From Li to U: Elemental Tracers of Early Cosmic Evolution
Proceedings IAU Symposium No. 228, 2005
V. Hill, P. François & F. Primas, eds.

doi:10.1017/S1743921305005351

Effective temperatures and lithium abundances of halo turnoff stars†

P.E. Nissen[1], C. Akerman[2], M. Asplund[3], D. Fabbian[3] and M. Pettini[2]

[1]Department of Physics and Astronomy, University of Aarhus, Denmark
email: pen@phys.au.dk

[2]Institute of Astronomy, Cambridge, UK

[3]Mount Stromlo Observatory, Australian National University, Australia

Abstract. Effective temperatures of 30 turnoff stars with $-3.2 < [Fe/H] < -1.5$ have been derived from the profiles of Balmer lines in high S/N, VLT/UVES spectra. While the systematic error of $T_{\rm eff}$ may be of the order of 100 K, the differential values of $T_{\rm eff}$ are determined with a one-sigma precision of $\sim$25 K. These precise $T_{\rm eff}$ values are used in a study of the slope and dispersion of the Li abundance as a function of [Fe/H]. A small, but significant cosmic dispersion in A(Li) appears to be present exemplified by the two very metal-poor stars G64-12 and G64-37.

Keywords. Stars: fundamental parameters, stars: abundances, cosmology: early universe

1. Introduction

From the baryon-to-photon ratio determined from WMAP data in combination with SBBN calculations, the primordial ^{7}Li abundance is predicted to be $^7{\rm Li/H} \simeq 4 \times 10^{-10}$, which is a factor 3–4 higher than Li abundances found in metal-poor stars on the Spite plateau (Spite & Spite 1982). The reason could be that the atmospheric Li abundance of these stars has been depleted, but models have difficulties in explaining the small dispersion in $A({\rm Li}) \equiv \log({\rm Li/H}) + 12.0$ among the plateau stars. Ryan *et al.* (1999), in particular, found a very small dispersion, $\sigma(A({\rm Li})) = 0.031$ dex, around a metallicity trend, $\Delta A({\rm Li})/\Delta[{\rm Fe/H}] \simeq 0.12$, for a sample of 21 turnoff stars with low metallicities. As a further study of this problem we have derived Li abundances for a sample of 30 metal-poor turnoff stars from VLT/UVES echelle spectra using effective temperatures derived from the profiles of Balmer lines.

2. Effective temperatures and abundances

The majority of the spectra used are from the C/O study of Akerman *et al.* (2004). Recently, the sample has been extended with new UVES spectra for 12 very metal-poor stars (unpublished). All these spectra have $R \simeq 60\,000$ and $S/N \simeq 300$, and Hβ was used to determine $T_{\rm eff}$. In addition, we have included the more metal-poor stars ([Fe/H] < -1.5) from the ^{6}Li survey of Asplund *et al.* (2005). For these stars, Hα was used to derive $T_{\rm eff}$.

Theoretical profiles of the Balmer lines were calculated as described in Barklem *et al.* (2002) and used to calibrate an index measuring the flux in two bands in the line wings relative to the flux in two bands near the line center as a function of $T_{\rm eff}$. By defining

† Based on observations collected at ESO, Chile (ESO No. 67.D-0106 and 73.D-0024)

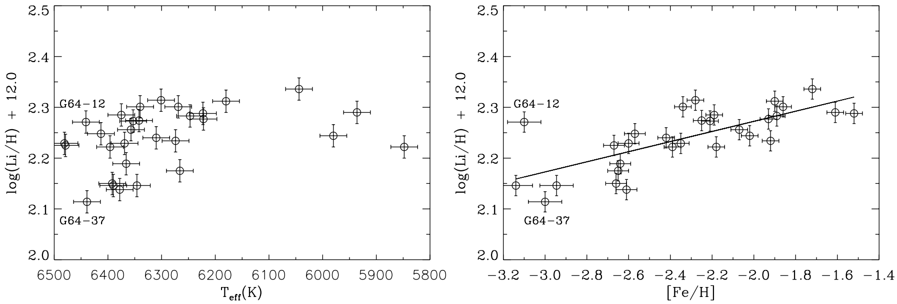

Figure 1. Li abundances vs. $T_{\rm eff}$ and [Fe/H]

the $T_{\rm eff}$ indices of the Balmer lines in this way, we avoid referring to the true continuum, which cannot be determined with high accuracy for echelle spectra.

The internal precision of the $T_{\rm eff}$ determination appears to be very high. Effective temperatures derived from the left and the right wing of the Hβ line have a mean difference of 13 ± 6 K only, and $T_{\rm eff}$'s determined from spectra of a given star obtained on different nights differ by less than 20 K. For nine stars with both Hα and Hβ observations, there is an average difference $T_{\rm eff}({\rm H}\beta) - T_{\rm eff}({\rm H}\alpha)$ of 57 K, but the rms dispersion of the difference is $\pm$19 K only. This suggests that the errors of differences in effective temperatures are very small, probably less than 25 K. Systematic errors in $T_{\rm eff}$ may, however, be considerably larger.

[Fe/H] is determined from Fe II lines as described in Nissen *et al.* (2004). The Li abundances are derived from the Li I 6708 Å line using MARCS model atmospheres and assuming LTE. From the error of the measured equivalent width of the Li line ($\pm$0.5 mÅ), and an internal error $\sigma(T_{\rm eff}) = \pm 25$ K, we arrive at an expected rms precision of $\sigma(A({\rm Li}))$ = 0.022 dex for the *differential* values of the Li abundances.

3. Results

The derived values of A(Li) are plotted as a function of $T_{\rm eff}$ and [Fe/H] in Fig. 1. As seen there is hardly any significant trend with $T_{\rm eff}$ but a probable increase of the Li abundance with [Fe/H]. A linear fit to the data gives A(Li) = 0.10 [Fe/H] + 2.47 with a rms dispersion of 0.041. This is significantly higher than the expected dispersion of 0.022 dex. A large contribution to the dispersion comes from the pair of very metal-poor stars, G64-12 and G64-37, which have nearly identical Hβ profiles corresponding to $T_{\rm eff}$ = 6440 K, but quite different values of the equivalent width of the Li I 6708 Å line, 22.5 and 16.1 mÅ, respectively. Even without G64-12, the dispersion (0.035 dex) remains higher than expected. Hence, in contrast to the study of Ryan *et al.* (1999), our data point to a small, but significant cosmic dispersion in A(Li) among metal-poor turnoff stars. This suggests that Li depletion has occurred in some of the Spite plateau stars.

References

Akerman, C.J., Carigi, L., Nissen, P.E., Pettini, M. & Asplund M. 2004, *A&A* 414, 931

Asplund, M., Lambert, D.L., Nissen, P.E., Primas, F. & Smith V.V. 2005, in preparation

Barklem, P.S., Stempels, H.C., Allende Prieto, C., Kochukhov, O.P., Piskunov, N. & O'Mara, B.J. 2002, *A&A* 385, 951

Nissen, P.E., Chen, Y.Q., Asplund, M. & Pettini, M. 2004, *A&A* 415, 993

Ryan, S.G., Norris, J.E., & Beers, T.C. 1999, *ApJ* 523, 654

Spite, F. & Spite, M. 1982, *A&A* 115, 357.

https://doi.org/10.1017/S1743921305005351 Published online by Cambridge University Press