The origin of weak r-process nucleosynthesis

Hiroko Okada (U.Hyogo)

Wako Aoki, Nozomu Tominaga (NAOJ),

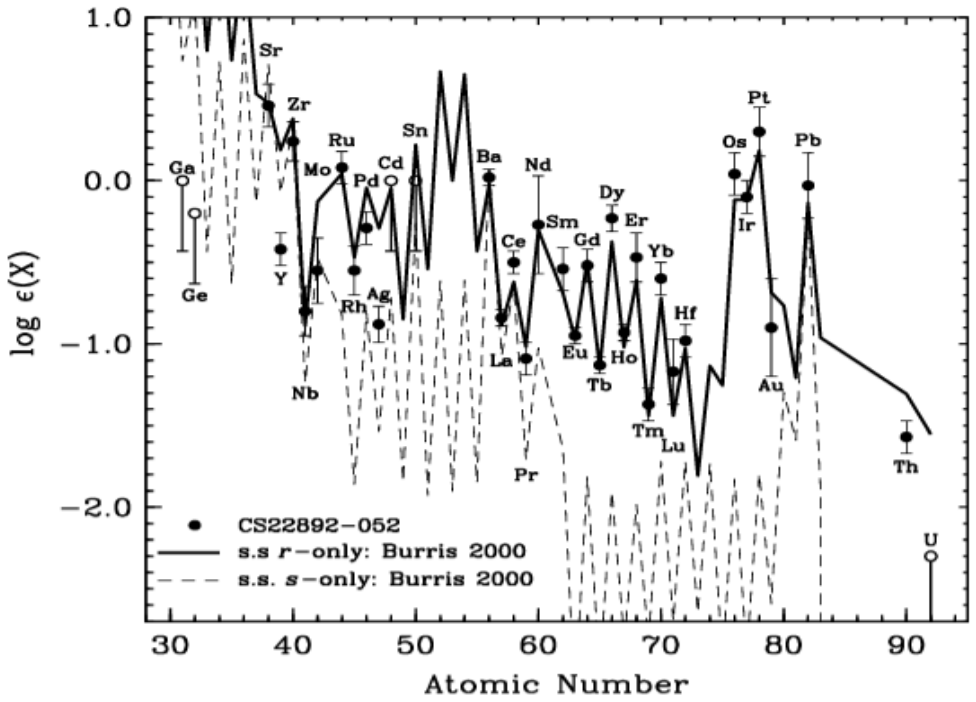
Satoshi Honda (U.Hyogo)

R-process abundance pattern in metal-poor star

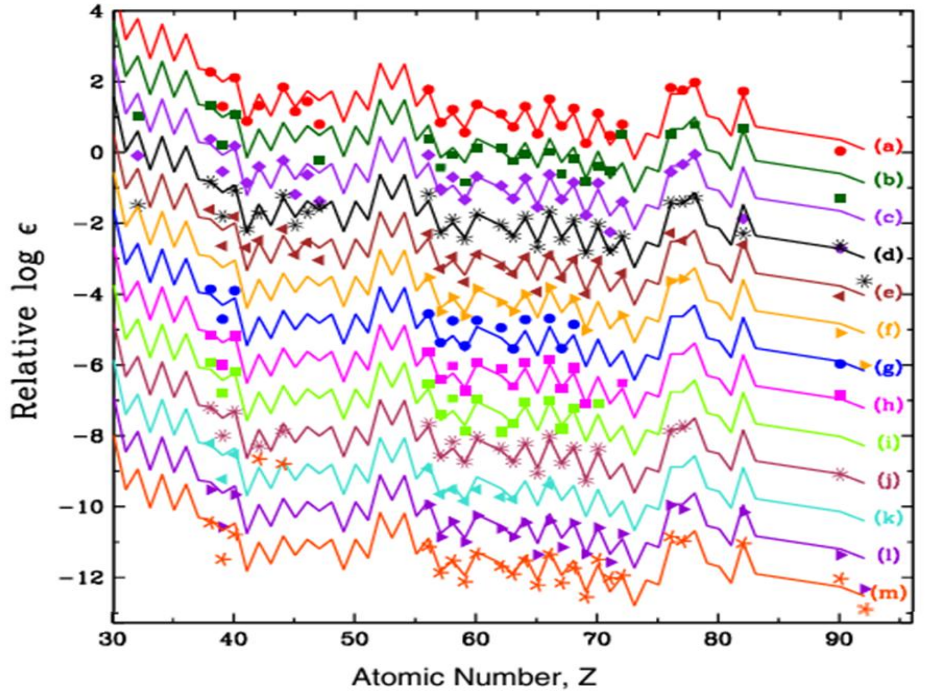
The abundance pattern of neutron-capture elements in metal-poor stars is consistent with the r-process abundance pattern of the solar system.

