Chemical abundance inventory in phosphorus-rich stars

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Problem

Galactic chemical evolution models fail to reproduce the observed P abundance in the Galaxy, discrepancy of ≈ 2.75 (*Cescutti+12*)

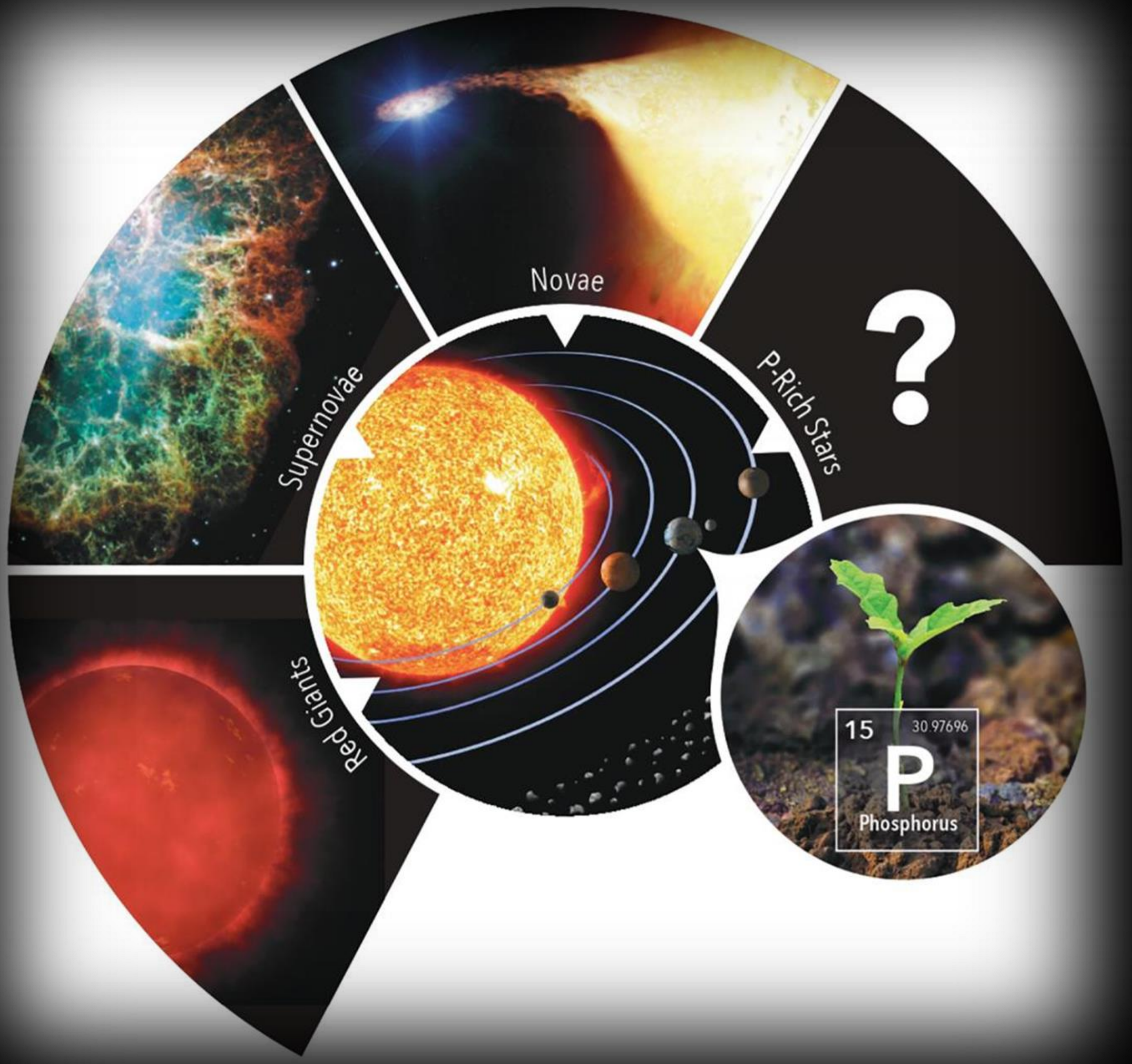
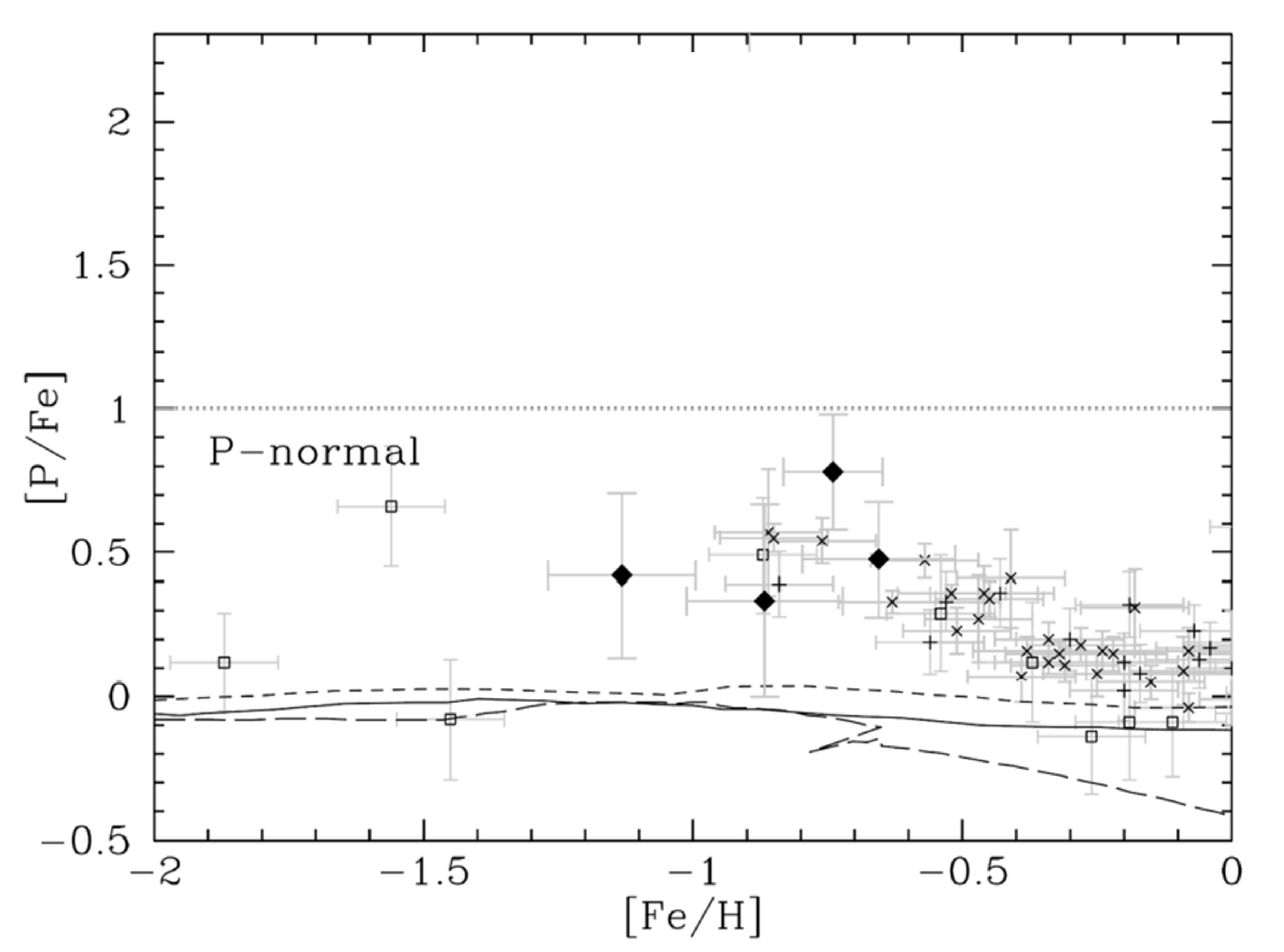


Image credit: Gabriel Pérez Díaz, SMM (IAC)

