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Measurements of magnetic fields in Herbig Ae/Be stars and stars with debris disks at the VLT 8-m telescope: statistical results of our long-term program

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Abstract. We present the results of magnetic field measurements for a sample of 23 young Herbig Ae/Be (HAEBEs) stars and 12 stars with debris disks. The spectropolarimetric data were obtained during four observing runs in 2003-2008 at the European Southern Observatory with the multi-mode instrument FORS 1 installed at the 8 m Kueyen telescope. Among the 23 HAEBEs studied, stellar magnetic fields of about 100-150G have been detected in 11 stars (i.e. ∼50%). The presence of circumstellar polarization signatures formed in the stellar wind supports the assumption that the magnetic centrifuge is one of the main mechanisms of the wind acceleration. No field detection at a significance level of 3σ was achieved in stars with debris disks.

Keywords. stars: magnetic fields, stars: early-type, stars: emission-line

1. Introduction

Numerous theoretical works predict the existence of a global magnetic field around HAEBEs. Nevertheless over an extended period of years all attempts to obtain reliable direct measurements of magnetic fields of HAEBEs have been rather unsuccessful. In the last years definite evidence for the presence of magnetic fields of the order of about 100G has been presented for several HAEBEs by Hubrig *et al.* (2004, 2006). After that time direct spectropolarimetric observations of several HAEBEs showed that magnetic fields are indeed present in intermediate mass pre-main sequence stars (e.g., Wade *et al.* 2007; Hubrig *et al.* 2009) indicating that magnetic fields are important ingredients of the star formation process (McKee & Ostriker 2007). Here we summarized our results of magnetic field measurements for HAEBEs obtained in a framework of our long-term program. For the measurement of the magnetic fields we used spectropolarimetric observations obtained with the 8m VLT+FORS1 (using low-resolution R=2000) during four observing runs in the years 2003-2008.

2. Results and Discussion

During four runs we were able to obtain circular polarization data for 23 HAEBEs and 12 debris disc stars. Among this sample the detections of a magnetic field were achieved in twelve HAEBEs, in most of them just occasionally on single nights (Hubrig *et al.* 2004; 2006; 2009). For a few stars we investigated the photospheric and circumstellar

(CS) magnetic field components separately, showing that the spectropolarimetric results strongly depend on the level of the CS contribution to the stellar spectra. Strong distinct Zeeman features at the position of the Ca II H&K lines were detected in four HAEBEs. These lines are very likely formed at the base of the stellar wind, as well as in the accretion gaseous flow and frequently display multi-component complex structures in both the Stokes V and the Stokes I spectra. In two HAEBEs, HD31648 and HD190073, such a structure was especially noticeable, and from their study we concluded that a magnetic field is present in both stars, but is most likely of circumstellar origin. For HD31648, we detected a magnetic field $B_z = 87 \pm 22$G. One of the HAEBEs, HD101412, showed the largest magnetic field strength ever measured in intermediate mass pre-main-sequence stars with $B_z = -454 \pm 42$G, confirming the previous FORS1 detection by Wade *et al.* 2007. Quite recently high-resolution spectropolarimetric observations with UVES at Kueyen/UT2 at the VLT and HARPS at the 3.6m telescope on La Silla (Hubrig *et al.* 2010) revealed that HD101412 possesses the strongest magnetic field ever measured in any Herbig Ae star, with a surface magnetic field $< B >$ up to 3.5kG. The evidence for the presence of Zeeman features in circumstellar Ca doublet lines in HD31648 was also confirmed by our recent observations at high spectral resolution, R = 30000, with SOFIN at the 2.56m Nordic Optical Telescope. The magnetic field in 12 Vega-like stars, if present at all, is less than 100G, and is almost below the detection limit of spectropolarimetric measurements with FORS 1.

3. Conclusions

Among the 23 HAEBEs studied, the detections of a magnetic field were achieved in 11 stars (or ∼50%). Apart from HD101412, we measured weak fields (∼100-300G) in other HAEBEs, but the high resolution spectropolarimetric observations show that fields can be much stronger. These strong (∼kG) fields are certainly present on the surface of few HAEBEs, but are difficult to detect due to very broad spectral lines. No definite detection was achieved for 12 stars with debris discs. Careful analysis of polarimetric spectra shows that previous (and sometimes recent) unsuccessful attempts to detect magnetic fields in HAEBEs and previous discrepancies in estimations of magnetic fields for a few stars observed on different dates, can possibly be explained by: a) weak level of their magnetic fields; b) possible variability of these fields; and c) variable contribution of circumstellar emission and absorption to the observed spectra. The measured magnetic field in some HAEBEs using low-resolution spectropolarimetry are frequently related to CS spectral lines and not to photospheric lines. The most sensitive indicator of the CS magnetic field in HAEBEs is the CaII doublet. Circular polarization features corresponding to this doublet are observed in most program targets. 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.

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Discussion during the welcome cocktail and coffee breaks. From left to right and top to bottom: Doug Gies and Pavel Koubsky; Jiri Krticka, ? and Stan Owocki; Philippe Stee and Christopher Russell; Catherine Lovekin, Adrian Potter and Nathan Smith; Eduardo Janot-Pacheco, Jean Zorec, ?, and Antono Pereyra; Gloria Koenigsberger, Mary Oksala, Richard Townsend and Thomas Rivinius; Myron Smith and Hideyuki Saio; Jean-Paul Zahn, Stéphane Mathis and André Maeder.

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