Astron. Astrophys. 359, 493–508 (2000)

ASTRONOMY
AND
ASTROPHYSICS

Deep optical imaging and spectroscopy of a sample of Wolf–Rayet galaxies*

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Received 14 April 2000 / Accepted 11 May 2000

Abstract. We present results of narrow-band (Hα and adjacent continuum) and broad-band (U, B and V) optical CCD imaging together with high- and intermediate-resolution optical spectroscopy for a sample dwarf and/or irregular Wolf–Rayet (WR) galaxies with absolute B magnitudes in the range -14 to -22 mag, taken from the catalogue of Conti (1991). We find that the recent star formation processes in the galaxies of the sample are distributed in different knots. These knots are H II regions probably ionized by so-called super star clusters (or aggregates of them) found in space observations of WR and interacting galaxies. A comparative study of the $U - B$ colour and the $-W$(Hα) of the different star-forming knots of the galaxies indicates that these two magnitudes give consistent age estimates. However, the $B - V$ colour give comparatively greater ages, which can be explained by the presence of underlying stellar populations in many of the objects. This is confirmed by the presence of a much more extended and diffuse morphology (in some cases with a disc shape) in broad-band compared to Hα images. Our study has also revealed that a substantial fraction of irregular and dwarf WR galaxies at first classified as isolated objects, may in fact be interacting or merging with other low surface brightness companions that escaped detection in previous studies. These interaction processes could be the cause of the triggering of the strong star formation we are now seeing in many of the objects. The Hα morphology of the galaxies indicates that the presence of bubble-like and low surface brightness filamentary structures is a rather common characteristic of these kinds of objects. Spectroscopic observations reported in this and previous papers confirm the presence of high-velocity asymmetric flows that extend to the outer zones in several galaxies.

Key words: galaxies: interactions – galaxies: kinematics and dynamics – galaxies: starburst – stars: Wolf-Rayet

1. Introduction

Wolf–Rayet (WR) galaxies are emission-line galaxies with WR signatures in their integrated spectra, in particular the broad emission feature of He II 4686 Å. Conti (1991) was the first to catalogue these kinds of galaxies, listing 37 objects. Since then, the number of WR galaxies has increased very rapidly to the more than 120 objects listed in the catalogue of Schaerer et al. (1999). According to their definition, the group of WR galaxies is very heterogeneous, with a great variety of morphological types, from irregular and low-mass blue compact dwarf galaxies (BCDGs) to massive spirals and very luminous IRAS galaxies. The presence of WR features in the integrated spectra of the galaxies indicates that star formation is now in progress or has recently taken place in the galaxies, creating stars massive enough to evolve to the WR phase. According to population synthesis models (e.g. Cerviño & Mas-Hesse 1994; Meynet 1995; Schaerer & Vacca 1998), the presence of this feature is an indication of the extreme youth of the burst (≤ 10 Myr).

In addition to this, it is interesting to note that there is direct evidence for large-scale, high velocity flows in the ionized gas associated with some BCDGs. Extensive low-intensity filamentary structures have been detected (using Hα imaging) in more than a dozen of these galaxies, of which almost half have been catalogued as WR galaxies (de Vaucouleurs et al. 1974; Caldwell & Phillips 1989; Dufour & Hester 1990; Marlowe et al. 1995; Martin 1998; Méndez et al. 1999b). This proportion is large if we compare it with the total ratio of WR to H II galaxies and take into account that surveys have not been devoted specially to WR galaxies. These structures dominate the low-intensity extended Hα emission, given the fact that their morphology is typically filamentary and bipolar, and in most cases aligned with the minor axis of the galaxy. High-resolution spectroscopic studies have been reported for some of these galaxies (Marlowe et al. 1995; Martin 1998; Méndez et al. 1999b). The structures appear to be hollow cavities with sizes of the order of kpc, expanding with velocities between 25 and 150 km s^{-1}. They could be produced by the combined action of supernova (SN) explosions and stellar winds leading to the so-called galactic winds (Leitherer 1994). The relative importance of galactic winds in WR galaxies is illustrated in the work of Stevens & Strickland (1998). These authors carried out a systematic study of the X-ray emission of a sample of WR galaxies. They found that the X-ray luminosities of WR galaxies are considerably higher than those of other galaxies with the same B luminosities

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and concluded that this is a consequence of the higher occurrence of superbubbles in WR galaxies.

Finally, the cause of the violent star formation that these objects are experiencing is still largely unknown. Several studies have proposed that interactions with H I companion clouds (Brinks 1997) or with optical low surface brightness companions (Esteban & Méndez 1999a) might be important in the triggering of star formation and the evolution of H II galaxies in general, and of WR galaxies in particular.

As part of a four-year PhD project we embarked on the detailed optical imaging of a selected sample of 13 isolated Wolf–Rayet galaxies taken from the Conti's catalogue. In particular, we chose isolated, dwarf or irregular objects with absolute B magnitudes in the range -14 to -22 mag. We also took spectra, at high and intermediate resolution, of particular zones of some of the objects of the sample. Results for some of the objects have been already presented elsewhere (Méndez et al. 1999; Méndez & Esteban 1999; Méndez et al. 1999a,b; Esteban & Méndez 1999b). Here we present results for the seven remaining objects of the sample. In Sect. 2 we describe our observations. Sect. 3 is devoted to the analysis of the optical images and spectra of these 7 galaxies. In Sect. 4 we discuss the general results for our complete sample of 13 objects, focusing mainly on aspects related to the most recent star formation processes.

2. Observations and data reduction

2.1. Optical imaging

Observations were carried out on 1997 February 4 and 6, and 1996 May 11 at the 2.56 m Nordic Optical Telescope (NOT) at the Roque de los Muchachos Observatory on La Palma (Canary Islands, Spain). We used two different cameras: the StanCam Camera with a TEK CCD detector (1024 $\times$ 1024 pixel) with a pixel size of 24 μm^2 and a plate scale of 0.176$''$ pixel^{-1} and the HIRAC Camera with a LORAL CCD detector of 2048 $\times$ 2048 pixel and with a pixel size of 15 μm^2 and a plate scale of 0.11$''$ pixel^{-1}. The narrow-band filters for the Hα and continuum images (with an FWHM of 50 Å in all cases) were selected taking into account the redshift of the galaxies given in the literature. Three exposures in each filter were added to obtain a good signal-to-noise ratio and an appropriate removal of cosmic rays in the final images. The images were bias-subtracted, flat-fielded and flux-calibrated following standard procedures.

For the narrow-band filters, the absolute flux calibration was achieved taking short exposures of the calibration stars BD+33°2642, BD+75°325 and HZ 44. These stars were selected from the catalogue of Oke (1990). The absolute flux calibration of all the broad-band images was performed taking short exposures of the stars 9621 and 104490 from the catalogue of Landolt (1992). All the images were were taken in photometric conditions.

The images were sky-subtracted and corrected for atmospheric and interstellar extinction. The atmospheric extinction correction was carried out by measuring standard stars at different airmasses throughout the night. For the interstellar extinction correction we used the Balmer decrement of the galaxies, together with the interstellar extinction law of Whitford (1958). The entire reduction process was done with the IRAF[1] package. The Hα images were corrected for [N II] emission taking into account the [N II]/Hα ratio. Data concerning the Balmer decrement and the [N II]/Hα ratio of the galaxies were taken from Vacca & Conti (1992) in the case of Mrk 1087 and Tol 2; Kunth & Joubert (1985) in the case of Mrk 33 and SZ I 59; Izotov & Thuan (1998) in the case of Mrk 750 and UM 461; and French (1980) in the case of Mrk 67. A list of all the imaging observations can be found in Table 1.

2.2. Intermediate-resolution spectroscopy

Observations were carried out on 1999 January 26 with the Twin spectrograph at the Cassegrain focus of the 3.5 m Telescope of the Centro Astronómico Hispano–Alemán (CAHA) at Calar Alto (Almería, Spain). Two SITe CCDs with a configuration of 800 $\times$ 1024 pixels of 15 μm each were used in the blue and red arms of the spectrograph. The slit was 240$''$ long and 1.2$''$ wide. Two gratings were used, the T06 of 1200 line mm^{-1} in the red arm and the T08 of 600 line mm^{-1} in the blue arm. These gratings give reciprocal dispersions of 36 and 72 Å mm^{-1}, respectively. The blue spectra cover from 3500 to 5500 Å and the red ones from 5770 to 6850 Å. The plate scale was 0.56$''$ pixel^{-1} in both cases. A list of the galaxies observed, together with the position angles (P.A.s), the exposure time and the date of the observation can be found in Table 2.

Comparison lamp exposures of He–Ar were taken after each spectrum for wavelength calibration. No flux calibration was attempted. All the CCD frames were reduced using the standard IRAF LONGSLIT reduction package.

2.3. High-resolution Hα spectra

Observations were carried out on 1998 February 22 and 23 with the IACUB spectrograph at the Cassegrain focus of the 2.56 m NOT and on 1999 January 24 and 25 with the UES spectrograph at the Nasmyth focus of the 4.2 William Herschel Telescope (WHT) also at the Roque de los Muchachos Observatory.

In the case of the IACUB observations, a 45$''$ $\times$ 0.9$''$ slit was used with narrow-band filters (FWHM of 50 Å) centred on the Hα wavelength of each galaxy in order to isolate the order corresponding to this line. The spectrograph gives a reciprocal linear dispersion of 1.74 Å mm^{-1} at Hα. We used a Thompson 1024 $\times$ 1024 pixel CCD with a pixel size of 19 μm^2 and a $\times$ 2 binning. At the wavelength of Hα, each binned pixel corresponds to 0.278$''$ in the spatial direction and to 0.066 Å in the spectral direction (i.e. the effective resolution in velocity is 6 km s^{-1}, which corresponds to 2 pixels). Exposures of a Th–Ar lamp were taken for wavelength calibration. No flux calibration was attempted. The technical specifications of the IACUB high-resolution spectrograph can be found in McKeith et al. (1993).

[1] IRAF is distributed by NOAO, which is operated by AURA, Inc., under cooperative agreement with the NSF.

Table 1. Summary of optical imaging observations.

