Long Term Variability of the Radial Velocities in the Coronal and Post-coronal Regions of the Oe Star HD 93521

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Abstract. We examine the timescale changes of C IV, N IV and N V spectral lines of the Oe star HD 93521, during a period of 16 years, applying the model proposed by Danezis et al. (2005). We found that the spectral lines consist of one or more Satellite Absorption Components (SACs or DACs) which construct the whole spectral profile. In this paper we present the time scale variation of the radial velocities.

Keywords: Oe stars, SACs, radial velocity.
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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=+63.130, Galactic length l=183.30, Costero & Stalio 1984) have made it a favorite target for studies regarding stars out of the Galactic plane (e.g. Pettini & West 1982).

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). The ultraviolet spectrum shows wind signatures at C IV, N V, and Si IV. The presence of a strong Si IV 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 C IV resonance line profile of HD 93521, Massa (1992) and Howarth & Reid (1993) 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 C IV, 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 Si IV and C IV, which is saturated out about -500 km/s; weaker absorption which extends to about -1200 km/s in C IV and N V and emission in C IV and N V which is unusually strong for a late O main sequence star.

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THE GAUSSIAN - ROTATIONAL MODEL (GR-MODEL)

With the following model we can calculate the apparent rotational and radial velocities, the Gaussian deviation of the random motions of the ions, 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 and the product of the Source function S and the optical depth ξ of the independent regions of matter which produce the main and the satellites components (SACs) of the studied spectral lines.

For our study the line broadening is caused by two reasons: The first one is the rotational velocity of the spherical region that produce the spectral line and the second one 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 i independent absorbing shells followed by j independent shells that both absorbs and emits and an outer absorbing shell. Such a structure produces DACs or SACs (Danezis et al. 2003) and the final line function is:

$$I_\lambda = \left[I_{\lambda 0} \prod_i \exp\{-L_i \xi_i\} + \sum_j S_{\lambda ej}\left(1 - \exp\{-L_{ej}\xi_{ej}\}\right)\right] \exp\{-L_g \xi_g\} \qquad (1)$$

where: $I_{\lambda 0}$**:** the initial radiation intensity,

L_i, L_{ej}, L_g: are the distribution functions of the absorption coefficients $k_{\lambda i}$, $k_{\lambda ej}$, $k_{\lambda g}$ respectively. Each L depends on the values of the apparent rotational velocity as well as of the radial expansion/contraction velocity of the density shell, which forms the spectral line *(V_{rot}, V_{exp}),*

$\xi = \int_0^s \Omega \rho ds$ is an expression of the optical depth τ, where Ω is an expression of k_λ, $S_{\lambda ej}$: the source function, which, at the moment when the spectrum is taken, is constant.

The function (1) does not depend on the geometry of the regions which create the observed feature. This means that L may represent any distribution which considers certain geometry, without changing anything in I_λ.

One of the hypotheses when we constructed the rotational model was that the line's width $\Delta\lambda$ is only a rotational effect. This means that the random velocities were very low and they did not contribute to the line broadening. In a new approach of the problem we also consider the parameter of random velocities in the calculation of the distribution function L and we have:

$$L(\lambda) = \frac{\sqrt{\pi}}{2\lambda_0 z} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[erf\left(\frac{\lambda - \lambda_0}{\sigma\sqrt{2}} + \frac{\lambda_0 z}{\sigma\sqrt{2}}\cos\theta\right) - erf\left(\frac{\lambda - \lambda_0}{\sigma\sqrt{2}} - \frac{\lambda_0 z}{\sigma\sqrt{2}}\cos\theta\right)\right] \cos\theta d\theta \qquad (2)$$

where λ_0 is the laboratory wavelength of a spectral line that arises from a specific point A_i of the equator of a spherical shell, $z = \frac{V_{rot}}{c}$ (V_{rot} is the rotational velocity of the point A_i). This *L(λ)* of the equation (2) is the distribution that replaces the rotational distribution L that Danezis et al (2003) proposed (see Danezis et al. 2003 and Danezis et al. 2005a,b).

LONG TERM VARIABILITY OF THE RADIAL VELOCITIES

The Analysis Of The Shapes

This study is based on eleven different spectra of HD 93521 taken with the IUE – Data satellite. We study the structure of the spectral lines C IV λλ 1548.155 Ǻ, 1550.774 Ǻ, N IV λ 1718.80 Ǻ and N V λλ 1238.821, 1242.804 Ǻ.

We present some spectral lines and their best fits of the C IV, N IV and N V regions of three different dates. These are the IUE - data SWP04472 (4.3.79), SWP44900 (9.6.72) and SWP30086 (12.1.87) respectively.

