

The ancient central population

IAU395, Paraty, Brazil

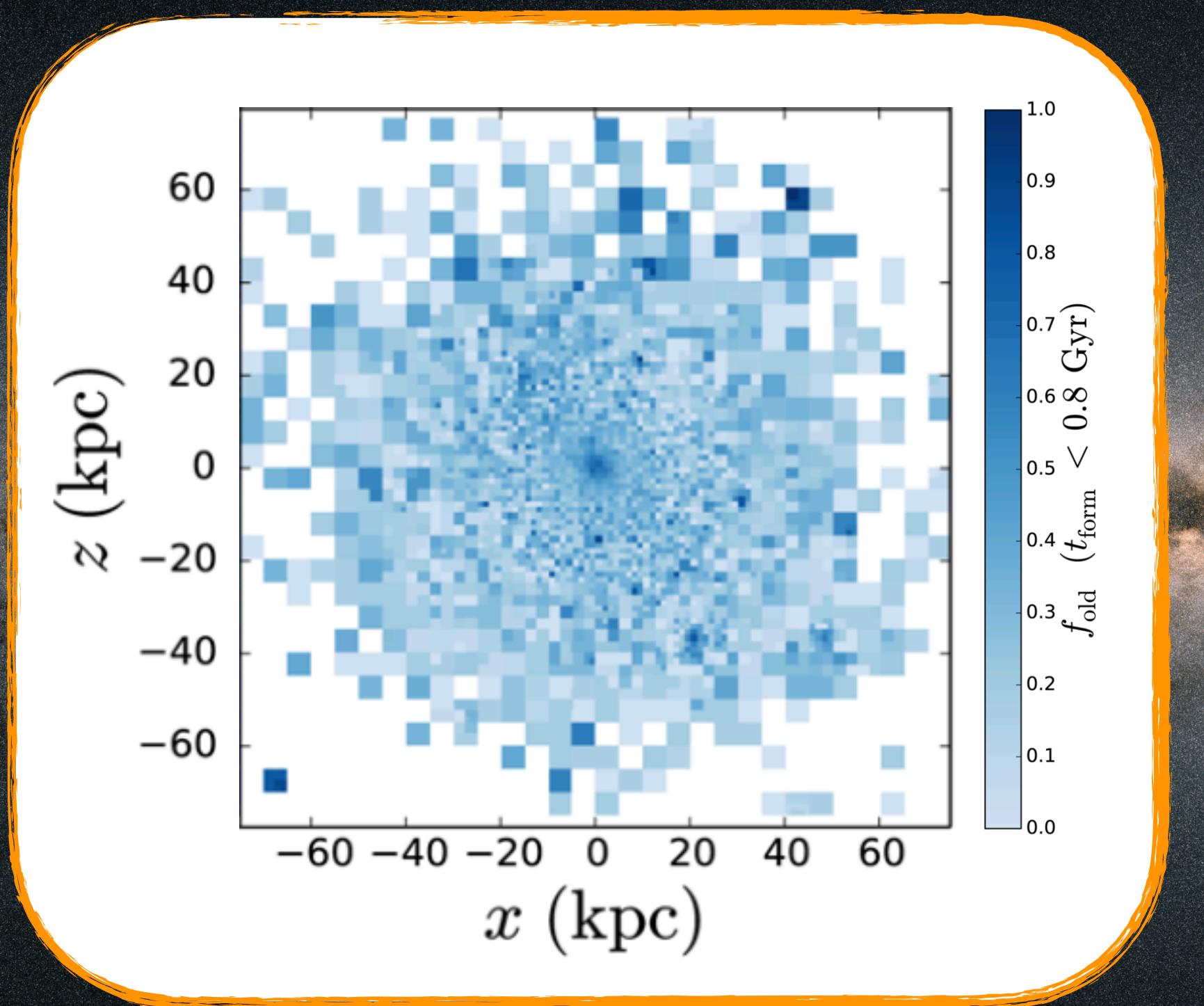
November 2024

Anke Ardern-Arentsen

Herchel Smith Postdoctoral Fellow — Institute of Astronomy, Cambridge



The oldest stars should be centrally concentrated



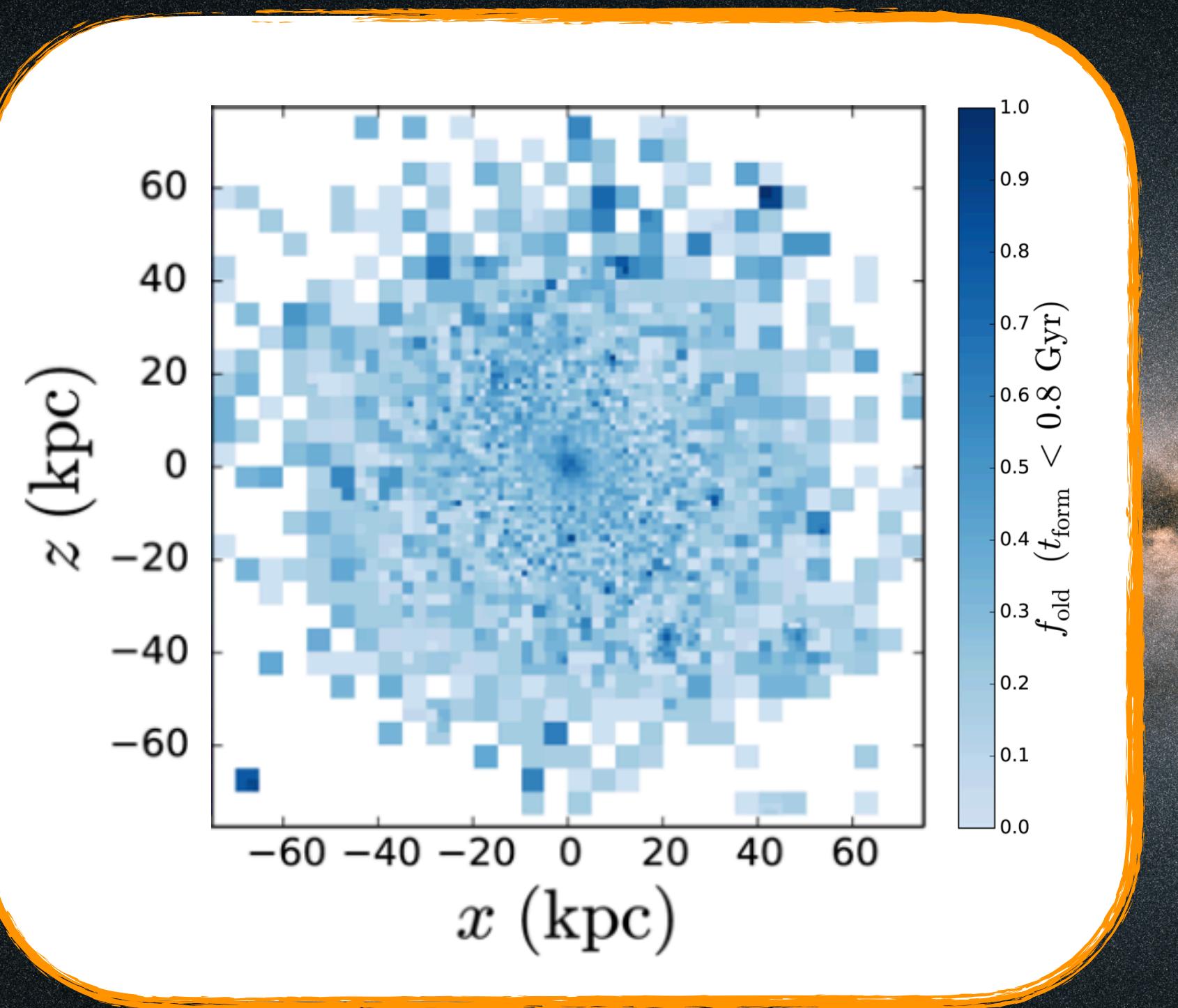
MW-like simulation coloured by fraction of VMP stars
born before $z \sim 7$ (Starkenburg+17b)

gaia

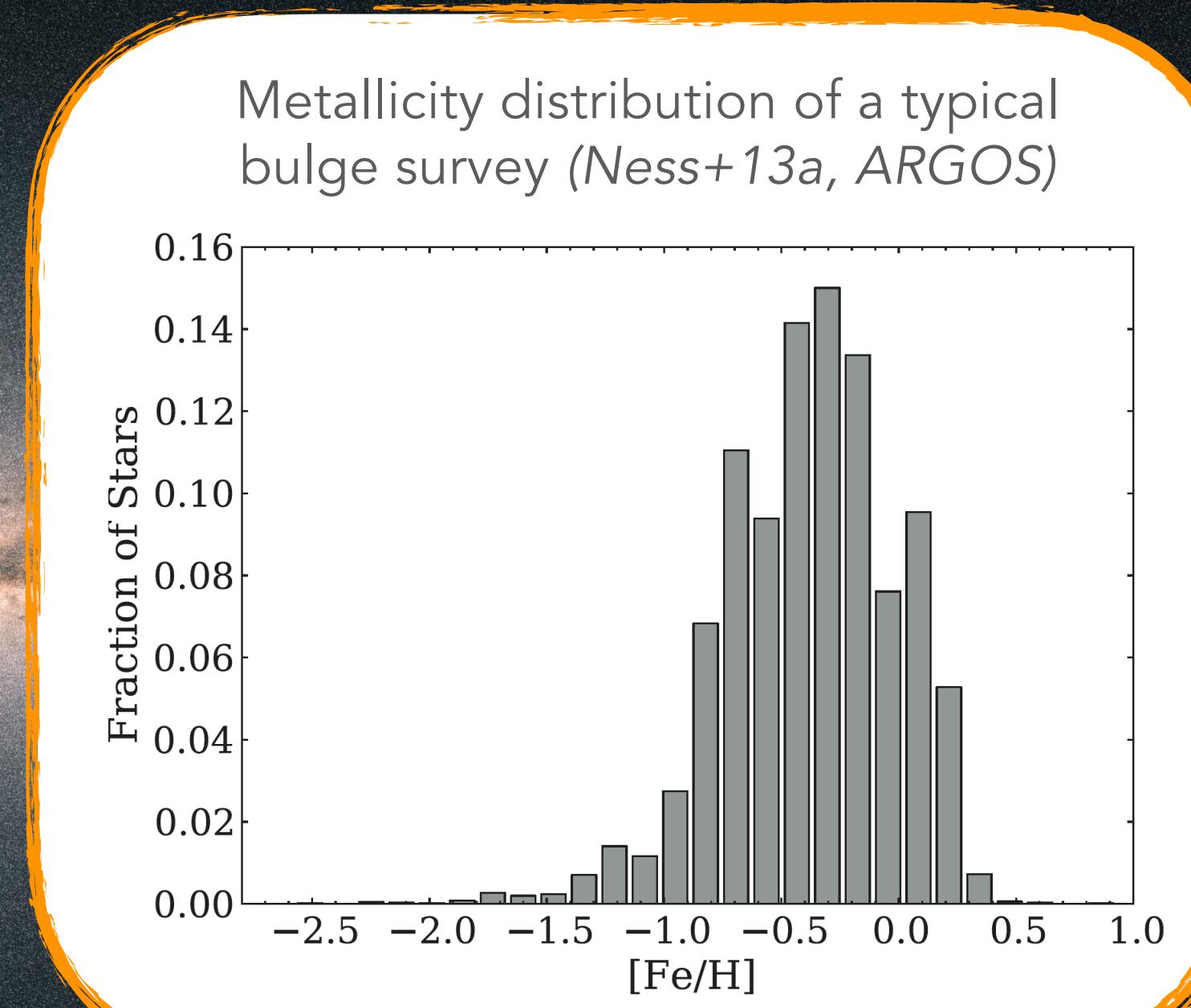


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But most central stars are relatively metal-rich



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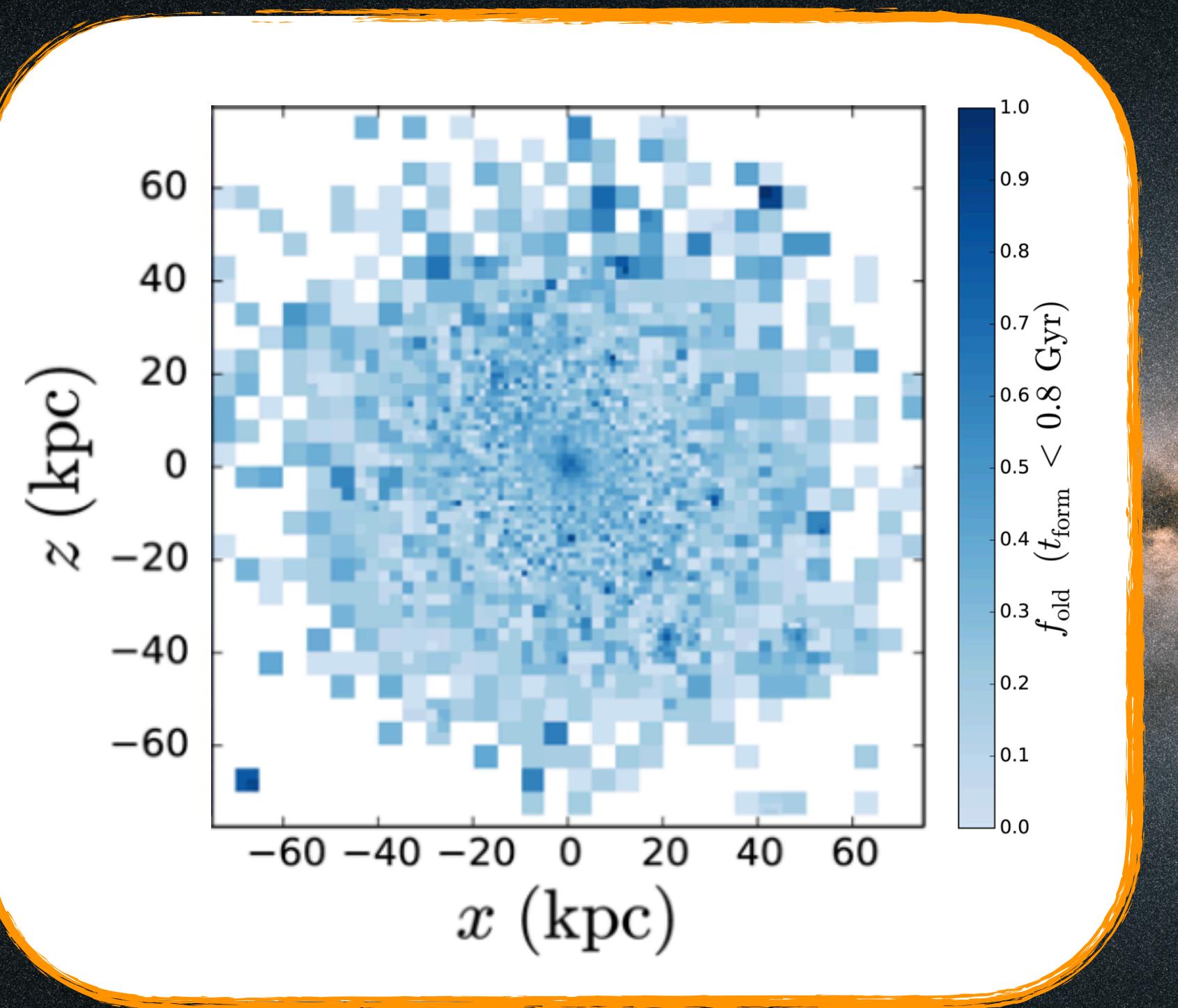


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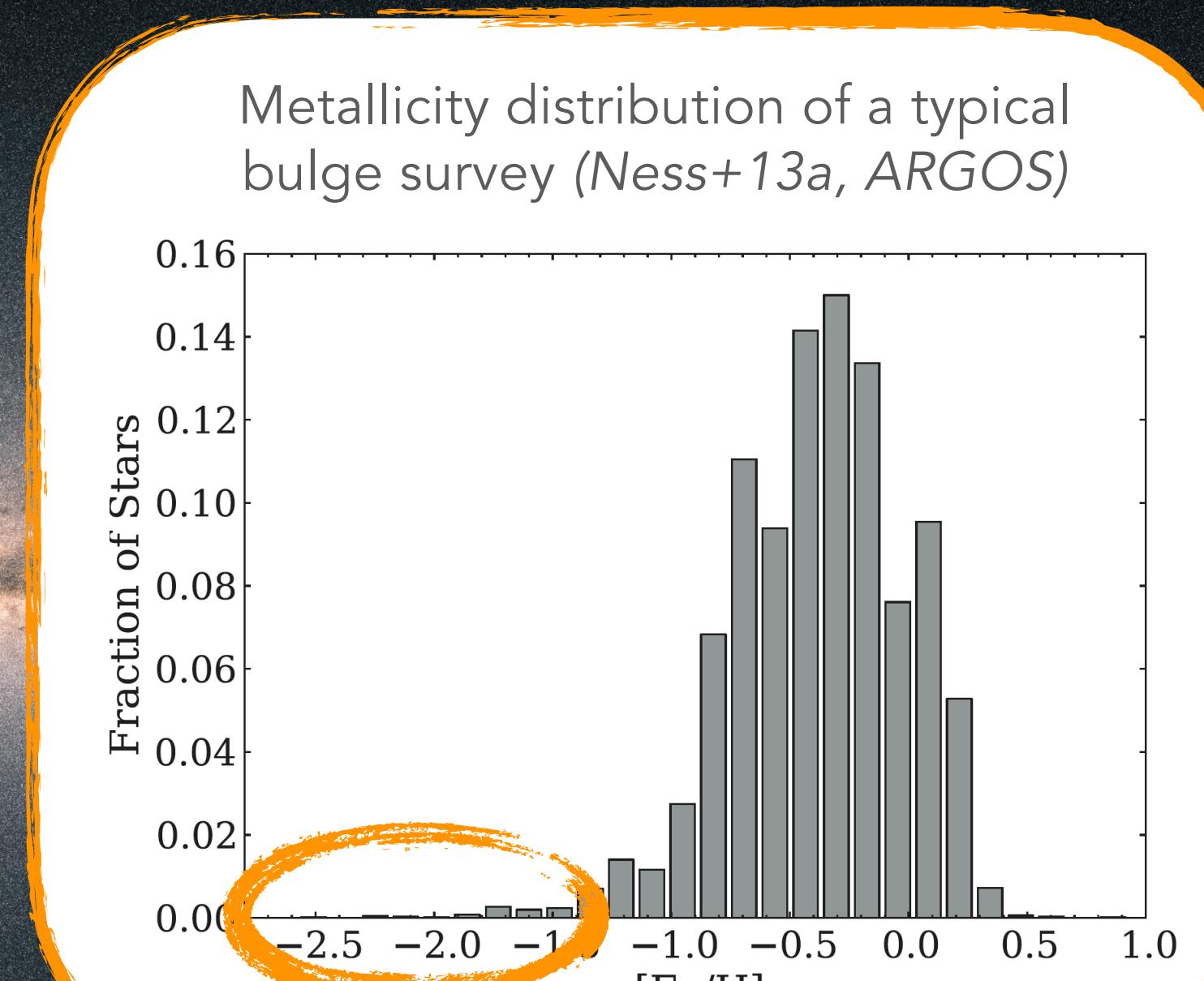


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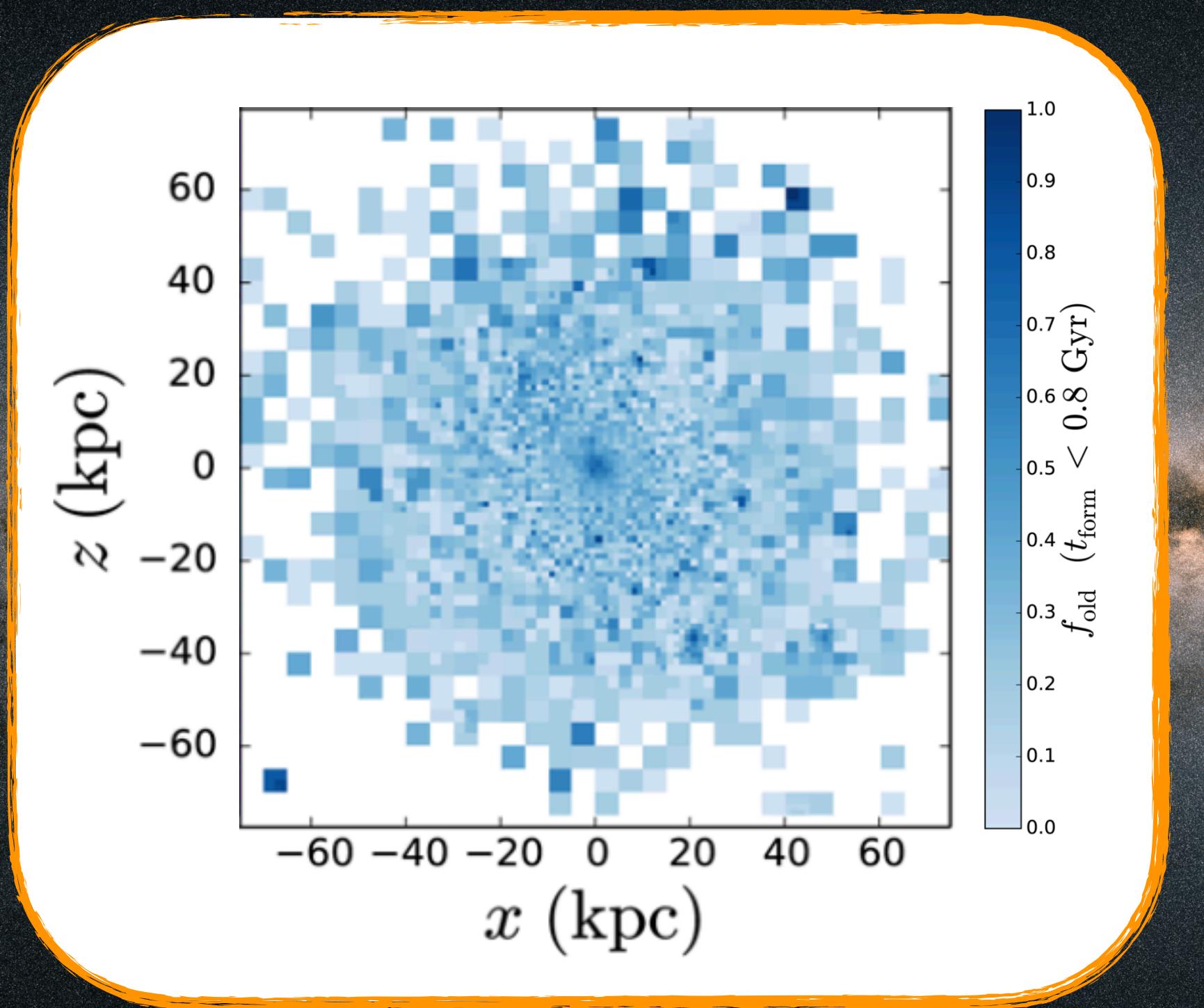
VMP stars: $[\text{Fe}/\text{H}] < -2$

gaia

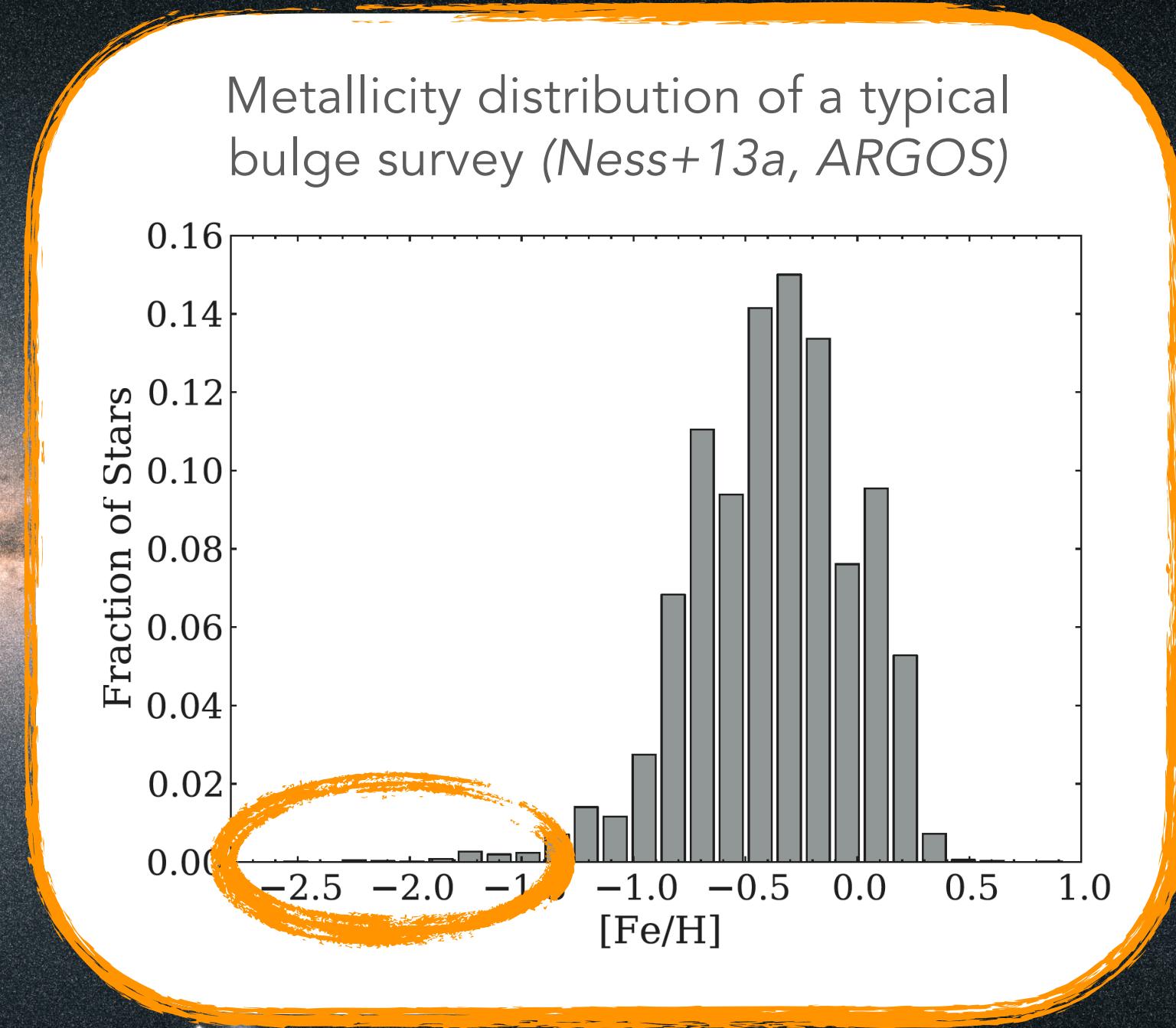


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+ dust...



