2nd LAMOST-Kepler Workshop

Exploring the early evolution of the Milky Way with LAMOST

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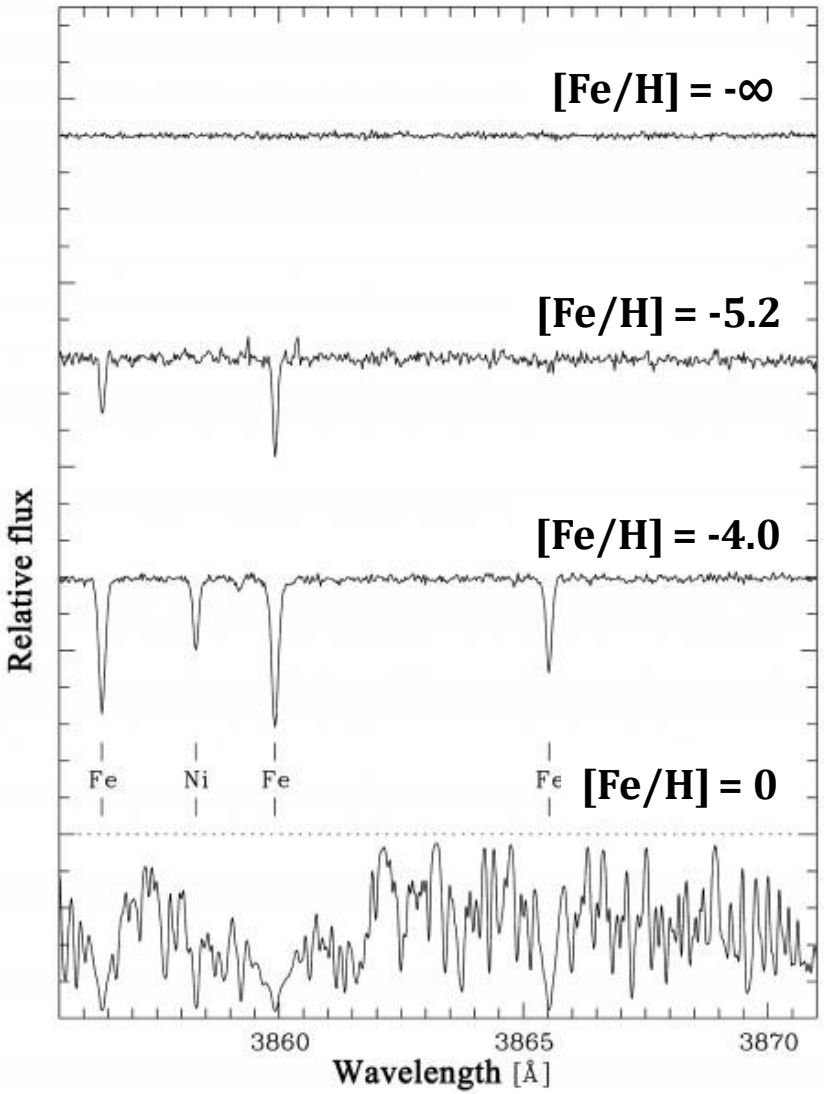
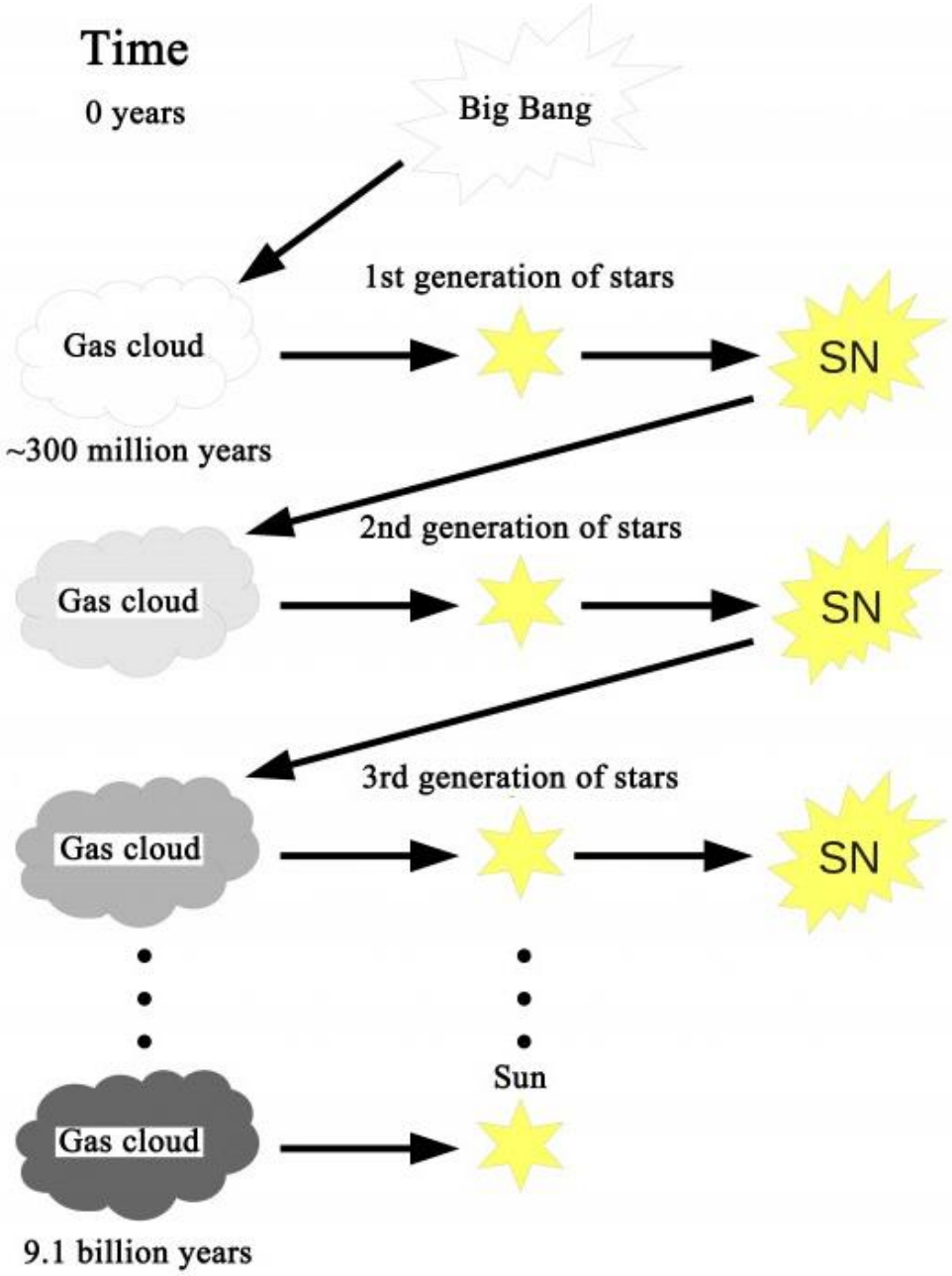
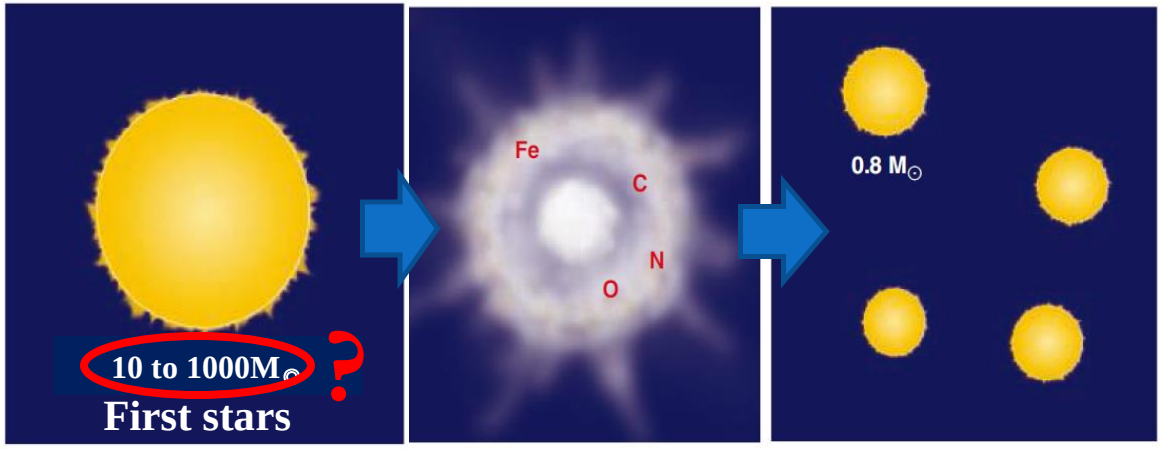
Metal-poor stars



