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THE COMPLEX STRUCTURE OF THE Mg II REGIONS OF 40 BeV STARS

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Abstract. In this paper we present a study of the UV Mg II resonance lines in 40 BeV stars' spectra. We used the model proposed by Danezis *et al.* (2002b, 2003). This model is based on the idea of independent density layers in the regions where the spectral lines that present SACs (DACs) are created. We calculated the apparent rotation (V_{rot}) and expansion/contraction velocities (V_{exp}) of these density regions, as well as their ξ value, which is an expression of the optical depth. We also present the relation among these parameters and their evolution with the spectral subtype.

1. INTRODUCTION

The definitive characteristics of the emission early type stars are the peculiar emission-absorption features in their spectra. In order to explain this phenomenon, first Struve (1931, 1942) developed a model, which accepts that the emission and/or absorption features are formed in an extended low-density equatorial envelope surrounding a rapidly rotating B star. This model implies small radial velocity fields in the shell but large rotational velocities throughout much of the disk or shell. In Be stars, the Balmer series in the optical range and the UV Mg II resonance lines present strong emission lines.

The Mg II resonance lines λλ 2795.523, 2802.698 Å arise from the transition $3s^2S$ - $3p^2P^0$. As the energy difference between the two levels is quite large (4.5 eV), the Mg II spectral lines are sensitive to Non-LTE effects (Underhill, 1970) and thus to the structure of the stellar atmosphere and its radiation field (Lamers *et al.* 1973). As a result, the study of the Mg II resonance lines in the spectra of early type stars is a significant tool for the study of the structure of the stellar atmospheres.

Mihalas (1972) used a model atom which gave a good fit to the observed equivalent widths of the λ 4481 Å line of Mg II on the range from O6 through B5 stars.

Hubert (1973) studied the optical spectra of eight Be stars and concluded the emission to be reinforced or disappeared, depending on the stars' phase (B or Be). Besides, during the star's transition from B to Be and from Be to B, the lines are stronger. Five of the studied stars, while in emission, keep their absorbing envelope.

Lamers *et al.* (1973) found that, in B stars, the equivalent width of the Mg II lines, which lies between the values 1 to 4.5 Å, does not really depend on the temperature. They studied the spectra of the Be stars κ CMa (B2Ve) and κ Dra (B7e) and found that the Mg II lines are about 0.6 times weaker than those of normal stars and that βMon (B3e), which is a classical shell star, presents Mg II lines with normal strength. They suggested that this behavior is due to the absorption lines being partially filled in with emission. They also found that the blended lines (mainly VII, CrII, FeII and TiII) contribute less than 25 per cent to the observed equivalent widths. In order to explain the observed equivalent widths in B1-B2 stars, in terms of microturbulence, they suggested a velocity of about 15 km/s, which exceeds the value derived from the optical spectrum (4 to 5 km/s) by quite a large factor. However, as the UV Mg II lines and the lines at 4481 Å, in the optical range, are formed at about the same optical depth, in early B stars, they should present the same microturbulent velocity.

Collins (1974) indicated that rotation may affect the measured equivalent widths of certain lines in the sense that higher rotation will increase the line strengths.

Underhill (1975) observed sharp components of the ions NII, CII and Mg II in the spectrum of HD 58350 and attributed the one velocity of 230 km/s to a gas cloud accelerated from the star and moving rapidly out of the star and the other velocity of about 25 km/s to a moving circumstellar shell.

Gurzadyan (1975) studied the Mg II resonance lines in the spectra of 51 relatively faint stars with spectral types from B1 to K5 and found that there is an empirical relationship between the equivalent width and the spectral type of the star. In the types B1 to K0 the Mg II lines are in absorption, while in some cases the Mg II lines present a wide absorption with a weak emission in the center. In the faint B stars the equivalent widths of the Mg II lines are small and mainly due to the interstellar component, while in the bright B stars they sometimes appear larger than the theoretically predicted values. He concluded the doublet to be more or less stable for a given spectral type.

Snijders and Lamers (1975) considered that the Mg II lines are sensitive to non-LTE effects and to the structure of the stellar atmosphere and its radiation field and that the interstellar Mg II resonance lines in the UV are usually strong in the spectra of early O and B stars. They calculated the equivalent widths and line profiles of the Mg II resonance lines at λλ 2795.523, 2802.698 Å, of their subordinate lines at λλ 2790.768, 2797.989 Å, as well as of the doublet at 4481 Å in the spectra of early type stars. They found that in stars later than B2 the observed and predicted (considering LTE) equivalent widths agreed reasonably, while the stars of types earlier than B3 showed lines stronger than predicted. They also found that microturbulence adds to the width of the line cores by a factor 1.3-1.5 for main-sequence stars and by a factor 2-3 for supergiants.

According to Kondo *et al.* (1975) "the Mg II features are of considerable interest for studies of both the interstellar medium and the structure of stellar atmospheres, where these lines may involve a significant part of the energy in some regions of the atmosphere". They studied the relation between the existence of emission cores at the bottom of the strong absorption lines and the existence of a chromosphere for stars of early to intermediate type. They suggested that, for the early type stars, the main question about the chromosphere is the physical problem of the energy source, meaning "whether the concept of acoustic waves, generated in a convection zone and growing into shock waves to heat a chromosphere, is relevant, or whether other mechanisms dominate". They used a synthetic spectrum to fit the Mg II absorption lines of the observed spectra, in order to have a quantitative evaluation of the lines' strength. This procedure was based on the idea that the absorption lines can be approximated by a Gaussian formula and did not include the possible emission and the interstellar absorption, for which, in some cases they used additional absorption functions. In this way they determined the equivalent widths and the full widths at half-depth for the Mg II resonance lines at λλ 2795.523, 2802.698 Å, as well as for their subordinate lines at λλ 2790.768, 2797.989 Å. The values they measured were in good agreement with those determined theoretically. They suggested that, in the spectral range from B2 to B6, the Mg II equivalent widths might be used as an indicator of luminosity. They also proposed that there exists a correlation of the equivalent width with Vsini. For the spectral region between O8 and B8 stars, they found emission features in the spectra of the earliest and latest spectral types. They attributed this phenomenon to "chromospheres being minimal at intermediate B type as a result of cross-over of different physical mechanisms for early and late-type stars".

