Magnetic Fields of CP Stars in the Orion OB1 Association. 
IV. Stars of Subgroup 1b

I. I. Romanyuk,1, * E. A. Semenko,1, A. V. Moiseeva,1 I. A. Yakumin,1,3 D. O. Kudryavtsev1
1Special Astrophysical Observatory, Russian Academy of Sciences, Nizhnii Arkhyz, 369167 Russia
2National Astronomical Research Institute of Thailand, Chiangmai, 50180 Thailand
3Saint Petersburg State University, Saint Petersburg, 199034 Russia

Abstract
The paper presents magnetic field measurements for 15 chemically peculiar (CP) stars of subgroup 1b in the Orion OB1 association. We have found that the proportion of stars with strong magnetic fields among these 15 CP stars is almost twice as large as in subgroup 1a. Along with this, the age of subgroup 1b is estimated as 2 Myr, and the age of subgroup 1a is in the order of 10 Myr. The average root-mean-square magnetic field \( \langle B_e \rangle \text{(all)} \) for stars in subgroup 1b is 2.3 times higher than that for stars in subgroup 1a. The conclusions obtained fall within the concept of the fossil origin of large-scale magnetic fields in B and A stars, but the rate of field weakening with age appears anomalously high. We present our results as an important observational test for calibrating the theory of stellar magnetic field formation and evolution.

Keywords: stars: magnetic field—stars: chemically peculiar

1. INTRODUCTION

The development of the theory of stellar magnetic field formation and evolution requires reliable observational tests which can show reliability of theoretical conclusions. As opposed to the Sun, where the formation and development of the field is observed directly on the surface, in the case of magnetic chemically peculiar stars everything is much more complicated. Here the observation of the field structure in detail is impossible, therefore we can only compare the results of our observations with magnetohydrodynamic calculations, taking into account many parameters, which often are not exactly quantifiable.

The question about a dependence between the magnetic field strength and the age of a star is one of the most important in the research of magnetic fields in Ap/Bp stars. Without mentioning specific works, we can note that researchers generally agree that there is a trend of weakening of the field and simplification of its geometry with age. However, these conclusions often appear to be insufficiently reliable due to the difficulties in determining the age of single stars, hence the intense interest in magnetic stars in clusters and associations.

In our research program, we decided to measure magnetic fields of all chemically peculiar stars in the Orion OB1 association with reliably determined ages of its individual subgroups. This article continues the series of our papers (Romanyuk et al. 2014, 2015, 2019, 2013, 2017) for complex investigation of magnetic chemically peculiar stars in Orion. The objectives of the program were presented in Romanyuk et al. (2013), the observation and data analysis method was described in Romanyuk et al. (2014, 2015, 2017).

Since our first publication (Romanyuk et al. 2013), a lot of new information has been accumulated in the world about the properties of the Orion OB1 association. The most important for our study are the results of the GAIA mission, which made it possible to establish the exact distances to individual stars of the association. These data in many respects confirmed the correctness of our estimates of the distances to those association members for which the parallax was either absent or its value diverged from other observed characteristics.

The final aim of our research program is to analyze possible evolutionary effects observed in Ori OB1 chemically peculiar stars, particularly answer the questions of whether the occurrence of peculiar stars relative to normal stars depends on age and how the occurrence of magnetic CP stars varies with age. By now, we have completed the study of the oldest subgroup 1a, the average age of the stars of which is about 10 Myr (Ro-
manyuk et al. 2019). In this next paper of the series, we present magnetic field measurements for CP stars of subgroup 1b of the association. The presentation of the results is similar to that in the paper of Romanyuk et al. (2019).

Subgroup 1b of the Orion OB1 association forms, almost entirely, the Orion belt asterism. All the previous numerous studies show that this region of the constellation belongs to the youngest in the association. The average age of stars in it is estimated as 2 Myr. Accuracy and reliability of these estimates are much higher than those in the case of age determination using spectroscopic data and evolutionary tracks.

2. MAGNETIC FIELD MEASUREMENTS

2.1. Selection of Stars to Observe

According to the method proposed in Romanyuk et al. (2013), we selected for observations sixteen CP stars in subgroup 1b of the Orion OB1 association. Table 1 gives information about individual stars: the object number in the HD catalog, the peculiarity type according to the catalog of Renson and Manfroid (2009), the galactic coordinates $l$ and $b$, the parallax $\pi$ obtained by Gaia, the distance $d$ to the star in parsecs, the magnitude $m_V$ in the $V$ band, and the total interstellar or circumstellar extinction $A_V$ towards the star (Romanyuk et al. 2013).

Table 1 shows that the selected stars are located rather densely in the space within the

| HD number | Peculiarity | $l$, degr. | $b$, degr. | $\pi$, mas | $d$, pc | $m_V$, mag. | $A_V$, mag. |
|-----------|-------------|------------|------------|------------|--------|-------------|-------------|
| 36046     | He-wk      | 203.74     | -18.57     | 2.91       | 343    | 8.06        | 0.15        |
| 36313     | He-wk, Si  | 203.77     | -18.05     | 3.17       | 315    | 8.20        | 0.12        |
| 36485     | He-r       | 203.84     | -17.73     | 2.57       | 389    | 6.85        | 0.12        |
| 36526     | He-wk, Si  | 205.08     | -18.31     | 2.44       | 410    | 8.29        | 0.18        |
| 36668     | He-wk, Si  | 203.18     | -16.98     | 2.36       | 424    | 8.07        | 0.01        |
| 36955     | CrEu       | 205.25     | -17.58     | 2.29       | 437    | 9.58        | –           |
| 37140     | He-wk      | 204.39     | -16.79     | 2.43       | 412    | 8.56        | 0.69        |
| 37149     | He-wk      | 205.62     | -17.42     | 2.38       | 420    | 8.02        | 0.05        |
| 37235     | He-wk      | 204.84     | -16.84     | 2.51       | 398    | 8.13        | 0.06        |
| 37321     | He-wk      | 205.58     | -17.04     | 1.56       | 640    | 7.09        | 0.17        |
| 37333     | Si         | 206.54     | -17.50     | 2.85       | 350    | 8.51        | 0.22        |
| 37479     | He-r       | 206.81     | -17.32     | 2.28       | 438    | 6.34        | 0.25        |
| 37525     | He-wk      | 206.89     | -17.29     | 2.29       | 436    | 8.06        | 0.17        |
| 37633     | EuSi       | 207.01     | -17.14     | 2.40       | 417    | 9.01        | 0.44        |
| 37776     | He-r       | 206.07     | -16.34     | 2.28       | 438    | 6.99        | 0.28        |
| 290665    | CrEuSr     | 204.74     | -17.29     | 2.48       | 403    | 9.44        | 0.19        |
galactic coordinates \( l = [203.2; 206.9] \) and \( b = [-16.3; -18.6] \) at distances from 315 to 440 pc. The only exception would be the binary star HD 37321, the parallax of which could be determined erroneously. Thus, the region occupied by the subgroup stars has a size of about \( 30 \times 15 \) pc in the perspective plane and no more than \( 100 \) pc in depth along the line of sight.

2.2. Measurements

Between 2015 and 2019, for each of the selected stars we obtained at least five spectra with a Zeeman analyzer (Chountonov 2004) at the Main Stellar Spectrograph (MSS) (Panchuk et al. 2014) of the 6-m telescope (BTA). The observation and data reduction techniques are completely similar to those used earlier (see Romanyuk et al. (2019)).

Table 2 shows the magnetic field measurements. The columns of the table present: the number of the star in the HD catalog; the Julian date of an observation; the signal-to-noise ratio \( S/N \); the longitudinal magnetic field in gauss, obtained using the modified Babcock method \( (B_e(z)) \) the regression method \( (B_e(r)) \), and by the H\( \beta \) hydrogen line \( (B_e(h)) \); the corresponding root-mean-square errors \( \sigma \). The magnetic-field measurement method is described in detail in the previous papers (Romanyuk et al. 2014, 2015, 2019, 2017). For sixteen stars, we obtained a total of 110 magnetic field measurements, at least five for each object.

