Kinematical parameters in the coronal and post-coronal regions of the Oe stars

A Antoniou[1], E Danezis[1], E Lyratzi[1,2], L Č Popović[3], and M S Dimitrijević[3]

[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athnes – Greece
[2]Eugenides Foundation, 387 Sygrou Av., 17564, Athens, Greece
[3]Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia

e-mail: ananton@phys.uoa.gr, edanezis@phys.uoa.gr, elyratzi@phys.uoa.gr, lpopovic@aob.bg.ac.yu, mdimitrijevic@aob.bg.ac.yu

Abstract. In this progress report we present the main results of our research. Using a new model we studied the kinematical parameters such as the random velocities of the ions, which create the spectral lines of C IV, N IV and N V in the spectra of 20 Oe stars, as well as the rotational and radial velocities of the regions, where the above ions are created. We calculated the values of the above parameters and we present the relations between them as well as their variation as function of the spectral subtype. We also present the random velocities of the ions for each one of the C IV, N IV and N V regions as a function of the photospheric rotational velocities. Finally, we propose an explanation for the large widths that we observe in the studied spectral lines, as these widths can not be explained as large rotational or random velocities.

1. Introduction

The spectra of Hot Emission Stars (Oe and Be stars) contain peculiar line profiles. In order to explain this peculiarity, we propose and use the Discrete Absorptions Components (DACs) [1] and Satellite Absorptions Components (SACs) [2] theory.

DACs or SACs arise from spherical density regions surrounding the star or lying far away from it, that having spherical (or apparent spherical) symmetry around the star or its own center [3].

In the case of DACs or SACs phenomenon we need to calculate the line function of the complex line profile. Recently, our group proposed a model in order to explain the complex structure of the density regions of hot emission stars and some Active Galactic Nuclei (AGNs), where the spectral lines which have SACs or DACs are created [2,4].

As we know, in order to find the mechanism responsible for the structure of DACs or SACs density regions we need to calculate the values of a group of parameters, such as the rotational, the random and the radial velocities, the Full Width at Half Maximum (FWHM), the optical depth, the absorbed or emitted energy, the column density, and the Gaussian standard deviation, as well as the relation among them. Directly from the model we can calculate the apparent radial velocities (V_{rad}) of the absorbing or emitting density regions, the Gaussian typical deviation (σ) of the random thermal motions, the apparent rotational velocities (V_{rot}) of the absorbing or emitting density region and the optical depth (ξ) in the center of the spectral line. From the above parameters we can calculate the percentage

Journal of Physics: Conference Series **133** (2008) 012028 doi:10.1088/1742-6596/133/1/012028

contribution (G%) of the random velocities to the broadening of the spectral line, the Full Width at Half Maximum (FWHM), the random velocities of the ions (V_{rand}) that produce the spectral lines, the absorbed or emitted energy (Ea, Ee) and the column density (CD).

We point out that with the proposed model we can study and reproduce specific spectral lines. This means that we can study specific density regions in the plasma surrounding the studied object.

In this paper we present some kinematical parameters of C IV, N IV and N V regions in the spectra of 20 Oe stars. We calculate the values of the rotational, random and radial velocities, the relation among them, as well as the variation of the radial velocities as a function of the spectral subtype. Finally, we give a possible explanation of the measured high values of the rotational velocities.

