fifth workshop on Millimetre
Astronomy in Italy
12-14 June 2023

“Metal enrichment in the CGM around high-z merging galaxies”

(Di Cesare et al., in prep)

Claudia Di Cesare

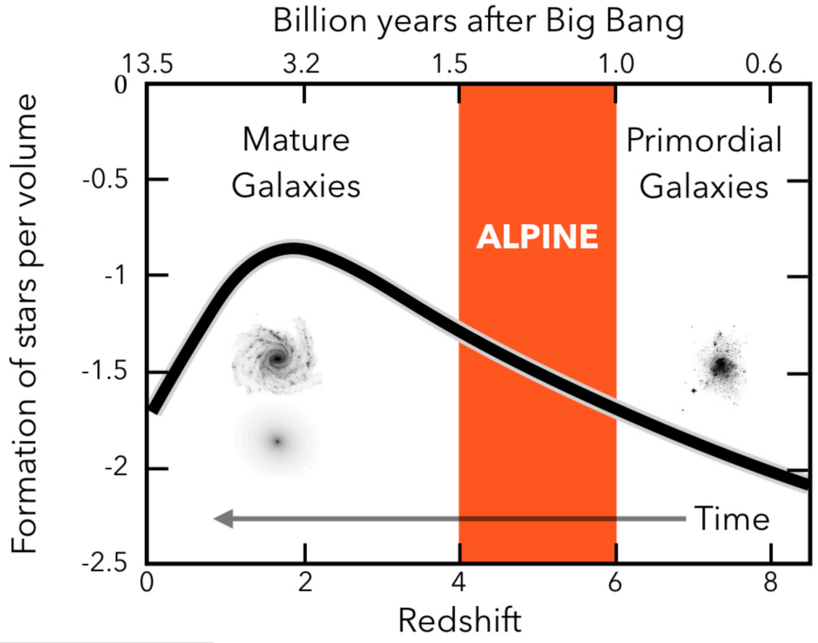
in collaboration with :

**Michele Ginolfi, Luca Graziani,
Raffaella Schneider, Michael Romano**

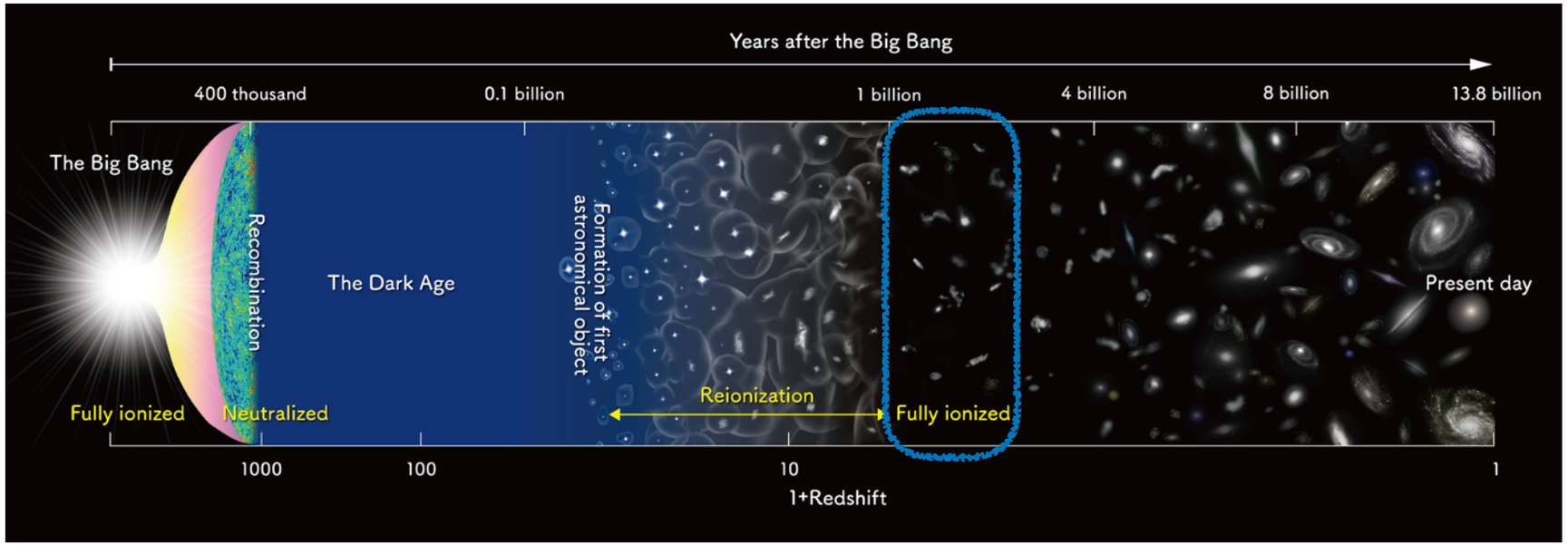
“Metal enrichment in the CGM around high-z merging galaxies”

4 < z < 6

post Epoch of Reionization



credits : ALPINE collab.