For statistical studies we use the root-mean-square magnetic field \( \langle B_e \rangle \), its error \( \sigma \), and the \( \chi^2/n \) value characterizing the reliability of field detection against the background of measurement errors (see formulas (1)–(3) adopted from (Thompson et al. 1987)). We consider a star to be magnetic if \( \chi^2/n > 5 \).

\[
\langle B_e \rangle = \left( \frac{1}{n} \sum_{i=1}^{n} B_{ei}^2 \right)^{1/2} \quad (1)
\]

\[
\langle \sigma \rangle = \left( \frac{1}{n} \sum_{i=1}^{n} \sigma_i^2 \right)^{1/2} \quad (2)
\]

\[
\chi^2/n = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{B_{ei}}{\sigma_i} \right)^2 \quad (3)
\]

Below, we comment on the measurements for each star. In addition, we supplement the information about the stars with our measurements of radial \( V_R \) and rotation \( v_e \sin i \) velocities, and also present the corresponding values from astronomical databases.

| Star    | JD, (2450000+) | S/N | \( B_e(z) \pm \sigma, \) G | \( B_e(r) \pm \sigma, \) G | \( B_e(h) \), G |
|---------|---------------|-----|-----------------|-----------------|--------|
| HD 36046 | 6640.320 | 220 | -750 \pm 1410 | -100 \pm 90 | - |
|         | 7740.416 | 200 | 910 \pm 790 | 180 \pm 460 | 100 |
|         | 8125.437 | 250 | -50 \pm 1200 | -150 \pm 260 | -400 |
|         | 8151.199 | 210 | -1690 \pm 610 | -70 \pm 150 | -1200 |
|         | 8446.449 | 260 | -1170 \pm 1570 | -30 \pm 110 | -250 |
| HD 36313 | 5554.321 | 400 | 120 \pm 120 | 560 \pm 180 | -1800 |
|         | 5842.500 | 350 | 160 \pm 160 | 480 \pm 190 | 1600 |
|         | 5843.542 | 350 | 40 \pm 130 | 250 \pm 270 | 1100 |
|         | 6995.325 | 250 | -160 \pm 400 | 280 \pm 210 | 2000 |
| Star       | JD, (2450000+) | S/N | \(B_e(z) \pm \sigma\), G | \(B_e(r) \pm \sigma\), G | \(B_e(h)\), G |
|-----------|---------------|-----|--------------------------|--------------------------|-------------|
| 7288.512  | 350           | −480 ± 370 | 340 ± 150     | −                       |
| 7288.528  | 400           | −300 ± 300 | −70 ± 190     | 600                      |
| 7289.492  | 300           | 280 ± 160  | −40 ± 120     | −500                     |
| 7290.483  | 300           | −60 ± 290  | 20 ± 180      | −1500                    |
| 8830.358  | 220           | 340 ± 150  | 280 ± 130     | 1900                     |
| 8830.452  | 240           | 110 ± 290  | −200 ± 210    | −2700                    |
| 8830.507  | 180           | 20 ± 190   | −200 ± 150    | −2000                    |
| 8834.479  | 140           | 760 ± 170  | 370 ± 180     | 700                      |
| HD 36485  | 5553.247      | 330           | −2350 ± 250 | −2310 ± 120 | −2100 |
|           | 5553.480      | 330           | −2330 ± 220 | −2210 ± 180 | −1900 |
|           | 5554.263      | 300           | −2400 ± 210 | −2270 ± 120 | −2300 |
|           | 5554.481      | 300           | −2700 ± 230 | −            | −3100 |
|           | 5555.253      | 330           | −2830 ± 260 | −2470 ± 160 | −2600 |
|           | 5555.486      | 270           | −2830 ± 320 | −2370 ± 120 | −2400 |
|           | 5582.279      | 370           | −2310 ± 240 | −2350 ± 120 | −2500 |
|           | 5583.280      | 320           | −3030 ± 260 | −2250 ± 120 | −2600 |
|           | 5873.540      | 300           | −3440 ± 320 | −2220 ± 140 | −2700 |
|           | 5962.381      | 390           | −2860 ± 320 | −2160 ± 50  | −          |
|           | 5963.427      | 320           | −2670 ± 210 | −2070 ± 40  | −          |
| HD 36526  | 5553.335      | 250           | 2730 ± 320  | 2180 ± 170  | 3200 |
|           | 5842.532      | 280           | 1500 ± 400  | −290 ± 210  | −2700 |
|           | 5963.292      | 280           | −            | 2790 ± 50   | −          |
|           | 6589.530      | 320           | 2150 ± 220  | 1970 ± 130  | 5700 |
|           | 7289.570      | 200           | 2730 ± 380  | 1120 ± 80   | 3200 |
|           | 7290.525      | 210           | 4600 ± 600  | 750 ± 90    | 1000 |
| HD 36668  | 5582.396      | 240           | −1040 ± 250 | −540 ± 140  | −1350 |
|           | 5583.310      | 310           | −1540 ± 220 | −1430 ± 150 | −3300 |
|           | 5842.475      | 300           | −1170 ± 350 | −1140 ± 50  | −3400 |
|           | 5962.323      | 300           | 2170 ± 180  | 1140 ± 50   | −          |
| Star     | JD, (2450000+) | S/N | $B_c(z) \pm \sigma$, G | $B_c(r) \pm \sigma$, G | $B_c(h)$, G |
|----------|----------------|-----|------------------------|------------------------|-------------|
| HD 36955|                |     |                        |                        |             |
| 3273.529 | 160           | −820 ± 190 | −350 ± 90          | −            |             |
| 3274.512 | 180           | −410 ± 200 | −            | −            |             |
| 3275.510 | 140           | −1300 ± 380 | −3          | −            |             |
| 4015.546 | 280           | −480 ± 210 | −            | 50           |             |
| 6233.412 | 110           | −750 ± 110 | −760 ± 100       | −2100        |             |
| 8447.419 | 170           | −970 ± 105 | −660 ± 110       | −700          |             |
| HD 37140|                |     |                        |                        |             |
| 5555.297 | 310           | −590 ± 90  | −350 ± 90        | −            |             |
| 5962.400 | 230           | 220 ± 210  | 220 ± 50        | −            |             |
| 5963.440 | 200           | 140 ± 210  | −210 ± 60       | −            |             |
| 8125.504 | 120           | −900 ± 170 | −460 ± 120      | −600          |             |
| 8151.227 | 200           | −720 ± 220 | −80 ± 140      | −100          |             |
| 8447.484 | 150           | 560 ± 290  | 50 ± 130       | −400          |             |
| HD 37149|                |     |                        |                        |             |
| 6643.344 | 200           | 5 ± 1200   | −320 ± 120     | −            |             |
| 8008.545 | 190           | −          | −180 ± 190     | 0            |             |
| 8446.475 | 200           | −700 ± 1800 | −160 ± 170    | 800          |             |
| 8512.408 | 240           | −3100 ± 3100 | 170 ± 190    | −400          |             |
| 8799.384 | 250           | −1800 ± 2400 | 150 ± 180   | 200          |             |
| HD 37235|                |     |                        |                        |             |
| 6643.321 | 200           | −          | 260 ± 120     | −300          |             |
| 8126.173 | 200           | 9100 ± 4500 | 170 ± 170    | −900          |             |
| 8151.252 | 180           | −700 ± 3800 | 190 ± 130    | 200          |             |
| 8153.219 | 190           | 1370 ± 1330 | 60 ± 210    | −500          |             |
| 8447.509 | 220           | 1800 ± 2200 | 380 ± 160    | 400          |             |
| 8550.243 | 160           | 90 ± 660   | 180 ± 210     | −800          |             |
| HD 37321|                |     |                        |                        |             |
| 6643.366 | 280           | −590 ± 470 | −580 ± 260     | −            |             |
| 7825.209 | 200           | 380 ± 650  | −160 ± 210     | −400          |             |
Table 2: (Continued)

