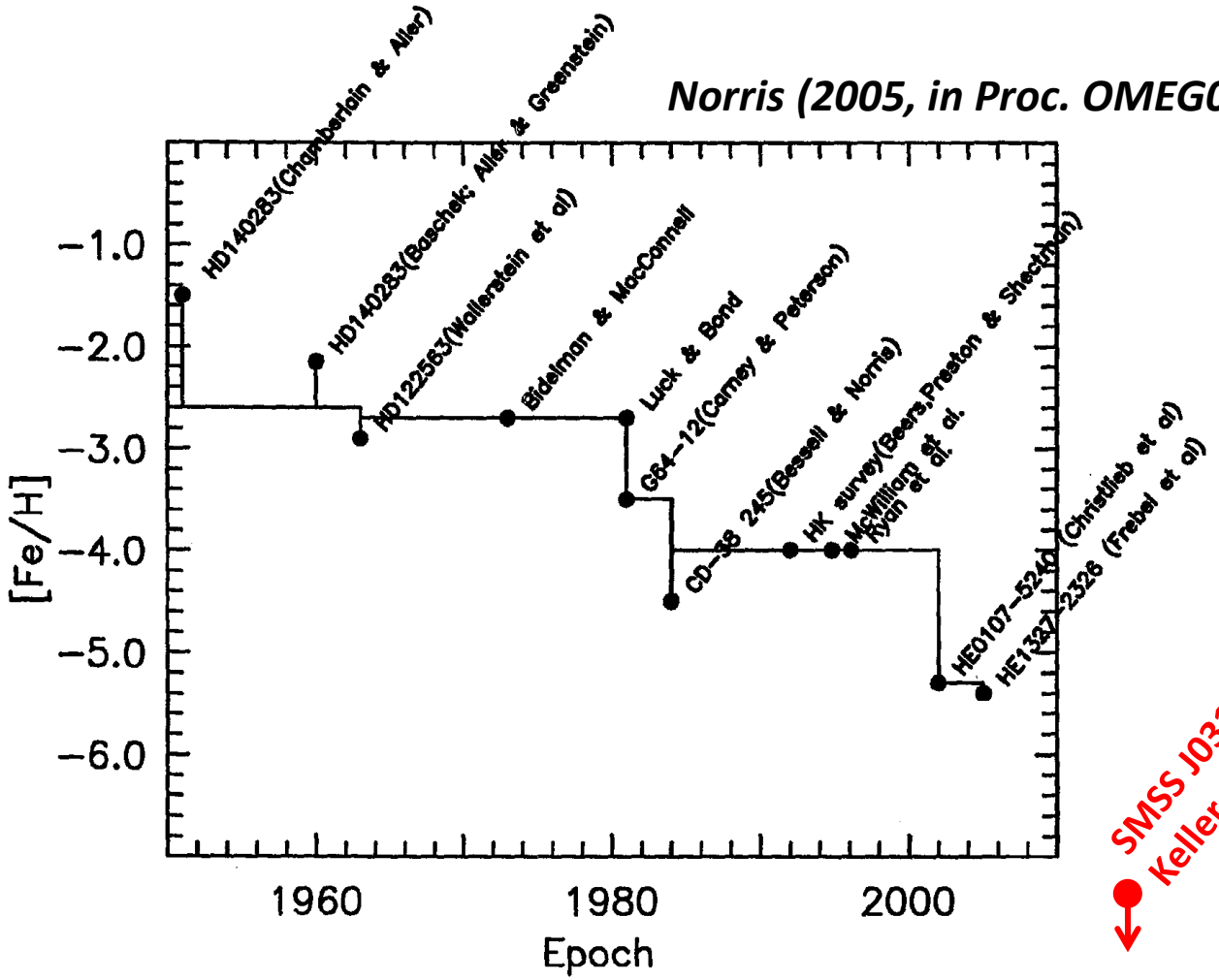
The 6th Subaru International Conference in Hiroshima
November 30, 2016

Spectroscopic approach to Galactic Archaeology with Subaru

Wako Aoki
NAOJ

Progress of searches for most metal-poor stars

Fe abundances (relative to the solar value)



Searches for metal-poor stars

cf. *Beers & Christlieb (2005, ARAA)*
Roederer et al. (2014, AJ 147, 136)

- **Bond (1981) "Where is population III?"**
  Bond (1970, 1980) Curtis Schmidt (Michigan)
  Bidelman & MacConnel (1973) Curtis Schmidt (CTIO)

- **Catalogue:**
  -Henry Draper (HD) e.g. HD122563 Honda et al. (2006)
  -Bonner Durchmusterung (BD) e.g. BD+44 493
  Ito et al. (2009,2013)
  -Córdoba Durchmusterung (CD) e.g. CD-38 245
  -Lowell Proper Motion survey (G) e.g. G64-12

Searches for metal-poor stars

- **HK survey (1980s-)**

  ***Beers et al. 1985, 1992*, etc.**

  -objective prism survey for Ca II H and K lines (R~800)

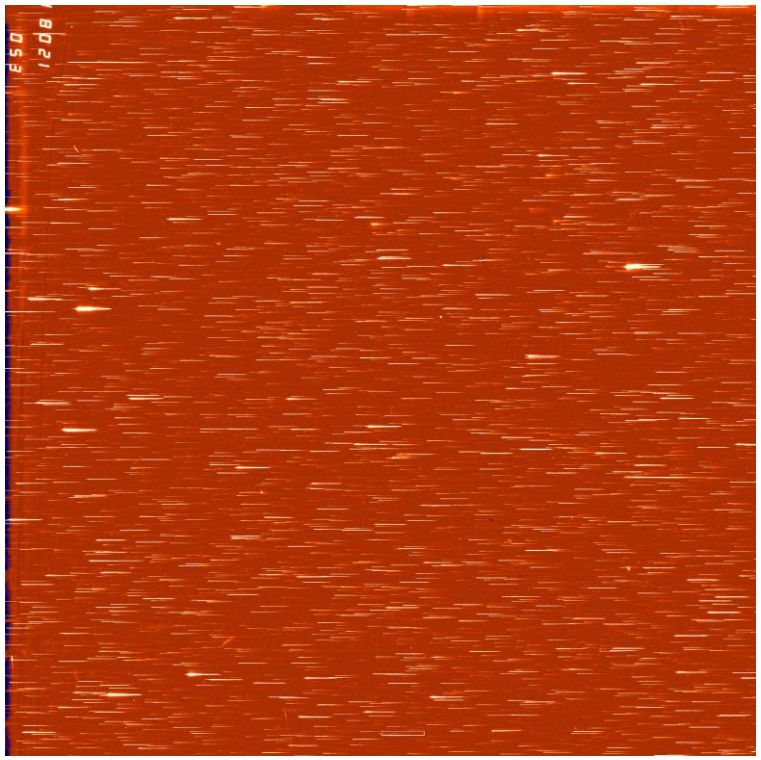
  -*B*~<15

Curtis Schemidt (CS) CTIO, e.g. BPS CS22892-052
Burell Schmidt (BS) KPNO, e.g. BPS BS16934-002

