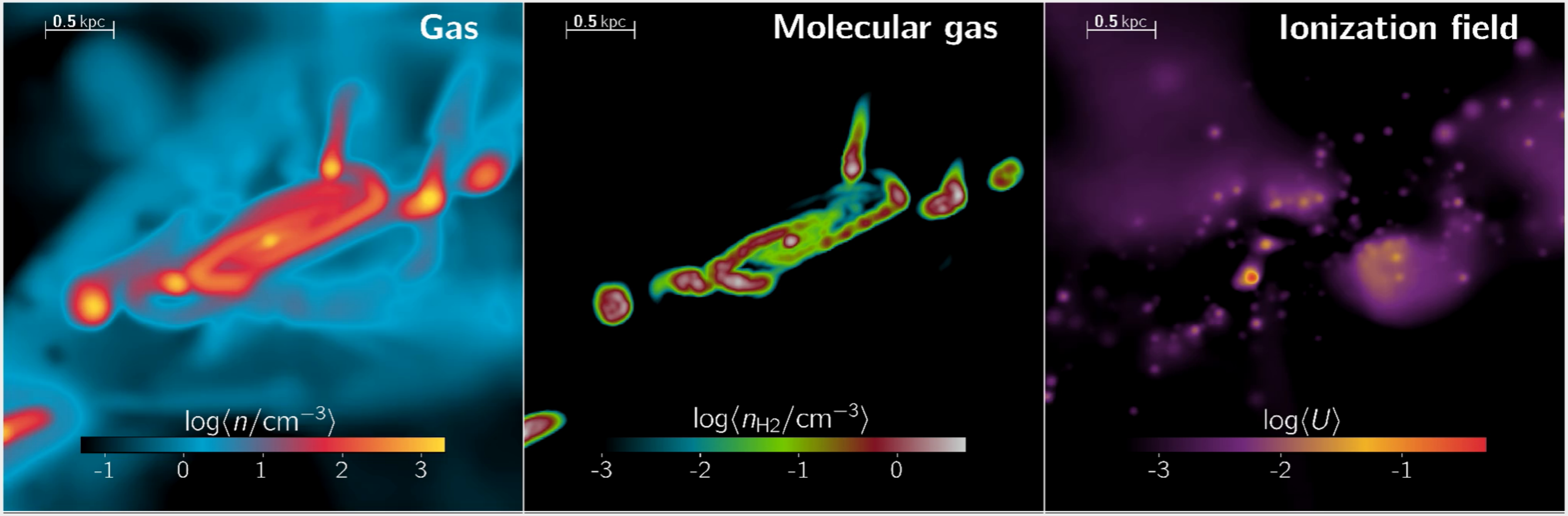
Simulations of ~~very high~~-redshift galaxies

actually z~4-12

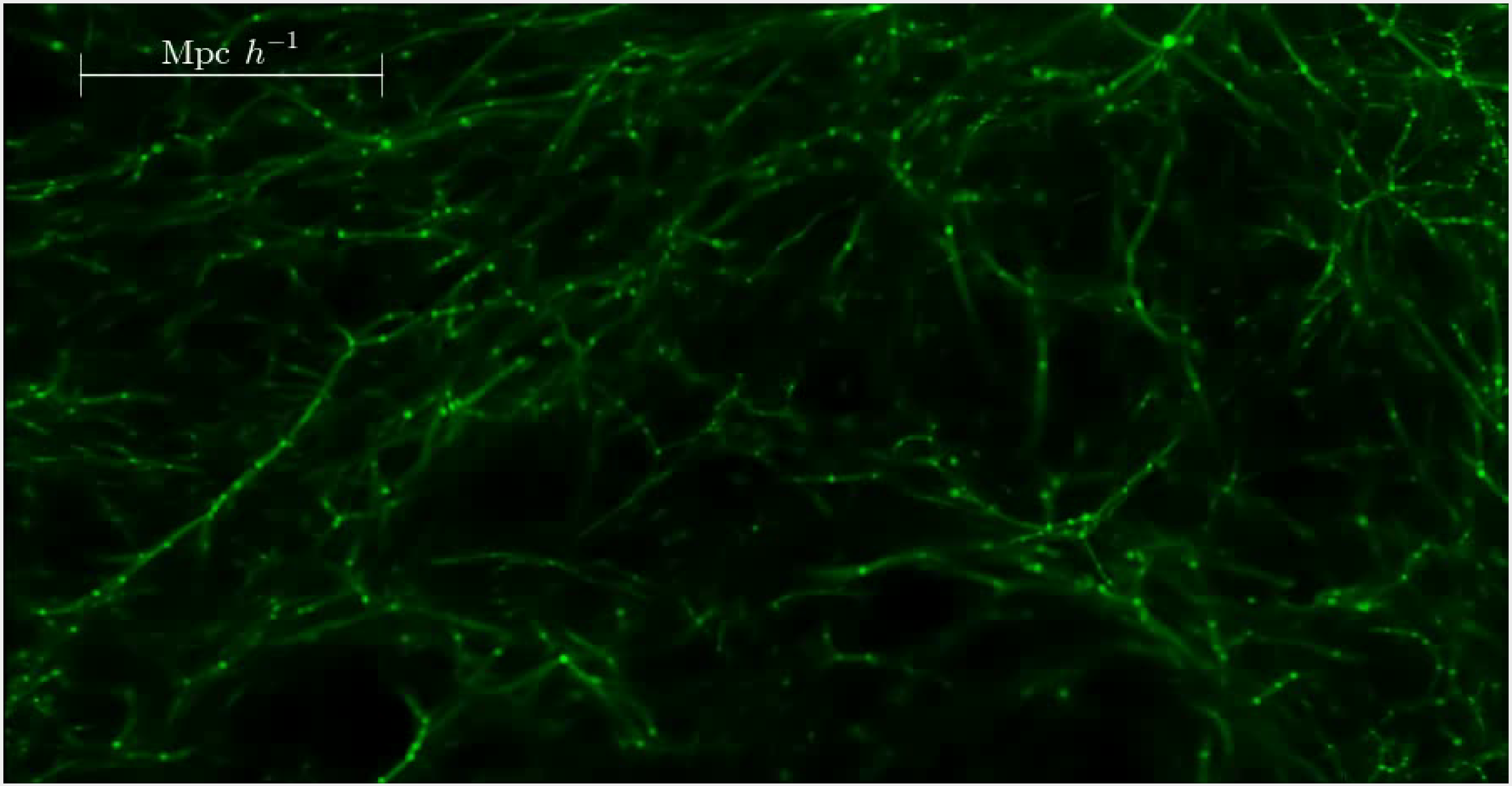


Main points for this discussion:

- What are the properties of “very” high-redshift galaxies?
- Which are our chances of finding first stars in these environments?
- How can we probe the stellar population of these galaxies?

Andrea Pallottini

Cosmological simulations of z~4-12 galaxies



Resolution	
gas mass	$\simeq 10^5 M$
spatial (AMR)	$\sim 20 - 1\,\mathrm{kpc/h}$
box size	$10\,\mathrm{Mpc/h}$

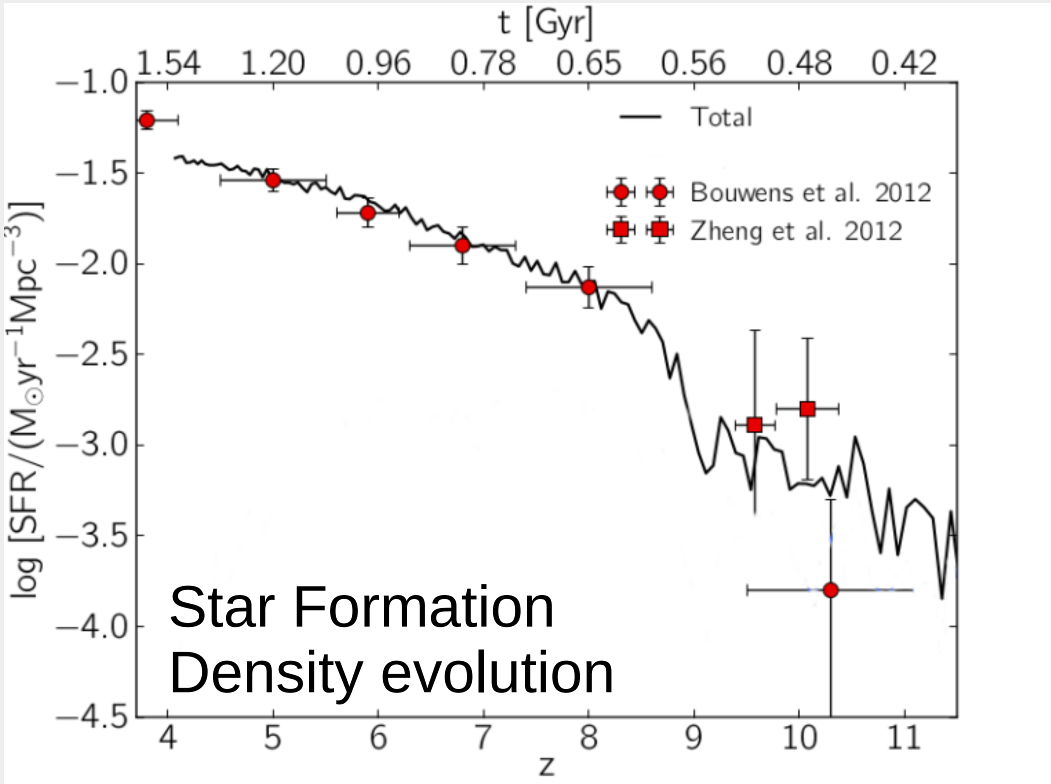
might feel a bit outdated, still results uncomfortably close to the current state of the art