credits : NAOJ

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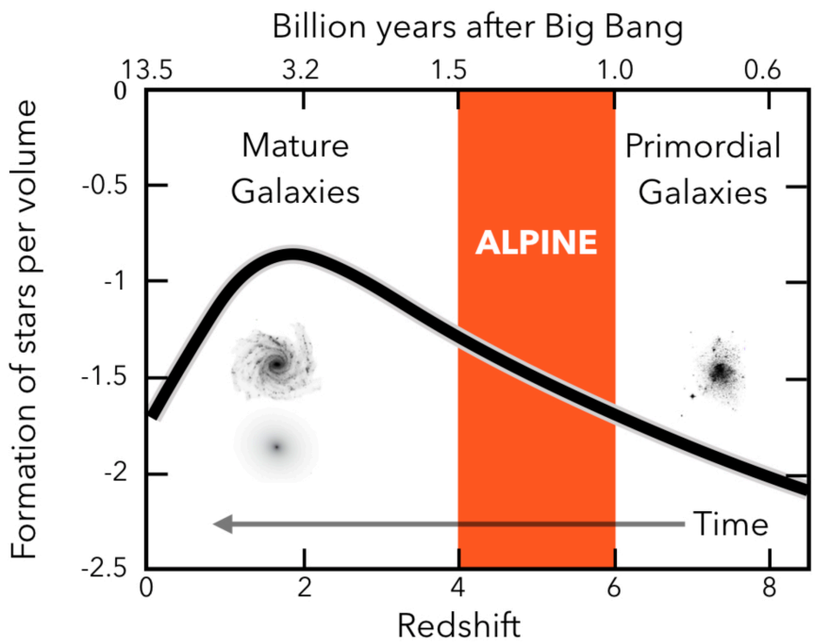
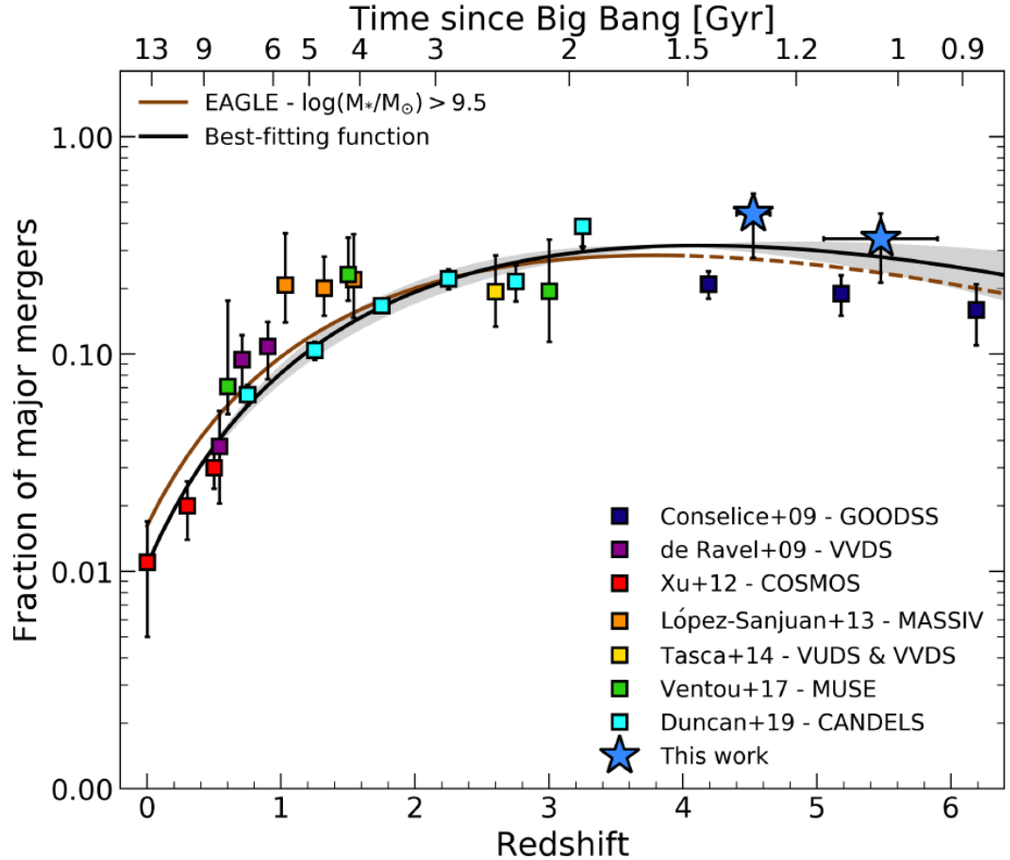


