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Research Note

uvby photometry of θ Coronae Borealis during 1994 and 1995⋆

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Abstract. We present differential *uvby* photometry of θ CrB obtained in 1994 and 1995, complemented by Balmer line spectroscopy. This star has been constant during this period, showing no short term periodic variability with an amplitude greater than 0.005 mag., nor long term variations greater than 0.01 mag. The lack of variability is associated with an inactive phase of the Be star, in which no emision features are present in the spectra.

The only remarkable event observed was a fading episode on JD 2449779, with an amplitude of about 0.02 magnitudes in all bandpasses and duration of 0.2 – 0.3 days.

Key words: stars: emission-line, Be – stars: individual: θ CrB

1. Introduction

θ Coronae Borealis (HR 5778, HD 138749) is a well known but, relatively little studied bright Be star. Its photometric behavior is complex, alternating variability at different time scales with periods of constant brightness. Roark (1971) detected rapid variations with a periodicity of about one day and a large decrease of brightness of 0.7 mag. in the u and v bands. Significant photometric variations on a time scale of days were also reported by Papoušek (1985) and by Percy et al. (1988) for 1986 and 1987. Guerrero et al. (1992) observed rapid light variations with a full amplitude of about 0.03 mag. during the period April 29 to May 8, 1989. They interpreted their light curve as a combination of a slow variation with a possible period of about 8 days and rapid variations with a period of either 0.869 or 0.459 days. The latter period was also found by Hubert et al. (1991) for the variability of the He I (λ 4471) and Mg II (λ 4481) line profiles, from spectra obtained during April 21-23, 1989. Finally, in the long term photometric survey conducted at the Hvar Observatory between 1972 and 1990, θ CrB is a low-amplitude variable, just above the detection limit (Pavlovski et al. 1997).

On the other hand, Fernandes et al. (1985) found θ CrB constant within a few hundreds of magnitude during May to July 1984. Further, Percy et al. (1988) and Percy & Attard (1992) did not detect any significant photometric variations in 1981, 1985, 1990 and 1991.

2. Observations

2.1. Photometry

Differential observations were made in the four filters of the *uvby* system. HR 5718 (50 Boo) and HR 5676 (χ Boo) were used as the comparison and check stars respectively. Observations were made during the periods February-March 1994 and March-July 1995 with the 0.75-m Four College Automated Photoelectric Telescope (FCAPT), then on Mt. Hopkins (AZ). The observing sequence starts with a measure of the dark count, and then in each filter the sky-ch-c-v-c-v-c-v-c-ch-sky, where sky is a reading of the sky background, ch that of the check star, c that of the comparison star and v that of the variable star. A total of 38 and 151 measurement were obtained, respectively, in each period. An additional 45 measures were obtained in the period 24-28 January 1994, with the 0.4-m telescope of the Círculo Astronómico del Mediterráneo (CAM) Observatory, located at Crevillente (Alicante, Spain), and equipped with the OPTEC SSP-5 photoelectric photometer. Readings were obtained sequentially through the four filters, following a sequence of the form c-v-sky-ch-v-sky-c-v-sky-ch... The mean differential values for the three observing periods, together with their standard deviations, are presented in Table 1. The complete set of individual measurements are given in Table 2.

The mean values of the two FCAPT series are the same within the errors. Thus no long term variability with an amplitude greater than 0.01 mag. occurred during 1994-1995. No direct comparison with the CAM data is presented as the differ-

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⋆ Table 2 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Table 1. Differential mean values with their dispersion for the three observing runs

band	v–c	v–ch	c–ch	σ_{v-c}	σ_{v-ch}	σ_{c-ch}
			CAM 1994			
u	–1.721	–2.045	–0.324	0.017	0.019	0.020
v	–1.298	–1.343	–0.045	0.014	0.015	0.015
b	–1.243	–1.189	0.054	0.014	0.015	0.013
y	–1.225	–1.119	0.106	0.013	0.014	0.015
			FCAPT 1994			
u	–1.743	–2.090	–0.347	0.009	0.009	0.006
v	–1.309	–1.354	–0.045	0.003	0.004	0.003
b	–1.260	–1.210	0.050	0.004	0.004	0.003
y	–1.242	–1.140	0.102	0.003	0.004	0.003
			FCAPT 1995			
u	–1.738	–2.085	–0.347	0.009	0.011	0.007
v	–1.306	–1.350	–0.044	0.006	0.007	0.004
b	–1.259	–1.208	0.051	0.006	0.007	0.004
y	–1.240	–1.139	0.101	0.006	0.007	0.005