Kondo *et al.* (1976a) considered that the Mg II doublet is a great tool for studying stellar chromospheres. They suggested that the chromospheric emission, if it exists, could imply the presence of a positive outward temperature gradient in the outer regions of the stellar atmospheres. The observational evidence for the existence of chomospheres in B stars is mainly the weak emission features at the bottom of the absorption lines of the resonance doublet at λλ 2795.523, 2802.698 Å. However, the weak emission at the bottom of the doublet's lines is strongly affected, even obliterated sometimes, by the quite pronounced interstellar absorption lines. They proposed that "the existence of an intervening spectral type of minimum chromospheric activities could imply an additional heating mechanism (other than acoustic heating from a convection zone) for the massive stars. In the case of a greatly extended atmosphere, the Mg II emission might not be a definite evidence of a chromosphere, as emission from regions outside the line of sight could overpower the usual effect that a cool gas will absorb more radiation in a spectrum line than it emits".

Kondo *et al.* (1976b) pointed out that it is difficult to determine the range of early spectral types, where the chromospheric emission disappears, as the circumstellar and interstellar Mg II emission lines may affect the determination of spectral type at which the emission disappears. They proposed that there is probably a difference among luminosity classes. They found that the shell absorption gets stronger from intermediate to late B stars and suggested that "it might be due to the rising temperature in the gaseous shell which converts Mg II to Mg III and to the weakening of the outward-driving mechanisms of the atmosphere". In early B type supergiants, the Mg II doublet consists of the photospheric resonance lines with superposed interstellar resonance absorption lines. The intermediate B supergiants present a value of about 100 km/s for the velocity of the escaping shell, maybe due to the transition from acoustic heating to radiation pressure.

Morgan *et al.* (1977) studied the Mg II resonance lines of γ Cas and ζ Tau and detected "significant absorption features" shortward of each resonance absorption, which they attribute to "additional absorption within the stars' extended atmosphere". They concluded that the Mg II resonance lines of ζ Tau were not formed in the same layer as their subordinate lines. They remark: "The strong subordinate lines are formed exterior to the regions where the bulk of the visible stellar spectrum is formed and interior to the portions of the circumstellar disk where the visible shell lines are formed". Finally, for ζTau, they calculated an outward velocity of 60-120 km/s from near the stellar surface layers all the way to the outer edge of the shell.

Kondo *et al.* (1977) calculated the equivalent widths of the Mg II resonance lines in the spectra of O to F stars and found that they increase from early to late B subtypes. They report that, while the emission in early type stars may arise from the star's chromosphere, when a binary system is concerned, the emission may be due to high-temperature plasma flowing in the system rather than to chromosphere of the primary star.

Marlborough *et al.* (1978) pointed out that the UV spectra of Be stars are very complex and contain many shell absorption lines which usually have velocity shifts. On the other hand, the emission lines are not usually present, probably due to the insufficient extent and/or density of the circumstellar envelope. They detected Mg II emission in four spectra of γCas (taken in the time interval from November 1974 to November 1976), which presented differences in position and strength. They tested three classes of Be star models proposed for the emission, in order to explain the spectra of γCas: a) the single-star models invoking detached rings of material responsible for the emission features (Struve 1931, McLaughlin 1961, Albert and Huang 1974, Huang 1977), b) models of binary systems, where a late-type companion loses material to form the observed extended atmosphere of a Be star (Kriz and Harmanec 1975, Harmanec and Kriz 1976), and c) single-star models in which the emission lines arise in the dense regions of a stellar wind (Poeckert and Marlborough 1978). All the three models failed to explain the observational data of γCas. Thus, they proposed an extension of the stellar-wind model, in which the terminal speed of the wind depends on the distance from the equatorial plane. At low distances the terminal wind speed is low, while at larger distances it is significantly higher. Turbulence due to differential rotation near the equatorial plane is responsible for the production of a coronal layer at larger distances above and below the equatorial plane. According to this model the observed optical and UV emission lines arise in the inner regions of the wind.

Slettebak and Snow (1978), in their study on γCas, suggested that since the Mg II resonance lines are very narrow, they cannot be photospheric but of circumstellar or, more probably, interstellar origin. They detected a narrow emission component shifted about 0.7 Å to the red of each Mg II line center, which corresponds to a velocity of 85 km/s.

De Jager *et al.* (1979) studied the spectra of 33 stars of all spectral types. They found variable mass loss from late B supergiants, due to "occasional stellar "puffs" superposed on a more or less regular wind". In the spectrum of the B8 star βOri, the Mg II resonance lines are shifted by -190 km/s. This fact indicates that "there are concentrations of low-ionization species in the stellar wind as a result of the occurrence of significant density variations". The Be and shell stars presented very strong and sharp resonance lines. The noninterstellar component was significantly shifted toward long wavelengths, suggesting that a new infall of shell material was occurring at the time of the observation (Delplace and van der Hucht 1978).

Lamers *et al.* (1980) studied the spectra of 9 Ap, Bp, Be, Bn and shell stars and found that the Mg II lines of Be stars are weaker than in normal stars and that the Bp, Bn and shell stars present normal Mg II lines.

