Active OB Stars: Laboratories for Stellar and Circumstellar Physics
ASP Conference Series, Vol. 361, 2007
S. Štefl, S. P. Owocki and A. T. Okazaki

Discovery of Magnetic Fields in Slowly Pulsating B Stars

S. Hubrig,[1] M. Briquet,[2] M. Schöller,[3] P. De Cat,[4] G. Mathys,[5] and C. Neiner[6]

[1]*European Southern Observatory, Casilla 19001, Santiago 19, Chile*

[2]*Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200B, B-3001 Leuven, Belgium*

[3]*European Southern Observatory, Casilla 19001, Santiago 19, Chile*

[4]*Koninklijke Sterrenwacht van België, Ringlaan 3, B-1180 Brussel, Belgium*

[5]*European Southern Observatory, Casilla 19001, Santiago 19, Chile*

[6]*Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200B, B-3001 Leuven, Belgium*

Abstract. We present the first observations and conclusions of a magnetic survey with FORS 1 at the VLT of a sample of 25 Slowly Pulsating B stars. A clear mean longitudinal magnetic field of the order of a few hundred Gauss was detected in eleven SPBs. Among them several SPBs show a magnetic field that varies in time. It becomes clear that SPBs cannot be regarded anymore as non-magnetic stars.

1. Sample of Stars and Observations

The recent discovery of a weak magnetic field in four Slowly Pulsating B stars (SPBs) with FORS 1 at the VLT (Hubrig et al. 2005) motivated us to perform a systematic search for magnetic fields in SPBs. With this aim we plan to gather many magnetic observations for a sample of some 30 confirmed SPBs. These B-type stars pulsating in many high-order gravity-modes are already thoroughly studied by astrophysicists of the Institute of Astronomy of the University of Leuven in the framework of a long-term project. The HD number of the already observed 25 SPB stars together with their basic stellar parameters are given in Table 1.

The observations reported here have been carried out in the last years at the European Southern Observatory with FORS 1 (FOcal Reducer low dispersion Spectrograph) mounted on the 8-m Melipal telescope of the VLT. This multi-mode instrument is equipped with polarization analyzing optics comprising super-achromatic half-wave and quarter-wave phase retarder plates, and a Wollaston prism with a beam divergence of 22″ in standard resolution mode. During the last year, we used the GRISM 600B in the wavelength range 3480–5890 Å to cover all hydrogen Balmer lines from H_β to the Balmer jump. The spectral resolution of the FORS 1 spectra taken with this setting was R∼2000.

Starting in April 2005 we used the GRISM 1200g to cover the H Balmer lines from H_β to H_8, and the narrowest available slit width of $0\farcs4$ to obtain a spectral resolving power of R$\sim$4000.

The mean longitudinal magnetic field is the average over the stellar hemisphere visible at the time of observation of the component of the magnetic field parallel to the line of sight, weighted by the local emergent spectral line intensity. It is diagnosed from the slope of a linear regression of V/I versus the quantity $-g_{\rm eff}\Delta\lambda_z\lambda^2\frac{1}{I}\frac{{\rm d}I}{{\rm d}\lambda}\,\langle B_z\rangle + V_0/I_0$ where V is the Stokes parameter which measures the circular polarization, I is the intensity observed in unpolarized light, $g_{\rm eff}$ is the effective Landé factor, λ is the wavelength, ${\rm d}I/{\rm d}\lambda$ is the derivative of Stokes I, and $\langle B_z\rangle$ is the mean longitudinal field. This procedure is described in detail by Bagnulo et al. (2002) and Hubrig et al. (2004). Our experience from a study of a large sample of magnetic and non-magnetic Ap and Bp stars revealed that this regression technique is very robust and that detections with $B_z > 3\,\sigma$ result only for stars possessing magnetic fields.

Table 1. The basic stellar parameters of our sample of studied SPBs together with their mean longitudinal magnetic field $\langle B_z\rangle$. Stars for which a longitudinal magnetic field has been detected at a 3 σ level are indicated in italic. In case we have more than one measurement, only the largest $\langle B_z\rangle$ value is presented.

