The bimodal A(Li) distribution of Milky Way's thin disk stars and the Galactic scale events

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Abstract:

It is well known that the lithium abundance in stellar atmospheres, A(Li), suffers from several enhancement and depletion processes during the lifetime of the star. Although several studies demonstrated that these processes are mostly related with the physics of star formation, of protostellar/protoplanetary disks, and of stellar internal dynamics, galactic scale events may also play an important role. The initial [Fe/H] and A(Li) of the star forming gas clouds sets the main properties of protostellar/protoplanetary disks, and thus, how the A(Li) evolves in the star's pre-main sequence and further on. In this paper we study how changes in the [Fe/H]induced by Galactic scale events, have an impact on the A(Li) evolution. We also investigate how the observed bimodal A(Li) distribution is generated and we confirm that the A(Li)-poor and A(Li)-rich components are connected by a region with low number of stars that we refer as an 'isthmus' throughout this work. We demonstrate that the bimodal A(Li) distribution is in fact a direct consequence of a particular Milky Way star formation history profile combined with the stellar evolution's ^{7}Li depletion mechanisms. We show that A(Li) evolution can be used as a proxy for the Star Formation History of our Galaxy.

CONTEXT

The Lithium problem

The discrepancy between the expected primordial A(Li) and the one measured in population II stars (Spite plateau), which is a factor of three to four lower, is still difficult to explain.
Furthermore, the A(Li) of young TTauri stars was shown to be almost a factor of 10 higher than the one of Pop II stars and 2-3 dex higher than Sun-like stars. This last result added a new level of complexity to the lithium problem, now referred as the **Galactic lithium problem**.

Lithium creation and depletion in stars

At least two different physical processes compete on the **creation/destruction of lithium** in stars:

i) ^{7}Li and ^{6}Li are **destroyed** and diluted in the epidermal stellar layers.

ii) ^{7}Li is **created** in stellar interiors and brought to the atmosphere.

The Li depletion occurs all along the stellar evolution. The Li abundance can be practically reduced to almost 0.
The Li creation occurs through the formation of new ^{7}Li in the stellar interiors of giant stars.

The Milky Way evolution in a cosmological context

In the last decade a flood of high quality data of physical properties and positions of stars in our Galaxy allowed researchers to better constrain its recent star formation history.
Using all this new knowledge we are now ready to investigate the A(Li) evolution from a **global perspective**.

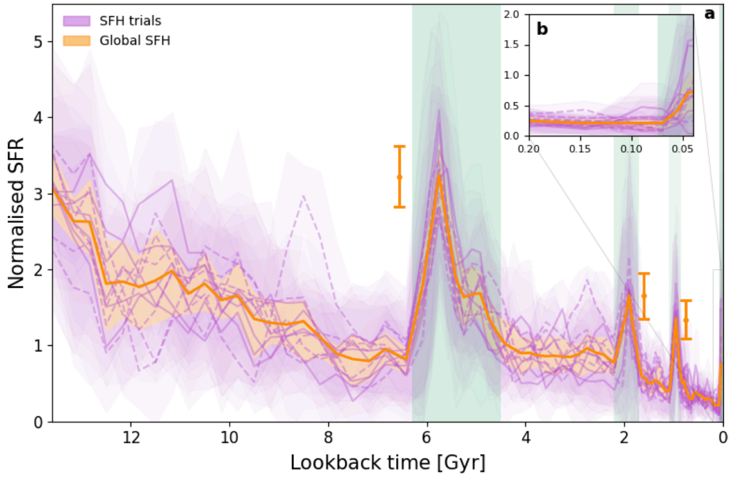

Fig 1. Milky Way recent Star Formation History (Ruiz-Lara et al. 2020)

DATA AND ANALYSIS TOOLS

We used **eleven catalogues** that provided us information of the A(Li). In addition to the data in published catalogues, we also used the **data obtained by our group**, which are well described in **Cavero et al. 2019**. In order to avoid any biases, we selected stars in the sample without any cut in age, metallicity, or in any other parameter like the detection of dust or planets around them.