= **Universality of r-process**

-> Unique origin of r-process nucleosynthesis (neutron star mergers?)



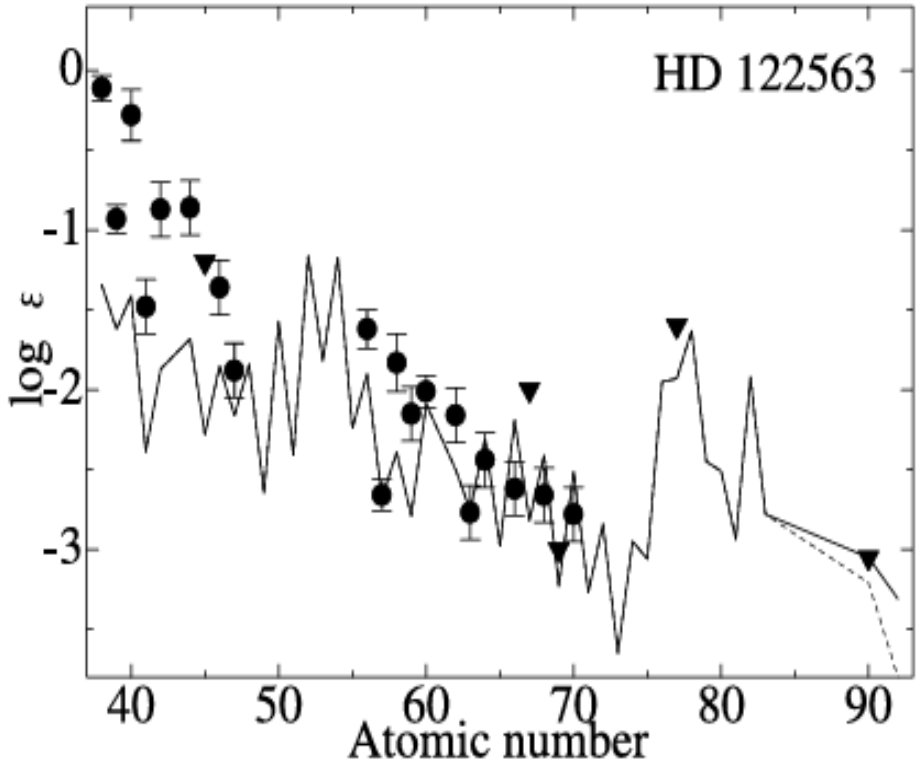
Sneden et al. 2008



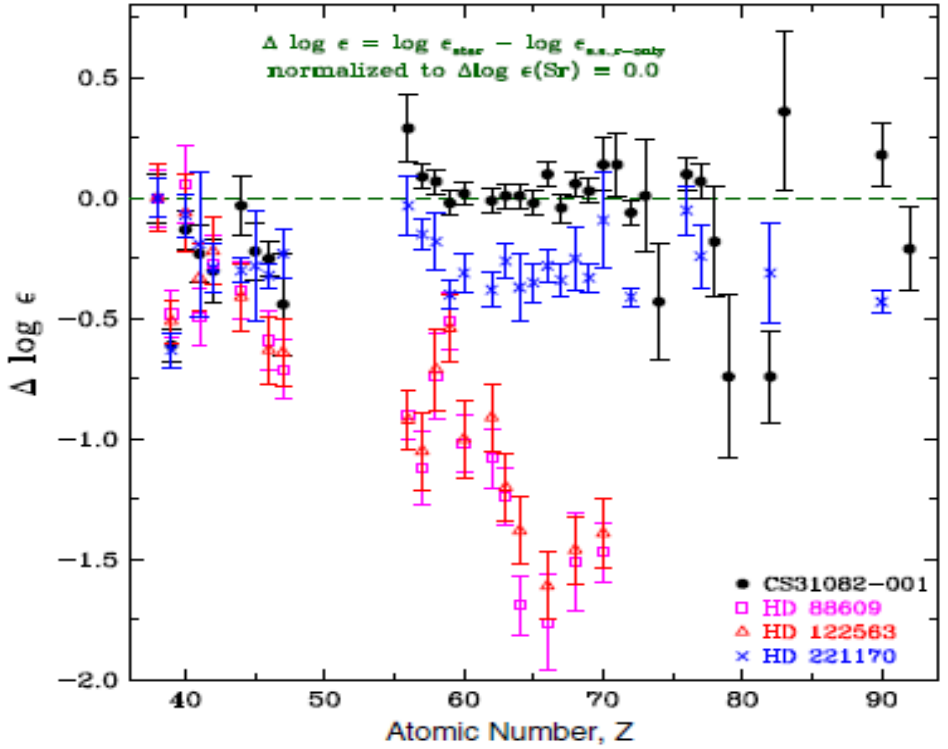
Cowan et al. 2021

