IUE MONITORING OF WR140 (WC7+O4-5)

D.Y.A. SETIA GUNAWAN[1], K.A. VAN DER HUCHT[1],
P.M. WILLIAMS[2], L. KAPER[3], H. HENRICHS[3] and W. WAMSTEKER[4]
[1] *Space Research Organization Netherlands, Utrecht, The Netherlands*
[2] *Royal Observatories, Edinburgh, U.K.*
[3] *University of Amsterdam, The Netherlands*
[4] *ESA IUE Observatory, Madrid, Spain*

Abstract. We present the first results of the *IUE* monitoring campaign of the WC7+O4-5 binary system WR140. Thirty-four high-resolution short-wavelength spectra were obtained in 1979–93, *i.e.*, over more than one orbital period of 7.9 yr. The spectra show variations in the strong resonance lines of CIV and SiIV: large variations occur at the blue edges of the absorption parts of their P-Cygni profiles just after periastron passage. The observed profile changes are discussed in terms of a velocity variation at periastron passage and/or turbulence in the sightline to the O4-5 star at this time.

Key words: stars: Wolf-Rayet – binaries – ultraviolet spectroscopy – individual: WR140

The long-period Wolf-Rayet binary system WR140 (HD 193793, WC7+O4-5, P=7.9 yr, e = 0.84) has been thoroughly observed at many wavelengths. Its binarity was established by re-analysis of available radial velocity data with a period inferred from the interval (7.94 yr) between infrared outbursts (Williams *et al.* 1987). Smith (1968) classified the WR component as WC7, the other component has been classified O4-5 by Lamontagne *et al.* (1984). At radio wavelengths the system displays periodic non-thermal emission on top of its free-free emission, disappearing around periastron passage (Williams *et al.* 1990, hereafter WHPFWW). At X-ray wavelengths, a (variable) flux about ten times brighter than expected for WR stars has been observed (Pollock 1987, WHPFWW, van der Hucht *et al.* 1992).

These observations lead to a model of a binary with interacting stellar winds that form two shock fronts with a contact discontinuity in between. As the WC7 component has a ~30 times larger mass loss rate than the O component, the cone-shaped contact discontinuity is formed close to the O component, with an opening angle depending on the mass-loss rate ratio and terminal velocity ratio, *i.e.*, on the wind momentum ratio of the two stars (see *e.g.*, Eichler & Usov 1993). Applying the orbital elements derived by WHPFWW, the O component is 'behind' the WR star roughly at phases $0 < \phi < 0.1$ (see Fig. 1). In this phase range the sightline to the O component passes through the densest part of the WC and O stellar winds and interaction region. Because the O component is about 0.7 mag brighter than the WC component in the UV (WHPFWW), absorption in its sightline will dominate the absorption spectrum of the WR140 system.

K. A. van der Hucht and P. M. Williams (eds.), Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution, 466–470.

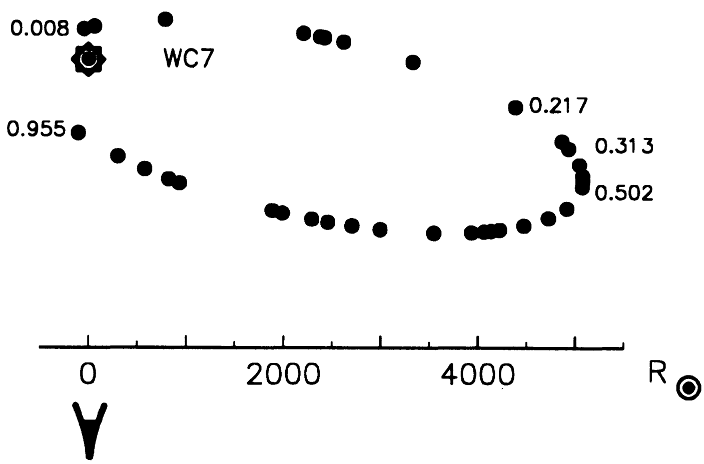

Fig. 1. **WR140. The postition of the O component with respect to the WR component at the time of the *IUE* observations listed in Table I. P=2900 d, e=0.84, ω=42**

Thirty-four high-resolution *IUE* SWP-LA images (1150-2050 Å) of WR140 were taken in the period 1979–93. The photometrically corrected images of the spectra were processed using the *STARLINK* program *IUEDR* (Giddings & Rees 1989). The spectra were aligned on their interstellar lines. The log of observations is given in Table 1.

The spectra are scaled to a constant flux level by conserving the total flux in the wavelength regions 1435–1500Å, 1565–1605Å and 1740–1840Å, where the spectra are relatively line free. In Fig. 2 parts of the spectra are displayed in grey-scale figures. The orbital phase at the time of observation is indicated by an arrow along the vertical scale, with orbital phase running upwards. The horizontal scale gives velocity with respect to the rest wavelength of the principal doublet line. The UV resonance doublets of Si IV (1393.755, 1402.769 Å) and C IV (1548.202, 1550.774 Å) are shown. Strong variations are apparent in the absorption part of the P-Cygni profiles around periastron passage ($\phi = 0$).

