# LAMOST study of Li-rich stars in the Milky way disk and halo: Is Li-rich episode(s) in giants universal ?

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Stellar Archaeology as a Time Machine to the First Stars
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in Collaboration with
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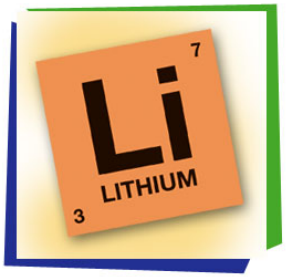
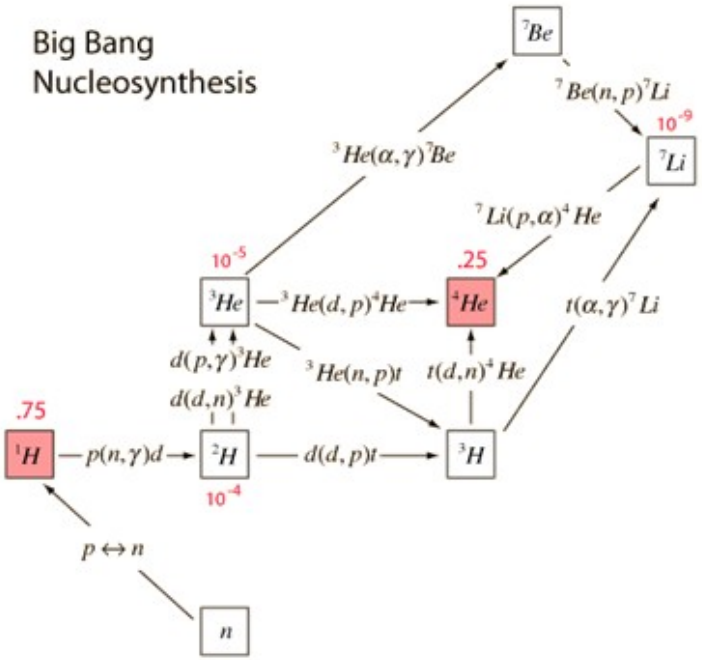
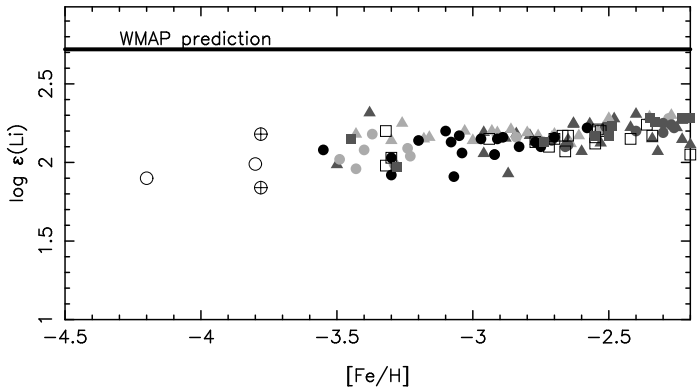


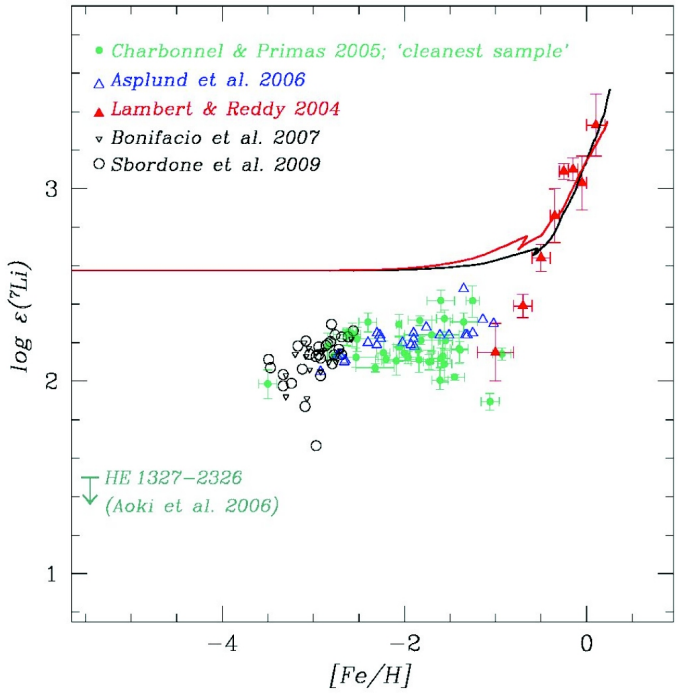




- Product of Big-Bang Nucleosynthesis
- Isotope - $^6$Li

- Fragile element - destroys at $2.5 \times 10^6$ K in stellar interiors

# Evolution of Li in the Universe




Matteucci+2010

| | | |
|---|---|---|
| Primordial $Li_P$ | 2.72±0.06 | Cyburt et al. 2008 |
| Primordial $Li_O$ | 2.27±0.03 | Lind et al. 2009 |
| Turn-off stars | 3.20 | Lambert & Reddy 2004 |
| ISM | 3.25 | Knauth et al. 2000;2003 |
| Meteoritic | 3.28 | Lodders et al. 2003 |
| Sun | 1.05 | Asplund et al. 2009 |

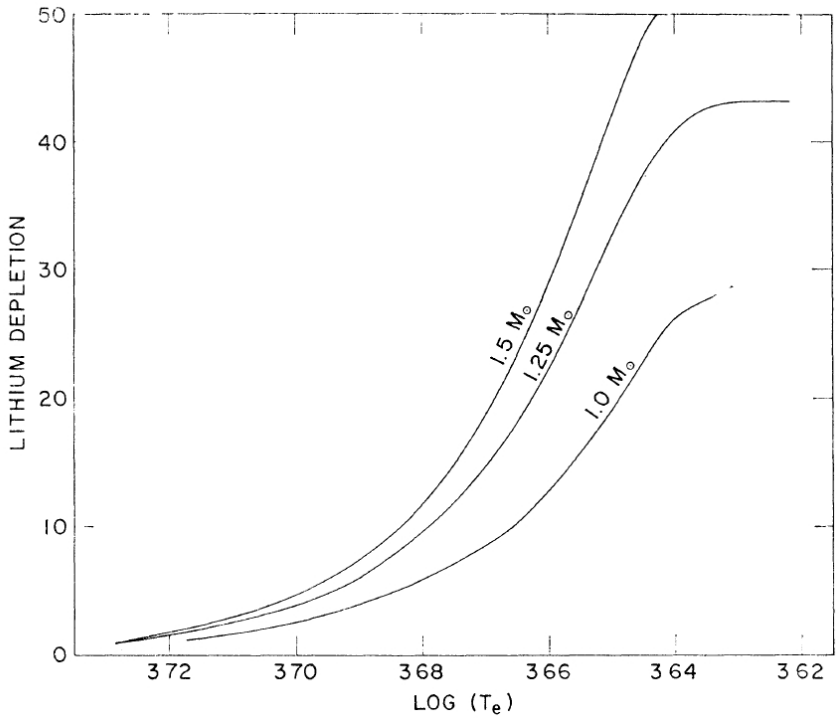
$A(Li) = \log\epsilon(Li/H)+12$

- Sources for Galactic Li enrichment
  - Cosmic ray spallation
  - Supernovae
  - Novae
  - AGB Stars
  - RGB stars

