Modelling infrared line emission from high-z galaxies

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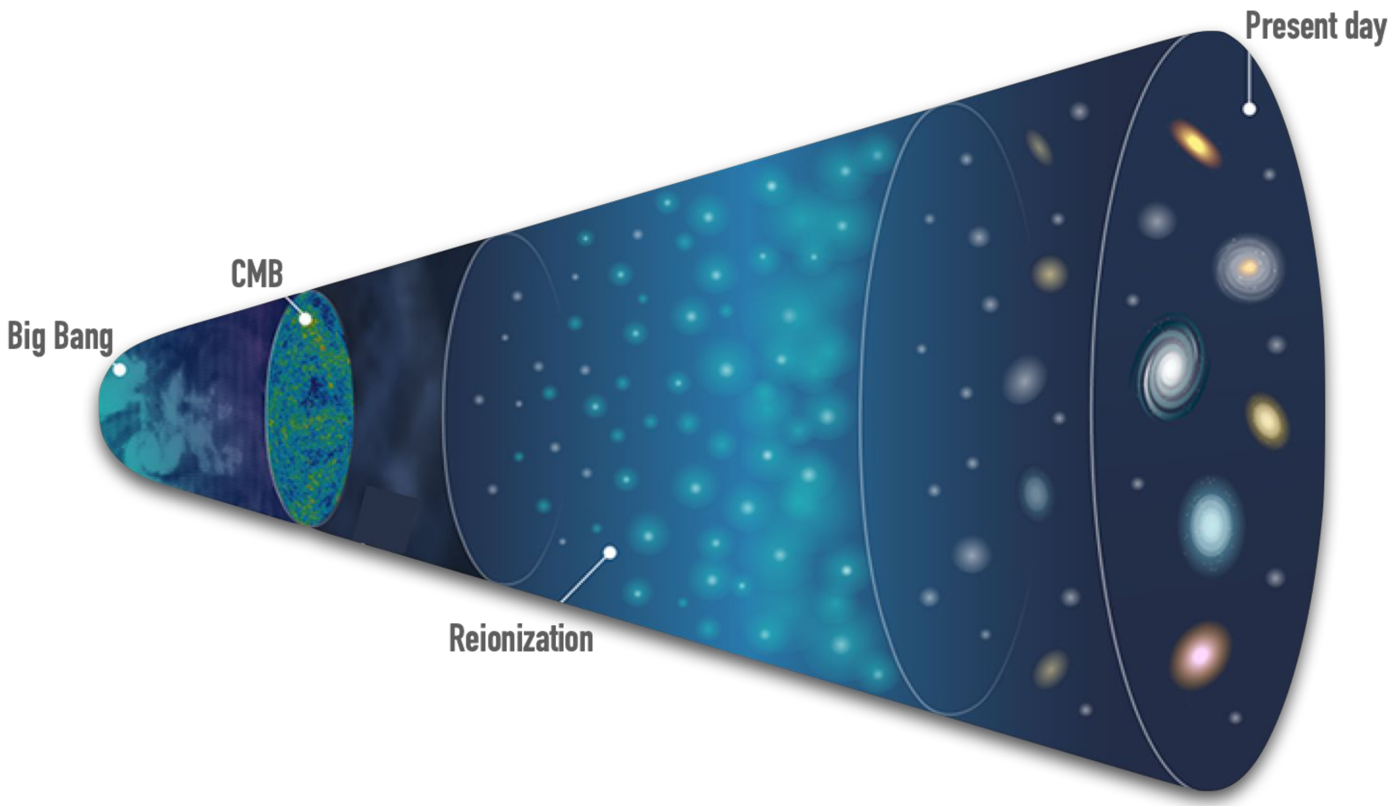
Motivation



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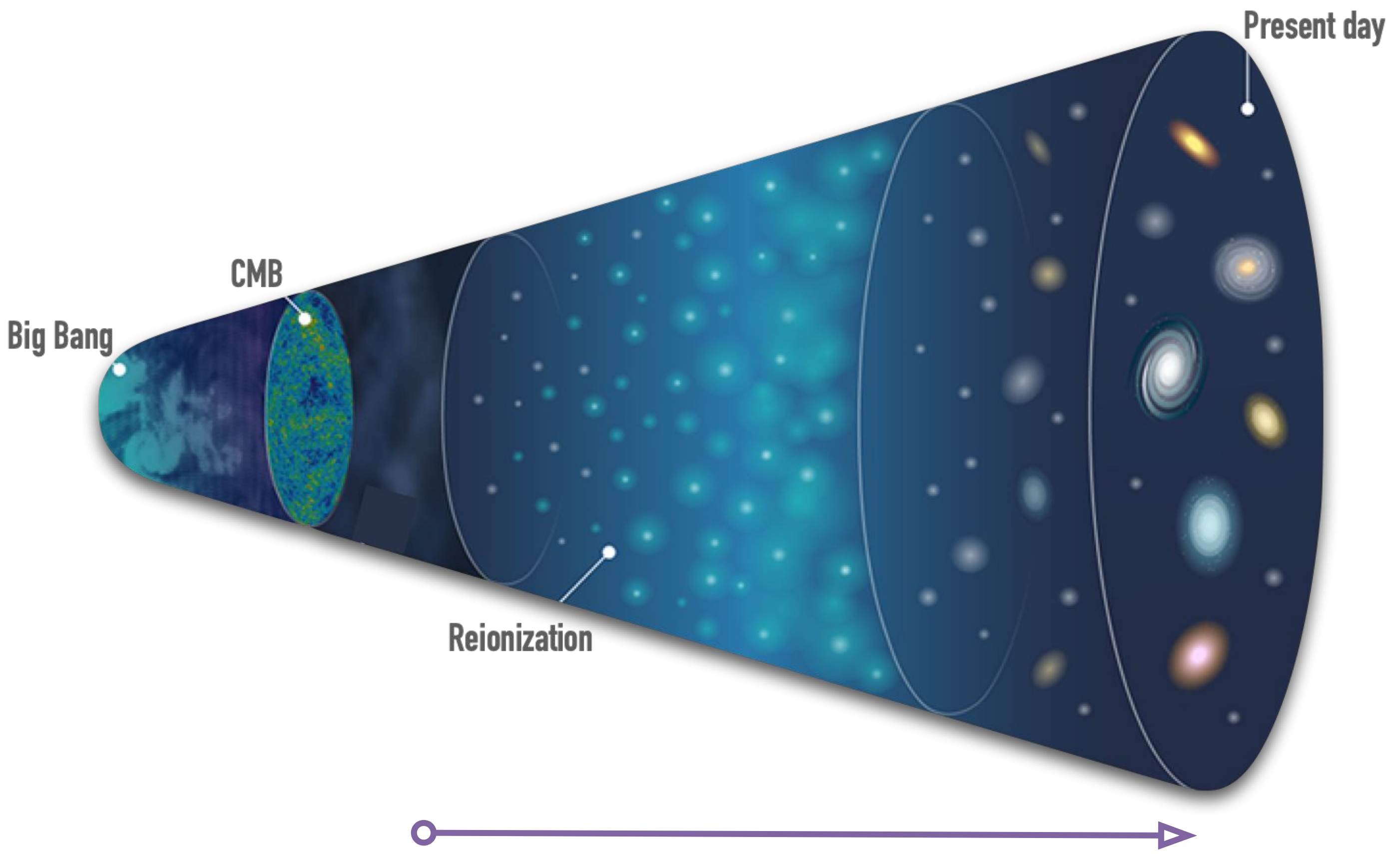

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ISM and CGM properties
density, different gas phases,metallicity…

conversion of gas into stars
Kennicutt-Schmidt relation, depletion time …

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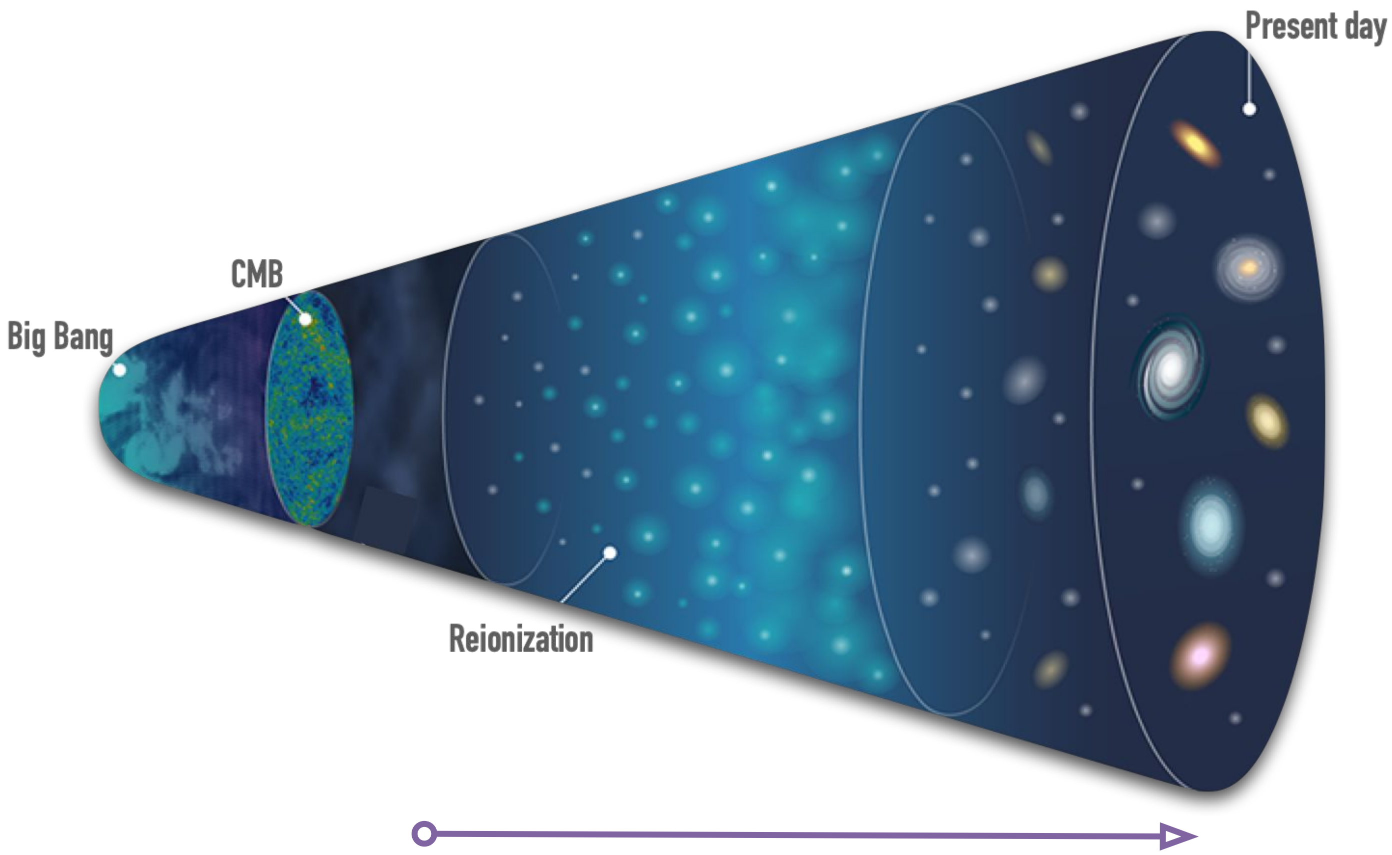

