Envisioning Scattering Regions in Wolf-Rayet Binary Stars

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Background

Wolf-Rayet (WR) stars are evolved massive stars characterized by active stellar winds [1].

WR + O binary star systems, like the one shown in Figure 1, are surrounded by colliding winds of gas and dust that scatter starlight and are known as scattering regions.

WR 42 and WR 79 are two nearly identical binary systems, which makes them good candidates for determining the underlying structure of these objects.

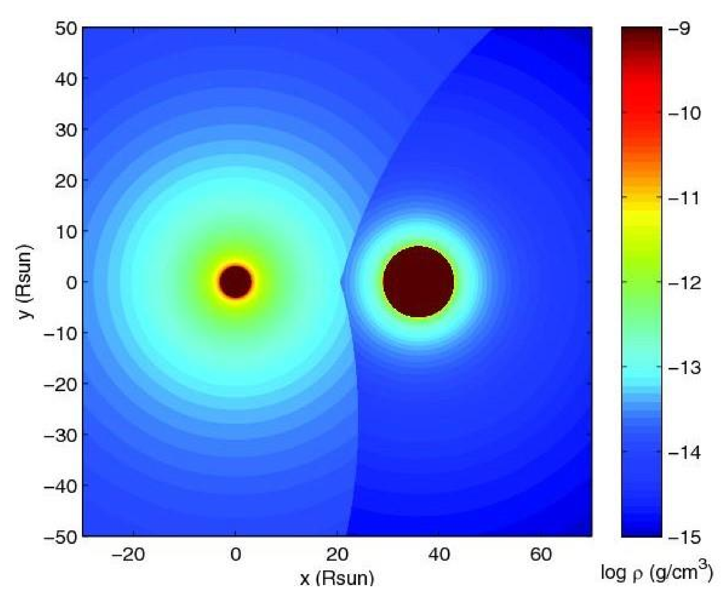

Figure 1: A model of the scattering region of V444 Cygni, a WR (left) and O star (right) binary system. [2]

We can use polarimetry, which measures the orientation of the scattered light waves, to map out the scattering regions in WR+O binaries..

This can be combined with observations of the chemical makeup, or spectrum, of these objects in a technique called spectropolarimetry.

Stokes parameters, u and q, can be used as a coordinate system for evaluating the structure and evolution of these objects.

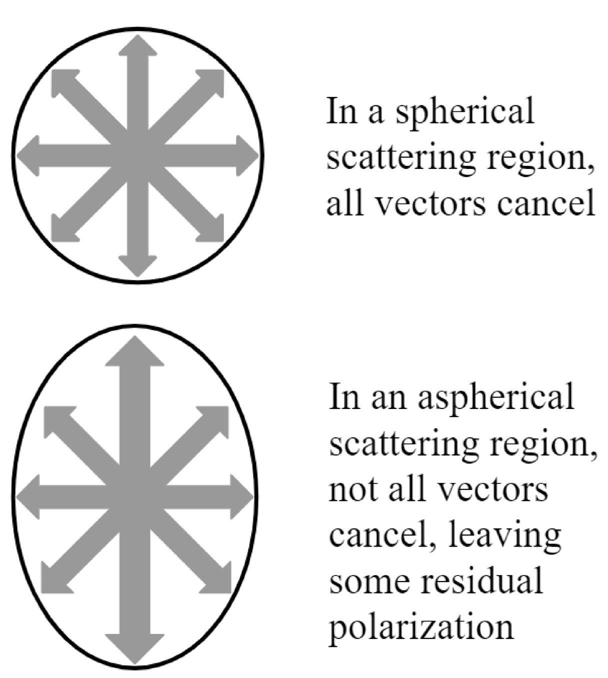

Figure 2: A depiction of spherical (top) and aspherical (bottom) scattering regions.

The Brown, McLean, and Emslie (BME) model computes a theoretical sinusoid to describe the variation of WR+O binaries. It assumes both stars to be point sources and the scattering region to be of low density [3]. This computed sinusoid can then be used to determine some inherent properties of the system.

