Astron. Astrophys. 348, 475–478 (1999)

ASTRONOMY AND ASTROPHYSICS

Indications for the presence of a postmaximum wind of nova V1500 Cyg

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Received 1 April 1999 / Accepted 16 June 1999

Abstract. We have studied spectra of nova V1500 Cyg (1975) shortly after its optical maximum. We find that the very wide red wing of the Hϵ plus Ca II H line blend in emission, which was invisible at maximum, appeared a few hours later. What was according to Duerbeck & Wolf (1977) an extremely blue shifted absorption component of Hβ was also seen soon after. These observations can be understood by the presence of a continuously ejected high velocity wind, which became visible during the time of these observations. Somewhat later observations by other observers indicating emission line narrowing, can then be understood as due to a weakening of the wind at such times. The significance of the position of the blue edge of the main absorption component of Hβ and Hδ is also discussed in relation to the region where this absorption is produced.

Key words: line: profiles – stars: individual: V1500 Cyg – stars: novae, cataclysmic variables

1. Introduction

V1500 Cyg is a classical nova, which had an extremely fast development after the beginning of its 1975 outburst. It has been claimed that this exceptional nova had only one envelope with a characteristic ejection velocity and that it ejected no material at a higher velocity (Starrfield et al. 1976). In fact some at least of such higher velocity material generally detected in nova spectra, is almost certainly material belonging to a wind. It is the existence of that wind, which generally explains many of the properties of nova spectra in their development after optical maximum (see for instance Friedjung 1996). There are good reasons, often neglected by present day workers in the field, for believing that the most blueshifted absorption components and the widest emission components seen in nova spectra after optical maximum, are not only produced by material with the highest ejection velocity belonging to this wind, but that the material is also in the deepest layers of the ejected envelope (McLaughlin 1947). In fact Duerbeck & Wolf (1977) observed very highly blue shifted absorption components of Hα and Hβ in the spectrum of V1500 Cyg for a short time, suggesting that the high velocity wind was also present in the case of this very fast nova. We give here additional evidence for the existence of that kind of wind for V1500 Cyg and we discuss its role. We mainly concentrate on the emission component of the Hϵ plus Ca II H line blend. This is especially relevant to studies of the properties of novae, as there has been confusion in recent years about the behaviour of the emission components of lines in their spectra. It has in particular been stated, that emission components narrow with time after optical maximum. Such an effect if real, could indicate contrary to what was previously believed and to what has been just stated in this paragraph, that the highest velocity material is at the outside of the ejected envelope. Apparent line narrowing could then be explained by a decrease of the optical thickness in the continuum of the ejected envelope after optical maximum, so line emission from slower moving material in deeper layers is able to escape from the envelope in later stages of the development of a classical nova.

Our present study is a continuation of that of Friedjung et al. (1996) referred to as Paper I. In that paper we examined the behaviour of the spectrum of V1500 Cyg and especially the profile of the Hβ absorption line before optical maximum; our results suggested deviations from spherical symmetry in the ejected envelope. Here we study the post maximum behaviour of the nova spectrum at stages when blue shifted absorption components of spectrum lines were still visible. This stage is quite different from the previously studied one before maximum and the spectra cannot be examined in the same way. As details about the geometry, kinematics and physics of the envelope are uncertain, we must use approximate semi-empirical methods to obtain information about what is happening. Detailed spectral syntheses, which have been performed by other authors for more recent novae, are probably not fully reliable at the present state of knowledge.

2. The nature of the spectra studied

Our study is based on photographic spectra taken with the Canadian Copernicus Spectrograph (CCS) mounted at the f/15 Nasmyth focus of the 90 cm reflector of the Toruń Observatory, Poland. Further details of the instrumentation and calibration of the spectra are the same as given in Paper I.

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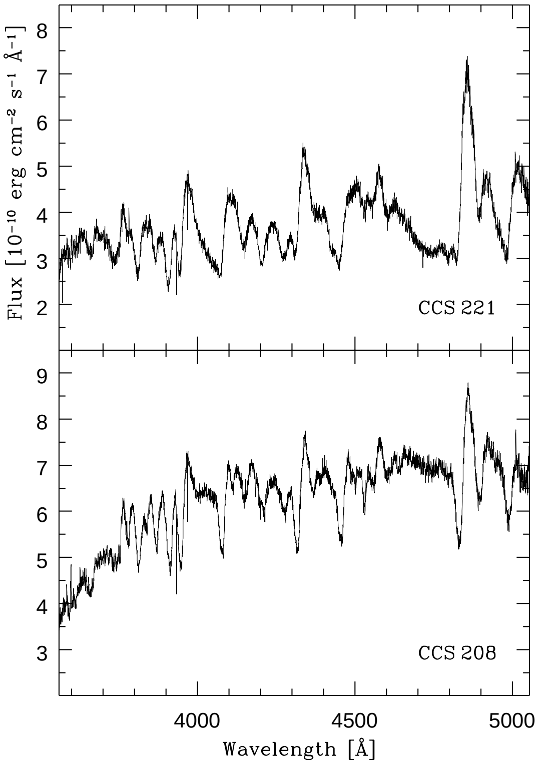

