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Subaru Users Meeting

Chemical Abundance Study for the First Generations of Stars from SDSS/SEGUE

（SDSS/SEGUEサンプルにもとづく初期世代星の化学組成の研究）

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Chemical Abundance Study for the First Generations of Stars from SDSS/SEGUE

Chemically antient (=extremely metal-poor) stars in the Galaxy provide

- Signature of first generations of stars
  - -Mass function of first stars
  - -Metal enrichment that affects following star/galaxy formation
- Record of early stages of Galaxy formation

Achievement in the past decade

Discoveries of the two "Hyper Metal-Poor" stars
([Fe/H]<-5)

•How did such low metallicity (iron abundance) objects form?

•Both objects are "carbon-rich" ([C/Fe]>4)

(Aoki et al. 2006)

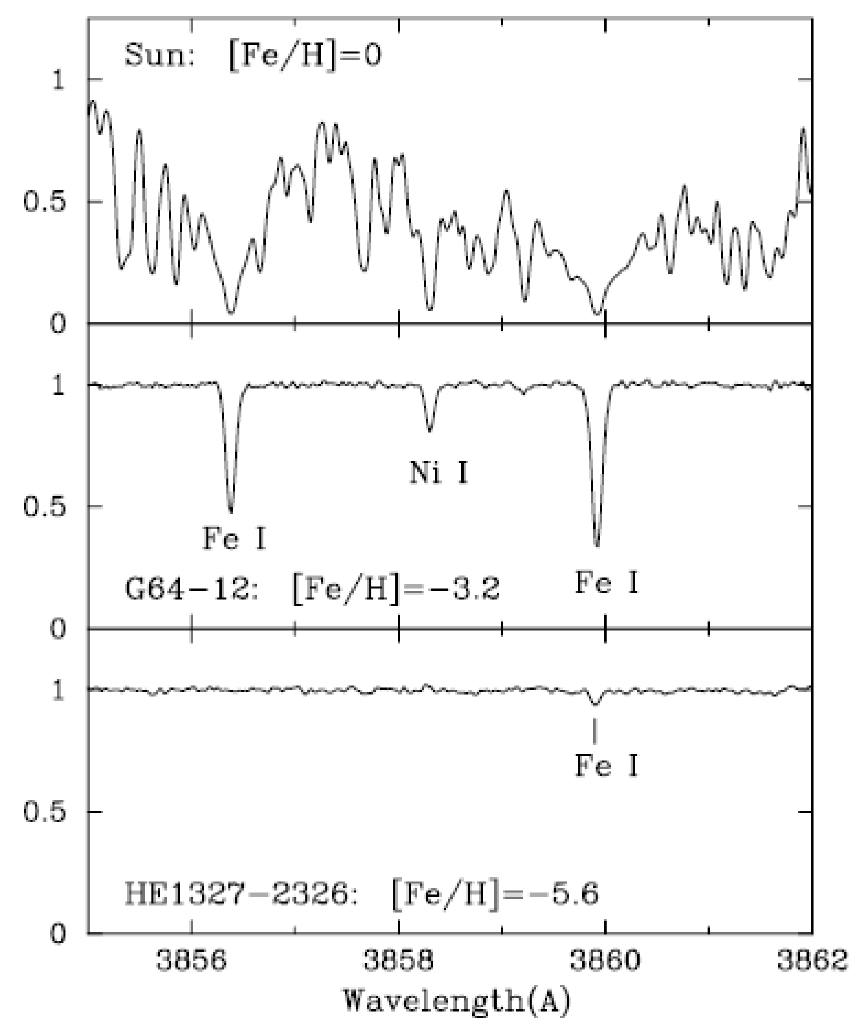


FIG. 1.—Fe I λ3860 line in the spectrum of HE 1327−2326 (*bottom*), compared with spectra of the Sun (*top*) and G64−12 (*middle*).

Aims of the intensive program

Understanding of the Hyper Metal-Poor stars and other extremely metal-poor stars *by increasing statistics*

topics:

(1) metallicity distribution in [Fe/H]<-3.5

(2) fraction of carbon-enhanced stars

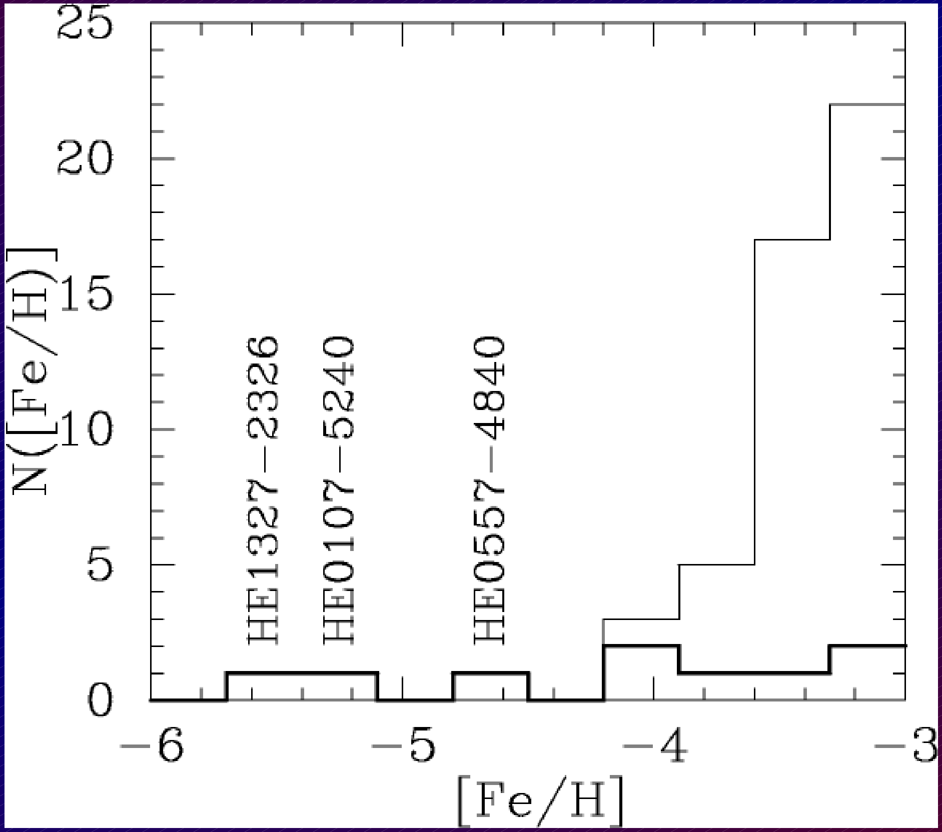
(3) Li abundance trend [Fe/H]<-3.5

(4) neutron-capture processes at lowest metallicity

(5) alpha and Fe-peak elements produced by first generations of stars

Metallicity distribution and fraction of carbon-enhanced objects

- How quickly decrease the metallicity distribution in [Fe/H]<-3.0 (and -3.5)?
- How high the fraction of carbon-enhanced objects in [Fe/H]<-3.0 (and -3.5)?



Discovery of new objects with [Fe/H]<-4?

