Lyra

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Dwarf galaxies on small scales in a cosmological context

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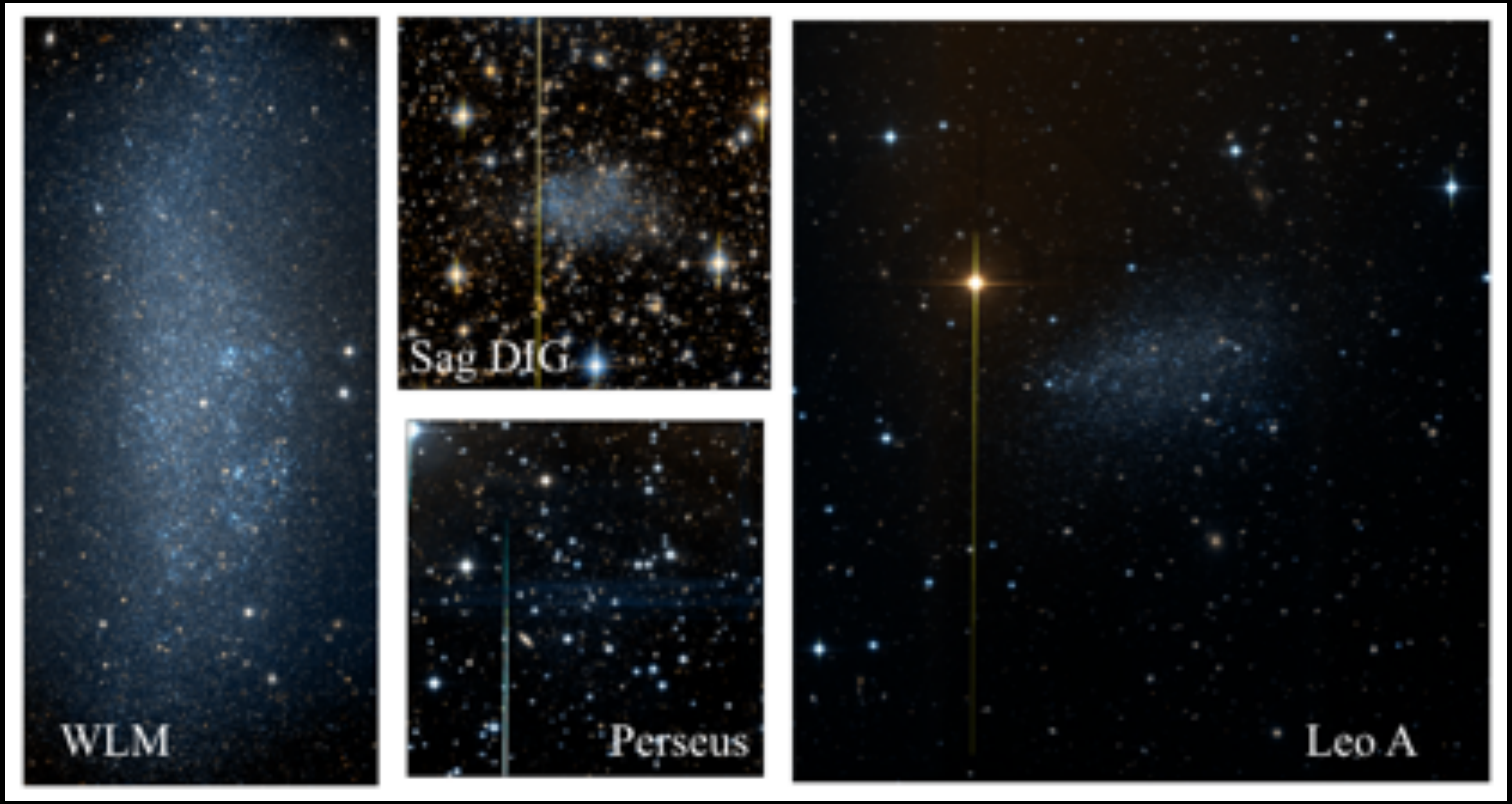
Collaborators: Volker Springel, Thorsten Naab, Rüdiger Pakmor

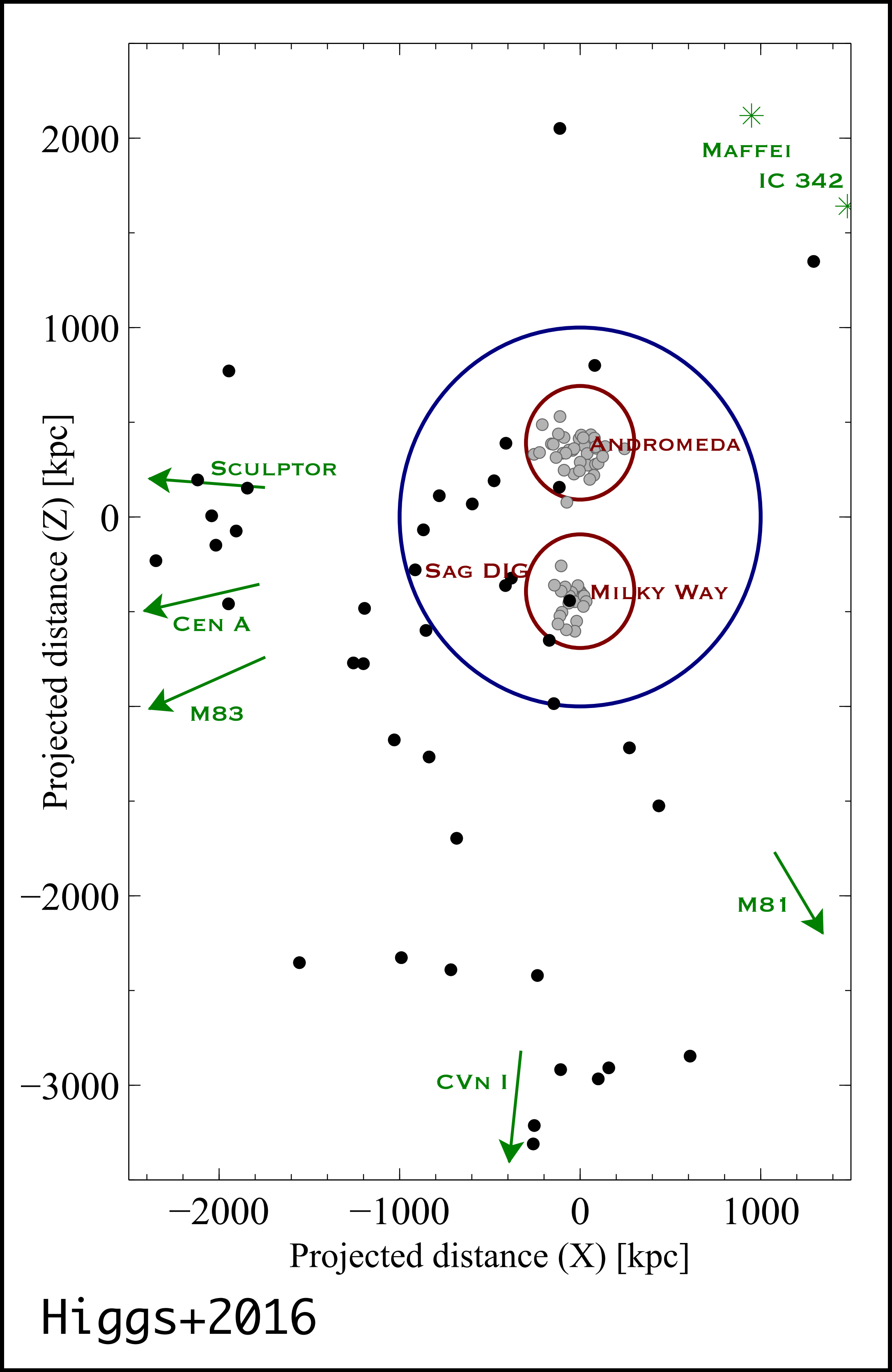


Some Local Group dwarf galaxies

Higgs+2021

- First galaxies to form in the Universe
- Building blocks of all more massive galaxies
- Sensitive to small potential perturbations
- Extreme systems in terms of age, metallicity, size, luminosity, kinematics
- Become satellites to i.e. the Milky Way

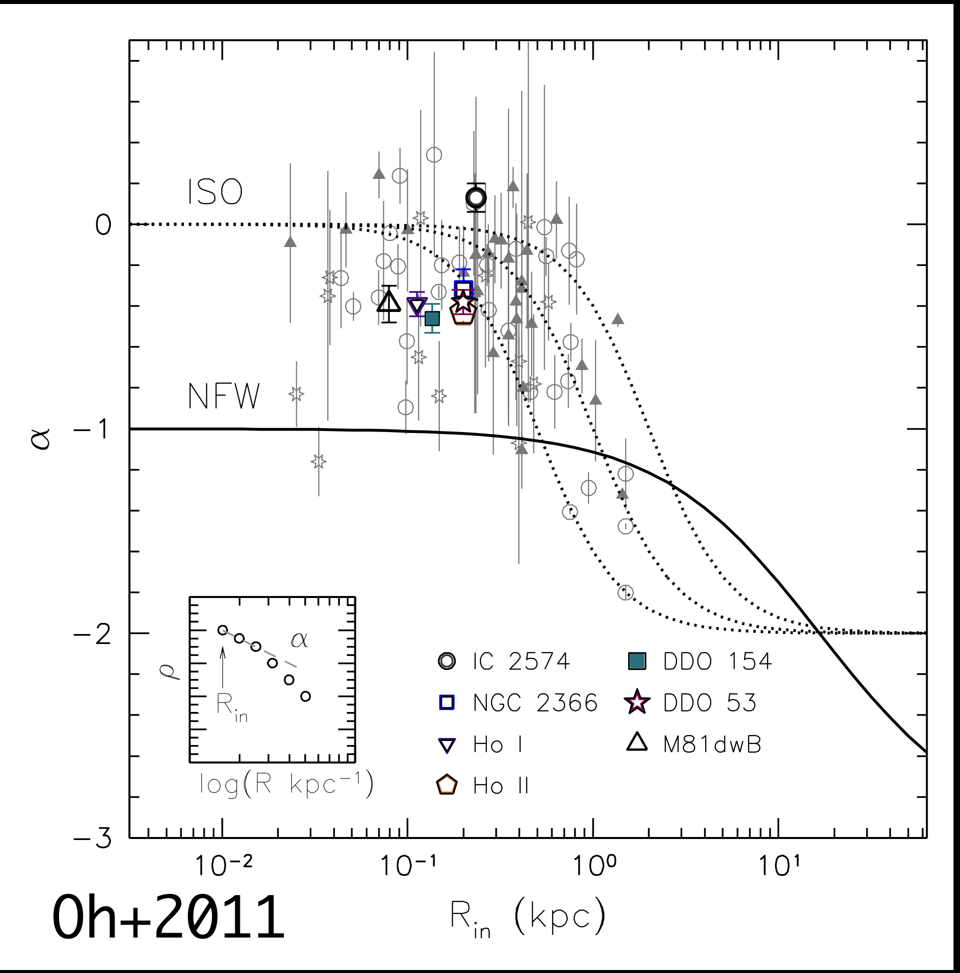
Most known dwarf galaxies



How do they evolve?

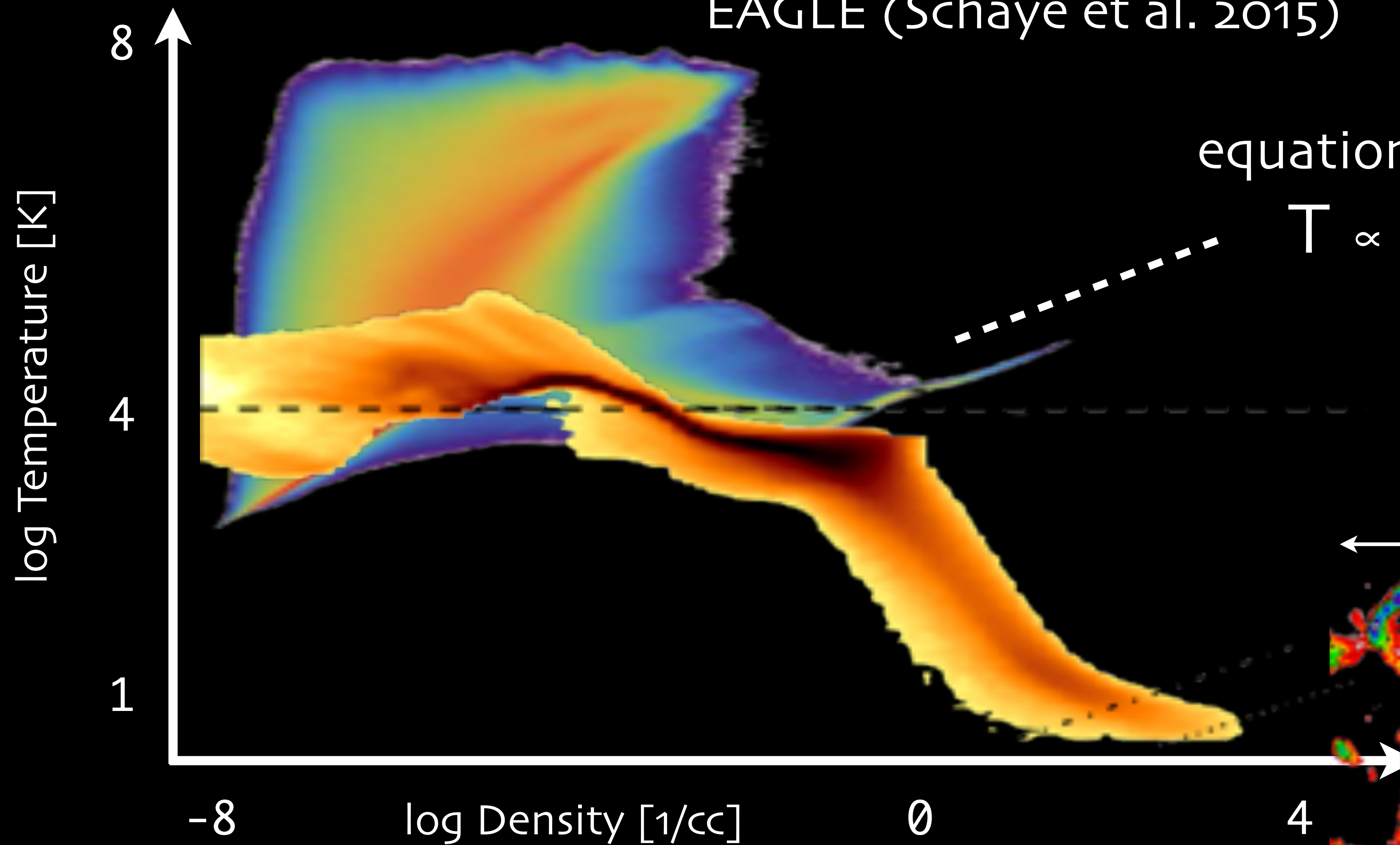
What can we learn about cosmology and galaxy formation from them?