Fig. 1. Examples of our spectra of V1500 Cyg

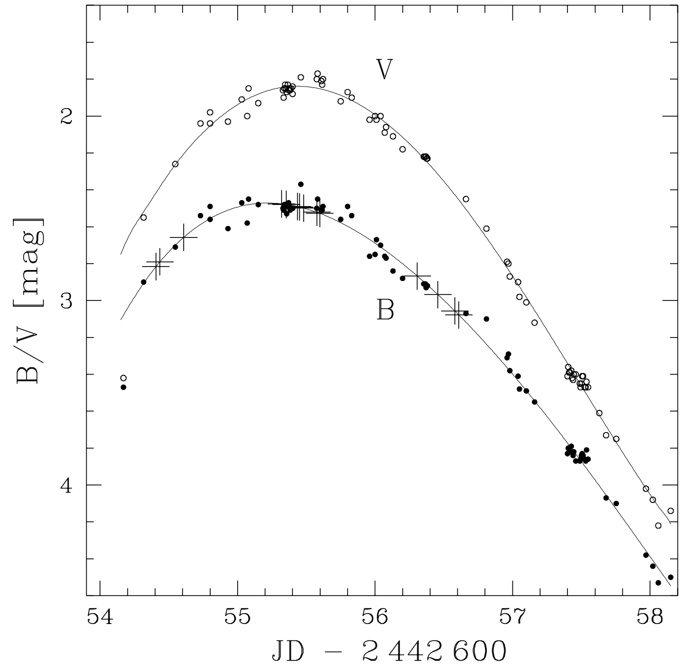

Fig. 2. B, V light curves of V1500 Cyg around maximum based on published photometry (Ichimura et al. 1975, Lindgren & Lindegren 1975, Young et al. 1976). Large crosses indicate the times of our spectroscopic observations discussed in Paper I and in this paper. Solid lines correspond to our polynomial fits.

Table 1. Journal of observations

Spectrum	JD 2 442 600+	Δt [days]	B [mag]	ΔB [mag]	Obs.
CCS 208	55.354	0.134	2.479	0.009	SK
CCS 209	55.435	0.215	2.490	0.020	SK
CCS 210	55.450	0.230	2.493	0.023	SK
CCS 211	55.481	0.261	2.499	0.029	SK
CCS 213	55.576	0.356	2.522	0.052	SK
CCS 214	55.598	0.378	2.528	0.058	SK
CCS 215	56.307	1.087	2.867	0.397	AB
CCS 218	56.457	1.237	2.968	0.498	AB
CCS 220	56.580	1.360	3.057	0.587	AB
CCS 221	56.609	1.389	3.078	0.608	AB

$\Delta t = t - t_{\max B}$, $\Delta B = B - B_{\max}$;
SK - S. Krawczyk, AB - A. Burnicki

Table 1 gives the general characteristics of the ten blue region spectra used by us, two of which are shown in Fig. 1. For each spectrum in Table 1, the phase from optical maximum in the B band, Δt, the observed B magnitude (obtained as in Paper I from a polynomial fit to the published B photometry around maximum; Fig. 2), and the difference between this magnitude and the maximum B, ΔB, are also given. Fe II is a major contributor to these spectra, which in this way are different from those obtained before optical maximum. As stated in Paper I, optical maximum in V occurred on JD 2 442 655.41, that is on the 30th August at around 21h 50m and in B on 2 442 655.22, which is 4 hours earlier. The material of the envelope would appear to be generally less ionized than before this maximum. Much of Hβ is blended with the strong Fe II 4924 Å multiplet 42 line. Indeed this phenomenon also explains the distortion of the red wing of Hβ in the last spectrum studied in Paper I. The width and blueshift of the absorption component seem to be fairly similar for the Fe II and Balmer lines.

In our work we have used the line identifications of Duerbeck & Wolf (1977). The blue wing of Hβ is fairly pure in the spectra studied, while there is little contribution to the spectrum from lines between Hδ and the blend of Hϵ and the Ca II H line. The wavelengths of the latter two lines are fairly close at 3970.07 and 3968.47 Å; this difference corresponding to a velocity of only 121 km s^{-1}, is small compared with the total line width. We shall therefore assume that this blend behaves as a single line, with a red wing which is relatively pure. The blue wings of the Hβ and Hδ lines are similarly relatively unblended.