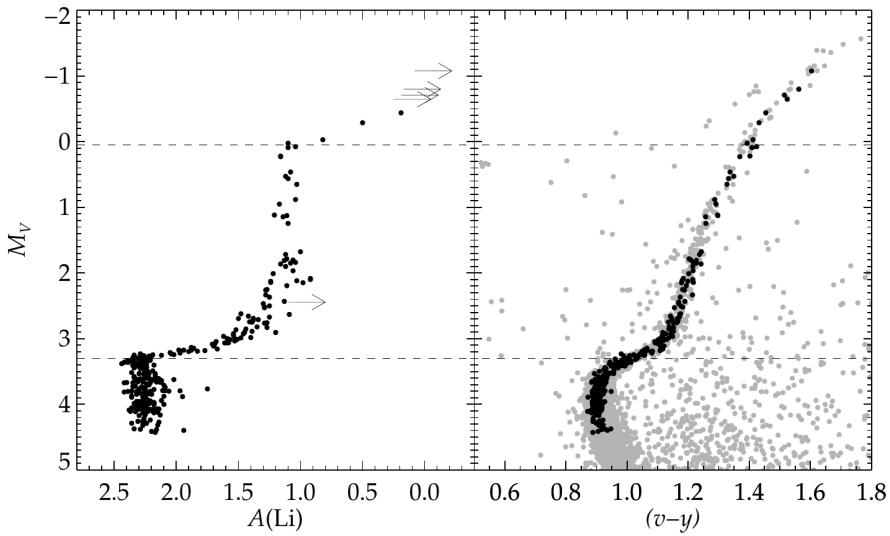
**Role of RGB stars in Galactic Li enrichment is not well understood !**

# Li in RGB stars

- Li gets depleted in low mass stars during first dredge-up due to expanding convective envelope on red giant branch



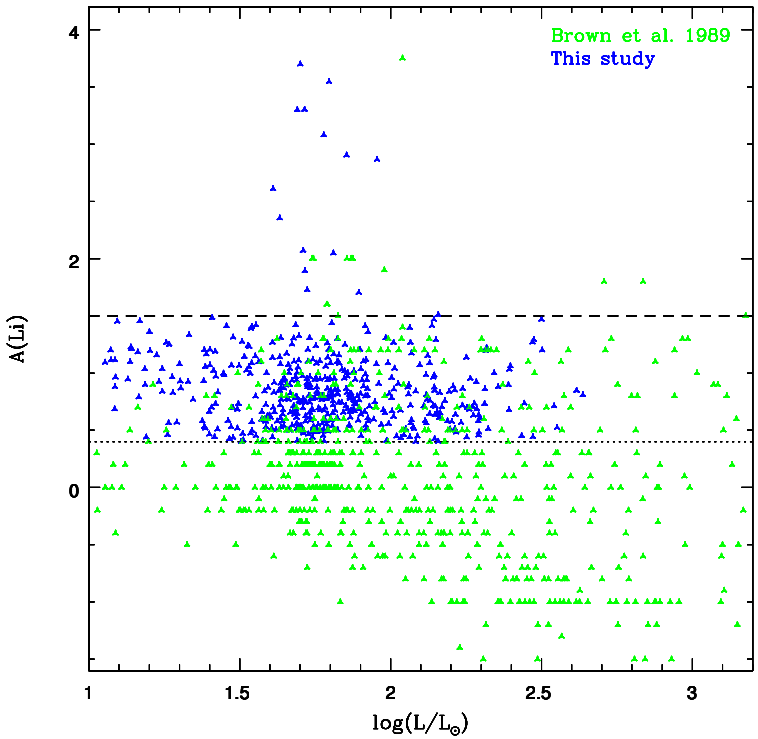

Iben (1967)

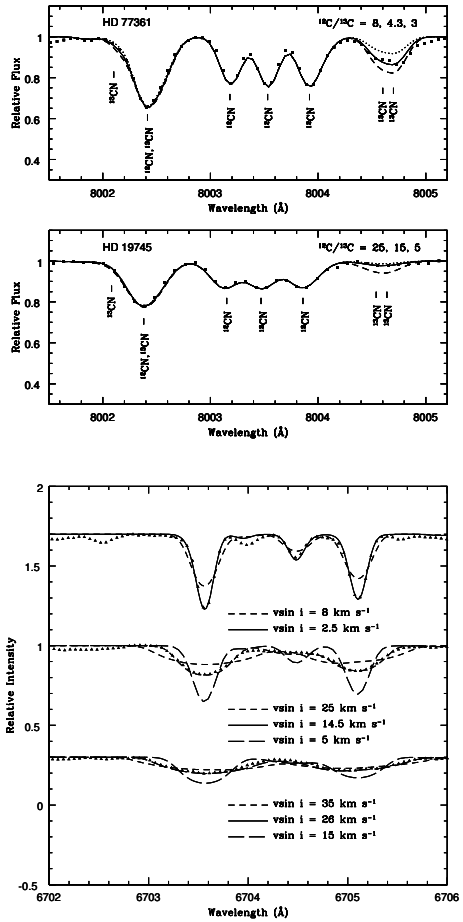


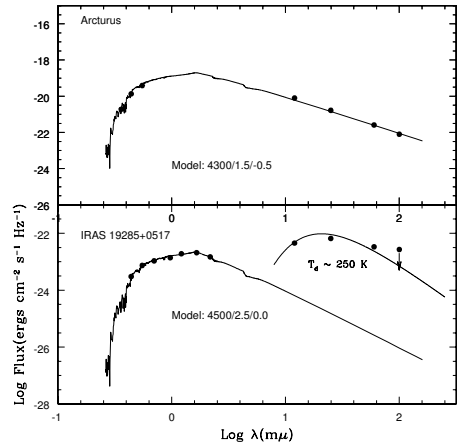

Lind+2009

# Li-rich giants, A(Li) >1.5 - 1% of RGB stars

Some of these Li-rich giants show other anomalies like low carbon isotopic ratios, infrared excess, and rapid rotation

