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Studying the location of SACs and DACs regions in the environment of hot emission stars

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Abstract. Hot emission stars (Oe and Be stars) present complex spectral line profiles, which are formed by a number of DACs and/or SACs. In order to explain and reproduce theoretically these complex line profiles we use the GR model (Gauss-Rotation model). This model presupposes that the regions, where the spectral lines are created, consist of a number of independent and successive absorbing or emitting density regions of matter. Here we are testing a new approach of the GR model, which supposes that the independent density regions are not successive. We use this new approach in the spectral lines of some Oe and Be stars and we compare the results of this method with the results deriving from the classical GR model that supposes successive regions.

Key words. Stars: hot emission stars– Stars: spectral lines – Stars: DACs, SACs

1. Introduction

In the spectra of Hot Emission Stars (Oe and Be stars) we observe peculiar line profiles. In order to explain this peculiarity, we propose and use the Discrete Absorption Components (DACs) (Bates & Halliwell 1986) and Satellite Absorption Components (SACs) theory (Danezis et al. 2005). DACs or SACs arise from density regions surrounding the star or lying far away from it. These density regions present spherical (or apparent spherical) symmetry around the star or their own center (Lyratzi et al. 2007). This model presupposes that the regions, where the spectral lines are created, consist of a number of independent and successive absorbing or emitting density regions of matter. In this study we are testing a new approach of GR model, which supposes that the density regions are independent but not successive. We use this new approach in order to study the density regions that produce the C IV ($\lambda\lambda$ 1548.155, 1550.774 Å) and the N V ($\lambda\lambda$ 1238.821, 1242.804 Å) resonance lines

Send offprint requests to: A. Antoniou of a number of Oe stars as well as the Mg II ($\lambda\lambda$ 2795.523, 2802.698 Å) resonance lines and the Fe II (λ 2585.876 Å) spectral lines of a number of Be stars. Comparing the results of this method with the results deriving from the classical GR model that supposes successive regions, we try to conclude to the best method for the case of hot emission stars.

2. Method of analysis

In order to reproduce the peculiar line profiles, which are due to the presence of DACs or SACs, we have to calculate the line function. Recently, Danezis et al. (2005, 2007) proposed a model (the so called Gaussian-Rotational model, GR model), in order to explain the complex structure of the density regions which create the spectral lines with SACs or DACs and which lie in the environment of hot emission stars and some Active Galactic Nuclei (AGNs). As we have already mentioned, this model presupposes that the regions, where the spectral lines are created, consist of a number of independent and successive absorbing or emitting density regions of matter, as the area that contains these spherical density regions is near the star and thus is limited. The GR line function (Danezis et al. 2007) has the following form:

$$I_\lambda = [I_{\lambda 0}\prod_i e^{-L_i\xi_i} + \sum_j S_{\lambda ej}(1-e^{-L_{ej}\xi_{ej}})]\prod_g e^{-L_g\xi_g} \quad (1)$$

where:
$I_{\lambda 0}$: is the initial radiation intensity,
L_i, L_{ej}, L_g : are the distribution functions of the absorption coefficients k_i, k_{ej}, k_g,
ξ: is the optical depth in the centre of the spectral line,
S_{ej}: is the source function that is constant during one observation.

The $e^{-L_i\xi_i}$ and $e^{-L_g\xi_g}$ are the distribution functions of each absorption satellite component and $S_{\lambda ej}(1 - e^{-L_{ej}\xi_{ej}})$ is the distribution function of each satellite emission component. In the GR line function, in the case of a number of independent but successive absorbing or emitting density layers of matter the final profile that is produced by a group of absorption lines is given by the product of the line functions of each component. On the other hand, the final profile that is produced by a group of emission lines is given by the addition of the line functions of each SAC. The addition of a group of functions is completely different from the multiplication of functions. The spectral line profile that results from the addition of a group of functions is exactly the same with the profile that results from a composition of the same functions. A new idea of our scientific group is to examine the form of the GR line function in the case that the density regions of matter which produce the satellite absorption or emission components are independent but not successive. In this case the above line function takes the following form:

$$I_\lambda = I_{\lambda 0}\sum_i e^{-L_i\xi_i} + \sum_j S_{\lambda ej}(1 - e^{-L_{ej}\xi_{ej}}) \quad (2)$$

The new idea of this study is to measure the new values of the parameters that we calculate in the case that the independent density regions of matter that produce the absorption or emission satellite components are successive or not.

