High-precision abundance analysis of a unique CEMP-no star in Sculptor

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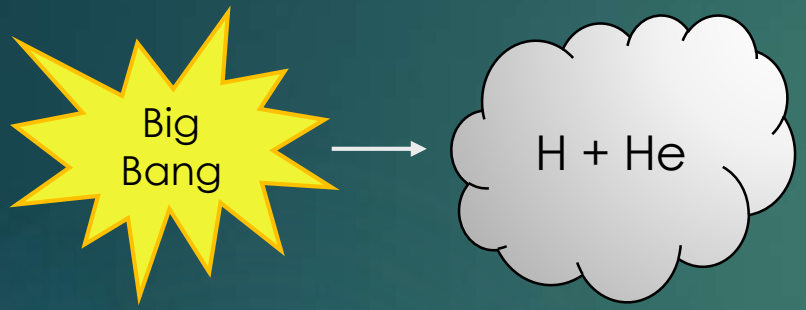
1st year PhD student

Supervisor: Ása Skúladóttir
Co-supervisor: Romain Lucchesi

First Stars



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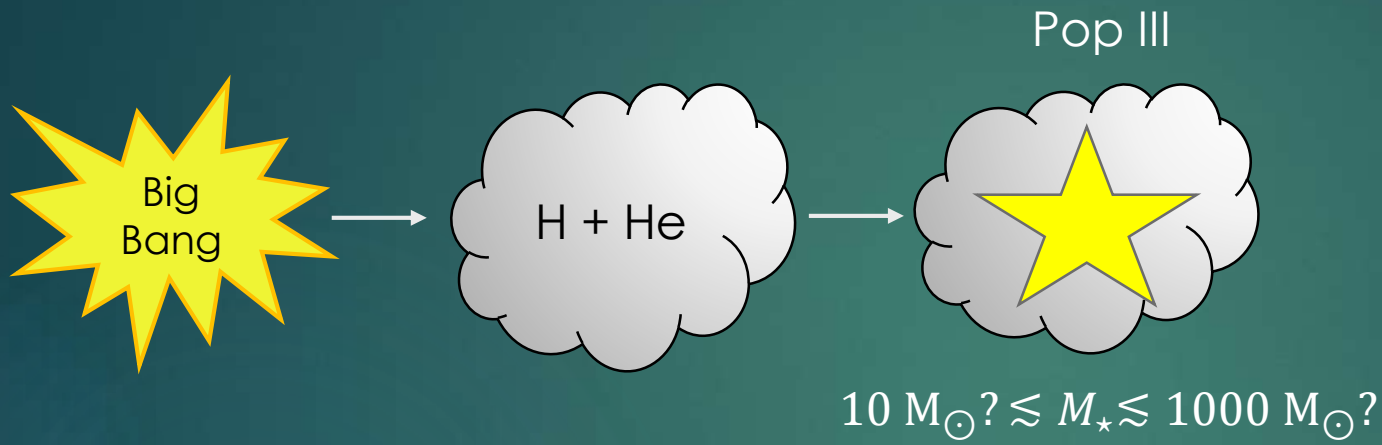

- Absence of metals ⟶ Population III (Pop III)
- Huge masses ⟶ brief lifetimes ($t_{lt} \sim$ Myr)
- Stellar nucleosynthesis + SNe ⟶ interstellar medium enrichment

[e.g., Hirano et al., 2014, Frebel and Norris, 2015, Rossi et al., 2021]

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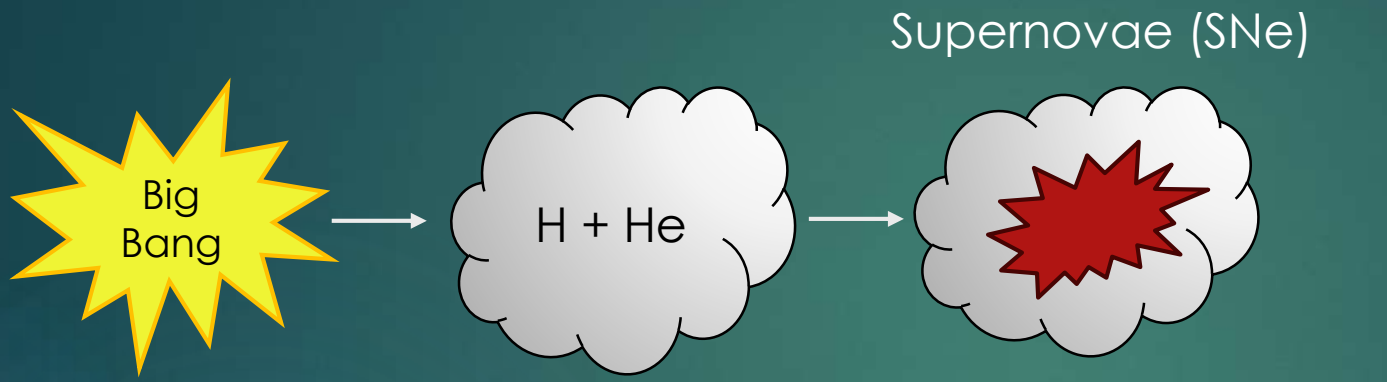

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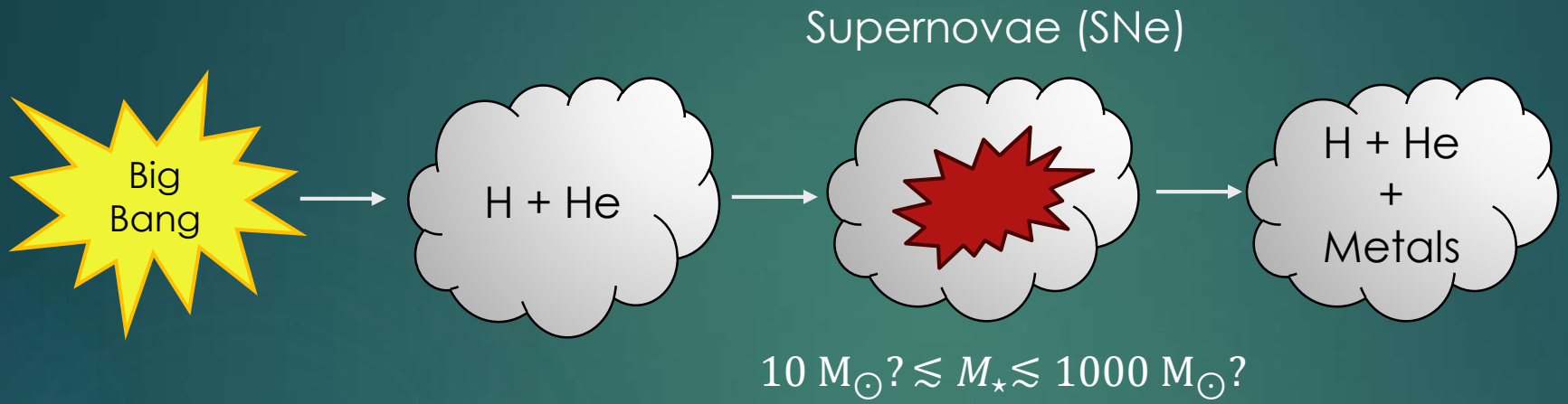

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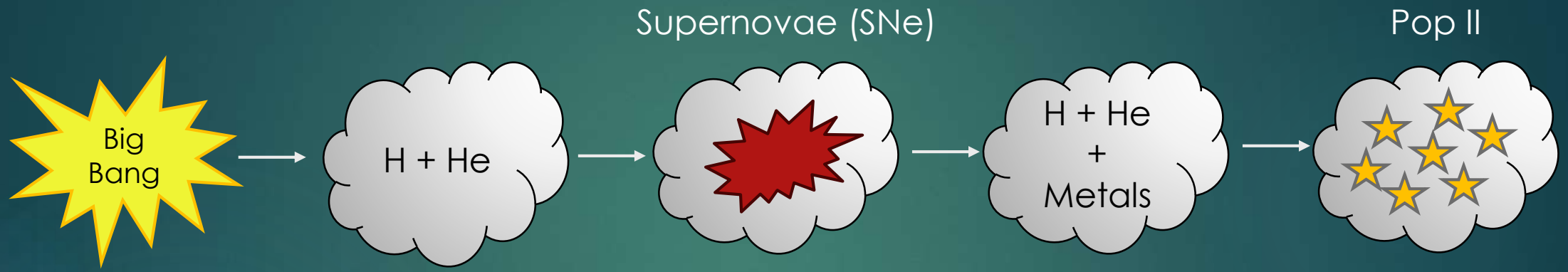

