Bright metal-poor star survey with Tomo-e and Nayuta

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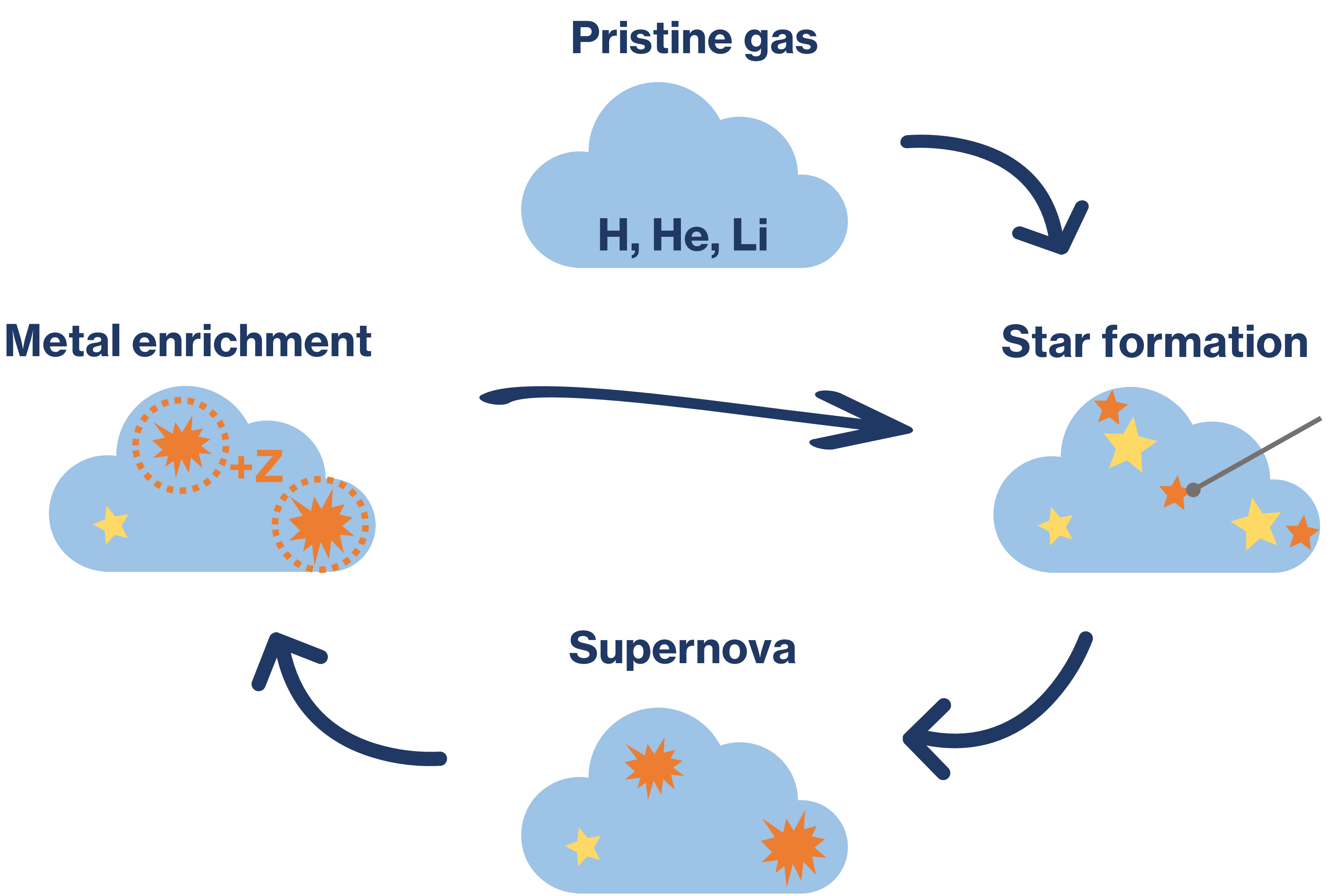
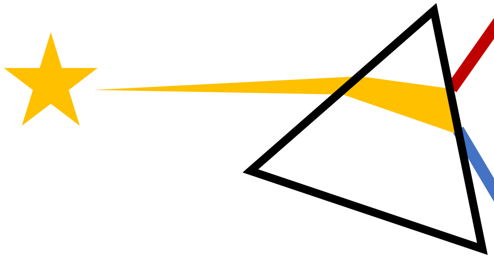
Chemical evolution

