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Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INAF ISTITUTO NAZIONALE DI ASTROFISICA

Chemical gradients of the thin disc:
NLTE spectral analysis of Classical Cepheids

Antonino Nunnari
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Supervisors:
Giuliana Fiorentino, Valentina D'Orazi, Giuseppe Bono

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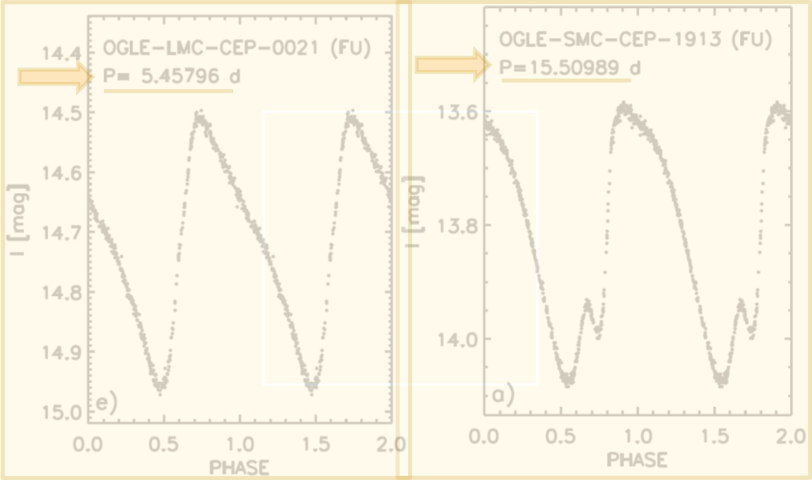
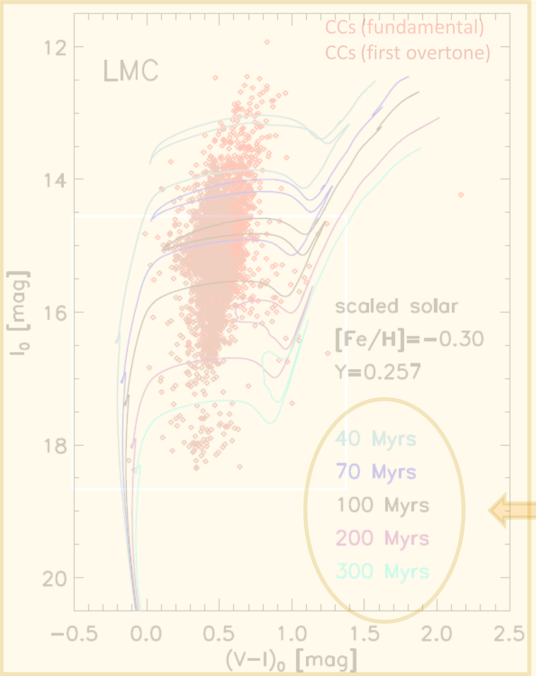
Classical Cepheids

Radially pulsating stars



Periods from days to months



Young stars

See Bono+24 review

Classical Cepheids

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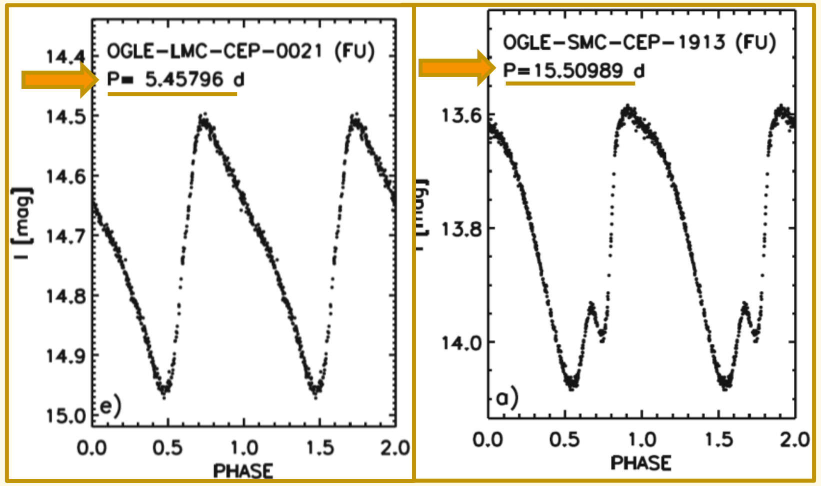

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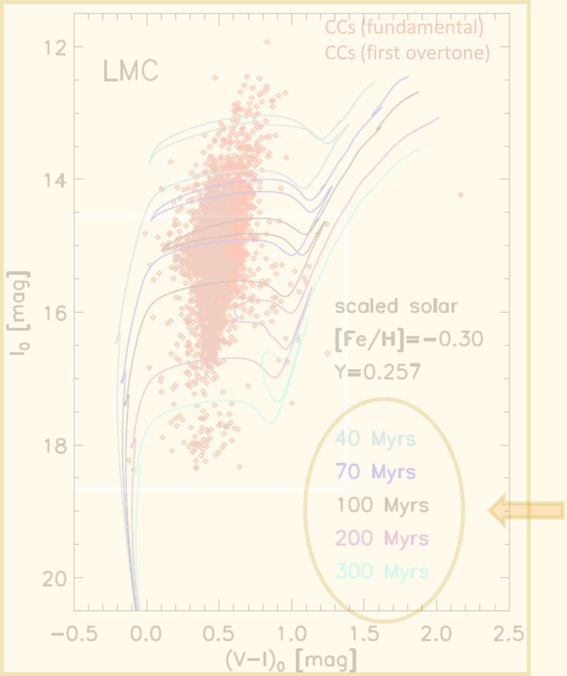

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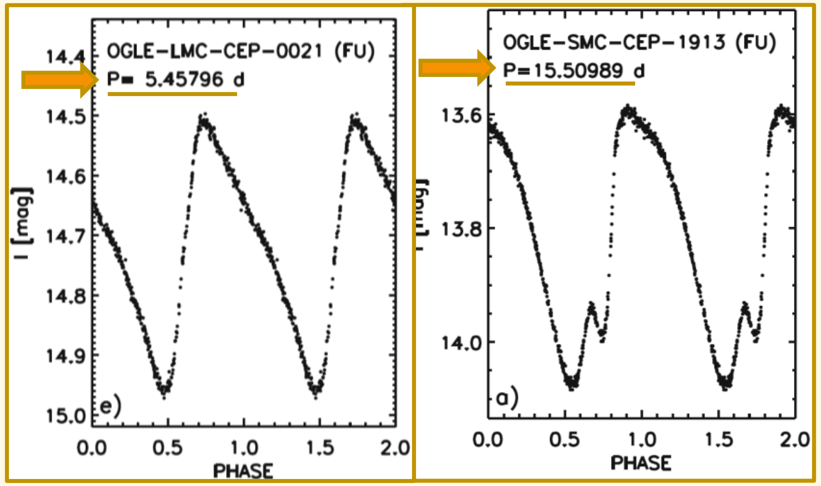

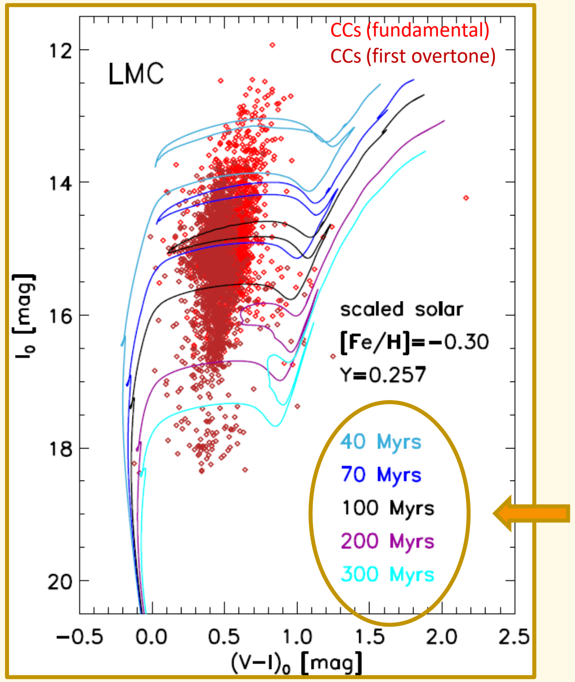

Radially pulsating stars

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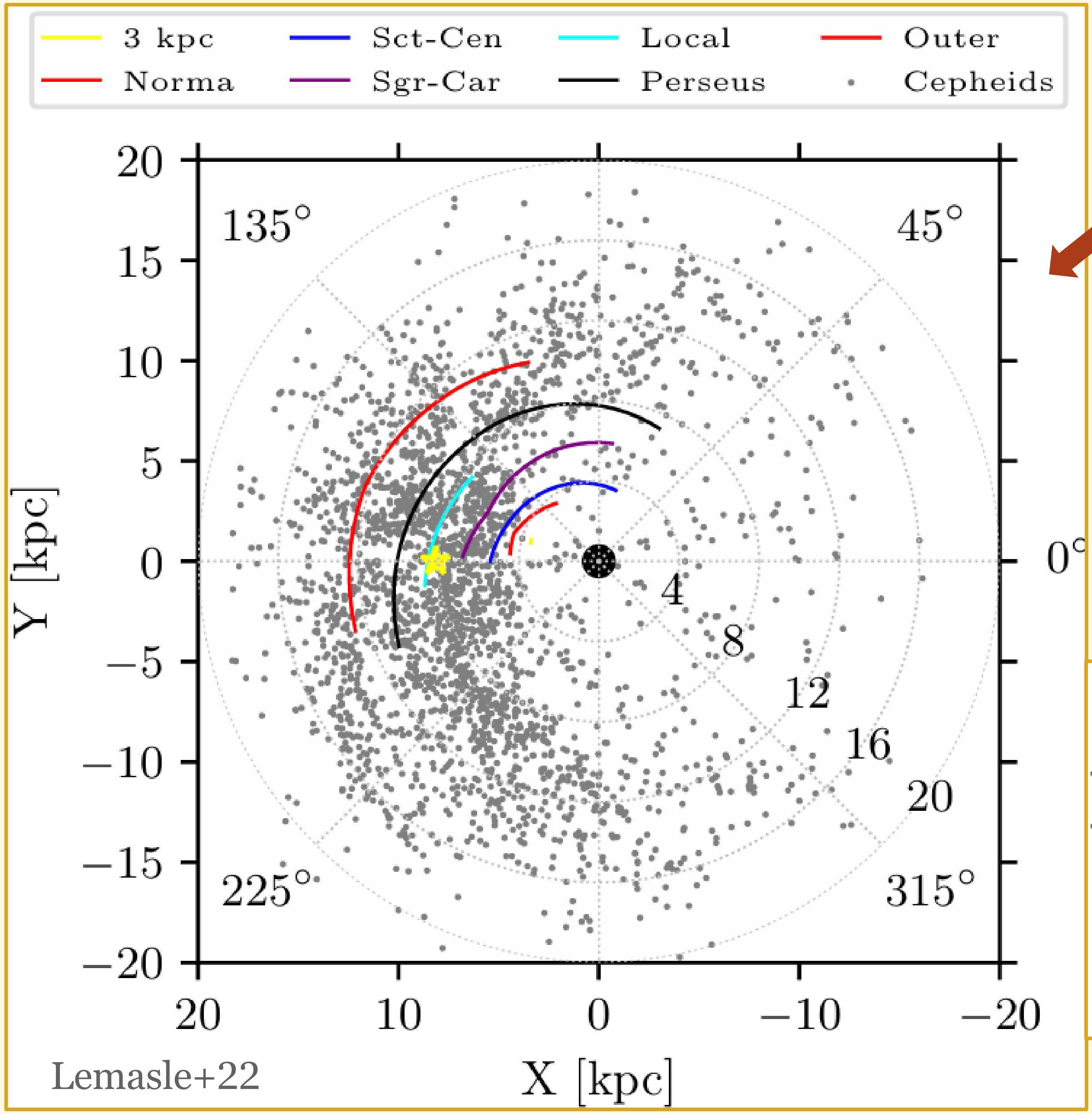
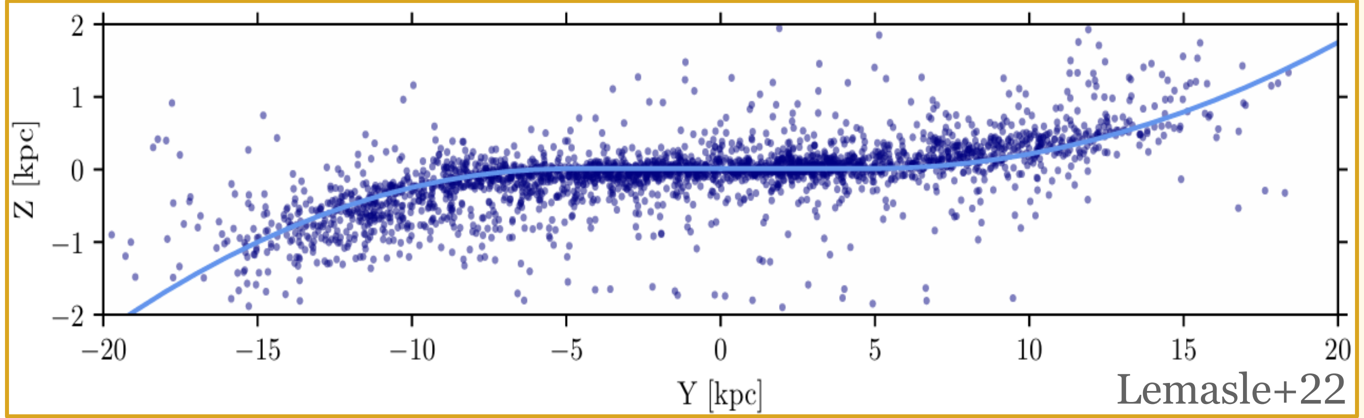


Galactic plane
(face on)

Classical cepheids
trace the thin disc!

Galactic plane
(edge on)



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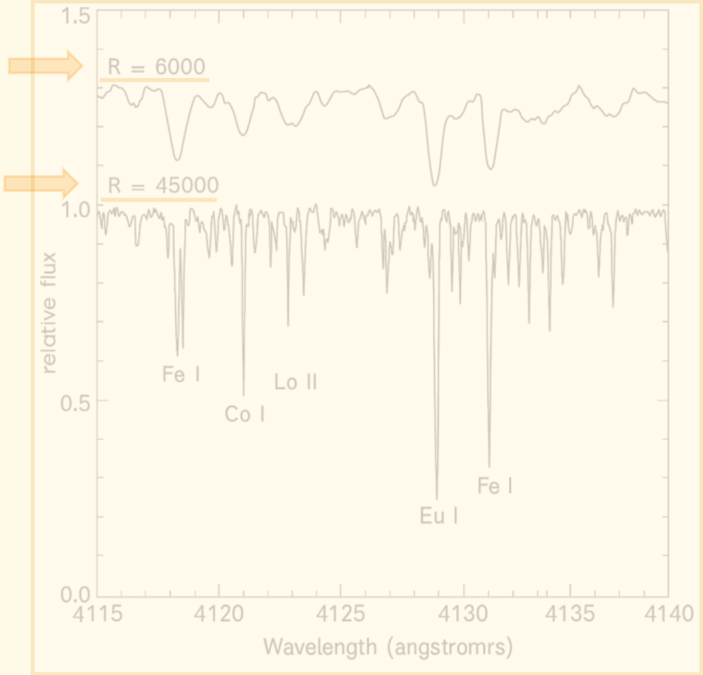
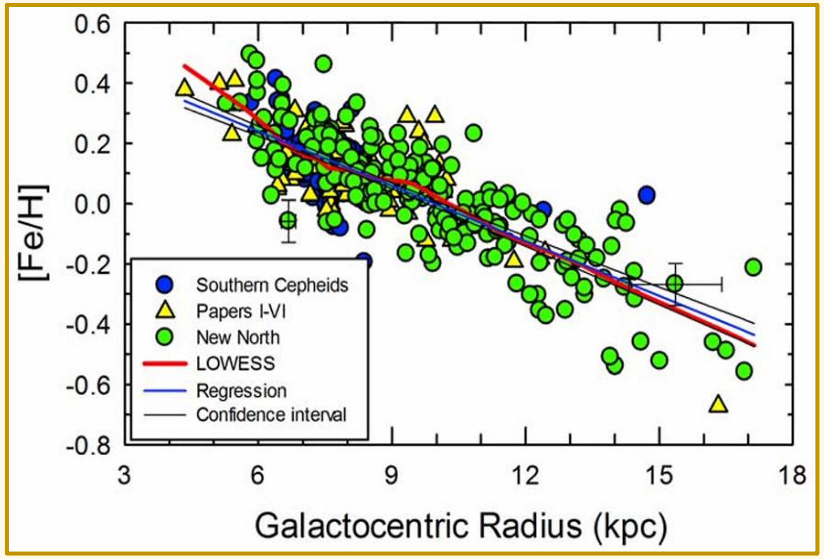
Abundance gradients

Chemical enrichment history

High Resolution Spectroscopy

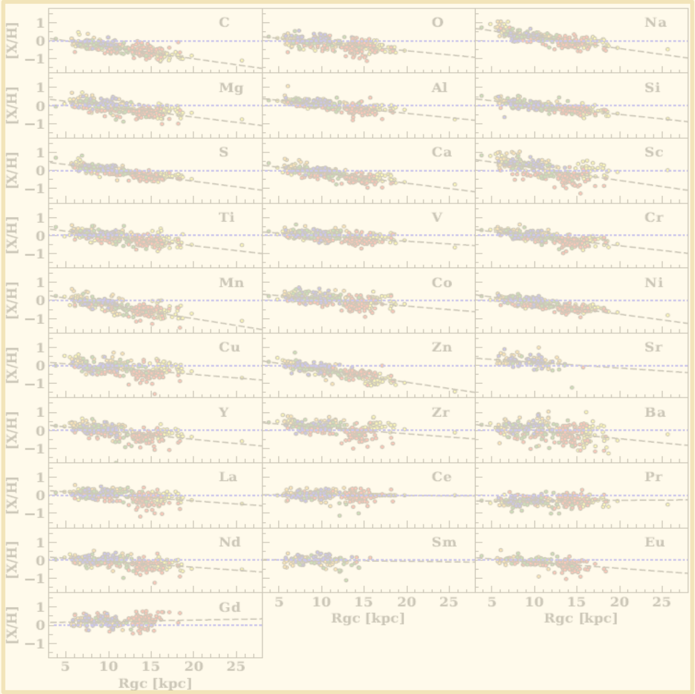


R. Guhathakurta, UCSC



Luck & Lambert 2011
Genovali+14

Elements from each production channel



Trentin+24

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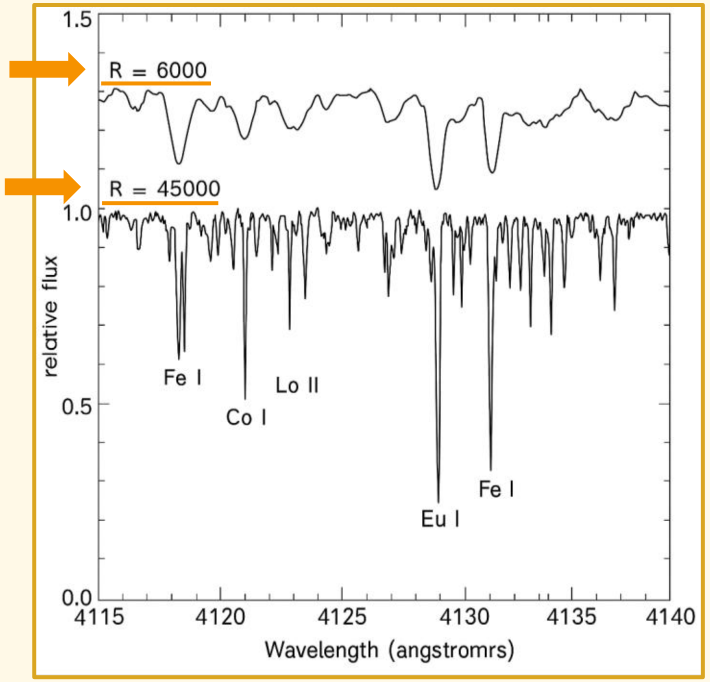