HD	$T_{\rm eff}$ (K)	log g (dex)	M/$M_\odot$	R/$R_\odot$	log ($L/L_\odot$)	$\langle B_z\rangle$ (G)
3379	*17270 ± 160*	*4.16 ± 0.15*	*5.3 ± 0.4*	*3.2 ±0.7*	*2.9 ± 0.2*	*+388 ± 70*
24587	13860 ± 70	4.26 ± 0.12	3.6 ± 0.2	2.4 ± 0.4	2.3 ± 0.1	−120 ± 66
26326	15210 ± 100	4.14 ± 0.14	4.4 ± 0.3	3.0 ± 0.6	2.6 ± 0.2	+119 ± 75
28114	14560 ± 80	4.00 ± 0.14	4.4 ± 0.3	3.6 ± 0.7	2.7 ± 0.2	+127 ± 60
34798	15590 ± 120	4.25 ± 0.13	4.3 ± 0.2	2.7 ± 0.4	2.6 ± 0.1	+117 ± 52
45284	14690 ± 110	4.40 ± 0.12	3.8 ± 0.1	2.2 ± 0.1	2.3 ± 0.1	+100 ± 50
46005	21140 ± 270	4.43 ± 0.18	6.9 ± 0.2	3.1 ± 0.2	3.2 ± 0.1	−7 ± 95
53921	*13690 ± 70*	*4.23 ± 0.12*	*3.6 ± 0.2*	*2.4 ± 0.4*	*2.3 ± 0.1*	*−296 ± 63*
74195	*16160 ± 130*	*3.91 ± 0.16*	*5.5 ± 0.5*	*4.4 ± 1.0*	*3.1 ± 0.2*	*−296 ± 88*
74560	16210 ± 150	4.15 ± 0.14	4.8 ± 0.3	3.1 ± 0.6	2.8 ± 0.2	−74 ± 80
85953	*18430 ± 180*	*3.91 ± 0.17*	*6.8 ± 0.7*	*4.9 ± 1.2*	*3.4 ± 0.2*	*−245 ± 63*
92287	16420 ± 140	4.00 ± 0.15	5.4 ± 0.5	3.9 ± 0.8	3.0 ± 0.2	−10 ± 57
123515	11990 ± 60	4.27 ± 0.09	2.9 ± 0.1	2.1 ± 0.2	1.9 ± 0.1	−132 ± 73
138764	14050 ± 80	4.20 ± 0.12	3.8 ± 0.2	2.6 ± 0.4	2.4 ± 0.1	+77 ± 63
140873	*13930 ± 80*	*4.35 ± 0.12*	*3.6 ± 0.1*	*2.3 ± 0.2*	*2.2 ± 0.1*	*+184 ± 56*
143309	*14000 ± 80*	*4.09 ± 0.13*	*4.0 ± 0.2*	*3.1 ± 0.5*	*2.5 ± 0.1*	*+177 ± 56*
160124	*14800 ± 110*	*4.34 ± 0.12*	*3.9 ± 0.1*	*2.4 ± 0.2*	*2.4 ± 0.1*	*+491 ± 73*
161783	*17600 ± 170*	*4.09 ± 0.15*	*5.7 ± 0.4*	*3.6 ± 0.7*	*3.0 ± 0.2*	*+411 ± 75*
163472	22420 ± 230	3.86 ± 0.19	9.9 ± 1.3	6.4 ± 1.7	3.9 ± 0.3	+156 ± 73
169820	*11780 ± 70*	*4.26 ± 0.09*	*2.9 ± 0.1*	*2.2 ± 0.2*	*1.9 ± 0.1*	*+243 ± 70*
177863	13380 ± 60	4.14 ± 0.12	3.6 ± 0.1	2.7 ± 0.3	2.3 ± 0.1	−33 ± 57
181558	*14680 ± 100*	*4.16 ± 0.13*	*4.1 ± 0.2*	*2.9 ± 0.5*	*2.5 ± 0.2*	*−788 ± 128*
182255	14100 ± 80	4.23 ± 0.12	3.8 ± 0.2	2.5 ± 0.4	2.4 ± 0.1	+18 ± 60
208057	16640 ± 150	4.15 ± 0.14	5.0 ± 0.3	3.2 ± 0.6	2.8 ± 0.2	+124 ± 79
215573	*13960 ± 80*	*4.09 ± 0.13*	*4.0 ± 0.2*	*3.0 ± 0.5*	*2.5 ± 0.1*	*−205 ± 57*

2. Results and Discussion

We present in Table 1 results of our determination of the mean longitudinal magnetic field $\langle B_z\rangle$ for all studied SPB stars. A longitudinal magnetic field at a level larger than 3 σ has been diagnosed for 11 SPB stars: HD 3379, HD 53921, HD 74195, HD 85953, HD 140873, HD 143309, HD 160124, HD 161783, HD 169820, HD 181558 and HD 215573. For a few targets we have several measurements showing the variability of their magnetic field. In particular, for

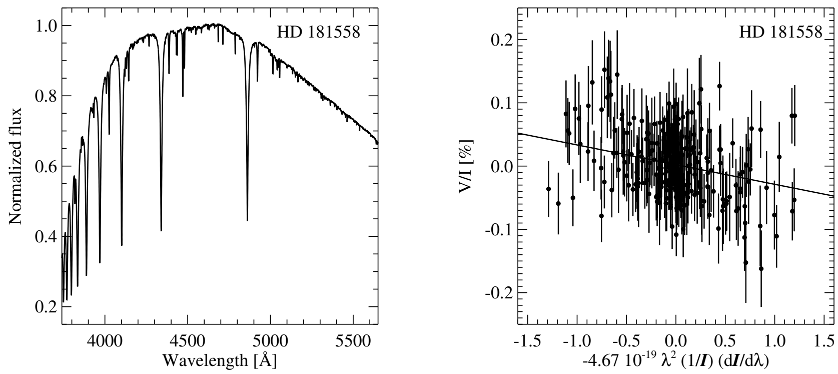

Figure 1. Stokes I spectrum (left) and regression detection (right) for HD 181558 ($\langle B_z \rangle = -311 \pm 69$ G).

HD 181558, we obtained $\langle B_z \rangle = -117 \pm 54$, $+190 \pm 62$, -788 ± 128, -311 ± 69 G. In Fig. 1 we present Stokes I and spectrum regression detection for HD 181558 ($\langle B_z \rangle = -311 \pm 69$ G).

The presented magnetic field measurements in SPB stars demonstrate that longitudinal magnetic fields in these stars are rather weak in comparison to kG fields detected in magnetic Bp stars. Certainly, all reported field detections need to be confirmed by further observations. However, in the present study we have almost reached the limit of what is currently feasible by using FORS 1 in spectropolarimetric mode. In this respect, we would like to mention the importance of future magnetic field measurements using high resolution spectropolarimeters such as ESPaDOnS, recently installed at the CFHT (Manset & Donati 2003). With such an instrument it will be possible to measure the magnetic field not only using hydrogen lines, but also lines of other chemical elements to study the magnetic field configuration at higher confidence level.

Acknowledgments. MB is Postdoctoral Fellow of the Fund for Scientific Research, Flanders.

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