Advances in Astronomy and Space Physics, **3**, 29-31 (2013)

MgH lines in the spectrum of Arcturus

I. O. Kushniruk[1]*, *Ya. V. Pavlenko*[2], *B. M. Kaminskiy*[2]

[1]Taras Shevchenko National University of Kyiv, Glushkova ave., 4, 03127, Kyiv, Ukraine
[2]Main Astronomical Observatory of the NAS of Ukraine, 27 Akademika Zabolotnoho St., 03680 Kyiv, Ukraine

The synthetic spectra of MgH lines were computed for the grid of the model atmospheres and compared with the observed spectrum of Arcturus. The parameters of the atmosphere of Arcturus for $\log g = 1.5$ and $T_{eff} = 4300K$ were via minimization of deviation between observed and computed spectra and compared with the results of other studies.

Key words: stars: atmospheres, fundamental parameters, individual (Arcturus), line: profiles

INTRODUCTION

The red giant Arcturus (α Boo, K2III) is one of the brightest stars on the sky. It is interesting for studying, because its mass is close to the mass of the Sun, but it is at the later stage of evolution out of the Main Sequence. In some sense Arcturus represents the future of our Sun. It is known as an excellent reference star for spectroscopic studies of red giants, therefore availability of precise atmospheric parameters for this star is very important. The atmospheric parameters of Arcturus were estimated by several authors using a variety of techniques, e. g., the PASTEL database of stellar parameters by Soubiran et al. [10], which lists 28 entries for Arcturus.

One of the common problems in studying cool stars is the difficulties of the surface gravity estimations. Balmer lines in the spectra of such stars are sensitive to changes of T_{eff} but not to $\log g$. In such case it is possible to use lines of some moleculas, which are sensitive to $\log g$ changes. MgH is suitable for this purpose, but we need to know abundances of magnesium and hydrogen, because MgH lines are very sensitive to them. In such case we need to search for the self-consistent solution for T_{eff}, $\log g$, and abundances of Mg and H using the iteration method [5].

At least three different MgH line lists are known at the present (lists by Yadin at al. [12], Weck et al. [11], and Kurucz [4]). Some of them describe spectra well, others not. In the present work we used MgH line list by R. Kurucz [4], which is very suitable for describing the spectrum.

We investigated a few tasks here: (i) can MgH lines be used to refine $\log g$ and effective temperature of Arcturus; (ii) how do MgH lines in the spectrum of Arcturus depend on $\log g$; and (iii) how do MgH lines in the spectrum of Arcturus depend on T_{eff}?

*nondanone@gmail.com

THE CALCULATIONS

We computed 28 model atmospheres with different $\log g$ and T_{eff}: $\log g$ within the range of 0.75 – 2.25 with the step 0.25, and T_{eff} within the range of 4200 – 4500 K with the step 100 by `SAM12` program [6]. The synthetic spectrum of Arcturus was obtained with `WITA6` [7] code. The line list data were taken from the VALD [3] database of atomic absorption spectra, the observed spectrum was taken from the Visible and Near Infrared Atlas of the Arcturus Spectrum by Hinkle et al. [5]. For the first approach we used chemical composition found in [9]. Smoothing of the spectra of the instrumental profile was taken into account (see Fig. 1). We chose 23 "good" MgH features, which consist of more or less clean (without atomic lines) MgH lines. Then we compared the observed spectrum and computed synthetic spectrum of Arcturus. In order to do that, we calculated the deviation S between the MgH features in the theoretical and observed spectra for all grid of the models:

$$\sum_{i=1}^{n} \frac{(f_{obs,i} - f_{comp,i})^2}{l_2 - l_1} = S_j, \sum_{j=1}^{N} S_j = S, \quad (1)$$

where n is the number of points in the feature, N is the number of features, S_i is a deviation for one of features, S is the total deviation for the model atmosphere with some $\log g$ and T_{eff}, l_1 and l_2 are boundary wavelengths of MgH feature.

The example of the obtained dependence of residual flux on $\log g$ for one of the 23 chosen lines is presented in Fig. 2 (here T_{eff} is a constant and $T_{eff} = 4300$ K). Arrows on the plots show the features l_1 and l_2 boundaries.

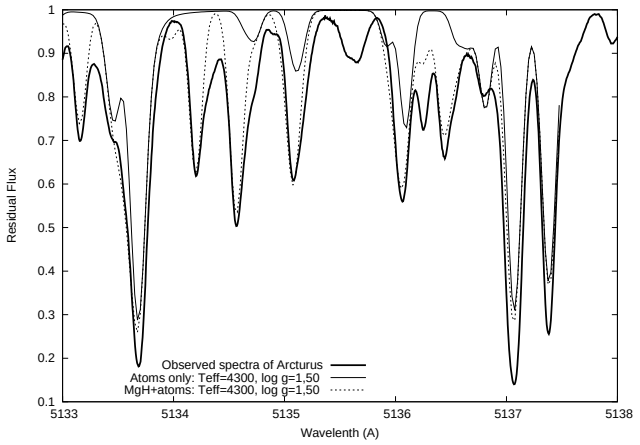

Fig. 1: Comparison of the observed spectrum of Arcturus with synthetic spectra of Arcturus computed with and without the MgH absorption taken into account shown by thick solid, thin solid and dashed lines, respectively.