| Star      | JD, (2450000+) | S/N | $B_e(z) \pm \sigma$, G | $B_e(r) \pm \sigma$, G | $B_e(h)$, G |
|-----------|----------------|-----|------------------------|------------------------|-------------|
| 8116.420  | 260            |      | $-250 \pm 280$         | 10 ± 140               |             |
| 8153.247  | 270            |      | $-590 \pm 460$         | $-180 \pm 200$         | $-200$      |
| 8446.498  | 400            |      | $80 \pm 210$           | $-150 \pm 180$         | 200         |
| HD 37333  | 7762.470       | 120  | 50 ± 310               | $-150 \pm 110$         | $-600$      |
|           | 7823.188       | 150  | 560 ± 310              | 70 ± 110               | 1300        |
|           | 8116.445       | 140  | $-1290 \pm 270$        | $-440 \pm 130$         | 800         |
|           | 8446.525       | 230  | $-1030 \pm 150$        | $-670 \pm 110$         | $-1200$     |
|           | 8512.215       | 160  | $-890 \pm 190$         | $-430 \pm 160$         | $-1700$     |
|           | 8512.240       | 140  | $-850 \pm 200$         | $-530 \pm 100$         | $-700$      |
| HD 37479  | 5555.324       | 350  | $-1050 \pm 1080$       | 140 ± 330              | $-200$      |
|           | 5582.343       | 310  | 4350 ± 540             | 1630 ± 270             | 4800        |
|           | 5583.350       | 280  | $-3400 \pm 1150$       | $-1860 \pm 480$        | $-4300$     |
|           | 5963.347       | 400  | 2320 ± 360             | 830 ± 70               |             |
| HD 37525  | 5963.360       | 280  | 2390 ± 2770            | $-20 \pm 90$           |             |
|           | 5555.337       | 270  | 670 ± 1670             | 20 ± 290               |             |
|           | 7764.361       | 260  | $-780 \pm 1080$        | 270 ± 250              | $-300$      |
|           | 8446.553       | 250  | 620 ± 930              | $-20 \pm 100$          | 1500        |
|           | 8514.409       | 100  | $-1460 \pm 2130$       | $-100 \pm 140$         | $-1700$     |
| HD 37633  | 6643.421       | 200  | 400 ± 60               | 320 ± 80               | $-400$      |
|           | 7740.496       | 500  | 180 ± 170              | 100 ± 110              |             |
|           | 8006.568       | 140  | 194 ± 190              | 160 ± 150              | $-100$      |
|           | 8126.455       | 130  | 810 ± 100              | 660 ± 80               | 400         |
|           | 8447.365       | 180  | 740 ± 80               | 460 ± 63               | 400         |
|           | 8758.511       | 160  | 440 ± 70               | 300 ± 80               | $-400$      |
| HD 37776  | 8777.441       | 320  | 15700 ± 3900           | $-140 \pm 155$         | 6600        |
|           | 8777.553       | 370  | $-2900 \pm 2200$       | $-460 \pm 140$         | $-3100$     |
|           | 8778.460       | 350  | 6400 ± 1800            | 70 ± 200               | 7000        |
|           | 8778.578       | 400  | $-10100 \pm 2900$      | $-580 \pm 160$         | 1500        |
|           | 8799.396       | 310  | $-2200 \pm 2200$       | 210 ± 180              | 7000        |
Table 2: (Continued)

| Star      | JD, (2450000+) | S/N | $B_c(z) \pm \sigma$, G | $B_c(r) \pm \sigma$, G | $B_c(h)$, G |
|-----------|----------------|-----|------------------------|------------------------|--------------|
| 8801.555  | 290            |     | $-800 \pm 4000$        | $150 \pm 160$         | 7800         |
| 8805.369  | 350            |     | $-7500 \pm 1000$       | $-1140 \pm 120$       | $-5300$      |
| 8805.559  | 350            |     | $1300 \pm 3000$        | $-60 \pm 190$         | 12300        |
| 8830.315  | 300            |     | $-3800 \pm 2600$       | $-200 \pm 150$        | 10700        |
| 8830.478  | 360            |     | $-6700 \pm 600$        | $-1240 \pm 110$       | $-4800$      |
| HD 290665 |                |     |                        |                        |              |
| 8007.527  | 130            | 3910 ± 120 | 3200 ± 40 | 2800         |
| 8151.336  | 180            | 830 ± 90  | 570 ± 80  | 1300         |
| 8447.442  | 150            | 1050 ± 100| 840 ± 50  | −            |
| 8448.392  | 150            | $-3700 \pm 140$| $-2670 \pm 50$| $-2500$      |
| 8534.209  | 190            | 3450 ± 110| 2960 ± 50 | 3000         |
| 8535.178  | 90             | 1068 ± 120| 960 ± 60  | 400          |
| 8550.287  | 130            | 3210 ± 120| 2660 ± 40 | 2700         |
| 8551.250  | 170            | $-2990 \pm 130$| $-2240 \pm 40$| $-1800$      |
| 8579.179  | 100            | $-2800 \pm 150$| $-1720 \pm 60$| $-300$       |
| 8581.176  | 150            | 3410 ± 130| 2810 ± 50 | 1600         |

2.3. Comments on Individual Stars

2.3.1. HD 36046 = BD $−00^\circ 964$
          = Renson 9290 = Brown 007b

In the catalogs of variable stars of the Orion OB1 association, HD 36046 is not presented. In the star spectrum in the region of 4400–4970 Å, there are several lines broadened by rotation ($v_e \sin i = 100$ km s$^{-1}$). In the SIMBAD database, the radial velocity is $V_R = 34.6$ km s$^{-1}$, however, according to our measurements, it is systematically slightly lower which may indicate the possible binarity of the star. The observed spectrum of HD 36046 corresponds to a star with the effective temperature $T_{\text{eff}} = 15000 \pm 250$ K and the surface gravity log $g = 4.0 \pm 0.3$.

The paper by Romanyuk et al. (2013) provides the references to studies, in which the attempts have been made to determine the mass of the star. Two values were obtained: 2.4 and 3.8 $M_\odot$. The second value is close to our data.

According to the paper by Bagnulo et al. (2015), the star was observed at the VLT with FORS in order to search for a magnetic field, but the result was negative. Our observations at the BTA also show no evidence of a magnetic field stronger than 500 G.

The star is included in the list of Ae/Be Herbig objects in close OB associations (Hernández et al. 2005), however, in our spectra in the region 4450–4950 Å, no evidence of emissions was detected.

2.3.2. HD 36313 = V1093 Orion = BD $−00^\circ 977$
          = Renson 9370 = Brown 014b

This binary star is variable. The companion is weaker than the main component by 0.5 mag. and is at the distance of 0″1 (Catalano and Renson 1998). North (1984) found the periodic vari-
ability with the elements

$$\text{IJD}(\text{min}) = 2444976.985 + 0.58933 \, E.$$  

The fluxes in all filters vary in the phase as a double wave.

Borra (1981) first discovered the magnetic field of the star. According to observations with the Balmer magnetometer, the variation limits of the longitudinal component of the magnetic field are from $-1520$ to $1110$ G. Our attempt to measure the field along the metal lines ended in failure (Romanyuk et al. 2016). More comprehensive analysis of the data showed that the spectrum of the star contains two sets of lines differentially broadened by rotation. In the spectrum, there are much more narrow lines belonging to a cool companion. Apparently, this component of the system does not have a large-scale field. On the other hand, the H$\beta$ hydrogen line successfully detects the magnetic field of the main component. The zero contribution of the companion reduces the total field by about 30% which is within the measurement error. For this reason, we decided to use the original measurements obtained along the $H\beta$ line to calculate the value $\langle B_e \rangle$ for this star:

$$\langle B_e \rangle = 1337 \, \text{G}, \quad \sigma = 500, \quad \chi^2/n = 7.2.$$  

We believe that the field measurement error $\sigma$ along a single line is 500 G.

The photometric light curve of the star obtained by the TESS satellite looks like a double wave. On closer examination of the curve, it appeared that it contains components of at least three periodic processes. The largest amplitude corresponds to brightness fluctuations with the period $P_{\text{magn}} = 0.58913$ days (Fig. 1) which almost coincides with the data obtained by North (1984). The other two processes with significantly smaller amplitudes have the periods $P_1 = 3^{d}6729$ and $P_2 = 2^{d}987$. Most likely, $P_1$ corresponds to the rotation period of the cool component, the lines of which dominate in the observed spectrum of HD 36313.

Figure 2 gives an idea of the nature of variations in the longitudinal magnetic field in our measurements. The period was taken from the value obtained from the TESS photometry, $T_0 = 2444976.985$. The values $B_e$ show large scattering, but the measurements obtained with the classical method and along the hydrogen line correlate well with each other. The phase shift of the photometric and magnetic curves is noteworthy.

