THE ABUNDANCES OF HEAVY ELEMENTS IN THE ATMOSPHERE OF HYADES GIANT δ TAURI

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ABSTRACT. Comparison of synthetic spectrum of the δ Tauri photosphere and high quality spectral atlas of this star permit us to identify absorption lines of iron and heavy elements ($Z \geq 30$) in the observed spectrum. The abundances of 16 heavy elements in the atmosphere of δ Tauri were determined with the differential method of spectrum synthesis. All the abundances are near solar values.

Key words: $r-, s-$process elements – stellar abundances

The determination of the heavy elements abundances in the stars of different ages allows to investigate the chemical evolution of the Galaxy. δ Tauri is a member of Hyades cluster. This is the nearest cluster to the Sun. In time it is only one-tenth the age of the Sun so its overall chemical abundance will provide evidence of any general enrichment that the Galaxy may have received in heavy elements since the birth of the Sun (Griffin & Holweger, 1989). Can we detect this enrichment?

Recently the abundances for 7 heavy elements was derived for δ Tauri by Luck & Challenger (1995) from observations with resolving power 30000. All the abundances was solar, but Cu and Y showed an overabundances near +0.4 dex. The present study is aimed at the determination of the abundances of iron and heavy elements in the photosphere of δ Tauri. A high resolution spectral atlas of this star was published by Gratton et al. (1975). The wavelength regions of the atlas is 3985-4812 Å, resolving power near 110000.

The synthetic spectra were calculated for K0 III type star and for solar type star within the wavelength range of spectral atlas of δ Tauri with interval of 0.01 Å. Tsymbal (1996) program was used.

For δ Tauri we used the atmosphere model from Bell et al. (1976) grid with parameters: $T_{\rm eff}$=5000 K, $lg\ g$=2.7. These parameters were derived by Mishenina et al. (1986) and were used earlier by Gopka et al. (1991). The value of microturbulent velocity $v_{\rm micro}$=1.9 km/s was obtained in this work from the analysis of equivalent widths of 27 iron lines with solar oscillator strengths (Gurtovenko & Kostik, 1989) reduced to solar iron abundance $lgN(Fe)$ =7.50 in the scale $lgN(H)$=12.00 (Grevesse et al., 1996). For Sun Holweger & Muller (1974) model was used: $T_{\rm eff}$=5770 K, $lg\ g$=4.44, $v_{\rm micro}$=1.0 km/s.

The synthetic spectra in the wide spectral region were used for identification: the unblended and faintly blended absorption lines of iron and heavy elements were selected from calculations. Each line selected from the computed list was investigated in the observed spectrum. The used lines of erbium were identified in the solar spectrum by Gopka & Yushchenko (1995).

The abundances of heavy elements were analyzed with the differential method of spectrum synthesis. Synthetic spectra were broadened by Gaussian type macroturbulence with velocity 5.5 km/s for δ Tauri or 1.8 km/s for Sun and rotation with velocity 1.9 km/s for δ Tauri (Gray & Endal, 1982) or 2 km/s for Sun. Instrumental profiles were assumed to be Caussians.

