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NEW OPPORTUNITIES FOR SEARCHING FOR MAGNETIC STAR CANDIDATES

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ABSTRACT

Spectropolarimetric observations required for direct measurement of stellar magnetic fields are technically complex and require a large amount of observation time. This fact is an obstacle to a large-scale search for new magnetic chemically peculiar stars. To improve the efficiency of the search for such objects, a reliable preliminary selection of candidates is necessary, which is traditionally based on the identification of characteristic photometric patterns and anomalies in the chemical composition. Recently, a new approach was proposed — selection by features of line splitting in unpolarized infrared spectra associated with the Zeeman effect. In this work, observations of 18 stars selected by these features were carried out using the Main Stellar Spectrograph on the 6-m telescope. As a result, the presence of a magnetic field was reliably confirmed for 15 objects, which demonstrates the high efficiency of the proposed selection criterion and opens up new opportunities for searching for magnetic star candidates.

Key words: stars: magnetic field – stars: chemically peculiar

1 INTRODUCTION

Despite numerous attempts to explain the phenomenon of large-scale magnetic fields of upper main sequence stars, their nature and the extent of their influence on evolution have not been fully described. Various theoretical models have been proposed to explain the origin and evolution of magnetic fields, but none of them can account for the full range of observed manifestations of stellar magnetism (Moss 1989; Mestel 2003; Schneider et al. 2019).

Magnetic fields have the most noticeable effect on some subclasses of chemically peculiar (CP) stars. The so-called Ap/Bp- and He-rich/weak stars (subclass CP2/CP4 according to Preston (1974)) show significant strengthening and variability of lines of various chemical elements. In particular, Ap stars are characterized by anomalously strengthened lines of silicon, strontium, chromium, and rare earth elements, whereas He-rich and He-weak stars of early B-classes exhibit anomalously strengthened or weakened helium lines. The observed anomalies in these objects are not associated with changes in atmospheric temperature but rather reflect the uneven distribution of chemical elements in the stellar atmosphere (Preston 1974).

These elements are concentrated in spots distributed nonuniformly across the stellar surface, causing strong photometric and spectral variability. As the star rotates, the observer sees different portions of its surface, leading to changes in both spectral and photometric characteristics. At the same time, the spots generally remain stable over long periods (Bohlender et al. 1993).

The most complete compiled catalog of CP stars contains 8205 objects. Since then, advances in large-scale photometric surveys (Kepler, TESS, ASAS-SN, ZTF) and spectroscopic surveys (LAMOST, Gaia-ESO, APOGEE) have enabled identification of CP stars based on homogeneous, high-quality data covering large samples. This has significantly expanded CP star catalogs, both in terms of photometric features (Hümmerich et al. 2018; Bernhard et al. 2020; Bauer-Fasching et al. 2024) and spectroscopic characteristics (Potravnov et al. 2024; Hümmerich et al. 2020, 2024).

2 MAGNETIC FIELD OF CHEMICALLY PECULIAR STARS

Ap/Bp stars have stable global magnetic fields with slow dissipation, the structure of which does not change over long periods of time (Romanyuk et al. 2024). In addition, they cover a wide range of ages and spatial distributions in the Galaxy (Kochukhov & Bagnulo 2006; Kudryavtsev et al. 2006), which allows us to study the evolutionary and kinematic aspects of stellar magnetism.

Babcock first detected a magnetic field in the CP star 78 Vir of spectral type A (Babcock 1947). This was the first reliable confirmation of the existence of a magnetic field in a star

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other than the Sun, marking the beginning of observational stellar magnetometry.

Since then, a large sample of known objects with confirmed magnetic fields has been accumulated to study the nature of CP star magnetism. The most noteworthy are large-scale observational programs using medium- and high-resolution spectropolarimetry (e.g., BOB (Morel et al. 2014), MiMeS (Alecian et al. 2015), BinaMIcS (David-Uraz et al. 2021), MOBSTER (Shultz et al. 2020)), as well as some statistical surveys (Kochukhov & Bagnulo 2006; Kudryavtsev et al. 2006; Mathys 1995; Wade et al. 2000, 2016; Sikora et al. 2019).

