Survey of neutron-capture enhanced metal-poor stars using WFMOS

1. The survey of field metal-poor stars.
2. Dwarf galaxies, Globular Clusters, bulge stars.

Satoshi Honda
(Gunma Astronomical Observatory)

Wako Aoki
(National Astronomical Observatory of Japan)

Subaru UM 2009

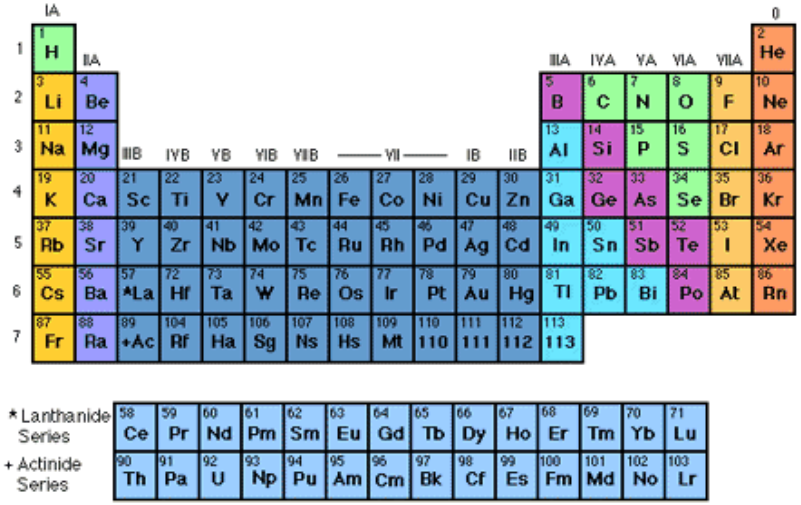
Observations of Very Metal-Poor Stars

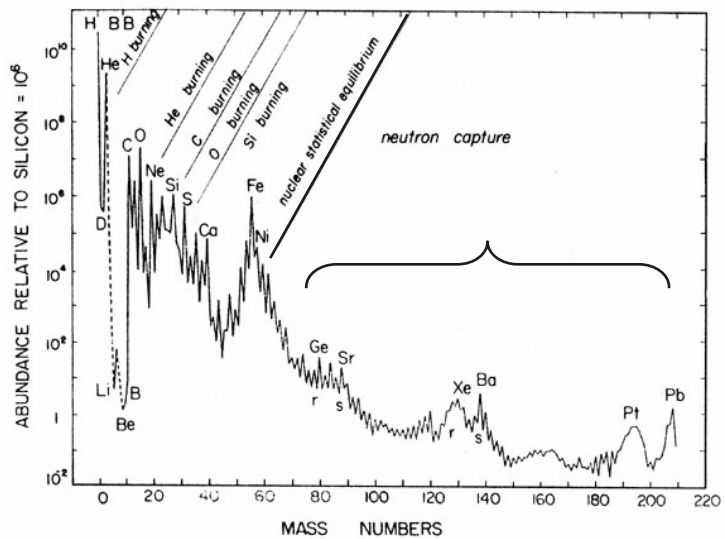
- Very metal-poor stars are usually considered to be born in the early galaxy.
  - It holds situation of early epochs of galaxy formation
- The chemical compositions are fossil records of the nucleosynthesis of single (or a few) process.
  - It is advantage for investigation the origin of elements

Nucleosynthesis

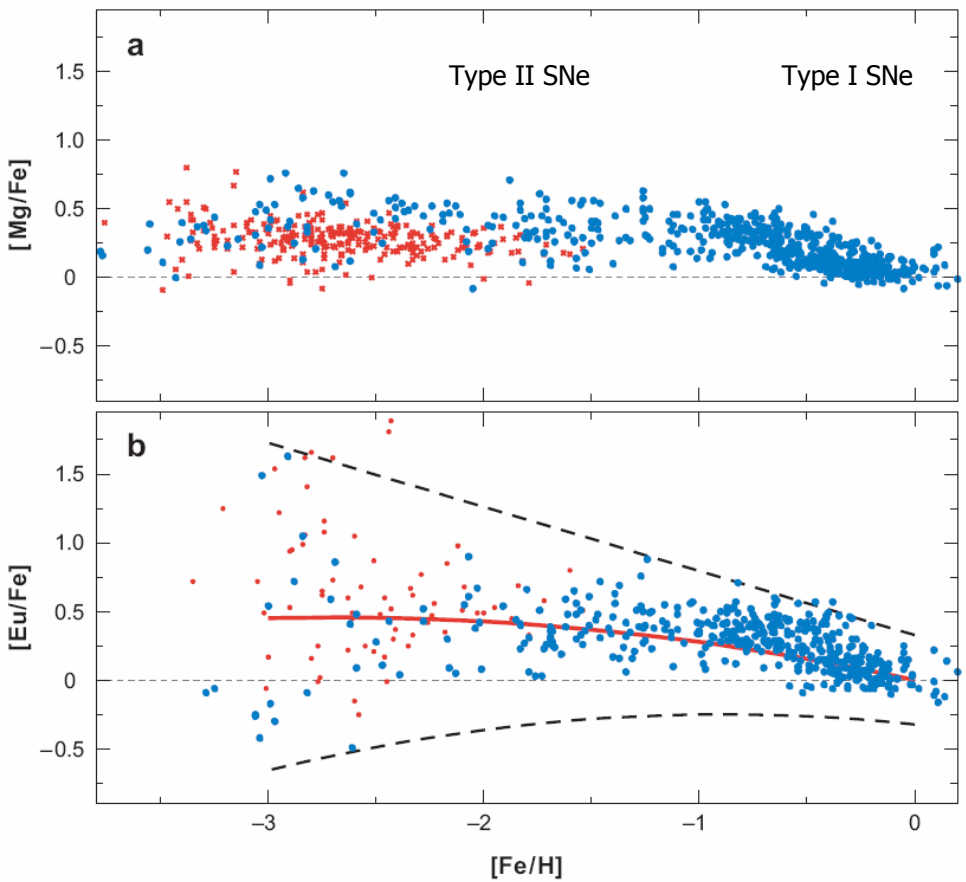
Burbidge, Burbidge, Fowler, Hoyle 1957

- H、He、(Li)
  - Big Bang Nucleosynthesis
- α-elements(Mg,Ca,Si…)、iron-peak
  - Stellar nucleosynthesis
    - α elements→Type II SNe
    - iron→Type Ia SNe
- The elements heaver than iron
  - Neutron capture
    - s-process(Ba, Pb, etc.)
      - AGB stars
    - r-process(Eu, Au, Th, etc.)
      - still unknown! (Type II SNe?)





Observations of neutron-capture elements.

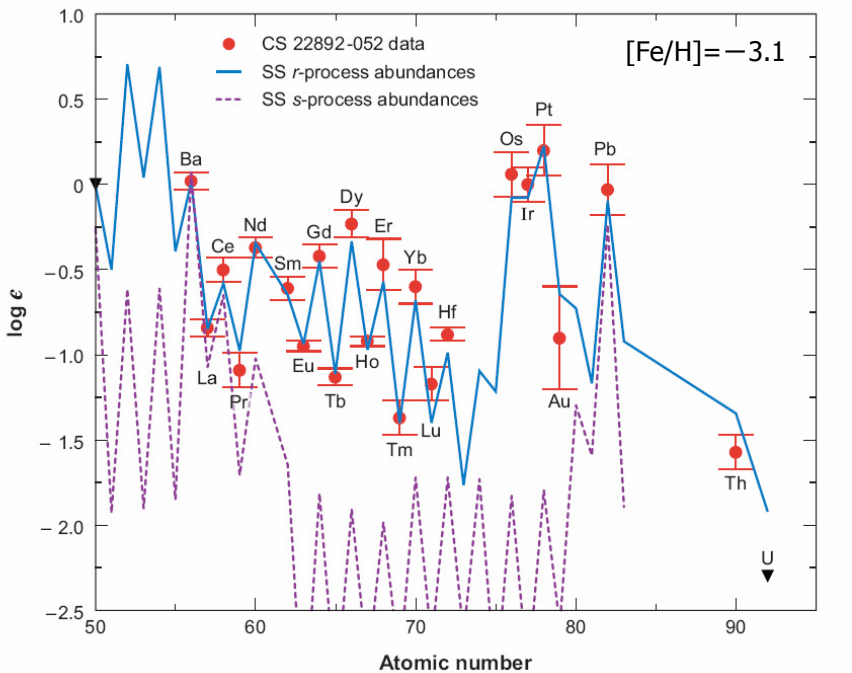


Sneden et al. 2008

- Large scatter in [Fe/H] < -2
  - ~ 2 dex (0.5 dex in alpha and iron peak elements)
- This scatter is due to the spatial inhomogeneity of the chemical composition of interstellar matter in the early Galaxy.
- Some objects show extremely large abundance.

