A Study Of DACs And SACs Regions In The Atmospheres Of Hot Emissions Stars

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Abstract. The presence of Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs) is a very common phenomenon in the atmospheres of hot emission stars and their result is the complex line profiles of these stars. The shapes of these lines are interpreted by the existence of two or more independent layers of matter nearby a star. These structures are responsible for the formation of a series of satellite components for each spectral line. Here we present a model reproducing the complex profile of the spectral lines of Oe and Be stars which psesent the DACs and SACs phenomenon. Generally, this model gives a line function for the complex structure of the spectral lines that present DACs or SACs. This line function includes a function L that considers the kinematics (geometry) of an independent region. In the calculation of the function L we have considered the rotational velocities of the independent regions, as well as the random velocities within them. This means that the function L is a synthesis of the Rotation distribution and a Gaussian one. Finally, with this method we can calculate the optical depth (τ) and the column density (d) of each independent density region.

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INTRODUCTION

One of the most important phenomena in the spectra of hot emission stars is the DACs (Discrete Absorption Components) phenomenon [1].

DACs are discrete but not unknown absorption spectral lines. They are spectral lines of the same ion and the same wavelength as a main spectral line, shifted at different $\Delta\lambda$, as they are created in different density regions which rotate and move radially with different velocities [2,3]. DACs are lines, easily observed, when the regions that give rise to such lines, rotate with low velocities and move radially with high velocities. However, if the regions, that give rise to such lines, rotate with large velocities and move radially with small velocities, the produced lines are quite broadened but have small shifts. As a result they are blended among themselves as well as with the main spectral line and thus they are not discrete. In such a case the name Discrete Absorption Component is inappropriate and we use only the name SACs (Satellite Absorption Components) [4,5].

DESCRIPTION OF THE MODEL

The Line Profile Function

Some years ago our research team proposed a new model to explain the complex structure of the density regions of hot stars, where the spectral lines that present SACs or DACs are created [2,3].

The main hypothesis of this model is that the atmospherical region where a specific line is created is not continuous, but it is composed of a number of successive independent absorbing density regions, a number of emission regions and an external general absorption region.

By solving the radiation transfer equations through a complex structure, as the described one, we conclude to a function for the line profile, able to give the best fit for the main spectral line and its Satellite Components in the same time (Eq. 1).

$$I_\lambda = \left[I_{\lambda 0} \prod_i e^{-\tau_{ai}} + \sum_j S_{\lambda ej} \left(1 - e^{-\tau_{ej}}\right) \right] e^{-\tau_g} \qquad (1)$$

where: $I_{\lambda 0}$: is the initial radiation intensity, $S_{\lambda ej}$ is the source function, which, at the moment when the spectrum is taken, is constant and $e^{-\tau_{ai}}$, $S_{\lambda ej}\left(1 - e^{-\tau_{ej}}\right)$, $e^{-\tau_g}$ are the distribution functions of the absorption, emission and general absorption lines, respectively. This function I_λ does not depend on the geometry of the regions which create the observed feature.

The Spherical Symmetry Hypothesis

In order to include in Eq. (1) some kinematical parameters such as the rotational and the radial velocities, we have to suppose a geometrical hypothesis. If we choose the spherical symmetry hypothesis, Eq. (1) becomes:

$$I_\lambda = \left[I_{\lambda 0} \prod_i e^{-L_{ai}\xi_{ai}} + \sum_j S_{\lambda ej} \left(1 - e^{-L_{ej}\xi_{ej}}\right) \right] e^{-L_g \xi_g} \qquad (2)$$

where: $I_{\lambda 0}$: is the initial radiation intensity, L_{ai}, L_{ej}, L_g: are the distribution functions (Rotation distribution) of the absorption coefficients $k_{\lambda ai}$, $k_{\lambda ej}$, $k_{\lambda g}$, respectively and ξ is the optical depth in the center of the line.

In the present work we propose an approach of the problem, where we calculate L as a function of the rotational and the random velocities (see [4,5]).

Calculation Of The New Distribution Function (Gauss-Rotation)

Let us consider a spherical shell moving radially and a point A_i in its equator (see Fig. 1a). If the laboratory wavelength of a spectral line that arises from A_i is λ_{lab}, the observed wavelength will be $\lambda_0 = \lambda_{lab} + \Delta\lambda_{rad}$ where $\Delta\lambda_{rad}$ is the radial displacement.

