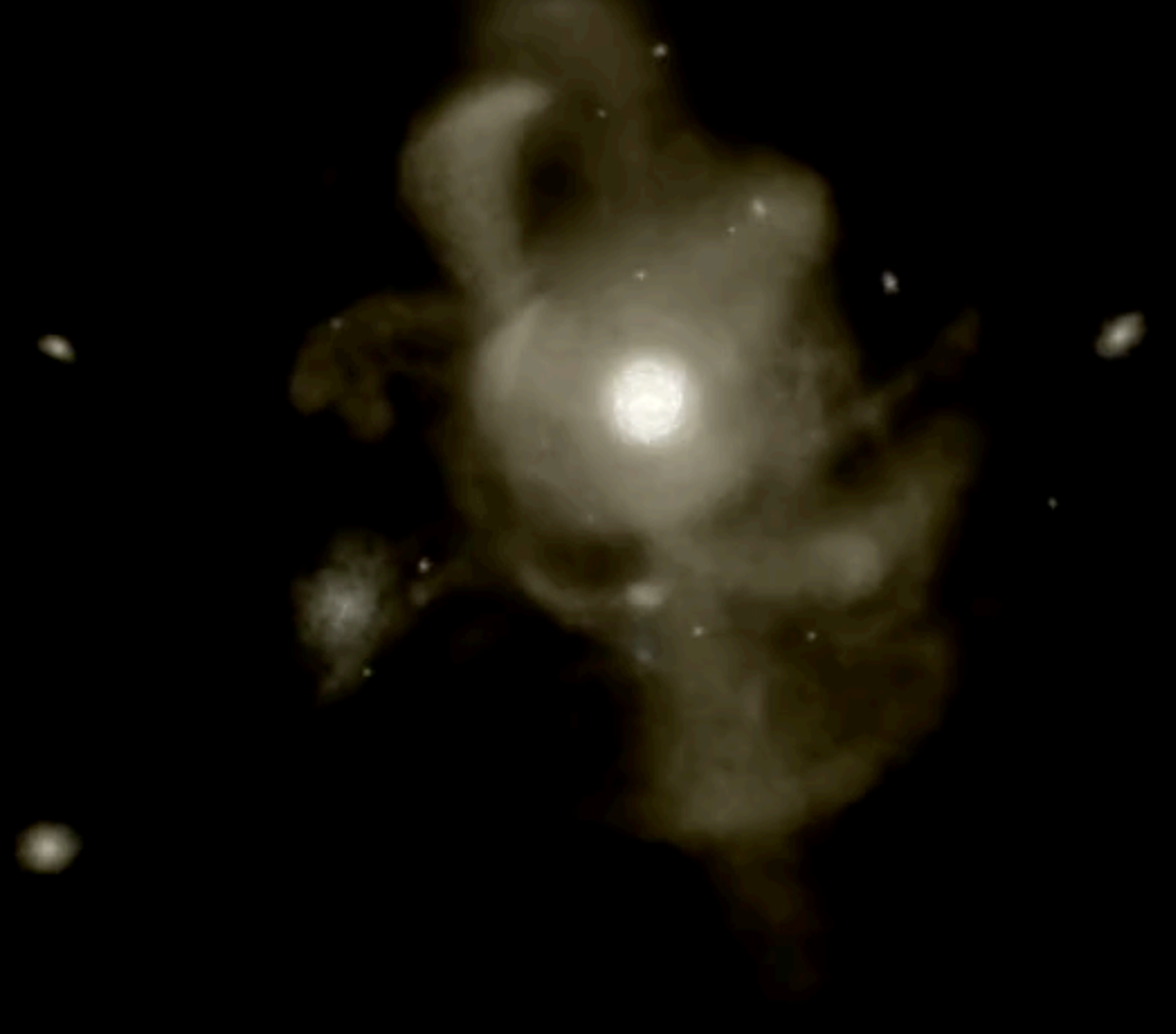
The challenge of simultaneously matching the diversity of chemical abundance patterns in cosmo hydro simulations



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Potsdam

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Matthias Steinmetz

somewhere in cyber space,
24.6.2021

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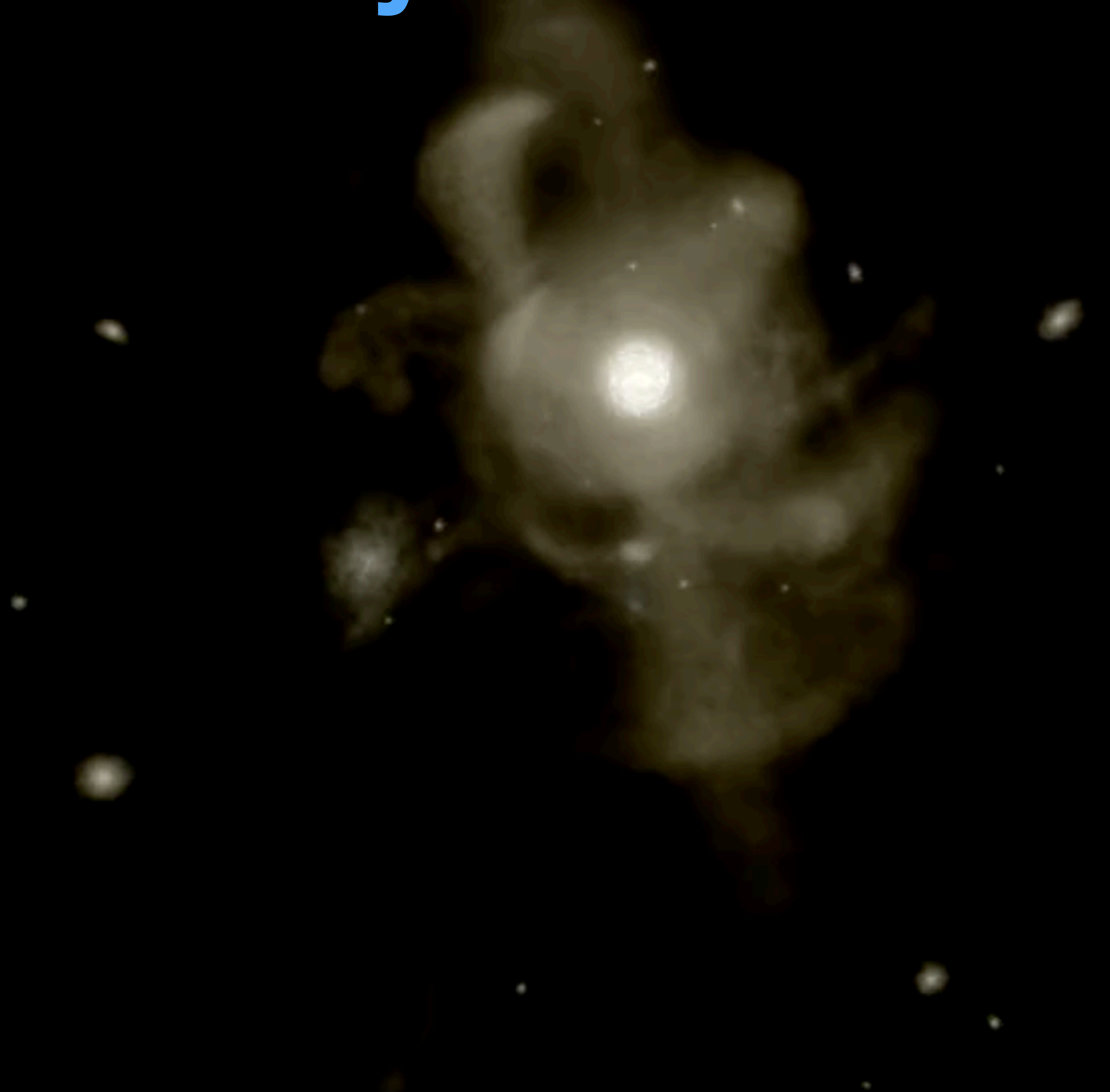

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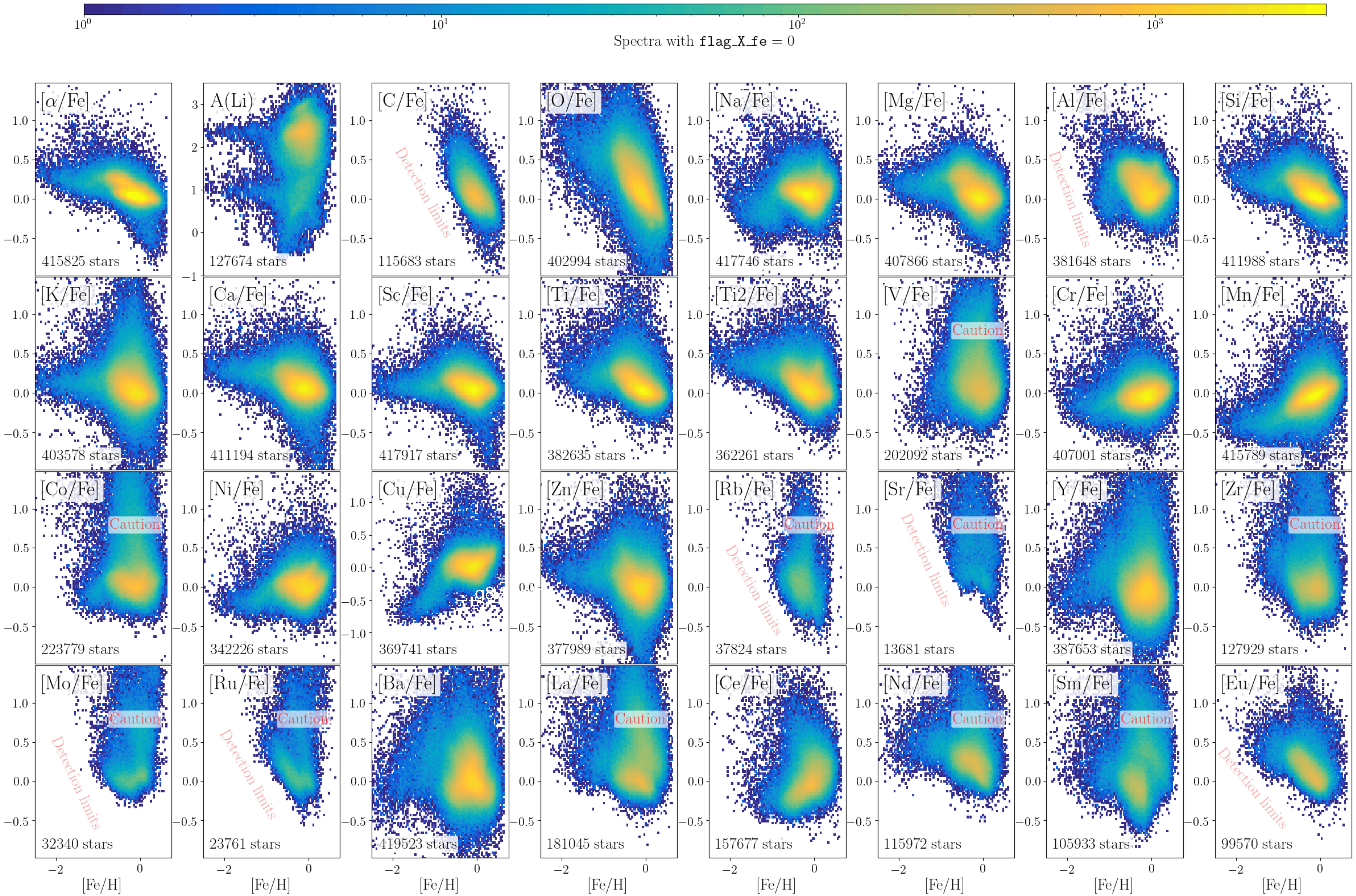
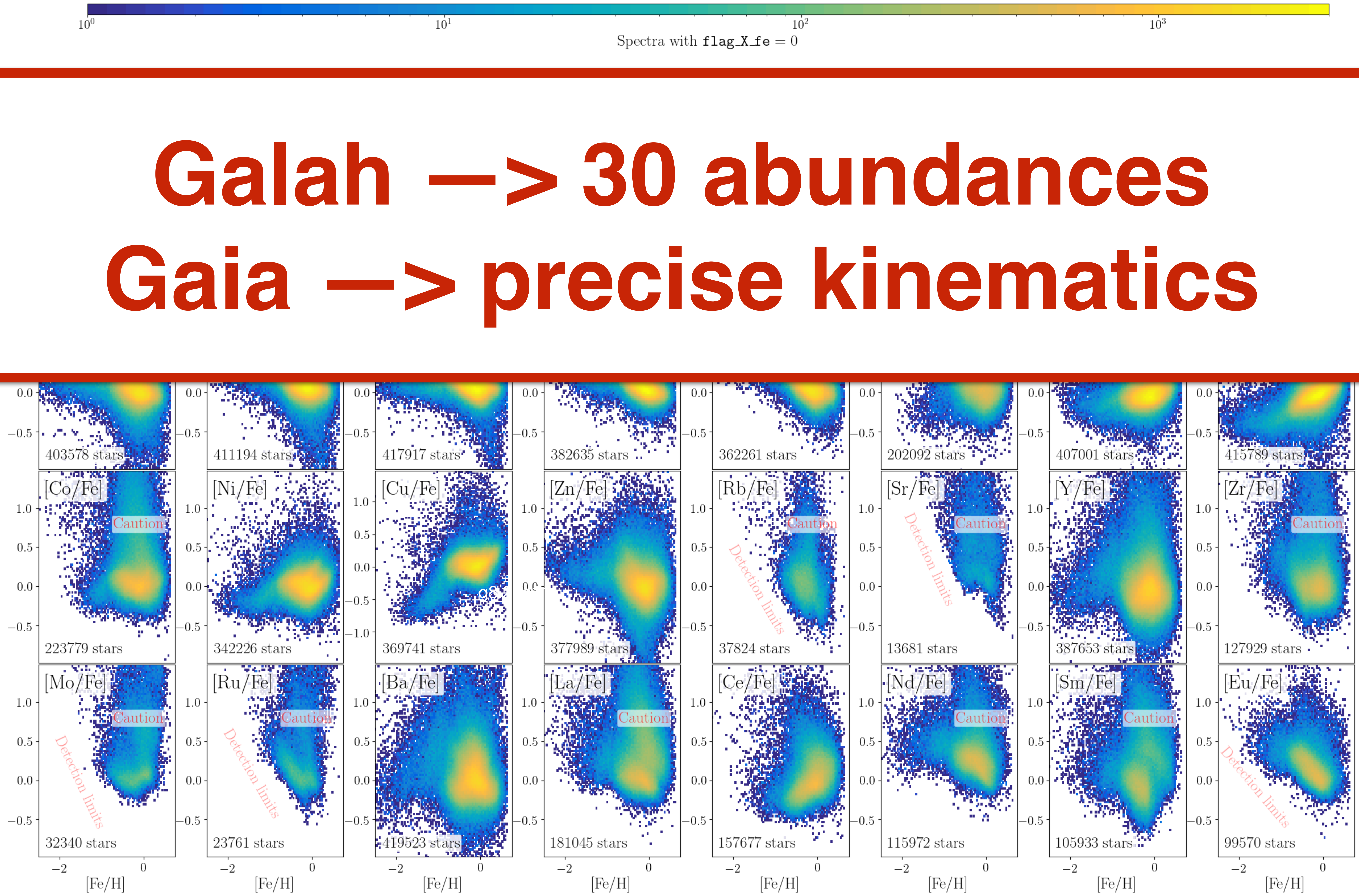
Milky Way chemo-dynamics