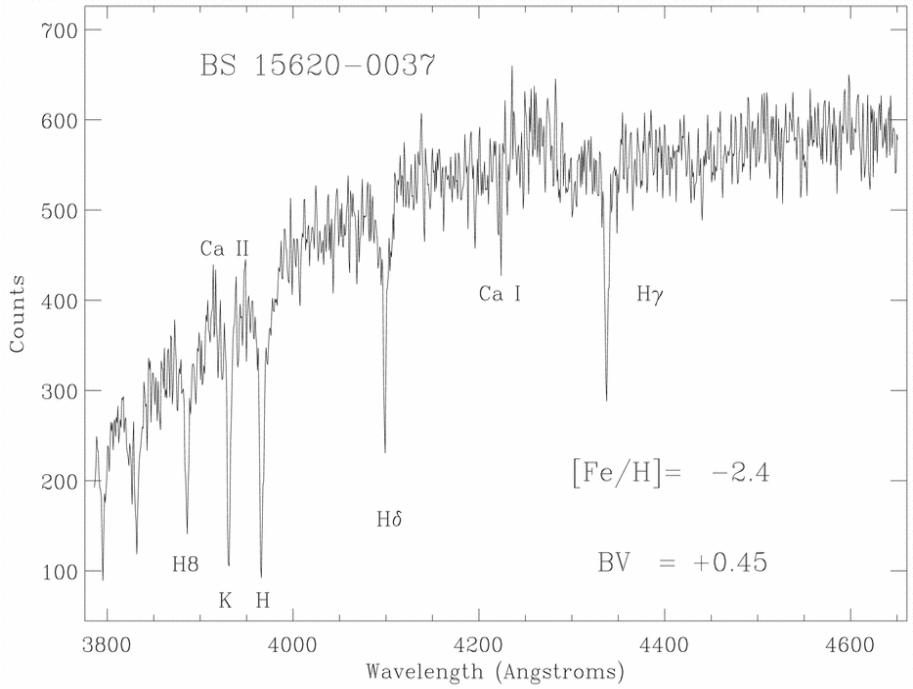
HK-II : re-analysis of the plates of HK survery

Objective prism survey of metal-poor stars (1980s～)

①wide-field spectroscopic survey



②follow-up medium resolution spectroscopy



Follow-up spectroscopy with Subaru/HDS for HK survey sample

- First Light of Subaru/HDS in 2000

Follow-up with Subaru/HDS (2000～)
Topics:
-r-process-enhanced stars (Honda et al. 2004)
-CEMP stars: s-process from CEMP-s, and establishing “CEMP-no” class (Aoki et al. 2002)

Searches for metal-poor stars

- **Hamburg/ESO survey (1990s-)**
  stellar content: *Christlieb et al. 2001* etc.
  → e.g. HE0107-5240 ([Fe/H]=-5.3, Christlieb et al. 2002)

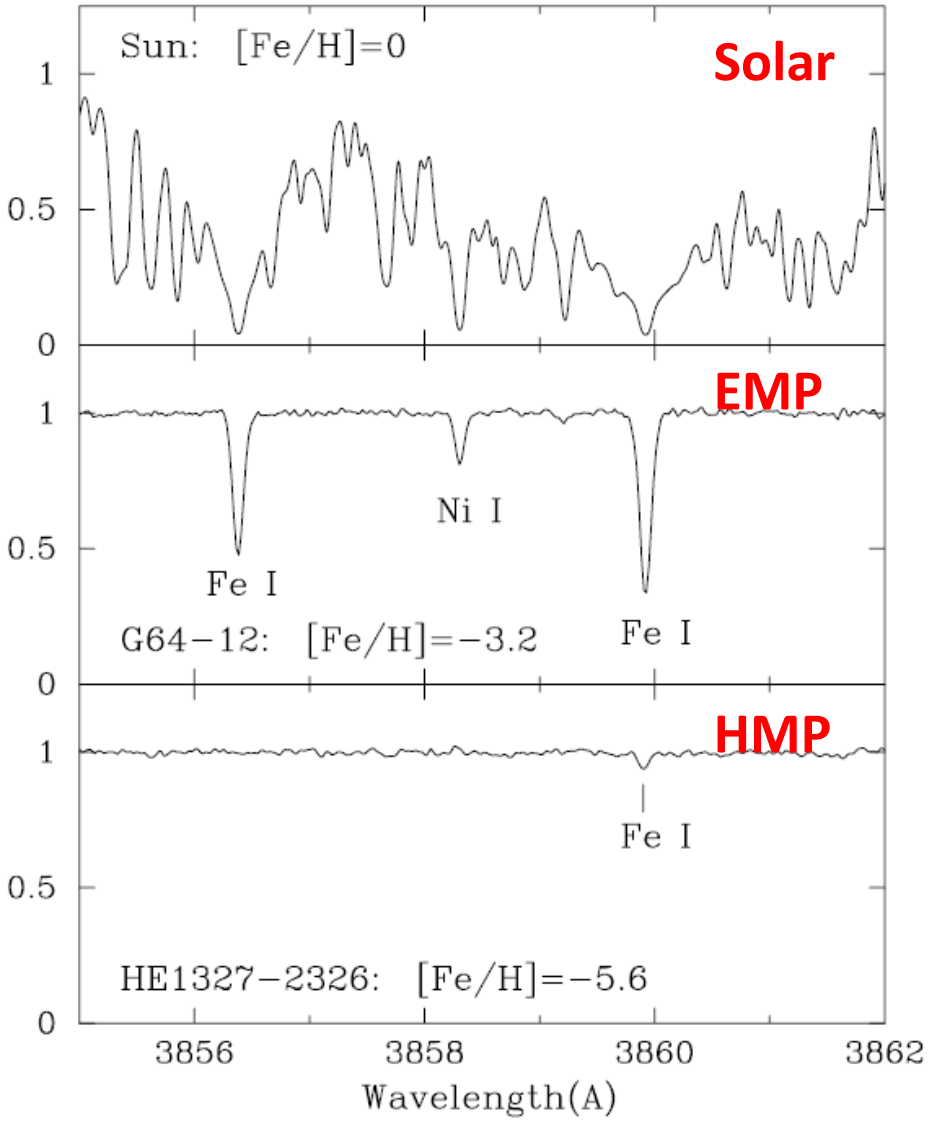
Follow-up with Subaru/HDS (2003～)
Topics:
- **most metal-poor stars (Frebel et al. 2005)**
- **CEMP stars (Aoki et al. 2007)**
- **Li (Aoki et al. 2009)**

