Li-enriched low mass giants: single star evolution vs binary interaction

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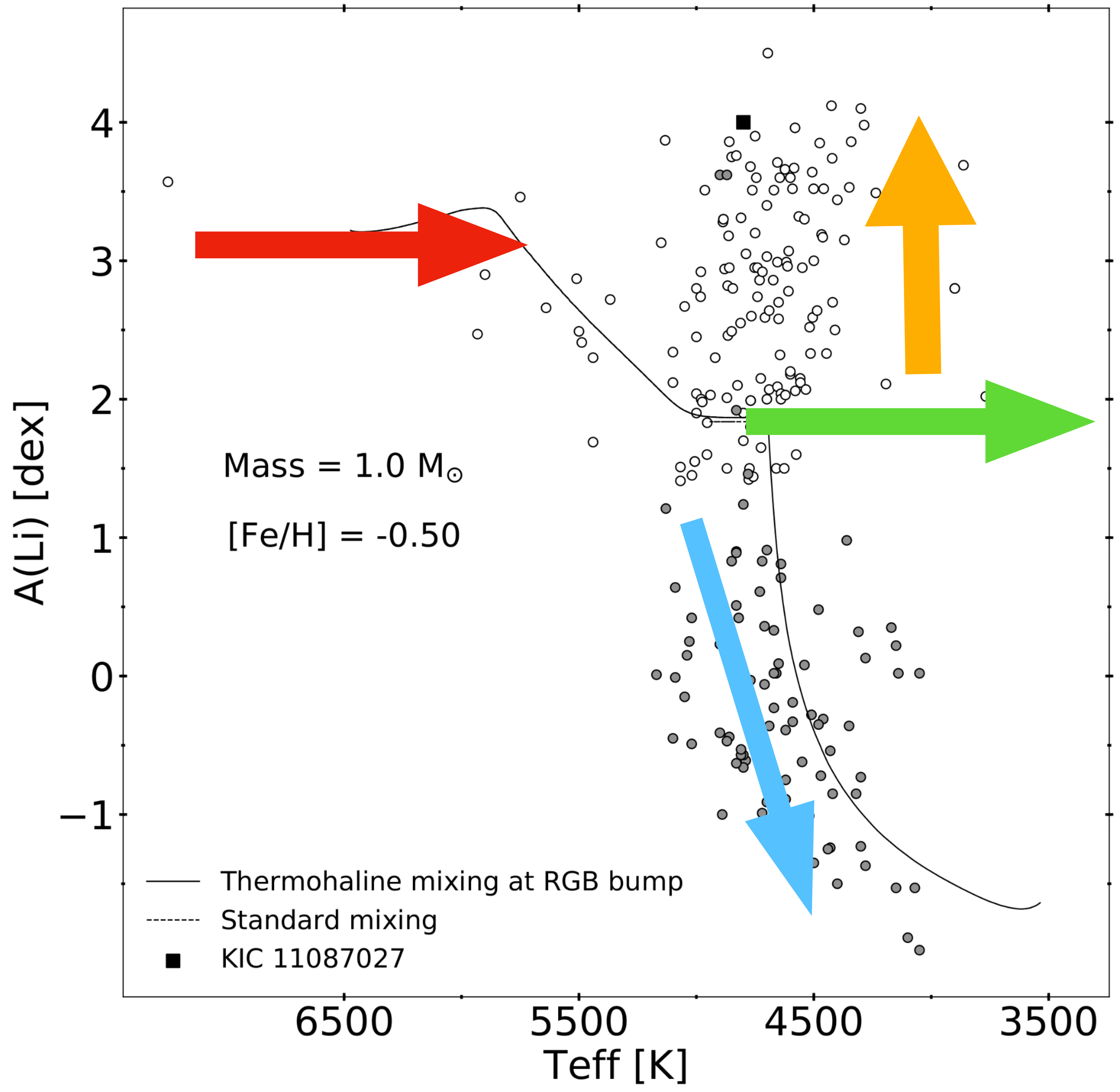
Outline:

- Introduction
- Few unsolved problems related to LiRG
- He-flash and Li production
- Peculiar features in KIC 11087027
- Summary

Li-rich giants (LiRG):

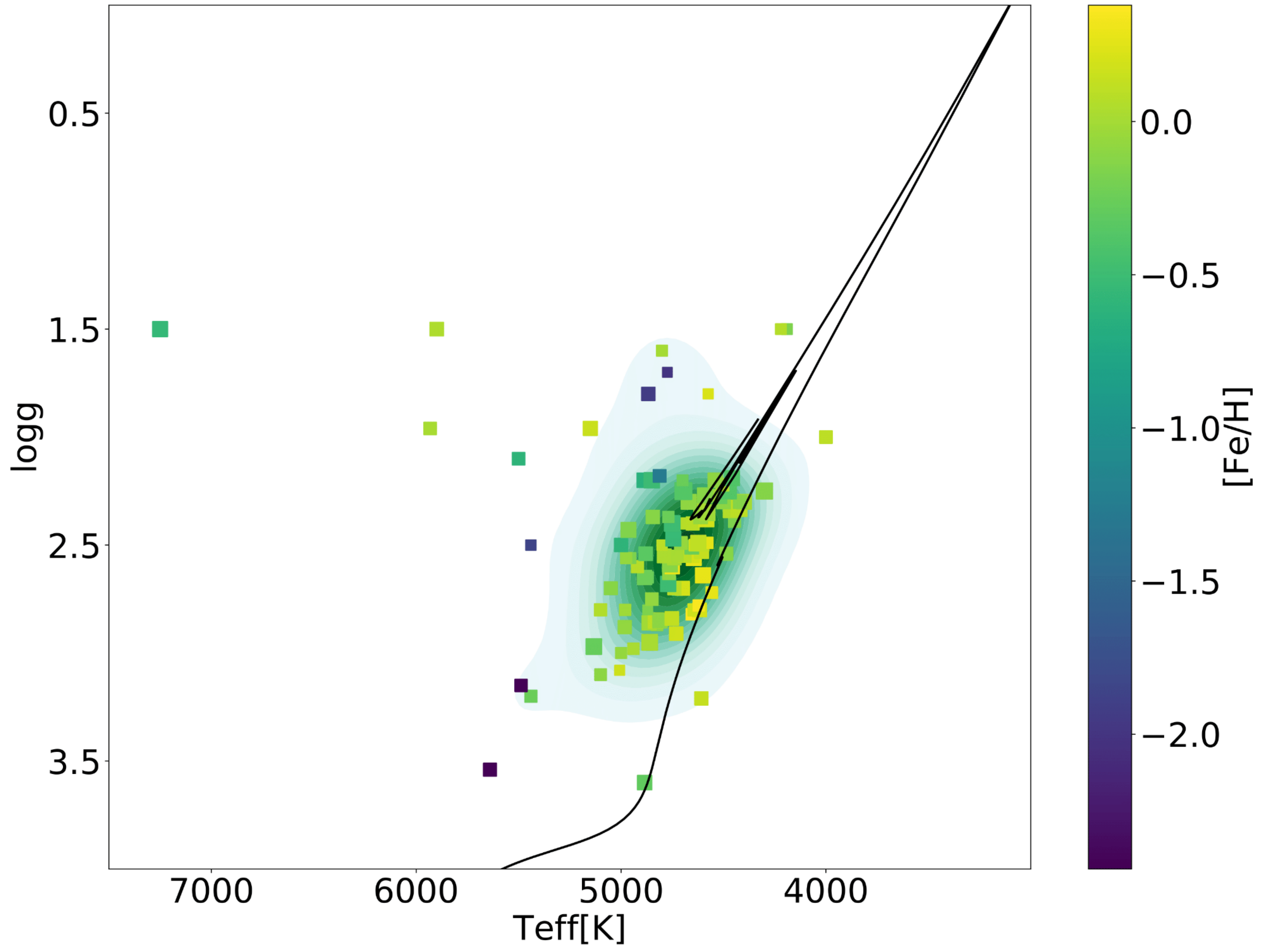
- Iben 1964 Stellar Evolution Models
- Wallerstein & Sneden 1982 first LiRG

1 — 2 %



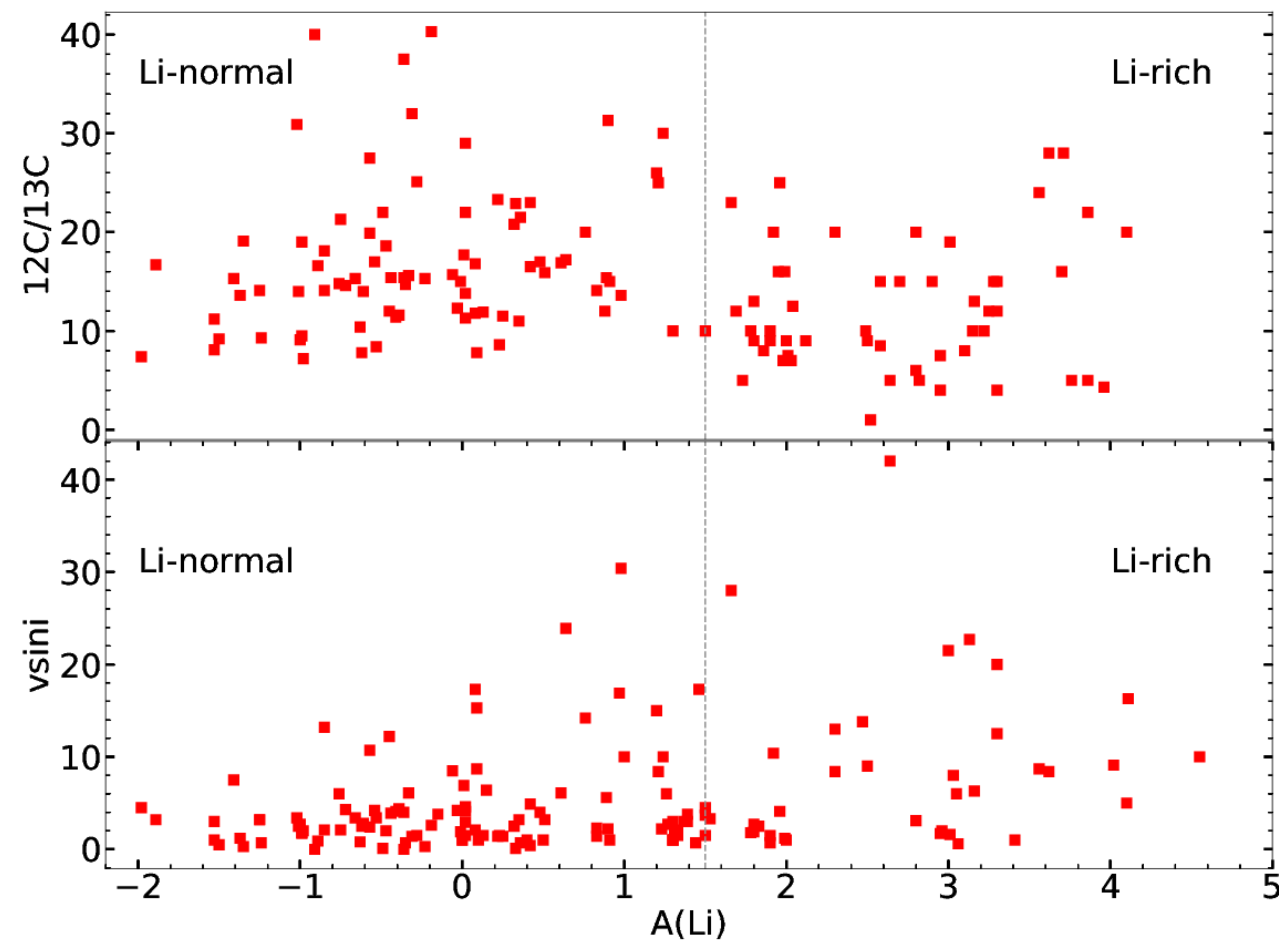
$M \leq 2M_{\odot}$

- Narrow region HRD



Data: Casey+2016

No correlation with vsini or $^{12}C/^{13}C$



Few unsolved problems related to LiRG

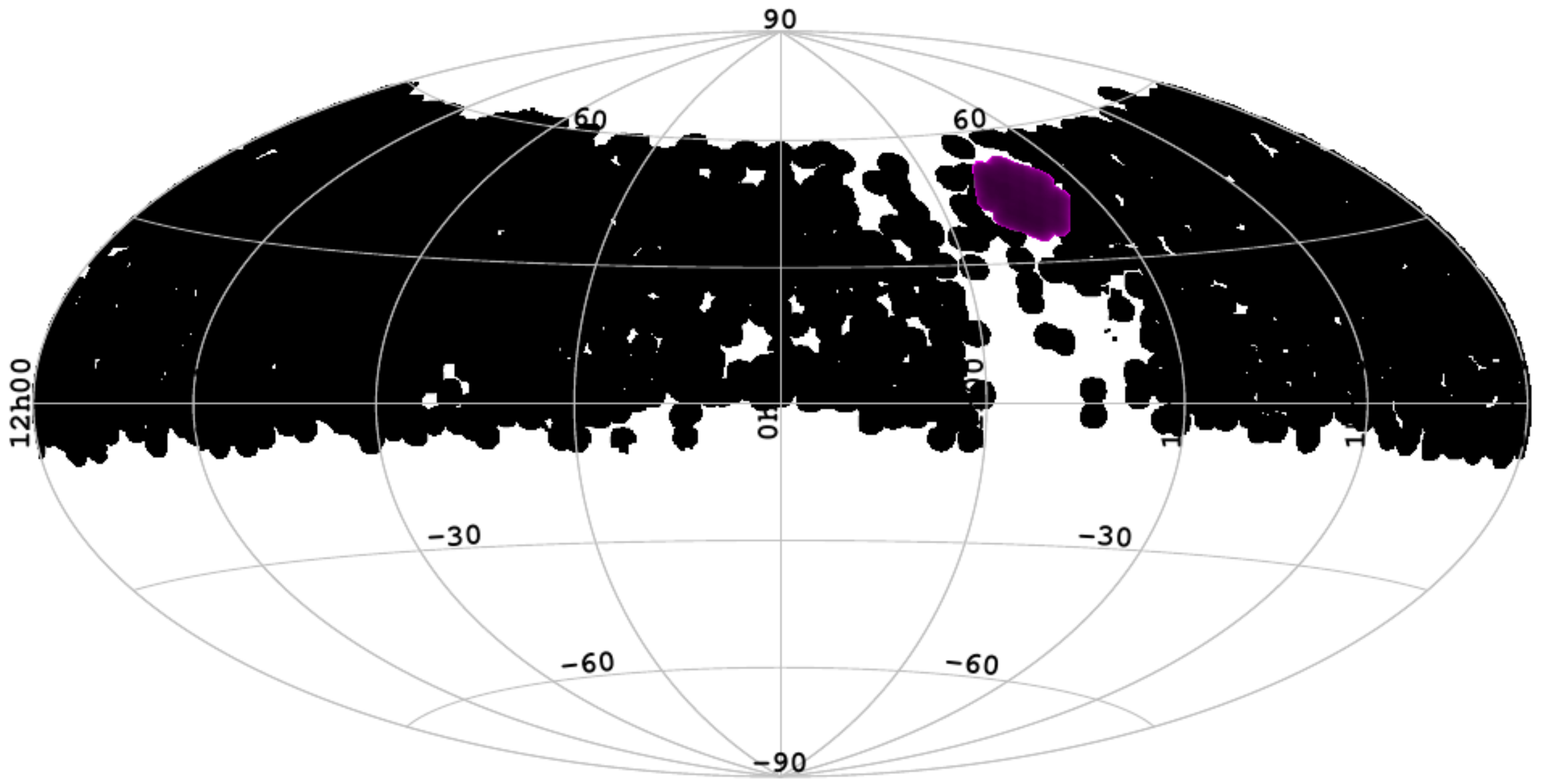
- What is exact evolutionary phase of Li rich stars?
- Relation with other stellar parameters?
- Cause of presence of excess Li in stars?