Galaxy	α (1950.0) (hh mm ss)	δ (1950.0) (° ′ ″)	λ_C Filter (Å)	Spatial scale (″ pix^{-1})	Date	Exposure time (s)	Seeing (″)
Mrk 1087	04 47 07.1	+03 14 54.7	U	0.176	97/02/06	3 × 300	≈1.0
			B	0.176	97/02/06	3 × 200	≈1.0
			V	0.176	97/02/06	3 × 200	≈1.0
Tol 2	09 59 10.9	−28 07 10.5	6563 (Hα)	0.110	96/05/11	3 × 600	≈1.3
			6880 (cont.)	0.110	96/05/11	3 × 300	≈1.3
			U	0.176	97/02/06	3 × 400	≈1.2
			B	0.176	97/02/06	3 × 300	≈1.3
			V	0.176	97/02/06	3 × 300	≈1.2
Mrk 33	10 29 22.2	+54 39 23	6600 (Hα)	0.110	96/05/11	3 × 900	≈1.0
			6880 (cont.)	0.110	96/05/11	3 × 600	≈0.9
			U	0.176	97/02/06	3 × 400	≈1.6
			B	0.176	97/02/06	3 × 300	≈1.7
			V	0.176	97/02/06	3 × 300	≈1.5
Mrk 750	11 47 28.1	+15 18 05	6563 (Hα)	0.176	97/02/04	3 × 300	≈1.0
UM 461	11 48 59.4	−02 05 41	B	0.176	97/02/06	3 × 300	≈0.8
			V	0.176	97/02/06	3 × 300	≈0.8
SZ I 59	11 54 54.0	−19 20 20	6600 (Hα)	0.176	97/02/04	3 × 900	≈1.1
Mrk 67	13 41 47.2	+30 32 18.7	6600 (Hα)	0.110	96/05/11	3 × 900	≈1.0
			6880 (cont.)	0.110	96/05/11	3 × 900	≈1.1
			U	0.176	97/02/06	3 × 200	≈0.9
			B	0.176	97/02/06	3 × 200	≈1.1
			V	0.176	97/02/06	3 × 200	≈1.1

In the case of the UES observations, a 237″ × 1.2″ slit was used, again with narrow-band filters (FWHM of 50 Å) centred on the Hα wavelength of each galaxy to isolate the order corresponding to this line with the 79 lines mm^{-1} grating to give a reciprocal linear dispersion of 2.82 Å mm^{-1} at Hα. We used a SITe 2148 × 2148 pixel CCD with a pixel size of 24 μm^2. At the wavelength of Hα, each pixel corresponds to 0.365″ in the spatial direction and 0.133 Å in the spectral direction (i.e. the effective resolution in velocity is 12 km s^{-1}). Exposures of a Th–Ar lamp were taken for wavelength calibration. No flux calibration was performed.

In both cases, all the CCD frames were reduced using the standard IRAF LONGSLIT reduction package. A list of the galaxies observed, together with the P.A.s, the exposure time and the date of the observation, can be found in Table 2.

Table 2. Summary of spectroscopic observations.

Galaxy	P.A. (°)	Date	Spatial scale (″ pix^{-1})	Spectral resolution (Å pix^{-1})	Exposure time (s)
Mrk 1087	4	98/02/23	0.28	0.066	3 × 1200
Tol 2	38	99/01/25	0.365	0.133	7 × 600
	71	99/01/25	0.365	0.133	3 × 600
Mrk 33	−86	98/02/22	0.28	0.066	3 × 1800
	−28	98/02/22	0.28	0.066	3 × 1800
UM 461	90	99/01/26	0.56	1.16–2.32	1 × 600
SZ I 59	−13	99/01/24	0.365	0.133	4 × 900
Mrk 67 (c3)	0	99/01/26	0.56	1.16–2.32	3 × 600

3. Results for individual objects

In this section we present the results of optical imaging and spectroscopy for each of the sample objects. As a general result, most of the galaxies show a structure of different emission zones in their continuum-subtracted Hα and broad-band images. In order to study and delimit all these zones, we used the IRAF FOCAS package[2] on the continuum subtracted Hα images of the objects. In the case of Mrk 1087 and UM 461 we could not obtain Hα images so we used the V ones instead. In some cases, the low signal-to-noise and the overlapping in the emission of specific areas of the images did not permit the use of FOCAS and we had to delimit the star-forming knots and extract their fluxes using synthetic apertures defined manually. Where possible, we compared the results from this synthetic aperture analysis with that carried out with FOCAS and found that the results of both methods were consistent.

In the case of the spectra, the analysis of the emission-line profiles was performed via Gaussian fitting making use of the Starlink DIPSO sofware (Howarth & Murray 1990). For each single or multiple Gaussian fit, DIPSO gives the fit parameters (radial velocity of the centroid, Gaussian σ, FWHM, etc.) and their associated statistical errors. All the radial velocities given are referred to the heliocentric reference frame.

[2] For a detailed description of the procedure see Méndez et al. (1999a).

3.1. Mrk 1087

Zwicky (1971) describes Mrk 1087, also known as II Zw 23 and UGC 3179, as an elliptically shaped blue compact galaxy with a very extended filament to the north and a less extended one to the south. Keel (1988) carries out a multi-frequency study of the object and concludes that Mrk 1087 is a galaxy in formation, whose most recent star formation is the result of the accretion of large amounts of neutral gas coming from a very massive H I cloud in which the object is embedded. According to this model, the filaments (which are redshifted with respect to the central zones of the galaxy) are produced as a consequence of the ionization of the gas that is falling on to the galaxy. Keel (1988) also proposes that the strong star formation process (which, according to his stellar population analyses, has been taking place continuously for the past $\sim 10^9$ yr) could be a consequence of the interaction with a companion galaxy located $\sim$10 ″ to the south of the nucleus of the main galaxy.

Kunth & Joubert (1985) detect the presence of WR features in the integrated spectrum of the galaxy, a fact confirmed by Vacca & Conti (1992), who report the presence of 1600 WNL stars in the galaxy.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 8330 km s^{-1} for the recession velocity of the object (calculated from our spectroscopic observations), Mrk 1087 lies at 111.1 Mpc. At this distance, the spatial scale is 538 pc arcsec^{-1}.

In Fig. 1 (*upper left*) we present our B image of the object[3]. In this figure it is possible to note the presence of five faint objects which are apparently connected to the main galaxy through low surface brightness bridges (the filaments detected by Keel 1988). The longest bridge (around 26 kpc), connecting the galaxy with an object located to the north, is very straight. This last object presents an extension to the east. All these objects are labelled in Fig. 1 (*lower centre*), in which it is also possible to detect the presence of a bright companion galaxy of Mrk 1087[4], located $\approx$ 81 kpc to the southwest and at the same distance.

At high intensities, Mrk 1087 shows a structure of different emission zones, possibly star-forming knots. These zones are also labelled in Fig. 1 (*centre right*). The brightest zone is #5, with an equivalent circular diameter of 1.3 kpc[5]. Emission zone #7 corresponds spatially with the position of a companion object, a dynamical system with a radial velocity redshifted $+320$ km s^{-1} with respect to the central parts of Mrk 1087 (Keel 1988) and that could be in interaction with it. In this sense, it is interesting to mention the presence of a structure with the shape of a tidal tail located to the south of the galaxy (see Fig. 1, *upper left*). We extracted the fluxes of all the emission zones and of the visual companion objects using synthetic apertures. Data on the absolute B magnitude (assuming that the companion objects are located at the same distance), $U-B$ and $B-V$ colours, together with the associated Poissonian uncertainties, are presented in Table 3. In the case of the companion objects connected through bridges to Mrk 1087, the signal-to-noise in these zones of the U image is so low that it does not permit the calculation of confident fluxes in that band. The $B-V$ colours of these objects are relatively redder in comparison with the $B-V$ colours of the central zones of the galaxy. The line labelled "Total" in Table 3 corresponds to the integrated values for the main galaxy.

We have applied population synthesis models of Leitherer & Heckman (1995) to estimate the ages of the different emission zones and those corresponding to the integrated properties of the galaxy. We have assumed instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$ and a metallicity of 0.25 $Z_\odot$ (the metallicity of the galaxy is 0.41 $Z_\odot$ according to Vacca & Conti, 1992). The ages obtained from the $U-B$ and $B-V$ colours are included in Table 3. We have found that the ages obtained from the $B-V$ colour are slightly larger than those calculated through the $U-B$ colour for the same object. In the case of the surrounding objects (#1, #2, #3, #11 and the companion located to the southwest), the $B-V$ colour gives older ages than in the main body of the galaxy. However, their $B-V$ colour is in most cases inside the range typical for tidal dwarfs (Duc et al. 1998). The colour of zone #12 lies outside the range of variation of the models, even in the case of continuous star formation. This is probably a highly reddened old object. On the other hand, if we assume continuous star formation, the ages obtained from the $B-V$ colour are slightly higher for the central knots, since for all the other zones the ages derived lie outside the range of variation of the models.

We took an Hα spectrum of the galaxy at P.A. = 4° in order to obtain kinematic data for the main axis of the galaxy and the companion object located to the south of the nucleus of Mrk 1087 (emission zone #7). The slit position and the two-dimensional spectrum are depicted in Fig. 2. The most remarkable feature of the spectrum is the presence of a gradient in the radial velocity as we move along the slit in the central zone. This behaviour, which had already been noticed by Keel (1988), is probably due to the rotation of the galaxy. Taking into account the maximum velocity difference ($\sim$215 km s^{-1}) and considering a radius for the main body of the galaxy of 6.6″ ($\approx$ 3.57 kpc), it is possible to obtain a value of 8.7×10^9 $M_\odot$ for the Keplerian dynamical mass of Mrk 1087 (assuming an inclination of 90°).

Another interesting feature of the two-dimensional Hα spectrum is the presence of two emission zones (labelled A and B in Fig. 2) at the northern and southern extremes respectively. These regions have heliocentric velocities of $\approx$ 8210 and $\approx$ 8445 km s^{-1}, shifted ≈ -120 and $\approx$ +115 km s^{-1}, respectively, with respect to the heliocentric velocity of the central emission zone of the galaxy, which is 8330 km s^{-1}. Region B also shows another component, much weaker and narrower and with a velocity redshifted $\approx$ 85 km s^{-1} with respect to the brightest

[3] North is at the top and east to the left in all the images shown in this paper.

[4] This galaxy is catalogued as K72 103a and has a radial velocity of 8383 km s^{-1} (Marzke et al. 1996).

[5] The equivalent circular diameter is defined as the diameter of a circle with the same area as the aperture used to obtain the photometry of the emission zone or star-forming knot.

Table 3. Results of aperture photometry and ages.

