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High resolution spectroscopy of two metal-poor red giants: HD 232078 and HD 218732

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An abundance analysis for 35 chemical elements based on a high-resolution (R = 67 000) optical spectra of two metal-poor ([Fe/H] ≈ -1.50) halo red giants, HD 232078 and HD 218732 is presented. Abundances of ten chemical elements were derived for the first time. Both red giants are chromospherically active and optically variable, located close to the red giant branch tip. Abundances of both stars generally follow typical halo star abundance distribution, while HD 218732 should have experienced a deep mixing episode and could be a first ascent AGB star.

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1. INTRODUCTION

Surface abundances of stars provide information about the interstellar medium (ISM) from which they were formed and the processes of nucleosynthesis in their interior. Spectroscopic studies of the metal-poor stellar population of the Galaxy provide information about its chemical evolution. During their evolution stars experience many mass loss episodes, when the processed material, including also the neutron capture elements from stellar interiors, is ejected into the ISM. Thus, understanding of the processes of mass loss in metal poor stars is crucial for studies of Galactic chemical evolution.

In this paper we present high resolution optical spectroscopy carried out for two metal-poor halo red giants HD 232078 ([1], [2], [3]) and HD 218732 ([4]), both showing Hα emission features and radial velocity variations suggesting that mass loss is ongoing in these stars. Abundances for 35 chemical elements were found, including many neutron capture elements not studied before. Our careful analysis provide clues about the origin and evolutionary state of these stars.

2. OBSERVATIONS

High resolution (R = 67 000) optical spectra of the program stars covering wavelength interval 3700−7300 Å were obtained on August 24th 2008 (JD 2454702.57626 and JD 2454703.47760 for HD 218732 and HD 232078 respectively) with the FIES optical echelle spectrograph at the 2.56 m Nordic Optical Telescope (NOT) on La Palma. Exposure times of 1800 s for HD 218732 and 600 s for HD 232078 ensured high quality of the obtained spectra (S/N > 100 per pixel). For the preliminary data reduction we used Python and PyRAF based data reduction software package FIEStool[1], especially developed for FIES and supplied by NOT. Procedures of bias subtraction, scattered light subtraction, flat-field division, spectrum extraction and blazeshape correction were performed. Thorium-Argon wavelength reference spectrum taken on the same day was used for wavelength calibration. Continuum division and equivalent width (EW) measurements were done using the DECH code [5].

3. ABUNDANCE ANALYSES AND RESULTS

Stellar effective temperatures were derived spectroscopically by measuring EWs for a set of iron lines with various excitation potentials and requiring a zero-correlation between the calculated abundances and excitation potential. From the measurements of 81 Fe I line using this technique we derive $T_{\rm eff}$ = 4000 K for HD 232078. For HD 218732 we have measured 180 Fe I lines and obtained $T_{\rm eff}$ = 4200 K with this technique. Since both our target stars are quite distant and do not have accurate parallax measurements, gravity was obtained from the ionization equilibrium of iron, i.e. by requiring that the mean abundances from Fe I and Fe II lines are equal. The microturbulence was estimated by requiring zero correlation between the derived abundances and the equivalent widths of the Fe I lines. All the model atmosphere parameters for program stars are listed in Table 1.

[1]http://www.not.iac.es/instruments/fies/fiestool/FIEStool.html

Table 1: Model atmosphere parameters for program stars used in abundance analysis.

Star	$T_{\rm eff}\,(K)$	$\log g$	ξ_t (km s^{-1})	[Z]
HD 218732	4200	0.50	2.4	-1.5
HD 232078	4000	0.50	2.0	-1.5