Pallottini+14

Model calibration and validation

calibration of subgrid parameters

Pallottini+14

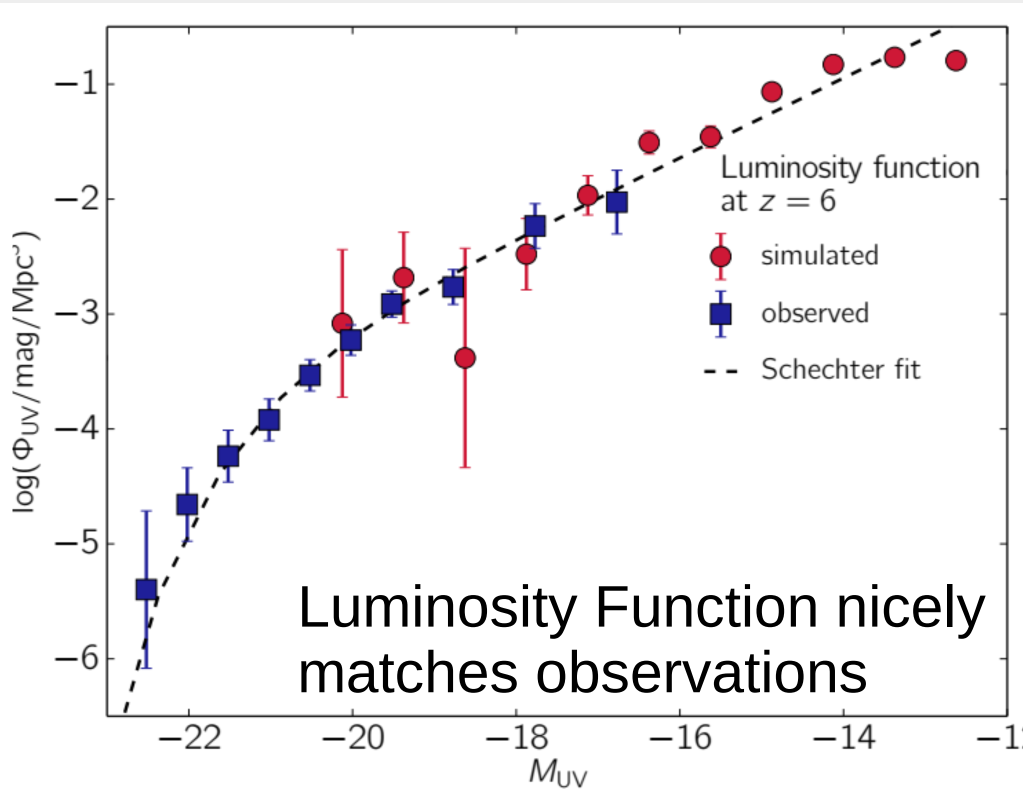


start formation and feedback
are calibrated to reproduce
the total SFR density evolution

higher SFR (SN coupling) efficiency
implies faster (slower) mass assembly

model validation

Pallottini+15a

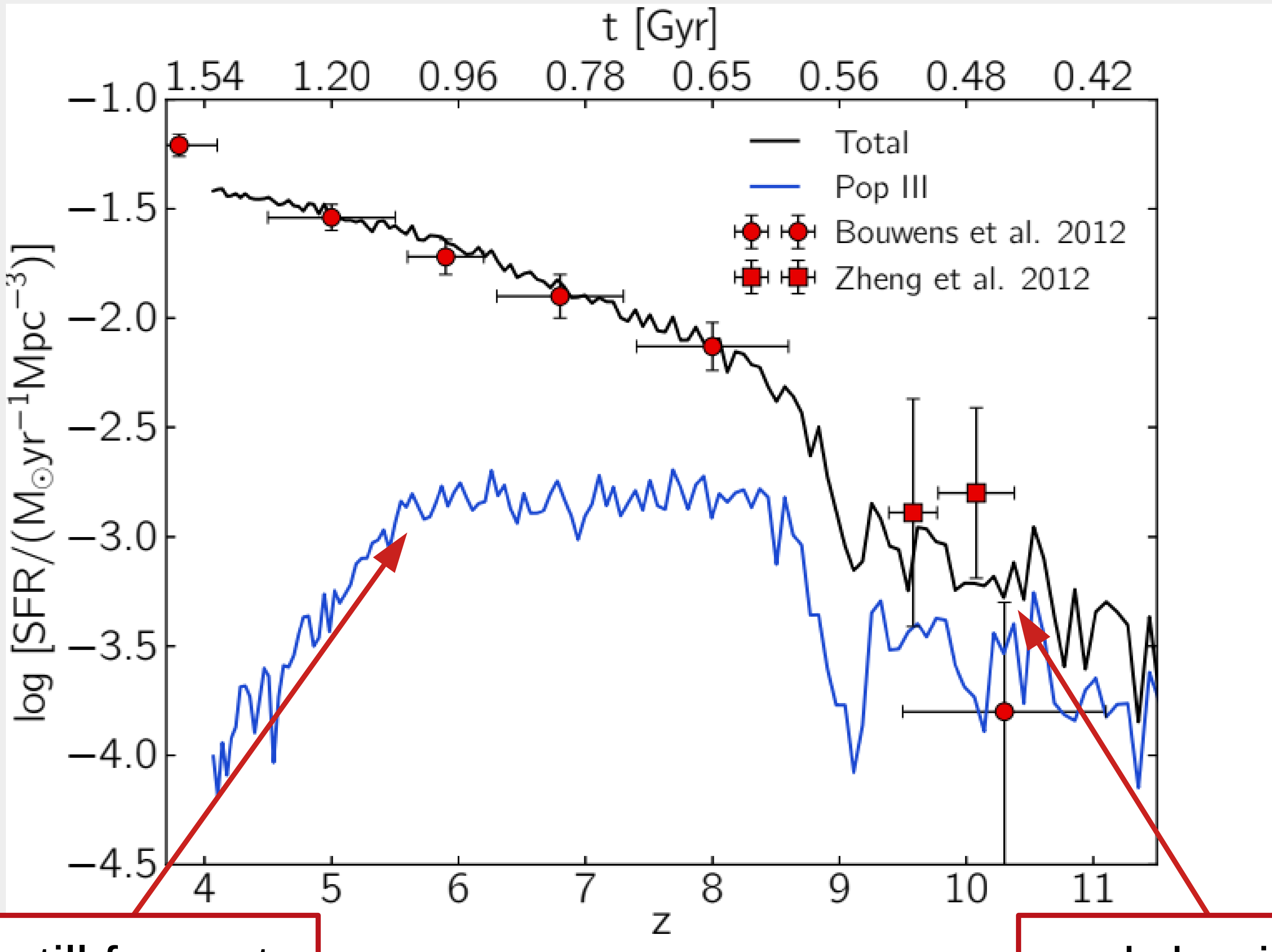


imposed constraint is global:
model can be validated
on a galaxy by galaxy basis

observations from Bowens+2014
see Yue+2015 for LF at different z

Pop III formation throughout cosmic time

Pallottini+14



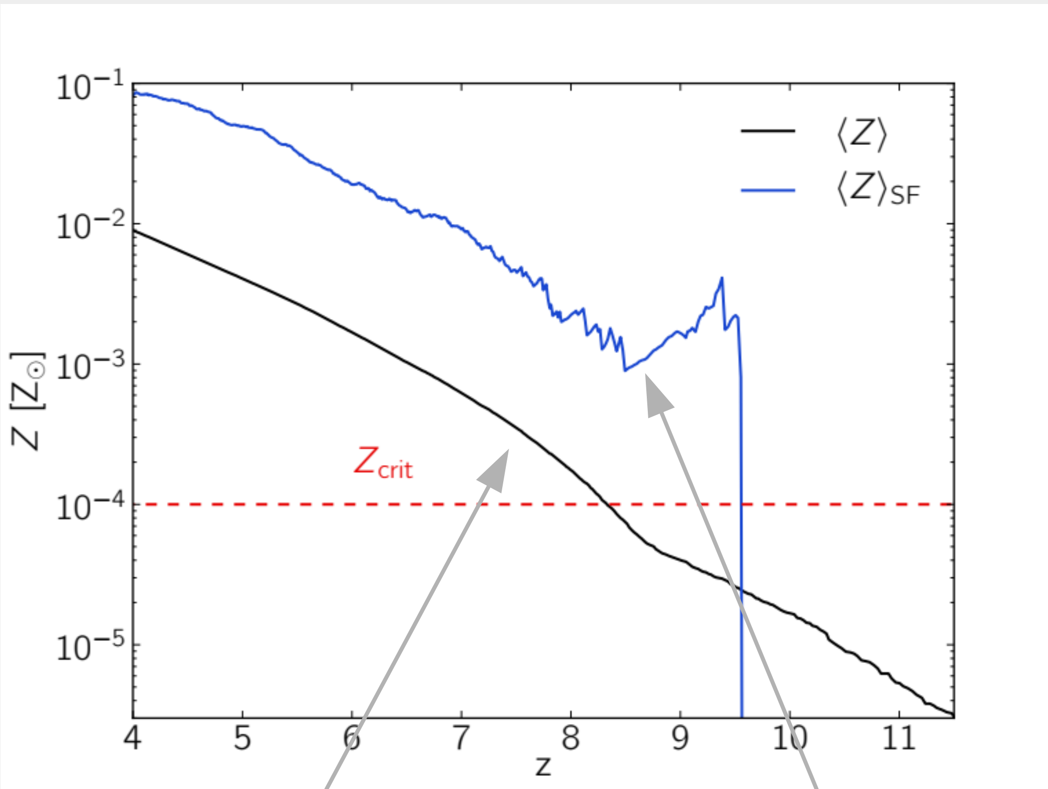
can still form at relatively low-z

subdominant even at high-z

How can Pop III still form down to z~4-6?