We finally ended up with a catalogue that contains **1382 stars** (1094 without known planets and 288 with confirmed planets)

Age scales

The unbiased Age determination is one of the most critical processes when studying the correlation between A(Li) evolution and Galactic scale events. In order to ensure Age values used here are trustful, we decided to use three independent Age scales:

Age_Lite: From literature (several authors)

Age_Param: Using PARAM 1.3 code (da Silva et al. 2006)

Age_RHK: From stellar activity empirical relation (Mamajek et al. 2008)

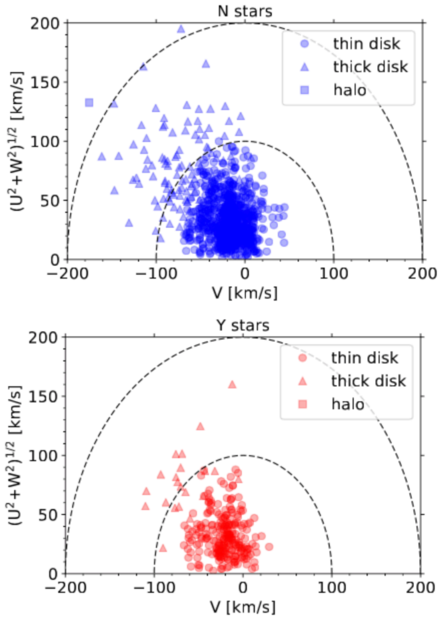

Fig 2. Toomre diagrams (kinematic decomposition)

Kinematic selection

By using kinematic data from Gaia-DR2 we constructed the Toomre diagram and we identified stars in belonging to one of the three galactic components by following the Bensby et al. 2014 approach

Fig. 2 shows that **most of the stars in our sample belong to the thin disk galactic component**

RESULTS: A(Li) evolution and the Galactic scale events

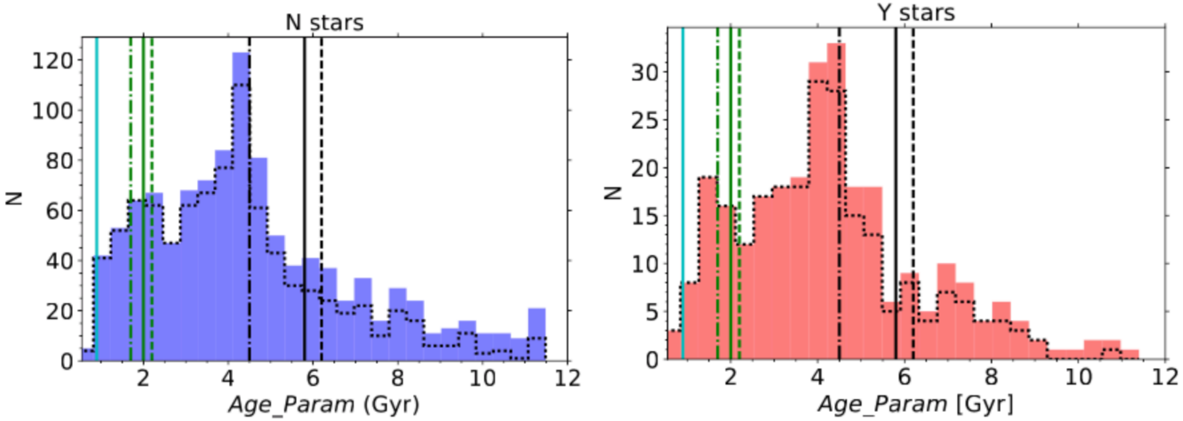

Fig 3. Number of stars per stellar age bin.

In our data sample **we detect two overabundances of stars**, both coincident with two of the **star formation bursts detected** by Ruiz-Lara et. al 2020.

