A statistical study of physical parameters of the C IV density regions in 20 Oe stars

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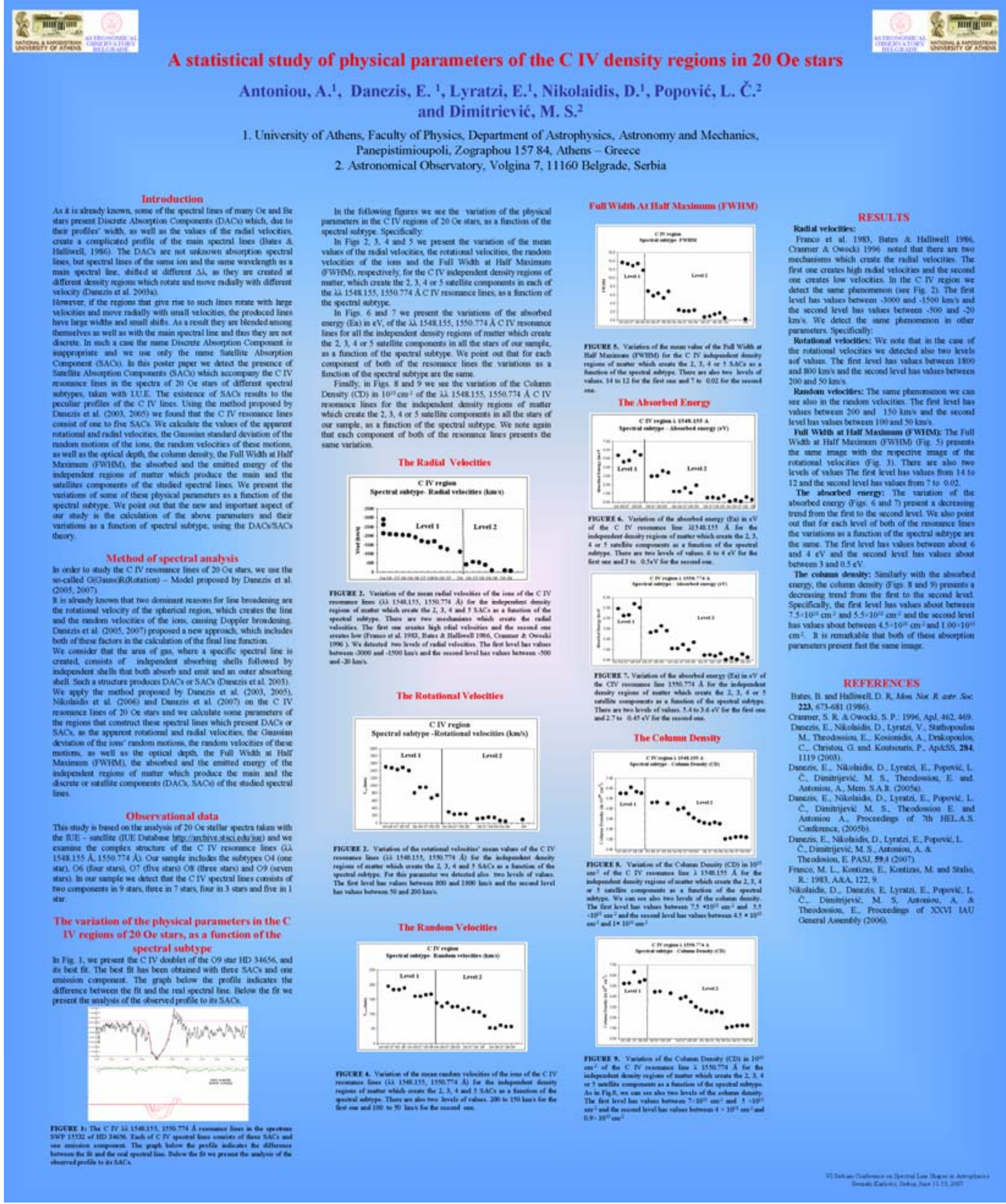

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Introduction

As it is already known, some of the spectral lines of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width, as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). The DACs are not unknown absorption spectral lines, but spectral lines of the same ion and the same wavelength as a main spectral line, shifted at different Δλ, as they are created at different density regions which rotate and move radially with different velocity (Danezis et al. 2003a).

However, if the regions that give rise to such lines rotate with large velocities and move radially with small velocities, the produced lines have large widths and 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 Satellite Absorption Component (SACs). In this poster paper we detect the presence of Satellite Absorption Components (SACs) which accompany the C IV resonance lines in the spectra of 20 Oe stars of different spectral subtypes, taken with I.U.E. The existence of SACs results to the peculiar profiles of the C IV lines. Using the method proposed by Danezis et al. (2003, 2005) we found that the C IV resonance lines consist of one to five SACs. We calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines. We present the variations of some of these physical parameters as a function of the spectral subtype. We point out that the new and important aspect of our study is the calculation of the above parameters and their variations as a function of spectral subtype, using the DACs/SACs theory.

