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A search for new magnetic stars in stellar groups and open clusters

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Abstract. We present new results of our ongoing project to find new magnetic stars in stellar groups and open clusters. Observations are carried out at the 6-m and 1-m telescopes of the Special Astrophysical Observatory. Candidates are selected by analyzing the profiles of the λ5200 broad, continuum features with low resolution spectra (a modification of the Cramer & Maeder method). These candidates are observed then with high resolution and a Zeeman analyzer. We present the measurements of 6 new magnetic stars and discuss results for 2 stars with outstanding magnetic fields. To date we found 31 new magnetic stars, listed for the most part in catalogues of stellar groups. Several stars have very strong magnetic fields, among them is the SrCrEu star HD 178892 with a surface magnetic field $B_s \geqslant 20$ kG.

Keywords. Stars: chemically peculiar, stars: magnetic fields, Galaxy: open clusters, stars: individual; (HD 178892)

1. Introduction

At present we know about 250 magnetic CP stars (Romanyuk 2000), that is about 3% of the total number of known CP stars (Renson *et al.* 1991). Such a small percentage reflects that investigations of magnetic fields may be made only with large telescopes, where observing time is in high demand. Before the appearance of CCD detectors it was possible to observe stars as faint as $V = 8$ with large telescopes. Now we can go two magnitudes fainter. This permits us to make a comparative analysis of the characteristics of magnetic stars relative to Galactic structure in the solar neighborhood.

We are observing stars in open clusters and in the solar neighborhood. Investigations of nearby stars attracted our attention as a result of the statistical analysis of the spatial distribution and motions of magnetic CP stars (Kudryavtsev & Romanyuk 2003). Romanyuk & Kudryavtsev (2001) had suggested some primary orientations of the magnetic fields of such stars. However these conclusions were based on insufficient data.

Starting in 2000 we searched for new magnetic CP stars using the catalogues of Egret & Jaschek (1981), Renson (1992), Kopylov (1987), and Niedzielski & Muciek (1988). Our first list from the catalogue of CP stars in stellar groups (Egret & Jaschek 1981) had only 3 stars from open clusters. Now we are trying to expand the list of candidates by observing stars in open clusters with the SAO 1-m telescope.

2. Observations and data reduction

Obtaining Zeeman spectra of many stars would take considerable observing time at the 6-m telescope. Thus we need a criterion for the probability of finding strong magnetic fields. Cramer & Maeder (1980) showed that the depth of the $\lambda5200$ broad continuum feature may be as an indicator of the presence of a magnetic field. Our method is a modification of this method, but we use low resolution spectra rather than a photometric index. Stars are first observed with the low resolution spectrograph UAGS on the SAO 1-m telescope. Then we select stars whose depth of spectral pecularities is $\geqslant 10\%$ in the $\lambda5200$ region.

We found magnetic fields by measuring their longitudinal components using Zeeman spectra observed with Main Stellar Spectrograph of the 6-m telescope with circular polarisation analysers (Naidenov & Chuntonov 1976, Chountonov 2000). The spectra were centered at $\lambda4500$ with a resolution of about 15000. The Zeeman shifts in the spectra of magnetic stars are very subtle. Thus we obtained at least three spectra for each star on different dates. We deviated from this rule only when the magnetic field was rather strong and its presence was obvious. Then we sometimes obtained only two measurements. Data reductions were made in ESO MIDAS using the programs for Zeeman spectra reduction (Kudryavtsev 2000).

Table 1. New magnetic stars. Longitudinal magnetic field measurements.

JD 2450000+	B_e (G)	σ
HD 34163		
2191.505	−170	110
2624.359	+190	90
2625.363	−230	60
2626.356	−620	70
2917.455	−290	120
2918.434	−750	130
HD 40759		
2917.581	+1970	320
2918.545	+2050	250
HD 49223		
2624.529	+330	150
2625.536	+590	160
2626.482	−120	190
2918.584	+340	260
3097.280	+420	260
HD 49713		
2690.338	+2200	540
3097.261	−2880	350
HD 182532		
2805.450	+620	110
2807.502	+570	80
2830.495	−40	150
2831.458	+40	80
HD 192224		
2835.531	+390	110
2840.502	+220	210
3096.579	−580	70

3. New magnetic stars

We found 31 new magnetic stars whose measurements for the most part were published in Elkin *et al.* (2002), Elkin *et al.* (2003), and Kudryavtsev *et al.* (2003). The measurements of the longitudinal magnetic fields are shown in Table 1.

Here we present the latest results: 6 new stars whose magnetic fields were detected for the first time.The stars are poorly studied. For HD 40759 Maitzen & Vogt (1983) found

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$\Delta a = 0.0028$, which suggested a strong magnetic field. HD 49713 was listed in Babcock (1958) as a star with too wide spectral lines for magnetic measurements. Despite this we found a magnetic field of over 2 kG. HD 49713 was also noted by Cramer & Maeder (1980) as a star with a possibly strong field. HD 40759 is a member of OriOB1. All the other stars are included in the catalogue of stellar groups. During the first half of 2004 we observed with the 1-m telescope and have already selected several candidates. Our observations will continue.

