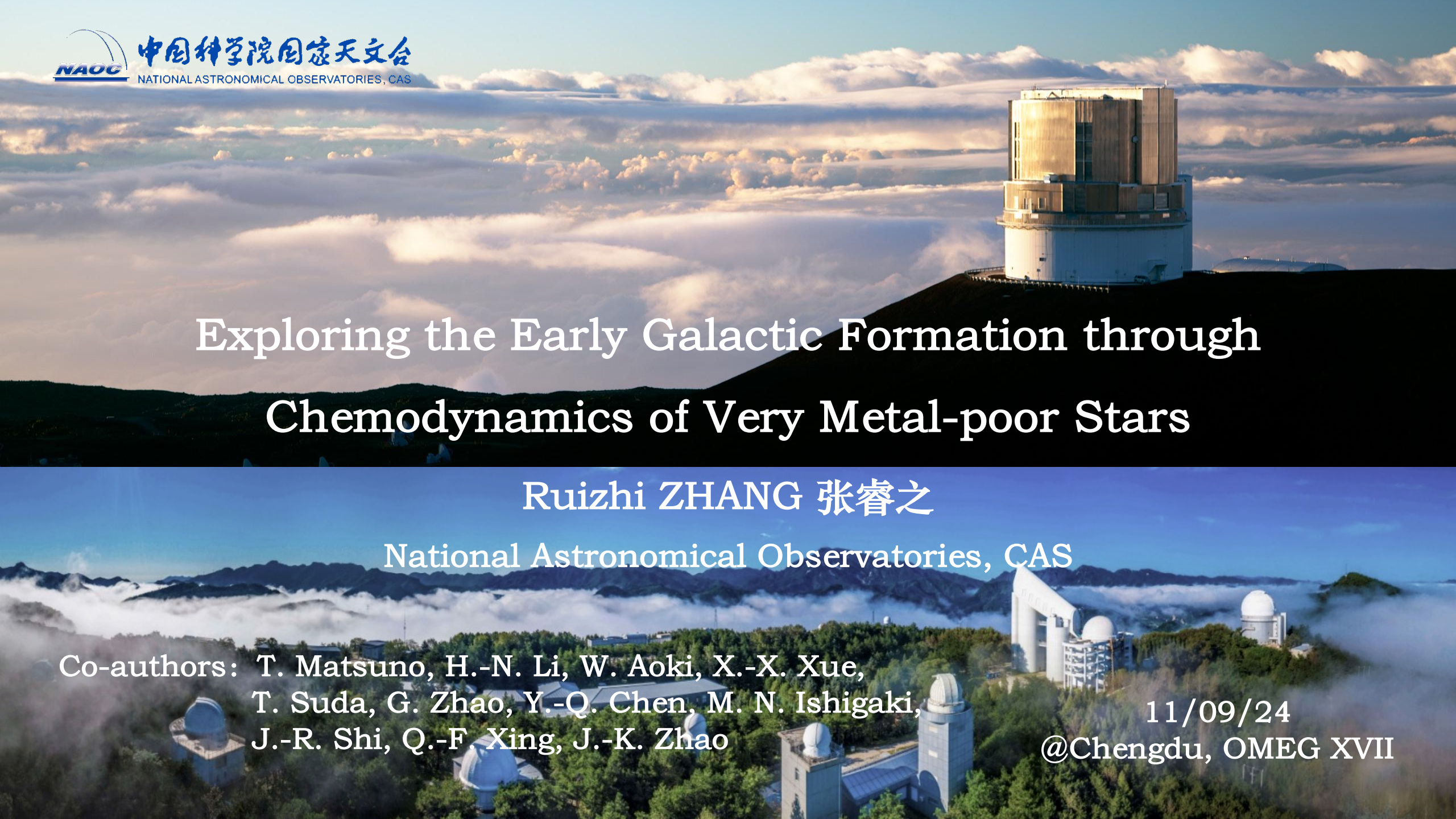

Exploring the Early Galactic Formation through Chemodynamics of Very Metal-poor Stars

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11/09/24

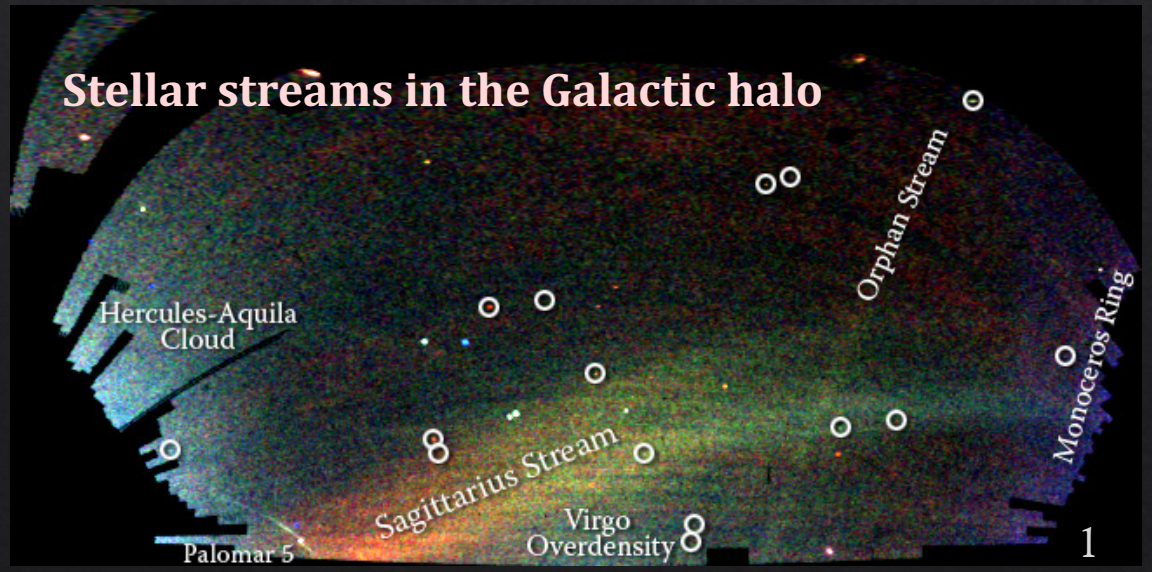
@Chengdu, OMEG XVII

The structure of our Milky Way

- Bar/Bulge
- Disk: thin disk, thick disk
- Halo: substructures from merger events