Buder+2021

see also Grand+2018, Kobayashi+2020, Agertz+2021, Renaud+2021 and Buck2020 for explanation of abundance tracks and of course all the great analytic models!

Milky Way chemo-dynamics



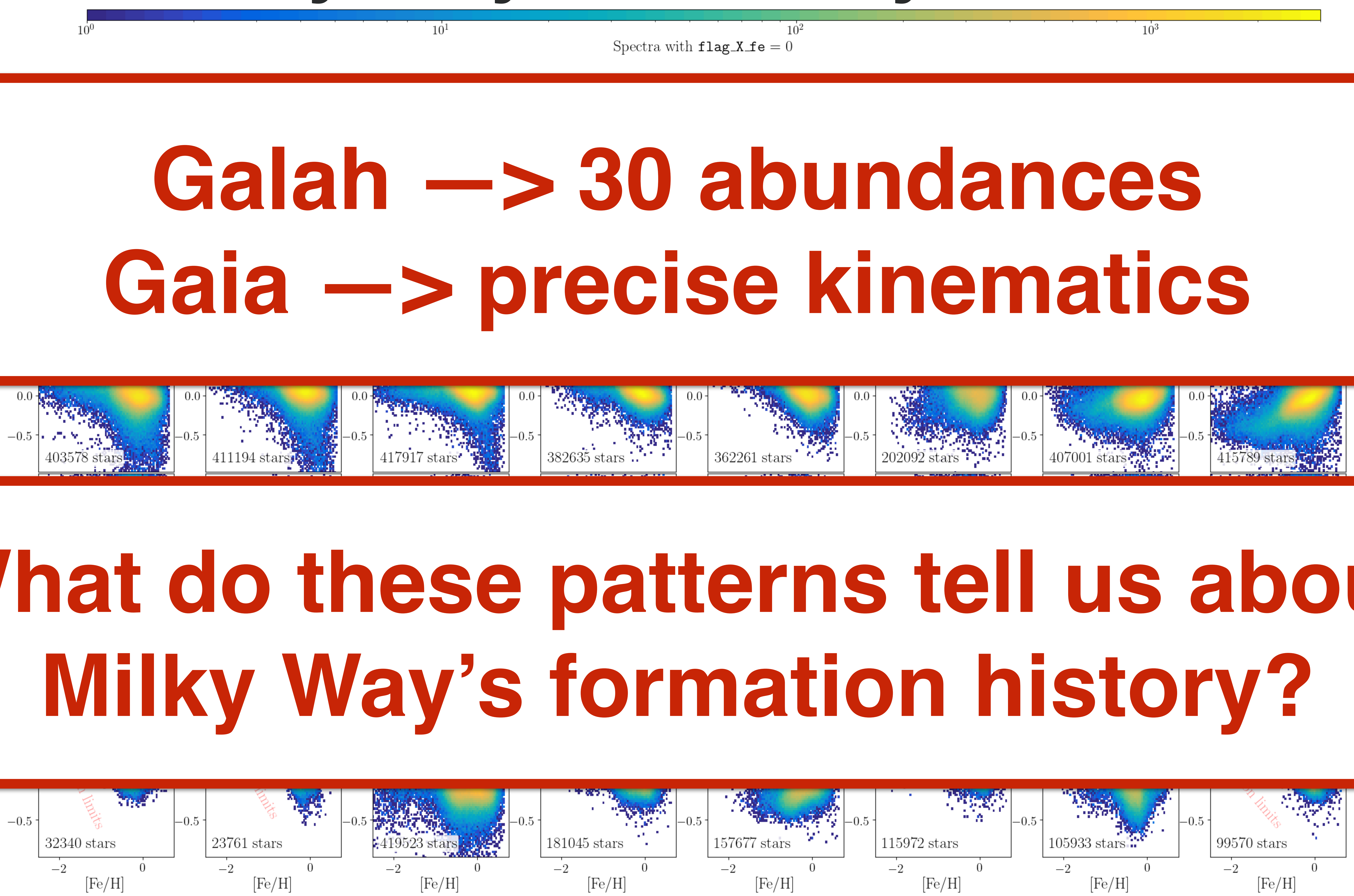
+2021

Galah —> 30 abundances

Gaia —> precise kinematics

see also Grand+2018, Kobayashi+2020, Agertz+2021, Renaud+2021 and Buck2020 for explanation of abundance tracks and of course all the great analytic models!

Milky Way chemo-dynamics



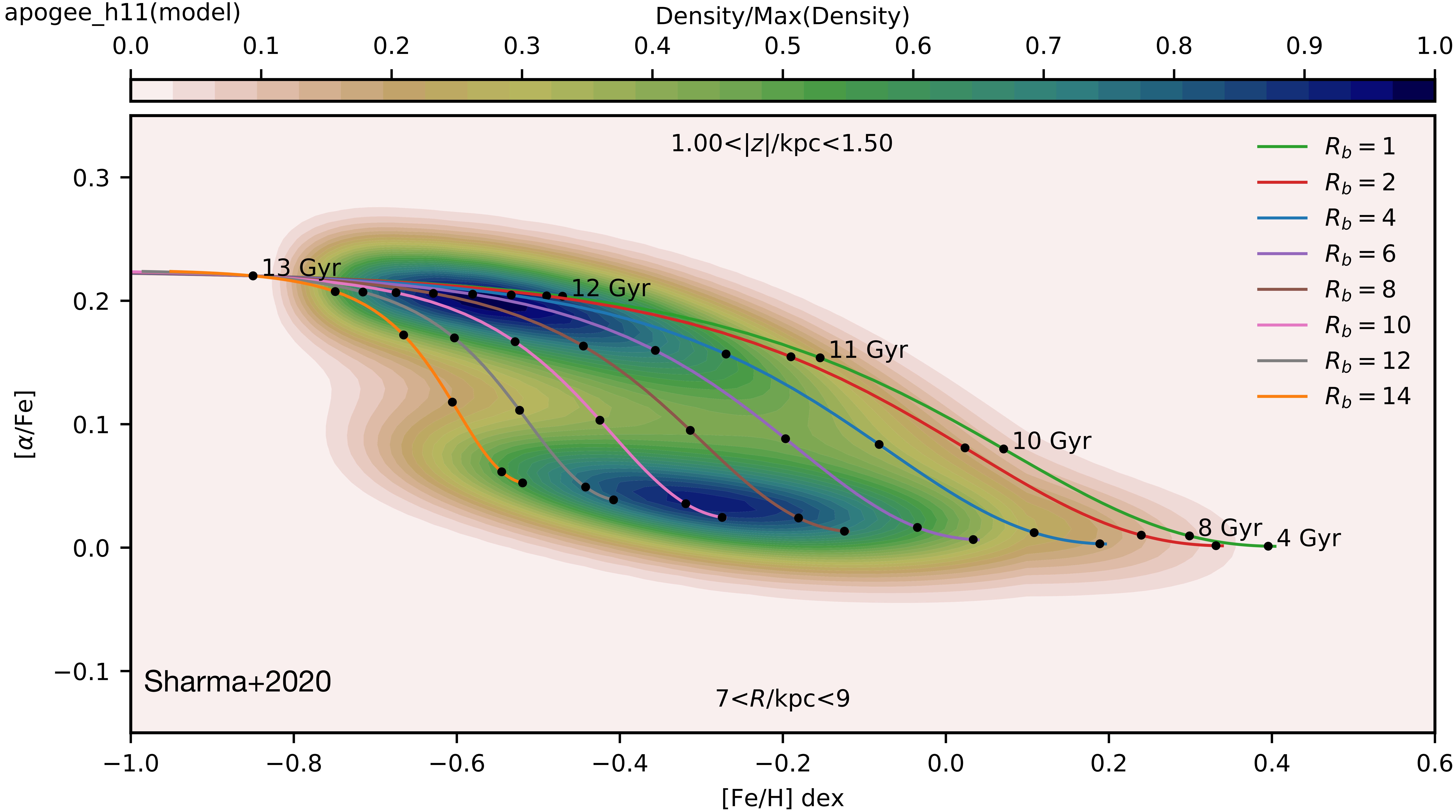
Galah —> 30 abundances
Gaia —> precise kinematics

What do these patterns tell us about Milky Way's formation history?

+2021

e also
d+2018,
ashi+2020,
z+2021,
+2021 and
2020 for
nation of
nce tracks
of course
all the great
analytic models!

