Long term variability of the coronal and post – coronal regions of the Oe star HD 149757 (ζ Oph)

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Introduction

HD 149757 (ζ Oph) is a bright O9V(e) star (Conti 1973), rapidly rotating and a strong non radial pulsator (Kambe, Ando & Hirata 1993; Reid et al. 1993) that, on occasion, shows distinct Hα emission (Barker & Brown 1974). It is a favorite source for UV absorption–line studies because its line of sight intercepts a nearby region of dense gas which is probably localized in space (e.g. Lambert et al. 1994). Hoffleit et al. (1991) and Hoogerwerf, R. et al. (2001) consider it as runaway star from Sco OB2 association. Specifically, Hoogerwerf, R. et al. (2001) note that the path of the runaway star ζ Ophiuchi intersected that of the nearby pulsar PSR J1932 + 1059, about 1 Myr ago, in the young stellar group Upper Scorpius. They propose that this neutron star is the remnant of a supernova that occurred in a binary system that also contained ζ Oph and deduce that the pulsar received a kick velocity of about 350 km/s in the explosion.

In this paper we apply the model proposed by Danezis et al. (2005), Nikolaidis et al (2006) and Danezis et al. (2007) for the outer atmospheres of Oe and Be stars, to 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 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.

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 λλ 1548.155 Å, 1550.774 Å

NIV λ 1718.80 Å

NV λλ 1238.821, 1242.804 Å

Method of spectral analysis

In order to study the C IV, N IV and N V spectral lines of HD 149767 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 spectra of the star HD 149757 and we examine the timescale 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 SACs.

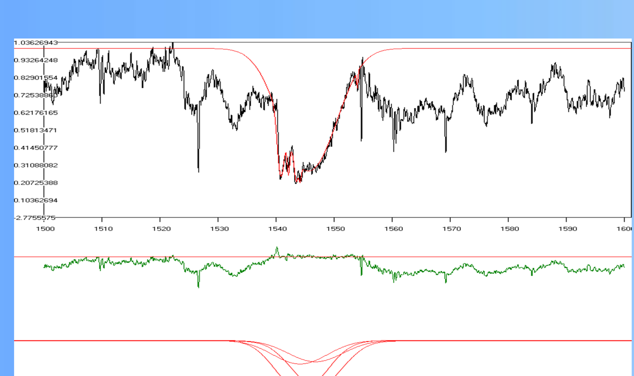

Figure 1: The best fit of the C IV resonance lines with two components in the spectrum SWP14270 of the star HD149757. The graph bellow the fit indicates the differences between the observed spectrum and the fit.. Below the fit we present the analysis of the observed profile to its SACs.

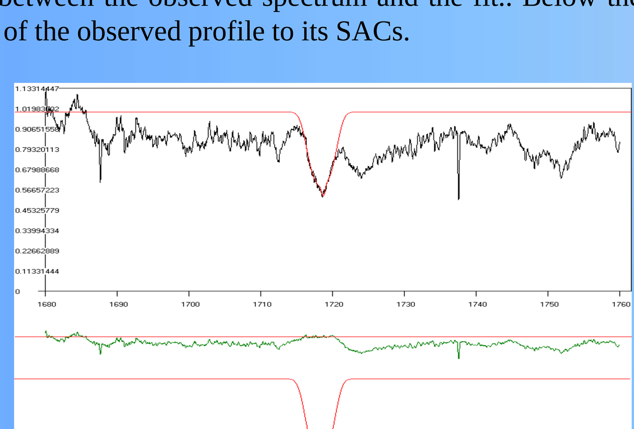

Figure 2 : The best fit of the N IV spectral line with one component in the spectrum SWP21166 of the star HD 149757. The graph bellow the fit indicates the differences between the observed spectrum and the fit. Below the fit we present the analysis of the observed profile to its SACs.