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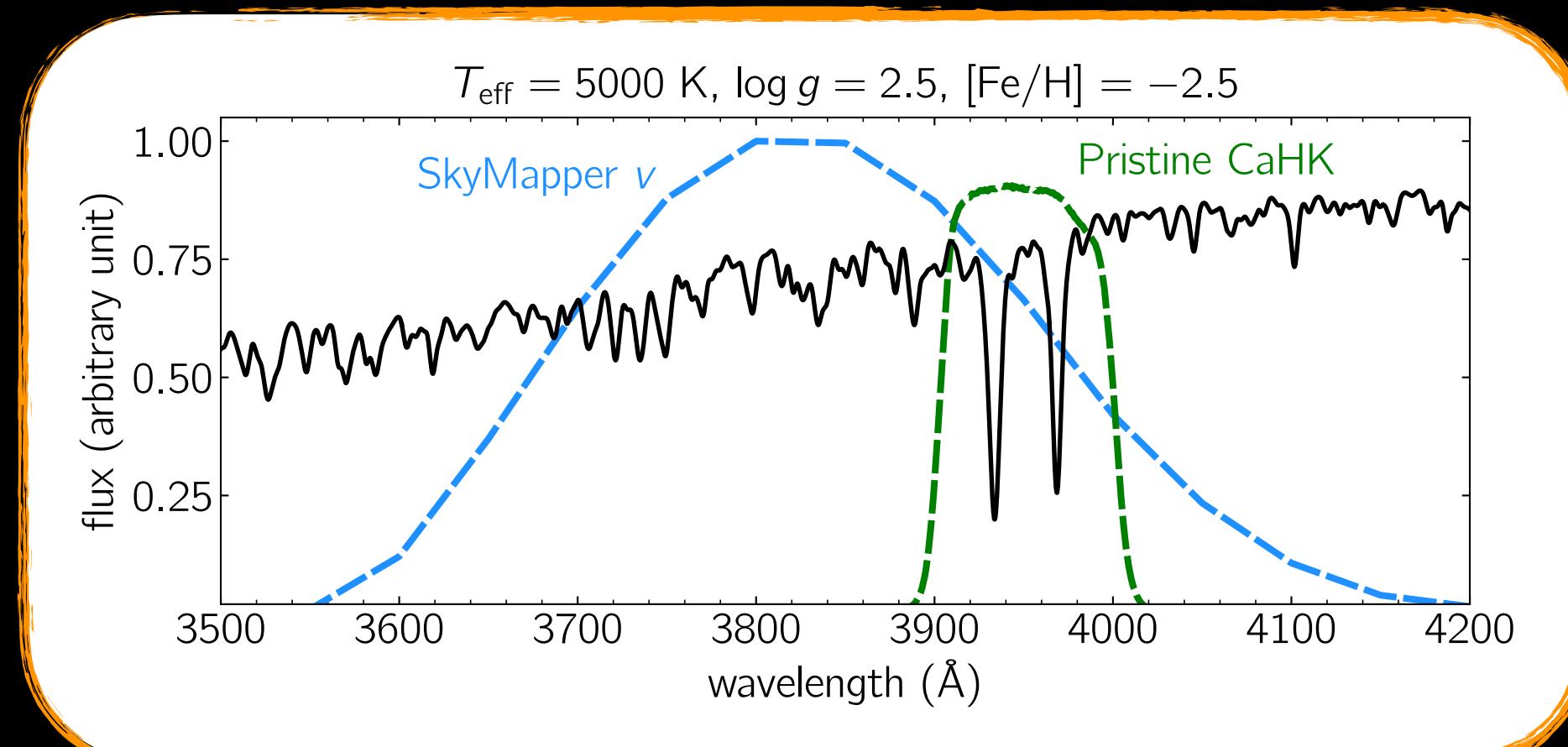
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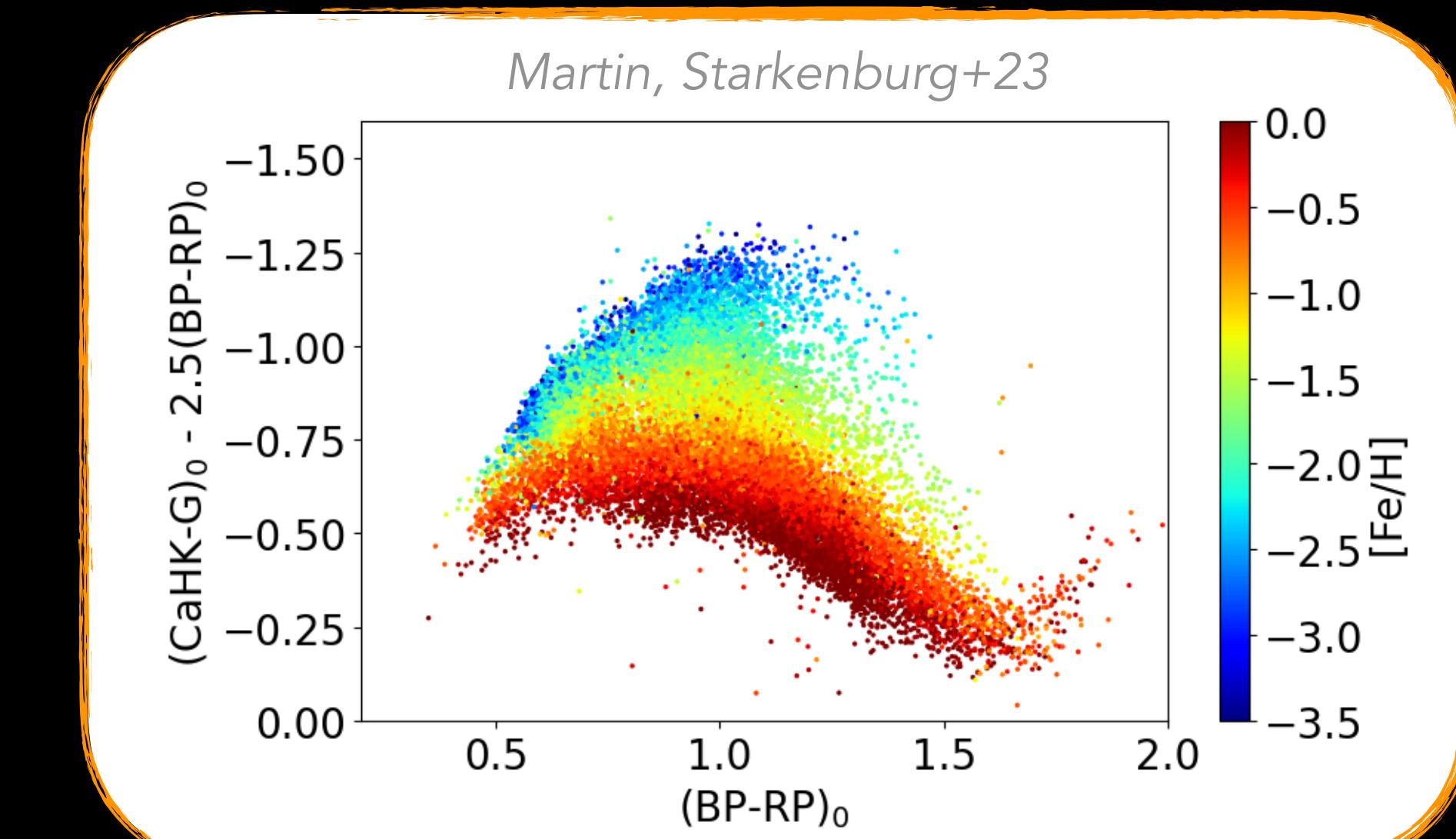
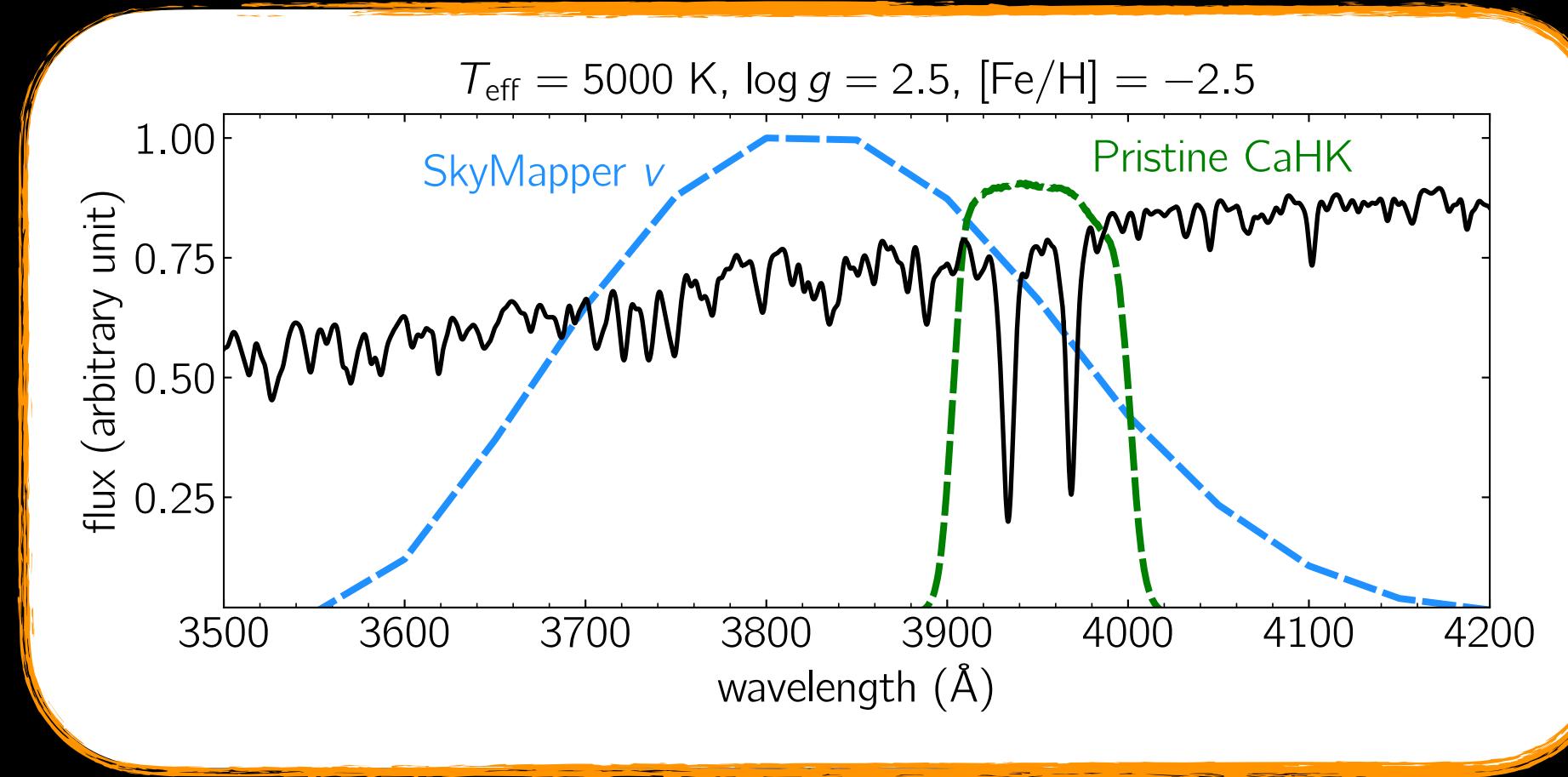
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(e.g. EMBLA [Howes+14,15,16], Koch+16,19, PIGS [AA+20a,b], COMBS [Lucey+19,21,22])



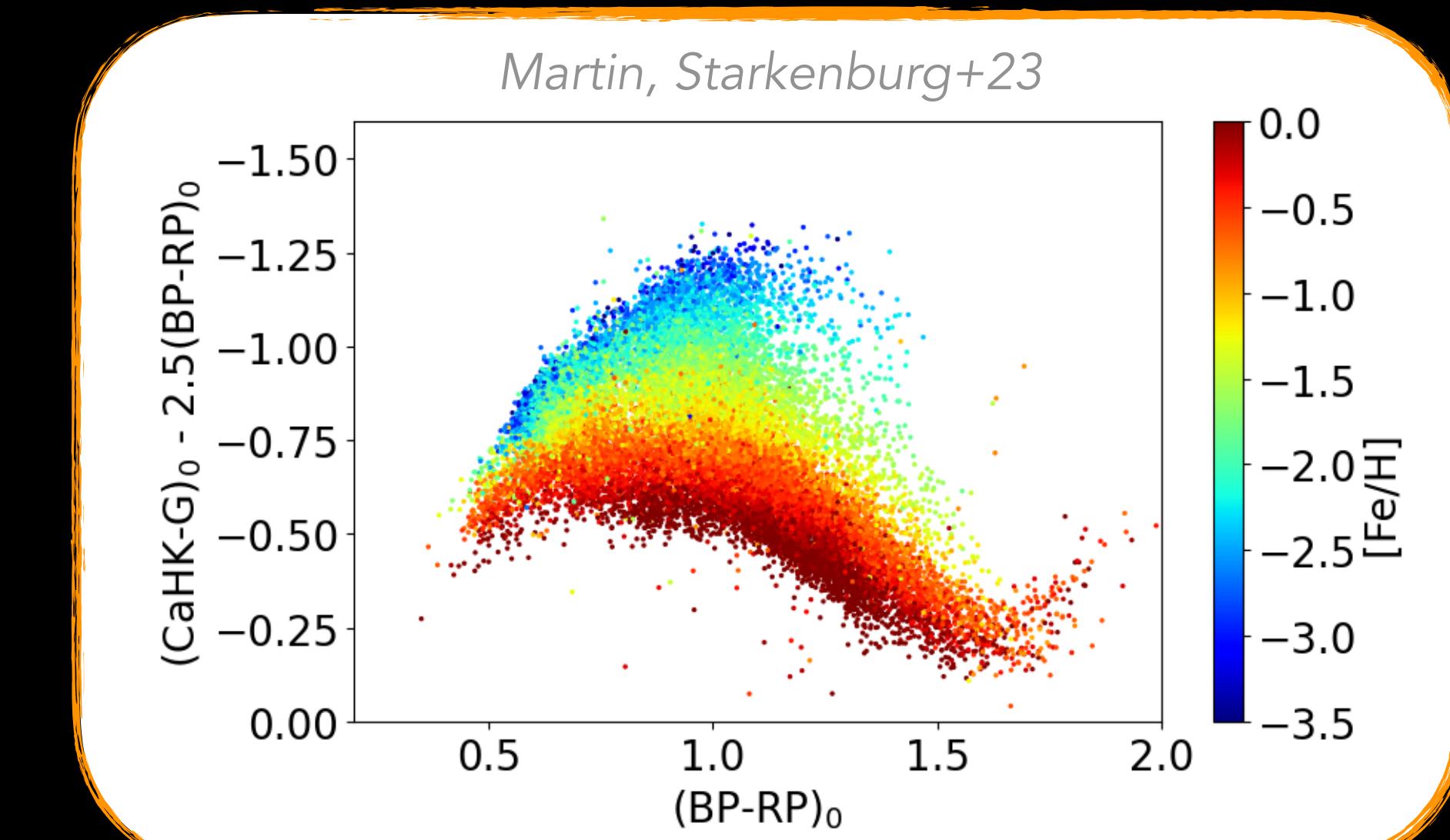
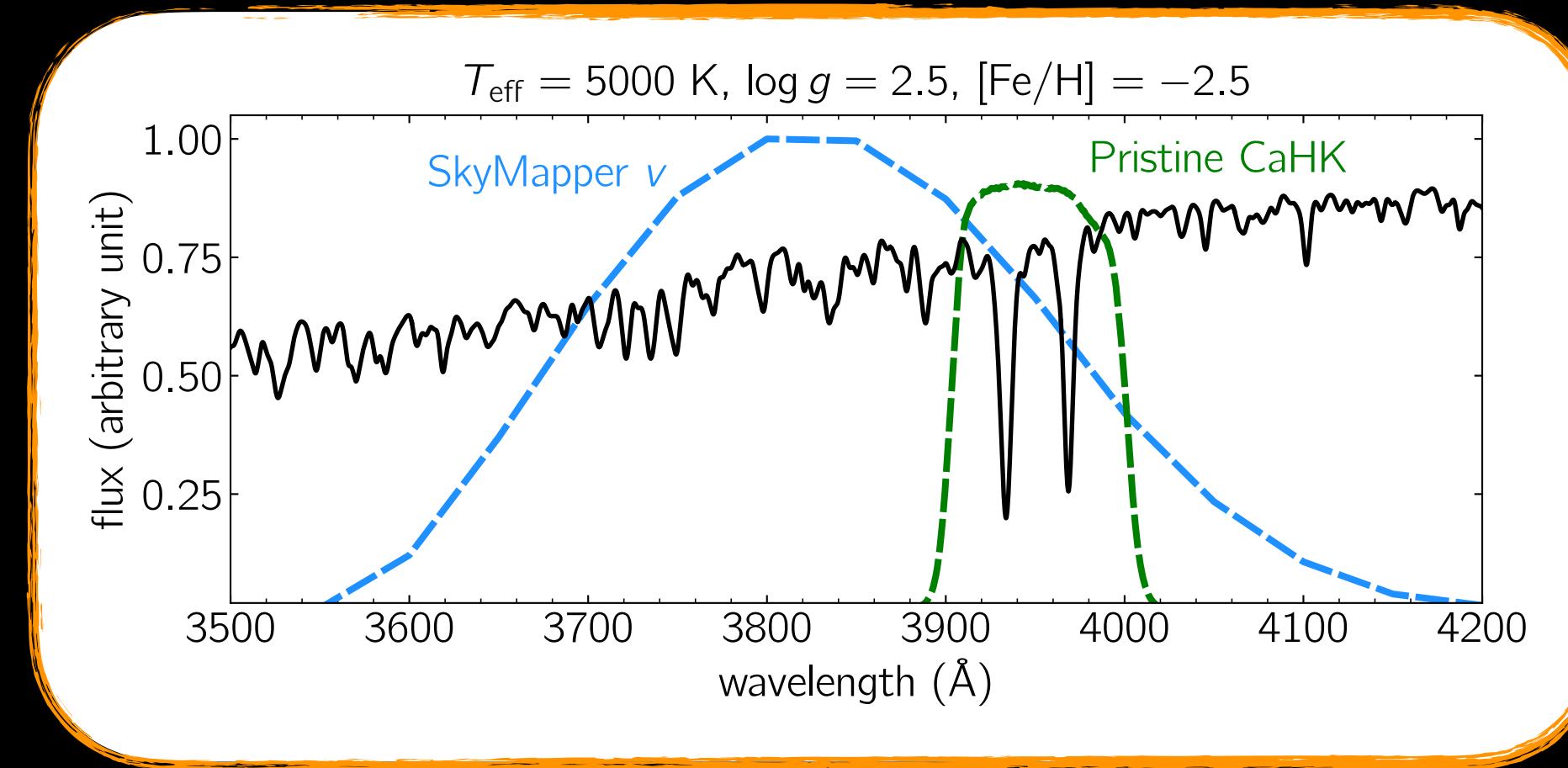
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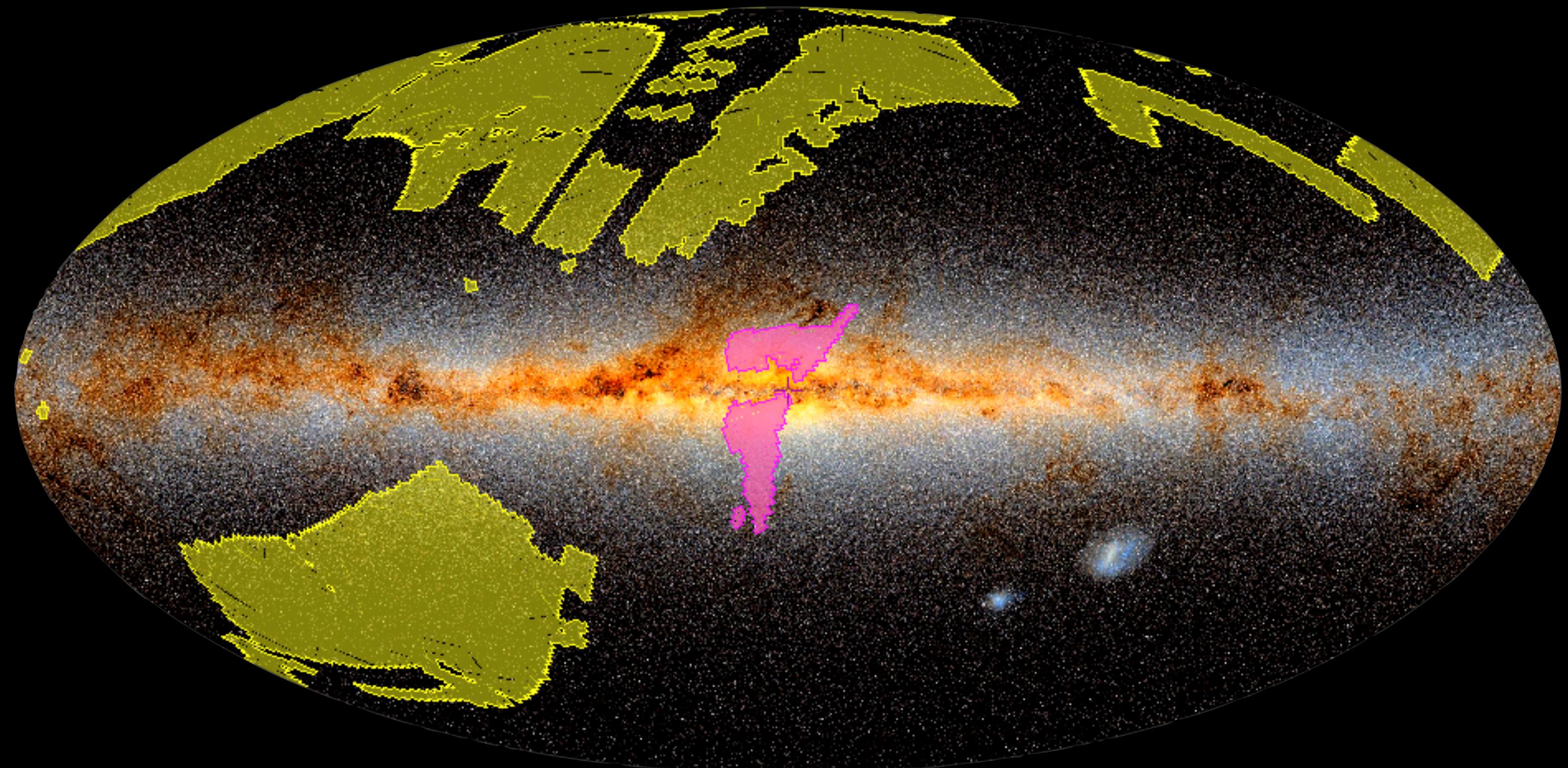


