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First registration of CS magnetic fields in classical Be stars with FORS1 at 8m-VLT

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Abstract. We have investigated the magnetic fields of 15 classical Be stars. The investigation is based on the low-resolution spectropolarimetric data collected in 2005 at the ESO (Chile) with the multi-mode instrument FORS1 at the 8m-VLT. We have used the data analysis, the same as in the case of young Herbig Ae/Be stars (Pogodin et al., these Proceedings). Significant polarization features have been revealed in CS components of the CaII K and H lines in the spectra of 5 Be stars. These features are likely to be formed in the equatorial gaseous disks surrounding the stars. Besides, a clear Stokes V signature is observed in a redshifted absorption component of the Hβ line profile in the spectrum of HD 58011. We conclude that it is an indicator of a magnetized gaseous flow infalling from the disk onto the star. We should like to emphasize that the presented results concern only the first stage of our investigation. The next step of our study will be a search for short-term magnetic field variability of Be stars which may result from the rotational modulation of polarization spectra by hypothetical local magnetic features in the CS envelopes of Be stars.

1 Introduction

We present results of our spectropolarimetric investigation of the second group of early-type stars with circumstellar envelopes — the classical Be stars. The first group of our programme objects is the young Herbig Ae/Be stars. Their magnetic properties are discussed in Pogodin et al. (these Proceedings). Similar to the Herbig Ae/Be stars, the classical Be stars are surrounded by CS envelopes containing an equatorial gaseous/dusty disk and a stellar wind zone at higher latitudes. But in contrast to the Herbig Ae/Be stars, the classical Be stars are not pre-main sequence objects. Their evolutionary status remains to be the matter of debate. But, in any case, they are likely to be evolved objects at a post-main sequence stage. Their gaseous disks are not relict but are formed from the wind matter accumulated in the equatorial plane. Their wind matter is much less dense and sufficiently hotter than the matter in the disk. Episodically the disk can dissipate, and the star is transformed into a typical B-type star. But then a new disk starts accumulate again. As a whole, the general picture of observed active phenomena in the classical Be stars is not less puzzling than in young Herbig Ae/Be stars.

Two main types of physical processes are considered now to be responsible for the Be phenomenon: pulsation and magnetic activity. Non-radial pulsations can be responsible for a periodic spectral and photometric variability observed on short-term scales (less than 1 day). Interpretation of more long-time variability and the mechanism of disk formation requires the presence of magnetic fields on the stellar surface. The well-known Wind-Compressed Disk Model by Bjorkman

Table 1: The list of classical Be stars — objects of the observing programme in 2005

Object	Spectral class	V sin i (km/s)	CS magnetic field
HD 53367	B01ve	30	-
HD 56014	B3IIIp+sh	144	-
HD 56139	B2.5Ve	109	-
HD 57219	B2Vne	117	-
HD 58011	B1Vnep	18	+
HD 58050	B2Ve	123	+
HD 79351	B2.5e	35	-
HD 105435	B2Ine	207	-
HD 117357	B0.5IIIne	78	+
HD 137432	B4Ve	127	-
HD 148259	B1.5Vpe	139	-
HD 148251	B2Ve	86	-
HD 153261	B2IVe	184	-
HD 155806	O8Ve	116	+
HD 181615	B2Ve	69	+

and Cassinelli (1993) does not lead to an equatorial disk with sufficient density without invoking magnetic field. Magnetic disconnections of the field lines are assumed to interpret the appearance of flaring events and discrete ejections of matter into circumstellar (CS) environment. Balona (2003) and his colleagues have developed a scenario of formation of co-rotating gaseous clouds accumulated in closed magnetic loops. Such loops can be responsible for periodic light and line profiles variations. According to modern theoretical predictions, magnetic fields of about 100 G are sufficient to explain the Be phenomenon (Maheswaren 2003). The developed models do not require the necessary presence of a large-scale organized field across the entire stellar surface. They assume also the existence of different types of local magnetized features.

2 Observations

Up to now, all previous attempts to measure directly magnetic fields in the classical Be stars have not lead to a definite positive result. In all cases, either the accuracy was not good enough (Neiner et al. 2003), or the objects of investigation were not typical Be stars (Donati et al. 2001).

