

# Long term variability of the coronal and post - coronal regions of the Oe star HD 149757 ( $\zeta$ Oph)

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1. University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens – Greece.  
 2. Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia.



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1. University of Athens, School of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens – Greece  
 2. Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia

### Introduction

HD 149757 ( $\zeta$  Oph) is a bright O9Ve star (Cook 1973), rapidly rotating and a strong ionized pulsar (Kluźniak & Stassun 1999; Field et al. 1999). In our previous work, we showed that this system (Stelzer & Stassun 1979), is in a favorable case for UV observation line ratios because its line of sight intercepts a nearby region of these gas which is probably localized in space (Lyra et al. 1991; Hoffert et al. 1991) and Bergemann, et al. (2005) consider it necessary to use line-OII correlation. Specifically, Bergemann, et al. (2005) state that the path of the ionizing star  $\zeta$  Ophielids intersected that of the nearby pulsar PSR 1502-1015 about 150 pc in the early past. In our previous work (Antoniou et al. 2005) we studied this system star in the context of a hypothesis that occurred in a binary system that contained  $\zeta$  Ophielids but that the pulsar received a kick velocity of about 350 km/s in the explosion.

In this paper we apply the model proposed by Danzeis et al. (2005), Nikolaidis et al. (2006) and Danzeis et al. (2007) for some members of Oe and the stars in the star HD 149757 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 zones absorbing and/or outer emitting shell and concludes in a function for the optical line ratio to reproduce the profiles of all the spectral lines with great accuracy. We calculate the apparent rotational, random and radial velocities for the spectral lines of the independent regions of matter which produce the main spectral lines of C IV, N IV and N V and five satellite components. Finally, we present the line - scale change for all the calculated parameters.

### Observational data

This project is based on eleven different spectra of HD 149757 taken with the IUE – Data satellite. We study the structure of the spectral lines  
 CIV  $\lambda$  1546,155 Å, 1550, 774 Å  
 NV  $\lambda$  1718,80 Å  
 NV  $\lambda$  1238,821, 1242,804 Å

### Method of spectral analysis

In order to study the C IV, N IV, N V and N V spectral lines of HD 149757 we use the so-called COGASIM(O)ration – Model proposed by Danzeis 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. Danzeis 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 size of an area, where a specific spectral line is created, consists of independent absorbing shells formed by independent shells that both absorb and emit and an outer absorbing shell, such a structure produces DACs or SACs (Danzeis et al. 2005). We apply the method proposed by Danzeis et al. (2005, 2006), Nikolaidis et al. (2006) and Danzeis et al. (2007) on spectra of the star HD 149757 and examine the time-scale variation of the physical parameters stated below.

### The study of the coronal and post - coronal regions of the moving atmosphere of the Oe star HD 149757

In Figs. 1, 2 and 3 we present a spectral line from each of C IV, N IV and N V regions and their best fit. In the graph below each profile we present the difference between the fit and the real spectral line. Below the fit we present the analysis of the observed profile to its DACs.

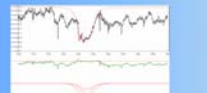


Figure 1: The best fit of the C IV resonance line with two components in the spectrum SWP3810 of the star HD 149757. The graph below the fit indicates the difference between the observed spectrum and the fit. Below the fit we present the analysis of the observed profile to its DACs.

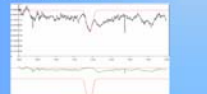


Figure 2: The best fit of the N V resonance line with two components in the spectrum SWP3810 of the star HD 149757. The graph below the fit indicates the difference between the observed spectrum and the fit. Below the fit we present the analysis of the observed profile to its DACs.

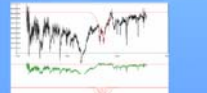


Figure 3: The best fit of the N V resonance line with two components in the spectrum SWP3810 of the star HD 149757. The graph below the fit indicates the difference between the observed spectrum and the fit. Below the fit we present the analysis of the observed profile to its DACs.

### A. The study of the C IV density region

In Figs. 4, 5, 6, 7a and 7b we present the line - scale change of the apparent rotational, radial and random velocities, as well as the column density of the  $\lambda$  1546,155, 1550, 774 Å C IV resonance lines for the independent density region of matter which create the 2 satellite components.