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- Gaia XP spectro-photometry (e.g. Rix+22, Lucey+23, AA+24b)



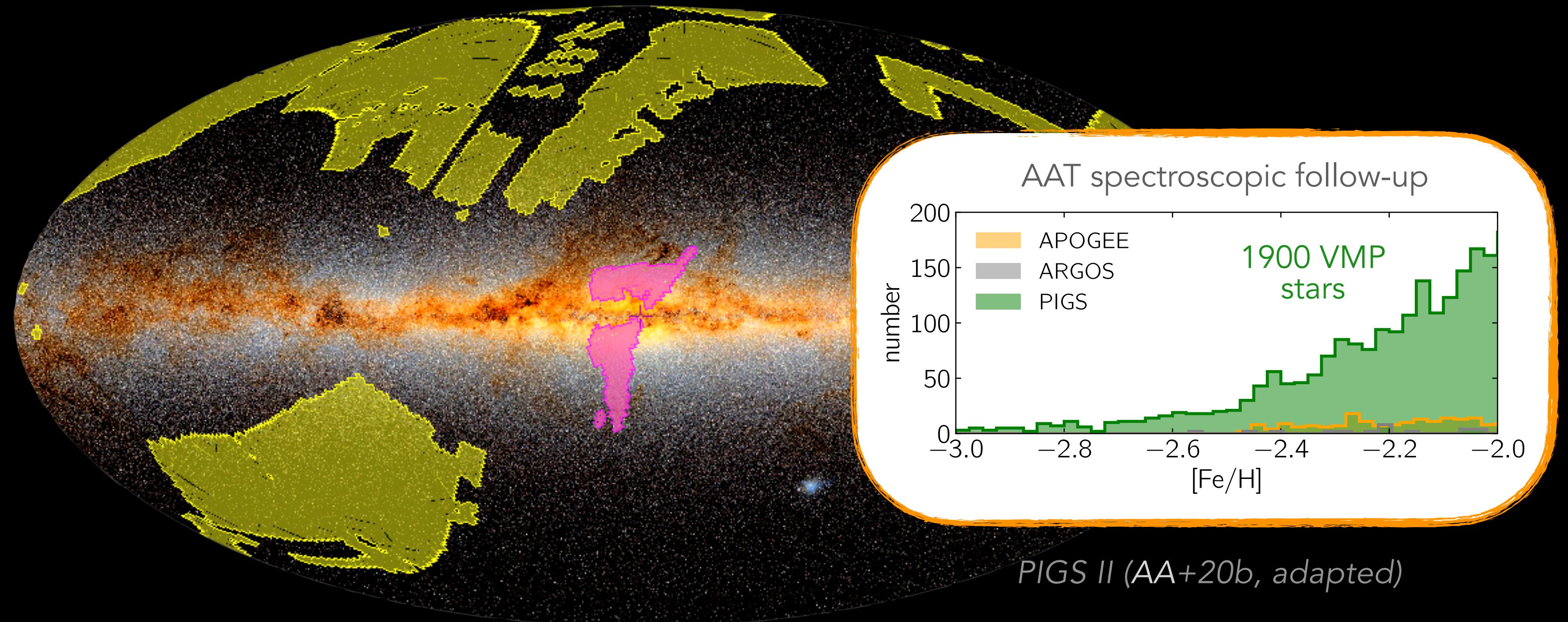
The Pristine Inner Galaxy Survey (PIGS)



PIGS: AA+20a,b,21,24a

Vitali,AA+22, Zhao+AA+23, Mashonkina,AA+23, Sestito+AA+23,24a,b,c, Aguado,AA+in prep

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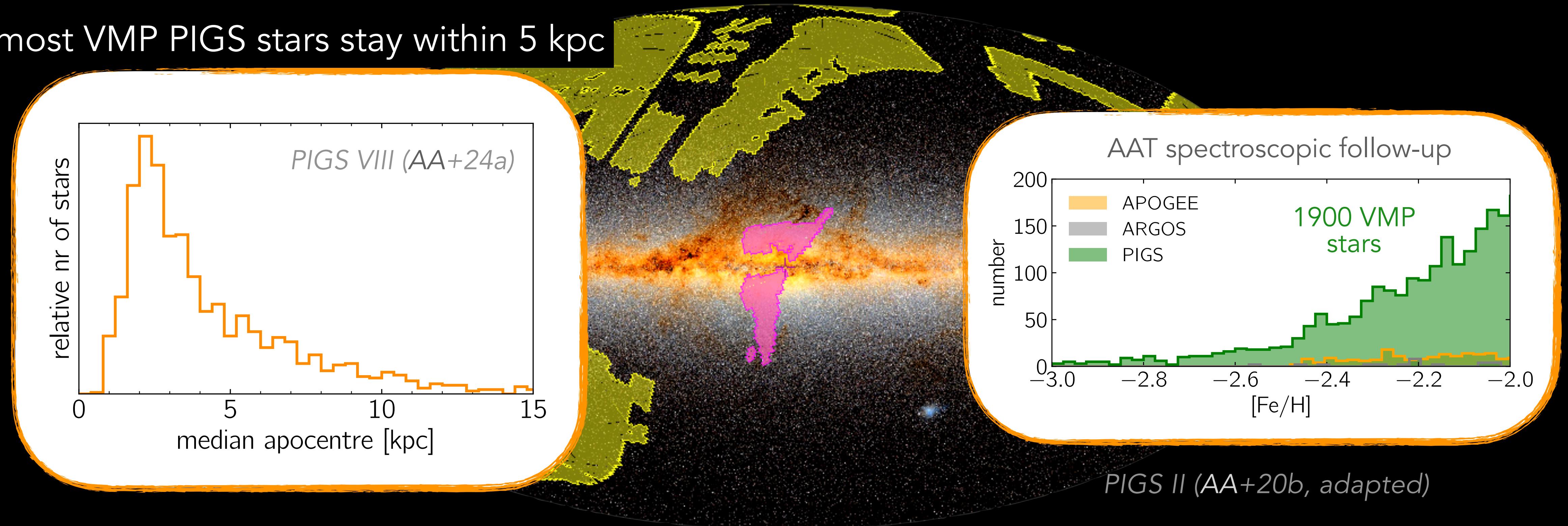
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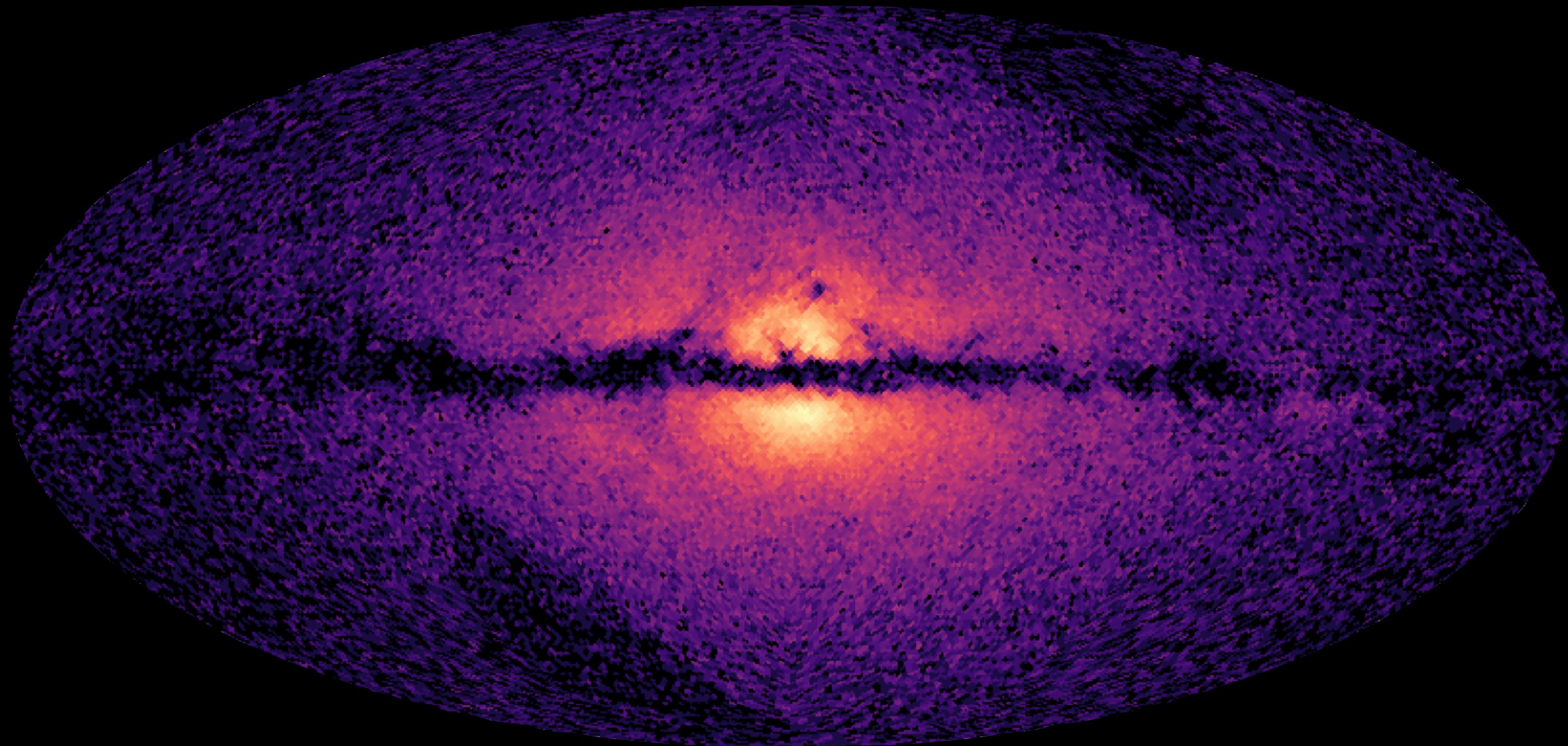
most VMP PIGS stars stay within 5 kpc



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Bright metal-poor stars from Gaia XP



Chandra et al. 2023

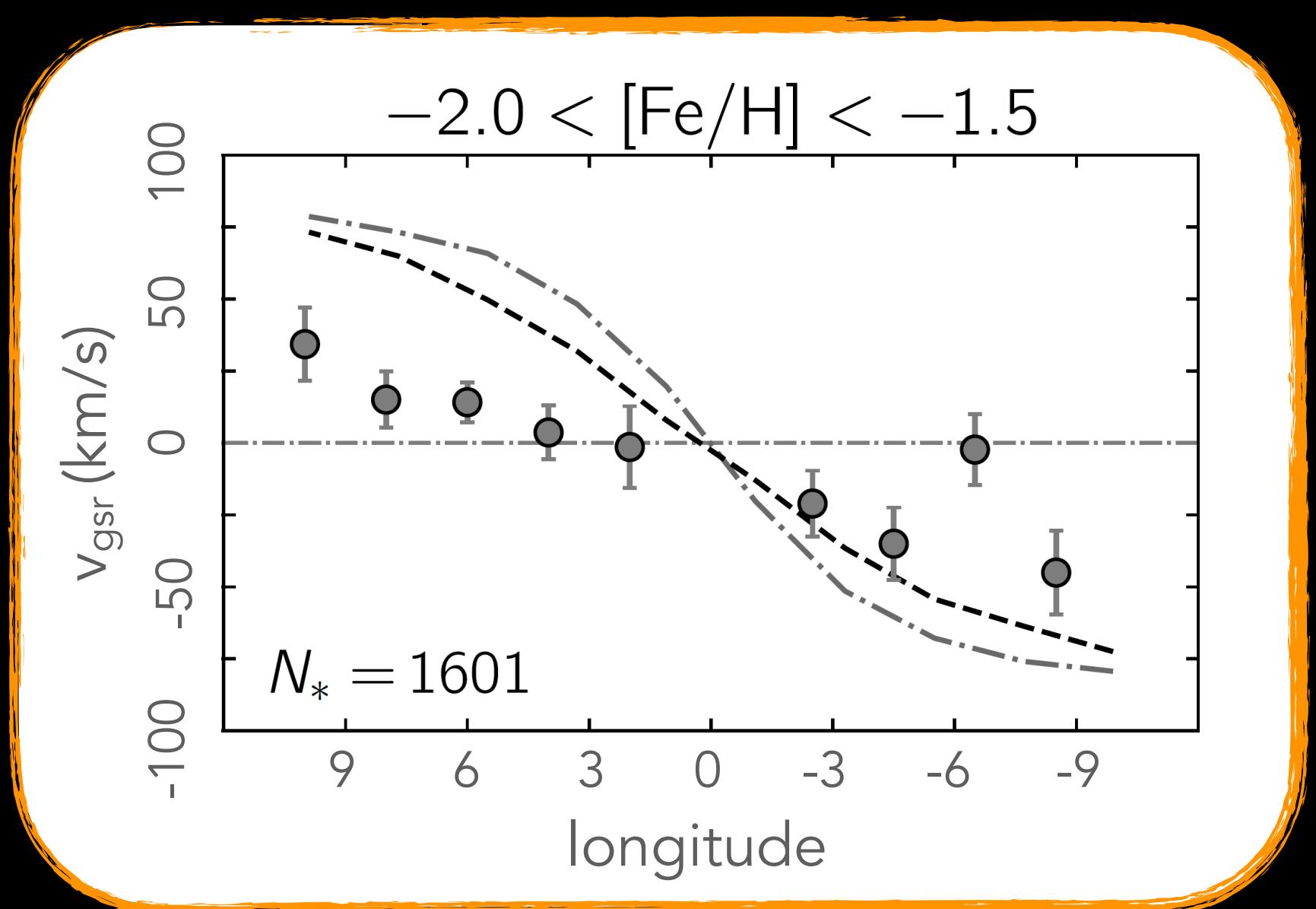
Kinematics of metal-poor PIGS stars





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Metal-poor stars rotate slower than
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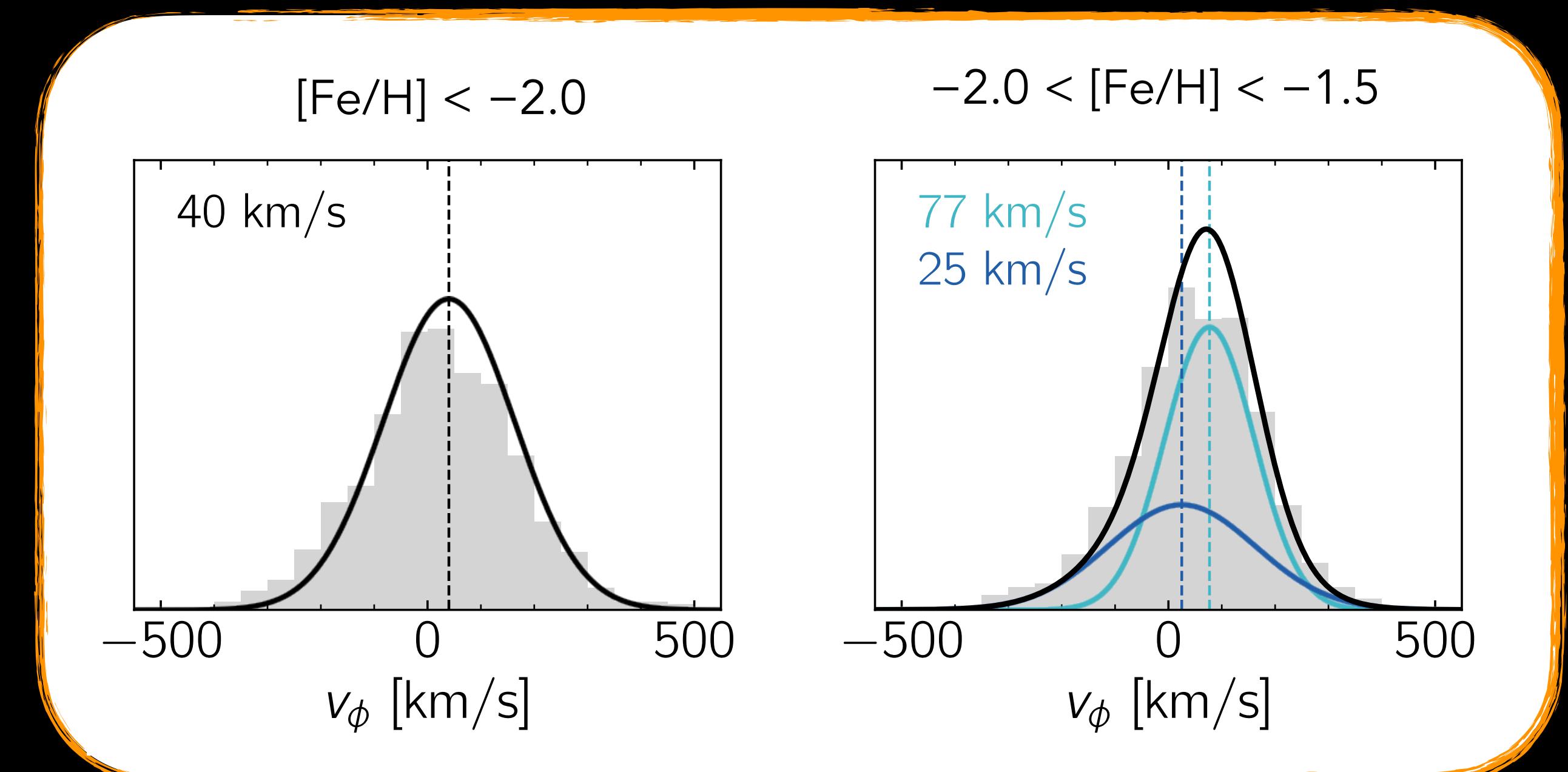
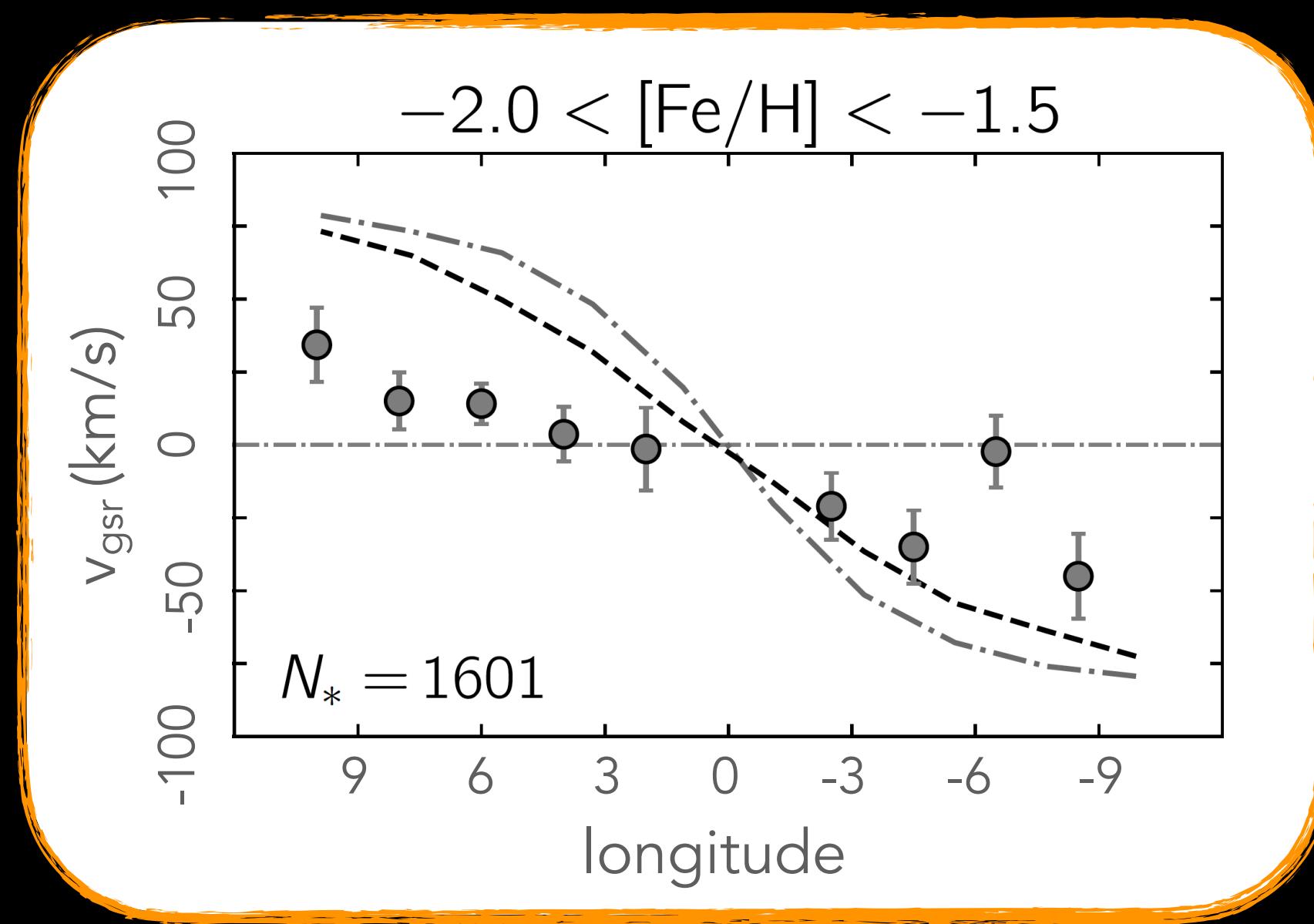
PIGS I (AA+20a), see also Rix+22



Kinematics of metal-poor PIGS stars

Metal-poor stars rotate slower than the bulk of the bulge

VMP stars still rotate, & there appear to be two components (clearly at intermediate low [Fe/H])



PIGS I (AA+20a), see also Rix+22

PIGS VIII (AA+24a)

