A STUDY OF THE MAGNETIC FIELD IN THE PHOTOSPHERIC AND CIRCUMSTELLAR COMPONENTS OF HERBIG AE STARS .

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Numerous theoretical works predict the existence of a global magnetic field of a complex configuration around Herbig Ae/Be stars. Nevertheless over an extended period of years all attempts to obtain reliable direct measurements of magnetic fields of HAEBEs have been rather unsuccessful. The lack of field detections could be explained by: (a) the weakness of the fields; (b) the low accuracy of all previous measurements; (c) possible time variability; and (d) non-adequate observational strategy. Quite recently, definite evidence for the presence of magnetic fields of the order of about 100G has been presented for several Herbig Ae stars by Hubrig et al., (2004, A&A 428, L1; 2006, A&A 446, 1089; 2007, A&A 463, 1039). The accuracy of the field determinations was about 30G that allowed us to detect the magnetic fields in three HAEBEs at the $3\sigma$ level. Those measurements have been carried out exclusively in the broad hydrogen lines. In the new analysis we have used the full spectrum, excluding only the regions which are contaminated by the circumstellar environment. The goals of our study are as follows: (a) to analyze the data of seven program stars and to separate photospheric and CS components of all spectral lines; (b) to re-measure the photospheric magnetic fields of HAEBEs without inclusion of spectral regions affected by the CS matter; (c) to derive information on the presence of magnetic fields in the CS environment.

DISCUSSION: Wade et al. (astro-ph/0701249) report that their reduction using the procedure introduced by Bagnulo et al. (A&A, 358, 929, 2000) of our FORS 1 spectra of a few Herbig Ae/Be stars retrieved from the ESO Science Archive did not present polarization features reported previously by Hubrig et al. (2007, A&A 463, 1039). However, we show here that these feature are indeed present in our spectra. The only difference between the reduction procedure developed by Bagnulo et al. and that of Hubrig et al. is that our procedure includes interpolation which, however, does not change in any way the magnetic information preserved in the Stokes V profiles. The difference between the Bagnulo et al./Wade et al. reduction and the reduction of Hubrig et al. is illustrated in Fig. 1 where we present our observation of HD 190073 with FORS 1 and GRISM 1200g (R~4000). The Ca II H and K profiles in the spectra of this star exhibit a multi-component structure of polarization features indicating the presence of a magnetic field in the magnetic circumstellar components of the Ca II H and K lines. The middle panel shows the results for a Stokes V spectrum using interpolation between detector pixels (the method used by Hubrig et al.). The lowest panel presents the Stokes V spectrum without interpolation (the method used by Bagnulo et al./Wade et al.). It is clear that the interpolation is not responsible for the appearance of the Zeeman features, which can already beyond doubt be seen in the non-interpolated data. Here we emphasize the importance of future magnetic field measurements using high resolution spectropolarimeters to be able to measure the magnetic field separately for lines of different elements in order to study both the magnetic field configuration in Herbig Ae/Be stars and the interaction of the circumstellar material with the magnetic field.

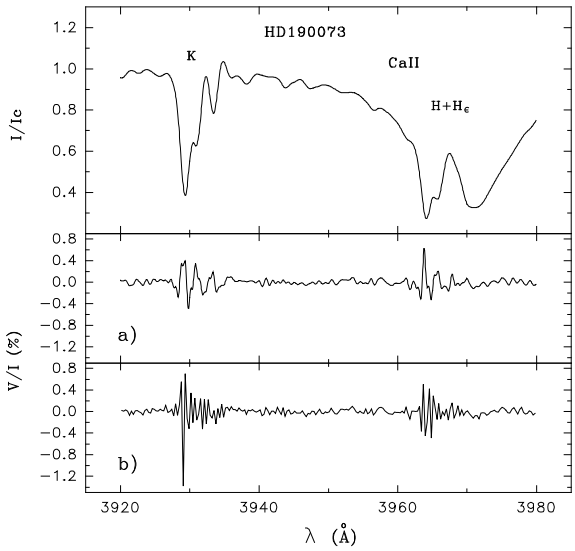


Figure 1: The Ca II H and K profiles (the upper panel) of HD 190073 in comparison with average polarisation spectrum - a) the Stokes V spectrum using interpolation between detector pixels ; b) the Stokes V spectrum without interpolation