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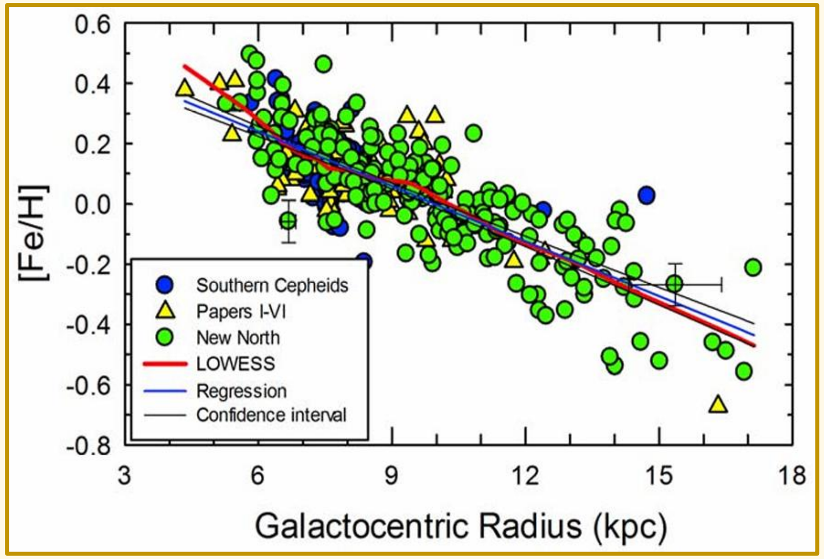

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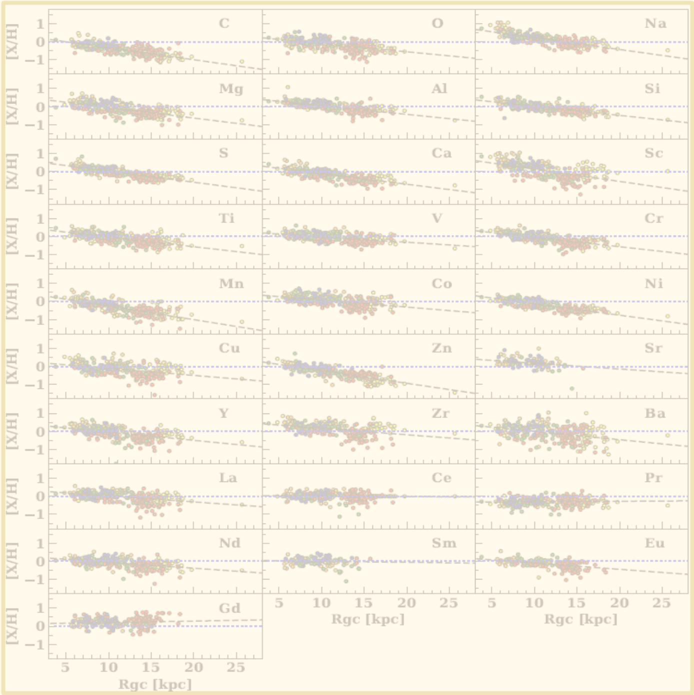

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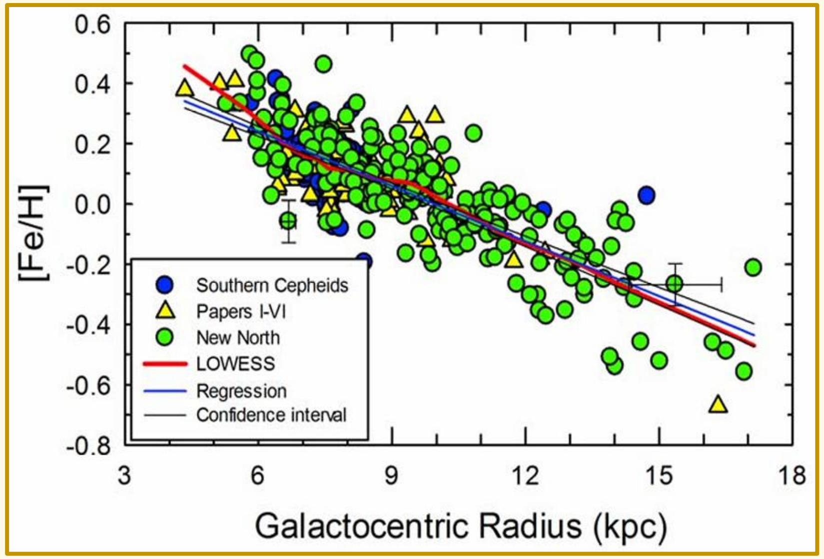

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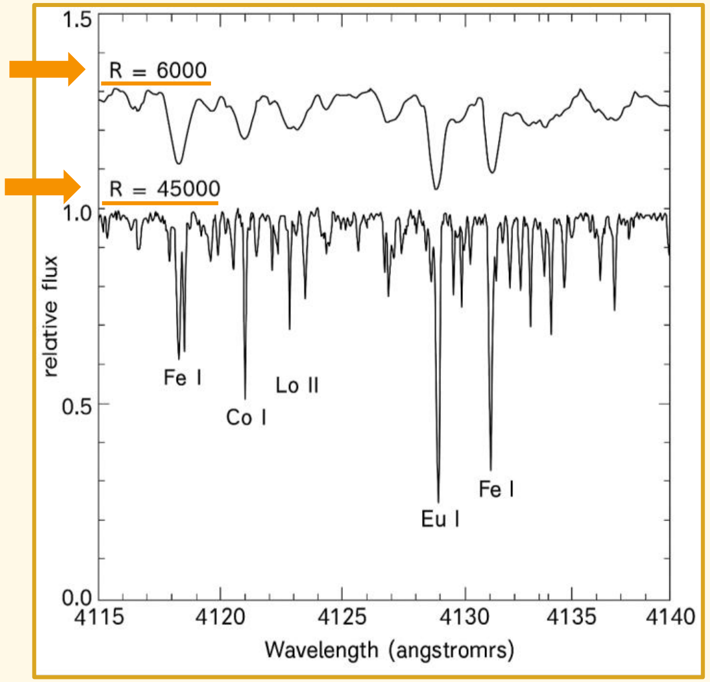

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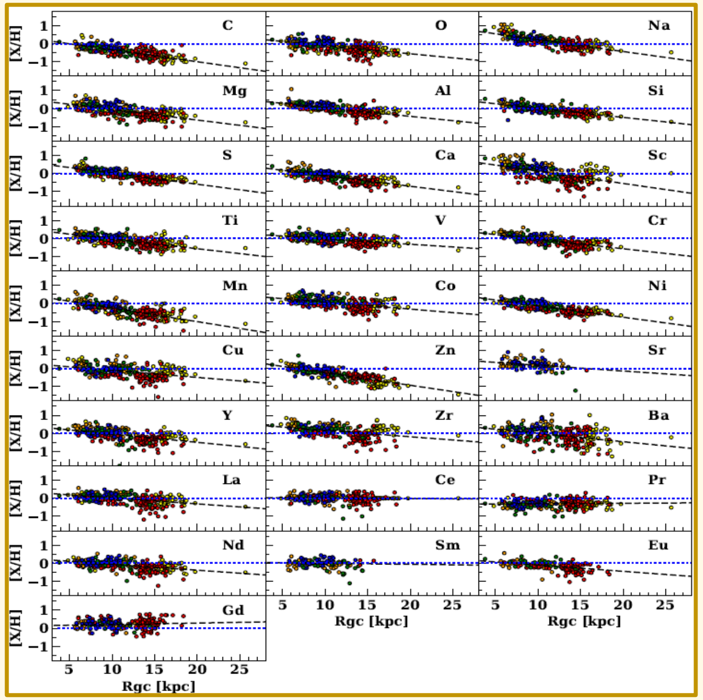

Trentin+24

Non Local Thermal Equilibrium (NLTE)

1D LTE models	Romaniello+08, Genovali+13 Luck+11, Luck & Lambert+11 Andrievsky+05, Andrievsky+14 da Silva+22, Ripepi+22, Trentin+24
Systematic errors	
Element and line dependent	
New NLTE grids available	

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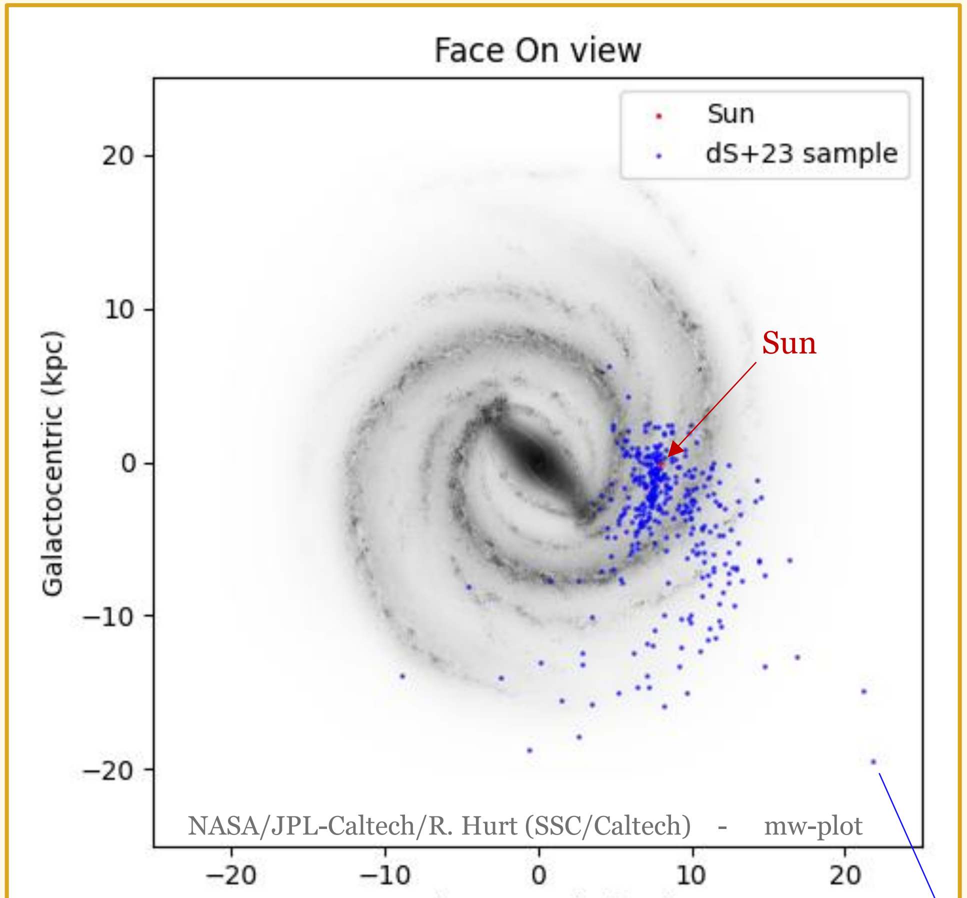
(optical) HR spectra dataset



Nunnari+ (in prep.)

$R_{GC} \simeq 29kpc$
(currently the farthest with HR spectrum!)

1285 HR spectra, 379 Classical Cepheids — da Silva+23

Spectrograph	N. of spectra	N. of stars	Resolution	Coverage [Å]
HARPS	183	10	~115000	[3790-6900]
STELLA	400	64	~55000	[3860-8800]
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UVES	363	215	~40000	[3800-9400]

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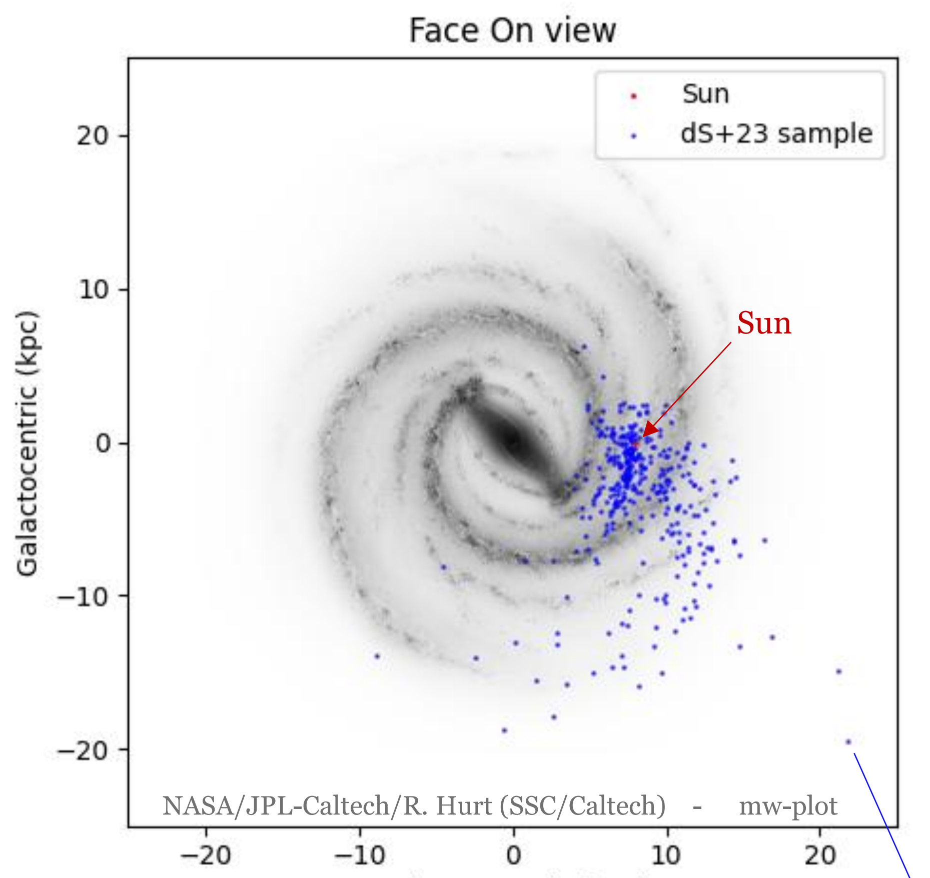

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39 HARPS-N from Inno L. and Ripepi V. programs

11 UVES from Ripepi V., Martin R. P., Andrievsky S. M. and Kovtyukh V. programs

16 ESPADONS from Martin R. P. programs

1351 HR spectra, 400 cepheids

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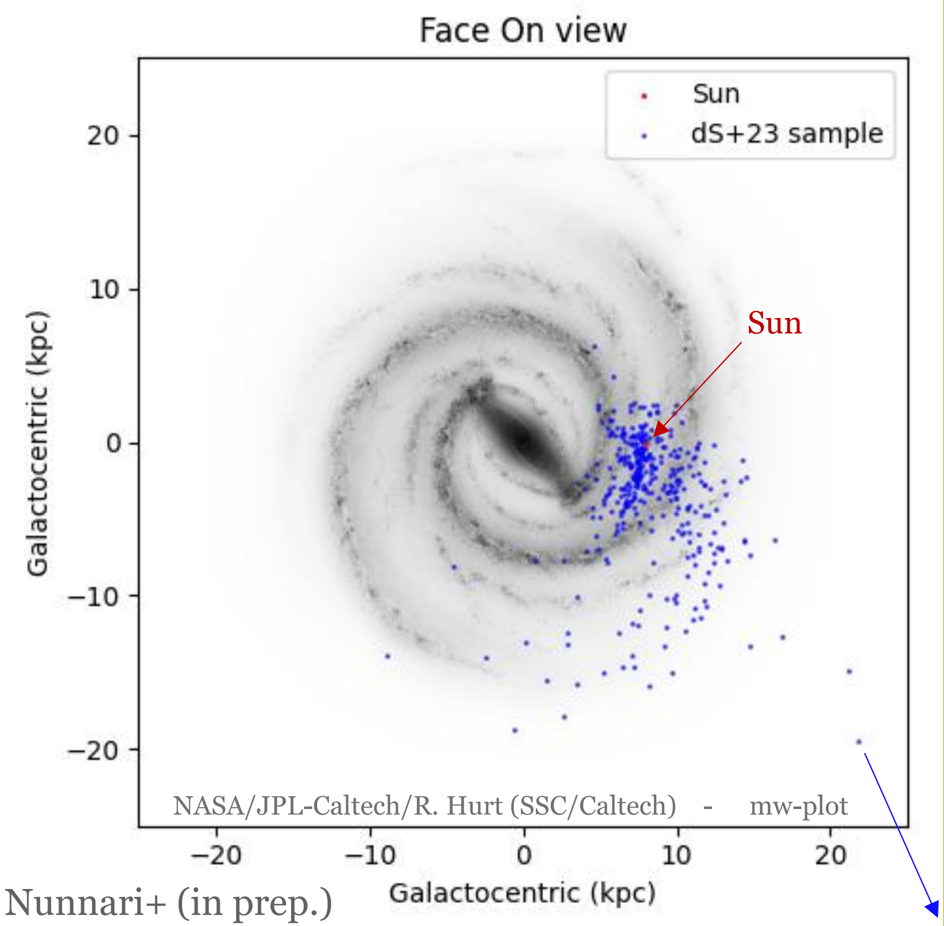

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1351 HR spectra, 400 cepheids

S/N $\gtrsim$ 100

$\sigma(T_{EFF}) \lesssim 12$ K

$\sigma(Log(g)) \lesssim 0.014$ dex

$\sigma([X/H]) \lesssim 0.01$ dex

Brewer+16

NLTE spectral analysis

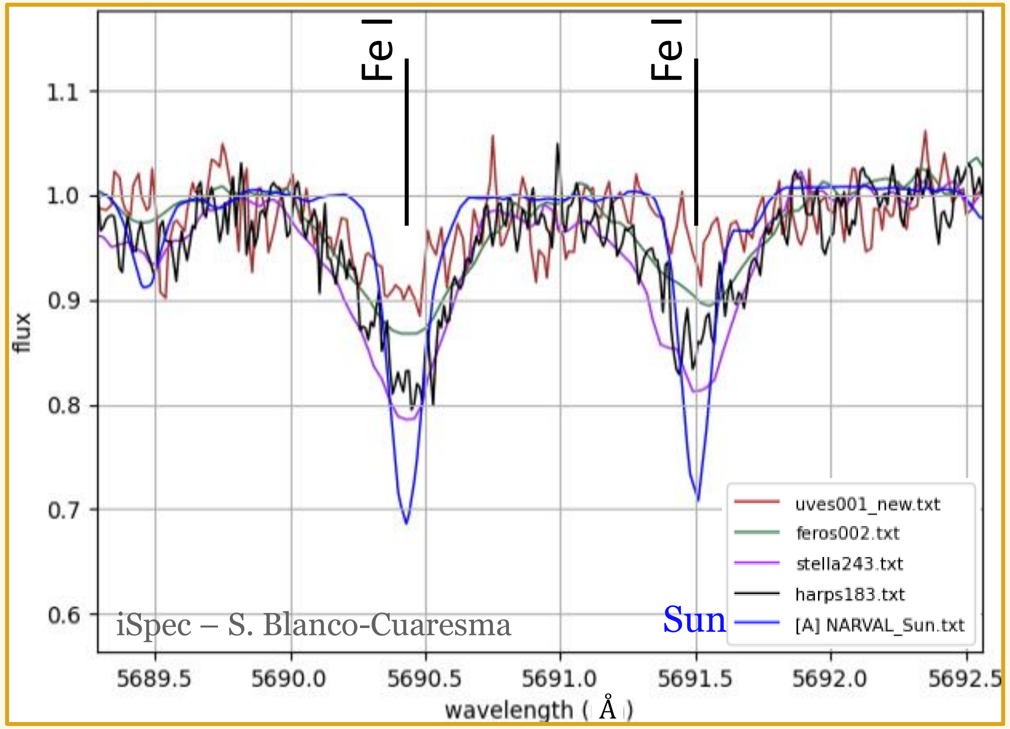
pySME + NLTE grids

Piskunov & Valenti 2017 — Amarsi+20

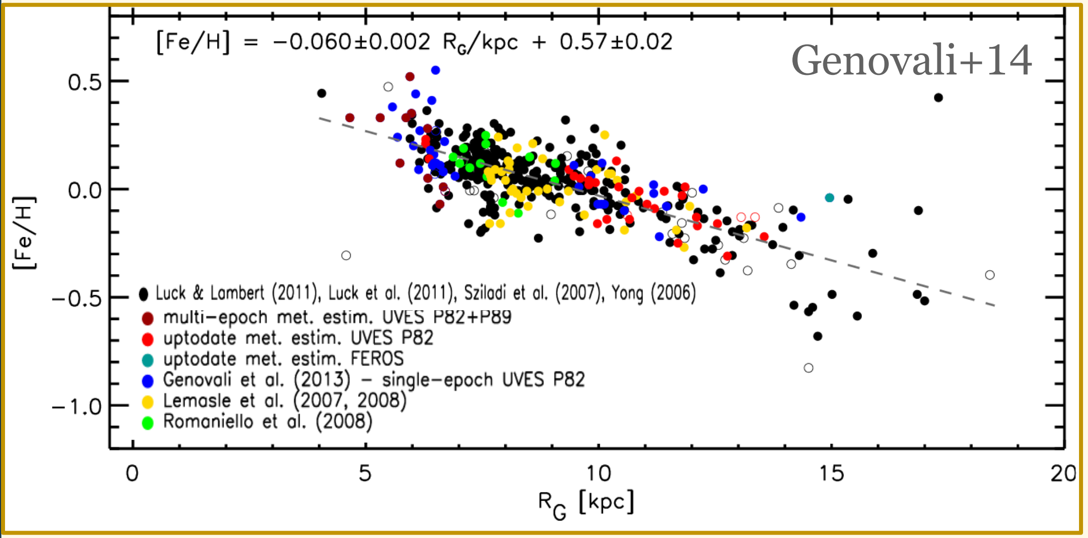
Synthesis of 40 lines (FeI, FeII, TiI, TiII)

