

The structure of the Si IV region in Be stars: a study of Si IV spectral lines in Be 68 stars

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Abstract. Using the GR model, we analyze the UV Si IV resonance lines in the spectra of 68 Be stars of different spectral subtypes, in order to detect the structure of Si IV region. We calculated the values of the rotational, radial and random velocities as well as the absorbed energy of each one of the $\lambda\lambda$ 1393.755, 1402.778 Å Si IV resonance lines and we present the relation between some of these parameters and their variation as a function of the spectral subtype.

1. Introduction

The Si IV resonance lines in the Be stellar spectra have a peculiar and complex profile. Additionally many researchers have observed the existence of absorption Si IV components shifted to the violet or red side of the main spectral line (e.g. Refs [1-5]). We named these components Discrete or Satellite Absorption Components (DACs: [6], SACs: [5]). DACs or SACs originate in separate density clouds, in the Si IV region and have different rotational and radial velocities. In any case, the whole observed feature of the Si IV resonance lines is not the result of a uniform atmospherical region, but results from different Si IV clouds with different physical parameters which create a number of components.

Using the Gauss-Rotation (GR) model ([3]), we analyze the UV Si IV $\lambda\lambda$ 1393.755, 1402.778 Å resonance lines in the spectra of 68 Be stars of different spectral subtypes, taken with IUE, in order to investigate the presence of Satellite Absorption Components (SACs) and Discrete Absorptions Components (DACs). From this analysis we can calculate the values of a group of physical parameters, such as the apparent rotational and radial velocities, the random velocities of the thermal motions of the ions, the Full Width at Half Maximum (FWHM), the optical depth, as well as the absorbed energy and the column density of the independent Si IV clouds of matter which produce the main and the satellite components of the studied spectral lines. In this paper, we present the variation of the rotational, radial and random velocities as well as the absorbed energy of each one of the $\lambda\lambda$ 1393.755, 1402.778 Å Si IV resonance lines, as a function of the spectral subtype. In some cases we give the relation among some of the calculated parameters. In these cases we calculate the Linear Regression and the Linear Correlation Coefficient R^2 .

2. Data

The spectrograms of the 68 Be stars have been taken by IUE satellite, with the Long Wavelength range Prime and Redundant cameras (LWP, LWR) at high resolution (0.1 to 0.3 Å). The list of the studied stars contains six B0, four B1, twenty five B2, seventeen B3, seven B5, two B6, one B7, three B8 and four B9 stars.

3. Variation of the physical parameters of the Si IV regions, as a function of the spectral subtype

In Fig. 1, we present the Si IV doublet of the B2 Ve star HD 58050, and its best fit. The best fit has been obtained with two SACs. The graph below the profile indicates the difference between the fit and the real spectral line.

In Figures 2-4 we present the variation of the values of the rotational and the radial velocities of the independent Si IV clouds as well as the random velocities of the ions of the Si IV resonance lines, as a function of the spectral subtype. We fitted the observed profiles with one, two or three components. In the case of the rotational velocities we detect three levels of values. The first level corresponds to the 1st component and has a mean value about 455 km/s, the second one corresponds to the 2nd component with mean value 221 km/s and the third one corresponds to the 3rd component with mean value 85 km/s. In the case of the radial velocities we found two levels of values. The first level corresponds to the 1st component and has values between -236 and 90 km/s (mean value -83 km/s) and the second one corresponds to the 2nd and 3rd component and has values between 360 and 10 km/s (mean value 137 km/s). Finally, in the case of the random velocities we detected an almost constant trend of the random velocities for each component. We found mean values of about 90 km/s for the first component, 51 km/s for the second one and 31 km/s for the third one.

In Figures 5 and 6 we present the variation of the absorbed energy (E_a) in eV, of each one of the $\lambda\lambda$ 1393.755, 1402.778 Å Si IV resonance lines as a function of the spectral subtype. We see a slightly increasing linear trend of the rotational velocities.