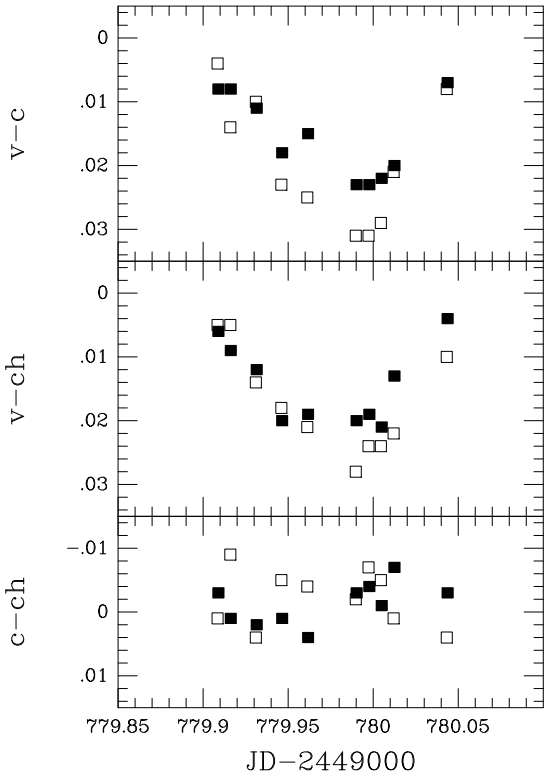

Fig. 1. Differential light curves of JD 2449779. Filled squares represent the y band values, and open squares the u band. Mean differential values have been substracted to put both bands on the same scale.

ential photometry is given in the instrumental system of each telescope.

To search for short term periodic variability we performed periodogram analyses separately for the data in each of the four *uvby* bandpasses, and for each observing run. Two periodogram techniques were used: a sine wave fitting and a phase dispersion minimization algorithm (PDM, Stellinwerf 1978). No significant peaks were apparent. Periodograms applied to the v–c and v–ch data presented the same aspect as the c–ch data. As a further check, for each set of data we drew composite light curves folded with the periods found by Guerrero et al. (1992). No apparent modulation is present in any of them. From the results of our analysis, periodic variability with an amplitude greater than 0.005 mag. can be excluded.

From the analyses of the light curves it was apparent that the photometric values for the day JD 2449779 were significantly fainter than average. A fading of about 0.02 magnitudes and a subsequent brightening is present in all four filters. In Fig. 1 we present the v–c and v–ch light curves for the y and u bands, together with the c–ch values for comparison. The mean differential values for the period have been subtracted to put the y and u values on the same scale. As the behavior in the b and v bands is similar, we have not shown them for simplicity. The total duration of the observation is about 0.15 days. Both at the beginning and the end of the light curve the observed values are below, although close, to the mean values for the period (value zero on the vertical axis). Hence we estimate the total duration of the fading event to be about 0.2 – 0.3 days. No other significant features are present in the light curves during the three observing periods.

2.2. Spectroscopy

Spectra of θ CrB were obtained during 1994 and 1995, in coincidence with the photometric observations with the 1.0-m Jacobus Kapteyn Telescope (JKT), located at the Observatorio del Roque de los Muchachos (La Palma, Spain), and equipped with the St Andrew's Richardson-Brealey Spectrograph (RBS) attached to its Cassegrain focus. Observations were made during four periods: 26 March 1994, 24-27 June 1994, 11-12 February 1995 and 5-7 August 1995. Different configurations were used, giving spectral resolutions between 1 and 2 Å. A total of 10 spectra were obtained, 4 centered on the Hα line, 5 in the blue region (4000-5000 Å) including the Hβ and Hγ lines, and one in the infrared region (8300-9100 Å) including the higher Paschen series lines.

In these spectra no signs of activity are apparent. All the observed Balmer and Paschen series lines appear in pure absorption, without any evident emission feature. Two representative Hα spectra are shown in Fig. 2.