In 2005 a sample of 15 classical Be stars became objects of our spectropolarimetric study. We tried to investigate magnetic properties of this class of objects. The spectropolarimeter FORS1 mounted at the 8m-VLT and the same observing programme were used as for young Herbig Ae/Be stars (Pogodin et al., these Proceedings). All observations were carried out with R=4000, and only Balmer lines were chosen for the field measurements. The list of all programme stars is presented in Table 1.

The standard method of data analysis described in Hubrig et al. (2006) led to a contradictory result. We tried to re-analyze our data following the same method as used for young Herbig Ae/Be stars (Pogodin et al., these Proceedings).

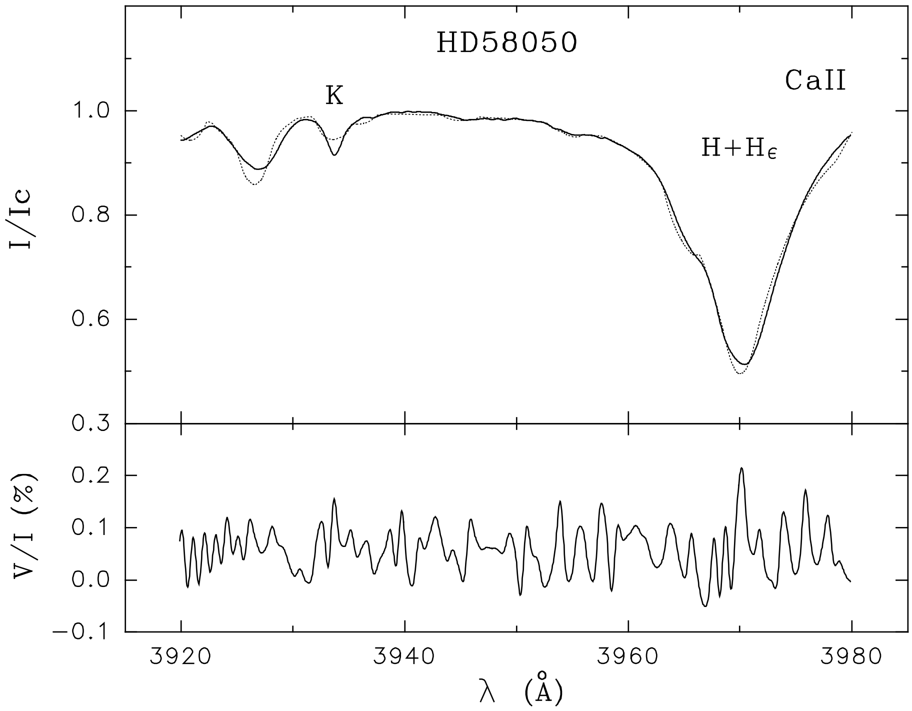

Figure 1: Normalized and polarization spectra of HD 58050 (B2Ve) near the CaII K and H lines. The synthetic spectrum is given for comparison by dotted line.

3 Results

3.1 CaII K and H lines

As a result of our analysis, we have found no obvious traces of atmospheric magnetic field in all 15 objects of our programme. However, significant polarization features indicating the presence of a field in the lines of the resonance CaII doublet were revealed in 5 Be stars. No doubt that these lines are of circumstellar (CS) origin. A comparison of the observed normalized spectra of these objects with synthetic shows that strong CaII absorption lines are observed, and these absorptions are much wider and deeper than the theoretical predictions for these photospheric lines (see Figs. 1-5). The observed CaII absorptions are likely to be formed in the rotating equatorial disk, which is much cooler than the stellar surface of B2-O8-type stars.

No polarization signatures are observed in other spectral regions (the only exception — a CS Hβ component in the spectrum of HD 58011). It should be noted that in the normalized spectra of all programme stars the Balmer lines demonstrate intense emission profiles. In our opinion, these objects can be included in group III (Pogodin et al., these Proceedings), and there is no possibility of diagnosing their stellar magnetic fields.

Figs. 1–5 illustrate polarization spectra of 5 Be stars with Stokes V signatures in the CaII K and H lines.

