Massive Stars Near and Far
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Double Vision: Combining X-ray and Spectropolarimetric Observations of WR Binaries

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Abstract. We present X-ray and spectropolarimetric observations of the WN+O binaries WR71 and WR97, which are analogs of the well-studied V444 Cygni. The combined results have the potential to constrain the locations and properties of wind interaction regions in these binaries, give clues to their subsequent evolution, and address the commonalities among WR+O systems.

Keywords. Spectropolarimetry, X-rays, WR stars, binary systems

1. Introduction

Massive, evolved Wolf-Rayet (WR) stars are often found in binary systems. WR+O systems are of particular interest due to their theorized capacity to evolve into gamma ray burst (GRB)-producing supernovae upon their deaths. Binary interactions may provide a mechanism to create the rapidly rotating WR stars necessary for GRB formation in the collapsar model (Woosley et al. 1993; Vink & de Koter 2005). Studying the strong wind collisions between stars in WR+O binaries allow us to investigate their mass loss and mass transfer properties, identify signatures of rapid rotation, and predict the nature of their explosive deaths.

By combining X-ray and spectropolarimetric observations of these systems, we can determine the location and characteristics of colliding wind regions. Optical spectropolarimetry constrains the shapes of the regions that emit and scatter continuum and line photons. X-ray observations reveal the locations and other properties of high-temperature wind collisions. Lomax et al. (2015) found a correlation between the X-ray and line polarization phase behavior in the WN+O binary system V444 Cygni. Analysis of these data pinpointed the location and structure of the colliding winds, revealing a shock cone with a wide opening angle and an off-center orientation due to Coriolis deflection, detected in V444 Cyg for the first time.

We present preliminary analysis of X-ray and optical spectropolarimetric variations in WR71 and WR97, short-period WN+O binaries chosen for their spectral similarity to V444 Cyg. We seek to understand how structurally comparable the three systems are.

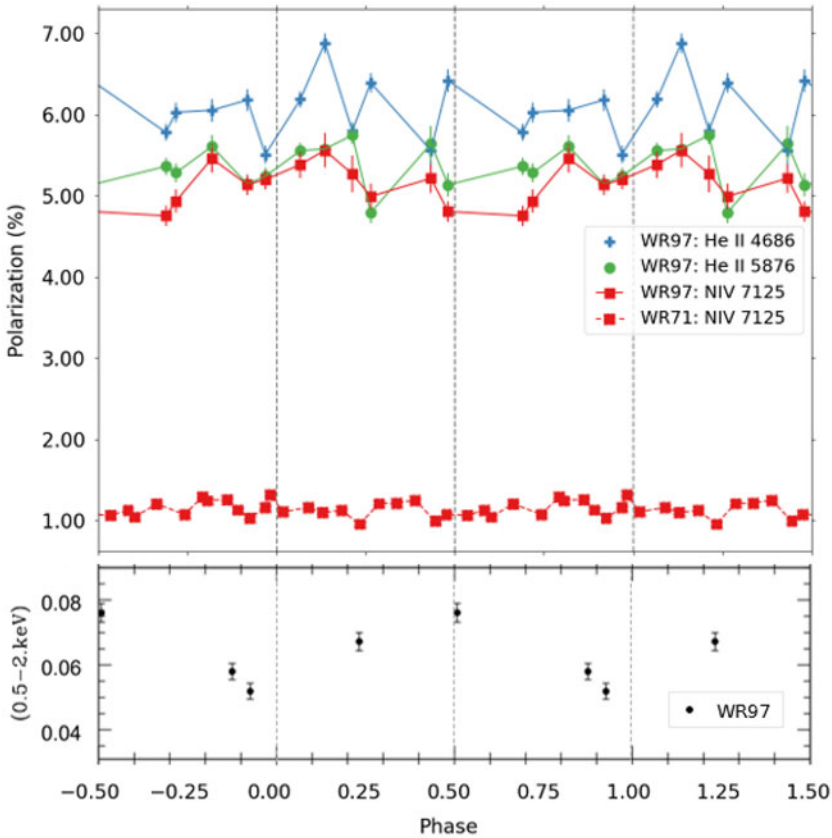

Figure 1. RSS line polarization phase variations for 3 emission lines in WR97 (*top, upper solid lines*), compared with its *Chandra* X-ray variations in the $0.5 - 2$ keV band (*bottom*). Polarization of one representative line of WR71 is also shown for comparison (*top, lower dashed line*), with error bars smaller than the points.

2. Methodology

We collected phase-sampled optical spectropolarimetry for WR71 and WR97 between 2018 and 2022 using the RSS instrument on the 11-m Southern African Large Telescope (Kobulnicky et al. 2003). We extracted narrow-band continuum (Massey 1984) and integrated polarization in the strong He and N emission lines for both targets. Lomax et al. (2015) found that these lines were significantly polarized and correlated with X-ray behavior in V444 Cyg. We also obtained 2 observations of WR71 with *XMM-Newton* and 4 observations of WR97 with *Chandra*, and combined these with archival data from *XMM-Newton*, *Chandra*, and *Swift*.

3. Results

WR97 shows both X-ray emission and line polarization variations with phase. There is some possible correlation between the two as in V444 Cyg, particularly in He II λ4686, which has intrinsic polarization changes as large as 1.5% (Fig. 1). However, it is difficult to explain the X-ray behavior with a colliding wind model. We are working to update the ephemeris and construct models that reproduce both the X-ray and polarization data.

By contrast, WR71 does not emit bright X-rays, and its continuum polarization variations suggest it may be a single rotating WR star rather than a binary. Several emission

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lines show low-amplitude polarization variability similar to that of the continuum (Fig. 1); these may be attributable to corotating interaction regions within the wind.

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