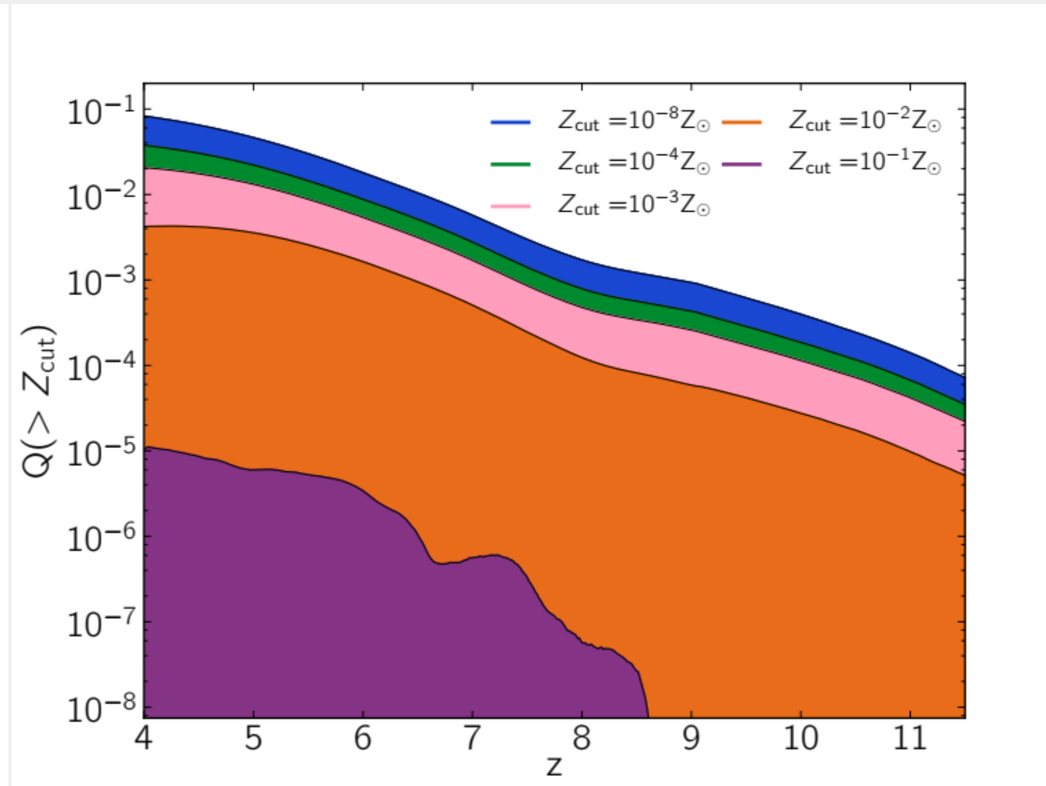
metallicity evolution

Pallottini+14



filling factor of metals

Pallottini+14



average in the whole cosmological volume

ISM average

about 10% of the volume has been enriched at z = 4

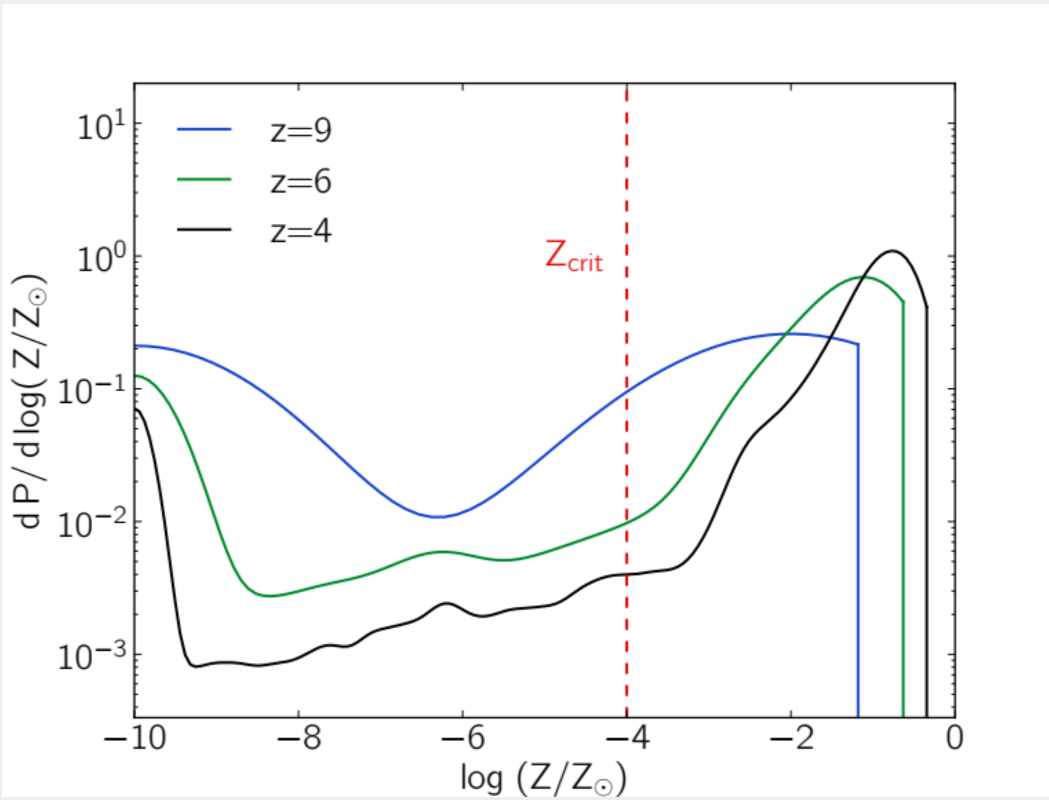
quick recap:

Pop III stars can still form in pockets of pristine gas till Reonization quenches SFR in low mass haloes

Where can we find Pop III stars?

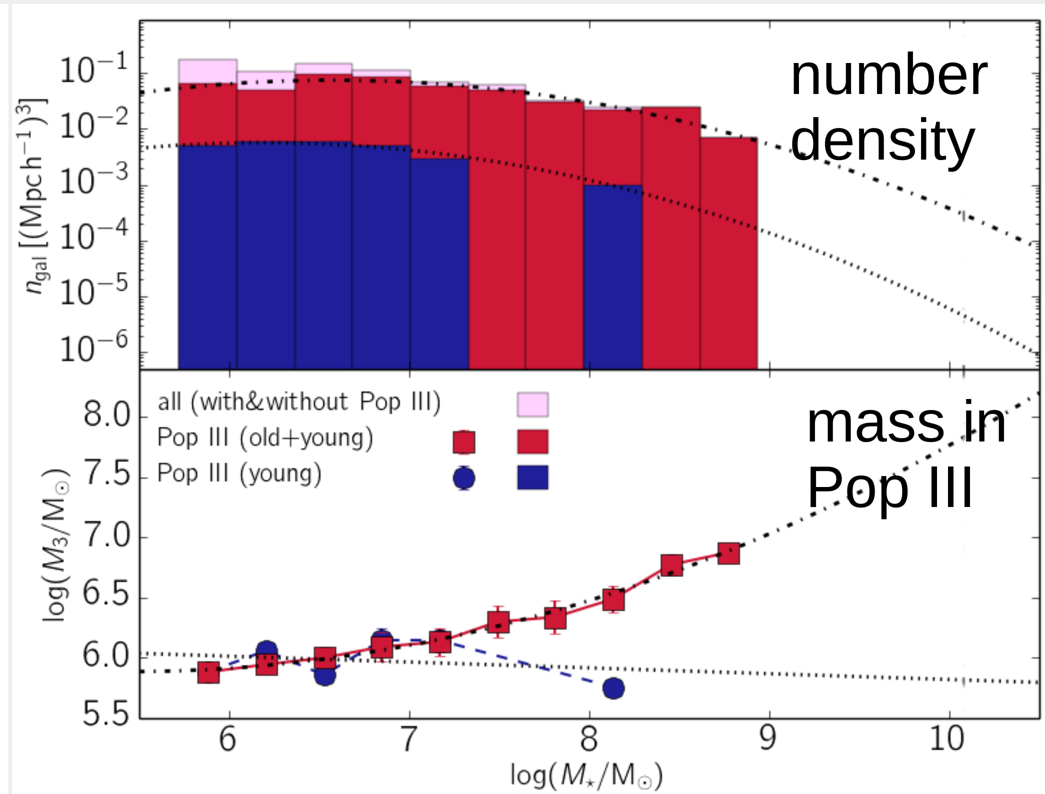
stellar Metallicity Distribution Function

Pallottini+14



Pop III in galaxies

Pallottini+15b



quite a bimodal distribution, with Pop III accounting for <10% of stars

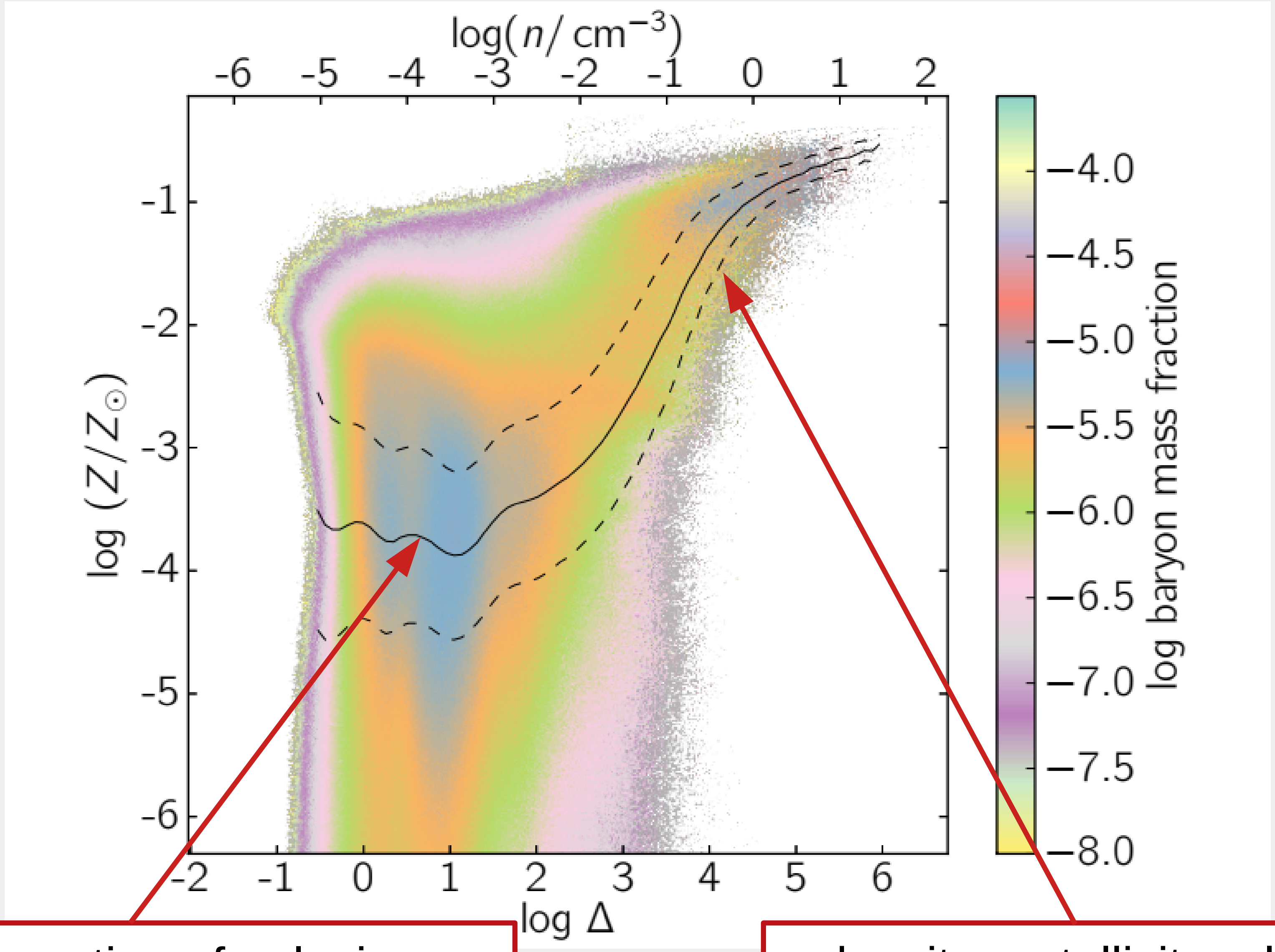
a single SN episode prevents Pop III formation within a galaxy