Line broadening in the spectrum corresponds to $v_e \sin i_1 = 160 \, \text{km s}^{-1}$ for the major component and to $v_e \sin i_1 = 30 \, \text{km s}^{-1}$ for the secondary. We determine the physical parameters of the major component as follows: $T_{\text{eff}} = 13000 \pm 480 \, \text{K}, \log g = 4.0 \pm 0.3$.

2.3.3. HD 36485 = δ Orion C = BD$-$00°982 = Renson 9440 = Brown 020b

The system δ Orion consists of four stars: the primary component A (HR 1852 = HD 36486) is a spectroscopic binary star itself with $m_V = 2.23$ mag., component B is at $33^7.0$ from the primary one and has the strength $m_V = 14.0$. The star C (HR 1851 = HD 36485) with strong helium lines is at a distance of $51^7.7$ from A and has the magnitude $m_V = 6.85$.

HD 36485 is a well-known magnetic star studied in detail in the paper by Bohlender (1989). The measurements of the magnetic field of the star are published mainly in the paper by Bohlender et al. (1987). The data show the measurement limits of $B_e$ from $-3800$ to $-3100$ G. Mathys and Hubrig (1997) found a longitudinal field of $-1850$ G from one measurement but could not explain the discrepancy with the Bolender’s results.

We have carried out our own observations of the star. Eleven of our measurements showed that along the metal lines the field varies from $-3400$ to $-2300$ G, and from the H$\beta$ line—from $-3100$ to $-1900$ G. The corresponding values of the root-mean-square longitudinal field obtained with the Babcock method and from hydrogen are as follows:

- $\langle B_e \rangle = 2724 \, \text{G}, \quad \sigma = 261, \quad \chi^2/n = 113$ (with the Babcock method),
- $\langle B_e \rangle = 2156 \, \text{G}, \quad \sigma = 132, \quad \chi^2/n = 635$ (from hydrogen).

It is known that HD 36485 is a spectroscopic
binary system, however, speckle interferometric observations reveal one more component. Tokovinin (2008) found a companion at the distance $\rho = 0\arcsec.327$ fainter than the major star by $\Delta m_V = 1.5$ mag. Thus, HD 36485 is a complex multiple system, the major component of which has a strong magnetic field of variable polarity.

Based on our spectra, we have determined the main parameters of the magnetic star: $v_e \sin i = 40 \text{ km s}^{-1}$, $T_{\text{eff}} = 18000 \pm 250 \text{ K}$, $\log g = 4.0 \pm 0.3$.

Fairly strong interstellar linear polarization is observed towards the star: $P = 0.18\%$.

The star was observed with the TESS satellite. However, due to the complex configuration of the system, it is not possible to separate the periodic signals in the existing compound light curve.

2.3.4. **HD 36526**

$BD -01^\circ 933 = V 1099 \text{ Orion} = \text{Renson 9460} = \text{Brown 023b}$

The magnetic field of the star with the extrema $B_e$ from $-1000$ to $+3500 \text{ G}$ was discovered by Borra (1981). The paper by Romanyuk et al. (2016) presents our measurements of its longitudinal field. North (1984) found the photometric variability of the star. According to this paper, the variability is observed in all filters with the weak secondary minimum and the elements

$$\text{HJD}(\text{min}) = 2444978.825 + 1.5405 \ E.$$  

The light curve obtained with the TESS shows the presence of two periods: $1^d.54170$ and $1^d.7073$. As is seen, the first value is close to that obtained by North (1984) and is the rotation period of the magnetic star. The light curve of a star phased with a period of $1^d.54170$ and $T_0 = 2444978.825$ is given in Fig. 3, and Figure 4 presents our measurements of the longitudinal magnetic field with the same elements.

The character of the spectral variability of HD 36526 in our data indicates the possible presence of lines of at least one more component. Such a component could be a companion detected by Balega et al. (2012) at a distance of $0\arcsec.15$. The brightness difference $\Delta m_V$ between two stars is only 1.3 mag. Thus, the spectrum of the companion can have significant impact on our measurements, as well as on the shape of the light curve of the magnetic star. According to our measurements, the root-mean-square field $\langle B_e \rangle$ of HD 36526 is the following:

- $\langle B_e \rangle = 2801 \text{ G, } \sigma = 384, \chi^2/n = 56.8$ (with the Babcock method),
- $\langle B_e \rangle = 1695 \text{ G, } \sigma = 137, \chi^2/n = 539.3$ (with the regression method).

Preliminary analysis of the spectra gives the following fundamental parameters of the magnetic star: $T_{\text{eff}} = 16000 \pm 210 \text{ K}$, $\log g = 4.0 \pm 0.3$. The rotational line broadening corresponds to $v_e \sin i = 50 \text{ km s}^{-1}$. There are no measurements of radial velocities in the lit-
Figure 2. Variability curves of the longitudinal magnetic field of HD 36313 built from our observations.
erature. Measurements of the spectra obtained with the BTA give the value: \( V_R = 30 \text{ km s}^{-1} \).

2.3.5. \( \text{HD 36668} = BD+00^\circ1113 = V1107 Orion = Renson 9560 = Brown 031b \)

For the first time, the magnetic field of the star was measured by Borra (1981) from observations with a Balmer magnetometer. The obtained \( B_e \) values ranged from \(-2100\) to \(+2000\) G. We carried out eight observations of the star. Measurements of the Zeeman effect in the metal and hydrogen lines confirm the presence of a strong field, but its variation limits are much larger than those published by Romanyuk et al. (2017).

Given the available data, the root-mean-square field values are as follows:

- \( \langle B_e \rangle = 1892 \text{ G}, \sigma = 451, \chi^2/n = 37.6 \) (with the Babcock method),
- \( \langle B_e \rangle = 953 \text{ G}, \sigma = 105, \chi^2/n = 203.5 \) (with the regression method).

This star is a photometric variable. North (1984) gives the following light curve elements:

\[
\text{HJD}(\text{min}) = 2444988.496 + 2.1211 E.
\]

The brightness variation occurs in the shape of a double wave, in which the secondary maximum is almost as deep as the main one. The star was observed with the TESS satellite, but its photometry was conducted separately in the CDIPS survey (Bouma et al. 2019). Analysis of the data cleared of instrumental trends gives the variability period \( P = 2.51204 \) close to that given above from the paper by North (1984). The final light curve of the star has a complex shape and is shown in Fig. 5.

We estimated the fundamental parameters: \( v_e \sin i = 60 \text{ km s}^{-1}, T_{\text{eff}} = 13500 \pm 250 \text{ K}, \log g = 4.0 \pm 0.4 \). Based on these data, as well as the position of the star in space, the luminosity and mass of the star can be found. These values for HD 36668 are equal to \( \log \frac{L}{L_\odot} = 2.4 \) and \( \frac{M}{M_\odot} = 3.7 \), respectively. The paper by Romanyuk et al. (2013) gives two mass estimates for HD 36668 equal to \( 3.8 M_\odot \), which coincides with the given results.

The paper by Bouy and Alves (2015) claims that HD 36668 does not belong to the association but to the stellar flow in the Orion and is closer to the observer. However, the parallax obtained during the GAIA mission disproves this claim. The value \( \pi = 2.36 \text{ mas} \) corresponds to the distance \( d = 424 \text{ pc} \), and this is the distance to the center of subgroup 1b of the association (Romanyuk et al. 2013).

Hernández et al. (2005) included HD 36668 into the catalog of Ae/Be Herbig stars in the nearby OB associations, but in our spectra in the region of 4450–4950 no evidence of Ae/Be stars was found.
Figure 4. Variability curves of the longitudinal magnetic field of HD 36526 built from our observations.
2.3.6. **HD 36955** = **BD−01°955** = Renson 9740  
= Brown 052b

We discovered the magnetic field of this star with the BTA (Kudryavtsev et al. 2006). The SIMBAD database indicates that HD 36955 is a binary or multiple system. The paper by Rastegaev et al. (2014) says about the presence of a companion with the brightness $m_V = 11$ mag. at a distance of 1.′′5.