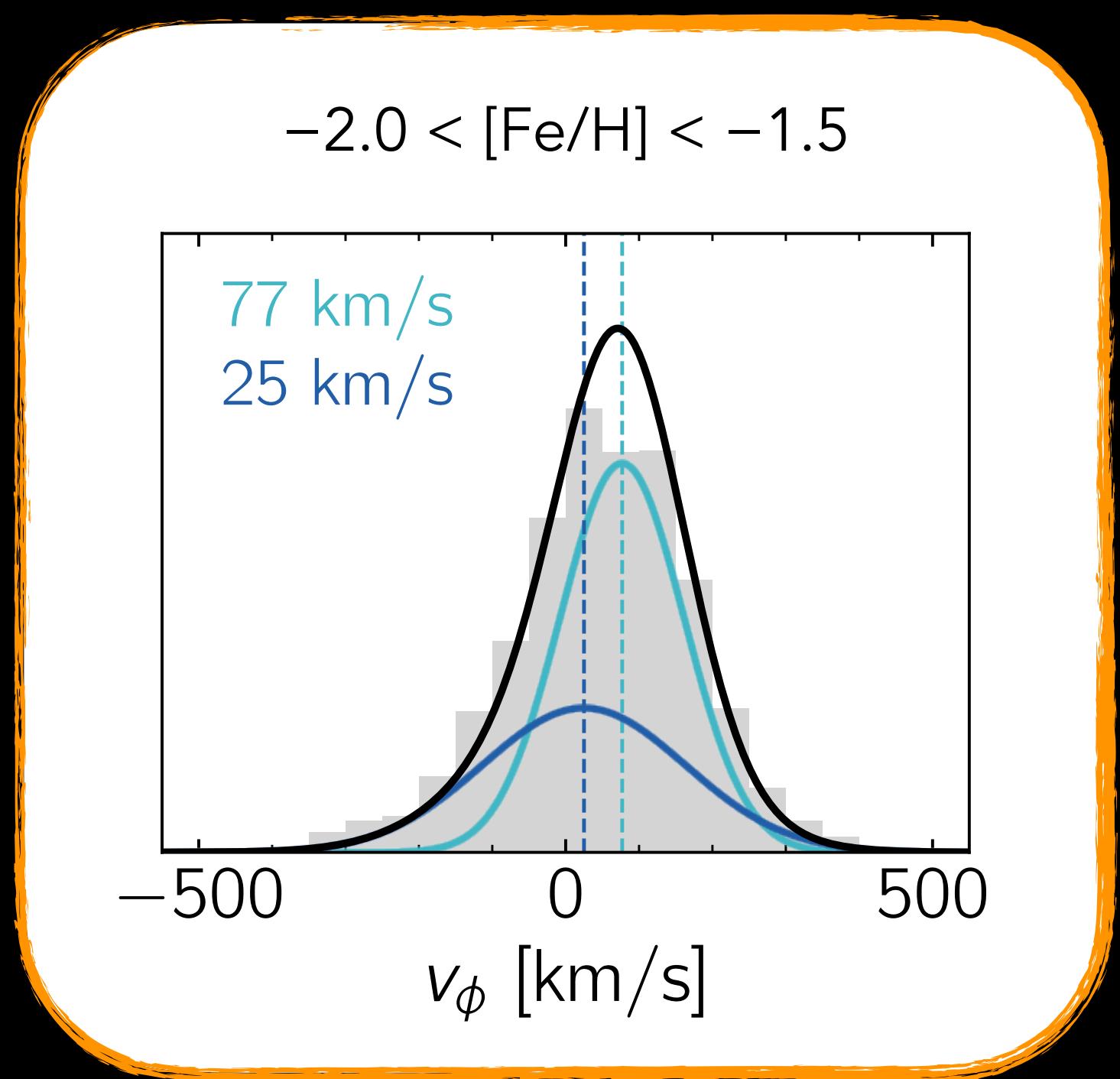
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1. prograde (but $v/\sigma \lesssim 1$), cooler, more metal-rich
2. stationary, hotter, more metal-poor



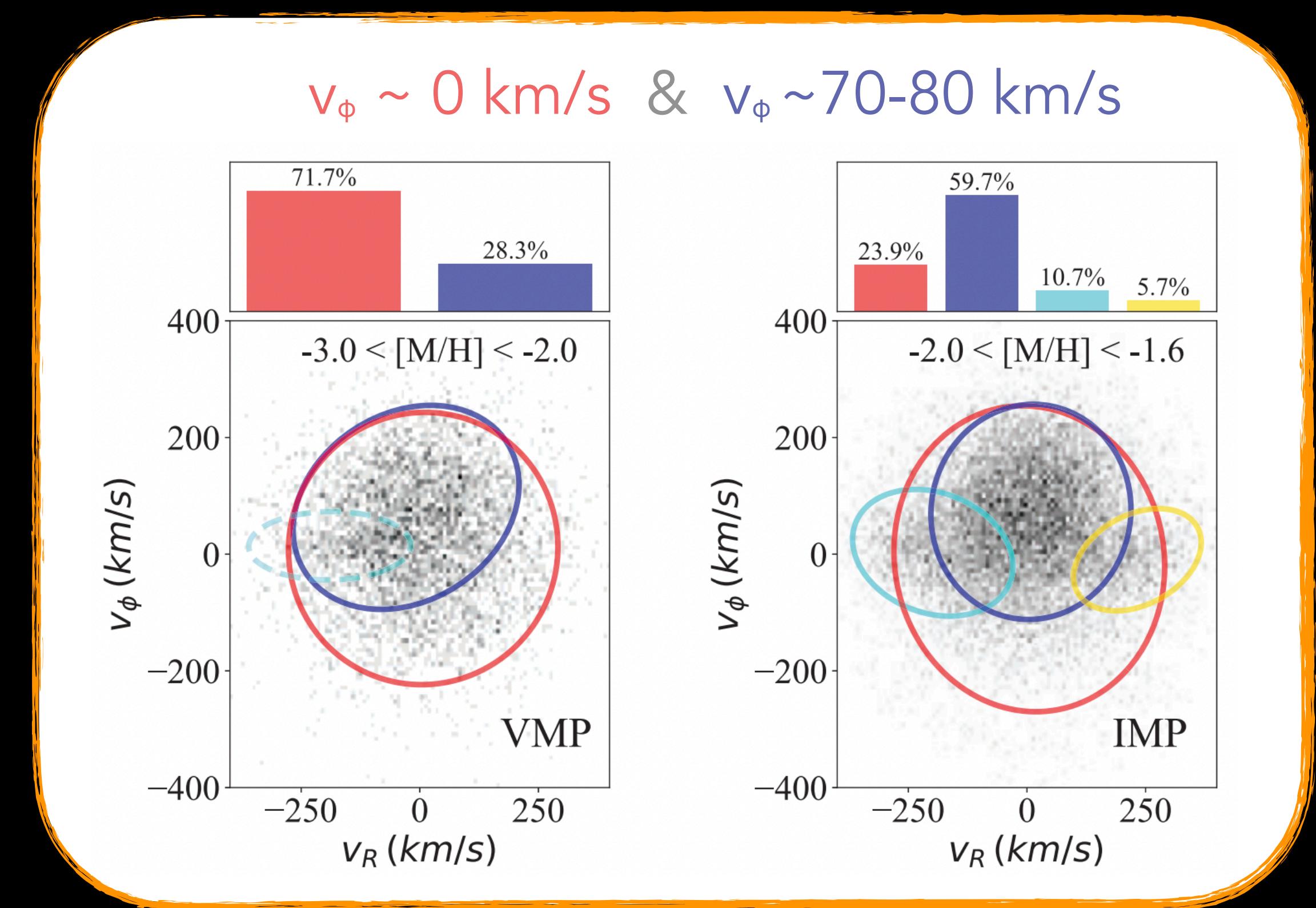
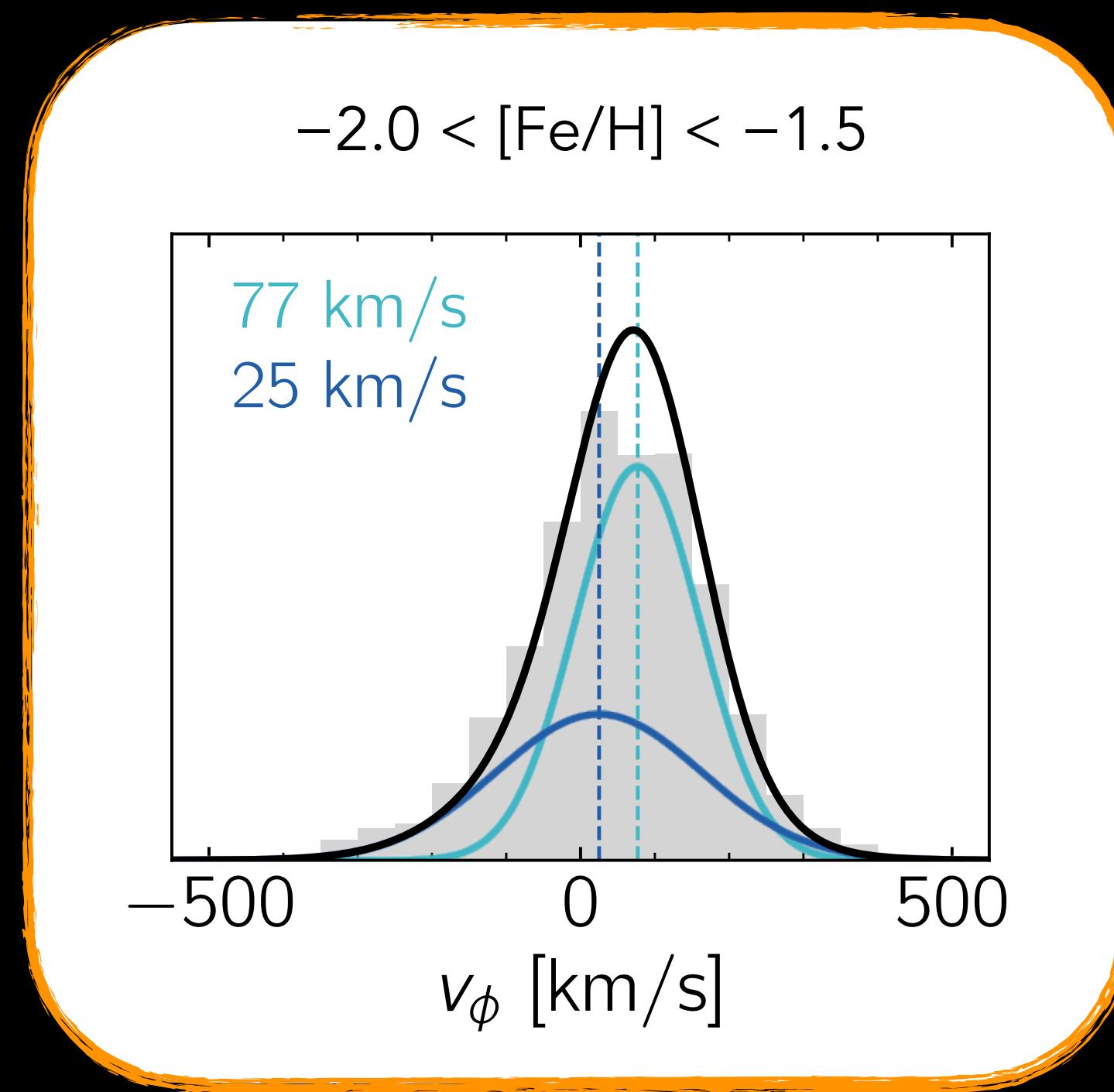
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Solar neighbourhood:



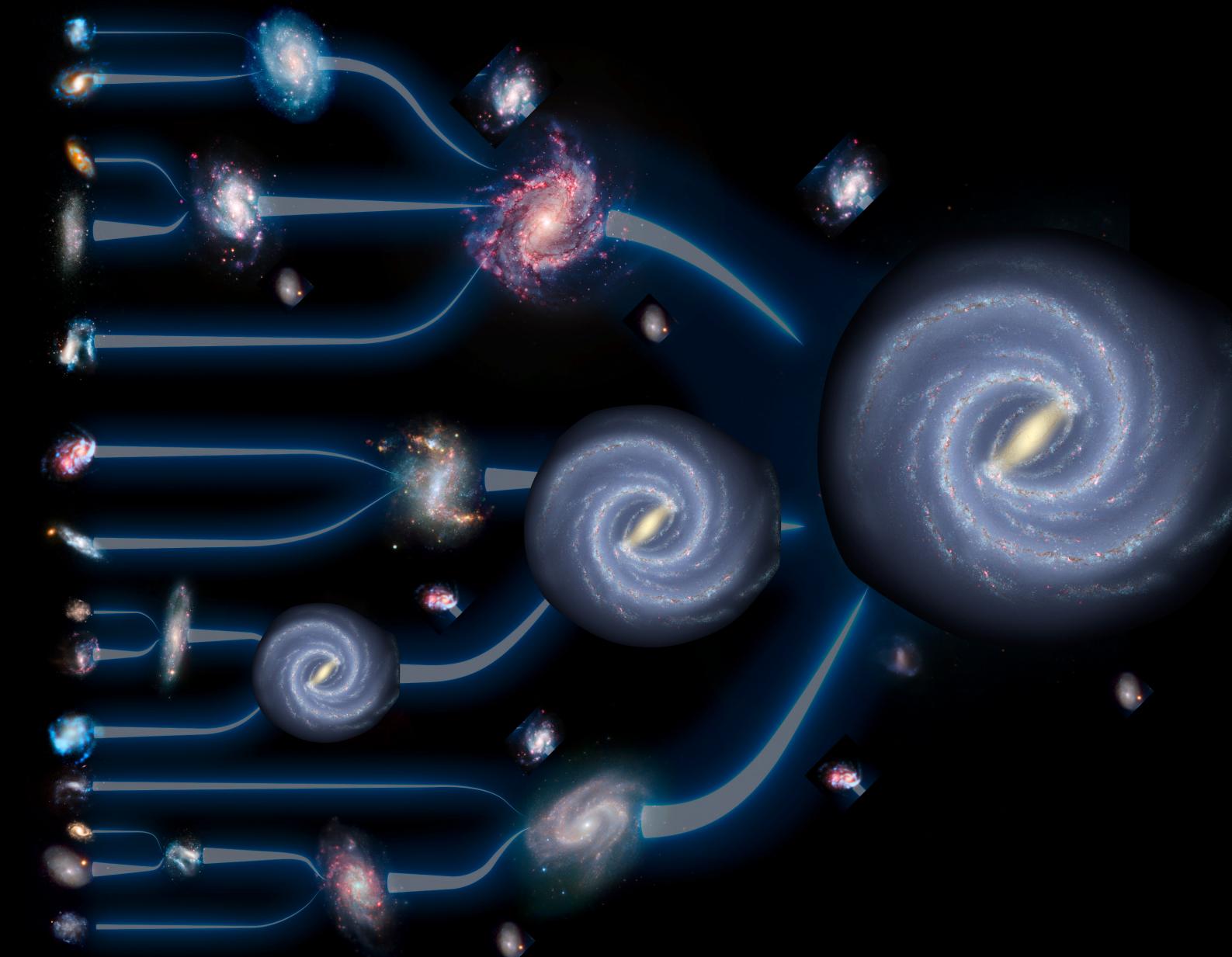
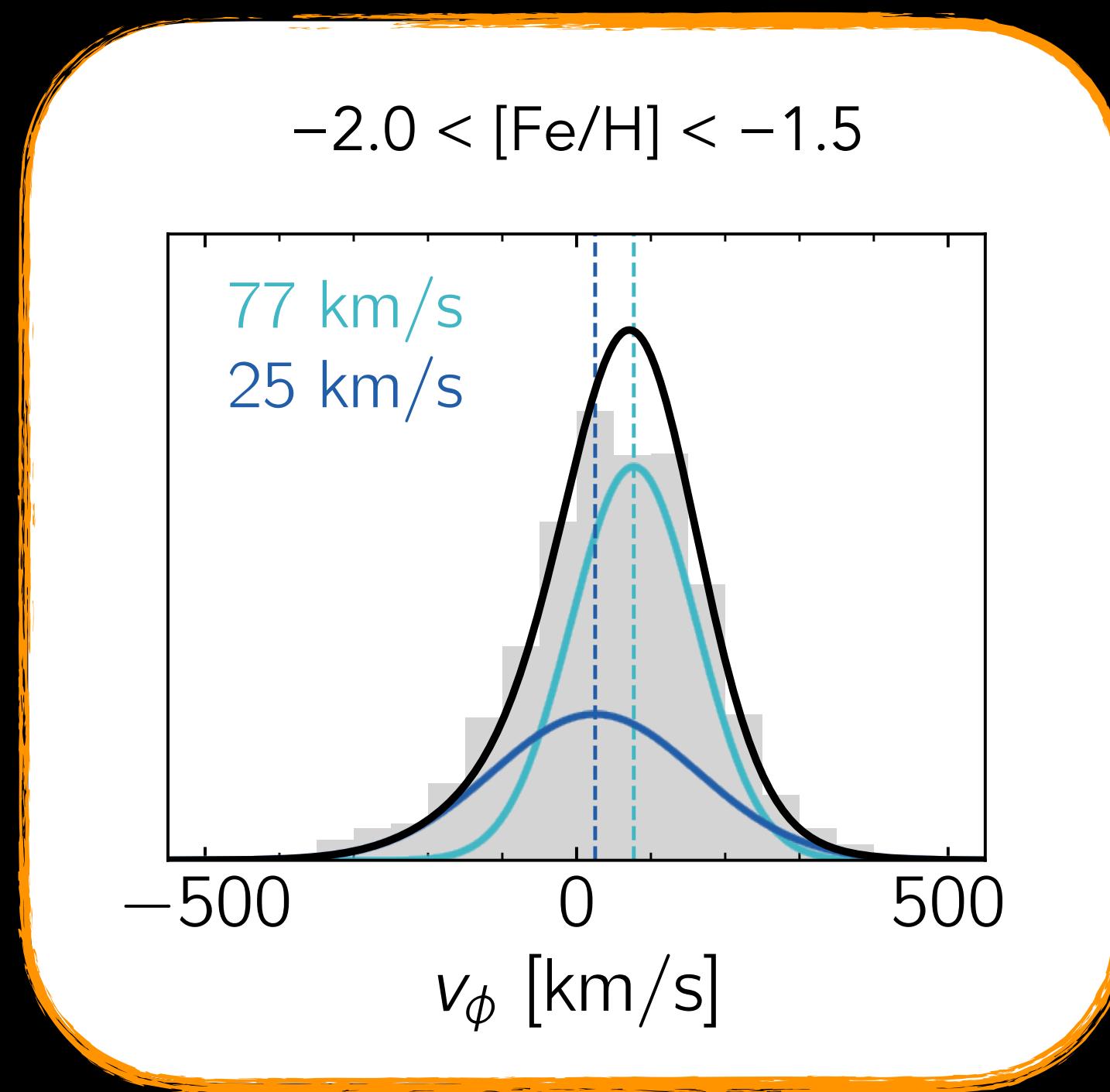
PIGS VIII (AA+24a)

Zhang, AA & Belokurov 24



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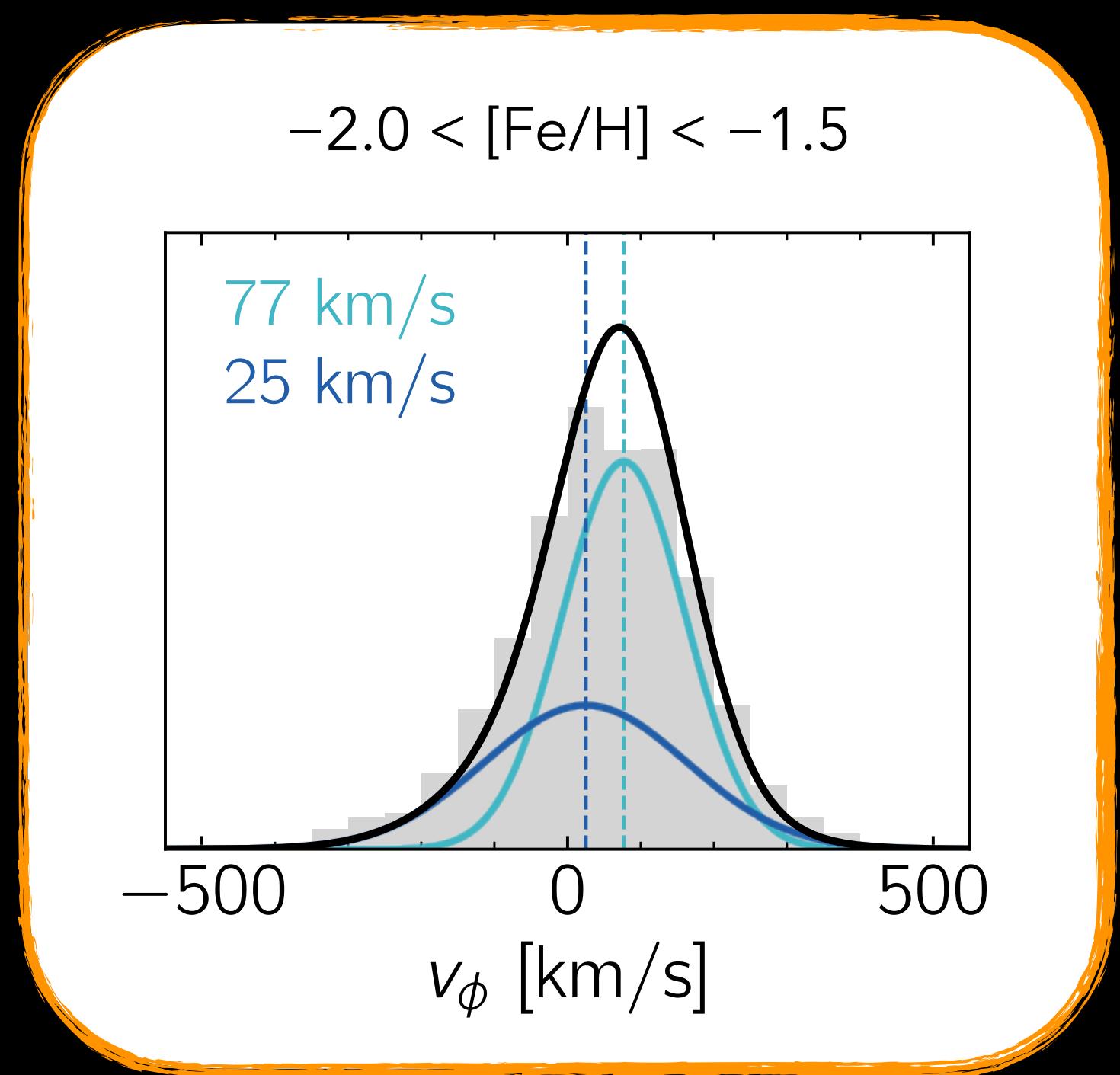
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(why is it rotating?)





