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EFFECTS OF WIND INTERACTIONS ON DOUBLE WR+O STARS SPECTRA

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Abstract. The phase dependent spectral variability of three WR + O binary system is discussed (WR79, WR155 and WR48). Three main effects are suggested to cause UV line profile variations. The line variability is found to be due mainly to the wind eclipse effect while the effects of the presence of wind – wind interaction region are less prominent but the absorbing O star wind is clearly detectable. It is suggested that in WR79 and WR155 the stagnation point is located so close to the O star surface that the front part of the O star wind does not reach its V_∞. In WR48 there are no wind interaction effects detectable.

1. INTRODUCTION

The determination of the properties of binary systems containing Wolf–Rayet (WR) star and a young massive companion is complicated by the presence of WR stars massive, radiation driven stellar winds. We can observe only the broad emission lines with violet shifted absorption components, originating in the wind. It's difficult to obtain a reliable radial velocity (RV) curve because of the asymmetries in the WR emission lines caused by the presence of the companion. So that the determination of the orbital parameters and the physical characteristics of the stars is uncertain. There is also a problem with the determination of the wind structure of WR stars. The observations show that the WR winds have more momentum than can be introduced by a single photon scattering. If we could observationally constrain the wind structure this could help our understanding of the WR wind acceleration mechanism. There is interaction between the winds of the two stars and a structure of two shock waves and a contact discontinuity (CD) is formed (Luo et al. 1990). The resulting cone–shaped structure can be regarded as a "hole" in the WR wind, filled with the O–star wind. The line profiles in the WR spectra are affected by the presence of the wind – wind interaction region (WWIR). The purpose of this paper is to find out if WWIR presence has the predicted effects on the spectrum of three WR+O binary systems (WR79, WR155 and WR48). The model predicted line profile variations are discussed

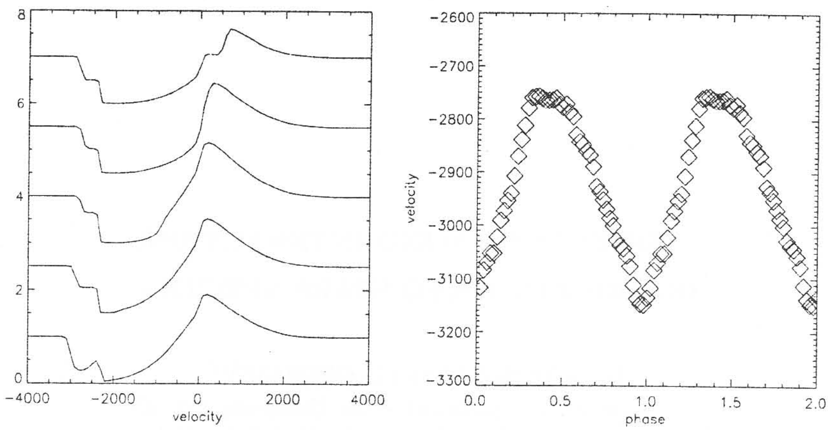

Fig. 1: Left: Line profile variations due to the wind eclipse effect for $i = 40^o$. Bottom - phase 0.0 next + 0.12 to top 0.48. Right: The expected behavior of the blue wing of the absorption component at level 0.8 of the continuum.

in section 2. The results and discussion are given in section 3.

2. PREDICTED LINE PROFILE VARIATIONS

2. 1. ABOUT THE MODEL

The calculation of the source functions is made under the assumption that the two winds are spherically symmetric and independent. The formal solution accounts for the deformation of the winds by the presence of the WWIR and the radiative interaction. The velocity fields of both winds are assumed to obey the standard β-law. The continuum opacity is grey and proportional to the electron density. The radiation field is calculated using local approximated Λ operator (Olson et al. 1986). The line source function is calculated in Sobolev approximation. The CD surface is calculated following Stevens at al. (1992). The flux is obtained using Monte Carlo integration of the emergent intensity along the system in direction to the observer. There are three main effects that cause line profile variations in WR + O binary systems.