Bruhweiler *et al.* (1982) studying the UV Mg II resonance lines in the spectra of the Be stars γCas, φPer and υCyg, proposed that the Mg II emission is a normal phenomenon in Be stars, since it appears in all the studied spectra. The Mg II absorption is shifted with respect to the emission by 5-10 km/s. Thus, a part of the absorption lines must originate from a slowly expanding circumstellar shell and another is expected to be of interstellar origin. They propose that the emission, which must originate in a region of low ionization and low expansion velocities, is due to a Bowen (1947) mechanism driven by Lyβ, since the widths of the Balmer and Mg II emission are comparable. Thus, the Mg II emission must originate in the same physical region as the hydrogen recombination spectrum.

Danezis (1984, 1986) and Danezis *et al.* (1991) studied the UV spectra of the gaseous envelope of AX Mon taken by the IUE satellite and noted that the absorption lines of many ionization potential ions (including Mg II), not only of those presenting PCygni profile, are accompanied by two strong absorption components of the same ion and the same wavelength, shifted shortward at different Δλ. This means that the regions where these spectral lines are created are not continuous, but they are formed by a number of independent density layers of matter. These layers of matter can rotate and move with different apparent velocities of the order of 10 km/s, -75 km/s and -260 km/s.

The existence of satellite components in the UV spectrum of AX Mon has been detected also by Sahade *et al.* (1984) and Sahade and Brandi (1985). For the Mg II absorption components, they found velocities between the values of -200 and 250 km/s. Also, Hutsemekers (1985), in the UV spectrum of another Be star, HD 50138, noticed a number of satellite components that accompanied the main spectral lines.

Laskarides *et al.* (1992) observed one more satellite component in the spectral lines of ions with low ionization potential in the absorption UV spectrum of AX Mon, lying at the red side of the main lines. The existence of these spectral lines has been proposed by Doazan (1982). This fact indicates contraction of the outer layers of the gaseous envelope.

Cidale (1998) adopted a model for the Be stars' atmospheres, in order to compute the Mg II line profiles. This model is called "chromospheric-wind model" and suggests that the atmosphere consists of a classical photosphere, an expanding high-temperature chromosphere and a cool envelope. This model accepts that the Mg II lines arise from a nonrotating and spherically expanding medium. They sometimes appear as pure absorption and sometimes they display emission wings and absorption cores (Dachs 1980, Doazan *et al.* 1991). The lines present PCygni profiles or blueshifted variable absorption components in the velocity range of -50 to -200 km/s. There is no relation between the emission and the spectral type or Vsini. However, the lines' profiles depend on the temperature structure and on the velocity and mass-density distributions. Particularly, the velocity law defines the profiles shape and the extension of the line-forming regions. High velocity gradients yield extended regions, which give rise to resonance lines with double absorption components or PCygni profiles. In this case the blueshifted component reveals the velocity of the most external layers, generally located in the cool envelope. She proposed that the undisplaced component originates in the photosphere, while the blueshifted component and the emission arise from the outer regions. The emission, which is related to the existence of a chromosphere, is very faint or does not exist at all in the early subtypes. It strengthens in the intermediate subtypes and appears quite prominent by the time the late subtypes are reached, indicating the presence of a chromosphere.

Finally, Danezis *et al.* (2002a) studied the Mg II resonance lines in the spectra of 21 BeV stars. They attributed many of the peculiarities occurring to these lines to the existence of Satellite Absorption Components (SACs). In order to study all the lines presenting SACs, they proposed a model for the structure of the regions where the spectral lines that present SACs are created (Danezis *et al.*, 2002b, 2003). Based on this model, they studied the variation of the apparent rotation (V_{rot}) and expansion/contraction velocities (V_{exp}) of the density regions where the Mg II resonance lines (λλ 2795.523, 2802.698 Å) are formed for a series of 21 Be V stars of all the spectral subtypes.

In this paper we apply the proposed by Danezis *et al.* (2003) model to 40 BeV stars, in order to calculate the apparent rotation and expansion/contraction velocities and the ξ values of the density regions where the UV Mg II resonance lines are created.

2. DATA

The data we used are the Mg II resonance lines of 40 Be V stars. The stars' spectrograms have been taken with IUE satellite and their spectral types have been taken by the SIMBAD database (Centre de Donnees Astronomiques de Strasbourg (CDS), Strasbourg, France). Our data are presented in Table 1.

Table 1					
Star	**Spectral Type**	**Camera**	**Star**	**Spectral Type**	**Camera**
HD 206773	B0 V : pe	Lwr 14808	HD 191610	B2.5 V e	Lwr 07342
HD 200310	B1 V e	Lwr 09544	HD 60855	B2/B3 V	Lwp 15477
HD 212571	B1 V e	Lwr 05948	HD 25940	B3 V e	Lwr 05950
HD 44458	B1 V pe	Lwp 30173	HD 45725	B3 V e	Lwp 10041
HD 200120	B1.5 V nne	Lwr 11035	HD 183362	B3 V e	Lwp 11044
HD 36576	B 2 IV-V e	Lwp 14029	HD 208057	B3 V e	Lwp 29221
HD 32991	B2 V e	Lwr 11426	HD 205637	B3 V : p	Lwr 05947
HD 58050	B2 V e	Lwr 14810	HD 217543	B3 V pe	Lwp 13326
HD 164284	B2 V e	Lwr 11038	HD 22192	B5 V e	Lwr 09071
HD 41335	B2 V ne	Lwr 07384	HD 217891	B6 V e	Lwr 09069
HD 52721	B2 V ne	Lwp 05462	HD 138749	B6 V nne	Lwr 07858
HD 58343	B2 V ne	Lwr 07363	HD 6811	B7 V e	Lwr 09070
HD 148184	B2 V ne	Lwr 06744	HD 192044	B7 V e	Lwp 08135
HD 202904	B2 V ne	Lwr 07343	HD 210129	B7 V ne	Lwp 23173
HD 65079	B2 V ne…	Lwp 30119	HD 47054	B8 V e	Lwp 13074
HD 28497	B2 V : ne	Lwr 07337	HD 58715	B8 V e	Lwp 10104
HD 45995	B2 V nne	Lwr 08648	HD 183914	B8 V e	Lwr 04609
HD 10516	B2 V pe	Lwr 07335	HD 23552	B8 V ne	Lwr 08744
HD 32343	B2.5 V e	Lwr 05890	HD 185037	B8 V ne	Lwp 08136
HD 65875	B2.5 V e	Lwr 05616	HD 199218	B8 V nne	Lwp 09903