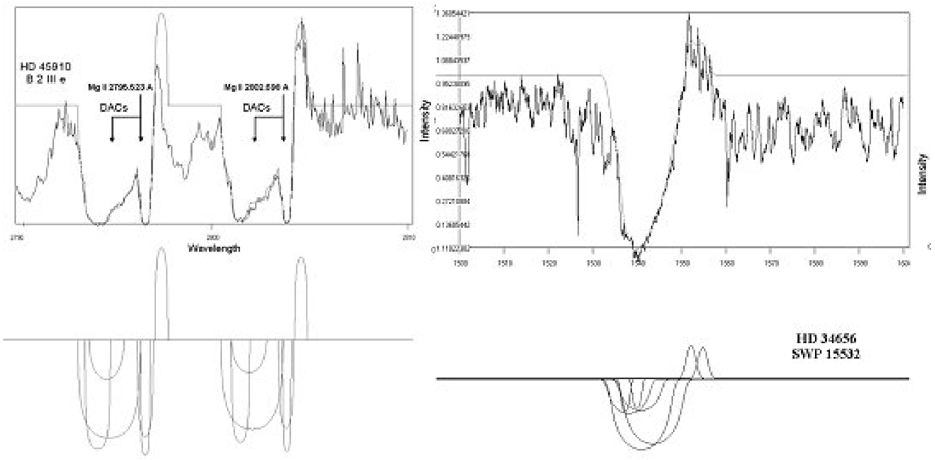

Figure 1. DACs in the spectrum of a Be star (left) and SACs in the spectrum of an Oe star (right). Below the fit one can see the decomposition of the observed profile to its DACs and SACs.

2. Observational Data

For this analysis we used the high resolution spectra (0.1 to 0.3 Å) taken with International Ultraviolet Explorer (IUE) found at the VILSPA database (http://archive.stsci.edu/cgi-bin/iue).

In Figure 1 we present the UV resonance lines of Mg II in the spectrum of HD 45910 and the UV resonance lines of C IV in the spectrum of HD 34656 which have DACs or SACs, respectively. In Table 1 we present the studied stars. As we know it is not possible to find stars between O0 and O3 spectral subtypes.

Table 1 The Studied Stars

The studied stars	**Spectral subtype**	**The studied stars**	**Spectral subtype**
HD24534	O9.5 III	HD57061	O9.0I
HD24912	O7.5 III ((f))	HD60848	O8.0Vpe
HD34656	O7 II (f)	HD91824	O7V((f))
HD36486	O9.5 II	HD93521	O9.5II
HD37022	O6 Vp	HD112244	O8.5Iab
HD47129	O7.5 III	HD149757	O9V(e)
HD47839	O7 III	HD164794	O4V((f))
HD48099	O6.5 V	HD203064	O8V
HD49798	O6p	HD209975	O9.5I
HD57060	O8.5If	HD210839	O6.0I

Journal of Physics: Conference Series **133** (2008) 012028 doi:10.1088/1742-6596/133/1/012028

3. Studying the rotational velocities of the density layers of matter

Using the mentioned model we are able to calculate the values of the apparent rotational velocities of the independent regions which produce the main and the satellite components of the studied spectral lines.

In Figure 2 we present the rotational velocities' mean values of the ions of the C IV (λλ 1548.155, 1550.774 Å) and N V (λλ 1238.821, 1242.804 Å) resonance lines. In the C IV regions we detected two levels of values. The first level has values between 800 and 1800 kms^{-1} and the second level has values between 50 and 200 kms^{-1}. We detected the same phenomenon in the N V region. The first level has values between 1200 and 1800 kms^{-1} and the second level has values between 200 and 400 kms^{-1}.

An important phenomenon that we can detect in the UV spectra of some hot emission stars [5 - 10] are the very broad absorption or emission lines that we can not explain as rotational or random velocities of the density layers that construct these lines.

In order to explain this very large width we propose that around a central density region which produces the main absorption lines (and which may have the form of spiral streams and have accepted values of rotational and random velocities), we can detect micro-turbulent movements, which produce narrow absorption components with different shifts (see Figure 3). These narrow lines create a sequence of lines, on the left and on the right side of the main components. The density of these lines and their widths, which are added, give us the sense of line broadening (SACs phenomenon, see [4, 11]). As a result, what we measure as very broad absorption line, is the composition of the narrow absorption lines that are created by micro-turbulent effects. If this hypothesis is correct, the calculated width gives only the maximum value of the radial velocities of these very narrow components. Their appearance depends on the inclination of the rotational axis of the stellar disk.