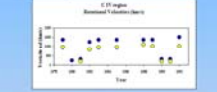


Figure 4: Time-scale variation of the apparent rotational velocities  $V_{rot}$  (km/s) of the two C IV line components between 1979 and 1992. The graph shows the variation of  $V_{rot}$  (km/s) over time (Year).

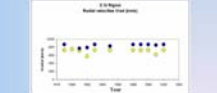


Figure 5: Time-scale variation of the apparent radial velocities  $V_{rad}$  (km/s) of the two C IV line components between 1979 and 1992. The graph shows the variation of  $V_{rad}$  (km/s) over time (Year).

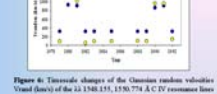


Figure 6: Time-scale change of the Gaussian random velocities  $V_{rand}$  (km/s) of the two C IV line components between 1979 and 1992. The graph shows the variation of  $V_{rand}$  (km/s) over time (Year).



Figure 7a: Time-scale change of the Column Density (CD) in  $10^{21} \text{ cm}^{-2}$  of each one of the C IV resonance lines for the independent density region of matter which create the satellite components.

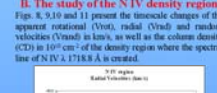


Figure 7b: Time-scale change of the Column Density (CD) in  $10^{21} \text{ cm}^{-2}$  of the density region where the spectral line of N IV  $\lambda$  1718,8 Å is created.

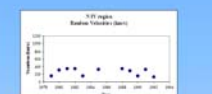


Figure 9: Time-scale change of the random velocities  $V_{rand}$  (km/s) of the two N IV resonance lines for the independent density region of matter which create the 2 satellite components.

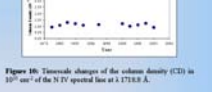


Figure 10: Time-scale change of the column density (CD) in  $10^{21} \text{ cm}^{-2}$  of the N IV spectral line at  $\lambda$  1718,8 Å.

### C. The study of the N V density region

In Figs. 11a, 11b we present the time-scale variations of the column density in  $10^{21} \text{ cm}^{-2}$  of the absorption component of the N V resonance lines  $\lambda$  1238,821, 1242,804 Å, respectively. In Figures 13 and 14 we present the mean values of the apparent radial velocities  $V_{rad}$  (km/s) and random velocities  $V_{rand}$  (km/s) respectively.



Figure 11a: Time-scale change of the Column Density (CD) in  $10^{21} \text{ cm}^{-2}$  of the two N V resonance lines.



Figure 11b: Time-scale change of the Column Density (CD) in  $10^{21} \text{ cm}^{-2}$  of the two N V resonance lines.

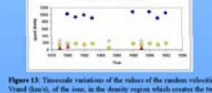


Figure 12: Time-scale variation of the values of the apparent radial velocity  $V_{rad}$  (km/s) for the independent density regions of matter which create the 2 or 3 satellite components of the N V resonance lines at  $\lambda$  1238,821, 1242,804 Å. The graph shows the variation of  $V_{rad}$  (km/s) over time (Year).



Figure 13: Time-scale variation of the values of the random velocity  $V_{rand}$  (km/s) for the independent density regions of matter which create the 2 or 3 satellite components of the N V resonance lines at  $\lambda$  1238,821, 1242,804 Å. The graph shows the variation of  $V_{rand}$  (km/s) over time (Year).

### Conclusions

The model proposed by Danzeis et al. (2005), Nikolaidis et al. (2006) and Danzeis et al. (2007), can fit accurately all the studied spectral lines.

### Radial velocities

The important differences in the radial velocities in the three studied regions are remarkable. Specifically, in the C IV region we calculate apparent radial velocities about -800 + 100 km/s for each satellite absorption component. However, in the N V region the apparent radial velocities are about -10 km/s and in the N V region we measured apparent radial velocities about -1100 + 200 km/s for each satellite absorption component (see Figures 5 and 11).

### Rotational velocities

We present time-scale variation of the rotational velocities only in the C IV region, where the best fit of the spectral lines has been obtained in 7 of the 11 cases with the rotational way with Gaussian correction (see Fig. 4). The values about 200 km/s correspond to the spectra that we fitted with the Gaussian way. Apart from these values, we see a constant behavior of the apparent rotational velocities, with values about 1400 km/s for the first component and about 950 km/s for the second one.