R-process abundance pattern in metal-poor star

Some metal-poor stars exhibit a sharp drop at the heavy neutron-capture elements (Z > 56). -> **Weak r-process**



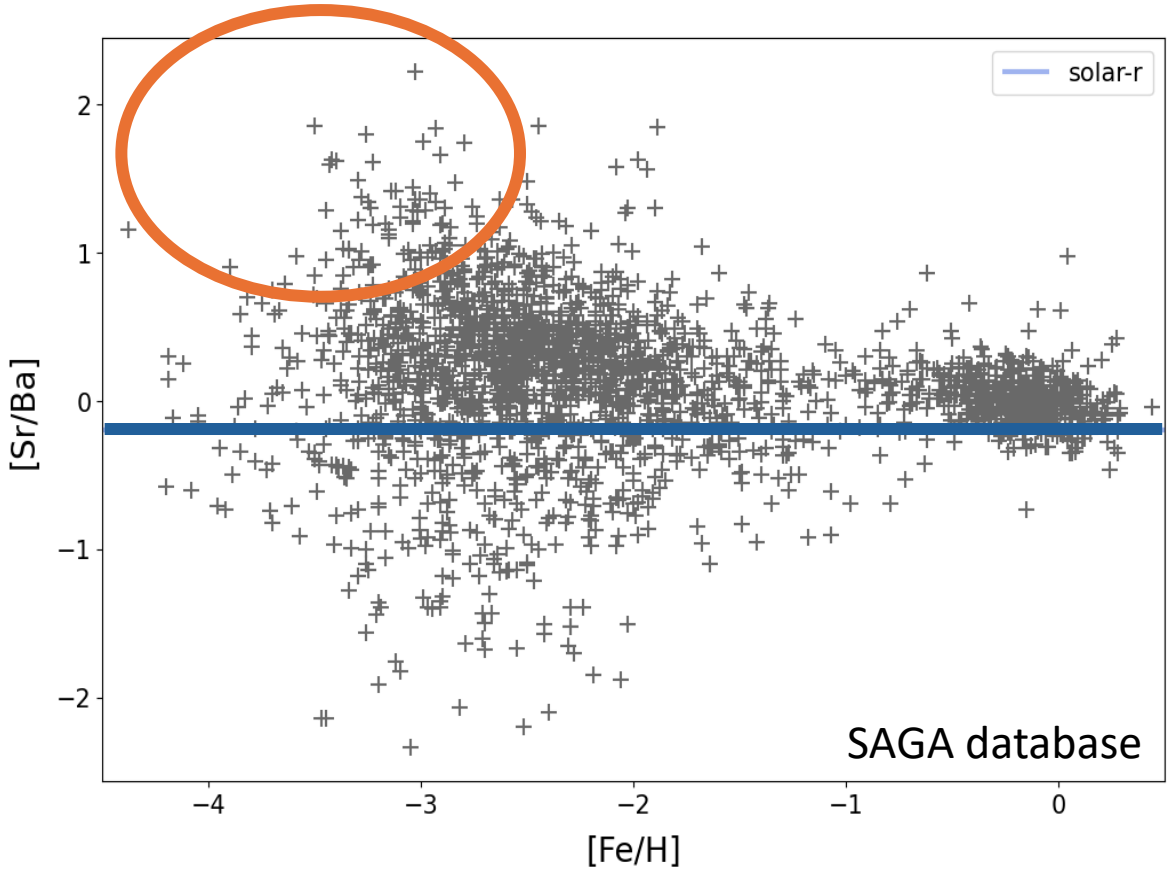
Honda et al. 2004



Reference?