Masseron, T., García-Hernández, D. A. et al. 2020a, Nature Communications



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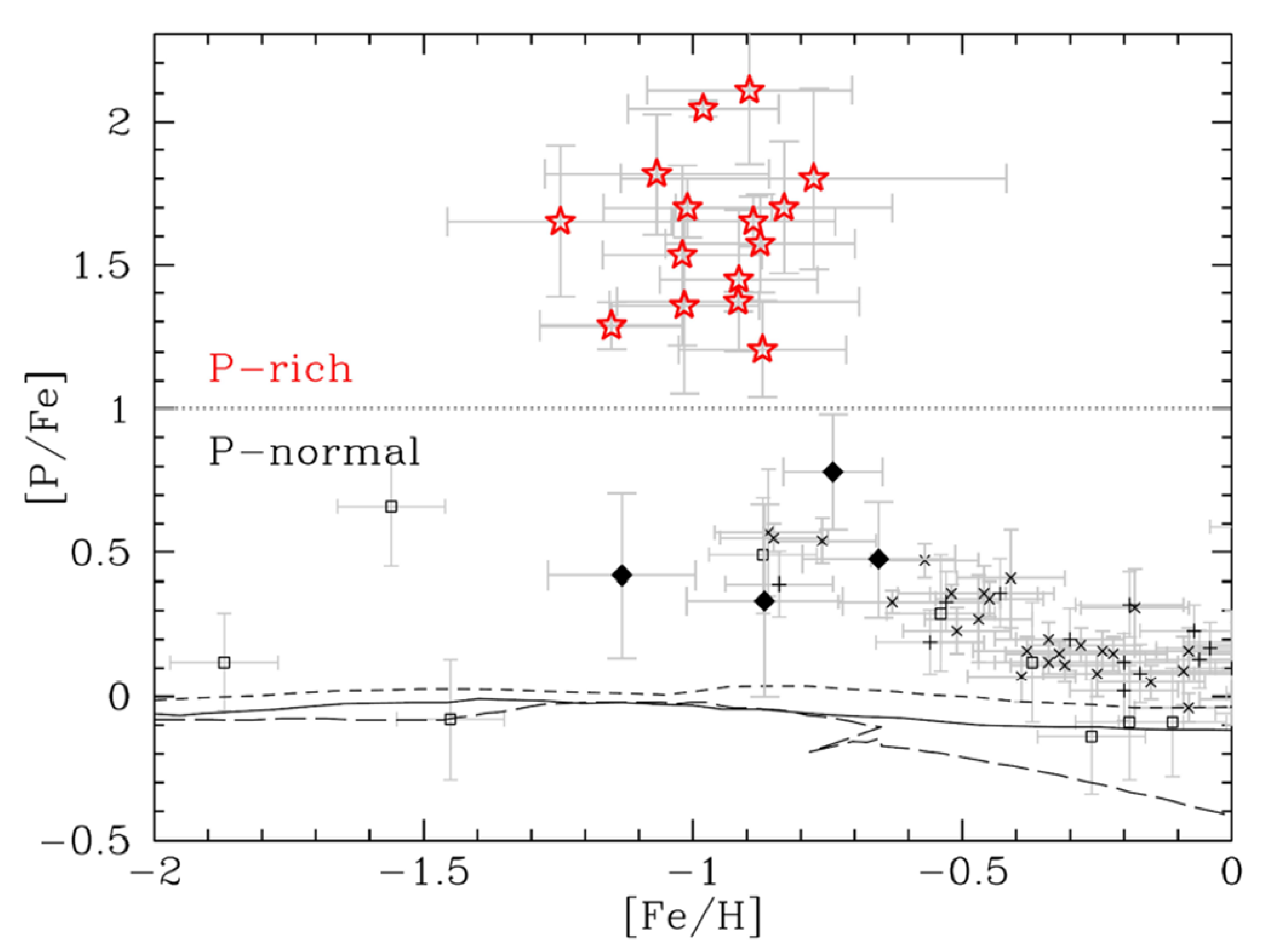

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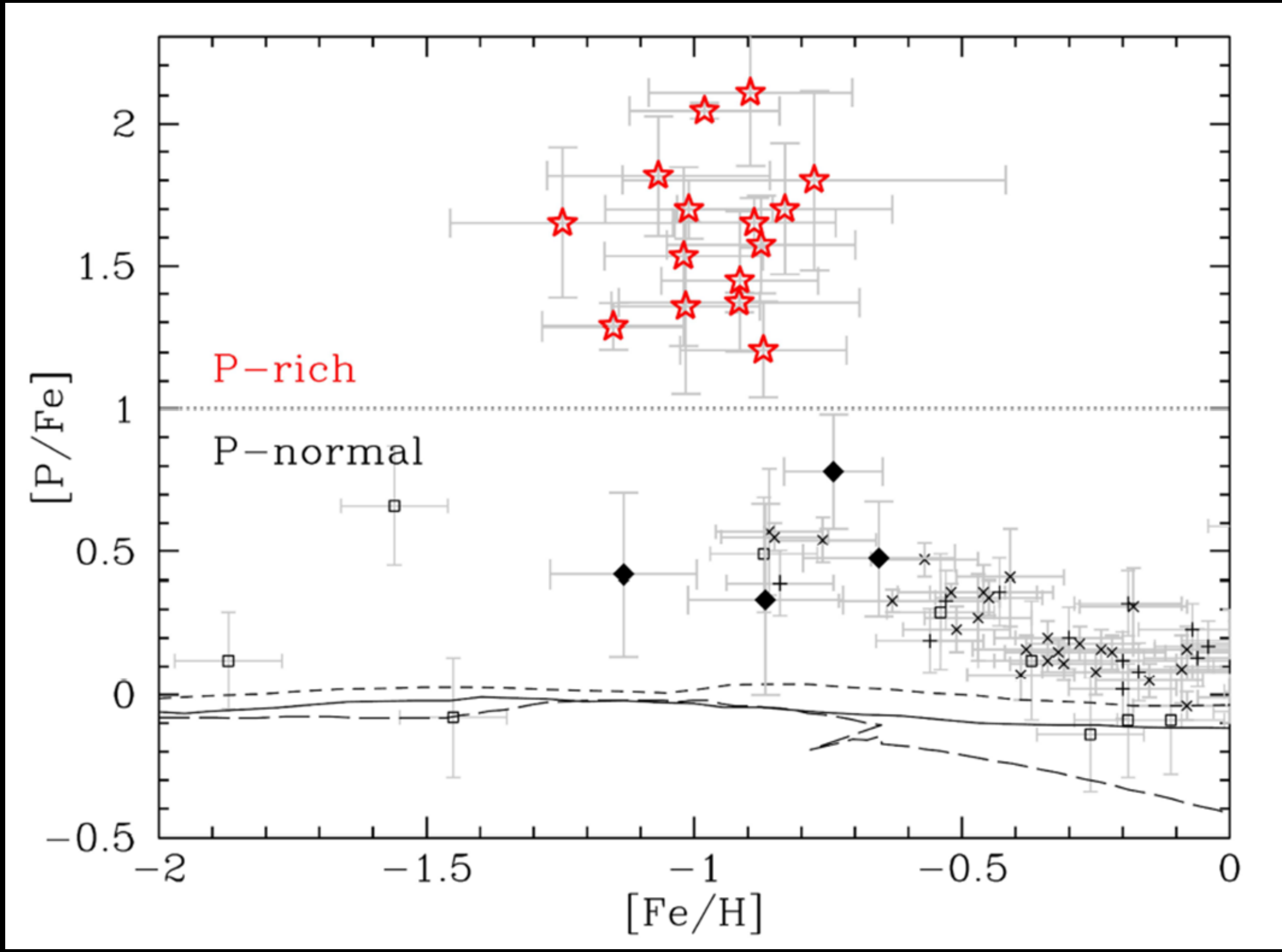
Discovery of **16 stars rich in P**
in APOGEE-2 DR14 (*Masseron+20ab*)

- metal-poor ([Fe/H] ≈ -1)
- low-mass giants



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Discovery of **<u>16 stars rich in P</u>**
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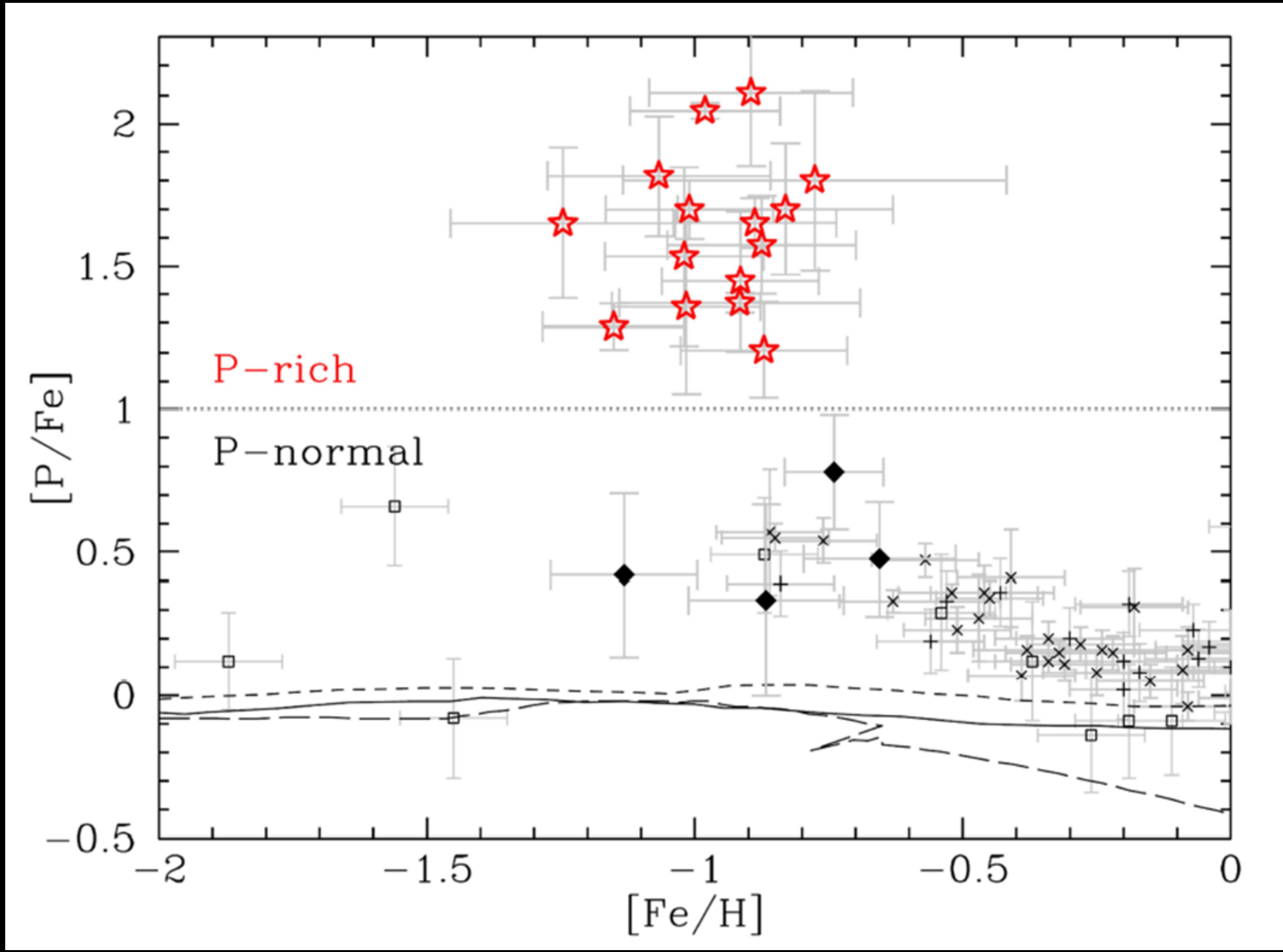
→ there must be a **progenitor / unknown source of P**



