Line-profile variability in the spectrum of WR 22 around periastron: binary interaction or intrinsic variability? *

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Abstract: We present spectroscopic observations of the WN7+abs + O binary WR 22 obtained around a recent periastron passage. These spectra exhibit profile variability in the He I λ 5876 line. We compare the new data to previous observations and discuss the possible contribution of enhanced binary interaction around the periastron passage on the one side and of intrinsic variations of the Wolf-Rayet wind on the other side.

1 Introduction

WR 22 ($\equiv$ HD 92740) is an eclipsing binary (Gosset et al. 1991) in the Carina OB1 association (Lundström & Stenholm 1984). The photometric eclipse corresponds to the occultation of the secondary by the WR primary. A systematic investigation of an extensive set of high resolution spectra of WR 22 allowed us to detect weak absorption features that could be attributed to the secondary (Rauw et al. 1996a). The orbital period is 80.325 days and the orbit is quite eccentric ($e = 0.56$) with a semi-major axis $a \sin i = 360R_{\odot}$. From the radial velocities of the secondary's absorption lines, we derive a minimum mass of the WN7+abs primary of $72M_{\odot}$ and a mass ratio $m_{\rm WR}/m_{\rm O}$ of 2.78 (Rauw et al. 1996a).

From the orbital parameters described above, one expects the strongest interaction between the two components to occur around the periastron passage. However, the orientation of the orbit ($\omega = 272°$) is such that the periastron passage and the conjunction nearly coincide and as a consequence the putative zone of interaction is hidden by the Wolf-Rayet star and will only be seen in an indirect way in the spectrum.

In the present paper, we discuss medium resolution spectra obtained around the May 1996 periastron passage and compare them to the line-profile variability observed around periastron in March 1995 (Rauw et al. 1996c).

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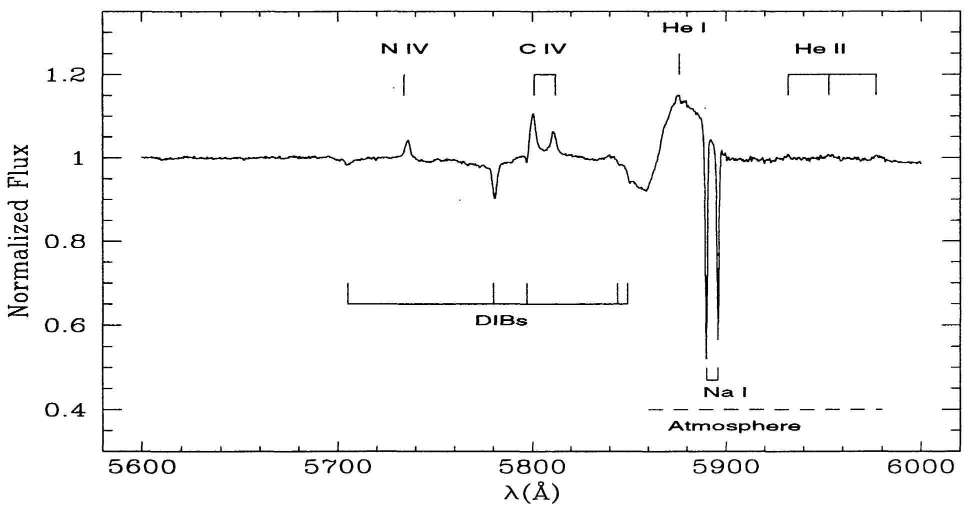

Figure 1: The spectrum of WR 22 between 5600 and 6000 Å as observed in April 1996. The most important lines of the WN7+abs star are identified above the spectrum. Interstellar absorptions are indicated below. The dashed line indicates the region affected by the telluric absorptions.

2 Observations

Medium resolution spectra of WR 22 covering the region 5350 – 6100 Å were obtained during the periastron passage of May 1996 at the ESO 1.5 m telescope equipped with a Boller & Chivens (B&C) Cassegrain spectrograph. The grating was ESO #32 (holographic grating, 2400 lines/mm) providing a reciprocal dispersion of 32.6 Å/mm. The detector was the new thinned, UV flooded CCD (ESO CCD#39). The slit width was set to 220 μm corresponding to 2″ on the sky. The spectral resolution as measured from the lines of the helium-argon calibration spectra is 1.1 Å (FWHM). Special care was taken to avoid any contamination of the He I line by a strange pattern which was due to a defect of the dioptric CCD camera and affected our data below 5600 Å. An additional spectrum was taken about one month earlier with the same equipment except for the grating (ESO #11, 1200 lines/mm) which was used in the second order providing a reciprocal dispersion of 33 Å/mm.