In Figure 7 we see the relation among the rotational velocities and the absorbed energy of the λ 1393.755 Å Si IV spectral line and finally, in Figure 8 one can see the relation among the rotational and radial velocities of the Si IV independent density clouds. In both cases we see a slightly increasing linear trend and a “good” linear correlation ($R^2=0.6752$ and $R^2=0.553$ respectively). We note that, if $R^2=1$ the linear correlation is ideal, if $0.5 < R^2 < 1$ the linear correlation is considered “good” and if $0.3 < R^2 < 0.5$ the linear correlation is considered “weak”.

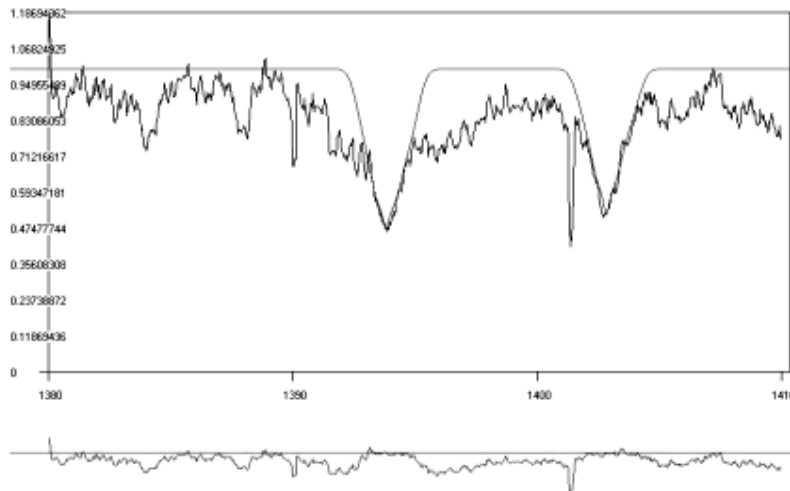


Figure 1. The Si IV $\lambda\lambda$ 1393.755, 1402.778 Å resonance lines in the spectrum of HD 58050. Each of Si IV spectral lines consists of two components. The graph below the profile indicates the difference between the fit and the real spectral line.

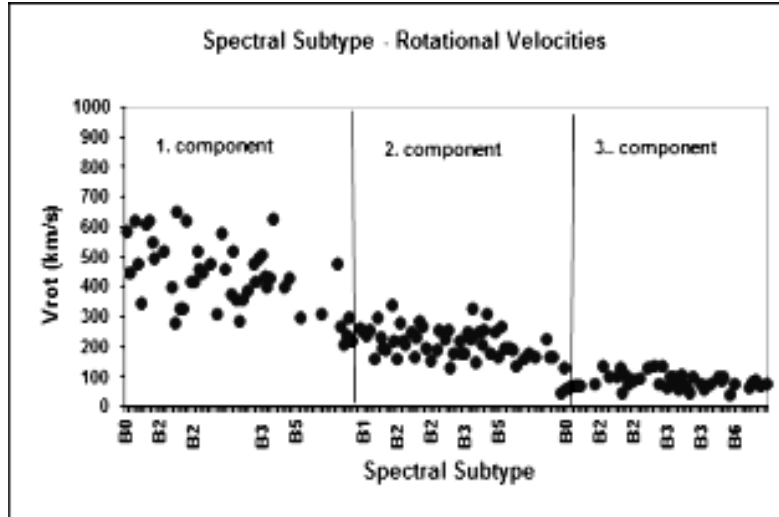


Figure 2. Variation of the values of the rotational velocities of the density clouds, which create the absorption components of the Si IV doublet ($\lambda\lambda$ 1393.755, 1402.778 Å) as a function of the spectral subtype. We detect three levels of values. The first level corresponds to the 1st component and has a mean value about 455 km/s, the second one corresponds to the 2nd component with mean value 221 km/s and the third one corresponds to the 3rd component with mean value 85 km/s.

