ABOUT THE HEAVY ELEMENTS ABUNDANCES IN SIRIUS A

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We have identified the absorption lines of Cu, Zn, Ga, Y, Zr, Nb, Mo, Cd, Sn, Hf, Ta, W, Re, Os, Hg, Pb, Th, U by comparing an atlas of the Sirius A spectrum with the synthetic one computed in the near-UV region (between 1649 Å an 3170 Å). The synthetic spectrum technique was used to determine the abundances of these elements in the Sirius A atmosphere. A summary table of the abundances of heavy elements is given. It is noted that abundances of gallium, tin, thorium, uranium were not studied early. The detected overabundances of heavy elements are in the range of 0.4–3.2 dex with respect to the meteoritic abundances.

The Am stars were first recognized as a group of peculiar stars of the main sequence by Titus & Morgan in 1940 [13]. They found that Ca K lines did not lead to the same classification as the hydrogen lines for some of the Hyades A stars. The abundances of CNO are generally below solar, while those of iron-peak elements are generally above solar, and the species in between can be either under- or overabundant [13]. The classical metallic-line A stars are characterized by a general enhancement of the metallic lines but a marked weakness of the lines of Ca and Sc when compared to normal A stars at the resolution of classification spectra. Heavy elements are systematically enhanced for most Am stars relative to the Sun. The best studied Am star is Sirius (HD 48915) – the brightest star in the sky. This star is a hot Am star. The Sirius is often used as a reference star in analysis of A-type stars. Parameters of atmosphere $T_{\rm eff}$ and $\log g$ are exceptionally well studied. Of all the fundamental stars, only Sirius and Procyon have truly fundamental values of both effective temperature and surface gravity. Chemical composition cannot be obtained in fundamental manner [12]. The present study is intended to determine the abundances of elements with atomic number $Z > 29$ in the atmosphere of Sirius A (Sirius B is white dwarf). The spectral lines of heavy elements are mainly populated the UV region of the spectrum. That is why the Copernicus Ultraviolet spectral Atlas of Sirius [7] was used as an observational spectrum. The Atlas covers the wavelength region from 1649 Å to 3170 Å, the spectral resolution is equal to 0.1 Å, and signal to noise ratio can reach 100.

Table 1: Lines of elements in the spectrum of Sirius and abundances of elements in the atmosphere of Sirius

Z	Ion	λ (Å)	$\log gf$	$\Delta \log N$	$* - \odot$	σ
29	Cu II	1989.855	-0.751	0.69	0.94	0.15
	Cu II	2037.127	-0.241	1.09		
	Cu II	2054.979	-0.177	1.04		
	Cu II	2104.796	-0.482	0.96		
30	Zn II	2099.937	-0.032	1.14	1.14	
31	Ga II	2090.771	-3.020	0.83	0.83	
39	Y II	2422.188	-0.200	0.93	0.92	
40	Zr II	2745.854	-0.270	0.77	0.91	0.14
	Zr II	3054.837	0.180	1.08		
	Zr II	3129.763	-0.650	0.76		
	Zr II	3138.683	-0.460	0.76		
	Zr II	3164.303	-0.180	0.87		
41	Nb II	2451.880	-0.280	1.51	0.49	
42	Mo II	2020.324	-0.900	1.94	2.08	0.13
	Mo II	2502.828	-1.090	2.25		
	Mo II	3152.813	-0.010	2.05		
48	Cd II	2265.018	-0.340	1.70	1.70	
50	Sn II	1899.898	-0.196	0.39	0.39	
72	Hf II	2496.993	-0.300	2.63	1.63	
73	Ta II	2400.637	1.650	2.87	1.87	
74	W II	2702.131	-0.230	2.89	2.89	
75	Re II	2504.563	1.000	2.02	2.25	
	Re II	2608.497	1.350	1.96		
76	Os II	2067.230	1.200	0.96	2.24	
	Os II	2580.024	1.620	1.16		
77	Ir II	2242.631	2.14	3.15 :	1.80	
80	Hg II	1942.313	-0.140	1.56	1.56	
82	Pb II	2203.534	-0.095	2.39	2.38	
90	Th II	2508.278	-0.020	3.08	3.20	0.11
	Th II	2774.066	-0.740	3.61		
	Th II	3019.422	-0.570	3.15		
	Th II	3080.217	0.238	3.11		
	Th II	3124.387	-0.406	3.32		
	Th II	3139.307	0.009	3.34		
92	U II	3111.618	-0.147	3.04	3.04	
	U II	3039.258	-0.260	3.04		

The abundance analysis is based on technique of synthetic spectra and comparison of synthetic spectrum with observed one. To study abundances in the atmosphere of Sirius we used the atmosphere model [4] with the following parameters: $T_{\mathrm{eff}} = 10000$ K, $\log g = 4.3$, $v_{\mathrm{turb}} = 2$ km/s. We calculated the synthetic spectra of Sirius in the wavelength region covered by observed spectrum using [14] program. The values of abundances of elements were adopted from previous investigations of this star. The abundances of the uninvestigated heavy elements were adopted as a function of atomic number. The values of this function varied from [A/H] = 1 for Z = 29 to [A/H] = 3 for Z = 92. We identified the lines of heavy elements. Abundances of selected elements were derived using URAN software for automatic spectrum synthesis [16]. We used SYNTHE code [4] for calculations of synthetic spectra in the region of line investigation. In each case the synthesis was performed taking into account all possible blending by atomic lines with measured wavelengths and oscillator strengths from [4] database (CD-ROMs 18, 23). Synthetic spectra were broadened by rotation and instrumental profile. The results are listed in Table 1. The designations in the table are following: the charge of nuclei (Z), identification of ion, wavelength, oscillator strength ($\log gf$), abundance in the scale $\log N(H) = 12.00$, mean relative abundances of the element in the Sirius atmosphere with respect to the solar system one [1] – ($* - \odot$), σ – the square error of one measurement.

All elements we consider show overabundances with respect to the solar system values. It should be noted that measurable lanthanides lines are absent in UV region of the spectrum. Lines of these elements are quite weak or strongly blended in UV. Our data for abundances of heavy elements show a good agreement with other data from visual and UV regions of the spectrum [2, 3, 5], [9]–[12], [15]. The abundances of 19 elements are defined in this work. It is noted that abundances of gallium, tin, thorium, uranium were not studied early. Our results can be used for testing various theories on the nature of Am phenomena. For example, the diffusion theory developed by Richer & Michaud [6] for light elements ($Z < 28$). We should to note that the total abundance pattern for Sirius A is 50 elements. It is the third abundance pattern after Sun and Procyon.

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