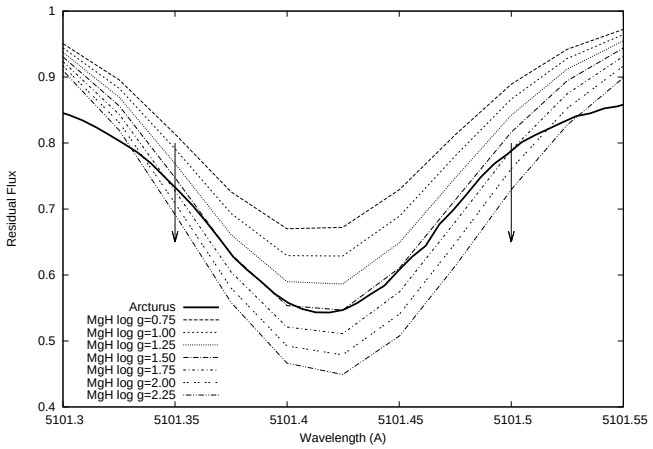

Fig. 2: Dependence of the residual flux on $\log g$ for $T_{eff} = 4300K$, $\log g$ changes from 0.75 to 2.25 (from top to bottom), solid line shows the observed spectrum. Arrows label spectral range used to compute S.

RESULTS AND DISCUSSION

The results of the S value computations for all 23 lines in the case of $T_{eff} = 4300\,\mathrm{K}$ are shown in Table 1, and in Fig. 3.

3D visualization of the dependences of S on T_{eff} and $\log g$ are shown in Fig. 4. We can find the minimum S value around $\log g = 1.5$ for $T_{eff} = 4300\,\mathrm{K}$. Here the obviously visible degeneration of $S(T_{eff}, \log g)$ exists. In other words, $\log g$ can be determined if T_{eff} is fixed by any other method. As Bell at al. [1] noted, a dominant source of errors of determination of $\log g$ using MgH lines is the error in T_{eff}.

The comparison of our result with results of other studies taken from the catalogue of Soubiran et al. [10] is present in Fig. 5. The line on the plot is the projection of minimum S on the plane T_{eff} vs. $\log g$, this line can be used as a calibration curve for $\log g$ determination. Our values (the cross in Fig. 5) are close enough to the middle of the range, and at the same time are in excellent agreement with the results of [9] and some most recent works (see [10] for the references). There is another work [1] where MgH lines were used for $\log g$ determination, which gave $\log g = 1.8$ for effective temperature of 4375 K. If we use our calibration curve for $T_{eff} = 4375\,\mathrm{K}$ we can obtain very close value of $\log g = 1.9$.

Table 1: Dependence of deviation on $\log g$ for $T_{eff} = 4300\,\mathrm{K}$.

$\log g$	S	ΔS
0.75	46.941200	0.2360
1.00	24.575607	0.1247
1.25	11.600469	$5.7159 \cdot 10^{-2}$
1.50	9.2575245	$3.9869 \cdot 10^{-2}$
1.75	16.896948	0.1063
2.00	32.928326	0.2056
2.25	54.842117	0.3246

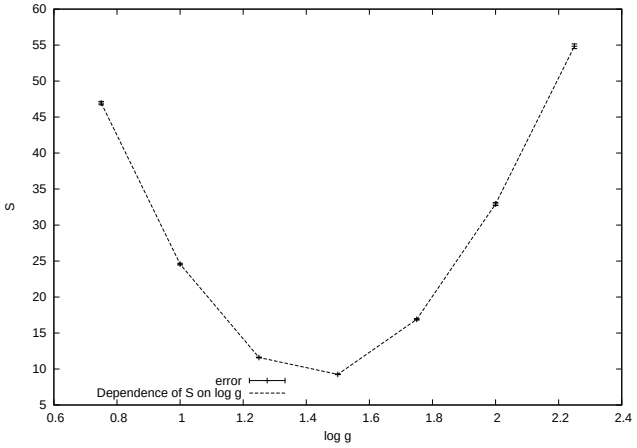

Fig. 3: Dependence of S on $\log g$ for $T_{eff} = 4300K$.

