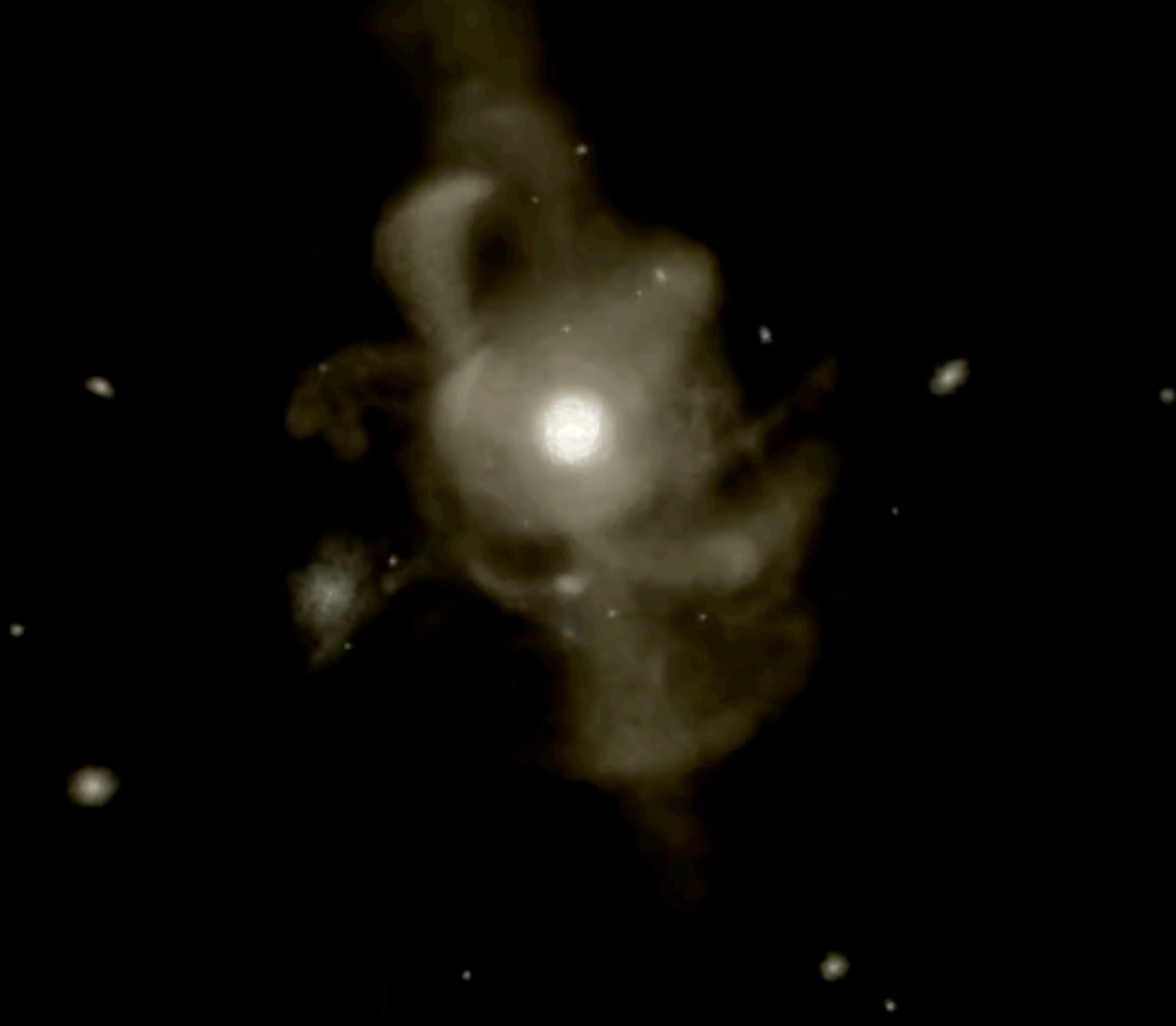
An improved chemical enrichment implementation in GASOLINE2



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somewhere in cyber space,
19.1.2021

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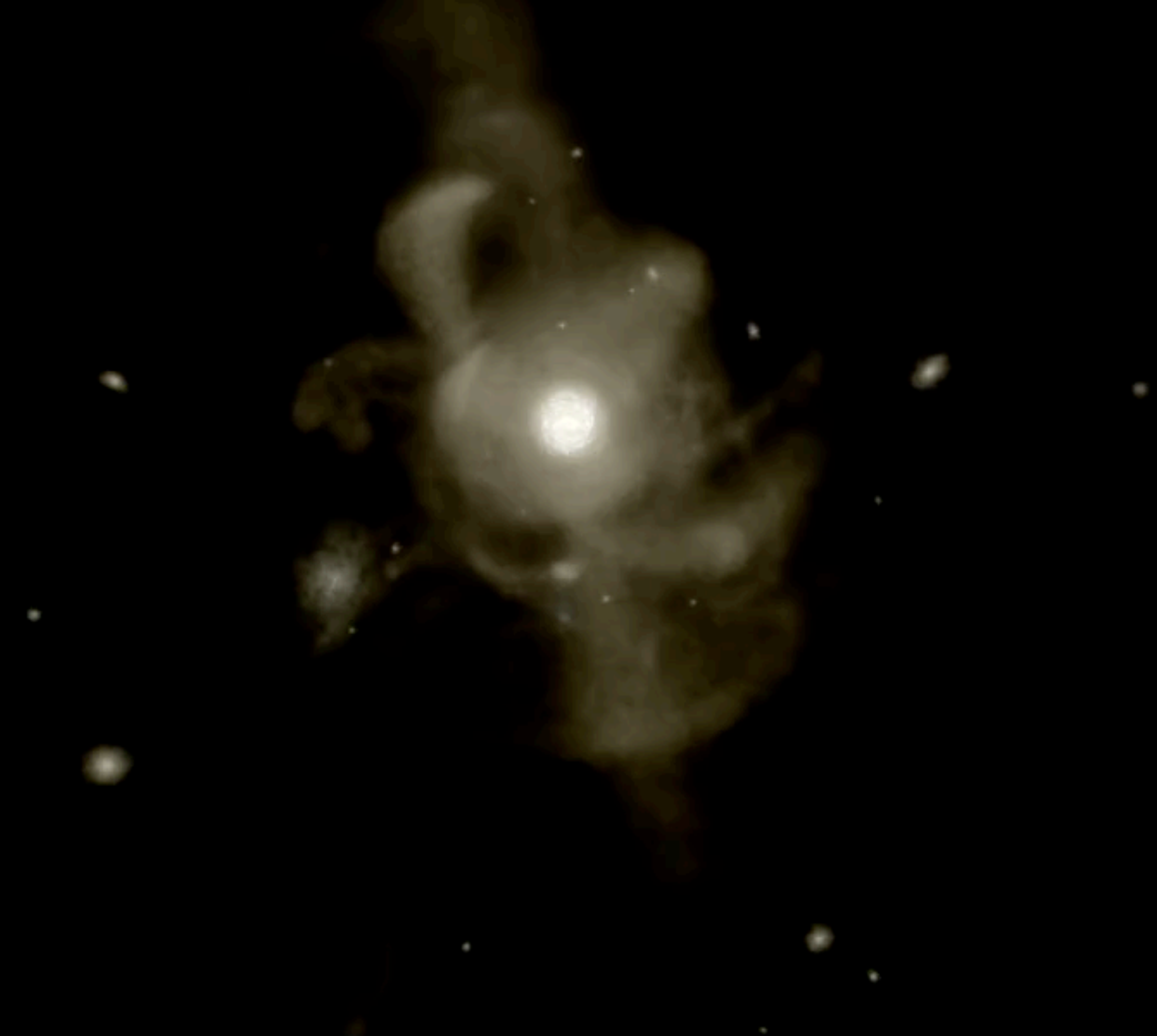