### Random velocities

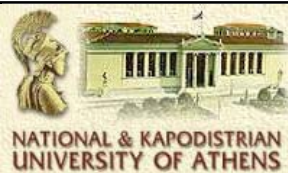
In the C IV region we detected two groups of random velocities. The first group has values about 1000 km/s. The second group has values between 100 and 350 km/s and corresponds to the spectra where we used the rotational way with Gaussian correction (see Fig. 6). In the N V region the values of random velocities are about 100 km/s and correspond to the spectra fitted with the rotational way. The values between 350 and 400 km/s correspond to the spectra fitted with the Gaussian way (see Fig. 9). In the N V region we calculated values about 1000 km/s for one satellite component and values about 200 km/s for the other (see Fig. 12). In each region and for each fitting way, the time-scale variation of the values of the random velocities are almost constant.

### Column density

Until now the Column Density was measured considering that the observed feature represents only one component. As our hypothesis is that the observed complex profile of the studied lines consists of a number of satellite components, we calculate lower values for the Column Density. Specifically, we calculated Column Density in each region with values between  $0,5 \times 10^{21}$  and  $2,5 \times 10^{21} \text{ cm}^{-2}$ . These values are lower than the typical values which are about  $10^{21}$  (Draa & Fottath, 1986) or  $10^{21}$  and  $10^{21} \text{ cm}^{-2}$  (Howarth & Praga, 1986). Besides, it is generally accepted that the calculation of the Column Density values depends on the method which one uses. (Howarth & Praga, 1986).

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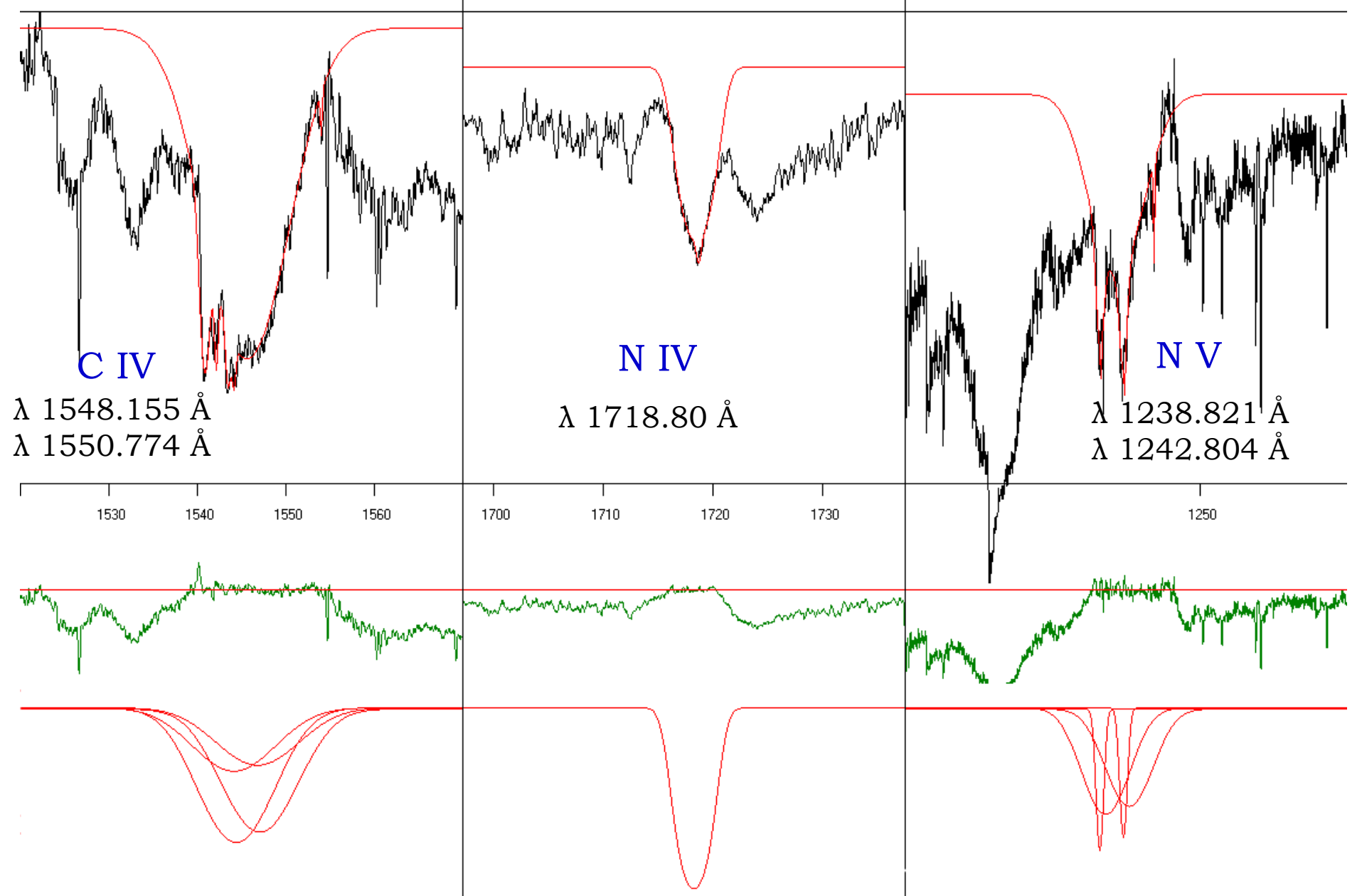
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University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics  
 Astronomical Observatory of Belgrade

