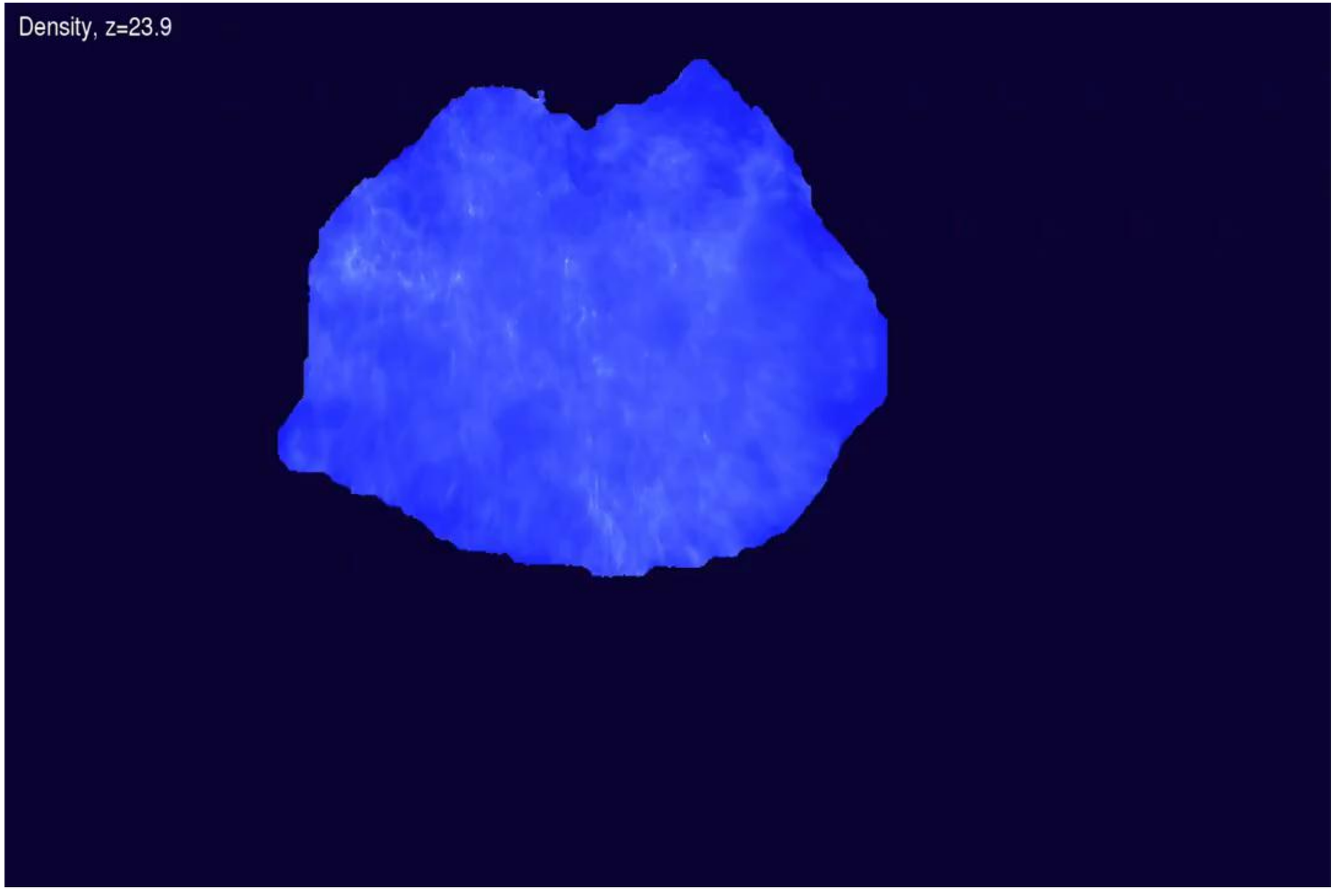
Surprising results from spectroscopic analysis of stars close to the supermassive black hole

OBSERVATOIRE DE LA CÔTE D'AZUR
UNIVERSITÉ CÔTE D'AZUR

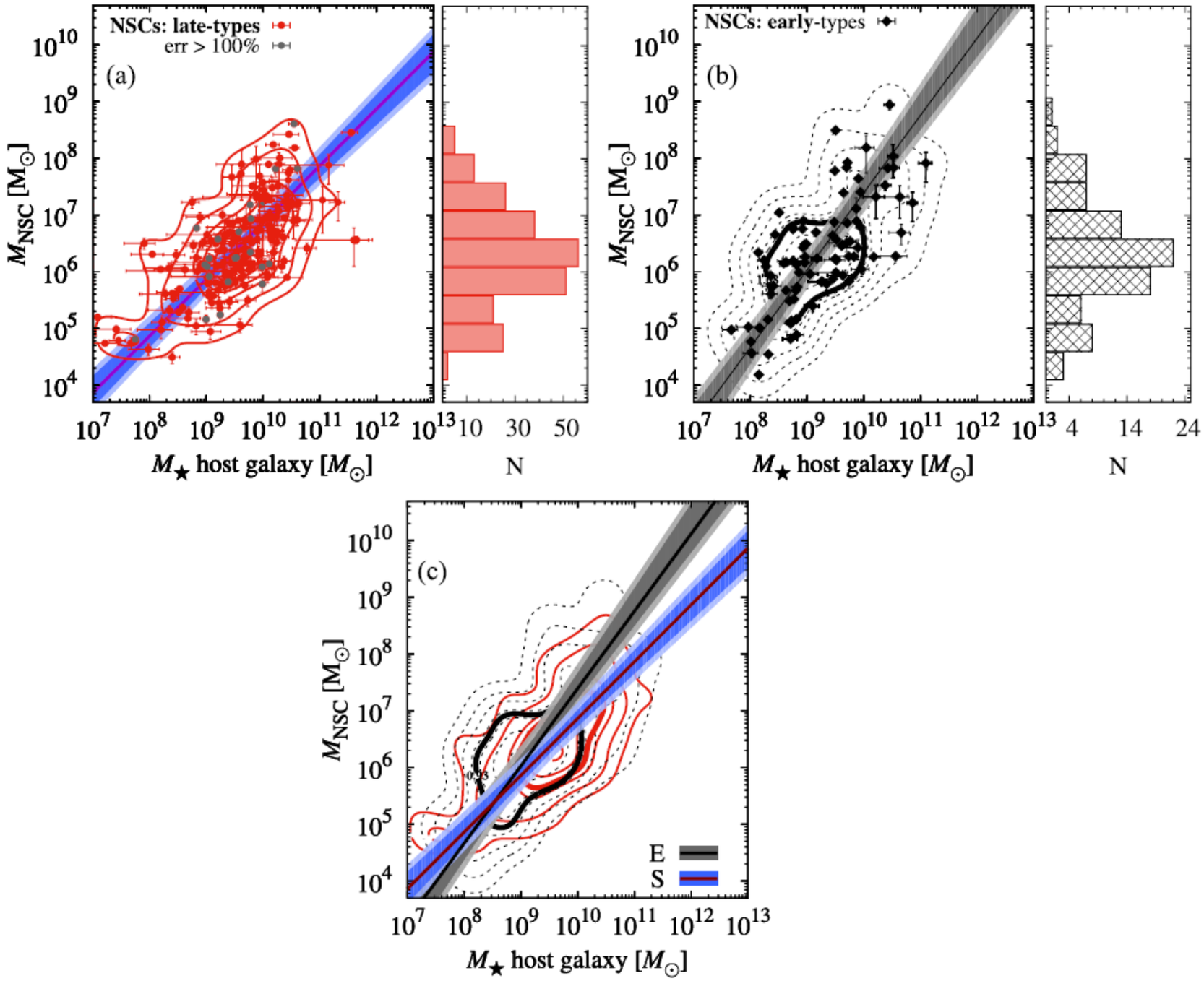
BRIAN THORSBRO,
JUNE 2025,
COMPAS, LUND

Galactic evolution



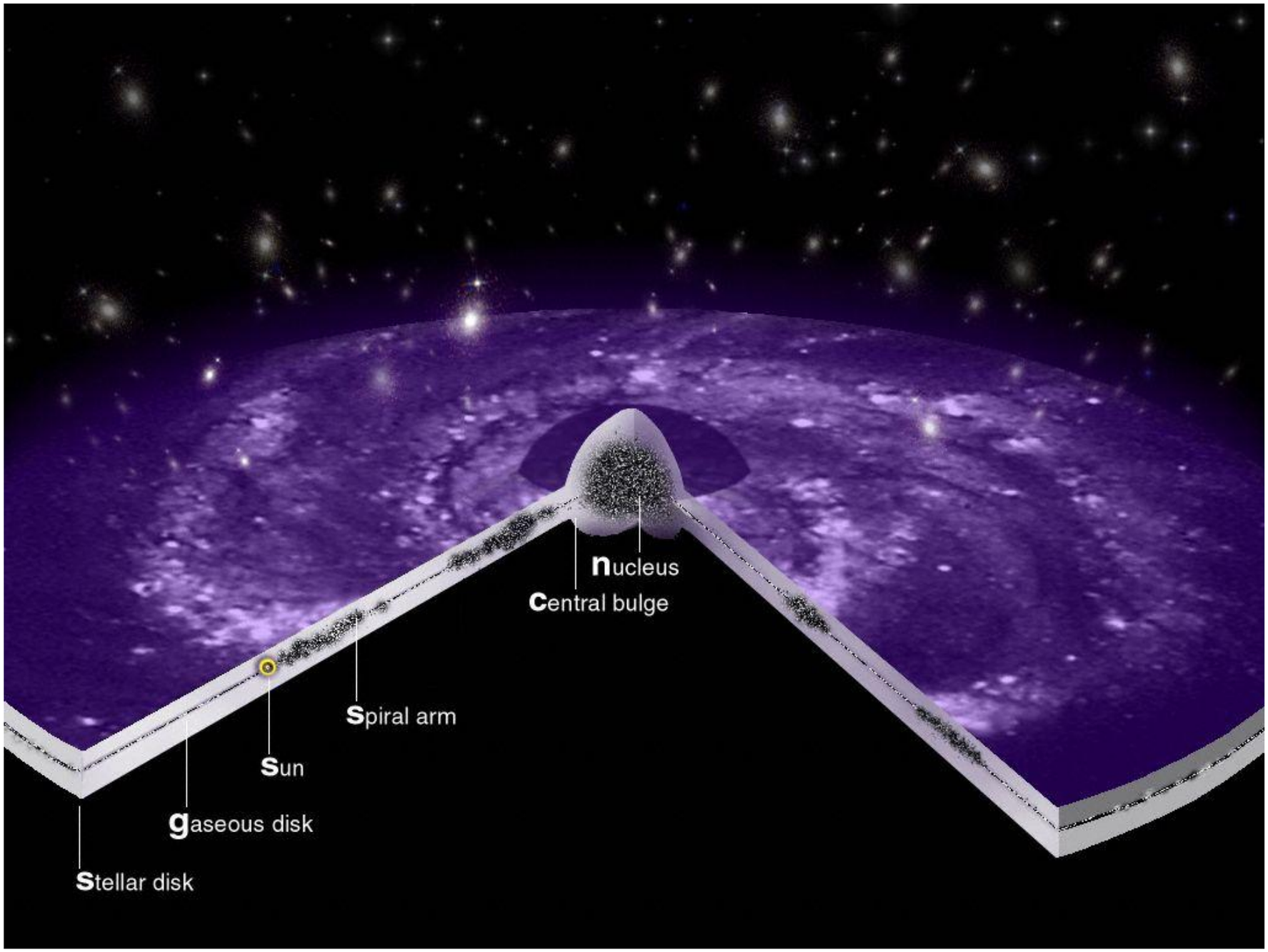
Credit: Oscar Agertz

Galaxies and their centres



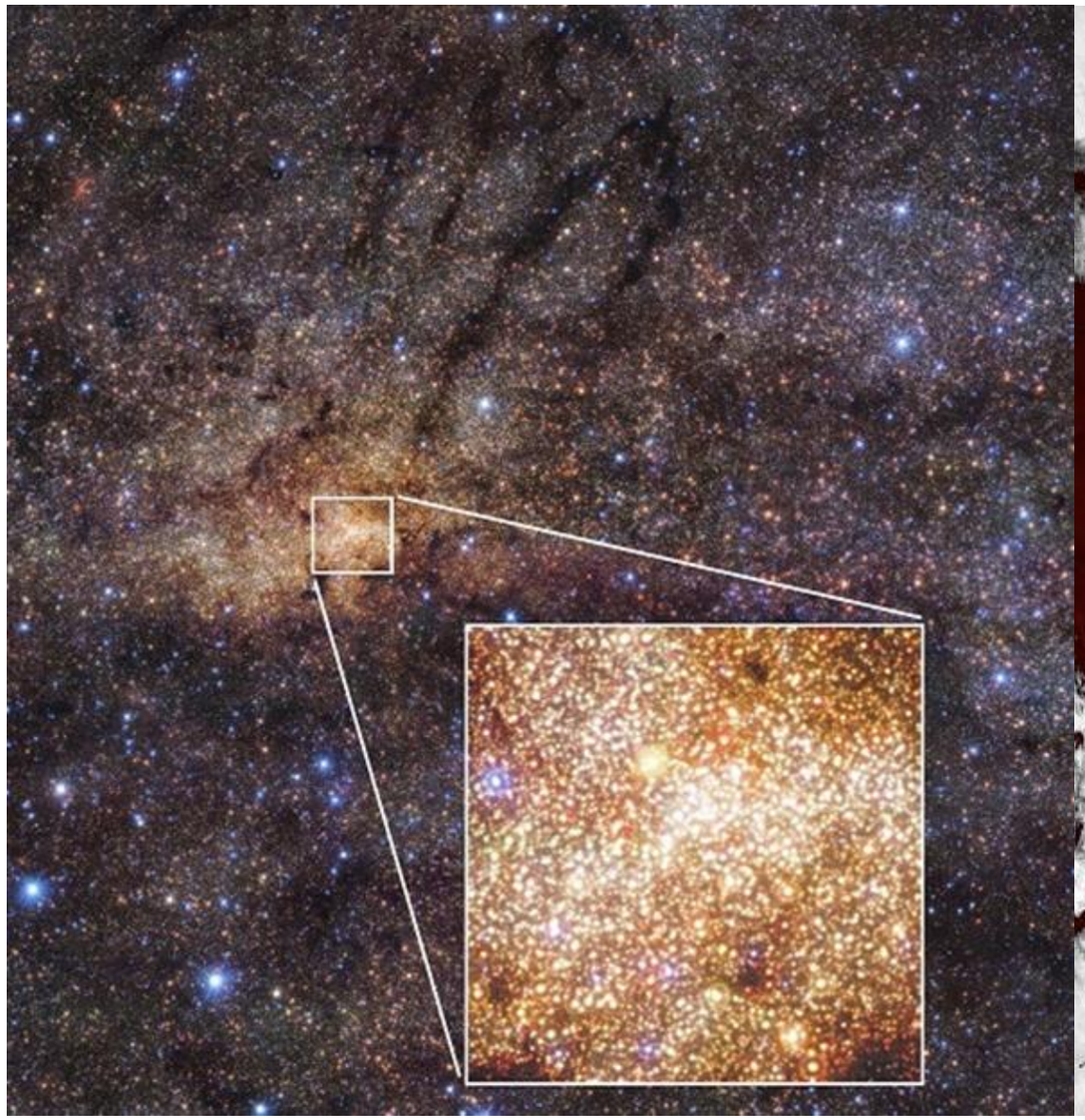
(Georgiev et al, 2016)