We compare line profiles of $\log F/F_{\rm cont}$, where $F_{\rm cont}$ is the continuum flux (Fig. 3). This enables us to directly compare profile shapes of line emission and absorption for profiles having different fluxes. It is not easy to decide exactly where is the continuum, particularly when the very broad wings of lines tend to blend with each other. In the later spectra studied by us, the Hϵ Ca II H blend wing extends very far to the red and the place where the flux is closest to that of the continuum level between it and Hδ, is not obvious. We have taken this to be the average flux in a 10 Å bin centered at 4035 Å, which is about half way between the unshifted line centers of the mean positions of the blend and Hδ at a radial velocity of more than 4800 km s^{-1} from each of the centers.

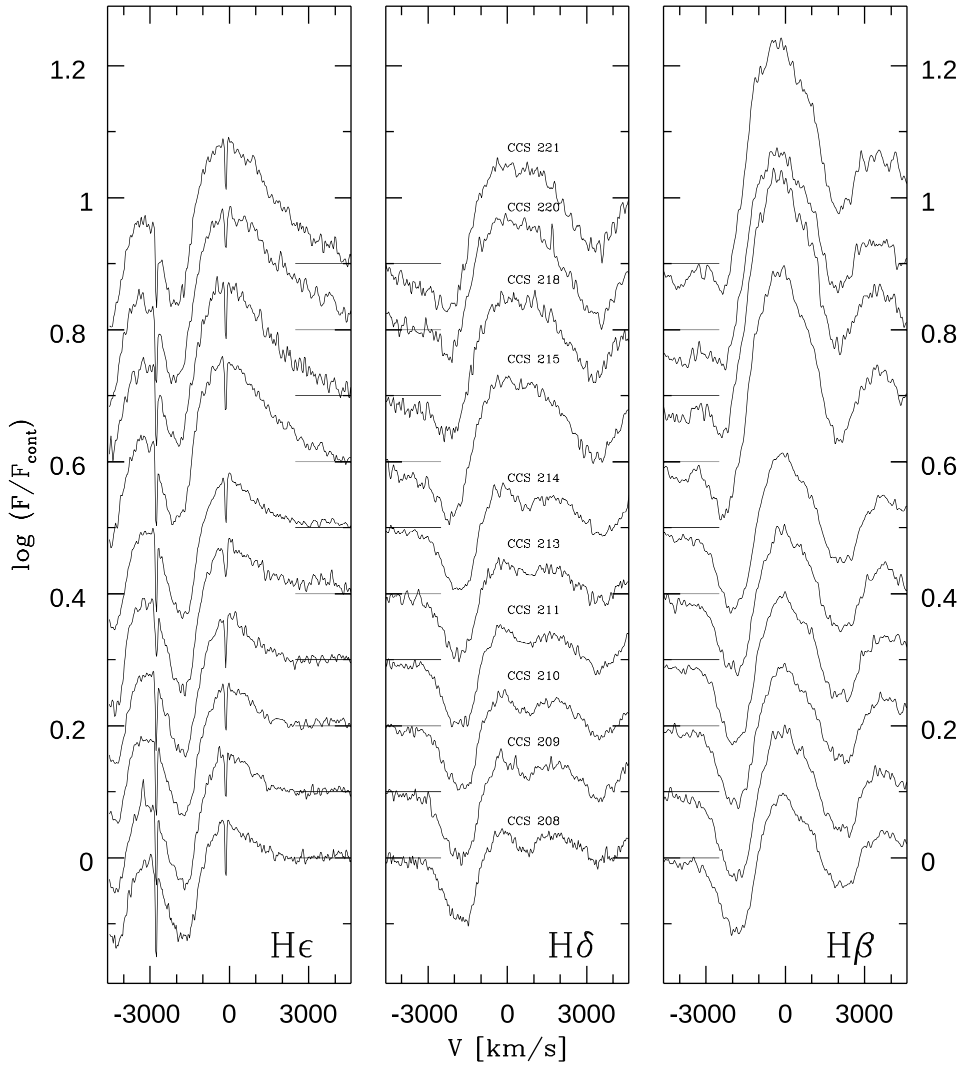

Fig. 3. H I Balmer lines profiles in V1500 Cyg. The continuum level for each profile is marked as a short line on the right side for Hϵ, and on the left side for Hδ and Hβ, respectively. The Hδ profiles are also labeled with the number of the spectrum (see Table 1 for details about each spectrum).