<http://www.cc.uoa.gr/fasma> e-mail: [elyratzi@phys.uoa.gr](mailto:elyratzi@phys.uoa.gr) [edanezis@phys.uoa.gr](mailto:edanezis@phys.uoa.gr)







**Column Density** (CD) in  $10^{10} \text{ cm}^{-2}$  of each one of the C IV resonance lines for the independent density regions of matter which create the satellite components.

**$\lambda$  1548.155 Å**

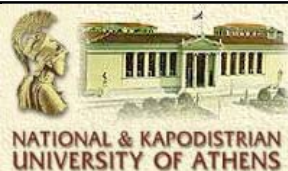
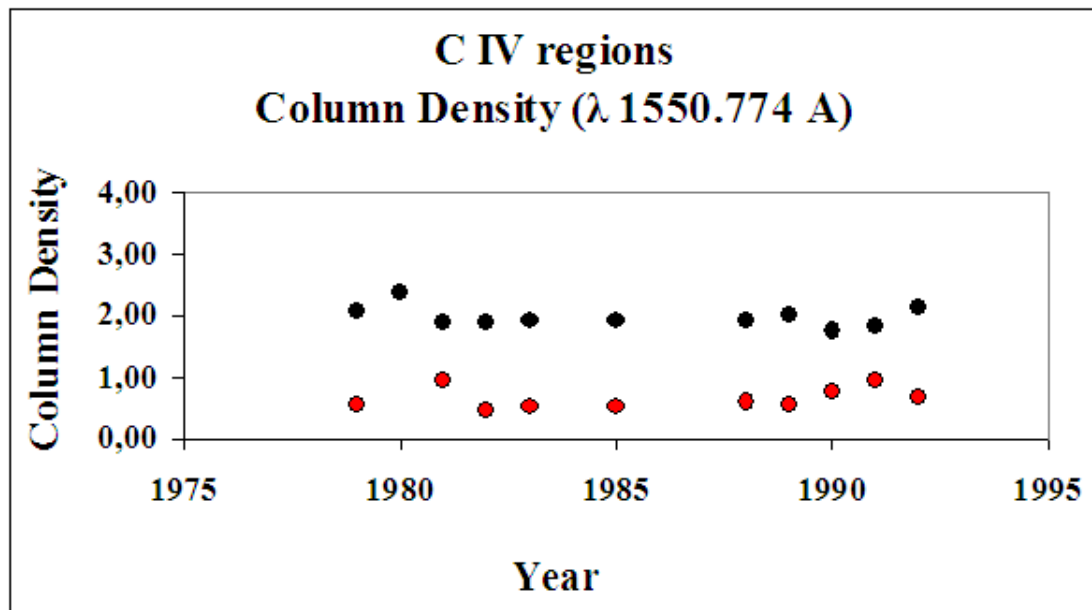
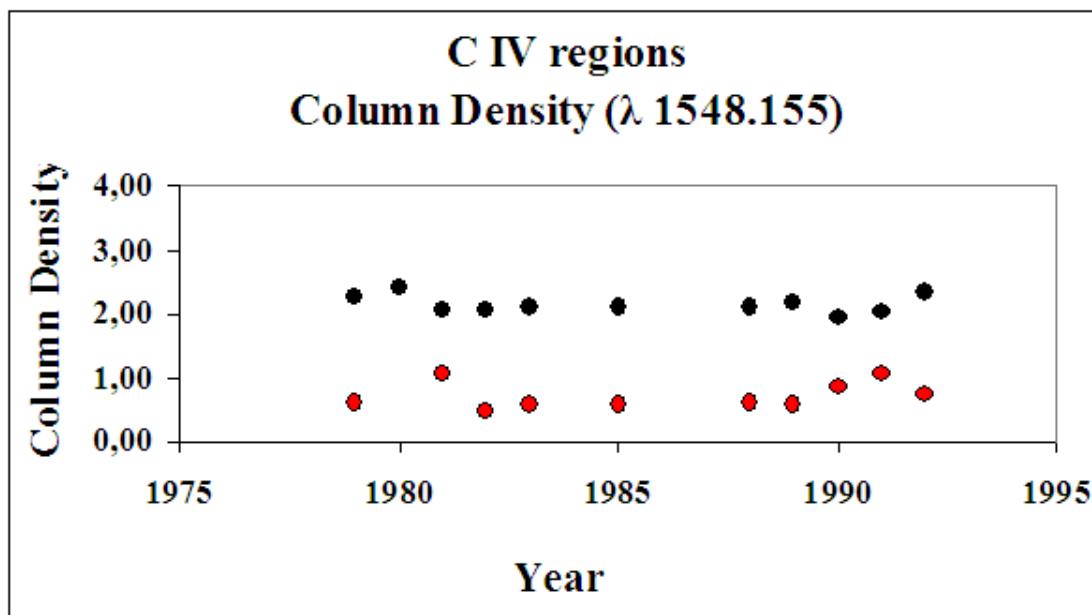
a component:  $2.15 \times 10^{10} \text{ cm}^{-2}$

