LITHIUM BLEND FITTING FOR roAp STAR HD101065 (PRZYBYLSKI'S STAR)

A.V. Shavrina[1], V. Khalack[1], N.S. Polosukhina[2], J. Zverko[3], J. Žhižnovský[3], V.F. Gopka[4], P. North[5], V.V. Tsymbal[6], A.V. Yushchenko[4]

[1]Main Astronomical Observatory of NAS of Ukraine
Golosiivo, 03650, Kyiv, Ukraine, *shavrina@mao.kiev.ua*
[2]Crimean Astrophysical Observatory
Nauchnyj, Crimea, Ukraine
[3]Astronomical Institute of the Slovak Academy of Sciences
05960 Tatranska Lomnica, the Slovak Republic
[4]Astronomical observatory, Odessa National University, Ukraine
65014, park Shevchenko, Odessa, Ukraine
[5]Inst. d'Astronomie, Univ. Lausanne, Switzerland
CH-1290 Chavannes-des-Bois, Switzerland
[6]Tavrian National University,
Simpheropol, Ukraine

ABSTRACT. We have considered the possibility for modelling of remarkable spectral feature 6708 Å for HD101065 (Przybyslski's star) in two ways - as a blend of Li and REE lines and as blend of REE lines only. We show by model calculations that Li lines absorb significantly in the range 6707.72 -6708.02 ÅÅ and resulting Li abundance 3.3 dex (in the scale lg N(H)=12.0) is near to the primordial value.

Key words: Stars: chemically peculiar; individual: HD101065 stars: individual: HD101065.

1. Introduction

Following to Cowley & Mathys (1998) and Cowley et al. (2000) we undertaken the new analysis of the spectrum of Przybylski's star (HD101065, V816 Cen), which has the most unusual of all stellar spectra (Wegner et al., 1983). As was first noted by it's discoverer, A. Przybylski (1961, 1977), in the spectrum of HD101065 the strongest spectral lines generally belong to lanthanides. For this star the relative abundances of elements depend critically on the assumed stellar temperature and applied line identification method (Cowley et al., 2000).

The strong complicated spectral feature at λ 6708 Å in the observable spectra creates the problem of correct line identification in this region. The comprehensive analysis of REE lines was performed and the main contribution of lithium was shown for this blend.

Table 1: List of observations for HD101065.

#	Date d.m.y	UT h m	Exp. [m]	HJD 2450000+	Range
04	11.3.96	5 11	20	153.726	6675–6735 Å
26	10.3.96	4 41	20	152.705	6120–6180 Å

2. The observations and their reductions

The observations were made by PN with the ESO Coudé Auxiliary Telescope. The Coudé Échelle Spectrograph was used with resolving power R=100000 and the S/N ratio for an individual spectrogram was better than 100 at the 1σ level. The detector was ESO CCD 34 with 2048 pixels along the dispersion. A thorium-argon lamp was used for the wavelength calibrations with an accuracy better than 0.3 km s^{-1}. Primary data reduction was done by PN during the observing run, using the old IHAP system of ESO. In Table 1 the date, exposure time and wavelength coverage are given.

3. Atmosphere model

The values of $T_{\rm eff} = 6750$, $\log g = 4.0$ and $v \sin i = 3.5 \pm 0.5$ km s^{-1}, that are close to the model parameters of Cowley et al. (2000) $T_{\rm eff} = 6600, \log g = 4.0$

Table 2: Abundances of the elements ($\log N/N_{tot}$) for HD101065 as compared with data of Cowley et al. (2000) for this star, for the HD166473 (Gelbmann et al., 2000) and for the Sun (Grevesse & Sauval, 1998).