Method of spectral analysis

In order to study the C IV resonance lines of 20 Oe stars, we use the so-called G(Gauss)R(Rotation) – Model proposed by Danezis et al. (2005, 2007).

It is already known that two dominant reasons for line broadening are the rotational velocity of the spherical region, which creates the line and the random velocities of the ions, causing Doppler broadening. Danezis et al. (2005, 2007) proposed a new approach, which includes both of these factors in the calculation of the final line function.

We consider that the area of gas, where a specific spectral line is created, consists of independent absorbing shells followed by independent shells that both absorb and emit and an outer absorbing shell. Such a structure produces DACs or SACs (Danezis et al. 2003).

We apply the method proposed by Danezis et al. (2003, 2005), Nikolaidis et al. (2006) and Danezis et al. (2007) on the C IV resonance lines of 20 Oe stars and we calculate some parameters of the regions that construct these spectral lines which present DACs or SACs, as the apparent rotational and radial velocities, the Gaussian deviation of the ions' random motions, the random velocities of these motions, as well as the optical depth, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the discrete or satellite components (DACs, SACs) of the studied spectral lines.

Observational data

This study is based on the analysis of 20 Oe stellar spectra taken with the IUE – satellite (IUE Database http://archive.stsci.edu/iue) and we examine the complex structure of the C IV resonance lines (λλ 1548.155 Å, 1550.774 Å). Our sample includes the subtypes O4 (one star), O6 (four stars), O7 (five stars) O8 (three stars) and O9 (seven stars). In our sample we detect that the C IV spectral lines consists of two components in 9 stars, three in 7 stars, four in 3 stars and five in 1 star.

The variation of the physical parameters in the C IV regions of 20 Oe stars, as a function of the spectral subtype

In Fig. 1, we present the C IV doublet of the O9 star HD 34656, and its best fit. The best fit has been obtained with three SACs and one emission component. The graph below the profile indicates the difference between the fit and the real spectral line. Below the fit we present the analysis of the observed profile to its SACs.

FIGURE 1: The C IV λλ 1548.155, 1550.774 Å resonance lines in the spectrum SWP 15532 of HD 34656. Each of C IV spectral lines consists of three SACs and one emission component. The graph below the profile indicates the difference between the fit and the real spectral line. Below the fit we present the analysis of the observed profile to its SACs.

In the following figures we see the variation of the physical parameters in the C IV regions of 20 Oe stars, as a function of the spectral subtype. Specifically:

In Figs 2, 3, 4 and 5 we present the variation of the mean values of the radial velocities, the rotational velocities, the random velocities of the ions and the Full Width at Half Maximum (FWHM), respectively, for the C IV independent density regions of matter, which create the 2, 3, 4 or 5 satellite components in each of the λλ 1548.155, 1550.774 Å C IV resonance lines, as a function of the spectral subtype.

In Figs. 6 and 7 we present the variations of the absorbed energy (Ea) in eV, of the λλ 1548.155, 1550.774 Å C IV resonance lines for all the independent density regions of matter which create the 2, 3, 4 or 5 satellite components in all the stars of our sample, as a function of the spectral subtype. We point out that for each component of both of the resonance lines the variations as a function of the spectral subtype are the same.

Finally, in Figs. 8 and 9 we see the variation of the Column Density (CD) in 10^{15} cm^{-2} of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the 2, 3, 4 or 5 satellite components in all the stars of our sample, as a function of the spectral subtype. We note again that each component of both of the resonance lines presents the same variation.

The Radial Velocities

FIGURE 2. Variation of the mean radial velocities of the ions of the C IV resonance lines (λλ 1548.155, 1550.774 Å) for the independent density regions of matter which create the 2, 3, 4 and 5 SACs as a function of the spectral subtype. There are two mechanisms which create the radial velocities. The first one creates high rdial velocities and the second one creates low (Franco et al. 1983, Bates & Halliwell 1986, Crammer & Owocki 1996). We detected two levels of radial velocities. The first level has values between -3000 and -1500 km/s and the second level has values between -500 and -20 km/s.

The Rotational Velocities

FIGURE 3. Variation of the rotational velocities' mean values of the C IV resonance lines (λλ 1548.155, 1550.774 Å) for the independent density regions of matter which create the 2, 3, 4 and 5 SACs as a function of the spectral subtype. For this parameter we detected also two levels of values. The first level has values between 800 and 1800 km/s and the second level has values between 50 and 200 km/s.