Galaxy	Z ($Z_\odot$)	Knot	log[L(Hα)] (cgs)	M_B (mag)	$U-B$ (mag)	$B-V$ (mag)	$-W$(Hα) (Å)	Age ($U-B$) (Myr)	Age ($B-V$) (Myr)	Age [$-W$(Hα)] (Myr)
Mrk 1087	0.41	#1	–	-16.24 ± 0.02	–	0.22 ± 0.03	–	–	7.4-59	–
		#2	–	-14.82 ± 0.04	–	0.33 ± 0.06	–	–	$\approx$100	–
		#3	–	-16.87 ± 0.01	–	0.42 ± 0.02	–	–	133-174	–
		#4	–	-16.66 ± 0.02	-0.68 ± 0.04	0.04 ± 0.03	–	$\approx$4.4	5.3-5.7	–
		#5	–	-20.08 ± 0.01	-0.48 ± 0.01	0.09 ± 0.01	–	4.7-9.2	5.4-6.0	–
		#6	–	-18.46 ± 0.01	-0.75 ± 0.02	0.00 ± 0.01	–	3.9-4.4	4.8-5.2	–
		#7	–	-17.27 ± 0.01	-0.77 ± 0.03	0.13 ± 0.02	–	3.8-4.1	5.5-22	–
		#8	–	-16.67 ± 0.02	–	0.16 ± 0.03	–	–	6.5-35	–
		#9	–	-15.11 ± 0.03	–	0.31 ± 0.05	–	–	$\approx$92	–
		#10	–	-15.33 ± 0.03	–	0.22 ± 0.05	–	–	7.3-55	–
		#11	–	-14.60 ± 0.04	–	0.35 ± 0.07	–	–	$\approx$107	–
		#12	–	-15.22 ± 0.03	–	0.97 ± 0.05	–	–	–	–
		Total	–	-21.73 ± 0.01	-0.31 ± 0.01	0.20 ± 0.01	–	5.1-27	7.2-51	–
		Comp.	–	-20.72 ± 0.01	0.34 ± 0.01	0.21 ± 0.01	–	–	7.3-55	–
Tol 2	0.13	#1	38.45	-12.76 ± 0.01	-0.09 ± 0.03	-0.49 ± 0.02	490 ± 40	–	–	$\approx$3.9
		#2	38.66	-12.72 ± 0.01	-0.61 ± 0.02	0.04 ± 0.01	200 ± 10	4.3-8.3	6.4-14	$\approx$5.2
		#3	39.59	-14.07 ± 0.01	-0.90 ± 0.01	0.13 ± 0.01	410 ± 10	$\approx$3.3	$\approx$3.3	$\approx$4.1
		#4	39.15	-14.25 ± 0.01	-0.73 ± 0.01	-0.04 ± 0.01	110 ± 5	3.9-4.2	2.4-6.2	$\approx$7.9
		#5	39.29	-13.38 ± 0.01	-0.85 ± 0.03	0.12 ± 0.02	385 ± 10	3.4-3.5	$\approx$31	$\approx$4.1
		#6	38.71	-12.39 ± 0.01	-0.67 ± 0.02	0.12 ± 0.01	220 ± 10	4.2-8	$\approx$31	$\approx$5.0
		#7	39.13	-13.18 ± 0.01	-0.84 ± 0.02	0.19 ± 0.01	325 ± 10	3.4-3.6	$\approx$50	$\approx$4.2
		#8	38.83	-12.24 ± 0.01	-0.83 ± 0.03	0.15 ± 0.02	335 ± 15	3.4-3.6	$\approx$38	$\approx$4.2
		#9	39.04	-12.39 ± 0.01	-0.89 ± 0.02	0.24 ± 0.02	655 ± 30	$\approx$3.3	$\approx$69	$\approx$3.8
		Total	40.42	-16.92 ± 0.01	-0.61 ± 0.01	0.22 ± 0.01	290 ± 5	4.3-8.3	$\approx$62	$\approx$4.3
Mrk 33	0.33	#1	40.40	-16.99 ± 0.01	-0.93 ± 0.01	-0.20 ± 0.01	145 ± 5	$\approx$3.7	$\approx$2.1	$\approx$5.8
		#2	40.74	-17.33 ± 0.01	-0.99 ± 0.01	-0.14 ± 0.01	280 ± 5	$\approx$3.6	2.5-3.2	$\approx$4.7
		#3	39.82	-14.92 ± 0.01	-1.01 ± 0.02	-0.14 ± 0.01	320 ± 15	$\approx$3.3	2.5-3.2	$\approx$4.7
		Total	41.23	-19.68 ± 0.01	-0.63 ± 0.01	-0.04 ± 0.01	90 ± 5	$\approx$4.5	2.0-5.0	$\approx$6.5
Mrk 750	0.19	#1	39.48	–	–	–	795 ± 5	–	–	$\approx$3.8
		#2	39.01	–	–	–	955 ± 10	–	–	$\approx$3.7
		Total	40.48	–	–	–	940 ± 5	–	–	$\approx$3.7
UM 461	0.07	#1	–	–	–	1.26 ± 0.05	–	–	–	–
		#2	–	–	–	1.14 ± 0.02	–	–	–	–
		#3	–	–	–	1.56 ± 0.05	–	–	–	–
		#4	–	–	–	0.89 ± 0.07	–	–	–	–
		#5	–	-9.35 ± 0.03	–	0.12 ± 0.05	–	–	5.5-18	–
		#6	–	-10.17 ± 0.02	–	0.08 ± 0.03	–	–	5.4-5.6	–
		#7	–	-8.81 ± 0.03	–	0.31 ± 0.06	–	–	$\approx$92	–
		#8	–	-12.35 ± 0.01	–	0.34 ± 0.01	–	–	$\approx$103	–
		#9	–	-14.09 ± 0.01	–	0.56 ± 0.01	–	–	–	–
		Total	–	-14.88 ± 0.01	–	0.47 ± 0.01	–	–	–	–
SZ I 59	0.30	Total	40.61	–	–	–	125 ± 5	–	–	$\approx$6.0
Mrk 67	0.19	#1	38.71	-11.74 ± 0.01	-0.64 ± 0.04	0.15 ± 0.02	205 ± 15	$\approx$4.5	6.4-31	$\approx$4.8
		#2	39.86	-13.83 ± 0.01	-0.66 ± 0.01	0.41 ± 0.01	480 ± 10	$\approx$4.5	130-370	$\approx$4.4
		#3	38.95	-11.92 ± 0.01	-0.68 ± 0.03	0.23 ± 0.02	280 ± 15	$\approx$4.4	7.5-62	$\approx$4.7
		Total	40.15	-14.99 ± 0.01	-0.57 ± 0.01	0.40 ± 0.01	325 ± 5	$\approx$4.7	$\approx$125	$\approx$4.7
		#c1	–	–	0.50 ± 0.09	1.38 ± 0.03	–	–	–	–
		#c2	–	–	0.05 ± 0.40	1.86 ± 0.16	–	–	–	–
		#c3	–	–	0.64 ± 0.02	1.14 ± 0.01	–	–	–	–

emission of this zone. Finally, our spectrum does not confirm the presence of the redshifted ($\approx$ 320 km s^{-1}) component in emission that could be associated with the companion object (#7) located to the south claimed by Keel (1988). The FWHMs of the Gaussian fittings of different one-dimensional zones of the spectrum (corrected for instrumental and thermal broadening and assuming a typical value of 10 000 K for the electronic temperature) vary between $\approx$ 70 km s^{-1} and $\approx$ 130 km s^{-1} from the external to the central zones, respectively.

The presence of objects connected with bridges around the main body of the galaxy suggest the possible interacting origin of the strong event of star formation that Mrk 1087 is now experiencing. It is necessary to carry out a complete spectroscopical study of the surrounding objects in order to establish whether they are emission-line galaxies and obtain their distance and chemical composition. The abundance analysis would help to discern whether the surrounding objects are tidal dwarfs or chemically unevolved young dwarf galaxies.

3.2. Tol 2

Smith et al. (1976) describe Tol 2, also known as Tol 0957$-$278, as a dwarf H II galaxy whose Hα emission is composed of two or three knots located to the east and south of a common envelope while its continuum emission is more diffuse and less localized. Kunth et al. (1988) detect clearly the presence of four different knots in a B image of the object. Kunth & Joubert (1985) detect a very weak emission band from WR stars in the integrated spectrum of the galaxy. Vacca & Conti (1992) confirm the presence of $\approx$ 11 WNL stars in the galaxy.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 980 km s^{-1} for the recession velocity of the object (calculated from our spectroscopic observations), Tol 2 lies at 13 Mpc. At this distance, the spatial scale is 63 pc arcsec^{-1}.

In Fig. 3 (*lower right* and *centre right*) we present our continuum-subtracted Hα image, at high and low intensities, respectively, of Tol 2. It is possible to detect nine different star-forming knots in the galaxy that are labelled in Fig. 3 (*lower right*). Data on the Hα luminosity and equivalent width of all these knots are presented in Table 3. Poissonian uncertainties of the Hα fluxes are always less than 2% of the values of these fluxes. In Fig. 3 (*upper left*) we present also our B image of Tol 2. The values of the absolute B magnitudes, as well as the $U-B$ and $B-V$ colours of the different knots, are presented in Table 3. As we can see, the B morphology of the galaxy is very different compared to the Hα one. While in the case of the Hα filter, the structure with higher surface brightness consists of a chain of knots (#5, #7 and #9) that extend to the southwest of knot #3, in the B filter the brightest emission is located to the west of knot #3 (knots #4 and #6) and also in knot #7. The presence of such a strong continuum, mainly in knot #4, should result in a lower $-W$(Hα) compared to that of the other knots. In addition, the broad-band images show an extended halo in the east and west directions which has no counterpart in the Hα image. On the other hand, the presence of gaseous filaments in the continuum-subtracted Hα image is clearly seen, especially to the north and west of the galaxy. These filaments show linear sizes up to 700 pc.

Following Kennicutt (1988) and taking into account the value of the integrated Hα luminosity of the galaxy, we obtain a value of 9.5 $\times$ 10^4 $M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$) in the whole galaxy. This value corresponds to the presence of 540 O5V equivalent stars, which is consistent with the $\approx$ 320 O7V equivalent stars found by Vacca & Conti (1992). Using the electronic density and temperature given by Vacca & Conti (1992) we obtain values of Q^o=10$^{52.4}$ s^{-1} and of $M_{\rm HII}/M_\odot$=10$^{6.2}$ for the whole galaxy.

The brightest and largest knot, #3, has an equivalent circular diameter of 225 pc, 0.7 times that of 30 Doradus (Kennicutt 1984) and a luminosity four times lower. This knot accounts for the 15% of all the Hα emission of the galaxy.

We have obtained the ages of the different knots applying population synthesis models (Leitherer & Heckman 1995) for instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$ and a metallicity of 0.10 $Z_\odot$ (the metallicity of the galaxy is 0.13 $Z_\odot$ according to Kunth & Joubert 1985). All the ages calculated are included in Table 3. We find that the ages calculated from the $-W$(Hα) and the $U-B$ colour of the different knots are consistent within an interval of 1 Myr, except in the case of knot #4. On the other hand, knot #4 has an age, calculated from its $-W$(Hα), of $\approx$ 7.9 Myr, a value which is larger compared to the $\approx$ 4 Myr calculated from its $U-B$ colour. As said before, this is probably due to the presence of a considerable amount of continuum emission in this zone (see Fig. 3, *lower left*). On the other hand, the ages obtained from the $B-V$ colour are very large compared to those calculated using the other estimators (except in the case of knots #2, #3 and #4, in which the ages calculated from the $B-V$ colour are consistent with those calculated from the $U-B$ colour). It is important to mention that the colours of knot #1 are very uncertain due to the low signal-to-noise of the images in this zone and do not permit the calculation of an age since they lie outside the variation range of the models.