To estimate the magnetic field magnitude using the spectropolarimetric method, a differential circular polarization analyzer is employed, which measures the relative shifts of circularly polarized components of spectral lines split due to the Zeeman effect (Babcock 1958). In this case, only the effective longitudinal field (the projection of the magnetic field vector onto the line of sight, weighted average over the stellar disk) is recorded; its magnitude varies as the star rotates. To explain the periodic magnetic variability, a model of an inclined rotator was proposed (Stibbs 1950), in which the magnetic axis is inclined relative to the rotation axis. Such a configuration leads to cyclic changes in the observed magnetic projection, typically producing a sinusoidal curve.

The above surveys are limited by both the number of telescopes equipped with polarimetric instruments and the high cost of observing time, making effective preliminary selection especially relevant. Although large-scale photometric (TESS, Kepler) and spectroscopic (LAMOST) surveys have significantly expanded the list of candidates, analysis of light curves or unpolarized spectra alone is insufficient to estimate the magnetic field strength. Modern works (Romanyuk et al. 2023; Yakunin et al. 2023; Chojnowski et al. 2019) demonstrate the high efficiency of combining large surveys with targeted spectropolarimetry to detect and confirm magnetic CP stars.

Increasing the sample of known magnetic CP stars will allow us to study possible connections between the magnetic fields of individual objects and the magnetic field of the Galaxy. Currently, magnetic fields of stars fainter than 11–12 mag are registered extremely rarely, which significantly limits the depth and volume of the sample. As a result, most known magnetic CP stars are concentrated within a radius of about 1 kpc from the Sun.

The relative scale of magnetic line splitting increases with wavelength, which significantly enhances the sensitivity of the technique in the infrared region of the spectrum (Leone et al. 2003). Therefore, the transition to infrared unpolarized spectra, where the Zeeman effect is more pronounced, opens new possibilities for detecting and analyzing magnetic fields, including those with complex structures. A large-scale search for magnetic stars based on Zeeman splitting in the IR region was first carried out by Chojnowski et al. (2019). Analysis of a large array of IR spectra from the APOGEE survey allowed classification of about 1000 CP stars. The authors identified 157 objects with signs of magnetic line splitting, from which they estimated the magnitude of the surface magnetic field, B_s. However, further spectropolarimetric observations in the optical range are required to unambiguously confirm the magnetic nature of the splitting.

3 MAGNETIC STAR CANDIDATES

As a first step in this work, we selected 33 stars from the catalogue (Chojnowski et al. 2019). For 18 of them, we carried out observations with the Main Stellar Spectrograph (MSS) (Panchuk et al. 2014) using the circular polarization analyzer (Chountonov 2016) during the period 2024–2025. Spectral data processing was performed following a standard method using the ZEEMAN context (Kudryavtsev 1999) of the ESO-MIDAS system.

On each observing night we measured standard stars with known longitudinal magnetic field variability curves, such as 53 Cam, α^2 CVn, and β CrB. We also regularly measured stars with magnetic fields clearly below the detection limit (“zero” field standards), such as β Gem and UMa. The level of the false instrumental magnetic field B_e does not exceed 100 G (Romanyuk et al. 2024).

We determined the longitudinal magnetic field B_e using a modified classical method (Babcock 1958). Since the rotation periods are unknown for many stars from the catalog (Chojnowski et al. 2019), we used the root-mean-square value of the field $B_{\rm rms}$, the corresponding error $\sigma_{\rm rms}$, and the normalized goodness-of-fit criterion χ^2/n (Bohlender et al. 1993) to analyze the magnetic nature of the objects.