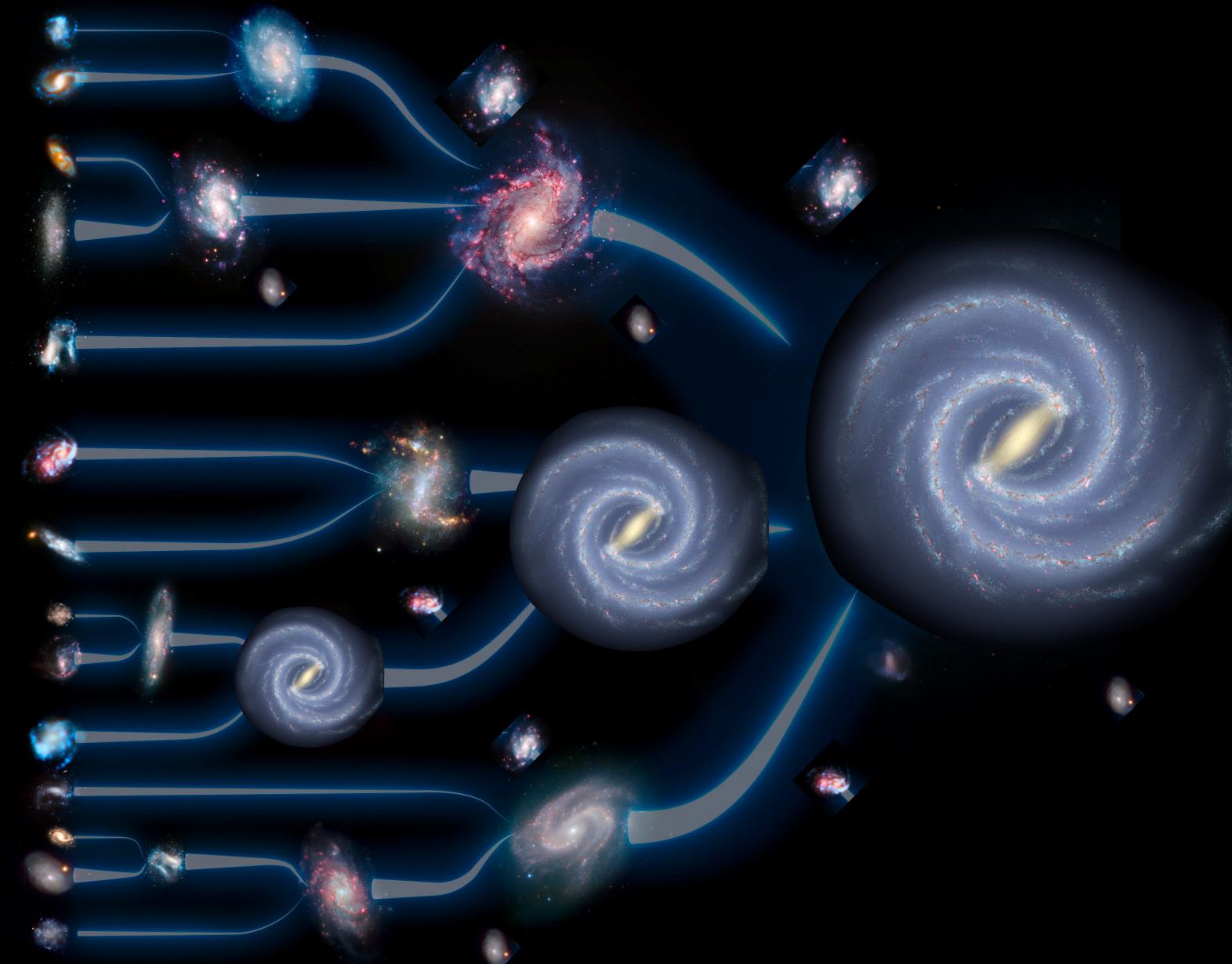
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PIGS VIII (AA+24a)

1. pre-disc “proto-Galaxy”?
(why is it rotating?)
2. accreted at a later time?
and/or from smaller systems?



This should leave traces in the chemistry!

A lot of recent spectroscopy work on the metal-poor inner Galaxy:

EMBLA (Howes+14,15,16), B&B (Schlaufman+14, Casey+15, Reggiani+20), BRAVA RR Lyrae (Kunder+16,20, Savino+20), Koch+16,19, COMBS (Lucey+19,21,22), HERBS (Duong+19a,19b), PIGS (AA+20a,20b,21,24, Sestito+23,24, Mashonkina+23), APOGEE (Horta+21,+24, Queiroz+21, Razera+22, Barbuy+24 and many others)

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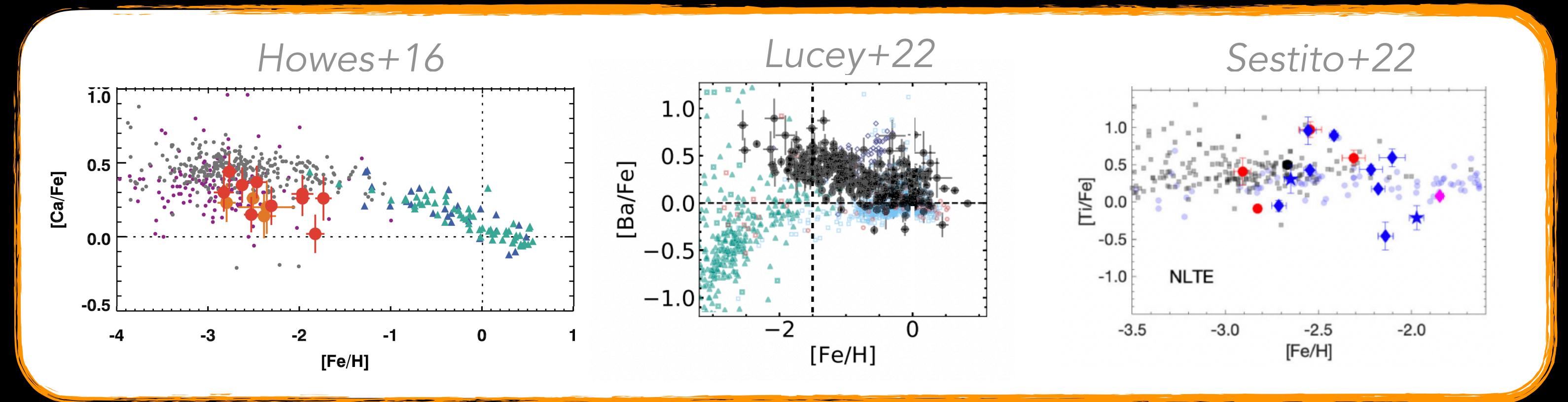
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Spectroscopic samples are small
and all analysed differently

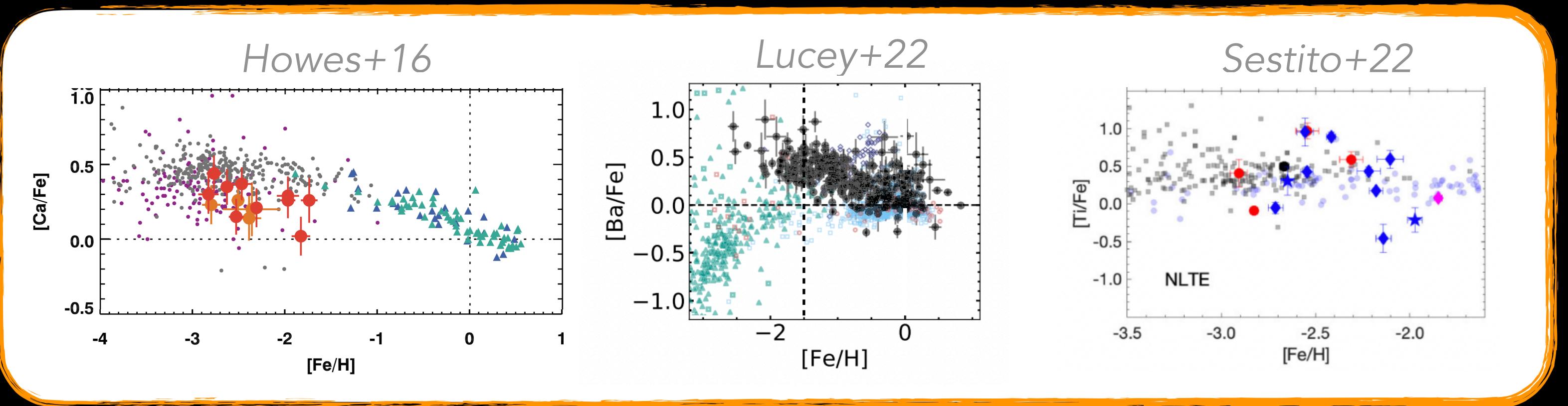


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 - Except for carbon? (*Howes+16, AA+21,24b*)

Ancient inner Galaxy chemistry will be boosted with 4MOST



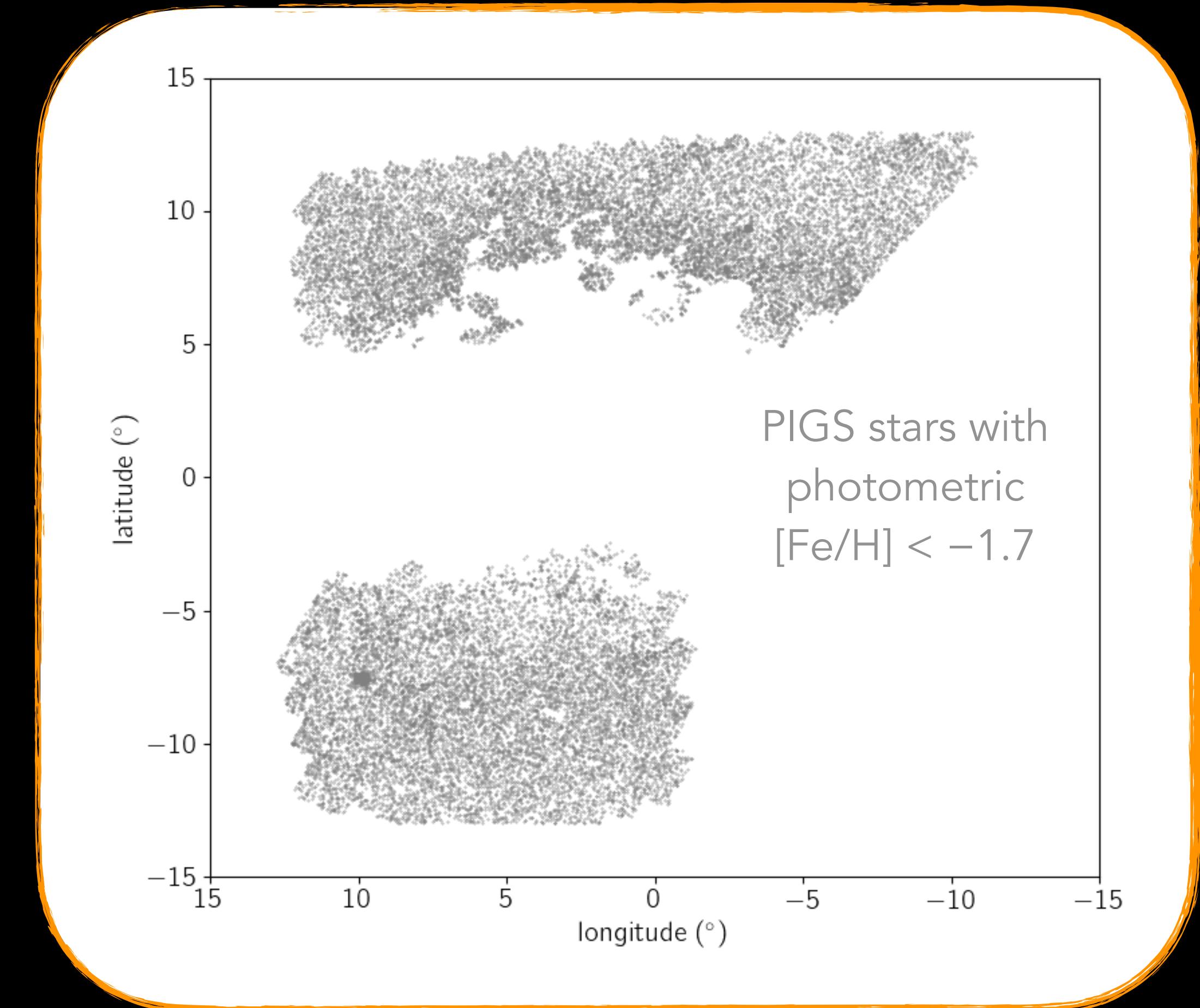
gaia



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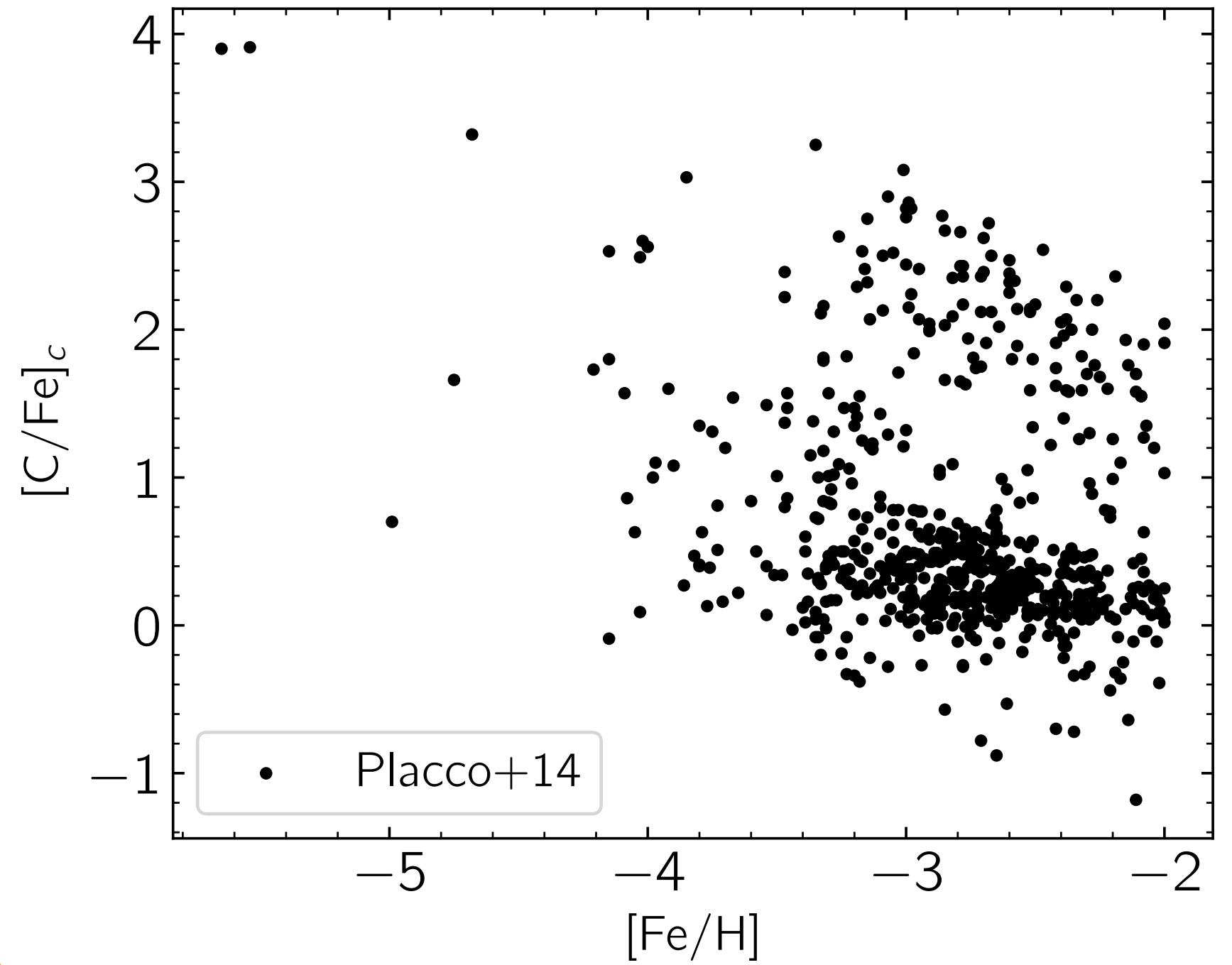
4MIDABLE-LR VMP_PIGS



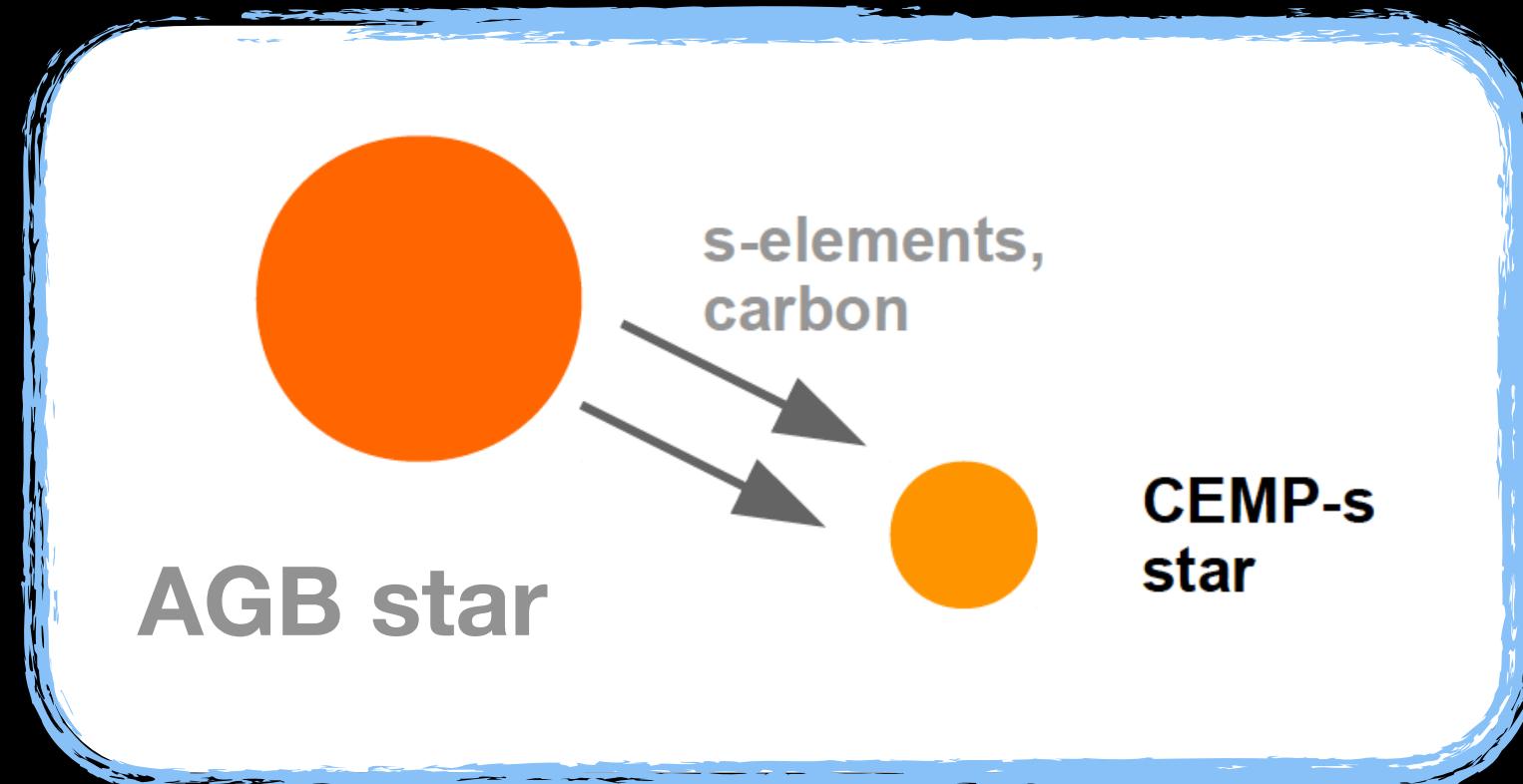
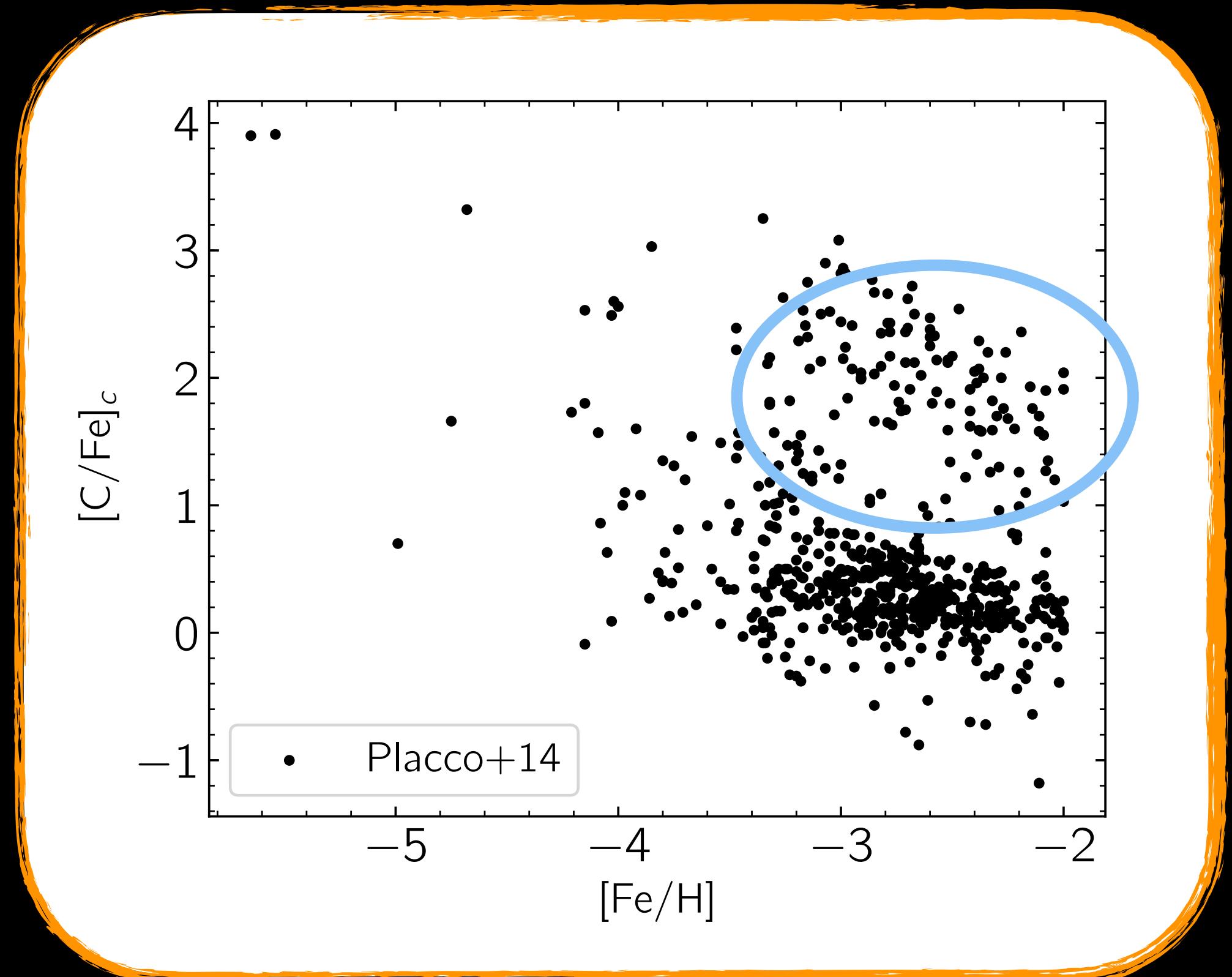
Plus MP candidates from XP (Anders+)

What's up with carbon?

