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Heaviest s-process elements in the atmospheres of barium stars HD204075 and HD101013

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The detailed chemical abundance patterns of barium stars HD204075 and HD101013 are used for investigations of heaviest s-process elements. Special attention is devoted to elements with Z>70, up to Pb. Spectrum synthesis method is used for abundance calculations. High resolution spectra were obtained at 2.7 meter telescope of McDonald observatory (spectral resolution R=60,000, signal to noise ratio S/N>400) and VLT (R=80,000, S/N>400). CNO and Fe abundances are found for HD204075 and HD101013. Heavy (Z≥64) elements abundances are found for HD204075. The results of previous investigations of HD204075 and our data is in good aggrement with s-process enriched pattern. Our estimates show that the abundances of Z≥64 elements in HD101013 are significantly higher than in HD204075.

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1. Introduction

The majority of Ba-stars have luminosities of normal giants, it is possible to point the stars of this type in a large range in luminosity from class IV-V to class Ib.

The most widely-accepted hypothesis is that the overabundances of heavy elements in the atmospheres of barium stars were produced by the accretion of matter ejected from their former AGB companions. These AGB companions have quickly evolved to be white dwarfs and can not be easily detected now.

This paper is devoted to investigation of two barium stars, and HD204075 (ζ Cap, G9Ib) and HD101013 (G9III). The stars were investigated in many papers, [8, 13] can be pointed as an examples. The most recent investigations of chemical composition of these objects were made by Antipova et al. [3, 4]. The abundances of 29 elements from Na to Dy and of 25 elements from C to Eu were found for HD101013 and HD204075 respectively.

We used abundance patterns, found in [3, 4] as the first approximation and tried to investigate Li, CNO, Fe and elements with Z$\geq$64 in the atmospheres of these stars. We found the abundances of 16 elements with Z$\geq$64 in the atmospheres of HD204075 and estimated that these elements are more abundant in HD101013 in comparison with HD204075. In the following sections we will describe the determination of atmosphere parameters, abundances of Li, CNO, Fe, Tc, and heavy (Z$\geq$64) elements. Comparison of abundance pattern of HD204075 with theoretical predictions is made in the final section. Detailed abundance pattern for barium stars in this range of atomic numbers is known only for prototype of mild barium stars HD202109 [12].

2. Observations and atmosphere models

Spectrum of HD101013 was obtained at 2.7 meter telescope of McDonald observatory. Spectral resolving power was R=60,000, signal to noise ratio is near S/N=400 in red region and near S/N=150 at wavelength λ=4000 . Wavelength coverage is from 3520 to 10211 Å. For HD204075 we used the spectrum observed at VLT [5] in the wavelength range from 3040 to 10400 Å, S/N$\geq$300 in red part of the spectrum and S/N near 100 at λ=3050 Å. Resolving power was pointed by [5] to be equal R=80,000.

To find atmosphere parameters we used the method of calculating the iron abundance for different atmosphere models. Details can be found in [12]. The grid of atmosphere models were interpolated from Kurucz ATLAS9 grid. We tried to find models where correlations of iron abundances vs equivalent widths and energies of low levels of iron lines were forced to zero. Additional requirements were the minimal error of iron abundance, zero difference of neutral and ionized iron abundances, and zero correlation of iron abundances with wavelength. Several iterations were made for each star.

For HD101013 we found effective temperature $T_{\rm eff}$=4930 K, surface gravity log g=2.74, microturbulent velocity $v_{\rm micro}$=1.56 km s^{-1}, and iron abundance logN(Fe)=7.33 in the scale logN(H)=12. This abundance scale will be used here after. 119 lines of neutral iron and 19 lines of ionized iron were used for calculation.

The result for HD204075 is $T_{\rm eff}$=5260 K, log g=1.72, $v_{\rm micro}$=2.55 km s^{-1}, logN(Fe)=7.31. 106 lines of Fe I and 31 lines of Fe II were used.