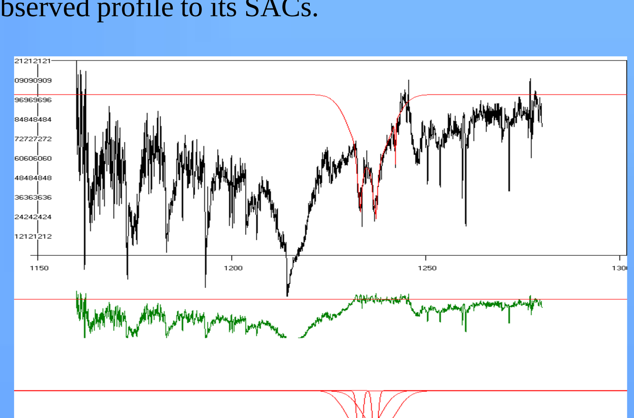

Figure 3: The best fit of the N V resonance lines with two components in the spectrum SWP38410 of the star HD 149757. The graph bellow the fit indicates the differences between the observed spectrum and the fit. Below the fit we present the analysis of the observed profile to its SACs.

A. The study of the C IV density region

In Figs. 4, 5, 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 2 satellite components.

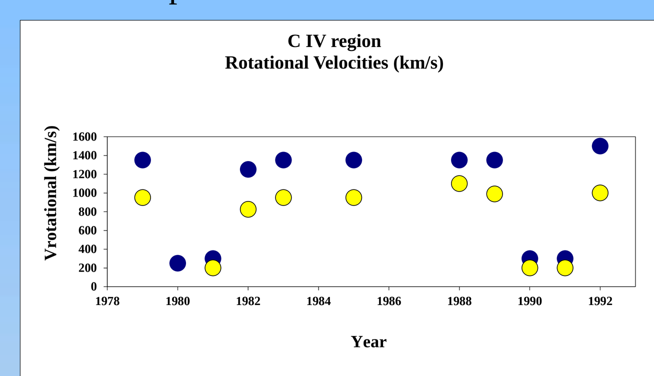

Figure 4: Timescale variations of the apparent rotational velocities Vrot (km/s) of the two C IV line components between 1979 and 1992. In the years 1980, 1981, 1990, 1991 the F-test indicated that the rotational velocities with relatively low values about 300 km/s, correspond to the spectra where the main reason for the line broadening is the random motions of the ions. 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.

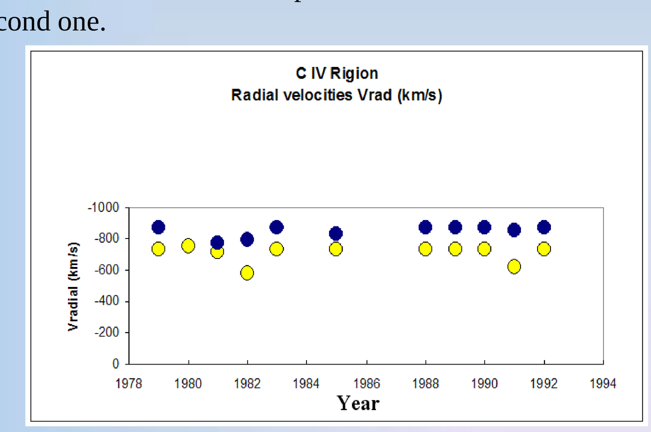

Figure 5: Timescale variations of the apparent radial velocities Vradi (km/s) of the two C IV line components between 1979 and 1992. We can see a constant behavior, where Vrad is about -800 km/s for the first component and about -700 km/s for the second component.

