Long term variability of the coronal and post – coronal regions of the Oe star HD 93521

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Introduction

HD 93521 is a relatively bright, very rapidly rotating O9.5V star (Hobbs et al, 1982). These characteristics, together with its exceptionally high Galactic latitude ($b=+63.13^0$, Galactic length $l=183.3^0$, Costero & Stalio, 1984) have made it a favorite target for studies regarding stars out of the Galactic plane (e.g. Pettini & West 1982; Hobbs et al. 1982; Danly 1989, Spitzer & Fitzpatrick 1992).

HD 93521 has been assigned to a population class II (by Bisiacchi et al., 1978 and Carrasco and Creze 1978) but Walborn (1983) has argued strongly against this interpretation. Garmany et al. (1980) consider it as a possible binary star.

Since its adoption as a spectrophotometric standard for IUE (Bohlin et al. 1980), it has acquired an increasingly well – documented record of spectroscopic variability (Garmany et al. 1980; Hobbs & Albert 1984; Fullerton 1990). The ultraviolet spectrum shows wind signatures at CIV, NV, and SiIV. The presence of a strong SiIV wind line is exceptional for a luminosity class V star; indeed, all the wind profiles have unusual morphologies (Prinja & Howarth 1986), which have been interpreted as evidence for a cylindrically (as opposed to spherically) symmetric wind (Massa 1992). According to CIV resonance line profile of HD93521, Massa (1992) and Howarth & Reid (1993, paper 45) also suggested, that there is a high – speed component in the polar outflow from the star as well as a low – speed component in the equatorial regions. Howarth & Reid (1993) supported that the mean profiles of the resonance lines of CIV, NV and SiIV show that the morphology of the lines is very unusual, and it is possible to identify three separate components: very strong, low - velocity absorption in SiIV and CIV, which is saturated out about – 500 Km/s; weaker absorption which extends to about – 1200 Km/s in CIV and NV; and emission in CIV and NV which is unusually strong for a late O main sequence star.

Finally Howarth & Prinja (1989) give the follow fit parameters

CIV Region: optical depth $\tau_0 > 10.0$, column density $N^p = 6.74$ (10^{14} cm^{-2}).

NV Region: optical depth $\tau_0=1.0$, column density $N^p=1.08$ (10^{14} cm^{-2}).

In this paper we apply the model proposed by Danezis et al. (2005) and Nikolaidis et al (2006) for the outer atmospheres of Oe and Be stars, to the star HD 93521 and we present some first results deriving from this application. This model allows the existence of many absorption shells or many independent density regions, considers that the expanding outer atmosphere consists of some absorbing and an outer emitting shell and concludes to a function for the spectral line able to reproduce the profiles of all the spectral lines with grate accuracy. We calculate the apparent rotational, random and radial velocities as well as the column density of the independent regions of matter which produce the main spectral lines of C IV, N IV and N V and their satellite components. Finally, we present the time- scale changes for all the calculated parameters.

The Gaussian - Rotational model (GR- Model)

For our study the line broadening is only an effect of two reasons: The first is the rotational velocity of the spherical region that produces the spectral line and the second one is the random velocities of the ions, which make thermal random motions. In this model we present a new approach, which describes both of these factors.

We consider that the area of gas, which creates a specific spectral line consists of independent absorbing regions followed by independent regions that both absorb and emit and an outer absorbing region. We apply the method proposed by Danezis et al. (2003- 2005) and Nikolaidis et al. (2006) on spectra of the star HD 93521 and we examine the timescale variation of the physical parameters stated below.

The IUE – Data

This project is based on eleven different spectra of HD 93521 taken with the IUE – Data satellite. We study the structure of the spectral lines

- CIV λλ 1548.155 Å, 1550.774 Å
- NIV λ 1718.80 Å
- NV λλ 1238.821, 1242.804 Å

The study of the coronal and post - coronal regions of the moving atmosphere of the Oe star HD 93521

In the Figs. 1, 2 and 3 we present a spectral line from each of CIV, NIV and NV regions and their best fit. We consider that in each region there are some very small Gaussian thermal motions and other blends, which are present in the spectrum as very small peaks. In the graph below each profile we present the difference between the fit and the real spectral line.

