Spectropolarimetric analysis of WR + O binaries with SALT*

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The Question

What can wind-wind interactions in Wolf-Rayet binary systems tell us about stellar evolution?

Colliding-wind WR+O binary systems may give rise to rapidly-rotating stripped-envelope stars. These are candidate progenitors for long duration gamma-ray bursts. Characterizing wind structures in WR+O binaries helps us understand WR mass loss and predict their ultimate fates.

WR113 (CV Ser)

WR113 is a WC8d+O8-9IV that is of particular interest because of a recent spectroscopic model by Hill+ 2018 (*MNRAS* **474**:3) that provided predictions about the wind region and orbital characteristics of WR113. As part of a project to investigate WR+O systems, we have collected spectropolarimetric data about WR113, and these data can provide a test of the current best model.

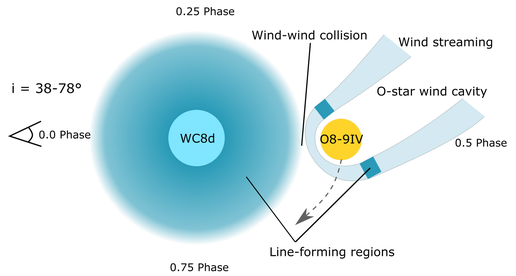

Figure 1: Sketch of the spectroscopically derived model for the geometry of the C III λ5696 emission line in WR 113 (Hill+ 2018).

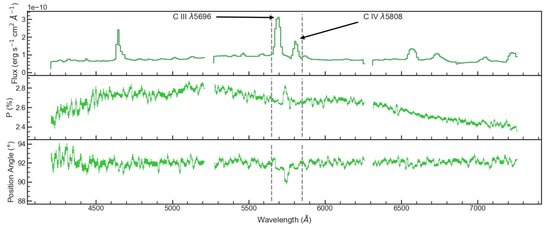

Figure 2: WR 113 flux, polarization, and position angle spectra, obtained with RSS/SALT at phase 0.962. Data are binned to 10 Å; shaded regions show 1σ errors. Vertical lines bracket the region plotted in Fig. 3. We have observed 17 additional WR+O binary systems with similar data quality.

Continuum Polarization

The continuum polarization of WR113 follows the typical sinusoidal pattern of a binary orbit. We fit the data with the Robert+ 1992 (*ApJ* **397**:277) model, which allows for simultaneous q and u fits to the data. The system inclination angle i is a parameter of the model. We tested the Hill+ 2018 model using its inclination angle result $i = 63.5°$ and found it to produce a good fit to the data as shown in Fig. 3.

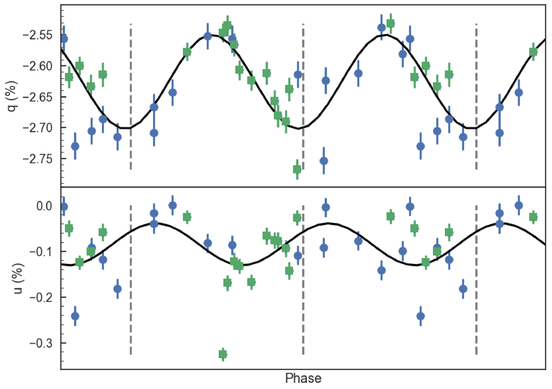

Figure 3: Johnson V-band q and u from both SALT (blue circle points) and unpublished data provided by A. Moffat (green square points) fit with the prescription from Robert+ 1992. The fit agrees with the inclination angle proposed by Hill+ 2018 of 63.5°. Interstellar polarization has not been subtracted.

Interstellar Polarization

Some initial progress has been made to extract the interstellar polarization (ISP) from the data that are available. We fit the empirical model from Serkowski+ 1975 (*ApJ* **196**:261) to the polarization spectrum (example in Fig. 2) and used it to estimate an ISP value for WR113 at each phase. The smallest value of P_{max} (the peak polarization of the model) and its associated fit was used for the ISP subtraction at every phase.