Oelkers et al. (2018) found the rotation period of the star: $P = 2^{d}284965$. The light curve, built from the photometry performed with the TESS satellite, is of a simple shape (Fig. 6). The refined value of the photometric variability period is equal to $2^{d}283506$. Both these values are in poor agreement with the values of the longitudinal magnetic field. Analysis of our measurements of $B_e$ testifies in favor of a slightly longer period: $2^{d}875108$ (Fig. 7). The reasons for these discrepancies remain to be understood.

The root-mean-square longitudinal magnetic field of the star measured with the Babcock and regression methods is as follows:

- $\langle B_e \rangle = 842$ G, $\sigma = 219$, $\chi^2/n = 28.2$,  
- $\langle B_e \rangle = 708$ G, $\sigma = 90$, $\chi^2/n = 93.9$.

The fundamental parameters of HD 36995 that we determined are: $v_e \sin i = 26$ km s$^{-1}$, $T_{\text{eff}} = 10800 \pm 250$ K, $\log g = 4.2 \pm 0.5$.

2.3.7. **HD 37140** = **V1130 Orion** = **BD−00°1018**  
= Renson 9910 = Brown 063b

The magnetic field of the star was found by Borra (1981). In his measurements, the longitudinal field component ranged from $-1050$ to $+400$ G. North (1984) found the photometric variability of the star with the elements

$\text{HJD(min)} = 2444978.036 + 2.7088 E$.

The light curves in all filters are sinusoidal. However, there is another probable rotation period in the literature: $0^{d}611465$ (Oelkers et al. 2018).

The photometry of the star based on the TESS images was carried out in the CDIPS project. The light curve cleared of trends is perfectly phased with a period of $P = 2^{d}704179$ which is close to North’s value. Rastegaev et al. (2014) argues that HD 37140 is a triple system with components of the A7 and F–K spectral types at the distances $d = 23$ au and 50 au. The hotter companion can be a pulsating star of the $\delta$Sct type, as there are the signs of specific pulsations of a small amplitude in the TESS photometry (see Fig. 8).

The star HD 37140 is magnetic: our longitudinal field measurements with two methods are given in Fig. 9. The root-mean-square longitudinal magnetic fields from our data depending on the method used (the modified Babcock method, the regression method) are the following:

- $\langle B_e \rangle = 585$ G, $\sigma = 207$, $\chi^2/n = 14.0$,  
- $\langle B_e \rangle = 270$ G, $\sigma = 107$, $\chi^2/n = 9.6$.  

![Figure 5. Photometric light curve of HD 36668 from the TESS observations.](image-url)
Figure 6. Photometric light curve of HD 36955 from the TESS observations.

Figure 7. Variability curve of the longitudinal magnetic field of HD 36955 obtained from the measurements of the metal lines.

Figure 8. Photometric light curve of HD 37140 from the TESS observations.
Figure 9. Variability curves of the longitudinal magnetic field of HD 37140 obtained from the measurements of metal lines with the Babcock method and the regression method.

Having analyzed the spectra, we found the following parameters of the star: $v_c \sin i = 30$ km s$^{-1}$, $T_{\text{eff}} = 13500 \pm 240$ K, $\log g = 3.7 \pm 0.4$.

2.3.8. HD 37149 = HIP 26319 = Renson 9920 = Brown 065b

In the catalog of chemically peculiar stars (Renson and Manfroid 2009), HD 37149 is named as He-wk, but the classification can be wrong: there is information in the literature that HD 37149 is a Be star. Despite the fact that there is no evidence of emission in our spectra obtained in the region of 4450–4950 Å, we will consider it a non-magnetic Be star. This assumption is also supported by unsuccessful attempts to detect the magnetic field of the star (with the Babcock method and by regression, respectively):

- $\langle B_c \rangle = 1826$ G, $\sigma = 2238$, $\chi^2/n = 0.4$,
- $\langle B_c \rangle = 205$ G, $\sigma = 170$, $\chi^2/n = 2.1$.

The stellar photometry conducted at the TESS satellite shows the multiperiodic small-amplitude variability (Fig. 10). Possible oscillation periods: $(P_1 = 0^d3196$ and $P_2 = 0^d3245$) are also typical for Be stars (Neiner and Hubert 2009). Since, HD 37149 is not a chemically peculiar star, we exclude it from our further con-
sideration.

2.3.9. HD 37235 = BD−00°1023 = Renson 9960
       = Brown 069b

This star has not been previously studied as for magnetic field searches. The available spectra show three more or less strong lines broadened by rotation. For this reason, the accuracy of the longitudinal magnetic field measurement is very low. The results of measurements of six Zeeman spectra indicate that there is no longitudinal magnetic field stronger than 1 kG. No evidence of the Zeeman signature is observed in either the metal or in the hydrogen lines. The root-mean-square magnetic field depending on the method is as follows:

- $\langle B_e \rangle = 4204$ G, $\sigma = 2889$, $\chi^2/n = 1.2$ (the modified Babcock method),
- $\langle B_e \rangle = 227$ G, $\sigma = 170$, $\chi^2/n = 2.3$ (the regression method).

The negative result of magnetic field searches for HD 37235 should not be considered a sign that the star is not chemically peculiar. The photometric light curve of HD 37235 is available in the CDIPS survey based on the analysis of images obtained with the TESS satellite. The periodogram clearly shows the signal corresponding to the period of the star variability $P = 0.48469$. According to this parameter, HD 37235 is one of the fastest rotators with the photometric variability. The brightness of the star varies within narrow limits in the shape of a double wave typical of CP stars (Fig. 11).

We determined the physical parameters of the star: $v \sin i = 320$ km s$^{-1}$, $T_{\text{eff}} = 13500 \pm 300$ K, $\log g = 4.0 \pm 0.3$.

2.3.10. HD 37321 = HIP 26439 = Renson 10000
       = Brown 075b

This massive star ($5.2 M_{\odot}$) is the major component of the binary system ADS 4222AB with a companion at a distance of 0.8 (Romanyuk et al. 2013). In the wavelength range of the spectra that we obtained, few lines are observed. The fast rotation of the star results not only in broadening of its lines but also significantly reduces the accuracy of the magnetic field measurement.

None of the five measurements of the longitudinal field showed any significant result: we could not find a magnetic field. The root-mean-square $\langle B_e \rangle$ values, that we found with the modified Babcock method and the regression method, are the following:

- $\langle B_e \rangle = 426$ G, $\sigma = 439$, $\chi^2/n = 0.9$,
- $\langle B_e \rangle = 290$ G, $\sigma = 202$, $\chi^2/n = 1.4$.

Our estimates of the physical parameters of the star are: $v \sin i = 130$ km s$^{-1}$, $T_{\text{eff}} = 15000 \pm 350$ K, $\log g = 4.1 \pm 0.4$, $L/M = 3.3$, $M/\odot = 5.8$, $R/\odot = 4.6$.

The mass is in good agreement with the estimate from the paper by Romanyuk et al. (2013). In TESS photometry (the CDIPS survey), the star exhibits weak multiperiodic variability typical of massive pulsating stars.

2.3.11. HD 37333 = BD−02°1319 = Renson 10010
       = Brown 077b

HD 37333 is a new star, the member of the $\sigma$ Orion cluster. The silicon lines in the star spectrum are strong.

Bagnulo et al. (2015) observed HD 37333 with FORS1 VLT, although, no magnetic field was found. We found a magnetic field for the first time, but the results have not been previously published. The root-mean-square longitudinal field $\langle B_e \rangle$ is as follows from our six observations:

- $\langle B_e \rangle = 869$ G, $\sigma = 246$, $\chi^2/n = 19.4$,
- $\langle B_e \rangle = 433$ G, $\sigma = 120$, $\chi^2/n = 14.6$.

As usually, the root-mean-square field measured with the regression method is smaller than that measured with the classical method.

In the catalog by Heinze et al. (2018), the rotation period of the star $P = 5.4612112$ is given; however, our measurements of $B_e$ do not agree with it. Analysis of the light curve obtained in the CDIPS survey based on the TESS observations shows that the current rotation pe-
period is 1^d 68339. With this period, the variations in the star brightness occurs in the form of a double wave with two minima of the same depth (Fig. 12). Magnetic measurements phased with a specified photometric period fall into the phase range of 0.45–0.85. These data are insufficient for any conclusions about the nature of the magnetic variability.

Based on the data available, we found the following fundamental parameters of the star: $v_e \sin i = 50$ km s$^{-1}$, $T_{\text{eff}} = 12000 \pm 370$ K, log $g = 4.5 \pm 0.3$.