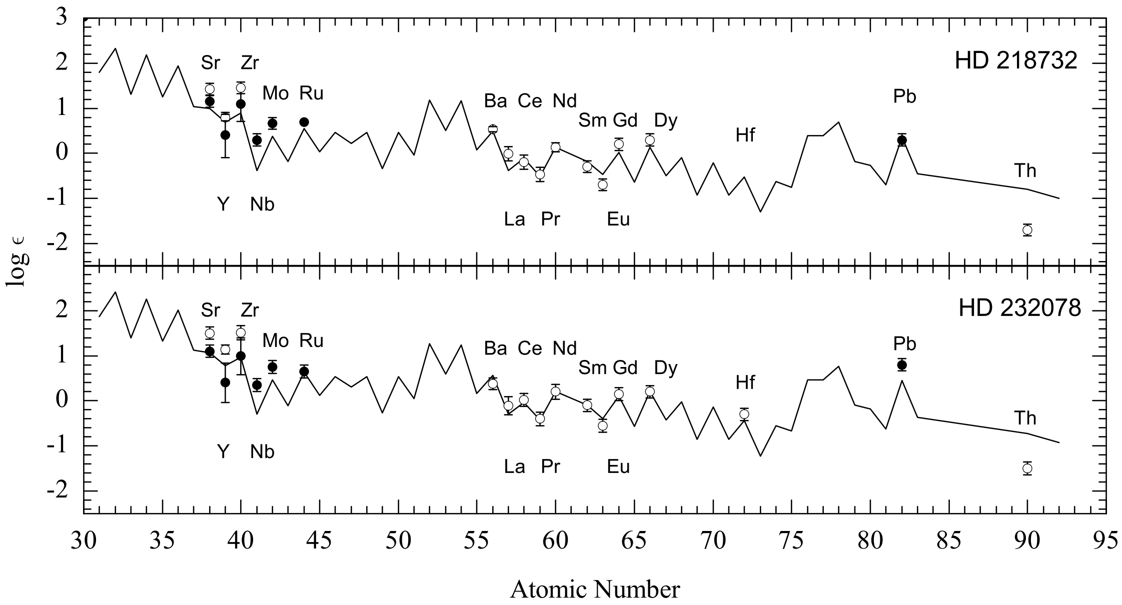

Figure 1: Mean abundances in HD 218732 and HD 232078 compared with a scaled solar system r-process abundance curve. Dots and open circles correspond to abundances obtained from lines of neutral and ionic lines respectively. Error bars are σ values from Table 2. The solar abundance distribution, plotted as a curve, is vertically downscaled to match the observed Nd abundances.

We adopt the following mean uncertainties in the atmospheric parameters: $\sigma(T_{\rm eff})$ = 100 K, $\sigma(\log g)$ = 0.3, and $\sigma(\xi_t)$ = 0.3 km s^{-1}.

We have derived abundances for 34 elements in HD 218732 and 35 elements in HD 232078 using the atmospheric parameters listed in Table 1. Abundances for ten elements, such as Sr, Nb, Ru and other neutron capture elements, were obtained for the first time. Most abundance determinations are based on equivalent width measurements. The results of our abundance analysis are listed in Table 2.

We used the LTE analysis program ABUNDANCE, available together with the stellar spectral synthesis program SPECTRUM written by [6][2] to calculate elemental abundances by standard analyses for the measured equivalent widths. Atmosphere models for calculations were taken from the updated ATLAS model atmosphere grid [7]. We choosed the scaled solar abundance models. For spectral synthesis the SPECTRUM code and atomic line data from the VALD ([8]) and DREAM ([9]) databases were used. Solar abundances were taken from [10].

