"Stellar magnetism" International Conference Proceedings, 1992, 67-71.

THE EFFECTIVE MAGNETIC FIELD OF HD 215441

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ABSTRACT. *New measurements of the effective magnetic field and radial velocity of the peculiar star HD 215441 obtained at the 6 m telescope are presented. Results of B differ in individual phases of the period from the data obtained by previous investigators. Possible reasons for this difference are discussed. A difference of the magnetic field strength on separate chemical elements is noted.*

1.INTRODUCTION

HD 215441 is a well-known peculiar star with a record magnetic field among non-degenerate stars. This field was discovered by Babcock (1960). He measured the surface magnetic field (B_s) from the Zeeman splitting of components of the spectral lines and found the field of 34 kilogauss. Babcock also measured the longitudinal components of the magnetic field or the effective magnetic field (B_e). The value of B varied irregularly from 4 to 11 kilogauss with a period of 9.5 days derived by Jarzebowski, (1960).

Preston (1969) obtained a number of spectrograms of HD 215441. He found that B_s varied periodically between 32 and 34.5 kilogauss with the period defined more precisely by Stepien (1968). Preston made a conclusion about departures of the magnetic field of HD 215441 from the dipole geometry, using the equivalent widths of π and σ separate components.

Borra and Landstreet (1978) measured B_e in the wings of H_β using the two-channel Pockels cell polarimeter. They found that the effective magnetic field varies nearly sinusoidally between 20.5 kGs in the maximum of V light, and 10.9 kGs in its minimum according to ephemeris by Leckrone (1974):

JD (max light λ>3300 A) = 2 436 864?88 + 9?4871E. (1)

Borra and Landstreet (1978) used the data on B_s derived by Preston (1969) and their owns on B_e, and constructed the most suitable model of the magnetic field geometry of HD 215441 - a decentered dipole model.

According to the program of investigation of Ap-stars a number of spectrograms of HD 215441 were obtained at the 6 m telescope. In this paper the effective magnetic field measured from these spectra is considered.

2. OBSERVATIONS AND REDUCTION

The spectra were taken with the second camera of the Main Stellar Spectrograph. The circular polarization analyzer was placed in front of the slit. The dispersion of the spectrograms was 9.1 A/mm and the spectral resolution 0.3 A. The spectra were widened to 0.35 mm on the plates for each circular polarization. The average exposure time was about 90 minutes.

The effective magnetic field was measured with the astrospeedometer by Antropov (1972) from the displacements of the centres of the weighted left and right circular polarization component of the spectral lines. HD 215441 belongs to silicon stars, i.e. to the hotter part of the classical CP-stars, besides the spectral lines are strongly distorted by the magnetic field. On this account the number of measurable lines is not too large, on the average about 23 - 30 lines in each spectrum. To measure the radial velocity, the mean value between the left and right circular polarization components was used. Calculation of B and radial velocities was made in the standard way.

3. RESULTS AND DISCUSSION

The results of measurements are listed in Table 1 which gives the Julian Date of the midpoint of the observation, the phase of the period according to the ephemeris (1), the effective magnetic field from all the lines with the standard deviation, the effective magnetic field from individual elements in kilogauss and radial velocities in kilometers per second. The standard deviations for individual chemical elements is approximately two times, in some cases three times larger, than from all the elements.

B_e measurements by different authors are plotted versus the phase in Fig. 1. Triangles and diamonds are photographic observations by Babcock (1960) and El'kin (presented in this paper) accordingly, squares are H_β magnetograph observations by Borra and Landstreet (1978). The lines show least-squares fitted sine curves, and the error-bars show the standard deviations. My results and those by Borra and Landstreet are very similar at minimum of V light. A considerable disagreement (about 7 kGs) between my and Borra and Landstreet results are at the maximum of V light when thei

B_e is also at maximum. There may be several reasons: first - various methods of measurements (when the field increases, the differences are also larger), second - irregular distribution of chemical elements on the surface of the star. Fairly often measurements of B_e by various methods give different results. The photoelectric B_e values are usually better represented by a sine curve than the photographic ones.