Data sources

- LAMOST (R = 1800, 7,500)
- APOGEE (R = 22,000)
- GALAH (R = 28,000)
- HCT HESP (R = 60,000), SUBARU
- Gaia, Kepler

Survey in LAMOST-Kepler field: 12500 red giant stars

Li abundance

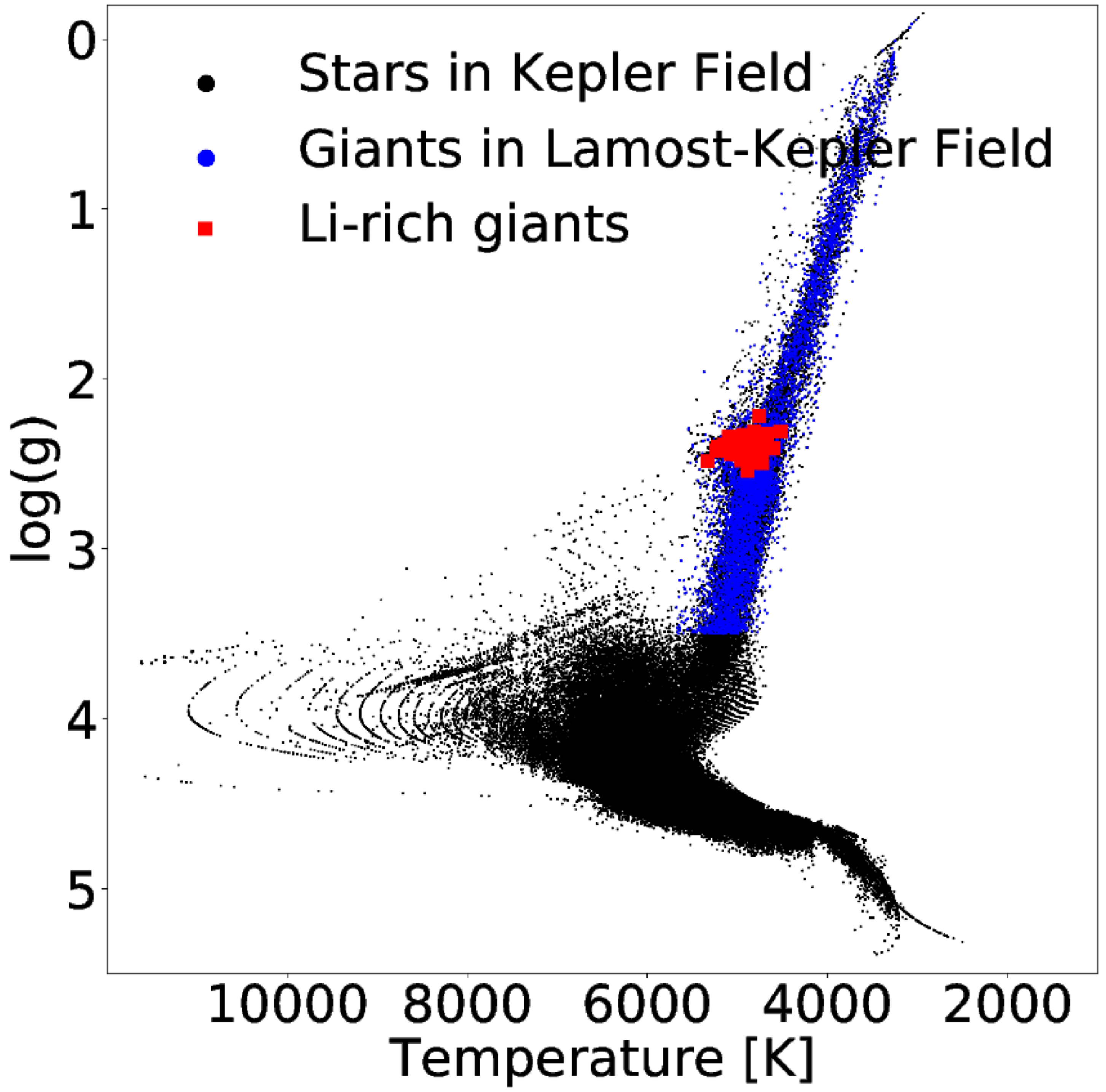


- LAMOST LR = 1800
- A(Li) > 3.3 dex

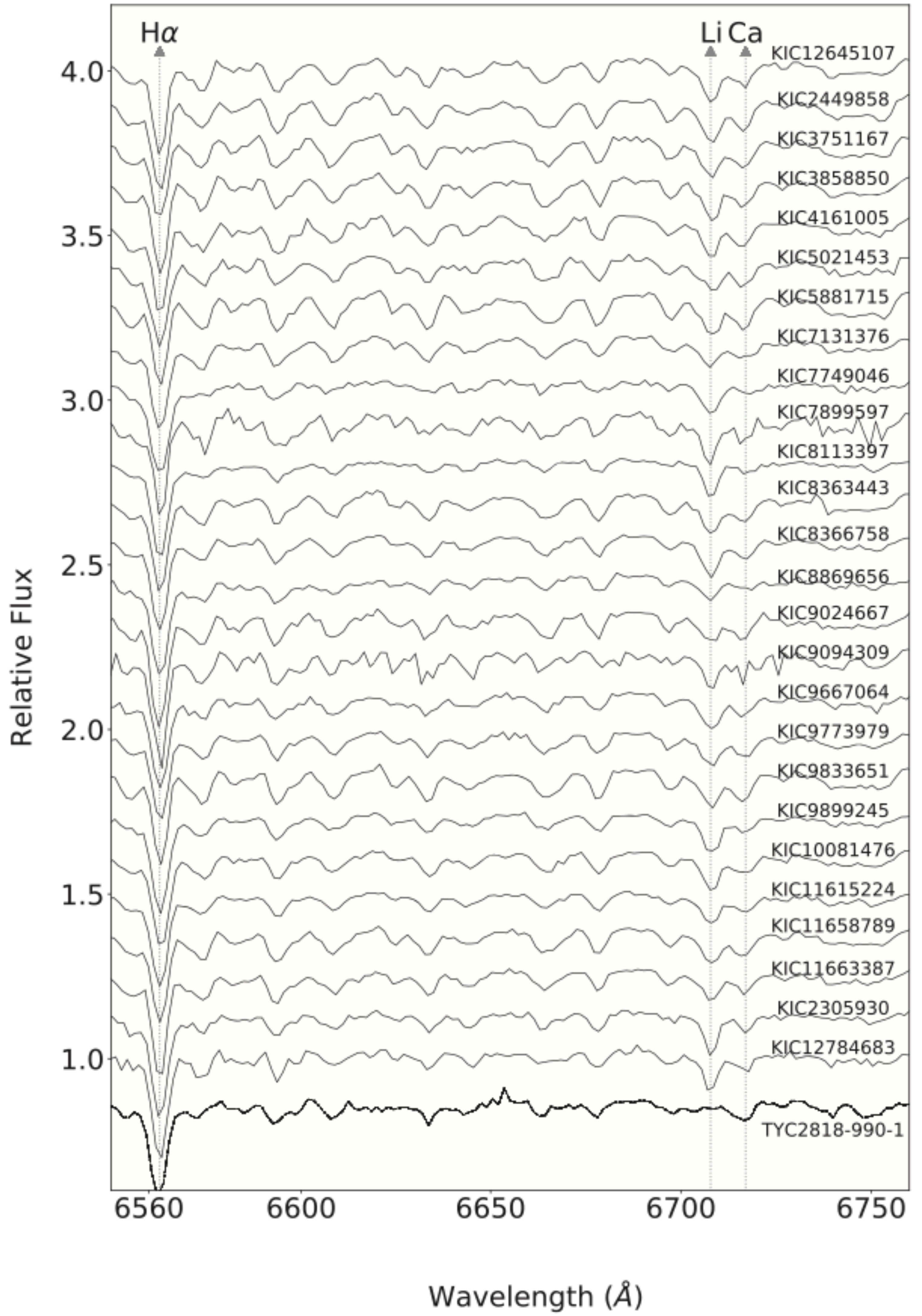
•SLR = 26/12500

•Teff < 5500 K

•log g < 3.5 dex

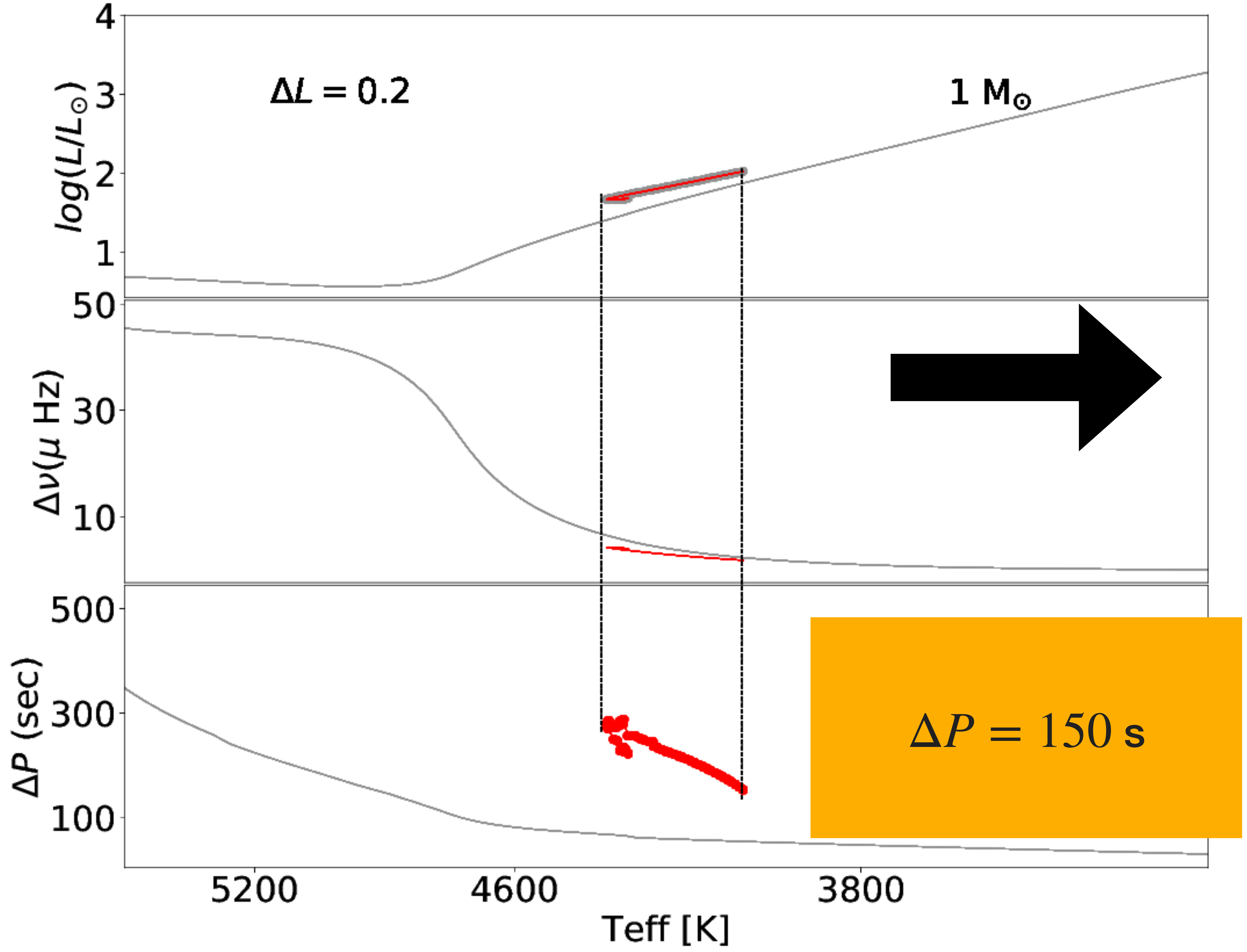


Singh et al.

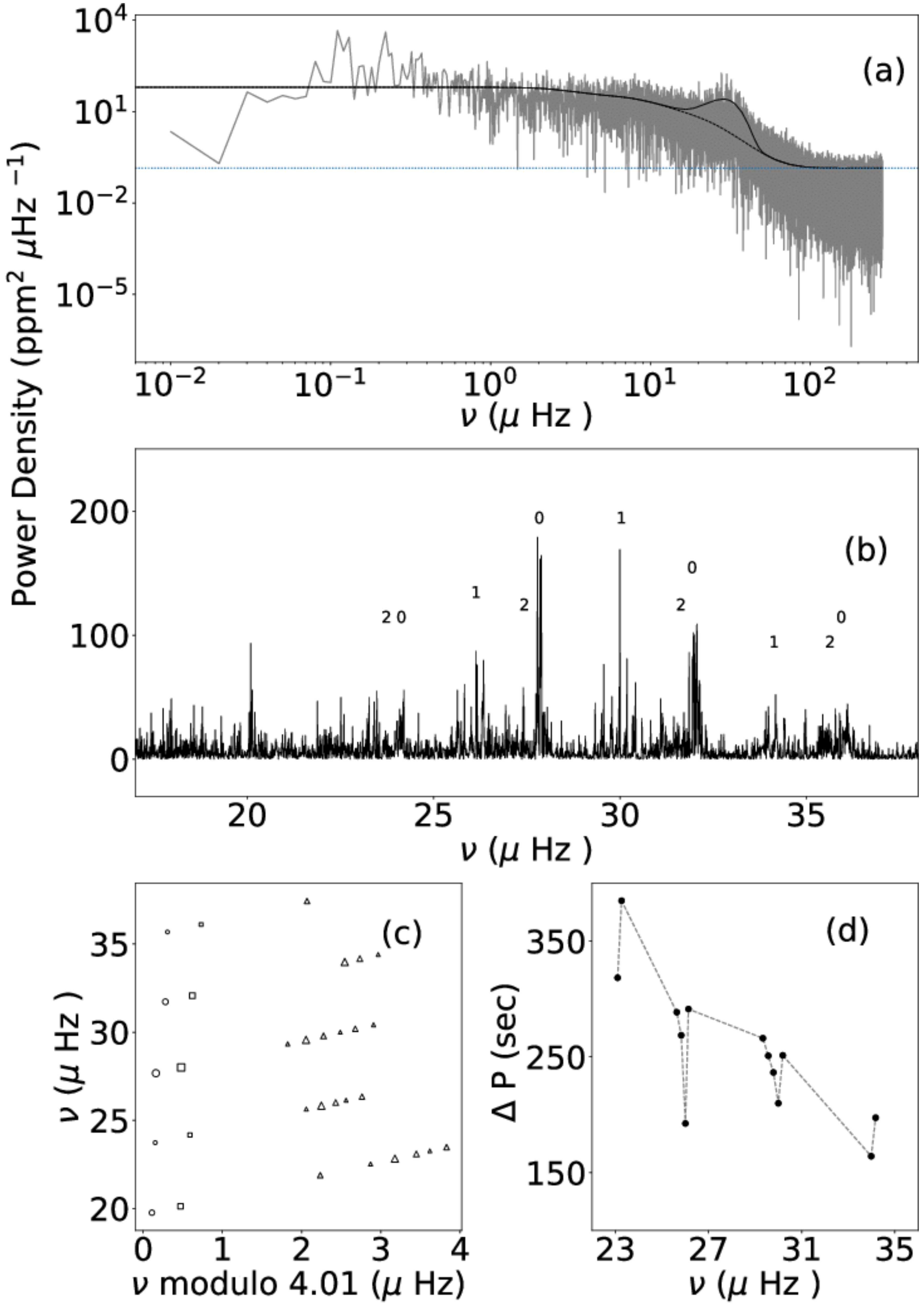


Asteroseismic analysis: Kepler data

$$\Delta\nu = \left(2\int_0^R \frac{dr}{c(r)}\right)^{-1} \text{ and } \Delta P = \sqrt{2}\pi^2\left(\frac{N dr}{r}\right)^{-1}$$



