Lithium problems:
in the main sequence
and
the red giant branch

Xiaoting FU
SISSA, Italy

Jan. 8, 2014. NAOC
xtfu@sissa.it
Why lithium is important?

Li ($^7\text{Li}$),

- is one of four isotopes synthesized immediately after the big bang;
- is easily destroyed at $T > 2.5 \times 10^6 \text{ K}$

• An important parameter to test the Big Bang Nucleosynthesis;
• A good probe of the stellar structure;
• An age indicator of stars and star clusters;
Story of lithium

Gray, David. 2005
Big Bang Nucleosynthesis

\[ \begin{align*}
1 & \rightarrow 1H + e^- + \bar{\nu} \\
1H + n & \rightarrow 2H + \gamma \\
2H + 1H & \rightarrow 3He + \gamma \\
2H + 2H & \rightarrow 3He + n \\
2H + 2H + 2H & \rightarrow 3H + 1H \\
2H + 3H & \rightarrow 4He + n \\
3H + 4He & \rightarrow 7Li + \gamma \\
3He + n & \rightarrow 3H + 1H \\
3He + 2H & \rightarrow 4He + 1H \\
3He + 4He & \rightarrow 7Be + \gamma \\
7Li + 1H & \rightarrow 4He + 4He \\
7Be + n & \rightarrow 7Li + 1H
\end{align*} \]
mean baryon density:
\[ \Omega_b h^2 = 2.207 \times 10^{-2} \]

\[ A(\text{\L}i) = 2.72 \text{ dex} \]

\[ A(Li) = \log \frac{n(\text{Li})}{n(H)} + 12 \]
Spite Plateau: $A(\text{Li}) \approx 2.2$

NGC6397: a metal-poor Globular Cluster

[Spite & Spite. 1982]
There must be something happened ...

NOTHING HERE!
Lithium problem in the main...

WHERE does the lithium GO TO???
1st interpretation

BBN is wrong. The primordial Li abundance should be \(\sim 2.2\) dex.
2nd interpretation

$^7$Li has been depleted in the atmosphere of the old metal-poor stars

diagram showing atmospheric diffusion and convective zone

Characteristic time scale:

$1/\tau_{Li} = 2.3 \times 10^{-22} A T^{3/2} M / Z^2 M_\odot$
3rd interpretation

2/3 of $^7$Li was destroyed before the formation of old metal-poor stars

- Astration in massive Pop III stars (Piau 2006)
- Compatible with BBN, but...
  
  The star would have produced heavy elements (oxygen etc.) and the metallicity would be much higher than that observed in extremely metal poor stars.

(Prantzos 2007)
4th interpretation

Pre-main sequence Li evolution with mass accretion

Fu et al. in prep.
Spite Plateau: $A({\rm Li}) \approx 2.2$ [Spite & Spite. 1982]

NGC6397: a metal-poor Globular Cluster

Extra mixing

$1^{\text{st}}$ dredge up

Lind et al, 2009
But Li-rich red giants do exist…

Lithium problem in the red giant branch: WHERE does the lithium come FROM???
No clear relationships with the stellar parameters

Other explanation

- engulfment of planets

- Pollution of ISM
All known lithium rich giants

NEED more data to study the nature of these unexpected stars

Fu et al. in prep.
New PARSEC (PAdova/TRieste) database of stellar evolutionary tracks and isochrones

✓ Metallicity down to $Z = 0.00001$;
✓ $\alpha$ enhancement [$\alpha/Fe$] = 0, 0.2, 0.4;
✓ Several Helium abundances for a given $Z$;
  (former version: $Y = 0.2485 + 1.78Z$)
✓ Extend to the pre-main sequence (PMS) phase;

With it we are now able to predict readily the evolution of stars for any chemical pattern of interest (varying CNO abundances, different $\alpha$ elements, C–N, Ne–O and Mg–Al abundance anti-correlations for Galactic globular clusters, etc.).

Fu et al. in prep.
Thank you!