El	HD101065	n	HD101065	HD166473	Sun
Li I	-8.70 ± 0.10	2	-	–	-10.88?
C I	-4.10 ± 0.10	3	-3.97 ± 0.01	-4.24 ± 0.11	-3.52
O I	-4.40 ± 0.10	3	-3.72 ± 0.25	-4.76 ± 0.21	-3.21
Na I	-5.50 ± 0.10	3	-5.81 ± 0.23	-5.84 ± 0.37	-5.72
Al I	-6.10 ± 0.10	1	-	-4.78 ± 0.37	-5.57
Si I	-4.60 ± 0.10	9	-4.38 ± 0.24	-4.10 ± 0.26	-4.48
Ca I	-6.35 ± 0.10	4	-6.67 ± 0.34	-5.34 ± 0.29	-5.69
Ti I	-7.05 ± 0.20	3	-7.08 ± 0.29	-6.70 :	-7.10
Cr I	-4.70 ± 0.20	6	-6.19 ± 0.21	-5.50 ± 0.45	-6.35
Fe I	-5.10 ± 0.20	6	-5.41 ± 0.26	-4.34 ± 0.22	-4.54
Co I	-6.20 ± 0.20	1	-5.67 ± 0.20	-6.03 ± 0.12	-7.13
Y I	-6.60 ± 0.20	3	-7.67 :	–	-9.81
Ba II	-9.10 ± 0.25	1	-7.69 ± 0.01	-10.37 ± 0.06	-9.82
La II	-7.82 ± 0.20	6	-7.75 ± 0.35	-8.30 ± 0.25	-10.82
Ce II	-7.35 ± 0.25	4	-7.19 ± 0.33	-7.55 ± 0.41	-10.41
Pr II	-9.16 ± 0.20	5	-8.63 ± 0.31	-8.81 ± 0.22	-11.24
Pr III	-8.00 ± 0.25	6	-7.05 ± 0.36	-7.60 ± 0.38	-11.24
Nd II	-7.55 ± 0.20	11	-6.91 ± 0.34	-7.97 ± 0.28	-10.55
Nd III	-6.10 ± 0.20	2	-6.52 ± 0.40	-6.43 ± 0.37	-10.55
Sm II	-7.60 ± 0.15	16	-7.12 ± 0.39	-8.25 ± 0.23	-11.06
Eu II	-7.53 ± 0.20	1	-8.03 ± 0.41	-8.43 ± 0.20	-11.49
Gd II	-7.52 ± 0.25	7	-7.14 ± 0.38	-7.87 ± 0.20	-10.95
Tb II	-8.90 ± 0.25	1	-	-	-12.10
Dy II	-7.64 ± 0.20	1	-7.52 ± 0.27	-7.79 ± 0.37	-10.87
Er II	-7.81 ± 0.20	1	-7.82 ± 0.28	-8.22 ± 0.17	-11.07
Yb II	-7.96 ± 0.20	2	-8.92 ± 0.34	-8.93 ± 0.32	-11.08
Lu II	-7.28 ± 0.25	1	-8.31 ± 0.28	-8.82 ± 0.27	-11.91
Os I	-7.59 ± 0.25	1	-	-	-11.55
Ir I	-7.95 ± 0.25	1	-	-	-11.65

and $v\ \sin i = 3.5 \pm 0.5\,\mathrm{km\ s^{-1}}$ were used by us for analysis. Model with [M/H]=0.0 was applied. In order to take into account the magnetic broadening of spectral lines for the surface magnetic field 2.3 kG Cowley et al. (2000) value of microturbulent velocity $V_{micro} = 2\,\mathrm{km\ s^{-1}}$ was applied.

4. Rotation and magnetic field

The high-speed photometric observations reveal that HD101065 pulsates with at least three frequencies near 1.37 mHz (Kurtz, 1978). But the detected frequencies are not equally spaced and hence cannot be straightforwardly interpreted in terms of the oblique pulsator model (Martinez & Kurtz, 1990). Therefore these authors can not obtain the value of stellar rotation velocity from the analysis of photometric data variability.

The first magnetic field observations for HD101065 were carried out by Wolff & Hagen (1976), that obtained the three evaluations of the mean longitudinal field ranging from -2100 to -2500 G, with estimated error of 450G. Such large uncertainties could be due to the severe blending (Cowley, 2000), that is usual as for the Przybylski's star. Another estimates of the mean longitudinal magnetic field $(-1408 \pm 50)\,G$ as well as of the crossover $(-2670 \pm 980)\,\mathrm{km\ s^{-1}}\,G$ and the mean quadratic field, with a 3σ upper limit of $8.7\,kG$, (the analysed spectrum of HD101065 was obtained in June 1992) were performed by Cowley & Mathys (1998) in the same way as described by Mathys & Hubrig (1997). The last derived value for the mean longitudinal field is marginally smaller (in absolute value) than previous ones. But in order to make a final conclusion about the reality of mean longitudinal magnetic field variation during the time interval of about 20 years, that separates these two determination moments, the new additional observations (Mathys, 2001) should be carried out. At the recent paper of Cowley et al. (2000) authors have relatively well represented the observed line profiles of HD101065 (obtained at

Table 4: The shares of main absorption contributors.