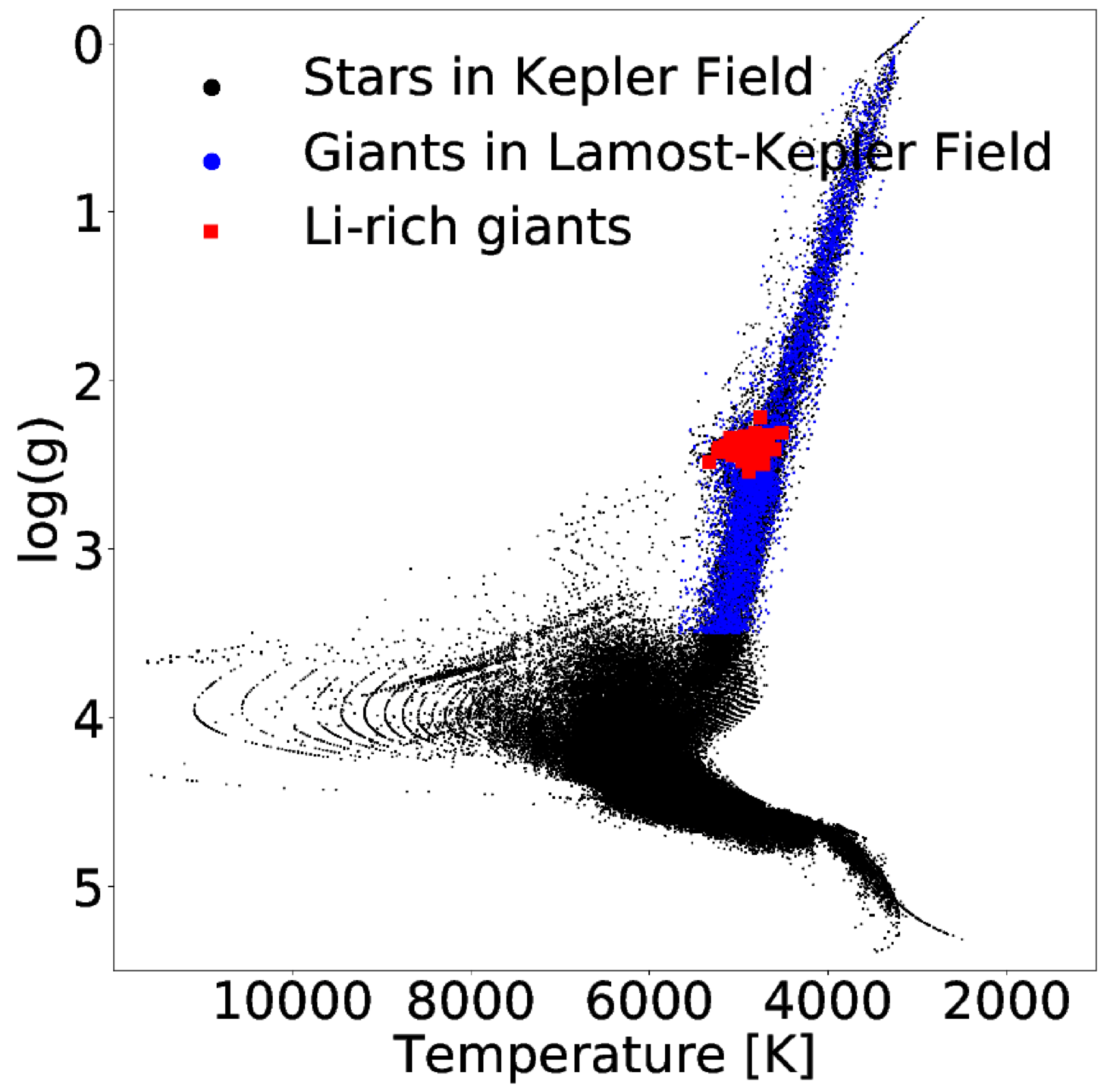
$\Delta P = 150$ s

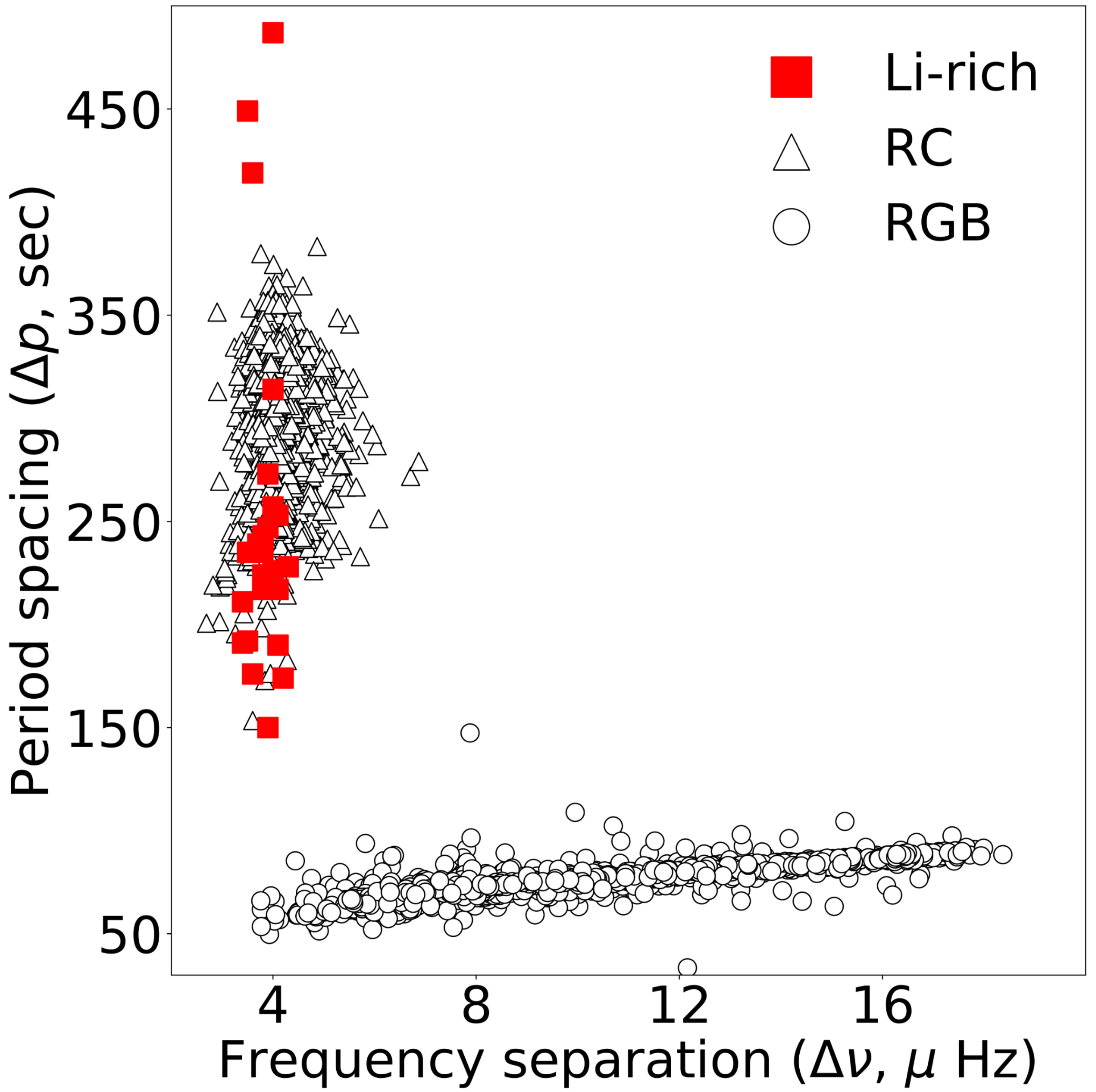


MESA-MIST: M = 1.0 and [Fe/H] = 0.0

Evolutionary phase of Li-rich giants: Asteroseismology

- **All LiRG with A(Li) > 3.3 dex are red clump stars**





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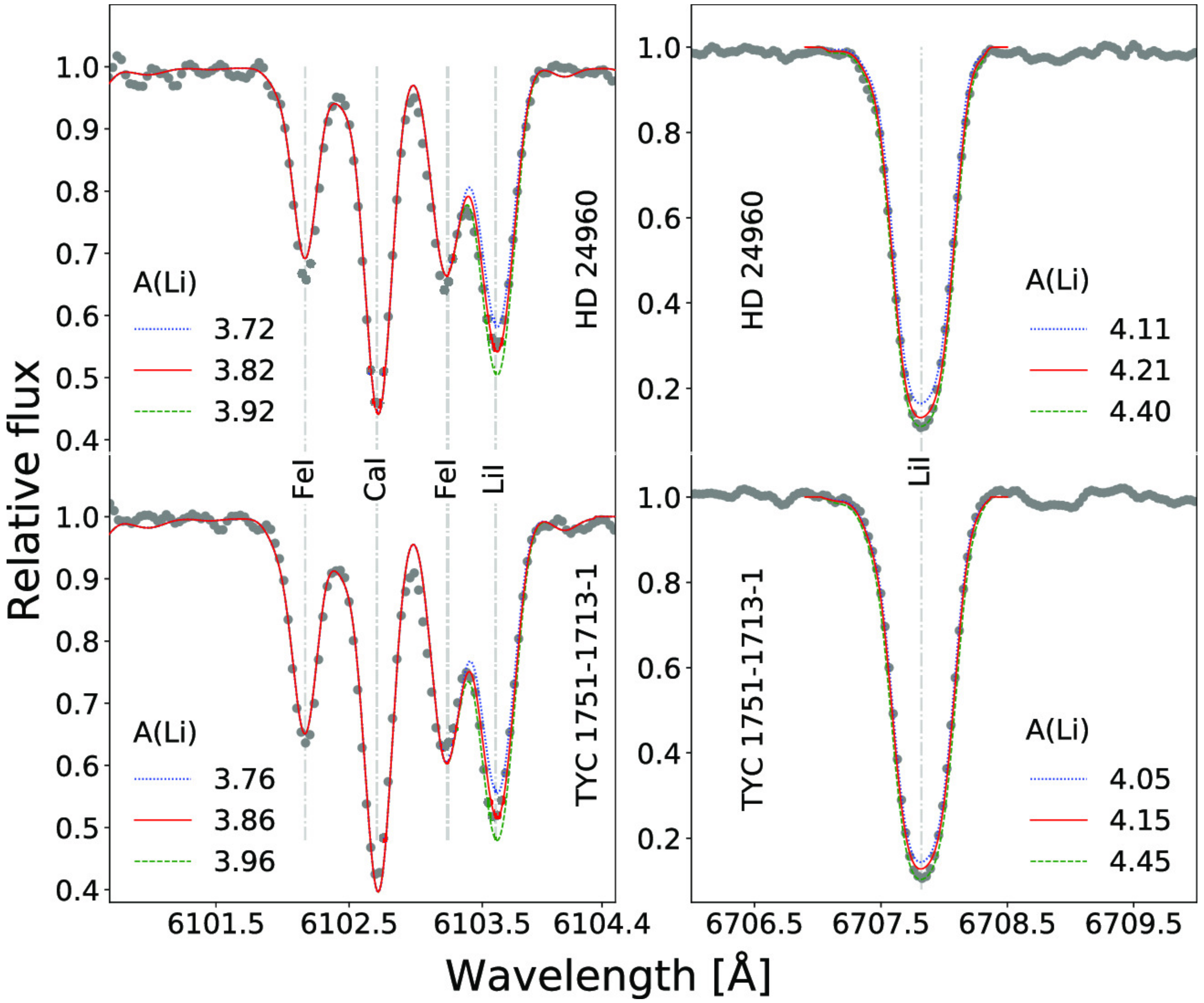
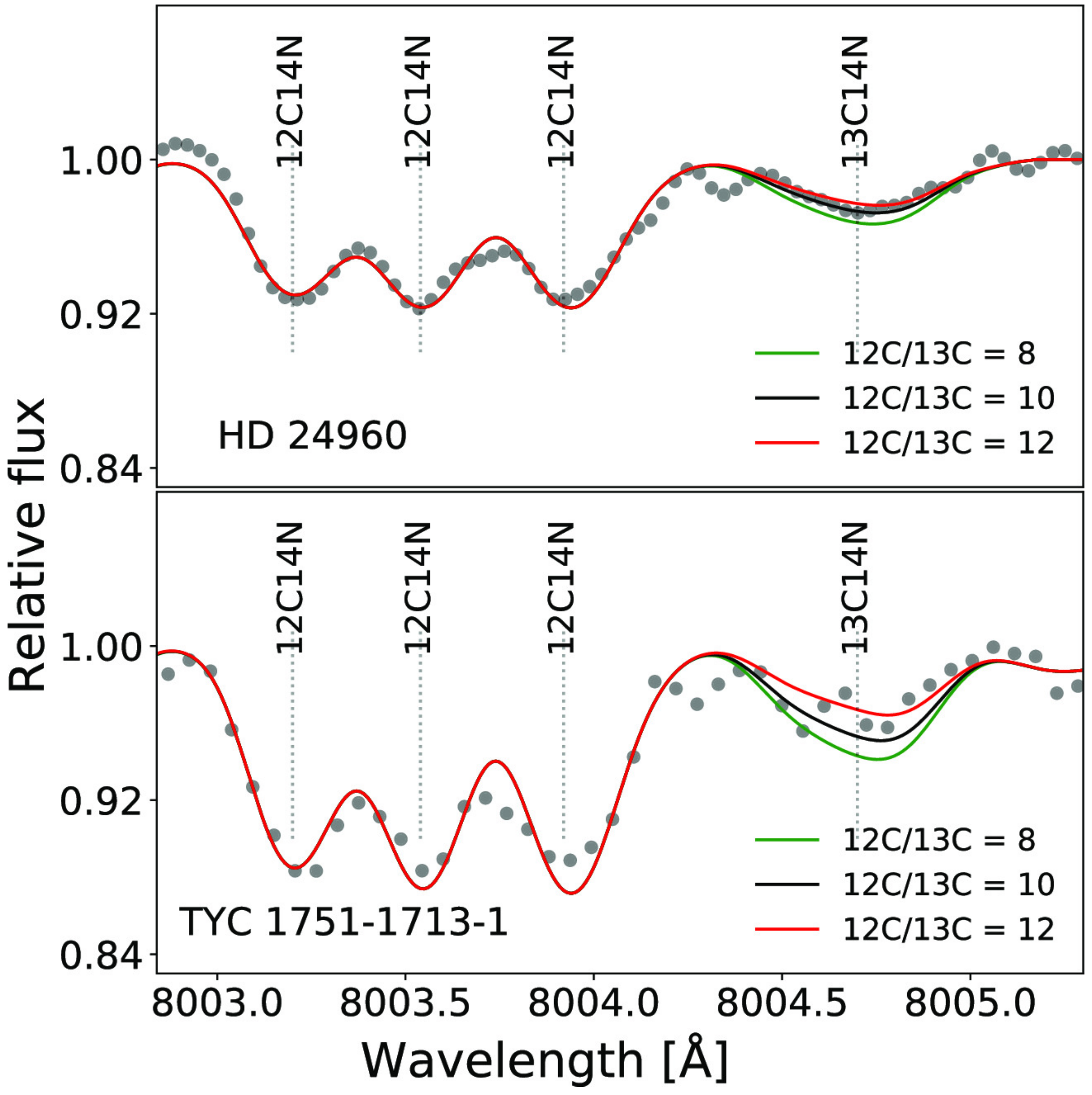
Singh et al. 2019

Evolutionary phase based: [C/N]

