A New Modeling Approach For 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 (Danezis et al. 2003, Lyratzi & Danezis 2004) and result to 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 will present a model reproducing the complex profile of the spectral lines of Oe and Be stars with DACs and SACs (Danezis et al. 2003, Lyratzi & Danezis 2004). In general, this model has a line function for the complex structure of the spectral lines with DACs or SACs and include a function L that considers the kinematic (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 new function of L is a synthesis of the rotational distribution and a physical Gaussian. Finally, we calculate the optical depth (ξ) 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 (Peton 1974, Underhill 1975, Lamers et al. 1982, Sahade et al. 1984, Sahade & Brandi 1985, Hutsemékers 1985, Danezis 1984, 1987, Danezis et al. 1991, 2003).

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 Δλ, as they are created in different density regions which rotate and move radially with different velocities (Danezis et al. 2003, Lyratzi & Danezis 2004). 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,

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the produced lines are very 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).

DESCRIPTION OF THE MODEL

The Line Profile Function

Some years ago our group 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 (Danezis et al. 1991, 1998, 2000a,b,c, 2002a,b,c, 2003), Laskarides et al. 1992a,b).

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

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

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 $e^{-x_{ai}}$, $e^{-x_{ej}}$, e^{-x_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 Rotation Distribution Function

One of the main hypotheses when we constructed the old version of the model (rotation model) was that the line's width Δλ is only a rotational effect and we consider spherical symmetry for the independent density regions, which create the satellite components. This means that the random velocities were very low and they did not contribute to the line broadening. In such a case Eq. (1) becomes:

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

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 present work we propose a new approach of the problem, as we also consider the parameter of random velocities in the calculation of the distribution function L (See Danezis et al. 2005). This new L is a synthesis of the rotation distribution that we had presented in the old rotational model and a Gaussian. This means that the new *L* has two limits, the first one gives us a Gaussian and the other the old rotation distribution.

Calculation Of The New Distribution Function (Gauss-Rotation)

Let us consider a spherical shell 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 $\lambda_0=\lambda_{lab}+\Delta\lambda_{rad}$.

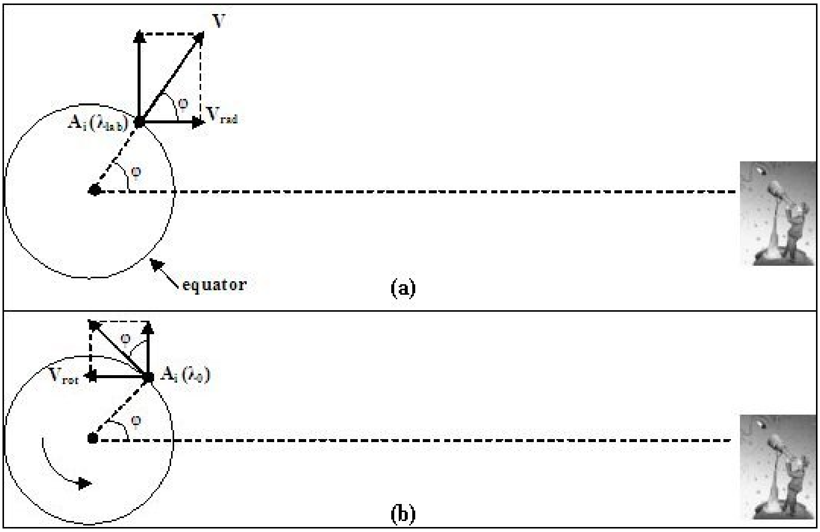

FIGURE 1. View of the equator of a blob. We can see the V_{rad} of the point A_i, from which arise the $\Delta\lambda_{rad}$ (a) and the V_{rot} from which arise the $\Delta\lambda_{rot}$ (b).

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 semiequator 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).

This $L_{final}(\lambda)$ is the distribution that replaces the old rotational distribution L in equation (2) that our group proposed some years ago (Danezis et al 2003).

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