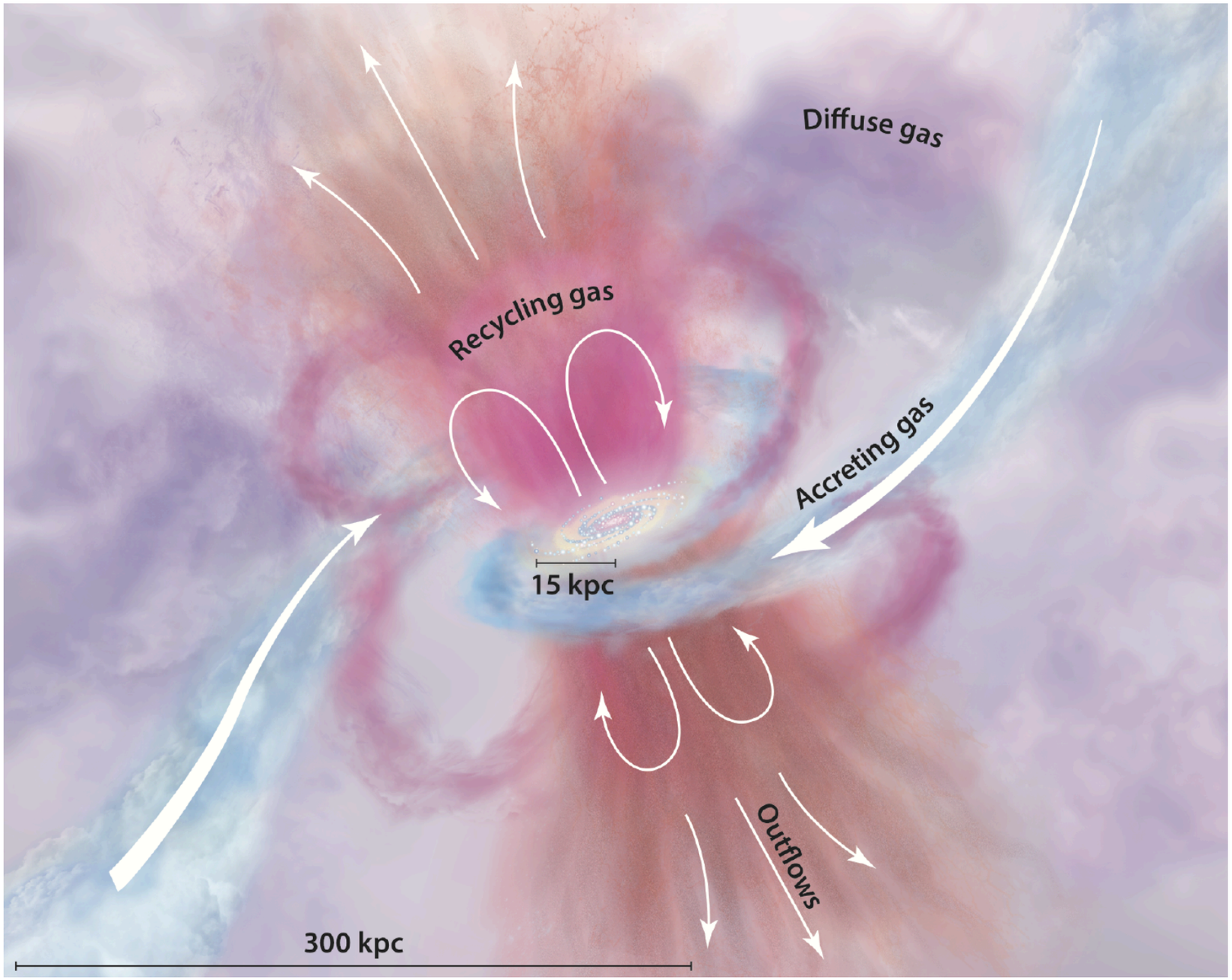
credits : ALPINE collab.

interacting systems at z > 4
increase from the Local to high-z Universe



Romano+2021

circum galactic medium



Tumlinson+2017

* The CGM is situated outside the galaxy (ISM), but inside the host DM halo of the galaxy

* CGM components: *diffuse multiphase* medium with rich gas dynamics, almost fully ionized in H

* it regulates *gas exchanges* and, as a consequence, the star formation activity and galaxy growth

“Metal enrichment in the CGM around high-z merging galaxies”

“Metal enrichment in the CGM around high-z merging galaxies”

MAIN MOTIVATIONS :

* What merging systems tell us about the metal enrichment of their CGM ?

* Where does diffuse [CII] emission come from ?

observations :
ALMA survey

cosmological simulations :
dustyGadget

OBSERVATIONS

ALMA Large Program to INvestigate C+ at Early times (ALPINE)

(Le Fèvre+2020, Faisst+2020, Béthermin+2020)

A2C2S | ALMA ALPINE [CII] Survey

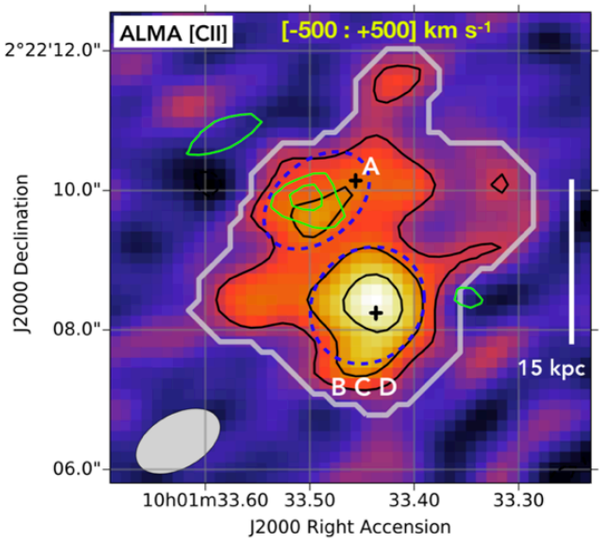
118 main sequence galaxies at $4.4 \leq z \leq 5.9$
with dust continuuum (23) and [CII] measurements (75)