The Si IV profile shows significant absorption dips in both doublet components at a velocity of −2800 km/s, reminiscent of the (*persistent*) discrete absorption components (DACs) in spectra of certain O-type stars (*e.g.*, 15 Mon and λ Ori, Kaper 1993). Although the absorption part of the red doublet component is contaminated by the emission part of the blue doublet component, we observe a corresponding tendency of variation: the absorption features in both doublet components are broader and deeper after periastron passage, and become even saturated. The C IV lines are always saturated,

TABLE I
Log of *IUE* observations of WR140 (WC7+O4-5)

SWP	JD 2440000+	phase	SWP	JD 2440000+	phase
6945	4168.659	0.313	40201	8222.090	0.711
8004	4291.392	0.356	41451	8368.655	0.762
9492	4431.433	0.404	41977	8440.377	0.786
25788	6182.845	0.008	42319	8494.281	0.805
27064	6379.234	0.076	42582	8529.256	0.817
28111	6526.655	0.126	43277	8591.218	0.838
29954	6788.988	0.217	43426	8610.147	0.845
31504	7015.321	0.295	44828	8775.473	0.902
33425	7283.600	0.387	44965	8794.447	0.908
34064	7383.367	0.422	45231	8830.465	0.921
35886	7614.743	0.502	45530	8871.210	0.935
36834	7752.213	0.549	46119	8929.235	0.955
37675	7855.045	0.595	47470	9089.794	0.010
38581	7993.774	0.632	47727	9132.558	0.025
38798	8027.741	0.644	48783	9259.224	0.069
39061	8053.660	0.653	49004	9285.142	0.078
39311	8100.363	0.669	49287	9313.078	0.087

but also show a similar broadening and deepening. At the blue end of these absorption features ($v_{\rm black}$) we measure a velocity of about -2800 km/s between $\phi = 0.30$–0.96, just after periastron passage suddenly increasing to about -3200 km/s for Si IV and -3100 km/s for C IV and then gradually decreasing back to -2800 km/s.

These high velocities are in accordance with the terminal wind velocities $v_\infty = 3200$ km/s for O4-5 stars (Conti 1988), while $v_\infty = 2860$ km/s was measured for WR140 by Williams & Eenens (1989) from the He I 2.058 μm line. If the O star is a main-sequence star (WHPFWW), the Si IV and C IV lines are formed in the winds of both the WC7 and O4-5 star. We have also checked the N V resonance lines at 1240 Å for variability (we expect nitrogen to be present in the O-star wind only), but unfortunately this line is blended by the C III emission line at 1247 Å where the signal-to-noise ratio is rather low.

The increase in absorption takes place when the O star passes the WR star at periastron and moves behind it (see Fig. 1, $0 < \phi < 0.3$). When the O star continues its orbit ($\phi > 0.3$), the absorption dip regains its "normal" strength and persists at a velocity of 2800 km/s, *i.e.*, close to the terminal