Sample selection from the SDSS specta

- SDSS spectroscopy:
  R~1800
  Covering 3900-9000A
  14<V<20

- Metallicity estimate from Ca II HK lines

- Standard stars in SDSS-I
- New surveys in SDSS-II (SEGUE)→240,000 stars

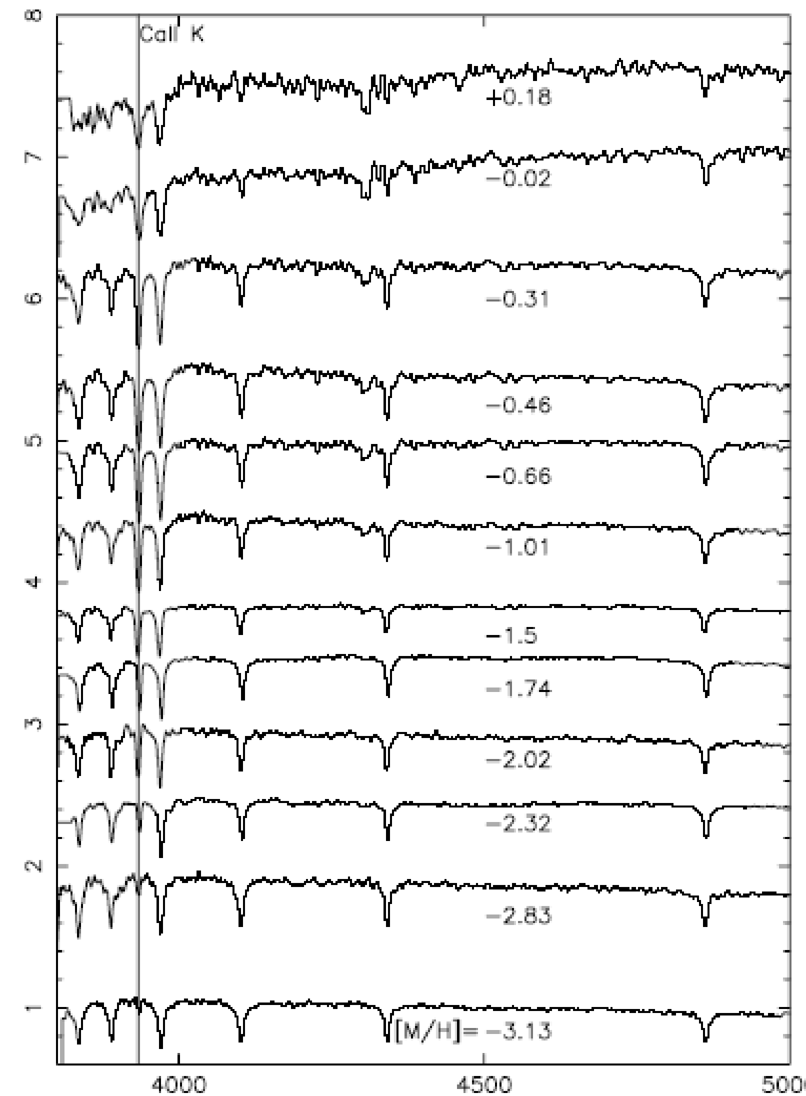


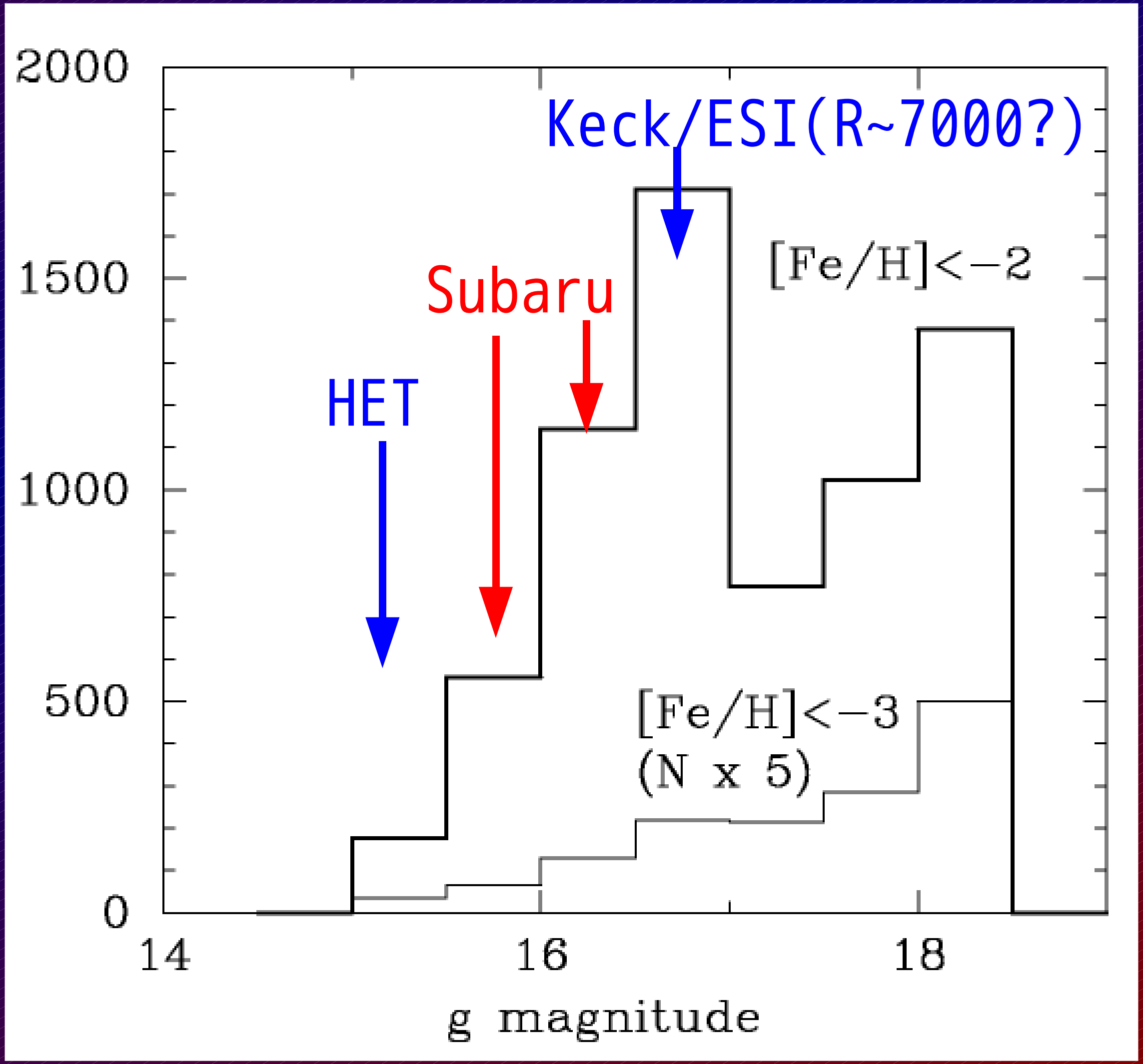
Figure 7. F star metal sequence—a set of SEGUE F stars, selected to show the range of metallicities sampled by the F subdwarf, F/G, spectrophotometric standard and reddening standard categories. All 13 stars have similar effective temperatures, near 6500 K, but the strength of the Ca K line at λ3933 indicates metallicities ranging from less than 0.001–1.5 times Solar.