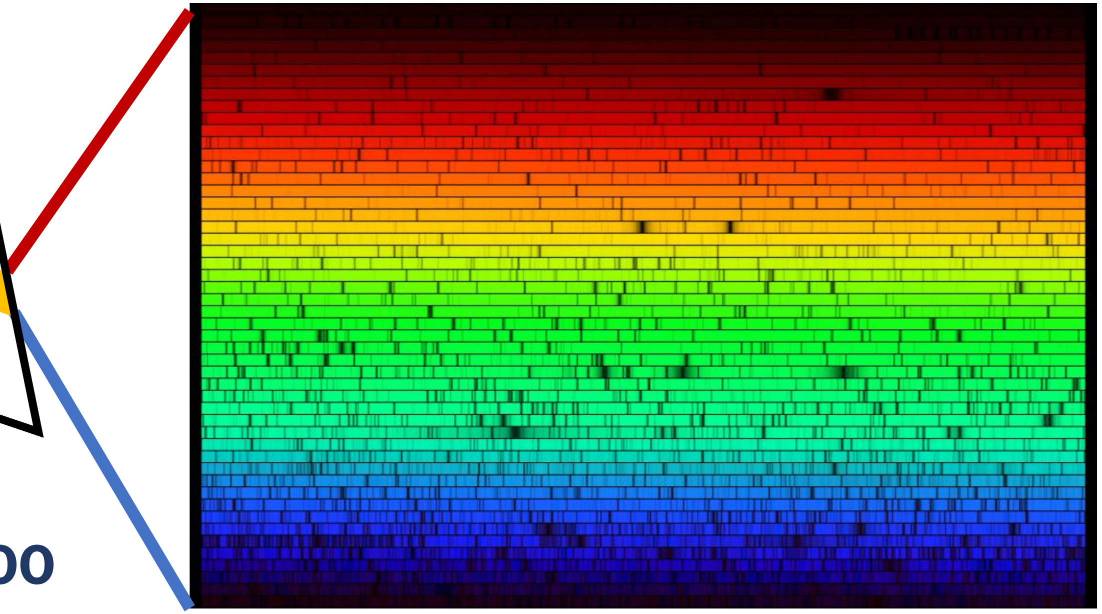


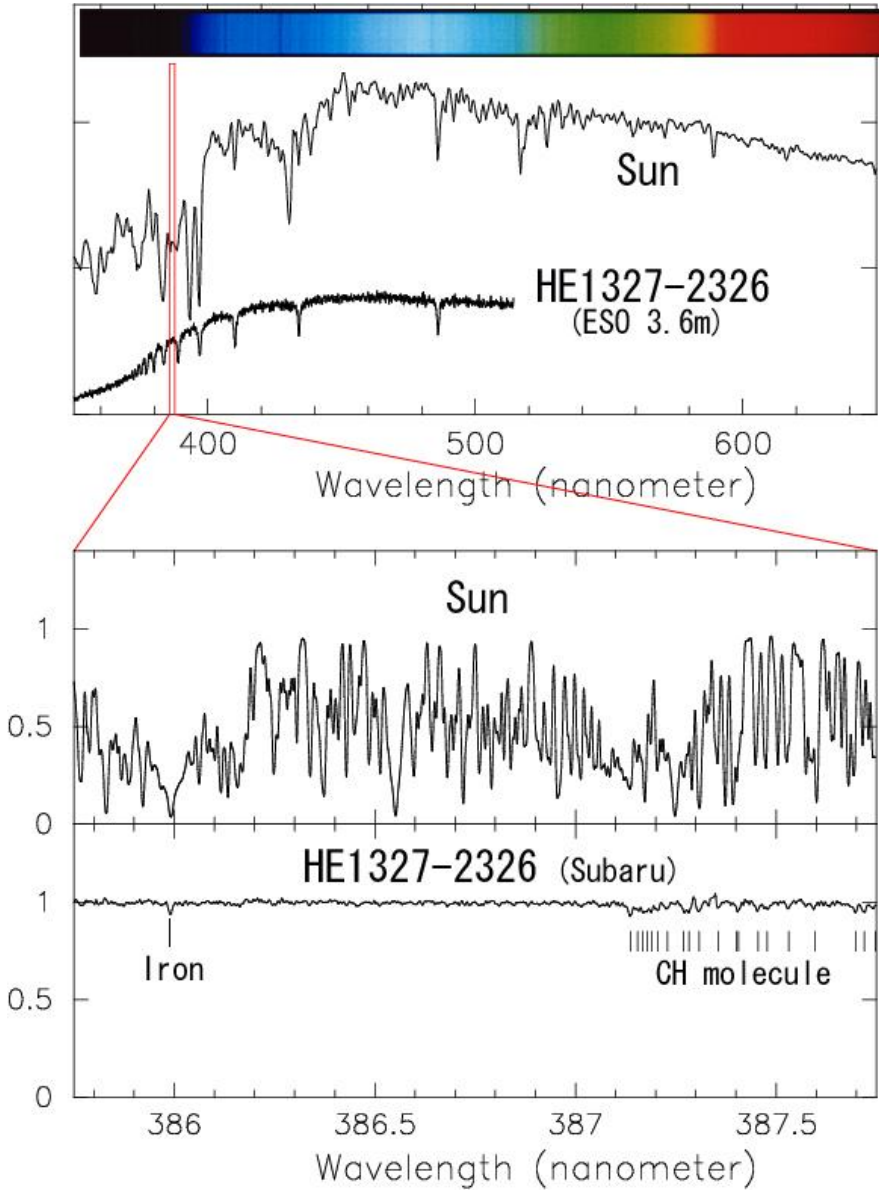
MAGNUM

High-resolution spectroscopy



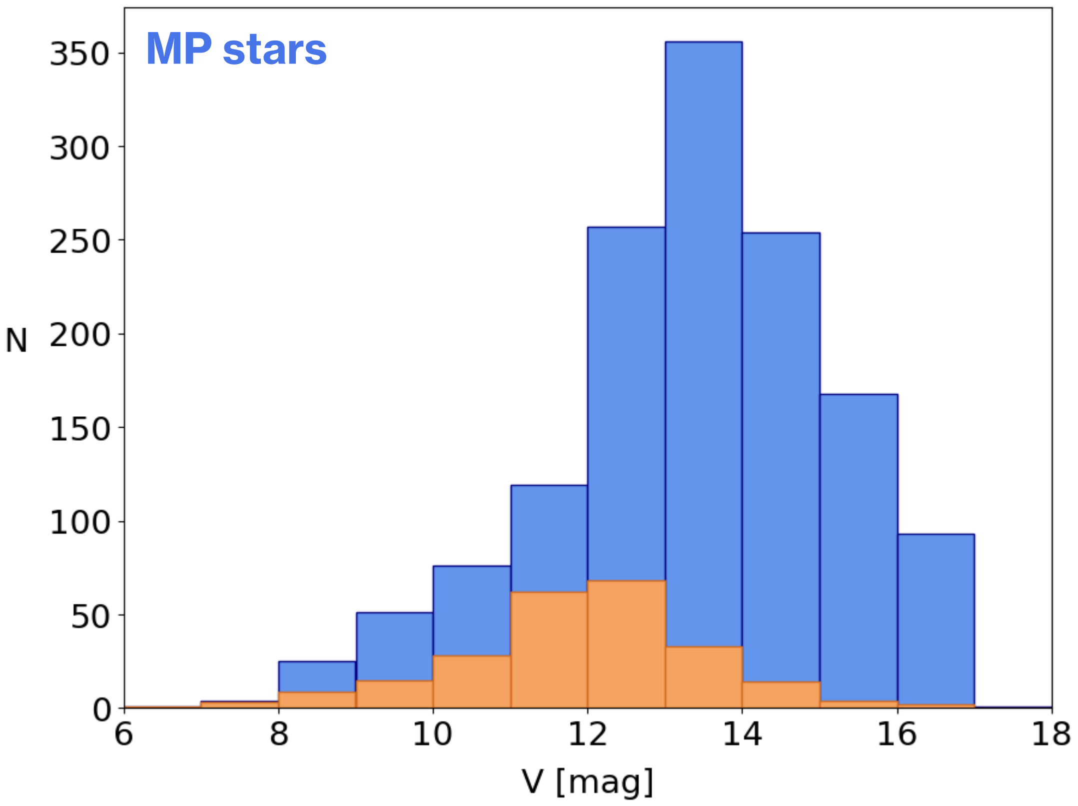
