Exploring the Galactic halo n-capture enrichment through the MINCE project

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s, i & r Element Nucleosynthesis (sirEN) Conference – Giulianova, June 10th, 2025

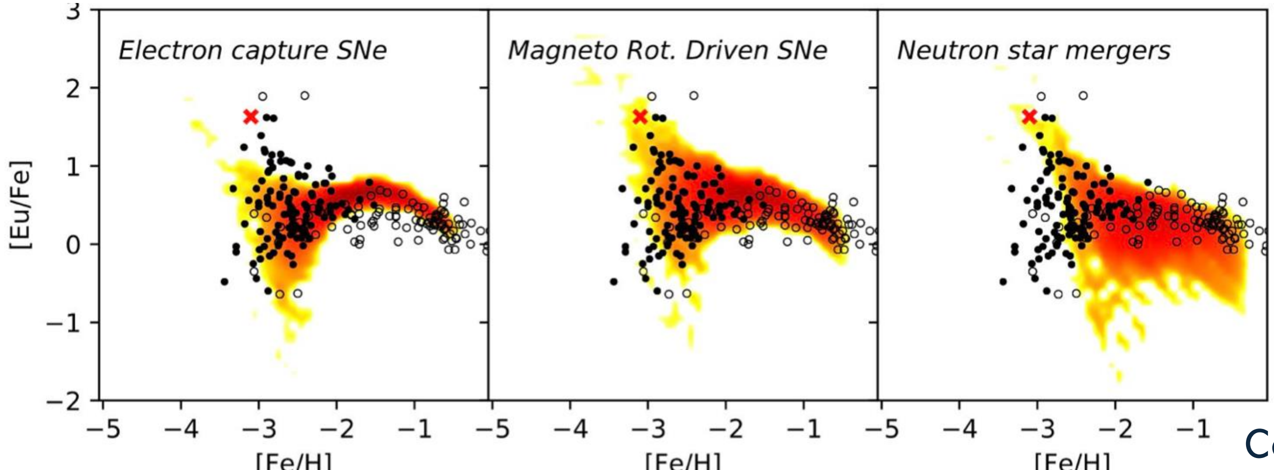
Measuring at Intermediate metallicity Neutron Capture Elements

MOTIVATION:

- Gathering high-quality spectra and deriving n-capture abundances (not only!) for hundreds of stars with $\boxed{-2.5 < [Fe/H] < -1.5}$ →
- Study the nucleosynthetic (s/i/r) processes that produced n-capture elements
- Study how the spread in n-capture elements at high metallicities shrinks

In this range:

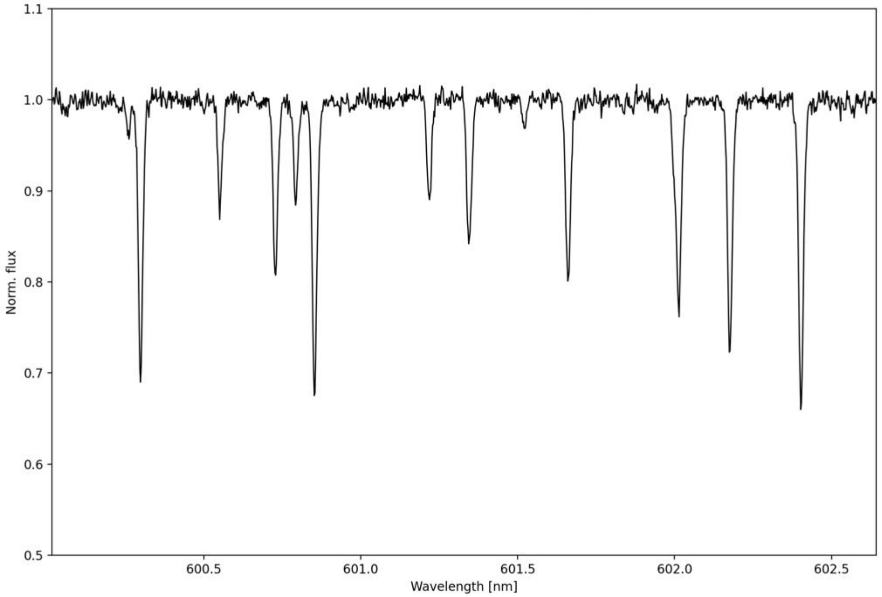
- 90% of stars of the Galactic halo MDF
- n-capture elements measurements have been provided for only 20% of stars



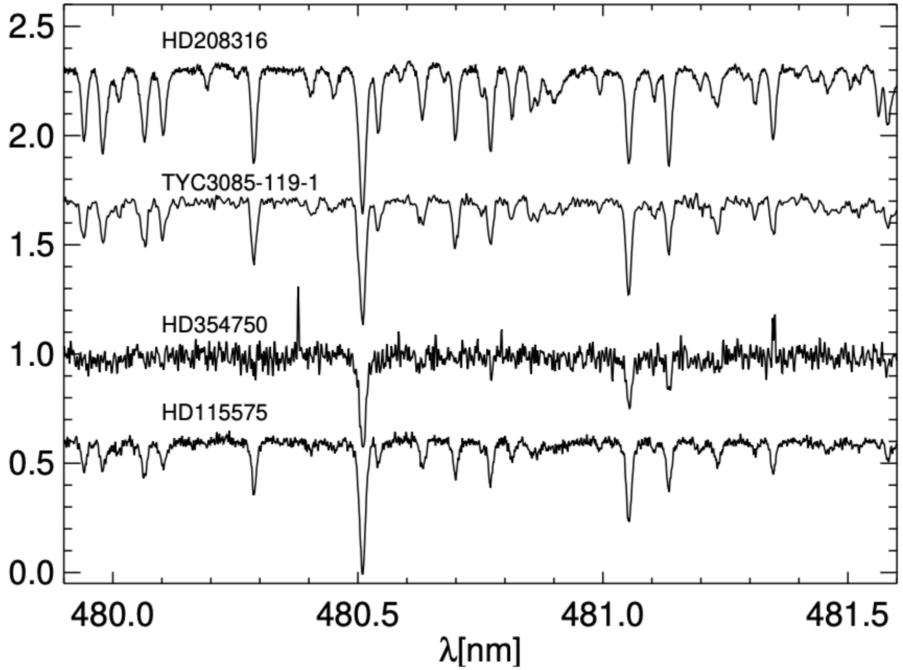
Cescutti & Chiappini 2014

Measuring at Intermediate metallicity Neutron Capture Elements

- Worldwide facilities (ESPaDOns, Sophie, FEROS, HARPS-N, MIKE, UVES, FIES, VUES)
  - R > 65000
  - S/N > 100 @ 500 nm



- Targets selection
  - Metal-poor: [Fe/H] < - 0.7
  - Bright: V < 10
  - Giants: T_{eff} < 5000 K
  - Kinematics: v_{tot} > 200 km/s



