ASTROPHYSICS

ZIRCONIUM ABUNDANCES IN THE CENTRAL PART OF THE dSph FORNAX GALAXY

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ABSTRACT. We derived LTE zirconium abundance in a sample of 81 giant stars in dwarf spheroidal Fornax galaxy. The LTE synthesis was used for this aim. We obtained the lower Zr abundance in Fornax galaxy comparing to the relevant value in the thick/thin disc of the Milky Way. We note that this result may be affected by the NLTE effects that decrease the real zirconium abundance.

Keywords: stars: abundances – galaxies: individual: Fornax – galaxies: evolution – galaxies: dwarf – galaxies: formation

Figure 1: Synthetic and observed spectra of three zirconium lines for the star BL211 (the best zirconium abundance is (Zr/H)=2.14). Circles – observed spectrum, continuos line – synthetic spectrum.

1. Introduction.

Dwarf spheroidal galaxy Fornax is one of the most luminous satellites of the Milky Way. Its stellar population was studied spectroscopically by many authors. In particular, Letarte et al. (2010) and Lemasle et al. (2014) determined abundances of α- and some s-process elements in the giants of this stellar system. Among s-process elements zirconium was not studied in the stars of this galaxy. Therefore we decided to fill in this gap.

2. Sample of the stars

The sample of our program stars has been previously investigated by Letarte et al. (2010). The spectra were secured with ESO VLT facilities with resolving power of about 20000 in the two ranges: 5340–5620 Å, and 6120–6701 Å. 81 RGB stars were selected in the central part of Fornax dSph galaxy. In this article we report the results of determination of zirconium abundnace. We used stellar parameters 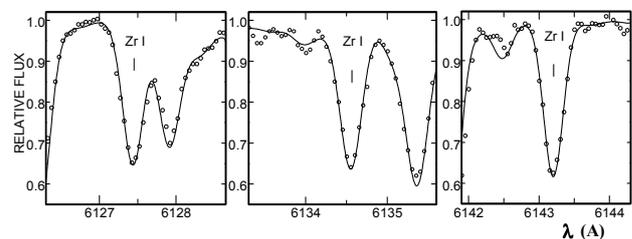and iron abundance determined by Letarte et al. (2010). The program stars and their iron abundance are listed in Table 2 together with our LTE abundance of Zr (see next sections).

3. Abundance determination details.

As we have already mentioned Letarte et al. did not derive abundance of zirconium. From the light s-process element they give abundance only for yttrium. We performed LTE profile synthesis for the three Zr I lines: 6127, 6134 and 6143 Å using SYNTHV code (Tsymbal 1996). Blending lines of other species were taking into account by using the Vienna Atomic Line Database (VALD, Kupka et al. 1999).[1] An example of the profile fitting is given in Fig. 1. Table 1 contains an information about zirconium line parameters used in our calculations. Zirconium abundance in our program stars is listed in Table 2.

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[1]http://vald.astro.univie.ac.at/ vald3/php/vald.php

Table 1: Zirconium line parameters.

El	λ (Å)	log gf
Zr I	6127.48	−1.06
Zr I	6134.59	−1.28
Zr I	6143.25	−1.10

Figure 2: [Zr/Fe] vs. [Fe/H]. Circles – our stars, the model data are from Bisterzo et al. (2017). Continuous line – thin disk, dashed line – thick disk, dotted line – halo.

4. Results and discussion.

It is generally accepted that zirconium nuclei are produced in the higher-mass AGB stars (Prantzos et al. 1990, Raiteri et al. 1992). Production rate of the first-peak (Sr, Y, Zr) elements depends also on the metallicity of the AGB star. Metal-poor AGB stars produce a larger amount of the *s*-process peak nuclei.

The ratio [Zr/Fe] in our program stars appears to be below the value which is predicted by the Galaxy model of chemical evolution for the thick/thin disc (Bisterzo et al. 2017) (see Fig. 2).

Battistini & Bensby (2016) having analysed 311 stars in the solar neighbourhood found an increase of zirconium abundance in the Galactic thin and thick disc with metallicity decrease. Their mean [Zr/Fe] value in the metallicity region from about –1 to –0.5 is approximately 0.3–0.4 dex which is significantly higher than the mean value from the Fornax star sample. On contrary, Reddy et al. (2003) analysed 181 F and G dwarfs from Galactic disc, and their result on zirconium shows that at least up to [Fe/H] ≈ -0.7 there is no sign of an increase of abundance of this element with iron abundance decrease. The similar result was published also by Brewer & Carney (2006). The situation with zirconium becomes even more entangled if we take into account that in the different studies the different Zr lines were used to derive abundance of this element (for instance, Battistini & Bensby (2016) employed Zr I 4687 Å, 4739 Å, and Zr II 4208 Å, 5112 Å lines, while we used set of the red zirconium lines). Could such a discrepancy in the literature data be the result of ignoring of the NLTE corrections? There is a very limited information in the literature concerning the NLTE corrections for zirconium LTE abundance derived from different lines. Here one can mention only the paper of Velichko et al.(2010), who provided some limited data on corrections that should be applied to abundances derived from Zr I 4687 Å, Zr II 4208 Å, and 5112 Å lines in cool giants. According to those authors corrections are of about 0.2–0.3 dex, and they should even increase the LTE abundances (later authors published erratum where they informed that they used wrong ionization potential for Zr I). Nevertheless, those authors say (but without quantitative estimates) that observed red zirconium lines should be weakened due to the NLTE effects, what means that our result on LTE zirconium
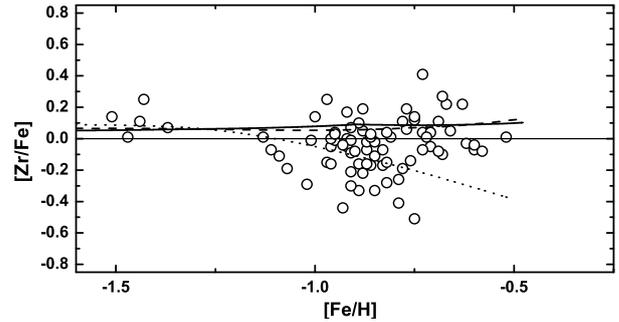
"underabundance" in the Fornax giants (Fig. 2) may be just an artefact. In our analysis we used Zr I 6127, 6134 and 6143 Å, for which no information about NLTE effect exists in the literature. Taking into account that different zirconium lines were used by the different authors to derive abundance in dSph Fornax galaxy and in the Milky Way, and no reliable data on the NLTE corrections for zirconium abundance derived from those lines exist in the literature, we leave the question about the detected difference in zirconium abundance in Fornax galaxy and the Milky Way stars open.