$R = \lambda/\Delta\lambda > 10{,}000$



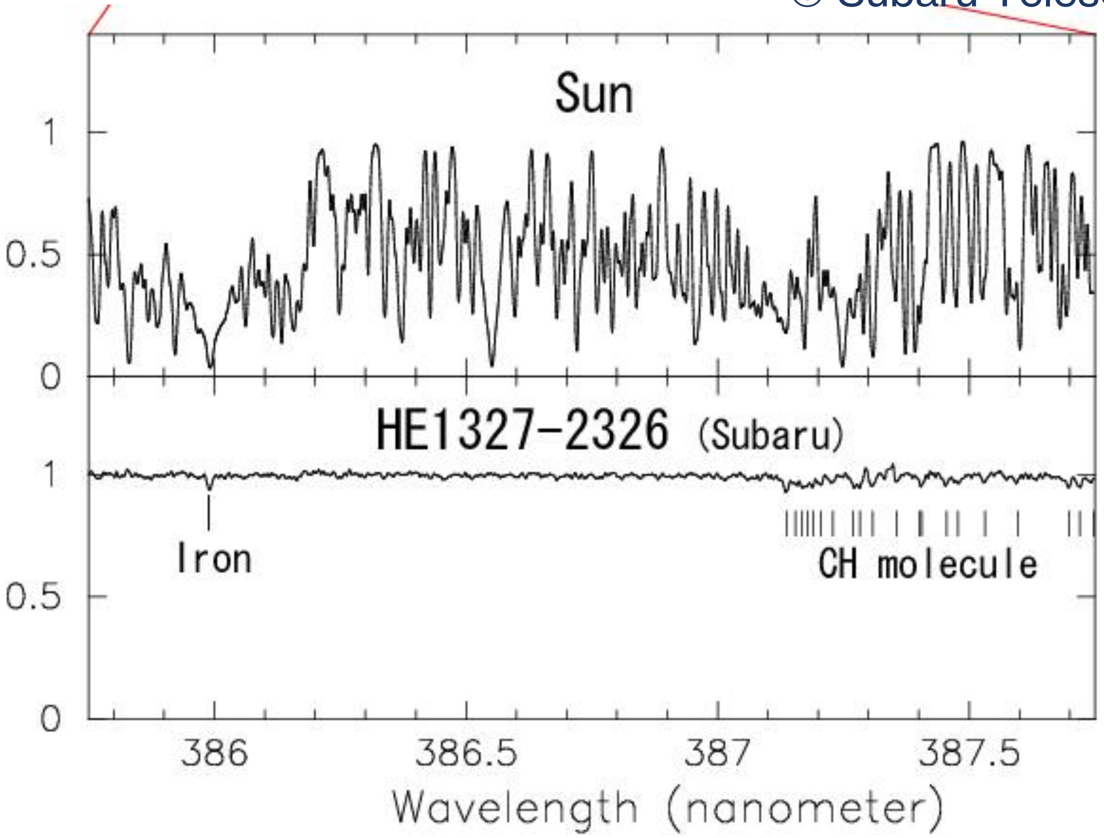


Profits from bright metal-poor stars