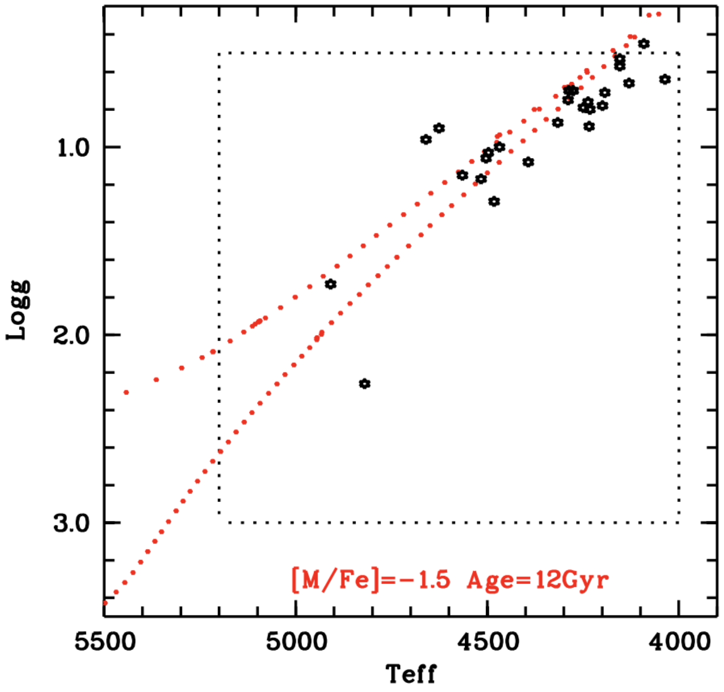
Cescutti et al. 2022

MINCE serie

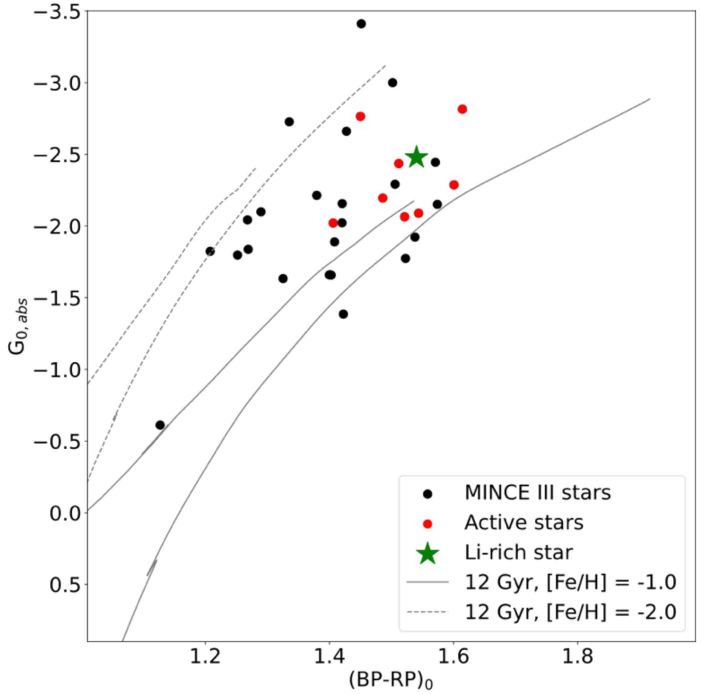
- Sample I : 46 → 33 stars (Cescutti+2022, François+2024)
  - TNG HARPS-N (R = 115000, λ = 383 – 693 nm)
  - NOT FIES (R = 67000, λ = 370 – 830 nm)
  - OHP Sophie (R = 75000, λ = 387.2 – 694.3 nm)
  - CFHT ESPaDOnS (R = 65000, λ = 370 – 1051 nm)

- Sample II: 99 → 32 stars (Lucertini+2025)
  - UVES (R = 65000, λ = 304 – 945 nm)

- Analysis:
  - Kinematics and RV
  - Stellar parameters
  - Chemical analysis
  - Comparison with chemical evoltion model



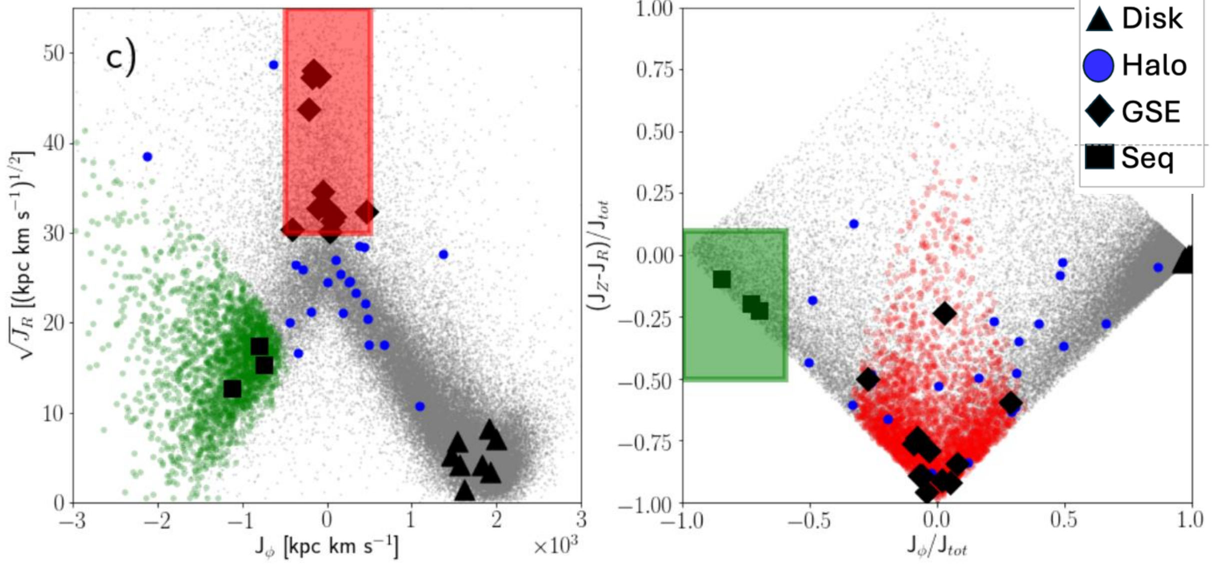
Cescutti et al. 2022



Lucertini et al. 2025

Kinematics

- Sample I
  - 8 Thin Disk star
  - 25 Halo stars → 12 GSE + 3 Seq candidates
- Sample II
  - 42 Thin Disk
  - 22 Thick Disk
  - 1 star in thin-to-thik disk transition
  - 34 Halo stars → 6 GSE + 3 Seq candidates



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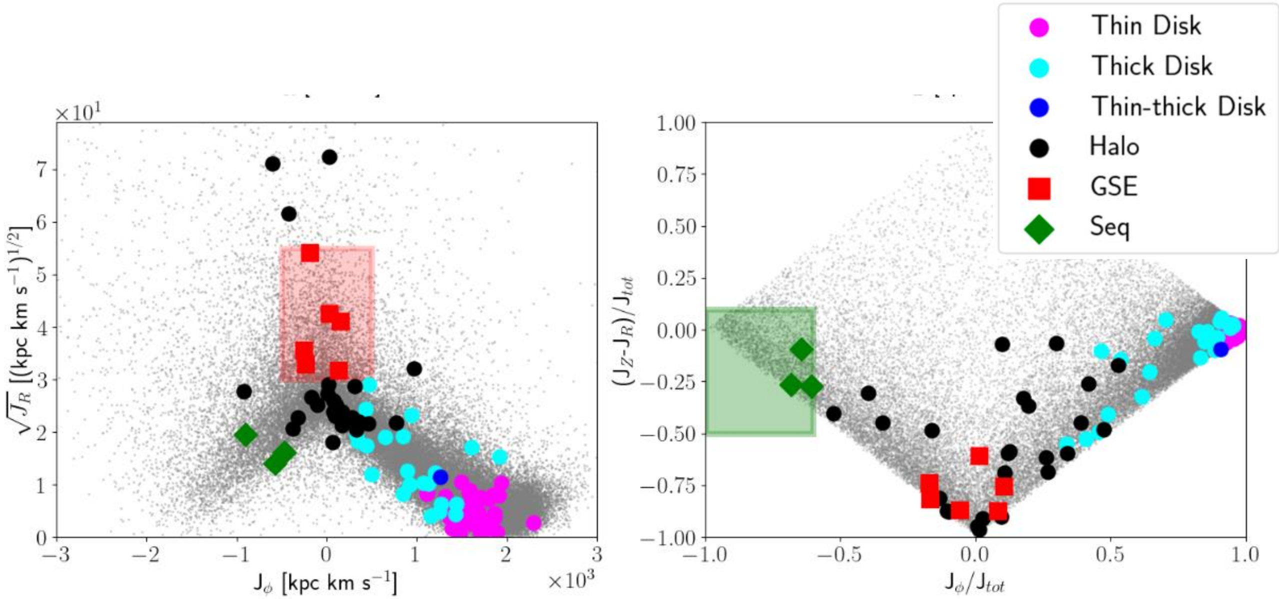

