

Research Note

A WN4 companion to BD +62°2296 in Cas OB5[★]

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Abstract. I report observations of the triple system BD +62°2296 showing that all its components are early-type stars, most likely physically related. The faintest component BD +62°2296B is a hitherto uncatalogued Wolf-Rayet star. The brightest component, star A, is shown to be a seemingly normal B2.5Ia supergiant. Long-slit spectroscopy of BD +62°2296B shows it to be a narrow-lined WN4 star. Given the spatial separation, the two objects are unlikely to form a physical binary. Spectra of the third visual component, BD +62°2296C, allow its classification as a B0III star. Such concentration of massive stars strongly suggests that BD +62°2296 is in reality a very compact young open cluster in the area of the OB association Cas OB5.

Key words. stars: early-type – stars: distances – stars: Wolf-Rayet – stars: individual: BD +62°2296 – stars: binaries: close – stars: binaries: spectroscopic

1. Introduction

During a recent survey in search of distant OB stars (Negueruela & Marco 2003), intermediate-resolution spectroscopy was obtained with the *Aurélie* spectrograph on the 1.52-m telescope at the Observatoire de Haute Provence (OHP) for a number of luminous stars in the region of the association Cas OB5. As part of this programme, a classification spectrum of BD +62°2296A was taken. On site examination of the raw spectrum of BD +62°2296A revealed the presence of a relatively strong and very broad emission line at the wavelength of He II $\lambda 4686$ Å, completely unprecedented at this spectral type. A reference to BD +62°2296B being a Wolf-Rayet star appears in Batarya et al. (1994), but no Wolf-Rayet star is catalogued at this position. As *Aurélie* offers no spatial resolution and the seeing during the observations was rather poor, further observations of the components of BD +62°2296 have been taken with long-slit spectrographs. These observations confirm that BD +62°2296B is a Wolf-Rayet star and suggest that BD +62°2296 is a compact cluster of young stars.

In spite of its brightness, BD +62°2296 has not been intensively studied, the only spectral classification for BD +62°2296A (B3Ia?) dating back to Morgan et al. (1955). BD +62°2296A does not appear to be photometrically very variable: Haug (1970) gives $V = 8.64$, $(B - V) = 1.07$, while Hiltner (1956) gives $V = 8.65$, $(B - V) = 1.09$. Its radial

velocity, averaging $v = -60.3$ km s⁻¹, was found to be variable by Abt et al. (1972). BD +62°2296 is catalogued as a visual triple system (Dembowski 1883). BD +62°2296C, also catalogued as CSI +62°2296 2, is clearly separated, situated approximately 11'' to the SE (see Fig. 1), while BD +62°2296B is separated by less than 2''. With such small separation, photometric measurements must contain both stars. The WDS catalogue gives magnitudes $V_T = 8.93$ and $V_T = 11.20$ from *Tycho* (Fabricius et al. 2002) for components A and B. These are untransformed *Tycho* magnitudes (see Negueruela & Marco 2003 for a discussion on the danger of using transformed magnitudes for reddened early-type stars).

2. Observations

Spectroscopy of BD +62°2296A was obtained with the *Aurélie* spectrograph on the 1.52-m telescope at the Observatoire de Haute Provence (OHP) in January 2002. The spectrograph was equipped with grating #3 and the Horizon 2000 EEV CCD camera (see Negueruela & Marco 2003 for details). This configuration gives a dispersion of ~ 0.22 Å/pixel, covering a wavelength range of ≈ 440 Å. BD +62°2296A was observed in four spectral regions, centred on $\lambda = 4175$ Å (Jan. 18), $\lambda = 4680$ Å (Jan. 19), $\lambda = 5850$ Å and $\lambda = 6600$ Å (both on Jan. 20).

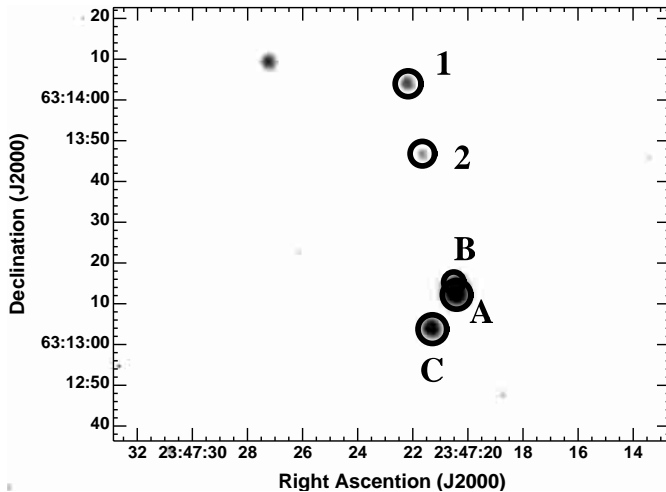
Further spectroscopy was taken with the *Carelec* spectrograph on the OHP 1.93-m on the nights of 6th and 7th July, 2002. I used grating #1 (1200 ln mm⁻¹), which gives a nominal dispersion ~ 0.45 Å/pixel in the blue range (resolution element