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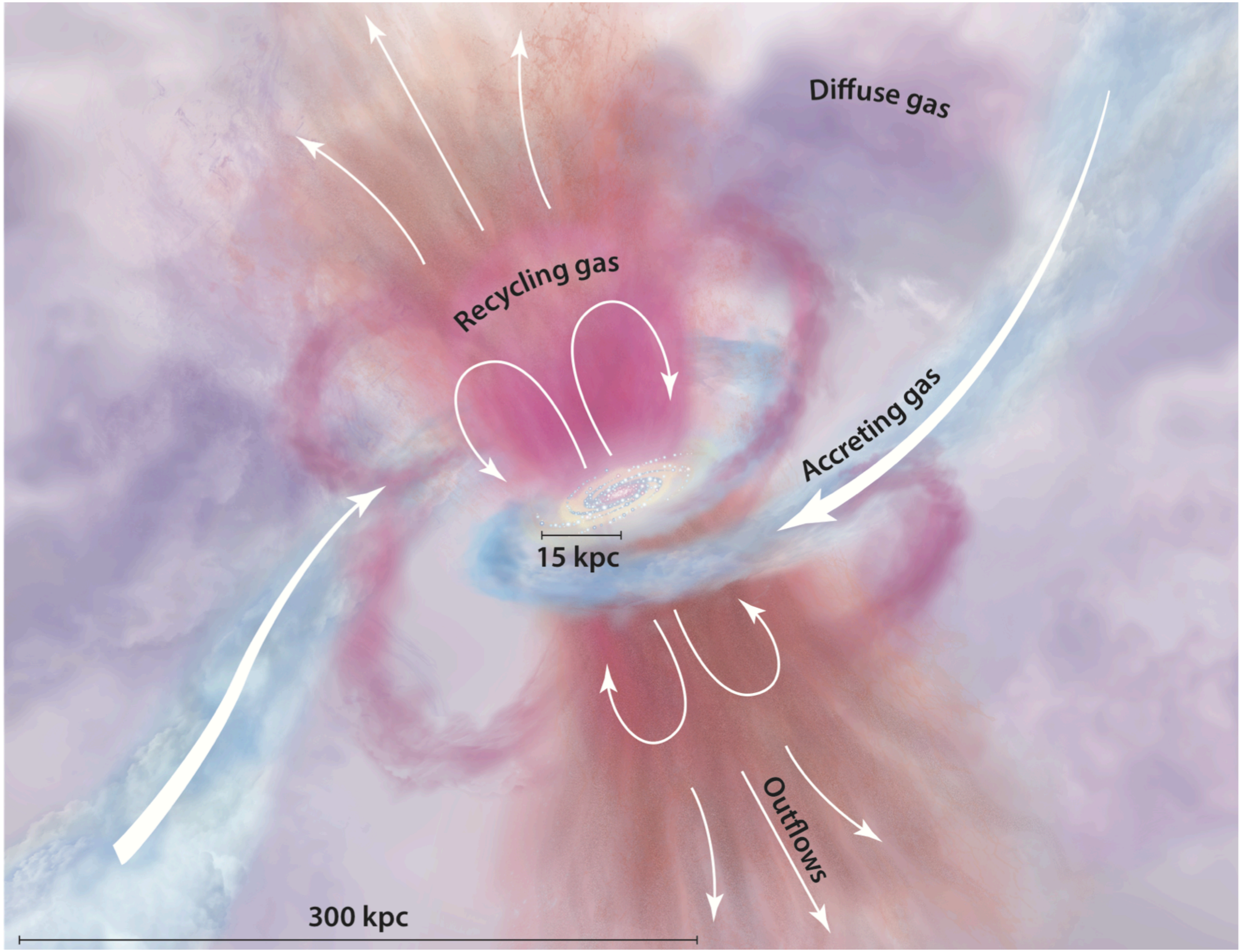
Tracing galaxy formation across time