Strategy of the program

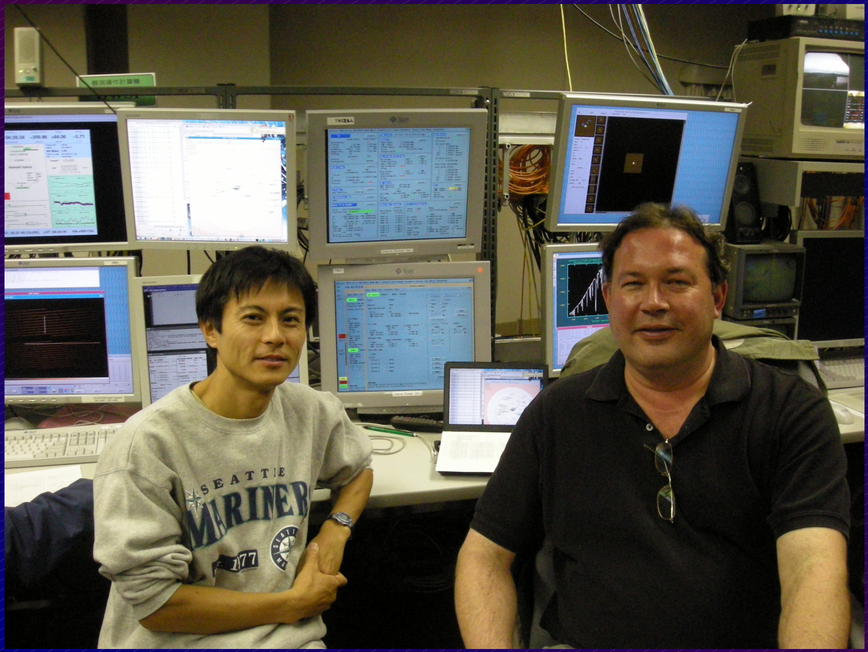
Two steps of high-resolution spectroscopy with Subaru for SDSS/SEGUE objects

(1)Moderate R & S/N
R=30,000
S/N~30
~150 objects
→metallicity
C/Fe
α/Fe

(2)High R & S/N
→detailed abundance pattern
Li (turn-off stars)



Project team



- SDSS/SEGUE sample selection
  Calibration of SDSS analysis
  Beers, Sivarani, Carollo

- Moderate S/N survey:
  Aoki, Honda, Hidai

- High S/N study: Li abundances, neutron-capture elements, etc.: Honda, Ito, Aoki, others

- Collaborations with programs with other telescopes
  Frebel, Norris

- Interpretation : Fujimoto, Suda

Results of observing runs in 2008 For moderate S/N spectroscopy

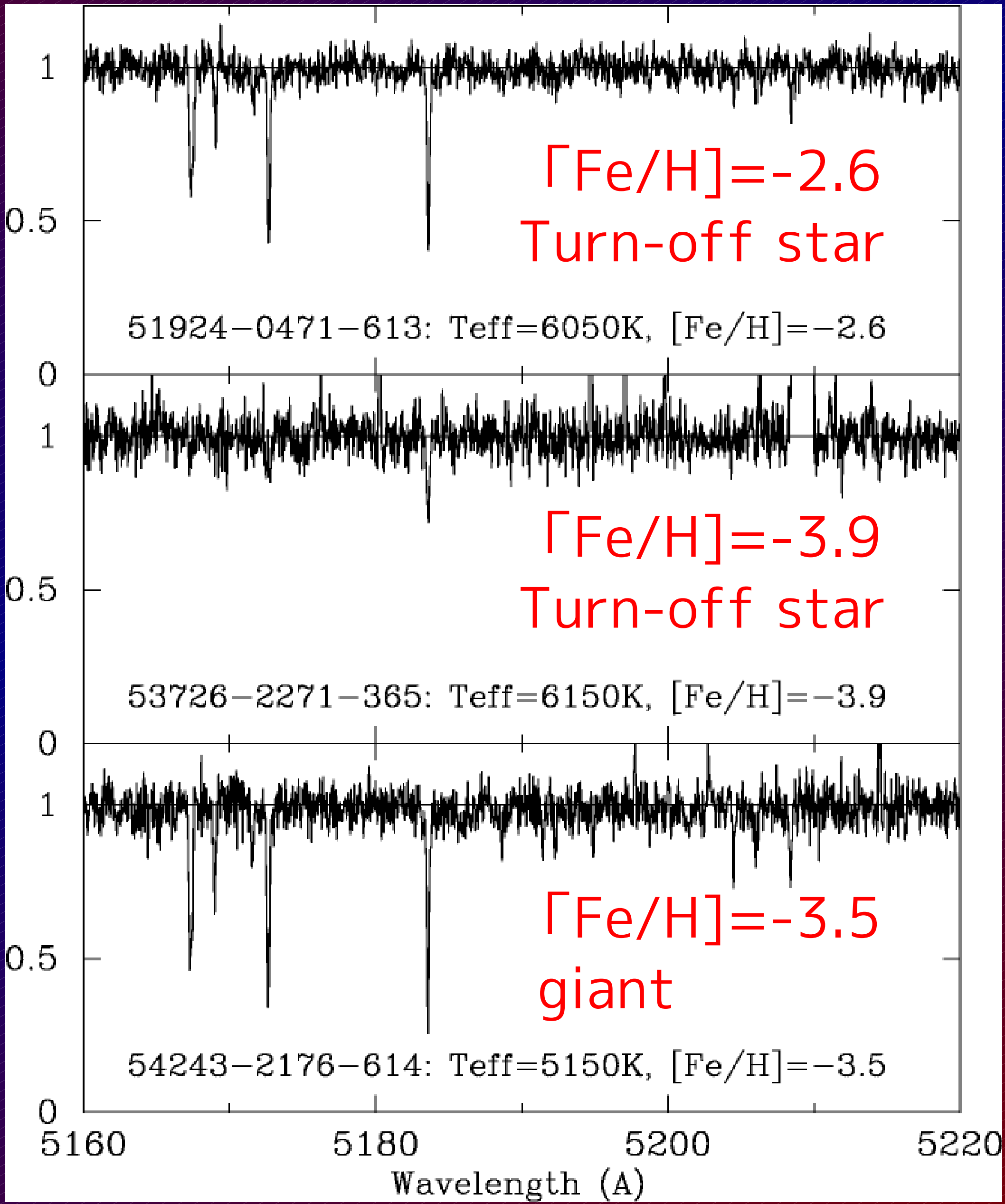
- March 7, 9: clear (half night was used for TOO)
- April 30 (half)=TOO compensation: cloudy
- May 1: clear
- July 3, 4, 5: clear
- August 20, 21(halfx2): clear
- October 3(half), 4, 5: clear
- November 15 (half): clear (1 hour lost)