The Random Velocities

FIGURE 4. Variation of the mean random velocities of the ions of the C IV resonance lines (λλ 1548.155, 1550.774 Å) for the independent density regions of matter which create the 2, 3, 4 and 5 SACs as a function of the spectral subtype. There are also two levels of values. 200 to 150 km/s for the first one and 100 to 50 km/s for the second one.

Full Width At Half Maximum (FWHM)

FIGURE 5. Variation of the mean value of the Full Width at Half Maximum (FWHM) for the C IV independent density regions of matter which create the 2, 3, 4 or 5 SACs as a function of the spectral subtype. There are also two levels of values. 14 to 12 for the first one and 7 to 0.02 for the second one.

The Absorbed Energy

FIGURE 6. Variation of the absorbed energy (Ea) in eV of the C IV resonance line λ1548.155 Å for the independent density regions of matter which create the 2, 3, 4 or 5 satellite components as a function of the spectral subtype. There are two levels of values. 6 to 4 eV for the first one and 3 to 0.5eV for the second one.

FIGURE 7. Variation of the absorbed energy (Ea) in eV of the CIV resonance line 1550.774 Å for the independent density regions of matter which create the 2, 3, 4 or 5 satellite components as a function of the spectral subtype. There are two levels of values. 5.4 to 3.6 eV for the first one and 2.7 to 0.45 eV for the second one.

The Column Density

FIGURE 8. Variation of the Column Density (CD) in 10^{15} cm^{-2} of the C IV resonance line λ 1548.155 Å for the independent density regions of matter which create the 2, 3, 4 or 5 satellite components as a function of the spectral subtype. We can see also two levels of the column density. The first level has values between $7.5 \cdot 10^{15}$ cm^{-2} and $5.5 \cdot 10^{15}$ cm^{-2} and the second level has values between $4.5 \cdot 10^{15}$ cm^{-2} and $1 \cdot 10^{15}$ cm^{-2}

FIGURE 9. Variation of the Column Density (CD) in 10^{15} cm^{-2} of the C IV resonance line λ 1550.774 Å for the independent density regions of matter which create the 2, 3, 4 or 5 satellite components as a function of the spectral subtype. As in Fig.8, we can see also two levels of the column density. The first level has values between $7 \cdot 10^{15}$ cm^{-2} and $5 \cdot 10^{15}$ cm^{-2} and the second level has values between $4 \cdot 10^{15}$ cm^{-2} and $0.9 \cdot 10^{15}$ cm^{-2}

RESULTS

Radial velocities:

Franco et al. 1983, Bates & Halliwell 1986, Crammer & Owocki 1996 noted that there are two mechanisms which create the radial velocities. The first one creates high radial velocities and the second one creates low velocities. In the C IV region we detect the same phenomenon (see Fig. 2). The first level has values between -3000 and -1500 km/s and the second level has values between -500 and -20 km/s. We detect the same phenomenon in other parameters. Specifically:

Rotational velocities: We note that in the case of the rotational velocities we detected also two levels aof values. The first level has values between 1800 and 800 km/s and the second level has values between 200 and 50 km/s.

Random velocities: The same phenomenon we can see also in the random velocities. The first level has values between 200 and 150 km/s and the second level has values between 100 and 50 km/s.

Full Width at Half Maximum (FWHM): The Full Width at Half Maximum (FWHM) (Fig. 5) presents the same image with the respective image of the rotational velocities (Fig. 3). There are also two levels of values The first level has values from 14 to 12 and the second level has values from 7 to 0.02.

The absorbed energy: The variation of the absorbed energy (Figs. 6 and 7) present a decreasing trend from the first to the second level. We also point out that for each level of both of the resonance lines the variations as a function of the spectral subtype are the same. The first level has values between about 6 and 4 eV and the second level has values about between 3 and 0.5 eV.

The column density: Similarly with the absorbed energy, the column density (Figs. 8 and 9) presents a decreasing trend from the first to the second level. Specifically, the first level has values about between $7.5 \cdot 10^{15}$ cm^{-2} and $5.5 \cdot 10^{15}$ cm^{-2} and the second level has values about between $4.5 \cdot 10^{15}$ cm^{-2} and $1.00 \cdot 10^{15}$ cm^{-2}. It is remarkable that both of these absorption parameters present fast the same image.