b component:  $0.72 \times 10^{10} \text{ cm}^{-2}$

**$\lambda$  1550.774 Å**

a component:  $1.98 \times 10^{10} \text{ cm}^{-2}$

b component:  $0.66 \times 10^{10} \text{ cm}^{-2}$



*University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics*  
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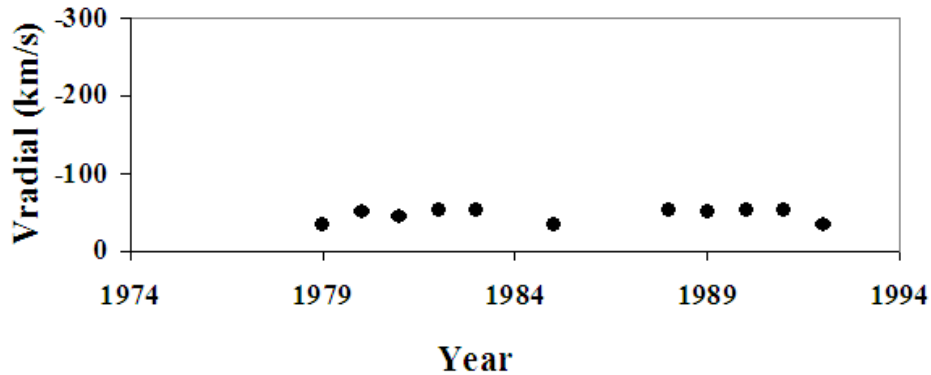
e-mail: [elyratzi@phys.uoa.gr](mailto:elyratzi@phys.uoa.gr)

[edanezis@phys.uoa.gr](mailto:edanezis@phys.uoa.gr)