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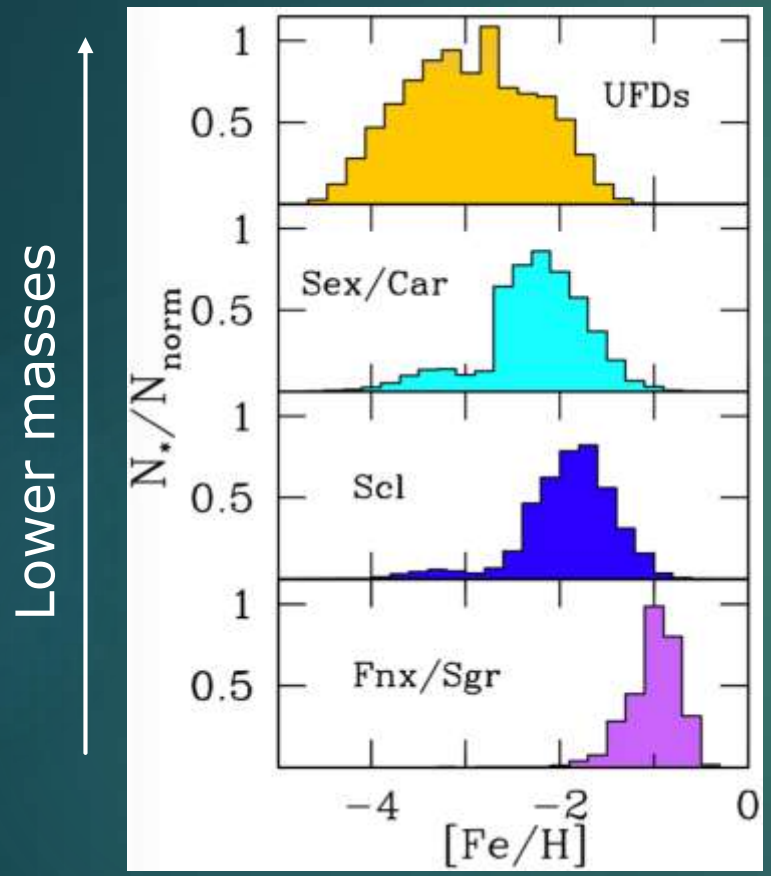
Stellar archaeology



[Based on Salvadori et al., 2015]

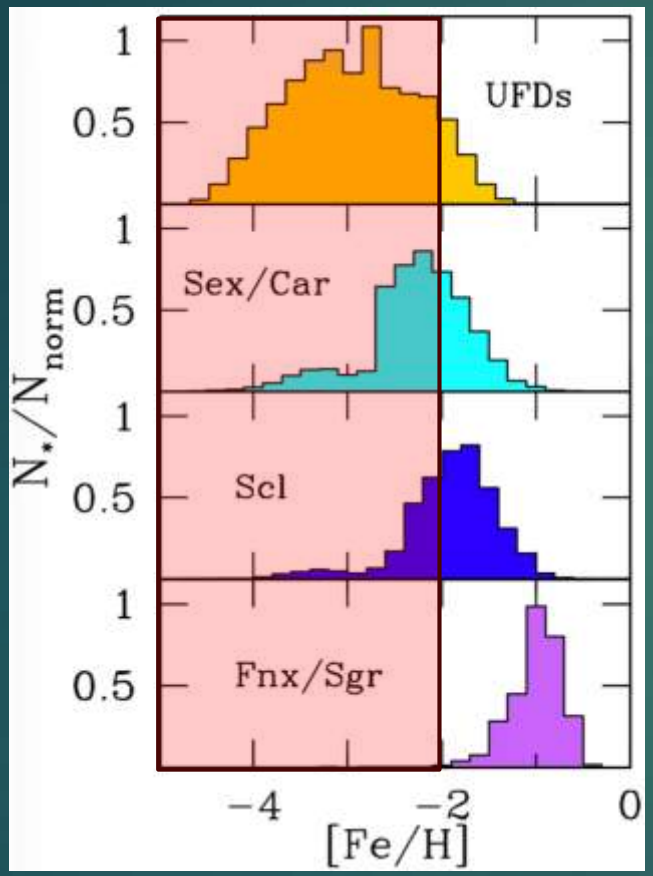
- Milky Way (MW) stellar Halo
- Dwarf galaxies satellites of the MW
  - Dwarf Spheroidal galaxies (dSphs)
  - Ultra Faint Dwarf galaxies (UFDs)

$$[\mathrm{X/Y}] \equiv \log\left(\frac{N(\mathrm{X})}{N(\mathrm{Y})}\right) - \log\left(\frac{N(\mathrm{X})}{N(\mathrm{Y})}\right)_{\odot}$$

Stellar archaeology

Metal-poor: < 1% solar

Lower masses



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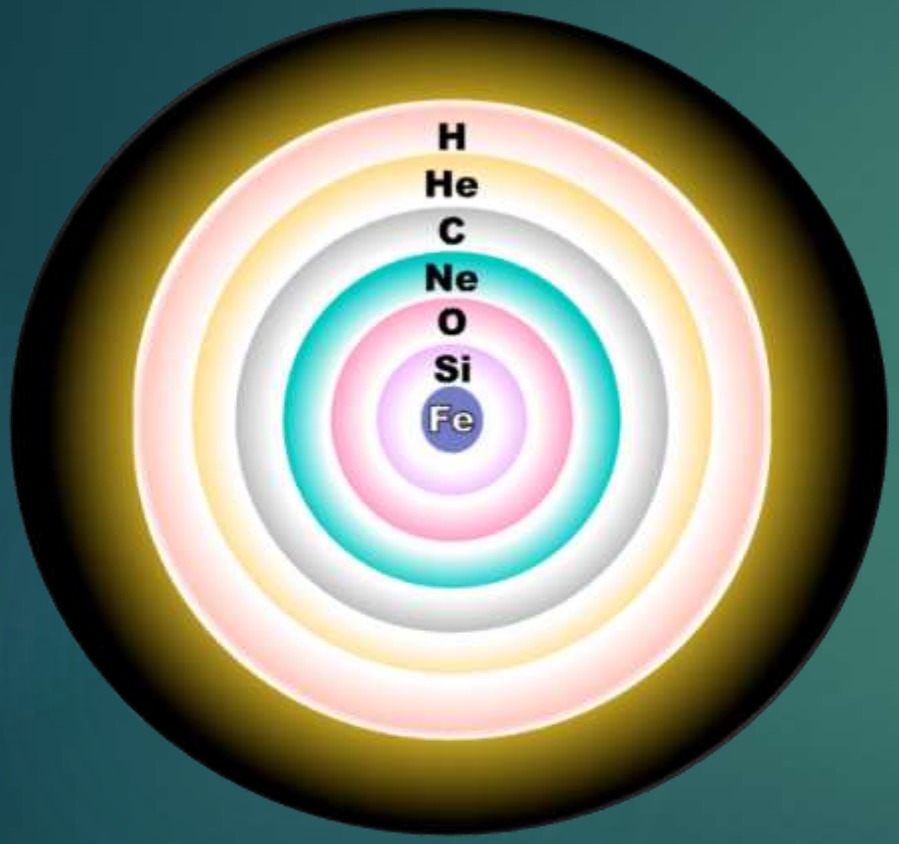
Carbon Enhanced Metal-Poor stars



[Credits: R. J. Hall]

