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HeIIλ4686 OBSERVATIONS OF T CORONAE BOREALIS

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We present spectroscopic observations of the HeIIλ4686 line of the recurrent nova T CrB. We have secured 22 spectra on 16 nights between April 1997 and January 2002 with the Coudé spectrograph of the 2.0 m RCC telescope of the Bulgarian National Astronomical Observatory "Rozhen". The spectra cover $\sim 100\,\text{Å}$ (before 971010) and $\sim 200\,\text{Å}$ (after 990105) around λ4686, with resolution of $\sim 0.2\,\text{Å}\,\text{pixel}^{-1}$. The S/N ratio achieved is 15-35. Two examples of our spectra are shown in Fig. 1. Journal of the observations is given in Table 1. The equivalent width (W) of the line is measured relative to the local continuum at $\lambda4677 - \lambda4690$ Å. The flux is calculated using B and V photometry. Typical errors in W and flux measurements are ±15-20% and ±20-30%, respectively. The radial velocity is measured at the top of the line and has an uncertainty of about ± 15 km s^{-1}.

T CrB consists of a red giant and a hot component (almost certainly a white dwarf). Iijima (1990) and Anupama & Mikolajewska (1999) reported the presence/absence of the HeII4686 line during the period 1987 – 1997. Combining their data with our new observations gives us the opportunity to discuss the appearance of the HeII emission during a period when the U brightness varies by more than 2 magnitudes (see Fig. 2). The times of HeIIλ4686 observations and detections are plotted on Fig. 2, together with the U band variability. We used our data, together with those of Iijima (1990) and Anupama & Mikolajewska (1999), as well as the long term light curve (Stanishev et al. 2003, and the references therein). As is apparent in Fig. 2, the appearance of HeIIλ4686 emission correlates with the U brightness of the object. Most of the detections clearly correspond to the short brightening in U of about ΔU$\sim$ 0.6 at JD2448050 and to the maximum at JD2450700. Variability in U reflects the changes is the mass accretion rate, provided that the spectral energy distribution does not change considerably, as is supposed from spectral fitting in high and low states (Stanishev et al. 2003).

The presence of a strong HeII line was reported in the period 1921 – 1946 (see Adams & Joy 1921, Minkowski 1943, Swings & Struve, 1943, among others). Bearing in mind that during the last decade the line was not strong and has been detected on a few occasions only, the older observations probably indicate a higher mass accretion rate during the 25 years preceding the 1946 outburst of Nova CrB (i.e. higher than the current value of about $2 \times 10^{-8}\, M_{\odot}\, yr^{-1}$ estimated by Selvelli et al. 1992).

In an attempt to detect the profile of the HeIIλ4686 line, we subtracted a template from the first 5 observations, when the line had W > 1Å, and seemed blue shifted. In practise, we used as templates epochs 000621, 010707, and 020123, where the HeII line was not detected. The upper limit ($W < 0.5$Å) was defined by comparing with (1) spectra of M giants from the library of stellar spectra of Le Borgne et al. (2003), (2) spectra of M4III stars (HD 4408 and HD 5316) observed with the same instrumental setup as T CrB.

The template was then shifted to match the observed red giant spectrum. The shifts have been calculated (i) via Fourier cross correlation, and (ii) using the orbital elements (from Stanishev et al. 2003). The shifted template has been subtracted from the 5 spectra from 970426 to 971010. Following this, the residual spectra have been shifted to the hot component velocity and averaged. The average profile of HeIIλ4686 obtained from these 5 template–subtracted spectra is plotted in Fig. 1b. The profile of Hα as observed in April 1997 (from Stanishev et al. 2003) is also plotted for comparison. The HeII profile is noisier than that of Hα because (i) the HeII line is weaker than Hα and (ii) the S/N of HeII spectra is lower than those in Hα.

As can be seen, the HeIIλ4686 profile is different from that of Hα. The HeII line is narrower (at half maximum), it does not exhibit double peak at the top, and it also seems to have an asymmetric profile with blue wing (Fig. 1b). We measured radial velocity in the higher flux regions of the line where it is practically symmetric. Part of the observational data (all cases when W > 1 Å) show that this velocity is negative relative to the orbital velocity of the hot component (the hot component orbital velocity is supposed to follow $V_h = -36.7 + 19.5\cos[2\pi(\phi - 0.563)]$ km s^{-1}, see Stanishev et al. 2003). Unfortunately, we cannot be sure whether we observe a blue wing and broad component close to the continuum level (like those detected in HeIIλ 1640 by Selvelli et al. 1992) because it is comparable with the noise and depends on the subtraction of the red giant flux. However, the blue shift at the peak and at half maximum seems to be detected. On the other two exposures (obtained on 990105) the line is weaker and its radial velocity coincides with the radial velocity of the hot component.

