Magnetic stars, 2004, 198-204

Spectrophotometry of the He-weak star HD 217833

Glagolevskij Yu. V., Leushin V. V., Kevlishvili A. G., Filonova S. V. , Chountonov G. A.

Special Astrophysical Observatory of the Russian AS, Nizhnij Arkhyz 369167, Russia

Abstract. Using spectra obtained at the 6 m telescope, the chemical composition was measured, an estimate of the strength of the surface magnetic field, $B_s = 4500$ G, was made from magnetic intensification of spectral lines, and the turbulent velocity value, $V_t = 0.75 \pm 1.00$ km/s, was derived. The small value of V_t may indicate that the atmosphere of the star is stabilized by the magnetic field, which explains the presence of diffusion processes causing chemical anomalies. Fe has slight excess (0.6 dex), He is strongly deficient, N(He)/N(H) = 0.001. Seemingly, this star can be classified as an extreme He-deficient one. Another characteristic distinction of HD 217833 is the presence of strong and numerous chromium lines in its spectrum, which are not observed in the spectrum of normal stars. At the same time the doublet SiII λ4128 Åand λ4131 Å have an approximately the same intensity as a normal star. The model atmosphere method was used to obtain the temperature $T_e = 16000K$ and the acceleration of gravity $lgg = 3.88$, which correspond to the position of the star on the main sequence between the ZAMS and V luminosity class stars.

Key words: stars: chemically peculiar – stars: magnetic fields – techniques: spectrophotometry – stars: individual: HD 217833

1 Introduction

He-weak stars are remarkable for that they possess a number of characteristic features similar to the rest of the CP stars, but show very strong anomaly of helium, the second in abundance element. The neutral helium lines in the visual region of the spectrum are actually invisible in the spectra of some He-weak stars, although in normal stars having the same temperatures and gravity accelerations the HeI lines are the most intensive after hydrogen. It is apparent that since these stars are comparatively young, helium must account for 30 % of their mass. All the more so its nearly complete absence in the atmospheres of some of these stars is striking. Physical conditions that favor removal of nearly 1/3 of the mass consisting of helium from the atmosphere must be very specific. For this reason, a thorough analysis of the atmospheres of such stars is very important.

Here we present results of investigation of physical conditions in the atmosphere of one of He-weak stars HD 217833.

2 Parameters of the atmosphere of the He-weak star HD 217833

The He-weak star 217833 is the A component of the visual binary system ADS 16474. The star shows brightness variability with period of 5.393 days (Veto 1993), $vsini = 30$ km/s (Abt et al. 2002). The distance of the system derived from the satellite HIPPARCOS data is 221.7 pc ($\pi = 4.51 mas$), the apparent stellar magnitude $V = 6^{\rm m}_{.}15$, consequently, $M_V = -0^{\rm m}_{.}213$. From the data of different authors B–V lies within the limits $0.008 \div -0.15$, U–B equals $-0.55 \div -0.56$. From measurements made by Glagolevskij, Chunakova (1985) the star has a strong magnetic field varying from -2000 to -5000 G. Glagolevskij (2002) and Glagolevskij,

Table 1: Parameters of the He-weak star HD 217833

V	6.516	6.516	6.516
π, mas	4.51	2.08	4.51
M_V	-0.213	-1.90	-0.213
M_{bol}	-1.513	-3.200	-1.513
$log\, L/L_{\odot}$	2.49	3.17	2.49
T, K	16000	16000	14000
$R/R_{\odot}$	2.04	4.00	3.20
$M/M_{\odot}$	4.6	4.6	4.6
$log\, g$	4.38	3.88	4.03

Kopylova (1990) estimated the temperature of the star to be 15500 K and $log\, g = 3.86$. The temperature estimates from the values of B–V computed by Kuruz (1998) yield 16000 K. It should be noted that the effective temperatures of CP stars are determined not quite reliably from calibrations of colors for normal stars because of chemical anomalies of the atmospheres of CP stars. At a correct temperature all the observed values must be consistent with one another, which is not always the case.

