# A study of DACs and SACs regions in the atmospheres of Hot emissions stars

Nikolaidis, D.[1], Danezis, E. [1], Lyratzi, E. [1], Popović, L. Č. [2], Antoniou, A. [1]
Dimitrijević, M. S. [2], and Theodossiou, E. [1]

1. University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, GR 157 84 Zographou, Athens, Greece
2. Astronomical Observatory, Volgina 7, 11160, Belgrade, Serbia

## 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 Δλ, 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 $I_\lambda$ 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: *Iλ0*: is the initial radiation intensity, *Lai*, *Lej*, *Lg*: are the distribution functions (Rotation distribution) of the absorption coefficients *kλai*, *kλej*, *kλg*, 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 Ai in its equator (see Fig. 1a). If the laboratory wavelength of a spectral line that arises from Ai is *λlab*, the observed wavelength will be *λ0=λlab+Δλrad* where *Δλrad* is the radial displacement

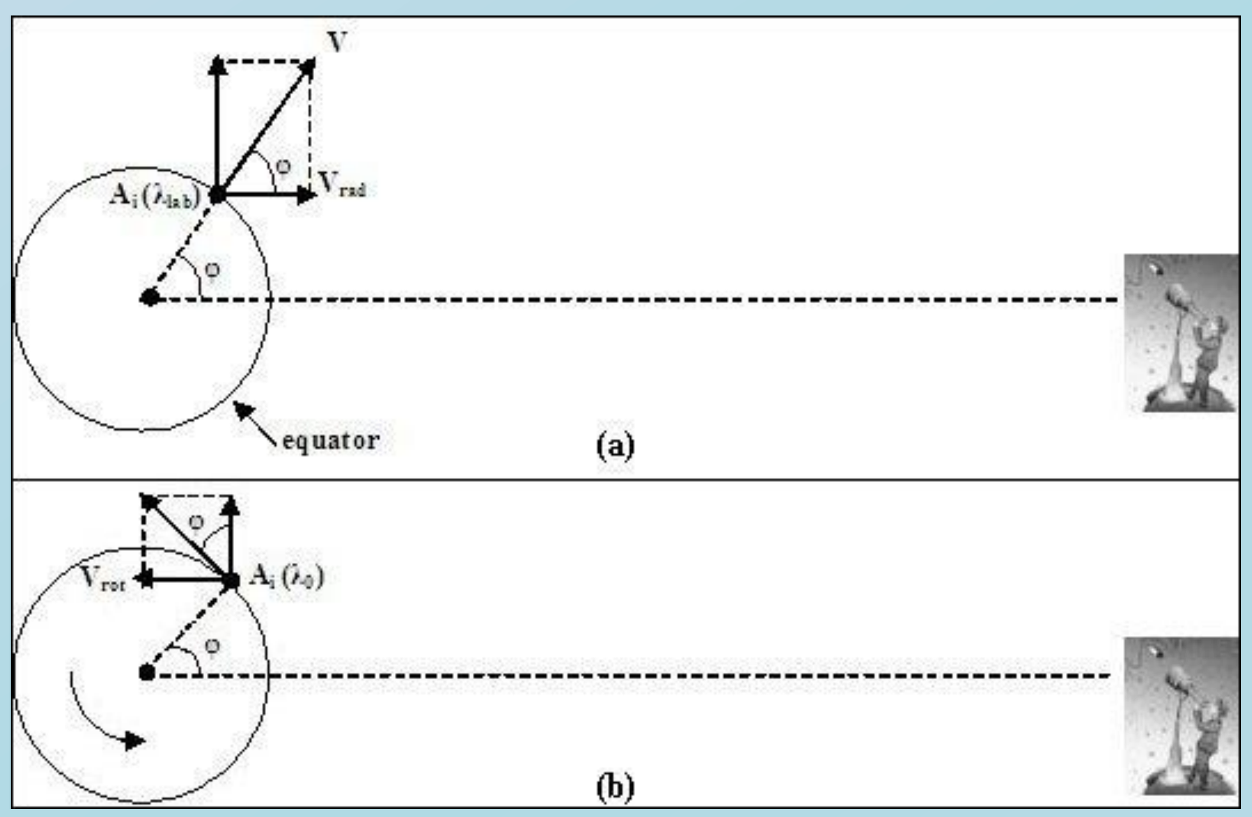


**FIGURE 1.** View of the equator of a blob. We can see the radial velocity (*Vrad*) of the point Ai, which results to the radial displacement (*Δλrad*) (a) and the rotational velocity (*Vrot*) which results to the width (*Δλrot*) (b).

If the spherical density region rotates (see Fig. 1b), we will observe a displacement *Δλrot* and the new wavelength of the center of the line *λi* 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 *Vrot* is the observed rotational velocity of the point Ai.

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 Ai. 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 transformations

$$\sin\varphi = x$$

$$u = \frac{\lambda - \lambda_0(1-zx)}{\sqrt{2}\sigma}$$

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

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

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

## ACKNOWLEDGMENTS

This research project is progressing at the University of Athens, Department of Astrophysics, Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work also was supported by Ministry of Science and Environment Protection of Serbia, through the projects "Influence of collisional processes on astrophysical plasma line shapes" and "Astrophysical spectroscopy of extragalactic objects".

## REFERENCES

1. B. Bates and D. R. Halliwell, *Mon. Not. R. Astr. Soc.* **223,** 673-681 (1986).
2. E. Danezis, D. Nikolaidis, V. Lyratzi, M. Stathopoulou, E. Theodossiou, A. Kosionidis, C. Drakopoulos, G. Christou and P. Koutsouris, Ap&SS, **284**, 1119-1142 (2003).
3. E. Lyratzi and E. Danezis, in *The Physics of Ionized Gases: 22nd Summer School and International Symposium on the Physics of Ionized Gases*, edited by Lj. Hadzijevski, T. Grozdanov and N. Bibić, AIP Conference Proceedings 740, Bajina Bašta, pp. 458-473 (23-27 August 2004).
4. E. Danezis, D. Nikolaidis, E. Lyratzi, L. Č. Popović, M. S. Dimitrijević, E. Theodossiou and A. Antoniou, Mem. S.A.It.Suppl., **7**, 107-113 (2005a).
5. E. Danezis, D. Nikolaidis, E. Lyratzi, L. Č. Popović, M. S. Dimitrijević, E. Theodossiou and A. Antoniou, Proceedings of 7th HEL.A.S. Conference, in press (2005b).

23rd Summer School and International Symposium on the Physics of Ionized Gases
August 28 - September 1, 2006, Serbia