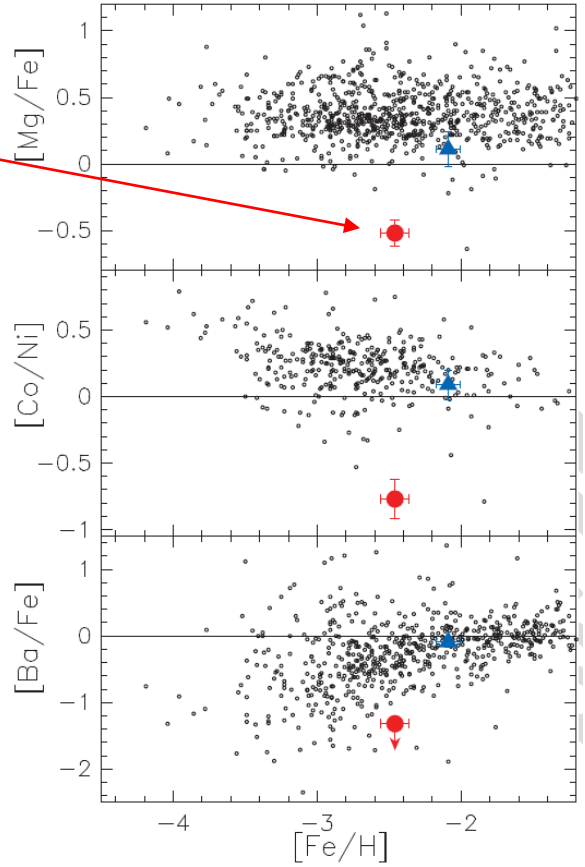


https://www.4most.eu/cms/surveys/galactic/

Metal-poor stars:
investigate the nucleosynthesis and chemical evolution



- The chemical compositions of metal-poor stars are fossil records of the nucleosynthesis of single (or a few) process.
- Comparison with chemical evolution models based on statistics of metal-poor stars.
- **Controversy in formation and evolution of First stars: can we find low-mass (< 1M$_\odot$) first star in the halo or bulge?**



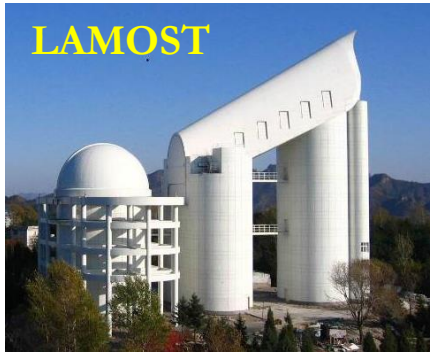
Aoki et al. (2014)

yields of a supernova of a very massive (>100M$_\odot$) star

Metal-poor stars:
searching status

- Survey projects
  - HK survey (1978), Hamburg/ESO Survey (1990)
  - RAVE (2003), SDSS/SEGUE (2004)
  - SkyMapper (2014), Pristine CaHK Survey (2015)
  - APOGEE (2011), 4MOST (2018)
- High-resolution follow-up
  - 6-10m telescopes (Magellan, Subaru, Keck, etc.)
- Number of the confirmed still limited
  - [Fe/H] < -3.0 (extremely metal-poor) : ~ 300
  - [Fe/H] < -4.0 (ultra metal-poor): 21(+3)
  - [Fe/H] < -5.0 (hyper metal-poor): 4 (+1)