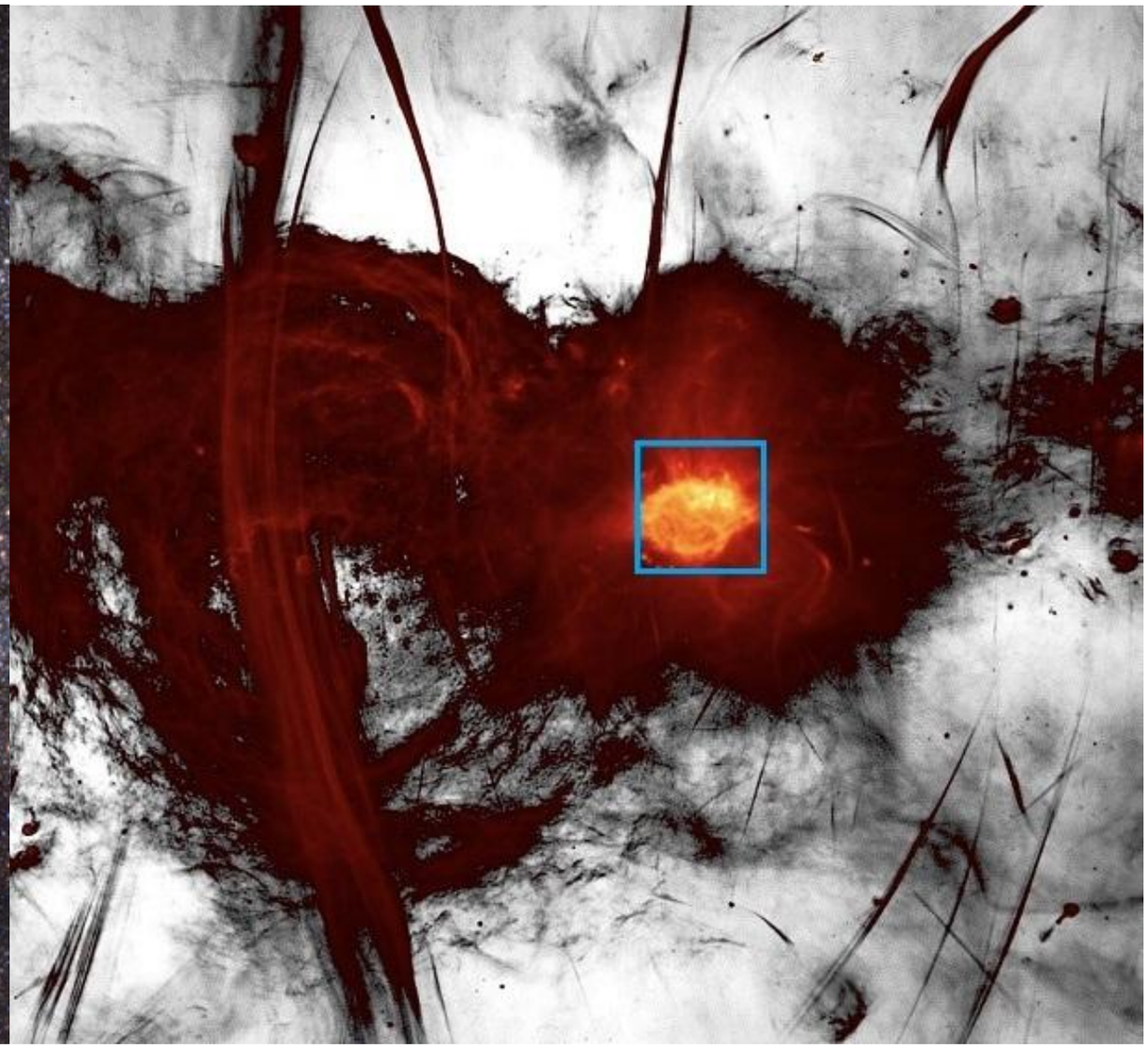
The Milky Way



Credit: ESO, Infrared Space Observatory

The nuclear star cluster



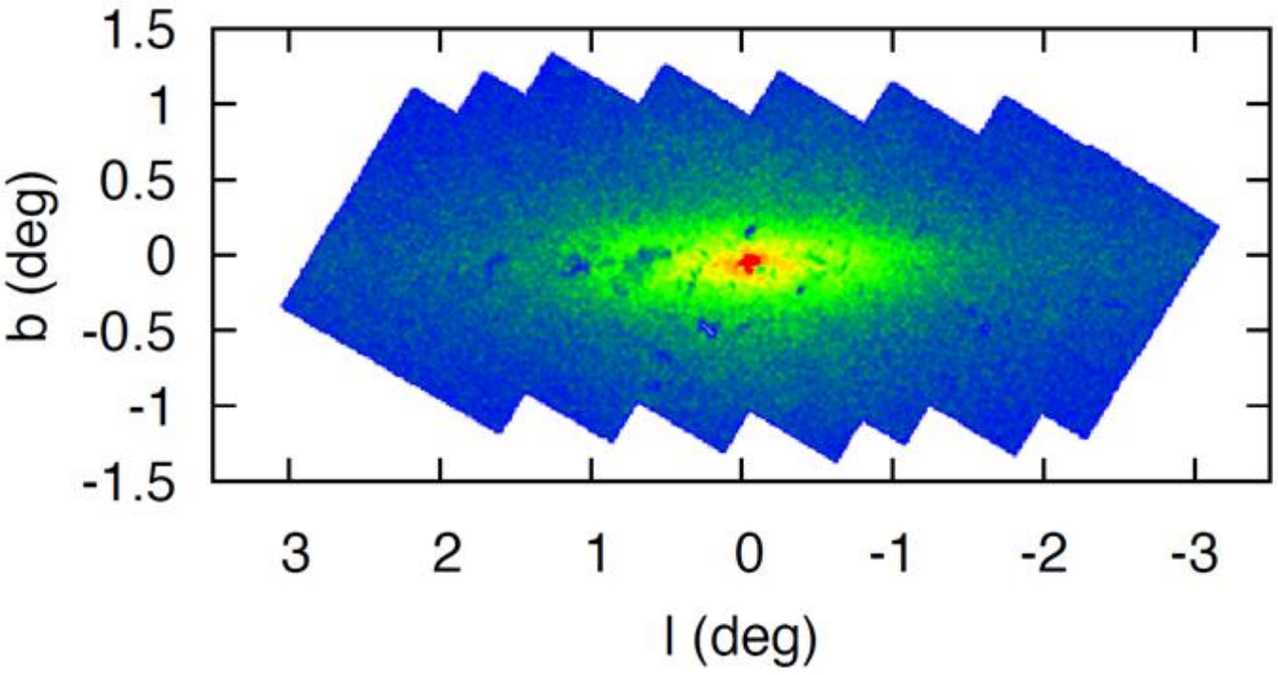


Square: 10x10 pc
SMBH in center

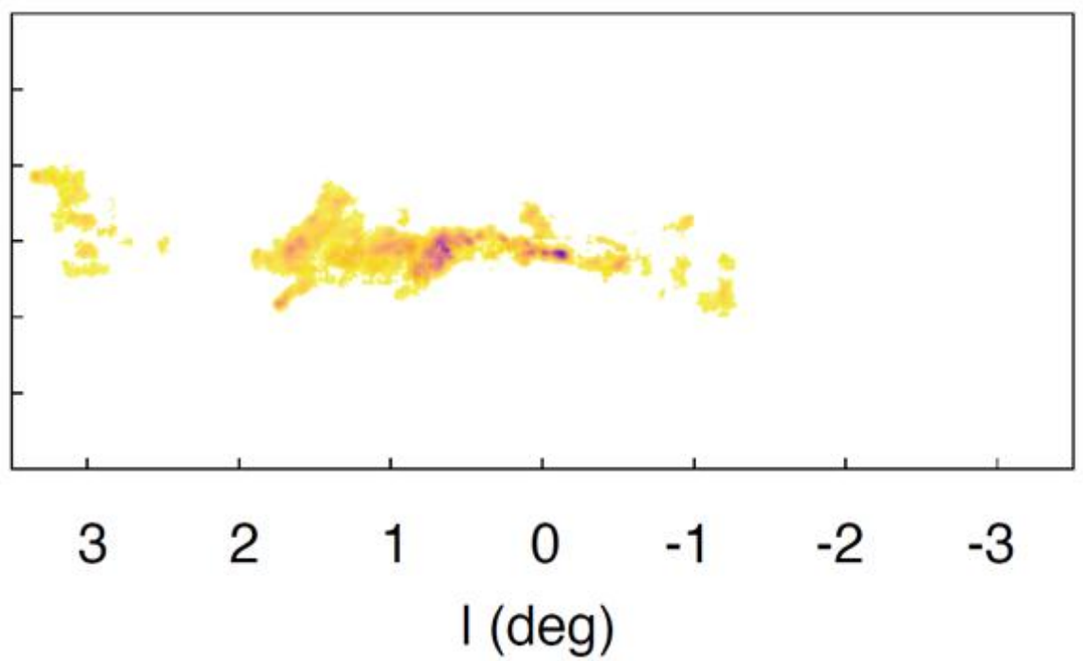
GALACTICNUCLEUS survey (Nogueras-Lara et al., 2018, 2019)
MeerKAT Galactic Center Mosaic (Heywood et al., 2022)

Nuclear cluster and disk and central molecular zone

Stars (NSC/NSD)



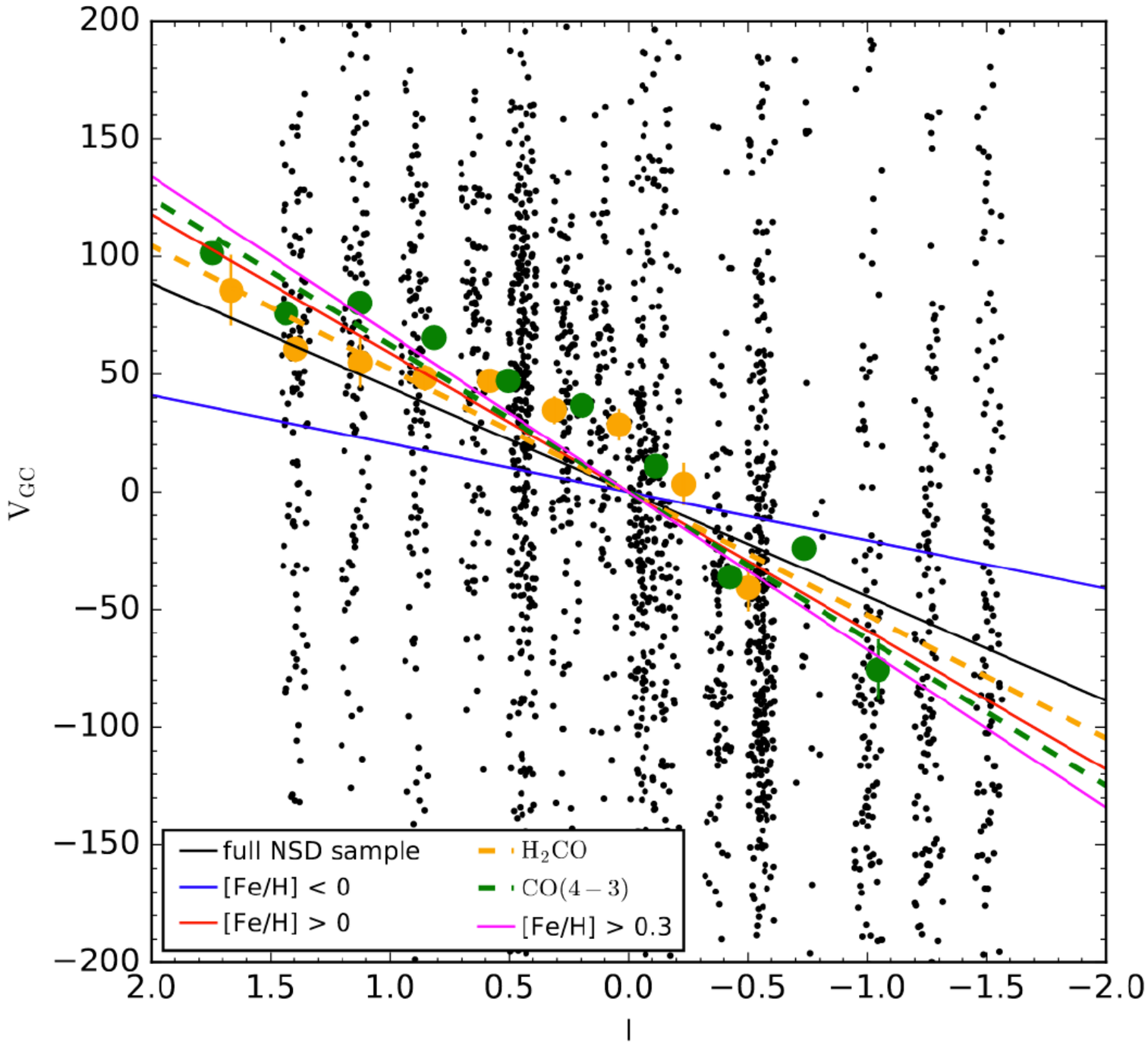
Gas (CMZ)



$1° \simeq 140$ pc

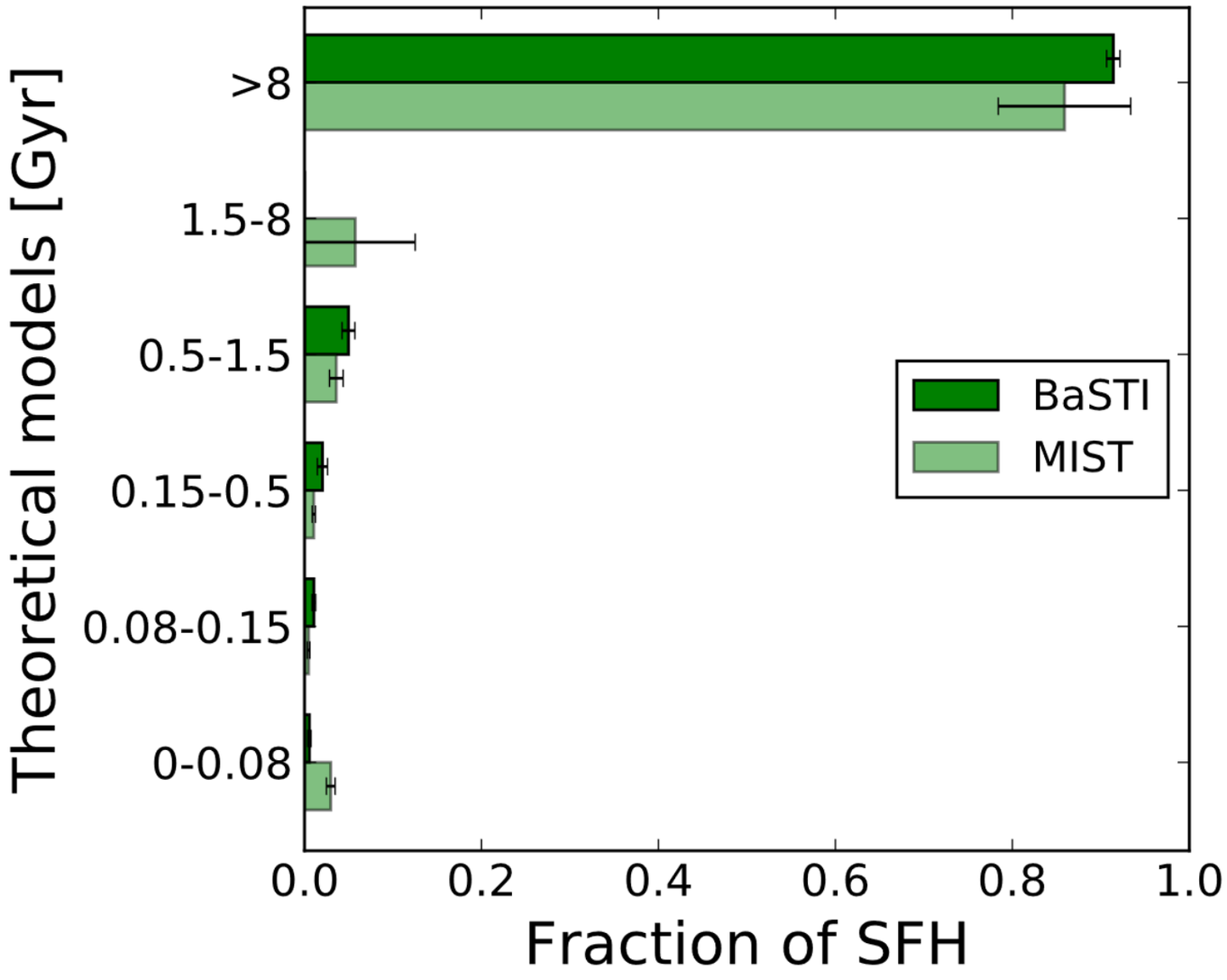
(Nishiyama et al. 2013, Purcell et al. 2012)

NSD and CMZ rotate together

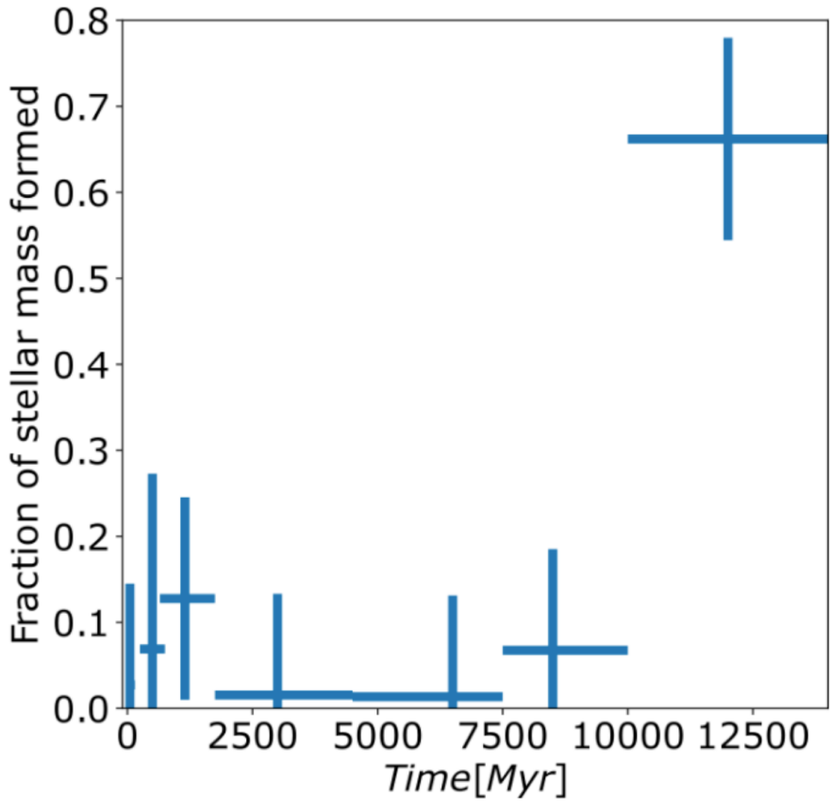


(Schöenrich et al. 2015, Schultheis et al. 2021)

NSD star formation history



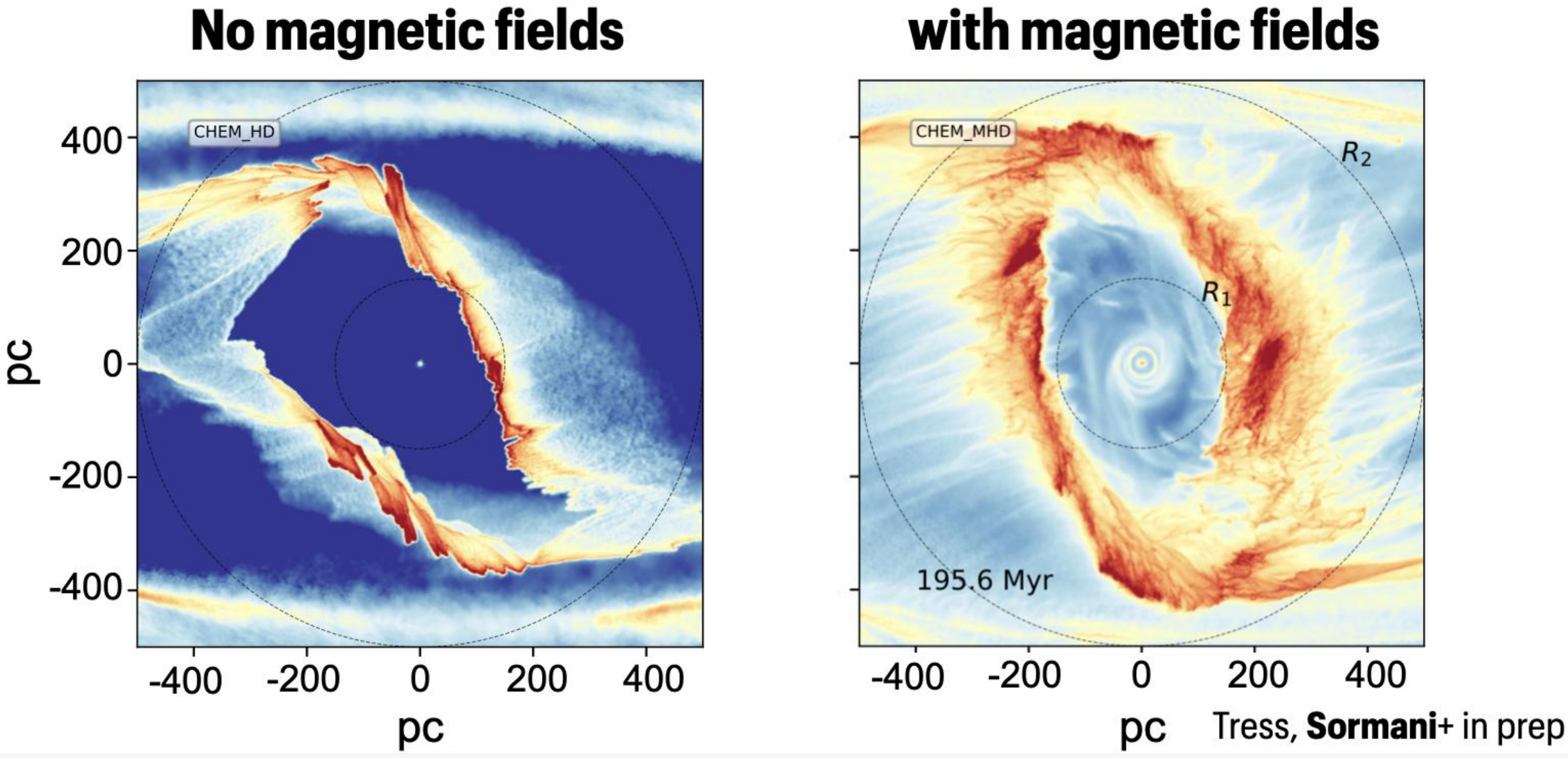
Big SF event,
Bar formation?