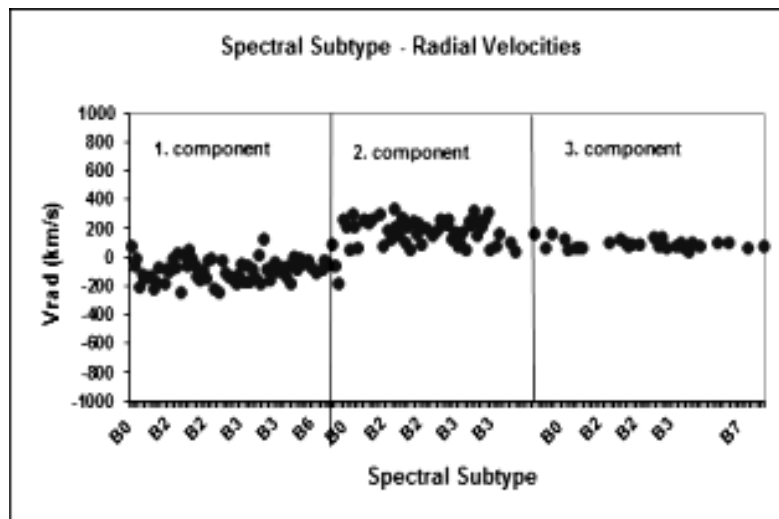


Figure 3. Variation of the radial velocities of the density clouds, which create the absorption components of the Si IV doublet ($\lambda\lambda$ 1393.755, 1402.778 Å) as a function of the spectral subtype. Here we found two levels of values. The first level corresponds to the 1st component and has values between -236 and 90 km/s (mean value -83 km/s) and the second one corresponds to the 2nd and 3rd component and has values between 360 and 10 km/s (mean value 137 km/s).

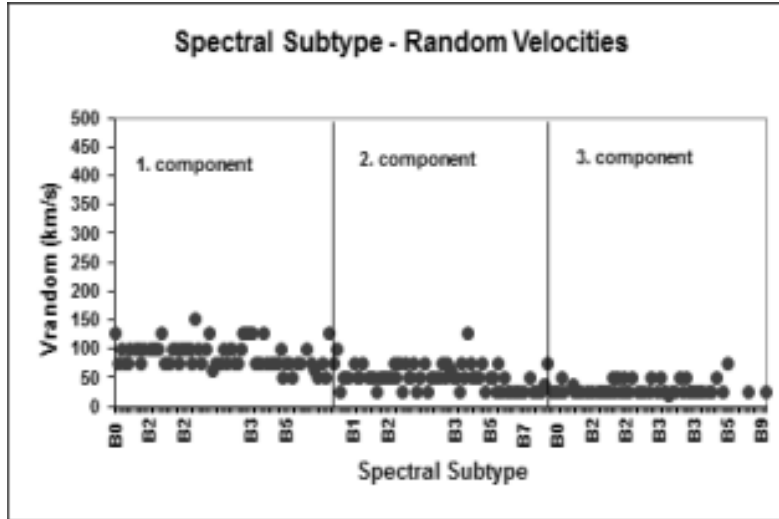


Figure 4. Variation of the random velocities of the Si IV ions of the density clouds, which create the absorption components of the Si IV doublet ($\lambda\lambda$ 1393.755, 1402.778 Å) as a function of the spectral subtype. We detected an almost constant trend of the random velocities for each component. We found mean values of about 90 km/s for the first component, 51 km/s for the second one and 31 km/s for the third one.