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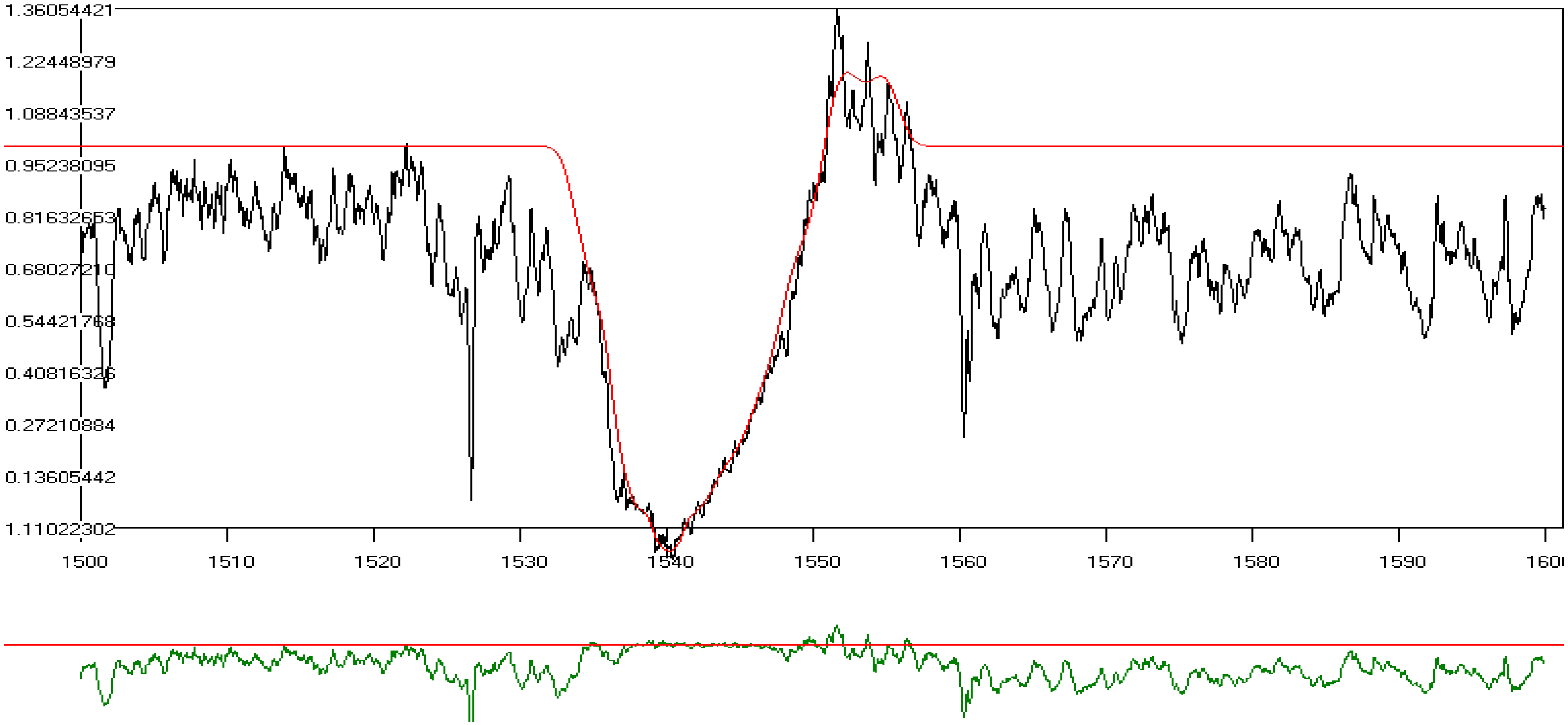
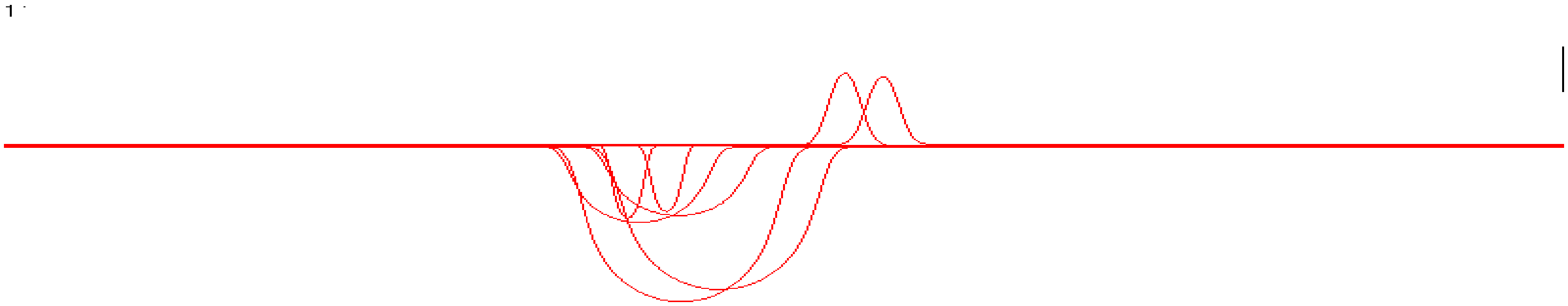
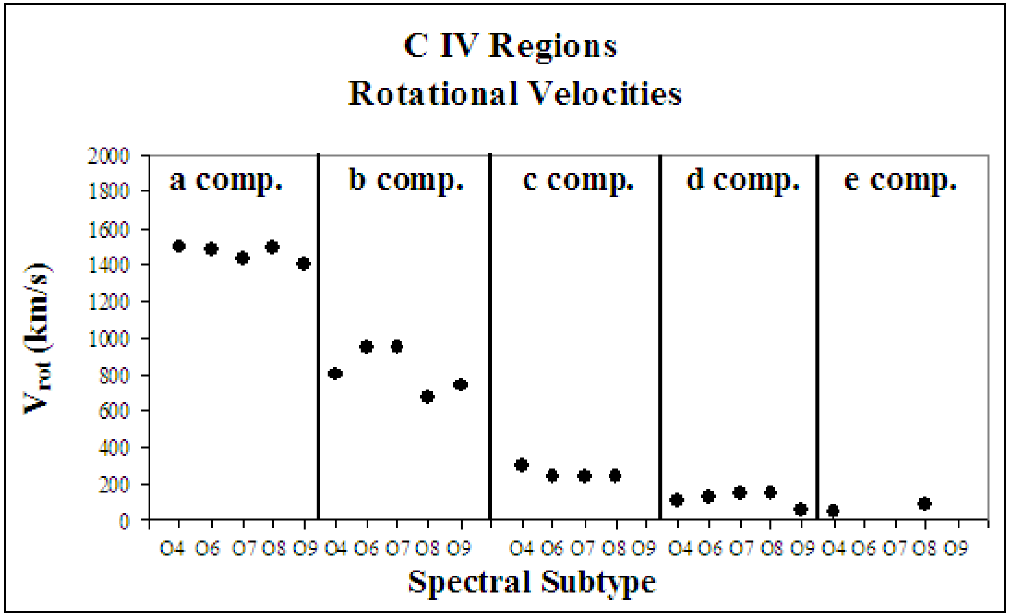