Clear nights : 95%

Obtained spectra and abundance analyses

R=30,000
4030-6800A
S/N~25-30
~150 objects

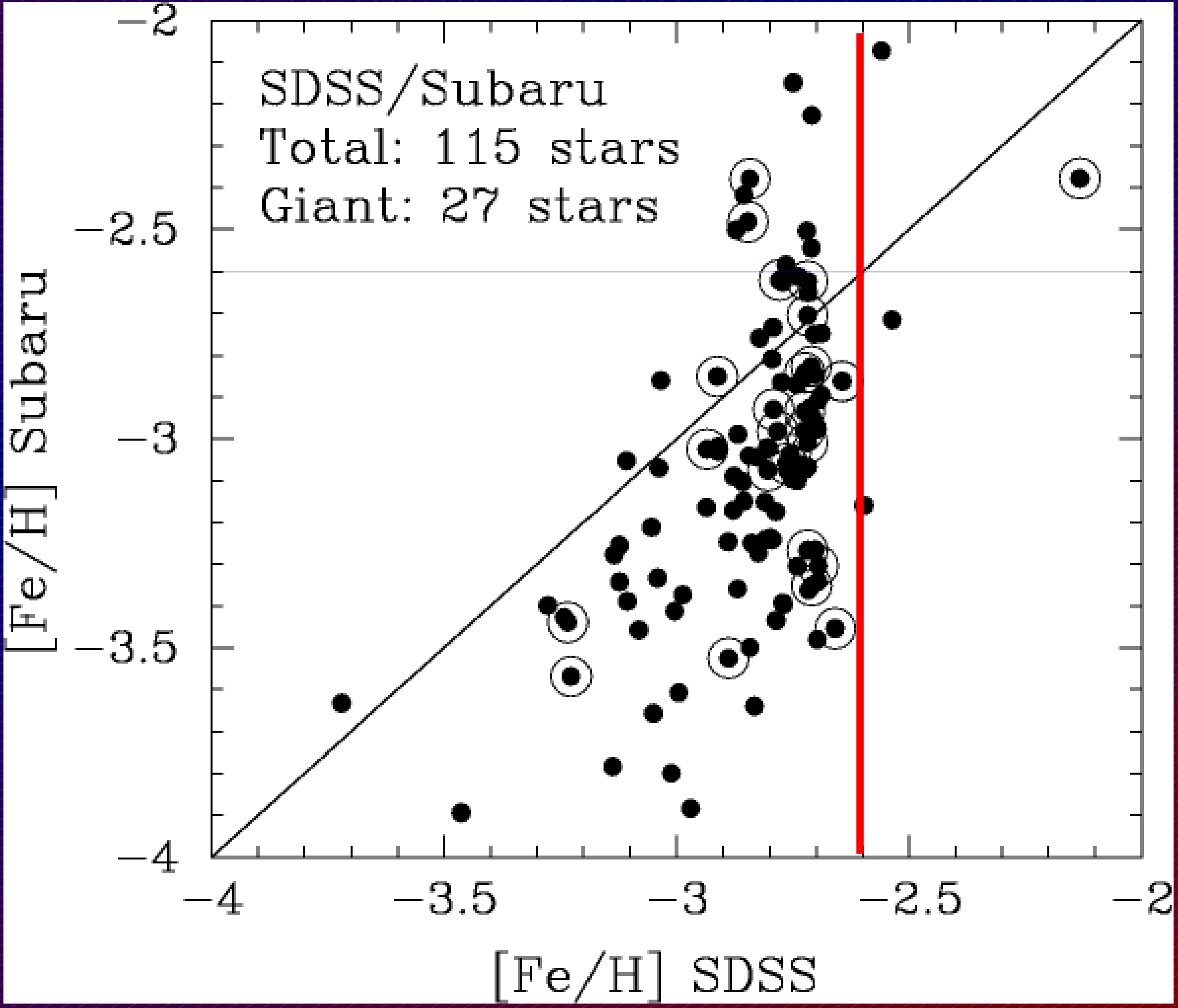
Example: Mg triplet around 5170A →



Metallicity from Subaru spectra and comparison with SDSS estimates

- Extremely metal-poor stars are *very efficiently* selected from SDSS spectra

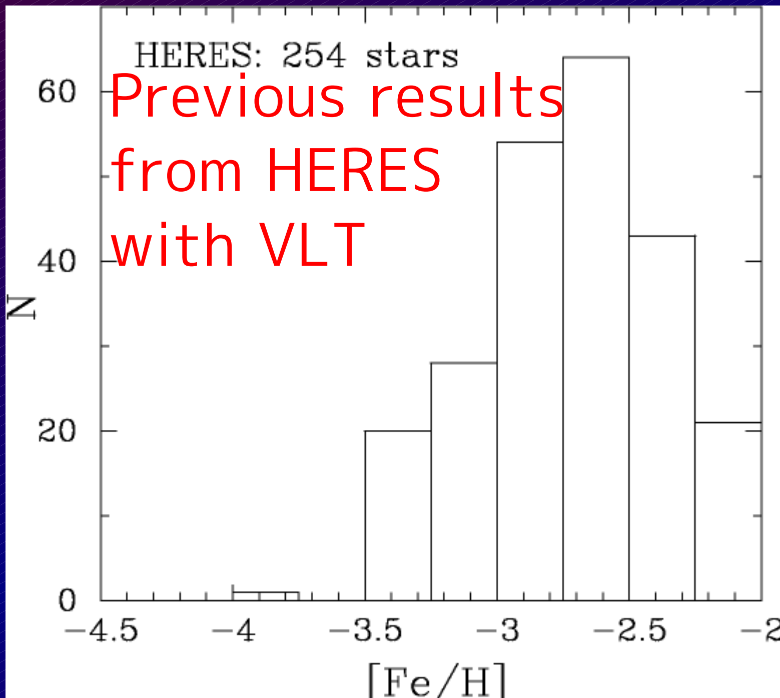
- High-res spectroscopy is required to accurately determine the metallicity for [Fe/H]<-3