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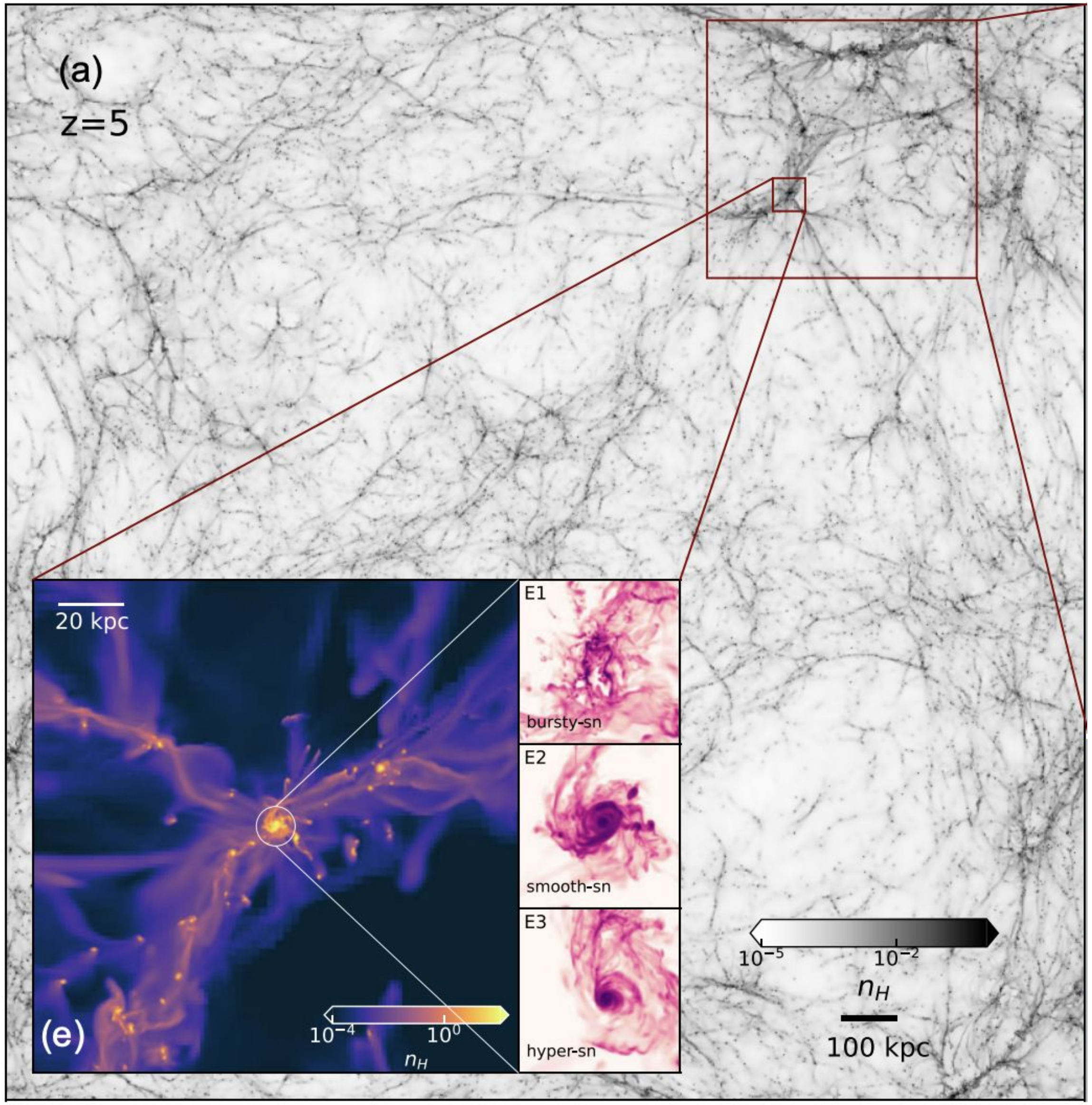
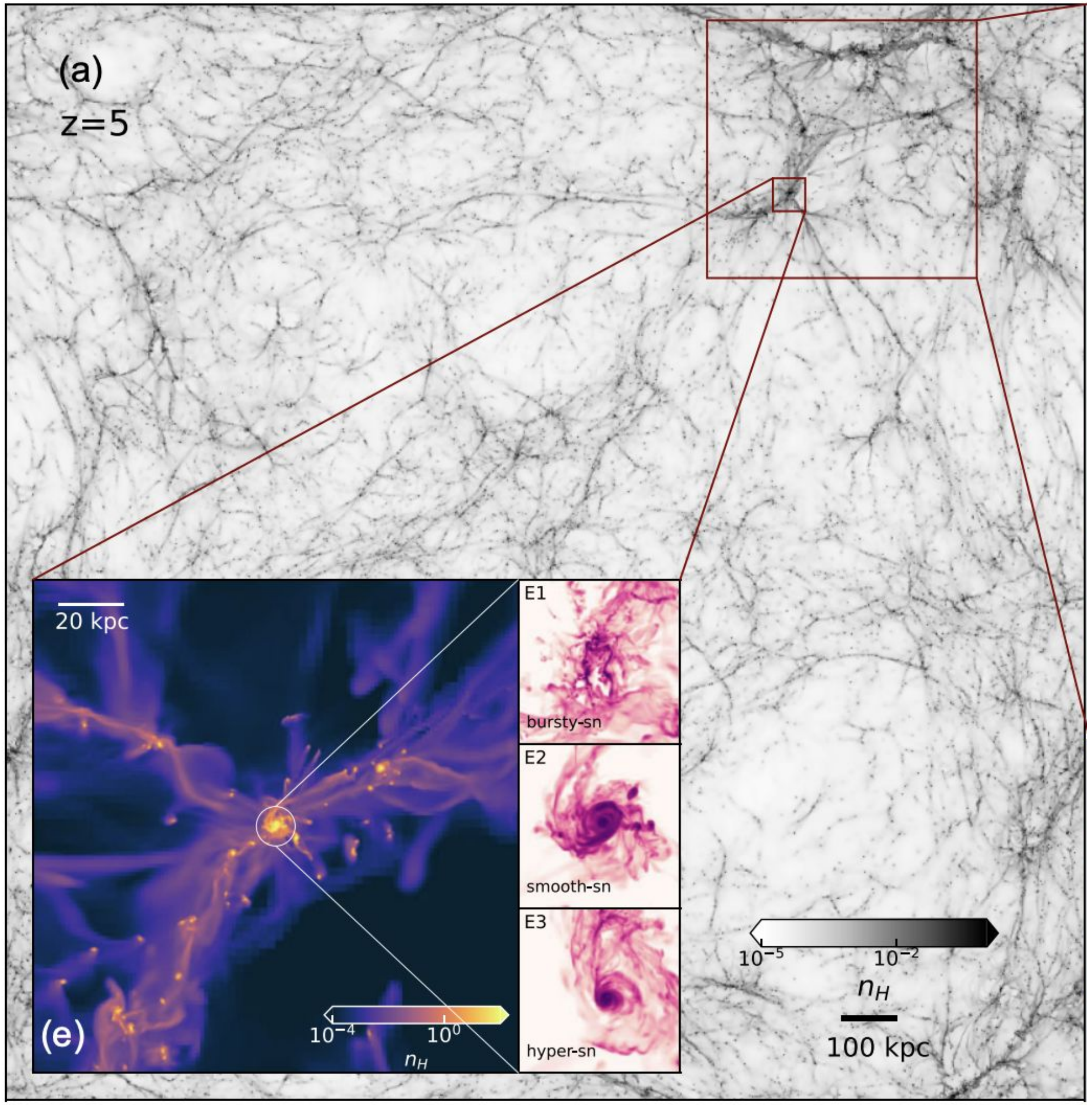


Bhagwat+23

Cosmological zoom in simulations

Effect of environment and gas flows

Effect of different feedback mechanisms



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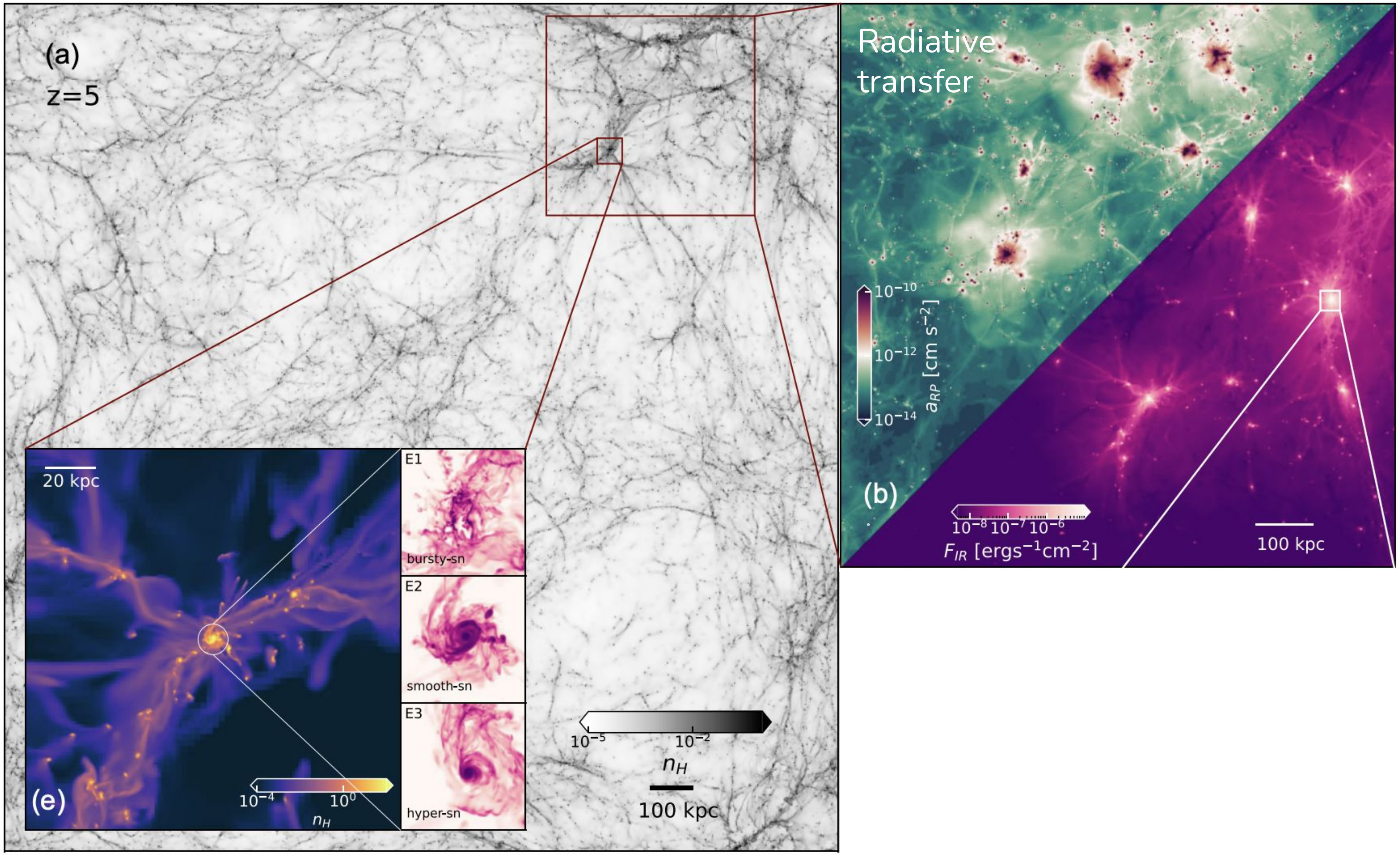

Emission at different frequencies

Bhagwat+23

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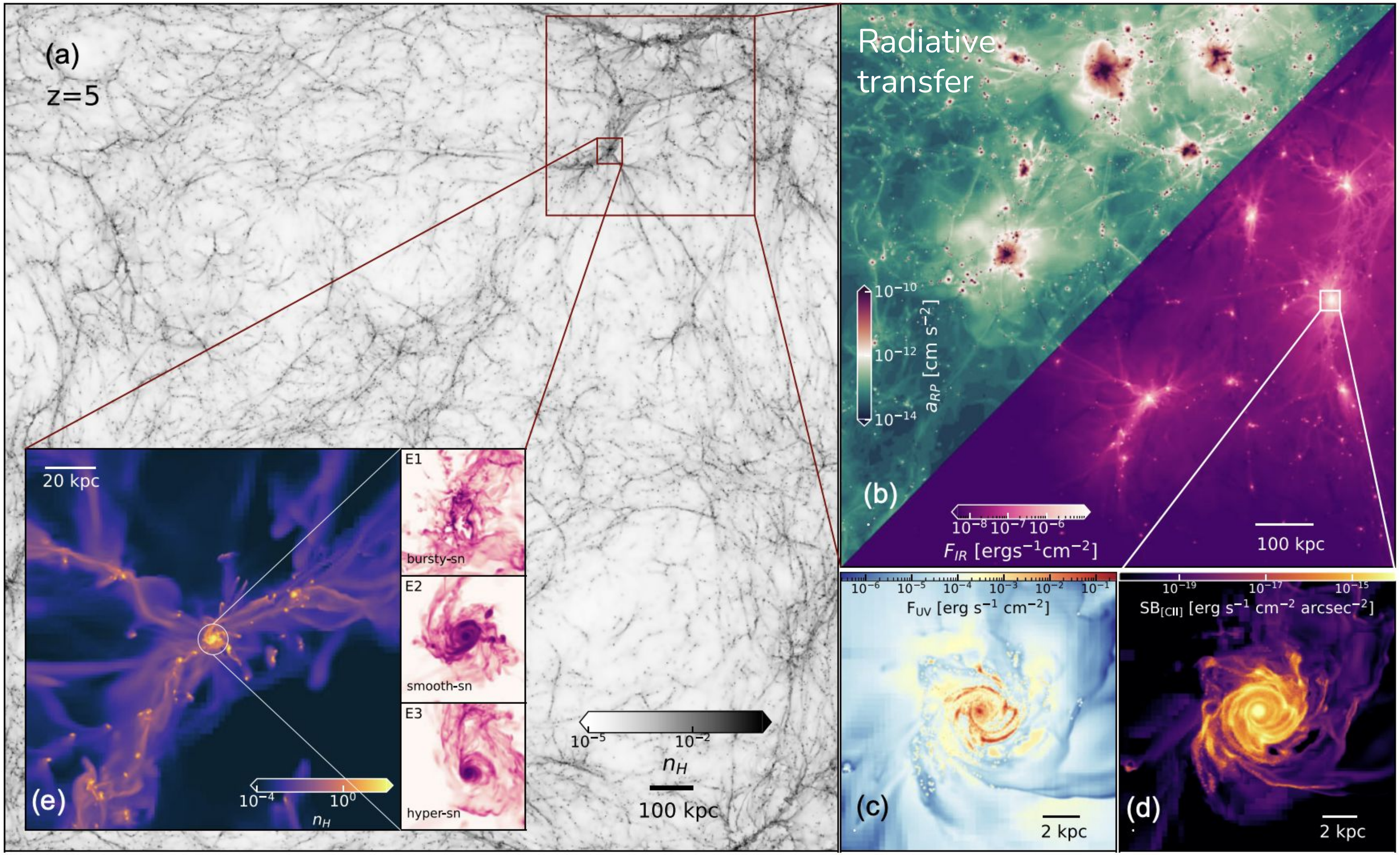


Bhagwat+23

Emission at different frequencies

Mock observations

The SERRA cosmological zoom-in simulation

Movie of the SERRA simulation

Pallottini,LV +19,22

model highlights

Resolution	
gas mass	$m_g \simeq 10^4 \mathrm{M}_\odot$
AMR	$\sim 80 - 0.1\,\mathrm{ckpc/h}$
at $z = 6$	$\Delta x \simeq 30\,\mathrm{pc}$