3. SPECTRAL ANALYSIS OF THE Mg II RESONANCE LINES IN THE UV SPECTRA OF 40 Be V STARS

Figures and diagrams

In Figs. 1 and 2 we present the Mg II lines' fittings of 9 BeV stars together with the normal B star's HD 30836 Mg II profile, in order to indicate the blended lines and the intense appearance of the SACs. The heavy line presents the observed spectral line's profile and the thin one the model's fit. The differences between the observed spectrum and its fit are sometimes hard to see, as we have accomplished the best fit. The dashed lines indicate the laboratory wavelengths of the Mg II resonance lines at λλ 2795.523, 2802.697 Å.

By the model's best fit of the Mg II resonance lines of 40 BeV stars, we calculated the apparent rotation (V_{roti}) and expansion/contraction (V_{expi}) velocities of each one of the absorption and the emission components of the lines. We have also calculated the values of ξ_i for each line. By the study of the interstellar lines we calculated a systematical error which leads to a displacement of about +98±18 km/s. This displacement is clearly seen in Figs. 1 and 2. Our results have undergone the appropriate corrections and appear in diagrams 1 to 14.

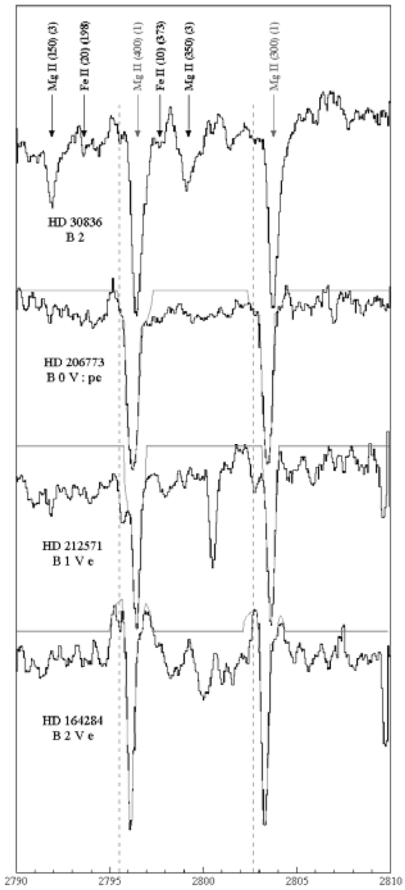

Fig. 1

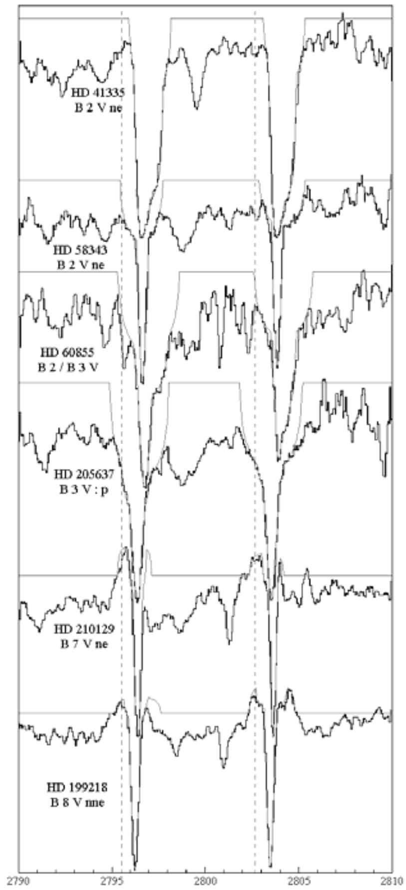

Fig. 2

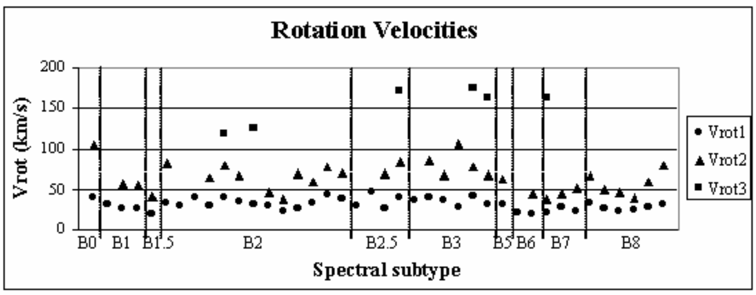

Diagram 1: Apparent rotation velocities of all the SACs as a function of the spectral subtype. The rotation velocity presents a uniform fluctuation, which we could not accept as accidental. Three rotation velocity groups are presented with the mean values of 31 km/s, 64 km/s and 153 km/s. These groups are presented separately in diagrams 3-5.