Metal-poor stars:
LAMOST-Subaru collaboration



- High-resolution spectra are demanded to really understand the nature and origin of metal-poor stars
- LAMOST+Subaru joint searching project since 2014
- Joint proposal for Subaru open-use program
  - Normal + Service + Intensive (2016.04-2018.01)
- CAS-JSPS joint project (2016.04-2019.12)
- Follow-up with Subaru/HDS runs (on-going)
  - **Over 300 VMP/EMP stars**
  - **A dozen Li-rich very metal-poor stars**
- A number of refereed papers published

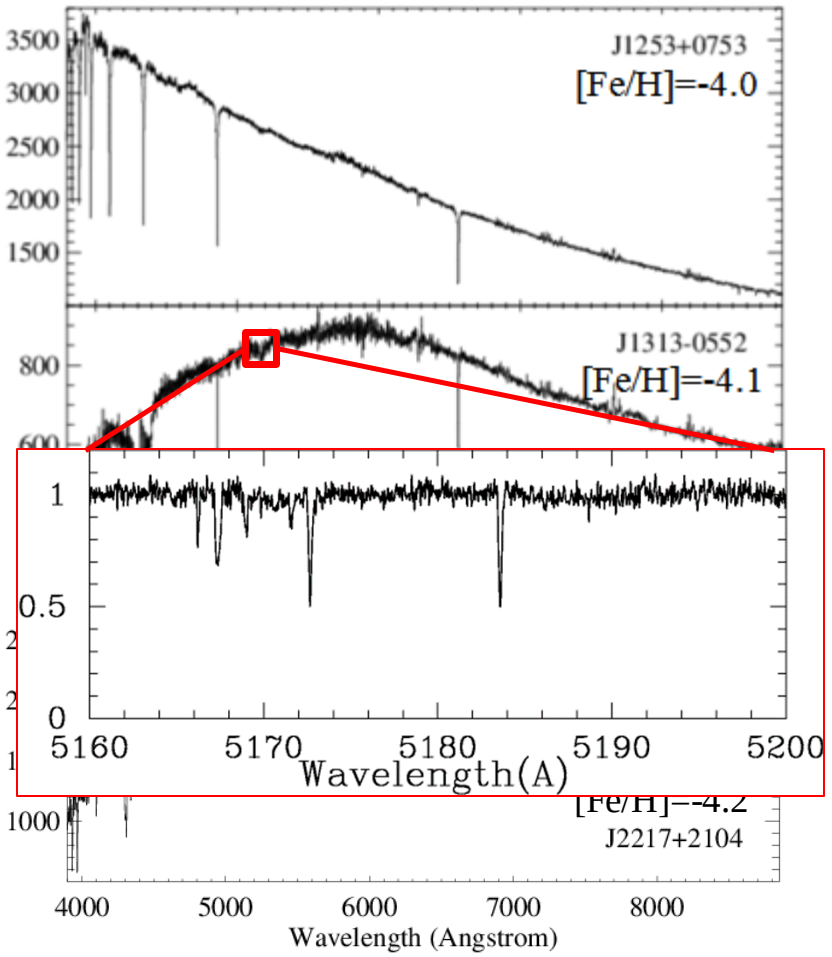
