∆EW(Hβ) ~ 100 Å, when the N/O ratio increases. Therefore, no correlation between EW(Hβ) and N/O is found in our sample galaxies. The reader must bear in mind that, in our case, we are concerned with the distribution of the physical properties within an individual galaxy and how that may affect the internal physical processes, as opposed to the statistical trends among different galaxies. If we compare the log (N/O) versus 12+log(O/H), in the lower panel of Fig. 17 for Tol 2146–391, we see that the log (N/O) values increase with the 12+log(O/H) abundance from ~7.70 to ~7.97. This data point distribution has similar patterns to those found in H ii/BCD galaxies (e.g. Izotov & Thuan 1999) of increasing N/O ratios with respect to the oxygen abundance. These studies suggest that at low metallicity [12+log(O/H) < 7.6] the N is associated with primary processes, at intermediate metallicities with a combination of primary and secondary processes, while at higher metallicities [12+log(O/N) ≥ 8.30] only with secondary processes. The inner region of Tol 2146–391 (near the peak of Hα) presents N/O ratios which are larger than those expected by the pure primary nature of nitrogen. This might be a signature of time delay between the release of oxygen and nitrogen (Kobulnicky & Skillman 1998) or even the presence of dynamical processes such as gas infall or outflow. In any case, for the metallicity of Tol 2146–391 secondary processes are implausible. No correlation is found between log(N/O) versus 12+log(O/H) in Tol 0104–388.

In Fig. 18, we show the radial distribution of oxygen abundance, nitrogen abundance, log(N/O) and EW(Hβ) with respect to the Hα continuum peak and EW(Hβ) with respect to 12+log(O/H) and 12+log(N/H) for the galaxy Tol 2146–391. The integrated properties of the galaxy are indicated with a continuous line and the two dotted lines show the uncertainties of these values at the 1σ level. Statistically, the bulk of data points lie in a region of ±1σ around the integrated value of oxygen and log(N/O) radial distribution. These results indicate that there is no significant variation across the galaxy. However, the 12+log(N/H) radial distribution shows that the highest values are located near the peak of continuum emission, with values reducing with radius.

If real, the observed trend of increasing 12+log(N/H) abundance in Tol 2146–391 would argue in favour of self-enrichment by the fresh heavy elements during the present burst of SF, on scales of hundreds of pc, or alternatively these heavy elements were produced during the previous burst of SF and dispersed in large scales across the galaxy in the current burst. If we assume that an instantaneous burst is a better description of the current burst in Tol 2146–391, we can obtain, using STARBURST99, that the mechanical luminosity released into the ISM via radiative winds and SNe in order to produce a supershell is ~12 × 10^39 erg s^{-1}. The radius in pc of an expanding supershell can be written as \( R_\text{s} = \frac{269(L_{38}/n_0)^{1/2}T_1^{1/5}}{c} \) (McCray & Kafatos 1987), where \( L_{38} \) denotes the mechanical luminosity in units of \( L_{38} \) erg s^{-1}, \( T_1 \) is \( t/10^7 \) yr and \( n_0 \) is the density of the ambient gas in cm^{-3}. Therefore, the distance reached by the supershell at 4 Myr is \( R_\text{s} \approx 0.6 \) kpc with a velocity of \( v_\text{s} \approx 241 \) km s^{-1}, assuming \( n_0 \approx 100 \) cm^{-3}. Hence, the expansion of these shells is sufficient for producing, within the age of the current burst, the dispersion of the metal at a distance \( R_\text{s} \lesssim 0.4 \) kpc. On the other hand, Peimbert, Peña-Guerrero & Peimbert (2012) determined the physical conditions in Tol 2146–391 considering the presence of thermal inhomogeneities \( \gamma^2 \). The high value of \( \gamma^2 \) found by Peimbert et al., in Tol 2146–391, agrees with the idea that radiative shocks coming from SNe explosions have higher effect on the thermal structure of the galaxy. In any case, a conclusive assessment of this issue is not possible with the present data, but this scenario appears to...
be viable and agrees within the overall observed properties of Tol 2146−391.