maybe lensing at relatively low-z is the best hope to find active Pop III

mostly relics (depending on IMF) can be found via JWST searches

The imprint left by metal pre-enrichment

Pallottini+14



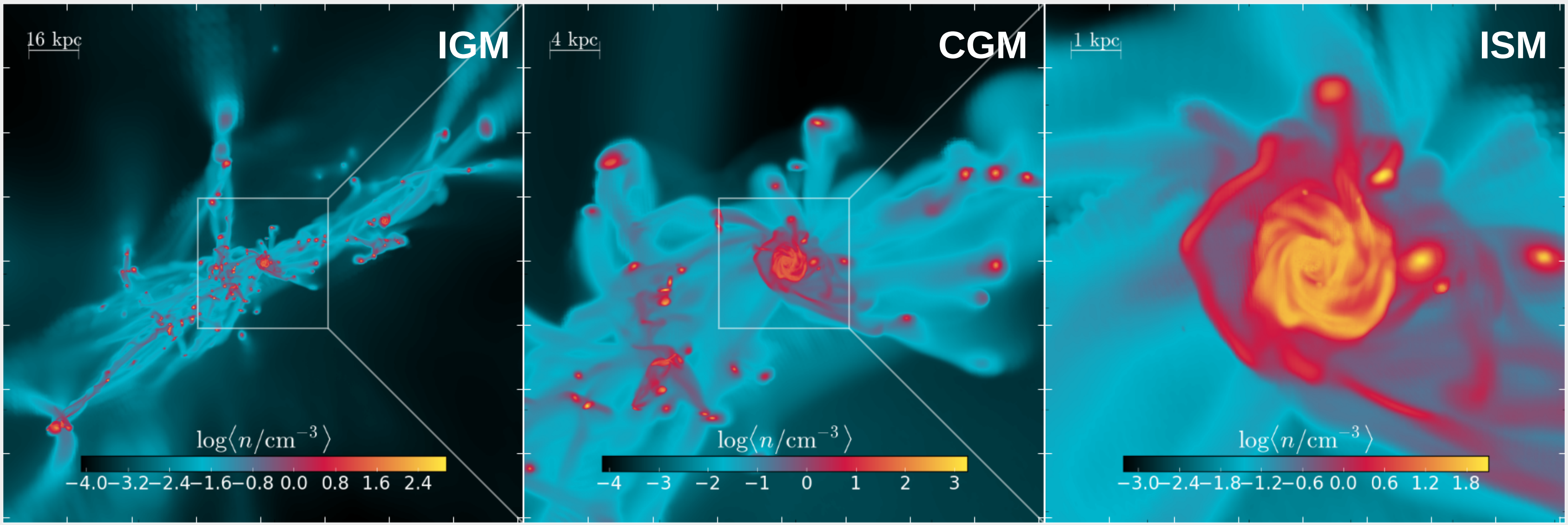
next generation of galaxies are build upon a metallicity floor

a density-metallicity relation is in place for enriched ISM/CGM

Zooming-in high-redshift galaxy formation

Pallottini+2017a

Dahlia, a simulated z=6 galaxy



key modeling features:

Resolution	
gas mass	$\simeq 10^4 M_\odot$
spatial (AMR)	$\sim 80 - 0.1\,\mathrm{ckpc/h}$
at $z = 6$	$\simeq 30\,\mathrm{pc}$

from cosmological to molecular cloud scales

ISM physics based on sub-pc obs/models

serra

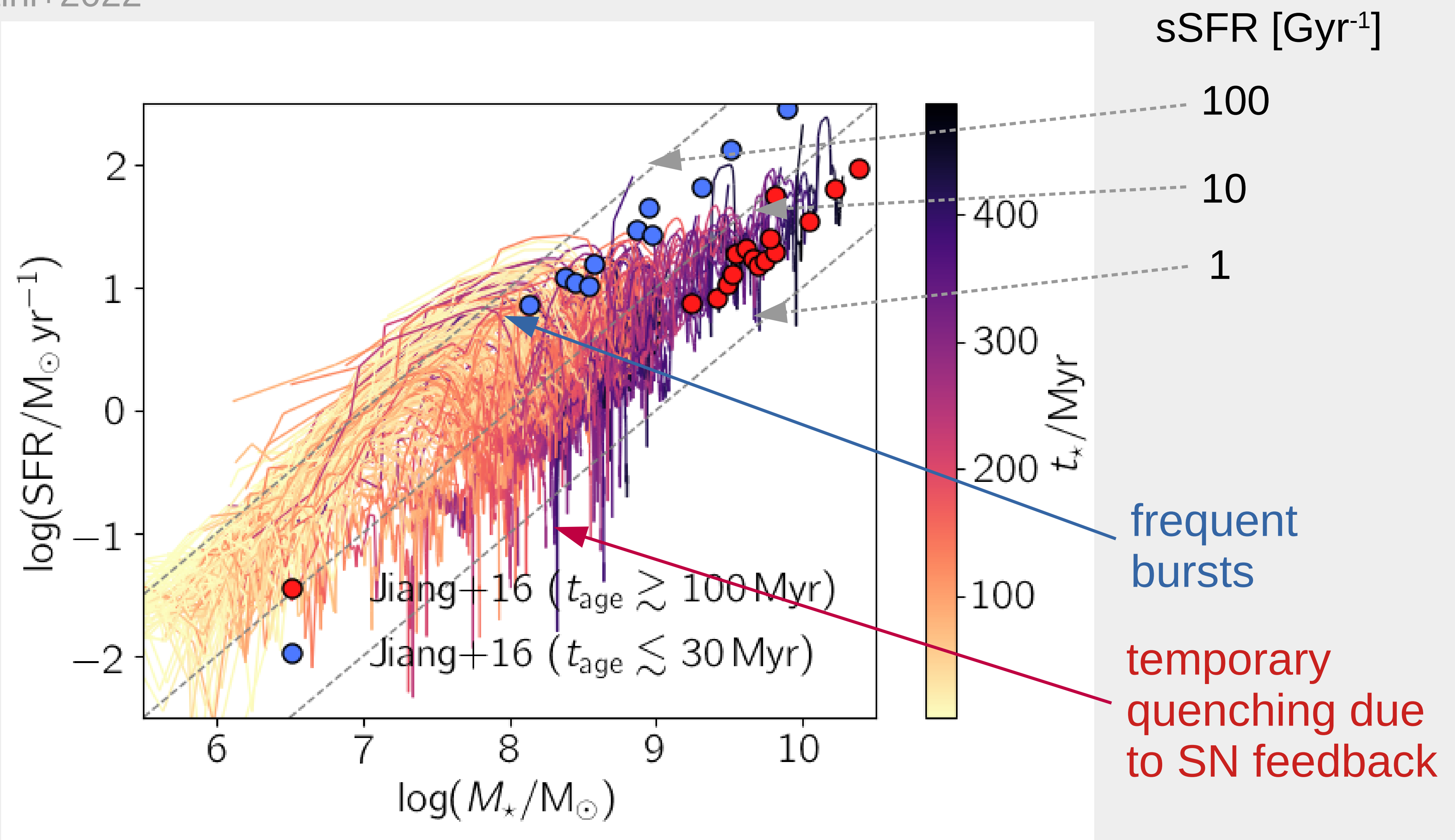
non-equilibrium chemical networks to form molecular hydrogen and in turn form stars Pallottini+2017b

radiation field tracked on the fly to account for ionization and photo-dissociation effects Pallottini+2019

“Main sequence” at high-z

~200 galaxies
selected z=7.7

Pallottini+2022



- early life is particularly turbulent, i.e. extreme sSFR
- consistent with observed “main sequence” at high-z
- a bit of lack of extreme bursts in massive galaxies