- $[\mathrm{Fe/H}] < -2$
- $[\mathrm{C/Fe}] > +0.7$
- No n-capture enrichment ⟶ CEMP-no
- Descendants of Pop III exploded as faint SNe ($\varepsilon_{SN} \lesssim 10^{51}\mathrm{erg}$)
- Light elements enrichment ⟶ high $[\mathrm{C/Fe}]$

[e.g., Beers et al., 2005, Vanni et al., 2023]

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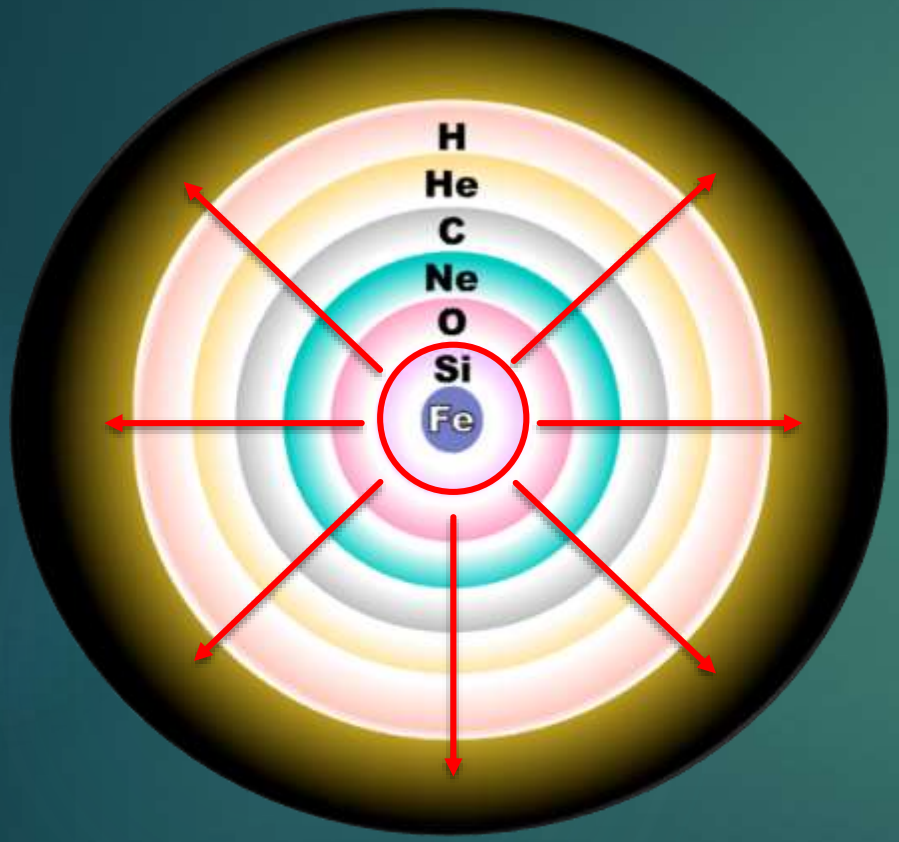

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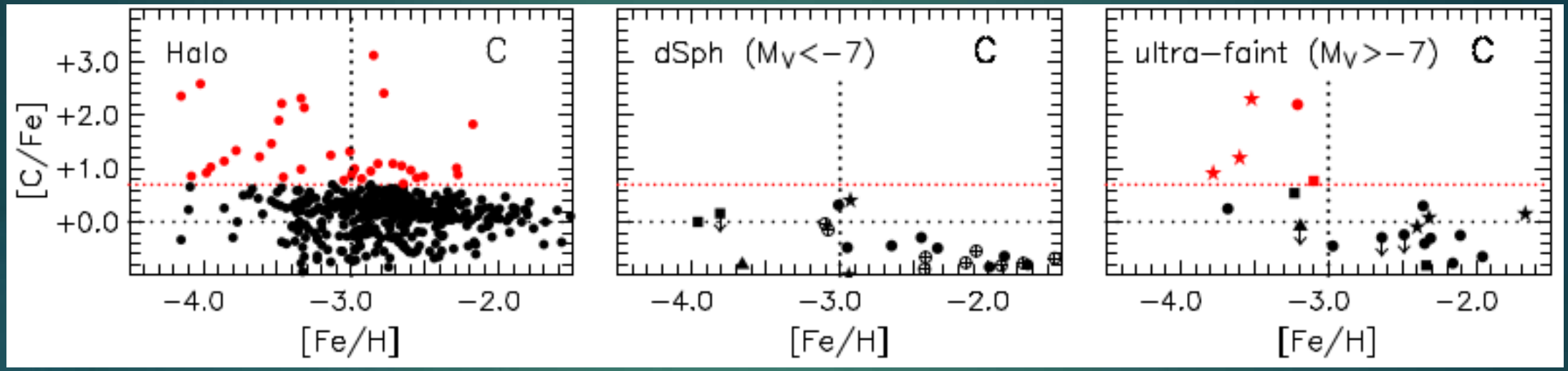
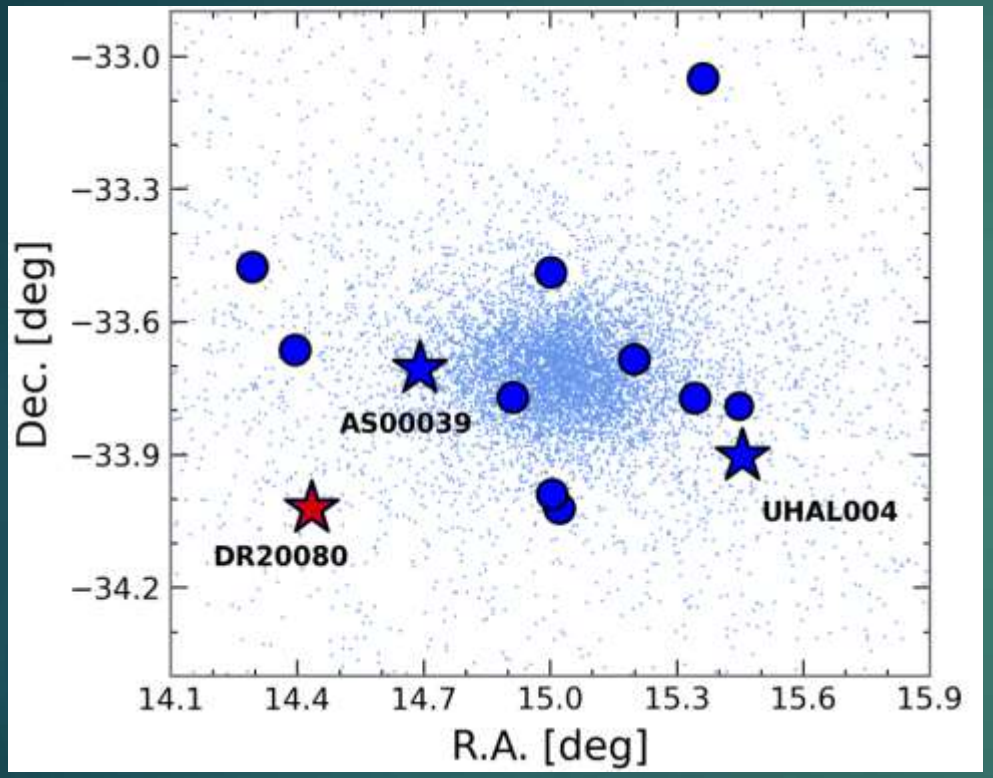
CEMP-no stars



[Frebel and Norris, 2015]

- Non-uniform distribution
  - Difference in star formation conditions
- Do the characteristics of Pop III stars depend on the formation environment?