Formation of the bimodality in [α/Fe] vs. [Fe/H] in analytic models

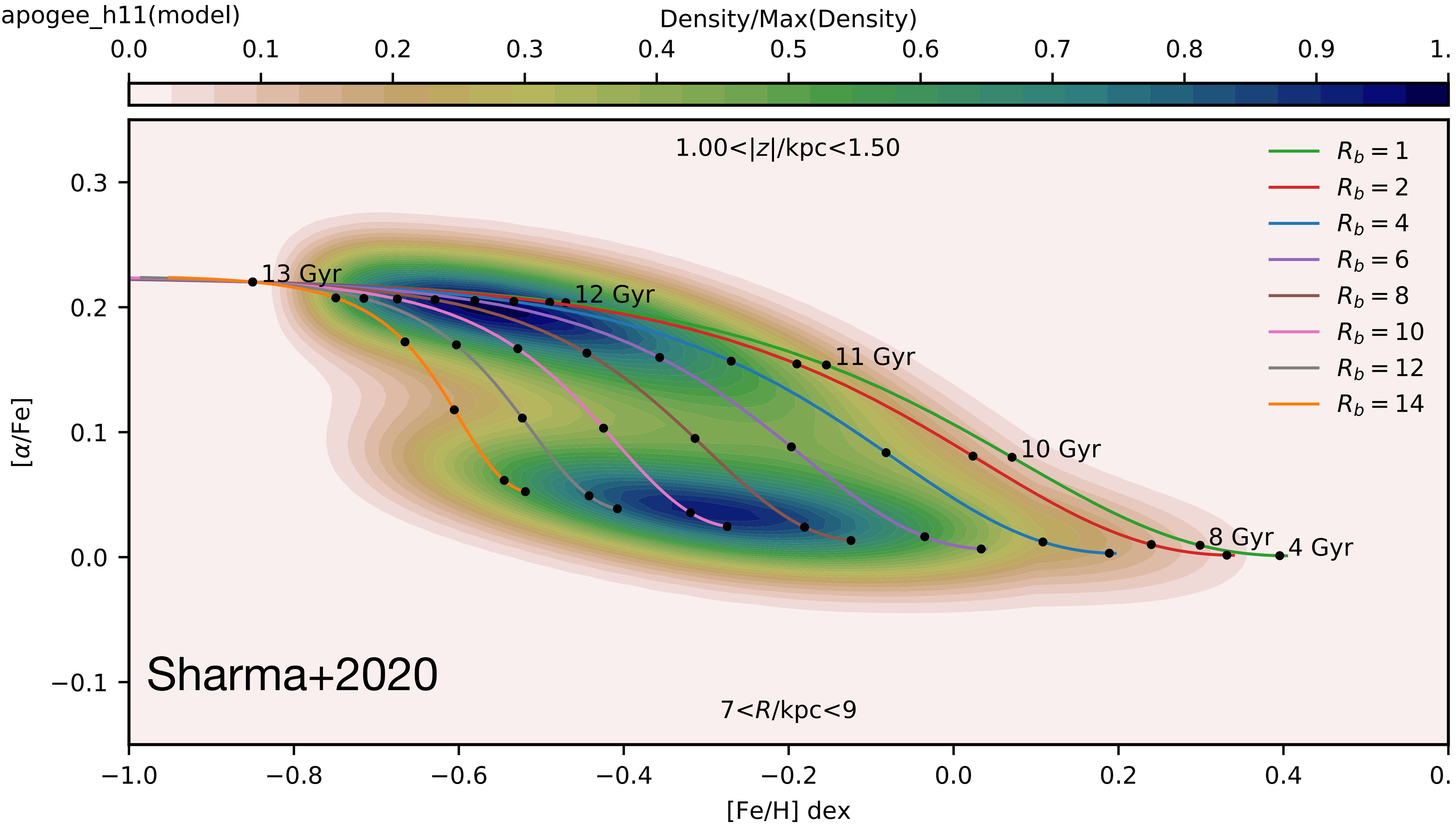


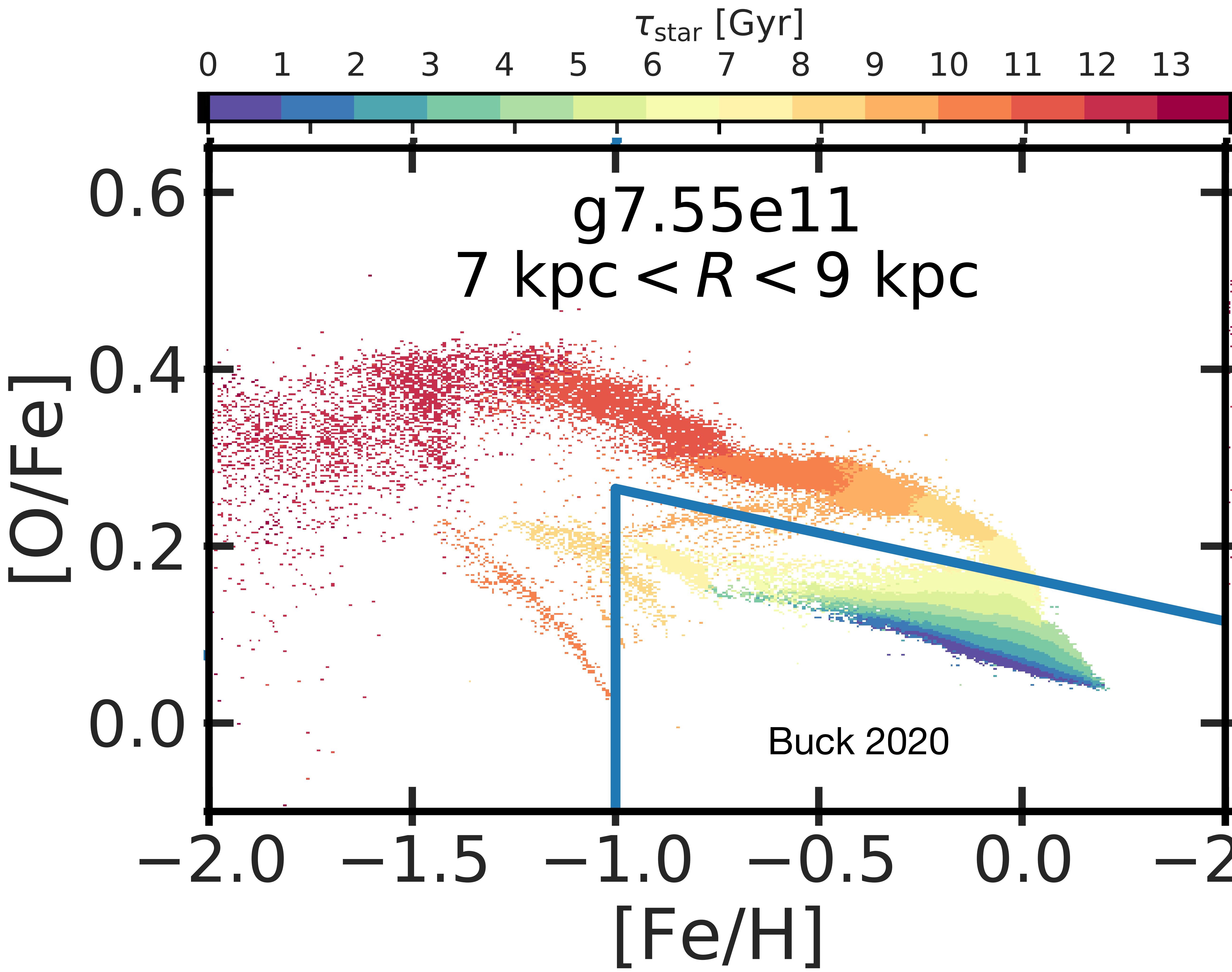
see also
Chiaki Kobayashi's great talk,
Chiappini+1997,
Spitoni+2021,
etc.

Formation of a simulated MW analogue

Formation of a simulated MW analogue

Formation of the bimodality in [α/Fe] vs. [Fe/H]