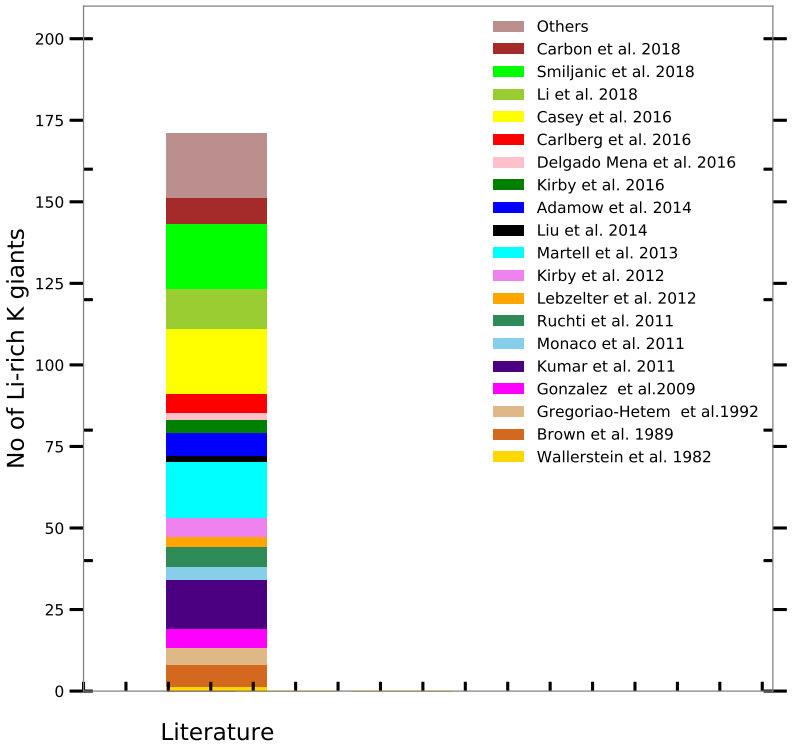


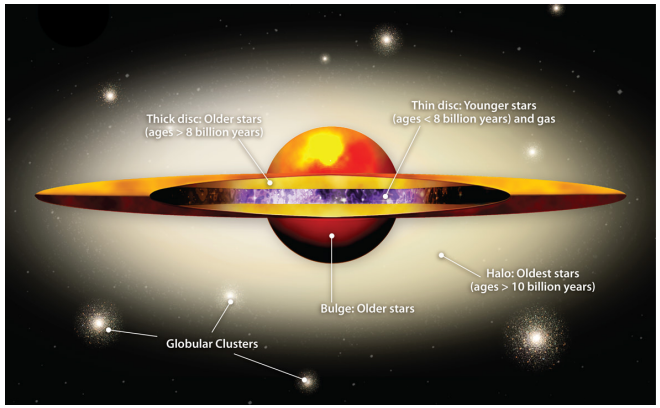



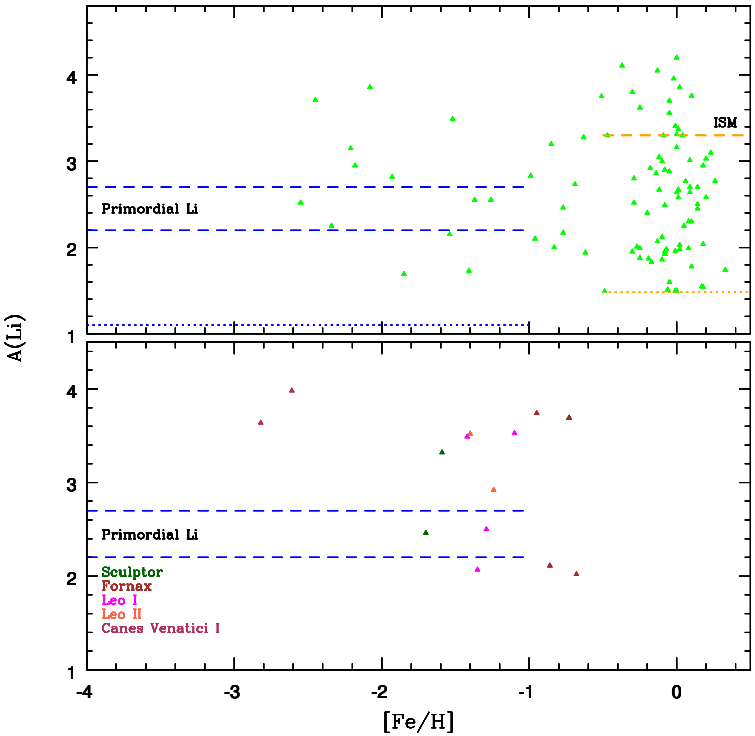




No clear correlations are found between Li and other peculiarities !

# Li-rich giants in Milky way disk & halo, dwarf spheroidals




**Does Li-rich episode(s) during low mass star's evolution is universal ?**

# LAMOST survey sample

Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST) DR5 contains 8 million spectra.

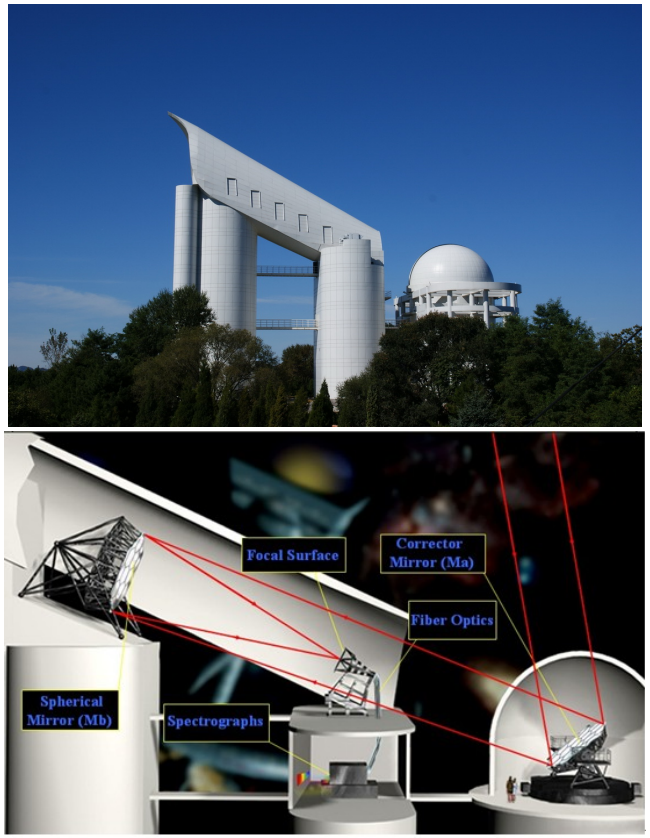
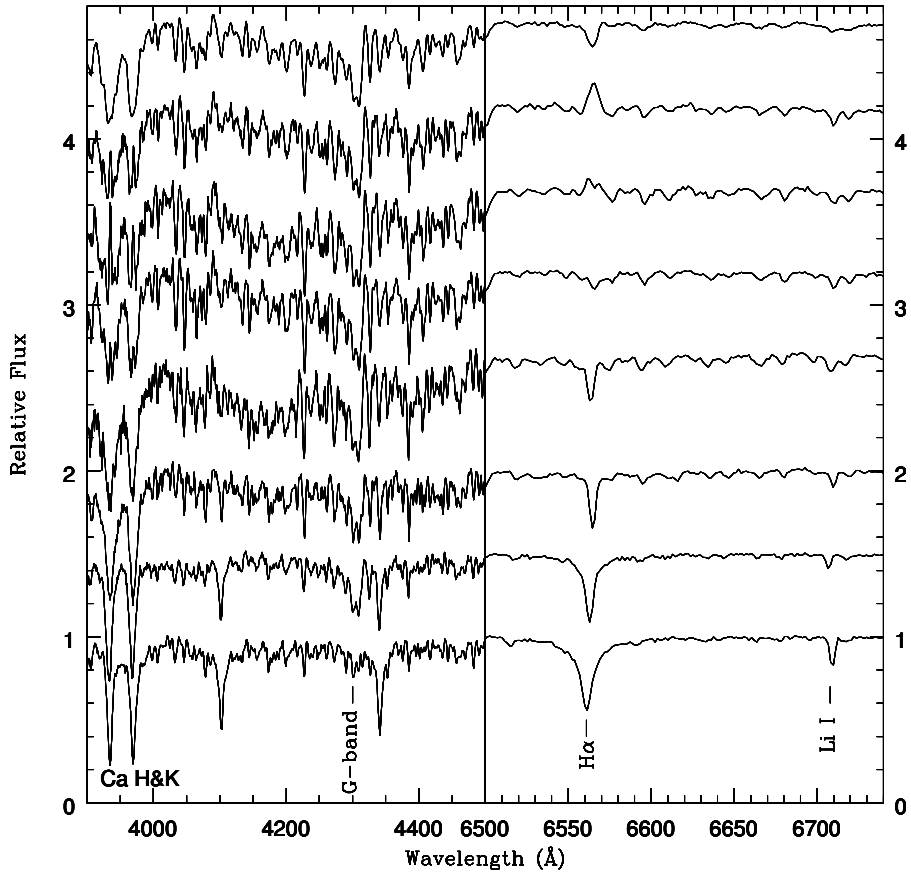
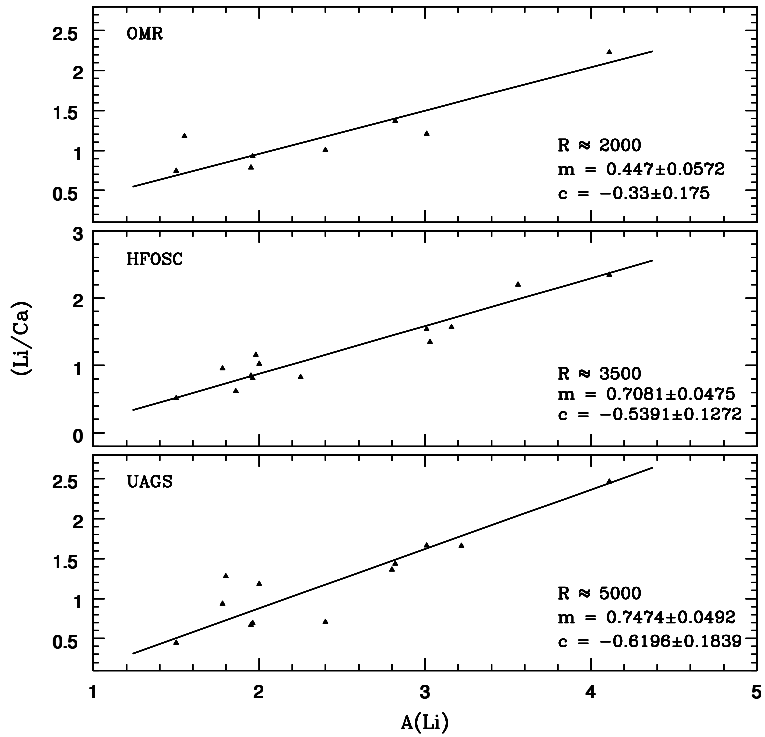


