Wind Opacity Issues

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Sept. 2006

The detailed wind modeling using PoWR produced this plot of wind opacity (essentially; note the y-axis label) for four stars. It appears that the only K-shell edge is that of (a single ion state of) nitrogen. This seems pretty crude. And it makes me wonder what elements are included in the calculation of the overall opacity, and how reliable the smooth portions of the curves are.

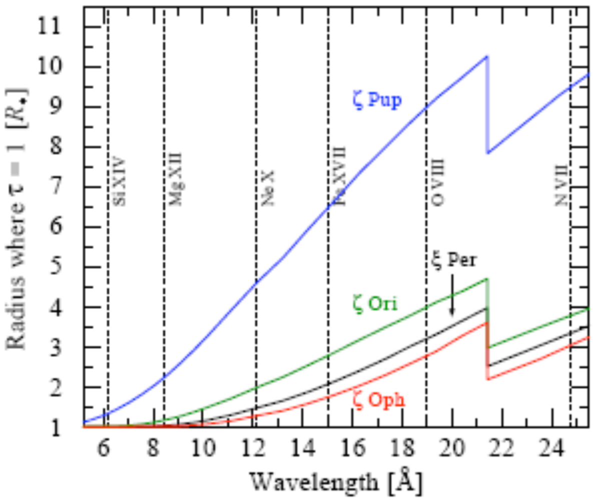

Figure 5. The radius were the radial optical depth of the wind becomes unity in dependence on the wavelength in the Chandra HETGS/MEG range. The calculations were done using the PoWR stellar atmosphere code (see text) with stellar parameters from Table 2. The prominent edge at λ 21.5 Å is due to oxygen. The vertical dashed lines correspond to the wavelengths of the studied lines (as indicated).

Below are three other calculations of wind opacity in the soft x-ray for OB stars from the literature. OFH06 would like to argue that the wavelength-dependence of the opacity is steep across the MEG range (functionally, for our purposes, ~8 to 22 Angstroms, or 0.6 to 1.3 keV), but see the calculations below and the effects of multiple ion stages and elements.

This pretty detailed and for a "typical early O star" calculated by Waldron et al. 1998. It shows the multiple ion stages, K- and L-shells of several elements, and the deviations from neutral (ISM) opacity, with the associated shifting of the K-shell edges to higher energies.

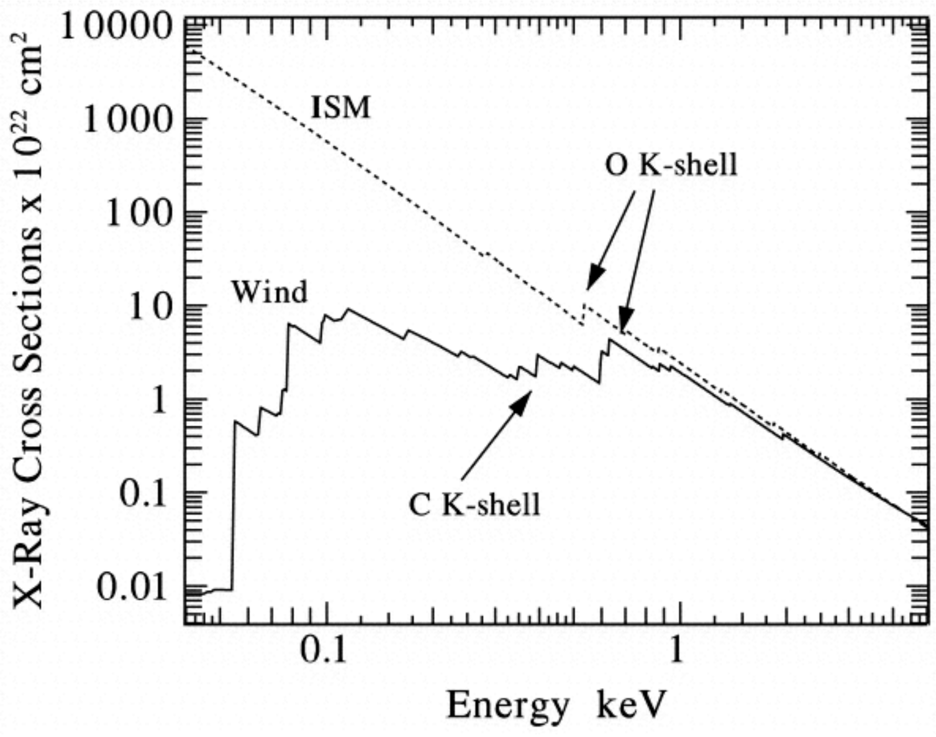

FIG. 2.—Comparison of ISM (cold) and stellar wind (warm) X-ray cross sections for a typical early O star (T_{eff} = 40,000 K). Note the large number of wind absorption edges and the relative flatness of the wind cross sections between 0.1 and 1 keV. Above 0.6 keV, the ISM and wind cross sections are essentially the same. The C and O K-shell edges are indicated. Comparing the ISM and wind cross sections we notice an energy shift (~0.08 keV) of the O K-shell edge, which is a reflection of the higher ionization state of the wind. [from Waldron et al., 1998, ApJS, 118, 217]

Similar overall opacity for a cooler early B star (specifically, epsilon CMa). Note more He+ than in Waldron’s calculation.