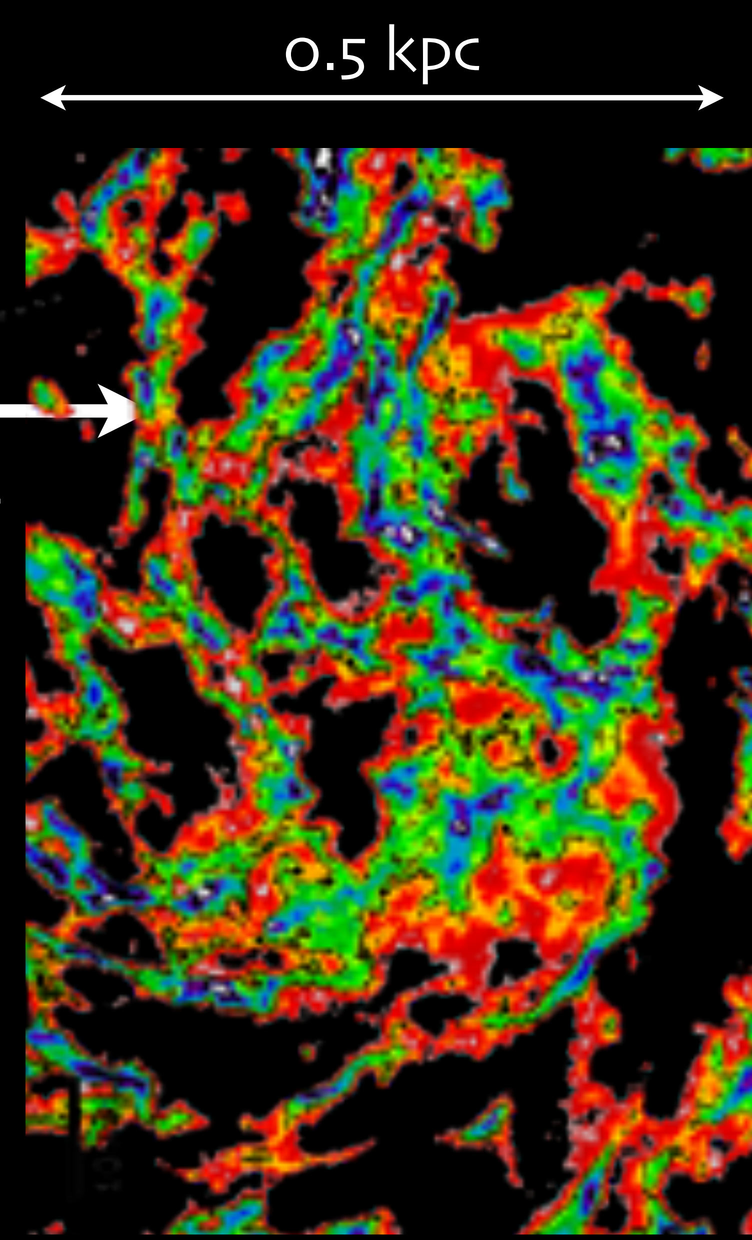
Flat dark matter profiles



Cosmological
simulations?

EAGLE (Schaye et al. 2015)



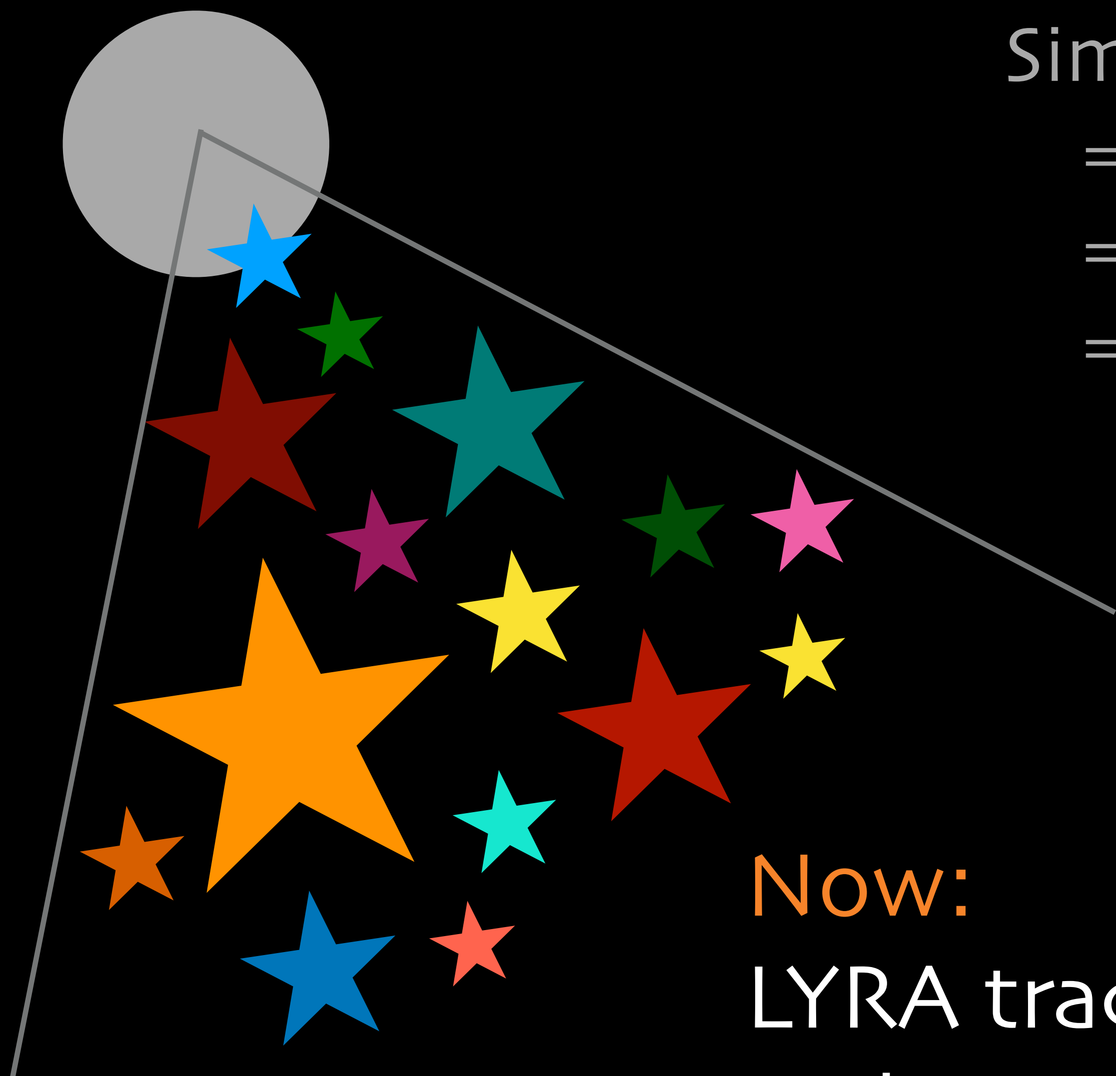


Replace the EoS for dense gas

Start seeing GMCs

SSP particles become stars

M ~ 10^3-10^5 M_{sun}



Previously:

Simulation

= Single

= Integra

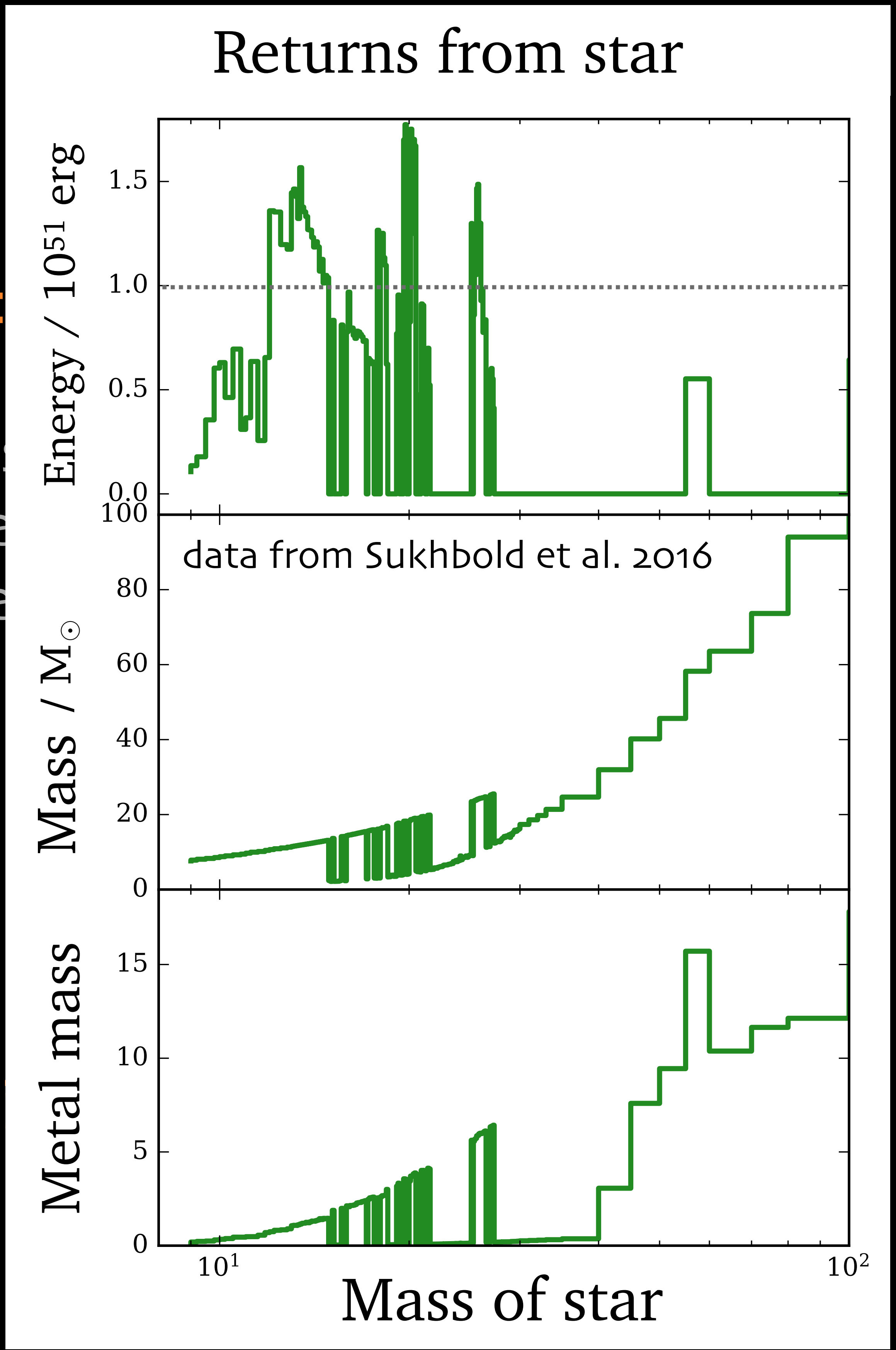
= Feedba

Now:

LYRA tracks ind

and temporally

deposition



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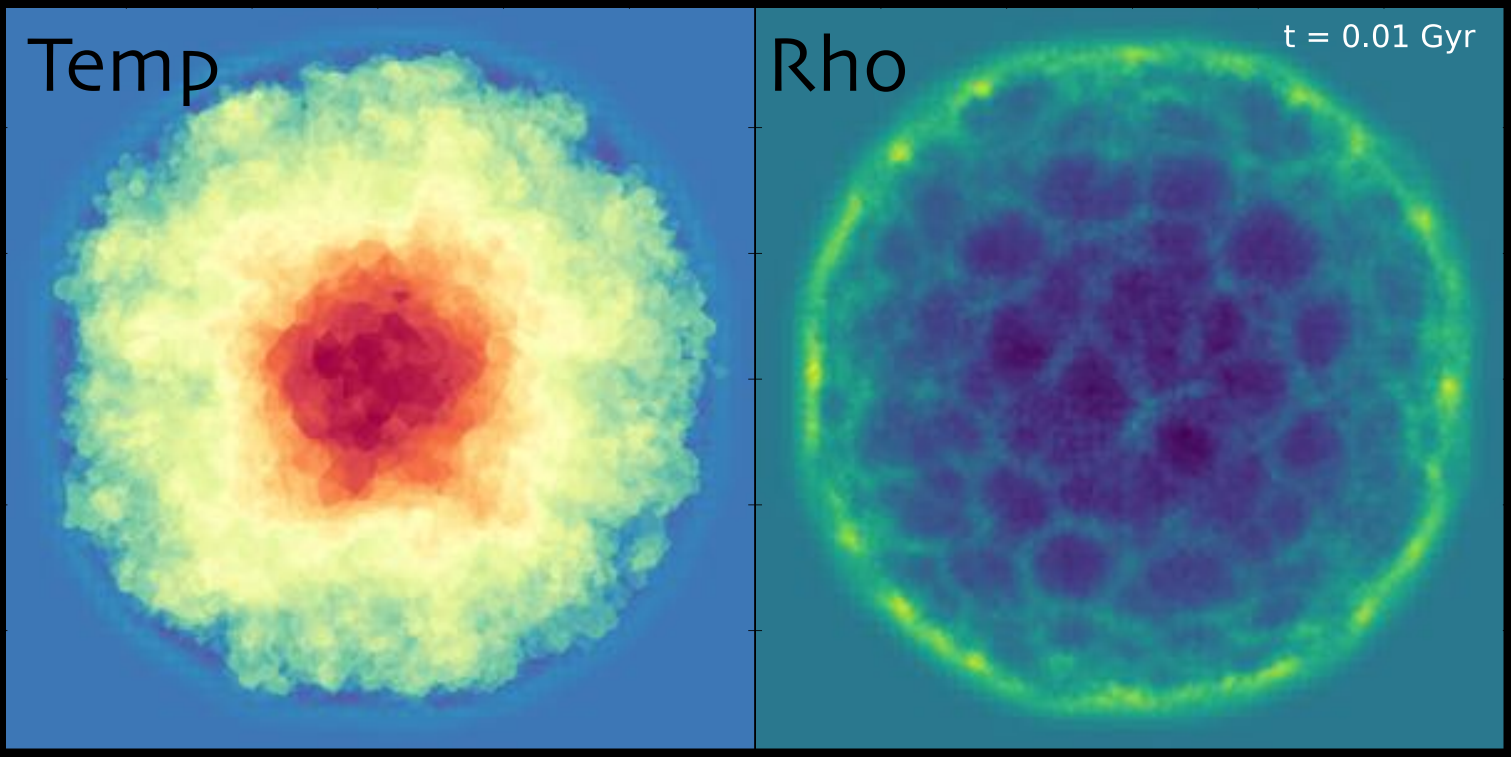
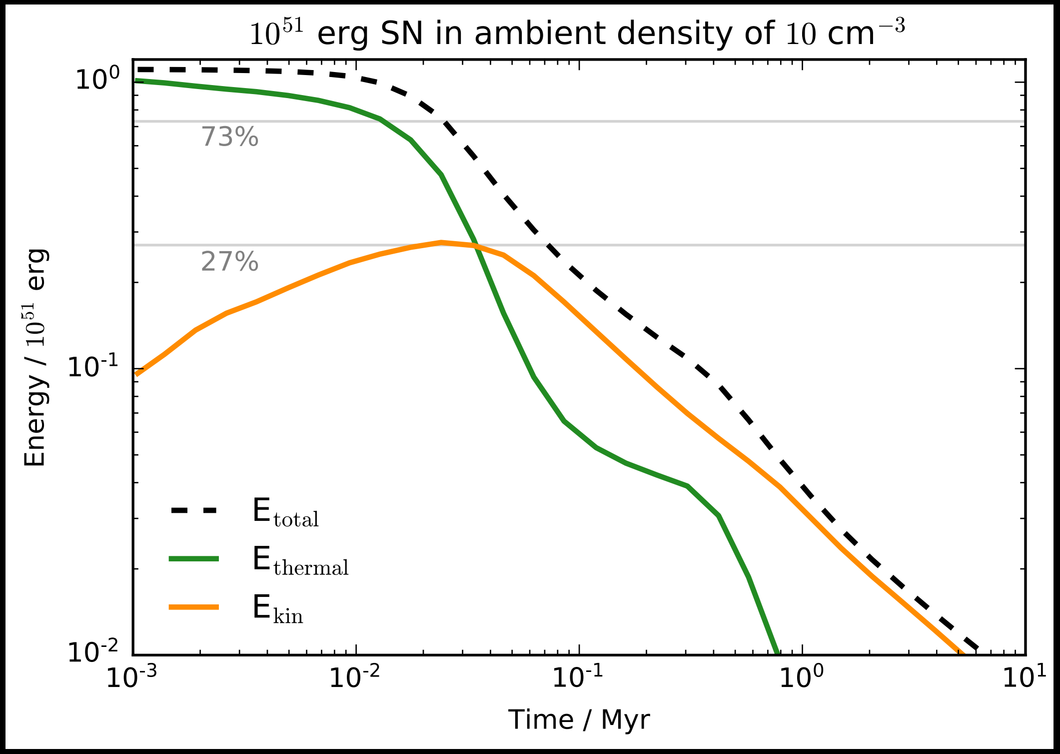
Single SN