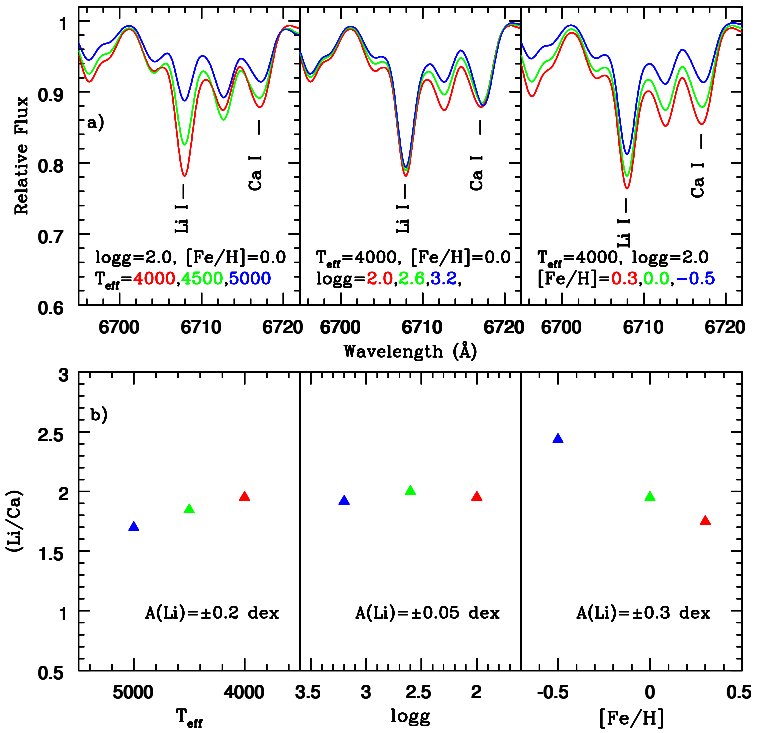

Figure 2 LAMOST overview




LAMOST spectra with strong Li line in stars on various parameter space.

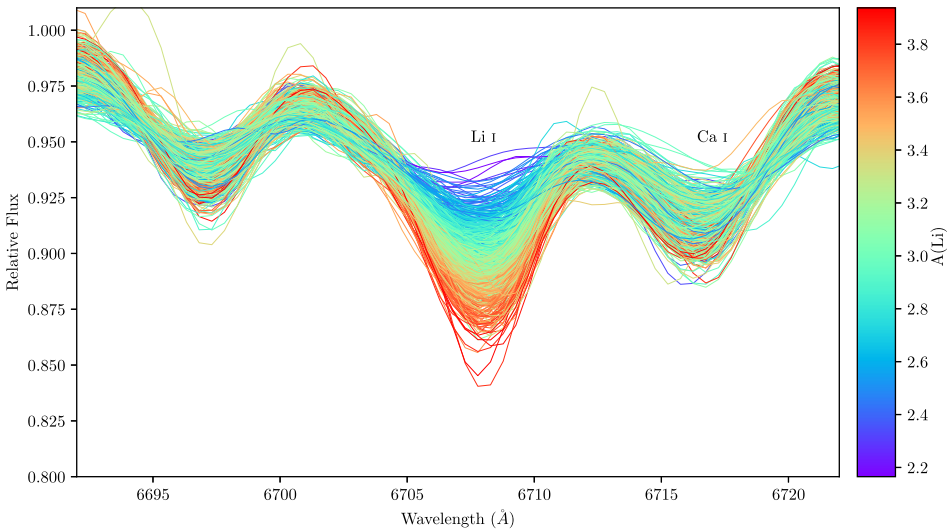
# Identifying Li-rich giants: Line Ratio method from Kumar+18



