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Abundances in Lithium-poor Halo Stars

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Abstract

Lithium is an astrophysically important element. Its abundance in different stars can be used to test stellar structure and evolution models, as well as in constraining cosmological parameters and models of galactic chemical evolution. Halo stars on the Spite plateau might provide the key to derivation of the primordial lithium abundance by virtue of their near-constant lithium content, which is believed (although this is still under investigation) to have undergone little processing since the stars formed. In around 7% of halo stars, however, the lithium abundance is undetectable. We present preliminary detailed abundance measurements for a range of elements, in an attempt to explore further how, and why, these stars differ from their lithium-normal counterparts.

1.1 Introduction

Lithium has an important role to play in astrophysics. It is the only metal formed in significant quantity in the Big Bang, and it is destroyed in stars at relatively low temperatures (2.5×10^6 K). Knowledge of the primordial lithium abundance (Li_P) should allow constraints from nucleosynthesis to be placed on such cosmological parameters as Ω_B (or equivalently η). Determination of Li_P requires detailed knowledge of processes which have altered the amount of lithium over time, to the values we determine today. Such processes could include Galactic chemical evolution processes (e.g. cosmic ray spallation), stellar evolution (AGB stars and supernovae), and mixing in stars which depletes abundances of fragile elements such as Li.

Population II stars are interesting places to study lithium, as many of them have very similar Li abundances (the *Spite plateau*). Thin convection zones, and therefore low temperatures at the base of the convection-zone (even on the PMS – Chaboyer & Demarque 1994) in these stars suggest that little, if any, Li depletion should have occurred. The flatness and thinness of the plateau region (6500 K$\leq T_{\rm eff} \leq$5800 K and [Fe/H]<-1.5) have also been taken as evidence no depletion or enhancement of Li has occurred in these stars (Spite & Spite, 1982). There have been, however, suggestions that the plateau is not truly flat, or that there is some scatter in Li abundances (Deliyannis, Pinsonneault & Duncan 1993; Thorburn 1994; but see also Ryan, Norris & Beers 1999), which have caused researchers to look again at Li trends in Pop. II field stars.

There is a small sub-population of stars in the plateau region which have very low or undetectable lithium abundances. There is no obvious distinction between these stars and other Li-normal ones when atmospheric parameters are considered. In order to probe the mystery of these objects further, we have undertaken a detailed abundance analysis of both Li-poor and Li-normal objects, considering a large range of elements. In this paper we present our *preliminary* findings.

Table 1.1. *Stellar parameters*

Star				T_{eff}	$\log g$	[Fe/H]	ξ	Refs.
HD	BD	G	Other	(K)			(km s^{-1})	
97916	+02 2406			6124	3.87	-1.10	1.0	[1]
		122-69		6000	4.0*	-2.67	0.8	[1]
		66-30	Wolf 550	6400	4.49	-1.75	0.9	[1]
		202-65		6390	3.64	-1.32	0.9	[1]
Li-normal standards								
140283	-10 4149			5750	3.75	-2.44	0.75	[2]
338529	+26 3578			6000	3.83	-2.24	1.0	[3]

*: Hipparcos data not available for this star. Initial values calculated from literature.
[1] Ryan et al. 2001; [2] Caretta et al. 2002; [3] Nissen et al. 2002

1.2 Data Reduction and Analysis

Data were obtained using the 4.2m William Herschell Telescope, La Palma, on 2001 April 03-05. The Utrecht Echelle Spectrograph was used with the 79 lines mm^{-1} grating and 2 EEV CCD chips. The central wavelength was 3426Å. Reduction was performed with the Starlink ECHOMOP and FIGARO packages. A linelist was compiled from the Kurucz Atomic Line Database (Kurucz & Bell 1995). Effective temperatures and initial iron abundances were taken from the literature. Gravities were calculated from the Hipparcos parallaxes, and microturbulent velocities were determined from a set of Fe lines using the method of Magain (1984). Lines were measured by direct integration below an assumed continuum using UCLSYN(Smith, 1992; Smalley, Smith & Dworetsky 2001). EWs were converted to abundances using the ATLAS 9 model atmospheres (Kurucz 1993) and WIDTH6 code. Stellar parameters used are presented in Table 1.1

1.3 Results

Preliminary results have been obtained for 11 elements, including those indicative of the α process, neutron-capture process, and the Fe-peak elements. They are presented in Table 1.2, and a sample of abundance comparisons against Li-normal stars from the literature are shown in Figure 1.1. At present there seems little to distinguish between ultra-Li-poor objects and Li-normal stars, and hence there are few if any chemical clues to their different origins or evolution. Similar UV spectra have been acquired for five other Li-poor stars which will added to the current set. Additionally, abundances will be derived for Mn and Sc once hyperfine structure is compensated for, and abundances or limits will be derived for C and N from the molecular NH and CH bands. A full error analysis and literature comparison will be performed at that time

Results are presented in Table 1.2, and selected plots are shown in Fig. 1.1.