↓

NLTE atmospheric parameters



Iron gradient



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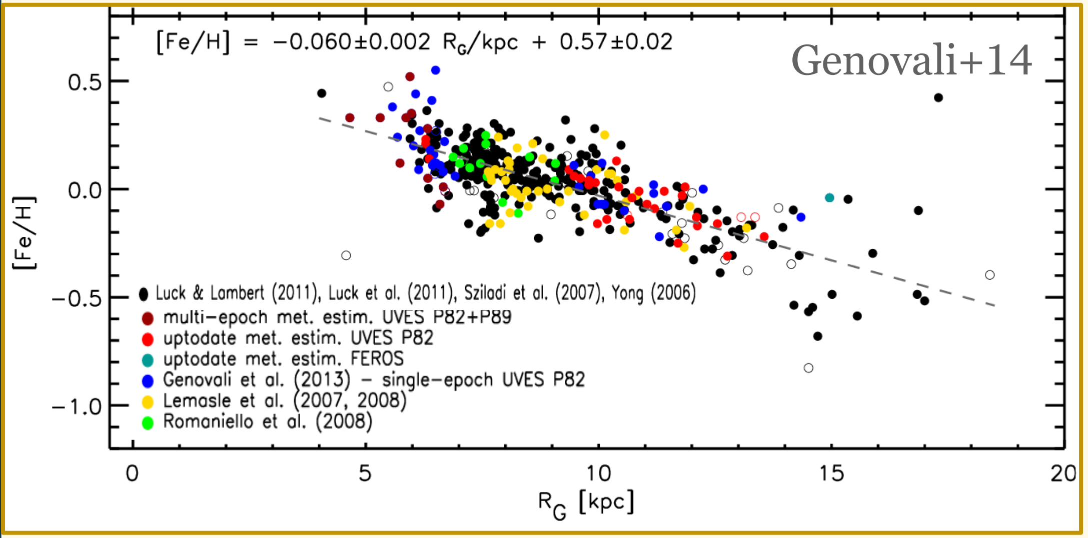

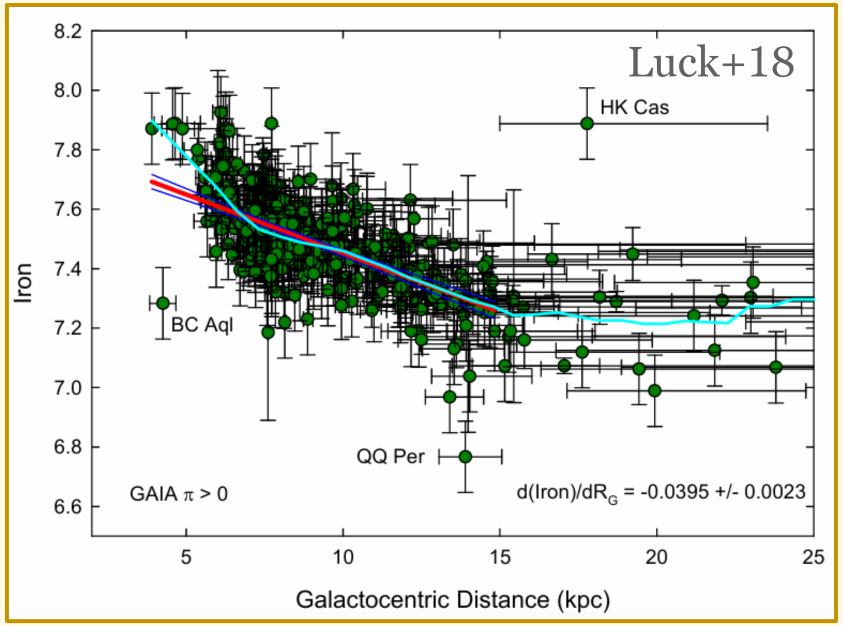

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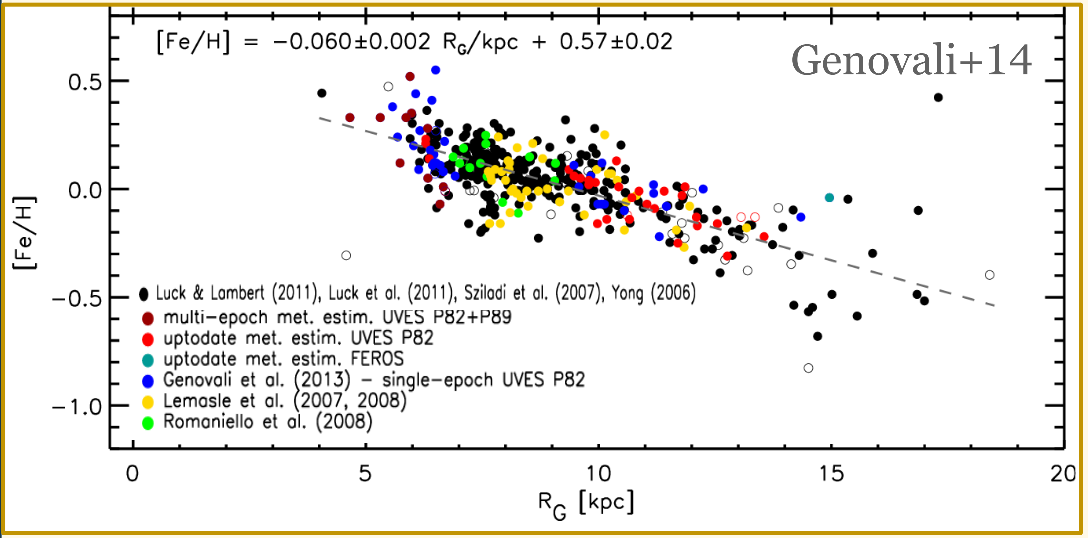

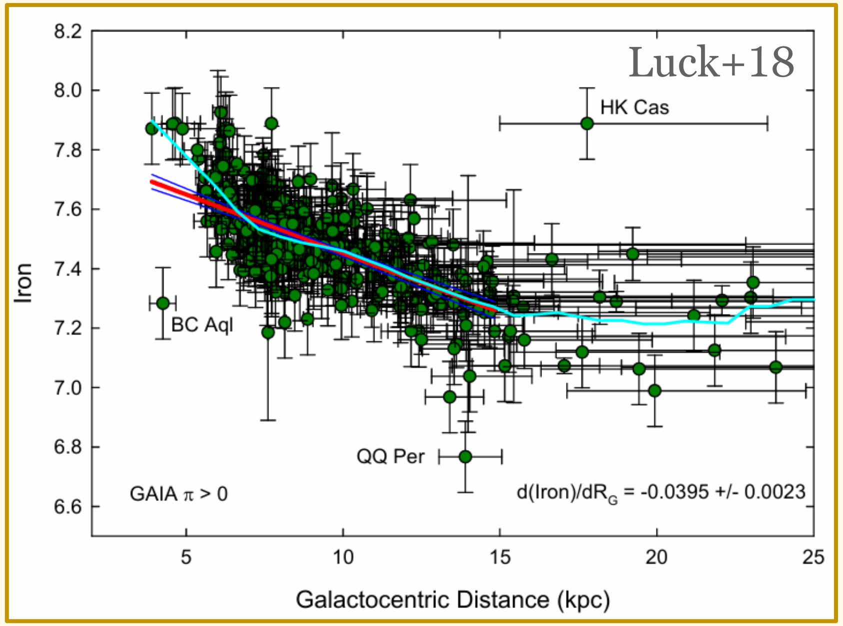

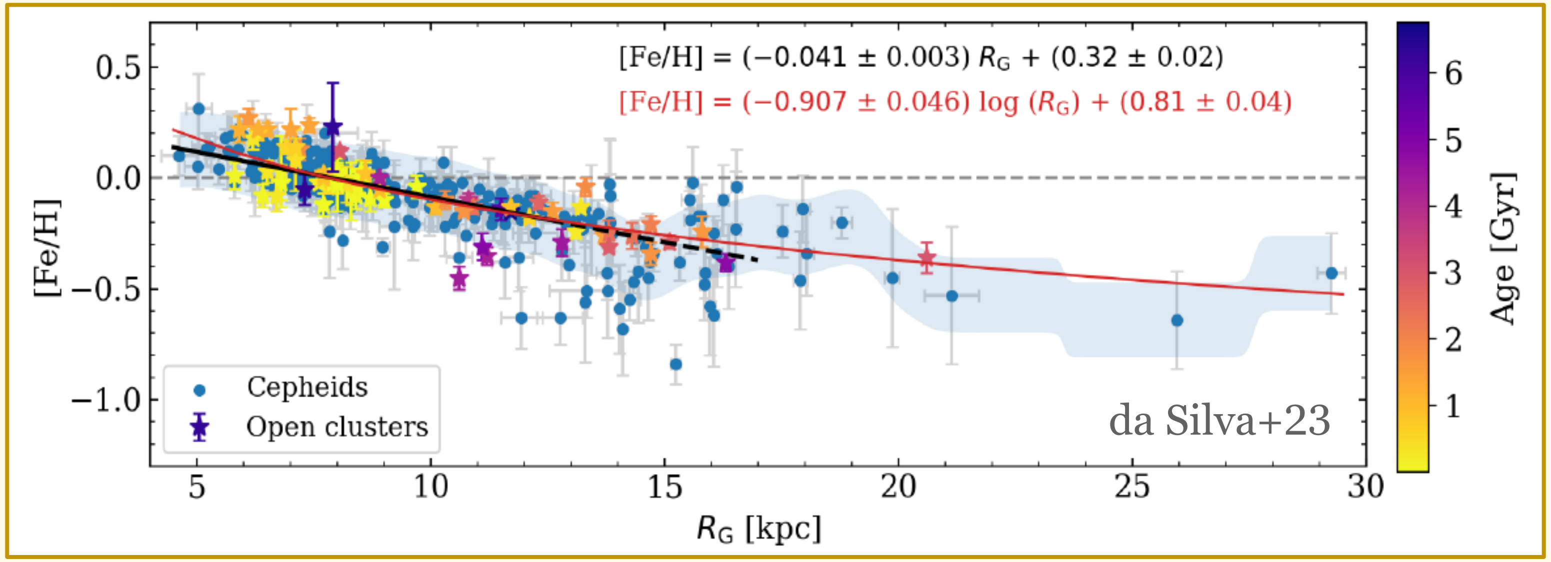

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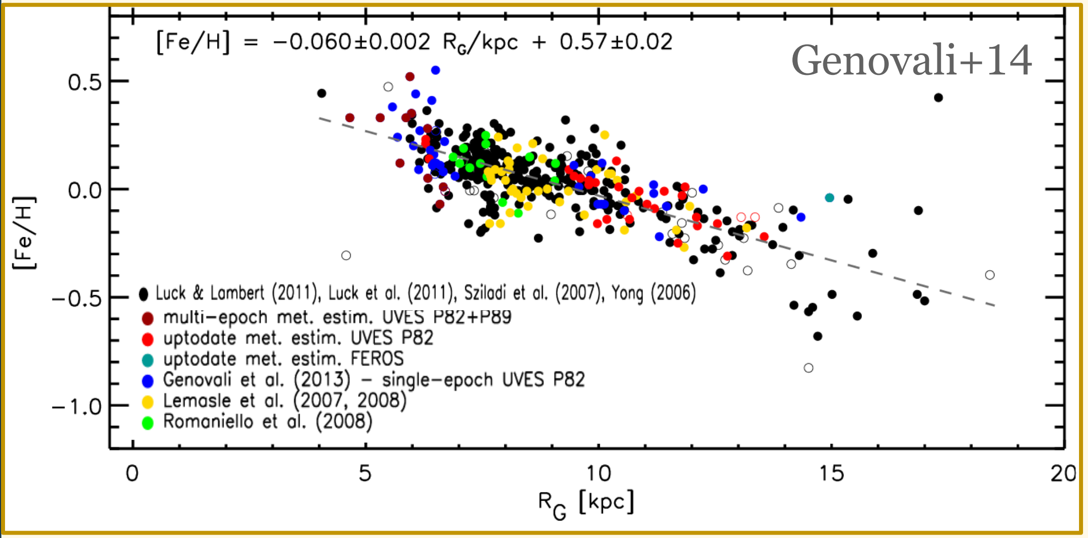
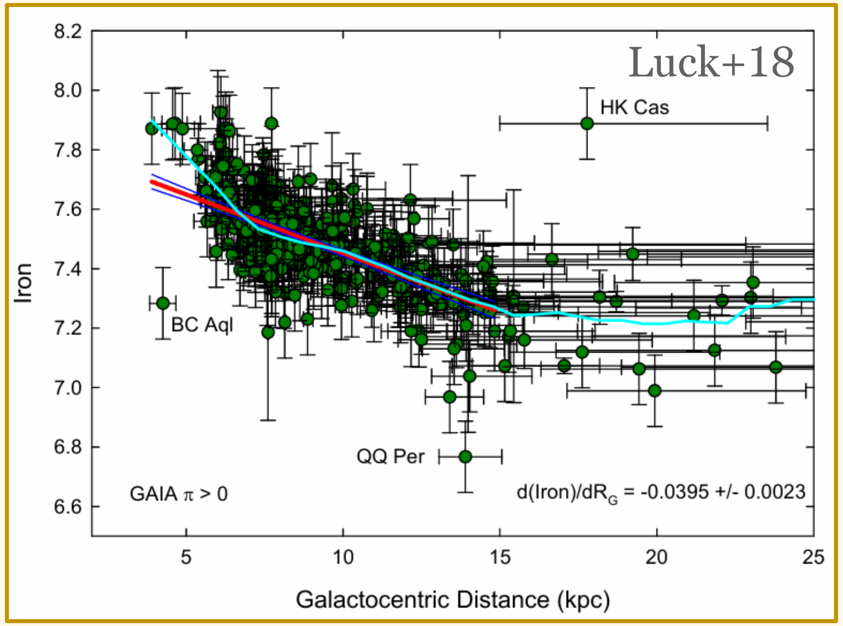
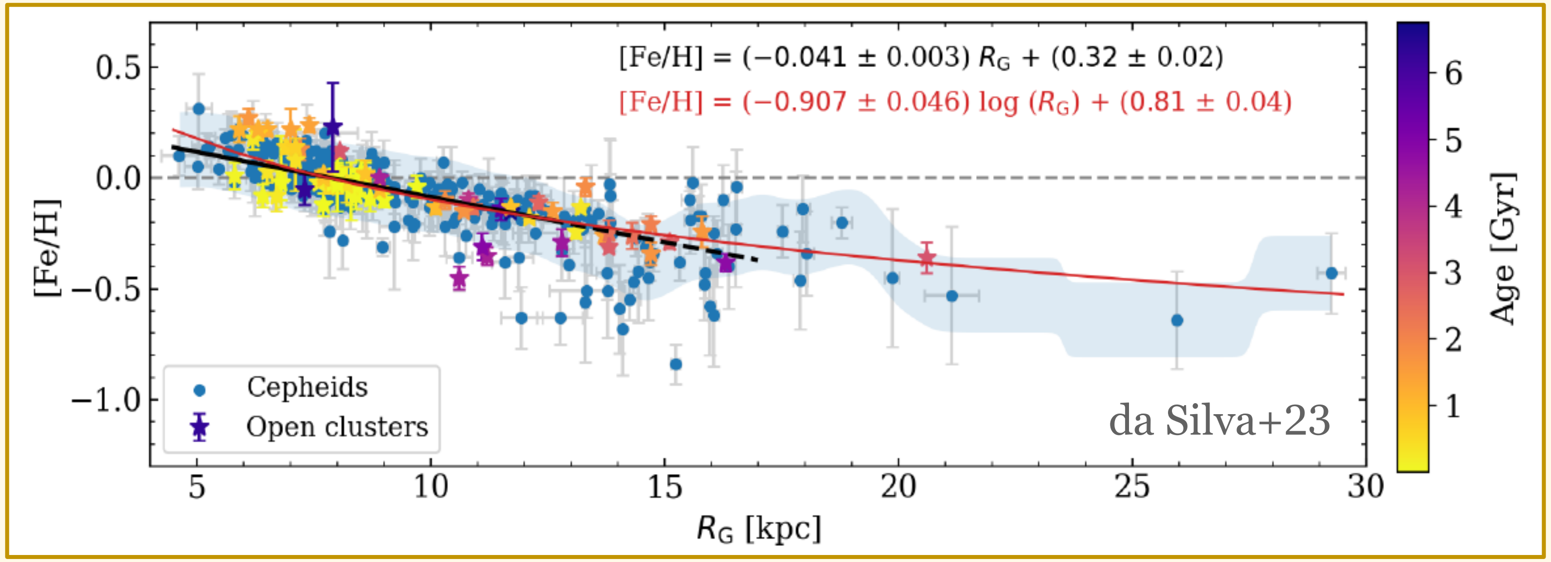
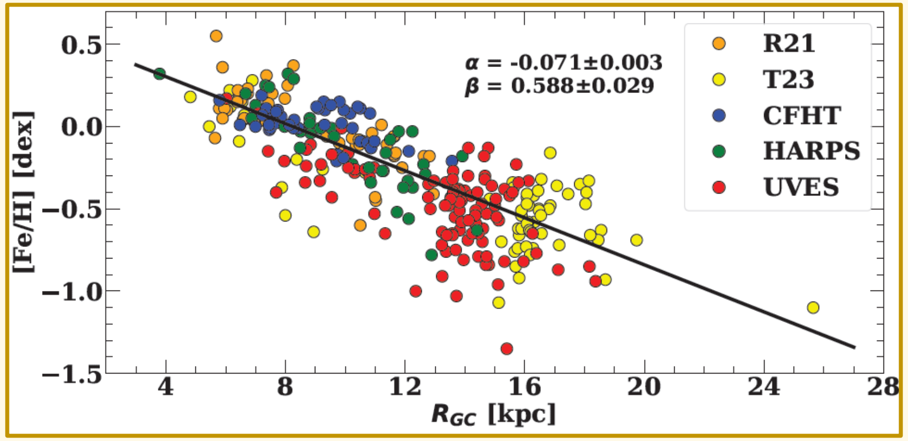