Table 1 presents sets of coordinated parameters for the He-weak star HD 217833. It follows from the data of the table that the star has a parallax twice as small as the one given by the HIPPARCOS catalog, or a temperature considerably lower than 16000 K. If, for instance, we take the parameters of the first column, then the star has $log\, g = 4.38$, which means that with its spectral class and mass it must be on the ZAMS.

To make the values of T_{eff} and $log\, g$ more precise, we have calculated a synthetic spectrum around the line H_{δ} by using the program SyntVa developed by Tsymbal (2003) and allowing for the whole list of the lines VALD. The theoretical spectrum was computed for different values of T_{eff} and $log\, g$ varying the abundances of some elements from the models interpolated from the grid of models (Kuruz 1999). Fig. 1 gives a comparison of the observed (see Section 3) spectrum of HD 217833 with the theoretical one for the model atmosphere with $T_{eff} = 16000$ K and $log\, g = 3.88$. The abundances of helium, iron and chromium proved to be as follows: [He] = 0.001, [Fe] = +0.6, [Cr] = +2.0 (see further). Herein there also presented a theoretical spectrum for the model with the normal atmosphere, with the same parameters $T_{eff} = 16000$ K and $log\, g = 3.88$. The conclusion is obvious: the parameters derived when $T_{eff} = 16000$ K and $log\, g = 3.88$ represent best the atmosphere of the He-weak star HD 217833. (By the way, the difference with the temperature from (Glagolevskij 2002) is only 3%, which is insignificant). The parameters obtained are collected in the second column of the table. It is remarkable that the value of π differs from the HIPPARCOS value by more than a factor of 2. The last column lists the parameters of the star derived when using the temperature 14000 K. This temperature does not correspond to the spectrum of the star.

3 Spectral lines in the spectrum of the He-weak star HD 217833

Observational data were obtained with the Main Stellar Spectrograph of the 6 m telescope with a CCD of 1K×1K and with a laminated slicer (Chountonov, Perepelitsin 2000). The spectral resolution corresponded to 0.14 Å/pixel, the S/N ratio was equal to 500, the spectral region was 4000–4265 A.

We have made careful identification and measurement of the spectrum of the He-weak star HD 217833 in the spectral region under investigation. It is noteworthy that the lines HeI λ4009.27 Å, HeI λ4023.97 Å, HeI λ4026.19 Å, HeI λ4120.82 Å, HeI λ4143.76 Å are practically absent in the spectral region studied. The