Avoid overcooling by resolving the SNe

$M_{gas} \sim 4M_{sun}$





27% of thermal energy is transformed to kinetic (Sedov solution)

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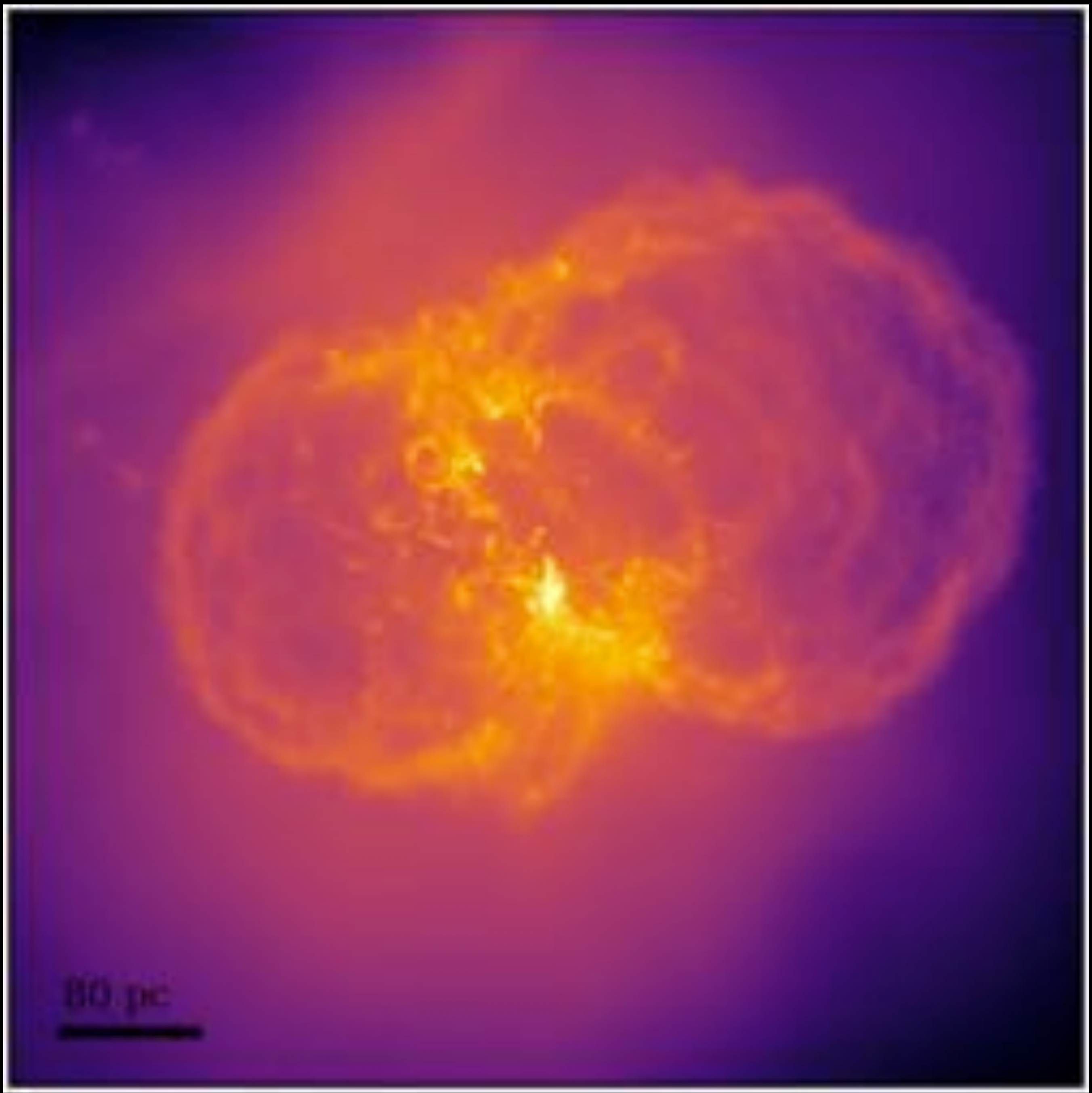
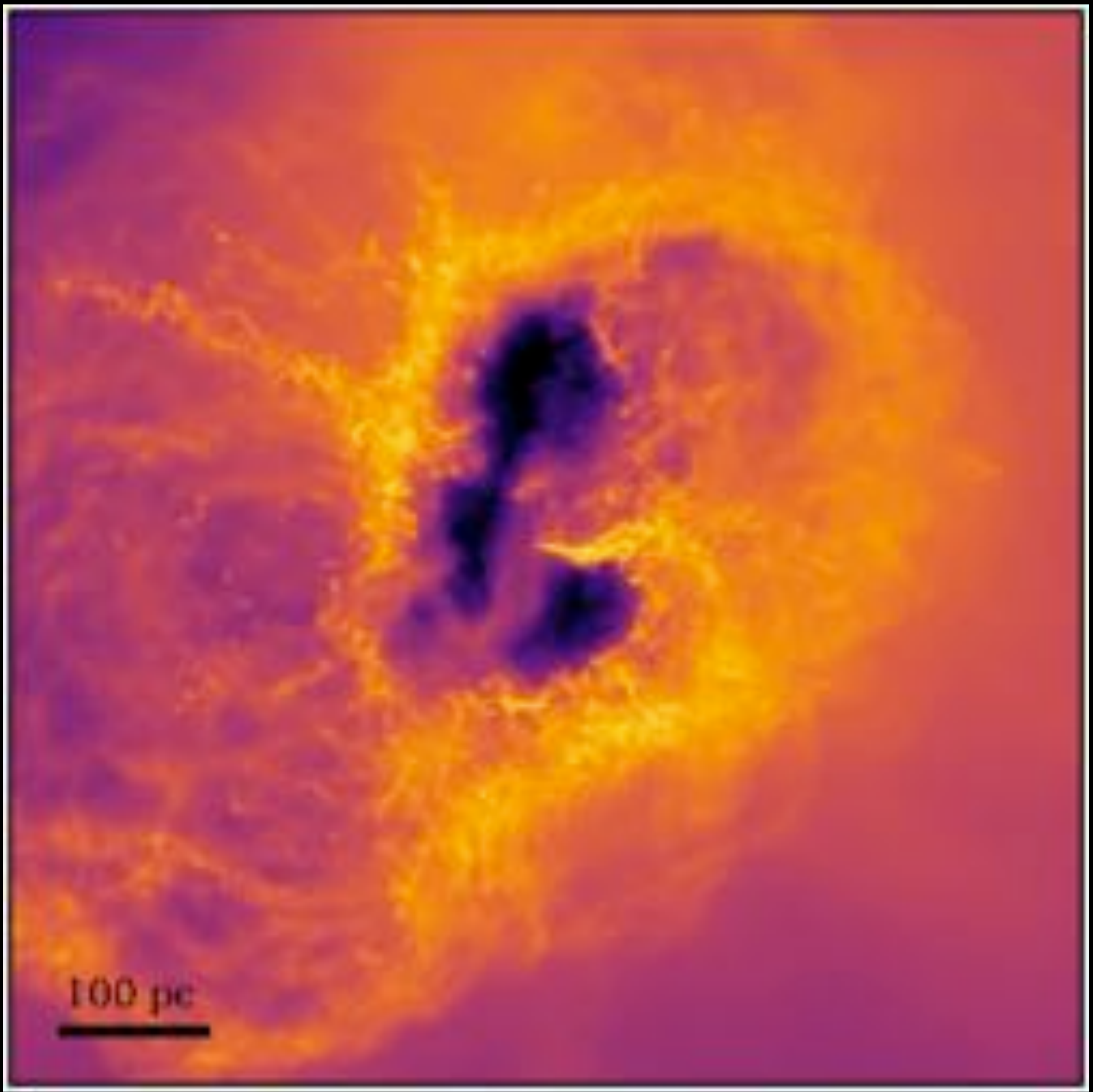
Superbubbles at high z