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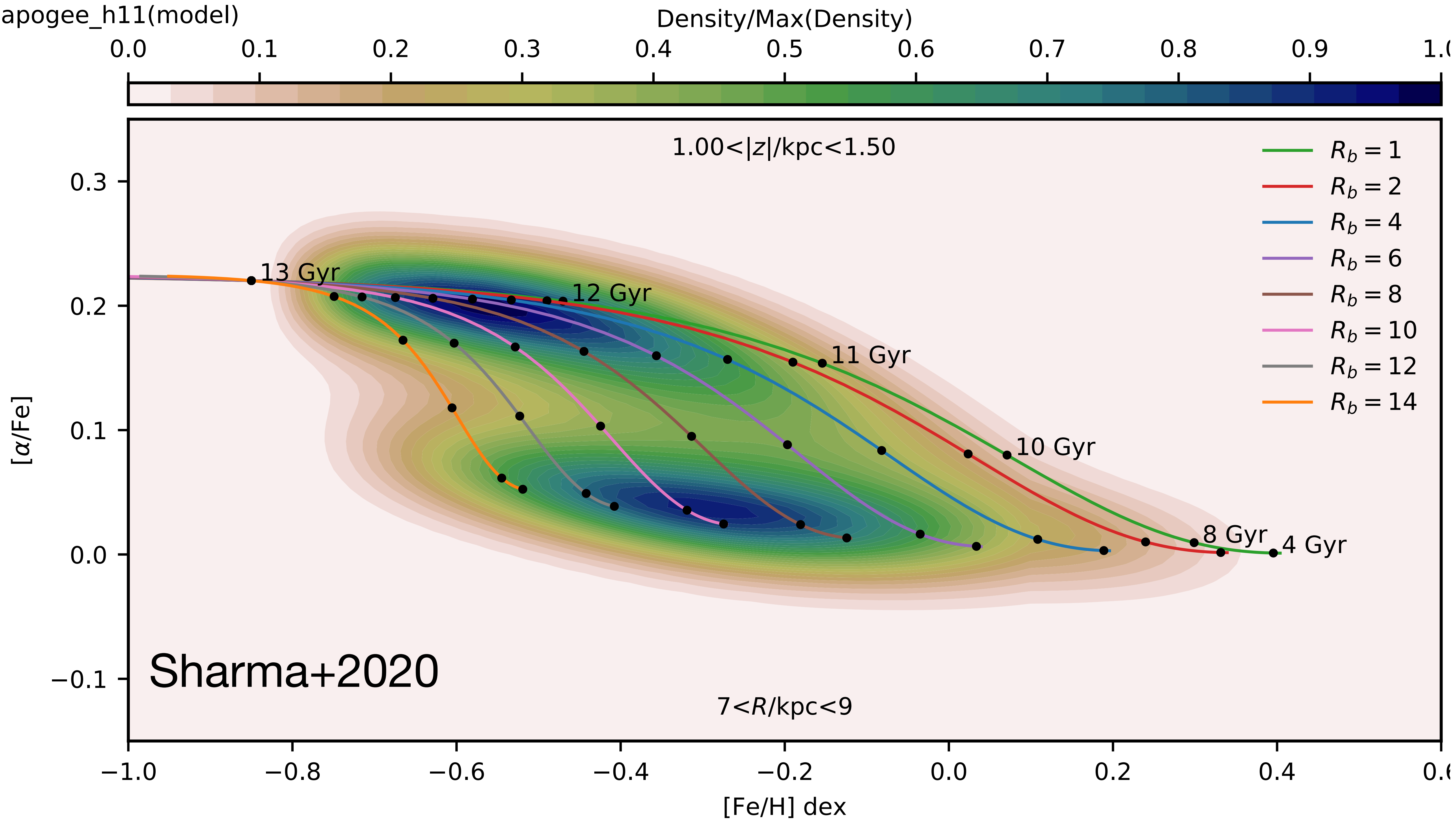
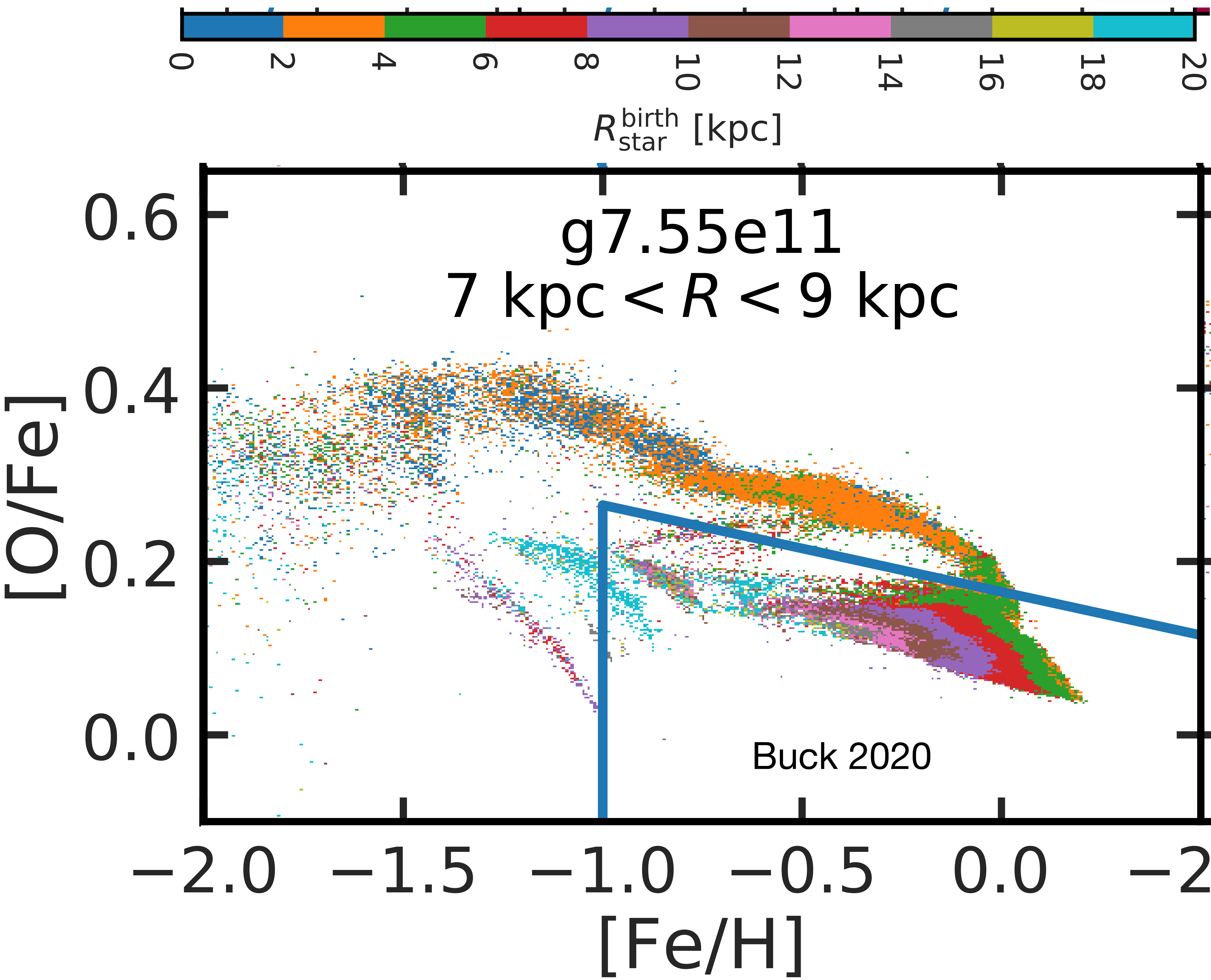
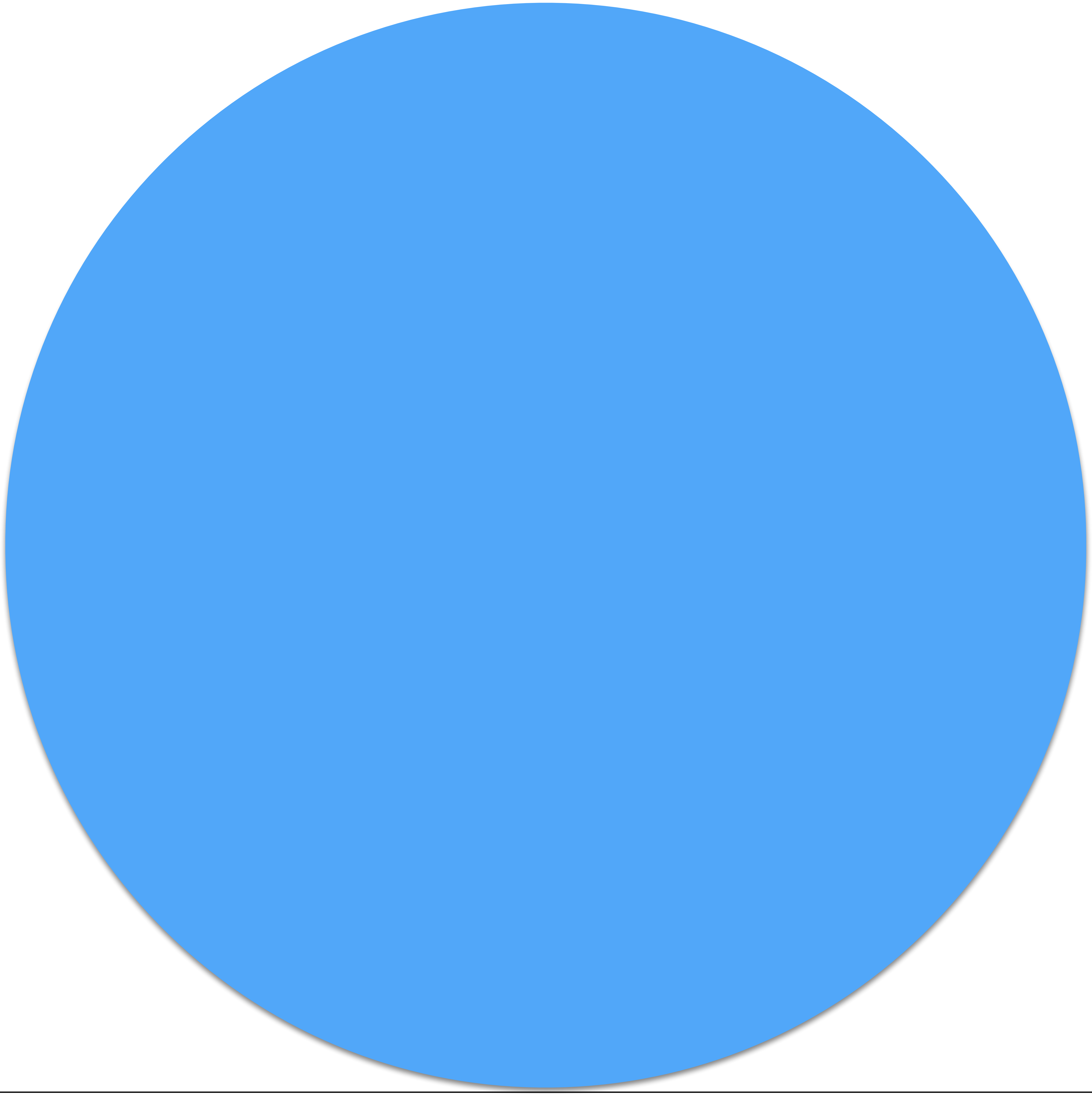





Aim:
Modify our cosmological numerical codes to keep up with the data quality and quantity of spectroscopic surveys