Credit: NAOJ/H. Fujiwara

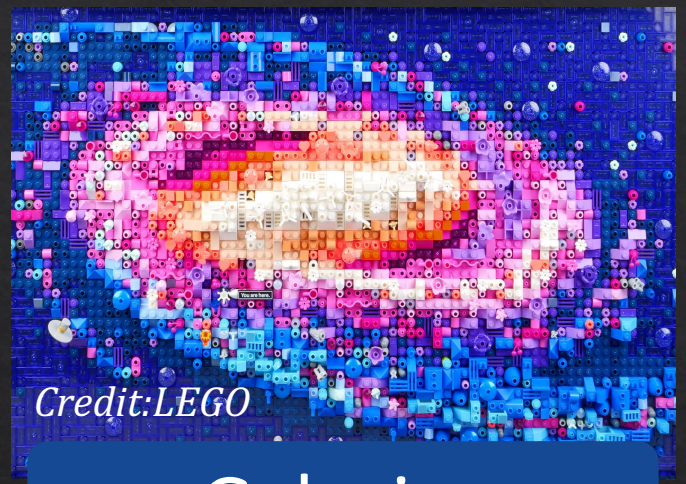
Credit: ESA/Gaia/DPAC; CC BY-SA 3.0 IGO



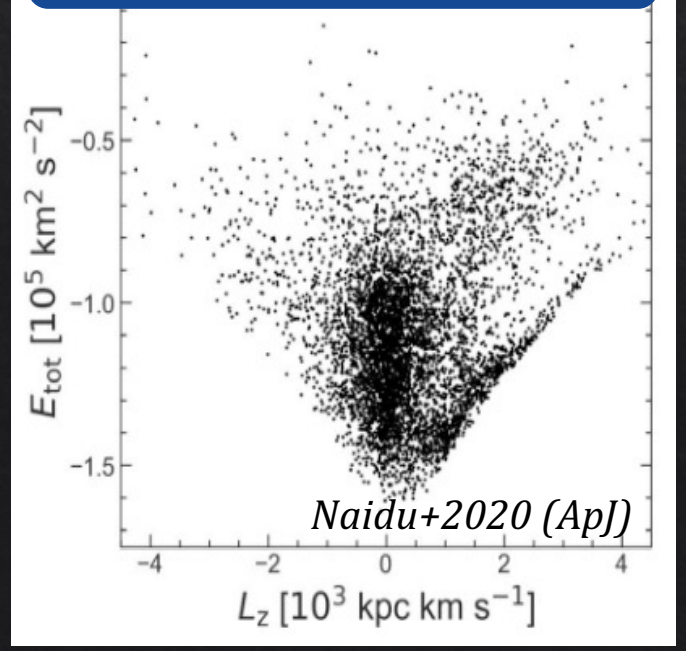
Credit: V. Belokurov and the SDSS

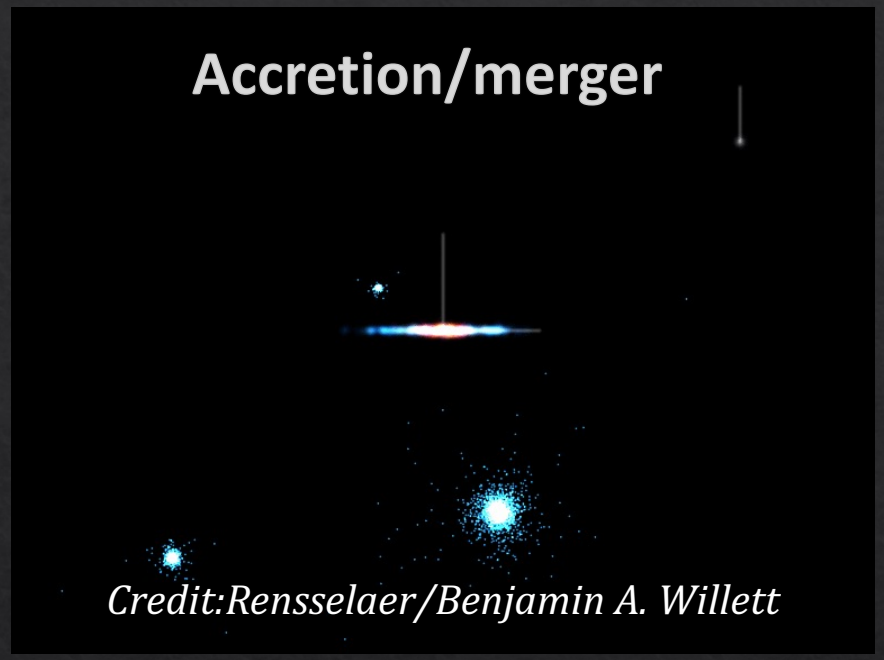
The Milky Way formed hierarchically

c.f. Haining LI's and Renjing XIE's talk



Galaxies



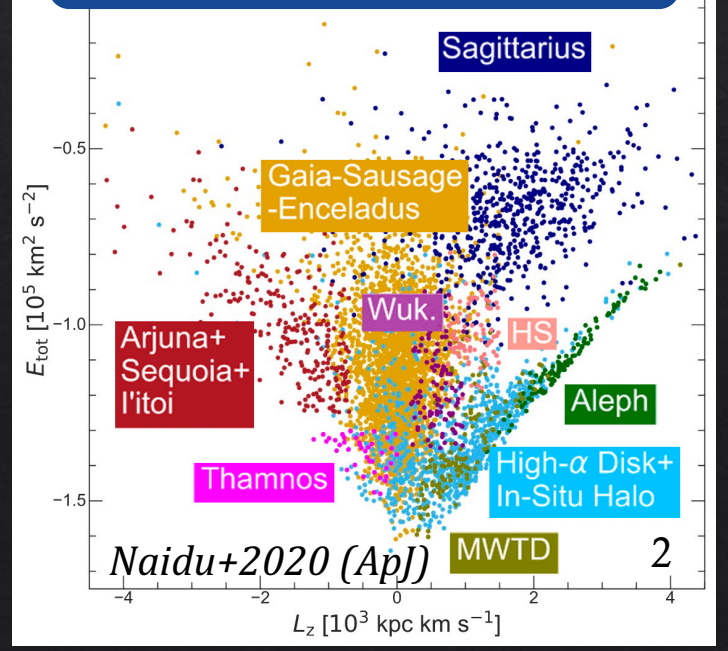


Building

Taking apart

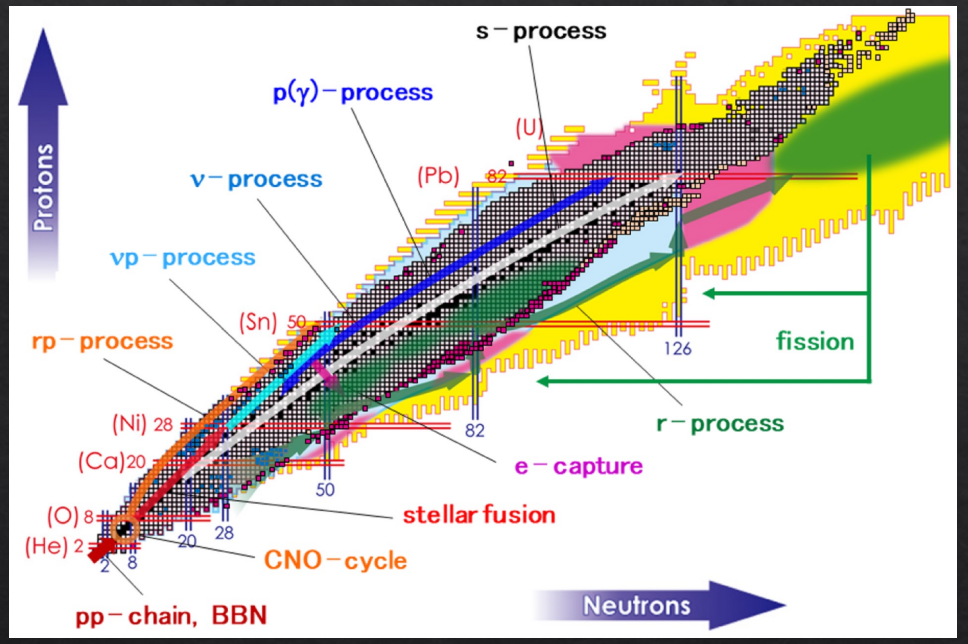
Dynamics, chemistry, ages, simulations, etc.

Blocks

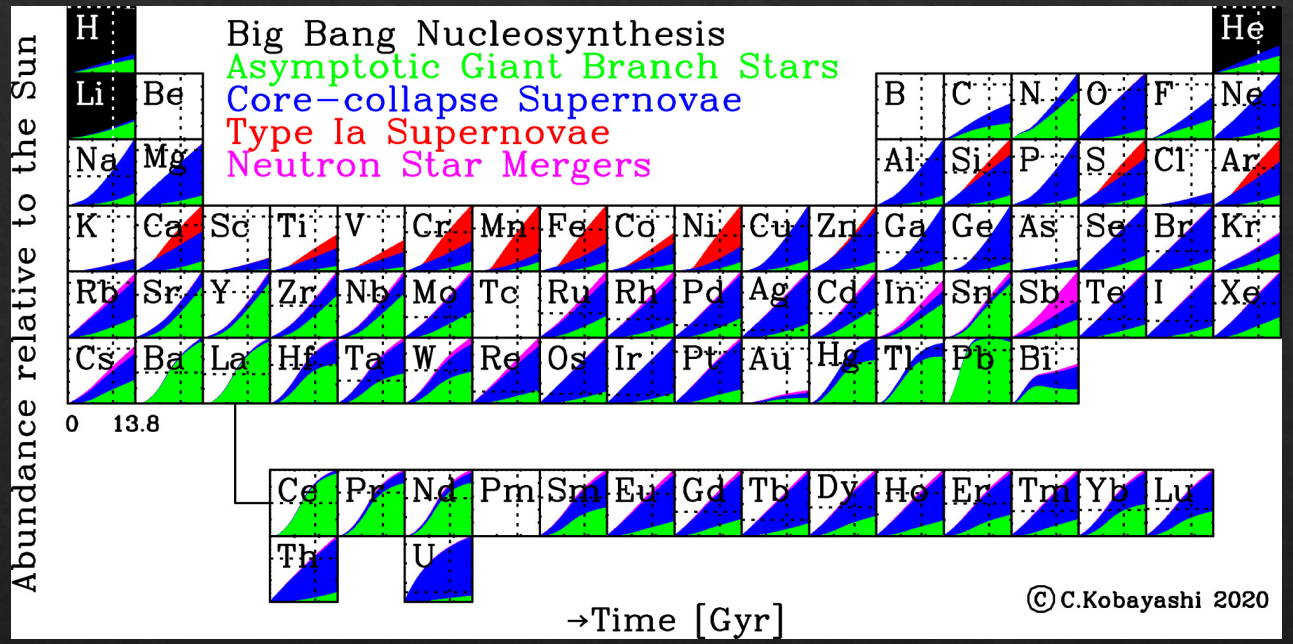


The nucleosynthesis and chemical abundances

Nuclear Astrophysicists



Astronomical researchers