We have plotted logarithmic profiles of the red wing of the Hϵ Ca II H line blend of the different spectra in Fig. 3. The ordinate is a radial velocity scale relative to the unshifted wavelength of Hϵ. The red emission wing on the earlier spectra ends at about 2000 km s^{-1}; it is much wider on CCS 213 taken more than two hours after the previous spectrum, as well as on later spectra. The wing then extends generally to 4000 km s^{-1} at least. Let it be noted that when the wings are so wide, the Hϵ Ca II H line blend can be disturbed by the extreme red wing of the Ca II K line at 3933.66 Å at least for radial velocities below +1200 km s^{-1}, the exact effect depending on the geometry of the envelope. The red wing of the blend is not disturbed in this way in the earlier spectra.

The profile of the Hϵ Ca II H line blend shows a sort of flat shoulder longwards of 2000 km s^{-1} on CCS 213 and CCS 214; the slope of the red wing is always negative in the later spectra, taken on the following night. The shape of the red wing does not change very much on these later spectra. The blue high velocity absorption component at around -4000 km s^{-1}, detected by Duerbeck and Wolf, is also seen on some of our later spectra (CCS 215, CCS 218 and CCS 221). This suggests that the absorption due to the high velocity material having a similar velocity to the corresponding emission, may have become visible somewhat later than that emission.

We can also obtain information on the nature of the main absorption component, by looking at the relatively unblended blue edges of the Hβ and Hδ lines. To do this we need to know the continuum level bluewards of Hβ and Hδ. We have for Hβ taken this to be the average flux in a 10 Å bin centered at 4775 Å, that is with a radial velocity of -5300 km s^{-1}. In the case of Hδ, we shall assume this to be the average flux at 4035 Å, which is that also used in the study of the red wing of the Hϵ Ca II H line blend. The logarithmic profiles of these absorption components are shown in Fig. 3. It will be seen that the blue edges hardly move from spectrum CCS 208 to CCS 215. They are less blueshifted on those spectra taken afterwards, when the main absorption component is visible.

3. Discussion

Our spectra clearly show a widening of the emission component of the Hϵ Ca II H line blend during the time our spectra were obtained. It appears that the widening was a fairly rapid event, suggesting that previously invisible layers rapidly became visible. This event seems later to have been followed by a narrowing of the Hα emission line, observed by Boyarchuk et al. 1976) in spectra taken from September 1 onwards. Therefore this nova seems to have shown initial emission line widening followed by emission line narrowing.

The rapid widening of the emission line profile is most easily explained by the material of a high velocity wind becoming visible. In this case the slower moving material further out must have become optically thin in the continuum, allowing line radiation from deeper faster layers to escape. Then the later narrowing of Hα, can be explained by a weakening of, followed by a disappearance of the wind. Such observations agree with the type of model proposed in the introduction. It is hard to explain them in another way. This does not prove that the same situation exists for other novae, but suggests what may be the reason of the observed emission line narrowing at least for some of them.

The relative constancy of the blue edge velocities of the main absorption component of the Hβ and Hδ lines in our earlier spectra, may be explained in more than one way. One of us (Friedjung 1987) suggested that the blueshifted absorption components of lines belonging to what is called the “principal absorption system” of novae, which appears at around optical maximum, are due to line absorption by material in a thin shell, produced by the collision of the fast wind with slower moving material ejected before optical maximum, which would then be swept up. The shell will eventually be separated from the wind by hot plasma, whose pressure will tend to accelerate the shell and contribute to the usually observed increasing blueshift of the absorption components of the principal system. Indeed the hard X-ray emission sometimes observed for novae, could be due to this sort of collision between material ejected at different velocities (O’Brien et al. 1994). All the material ejected before maximum will however not be immediately swept up and some could survive for a fairly long time. If the material ejected before maximum had been instantaneously ejected by a shock wave, it could be expected to have a “Hubble flow”, with a velocity which was larger at greater distances from the center of the envelope. It is then perhaps easiest to understand the blue edge of the main absorption of this exceptionally fast nova, as produced by the material ejected before optical maximum with the highest velocity and which has travelled the largest distance. The apparent decrease of this velocity for our later spectra, could be due to the highest velocity material becoming optically thin at later times. This type of explanation would not work if the material were in a thin shell, which would moreover, as already stated, tend to be accelerated.

4. Conclusions

The examination of the present spectra show that V1500 Cyg had a behaviour, similar to that expected for most classical novae. A very high velocity wind appears to have been present for a short time in the deepest layers. The main absorption is most easily explained as produced by material ejected before the optical maximum. However only detailed studies of other classical novae can show to what extent the behaviour found here particularly concerning the emission line width, generally occurs.

Acknowledgements. This research was partially supported by the KBN grant No. 2P03D 021 12 and by the JUMELAGE program “Astronomie France-Pologne” of CNRS/PAN.

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