Large sample of very metal-poor

- More than 500 very metal-poor candidates have been selected from LAMOST

low-resolution spectra

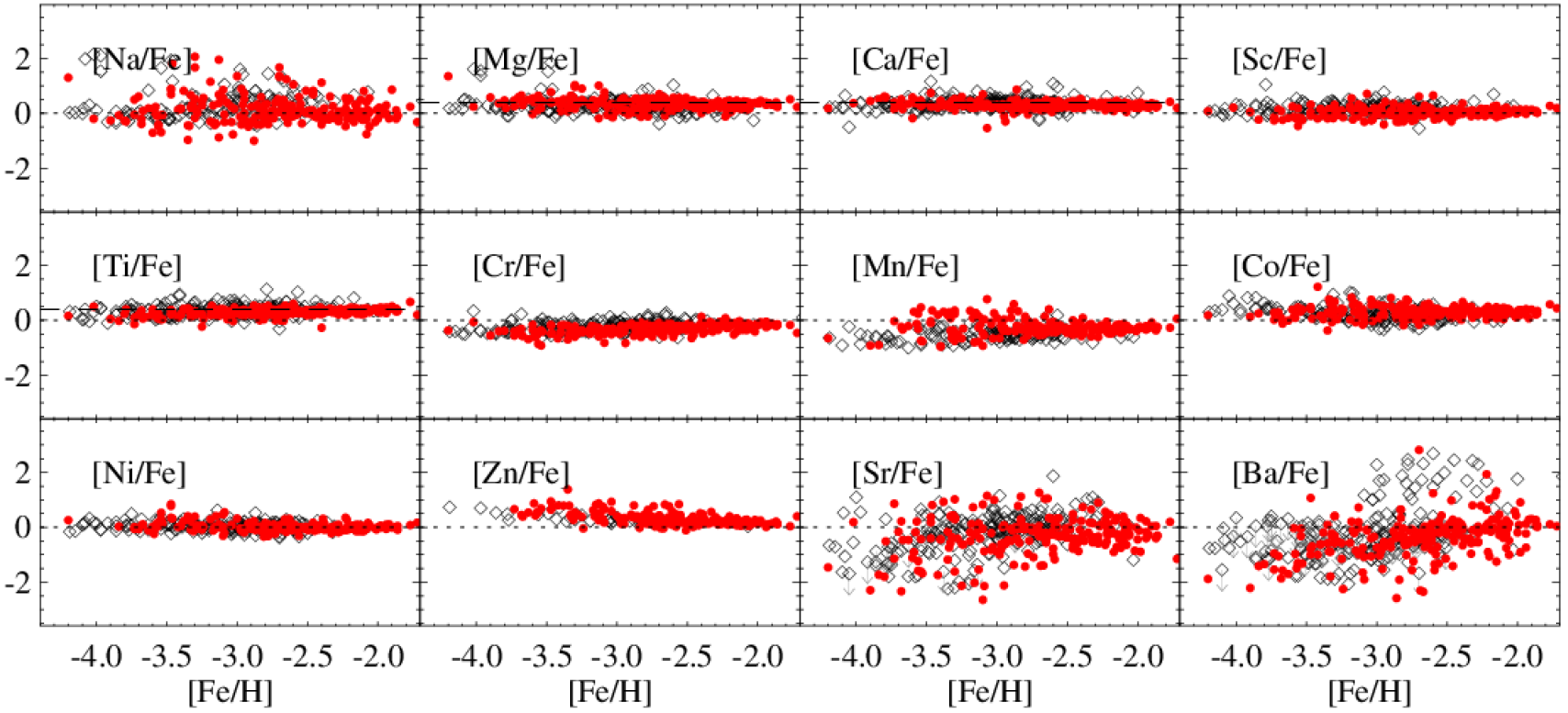
high-resolution spectroscopy

- Follow-up for ~300 stars with six Subaru/HDS runs
  - Searching efficiency > 90% for VMP stars

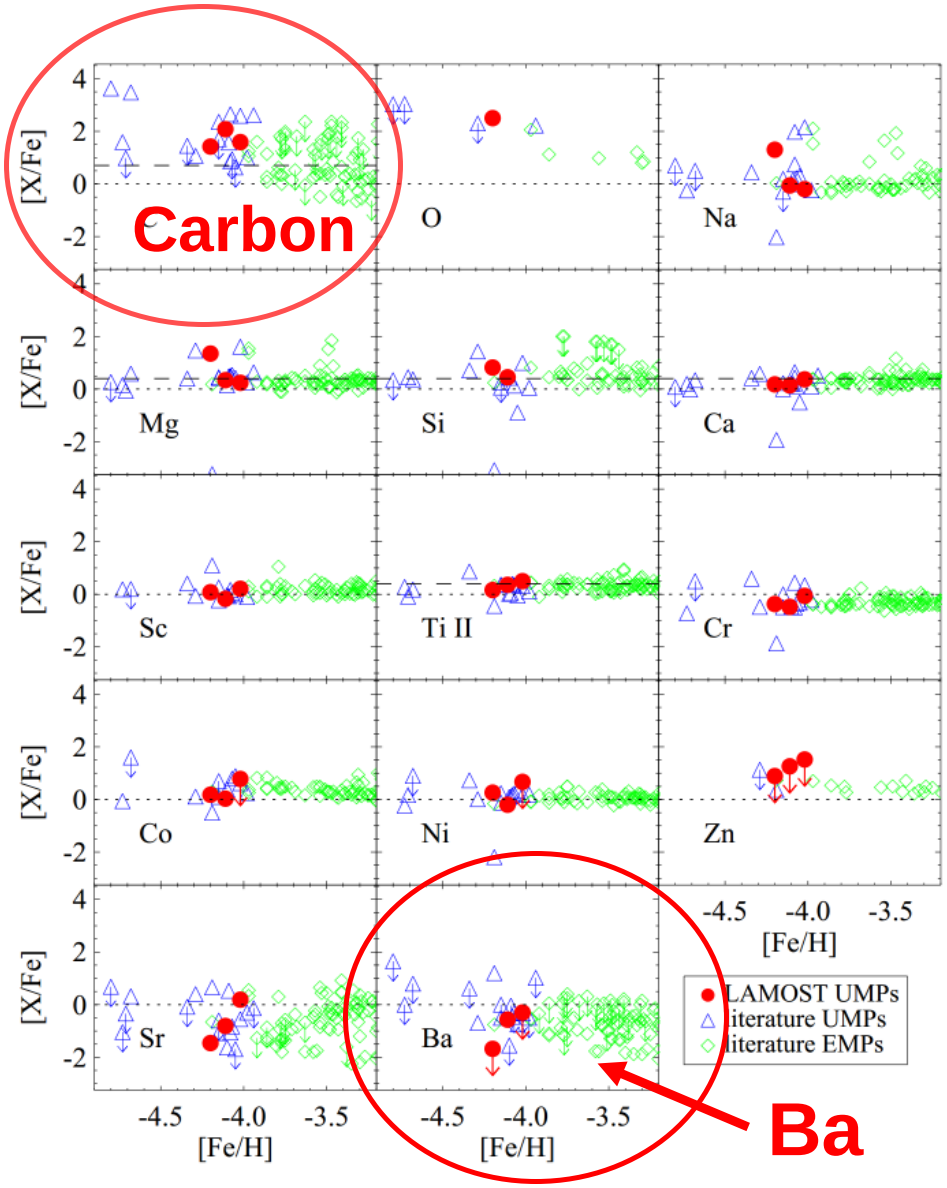


Large sample of very metal-poor stars:
Abundance pattern

- Abundance pattern of about 250 VMP stars
  - Largest uniform VMP sample to date
  - consistent with previous sample (with smaller scatter)