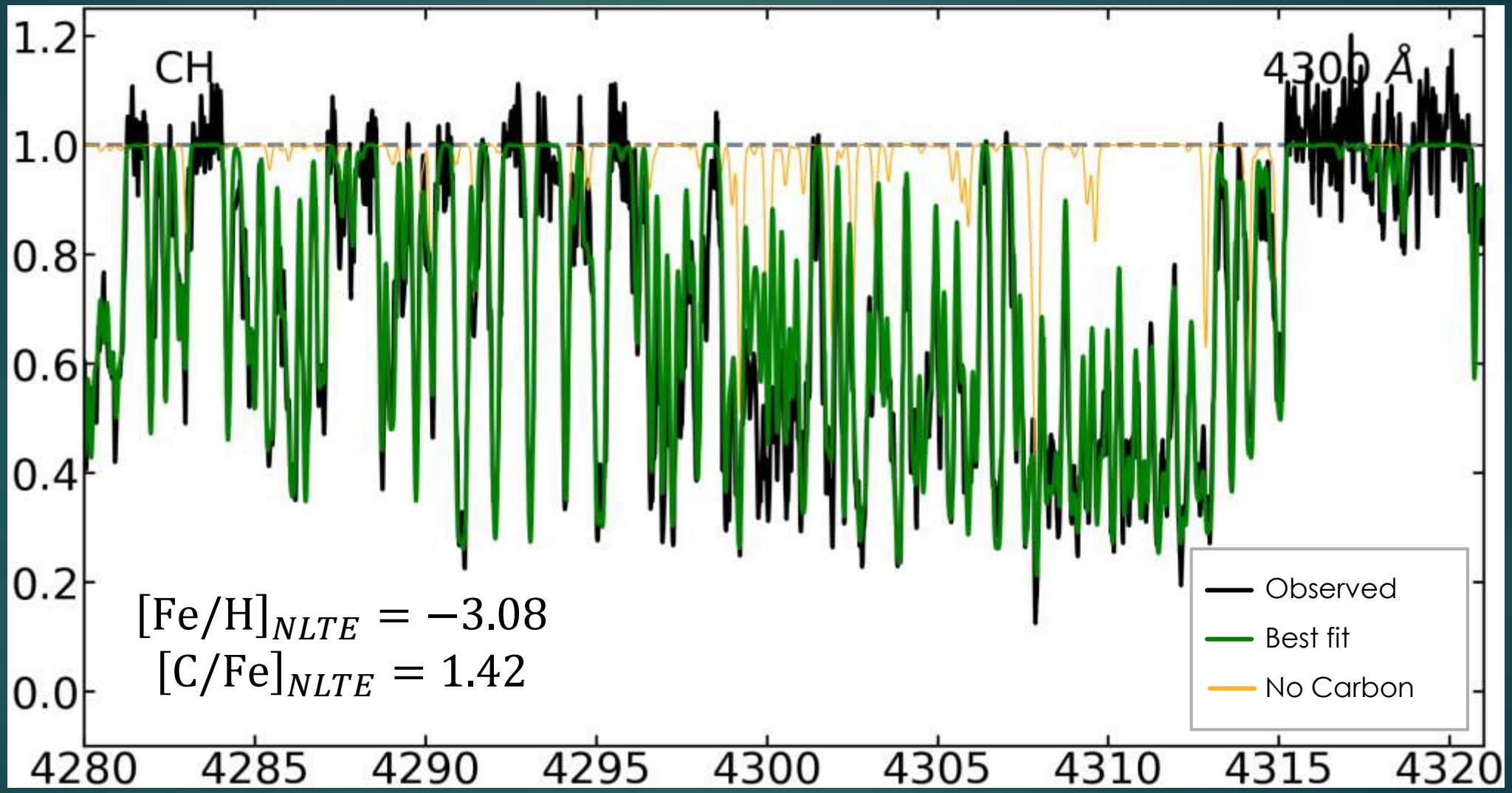
DR20080



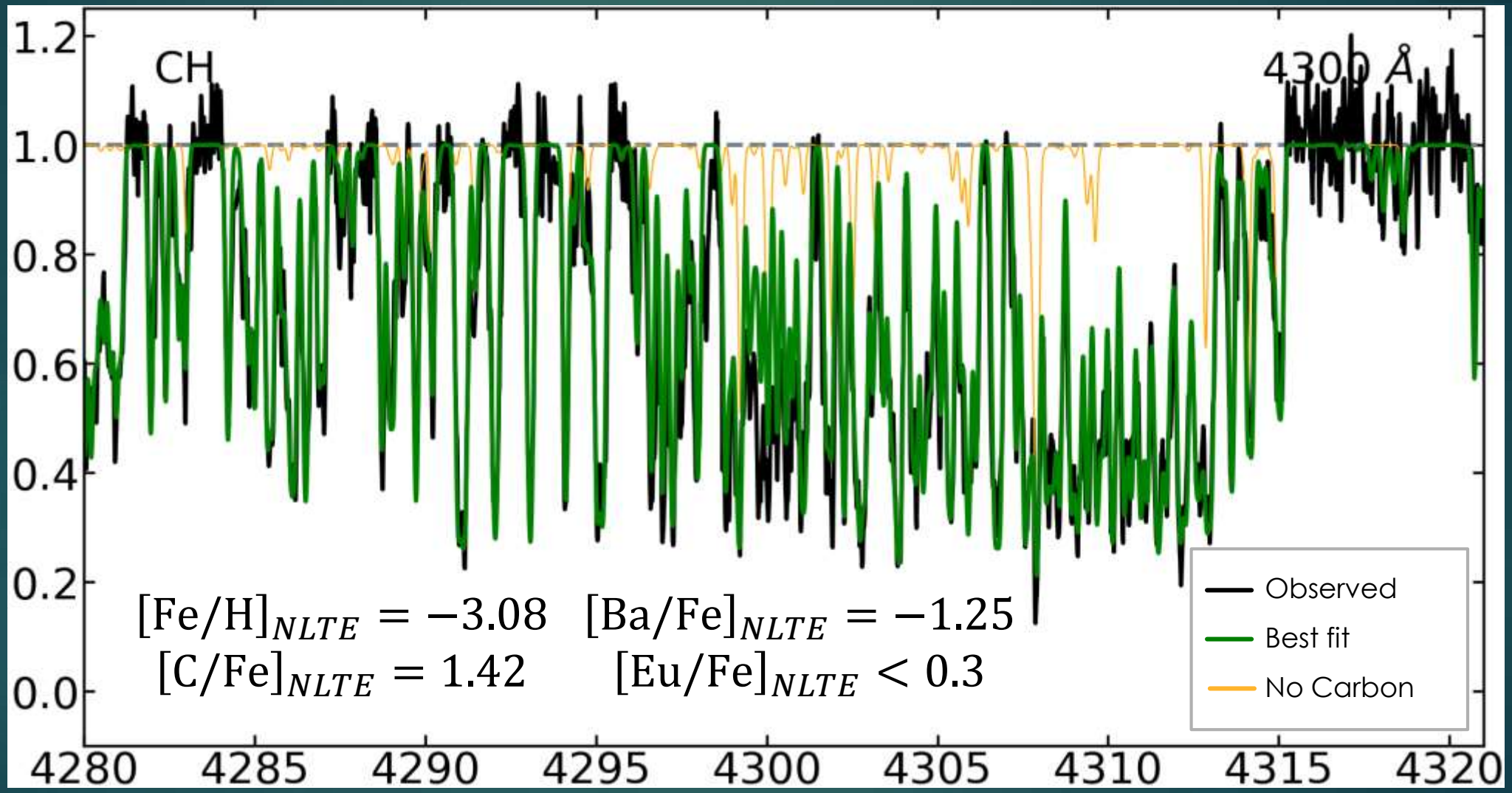
[Skúladóttir et al., 2024]

- Sculptor dSph – New CEMP-no star!
- Recently discovered [Skúladóttir et al., 2024]: medium-resolution ($R = {}^{\lambda}/_{\Delta\lambda}$) and low S/N
- VLT/UVES high-resolution follow-up
- 8 h observations in 3 spectral bands (optical

Carbon band


CH
4300 Å
Normalised Flux
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4280
4285
4290
4295
4300
4305
4310
4315
4320
λ [Å]
$[\mathrm{Fe/H}]_{NLTE} = -3.08$
$[\mathrm{C/Fe}]_{NLTE} = 1.42$
Observed
Best fit
No Carbon