Star particles in cosmological simulations

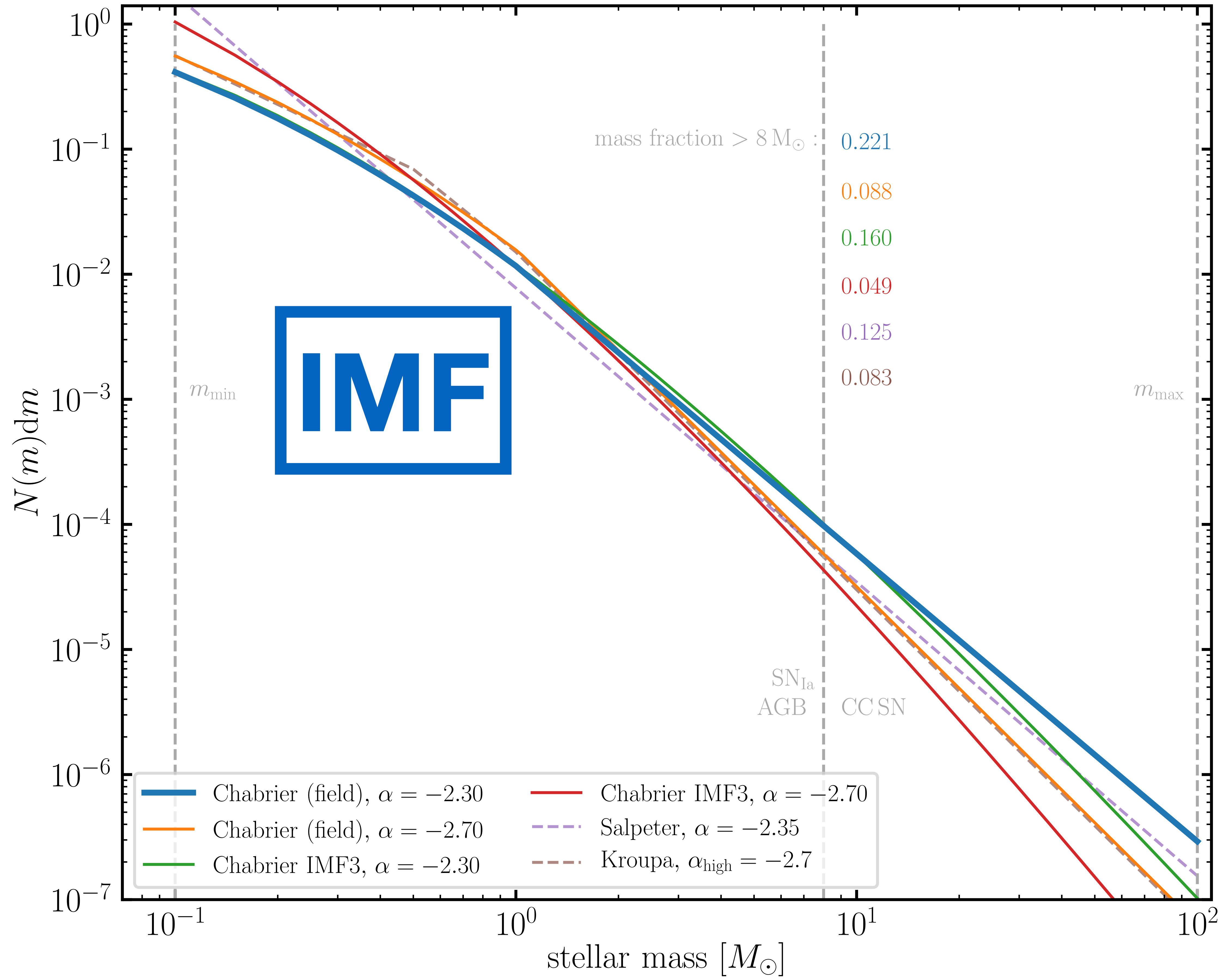


Star particles in cosmological simulations

Simple stellar population

mass, metallicity, age

Simple stellar population



Simple stellar population

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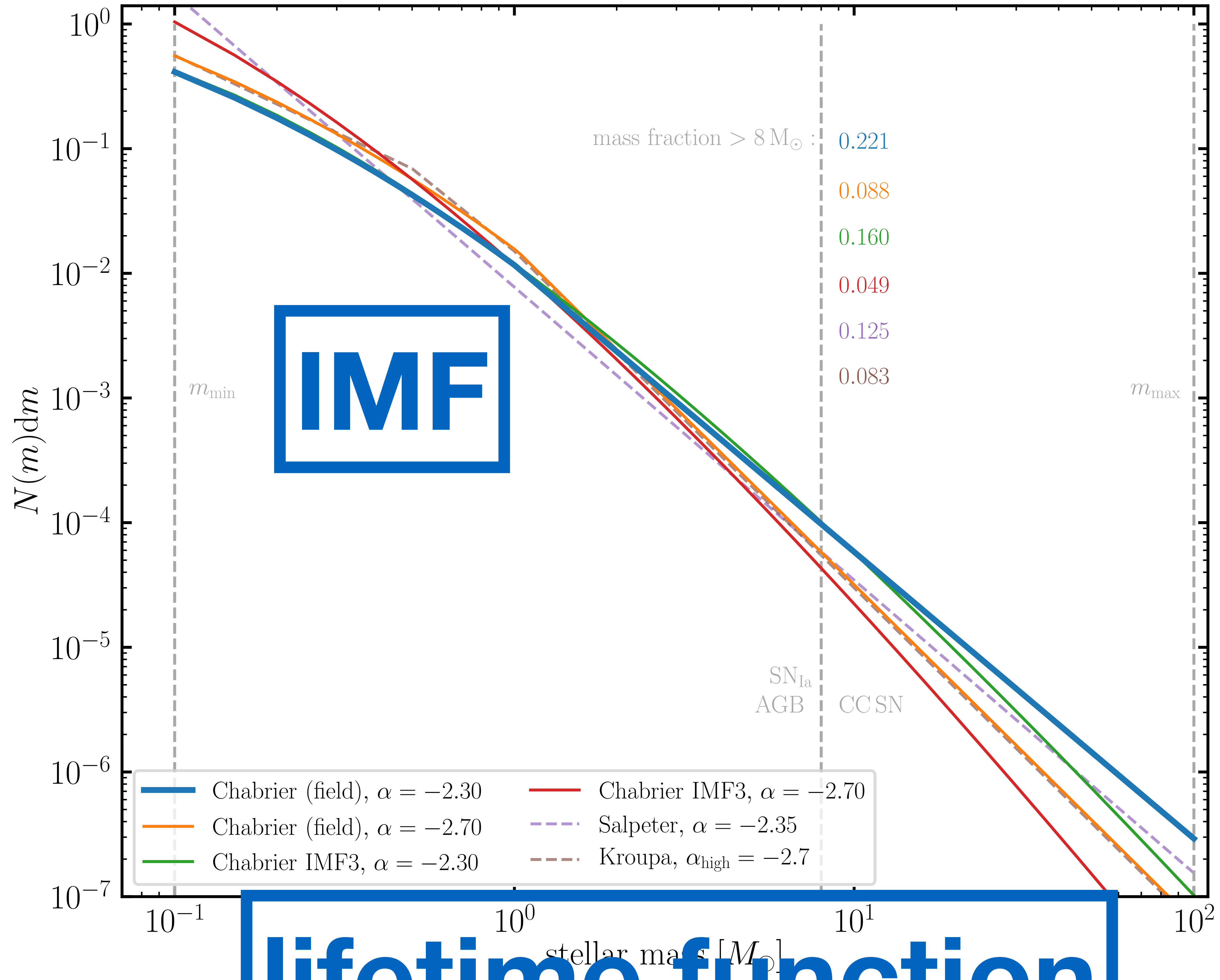
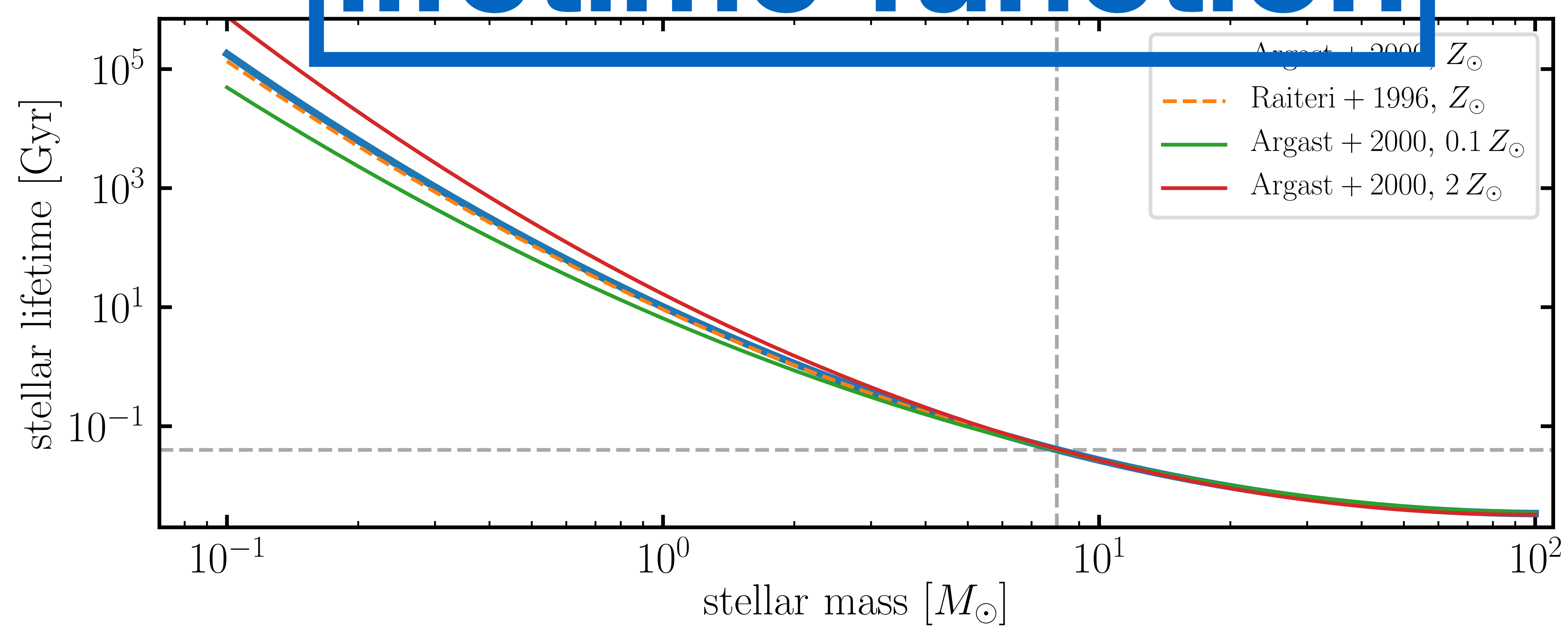
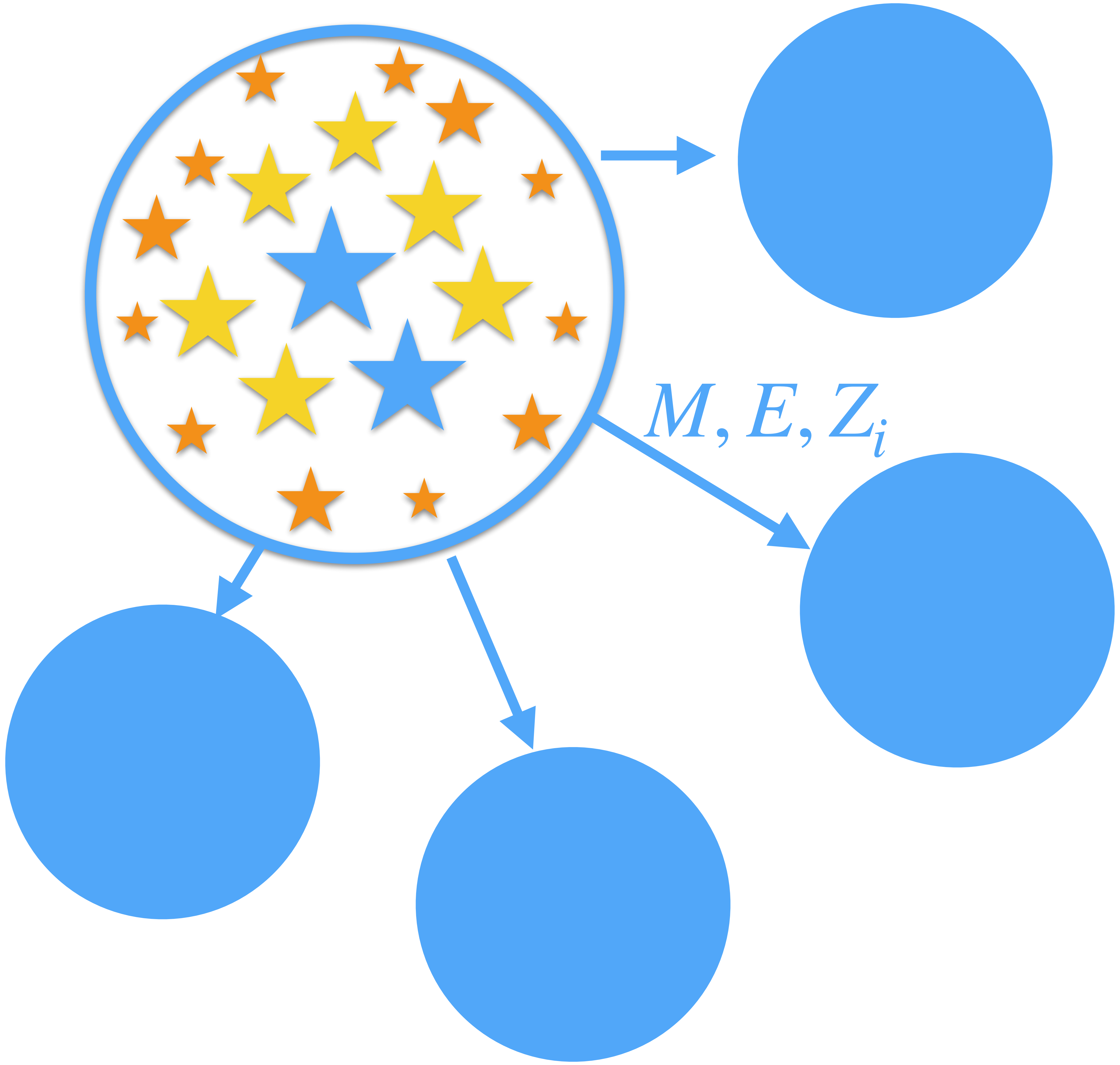




Chemical composition of mass return

nucleosynthetic yield tables for element production inside stars



Yield Table	Masses	Metallicities
	CC SN	
Portinari et al. (1998)	[6,120]	[0.0004,0.05]
François et al. (2004)	[11,40]	[0.02]
Chieffi & Limongi (2004)	[13,35]	[0,0.02]
Nomoto et al. (2013)	[13,40]	[0.001,0.05]
Frischknecht et al. (2016)	[15,40]	[0.00001,0.0134]
West & Heger (in prep.)	[13,30]	[0,0.3]
Ritter et al. (2018b)	[12,25]	[0.0001,0.02]
Limongi & Chieffi (2018)[a]	[13,120]	[0.0
	SN_{Ia}	
Iwamoto et al. (1999)	[1.38]	
Thielemann et al. (2003)	[1.374]	[0.02]
Seitenzahl et al. (2013)	[1.40]	[0.02]
	AGB	
Karakas (2010)	[1,6.5]	[0.0001,0.02]
Ventura et al. (2013)	[1,6.5]	[0.0001,0.02]
Pignatari et al. (2016)	[1.65,5]	[0.01,0.02]
Karakas & Lugaro (2016)	[1,8]	[0.001,0.03]
TNG[b]	[1,7.5]	[0.0001,0.02]
	Hypernova	
Nomoto et al. (2013)	[20,40]	[0.001,0.05]