HD 34656
SWP 15532



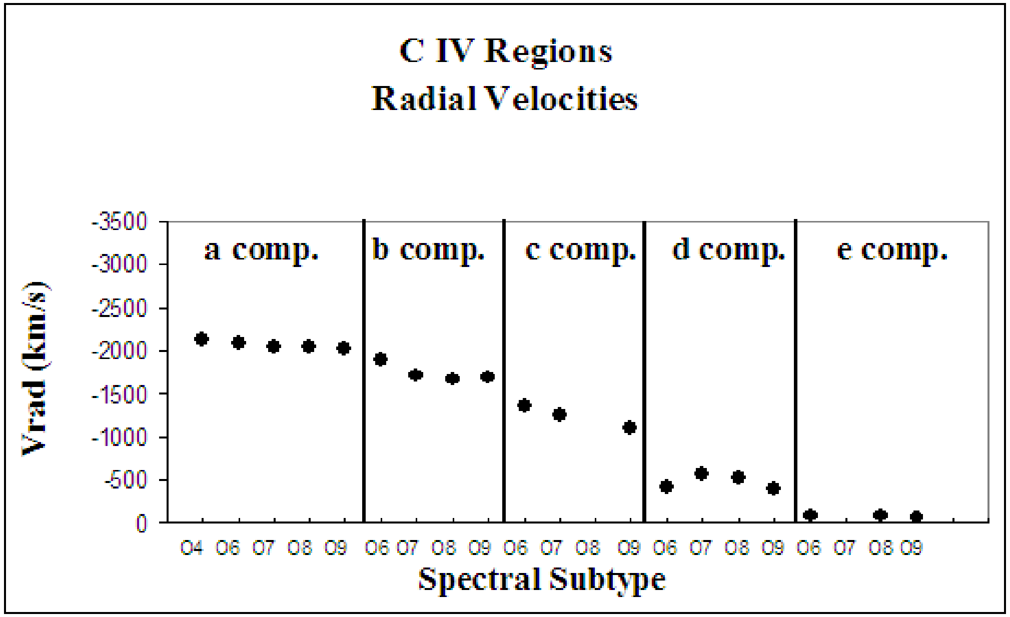
Rotational Velocities:

a component: 1458 km/s
b component: 821 km/s
c component: 251 km/s
d component: 133 km/s
e component: 65 km/s