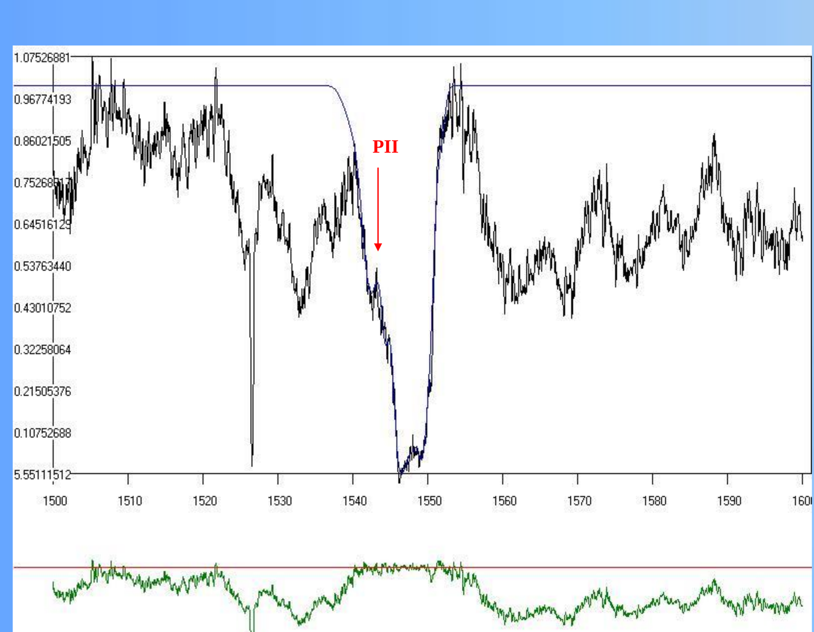


Figure 1: The CIV λλ 1548.155, 1550.774 Å resonance lines in the spectrum of HD 93521. Each of CIV spectral lines consists of five SACs. Along the CIV doublet we can detect some PII lines that blend with it.

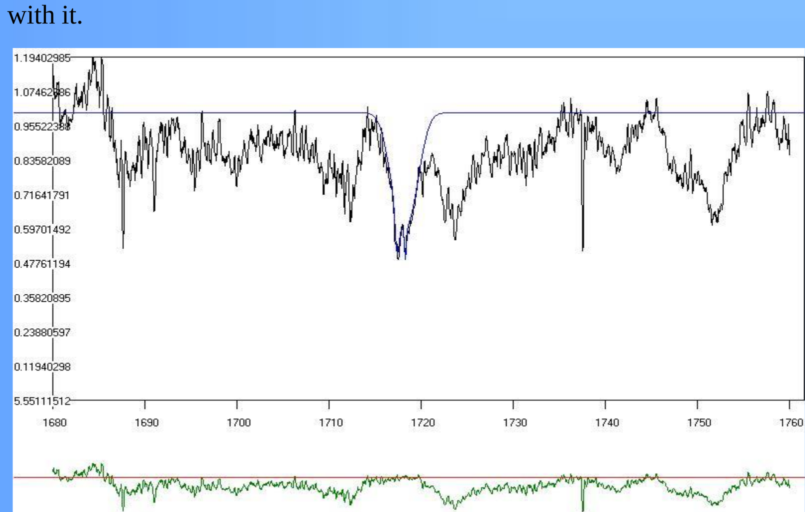


Figure 2: The NIV λ 1718.80 Å absorption line in of HD 93521. The NIV spectral line consists of one SAC.