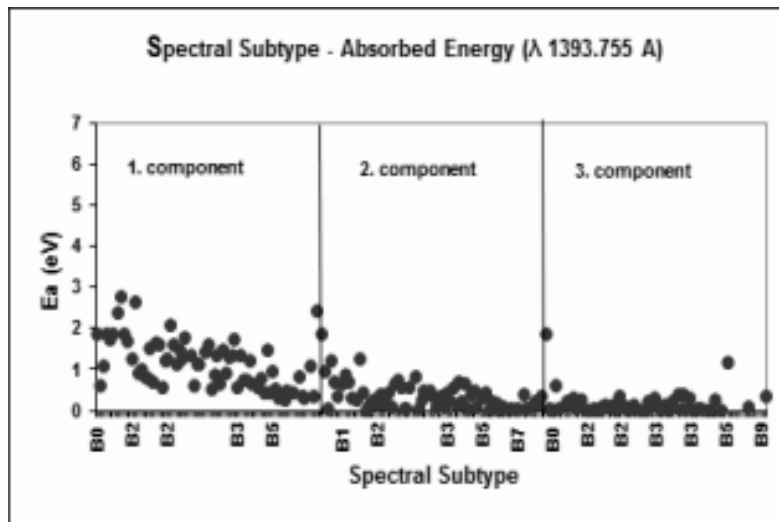


Figure 5. Variation of the absorbed energy (E_a in eV) of the Si IV line λ 1393.755 Å, for the independent density clouds, which create the absorption components as a function of the spectral subtype.

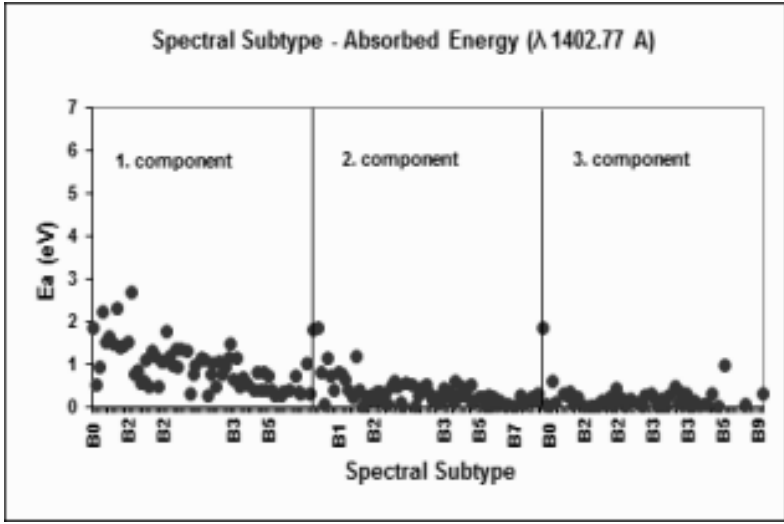


Figure 6. Variation of the absorbed energy (E_a in eV) of the Si IV line λ 1402.77 Å, for the independent density clouds, which create the absorption components as a function of the spectral subtype.

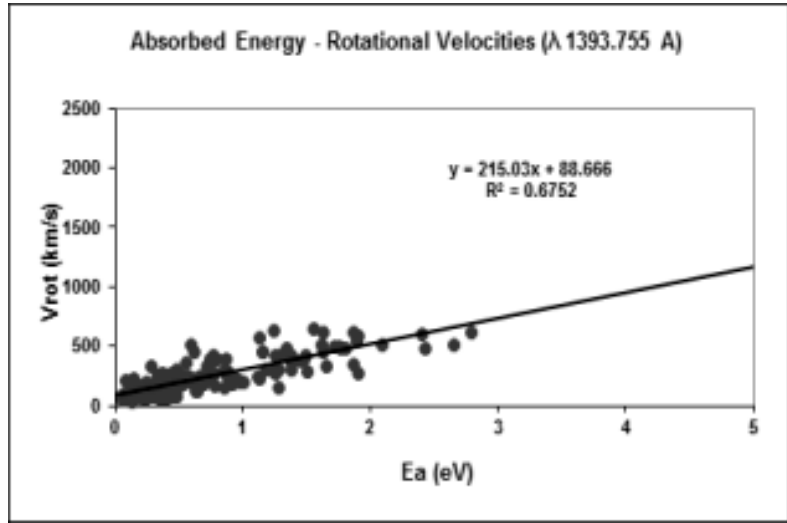


Figure 7. Variation of the rotational velocities of the independent density clouds which create the absorption components of the λ 1393.755 Å Si IV spectral line as a function of the absorbed energy. We see a slightly increasing linear trend of the rotational velocities.

