MAIN RESULTS OF MAGNETIC FIELD OF CP STARS STUDIES WITH THE 6M TELESCOPE BTA IN LAST DECADE (2005-2019).

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Spectropolarimetric observations of more than 200 chemically peculiar stars have been carried out during 2005-2019 at the 6m telescope with the aim of searching for the presence of stellar stellar magnetic fields. Magnetic fields have been detected in 80 of them. Different correlation between magnetic fields and anomalies in the energy distribution in the continua of the stars have been considered.
We have studied magnetic fields and other physical parameters of chemically peculiar stars in Orion OB1 association. We have obtained at least 500 zeeman spectra for 55 very young stars, we have found 10 new magnetic stars in association.
We have studied very slow rotation of magnetic stars with period of rotation more than 1 year. We have found very long period of rotation for three stars: 3.7 years for HD 18078, 29 years for HD 50169 and 17 years for HD 965. The results of unique star observations are discussed.

Keywords: Stars—Chemically peculiar stars—Magnetic field

1. GENERAL REVIEW

Time Allocation Committee offered 550 nights from 2005 to 2019 for all type of magnetic stars for observations with the BTA, which corresponds to approximately 13% of the distributed time.

Largest long-term programs from 2005 to 2019 are shown in Table 1.

In addition telescope time was allocated for short-term programs by Yu. V. Glagolevskij, E. A. Semenko, I. S. Savanov, A. I. Kolbin et al. Total 12000 zee-

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Table 1. Largest long-term programs.

Kudryavtsev D.O.	SAO RAS	New magnetic CP stars	101
Romanyuk I.I.	SAO RAS	Magnetic field of massive stars	85
Wade G.	Canada	Geometry of magnetic field of CP stars	71
Piskunov N.E.	Sweden	Magnetic mapping of CP stars	48
Lamzin S.A.	SAI MSU	Magnetic field of T Tau stars	45
Polosukhina N.S.	Crimea	Litium in magnetic stars	32
Kholtygin A.F.	SPBU	Microvariability of OB stars	25
Valyavin G.G.	SAO RAS	Magnetic field of white dwarfs	25

man and echelle-spectra were obtained. Most of observations were executed using Main Stellar Spectrograph (MSS) (R=15000, CCD 4600x2000 px, $\Delta\lambda = 500$ Å) [13]. Zeeman analyzers designed and constructed by G. A. Chountonov [3].

Raw MSS frames were reduced in a common spectroscopic way using the sets of routines from ESO-MIDAS [5] and IRAF system.

2. MAIN RESULTS OF MAGNETIC FIELD MEASUREMENTS, OBTAINED BY SAO GROUP

Main directions of SAO RAS group activity concerning on magnetic chemically peculiar stars study:

- search for new magnetic stars;
- magnetic field of massive stars;
- very slowly rotating stars;
- study of various unique stars.

2.1. Search for new magnetic stars

The Zeeman effect is very weak and its influence on the spectrum in general is insufficient. Only 25% of chemically peculiar stars have measurable magnetic fields. Search for effective candidates is very important because of high pressure for observation time at large telescopes. The best way for selections of magnetic candidates is study of CP stars with large flux depression at λ 5200 Å. The results are know from Δa [7] photometry from the Vienna observatory and Z-parameter from Geneva photometric system [12].

Cramer and Maeder [4] found correlation between intensity of flux depression and magnetic field value on the surface of CP stars.

We observed all possible CP stars with large Δa or Z-parameters. Practically all of the stars have large magnetic field. We founded 72 new magnetic CP stars among 96 candidates [6] and more than 70 new magnetic CP stars after 2006 [16–20] and now the total number of magnetic CP stars is about 500. Two hundred of them were found with the 6-m telescope.

A few conclusions concerning on the all sample of magnetic CP stars.

1. No large-scale magnetic field stronger than 50 kG is found in CP stars. This is the limit: a stronger field cannot be formed in CP stars.

2. The distribution function of a magnetic field of CP stars: the number of stars strongly decreases for field larger than 1 kG. For the stars with field weaker then 1 kG very strong influence of different instrumental effect.

3. Magnetic CP stars are observed in the age interval from 1 million to hundreds of million years in clusters of different ages and in the field.