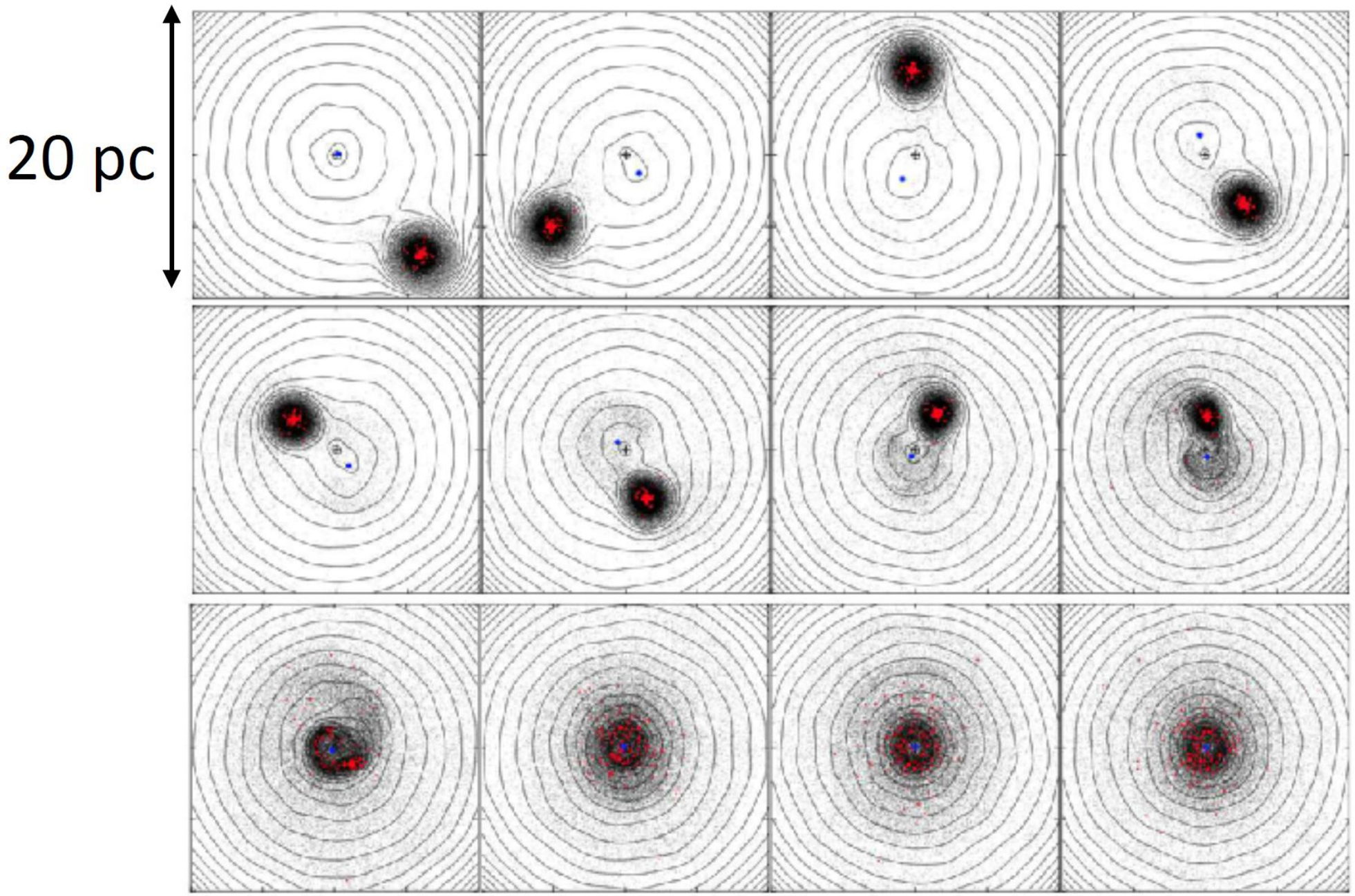
Quintuplet region
(excluding the cluster)

(Nogueras-Lara et al. 2020, Schödel et al. 2023)

Gas flow from NSD to NSC

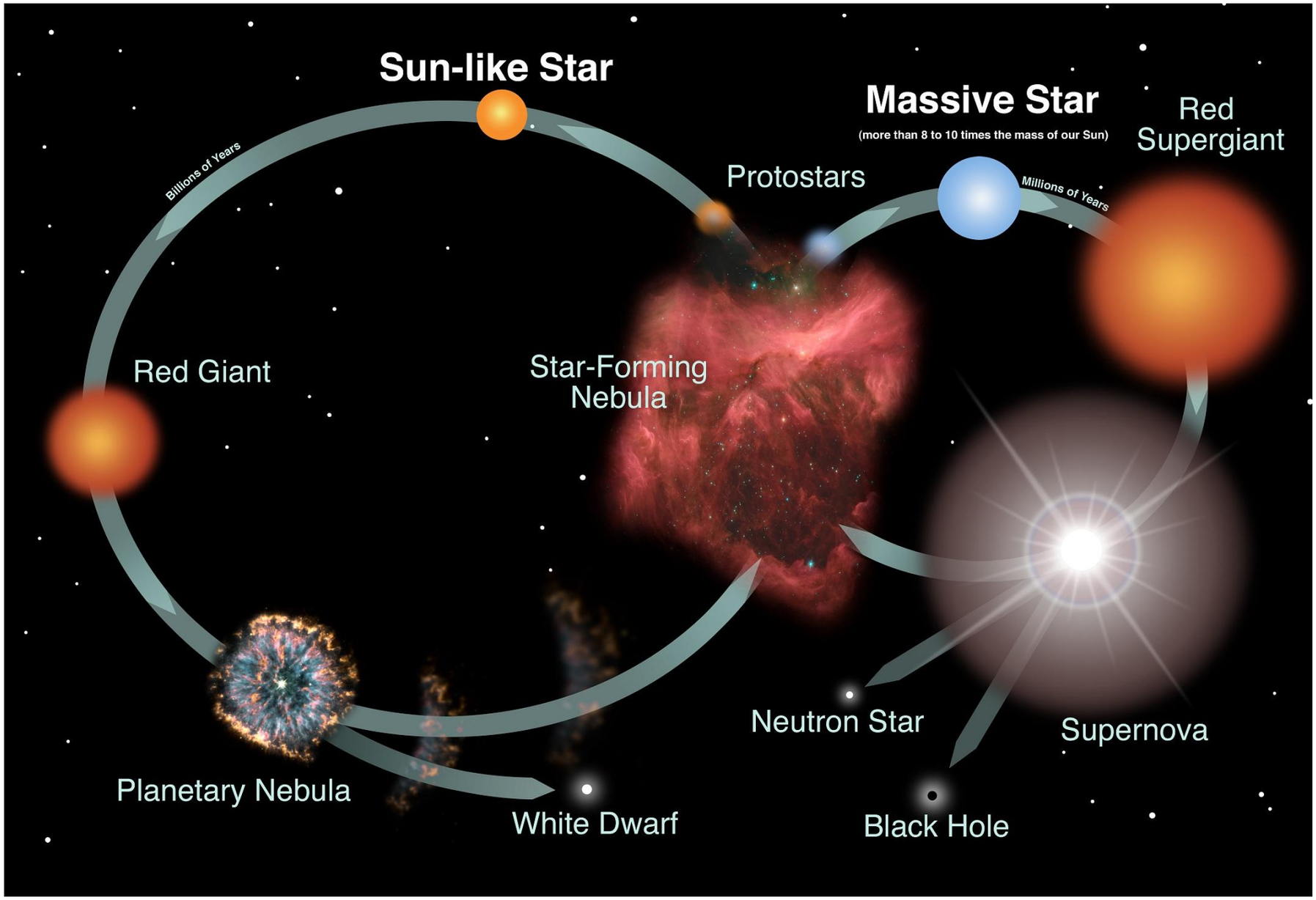


Infalling globular clusters



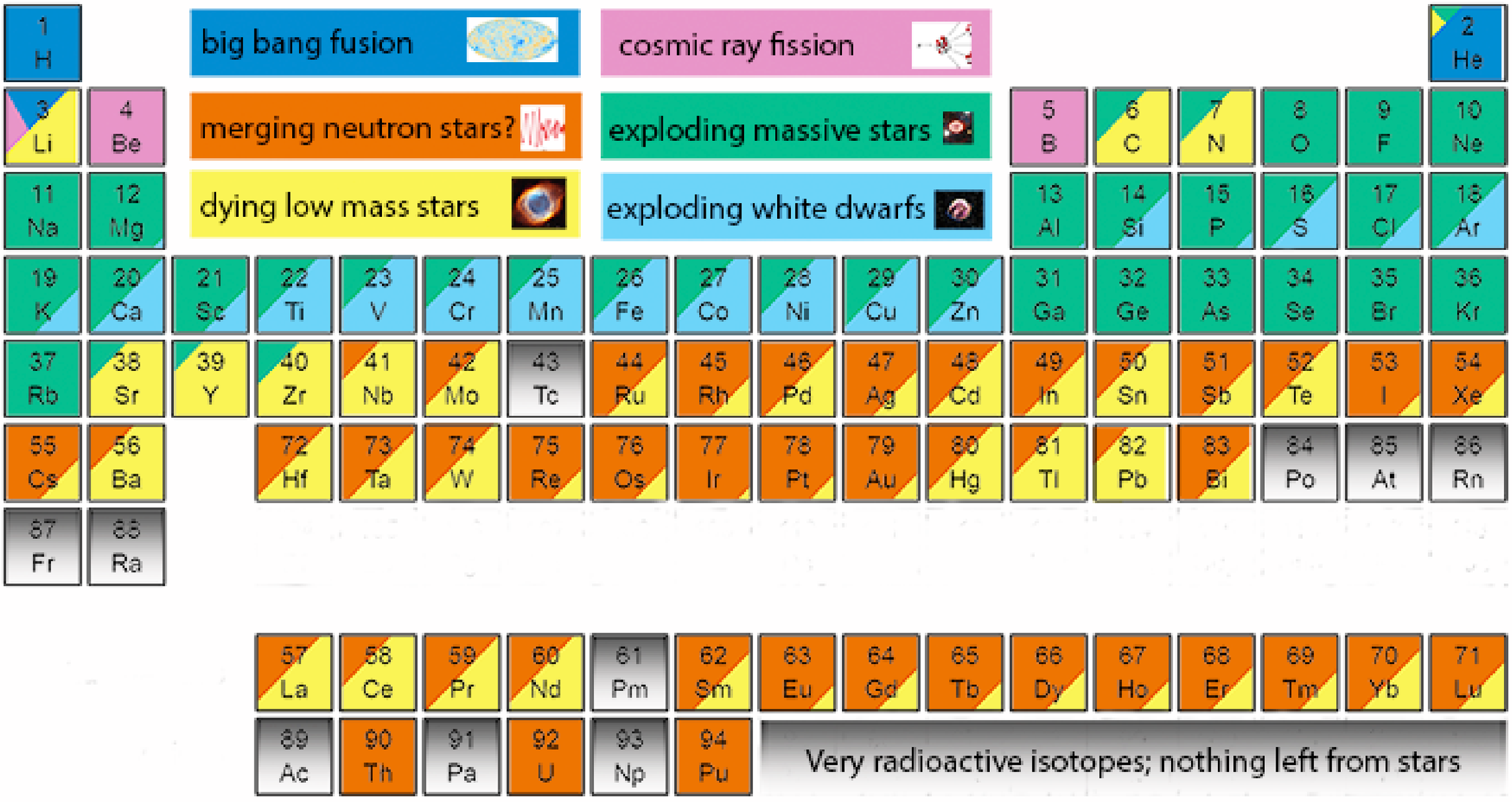
(Antonini, 2014)

Stellar evolution



Credit: NASA and the Night Sky Network

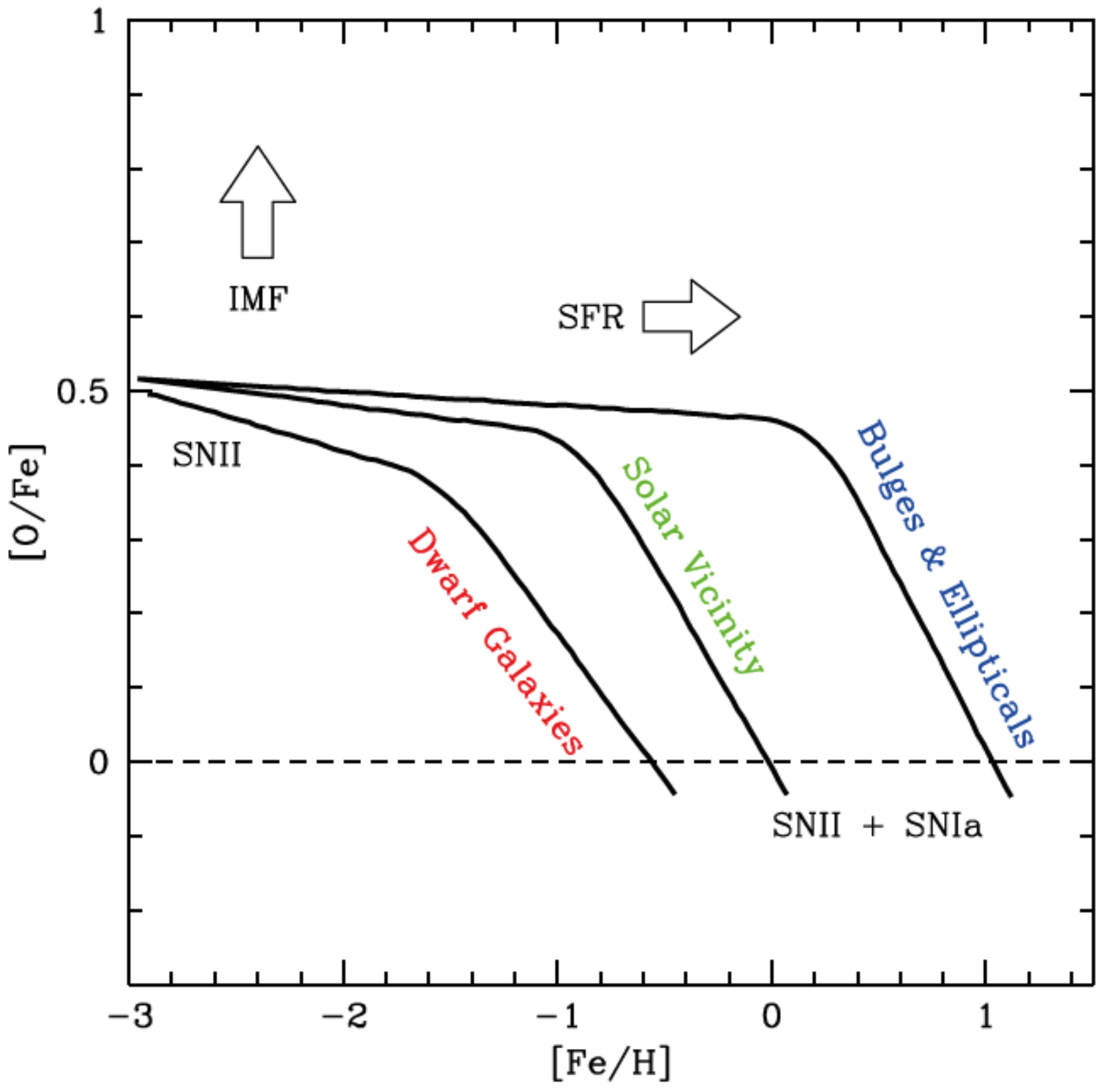
Nucleosynthesis



Graphic created by Jennifer Johnson
http://www.astronomy.ohio-state.edu/~jaj/nucleo/

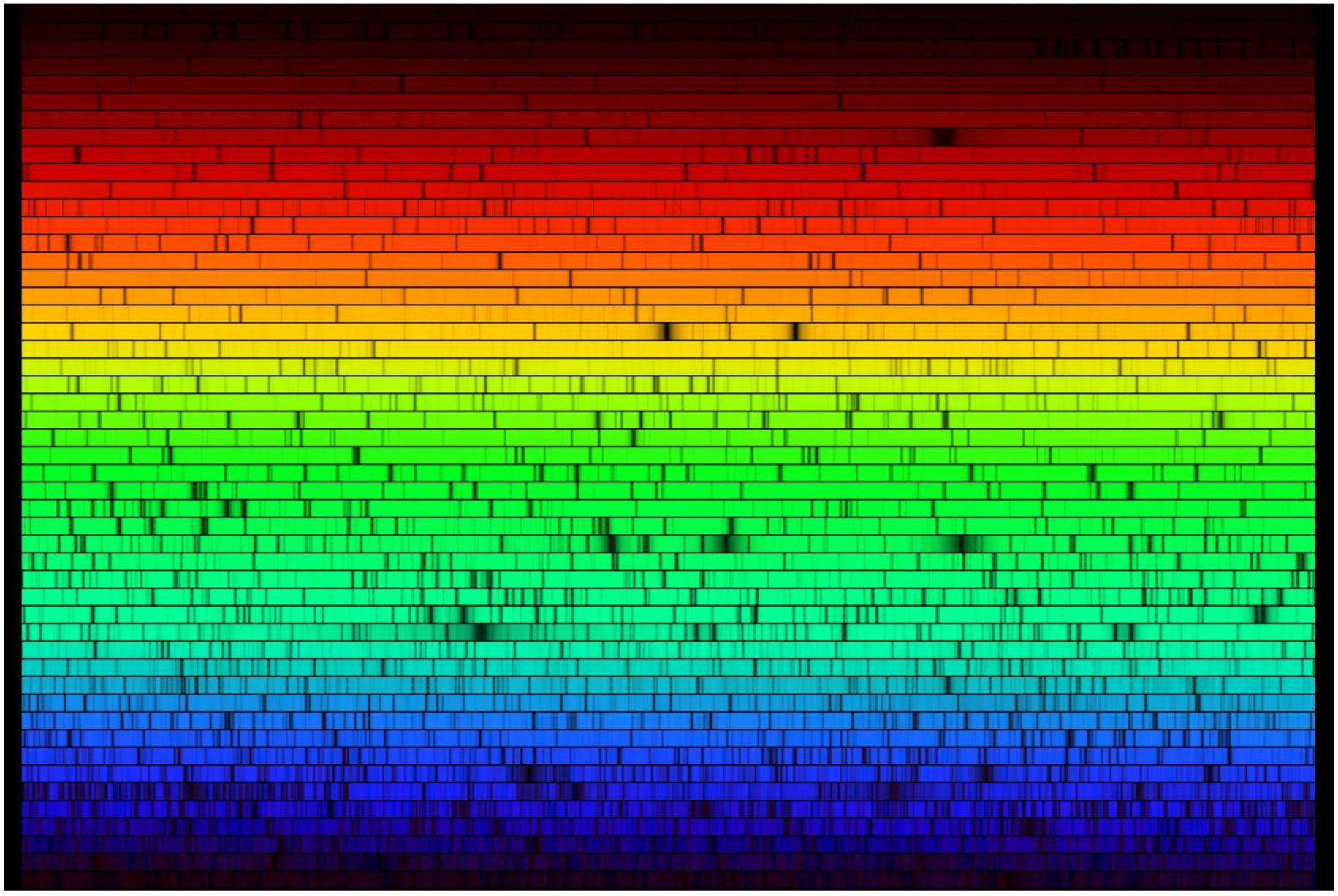
Astronomical Image Credits:
ESA/NASA/AASNova

The “alpha-knee”



(McWilliam, 2016)

The observables

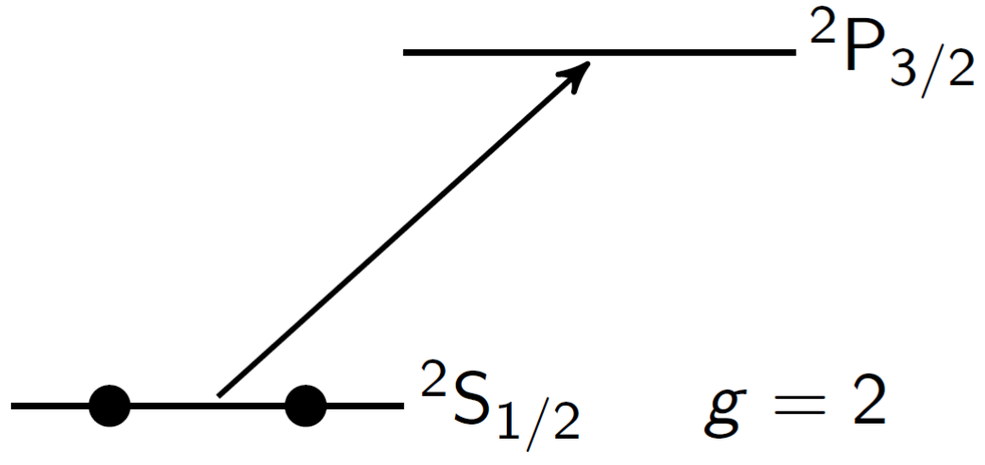


Credit: NOAO, McMath Pierce Solar Telescope

Line properties

Statistical weight:

$$g = 2J + 1$$



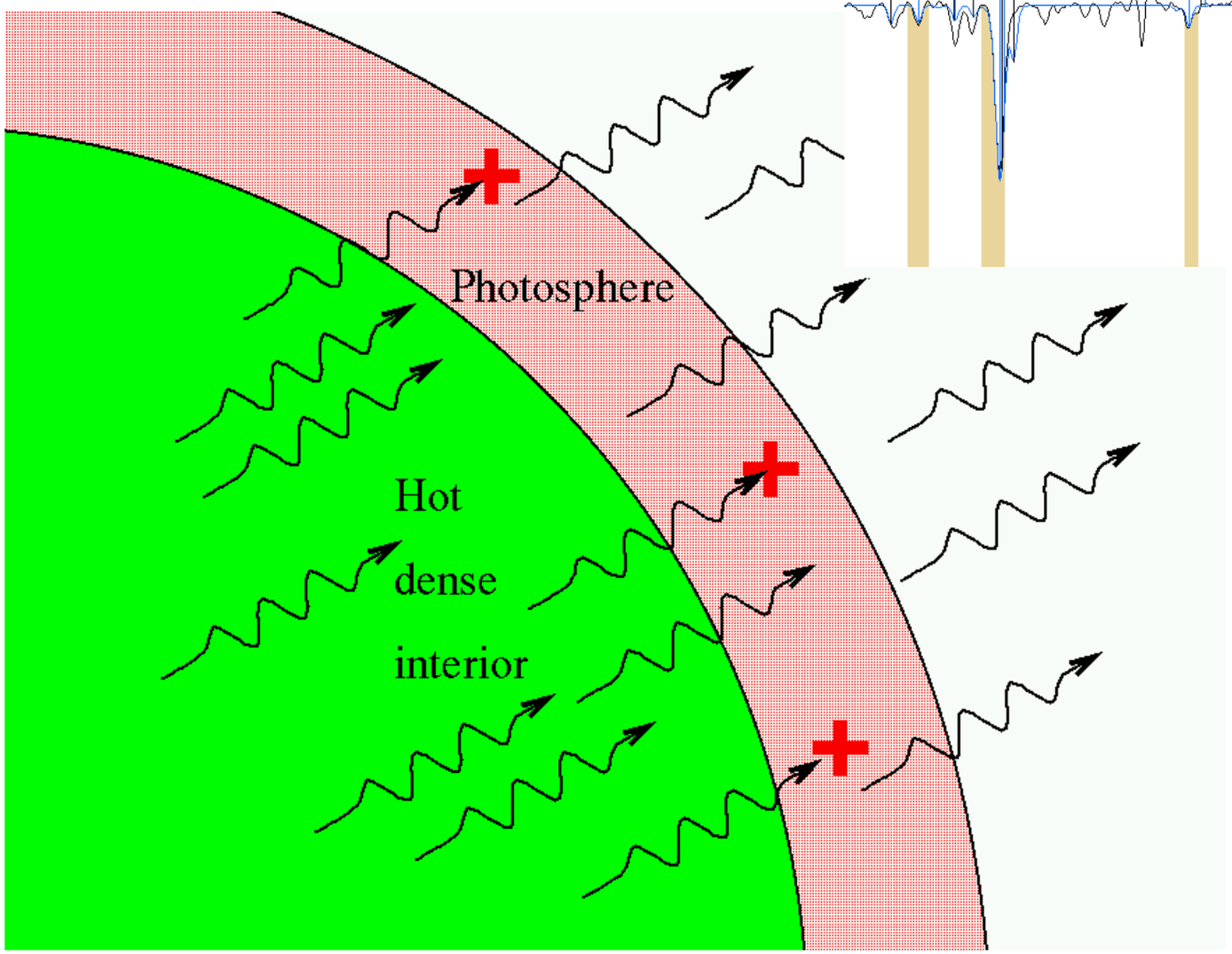
Example: Iron line $3d^7(^4F)5s\ ^3F_3 - 3d^7(^4F)5p\ ^5D_4$