$$[\mathrm{X/Y}] = \log(N_\mathrm{X}/N_\mathrm{Y}) - \log(N_\mathrm{X}/N_\mathrm{Y})_\odot$$

c.f. Prof. Nozomu TOMINAGA's talk

The assembly history of the Milky Way remains unclear

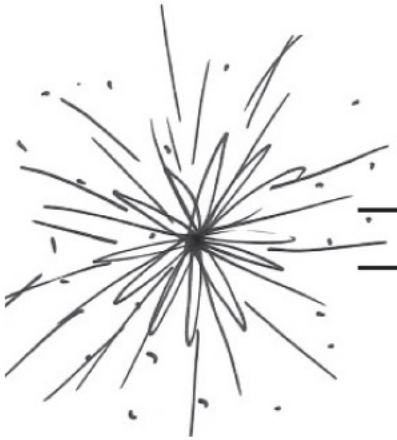
Relatively recent and massive merger events

Gaia–Enceladus / Sausage

[Helmi+ 2018, Belokurov+ 2018]

Sagittarius

Magellanic clouds

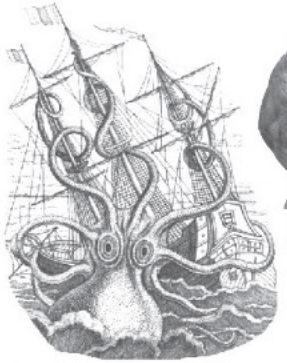


10 Gyr

3 Gyr

0.5 Gyr

Early or minor merger events



Kraken

[Kruijssen+ 2019]

Herakles

[Horta+ 2020]

Koala

[Forbes 2020]

Sequoia

[Myeong+ 2019]

Pontus

[Malhan+ 2022]

Arjuna

[Naidu+ 2020]

Thamnos

[Koppelman+ 2019]

Wukong

[Naidu+ 2020]