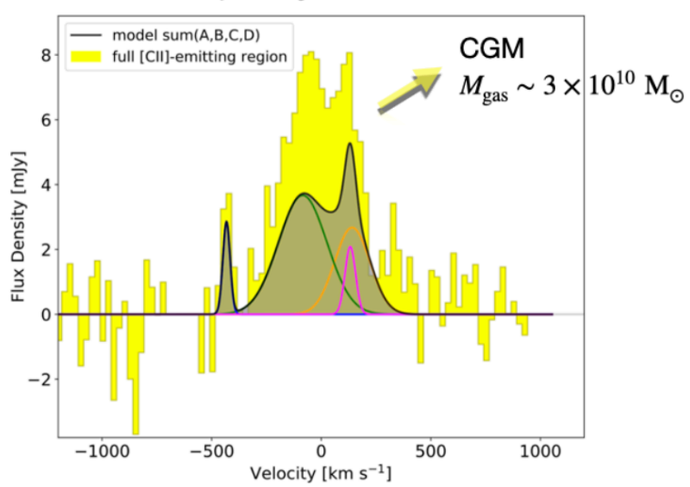
Ginolfi+2020b :

major merging system at z ~ 4.57
[CII] emission from CGM up to ~30 kpc — 50% of total flux *between* the galaxies

Romano+2021 :

morpho-kinematic information from [CII] emission
fraction of major merger systems in the ALPINE survey
~40% systems in ALPINE are mergers





Ginolfi+2020b

candidates selection

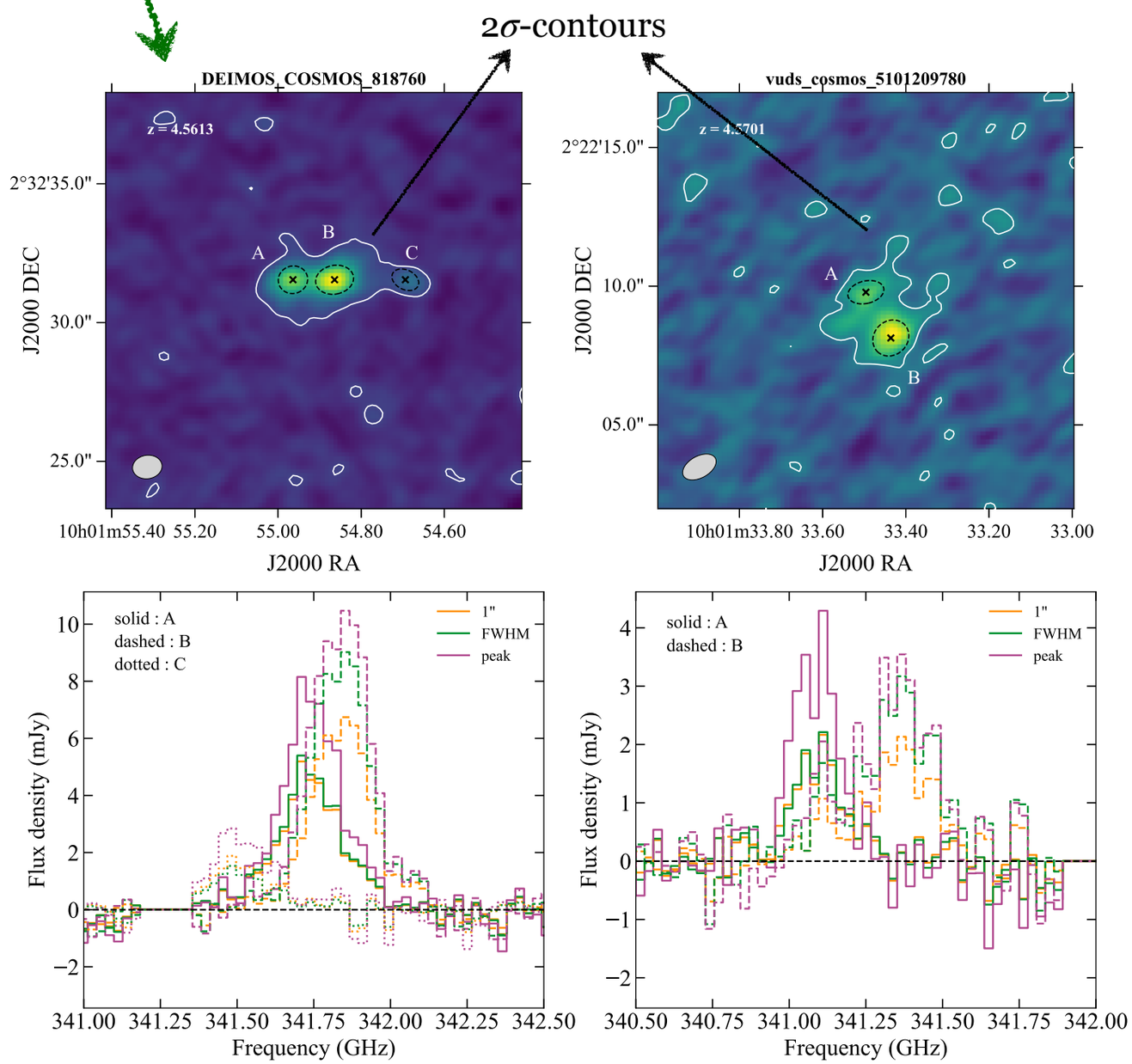
Source	z_1	z_2	Δv [km s^{-1}]	r_p [kpc]	$\mu_{[CII]}$	μ_K
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CG_38	5.5731	5.5698	152.3	2.7	1.8	–
DC_308643	4.5238	4.5221	92.3	3.0	1.2	–
DC_372292	5.1345	5.1374	144.0	1.8	2.7	2.9
DC_378903	5.4311	5.4293	94.5	0.9	1.9	–
DC_417567	5.6676	5.6700	106.7	5.3	2.1	–
DC_422677	4.4361	4.4378	92.8	0.0	1.4	–
DC_434239	4.4914	4.4876	206.1	5.5	6.9	–
DC_493583	4.5122	4.5141	103.4	1.0	4.7	–
DC_519281	5.5731	5.5765	158.0	0.9	4.5	–
DC_536534	5.6834	5.6886	234.6	4.4	2.7	–
DC_665509	4.5244	4.5261	95.9	1.0	2.0	–
DC_680104	4.5288	4.5308	106.4	0.0	1.0	–
DC_773957	5.6802	5.6770	141.2	3.0	1.6	5.6
DC_814483	4.5823	4.5796	145.5	7.9	2.4	–
DC_818760	4.5626	4.5609	92.3	9.9	1.3	2.6
DC_834764	4.5076	4.5055	119.0	1.0	1.7	–
DC_842313	4.5547	4.5406	751.5	11.6	32.9	1.5
DC_859732	4.5353	4.5315	205.2	4.9	3.9	–
DC_873321	5.1545	5.1544	4.5	6.5	1.2	3.1
vc_5100541407	4.5628	4.5628	1.9	13.8	1.6	1.4
vc_5100822662	4.5210	4.5205	22.3	10.9	1.6	1.7
vc_5101209780	4.5724	4.5684	217.3	10.8	4.1	2.5
vc_5180966608	4.5294	4.5293	8.9	7.2	3.0	3.7