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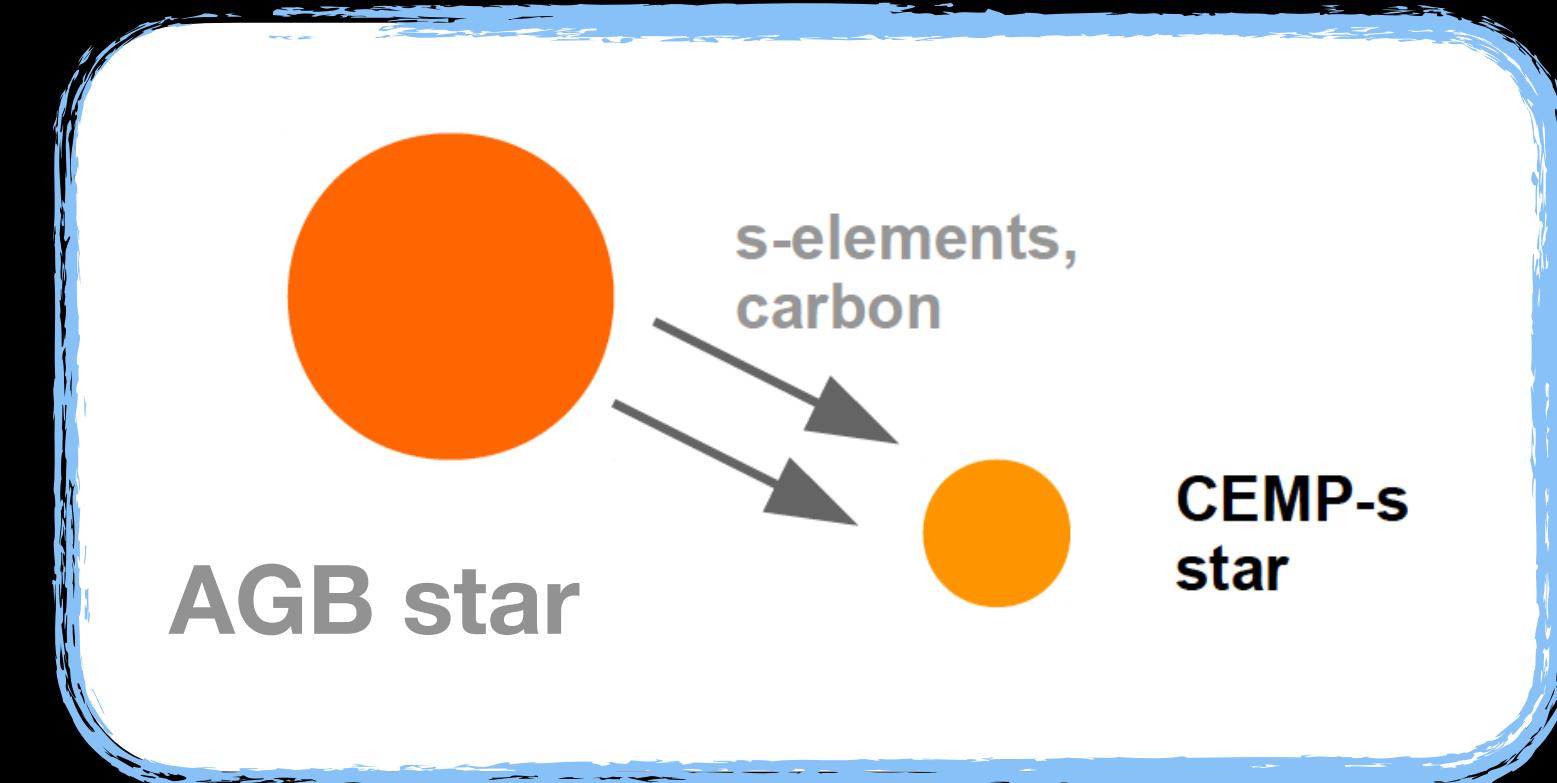
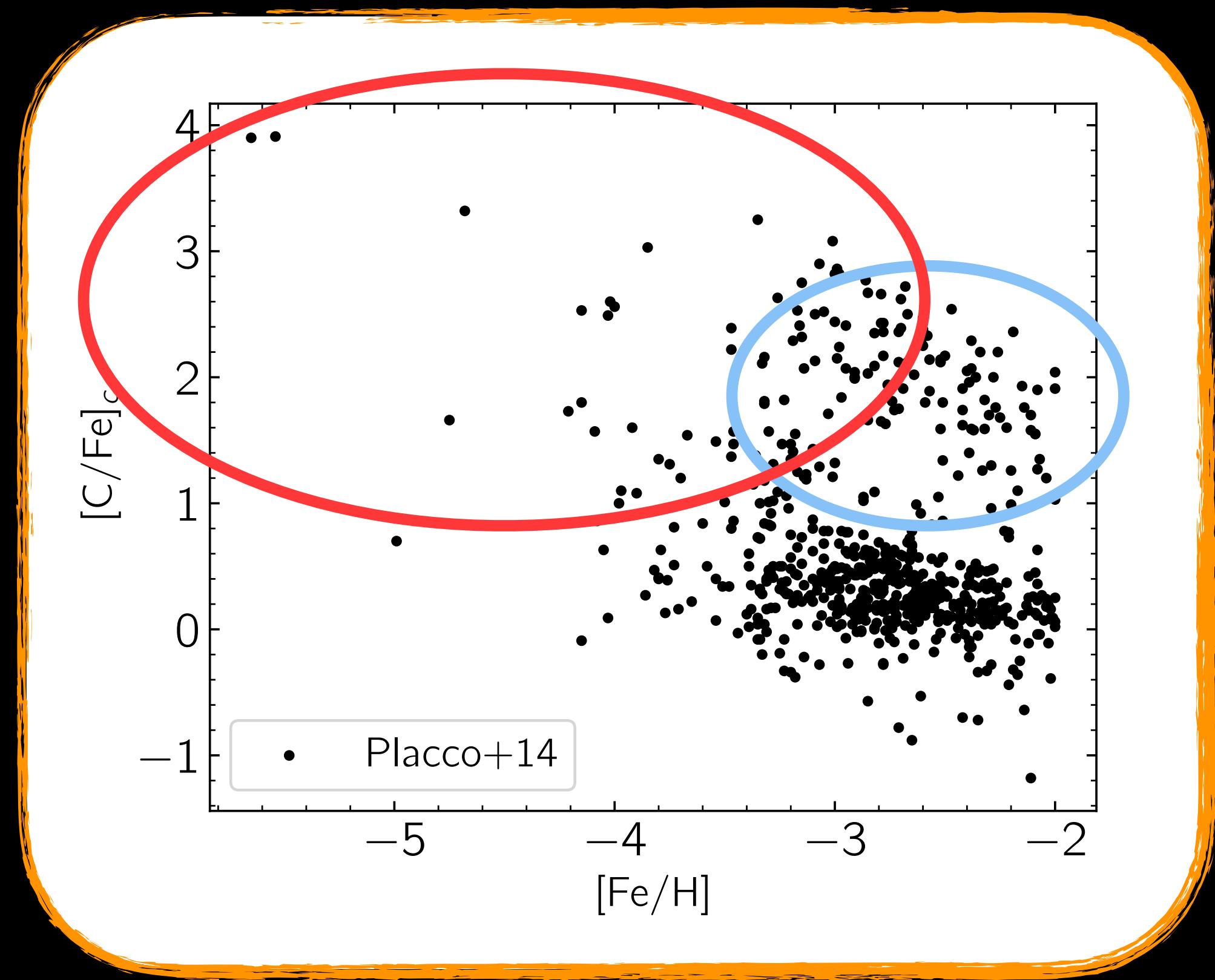


What's up with carbon?



► CEMP-s (Ba-rich, mostly RV binaries)

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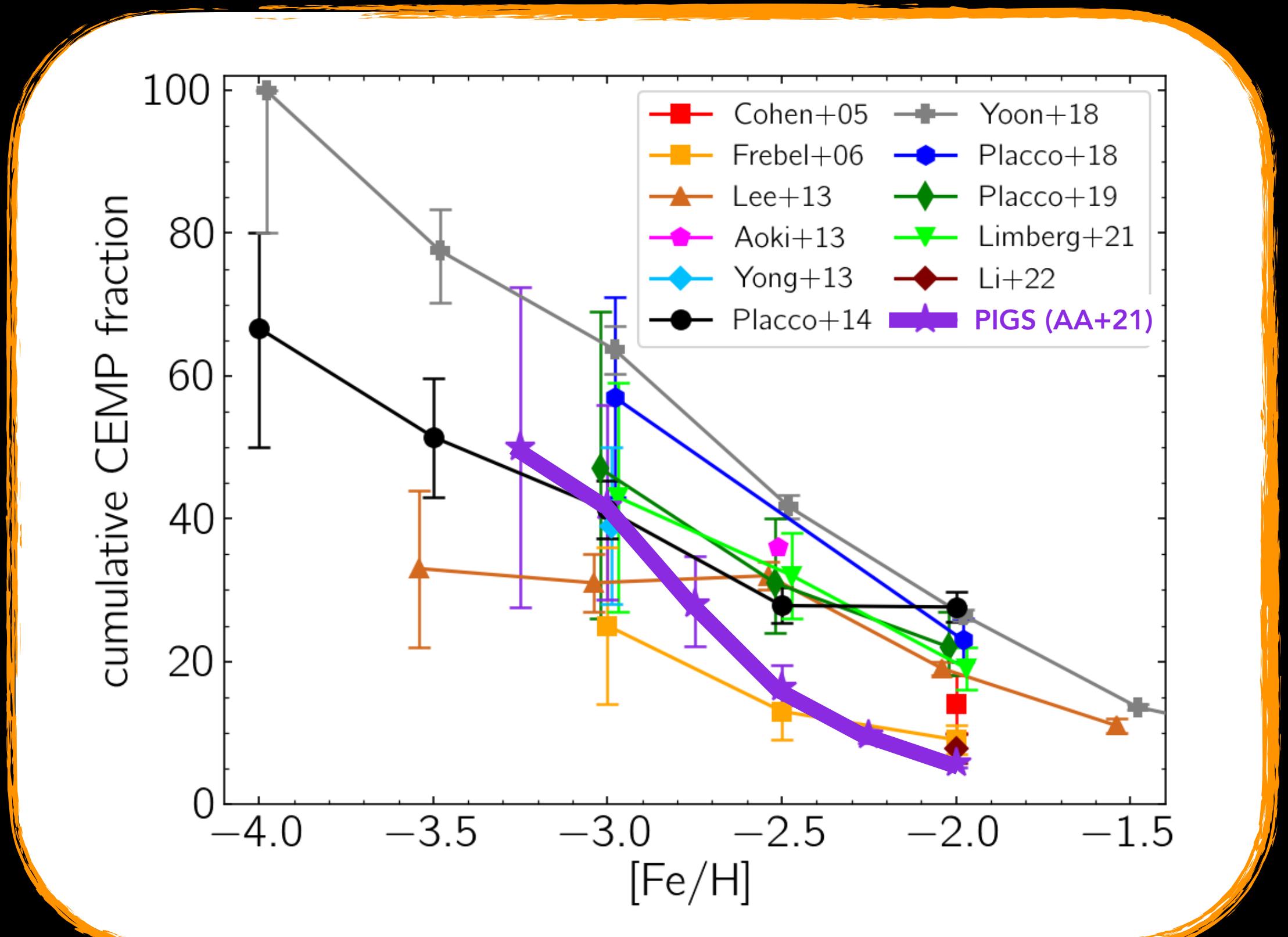


- CEMP-s (Ba-rich, mostly RV binaries)
- CEMP-no (not Ba-rich, also other peculiar abundances, mostly single)



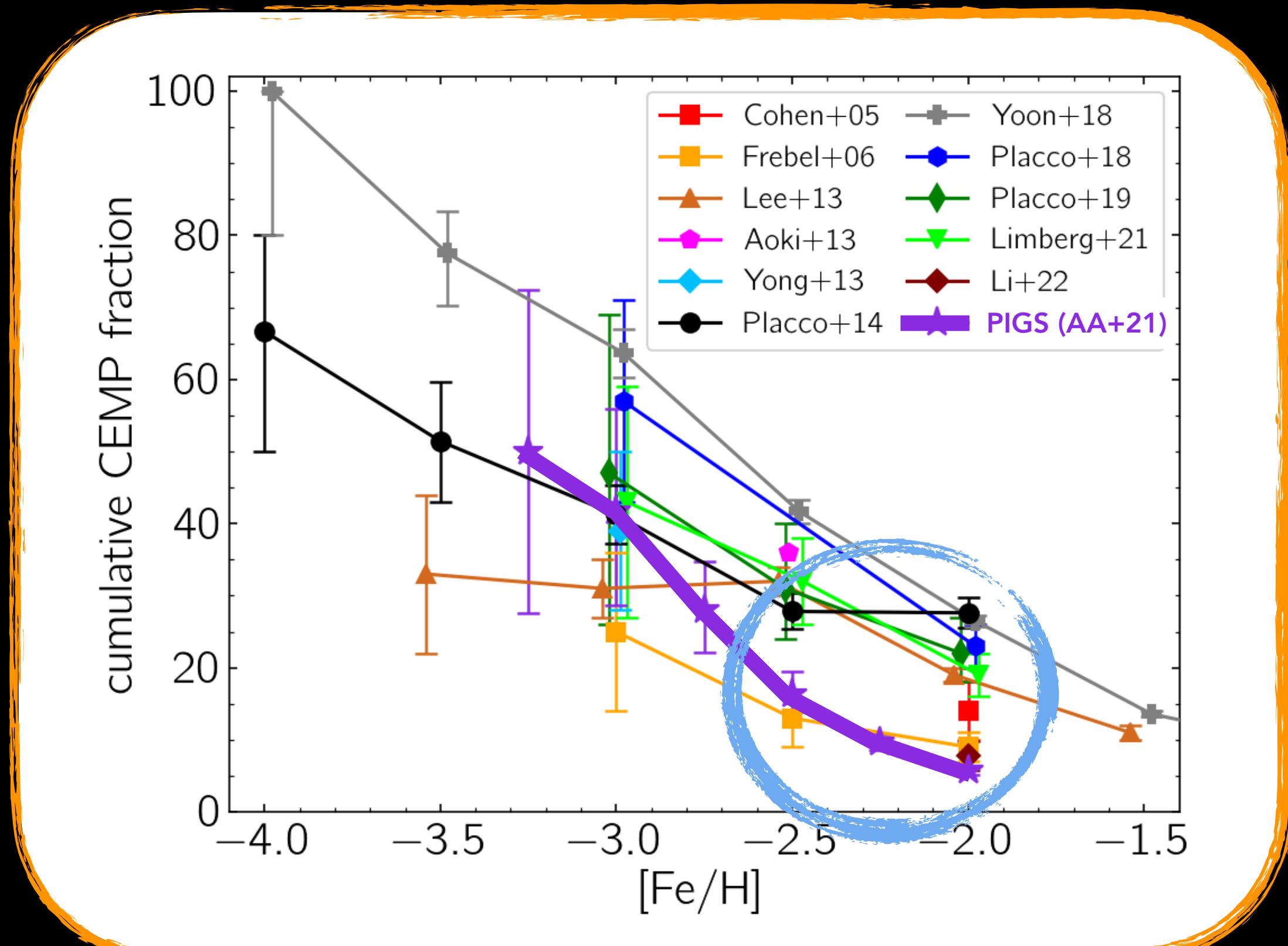
Fraction of CEMP stars in the inner Galaxy

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AA+21,22

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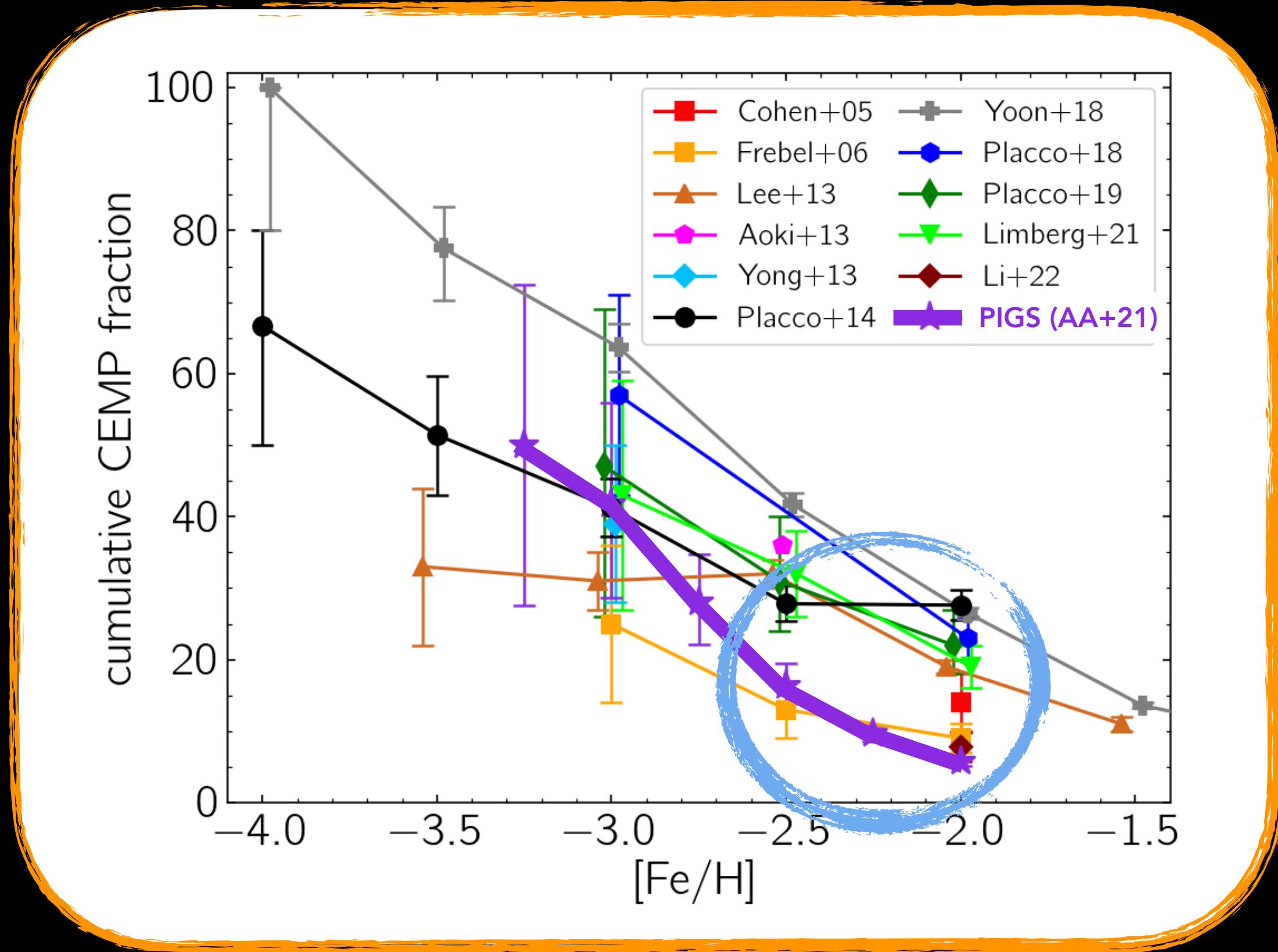


Ignoring all caveats... (do ask me)

Most discrepant in the [Fe/H] regime
of **CEMP-s** stars (binary transfer)

Fraction of CEMP stars in the inner Galaxy

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AA+21,22

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Lower binary fraction?

Globular clusters are expected to
destroy binaries.

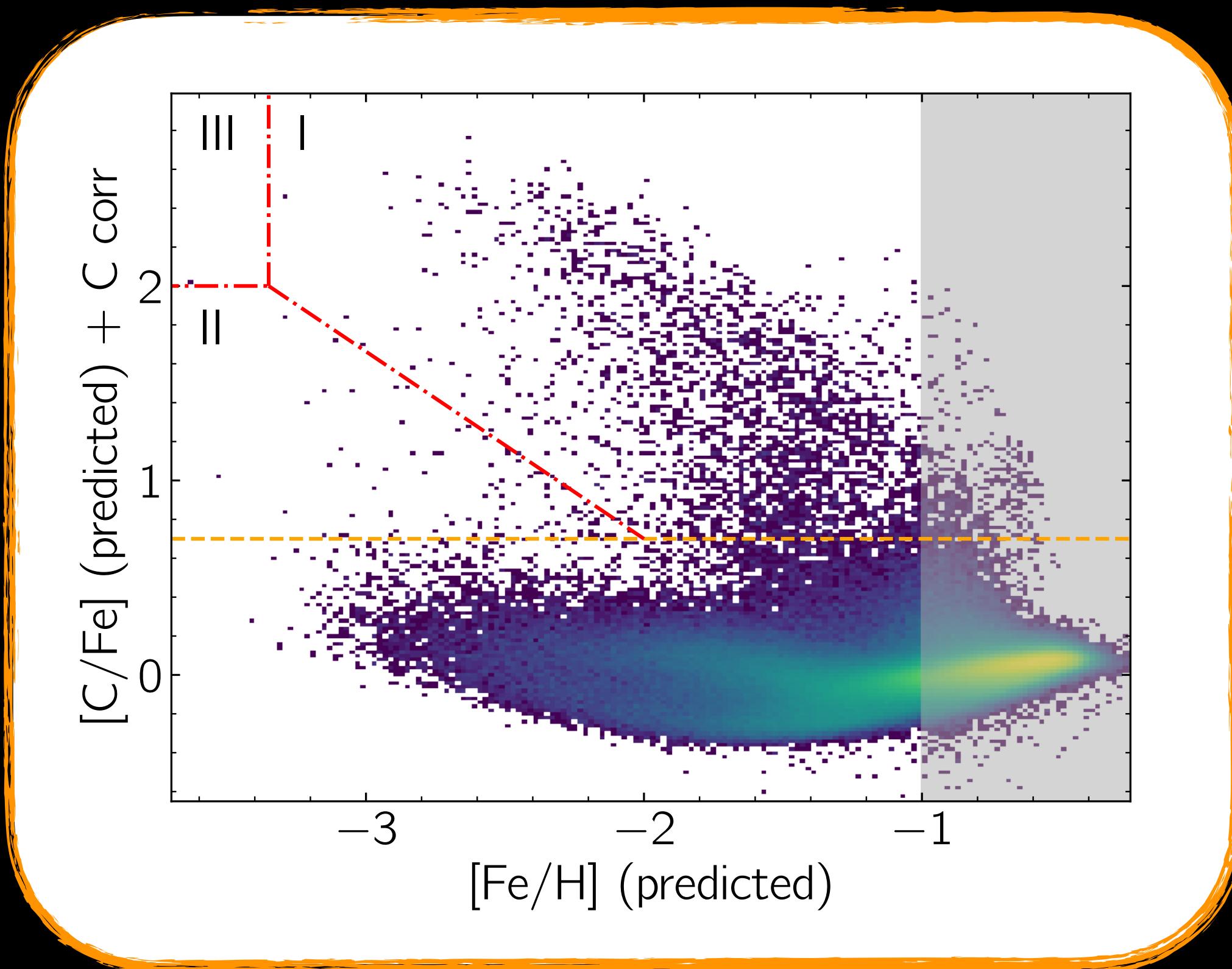
Larger GC contribution among
VMP stars in the inner Galaxy?

Homogeneous all-sky carbon abundances?