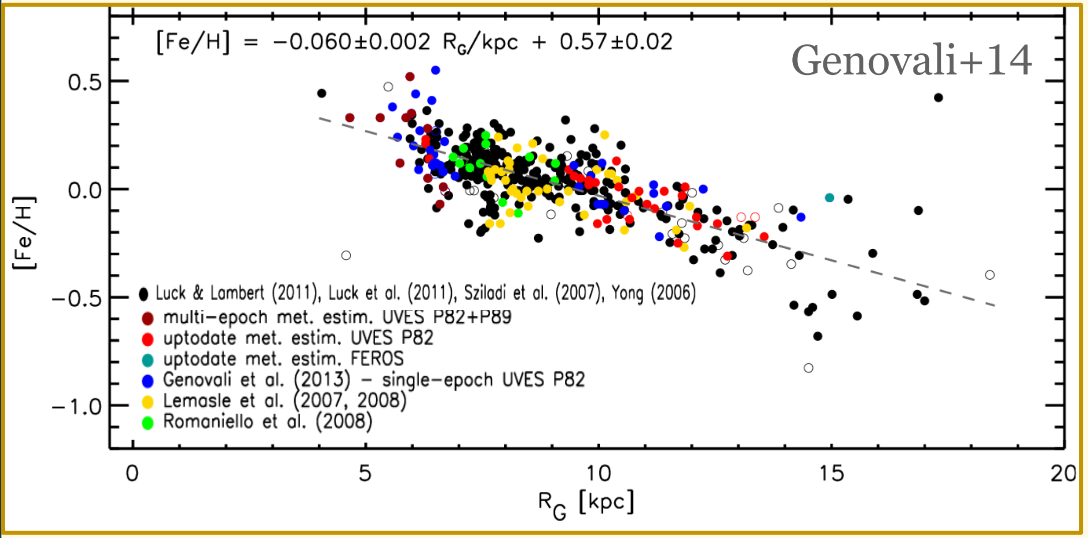






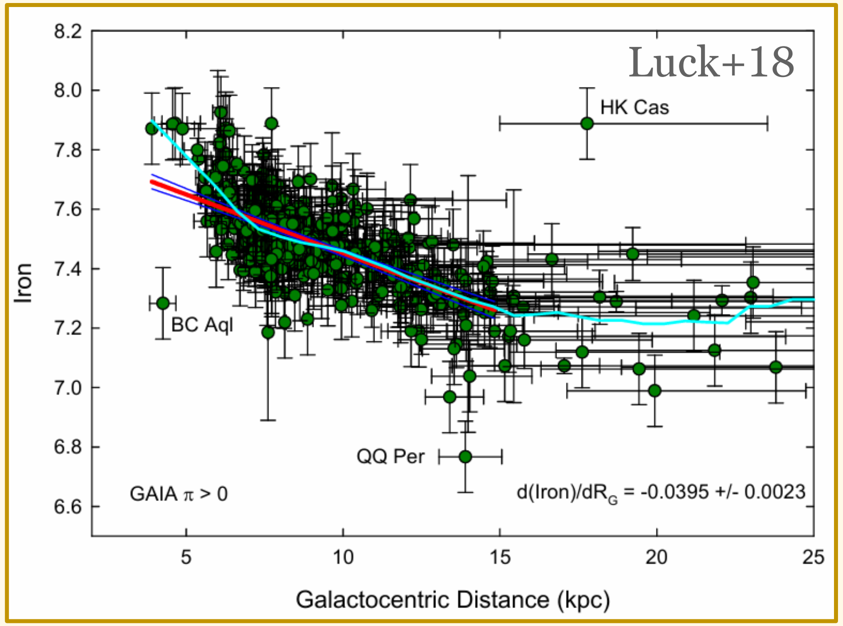
Trentin+24

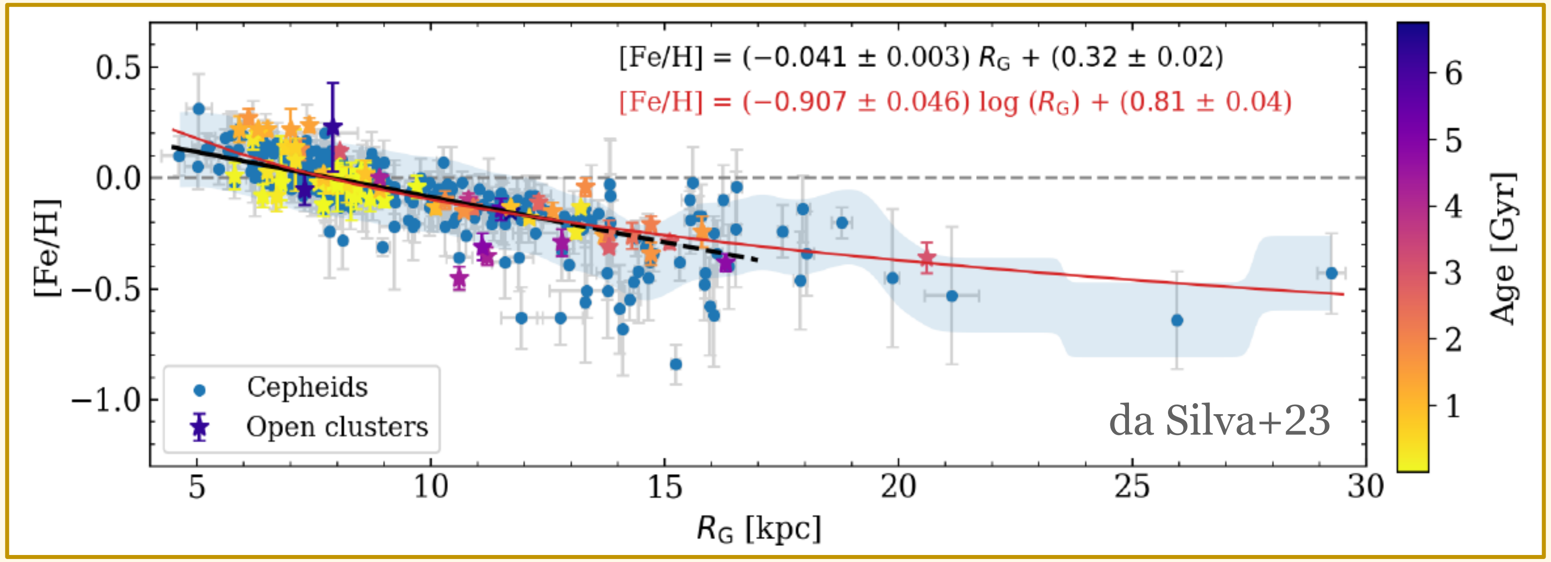
Iron gradient

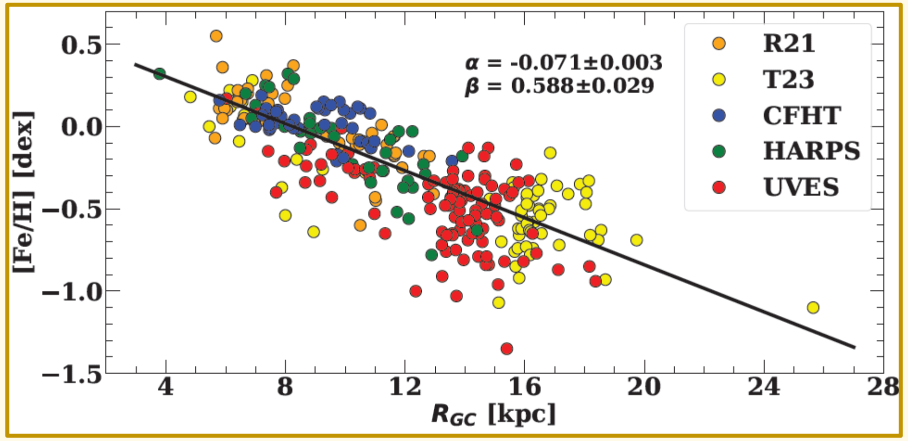


iron gradient is now well established!

...but still uncertain in the inner and outer disc

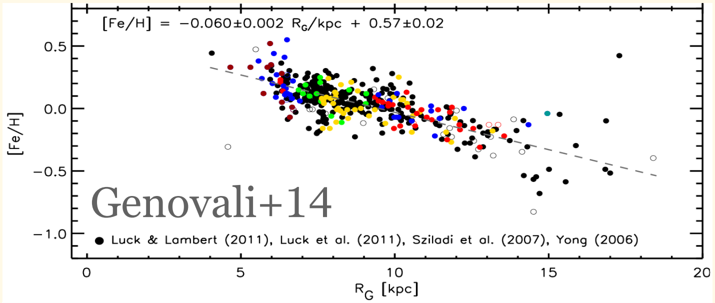


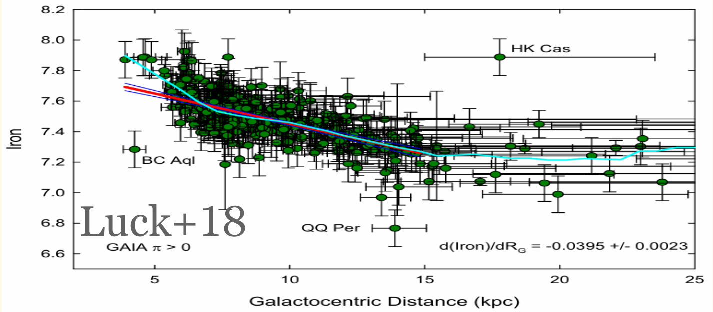


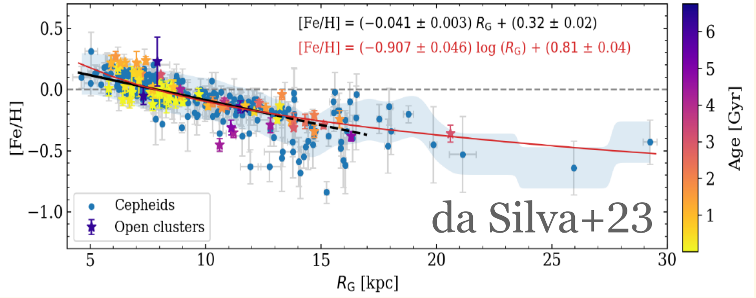


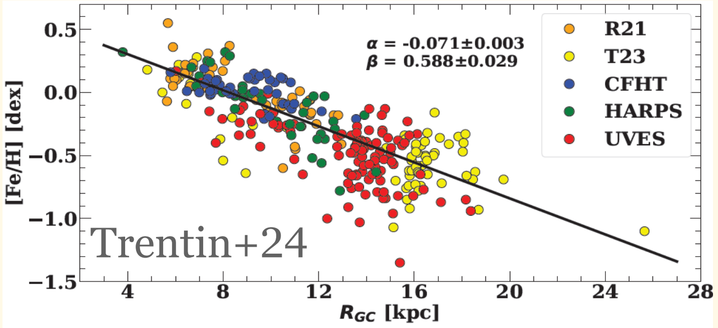
Trentin+24

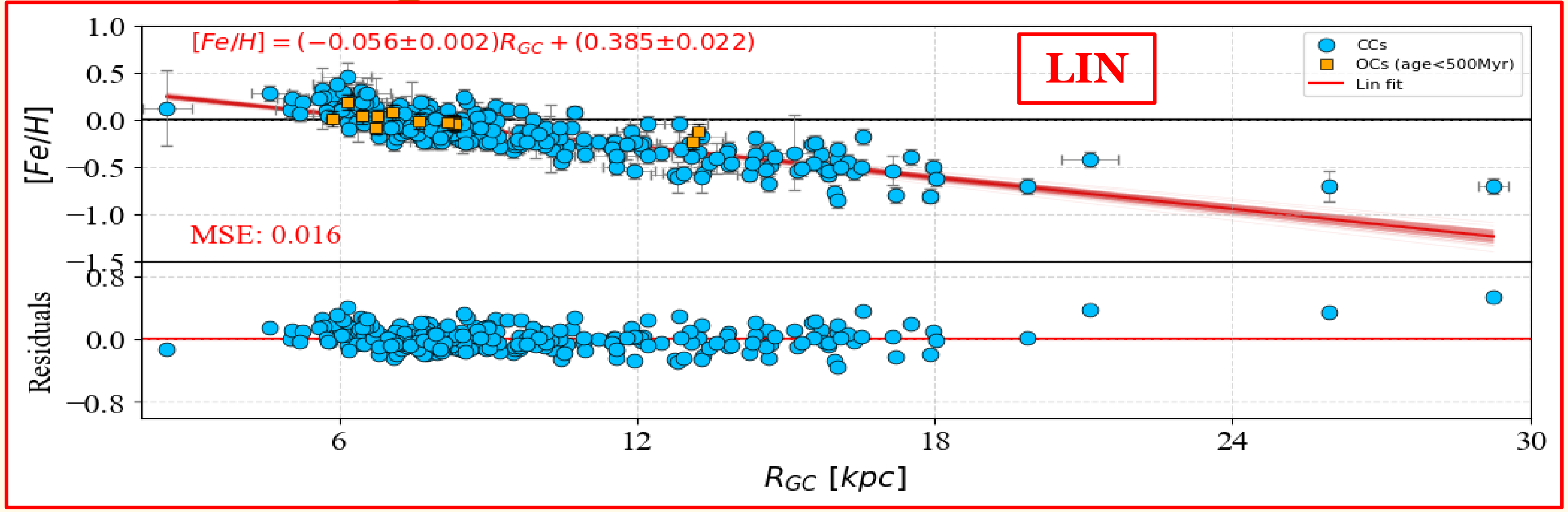
Iron gradient





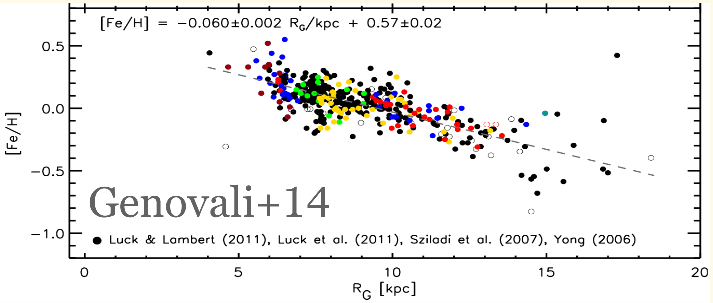


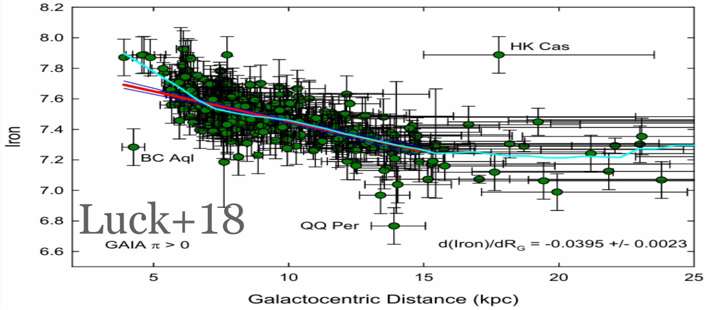


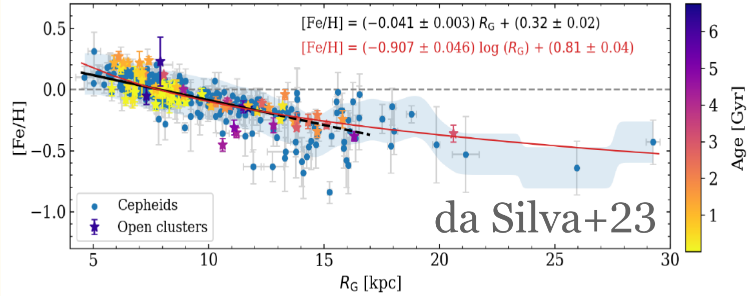


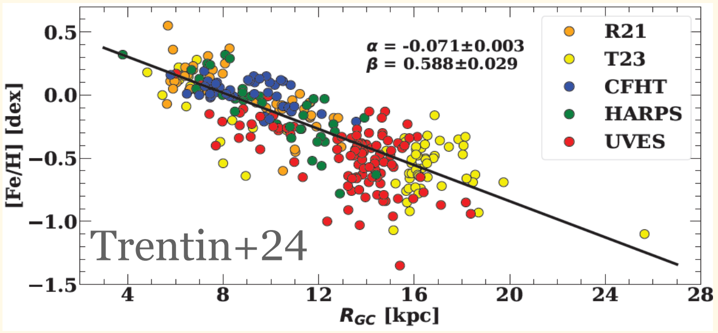
Nunnari+ (in prep.)