Credit: E. Vasiliev

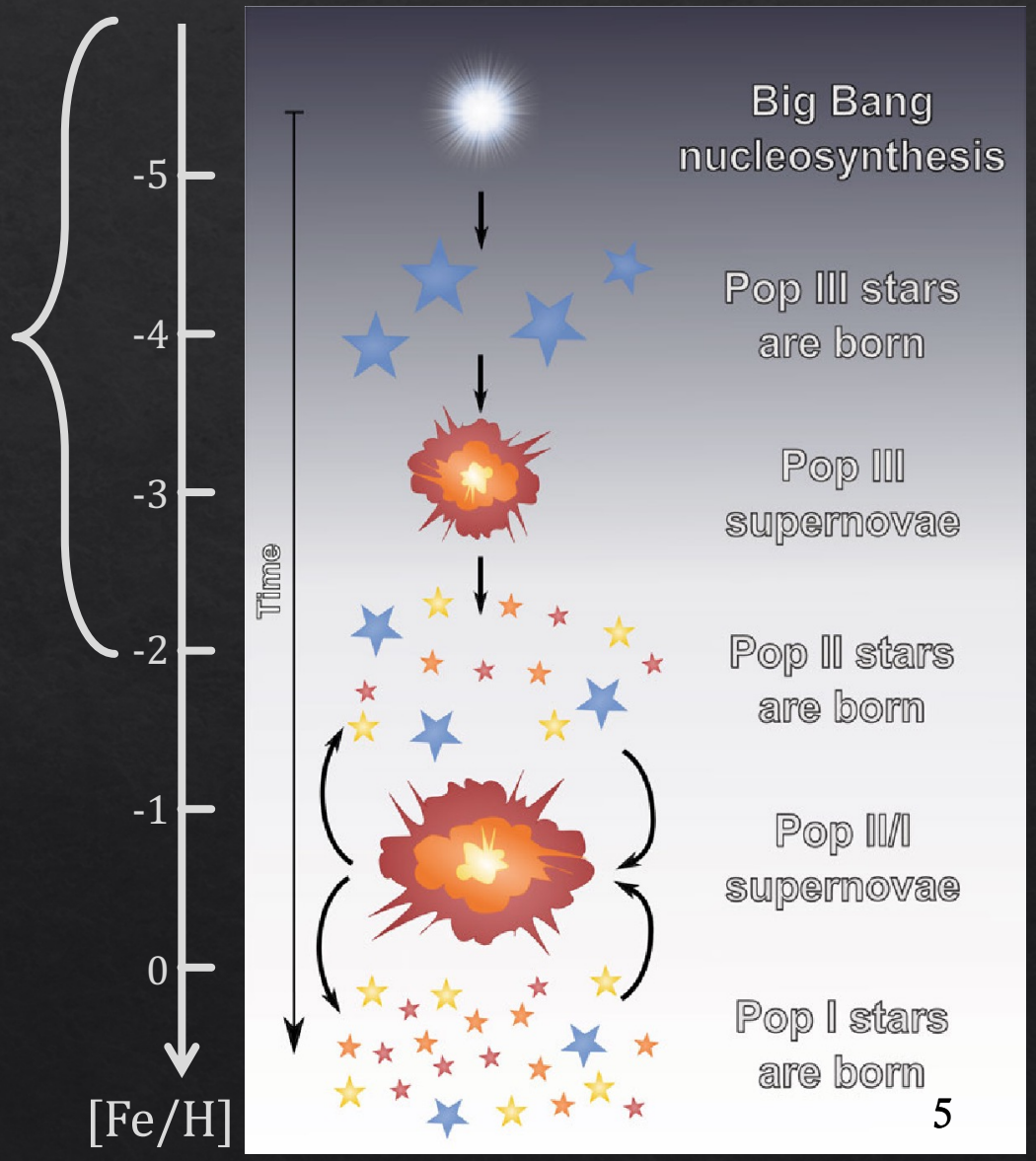
Tracing the Galactic early assembly history

- **Very metal-poor (VMP) star: [Fe/H]<-2**
  local equivalents of high redshift
  - ➢ **Earlier properties of substructure progenitor**
  - ➢ **Search for accreted ultra-faint dwarf galaxies**
  - ➢ **Unraveling early nucleosynthesis and the origin of r-process elements**

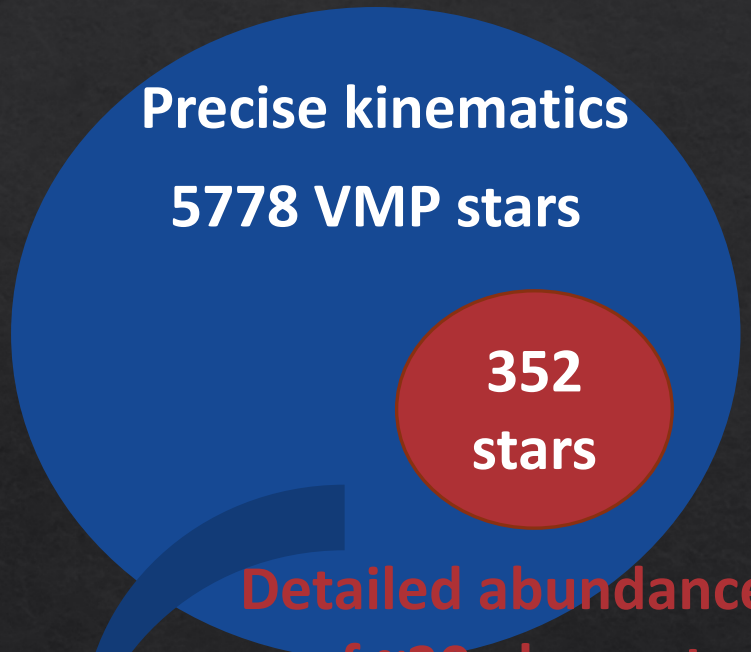
c.f. Prof. Toshitaka KAJINO's talk (He+2024, ApJL)

Shilun JIN's talk, Hiroko OKADA's poster, etc.