[light-n/Ba] in metal-poor stars

Recent observations of metal-poor stars reveal two r-process classes.



- **Main r-process**
  produce both light and heavy n-cap elements
- **Weak r-process**
  produce up to light n-cap elements

What is the astrophysical site of weak r-process?

Candidates for (weak) r-process site

- **Neutron-star merger (e.g., Fujibayashi et al. 2020)**
  Coalescence of binary NSs.
  The mass ratio of NSs changes the mass ratios between dynamical ejecta with low Ye and post-merger ejecta with high Ye.

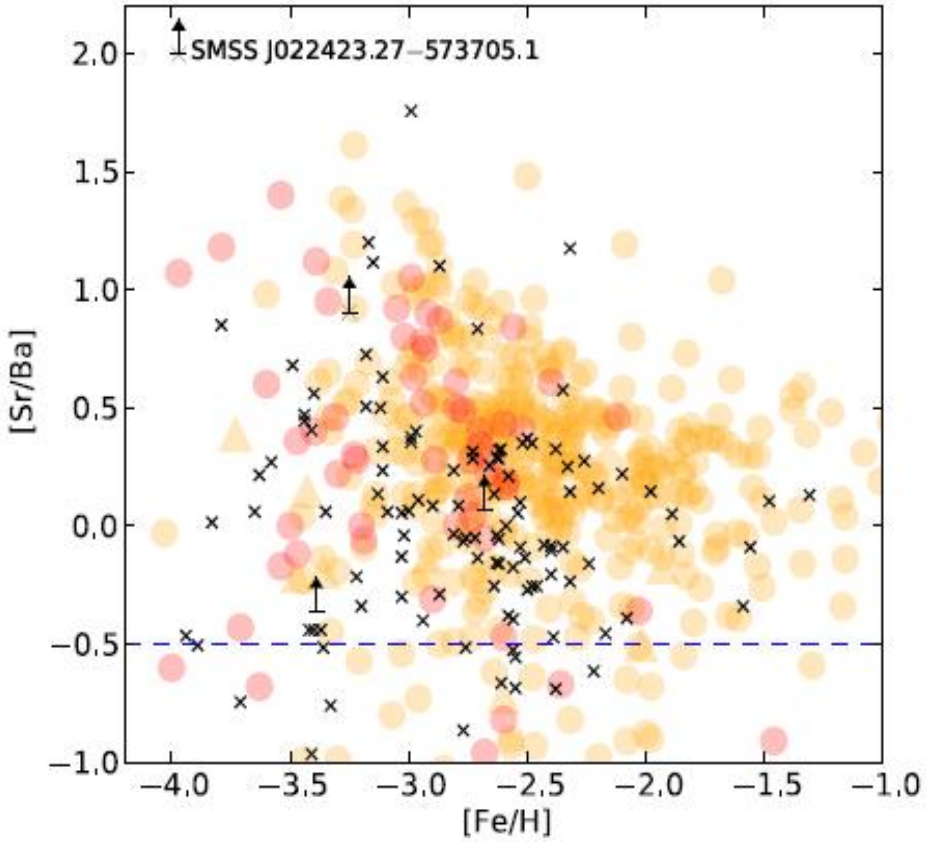
- **Proto-neutron-star wind (e.g., Wanajo 2013)**
  Outflow driven from the surface of PNS by neutrino heating.
  The mass of PNSs changes the entropy and the cooling time scale, and thus the efficiency of r-process nucleosynthesis.

- **Magneto-rotational supernova (e.g., Nishimura et al. 2015)**
  Core-collapse supernova powered by magnetically driven jets.
  The strength of magnetic field changes the neutron richness of the ejecta.