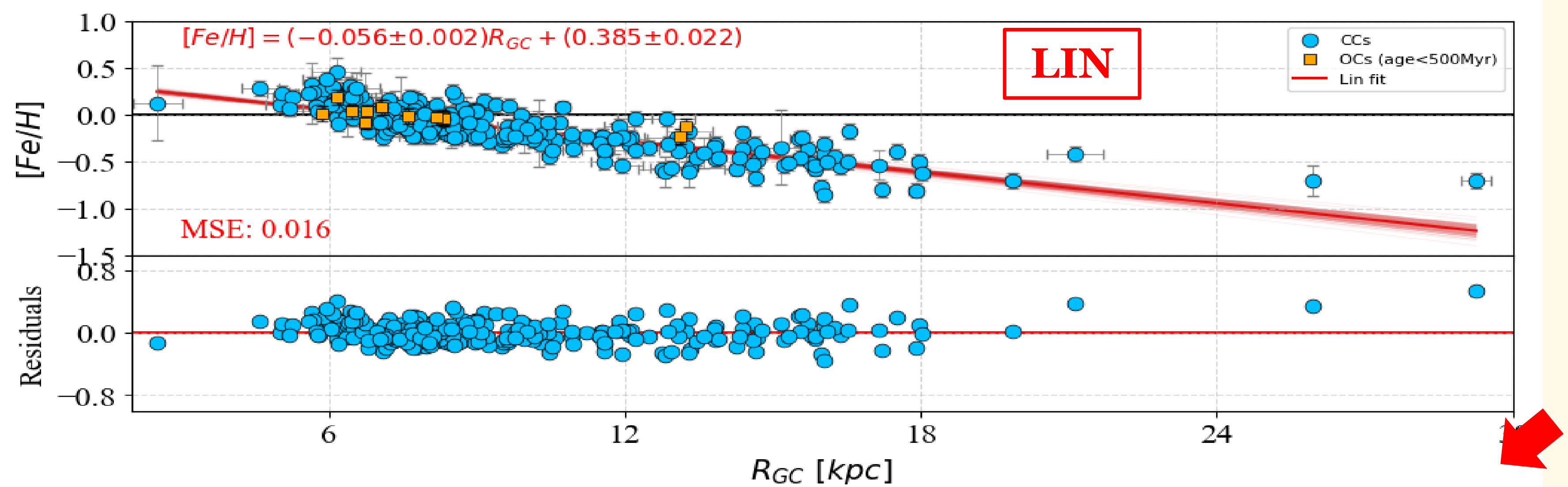
Iron gradient

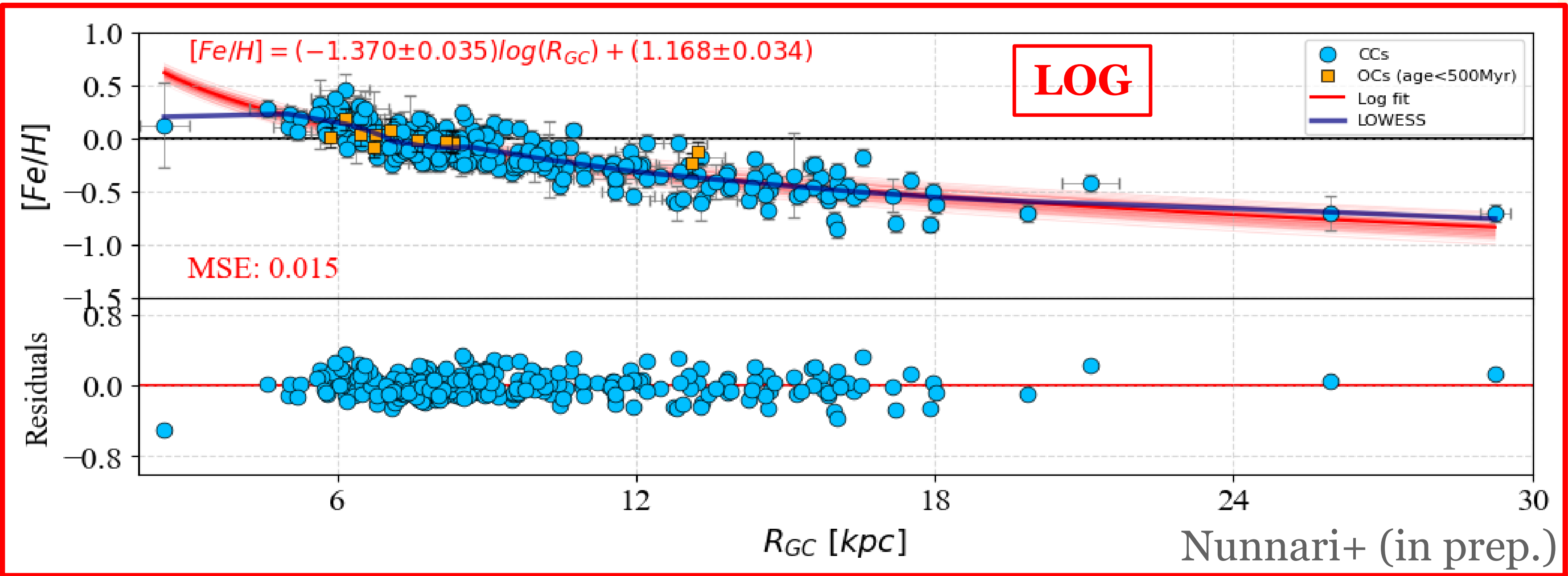












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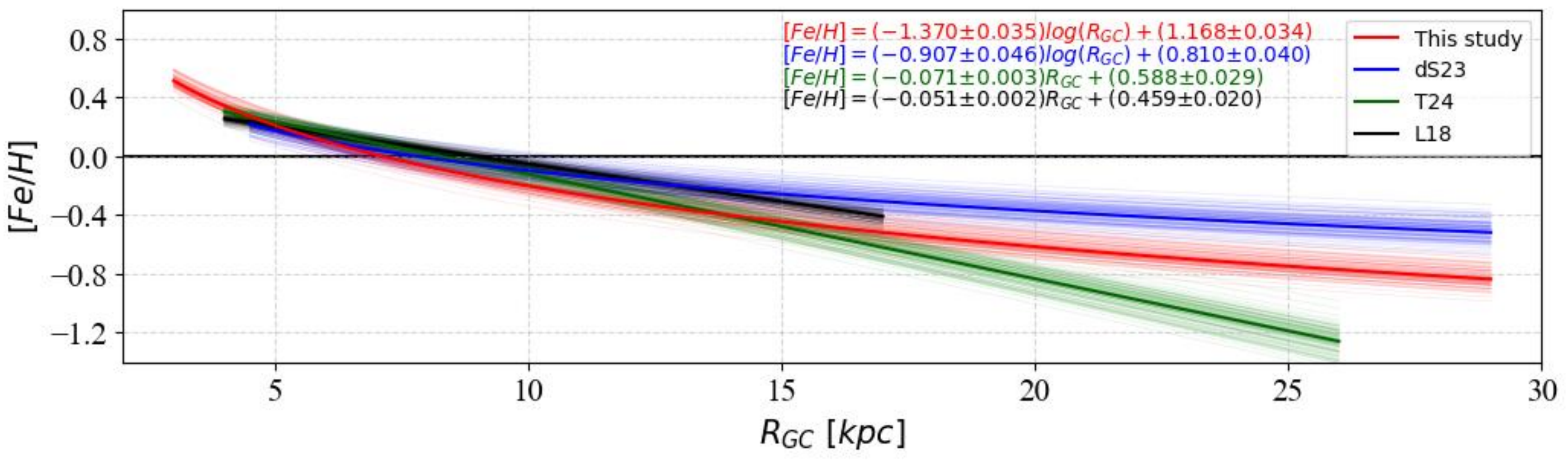
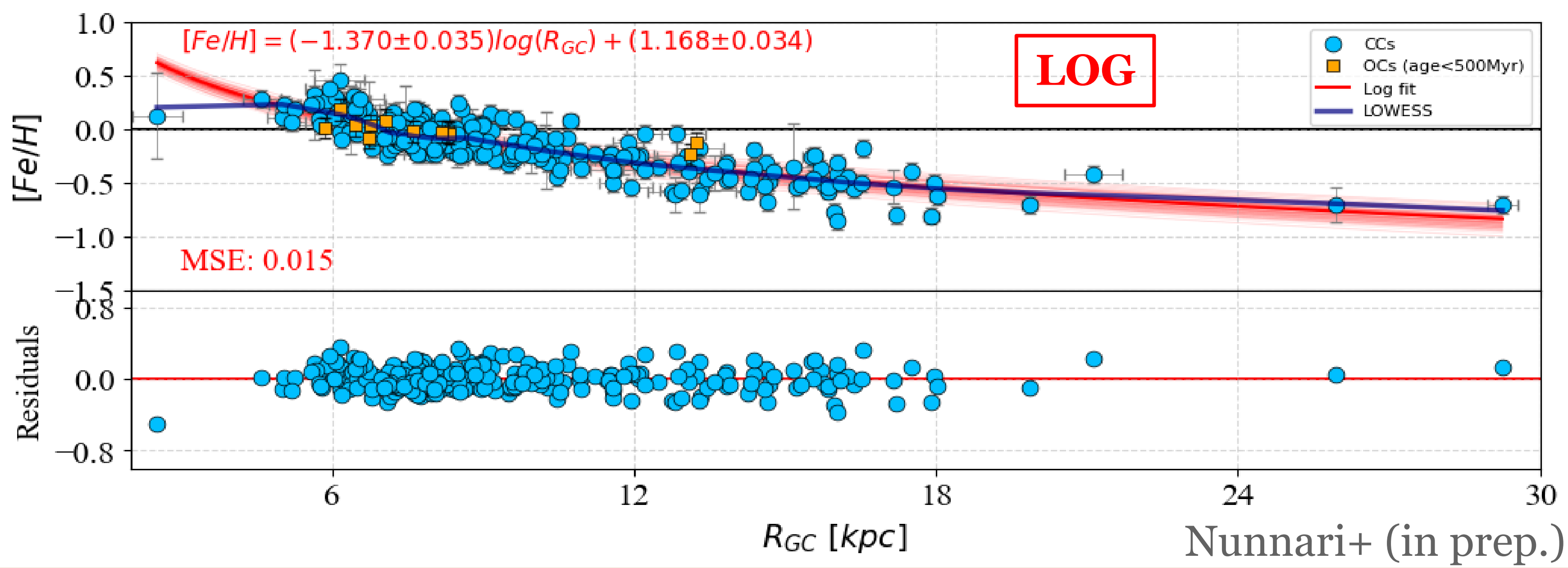


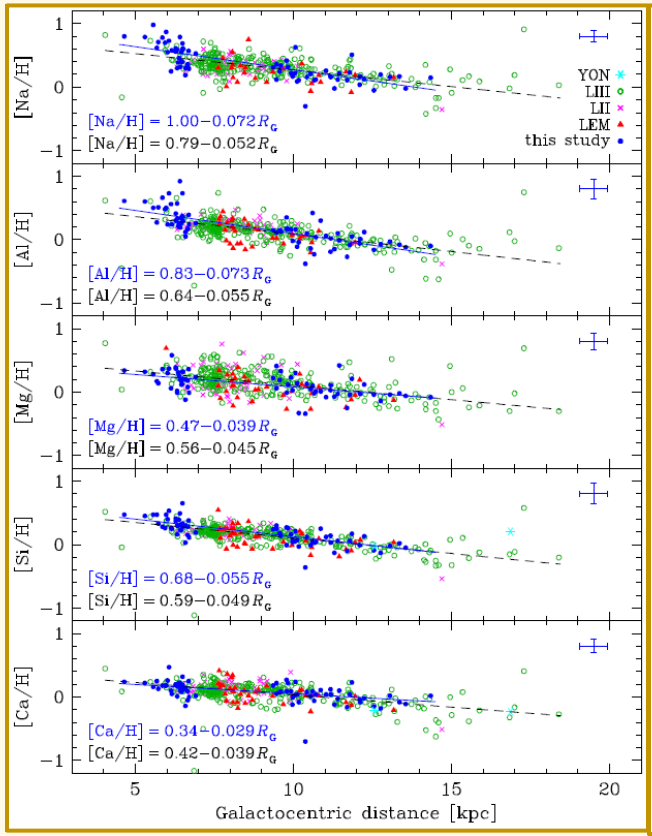


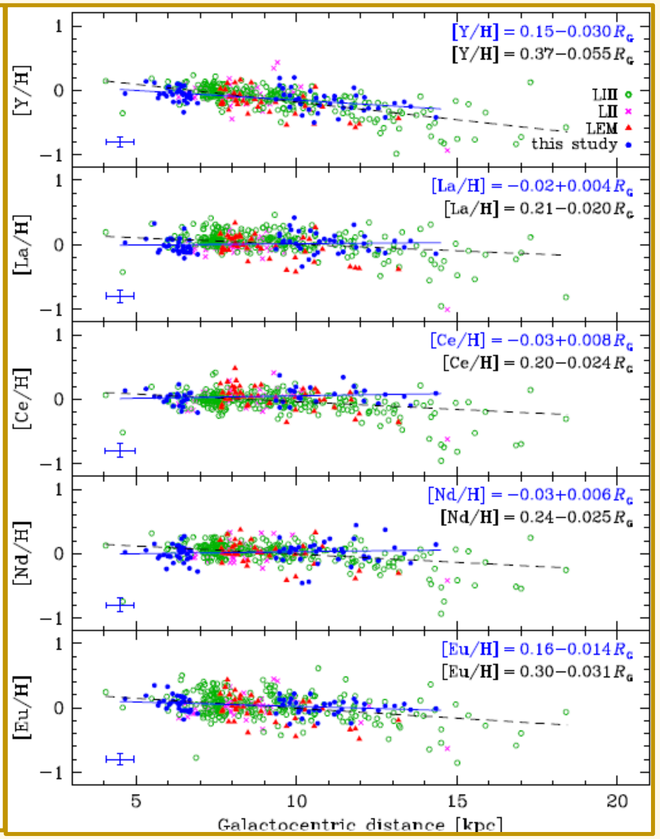
Consistent around solar R_{GC}

Disagreement for $R_{GC} \gtrsim 17 kpc$

Nunnari+ (in prep.)

Present chemical gradients





Genovali+15

da Silva+16

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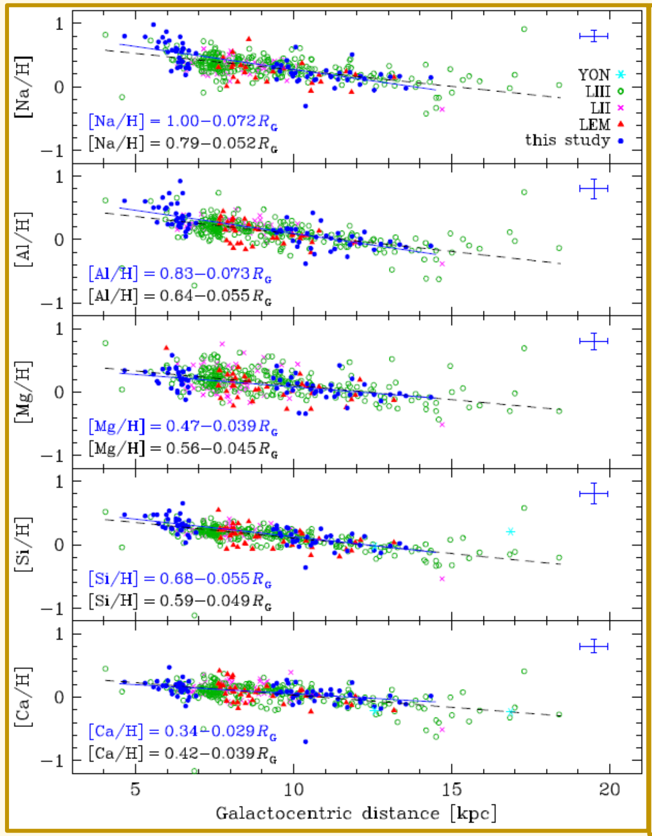
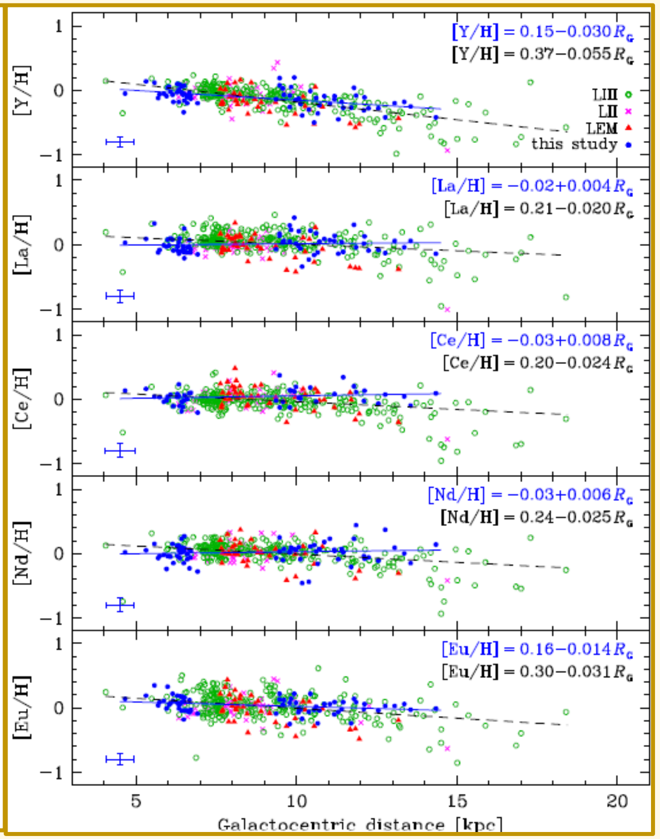
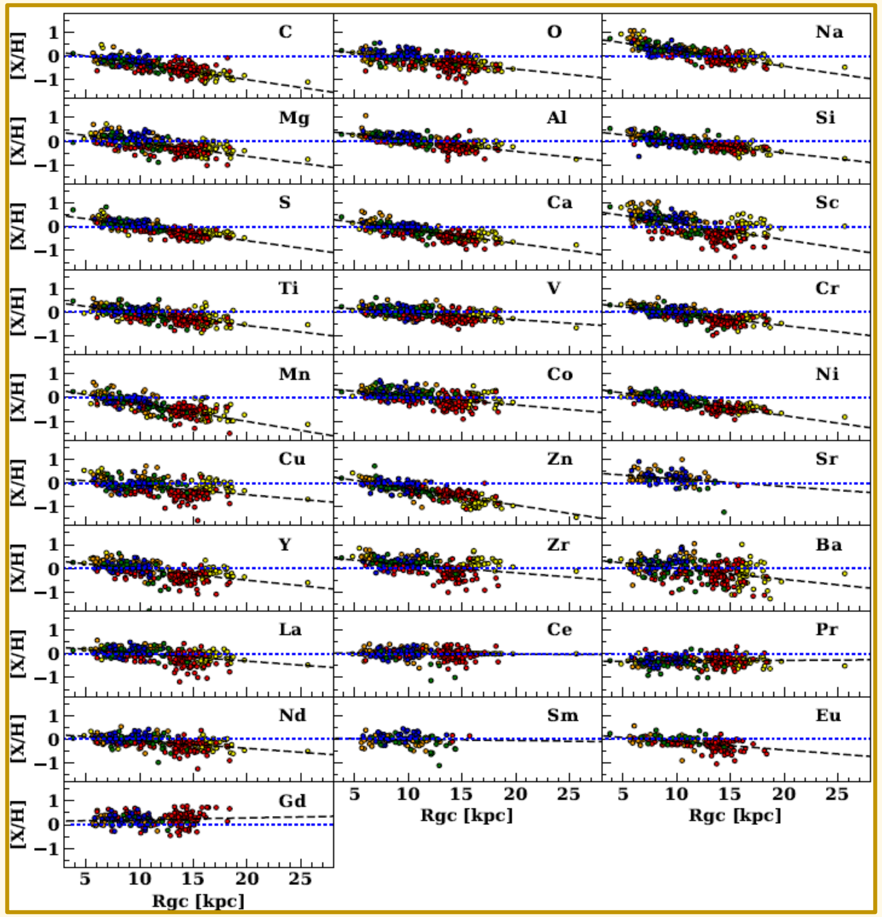


Genovali+15



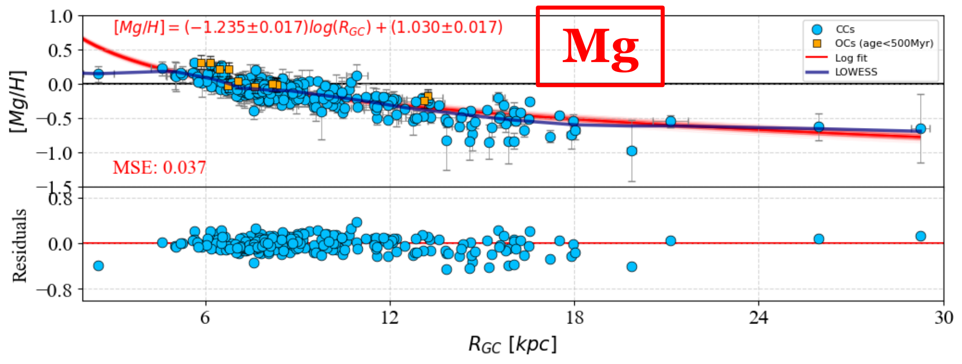
da Silva+16



Trentin+24

Clear negative gradient for most of the elements
Limitation to $\lesssim 18kpc$

Chemical gradients for Mg, Si, Ti, Ca, O, S, Na, Al, Cu, Mn



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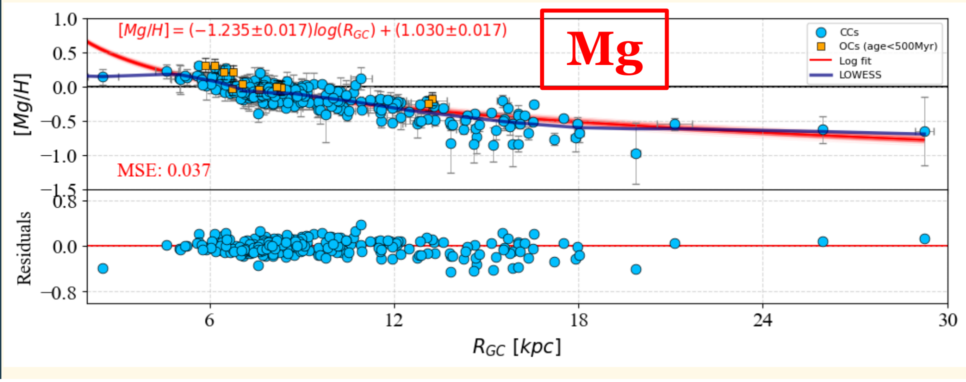

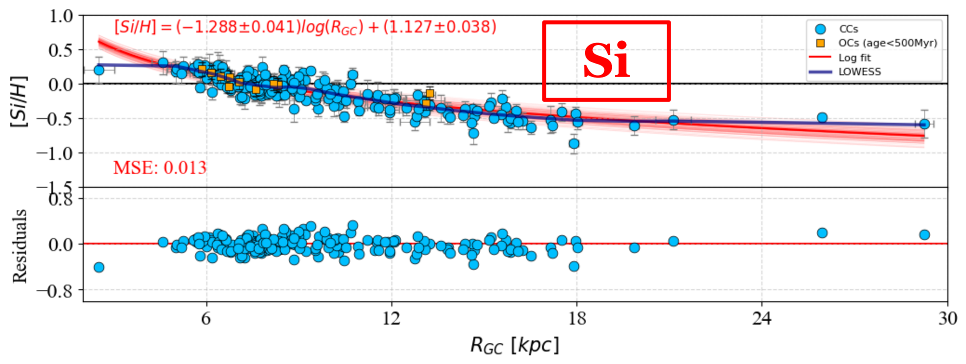

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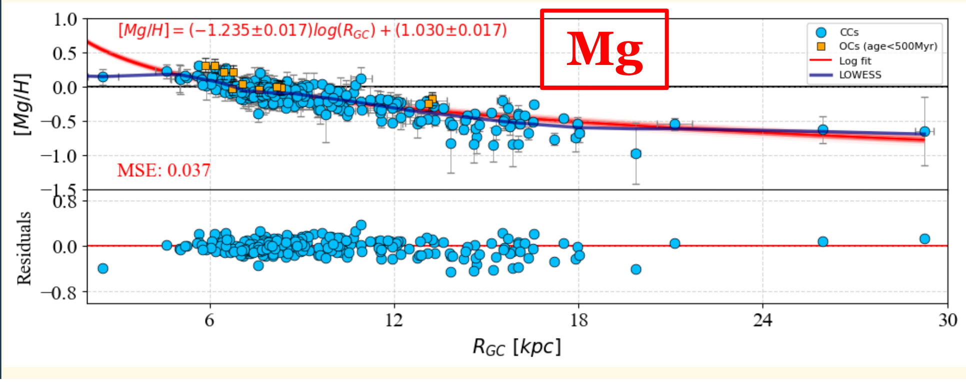

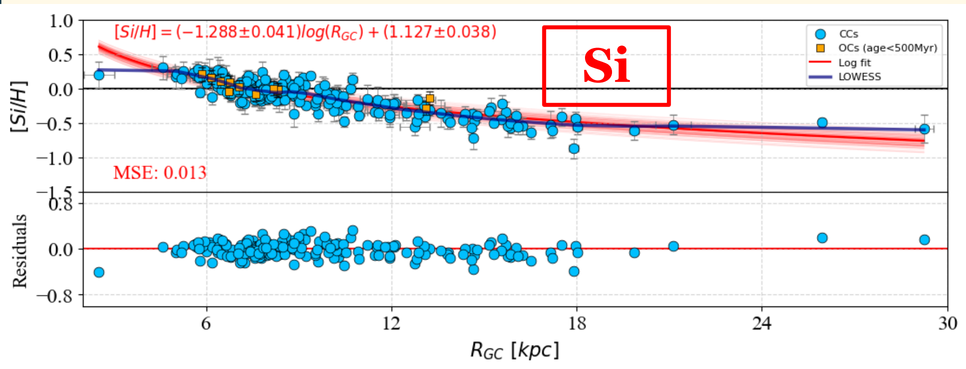

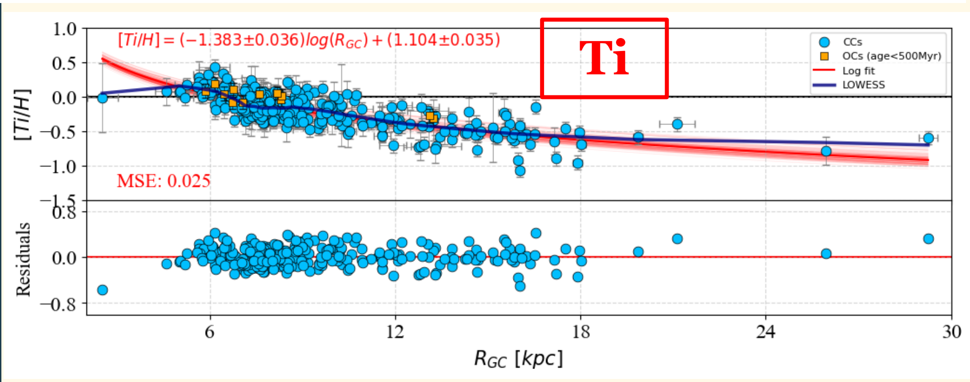

Logarithmic fit is working!