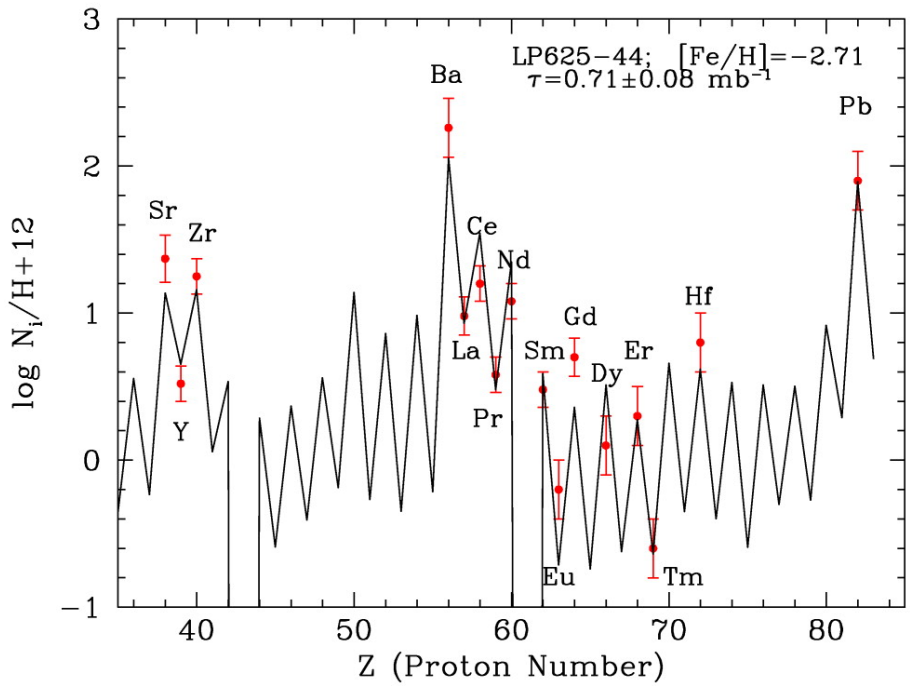
abundance patterns of n-capture rich stars

r-process



Sneden et al. 2003

s-process

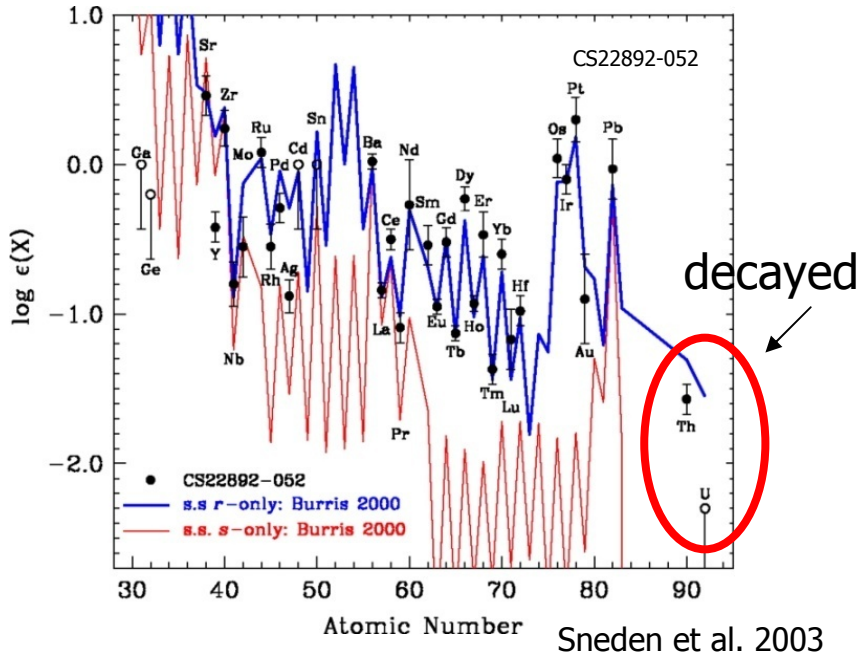


Aoki et al. 2001

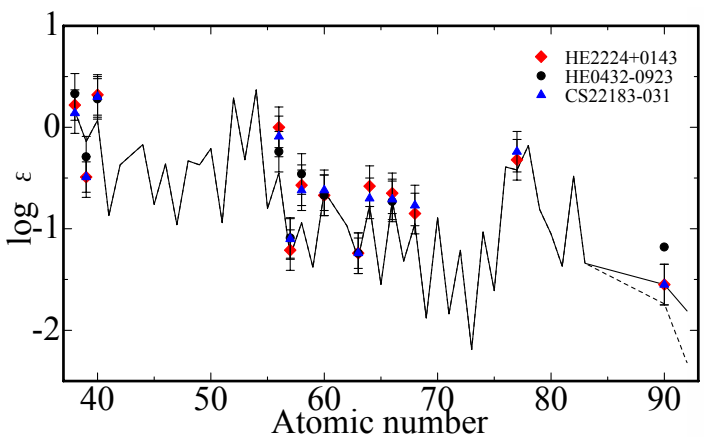
These stars show pure r-/s- process patterns.

Detailed analysis of r-process rich stars

- Universal pattern
  - 56≤Z≤72
- Th, (and U) line was detected.
  - age determination

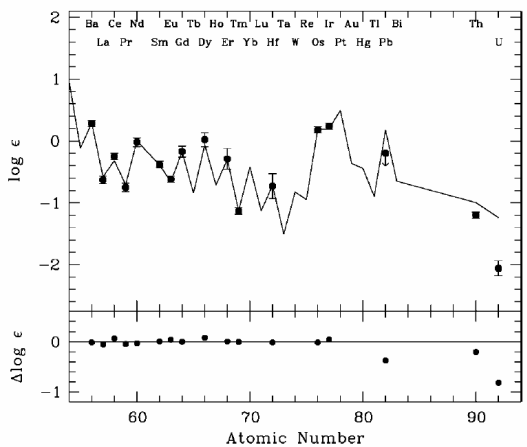


Sneden et al. 2003



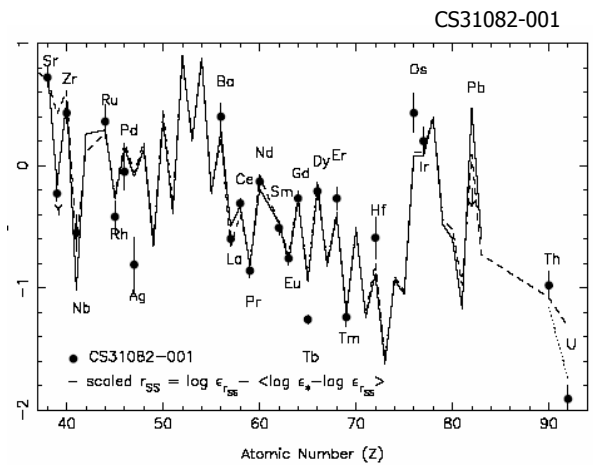
Honda et al. in prep.