The 2nd HMP star HE1327-2326

Frebel et al. (2005)

very weak Fe lines
→[Fe/H]=-5.4

detection of CH molecular bands
→excess of carbon

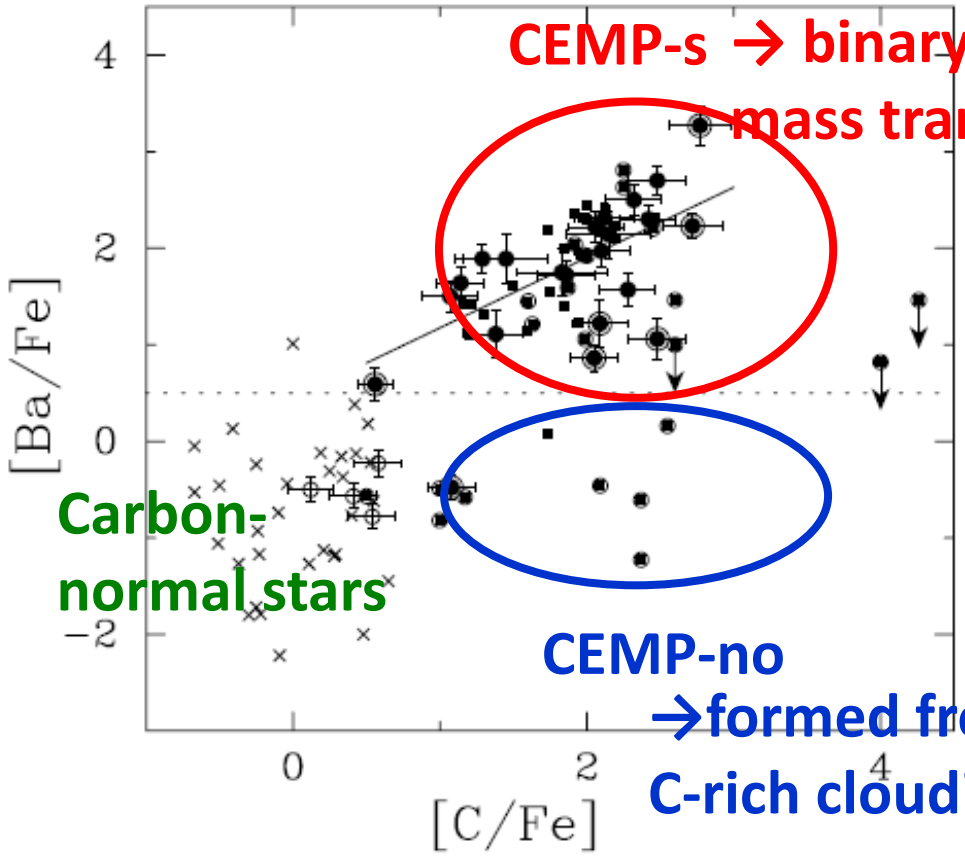


Origins of Carbon-Enhanced Metal-Poor stars (CEMP)

Aoki et al. (2007)

- Definition of CEMP
- Classification into CEMP-s (Ba-rich) and CEMP-no (Ba-normal)
- Metallicity and carbon-abundance distributions of CEMP-s and CEMP-no

... different origins of the two classes



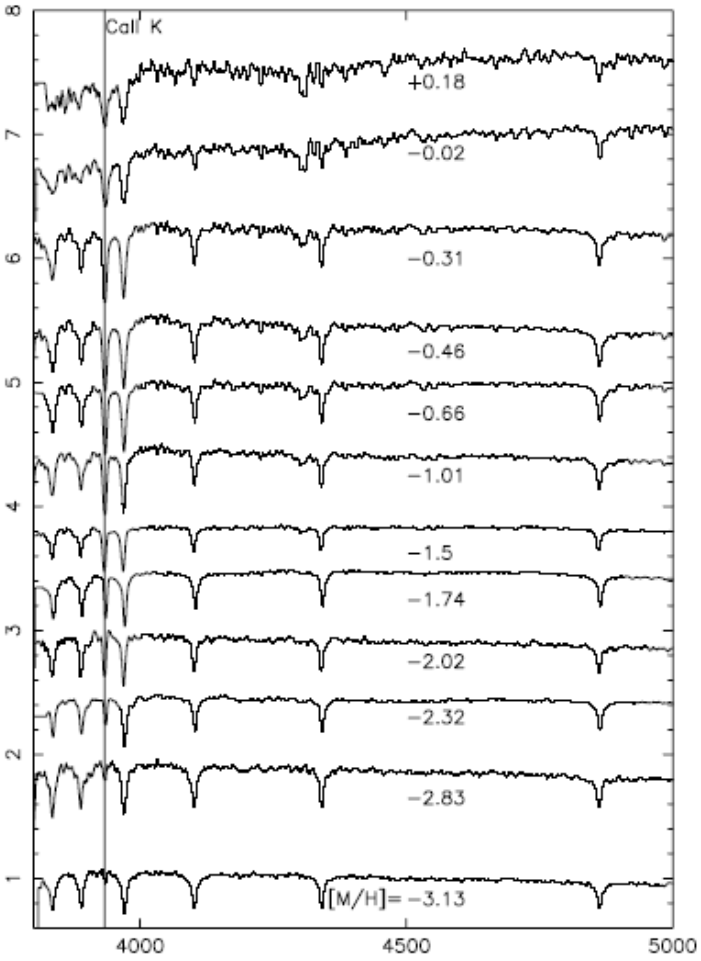
SDSS/SEGUE

Searches for very/extremely metal-poor stars by SDSS/SEGUE

The 2.5m telescope at Apache Point Observatory

- Imaging/spectroscopic surveys
- <u>Surveys of Galactic stars 240,000</u>

R~2000

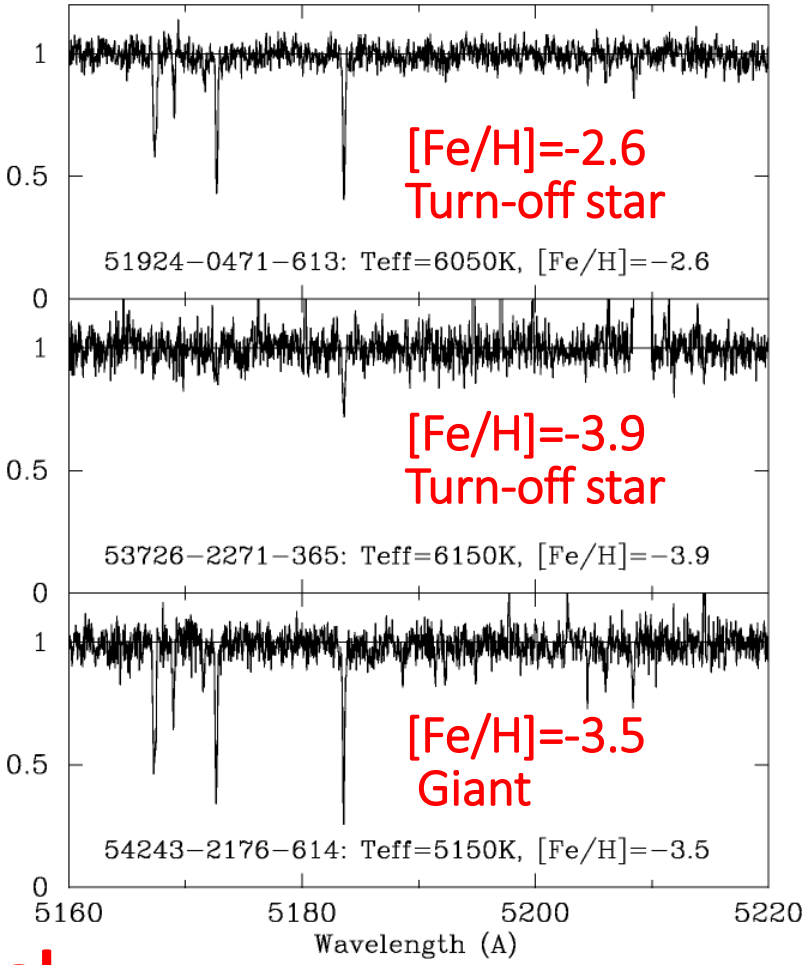


Wavelength (A)