In Fig. 4 (*upper left*) we show the two slit positions (P.A. = 38° and 71°) observed for this object. Both P.A.s were chosen in order to study the radial velocity distribution of the different star-forming knots of the galaxy. The two-dimensional Hα spectra are also presented in Fig. 4 (*upper right* and *lower right*). In the case of P.A. = 71°, we can barely detect the emission of knots #3 and #4 due to the low signal-to-noise of the spectrum. These zones of the spectrum have heliocentric velocities (calculated from the centroid of the Gaussian fitting to the emission line profiles) of $\approx$ 985 and $\approx$ 970 km s^{-1} respectively, values which are consistent with the mean velocity obtained by Vacca & Conti (1992). In the case of P.A. = 38°, the signal-to-noise is also low, but it is possible to detect clearly the emission of knots #3, #5, #7 and #9. The heliocentric velocities of these zones turn out to be $\approx$ 985, $\approx$ 975, $\approx$ 955 and $\approx$ 965 km s^{-1}, respectively. As we can see, there is a slight inversion in the velocity distribution, which, although very small numerically, is clearly seen in the two-dimensional spectra. This fact could suggest, although weakly, the possibility of a merger event of different stellar systems (with different initial velocities) in Tol 2. The FWHMs of the Gaussian fittings to the Hα emission associated with the knots, corrected for instrumental and thermal broadening (taking into account the electronic temperature of 13 000 K given by Vacca & Conti 1992) lie between $\approx$ 40 and $\approx$ 50 km s^{-1}. In Fig. 4 (*lower left*) we show the clearly non-Gaussian Hα line profile of #9, which indicates the complex gas kinematics of the zone. Similar profiles are seen in most of the knots.

3.3. Mrk 33

Mrk 33, also known as Haro 2 and Arp 233, is an elliptically shaped galaxy but with a very blue nucleus (Loose & Thuan 1986). This galaxy presents features typical of H II regions and a metallicity three times lower than solar (Davidge 1989). Kunth & Joubert (1985) detected for the very first time the presence of WR features in the integrated spectrum of Mrk 33, a fact confirmed later by Mas-Hesse & Kunth (1991, 1999). Lequeux et al. (1995) notice that the Lyα emission line profile of the galaxy is clearly asymmetric, with a P Cygni shape that indicates the outflow of partially ionized gas at $\sim$ 200 km s^{-1} with respect to the central H II region. This outflow is confirmed by the Hα observations of the galaxy presented by Legrand et al. (1997). The presence of these kinds of outflows is consistent with the ultraviolet absorption lines, associated with massive stars with strong winds which appear in the spectrum of the galaxy (Kinney et al. 1993) and with a value of the radio spectral index of -0.59 (Klein et al. 1991), which is highly non-thermal.

On the other hand, Mollenhoff et al. (1992) present a 20 cm radio map of the object in which it is possible to detect the presence of a radio source located around 30$''$ to the north of the central emission of the galaxy together with a small extended tail pointing to this radio source. If this radio source is at the same distance as Mrk 33, the distance between both objects would be of 2.8 kpc. In any case, as Mollenhoff et al. (1992) state, without kinematic data about the radio source, it is impossible to confirm that this source is really a companion system of Mrk 33.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1}and given a value of 1450 km s^{-1} for the recessional velocity of the object (calculated from our spectroscopic observations) Mrk 33 lies at 19.3 Mpc. At this distance, the spatial scale is 93.7 pc arcsec^{-1}.

In Fig. 5 (*centre right* and *lower right*) we present our continuum-subtracted Hα image of Mrk 33, at high and low intensities respectively. At low intensities, the most remarkable feature is the presence of faint filamentary extended structures located mainly to the west of the nuclear emission (and also to the south and north of the galaxy). The most interesting structure is a sort of shell that extend to the west to 1.3 kpc from the centre of the galaxy. This structure also appears in the W(Hα) map of the galaxy (Fig. 3, *lower left*). The morphology and the size of this structure are very similar to those of the shell-like structures found in other star-forming galaxies (Marlowe et al. 1995; Martin 1998; Méndez et al. 1999b), which could be associated with the interaction of superbubbles with the interstellar medium. The presence of these kinds of structures in Mrk 33 is consistent with the above mentioned spectroscopic studies that indicate the presence of outflows of ionized gas from the galaxy (Lequeux et al. 1995, Legrand et al. 1997).

At high intensities, the Hα emission of the galaxy is distributed in three different star-forming knots, as labelled in Fig. 5 (*lower left*). Data on the Hα luminosity and equivalent width of all these knots, together with the corresponding integrated values for the whole galaxy, are presented in Table 3. Poissonian uncertainties for the Hα fluxes are always less than 1% of the values of these fluxes. The largest and brightest knot is the central one (#2), which has an equivalent circular diameter of $\approx$ 230 pc, 1.5 times that of 30 Doradus, and with an Hα luminosity three times larger. This knot accounts for 32% of the total Hα emission of the galaxy.

Following Kennicutt (1988), we obtain a value of 6.1 $\times$ 10^5 $M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$) in the galaxy. This value corresponds to the presence of 3300 O5V equivalent stars. Assuming values of 100 cm^{-3} and of 10 000 K for the electron density and temperature, we obtain Q^0=10$^{53.2}$ s^{-1} and $M_{\rm HII}/M_\odot$=10$^{6.7}$ for the whole galaxy.

In Fig. 5 (*upper left*) we also present our B image of Mrk 33. In this filter, apart from the central nucleus, which is also present in the net Hα image, the galaxy shows a diffuse halo that extends out to more than 2 kpc from the central nucleus. It is possible to detect the three different star-forming knots in the three broad-band images, but they are less well defined than in the Hα image. The absolute B magnitudes together with the $U-B$ and $B-V$ colours of the different knots, as well as the corresponding integrated values, are presented in Table 3. We have applied population synthesis models (Leitherer & Heckman 1995) to estimate the ages of the different knots assuming an instantaneous burst with a Salpeter IMF, an upper cut-off of 100 $M_\odot$, and a metallicity of 0.25 $Z_\odot$. The ages are included in Table 3. We find that the ages of the three knots calculated from the $-W$(Hα) are systematically larger than those obtained from the $U-B$ colour. On the other hand, the values of the $B-V$ colours of the central knots lie outside the variation range of the models, precluding the derivation of ages from them. The behaviour of the $B-V$ colour map (Fig. 5, *middle left*) is the inverse of that of the $U-B$ colour map in the nucleus of the galaxy (Fig. 5, *upper right*), although the differences are small. The fact that the behaviour of the $-W$(Hα) is similar to that of the $U-B$ colour map suggests that the explanation of this effect is the somewhat different spatial distribution of the youngest stellar population with respect to the older stars. The mean age of the most recent burst of star formation of the galaxy calculated from the integrated $-W$(Hα) is $\approx$ 6.5 Myr. If we calculate this age using the $U-B$ colour, we obtain $\approx$ 4.5 Myr, a value more consistent with the estimate of 4.8 Myr obtained by Mas-Hesse & Kunth (1999) from spectroscopic observations of the $-W$(Hβ). If we use the $B-V$ colour, we obtain an interval of 2–5 Myr, a value which is broadly consistent with that obtained from the $U-B$ colour. From these figures, we might think that our values of the $-W$(Hα) is slightly underestimated, possibly due to the effect of underlying absorption of the Hα flux in emission.

In Fig. 6 (*upper left*) we show the two different slit positions (P.A. = -86 ° and P.A. = -28°) that were used for Mrk 33. The P.A. of -28° was chosen in order to study the possible variations in the radial velocity of the three central knots, which are distributed along the apparent major axis of the galaxy. The P.A. of -86° was chosen in order to study the kinematics of the shell-like structure located in the western part of the galaxy. In Fig. 6 (*upper right*) we show the Hα two-dimensional spectrum of the galaxy for P.A. = -28°. The value of the heliocentric velocity for the integrated emission-line profile of this P.A. is $\approx$ 1450 km s^{-1}, consistent with the velocities tabulated from different optical emission lines by Legrand et al. (1997). The most remarkable feature of the spectrum of Mrk 33 for this P.A. of -28° is the presence, as in the case of Mrk 1087, of a velocity gradient as we move along the slit. The central knots of the object, #1, #2 and #3, clearly show this behaviour, with heliocentric velocities of $\approx$ 1430, $\approx$ 1450 and $\approx$ 1465 km s^{-1}, respectively. This velocity distribution, as in the case of Mrk 1087, is probably due to the rotation of the galaxy about its major axis. Taking into account the velocity difference between the most external zones ($\approx$ 65 km s^{-1}) and considering a radius for the galaxy of 8″ ($\approx$ 745 pc), we obtain a value of 1.83 $\times$ 10^{8} $M_{\odot}$ for the Keplerian dynamical mass of Mrk 33 (assuming an inclination of 90°). In Fig. 6 (*lower right*) we show the two-dimensional Hα spectrum of the galaxy for P.A. = -86°. Unfortunately, this spectrum has a very low signal to noise away from the nucleus of the galaxy, and it is therefore not possible to detect any emission in the zone corresponding to the bubble-like structure; therefore, it is not possible to obtain any kinematic information about this feature.

In Fig. 6 (*lower left*) we show the Hα emission line profile for knot #2 (P.A. = -28°) of Mrk 33. This profile shows residuals (broad wings) to a single-Gaussian narrow behaviour, indicating the presence of complex kinematic processes in the ionized gas of the galaxy (similar to the four WR galaxies studied by Méndez & Esteban 1997). Similar features are also observed in the other knots and the spectrum of P.A. = -86°. In the case of P.A. = -28°, the broad wings (always more intense on the blue side) extend over the entire central zone of the galaxy ($\approx$ 950 pc). Further away, the signal to noise of the spectra is so low that it does not permit the existence of these broad wings to be confirmed. The maximum velocities are reached in the central parts of the galaxy and are -230 km s^{-1} in the blue wing and $+215$ km s^{-1} in the red one. The FWHMs of the central narrow components, corrected for instrumental and thermal broadening (assuming a typical value of electron temperature of 10 000 K) vary between 90 km s^{-1} (region 1) and 120 km s^{-1} (region 3). In the case of P.A. = -86°, the broad wings, which are also more intense on the blue side, extend out to the central $\approx$ 650 pc. The maximum velocities (-245 km $^{-1}$ for the blue wing and $+225$ km s^{-1} for the red wing) are reached again in the central zones of the object. In this case, the FWHMs of the central narrow components are very constant in all the zones where the fits can be carried out reaching values close to 120 km s^{-1}. These results are consistent with those obtained by Legrand et al. (1997), who proposed the existence of a superbubble with a maximum velocity of $\approx$ 200 km s^{-1} in Mrk 33. The characteristics of the faint broad wings in the spectral lines of Mrk 33 are very similar to those obtained for the WR galaxies He 2-10, II Zw 40, POX 4 and Tol 35 by Méndez & Esteban (1997), indicating that probably a superbubble blowout process developing in a cloudy medium is taking place in the galaxy. In this sense, it is interesting to mention that Mrk 33 shows notable X-ray emission detected with *ROSAT* and the PSPC camera (Stevens & Strickland 1998). This X-ray emission is probably produced by hot gas contained in a superbubble.

