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A SPECTRUM OF R CrB DURING RECOVERY FROM 2000 MINIMUM

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The eponym of the R Coronae Borealis stars was observed by V. Klochkova, V. Panchuk and M. Yushkin with the prime focus echelle spectrometer of a 6-m telescope (Panchuk et al. 1998) on 7 January, 2001 during a program not directly devoted to R CrB stars. At the moment of these observations the star happened to be in the recovery state after a quite deep ($V \sim 13$ in minimum) brightness decline which started 53 days earlier according to AFOEV (2001) data.

The spectra were obtained with a spectropolarimetric device attached before the slit and each set of exposures consists of two exposures with different position of the analyser of linear polarization. In this note, however, the polarization measurements are not addressed. The spectra cover the wavelength region $\lambda\lambda$ 5000–6600 with the resolution $R \approx 12000$. The reduction of the spectra was performed using the image reduction system IRAF[†].

The 2000 decline started only about 260 days after the recovery from the previous very deep decline and therefore it is not clear whether some residual effects of that decline were present. Before the 1995–1996 decline which was thoroughly discussed by Kameswara Rao et al. (1999) the star stayed at its maximum brightness for much longer time.

Our spectra reveal most of the spectroscopic components found in earlier accounts:

1. Sharp emission lines. The low excitation lines of Sc II, Ti II, Fe II, Fe I, Mg I, Y II and Ba II were observed in emission. These are the lines belonging to the type E2 according to Alexander et al. (1972). The radial velocity measured from those lines is 16.8 ± 2.5 km s^{-1}.

The mean systemic velocities published for different observations differ more than the stated errors. We adopt the mean value of 22.5 km s^{-1} (Kameswara Rao et al. 1999). In that case the sharp emission lines show a blueshift around 6 km s^{-1} which is very close to the value of 4 km s^{-1} reported by Kameswara Rao et al. (1999) and this supports their suggestion that the sharp emission lines are the permanent features.

The onset of the decline on JD 2451863 started at maximum light of the pulsational variations, or more precisely, the brightness smoothly followed the cosine curve from its maximum to decline. Photometrically, the last cycle before the onset of decline is better distinguishable than the previous ones.

Here raises a question how the systemic velocity compares with the photospheric velocity. If the photospheric radial velocity at the onset of decline had its maximum value

[†]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

as for the 1995–1996 decline and the radial velocity has the period of about 43 days with the range of 6 $\mathrm{km\,s^{-1}}$ (Kameswara Rao et al. 1999) we could expect that at the moment of our observations ($\phi = 1.23$) the photospheric radial velocity should have been at its mean value. This assumption is, however, not fully justified. The fadings of R CrB and its radial velocity variations are not found to be locked to photometric phases (Fernie 2000).

Many authors have found that the pulsational period in the photometric variation of R CrB is itself variable (e.g. Lawson & Kilkenny 1996). Now, more data on R CrB photometry is available. We analysed for periodicities the photometry from the full time interval covered by AAVSO Monographs (1963–1995) (Mattei et al. 1991 & 1996) and AFOEV Database (1995–2000), excluding obvious light declines. As a tool a set of codes ISDA for irregularly spaced data analysis developed by Pelt(1992) was used. The mean period of 45.5 days was found for 1993–2000. The shorter intervals limited by the fadings gave very much different periods spanning from 35.3 to 51.4 days confirming the earlier results by other authors. The time dependence of those periods was also studied. There is a slight indication that these periods themselves vary cyclically with a timescale around 3.3 years or its multiples.

All sharp emission lines show an inverse P Cygni profile. In Fig. 1. some of these lines are shown. The mean differential velocity between the emission core and the redshifted absorption minimum is $\Delta v_{\mathrm{r}} = 42.0 \pm 2.5\ \mathrm{km\,s^{-1}}$.