[★] Based on observations made at Observatoire de Haute Provence (CNRS), France, and the Isaac Newton Telescope (La Palma, Spain).

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Table 1. *Tycho* positions (Fabricius et al. 2002) for the three components of BD +62°2296.

Component	RA (J2000)	Dec (J2000)
A	23 47 20.4	+63 13 12
B	23 47 20.4	+63 13 14
C	23 47 21.3	+63 13 04

**Fig. 1.** Close-up of the area surrounding BD +62°2296 (*u*-band image taken with the 2.2-m telescope at Calar Alto on October 24th, 2002, using the BUSCA camera). The components of BD +62°2296 are marked as A, B and C. Stars #1 & #2 are B-type stars. Positions for the components are listed in Table 1.

~ 1.5 Å). During the first night, the central wavelength was set to $\lambda 4420$ Å. In the second night, two settings, centred at $\lambda 4450$ Å and $\lambda 5450$ Å were used.

Finally, spectroscopy was taken on July 22nd–25th 2002, using the 2.5-m Isaac Newton Telescope (INT) at La Palma, Spain. The telescope was equipped with the Intermediate Dispersion Spectrograph (IDS) and the 235-mm camera. On the night of the 22nd, the detector used was an EEV10 CCD, while on the three other nights it was the Tek#5 CCD. The slit width was set to $1''.2$ and the R1200Y grating was used. This configuration gives a nominal dispersion of ≈ 0.48 Å/pixel with the EEV and ≈ 0.8 Å/pixel with the Tek#5. During these nights, observations were performed with seeing slightly better than $1''$. Under these conditions, components A and B were clearly resolved. Exposures of all three components were obtained at different wavelengths, taking care that the other components were left outside the slit.

The complete log of observations is given in Table 2. All the data have been reduced with the *Starlink* packages CCDPACK (Draper et al. 2000) and FIGARO (Shortridge et al. 1997) and analyzed using FIGARO and DIPSO (Howarth et al. 1997).

3. Results

The spectrum of BD +62°2296A obtained with *Aurélie* can be seen in Fig. 2, as a dotted line. The most striking feature is clearly the prominent broad emission line centred on the wavelength of He II $\lambda 4686$ Å. This line is not seen at all at this

Table 2. Log of spectroscopic observations of the three components of BD +62°2296. The brighter component A is a B2.5Ia supergiant; component C is B0III, while component B is WN4. Observations marked A+B were performed under seeing conditions not allowing the separation of the two components. All dates refer to 2002.

Component	Telescope	Date	Wavelength range
A + B	OHP 1.52-m	Jan. 18	3960–4410 Å
A + B	OHP 1.52-m	Jan. 19	4460–4910 Å
A + B	OHP 1.52-m	Jan. 20	5630–6080 Å
A + B	OHP 1.52-m	Jan. 20	6890–6940 Å
A + B	OHP 1.93-m	Jul. 6	3960–4980 Å
C	OHP 1.93-m	Jul. 6	3960–4980 Å
A + B	OHP 1.93-m	Jul. 7	3960–5900 Å
A	INT 2.5-m	Jul. 22	3750–8000 Å
C	INT 2.5-m	Jul. 22	3750–5100 Å
B	INT 2.5-m	Jul. 23	4050–4910 Å
C	INT 2.5-m	Jul. 24	6300–7100 Å
B	INT 2.5-m	Jul. 25	6300–7100 Å

spectral type, while its presence in emission is an indication of strong mass loss in bright O-type stars and Wolf-Rayet stars.

Unlike *Aurélie*, the long-slit spectrograph *Carelec* produces spatially resolved spectra. In the spectrum taken on July 7th 2002, with a seeing $\approx 2''$ (estimated from the FWHM of the spectra of stars #1 and #2), components A and B are not entirely resolved. By extracting 5 pixels on the Northern side of the spectrum, centred 4 pixels away from the peak in the spatial direction, I obtained a spectrum of component B, displayed in Fig. 3.