- non-equilibrium chemical networks to form molecular hydrogen and in turn it into stars
- radiation field traked on the fly to account for ionization and photodissociation effetcs

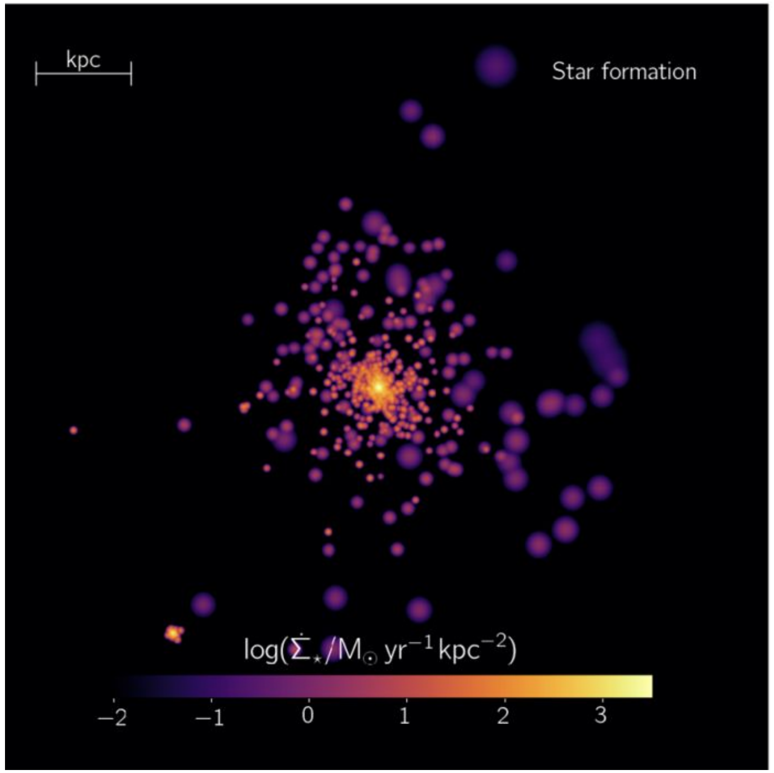
properties of SERRA galaxies

number:	**~1000 (keep growing)**
redshift range:	15<z<4
stellar mass:	$10^7 < M_\star/M_\odot < 5\times10^{10}$
UV magnitude:	$-21 < M_{UV} < -16$
FIR luminosities:	$10^9 < L_{UV}/L_\odot < 10^{12}$
[CII] luminosities:	$10^7 < L_{UV}/L_\odot < 10^9$ Lsun

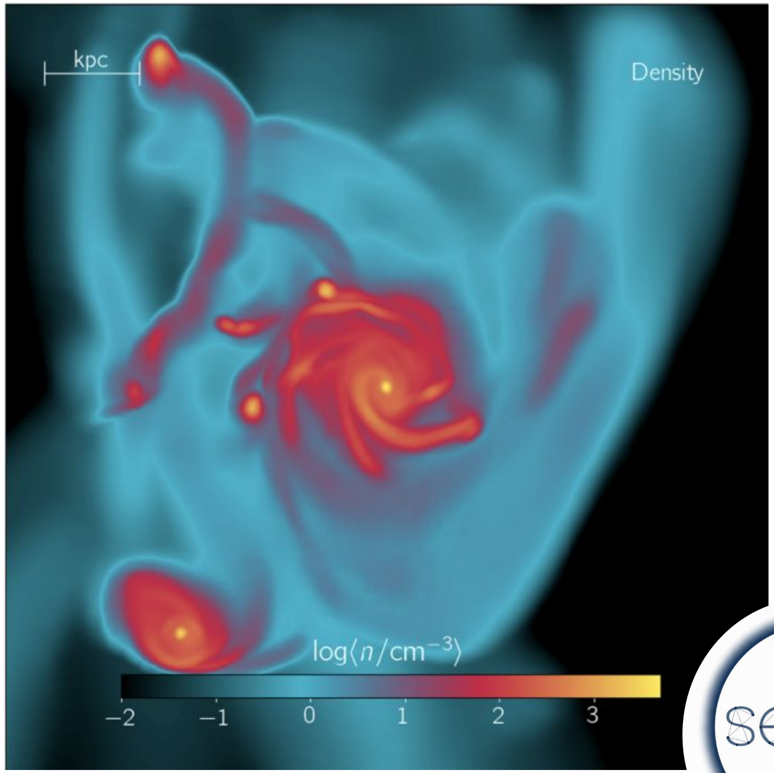
from cosmological to molecular cloud scales

Resolving the star formation down to GMC scales

map of Σ_{sfr}



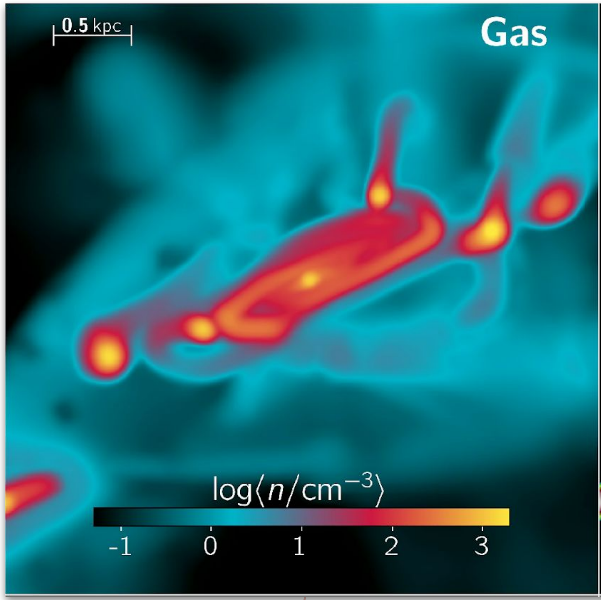
map of Σ_{gas}



Pallottini+19,22, Vallini+21

serra

Implementing ISM physics in simulations



PDR models
including heating and
cooling in neutral gas

[CII], [OI] emission

Vallini+15,17

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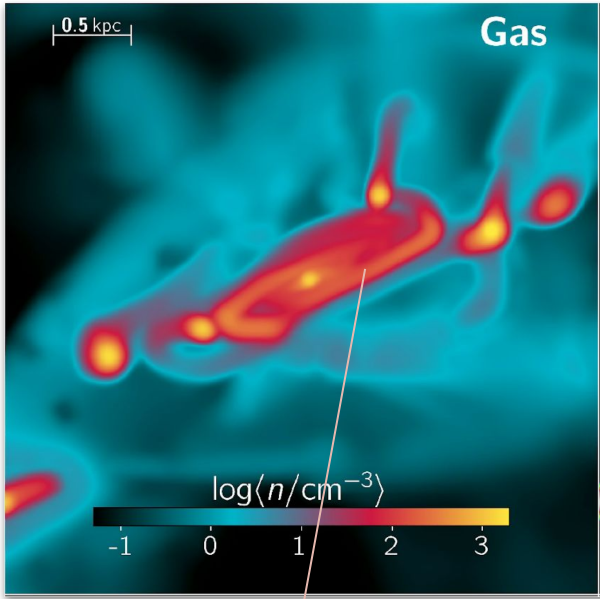

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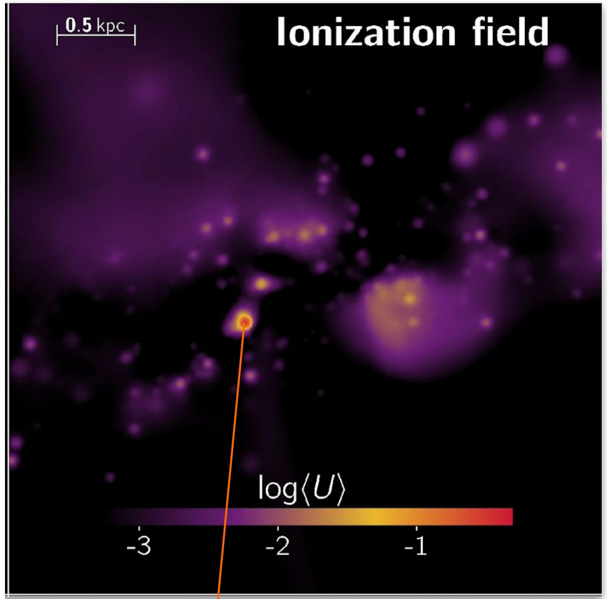


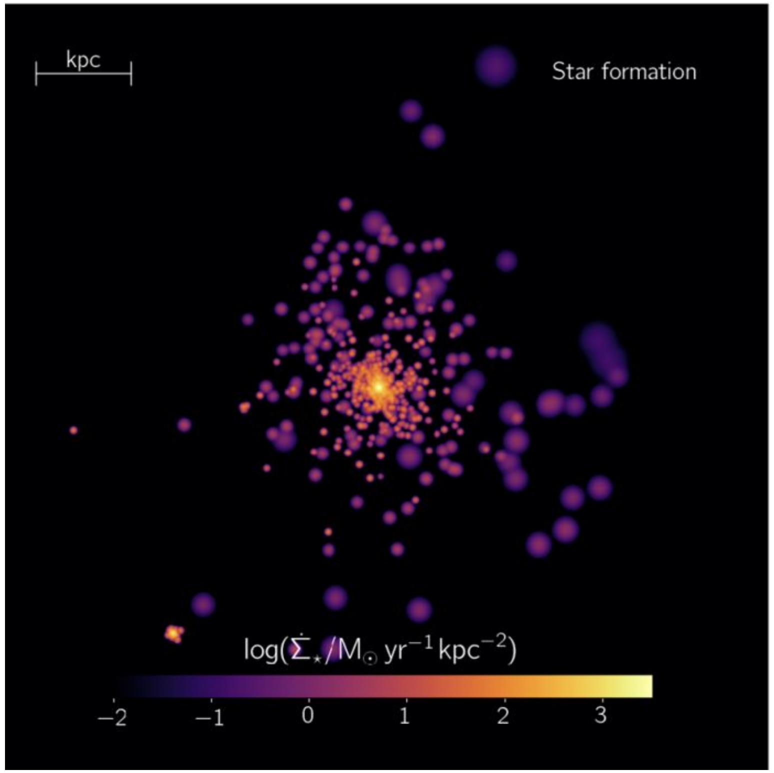
Radiative transfer
for computing the HII
region properties and

