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Spectro- & photopolarimetric monitoring on the HAeBe star VV Serpens

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EXPORT

Abstract. The Herbig Ae star VV Serpens was monitored intensively during the EXPORT 1998 observing programme. Variations were detected in the spectroscopy, photometry and polarimetry of time-scales of days and months. The photo-polarimetry observations can be explained by the presence of an edge-on seen dust disk with obscuring cloud structures. Spectroscopic changes indicate to accretion activities of this $3M_\odot$ and few million year old system. Although it is remarkable similar to earlier observed UXORs, its deviations from this group is most interesting for the study of CS disks around pre-MS objects. Further detailed study on this object is most welcome though.

1. Introduction

Planetary systems originate from system of a young star and its circumstellar (CS) material. If this simple statement is realistic the study of the latter should give key information on the formation of planets. Studies of relative young MS stars revealed in a few cases disks with inhomogeneous structures, e.g. Backman & Paresce (1993). Evidences for more solid bodies in the CS disks structures of pre-MS and MS are also reported (e.g. Grady et al. 2000, other contributions in PPIV 2000).

Information on the outer regions of young disk evolution can be obtained by images and photo-polarimetry (see several contribution in this volume). With spectroscopy gaseous regions up to the stellar photosphere can be investigated

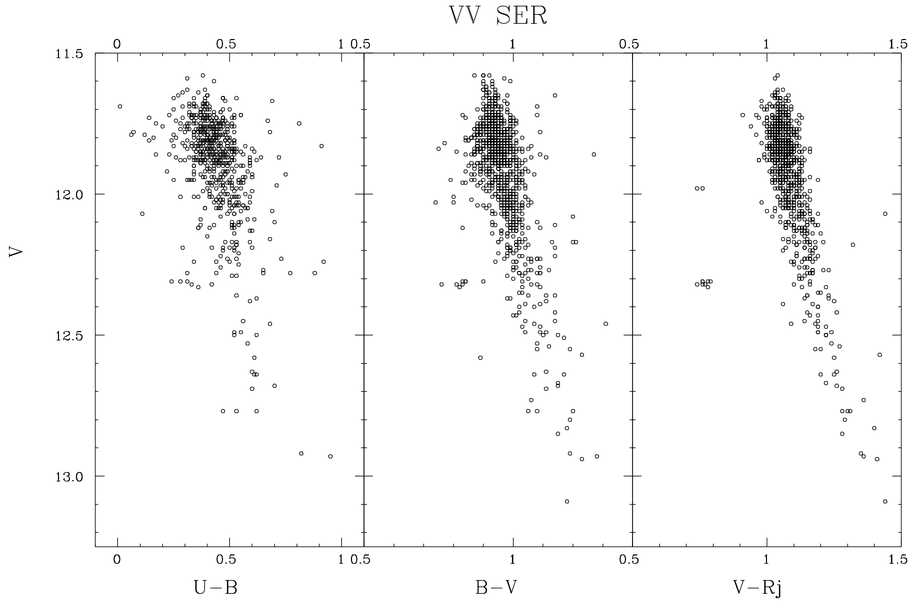

Figure 1. The photometric behaviour of VV Ser presented in colour-magnitude diagrams. Besides EXPORT results we added monitoring data of Shevchenko et al. (1993).

though. Many young MS and pre-MS are highly variable in their spectroscopic line structure. If non-photospheric, such variation are a powerful tool to study the gaseous disk. Indeed spectroscopic monitoring revealed solid disk contents for a few pre-MS and MS stars, such as star grazers and other orbiting structures. Good examples are the HAeBes UX Ori (Grinin et al. 1994) and BF Ori (de Winter et al. 1999), and the Vega type star β Pic (Beust et al. 1998).

Being time consuming but very successful though, we introduced the monitoring of young intermediate mass stars as one of the main projects within the EXPORT proposal (Eiroa et al. this volume). Here we report the monitoring results on VV Ser, an object quite similar to UX and BF Ori, see Table 1.