In Table 2 we give only the observed magnetic field extrema of our first 31 magnetic stars as the original measurements were published before. Note that in some cases we have only 2 or 3 spectra for a star and thus possibly have not observed the real extrema, but these values still give some idea about the magnetic field strength.

HD 178892, HD 293764, HD 343872, and HD 349321 with very strong magnetic fields where the longitudinal component is 4 kG or more are marked in gray. We are observing them. For HD 178892 and HD 343872 we already have sufficient results to discuss them.

Table 2. Our first 31magnetic stars

HD /BD	Mag	B_e (G)	B_{extr} (G)	Pec	Cluster
HD 6757	7.7	+2170	+3100	CrEuSi	
HD 29925	8.3	−1100	−200	Si	
HD 34162	8.7	−750	+190	SrCrEu	Ori OB1
HD 38823	7.3	−2490	+1520	SrEu	
HD 39658	8.8	−970	+1350	CrEu	
HD 40711	8.4	−650	+330	SrCrEu	Ori OB1
HD 40759	8.6	+1970	+2050	CrEu	
HD 49223	9.0	−120	+590	SrEu	
HD 49713	7.3	−2880	+2200	CrEuSi	
HD 115606	8.6	−760	+680	Cr	
HD 134793	7.5	−810	+950	SrEuCr	
HD 142554	9.8	−770	+1740	CrEu	
HD 158450	8.6	−2980	+810	SrCrEu	
HD 168796	7.9	−870	+510	SiSrCr	
HD 169887	9.0	−2340	+2020	Si	
HD 170565	9.1	+1580	+1960	SrCrEu	
HD 170973	6.4	−400	+630	SiCrSr	
HD 178892	8.9	+1670	+8490	SrCrEu	
HD 182532	9.3	−40	+620	CrEu	
HD 189963	9.9	−700	+360	SrCrEu	
HD 192224	8.9	−580	+390	CrEu	
HD 196691	8.6	−1940	+2290	Si	
HD 209051	8.8	−3300	−1040	SrCrEu	
HD 231054	10.0	+380	+2530	SiSr	
HD 293764	9.5	+3590	+4040	SrCrEu	
HD 338226	9.8	+440	+1490	Si	
HD 343872	9.9	−760	+4590	SrCrEu	
HD 349321	9.3	−5560	+2190	Si	
BD +17.3622	8.8	+980	+1600	SrCrEu	
BD +32.2827	9.9	−770	+60	SrCrEu	
BD +35.3616	9.5	−520	+540	SrEu	

4. Stars with strong magnetic fields

4.1. *HD 178892*

Our observations with the 1-m telescope revealed a prominent feature near λ5150. With the 6-m telescope we obtained 17 Zeeman spectra for HD 178892. It possesses a strong

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magnetic field whose longitudinal component can be as great as 8 kG. Only 4 stars have comparable or stronger magnetic fields. These are HD 37776, HD 215441, HD 175362, and the recently discovered NGC2244 – 334 (Bagnulo *et al.* 2004). All are hot ($T_{\rm eff} \geqslant$ 15000 K) and have He or Si anomalies, but HD 178892 is a SrCrEu star, so it is definitely cooler. Among the SrCrEu stars, HD 178892 is now a record holder for magnetic field strength which makes it very interesting. As it is the coolest HD 178892 might be older than the other four stars with the similar magnetic fields. By carefully determining its age (temperature) this star may help to decide whether only young stars have strong magnetic fields.

Using our measurements of the longitudinal magnetic field we found the rotational period of HD 178892 P=8.27±0.08 days. We also tried to determine the period from Hipparcos photometry, but the star did not show sufficient photometrical variability. Using the longitudinal magnetic field curve we find $B_{\rm s} \geqslant 20$ kG. Values of $v \sin i$ vary from 20 (instrumental profile) to 45 km s^{-1} depending on the Landé g factor. This is the direct evidence of magnetic strengthening.

