A survey of Ap stars for weak longitudinal magnetic fields

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Abstract.

We are conducting a magnetic survey of a sample of about 12 spectroscopically-identified A_p stars (selected from the HD catalogue), but with faint or previously undetected magnetic fields. We use the MuSiCoS spectropolarimeter at Telescope Bernard Lyot (Pic du Midi Observatory, France) and the cross-correlation technique Least Squares Deconvolution (LSD; Donati et al, 1997). For 10 studied stars, we have obtained the detections of Stokes V Zeeman signatures (data quality and phase coverage may explain our lack of detection of any field in some objects). Our results suggest that all **Ap** stars are magnetic and, furthermore that there may exist a minimum field strength for which Ap-type characteristics are produced.

Key words: stars: chemically peculiar – stars: A_P stars – stars: magnetic fields – Polarization

1. Introduction

Preston's (1974) classification of the chemically peculiar **A** and **B**-type stars into magnetic and non-magnetic subtypes has generally been found to be valid. The existence of strong, ordered magnetic fields in many A_P **SrCrEu, He**-weak **SiSrTi,** and **He**-strong stars, and the lack of detectable fields among the A_P **HgMn,** A_m and λ **Boo** stars (Borra & Landstreet, 1990; Borra et al, 1983; Landstreet, 1982) appears to be real (and important) physical property distinguishing the two classes.

Though thousands of chemically peculiar and A_P (chemically peculiar A-type) stars are catalogued (Renson et al, 1991), only about 210 A_P stars have magnetic field measurement (Remanyuk, 2000). For some A_P stars that characterized to be magnetized, there is no detection of magnetic field until now.

In this work the circular spectropolarimetric observation of 12 A_P stars were obtained in an attempt to detect magnetic fields via the longitudinal Zeeman effect in their spectral lines.

2. Detection of stellar magnetic field in A_P stars

The classical method for detecting stellar magnetic fields in the mid to upper main sequence has been the detection of circular polarization in spectral lines due to the line-of-sight component of a star's magnetic field. The quantity inferred from spectropolarimetric observations is the line-intensity weighted average over the stellar disk of the line-of-sight component of the magnetic field, referred to as the longitudinal field or effective field. Stars which have detectable longitudinal magnetic fields exhibit the chemical peculiarities we now associate with magnetic A_P stars, and the nearly always exhibit photometric and/or line profile variation with the same period as the variation in longitudinal field. Stars which show chemical peculiarities typical of magnetic A_P stars and/or periodic photometric and line profile variations, but for which no longitudinal fields have been detected, are usually assumed to have fields smaller than the observational errors.

3. Observations and data reduction

Stokes **V** and Stokes **I** spectra of 12 A_P stars were obtained using the MuSiCoS spectropolarimeter attached the 2 m Bernard Lyot telescope (TBL) at Observatoire du Pic du Midi. MuSiCoS spectropolarimeter is composed of a cross-dispersed echelle spectrograph (Baudrand & Bohm, 1992) and dedicated polarimeter module (Donati et al, 1999). The spectrograph is a table-top instrument, fed by a double optical fiber directly from the Cassegrain-mounted polarization analyzer. In one single exposure , this apparatus allows the acquisition of a stellar spectrum in a given polarization (stokes **V** in this case) throughout the spectral range 450 to 660 nm with a resolving power of about 35000. Spectra in both orthogonal polarizations are recorded simultaneously by the **CCD** detector. A complete stokes **V** exposure consist of a sequence of four subexposures, between which the quarter-wave plate is rotated by 90°. This has the effect of exchanging the beams in the whole instrument, and in particular switching the positions of the two orthogonally polarized spectra on the **CCD**, thereby reducing polarization signatures.

The echelle polarization spectra are reduced using the ESPRIT package (Donati et al, 1997). Figure 1 show the example of clear detection of magnetic field in the A_P star 3Hya. Observation and reductions procedures are the same as more thoroughly described in Shorlin et al (2002).

The observed stars are listed in Table 1. Their HD number, period, radius and spectral type are given. We have used these data to find the Oblique Rotator Model parameters such as inclination angle, i, the obliquity angle, β and the Dipole field strength, B_d. Furthermore we extract the projected rotation velocities from stokes I profile of the LSD Zeeman signatures, using the Shorlin formula (Shorlin et al, 2002):

$$v \sin i = (0.617 \pm 0.020) \times FWHM + (0.86 \pm 0.61)$$

Where **FWHM** is the full-width at half-maximum of Gaussian fits to their **LSD** stokes I profiles, and compare the results with the values quoted in Table.1 that from Royer

Catalogue (2002).