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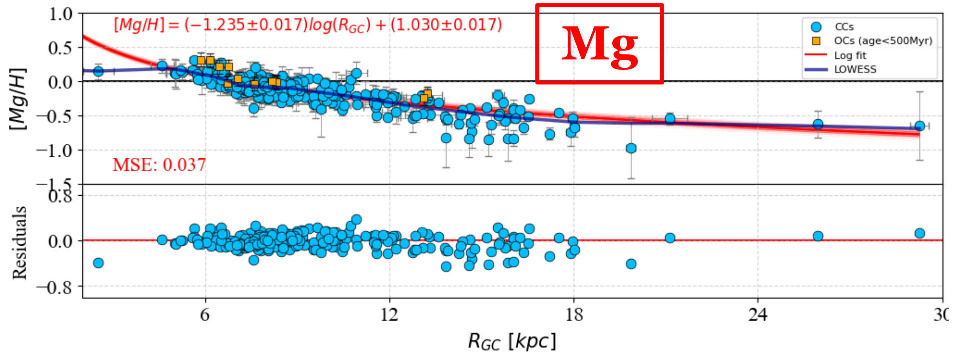
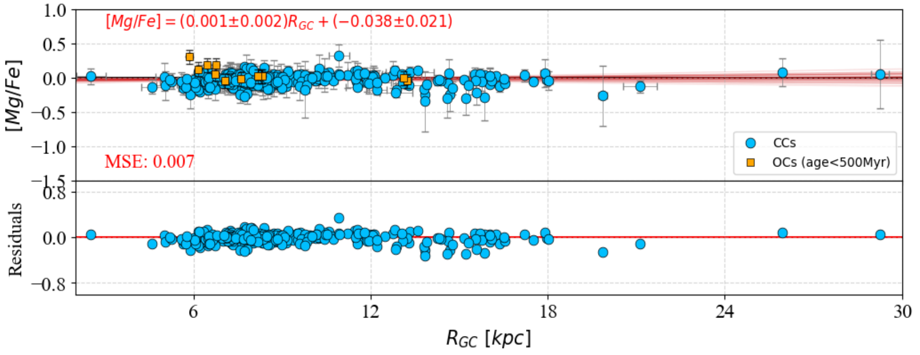
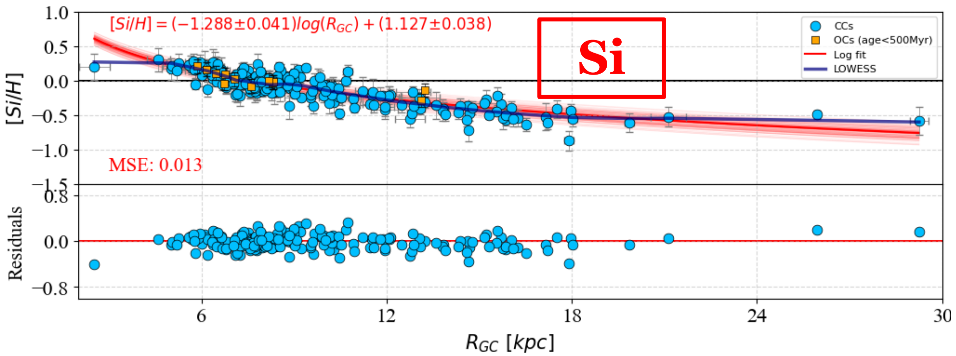
Chemical gradients for Mg, Si, Ti, Ca, O, S, Na, Al, Cu, Mn

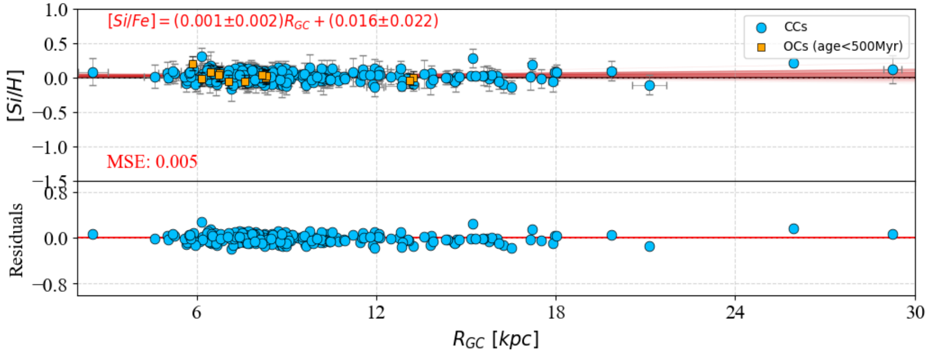
Mg



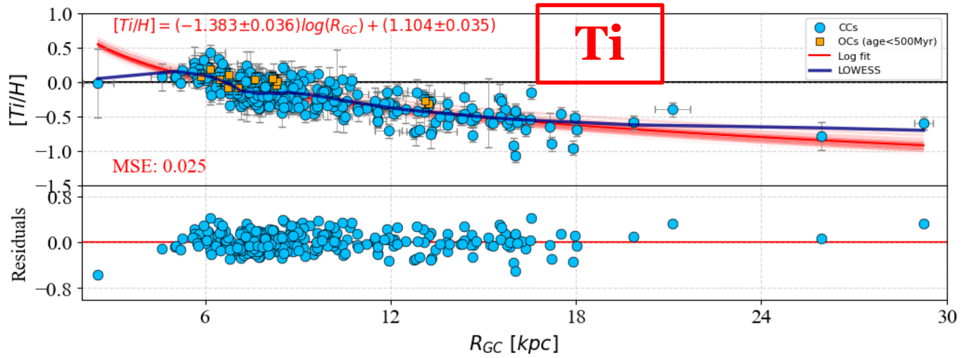


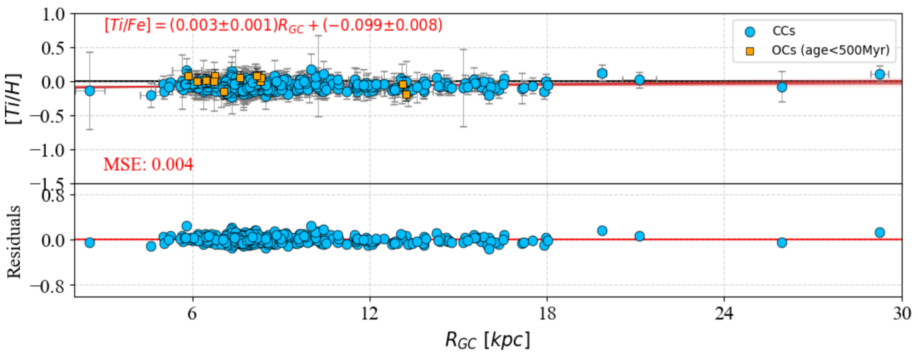
Si





Ti





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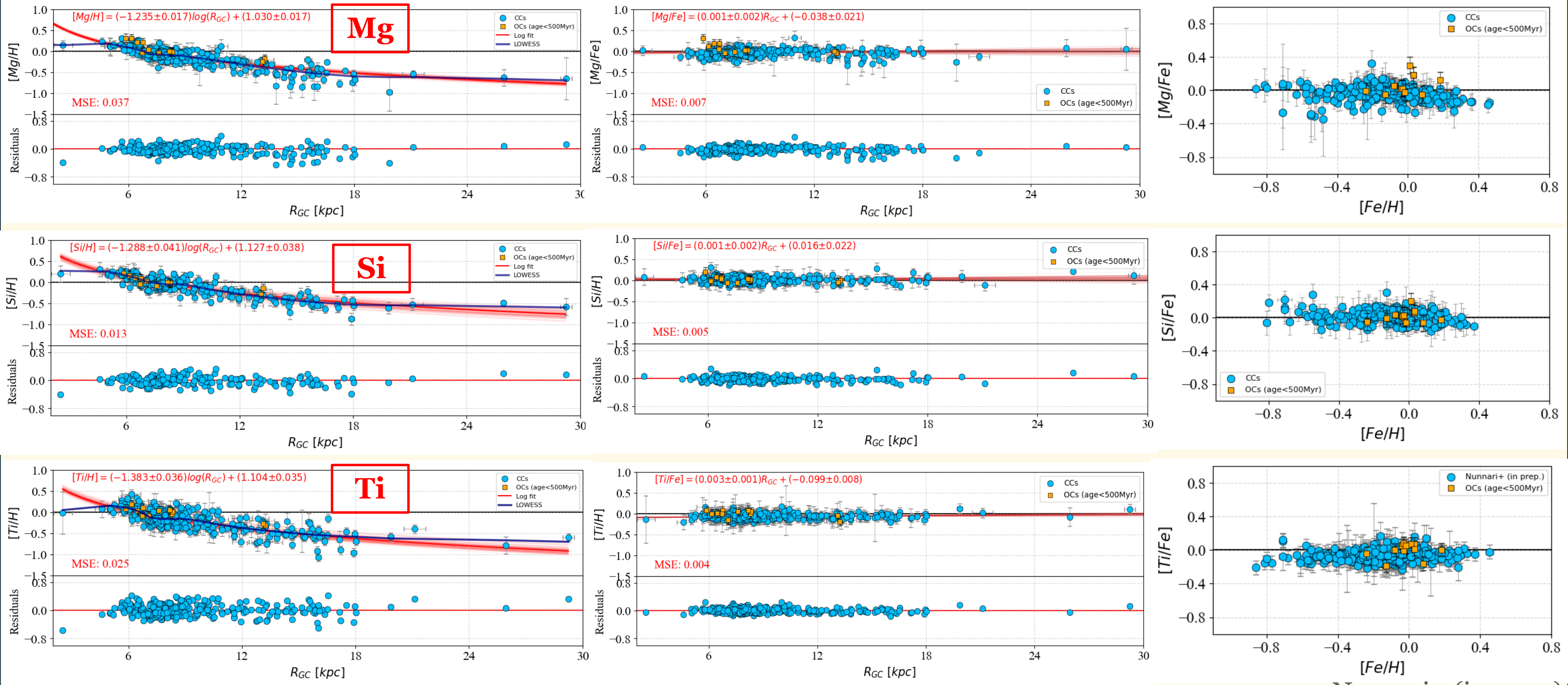
Chemical gradients for Mg, Si, Ti, Ca, O, S, Na, Al, Cu, Mn



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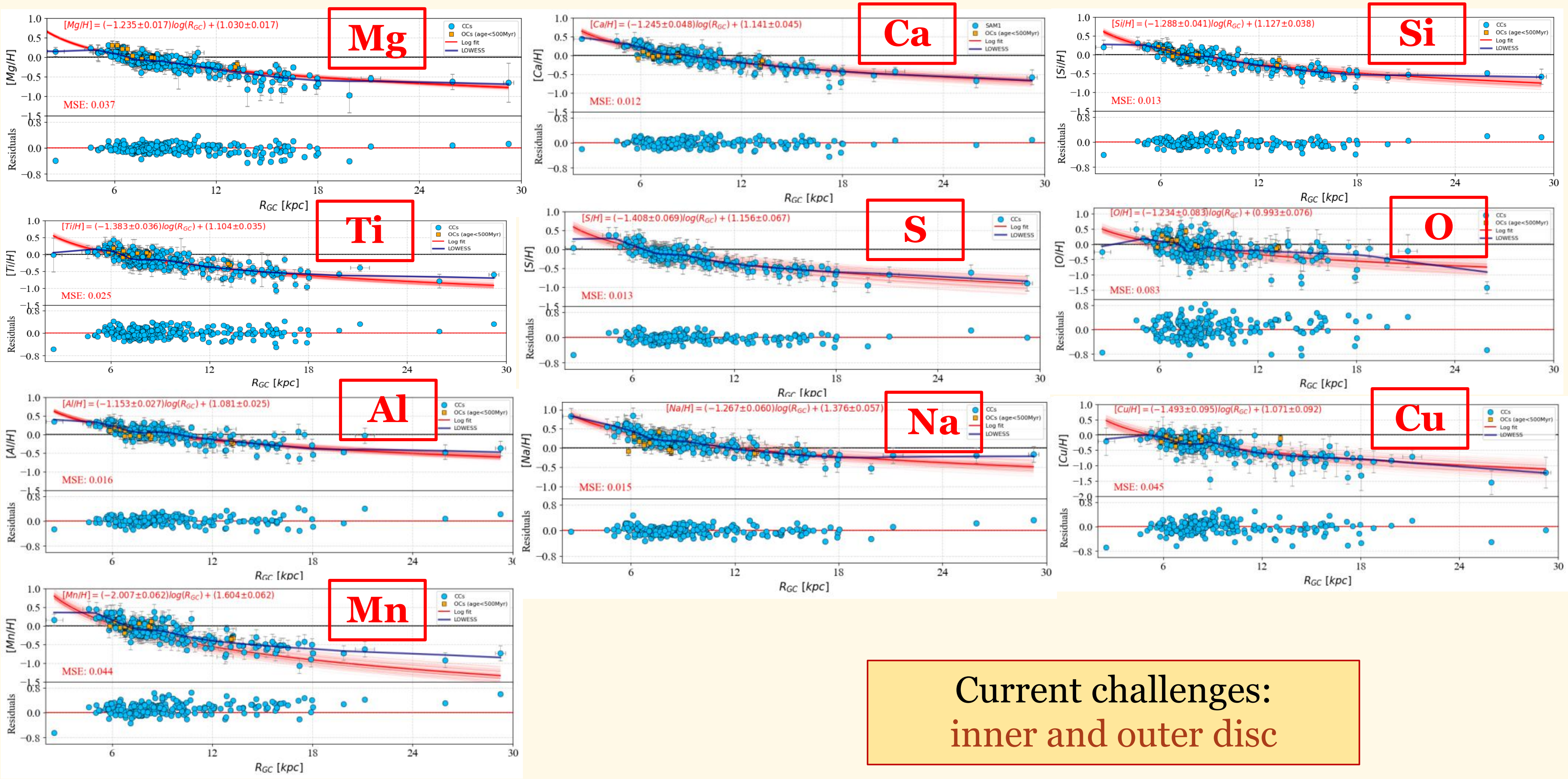
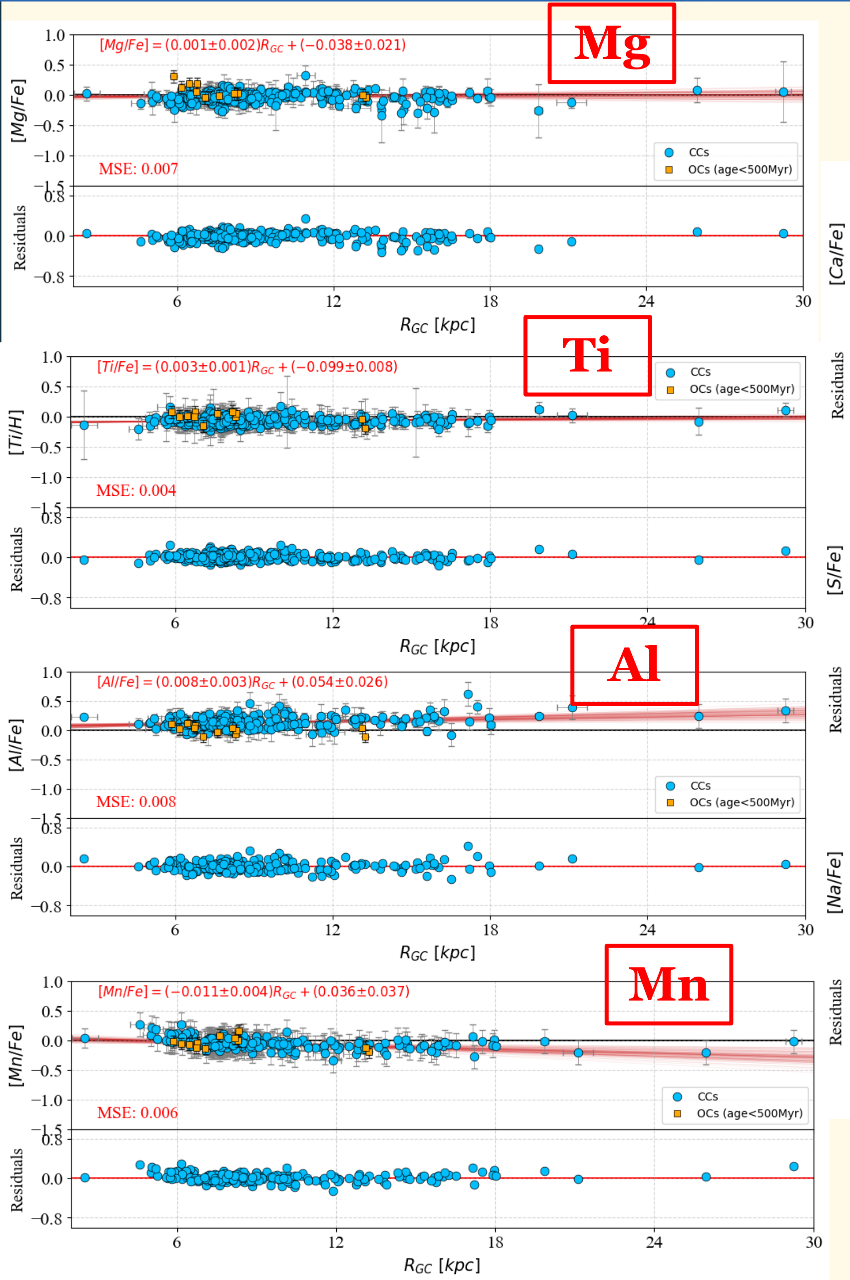
Chemical gradients

