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Research Note

Further Wolf-Rayet stars in the starburst cluster Westerlund 1[⋆]

I. Negueruela[1] and J. S. Clark[2,3]

[1] Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal, Universidad de Alicante, Apdo. 99, E03080 Alicante, Spain
e-mail: `ignacio@dfists.ua.es`
[2] Department of Physics and Astronomy, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK
[3] Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

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Abstract. We present new low and intermediate-resolution spectroscopic observations of the Wolf Rayet (WR) star population in the massive starburst cluster Westerlund 1. Finding charts are presented for five new WRs – four WNL and one WCL – raising the current total of known WRs in the cluster to 19. We also present new spectra and correct identifications for the majority of the 14 WR stars previously known, notably confirming the presence of two WNVL stars. Finally we briefly discuss the massive star population of Westerlund 1 in comparison to other massive young galactic clusters.

Key words. stars: Wolf-Rayet – stars: evolution – stars: general – open clusters and associations: individual: Westerlund 1

1. Introduction

Wolf-Rayet (WR) stars represent the last stage in the evolution of massive stars and are characterised by very high temperatures and exhaustive mass loss (see van der Hucht 2001, for a recent review). In spite of their interest, our current understanding of their evolutionary paths is still rather limited. The evolutionary links between different WR subtypes are not well established and, more importantly, the correspondence between observed characteristics and position on theoretical tracks is still unclear (cf. Meynet & Maeder 2003).

Observation of WR stars in open clusters and comparison with other massive members have yielded most of the constraints on which understanding of these objects is based, providing ages and progenitor masses (e.g., Massey et al. 2001). Unfortunately, the number of WR stars in clusters is relatively small and generally each cluster contains only one or two WR stars, resulting in rather poor evolutionary constraints.

The young open cluster Westerlund 1 (henceforth Wd 1, Westerlund 1961) offers the possibility of studying an important population of WR stars of a given age and chemical composition within the context of a large homogeneous population of massive stars. This highly reddened cluster is found at a distance of between 2 and 5 kpc (most likely close to the upper limit; see Clark et al. 2005) and contains a large number of evolved massive stars.

Spectra of 11 WR stars obtained with the ESO 1.5-m telescope were presented by Clark & Negueruela (2002, henceforth Paper I). Because of the small size of the telescope and the low spatial resolution of the configuration used (as well as the lack of appropriate finding charts for the field), the identification of some of these objects was problematic, as many WR spectra appeared to arise from what were obviously unresolved blends of stars. Moreover the Signal-to-Noise Ratio (SNR) of several of the spectra was low, allowing only very approximate spectral classifications. The objects observed comprised 5 late WC stars (WCL), 5 late WN stars (WNL) and one broad-lined, presumably early, WN star.

Clark et al. (2005) reported the identification of three further objects with WR-like characteristics. Two of them had been observed serendipitously at intermediate resolution as they fell on the slit when observations of brighter objects were taken. Their spectra were therefore of very low SNR, but were suggestive of a WCL and a transitional Ofpe object, belonging to a class recently rechristened as very late WN stars (WNVL). The third object had only been observed at very low resolution and it appeared as an OB supergiant with very strong emission lines, also suggestive of a transitional object.

Here we present higher quality spectra of the majority of these objects, taken under exceptional seeing conditions, allowing a much better characterisation of the WR population in Wd 1. We also present spectra of 5 new WR stars found in the field of Wd 1. This brings the total number of WR stars known in Wd 1 to 17 + two transitional objects. In what follows,

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[⋆] Based on observations collected at the European Southern Observatory, La Silla, Chile (ESO 71.D-0151).

we will adopt the naming convention of Clark et al. (2005), but will drop the word "candidate" from the name of those Wolf-Rayet stars whose identification has been secured.

2. Observations and data reduction

Observations of Wd 1 were obtained with the ESO Multi-Mode Instrument (EMMI) on the 3.5-m New Technology Telescope (NTT) at La Silla, Chile. They were taken during a run on 2003 June 5th–8th, though only the 6th and the 7th were useful because of cloud cover. On the night of the 6th, though some high cirrus were present, the seeing was exceptionally good, staying below $0\farcs6$ for most of the night and reaching $<0\farcs4$ at times. Imaging of the cluster area was obtained using the R and Hα (#654) filters.