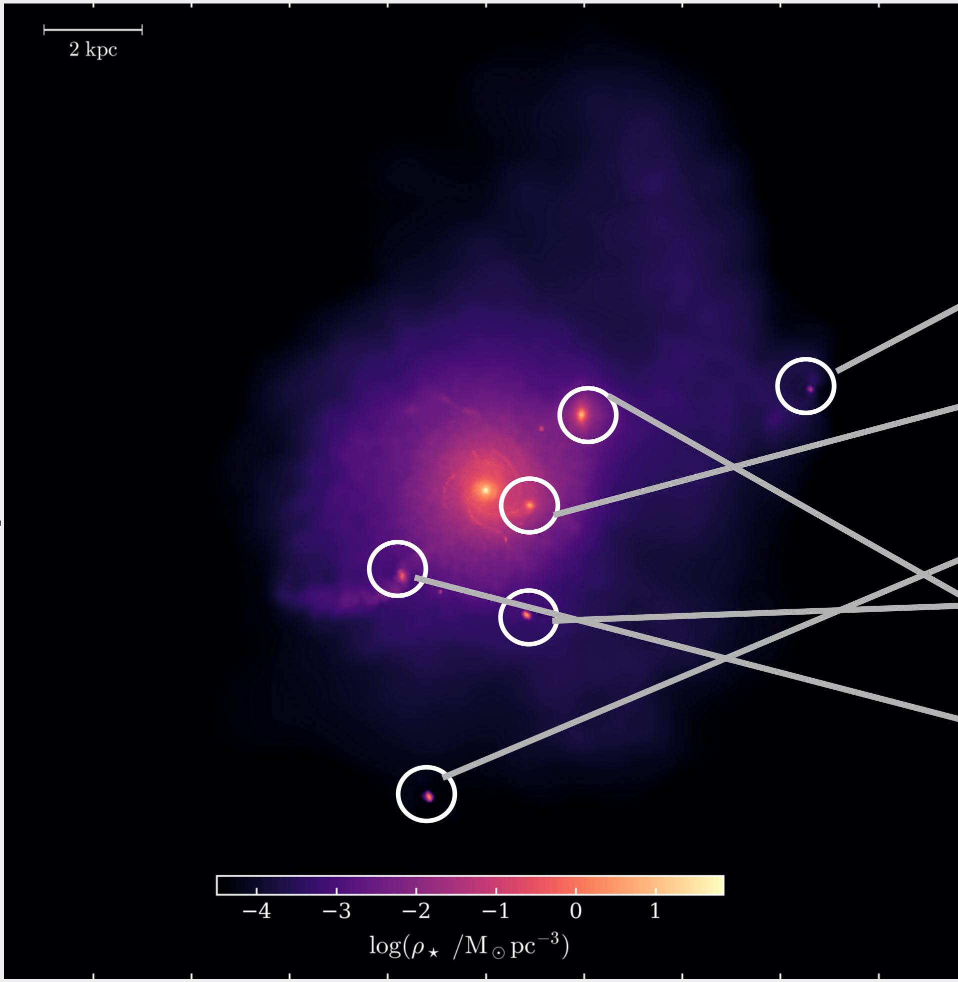
see Ferrara+2023

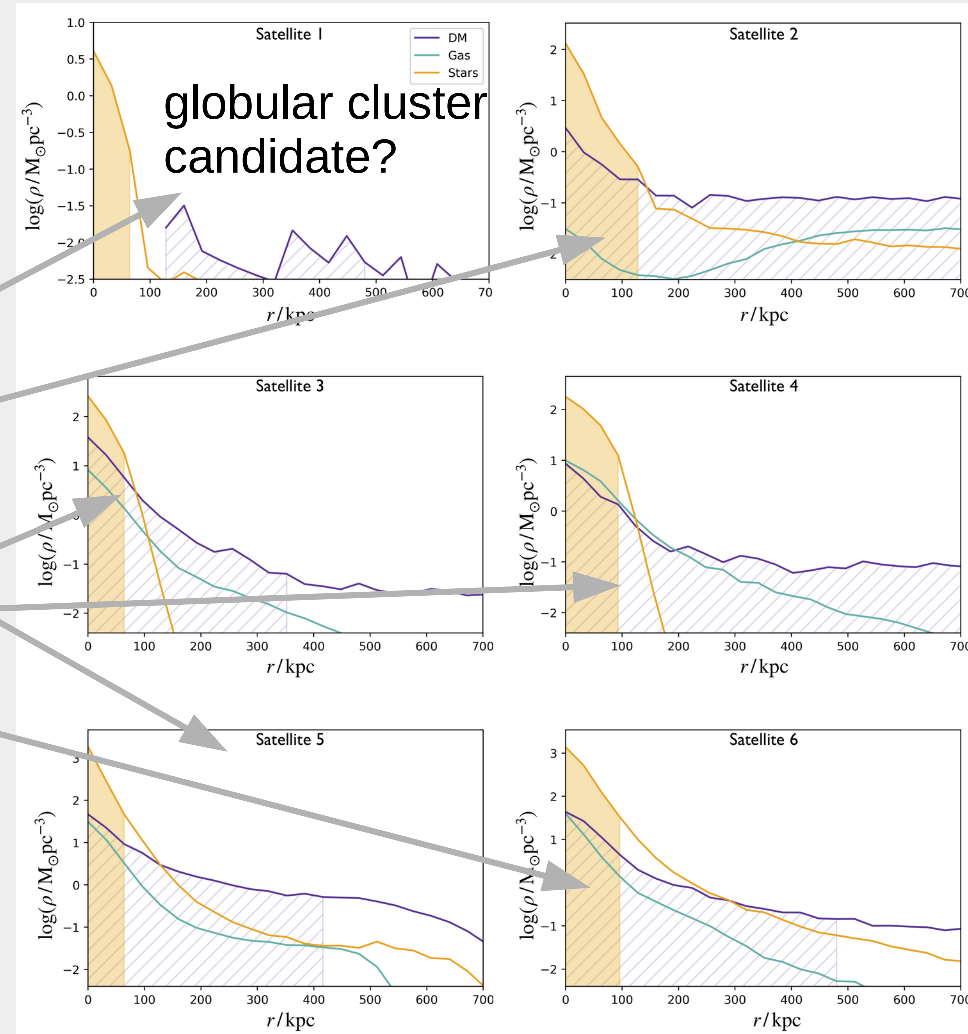
Breakdown of the stellar environment

Gelli+2020

star, gas, DM, mass distributions

stellar map of Althæa





Satellite	$D_{\mathrm{Althaea}}[kpc]$	$M_{\star}[10^8 \mathrm{M}_{\odot}]$	$M_{gas}[10^8 \mathrm{M}_{\odot}]$	$M_{DM}[10^8 \mathrm{M}_{\odot}]$
S1	11.42	0.022	0.00020	0.056
S2	2.45	0.72	0.53	3.1
S3	6.85	1.3	0.16	1.2
S4	2.85	2.2	0.47	2.3
S5	1.23	5.9	0.42	5.1
S6	4.86	11.1	0.53	3.6

focusing on the satellites sample:

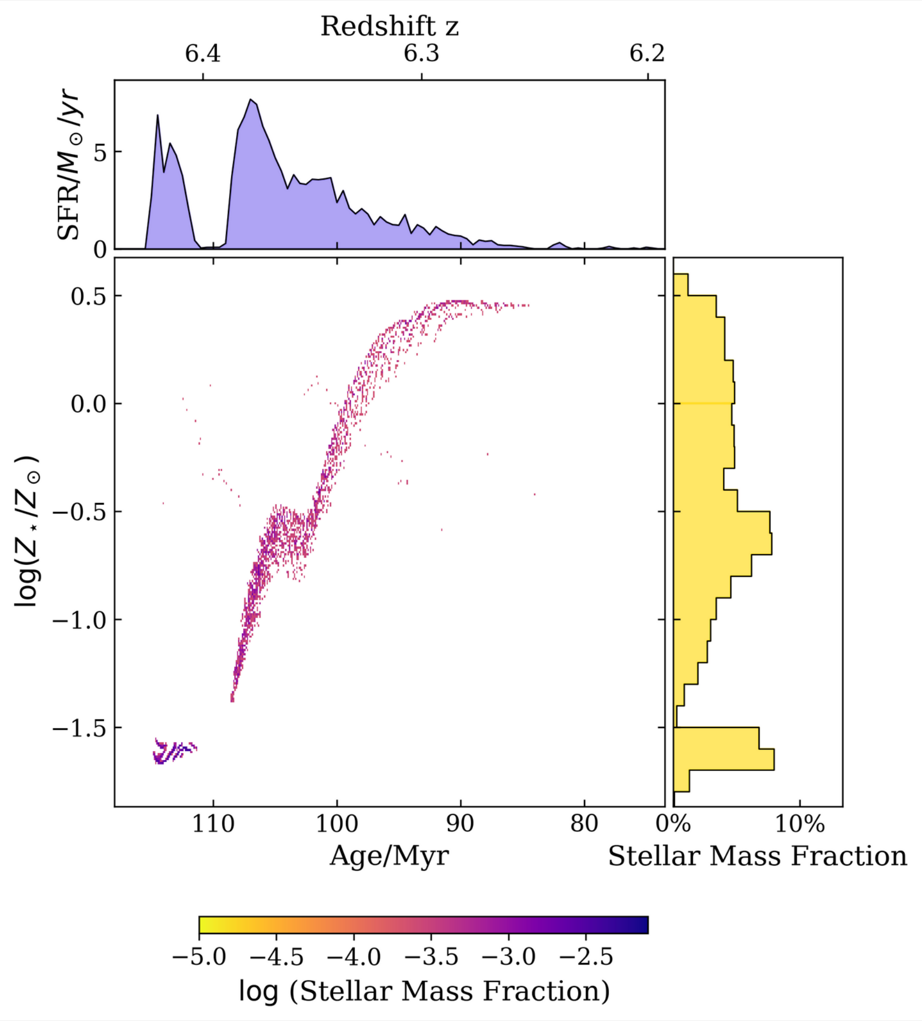
- what does determine their SFRh?
- can they host metal poor stars?