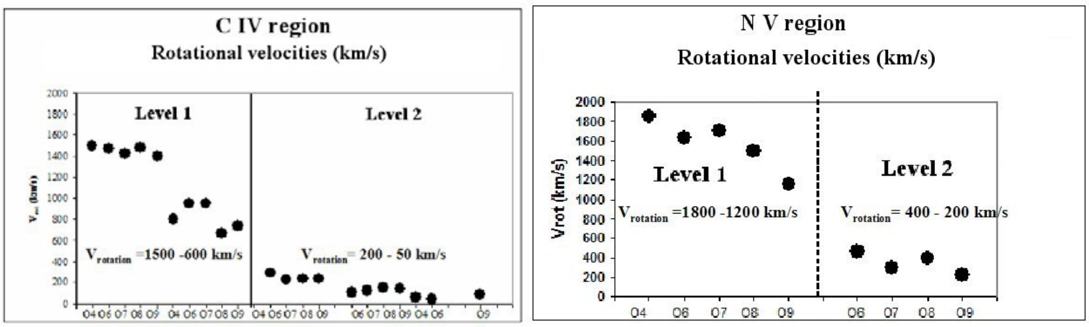

Figure 2. The rotational velocities' mean values of the ions of the C IV (λλ 1548.155, 1550.774 Å) (left) and N V (λλ 1238.821, 1242.804 Å) (right) resonance lines.

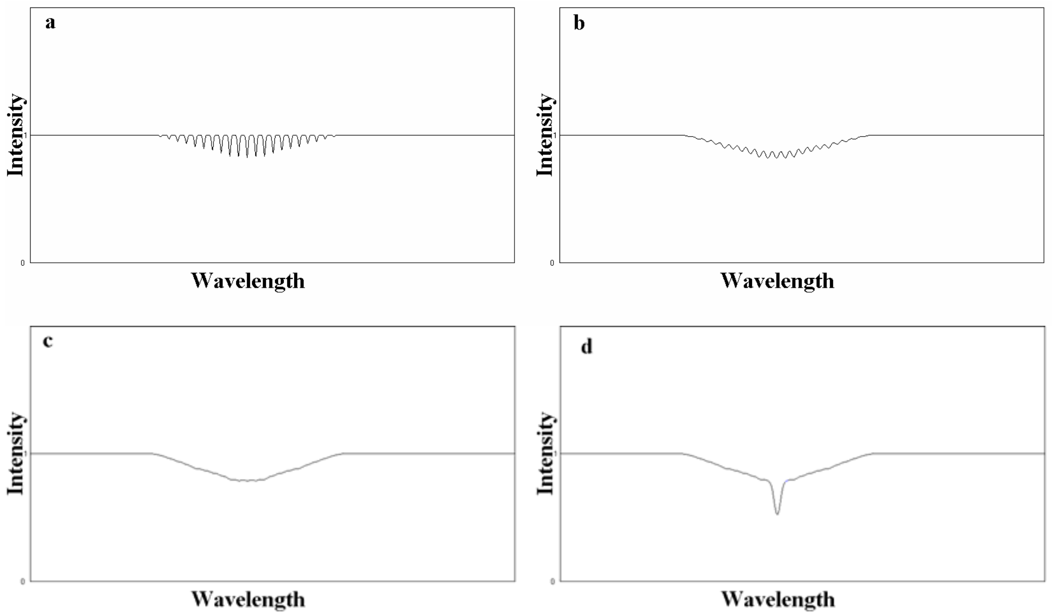

Figure 3. In (a) to (c) one can see how a sequence of lines could produce an apparent very broad absorption spectral line as an effect of SACs phenomenon. This means that when the width of each of the narrow lines is increasing (from a to c), the final observed feature looks like a single very broad absorption spectral line. In (d) one can see a combination of the apparent very broad absorption spectral line with a classical absorption line.