High resolution followup and APOGEE abundances



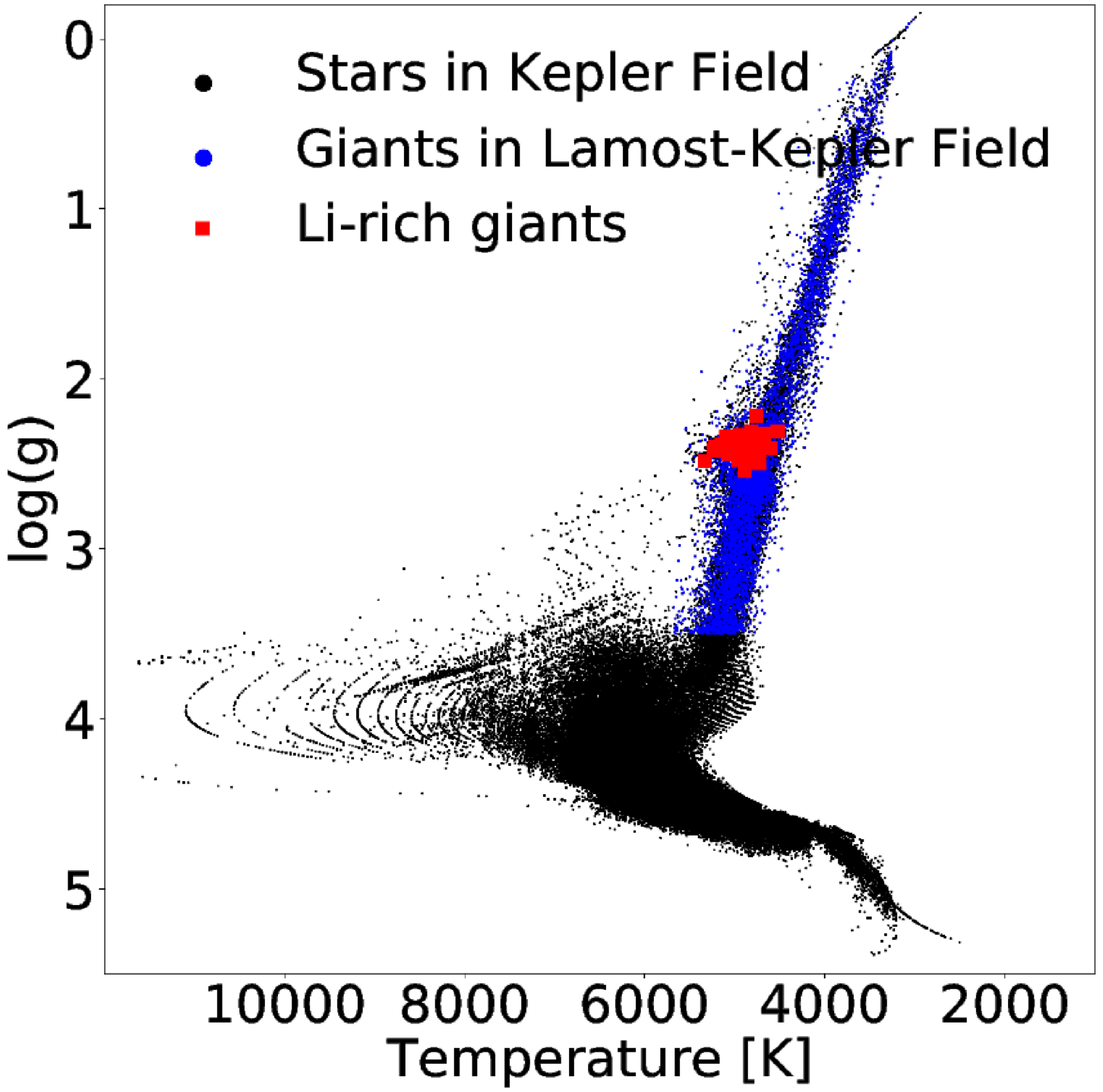
Singh et al. 2018

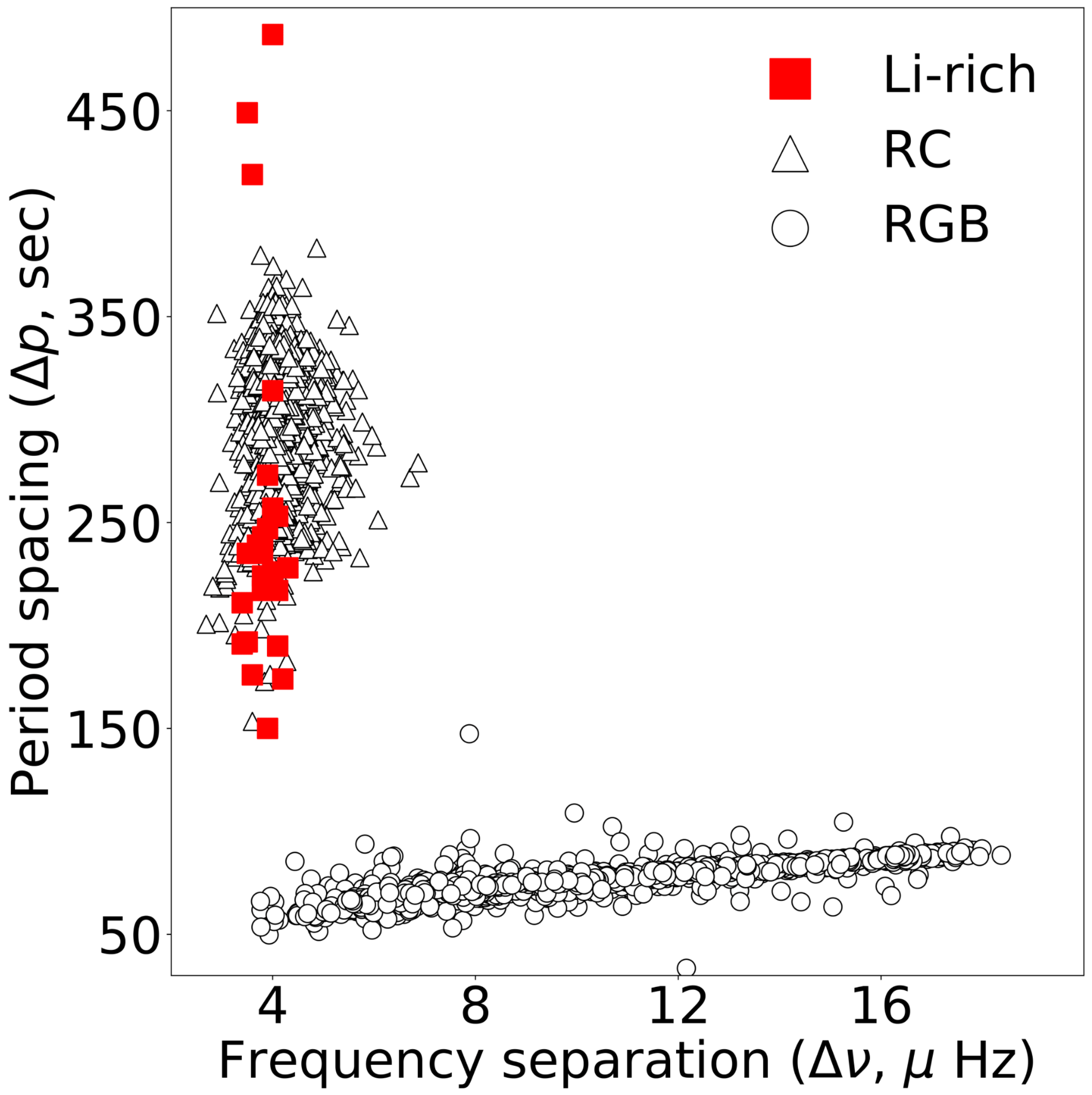


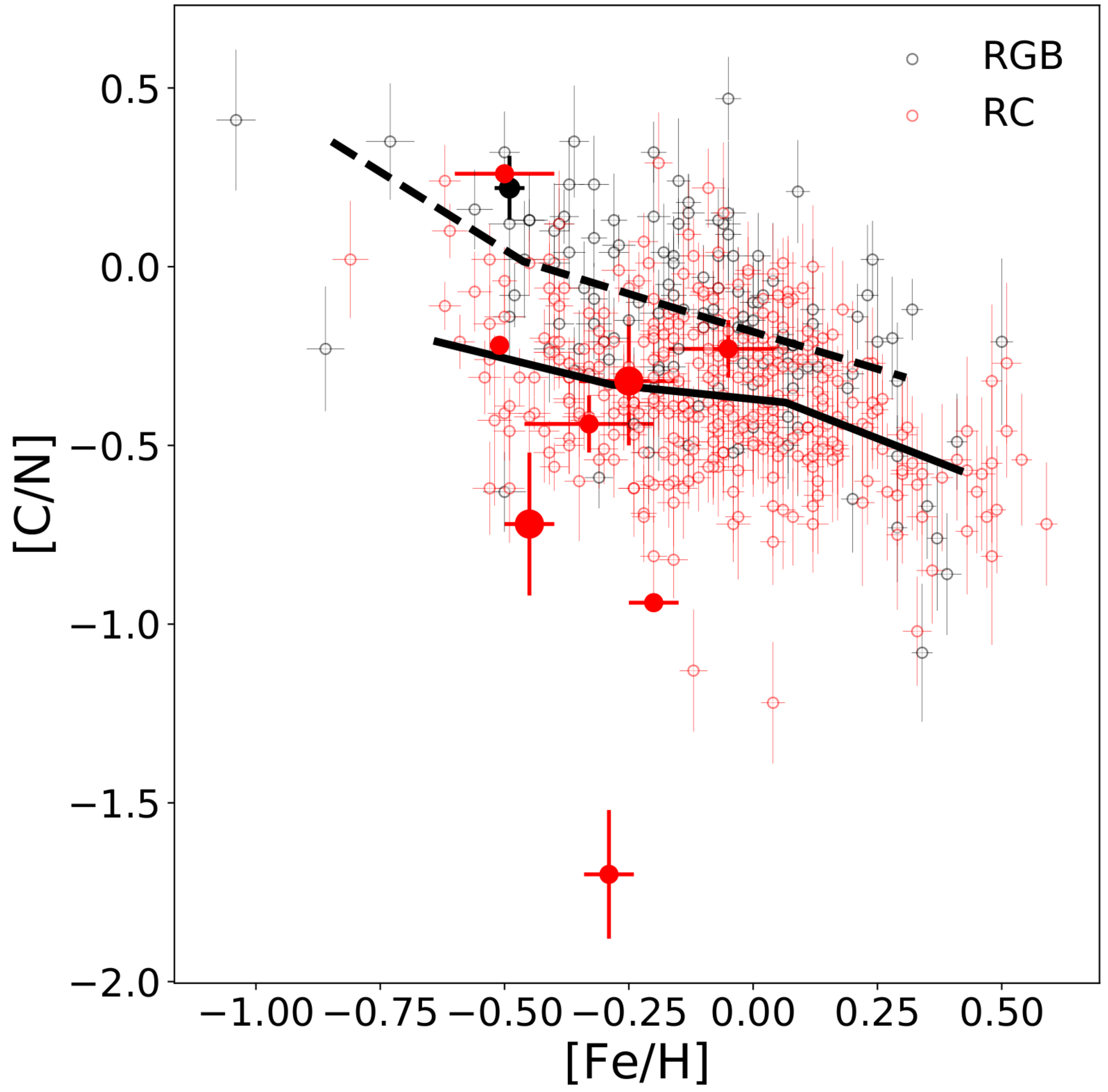
Singh et al. 2019

Evolutionary phase of Li-rich giants:

RC stars







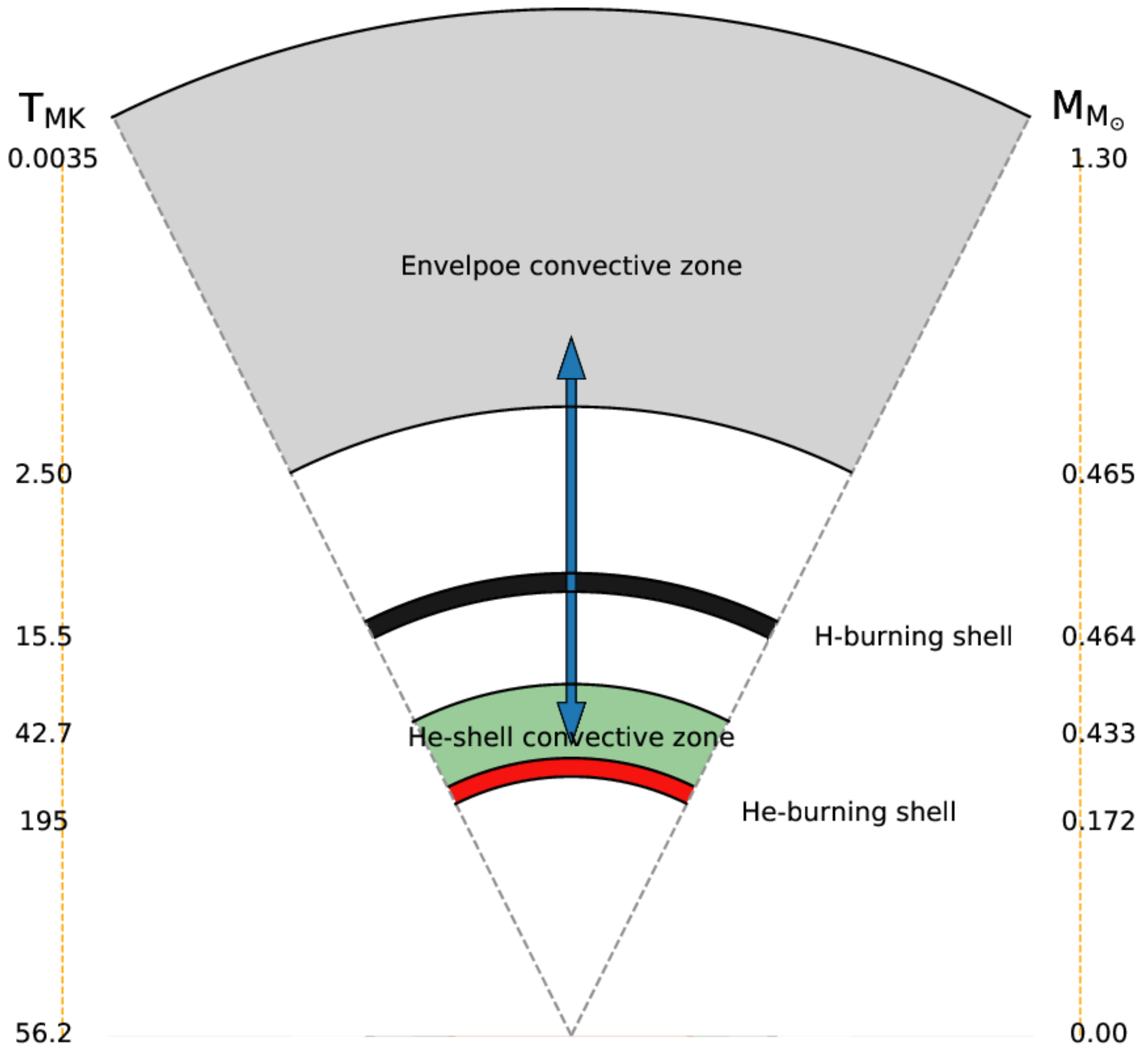
Singh et al. 2018

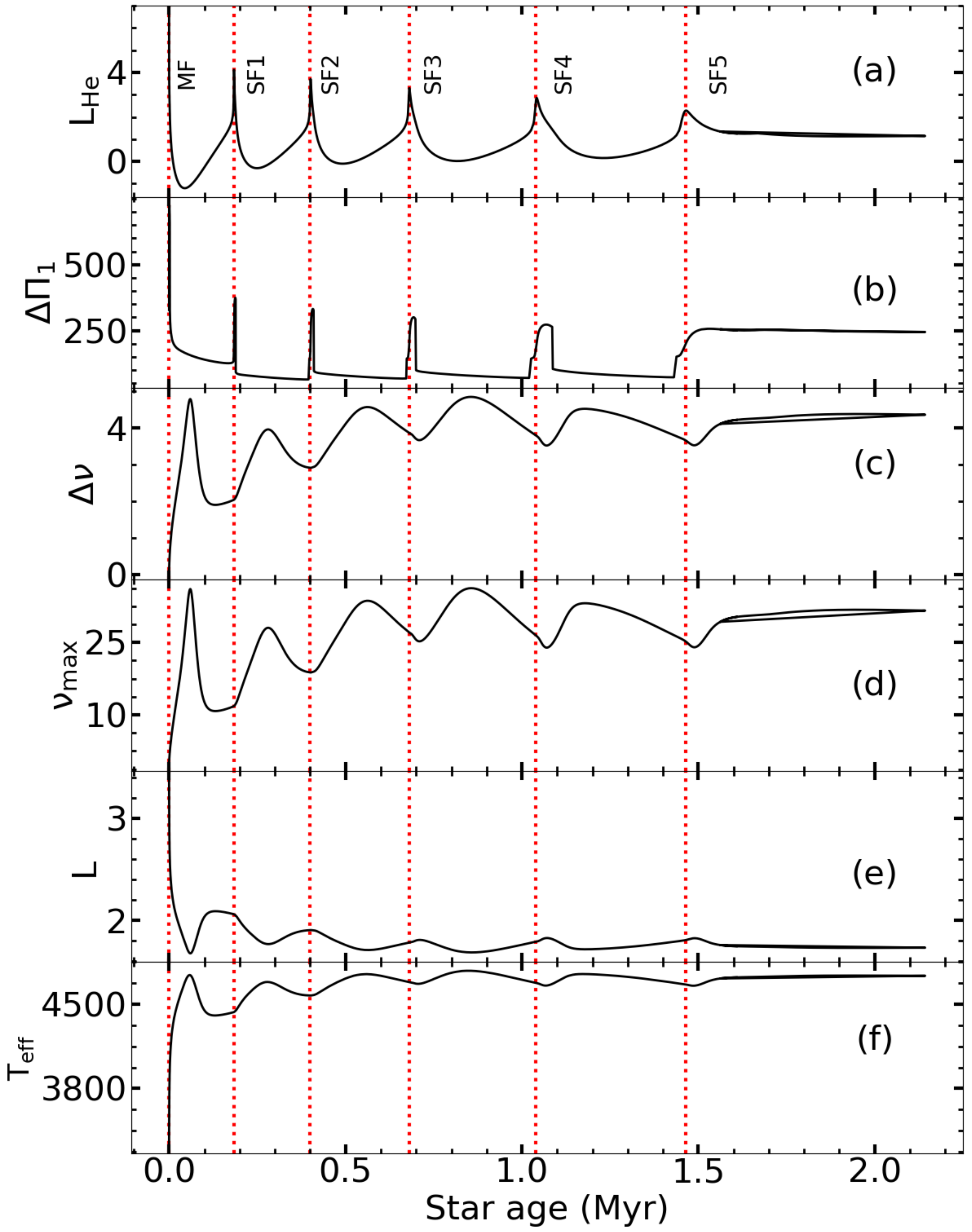
Singh et al. 2019

A(Li) in RGB $\leq$ 2. 4 dex (Yan et al. 2021)

Production mechanism: *in situ*

- Single evolutionary phase of Li-rich giants suggests that one single event is producing Li.
- Now question arises where exactly Li is getting produced i.e in red clump phase or just preceding He flash or near tip of RGB.



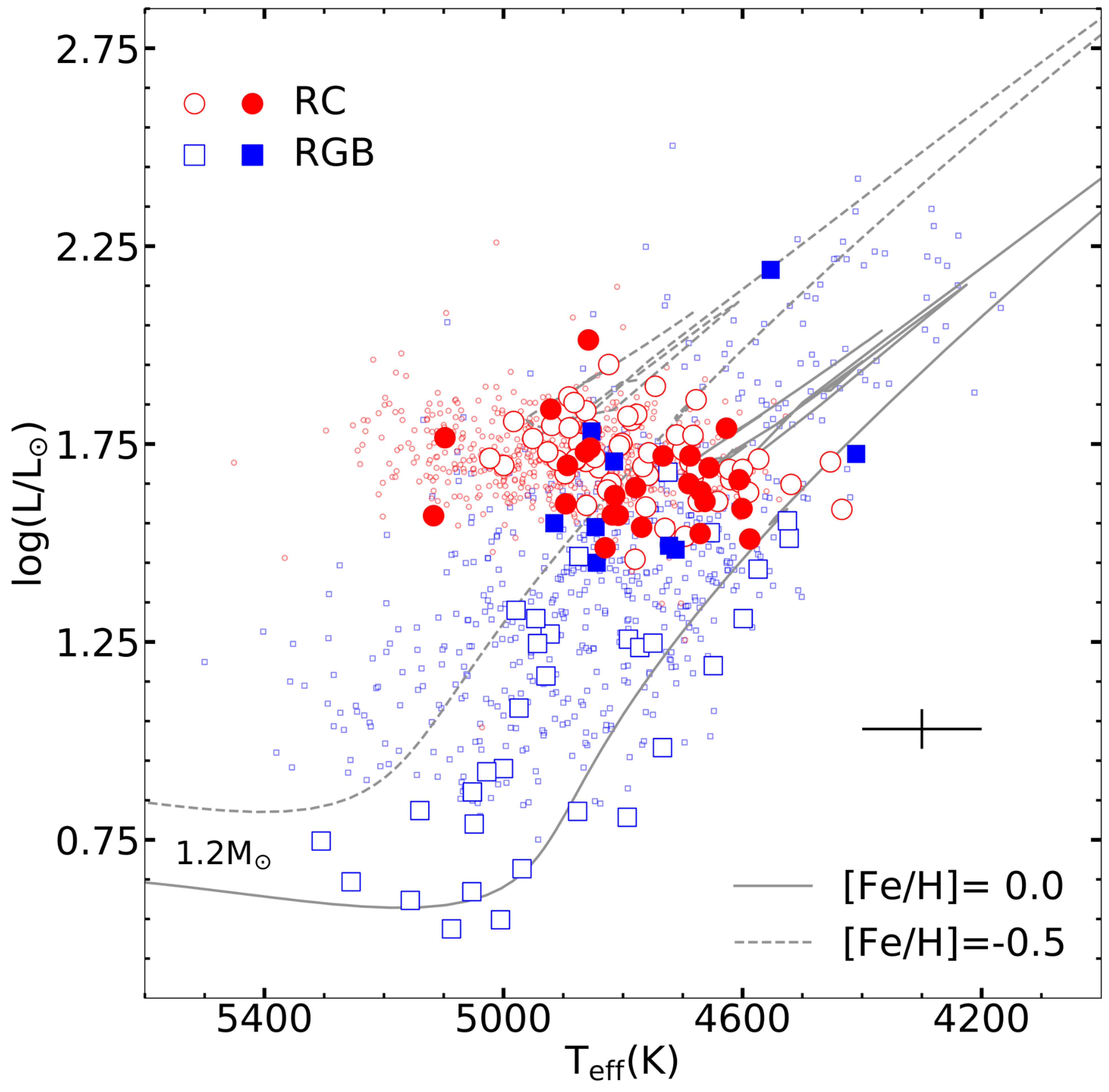


- Previous work of **Mocak et al. 2011** found that Li can produce during He flash based on their simulation and **Schwab 2020** also found Li production during He flash. Their model suggested fast depletion of Li.

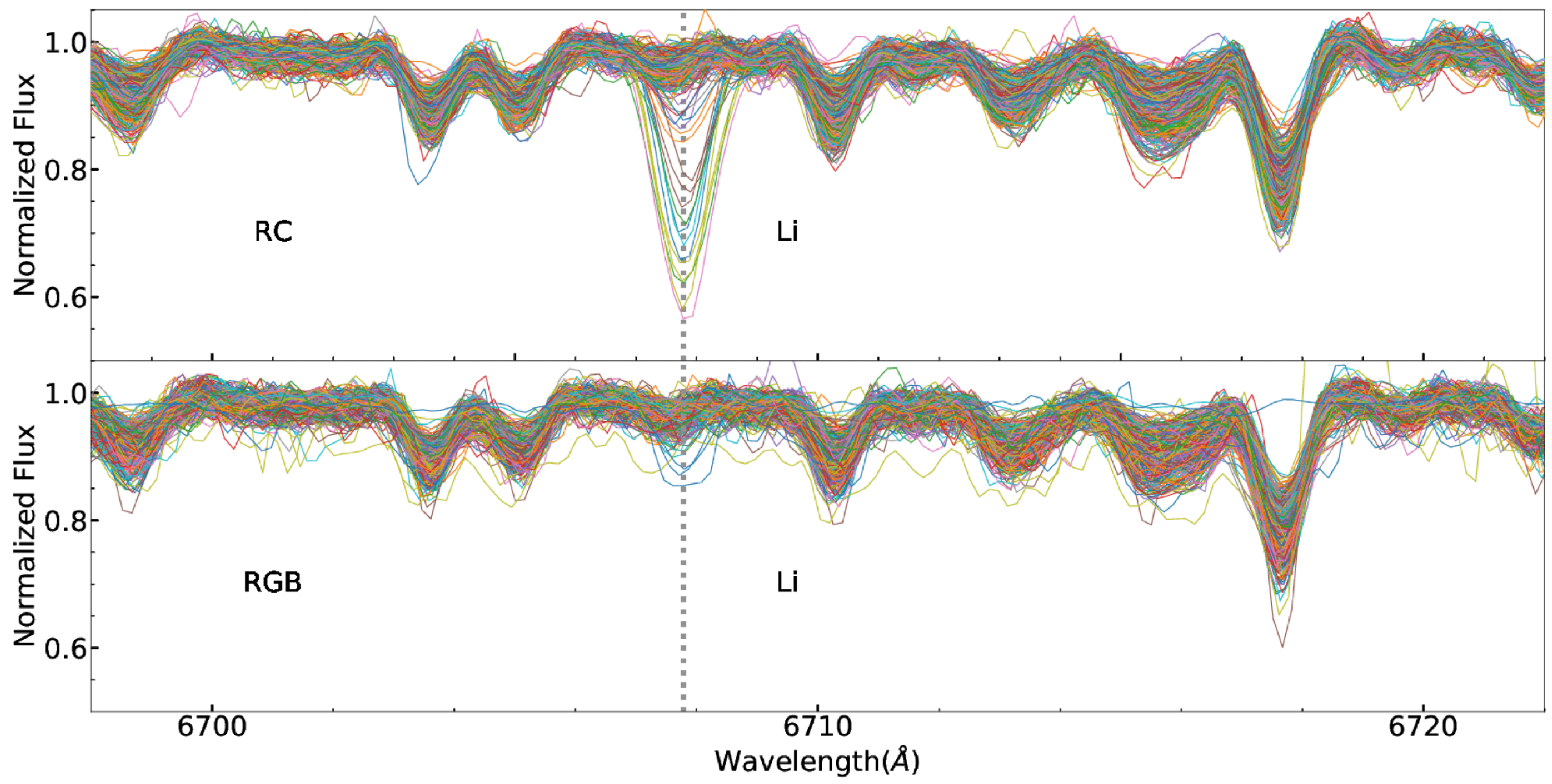
- To exactly identify the moment where Li is getting first produced can help to understanding Li production mechanism.