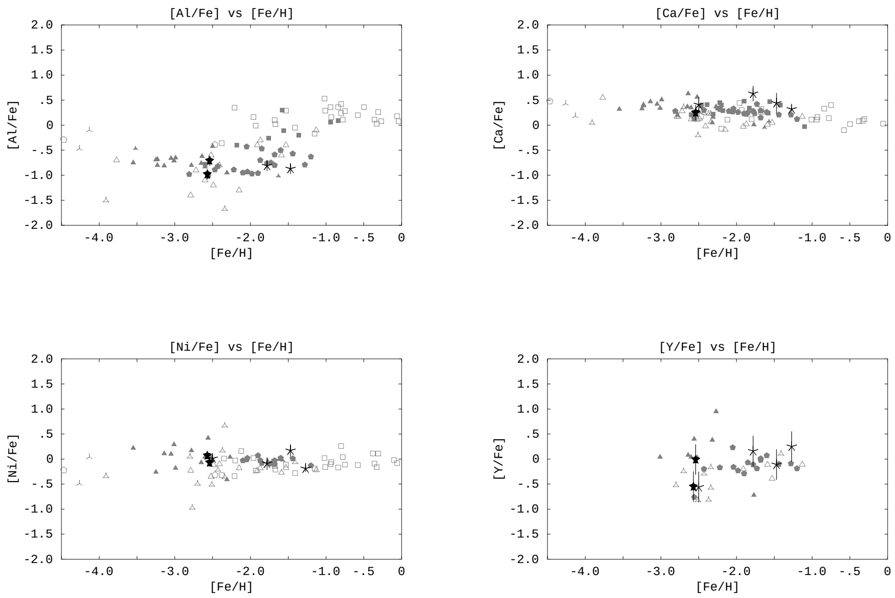

Fig. 1.1. Results for **Al**, α-peak element **Ca**, Fe-peak element **Ni** and neutron-capture element **Y** plotted against [Fe/H]. Asterisks = Li-poor objects; filled stars = Li-normal objects; grey symbols represent data from the literature

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Table 1.2. *Calculated abundances for 4 lithium-poor stars and 2 lithium-normal objects (HD 140283 and BD+26*$^{\mathrm{deg}}$*3578). Typical (measurement + atmospheric) errors are expected to be 0.1-0.3 dex. Results are the weighted average of two ionization states where applicable (Fe, Sc, Ti, Cr, Mn, Co). Note, Sc and Mn results are not yet corrected for hyperfine splitting. The number of lines used for each measurement is given in brackets.*

	$[\frac{Fe}{H}]$	$[\frac{C}{Fe}]$	$[\frac{Al}{Fe}]$	$[\frac{Ca}{Fe}]$	$[\frac{Sc^*}{Fe}]$	$[\frac{Ti}{Fe}]$	$[\frac{Cr}{Fe}]$	$[\frac{Mn^*}{Fe}]$
HD 97916	-1.27 (28)	....	....	0.32 (2)	.....	0.48 (5)	0.00 (3)	0.07 (2)
G 122-69	-2.50 (27)	....	....	0.41 (1)	-0.81 (3)	0.30 (9)	0.25 (1)	-0.47 (2)
G 66-30	-1.78 (45)	....	-0.81 (1)	0.63 (1)	-0.21 (4)	0.24 (11)	0.03 (3)	0.06 (5)
G 202-65	-1.47 (47)	0.75 (1)	-0.87 (1)	0.44 (2)	-0.84 (1)	0.07 (9)	0.02 (5)	0.14 (3)
HD 140283	-2.57 (47)	....	-0.98 (1)	....	-0.34 (3)	0.27 (12)	0.02 (2)	-0.15 (6)
BD+26 3578	-2.54 (29)	....	-0.71 (1)	0.25 (1)	-0.45 (3)	0.02 (9)	0.26 (2)	-0.08 (4)

	$[\frac{Fe}{H}]$	$[\frac{Co}{Fe}]$	$[\frac{Ni}{Fe}]$	$[\frac{Sr}{Fe}]$	$[\frac{Y}{Fe}]$	$[\frac{Zr}{Fe}]$	$[\frac{La}{Fe}]$	$[\frac{Nd}{Fe}]$	$[\frac{Dy}{Fe}]$
HD 97916	-1.27	0.64 (1)	-0.19 (4)	....	0.25 (3)	0.32 (1)	0.43 (1)	0.74 (1)	....
G 122-69	-2.50	0.17 (8)	0.01 (12)	....	-0.56 (1)	....	....	....	1.77 (1)
G 66-30	-1.78	0.23 (8)	-0.09 (12)	....	0.16 (5)	0.38 (1)	....	0.88 (1)	....
G 202-65	-1.47	0.02 (5)	0.17 (8)	....	-0.11 (4)	0.03 (1)	....	0.49 (1)	....
HD 140283	-2.57	0.50 (8)	0.07 (14)	0.24 (1)	-0.55 (3)	0.45 (1)	....	1.80 (1)	....

* Hyperfine structure corrections have not yet been applied to Mn and Sc abundances.