Due to the varied science goals of the observations and the serendipitous nature of many of the detections, spectra of a number of sources were obtained using a varied set of instrumental configurations. For intermediate resolution spectra, we used the red arm with gratings #6 and #7. On the night of June 6th, grating #6 covered the $\lambda\lambda$6440–7140 Å range. On June 7th, grating #6 covered $\lambda\lambda$8225–8900 Å and grating #7, $\lambda\lambda$6310–7835 Å.

For low resolution, we used the red arm with grisms #1 and #4. Grism #1 covers the $\lambda\lambda$3850–10 000 Å range, with a resolution $R = 263$. Grism #4 covers the $\lambda\lambda$5550–10 000 Å range, with a resolution $R = 613$. Note, however, that because of the high reddening, the signal-to-noise ratio rapidly decreases in the blue end of the spectra – effectively limiting the spectra to $\lambda > 6500$ Å for grism #4 and $\lambda > 5500$ Å for grism #1.

An observation of the field to the South of the cluster was also conducted in slitless spectroscopy mode. This technique, based on the use of a low dispersion grism (in our case, #1) coupled with a broad-band filter (Bessel R) resulting in an "objective prism-like" spectrogram of all the objects in the field, has been used by Bernabei & Polcaro (2001) to search for emission line stars in open clusters.

Image pre-processing was carried out with *MIDAS* software, while data reduction was achieved with the *Starlink* packages CCDPACK (Draper et al. 2000) and FIGARO (Shortridge et al. 1997). Analysis was carried out using FIGARO and DIPSO (Howarth et al. 1997).

The results of this inevitably somewhat varied observational approach was the identification of a further 5 WR stars within Wd 1. Inspection of the slitless image led to the location of three obvious candidates lying in the outskirts of the cluster, which were later confirmed as WR stars by long-slit spectroscopy. A fourth WR star was found serendipitously while obtaining spectra of objects in the Southern part of the cluster. Following the notation used in Paper I, these are WR stars N, O, P and Q. Finally, as part of a dedicated investigation into the apparent Ofpe star W14, we identified a final WR, designated R.

For aesthetic reasons, the finder in Fig. 2 is based on an R-band image obtained with VLT UT1/FORS2 on June 10th 2004, in service mode.

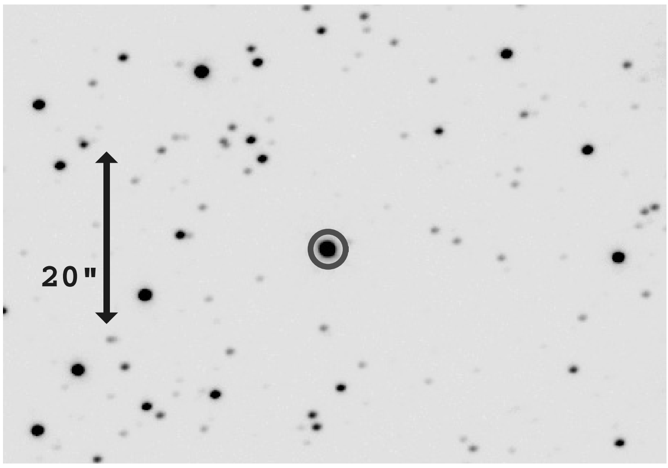

Fig. 1. R-band finding chart for WR star N, an outlier to the South of the cluster. This object is catalogued as USNO-B1.0 0440-0523445.

3. Results

Due to crowding and the low spatial resolution of the Boller & Chivens spectrograph, the exact identifications of some of the WR stars presented in Paper I and Clark et al. (2005) were uncertain. The WR features were observed in spectra attributable to a blend of several objects, an example of this being the identification of the continuum of an O-type supergiant and emission lines typical of a WR star in the low-resolution spectrum of W14 (Clark et al. 2005).

This situation has been somewhat alleviated with the current dataset. We now can confirm the exact identification for all but 5 of the currently identified WR stars. For the purposes of this paper, we consider that a WR identification is sufficiently secure when either several spectra of the same star exist, all displaying the WR features, or a spectrum with sufficiently high spatial resolution allows the identification of a single candidate. This is the case for WR star N (Fig. 1), and all the objects circled in Fig. 2 (also marked by their corresponding letters). For those objects without such secure identification, the word "cand" is shown in front of the corresponding letter, with an arrow pointing to the most likely identification.

Of the previously identified WRs, the new observations have confirmed the positions of WRs A, B, C, E, F, L and M, while the most probable candidates for WRs D, G, I and J remain unchanged. However, we present a new identification for WR K and suggest a different candidate for WR H.

