DYNAMICS OF THE WIND OF LBV STARS

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Luminous Blue Variables are among the brightest objects and lie at the Humphreys-Davidson empirical limit of maximum luminosity (Lamers 1986b). A distinct feature of these stars is the higher rate of mass loss and the relatively lower terminal velocity than for other stars of the same spectral type. LBV stars show moderate photometric variations with $\Delta V \simeq 1 - 2^m$. They have higher $\dot{M}$ and lower v_∞ when they are brighter (*i.e.*, have a low T_{eff}). These stars probable represent a short phase in the evolution along the chain O $\rightarrow$ O$f\rightarrow$ LBV$\rightarrow$ WR. After investigating the dynamics of the wind of P Cygni, Lamers (1986a) concluded that the wind was best explained by radiation pressure arising from a large number of optically thin lines in the Balmer continuum. Recently Chen & Marlborough (1993) applied this driving mechanism to Be stars. Application of this mechanism to P Cygni has been criticized by Pauldrach & Puls (1990) who found that P Cygni's wind is driven by radiation pressure due to both optically thick (60 %) and optically thin lines and that it gives rise to the typical β velocity law. In our calculations we used a method developed by Vilkoviskij and Tambovtseva (1992). We assume that T_{eff}, M_*, R_*, $\dot{M}$ and initial velocity v_0 at the stellar surface are given. The input parameters have been taken from Lamers (1986b). All four LBV's (except P Cygni) are considered in their maximum phase, *i.e.*, when their winds are expected to be driven by radiation pressure in optically thin lines. A constant value of $v_o = 20$ km/s has been adopted. Force-multiplier parameters k and δ have been taken from Abbott (1982). If we assume that the acceleration of the wind is due to optically thin lines of metals in the Balmer continuum, than we must have $\alpha \ll 1$ (Abbott 1982). We stress that there are no calculations available to determine that quantity in the optically thin limit. We will estimate α later for P Cygni but for other stars we will use α as a free parameter. Note that α depends on the ratio of optically thick to optically thin lines in the wind. Basically k depends on the number of lines that produce radiation pressure and in our case a value of k can be even larger than given by Abbott (1982). The results of our calculations are presented in Table I. We give the values of v_∞ calculated for the indicated values of input parameters. The terminal velocities are in good agreement with the observational data (Lamers 1986b). As we outlined

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TABLE I
Calculated terminal velocities for four LBV stars

star	$M_*/M_\odot$	$R_*/R_\odot$	$\dot{M}$ ($10^{-5}M_\odot yr^{-1}$)	T_{eff} (10^4K)	α	k	δ	v_∞ (km/s)
Var A_{max}	78	65	5.8	2.70	0.25	0.32	0.2	359
Var B_{max}	50	65	1.0	2.29	0.30	0.32	0.2	343
AF And	74	72	3.5	2.50	0.25	0.32	0.2	347
P Cyg	27	78	1.5	1.93	0.28	0.32	0.2	203

above, to carry out the numerical calculations we must estimate α. This can be done for P Cygni. We used the equation

$$\alpha = \frac{1 - \gamma(1 - <\tau>)}{1 + N_2/N_1 <\tau>} \quad (1)$$

where N_2 and N_1 are respectively the numbers of optically thin and thick lines, $<\tau>$ is the average optical depth at which the optically thin lines are produced, and $\gamma = \mathrm{dln}N_1/\mathrm{dln}t$ where t is the optical depth in the wind. On the basis of our estimates and according to Lamers (1986a) we have $N_2 \sim 10^3$, $N_1 \sim 10^2$ and $<\tau> \geq 0.3$. Abbott (1982) has given a table of values of γ, but he calculated them under the assumption of optically thick lines. From physical considerations we can take $\gamma = 0$ for P Cygni, which corresponds to $\alpha = 0.25$. With the obtained velocity law we calculated the emission line profiles of several UV resonance lines (Israelian *et al.* 1993) and found that C lines form in deeper layers than the lines of Si ions. For Si we found a better agreement with the observed profiles.

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