Search for new magnetic stars in stellar groups and open clusters

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We present new results of the ongoing project of the searching for 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 depression profile at a wavelength of 5200A with low resolution spectra (a modification of the Cramer and Maeder method). These candidates are observed then with high resolution and a Zeeman analyzer. Here we present the measurements of 6 new magnetic stars, the full list of stars founded during execution of the project and discuss results for 2 stars with outstanding magnetic fields. To this date we found 31 new magnetic stars, mostly from the catalogue of stellar groups. Several stars have very strong magnetic fields, among them the SrCrEu star HD 178892 with the surface magnetic field Bs ≥ 20kG.

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 number caused of the fact that investigations of magnetic fields may be carried out only with large telescopes, where observational time is very critical. Moreover, before the appearance of CCD detectors it was possible to observe stars with up to 8 magnitude only, even with large telescopes.

Now the appearance of new detectors allowed us to search and investigate magnetic fields of stars with up to 10 magnitudes (with the 6-m telescope). It allows to expand the space limits, where magnetic stars are observed, and for the first time make a comparative analysis of different characteristics of magnetic stars in dependence of the Galaxy structure in the Sun surroundings.

First of all we decided to observe spacely close stars and stars in open clusters. Investigations of spacely close stars attracted our attention as a result of the statistical analysis of the spatial distribution and motions of magnetic CP stars *(Kudryavtsev D.O., Romanyuk I.I., 2003; Romanyuk I.I., Kudryavtsev D.O., 2001)* pointing at some primary orientation of the magnetic fields of close stars. However these conclusions based on insufficient amount of data which must be increased.

From the 2000 we are searching for new magnetic CP stars basing on the catalogues of *Egret and Jaschek (1981)*, *Renson (1992)*, *Kopylov (1987)*, *Niedzielski and Muciek (1988)*. Our first list of candidates based on the catalogue of CP stars in stellar groups *(Egret & Jaschek, 1981)*, so here you can find only 3 stars from open clusters. Now we are trying to expand the list of candidates by observing stars from open clusters with the SAO 1-m telescope.

Observations and data reduction

Obtaining of zeeman spectra for all stars would take a lot of observational time of the 6-m telescope, so we need a criterion pointing with some probability at the presence of the strong magnetic field. We use the analysis of the 5200A depression profile. As early as 1980 *Cramer and Maeder (1980)* showed that the depth of the 5200A depression may be an indicator of the presence of the magnetic field. Our method may be considered as some modification of the Cramer and Maeder method, but they are different by the fact that we use low resolution spectra but not a photometrical index. Stars is preliminarily observed with the low resolution spectrograph UAGS at the SAO 1-m telescope and after that we select the candidates with the depth of spectral pecularities not less than 10% in the 5200A region.

Search of the magnetic field was realised by measurements of its longitudinal component using zeeman spectra observed with Main Stellar Spectrograph of the 6--m telescope with analysers of the circular polarisation *(Naidenov, Chuntonov, 1976; Chountonov, 2000)*. The spectra were observed at 4500A with resolution of about 15000. The Zeeman shift in spectra of magnetic stars is a very subtle effect, therefore we observed not less than three spectra for each star in different dates to exclude any fortuities and also to avoid, where it was possible, hits at the phase of zero longitudinal magnetic field. We deviated from this rule only when the magnetic field was rather strong and its presence was obvious. In this case we sometimes limited ourselves with two measurements.

Data reduction were made in ESO MIDAS using the programs for zeeman spectra reduction *(Kudryavtsev, 2000)*.

New magnetic stars

At present we found 31 new magnetic stars. The measurements for most part of them were published earlier in papers *Elkin et al. (2002)*, *Elkin et al. (2003)*, *Kudryavtsev et al. (2004)*. In this section we present the latest results of our project: 6 new stars where the magnetic field was detected for the first time. The measurements of the longitudinal magnetic field are shown in Table 1.

The stars are weakly studied. For HD 40759 *Maitzen & Vogt (1983)* measured the index a=28, it was pointed to a strong magnetic field. HD 49713 was listed in the Babcock's catalogue (1957) as a star with too wide spectral lines for magnetic measurements. In spite of this we succeeded in finding the magnetic field of over 2kG. HD 49713 was also noted by *Cramer & Maeder (1979)* as a star with the possible strong field.

HD 40759 is a member of OriOB1. All other stars are included in the catalogue of stellar groups. As noted above we are going to extend the list of candidates for observations to get some more stars from clusters. For this purpose during the first half of 2004 we carried out series of observations with the 1-m telescope and already selected several candidates. The observations will be continued.

JD 2450000+	Be, G	
HD 34162		
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

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

HD/BD	m	Be (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	Ori OB1
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	

Table 2. List of all the founded magnetic stars

The list of all the founded 31 magnetic stars are shown in Table 2. We give only observed magnetic field extrema as the original measurements were published before. Note that in some cases we have only 2-3 spectra for a star and thus possibly did not observe the real extrema, but these values give some idea about the magnetic field strength.

