Effects of X-Rays on the Ionization State of Be Star Winds

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It is important to understand the ionization state of Be star winds for several reasons, including: (1) if known, mass loss rates can be determined from UV P Cygni profiles; (2) the radiation line driving force which accelerates the winds depends on the ionization distribution; and (3) analysis of line profiles, in conjunction with polarization data, can help assess the credibility of various hypotheses for the asymmetric nature of Be star winds.

Here, we describe preliminary calculations to predict the ionization state in Be star winds. Calculations were performed for η Cen (B1.5 Ve), which has a mass loss rate constrained by UV observations of Si IV and Si III lines (Snow 1981), and an X-ray luminosity recently measured by ROSAT (Cassinelli *et al.* 1993). A list of stellar parameters used in our calculations is shown in Table I.

In our model, multilevel statistical equilibrium equations are solved self-consistently with the radiation field to determine atomic level populations (MacFarlane *et al.* 1993). Approximately 200 atomic levels were included in

TABLE I

Adopted Parameters for η Cen

$\mathrm{M} = 3 \times 10^{-10}\ \mathrm{M}_\odot/\mathrm{yr}$	$T_{eff} = 24,000$ K	$T_X = 2 \times 10^6$ K
$v_\infty = 770$ km/sec	$\log g = 4.0$	$L_X = 9.3 \times 10^{28}$ erg/sec
$T_{wind} = 24,000$ K	$R_* = 7.5\ R_\odot$	$L_X/L_{bol} = 7.8 \times 10^{-9}$

the multi-component plasma model consisting of H, He, C, N, O, and Si. The radiation field included contributions from the photosphere (Mihalas 1972), diffuse radiation from the wind, and X-rays from a high-temperature plasma source ($T = T_X$). Radiative transfer effects were computed assuming spherical symmetry using a multi-ray impact parameter model.

Results for the calculated ionization distributions for He and Si are shown as a function of scaled velocity ($\equiv v/v_\infty$) in Fig. 1. For both species, results are shown for 2 cases: one with an X-ray source distributed throughout the wind, and the other with no high-temperature X-ray source. Without X-rays, He II is predicted to be the dominant ionization stage throughout the wind, with the ionization fractions q(He I) and q(He III) being $< 10^{-4}$. However, when X-rays are included, He III is predicted to be the dominant ionization stage in the outer part of the wind ($v > 0.12\ v_\infty$; $r > 1.1\ R_*$).

Fig. 1 also shows that Si V is predicted to be the dominant ionization stage at $v < 0.45\ v_\infty$ when X-rays are neglected, and throughout the wind when X-rays are included. The Si V is produced by photoionization out of highly excited states of Si IV. With X-rays, q(Si IV)+q(Si III) $\leq$ 0.2 throughout the wind. This suggests that the mass loss rate determined by assuming that all Si resides in Si III or Si IV (Snow 1981) may be too low by roughly a factor of 5. It is important to note, however, that the above calculations do not include effects of density clumping (due to shocks), non-spherical winds, and disks. Further investigations are in progress.

References

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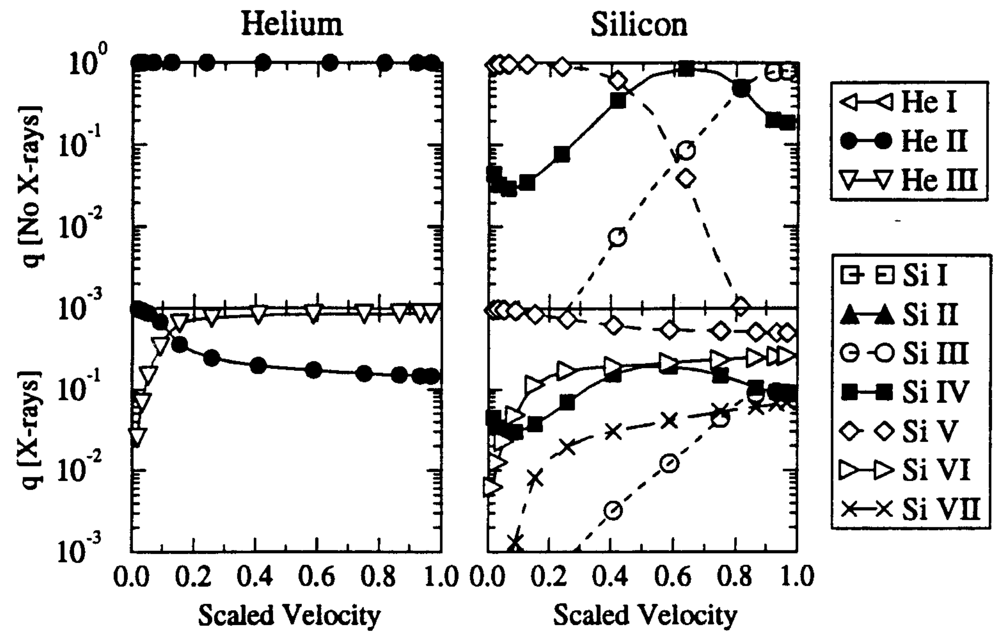

Fig. 1. Calculated ionization distributions for He and Si. The effect of X-rays can be seen by comparing the top and bottom figures for each species.