2. EXPORT observations on VV Ser

Details of the EXPORT observing nights and conditions can be found in this volume in the contributions of Eiroa et al., Mora et al., and Oudmaijer et al. The following monitoring results were obtained for VV Ser:

UBVRI Polarimetric observations:

We obtained 12 polarimetric observations of VV Ser: 14-16/May, 28-31/July and 22-25/Oct. 1998. The light of VV Ser is significantly polarised and variations behave as follows: $U = 1.40$ - 1.85, $B = 1.42$ - 1.91, $V = 1.48$ - 2.20, $R = 1.41$ - 1.80, $I = 1.05$ - 1.62 degrees of polarisation. The errors can be as high as these intervals though. However, it is clear that VV Ser shows variable polarisation on all our time scales. Also we observed a roughly constant position angle of 73 - 86

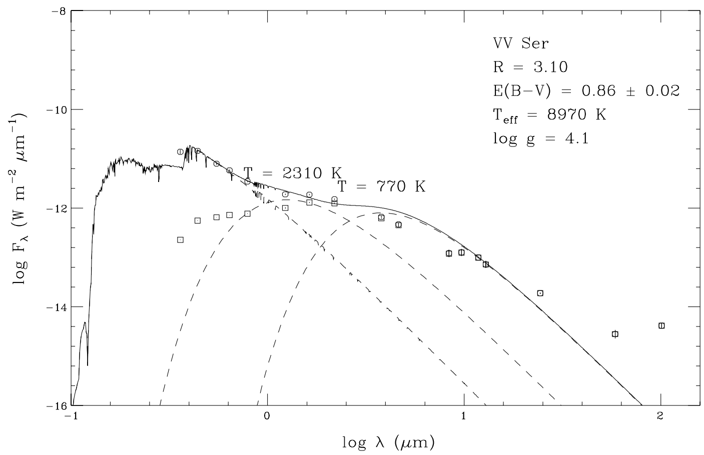

Figure 2. The SED of VV Ser. Applicable photometry was taken from the EXPORT results, Berrilli et al. (1992), and Hillenbrand et al. (1992). For the astrophysical parameters see Table 1. The IR-excess was fitted with two appropriate planck-curves.

degrees throughout.

UBVRI Photometric observations:

VV Ser was observed 7 times on 14-15/May, 28/July and 22-25/Oct. 1998. During all these observations VV Ser was near maximum light, see Fig. 1. Only on 24/Oct. all magnitudes were about $0^{\rm m}.2$ brighter. Neglecting this observation VV Ser remained at the following magnitudes: $U = 13^{\rm m}.23$ - $13^{\rm m}.27$, $B = 12.76$ - 12.85, $V = 11^{\rm m}.85$ - $11^{\rm m}.94$, $R = 11^{\rm m}.11$ - $11^{\rm m}.23$, $I = 10^{\rm m}.33$ - $10^{\rm m}.54$. This means that the amplitude increases by longer wavelengths.

JHK Photometric observations:

We collected 9 *JHK* observations for VV Ser on: 29/May, 27-30/July and 22-25/Oct. In all three pass-bands VV Ser was variable: $J = 8^{\rm m}.70$ - $9^{\rm m}.06$, $H = 7^{\rm m}.47$ - $7^{\rm m}.74$, $K = 6^{\rm m}.31$ - $6^{\rm m}.51$. Variations were seen between the different runs as well as on consecutive nights.

Intermediate resolution INT spectroscopic observations:

VV Ser was observed 18 times: 3 times during 15-17/May, 10 times between 28-31/July and 5 times during 24-28/October 1998. The first run covered the 5854-6728 Åregion with a 0.707 Å/pixel resolution. The other two runs had an 0.474 Å/pixel resolution in the 5712 to 6812 Åcoverage. *High resolution WHT spectroscopic observations:*

With the use of the UES we obtained a 49000 resolving power and 11 spectra from 3800 to 5900 Åtaken during the same observing periods as the INT observations.

3. Photometric and polarimetric results

Comparison of our optical photometry with known monitoring results (e.g. Shevchenko et al. 1993) shows that our data fit well to previous observations, see Fig. 1., also that VV Ser was close to maximum light and in a relative state