Figure 2 shows a classification spectrum of BD +62°2296A, taken with the INT, without any contribution from the WR star. The presence of moderately strong Mg II $\lambda 4481$ Å confirms that the star is a mid-range B supergiant. The strength of the O II spectrum and the relative weakness of Mg II $\lambda 4481$ Å support a spectral type around B3Ia. At B2Ia, Si III $\lambda 4552$ Å is almost as strong as He I $\lambda 4471$ Å and C II $\lambda 4267$ Å is still weak compared to the O II lines. BD +62°2296A is therefore later and a spectral type B2.5Ia seems adequate. A lower luminosity class is precluded by the strength of the Si II $\lambda \lambda 128–30$ Å doublet in comparison to the neighbouring He I lines (for classification criteria, see Walborn & Fitzpatrick 1990 and Lennon et al. 1990).

The INT spectrum of BD +62°2296B is shown in Fig. 3. It is typical of a WN4 star. N III $\lambda 4640$ Å is hardly seen, while N IV $\lambda 4057$ Å and N V $\lambda 4604$ Å have comparable strengths. All the other line ratios are compatible with this spectral type. The line widths are typical of a narrow-lined Wolf-Rayet. The red spectrum of BD +62°2296B taken on July 25th displays broad strong emission lines corresponding to He II $\lambda 6560$ Å and the N IV $\lambda 7103–7128$ Å complex (the latter just on the spectrum edge). Very weak lines corresponding to He II $\lambda \lambda 6406$ & 6683 Å are likely present, as well. The presence of all these lines is in perfect accord with the spectral classification derived from the blue. Both the blue and red spectra show features

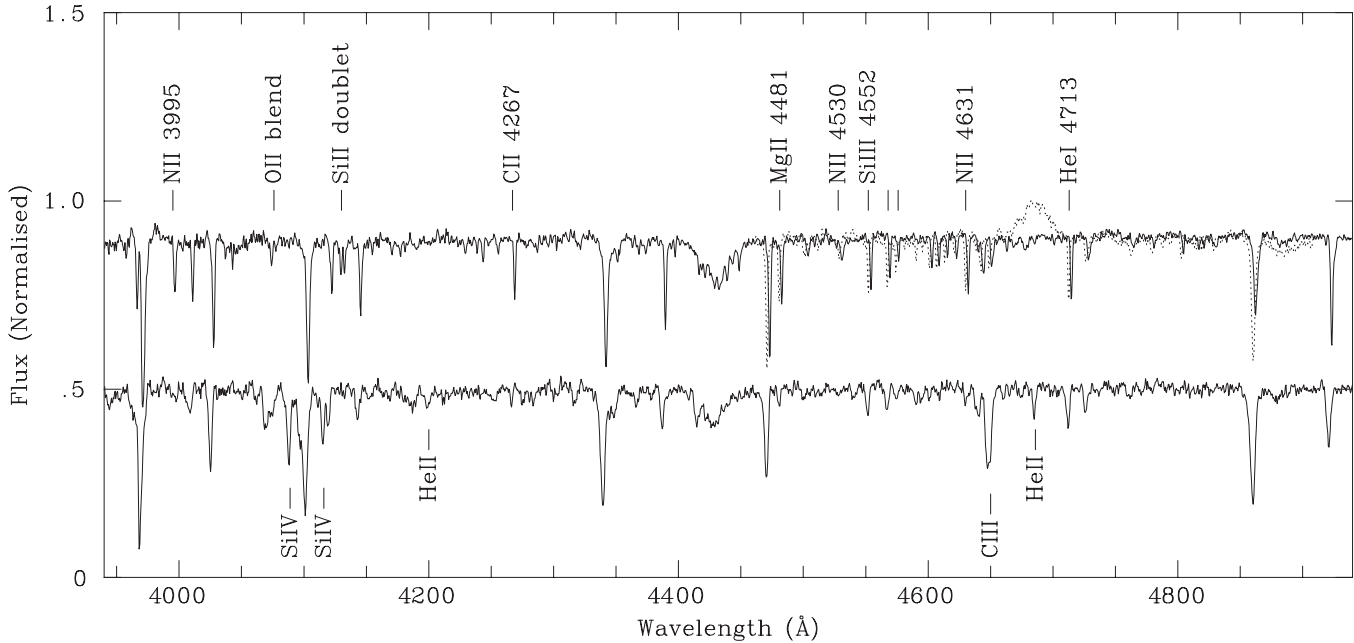


Fig. 2. Blue spectra of BD +62°2296A (top) and BD +62°2296C (bottom), taken on July 22nd, 2002, with the INT. The strength of N II lines and Mg II $\lambda 4481$ Å in the spectrum of BD +62°2296A identify the star as a supergiant. The spectrum of BD +62°2296A taken with the 1.52-m OHP on Jan 19th, 2002, is superimposed as a dotted line. The emission feature at $\lambda 4686$ Å, completely unexpected at this spectral type, arises from the unresolved companion.