HE1593-0901



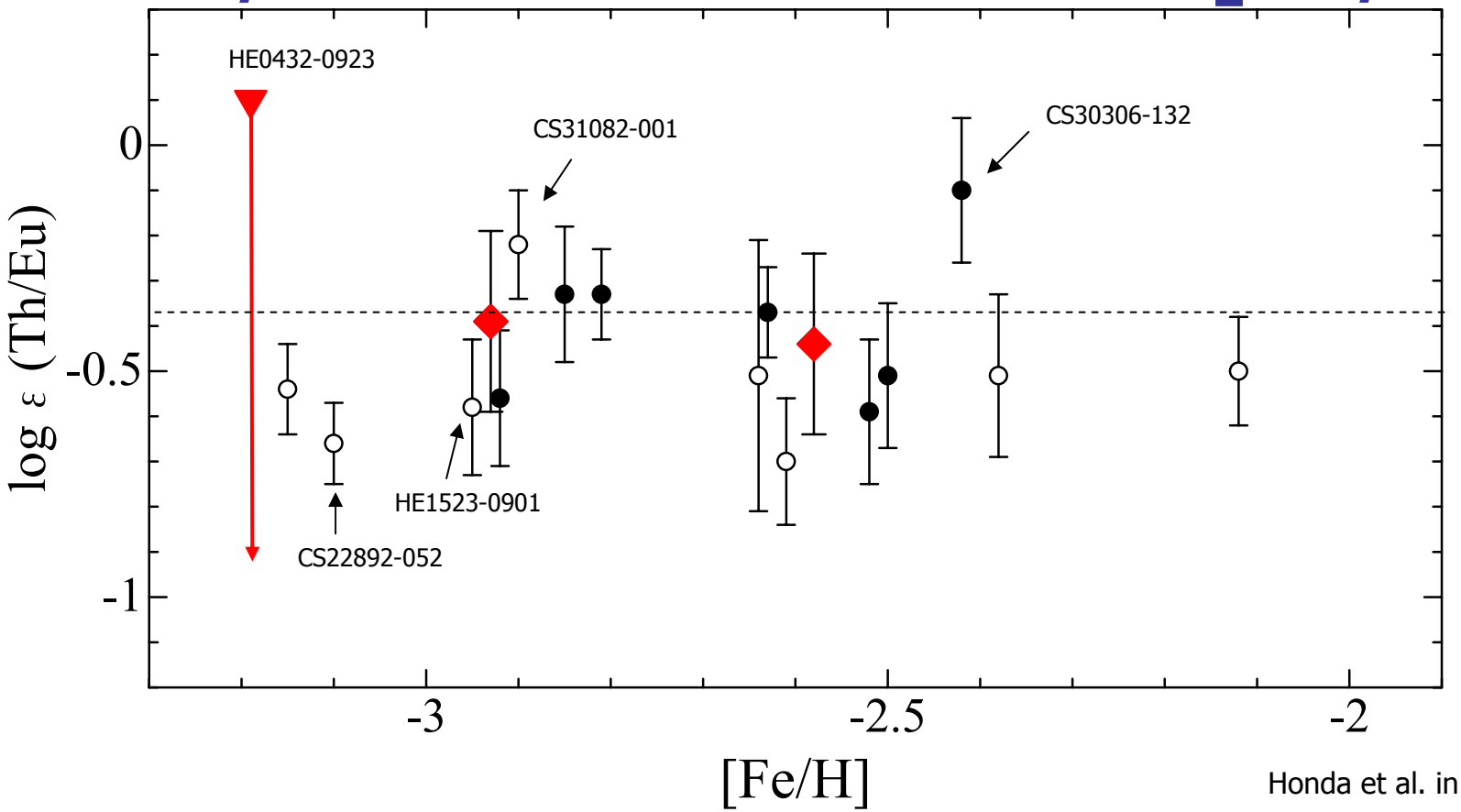
Frebel et al. 2007

CS31082-001



Hill et al. 2002

Th/Eu as a function of [Fe/H]

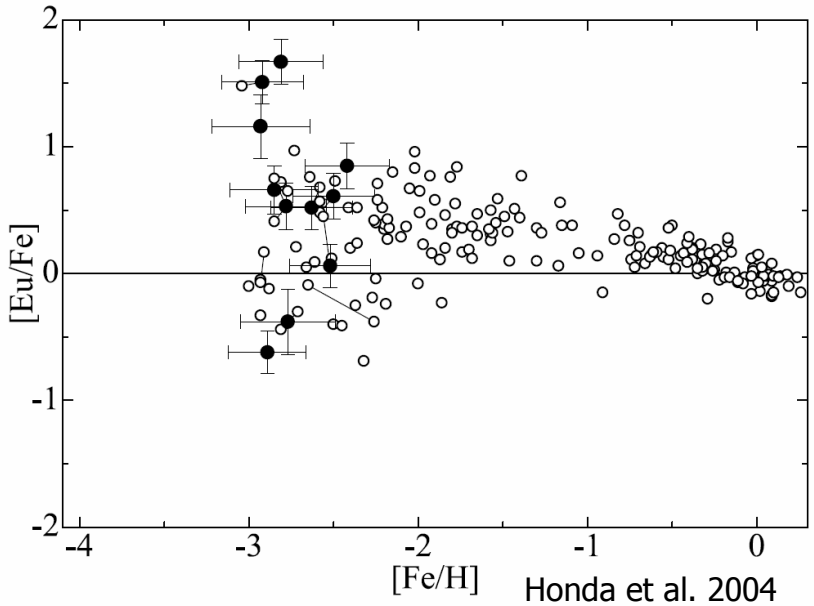


Honda et al. in prep.

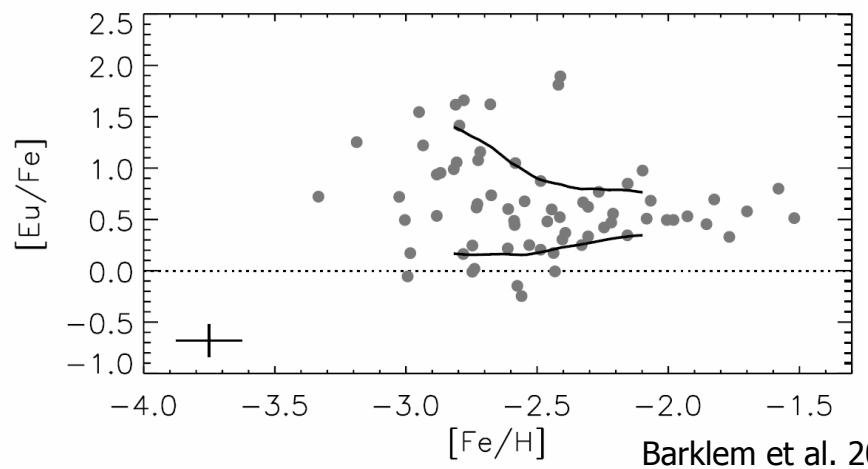
- The ratio of Th/Eu show scatter.
  - The width of the scatter is not so large.

Survey of neutron-capture elements in very metal-poor stars with High-dispersion spectrograph

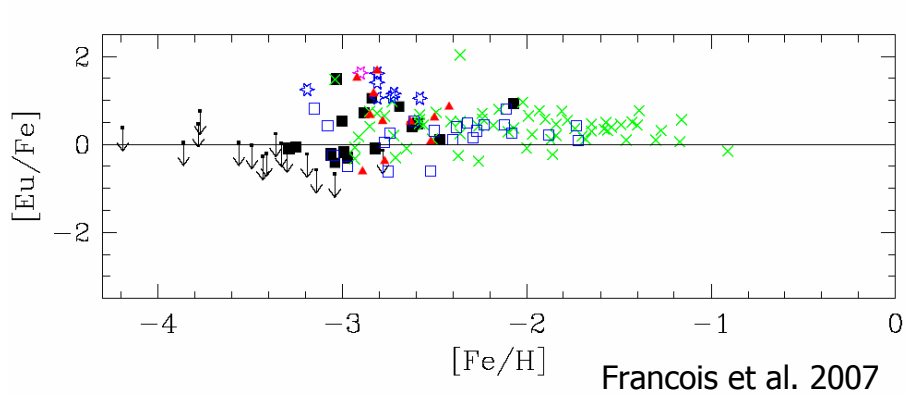
- Subaru/HDS
- VLT/UVES（ESO Large Program）
  - HERES
  - First stars
- Keck/HIRES
- HRS/Hobby-Ebberly
- （SDSS/SEGUE＋HDS）



Honda et al. 2004
Subaru/HDS



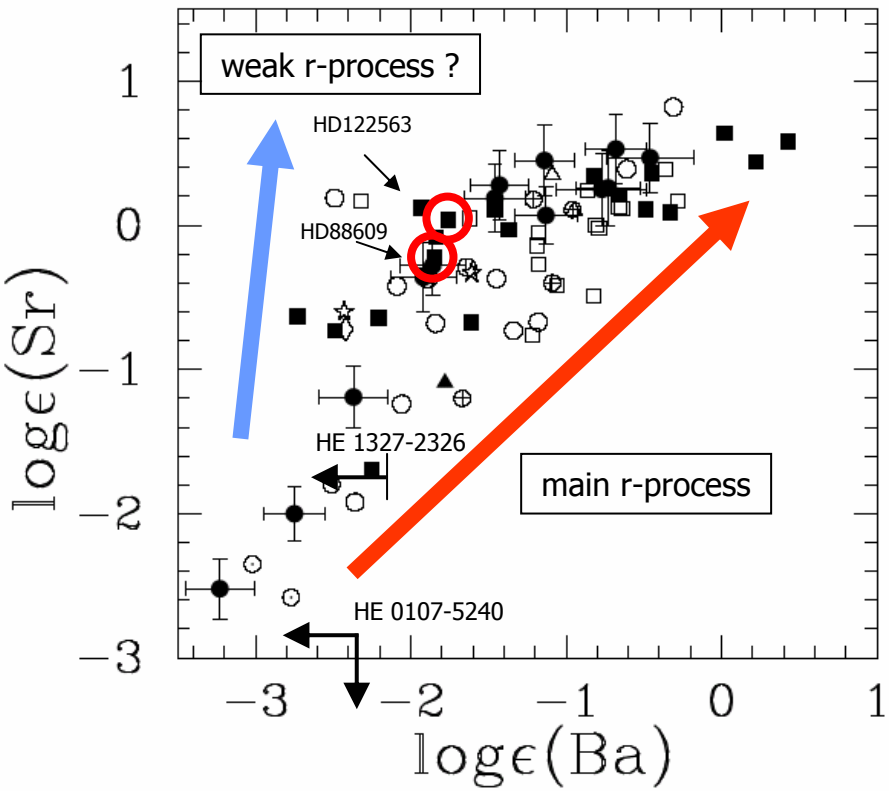
Barklem et al. 2005



Francois et al. 2007
VLT/UVES

Existence of two processes ?

