ABOUT THE HEAVY ELEMENTS ABUNDANCES IN THE ATMOSPHERES OF STARS WITH LOW METALLICITY

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ABSTRACT. We present results of preliminary determinations of abundances of heavy elements in three metal-poor stars: HD37828, HD44008, HD221170. Careful comparison of observed and synthetic spectra permit us to increase the number of lines heavy elements identified in observed spectra. Results will be used for determinations of the abundances of these elements with the spectrum synthesis method in these and other metal-poor stars.

Key words: nucleosynthesis; stars: abundances; stars: poor-metal; stars: individual: Arcturus, HD37828, HD44008, HD221170.

1. Introduction

The elements heavier than the iron peak are mainly produced through neutron capture reactions. Two main mechanisms are generally distinguished: the s-process (slow) and r-process (rapid), depending on the magnitude of the neutron flux available. Other mechanisms are p-process and α-process (Woosley, Hofman, 1992). The site of the r-process is explosive situations, such us those encountered in Type II supernovae seem's to be required. The most popular site for the operation of the s-process is the thermally pulsing shell in intermediate mass asymptotic giant branch (AGB) stars.

Investigation of abundances of heavy elements in the atmospheres of old stars with low metal content is the direct method for detection of AGB stars, for testing the theories of stellar evolution and nucleosynthesis.

Table 1: Parameters of atmosphere models for Arcturus and program stars

Star	T_{eff} (K)	lg g	V_{micro} (km s^{-1})
Arcturus	4350	1.60	1.6
HD37828	4350	1.00	1.5
HD44007	4950	2.25	1.5
HD221170	4500	1.00	1.5

The comparison of chemical composition of stars of different populations is very interesting because of the information about the process of chemical enrichment during early stages of Galaxy formation.

2. Observations

In this work we report the preliminary results of determination of chemical composition of Arcturus-like red-giants stars with low metallicity: HD37828, HD44008 and HD221170. Spectra of these stars were selected from a library of high-resolution stellar spectra (Soubiran et al., 1998). The spectra of the library were obtained with the echelle spectrograph ELODIE attached to the 1.93 m telescope at the Haute-Provence, France. The spectra cover the spectral range 4400-6800 Å, resolving power was R=42000, signal to noise ratio was about S/N=100 and higher. Wavelength calibration, continuum fitting and other preliminary data reduction were made by Mishenina & Kovtyukh (2001).

Griffin (1968) Atlas of Arcturus spectrum and Delbouille et al. (1973) Atlas of the spectrum of the center of solar disk were used as a spectra of comparison stars. The resolving power of these Atlases are R=150000 and R=500000, signal to noise ratio are R=100 and more than one thousand respectively.

3. Methodics

The abundance analysis needs little description. It is based on technique of synthetic spectra and comparison of synthetic spectrum with observed one. We calculated the synthetic spectra of Arcturus, Sun and program stars in the wavelength region covered by observed spectra using Kurucz (1995) SYNTHE program. Synthesis was performed taking into account all possible blending by atomic and molecular lines with measured wavelengths and oscillator strengths from Kurucz (1995) database (CD-ROMs 1, 15, 18, 23). We used also new data from VALD database (Piskunov et. al., 1995) and recently published Morton (2000) data.

The values of abundances of elements were adopted from previous investigations of the stars (see Mishenina

Table 2: Abundances of heavy elements in Arcturus and three metal-poor stars

		Arcturus (Griffin)		Arcturus (ELODIE)		HD37828		HD44007		HD221070	
Z	Element	ΔlgA	N	ΔlgA	N	ΔlgA	N	ΔlgA	N	ΔlgA	N
30	Zn I	-0.83	3	-0.92	1	-1.33	4	-1.45	3	-1.97	3
38	Sr I	-0.63	4	-0.83	1	-1.35	2	-1.61	1	-1.62	3
39	Y I	-0.79	3			-1.43	2	-1.26	1		
	Y II	-0.72	15	-0.64	6	-1.47	7	-1.46	12	-2.22	7
40	Zr I	-0.65	17	-0.63	9	-1.21	9			-1.80	3
	Zr II					-1.33	3			-1.84	3
41	Nb I									-2.02	1
42	Mo I	-0.45	2	-0.51	1	-1.04	1	-1.10	1		
44	Ru I	-0.62	1	-0.65	1	-1.20	1				
56	Ba II	-0.72	2			-1.40	2				
57	La II	-0.68	11	-0.71	9	-1.44	10	-1.46	7	-1.99	8
58	Ce II	-0.69	22	-0.68	14	-1.32	15	-1.52	7	-1.83	11
59	Pr II			-0.83	2	-1.63	3	-1.34	1	-1.86	1
60	Nd II	-0.49	25	-0.50	19	-1.20	20	-1.20	12	-1.74	10
62	Sm II	-0.51	20	-0.52	9	-1.27	9	-1.25	23	-1.82	9
63	Eu II	-0.41	2	-0.41	1	-1.50	2	-0.99	1	-1.40	1
64	Gd II	-0.62	2	-0.31	1	-1.57	2	-1.21	1		
66	Dy II	-0.37	1							-1.46	1
68	Er II	-0.36	1							-1.25	1
74	W I	-0.82	1							-2.29	1

& Kovtyukh (2001) and references there in). Careful comparison of calculated and observed spectra permit us to identify the lines of heavy elements. URAN software (Yushchenko, 1998) was used for screening the observing and synthetic spectra of program and comparison stars simultaneously in any desired scale. This methodics permit us to minimize the number of errors in the identifications of faint spectral lines and to find new lines of heavy elements in the spectra of program stars.