Line (λ_0, Å)	El	λ (Å)	Share (%))	El	λ (Å)	Share (%)
6707.72	^{7}Li I	6707.756	11	^{7}Li I	6707.768	16
	*Sm II	6707.779	1			
6707.82	^{7}Li I	6707.756	9	^{7}Li I	6707.768	17
	*Sm II	6707.779	1	^{7}Li I	6707.907	2
	^{7}Li I	6707.908	1	^{6}Li I	6707.916	2
	^{7}Li I	6707.919	3	^{7}Li I	6707.920	2
	^{6}Li I	6707.928	2			
6707.92	^{7}Li I	6707.756	1	^{7}Li I	6707.768	2
	^{7}Li I	6707.907	4	^{7}Li I	6707.908	2
	^{6}Li I	6707.916	4	^{7}Li I	6707.919	6
	^{7}Li I	6707.920	4	^{6}Li I	6707.928	6
6708.02	^{7}Li I	6707.907	1	^{7}Li I	6707.908	1
	^{6}Li I	6707.916	1	^{7}Li I	6707.919	2
	^{7}Li I	6707.920	1	^{6}Li I	6707.928	3
	^{6}Li I	6708.067	1	^{6}Li I	6708.068	1
	^{6}Li I	6708.079	1	^{6}Li I	6708.080	1
	*Ce II	6708.099	6			

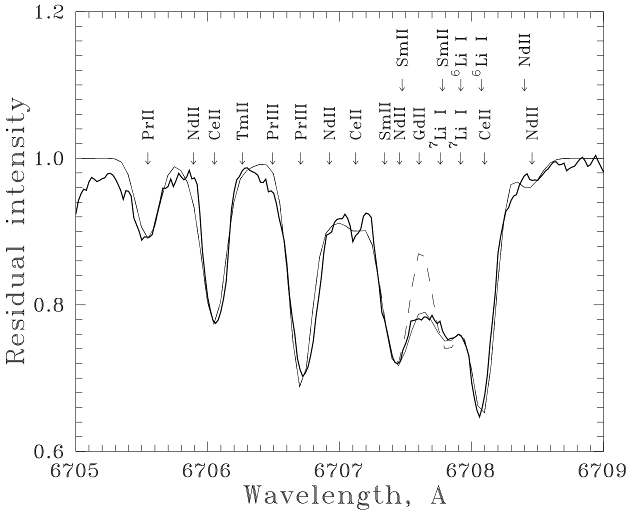

Figure 1: The observed (thick line) and simulated with Gd II 6707.462 Å line (dashed thin line) spectra for HD101065. Thin line - calculated spectrum with shifted Gd II line 6707.602 Å.

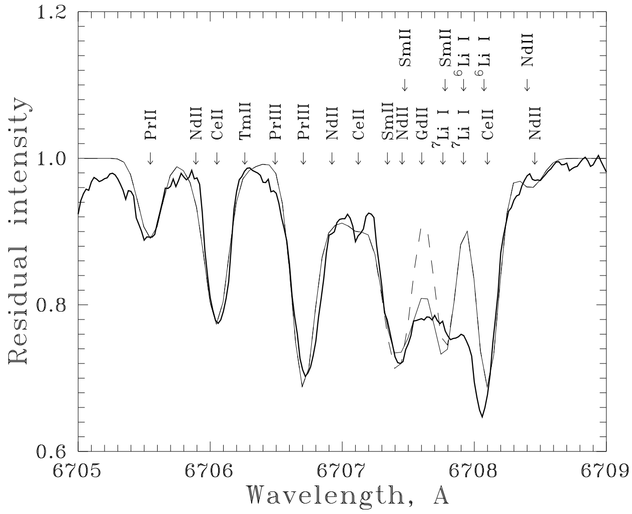

Figure 2: The same as at the Fig.1, but without the lithium lines (only REE lines).