Moving to the new WRs, star N is an outlier some $4\farcm5$ South of the cluster. This object is listed in the USNO catalogue as USNO-B1.0 0440-0523445, with no measured blue magnitudes, red magnitudes $r_1 = 16.6$ and $r_2 = 16.9$ and infrared magnitude $i = 13.0$. These magnitudes and colour make it a very likely cluster member, further supported by its late-WC classification (see Sect. 3.1.1). A finder for this object is shown in Fig. 1.

Another nearby object, USNO-B1.0 0440-0523458, was found to display emission lines, but its spectrum shows it to be a foreground Be star. Its foreground character is confirmed by the relatively low reddening ($b_2 = 14.08$, $r_2 = 13.04$).

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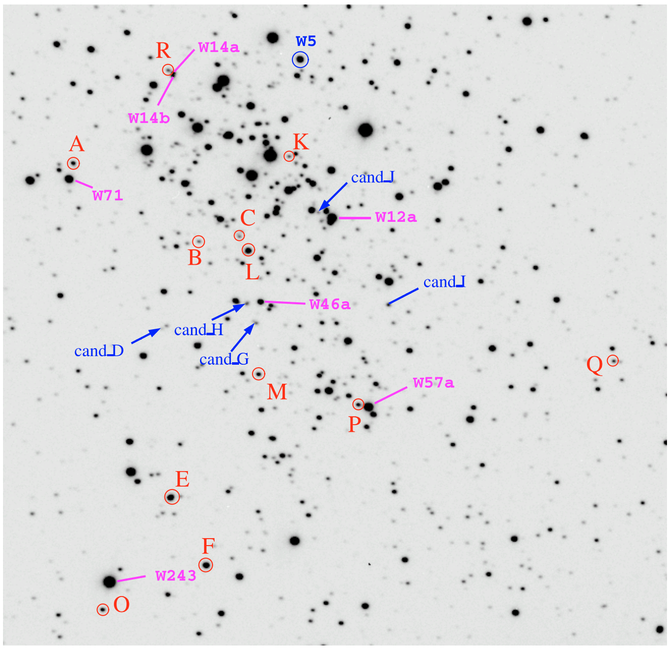

Fig. 2. *R*-band finding chart for WR stars in the central region of Wd 1. Stars surrounded by circles are secure identifications of the WRs, while objects for which the identification is not secure (in the sense defined in the text) are marked with the word "cand". A few other objects, useful for the discussion, are indicated, following the naming convention of Paper I. W5, which could be a very late WN or an extreme B supergiant is also circled.

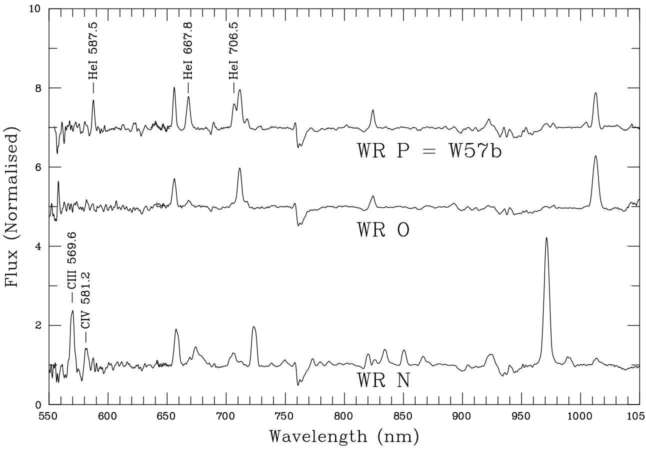

Fig. 3. Spectra of three WR stars that were observed only with grism #1. WR stars P and O are WNs, while WR star N is a late WC.

WR stars O and P are within the area of the cluster previously explored and their positions are identified in Fig. 2; no photometry is available for either object. Their spectra are shown in Fig. 3.

WR star Q lies on the Southwestern reaches of the cluster and it is one of the westernmost likely members identified by Clark et al. (2005), who give the following magnitudes B = 23.7, V = 20.3, R = 17.5, I = 14.7. Its spectrum is shown in Fig. 4 and discussed in Sect. 3.1.2. Its location with respect to the main body of the cluster can be seen in Fig. 2.

Table 1. Observation log, presenting all the spectroscopic observations for each target. See text for the configurations resulting in each spectral range.