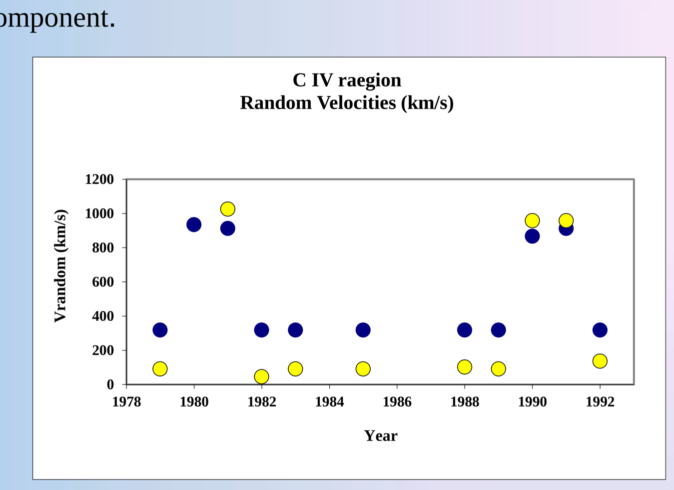

Figure 6: Timescale changes of the Gaussian random velocities Vrand (km/s) of the λλ 1548.155, 1550.774 Å C IV resonance lines for the independent density regions of matter which create the satellite components.

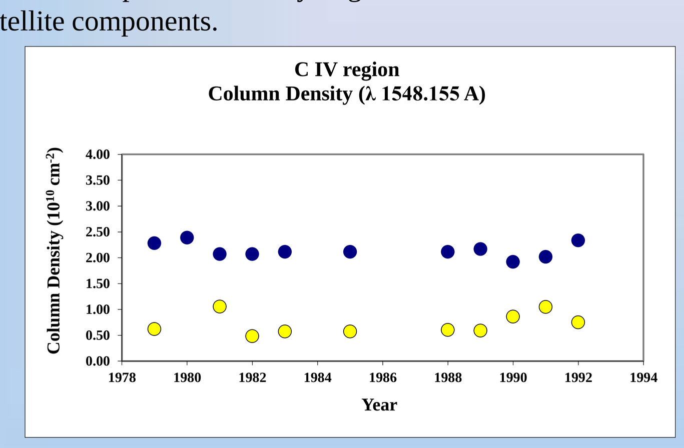

Figure 7a

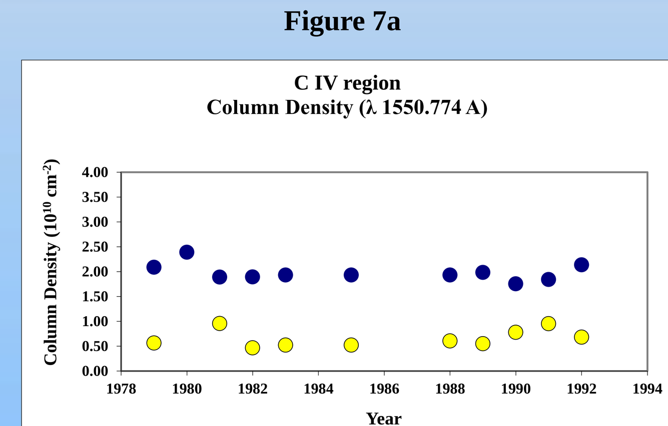

Figure 7b

Figures 7a, b: Timescale changes of the Column Density (CD) in 10^{10} cm^{-2} of each one of the C IV resonance lines for the independent density regions of matter which create the satellite components.

B. The study of the N IV density region

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

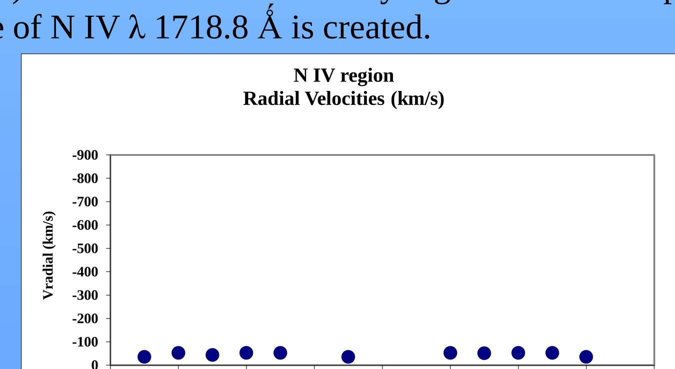

Figure 8: Timescale changes of the apparent radial velocities Vrad (km/s) of the density region where the N IV λ 1718.8 Å spectral line is created. The maximum value of the radial velocity is about -50 km/s.