4. Studying the random velocities of the density layers of matter

Using our model we calculated the random velocities of the ions in the layers that produce the C IV, N IV and N V satellite components in the spectra of 20 Oe stars, which have different photospheric rotational velocities. In Figures 4, 5 and 6 we present the random velocities (V_{rand}) of the C IV, N IV and N V ions as a function of the apparent photospherical rotational velocities (V_{phot}), respectively.

In the C IV region the obtained values are about 160 kms^{-1} for the first component, 115 kms^{-1} for the second, 80 kms^{-1} for the third and 90 kms^{-1} for the fourth component. In the N IV region the obtained values are about 267 kms^{-1} for the first component and 133 kms^{-1} for the second one. Finally, in the N V region the measured values are about 190 kms^{-1} for the first component, 160 kms^{-1} for the second and 108 kms^{-1} for the third one. In each region we detected similar average values of the random velocities of the ions for each component for all the studied stars. This happens because the ionization potential of each studied ion, for all the studied stars, is the same, so the respective random velocities should be the same. As the values of the random velocities do not depend on the inclination of the rotational axis, we expect similar average values of the random velocities for each component, for all the studied stars.

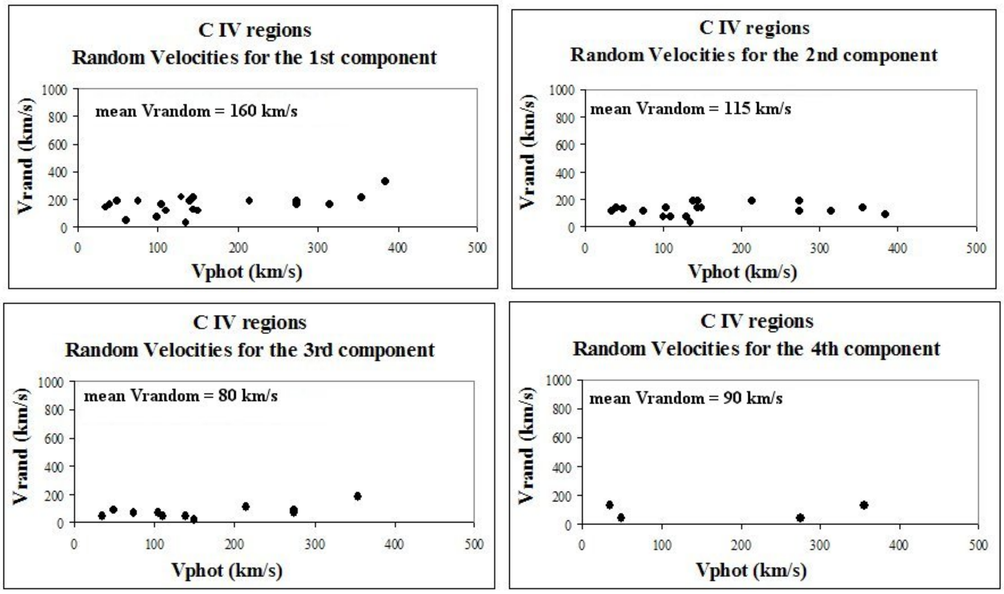

Figure 4. Random velocities (V_{rand}) of the C IV ions as a function of the apparent photospheric rotational velocities (V_{phot}).

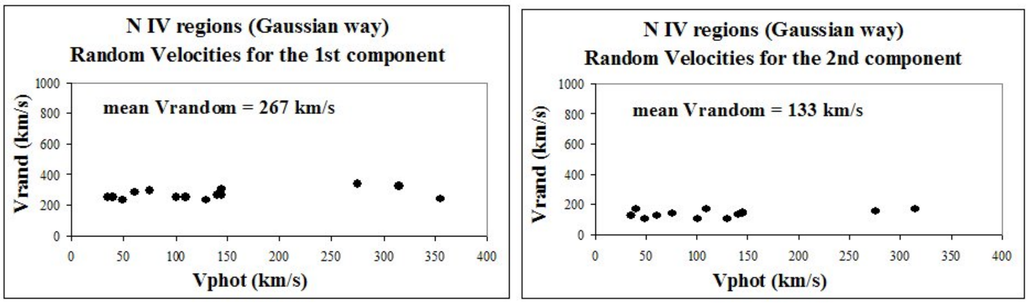

Figure 5. The same as in Figure 4 but for the N IV ions.