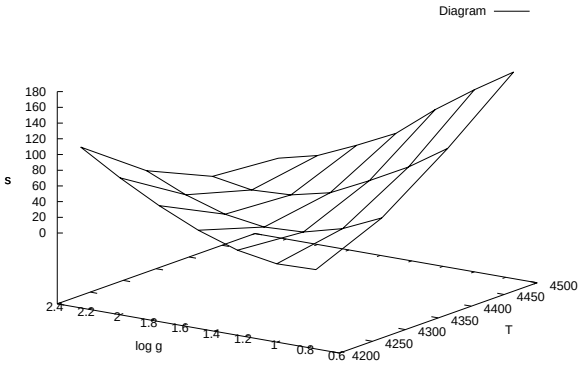

Fig. 4: Dependence of S on $\log g$ and T_{eff}.

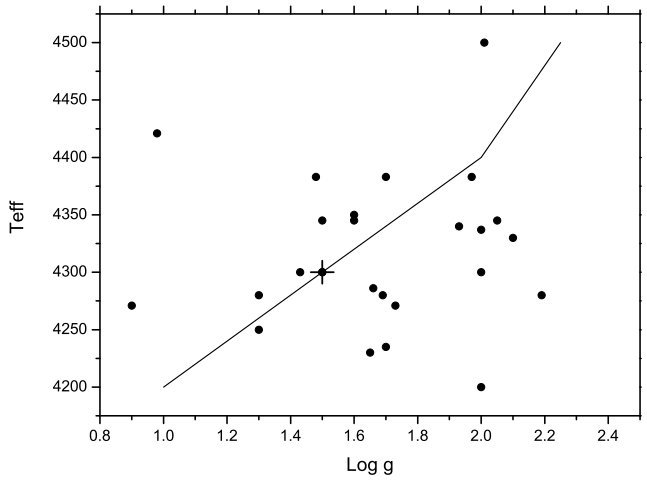

Fig. 5: Projection of S minima (see Fig. 4) onto the plane T_{eff} vs. $\log g$. Our values of T_{eff} and $\log g$ are shown by cross, dots are the values of these parameters from other works mentioned in [8].

CONCLUSIONS

Our analysis was performed in the framework of the classical approach. We did not take into account a few important processes which might affect the intensities and profile shapes of spectral lines in stellar spectra, i. e. NLTE, dependence of V_t on depth, rotation, chromospheres (see [1] for more details). Nevertheless, we obtained several interesting results of the common interest:

- We selected 23 more or less clean from the atomic lines MgH features in the wavelength range 5100–5200 Å. The information about them is available in the web[1].
- We show that absorption spectrum of MgH molecule is suitable for finding fundamental parameters of cool stars such as Arcturus.
- There is a degeneration of S on $\log g$. We obtained the calibration curve which can be used for $\log g$ determination if T_{eff} and abundance of Mg are fixed by any other independent method.
- Our values of T_{eff} and $\log g$ determined for Arcturus are in a good agreement with the results of other authors.

ACKNOWLEDGEMENT

We thank to Profs. Hinkle, Kurucz, and VALD team for providing databases of astrophysical data used in our work, Oleksiy Ivanyuk and Larisa Yakovina for the helpful comments, and anonymous Referee for some positive remarks.

REFERENCES

[1] Bell R. A., Edvardsson B. & Gustafsson B. 1985, MNRAS, 212, 497
[2] Hinkle K., Wallace L., Valenti J. & Harmer D. 2000, *Visible and Near Infrared Atlas of the Arcturus Spectrum 3727–9300 A*, San Francisco
[3] Kupka F., Piskunov N., Ryabchikova T. A., Stempels H. C. & Weiss W. W. 1999, A&AS, 138, 119
[4] Kurucz R. & Bell B. 1995, *Atomic Line Data* Kurucz CD-ROM No. 23, Cambridge, Mass.: Smithsonian Astrophysical Observatory
[5] Lyubimkov L. S. 1995, *Chemical composition of stars: method and result of analysis*, Astroprint, Odessa
[6] Pavlenko Ya. V. 2003, Astron. Rep., 47, 59
[7] Pavlenko Ya. V. 1997, Astrophys. and Space Science, 253, 43
[8] Ramírez I. & Allende Prieto C. 2011, ApJ, 743, 135
[9] Peterson R. C., Dalle Ore C. M. & Kurucz R. L. 1993, ApJ, 404, 333
[10] Soubiran C., Le Campion J.-F., Cayrel de Strobel G. & Caillo A. 2010, A&A, 515, 111
[11] Weck P. F., Schweitzer A., Stancil P. C., Hauschildt P. H. & Kirby K. 2003, ApJ, 582, 1059
[12] Yadin B., Veness T., Conti P. et al. 2012, MNRAS, 425, 34

[1] `http://www.mao.kiev.ua/staff/yp/Results/MgHclean.ascii`