Kurucz (1995) SYNTHE spectrum synthe-

Table 1: Lines of heavy elements in the spectrum of δ Tauri

Z	Ident.	λ (Å)	$lg\ gf$	$\Delta lg\ gf_\odot$	$\%_\odot$	$\%_\delta$	ΔlgN
30	Zn I	4680.134	-0.81	-0.14	99	98	-.18
	Zn I	4722.153	-0.34	-0.09	100	100	-.09
	Zn I	4810.528	-0.14	-0.06	100	100	-.35
39	Y I	4674.849	-0.46	-0.29	71	97	.17
	Y II	4199.277	-2.15	0.01	75	99	-.03
	Y II	4398.013	-1.00	-0.04	98	100	-.12
40	Zr I	4739.480	0.23	-0.23	88	94	-.18
	Zr I	4772.323	0.04	-0.03	77	95	-.14
	Zr I	4784.913	-0.49	0.03	81	85	-.12
	Zr I	4805.889	-0.42	-0.02	88	83	-.13
	Zr II	4050.316	-1.00	0.07	99	100	-.21
	Zr II	4085.720	-0.12	0.08	87	93	-.11
44	Ru I	4584.443	-0.42	0.01	68	97	.12
49	In I	4511.307	-0.21	-0.04	92	92	-.07
56	Ba II	4130.645	-0.68	-0.16	99	99	-.03
57	La II	4086.709	-0.15	-0.04	100	100	-.16
	La II	4123.218	0.12	-0.05	98	100	-.04
	La II	4322.503	-1.12	-0.01	75	92	-.03
	La II	4662.498	-1.24	-0.04	90	99	.06
58	Ce II	4222.597	-0.30	0.25	98	100	-.13
	Ce II	4364.653	-0.20	-0.02	72	93	.00
	Ce II	4562.359	0.08	0.24	100	100	.17
	Ce II	4628.161	0.01	0.20	99	100	.01
59	Pr II	4408.819	-0.30	-0.07	94	90	.01
60	Nd II	4018.823	-0.89	0.01	97	100	-.07
	Nd II	4109.448	0.30	-0.07	100	100	.03
	Nd II	4446.384	-0.59	0.13	100	100	.07
62	Sm II	4318.927	-0.61	0.18	83	99	.06
63	Eu II	4129.720	0.20	-0.04	hfs	hfs	-.16
64	Gd II	4037.893	-0.49	0.22	100	97	-.11
	Gd II	4085.558	-0.01	0.09	94	98	-.13
66	Dy II	4073.121	-0.10	-0.25	87	98	-.14
	Dy II	4449.704	-1.30	0.24	95	98	-.09
68	Er II	4043.008	-0.86	-0.03	88	98	-.11
	Er II	4048.342	-0.57	0.35	96	87	-.12
76	Os I	4420.468	-1.53	-0.03	83	96	.12
	Os I	4550.409	-0.71	-0.48	66	84	.19

Table 2: Abundances of iron and heavy elements in the atmosphere of δ Tauri

Z	Ident.	ΔlgN	σ	n	Z	Ident.	ΔlgN	σ	n
26	Fe I	0.11	0.12	27	58	Ce II	0.01	0.11	4
30	Zn I	-0.20	0.11	3	59	Pr II	0.01		1
39	Y I	0.17		1	60	Nd II	0.01	0.06	3
	Y II	-0.08	0.05	2	62	Sm II	0.06		1
40	Zr I	-0.14	0.02	4	63	Eu II	-0.16		1
	Zr II	-0.16	0.05	2	64	Gd II	-0.12	0.01	2
44	Ru I	0.12		1	66	Dy II	-0.11	0.03	2
49	In I	-0.07		1	68	Er II	-0.11	0.01	2
56	Ba II	-0.03		1	76	Os I	0.15	0.04	2
57	La II	-0.04	0.08	4					

sis program and automatic spectrum synthesis software URAN (Yushchenko, 1998) were used. All atomic and molecular lines with non-predicted wavelengths and oscillator strengths from Kurucz (1995) database were included in calculations. Hyperfine and isotopic structure data (Kurucz, 1995) were taken into account for europium.

The Sun was used as a comparison star in our work. Deulboille et al. (1984) atlas of solar spectrum was used. The continuum placement in the solar spectrum was corrected in accordance with Rutten & van der Zalm (1984). For all selected lines of heavy elements the solar oscillator strengths were derived for investigated line and for all lines in it's vicinity. These solar oscillator strengths were used for analysis of δ Tauri spectrum.

Line data for heavy elements are shown in Table 1: charges of nuclei, identifications, wavelengths, oscillator strengths, corrections to the oscillator strengths, obtained from the solar spectrum, the ratios of line absorption due to investigated line to the total line absorption at a given wavelength for the solar and δ Tauri spectra (in percents), the abundances of the element in the atmosphere of δ Tauri relative to the Sun calculated for given line.

The mean abundances (relative to Sun) of iron and heavy elements in the atmosphere of δ Tauri relative to the solar ones are gathered in Table 2: charges of nuclei, identifications, relative abundances, mean square errors of relative abundances for one line, number of used lines.

The abundances of iron and 16 heavy elements in the atmosphere of δ Tauri are solar (in the range of errors). The possible enrichment of δ Tauri atmosphere by heavy elements (if exist) is within the box of possible systematic errors due to the uncertainties of spectrum synthesis analysis - less than 0.2 dex. The similar result was obtained for the abundances of 20 heavy elements in the atmosphere of other Hyades giants γ Tauri by Gopka & Yushchenko (1999). Observations of δ Tauri with better signal to noise ratio and highest spectral resolution are desired to obtain a more precise result.

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