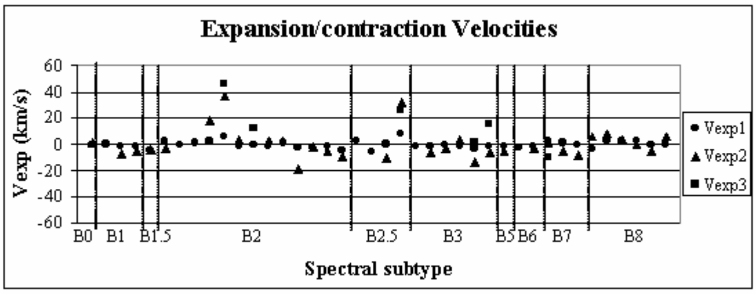

Diagram 2: Expansion/contraction velocities of all the SACs as a function of the spectral subtype. The values of the expansion/contraction velocities of all the SACs lie in a narrow range between -18 km/s and +18 km/s and present two maxima of +42 km/s and +29 km/s, which correspond to stars with spectral subtypes B2 and B2/B3, respectively.

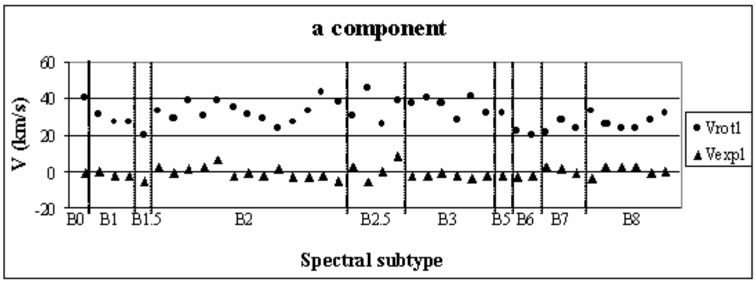

Diagram 3: Apparent rotation and expansion/contraction velocities of the first SAC as a function of the spectral subtype. As one can see, the first SAC's rotation and expansion/contraction velocities present a uniform fluctuation around the values of 31 km/s and -1 km/s respectively.

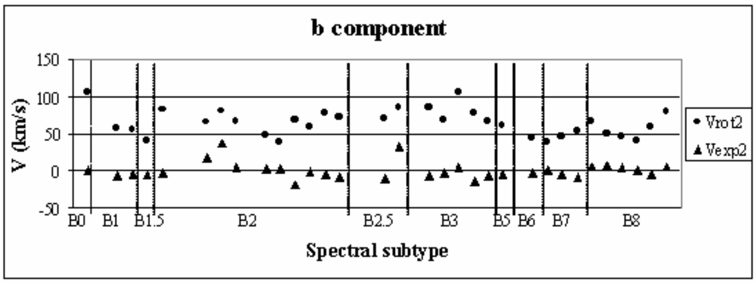

Diagram 4: Apparent rotation and expansion/contraction velocities of the second SAC as a function of the spectral subtype. A less intense uniform fluctuation is also presented in the second SAC's rotation and expansion/contraction velocities around the values of 64 km/s and 0 km/s respectively.

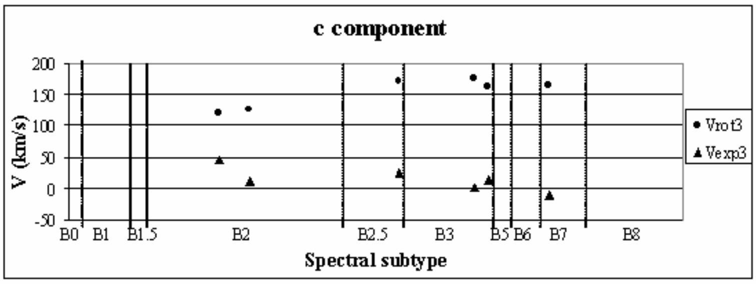

Diagram 5: Apparent rotation and expansion/contraction velocities of the third SAC as a function of the spectral subtype. A slight increase is observed in the rotation velocity of the third SAC around the value of 153 km/s, whereas the respective expansion velocity presents a slight decrease around the value of +15 km/s.

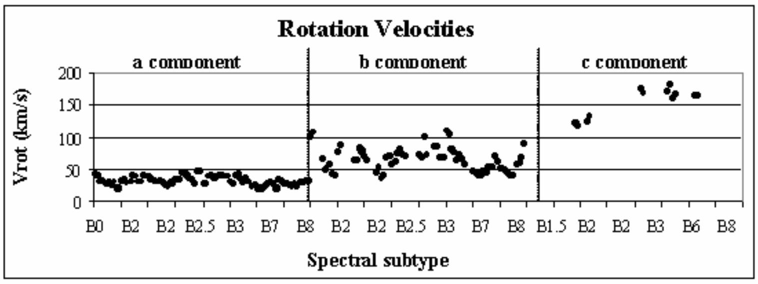

Diagram 6: Apparent rotation velocities of all the SACs as a function of the spectral subtype (presented separately). The rotation velocity of the first SAC presents a small dispersion around the value of 31 km/s whereas in the case of the second SAC the dispersion increases around the greater value of 64 km/s. The third SAC's rotation velocity increases more and presents a greater dispersion around the value of 153 km/s.

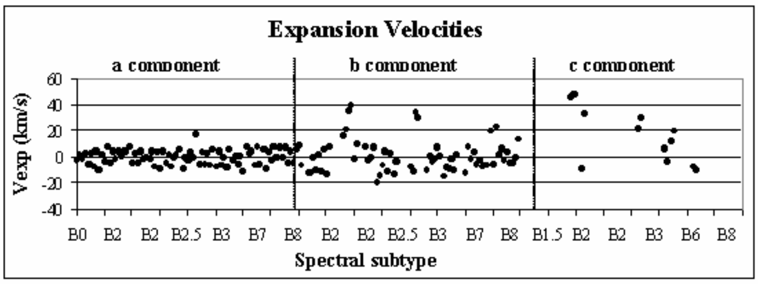

Diagram 7: Apparent expansion/contraction velocities of all the SACs as a function of the spectral subtype (presented separately). As in the case of the rotation velocity, the expansion/contraction velocities of the first, second and third SAC present increasing dispersion around the values of -1 km/s, 0 km/s and +15 km/s, respectively.