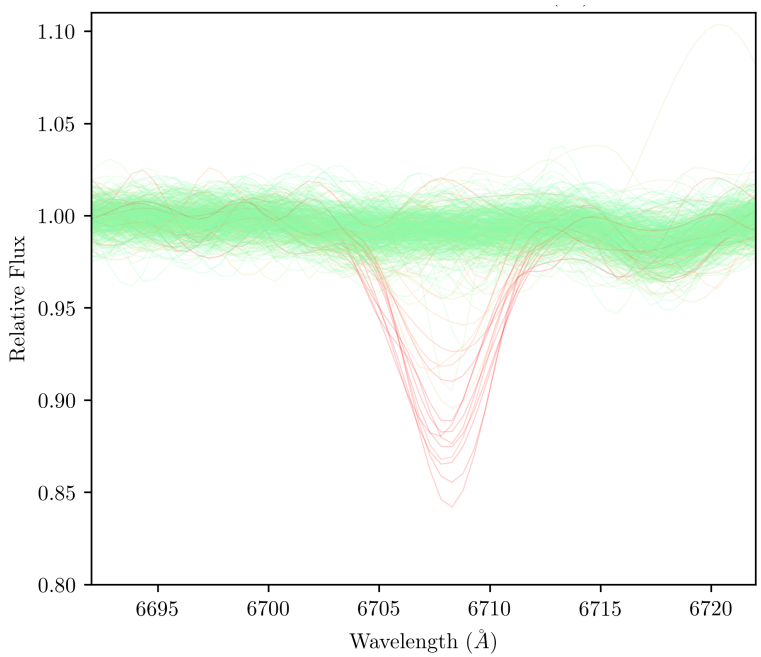




Estimated errors for LAMOST spectral resolution spectra ≈ 0.35 dex

# New Li-rich giants from LAMOST




Disk

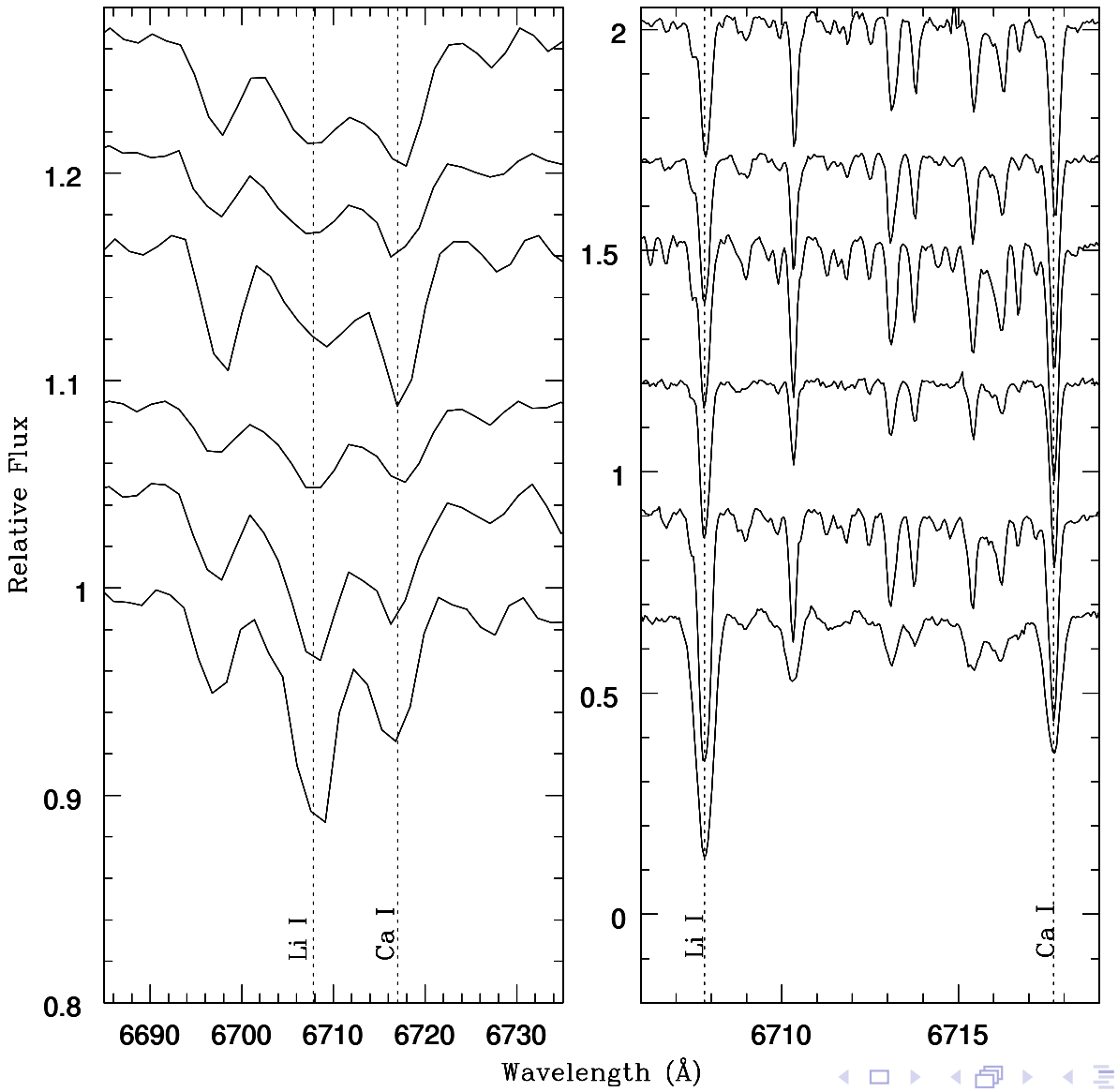



Halo

# Observations of high resolution spectra

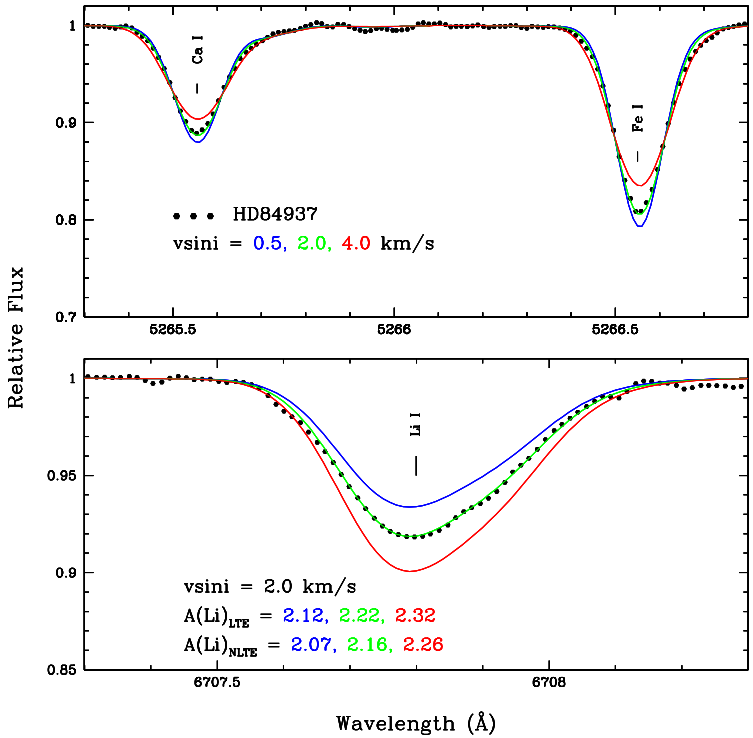
- High resolution (R$\sim$60000) spectra of LAMOST Li-rich disk stars are mostly observed using three telescopes: Subaru telescope at Hawaii, 2.7-m Harlan J.Smith telescope at McDonald Observatory, and 2-m HCT at Hanle
- All Li-rich halo stars are observed from Subaru telecope
- Near-UV high resolution spectra for Be measurements are also obtained from Subaru HDS

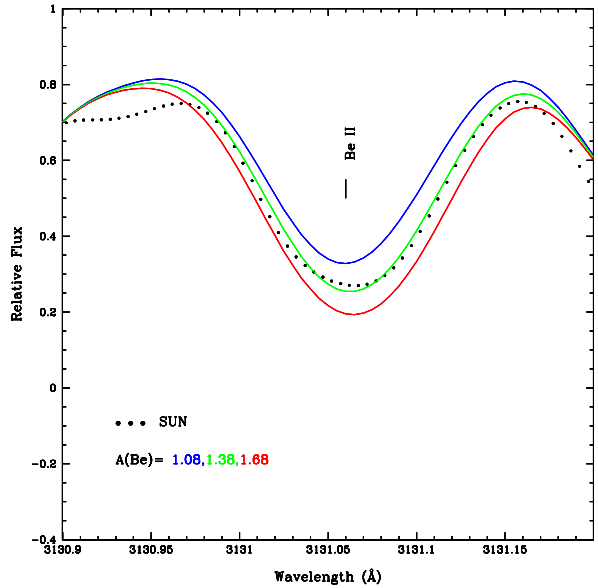
# Low and high resolution spectra of Li-rich giants