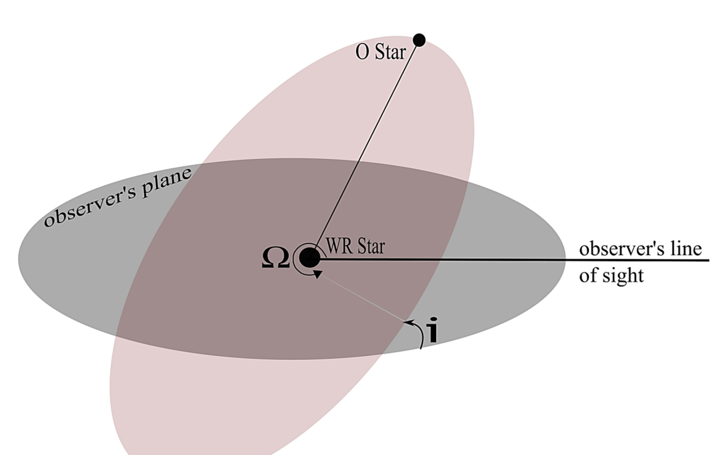

Figure 3: In this figure, the ecliptic plane lies along our line of sight. The inclination angle, i, measures the angle between the ecliptic plane and the plane of the orbit of the O star. Omega (Ω) is the angle of the orbit of the O star projected onto the sky.

Results

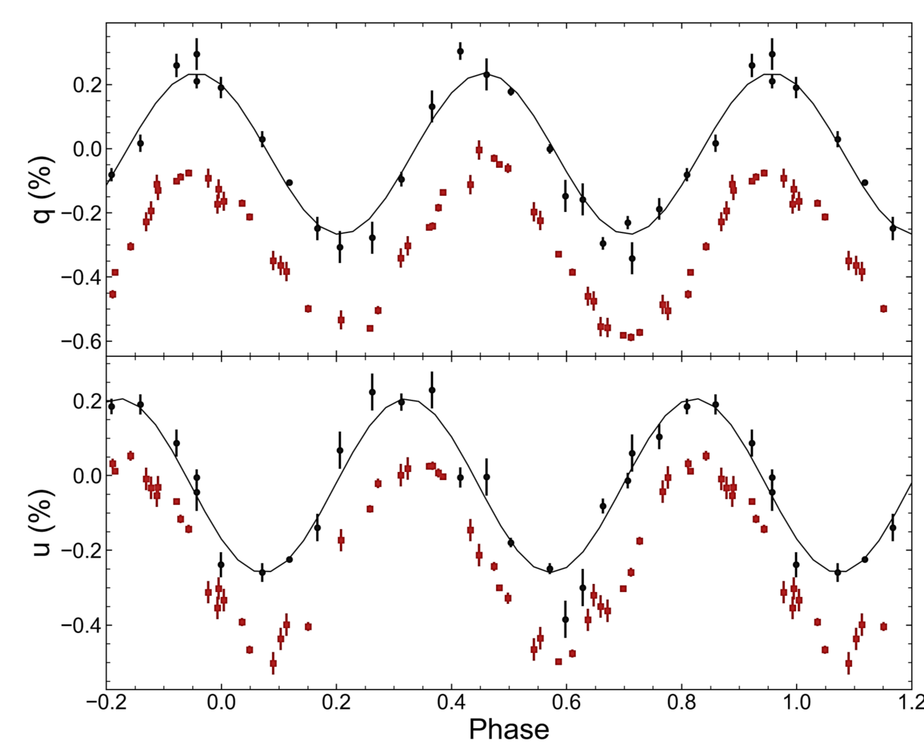

Figure 4: The error-weighted average (black circles) of the continuum polarization for WR 79, plotted against orbital phase, which is the position of the stars in their orbit. The curve fit produced by the BME model (black curve) is also plotted. The red squares are the points found by St. Louis et al. in 1987 for this object, and have been phase shifted by +0.09. [4]