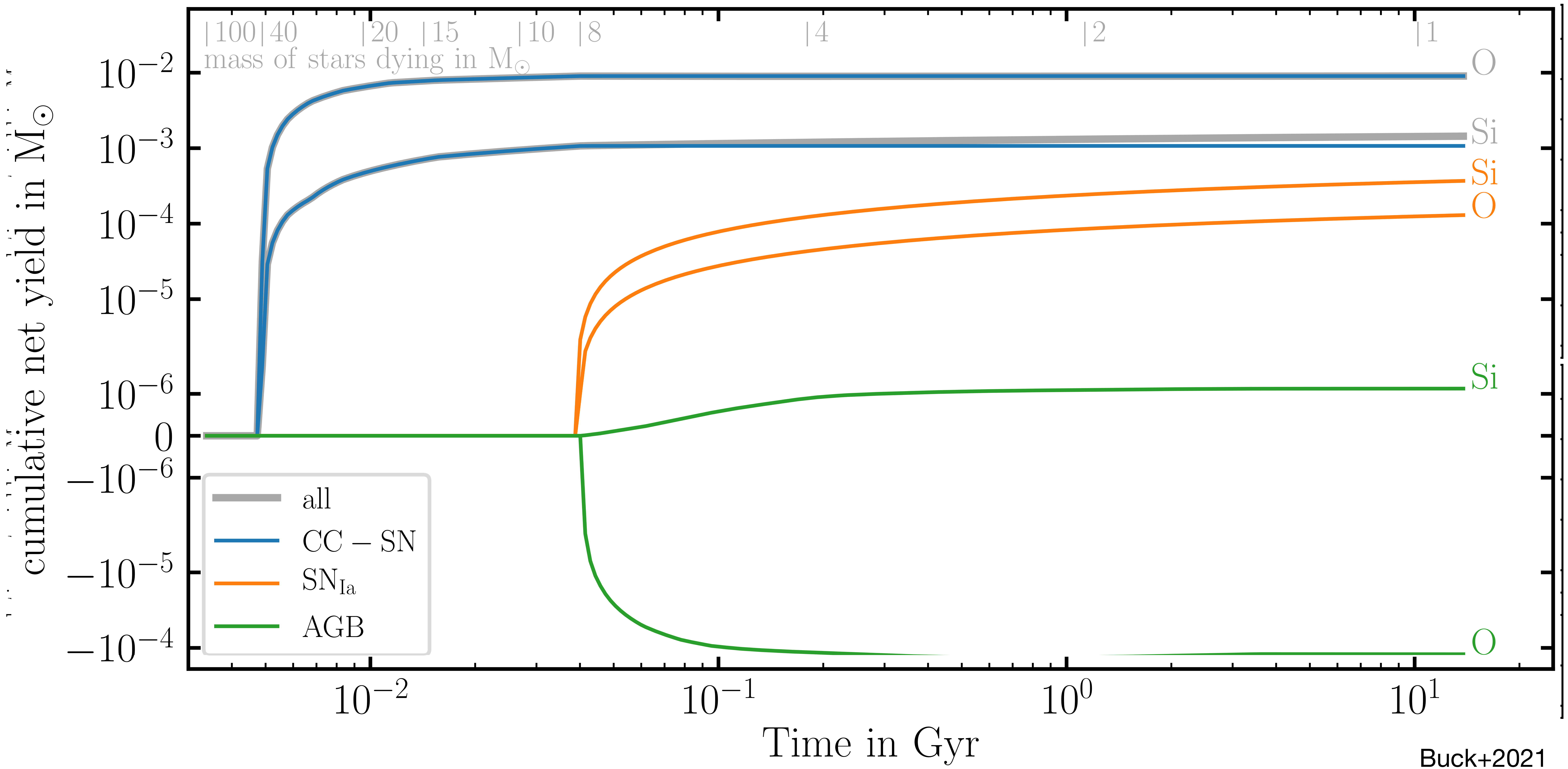
17 yield tables

Buck+2021

Importance of tracing a large set of elements

see also Chiaki Kobayashi's
extensive work on this topic!

Time release of newly produced elements



Buck+2021

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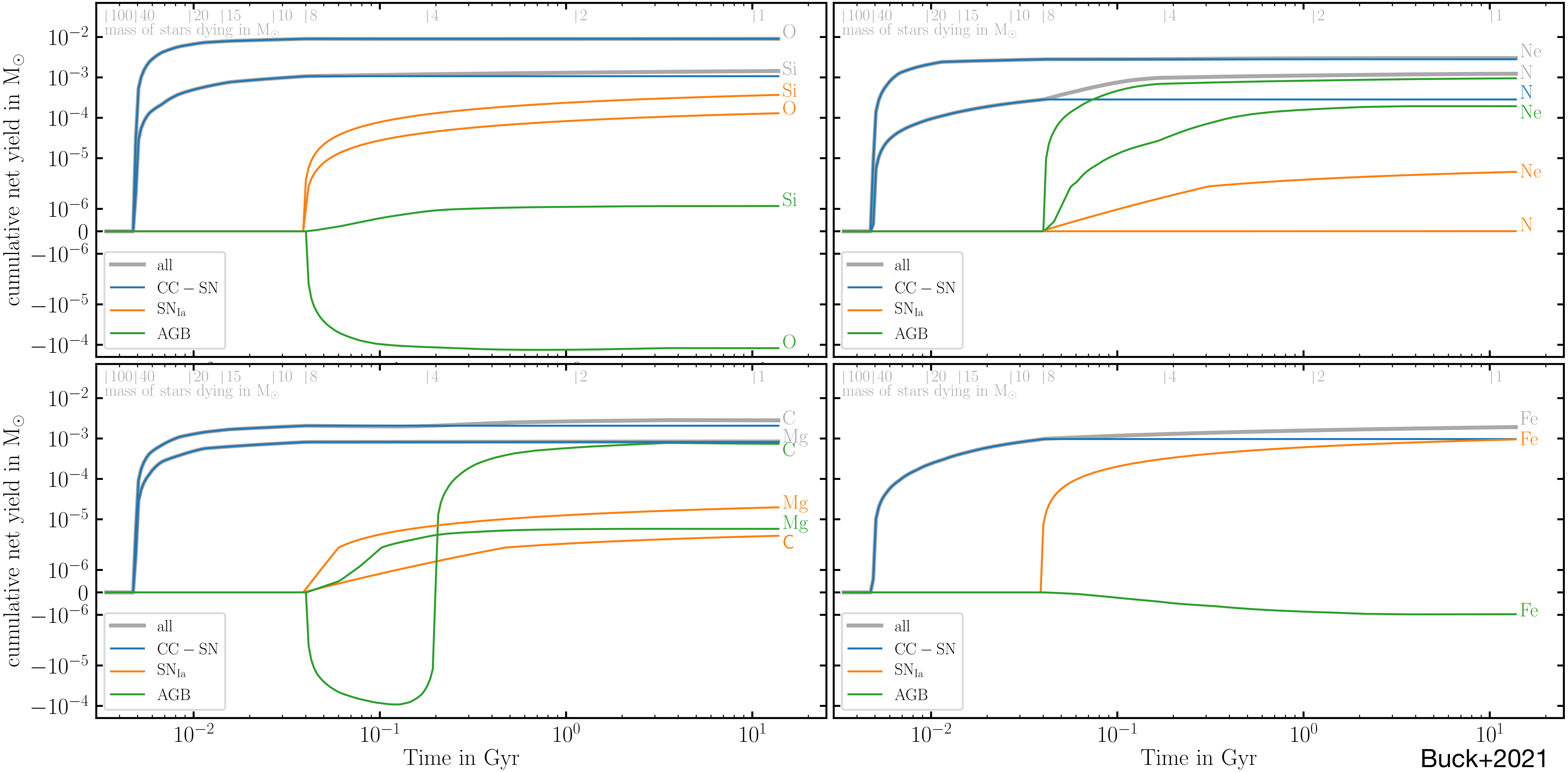

Buck+2021

Simulation Physics in Gasoline2

1

GASOLINE2
smooth particle hydrodynamics

„modern“ implementation of hydrodynamics, metal diffusion

Wadsley+2017, Keller+2014

2

gas cooling

via hydrogen, helium and various metal lines

gas heating

via Photoionisation (e.g. from the UV background)

Shen+2010, Haardt&Madau 2012

3

self consistent star formation from cold, dense gas

Stinson+2006

star formation regions

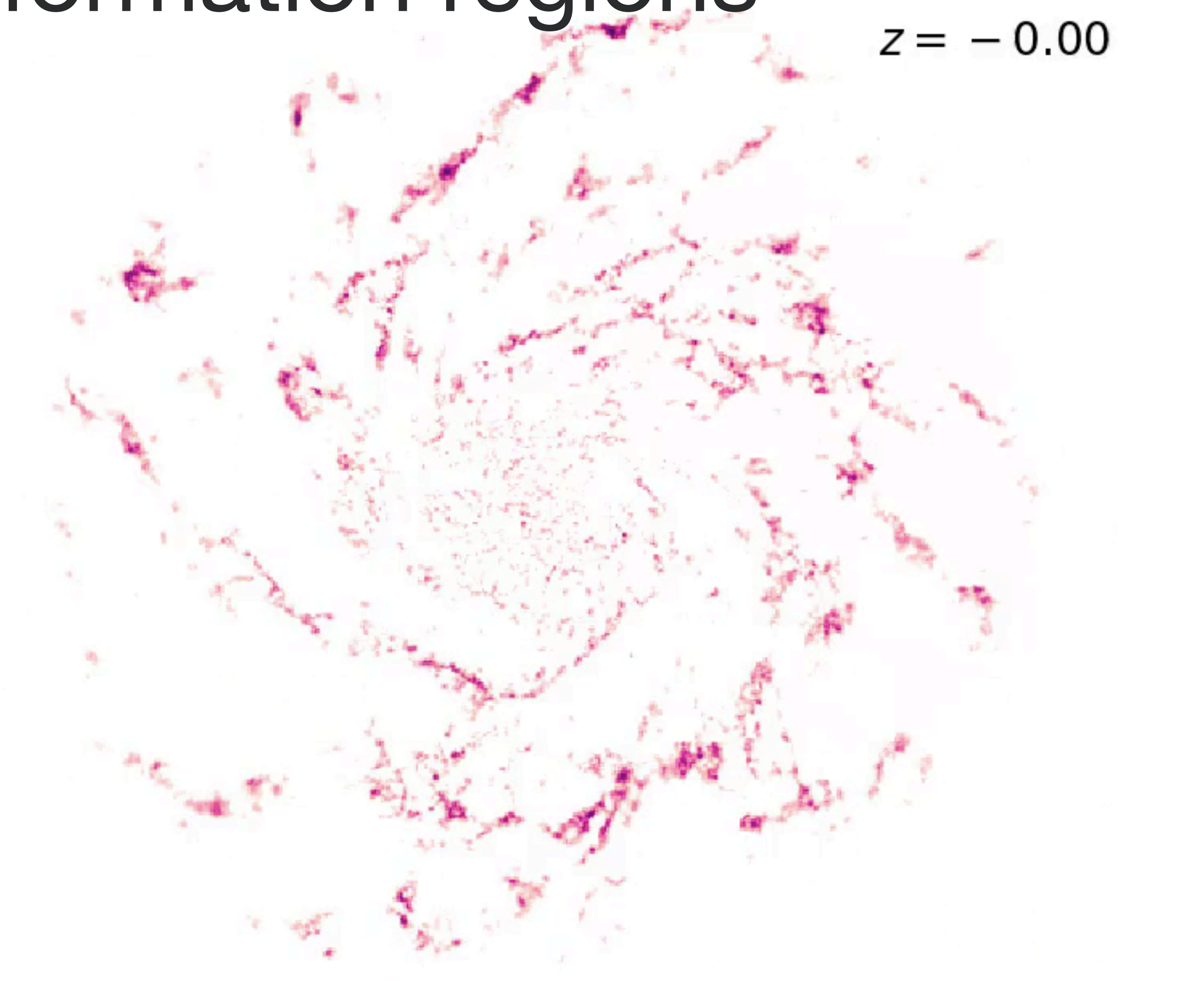

image size: 50x50 kpc

Animation by T. Buck (MPIA, NYUAD) based on NIHAO simulations

Buck+2019a

4

energetic feedback from young massive stars and supernovae

Stinson+2013

previously: chemical enrichment limited to Fe and O

$$M_{\rm ej} = 0.7682\, M^{1.056}\,,$$

$$M_{\rm Fe} = 2.802 \times 10^{-4} M^{1.864}\,,$$

$$M_{\rm O} = 4.586 \times 10^{-4} M^{2.721}\,.$$

Raiteri+1996

Now: in principle 81 elements possible to trace!