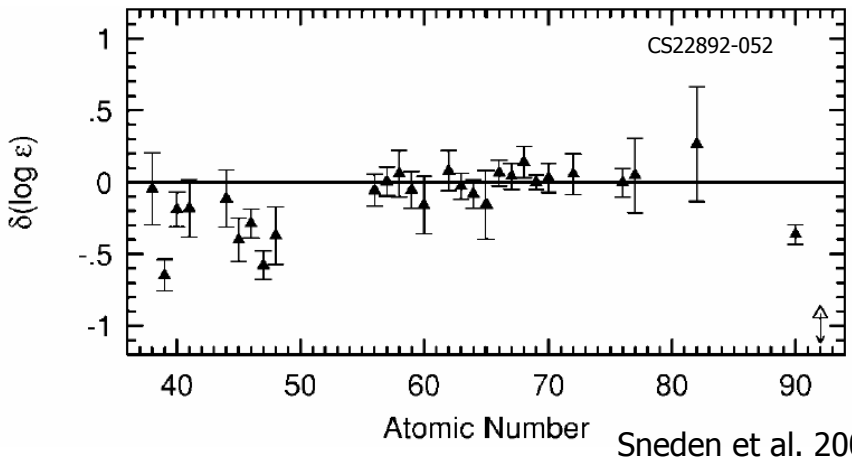
[Fe/H] ≤ -2.5, no s-rich stars



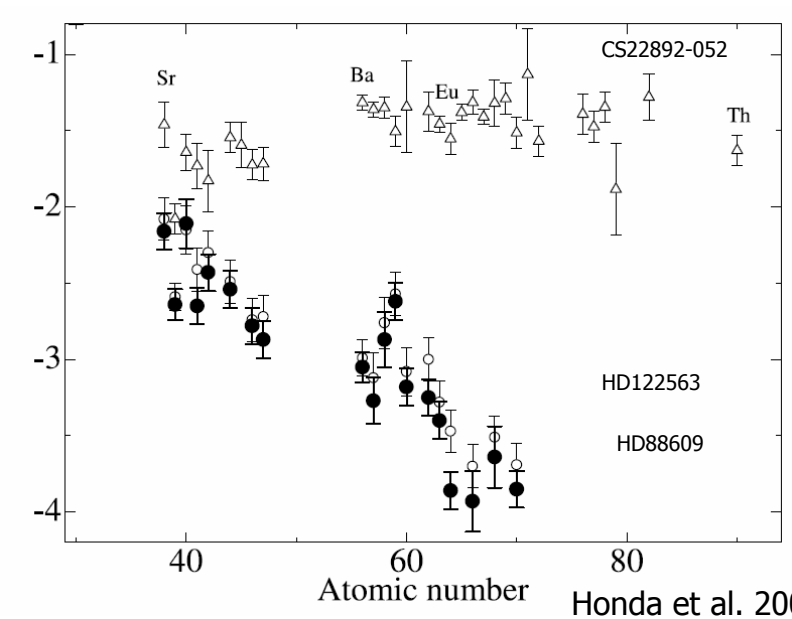
Aoki et al. 2005

- Our inspection of the correlation between Sr and Ba abundances in very metal-poor stars reveals that the dispersion of the Sr abundances clearly decreases with increasing of Ba abundance.
- Existence of two processes.
  - Synthesizing Sr and Ba in similar proportions. (main r-process)
  - Synthesizing Sr without Ba. (weak r-process ?)

Multiple r-process sites



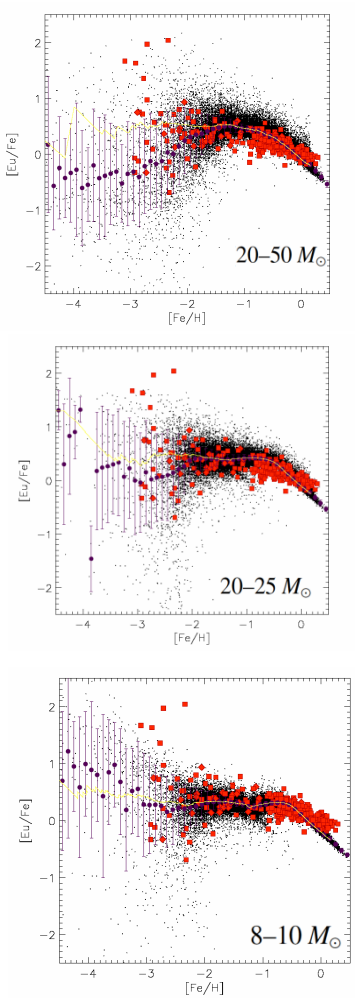
Sneden et al. 2000



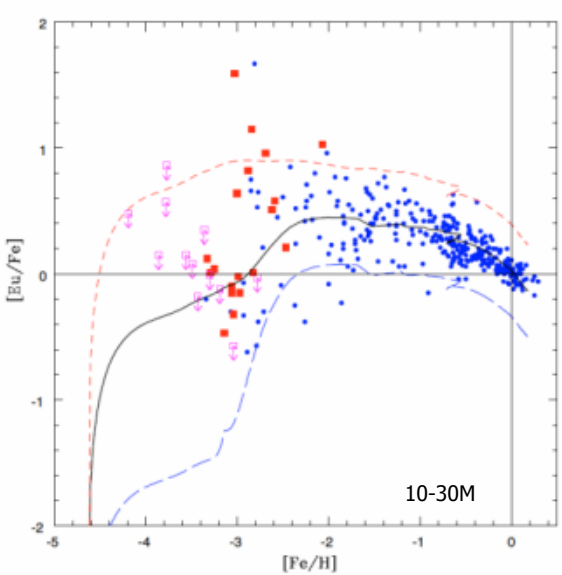
Honda et al. 2007

- Some metal-poor stars show a significantly different abundance pattern from that of the solar system r-process abundance pattern.
- This results support the existence of two process (main and weak r-process).

