Li depletion in solar analogues with exoplanets

E. Delgado Mena[1], G. Israelian[2,3], J. I. González Hernández[2,3], S. G. Sousa[1,2,4], A. Mortier[1,4], N. C. Santos[1,4], V. Zh. Adibekyan[1], J. Fernandes[5], R. Rebolo[2,3,6], S. Udry[7] and M. Mayor[7]

[1] Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[2] Instituto de Astrofísica de Canarias, C/ Via Lactea s/n, 38200 La Laguna, Tenerife, Spain
[3] Departamento de Astrofísica, Universidad de La Laguna, 38205, La Laguna, Tenerife, Spain
[4] Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, 4169-007 Porto, Portugal
[5] CGUC, Department of Mathematics and Astronomical Observatory, University of Coimbra, 3049 Coimbra, Portugal
[6] Consejo Superior de Investigaciones Científicas, CSIC, Spain
[7] Observatoire de Genève, Université de Genève, 51 ch. des Maillettes, 1290 Sauverny, Switzerland

e-mail: Elisa.Delgado@astro.up.pt

Centro de Astrofísica da Universidade do Porto

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The importance of light elements

Light elements provide information regarding the distribution and mixing of matter within a star. Lithium is depleted at a temperature of 2.5 million K primarily during the PMS but it can also be destroyed in stellar envelopes if any mixing process exists.

Li abundances depend on several parameters such as T_{eff}, [Fe/H] and age. Cooler stars are more Li-depleted because their deeper convective envelopes allow the material to reach the Li-burning layers. On the other hand, when the temperature is close to 5900 K, most of the stars have preserved higher amounts of Li (due to their shallower convective envelopes) but still present signs of depletion that are not expected from standard models. However, in the T_{eff} range 5600-5900K we find a wide spread in Li abundances, the convective envelope is not as deep as in cooler stars but lies very close to the Li burning layer. As a consequence, this type of stars are very sensitive to non-standard mixing processes. It is in this T_{eff} range where we find that planet hosts show an enhanced Li depletion when compared to stars without detected giant planets.

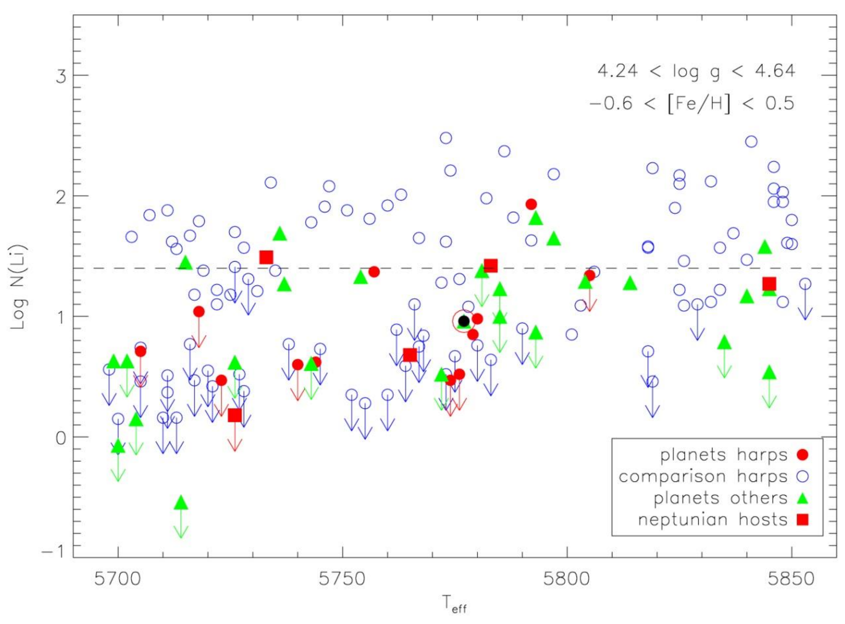

Figure 1: Li abundances from HARPS-GTO sample and from a sample of planet hosts observed in several high resolution spectrographs

Table 1: Distribution of Li depleted stars in different subsamples

Name	T_{eff} (K)	[Fe/H]	log g (cm s^{-2})	planet hosts^{a}	single stars	planet hosts A(Li)>1.4	single stars A(Li)>1.4
Solar type	5600,5900	-0.85,0.5	3.8,4.7	43+49	233^{b}	28% +5% -4%	43% ±3%
Solar analogues	5697,5857	-0.6,0.5	4.24,4.64	18+25	99	19% +7% -4%	47% ± 5%
Solar twins	5697,5857	-0.2,0.2	4.24,4.64	9+13	60	18% +10% -5%	48% ±6%

(a) Planets hosts from HARPS (including the Sun)+planet hosts from other surveys.

Li abundances are also expected to decrease with age though this effect takes place primarily during the first 1-2 Gyr and depends on initial rotation rates. Moreover, stars with more metals (at a given mass) are expected to have deeper convective envelopes which favour Li depletion. However, different degrees of Li depletion have been observed in stars of similar T_{eff} in open clusters (where they also share a common [Fe/H] and age) and in fields stars.