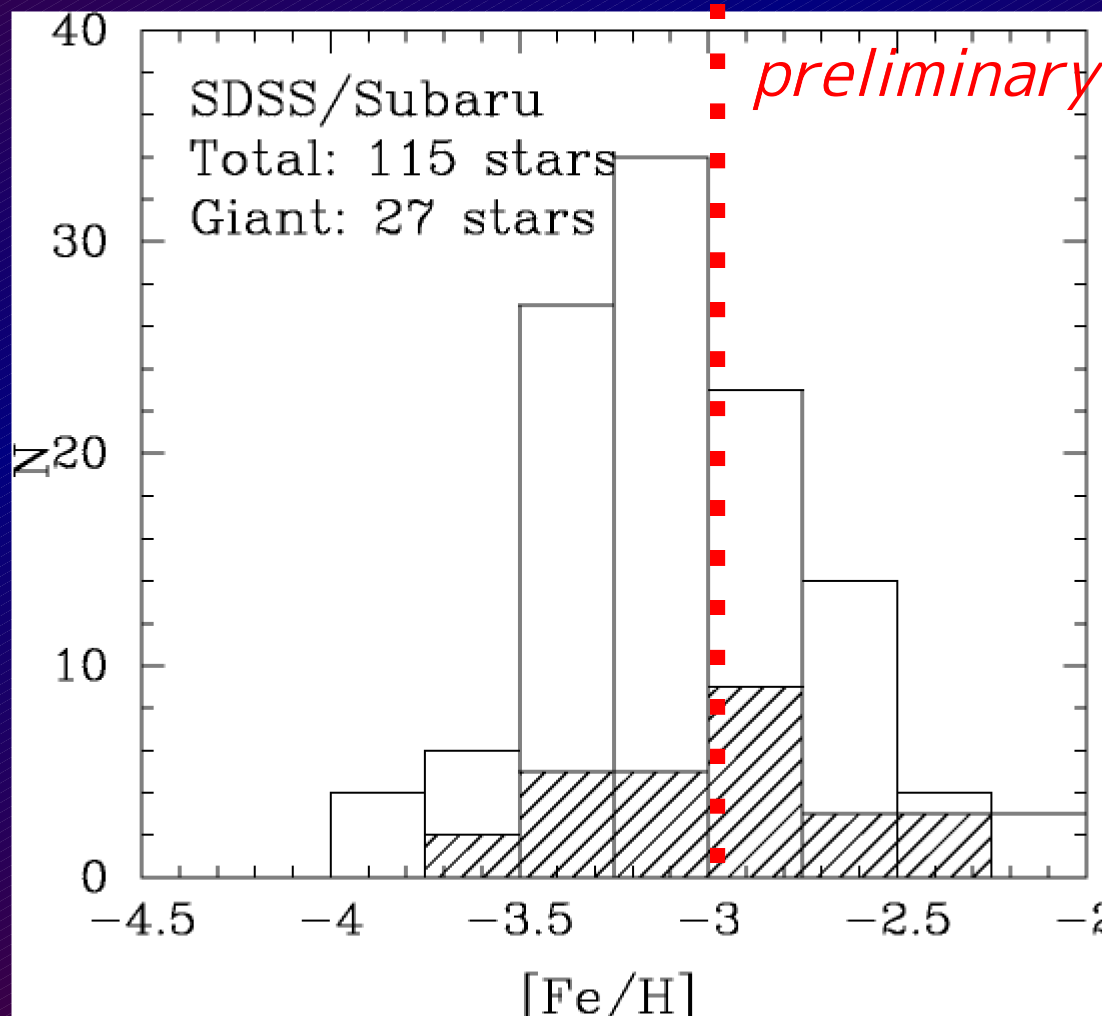


Metallicity distribution

Metallicity estimate from Subaru spectra:
The sample is roughly complete for [Fe/H]<-3

Rapid decrease in [Fe/H]<-3.5 is confirmed





Ongoing work from the moderate S/N spectroscopy

- Calibration for the analyses of SDSS spectra

- Fraction of carbon-enhanced stars

- Correlation between chemical abundance and kinematics

- Fraction of double-lined spectroscopic binary

Results of observing runs in 2009 for high S/N spectroscopy

March 4,5: cloudy
June 28,29, July 1: mostly clear
September 10-12: clear
November 24,25: 50% clear

