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The Effects of a Weak Magnetic Field in the Line Profiles of A-type Supergiant Winds

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Solutions for the stellar winds of hot luminous stars are obtained by solving the magnetohydrodynamic (MHD) equations, combined with the theory of radiation-driven winds. The formalism is basically the same as developed by Rotstein & Giménez de Castro (1996). We have considered the interaction of radiation pressure with an open magnetic field . The magnetic field lines are pushed by the intense radiation field and adopt a purely radial configuration:

$$B_r = \frac{2a}{r^2}\cos\theta, \qquad B_\theta = B_\phi = 0 \tag{1}$$

and the polar magnetic flux at the photosphere:

$$B(x=1,\theta=0) = \frac{2a}{R_*^2} \quad \text{with} \quad x = \frac{r}{R_*}. \tag{2}$$

Rotstein & Giménez de Castro (1996) assume all the lines contributing to the radiation pressure are optically thick (α=1) in order to decouple the MHD equations. Here the model has been improved to adopt a value of α=0.6 which is a better approach for A-supergiants.

The formalism has been solved for a slowly rotating star (47 km s^{-1}) with a wind of $v_\infty = 307$ km s^{-1}, $\dot{M} = 10^{-7} M_\odot \mathrm{yr}^{-1}$ and $\alpha = 0.6$ plus a magnetic field in equipartition, which yields a value for the polar magnetic flux of 2.5 G. The presence of a magnetic field modifies the classical β-velocity law. It introduces a smooth discontinuity at the Alfvén point because the slope of the velocity curve changes significantly from the slow magnetosonic to the fast magnetosonic points. As a result, a shell is generated in the wind. In fact, when we use a velocity law of this form to model the Hα profiles with the Alfvén point at $20R_*$ and a velocity in this point of $v_\infty/2$, the modifications of the line profiles are clear: 1) The emission strength is much higher than the one produced by a classical β-law for the same values of mass-loss. Simultaneously the absorption depth decreases. 2) The models with high values of mass-loss rate give a line profile with absorption components as observed in the line profiles of α-Cygni type A-supergiants, whereas for smaller values of the mass-loss rate we obtain highly structured profiles which are also observed in late A-supergiants.

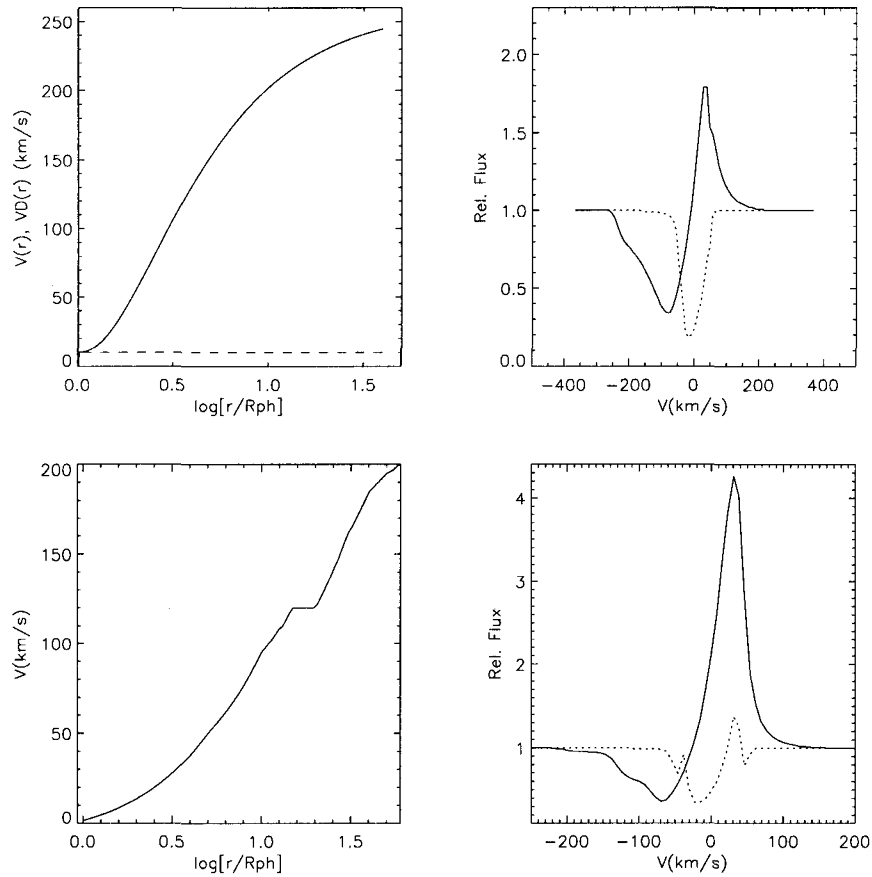

Figure 1. β (top left) and MHD (bottom left) velocity laws and the Hα profiles for two models with $\dot{M} = 0.8$ and $8.0 \times 10^{-7}\ M_\odot \mathrm{yr}^{-1}$.

References

Rotstein, N., Giménez de Castro, C.G. 1996, ApJ, 464, 859

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