Carbon band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$[Eu/Fe]_{NLTE} < 0.3$
Observed
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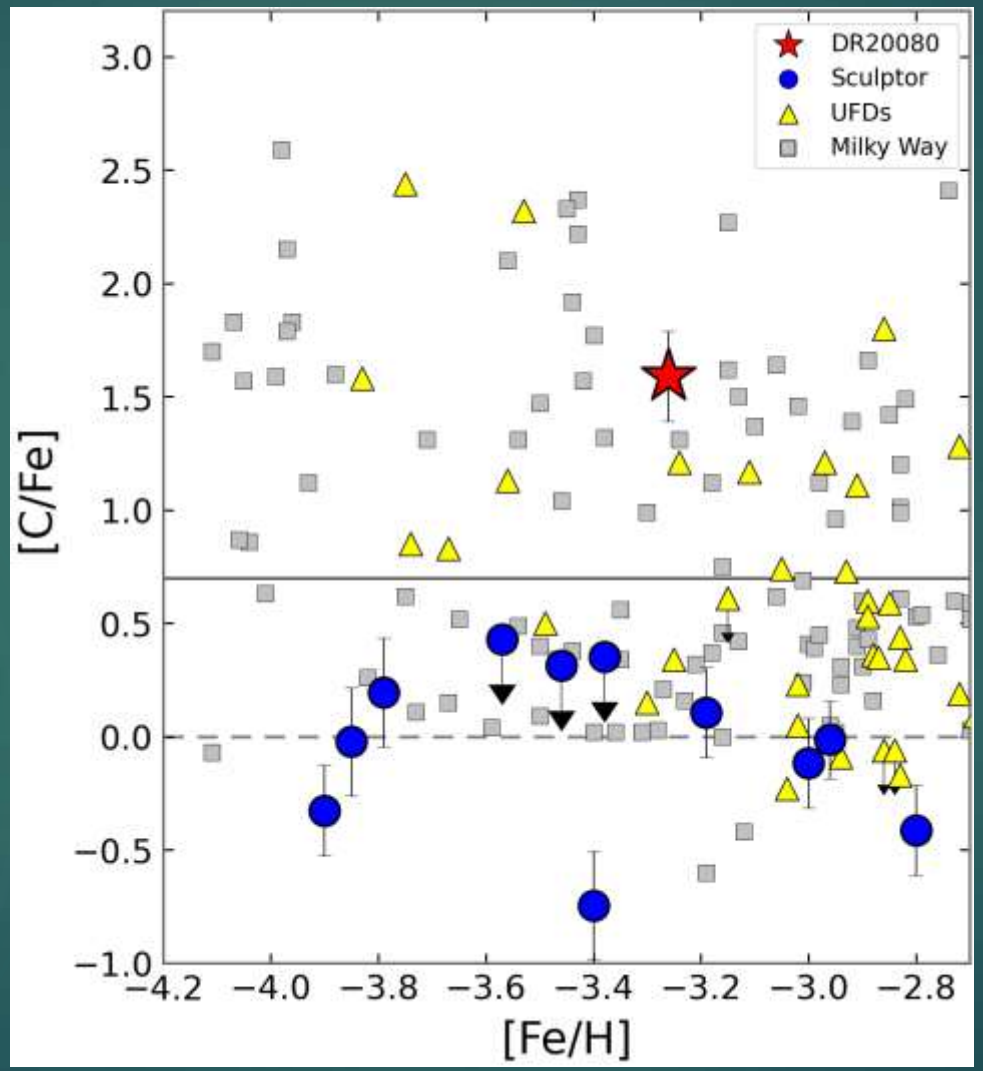
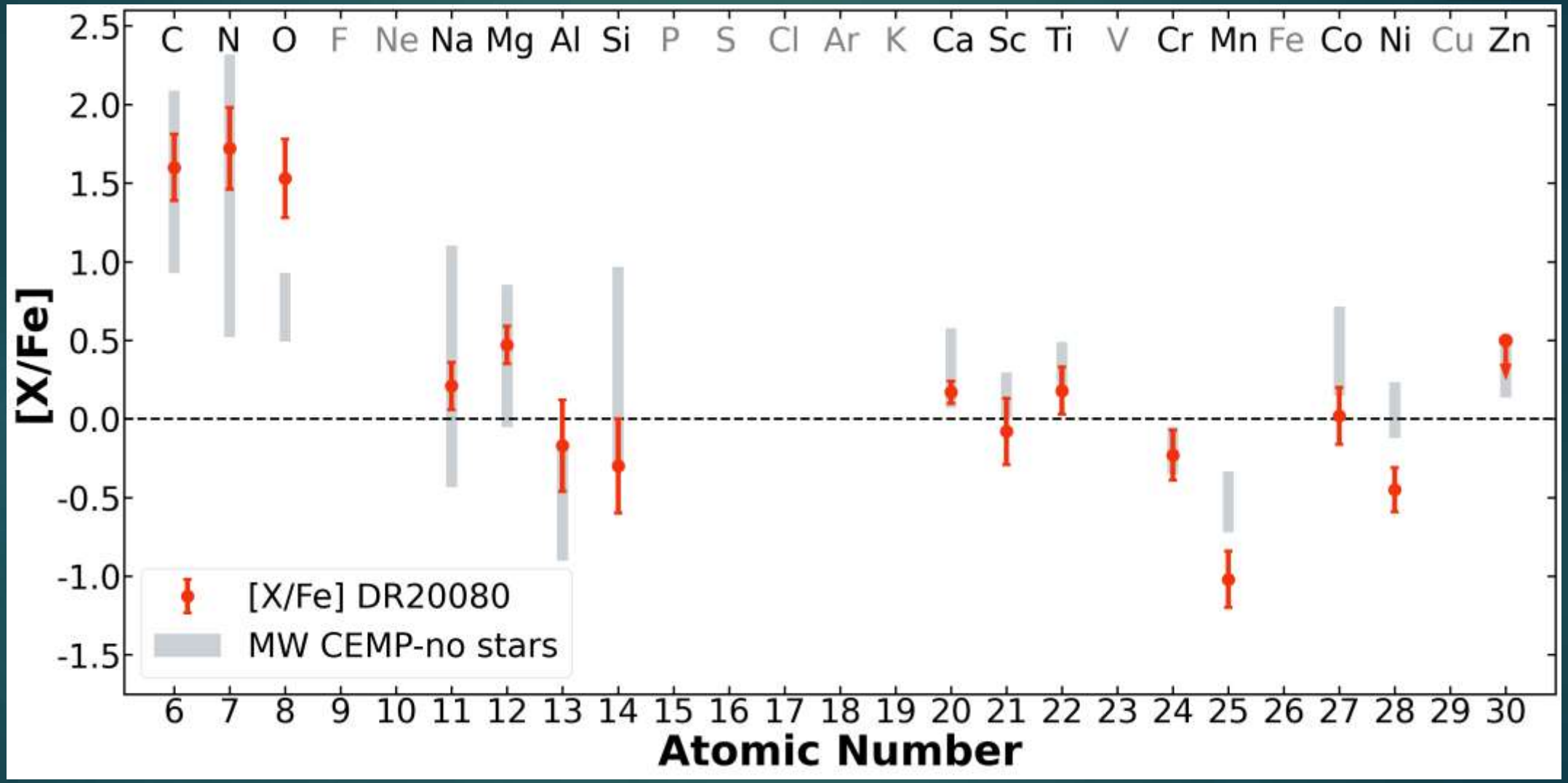
Abundances derivation



[Adapted from Skúladóttir et al., 2024]