Object	Wavelength range (Å)
WR A	5550–10 000
WR B	5550–10 000
WR C	5550–10 000
WR K	5550–10 000
	6440–7140
WR L	5550–10 000
WR M	3850–10 000
	5550–10 000
	6440–7140
WR N	3850–10 000
WR O	3850–10 000
WR P	3850–10 000
WR Q	5550–10 000
WR R	5550–10 000
W5	5550–10 000
	6440–7140
	6310–7835

Finally, in our new images, W14 is clearly resolved into three objects of similar brightness, which we designate W14a, b and c. (see Fig. 2 for identifications). Individual spectra of all three objects have been obtained and WR features are unmistakably associated with the Easternmost object, W14c which we designate as WR R; its spectrum is displayed in Fig. 4, but no photometry is available for the individual components of W14.

3.1. Spectral classification

Our new spectroscopic observations – listed in Table 1 – allow the classification of the newly identified WRs (WRs N–Q), while permitting a more accurate analysis of stars previously observed at lower resolution and/or *S/N* (WRs A, B, C, K–M). The results are summarised in Table 2.

3.1.1. WC stars

Red spectra of WC stars are displayed in Fig. 4. The lower-resolution spectrum of WR star N can be seen in Fig. 3. Spectroscopic classification criteria for WCL stars between 6–10 000 Å are discussed in Paper I. We employ the ratio between the Equivalent Width (*EW*) of C II 9900 Å and C III 9710 Å as a key diagnostic, found to be >0.14 for WC9 stars.

WR M was preliminarily classified WC9 by Clark et al. (2005) based on a rather noisy *R*-band spectrum. Our new spectrum, shown in Fig. 4, for which *EW*(C II)/*EW*(C III) = 0.17±0.03, corroborates this classification, showing an obvious resemblance to the spectra of the WC9 stars WR E and WR F displayed in Paper I.

The new spectrum of WR C – which Paper I classified as WC8 – is also presented in Fig. 4. It is clearly very similar to

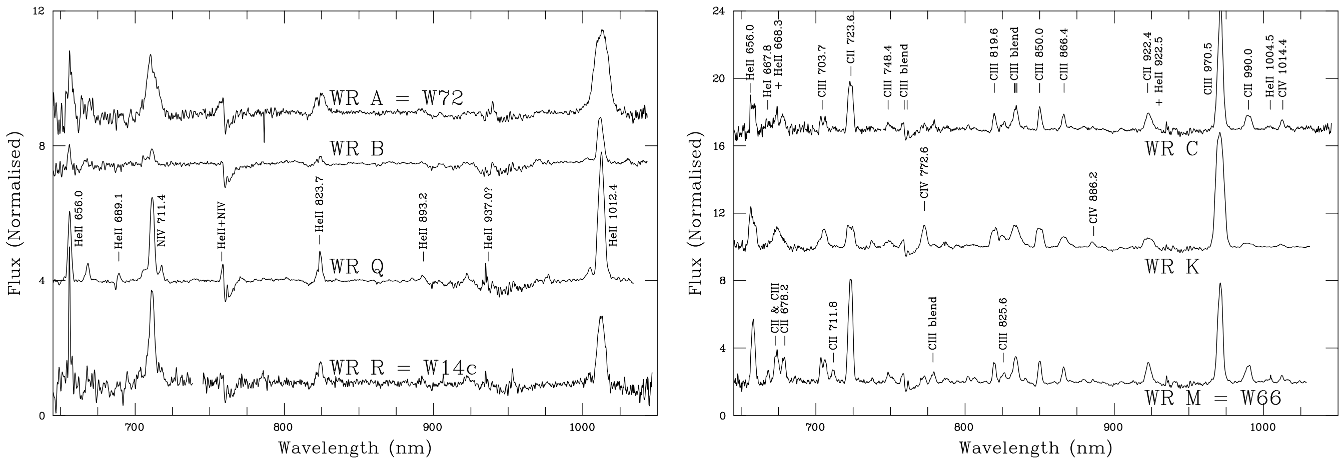

Fig. 4. Grism #4 spectra of WR stars in Wd 1. *Left*: *WN stars*. Stars Q and R are WN6-7, while the spectral types of A and B are not certain. Star A is earlier than WN7 and star B could be WN8+OB. *Right*: *WC stars*. All are late WC, with star K being the earliest WC star known in Wd 1 at WC7.