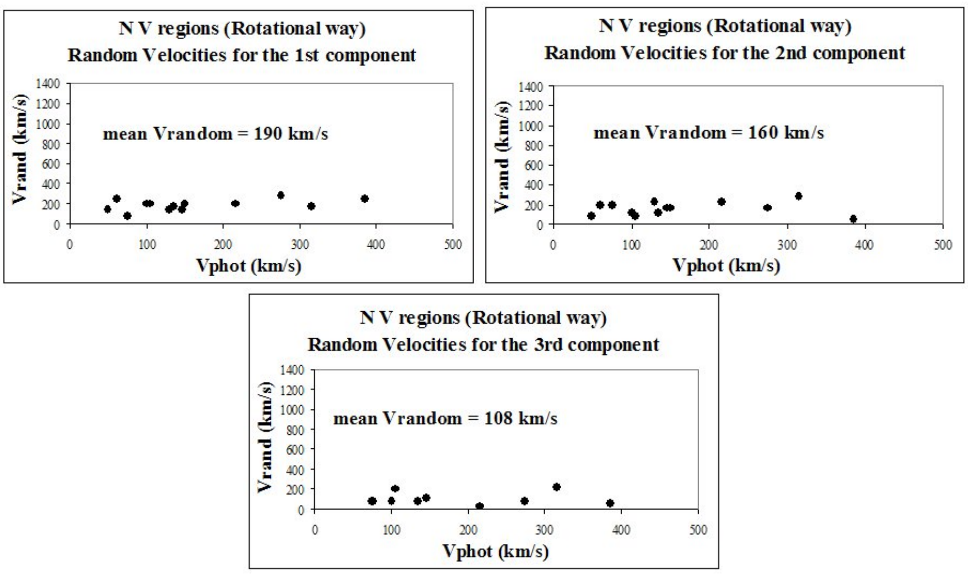

Figure 6. The same as in Figure 4 but for the N V ions.

5. Studying the relations among the kinematical parameters

In Figures 7 and 8 we present the relations among the studied kinematical parameters (V_{rand}, V_{rad}, V_{rot}), for C IV and N V density regions of the studied 20 Oe stars.

In Figure 7 we see the random (left) and the rotational velocities (right) as a function of the radial velocities in the C IV regions of the studied 20 Oe stars and in Figure 8 we present the corresponding results for the N V regions. In most cases we detect that the random and the rotational velocities increase when the absolute radial velocities increase.

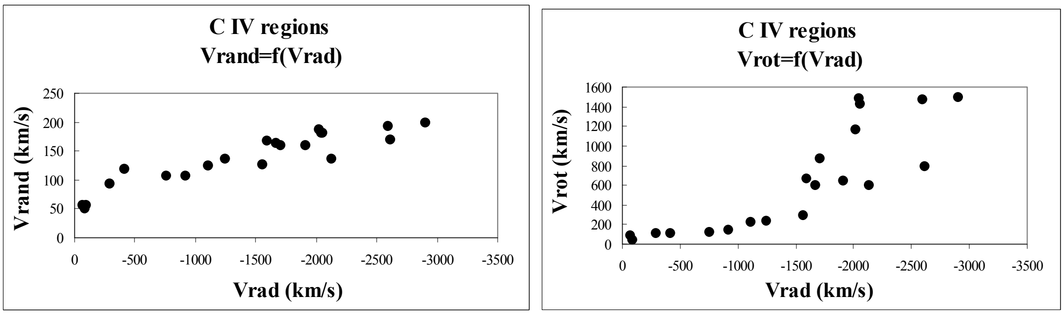

Figure 7: Random velocities (V_{rand}) (left) of the ions and rotational velocities (V_{rot}) (right) in the C IV regions, as a function of the radial velocities (V_{rad}).