Comparison with MW CEMP-no stars



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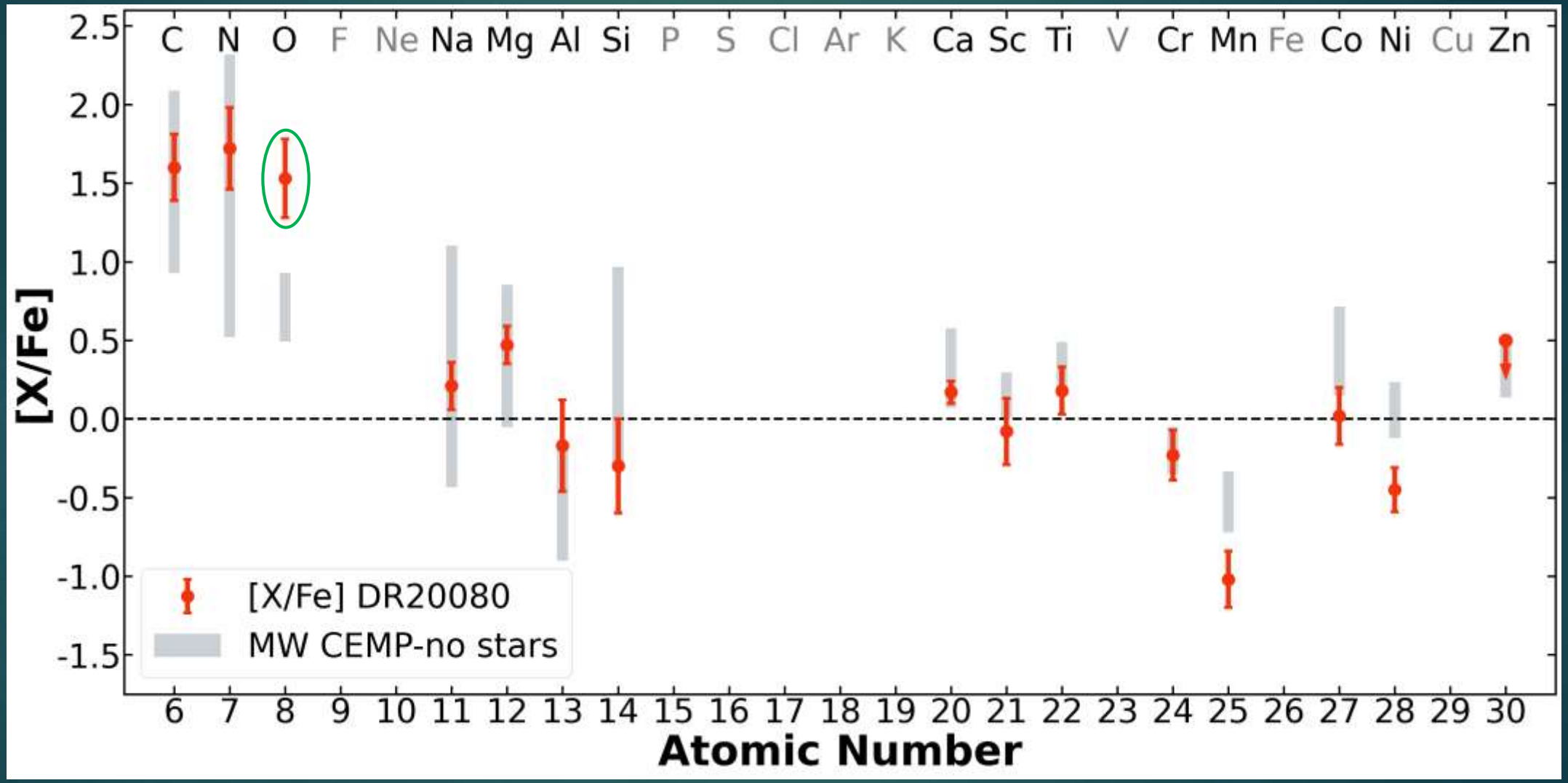

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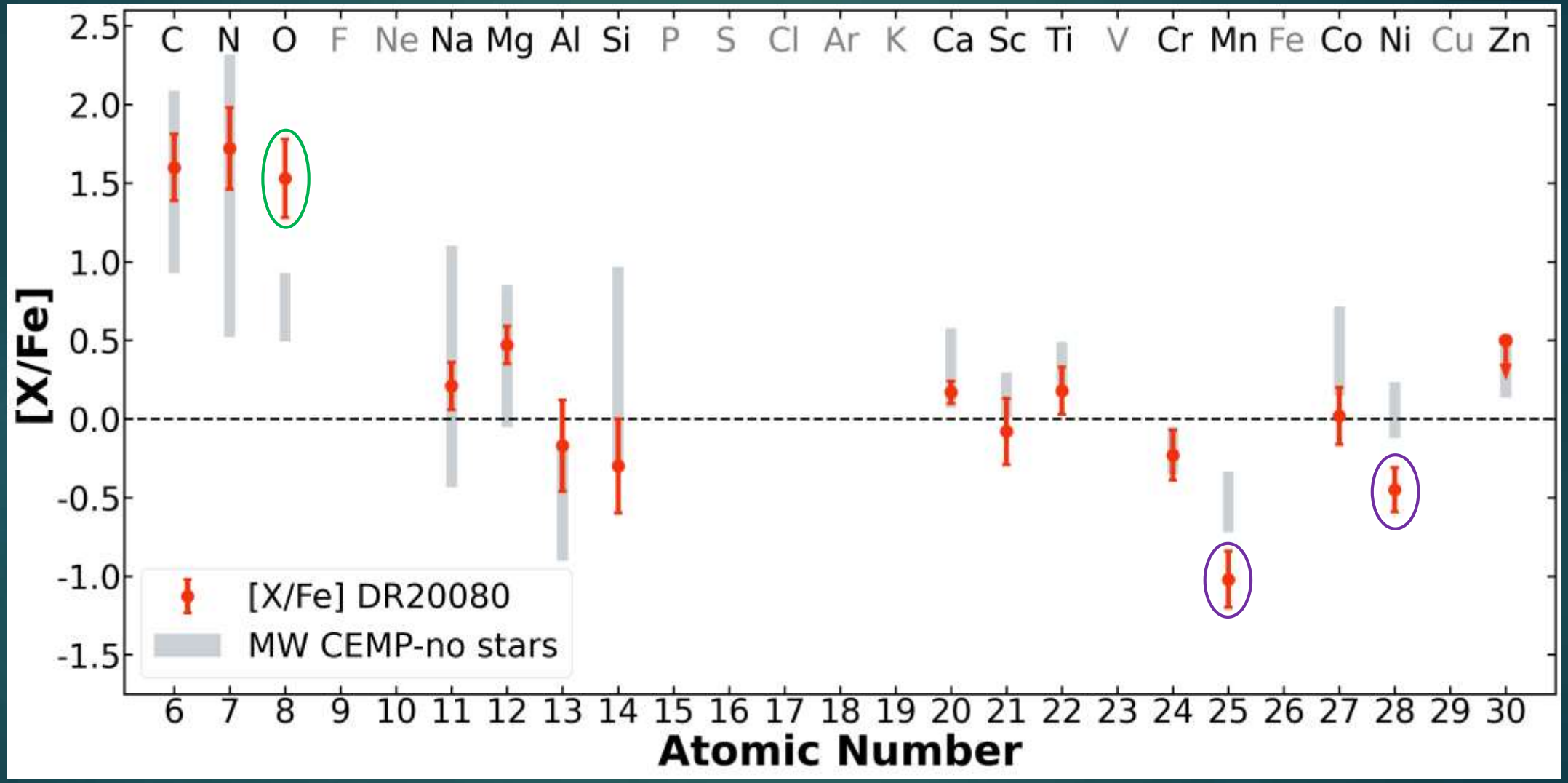
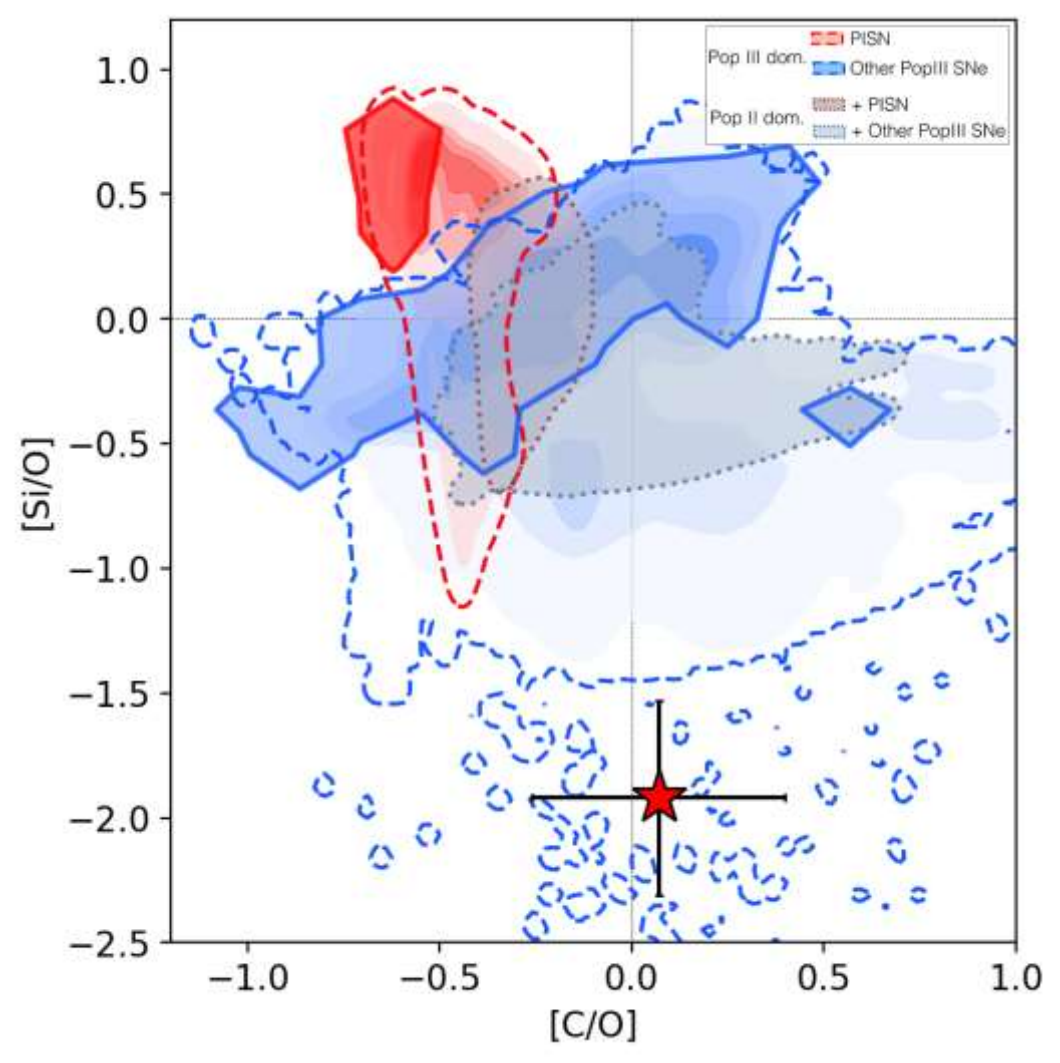