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Carbon abundances from millions of Gaia XP spectra using a neural network

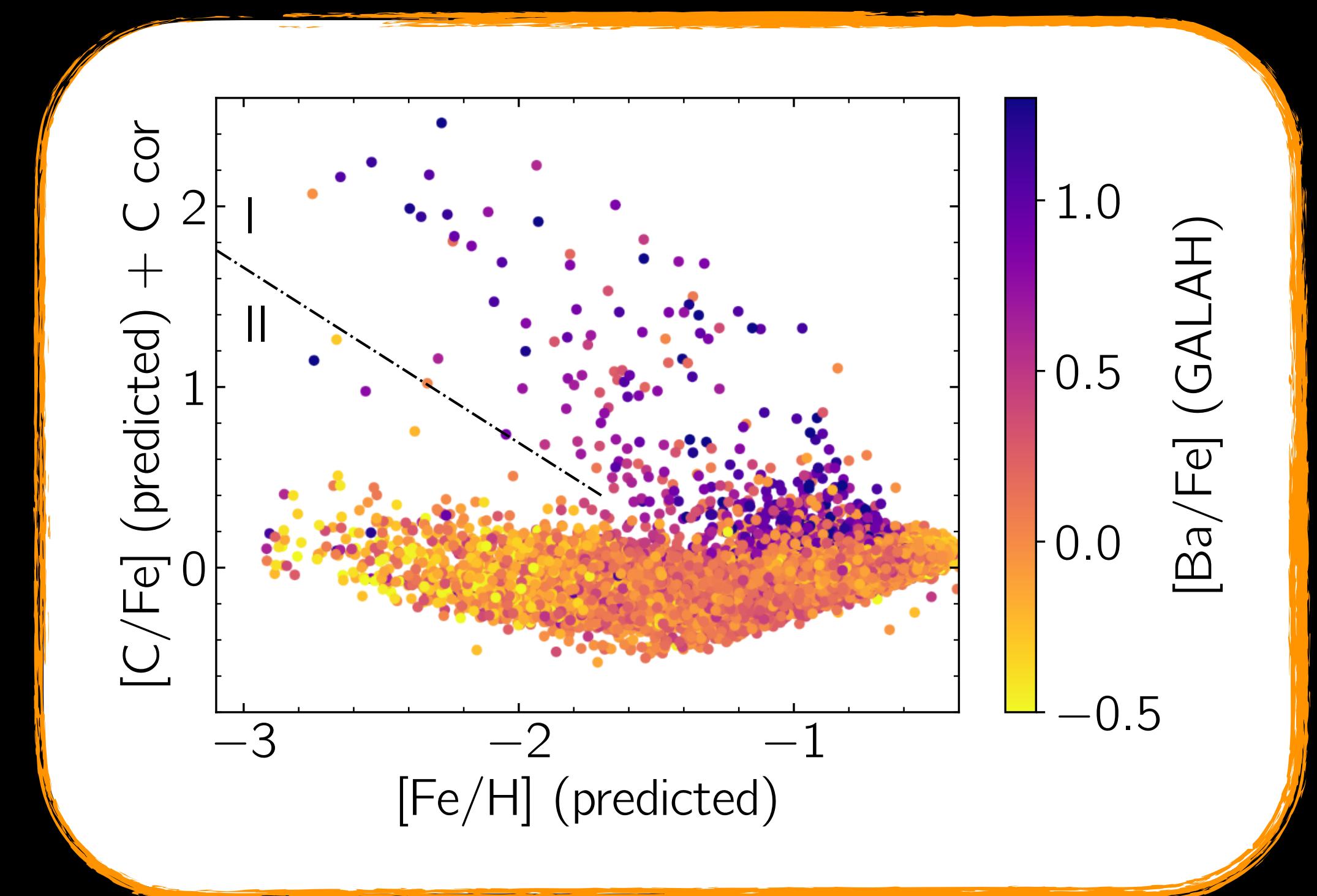
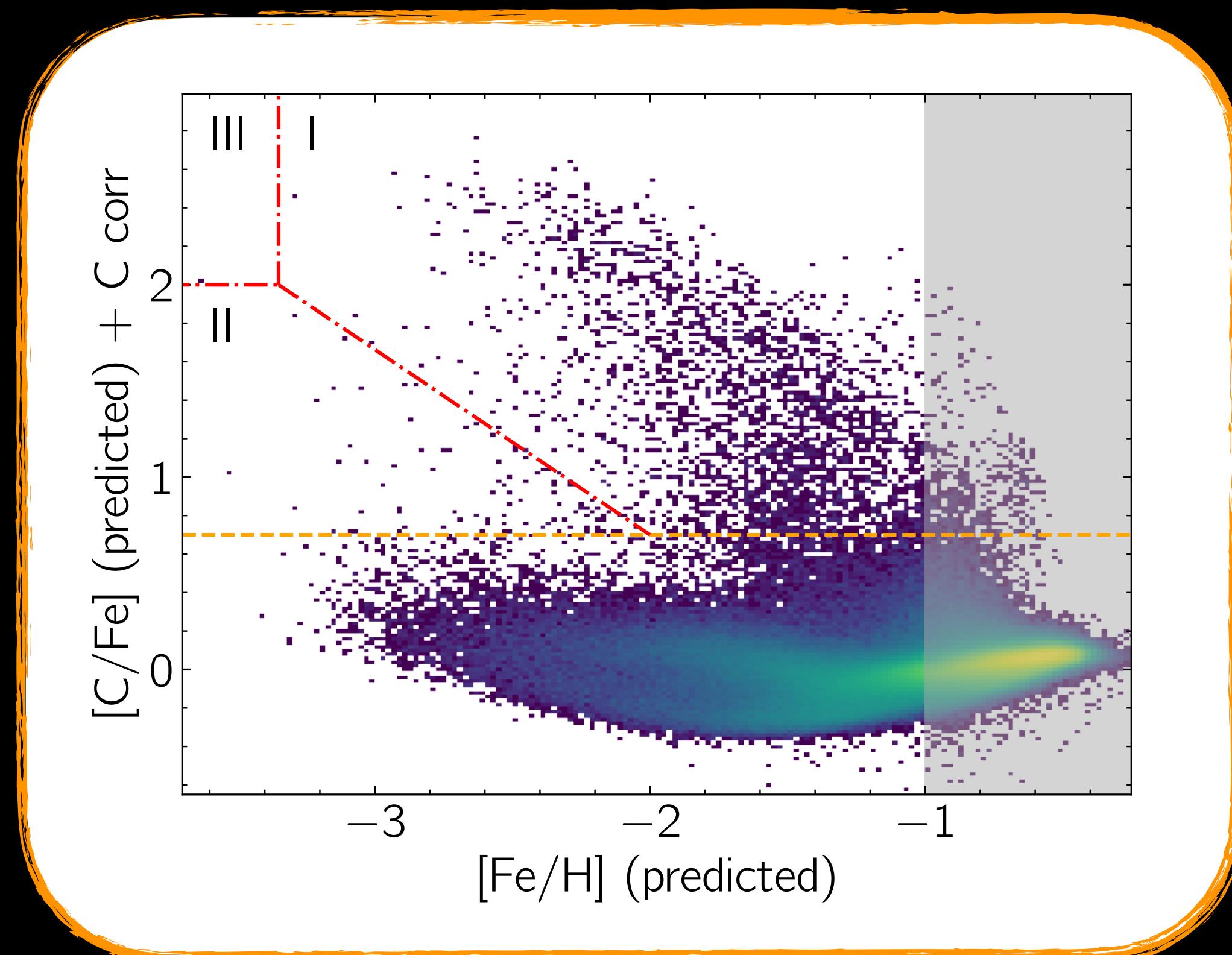
(AA+24b, inspired by Lucey+23)



Homogeneous all-sky carbon abundances?

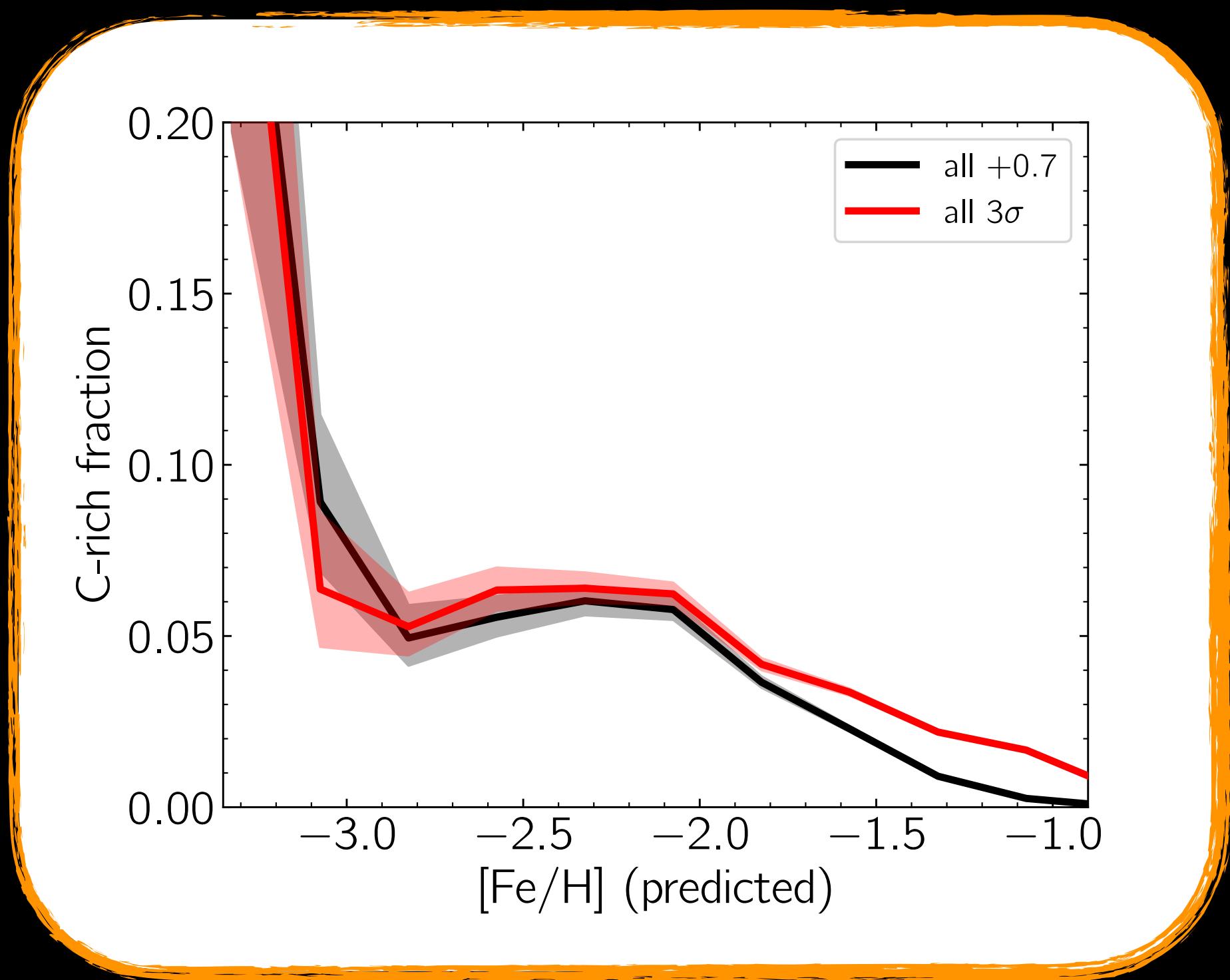
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mostly Ba-rich (binary interaction type)



Frequency of CEMP stars

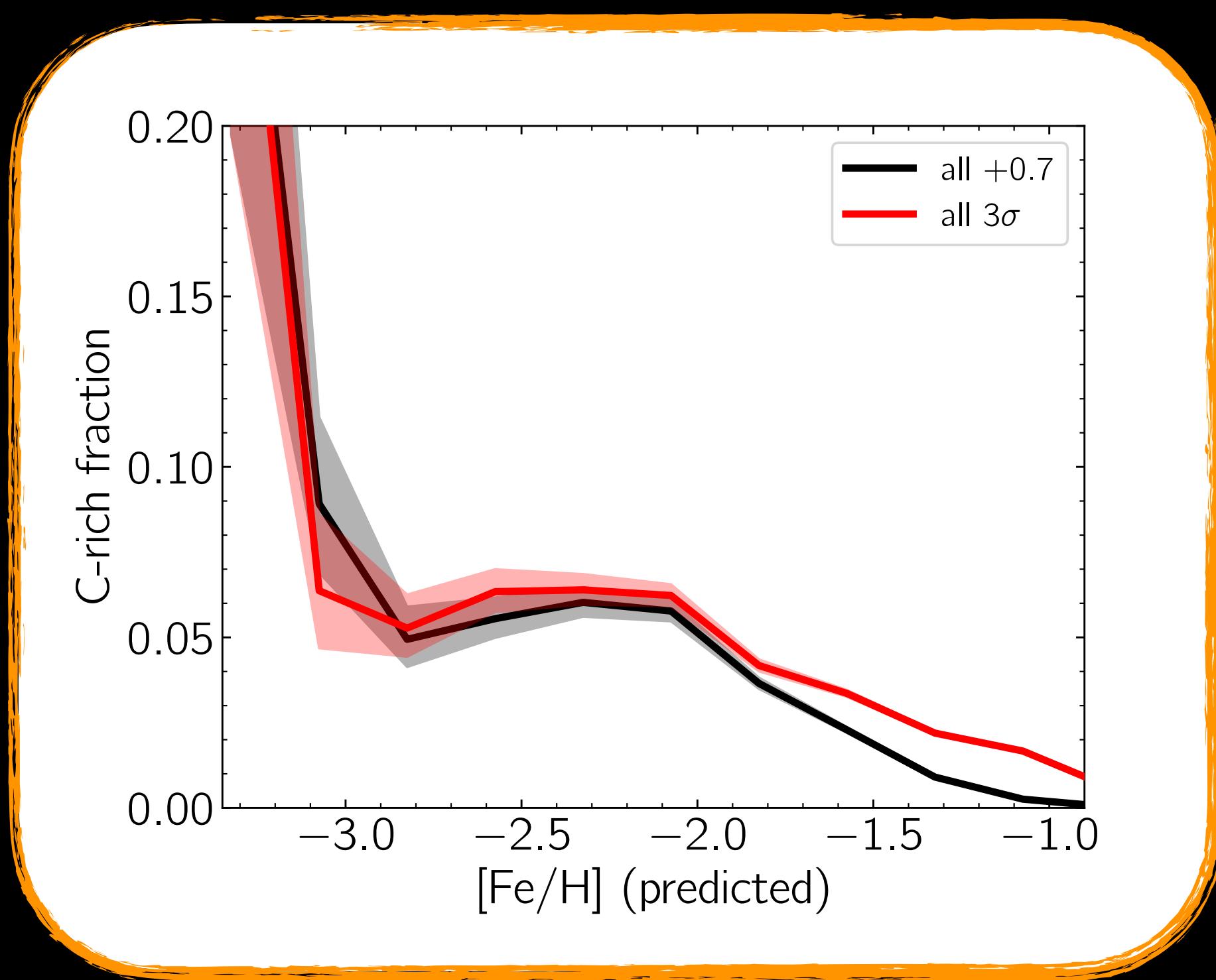
CEMP fraction increases towards lower [Fe/H],
but appears lower than in previous work



AA+24b

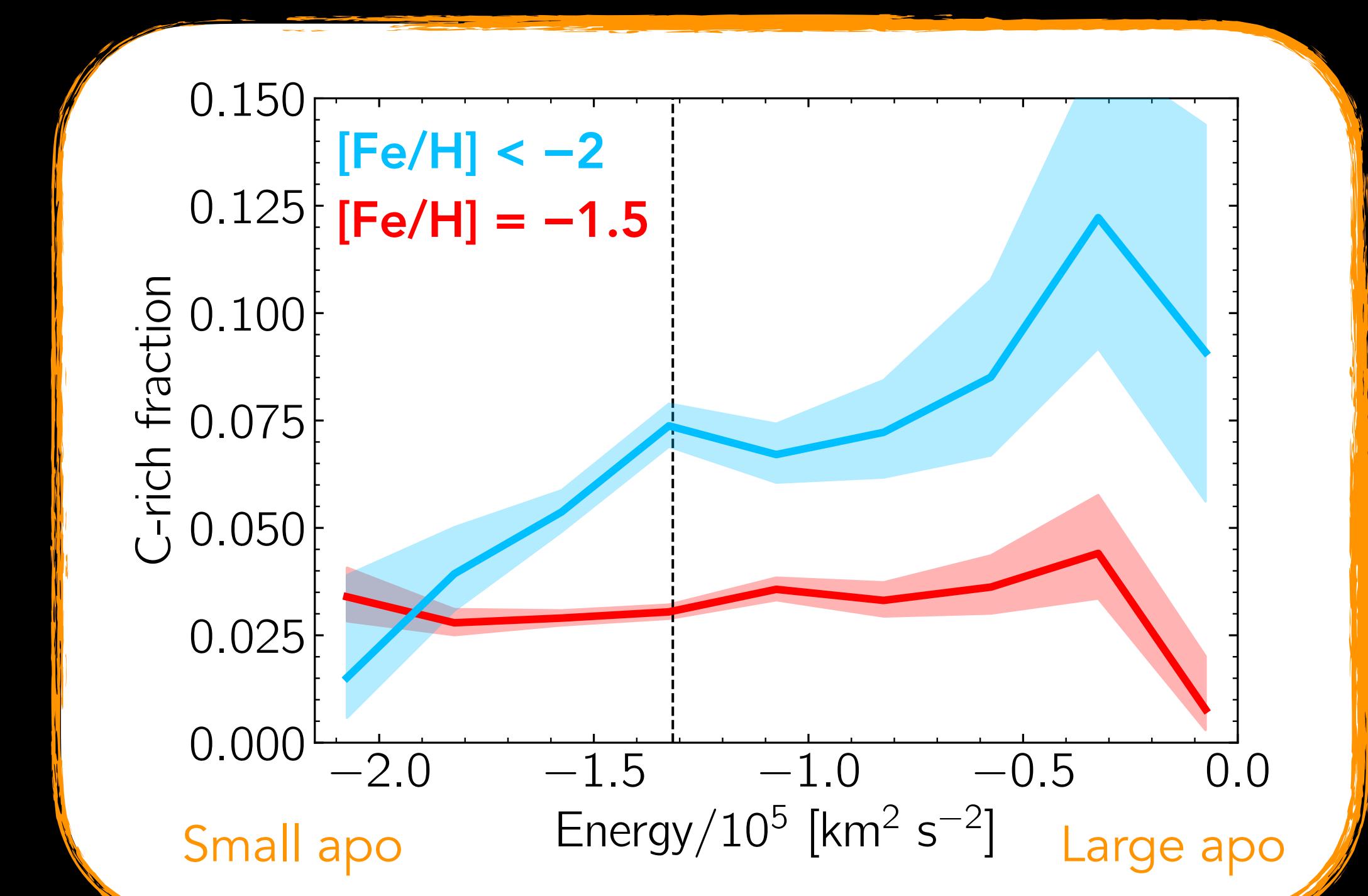
Frequency of CEMP stars

CEMP fraction increases towards lower $[\text{Fe}/\text{H}]$,
but appears lower than in previous work



AA+24b

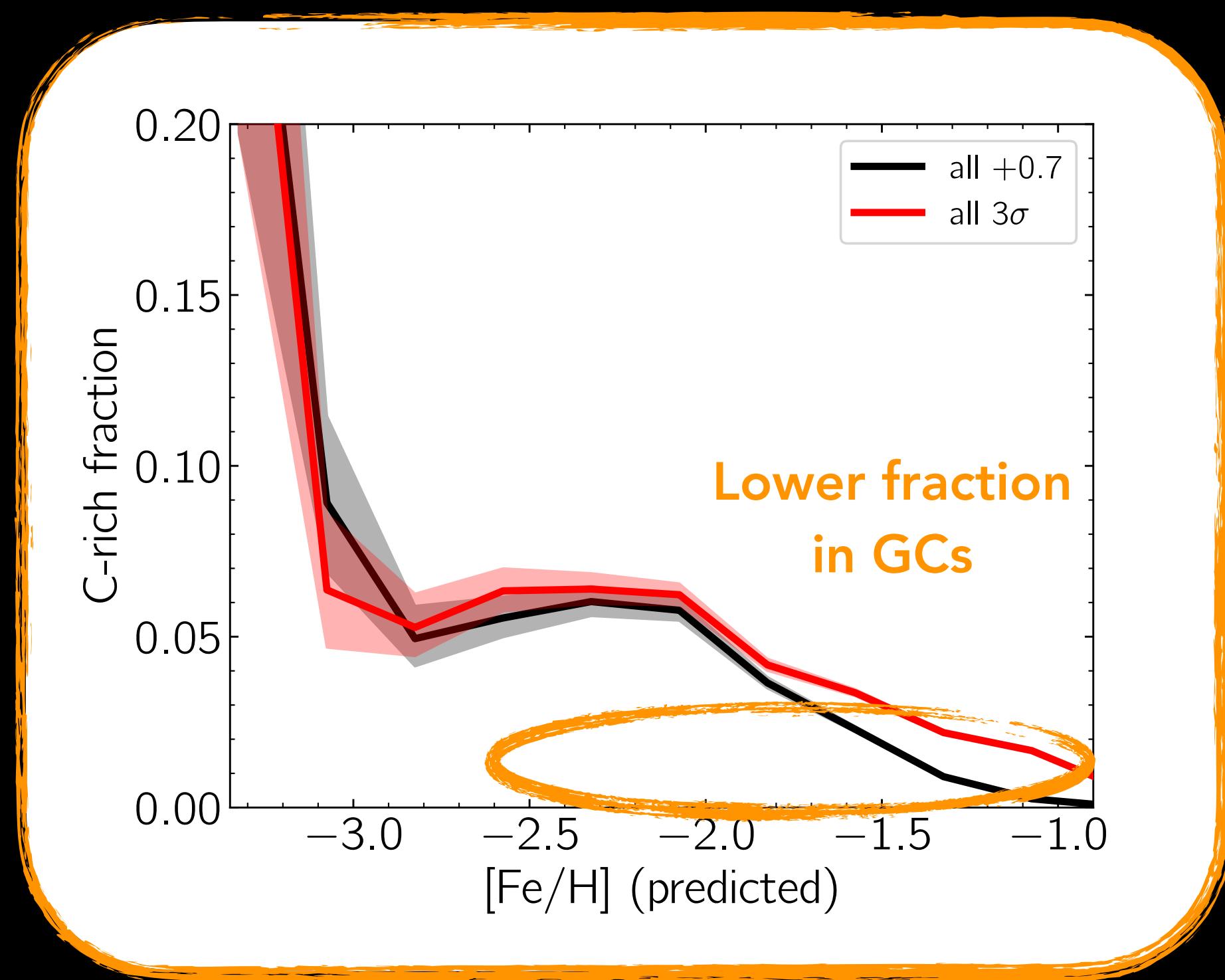
CEMP fraction decreases for more bound stars
(smaller apocentres)



Vertical line: Belokurov & Kravtsov 22
"accreted" vs "in-situ" boundary (apo ~ 10 kpc)