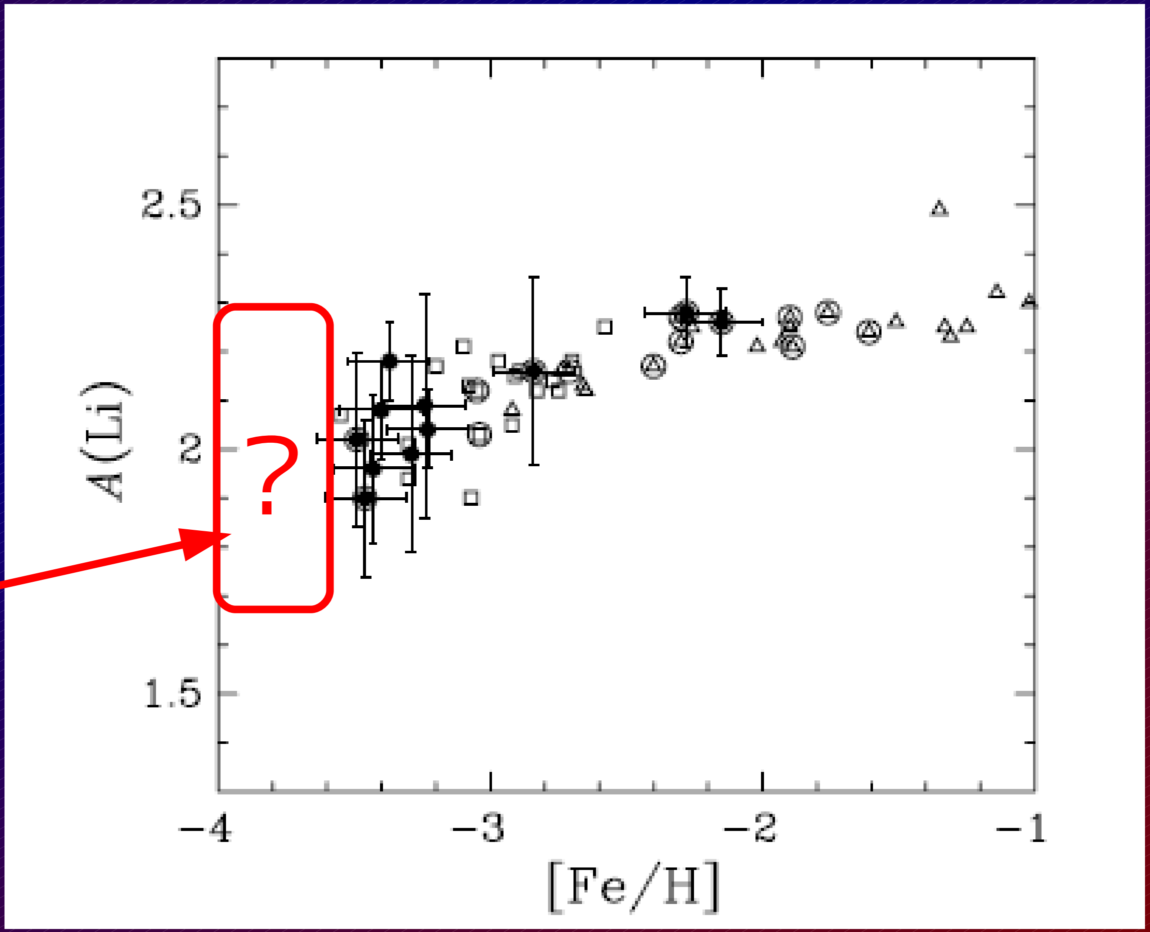
Clear nights: 65%

Results *expected* from high S/N spectroscopy

1. Li abundance trend at the lowest metallicity

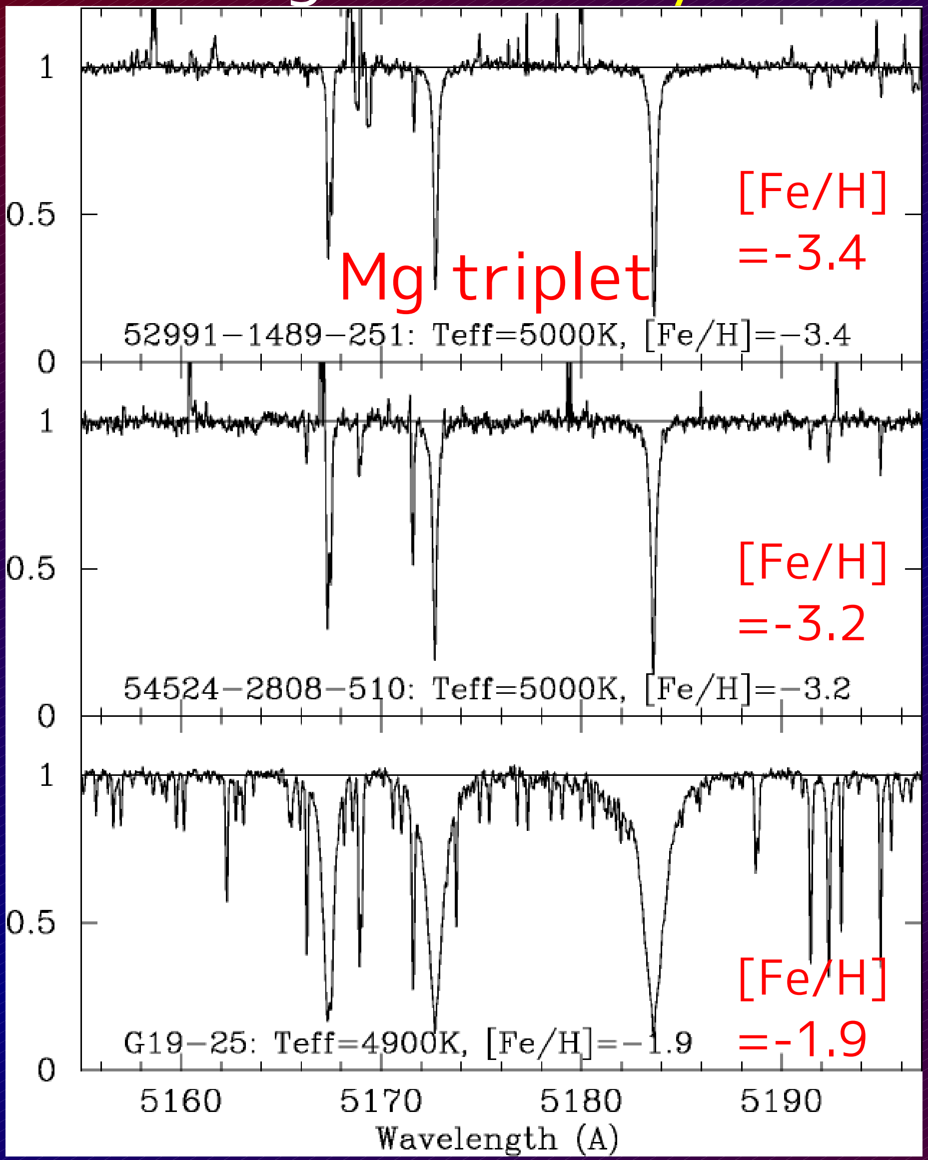
Scatter or trend of Li abundance at the lowest metsallicty ([Fe/H]<-3)

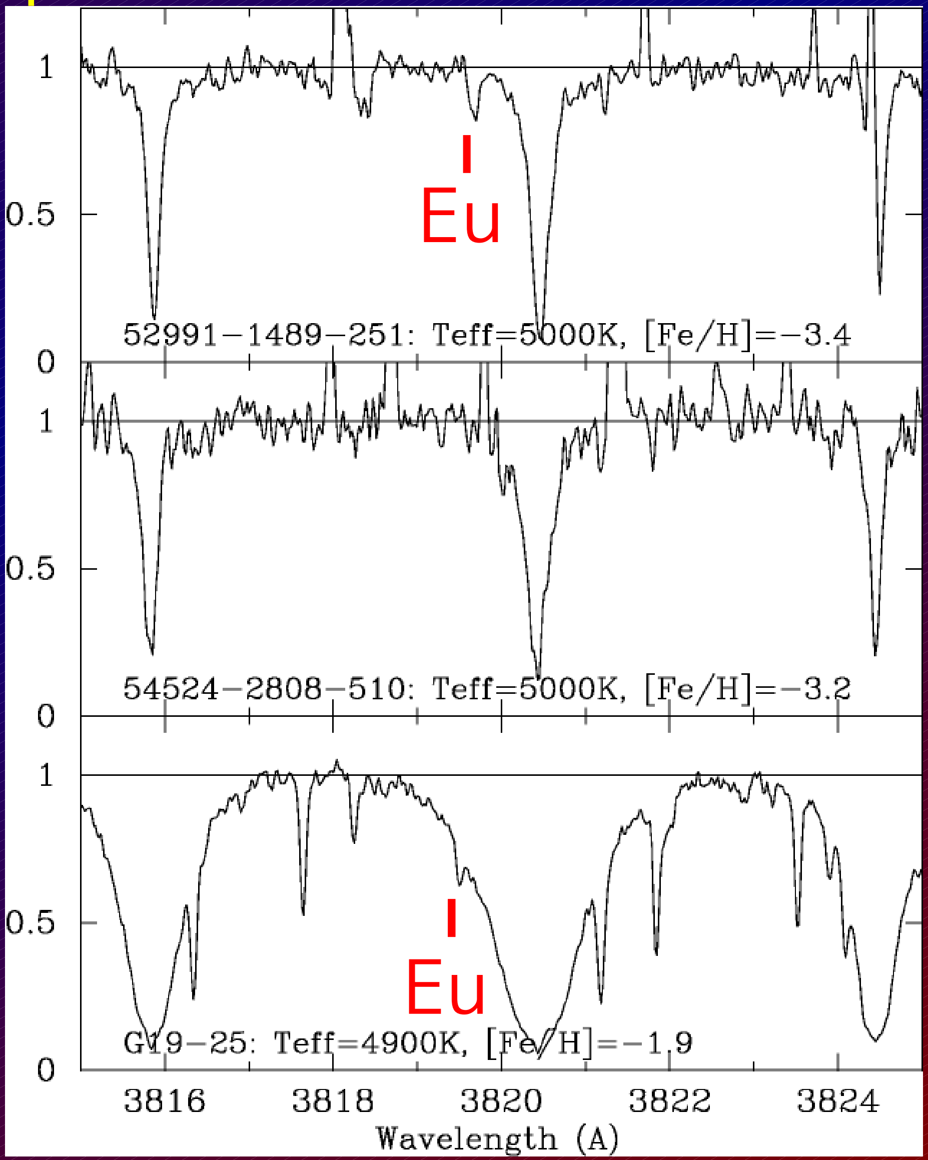
How is the trend in [Fe/H]<-3.5?