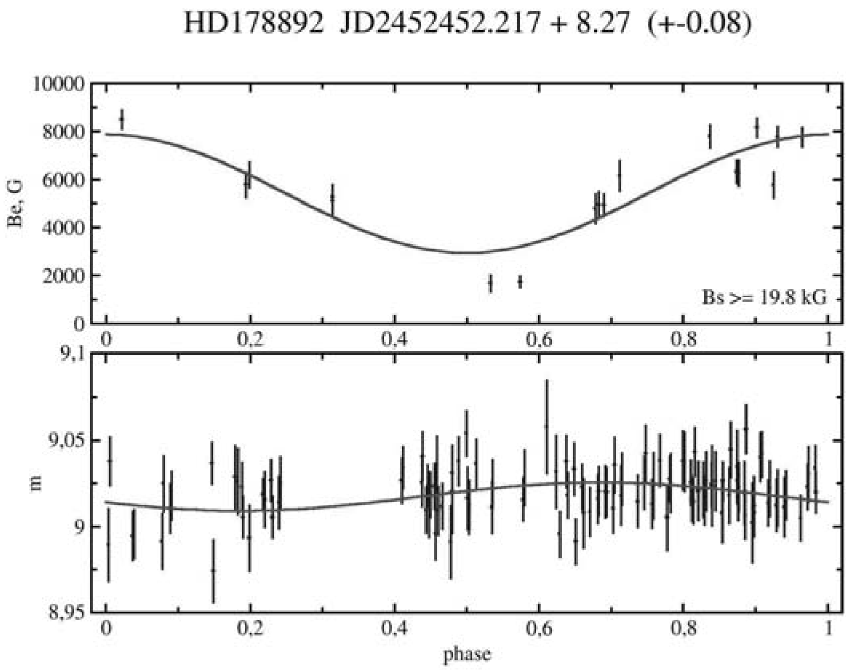

Figure 1. HD 178892, the SrCrEu star with strong magnetic field. The longitudinal magnetic field curve (top) and the HIPPARCOS photometry shown as functions of the rotational period.

4.2. *HD 343872*

We have over 20 Zeeman spectra of HD 343872. Using the measurements of the longitudinal magnetic field we found its rotational period was P=8.79±0.02 days. Tycho photometry did not show any measurable variability. The longitudinal magnetic field curve corresponds with the lower limit of the surface magnetic field $B_{\rm s} \geqslant 9$ kG.

With such a surface field $B_{\rm s}$ magnetic broadening can contribute up to 50% of the total line width. Values of $v \sin i$ determined by different lines vary from 25 to 35 km s^{-1} depending on the Landé g factor. So the contribution of magnetic broadening cannot be ignored when studying the chemical composition of the stellar atmosphere.

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Preliminary analysis of the Balmer lines profiles shows that HD 343872 has a rather high temperature ($\geqslant$ 10000 K) for a SrCrEu star and low $\log g$ (about 3.5). Spectroscopic observations by Kroll (1992) resulted in $T_{\rm eff} = 10500$ K and $\log g = 3.1$, suggesting that it is an evolved star. In any case the star is rather unusual. It is necessary to further model of its spectra to determine its atmosphere parameters and chemical composition.

References

Babcock, G. 1958, *ApJS* 3, 141

Bagnulo, S., Hensberge, H., Landstreet, J.D., Szeifert, T., Wade G.A. 2004, *A&A* 416, 1149

Cramer, N., Maeder, A. 1980, *A&AS* 41, 111

Chountonov, G.A. 2000, in: Yu.V. Gladolevskij and I.I. Romanyuk (eds.), *Magnetic Fields of CP and Related Stars*, Proc. of intern. meeting (Moscow), p. 94

Egret, D., Jaschek, M. 1981, *Comptes Rendus Symp. Liege*, vol. 23, p. 495

Elkin, V.G., Kudryavtsev, D.O., Romanyuk, I.I. 2002, *Astron. Letters*, 28, 195

Elkin, V.G., Kudryavtsev, D.O., Romanyuk, I.I. 2003, *Astron. Letters*, 29, 455

Kopylov, I.M. 1987, *Astrofizicheskie Issledovaniya (Izv. SAO)* 24, 44

Kroll, R. 1992, in: M.M. Dworetsky, F. Castelly, R. Farragiana (eds.), *Peculiar Versus Normal Phenomena in A–type and Related Stars*, Proc. of IAU Coll. 138 (ASP Conf. Ser.), vol. 44, p. 75

Kudryavtsev, D.O. 2000 in: Yu.V. Gladolevskij and I.I. Romanyuk (eds.), *Magnetic Fields of CP and Related Stars*, Proc. of intern. meeting (Moscow), p. 84

Kudryavtsev, D.O., Romanyuk, I.I. 2003, *Astrophysics* 46, 234

Kudryavtsev, D.O., Romanyuk, I.I., Elkin, V.G. 2004, in: Yu.V. Gladolevskij, D.O. Kudryavtsev and I.I. Romanyuk (eds.), *Magnetic Stars*, Proc. of intern. meeting (Moscow), (in press)

Maitzen, H.M., Vogt, N. 1983, *A&A* 123, 48

Naidenov I. D., Chuntonov G. A. 1976, *Soobscheniya SAO* 16, 63

Niedzielski, A., Muciek, M. 1988, *Acta Astronomica* 45, 375

Renson, P., Gerbaldi, M., Catalano, F. 1991, *A&AS* 89, 429

Renson P. 1992, *Bull. Inf. Centre Donnees Stellaires* 40, 97

Romanyuk, I.I. 2000 in: Yu.V. Gladolevskij and I.I. Romanyuk (eds.), *Magnetic Fields of CP and Related Stars*, Proc. of intern. meeting (Moscow), p. 18

Romanyuk I. I., Kudryavtsev D. O. 2001, *ASP Conf. Ser.* 248, 299