Table 1. Measured effective magnetic fields B_e and radial velocities RV of HD 215441

JD(2 440 000+)	phase	B_e (kGs)						RV (km/s)
		all lines	± σ	Si II	Cr II	Ti II	Fe II	
4416.471	0.98	9.3	0.7	14.1	9.2	9.0	7.5	-7.0
4418.279	0.19	12.5	1.0	11.9	12.0	8.7	17.5	-4.4
4455.431	0.09	10.9	0.8	9.7	10.1	8.8	11.8	-13.2
4527.236	0.66	12.8	0.8	10.1	12.4	12.6	15.9	-4.0
4532.194	0.19	16.3	0.7	17.5	18.5	14.9	13.8	-5.5
4533.213	0.29	15.1	0.9	14.9	17.8	14.9	21.0	-3.2
4534.200	0.39	13.3	0.7	14.3	16.5	11.3	16.0	-3.2
4590.221	0.30	13.4	0.7	12.2	19.2	14.1	13.1	-9.5
4860.438	0.78	13.4	0.7	12.9	16.5	12.2	8.6	-10.5
4889.429	0.84	13.6	0.5	11.1	13.7	14.6	13.5	-11.2
4890.300	0.93	13.0	0.9	12.0	12.4	12.9	17.6	-10.0
5334.145	0.55	13.0	0.8	8.9	14.2	12.0	13.6	-5.3
5512.454	0.51	11.7	1.1	11.4	14.2	7.2	10.2	-8.2
8143.488	0.83	15.0	0.9	12.0	15.2	14.6	14.1	-8.0

On the whole, my B_e exceeds that of Babcock by more than 5 kGs, although some of his results are close to mine. Partially the disagreement between my and Babcock's data on B_e can be explained by individual methods of measurements.

A comparison of magnetic measurements of 53 Cam for the control of the methods is done. In Fig. 2 there are plotted the data on B for 53 Cam obtained by Babcock (1958) and El'kin (this paper) with photographic, and by Borra and Landstreet (1977) with photoelectric techniques. The symbols are the same as in Fig. 1. New data of B_e for 53 Cam are presented in Table 2.

Table 2. Effective magnetic field B_e of 53 Cam

JD 2 440 000 +	Phase	B_e (kGs)	± σ (kGs)
4509.604	0.14	1.8	0.1
4527.455	0.37	3.0	0.2
5069.333	0.87	-4.3	0.2
5071.243	0.11	1.9	0.2
5072.260	0.24	3.3	0.1
6457.231	0.78	-4.4	0.2
7930.504	0.34	3.5	0.2
8344.550	0.91	-4.2	0.5

Fig. 2 shows a good agreement of B_e points by Borra and Landstreet with my results. Some measurements by Babcock differ rather much. Insufficient accuracy of the period can be one of the reasons. Nevertheless all the three methods of B_e determination give very similar data for 53 Cam. But the magnetic field in HD 215441 is fa stronger than in 53 Cam, therefore, the systematic difference between various method may increase.

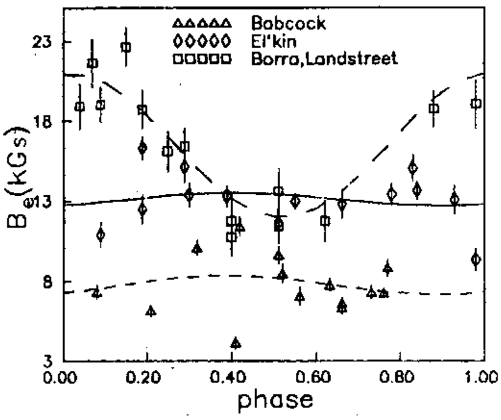

Fig. 1. Observations of the effective magnetic field of HD 215441.

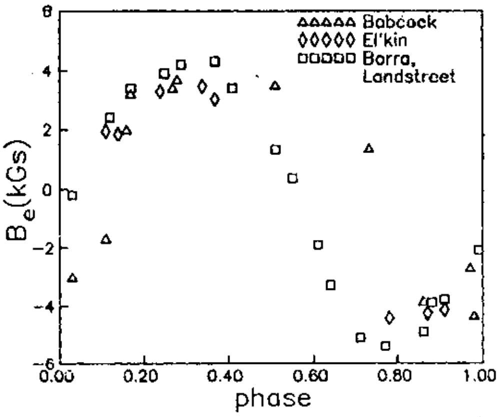

Fig. 2. Observations of the effective magnetic field of 53 Cam.

