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Hydrodynamic solutions of radiation driven wind from hot stars

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Abstract. We show the application of the δ- and Ω-slow hydrodynamical solutions to describe the velocity profiles of massive stars. In particular, these solutions can help to unravel some of the problems within the winds of massive stars such as the approximation of the β-law for the velocity profile of B supergiant stars and the slow outflow wind observed in Be stars.

Keywords. stars: early-type, stars: winds, outflows, stars: mass loss, stars: atmospheres, hydrodynamics

1. Context

The standard or *fast* solution from Castor et al. (1975) and later improved by Friend & Abbott (1986, hereafter m-CAK) reproduce quiet well the observed winds of massive stars, however some B-types on the main sequence and on the supergiant phases usually present a much slower velocity profile. In the following we present other two hydrodynamical solutions founded by our massive star group, which are useful to describe in particular the wind of B stars.

2. The δ-slow solution

The δ-slow regime (see Curé et al. 2011) is present when $\delta \gtrsim 0.28$ and is characterized by a slower terminal velocity and depending on the value of k, larger or smaller mass loss rate values are obtained compared to the values of the fast solution (Araya et al. 2021). By using the m-CAK hydrodynamic (instead of the generally used β-law) and the Non-LTE radiative transport code FASTWIND, we created a grid of models for fast and δ-slow regimes, setting the line-force parameters as free ones in a suitable range of values (`ISOSCELES` grid, Araya et al. 2022 in preparation) to study the wind of massive stars. The Fig. 1 shows the simultaneous fit of six spectral lines of the star HD99953.

3. The Ω-slow solution

For $\Omega = v_{rot}/v_{crit} \gtrsim 0.75$, the fast solution ceases to exist, and a much slower and denser solution is present, we called this solution Ω-slow (Curé 2004). Following de Araujo (1995), we implemented a mimicking viscosity parameter via

$$V_\phi = \Omega\sqrt{GM(1-\Gamma)/R}\,(R/r)^{\gamma_{vis}}, \qquad (3.1)$$

being V_ϕ the rotational velocity component of the wind in the equatorial plane and γ_{vis} a viscosity mimicking parameter. When $\gamma_{vis} = 1$ angular momentum is conserved and $\gamma_{vis} = 0.5$, describes a Quasi-Keplerian outflowing wind. Fig. 2 shows the velocity profile for a Be star with $\gamma_{vis} = 0.52$, and stellar parameters: $T_{\rm eff} = 21000K$, $\log g = 4.0$,

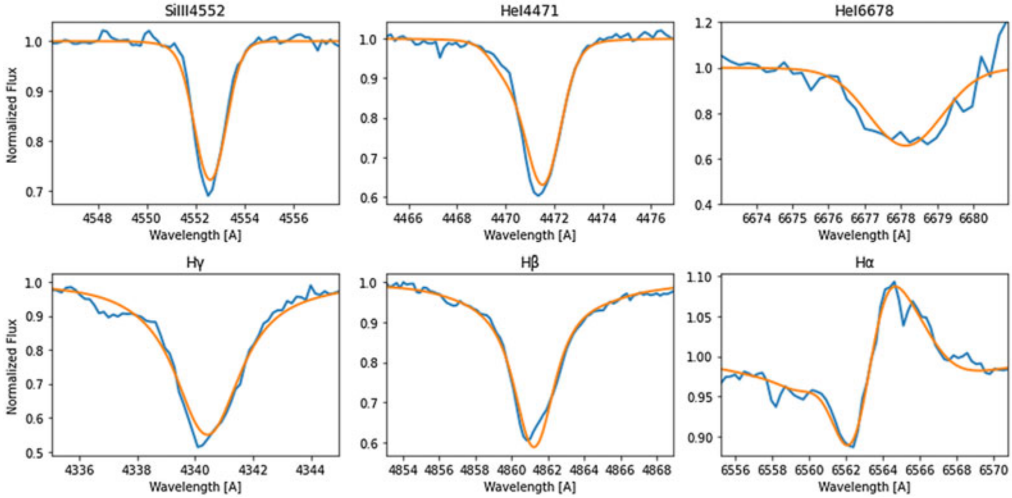

Figure 1. HD99953 (B2 Ia): Best fit for six stellar lines. Observed line profiles are in solid blue line and the synthetic best model in solid orange line. Stellar and wind parameters are the following: $T_{\rm eff} = 18500\,K$, $\log g = 2.4$, $R = 45.6\,R_\odot$, $V_\infty = 254\,{\rm km/s}$ and $\dot{M} = 2.43 \cdot 10^{-7} M_\odot/yr$.

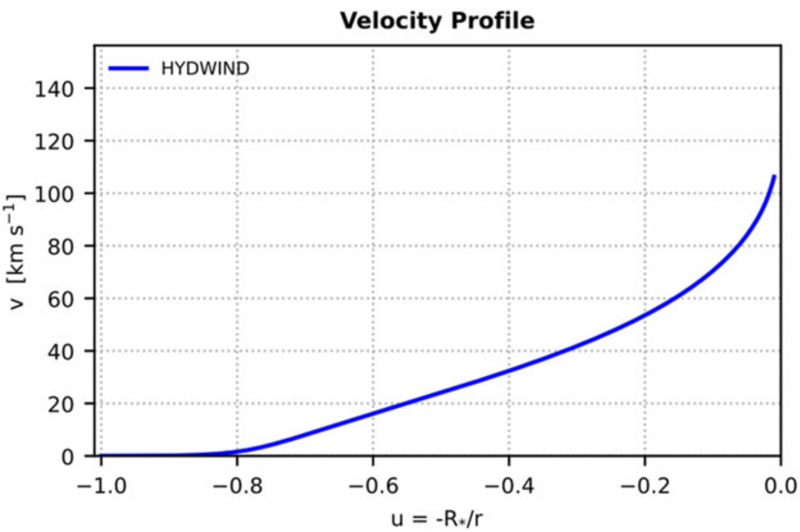

Figure 2. Velocity profile of a Ω-slow solution as a function of the inverse radial coordinate $u = -R/r$, with a γ_{vis}=0.52 which describe a Quasi-Keplerian outflowing decretion disk wind.

$R = 4.5\,R_\odot$ and $\Omega = 0.99$. The terminal velocity is 100 km/s, much lower than the case when angular momentum is conserved.

4. Conclusions

We have shown that both δ- and Ω-slow solutions can explain some of the current ‘problems’ that faces the massive star community. The δ-slow solution describes properly the winds of B stars and the Ω-slow solution with the inclusion of viscosity explains the viscous decretion disks of Classical Be stars.

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