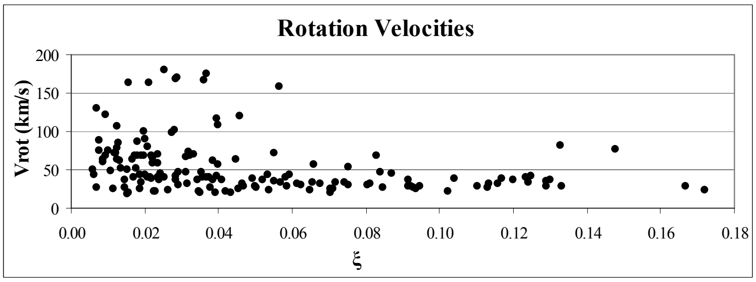

Diagram 8: Apparent rotation velocities of all the SACs as a function of the respective value of ξ. For small values ξ the rotation velocity lies in the range of 16 to 100 km/s. As the ξ value increases the rotation velocity's values lie in a smaller range between 20 and 82 km/s. The points referring to greater rotation velocity values (between 102 and 180 km/s) correspond to the third SAC which presents small values of ξ (between 0.007 and 0.057).

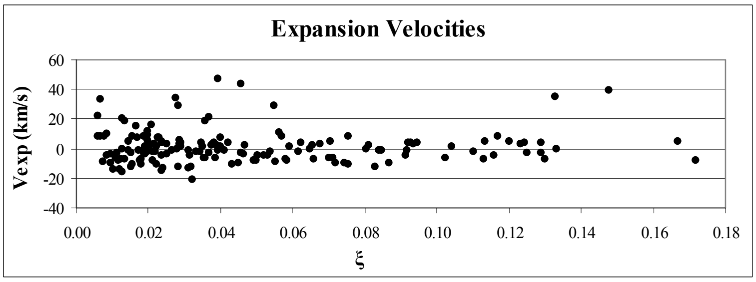

Diagram 9: Expansion/contraction velocities of all the SACs as a function of the respective ξ value. For small ξ values the expansion/contraction velocity lies in the range of -21 to +47 km/s. As the ξ value increases the expansion/contraction velocity's values lie in a smaller range between -12 and +8 km/s. The points referring to greater values of expansion/ contraction velocities (between +20 and +47 km/s) correspond to the second and third SAC.

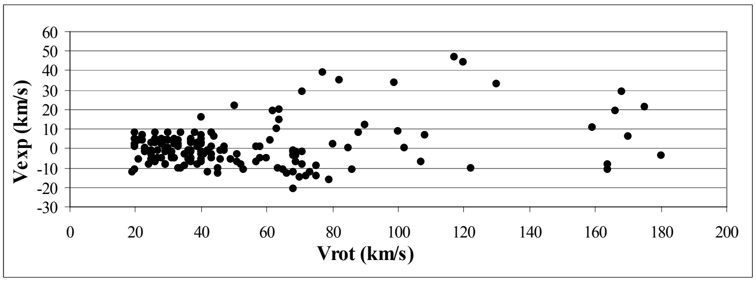

Diagram 10: Expansion/contraction velocities of all the SACs as a function of the respective apparent rotation velocities. For small values of the rotation velocity, between 16 and 66 km/s, the values of the expansion/contraction velocity lie in a small range between -11 and +22 km/s. As the rotation velocity increases, the expansion/contraction velocity presents greater dispersion and its values, which lie between -21 and +47 km/s, seem to gather into two branches around 0 and +35 km/s.

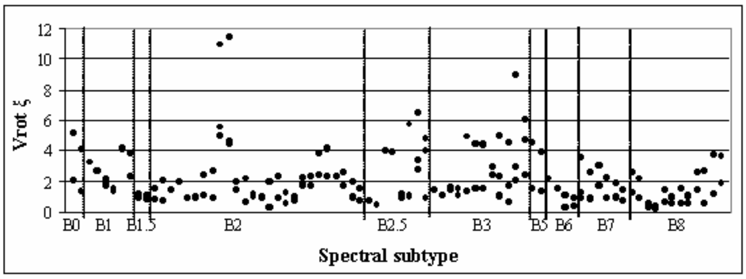

Diagram 11: Values of the product of ξ and the apparent rotation velocities (V_{rot}) as a function of the spectral subtype.

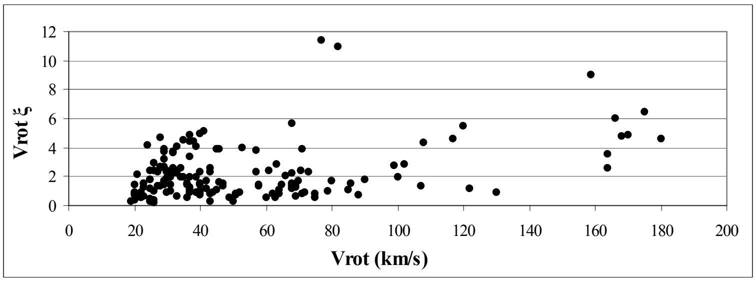

Diagram 12: Values of the product of ξ and the apparent rotation velocities (V_{rot}) as a function of the apparent rotation velocities.