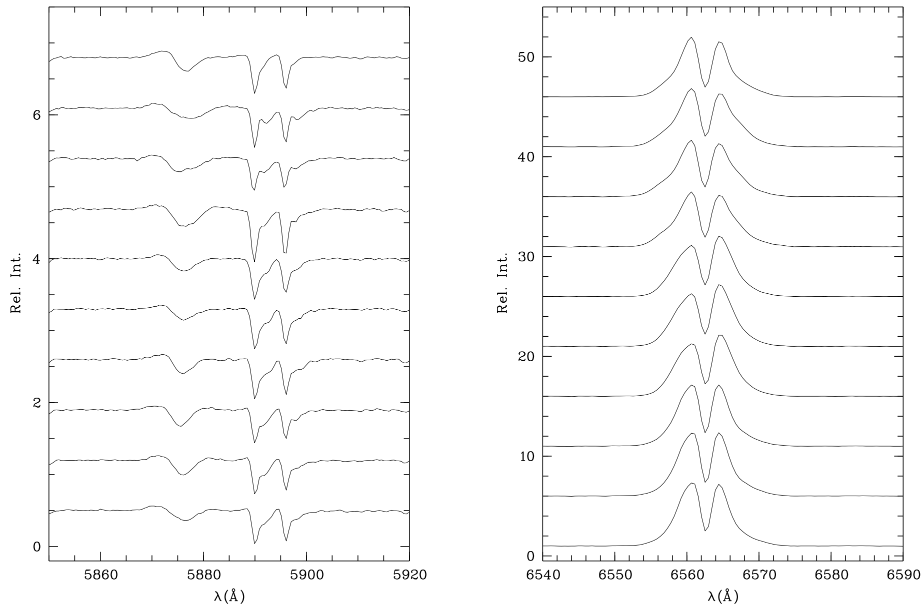

Figure 3. INT intermediate resolution spectral monitoring results for VV Ser. Shown are regions around the He I, Na I D and Hα lines. Spectra are taken on 28 July, top, and three spectra, with 2 hour intervals, on 29, 30 and 31 July 1998, bottom.

of quiescence. These magnitude-colour diagrams shows that VV Ser is more reddened at lower light levels, probably due to extra extinction. Such a behaviour is known for UXORs (Grinin et al. 1994). The UXOR turn-around phenomenon, getting bluer again in deep minima, might be valid for the $U-B$ colour only though. Also the polarisation of VV Ser and variations herein are similar to UXOR type objects. Photo-polarimetrically seen VV Ser is alike an UXOR for which the light behaviour are usually explained by dust clouds orbiting the central star in the CS disk (Grinin et al. 1994).

The obtained infrared photometry has colours much redder than of any A-type star. Indeed, when we plot the spectral energy distribution (SED) of VV Ser, see Fig. 2, a large near- to far-IR excess is seen. Such an excess is indicative for large amounts of CS dust. Combined with the polarisation results we propose that it is distributed in a disk indeed (Oudmaijer et al., this volume).

The photometric IR variations of VV Ser diminish at longer wavelength. This could be due to suppression of the direct stellar light. However, in the visual the amplitude we observed was only $0\overset{\text{m}}{.}14$ to $0\overset{\text{m}}{.}30$ in the red and even $0\overset{\text{m}}{.}36$ in J. A reason could be that also part of the disk, being redder than the star, light is obscured. At longer wavelengths the amplitude gets lower then as this radiation comes from outer disk regions being less affected by obscurations. More detailed analyses is necessary though, especially as for the blue colours our amplitude variations are close to the observational errors.