In Fig. 2 we present an example of Stokes I and Stokes V profiles in another A-type star with strong Ca II H and K lines observed recently with FORS 1 with the same spectral resolution. Our reduction has been carried out in the same way as for HD 190073. No Zeeman features could be detected at the positions of the Ca II H and K lines. However, very distinct Zeeman features are clearly visible at the position of the hydrogen H$\beta$ and H$\gamma$ lines indicating the presence of a magnetic field on the surface of this star.

RESULTS: We suggest that the observations of the studied HAEBEs can be divided into three groups. The first group contains objects with photospheric magnetic fields which have been detected at a high confidence level of about 7s. The objects with only weak circular polarisation signatures which however can not be determined with sufficient precision constitute the second group. Objects with clear circular polarisation signatures mainly of CS origin have been distinguished as a third group. The differences are illustrated in the Fig. 3.

CONCLUSIONS: 1. We conclude that previous discrepancies in estimations of magnetic fields for a few HAEBEs observed on different dates are likely the result of a variable

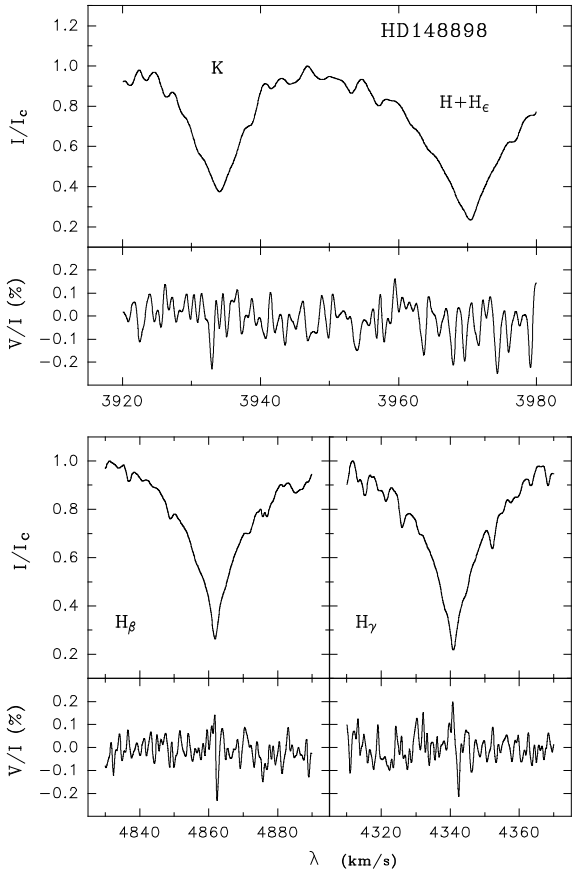


Figure 2: The Ca II H and K profiles (upper panel) and H$\beta$, H$\gamma$ profiles (down panel) of HD 148898 in comparison with average polarisation spectrum

CS contribution to photospheric spectra. 2. We have improved the accuracy of the photospheric magnetic field determination of the two objects (HD139614, HD144432) to a significance level of about 7$\sigma$. This leaves little doubt about the presence of a magnetic field. 3. We deduce that the measured magnetic fields of HD31648 and HD190073 are not of photospheric but mostly (HD31648) or exclusively (HD190073) of CS origin. 4. We found that the most sensitive indicator of the CS magnetic field in Herbig Ae stars is the CaII doublet. The magnetic field diagnosed in the CaII lines is generated in the CS matter in the vicinity of the stellar surface where the base of the stellar wind as well as gaseous flows infalling onto the star are likely located.