2. 2. MAIN EFFECTS

1. Wind eclipse: This effect is due to the presence of the WR stars wind only! Let us assume for a moment that the O star has no wind. During its orbital motion the disk of the O star is eclipsed by different parts of the WR star wind. The WR wind absorbs the O star continuum much more intensively in its line frequencies than in its continuum. So a in a line originating in the WR wind appears additional absorption that widens with the O star motion to the back side of the WR star because of the larger velocity range of the WR wind projected on its disk. (See Fig. 1 left pannel)

2. "Hole" in the WR wind: Let the O star wind be transparent in the line frequencies. Then there is a hole in the WR wind surrounding the O star and changing its position towards the observer in the orbital motion. Hence at phase 0 (O star in

Table 1: Orbital elements

Star	*SpClass*	*P(days)*	$i(^o)$	Reff.
WR79	WC7+O5-8V	8.8908	44	Seggewiss (1974)
WR155	WN6+O9II-Ib	1.6412	65	Walker et al. (1983)
WR48	WC6+O9.5/B0Ia)	18.341	-	Moffat & Seggewiss (1977)

front) the hole "cuts off" the maximal negative velocities of the PCyg absorption. Passing at back it cuts parts of the WR wind with greater velocities but there the effect is hardly detected.

3. Absorbing O star wind: This effect is due to the O star wind opaque in the considered line. The cone shaped volume around the O star absorbs at the line frequencies and if its terminal velocity is greater than that of the WR wind, an additional violet absorption should occur at velocities equal to the O star V_∞. If the O star wind is evacuated from the front part of the WWIR the additional high velocity absorption occurs at phase 0, and then the blue wing of the absorption decreases its velocity. (Fig.1 right)

3. RESULTS AND DISCUSSION

The orbital parameters of the regarded systems are given in Table 1.

The phases are calculated so that $ph = 0.0$ is the passage of the O star in front of the WR star. Our study of the systems is based on the 21 (WR79), 13 (WR155), 17 (WR48) IUE high dispersion spectra in the wavelength region 1200, 1990 Å. The spectra where processed using IDL package. The spectra were rebinned to have uniform dispersion, and the normalization to the continuum was made in the regarded spectral lines. Our measurements of the WR radial velocity confirm the 8.8908d period obtained by the other authors for WR79, but the semi-amplitude of our RV curve is significantly lower. This could be a result of the different method of determination of RV. Seggewiss at al. and Lurs at all. (1997) make measurements of the radial velocity using the center of broad emission lines in the optical wavelengths. Our measurements are of the center of the blue shifted PCyg absorption of the $CIII]$ λ1909Å line. The effect of wind eclipse introduces great asymmetries in the line profiles of optically thick lines, which could make emission line center deviations from the laboratory wavelength inappropriate for measuring the radial velocities of the star. The $CIII]$ λ1909Å line used for our measurements is optically thin so the wind eclipse should not affect its form. For WR155 we obtain an RV curve in good agreement with the published period. For WR48 there has not been obtained a reliable RV curve.

We use the 3 emission lines of the WR star spectrum to compare the predicted line profile variations with the observations.

1. The resonance doublets $SiIV$ $\lambda\lambda$1393, 1402Å and CIV $\lambda\lambda$1548, 1550Å should show the wind eclipse. Also the absorbing O star wind effect should be seen if present, because the doublets originate in both winds. The wind eclipse effect is clearly observable in our data for WR79 and WR155. In Fig. 2 (left) there are shown the blue wing velocities of the considered emission lines for WR79. The behavior of $SiIV$ doublet in WR155 is similar. The line shows phase dependent variations predicted to

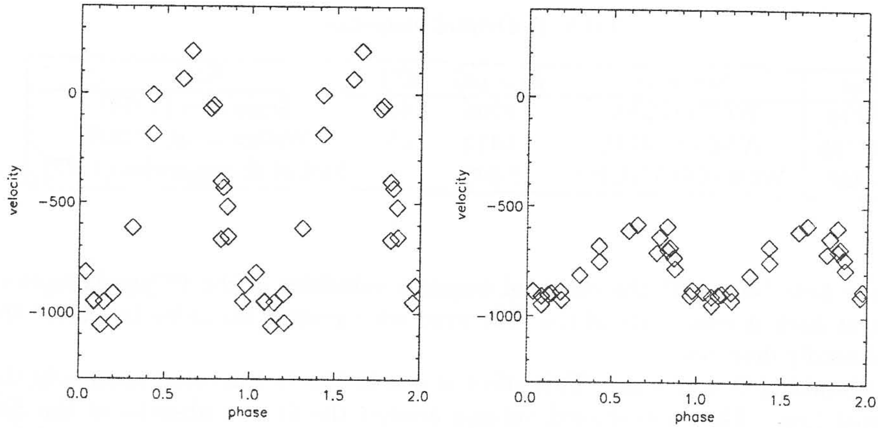

Fig. 2: WR79 blue wing of the $SiIV$ $\lambda\lambda 1393, 1402$Å (left), and CIV $\lambda\lambda 1548, 1550$Å (right) emission line

