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2009: A Colliding-Wind Odyssey

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Abstract. We present the results from two optical spectroscopic campaigns on colliding-wind binaries (CWB) which both occurred in 2009. The first one was on WR 140 (WC7pd + O5.5fc), the archetype of CWB, which experienced periastron passage of its highly elliptical 8-year orbit in January. The WR 140 campaign consisted of a unique and constructive collaboration between amateur and professional astronomers and took place at half a dozen locations, including Teide Observatory, Observatoire de Haute Provence, Dominion Astrophysical Observatory, Observatoire du Mont-Mégantic and at several small private observatories. The second campaign was on a selection of 5 short-period WR + O binaries not yet studied for colliding-wind effects: WR 12 (WN8h), WR 21 (WN5o + O7 V), WR 30 (WC6 + O7.5 V), WR 31 (WN4o + O8), and WR 47 (WN6o + O5). The campaign took place at Leoncito Observatory, Argentina, during 1 month. We provide updated values of most of these systems for the orbital

parameters, new estimates for the WR and O star masses and new constraints on the mass-loss rates and colliding wind geometry.

1. Radial Velocities

The WR 140 and WR 30 radial velocities (WR component) were computed by cross-correlation with a reference spectra. The other WR radial velocities were obtained by measuring the centroid of nitrogen emission lines. The O star RVs were obtained by measuring the centroid of absorption lines. The present data were combined with previous RV measurements from Gamen & Niemela (1999), Rauw et al. (1996), Niemela, Mendez, & Moffat (1983), and Marchenko et al. (2003) in order to get the best possible orbits (Tab. 1). See our MNRAS papers, Fahed et al. (2011) and Fahed & Moffat (in prep.), for the complete list of parameters.

Table 1. A selection of orbital and fundamental stellar parameters obtained in this study. The wind momentum ratio is deduced from using the analytic formula of Cantó, Raga, & Wilkin (1996).

	WR 12	**WR 21**	**WR 30**
Adopted Spectral class	WN8h + ?	WN5o + O7 V	WC6 + O7.5 V
a [A.U.]	—	0.2681 ± 0.0061	0.536 ± 0.035
Period [d.]	23.92336 ± 0.00001	8.25443 ± 0.00003	18.8061 ± 0.0004
i [°]	—	68.5 ± 3.3	61.2 ± 6.8
Previously published i	78.8 ± 2.2[1]	49.6 ± 3.7[1]	78.3 ± 5.8[1]
η	—	0.026 ± 0.005	0.017 ± 0.005
$M_{\rm WR}$ [$M_\odot$]	—	13.44 ± 0.64	18.9 ± 5.4
$M_{\rm O}$ [$M_\odot$]	—	24.34 ± 1.00	39.4 ± 6.0
	WR 31	**WR 47**	**WR 140**
Adopted Spectral class	WN4o + O8 (V)	WN6o + O5 (V)	WC7pd + O5.5fc (III)
a [A.U.]	0.1342 ± 0.0057	0.3010 ± 0.0067	15.3 ± 0.5
Period [d.]	4.830657 ± 0.000013	6.23930 ± 0.00002	2896.5 ± 0.7
i [°]	61.7 ± 4.5	67 ± 3	55 ± 6
Previously published i	61.6 ± 1.7[2]	67.1 ± 1.9[3]	50 ± 15[4]
η	0.017 ± 0.004	0.036 ± 0.006	0.039 ± 0.016
$M_{\rm WR}$ [$M_\odot$]	4.32 ± 0.40	42.6 ± 3.6	16 ± 3
$M_{\rm O}$ [$M_\odot$]	9.52 ± 0.76	51.0 ± 2.8	41 ± 6

References : [1] Lamontagne et al. (1996), [2] Lamontagne & Moffat (1987), [3] Moffat et al. (1990), and [4] Marchenko et al. (2003).