EMP star with weak r-process signature

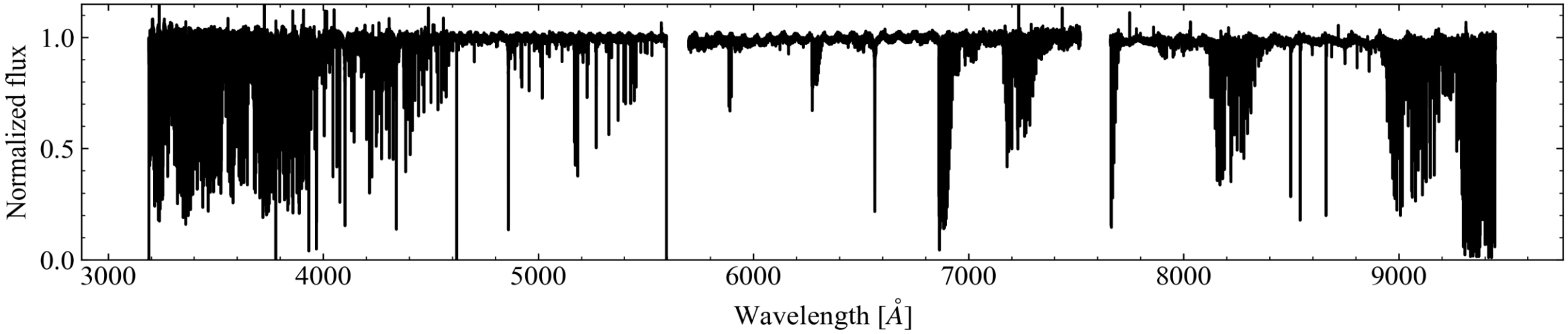
SMSS J022423.27-573705.1
discovered by SkyMapper Southern Sky Survey (Jacobson et al. 2015)

- **Bright**, V = 13.4
- **Extremely metal-poor**, [Fe/H] = −3.97
  = Only a single process contributed
- **High [Sr/Ba]** > +2.0
  No Ba line was detected !



Observation

High-resolution spectroscopy were carried out with VLT/UVES in Aug 2018.
(PI: Misa Aoki)



- Wavelength: 320 -- 940 nm
- R = 40,000 (BLUE), 50,000 (RED)
- S/N > 100 at 4500 Å

Abundance measurements

Okada et al. in prep.

Abundance measurements

We determine 26 elemental abundances
by equivalent widths measurement and spectrum synthesis using iSpec.

Okada et al. in prep.

Abundance measurements

Okada et al. in prep.

Abundance pattern of n-cap elements

Okada et al. in prep.

Neutron-star merger

Okada et al. in prep.

Proto-neutron-star wind

Okada et al. in prep.

Magneto-rotational supernova

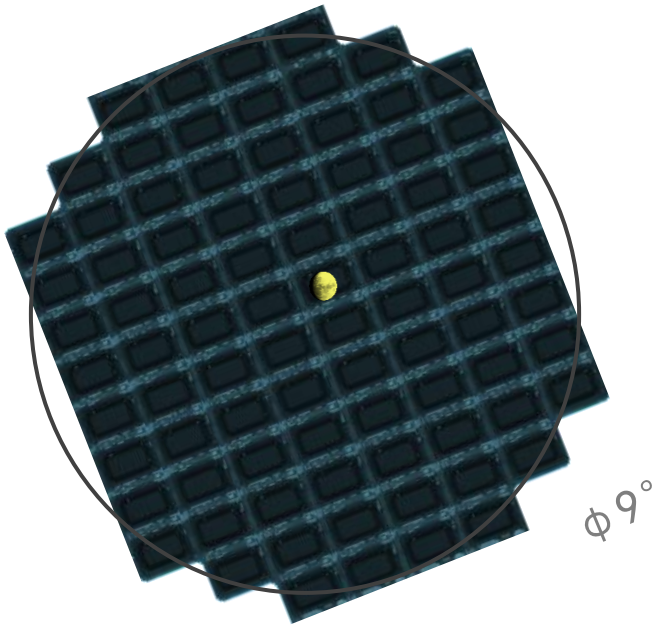
Okada et al. in prep.