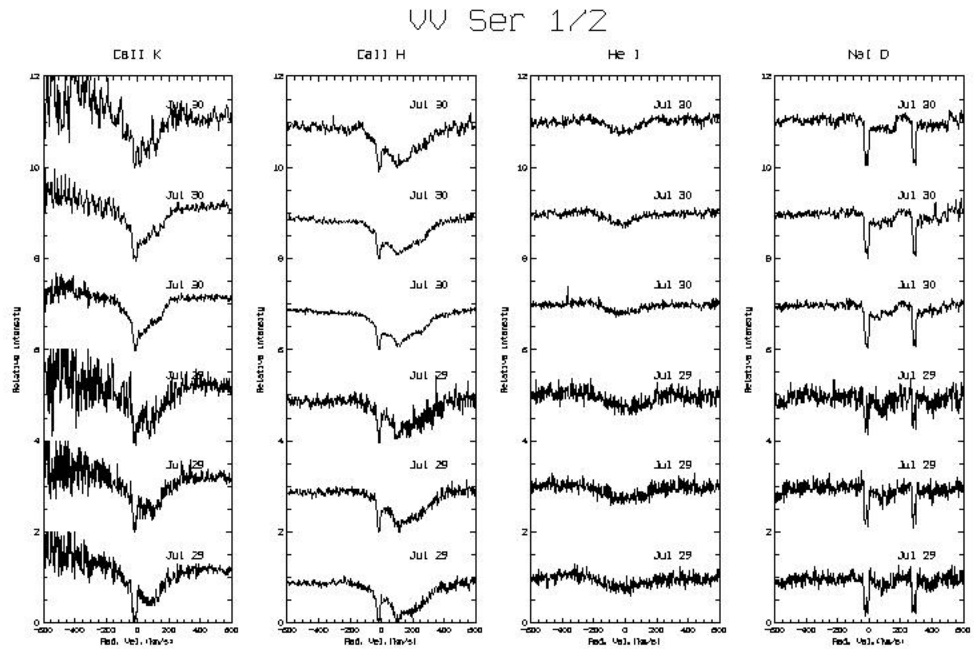

Figure 4. WHT high resolution spectral monitoring results for VV Ser. Shown are regions around the Ca II He I, Na I D lines. Observing dates are indicated. The spectra are taken simultaneous with the INT spectra, see Fig. 3.

In table 1 we compare the astrophysical parameters of VV Ser with those of two very similar UXORs: UX Ori and BF Ori. Although their similar astrophysical parameters the *vsini* as well the A_V is significantly higher for VV Ser.

Table 1. Astrophysical parameters of VV Ser and the UXORs: UX Ori and BF Ori. The data were collected from Thé et al. (1994), van den Ancker et al. (1997), and Solano et al. (this volume).

$Name$	V_{max}	A_v	$Sp.T.$	$LogT_{eff}$	$D(pc)$	$vsini$
BF Ori	9.7	0.3	A5III	3.908	430	100(10)-34
UX Ori	9.5	1.1	A3III	3.934	460	70(6)-189
VV Ser	11.6	2.8	A2III	3.953	440	200(20)

4. Spectroscopic monitoring results

Intensive monitoring allows us to study VV Ser's high and intermediate resolution spectroscopic behaviour on time-scales of hours, days and months. The spectrum of VV Ser is a combination of an A2 photospheric spectrum enriched with shell lines, e.g. Si II and Fe II, and emission at Hα, Hβ and [O I]. A more detailed look on the spectra reveals many variable lines on any of the monitoring time-scales. Only a few monitoring results can be presented here though.

Interesting are variations in the He I, Na I D and Hα lines, e.g. Fig. 3 for the July 1998 data-set. Reversed P Cygni is seen for the HeI line, together with red shifted absorption components (RACs) for the sodium lines. Note the co-variation of the RACs with the red He I absorption wing at similar velocities. Hα is double peaked in emission with the red peak the strongest, only on the third night peak intensities are reversed. Such a reversal as well as RACs in the sodium lines and the presence of (variable) He I in A-type stars is known for UXORs. Similar line behaviour are studied and explained for UX and BF Ori (Grinin et al. 1994, de Winter et al. 1999). In their model RACs are due to evaporating star-grazers, He I is noted when these bodies are volatile rich or cause heated (shock) regions, co-variations are also seen in the Hα profiles. However, additional effects of stellar rotation and orbiting bodies are needed to fully explain more complex line variations as also visible in our data-sets.

The high resolution monitoring allows us better study of the variations in velocity scale and to other species, e.g. Fig. 4. In these spectra RACs are also seen for Fe II and Ca II lines. RACs in these lines range up to 250km/s. The He I variations are detected up to similar velocities. Very interesting are the RACs detected in Hγ and Hδ, with co-variations and equal velocities of the Na I D RACs. Note the double absorption peaked Na I D lines near rest velocity for some of the profiles, this might indicate to an accompanying object.

5. Conclusions

Spectrometric and photopolarimetric monitoring of VV Ser on times scales from hours up to months revealed variations almost identical to those known for the UXORs UX and BF Ori. It is, therefore, proposed that VV Ser has an edge-on seen CS disk with star-grazer bodies. Also in astrophysical parameters VV Ser is a twin to these objects. Main differences are its higher $vsini$, A_V and lack of scatter light in deep minima. This might tell us more on the disk properties of pre-MS objects in which (proto-)planet formation might be active. More work is also needed to investigate our complete data-set and to make better use of the simultaneity of our observations.

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