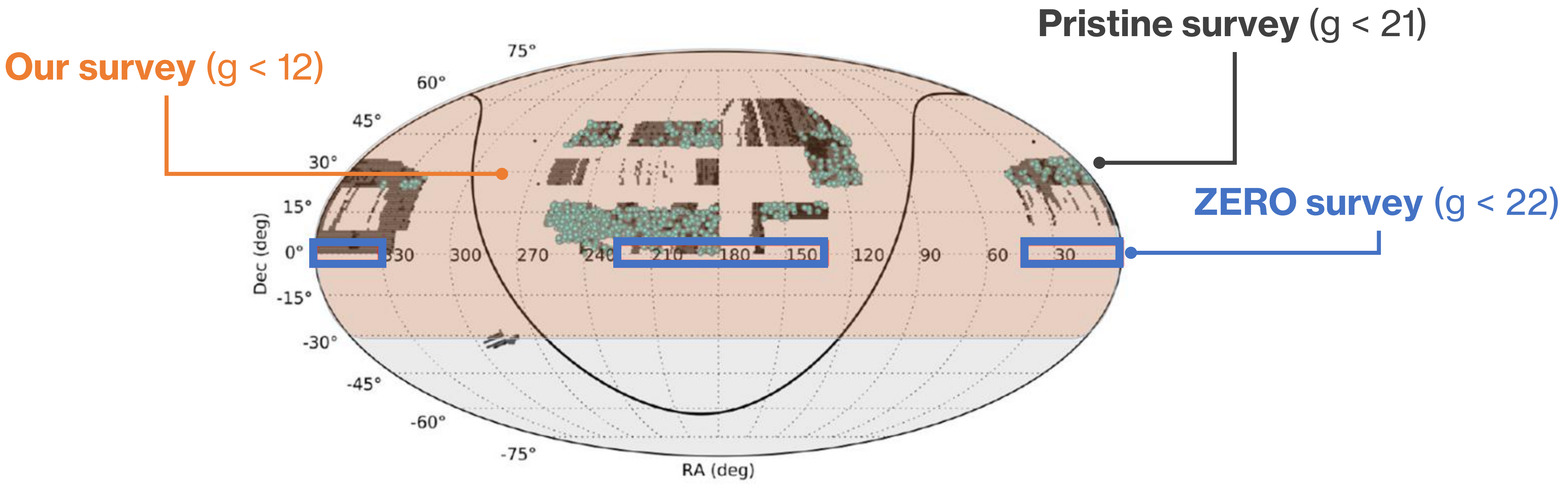
Bright metal-poor stars enable
① Measurement of **rare elements**
② Measurement of **low abundance** or **stringent upper limit**