4. No differences in spatial distribution between peculiar and normal A and B-stars.

Unfortunately, no new measurements of Vienna Δa and Geneva Z-parameters. New possibilities have appeared recently. Accurate photometric observations with satellites Kepler and TESS are available now. Light curves of magnetic CP stars are of typical shape. Hundreds of light curves have been obtained for CP stars already. These new opportunity to search for them is available (detail in the paper by Yakunin et el, this meeting).

We calculated fundamental parameters of 160 new magnetic CP stars [11]. New data are in the good coincidence with the previous one.

2.2. Magnetic field of massive stars

2.2.1. Introduction

It is need to know the age of different type of CP stars for study the evolution of their magnetic fields. Most of Ap stars (70%) are field stars and their ages are poorly know. Most of Bp stars (75%) are cluster members with well determined ages. We selected 17 open clusters and associations with 3 CP stars at least.

The list of these clusters are presented in Table 2.

Ages were taken from Paunzen's catalogue WEBDA [14].

Orion OB1 association matched best, we selected 85 CP stars in it using the catalogue of Renson and Manfroid [15]. Among them: 23 Am-stars, 7 -He-rich, 27 - He-weak,19 - Si,Si+ and 9 peculiar stars of other type.

Table 2. Ap/Bp stars in open clusters and association.

Cluster	Age (log t)	Number of stars
Orion OB1	6-7	85
Sco-Cen	6-7	34
Pleiades	8.13	5
Alpha Per	7.85	8
Coma	8.65	8
NGC 2242	7.85	7
NGC 2287	8.38	12
IC 4756	8.70	6
IC 4665	7.63	3
Hyades	8.90	3
Berkley 11	7.72	3
NGC 884	7.03	3
NGC 1039	8.25	4
NGC 6350	6.87	3
NGC 6871	6.96	3
NGC 7092	8.45	4
Trumpler 57	7.05	7

2.2.2. CP stars in Orion OB1 association

Stellar content of Orion OB1 association numbers of 814 objects [2]. Total fraction of CP stars is 10.4% which is usual for field stars (see Figure 1).

Age of subgroups and number of all A and B-stars and CP-stars are presented in Table 3.

Table 3. Age of subgroups and number of all A and B-stars and CP-stars.

Subgroups	Age (log t)	All stars	CP stars	Fraction
A	7.05	311	24	7.7%
B	6.23	139	21	15.1%
C	6.66	350	37	10.6%
D	> 6.0	14	3	21.4%

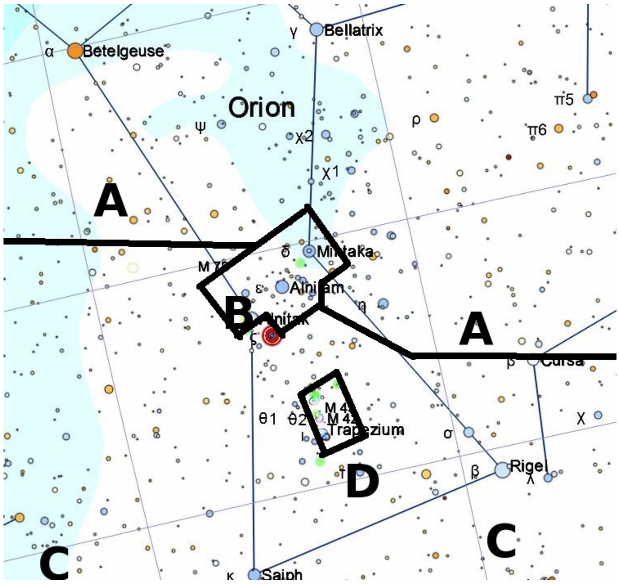

Fig. 1. Four subgroups in Orion OB1 association.

The fraction of CP stars decrease with age from 21.4% (subgroup D) to 7.7% (subgroup A). Gaia parallaxes indicate distances from 100 and 300 pc for 23 Am stars, they appeared not to be members of the Orion OB1 association 59 Bp stars, account 13.4% of the total number of B-stars in association.