Large sample of very metal-poor stars:
New ultra metal-poor stars



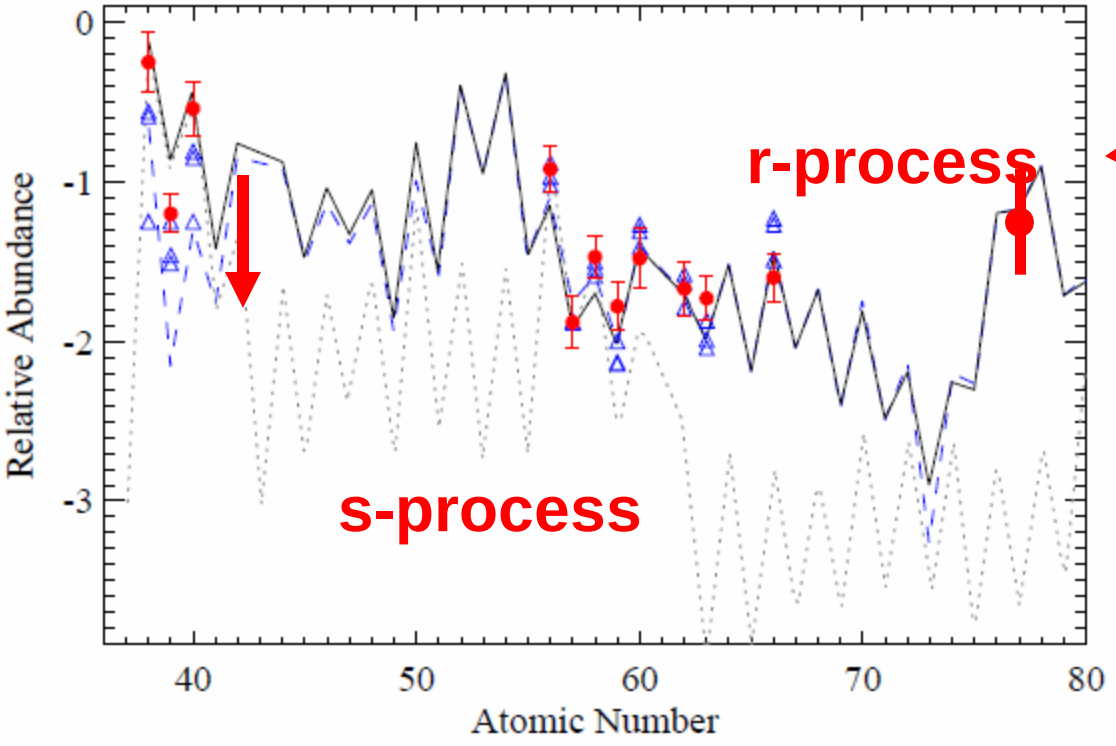
- All are CEMP-no stars with low [Sr/Fe] and [Ba/Fe]: no significant contribution from s-process
- Follow the general trend: a dominant "normal population" at low metallicities.

Large sample of very metal-poor stars:
New r-rich metal-poor stars (r-II stars)

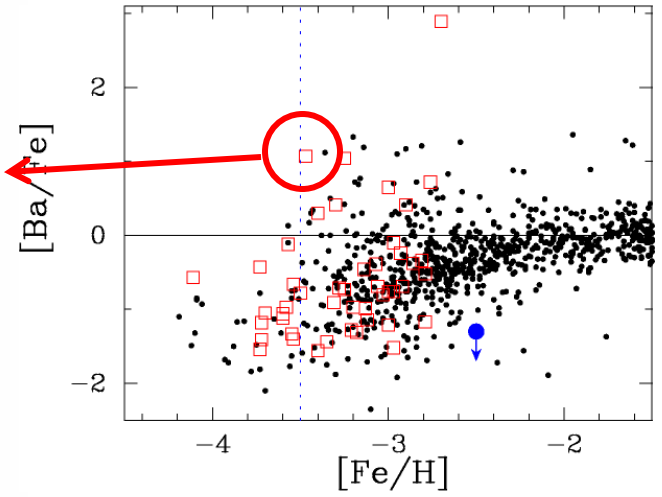
Bright object ($g \sim 12$)

[Fe/H]=-3.4, [Eu/Fe]=+1.2, [C/Fe]= -0.57

New r-II star with the lowest Fe and C



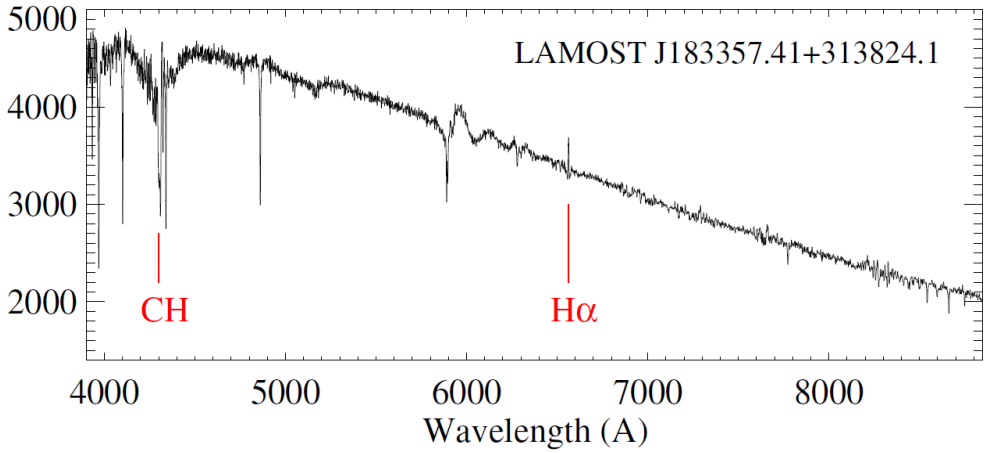
Li et al. (2015b)

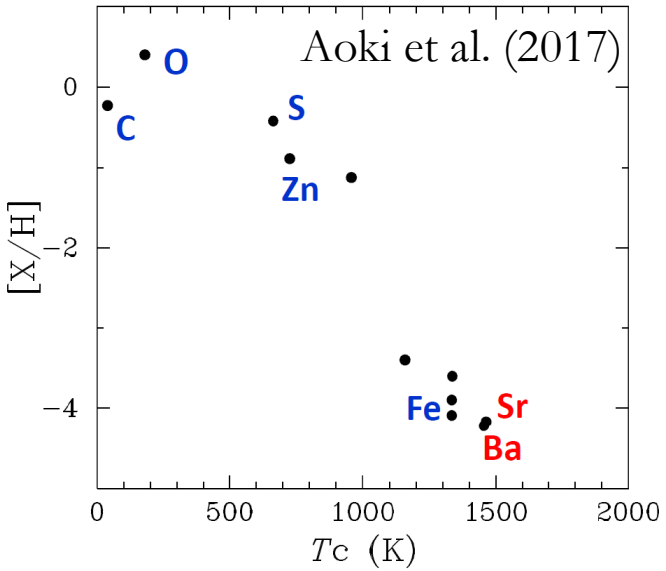


UV spectrum obtained and analysis ongoing

Large sample of very metal-poor stars:
Revisiting metal-poor post-AGB CC Lyr

- Rediscovery and detailed abundance analysis of CC Lyr
- First detection of low Sr and Ba