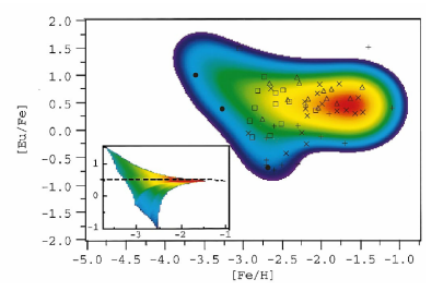
Models of galactic chemical evolution



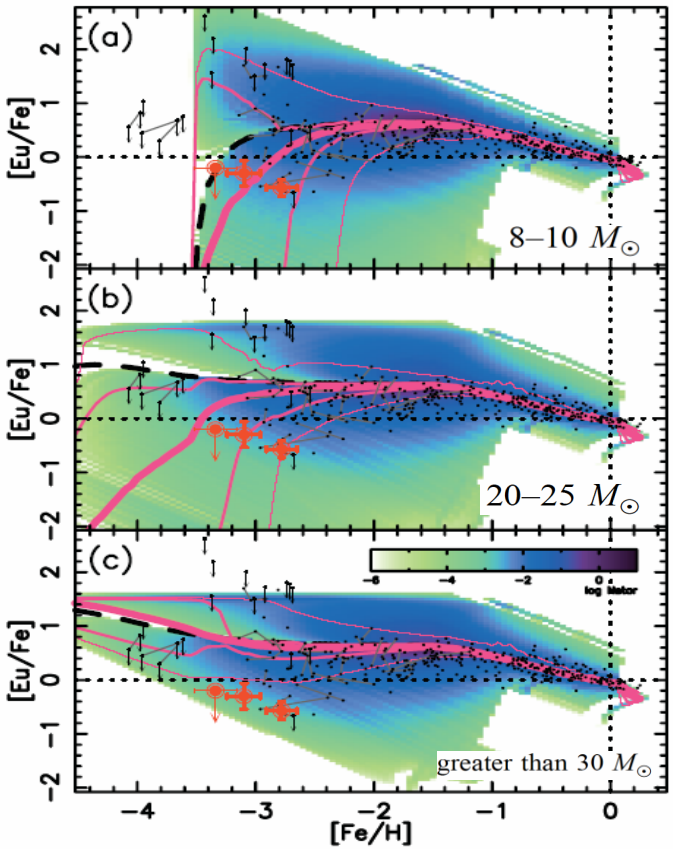
Argast et al. 2004



Cescutti et al. 2006



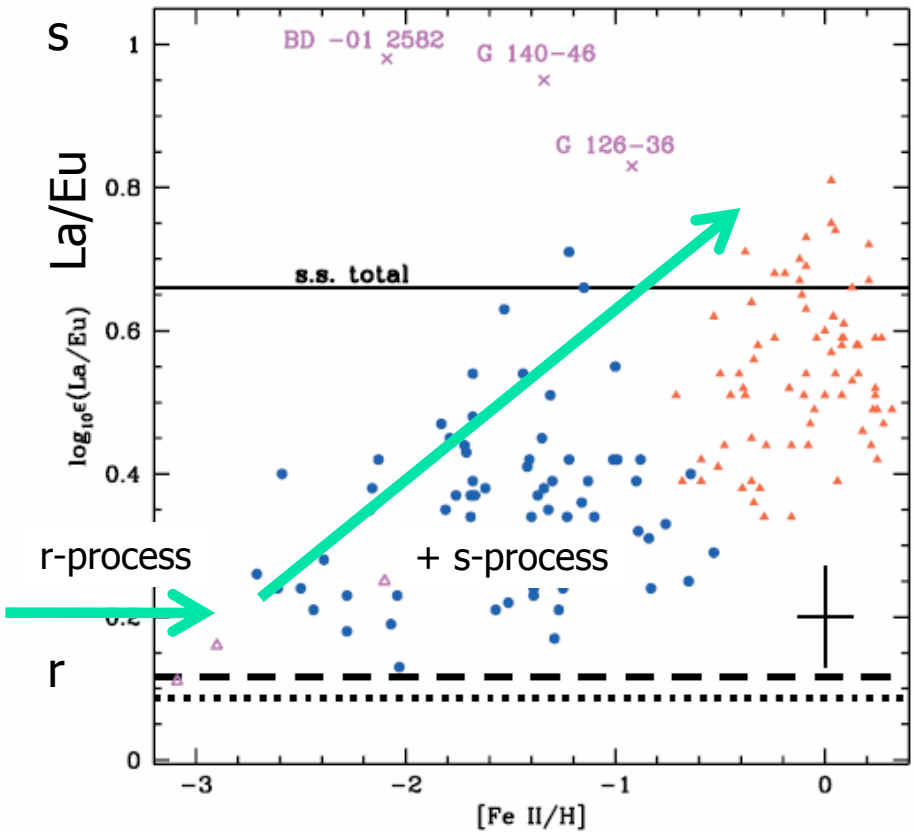
Tsujimoto et al. 1999

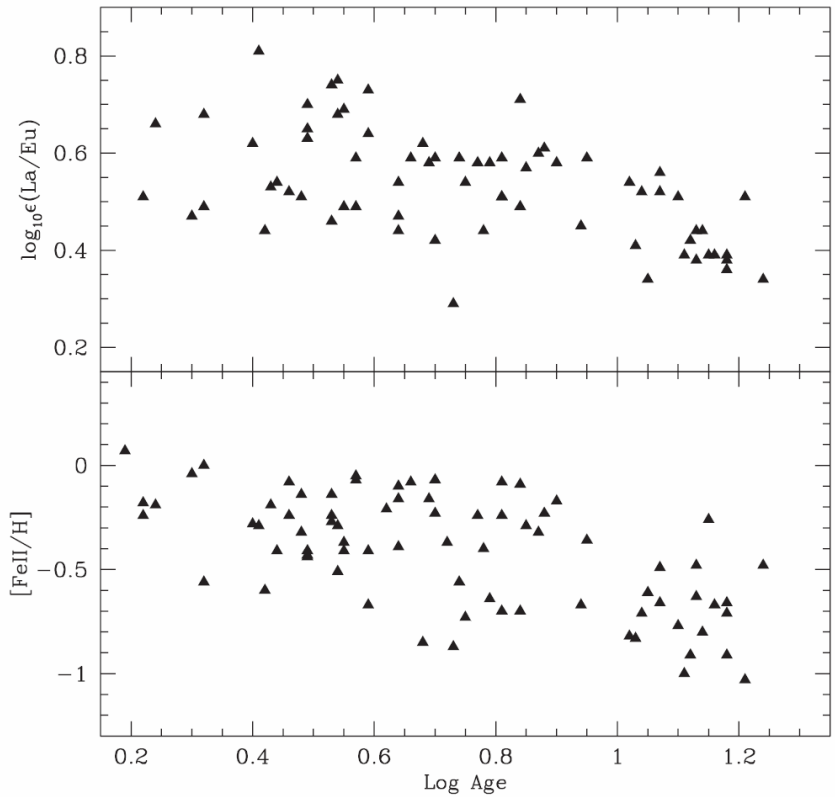


Ishimaru et al. 2004

[Fe/H]<-3 is important

Where s-process production begins ?



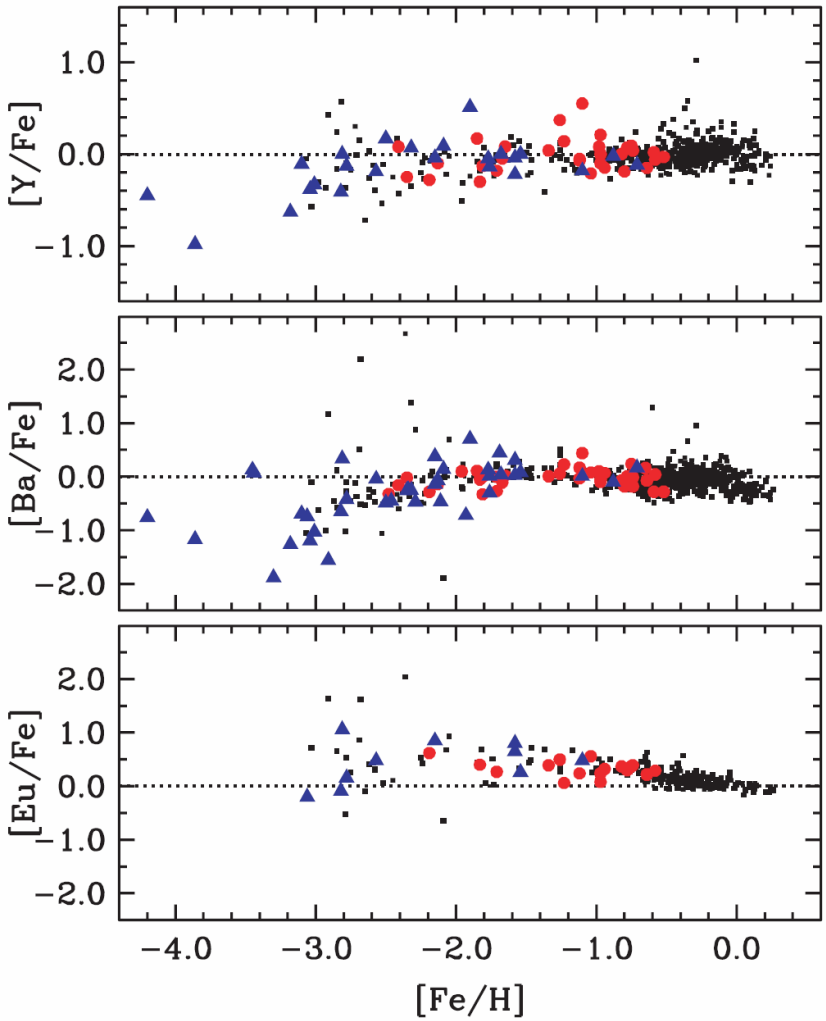


Simmerer et al. 2004

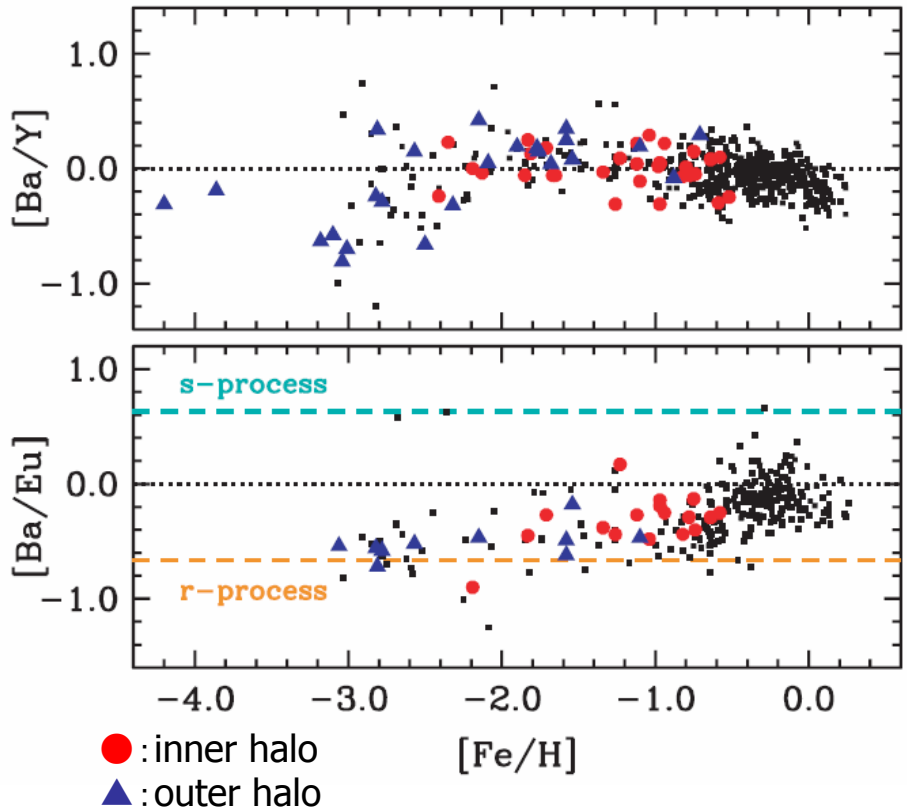
lower-mass stars have time to evolve and enrich the interstellar gas with s-process-rich ejecta, but

s-process contribution even at very low metallicites.

