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A Comparison of the Well-constrained Geometry of V444 Cygni and Two Possible Analogs: WR 21 and WR 62a

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1. Introduction

Massive stars show a statistical propensity for forming in binary systems, where the presence of a companion affects their evolution (Sana et al. 2012). WR+O binary systems are particularly interesting examples, as they may create the rapidly rotating WR stars that likely give rise to ultra-energetic GRB explosions (Woosley et al. 1993; Shara et al. 2017).

V444 Cygni is a well-studied eclipsing WN5+O6II-V system ($i = 78^\circ 3$, 4.2 days period; Eriş & Ekmekçi 2011) whose polarimetric behavior is influenced by a rotationally distorted cavity in the WN star wind (St-Louis et al. 1993; Lomax et al. 2015). In this paper, we compare the line polarization behavior of V444 Cyg, including 10 new observations, with that of two similar but non-eclipsing WR+O binaries: WR 21 (WN5+O7; $i = 50^\circ - 69^\circ$; 8.9 days period; Lamontagne et al. 1996; Fahed & Moffat 2012) and WR 62a (WN5+O5.5-6, i unknown; 9.1 days period; Shara et al. 1999; Collado et al. 2013). We aim to assess whether the latter 2 systems show similar wind structures to that of V444 Cyg.

2. Observations

We obtained new polarization spectra for V444 Cyg between 2013 July and October using the Half-Wave

Spectropolarimeter (HPOL) on the University of Toledo's 1 m Ritter Observatory telescope (Davidson et al. 2014). We calculated orbital phases for all V444 Cyg observations, including those in Lomax et al. (2015), using the updated quadratic ephemeris of Eriş & Ekmekçi (2011).

The spectropolarimetric data for WR 21 and WR 62a were collected between 2017 December and 2019 August with the Robert Stobie Spectrograph (RSS; Kobulnicky et al. 2003) on the 11 m Southern African Large Telescope (SALT; Buckley et al. 2006). We used ephemerides from Fahed & Moffat (2012, WR 21) and Collado et al. (2013, WR 62a) to determine the phases of these observations.

3. Line Polarization

For each target, we obtained the integrated polarization in the He II $\lambda 4686$ line using the *pfew* method (Lomax et al. 2015). To account for the different orientations of the three objects, we rotated the line polarization data for each to the mean position angle of its nearby continuum; this relates the polarization of each line to the intrinsic axis of its system. We did not attempt to remove interstellar polarization. We compare the results in Figure 1.

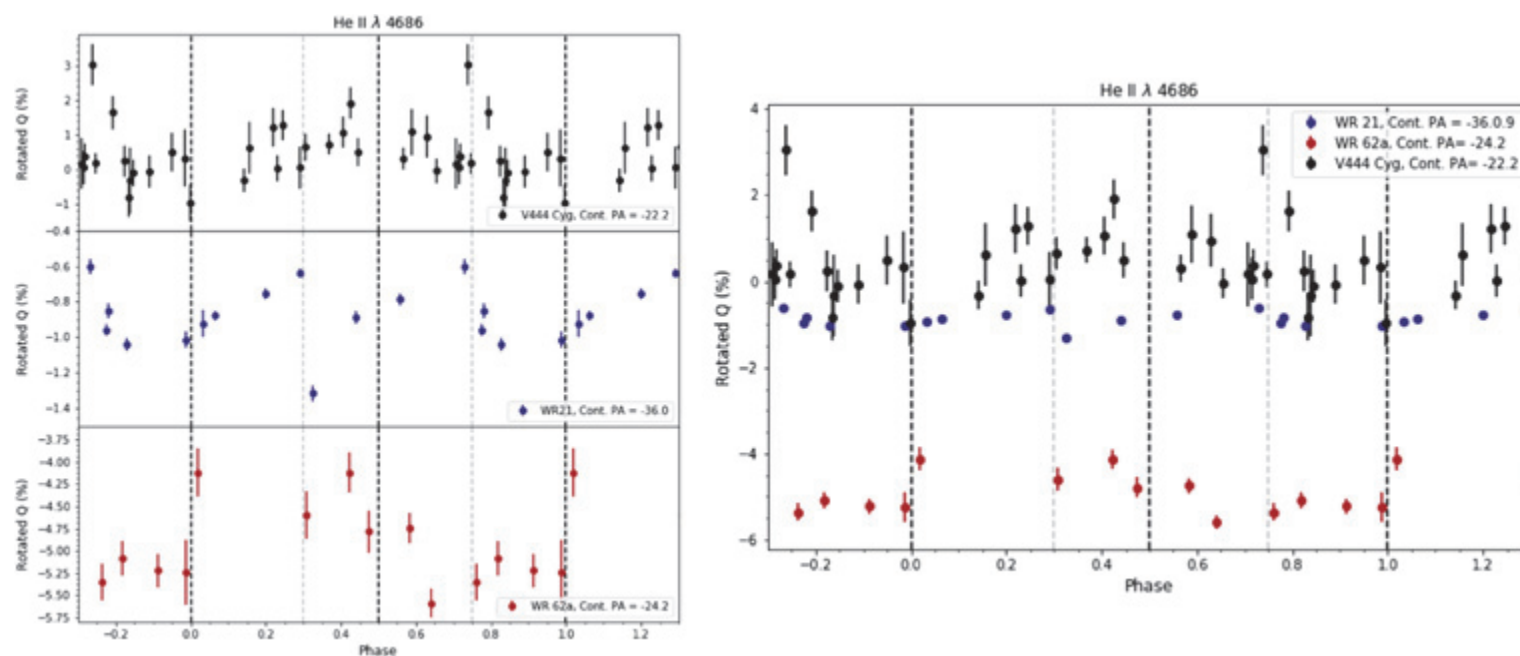


Figure 1. Rotated integrated He II $\lambda 4686$ polarization as a function of orbital phase for our three targets. Error bars represent 1σ intrinsic uncertainties. Black dashed lines mark eclipse phases; gray dashed lines indicate shock cone boundaries determined from an X-ray model of V444 Cyg (Lomax et al. 2015). Differences in absolute q values are likely due to differing interstellar polarization contributions.

4. Discussion

The new data for V444 Cyg support our previous conclusions that the line polarization behavior reflects the influence of a shock cone in the colliding winds between phases 0.3 and 0.75 (Lomax et al. 2015). The differences among the three curves arise from a combination of factors: the orbital period determines the amount of Coriolis distortion of the shock cone (Lomax et al. 2015); the orbital separation controls the amount of radiative braking/inhibition and thus the

opening angle of the cone (Stevens & Pollock 1994; Owocki & Gayley 1995); and the orbital inclination determines the resulting asphericity of the wind seen from our viewing angle. WR 21 shows similar polarization variations to V444 Cyg at similar phases, but with a smaller amplitude, suggesting it may have a similar wind geometry but a lower inclination angle. WR 62a shows intrinsic variations that do not resemble the others', which may indicate that its inclination is very low. Further analysis and modeling of the line variations will allow quantitative comparisons of the inclination angles and other system properties.

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