Determination of equivalent widths was made with URAN software (Yushchenko, 1998). Fig. 1 show the comparison of equivalent widths of heavy elements obtained from the two spectra of Arcturus - Griffin's atlas and ELODIE spectrum.

The overabundance of lanthanides (with respect to iron) in the atmosphere of HD221170 was detected without difficulties. As an example on Fig. 2 we show an example of the spectra of Arcturus and HD221170 in the vicinity of Nd II λ 5291.815 Å and Fe I λ 5320.039 Å lines. The Fe line can be detected only in the spectrum of Arcturus, while the Nd line is well detected in both spectra.

The used parameters of atmosphere models were determined by Mishenina & Kovtyukh (2001) and can be found in Table 1. Abundances of selected heavy elements were derived using WIDTH9 code (Kurucz, 1995).

4. Results

The mean values of abundances of heavy elements derived for Arcturus and program stars can be found in Tab. 2. In this table one can found the relative abundances with respect to the solar values and number of lines, used for determination of abundance of investigated heavy elements.

The difference in abundances of heavy elements in the atmosphere of Arcturus, obtained from spectra with different resolving power (Griffin's atlas and ELODIE spectrum) is quite little. The are no big systematic trends in determinations of equivalent widths (see Fig. 1) and, respectively, in calculated abundances.

The abundance patterns for HD37828 and HD44007 are similar to that of Arcturus, shifted approximately by -0.9 dex (see Fig. 3). The abundances of heavy elements in HD221170 is different from scaled Arcturus and solar patterns. The abundances of heavy lanthanides in the atmosphere of this star show large overabundance with respect to iron (see Fig. 4). The overabundance reach 0.8 dex for erbium.

5. Conclusion

We made a detailed analysis of abundance of heavy elements in the atmospheres of three stars with low metal

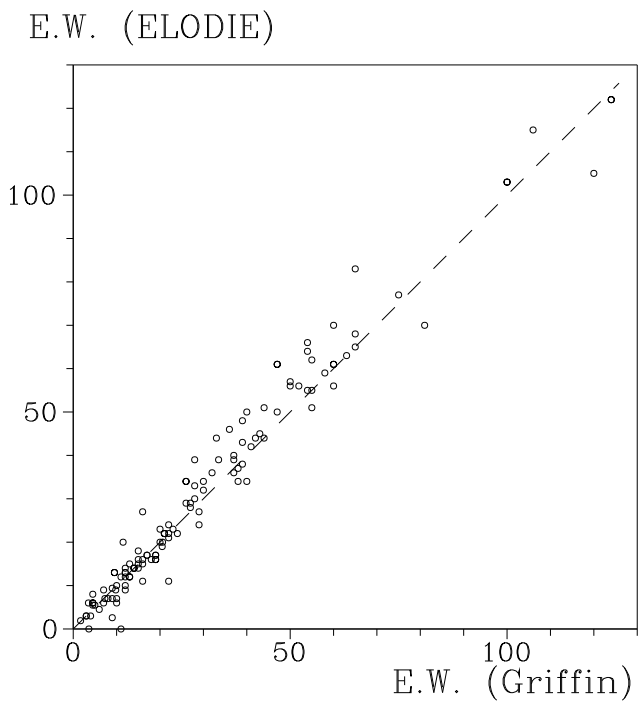

Figure 1: The comparison of equivalent widths of heavy elements measured in the Atlas of the spectrum of Arcturus (Griffin, 1968) and in the ELODIE spectrum of the Arcturus.