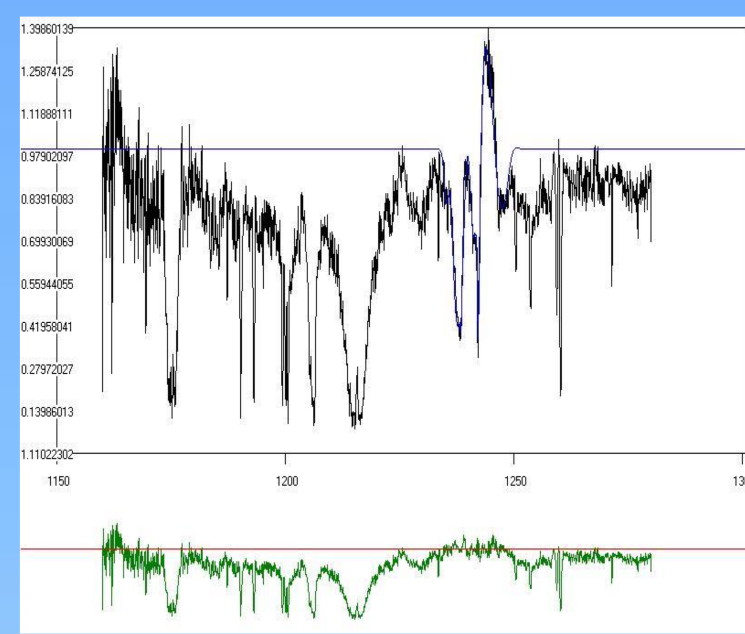


Figure 3: Each of NV λλ 1238.821, 1242.804 Å resonance lines in the spectrum of HD93521 shows a characteristic P Cygni profile. Each of these spectral lines consists of one SAC.

A. The CIV region

In Figures 4, 5 and 6, 7a and 7b we present the time - scale change of the apparent rotational, radial and random velocities, as well as the column density of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the 5 satellite components.

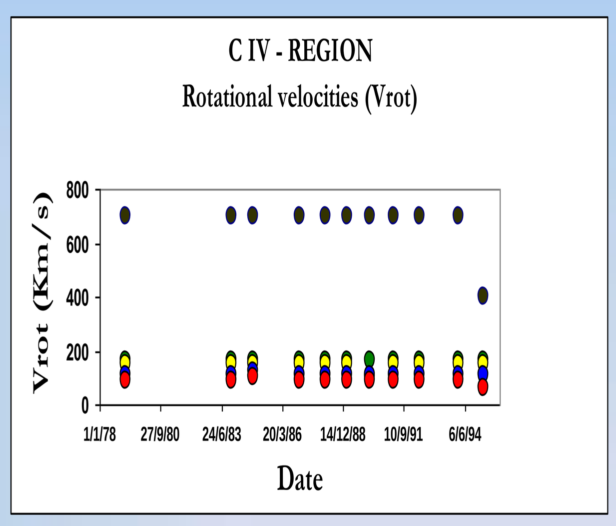


Figure 4: Timescale changes of the apparent rotational velocities Vrot(i) (km/s) of the C IV resonance lines (λλ 1548.155, 1550.774 Å) for the independent density regions of matter which create the 5 satellite components.

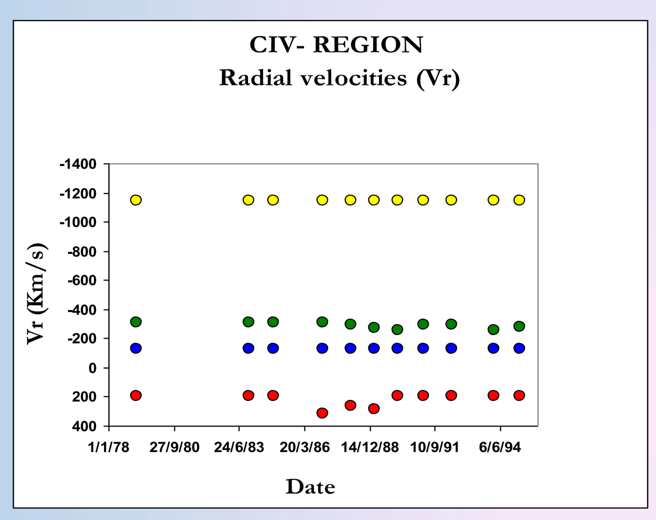


Figure 5: Timescale variations of the apparent radial velocities Vrad (km/s) of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the 5 satellite components.