The spectra were corrected for the telluric absorptions between 5860 and 5980 Å and the original He I profiles were restored by removing the interstellar Na I absorptions at $\lambda\lambda$5890, 5896. All the reductions were performed using the MIDAS software developed at ESO.

Figure 1 illustrates the normalized spectrum of WR 22 between 5600 and 6000 Å as observed in April 1996. The spectrum is dominated by the P-Cygni profile of He I λ5876. Beside some emission lines seen at λ5734 (N IV), $\lambda\lambda$5801, 5812 (C IV) and $\lambda\lambda$5932, 5953, 5977 (He II), the spectrum exhibits the prominent Na I interstellar absorptions and several diffuse interstellar bands (DIBs). The mean heliocentric radial velocities of the Na I interstellar lines as measured on our spectra are 0.2 ± 1.7 km/s and 0.9 ± 1.9 km/s for the λ5890 and λ5896 line respectively.

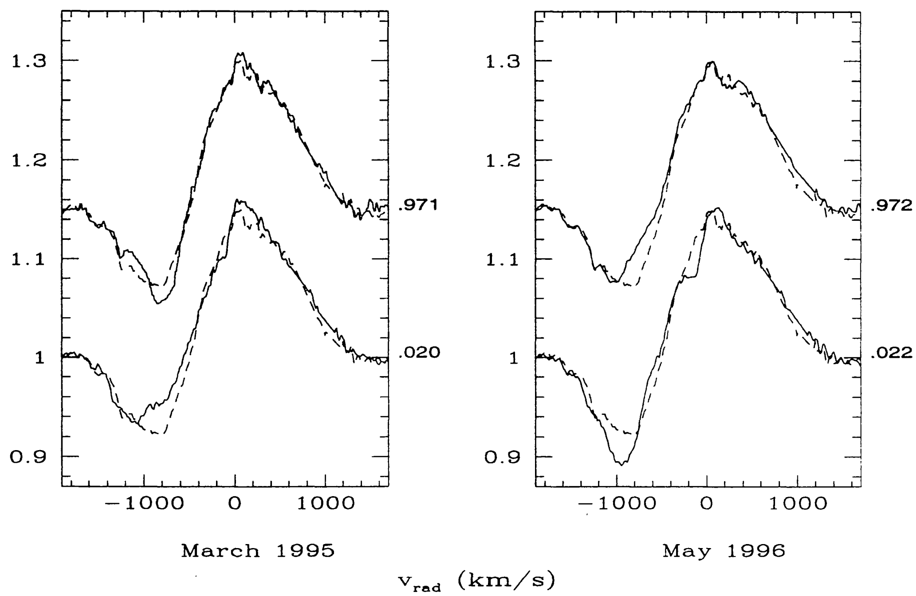

Figure 2: Example of line-profile variability of the "restored" and normalized He I λ5876 line in the spectrum of WR 22 around the periastron passages in March 1995 (left panel) and May 1996 (right panel). The phases of the observations are indicated on the right of each panel. The spectrum obtained in April 1996 at phase $\phi = 0.701$ is shown for comparison (dashed line).

3 Discussion

Figure 2 illustrates the line-profile variability of the He I λ5876 line as seen in our data obtained in March 1995 (left panel) and May 1996 (right panel). The individual spectra have been corrected for the orbital motion of the WN7+abs primary and the quoted radial velocities are thus relative to the WN7+abs star. The spectrum obtained in April 1996 (JD2450183.7, $\phi = 0.701$) is shown for comparison (dashed line).

Figure 2 reveals strong variability affecting the absorption component and the emission peak of the P-Cygni profile. Regarding the variations of the emission peak, we notice a striking similarity between the 1995 data and our new observations. These variations can be interpreted as the result of the blend of the emission component of the Wolf-Rayet line and of a weak absorption line belonging to the "late O" secondary star as suggested in Rauw et al. (1996c). The radial velocities of the absorption feature seen on top of the emission line are in good agreement with the radial velocity curve of the secondary star (Rauw et al. 1996a).