SAGA database (Suda et al. 2017)



Northern-sky survey for bright metal-poor stars



Aims:

- Precise measurements of rare elements
- Understanding of the nature of first stars and the origin of element

Survey design

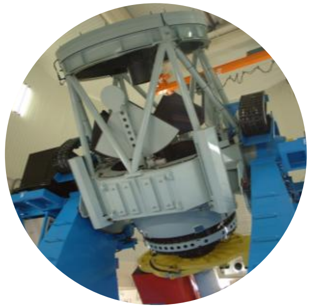
STEP 1

Kiso (1.05 m)

Survey (Tominaga-san's talk)

- Narrow-band photometry with Tomo-e Gozen
- Select bright MP candidates with [Fe/H] < -2

STEP 2



Nayuta (2 m)

Metallicity estimation

- Medium-res. Spectroscopy with MALLS
- R ~ 7500
- Opt. (4900-5300Å)
- Metallicity (Fe) and alpha (Mg) abundance

STEP 2.5

Seimei (3.8 m)

Abundance determination

- High-res. spectroscopy with GAOES-RV
- R ~ 65000
- Opt. (5160-5930 Å)
- Individual elements (Mg, Ca, Sc, Ti, Cr, Fe, Ni, Ba)

STEP 3

Subaru (8.2 m)

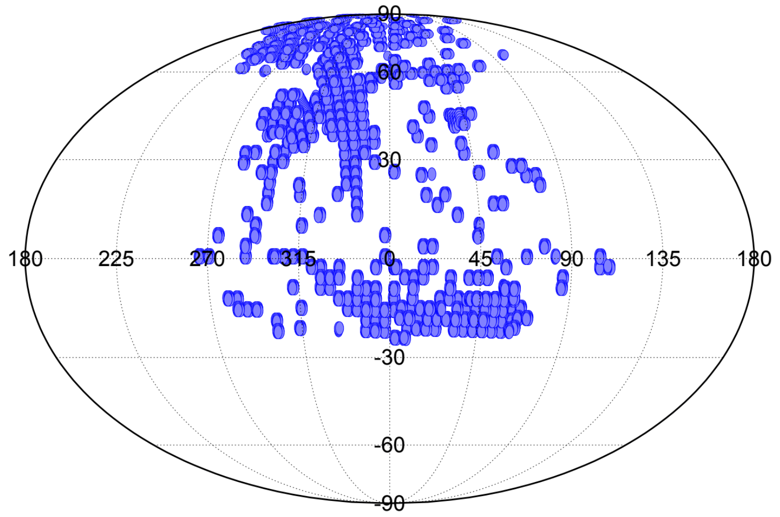
Abundance determination

- High-res. spectroscopy with HDS
- R > 45000
- Opt. and UV
- Individual elements incl. rare elements (Zn, Eu)