z~8

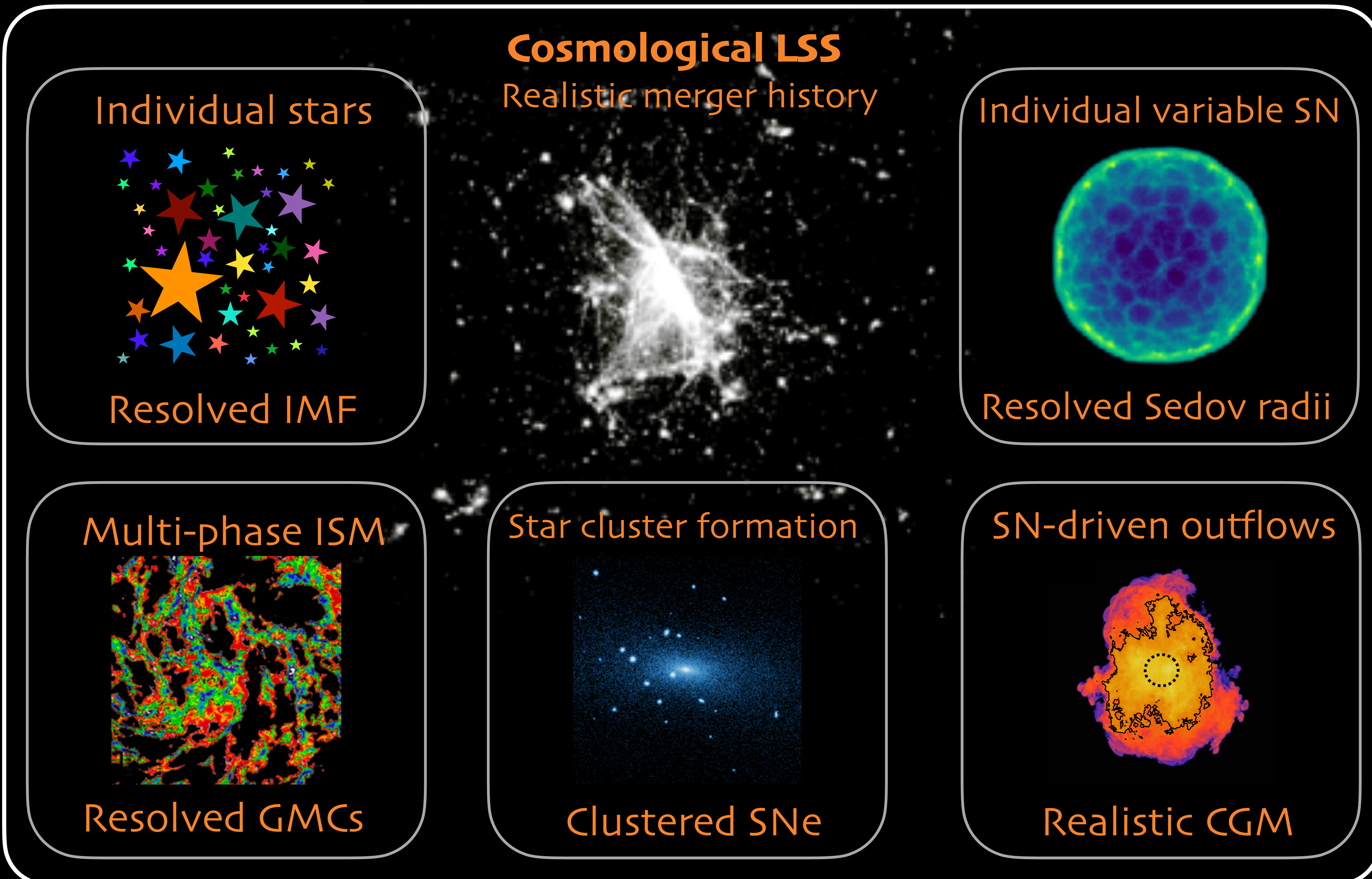


z~4



Beautiful ISM structure in response to clustered SN

the Lyra model



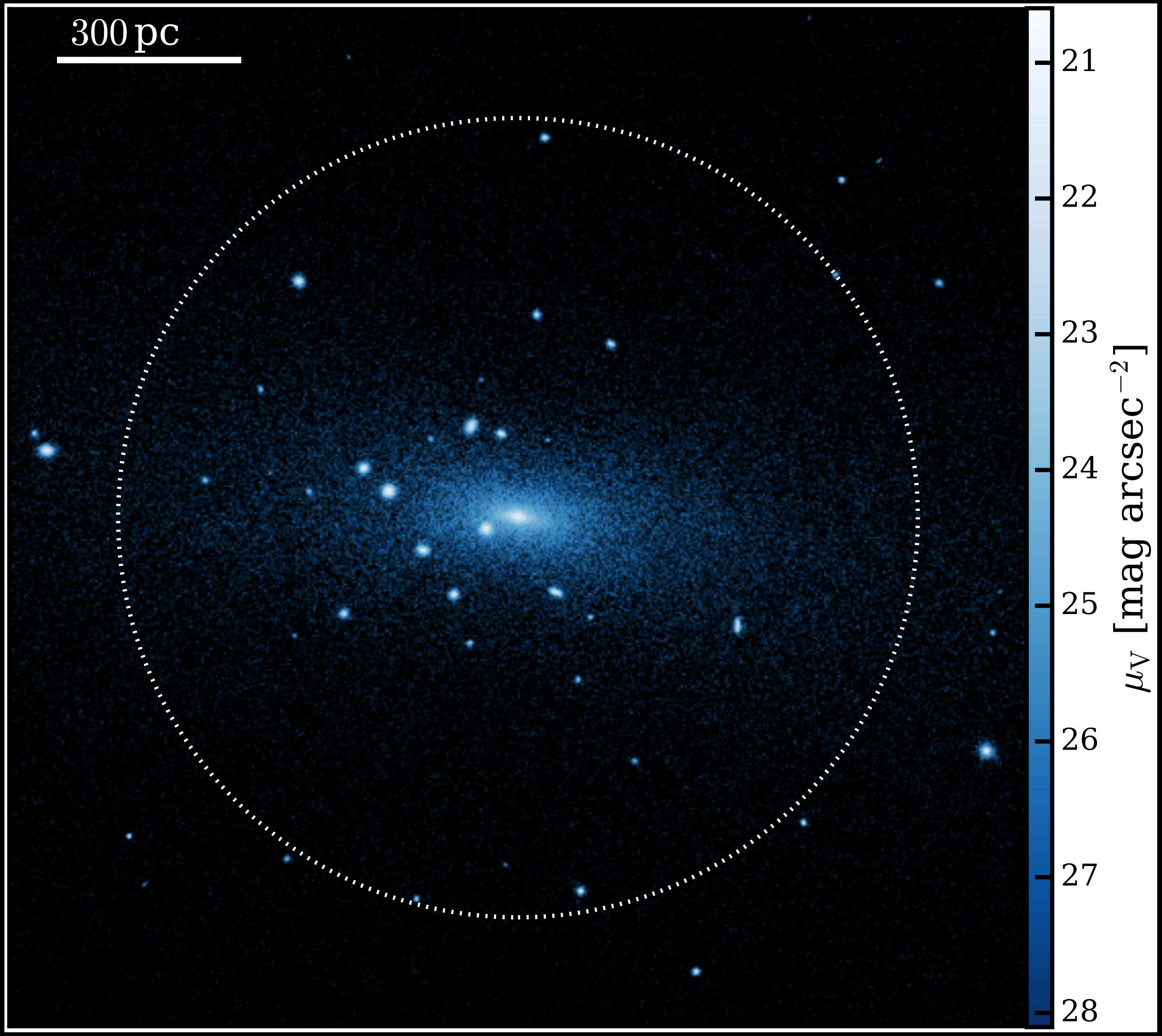
Suite of Lyra dwarfs

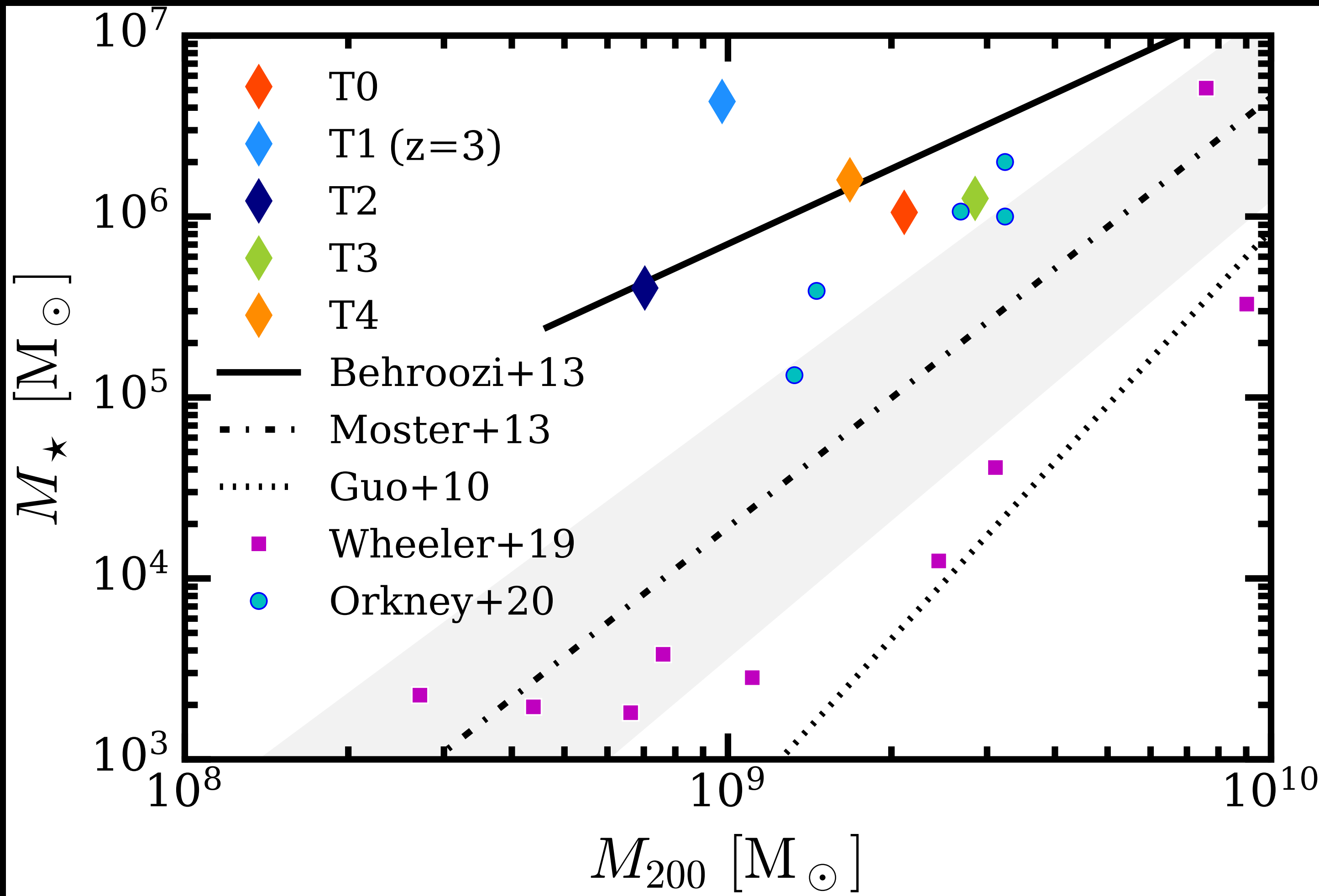
~10^9 M_{sun} halo mass

10^{6-7} M_{sun} stellar mass

Resolution:
4 M_{sun}
AREPO gas cells

Generally **great** agreement with observations!



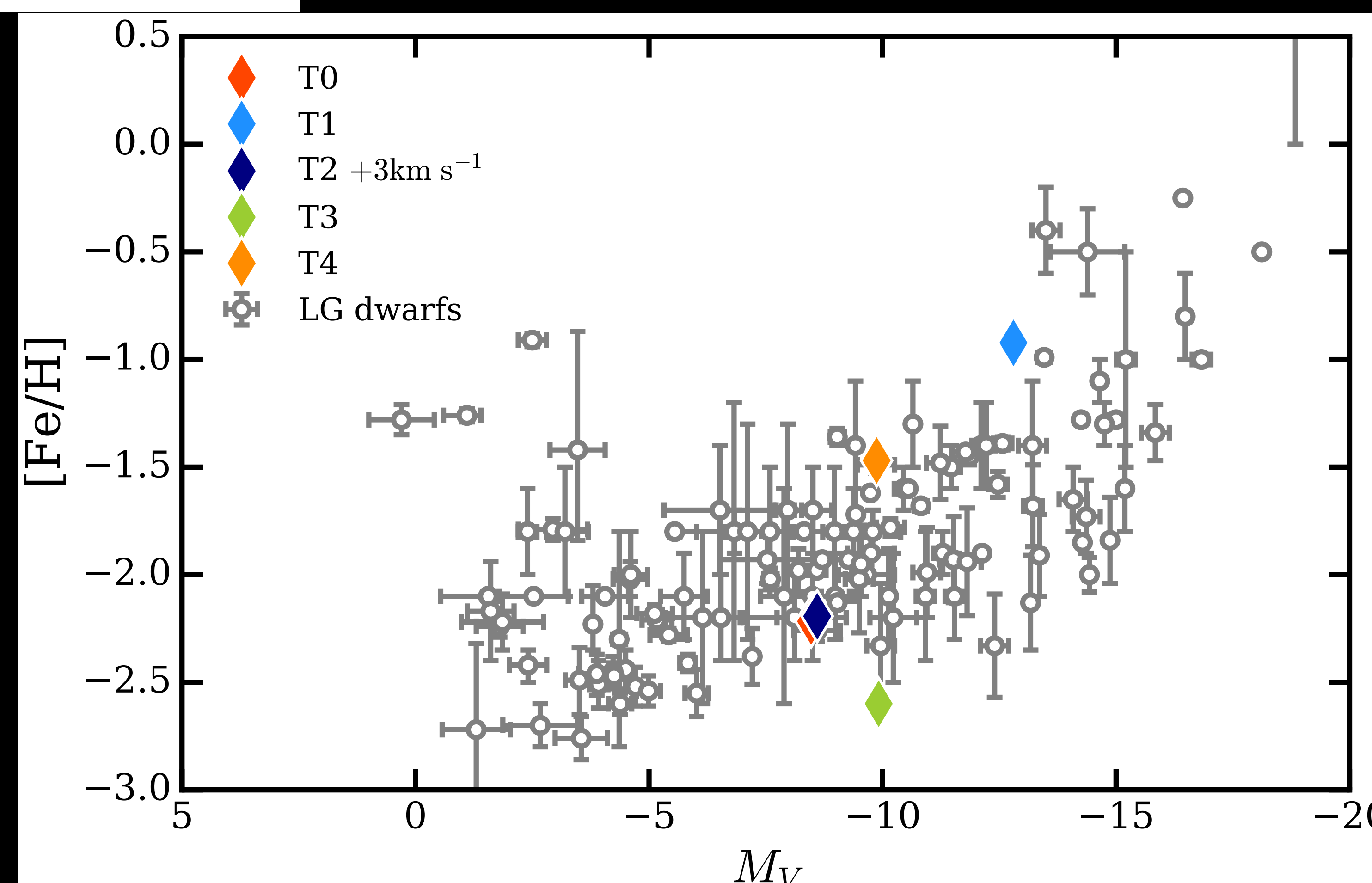


Stellar - halo mass

Photoionization will affect this!

Magnitude - metallicity

Generally difficult to match!



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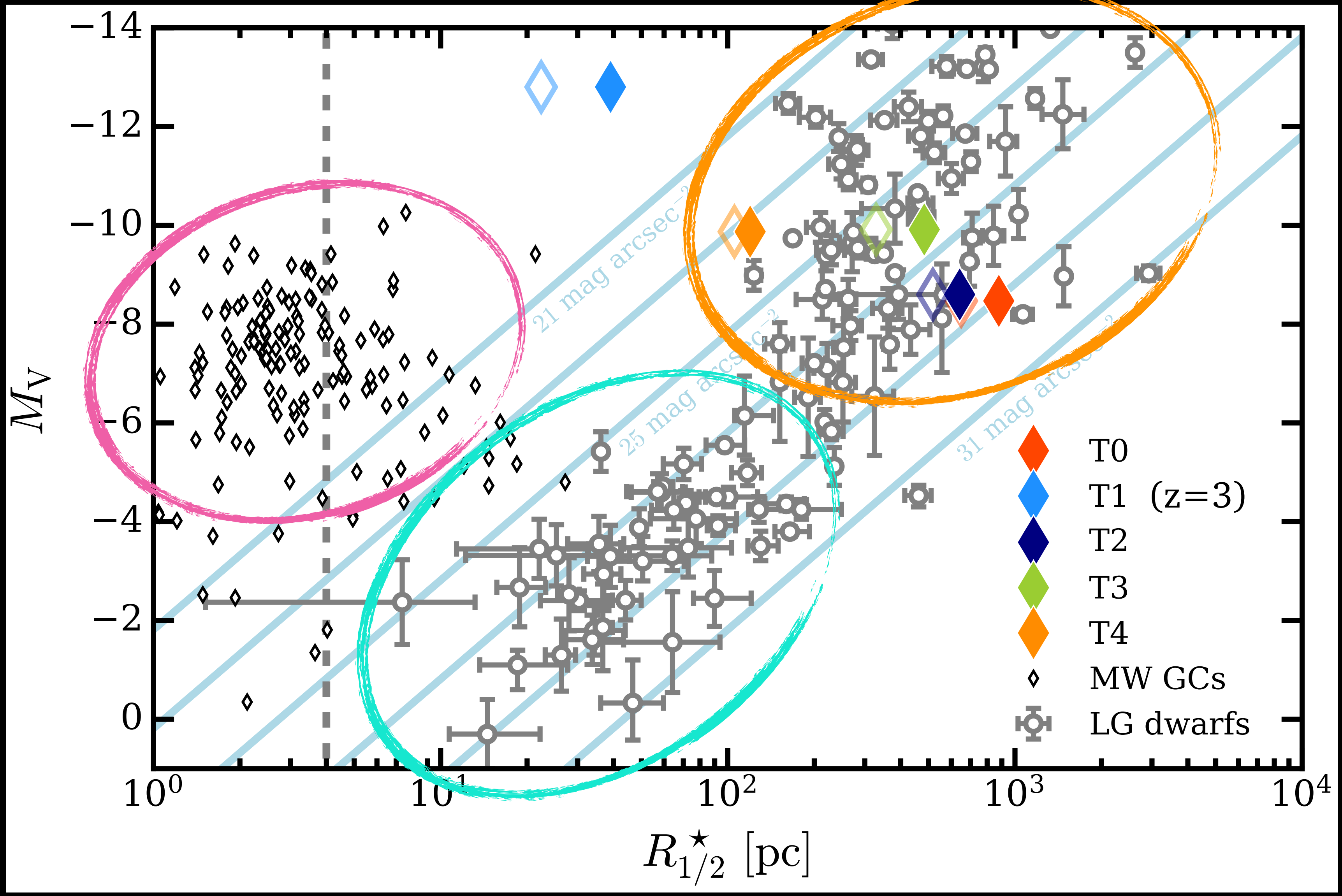
Stellar size - magnitude

Photometric modeling reveals
size and magnitude
in line with
classical MW dwarfs

MW globular clusters

classical dwarfs



ultra-faint dwarfs

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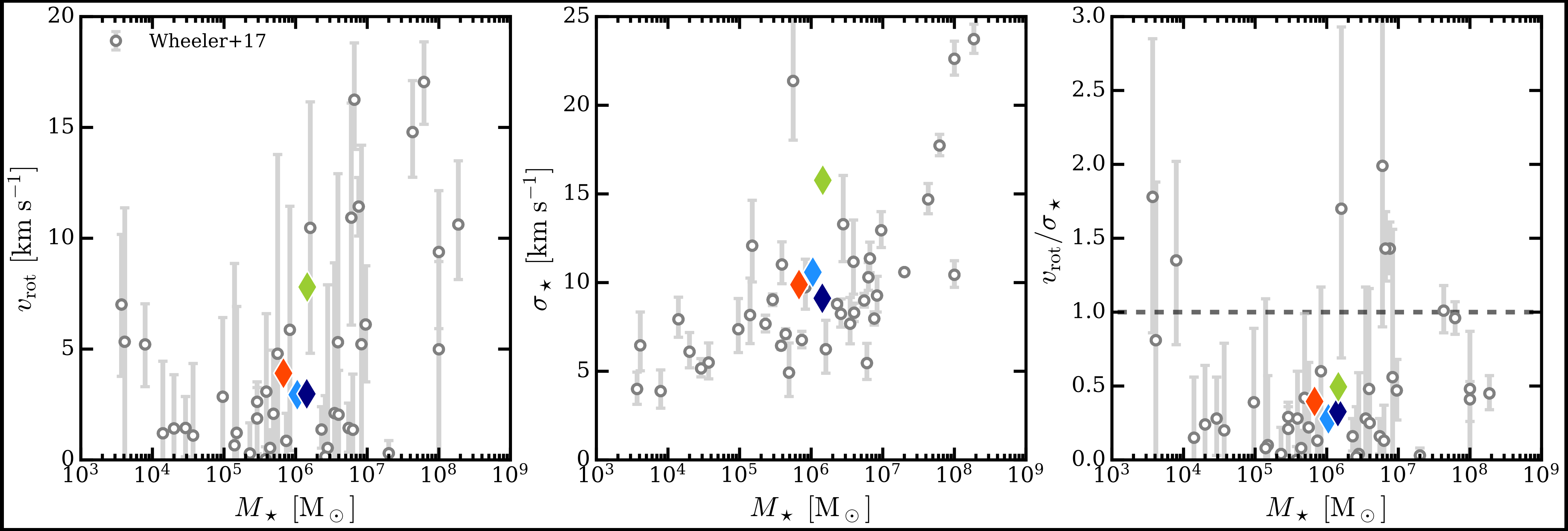
Stellar kinematics