[OIII] 52μm,88μm

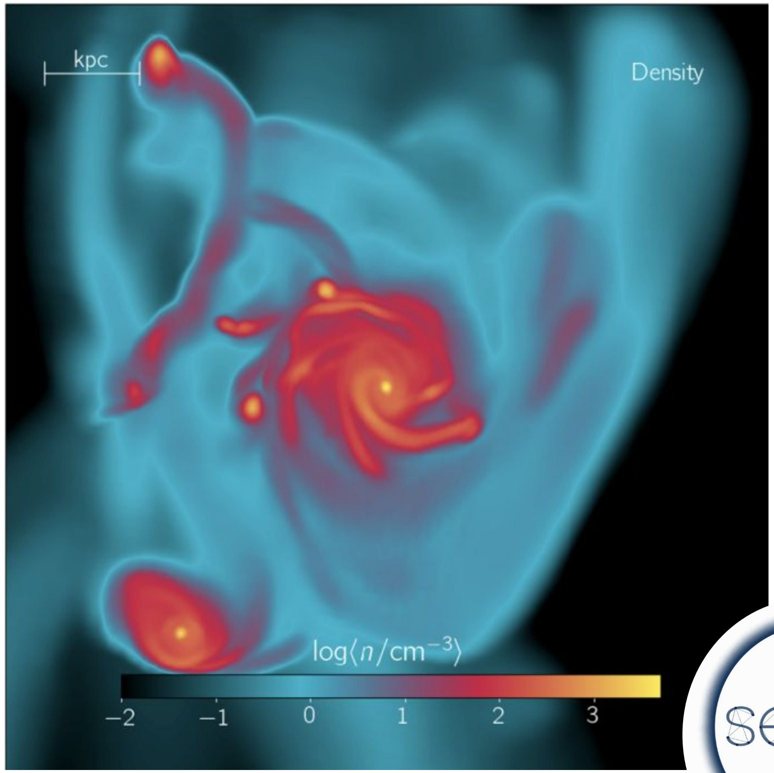
Vallini+21

Linking the star formation and gas surface densities

map of Σ_{sfr}



map of Σ_{gas}

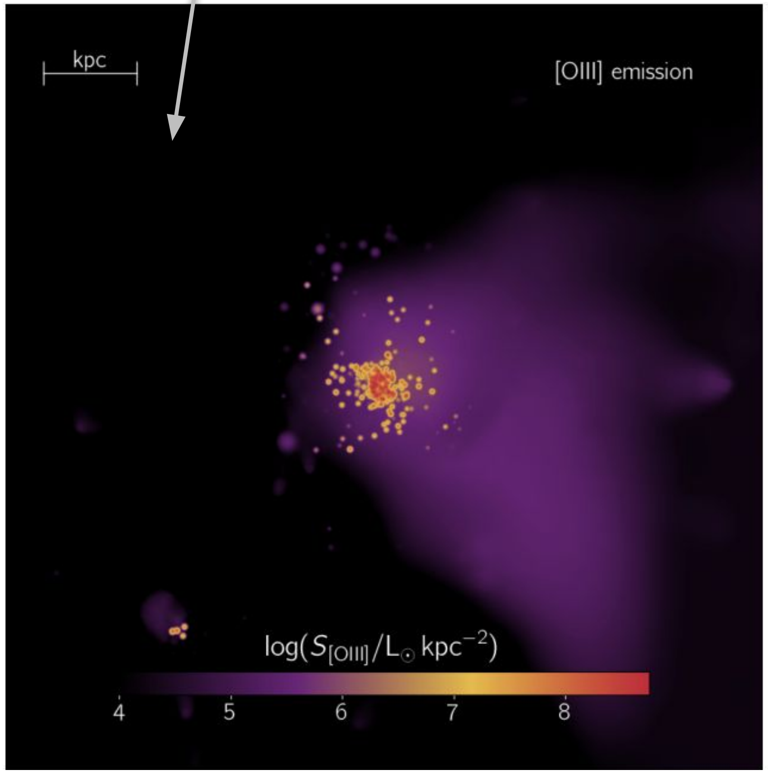


Pallottini+19,22, Vallini+21

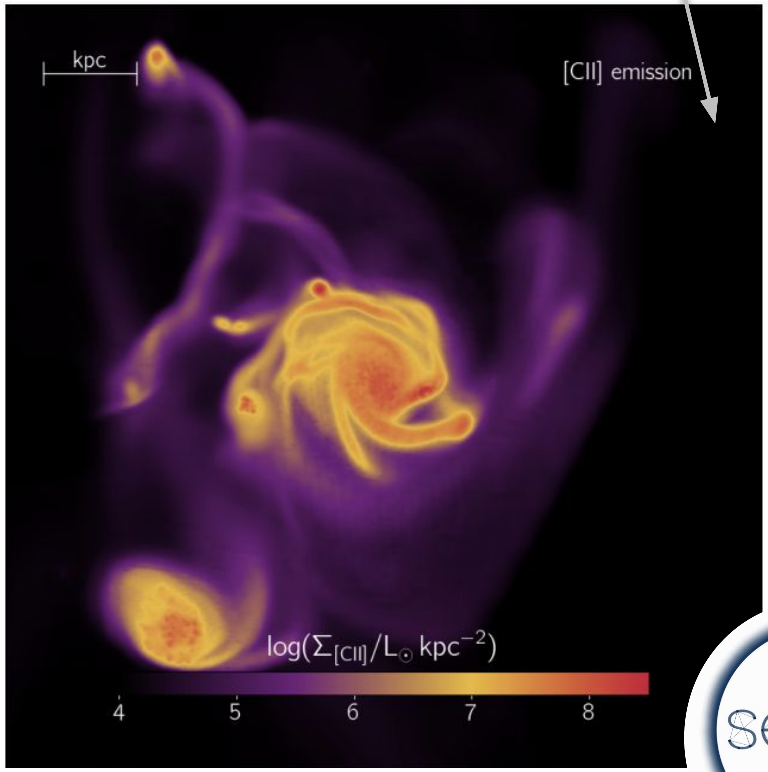
Linking the star formation and gas surface densities to line emission

Using tracers of **different gas phases** to investigate the conversion of gas into stars

map of Σ_{OIII}



map of Σ_{CII}

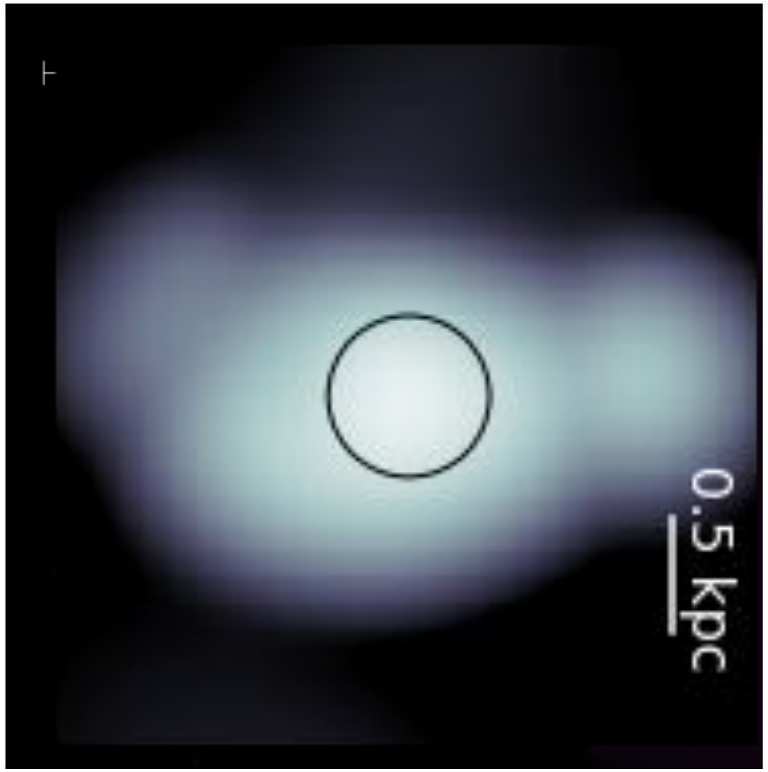


Pallottini+19,22, Vallini+21

Matching observational constraints

Take into account of observational setup, such as beam size, sensitivity, noise

map of Σ_{OIII}



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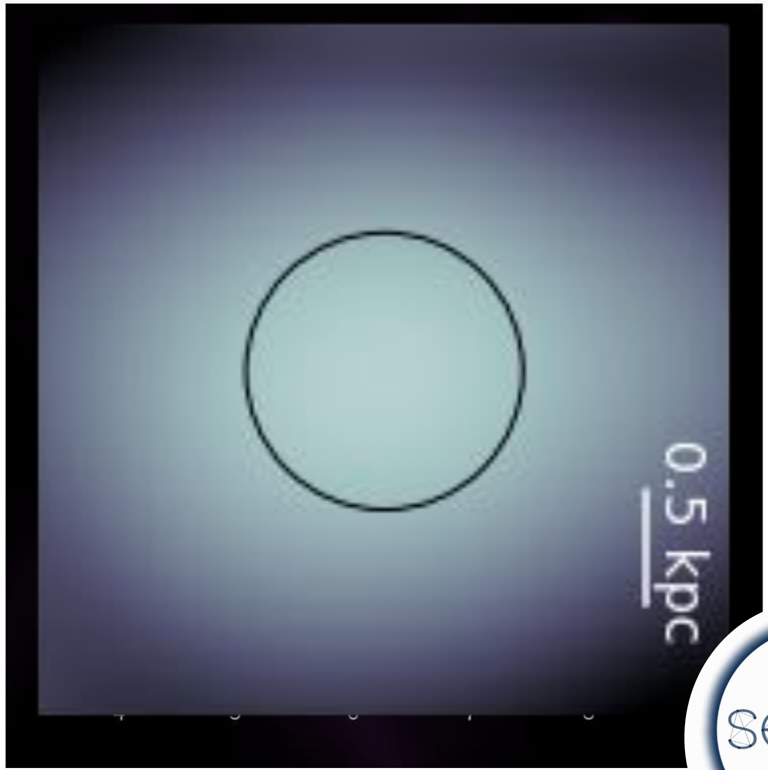
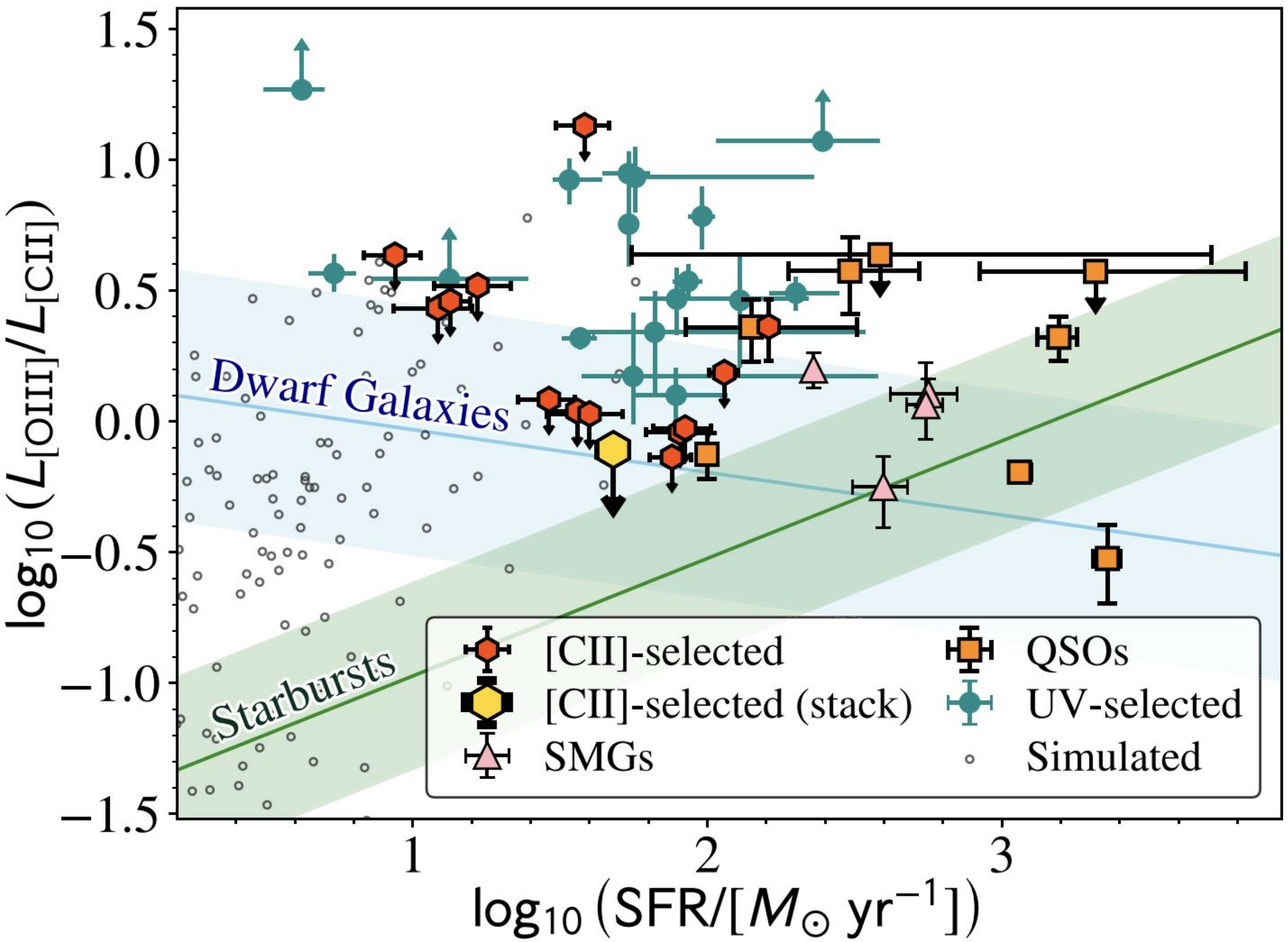


Pallottini+19,22, Vallini+21

High [OIII]/[CII] ratios at high-z: myth or reality?

Bakx+24



See also: Harikane+20, Carniani+20

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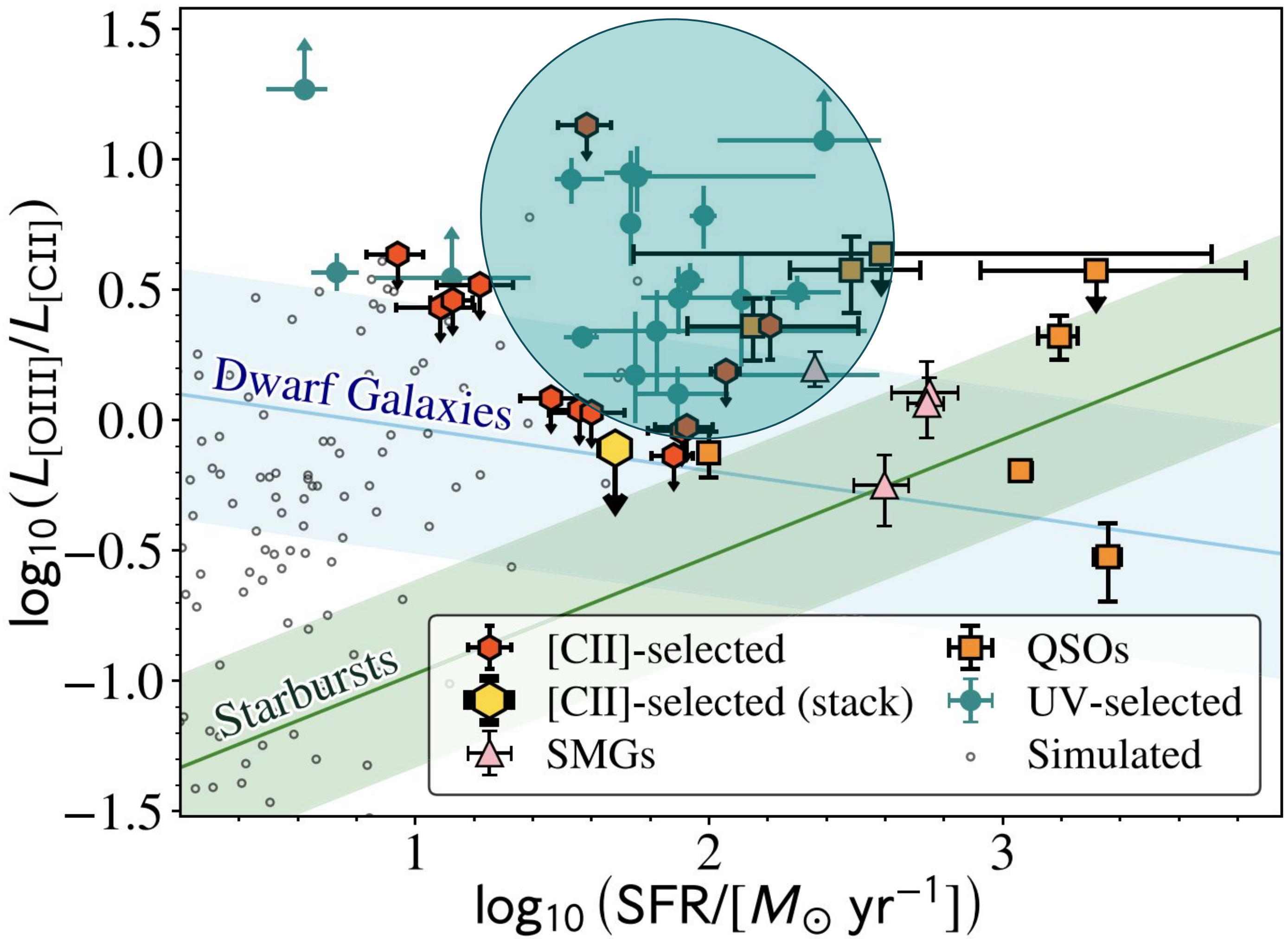