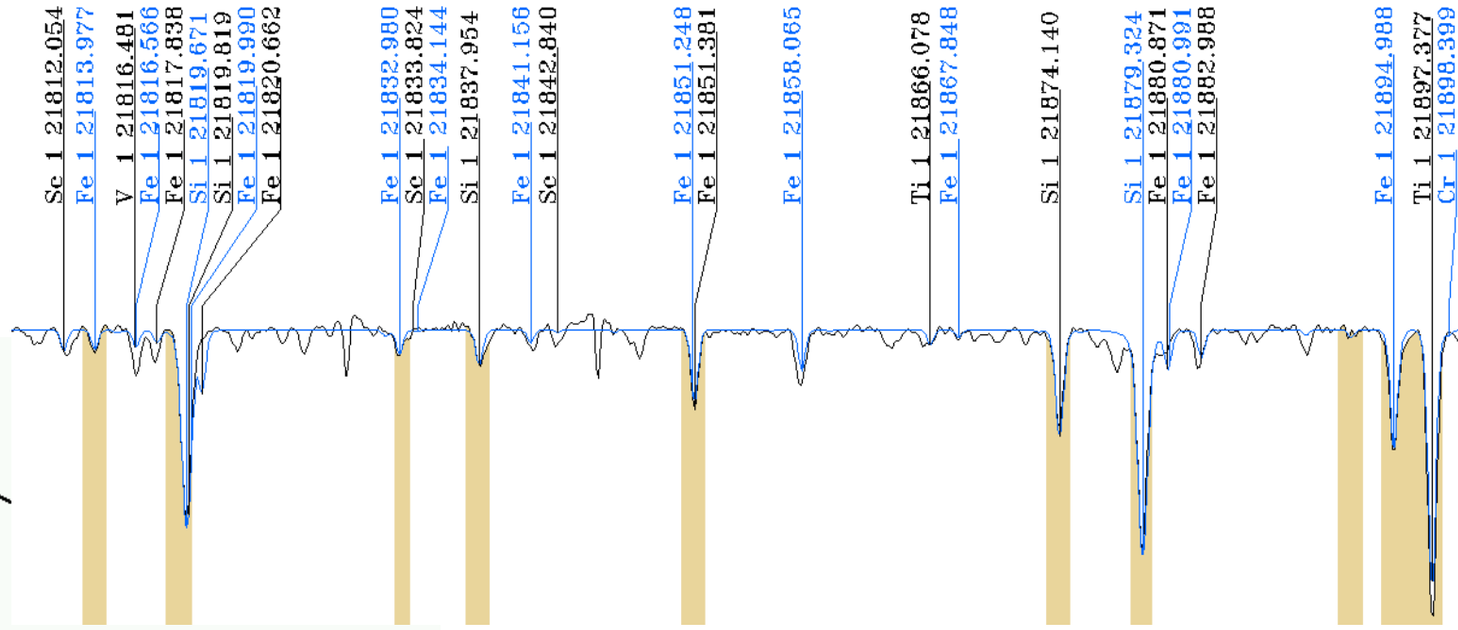
Line properties:

Wavelength: 19685.30 Å (air)

gf-value: log(*gf*) = -1.230

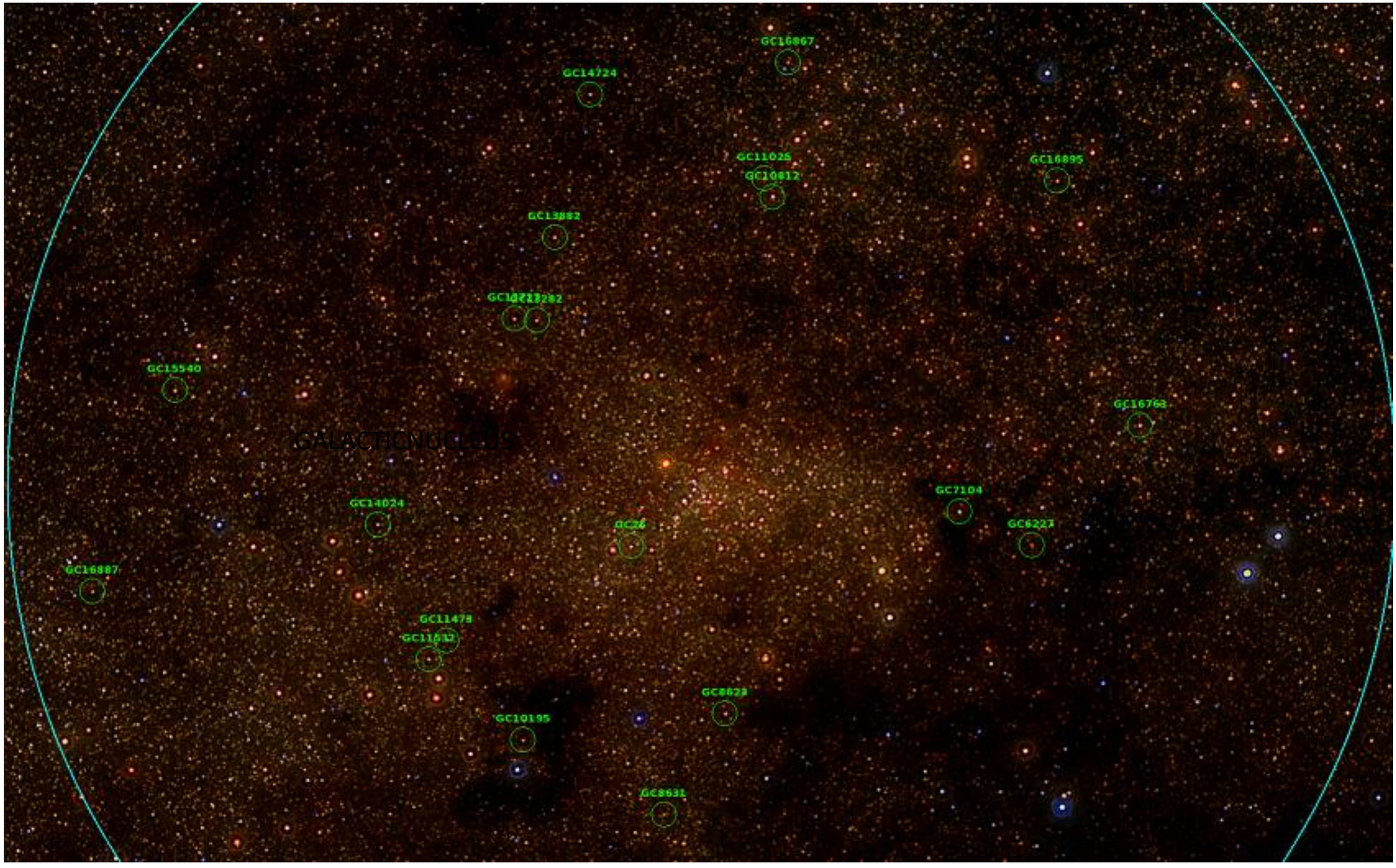
The photosphere





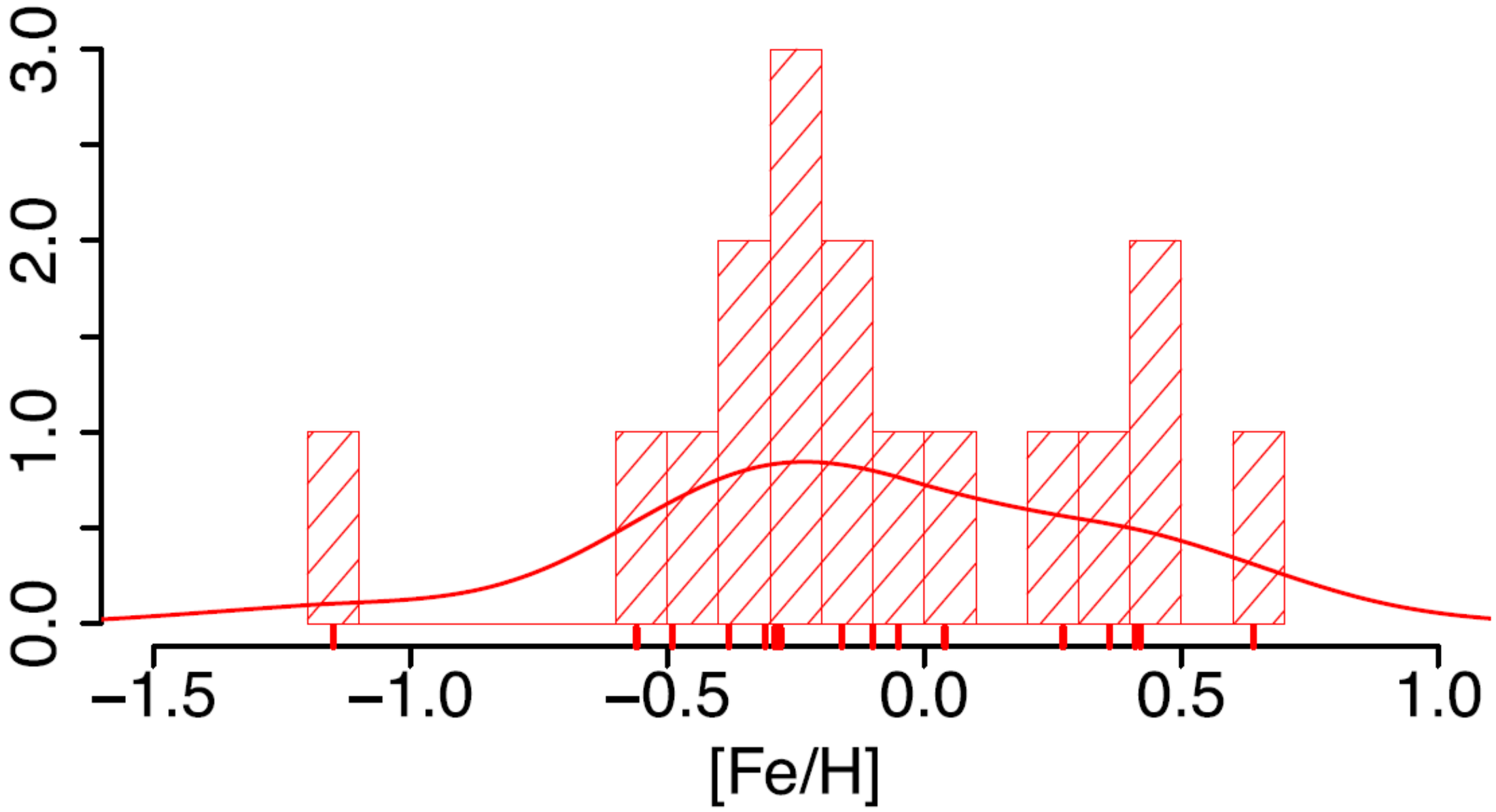
Spectrum of Arcturus

Targeted stars, with KECK/NIRSPEC



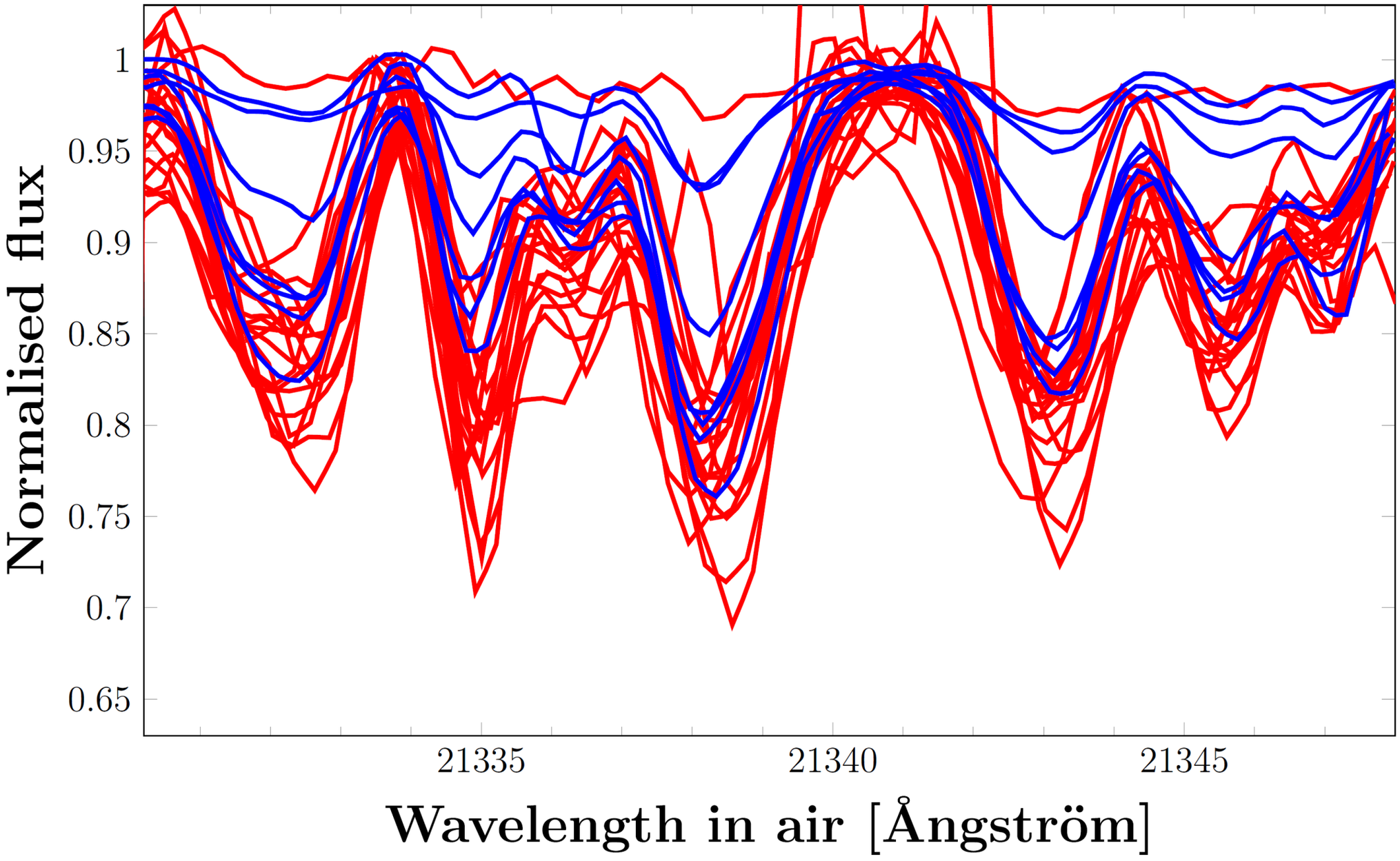
JHKs RGB image from the GALACTICNUCLEUS survey (Nogueras-Lara et al. 2018, 2019)

Galactic centre MDF



(Rich et al., 2017)