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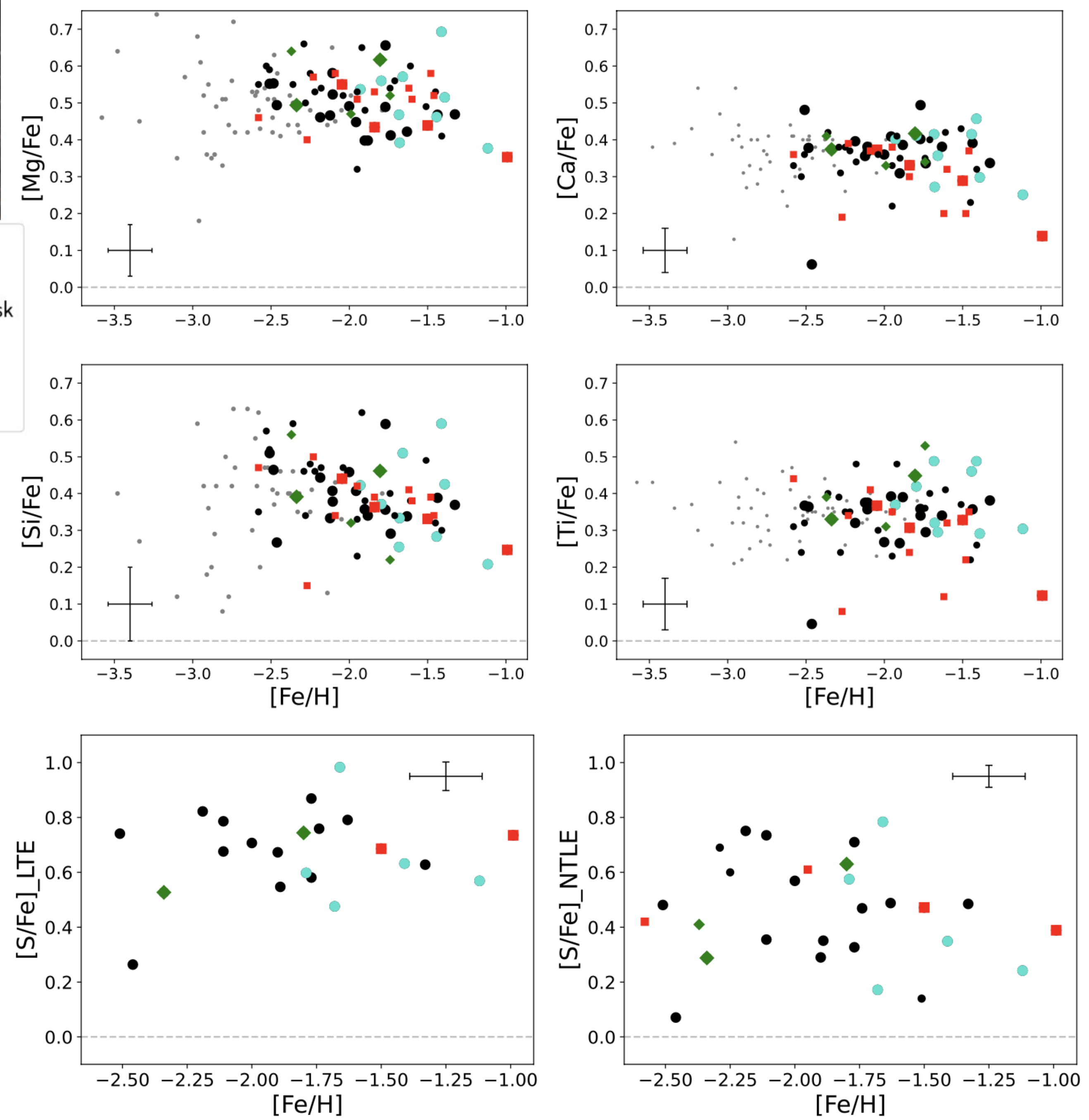
α-elements



- Mainly produced by SNe-II

- The stars of the different structures seem to share the same plateau in all panels in the metallicity range -2.5 < [Fe/H] < -1.5

See talks by L. Lombardo & J. L. SCHIAPPACASSE

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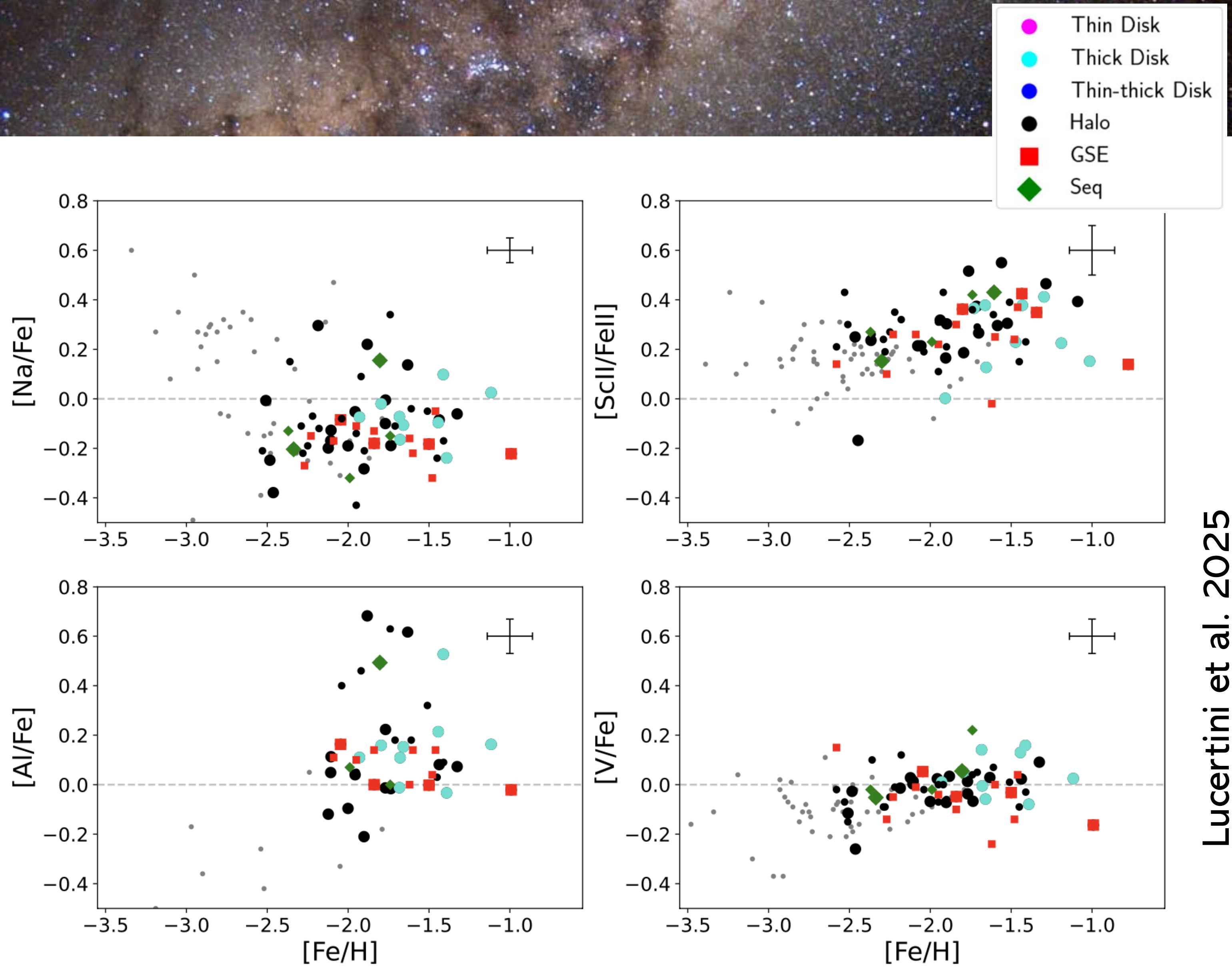
Light-odd elements