Table 2. Summary table for the currently identified Wolf-Rayet population within Westerlund 1; new or revised results from this paper are presented in bold face. Columns 1 and 2 present the various identifiers (including tentative numbers in the catalogue system of van der Hucht 2001). Co-ordinates (J2000) are presented in Col. 3. For objects correctly identified in Clark et al. (2005), co-ordinates are determined from 3.6-cm radio images (Dougherty et al., in prep.; formal errors are $\sigma_\alpha = \pm 0.003^s$, and $\sigma_\delta = \pm 0.04''$). For new identifications, co-ordinates are simply extracted from the astrometric solution of the VLT/FORS2 image. Both solutions agree to better than 0.″2. Co-ordinates for uncertain counterparts (as defined in Sect. 3) are given in italics. Where available, broadband *VRI* photometry is presented in Cols. 4–6. Finally the spectral classifications are presented in Col. 7.

WR star	Alternative names	α	δ	V	R	I	Spectral type
A	WR 77s, W72	16h47m08.32s	−45°50′45.″5	19.69	16.59	13.68	**<WN7**
B	WR 77n	16h47m05.35s	−45°51′05.″0	20.99	17.50	14.37	**WN8?**
C	WR 77l	16h47m04.40s	−45°51′03.″8	–	–	–	**WC8.5**
D	WR 77q	*16h47m06.24s*	*−45°51′26.″5*	–	–	–	WN6-8
E	WR 77p, W241	16h47m06.06s	−45°52′08.″3	–	–	–	WC9
F	WR 77m, W239	16h47m05.21s	−45°52′25.″0	17.86	15.39	12.90	WC9
G	WR 77i	*16h47m04.02s*	*−45°51′25.″2*	20.87	17.75	14.68	WN6-8
H	WR 77k	*16h47m04.1s*	*−45°51′20.″0*	–	–	–	WC9
I	WR 77e	*16h47m01.67s*	*−45°51′19.″9*	–	–	–	WN6-8
J	WR 77c	*16h47m00.89s*	*−45°51′20.″9*	–	–	–	WNL
K	WR 77g	**16h47m03.1s**	**−45°50′43″**	–	–	–	**WC7**
L	WR 77j, W44	16h47m04.20s	−45°51′07.″0	18.86	15.61	12.52	**WN9**
M	WR 77h, W66	16h47m04.0s	−45°51′37.″5	19.79	16.85	13.96	**WC9**
N	WR 77b	**16h46m59.9s**	**−45°55′26″**	–	**16.9**	**13.0**	**WC8**
O	WR 77r	**16h47m07.6s**	**−45°52′36″**	–	–	–	**WN6**
P	WR 77d, W57c	**16h47m01.5s**	**−45°51′45″**	–	–	–	**WN8**
Q	WR 77a	**16h46m55.4s**	**−45°51′34″**	**20.3**	**17.5**	**14.7**	**WN6-7**
R	WR 77o, W14c	**16h47m06.0s**	**−45°50′22″**	–	–	–	**WN6-7**
S	WR 77f, W5	16h47m02.97s	−45°50′19.″5	17.49	14.98	12.48	**WNVL**

that of WR M, the main difference being the slightly weaker C II features. The *EW*(C II)/*EW*(C III) ratio is 0.12 ± 0.03, on the borderline between WC8 and WC9.

The new spectrum of WR K, also seen in Fig. 4, is clearly earlier than those of WR M and WR C. The C II features are clearly much weaker and the C IV 7726 Å line is very obviously present. The *EW*(C II)/*EW*(C III) ratio is only 0.03 ± 0.01, suggesting that WR K is WC7.

This is confirmed by the much higher resolution spectrum shown in Fig. 5. The blend around the position of Hα is dominated by C II 6581 Å in WC9 spectra (Vreux et al. 1983), but in WR K, it peaks at λ6568 Å as is typical of earlier-type WC stars, where it is dominated by He II 6560 Å. The blend around λ7065 Å is likely dominated by C IV 7062 Å.

Finally, we examine the newly discovered WR N, for which we only have the low-resolution grism#1 spectrum shown in Fig. 3. The ratio between C III 5696 Å and C IV 5812 Å is suggestive of a WC9 spectral type. However, the absence of He I 5875 Å supports an earlier type. As the *S/N* ratio is rather low in the $\lambda\lambda$5500–6000 Å region, we prefer to use the

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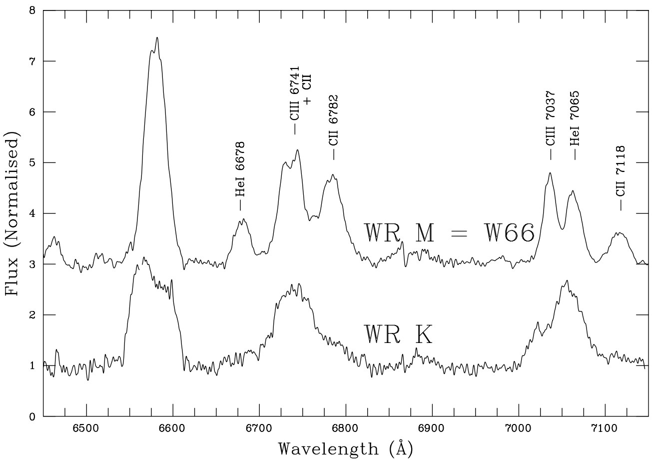