SDSS/SEGUE

Follow-up high resolution spectroscopy with Subaru for selected SDSS objects

Follow-up with Subaru/HDS for 150 objects (2008-2009)
Topics:
-chemical compositions of 137 very/extremely metal-poor stars
-binary frequency



→see poster by Matsuno et al.:
Most metal-poor main-sequence turn-off stars

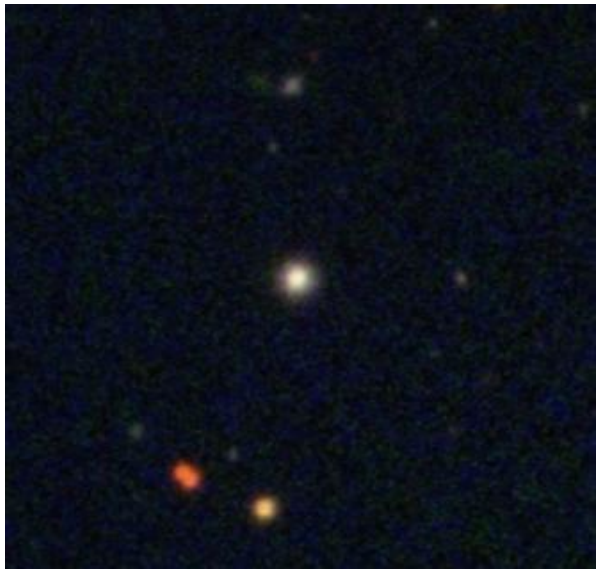
SDSS/SEGUE

Discovery of a low-mass star with peculiar chemical composition

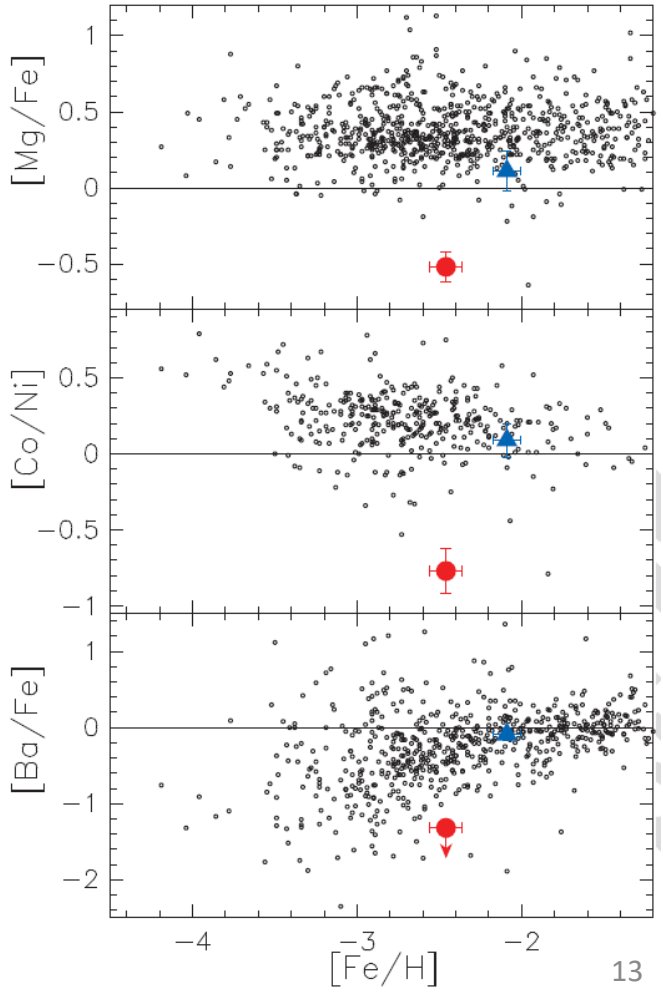
Aoki, Tominaga, Beers, Honda, Lee (2014, Science)

SDSS J001820.51-093939.2

- [Fe/H]=-2.5
- Low C, Mg, Co, Ba etc. abundances
  → excess of Fe
- A low-mass main-sequence star



Taken from SDSS



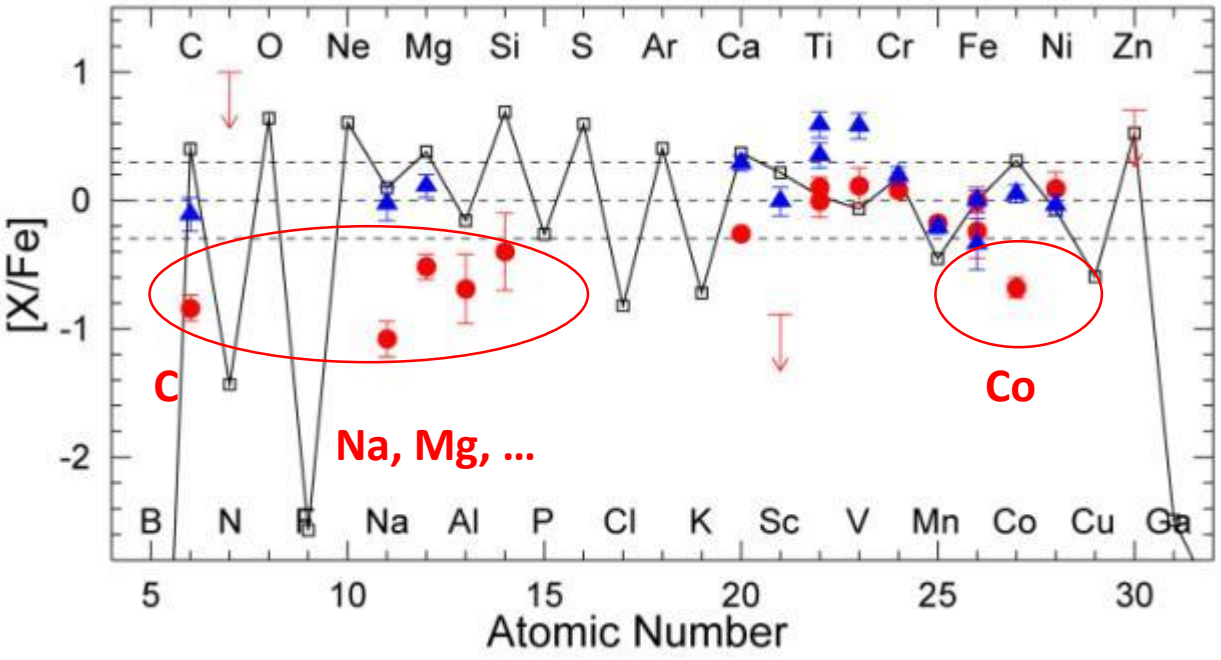
SDSS J0018-0939 -- a low-mass star with a peculiar abundance pattern