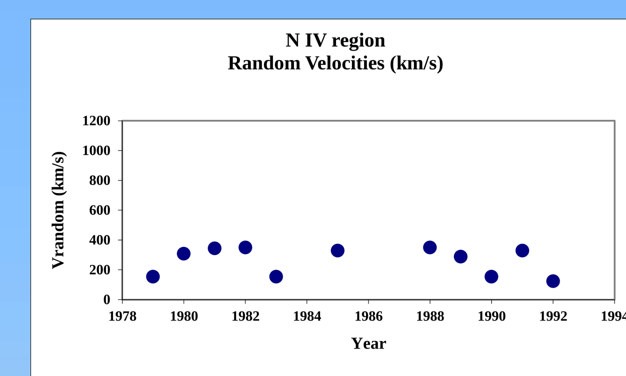

Figure 9: Timescale changes of the random velocities Vrand (km/s) of the ions which contribute to the broadening of the N IV spectral line at λ 1718.8 Å.

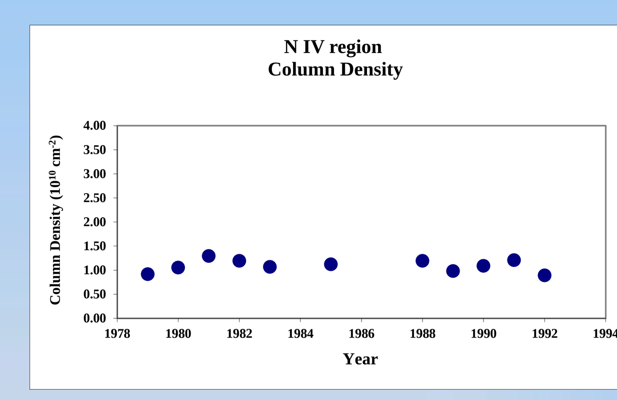

Figure 10: Timescale changes of the column density (CD) in 10^{10} cm^{-2} of the N IV spectral line at λ 1718.8 Å.

C. The study of the N V density region

In Figs. 11a, 11b we present the timescale variations of the column density in 10^{10} cm^{-2} of the absorption component of the N V resonance lines λλ 1238.821 1242.804 Å respectively. In Figures 13 and 14 we present the mean values of the apparent radial velocities Vrad (km/s) and random velocities Vrand (km/s) respectively.