Among these stars we marked 4 stars with very strong magnetic fields where the longitudinal component runs up to 4kG and more: HD 178892, HD 293764, HD 343872, HD 349321. We are proceeding to observe these stars. For HD 178892 and HD 343872 we already have some results which are presented below.

Stars with strong magnetic fields

We will discuss here the data obtained for two stars with outstanding magnetic fields. For other stars with strong magnetic fields we did not have enough observations yet.

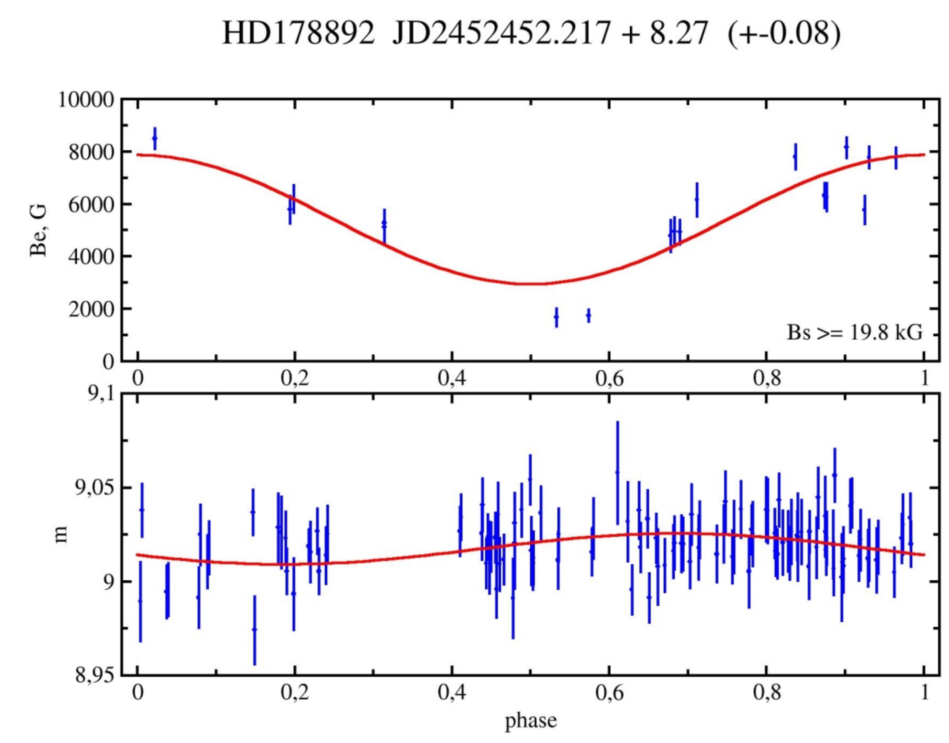
HD 178892

Our observations with the 1-m telescope revealed a prominent feature at a wavelength near 5150A. With the 6-m telescope we obtained 17 Zeeman spectra for this star. It possesses a strong magnetic field whose longitudinal component runs up to 8kG.

At present we know only 4 stars with a comparable or higher magnetic fields. These are HD 37776, HD 215441, HD 175362 and recently discovered NGC2244-334 *(Bagnulo et al., 2004)*. All the stars are hot (the effective temperature Te is equal or higher of 15000K) and have He or Si anomalies, while HD 178892 is a SrCrEu star, so it is definitely cooler. Among the numerous and cooler SrCrEu stars, HD 178892 can be a record holder by its magnetic field strength.

This fact makes the star very interesting. By its temperature HD178892 "have a chance" to be older than the other stars with strongest magnetic fields. So in the future it will be necessary to carefully determine its age (this actually means its temperature). It may become a strong argument in support of one of the sights of view: either only young stars have strong magnetic fields or vice versa.

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 evaluated the lower limit of the surface magnetic field Bs ≥ 20kG. Values (v sin i) vary from 20 (instrumental profile) to 45km/s in dependence of the Lande factor. This is the direct evidence of the magnetic strengthening.



HD 178892 - SrCrEu star with strong magnetic field. Longitudinal magnetic field curve (up) and Hipparcos photometry shown with the rotational period

HD 343872

We got over 20 Zeeman spectra for this star. Using the measurements of the longitudinal magnetic field we found the rotational period for the star P=8.79∓0.02 days. Tycho photometry did not show sufficient variability. The longitudinal magnetic field curve corresponds with the lower limit of the surface magnetic field Bs ≥ 9kG.

With such a surface field Bs magnetic broadening can contribute up to 50% of the total line width. Values (v sin i) determined by different lines vary from 25 to 35km/s in dependence of the Lande factor. So the contribution of magnetic broadening cannot be ignored when studying the chemical composition of the stellar atmosphere.

Preliminary analysis of Balmer lines profiles shows that HD343872 has rather high temperature (over 10000) for a SrCrEu star and low lg g (about 3.5). Note, that *Kroll (1992)* carried out its spectroscopic observations and found Te=10500K and lg g=3.1, suggesting that HD343872 is an evolved star.

In any case the star is rather unusual. It is necessary to make further modeling of its spectra for determination of the atmosphere parameters and chemical composition.