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# Magnetic field of massive chemically peculiar stars in the Orion OB1 association

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**Abstract.** Spectropolarimetric observations of 55 chemically peculiar stars in the Orion OB1 association were obtained at the 6 m telescope of the Russian Academy of Sciences with the aim of searching for the presence of stellar magnetic fields. We found 8 new magnetic stars in addition to 20 previously known objects. The frequency of chemically peculiar A and B-type stars among normal A and B-type stars and the frequency of magnetic stars among all chemically peculiar stars decreases with age in the Orion OB1 association.

**Key words:** stars: magnetic field – stars: evolution – open clusters and associations: general

## 1. Introduction

The search for new magnetic stars is a complicated and time-consuming task, because magnetic field measurements require either special spectropolarimeric methods (Zeeman measurements), very high spectral resolution, or both. Chemically peculiar (CP) stars were the first objects other the Sun in which a magnetic field was found (Babcock, 1947), and currently magnetic fields were detected in about 450 CP stars. However, the latest catalogue of CP stars (Renson & Manfroid, 2009) contains a much larger number of 8200 objects, about half of them are non-magnetic Am stars, and the second half are potentially magnetic Ap and Bp stars.

The process of formation and evolution of magnetic CP stars is not clear yet, but the fossil field theory has a number of advantages compared to the alternative dynamo mechanism. Observations of magnetic CP stars in open clusters of different ages is the best way to study the formation and evolution of these objects. However, observations of stars in cluster areas also result in some selection effect towards more massive and brighter cluster members owing to the instrumental magnitude limit. Therefore, most of the observed Ap stars (70%) in cluster areas are actually field stars and their ages cannot be directly constrained, but most of the Bp stars (75%) are cluster members and provide a well-determined age (see discussion by Romanyuk et al., 2013).

## 2. CP stars in Orion OB1 association

For the observations with the 6-m telescope we selected 17 stellar populations of various ages that host at least three CP stars. Two groups, the Orion and the Scorpius-Centaurus associations, have been investigated in sufficient detail earlier, thus there are also a lot of additional data available in the literature.

In the Orion OB1 association we find 85 chemically peculiar stars based on the catalogue by Renson & Manfroid (2009), the by far largest number of CP stars in an association. Blaauw (1964) identified four regions inside the assocation: the subgoups (a), (b), (c), and (d) that slightly differ in the age and stellar content. The age ranges from about one million years to about 10 millions of years (see Romanyuk et al., 2013, for details). Additionally, Brown et al. (1994) provide a list of O, B, A and early F-star members of the Orion OB1 association. The average frequency of CP stars in the association is 10.4%, which is generally the same value as often quoted in the literature for the overall Galactic frequency of CP stars. Among the selected 85 CP stars we find 23 Am, 7 He-strong, 27 He-weak, 19 Si and Si+ stars, and nine stars of other types.

Table 1 shows the distribution of normal and peculiar stars for the individual Orion subgroups. The data indicate that the fraction of CP stars decreases with the age from 21.4% (subgroup d) to 7.7% (subgroup a).

**Table 1.** The age of the subgroups and the number of normal stars and CP objects in the Orion O B1 association.

| Subgroup | 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% |

However, parallaxes by the Hipparcos mission and proper motions indicate that the Am stars probably do not belong to the association and are most likely foreground objects. Thus, we exclude them from our investigation and continue our study with only 62 potentially magnetic Bp and Ap stars. For five of these objects we have no magnetic field measurements yet, therefore in our following analysis we consider 57 Bp and Ap stars: 15 in subgroup (a), 15 in subgroup (b), 24 in subgroup (c), and 3 in subgroup (d).

## 3. Magnetic field of CP stars in Orion OB1 association

Borra & Landstreet (1979) were among the first to measure the magnetic field of some CP stars in the Orion association. We continue these efforts using the 6 m telescope of the Russian Academy of Sciences (e.g. Romanyuk et al., 2016b). In

2011-2016 we obtained more than 500 polarized Zeeman spectra of 55 Ap and Bp stars in this association. The measurements have been published earlier: Yakunin (2013); Semenko et al. (2014); Romanyuk et al. (2016a, 2017).

The most interesting object among new detected magnetic stars in the association is certainly HD 34736. It belongs to the subgroup (c) and the spectrum shows strong silicon lines. The star has a very strong magnetic field with a longitudinal component that varies from $-5$ to $+5$ kG. We obtained more than 130 measurement of the longitudinal field $B_e$ and constructed the $B_e$ variability curve with a period of $P = 1.29$ days (Fig. 1). The curve is clearly anharmonic, suggesting that the magnetic field topology significantly deviates from that of a dipole configuration. Furthermore, the star is a SB2 system with effective temperatures for the primary and secondary component of 13700 K and 11500 K, respectively. The spectral lines of the primary component are broad and indicate a projected rotational velocity $v_e \sin i = 75$ km s$^{-1}$, while the spectral lines of the secondary component even show a $v_e \sin i$ of more than 100 km s$^{-1}$.