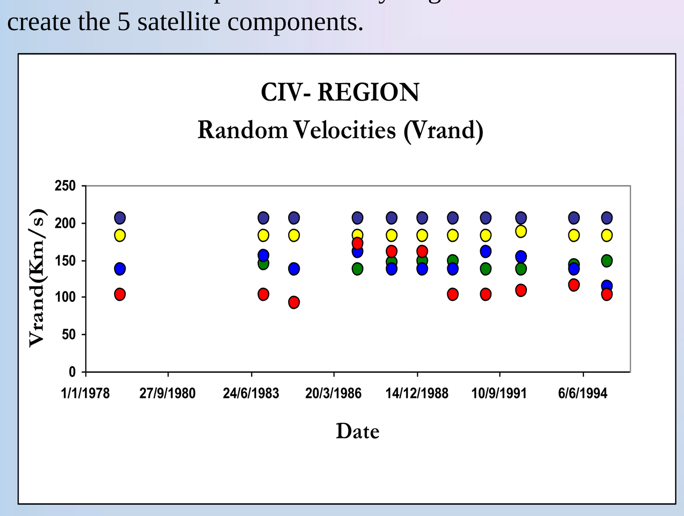


Figure 6: Timescale changes of the Gaussian random velocities Vrand (km/s) of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the 5 satellite components

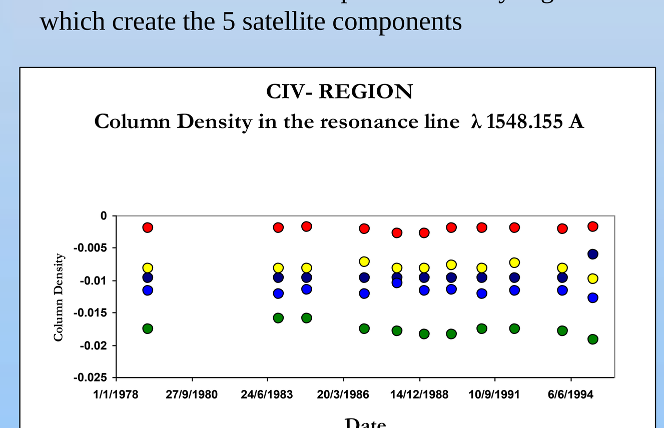


Figure 7a: Timescale changes of the Column Density (CD) in 10^9 cm^{-2} of the C IV resonance line λ1548.155 Å for the independent density regions of matter which create the 5 satellite components

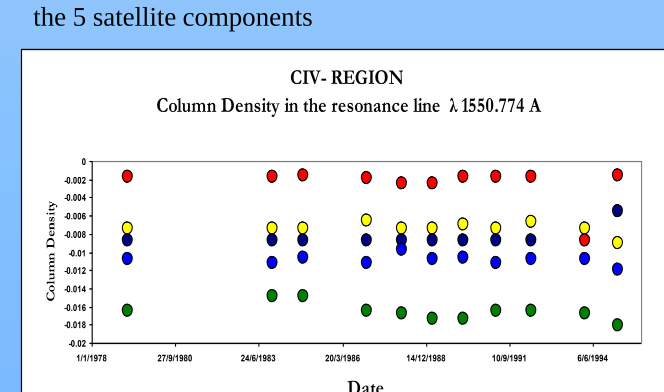


Figure 7b: Timescale changes of the Column Density (CD) in 109cm-2 of the C IV resonance line λ1550.774 Å for the independent density regions of matter which create the 5 satellite components.

B. The NIV Region

Figures 8, 9,10 and 11 present the timescale changes of the apparent rotational, radial velocities Vrad (km/s) and random velocities as well as the column density in 10^{10} cm^{-2} of the density region which the spectral line of N IV λ 1718.8 Å is created.

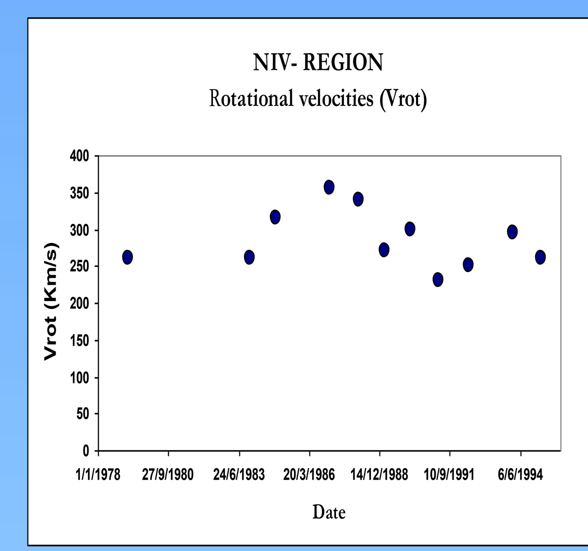


Figure 8: Timescale changes of the apparent rotational velocities Vrot (km/s) of the density region which creates the N IV spectral line λ 1718.8 Å