Tumlinson+2017

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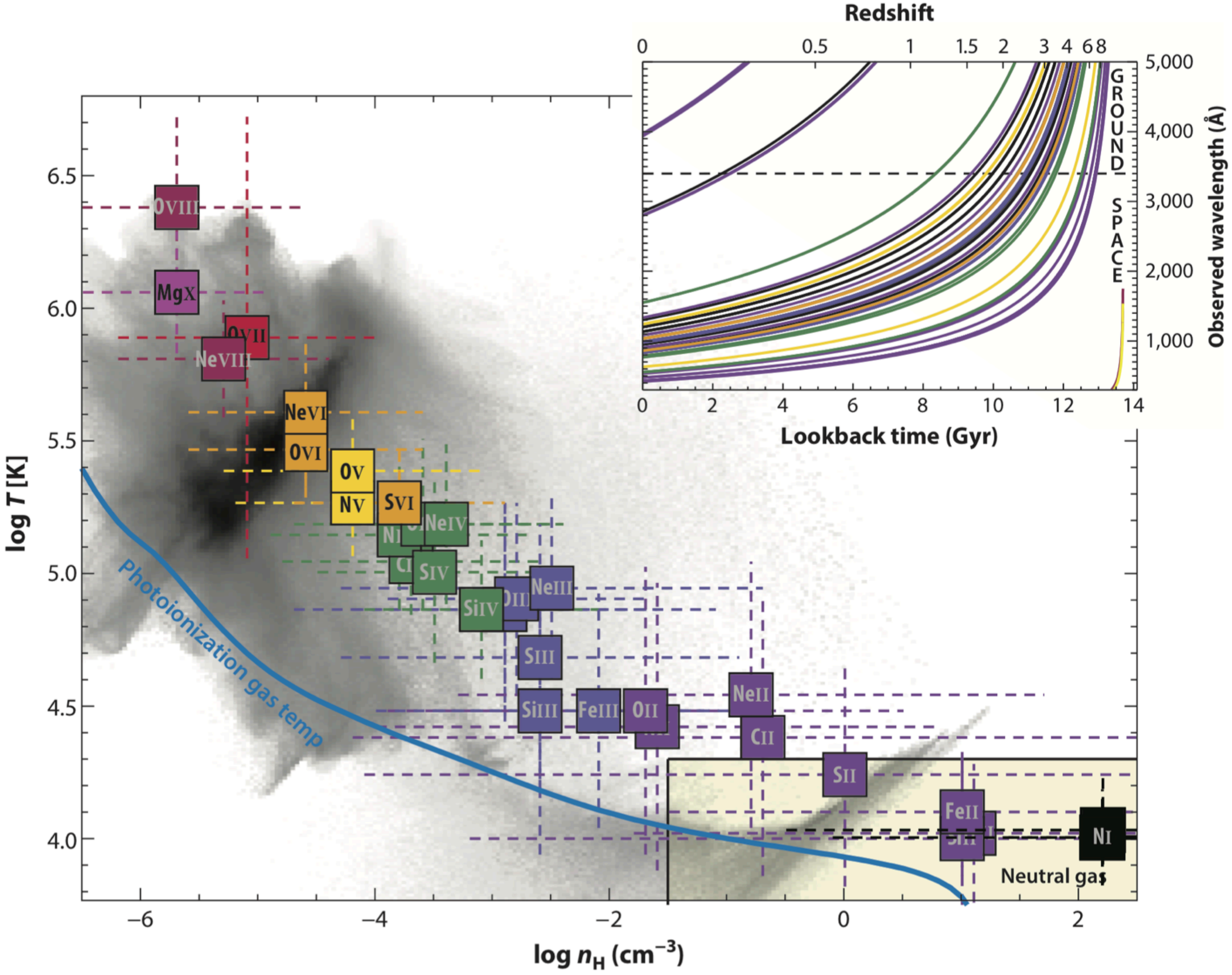
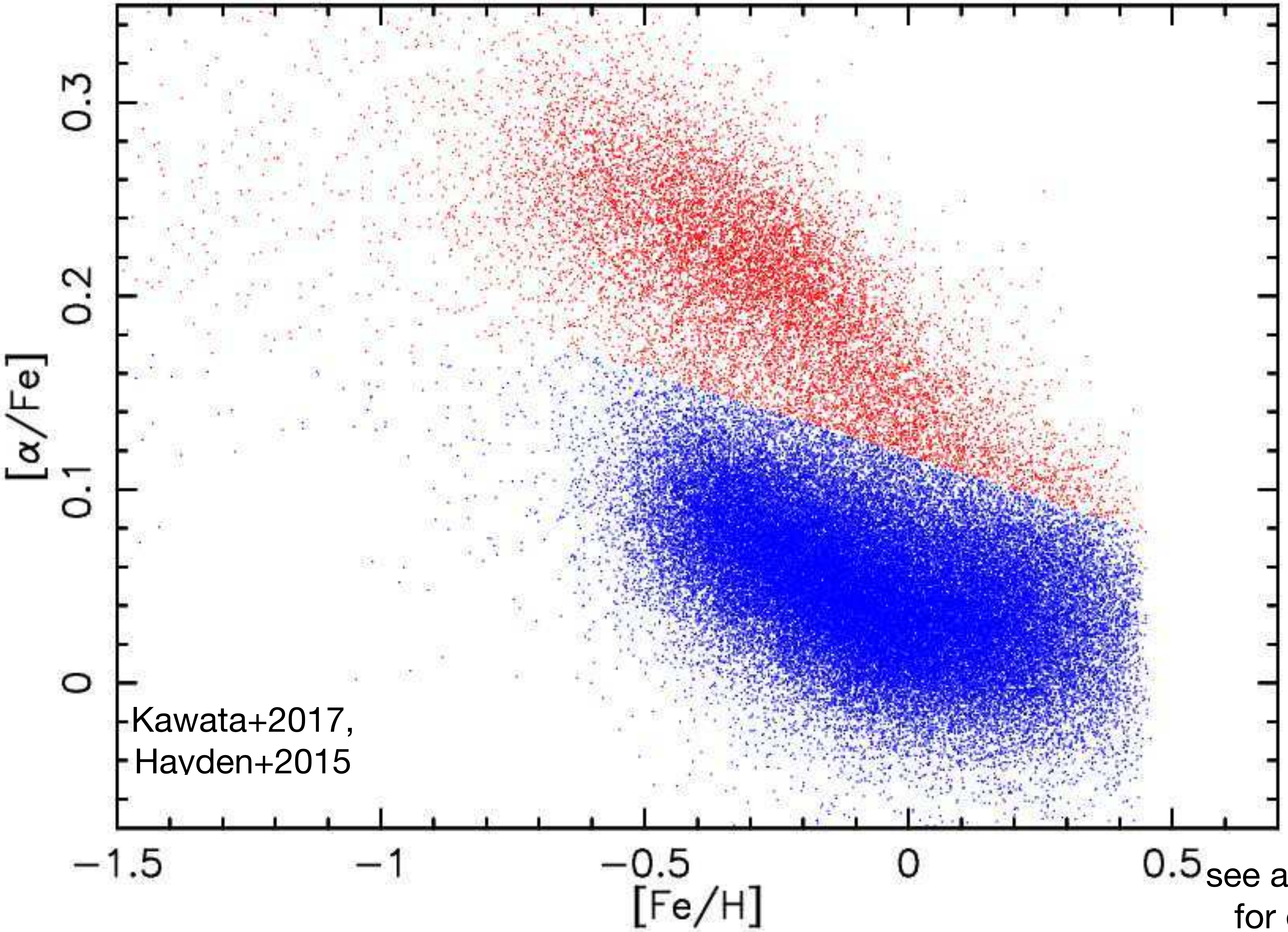


