ROTATIONAL VARIATION OF THE MAGNETIC FIELD OF β CrB IN DIFFERENT SPECTRAL LINES

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ABSTRACT. The results of spectropolarimetic study of one of the coolest Ap-stars β CrB are presented. It was shown that effective magnetic fields measured in different spectral lines and folded in phase with the rotational period of the star significantly differ from each other in amplitudes and mean values of the magnetic field curves.

Key words: Stars: magnetic fields; stars: peculiar; stars: individual: β CrB

1. Introduction

An unexplained effect on some chemically peculiar magnetic stars is that the values of effective magnetic field of the same star measured by different authors are significantly different from each other in shapes, amplitudes and mean values (see, for example, Leone and Catanzano 2001). This effect is illustrated in the Fig. 1, where the effective magnetic fields of one of the coolest Ap-stars β CrB obtained from data of different authors are folded in phase with the 18.478-day rotation period of the star. One can see that while magnetic fields measured by Wade et al. (2000) and our data vary sinusoidally with stellar spin period, magnetic field curve obtained from the measurements of Borra and Landstreet (1980) exhibits secondary bump in the phase of the field minima.

It should be noted, that different researchers use different bulks of spectral lines for stellar effective magnetic field measurement. For example, Borra and Landstreet (1980) measured magnetic field of β CrB in the line H_{β}, Wade et al. (2000) used bulk of lines in the spectral range of 4500-6000 Å and we used nine spectral lines in the range of 6136-6162 Å (see Fig. 1). Plachinda and Tarasova (1999) noted that systematic differences exist in the mean longitudinal magnetic field of β CrB measured in the two lines of Fe I and singe line of Ca I. One can suppose that the differences in magnetic field curves can be the result of non-uniform distribution of chemical elements (Wade and Smolkin 2004) and temperature inhomoheneties existing on the surface of β CrB (Plachinda and Tarasova 1999). I.e. magnetic field curves obtained in spectral lines of different chemical elements correspond to different parts of stellar surface and therefore, in assumption of dipole field configuration, corresponds to different magnetic field strength.

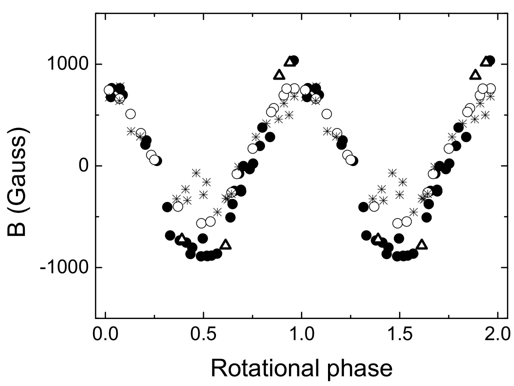

Figure 1: Effective magnetic field of β CrB obtained from data of Borra and Landstreet (1980) (crosses) and Wade et al. (2000) (open circles) and our data: CrAO (field circles) and BOAO (open triangles).

Studying effective magnetic field of β CrB in the individual spectral lines we paid attention to the fact that not only magnetic fields measured in spectral lines of different chemical elements but also magnetic fields measured in different spectral lines of the same chemical element exhibit systematic difference. The results of the initial study are presented in this paper.

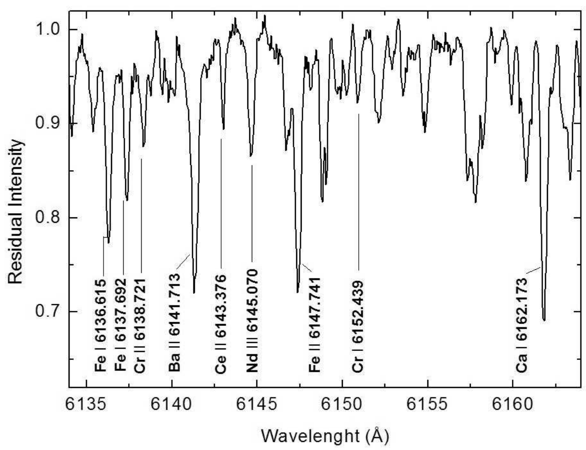

Figure 2: Spectral lines used for effective magnetic field of β CrB measurements.

2. Observations

An intensive spectropolarimetric study of the β CrB has been performed in the nine individual lines (Fig. 2) during 32 nights from 1993 to 2004 using coude spectrograph of the 2.6-m Shajn telescope at the Crimean Astrophysical Observatory and during 4 nights in 2007 and 2008 using eshelle spectrograph BOES at the Bohyunsan Optical Astronomy Observatory (BOAO, South Korea). Signal-to-noise ratios of a single spectrum were 150-350 with resolving power of spectra approximately 30000 (CrAO) and 45000 (BOAO). The study of the magnetic field of the star was carried out with the same equipment and 'Flip-Flop' procedure that have been discussed in detail by Butkovskaya & Plachinda (2007).