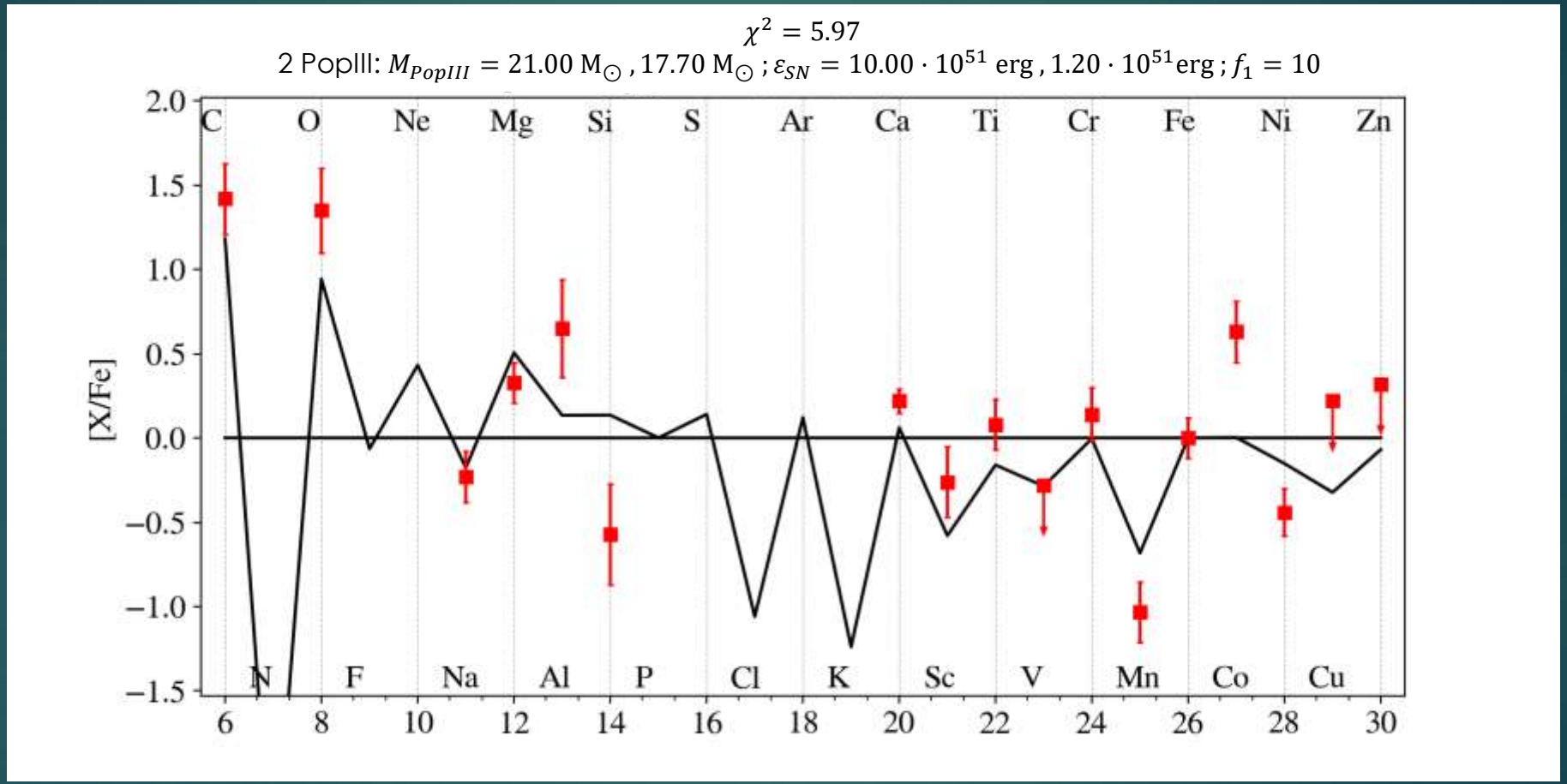
Multiple enrichment models



[Adapted from Vanni et al., 2024]

- $[\mathrm{Si/O}]_{NLTE} = -1.92 \pm 0.39$
- $[\mathrm{C/O}]_{NLTE} = 0.07 \pm 0.33$
- Region sparsely populated by SN yield models
- Only Pop III dominated models are consistent