Tumlinson+2017

Milky Way chemo-dynamics

Bimodality in [α/Fe] vs. [Fe/H] plane



see also Buck 2020 or Agertz+2021
for explanation of this sequence

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

star formation regions

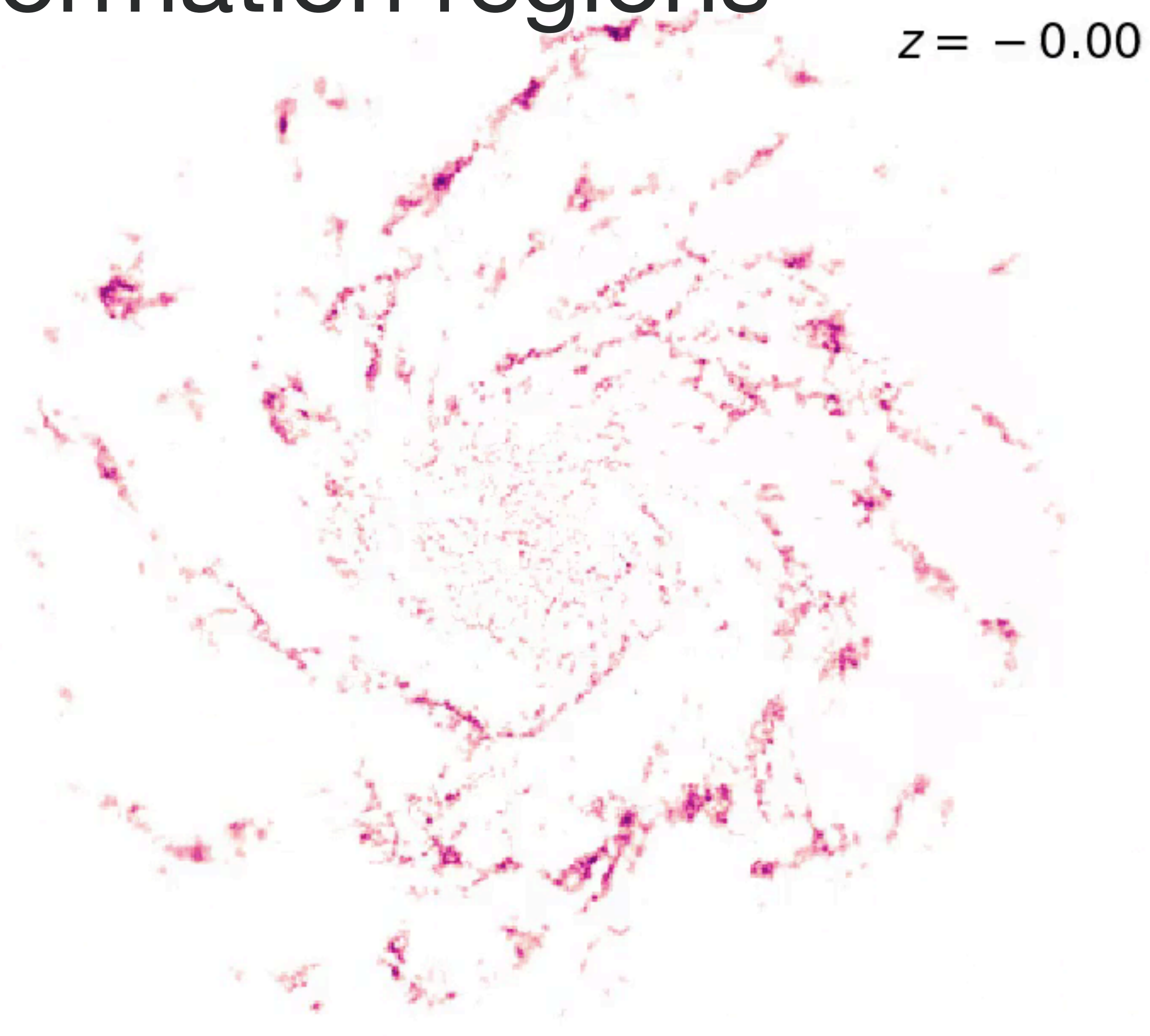


image size: 50x50 kpc

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

Buck+2019a

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