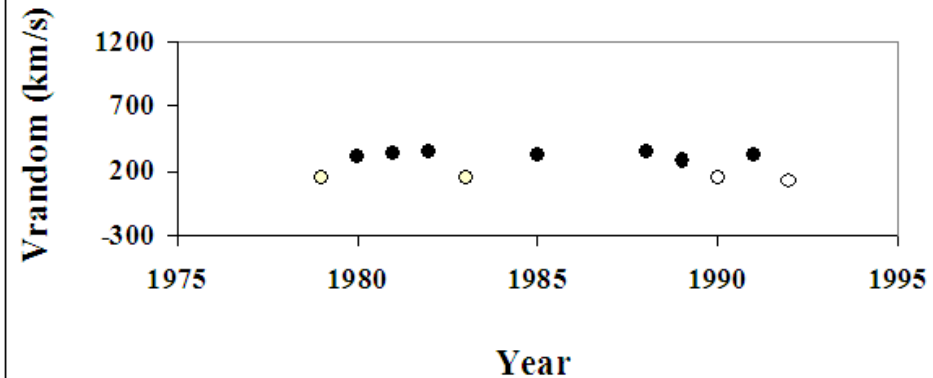


# N IV region

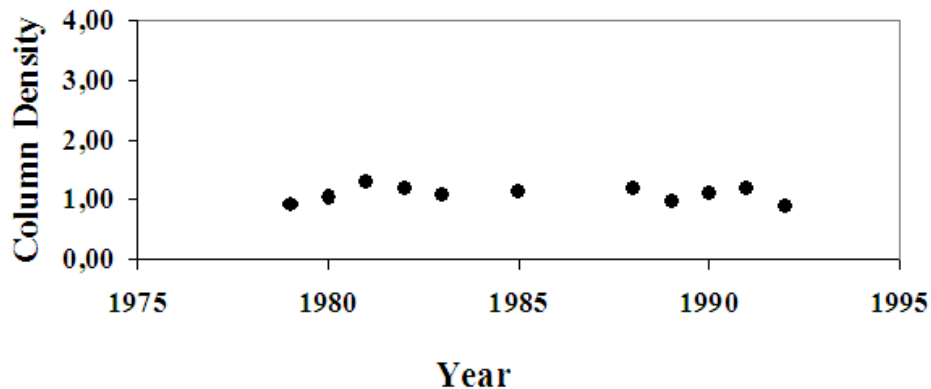
N IV region  
Radial Velocities (km/s)



N IV region  
Random Velocities (km/s)