As we mentioned previously in Section 4.2, the examination of each individual 0.2 arcsec spaxel and in the binned maps (see Fig. 14), in both galaxies in our sample, does not reveal any clear WR feature. The detection of WR stars is not easy, and different studies show different results. For example, in the galaxy UM 420, López-Sánchez & Esteban (2010b), using long-slit spectroscopy, detected the presence of WR stars, but using VLT-VIMOS observations James, Tsamis & Barlow (2010) did not find any evidence of WR signature in this galaxy. This discrepancy indicates that the detection of WR features in galaxies depends on the quality of the spectra, location and size of the apertures (Schaerer, Contini & Pindao 1999). Therefore, if the detection of WR stars in Tol 2146−391 is not proven, the observed trend could be due to the outflow of previously enriched gas. Since the metallicity and composition of the ISM evolve with time, the supershell wind will produce a metallicity gradient, with the inner parts containing a larger proportion of metals. In the case of Tol 2146−391, the presence of these energetic winds is supported by the observation of an irregular and broad component in the base of the emission lines (Bordalo & Telles 2011).

In any case, the results obtained in this work suggest that even though a slight gradient, in scales of hundreds of pc, of N is observed in the ISM of Tol 2146−391 (as a result of the starburst activity), the properties across the galaxies are fairly well mixed. This suggests that the O and N enrichment and dispersion are likely related with a global process in the galaxies. Pérez-Montero et al. (2011) studied a sample of three BCD galaxies with high value of N. They found that the globally high N/O ratio in these objects is not likely produced by stellar winds coming from WR stars, but on the contrary, could be related more to other global processes affecting the metal content of the whole galaxy. We suggest that global hydrodynamical effects, such as starburst-driven supershells, might be attributed to efficient transport and mixing of metals across the galaxies, so keeping the N/O ratio constant through the ISM at large scales. These no significant variation in abundance across the ISM of the galaxies would be indicative of uniform SF history, which is likely the case of low luminosity and compact H II galaxies, where the SF appear to be simultaneous over short time-scales (Lagos et al. 2011). This scenario agrees with the idea that most of the H II λ4686 emission is produced by radiative shocks powered by a plethora of unresolved star clusters. Therefore, these H II galaxies are a genuine example of the simplest starburst occurring in galactic scale, possibly mimicking the properties one expects for young galaxies and/or H II galaxies at intermediate and high redshift.

5 CONCLUSIONS

Using new GMOS–IFU spectroscopic observations of the compact H II/BCD galaxies Tol 0104−388 and Tol 2146−391, we studied the spatial distribution of the high-ionization emission line He II λ4686 and the chemical pattern through the ISM of the galaxies in an extended region of 3.2 × 5 arcsec², equivalent to ~1372 × 2058 pc².
and ~1820 x 2730 pc² for Tol 0104−388 and Tol 2146−391, respectively. Based on the analysis of its properties, we have obtained the following results.

(i) The examination over each individual 0.2 arcsec spaxel and also in the integrated spectra, in both galaxies in our sample, does not reveal any clear stellar WR features.

(ii) Both galaxies show the presence of the emission line \( \text{He}^\text{II} \lambda 4686 \) with an integrated intensity relative to \( \text{H}^\beta \) of \( I(\text{He}^\text{II} \lambda 4686)/I(\text{H}^\beta) < 0.02 \). We did not detect a clear correlation between the spatial distribution of \( E(W(\text{He}^\beta)) \), 12+log(O/H) and log(N/O) with respect to the hardness of this high-ionization radiation across the spaxels in Tol 2146−391.

(iii) Given the spatial distribution of \( \text{He}^\text{II} \lambda 4686 \) emission in our two analysed galaxies, this high-ionizing radiation is likely associated with a mix of sources, where WR stars, HMXB and O stars cannot be excluded, while expanding shells powered by a plethora of unresolved star clusters are likely producing most of the observed \( \text{He}^\text{II} \lambda 4686 \) emission in our sample galaxies, at least in Tol 2146−391.

(iv) We found some evidence that the 12+log(N/H) radial distribution, in Tol 2146−391, shows a slight trend, with the values decreasing with distance from \( \text{H}^\alpha \) continuum peak. If real, this observed trend of 12+log(N/H) abundance would argue in favour that these heavy elements were produced during the previous burst of SF and are currently dispersed by the expansion in the ISM of the ISM of starburst-driven supershells. However, the spatial constancy of the N/O ratio might be attributed to efficient transport and mixing of metals by hydrodynamical effects during the previous episodes of SF.