Stellar population of high-z dwarf galaxies

Gelli+2020

low mass example

$M_\star \lesssim 5 \times 10^8 \mathrm{M}_\odot$



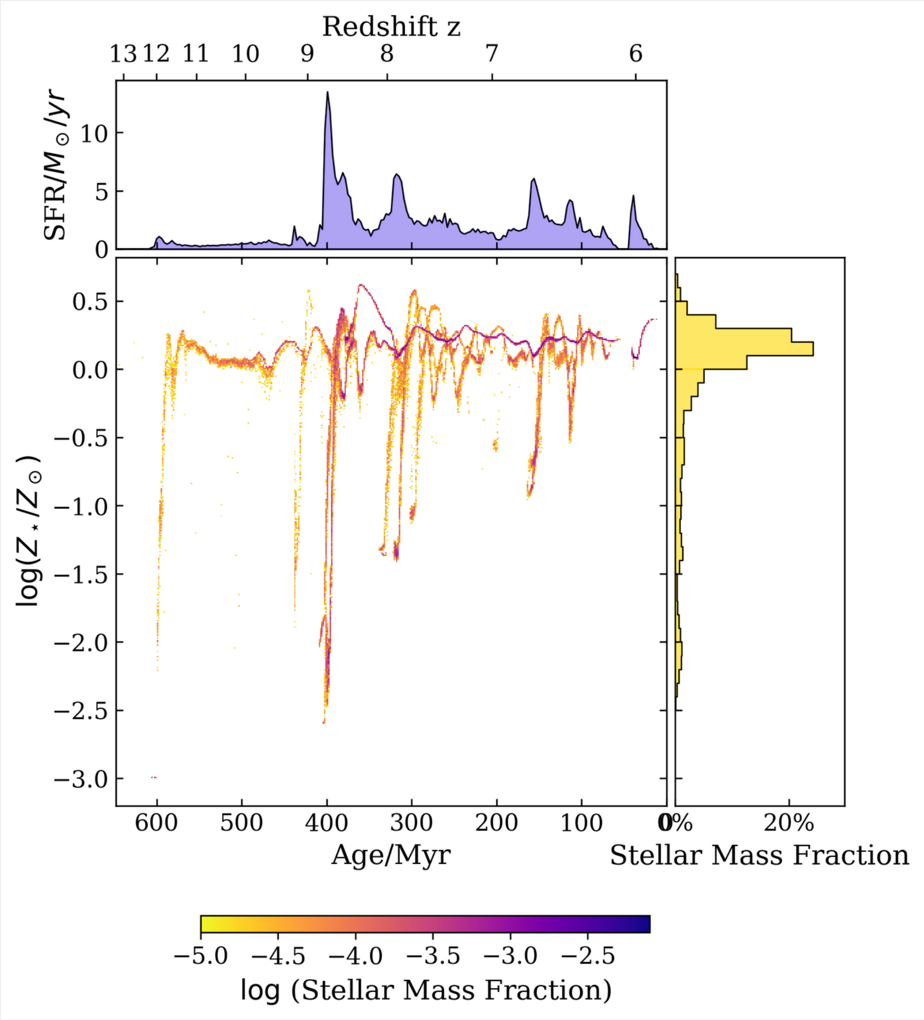
simple and short SFRh

quenched via internal SNs

high metal poor star fraction

high mass example

$M_\star \gtrsim 5 \times 10^8 \mathrm{M}_\odot$



complex & continued SFRh

merging causes SFR bursts

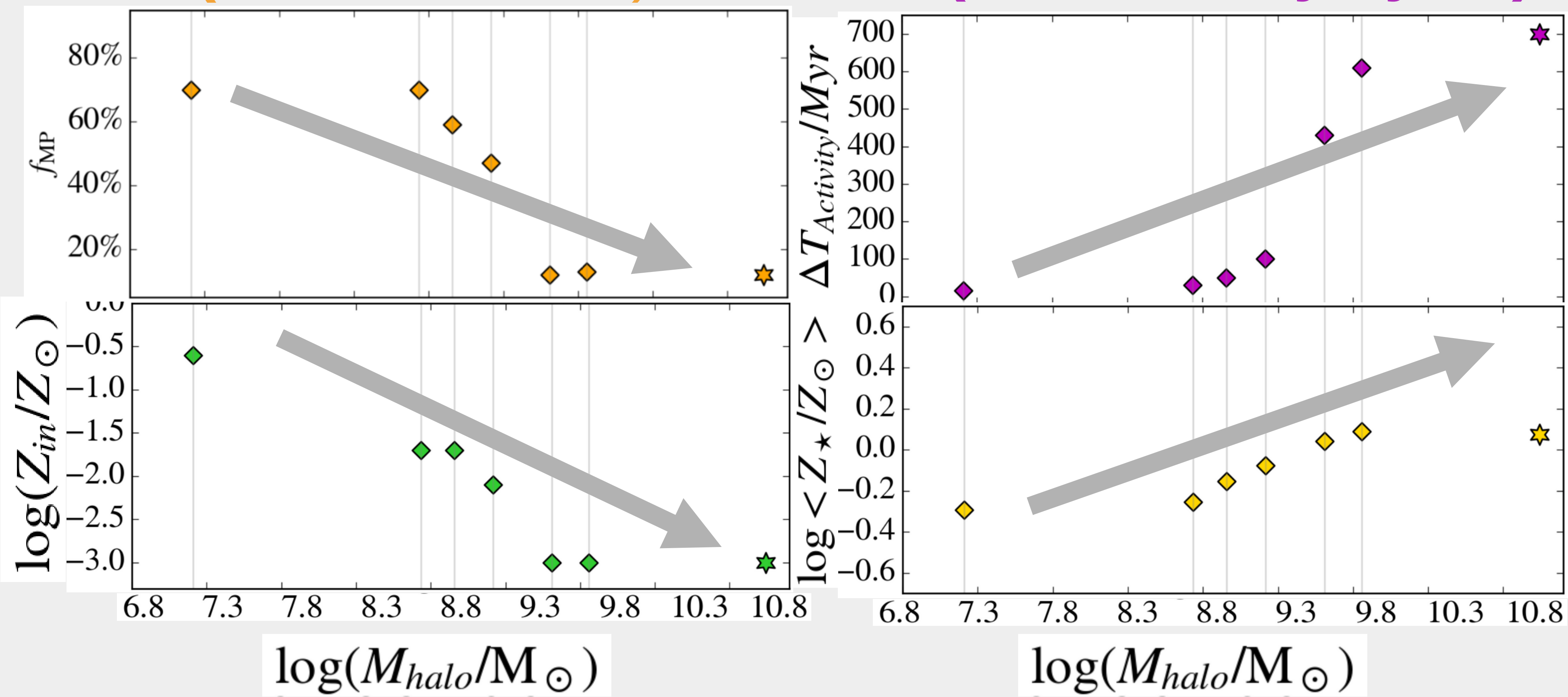
lower metal poor star content

Expected trends for the galaxy sample

Gelli+2020

metal poor fraction
(for $Z_* < 10^{-0.5} Z_\odot$)

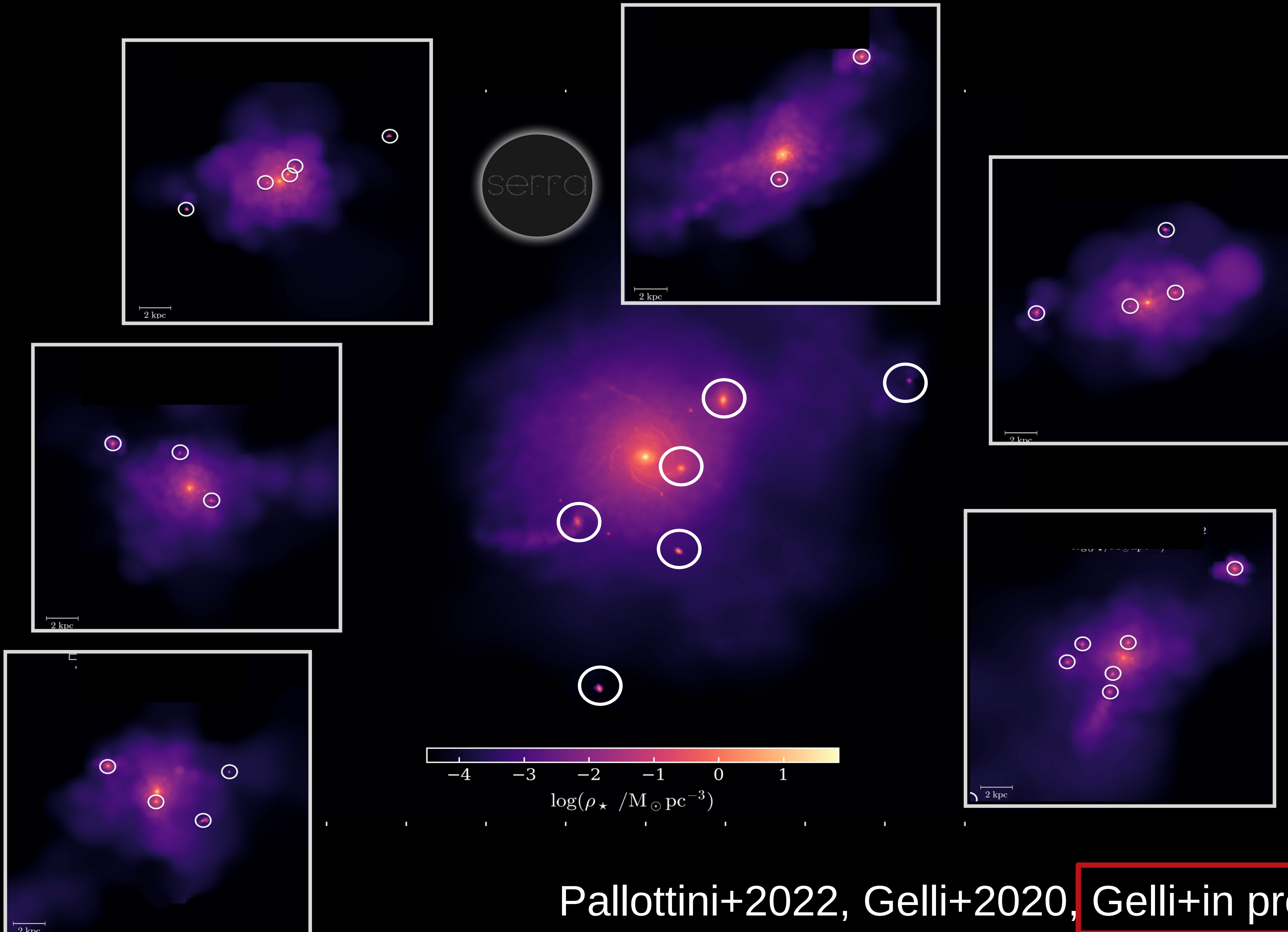
time of SF activity
(i.e. the duty cycle)