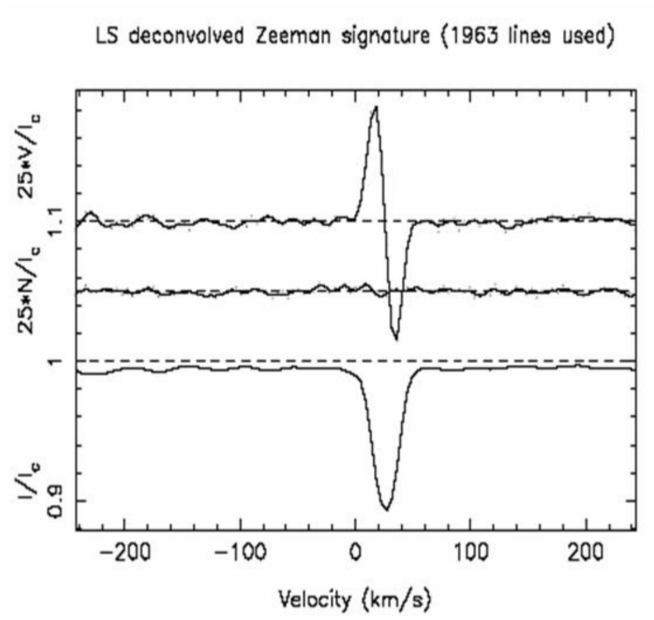

Figure1. Stokes LSD Zeeman signature of the Ap star 3Hya. A strong Stokes V signature is clearly detected. Note, for the display purpose, the Stokes V profile has been expanded by a factor of 25 and shifted upward by 1.1

Star	*HD number*	*Period* (day)	*Vsini* $\pm \sigma_{vsini}$ (km/s)	*Radius* (Rsun)	*i* (degree)	*Spectral Type*	$B_e \pm \sigma_{B_e}$ Gauss
56Tau	27309	1.56	44 ± 4	1.9	45.89	A0pSiCr	693.198 ± 68.07
11Ori	32549	4.64	39 ± 4	4.85	47.50	A0pSiCr	113.59 ± 46.97
-	32650	2.73	23 ± 4	2.55	33.42	B9pSi	71.00 ± 60.014
-	43819	1.0785	18 ± 4	3.32	6.6	B9pSiCr	474.12 ± 33.99
15Cnc	68351	3.18	33 ± 4	6.68	14.71	A0pSiCr	153.58 ± 65.6
3Hya	72968	11.305	18 ± 4	2.68	56.47	A1pSrCr	352.21 ± 21.53
45Leo	90569	1.4438	18 ± 4	2.35	12	A0pSiCr	348.22 ± 29.6
21Com	108945	2.0043	75 ± 4	3.08	74.7	A2pSrCr	164.40 ± 73.60
ωHer	148112	3.042	44 ± 4	2.88	66.7	A0pCrEu	199.95 ± 33.93
45Her	151525	4.1164	44 ± 4	4.46	44	B9EuCr	103.49 ± 76.15
19Lyr	179527	1.16089	28 ± 4	4	9.24	B9pSi	106.23 ± 68.13

Table1. Journal of observations. The second column are the HD (Henry-Draper catalogue) number of projected stars. The periods in Col.3 and the radiuses in Col.5 are from the Abt (2001) paper. The Vsini quantities are from Royer(2002) paper. The inclination angles in Col.6 and the Root Mean Square Longitudinal Fields Strength in the last column are measured in this work

4. Results

Almost for all the stars included in this survey maximum and minimum longitudinal magnetic fields (B_lMax & B_lMin) are given in Table 2. In those stars that we had enough data the Oblique Rotator Model parameters (i, β, B_d) are calculated. Furthermore using the Shorlin formula, we have obtained the rotation velocities for these stars. In the last column the effective longitudinal magnetic fields are given using the Byshkov (Byshkov et al, 2003) formula.

Star Name	HD Number	Vsini+σ (km/s)	B_l Max	B_l Min	i	β	B_d (Gauss)	Be$\pm\sigma$ (Gauss)
56Tau	HD27309	44+2	-630	-800	46	7	-3,492	693+68
11 Ori	HD32549	38+2	187	-233	39	85	-1,132	114+47
-	HD32650	26+2	92	52	33	23	316	71+60
-	HD43819	12+1	736	-196	8	85	11,602	474+34
15Cnc	HD68351	27+2	?	?	?	?	?	?
3Hya	HD72968	16+1	370	316	**Sini>1**	?	?	352+21
45Leo	HD90569	12+1	520	0	12	77	4,130	348+30
21Com	HD108945	52+3	495	-569	55	84	-2,194	164+74
ω HER	HD148112	39+2	-176	-216	47	5	-974	200+34
45Her	HD151525	12+1	150	-70	44	71	568	104+76
19 Lyr	HD179527	27+2	254	-295	80	42	1,008	106+68

Table2. Table of Physical data derived in this work

5. Conclusion

We have searched for magnetic fields in the photospheres of 12 magnetic $\mathbf{A_P}$ stars using the circular spectropolarimetry and Least-Squares Deconvolution, a technique shown to be effective for detecting complex fields in active stars (Donati et al. 1997). For the 12 stars classified as magnetic $\mathbf{A_P}$ stars, we provide the first detection of a fields for **HD**148112 (ω Her), as well as a convincing detection for HD151525 (45 Her). All other stars previously shown to be magnetic are reconfirmed here, and precise longitudinal field measurements have been made.

The remarkable detection rate obtained in our survey strongly suggests that all A_P stars having magnetic behavior (Preston, 1974) actually harbor magnetic fields of at least a few hundreds of Gauss.

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Also we made use of the Simbad data base, operated at **CDS**, Strasbourg, France.

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