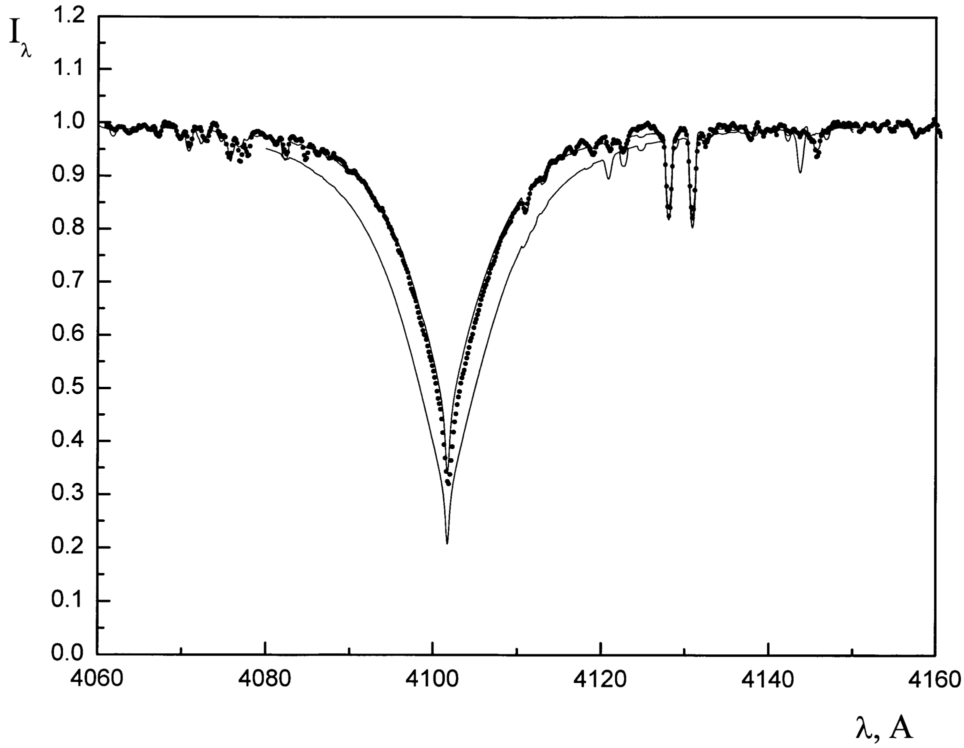

Figure 1: *Comparison of the observed H_δ profile (dots) with the theoretical one. The best fit is reached for the model with the parameters: T_{eff}=16000 K and log g=3.88, N(He)/N(H)=0.001, [Fe]=+0.6, [Cr]=+2.0. Here also is presented the synthetic spectrum for the normal atmosphere model with T_{eff}=14000 K and log g=3.88.*

equivalent widths of these lines in spectra of normal stars reach 300 mÅ, whereas in the spectrum of HD 217833 the lines FeII and FeIII with an equivalent width of about 20 mÅ are identified in these regions of spectrum. The weakest lines measured from our spectra have $1 \div 3$ mÅ. The mean helium abundance that we have derived is N(He)/N(H) = 0.001. In the paper by Glagolevskij, Kopylova (1990) N(He)/N(H) = 0.014. The difference in the estimates by more than an order of magnitude is indicative of strong inhomogeneity of chemical composition over the surface. A characteristic distinction of the line spectrum of the star being discussed is the presence of comparatively strong lines of FeIII, which is evidence that the effective temperature of the atmosphere is obviously higher than 14000 K. Another distinction of the spectrum of HD 217833 is the presence of strong and numerous lines of chromium (see Fig. 2), which are not observed in the spectrum of normal stars (HD119857 in Fig. 2). At the same time the silicon doublet Si λ4128 Å and λ4131 Å has approximately the same intensity as in a normal star spectrum. The abundance of chromium turns out to be [Cr] = 2.0.

4 Determination of microturbulent velocity and magnetic field in the atmosphere of HD 217833 from iron lines

In the spectral region being investigated, 34 lines of FeII and FeIII were measured. These lines were divided into two groups according to the value of the Lande factor (z). The first group included the lines with $z < 1.20$, the second group was comprised of the lines with $z \geqq 1.20$. Thus, the sensitivity of the lines of the former to the influence of magnetic intensification was lower than that of the latter. The lines of the first group were used to determine microturbulent velocity. Computations were conducted for the model chosen above with T_{eff} = 16000 K and $log\, g$ = 3.88 and the helium abundance N(He)/N(H) modified for calculations by the program KONTUR (Leushin, Topil'skaya 1986; Leushin 1995). The parameters of the lines were selected