Radial Velocities:

a component: -2066 km/s
b component: -1743 km/s
c component: -1235 km/s
d component: -469 km/s
e component: -80 km/s



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Random Velocities:

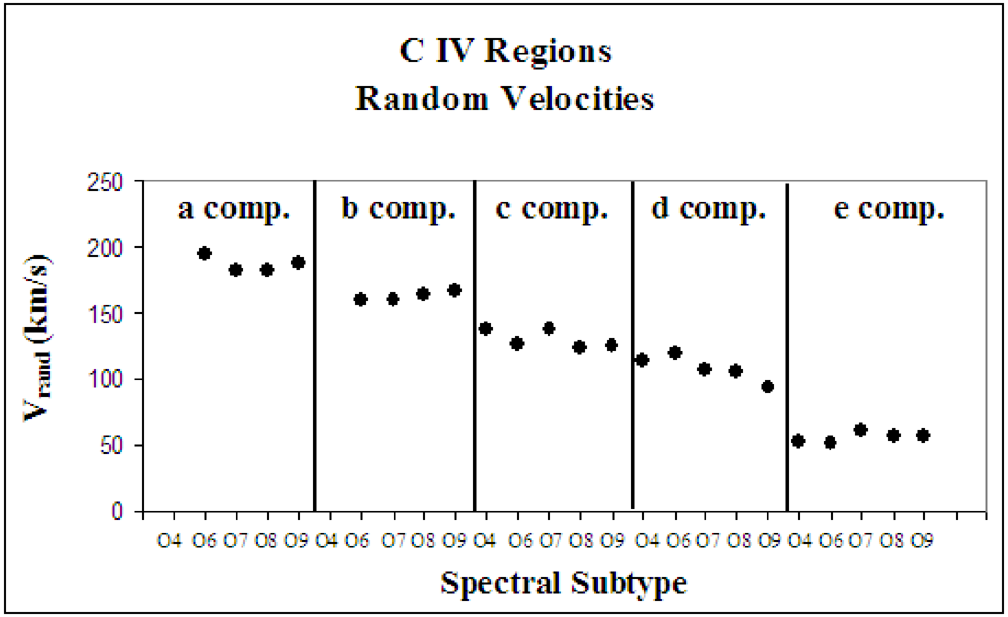
a component: 187 km/s

b component: 163 km/s

c component: 130 km/s

d component: 108 km/s

e component: 56 km/s



FWHM:

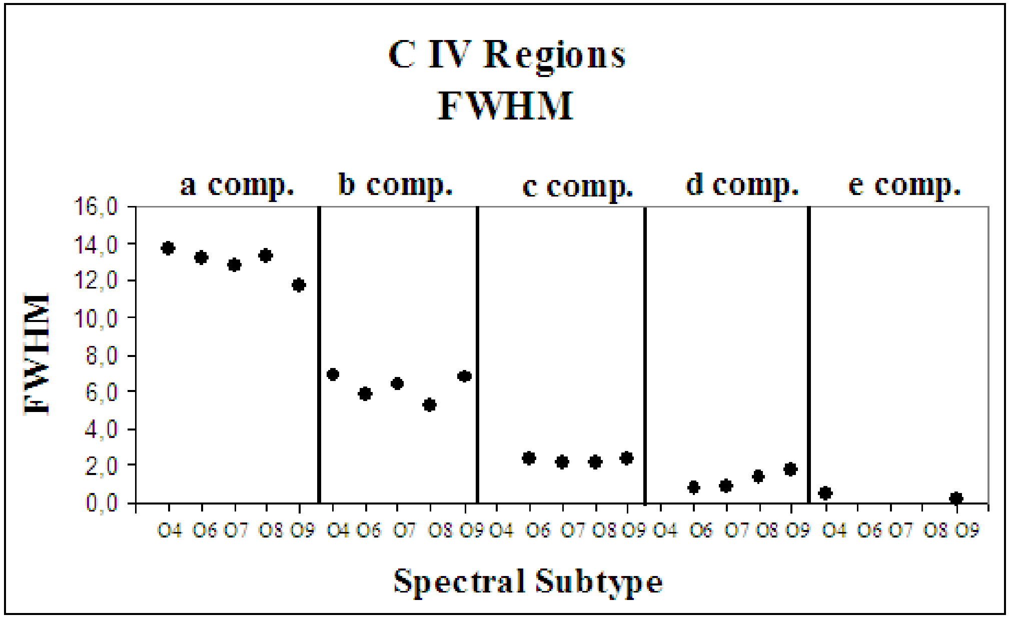
a component: 13.0 Å

b component: 6.2 Å

c component: 2.2 Å

d component: 1.2 Å

e component: 0.4 Å



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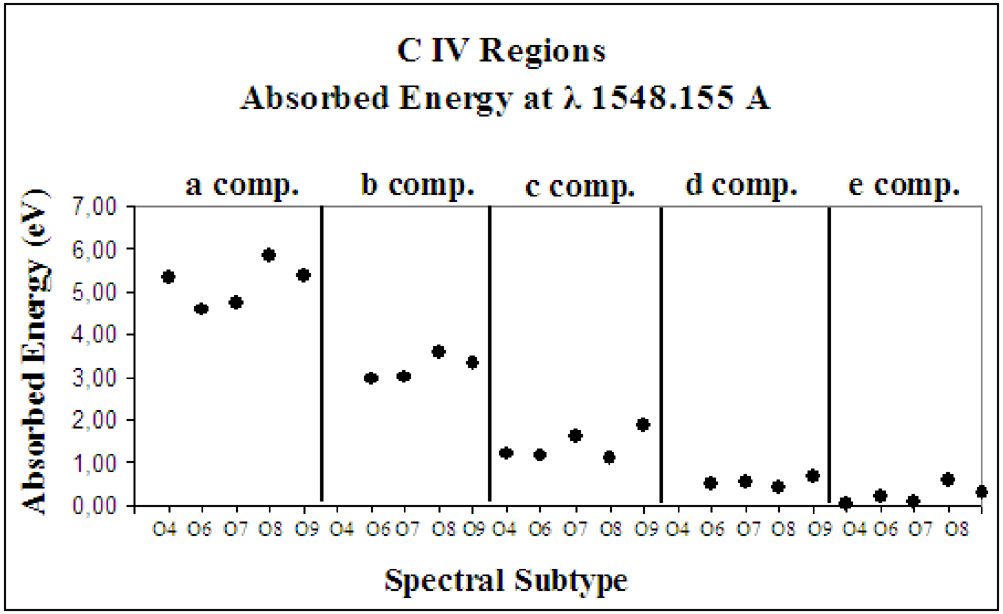
Absorbed Energy (E)

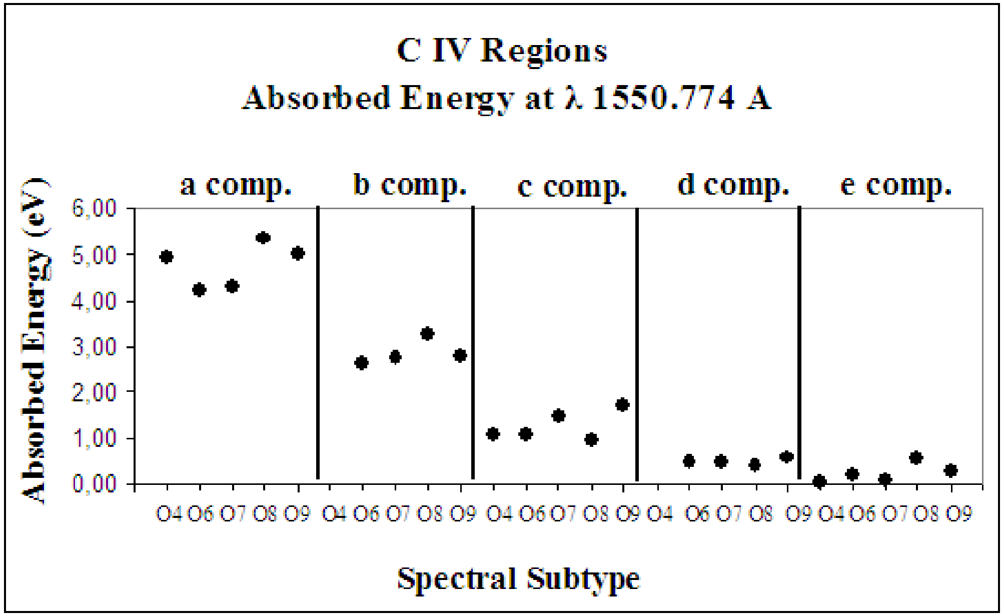
λ 1238.821 Å

a component: 5.18 eV
b component: 3.21 eV
c component: 1.39 eV
d component: 0.53 eV
e component: 0.24 eV

λ 1242.804 Å

a component: 4.76 eV
b component: 2.85eV
c component: 1.26 eV
d component: 0.48 eV
e component: 0.22 eV