Step I: Analyzing APOGEE-2 DR17 spectra

P-rich stars also show high Si abundances (*Masseron+20ab*)

→ check if Si-rich stars (*Fernández-Trincado+19,20*) are also P-rich

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High resolution (R~22,500), **high SNR** (>100), **H-band spectra** (1.51-1.70 μm)

Abundance calculations done with **BACCHUS** (**B**russels **A**utomatic **C**ode for **C**haracterizing **H**igh acc**u**racy **S**pectra) (*Masseron+16*)

Image Credit: Dana Berry / SkyWorks Digital Inc. And the SDSS Collaboration

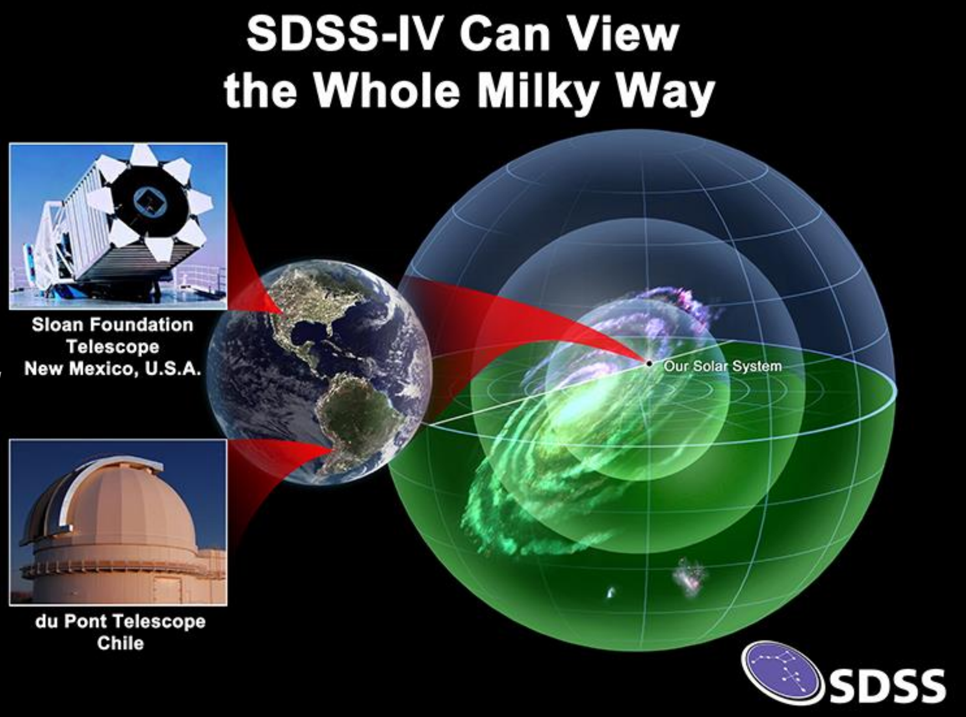
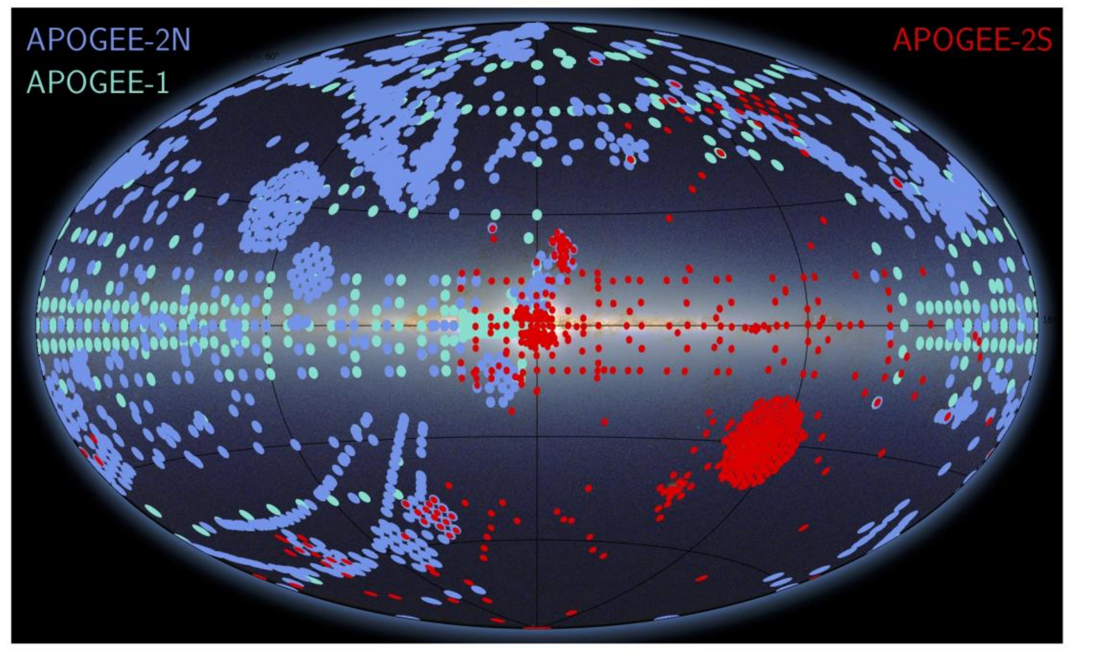
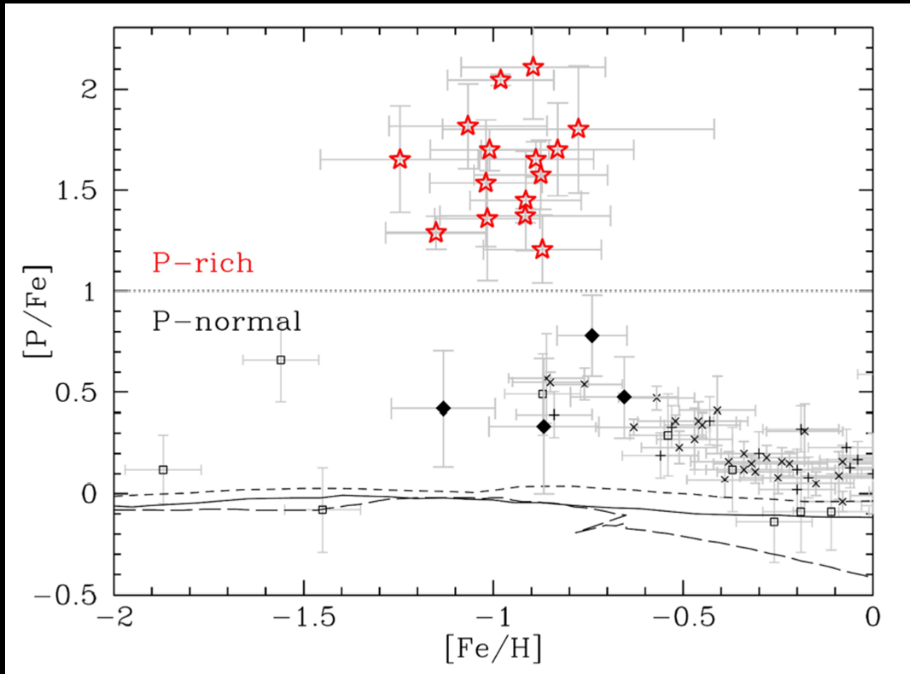


Image Credit: C. Hayes, 2MASS (Background Image)



Step I: Analyzing APOGEE-2 DR17 spectra

DR14, 16 stars
(*Masseron+20ab*)



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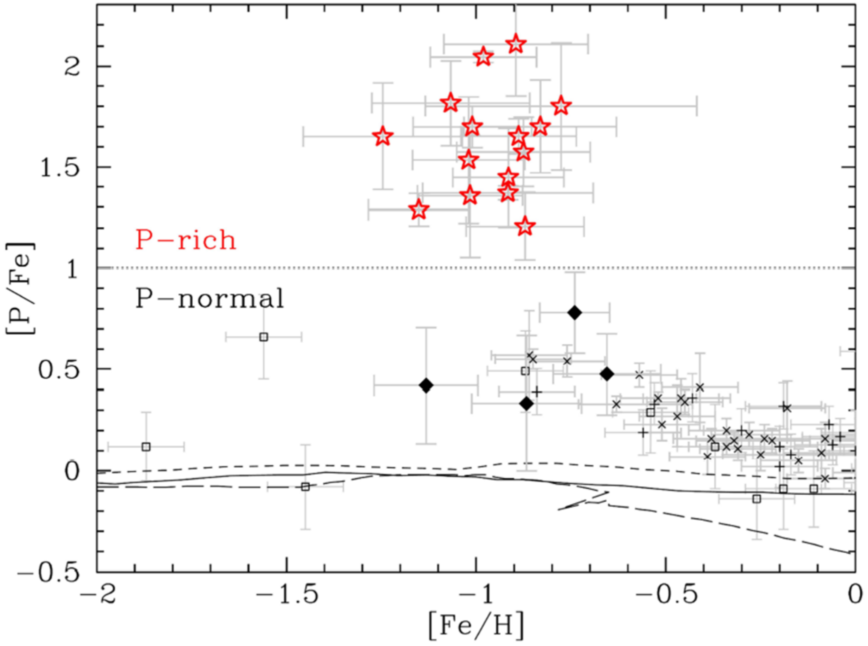