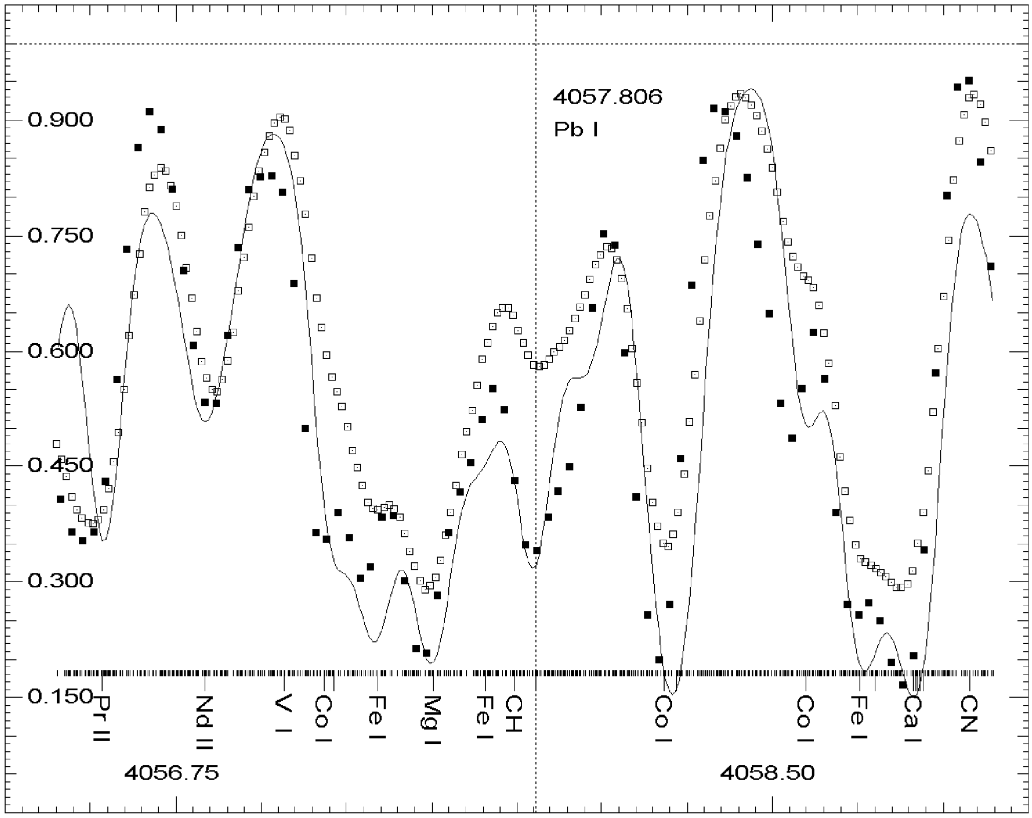

Figure 1: Spectra of HD204075 and HD101013 in the vicinity of Pb I line 4057.806 Å. Axes are wavelength in angstroms and relative fluxes. Open squares – observed spectrum of HD204075 (VLT spectrum). Filled squares – observed spectrum of HD101013 (McDonald observatory 2.7 m telescope). Curve – synthetic spectrum of HD101013. The strongest lines in synthetic spectrum are marked in the bottom part of the plot. Position of Pb line is pointed by vertical dotted line.

3. Abundance determinations

Spectrum synthesis was used to find the abundances of all elements except iron. See [12] for full description of used programs and line lists.

3.1 Li and CNO

CNO elements strongly influence the appearance of the spectrum. To find the abundances of these elements atomic and molecular lines, mainly in red spectral region, were used. After several iterations we found the following abundances:

HD101013 – logN(Li)$<$0.4, logN(C)=8.54, C_{12}/C_{13}=16, logN(N)=8.20, logN(O)=8.75;
HD204075 – logN(C)=8.7, $C_{12}/C_{13}>$20, logN(N)=8.1, logN(O)=8.43.

These values were used for calculations of abundances of heavier elements. Our results are in good agreement with previous determinations of Li abundance in barium stars [9].

3.2 Technetium

We used the list of oscillator strengths of lines of neutral and ionized technetium published in

Table 1: Abundances of heavy elements in HD204075

		HD204075		
		n	ΔlogN	logN
64	Gd I	8	0.74(21)	1.86
66	Dy II	10	0.09(27)	1.23
67	Ho I	2	−0.10(19)	0.16
68	Er II	20	0.11(24)	1.04
69	Tm II	4	−0.01(25)	−0.01
70	Yb I	2	−0.03(16)	1.05
	Yb II	1	−0.43	0.65
71	Lu II	2	0.72(21)	0.78
72	Hf II	9	0.28(23)	1.16
74	W I	2	0.83(17)	1.94
76	Os I	4	0.53(21)	1.98
77	Ir I	3	−0.10(29)	1.25
78	Pt I	1	0.00	1.80
81	Tl I	1	0.80	1.70
82	Pb I	3	−0.47(28)	1.48