3.2 CS Hβ component

The only programme object demonstrating polarization features not only in ionized calcium lines but also in Hβ is HD 58011. The significant feature corresponds to a narrow redshifted absorption component of the line possessing an inverse P Cyg-type profile (Fig. 6). Profiles of such a type are indicators of the presence of matter infall from the CS disk onto the star. Therefore, we can assume

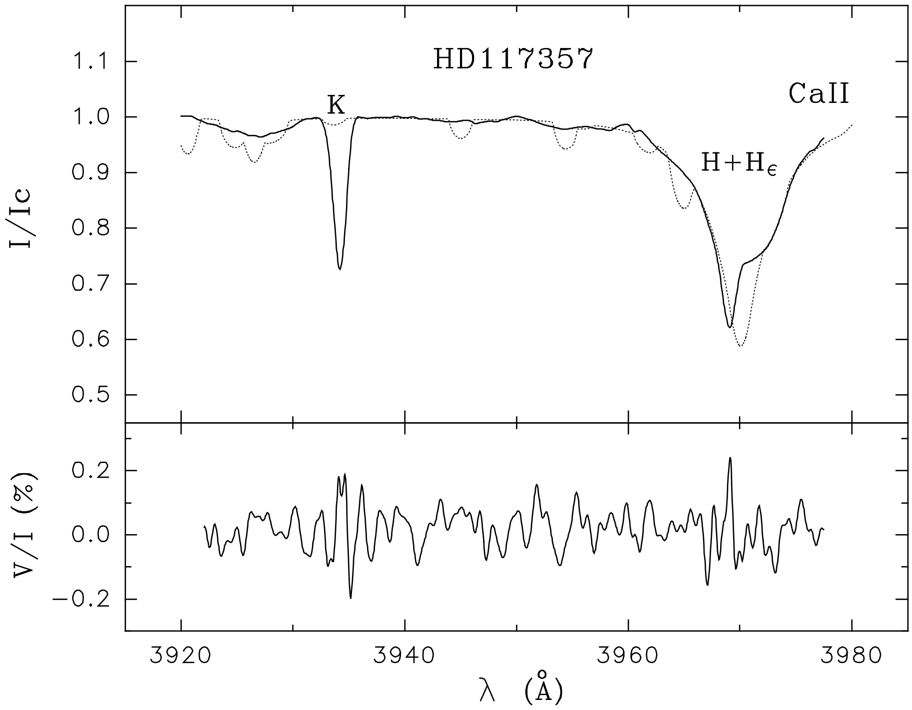

Figure 2: The same as Fig.1, but for HD 117357 (B0.5IIIne).

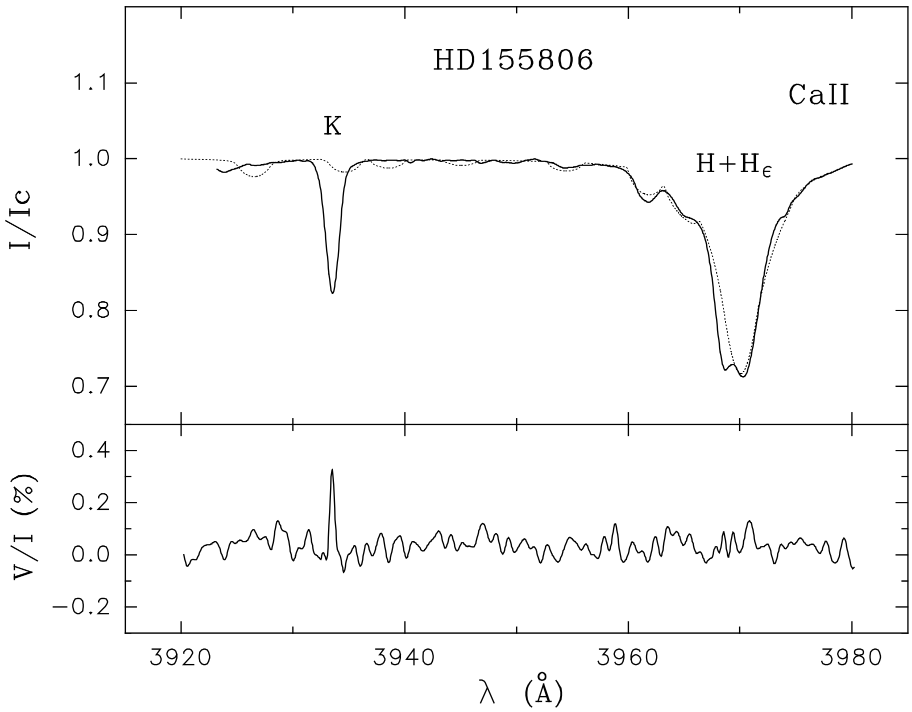

Figure 3: The same as Fig.1, but for HD 155806 (O8Ve).