Future ISP characterization will be completed with data reduction work on field star imaging spectropolarimetry that has also been collected using SALT.

Line Polarization

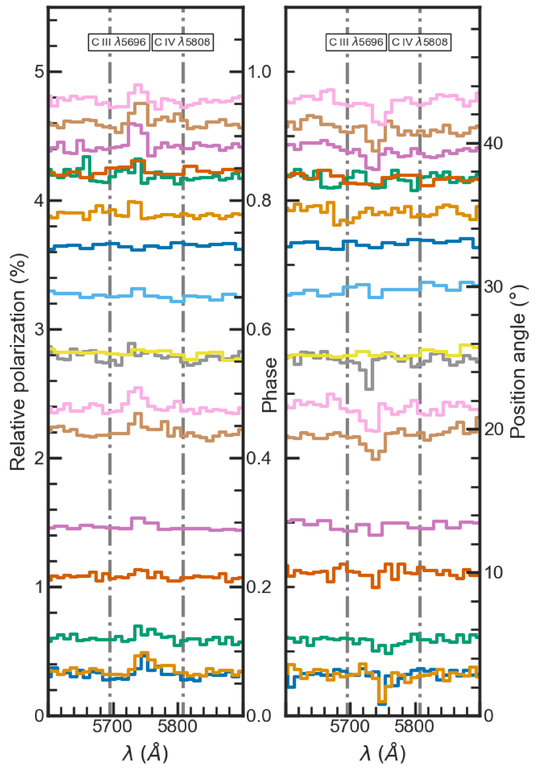

Figure 4: Polarization (*left*) and position angle (*right*) of the C III λ5696 / C IV λ5808 line region in WR 113 plotted against wavelength and phase. ISP has been removed. Data are binned to 10Å; uncertainties are not plotted for clarity.

The largest phase variations in both polarization and PA occur near 5740 Å, not aligned with either line in the flux spectrum (*vertical lines*). This spectral feature is not present in other WC+O stars in the sample. If it is associated with the C III line, its relative velocity is a redshift of 2500 km s^{-1}; if it is associated with the C IV line, it is blueshifted by 3000 km s^{-1}.

Analysis

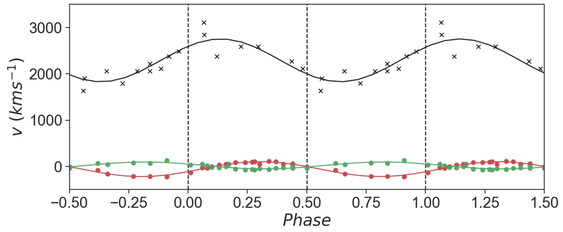

Figure 5: Preliminary "polarized feature" line velocity in black, derived from Gaussian profile fits to the $\%q$ polarization data, after initial interstellar polarization subtraction. Reference line is C III λ5696. Red is Hill+ 2018 velocity measurements of C IV λ5808, green is He II absorption from Hill+ 2018. The C IV line is a proxy for the WR star motion; the He II line is a proxy for the O star motion. Line fits are simple sinusoids of the form $v\sin(2\pi x + \phi) + v_0$.

The polarized feature around 5740 Å may represent red-edge C III λ5696 emission scattered from the far side of the dense, fast-moving wind streaming region (see Fig. 1). Its mean velocity is higher than that of the typical WR wind for a star of this types (~2500 vs 2000 km s^{-1}), which implies some additional acceleration has taken place, such as in a wind stream. It also has a higher range of velocities than the O star or WR star, placing it at some point in the circumstellar material. Furthermore, its phase behavior is different from both stellar proxy lines, with a phase difference that is around half that of the proposed value for the O star wind cavity in the Hill+ 2018 model- making it likely located on one edge of the cavity.

The Takeaway

The phase dependence and velocity of the ionized carbon line polarization in WR 113 suggests that the system contains an orbiting line emission region, arising from strong interaction of the WR+O star winds. Further modeling of this region can constrain the mass and momentum transferred between the stars, giving clues to their future evolution.

Acknowledgements

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