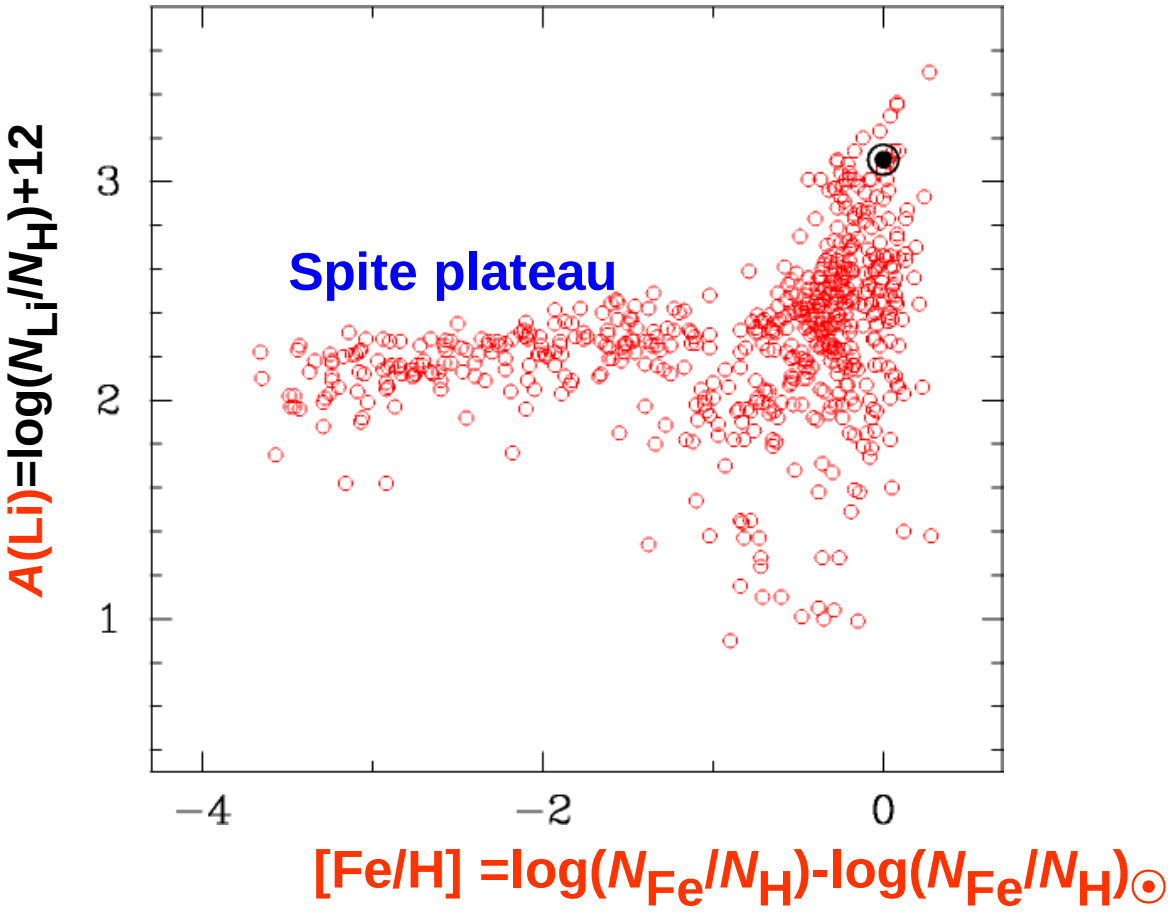




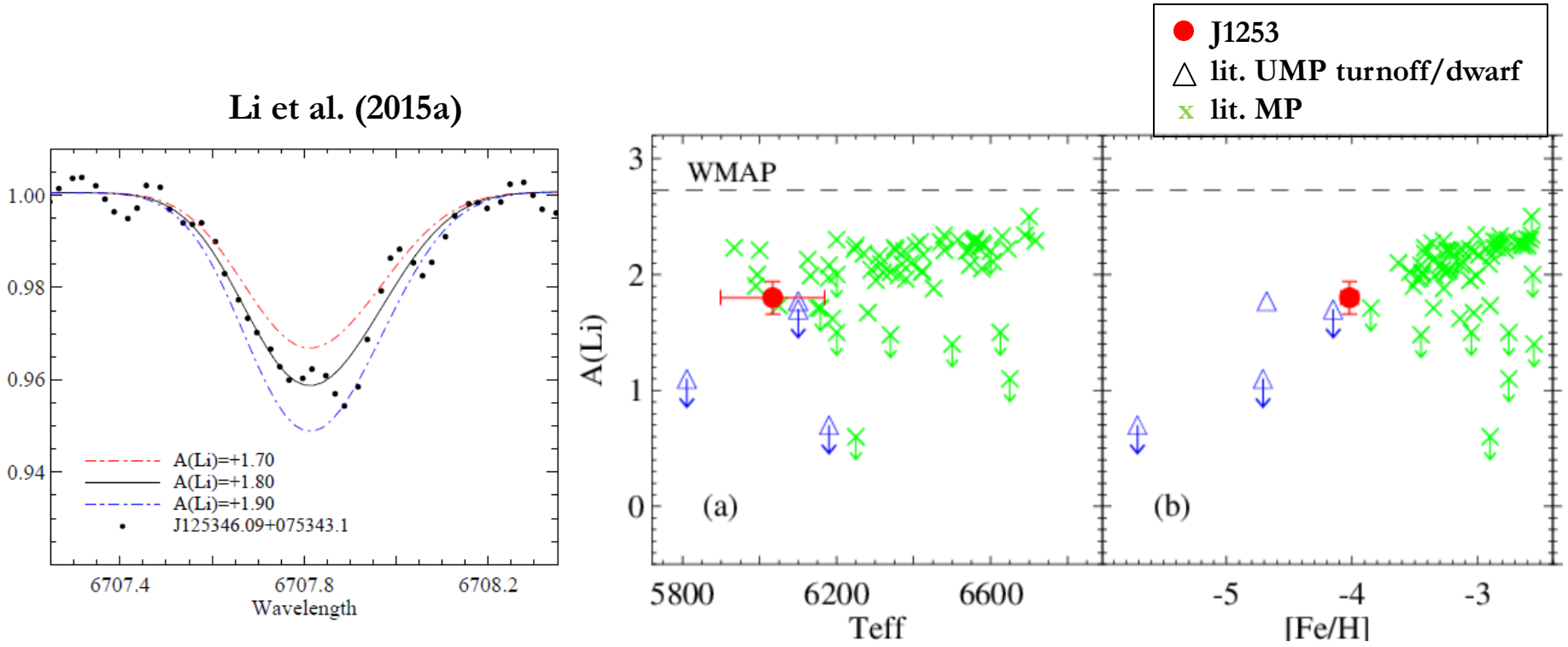
- Clear correlation between abundance ratios and the condensation temperature indicates that dust depletion is the cause of its abundance anomaly
- Contribute to the understanding of the late phase of low-mass star evolution