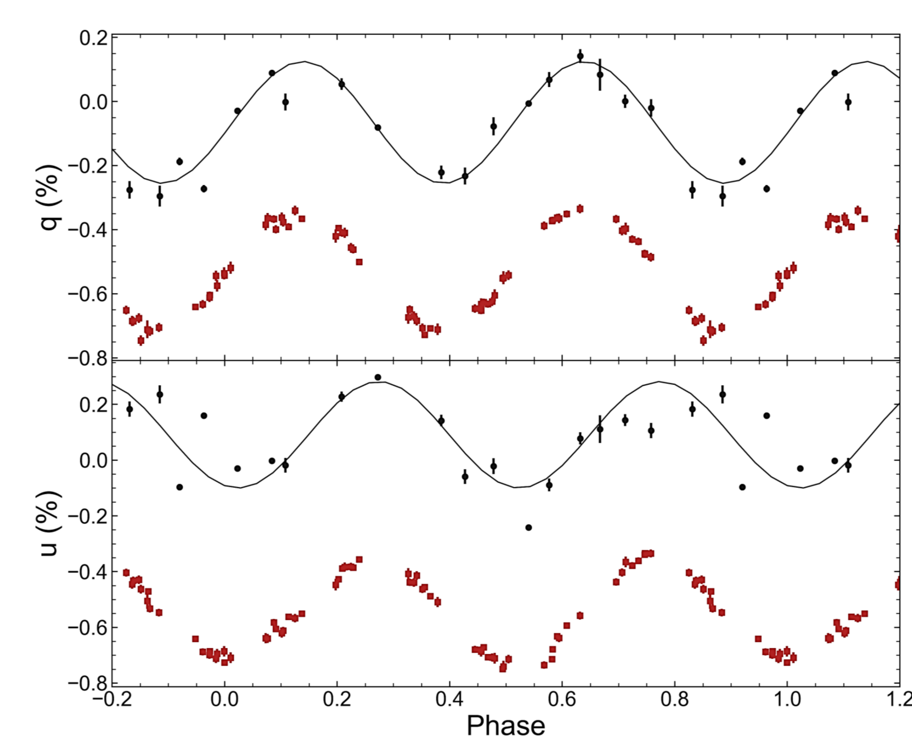

Figure 5: As in Figure 4, but for WR 42. The St. Louis et al. data (red squares) has been phase shifted by +0.04. [4]

I fit the BME model to the continuum polarization data of WR 79 and WR 42 obtained by the RSS spectropolarimeter on the Southern African Large Telescope (SALT). This model returned six primary variables, which I then used to calculate all orbital parameters [5].

Generally the SALT data matches the predicted BME model, although there are slight deviations in q and u that could indicate that the initial assumptions made are not a complete reflection of the system.

The error estimates in Table 1 for the SALT data are based upon the Wolinski & Dolan method [6], which account for intrinsic polarimetric biases as well as fit uncertainties.

	WR 79 SALT Data	WR 79 St. Louis Data [3]	WR 42 SALT Data	WR 42 St. Louis Data [3]
i	55° ± 3.9°	44.8° ± 5°	53° ± 6.3°	43.5° ± 5°
Ω	-29° ± 15°	34.4° ± 8°	-46° ± 20°	-43.8° ± 9.3°
λ_2	3° ± 9°	-44.8° ± 3.6°	-29° ± 10°	-26.5° ± 5.7°

Table 1: BME parameters returned by the error weighted average (SALT) and the St. Louis et al. data [4]. Lambda_2 (λ_2) is the measure of the distribution of scattering material with respect to the line between the stars [3].

Discussion & Conclusions

Some of the difference in calculated orbital parameters between St. Louis et al. and my work can be attributed to the different bands, or sections of the spectrum, used to study these objects. St. Louis used a wide band that covered the strongest emission line in the spectrum of these stars. Since line photons likely exhibit different polarization behavior than continuum photons, using a wide band could pollute the continuum measurement.

The BME model tends to return over-estimations for inclination angle (Figure 3). Since all further calculations for orbital parameters are based upon this value, any error introduced here is magnified.

Values obtained for u and q are not centered at the zero line, which indicates there is still some intrinsic polarization that we have not accounted for. This is most likely either some remaining interstellar polarization that has not been subtracted or that there is an elongated scattering region surrounding the stars.

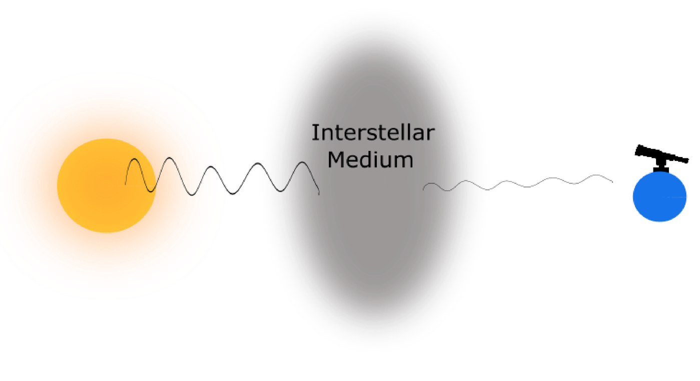

Figure 6: Light emitted from stars passes through the interstellar medium (ISM), the gas and dust floating in space, before it can reach our telescopes. The ISM imprints its own polarization signature, known as interstellar polarization.

Although the BME model of the scattering regions can provide a basic model of their behavior, it does not fully capture the complex nature of these stellar winds. Some of the deviations from the BME model present in our curve are likely due to a higher density scattering region and additional scattering material, such as gas lying in the orbital plane of the system, that the model does not account for.

Further studies of these systems using emission line polarization can help to further map the wind interaction regions and can provide a clearer pictures of the life of these stars.

References

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[6] – Wolinski, Karen G., & Joseph F. Dolan, *Monthly Notices of the Royal Astronomical Society*, vol. 267, 1994

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