Turning now to the absorption component, one notices a clear difference in the behaviour observed in 1995 and in 1996. The equivalent widths of the absorption component of the He I λ5876 line corrected for the continuum light curve during the secondary eclipse ($\phi = 0.987 - 0.007$) are shown as a function of the orbital phase in Figure 3. In March 1995, the equivalent width of the absorption component reached a minimum just after the periastron passage and remained at about the same value for at least 4 nights ($\phi = 0.008 - 0.045$). On the contrary, EW_{abs} varies on shorter time-scales during the 1996 observations and reaches its maximum value at $\phi = 0.022$

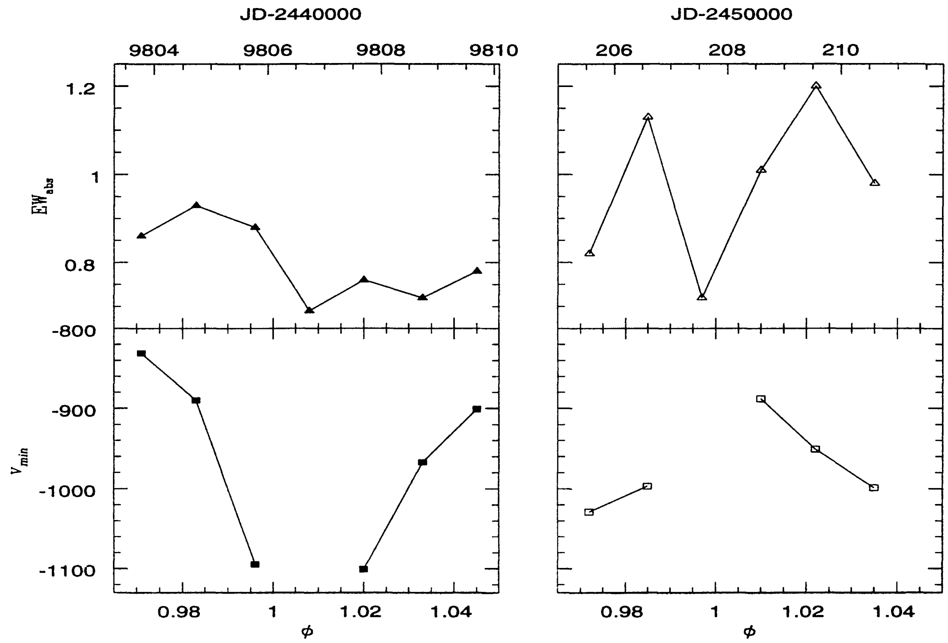

Figure 3: Plot as a function of time of the equivalent width of the entire absorption component (EW_{abs}) of the He I $\lambda5876$ line, as well as of the velocity of the absorption trough (v_{min}). The left and right panels illustrate the variations seen during the periastron passage of March 1995 and May 1996 respectively. The dates of the observations are given on top of the figures, the phases are indicated below. The equivalent widths were corrected for the continuum light curve during the secondary eclipse. For comparison the spectrum obtained in April 1996 indicates EW_{abs} = 1.02 Å and $v_{min} = -815$ km/s. The two spectra obtained on JD2449806.8 and JD2450207.5 display a broad, shallow absorption trough that extends from -800 to -1200 km/s and from -800 to -1100 km/s respectively and therefore it was not possible to measure v_{min}.

i.e. at a phase where it was near its minimum value one year before (Figure 3). During the 1995 campaign, the absorption trough was first observed at velocities of $v_{min} \sim -830$ km/s before it moved towards more negative velocities (~ -1100 km/s) around $\phi = 0.0$ and returned to $v_{min} = -900$ km/s at the end of the observing run. During the May 1996 periastron, v_{min} behaved exactly in the opposite direction (see Figure 3). In fact, the least negative velocity is observed immediately after periastron i.e. at $\phi = 0.010$.

From this comparison we conclude that the variations of the absorption component around the periastron passage are not phase-locked and unlike our previous suggestion (Rauw et al. 1996c) they are probably not related to any known kind of binary interaction: we have rather to deal with an intrinsic variability of the WN7+abs wind.

Intrinsic variability in the absorption components of He I P-Cygni profiles in the spectra of WR stars and extreme O supergiants has been known for a long time (see e.g. Seggewiss & Moffat 1979, Rauw et al. 1996b, Prinja et al. 1996).

Since the He I $\lambda5876$ line is mainly formed by recombination, it is sensitive to density variations and therefore, the observed variability points towards a non-steady mass loss along the line of

sight of the star. Figure 3 indicates that variations on time-scales of a few days and probably even shorter exist. The bulk of the variability arises between −400 and −1400 km/s. If we assume a "β velocity-law" with the parameters of the steady-state model A of Crowther et al. (1995)(i.e. v_∞ = 1785 km/s, β = 1) this corresponds to a range in distance from the stellar center between 1.3 and 4.6 R_*.
In the case of the O8 supergiant HD 151804, Prinja et al. (1996) detected blueward migrating discrete absorption components (DAC's) moving on time-scales of ~ 24 hours in the He I λ5876 absorption component. Some of the features seen in the spectrum of WR 22 could be related to a similar phenomenon, but a rigorous investigation of such variations would require a more extensive dataset with a better time coverage.

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