3

self consistent star formation from cold, dense gas

Stinson+2006

4

energetic feedback from young massive stars and supernovae

Stinson+2013

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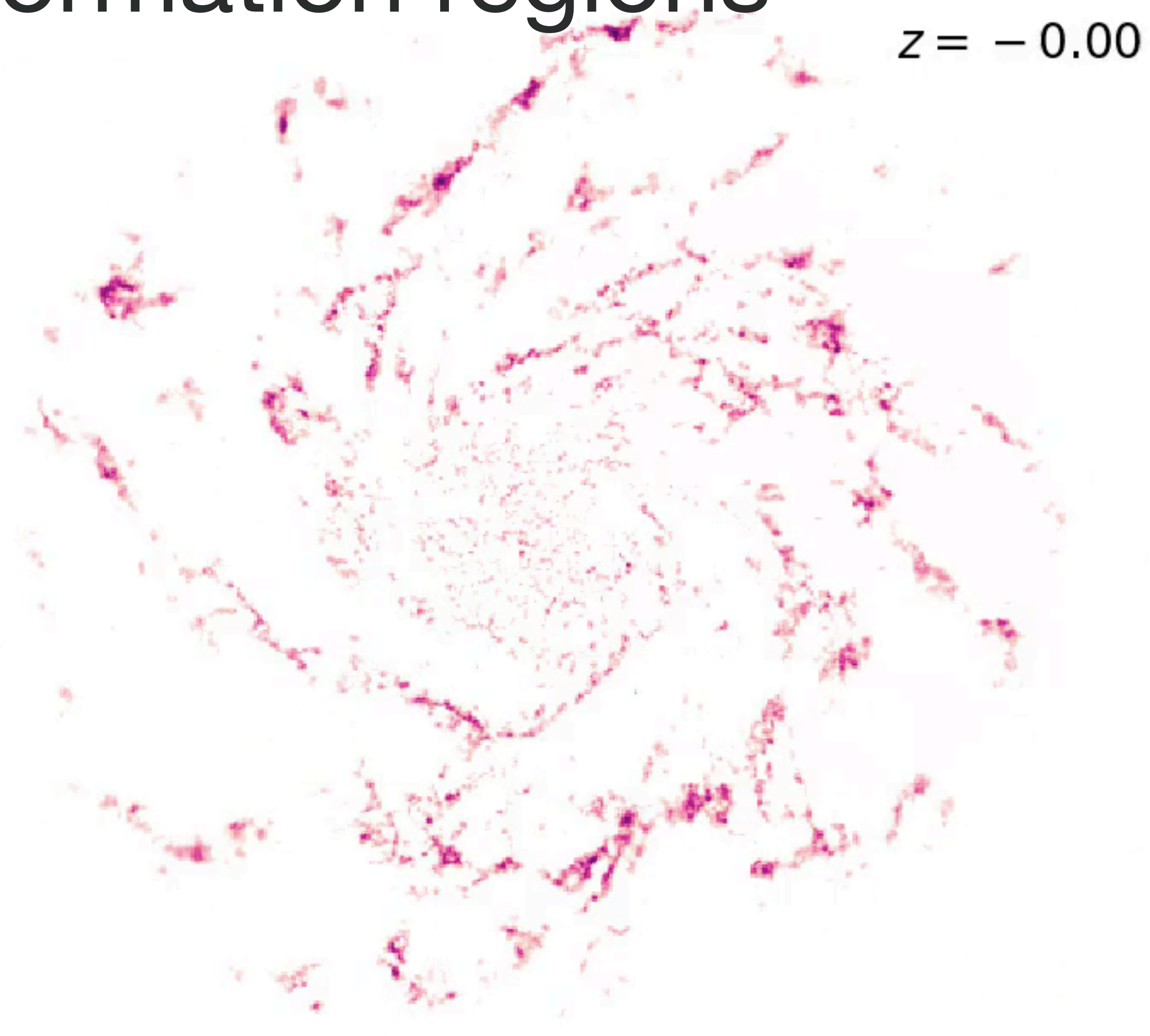

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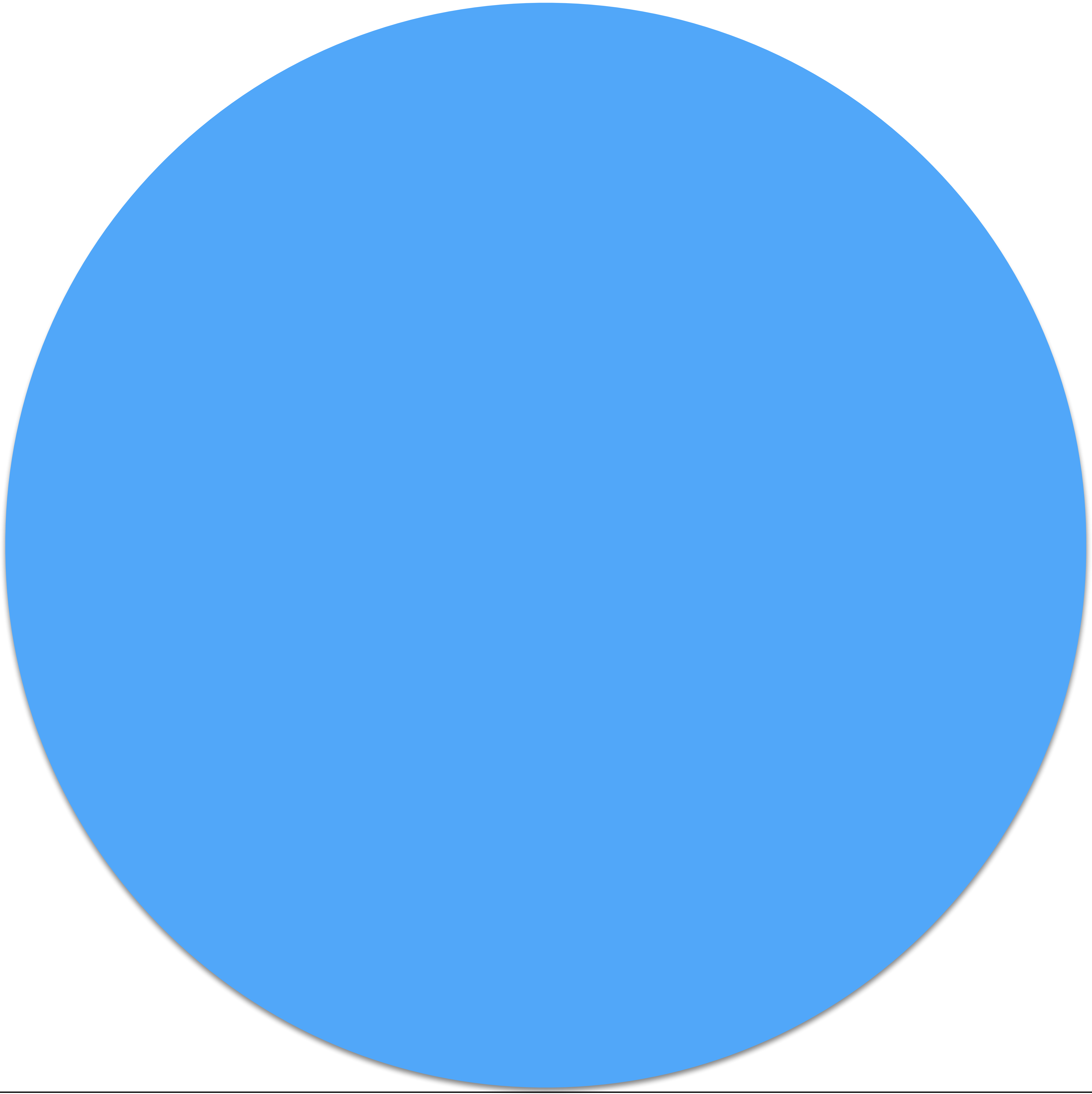
Star particles in cosmological simulations