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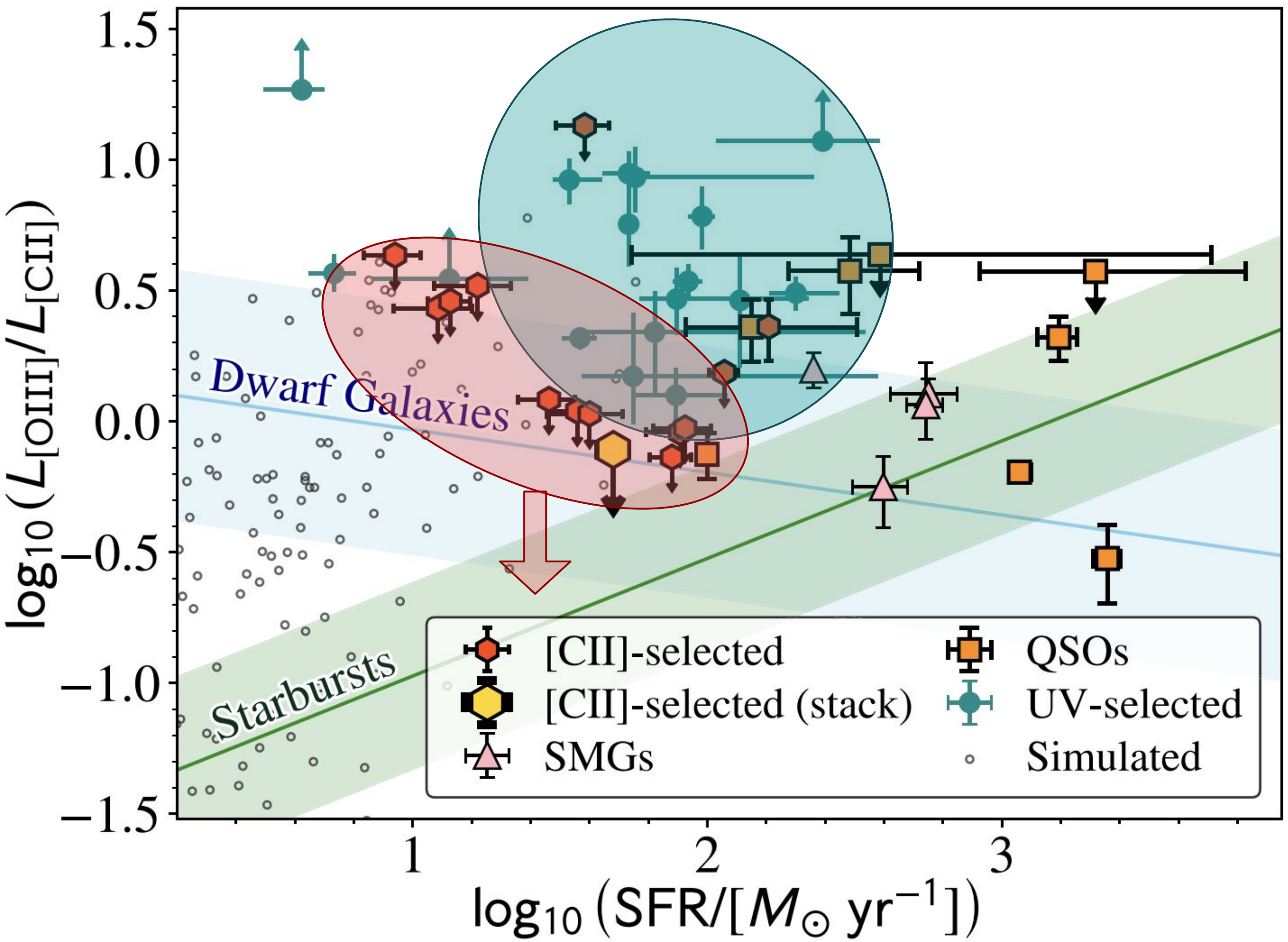

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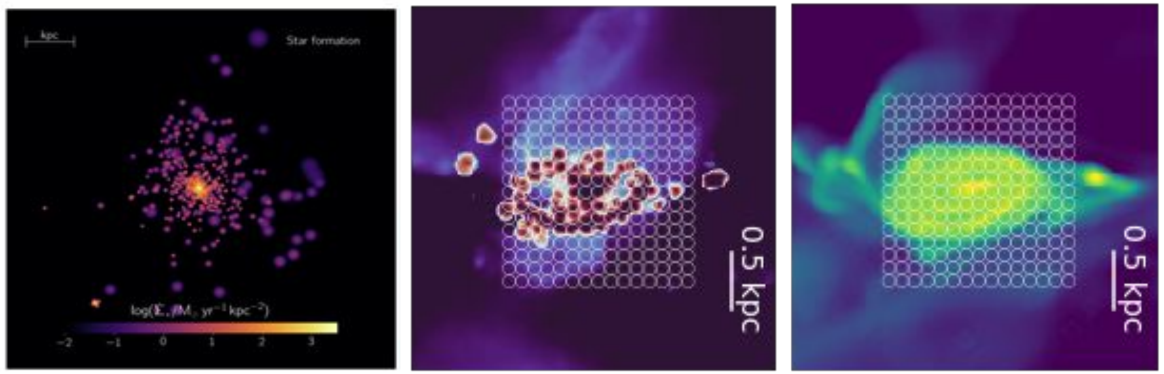
Explaining the high [OIII]/[CII] ratios in the EoR

Vallini+21



UV map [OIII] map [CII] map

Resolution of the simulation ~10 pc

Explaining the high [OIII]/[CII] ratios in the EoR

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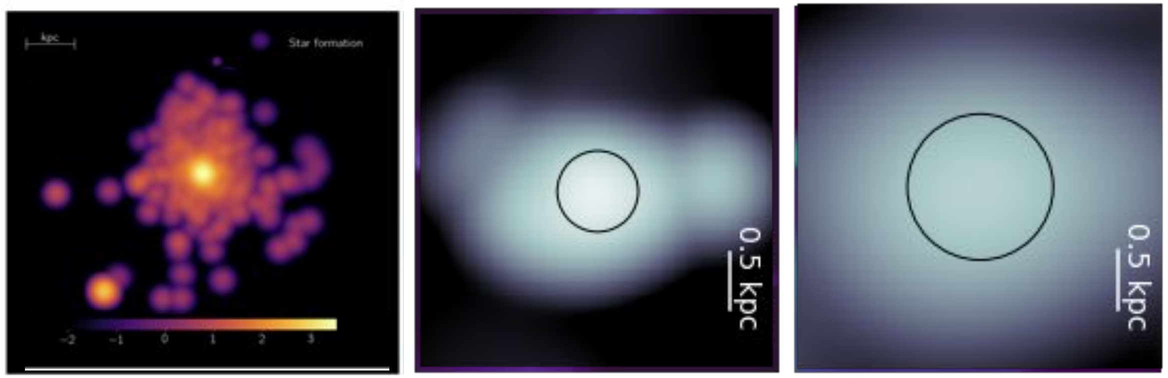

UV map [OIII] map [CII] map

Considering the beam smearing of typical ALMA observations in the EoR

↓

Computing Σ_{CII} and Σ_{OIII}

Explaining the high [OIII]/[CII] ratios in the EoR

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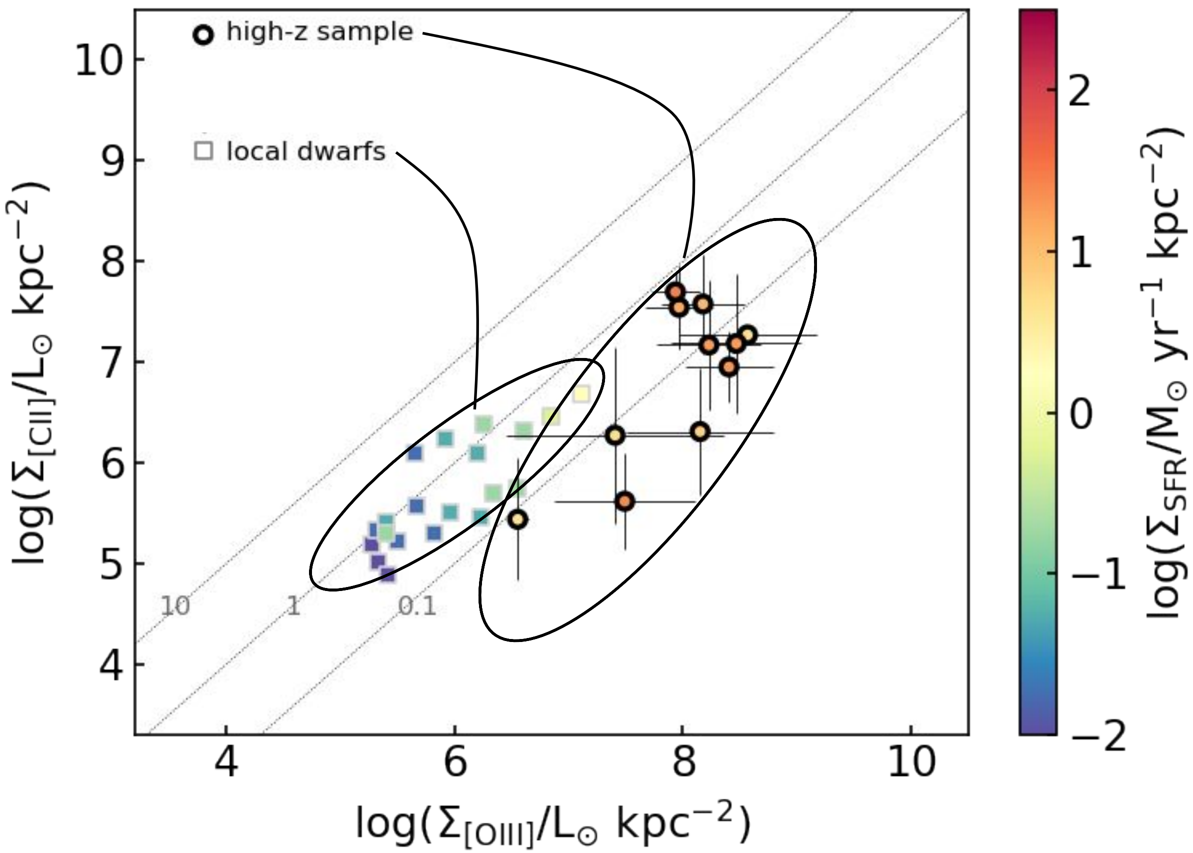

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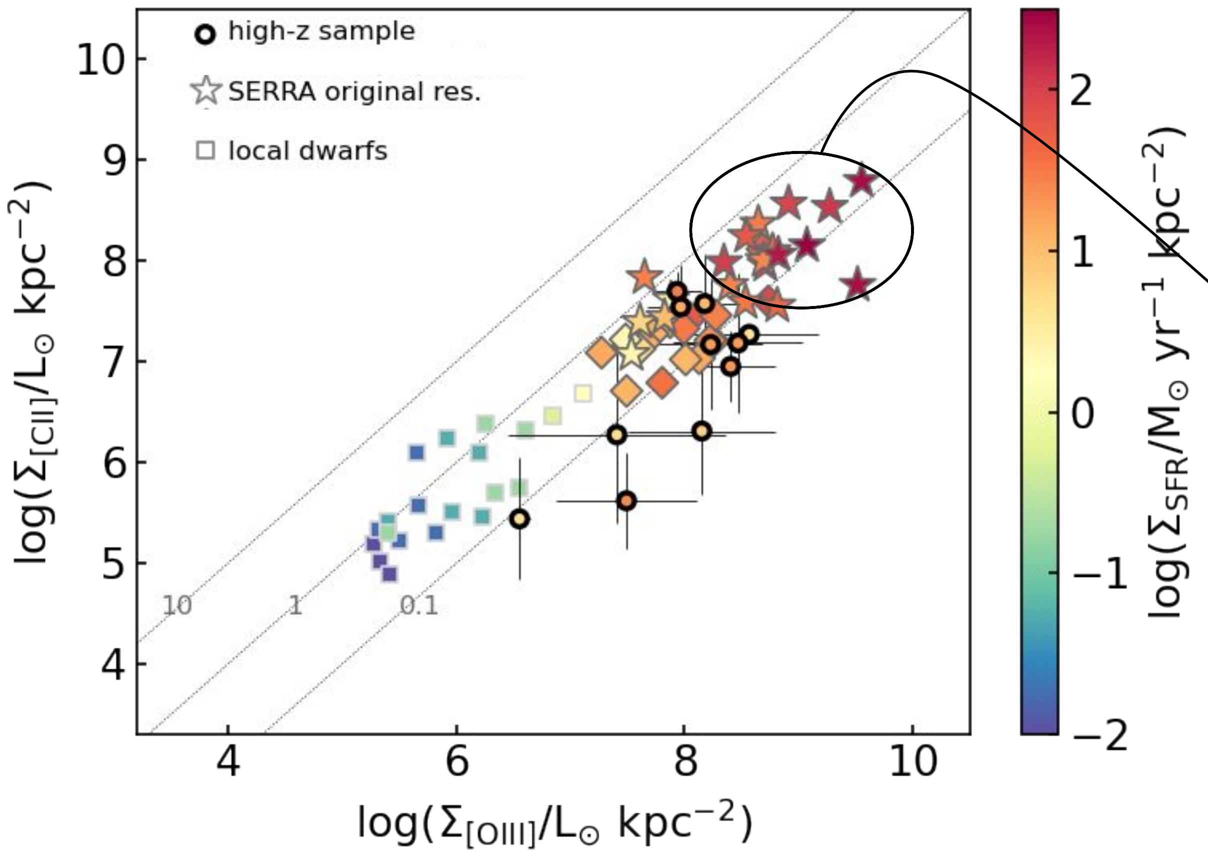