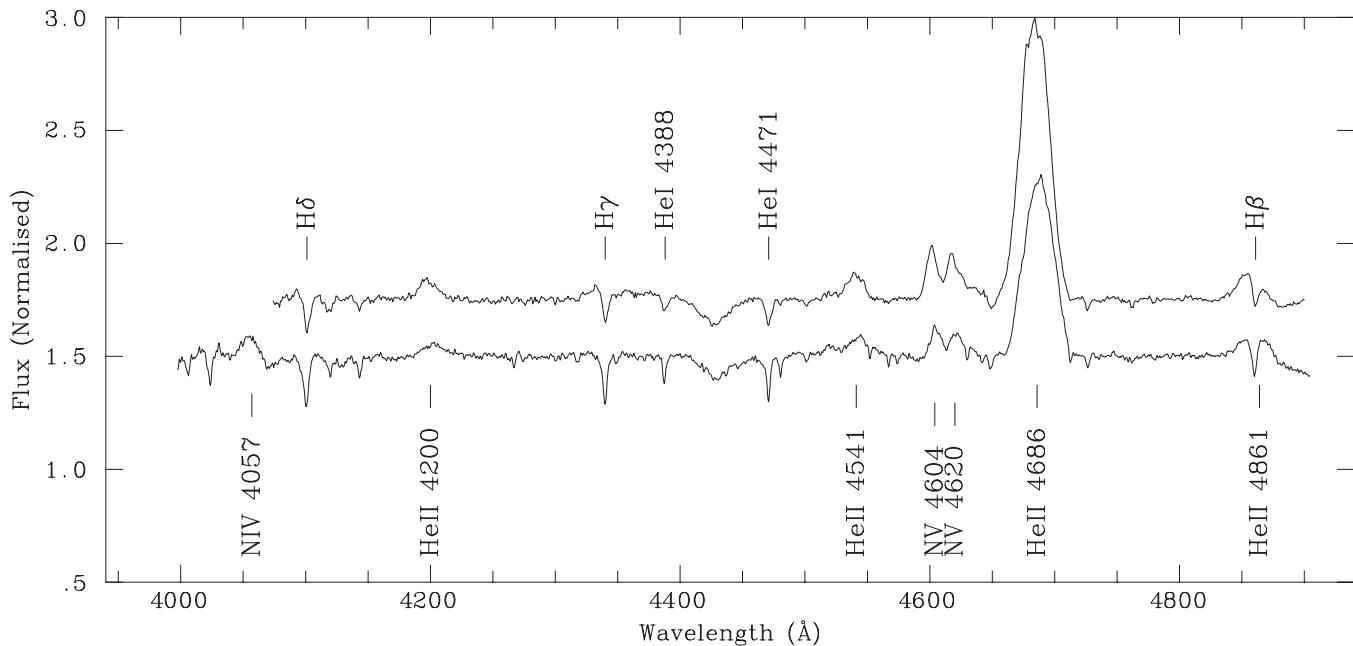


Fig. 3. Blue spectra of BD +62°2296B. The bottom spectrum was taken on July 7th 2002 with the 1.93-m OHP telescope and represents the extraction of a 5-pixel-wide strip centred 4 pixels away from the spectrum peak and therefore includes an important contribution from the spectrum of BD +62°2296B, which was not resolved in relatively poor seeing. The top spectrum was taken on July 25th 2002 with the INT and the slit was set on top of the WR star (which was resolved) and perpendicular to the axis joining the two stars. Though all emission lines are stronger, a small light contribution from the supergiant is evident (note also the lower spectral resolution).

attributable to component A, in spite of the orientation of the slit intending to leave it out.