(Romano+2021)

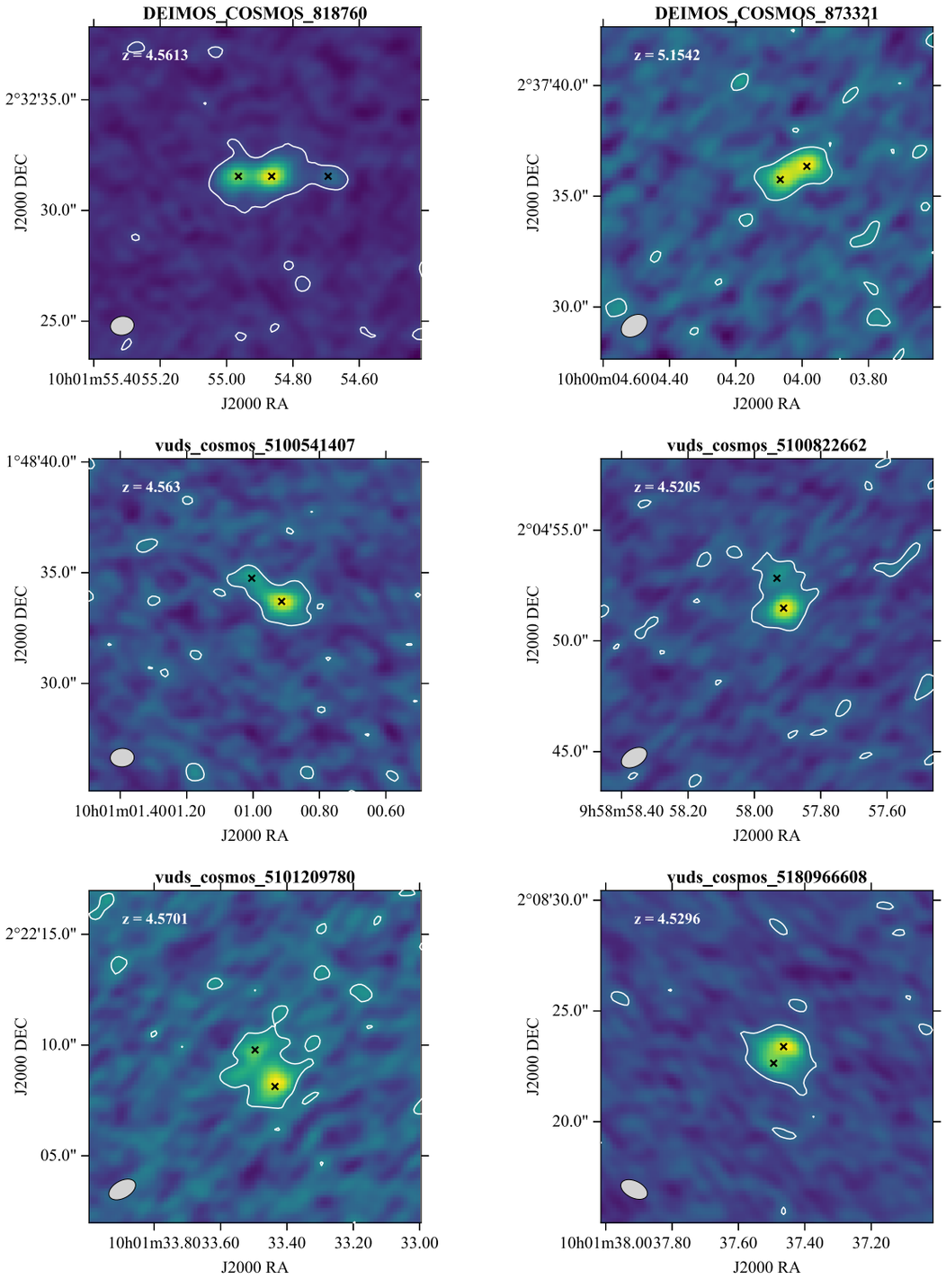
$r_p > 4\ kpc$

$1 < \mu_K < 4$

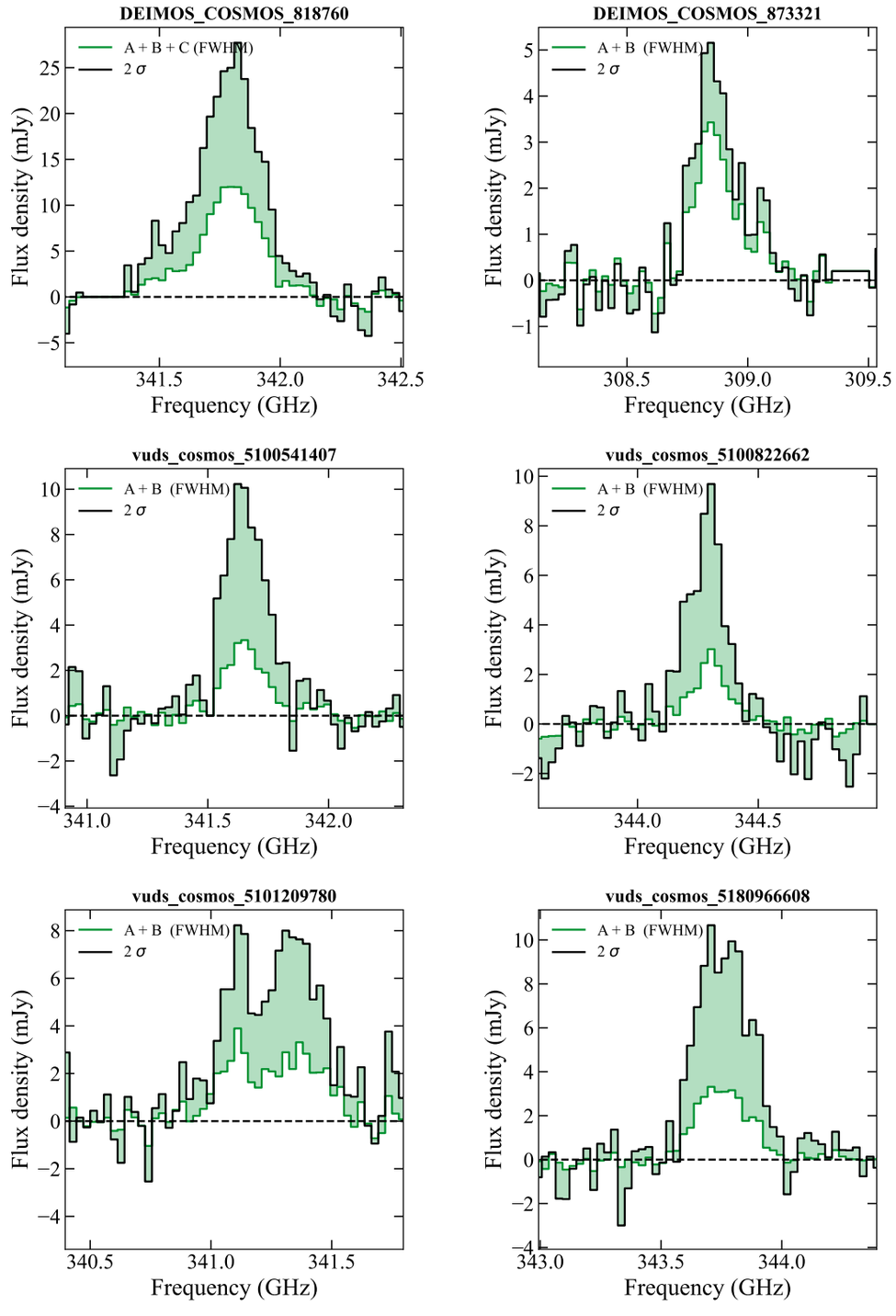
ALMA data analysis



momento zero maps of the selected candidates

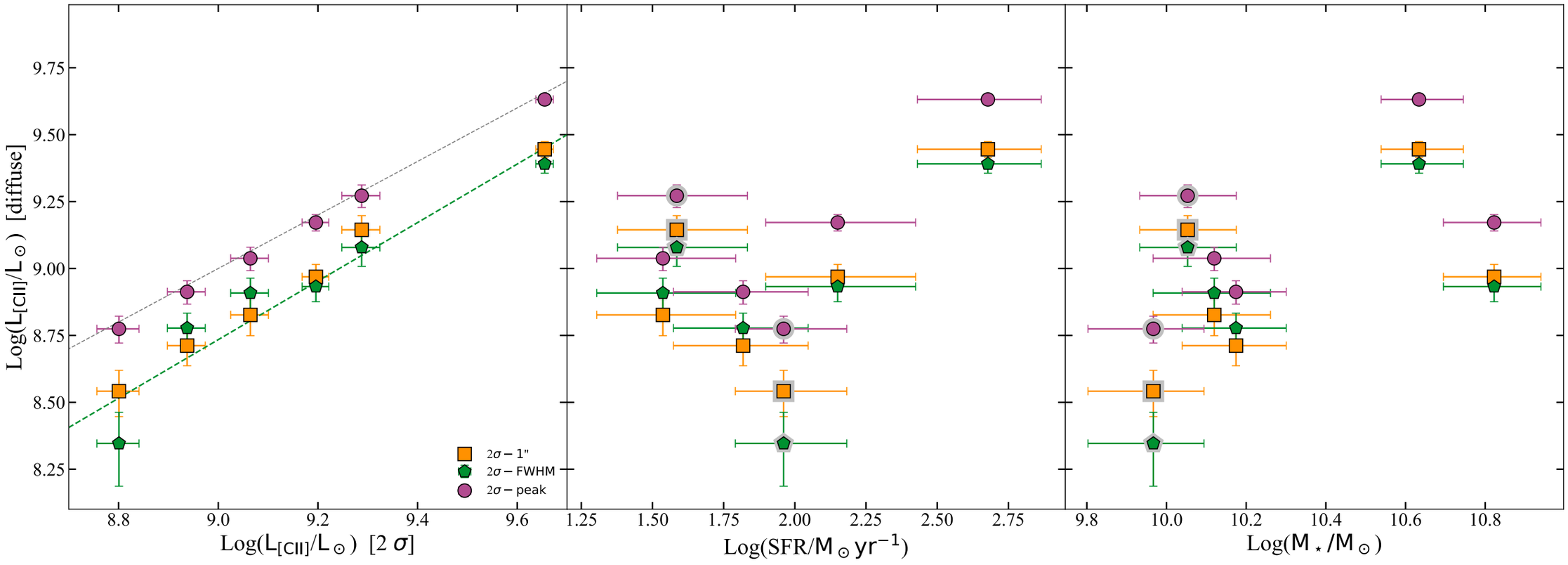


sum of componets emission from optimal apertures



qualitatively : [CII] emission coming from the diffuse medium