Return to HD 215441. It should be noted that the effective magnetic field by Borra and Landstreet is too large as compared with the surface magnetic field by Preston (1969). For the centered dipole model B_e does not exceed 40% of the surface field strength. For B_s=34.5 kGs, the effective field must be no larger than about 14 kGs (Landstreet et al.,1989). On this account Borra and Landstreet used the decentered dipole model. My data of B_e are quite suitable for a centered dipole in value, but do not show a harmonic curve.

Frequently chemical elements are distributed irregularly on the surface of Cp-stars. This irregularity may be expressed by some difference in the magnetic field strength determined from separate chemical elements. It is possible to establish a certain tendency in spite of not high accuracy and the considerable scatter of the results, first of all connected with the asymmetry of line profiles and their small number.

The average magnetic field measured from Si II (λ 4128 A, λ 4131 A) and Ti II (about 10 lines) proves to be by 2 kilogauss lower than from the Cr II (about 7 lines) and Fe II (average 4 lines). These fields calculated from the elements as indicated in Table 1 are plotted versus phase from equation (1) in Fig. 3: for Si II - triangles and Ti II - crosses; and in Fig. 4: for Cr II - diamonds and Fe II - squares. Least-squares fitted sine curves are drawn for each element. The magnetic field calculated from Si III λ 4553 A line is on the average by 0.5 kilogauss stronger than from Si (λ 4128 A λ 4131 A). Babcock also measured the magnetic field from H and K Ca II lines and found Zeeman displacement corresponding to a field from 600 to 675 Gauss. I used only Ca II λ 3933 A line since the other is in the wing of the hydrogen line. The magnetic field obtained from λ 3933 A is about 3.8 kGs. From our determination the average field from all the lines is 12.9 kGs, therefore the field of 3.8 kGs may correspond to 0.5 radius of the star from its surface. By Babcock this value is 1.2 radius of the star. Babcock found that the radial velocities determined from H and K Ca II lines differ by 5 km/s from those determined from the other lines. We obtained the average radial velocity RV=-7.5 km/s and from Ca II λ 3933 A line RV=-12.9 km/s, i. e. different from the Babcock's by about 5 km/s. This evidences about the ejection of matter from the star, as Babcock suggested.

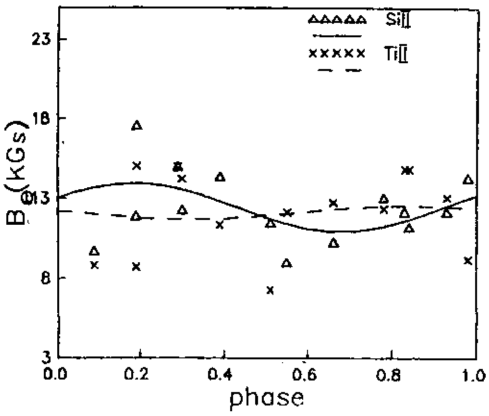

Fig. 3. Variations of the effective magnetic field of HD 215441 for SiII and TiII lines.

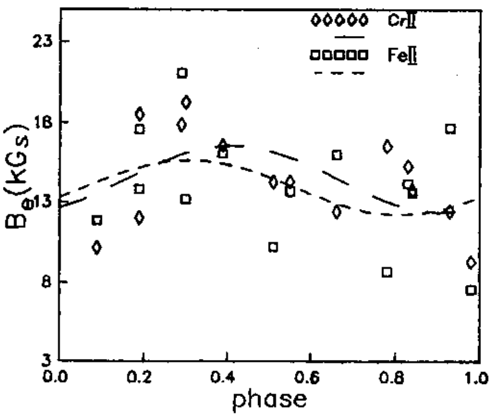

Fig. 4. Variations of the effective magnetic field of HD 215441 for CrII and FeII lines.

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