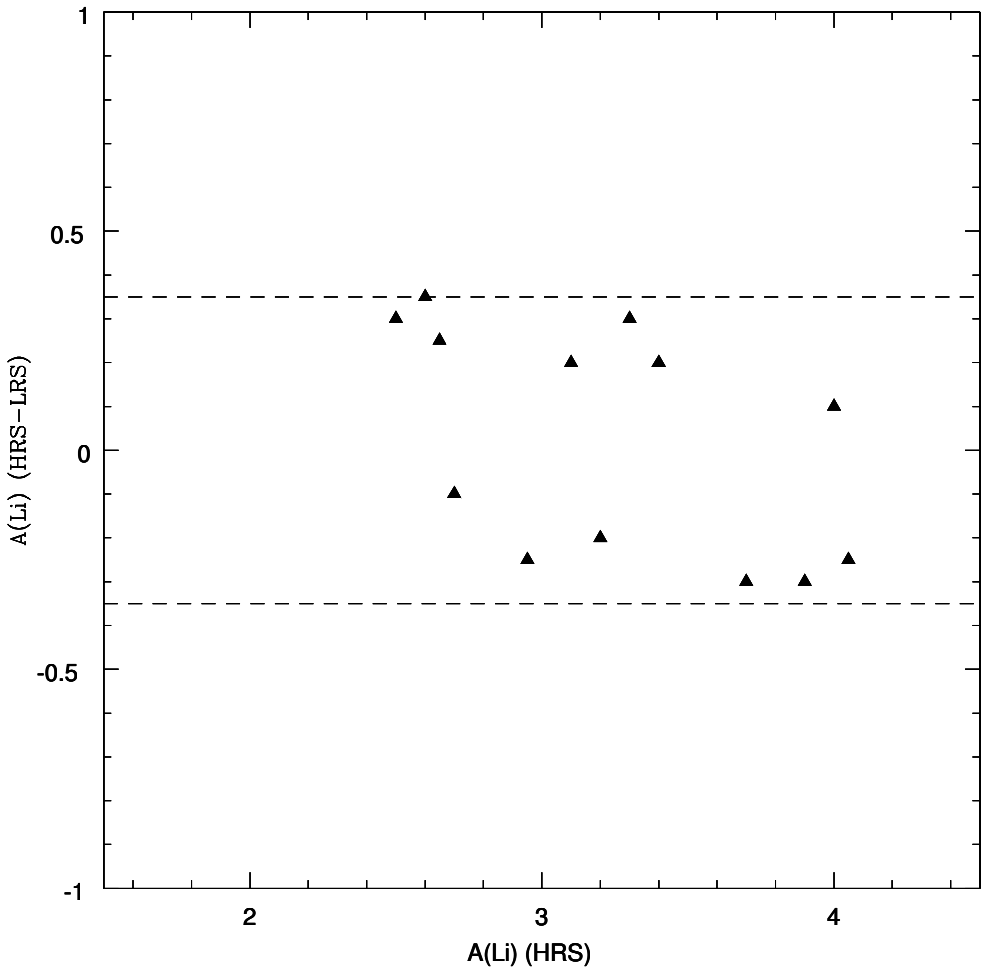
# Abundance measurements from high resolution spectra

Standard procedure: $T_{eff}$, logg, [Fe/H], $\xi_t$ and synthetic spectra from well tested linelist, LTE Kurucz model atmospheres, MOOG, NLTE Li corrections from Lind et al. (2009). Sample measurements are shown below,