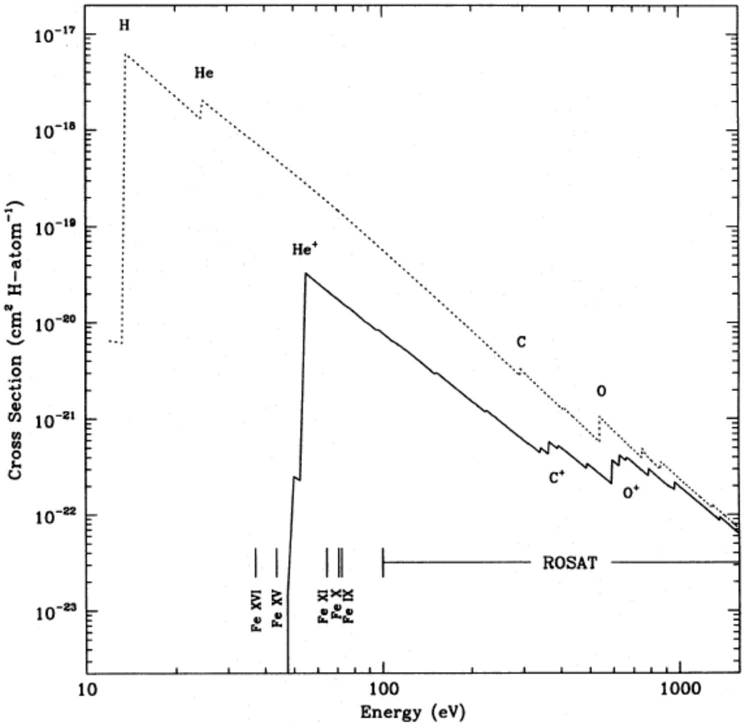

FIG. 4.—The cross section per hydrogen atom for the ions in the stellar wind (*solid line*) and for neutral elements in the interstellar medium (*dotted line*) is plotted vs. photon energy. It should be noted that while the interstellar medium has a much higher opacity per particle than does the wind material, the total column of material in the interstellar medium is, for ϵ CMa, much less than the wind column. Therefore above 54 eV the stellar wind is the primary source of opacity. The locations of the five detected EUV lines are indicated along the bottom of the plot, along with the *ROSAT* bandpass.

This is from the Hillier et al. (1993) analysis and modeling of zeta Pup (note: same y-axis as OFH06). Multiple elements (and according to the caption, accounting for the specific abundances of zeta Pup) are present, but maybe not multiple ionization states.

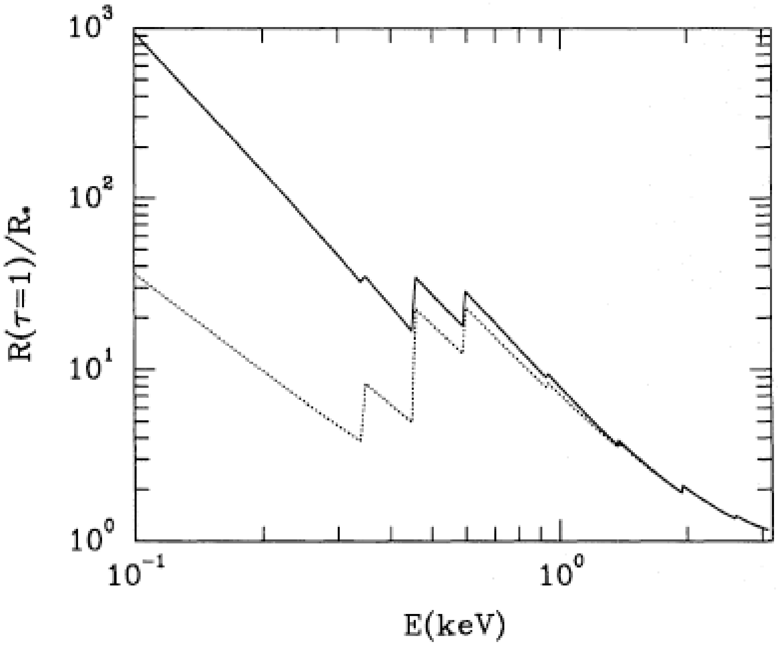

Fig. 1. Radius of optical depth unity as a function of X-ray energy. (solid - Model 1; dashed - Model 2). The observed X-ray flux scales approximately as the inverse of R(τ = 1). Note the strong K shell edge (near 0.5 keV) due to nitrogen, whose abundance is considerably enhanced over solar values (see Table 2)