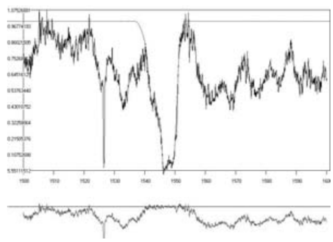

FIGURE 1. The C IV λλ 1548.155, 1550.774 Ǻ resonance lines in the spectrum of HD 93521. Each of C IV spectral lines consists of five SACs. The graph bellow the fit indicates the difference between the observed spectrum and the fit.

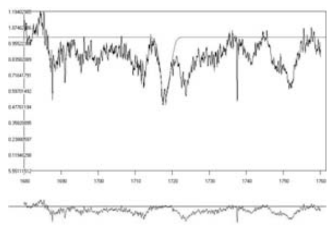

FIGURE 2. The N IV λ 1718.80 Ǻ absorption line in the spectrum of HD 93521. The N IV spectral line consists of one SAC. The graph bellow the fit indicates the difference between the observed spectrum and the fit.

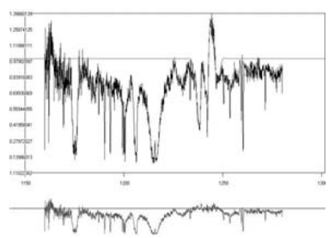

FIGURE 3. Each of N V λλ 1238.821, 1242.804 Ǻ resonance lines in the spectrum of HD 93521 shows a characteristic P Cygni profile. Each of these spectral lines consists of one SAC. The graph bellow the fit indicates the difference between the observed spectrum and the fit.

Results

The following diagrams describe the time scale changes of the radial velocities of the coronal regions where are created the C IV, the N IV and the N V ions. We took into account that the shift of the interstellar lines corresponds to a mean value of the radial velocity about -387 km/s. We took also into account that the radial velocity of the star is about -11 km/s (Garmany et al. 1980).

The C IV Region

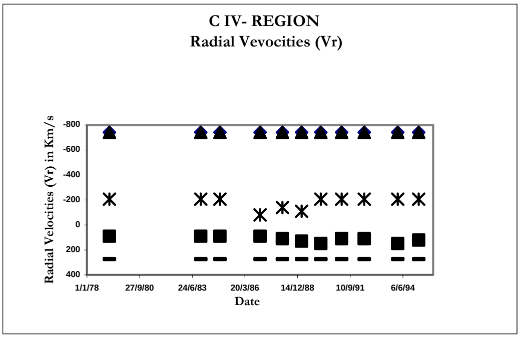

FIGURE 4. Timescale variations of the apparent radial velocities V_{rad} (km/s) of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the 5 satellite components. We see that the radial velocity in each component remains constant.

The N IV Region

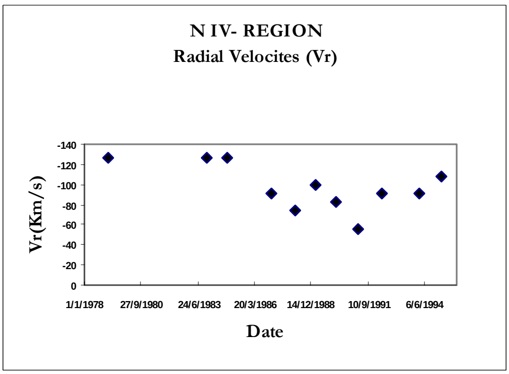

FIGURE 5. Time scale changes of the apparent radial velocities V_{rad} (km/s) of the density region which creates the N IV spectral line λ 1718.8 Å. The time scale variability is remarkable.

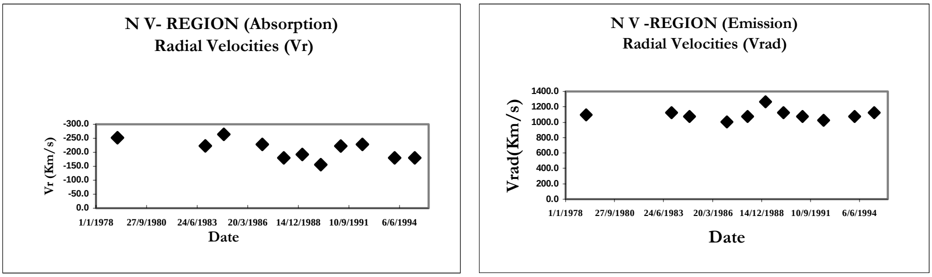

FIGURE 6. Timescale variations of the mean values of the apparent radial velocity V_{rad} (km/s) of the absorption and emission component of the N V resonance lines λλ 1238.821, 1242.804 Å. In each case we note also remarkable time scale variability.

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