[2]http://www1.appstate.edu/dept/physics/spectrum/spectrum.html

Table 2: Elemental abundances derived for program stars

			HD 218732			HD 232078		
Ion	Z	$\log \varepsilon_\odot$	$\log \varepsilon_*$ [a]	σ [b]	n [c]	$\log \varepsilon_*$	σ	n
Li I	3	< 1.05	< −1.10*	0.13	1	−0.55*	0.14	1
C I	6	8.43	6.60*	0.13	-	7.62*	0.14	-
N I	7	7.83	7.40*	0.13	-	6.70*	0.14	-
O I	8	8.69	7.83*	0.13	1	8.26*	0.14	1
Na I	11	6.24	4.87	0.15	5	4.67	0.12	5
Mg I	12	7.60	6.45	0.13	4	6.54	0.15	4
Al I	13	6.45	4.95*	0.13	2	4.81*	0.14	2
Si I	14	7.51	6.59	0.16	20	6.61	0.18	20
Ca I	20	6.34	5.11	0.11	15	5.23	0.14	26
Sc II	21	3.15	1.68	0.13	15	1.76	0.14	12
Ti I	22	4.95	3.78	0.09	58	3.86	0.11	46
Ti II	22	4.95	3.83	0.12	13	3.96	0.16	11
V I	23	3.93	2.66	0.10	25	2.69	0.13	23
V II	23	3.93	2.68	0.13	2	2.67	0.14	1
Cr I	24	5.64	4.18	0.11	11	4.27	0.10	19
Cr II	24	5.64	4.35	0.16	6	4.62	0.16	6
Mn I	25	5.43	3.81	0.20	9	3.92	0.05	9
Fe I	26	7.50	6.01	0.13	180	6.01	0.09	81
Fe II	26	7.50	5.98	0.10	16	6.00	0.10	19
Co I	27	4.99	3.65	0.13	21	3.74	0.17	15
Ni I	28	6.22	4.71	0.10	44	4.82	0.15	38
Cu I	29	4.19	2.55	0.15	3	2.75	0.24	2
Zn I	30	4.56	3.03	0.13	2	3.29	0.14	2
Sr I	38	2.87	1.15*	0.13	1	1.10*	0.14	1
Sr II	38	2.87	1.43*	0.13	2	1.50*	0.14	2
Y I	39	2.21	0.41	0.50	2	0.40	0.43	4
Y II	39	2.21	0.79	0.07	5	1.14	0.10	5
Zr I	40	2.58	1.09	0.38	6	0.99	0.41	9
Zr II	40	2.58	1.45	0.13	2	1.51	0.16	3
Nb I	41	1.46	0.30*	0.14	4	0.35*	0.13	3
Mo I	42	1.88	0.67	0.13	2	0.75	0.14	2
Ru I	44	1.75	0.70*	0.13	2	0.65*	0.13	4
Ba II	56	2.18	0.54	0.06	3	0.38	0.13	3
La II	57	1.10	−0.01	0.16	5	−0.11	0.20	6
Ce II	58	1.58	−0.19	0.16	7	0.02	0.14	5
Pr II	59	0.72	−0.47	0.16	2	−0.40	0.15	2
Nd II	60	1.42	0.13	0.10	9	0.20	0.16	12
Sm II	62	0.96	−0.30*	0.14	3	−0.10*	0.13	3
Eu II	63	0.52	−0.70*	0.13	1	−0.55*	0.14	1
Hf II	72	-	-	-	-	−0.30*	0.14	1
Pb I	82	1.75	0.30*	0.13	1	0.80*	0.14	1
Th II	90	0.02	−1.70*	0.13	1	−1.50*	0.14	2

[a] Asterisk marks the abundances derived using spectrum synthesis.
[b] σ is the line-to-line scatter of an abundance.
[c] n is the number of spectral lines used for abundance calculation.

4. CONCLUSIONS

Based on our analysis of high-resolution spectra taken with the FIES optical echelle spectrograph at the 2.56 m Nordic Optical Telescope we have derived atmospheric parameters and accurate abundances of more than 30 elements in two metal-poor ([Fe/H] ≈ -1.50) halo red giants: HD 218732 and HD 232078. Abundances of some elements are derived for the first time. From our analysis we found that α-elements are enhanced similarly as in other metal-poor halo stars and abundances of the iron group elements generally follow the typical behaviour of halo stars. The abundances of most neutron capture elements are well described by the solar r-process abundance curve, suggesting a large r-process contribution. By comparing the obtained C and N abundances with the data of [11] for extremely metal-poor giants, we conclude that our observed stars belong to different groups. Abundance pattern of HD 232078 is similar to other unmixed halo stars whereas HD 218732 should have experienced a deep mixing episode that has affected its surface abundances. The second fact that supports this conclusion is the absence of Li 6707.8 Å feature in the spectrum of HD 218732. Both stars are close to the red giant branch tip and are experiencing slow mass loss as indicate the blue shifted cores and emission in the wings of Hα line, although HD 218732 could be a first ascent AGB star. More detailed studies of these stars could provide a better understanding about the chromospheric activity, pulsations and mass loss processes of metal-poor red giants near the red giant branch tip.

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