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Presence of Mg II emission in R Coronae Borealis at maximum light

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Summary. The high dispersion spectrum of R CrB in the long wavelength obtained near its maximum with the *International Ultraviolet Explorer* shows the presence of chromospheric Mg II emission. For comparison the spectrum of γ Cyg was obtained immediately afterwards. The Mg II emission width of R CrB is found to be the same as that of γ Cyg.

1 Introduction

R Coronae Borealis is the prototype of a group of low-mass hydrogen-poor carbon-rich irregular variables. These stars experience, at sporadic intervals, decreases in light anywhere between 2 to 8 mag, which is attributed to extinction by carbon particles formed around the star. The spectrum of R CrB at maximum light is classified as F8Ib. Except for the obvious peculiarities of weak or absent hydrogen lines, and enhanced strength of C I lines and C_2 bands, the spectrum of R CrB is a good match to γ Cyg, a normal F8Ib star (Berman 1935; Gaposchkin 1963).

Supergiants of spectral type G0 or later show the presence of substantial chromospheres inferred from the presence of emission cores for both Ca II *H* and *K* (Wilson & Bappu 1957; Wilson 1976) and Mg II *h* and *k* lines. The supergiants of F8 to G0 occupy the transition region for stars with and without substantial chromospheres (Böhm-Vitense & Dettmann 1980; Parsons 1980). The surface convection zones due to H, He ionization are considered as a necessary condition for the formation of stellar chromospheres (Böhm-Vitense & Nelson 1976). In this context it is of particular interest to see whether hydrogen-poor carbon-rich stars also show the presence of chromospheres and whether differences in chemical composition change the characteristics of the chromosphere. Moreover, from the study of the sharp emission line spectrum of R CrB at minimum light it was suggested that R CrB has a chromosphere even at maximum light (Gaposchkin 1963; Rao 1974, 1975). The indication that this phenomenon is common to other R CrB stars comes from the study at minimum light of low dispersion spectra of RY Sgr (Alexander *et al.* 1972), SU Tau (Herbig 1958) and others. The weak stellar continua in the ultraviolet would facilitate detection and study of emission features of chromospheric origin. Emission in the cores of the Mg II resonance doublet ($\lambda\lambda$ 2795.5, 2802.7) is an excellent indicator of the presence of a chromo-

sphere. Böhm-Vitense & Dettmann (1980) also find a strong correlation between the presence of Mg II emission and the presence of ultraviolet emission lines in the 1150–2000 Å region. With this in view, we obtained high dispersion spectra of R CrB near its maximum with the *International Ultraviolet Explorer* (*IUE*) (Boggess *et al.* 1978) and the results are presented here.

2 Observations

High resolution (0.2 Å) *IUE* spectra of R CrB in the long wavelength range were obtained with the large aperture on 1980 October 5, 7. The spectrum of γ Cygni was also obtained for comparison immediately after. The details are given in Table 1. The counts from the fine error sensor (FES) on *IUE* have been converted to visual magnitude from the relation given by Holm & Crabb (1979). This magnitude is supposed to be accurate to ± 0.1 mag. At the time of these observations FES mag shows that R CrB might be ~ 0.3 mag fainter compared to the max light value of $V \simeq 5.8$. Small fluctuations of this order are common for R CrB even at maximum light. The reduced spectra were provided by the *IUE* Observatory, VILSPA. Fig. 1 shows the line profiles of Mg II lines for R CrB (image no. 8964) and γ Cyg (image no. 8965).

Table 1.

Name	Image no.	D/AP	Exposure time (min)	Wave-length	JD 244000+	m (FES)
R CrB	LWR 8958	H LG	79	LWR	518.359	
	LWR 8964	H LG	232	LWR	520.278	6.19
γ Cyg	LWR 8965	H LG	10	LWR	520.384	2.23