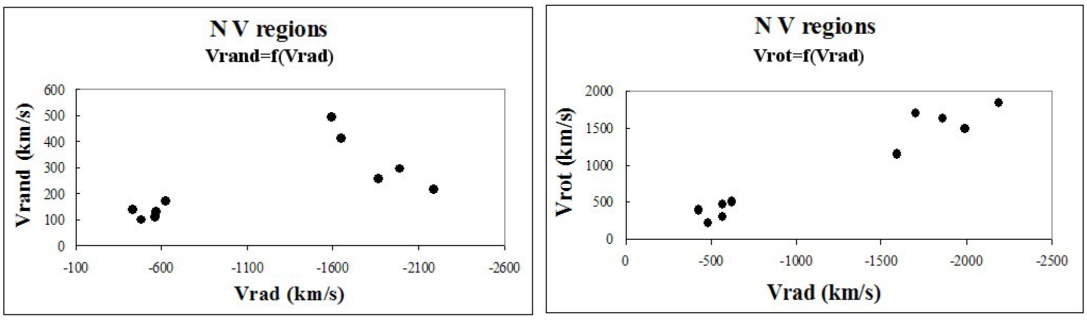

Figure 8. The same as in Figure 7 but for the N V regions.

6. Studying the radial velocities as a function of the spectral subtypes

Using the mentioned model we are able to calculate the values of the apparent radial velocities, of the independent regions which produce the main and the satellite components of the studied spectral lines as a function of spectral subtype.

In Figure 9 we present the radial velocities' mean values of the ions for the C IV (λλ 1548.155, 1550.774 Å) (left) and N V resonance lines (λλ 1238.821, 1242.804 Å) (right) as a function of the spectral subtype. In the C IV region we detected two levels of radial velocities. The first level has values between -3000 and -1500 kms^{-1} and the second one between -500 and -20 kms^{-1}. In the N V region we also detected two levels of values. The first level has values between -2300 and -1500 kms^{-1} and the second one between -500 and -100 kms^{-1}. There are two mechanisms which may create the radial velocities. One of these mechanisms creates high radial velocities and the second one low [2]. From many observations of Be stars, it has become clear over the last decade(s) that the slow part of the wind is equatorially condensed in a disk-like structure. Fore the hottest Be stars this disk co-exists with a fast stellar wind (most likely at higher latitudes). In this fast wind DACs are seen at high velocities (more than 1000km/s towards the observer). The fast winds are radiation driven from relatively slow speeds near the star, to very high speeds far away from the star.

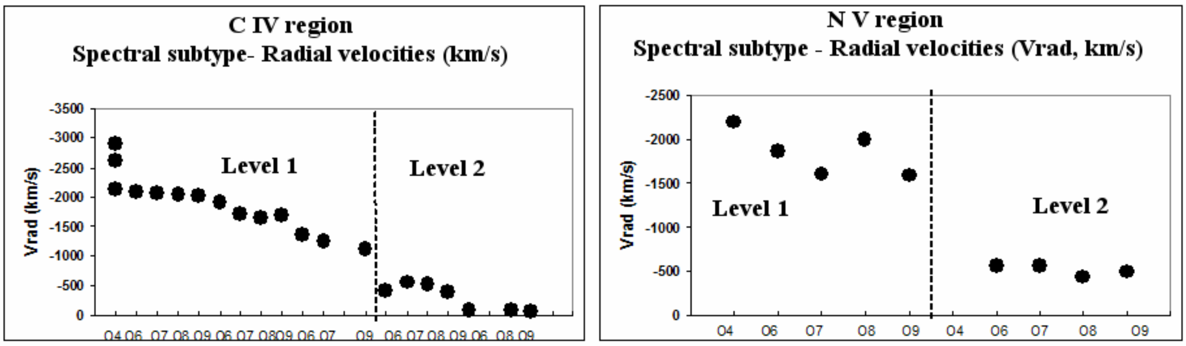

Figure 9. Radial velocities (V_{rad}) in the C IV region (left) and in the N V region (right) as a function of the spectral subtype. We detect two levels of radial velocities in both regions. The first level has high values (between -3000 and -1500 kms^{-1} in the C IV region and between -2300 and -1500 kms^{-1} in the N V region) and the second level has low values (between -500 and -20 kms^{-1} in the C IV region and between -500 and -100 kms^{-1} in the N V region).