N IV region  
Column Density



GR method

$V_{\text{rad}}$ ,  $V_{\text{rand}}$ , CD: Constant with time

**Radial Velocities:** -47 km/s

**Random Velocities:** 262 km/s

**Column Density:**  $1.09 \times 10^{10} \text{ cm}^{-2}$



# N V regions

GR method

$V_{\text{rad}}$ ,  $V_{\text{rand}}$ : Constant with time

## Radial Velocities:

a component: -1138 km/s

b component: -1374 km/s

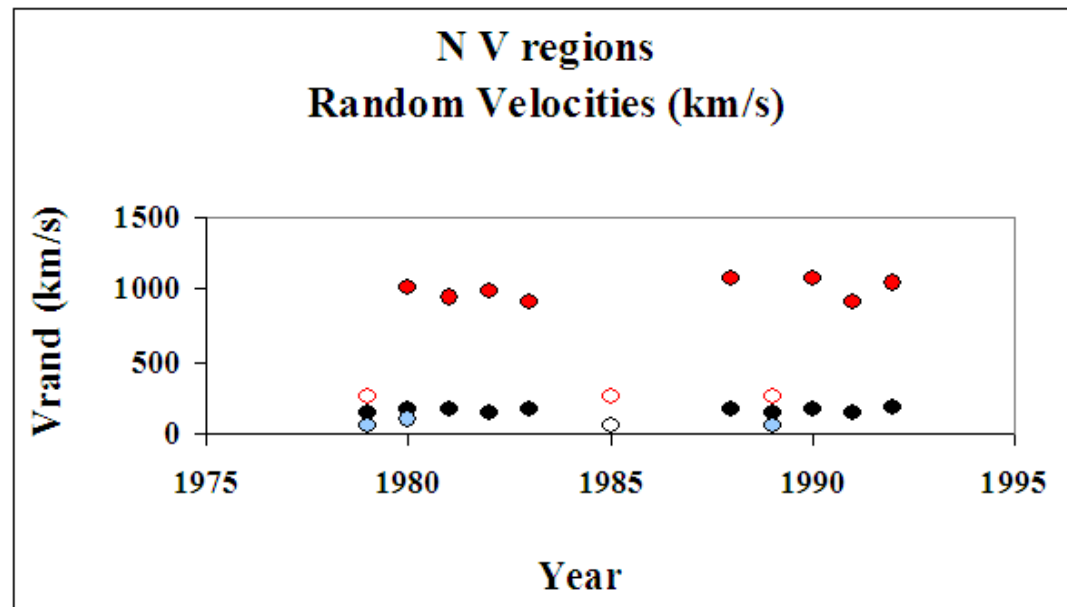
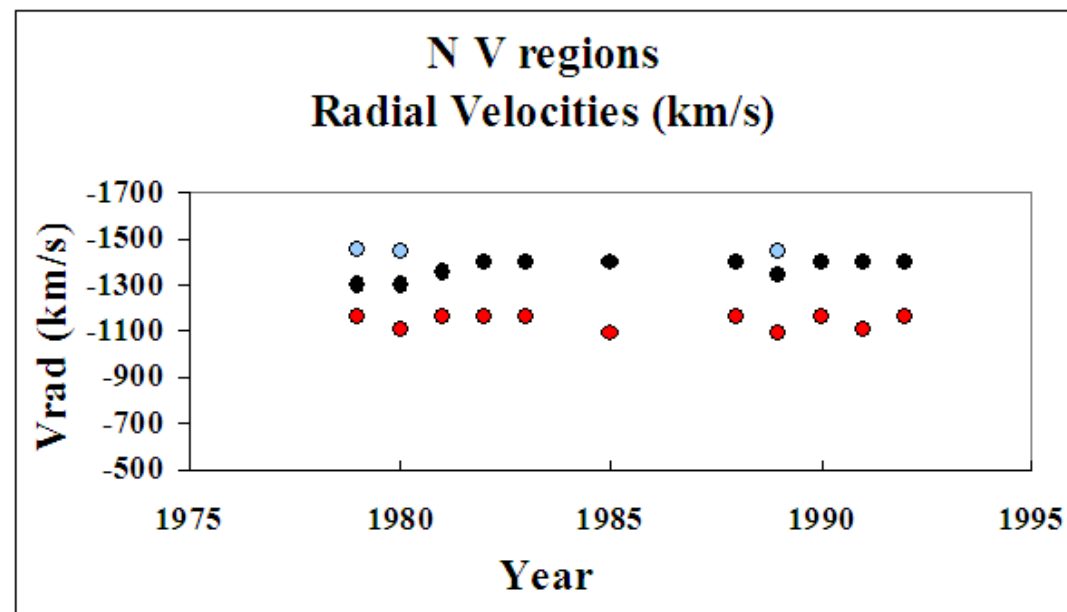
c component: -1450 km/s

## Random Velocities:

a component: 797 km/s

b component: 152 km/s

c component: 71 km/s



**Column Density** (CD) in  $10^{10} \text{ cm}^{-2}$  of each one of the N V resonance lines for the independent density regions of matter which create the satellite components.