2.3.12. **HD 37479 = σ Orion E = BD −02°1327**

HD 37479 is a well-studied magnetic peculiar star with strong helium lines. Bohlender et al. (1987) performed 22 measurements of the star longitudinal magnetic field with the Landstreet’s Balmer magnetometer. The authors obtained an approximately sinusoidal curve. The purpose of our measurements is to obtain data for all magnetic stars in a uniform manner in a homogeneous system in order to be able to compare the results obtained from the H$\beta$ hydrogen line and from the metal lines. Other details of our research are given in the paper by Romanyuk et al. (2013).

We confirm that star has a very strong magnetic field. The root-mean-square longitudinal
fields obtained with the Babcock method and with the regression method are as follows:

- $\langle B_e \rangle = 3040$ G, $\sigma = 853$, $\chi^2/n = 29.2$,
- $\langle B_e \rangle = 1307$ G, $\sigma = 324$, $\chi^2/n = 46.6$.

There is a very large difference in the results obtained with these two methods.

The fundamental parameters of the star are the following: $v_e \sin i = 150$ km s$^{-1}$, $T_{\text{eff}} = 21000 \pm 550$ K, $\log g = 3.5 \pm 0.4$.

2.3.13. HD 37525 = BD$-02^\circ1328 = Renson$ 10110 = Brown $088b$

This star is presented in the SIMBAD database as a young object. The binary system HD 37525AB belongs to the $\sigma$ Orion cluster. The catalog by Renson and Manfroid (2009) classifies the star as peculiar with weak helium abundance; however, in the spectrum, the helium 4471 Å line is significantly stronger than the MgII 4481 Åline. This means that the helium abundance is not that small. One cannot exclude that HD 37525 is a normal star of a corresponding spectral type.

There are no data on any measurements of its magnetic field in the literature. In five observations at the BTA with the Zeeman analyzer, no longitudinal field with an upper limit of 500 G was found also. The root-mean-square field $\langle B_e \rangle$ is as follows from our observations:

- $\langle B_e \rangle = 1362$ G, $\sigma = 1845$, $\chi^2/n = 0.5$ (with the Babcock method),
- $\langle B_e \rangle = 127$ G, $\sigma = 192$, $\chi^2/n = 0.3$ (with the regression method).

Fundamental parameters HD 37525 that we obtained are as follows: $v_e \sin i = 160$ km s$^{-1}$, $T_{\text{eff}} = 17000 \pm 270$ K, $\log g = 4.1 \pm 0.3$.

2.3.14. HD 37633 = BD$-02^\circ1332 = Renson$ 10130 = Brown $093b$

We found the magnetic field of this star in 2013, but the measurements have not been previously published. Bagnulo et al. (2015) obtained one measurement of the longitudinal field with the FORS1 VLT: $B_z = 440 \pm 200$ G.

North (1984) found periodic photometric variability with the elements

$$\text{HJD}(\text{min}) = 2444983.923 + 1.5718 \ E.$$  

The light curve of a star, as observed by TESS, has two harmonics with the flatter minimum. (Fig. 13). The variability period practically coincides with the period from the paper by North (1984): $P = 1^d57305$. Our longitudinal magnetic field measurements are in good agreement with this value (Fig. 14).

The root-mean-square longitudinal magnetic field indicates that star is magnetic:

- $\langle B_e \rangle = 520$ G, $\sigma = 121$, $\chi^2/n = 41.2$ (with the Babcock method),
Figure 13. Photometric light curve of HD 37633 from the TESS observations.

- $\langle B_e \rangle = 382$ G, $\sigma = 97$, $\chi^2/n = 25.5$ (with the regression method).

According to various sources, the star is included in the $\sigma$ Orion and Collinder 70 clusters.

We found the following parameters of the star: $v_e \sin i = 35$ km s$^{-1}$, $T_{\text{eff}} = 13000 \pm 250$ K, $\log g = 4.0 \pm 0.4$.

2.3.15. HD 37776 = V901 Orion = BD$-01^\circ\!1005$

= Renson 10190 = Brown 104b

HD 37776 is a well-known magnetic chemically peculiar star studied many times by various authors, including the authors of this paper, over decades. The star has an extremely strong field of a complex non-dipole configuration (Kochukhov et al. 2011). Despite the unconditional progress in the study of this unique object, in our opinion, a satisfactory magnetic model of HD 37776 has not yet been built. New high-accuracy photometric observations with the TESS mission raised new issues rather than brought researchers closer to unravelling the HD 37776 phenomenon.

During the winter season of 2019/2020, we carried out fourteen observations of the star with the Zeeman analyzer. The lines in the spectrum of HD 37776 are of a very complex shape; there is an extremely strong circular polarization in the lines caused by the Zeeman effect. In this case, the lines of different chemical elements behave differently which results in strong scattering of field measurements. The use of the regression method appeared to be ineffective due to a strong field of complex geometry.

The root-mean-square $\langle B_e \rangle$ values found from the measurements of metal lines and hydrogen are the following:

- $\langle B_e \rangle = 7285$ G, $\sigma = 2686$, $\chi^2/n = 17.2$ (with the Babcock method),
- $\langle B_e \rangle = 8644$ G, $\sigma = 500$, $\chi^2/n = 298.9$ (by hydrogen).

Table 3 presents the results of measurements of the longitudinal field for four elements: H$\beta$, Mg II (4481 Å), He I (4471, 4713, 4922 Å), and Si III (4552, 4567, 4574 Å). For helium and silicon, the average values were taken along the indicated three lines.

The longitudinal magnetic field exhibits very different behavior depending on the element. As the rotation period, we took the value $1^d 539494$ determined from the TESS photometry (Fig. 15). Figure 16 shows variations of the longitudinal magnetic field depending on the rotation period phase.

The line profiles in the available spectra often bifurcate indicating Zeeman splitting in the field within the order of 70 kG. It can be clearly seen that the brightness extrema coincide with the extrema of the magnetic field. In this case, the field varies in different ways for different elements. For example, the field along the helium and silicon lines changes in anti-phase. In this paper, we publish only the first results. More de-
Figure 14. Variability curves of the longitudinal magnetic field of HD 37633 obtained from the measurements of the metal lines and hydrogen.
Table 3. Longitudinal field $B_e$ measurements of the star HD 37776 by specified elements

| JD, (2450000+) | $B_e$(H$\beta$), kG | $B_e$(Mg II), kG | $B_e$(He I), kG | $B_e$(Si III), kG |
|---------------|---------------------|-----------------|-----------------|-----------------|
| 8777.441      | 6.6                 | −12.2           | 11.1 ± 4.0      | 30.5 ± 3.0      |
| 8777.553      | −3.1                | −9.0            | −6.8 ± 1.9      | −5.3 ± 2.2      |
| 8778.460      | 7.0                 | −                | 5.2 ± 5.1       | −                |
| 8778.578      | 1.5                 | −10.9           | 0.8 ± 1.1       | −20.8 ± 3.0     |
| 8799.396      | 6.9                 | −5.0            | 9.0 ± 1.2       | −15.5 ± 1.4     |
| 8801.555      | 7.8                 | −9.5            | 7.1 ± 9.3       | −18.5 ± 1.6     |
| 8805.369      | −5.3                | −4.8            | −5.3 ± 0.8      | −7.2 ± 0.1      |
| 8805.559      | 12.3                | −                | 16.0 ± 11.5     | −5.5 ± 2.2      |
| 8830.315      | 10.8                | −7.4            | 4.7 ± 7.3       | −13.9 ± 2.3     |
| 8830.478      | −4.8                | −6.8            | −5.8 ± 1.1      | −7.6 ± 1.2      |
| 8834.418      | 4.3                 | −11.5           | 4.5 ± 2.2       | 27.6 ± 0.9      |
| 8834.511      | −2.5                | −4.6            | −4.6 ± 0.4      | −5.2 ± 3.5      |
| 8855.184      | −0.7                | −4.9            | −2.9 ± 0.5      | −7.1 ± 1.0      |
| 8857.255      | −15.6               | 12.7            | −6.7 ± 7.7      | 20.0 ± 2.8      |

Figure 15. Photometric light curve of HD 37776 from the TESS observations.

tailed analysis of the HD 37776 field is to be performed, but the presence of a very large (many dozen kG) and complex, unparalleled field is obvious.