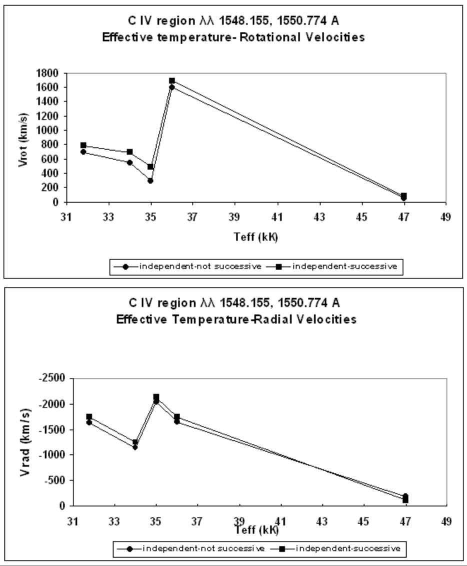

Fig. 1. Variation of the values of the rotational (up) and radial (down) velocities of the C IV ($\lambda\lambda$ 1548.155, 1550.774 Å) density regions, as a function of the effective temperature of the studied Oe stars.

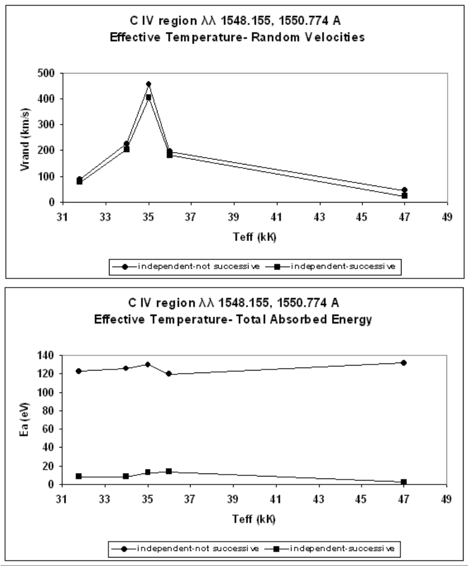

Fig. 2. Variation of the values of the random velocities (up) and the total absorbed energy (down) of the ions of the C IV ($\lambda\lambda$ 1548.155, 1550.774 Å) density regions, as a function of the effective temperature of the studied Oe stars.

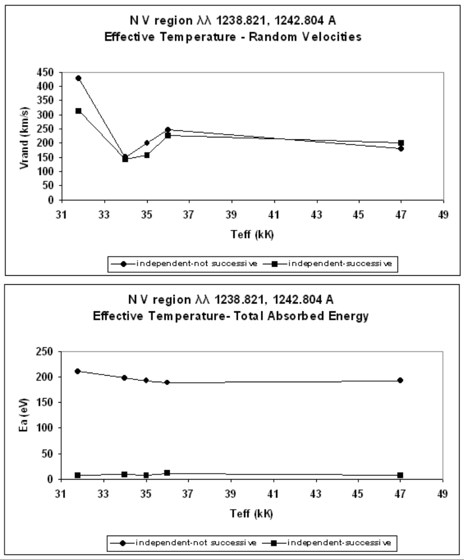

Fig. 4. Variation of the random velocities (up) and the total absorbed energy (down) of the N V ($\lambda\lambda$ 1238.821, 1242.804 Å) density regions, as a function of the effective temperature of the studied Oe stars.