**$\lambda$  1238.821 Å**

a component:  $1.13 \times 10^{10} \text{ cm}^{-2}$

b component:  $0.25 \times 10^{10} \text{ cm}^{-2}$

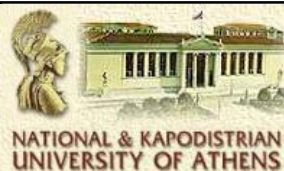
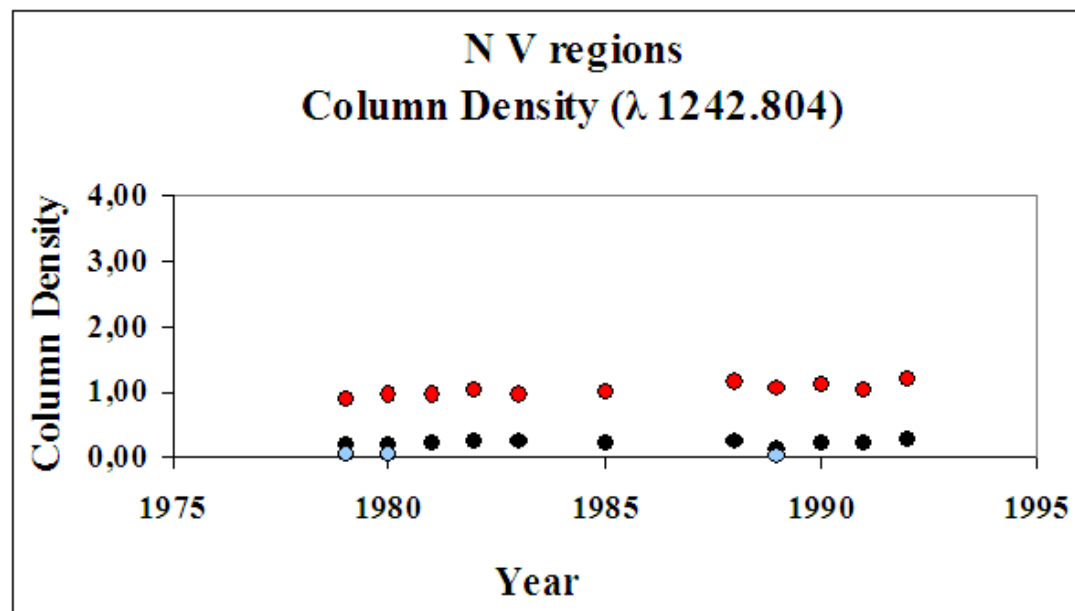
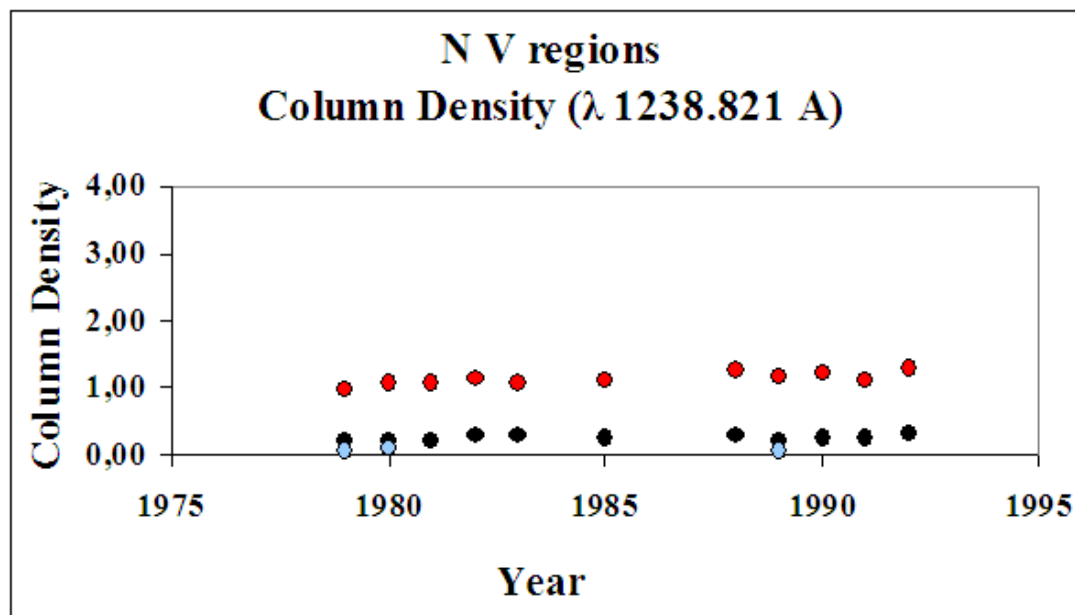
c component:  $0.07 \times 10^{10} \text{ cm}^{-2}$

**$\lambda$  1242.804 Å**

a component:  $1.03 \times 10^{10} \text{ cm}^{-2}$

b component:  $0.23 \times 10^{10} \text{ cm}^{-2}$

c component:  $0.06 \times 10^{10} \text{ cm}^{-2}$



*University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics*  
*Astronomical Observatory of Belgrade*

<http://www.cc.uoa.gr/fasma>

e-mail:

[elyratzi@phys.uoa.gr](mailto:elyratzi@phys.uoa.gr)

[edanezis@phys.uoa.gr](mailto:edanezis@phys.uoa.gr)