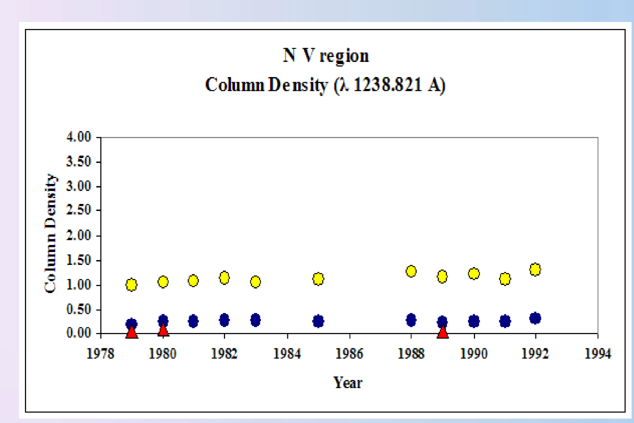

Figure 11a

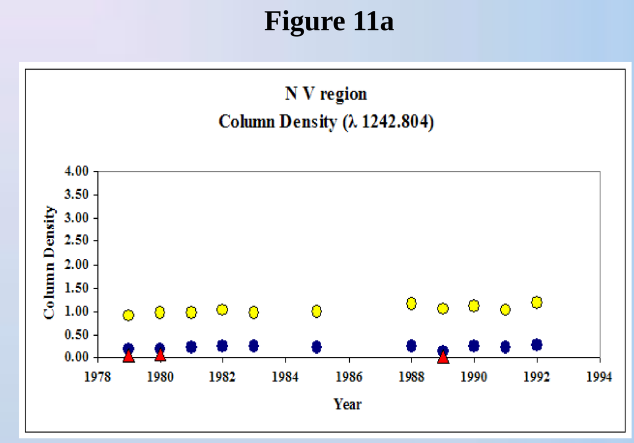

Figure 11b

Figures 11a, 11b: Timescale changes of the Column Density (in 10^{10} cm^{-2}) of the two or three absorption components of the λλ 1238.821, 1242.804 Å N V resonance lines

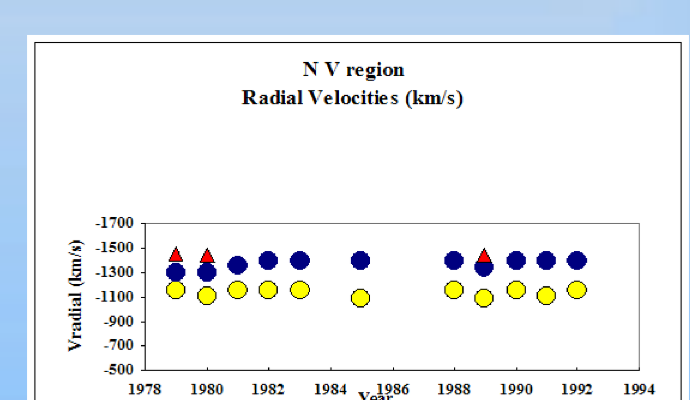

Figure 12: Timescale variations of the values of the apparent radial velocity Vrad(i) (km/s), for the independent density regions of matter which create the 2 or 3 satellite components of the N V resonance lines at λλ 1238.821, 1242.804 Å. We see a constant behavior of the radial velocities with values between -1160 km/s and -1450 km/s for each component.

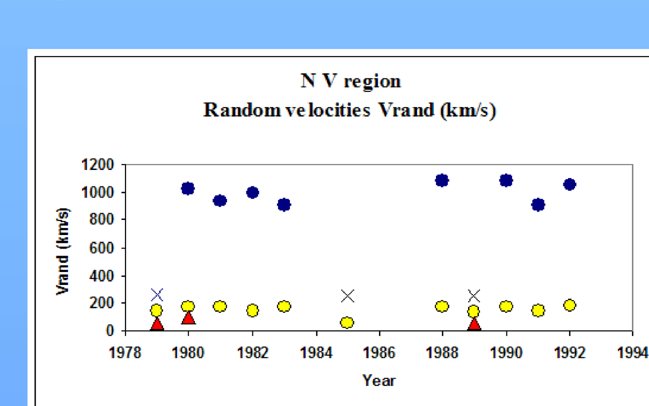

Figure 13: Timescale variations of the values of the random velocities Vrand (km/s), of the ions, in the density region which creates the two or three absorption components of the N V resonance lines at λλ 1238.821, 1242.804 Å. We calculated values about 1000 km/s for the first satellite component (points ●), values about 200 km/s for the second component (points ●) and about 50 km/s for the third one (points ▲). The points × correspond to the spectral lines which are best fitted with the rotational way. This means that in this case the random velocities of the ions contribute less to the broadening of the spectra lines.

Conclusions

The model

Applying the GR – Model (Danezis et al., 2005, Nikolaidis et al. 2006 and Danezis et al. 2007), we 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 -50±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, 8 and 11).