February 1998) by synthetic profiles calculated with a mean surface magnetic field $Bs = 2300 \pm 350\,G$ and $v \sin i = 3.5 \pm 0.5\,\mathrm{km\ s^{-1}}$.

5. Abundance analysis

All the available spectra have been analysed with the help of "STARSP" and "ROTATE" code developed by V.Tsymbal (1996). The last code was modified by A. Yushchenko. "URAN" (Yushchenko, 1998) and "SYNTHE" (Kurucz, 1995) codes were also used.

The chemical element abundances used in synthetic spectra simulations are given in Table 2. Table 3 contains the line list used in model calculations. The wavelengths of lines marked by asterisk were calculated on the base of NIST energy levels. Corresponding gf-values were estimated by us using the abundances of each element determined on the base of other lines with known gf-values (from VALD and Kurucz lists) in two spectral regions, 6113-6173 ÅÅ and 6675-6735 ÅÅ.

The line Sm II λ 6707.779 Å coincides almost with the centre of lithium blend λ 6707.844 Å. We tried to

Table 3: Line list used in synthetic spectra.

El	λ (Å)	E_{low} (eV)	$\log gf$
*Pr II	6705.5470	0.000	-2.985
Ce II	6706.0510	1.840	-1.253
*Tm II	6706.2620	3.955	-1.253
*Pr III	6706.4920	3.104	-1.285
Pr III	6706.7050	0.550	-1.285
*Nd II	6706.9220	3.211	-2.179
*Ce II	6707.1210	1.255	-2.303
*Sm II	6707.3420	0.885	-2.579
*Nd II	6707.4530	2.880	-2.179
Sm II	6707.4730	0.930	-2.679
*Gd II	6707.6021	3.270	-0.679
^{7}Li I	6707.7560	0.000	-0.427
^{7}Li I	6707.7680	0.000	-0.206
*Sm II	6707.7790	2.037	-2.679
^{7}Li I	6707.9070	0.000	-0.931
^{7}Li I	6707.9080	0.000	-1.161
^{6}Li I	6707.9160	0.000	-0.927
^{7}Li I	6707.9190	0.000	-0.712
^{7}Li I	6707.9200	0.000	-0.931
^{6}Li I	6707.9280	0.000	-0.706
^{6}Li I	6708.0670	0.000	-1.431
^{6}Li I	6708.0680	0.000	-1.661
^{6}Li I	6708.0790	0.000	-1.212
^{6}Li I	6708.0800	0.000	-1.431
*Ce II	6708.0990	0.700	-1.950
*Nd II	6708.4580	3.536	-2.579

*gf-values were estimated by us (see text).

calculate this blend without lithium lines with shifted Sm II line on λ 6707.844 Å. Result fitting was bad (see Fig. 2). Only the including of ^{7}Li and ^{6}Li doublets with ratio $^6Li/^7Li = 0.3$ permitted us to well represent the observed profile of blend (see Fig. 1). In Table 4 we show the shares in total absorption of the main contributors as ones were given by "STARSP" code in four representative wavelengths for lithium doublet range 6707.72-6708.02 ÅÅ of blend profile (for $V_{micro} = 2$ km s^{-1}) without instrumental smoothing.

6. Discussion

We have considered the possibility for modelling of remarkable spectral feature 6708 Å for HD101065 (Przybyslski's star) in two ways - as a blend of Li and REE lines and as blend of REE lines only. We show by model calculations that Li lines absorb significantly in the range 6707.72-6708.02 ÅÅ and resulting Li abundance 3.3 dex (in the scale lgN(H)=12.0) is near to the primordial value.

Our synthetic spectra calculations show the necessity of additional absorption at 6707.6 Å. Instead of including of new unknown lines for better fitting to observed profile we shifted Gd II line centre at 6707.602 Å. We changed the gf-value for +0.2 dex for line Gd II 6707.462 Å, calculated by us, when shifted it at 6707.602 Å with fixed Gd abundance. In the Li absorption range (6707.72-6708.02 ÅÅ) this line does not add any noticeable contribution (see Table 4).

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