- Models predict variation of asteroseismic parameters during He flash (**Bildsten et al. 2012**).

Li-rich giants: LAMOST-MRS



Singh et al. 2021

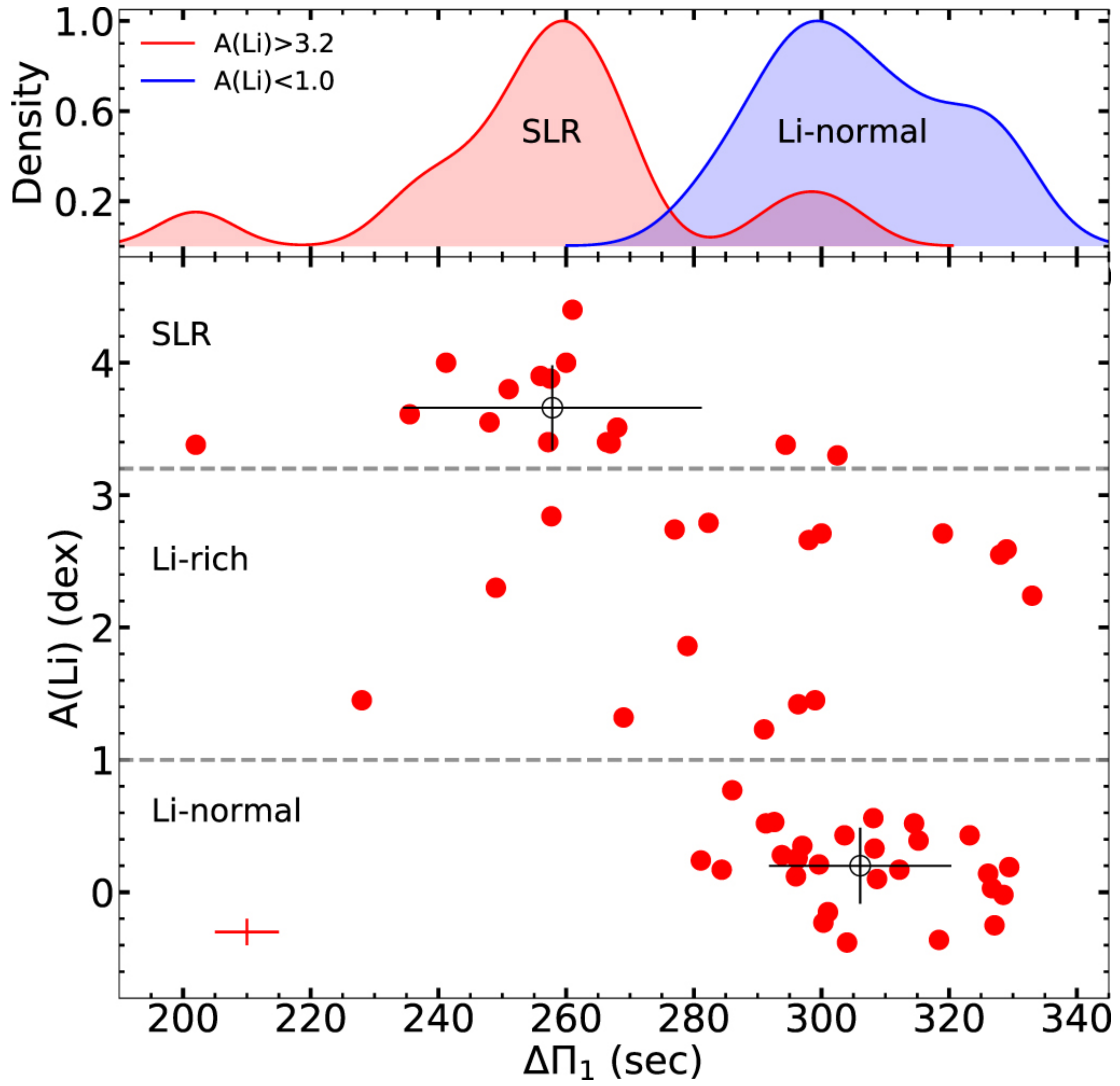


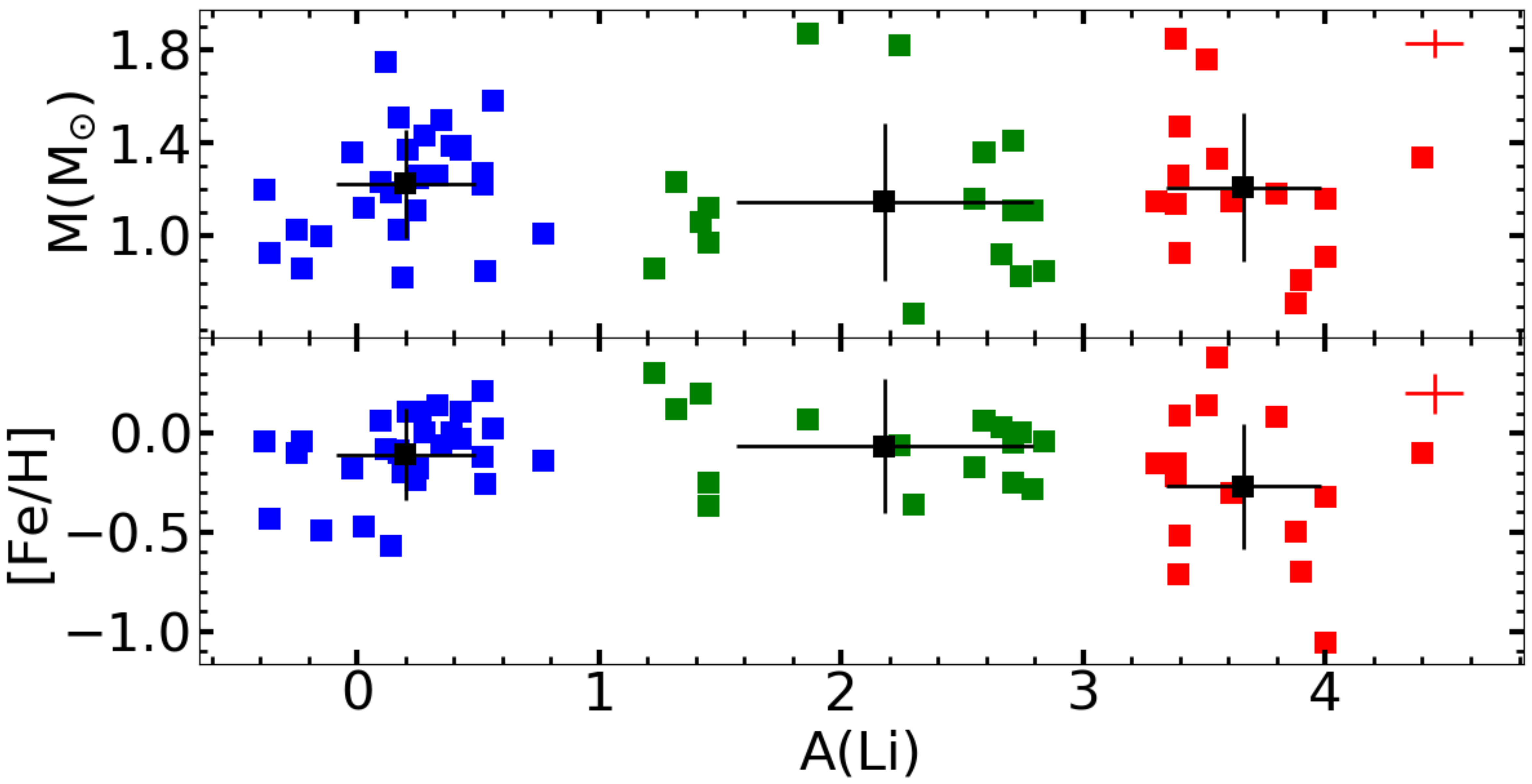
- RGB stars = 580, A(Li) < 2.2 dex
- RC stars = 577 1.45 < A(Li) < 4.0 dex

Production site: During or just after He-flash

- 59 RC stars with A(Li) and $\Delta\Pi_1$

- SLR A(Li) > 3.3 dex
- LR 1.0 < A(Li) < 3.3 dex
- LN A(Li) < 1.0 dex



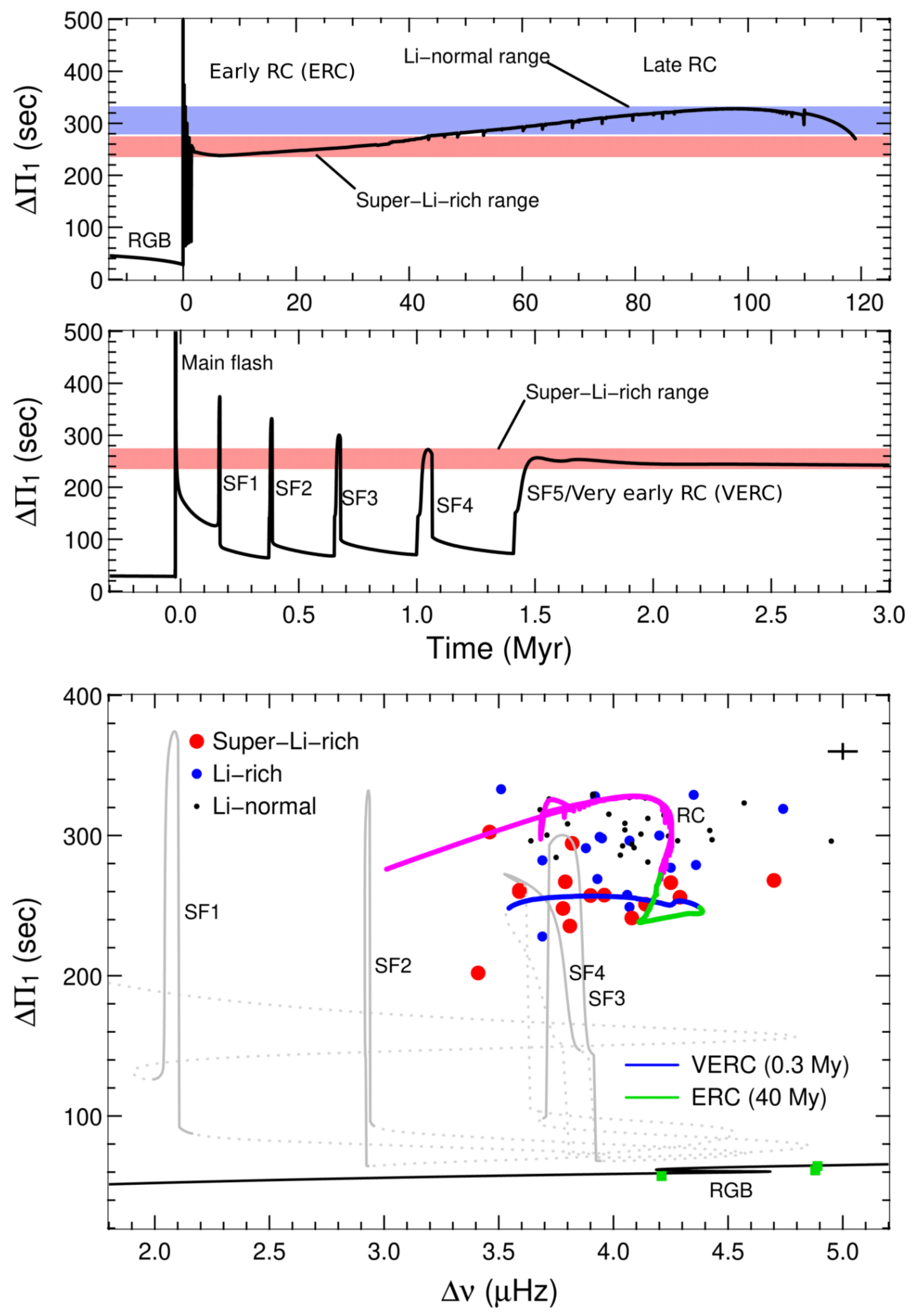


Singh et al. 2021

Production site:

SLR stars are young red clump stars:

- Fraction of SLR based on large survey:
  - Singh+2019 = 0.3, Kumar+2020 = 0.5
- ERC = 40 Myr
- VERC = 0.3 Myr
- SF4 = 0.04 Myr
- Degeneracy between ERC and VERC stars
  - M = 0.9 —1.4
  - [Fe/H] = -0.4—0.0

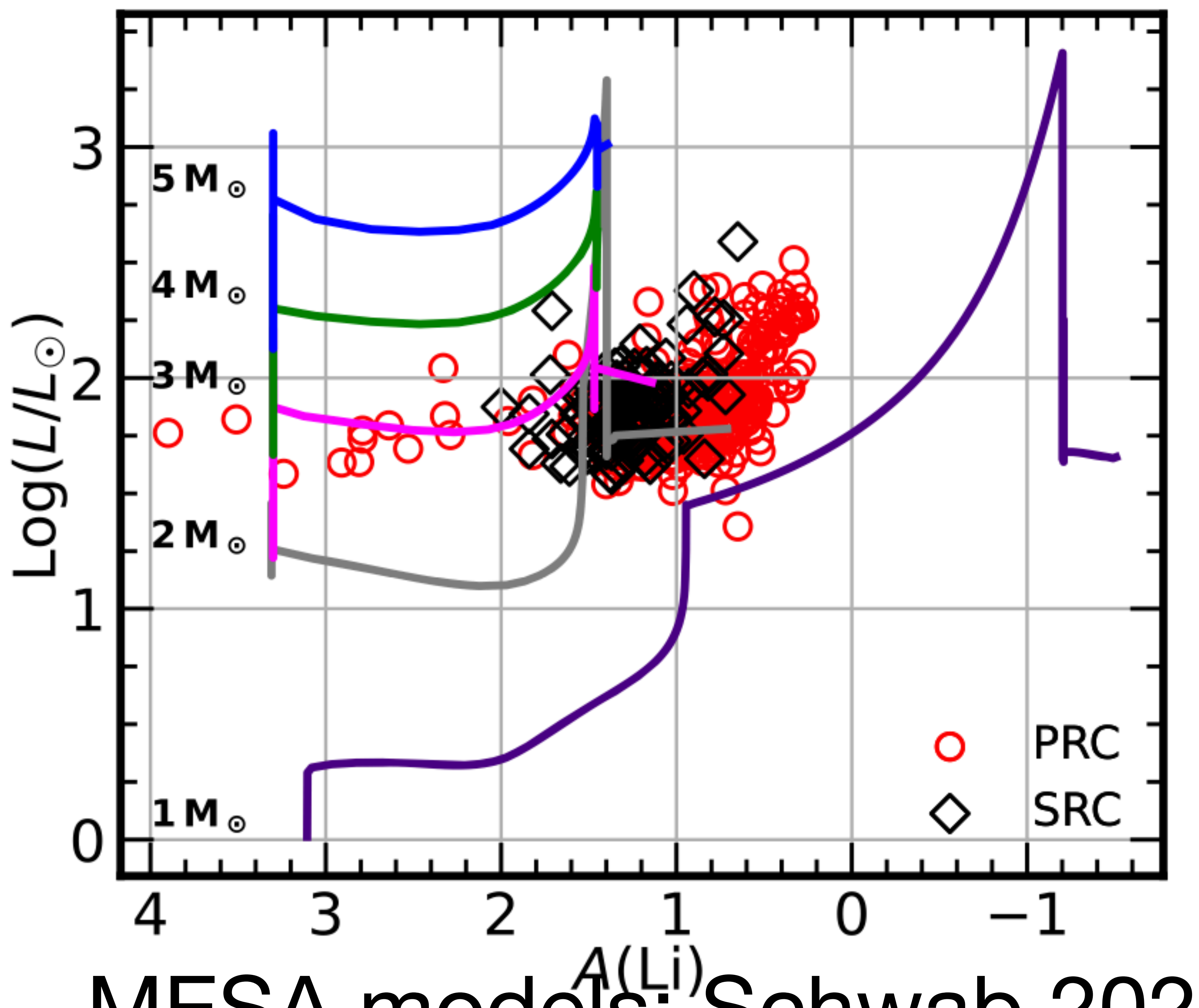


- MESA v12778
- M =1.2 , [Fe/H] = -0.14

Li production: He-flash limited to low mass stars

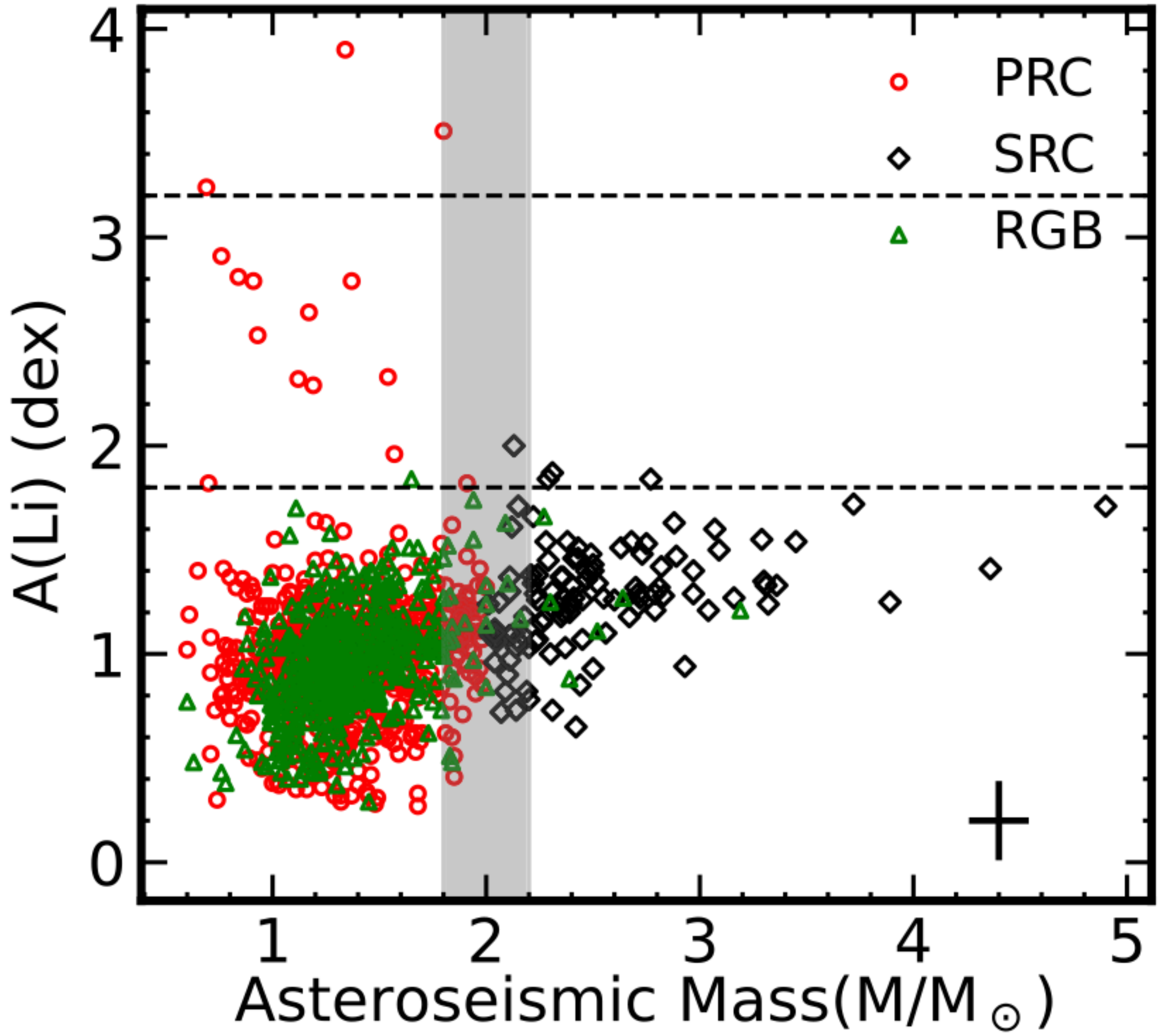
Kjeldsen H. & Bedding, T., R 1995

$$\frac{M}{M_\odot} = \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4}\left(\frac{\nu_{max}}{\nu_{max,\odot}}\right)^{-3}\left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{-3/2}$$