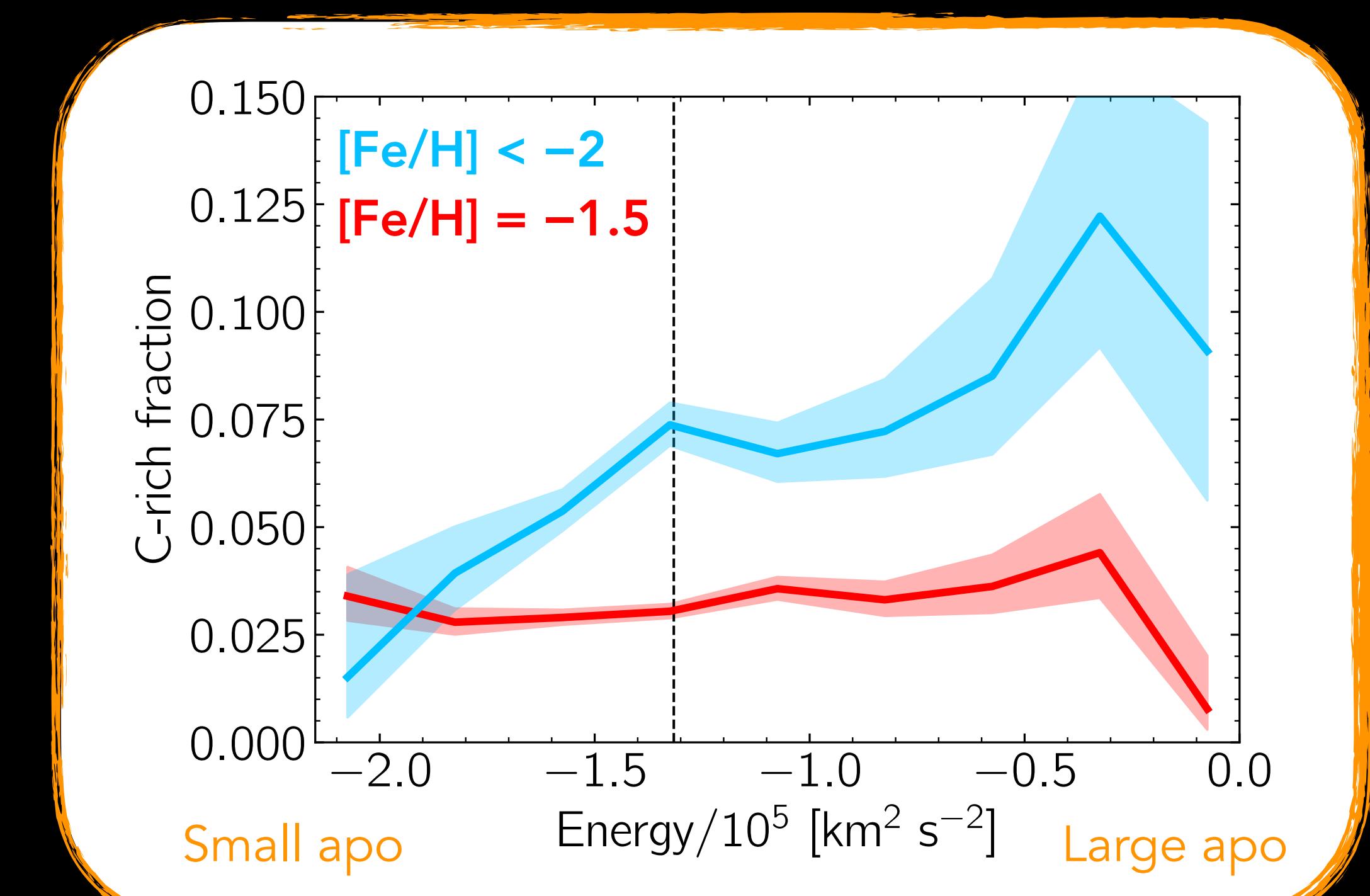
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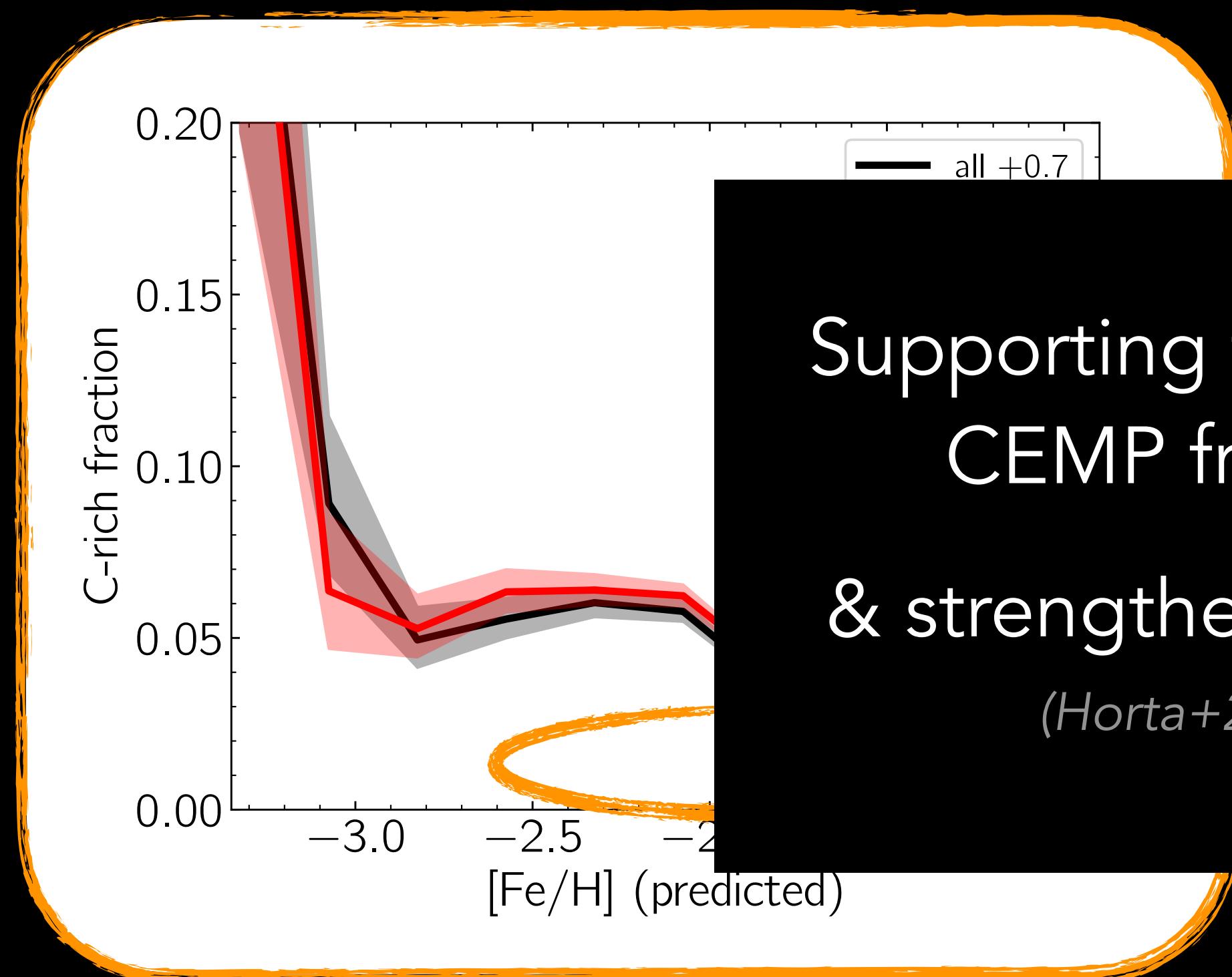


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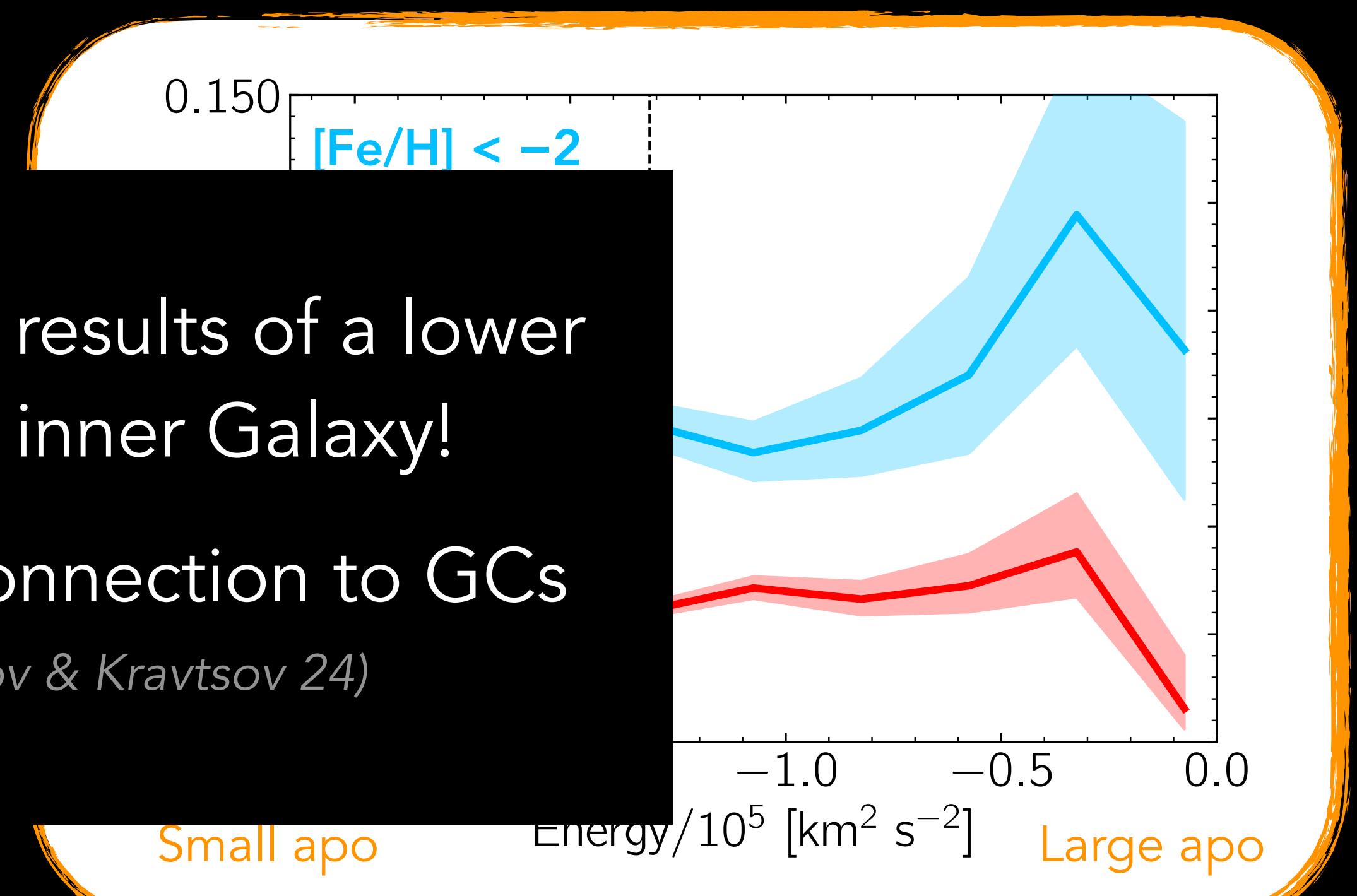
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Supporting the PIGS results of a lower
CEMP fraction in inner Galaxy!

& strengthens the connection to GCs

(Horta+21b, Belokurov & Kravtsov 24)



Small apo

Energy/ $10^5 \text{ km}^2 \text{ s}^{-2}$

Large apo

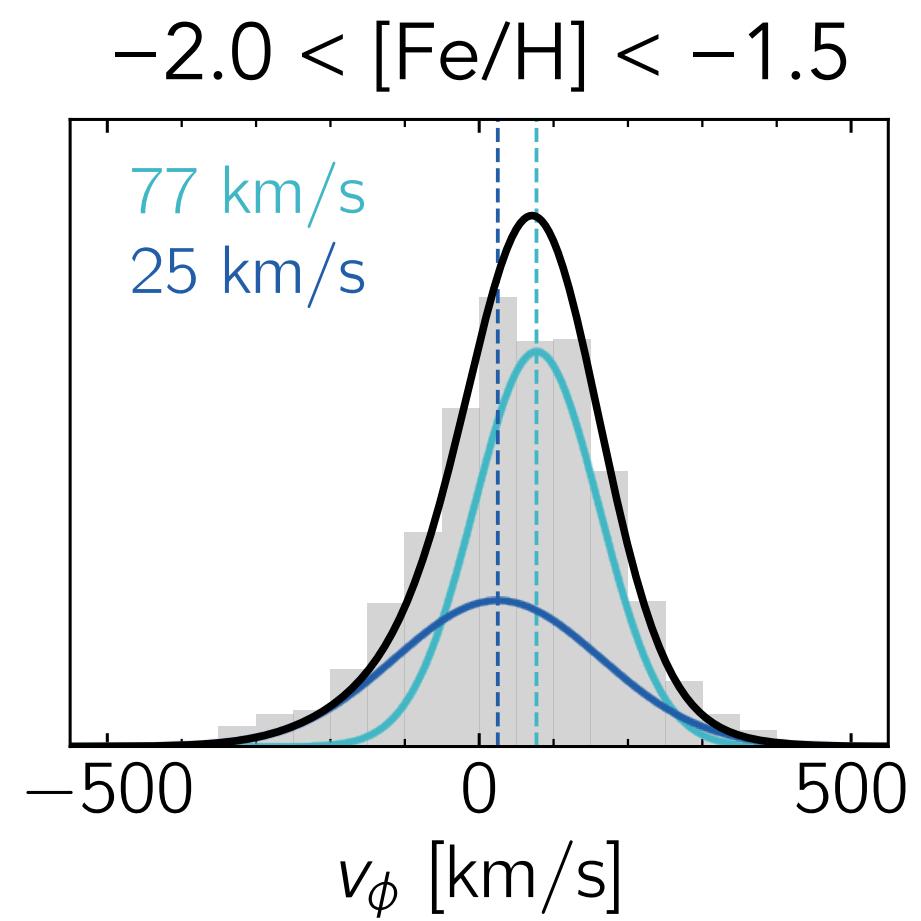
AA+24b

Vertical line: Belokurov & Kravtsov 22
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The ancient heart of the Milky Way

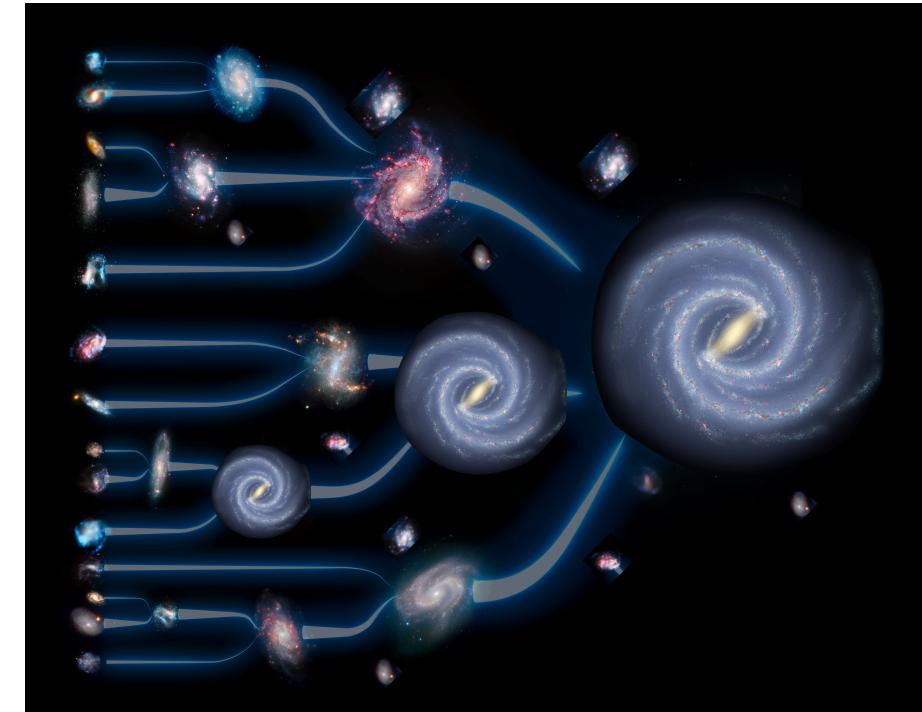
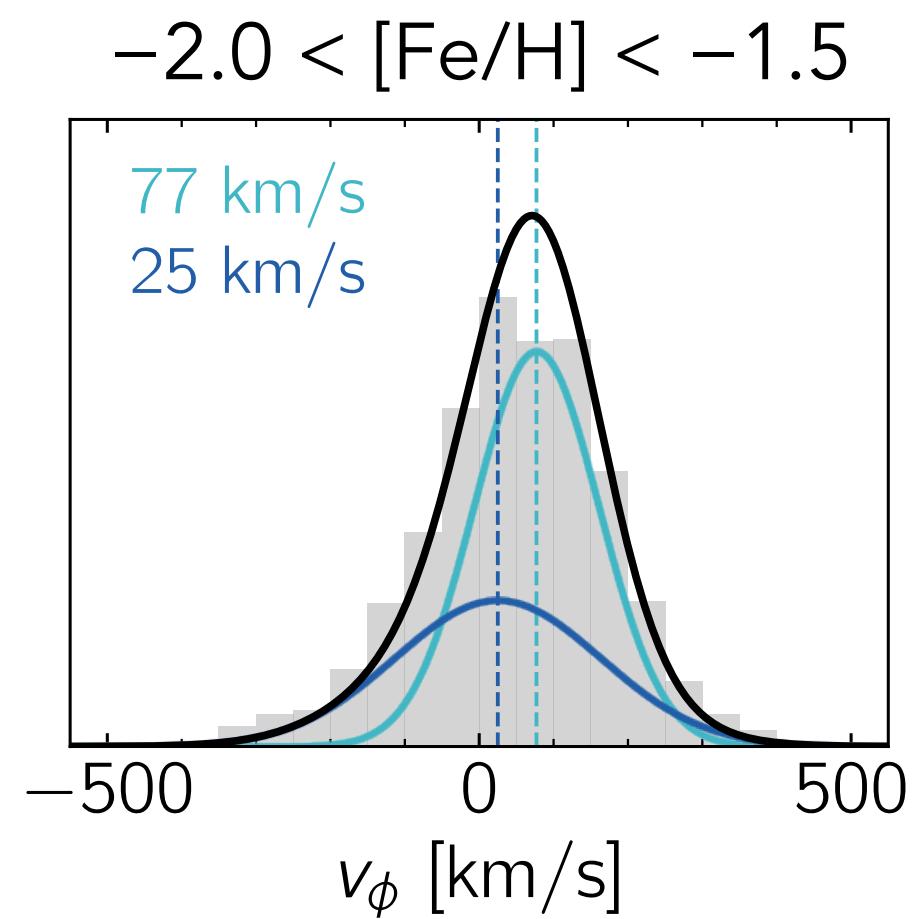
- There is a central, slowly rotating concentration of old stars in our Galaxy





The ancient heart of the Milky Way

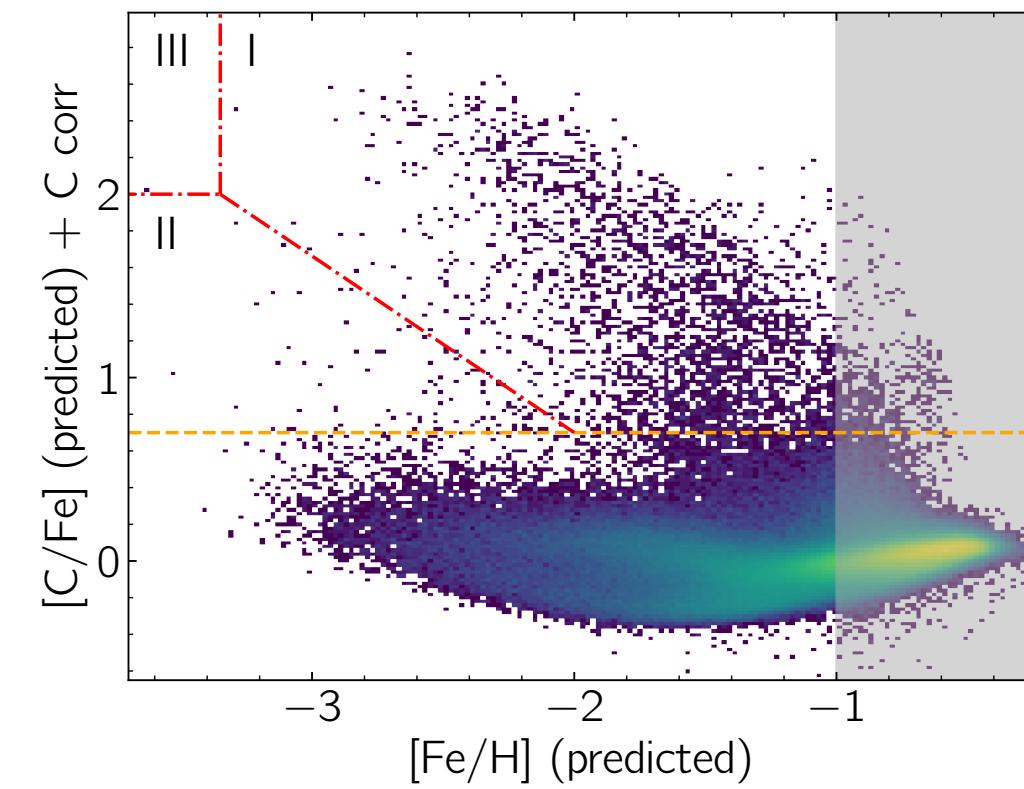
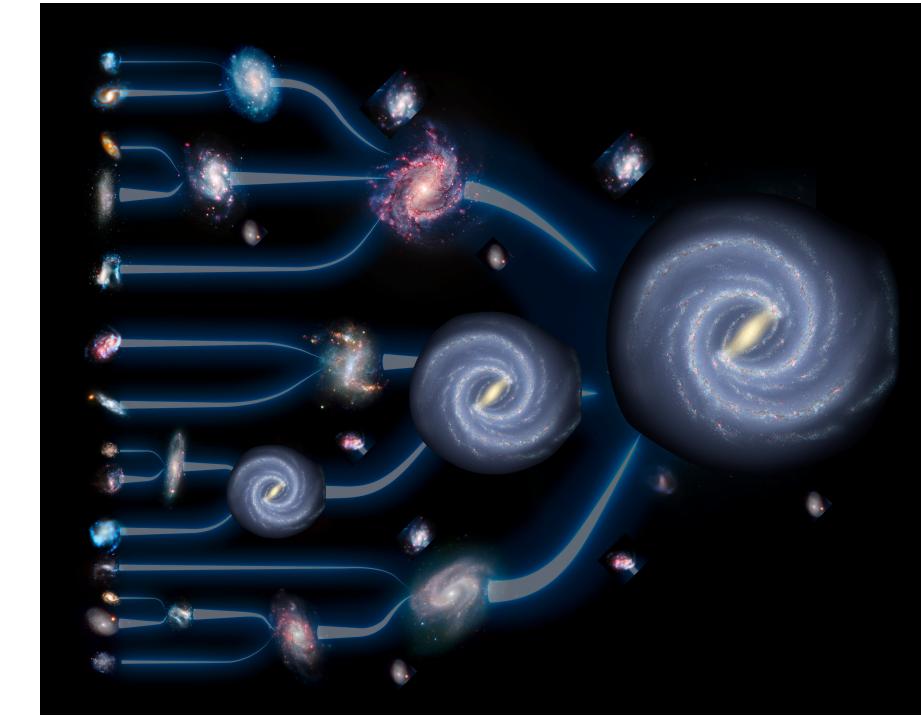
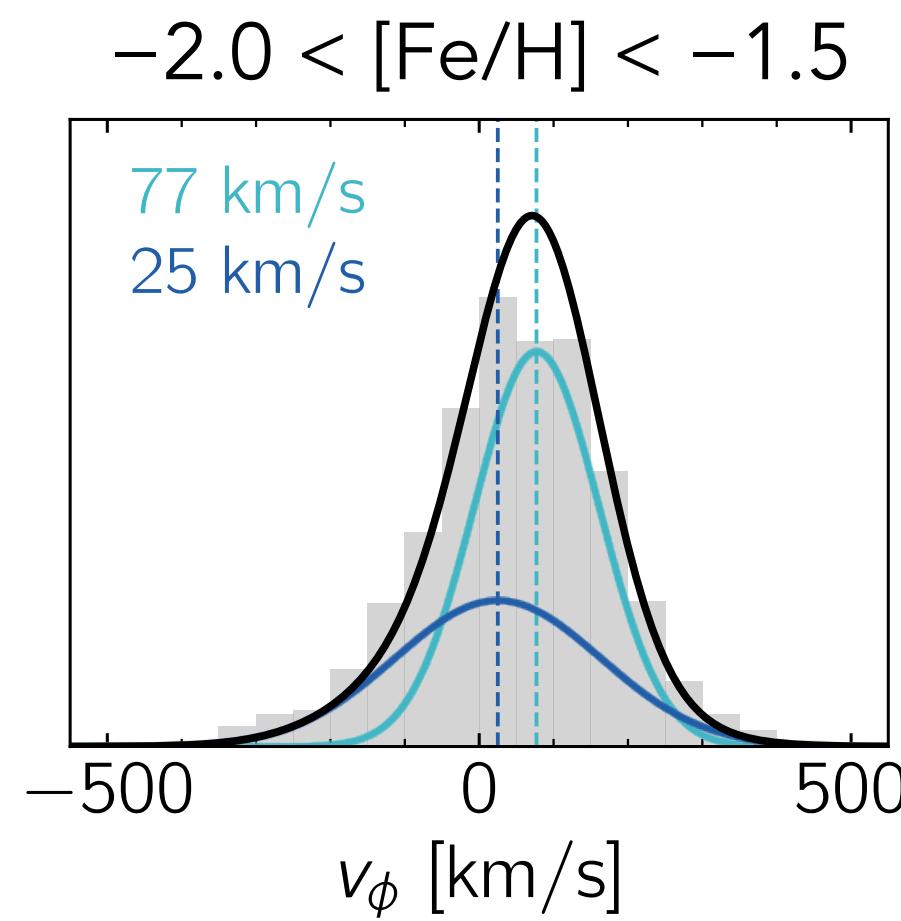
- There is a central, slowly rotating concentration of old stars in our Galaxy
- What is it made of? Probably a mix of *in-situ*, accretion, disrupted GCs, ...





The ancient heart of the Milky Way

- There is a central, slowly rotating concentration of old stars in our Galaxy
- What is it made of? Probably a mix of *in-situ*, accretion, disrupted GCs, ...
- Unique probe: carbon-enhanced metal-poor stars (binaries & early chemical evolution)





The ancient heart of the Milky Way

- There is a central, slowly rotating concentration of old stars in our Galaxy
- What is it made of? Probably a mix of *in-situ*, accretion, disrupted GCs, ...
- Unique probe: carbon-enhanced metal-poor stars (binaries & early chemical evolution)
- Looking forward to 4MOST (especially the 4MIDABLE-LR & HR surveys)