Rotation

Dispersion



Dispersion dominated

Properties are in line with dSph morphology

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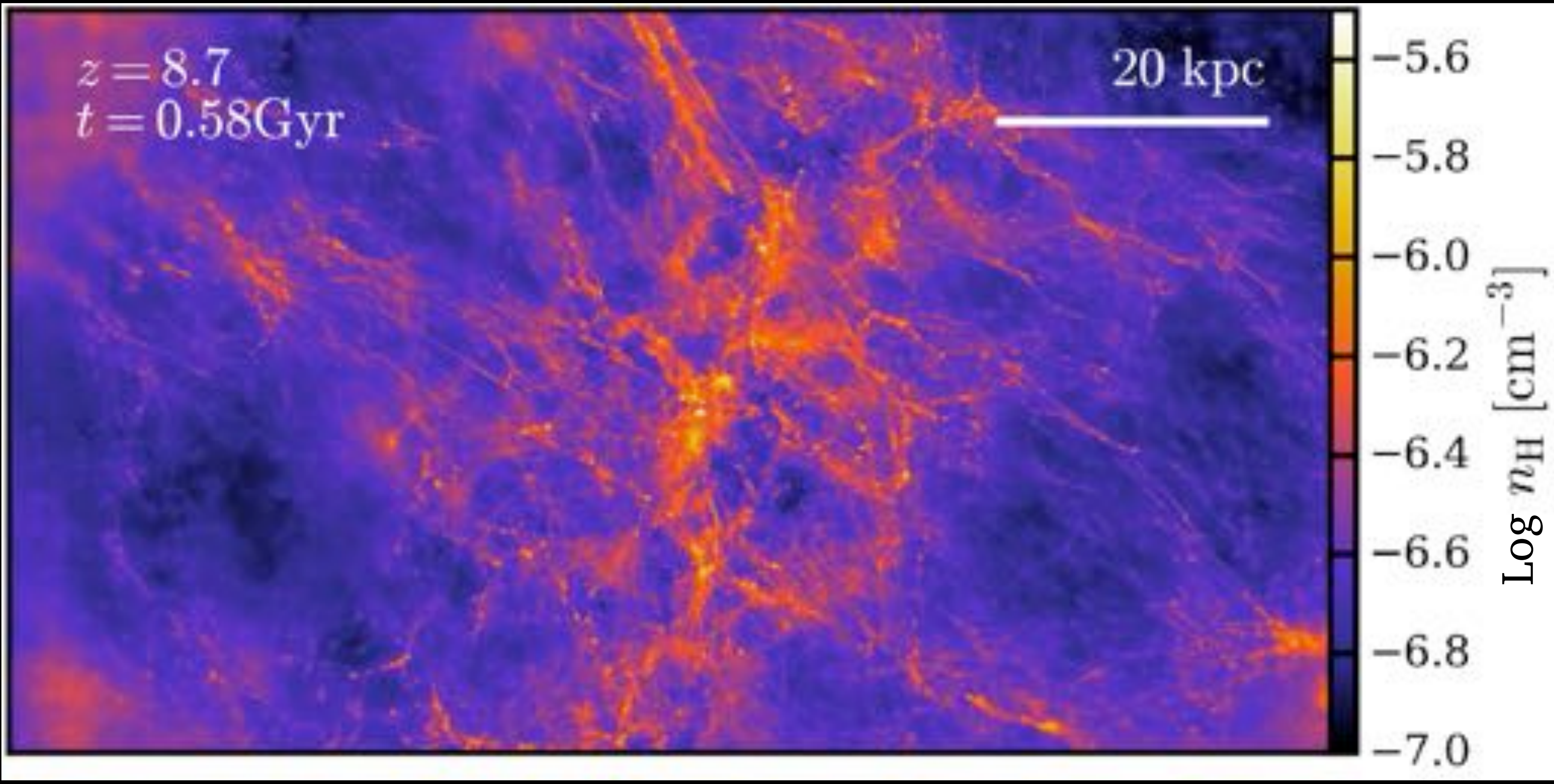
What happened at high redshift?

Gas density



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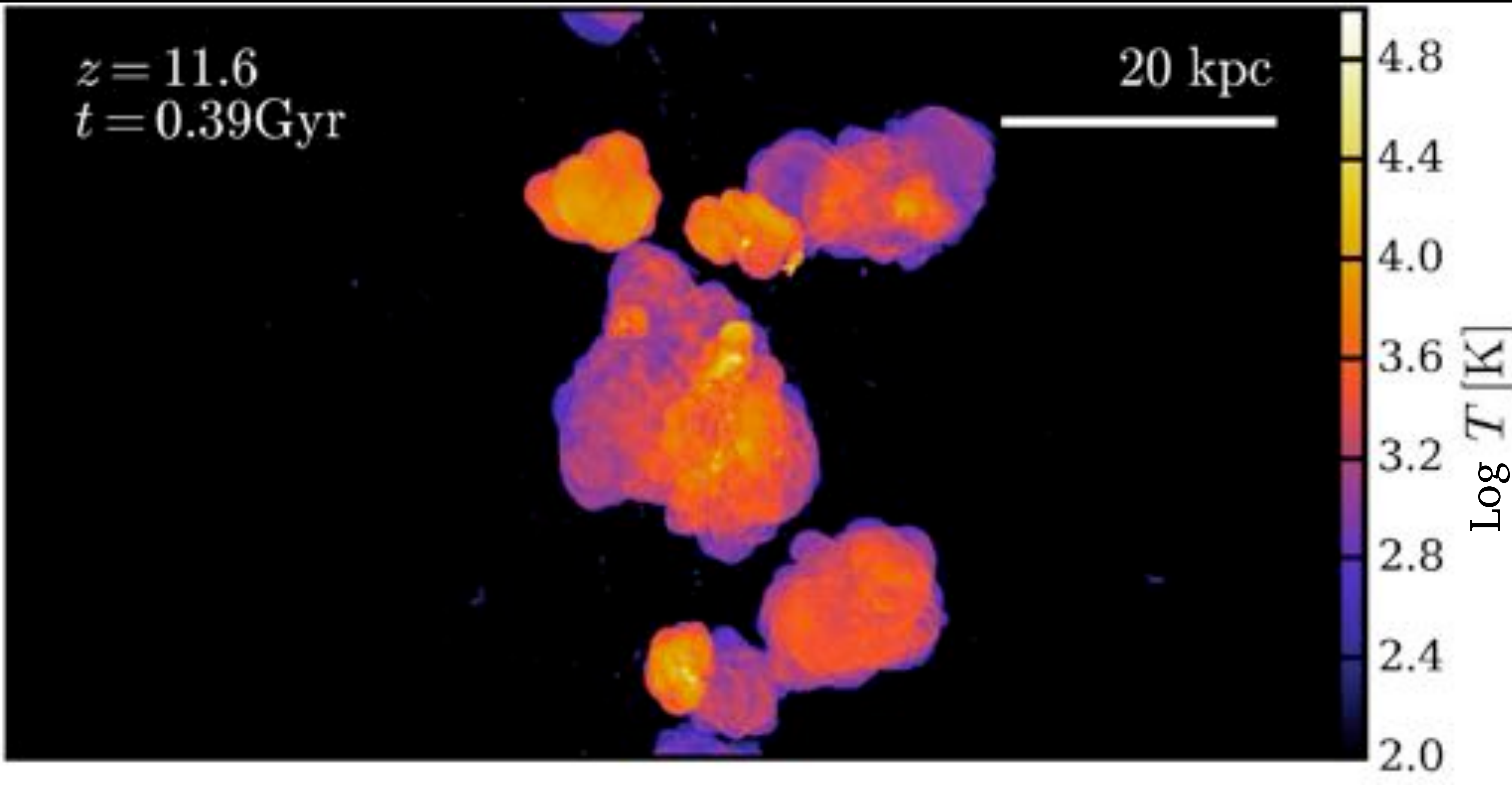
Gas temperature



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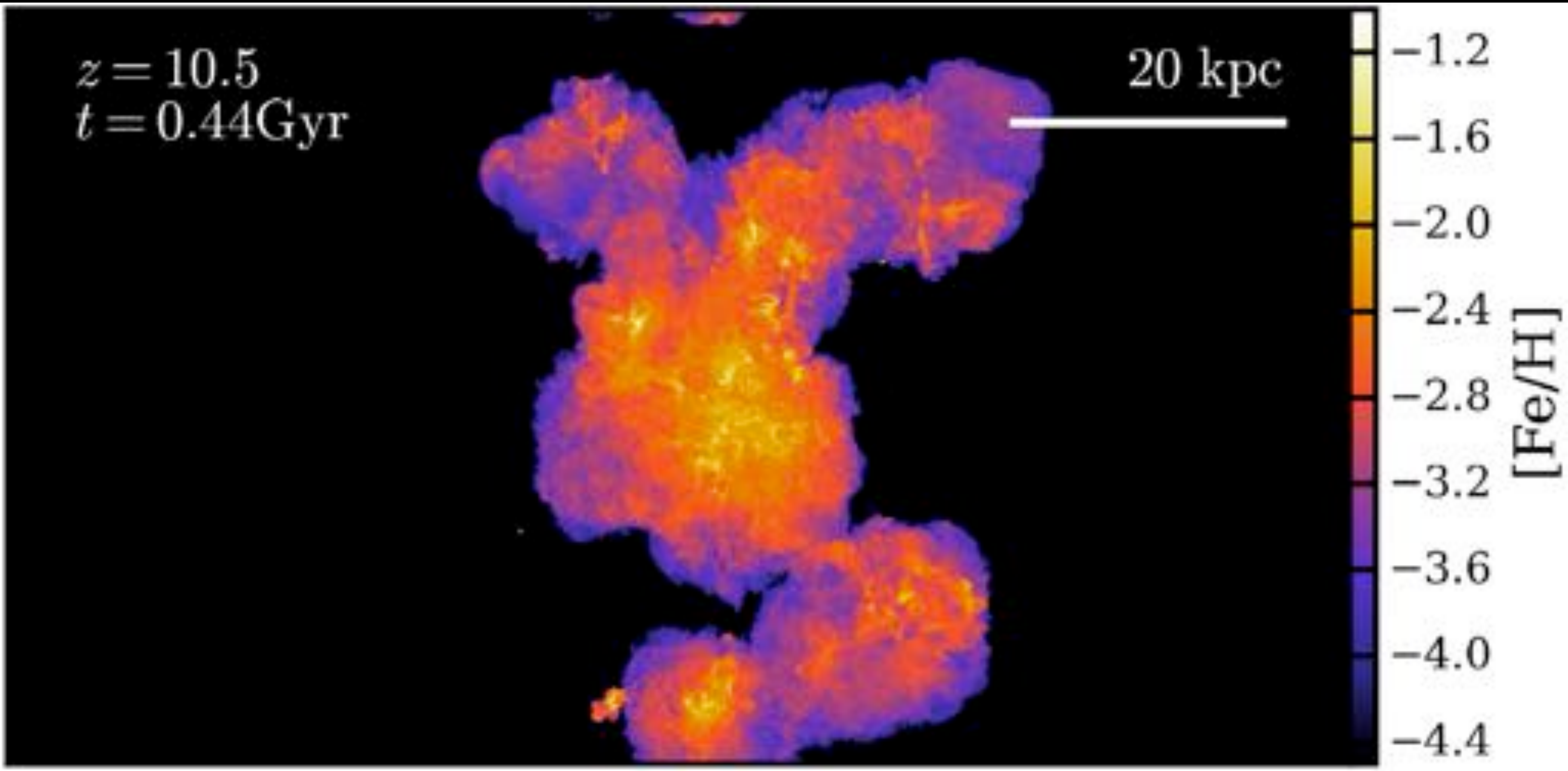
Gas metallicity