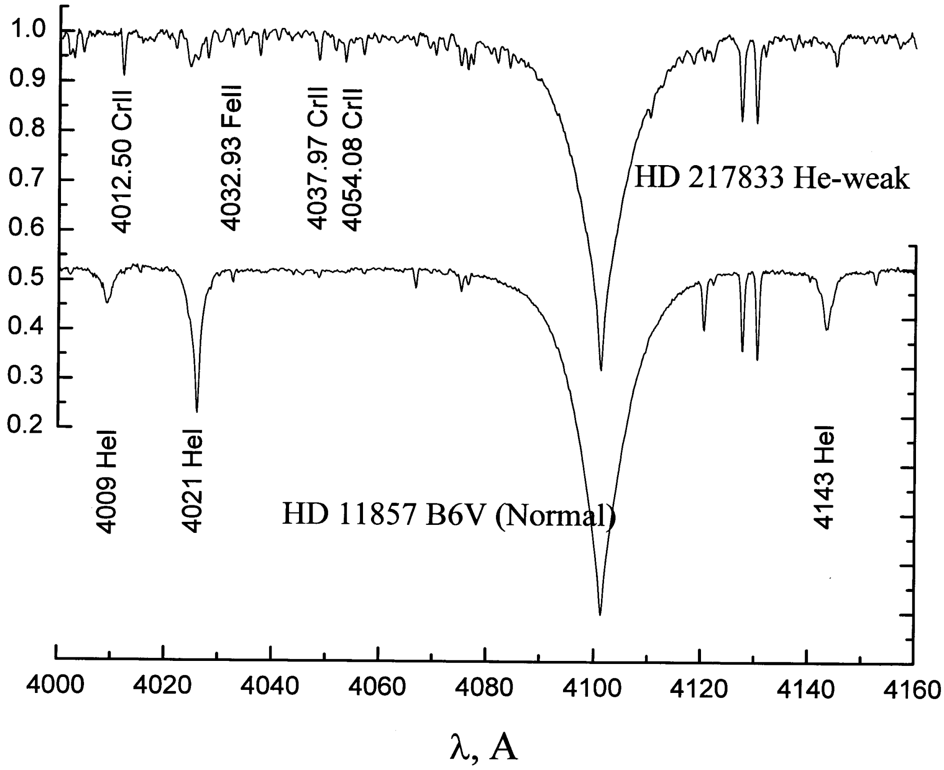

Figure 2: *Comparison of spectra of the He-weak star HD 217833 and the normal star HD 11857 (B6V), having close parameters.*

from the list VALD (Kupka et al. 1999).

Comparison of the values of $log\, N(Fe)$, derived for each line, with the equivalent width, when varying the microturbulent velocity, allows a correct value of this parameter to be found. For this purpose, the linear regression in the form

$log\, N(Fe) = log\, N(Fe)_0 + kw$

is used. The results of calculations for the first group of 16 lines are presented in Table 2.

The relationships between $log\, N(Fe)$ and equivalent width presented by the linear regression yield the coefficient k which indicates the direction of the necessary correction of the microturbulent velocity value. Thus, the data of Table 2 show that the microturbulent velocity in the atmosphere of the He-weak star HD 217833 is $V_t = 0.75 \pm 1.00$ km/s.

The second group consisting of 18 lines was used for determination of the surface magnetic field. Here too the linear regression $log\, N(Fe)$ vrs line equivalent width for different magnetic field values were constructed. The results of calculation of $log\, N(Fe)$ from these lines for $V_t = 0.75$ km/s and different field strengths are collected in Table 3.

The same considerations as stated above show that the magnetic intensification of lines in the atmosphere of the He-weak star HD 217833 corresponds to the mean surface field $H_s = 4500 \pm 1000$ G. It should be noted that this value may prove to be the lower limit of the surface field since the relationship between spectral line intensity and surface field undergoes saturation at a field strength above 5000 G. Several measurements of the mean effective field showed the value $B_e = -5500 \div 2000$ G (Glagolevskij, Chunakova 1985; El'kin 1994).

5 Iron abundance in the atmosphere of HD 217833

The data of Table 2 and 3 show that the iron abundance in the atmosphere of HD 217833 calculated from the two groups of lines, when varying the microturbulent velocity and magnetic field values, may change

Table 2: Parameters of the linear regression for the relationship between iron abundance and equivalent width for different values of microturbulent velocity

V_t, km/s	$log\,N(Fe)_o$	k	$log\,N(Fe)$	σ
1.50	8.266	-0.00315	8.237	±0.072
1.00	8.266	-0.00091	8.258	±0.072
0.80	8.265	-0.00021	8.265	±0.072
0.75	8.263	-0.00007	8.239	±0.070
0.50	8.104	+0.00756	8.205	±0.104

Table 3: Parameters of the linear regression for the 'iron abundance – equivalent width' relation for different magnetic field values