imprint from
pre-enrichment

mass-metallicity
relation

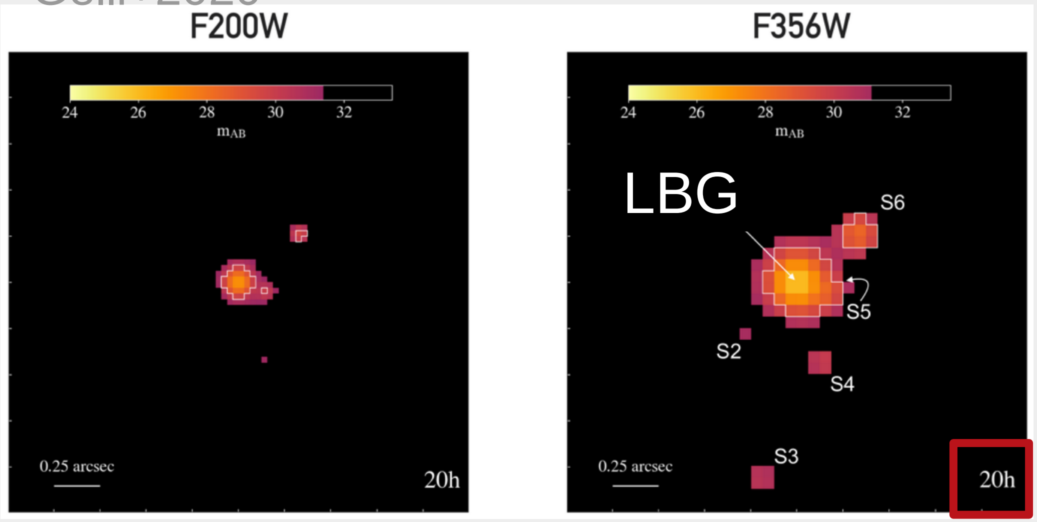
Building up statistics with SERRA



Pallottini+2022, Gelli+2020, Gelli+in prep

High-z galaxies via imaging & spectroscopy

Gelli+2020

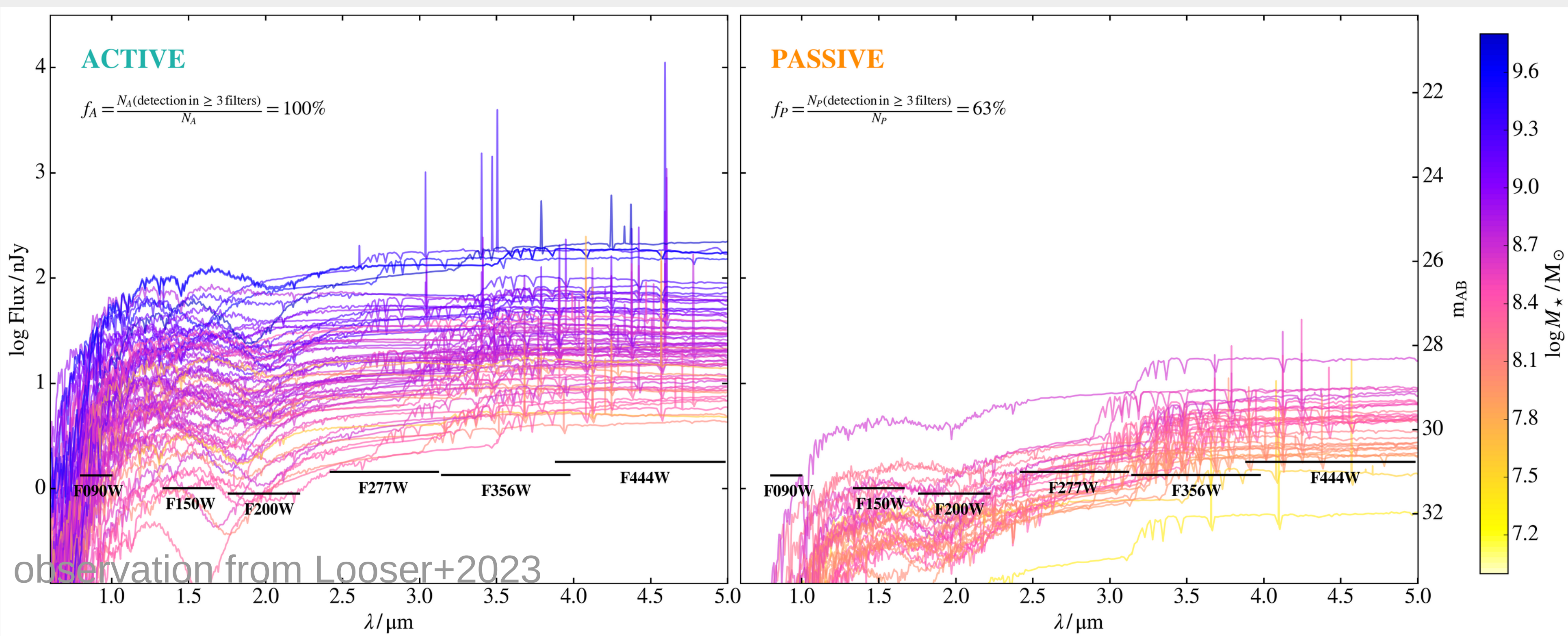


ongoing deep surveys (e.g. JADES) will catch dwarf galaxies for free

~30% of dwarf galaxies are expected to be passive

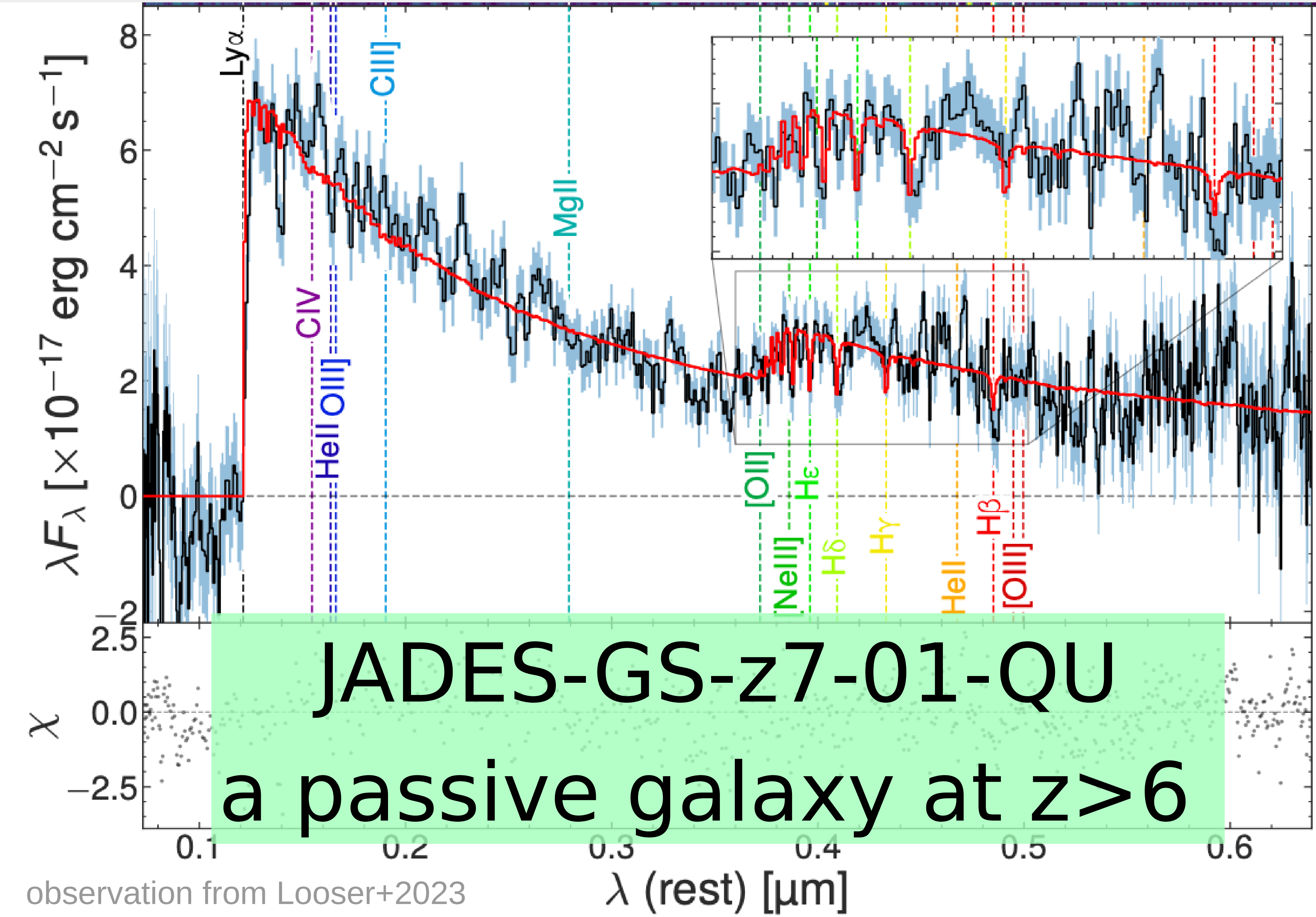
cfr Looser+2023, Gelli+23

Gelli+in prep



observation from Looser+2023

High-z galaxies via imaging & spectroscopy



observation from Looser+2023

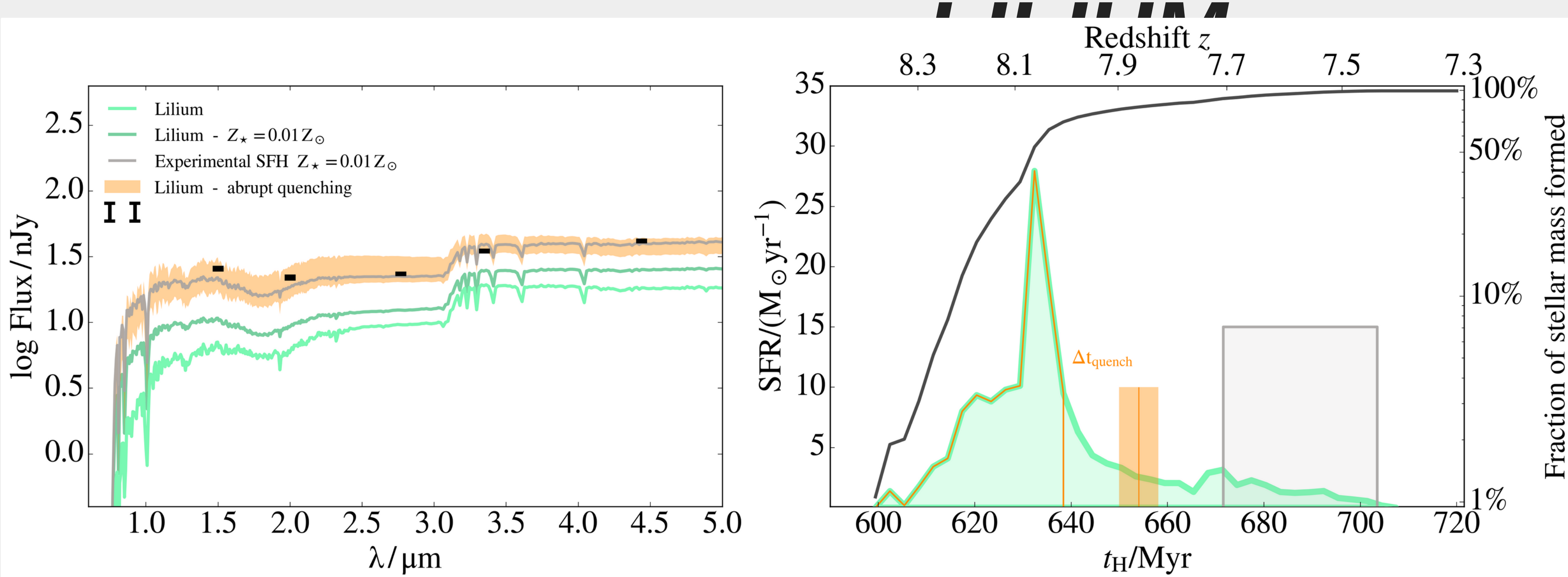
λ/µm λ/µm

Can we explain this passive galaxy at z=7.3?