Fig. 5. Intermediate resolution *R*-band spectrum of two WC stars in Wd 1. WR M = W66 displays a typical WC9 spectrum. The spectrum of WR K clearly implies an earlier spectral type. All the C II transitions are very weak or absent and the emission lines are broad, several of them dominated by C III and C IV transitions (see text for details).

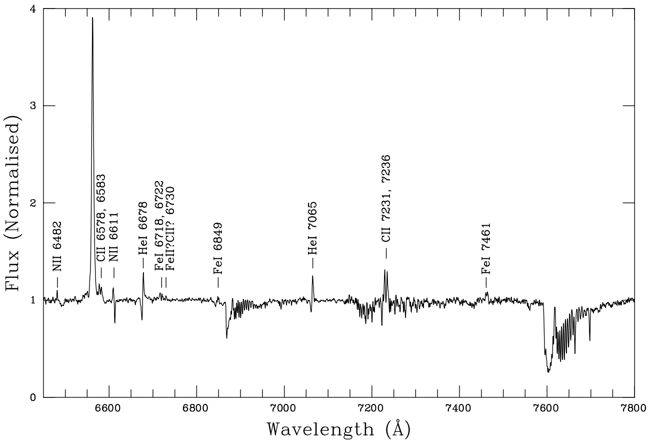

Fig. 6. Intermediate resolution spectrum of the candidate WNVL star W5, showing tentative identifications for emission lines. Note the P-Cygni profiles in some of the He I transitions.

red-end classification criteria. The *EW*(C II)/*EW*(C III) ratio is 0.07 ± 0.02, typical of WC8 and indeed the strength of C II features appears intermediate between that of WR M and WR K. We therefore adopt WC8 for WR N.

3.1.2. WN stars

Spectra of four WN stars observed with grism #4 are displayed in Fig. 4, while two other objects observed at lower resolution are shown in Fig. 3. Of the four newly discovered WN stars, the best *S/N* ratio has been achieved for WR Q, which we therefore choose to discuss first. We find its spectrum to be extremely similar to that of the WN6 star WR 85 displayed by Vreux et al. (1983). Indeed the weakness of He I 7065 Å and He I 6678 Å + He I 6683 Å argues against a spectral type later than WN7. Unfortunately, the region covered by our spectra is not very sensitive to the spectral type of WN stars and so a spectral type WN7 cannot be ruled out.

The spectrum of WR star R (also in Fig. 4) has a much lower *S/N* ratio, but does not appear to differ in any important respect from that of WR star Q, leading to the same classification.

For WR star O, we have a low-resolution spectrum reaching λ5500 Å (Fig. 3). The general aspect is very similar to those of WR stars R and Q. Both He I 5875 Å and C IV 5808 Å appear to be absent (within the – rather large – uncertainty allowed by the limited *S/N* ratio), supporting a WN6 classification.

The spectrum of WR star P (also in Fig. 3) is very different. The strength of all the He I lines supports a WN8 spectral type. Specifically, only the WN8 stars in the catalogues of Vreux et al. (1983) and Vreux et al. (1989) fulfil the condition He I 6678 Å(+He II 6683 Å) $\lesssim$ Hα (+He II), as happens in WR star P.

WR star B was previously unclassifiable, due to the extremely low *S/N* ratio of the available spectrum. Our new spectrum, presented in Fig. 4, reveals the emission lines of this star to be very weak, strongly suggesting the presence of an OB companion in the spectrum. Within the very limited *S/N* ratio, He I 7065 Å seems to be rather strong compared to N IV 7114 Å, suggesting a spectral type WN8, but an exact classification cannot be given.

Finally, we present a new higher *S/N* spectrum of WR star A, the only broad-lined object in our sample (Fig. 4). The spectrum does not offer any clues for classification, except for the fact that it should be earlier than WN7.