3.4. Mrk 750

Kunth & Joubert (1985) detected for the first time broad He II λ4686 Å emission produced by WR stars in the BCDG Mrk 750. Conti (1991) reports also the detection of N III λ4640 Å according to a spectrum obtained by J. Salzer. These results are consistent with those obtained by Izotov & Thuan (1998). The reanalysis of Guseva, Izotov & Thuan (2000) reveals also the presence of C IV λ5808 Å emission.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 900 km s^{-1} for the recessional velocity of the object (Kunth & Joubert 1985), Mrk 750 lies at 12 Mpc. At this distance, the spatial scale is 58.2 pc arcsec^{-1}.

In Fig. 7 we present the first Hα image obtained for this galaxy. At low intensities, the most remarkable feature is the presence of low surface brightness structures located to the north and south of the galaxy. At high intensities, it is possible to detect two different star-forming knots labelled in Fig. 7. Knot #1 is the larger of the two, with an equivalent circular diameter of $\approx$ 65 pc. The Hα luminosity and equivalent width of these two knots, together with the integrated values for the whole galaxy, are shown in Table 3. Poissonian uncertainties of the Hα fluxes are always less than 0.2% of the value of these fluxes. On the other hand, the continuum image (6640 Å) of Mrk 750 shows a morphology completely different from the net Hα one. In Fig. 8 we present a contour map (white) of the continuum image superimposed on a grey-scale representation of the net Hα image. In the continuum image, Mrk 750 shows two apparently detached zones. One of these zones, with a luminosity in the 6640 Å filter of 1.64 $\times$ 10^{39} erg s^{-1}, corresponds spatially with the central Hα emission (mainly with knot #1). The other zone, with a luminosity in the 6640 Å filter of 4.74 $\times$ 10^{38} erg s^{-1}, is located around 530 pc to the northeast of the central zone, with no counterpart in Hα, except a faint knot located to the east of the continuum patch. Although hardly seen in the contour map, both emission zones seem to be connected by an extremely weak extended emission. It is remarkable that the extended arc of Hα emission located to the north is also pointing to the location of that continuum patch. This peculiar morphology suggests the presence of a possible interaction process.

Following Kennicutt (1988) and taking into account the integrated Hα luminosity of the galaxy, we obtain a value of 1.1.

$\times\ 10^5\ M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$). This value corresponds to the presence the equivalent of 600 O5V stars. Using the electron density and temperature given by Izotov & Thuan (1998), we obtain values of Q^0=$10^{52.5}$ s^{-1} and of $M_{\rm HII}/M_\odot$ = $10^{6.0}$ for the whole galaxy.

As in the previously mentioned galaxies, we have applied population synthesis models (Leitherer & Heckman 1995), assuming instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$ and a metallicity of 0.25 $Z_\odot$ (the metallicity of the galaxy is 0.19 $Z_\odot$ according to Kunth & Joubert 1985). We find that both star-forming knots have very similar ages calculated from their $-W$(Hα), as can be seen in Table 3.

3.5. UM 461

UM 461 is a BCDG that was first detected by MacAlpine & Williams (1981) in their Curtis–Schmidt survey of emission line objects (University of Michigan, List V). Telles & Terlevich (1997) describe the galaxy as a double object with regular external isophotes. Conti (1991) notes the presence of broad He II λ4686 Å, as well as strong nebular lines of [Ar IV], according to a spectrum by Salzer, and classifies the galaxy as WR. Doublier et al. (1999) have obtained deep B and R CCD images of the galaxy.

Taylor et al. (1995) report that the galaxy forms an interacting pair with UM 462, located around 70 kpc to the southeast and at the same distance (with a recessional velocity of 1051 km s^{-1}, Grogin et al. 1998). These authors reach this conclusion after the detection of extended emission, possibly a tidal tail, in the H I image of UM 461 in the direction of UM 462. Their interpretation is that the gravitational action of UM 462 causes this distortion in the H I emission of the external zones of UM 461. On the other hand, van Zee et al. (1998) present a new H I image of the pair of galaxies, in which there is no sign of the tidal tail that appeared in the image by Taylor et al. (1995), which could have been caused by solar interferences. Van Zee et al. (1998) indicate that it is not possible to affirm that both galaxies are in interaction and that, even in the case that both systems were associated physically, it is not very likely that the strong star formation process they are experiencing is caused by their mutual interaction.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 1050 km s^{-1} for the recession velocity of the object (calculated from our spectroscopic observations), UM 461 lies at 14 Mpc. At this distance, the spatial scale is 67.9 pc arcsec^{-1}.

In Fig. 9 (*upper left*) we show our B image of UM 461. At high intensities, the galaxy presents a structure of two different main emission zones (possibly star-forming knots), a larger and brighter one located to the east (#9), and another one located to the west (#8), as well as three additional fainter and smaller zones located to the northwest of #8. These five emission zones are labelled in the V image of the object shown in Fig. 5 (*lower center*). The flux extraction was carried out using synthetic apertures. Data on the B absolute magnitude and the $B-V$ colours, together with the associated Poissonian uncertainties, are presented in Table 3. At lower intensities, the galaxy has a peculiar halo, extending mainly to the southwest, out to distances greater than 1 kpc from the centre. Doublier et al. (1999) indicate that the shape of this halo suggests a tidal event, probably produced by the merging of the two bright knots at the center of the object.

It is interesting to note the presence of other galaxies in the same field of view of UM 461, perhaps possible companions (awaiting spectroscopic confirmation), which are also labelled in Fig. 5 (*lower centre*). Data on the $B-V$ colours of these galaxies, together with the associated Poissonian uncertainties, are presented in Table 3 (absolute magnitudes are not included due to the unknown distance of the objects). The $B-V$ colours of these objects are very red, indicating that, if they are not at very large distances from us, these objects are dominated by old populations and/or are strongly reddened due to the presence of dust. The object located to the south of objects #1 and #3 and to the west of #4 is a foreground star.

Following Kennicutt (1988) and taking into account the value of the integrated Hα luminosity of the object given by van Zee et al. (1998), we obtain a value of 3.6 $\times\ 10^4\ M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$). This value corresponds to the presence of the equivalent of 150 O5V stars. Using the electron density and temperature given by Izotov & Thuan (1998), we obtain values of Q^0=$10^{52.0}$ s^{-1} and of $M_{\rm HII}/M_\odot$=$10^{5.5}$ for the whole galaxy.

We obtain the ages of the different knots from the observed $B-V$ colour and by applying population synthesis models (Leitherer & Heckman 1995) for instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$ and a metallicity of 0.10 $Z_\odot$ (the metallicity of the galaxy is 0.07 $Z_\odot$ according to Izotov & Thuan 1998). The results are included in Table 3. The $B-V$ colour of the emission zone #9 (the most extended and bright one), as well as the integrated emission for the whole galaxy and nearby objects (#1, #2, #3 and #4), lie outside the range of variation of the models, even in the case of a continuous burst. Taking into account that UM 461 is an H II galaxy, it is likely that the ages of the brightest knots are overestimated perhaps as a consequence of the presence of an underlying population or due to contamination by nebular emission lines. Observations in the Hα emission line and in the U filter would be necessary to estimate these ages more accurately.

In Fig. 10 we show the slit position observed and the two-dimensional Hα spectrum of UM 461. The central knots (#9 and #8) have heliocentric velocities of $\approx$ 1039 and $\approx$ 1062 km s^{-1} respectively. These velocities are slightly higher than the 900 km s^{-1} indicated by Terlevich et al. (1991), but are consistent with the $\approx$ 1040 km s^{-1} given by Taylor et al. (1995) and van Zee et al. (1998). The difference in velocity between both emission zones could be attributed to the rotation of the galaxy (in this case we would obtain a Keplerian dynamical mass of 1.3 $\times\ 10^7\ M_\odot$), but apparently there is not a continuous variation of velocity along the spatial direction (twisting) as expected for a typical rotation curve. Moreover, the shape of the two-dimensional spectrum is more consistent with the simple superposition of two emission zones with different velocity, this favours the merger hypothesis between both nuclei as suggested by Doublier et al. (1999).

3.6. SZ I 59

SZ I 59 is a dwarf galaxy that was first discovered by Zwicky and included in his catalogue of *Selected Compact Galaxies and Post-Eruptive Galaxies* (1971). Rodgers et al. (1978) indicate the presence of strong emission lines and a very blue continuum in the integrated spectrum of the object, classifying it as an H II galaxy according to the definition given by Searle & Sargent (1972). Kunth & Joubert (1985) detect the presence of broad He II λ4686 Å emission in the object and classify it as a WR galaxy. Doublier et al. (1999) have obtained deep B and R CCD images of the galaxy.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 1840 km s^{-1} for the recessional velocity of the object (calculated from our spectroscopic observations), SZ I 59 lies at a distance of 24.5 Mpc. At this distance, the spatial scale is 119 pc arcsec^{-1}.

In Fig. 11 we present the first Hα image obtained for this galaxy. The most remarkable feature of the image is the presence of filamentary faint structures located to the north and south of the galaxy. These structures extend, in the north, up to $\sim$ 1 kpc from the centre of the galaxy. At high intensities, the galaxy shows just one nucleus (at least at our resolution), slightly elongated in the northwest direction. The integrated Hα luminosity and equivalent width of the galaxy are shown in Table 3. The Poisson uncertainty associated with the value of the Hα flux is 0.06% of the value of this flux. The morphology of our Hα image is very different from that in B obtained by Doublier et al. (1999), where the galaxy is very elongated in the north-south direction (10 kpc $\times$ 3 kpc); it is therefore clear that the starburst is confined to the centre of the galaxy.