HeII lines are supposed to be formed in the immediate vicinity of the hot component. The blue shift of HeII4686 indicates a motion from the hot component toward the observer. The most plausible explanation is that it arises in an outflow from an accretion disk (most probably a disk wind at the high state of the system). A receding part of this outflow can also exist, but it has to be obscured by the disk itself.

In T CrB the main the accretion is the Roche lobe overflow from the giant. In addition to the flow via L_1, accretion from a stellar wind can supply about 15% of the total mass accretion rate (Selvelli et al. 1992). However, in nova–like cataclysmic variables at accretion rates $\sim 1 \times 10^{-8}\, M_\odot\, yr^{-1}$ (like that of T CrB) the accretion disk is expected to lose about 0.001 - 0.15 of the accreting material via an accretion disk wind (i.e. Vitello & Shlosman 1993; Long & Knigge 2002). It is worth noting that accretion disk winds in cataclysmic variables are best visible as absorption lines and P Cyg profiles in the UV (for example Prinja et al. 2003). The available UV spectra of T CrB are however too noisy for clear detection of the UV line profiles (see Selvelli et al. 1992 and IUE archive), but the profile of HeII4686 suggests the presence of an outflow (at least in high state).

We conclude, that the appearance of the HeII emission in T CrB is connected with U band variability, and probably therefore with epochs of higher mass accretion rate. Whether we have accretion disk wind or accretion from a stellar wind (in addition to Roche lobe overflow) could be answered by careful investigation with better optical and UV spectra. This could also help us to understand when and how accretion from stellar winds, in wind-fed symbiotics, can exist together with outflows from the accreting component.

Table 1: HeIIλ4866 line observations of T CrB. The date is in the format YYMMDD. The orbital phase (ϕ) is calculated using the ephemeris $T_0=2447918.62+227\overset{d}{.}5687E$ (Fekel et al. 2000). The equivalent width (W), flux of the line and radial velocity are given. The flux is in units of 10^{-13} erg cm^{-2} s^{-1}. The non–detections (nd) of the line correspond to upper limits of about W <0.5 Å (equivalent to $< 0.6\times10^{-13}$ erg cm^{-2} s^{-1}). The calculated radial velocity of the hot component,V_h, is also given (see the text).

Date	HJD	ϕ	W [Å]	Flux	V_r km s^{-1}	V_h km s^{-1}	Date	HJD	
970426	50565.529	0.631	2.0	4.22	−67	−19.0	000516	51681.353	nd
970426	50565.543	0.631	2.7	5.70	−99	−19.0	000516	51681.368	nd
970427	50566.391	0.635	2.1	4.43	−75	−19.2	000621	51717.396	nd
971010	50732.219	0.364	1.4	3.31	−70	−30.6	000818	51775.320	nd
971010	50732.234	0.364	1.6	3.78	−75	−30.6	000917	51805.288	nd
990105	51184.632	0.352	0.9	1.78	−26	−32.0	010316	51985.438	nd
990105	51184.646	0.352	1.0	1.98	−22	−32.0	010407	52007.387	nd
990309	51247.438	0.628	nd	–	–		010502	52032.350	nd
990309	51247.452	0.628	nd	–	–		010707	52098.312	nd
990919	51441.325	0.480	nd	–	–		010904	52157.341	nd
990919	51441.343	0.480	nd	–	–		020123	52297.684	nd