more *quantitative* analysis



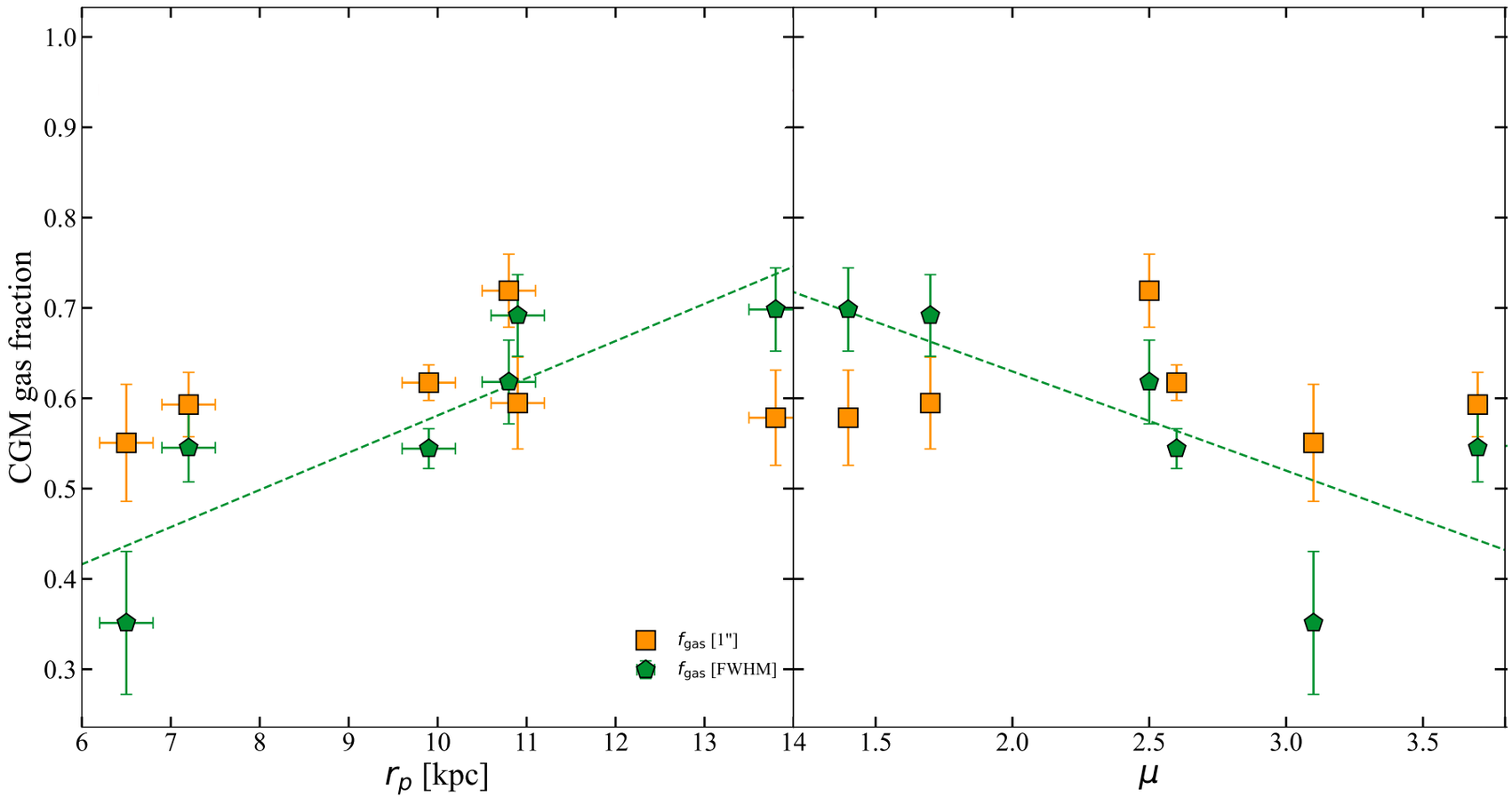
outflows ?

satellites ?
dynamical interaction ?

more *quantitative* analysis

30%-70% gas coming from the diffuse medium

the higher the distance the higher the CGM gas fraction :
more gas in the diffuse medium



lower μ (major merger) results in a more efficient stripping
