A mass-loss rate determination for zeta Puppis from the quantitative analysis of X-ray emission line profiles

David H. Cohen (1), Maurice A. Leutenegger (2), Emma E. Wollman (1,3), Janos Zsarg'{o} (4,5), D. John Hillier (4), Richard H. D. Townsend (6,7), Stanley P. Owocki (6)

(1) Swarthmore College, (2) NASA-GSFC, (3) Caltech, (4) Univ. Pittsburgh, (5) IPN, Mexico City, (6) Univ. Delaware, (7) Univ. Wisconsin

We fit every emission line in the high-resolution Chandra grating spectrum of zeta Pup with an empirical line profile model that accounts for the effects of Doppler broadening and attenuation by the bulk wind. For each of sixteen lines or line complexes that can be reliably measured, we determine a best-fitting fiducial optical depth, tau_* = kappa*Mdot/4{pi}R_{ast}v_{infty}, and place confidence limits on this parameter. These sixteen lines include seven that have not previously been reported on in the literature. The extended wavelength range of these lines allows us to infer, for the first time, a clear increase in tau_* with line wavelength, as expected from the wavelength increase of bound-free absorption opacity. The small overall values of tau_*, reflected in the rather modest asymmetry in the line profiles, can moreover all be fit simultaneously by simply assuming a moderate mass-loss rate of 3.5 pm 0.3 times 10^{-6} Msun/yr, without any need to invoke porosity effects in the wind. The quoted uncertainty is statistical, but the largest source of uncertainty in the derived mass-loss rate is due to the uncertainty in the elemental abundances of zeta Pup, which affects the continuum opacity of the wind, and which we estimate to be a factor of two. Even so, the mass-loss rate we find is significantly below the most recent smooth-wind H-alpha mass-loss rate determinations for zeta Pup, but is in line with newer determinations that account for small-scale wind clumping. If zeta Pup is representative of other massive stars, these results will have important implications for stellar and galactic evolution.

Reference: Monthly Notices of the Royal Astronomical Society, in press.
Status: Manuscript has been accepted

Weblink: http://arxiv.org/abs/1003.0892

Comments: 17 pages, including 14 figures (7 color)

Email: dcohen1@swarthmore.edu