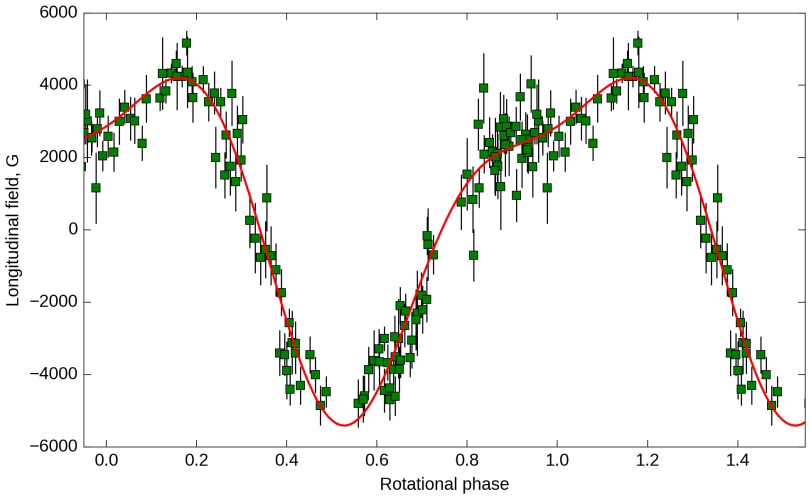


**Figure 1.** Longitudinal field $B_e$ variations for HD 34736 with a period of $P = 1.29$ days.

We have collected all $B_e$ measurements for stars in the Orion OB1 association, both our own and taken from the literature. Table 2 lists the magnetic stars with reliably measured magnetic fields, i.e. the stars for which $\langle B_e \rangle$ is larger than $3\sigma$ and/or for that Zeeman signatures are clearly seen in the spectra. The table provides the identifier in the HD catalog, the subgroup in the association, spectral and peculiarity types, the logarithm of the effective tem-

perature $\log T_{\rm eff}$, the root-mean-square magnetic field $\langle B_{\rm e}\rangle$, its error $\sigma$, and the number of measurements $N$.

**Table 2.** List of magnetic stars.

| Star (subgroup) | Sp, pec | $\log T_{\rm eff}$ | $\langle B_{\rm e}\rangle$, G | $\sigma$, G | $N$ |
|---|---|---|---|---|---|
| HD 34736 (c) | B8 Si | 4.11 | 4700 | 350 | 130 |
| HD 34889 (c) | B9 Si | 4.02 | 636 | 120 | 2 |
| HD 35008 (a) | B9 Si | 4.12 | 300 | 100 | 2 |
| HD 35298 (a) | B6 He-wk | 4.20 | 2145 | 139 | 30 |
| HD 35456 (a) | B7 He-wk | 4.16 | 441 | 96 | 8 |
| HD 35502 (a) | B6 He-wk | 4.20 | 1490 | 140 | $> 10$ |
| HD 36313 (b) | B8 He-wk | 4.06 | 1020 | 450 | 15 |
| HD 36429 (a) | B6 He-wk | 4.23 | 425 | 170 | 5 |
| HD 36485 (b) | B2 He-r | 4.29 | 3220 | 318 | 15 |
| HD 36526 (b) | B8 He-wk,Si | 4.16 | 2820 | 380 | 15 |
| HD 36540 (c) | B7 He-wk | 4.20 | 470 | 220 | 10 |
| HD 36668 (b) | B7 He-wk | 4.10 | 1875 | 447 | 16 |
| HD 36697 (c) | A0p | 4.00 | 1137 | 64 | 2 |
| HD 36916 (c) | B8 He-wk | 4.15 | 464 | 180 | 8 |
| HD 36955 (b) | A2 CrEu | 3.99 | 920 | 230 | 6 |
| HD 36982 (d) | B2 He-r | 4.33 | 1150 | 330 | 1 |
| HD 36997 (c) | B9 SiSr | 4.04 | 1227 | 87 | 2 |
| HD 37017 (c) | B2 He-r | 4.32 | 1488 | 338 | 12 |
| HD 37058 (c) | B3 He-wk,Sr | 4.24 | 728 | 62 | 14 |
| HD 37140 (b) | B8 SiSr | 4.18 | 450 | 210 | 5 |
| HD 37479 (b) | B2 He-r | 4.39 | 1980 | 155 | 20 |
| HD 37633 (b) | B9 EuSi | 4.10 | 310 | 125 | 2 |
| HD 37642 (c) | B9 He-wk,Si | 4.15 | 2110 | 180 | 5 |
| HD 37687 (c) | B7 He-wk | 4.16 | 560 | 35 | 10 |
| HD 37776 (b) | B2 He-r | 4.36 | 1260 | 350 | >10 |
| HD 37808 (c) | B9 Si | 4.12 | 480 | 130 | 2 |
| HD 40759 (c) | B9 SrCrEu | 3.98 | 1990 | 240 | 4 |
| HD 290665 (b) | B9 SrCr Eu | 3.99 | 1700 | 100 | 3 |

Reliable magnetic fields were detected for 28 stars in the Orion OB1 association. In subgroup (a) ($\log t = 7.05$) we find five magnetic stars out of 15 measured Ap/Bp stars (33.3%), in subgroup (b) ($\log t = 6.23$) there are 10 magnetic objects out of 15 Ap/Bp stars (66.7%), in subgroup (c) ($\log t = 6.66$) 12 magnetic stars out of 24 investigated Ap/Bp stars (50.0%), and finally a single magnetic star was found among three stars in subgroup (d).

If we exclude the three stars from subgroup (d) because of the very low statistics for this group, then we notice a clear correlation based on 27 stars with reliably measured magnetic fields: the fraction of magnetic stars decreases with age in the Orion OB1 ssociation. Most of the Bp stars in the youngest

subgroup (b) possess magnetic fields, and most of the Bp stars in the oldest subgroup (a) are non-magnetic.

## 4. Conclusion

We conclude that about 50% of all Ap/Bp stars in the Orion OB1 association possess strong magnetic fields and, in addition, about 20% of them are probably magnetic. No magnetic field has been found in approximately 30% of Ap/Bp stars. Furthermore, based on the analysis of subgroups of different ages, the fraction of CP stars among normal type stars and the fraction of magnetic stars among Ap/Bp stars decreases with age in the Orion OB1 association.

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