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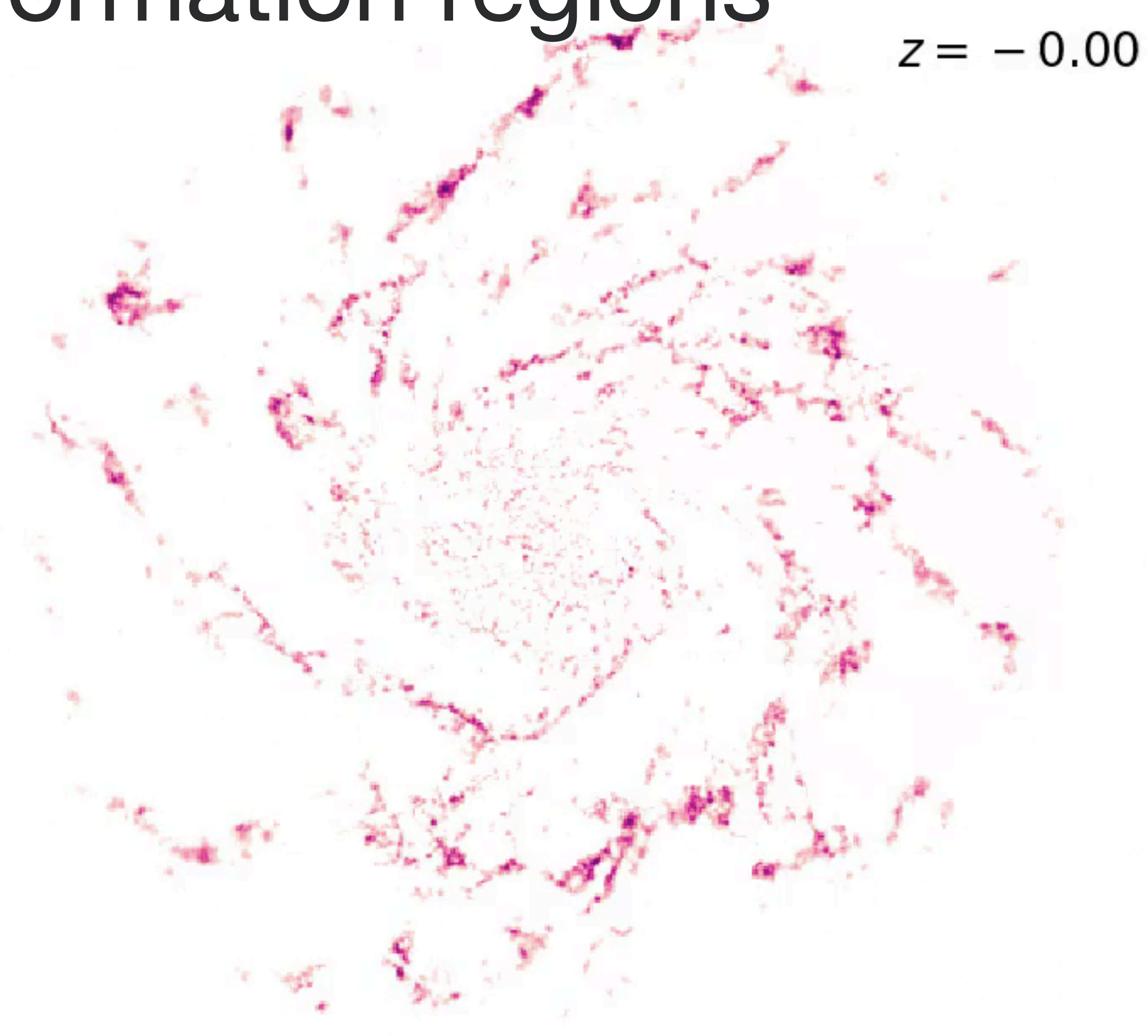

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Now: in principle 81 elements possible to trace!

Results: mass metallicity relation unchanged

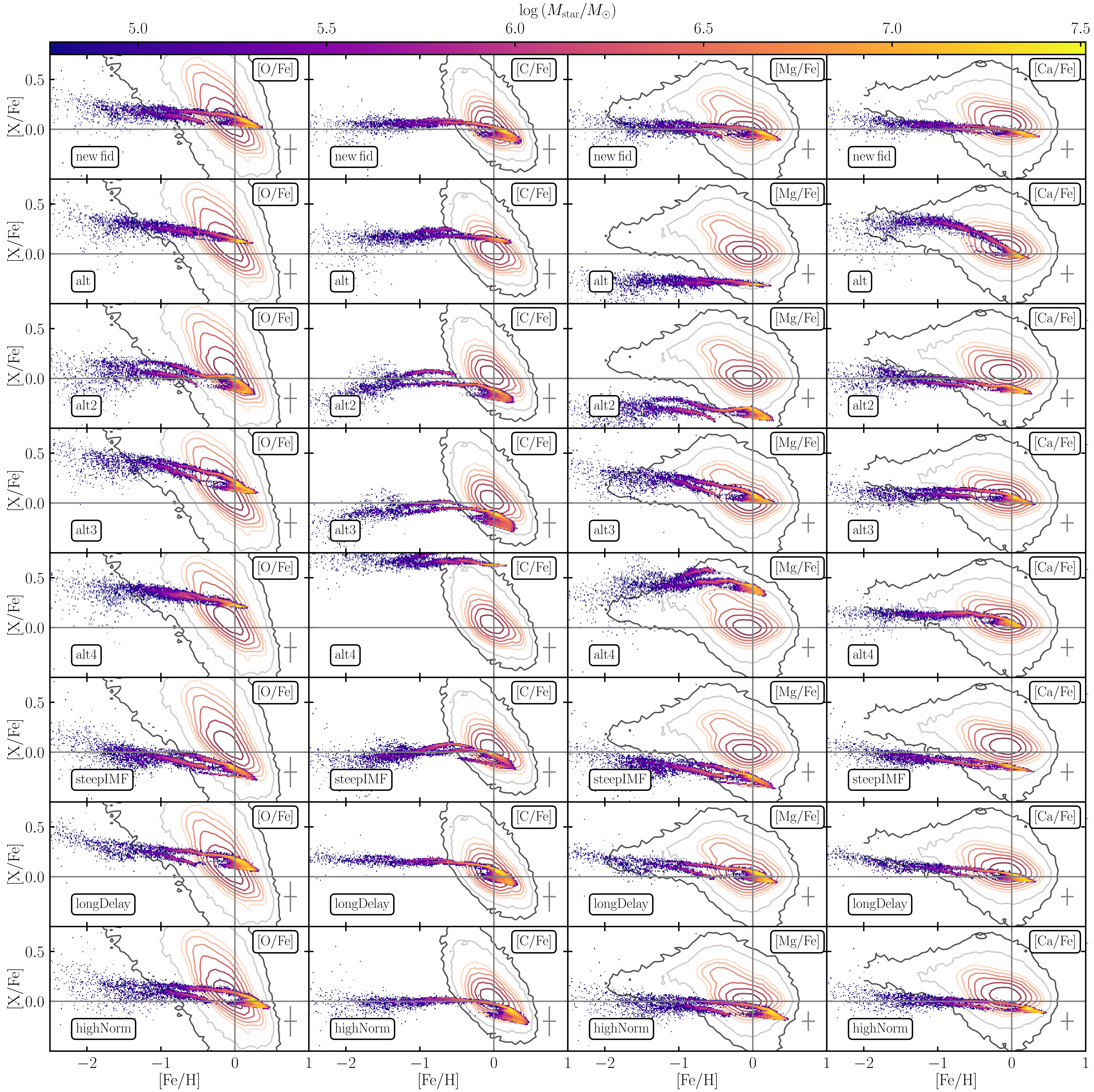
Differences in element distributions - MW mass

Buck+2021

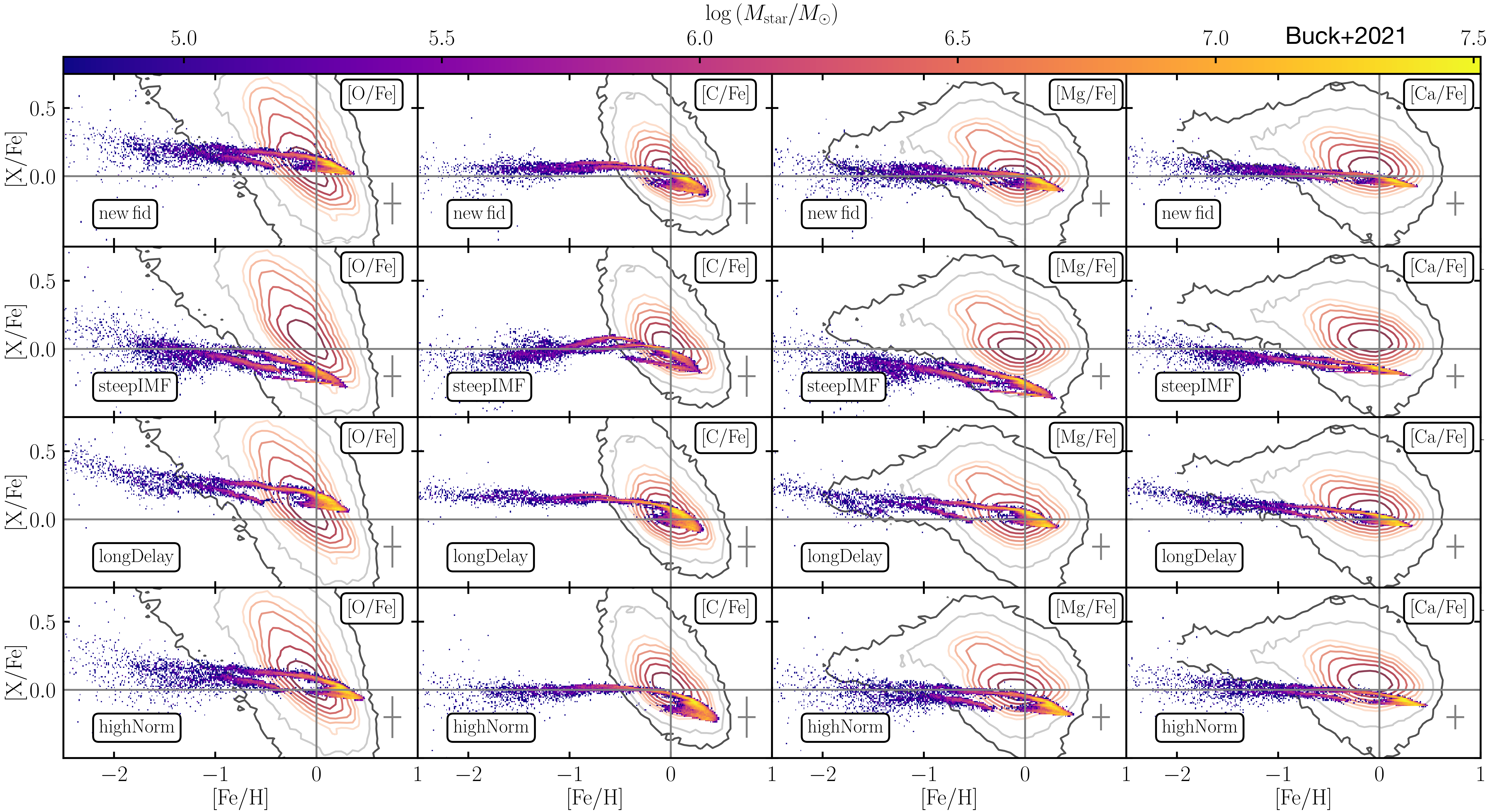
Differences in [α/Fe] vs. [Fe/H]

