Lithium depletion in open clusters and field solar twins

Precision Spectroscopy 2019

Marília Carlos

Supervisor: Jorge Meléndez

Collaborators: P. Nissen, L. Spina, L. A. dos Santos, M. Bedell, I. Ramirez, M. Asplund, J. L. Bean, D. Yong, J. Yana Galarza and A. Alves-Brito

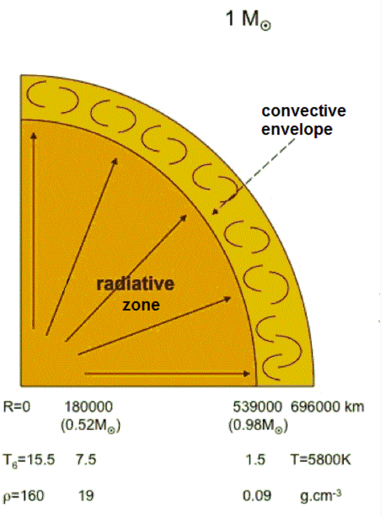
Solar twins

⇒ Solar twins are stars very similar to the Sun in $\mathrm{T_{eff.}}$, surface gravity (log g) and [Fe/H].

→ Stars with stellar parameters within $\mathrm{T_{eff,\odot}} \pm 100$ K, log $\mathrm{g_\odot} \pm 0.1$ and $\mathrm{[Fe/H]_\odot} \pm 0.1$ are considered solar twins!

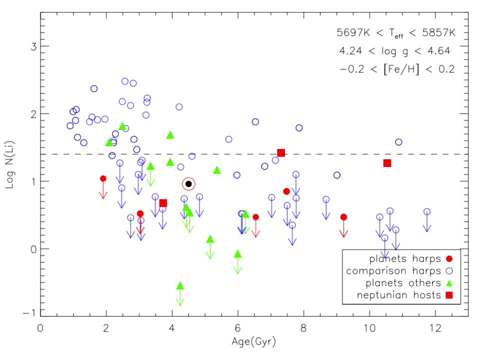
⇒ Study solar twins can constrain stellar structure and evolution beyond the Sun's age.

Lithium destruction



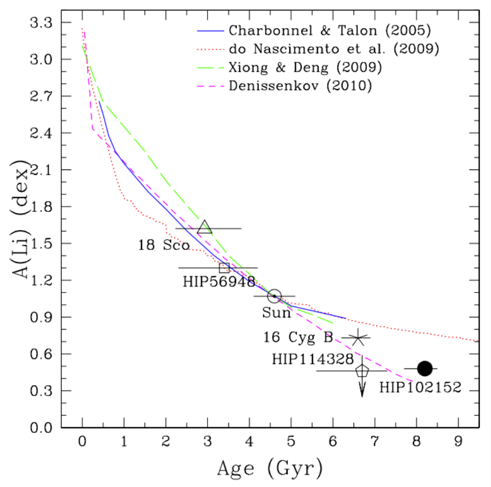
- Li is destroyed at T$\approx 2.5 \times 10^6$ K through the reaction $\rightarrow$ ^{7}Li(p,α)α.
- The Li on the star surface is transported to inner regions through convective motions, by inertia, overshooting (and possible others factors) and it is destroyed in the stellar interior.
- The amount of Li burning depends on the convective zone thickness, mass and metallicity. $\Rightarrow$ Thus, could also depend on age or presence of planets...

Planet connection?



- Several works such as Israelian et al. (2009) and Delgado Mena et al. (2014) claim that lithium depletion in stars is due to presence of planets: Planetary formation could change the initial angular momentum of the star and according to Takeda et al. (2010) and Gonzalez et al. (2010) there is an increase in the lithium burning the lower the angular momentum is.

Age dependence?



⇒ Meléndez et al. 2014 showing the connection between age and lithium depletion compared with non-standard evolution models!