MESA models: Schwab 2020

- 777 RC M < 2.0 $M_\odot$
- 109 RC M > 2.0 $M_\odot$

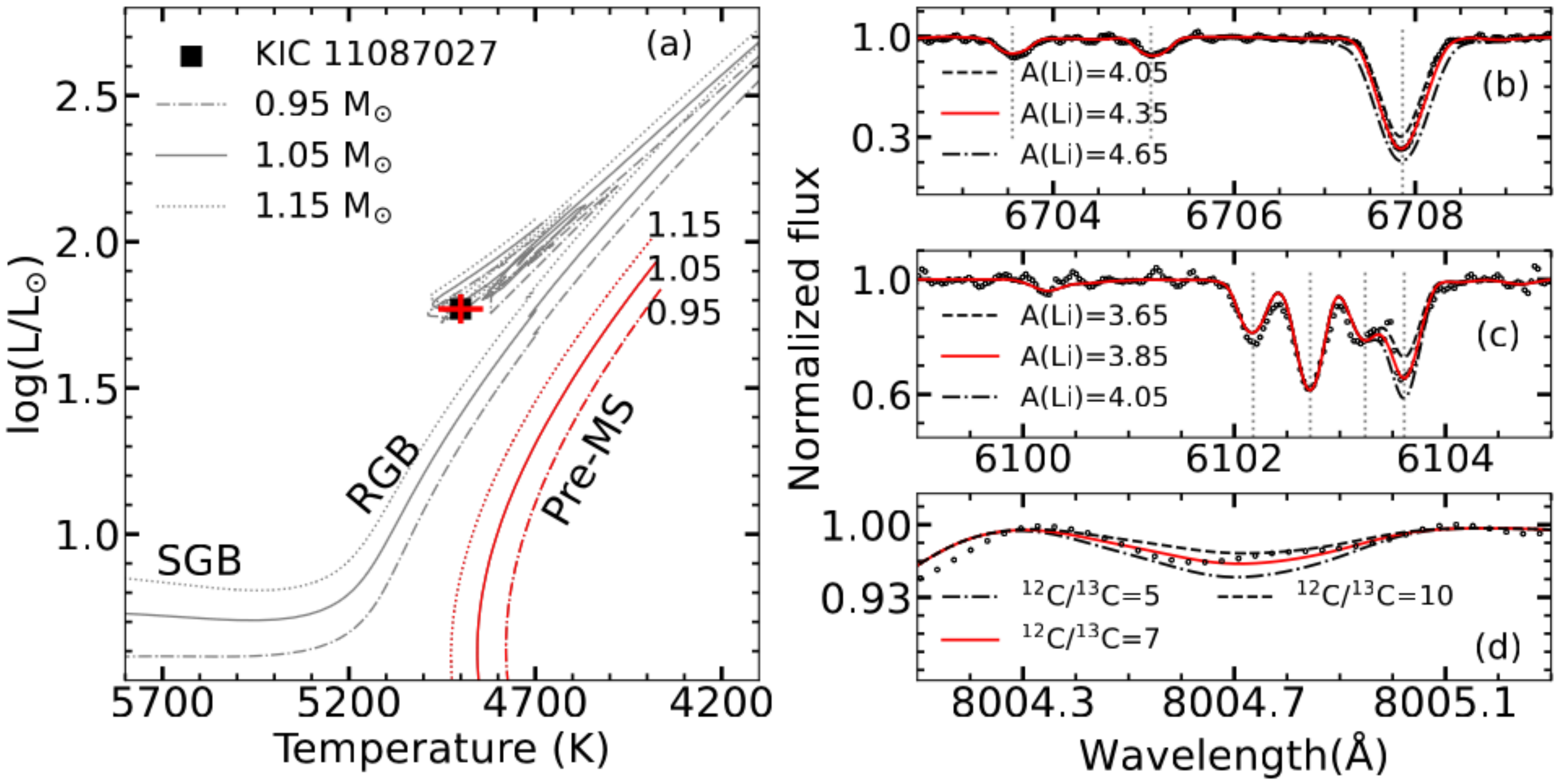


Mallick, Singh and Reddy, 2023

KIC11087027: Singh+2019

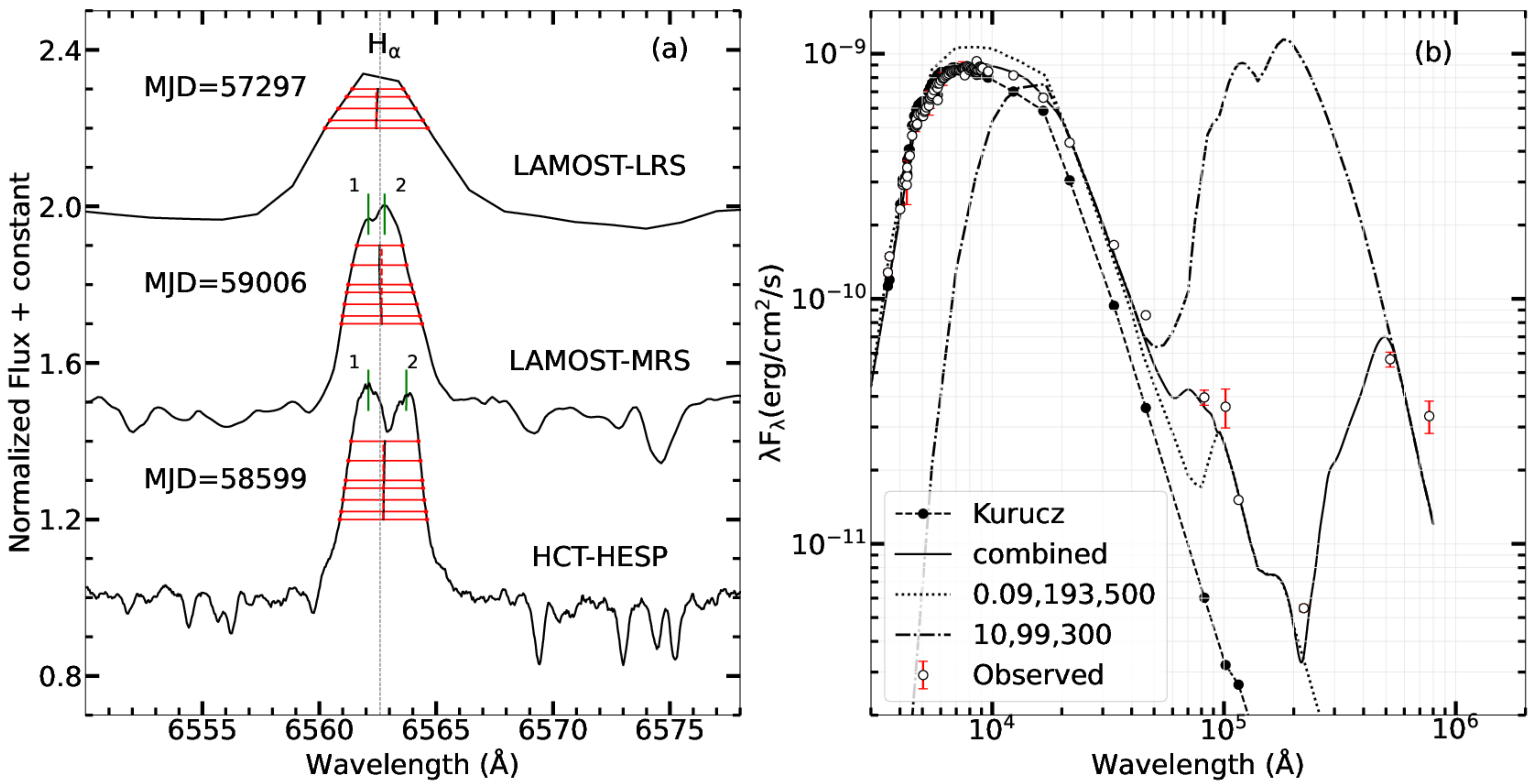
Presence of IR excess and other peculiar features:

- A(Li) = 4.1 ± 0.08 dex
- $^{12}C/^{13}C$ = 7±1.2
- [Fe/H] = -0.55
- [C/N] = -0.76
- Vsini = 10.5 km s^{-1}



Singh et al. 2024

Emission in H-alpha and IR excess



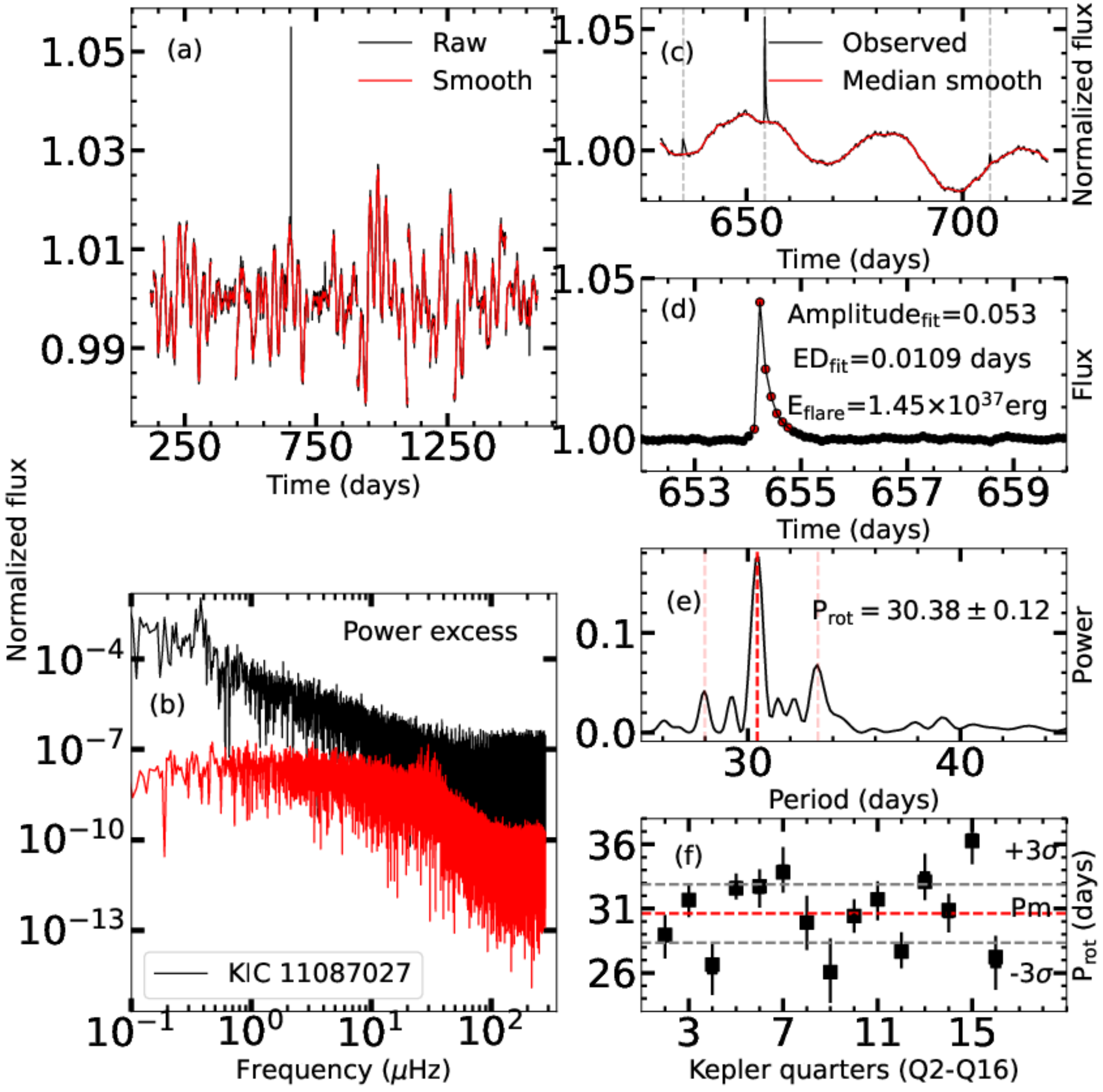
Double dust shell

- Td,inner = 193 K
- Td, outer = 99 K

- At higher resolution double peaks, asymmetry

KIC11087027

- Rotational modulation
- Absence of power excess
- Flares: 15 super flares.
- Multiple periods



Evolutionary phase based on spectra:

$\Delta\Pi_1$=187 s and $\Delta\nu$ = 4 μHz

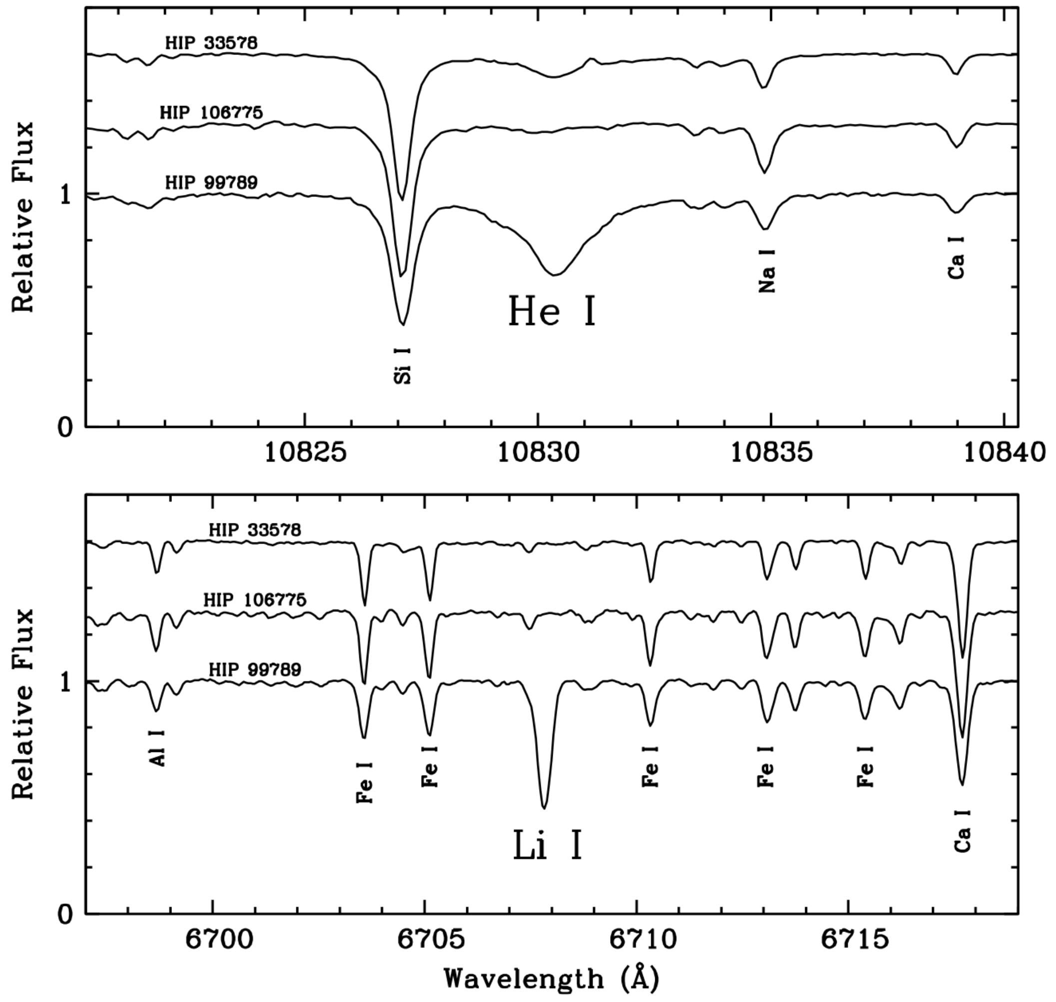
Primary RC star

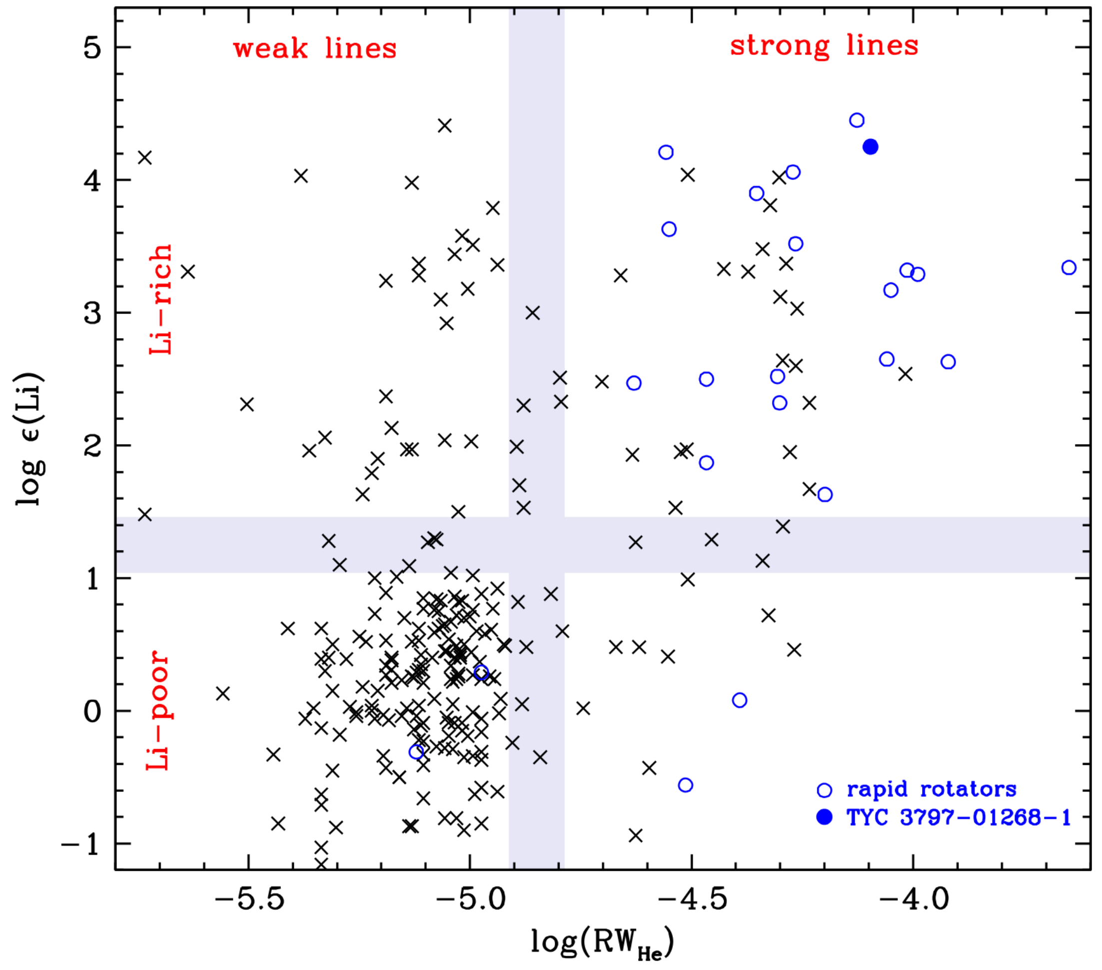
For R = 11.69 $R_\odot$, V = 2 π R/P = 20 km s^{-1}