H, gs	$log\,N(Fe)_o$	k	$log\,N(Fe)$	σ
3000	8.308	+0.00289	8.358	±0.099
3500	8.305	+0.00187	8.336	±0.099
4000	8.304	+0.00093	8.319	±0.099
4500	8.300	-0.00002	8.301	±0.100
5000	8.297	-0.00054	8.288	±0.100
7000	8.205	-0.00293	8.243	±0.102

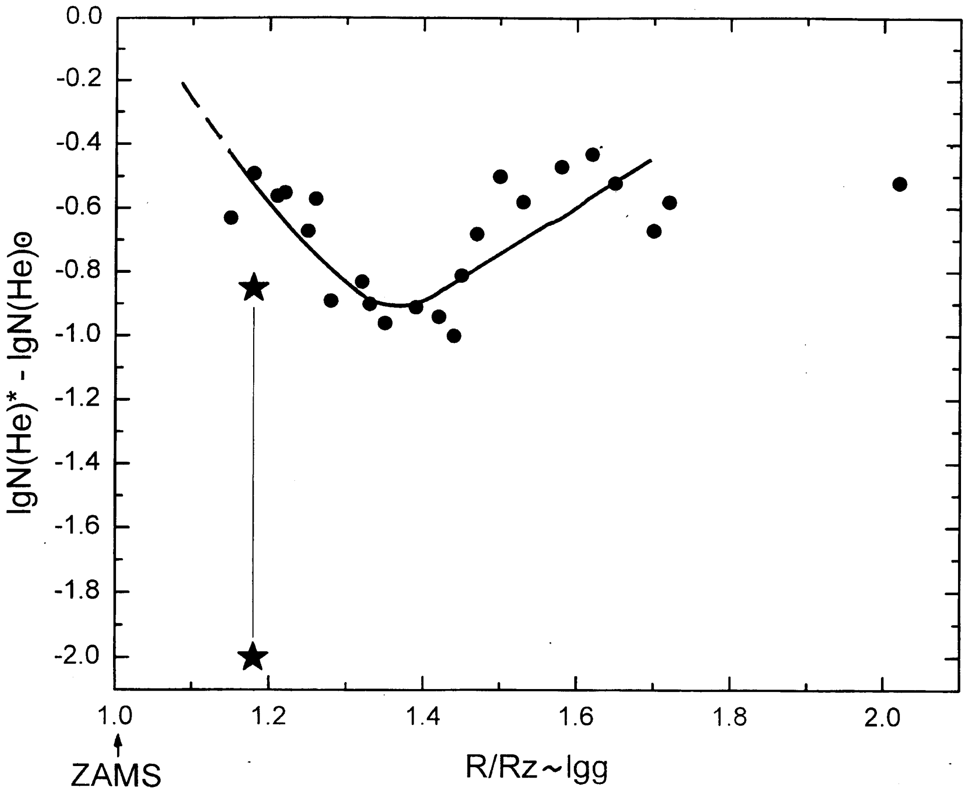

Figure 3: *Two estimates of helium abundance obtained at different times (asterisks). The circles stand for the mean relationship of helium abundance in He-weak stars and age.*

within 0.16 dex at a formal determination error of $\pm 0.1\,dex$. At the same time, our data point definitely to overabundance of iron in the atmosphere of HD 217833 by $\pm 0.6\,dex$ $(log\,N(Fe) = 7.5)$ in comparison with normal. It can be noted that the same overabundance of the iron peak elements is also found in CP stars by other authors (Ryabchikova 1992). However, we have to take into account the fact that the value 7.50 is calculated with respect to the abundance of hydrogen $log\,N(Fe) = 12.00$. In our case, helium deficit in the atmosphere (helium mass accounts for 30 % of the total for normal stars) causes hydrogen abundance to increase to $log\,N(Fe) = 12.15$. Thus, the iron abundance that we have found above should be smaller by 0.15 dex. Table 4 gives the abundance of iron computed from all the lines that we have measured for the model atmosphere with the parameters $T_{eff} = 16000\,\mathrm{K}$, $log\,g = 3.88$, helium abundance N(He)/N(H) = 0.001, microturbulent velocity $V_t = 0.75\,\mathrm{km/s}$, and magnetic field $H_s = 4500\,\mathrm{G}$. The mean value of $log\,N(Fe) = 8.089 \pm 0.070$.