[6, 2, 11] and other papers. There were no signs of Tc in HD101013, but we detected the possible Tc lines in the spectrum of HD204075. Four lines of neutral technetium, namely 3726.345, 4124.217, 4262.270, and 5924.468 Å, and one line of Tc II (3195.21 Å) permit to calculate the upper limits of abundances 1.7, 2.2, 1.5, 2.0, 1.5 respectively. Similar limit (1.6) was found by [7]. [10] also reported the absence of Tc lines using IUE spectra.

3.3 Heavy elements

For all lines of heavy elements we tried to find the counterparts in the solar spectrum. These procedure is usually accepted to avoid the uncertainties in oscillator strengths. But it was impossible to find the corresponding features in the solar spectrum for majority of the lines. That is why our analysis is based mainly on absolute values of oscillator strengths. The values of abundances for HD204075 can be found in Table 1. The columns are the atomic number and identification of the element (ion), the number of used lines and mean abundance with final figures of error in brackets. There are relative (with respect to solar values [1]) and absolute abundances. Errors are pointed only for relative abundances. It should be mentioned that the majority of lines of these elements are located in the blue and near ultraviolet part of the spectrum and derived abundances are strongly affected by continuum placement.

Our preliminary results for HD101013 show that the abundances of heavy elements in this star can be higher than in HD204075. As an example we compare the spectra of both stars in Fig. 1. It is evident, that the lead line λ 4057.806 Å in the spectrum of HD101013 is significantly stronger than in the spectrum of HD204075.

These results can be treated as preliminary values for detailed analysis of chemical composition of the stars.

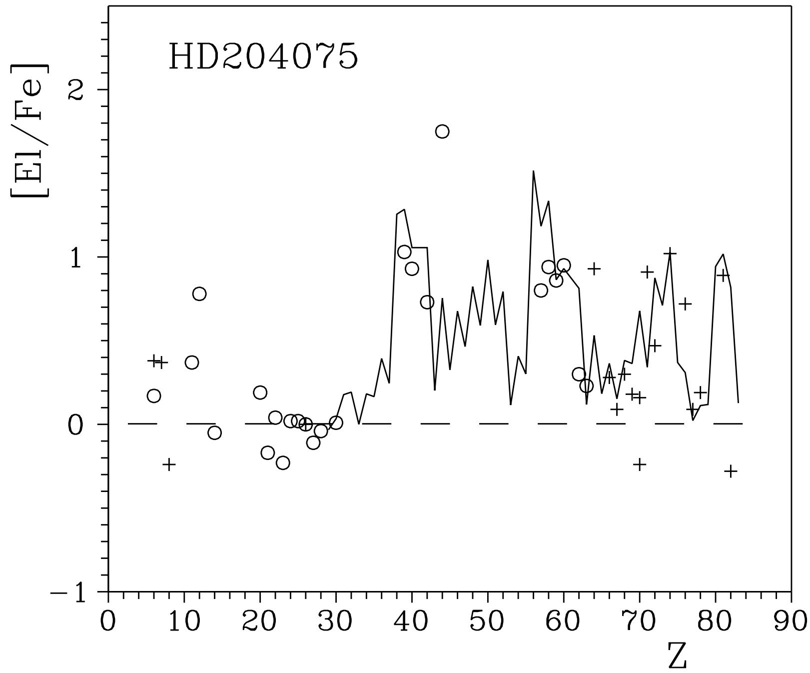

Figure 2: Abundance pattern of HD204075. Axes are atomic numbers and abundances with respect to iron. Antipova et al. [4] data are marked by circles, our values – by crosses. Line – s-process enriched matter. The curve is taken from [12] and scaled by factor 3.0.

4. Conclusion

Figure 2 shows the abundance patterns of HD204075. The extremums of abundance curves can be fitted by scaled s-process enriched pattern taken from [12]. This pattern was calculated for wind accretion scenario. The abundances of the heaviest s-process elements in HD101013 are higher than that in HD204075, this result is preliminary and needs additional investigation. Special attention was devoted to technetium, the lines of this element in HD204075 can exist.

The results of this paper will be used as the first approximation to find the homogeneous abundance patterns, to compare it with previous investigations and with theoretical predictions.

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