The abundance pattern is not explained by normal core-collapse supernovae

Aoki, Tominaga, Beers, Honda, Lee (2014)

● SDSS J0018-0939 ▲ comparison star (G39-36)

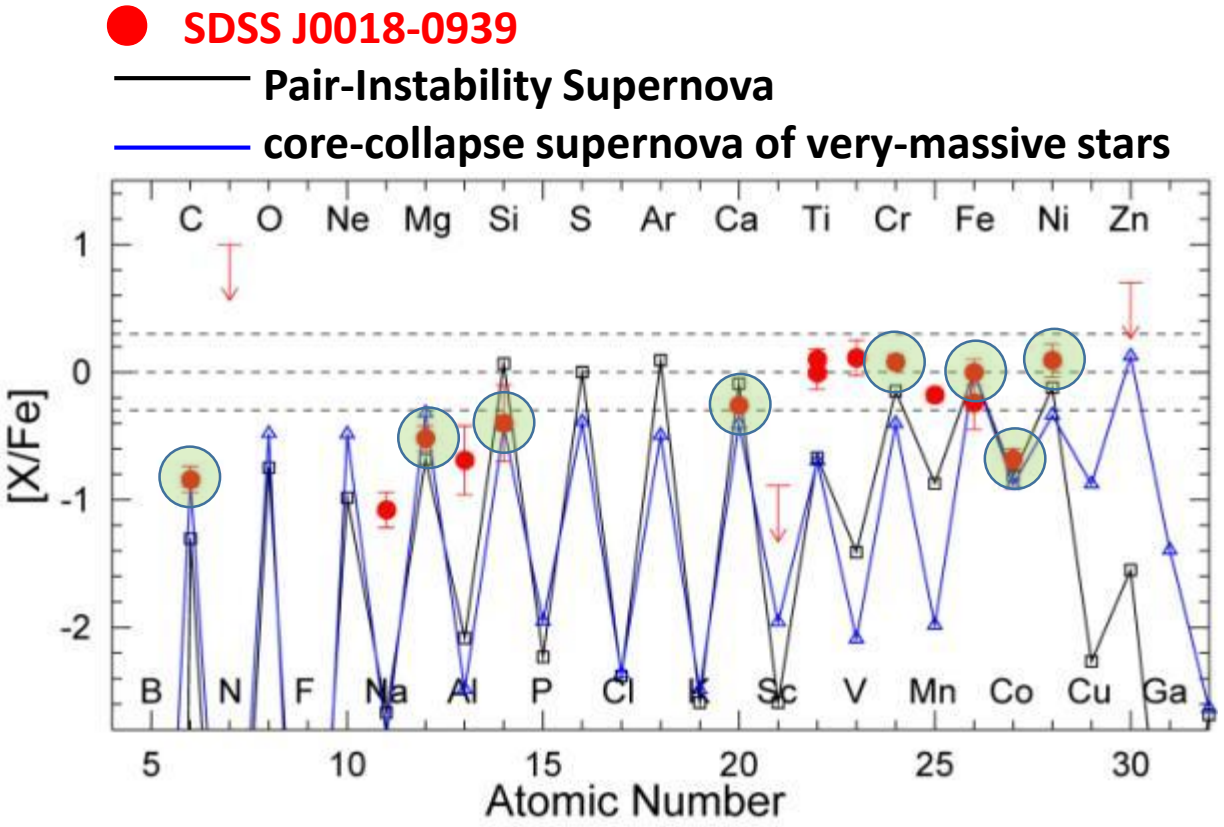
——— core-collapse supernova model



SDSS J0018-0939 -- a low-mass star with a peculiar abundance pattern

Aoki, Tominaga, Beers, Honda, Lee (2014)

Recording yields of a very-massive star?



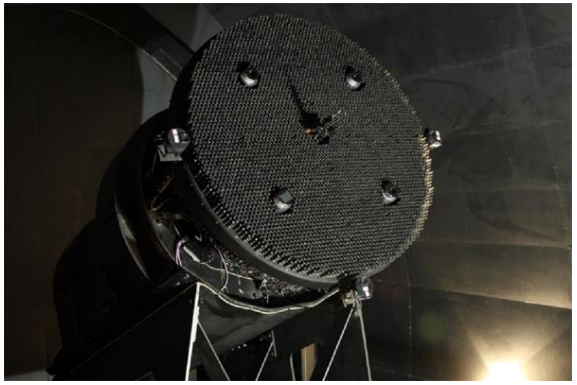
LAMOST

Exploring the early chemical evolution of the Milky Way with LAMOST and Subaru

H.N. Li, Wako Aoki, T. Suda, G. Zhao, S. Honda, N. Christlieb

LAMOST survey

-R=1800
-4000 fibers
-r<19

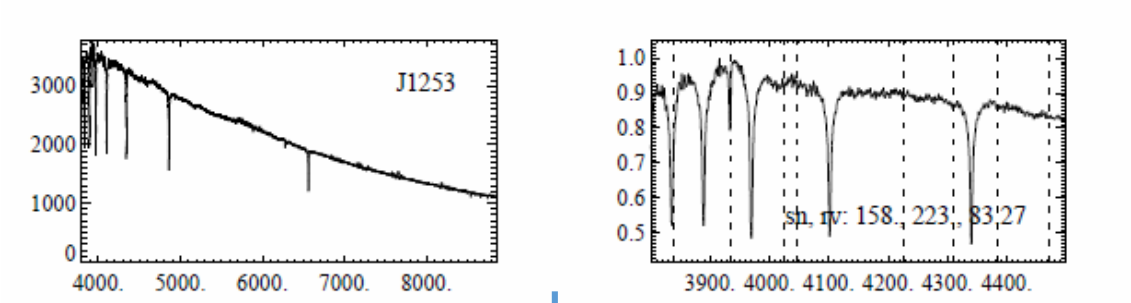


Fibers on the focal plane

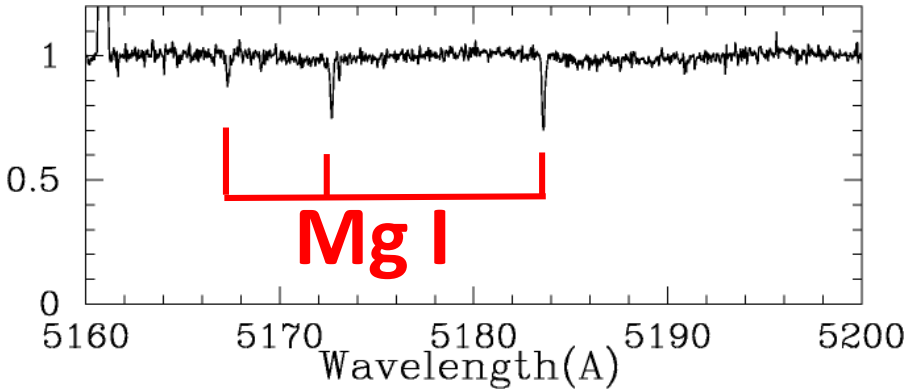
- LAMOST Experiment for Galactic Understanding and Exploration (LEGUE)
- Target selection: random selection for a given magnitude/temperature range
  cf. SDSS/SEGUE
- Data Release 3 (DR3): 5.7 million spectra including 4 million AFGK stars