occur if the wind eclipse effect is present. The maximally affected by the wind eclipse velocities in WR79 are about 1600 km/s which if we assume $V_{\infty} = 2270 km/s$ gives 45° for the inclination angle. This is in good agreement with the value obtained by St. Louis in pollarimetric study. In the spectra of WR48 there is no phase dependent variability of the blue wing of the emission lines, so there is no wind eclipse effect observable in this system. The lack of this effect is supporting the suggestion of St. Louis et al. (1987), that the O star companion of WR48 does not participate in the orbit.

In Fig. 3 is shown the behavior of the blue wing of the absorption component of $SiIV$ $\lambda 1393$Å measured at level 0.8 of the continuum.

The phase dependent variability is clearly visible for both WR79 and WR155. Such a behavior could be expected if the absorption line in the O star wind is formed in a region deformed by the CD surface so that the absorption in the O wind occurs only at phases close to 0.0 when the unperturbated O wind is directed towards the observer. In the front part of the WWIR the line does not originate so the high velocity blue wing gradually disappears towards phase 0.5. In the WR48 spectra such effect is not detectable.

2. The line $CIII]$ $\lambda 1909$Å is chosen because it is assumed not to occur in the O star wind, so we can test if the presence of non absorbing "hole" in the WR wind could be seen in this system. (For WC stars only). The line is collisionally existing so the wind eclipse effect should not be present. The emission line profile does not show significant variations. Thus it is not affected by the wind eclipse effect and could be used for radial velocity determination. The other effect expected to contribute to the CIII] variability – "hole" in the WR wind – is not present or not detectable in WR79. The blue wing of the absorption component remains at constant velocities with 40 km/s dispersion which is within the error limits.

If the "hole" effect is absent, it means that at phase 0 (O star in front) the cone shaped WWIR does not disturb the minimal radial velocities. Hence, knowing the

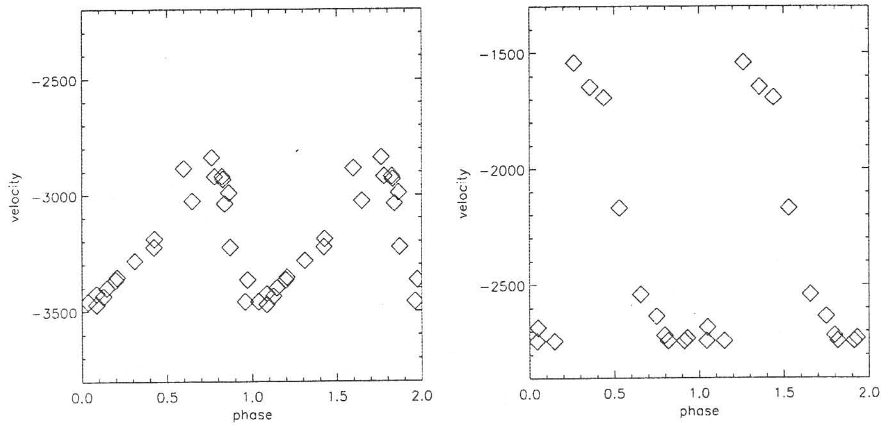

Fig. 3: WR79 blue wing of the *SiIV* λ1393Å absorption line at level 0.8. Left: WR79. Right: WR155

inclination of the system to be $i = 45°$, we can conclude that the half opening angle of the cone should be less than 45°.

We can conclude that the main effect which causes phase dependent line profile variations of WR79 and WR155 spectral lines is the wind eclipse. The contribution of the presence of a "hole" in the case of transparent O star wind is not detectable in this binary systems. In both systems the absorption from the O star wind is clearly detected, which allows us to use this effect for determination of O star wind properties. In the WR48 spectra there are not any of discussed effects detectable. It confirms the suggestion that the WR and the O star do not orbit around each other.

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