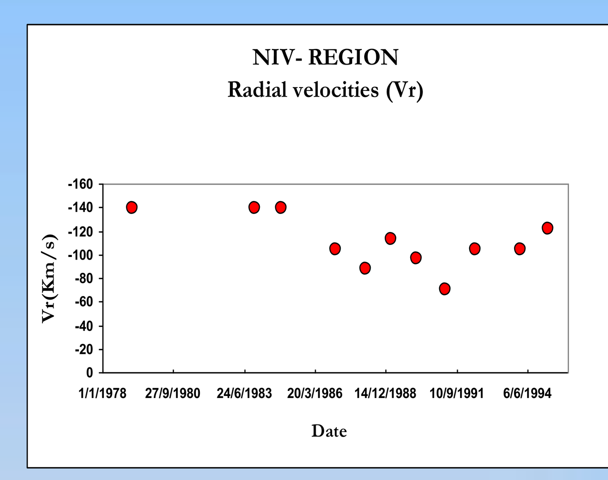


Figure 9: Timescale changes of the apparent radial velocities Vrad (km/s) of the density region which creates the N IV spectral line λ 1718.8 Å

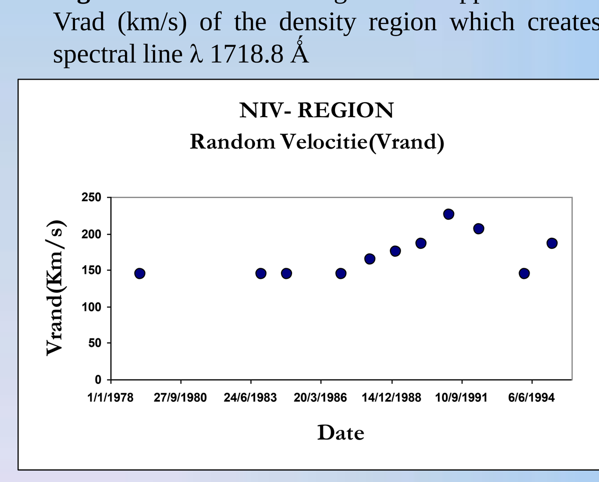


Figure 10: Timescale variations of the random velocities Vrand (km/s) of the ions which contribute to the broadening of the N IV spectral line λ 1718.8 Å.

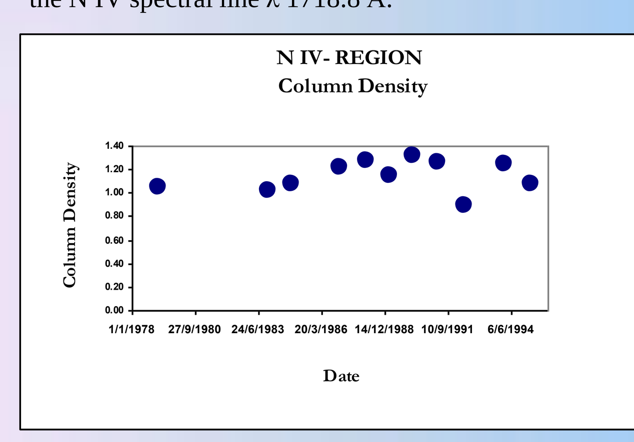


Figure 11: Timescale changes of the column density (CD) in 10^{10} cm^{-2} of the N IV spectral line λ 1718.8 Å.

C. The N V region

i) The absorption lines

Figures 12, 13, 14, 15a and 15b present the timescale variations of the mean values of the apparent rotational Vrot (km/s), radial velocity Vrad (km/s) random velocity Vrand (km/s) as well as the column density in 10^{10} cm^{-2} of the absorption component of the N V resonance lines λλ 1238.821 1242.804 Å.