$D_{mix} = 10^{11}\ cm^2\ s^{-1}$

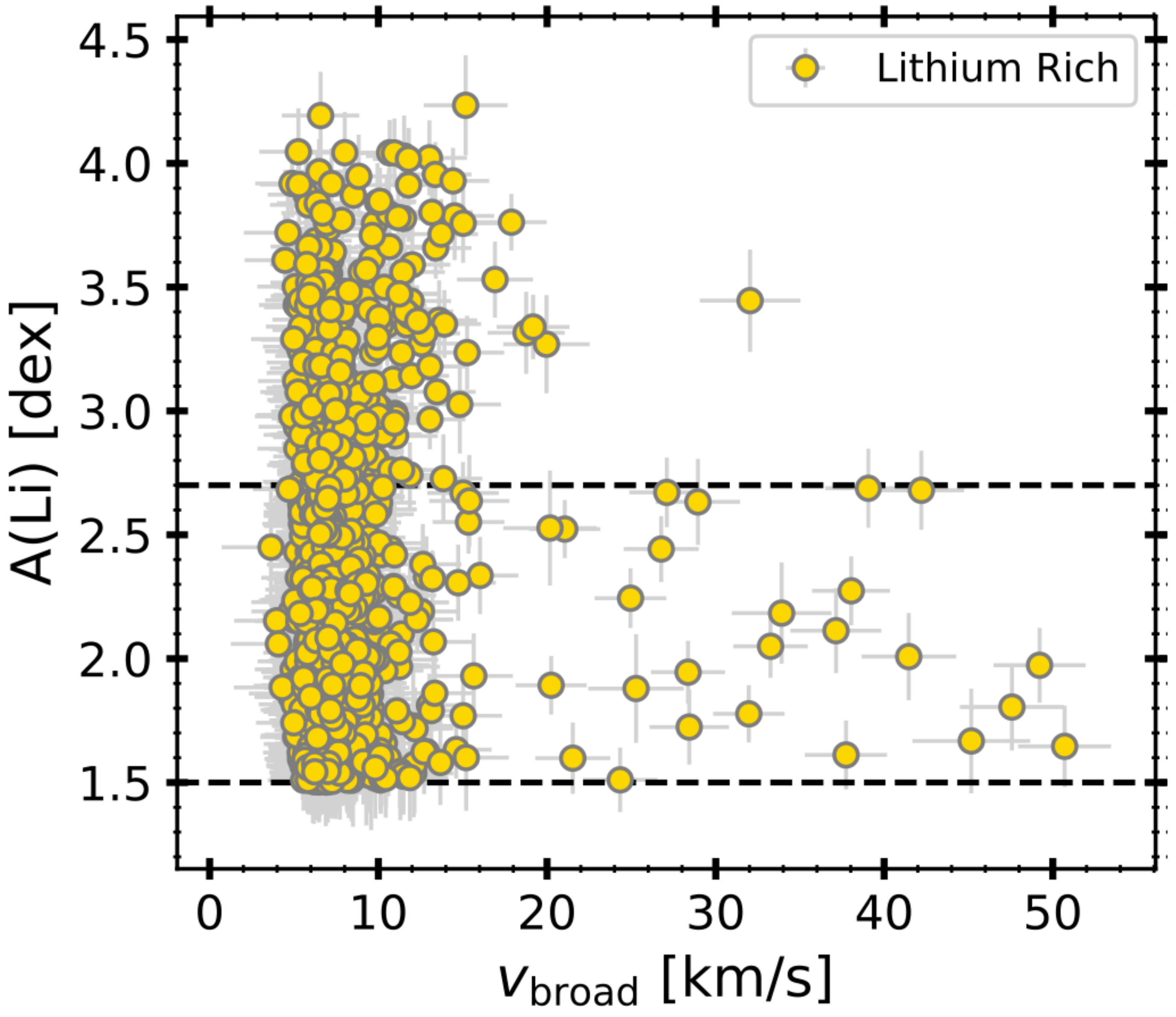
Denisenkov et al. 2004

Stellar activity in Li-rich giants:





Sneden et al. 2022



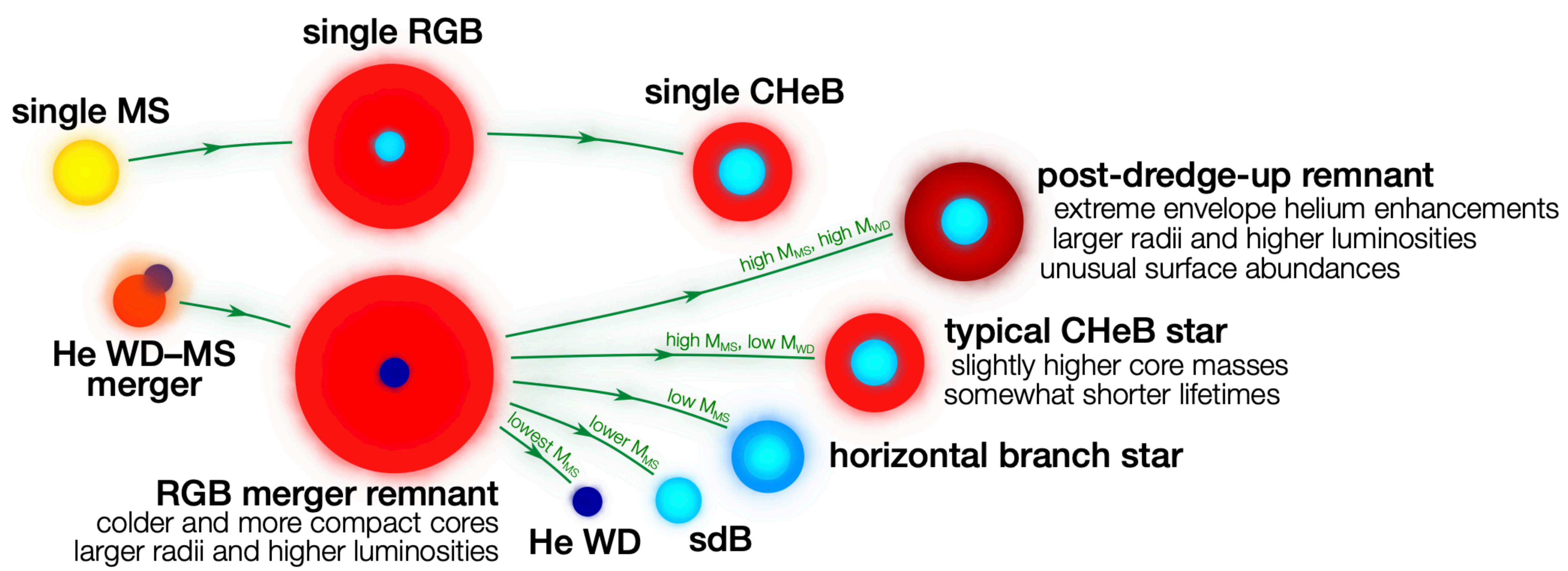
Frequency of rapid rotation in LiRG is twice than Li normal stars.

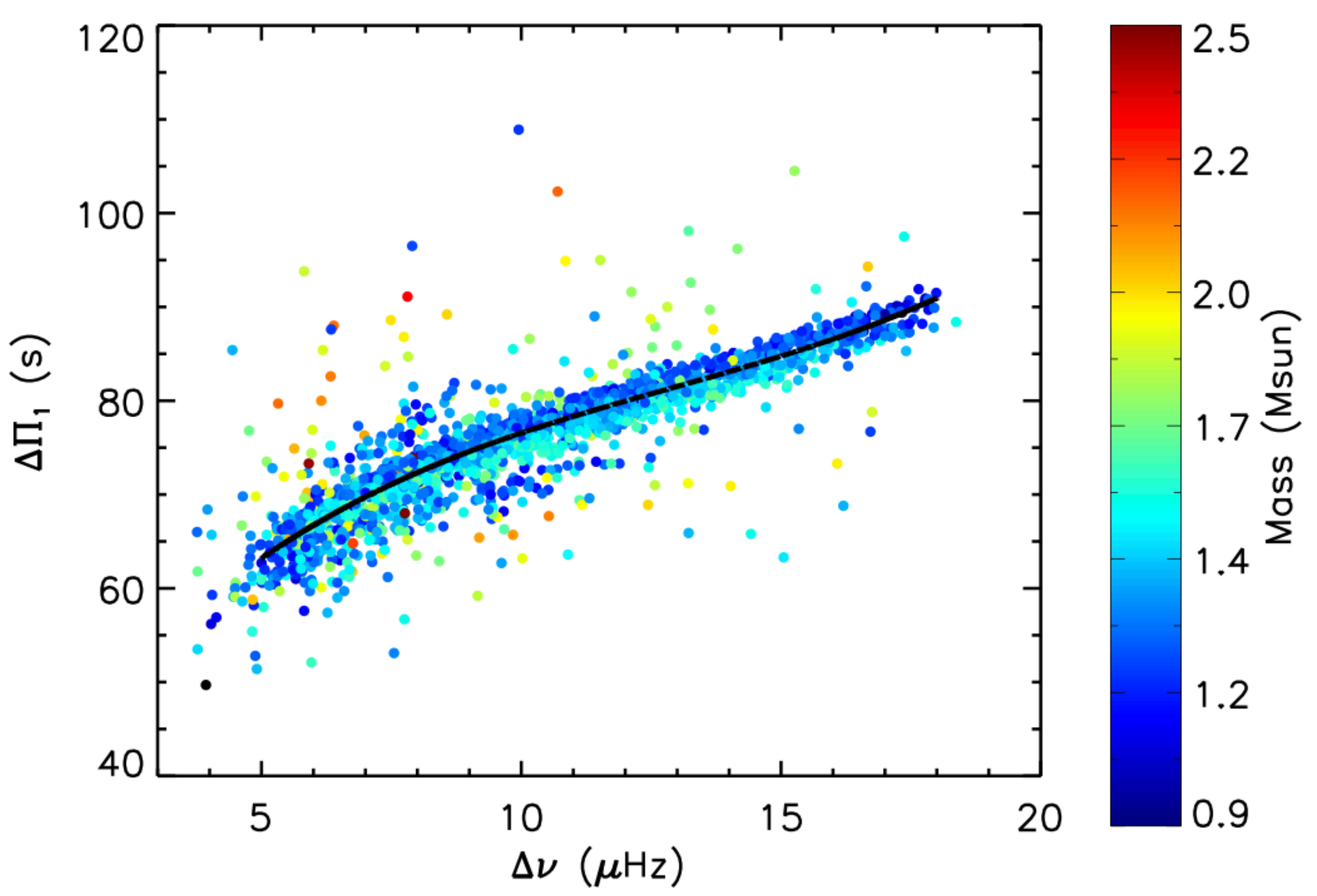
Sayeed et al. 2024

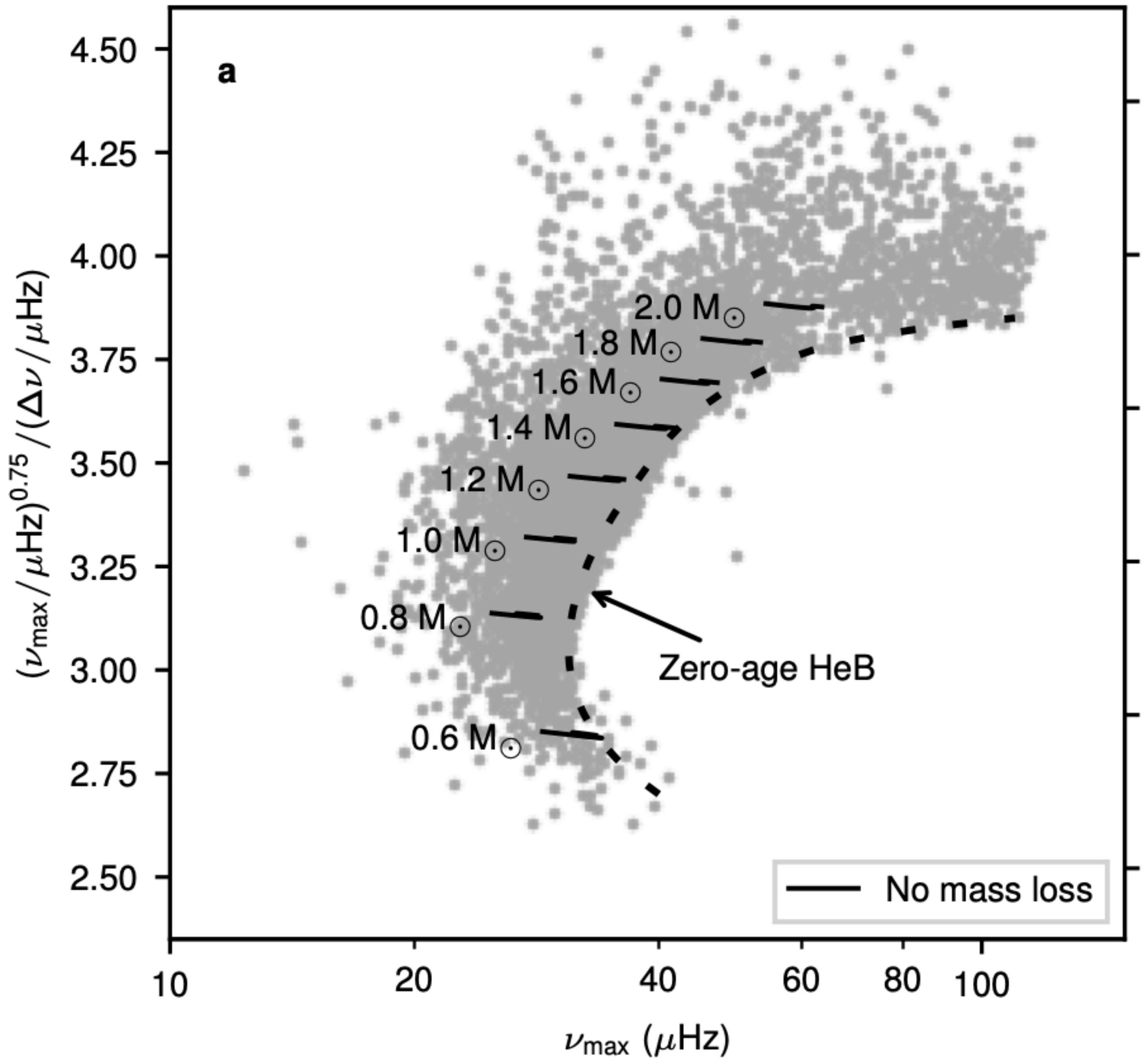
Binary fraction is same in LiRG and Li normal Stars.