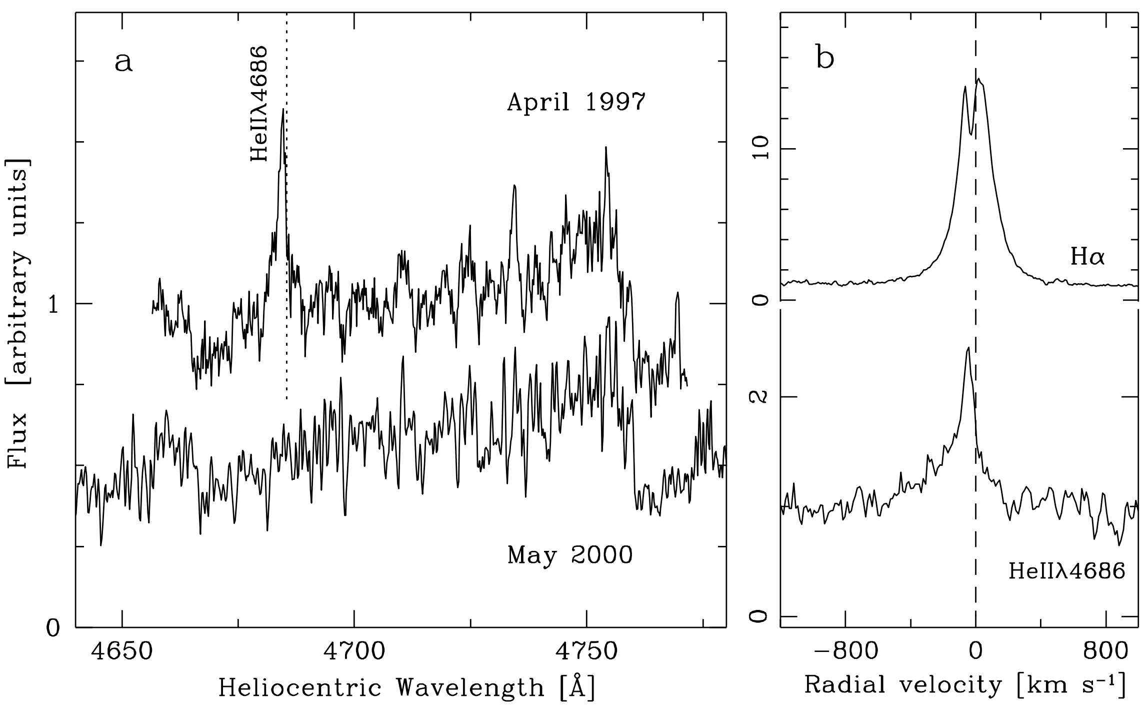

Figure 1. a) The region around the HeII line. The dotted line corresponds to the calculated radial velocity of the white dwarf (V_r=−19 km s^{-1}) **b)** Cleaned profiles of HeIIλ4686 and Hα. Both are normalised to the remaining hot component continuum, after the subtraction of the red giant spectrum. The zero of the X-axis corresponds to the calculated radial velocity of the hot component.

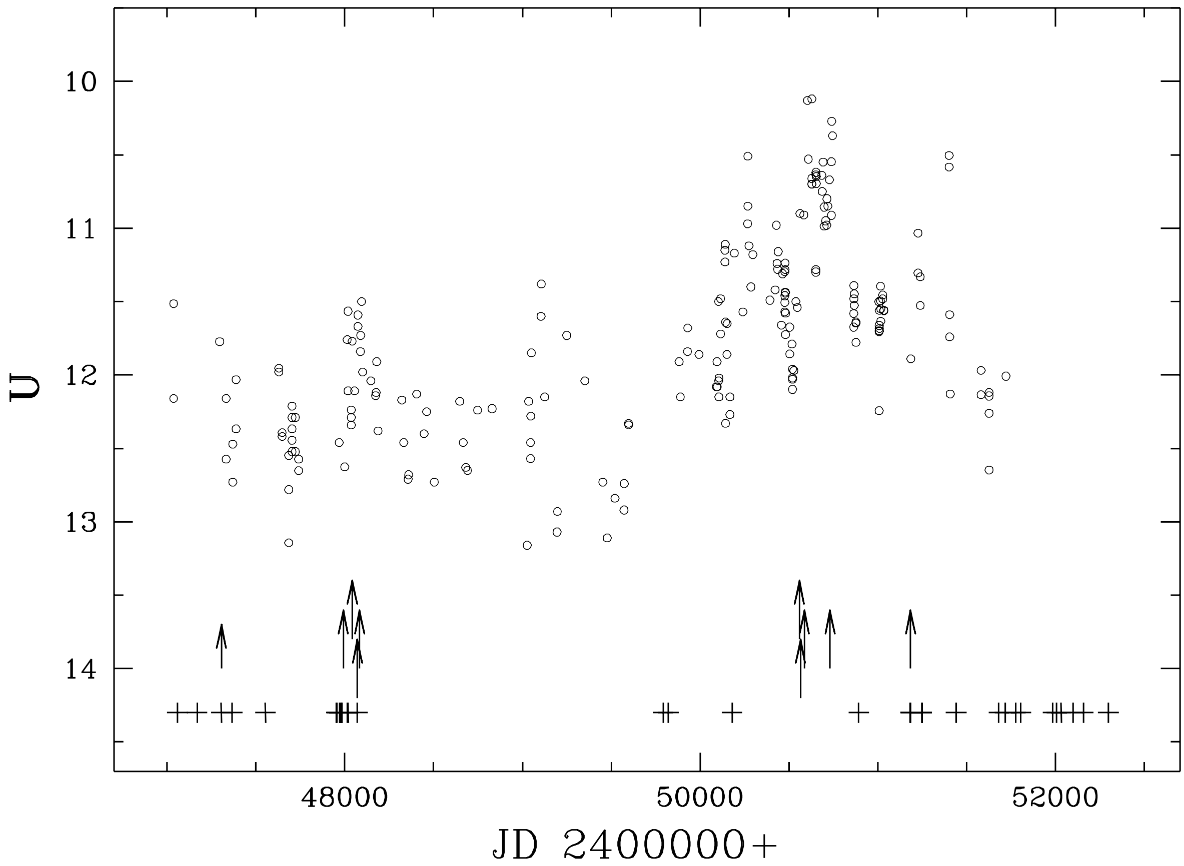

Figure 2. Johnson U band light curve of T CrB and observations of the HeIIλ4686 line. The arrows and crosses indicate the times of HeIIλ4686 observations. The arrows refer to detections, and crosses to non–detections of the HeIIλ4686 emission line.

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