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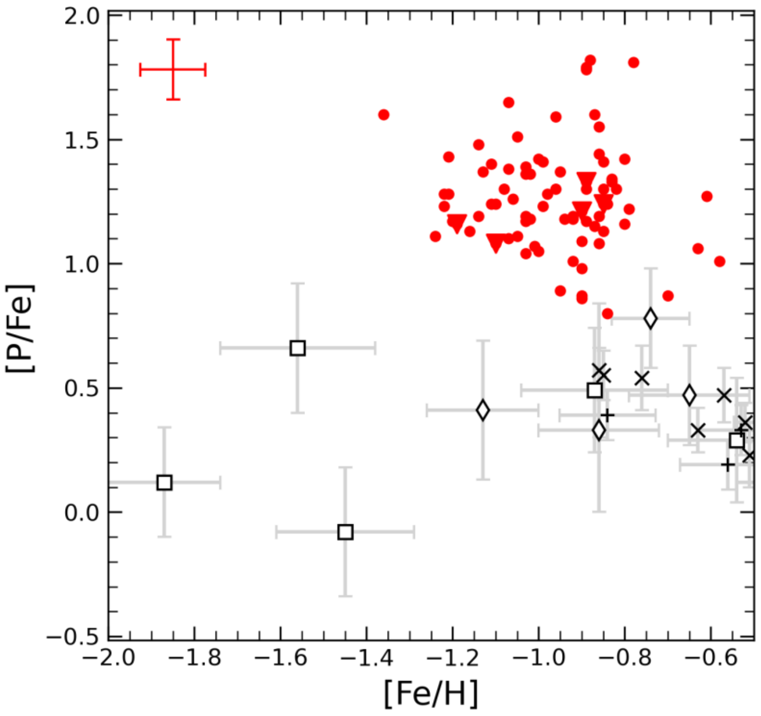
☑

DR17, **78 stars**
(*Brauner+23*)



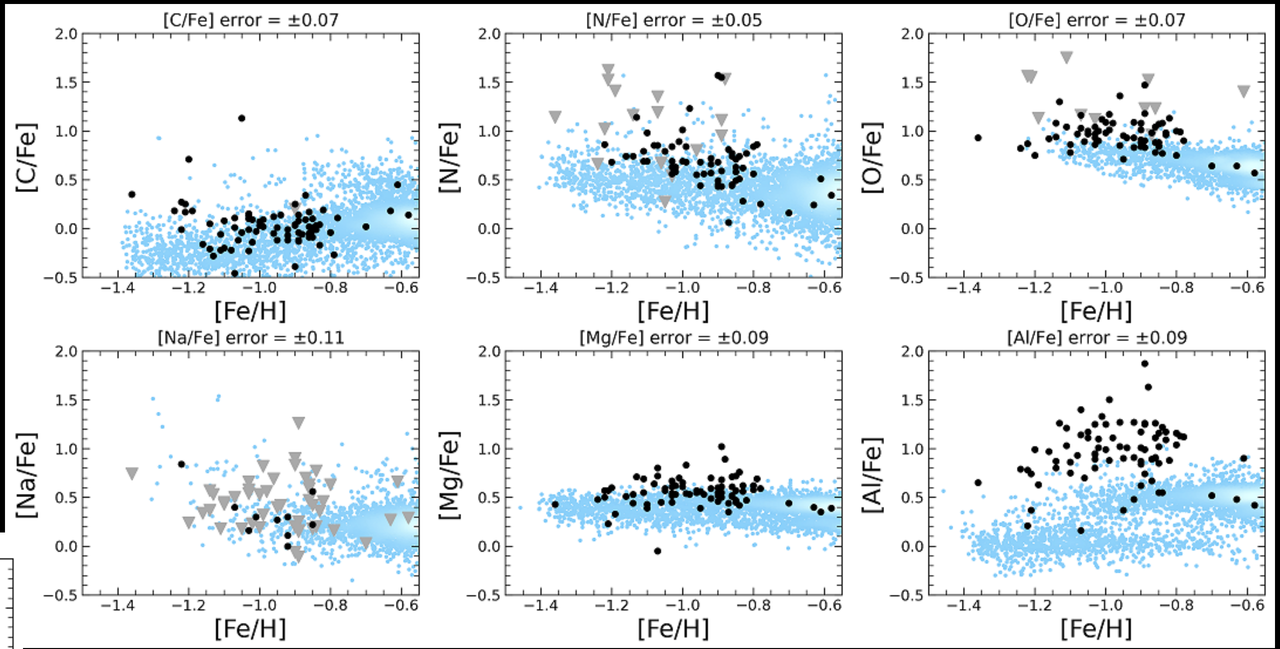
Step I: Analyzing APOGEE-2 DR17 spectra

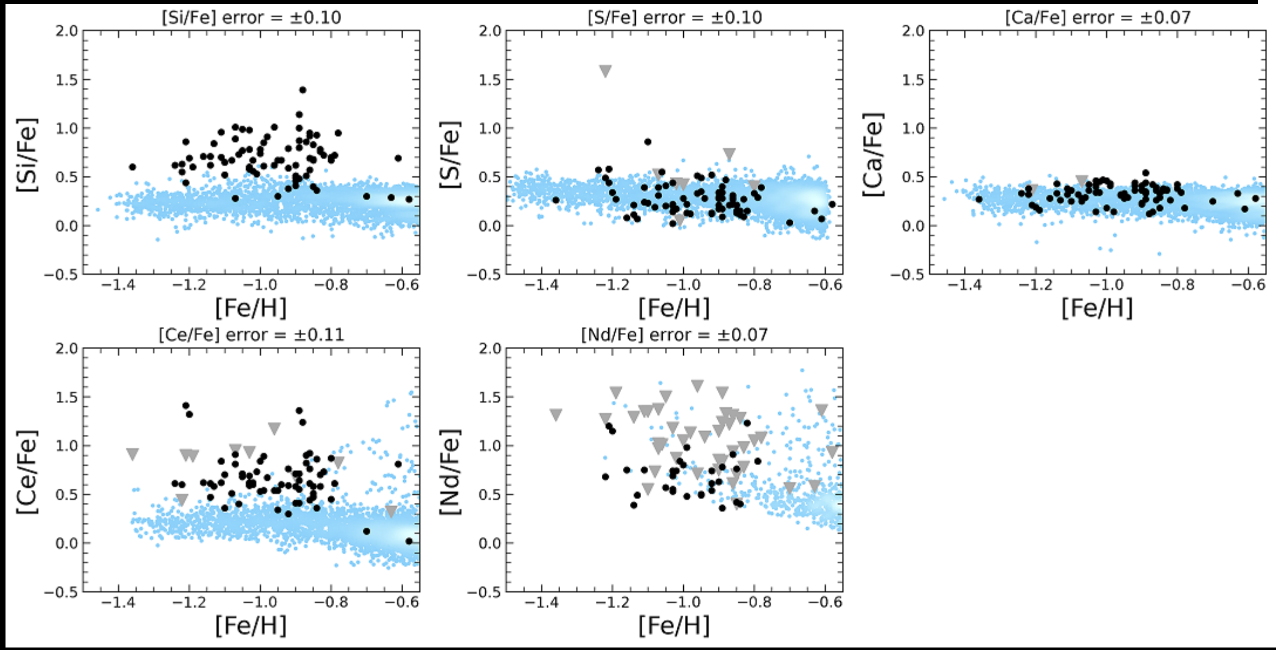
Chemical finger print found:

Overabundances in O, Al, Si, Ce, correlated with P

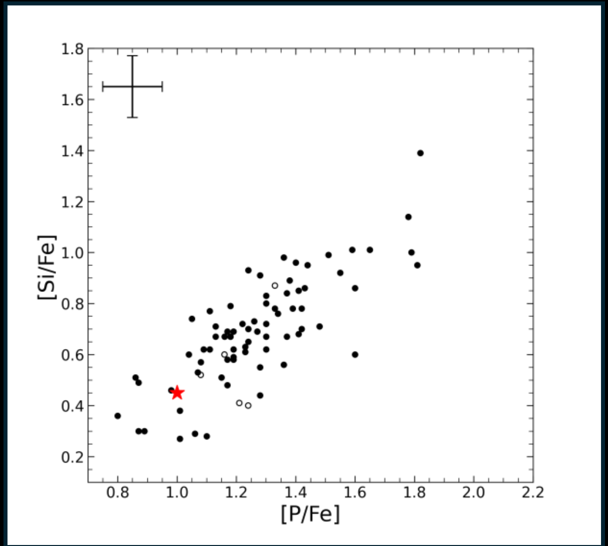
Mg enhanced in some of the stars, correlated with P

S and Ca are **not** enhanced





Brauner+23



Step II: Analyzing optical UVES spectra

Brauner+24

1D LTE abundance analysis of the **four** brightest P-rich stars in the **optical**