High [Sr/Ba] of SMSS 0224-5737

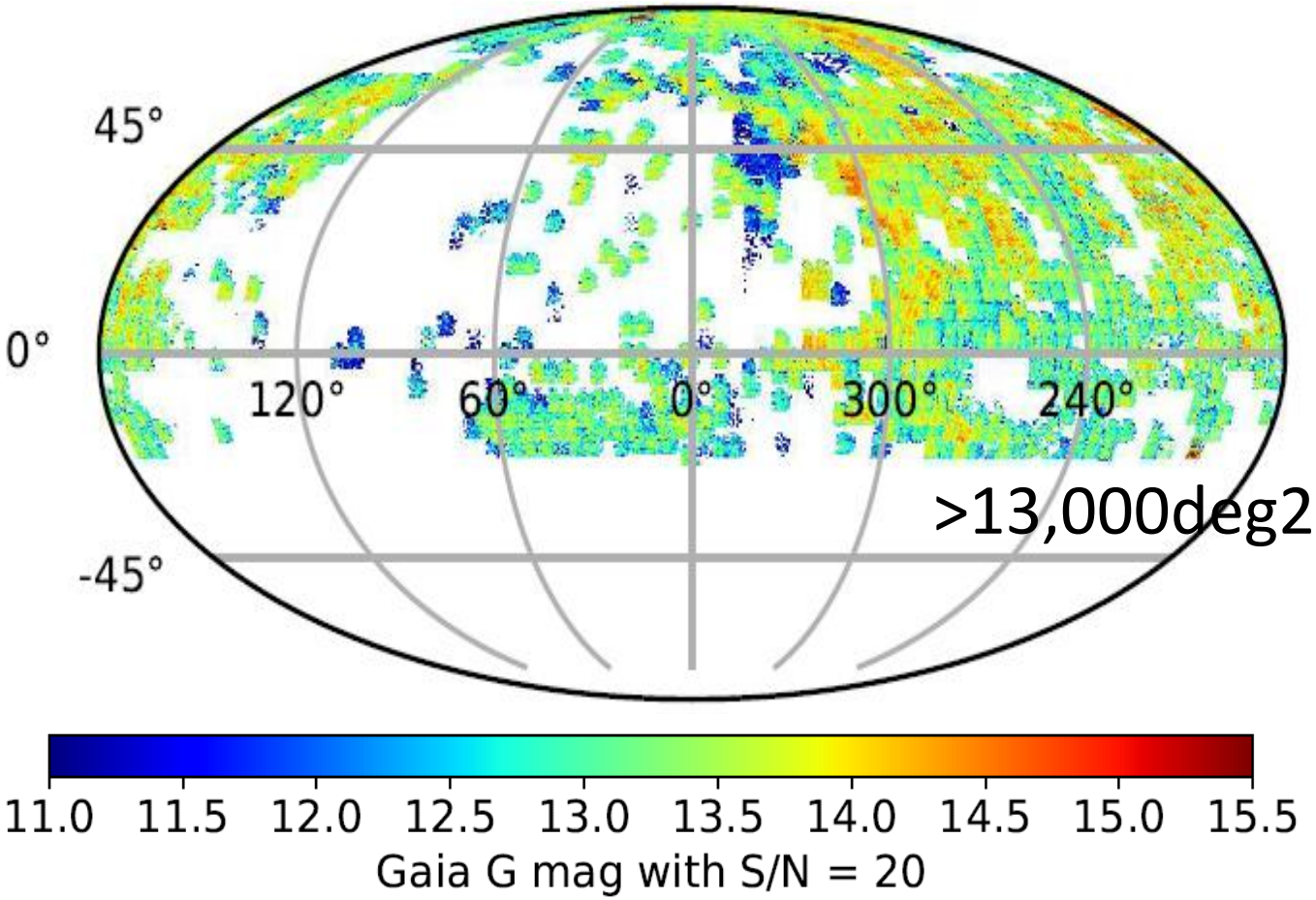
Okada et al. in prep.

Bright metal-poor star survey

Okada, Tominaga+



Tomo-e Gozen Camera



Lady Tomo-e

-> High-res spectroscopy with Subaru/HDS

Summary

We analyzed UVES spectra of the weak-r EMP star, SMSS 0224-5737.

Okada et al. in prep.

We are performing a narrow-band survey for bright metal-poor stars in northern sky using Tomo-e Gozen Camera.

- Bright metal-poor stars to obtain all light n-cap elements