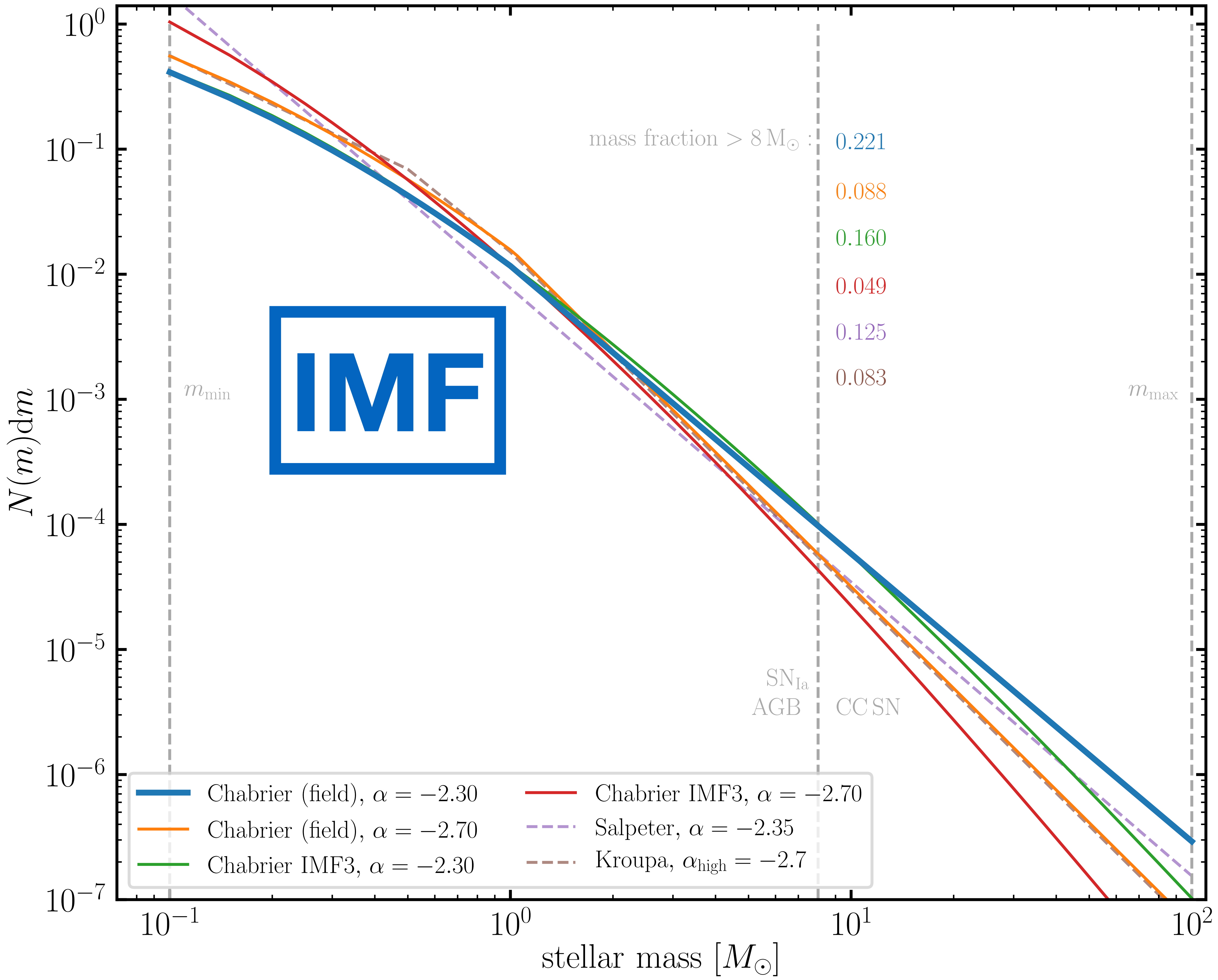


Star particles in cosmological simulations

Simple stellar population

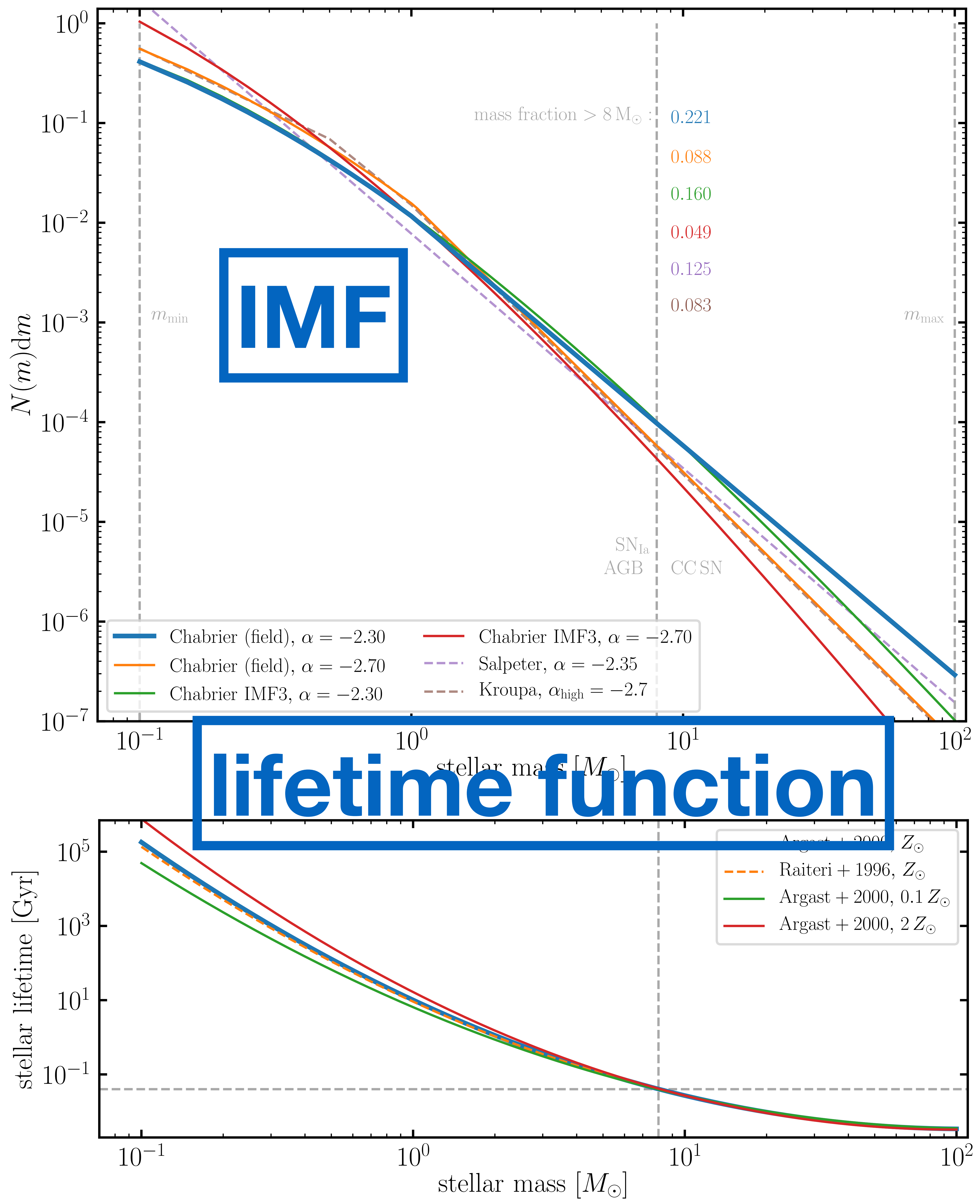
Simple stellar population

mass, metallicity, age



Simple stellar population

mass, metallicity, age