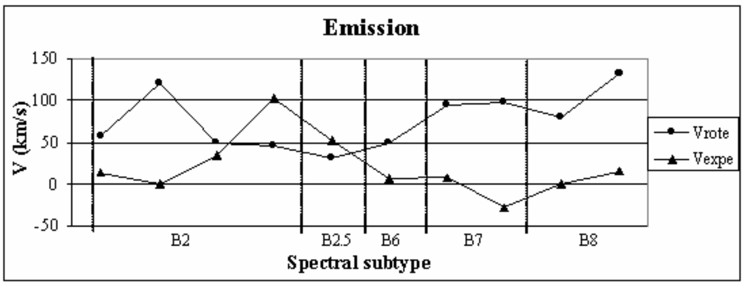

Diagram 13: Apparent rotation and expansion/contraction velocities of the emission component as a function of the spectral subtype.

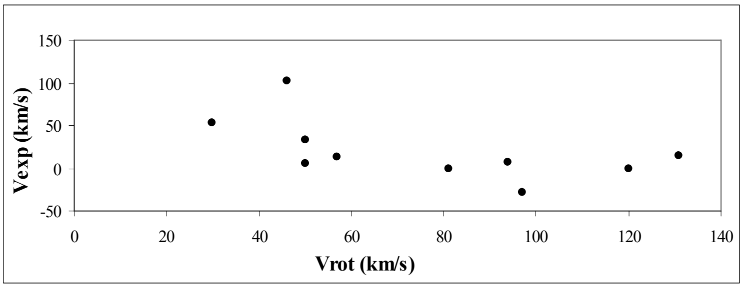

Diagram 14: Expansion/contraction velocities of the emission component as a function of the respective apparent rotation velocities. As the values of the rotation velocity increase, the values of the expansion/contraction velocity decrease.

4. CONCLUSIONS

1. By applying the proposed by Danezis *et al.* (2002b, 2003), model we are able to reproduce, with great accuracy, the profiles of the Mg II doublet of the 40 BeV stars we studied. This means that the coronal model allowing the existence of successive, independent density shells of matter represents accurately the structure of the Mg II region of the Be stars. This result verifies the proposition of de Jager *et al.* (1979) that "there are concentrations of low-ionization species in the stellar wind as a result of the occurrence of significant density variations", as well as the fact that there are "significant absorption features" shortward of each resonance absorption, which, according to Morgan *et al.* (1977) are attributed to "additional absorption within the stars' extended atmosphere". These "significant absorption features" are the Satellite Absorption Components (SACs) that appear in the spectra of the early type stars. Danezis *et al.* (2003) explained that the peculiar phenomena observed in the spectra of Oe and Be stars, such as the SACs, are due to independent density regions in the stars' environment. Such regions may be structures that cover all or a significant part of the stellar disk (shells, blobs, puffs, bubbles) (Underhill 1975, de Jager *et al.* 1979, Henrichs 1984, Underhill and Fahey 1984, Bates and Halliwell 1986, Grady *et al.* 1987, Lamers *et al.* 1988, Waldron *et al.* 1992, Cranmer and Owocki 1996, Rivinious *et al.* 1997, Kaper *et al.* 1996, 1997, 1999, Markova 2000), interaction of fast and slow wind components, CIRs, structures due to magnetic fields or spiral streams as a result of the star's rotation (Underhill and Fahey 1984, Mullan 1984a,b 1986, Prinja and Howarth 1988, Cranmer and Owocki 1996, Fullerton *et al.* 1997, Kaper *et al.* 1996, 1997, 1999, Cranmer *et al.* 2000).
2. The SACs phenomenon appears to be a classical one for the Be stars. From the present study, we observe that all the 40 Be V stars present SACs, though, they are not presented as intensively as they are in the case of the Be III stars, such as HD 144 or HD 45910 (paper II), where the SACs appear as discrete lines. In the case of the Be V stars, the relatively small values of the expansion/contraction velocities result in the SACs being blended among them as well as with the main spectral line, making it difficult for the observer to detect them.
3. In Figs. 1 and 2, in Table 2 and in diagram 1 one can see that all the studied stars present discernible or indiscernible SACs of the Mg II resonance lines. The indiscernible SACs appear in the spectra of the stars with spectral subtypes B0-B1, B4-B6 and B8. This is due to the fact that the SACs of the Mg II resonance lines in the

spectra of the stars of these spectral subtypes present similar radial velocities. In this case, we can separate these lines by the systematic differentiations of the apparent rotation velocities and the values of ξ_i. The SACs of the Mg II resonance lines are more discernible in the spectra of the stars with spectral subtypes B2-B3 and B7, as they present quite different radial shifts. In this case the density regions' apparent rotation velocities present greater values.