The star has the following physical parameters: $v_e \sin i = 80$ km s$^{-1}$, $T_{\text{eff}} = 22000 \pm 350$ K, $\log g = 3.7 \pm 0.6$. The effective temperature found that we found is in good agreement with plenty of published data. The mass of the star, according to different sources, ranges from 6.4 to 10 $M_\odot$ (Romanyuk et al. 2013).
2.3.16. HD 290665 = BD−00°1008 = Renson 9760 = Brown 128b

We detected the magnetic field of this star at the 6-m BTA telescope. The longitudinal component field varies from $-3700$ to $3900$ G. One more measurement field of this star was performed by Bagnulo et al. (2006) with the VLT: $B_l = -1664 \pm 44$ G.

Oelkers et al. (2018) gives the star rotation period: $P = 5.162896$. We obtained a close period from the analysis of the HD 290665 light curve obtained in the CDIPS survey basing on the TESS images: $P_{\text{TESS}} = 5.176873$.

Ten observations of the star at the BTA show that the period is indeed close to 5 days, but our measurements are in better agreement with the period published by Oelkers et al. (2018). The root-mean-square longitudinal magnetic fields of the star are as follows:

- $\langle B_e \rangle = 2871$ G, $\sigma = 121$, $\chi^2/n = 544.2$ (with the Babcock method),
• $\langle B_e \rangle = 2260 \text{ G, } \sigma = 54, \chi^2/n = 2343.4$ (with the regression method).

We determined the fundamental parameters of the star: $T_{\text{eff}} = 10400 \pm 350 \text{ K, } \log g = 4.0 \pm 0.3$.

### 3. DISCUSSION OF RESULTS

Before comparing the magnetic properties of CP stars in the two studied subgroups, 1a and 1b, let us once again recall the basic data about the Orion OB1 association.

The OB1 association in Orion has an evident heterogeneous structure. Blaauw (1964) divided the whole area of the association into four subgroups. Brown et al. (1994) identified 814 stars in the association. The distribution of these stars by subgroups of different ages is as follows:

- Orion OB1a with an average age of 10 Myr contains 311 stars;
- Orion OB1b, an age of 2 Myr, 139 stars;
- Orion OB1c, an age of 5 Myr, 350 stars;
- Orion OB1d is a very small subgroup of 14 stars with an age smaller than 1 Myr.

Almost all of the listed objects are B and A stars of the main sequence. The fraction of hot stars with effective temperatures $T_{\text{eff}} > 10000 \text{ K}$ is higher for inner subgroups: 71.9% for 1b and 92.9% for 1d. For outer subgroups 1a and 1c, this values are 51.1% and 47.7% respectively (Moiseeva et al. 2019, Romanyuk et al. 2013).

The procedure of selecting chemically peculiar stars in the association was thoroughly described in Romanyuk et al. (2013). We identified 85 chemically peculiar stars in it. In general, the proportion of hotter stars among the chemically peculiar is greater than that among the normal stars.

Now let us compare the magnetic field measurements for subgroups 1a and 1b in the Orion association. After excluding the non-peculiar star HD 37149 from consideration, the number of CP stars in both subgroups is equal: 15 stars in each group. For all these stars we measured their magnetic fields in the same way. In subgroup 1a, 7 out of 15 chemically peculiar stars (46.7%) appeared to be magnetic, while in subgroup 1b there were eleven magnetic stars (73.3%). As a criterion for the presence of a magnetic field, we consider the value $\chi^2/n > 5$.

Thus, the fraction of magnetic stars among chemically peculiar stars in younger subgroup 1b is 1.5 times higher than in subgroup 1a. If we compare the proportions of stars with detected magnetic fields relative to all stars in the corresponding subgroup, the difference is even more striking: the proportion of magnetic stars relative to all OBA stars in subgroup 1a is 2.25% (7 out of 311), and in subgroup 1b it is 7.91% (11 out of 139), or 3.5 times greater. This means that with an increase in the age of stars from 2 to 10 Myr, a very sharp decrease in the proportion of magnetic stars relative to the total sample is observed in the Orion OB1 association.

Let us now consider the average magnetic fields of the stars in the studied regions of the association. Obviously, non-magnetic stars should be excluded from comparison, otherwise different proportions of magnetic stars would distort the results. We determine the average root-mean-square (rms) longitudinal magnetic field $\langle B_e \rangle$ for the entire subgroup similar to formula (1), taking the $\langle B_e \rangle$ value for each star as an individual measurement. The individual rms fields of the stars in subgroups 1a and 1b are presented in Tables 4 and 5. The magnetic field measurements of the stars in subgroups 1a and 1b are taken from Romanyuk et al. (2019). There are only three stars in subgroup 1a (HD 35298, HD 35456, and HD 35502) the magnetic field of which are determined absolutely reliably ($\chi^2/n > 30$). In subgroup 1b $\chi^2/n > 30$ for seven stars, and $\chi^2/n > 5$ for all the stars in the table. In the case of HD 36313 and HD 37776 for the reasons mentioned above in the comments for individual stars, the field measurements were taken only by the Hβ line (the stars are marked with '*' in Table 5).

The average rms magnetic field $\langle B_e \rangle$ for all the magnetic stars in subgroup 1a:

- $\langle B_e \rangle = 2286 \text{ G, } \sigma = 1000, \chi^2/n = 16.8$ (measured by the Babcock method),
- $\langle B_e \rangle = 1286 \text{ G, } \sigma = 229, \chi^2/n = 29.8$ (measured by the regression method).
the stars in subgroup 1b of the Orion OB1 association

Table 4. Root-mean-square magnetic fields \( \langle B_e \rangle \) of the stars in subgroup 1a of the Orion OB1 association

| Star     | \( \langle B_e(z) \rangle \pm \sigma, \ \ G \) | \( \chi^2/n \) | \( \langle B_e(r) \rangle \pm \sigma, \ \ G \) | \( \chi^2/n \) |
|----------|---------------------------------|----------|---------------------------------|----------|
| HD 34859 | 1138 ± 692                      | 3.8      | 302 ± 120                       | 9.9      |
| HD 35008 | 1530 ± 1440                     | 3.8      | 258 ± 155                       | 7.0      |
| HD 35177 | 1423 ± 1558                     | 4.3      | 940 ± 275                       | 12.4     |
| HD 35298 | 4600 ± 563                      | 120.5    | 2323 ± 330                      | 71.4     |
| HD 35456 | 447 ± 96                        | 34.3     | 440 ± 80                        | 37.7     |
| HD 35502 | 2221 ± 478                      | 35.3     | 1647 ± 333                      | 41.7     |
| HD 294046| 2153 ± 1214                     | 4.6      | 1496 ± 164                      | 13.3     |

Table 5. Root-mean-square magnetic fields \( \langle B_e \rangle \) of the stars in subgroup 1b of the Orion OB1 association

| Star     | \( \langle B_e(z) \rangle \pm \sigma, \ \ G \) | \( \chi^2/n \) | \( \langle B_e(r) \rangle \pm \sigma, \ \ G \) | \( \chi^2/n \) |
|----------|---------------------------------|----------|---------------------------------|----------|
| HD 36313 * | 1338 ± 500                      | 7.2      |                                 |          |
| HD 36485 | 2724 ± 261                      | 113.8    | 2156 ± 132                      | 635.1    |
| HD 36526 | 2801 ± 384                      | 56.8     | 1695 ± 137                      | 539.3    |
| HD 36668 | 1892 ± 451                      | 37.6     | 953 ± 105                       | 203.5    |
| HD 36955 | 843 ± 219                       | 28.2     | 708 ± 90                        | 93.9     |
| HD 37140 | 585 ± 207                       | 14.0     | 270 ± 107                       | 9.6      |
| HD 37333 | 870 ± 246                       | 19.4     | 433 ± 120                       | 14.6     |
| HD 37479 | 3040 ± 853                      | 29.2     | 1307 ± 324                      | 46.6     |
| HD 37633 | 520 ± 122                       | 41.2     | 382 ± 97                        | 25.5     |
| HD 37776 * | 7285 ± 2686                     | 17.2     | 8644 ± 500                      | 298.9    |
| HD 290665| 2871 ± 121                      | 544.2    | 2260 ± 54                       | 2343.4   |

Thus, both methods of measuring magnetic fields give the same result: the magnetic field of stars in younger subgroup 1b is much stronger than that in subgroup 1a.