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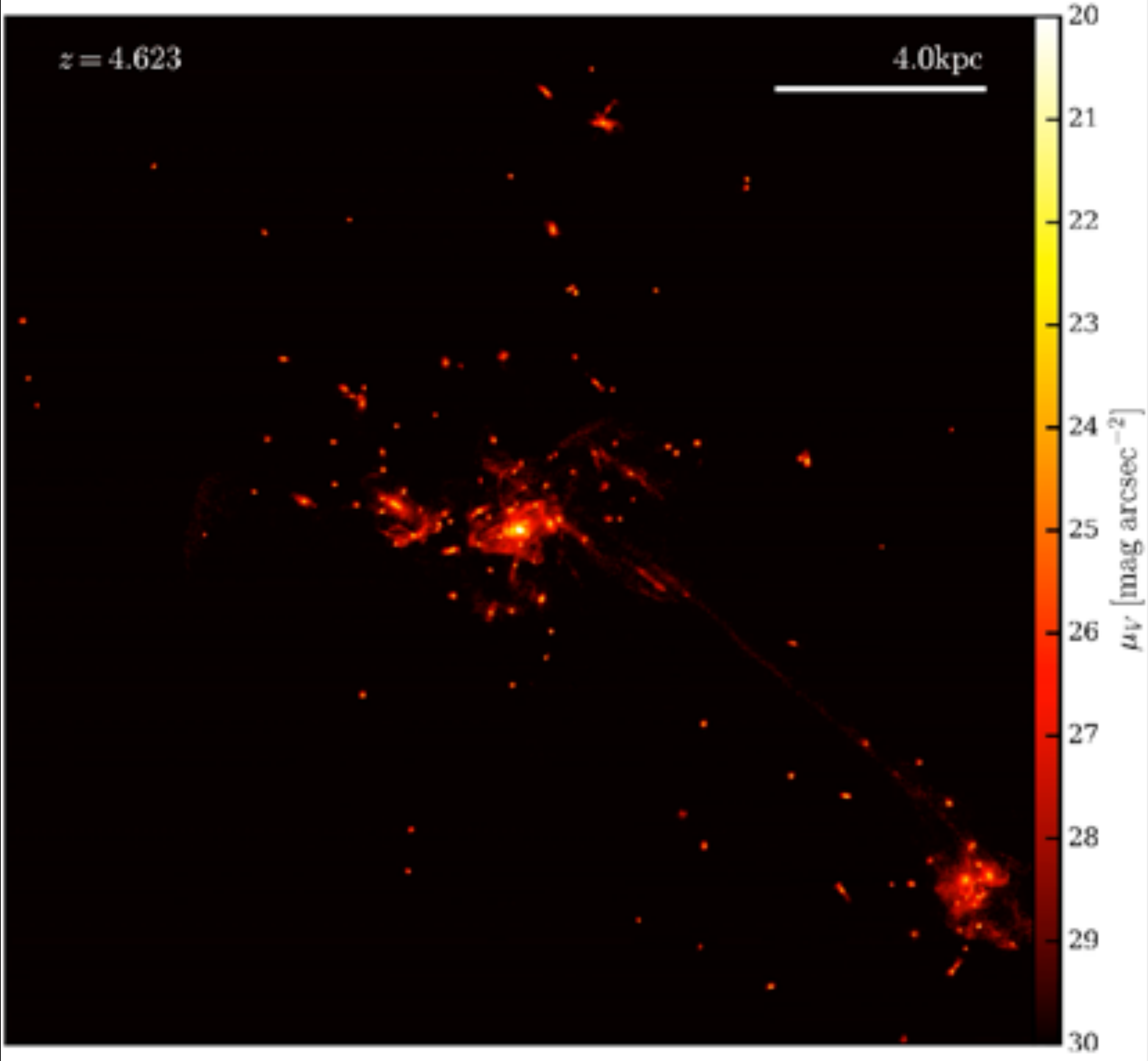
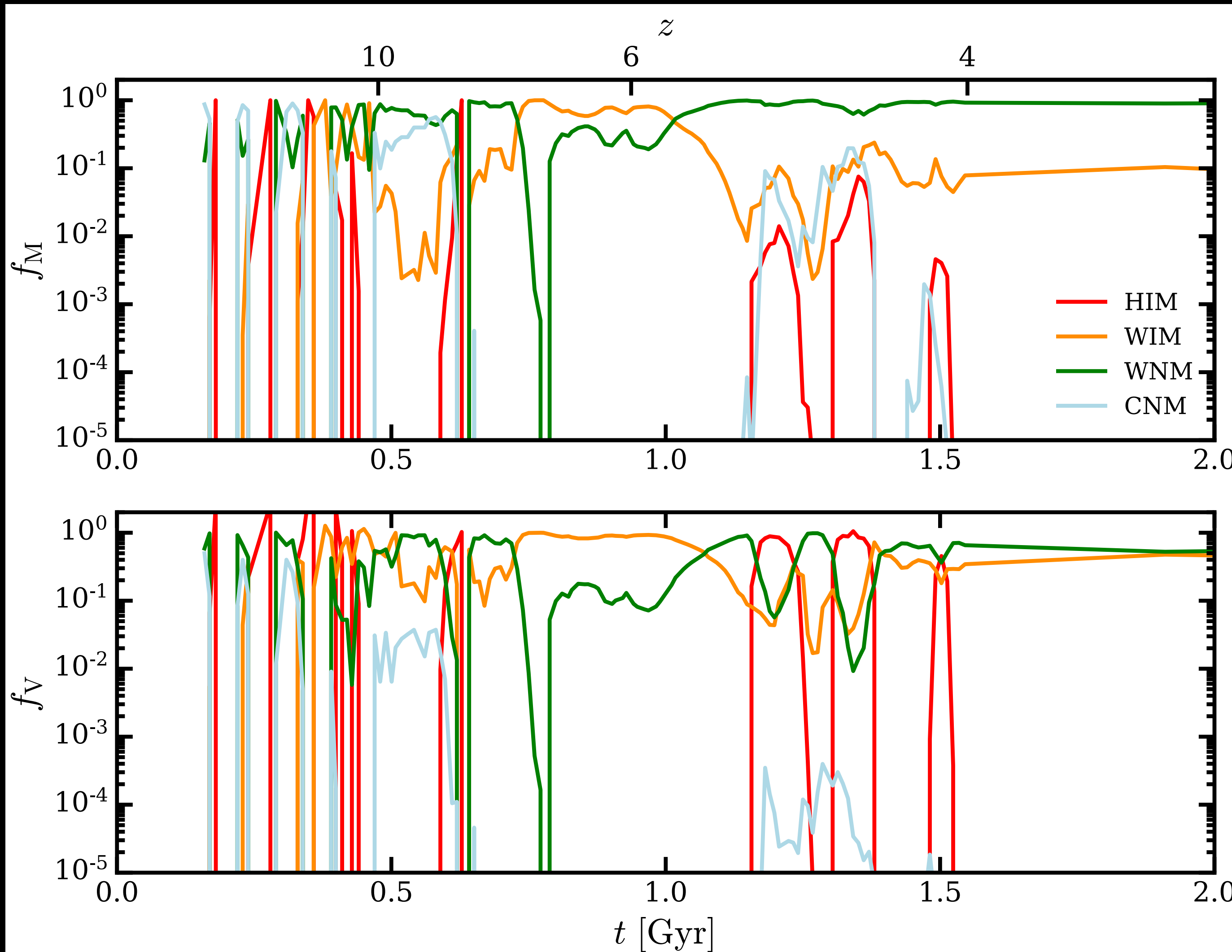
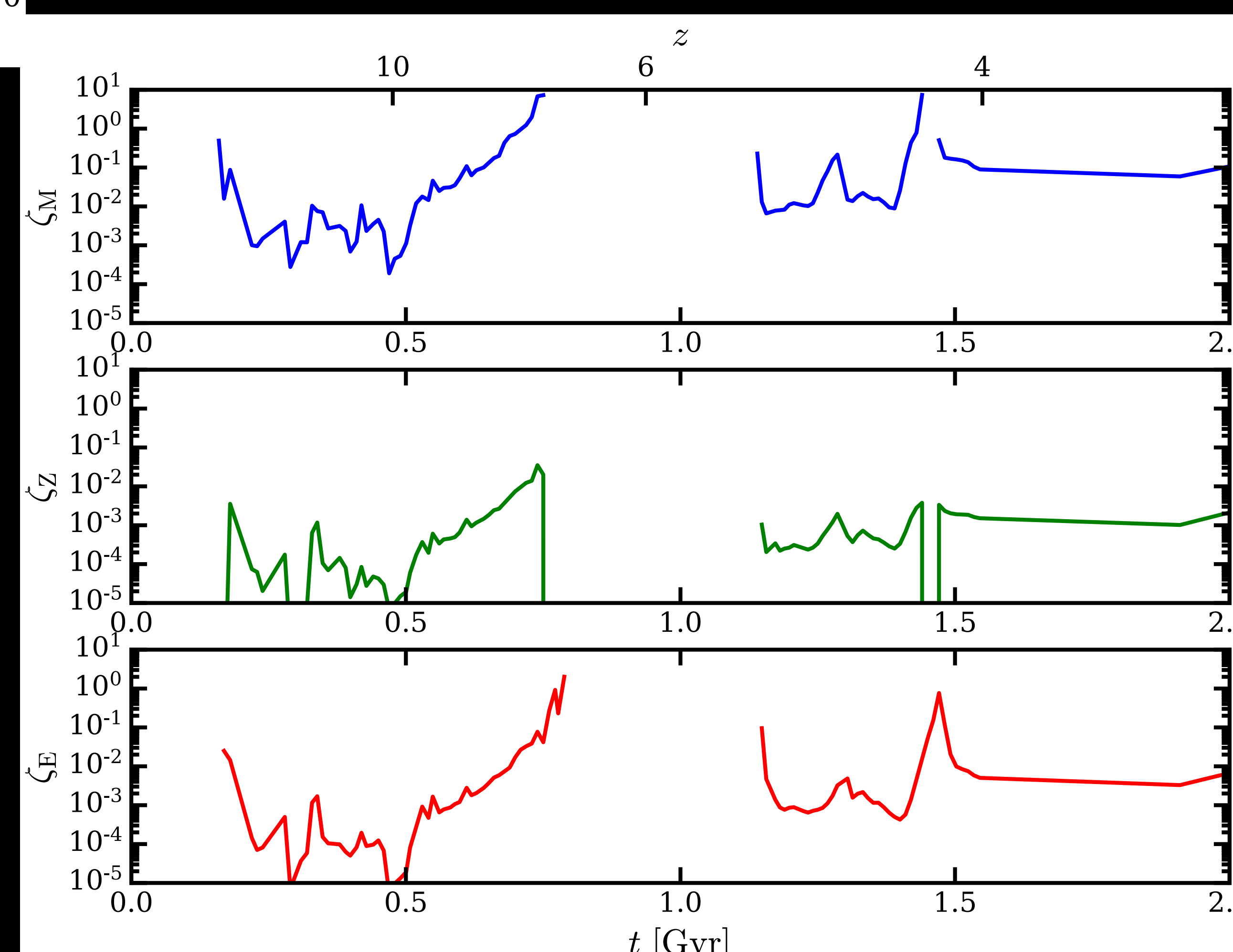


$z = 4.623$
4.0kpc
20
21
22
23
24
25
26
27
28
29
30
μ_V [mag arcsec^{-2}]



Phases of the ISM within 0.1 R_{vir}

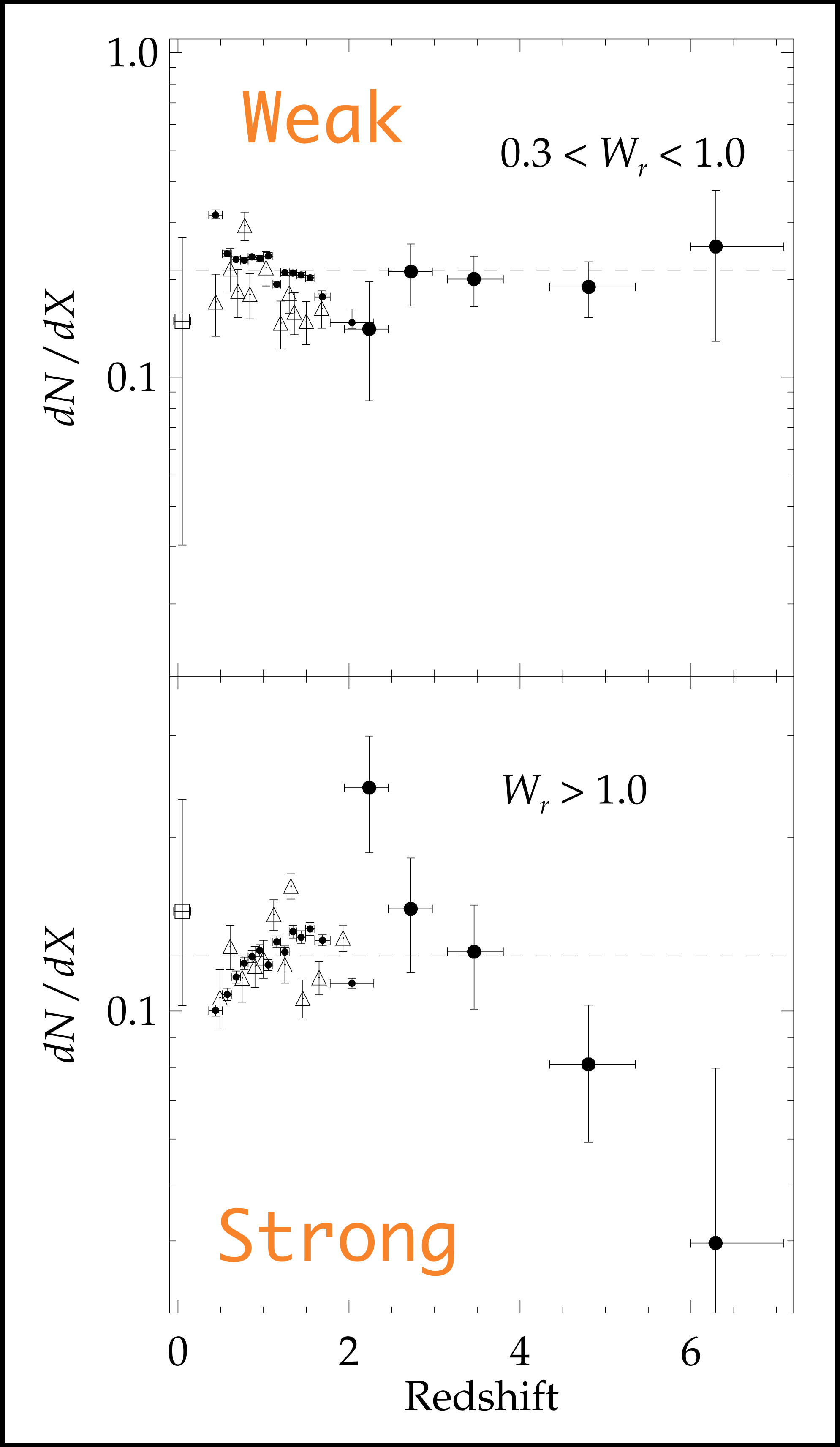


Loading factors measured across R_{vir} surface

Prediction #1
IGM pollution

Weak MgII absorption stays constant out to z~7

Are dwarf galaxies responsible for the weak absorption at high-z in the IGM?