All results presented here are suggestive that the physical conditions in these two galaxies, as in the case of the low luminosity and compact galaxy UM 408 (Lagos et al. 2009), vary in a very small dynamical range and are quite homogeneous. Therefore, the lack of significant variation in abundance across the ISM of the galaxies would be indicative of uniform SF history occurring in galactic scales.

ACKNOWLEDGMENTS

We would like to thank the anonymous referee for his/her comments and suggestions which substantially improved the paper. PL is supported by a Post-Doctoral grant SFRH/BPD/72308/2010, funded by FCT (Portugal). PL would like to thank Polychronis Papaderos and Andrew Humphrey for their very useful comments, suggestions and discussions which have improved the paper. This paper is based on observations obtained at the Gemini Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the NSF on behalf of the Gemini partnership: the National Science Foundation (United States), the Science and Technology Facilities Council (UK), the National Research Council (Canada), CONICYT (Chile), the Australian Research Council (Australia), Ministério da Ciência e Tecnologia (Brazil) and Ministerio de Ciencia, Tecnología e Innovación Productiva (Argentina). Gemini Program ID: GS-2004B-Q-59 and GS-2005B-Q-19.

REFERENCES

Abel T., Bryan G. L., Norman M. L., 2002, Sci, 295, 93
Allington-Smith J. et al., 2002, PASP, 114, 892
Allinhon D., Collin-Souffrin S., Joly M., Vigroux J. M., 1979, A&A, 78, 200
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Baldwin J. A., Phillips M. M., Terlevich R., 1981, PASP, 93, 5
Bordalo V., Telles E., 2011, ApJ, 735, 52
Brinchmann J., Kunth D., Durret F., 2008, A&A, 485, 657
Buckalew B. A., Kobulnicky H. A., Dufour R. J., 2005, ApJS, 157, 30
Cairós L. M., Caon N., Papaderos P., Noeske K., Vilchez J. M., Lorenzo B. G., Muñoz-Tuñón C., 2003, ApJ, 593, 312
Cairós L. M., Caon N., Papaderos P., Kehrig C., Weilbacher P., Roth M., Zurita C., 2009a, ApJ, 707, 169
Cairós L. M., Caon N., Zurita C., Kehrig C., Weilbacher P., Roth M., 2009b, A&A, 507, 1291
Cairós L. M., Caon N., Zurita C., Kehrig C., Roth M., Weilbacher P., 2010, A&A, 520, 90
Campbell A., Terlevich R., Melnick J., 1986, MNRAS, 223, 811
Cardelli J. A., Clayton G. C., Mathis J. S., 1989, ApJ, 345, 245
Chu Y. H., Kennicutt R. C., Jr, 1994, ApJ, 425, 720
de Mello D. F., Schaefer D., Heldmann J., Leitherer C., 1998, ApJ, 507, 199
De Robertis M. M., Dufour R. J., Hunt R. W., 1987, J. R. Astron. Soc. Can., 81, 155
Dopita M. A., Sutherland R. S., 1996, ApJS, 102, 161
Edmunds M. G., Pagel B. E. J., 1978, MNRAS, 185, 77
Fricke K. J., Izotov Y. I., Papaderos P., Guseva N. G., Thuan T. X., 2001, AJ, 121, 169
Garnett D. R., 1990, ApJ, 363, 142
Garnett D. R., 1992, AJ, 103, 1330
Garnett D. R.,Kennicutt R. C., Jr, Chu Y.-H., Skillman E. D., 1991, ApJ, 373, 458
Guseva N. G., Izotov Y. I., Thuan T. X., 2000, ApJ, 531, 776
Guseva N. G., Izotov Y. I., Papaderos P., Fricke K. J., 2007, A&A, 464, 885
Guseva N. G., Izotov Y. I., Stasińska G., Fricke K. J., Henkel C., Papaderos P., 2011, A&A, 529, 149
Guseva N. G., Izotov Y. I., Fricke K. J., Henkel C., 2012, A&A, 541, 115