- Produced by proton-capture reactions at high T_{eff} during H-burning in massive stars
- Na-rich: 6 halo , 2 thick-disk, 1 Seq stars
- Al-rich: 4 halo, 1 thick-disk, 1 Seq stars
- Sligth increase of [Sc/Fe] and [V/Fe] ratios with metallicity



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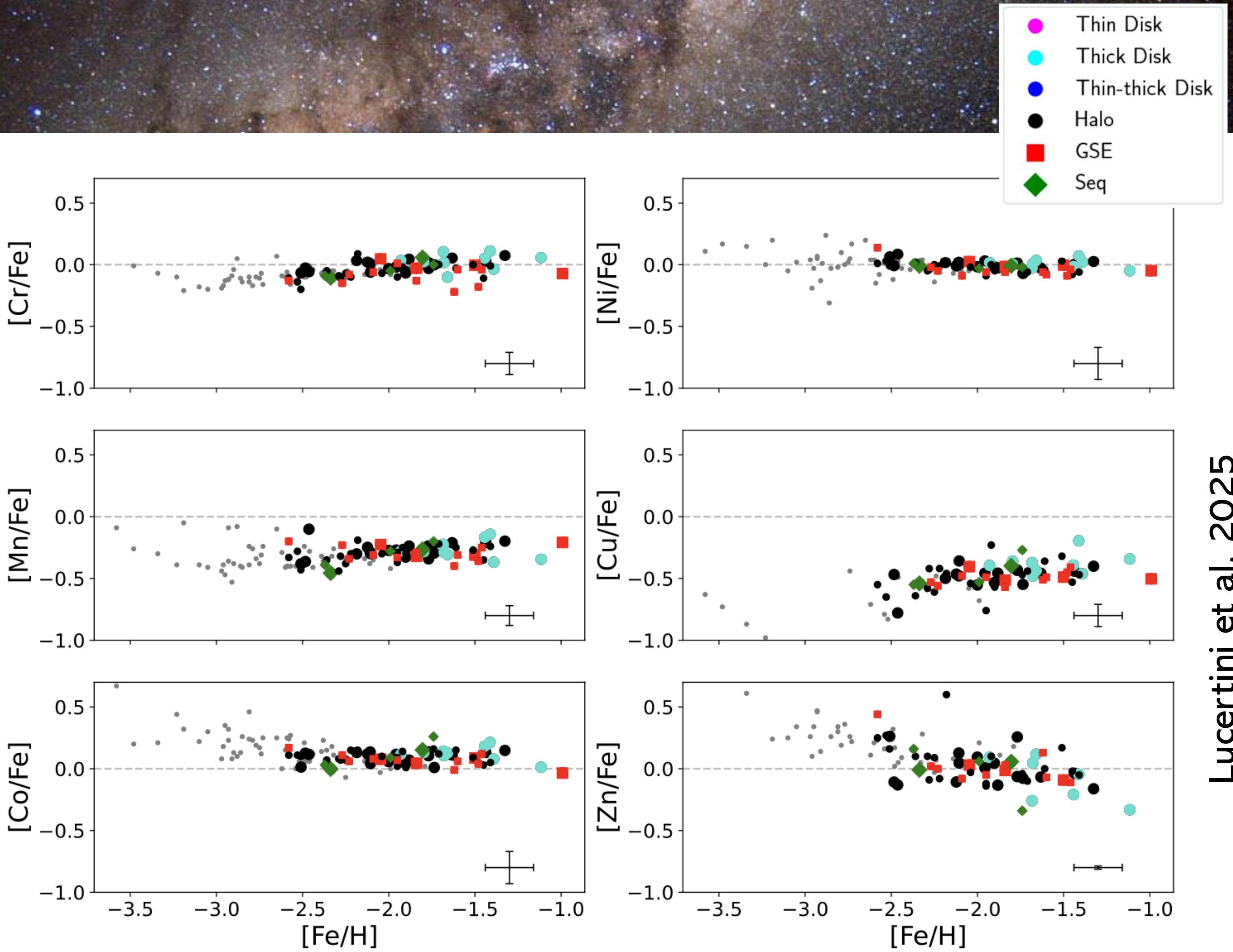
Iron-peak elements

Produced in similar manner by SNe-II and SNe-Ia

- Cr, Ni, Co and Zn show a solar ratio as expected
  - Co, Ni flat trends
  - Cr, Zn have increasing, decreasing trend with [Fe/H]

- Mn, Cu show sub-solar trends increasing with [Fe/H] → different enrichment mechanisms



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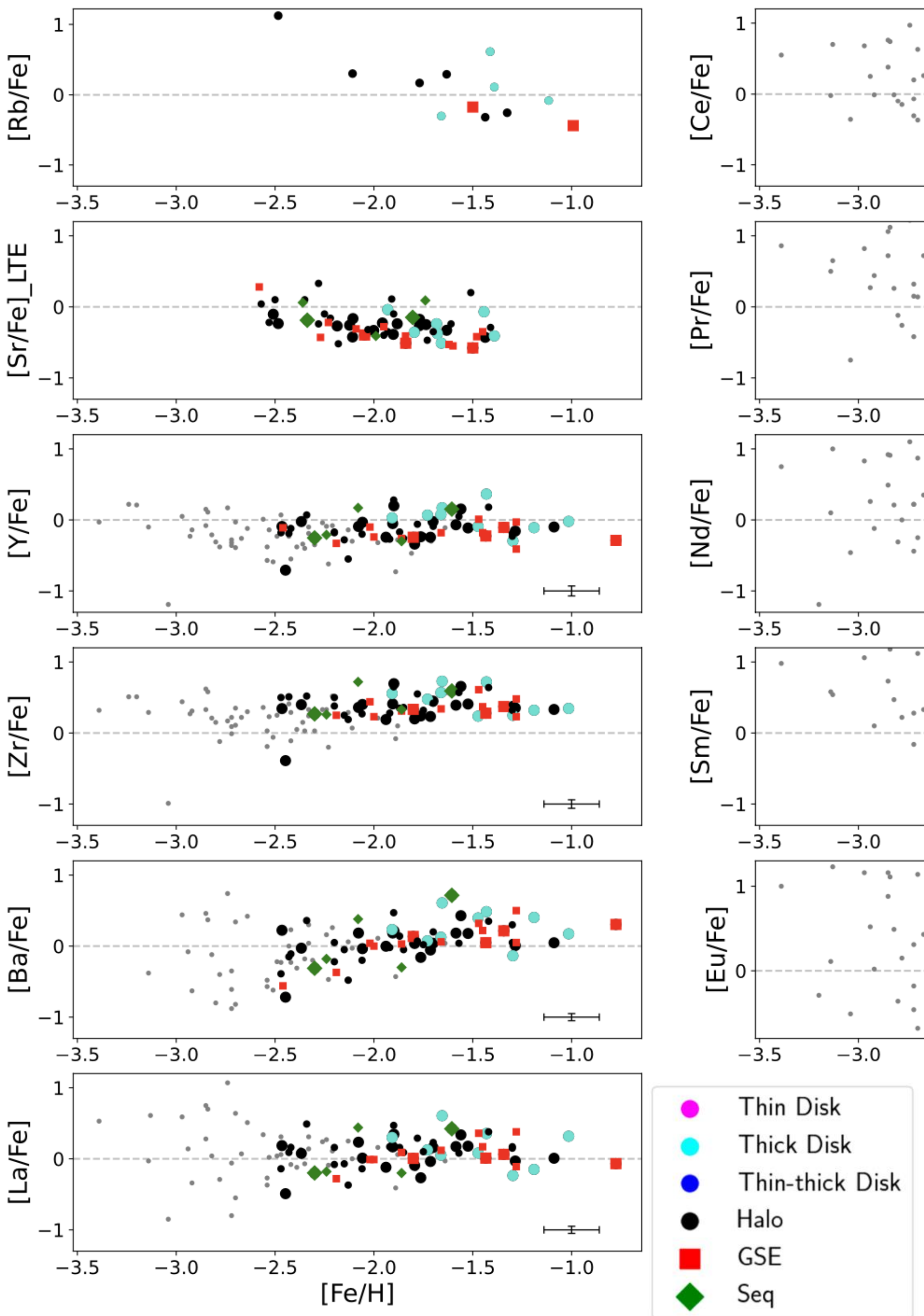
n-capture elements

