Chemical Abundances in the Universe: Connecting First Stars to Planets
Proceedings IAU Symposium No. 265, 2009
K. Cunha, M. Spite & B. Barbuy, eds.

doi:10.1017/S1743921310000220

Precise Li abundances in metal-poor stars: depletion in the Spite plateau

J. Meléndez[1], L. Casagrande[2], I. Ramírez[2] and M. Asplund[2]
[1]Centro de Astrofísica da Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[2]Max-Planck-Institut für Astrophysik, Germany

Abstract. We present Li abundances for 73 stars in the metallicity range $-3.5 <$ [Fe/H] < -1.0 using improved IRFM temperatures (Casagrande *et al.* 2009) with precise *E(B-V)* values obtained mostly from interstellar NaI D lines, and high-quality equivalent widths ($\sigma_{EW} \sim 3\%$). At all metallicities we uncover a fine-structure in the Li abundances of Spite plateau stars, which we trace to Li depletion that depends on both metallicity and mass. Models including atomic diffusion and turbulent mixing seem to reproduce the observed Li depletion assuming a primordial Li abundance $A_{\rm Li}$ = 2.64 dex (MARCS models) or 2.72 (Kurucz overshooting models), in good agreement with current predictions ($A_{\rm Li}$ = 2.72) from standard BBN.

Keywords. nucleosynthesis – cosmology: observations – stars: abundances

---

1. Li depletion in Spite plateau stars

One of the most important discoveries in the study of the chemical composition of stars was made in 1982 by M. and F. Spite, who found an essentially constant Li abundance in warm metal-poor stars (Spite & Spite 1982), a result interpreted as a relic of primordial nucleosynthesis. Due to its cosmological significance, there have been many studies devoted to Li in metal-poor field stars (e.g. Meléndez & Ramírez 2004; Charbonnel & Primas 2005; Asplund *et al.* 2006; Bonifacio *et al.* 2007), with observed Li abundances at the lowest [Fe/H] from as low $A_{\rm Li}$ = 1.94 to as high as $A_{\rm Li}$ = 2.37.

Using the theory of big bang nucleosynthesis (BBN) and the baryon density obtained from WMAP data, a primordial Li abundance of $A_{\rm Li} = 2.72^{+0.05}_{-0.06}$ is predicted (Cyburt *et al.* 2008), which is a factor of 2–6 times higher than the Li abundance inferred from halo stars. There have been many theoretical studies on non-standard BBN trying to explain the cosmological Li discrepancy by exploring the frontiers of new physics. Alternatively, the Li problem could be explained by a reduction of the original Li stellar abundance due to internal processes (i.e., by stellar depletion). In particular, stellar models including atomic diffusion and mixing can deplete a significant fraction of the initial Li content.

Due to the uncertainties in the Li abundances and to the limited samples available, only limited comparisons of models of Li depletion with stars in a broad range of mass and metallicities have been performed. We have recently finished such a study (Meléndez *et al.* 2009), achieving errors in Li abundance lower than 0.035 dex, for a large sample of metal-poor stars ($-3.5 <$ [Fe/H] < -1.0), for the first time with precisely determined $T_{\rm eff}$ (Casagrande *et al.* 2009) and masses in a relatively broad mass range (0.6–0.9 $M_\odot$).

Our work shows that Li is depleted in Spite plateau stars. The spread of the Spite plateau at any metallicity is much larger than the error bar. Also, there is a correlation between Li and stellar mass at any probed metallicity (Fig. 1), showing thus that Li has been depleted in Spite plateau stars at any metallicity. In Fig. 1 we confront the stellar evolution predictions of Richard *et al.* (2005) with our inferred stellar masses and Li abundances. The models include the effects of atomic diffusion, radiative acceleration and

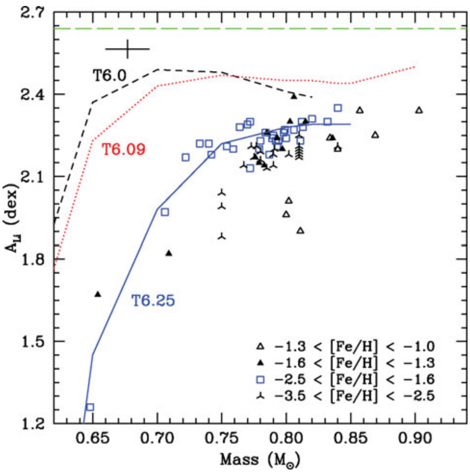

Figure 1. Li abundances as a function of stellar mass in different metallicity ranges. Models at [Fe/H] = −2.3 including diffusion and T6.0 (short dashed line), T6.09 (dotted line) and T6.25 (solid line) turbulence (Richard *et al.* 2005) are shown. Figure from Meléndez *et al.* (2009).

gravitational settling but moderated by a parametrized turbulent mixing. The agreement is very good when adopting a turbulent model of T6.25 and an initial $A_{\rm Li} = 2.64$. The stellar Li abundances used above were obtained with the latest MARCS models (Gustafsson *et al.* 2008), but if we use instead the Kurucz convective overshooting models, then the required initial abundance to explain our data would be $A_{\rm Li} = 2.72$.

Our results imply that the Li abundances observed in Li plateau stars have been depleted from their original values and therefore do not represent the primordial Li abundance. It appears that the observed Li abundances in metal-poor stars can be reasonably well reconciled with the predictions from standard Big Bang nucleosynthesis (e.g. Cyburt *et al.* 2008) by means of more realistic stellar evolution models that include Li depletion through diffusion and turbulent mixing (Richard *et al.* 2005). We caution however, that, although encouraging, our results should not be viewed as proof of the correctness of the Richard *et al.* models until the free parameters required for the stellar modeling are better understood from basic physical principles. In this context, new physics should not be discarded yet as a solution of the cosmological Li discrepancy, as perhaps the low Li-7 abundances in metal-poor stars might be a signature of supersymmetric particles in the early universe, which could also explain the Li-6 detections in metal-poor stars (e.g. Asplund *et al.* 2006; Asplund & Meléndez 2008).

References

Asplund, M., Lambert, D. L., Nissen, P. E., Primas, F., & Smith, V. V. 2006, *ApJ*, 644, 229
Asplund, M. & Meléndez, J. 2008, First Stars III, 990, 342
Bonifacio, P., *et al.* 2007, *A&A*, 462, 851
Casagrande, L., Ramírez, I., Meléndez, J., Bessell, M., & Asplund, M. 2009, *A&A*, submitted
Charbonnel, C. & Primas, F. 2005, *A&A*, 442, 961
Cyburt, R. H., Fields, B. D., & Olive, K. A. 2008, *J. Cosmology & Astro-Particle Phys.*, 11, 12
Gustafsson, B., Edvardsson, B., Eriksson, K. *et al.* 2008, *A&A*, 486, 951
Meléndez, J. & Ramírez, I. 2004, *ApJ* (Letters), 615, L33
Meléndez, J., Casagrande, L., Ramírez, I., & Asplund, M. 2009, *A&A*, submitted
Richard, O., Michaud, G., & Richer, J. 2005, *ApJ*, 619, 538
Spite, F. & Spite, M. 1982, *A&A*, 115, 357

https://doi.org/10.1017/S1743921310000220 Published online by Cambridge University Press