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Radiation driven winds with rotation: the oblate finite disc correction factor

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Abstract. We have incorporated the oblate distortion of the shape of the star due to the stellar rotation, which modifies the finite disk correction factor (f_D) in the m-CAK hydrodynamical model. We implement a simplified version for the f_D allowing us to solve numerically the non–linear m-CAK momentum equation. We solve this model for a classical Be star in the polar and equatorial directions. The star's oblateness modifies the polar wind, which is now much faster than the spherical one, mainly because the wind receives radiation from a larger (than the spherical) stellar surface. In the equatorial direction we obtain slow solutions, which are even slower and denser than the spherical ones. For the case when the stellar rotational velocity is about the critical velocity, the most remarkable result of our calculations is that the density contrast between the equatorial density and the polar one, is about 100. This result could explain a long-standing problem on Be stars.

Keywords. stars: rotation, stars: winds, outflows, stars: early-type, stars: emission-line, Be

1. Introduction

Pelupessy *et al.* (2000) formulated the wind momentum equation for sectorial line driven winds including the finite disk correction factor for an oblate rotating star with gravity darkening for both the continuum and the lines. They calculated models with line–force parameters around the bi–stability jump at 25 000 K. In this case, from the pole to the equator, the mass flux increases and the terminal velocity decreases. Their results showed a wind density contrast $\rho(equator)/\rho(pole)$ (hereafter ρ_e/ρ_p) of about a factor 10 independent of the rotation rate of the star.

In this work, we implement an approximative version for the oblate finite–disk correction factor, f_O, allowing us to solve numerically the non linear m–CAK momentum. We solve then this equation for a *classical Be* star, for polar and equatorial directions. In this study we do not take into account the bi–stability jump.

2. Oblate Factor

In order to incorporate the oblate distortion of the shape of the star due to the stellar rotation to the m–CAK hydrodynamic model, we implement an approximative function. In view of the behaviour of f_O and f_D we approximate its ratio f_O/f_D via a sixth order polynomial interpolation in the inverse radial variable $u = -R_\star/r$, i.e., $f_O = Q(u)\, f_D$. In this form, we assure that the topology found by Curé (2004) is maintained by the f_D term, but it is modified by the incorporation of the $Q(u)$ polynomial. With this approximation we can solve numerically the non–linear m–CAK differential equation.

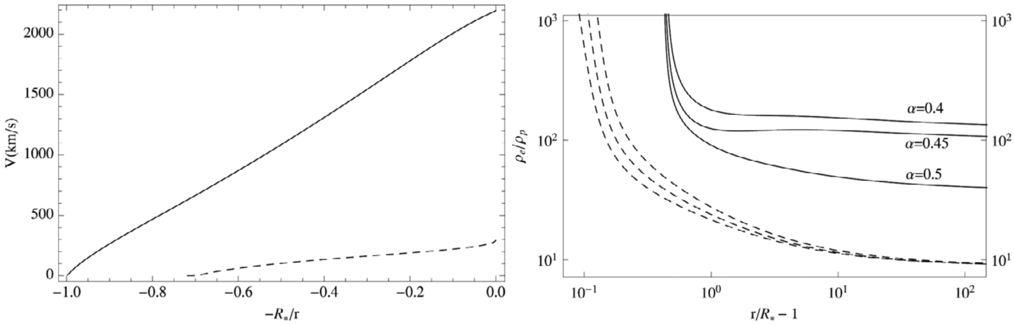

Fig. 1a Fig. 1b

Figure 1. a) Velocity versus u for equator (*dashed line*) and pole (*solid line*) with $\alpha = 0.4$ and $\delta = 0.07$. b) Solid lines: Density constrasts for $\omega = 0.99$ and $\delta = 0.07$. Dashed lines: Spherical cases.

3. Results

We solve the oblate m–CAK equations for a classical Be star with the following stellar parameters: $T_{eff} = 25\,000$ K, $log\,g = 4.03$, and $R/R_\odot = 5.3$ (Slettebak *et al.* 1980) and line–force parameter $k = 0.3$. For the other parameters, we have used two different values for δ, namely: $\delta = 0.07$ and $\delta = 0.15$, and three values for α, i.e., $\alpha = 0.4, 0.45, 0.55$. In this study, we have considered *the same value of* α*,* k *and* δ for the pole and equator, i.e. without taking into account the bi–stability jump. We show only solutions for $\omega = 0.99$ at the equator and pole. For the cases where $\alpha = 0.4$ and $\alpha = 0.45$, the density contrasts exceed a factor 100, values which are in agreement with observations (Lamers & Waters 1987).

4. Summary and Conclusions

The oblate correction factor has been implemented in an approximative form. The factor Q_r in the oblate correction factor certainly modifies the topology of the hydrodynamical differential equation and we suspect from first calculations that other critical points may exists and, therefore, more solutions might be present. We recover the observed density contrast only when the rotational velocity of the star is near the break-up velocity, confirming other theoretical works (see e.g., Townsend *et al.*, 2004). The use of a set of self–consistent line force parameters is necessary to understand the wind dynamics of these rapid rotators. The full version of the oblate correction factor will be implemented to study the topology of the wind.

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