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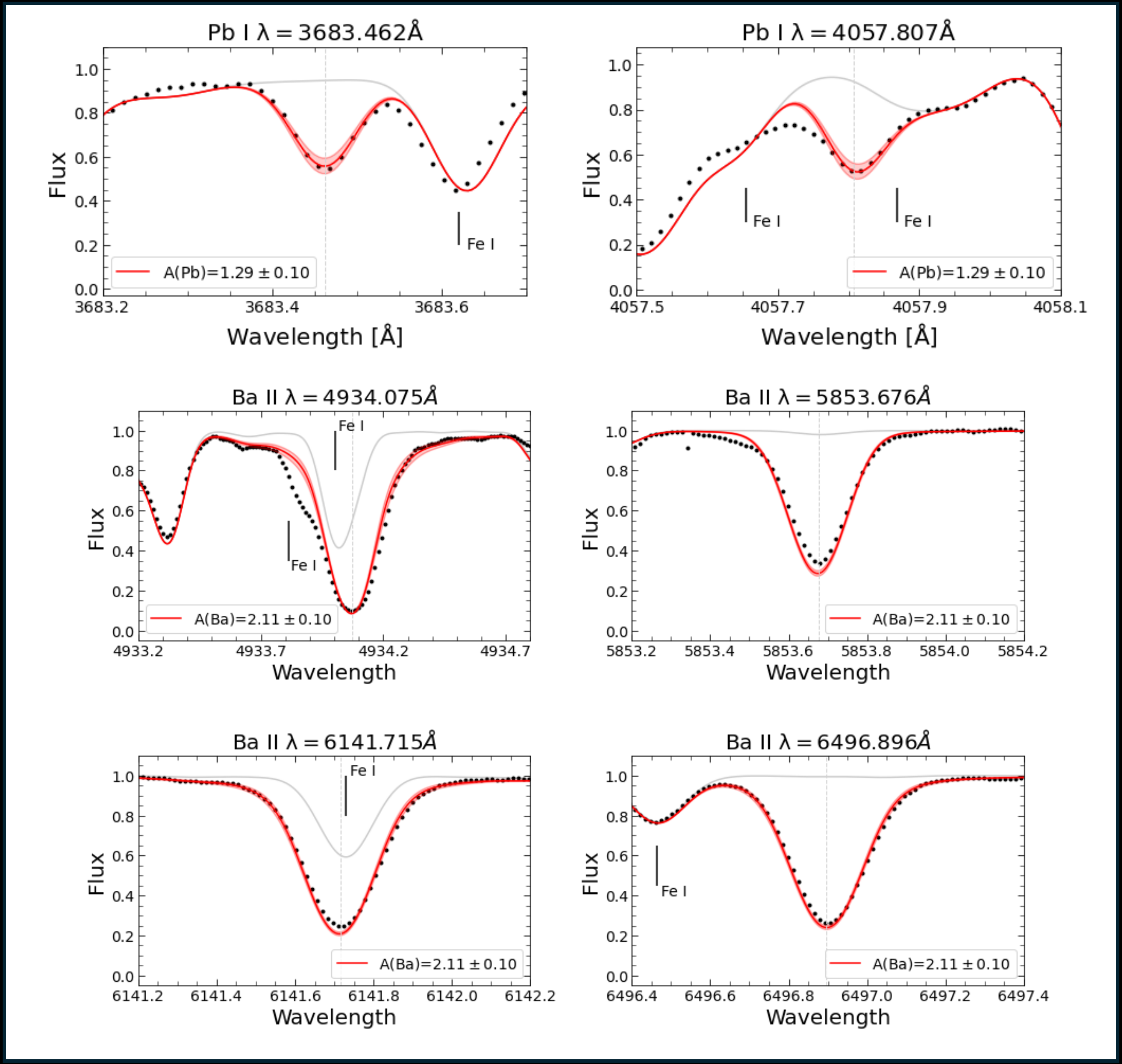
48 light and heavy elements up to Pb, focusing on the neutron-capture elements



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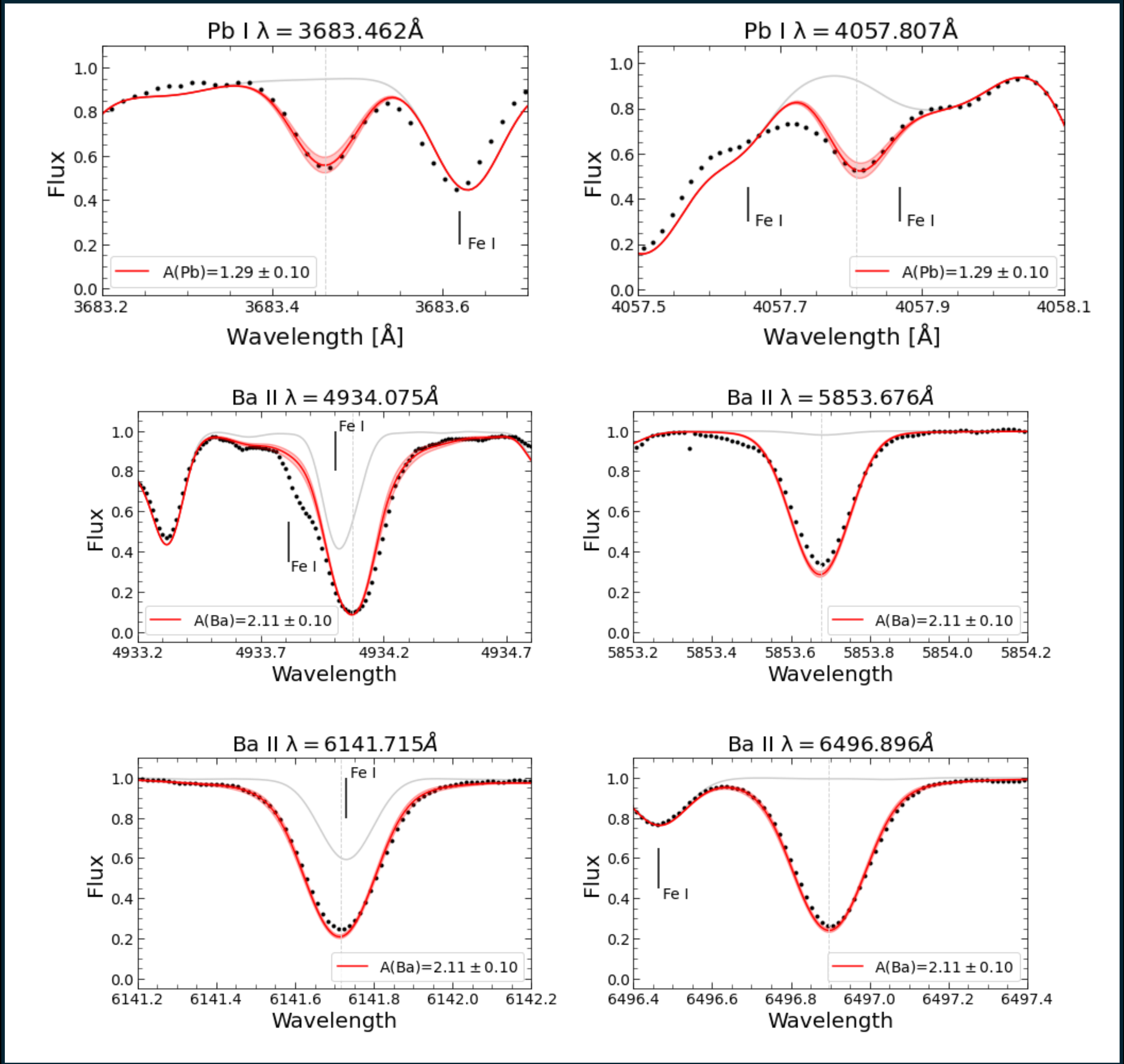
Extremely **high Ba** ([Ba/Fe]>1) abundances found, slight enhancement in some elements between Rb and Sn and other heavy elements (e.g. [Pb/Fe] ≈ 0.45)