3.1.3. The WNVL candidates

Clark et al. (2005) identified the first example of a WNVL star within Wd 1, the WN9 object W44 (=WR star L), while speculating that the emission line star W5 may possess an even later classification. New low resolution spectra (Table 1, not presented here) confirm the line identifications previously reported for both stars – with the addition of weak He I 7282 Å emission in W44 – the emission lines appearing to be narrow and single peaked. In Fig. 6, we present a higher resolution spectrum of W5 which reveals a wealth of new details, including P Cygni He I emission lines and emission from low excitation metallic species such as N II and C II. In particular we are able to confirm the presence of the strong emission feature at ~7235 Å, which we attribute to a C II doublet.

As with W44, the lack of N IV 7114 Å precludes a classification earlier than WN9 for W5. The H I and He I emission spectrum is similar to that of the WN11 star S119, although the presence and strength of the C II emission suggests a temperature lower than the 24 kK inferred for S119 (Paul Crowther, private communication 2004). If W5 is cooler than 24 kK, it is not expected to display He II emission. Observationally, this is difficult to check, as He II 4686 Å is outside our spectral range and He II lines in the red would be expected to be very weak. A lack of He II emission would prevent a WR classification, making W5 an early B supergiant. In this case, the strength of the emission lines and the lack of a P-Cygni profile in Hα would indicate a very extreme early B0−0.5Ia$^+$ classification (Paul Crowther 2004, private communication). Given this uncertainty, we choose to denote W5 as *Candidate* WR star S and adopt a provisional classification of WNVL/early BIa$^+$, apparently intermediate between the bona fide WN9 star W44 and the extreme B5Ia$^+$ stars W7 and W33 (Clark et al. 2005).

4. Discussion and concluding remarks

Our current census for the WRs within Wd1 consists of 2 transitional/WNVL(9−11), 9 WNL(6−8), one indeterminate WN (the broad-lined WR star A) and 7 WCL(7−9) stars. As such, we appear to be lacking early WR stars of both flavours. This may be most simply explained by the intrinsic faintness of such objects. Given a median value of $V - M_V \sim 25.3$ for Wd 1 (Clark et al. 2005), assuming the absolute visual magnitudes for early WR stars presented by van der Hucht (2001) yields apparent V-band magnitudes $\gtrsim$22, clearly beyond the reach of our current photometry and spectroscopy. Theoretical models (Meynet & Maeder 2003) also predict that WNE stars will be rare compared to both WNL and WCL stars, due to their shorter lifetimes.

With the above considerations in mind, it is of interest to compare the currently identified WR population of Wd 1 to those of other young massive clusters in the Galaxy. First, we would like to note that the resolution of W14 into three components, including a WNL, and the consequent refutation of a possible early O supergiant classification removes the sole observational datum that might suggest non-coevality for Wd 1. As discussed in Clark et al. (2005), an age of 3.5−5 Myrs may safely be estimated for Wd 1. Therefore we expect its population to differ from those of the younger NGC 3603 and Arches clusters, which are found to be dominated by WN stars (e.g., Crowther & Dessart 1998; Figer et al. 2002). A more revealing comparison may be established with the Quintuplet cluster (Figer et al. 1999) and the concentration of massive stars within the central parsec of the Galactic Centre (e.g., Horrobin et al. 2004; Genzel et al. 2003), which have estimated ages similar to those of Wd 1.

Excluding the five Quintuplet Proper Members, which may be exceptionally dusty WCLs, the Quintuplet hosts 6 WN and 5 WCL stars (Figer et al. 1999; Homeier et al. 2003). While the population of WC stars in both the Quintuplet and Wd 1 consists exclusively of WC7−9 stars, five of the six Quintuplet WN stars are classified as WN9 or later, with only one earlier WN6 object (Figer et al. 1999, and refs. therein); by comparison, we have only found two ≥WN9 stars within Wd 1, with 9 of the remaining 10 objects being WN6−8.

Inevitably, this comparison is prone to concerns due to completeness and selection effects. Given that the majority of the currently identified non-dusty WRs are amongst the faintest spectroscopically surveyed stars within the Quintuplet, it is possible that a further population of earlier WN stars lies below current detection thresholds. Moreover, Figer et al. (1999) infer very high intrinsic luminosities for the WNL stars within the Quintuplet when compared to those within Wd 1. Further observational and analytic efforts – to arrive at a common detection threshold and to determine if the stellar parameters of the WNLs in both clusters systematically differ – are required before meaningful conclusions as to the relative WR populations of both clusters may be drawn.