Results from high S/N spectroscopy

2. Discovery of an r-process enhanced object among extremely metal-poor cool dwarfs

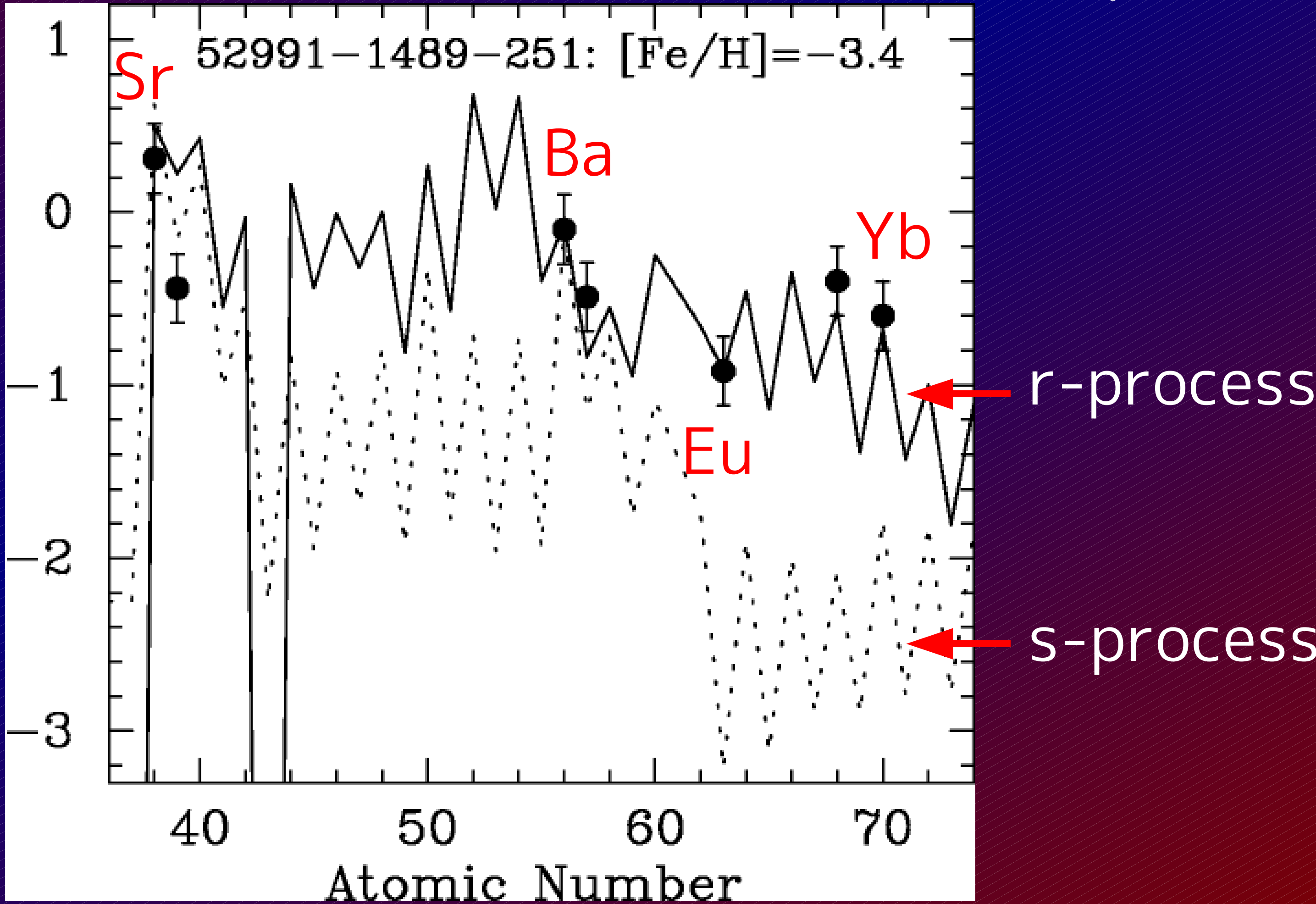




Results from high S/N spectroscopy

Heavy elements in 52991-1489-251 clearly show the r-process abundance pattern

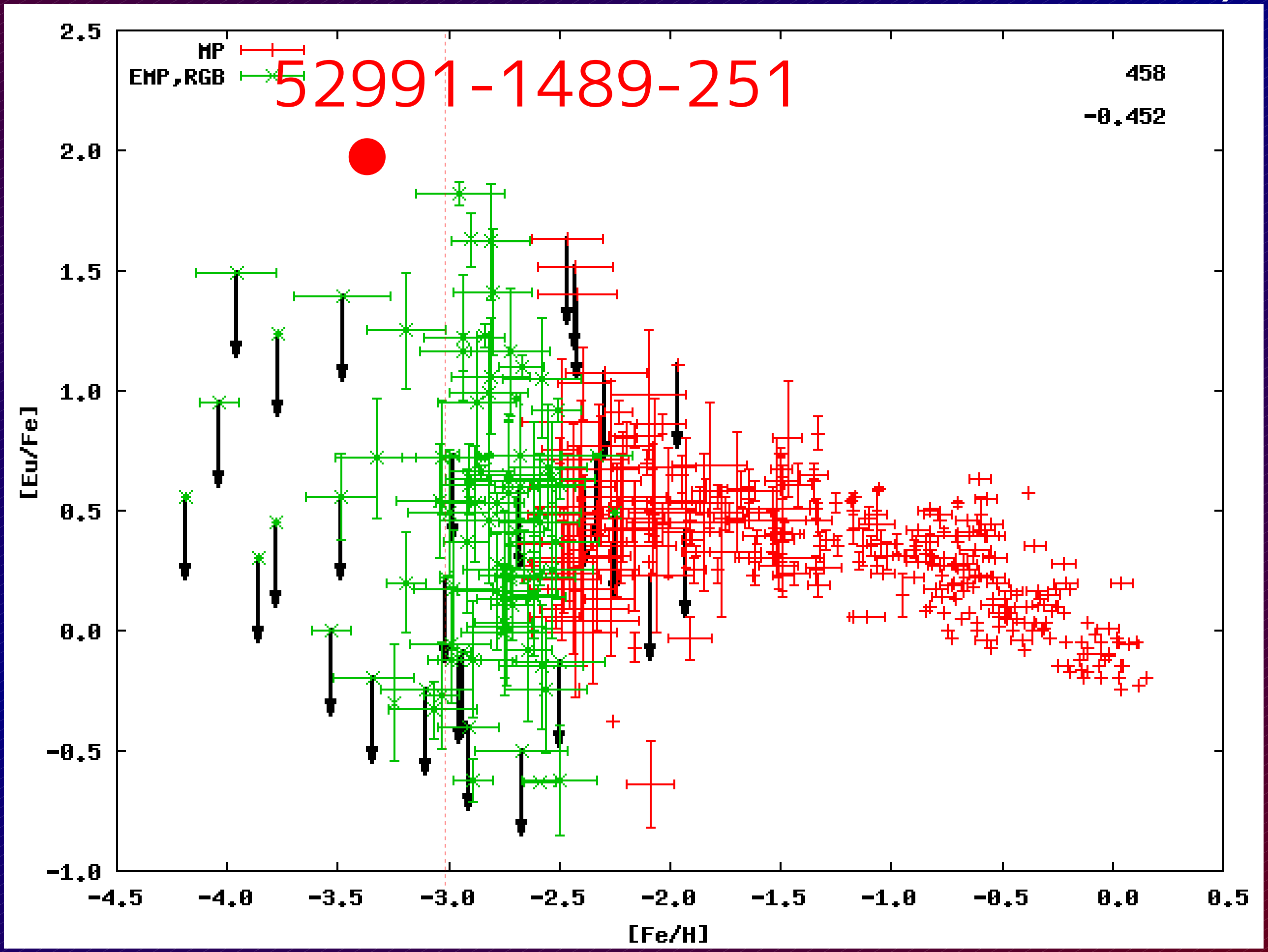
Preliminary results



Results from high S/N spectroscopy

52991-1489-251 shows the largest excess of r-process elements at lowest metallicity

Preliminary results



[Eu/Fe]

-3.0 [Fe/H]

from SAGA database

Results from back-up observations

Spectroscopic survey of bright (V<12) metal-poor stars during twilight and cloudy nights:

- -Bright candidates of very metal-poor stars
- -Cool red giants with low metallicity
  => measurements of heavy elements like Th & Pb
- -Cool subdwarfs as reference stars

An extremely metal-poor star found among backup targets

BD+44 493: [Fe/H]=-3.7, subgiant, V=9.1!