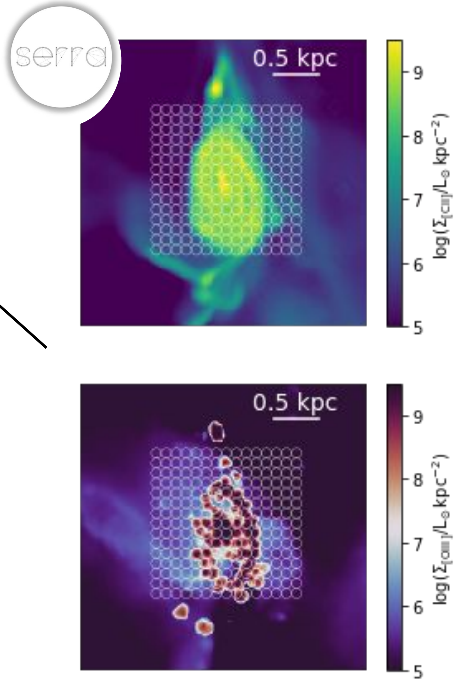

SERRA Simulation at z=7.7

Pallottini+22

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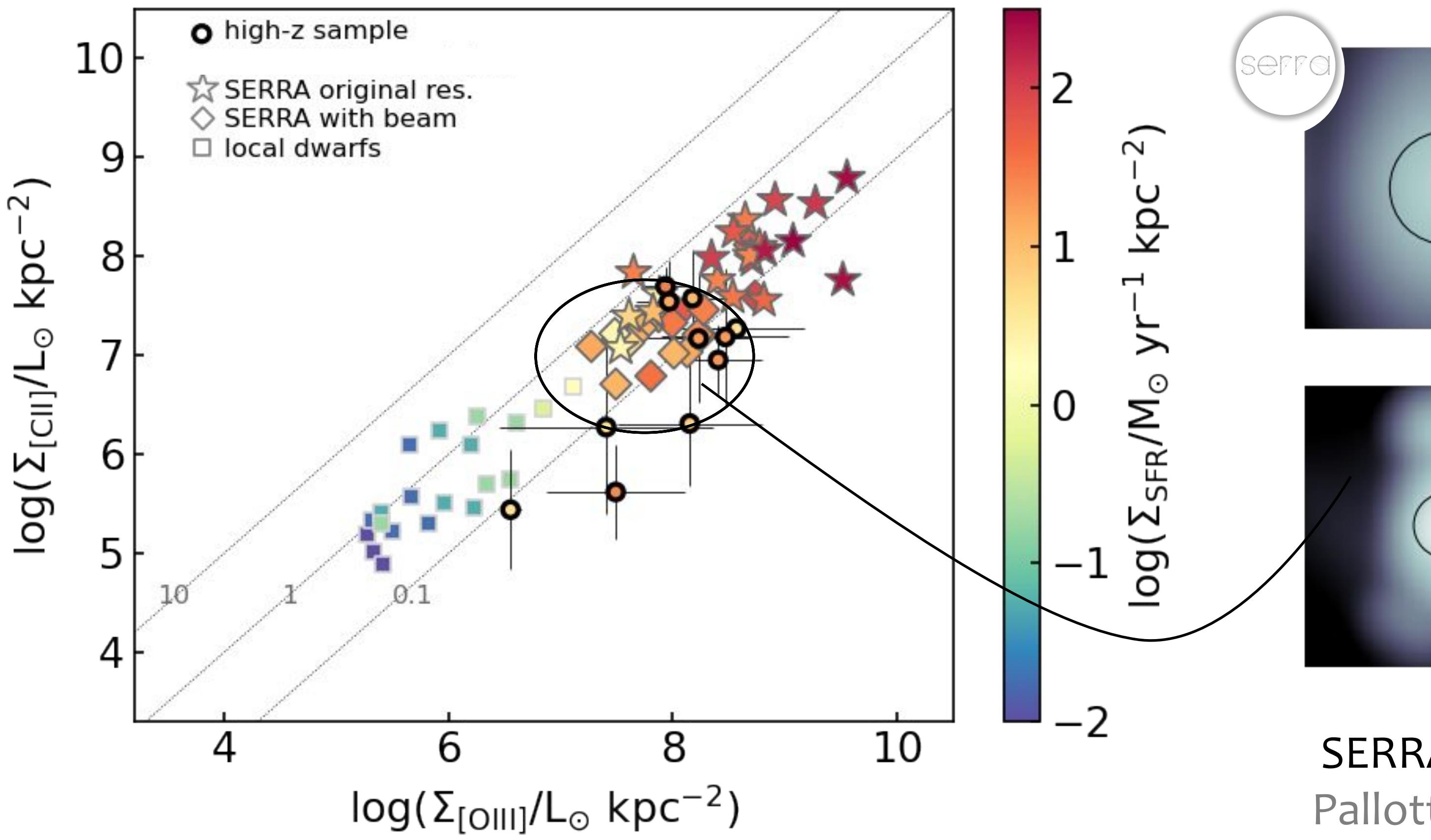

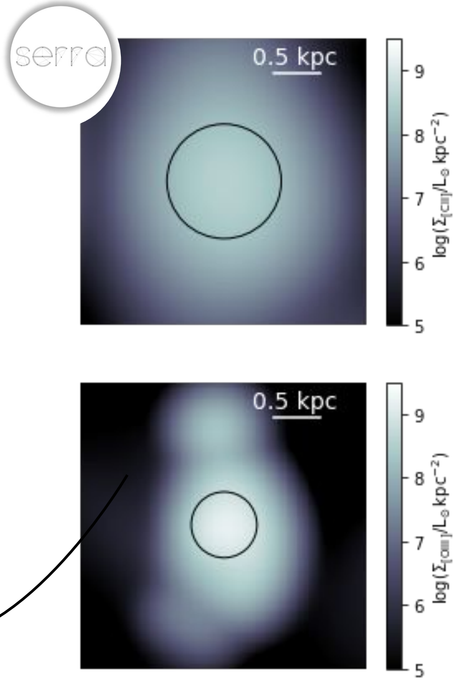

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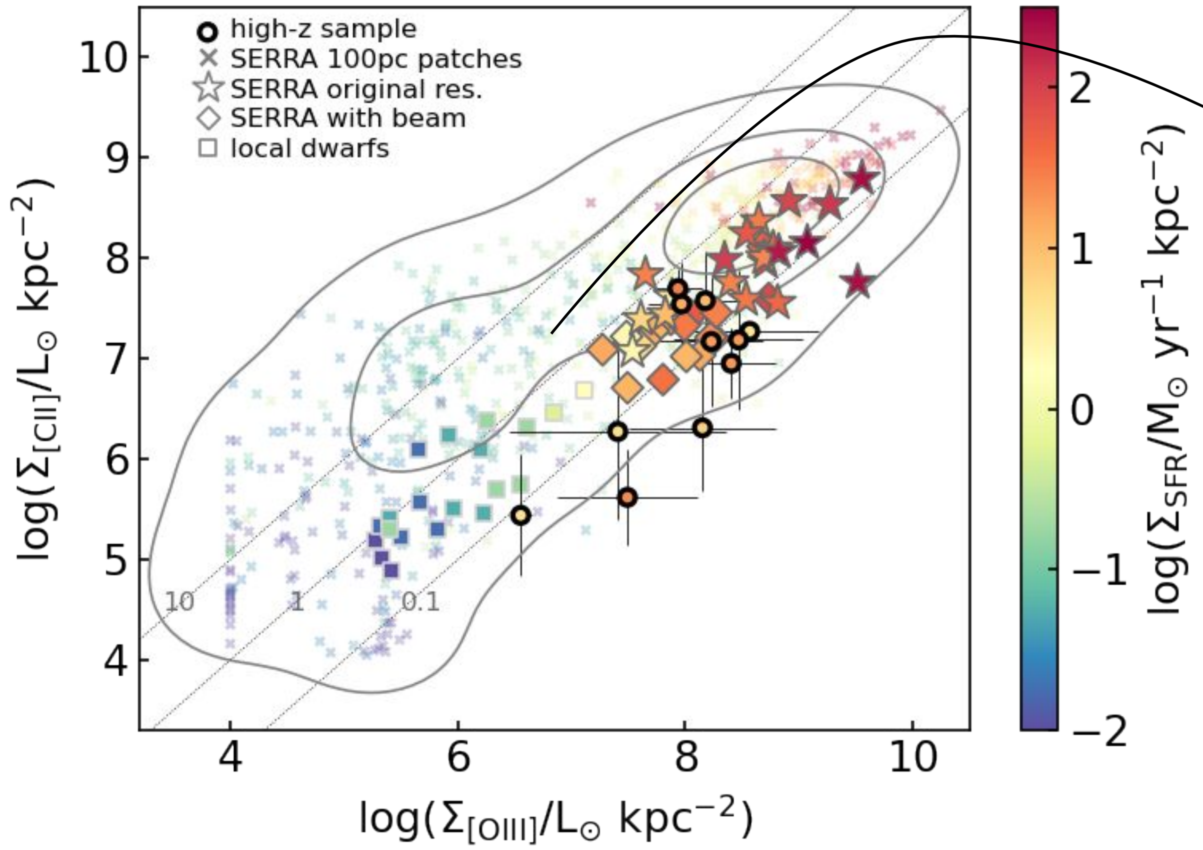

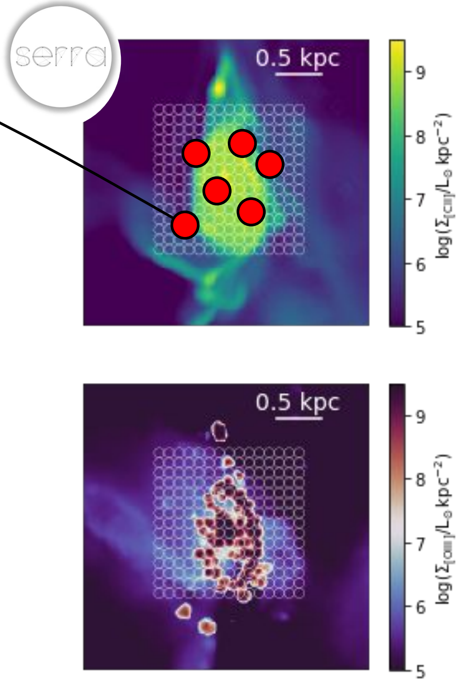

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High [OIII]/[CII] ratios correlate with burstiness

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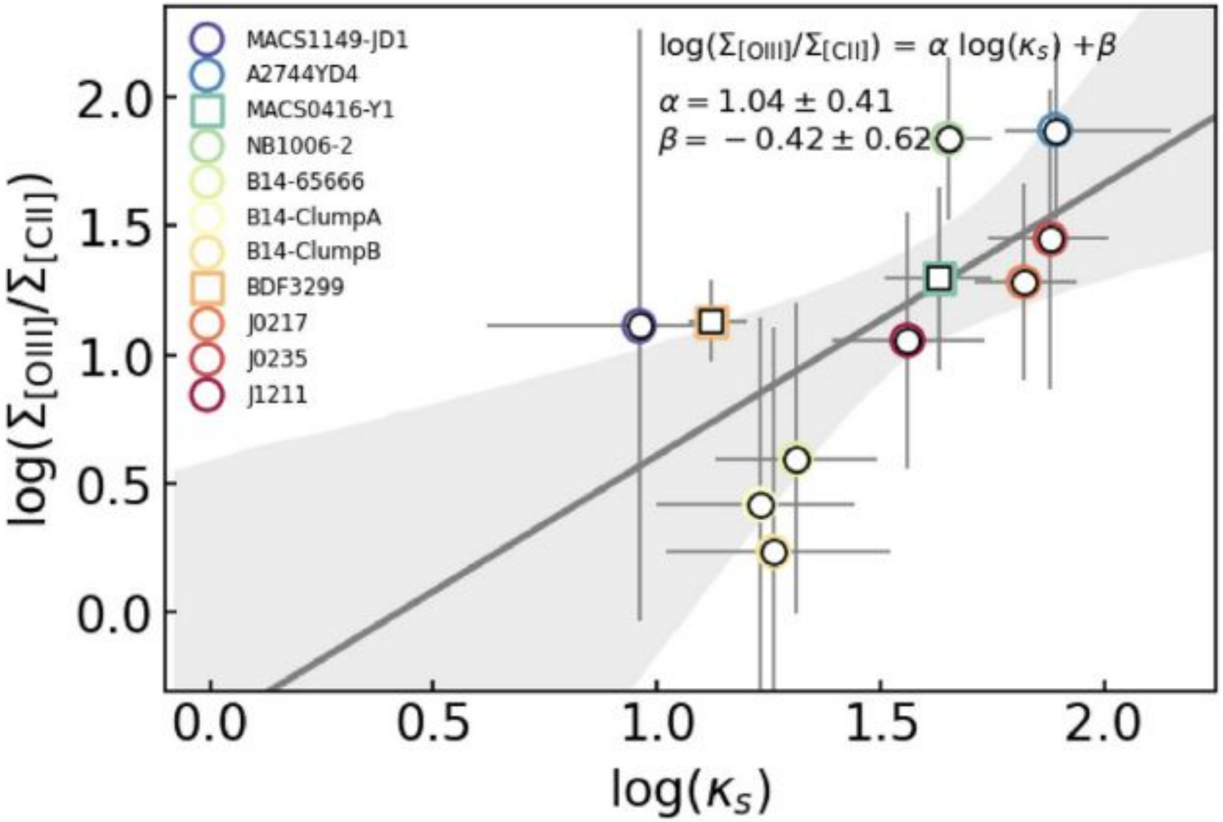