In contrast, the evolved population of the central parsec – as currently determined – is remarkably similar to that of Wd 1. To date, it consists of 6 Ofpe/LBV[1], 8 WNL (7−9), 4 WNE (5/6), 10 WCL (8/9)[2] and 1 WCE (5/6) stars, of which only the latter spectral type is not represented in Wd 1 (Genzel et al. 2003; Genzel 2004, priv. comm.; Maillard et al. 2004).

In spite of this similarity, the Galactic Centre population may not represent a good analogue for Wd 1, as the origin of these massive evolved stars in the central parsec is at present unclear, with Genzel et al. (2003) finding that they occupy two thin coeval discs, each with similarly-sized populations of evolved stars, about half the size of the currently identified population of Wd 1. One possibility for the formation of such a distribution is the spiral in of two clusters – indeed a possible remnant of such a disrupted cluster, IRS13, is found to be associated with one ring (Genzel 2004, priv comm.; Maillard et al. 2004). Alternatively, Genzel et al. (2003) suggest that a collision between two interstellar clouds resulted in two counter-rotating discs of gas which then formed the (evolved) massive stellar population. In any event, the stars found within the central parsec do not appear to form a stellar cluster in the same manner as apparently "monolithic" clusters such as Wd 1 and the Arches.

We therefore find that, at present, Wd 1 possesses the largest WR population of any known galactic cluster. Indeed, given the combination of distance and high reddening to Wd 1, the intrinsic faintness of even WNL and WCL objects (van der Hucht 2001), crowding in the central regions of the cluster and the somewhat *ad hoc* nature of the current observations, we suggest that our current census likely remains significantly incomplete. Further investigation is needed in order to achieve a full characterisation of the WR population of Wd 1, but the results presented here already show that this cluster can provide us with a unique laboratory to study the evolutionary paths followed by massive stars.

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[1] Compared to the WNVL/early BIa$^+$ star W5, the LBV W243, the B5Ia$^+$ stars W7, 33 and 42 and arguably the six YHGs within Wd 1 – Smith et al. (2004) claim that YHGs occupy a closely related *evolutionary* state to LBVs.

[2] Additional dusty objects such as IRS13 E3A & B may also host WCL stars (Maillard et al. 2004).

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References

Bernabei, S., & Polcaro, V. F. 2001, A&A, 371, 123
Clark, J. S., & Negueruela, I. 2002, A&A, 396, L25
Clark, J. S., Negueruela, I., Crowther, P. A., & Goodwin, S. P. 2005, A&A, 434, 949
Crowther, P. A., & Dessart, L. 1998, MNRAS, 296, 622
Draper, P. W., Taylor, M. , & Allan, A. 2000, Starlink User Note 139.12, R.A.L.
Figer, D. F., McLean, I. S., & Morris, M. 1999, ApJ, 514, 202
Figer, D. F., Najarro, F., Gilmore, D., et al. 2002, ApJ, 581, 258
Genzel, R., Schoel, R., Ott, T., et al. 2003, ApJ, 594, 812
Howarth, I., Murray, J., Mills, D., & Berry, D. S. 1997, Starlink User Note 50.20, R.A.L.
Horrobin, M., Eisenhauer, F., Tecza, M., et al. 2004, AN, 325, 88
van der Hucht, K. A. 2001, New Ast. Rev. 45, 135
Homeier, N. L., Blum, R. D., Pasquali, A., Conti, P. S., & Damineli, A. 2003, A&A, 408, 153
Maillard, J. P., Paumard, T., Stolovy, S. R., & Rigaut, F. 2004, A&A, 423, 155
Massey, P., DeGioia-Eastwood, K., & Waterhouse, E. 2001, AJ, 121, 1050
Meynet, G., & Maeder, A. 2003, A&A, 404, 975
Paumard, T., Genzel, R., Maillard, J. P., et al. 2005, in Young Local Universe, in press, Proc. of XXXIXth Recontres de Moriond, La Thuile, Aosta Valley, Italie, March 21−28, 2004, ed. A. Chalabaev, T. Fukui, T. Montmerle, & J. Tran-Thanh-Van (Paris: Éditions Frontières) [`arXiv:astro-ph/0407189`]
Shortridge, K., Meyerdicks, H., Currie, M., et al. 1997, Starlink User Note 86.15, R.A.L.
Smith, N., Vink, J. S., & de Koter, A. 2004, ApJ, 615, 475
Vreux, J. M., Dennefeld, M., & Andrillat, Y. 1983, A&AS, 54, 437
Vreux, J. M., Dennefeld, M., Andrillat, Y., & Rochowicz, K. 1989, A&AS, 81, 353
Westerlund, B. E. 1961, PASP 73, 51