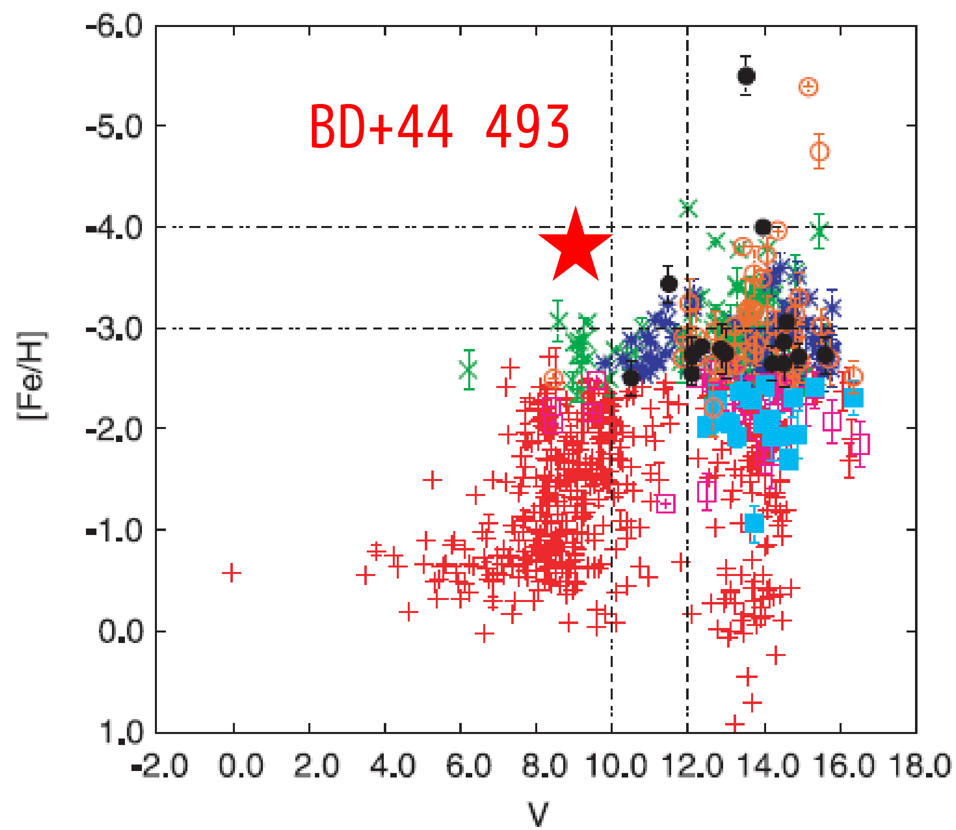
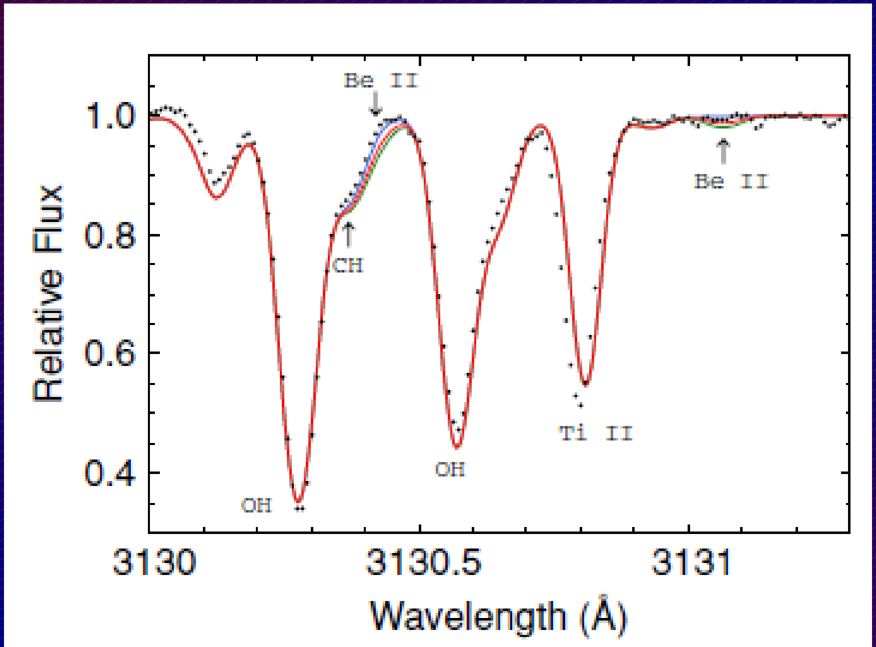


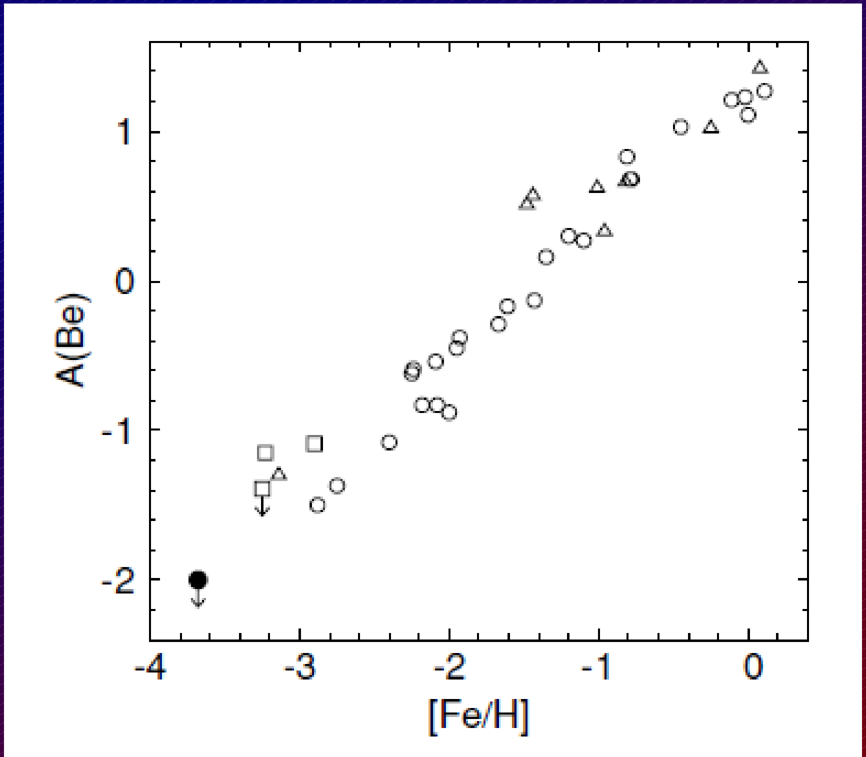
Fig. 7. Relationship between the metallicity and V-magnitude in 767 sample stars. The meanings of the symbols are the same as in figure 4.

from SAGA database

Brightness is important: Measurements of Be at 3130A

The very low upper limit of Be abundance:
Ito et al. (2009)





Summary

- We have conducted high-resolution, follow-up spectroscopy with Subaru for candidate metal-poor stars found by SDSS/SEGUE.
  -10 (9.5 clear) nights for the moderate S/N study
  -10 (6.5 clear) nights for high S/N study
- No object with [Fe/H]<-4 is discovered in the sample, while ~10 objects with -4<[Fe/H]<-3.5 are found.
  → new constraints on metallicity distribution
- Calibaration for the estimates of metallicity etc. of extremely metal-poor stars from SDSS are provided.
- Measurements of Li abundances, heavy elements etc. are ongoing from the high S/N study