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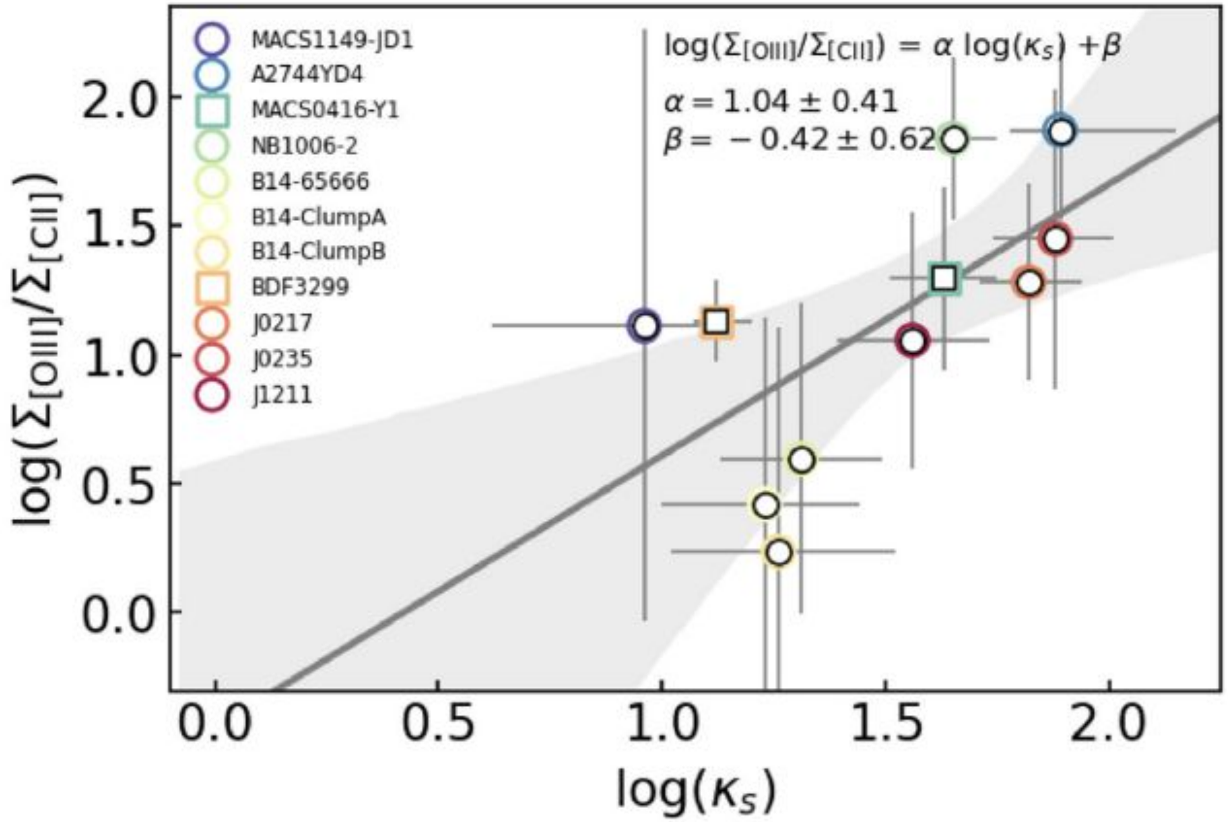
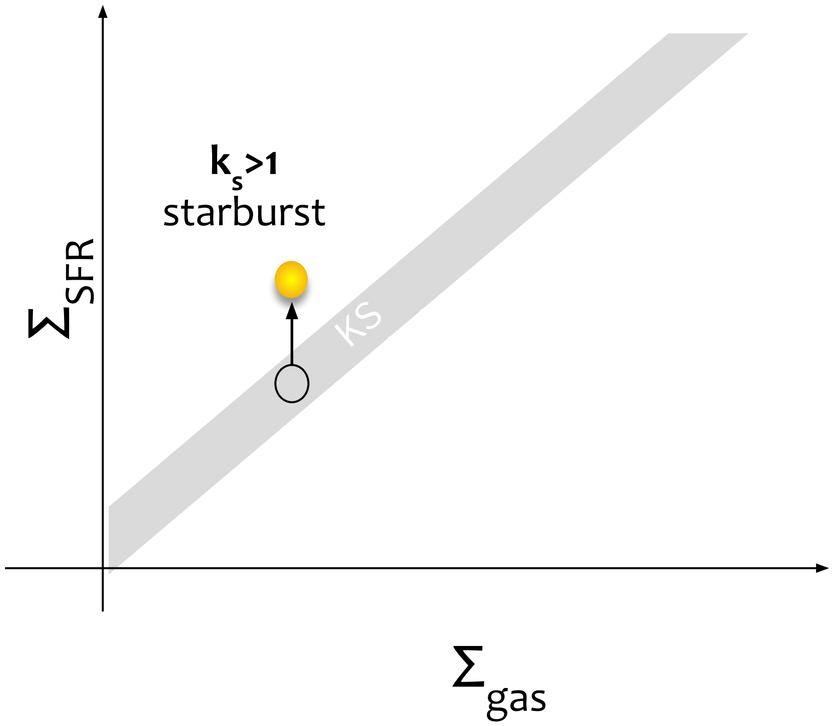


The KS relation $\Sigma_{SFR} = \mathbf{k_s}\, \Sigma_{gas}^{1.4}$



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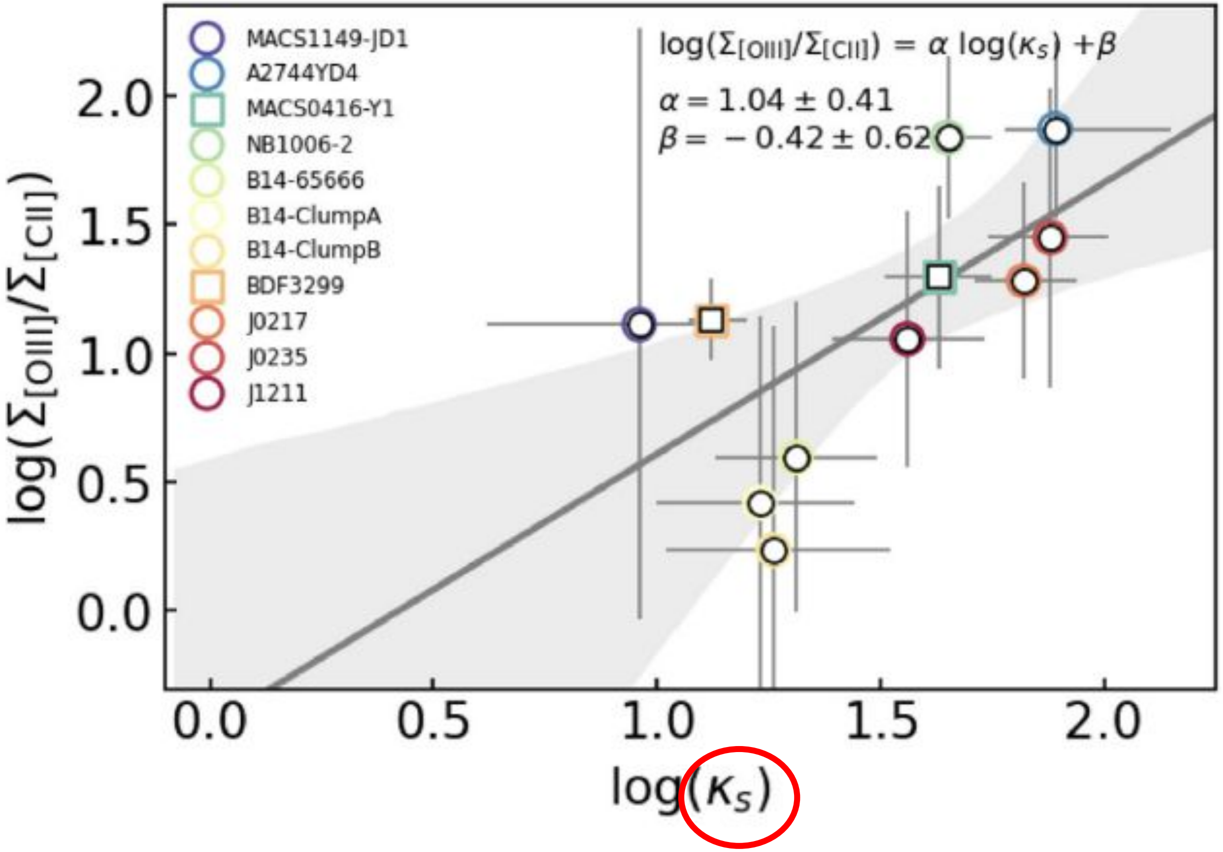

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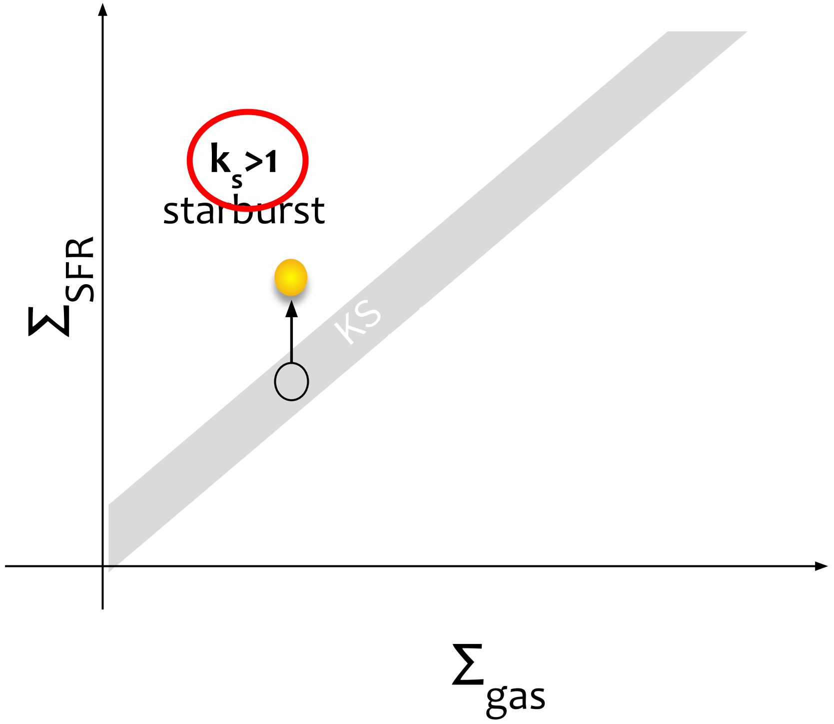
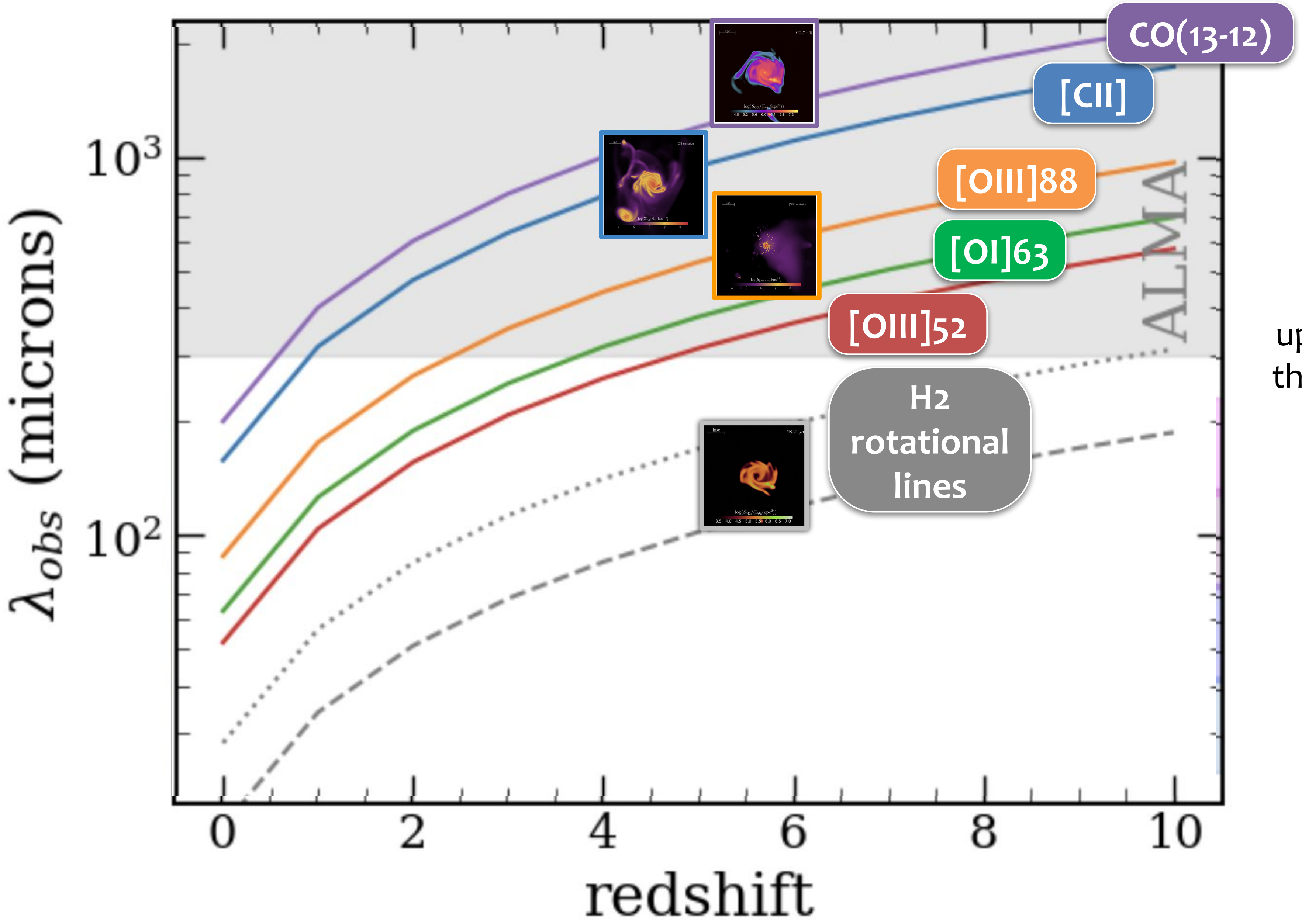


[OIII]/[CII] evolves with redshift?