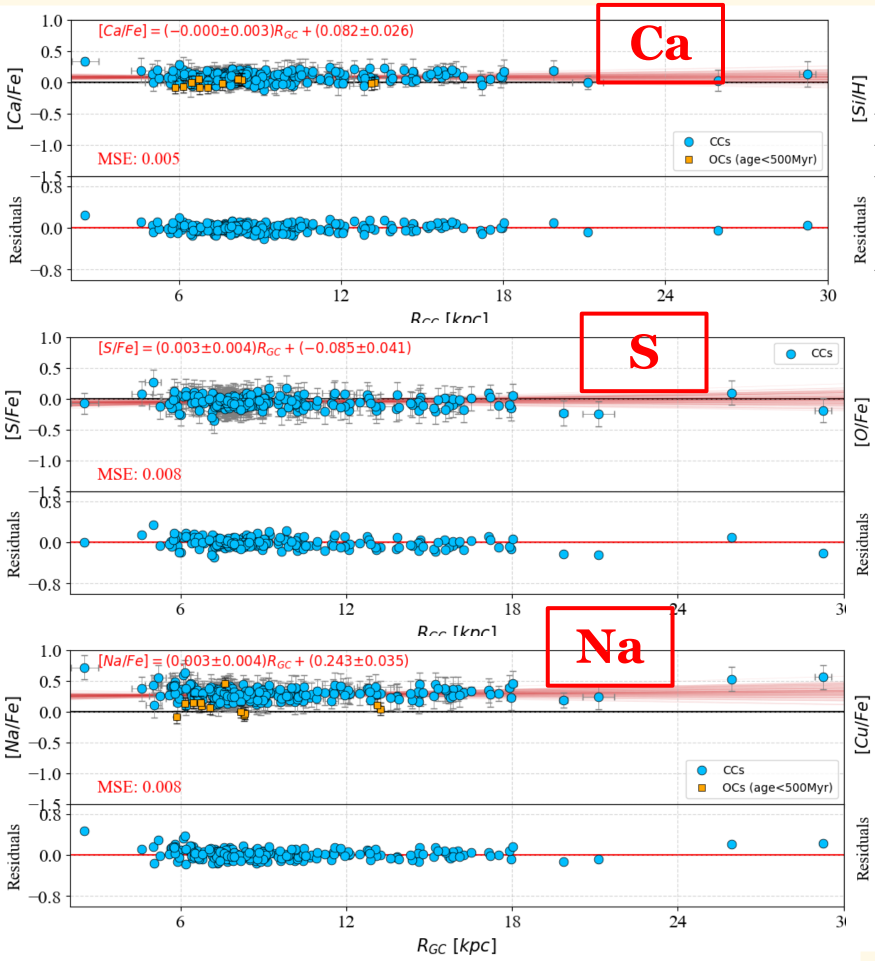


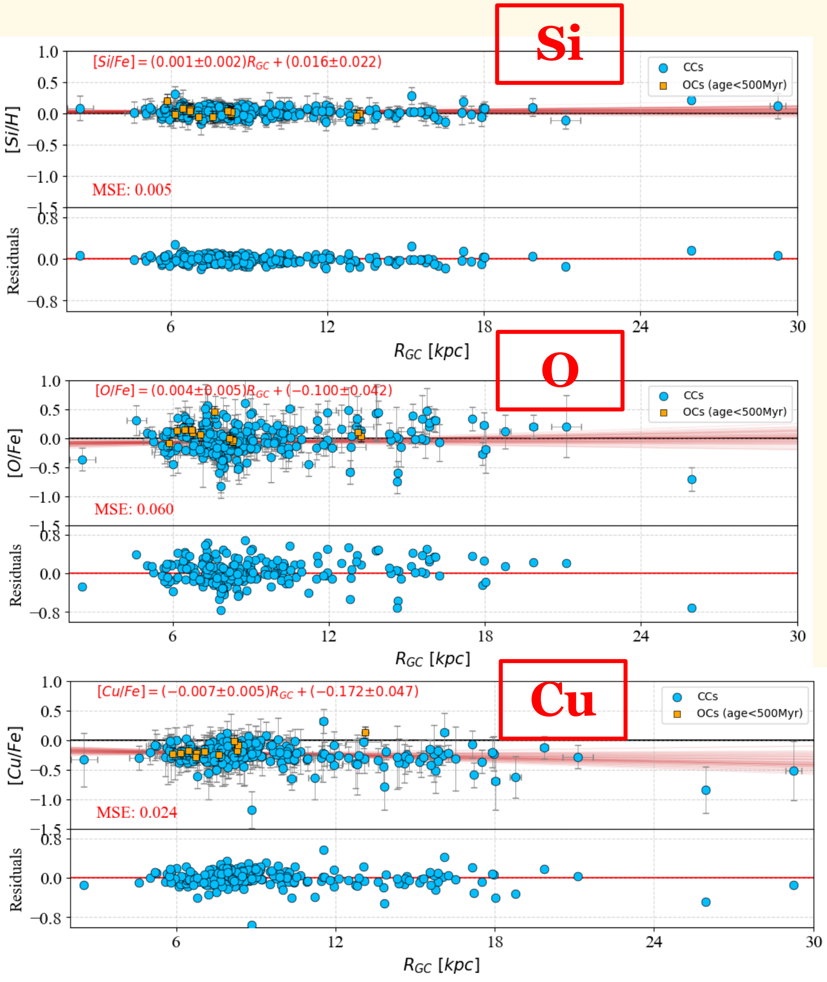
Current challenges:
inner and outer disc

Nunnari+ (in prep.)

Chemical ratios

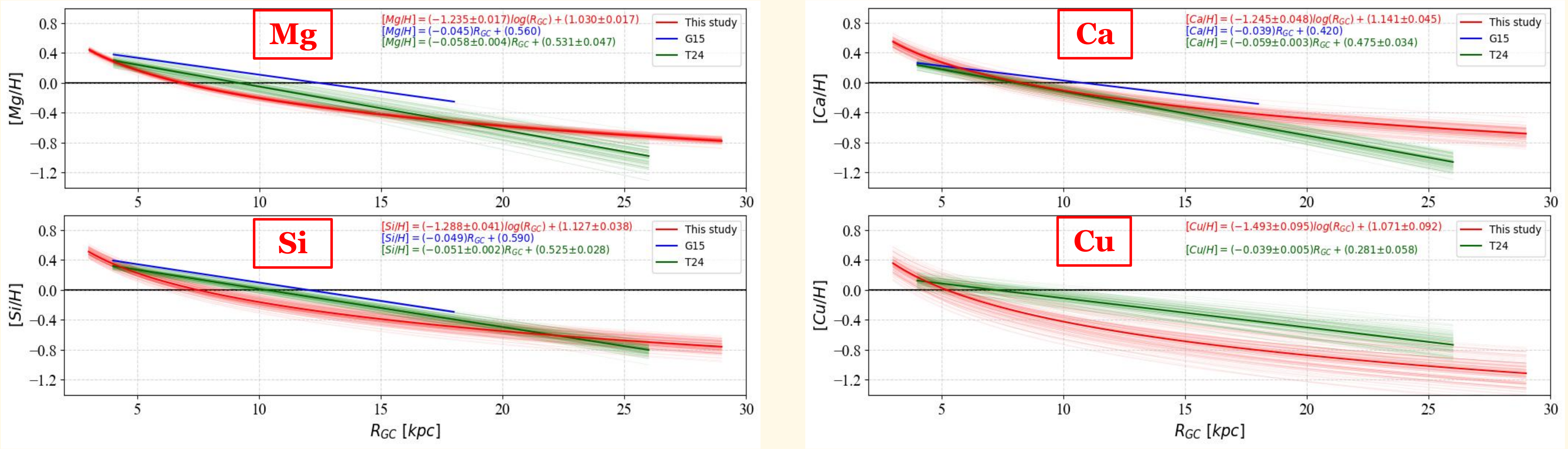






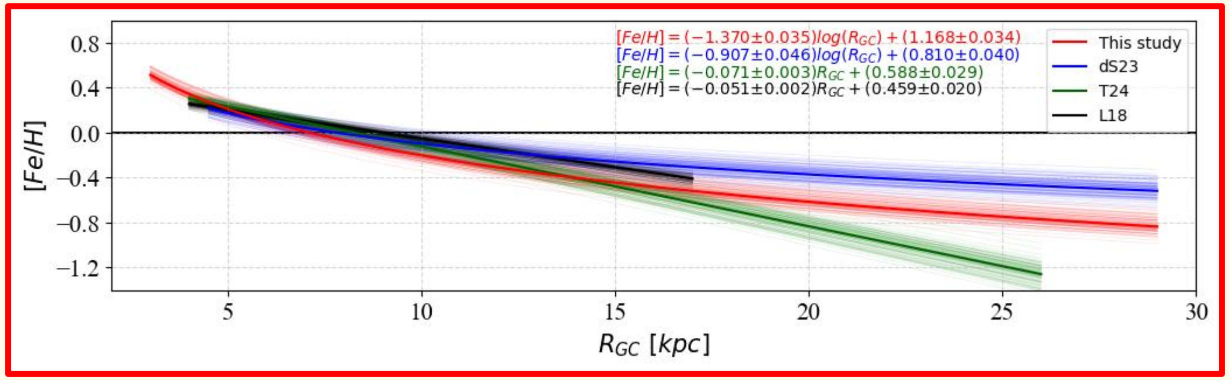
Nunnari+ (in prep.)

Chemical gradients



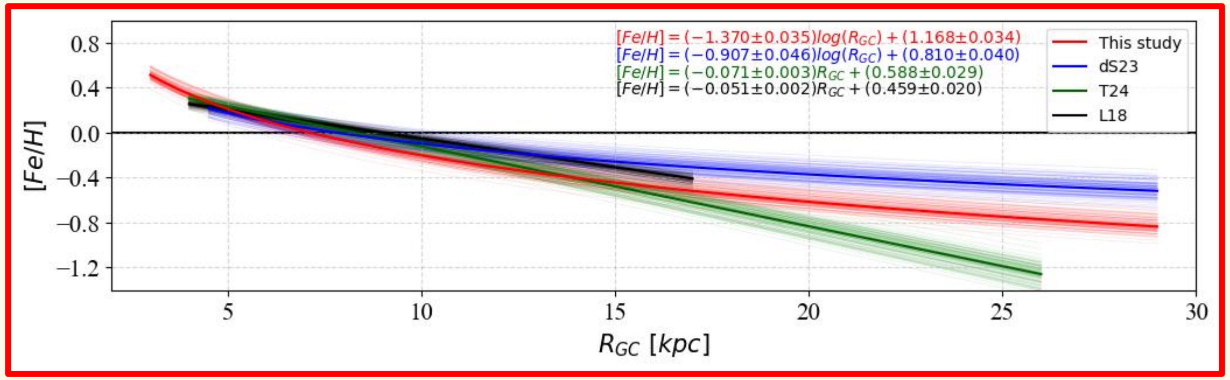
Logarithmic behaviour

Solid evidences

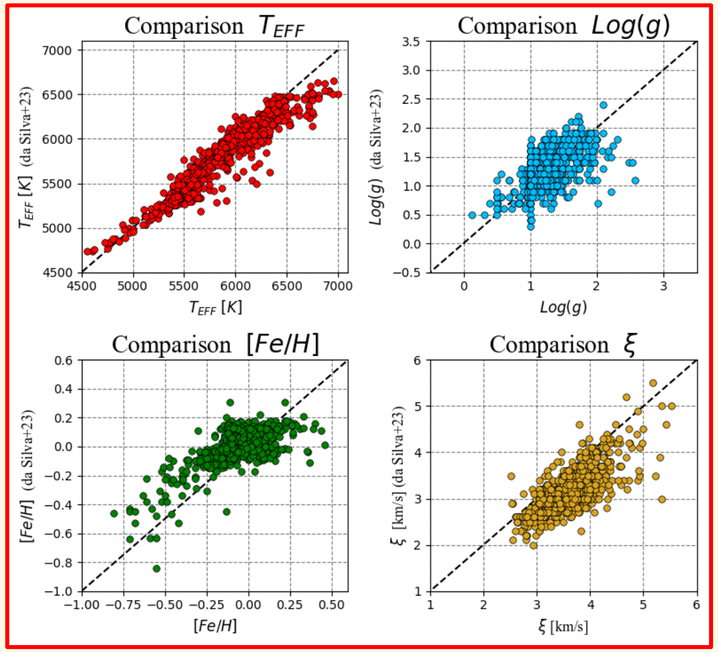


Flattening at large R_{GC}

Solid evidences



Flattening at large R_{GC}



NLTE effects

(on average) higher temperatures (+200K)

(on average) higher gravities (+0.2 dex)

higher dispersion in metallicity

(on average) higher values in microturbulence (+0.5km/s)

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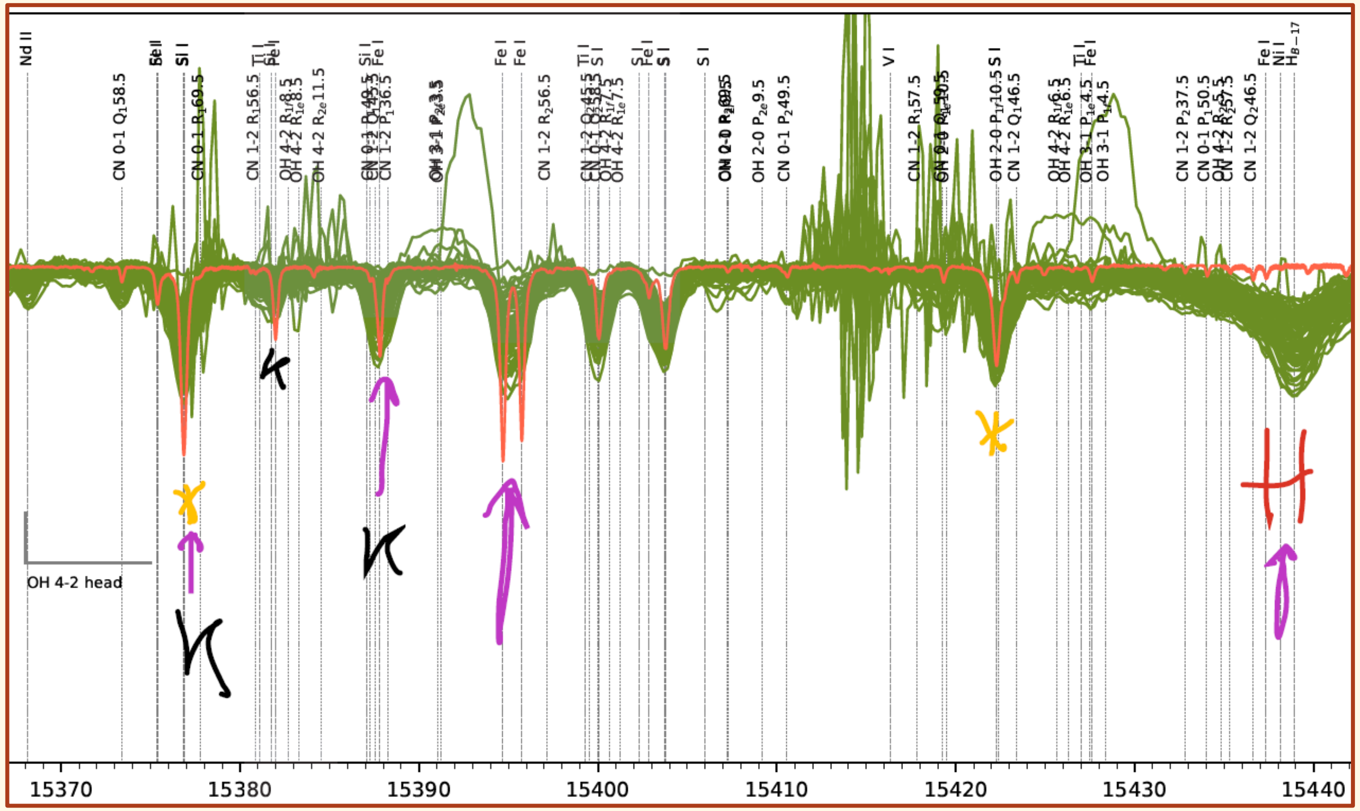
Current challenges and upcoming solutions...

Infrared NLTE specral analysis

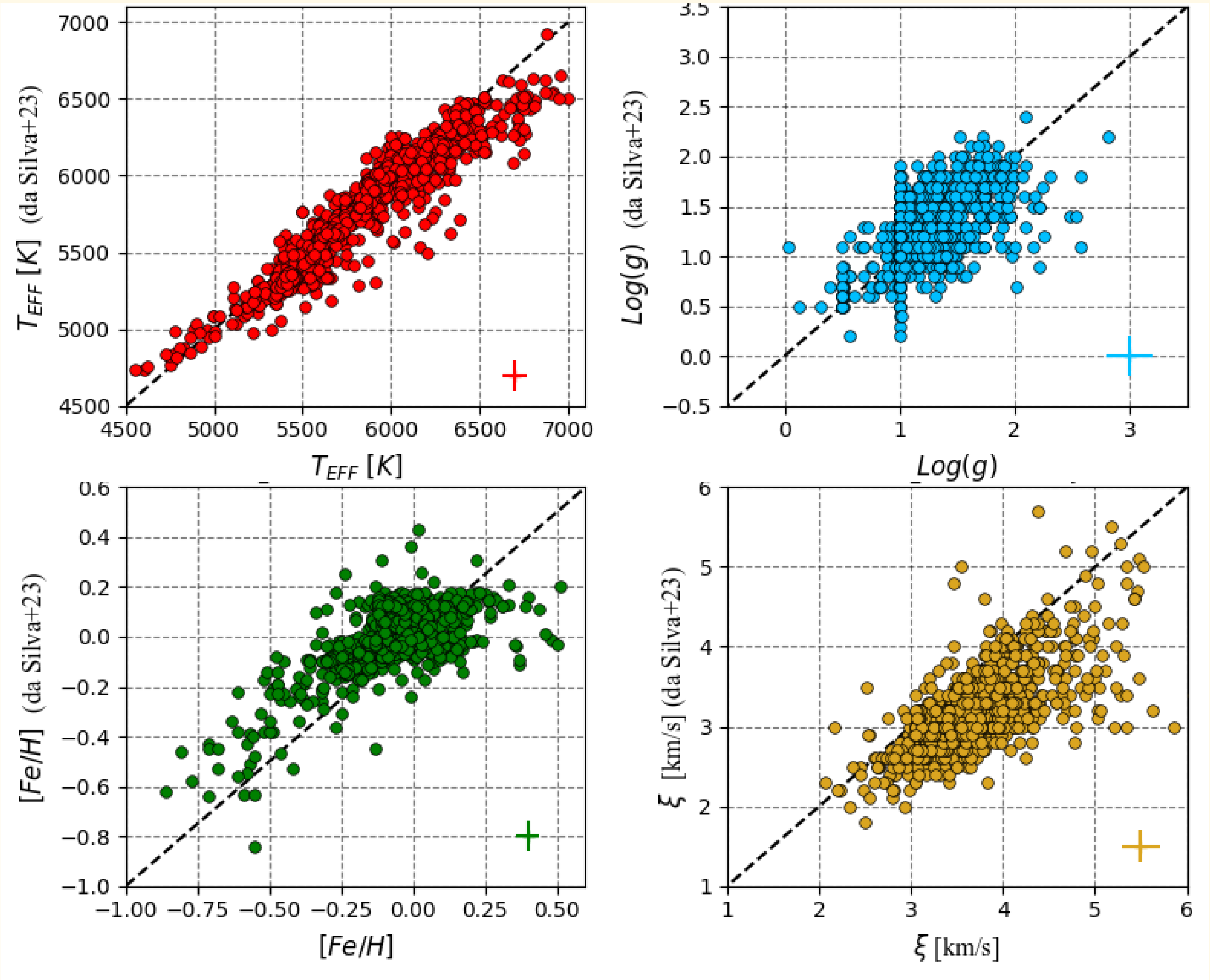
350 APOGEE spectra, 300 Classical Cepheids



Credits to Henrik Jönsson

Galactic and Magellanic cepheids!

