The Gaia-ESO Survey:

Enrichment Histories of the Galactic thick and thin disc


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The Road Map of Li studies:

- **Cosmological lithium problem**
  - Non-standard cosmological model
  - New particle physics to destroy Li
  - Altering nuclear reaction (e.g., cross section)
  - Magnetic field: ionize Li and blow it away during star formation

- **Galactic Li enrichment**
  - Diffusion during main sequence
  - Burned by rotational induced mixing
  - Internal gravitational waves

- **Li in ISM**
  - Pre-main sequence depletion + mass accretion + main sequence diffusion

- **Li-rich RGB stars**
  - Planetary brown dwarf
  - White dwarf as a binary companion
  - Brown Li

- **Li problem in the Sun**
  - Brief and universal in stellar evolution
  - The preservation
  - The ejection of circumstellar shells or disk

- **Lithium**
  - $\text{Li}^+$
  - Neutral atoms
  - Isotope fraction
  - Molecular Absorption line at 440.99 GHz ($\nu = 1$), can be observed with ALMA

- **Galactic thick disk**
  - Li-alpha anti-correlation & Li-alpha correlation
  - Decrease after the solar metallicity

- **Galactic thin disk**
  - Decrease in Li abundance

- **AGB stars**
  - Mixing processes from main sequence turn-off to RGB bump
  - Li production
  - Li depletion
  - Li burning time is fixed by the luminosity of RGB bump
  - Use the Li depletion to constrain mix or extra-mixing (enshrouding etc.)

- **The Galactic Li enrichment**
  - Connect to binary fraction
  - Nova
  - ENSI process in the shell of post-collapse BLM
  - (NO observation evidence yet)
  - Galactic Cosmic Ray
  - Globular clusters
  - Open clusters
  - Dwarf galaxies
  - Environmental sensitivity?

- **Li problem in the Sun**
  - Pre-main sequence depletion + mass accretion + main sequence diffusion
  - The preservation
  - The ejection of circumstellar shells or disk
  - Connect to RGB mass loss
  - Can be checked with IF excess

- **Li-rich RGB stars**
  - Non-universal or not-brief enrichment
  - Rotational induced mixing
  - Magnetic fields

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The unique role of Gaia-ESO survey

The only large public survey available for this study
The Galactic Li enrichment

- Novae: binary fraction
- AGB: HBB
- Li-rich RGB: problem
- Core-collapse SNe: No evidence yet
- Galactic Cosmic Ray

Charbonnel and Primas (2005)
Sbordone et al. (2010)
Ramírez et al. (2012)
Lodders et al. (2009)

Izzo et al., 2015
The Galactic Li enrichment

sources

- Novae
- AGB
- Li-rich RGB
- Core-collapse SNe
- Galactic Cosmic Ray

The Galactic thick disc

The Galactic thin disc

GC, OC, dwarf galaxies...
The Galactic Li enrichment

• Li-[$\alpha$/Fe] anticorrelation
• Li-s(-process elements) correlation
GES iDR4, UVES, field single stars, log(g)>3.7, [Fe/H] err<0.13 & Li NLTE

- Checked Li measurements: 302 stars, median SNR=83
- Labeled Li upper limits: 1097 stars, median SNR=63
Tentative thick/thin separation

\[ n(\alpha) = n(\text{Mg I}) + n(\text{Ca I}) + n(\text{Si I}) + n(\text{Ti I}) + n(\text{Ti II}) \]

\[ [\alpha/\text{Fe}] = \log\left(\frac{n(\alpha)}{n(\text{Fe})}\right)_\ast - \log\left(\frac{n(\alpha)}{n(\text{Fe})}\right)_\odot \]