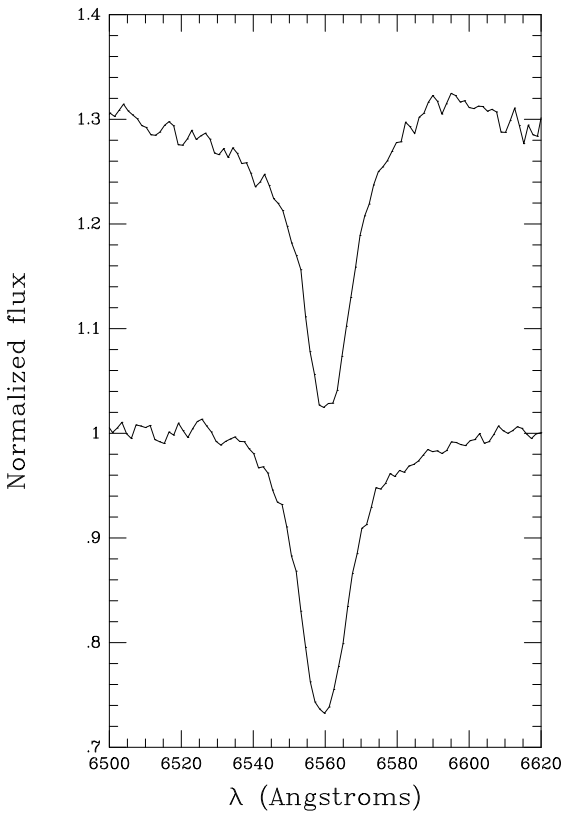

Fig. 2. Hα spectra obtained on 26 June 1994 (top) and 11 February 1995 (bottom). Continua have been normalized to unity, and a value of 0.3 has been added to the top spectrum for display.

3. Discussion

The spectroscopic activity and the short term variability in peridic variable Be stars appear correlated. Balona et al. (1992) studied photometrically λ Eri for several years, and found the maximum amplitude of the periodic light variation in coincidence with the increased spectroscopic activity reported by Smith (1989). Cuypers et al. (1989) observed μ Cen in an unusual high state of photometric activity three months after an Hα outburst reported by Ghosh at al. (1987). Conversely, our data (see Sect. 2) show a coincidence between a phase of constant brightness and the lack of any Be activity, as indicated by the absence of emission in the lines. The general picture that emerges from these facts is that the photometric variability is related to the active status of the Be star, dissapearing during the pure absorption-line phases.

Rapid aperiodic variability, both spectroscopic and photometric, has been reported for several Be stars. Peters (1986) observed the development of an Hα emission line in μ Centauri in only two days. Gorrod et al. (1993) detected a significant diminution in the Hα line strength of X Persei over a period of thirty minutes. Sudden photometric brightenings on 1-2 days timescales have been observed in κ CMa (Balona 1993) and ϵ Cap (Balona 1990). Fading events, with an amplitude of several tenths of mag. and lasting a few days have been already observed in θ CrB (Roark 1971) (see Sect. 1), and in the Be/X-ray binary LS I +61° 303 (Fabregat, unpublished). Such fast and aperiodic variability is usually interpreted in terms of local mass ejection episodes from the surfaces of Be stars (Smith 1994).

The fading event we have observed is of much lower amplitude and shorter time scale than those reported above. As far as we know episodes of similar characteristics are not described in the literature. Probably the main reason is the difficulty of detection. The observational evidence seems to indicate than episodic short time scale variability is a common feature of Be stars. However its unpredictable nature and sometimes low amplitude make it extremely difficult to detect. Extended observing campaigns and accurate photometry would be needed to find other similar events. It is important to monitor stars such as θ CrB to be able to get a better idea of duration of its active and quiescent phases.

4. Conclusions

θ CrB has been constant in brightness during 1994 and 1995. No regular periodic variations with amplitude greater than 0.005 mag. are present in our data. In the same way, no long term variability greater than 0.01 mag. occurred during the span of our observations. The lack of variability is related to an inactive phase of this Be star, in whose spectra no emission lines are present.

The only remarkable feature during the period considered has been a fading event of an amplitude of about 0.02 mag in all four *uvby* bands, with a duration of 0.2 – 0.3 days. This variation could be related to a sudden mass ejection from the stellar photosphere.

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