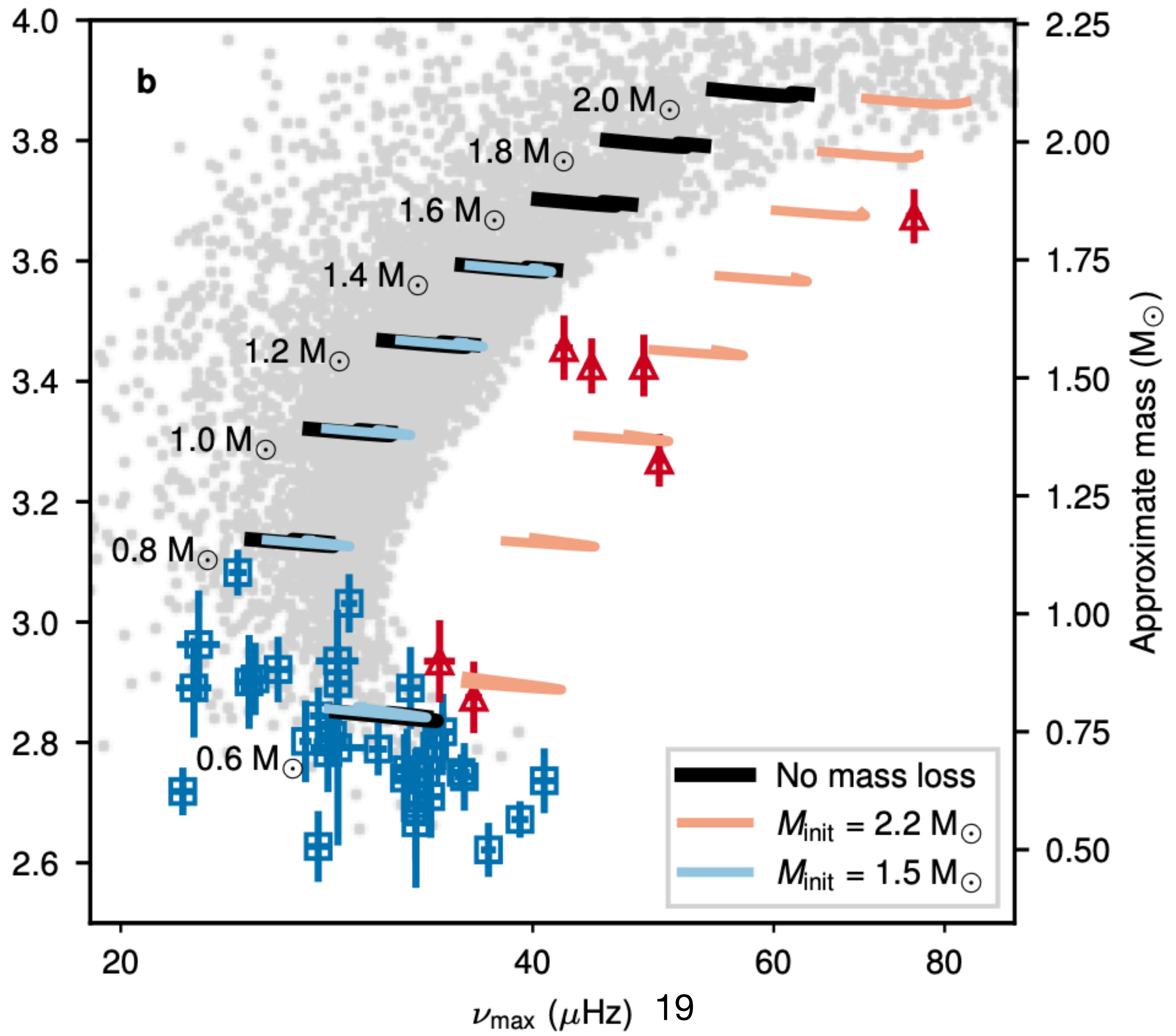
Castro-Tapia et al. 2024

Identification of Post merger stars merger stars:









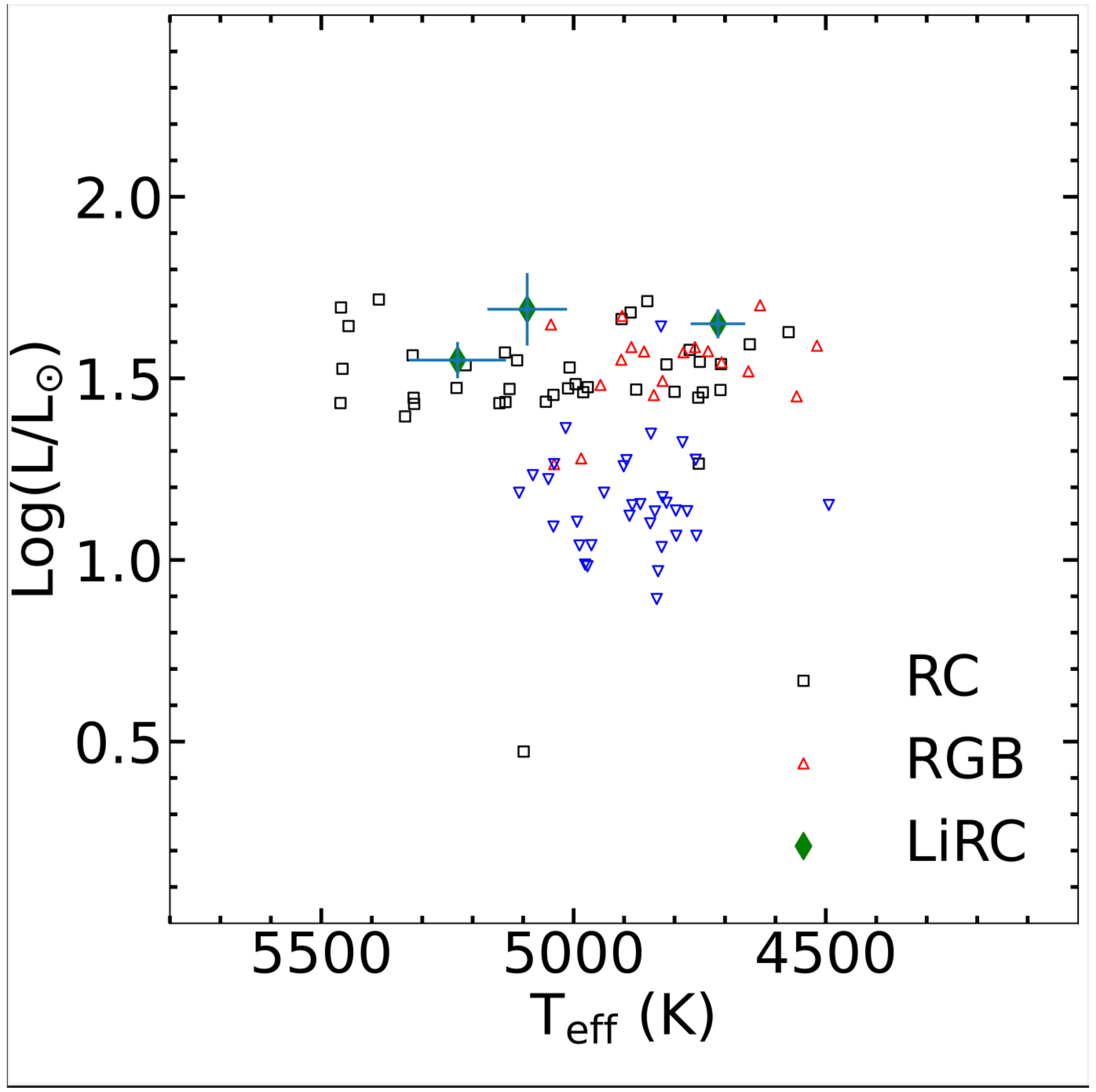
Credit:

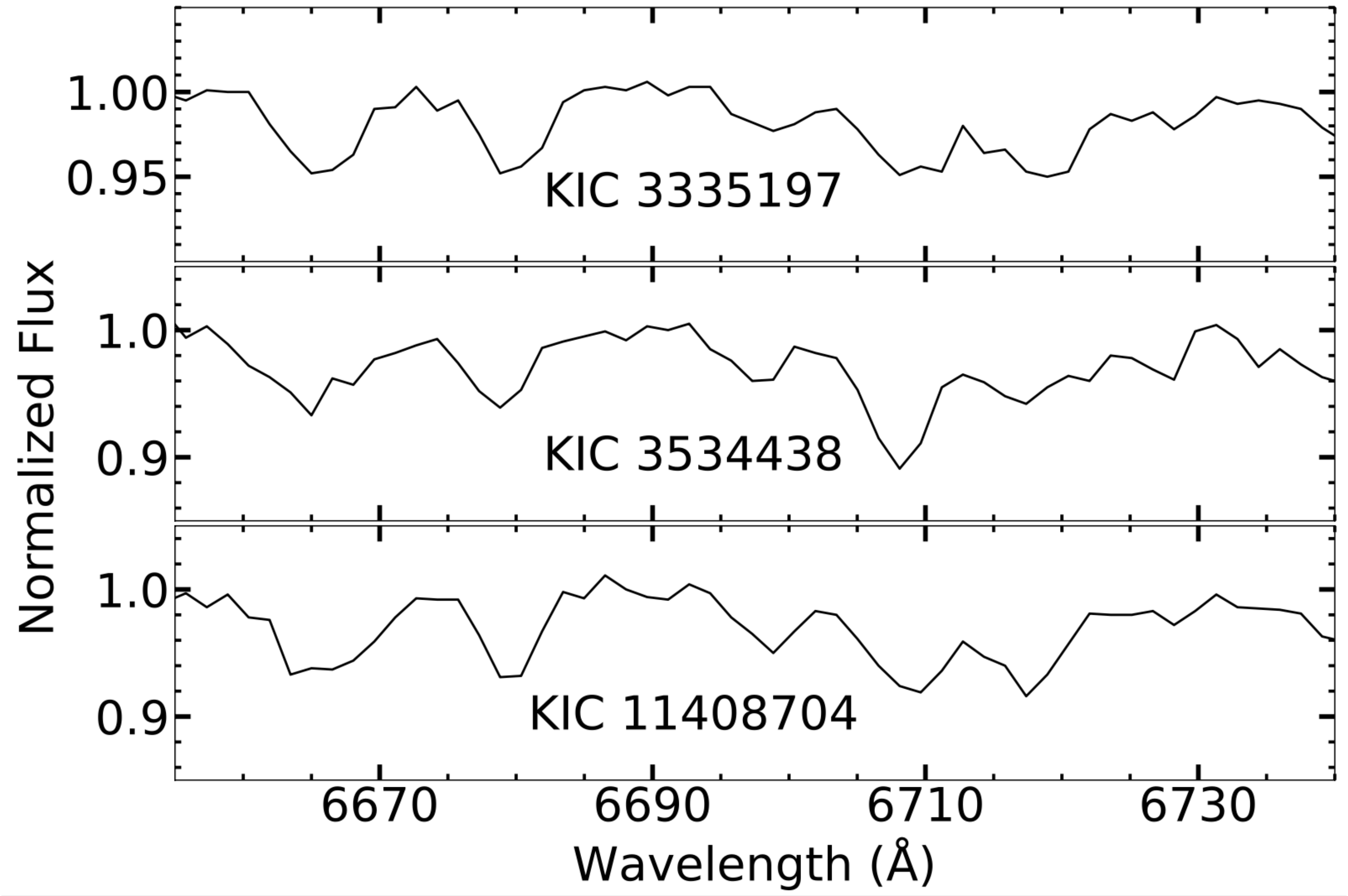
Li et al. 2022

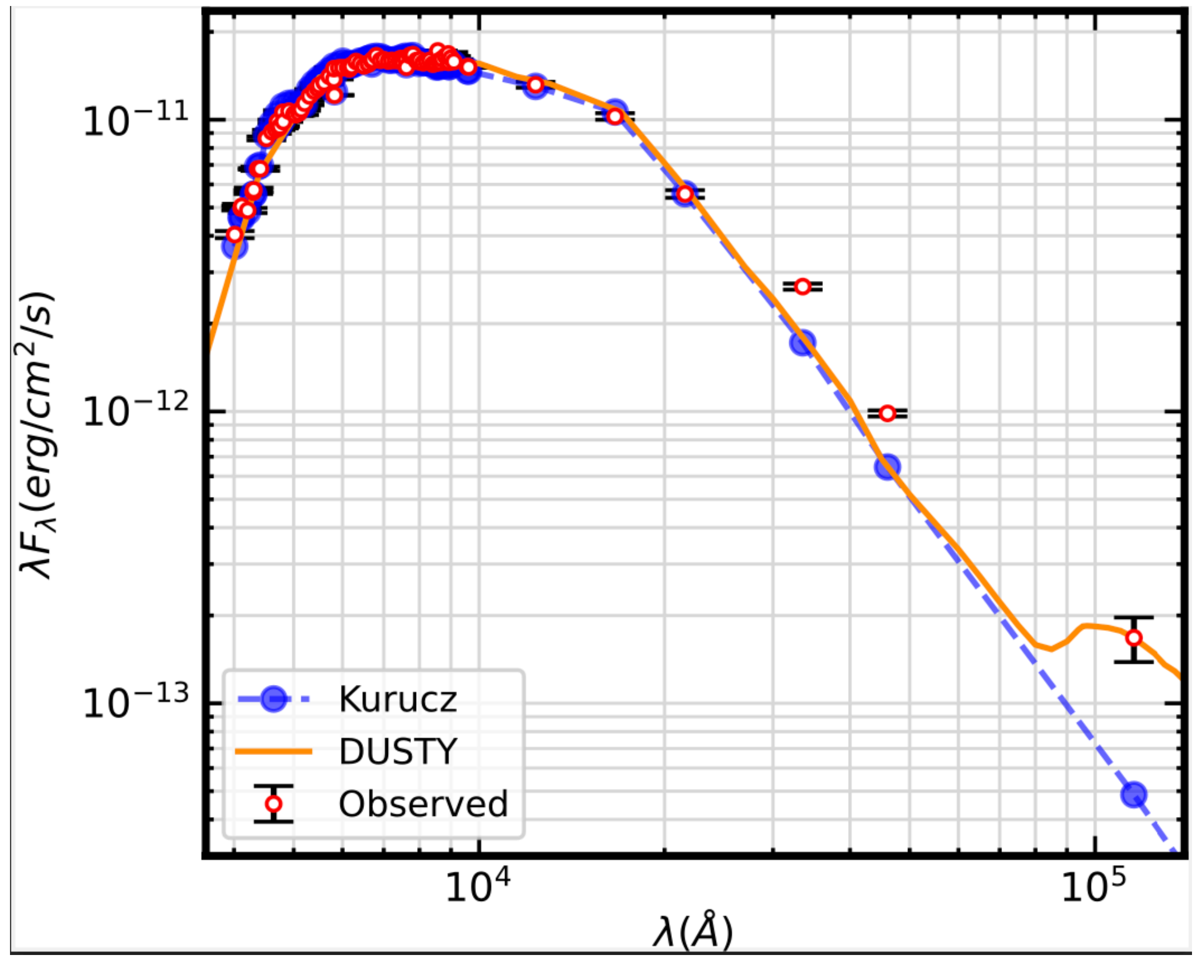
Deheuvels 2022

Rui and Fuller 2024

Li-enrichment in post mass transfer stars:

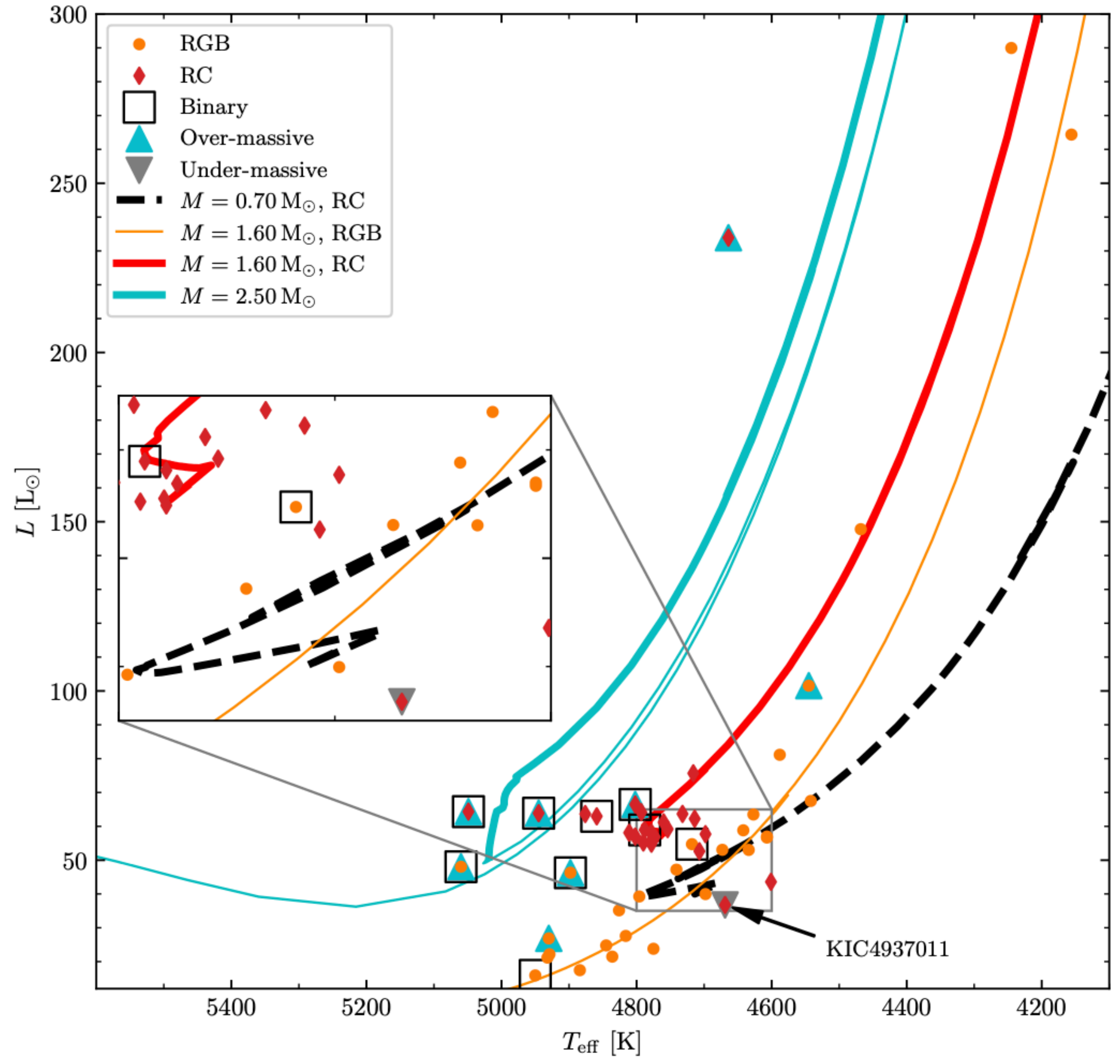






Stellar clusters can be site

KIC4937011, A(Li) = 2.3 dex)



Star with highest A(Li), KIC3534438, has IR excess as well as high rotation (P =16 ± 0.2 days).

15 % of post mass transfer RC stars are Li enriched.

NO RGB post mass transfer star with excess Li.

NGC 6819, Metteuzzi+2024

Summary and future plans:

- Evolutionary phase of Li-rich giants. Most of LiRG are core He burning stars.
- LiRG are young RC stars and Li abundance is evolving rapidly in RC phase.
- Rotation: one of the source of mixing.
- High rotation caused by binary interaction; can induce mixing.
- We plan to extend this work in TESS field, to constrain A(Li)-$\Delta\Pi_1$, increase sample of LiRG with rotation and sample of post mass transfer stars.

Thank you for your attention!