Candidate selection

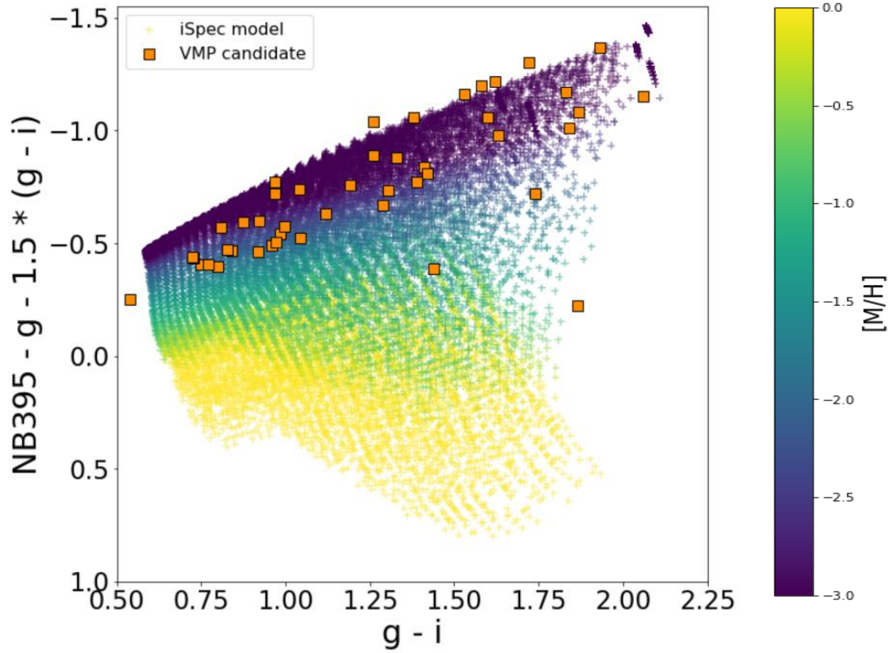
Test observation in 2022

- 2 narrow-band filters
  covered 395 nm (CaHK) and 433 nm (CH)
- Survey area: ~ 5300 deg^2
- Number of bright stars (g < 12): >~ 500,000 stars



Candidate selection

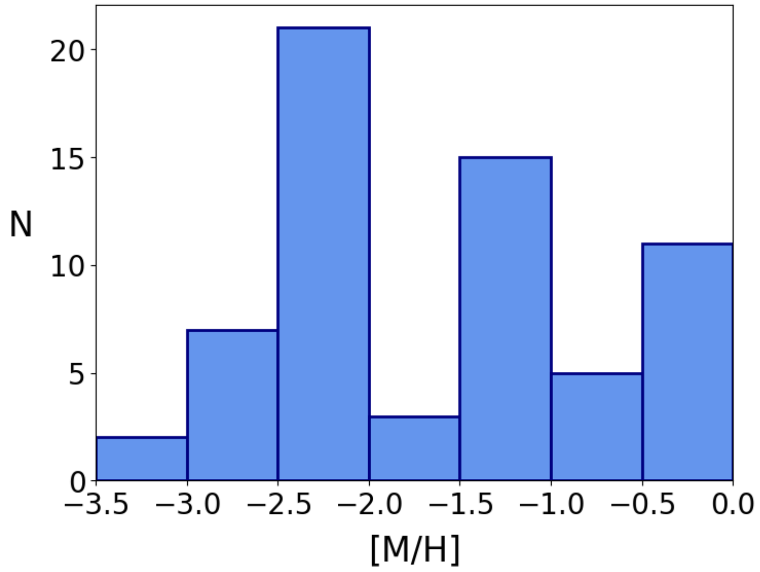
- The color-color diagram using CaHK photometry
- Pick up MP candidates located in the low metallicity region of the model
- Prioritize them using Tomo-e Gozen and other information (Gaia distance, XP/RV spectra)



Follow-ups of MP candidates

MR-spectroscopy with Nayuta

- 4 nights in 2022B (open use) and ~20 nights in 2023
- Identify 30 metal-poor stars among 65 candidates
- Purity: 46 % / > 65 % (+ other information)



HR-spectroscopy with Seimei and Subaru

- **Seimei**
  - 3 nights (open use) and 7.5 nights (observation time of Kyoto Univ.) in 2023B and 2024A

- **Subaru**
  - S24A (service program) and S25A 1.5+0.5 nights

Abundance analysis is now ongoing !