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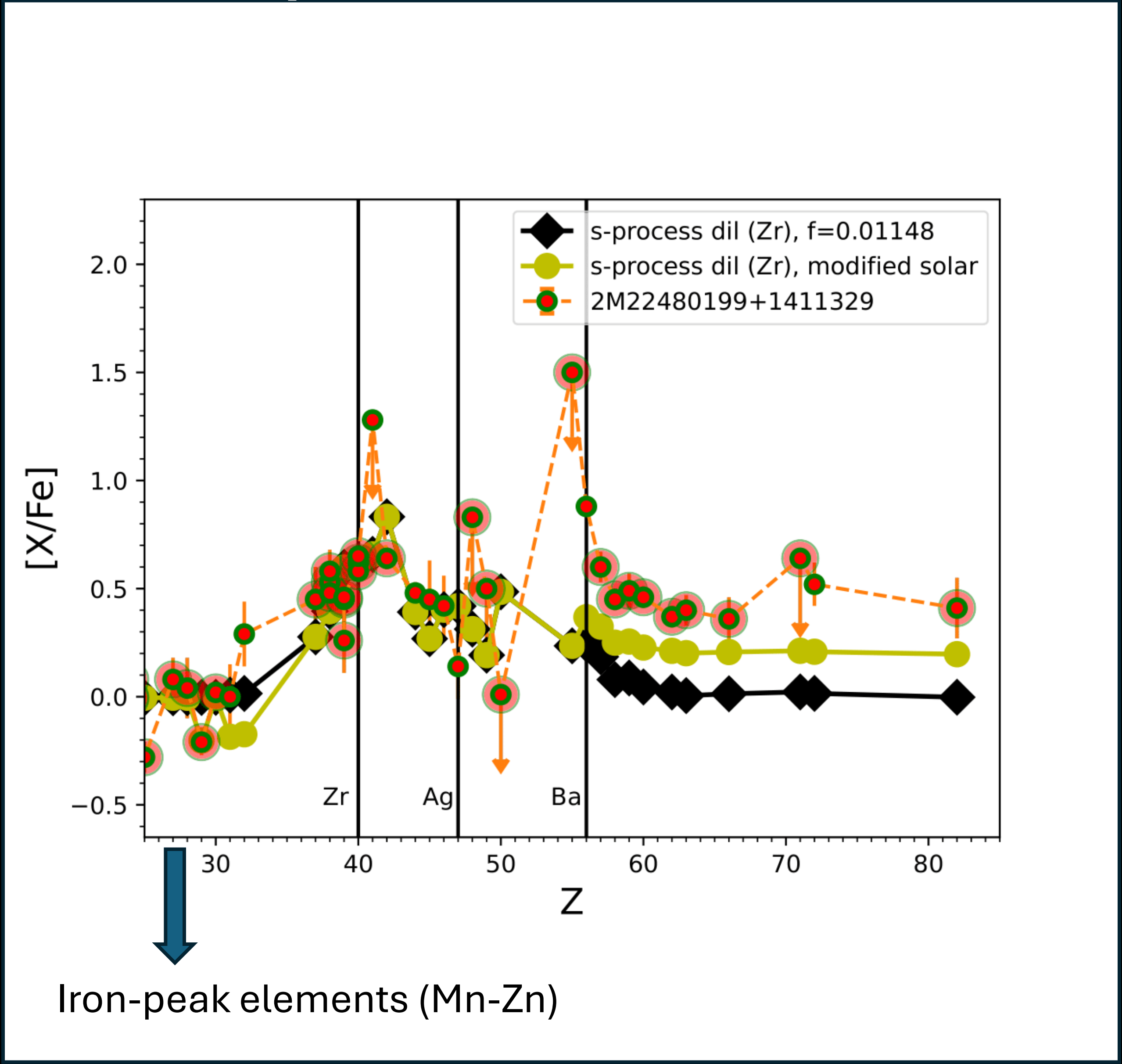
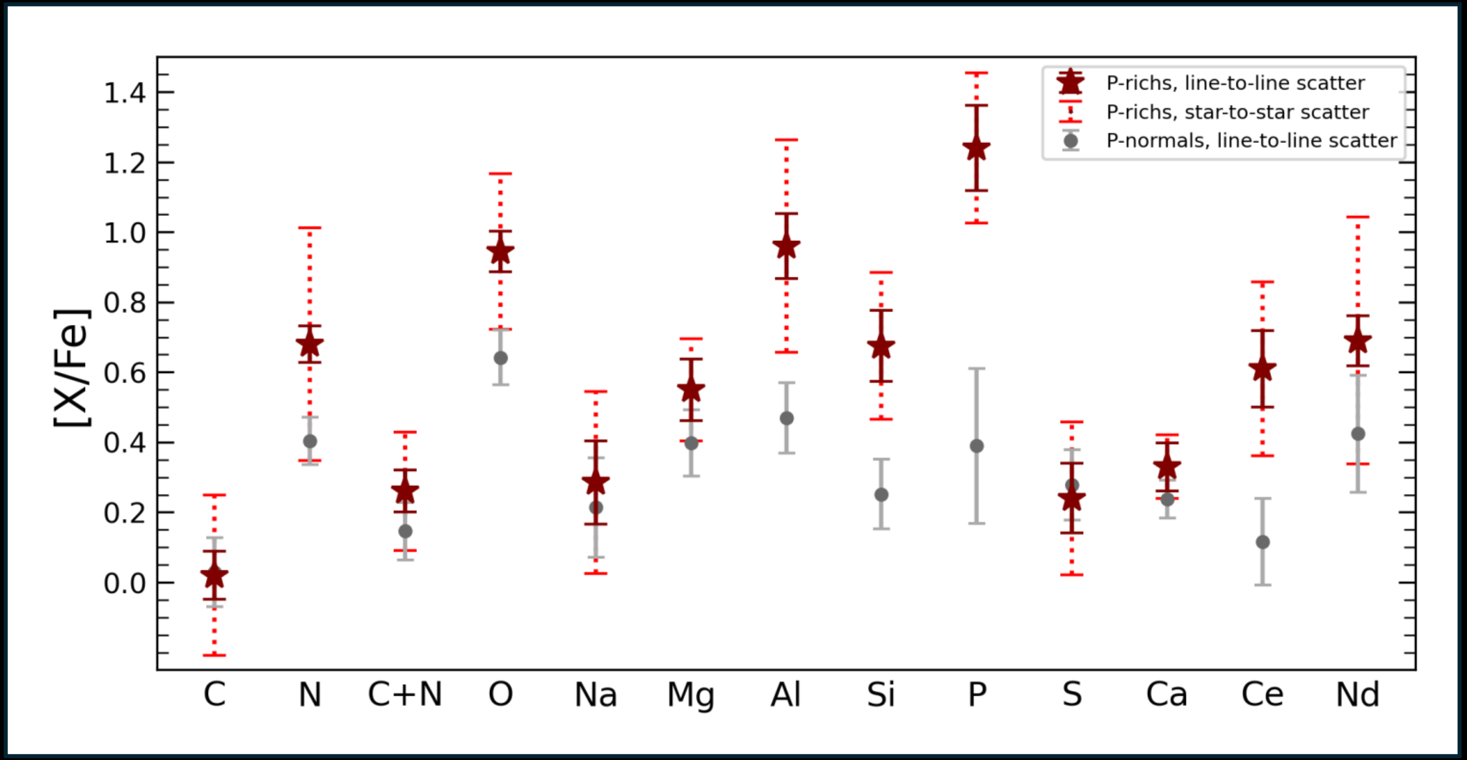
Comparison with nucleosynthetic models of s- and/or i-process

least discrepancies found for a **combination of s- and i-process** → highly uncertain! → i-process is not well constrained yet



What produces the strange pattern?

Discrepancy GCE/nucleosynthetic models persists *(Brauner+23,24)*



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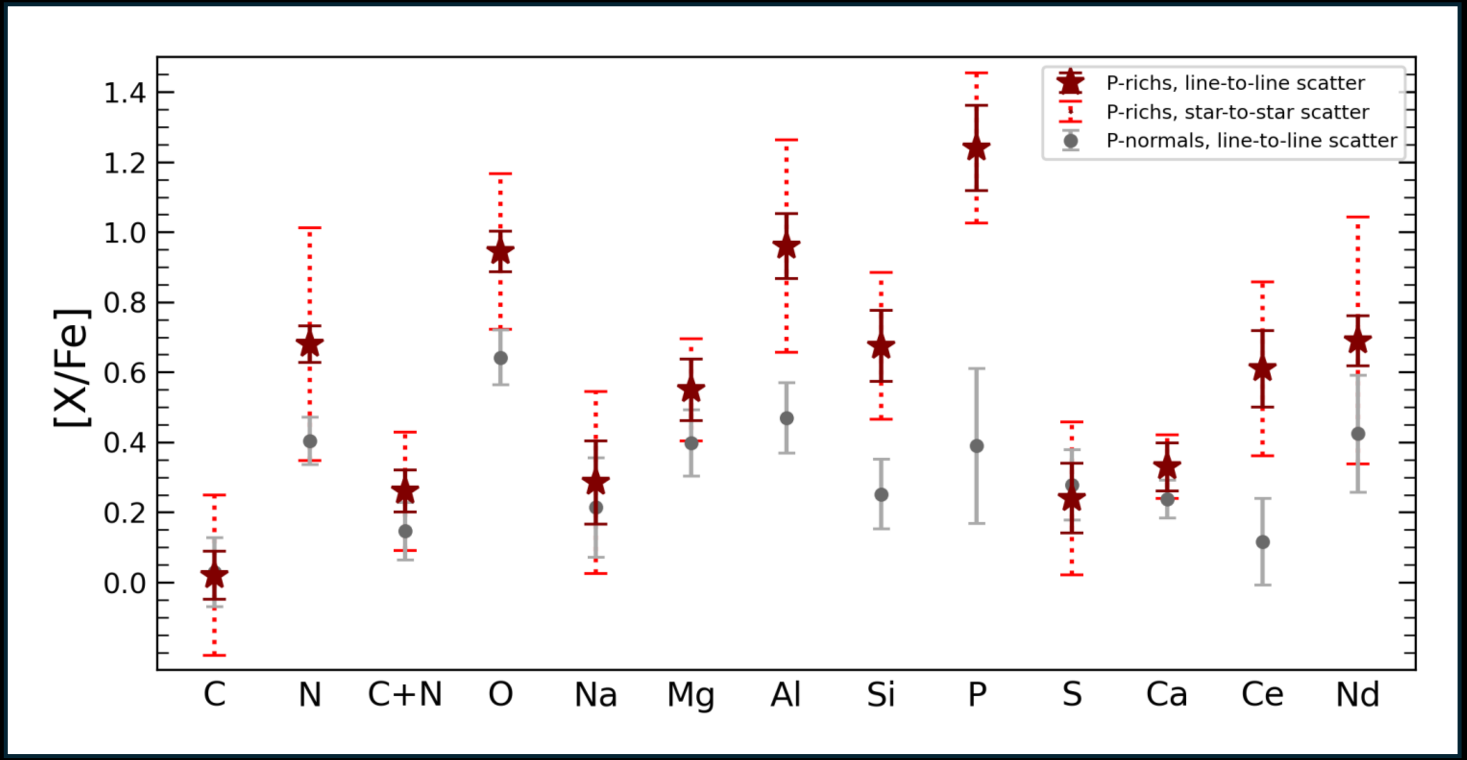
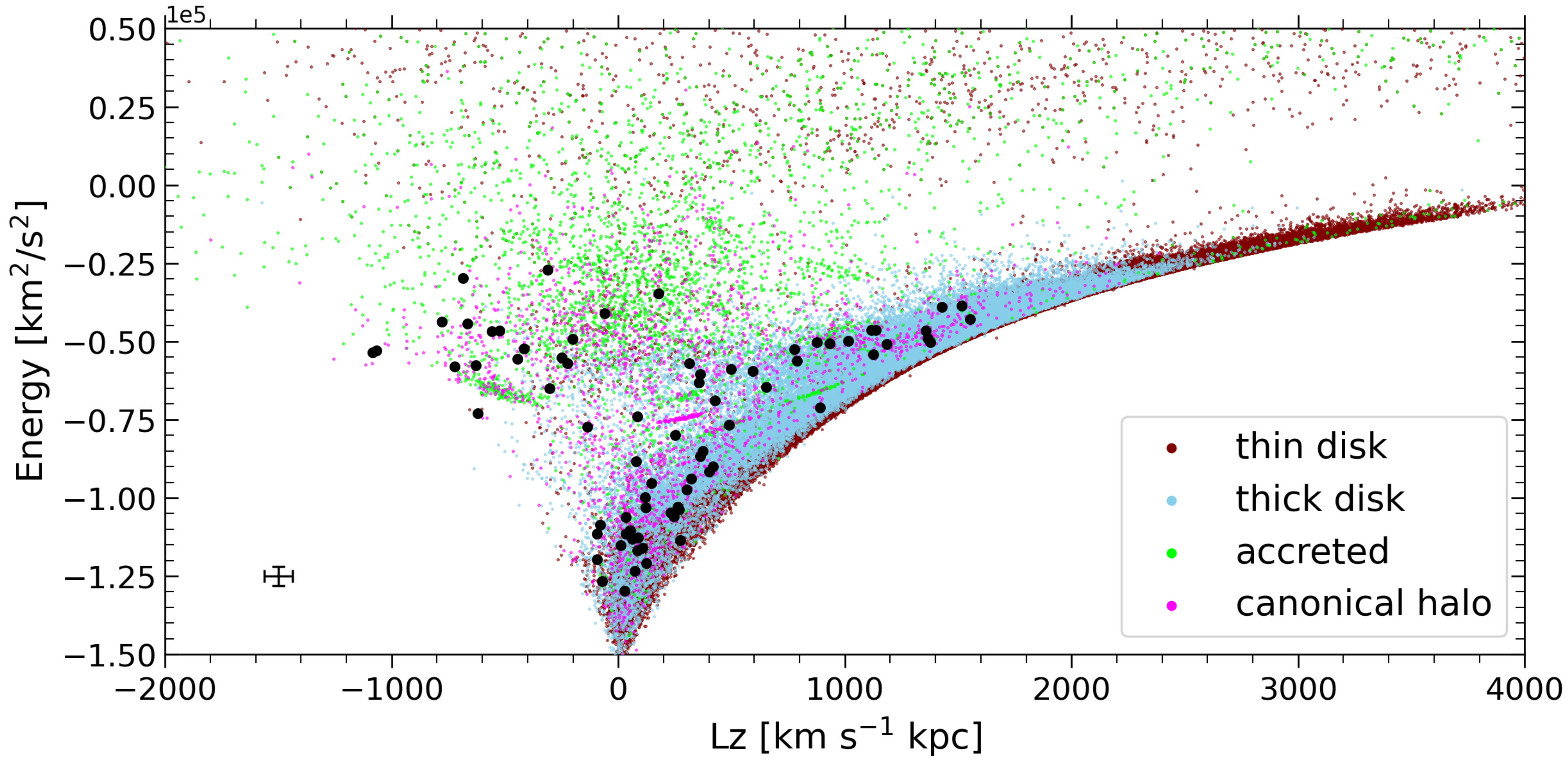
(Masseron+20ab)