- Produced through r-, s- and i-processes
- Flats trends overall, with the exception of Sr and Ba that decreases and increases with [Fe/H]
- Slightly higher dispersion at lower metallicities



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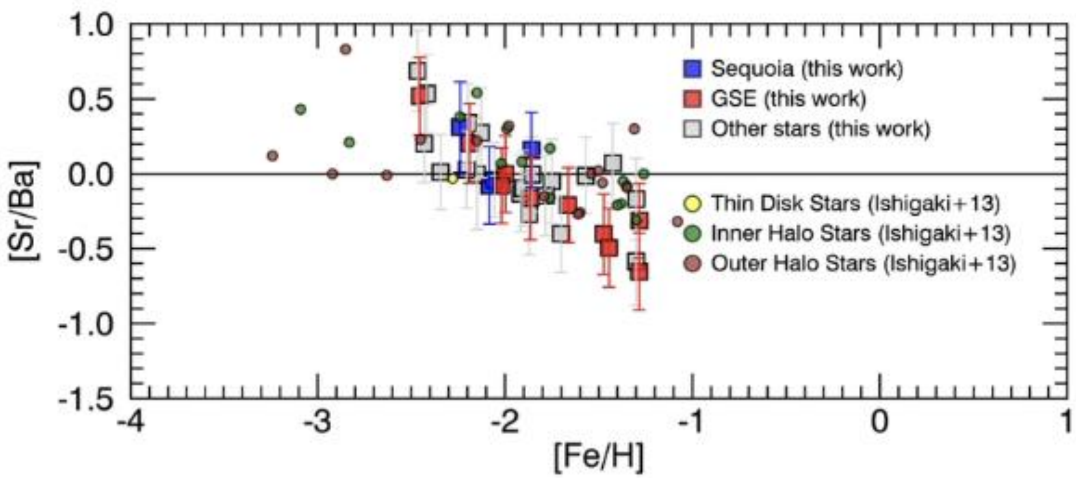
n-capture elements

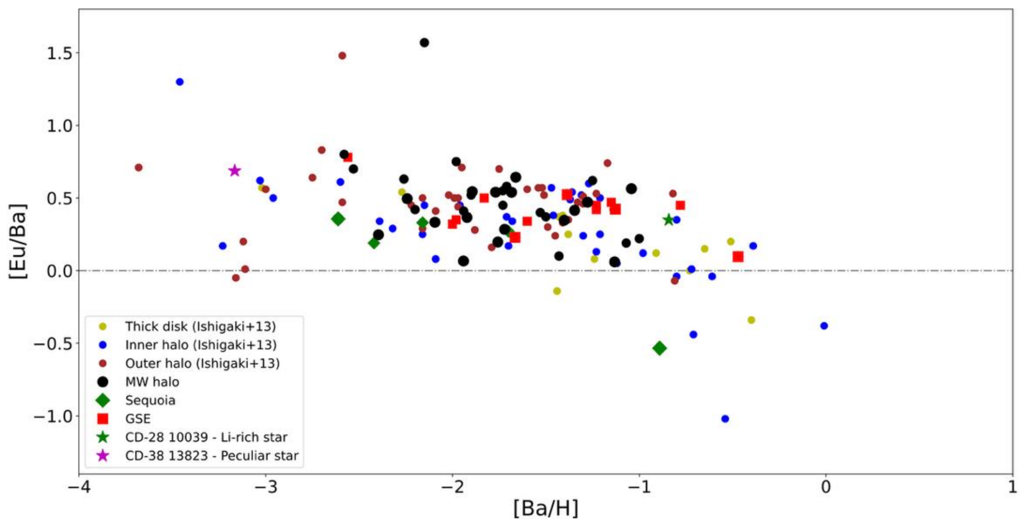
- GSE and Seq show decreasing [Sr/Ba] as [Ba/H] increases