Buck+2021

Differences in [X/Fe] vs. [Fe/H] for X=O,C,Mg,Ca

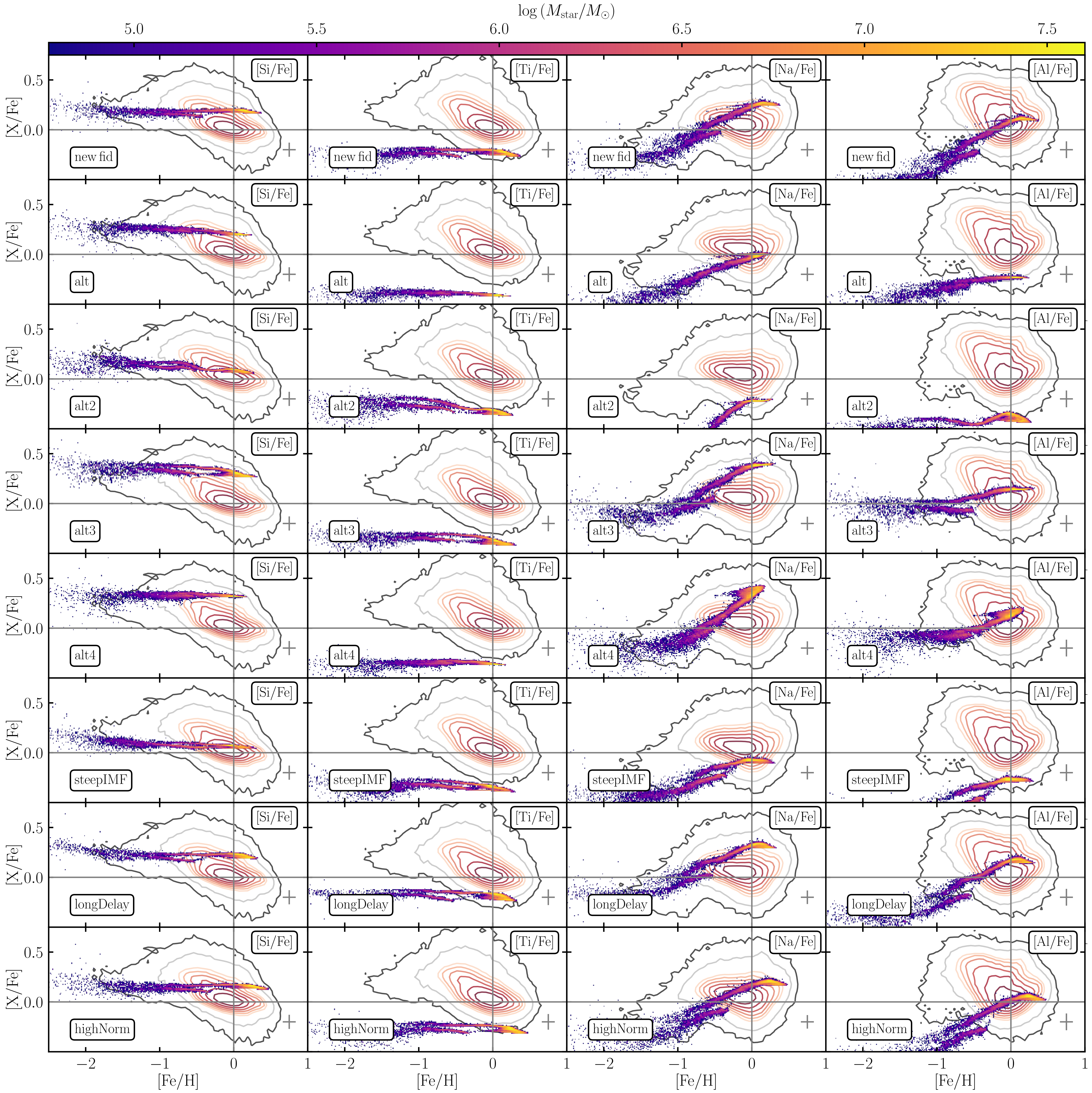


Buck+2021



Buck+2021
log $(M_{\mathrm{star}}/M_{\odot})$
5.0
5.5
6.0
6.5
7.0
7.5
[O/Fe]
[C/Fe]
[Mg/Fe]
[Ca/Fe]
new fid
steepIMF
longDelay
highNorm
[X/Fe]
[Fe/H]

Differences in [X/Fe] vs. [Fe/H] for X=Si,Ti,Na,Al



Buck+2021

A flexibel chemical enrichment implementation for cosmological simulations: great potential for MW chemo-dynamics

Great diversity in abundance tracks

data publicly available at:
https://tobibu.github.io/#sim_data

or simply drop me a mail: tbuck@aip.de

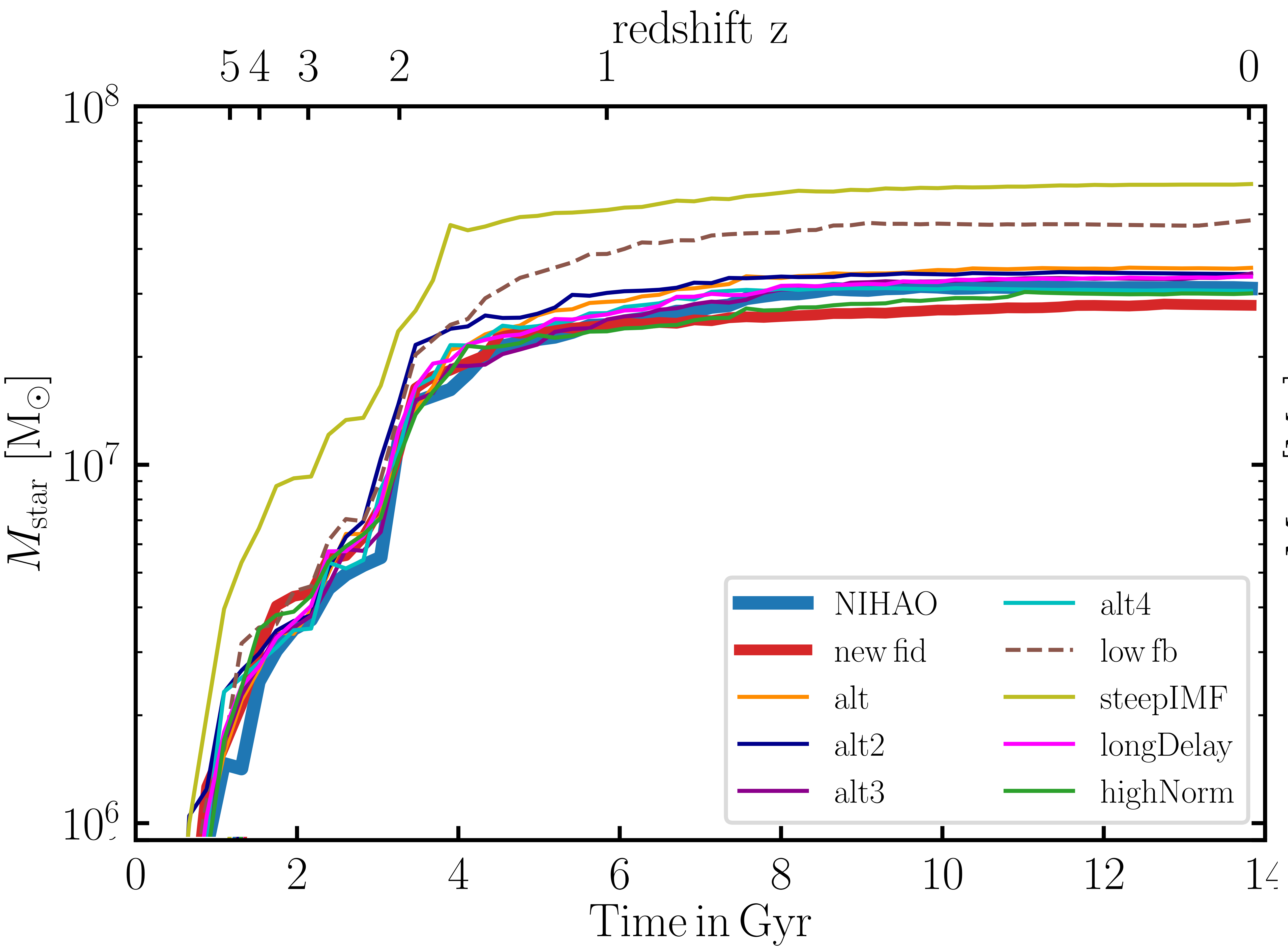
Simple stellar population model

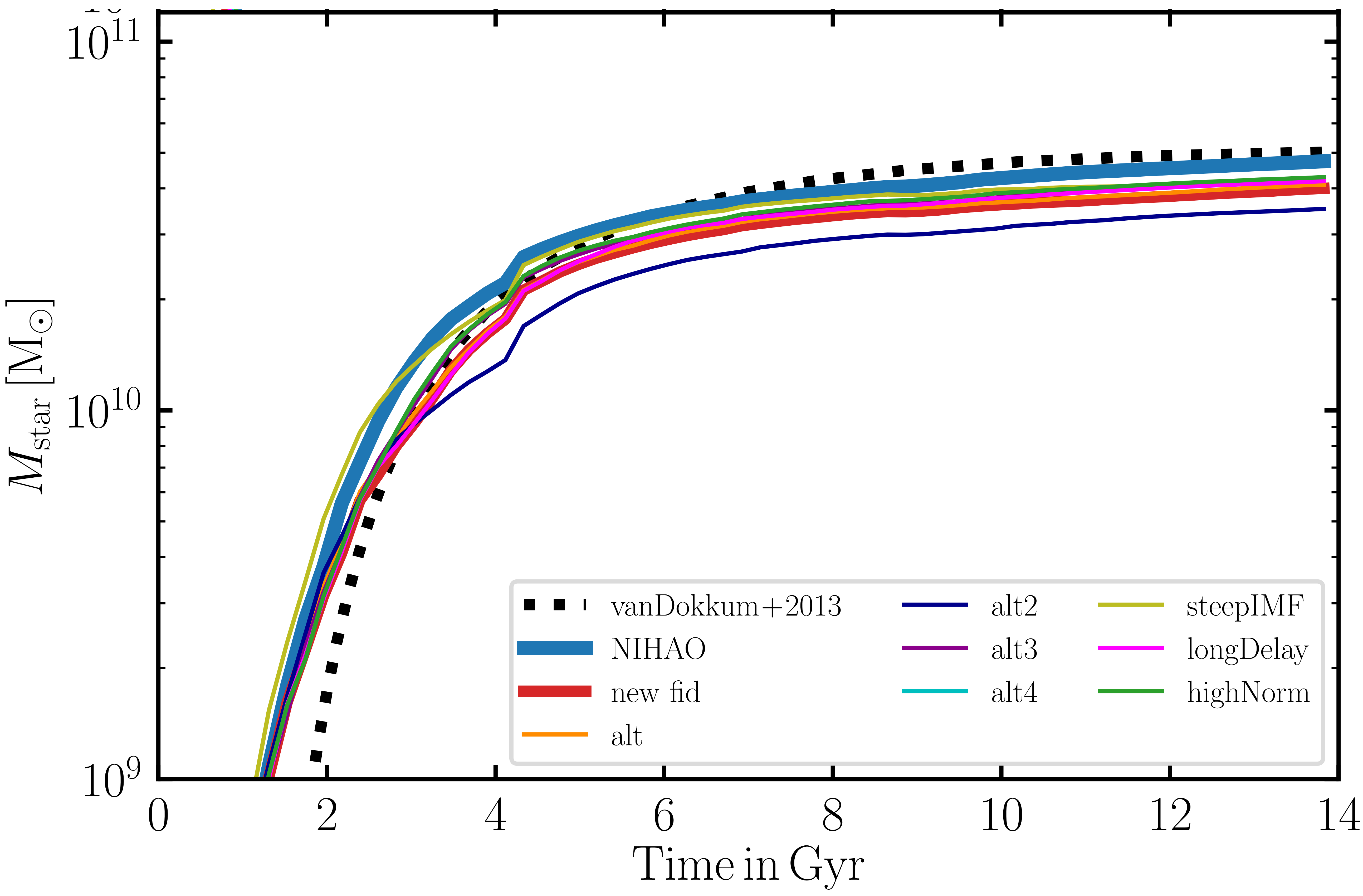
assume mass ranges for CC-SN, AGB stars and SN Ia
here the number of SN Ia follows empirical delay time distribution

massive stars dying

low mass stars dying

Star formation history





Buck subm.