Following Kennicutt (1988), we obtain a value of 1.5 $\times$ 10^5 $M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$). This value corresponds to the presence of the equivalent of 800 O5V stars. Assuming values of 100 cm^{-3} and of 10 000 K for the electron density and temperature, we obtain values of Q^0=10$^{52.6}$ s^{-1} and $M_{\rm HII}/M_\odot$=10$^{6.1}$ for the whole galaxy.

We have applied population synthesis models (Leitherer & Heckman 1995) for instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$ and a metallicity of 0.25 $Z_\odot$ (the metallicity of the galaxy is 0.30 $Z_\odot$ according to Kunth & Joubert 1985) to obtain the age of the galaxy from its $-W$(Hα), which is included in Table 3.

In Fig. 12 we present the two-dimensional Hα spectrum for P.A. = $-13°$ (the direction of the main axis of the nucleus, see Fig. 11) of SZ I 59. The mean heliocentric velocity of the Hα emission is $\approx$ 1840 km s^{-1}, slightly higher than that tabulated by Kunth & Joubert (1985). There is no significant variation in velocity along the slit. The integrated Hα emission line profile shows a single-Gaussian behaviour, although it is possible to detect some low intensity residual on the blue side. The FWHMs of the Gaussian component, corrected for instrumental and thermal broadening (assuming a typical value of 10 000 K for the electronic temperature), is between 60 and 65 km s^{-1}.

3.7. Mrk 67

Mrk 67, also known as UGC 372, is an emission-line dwarf galaxy with an elliptical shape and a spheroidal nucleus (Barbieri et al. 1979). Conti (1991) reports the detection of weak and broad emission due to WR stars according to an integrated spectrum of the object obtained by J. Salzer.

Assuming a uniform Hubble flow with H_0 = 75 km s^{-1} Mpc^{-1} and given a value of 1050 km s^{-1} for the recessional velocity of the object (Conti 1991), Mrk 67 lies at 14 Mpc. At this distance, the spatial scale is 67.9 pc arcsec^{-1}.

In Fig. 13 (*lower centre*) we present the continuum-subtracted Hα image of the object. At our resolution and sensitivity, the galaxy does not show clear evidence of a filamentary or bubble-like structure. Its morphology is elliptical, with linear sizes of 600 and 500 pc for the major and minor axes, respectively. At high intensities it is possible to detect three different star-forming knots, which are labelled in Fig. 13 (*lower centre*). Data on the Hα luminosity and equivalent width of the different knots, as well as the values related to the whole galaxy, are shown in Table 3. The Poissonian uncertainties in the values of the fluxes are always less than 4% of these values. The brightest and largest knot is the central one (#2) with an equivalent circular diameter of $\approx$ 180 pc, half that of 30 Doradus, and an Hα luminosity also half that of 30 Doradus. The other knots have Hα luminosities an order of magnitude lower than that of knot #2 and equivalent circular diameters around 100 pc.

Following Kennicutt (1988), we obtain a value of 5.1. $\times$ 10^4 $M_\odot$ for the mass of ionizing stars (10–100 $M_\odot$). This value corresponds to the presence the equivalent of 280 O5V stars. Assuming a value of 100 cm^{-3} for the electron density and taking into account the value of 11 900 K given by French (1980) for the electron temperature, we obtain values of Q^0=10$^{52.3}$ s^{-1} and of $M_{\rm HII}/M_\odot$ = 10$^{5.7}$ for the whole galaxy.

In Fig. 13 (*upper left*) we show the B image of the galaxy. The morphology in this as well as in the other broad-band filters, is very similar to that of the Hα image, apart from the fact that the galaxy is more extended in the broad-band filters. In this sense, there exists an emission zone (at very low intensities) located to the southwest of the galaxy, which appears in the three broad-band filters but with no counterpart in Hα. The absolute B magnitudes as well as the $U-B$ and $B-V$ colours of the different knots and the integrated values for the whole galaxy, are presented in Table 3. On the other hand, it is important to mention the presence of three objects located 29$''$, 40$''$ and 50$''$ to the south of Mrk, 67 respectively. These objects (#c1, #c2 and #c3) are labelled in the V image of the field of Mrk 67 shown in Fig. 13 (*middle right*). Mrk 67 is the galaxy located to the north in this image. The object #c3, which has an elliptical shape, with its major axis orientated to the northwest–southeast, is the brightest one. The object #c2 presents a very weak emission and the object #c1 also has an elliptical shape (although less well defined than the one of #c3), with its major axis orientated to the north. These three objects are probably dominated by an old population, as indicated by their redder $U - B$ and $B - V$ colours, which are presented in Table 3.

In order to know whether these objects are real companions of Mrk 67, we took a spectrum with P.A. = 0° passing through #c1, #c2 and #c3. None of the companions shows emission lines in its spectrum. The object #c3 is the only one for which we reach a good signal-to-noise in the continuum. A redshift of $\approx$ 0.077 was measured from the Ca H and K absorption lines. Assuming a uniform Hubble flow with H_0 = 75 km s^1 Mpc^{-1}, this corresponds to a distance of 308 Mpc; therefore, #c3 is a background galaxy and not a companion to Mrk 33.

As in all the previously mentioned galaxies, we have estimated the ages of the different star-forming knots applying the population synthesis models (Leitherer & Heckman 1995) for instantaneous bursts with a Salpeter IMF, an upper cut-off of 100 $M_\odot$, and a metallicity of 0.25 $Z_\odot$ (the metallicity of the galaxy is 0.19 $Z_\odot$ according to Garnett 1990). The results are included in Table 3. We find that the ages calculated from the $-W$(Hα) and the $U - B$ colours of the different knots of Mrk 67 are very similar and consistent within an interval of 0.3 Myr. On the other hand, the ages derived from the $B - V$ colour are systematically larger, this effect being more critical in the case of the central knot (#2). Perhaps we have an important underlying contribution of the emission of an older population, which, in contrast, does not affect apparently the $-W$(Hα).

4. Discussion

4.1. The recent star formation processes

As we have seen in the previous section, the recent star formation is distributed in different knots in most of the objects of the sample. These knots are H II regions ionized by clusters of massive stars that in some cases (and at our resolution limit) can be even larger and brighter than the largest and brightest ones in the Local Group, such as 30 Doradus or NGC 604. Similar objects have been also found from HST observations of some nearby WR galaxies, such as He2-10 (Conti & Vacca 1994), NGC 1741 (Conti et al. 1996; Johnson et al. 1999), and NGC 4214 (Leitherer et al. 1996), as well as in interacting or merging starburst galaxies (e.g. Whitmore & Schweizer 1995; Schweizer et al. 1996; Stiavelli et al. 1998; Whitmore et al. 1999). These massive star-forming knots are usually known as "super-star clusters" (SSCs; Meurer et al. 1995) and are probably extremely young globular clusters which have been formed recently (Conti & Vacca 1994). In our case, due to our lower spatial resolution and taking into account the typical diameter of the SSCs (about 5 pc), our knots can in most cases be unresolved aggregates of SSCs. The absolute magnitudes of the brightest SSCs measured from HST observations are between M_V = −12 and −15 (e.g. Whitmore & Schweizer 1995; Schweizer et al. 1996; Johnson et al. 1999), and this is the order of the magnitudes measured for the knots of most of our galaxies.

We have estimated the star formation rate (SFR) of the galaxies at two different epochs taking into account the model developed by Gallagher et al. (1984). This model assumes that the IMF is invariant in time and well represented by a Salpeter function with a lower stellar mass limit of 0.1 $M_\odot$ and an upper one of 100 $M_\odot$. Using the blue luminosity of the object we can estimate the SFR in the past few billion years and, using the Lyman continuum photon fluxes derived from the Hα luminosity, we can obtain the current ($< 10^7$ yr) SFR. In Table 4 we present these two SFRs for the galaxies studied in this paper plus additional similar objects studied in previous studies made by our group (the references of these papers are included in the table). This sample of 13 galaxies will be called for convenience "our complete sample" along the rest of the paper. In the case of Mrk 1087 we cannot give an estimation of the current SFR since there are no measurements of the integrated Hα luminosity available for the galaxy. As we can see in Table 4, the current SFR is higher, between 200 (Mrk 750) and 10 (Mrk 33, Tol 35) times, the SFR averaged during the last few billion years in all the objects. These figures indicate the obvious result that these galaxies are now experiencing a very strong star formation burst, a fact that is consistent with their high numbers of WR stars. The important result is that the ratios between the current SFR and the SFR averaged over the last few billions years for the galaxies in our complete sample are considerably higher than those obtained by Gallagher et al. (1984) for a general sample of irregular and spiral galaxies. The ratios between the current SFR and the SFR averaged over the last few billions years of the general sample of irregular and spiral galaxies of those authors is < 1.7, apart from three objects (NGC 1569, NGC 3353 and NGC 4670) where the ratios are higher ($\approx$ 5.6, $\approx$ 4.5 and $\approx$ 4.3, respectively). Incidentally, these objects are precisely the only

Table 4. Star formation rates

Galaxy	SFR (Hα) ($M_\odot$ yr^{-1})	SFR (B) ($M_\odot$ yr^{-1})	Bibliography
Mrk 1087	–	1.67	B (1)
Mrk 1094	2.83	0.07	Hα (2), B (3)
Mrk 8	6.40	0.48	Hα and B (4)
He 2-10	4.48	0.05	Hα (5), B (6)
Zw 0855+06	1.10	0.05	Hα and B (7)
Tol 2	0.39	0.02	Hα and B (1)
Mrk 33	2.43	0.25	Hα and B (1)
Mrk 750	0.44	0.002	Hα (1), B (6)
POX 4	5.33	0.11	Hα and B (8)
UM 461	0.07	0.003	Hα (9), B (1)
SZ I 59	0.58	0.004	Hα (1), B (3)
Tol 35	1.68	0.18	Hα y B (8)
Mrk 67	0.21	0.003	Hα y B (1)

[1] This study.
[2] Méndez et al. (1999a).
[3] Walter et al. (1997).
[4] Esteban & Méndez (1999b).
[5] Méndez et al. (1999b).
[6] Schaerer et al. (1999).
[7] Méndez et al. (1999).
[8] Méndez & Esteban (1999).
[9] Van Zee et al. (1998).

objects of the sample of Gallagher et al. (1984) – together with NGC 4214, which has a ratio of ≈ 1.2 – showing WR features in their integrated spectra (see Schaerer et al. 1999).