Rotational velocities

We present timescale 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 Figure 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 regions 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 Figure 6). In the N IV 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 Figure 9). In the N V regions we calculated values about 1000 km/s for one satellite component and values about 200 km/s for the others (see Figure 12). In each region and for each fitting way, the timescale 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 $0.5x10^{10}$ and $2.5x\ 10^{10}$ cm^{-2}. These values are lower than the typical values which are about 10^{12} (Pwa & Pottash, 1986) or 10^{14} and 10^{15} cm^{-2} (Howarth & Prinja, 1986). Besides, it is generally accepted that the calculation of the Column Density values depends on the method which one uses. (Howarth & Prinja, 1986).

References

Barker, P. K., Brown, T. 1974, ApJ, **192**, 11.

Bjorkman, J, E., Ignare, R., Tripp, T. M., Cassinelle, J. P. 1994, ApJ, **435**, 416.

Code, A. D. &, Bless R. C. 1974, BAAS, **6**, 446.

Conti, P. S. 1973, ApJ, **179**,181.

Conti, P. S. & Ebbets, D. 1977, ApJ, **213**, 438.

Danezis, E., Lyratzi, E., Nikolaidis, D., Stathopoulou, M., Theodossiou, E., Drakopoulos, C., Soulikias, A. & Antoniou, A.: 4th Serbian Conference on Spectral Lines Shapes, 2003 Arandjelovac, Serbia..

Danezis, E., Nikolaidis, D., Lyratzi, E., Popović, L. Č., Dimitrievć, M. S., Theodossiou, E. & Antoniou, A. Intenational 5th Serbian Conference on Spectral Lines Shapes in Astrophysics (V SCSLSA)" Vrsac, Serbia, June, 2005.

Danezis, E., Nikloaidis, D., Lyratzi, E., Popović, L. Č., Dimitrievć, M. S., Antoniou, A. & Theodossiou, E. 2007, PASJ, **59**, 4 (in press).

Hanbury Brown, R., Davis, J. 1974, MNRAS, **167**,121.

Henrichs, H. F., Hammerschlag - Hensbergs, G., Howarth, I.P. and Barr, P. 1983, ApJ., **268,** 807.

Herrero, A. 1993, SSRv, **66,** 137.

Hoffleit, D. 1964, cbs, book H.

Hoffleit, D. 1991 bsc, book H

Hoogerwerf, R., Bruijne, J. H. J., De Zeeuw, P. T. 2001, ApJ, **544**, 133.

Howarth, I., Prinja, R. K.; Willis, A. J. 1984, MNRAS, **208**, 525.

Howarth, I. D., & Prinja, R, 1986, ApJ, **61**, 357.

Howarth, I. Reid, A. 1993, A&A, **279**, 148.

Hutchings, J. B., & Stoeckley, T. R. 1977, PASP, **89**, 19.

Kambe, E., Ando, H., & Hirata, R. 1993, Ap&SS, **210**, 219.

Lambert, D.L, Sheffer, Y., Gilliland, R.L, Federman, S. R.1994, ApJ, **420**, 756.

Massa, D. 1995, ApJ, **438**, 376.

Morton, D. C. 1976, ApJ, **204**, 1.

Nikolaidis, D., Danezis, E., Lyratzi, E., Popović, L. Č., Antoniou, A., Dimitrijević, M. S., & Theodossiou, E.: 23rd SPIG Serbia, 2006.

Penny, Laura R. 1996, ApJ, **463**, 737.

Pwa, T. H., & Pottash, S. R. 1986, A&A, **164**, 116.

Reid, A. H. N., Bolton, C. T., Crowe, R. A., Fieldus, M. S., Fullerton, A. W., Gies, D. R., Howarth, I. D., McDavid, D., Prinja, R. K., Smith, K. C.: 1993, ApJ, 417, 320R.

Underhill, A. B., Divan, L., Prevot-Burnichon, M.-L., Doazan, V.1979, MNRAS, **189**, 601U.

Walborn, N. R., Nichols-Bohlin, J., Panek, R. J.1985, NASAR, 1155, 0W.

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Sremski Karlovci, Serbia, June 11-15, 2007