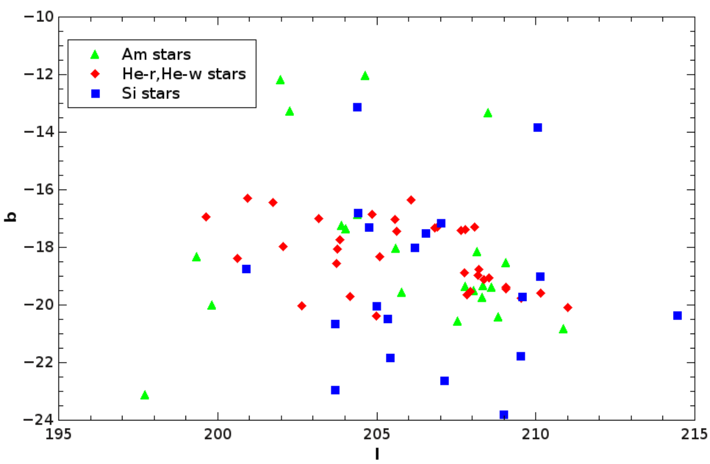

Fig. 2. Spatial distribution of CP stars in Orion OB1 association.

We determined magnetic fields, radial velocities V_R, rotational velocities $v_e \sin i$, effective temperatures T_{eff} and other fundamental parameters for most stars in association (see dissertation thesis by A. V. Moiseeva, 2018). We found 10 new magnetic CP stars in Orion, HD 34736 among them is extremely anomalous [21] and more than 15 new double and multiple stars.

Preliminary results on magnetic field measurements of CP stars in different subgroups of association are as follows:

- subgroup A: 7 stars out of 15 (46.7%) are magnetic, for 7 magnetic stars average $<B_e>$ = 915 ± 298 Gs using regression method [1];
- subgroup B: 10 magnetic and 4 probably magnetic stars out of 16 Ap/Bp stars;
- subgroup C: 12 magnetic and 4 probably magnetic stars out 24 Ap/Bp stars;
- subgroup D: no data for 3 CP stars.

We need to get new observations for subgroups B.C and D. The proportion of CP stars among normal and the proportion of magnetic stars (for subgroups A,B,C) decrease with age in the Orion OB1 association. Because of the effective temperatures in subgroups A,B and C are approximately equal, we have age dependence but not temperature dependence.

2.3. Very slowly rotation magnetic stars.

We studied very slowly rotating stars (with period of rotation more than 1 year). We will demonstrate below results of our magnetic monitoring for 3 Ap stars: HD 18078, HD 50169 and HD 965.

2.3.1. HD 18078

Period of rotation P = $1358^d \pm 12^d$. More detail study described in paper [8]. Magnetic field variation see in Figure 3.

2.3.2. HD 50169

Period of rotation P = $29^y.04 \pm 0^y.82$.

At Figure 4 different symbols indicates results of measurements by Babcock (1958), Mathys and Hubrig (1997), Mathys (2017), Romanyuk et al. (2014). For more details see [9].

2.3.3. HD 965

Period of rotation P = $16^y.5 \pm 0^y.5$. Magnetic measurements variation see at Figure 5.

For more details see [10].

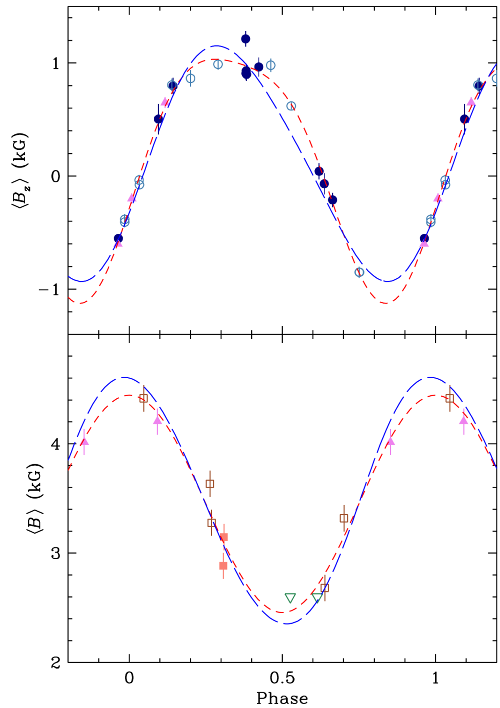

Fig. 3. Mean longitudinal magnetic field (top) and mean magnetic field modulus (bottom) of HD 18078 against rotation phase.