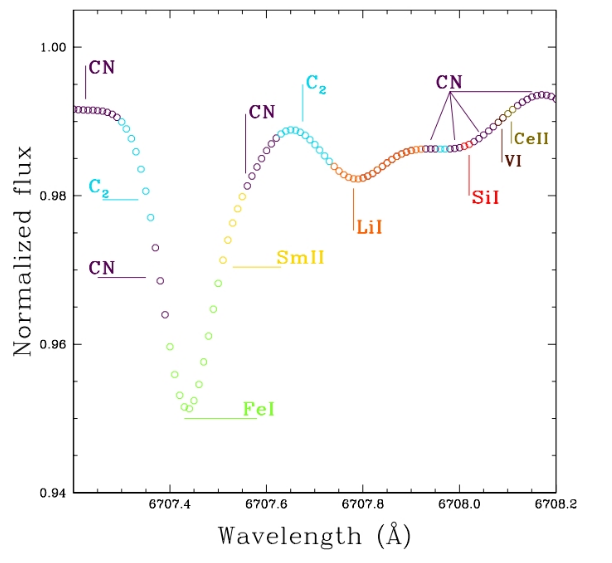
Field solar twins

$\Rightarrow$ In order to shed some light at this discussion 2 different samples of solar twins were analyzed:

$\rightarrow$ Sample 1: 21 solar twins observed with the HARPS spectrograph at high spectral resolution (R$\sim$ 115000) and very high signal-to-noise ratio ($600 \leq \mathrm{S/N} \leq 2400$).

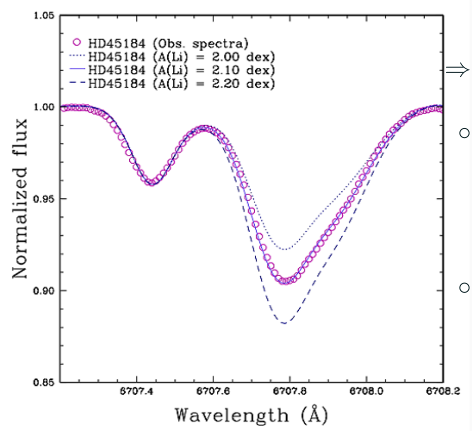
$\rightarrow$ Sample 2: 77 solar twins observed with the HARPS spectrograph at high spectral resolution (R$\sim$ 115000) and very high signal-to-noise ratio ($300 \leq \mathrm{S/N} \leq 1800$).

Analysis



Solar synthetic spectrum in the region of the 6707.75 Å Li I line (Carlos et al. 2016).

Analysis

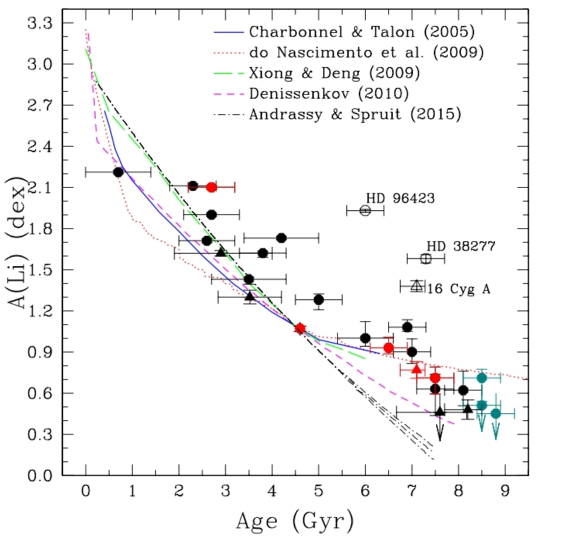


Carlos et al. (2016)

$\Rightarrow$ Spectral Synthesis:

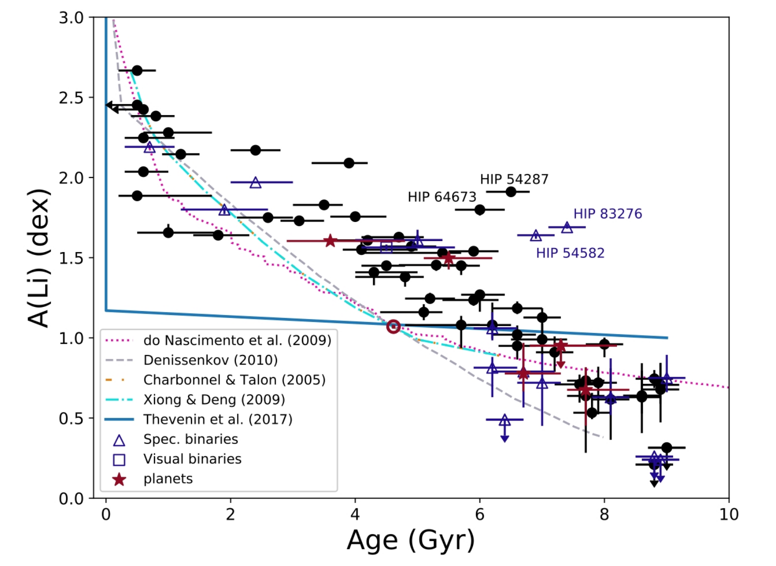
- We use the 1D LTE code MOOG and determine Li abundances through the analysis of the 6707.75 Å Li I line region.
- Errors: uncertainties in the stellar parameters, the rms deviation of the observed line profile relative to the synthetic spectra, and uncertaints in the continuum setting.

Sample 1



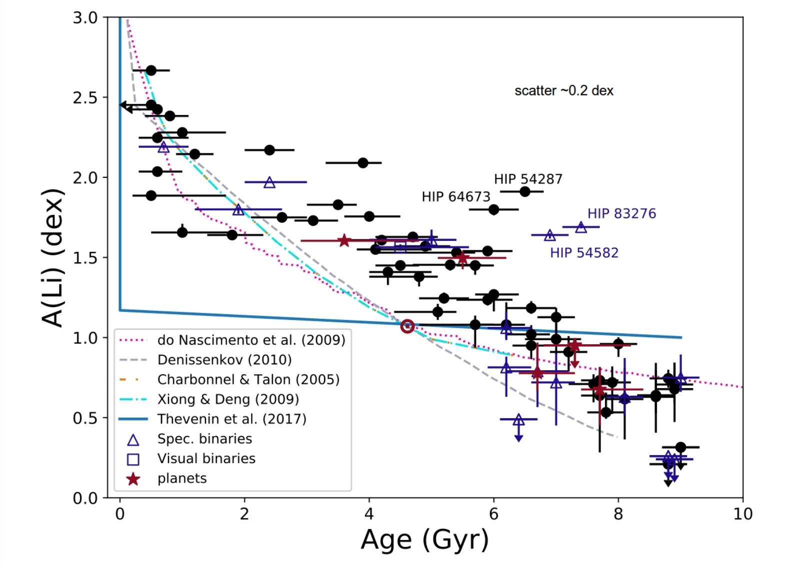
- → Carlos et al. 2016, the data is compared with non-standard evolution models too.
- → red symbols: hosting planets stars.
- → triangles: 16 Cyg A (no planet detected) and 16 Cyg B (planet detected).