- At a given [Fe/H],
  [Sr/Ba]_Seq > [Sr/Ba]_GSE

- GSE: <[Eu/Ba]> = 0.45,
  Seq: <[Eu/Ba]> = 0.27



François et al. 2023



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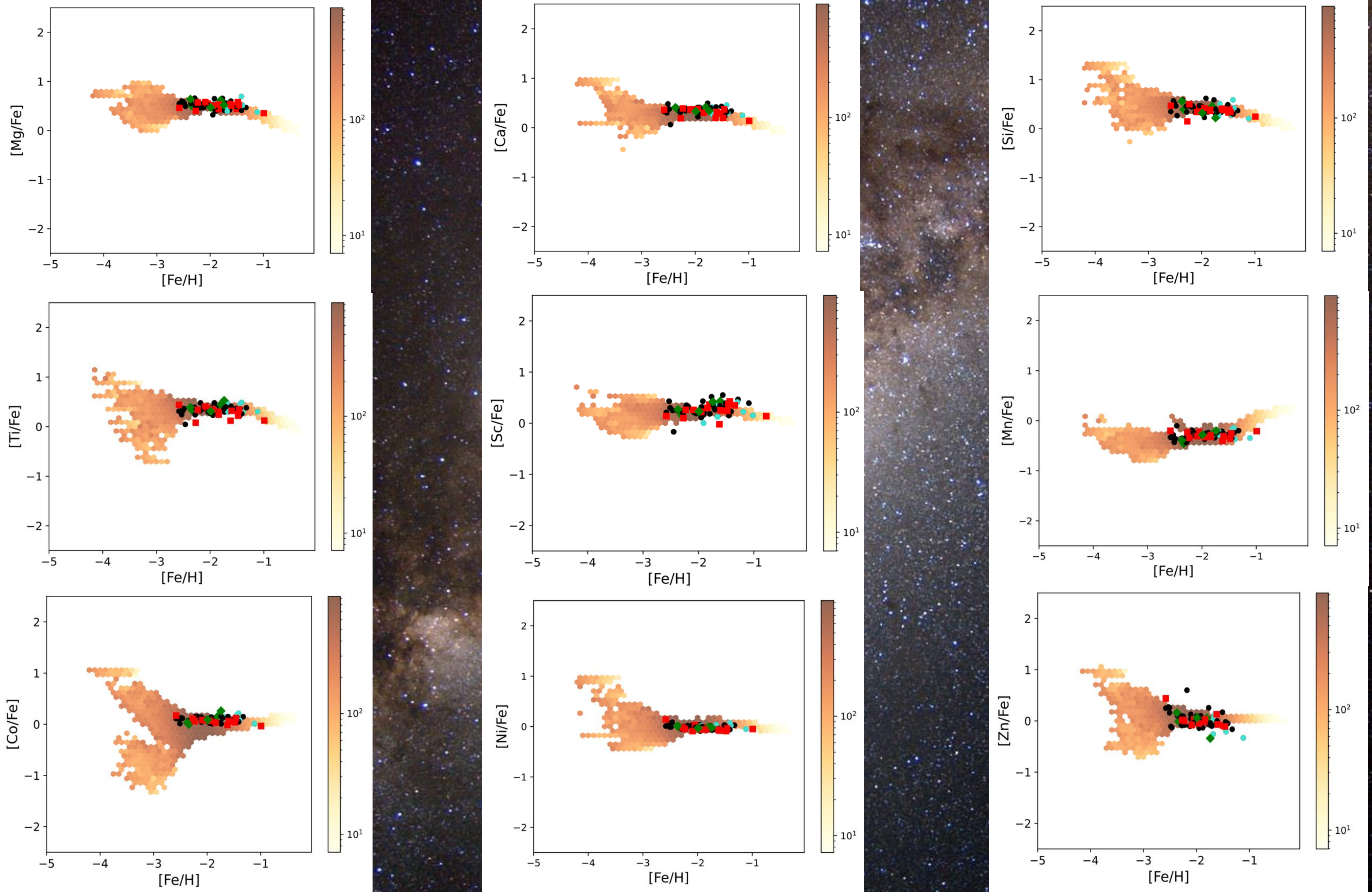
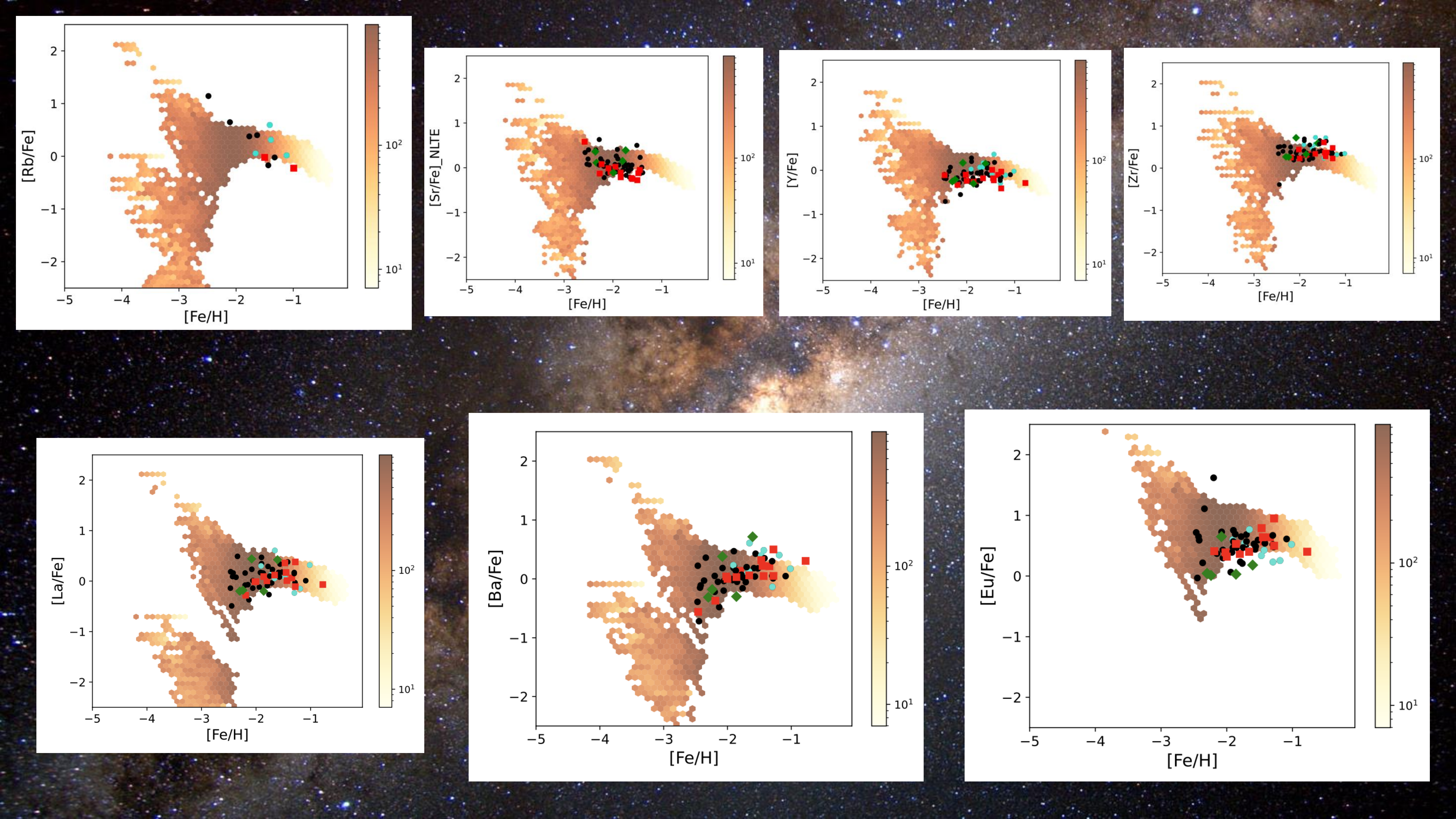
Stochastic chemical evolution models

Nucleosynthesis from Cescutti & Chiappini (2014):

- r-processes enrichment by magneto-rotational driven SN, rotating massive stars (yields by Frischknecht et al 2016)
- s-processes enrichment by AGB stars (yields by Cristallo et al 2011)