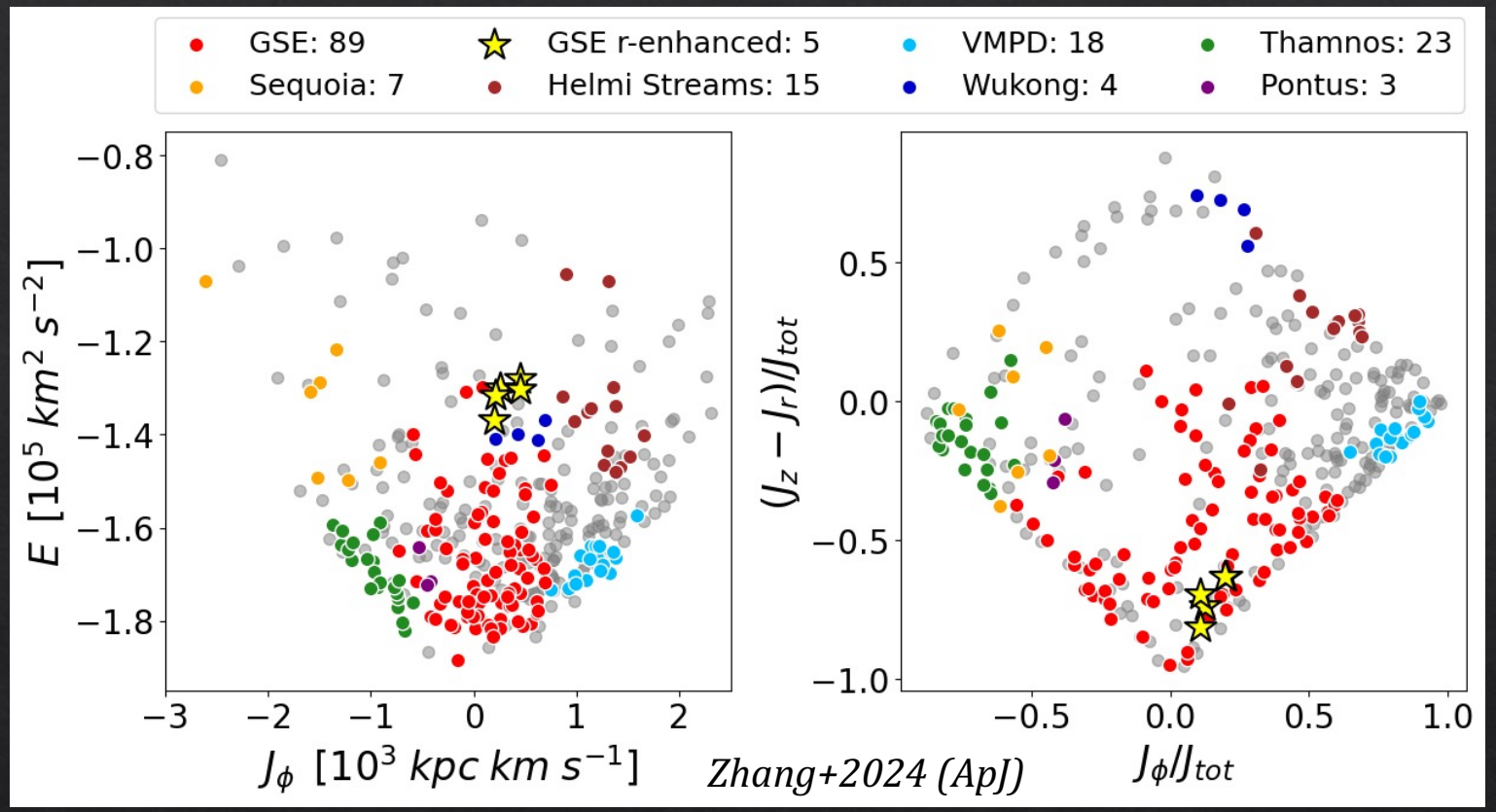
Nordlander 2017



First systematic chemodynamical analysis for VMP stars



Clustering algorithm



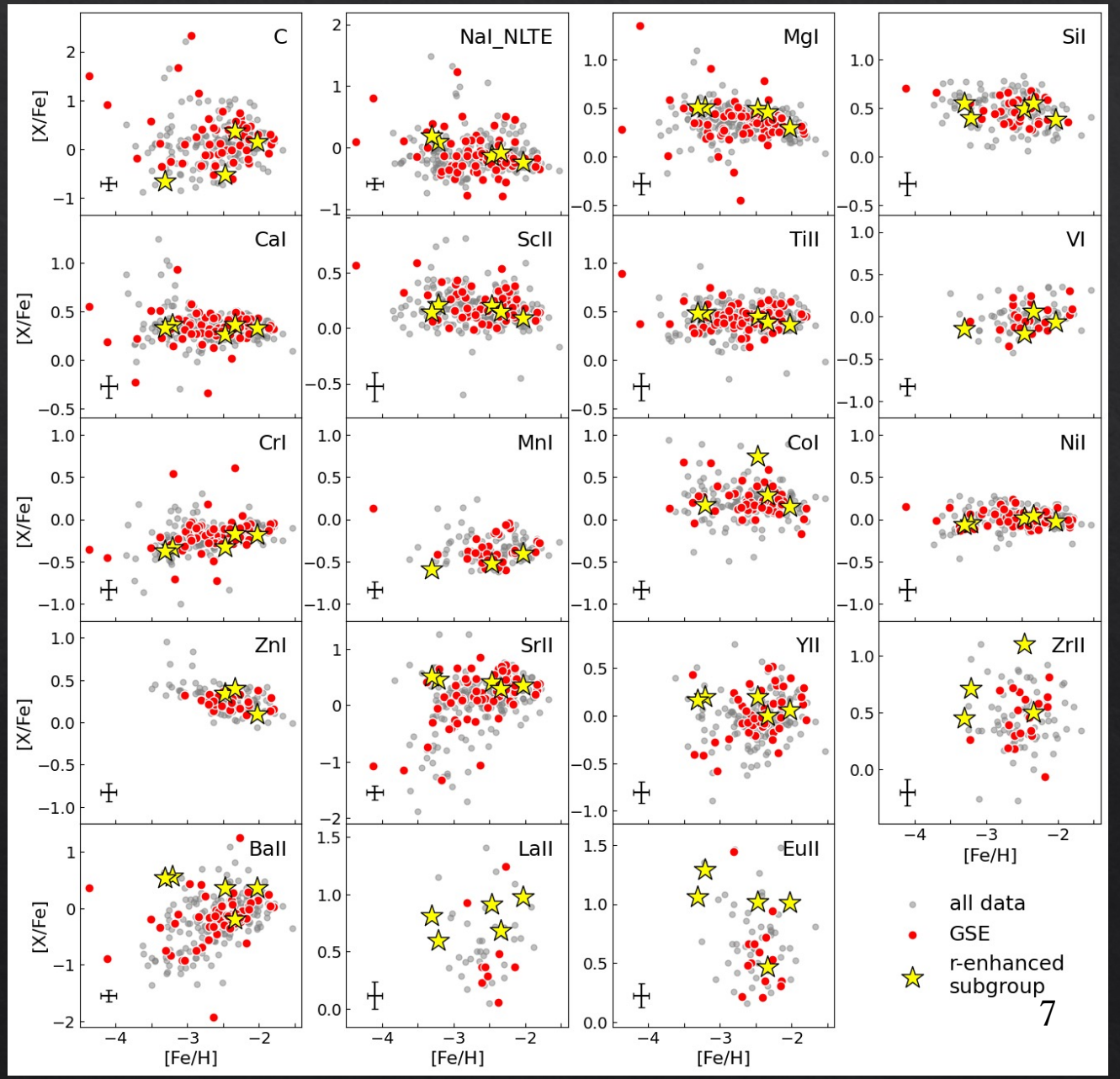
- **Substructure association**
  - ➢ **GSE, Thamnos, Sequoia, Helmi streams, Wukong/LMS-1, Pontus**
- **Newly define a very metal-poor disk (VMPD)**

Gaia-Sausage-Enceladus (GSE)

Zhang+2024 (ApJ)