Earlier, we repeatedly showed that classical measurements by the Babcock method for hot helium stars are extremely difficult because of the small number of spectral lines suitable for measurements and their complex profiles. The regression method looks more preferable, but even in the cases of a strong field with a complex structure, for example as in the star HD 37776, it can yield underestimated fields. Such cases require special attention, so we consider the measurements made by the regression method separately.

Comparing our measurements of magnetic fields of CP stars in subgroups 1a and 1b of the Orion OB1 association, we come to the conclusion that, on average, the field in the group of seven stars with an age of about 2 Myr is 2.3 times higher than that in the older group of eleven stars with an age of 10 Myr. We also see that \( \chi^2/n \), which characterizes reliability of magnetic field detection, is an order of magnitude higher for stars of subgroup 1b, this as well indirectly indicates that the magnetic field of the stars in subgroup 1b is determined much more reliably than that of the stars in subgroup 1a. It is possible that some stars from our lists in subgroups 1a and 1b have weak fields and we have not detected them, but this in no way affects the conclusions we have obtained in this paper. Long ago, Babcock noted that at the accuracy level in the order of 200 G, only every fourth peculiar star has a magnetic field. With the improved measurement accuracy, this number increased, but in every case it does not exceed half of all measured CP stars. In the Orion OB1 association of young stars, in all its subgroups, the proportion of CP stars with detected magnetic fields
is higher than the Babcock’s estimate; this fact also coincides with our conclusions about higher occurrence of magnetic stars among the young population.

4. CONCLUSION

Thus, a preliminary analysis of magnetic field measurements for the stars in subgroups 1a and 1b of the Orion OB1 association indicates that not only the proportion of peculiar stars relative to normal ones decreases with age, which we showed earlier in Romanyuk et al. (2013), but the proportion of magnetic stars relative to all peculiar stars in the subgroup also significantly drops, as well as the strength of the magnetic field. The rate of the field weakening in the time interval from 2 to 10 yr is unexpectedly large.

On average, the temperature of stars in subgroup 1a appears to be somewhat lower than that in subgroup 1b (Moiseeva et al. 2019, Romanyuk et al. 2013). However, the dependences that we have found cannot be explained by temperature effects. Previously, a number of searches for a dependence between the magnetic field and the temperature were repeatedly carried out and, at best, a weak trend was seen, indicating a decrease of the field with higher temperatures (see, for example, Landstreet et al. (2007)). Based on the aforementioned, we believe that the regularities we have found have evolutionary meaning.

It is possible that younger stars have a developed small-scale field structure which rapidly decays with age, and its contribution in the resulting field significantly decreases. Observationally, this can appear as significant differences in the field strengths obtained from the lines formed at different heights in the atmosphere. This is a goal for future research. On the whole, our result supports the idea of the fossil origin of magnetic fields in CP stars. It is also obvious that the theory of magnetic field formation in hot stars needs further development. At this stage of the research, we have obtained the data that can become an important quantitative observational test for calibrating various mechanisms of formation and evolution of large-scale stellar magnetic fields.

ACKNOWLEDGEMENTS

The authors are grateful to the Russian Telescope Time Allocation Committee for providing the observing time. The data were obtained with polarization analyzers designed and developed by G. A. Chountonov. We made use of the SIMBAD, VIZIER, and NASA/ADS astronomical databases.

FUNDING

Observations carried out with the 6-m BTA are supported by the Ministry of Science and Higher Education of the Russian Federation (including agreement No. 05.619.21.0016, project ID RFMEFI61919X0016). The renovation of telescope equipment is currently provided within the national “Science” project. I.I.R., A.V.M., and I.A.Y. thank the Russian Foundation for Basic Research for partial financial support of this work (RFBR grants No. 20-02-00233, 18-29-21030, 19-32-60007).

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this paper.

S. Bagmulo, L. Fossati, J. D. Landstreet, and C. Izzo, Astron. and Astrophys. 583, A115 (2015).  
S. Bagmulo, J. D. Landstreet, E. Mason, et al., Astron. and Astrophys. 450 (2), 777 (2006).  
Y. Y. Balega, V. V. Dyachenko, A. F. Maksimov, et al., Astrophysical Bulletin 67 (1), 44 (2012).  
A. Blaauw, Annual Rev. Astron. Astrophys. 2, 213 (1964).  
D. A. Bohlender, Astrophys. J. 346, 459 (1989).  
D. A. Bohlender, D. N. Brown, J. D. Landstreet, and I. B. Thompson, Astrophys. J. 323, 325 (1987).  
E. F. Borra, Astrophys. J. 249, L39 (1981).
L. G. Bouma, J. D. Hartman, W. Bhatti, et al., Astrophys. J. Suppl. 245, 13 (2019).
H. Bouy and J. Alves, Astron. and Astrophys. 584, A26 (2015).
A. G. A. Brown, E. J. de Geus, and P. T. de Zeeuw, Astron. and Astrophys. 289, 101 (1994).
F. A. Catalano and P. Renson, Astron. and Astrophys. Suppl. 127, 421 (1998).
G. A. Chuntonov, in Proc. Int. Conf. on Magnetic Stars, Nizhniy Arkhyz, Russia, 2003, Ed.by Yu. Glagolevskij, D. Kudryavtsev, and I. Romanyuk (Nizhniy Arkhyz, 2004), pp. 286–291.
A. N. Heinze, J. L. Tonry, L. Denneau, et al., Astron. J. 156 (5), 241 (2018).
J. Hernández, N. Calvet, L. Hartmann, et al., Astron. J. 129 (2), 856 (2005).
O. Kochukhov, A. Lundin, I. Romanyuk, and D. Kudryavtsev, Astrophys. J. 726 (1), 24 (2011).
D. O. Kudryavtsev, I. I. Romanyuk, V. G. Elkin, and E. Paunzen, Monthly Notices Royal Astron. Soc. 372 (4), 1804 (2006).
J. D. Landstreet, S. Bagnulo, V. Andretta, et al., Astron. and Astrophys. 476 (2), 685 (2007).
G. Mathys and S. Hubrig, Astron. and Astrophys. Suppl. 124, 475 (1997).
A. V. Moiseeva, I. I. Romanyuk, and E. A. Semenko, ASP Conf. Ser. 518, 52 (2019).
C. Neiner and A.-M. Hubert, Commun. Asteroseismology 158, 194 (2009).
P. North, Astron. and Astrophys. Suppl. 55, 259 (1984).
R. J. Oelkers, J. E. Rodriguez, K. G. Stassun, et al., Astron. J. 155 (1), 39 (2018).
V. E. Panchuk, G. A. Chuntonov, and I. D. Naidenov, Astrophysical Bulletin 69 (3), 339 (2014).
D. A. Rastegaev, Y. Y. Balega, V. V. Dyachenko, et al., Astrophysical Bulletin 69 (3), 296 (2014).
P. Renson and J. Manfroid, Astron. and Astrophys. 498 (3), 961 (2009).
I. I. Romanyuk, E. A. Semenko, and D. O. Kudryavtsev, Astrophysical Bulletin 69 (4), 427 (2014).
I. I. Romanyuk, E. A. Semenko, and D. O. Kudryavtsev, Astrophysical Bulletin 70 (4), 444 (2015).
I. I. Romanyuk, E. A. Semenko, A. V. Moiseeva, et al., Astrophysical Bulletin 74 (1), 55 (2019).
I. I. Romanyuk, E. A. Semenko, I. A. Yakunin, and D. O. Kudryavtsev, Astrophysical Bulletin 68 (3), 300 (2013).
I. I. Romanyuk, E. A. Semenko, I. A. Yakunin, et al., Astrophysical Bulletin 71 (4), 436 (2016).
I. I. Romanyuk, E. A. Semenko, I. A. Yakunin, et al., Astrophysical Bulletin 72, 165 (2017).
I. B. Thompson, D. N. Brown, and J. D. Landstreet, Astrophys. J. Suppl. 64, 219 (1987).
A. Tokovinin, Monthly Notices Royal Astron. Soc. 389 (2), 925 (2008).