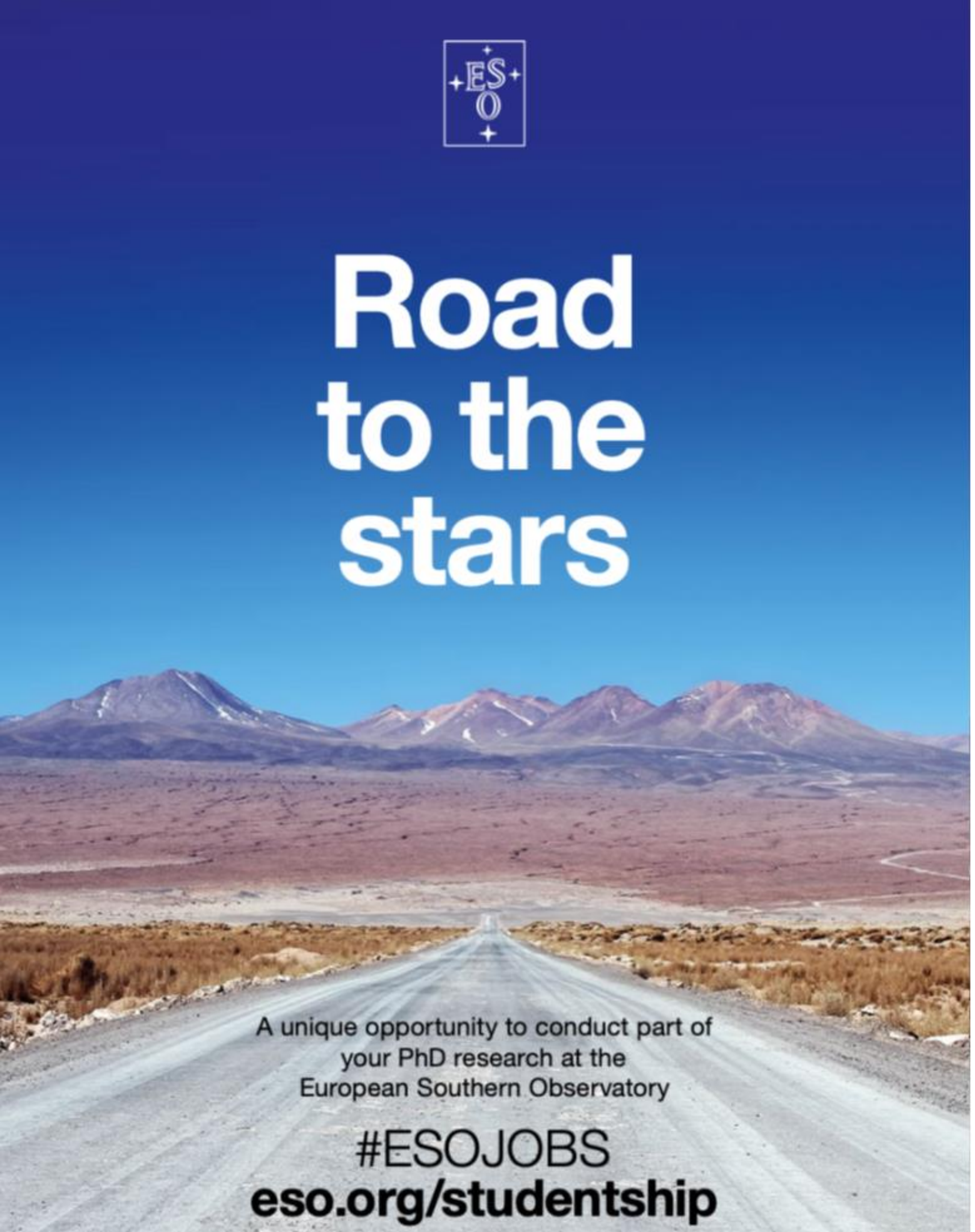


[Mg/Fe]
[Fe/H]
[Ca/Fe]
[Fe/H]
[Si/Fe]
[Fe/H]
[Ti/Fe]
[Fe/H]
[Sc/Fe]
[Fe/H]
[Mn/Fe]
[Fe/H]
[Co/Fe]
[Fe/H]
[Ni/Fe]
[Fe/H]
[Zn/Fe]
[Fe/H]


[Rb/Fe]
[Sr/Fe]_NLTE
[Y/Fe]
[Zr/Fe]
[La/Fe]
[Ba/Fe]
[Eu/Fe]
[Fe/H]
10^1
10^2

Conclusions

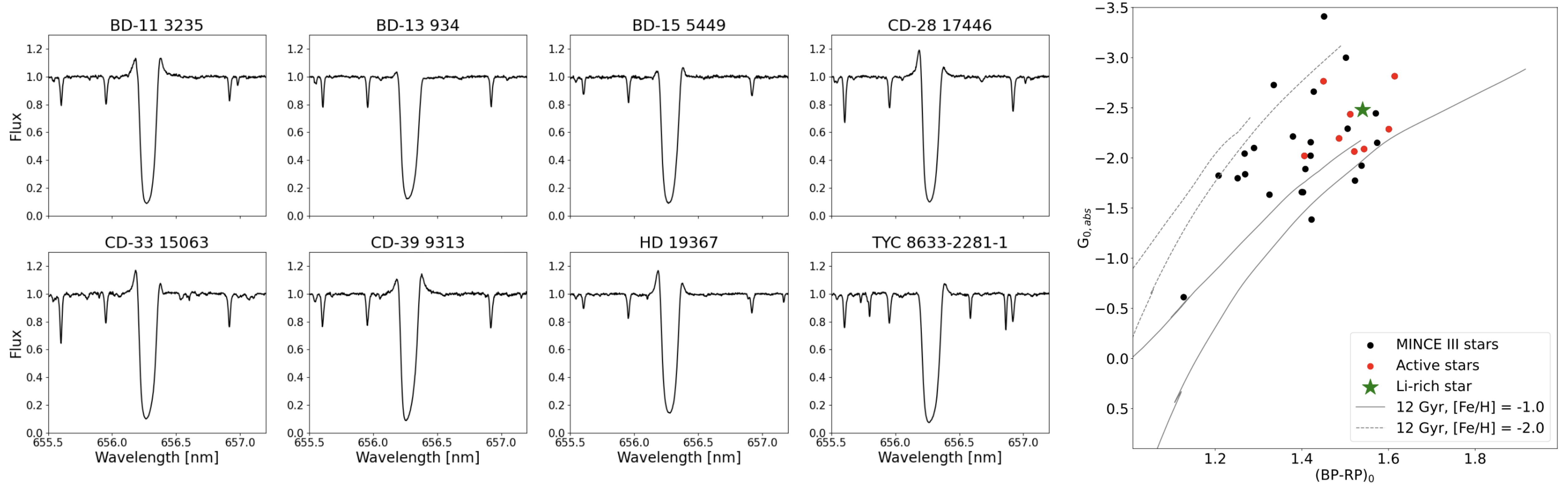
- The approach of using multiple middle-sized facilities allows to collect meaningful amounts of high-quality data in a relatively short amount of time.
- High quality abundances of light and n-capture elements have been derived
- The MINCE project has already significantly increased the number of neutron-capture elements measurements in the metallicity range $-2.5 < [Fe/H] < -1.5$
- The good agreement between the chemical abundances and the stochastic chemical evolution model of the Galactic halo supports the nucleosynthetic processes adopted to describe the origin of the n-capture elements.
- The small GSE and Sequoia samples do not allow to define a peculiar behavior of [X/Fe] vs [Fe/H] distribution in these substructures
- The higher <[Sr/Ba]> value of Seq in comparison to GES reveals different level of n-capture enrichment in these two systems



ESO Chile opportunity

- Visitor program (any time of the year)
- Studentship (up to 2 years)
- Fellowship (Garching 3 and Chile 4 years)
- Internship (up to 2 months, second half of the year)
- Office for Science funds