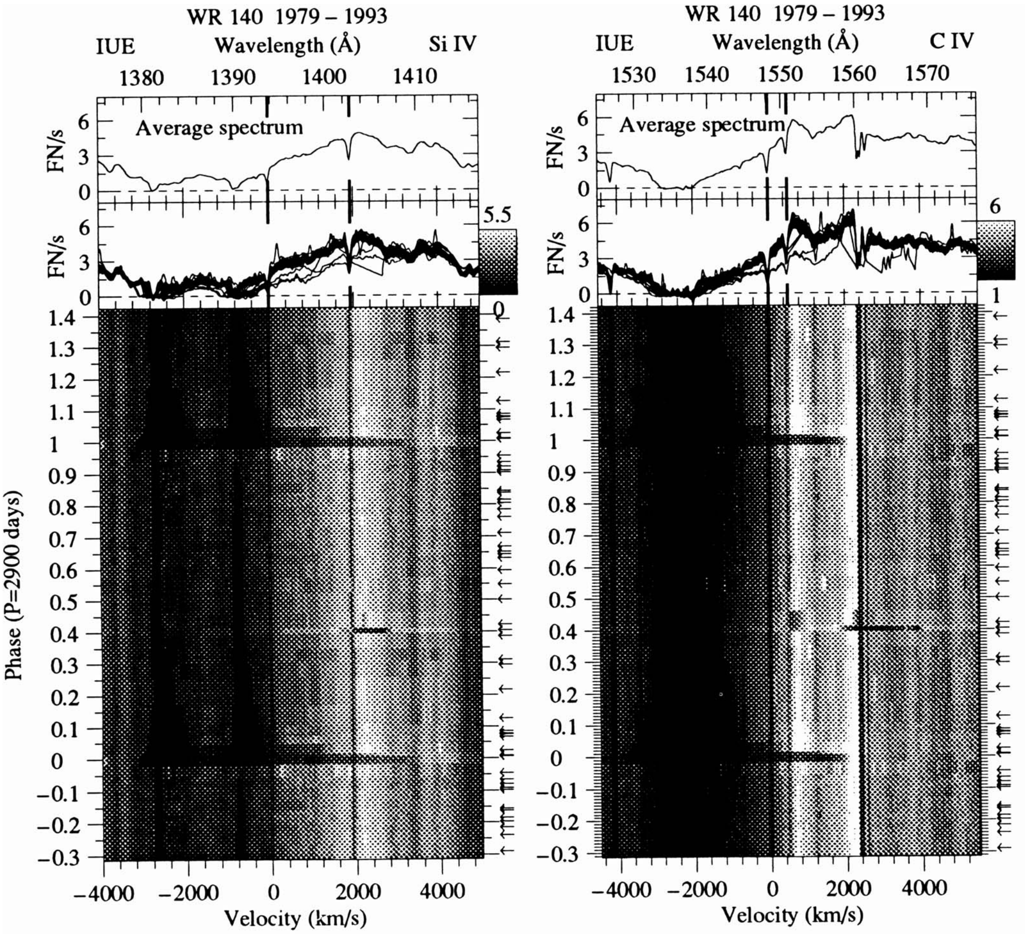

Fig. 2. The SiIV (left) and CIV (right) resonance doublets of WR140 in grey-scale representation. Intensity is converted into levels of grey, the epoch of each observation is indicated arrows. The horizontal scale gives the velocity with respect to the rest wavelength of the principal doublet component; note the interstellar lines that mark the rest wavelengths of both components. Near periastron passage ($\phi = 0$) absorption at the blue edge of the profile is strongly increased.

velocity of the WR wind. The increase in maximum blue-shifted velocity (to 3200 km/s) cannot be solely due to the O star wind (which has the higher v_∞), because most of the absorption at these orbital phases occurs through the much stronger WR star wind. There are two possible explanations. At these phases, the sightline to the brighter O star passes close to the WR star and through the densest part of its wind where the anomalously broad emission lines (*e.g.,* Torres *et al.* 1986) are formed. Both manifestations of broadening may be caused by turbulence in the wind, probably arising from the wind collison.

Also, because the luminosity of the O star is about twice that of the WR star, when the two stars are very close, one might expect the acceleration of the WR wind to be affected by the O-star's radiation field too and the WR wind velocity to be higher.

Only when the O star is in front of the WR star ($\phi \sim 0.8 - 0.9$, remember that the O-star wind is confined to a small cone in the WR wind), do we observe uncontaminated O-star material in the line of sight towards that component. After periastron passage ($0 < \phi < 0.8$), the dense WR wind is in front of the O star, dominating the circumstellar absorption.

A full paper on this study will be submitted to *A&A* .

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References

Conti, P.S. 1988, in: P.S. Conti & A.B. Underhill (eds.), Stars and Wolf-Rayet Stars, *NASA SP-497* (Wahington: NASA), p. 121

Eichler, D., Usov, V. 1993, *ApJ* **402**, 271

Giddings, J.R., Rees, P.C.T. 1989, SERC Starlink User Note 37.7

van der Hucht, K.A., Williams, P.M., Spoelstra, T.A.Th., de Bruyn, A.G. 1992, in: L. Drissen, C. Leitherer & A. Nota (eds.), Non-isotropic and Variable Outflows from Stars, *ASP Conf. Series* **22**, p. 253

Kaper, L. 1993, Wind Variability in Early-Type Stars, PhD thesis, University of Amsterdam

Lamontagne, R., Moffat, A.F.J., Seggewiss, W. 1984, *ApJ* **277**, 258

Pollock, A.M.T. 1987, *A&A* **171**, 135

Smith, L.F. 1968, *MNRAS* **138**, 109

Torres, A.V., Conti, P.S., Massey, P. 1986, *ApJ* , **300**, 379

Williams, P.M. & Eenens, P.R.J. 1989, *MNRAS* **240**, 445

Williams, P.M., van der Hucht, K.A., van der Woerd, H., Wamsteker,W.M., Geballe, T.R., Garmany, C.D., Pollock, A.M.T. 1987, in: H. Lamers & C.W.H. de Loore (eds.), Instabilities in Luminous Early Type Stars (Dordrecht: Reidel), p. 221

Williams, P.M., van der Hucht, K.A., Pollock, A.M.T., Florkowski, D.R., van der Woerd, H., Wamsteker, W.M. 1990, *MNRAS* **243**, 662 (WHPFWW)