Hodge P. W., 1974, ApJ, 191, 21
Hook I., Jørgensen I., Allington-Smith J. R., Davies R. L., Metcalfe N., Murowinski R. G., Cranston D., 2004, PASP, 116, 425
Izotov Y. I., Thuan T. X., 1999, ApJ, 511, 639
Izotov Y. I., Dyak A. B., Challée F. H., Folz C. B., Kniazev A. Y., Lipovetsky V. A., 1996, ApJ, 458, 524
Izotov Y. I., Challée F. H., Schaefer D., 2001, A&A, 378, 45
Izotov Y. I., Papaderos P., Guseva N. G., Fricke K. J., Thuan T. X., 2004, A&A, 421, 539
Izotov Y. I., Schaefer D., Blecha A., Royer F., Guseva N. G., North P., 2006a, A&A, 459, 71
Izotov Y. I., Stasińska G., Meynet G., Guseva N. G., Thuan T. X., 2006b, A&A, 448, 955
James B. L., Tsamis Y. G., Barlow M. J., 2010, MNRAS, 401, 759
Kehrig C., Vilchez J. M., Telles E., Cuisinier F., Pérez-Montero E., 2009, A&A, 517, 477
Kewley L. J., Dopita M. A., Sutherland R. S., Heisler C. A., Trevena J., 2001, ApJ, 556, 121
Kingsburgh R. L., Barlow M. J., 1994, MNRAS, 271, 257
Kobulnicky H. A., Skillman E. D., 1998, ApJ, 497, 601
Kobulnicky H. A., Skillman E. D., Roy J.-R., Walsh J. R., Rosa M. R., 1997, ApJ, 477, 679
Kunth D., Sargent W. L. W., 1983, ApJ, 273, 81
Lagos P., Telles E., Melnick J., 2007, A&A, 476, 89
Lagos P., Telles E., Muñoz-Tuñón C., Carasco E. R., Cuisinier F., Tenorio-Tagle G., 2009, AJ, 137, 5068
Lagos P., Telles E., Nigoche-Neto A., Carasco E. R., 2011, AJ, 142, 162
Leitherer C. et al., 1999, ApJS, 123, 3
López-Sánchez A. R., Esteban C., 2010a, A&A, 517, 85
López-Sánchez A. R., Esteban C., 2010b, A&A, 516, 104
McCray R., Kafatos M., 1987, ApJ, 317, 190
Martin C. L., 1998, ApJ, 506, 222
Masegosa J., Moles M., del Olmo A., 1991, A&A, 244, 273
Meynet G., Maeder A., 2005, A&A, 429, 581
Mouroulis A., Vilchez J. M., Walsh J. R., Muñoz-Tuñón C., 2010, A&A, 517, 27
Osterbrock D. E., Ferland G. J., 2006, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei, 2nd edn. University Science Books, Sausalito, CA
Pagel B. E. J., Simonson E. A., Terlevich R. J., Edmunds M. G., 1992, MNRAS, 255, 325
Papaderos P., Loose H. H., Thuan T. X., Fricke K. J., 1996, A&AS, 120, 207
Papaderos P., Izotov Y. I., Thuan T. X., Noeske K. G., Fricke K. J., Guseva N. G., Green R. F., 2002, A&A, 393, 461
Papaderos P., Guseva N. G., Izotov Y. I., Noeske K. G., Thuan T. X., Fricke K. J., 2006, A&A, 457, 45
Peimbert A., Peña-Guerrero M. A., Peimbert M., 2012, ApJ, 753, 39
Peña M., Ruiz M. T., Maza J., 1991, A&A, 251, 417
Pérez-Montero E. et al., 2011, A&A, 532, 141
Sargent W. L. W., Searle L., 1970, ApJ, 162, 155
Schaerer D., 1996, ApJ, 467, 17
Schaerer D., 2002, A&A, 382, 28
Schaerer D., 2003, A&A, 397, 527
Schaerer D., de Koter A., 1997, A&A, 322, 598
Schaerer D., Contini T., Pindao M., 1999, ApJ, 497, 618
Stasińska G., 1990, A&AS, 83, 501
Telles E., Terlevich R., 1997, MNRAS, 286, 183
Telles E., Melnick J., Terlevich R., 1997, MNRAS, 288, 78
Thuan T. X., Izotov Y. I., 2005, ApJS, 161, 240
Thuan T. X., Bauer F. E., Papaderos P., Izotov Y. I., 2004, ApJ, 606, 213
van Zee L., Salzer J. J., Haynes M. P., 1998, ApJ, 497, 1
Westmoquette M. S., Exter K. M., Smith L. J., Gallagher J. S., 2007, MNRAS, 381, 894

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