Chandra X-ray spectroscopy of the very early O supergiant HD 93129A: constraints on wind shocks and the mass-loss rate

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We present analysis of both the resolved X-ray emission line profiles and the broadband X-ray spectrum of the O2 If* star HD 93129A, measured with the Chandra HETGS. This star is among the earliest and most massive stars in the Galaxy, and provides a test of the embedded wind shock scenario in a very dense and powerful wind. A major new result is that continuum absorption by the dense wind is the primary cause of the hardness of the observed X-ray spectrum, while intrinsically hard emission from colliding wind shocks contributes less than 10% of the X-ray flux. We find results consistent with the predictions of numerical simulations of the line-driving instability, including line broadening indicating an onset radius of X-ray emission of several tenths Rstar. Helium-like forbidden-to-intercombination line ratios are consistent with this onset radius, and inconsistent with being formed in a wind-collision interface with the star's closest visual companion at a distance of ~100 AU. The broadband X-ray spectrum is fit with a dominant emission temperature of just kT = 0.6 keV along with significant wind absorption. The broadband wind absorption and the line profiles provide two independent measurements of the wind mass-loss rate: Mdot = 5.2_{-1.5}^{+1.8} times 10^{-6} Msun/yr and Mdot = 6.8_{-2.2}^{+2.8} times 10^{-6} Msun/yr, respectively. This is the first consistent modeling of the X-ray line profile shapes and broadband X-ray spectral energy distribution in a massive star, and represents a reduction of a factor of 3 to 4 compared to the standard H-alpha mass-loss rate that assumes a smooth wind. Finally, we also model the H-alpha emission line, using our lower mass-loss rate and a clumping factor of f_V = 0.08. We find that a clump onset radius of 1.05 Rstar is required to fit the data.

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

Weblink: http://adsabs.harvard.edu/abs/2011arXiv1104.4786C

Comments: 12 pages; 2 tables; 10 figures (5 color).
Further information available at http://astro.swarthmore.edu/~cohen/papers.html#hd93129

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