Sample 2



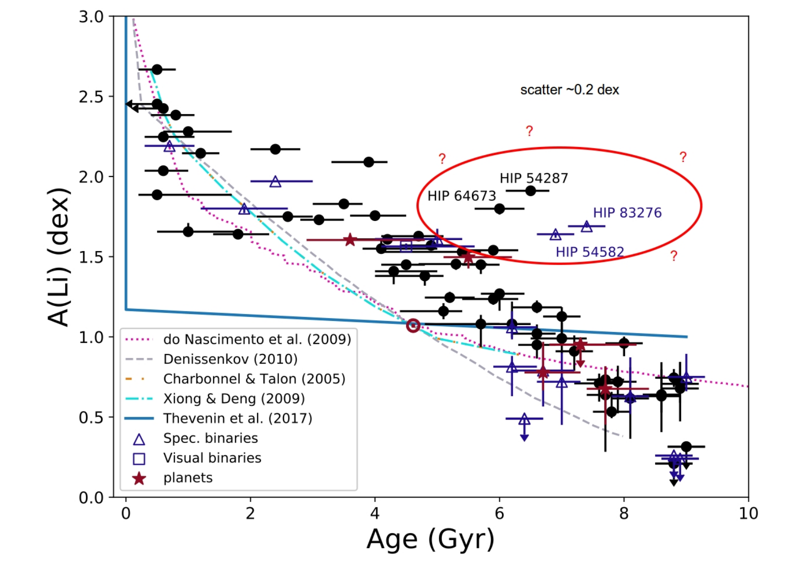
Carlos et al. 2019

Sample 2



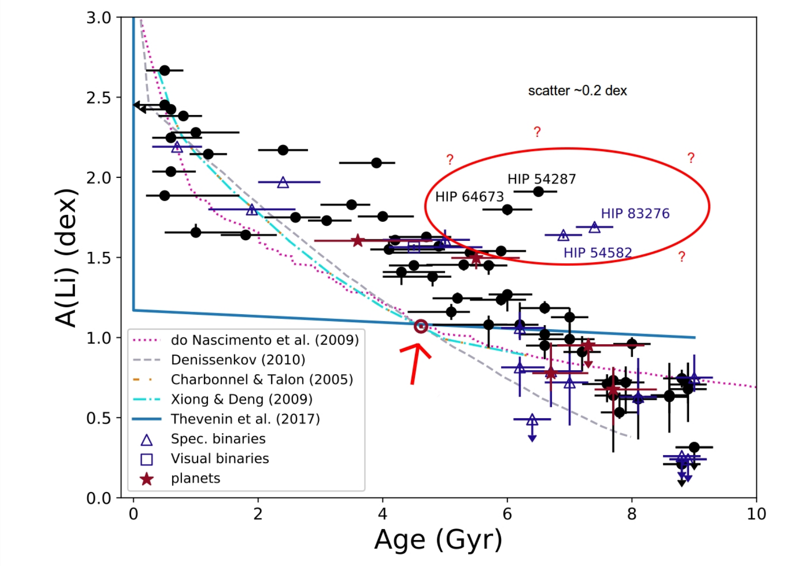
Carlos et al. 2019

Sample 2



Carlos et al. 2019

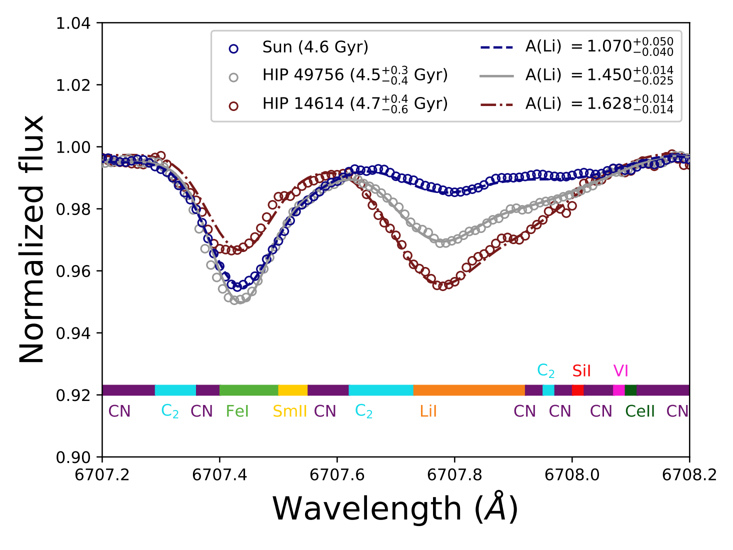
Sample 2



Carlos et al. 2019

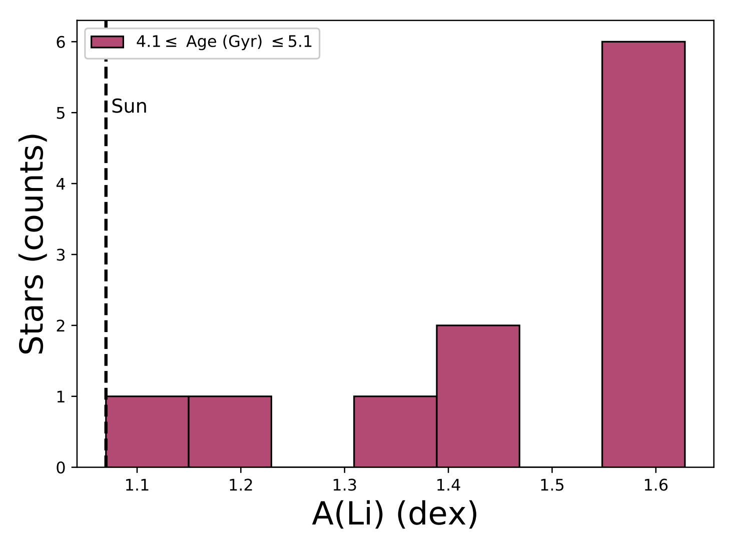
Sample 2

The Sun has a typical rotation and activity (dos Santos et al. 2016, Lorenzo-Oliveira et al. 2018), so why is the Sun Li poor?

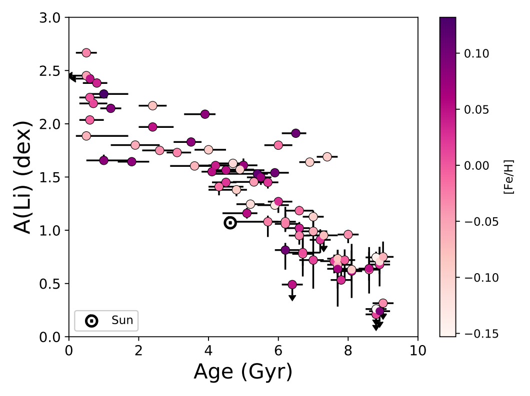


Sample 2

The Sun has a typical rotation and activity (dos Santos et al. 2016, Lorenzo-Oliveira et al. 2018), so why is the Sun Li poor?

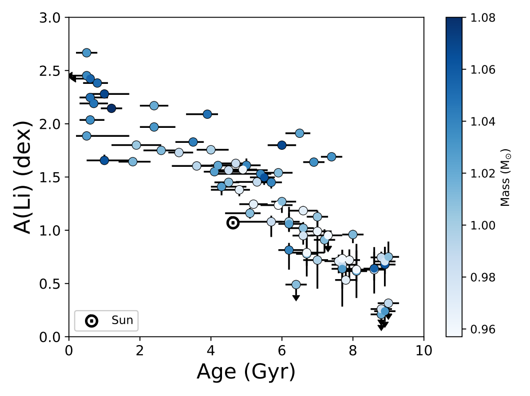