In Fig. 14 we plot the current SFR of the galaxies of our complete sample (calculated from the Hα luminosity) versus their U and B absolute magnitudes. The figure shows a clear correlation between the SFR and both magnitudes; that is to say, galaxies with a higher current SFR present larger U and B emission. This correlation is produced by the presence of a large population of massive stars in the galaxies that overwhelms the contribution of the older populations. These massive stars are therefore responsible for both the photoionization of the interstellar gas and most of the continuum emission in the U and B bands. On the other hand, Sargent & Filippenko (1991) also noted a correlation between the continuum level and the location of WR stars in NGC 4214 in the sense that the WR stars are located where the continuum was the strongest. The WR stars are tracers of the recent star formation and therefore that correlation is also consistent with the one shown in Fig. 14. The dispersion in the points in Fig. 14 could be due to many different causes:

- The presence of dust (affecting differentially the U and B fluxes of the different galaxies of the sample). The extinction correction of the fluxes has been made taking into account spectroscopic data from the literature related mainly to the brightest zones of the objects. Spatial differences in the internal reddening in the galaxies are, in principle, probably present.
- The different relative importance of the absorption of the nebular Hα flux due to the absorption lines associated with the integrated spectrum of the underlying older stellar population.
- The presence of an additional continuum (related to an underlying population) different from one galaxy to another. This effect would be more important in the case of the B filter.
- Differences in the slope of the IMF and the mass interval among the different galaxies of the sample.
- Differential absorption (by some galaxies of others) of the Lyman continuum photons due to dust or to the presence of density-bounded H II regions in some objects of the sample.

The similarity between the M_B–SFR and M_U–SFR diagram (if we consider only the galaxies for which we have data in both broad-band filters) indicates that neither the presence of dust affecting differentially the U and B fluxes nor the presence of an additional continuum (due to the emission of an underlying population) seems to be the main cause of the dispersion observed in Fig. 15. Indeed, the differences in the slope of the IMF and in the mass interval considered for the calculation of the current SFR could explain the dispersion in Fig. 14 (see Méndez et al. 1999b and their calculation of the current SFR of He 2-10 considering different IMFs and mass intervals). Nevertheless, we must not forget that other effects (mainly the absorption of Hα flux by stellar absorption lines) could also play an important role in the observed behaviour.

In Fig. 15, we plot the absolute B magnitude versus the logarithm of the number of ionizing photons (calculated from the Hα luminosity) for the different knots and the integrated values of the galaxies of our complete sample. There is a clear but also expected correlation since this figure is a slightly different presentation of the magnitudes shown in one of the diagrams of Fig. 14. The correlation in this case is very linear, since both magnitudes are logarithmic with respect to the number counts in the Hα and B filters (a similarly close correlation is found for Hα and V absolute magnitudes). This kind of correlation for WR galaxies had already been reported by Conti (1991) as an extension to higher luminosities of the behaviour observed in giant H II regions from data by D'Odorico et al. (1983). The originality of the diagram that we show is that it includes both the different star-forming knots of the WR galaxies of the sample and the integrated values. In this sense, it is important to remark that the dispersion in our diagrams is considerably lower than that in Conti's diagram. The explanation of the large dispersion in that diagram has been already given by Conti (1991); namely, that (except in the case of the giant H II regions) the data for the ionizing photon flux from D'Odorico et al. (1983) come from spectroscopic Hβ fluxes (related only to the central zones of the objects) while in the case of the M_B, the data are photometric and correspond to the whole spatial extent of the objects. In our diagrams this does not have effect since our data come from two-dimensional photometry in both cases. In any case, the relatively small dispersion seen in these diagrams could be explained, in general, by the same factors commented on above affecting the behaviour of Fig. 14. The upper envelope of the points in Fig. 15 should correspond to radiation-bounded H II regions, whose ionizing photons are barely absorbed by dust and whose B emission does not present a substantial contribution from the continuum of non-ionizing stars.

In Table 5, as a summary, we show the values of the photon ionizing flux, the ionized hydrogen mass, the mass in ionizing stars, the number of equivalent O5V stars and the average age of the massive star population (as described in Sect. 3) of the galaxies in our complete sample. As can be seen in the table, the ages obtained from the $U-B$ colour and from the $-W$(Hα), that is, age indicators related to the young massive star populations, are consistent in most cases where both indicators can be used. For example, for Mrk 8, Tol 2, Mrk 33, POX 4 and Mrk 67 the difference in the age obtained from both indicators is less than 2 Myr; in the case of Mrk 1094 and Tol 35, the ages derived from $-W$(Hα) are at least consistent with the lower limits derived from the $U-B$ colour. This consistency is quite striking taking into account the different effects that can affect the observed fluxes and colours. Firstly, there is an age/reddening degeneracy for starburst knots, as it has been noticed by Whitmore & Schweizer (1995) and discussed by Johnson et al. (1999). This degeneracy does not permit to disentangle age and reddening for any given SSC using only the broad-band colours. However, although we have assumed the reddening derived from optical spectroscopy of the whole galaxy (or the brightest knots) for all the knots, their $U-B$ and $B-V$ colours are remarkably uniform inside a given galaxy (standard deviations vary between

Table 5. Physical parameters and ages of the massive stellar population and ionized gas in our complete sample of galaxies

Galaxy	$\log(Q^0)$	$\log(M_{\rm HII}/M_\odot)$	Mass in ionizing stars ($M_\odot$)	$N_{\rm O5V}$	Age ($U-B$) (10^6 yr)	Age ($B-V$) (10^6 yr)	Age [$-W$(Hα)] (10^6 yr)
Mrk 1087	–	–	–	–	5.1–27.3	7.2–51.3	–
Mrk 1094	53.29	6.86	7.2×10^5	3900	5.1–25.5	7.3–58.7	≈ 4.6
Mrk 8	53.65	7.16	1.6×10^6	8900	≈ 4.7	≈ 103.2	≈ 6.4
He 2-10	53.49	6.31	1.1×10^6	6200	–	–	≈ 7.7
Zw 0855+06	52.88	6.01	2.6×10^5	1500	–	≈ 5.0	≈ 6.0
Tol 2	52.43	6.15	9.5×10^4	540	4.3–8.3	≈ 62	≈ 4.3
Mrk 33	53.22	6.74	6.1×10^5	3300	≈ 4.5	2.0–5.0	≈ 6.5
Mrk 750	52.48	5.99	1.1×10^5	600	–	–	≈ 3.7
POX 4	53.56	6.89	1.3×10^6	7300	≈ 4.7	–	≈ 3.6
UM 461	52.00	5.51	3.6×10^4	150	–	–	–
SZ I 59	52.60	6.11	1.5×10^5	800	–	–	≈ 6.0
Tol 35	53.06	6.89	4.2×10^5	1800	5.2–38.5	5.4–5.6	≈ 5.3
Mrk 67	52.15	5.70	5.1×10^4	280	≈ 4.7	≈ 125.4	≈ 4.7

0.03 and 0.13 mag for the different galaxies). This indicates that there are no important differences in the amount of internal dust inside a given galaxy, and that its effect is therefore limited. Secondly, a third parameter, the metallicity, can affect the colours due to that the contribution of the supergiants to the integrated colour of the galaxy depends on the age of the starburst (Cerviño & Mas-Hesse 1994). Thirdly, although the Hα equivalent width is not affected by the above-mentioned age/reddening/metallicity degeneracy, it could be affected by the continuum emission and line absorption of the underlying older population and, therefore, the equivalent widths we have measured should necessarily be lower limits to the true values for the ionized gas. This implies that the ages derived from $-W$(Hα) must be upper limits of the true ages of the burst populations. On the other hand, models by Schaerer & Vacca (1998) predict that the stellar lines that produce the WR features reach the greatest strengths between 3 and 6 Myr. Most of the values of the ages given in Table 5 (those obtained from Hα equivalent width and $U-B$ colour) are within that range and therefore consistent with the theoretical predictions. A similar result has been obtained by Conti (1999) making use of ages derived from Hβ equivalent width. Taking into account all the consistent results discussed above, we consider that the ages derived from the $U-B$ colour and $-W$(Hα) may be considered as relatively confident age indicators for young starbursts.

4.2. Previous star formation processes?

As can be seen in Tables 3 and 5 and as mentioned in Sect. 3 for each object, the ages of the different star-forming knots calculated from their $B-V$ colours are in most cases greater than those calculated from the $U-B$ colours or from the $-W$(Hα). This can be clearly seen in Fig. 16, 17 and 18. In the three figures we have separated the values corresponding to the different star-forming knots (diagrams on the *left*) from the integrated values of the galaxies (diagrams on the *right*). As can be seen in Fig. 16 (where we show log[$-W$(Hα)] vs. $U-B$), apart from some knots in POX 4 and Mrk 1094, knot #1 in Mrk 8 and knot #1 in Tol 2, the knots of the different galaxies in our complete sample are located close to the lines of the same age predicted by the models of Leitherer & Heckman (1995) for instantaneous bursts. This consistency is far better in the diagram including the integrated values of the galaxies. In contrast, in Figs. 17 and 18 (where we show log[$-W$(Hα)] vs. $B-V$ and $U-B$ vs. $B-V$, respectively) it can be seen that most of the knots have a $B-V$ colour systematically redder when compared to the predicted values for the ages calculated through the log[$-W$(Hα)] or the $U-B$ colour and the models of Leitherer & Heckman (1995). Moreover, in Figs. 17 and 18 the dispersion in age does not disappear if we focus only on the integrated values, contrary to the case of Fig. 16. If we assume that the ages calculated through the log[$-W$(Hα)] and the $U-B$ colour are more representative to the true ages of the massive star population, the discrepancy observed in the values of the ages obtained with $B-V$ and the other indicators could be due to at least two main causes: nebular emission-line contamination of the broad-band fluxes and/or continuum emission of an older underlying stellar population.

Table 6. Colour corrections due to nebular emission lines

Galaxy	$U-B$ correction (mag)	$B-V$ correction (mag)	Bibliography
Mrk 1087	0.057	-0.023	1
Mrk 8	0.066	-0.035	2
Zw 0855+06	–	-0.12	1
Tol 2	0.13	-0.16	1
Mrk 33	0.13	-0.035	2
POX 4	0.17	-1.15	1
UM 461	–	-0.78	3
Tol 35	0.12	-0.4	1
Mrk 67	0.12	-0.51	4

[1] Vacca & Conti (1992).
[2] Kunth & Joubert (1985).
[3] Izotov & Thuan (1998).
[4] French (1980).