$$B_{\rm rms} = \left(\frac{1}{n} \sum_{i=1}^{n} B_{{\rm e}i}^2 \right)^{1/2} \qquad (1)$$

$$\sigma_{\rm rms} = \left(\frac{1}{n} \sum_{i=1}^{n} \sigma_i^2 \right)^{1/2} \qquad (2)$$

$$\chi^2/n = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{B_{{\rm e}i}}{\sigma_i} \right)^2 \qquad (3)$$

The first results of the magnetic field measurements are presented in Table 1. The columns of the table include: the name of the star in the HD, BD, and TYC catalogues; the apparent stellar magnitude from SIMBAD; the peculiarity type from the catalogue (Renson & Manfroid 2009); surface magnetic field measurements from Chojnowski et al. (2019); our measurements of the root-mean-square magnetic field $B_{\rm rms}$ and the χ^2/n criterion; and the number of spectra obtained.

4 CONCLUSION

This paper presents the first intermediate results of spectropolarimetric observations of 18 stars selected from a sample of 33 objects in the catalogue (Chojnowski et al. 2019).

Table 1. Results of magnetic field assessment of 18 stars from the list of (Chojnowski et al. 2019).

Star	m_V (mag)	Sp. pec	$B_s \pm \sigma$ (kG)	$B_{\rm rms} \pm \sigma$ (kG)	χ^2/n	n
HD2887	8.4	B9 Si	4.95 ± 0.24	0.44 ± 0.25	8.1	6
HD13404	8.8	A0 SrCrEu	21.89 ± 0.52	3.68 ± 0.38	92.8	19
HD14873	9.1	B9 Si	5.63 ± 0.34	0.82 ± 0.14	42.2	4
HD18410	9.2	B9 Si	5.01 ± 0.40	2.41 ± 0.32	110.8	4
HD36644	9.6	A0 SrCrEu	18.48 ± 0.27	2.09 ± 0.15	408.4	14
HD38586	9.3	B9 Si?	6.73 ± 0.66	0.85 ± 0.50	2.9	2
HD46297	9.0	B9 Si?	6.06 ± 0.23	1.05 ± 0.52	483.6	4
HD47074	9.4	B9 Si	11.85 ± 0.15	2.40 ± 0.13	336.8	2
HD188103	8.0	B9 Si	10.10 ± 0.62	0.29 ± 0.19	5.3	4
HD225114	8.1	A0 Si	7.46 ± 0.53	0.97 ± 0.22	30.6	10
BD+57°764	10.0	B9 Si	5.60 ± 0.98	0.56 ± 0.26	4.8	2
BD+60°562	10.1	A0 SrCrEu	9.88 ± 0.34	3.83 ± 0.18	–	1
BD+62°352	10.2	B9 Si	7.34 ± 1.16	0.43 ± 0.49	–	1
BD+64°352	9.5	A0 SrCrEu	10.98 ± 0.55	4.24 ± 0.39	448.2	15
TYC3676-505-1	11.2	A0 SrCrEu	18.49 ± 0.76	0.76 ± 0.08	–	1
TYC3681-1528-1	10.5	A0 SrCrEu	9.67 ± 0.50	1.51 ± 0.08	–	1
TYC4299-696-1	10.6	A0 SrCrEu	7.92 ± 0.89	1.45 ± 0.35	–	1
TYC4306-1062-1	10.8	A0 SrCrEu	4.17 ± 0.28	1.80 ± 0.07	–	1

The observations were carried out during 2024–2025 at the 6-m BTA telescope using the MSS spectropolarimeter equipped with a circular polarization analyser.

More than 80 per cent of the observed stars exhibit magnetic fields exceeding 300 G, highlighting the high efficiency of the selection method employed. Several objects, including HD 38586, BD+57°764, and BD+62°352, require further observations but can already be regarded as promising candidates for magnetic CP stars.

These results demonstrate that the preliminary selection of magnetic CP stars based on unpolarized infrared spectra can serve as a highly effective complement to spectropolarimetric techniques. This approach enables the expansion of the candidate sample for targeted follow-up observations, which remain essential for the accurate confirmation and quantitative determination of stellar magnetic fields.