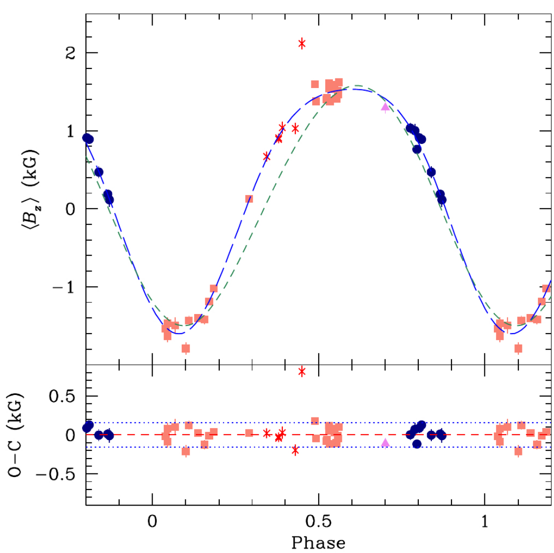

Fig. 4. Mean longitudinal magnetic field of HD 50169 against rotation phase.

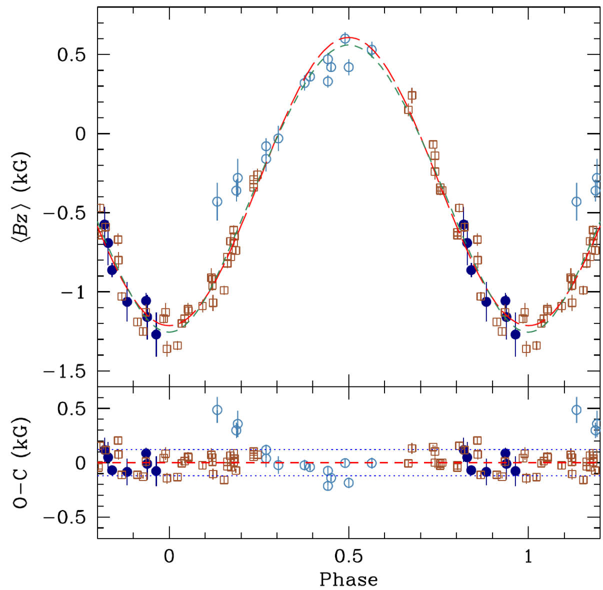

Fig. 5. Mean longitudinal magnetic field of HD 965 against rotation phase.

2.4. Unique stars.

We have detailed study of most interesting stars with rotational phase. As for example, we demonstrated below the results of our investigation of chemically peculiar star HD 34736, member of Orion OB1 association.

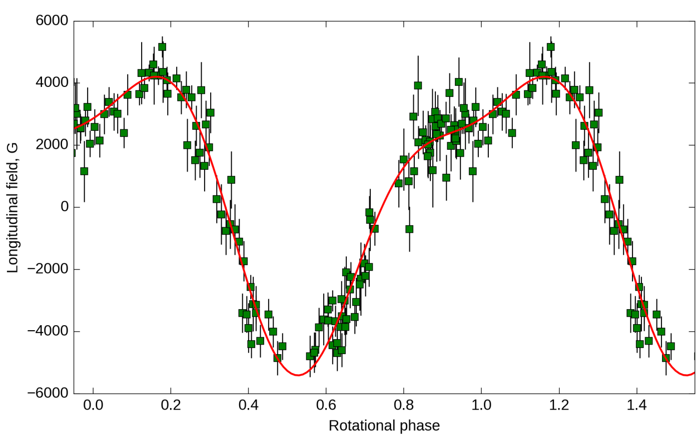

Fig. 6. Longitudinal field variations of HD 34736 against phase of rotation period P $= 1^{d}.29$.

The star is a SB2 binary. The primary, secondary components have temperatures of 13700 K and 11500 K. The lines of the primary component are broads with $v_e \sin i = 75$ km s^{-1}, the secondary component lines are even broader with $v_e \sin i > 100$ km s^{-1}. The orbital period is not determined exactly and is in within the limits from 80^d to 85^d, eccentricity exceeds $e = 0.8$.

Magnetic field of the star was discovered from observation from 6-m telescope. We have obtained more than 130 zeeman spectra (see Figure 6). Magnetic field in the surface of the star exceed 10 kG.

3. CONCLUSION

The BTA remains one of the main world telescope, where magnetic fields are measured. As for CP stars, 200 out of 500 magnetic stars have been discovered with our telescope.

4. ACKNOWLEDGEMENT

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