The existence of the **two well known A(Li) populations** (i.e. A(Li)-rich and A(Li)-poor), is **closely related with the eldest burst of star formation**.

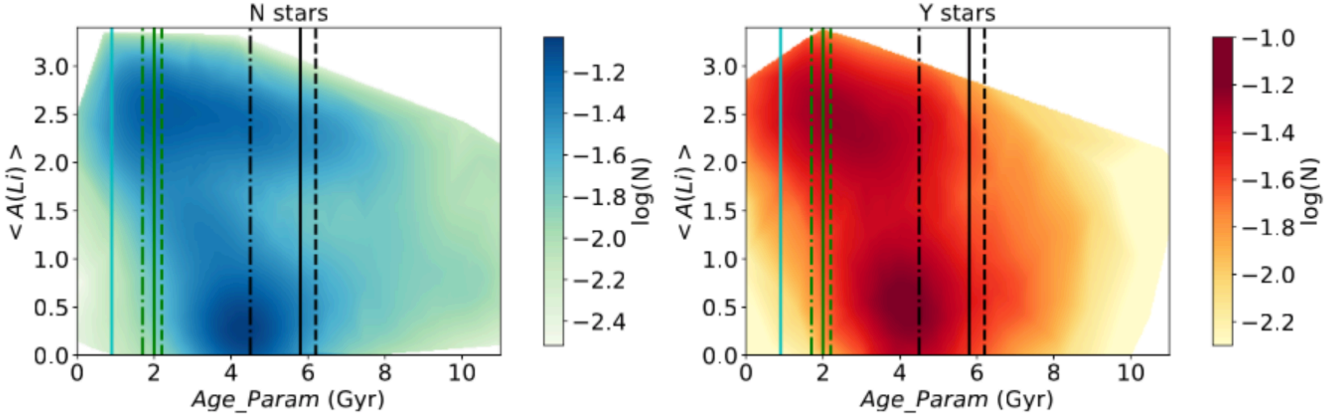

Fig 4. Lithium abundance as a function of stellar age. Vertical lines indicate the position of star formation bursts as in Ruiz-Lara et al. 2020.

RESULTS: The A(Li) "isthmus"

A low star density region exists in between the two A(Li) populations.

We called this region "the isthmus" and it contains stars that are transiting from the A(Li)-rich to the A(Li)-poor populations.

The number of stars contained **inside each Lithium popullation**, and also inside the isthmus, is **a reflex of the star formation history** of the Galaxy.

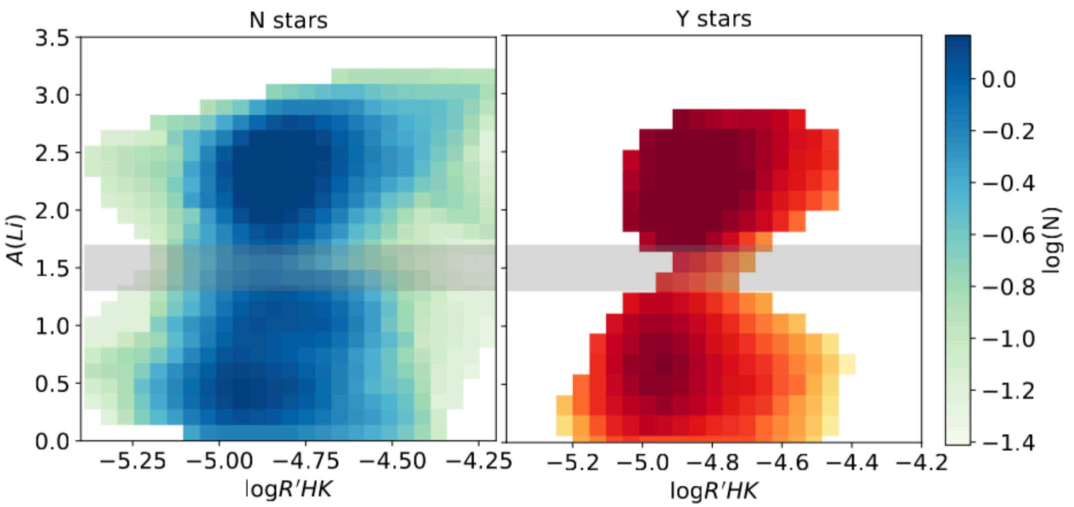

Fig 5. Lithium abundance as function of stellar activity parameter.