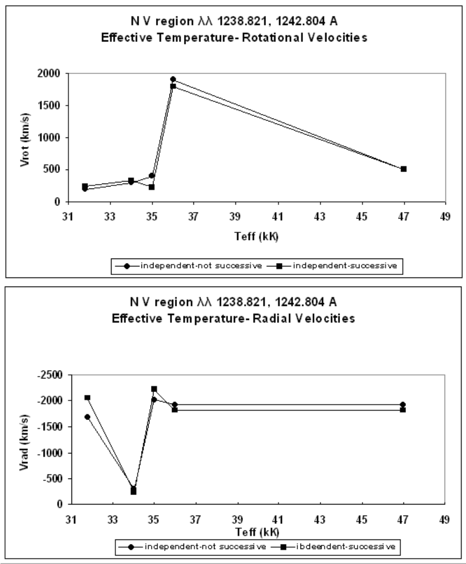

Fig. 3. Variation of the values of the rotational (up) and radial (down) velocities of the N V ($\lambda\lambda$ 1238.821, 1242.804 Å) density regions, as a function of the effective temperature of the studied Oe stars.

3. The results of our study

We study the density regions that produce the C IV ($\lambda\lambda$ 1548.155, 1550.774 Å) and the N V ($\lambda\lambda$ 1238.821, 1242.804 Å) resonance lines in the HD 57061, HD 93521, HD 47129, HD 24911 and HD 49798 Oe stars, as well as the Mg II ($\lambda\lambda$ 2795.523, 2802.698 Å) resonance lines and the Fe II (λ 2585.876 Å) spectral line in the HD 30386, HD 42335, HD 53367, HD 45910 and HD 200120 Be stars.

3.1. The Oe stars

In figures 1 and 2 we present the variation of the values of the rotational, the radial and the random velocities as well as the total absorbed energy of the density layers of matter which corresponds to the highest value of the radial velocity in the C IV ($\lambda\lambda$ 1548.155, 1550.774 Å) regions, as a function of the effective temperature of the studied Oe stars.

In figures 3 and 4 we present the variation of the same parameters in the N V ($\lambda\lambda$

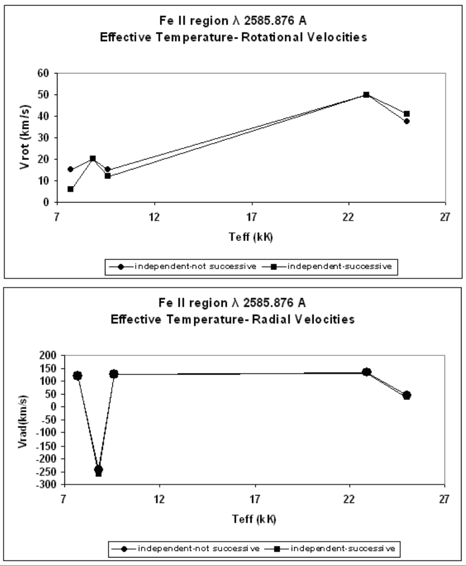

Fig. 5. Variation of the values of the rotational (up) and radial (down) velocities of the Fe II (λ 2585.876 Å) density regions, as a function of the effective temperature of the studied Be stars.

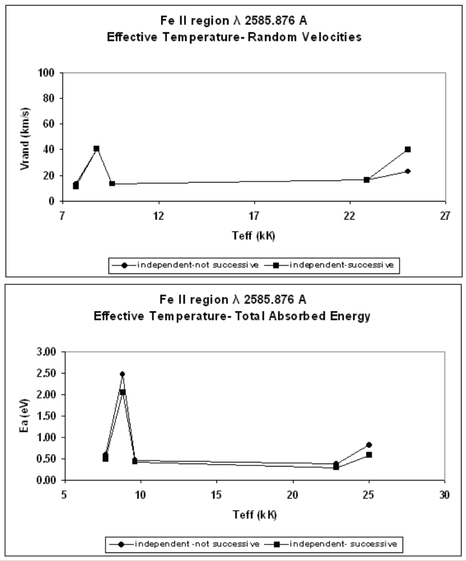

Fig. 6. Variation of the values of the random velocities (up) and the total absorbed energy (down) of the Fe II (λ 2585.876 Å) density regions, as a function of the effective temperature of the studied Be stars.

1238.821, 1242.804 Å) regions, as a function of the effective temperature of the studied Oe stars. In each case the points indicated with a circle correspond to the case of independent but not successive layers of matter, while the points indicated with a square correspond to the case of the independent and successive layers of matter.