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Table 2: Program stars, their metallicity and abundances of Zr and Ba. (El/H)=$\log \epsilon$(El)+12.00; [El/H] = (El/H)$_{star}$ − (El/H)$_{Sun}$.

Star	[Fe/H]	(Zr/H)	[Zr/Fe]	Star	[Fe/H]	(Zr/H)	[Zr/Fe]
BL038	−0.88	1.76	0.05	BL185	−0.71	1.92	0.04
BL045	−1.09	1.39	−0.11	BL190	−0.79	1.39	−0.41
BL052	−1.02	1.28	−0.29	BL195	−0.97	1.87	0.25
BL065	−1.43	1.41	0.25	BL196	−1.07	1.33	−0.19
BL076	−0.85	1.63	−0.11	BL197	−0.89	1.54	−0.16
BL077	−0.79	1.54	−0.26	BL203	−0.83	1.69	−0.07
BL079	−0.52	2.08	0.01	BL204	−1.00	1.73	0.14
BL081	−0.62	1.94	−0.03	BL205	−0.69	2.01	0.11
BL084	−0.85	1.41	−0.33	BL208	−0.66	1.98	0.05
BL085	−2.59	−	−	BL210	−0.76	1.69	−0.14
BL091	−0.96	1.58	−0.05	BL211	−0.67	2.14	0.22
BL092	−0.95	1.63	−0.01	BL213	−0.93	1.62	−0.04
BL096	−0.75	1.33	−0.51	BL216	−0.77	1.88	0.06
BL097	−0.92	1.67	0.00	BL218	−0.60	1.92	−0.07
BL100	−0.93	1.22	−0.44	BL221	−0.86	1.74	0.01
BL104	−0.96	1.63	0.00	BL227	−0.91	1.75	0.07
BL113	−0.75	1.96	0.12	BL228	−0.88	1.49	−0.22
BL115	−1.47	1.13	0.01	BL229	−0.71	1.83	−0.05
BL123	−0.97	1.47	−0.15	BL233	−0.68	1.81	−0.10
BL125	−0.73	1.90	0.04	BL239	−0.91	1.47	−0.21
BL132	−0.89	1.37	−0.33	BL242	−1.11	1.41	−0.07
BL135	−0.95	1.68	0.04	BL247	−0.82	1.62	−0.15
BL138	−1.01	1.57	−0.01	BL250	−0.68	2.18	0.27
BL140	−0.87	1.65	−0.07	BL253	−0.73	1.79	−0.07
BL141	−0.82	1.49	−0.28	BL257	−0.58	1.93	−0.08
BL146	−0.92	1.62	−0.05	BL258	−0.60	1.95	−0.04
BL147	−1.37	1.29	0.07	BL260	−0.87	1.56	−0.16
BL148	−0.63	2.18	0.22	BL261	−0.86	1.76	0.03
BL149	−0.91	1.59	−0.09	BL262	−0.78	1.92	0.11
BL150	−0.83	1.59	−0.17	BL266	−1.44	1.26	0.11
BL151	−0.86	1.56	−0.17	BL267	−0.72	1.88	0.01
BL155	−0.75	1.98	0.14	BL269	−0.81	1.79	0.01
BL156	−1.13	1.47	0.01	BL278	−0.73	2.27	0.41
BL158	−0.87	1.70	−0.02	BL279	−1.51	1.22	0.14
BL160	−0.95	1.67	0.03	BL295	−0.69	1.82	−0.08
BL163	−0.77	2.01	0.19	BL300	−0.92	1.84	0.17
BL166	−0.89	1.80	0.10	BL304	−0.96	1.47	−0.16
BL168	−0.88	1.90	0.19	BL311	−0.78	1.62	−0.19
BL171	−0.90	1.61	−0.08	BL315	−0.82	1.81	0.04
BL173	−0.85	1.72	−0.02	BL323	−0.91	1.38	−0.30
BL180	−0.91	1.67	−0.01				

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