Inner and Outer Halo populations



Roederer 2009

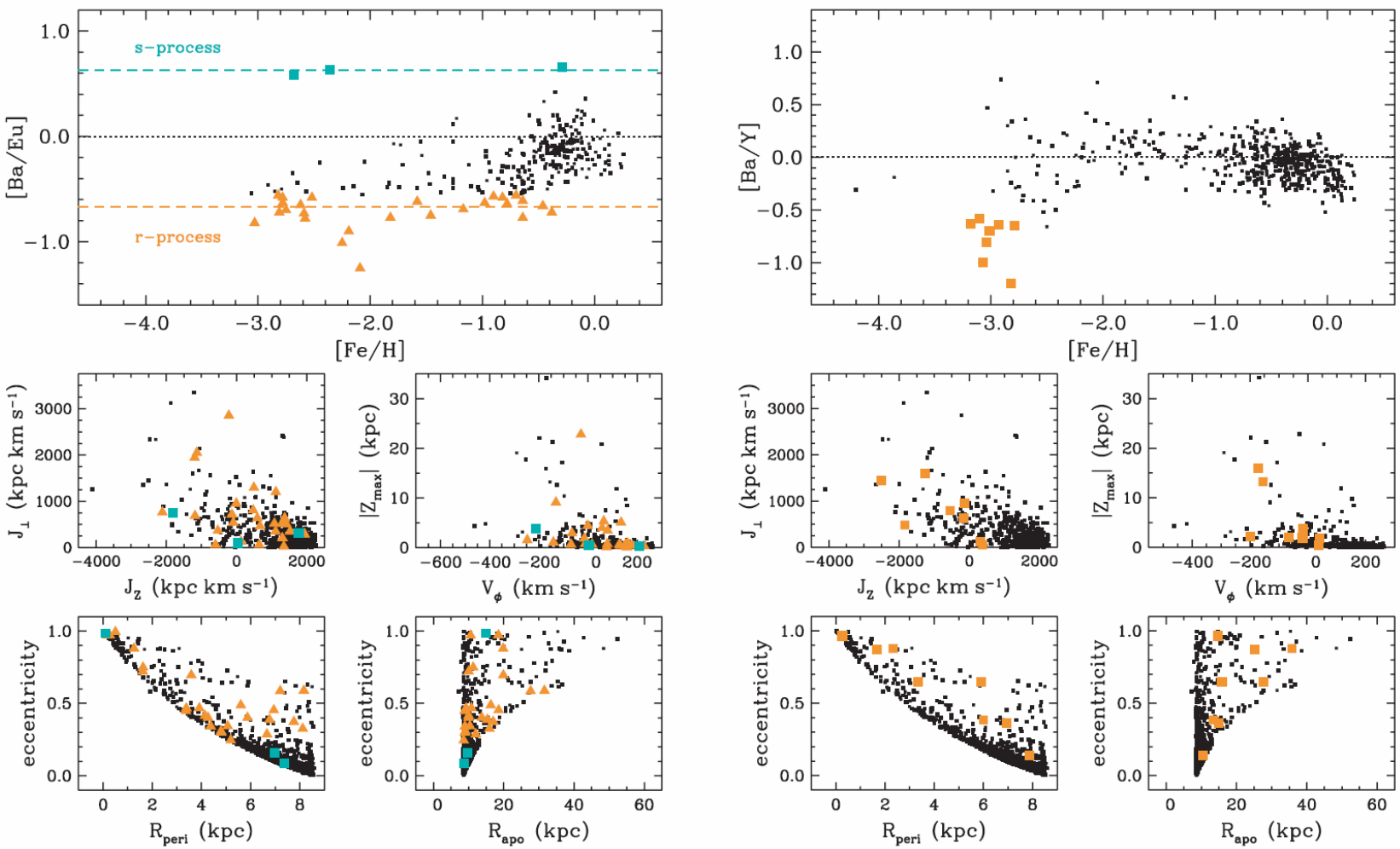


The scatter of the inner halo is smaller than the scatter of outer halo.

⟶ origin from a well-mixed ISM

⟶ local SN events

n-capture enrichment signatures.



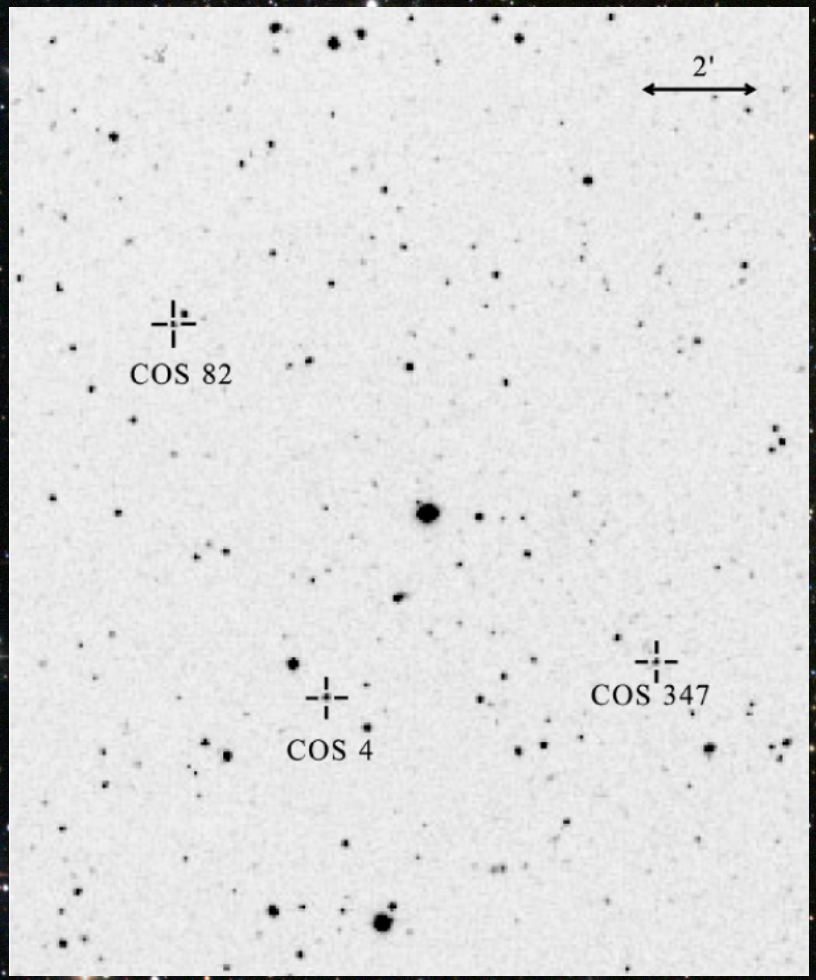
Roederer 2009

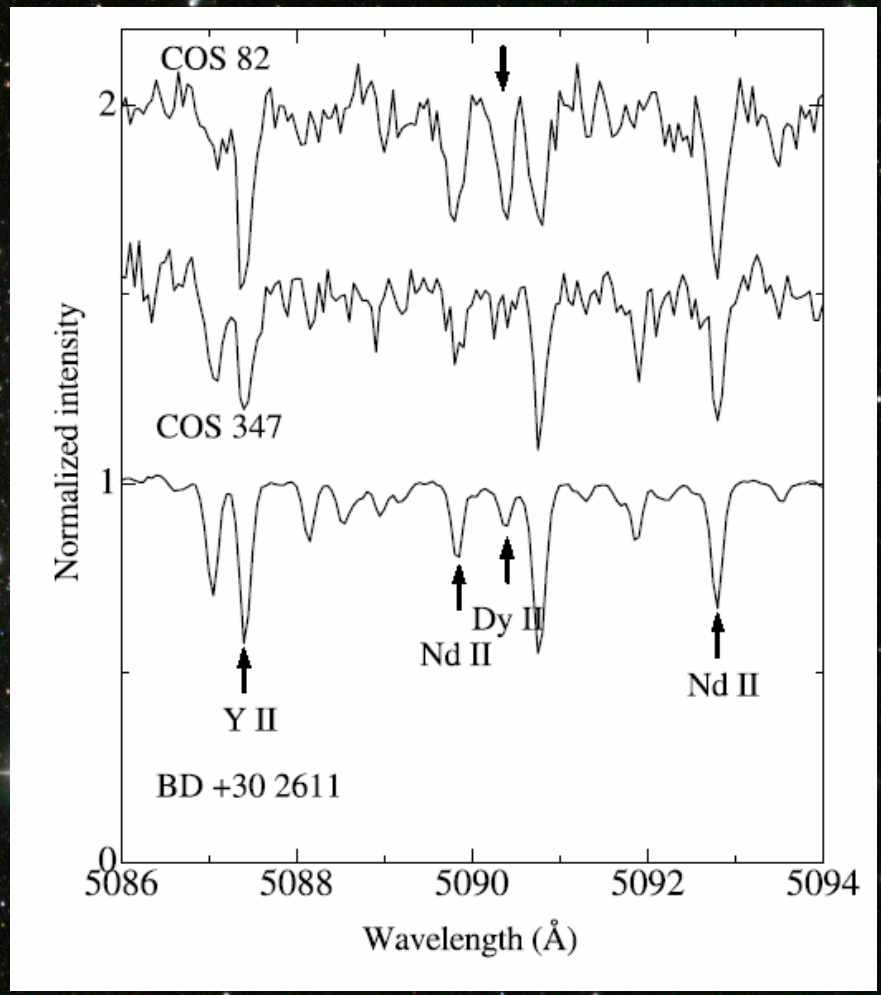
no preferred kinematic properties.