Division proposed by Adibekyan et al. 2012
Tentative thick/thin separation

stars with enriched Li

Thin disc:
stronger Li enrichment

Thin disc:
higher overall level of Li enrichment
Li-[α/Fe] ANTIcorrelation

Need to eliminate the [Fe/H] evolutionary effect
Li-[\(\alpha/\text{Fe}\)] ANTlcorrelation

stars with Li measurements

\[ R(p) = -0.289 \quad p = 0.578 \]
\( -1.00 \leq [\text{Fe/H}] \leq -0.74 \)

\[ R(p) = -0.034 \quad p = 0.862 \]
\( -0.87 \leq [\text{Fe/H}] \leq -0.61 \)

\[ R(p) = -0.217 \quad p = 0.084 \]
\( -0.74 \leq [\text{Fe/H}] \leq -0.48 \)

\[ R(p) = -0.422 \quad p = 2.0 \times 10^{-5} \]
\( -0.61 \leq [\text{Fe/H}] \leq -0.35 \)

\[ A_{\text{Li}} \]

\[ R(p) = -0.319 \quad p = 0.001 \]
\( -0.48 \leq [\text{Fe/H}] \leq -0.22 \)

\[ R(p) = -0.041 \quad p = 0.704 \]
\( -0.35 \leq [\text{Fe/H}] \leq -0.09 \)

\[ R(p) = -0.224 \quad p = 0.046 \]
\( -0.22 \leq [\text{Fe/H}] \leq 0.04 \)

\[ R(p) = -0.181 \quad p = 0.142 \]
\( -0.09 \leq [\text{Fe/H}] \leq 0.17 \)

\[ R(p) = -0.250 \quad p = 0.094 \]
\( 0.04 \leq [\text{Fe/H}] \leq 0.30 \)

\[ R(p) = -0.695 \quad p = 4.6 \times 10^{-4} \]
\( 0.17 \leq [\text{Fe/H}] \leq 0.43 \)

\[ R(p) = -0.750 \quad p = 0.032 \]
\( 0.30 \leq [\text{Fe/H}] \leq 0.56 \)

\( [\text{Fe/H}] \text{ binsize} = 0.26 \)

\( P < 0.05 \)
Li-[α/Fe] ANTIcorrelation

Preliminary results with iDR5

[Fe/H] binsize = 0.26

P < 0.05
Theoretical trend for thick disc predicted by Bisterzo et al., 2017
Li-[Ba/Fe] correlation

$P < 0.05$

[Fe/H] bin size = 0.26
Li-[Ba/Fe] correlation

P<0.05

Preliminary results with iDR5
A(Li) decline for super-solar metallicity objects
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Similar trend is also seen in

Ramírez et al., 2012
Delgado Mena et al., 2015
Guiglion et al., 2016
A(Li) decline for super-solar metallicity objects

Possible: due to a stronger Li depletion in the super metal-rich stars.

But... highly sensitive to the **stellar mass**

Possible: contribution from novae declines at super-solar metallicity.

The fraction of close binaries decrease with increasing $[\text{Fe/H}]$ (Gao et al., 2014; Yuan et al., 2015; Gao et al., 2017)

Needs to be tested by means of detailed chemical evolution model
A(Li) decline for super-solar metallicity objects

If it is real...

From the perspective of the Galactic chemical evolution:

During the last ~5Gyr, there is a threshold in the gas density

The star formation has several short periods of activity intercut

Li production from AGB stars and core-collapse SNe is reduced

Romano et al., 2001
A(Li) decline for super-solar metallicity objects

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May hold as well for s-process elements

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\[ A(Ba) = \log \left( \frac{n(Ba)}{n(H)} \right) + 12 \]

**A(Ba) plateau at super-solar metallicity?**
Summary:

- The Galactic thin disc has stronger and higher overall level of Li enrichment than the thick disc;
- Li-[$\alpha$/Fe] anticorrelation
- Li-[s-process elements] correlation
- Li decline at super-solar metallicity

Does migration matter?
- Connected to Li-rich giant problem
- Connected to AGB yields
- Connected to star formation history
- Connected to nova rate

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submitted to A&A