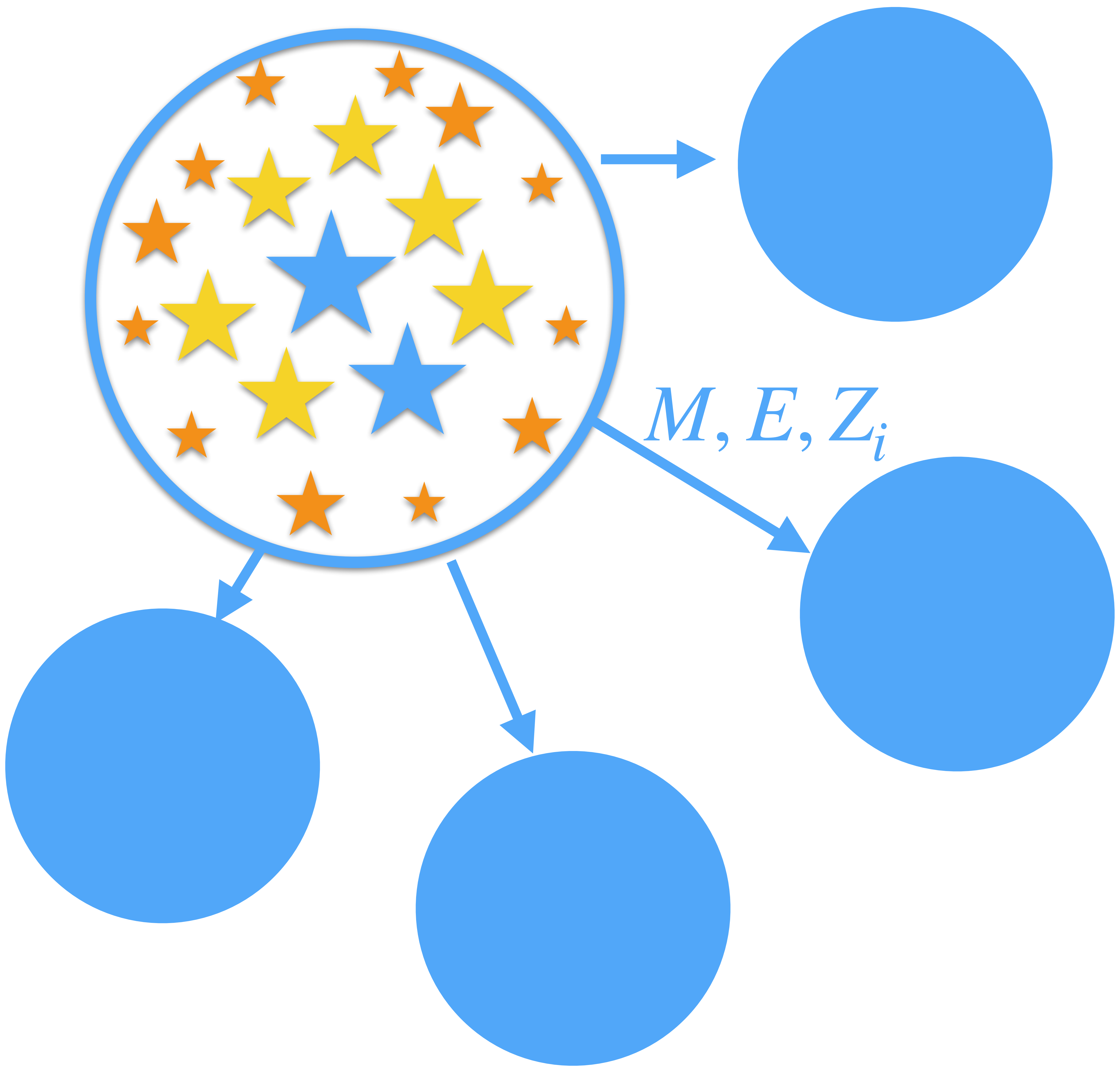
Simple stellar population model

assume stellar evolution models to calculate time evolution of the SSP
i.e. massloss and stellar remnant masses

massive stars dying
low mass stars dying

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 to be subm.