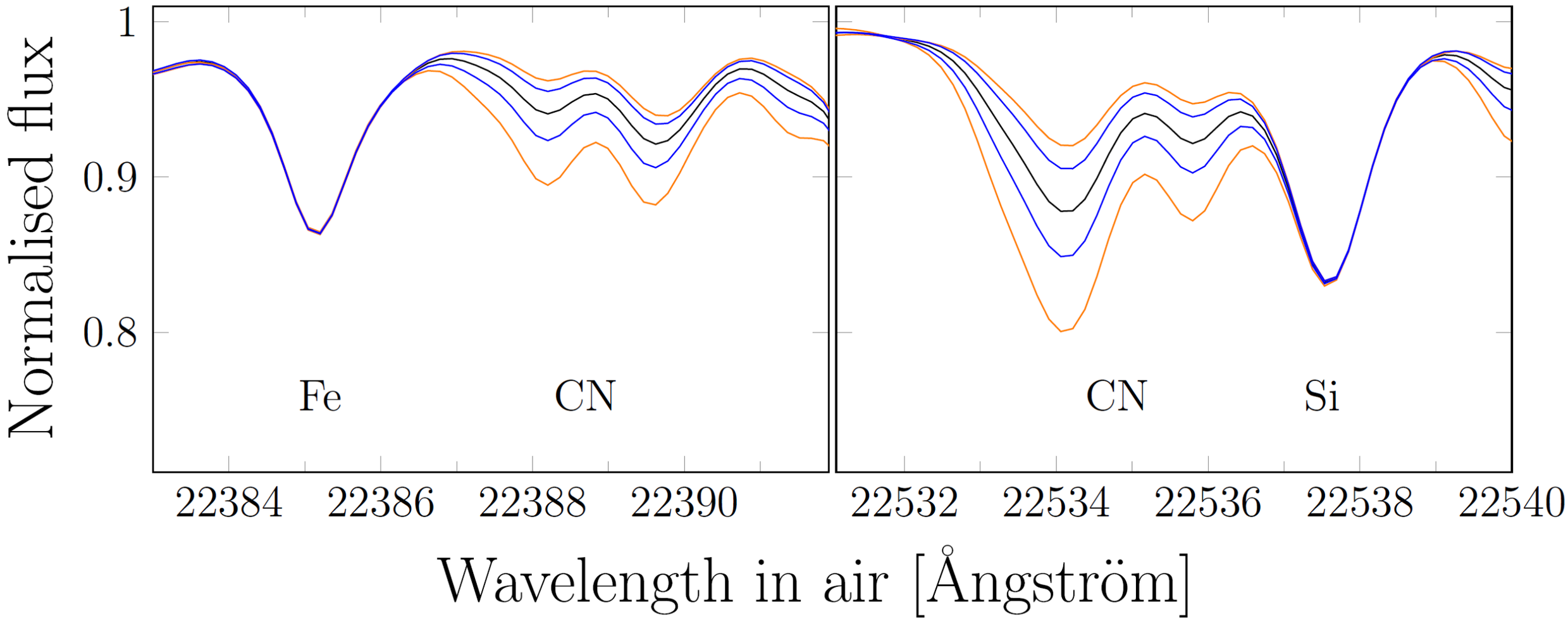
CN features challenging



Red: NSC stars

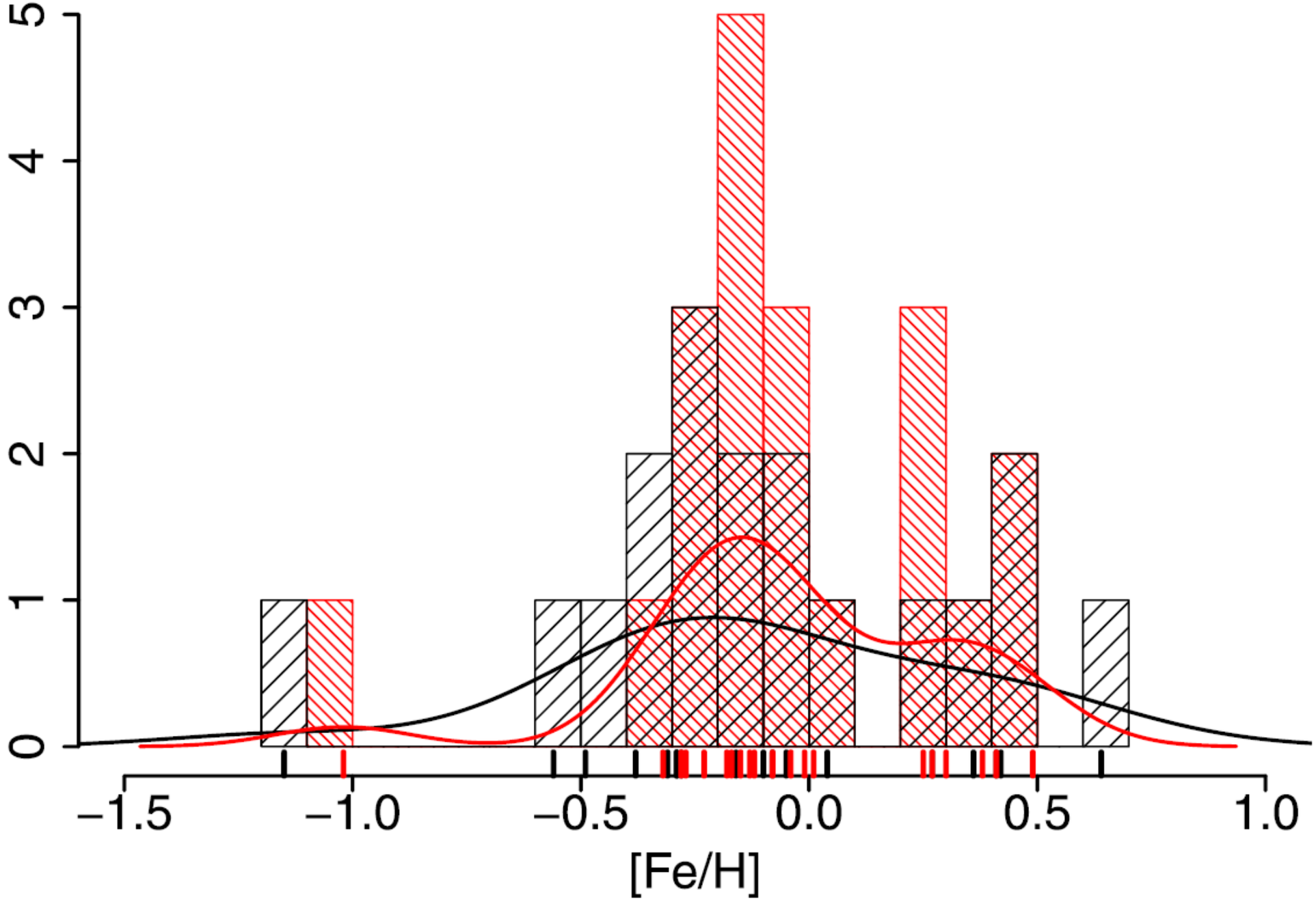
Blue: Local disk stars

Line List rework



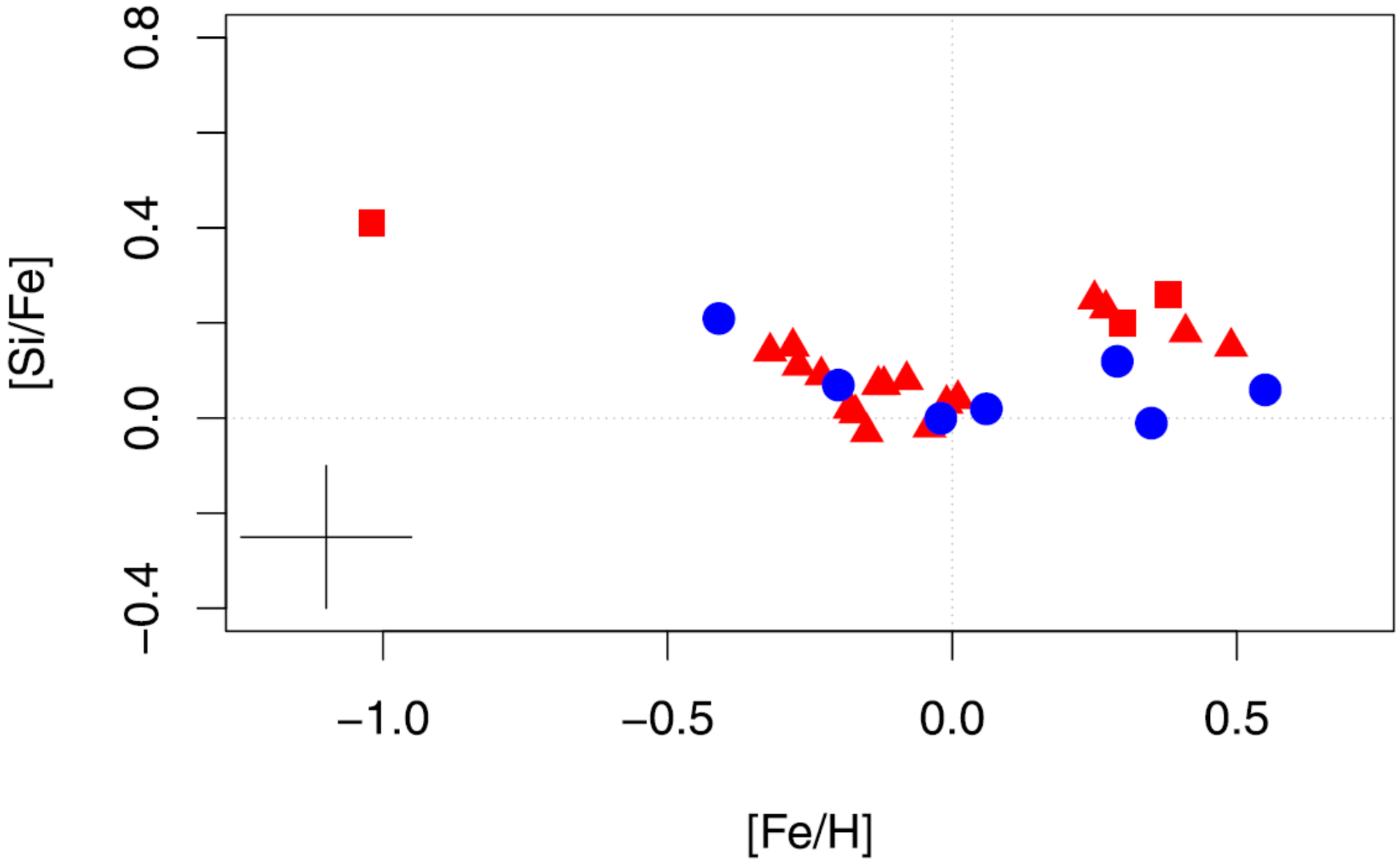
(Thorsbro et al., 2020)

MDF revisited



Black from Rich et al. (2017), Red from Thorsbro et al. (2020)

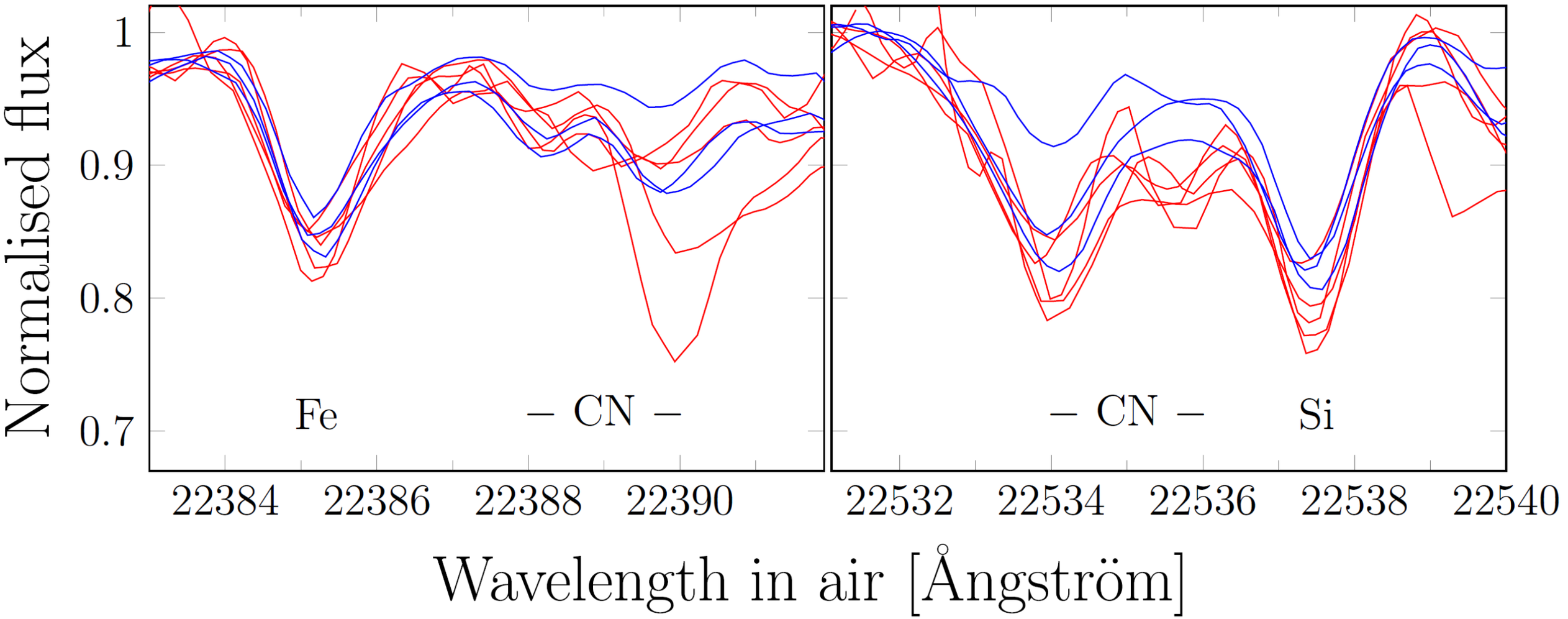
NSC Alpha abundances



Red: NSC stars (squares NSD)
Blue: Local disk stars

(Thorsbro et al., 2020)

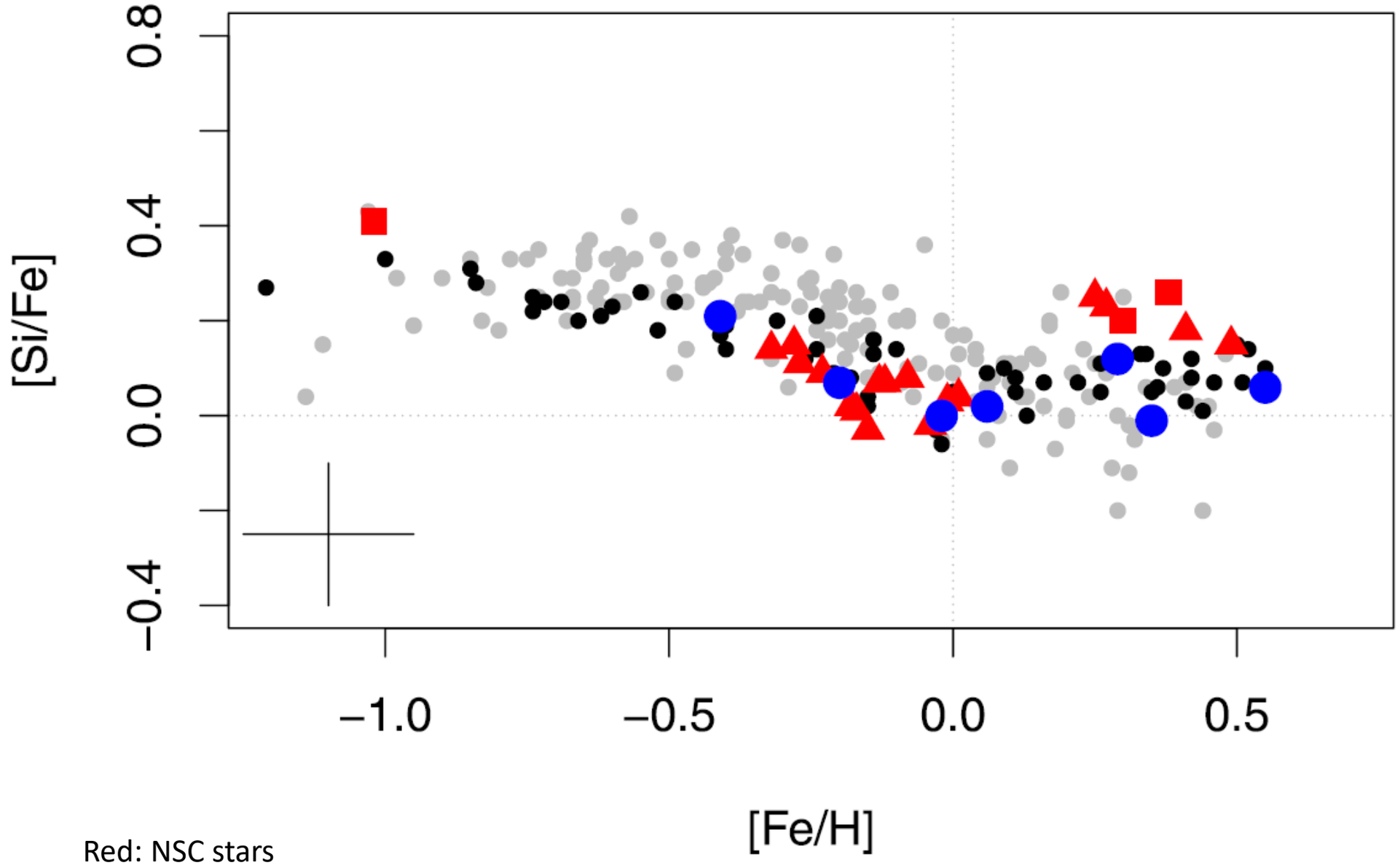
Observed lines



Red: NSC/NSD stars
Blue: Local disk stars

(Thorsbro et al., 2020)

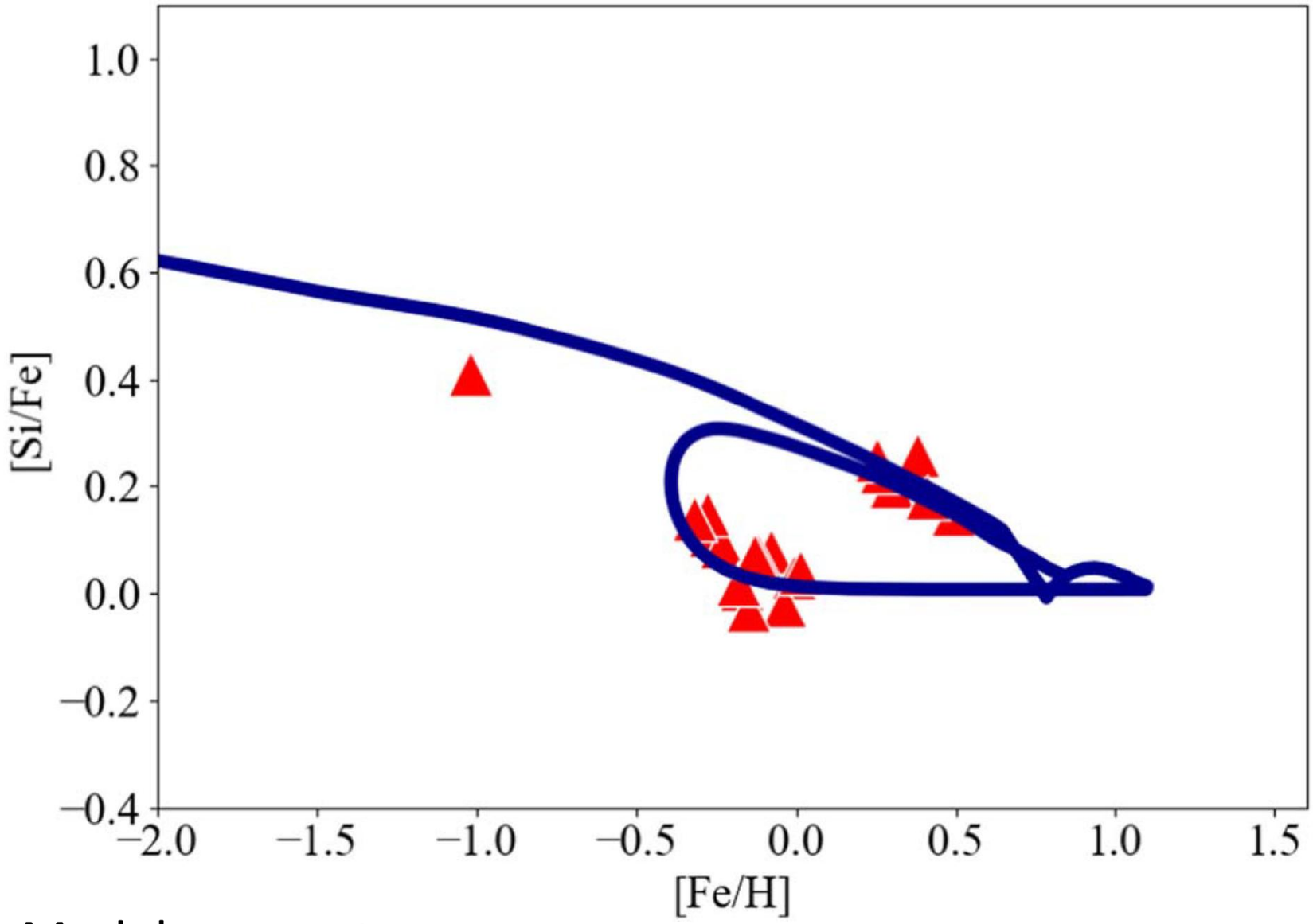
NSC Alpha abundances



Red: NSC stars
Blue: Local disk stars
Grey: Johnson bulge giants
Black: Bensby microlensed bulge dwarves

(Thorsbro et al., 2020)
(Johnson et al., 2014)
(Bensby et al., 2013)

Silicon GC chemical evolution



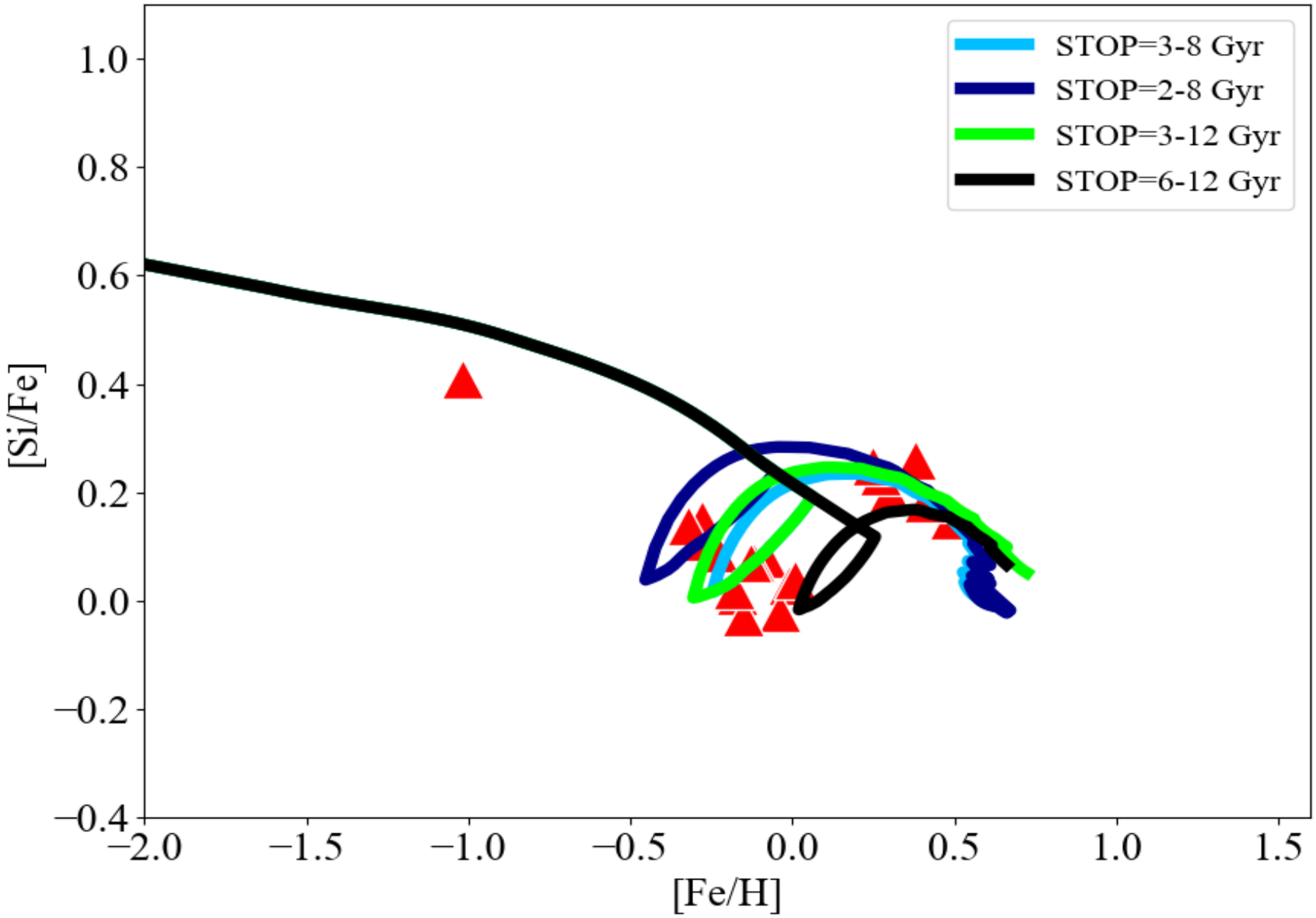
Model parameters:

2nd infall approx. 2 Gyr ago as per Pfhul et al. 2011

Primordial gas

(Thorsbro et al., 2020)

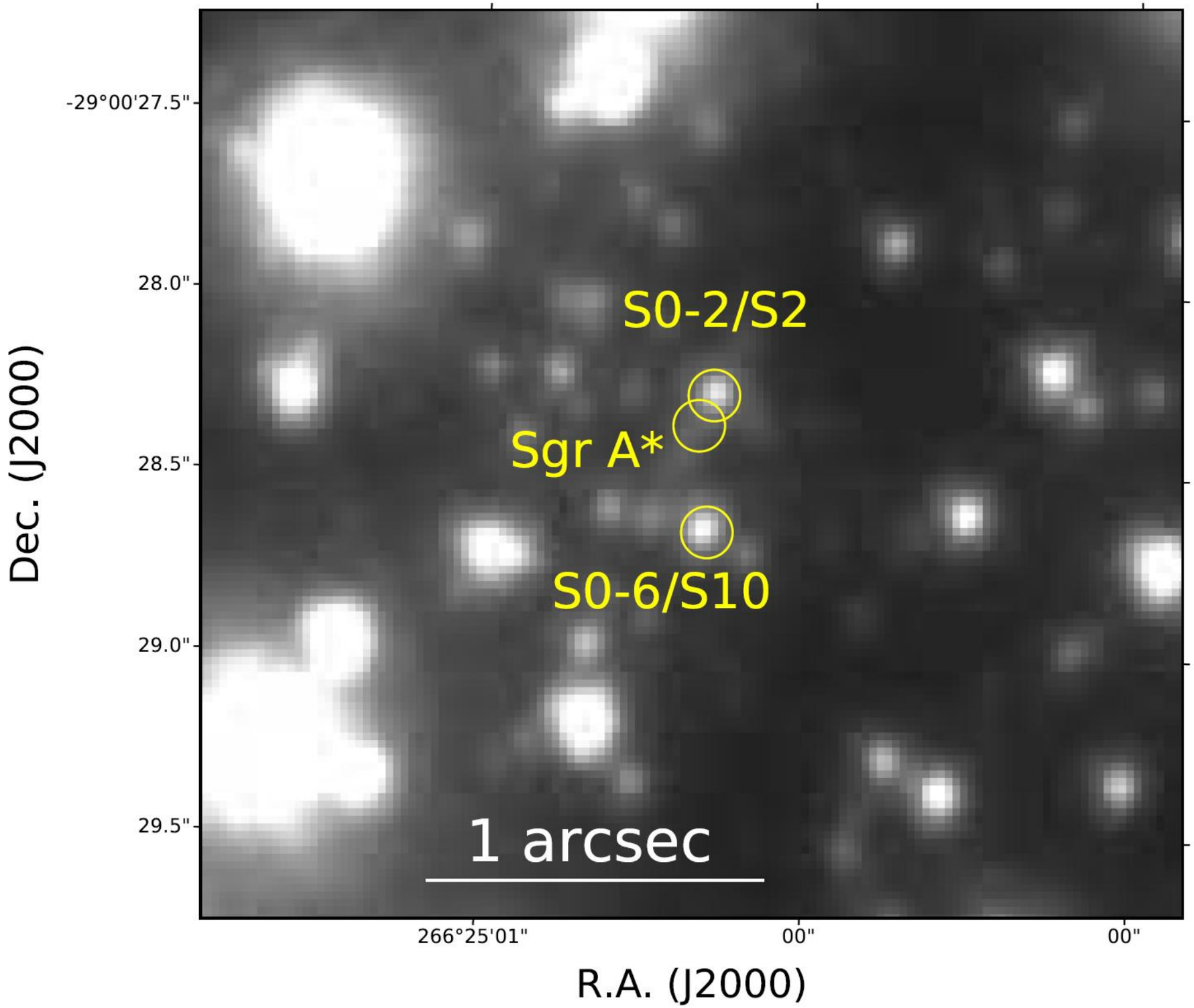
Silicon GC chemical evolution



Stop in star formation

(Thorsbro et al., 2020)

S0-6, 0.01 pc from Sgr A*



(Nishiyama et al., 2024)

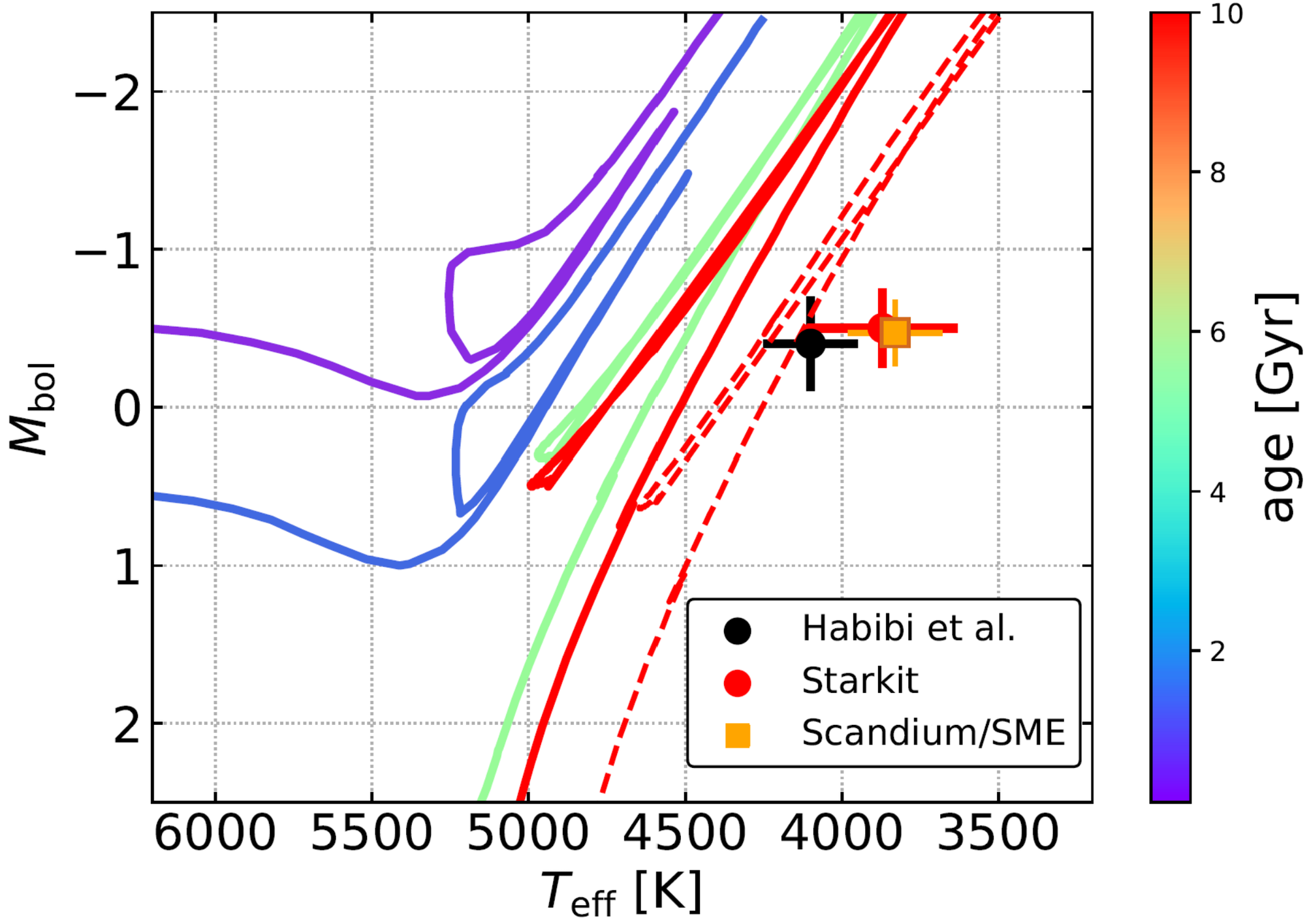
S0-6, observations

Date	S/N ratio		
	order 27	order 26	order 25
2014.379	23.1	22.9	21.1
2015.635	22.5	23.5	20.4
2016.381	18.9	18.2	16.4
2017.341	22.1	20.7	19.6
2017.344	33.1	36.2	30.6
2017.347	30.1	30.2	28.9
2017.603	11.2	13.3	9.3
2017.609	23.1	23.1	14.1
2018.087	22.1	24.5	19.6
2021.420	28.1	12.3	22.7
Combined[a]	57.3	52.5	41.8

[a] Combined spectra from 2014 to 2021.

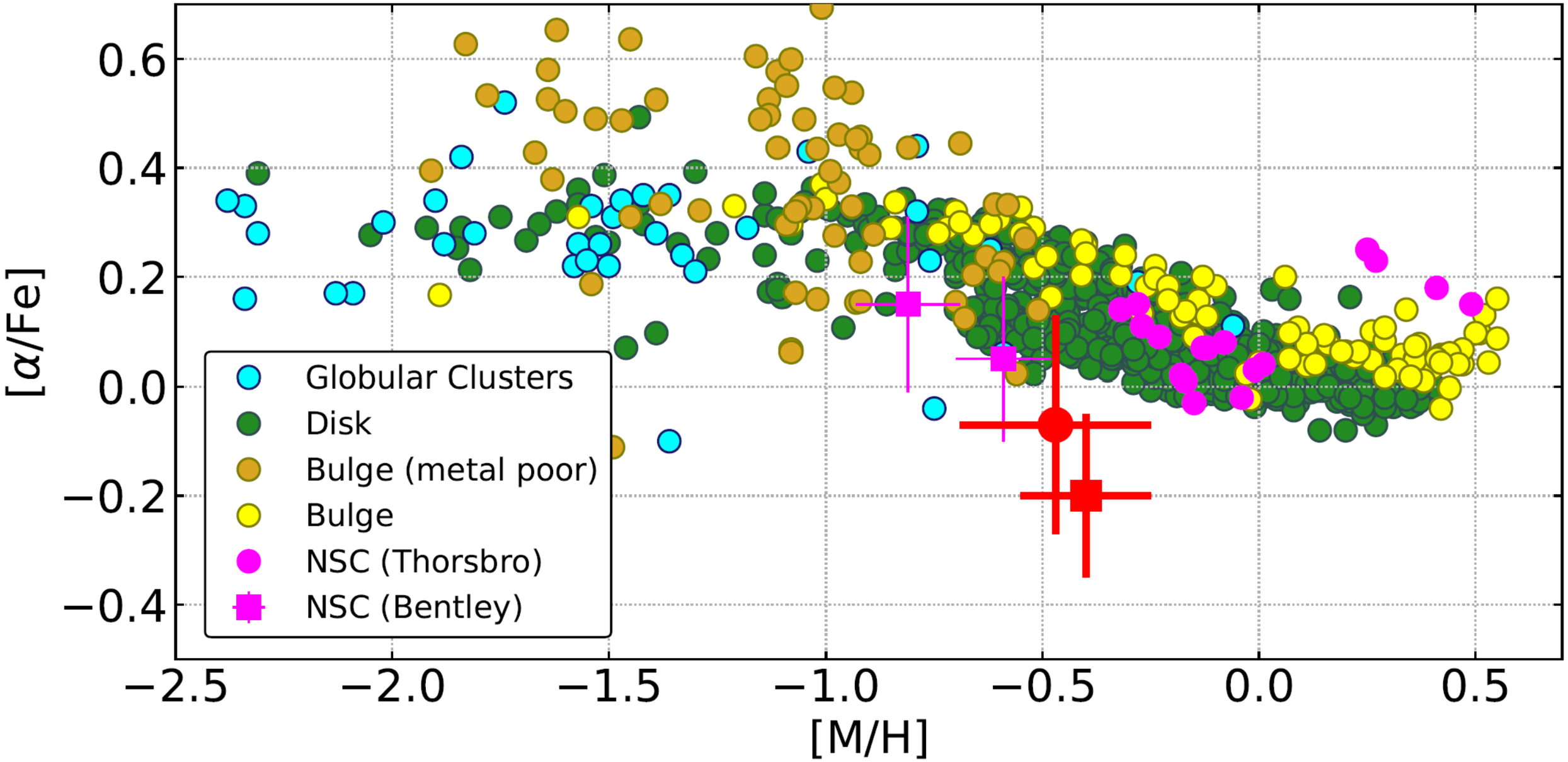
(Nishiyama et al., 2024)

S0-6, old star



(Nishiyama et al., 2024)

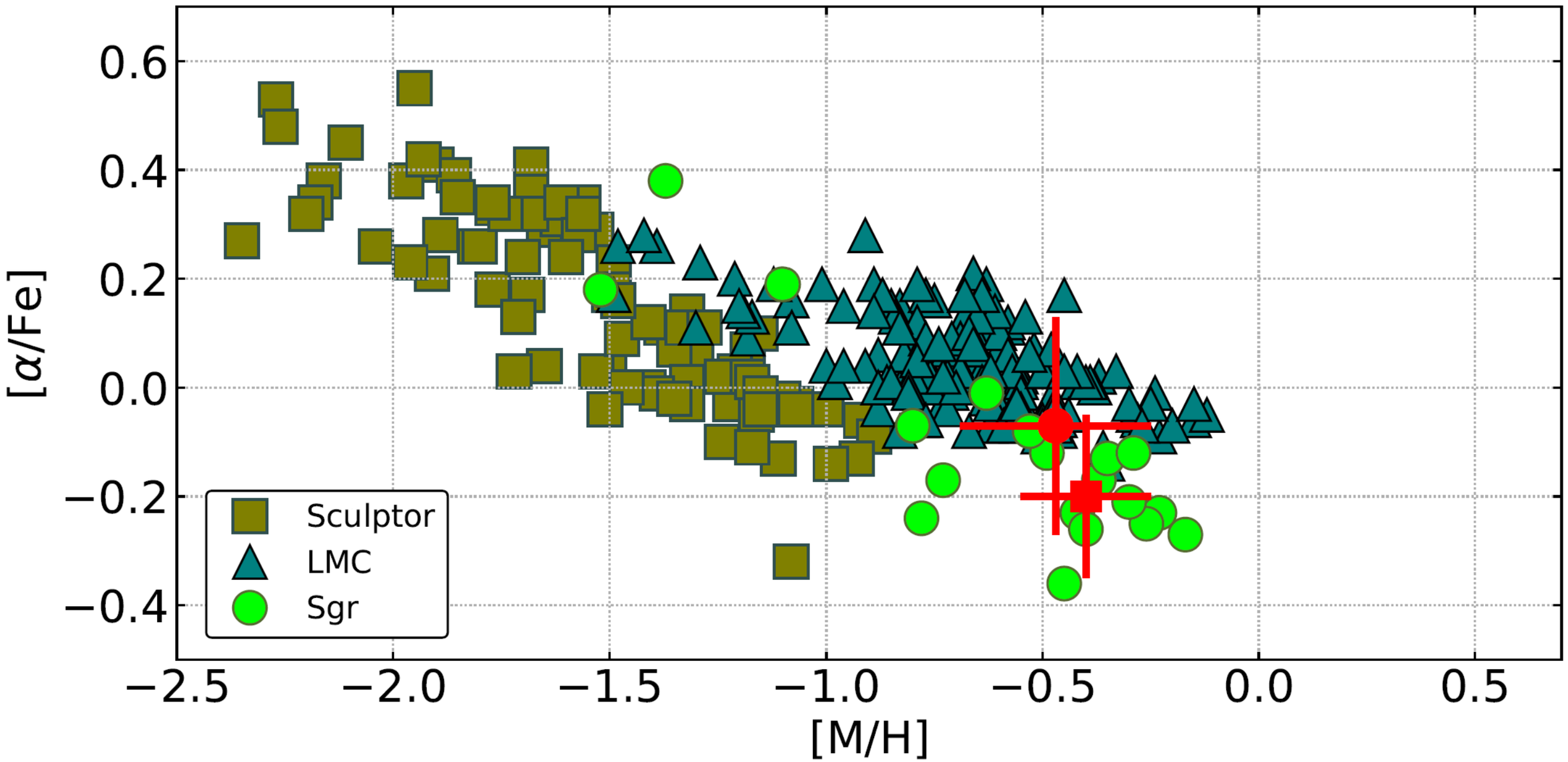
S0-6, low alpha



Red disc: starkit, red square: SME

(Nishiyama et al., 2024)