In Table 6 we show the corrections estimated for the $U-B$ and $B-V$ colours of the objects due to the presence of emission lines of [O II] 3727 Å (in the U filter), Hβ 4861 Å (in the B filter, except in the case of Mrk 1087 where due to its relatively high redshift this line falls in the V filter) and [O III] 5007 Å and 4959 Å (in the V filter). These corrections were obtained applying the formulae given by Telles & Terlevich (1997) and taking into account the spectroscopic data available in the literature (see Table 6 for references). For the calculation of the equivalent width of each emission line we have scaled the value of the Hβ equivalent width with the value of the flux ratio of the line with respect to Hβ. This procedure assumes that the continuum level of the different emission lines is the same as that of the continuum at the Hβ wavelength, which is obviously a rough approximation, especially in the case of the [O II] 3727 Å line, which is considerably bluer than Hβ. On the other hand, it is important to note that the spectroscopic data we have used for the derivation of the correction factors showed in Table 6 are referred only to the central and/or brightest zones of the galaxies and obtained from long-slit spectroscopy. Taking into account that the intensity of the emission lines may change from one knot to another, that many of our objects are extended, and that in some cases these present emission zones totally detached with respect to the central emission, the values listed in Table 6 must be taken as simply rough estimates of the true values of the corrections for the individual knots. In any case, if we apply these corrections to the values of the colours of the different knots (adding the values given in Table 6) and re-calculate the ages, we find that in some cases, such as Mrk 1087, Tol 2 and the knot #2 of Mrk 67, the age discrepancies disappear[6]. However, the problem remains unsolved for objects such as Mrk 33 and Mrk 8, where the emission-line corrections are very small. In the case of POX 4, Tol 35 and UM 461 the problem is the inverse; that is, the corrections for the $B-V$ colour are very large, making the new corrected colours fall outside the range of variation of the models and thereby not permitting the derivation of ages. Incidentally, these three galaxies are among the objects with the highest excitation degree (the highest [O III]/Hβ ratio). It is well known that long-slit spectra of this kind of objects are usually taken from the brightest parts, which coincide with the location of the ionizing clusters and hence with the zones of higher excitation. Excitation is a parameter with strong spatial variation, which depends on the distance to the ionizing cluster and the value of the local ionization parameter. Therefore, it is not unusual that the magnitude of the corrections is unsuitable for all the knots inside the objects.

The emission of an underlying older stellar population (related to previous star formation processes) could also produce a contamination of the broad-band fluxes, especially in the case of the V filter, due to the redder continuum of the old populations. This is qualitatively consistent with the general behaviour observed in Figs. 17 and 18, where the V fluxes are the ones that diverge most from the predicted values. Indeed, we have found indications of the presence of underlying older population in some of the galaxies of our complete sample. Preliminary studies in this aspect of the galaxy Mrk 1094 (Cairós et al., in preparation) clearly indicate the presence of an extended underlying population, with a mean age of several Gyr, distributed mainly in the central zones of the star-forming regions (see Méndez et al. 1999a). Another example is Mrk 8, where the age discrepancy in some of the knots could be easily explained by the presence of an underlying population whose relative importance with respect to the massive star emission is greater in the external zones of the galaxy (to the northeast and to the southwest), where the recent star formation burst is less intense (see Esteban & Méndez 1999b). A similar case is that of Tol 35, where the morphology in the broad-band filters also favours this possibility (see Méndez & Esteban 1999). Other examples presented in this paper are Tol 2, Mrk 33 and SZ I 59, which present a more extended and diffuse morphology (with a disc or elliptical shape) in the broad-band filters than in the Hα images, indicating clearly the presence of an underlying population.

In order to characterize this underlying population, it would be necessary to carry out a complete study of the galaxies, including images in the I filter (and in near-IR filters, such as J, H and K), as well as narrow-band images in the brightest nebular emission lines (in order to correct for emission-line contamination and obtain two-dimensional extinction and metallicity maps). This kind of investigation would be very interesting in order to check whether the population synthesis models reproduce accurately the behaviour of the different age indicators [apart form the $-W(\mathrm{H}\alpha)$ and the $U-B$ colour, which, as we saw in the previous section, give highly consistent values] for the different star-forming knots and for the integrated emission, and, on the other hand, to see the influence that the previous star formation bursts have on these age indicators.

4.3. Interactions: a common origin for WR galaxies?

Among the 13 galaxies of our complete sample studied in this and previous papers, six show clear signs of suffering interaction or merger processes (Zw 0855+06, POX 4, Tol 35, Mrk 1094, Mrk 8 and Mrk 1087). This implies that 46% of the galaxies of our complete sample are interacting or merging objects. In most cases, this interaction is with other low surface brightness dwarf objects. On the other hand, as mentioned in Sect. 3, there are also some indications of a possibly interacting nature in four more other objects in our complete sample (He 2-10[7], UM 461, Mrk 750 and Tol 2). If the interacting nature of these galaxies is confirmed, the proportion of interacting and/or merging objects in our complete sample would be 77%. This percentage is very high taking into account the intrinsic difficulties of finding these kinds of interacting and/or merging features, especially in small and faint objects, as is the case for most of the galaxies in our

[6] In the special case of Mrk 1087, these corrections solve the problem of the age discrepancy of the central emission zones of the object, increasing by 1 Myr the ages calculated via the $U-B$ colour as presented in Sect. 3.1.

[7] Conti (1998) indicates the presence of two tidal tails in an HST V image of this object.

sample. It is even possible that this fraction will increase in the future when more detailed observations are available.

In Sect. 3 it has been shown that the recent star formation activity is divided into different knots in these galaxies. This is a well known result since the work of Conti & Vacca (1994) based on HST images of He 2-10. On the other hand, there is growing evidence that these knots (or SSCs) are young globular clusters formed during the merger or interaction of gas-rich galaxies. They have been found in HST images of well known interacting or merger galaxies, such as NGC 4038/4039 ("The Antennae", Whitmore & Schweizer 1995), NGC 3921 (Schweizer et al. 1996), NGC 454 (Stiavelli et al. 1998), NGC 7252 (Schweizer & Seitzer 1998), as well as in other very well studied interacting WR galaxies, such as NGC 4214 (Leitherer et al. 1996) and NGC 1741 (Johnson et al. 1999). This analogy reinforces the hypothesis of an interacting or merging origin for at least a substantial proportion of the WR galaxies in our complete sample or perhaps of the group of WR galaxies as a whole. In this sense, if we explore Conti's catalogue of WR galaxies in detail (including our own results and those from the literature) and consider also the galaxies of his Tables 2 and 3 whose WR nature has been subsequently confirmed, we find that of 45 objects 17 show clear signs of interaction and/or merger processes, this represents 38%. Moreover, there are seven other galaxies (Tol 2, He 2-10, Tol 9, Tol 89, POX 139, Mrk 750 and UM 461) for which there are weaker indications of these kinds of processes. If these indications are confirmed, the proportion of interacting and/or merging objects in Conti's catalogue would be 53%. As can be seen, interactions could play a definitive role in the origin of the WR galaxy phenomenon.

This proposed role could be especially interesting in the case of dwarf WR galaxies. Dwarf galaxies do not suffer from the physical processes responsible for the star formation in larger spirals and ellipticals. The formation of massive star-forming knots (or SSCs) in this kind of galaxies requires very high gas densities and pressures. Moreover, the timescales for building up these proto-SSCs must be shorter than the timescale for the destruction of the parental molecular clouds. It is very difficult to understand how this conditions can be reached in a dwarf galaxy without the action of a merger event with (or between) gas-rich galaxies or pure gas clouds (see the case of the blue compact galaxy ESO 338-IG04 studied by Östlin et al. 1998).

Another important consequence of our study is that the intense star-forming bursts we see in relatively low mass WR galaxies could be due to interactions not only with luminous galaxies but mainly with other low mass and low surface brightness companions that had escaped to previous detection. It would be very interesting (but difficult) to study the properties and spatial density of these objects. In fact, hierarchical models of galaxy formation (e.g. Kauffmann et al. 1997) predict that the bulk of galaxy population formed from small protoclouds. Perhaps the low surface brightness companions we are detecting around many dwarf WR galaxies correspond to these primordial galactic units.

5. Conclusions

Our study has revealed that the recent star formation in a sample of WR galaxies is distributed in different knots. These knots are H II regions ionized by clusters of massive stars which in some cases and at our resolution limit can be larger and brighter than the largest and brightest H II regions of Local Group galaxies, such as 30 Doradus or NGC 604. These knots may be analogous to, or aggregates of, the so-called super star clusters (SSCs) found in HST images of WR galaxies and interacting galaxies.

The recent star formation processes are very intense in the objects studied; that is to say, the current SFR is considerably higher, between 200 (Mrk 750) and 10 (Mrk 33 and Tol 35) times the SFR averaged during the last few billion years. In this sense, it is important to note that the ratios between the current SFR and that averaged over the last few billions of years for our WR galaxies are considerably higher than those obtained by Gallagher et al. (1984) for a general sample of irregular and spiral galaxies

We have found a correlation between the M_B and the $\log(Q^0)$ for all the galaxies in our sample (already reported by Conti 1991). In our study, carried out with more accurate photometric data, we find that his correlation may also be extended to the different star-forming knots of the WR.

A comparative study of the $U-B$ colour and the $-W(\mathrm{H}\alpha)$ of the different star-forming knots of the galaxies of the sample indicates the robustness of these two magnitudes as age indicators and supports the validity of the models by Leitherer & Heckman (1995) for galaxies with strong star-forming bursts. The comparison with the ages calculated through the $B-V$ colour, together with the fact that some of the galaxies show a much more extended and diffuse morphology (in some cases with a disc shape) in the broad-band compared to the Hα images, indicates the presence of underlying populations in many of the objects.

Our study has also revealed that many of the irregular WR galaxies that had previously been catalogued as isolated objects have low surface brightness companions that had previously escaped detection. In this sense, one of the most important consequences of our study is that the processes that trigger the intense star-forming bursts in relatively low mass WR galaxies could be due to interactions not only with luminous galaxies but also with low-mass and low surface brightness companions that had escaped previous detection, or with H I companion clouds.

A detailed inspection of the catalogue of WR galaxies by Conti (1991) shows that 38% of the objects do present clear signs of interaction and/or merger processes. Other objects in the catalogue, still awaiting more detailed observations, show also possible indications of these kinds of processes. If these indications are confirmed, the proportion of interacting and/or merging objects of the catalogue by Conti (1991) would be 53%.

The Hα morphology of many of the objects of the sample indicates the presence of bubble-like and low surface brightness filamentary structures. Spectroscopic observations confirm the presence of high-velocity asymmetric flows that extend up to the external zones in an important fraction (60%) of the objects in our complete sample for which we have high spectral resolution data. This kind of structures can be associated with the combined action of stellar winds from massive stars and SN explosions over the ionized gas surrounding the star-forming knots.

Acknowledgements. We are grateful to the referee, P.S. Conti, for a careful review of the paper and to Romano Corradi for his valuable help during the IACUB observations at the NOT. We thank L. Cuesta for his help with the GRAFICOS program. We are also very grateful to Marc Balcells for his help in the calculation of the redshift of the visual companion (#c3) of Mrk 67. Thanks are due to the IAC's Scientific Editorial Service for linguistic and stylistic corrections to the text. This research was partially funded through grant n° PB 94-1108 from the Dirección General de Investigación Científica y Técnica of the Spanish Ministerio de Educación y Ciencia.

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