Gelli+2023

closest analogue in SERRA

largest difference from the SFRh



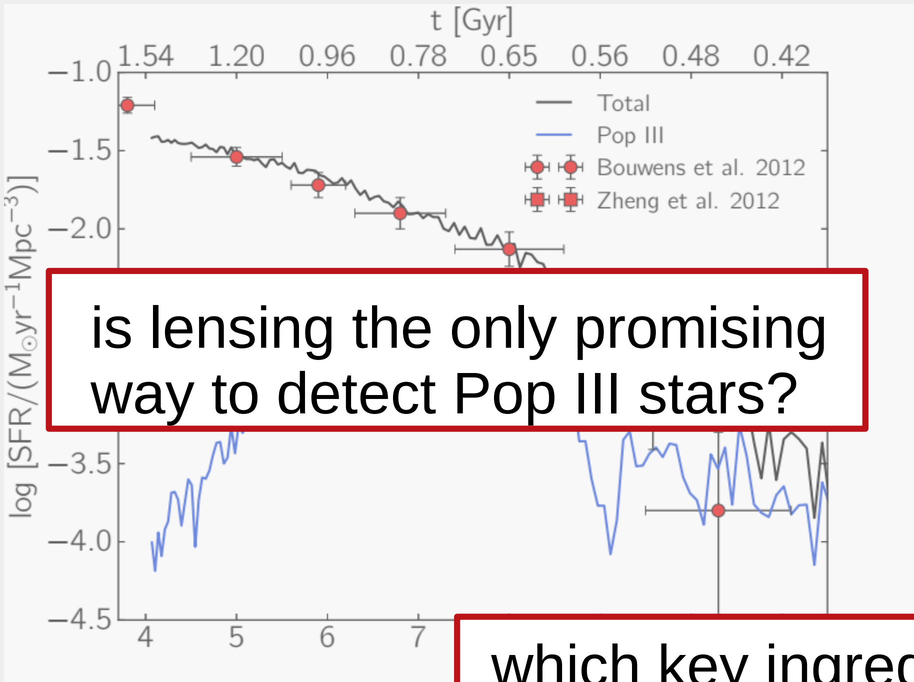
SN feedback cannot be the only responsible for the quenching of JADES-GS-Z7-01-QU

$/\mathrm{Z}_\odot \sim 10^{-2}$

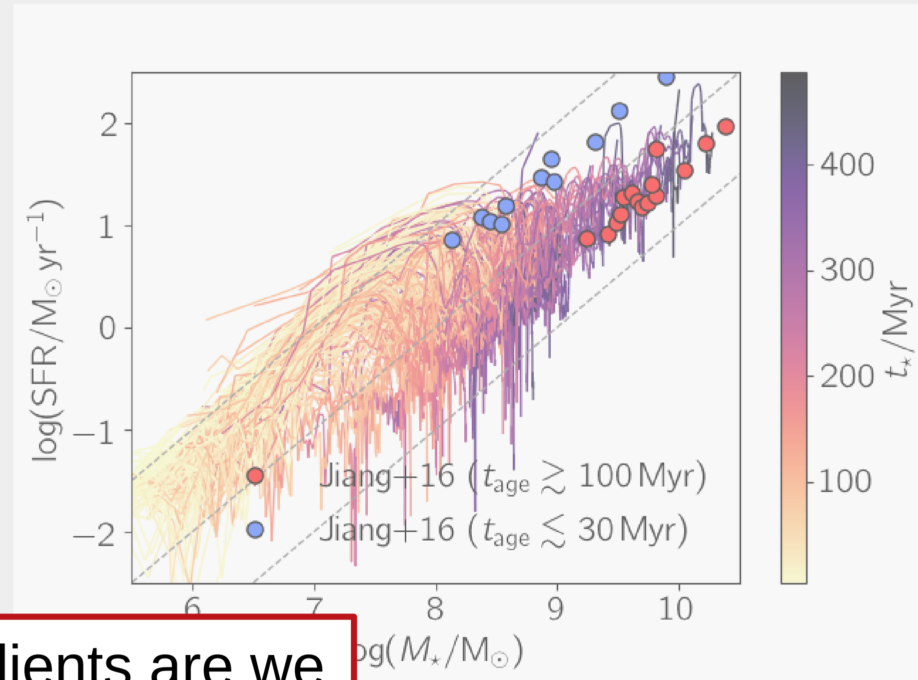
$/\mathrm{Z}_\odot \sim 0$

Conclusions/possible discussion points

Pallottini+2014



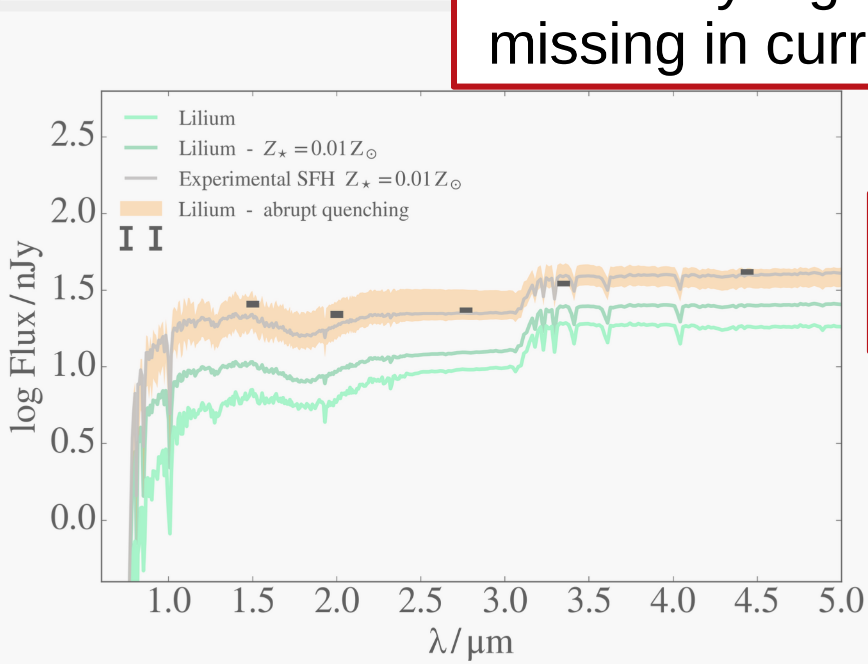
is lensing the only promising way to detect Pop III stars?

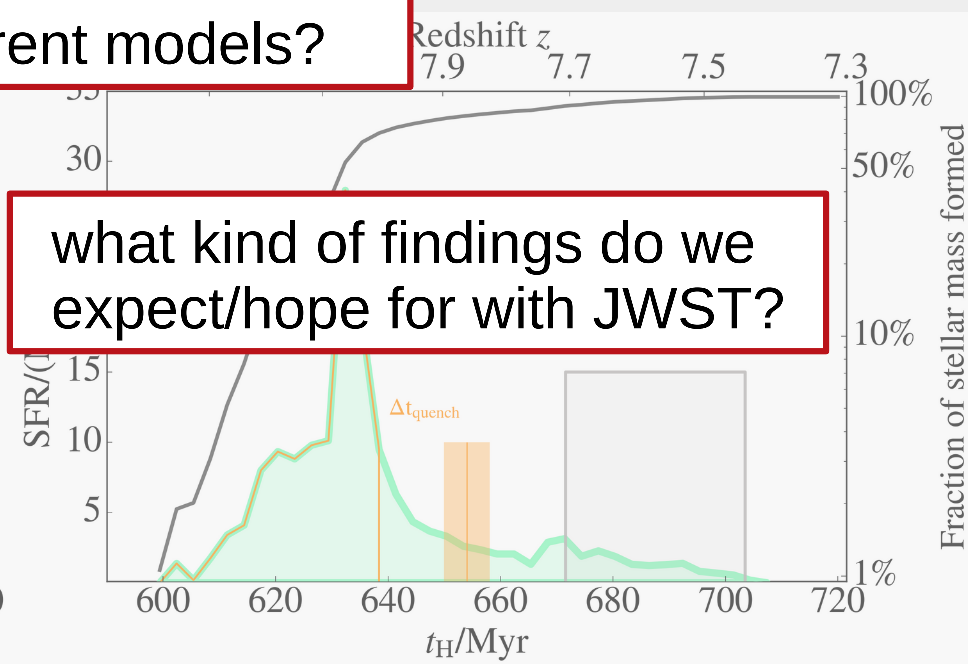


Pallottini+2022

which key ingredients are we missing in current models?

Gelli+2023





what kind of findings do we expect/hope for with JWST?