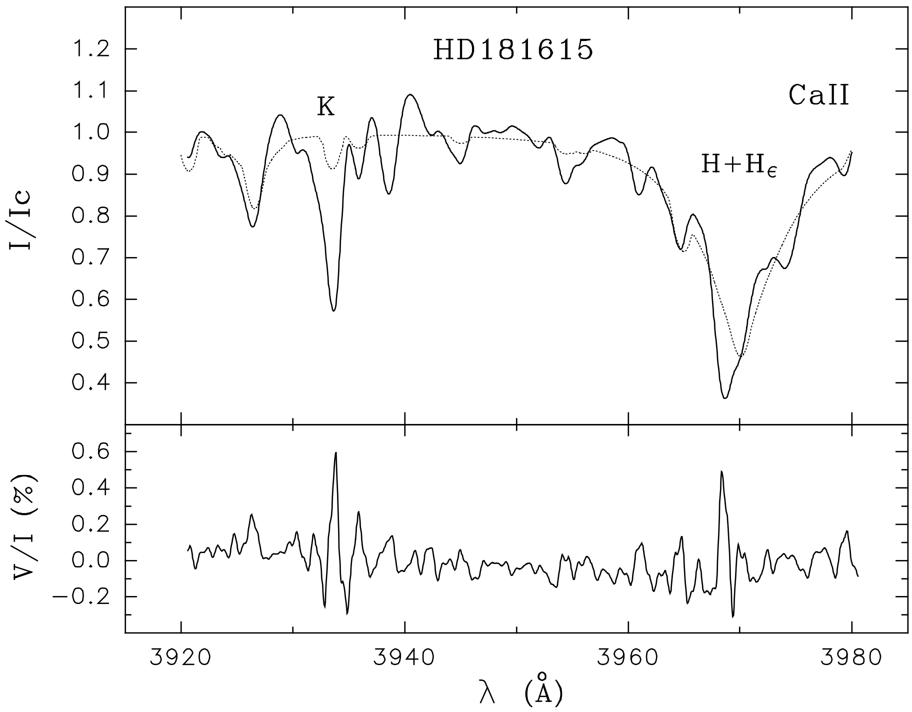

Figure 4: The same as Fig.1, but for HD 181615 (B2Vpe).

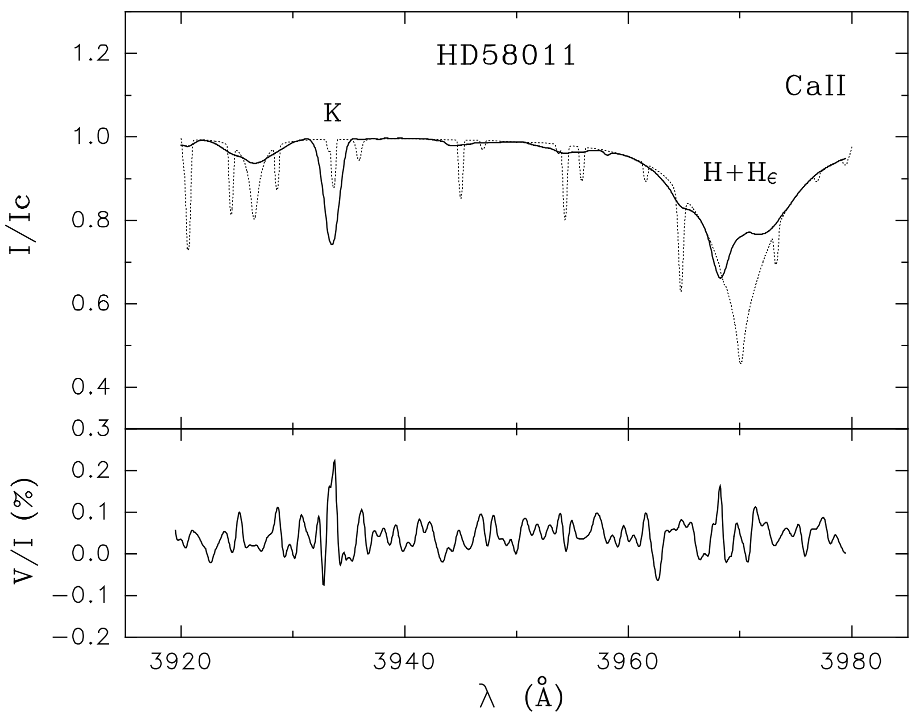

Figure 5: The same as Fig.1, but for HD 58011 (B1Vnep).