Target selection from LAMOST sample

LAMOST medium resolution spectra



Subaru high-resolution follow-up spectroscopy



J1253+0753 [Fe/H]=-4.0 main-sequence turn-off

Exploring the early chemical evolution of the Milky Way with LAMOST and Subaru

- Programs in 2014-15 + Intensive program in 2016-17: ~300 stars to date
- Searches for rare but key objects:

-signature of first stars

-neutron-capture element-enhanced stars

- Statistics of very metal-poor stars:

-metal-poor tail of the metallcity distribution function

-binary frequency from double-lined binaries

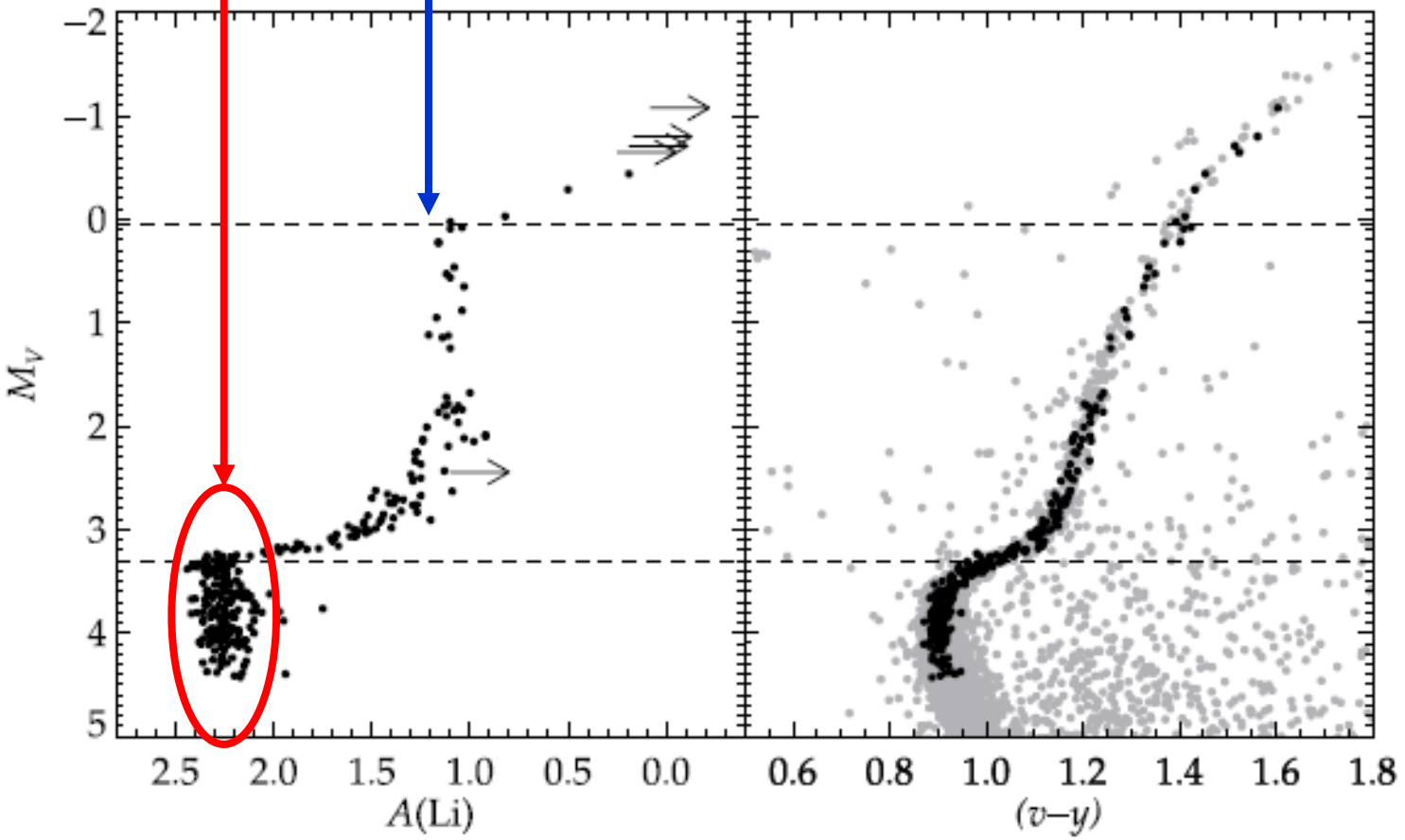
-trend and scatter (or clustering) of elemental abundance ratios

Li in stars from main-sequence to giant branch traced by globular cluster stars

Constant Li in main-sequence turn-off

Depletion of Li in red giants

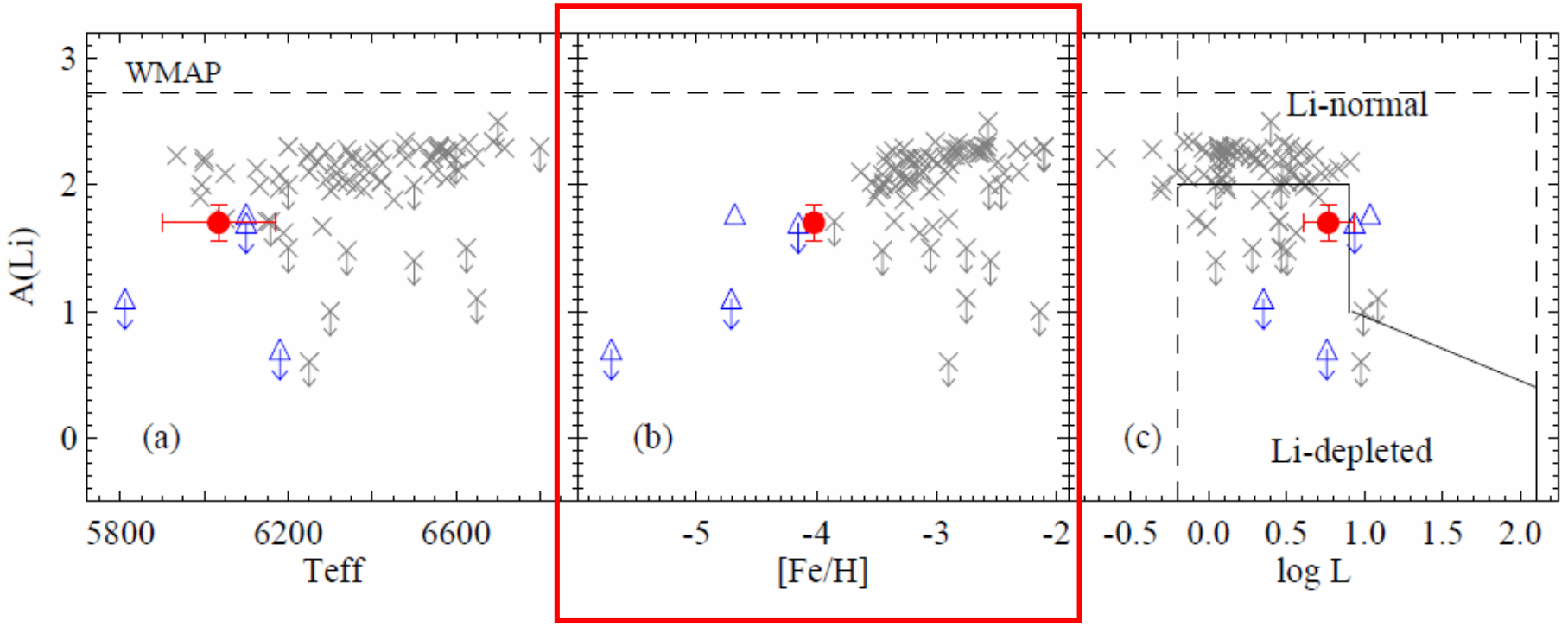
Lind et al. (2009)