Li in very metal-poor stars:
Spite plateau of warm metal-poor stars

- Li abundances in metal-poor stars before evolving to red giants are nearly constant → **Spite plateau**

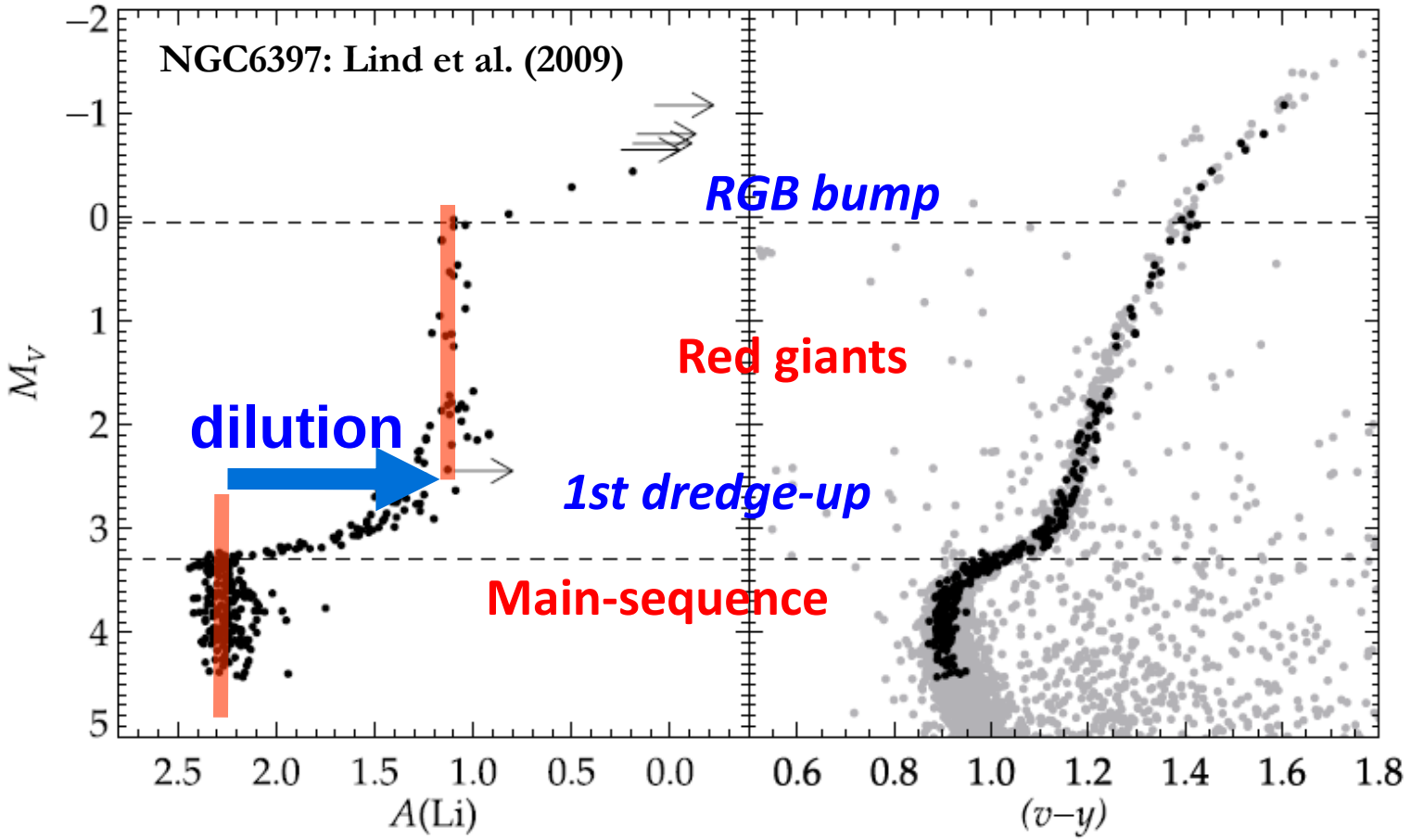


Li in very metal-poor stars:
Lithium in ultra metal-poor turnoff star



- A(Li) = 1.80: lower than the Li plateau (A(Li) ~ 2.2)
- Unique evidence for the "meltdown" of Li plateau at extremely metal-poor region

