X-ray Emission Line Profile Modeling of O stars: ζ Puppis as a Wind-Shock Source

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The velocity of the wind is given by

\[ v(r) = v_0(1 - R_*/R)^{1/2}. \]  

Combining these assumptions, the line profile, parameterized by \( \tau \), is given by

\[ I_{\nu}(\lambda) \propto \left( \frac{R_*}{R} \right)^{1/2} \tau(\Delta \lambda) \]  

We adopt the flexible line profile model developed by Owocki & Si, and S, and L-shell lines of Fe). Needed to produce such ionization states is a mystery, but leading to density squared, with an extra factor of \( 10^{53} \). For an electronic version of this poster, paper preprints, and updates, visit https://www.sccs.swarthmore.edu/~roban/x-ray/ or http://astro.swarthmore.edu/~cohen/

Results for the Chandra spectrum of ζ Puppis

Best-fit and extreme models for the O XVIII line at 18.97 Å are shown demonstrating the range of models that can be fit to a single line. Shown are the fit with \( \tau_* \) held at its 95.4% confidence upper limit (\( \tau_* = 5.0 \), line profile green, left wind map), best fit (\( \tau_* = 2.3 \), line profile black, center wind map) and fit with \( \tau_* \) held at its 95.4% confidence lower limit (\( \tau_* = 1.0 \), line profile in purple, right wind map).

Model parameters versus wavelength (best-fit values and 95.4% confidence limits) for seven analyzed lines (to appear in Kramer, Cohen, & Owocki, 2003). All fits were performed with a fixed value of \( \beta = 1 \).

Key conclusions:
1. ζ Puppis line profiles are well fit by a spherically-symmetric, distributed-wind-shock model.
2. X-ray emission begins near the surface of the star (indicated by small \( R_* \) values).
3. Wind x-ray opacity is low but non-zero.
4. Fit parameters exhibit no obvious trends with line wavelength.

Conclusion 3 is surprising because significantly higher values of \( \tau_* \) were expected, given prior determinations of the star’s mass-loss rate. This may be indicative of clumping, which could reduce the effective opacity of the wind. We were also intrigued to find little variation in \( \tau_* \) with wavelength. This is surprising because photonization cross sections should scale roughly as \( \lambda^2 \). This could be an effect of the distribution of ionization edges, or perhaps, extreme clumping.

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