Early result 1. new ultra metal-poor stars

The second example of Li detection in Ultra Metal-Poor ([Fe/H]<-4) stars

Li, Aoki et al. (2015, PASJ)



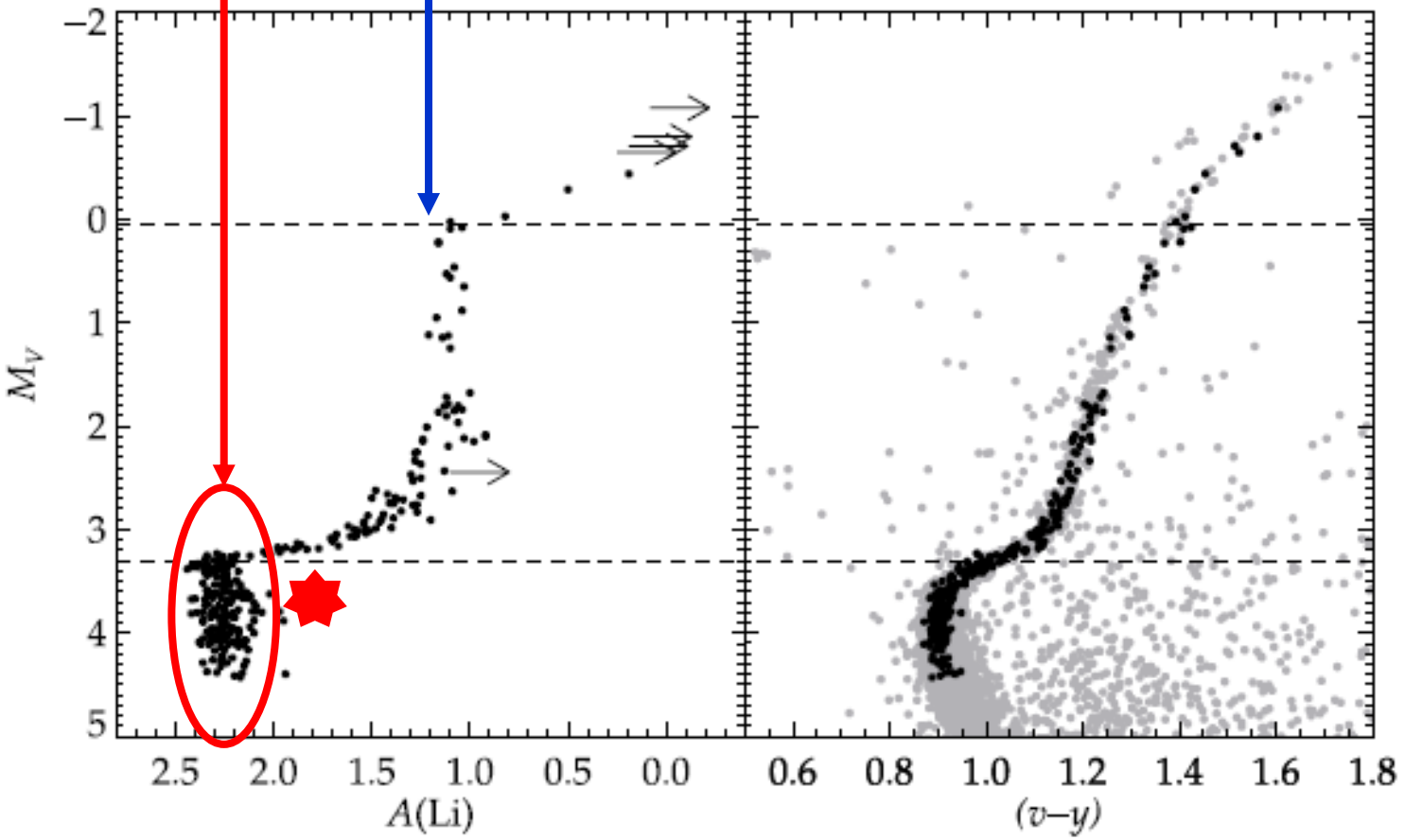
→Li depletion in the most metal (iron)-poor stars ([Fe/H]<-4)