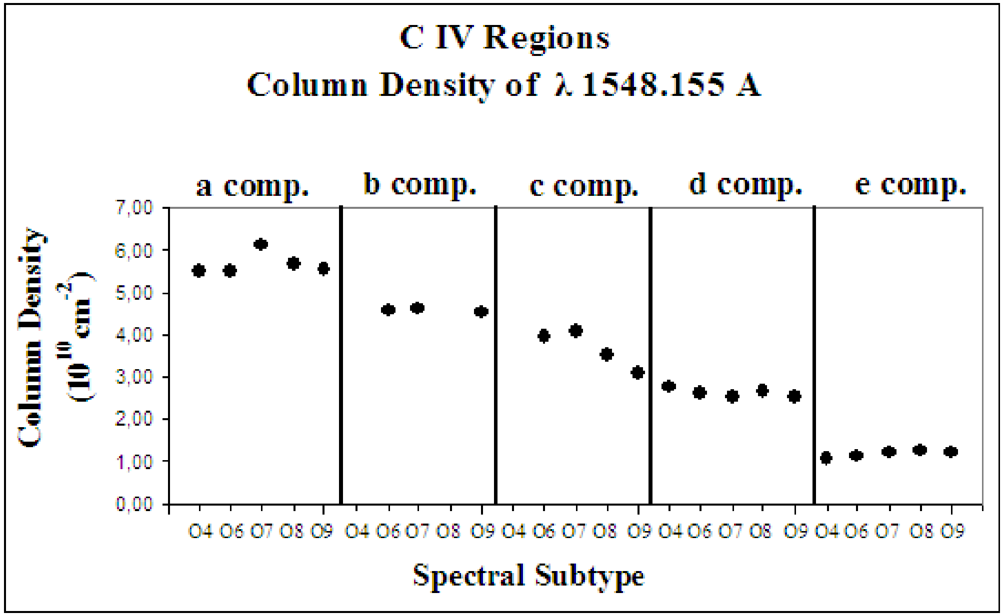
Column Density (CD)

λ 1238.821 Å

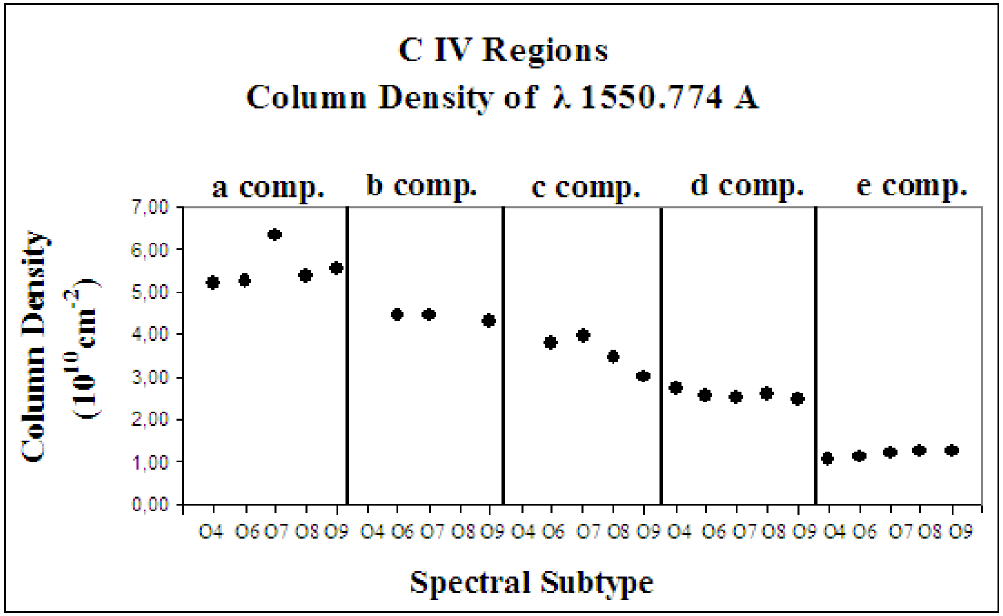
a component: 5.65 ×10^{10} cm^{-2}
b component: 4.58 ×10^{10} cm^{-2}
c component: 3.65 ×10^{10} cm^{-2}
d component: 2.62 ×10^{10} cm^{-2}
e component: 1.17 ×10^{10} cm^{-2}

λ 1242.804 Å

a component: 5.54 ×10^{10} cm^{-2}
b component: 4.39 ×10^{10} cm^{-2}
c component: 3.56 ×10^{10} cm^{-2}
d component: 2.56 ×10^{10} cm^{-2}
e component: 1.17 ×10^{10} cm^{-2}



C IV Regions
Column Density of λ 1548.155 A



C IV Regions
Column Density of λ 1550.774 A

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