Chen+2017

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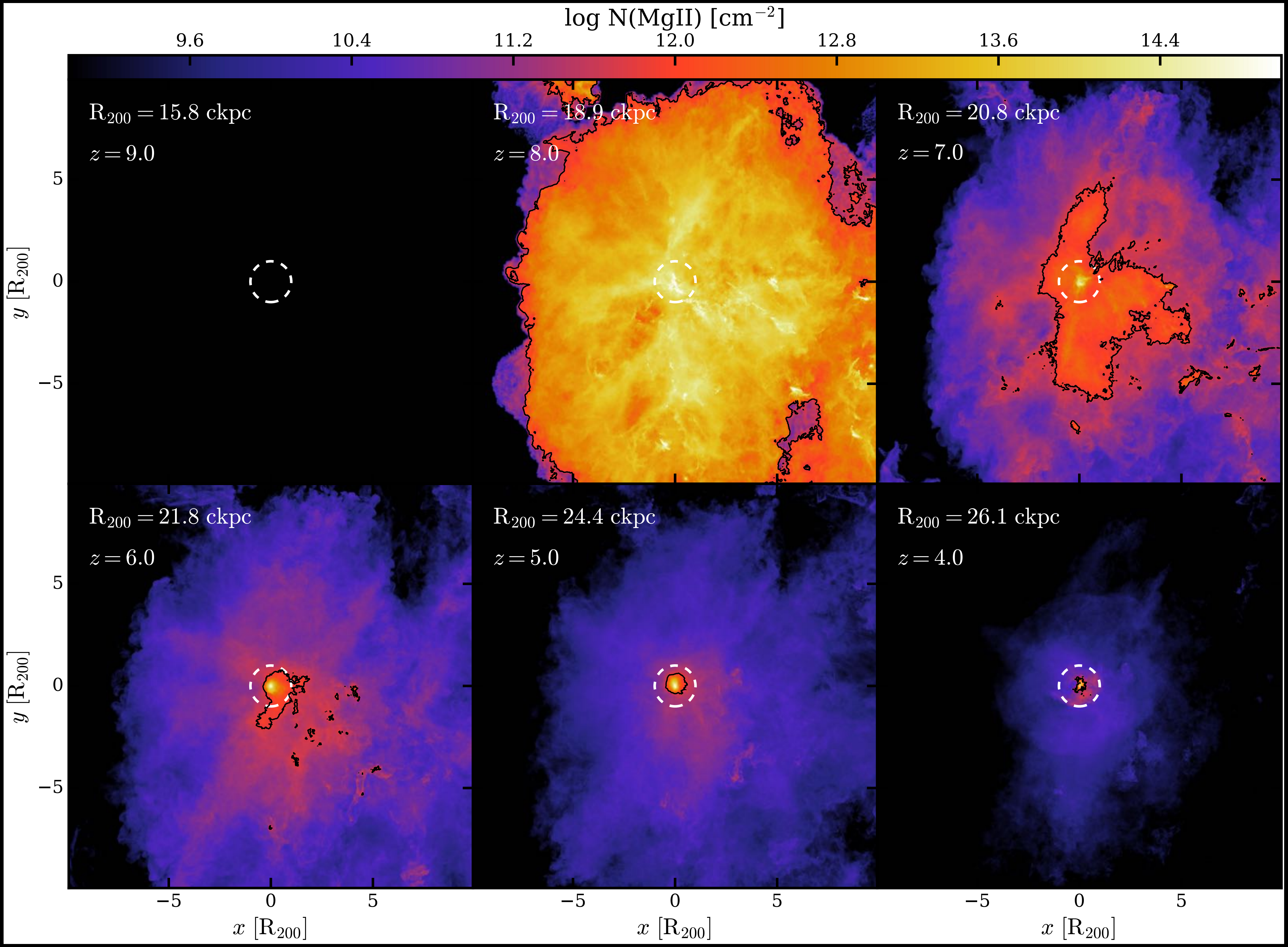
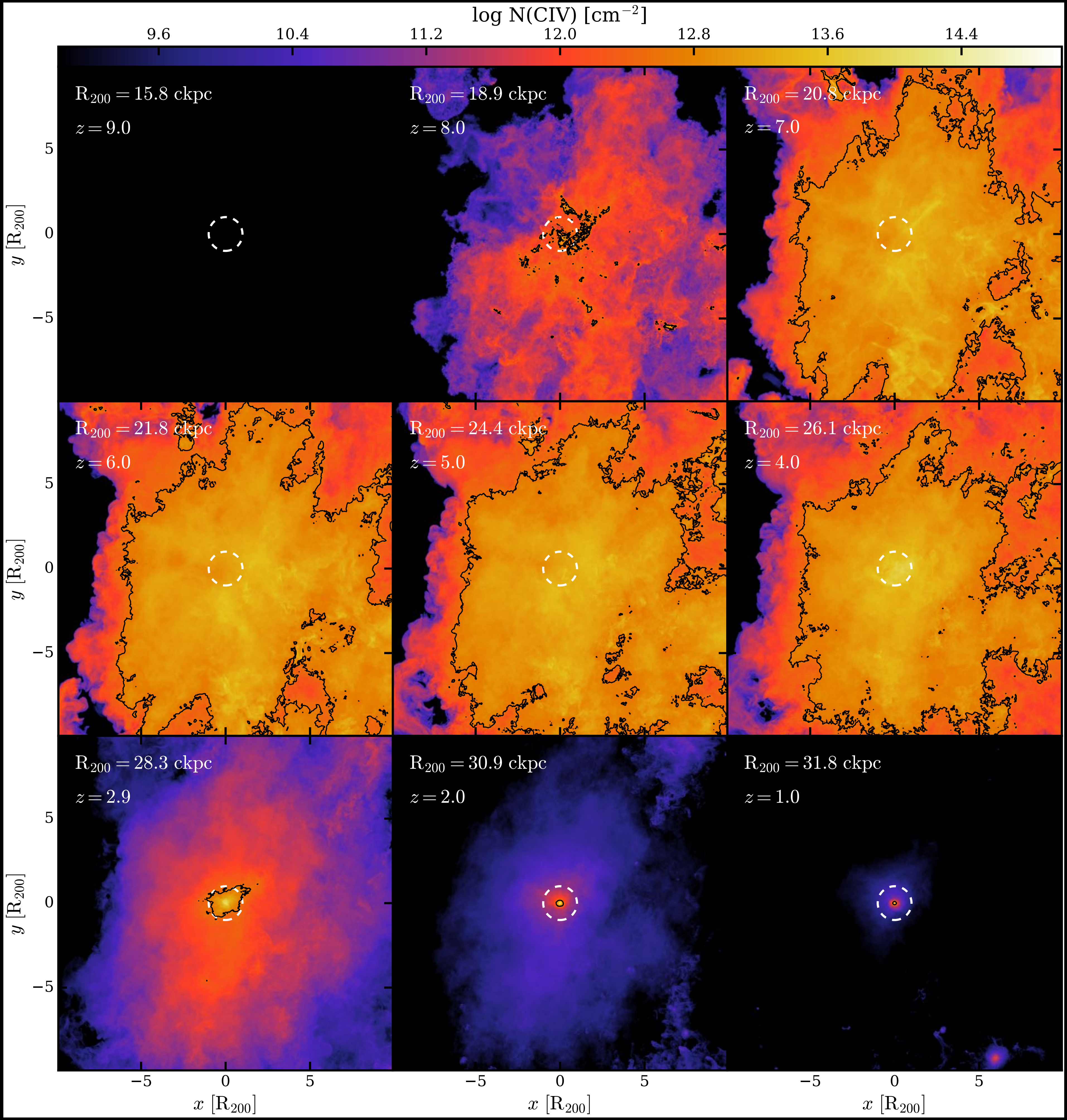
IGM enrichment (MgII)

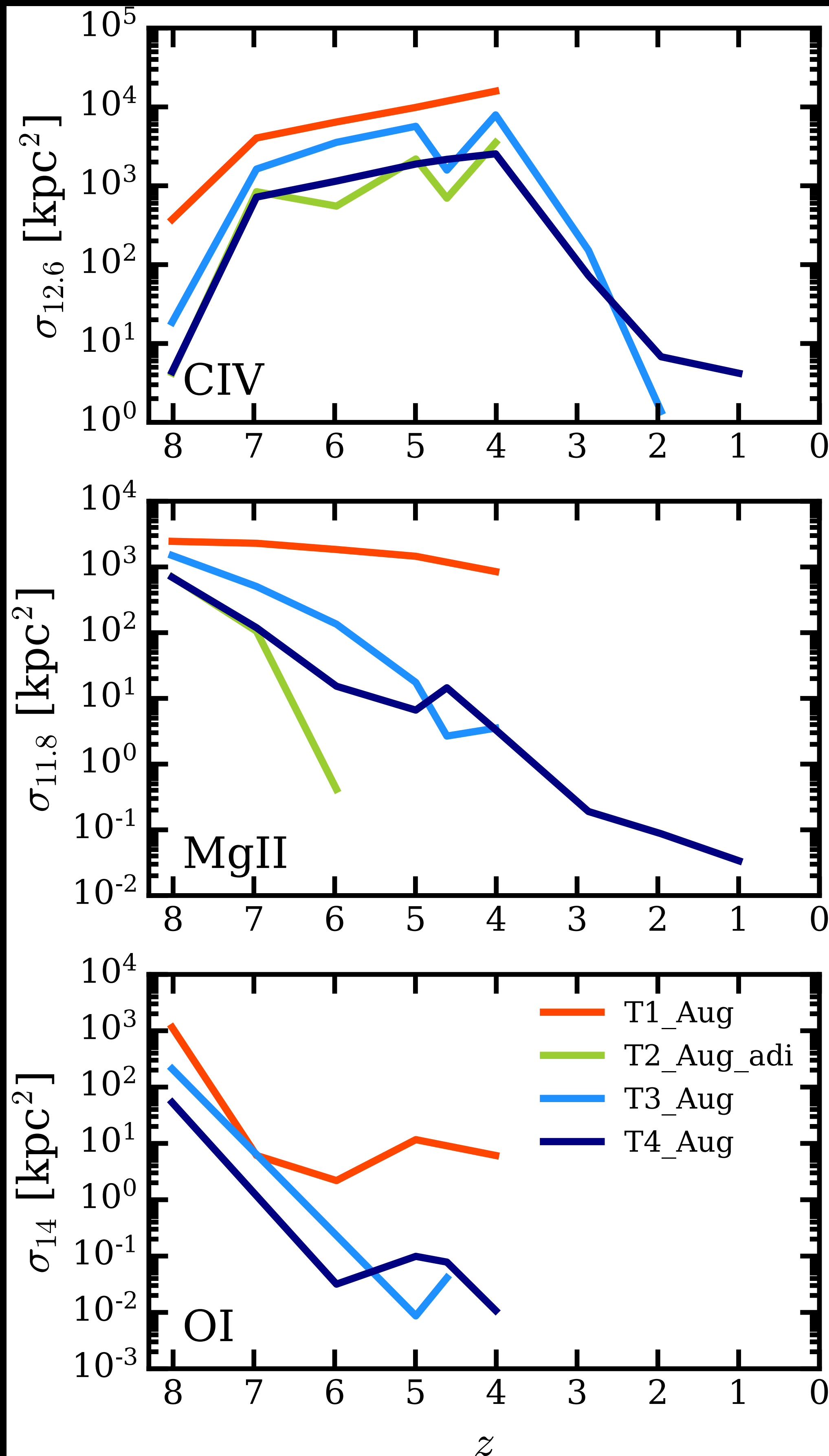




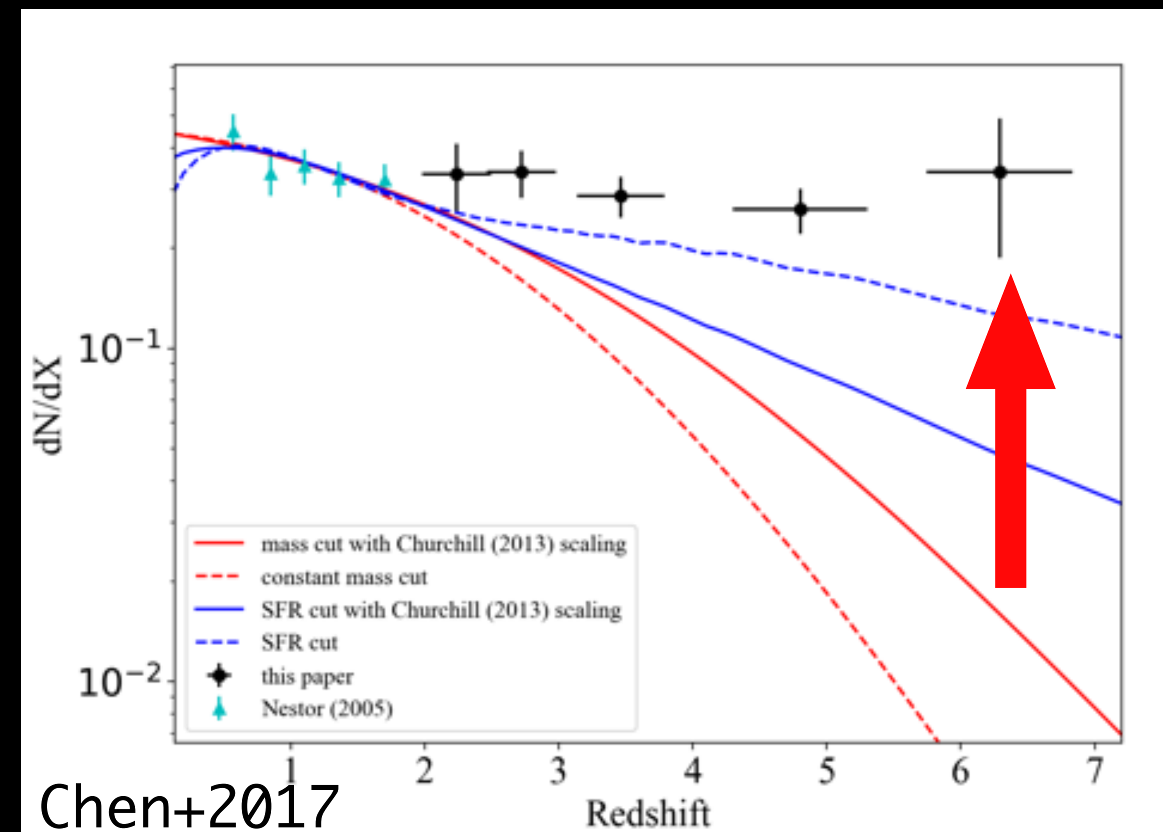
log N(CIV) [cm^{-2}]
9.6
10.4
11.2
12.0
12.8
13.6
14.4
$R_{200} = 15.8$ ckpc
$z = 9.0$
$R_{200} = 18.9$ ckpc
$z = 8.0$
$R_{200} = 20.8$ ckpc
$z = 7.0$
$R_{200} = 21.8$ ckpc
$z = 6.0$
$R_{200} = 24.4$ ckpc
$z = 5.0$
$R_{200} = 26.1$ ckpc
$z = 4.0$
$R_{200} = 28.3$ ckpc
$z = 2.9$
$R_{200} = 30.9$ ckpc
$z = 2.0$
$R_{200} = 31.8$ ckpc
$z = 1.0$
y [R_{200}]
x [R_{200}]