The only spectrum including BD +62°2296B in the yellow region is that of July 7th. Unfortunately, it is less well resolved than the blue one from the same date, perhaps reflecting the larger difference in magnitude between the supergiant and the

Wolf-Rayet star towards longer wavelengths. In spite of this, broad He II $\lambda 5411$ Å and C IV $\lambda 5808$ Å emission lines are seen, with comparable strength. He I $\lambda 5875$ Å is weakly in emission, though its strength is difficult to assess due to its nearness to the edge of the spectrum. All these lines must be contributed by the WN4 star.

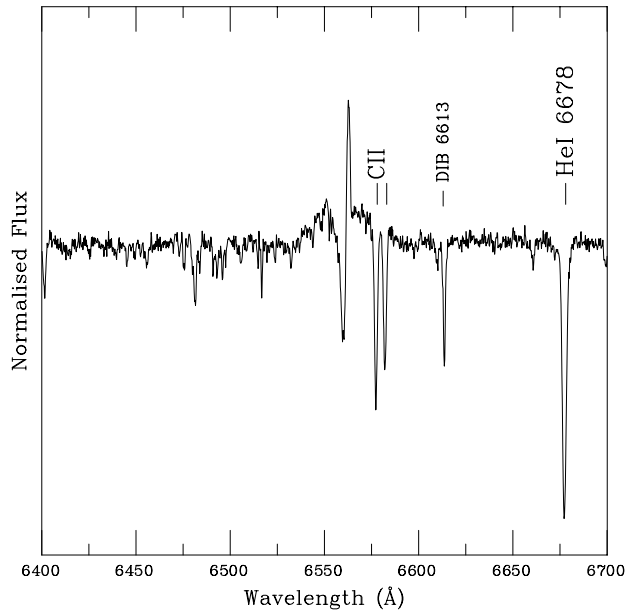


Fig. 4. $H\alpha$ spectrum of BD +62°2296A, taken on Jan. 20, 2002. Stellar features are marked, except for $H\alpha$, which clearly has two components, a narrow P-Cygni profile superimposed on a much broader base.

4. Discussion

The close companion to the B2.5Ia supergiant BD +62°2296A, BD +62°2296B, is a WN4 Wolf-Rayet star. Its Wolf-Rayet number will be WR 159 (van der Hucht, priv. comm.) BD +62°2296 appears listed as an emission line star in the catalogue of Wackerling (1970). The $H\alpha$ spectrum of BD +62°2296A is displayed in Fig. 4. There is a narrow P-Cygni profile, with an edge velocity of $v_{\text{edge}} \approx 500 \text{ km s}^{-1}$, superimposed on a broad emission bump. Such features are typical of blue supergiants of high luminosity and indicate the presence of a relatively slow radiative wind. From comparison of the OHP and INT spectra, there does not seem to be a significant contribution from the WR star to this emission feature.

From its spectrum (see Fig. 2), BD +62°2296C is a B0III star. Its V_T magnitude is 10.74 from *Tycho*. The difference in magnitude with component A is compatible with their being at the same distance. For BD +62°2296A, assuming the intrinsic colour of a B2.5Ia star $(B - V)_0 = -0.14$ (Wegner 1994), a dereddened distance modulus $DM = 12.0$ for Cas OB5 (Humphreys 1978) and a standard reddening law ($R = 3.1$), we find $M_V = -7.1$ using the photometry from Haug (1970) (though this measurement very likely includes component B). This luminosity is typical of a bright supergiant of this spectral type.

The absorption lines in the spectrum of BD +62°2296B appear to be due to light contamination from component A (for example, the characteristic C II doublet is seen in absorption close to He II $\lambda 6560 \text{ \AA}$). This does not rule out the possibility that component C is itself a close binary. As a matter of fact, if it is at the same distance as component A, and its *Tycho* magnitude is correct, it would be rather more luminous than corresponds to its spectral type. The average absolute magnitude of a WN4 star is $M_V = -3.5$ (van der Hucht 2001).

At a distance in excess of 2 kpc, an angular separation of $\approx 2''$ implies a distance between components A and B ($\approx 5000 \text{ AU}$) far too large to be consistent with their being an interacting binary. The composite spectrum shown by BD +62°2296A under moderate seeing serves as a cautionary tale when considering observations of more distant massive stars. Only because the system is relatively nearby are we able to resolve components A and B, in spite of their rather large spatial separation.

The fact that the three components of BD +62°2296 are early-type massive stars can hardly be due to a chance alignment. As a matter of fact, two other objects which fell along the slit (marked #1 & #2 in Fig. 1) are also B-type stars. BD +62°2296 is therefore likely a previously unrecognised compact young open cluster. A photometric study of this area will be presented in a future paper.

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