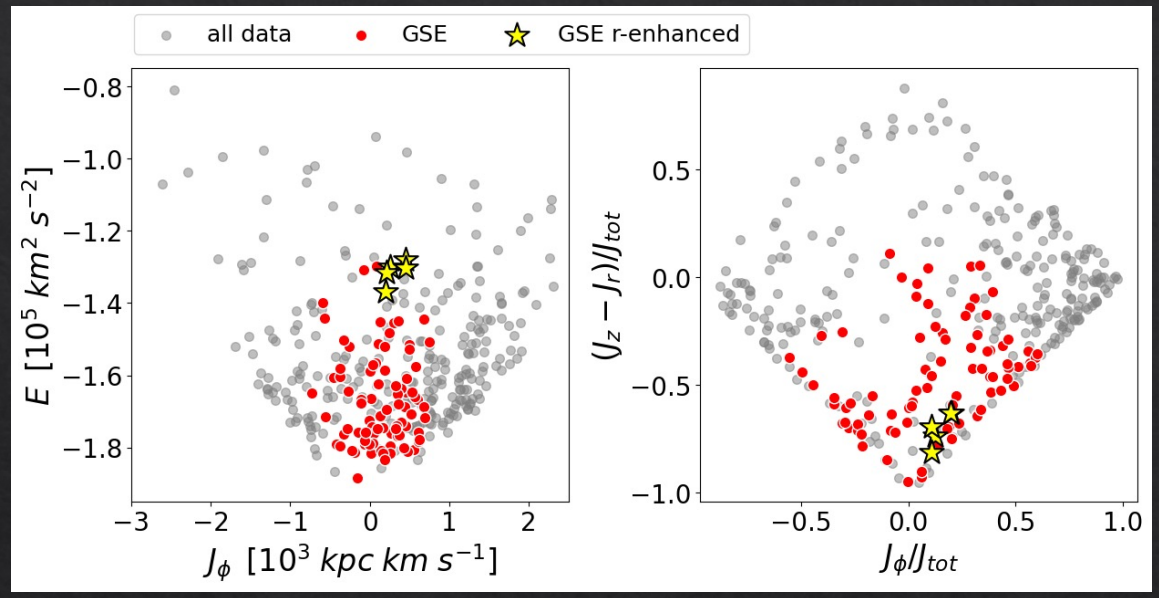
- 89 member stars

- Large scatter
  - ➢ Complex chemical evolution history of GSE progenitor
- R-process-enhanced subgroup
  - ➢ Dynamical clustered subgroup
  - ➢ Small scatter in most elements
  - ➢ Extremely r-process enhanced

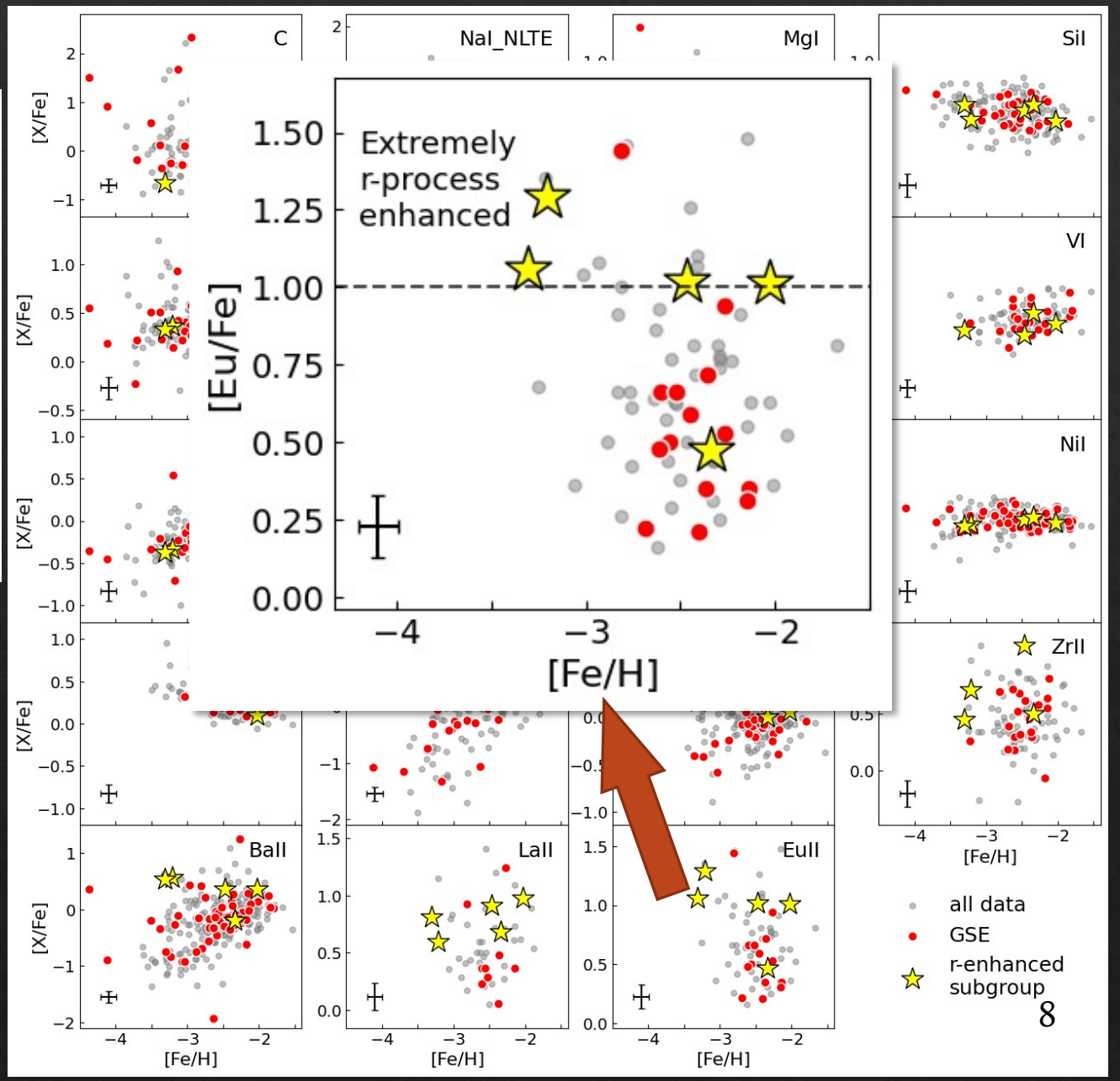


Gaia-Sausage-Enceladus (GSE)

Zhang+2024 (ApJ)



- **R-process-enhanced subgroup**
  - ➢ **Dynamical clustered subgroup**
  - ➢ **Small scatter in most elements**
  - ➢ **Extremely r-process enhanced**