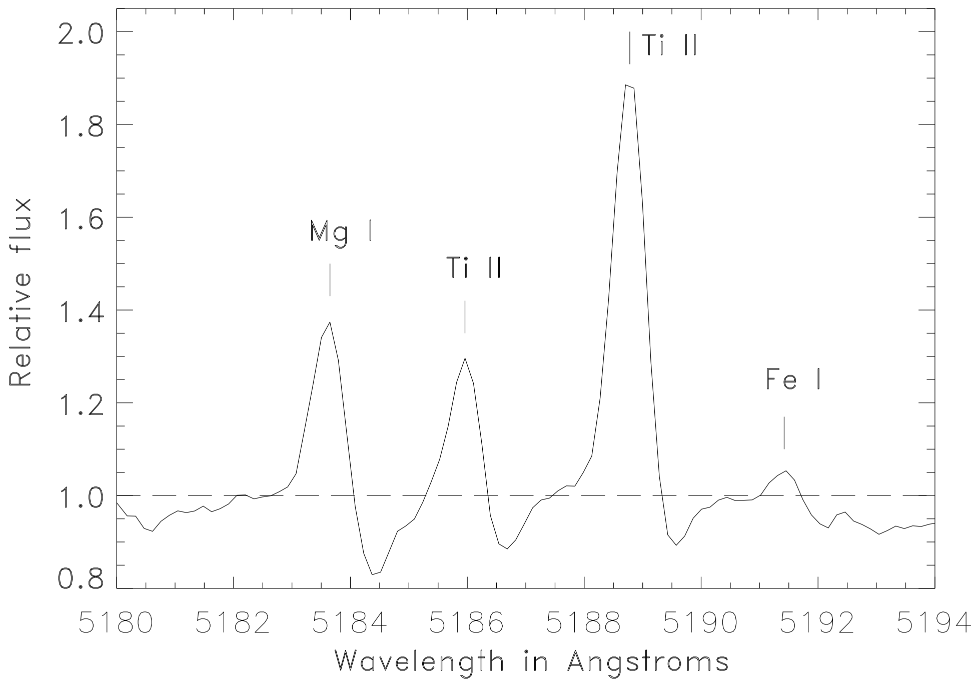

Figure 1. The group of sharp emission lines at λ 5190. Note the large (42 $\mathrm{km\,s^{-1}}$) redshift of the absorption components

2. Photospheric absorption lines. Along with the emission lines the star showed a rich absorption spectrum. The strongest lines belonged to C I. Other lines included Fe I, Fe II, Cr I, O I, Mg I, Na I, and Si II. The mean radial velocity found from these lines is 38.4 ± 3.2 km s^{-1} without any noticeable dependence from the line strength and excitation potential. Compared with the mean systemic velocity this corresponds to the redshift of around 16 km s^{-1}. The explanation of this redshift was proposed by Kameswara Rao et al. (1999) as the effect of multiple scattering of the photospheric photons by the circumstellar dust moving out from the star. The effect was in details studied by Van Blerkom & Van Blerkom (1978) and shown to depend both on the optical and geometrical parameters of that cloud. Therefore from this single datum the expansion velocity of the cloud could not be determined.

Returning to the redshifted absorption components of the sharp emission lines one could expect that those are the absorption lines corresponding to the emission lines and are also redshifted due to the scattering. Vanture & Wallerstein (1995) explained the similar pseudo-P Cygni profiles in the spectrum of RY Sgr on the recovery phase as the superposition of blueshifted emission lines and photospheric lines at the systemic velocity. However, in our case the redshift of these absorption components compared to the photospheric velocity is much larger (around 36 km s^{-1}) than the other absorption lines (16 km s^{-1}). Therefore the scattering in the same clouds could not explain these results.

3. Molecular emission. The emission in C_2 (0,0) λ 5165, (0,1) λ 5635 and (0,2) λ 6191 bands was visible but too weak for radial velocity measurements.

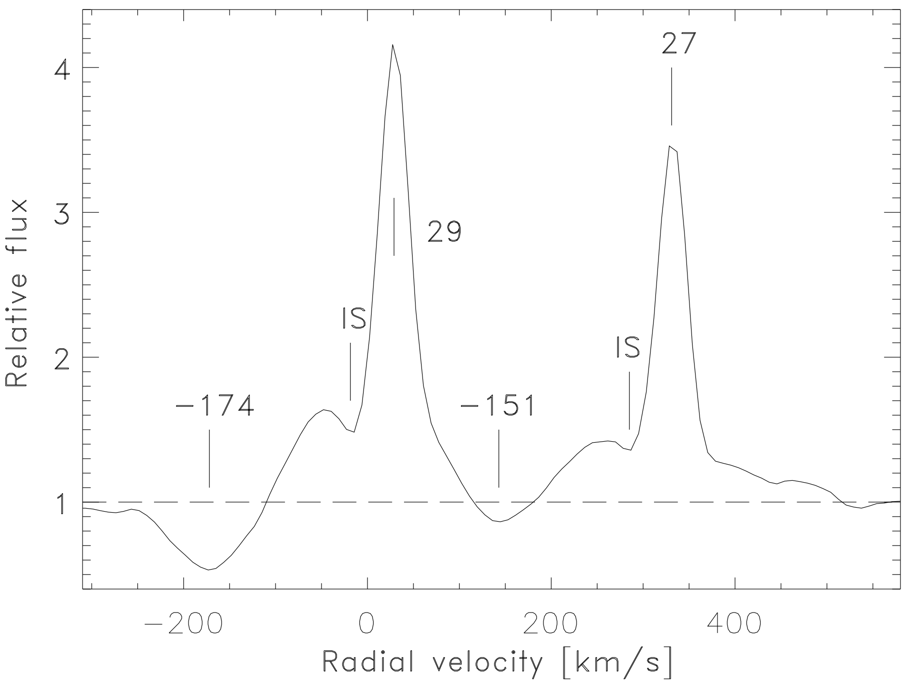

Figure 2. Na I doublet in the spectrum of R CrB in velocity scale. The sharp and broad emission components and interstellar and high speed absorptions are visible and their radial velocities indicated

4. Broad emission lines. From the category of broad emission lines only the broad components of Na I doublet were observed. Fig. 2. shows the Na I doublet. The full width at its base of D_1 is almost 400 km s^{-1}. The width of D_2 is about a half of that due to blending with the absorption in D_1. The radial velocity of the blueshifted absorption component of D_2 is -174 km s^{-1} measured at the deepest point of the profile. The full width at the continuum level is 133 km s^{-1}. The He I λ 5876 line, which showed broad emission during the 1995–1996 decline (Kameswara Rao et al. 1999), was present in absorption.

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