CIV

Absorber size



MgII weak absorber number density

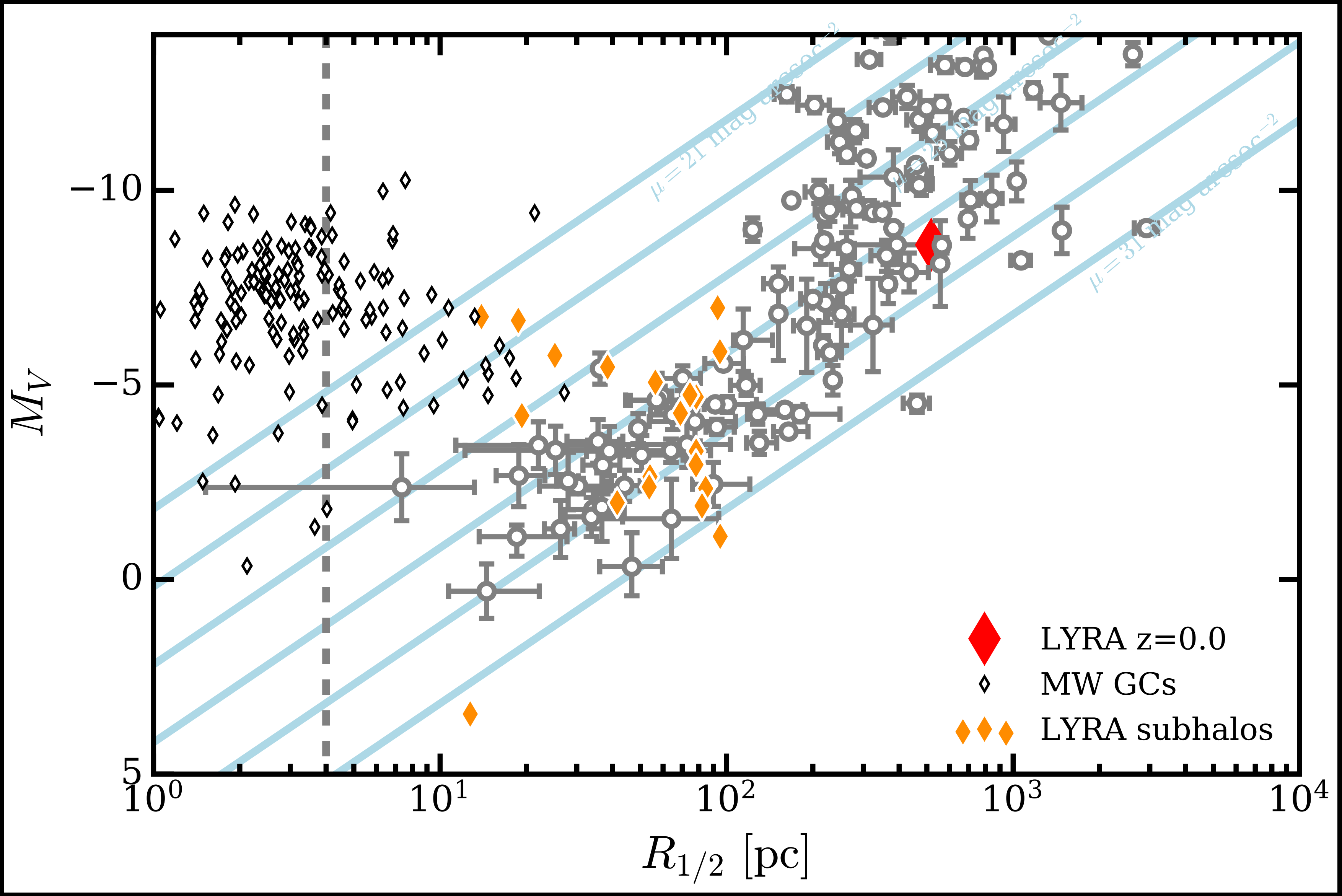


Models calibrated at z<2

Dwarf galaxies may be dominant polluter at high-z

Prediction #2
Dwarf substructure

Dwarf subhalos look like ultra-faint dwarfs



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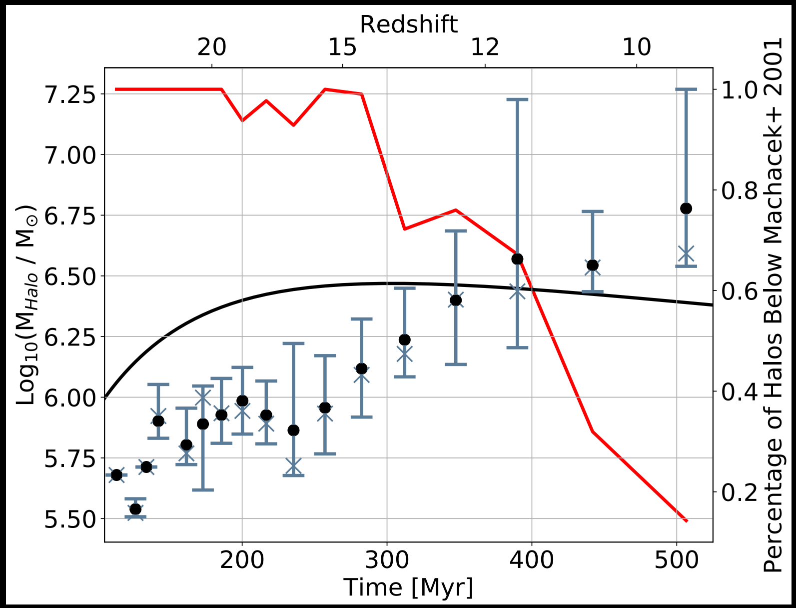
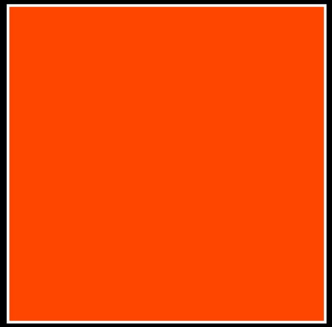
Which halos do PopIII stars form in?



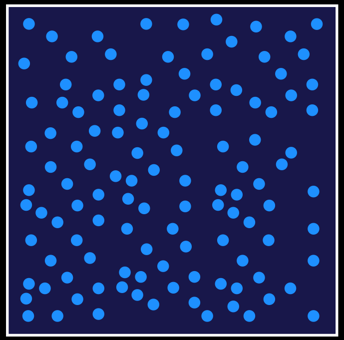
Skinner+2020

Three simple models introducing the first metals



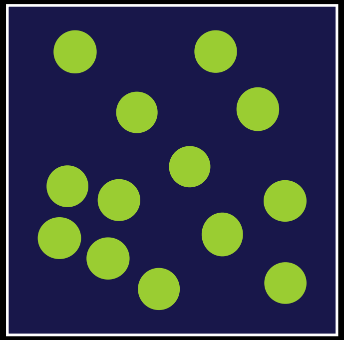
Homogeneous

Metals are everywhere from the beginning



$M_{thres} = 10^6\ M_{sun}$

Metals are introduced in many small halos

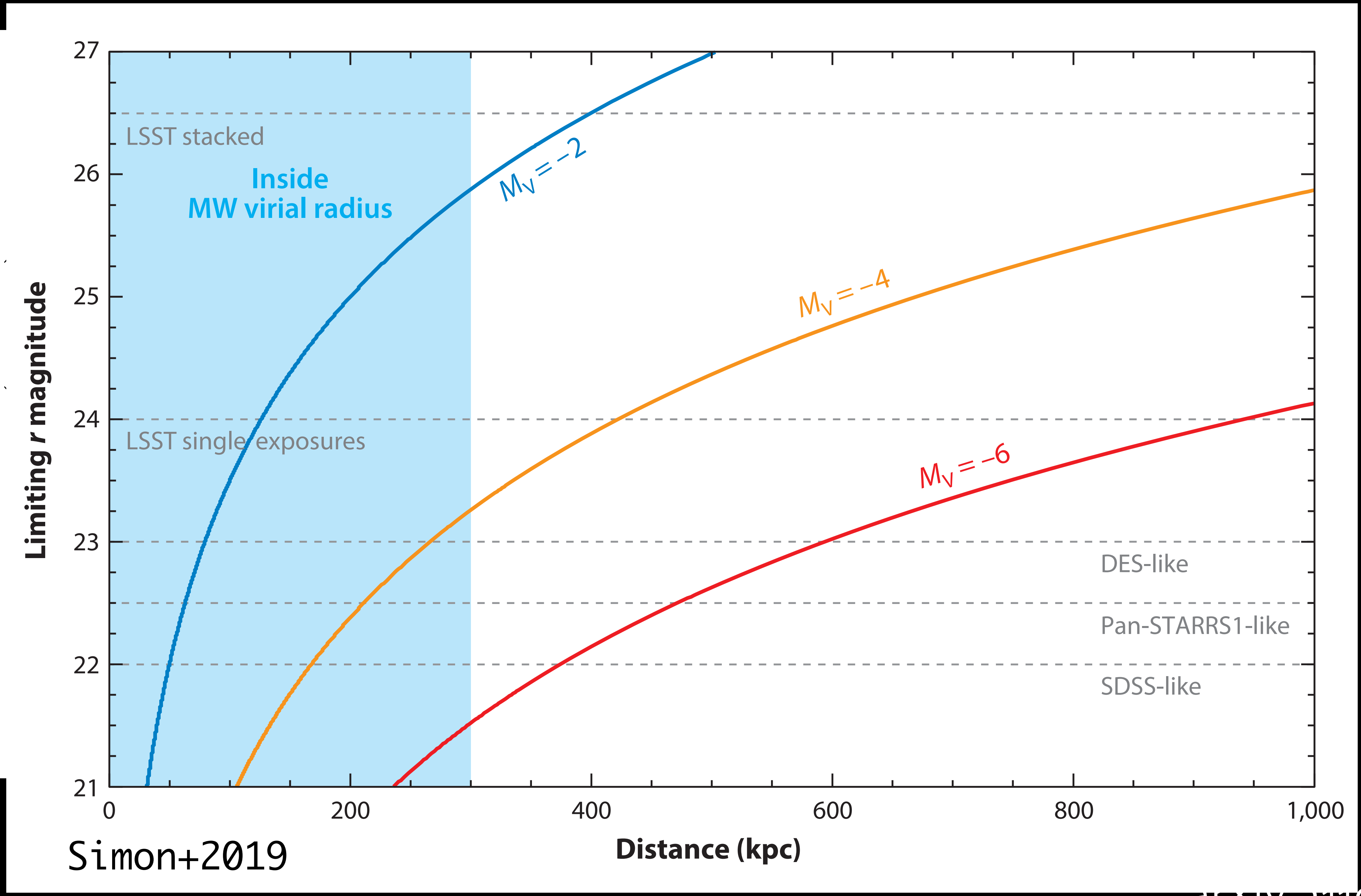


$M_{thres} = 10^7\ M_{sun}$

Metals are introduced in a few large halos

Dwarf substructure counts

PopIII halo mass may be constrained by future observations of dwarf substructure (JWST/Rubin)

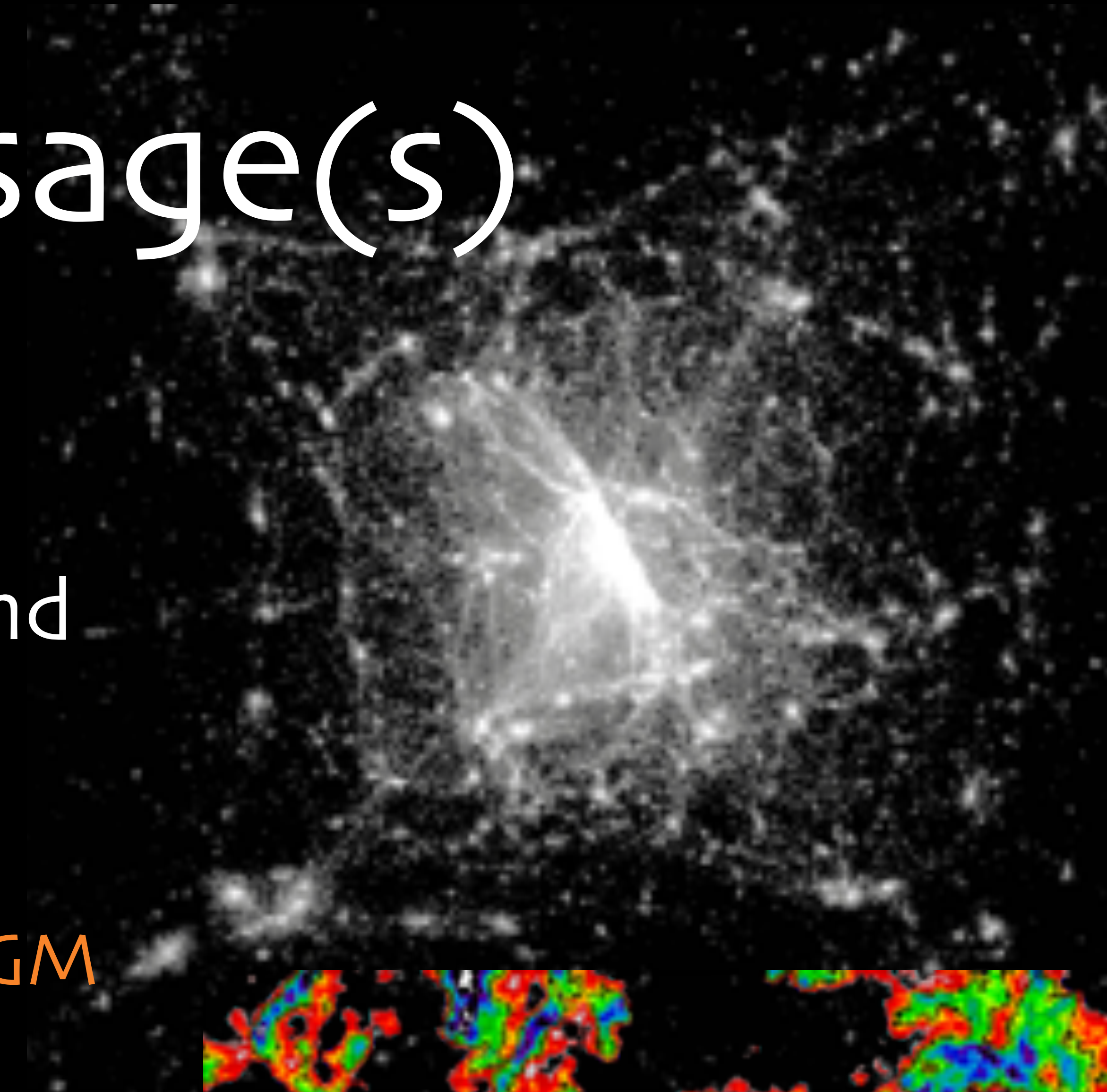


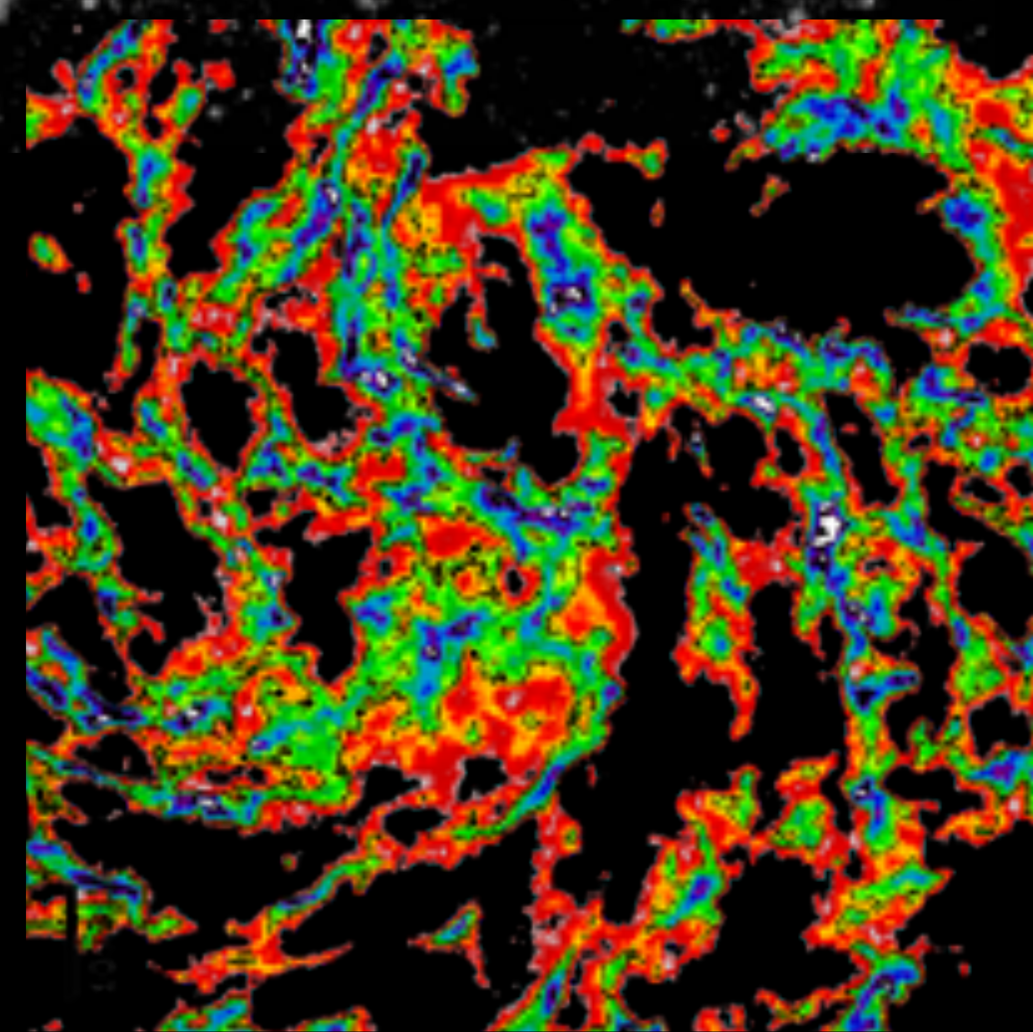
arxiv.2110.06233

Take home message(s)

Lyra brings together small scale baryonic physics and the cosmological context

- Dwarf galaxies may be dominant IGM polluter at high-z
- Dwarf subhalos look like LG ultra-faint dwarfs
- PopIII halo mass may be constrained by dwarf substructure counts





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