Sample 2



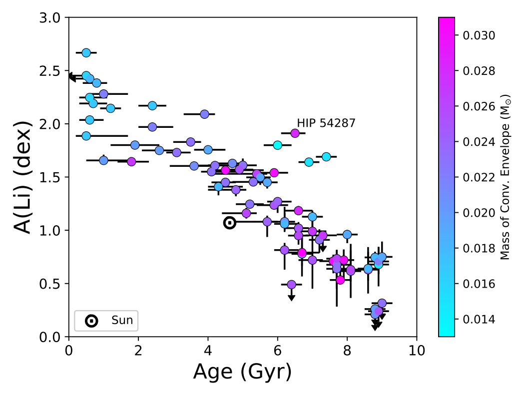
→ The sample is homogeneous regarding metallicity and stellar age ⇒ and because we work with only solar twins there is no apparent trend in Li abundances with [Fe/H] for a given age. Also, the outliers have substantial differences in [Fe/H] varying from −0.096 dex to 0.107 dex.

Sample 2



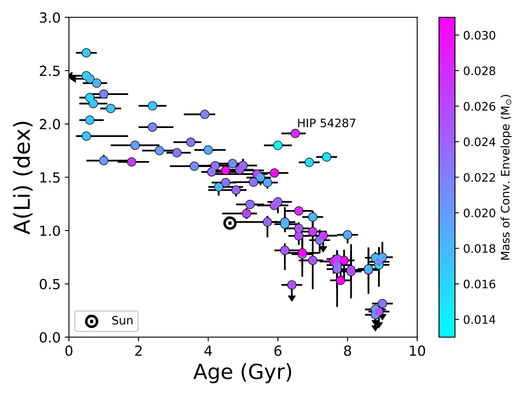
→ Likewise the [Fe/H], the stellar mass distribution is somewhat homogeneous in all the age interval, apart from the youngest stars with age $\lesssim 2.0$ Gyr where we lack stars with mass $\lesssim 0.98 \mathrm{M}_{\odot}$.