3. Results

The rotational variations of the effective magnetic field of β CrB measured using individual spectral lines are presented in Fig. 3. One can see that all the magnetic field curves are well fitted by sinusoids, but these sinusoids significantly differ in amplitude and mean value from each other. The amplitudes and the mean values of the magnetic field curves are given in Table 1. In the first, second and third columns the chemical elements, wavelength and excitation potential are presented, in the two last columns the amplitudes B_e and the mean magnetic fields B_0 are given in Gauss.

Table 1: Parameters of the magnetic field curves.

Elem.	λ (Å)	Excit (eV)	Amplitude B_e (G)	Mean B_0 (G)
Fe I	6136.615	2.453	582 ± 36	23 ± 26
Fe I	6137.692	2.588	821 ± 24	137 ± 17
Cr II	6138.721	6.484	1250 ± 49	159 ± 36
Ba II	6141.713	0.704	1158 ± 38	459 ± 28
Ce II	6143.376	1.696	1221 ± 63	-448 ± 45
Nd III	6145.070		1273 ± 74	-261 ± 53
Fe II	6147.741	3.889	998 ± 28	177 ± 20
Cr I	6152.439	4.207	1100 ± 41	-11 ± 30
Ca I	6162.173	1.899	774 ± 18	-224 ± 13
All lines			855 ± 29	14 ± 21

Table 1 shows that amplitudes and mean values of individual magnetic field curves significantly differ from each other. The parameters of magnetic curves obtained using different lines of the same chemical element (Cr I 6152.439 and Cr II 6138.721; Fe I 6136.615, Fe I 6137.692 and Fe II 6147.741) show systematic differences. Moreover, the parameters of magnetic curves obtained using spectral lines of the same chemical element with the same ionization state and almost equal excitation potentials (Fe I 6136.615 and Fe I 6137.692) show systematic differences also. Strongly negative mean magnetic fields exhibit Ce II 6143.376, Nd III 6145.070, and Ca I 6162.173. We can expect that Ca as well as Fe are uniformly distributed on the stellar surface, therefore, the magnetic field obtained using the spectral lines of these elements would be equal within the measurement errors. Nevertheless, in the case of β CrB we see significant shift in the mean magnetic fields from 137 ± 17 Gs (Fe I 6137.692) to negative value -224 ± 13 (Ca I 6162.173).

Acknowledgements. V. Butkovskaya, D. Baklanova, D. Lyashko, S. Plachinda and V. Tsymbal acknowledge support from the Ukrainian Fundamental Research State Fund (25.2/074, M/364). D. Lyashko, S.Plachinda and V. Tsymbal acknowledges support in part from the Austrian Science Fund (P17890).

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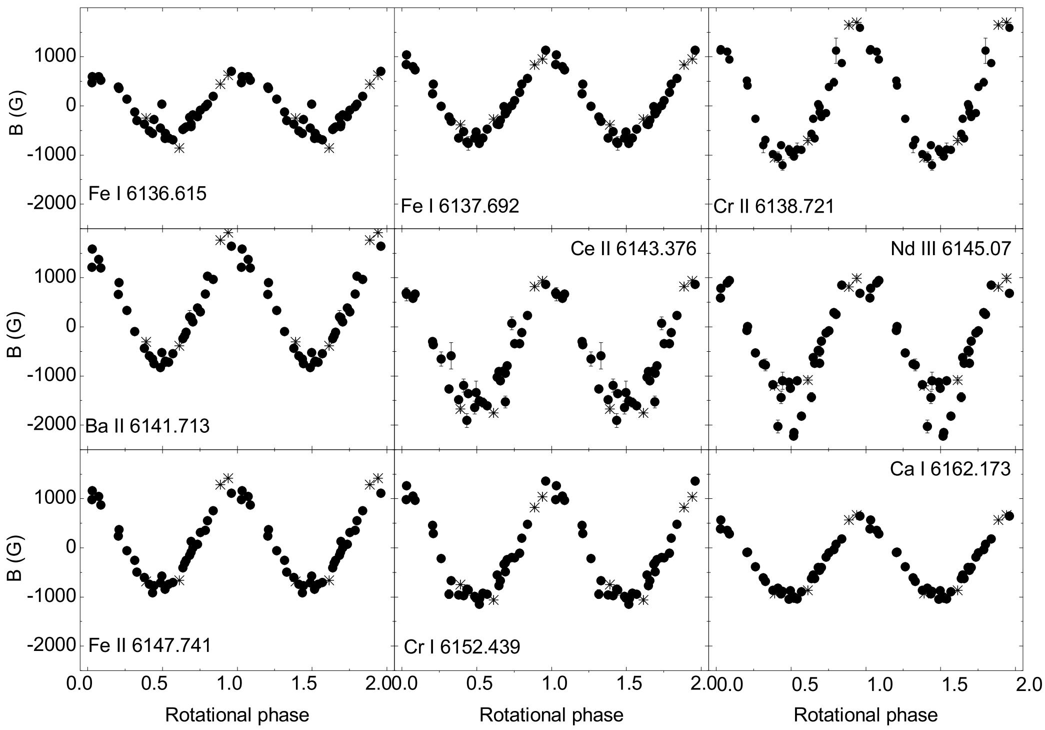

Figure 3: Effective magnetic field of β CrB measured in different spectral lines and folded in phase with the 18.478-day rotation period of the star.