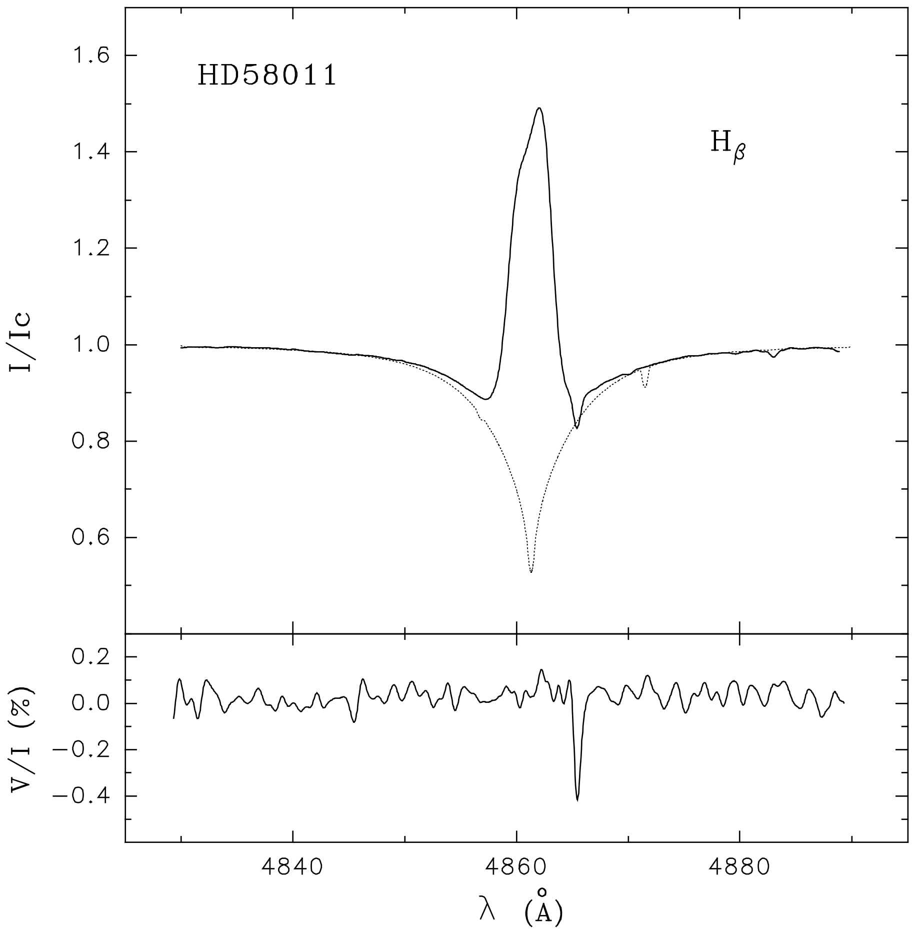

Figure 6: The same as Fig.5, but for the Hβ line.

that the infalling flow in the CS envelope of HD 58011 is magnetized. It should be noted, that the list of our programme objects contains several stars with the inverse P Cyg-type profile of Hβ. But all of them (except HD 58011) demonstrate no polarization signatures in this line.

It is remarkable that the profiles of polarization features observed in the CaII and in the Hβ lines in the spectrum of HD 58011, are not similar (Fig. 6). This fact indicates that the CS regions of their formation are likely to be different.

4 Conclusions

We have presented now only the results of the first stage of our investigation of magnetic fields in classical Be stars. For the time being, we make no conclusion as to the origin and physical properties of the revealed magnetic field signatures.

The next step of our study is to obtain long-term series of spectropolarimetric observations for a number of Be stars from an extended list of programme objects on a time scale of several hours. That is comparable with times of rotation periods of classical Be stars. These data will allow us to reveal traces of the rotational modulation of polarization spectra connected with the existence of local magnetic fields in the CS media around these objects.

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