Sample 2



- → The sample is homogeneous for Age $\gtrsim$ 2 Gyr, excluding the outliers.
- → Three of the four objects present a less massive convective envelope (combination of [Fe/H] and mass values).
- → **The small size of the convective envelope difficult the lithium burning, which causes the discrepancy in the Li content in these three stars in comparison to the rest of the sample.**

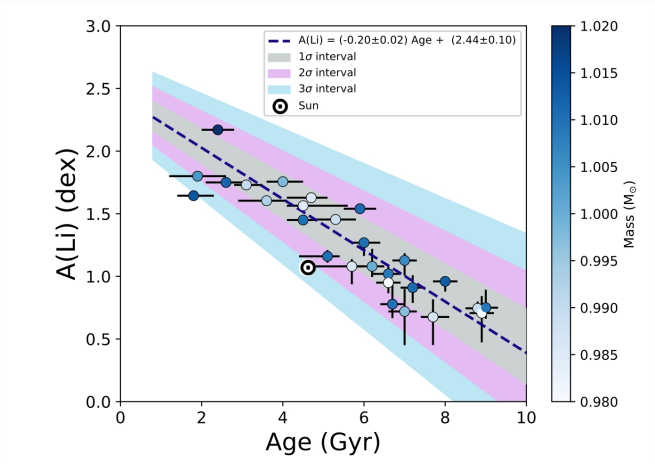
Sample 2



$\rightarrow$ Although the star HIP 54287 has a ‘regular’ convective envelope to burn Li at the same extent as other stars at the same bin of age (excluding the outliers), the high Li content indicates that this object could have experienced a planet engulfment (Montalbán & Rebolo 2002 and Sandquist et al. 2002).

$\rightarrow$ If this is true, we might be luck and are observing a short-duration event ($\sim$ 50 Myr, Théado & Vauclair 2012).

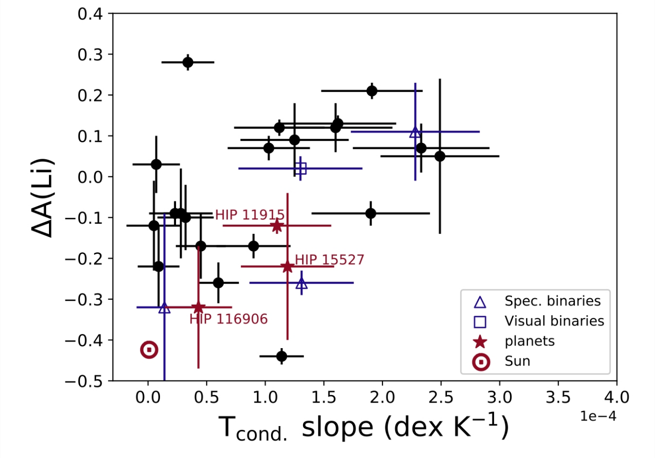
Sample 2



→ Sub-sample with solar twins in the interval $0.98 \leq \mathrm{M}/\mathrm{M}_\odot \leq 1.02$, excluding upper limits and outliers. The Sun is Li poor in $\sim 2\sigma$.

Sample 2

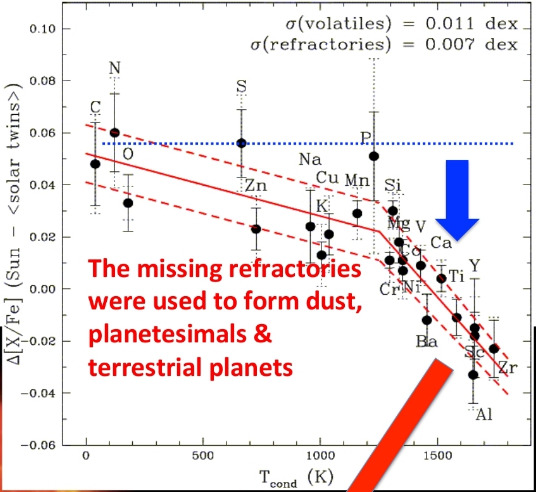
$\Rightarrow \Delta$A(Li) vs. T$_{cond.}$ slope:



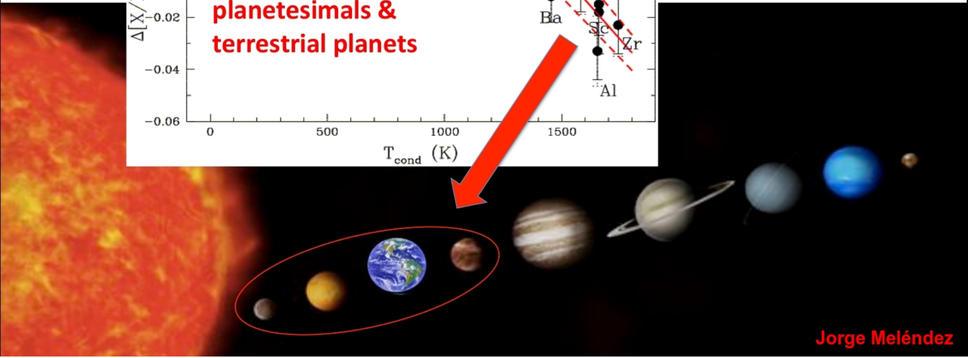
$\rightarrow$ $\Delta A(Li) = A(Li)_{obs.} - A(Li)_{mod.}$

$\rightarrow$ $T_{cond.}$ slope from Bedell et al. 2018.

Meléndez et al. 2009

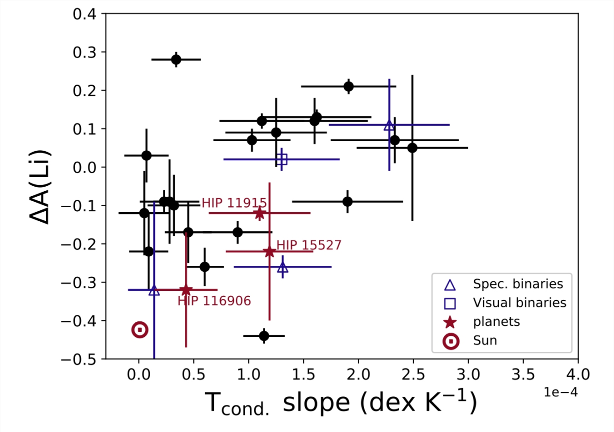


The late accreted gas in the convection zone was deficient in refractories



Jorge Meléndez

Sample 2 – ΔA(Li) vs. $T_{cond.}$ slope



→ The more lithium depleted stars have less content of refractory material.

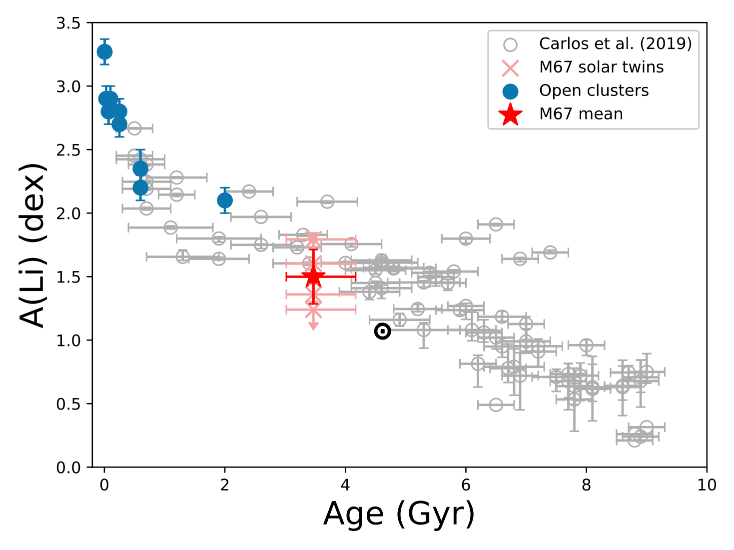
→ The Sun presents a refractory- to-volatile deficiency relative to 93% of the sample (Bedell et al. 2018) $\Rightarrow$ the lower solar lithium content in comparison with stars at similar age could be related to our solar system configuration and the presence of rocky planets.