~~r-process~~

~~“classical” s-process~~





1e5
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
−1.50
Energy [km^2/s^2]
−2000
−1000
0
1000
2000
3000
4000
Lz [km s^{-1} kpc]
thin disk
thick disk
accreted
canonical halo

What produces the strange pattern?

(Brauner+23)

Accreted population

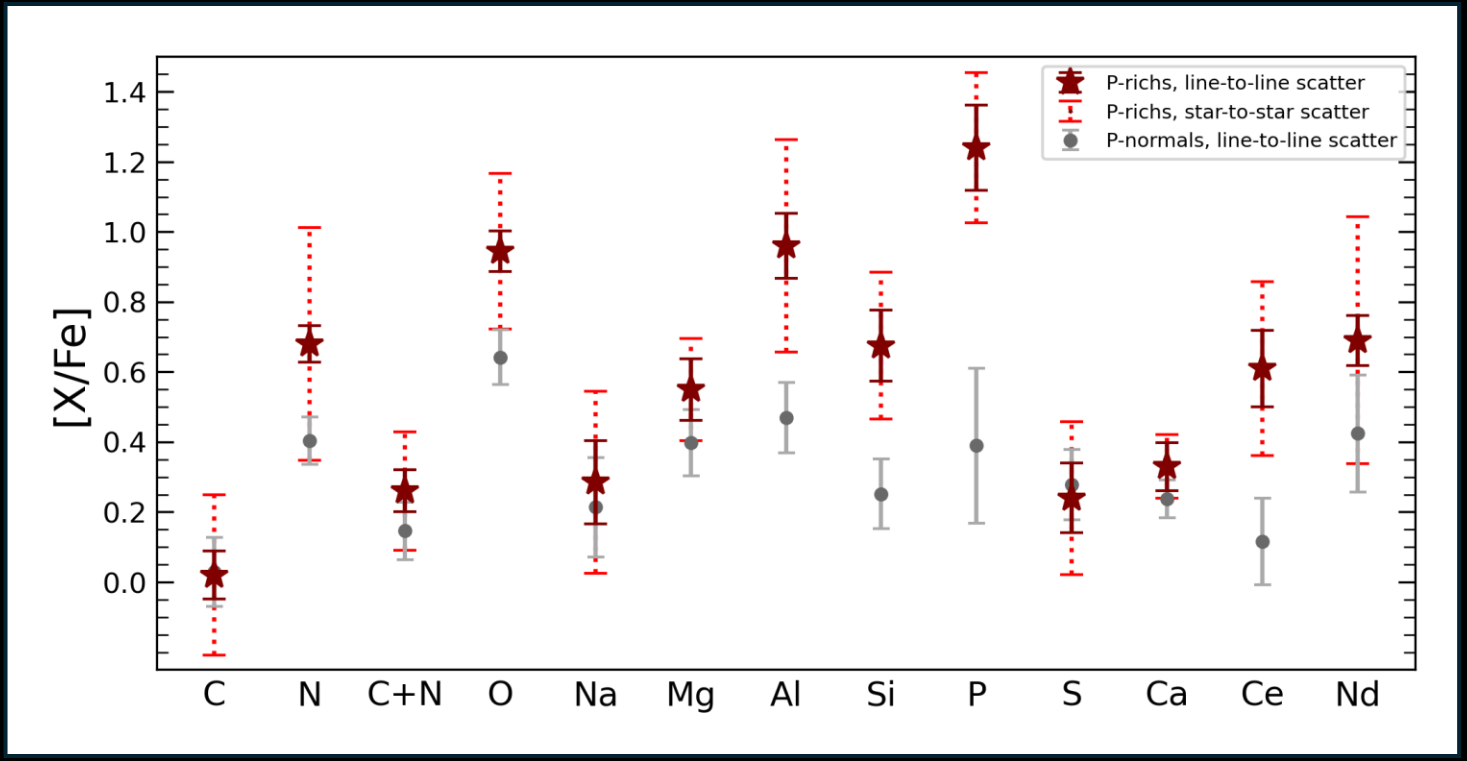
Sub-Chandrasekhar SNeIa

Pair-instability SNe

Discrepancy GCE/nucleosynthetic models persists *(Brauner+23,24)*

(Masseron+20ab) r-process

“classical” s-process



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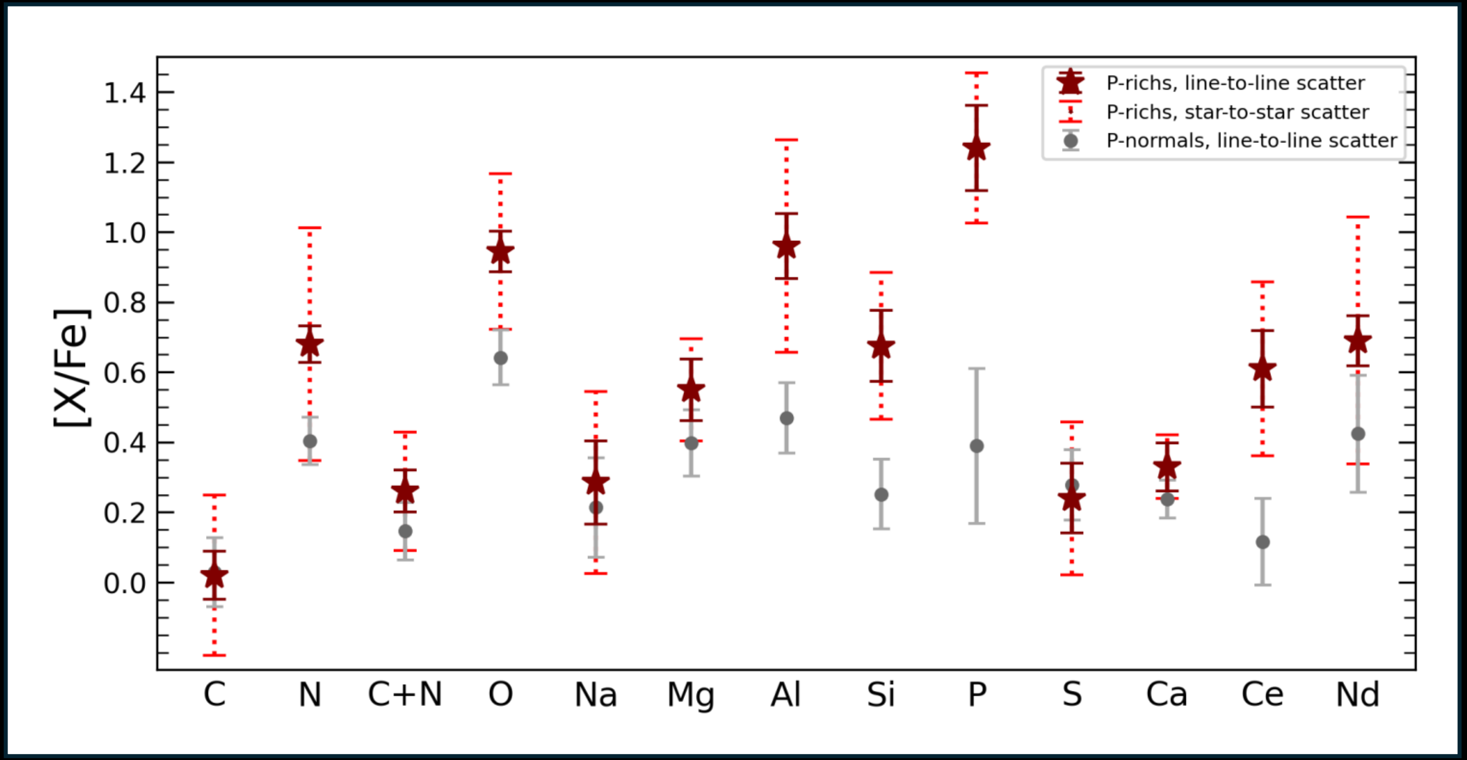
Binary interaction? *(Brauner+23,24)*

i-process?