3.2. The Be stars

In figures 5 and 6 we present the variation of the values of the rotational, the radial and the random velocities, as well as the total absorbed energy of the density layer of matter, which corresponds to the highest value of the radial velocity in the Fe II (λ 2585.876 Å) region, as a function of the effective temperature of the studied Be stars.

In figures 7 and 8 we present the variation of the same parameters in the Mg II ($\lambda\lambda$ 2795.523, 2802.698 Å) regions as a function of the effective temperature of the studied Be stars. The points indicated with a circle correspond to the case of independent but not suc-

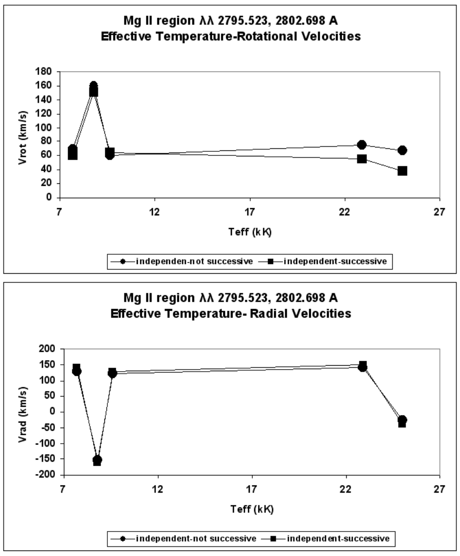

Fig. 7. Variation of the values of the rotational(up) and radial (down) velocities of the Mg II ($\lambda\lambda$ 2795.523, 2802.698 Å) density regions, as a function of the effective temperature of the studied Be stars.

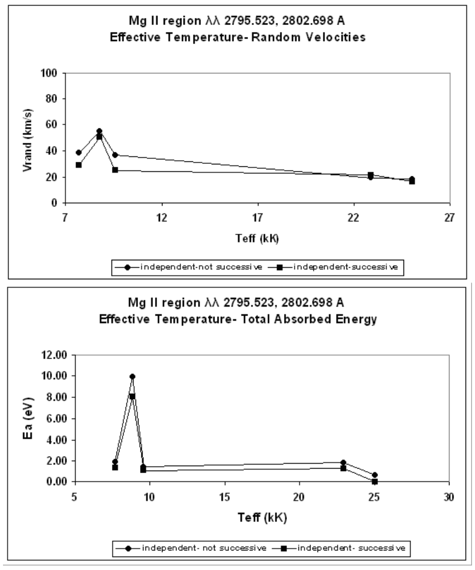

Fig. 8. Variation of the values of the random velocities (up) and the total absorbed energy (down) of the Mg II ($\lambda\lambda$ 2795.523, 2802.698 Å) density regions, as a function of the effective temperature of the studied Be stars.

cessive layers of matter, while the points indicated with a square correspond to the case of the independent and successive layers of matter.

4. Conclusions

In all cases, comparing the results, we observe that the mean values of all the kinematic parameters do not change depending on the applied method. However, in the case of Oe stars, studying the absorbed energy of C IV and N V spectral lines, the method of the independent but not successive layers of matter gives higher values than the method of the independent and successive layers of matter. This is what we theoretically expected. On the contrary, in the case of Be stars, studying the absorbed energy of the Fe II and Mg II spectral lines both methods give the same results. Theoretically, in all cases (of Oe and Be stars), we expected to find higher values for the total absorbed energy when we supposed not successive layers of matter, than when we supposed successive layers of matter. As we said, this is what we found in the case of Oe stars, studying the C IV and N V spectral lines, which lie in the post-coronal regions, which are hotter regions, in small distance from the star (Underhill & Doazan 1982). However, in the case of Be stars, studying the Fe II and Mg II spectral lines, which lie in the cool envelope (i.e. cooler regions, in greater distance from the star (Underhill & Doazan 1982)), both methods (of successive and not successive layers of matter) gave the same values for the total absorbed energy. This difference is a quite interesting phenomenon and our future work includes a study of a great number of Oe and Be stars, in order to make a statistical study on this different behavior. Probably, it depends on the extent of the area in which the density regions of matter evolve, as well as on the optical depth of the lines that are created in these regions.

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