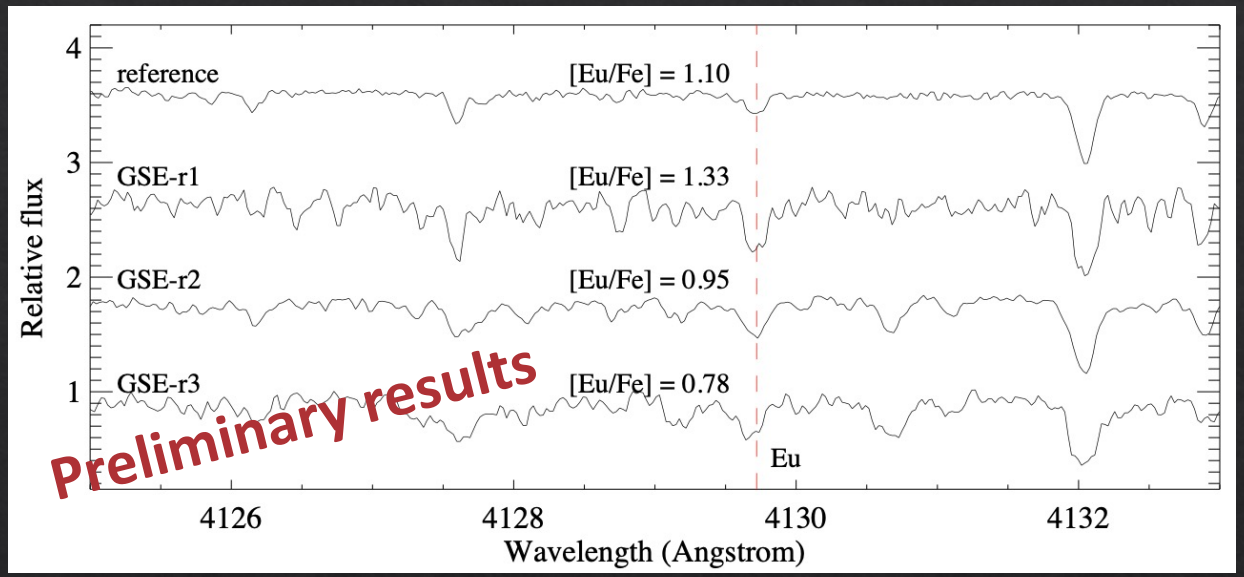


GSE: extremely r-process enhanced subgroup

- The first discovery of an extremely r-process enhanced subgroup in the accreted systems
  - Follow-up of 7 subgroup members:

    6 r-process-enhanced stars ([Eu/Fe]>0.3)

    3 potential r-II stars ([Eu/Fe]>0.7)
- Valuable opportunity to study the r-process in dwarf galaxies



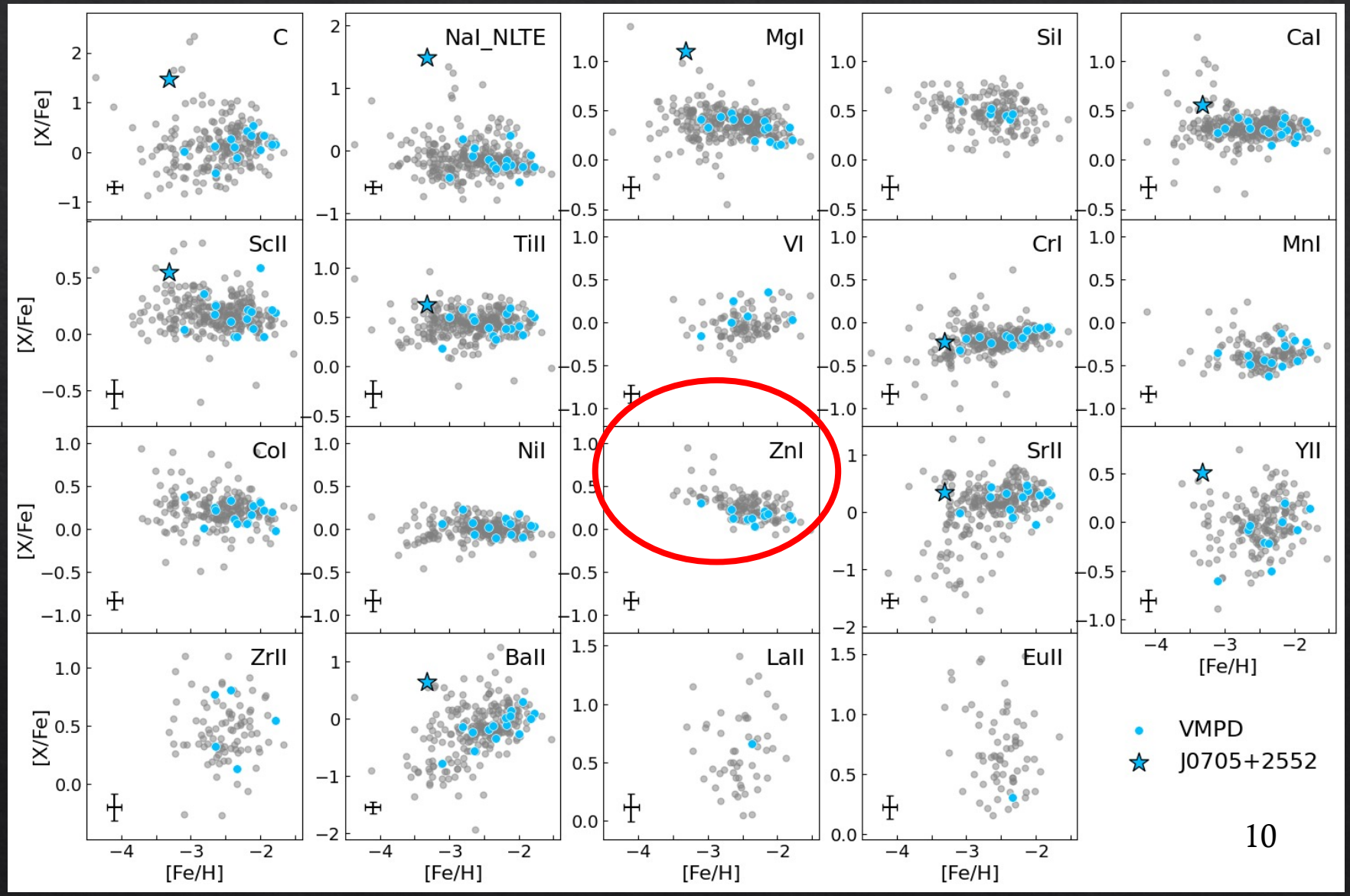
☐ Enriched by an independent nucleosynthesis event in the GSE?

☐ The remnants of accreted/satellite galaxy that have been accreted with GSE?