Subaru observation in S25A

Okada et al. in prep

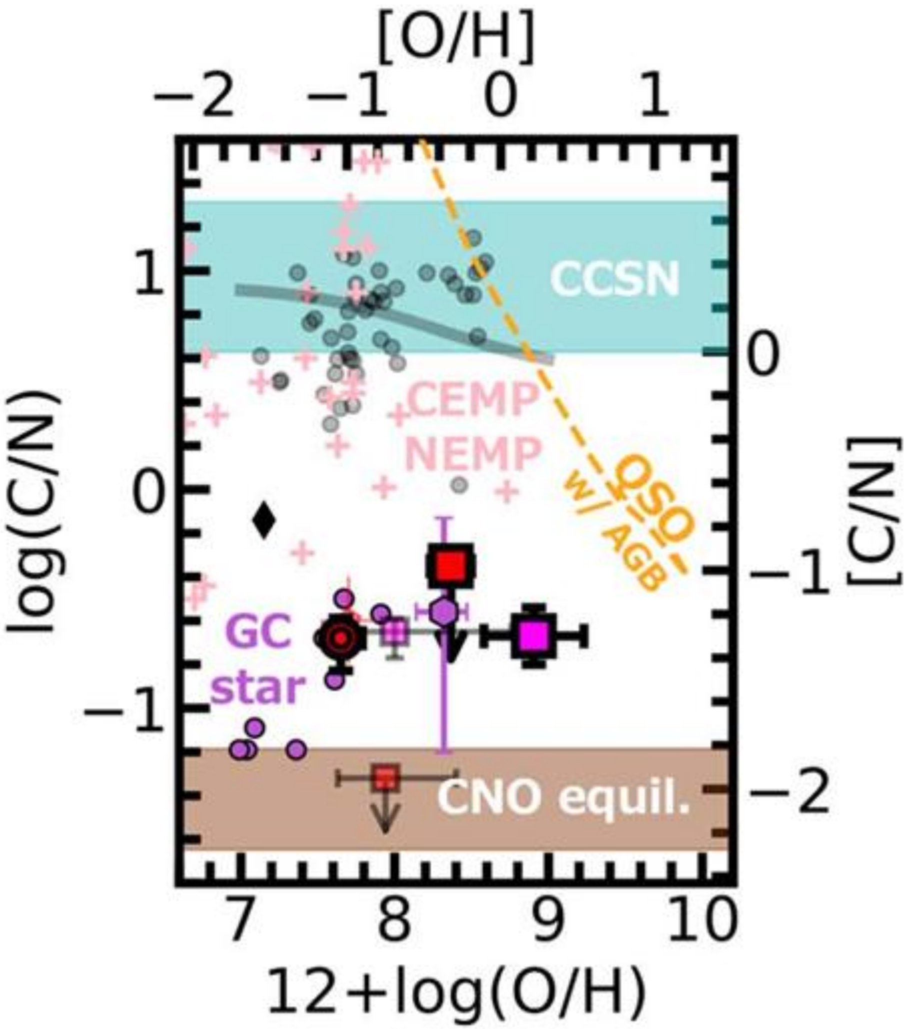
Key elements: CNO

Isobe et al. (2023)

Carbon, Nitrogen, and Oxygen (CNO)

- Efficient coolants in the early Universe
  -> Necessary to form low-mass stars with ~Msun
- Smoking gun to clarify the rotation and initial mass function of first stars
- JWST observation of high-z galaxies
  - High N abundance of some high-z galaxies
  - Consistent with the stars in globular clusters
  - Comparable with the equilibrium of CNO cycle

The detailed abundance needs to be investigated using the MP stars !



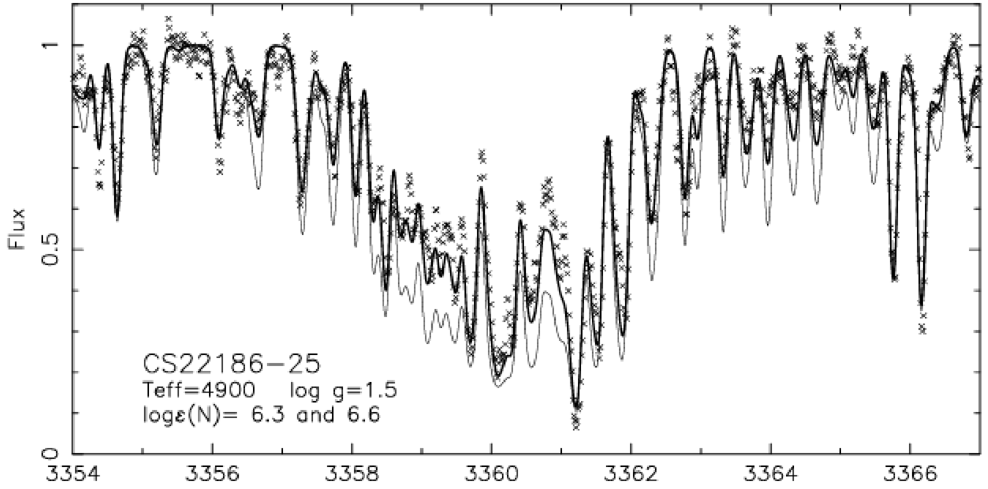
Difficulties of CNO abundance measurement