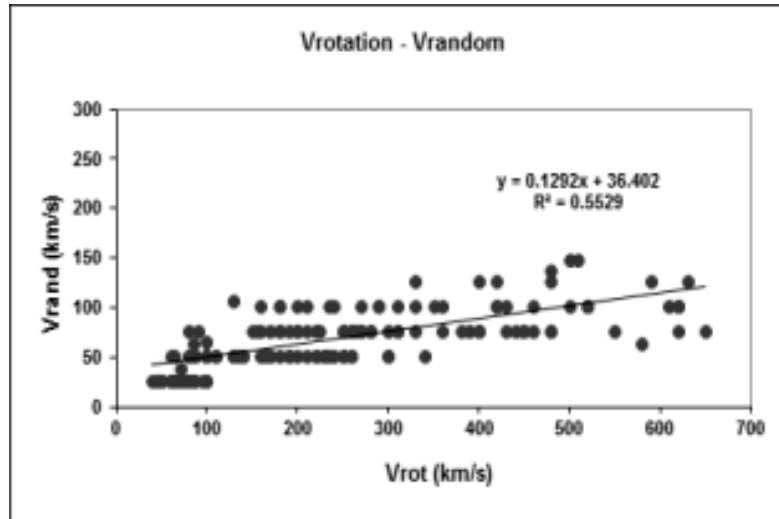


Figure 8. Variation of the rotational velocities of the independent density clouds which create the absorption components of the Si IV resonance lines ($\lambda\lambda$ 1393.755, 1402.778 Å) as a function of the random velocities. Here also we see a slightly increasing linear trend of the random velocities and a “good” linear correlation ($R^2=0.553$).

4. Discussion and conclusions

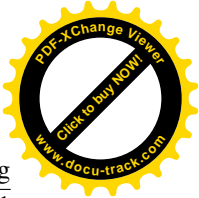
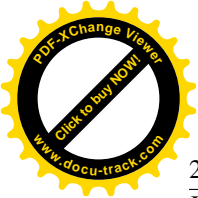
Our general comments are the following: Firstly, the values of all the calculated parameters are in agreement with the physical theory. Secondly, we accomplished the best fit using one absorption component in eleven of the 68 studied stars, with two components in twenty eight of them and with three components in twenty nine of them.

Rotational velocities: The kinematical independent clouds rotate with different mean velocities. We detected three levels of values. The first level corresponds to the 1st component and has values between 620 and 310 km/s (mean value 455 km/s), the second one corresponds to the 2nd component and has values between 300 and 210 km/s (mean value 221 km/s) and the third one corresponds to the 3rd component and has values between 140 and 40 km/s (mean value 85 km/s). We also note that the rotational velocities of the three independent regions present a uniform fluctuation with the spectral subtype.

Radial velocities: Here we detected three components but two levels of values. The first level corresponds to the 1st component and has values between -236 and 90 km/s (mean value -83 km/s) and the second one corresponds to the 2nd and 3rd component and has values between 360 and 10 km/s (mean value 137 km/s).

Random velocities: We detected an almost constant trend of the random velocities for each component. We found values from about 110 to 70 km/s for the first component, from about 70 to 50 km/s for the second one and from about 50 to 30 km/s for the third one. This is expected because the random motions of the ions depend on the temperature of the region in which the specific spectral lines are created.

Absorbed Energy: We note that this parameter has the same behavior as the rotational velocities. We detected a descending trend from the first to the third component.



Absorbed Energy- Rotational Velocities $V_{rot}=f(Ea)$: We detected a slightly increasing linear trend of the rotational velocities in the Si IV spectral line and a “good” linear correlation ($R^2=0.675$). This means that high values of the absorbed energy indicate high values of rotational velocities.

Rotational Velocities – Random Velocities $V_{rand}=f(V_{rot})$: We also detected a slightly increasing linear trend of the random velocities as a function of the rotational velocities and a “good” linear correlation ($R^2=0.558$).

In the cases of $V_{rot}=f(Ea)$ and $V_{rand}=f(V_{rot})$ the fact that the calculated linear correlation is “good” indicates that in Be stars, if we know the value of one of them, we could estimate the other one. This idea must be confirmed by a much greater sample of Be stars and it is part of our future work.

Acknowledgments

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5. References

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