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REFERENCES

Alecian E., Neiner C., Wade G. A., et al., 2015, Proc. IAU Symp., 307, 335

Babcock H. W., 1947, Astrophys. J., 105, 105

Babcock H. W., 1958, Astrophys. J. Suppl. Ser., 3, 141

Bauer-Fasching B., Bernhard K., Brändli E., et al., 2024, A&A, 687, A211

Bernhard K., Hümmerich S., Paunzen E., 2020, MNRAS, 3330

Bohlender D. A., Landstreet J. D., Thompson I. B., 1993, A&A, 269, 376

Chojnowski S. D., Hubrig S., Hasselquist S., et al., 2019, ApJ Lett., 873, L5

Chountonov G. A., 2016, Astrophys. Bull., 71, 495

David-Uraz A., Shultz M. E., Petit V., et al., 2021, MNRAS, 504, 4849

Hümmerich S., Mikulášek Z., Paunzen E., et al., 2018, A&A, 619, A98

Hümmerich S., Paunzen E., Bernhard K., 2020, A&A, 640, A40

Hümmerich S., Bernhard K., Paunzen E., 2024, A&A, 692, A231

Kochukhov O., Bagnulo S., 2006, A&A, 450, 763

Kudryavtsev D. O., 1999, in Proc. Intern. Meeting on Magnetic Fields of Chemically Peculiar and Related Stars, SAO RAS, Nizhnij Arkhyz, Russia, Ed. by Y. V. Glagolevskij and I. I. Romanyuk, 84

Kudryavtsev D. O., Romanyuk I. I., Elkin V. G., Paunzen E., 2006, MNRAS, 372, 1828

Labadie-Bartz J., Hümmerich S., Bernhard K., et al., 2023, A&A, 676, 55

Leone F., Vacca W. D., Stift M. J., 2003, A&A, 409, 1055

Mathys G., 1995, A&A, 293, 746

Mestel L., 2003, ASP Conf. Ser., 305, 3

Morel T., Castro N., Fossati L., et al., 2014, Messenger, 157, 27

Moss D., 1989, MNRAS, 236, 629

Panchuk V. E., Chuntonov G. A., Naidenov I. D., 2014, Astrophys. Bull., 69, 339

Paunzen E., Prišegen M., Hümmerich S., et al., 2024, Contrib. Astron. Obs. Skalnaté Pleso, 54, 5

Potravnov I., Piskunov N., Ryabchikova T., 2024, A&A, 689, A111

Preston G. W., 1974, ARA&A, 12, 257

Renson P., Manfroid J., 2009, A&A, 498, 961

Romanyuk I. I., Moiseeva A. V., Kudryavtsev D. O., et al., 2023, Astrophys. Bull., 78, 49

Romanyuk I. I., Kudryavtsev D. O., 2008, Astrophys. Bull., 63, 139

Romanyuk I. I., Moiseeva A. V., Yakunin I. A., Kudryavtsev D. O., 2024, Astrophys. Bull., 79, 644

Schneider F. R. N., Ohlmann S. T., Podsiadlowski P., et al., 2019, Nature, 574, 211

Semenko E., Romanyuk I., Yakunin I., et al., 2022, MNRAS, 515, 998

Shultz M. E., Owocki S., Rivinius T., et al., 2020, MNRAS, 499, 5379

Sikora J., Wade G. A., Power J., Neiner C., 2019, MNRAS, 483, 2300

Stibbs D. W. N., 1950, MNRAS, 110, 395

Thomson-Paressant K., Neiner C., Labadie-Bartz J., 2024, A&A, 689, 208

Wade G. A., Donati J.-F., Landstreet J. D., Shorlin S. L. S., 2000, MNRAS, 313, 851

Wade G. A., Neiner C., Alecian E., et al., 2016, MNRAS, 456, 2

Yakunin I. A., Semenko E. A., Romanyuk I. I., et al., 2023, Astrophys. Bull., 78, 141