The active stars



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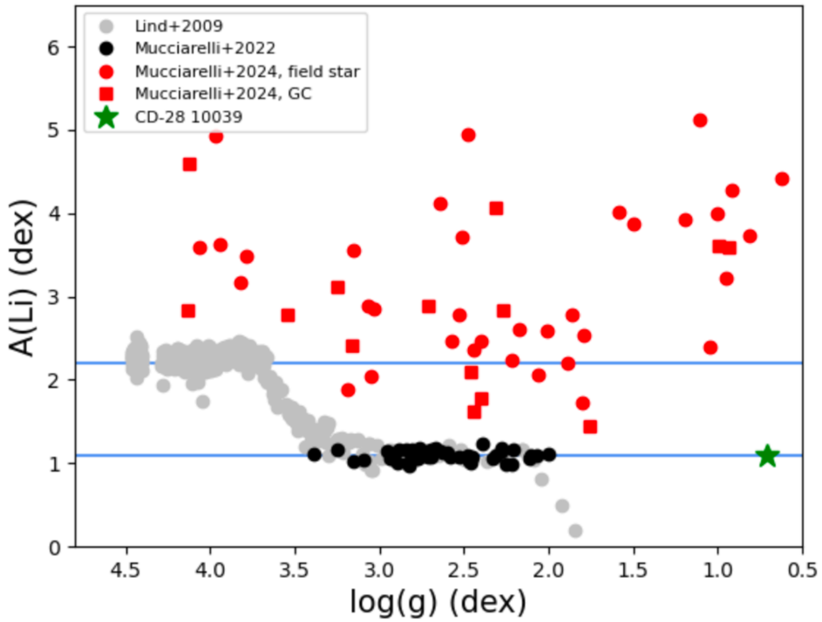
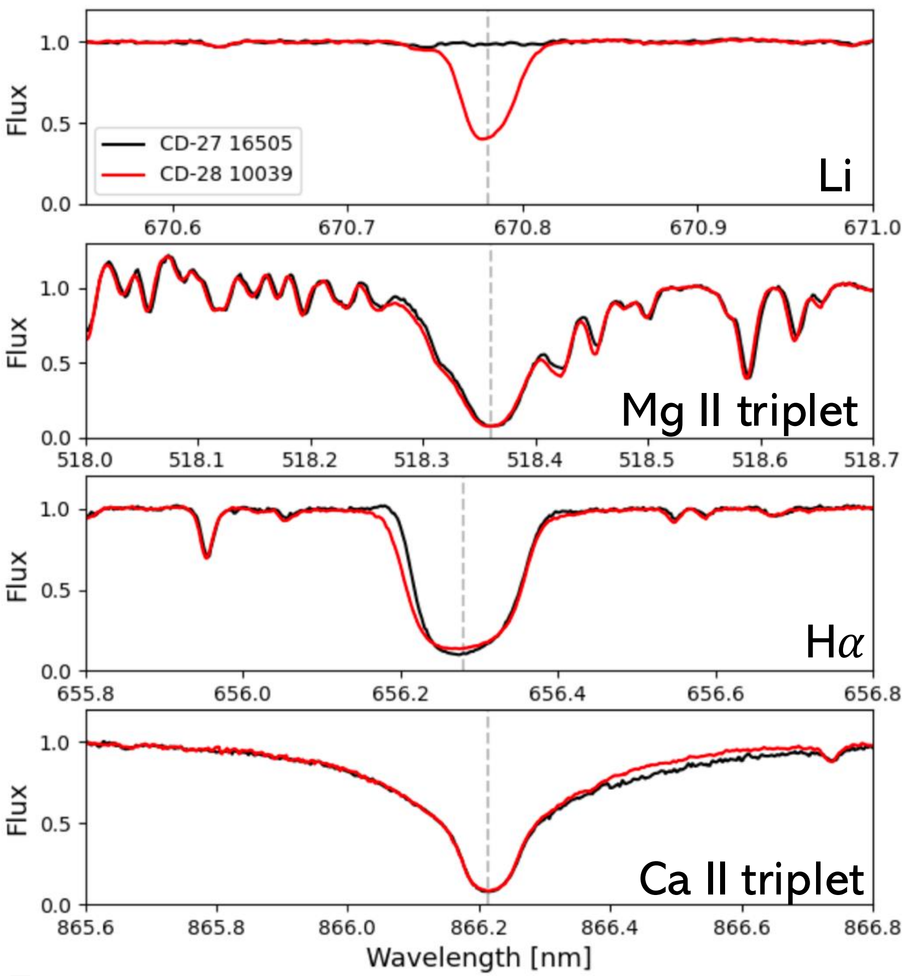
CD-28 10039: a Li-rich star

- A(Li) = 1.1
- Thick-disk star
- Enhancement not due to standard stellar evolution or non-canonical mixing processes
- A(Y) = 1.17, A(Ba) = 1.34, A(Eu) = 0.04
- [Rb/Y] = -0.06 → low neutron density sites





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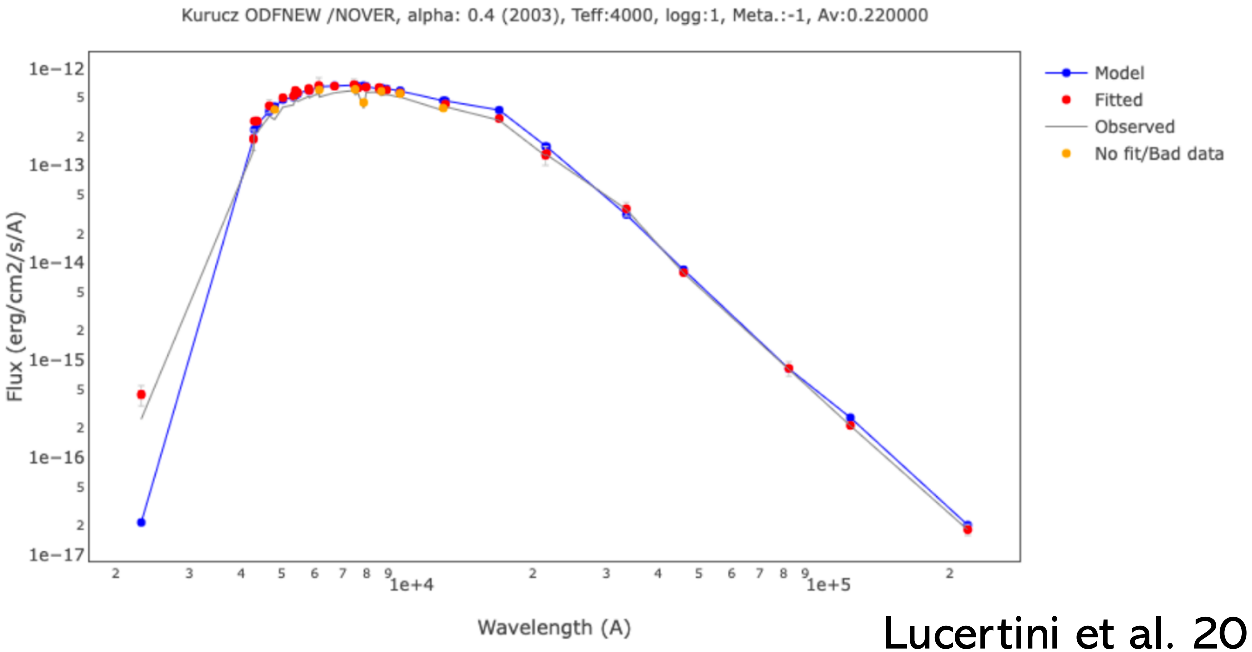
CD-28 10039: a Li-rich star

- SED generated adopting Av = 0.22 mag, d = 2.14 kpc

- Near UV excess → hot companion? WD?

  The Gaia DR3 astrometry quality parameters are NOT suggestive of binarity, but our RV does not match the Gaia one



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CD – 38 13823

- T_{eff} = 4515 K, logg = 0.85 cgs, v_m =2.15 km/s, [Fe/H]= - 2.46
- Halo kinematic
- It is the most retrograde star of the sample II
- It does not fit Sequoia criteria, but is very close → accreted star?

- Alpha-elements: [Mg/Fe] = 0.49, [Si/Fe] = 0.27, [S/Fe] = 0.26, [Ca/Fe] = 0.06, [Ti/Fe] = 0.06
- Light-odd elements: low [Na] = -0.38, [Sc/Fe] = -0.17, [V/Fe] = 0.26
- Iron-peak elements: most Mn-rich, [Mn/Fe] = -0.10; most Cu-poor, [Cu/Fe] = -0.78
- n-capture elements: low [Y/Fe] = -0.70, [Zr/Fe] = -0.39, [Ba/Fe] = -0.72, [La/Fe] = -0.49, [Sm/Fe] = -0.24, [Eu/Fe] = -0.03