Constructing a non-biased sample

In order to allow for a non-biased comparison between planet hosts and 'single' stars we have to make sure that our samples are formed but stars with very similar parameters: T_{eff}, logg, [Fe/H] and age. In Figure 2 we can see how Li abundances for solar twins (as defined in Table 1) decrease slightly with age but planet hosts always show a lower Li average abundance than non-hosts.

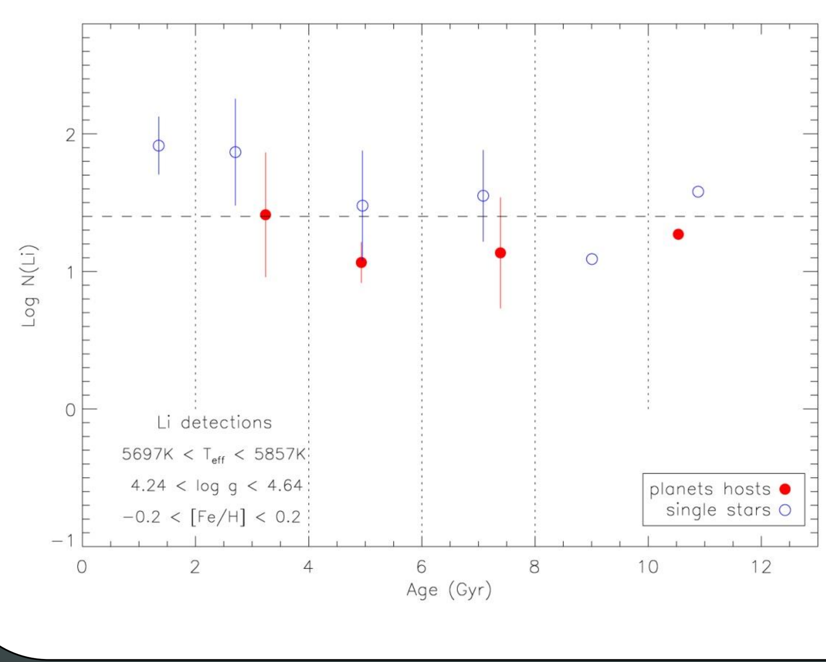

Figure 2: Average of Li detections for solar twins in different age bins. The points in each bin are situated in their average age. The bars indicate the dispersion in Li abundances if there are more than one star in each bin.

An extra parameter governing lithium depletion

Although Li abundances are known to depend on previously mentioned parameters, we can find several couples of very similar stars which still show a clear different degree of Li depletion. A similar spread in Li abundances has also been observed in clusters such as M67, where all stars have solar metallicity and age. Therefore, what else is affecting Li depletion?

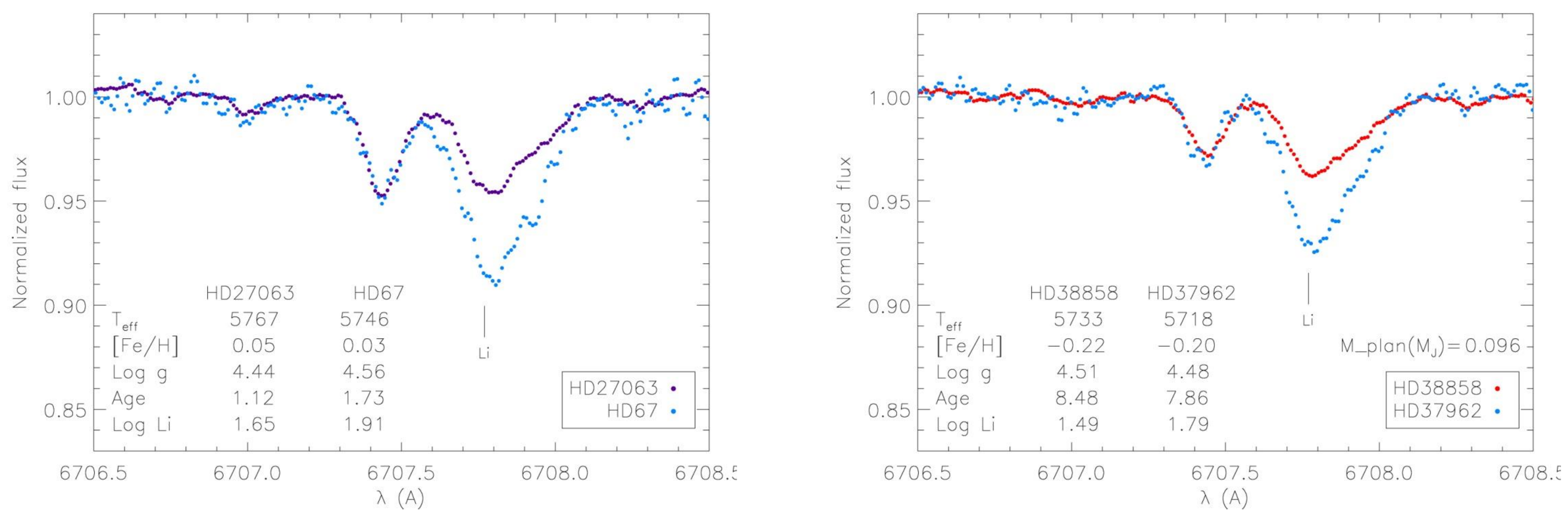

Figure 3: Observed spectra of stars with very similar parameters. and different Li abundances.