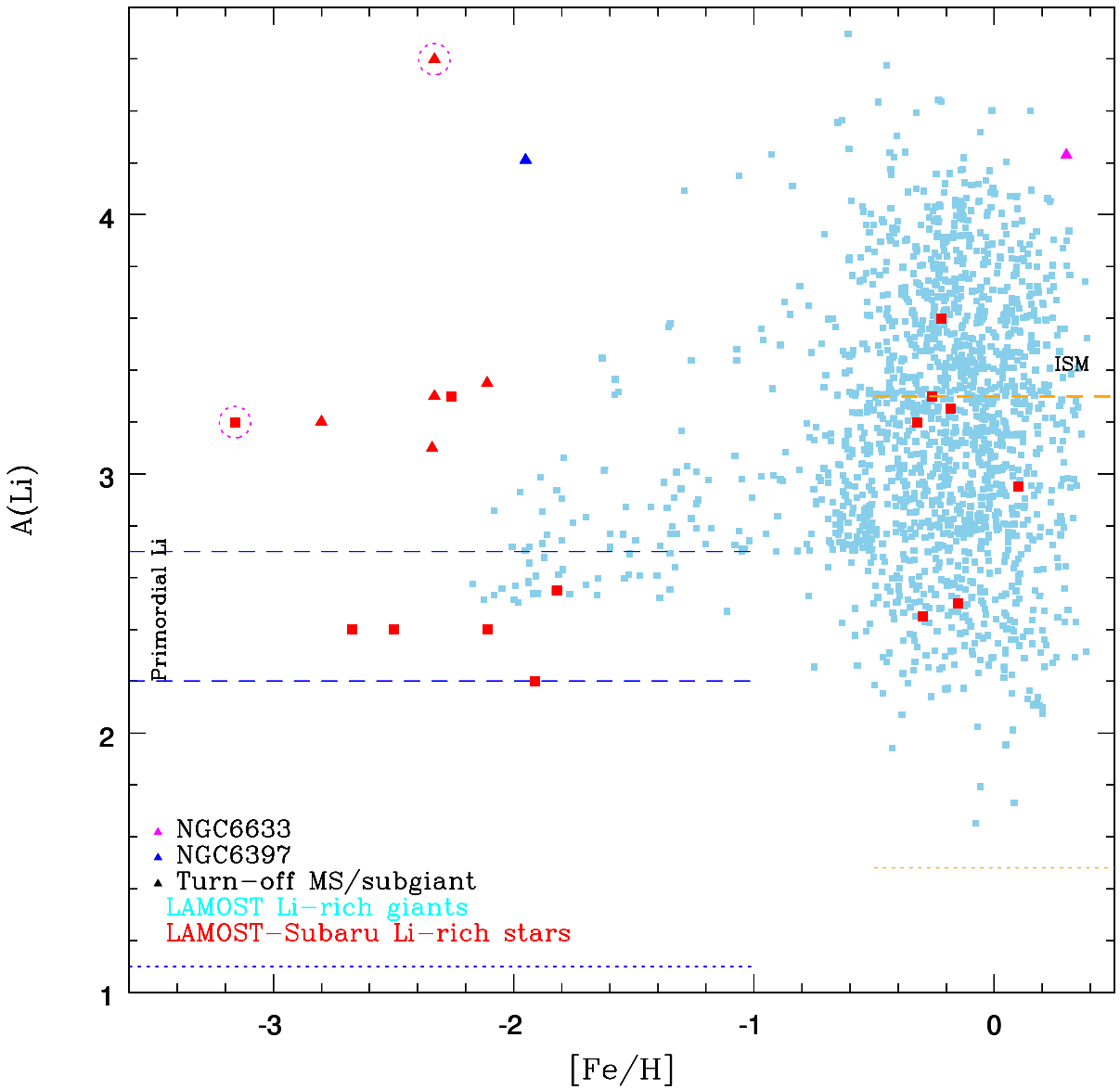



# Li abundances from low and high resolution spectra

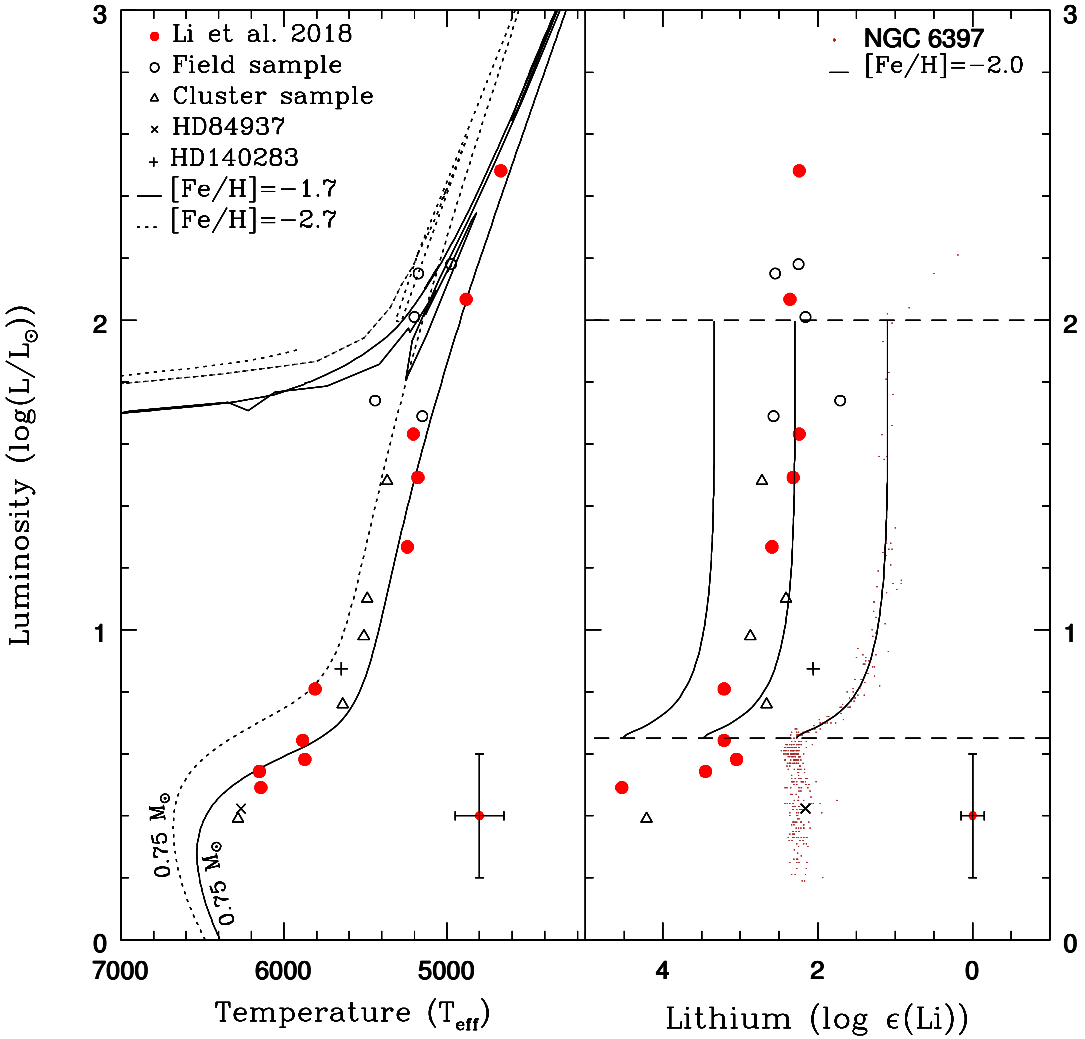



**Li abundances from high resolution spectra are also used to calibrate relations from Lamost spectra.**

# New Li-rich giants from Disk and Halo

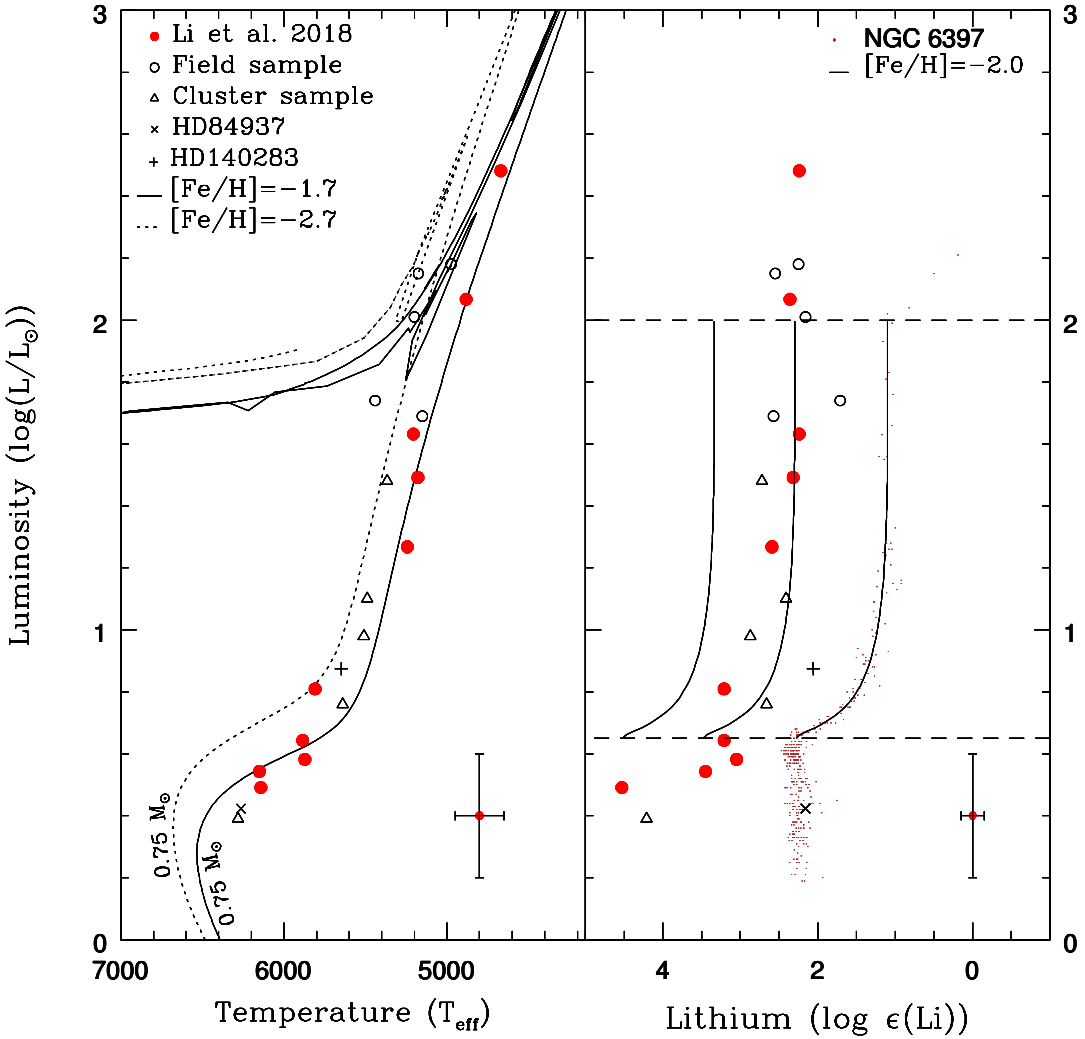


# Li-rich Halo giants: preservation from its progenitors ?




- Li-rich turn-off stars/subgiants
  - Internal mechanism - Diffusion ?
  - **Planet Ingestion ?**
  - External pollution: Novae/Upper RGB/ AGB

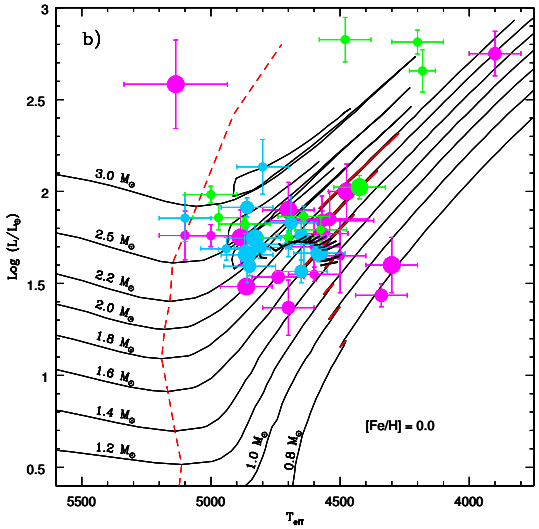
# Li-rich Halo giants: preservation from its progenitors ?