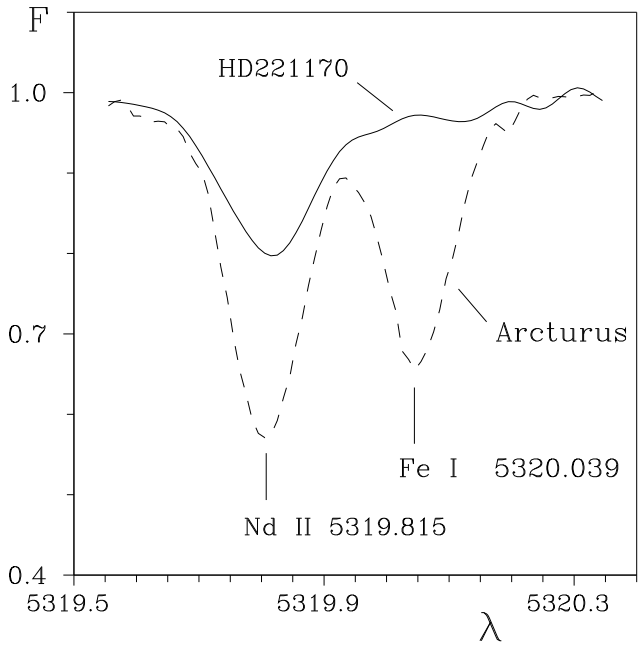

Figure 2: Spectra of HD221170 and Arcturus in the vicinity of Nd II line λ 5291.815 Å. Fe I line λ 5320.039 is well detected in Arcturus spectrum but disappears in the spectrum of HD221170. The decrease of strength of Nd II λ 5291.815 Å line is significantly less than the decrease of iron line. in HD221170

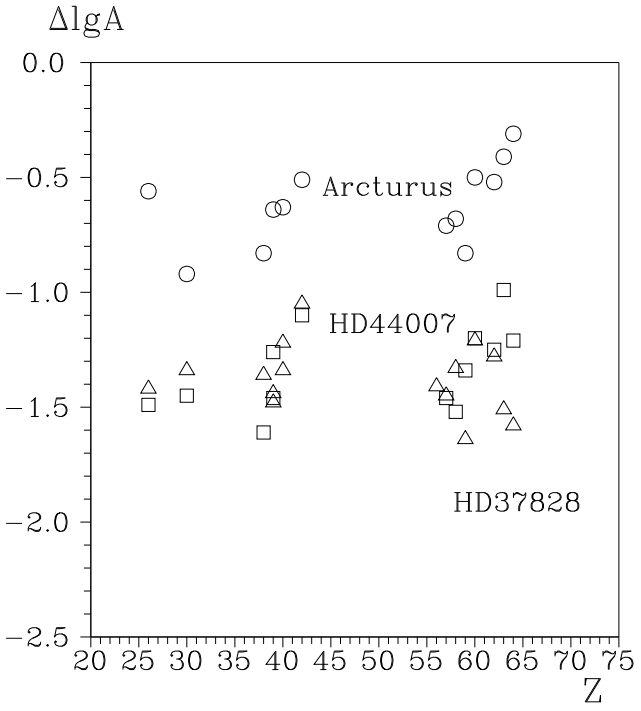

Figure 3: Relative abundances (with respect to the Sun) of iron and heavy elements in the atmospheres of Arcturus (circles), HD37828 (triangles), HD444007 (squares) obtained from ELODIE spectra. The abundances of iron were determined by Mishenina and Kovtyukh (2001).

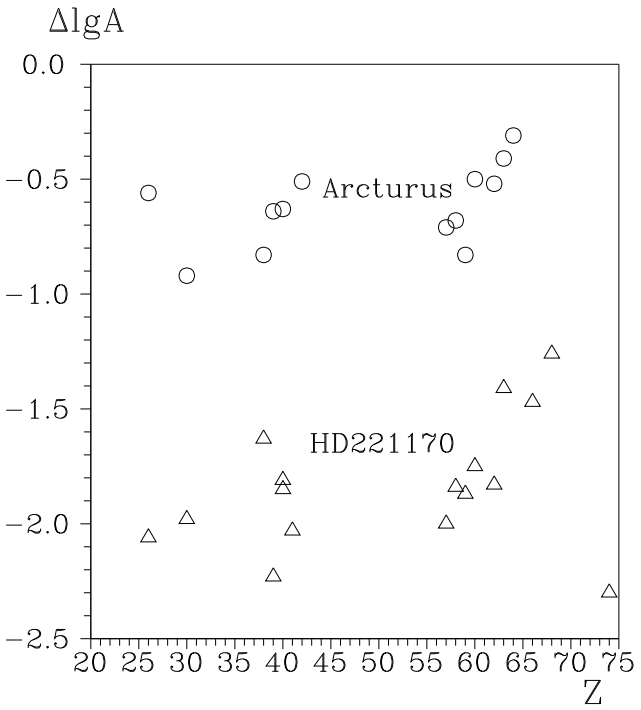

Figure 4: The same as Fig. 3 for Arcturus (circles) and HD221170 (triangles)

Table 3: The number of heavy elements investigated in program stars

Star	[Fe/H]	N
Arcturus	-0.56	13
HD37828	-1.41	14
HD44007	-1.49	11
HD221170	-2.05	14

content. Our methodics permit to identify the bigger number of lines of heavy elements in the observed spectra. In Table 3 one can find the number of heavy elements, which were investigated in the atmosphere of Arcturus and program stars. The values of [Fe/H] were determined by MIshenina & Kovtyukh (2001).

These preliminary results will be used for more detailed investigations of these and other metal-poor stars with spectrum synthesis method.

Arcturus and Arcturus-like stars with low metallicity showed abundance patterns for heavy elements:

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