It seems that rotation-induced mixing and angular momentum loss are the most efficient processes destroying Li in solar-type stars on the Main Sequence. Internal waves or overshooting mixing are also claimed as responsible for Li depletion. Other mechanisms directly related to the presence of planets have been proposed, such as the instabilities caused by planet migration or by the differential rotation rates induced by long-lasting proto-planetary discs during the Pre-Main Sequence. Furthermore, the infall of planetary material might also affect the mixing processes of those stars by thermohaline convection and the episodic accretion of planetary material can increase the temperature in the bottom of the convective envelope and hence increase Li depletion.

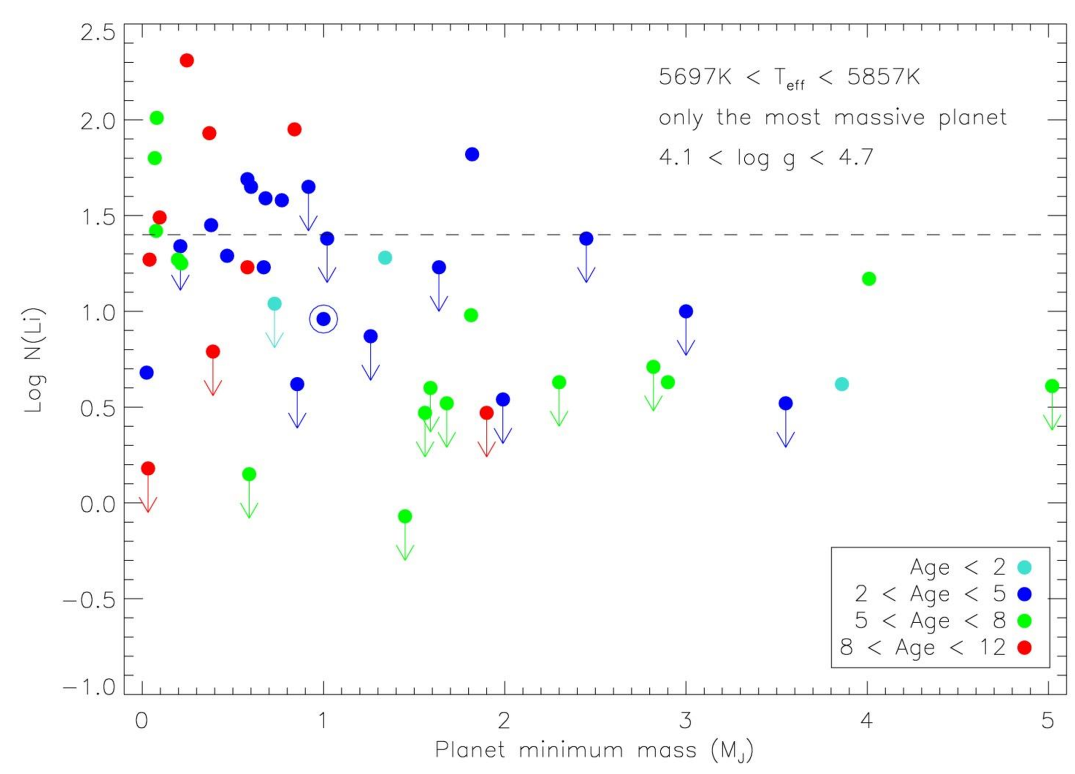

Figure 4: Li abundances as a function of the planetary mass of the most massive planet in each system

We propose that the presence of giant planets (among other possible causes) might affect the Li content in solar analogues. It seems that the destruction of Li (see Fig. 4) is stronger when the planet is more massive. This would make sense in a scenario where the disc is affecting the evolution of angular momentum and hence mixing mechanisms, since we could expect a higher effect if the disc is more massive and has a longer lifetime, conditions needed to form a giant planet. Furthermore, the accretion processes are expected to be more frequent and violent when there is a giant planet in the disc and, as a consequence, produce Li destruction either by the increase of temperature in the base of the convective envelope or by extra-mixing triggered by thermohaline convection.

The discovery of planets in open clusters and the accurate determination of ages and rotation rates (through asteroseismology) will help to better understand this process.

References: Delgado Mena et al. A&A, 562, A92 and references therein