Large survey of field metal-poor stars with high dispersion spectrum

- Search for neutron-capture elements enhanced stars.
- Behavior of Eu in EMP stars ([Fe/H] < -3).
- Where is the rise of s-process ?
- Is there any difference in Halo and thick disk stars ?
- Follow up of SDSS/SEGUE.

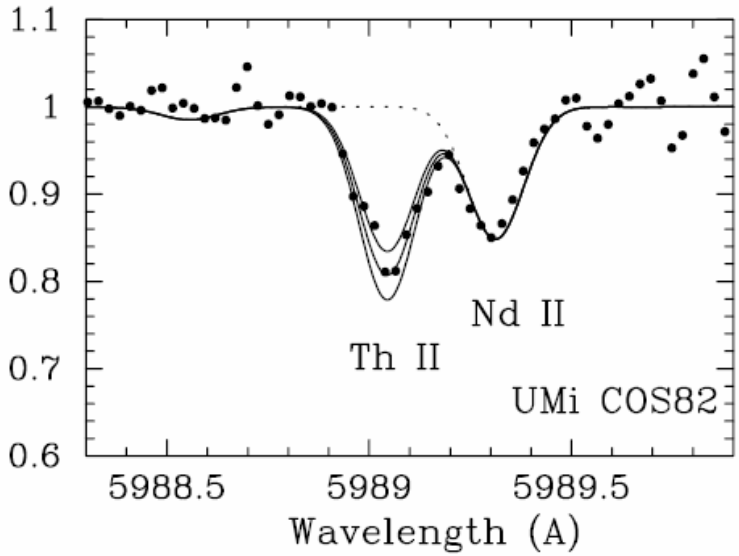
Ursa Minor dwarf galaxy



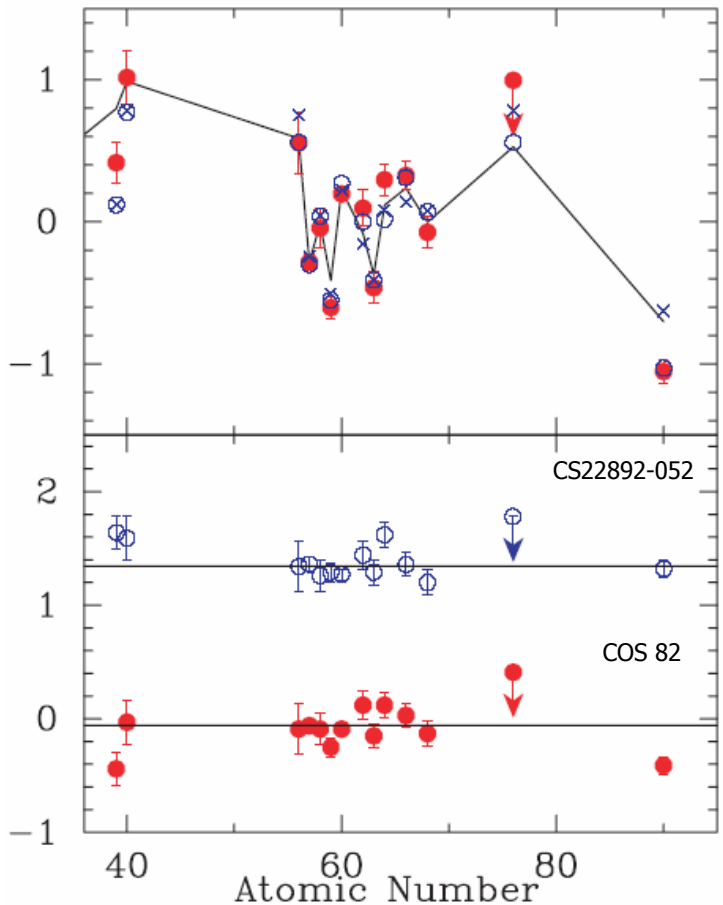


Sadakane et al. 2004

First Detection of Thorium in an Extragalactic Star.



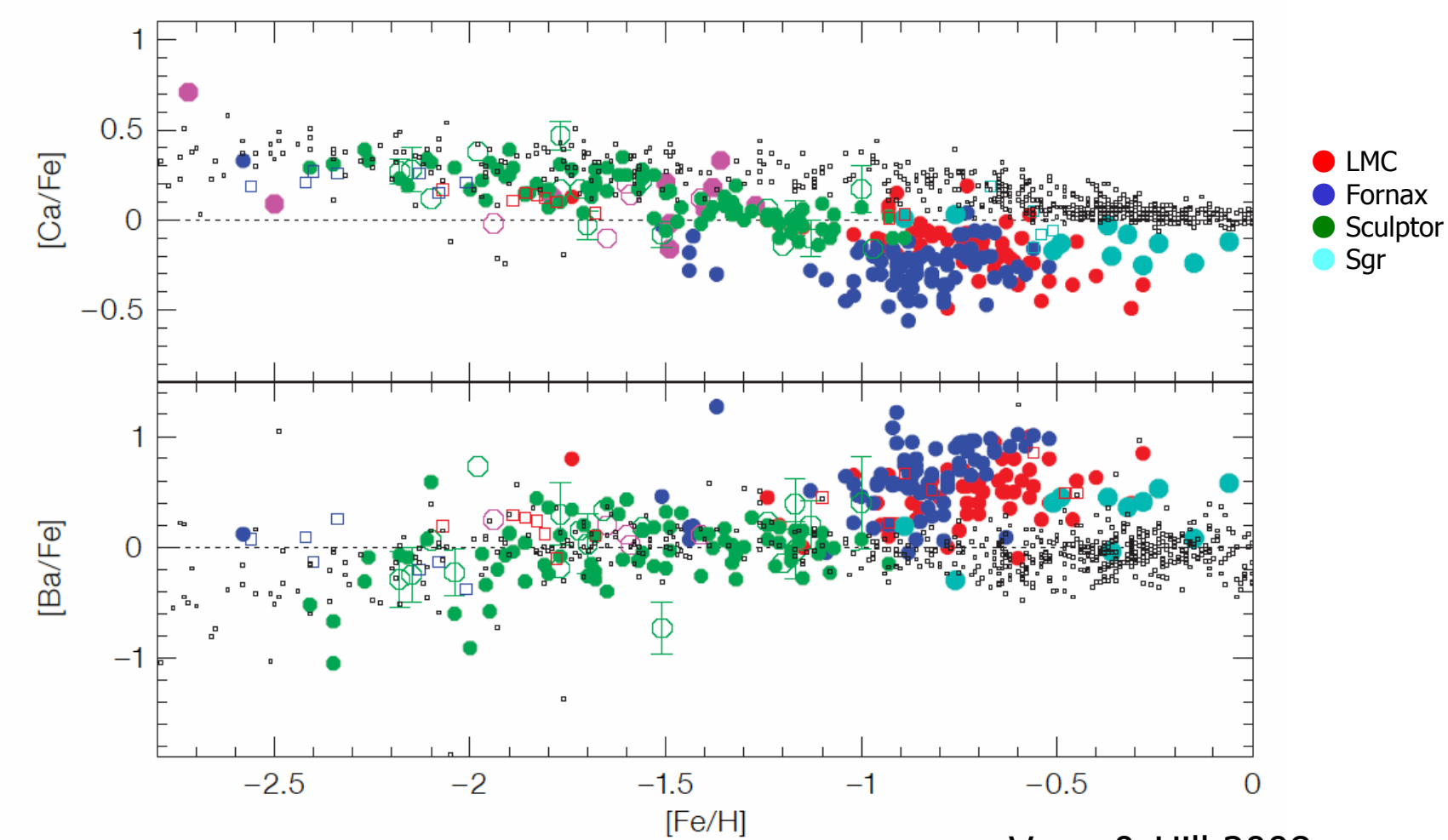
r-process pattern !



Red giant (V=17)
T_{eff} = 4300K logg = 0.6
[Fe/H] = −1.5
[Eu/Fe] = +1.5
Age $\gtrsim$ 12 Gyr?