Solar twins in open clusters

- Although the large studies of Carlos et al. (2016, 2019) with field stars found a strong correlation between stellar age and lithium abundances, **we must be cautious as field stars have large errors in age.**
- To improve these errors, it is urgent an analysis of stars which belong to clusters.
- Star clusters provide good values on their ages, since they are well determined by analysing their colour-magnitude diagrams.

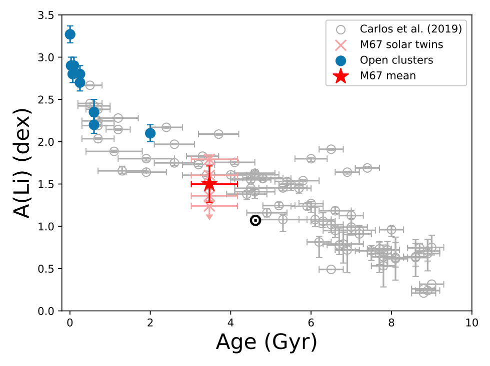
Solar twins in open clusters

⇒ M67 solar twins:



Solar twins in open clusters

⇒ M67 solar twins:

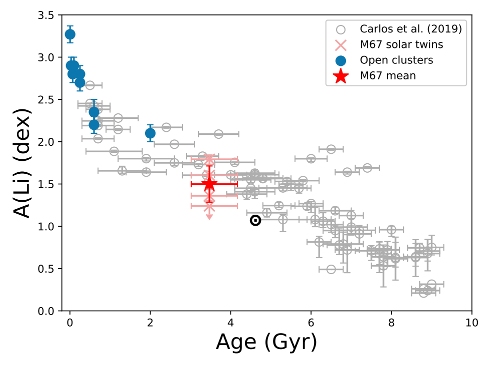


→ Results from the literature and our M67 Li abundances follow the same trend found for our field solar twins.

→ Interestingly, the scatter of the Li abundance of the four M67 solar twins is similar to the scatter found in the field solar twins sample.

Solar twins in open clusters

⇒ M67 solar twins:



- → Results from the literature and our M67 Li abundances follow the same trend found for our field solar twins.
- → Interestingly, the scatter of the Li abundance of the four M67 solar twins is similar to the scatter found in the field solar twins sample. **Maybe due to slightly different initial conditions in star formation.**

Summary

- The study of the chemical composition of stars is crucial to understanding stellar evolution.

Summary

- The study of the chemical composition of stars is crucial to understanding stellar evolution.
- Li abundance decreases by almost 2 dex, which we interpret as being due to gradual destruction of lithium near the bottom of the outer convection. Some outliers in this work can be explained when considering the respective masses of their convective envelopes.

Summary

- The study of the chemical composition of stars is crucial to understanding stellar evolution.
- Li abundance decreases by almost 2 dex, which we interpret as being due to gradual destruction of lithium near the bottom of the outer convection. Some outliers in this work can be explained when considering the respective masses of their convective envelopes.
- **The Sun is lithium poor in comparison with solar twins at similar age!**

Summary

- The study of the chemical composition of stars is crucial to understanding stellar evolution.
- Li abundance decreases by almost 2 dex, which we interpret as being due to gradual destruction of lithium near the bottom of the outer convection. Some outliers in this work can be explained when considering the respective masses of their convective envelopes.
- **The Sun is lithium poor in comparison with solar twins at similar age! (Solar system unique configuration?)**

Summary

- The study of the chemical composition of stars is crucial to understanding stellar evolution.
- Li abundance decreases by almost 2 dex, which we interpret as being due to gradual destruction of lithium near the bottom of the outer convection. Some outliers in this work can be explained when considering the respective masses of their convective envelopes.
- **The Sun is lithium poor in comparison with solar twins at similar age! (Solar system unique configuration?)**
- A(Li) from open cluster follow the same trend as field solar twins.

Thank you!