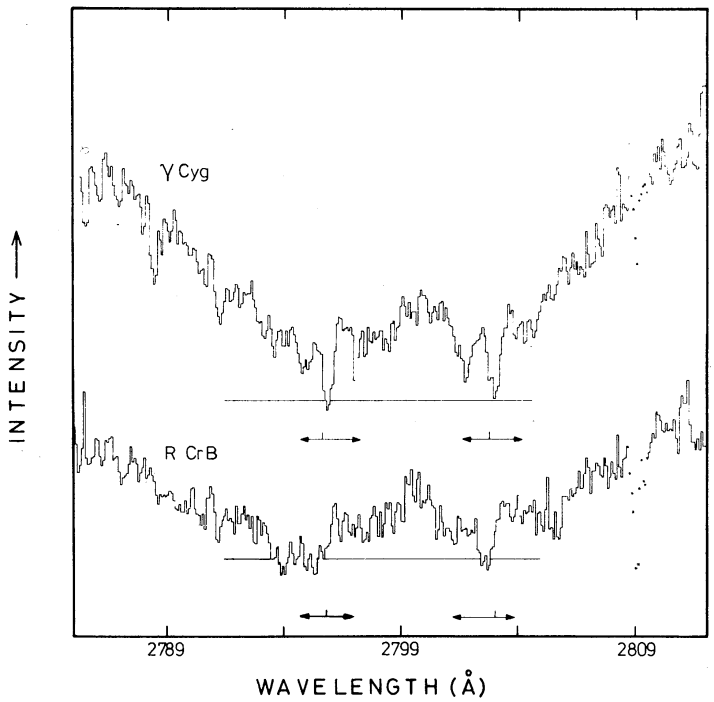

Figure 1. Intensities from *IUE* high dispersion exposures of the F8Ib supergiant γ Cyg (top) and R CrB in the vicinity of Mg II doublet ($\lambda\lambda$ 2796, 2803). The horizontal lines indicate the zero levels. On both curves, the intensities between 2797–2804 Å are the mean of scans from two orders. Portions marked with crosses are due to reseau marks. The arrows indicate the estimated h_1, k_1 widths for both stars. The vertical lines mark the locations of the line centre for a radial velocity of $-8.0\,\mathrm{km\,s^{-1}}$ for γ Cyg and $+24.0\,\mathrm{km\,s^{-1}}$ for R CrB.

3 Results

The observations of both γ Cyg and R CrB show that in the centre of the strong absorption lines of the Mg II doublet, the emission cores (k_2, h_2) are present with self reversed absorption feature (k_3, h_3). The violet components of emission are lower in intensity than the red (i.e. $k_{2V} < k_{2R}$: $h_{2V} < h_{2R}$). Similar self reversals have been observed in other normal F–G supergiants (Kondo, Morgan & Modisette 1976; Weiler & Oergerle 1979). The profile of γ Cygni is similar to that seen by Parsons (1980). However, Böhm-Vitense & Dettmann (1980) apparently have not detected the central emission in Mg II for γ Cyg. Probably the Mg II emission is variable in γ Cyg. In Fig. 1, the vertical line indicates the expected line centre after applying solar correction (satellite's motion is neglected). The mean h_3 and k_3 velocity in R CrB is $-28\,\mathrm{km\,s^{-1}}$ with respect to the velocity of normal absorption lines at maximum. A weak displaced absorption component can also be located in h_3 with a velocity of $-55\,\mathrm{km\,s^{-1}}$. This is presumably the ionized magnesium counterpart of that observed at maximum by Keenan & Greenstein (1963) for sodium with a velocity of $-45\,\mathrm{km\,s^{-1}}$. Rao (1974) has observed this feature even on spectrograms obtained at the minimum. This feature has been attributed to the interstellar medium. The Ca II emission profiles obtained at ~ 3 mag or more below max light also show similar velocities for K_3, H_3 components. This blueshift of the k_3, h_3 components might indicate a continuous mass loss at maximum light. The k_3, h_3 of the Mg II lines in γ Cyg show a redshift of about $23\,\mathrm{km\,s^{-1}}$.

We have measured the full Mg II emission widths at the base of the h_2 emission for both stars, following Kondo *et al.* (1976) and Weiler & Oegerle (1979). These are $+2.5 \pm 0.1$ Å for h_2, k_2 of γ Cyg and $+2.6 \pm 0.1$ Å for h_2 of R CrB.

A measurement of k_2 width of R CrB gives a value of 2.7 Å but this value is uncertain because the k_2 violet component is almost lost in the background noise. One can notice, however, that on the tracings the violet and red components are also retained by the k_2 line.

4 Discussion

It is known that the Mg II emission width is correlated with the absolute magnitude for normal late-type stars and that γ Cygni also follows this relation (Weiler & Oegerle 1979). The fact that the emission width of R CrB is the same as that of γ Cyg shows that if R CrB also follows this relationship, it should have the same absolute visual magnitude as γ Cyg. The normal M_V for F8Ib supergiants is -4.6. There are numerous estimates of M_V for R CrB stars in the literature. Eggen (1969) derives for R CrB a value of -3.1, assuming the star to be a member of the Wolf 630 group. Andrews *et al.* (1967) obtain M_V of -4 for RY Sgr from measures of the luminosity of a possible companion. Feast (1972) has observed three of these stars in the LMC and obtained values of M_V ranging from -4.0 and -5.1 for W Men.

The Ca II H and K profiles obtained at minimum light also support this estimate of M_V for R CrB. The emission line profiles of H and K lines derived from the $16\,\mathrm{Å\,mm^{-1}}$ Lick coudé spectrograms (Rao 1980), obtained during the 1962–63, minimum by Herbig when the star was faint by about 2.5 mag show profiles almost similar to Mg II. The average full width obtained after correcting for the instrumental broadening is $\log W_t = 2.42$. From this, an M_V of -4.2 is obtained for R CrB using the Wilson–Bappu relation as obtained by Richer (1975). We thus note that both the ionized calcium and magnesium lines of R CrB follow the standard Wilson–Bappu relation for normal stars. Similar absolute magnitudes of -4 were derived by Richer for the hydrogen poor carbon stars HD 182040 and 137613.

5 Conclusions

The presence of Mg II emission in R CrB at maximum light confirms our earlier expectation that a chromosphere is a normal permanent characteristic of R CrB type stars. Even though the chemical composition of R CrB is different from that of the normal supergiant γ Cyg the shape and width of the Mg II emission shows that their chromospheric properties may be similar.

Our estimate of $M_V = -4.6$ from the similarity of the chromospheric emission widths of γ Cyg and R CrB confirms the high luminosity of these objects.

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