6 Conclusions

The spectrophotometric analysis made for the atmosphere of HD 217833 shows that this is a He-weak star, it has the microturbulent velocity close to zero and a rather strong mean surface magnetic field. The field is likely to stabilize the atmosphere of the star, favoring the diffusion processes that cause separation of elements in the atmosphere. The separation is mainly displayed by movement of helium from the atmosphere deep into the star and causing in it iron to be in excess of $\pm 0.6\,dex$.

Based on the data obtained earlier (Glagolevskij, Kopylova 1990), we have derived a smoothed relationship between helium underabundance $(lg\,N(He)_* - lg\,N(He)_\odot)$ in He-weak stars and relative radius R/R_z, which is displayed in Fig. 3. R is the radius of the star at the present time, while R_z is its radius on the ZAMS. The parameter $R/R_z \propto lgg$ is also proportional to the age of the star on the main sequence. The solid line exhibits the mean relationship which, as expected, vanishes at the ZAMS, the minimum of the relationship falls on the main sequence band corresponding to stars of luminosity class V. This relation is not in contrast with our preliminary conclusions that stars became magnetic chemically peculiar ones near the ZAMS (Leushin et al. 2002), prior to that they had no anomalies (Glagolevskij et al. 1987). Between the point $R/R_z = 1$ that corresponds to ZAMS and the first points on the relationship there is a gap due to observational selection. The asterisks mark the values of the relative abundance of helium for HD 217833, which have been obtained herein and in (Glagolevskij, Kopylova 1990). We draw the conclusion that the distribution of helium over the surface is extremely nonuniform.

7 Spectral lines in the spectrum of the He-weak star HD 217833

It can be readily seen from Fig. 3 that HD 217833 is located between the ZAMS and stars of luminosity class V, i.e. this is a relatively young star. The error of location of the star on this diagram on the horizontal axis is, on average, ±0.1 (Glagolevskij 2002).

The underabundance of helium in HD 217833 is much higher than the average for stars of the same age. This is why it can be ranked among extreme He-weak stars.

References

Abt H. A., Levato H., Grosso M., 2002, Astrophys. J., **573**, 359A

Chountonov G.A., Perepelitsin E.I., 2000, in: Magnetic Fields of Chemically Peculiar and Related Stars, Moscow, 255

El'kin V. G., 1994, in: Chemically Peculiar and Magnetic Stars, Eds: Zverko J., Ziznovsky J., Tatranska Lomnica, 35

Glagolevskij Yu. V., 2002, Bull. Spec. Astrophys. Obs., **53**, 33

Glagolevskij Yu. V., Chunakova N. M. 1985, Astrofiz. Issled. (Izv. SAO), **19**, 37

Glagolevskij Yu. V., Klochkova V. G., Kopylov I. M., 1987, Astron. J., **64**, 360

Glagolevskij Yu. V., Kopylova F. G., 1990, in: Hot Chemically Peculiar and Magnetic Stars, ed. By G. Scholz, Potsdam-Babelsberg, 62

Kuruz R., 1999 //http://kuruch. Harvard/edu

Kupka F., Piskunov N. E., Ryabchikova T. A., Stempels H.C., Weiss W., 1999, Astron. Astrophys. Suppl. Ser., **138**, 119

Leushin V. V., 1995, Astron. Zh., **72**, 543

Leushin V. V., Glagolevskij Yu. V., North P., 2000, in: Magnetic Fields of Chemically Peculiar and Related Stars, Moscow, 173

Leushin V. V., Topil'skaya G. P., 1986, Astrophysics, **22**, 121

Ryabchikova T. A., 1992, Chemical evolution of stars and galaxies (in Russian), Moscow, "Kosmoinform", 119

Tsymbal V. V., 2003, private communication

Veto B., 1993, in: Proc. IAU Coll. 138, eds.: Dworetskij M. M., Castelli F., Faraggiana R., ASP Conf. Series, **44**, 340