SUBIONIZATION AND DECELERATED-FLOW IN THE VICINITY OF A B-SHELL STAR

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Three types of spectra have been extensively observed among main-sequence B stars. B-normal is the classical absorption spectrum which defines a normal main-sequence B star. Be is a B-normal spectrum except : (i) some absorption lines, notably the first hydrogen Balmer series members, are replaced by emission lines; (ii) some lines from some singly-ionized metals, not normally present in B stars, sometimes appear, either in emission or absorption. Be-shell is a Be spectrum with narrow and deep absorption cores in the Balmer and singly-ionized metal lines. A fourth type, B-shell, has been identified as a B-normal, absorption, spectrum except for the presence of FeII lines, and narrow, deep absorption cores in these and the hydrogen Balmer lines. Once thought to each represent a different kind of star, these spectra are now realized to simply represent different temporal phases, which one and the same star can traverse, apparently in no (as yet) fixed order. Some of the brightest stars --- eg γ Cas, 59 Cyg, Pleione --- have been observed in all of the 3 prominant phases; some stars, in only some of them; 70 % of the B stars have been observed only in the B-normal phase.

In the farUV, the distinction between Be and B-normal stars mainly vanishes, in the sense that most lines are in absorption --- except for a few like MgII h and k --- and in all these, both B and Be appear the same. The peculiarity in the farUV, instead of being emission lines and sub-ionized metal lines in some B stars, is the presence in all B stars of a variety of super-ionized lines --- up to OVI. Some stars, both Be and B, show coronal-level x-rays. The statistical difference between B and Be, especially among the hotter B stars, lies in Be stars showing much larger line-displacements than do B-normal stars. Also, when the singly-ionized metals appear in the visual spectrum, both singly and doubly ionized such ions appear in the farUV.

Current attempts to model atmospheres that can produce the above phenomena usually focus on the emission-lines in the visual, the highly-displaced ionized lines in the farUV, and the x-rays. Explanations center around the added effects of mass- and nonradiative energy-fluxes in producing an outer atmosphere supplementary to the classical photosphere

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with properties fixed by the radiative flux. However, the phenomena of the sub-ionized species which, together with the Balmer lines, only show line-displacements $\lesssim$ 100 km/s, provide equally-puzzling modeling problems. The super-ionized, highly-superthermic flow requires heating and acceleration in the first few stellar radii above the photosphere. The sub-ionized, $\lesssim$ 100 km/s flow, requires cooling and deceleration in the region between some 5 and 100 stellar radii. (This upper limit comes because an r^{-2} density distribution, accompanying a mass-flow, would otherwise give too rapid a density drop to provide HI, and permitted FeII, lines.) Such cooling and deceleration is not surprising by itself; many authors discuss an eventual deceleration and cooling of stellar winds, but at distances of about a parsec, much greater than the preceeding distances.

To put the problem into focus, I present a simple calculation in which the wind is decelerated, and cooled, by interaction with the ISM and with the preceeding wind. I simply balance the momentum originally lying in the wind, having maximum velocity V_o at a place where its particle concentration is N_o, against that of wind+ISM at some shell-front, moving at V_r and with particle-concentration N_r. I assume the undisturbed ISM had concentration N_m; and that the space between star and wind has been swept clean of ISM material, so that deceleration occurs only at the shell; but I ignore the details of shocks, compression, heating and eventual cooling, etc. These are considered in a following discussion (Doazan, Thomas, Zorec, 1981). The descriptive equation is then :

$$\dot{M}V_o t = (4\pi N_m r^3 m_H/3 + \dot{M}t)V_r \qquad (1)$$

$$\dot{M} = 4\pi\ r_o^2\ N_o m_H V_o \qquad (2)$$

where t is the time since the star began the phase with mass-flux $\dot{M}$. So at the epoch where the "shell" has an expansion velocity V_r/V_o, the location of the shell is given by :

$$\frac{r}{r_o} = \left\{(V_o/V_r - 1)\ (N_o/N_m)\ (3V_o t/r_o)\right\}^{1/3} \qquad (3)$$

Clearly, a <u>lower limit</u> on r/r_o is set by taking $V_o t = r$; in which case,

$$r/r_o = \left\{3(V_o/V_r - 1)\ (N_o/N_m)\right\}^{1/2} \qquad (4)$$

Taking $V_r \sim 100$ km/s $\sim 0.1V_o$; and $N_m = 1, N_o = 10^{10}$; we obtain an $r/r_o \sim 5.10^5$, and t ~ 300 years for $r_o \sim 3$ stellar radii ~ 30 solar radii. Such a shell, occuring at about 0.3 psc, after about 300 years of steady mass-flow, hardly satisfies the sub-ionization, and shell-phase, observations. To postulate a locally-denser ISM to resolve the conflict requires essentially mass-flow densities, because of the 1/3 or 1/2 dependance on N_m. Thus, it would appear that one requires interaction between two mass-flux epochs : an earlier one, of lower size but still exceeding very considerably the ISM; and a later one, of larger size and velocity. These

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phenomena, and simple calculations, illustrate the difficulty in trying to represent that observations by a constant mass-flux into a normal ISM environment. In a following paper, we (Doazan, Thomas, Zorec) attempt to put together data ranging from the x-ray to the radio, and across the phase-range of the B-stars, to suggest a preliminary, coherent, empirical picture.