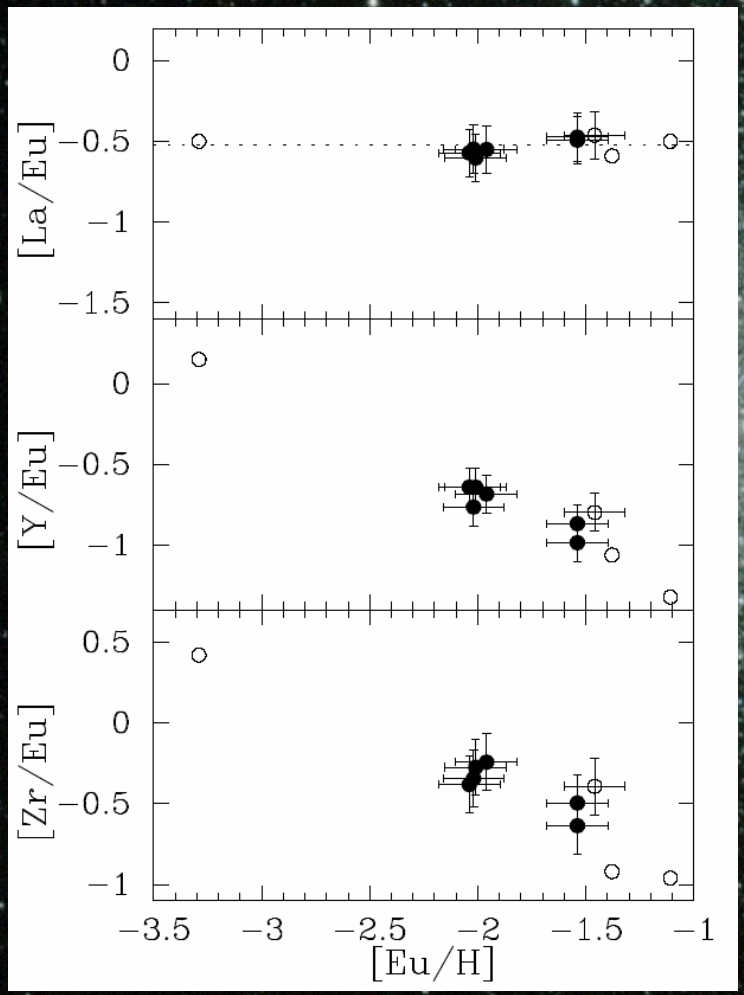
Aoki et al. 2006

Chemical Signatures in Dwarf Galaxies

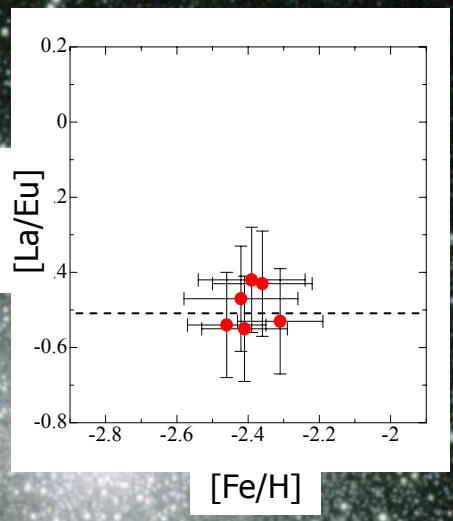


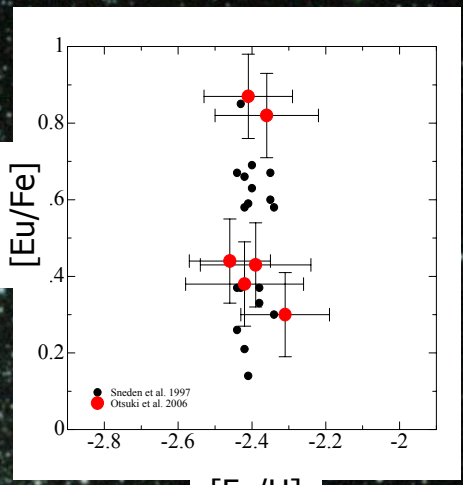
Venn & Hill 2008

n-capture elements in Globular Clusters



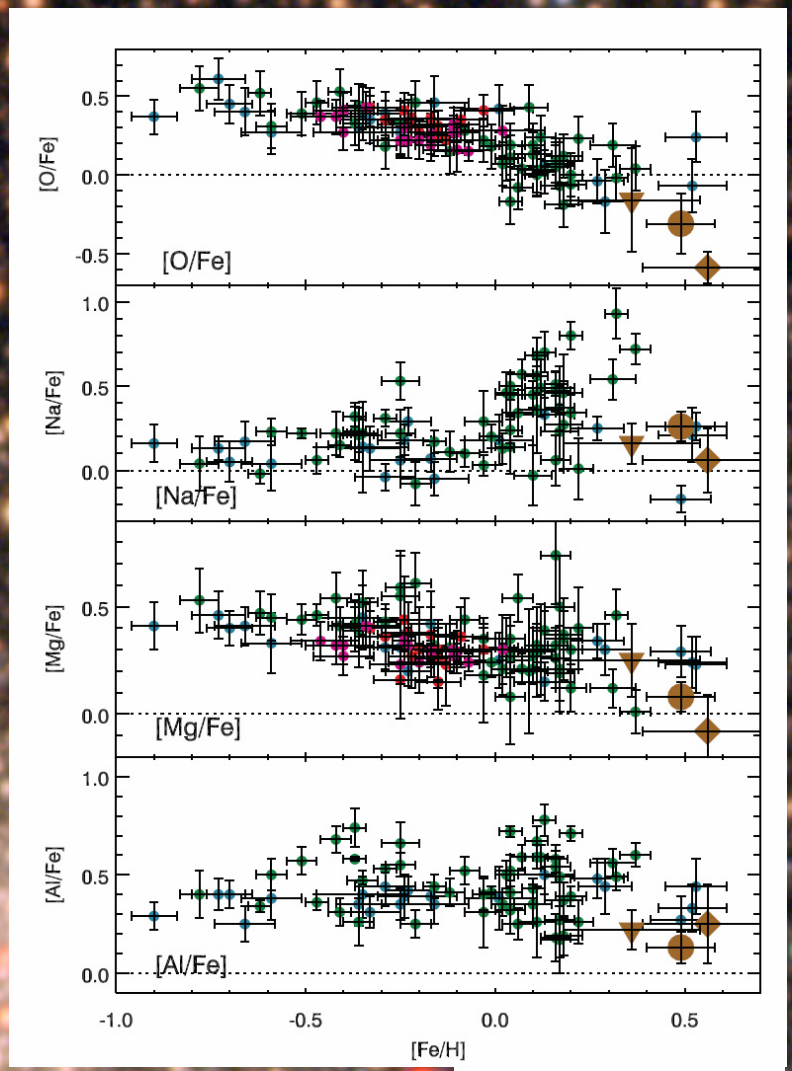
Otsuki et al. 2006



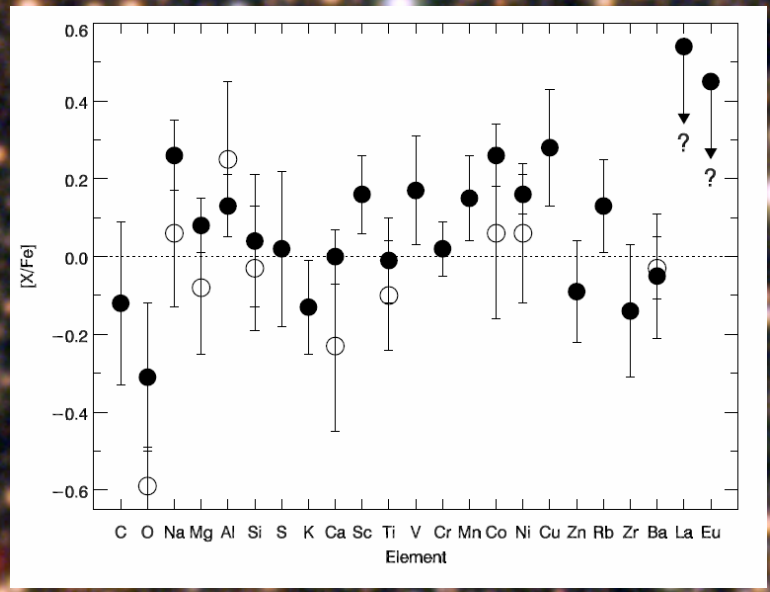


- Large scatter in [n/Fe].
- No contribution of s-process.
- Contribution of the weak-r-process is found.
  - weak r-process is primary process ?

Galactic Bulge stars



Cohen et al. 2008



- There is a very small sample for dwarf
- Baade's window

summary

- The large survey of field metal-poor stars with WFMOS is very effective for the study of the origin of neutron-capture element.
- WFMOS is powerful tool not only to survey observation but also observations of compact object.
- We need the High-dispersion (R > 40,000) mode of WFMOS.