Importance of tracing a large set of elements

some yield tables allow to trace all 81 elements

Time release of newly produced elements

Buck to be subm.

Time release of newly produced elements

Buck to be subm.

Calculate time release of newly produced elements

Calculate time release of newly produced elements

synthesise look-up tables
using chempy (Rybizki+2017)

→ 8 parameters + 3 yield tables

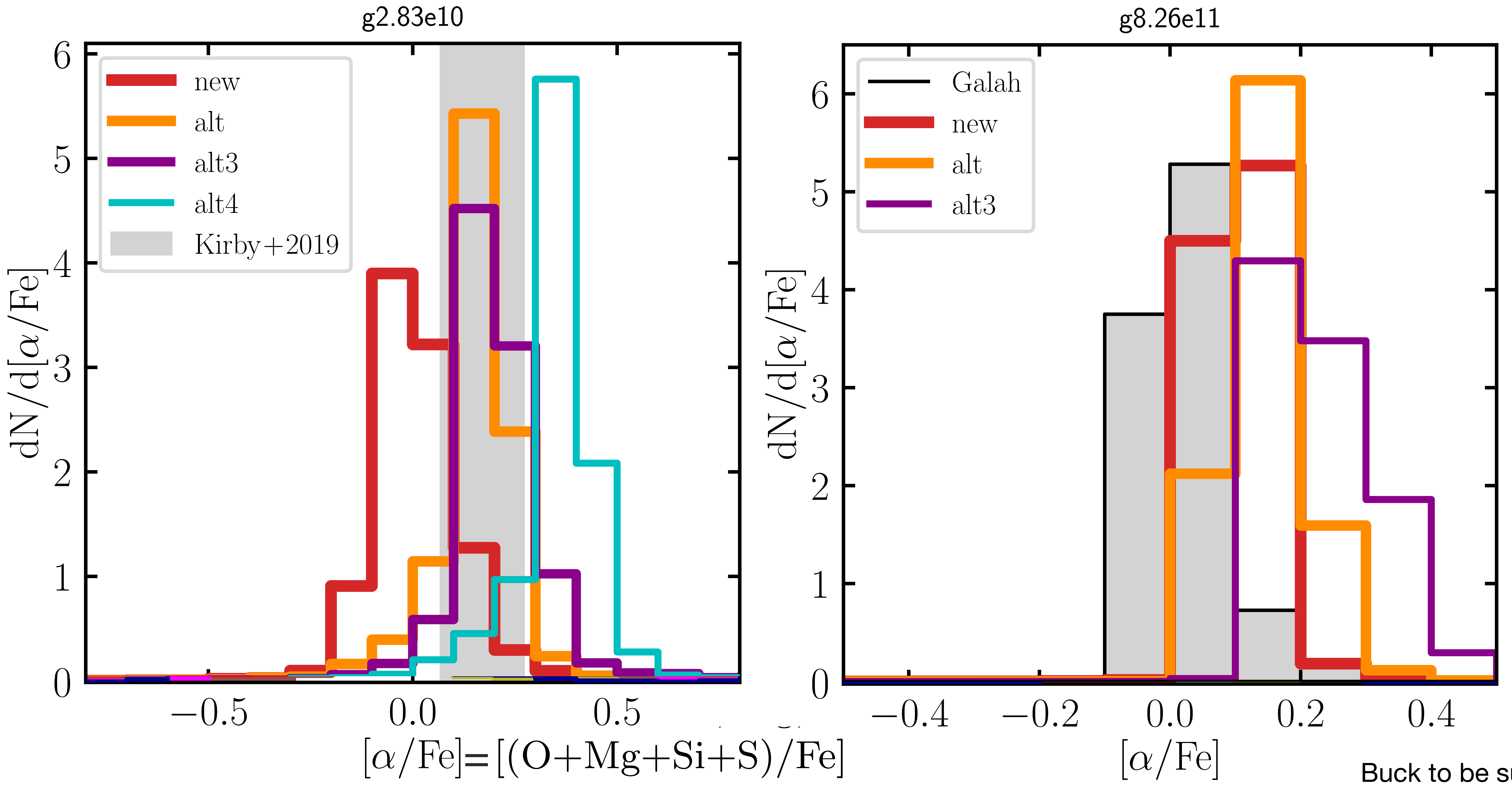
50 bins in Z (1e-5…0.05)
100 bins in log(t) (0…13.8 Gyr)

Table 1. Free stellar (SSP) evolution parameters, θ, used in `Chempy` together with the fiducial values adopted in this work.

θ	description	$\overline{\theta}_{\text{fiducial}}$
IMF type	functional form of IMF	
α_{IMF}	Chabrier high-mass slope	-2.3
	IMF mass range	$0.1-100\ \mathrm{M}_\odot$
	CC-SN mass range	$8-40\ \mathrm{M}_\odot$
	SNIa delay time exponent	1.12
$\log_{10}(\mathrm{N}_{\text{Ia}})$	normalization of SN Ia rate	-2.9
$\log_{10}(\tau_{\text{Ia}})$	SN Ia delay time in Gyr	-1.4
Z_{SSP}	metallicity of the SSP	$10^{-5}Z_\odot - 2Z_\odot$

Results: mass metallicity relation unchanged

Differences in element distribution functions



Buck to be subm.

Differences in [α/Fe] vs. [Fe/H]

Buck to be subm.

A flexibel chemical enrichment implementation* for cosmological simulations

great potential for chemo-dynamics of the MW

CGM absorption studies

*I am happy to share the code with the community, drop me a mail or talk to me during the discussions

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