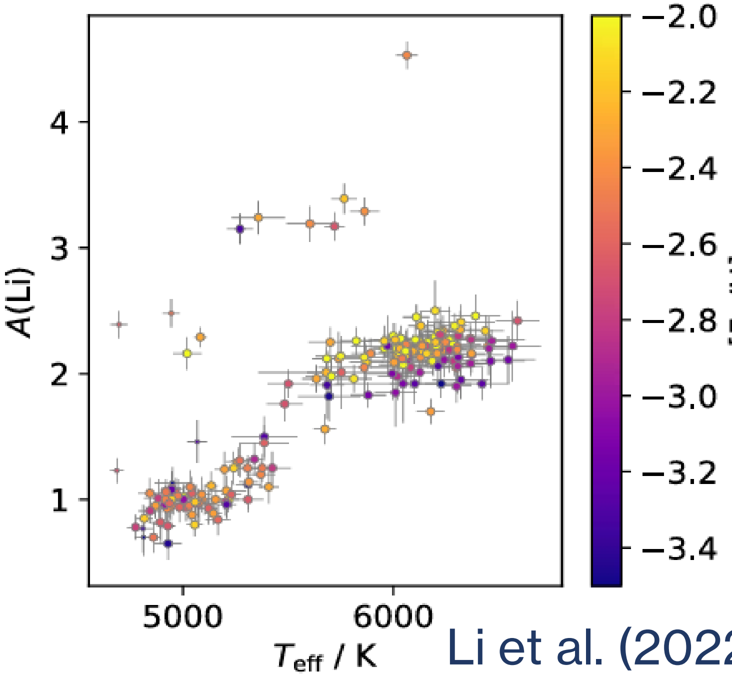
- Surface CNO abundances are altered by the mixing during the evolution of MP stars
  -> high Teff **(unevolved)**
- The CNO molecular bands are stronger for the cooler, more evolved stars
  -> low Teff

The cooler and unevolved MP stars are needed

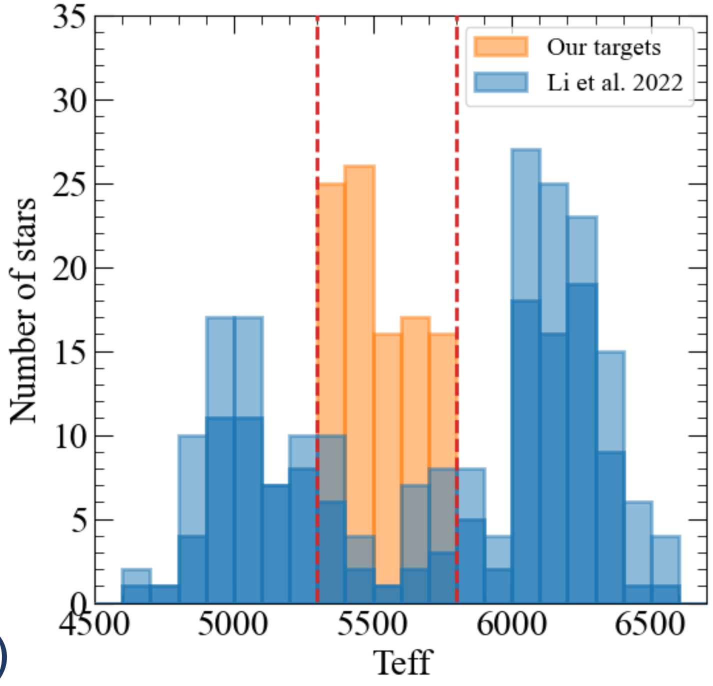
- The **Li abundance** is the good indicator of the mixing in the metal-poor stars because it is a fragile element

Spite et al. (2005)





Li et al. (2022)



Li line

Okada et al. in prep

Summary

The detailed abundance available only in metal-poor stars provides unique information on the origin of element and the nature of first stars

Follow-ups of bright MP candidates is ongoing

- **MR follow-ups with Nayuta/MALLS**
  - ✓ Metallicity and alpha abundance in MP candidates were measured
  - ✓ 30 new MP stars were identified
- **HR follow-ups with Subaru/HDS** (S24A service, S25A-Feb)
  - ✓ ~30 new MP stars were identified
  - ✓ Li lines were detected for 11 stars
- **Future plans**
  - ✓ Additional observation (2nd half night, Jun 11)
  - ✓ Candidate selection and follow-ups using Tomo-e NB data taken on May, 2025
  - ✓ UV observation proposed