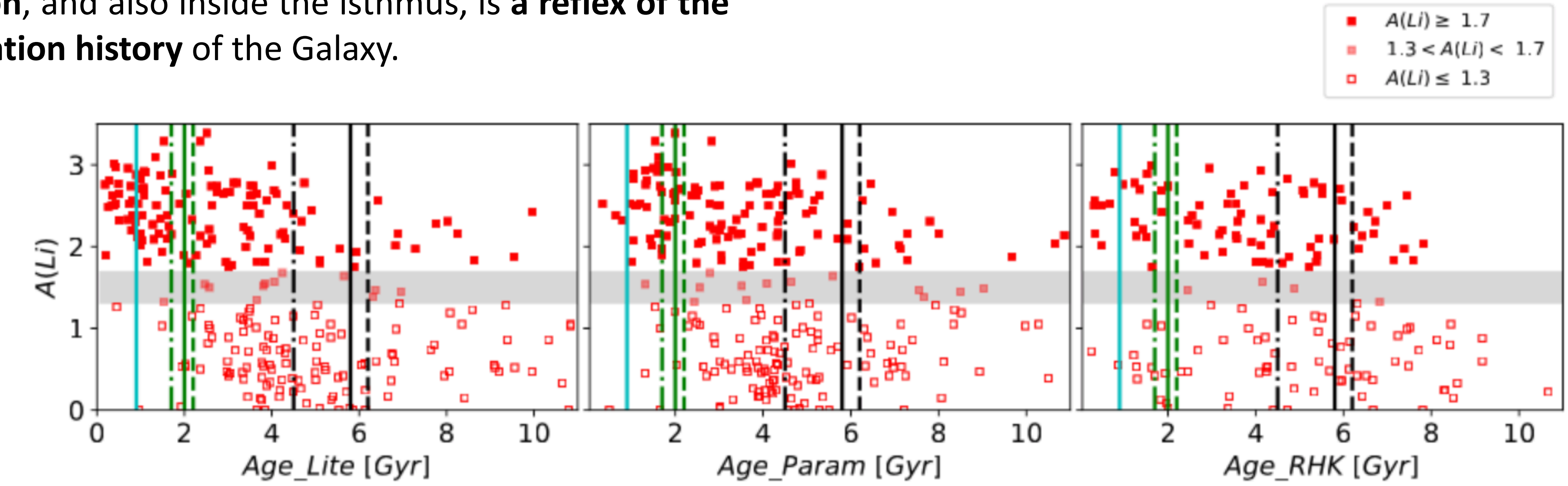

Fig 6. Lithium abundance as function of the three age scales.

CONCLUSIONS AND FUTURE WORK

- The A(Li) evolution of thin disk stars closely attends the Milky Way star formation history profile presented in the most recent works.

- Two recent star formation bursts, which were probably provoked by a satellite flyby (1.0 and 2.0 Gyr ago), and an older Galactic scale event occurred 4-7 Gyr ago (a massive IGM gas inflow followed by a satellite pericenter) shaped the chemical properties of stars in the galactic thin disk.

- The Age-A(Li) relation, combined with information on the stellar rotation (v sin i), may be used as a new constrain in exoplanets search.

Coming soon, from our collaboration:

- Stellar rotation and lithium depletion inside stars.

- The role that planets engulfment by their host stars, as well as tidal interactions, play on the stellar lithium evolution.

- Open clusters disruption and moving groups vs. lithium evolution.