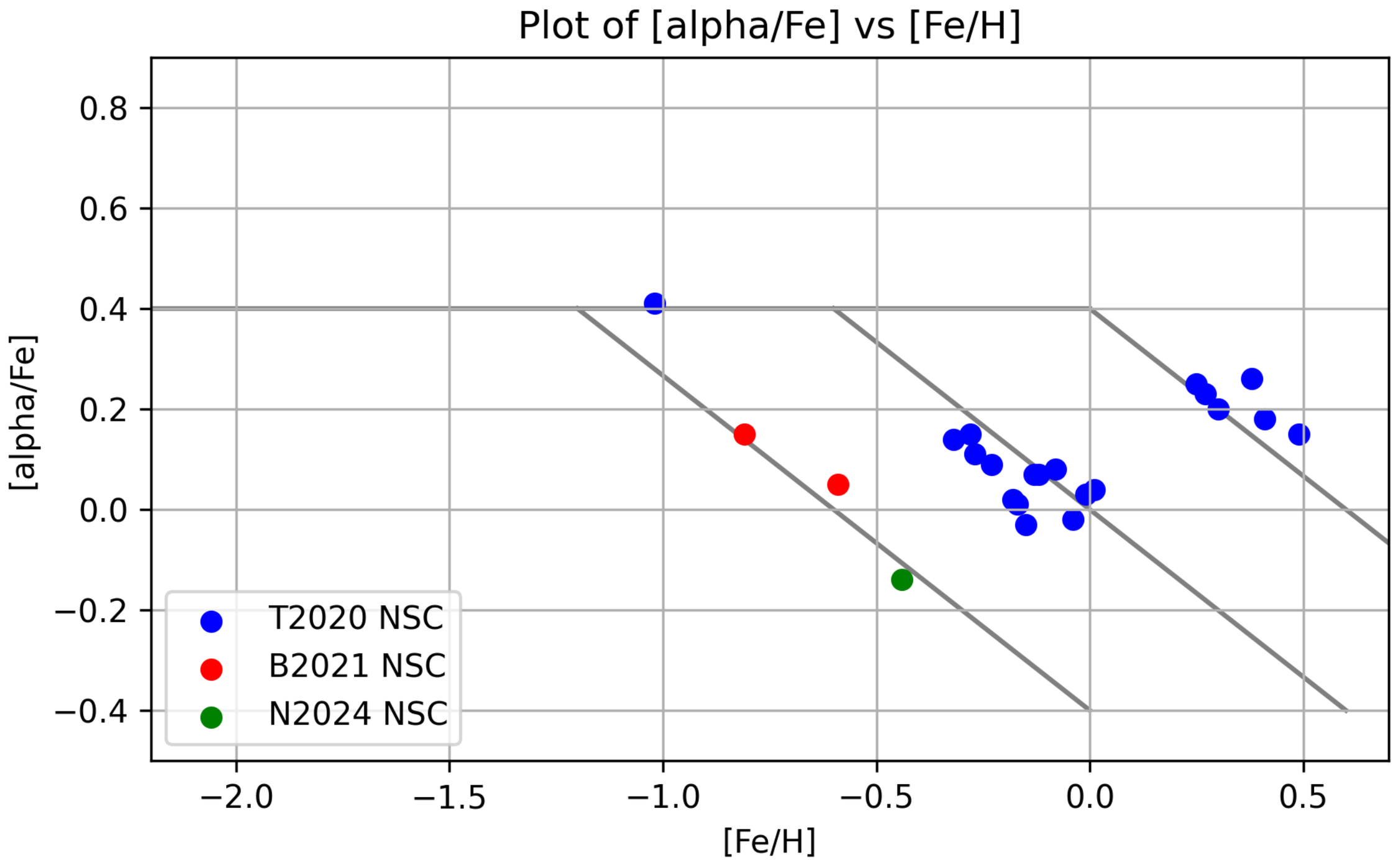
S0-6, 0.01 pc from Sgr A*



Red disc: starkit, red square: SME

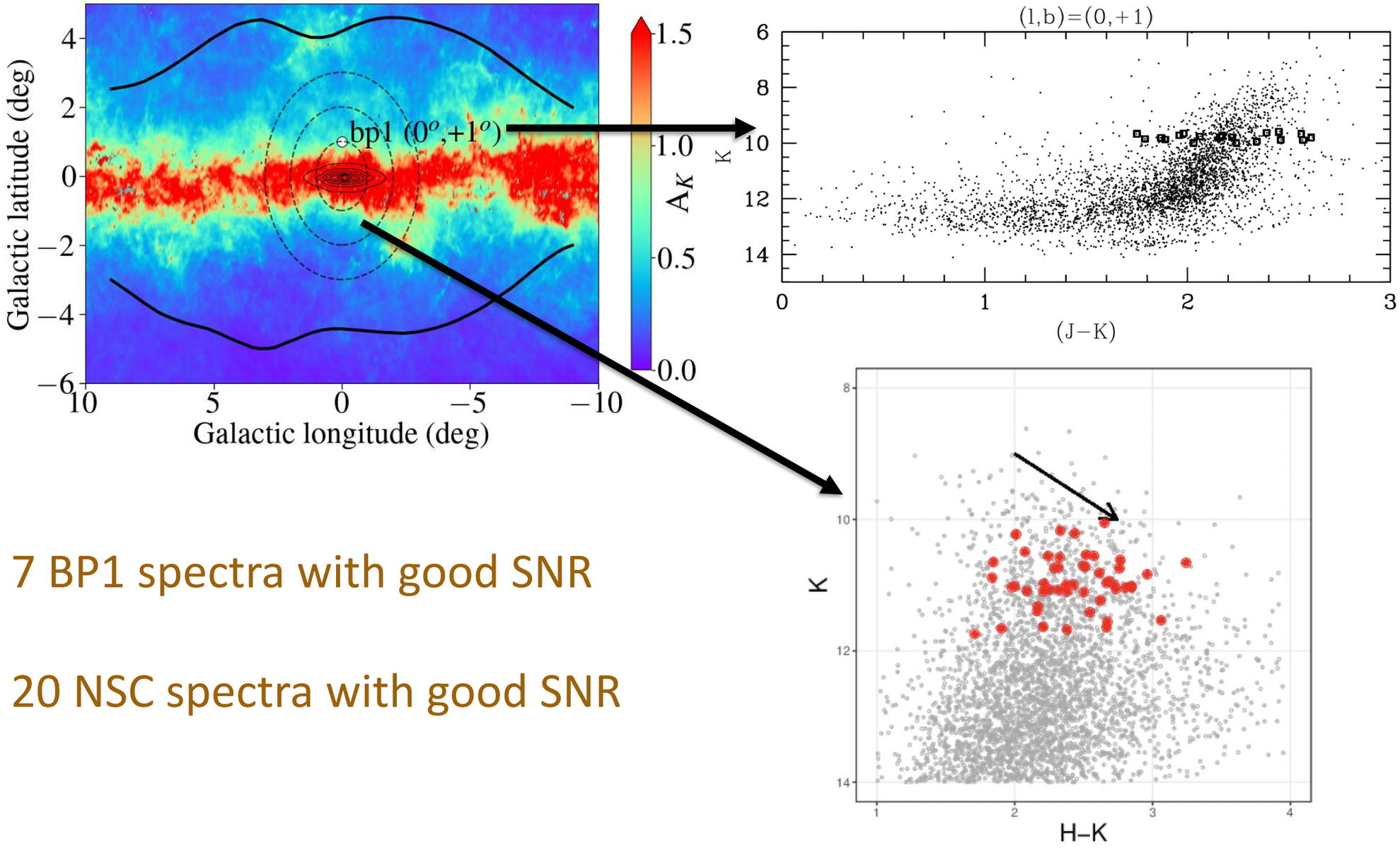
(Nishiyama et al., 2024)

Summary of results so far



IGRINS spectrograph, R~45000

(Nandakumar et al., 2024)



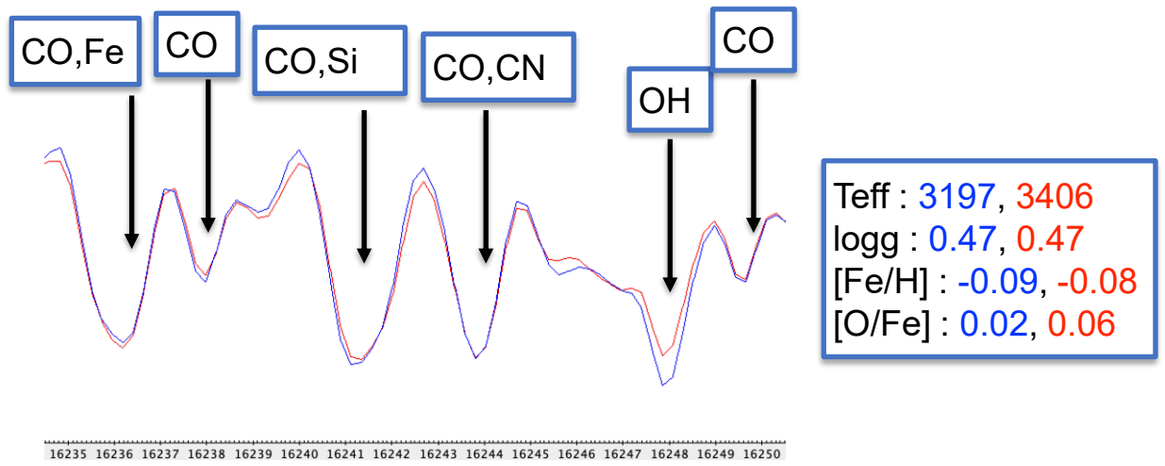
7 BP1 spectra with good SNR

20 NSC spectra with good SNR

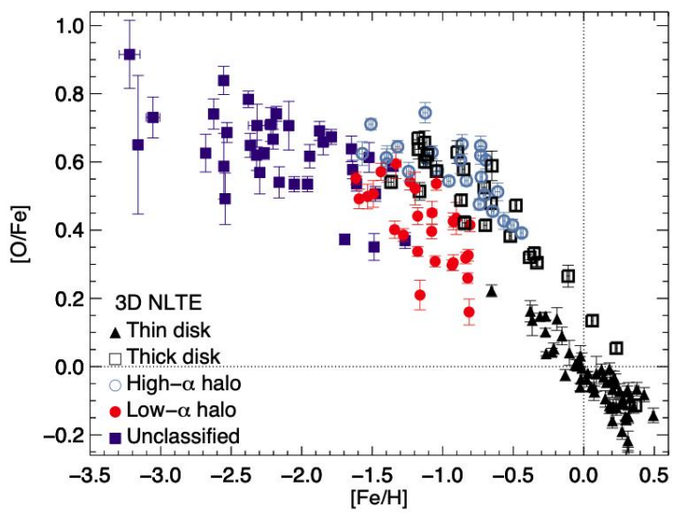
(Ryde et al., submitted)

Different method for Teff

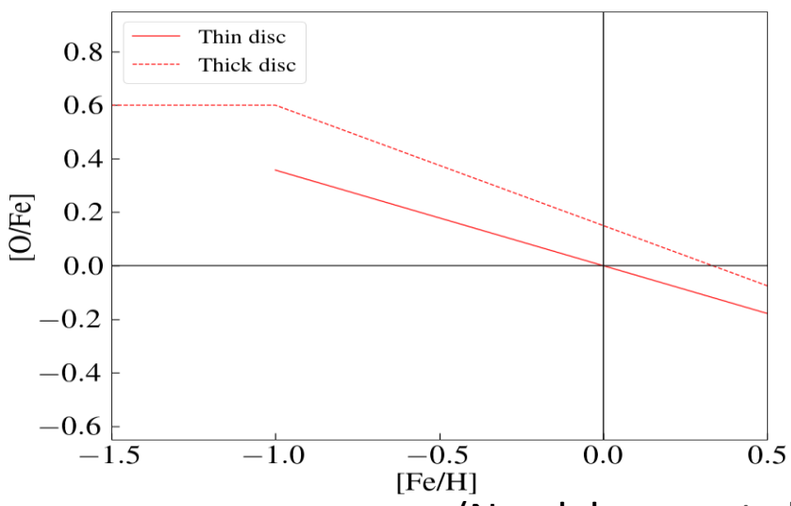
OH lines sensitive to Teff:



Degeneracy between O abundance and Teff, solution: fix O abundance:

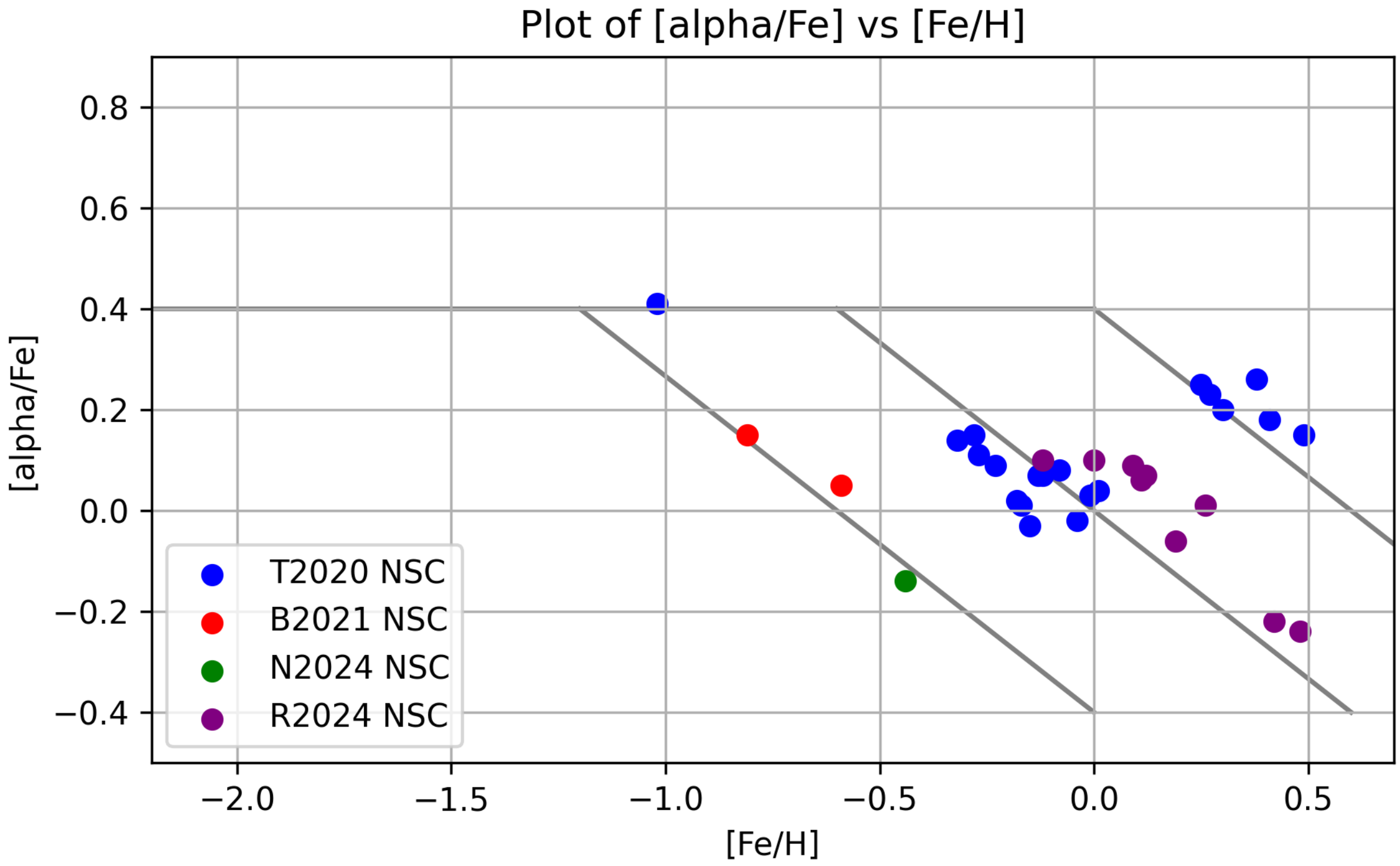


(Amarsi et al., 2019)

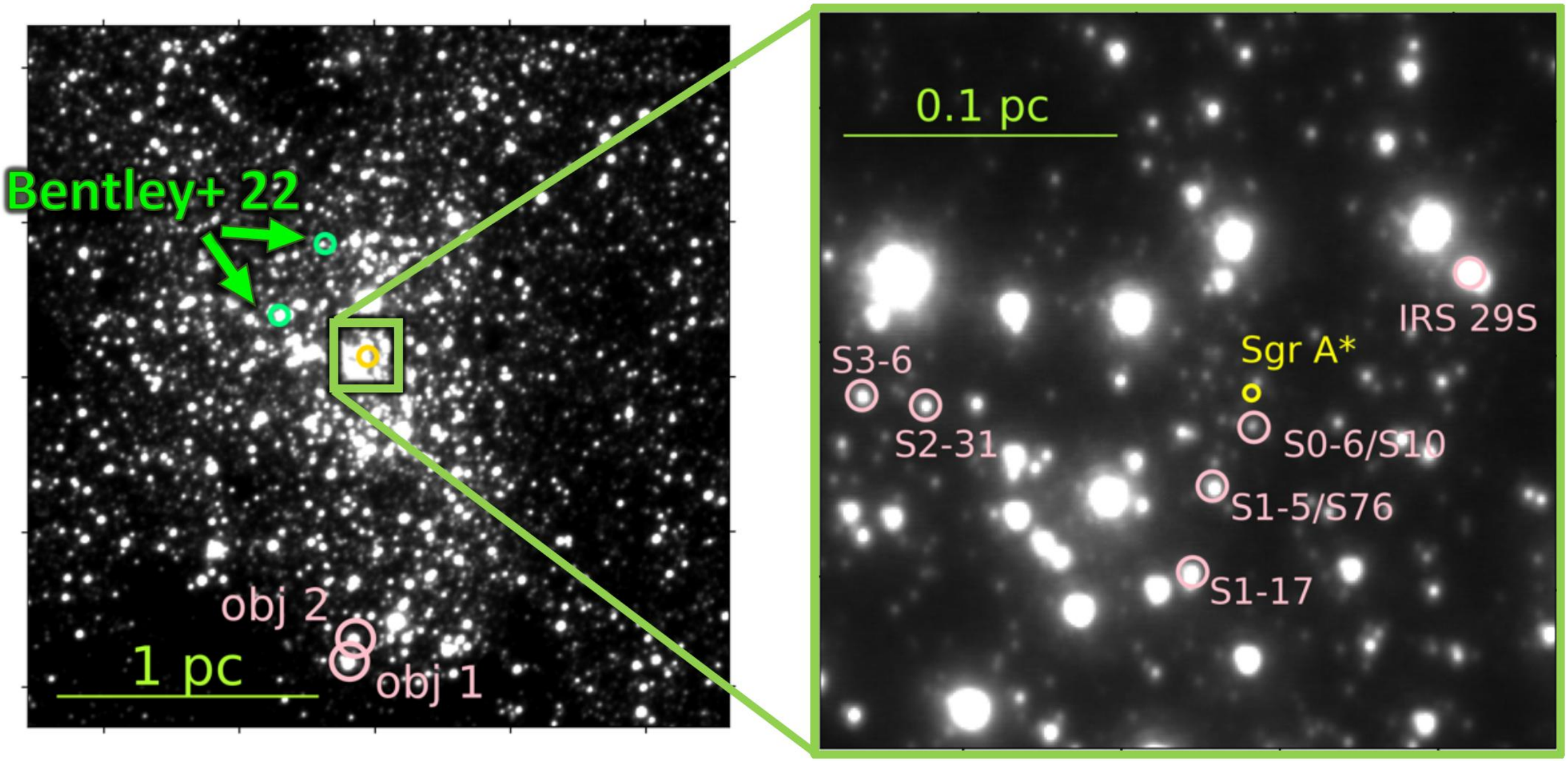


(Nandakumar et al., 2023)