Li in stars from main-sequence to giant branch traced by globular cluster stars

Constant Li in main-sequence turn-off

Depletion of Li in red giants

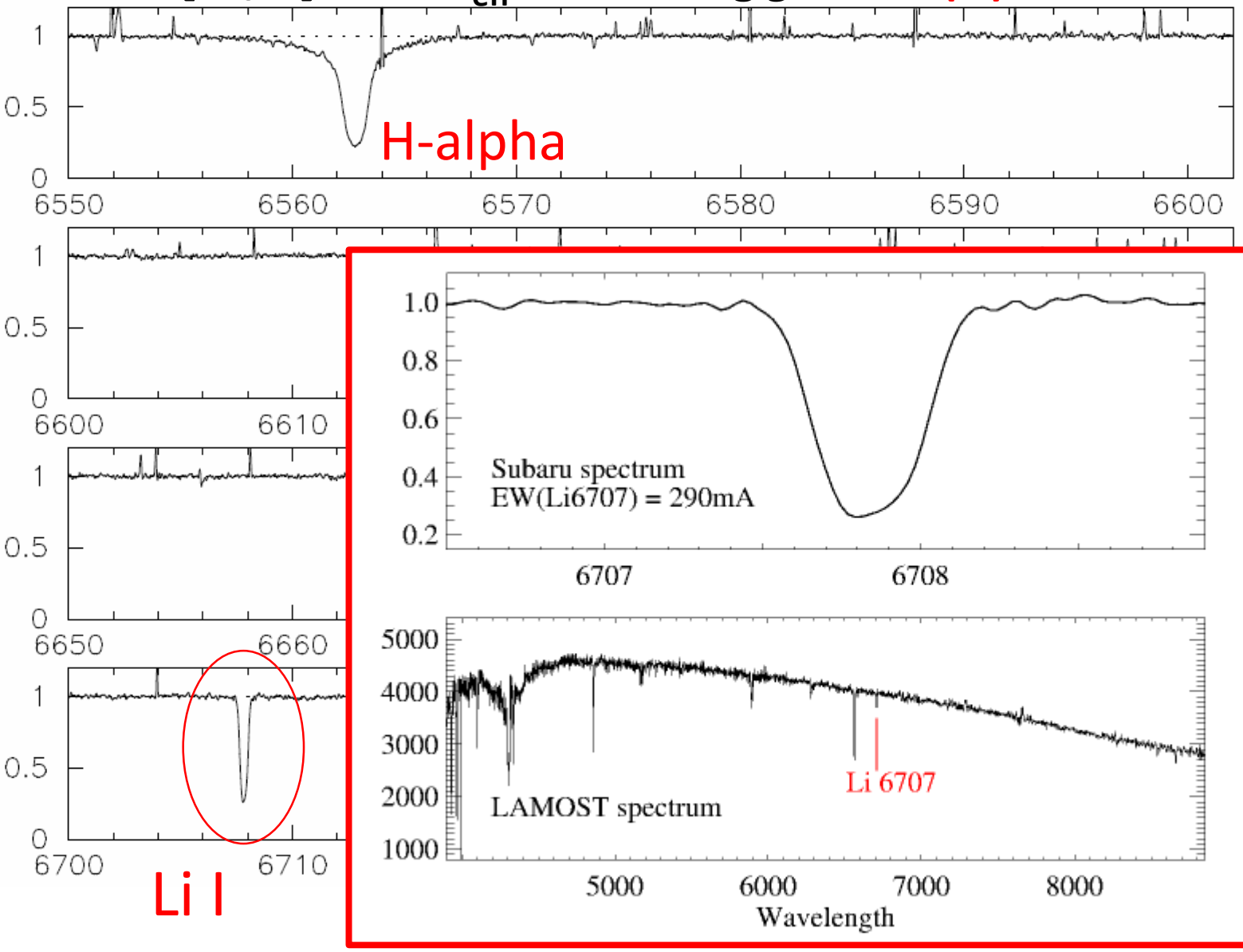
Lind et al. (2009)



Early result 2. Super Li-rich red giant!

LAMOST

[Fe/H]=-3.3, T_{eff}=5200K, log g=2.2, A(Li)～3.0

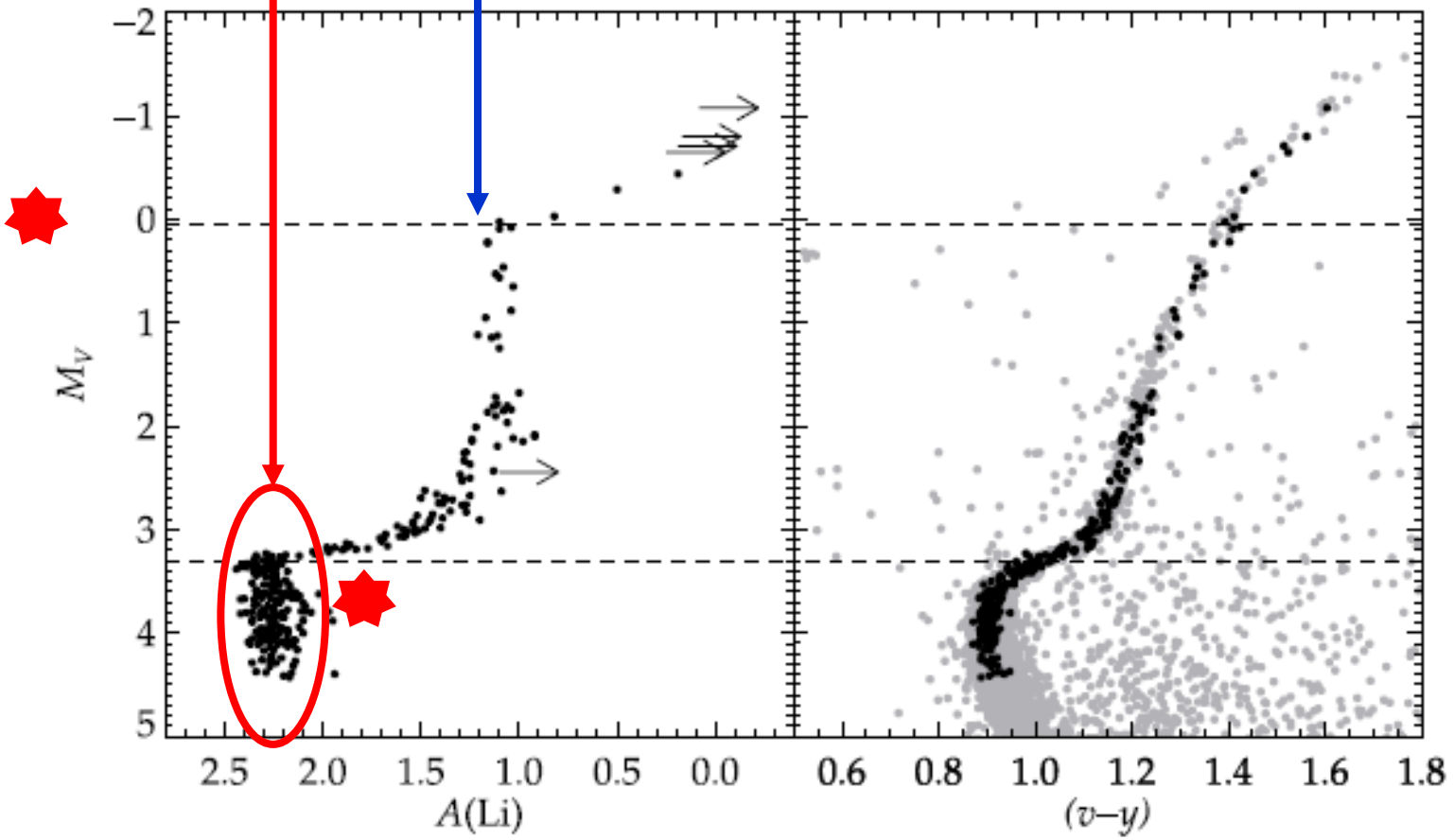


Li in stars from main-sequence to giant branch traced by globular cluster stars

Constant Li in main-sequence turn-off

Depletion of Li in red giants

Lind et al. (2009)



Summary and future prospect

- **High resolution follow-up spectroscopy have been conducted for candidates of metal-poor stars discovered by large surveys (HK, HES, SDSS/SEGUE)**
- **LAMOST is providing huge samples of metal-poor stars and other chemically/kinematically interesting objects. We are conducting follow-up spectroscopy with Subaru for 500 stars**

◆ **LAMOST objects studied with Subaru are relatively bright, providing good sample for detailed abundance studies.**

◆ **Combining kinematics data provided by Gaia**