7. Conclusions

The results deriving from this study are the following:

1. Using the proposed model, we can calculate the values of some parameters, such as the rotational, the random and the radial velocities, the FWHM, the optical depth, the absorbed or emitted energy, the column density and the Gaussian typical deviation, as well as the relation among them. This means that now we can try to understand the mechanism that is responsible for the DACs or SACs phenomenon.
2. The acceptance of SACs and DACs phenomena as the reason of the spectral line complex structure lead us to accept smaller values of the FWHM, the rotational and random velocities and the column densities and different values for the radial velocities and the optical depths because now the idea is that the complex line profile does not present a single spectral line, but a group of satellite components (DACs or SACs). This idea leads us to a different mechanism for the construction of the density regions that produce the DACs or SACs regions.
3. Finally, we propose an explanation for the large widths that we observe in the studied spectral lines, as these widths can not be explained as large rotational or random velocities. Around a central density region that produces the main absorption lines (that may have the form of spiral streams and which have accepted values of rotational and random velocities), we can detect micro-turbulent movements, which produce narrow absorption components with different shifts. These narrow lines create a sequence of lines, on the left and on the right of the main components. The density of these lines and their widths, which are superposed, give us the sense of line broadening [12]. As a result, what we measure as very broad absorption line, is the composition of the narrow absorption lines that are created by micro-turbulent effects. If this hypothesis is correct, the calculated width gives only the maximum value of the radial velocities of these very narrow components. Their appearance depends on the inclination of the rotational axis of the stellar disk.

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 Technological Development of Serbia and, through the projects “Influence of collisional processes on astrophysical plasma line shapes” and “Astrophysical spectroscopy of extragalactic objects”.

Journal of Physics: Conference Series **133** (2008) 012028 doi:10.1088/1742-6596/133/1/012028

References

[1] Bates B and Halliwell D R 1986 *Mon. Not. R. Astr. Soc.* **223** 673
[2] Danezis E, Nikolaidis D, Lyratzi E, Antoniou A, Popović L Č and Dimitrijević M S 2005 *Mem. Soc. It. Suppl.* **7** 107
[3] Lyratzi E, Danezis E, Popović L Č, Dimitrijević M S, Nikolaidis D and Antoniou A 2007 *Publ. Astron. Soc. Japan* **59** 357
[4] Danezis E, Nikolaidis D, Lyratzi E, Popović L Č, Dimitrijević M S, Antoniou A and Theodosiou E 2007 *Publ. Astron. Soc. Japan* **59** 827
[5] Andrillat Y and Fehrenbach Ch 1982 *Astron. Astrophys.* **48** 93
[6] Andrillat Y 1983 *Astron. Astrophys*. **53** 319
[7] Marlborough J M 1969 *Astrophys. J*. **156** 135
[8] Poeckert R, Marlborough J M 1979 *Astrophys. J.* **233** 259
[9] Doazan V 1970 *Astron. Astrophys.* **8** 148
[10] Antoniou A, Danezis E, Lyratzi E, Popović L Č, Dimitrijević M S 2008 *Publ. Astron. Soc. Japan* (submitted)
[11] Lyratzi E and Danezis E 2004 *AIP Conf. Proc.***740** 458
[12] Danezis E, Lyratzi E, Popović L Č, Antoniou A and Dimitrijević M S 2008 *Publ. Astron. Obs. Belgrade* **84** 463