Summary of results so far

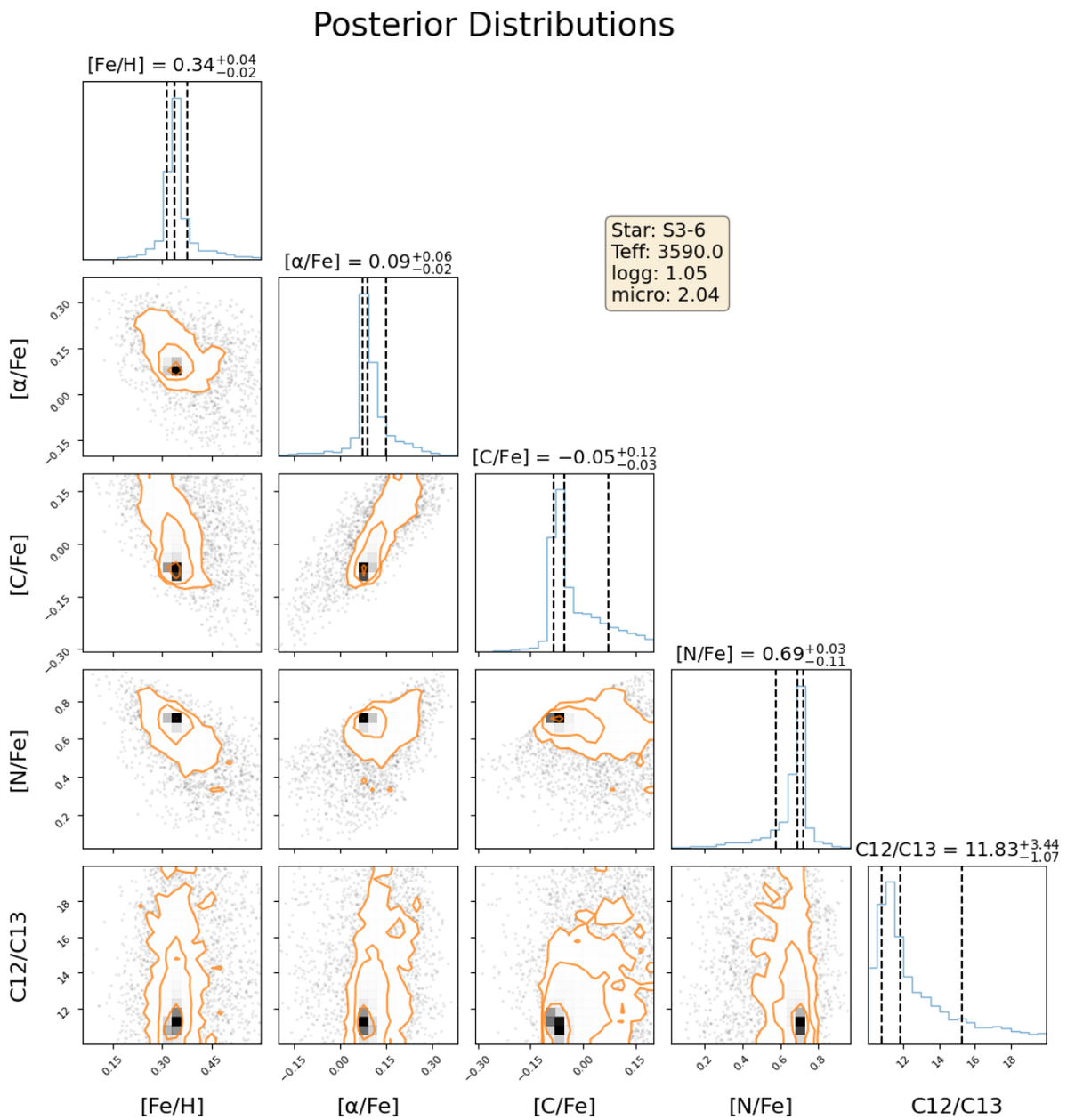


New targets



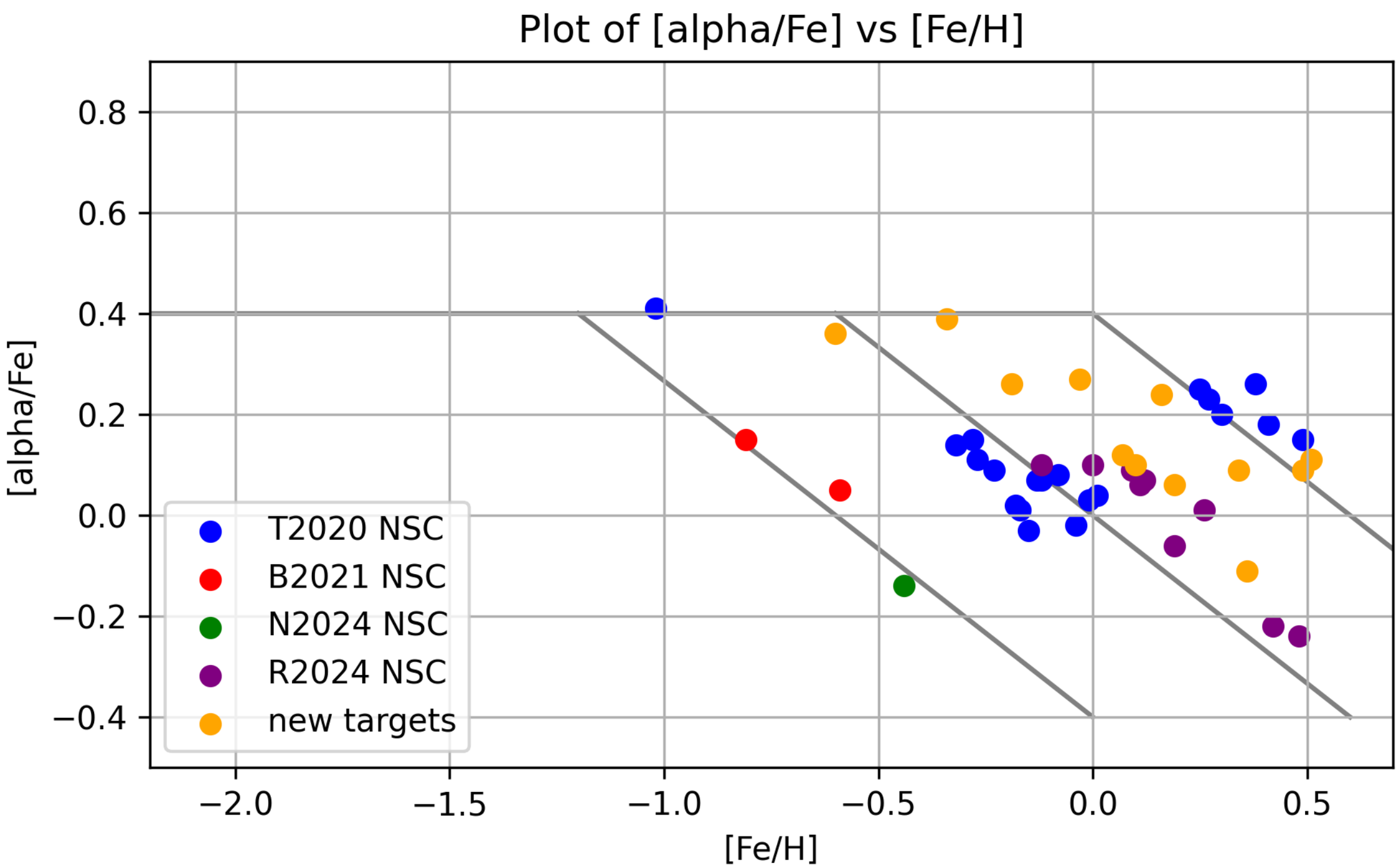
(Nishiyama, Thorsbro et al., in prep)

New targets

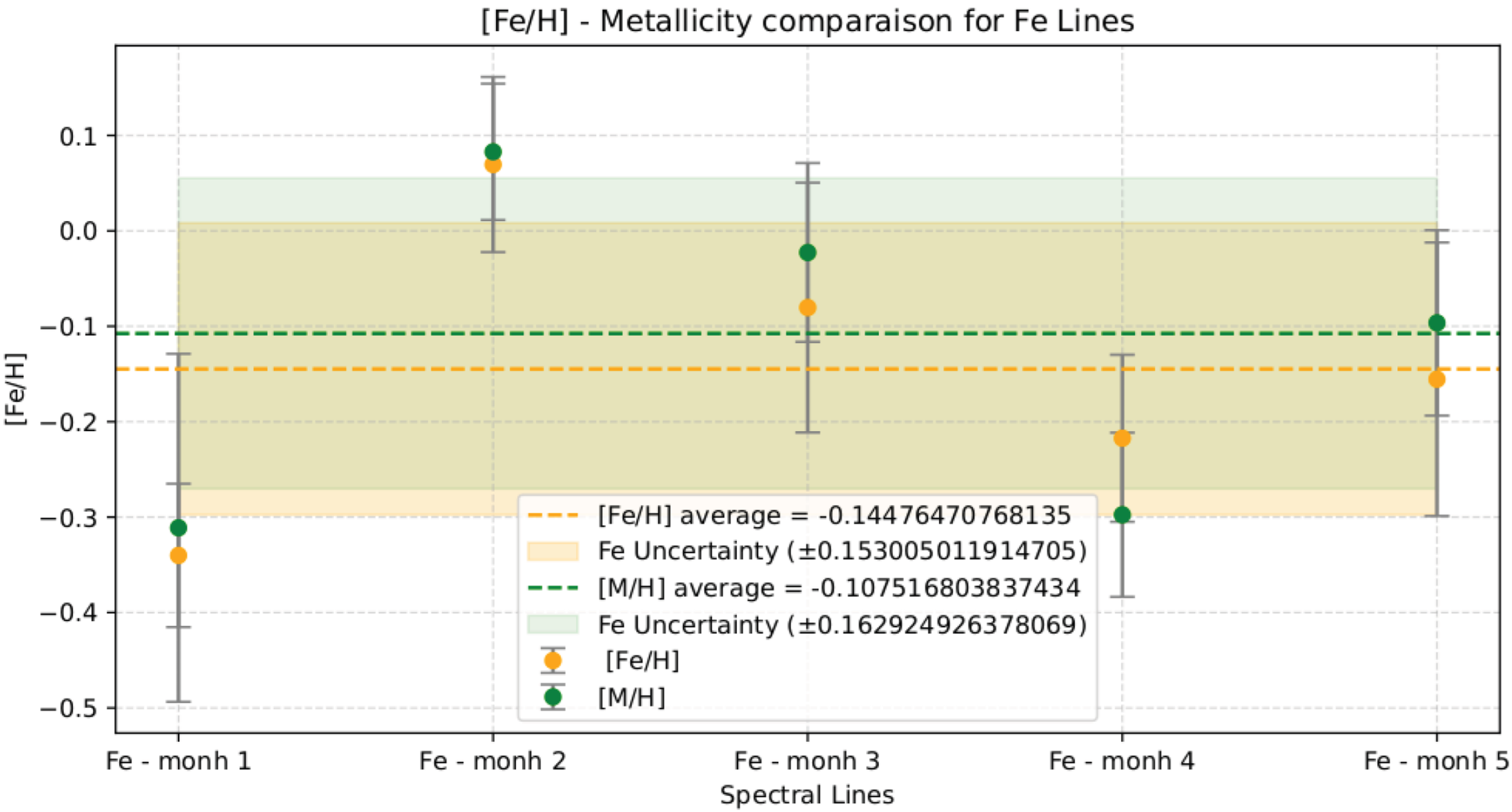


(Nishiyama, Thorsbro et al., in prep)

Summary of results so far

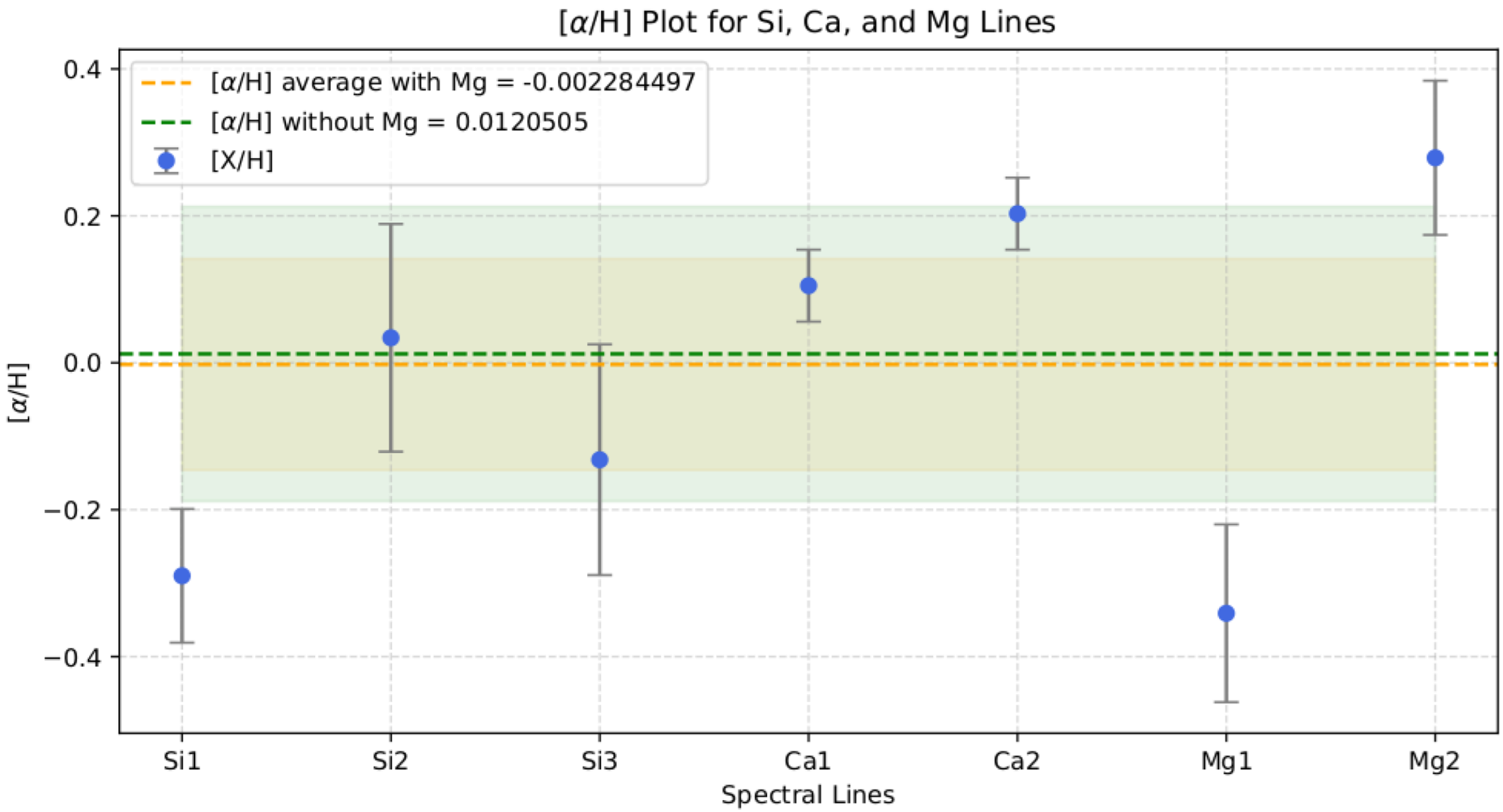


(GC)IRS 22



(Thorsbro, Khalidy, Rich et al., in prep)

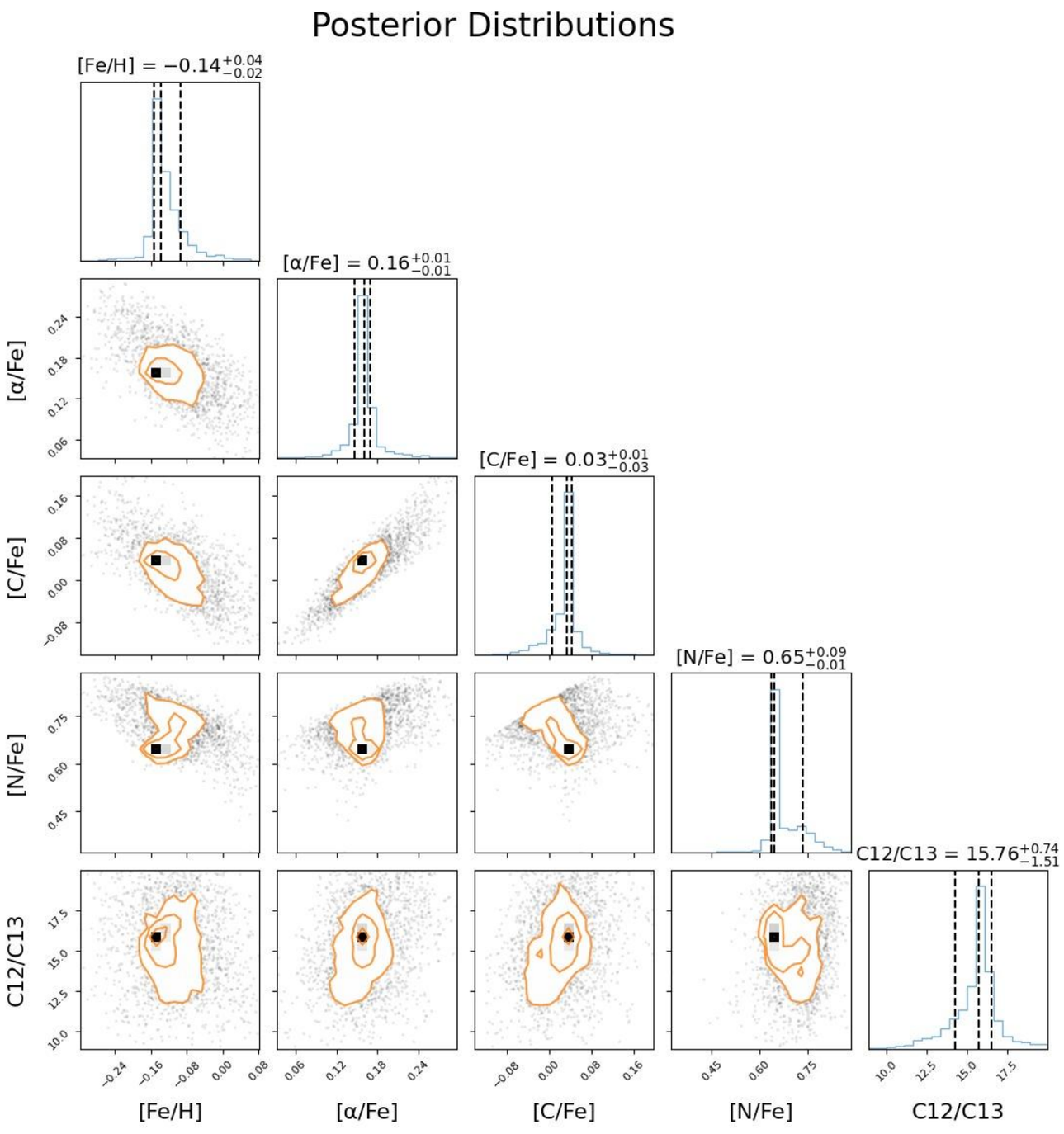
(GC)IRS 22



[Ca/Fe] without NLTE: 0.45 dex

(Thorsbro, Khalidy, Rich et al., in prep)

(GC)IRS 22 starkit method

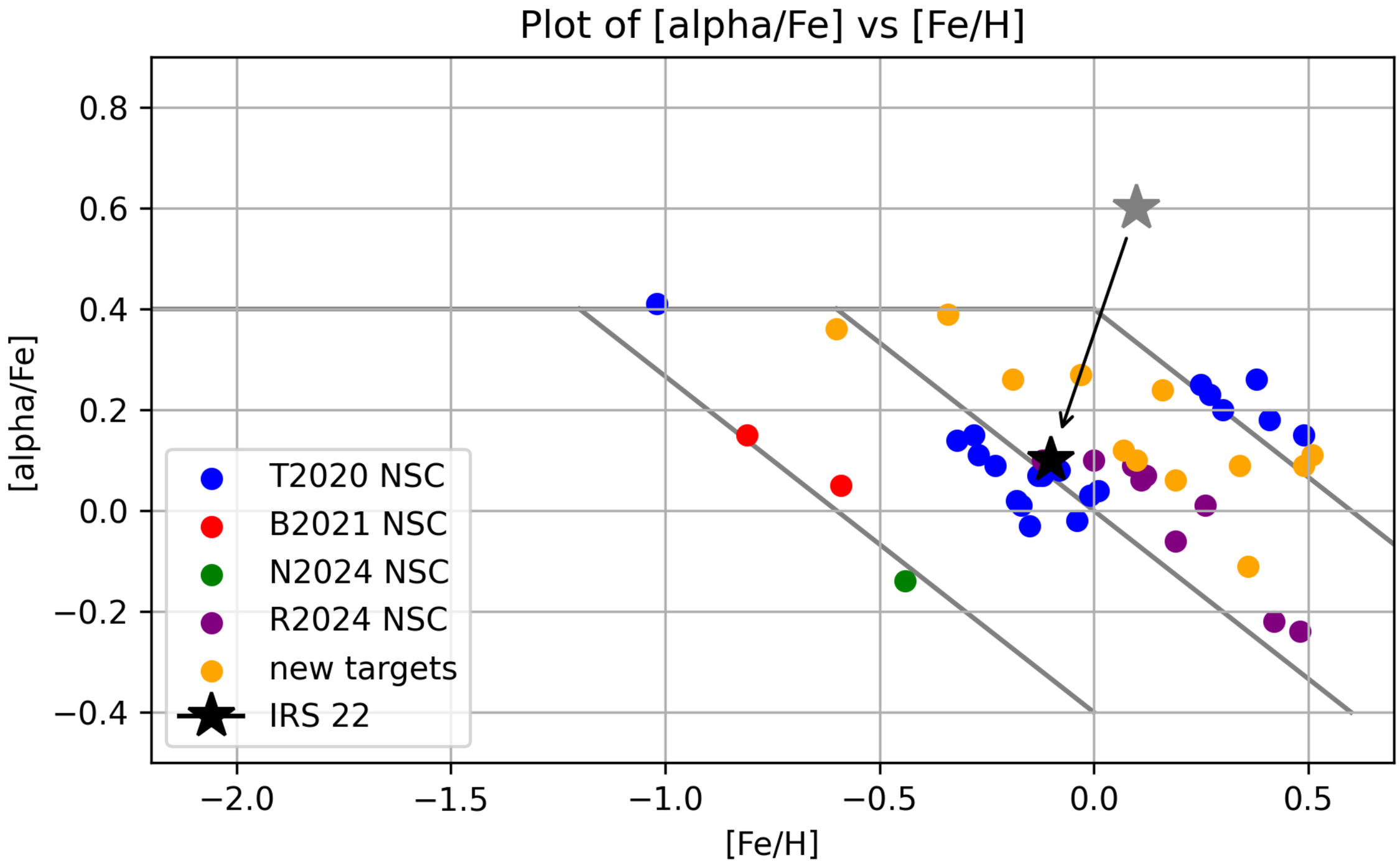


(GC)IRS 22 summary

Quantity	Simulation Results	Cunha et al, 2007
Teff	3350 ± 150 K	3750 K
log(g)	-0.12 ± 0.24	0.2
Mbol	-6.46 ± 0.1	-6.49
M	6 M⊙<M<9M⊙	10 M⊙
vmic	2.3 km/s	2.3 km/s
vmac	10 km/s	11 - 16 km/s
Metallicity	-0.145 ± 0.161	0.12 ± 0.15
[Ca/H]	0.154 ± 0.08	0.63 ± 0.15

(Thorsbro, Khalidy, Rich et al., in prep)

Summary of results so far



Thank you!