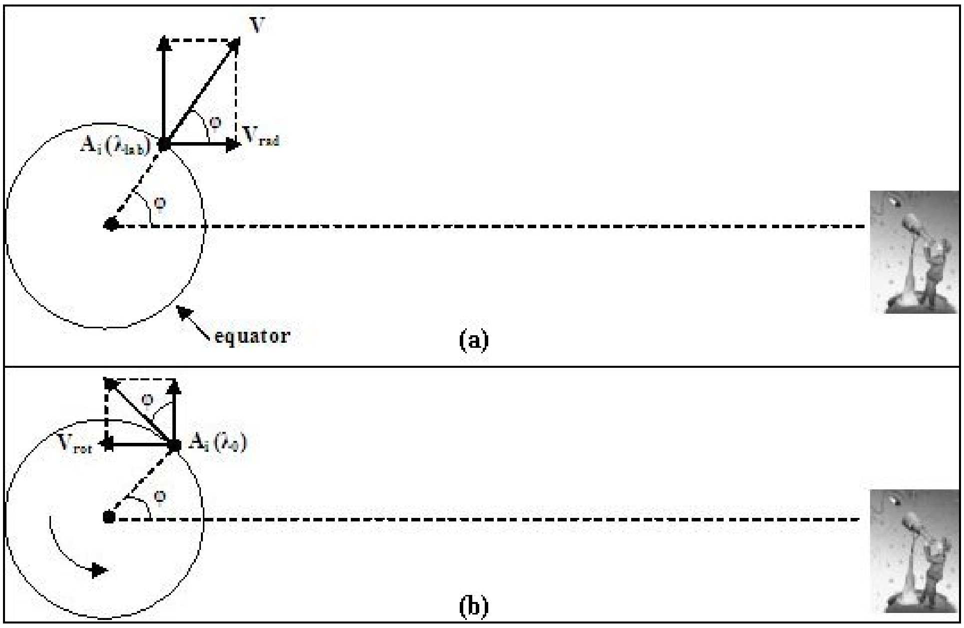

FIGURE 1. View of the equator of a blob. We can see the radial velocity (V_{rad}) of the point A_i, which results to the radial displacement ($\Delta\lambda_{rad}$) (a) and the rotational velocity (V_{rot}) which results to the width ($\Delta\lambda_{rot}$) (b).

If the spherical density region rotates (see Fig. 1b), we will observe a displacement $\Delta\lambda_{rot}$ and the new wavelength of the center of the line λ_i is $\lambda_i = \lambda_0 \pm \Delta\lambda_{rot}$, where $\Delta\lambda_{rot} = \lambda_0 z \sin\varphi$ and $z = \frac{V_{rot}}{c} = \frac{\Delta\lambda_{rot}}{\lambda_0 \sin\varphi}$, where V_{rot} is the observed rotational velocity of the point A_i.

This means that $\lambda_i = \lambda_0 \pm \lambda_0 z \sin\varphi = \lambda_0(1 \pm z\sin\varphi)$ and if $-\frac{\pi}{2} < \varphi < \frac{\pi}{2}$ then $\lambda_i = \lambda_0(1 - z\sin\varphi)$.

If we consider that the spectral line profile is a Gaussian distribution we have: $P(\lambda) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\left[\frac{\lambda-\kappa}{\sigma\sqrt{2}}\right]^2}$ where κ is the mean value of the distribution and in the case of the line profile it indicates the center of the spectral line that arises from A_i. This means that $P(\lambda) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left[\frac{\lambda-\lambda_0(1-z\sin\varphi)}{\sigma\sqrt{2}}\right]^2} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{[\lambda-\lambda_0(1-z\sin\varphi)]^2}{2\sigma^2}}$. For all the semi-equator we have $L(\lambda) = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{[\lambda-\lambda_0(1-z\sin\varphi)]^2}{2\sigma^2}} \cos\varphi d\varphi$. If we make the transformation $\sin\varphi = x$ and $u = \frac{\lambda - \lambda_0(1-zx)}{\sqrt{2}\sigma}$, then $L(\lambda) = \frac{1}{\lambda_0 z\sqrt{\pi}} \int_{\frac{\lambda-\lambda_0(1+z)}{\sigma\sqrt{2}}}^{\frac{\lambda-\lambda_0(1-z)}{\sigma\sqrt{2}}} e^{-u^2} du$ or

$$L(\lambda)=\frac{1}{\lambda_0 z\sqrt{\pi}}\left[\int_0^{\frac{\lambda-\lambda_0(1-z)}{\sigma\sqrt{2}}} e^{-u^2}du-\int_0^{\frac{\lambda-\lambda_0(1+z)}{\sigma\sqrt{2}}} e^{-u^2}du\right]$$

and $L(\lambda)=\frac{\sqrt{\pi}}{2\lambda_0 z}\left[erf\left(\frac{\lambda-\lambda_0(1-z)}{\sqrt{2}\sigma}\right)-erf\left(\frac{\lambda-\lambda_0(1+z)}{\sqrt{2}\sigma}\right)\right].$

The distribution function from the semi-spherical region is

$$L_{final}(\lambda)=\frac{\sqrt{\pi}}{2\lambda_0 z}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\left[erf\left(\frac{\lambda-\lambda_0}{\sqrt{2}\sigma}+\frac{\lambda_0 z}{\sqrt{2}\sigma}\cos\theta\right)-erf\left(\frac{\lambda-\lambda_0}{\sqrt{2}\sigma}-\frac{\lambda_0 z}{\sqrt{2}\sigma}\cos\theta\right)\right]\cos\theta d\theta \quad (3)$$

(Method Simpson).

Eq. (3) gives the final distribution function, which is a synthesis of the Rotation distribution and a Gaussian one.

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