4. The regions where the Mg II resonance lines are created present three velocity groups, which do not appear, though, in all the 40 Be V stars we studied in this paper. All of the studied stars present the SAC with rotation velocity of the order of 31±7 km/s. The SAC with rotation velocity of the order of 64±18 km/s appears in most of the stars except in a B1, a B2, two B2.5, a B3 and a B6 star. These two SACs present an almost zero expansion/contraction velocity. The third rotation velocity group of the order of 153±24 km/s presents expansion/contraction velocity of the order of +15 km/s. This SAC appears in some stars of spectral subtypes B2-B3 and B7. All the above means that the Mg II doublet is more or less stable for a given spectral type as Gurzadyan (1975) proposed. In diagram 2 one can see that the values of the expansion/contraction velocity of all the SACs lie in a narrow range between -18 km/s and +18 km/s and present two maxima of +42 km/s and +29 km/s, which correspond to stars with spectral subtypes B2 and B2/B3, respectively. In diagrams 1-3, 6 and 7 one can see that the apparent rotation and expansion/contraction velocities of the first SAC present a uniform fluctuation in a narrow range around the values 31 km/s and -1 km/s, respectively. The same phenomenon is presented in the second SAC (diagrams 1, 2, 4, 6 and 7), where the apparent rotation and expansion/contraction velocities fluctuate around the values 64 km/s and 0 km/s, respectively and present greater dispersion than the one presented in the values of the first SAC. The third SAC (diagrams 5, 6 and 7) presents greater values of rotation and expansion/contraction velocity, which lie in wider ranges between 102 km/s and 180 km/s and-10 km/s and +47 km/s, respectively. The rotation velocity values of the third SAC increase slightly, around the value of 153 km/s, while the respective expansion/contraction velocity values decrease slightly, around the value of +15 km/s. In diagram 10 we present the relation between the expansion/contraction velocity and the apparent rotation velocity. We observe that, as the apparent rotation increases, the expansion/contraction velocity increases too and presents a greater dispersion, while its values gather into two branches.
5. In diagrams 8 and 9 one can see the variation of the apparent rotation and expansion/contraction velocity with ξ, respectively. For small values of ξ the two velocities lie in a wide range, while by the increase of ξ the velocities' range becomes narrower. In diagrams 11 and 12 we present $V_{rot}\xi$ as function of the spectral subtype and the apparent rotation velocity, respectively. As the product of the rotation velocity and the values of ξ ($V_{rot}\xi$) is an evaluation of the absorbed energy, we would like to extract some first conclusions about the variation of the absorbed energy with the spectral subtype and the apparent rotation velocity, as well as to verify other researchers' conclusions. Gurzadyan (1975) concluded that there existed an empirical relationship between the equivalent width and the spectral type of the star, while Kondo *et al.* (1977) concluded that the equivalent widths were increasing from early to late B subtypes. According to diagram 11, for the Be V stars, $V_{rot}\xi$ is more or less stable with the spectral subtype, presenting a fluctuation. In diagram 12 one can see that $V_{rot}\xi$ increases as the values of the apparent rotation velocity increase, meaning that there exists a correlation of the equivalent width with Vsini (Kondo *et al.* 1975). More conclusions about the energy will be presented in a forthcoming paper (paper II).

6. The stars that present emission are of spectral types B2, B6, B7 and B8 (diagram 13). This means that the emission appears in the spectra of the earliest and latest spectral subtypes of the Be V stars (Kondo *et al.* 1975). The expansion/contraction velocity of the emission component decreases as the rotation velocity increases. The emission component presents positive or negative expansion velocities. The calculated values correspond to the regions where the emission component is created (strings, blobs, puffs, bubbles), and not to a uniform region around the star. This means that the emission region may approach or move away from the observer and its different position and motion around the star is responsible of whether this value is positive or negative. In diagrams 13 and 14 one can see that, as the apparent rotation velocity increases, the expansion/contraction velocity decreases in contrast with the relation of the two velocities of the absorption components. At this point, we would like to point out that the emission component is blended with absorption lines of other ions, making difficult the evaluation of the apparent rotation and expansion/contraction velocity. As a result the calculated values present greater statistical error than the absorption components.
7. Until now, the main idea of the Mg II doublet was that the resonance lines were created in a specific region in the star's atmosphere and consisted of an absorption feature and a possible emission feature. Based on this idea, the equivalent width was calculated supposing that the whole absorption feature represents one absorption line, the rotation velocity was calculated by the width of the blue edge and the expansion velocity was calculated by the line shift, supposing that the deepest point of the feature corresponds to the wavelength at which the absorption appears. As we have already mentioned, according to the model presented by Danezis *et al.* (2002b, 2003), the Mg II resonance lines consist in a main absorption line accompanied by a number of SACs and a possible emission line. Thus, the above mentioned ways of the equivalent width and the rotation and expansion/contraction velocities' calculation can not be taken for granted. This fact can be explained, if we accept the existence of density regions (blobs, puffs, strings, bubbles) in the cool envelope. In this way we do not have to accept that the Mg II resonance lines are created in regions lying behind and in front of the corona, where the temperature is higher than the one needed for the creation of the Mg II ions. Finally, we could accept that in the cool envelope, around the density regions (blobs, puffs, strings, bubbles), there may exist sub-regions with similar structure, which give rise to narrow and faint absorption lines.
8. At this point we would like to point out that the calculated values of the apparent rotation and expansion/contraction velocities correspond to the regions, where the Satellite Absorption Components (SACs) are created, and not to the star. Specifically, these values correspond to the density regions (blobs, puffs, bubbles) which result when streams of matter are twisted and form strings that produce blobs, puffs or bubbles.It is important to make clear that the observed fluctuations of the apparent rotation and expansion/contraction velocities correspond to the regions where the SACs are created (strings, blobs, puffs, bubbles) and do not refer to a uniform shell around the star. Specifically, the calculated velocities correspond to the rotation of the region around itself and not around the star.
9. Finally, we would like to point out that a part of the measured apparent rotation velocity must be attributed to the expansion of the studied region. As it is known, the star ejects mass with a specific radial velocity. The stream of matter is twisted, forming density regions such as interaction of fast and slow wind components, corotating interaction regions (CIRs), structures due to magnetic fields or spiral streams as a result

of the star's rotation (Underhill and Fahey 1984, Mullan 1984ab, 1986, Prinja and Howarth 1988, Cranmer and Owocki 1996, Fullerton *et al.* 1997, Kaper *et al.* 1996, 1997, 1999, Cranmer *et al.* 2000)). This means that hydrodynamic and magnetic forces take effect as centripetal forces, resulting in the outward moving matter twisting and moving around the star. As a result, a part of the outward velocity is measured as rotation velocity. This motion of the matter is responsible for the formation of high density regions (shells, blobs, puffs, spiral streams), which, either are spherically symmetric around the star, or appear to the observer as spherically symmetric (Danezis *et al.* 2003).

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