Pop III progenitor(s) properties



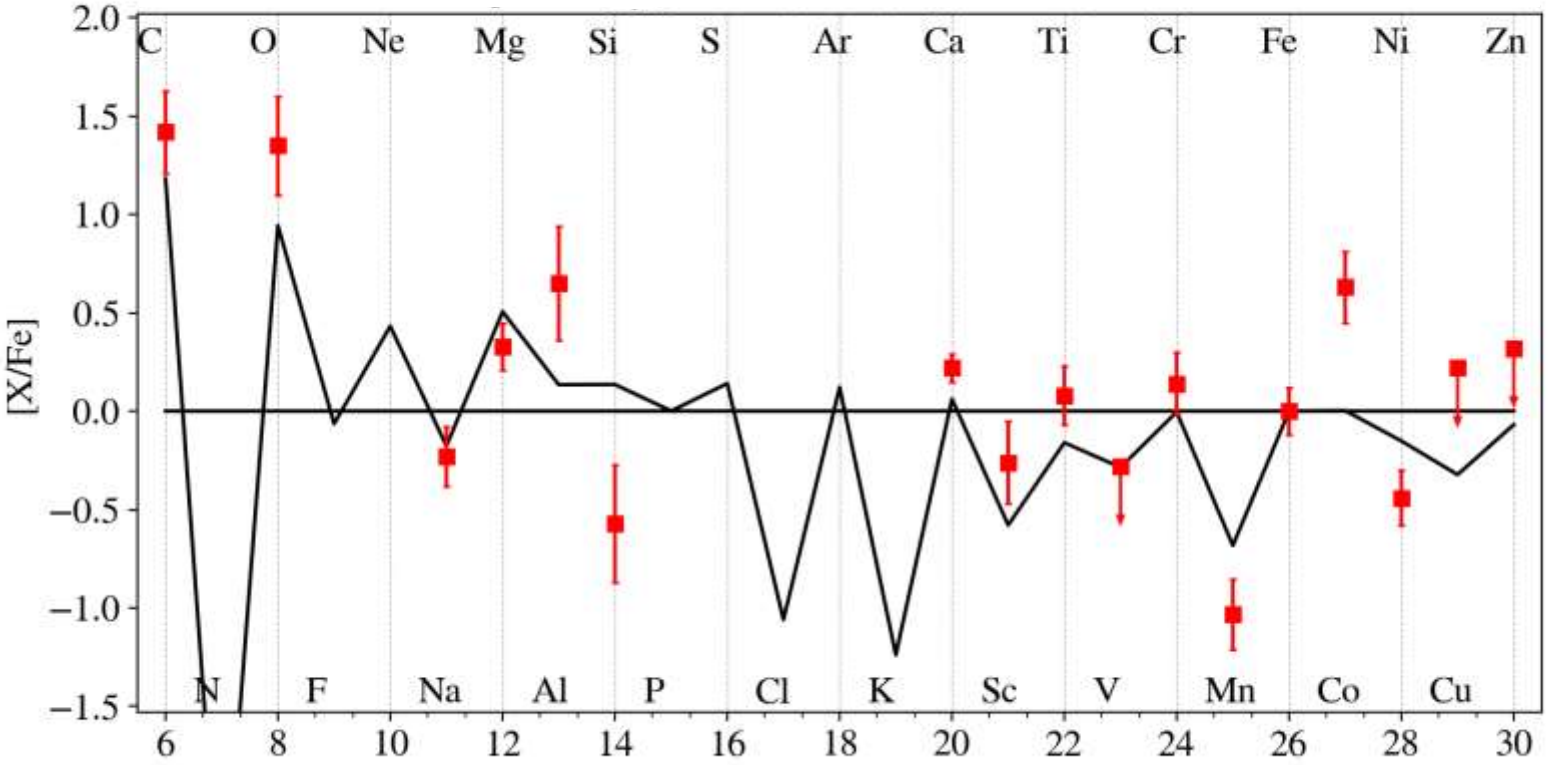
[Following the approach of Vanni et al., 2024]

Pop III progenitor(s) properties

NOT A GOOD FIT!

$\chi^2 = 5.97$

2 PopIII: $M_{PopIII} = 21.00\ \mathrm{M}_\odot, 17.70\ \mathrm{M}_\odot$; $\varepsilon_{SN} = 10.00 \cdot 10^{51}\ \mathrm{erg}, 1.20 \cdot 10^{51}\ \mathrm{erg}$; $f_1 = 10$



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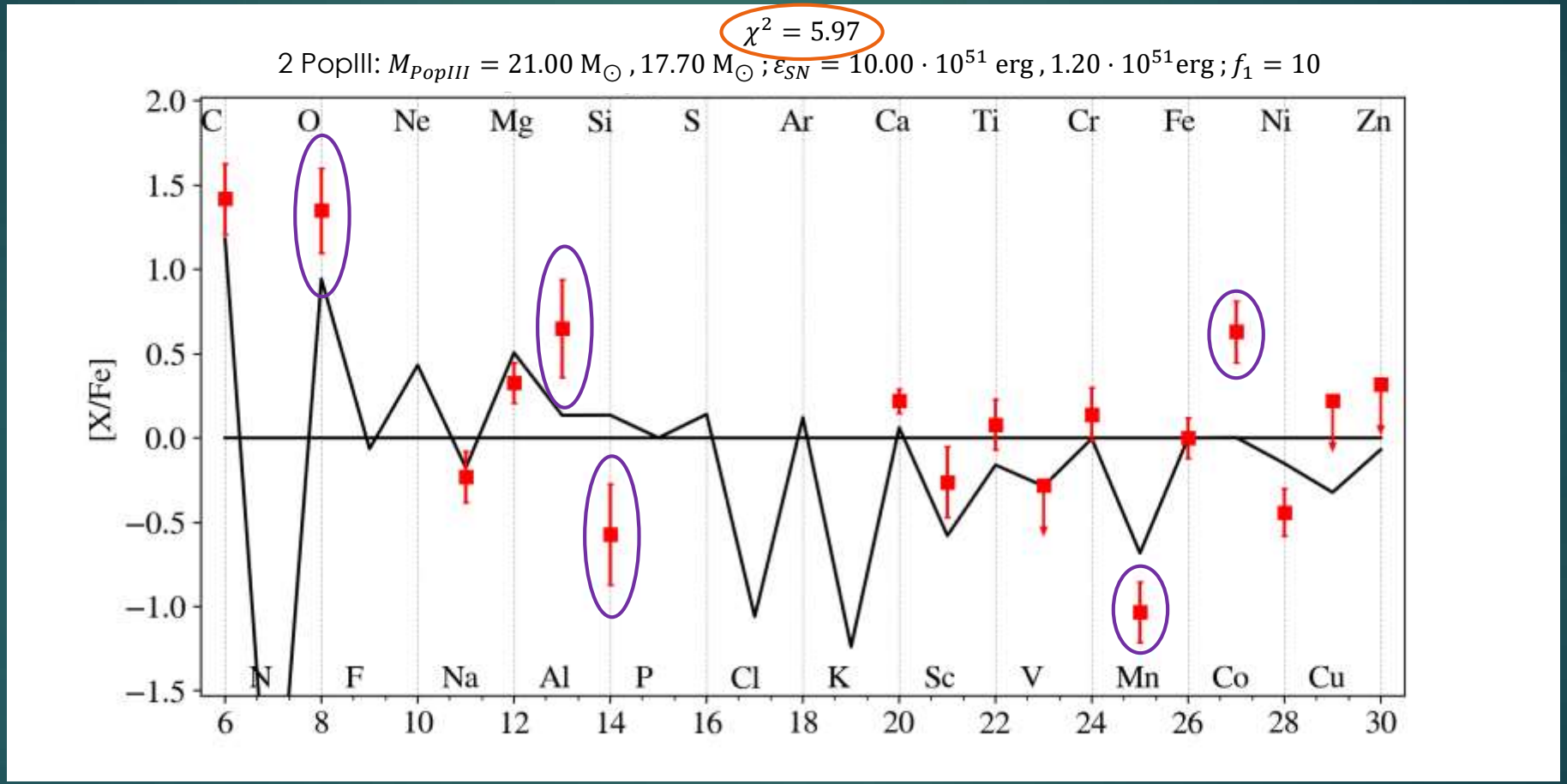

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Conclusions

- First high-precision analysis of DR20080!
  - Abundances measured for 17 elements + 4 upper limits
  - CEMP-no star: $[\mathrm{Fe/H}]_{NLTE} \simeq -3.08$; $[\mathrm{C/Fe}]_{NLTE} \simeq +1.42$; $[\mathrm{Ba/Fe}]_{NLTE} \simeq -1.25$; $[\mathrm{Eu/Fe}]_{NLTE} < +0.3$
- Unique abundance pattern
- SNe yield model fitting ⟶ multiple enrichment dominated by Pop III stars
- DR20080 is an excellent candidate to be a direct descendant of Pop III stars

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