Novae? *(Bekki & Tsujimoto 24)*



What’s next?

Search for more P-rich stars in APOGEE-2 DR17 (≈ 650,000 targets) applying **<u>unsupervised learning/clustering</u>** on spectra

Image AI generated (https://pixlr.com/es/image-generator/)

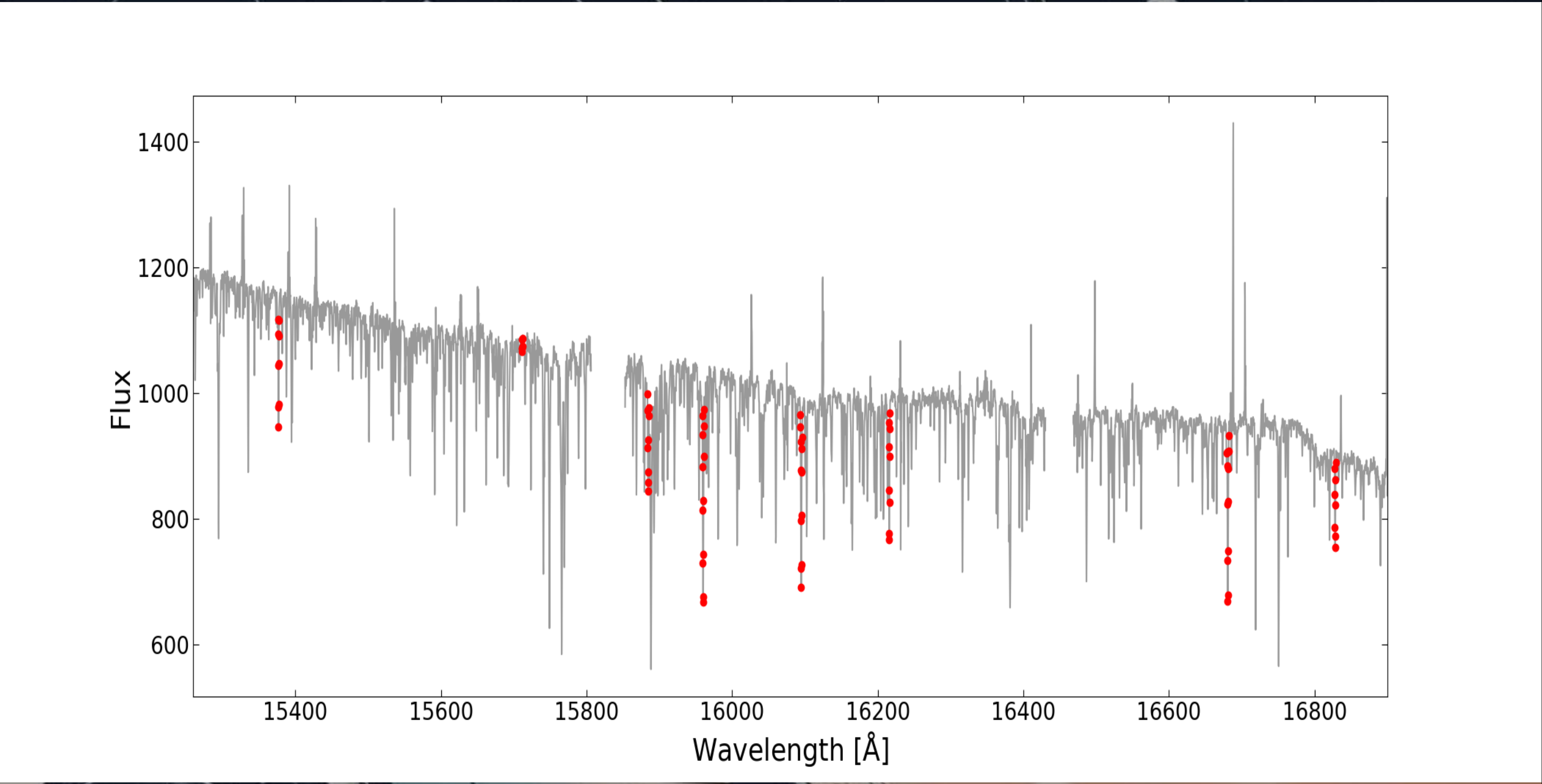
Cut features of interest

→

N-dimensional pixel (flux) vector

→

t-SNE reduces dimension....



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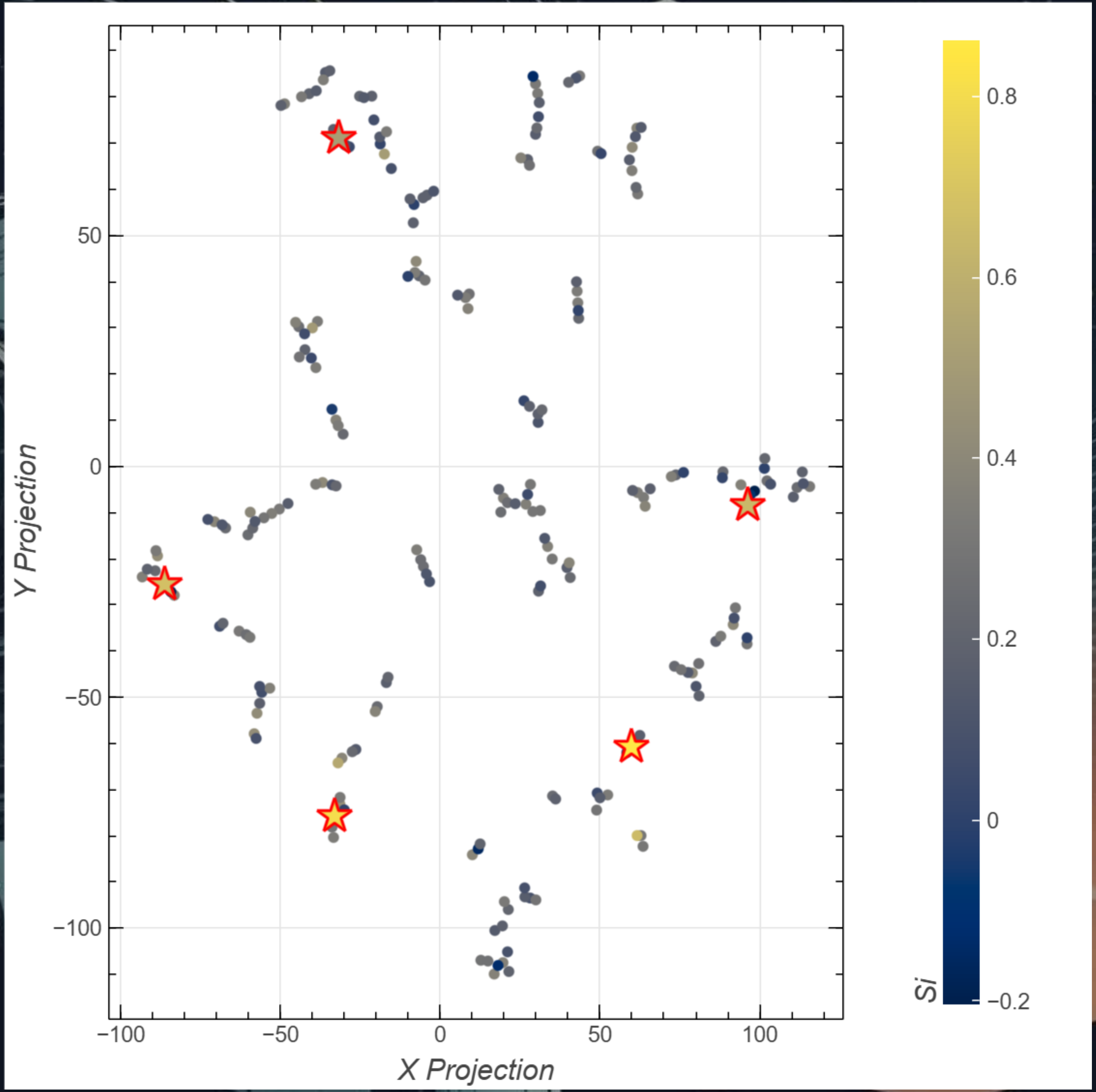
Search for more P-rich stars in APOGEE-2 DR17 (≈ 650,000 targets) applying **unsupervised learning/clustering** on spectra

Mainly using **t-SNE** (=t-distributed stochastic neighbor embedding)

...and uncovers similarities

Work in collaboration with R. Santoveña (Universidade da Coruña)



Summary

No nucleosynthetic model satisfactorily produces the abundance pattern of P-rich stars

We look for a source that produces (a lot of) **P**, O, Mg, Si, Al, Ce, and (a lot of) **Ba**

Binary interaction, i-process contribution, spallation processes, and the role of novae need further investigation