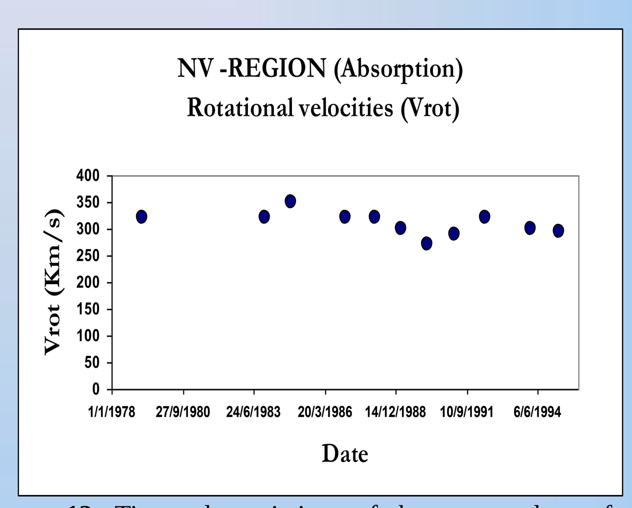


Figure 12: Timescale variations of the mean values of the apparent rotational velocity Vrot (km/s) of the absorption component of the N V resonance lines λλ 1238.821 1242.804 Å.

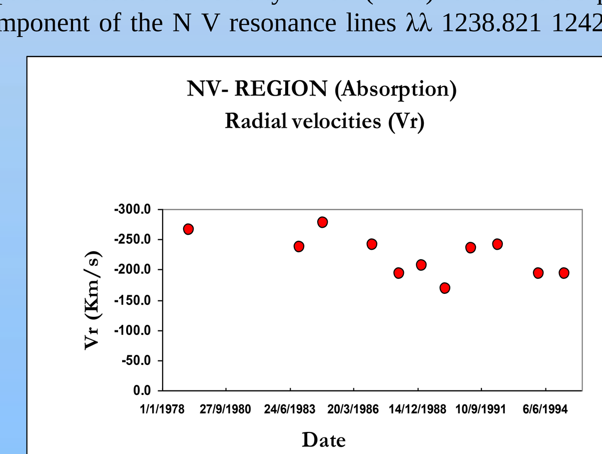


Figure 13: Timescale changes of the mean values of the apparent radial velocity Vrad (km/s) of the absorption component of the N V resonance lines λλ 1238.821 1242.804 Å.

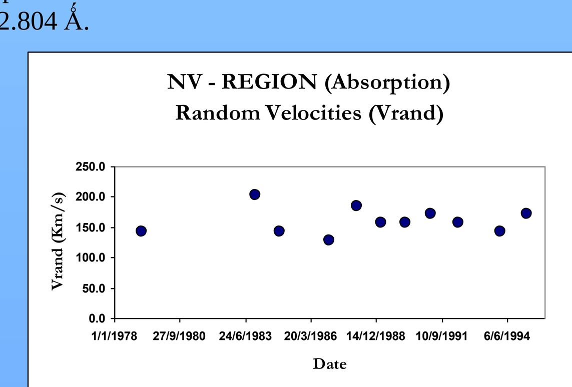
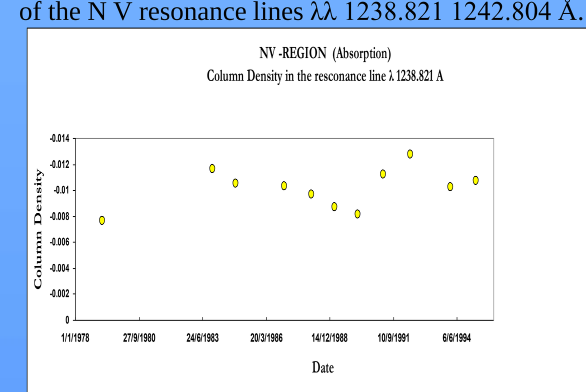


Figure 14: Mean random velocities Vrand (km/s) of the ions, of the density region which creates the absorption component of the N V resonance lines λλ 1238.821 1242.804 Å.