NLTE atmospheric parameters



(on average) higher temperatures (+200K)

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Nunnari+ (in prep.)

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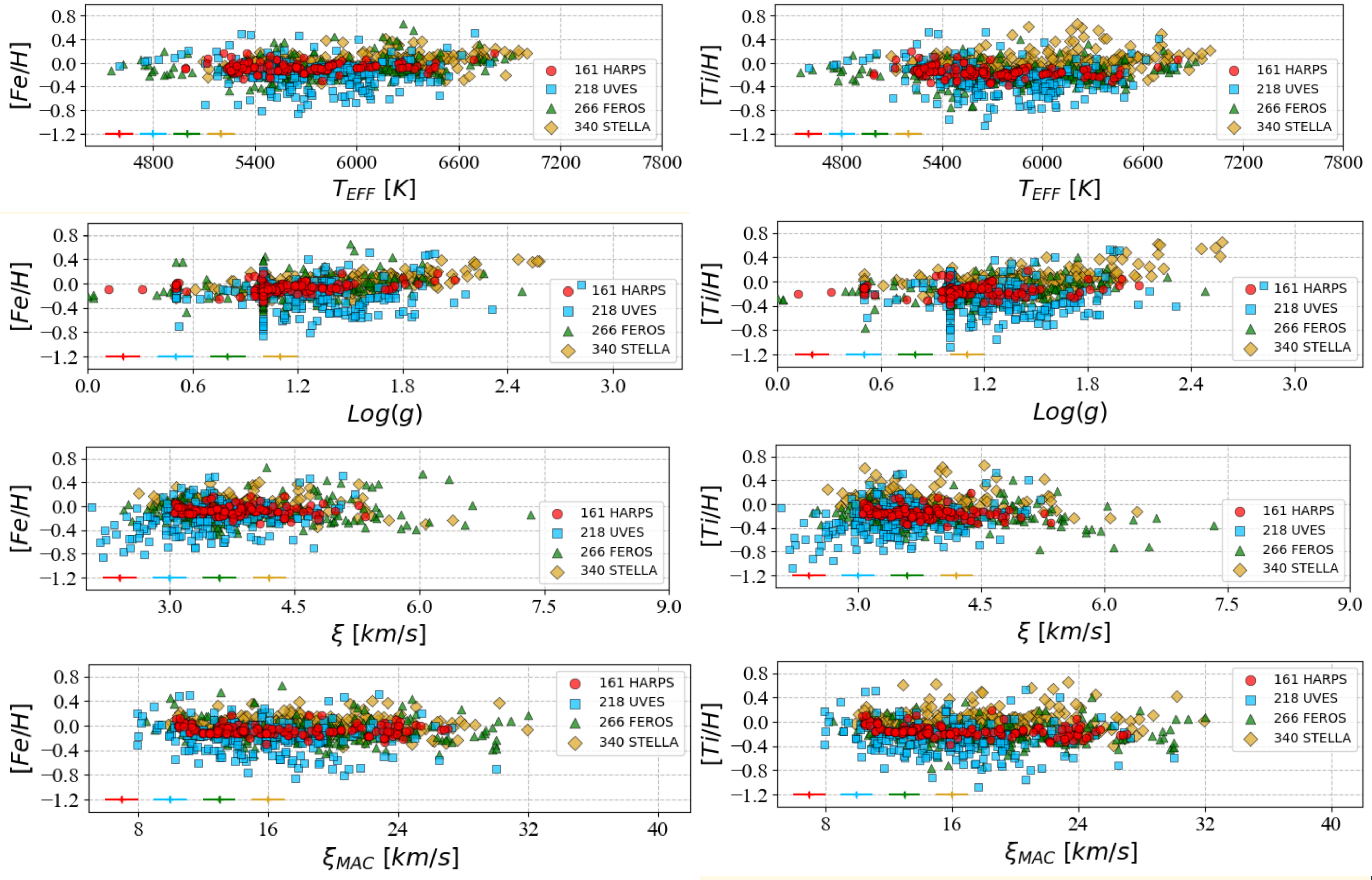
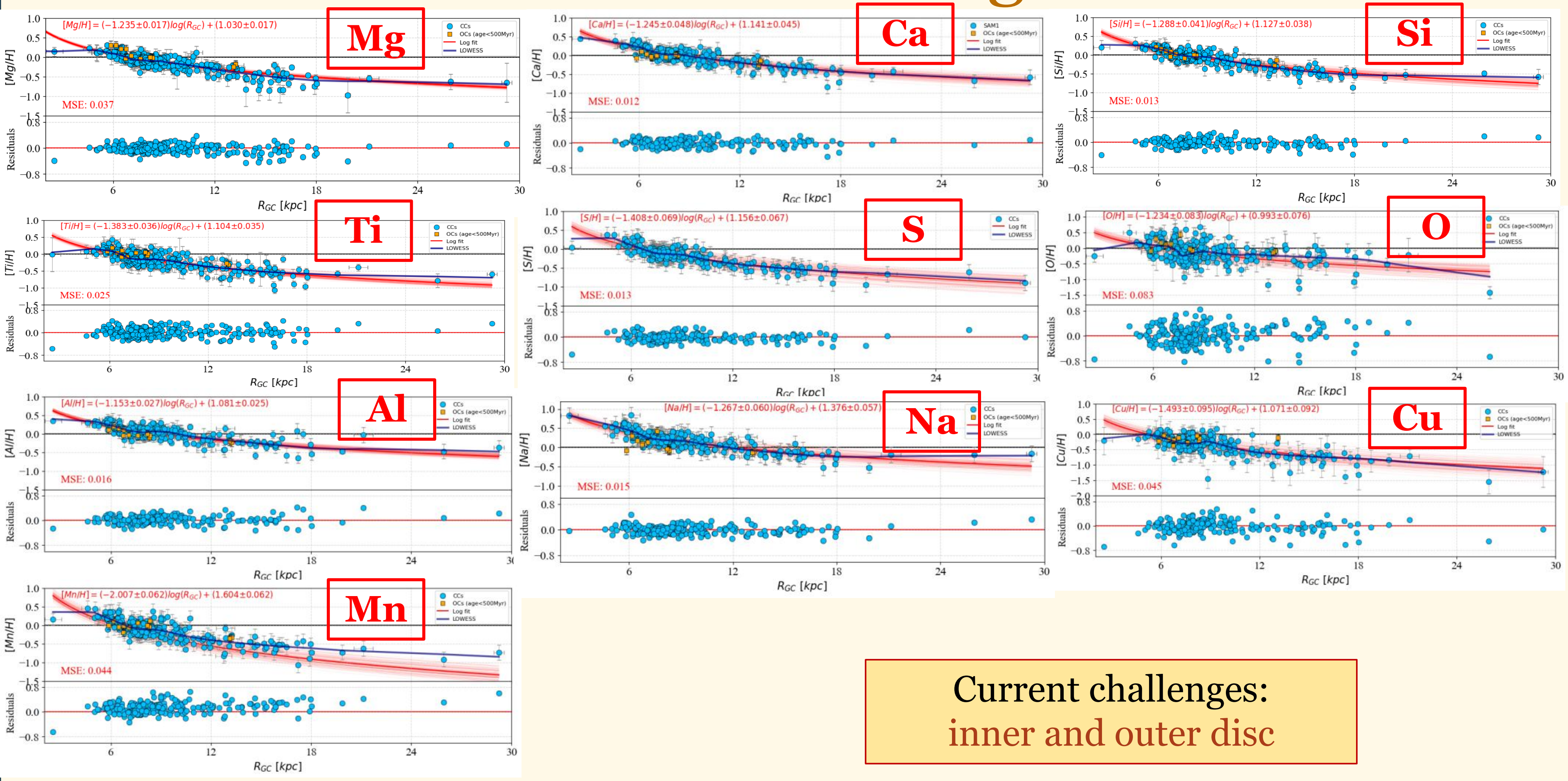
No trends!



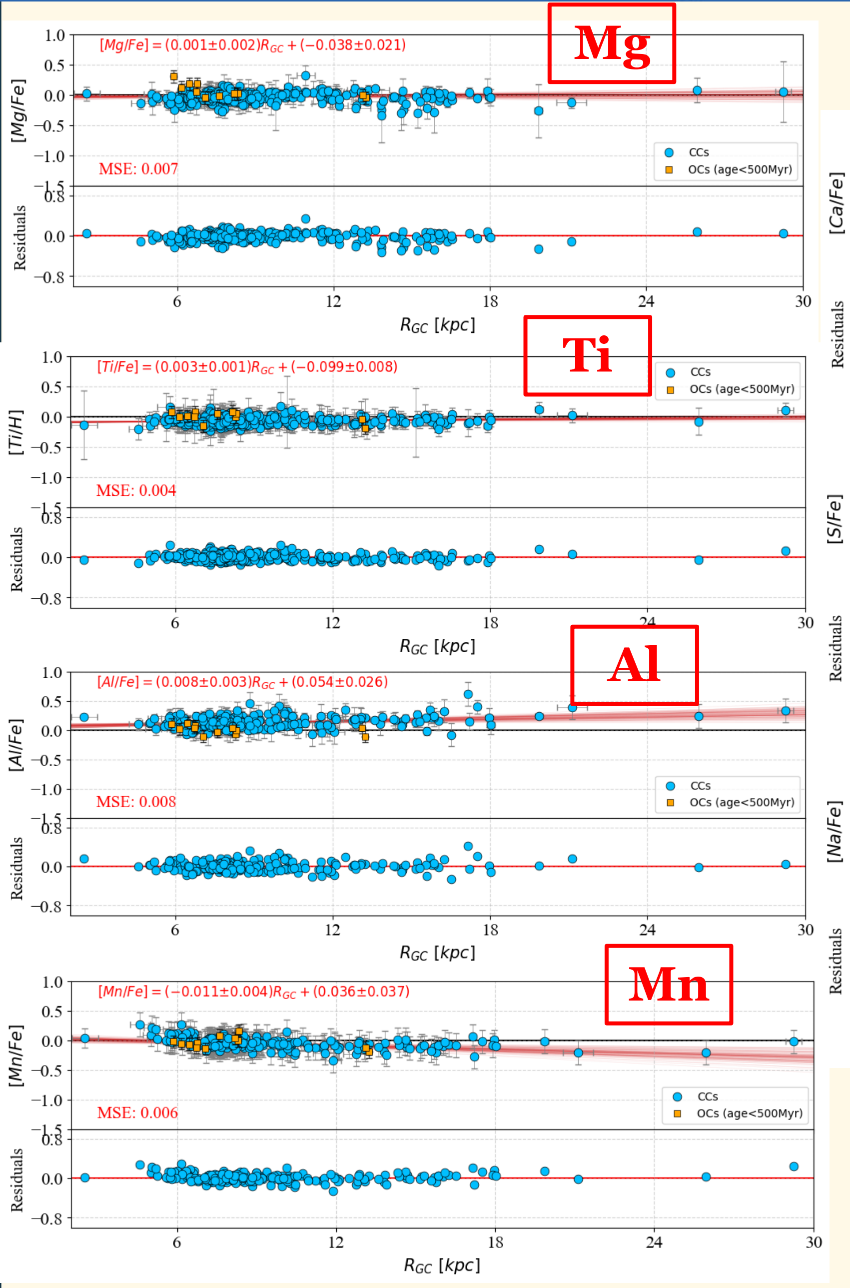
Nunnari+ (in prep.)

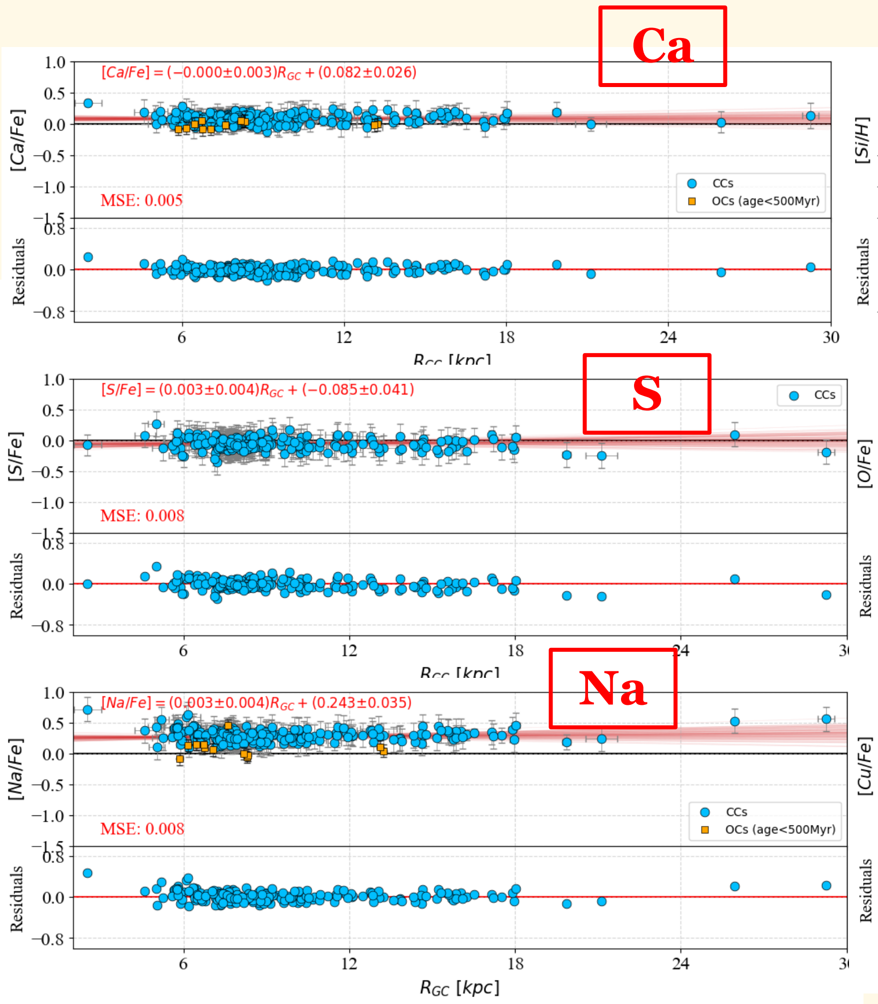
Chemical gradients

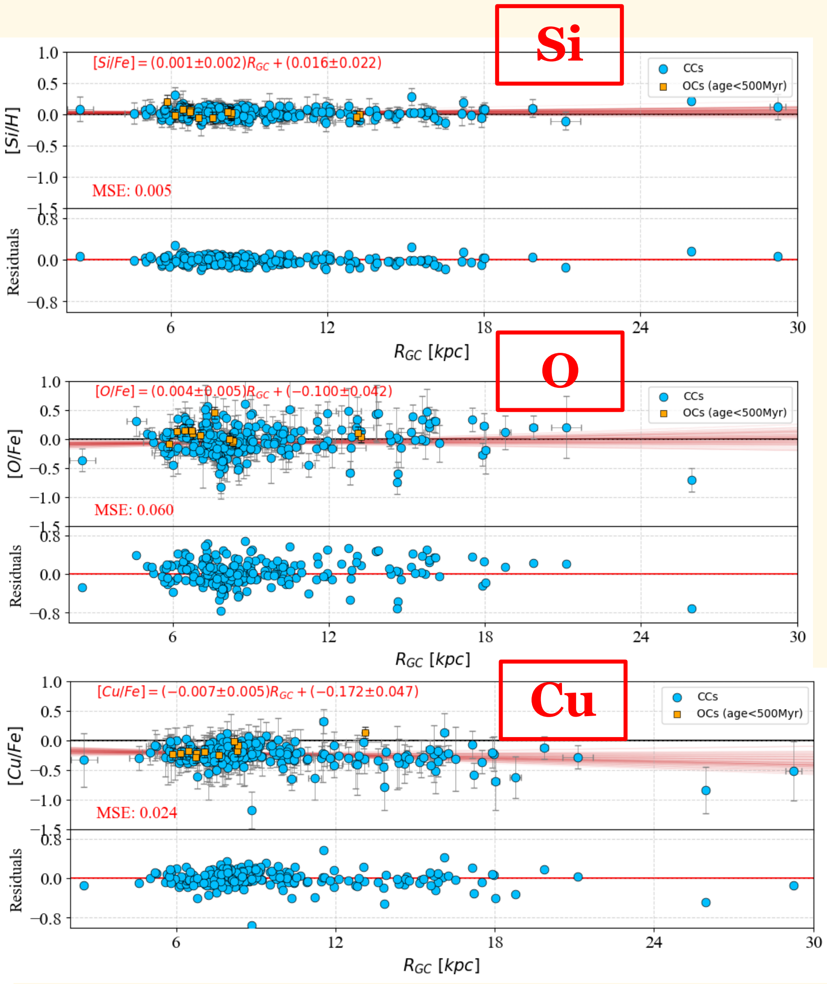


Current challenges:
inner and outer disc

Nunnari+ (in prep.)



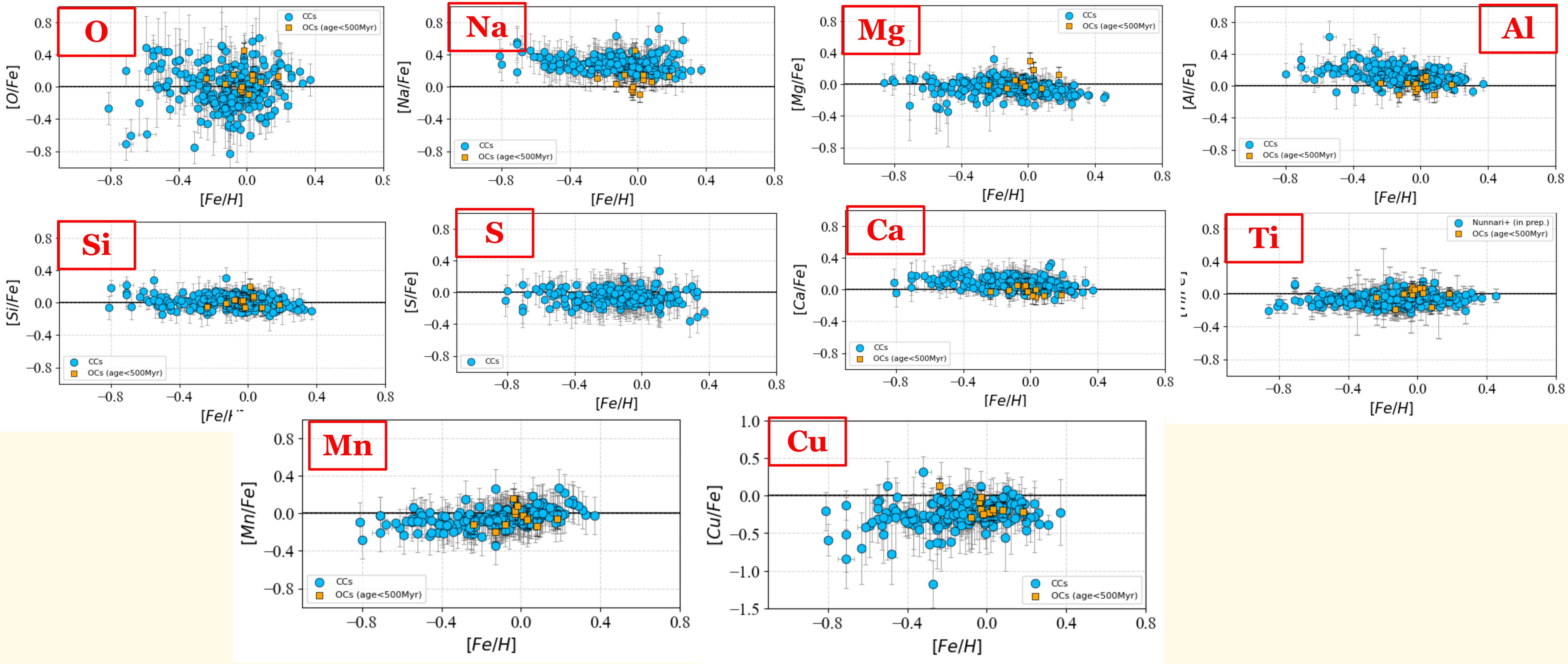




Nunnari+ (in prep.)

Nunnari+ (in prep.)

Chemical planes



Nunnari+ (in prep.)

Age effects