Li in very meta-poor stars:
Evolution of Li in low-mass stars

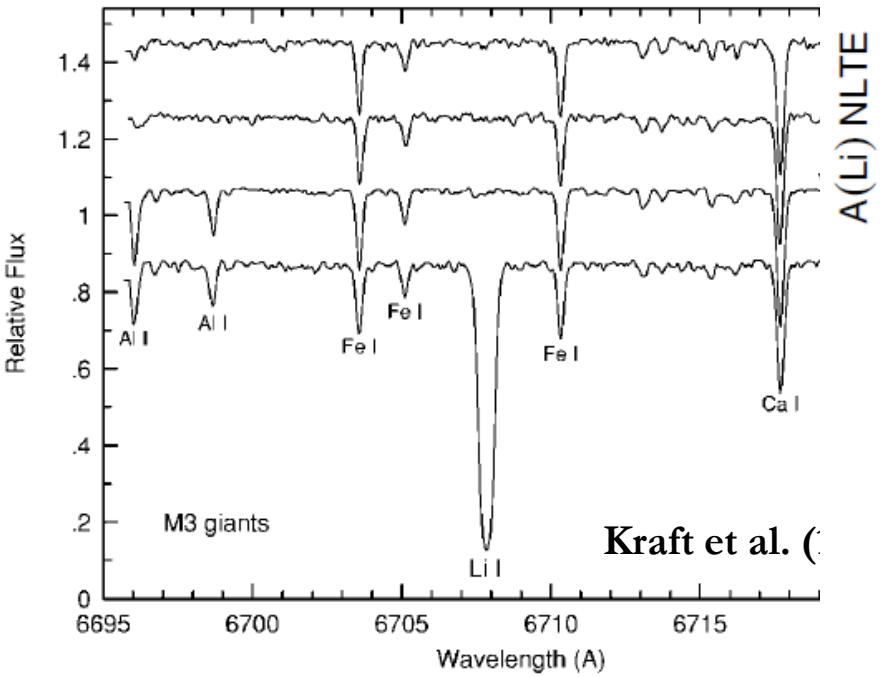


Li in very meta-poor stars:
Li-enhanced low-mass stars

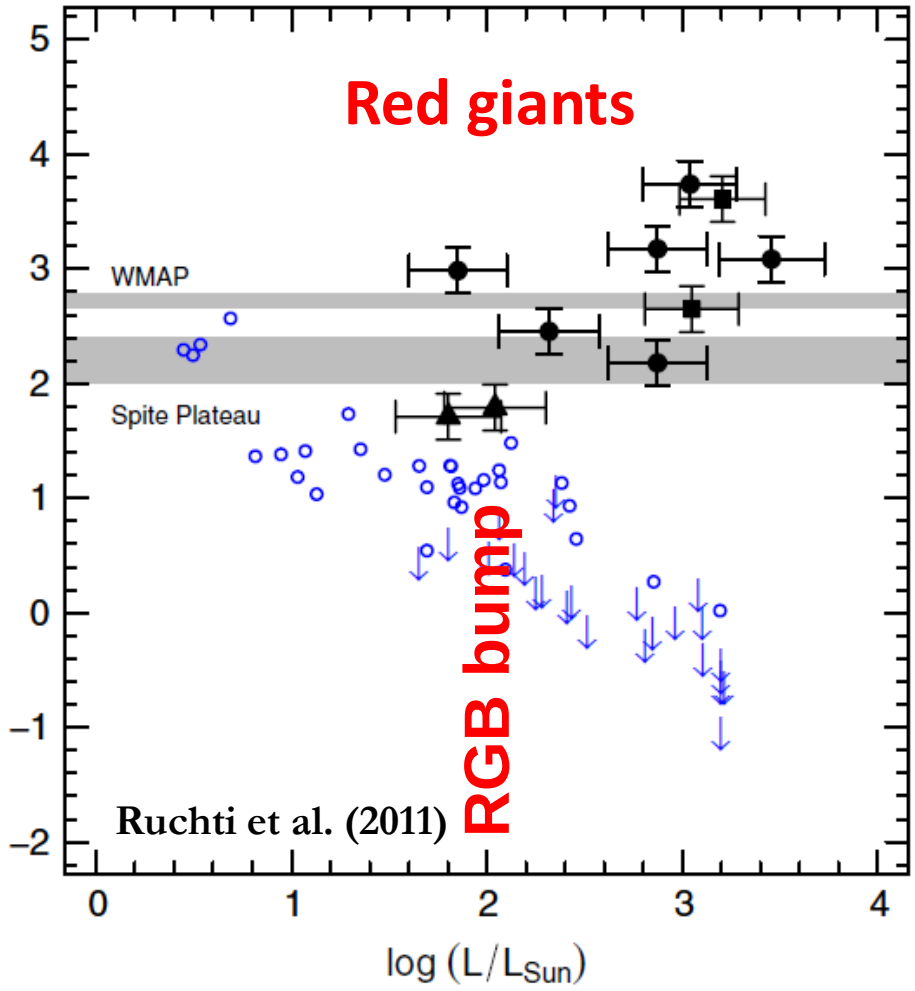
Rare cases, but significant excess

Li-rich stars found by RAVE:

- highly evolved red giants
- Frequency is about 1%



red giants in globular clusters



Field red giant

Li-rich very metal-poor stars:
Formation scenarios proposed but not established

Extra mixing for "Cameron-Fowler mechanism"

- at RGB bump / Clump/ Horizontal branch

  … but Li-rich stars distribute widely in HR diagram

Engulfment of a companion (planet etc.)?

- supply of Li by the companion

  … amount sufficient?

- increasing rotation rate

  … but no signature of high rotation in Li-rich stars

Mass transfer across a binary system?

- accretion of Li-rich material from an AGB/RGB companion

  … possibly, but how is binary frequency?

Summary and prospect

- Large sample of very metal-poor stars observed with LAMOST survey and Subaru follow-up
  - ultra metal-poor stars, r-rich stars
  - twelve new Li-rich very metal-poor stars including 5 warm subgiants before evolving to red giants
- Homogeneous abundance data for 500 very metal-poor stars will be obtained by early 2018
  - chemo-dynamical studies combined with Gaia DR2
- Very metal-poor stars in the Kepler field would be very interesting to explore the nature of these objects

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THANKS