2. Excess Emission

The presence of a shock cone around the O star induces an excess emission that we measured on the top of lines C III λ5696, He II λ4686 and C IV λ4650. This excess emission moves periodically from the blue side to the red side of the line and back again, and can be explained by a simple geometric model developed by Lührs (1997). It takes into account the half opening angle of the shock cone, the velocity of the plasma along the cone $v_{\rm strm}$, the orbital inclination i and an angular shift due to Coriolis forces (see Fig. 1, bottom panel). We fitted this model to the radial velocity and the width of our excess profiles as a function of orbital phase and deduced estimations of the orbital inclination, stellar masses, and mass-loss rates for 5 of our 6 stars (see Fig. 1, top panel

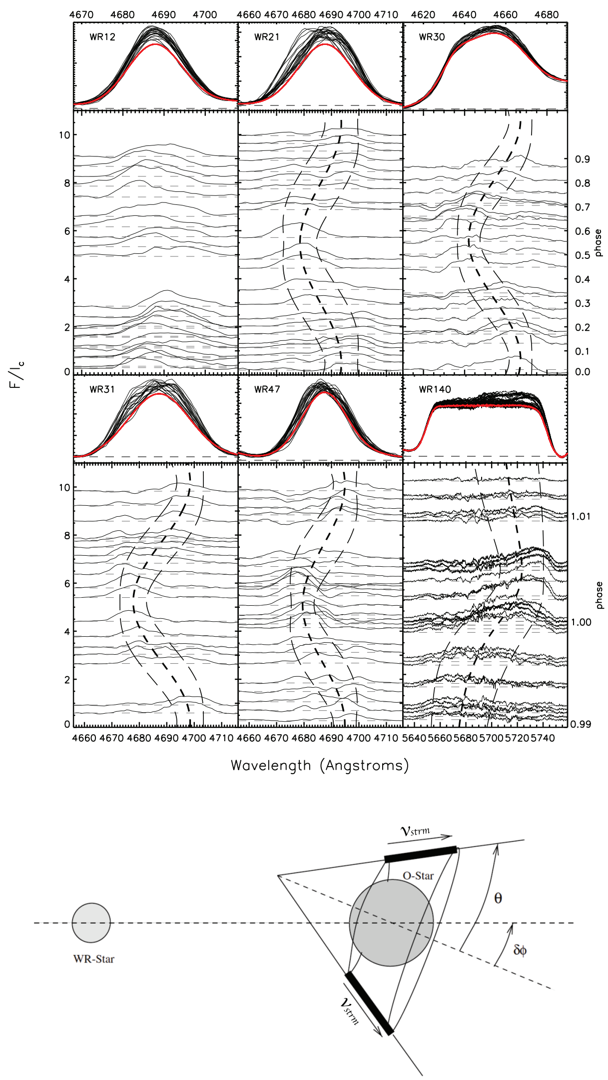

Figure 1. **Top panel**: Excess emission profiles estimated by subtraction of a reference (unperturbated) profile (shown in red) from the ensemble of spectra. We also show the position (short dashed line) and width (long dashed line) resulting from the Lührs model fit. One star, WR 12, did not lead to a reasonable fit, probably due to enhanced turbulence or instabilities in the shock region. **Bottom panel**: Schematic view of the geometric model by Lührs (1997), taken from Bartzakos, Moffat, & Niemela (2001). The full width and radial velocity of the excess are given by $FW_{\rm ex} = C_1 + 2\,v_{\rm strm}\,\sin\theta[1 - \sin^2 i\,\cos^2(\phi - \delta\phi_0)]^{1/2}$ and $RV_{\rm ex} = C_2 + v_{\rm strm}\,\cos\theta\,\sin i\,\cos(\phi - \delta\phi_0)$.

and Tab. 1). To compute the WR mass-loss rates from, we adopted WR mean terminal velocities from van der Hucht (2001), and O-star mass-loss rates and v_∞ from the models of Martins, Schaerer, & Hillier (2005) and the mass-loss predictions of Vink, de Koter, & Lamers (2001) with $v_\infty = 2.6 \times v_{\rm esc}$. For simplicity, WR 31 and 47 O-star components are assumed class V luminosity stars, while the O-star component of WR 140 was taken to be class III.

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