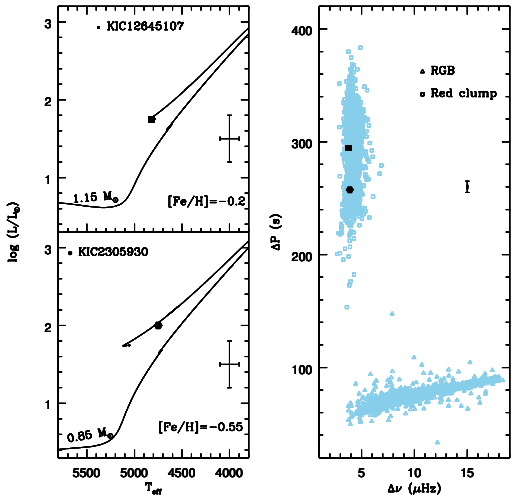



- It is clear from figure that high Li in RGB stars are preserved from its progenitors after experiencing the first dredge-up
- **Li-rich episode on RGB in halo stars ?**

# Li-rich disk stars: Increasing Red clump stars

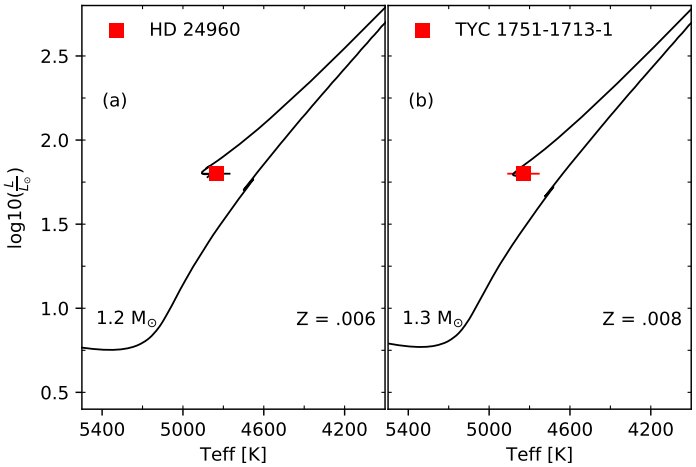
Kumar+11, ApJL

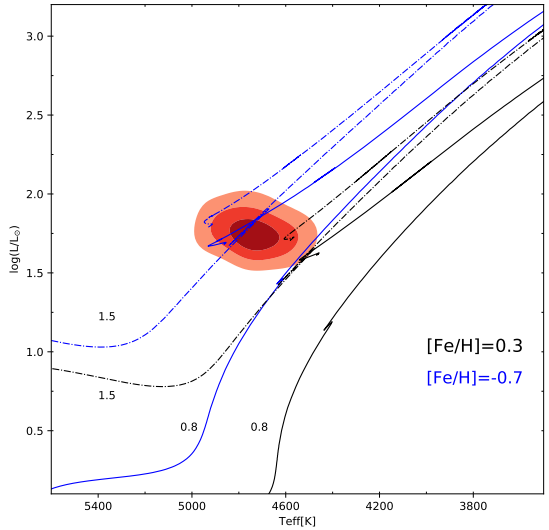



Bharat Kumar+18, ApJL)

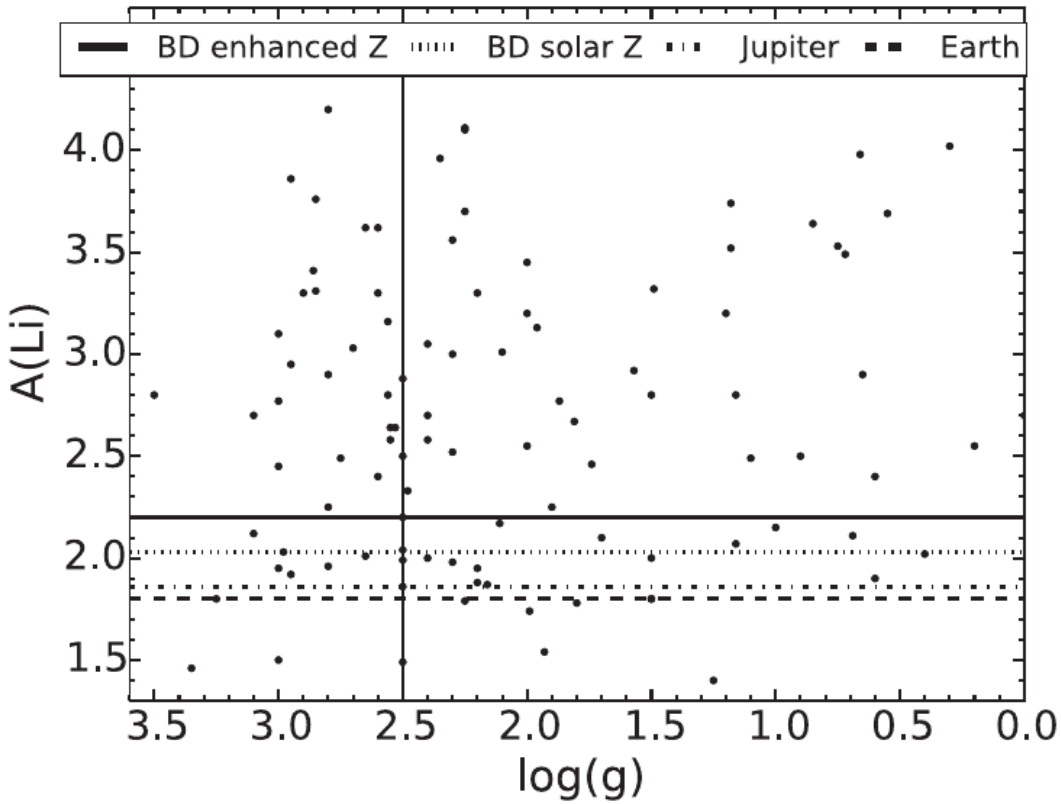
Singh+18




Bharat Kumar+(in preparation)

# Li-rich Halo & Disk giants: planet engulfment scenario - Unlikely




- Our Be analysis from near-UV Subaru spectra of Li-rich disk giants also shown the absence of Be-enrichment.

Aguilera-Gomez+2016

# Summary

- LAMOST survey increased Li-rich stars to 10 fold to existing catalog spanning large metallicity range covering disk and Halo of Milky Way
- Added more Li-rich stars to turnoff/subgiant branch and red clump phase of low mass star's evolution
- High Li in halo RGB stars seems to be preserved from its progenitors. However, need more Li-rich turnoff/subgiants to confirm it. Li-rich episode on RGB of halo stars needs more investigation.
- More Li-rich stars in disk are found to be at red clump
- External pollution through novae or binary mergers seems to be a possible sources for Li anomaly in Li-rich turn-off stars/subgiants in halo and Li-rich core He-burning stars in disk, respectively
- Need a revisit to "1% of RGB stars are Li-rich", which may put constraints on RGB star's Li contribution to Galactic Li enhancement

*Thanks for your attention*