Very Metal-poor Disk (VMPD)

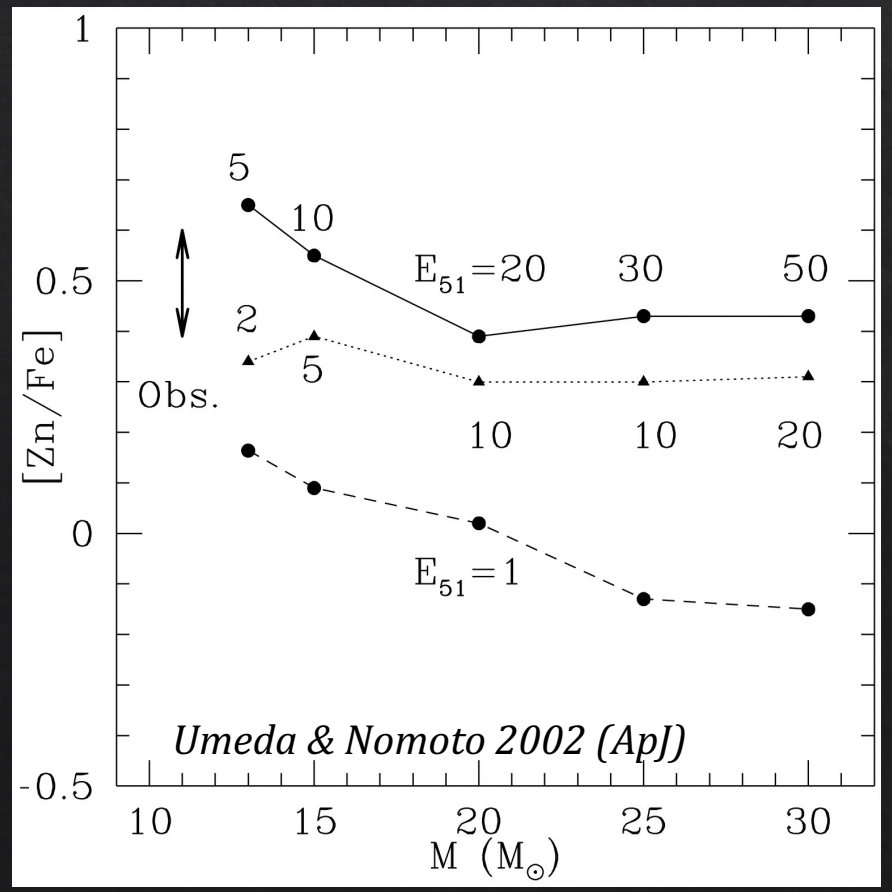
Zhang+2024 (ApJ)

- Canonical disk
  - [Fe/H]>-1
- Small scatter
  - Common origin
- Low Zn abundance
  - VMPD: 0.16
  - All sample: 0.25



VMPD: low-mass building-block of proto-galaxy

- Production site of Zn: Hypernovae (HNe)
- HNe: explosion of massive star



Low [Zn/Fe]

↓

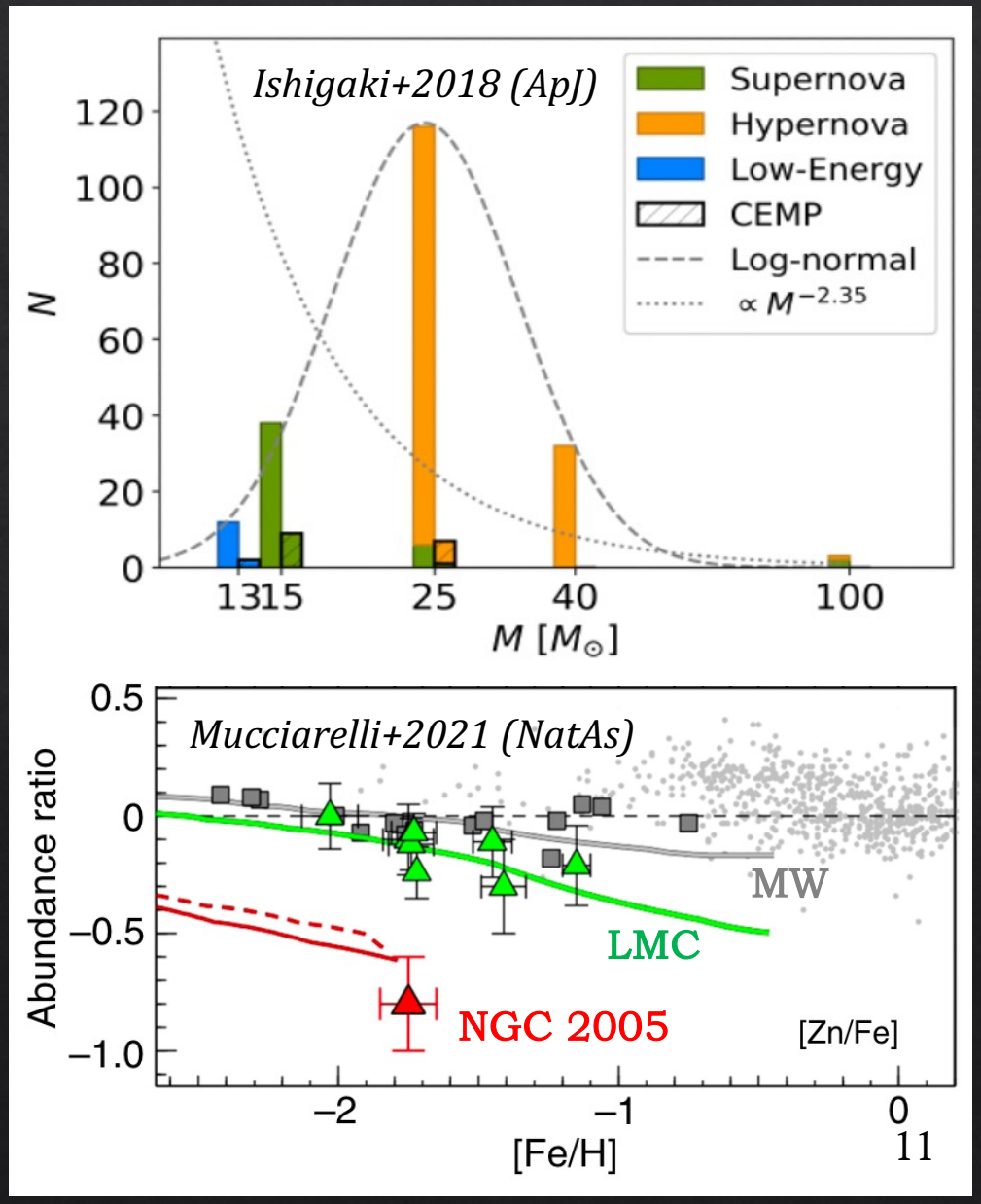
Low HNe event rate

↓

Less massive stars

↓

low-mass building-blocks of proto-galaxy



Summary

- First systematic chemodynamical analysis for very metal-poor stars
- GSE:
  - ✓ Large scatter, similar to galactic field stars
  - ✓ An r-process-enhanced subgroup in GSE
  - ✓ Valuable opportunity to study the r-process ex-situ
- VMPD:
  - ✓ Small scatter: common origin
  - ✓ Deficiency in Zn: low-mass progenitor systems?
  - ✓ Low-mass building-blocks of proto-galaxy

My orcid