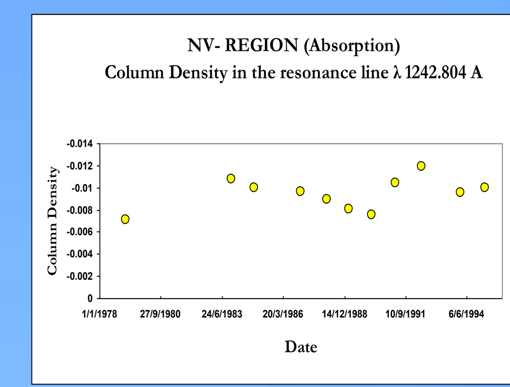


Figure 15a, 15b: Timescale change of the Column Density (in 10^{10} cm^{-2}) the absorption component of the N V resonance lines λλ 1238.821, 1242.804 Å.

ii) The emission lines

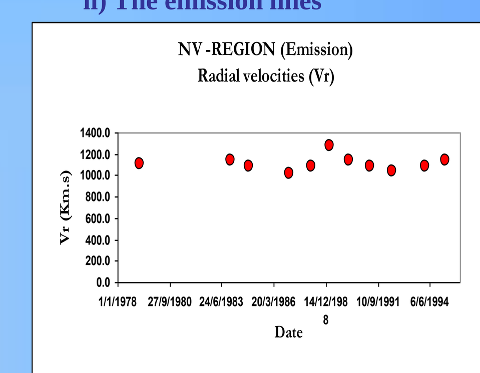


Figure 16: Timescale variations of the mean values of the apparent radial velocity Vrad (km/s) of the emission component of the N V resonance lines λλ 1238.821 1242.804 Å

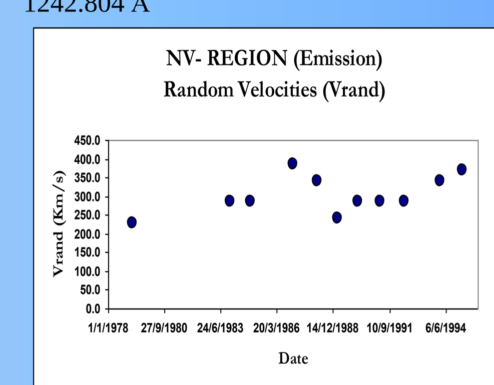
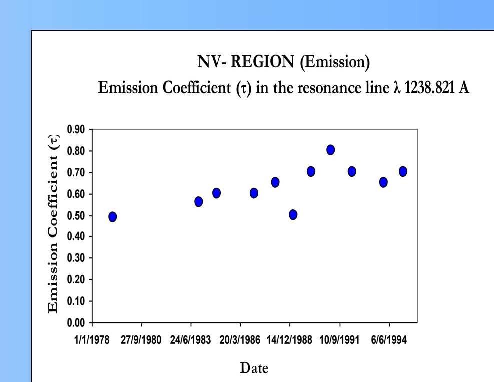


Figure 17: Timescale change of the mean random velocities Vrand (km/s) of the density region, which creates the emission component of the N V resonance lines λλ 1238.821 1242.804 Å.



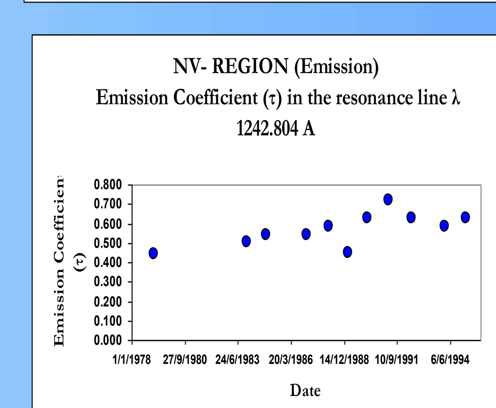


Figure 18a, 18b: Timescale change of the emission parameter τ=Sξe of the N V resonance line λ 1238.821, 1242.804 Å.

Results

As a first result we detect that the above spectral lines consist of one or more Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we can calculate the time scale variation 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 calculated some of these.

Discussion

We point out that the new and important aspect of our study is the values' calculation of the above parameters and their time scale variations, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005), Nilolaidis et al. (2006) proposed method.

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