What about the ratios at cosmic noon?

- Large samples of [OIII]88 and [OIII]52 emitters are needed
- [OI]63um from PDRs can be used instead of [CII]158um, if needed

How to bridge the gap between redshifts?



SERRA simulations are available up to z=4, with the plan of evolving the simulation up to lower redshifts

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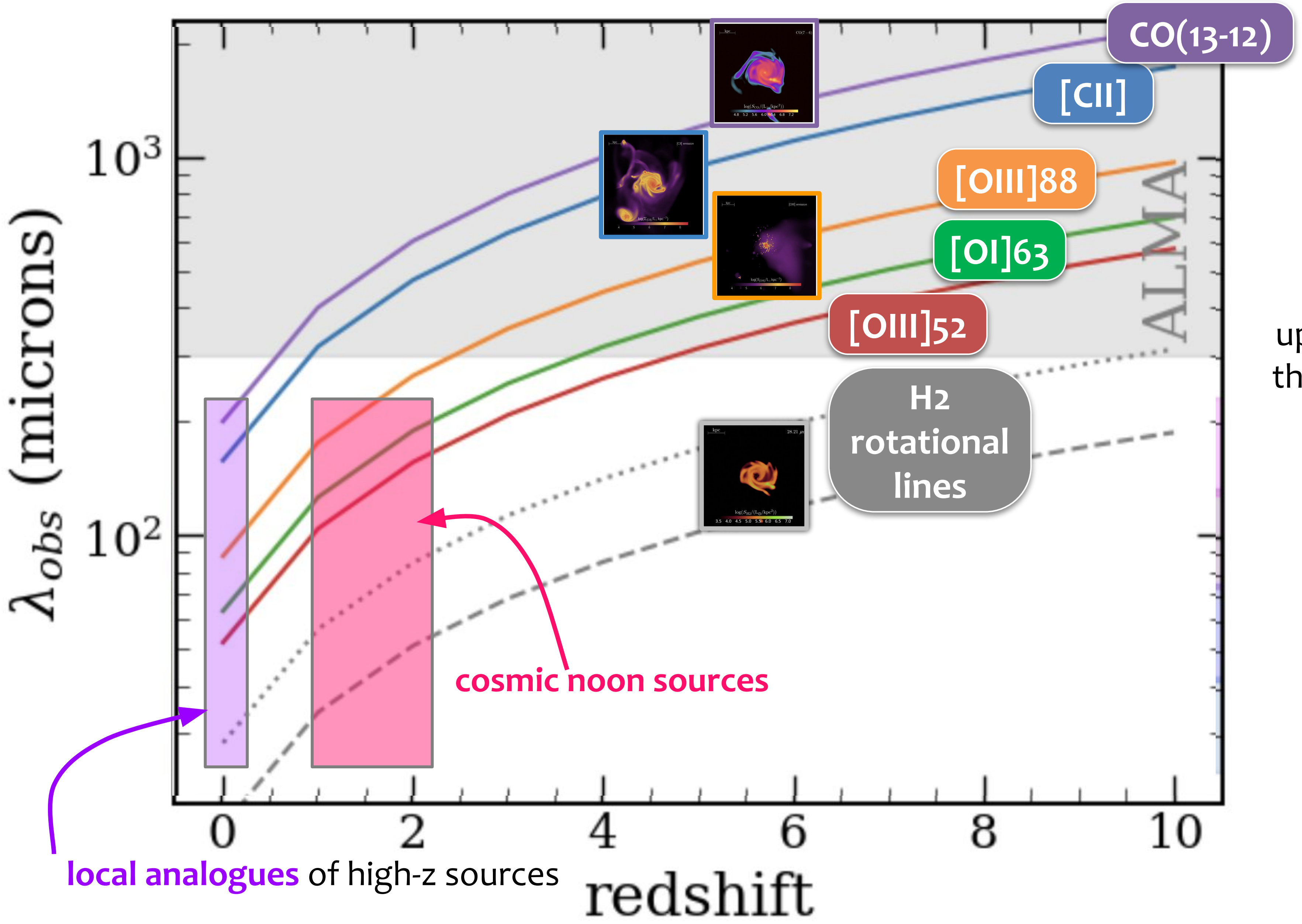

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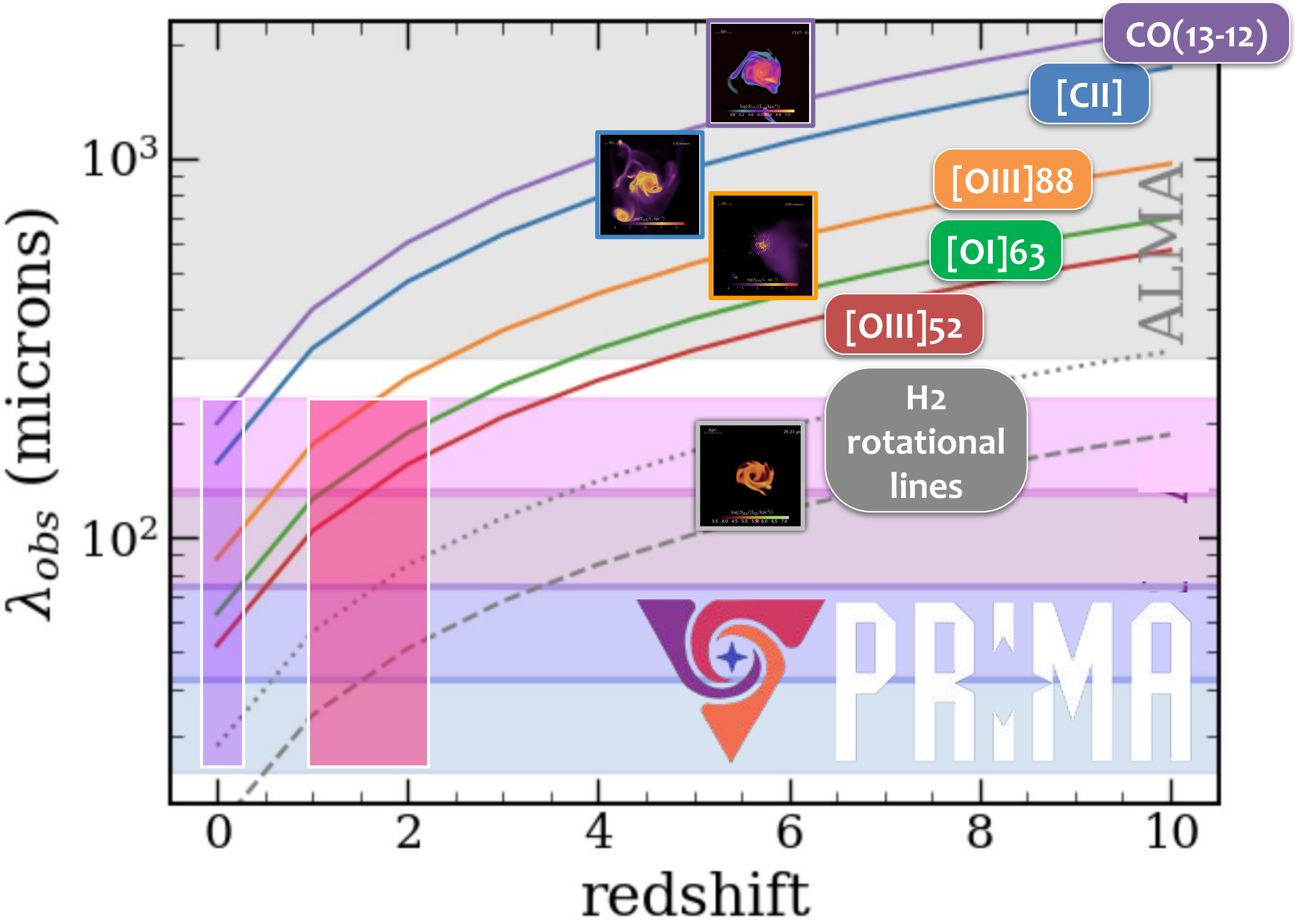
PRIMA will be key



PRIMA will be key

$L_{[OIII]} = 5 \times 10^8\ L_\odot$ @ z=1 → Flux = 3.5×10^{-19} W/m^2
PRIMA ETC → 0.29 hours

$L_{[OI]63} = 5 \times 10^7\ L_\odot$ @ z=1 → Flux = 3.5×10^{-20} W/m^2
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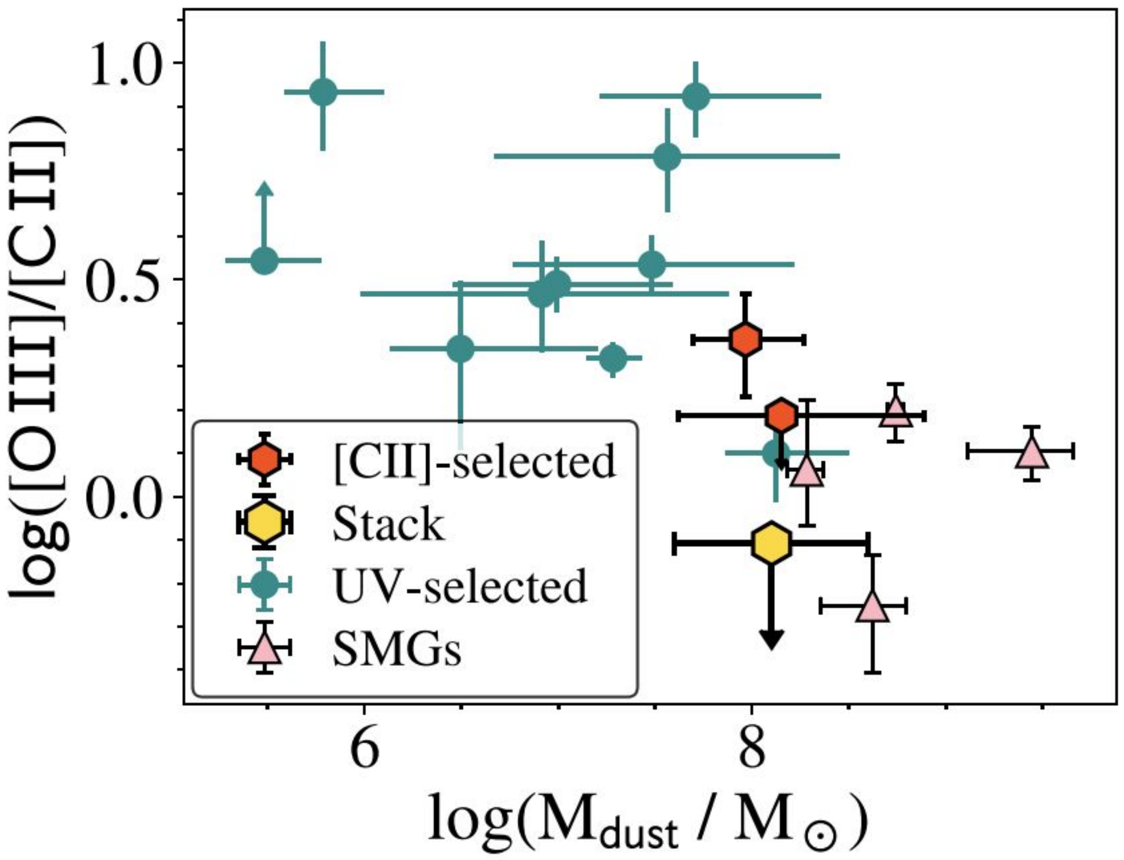

Conclusions

1. The ISM properties of the first galaxies are more extreme (higher density, turbulence) and vary a lot within short timescales

2. Likely the KS relation evolve with redshifts and it seems to be strongly impacted by the higher gas density of first galaxies

3. Line ratios of ionized vs neutral gas tracers can track down this evolution

4. PRIMA will provide insights on galaxies at cosmic noon and guide future developments of zoom-in simulations evolved towards lower redshifts