leading to a more polluted CGM

why do we want to compare these observations with **simulations** ?

1. time evolution of the merging systems

2. CGM emitting? or satellites galaxies we can't observe (resolution)?

SIMULATIONS

dustyGadget (Graziani+2020)

[extension of Gadget-2 Springel+2005]

WHAT DOES dustyGadget DO?

i) SPH hydrodynamical simulations with PopIII/PopII stellar populations
ii) chemical evolution of the gas [Tornatore+2007]
iii) dust production and evolution in the ISM (cold and hot phases)

→ the code follows the spreading of **grains and atomic metals** through galactic winds at the scales of CGM and IGM

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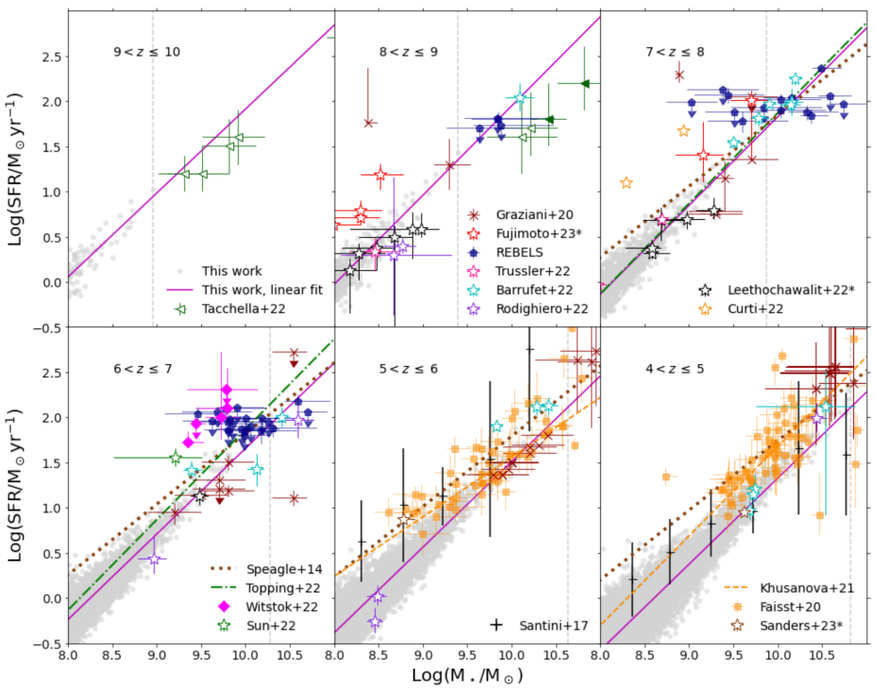
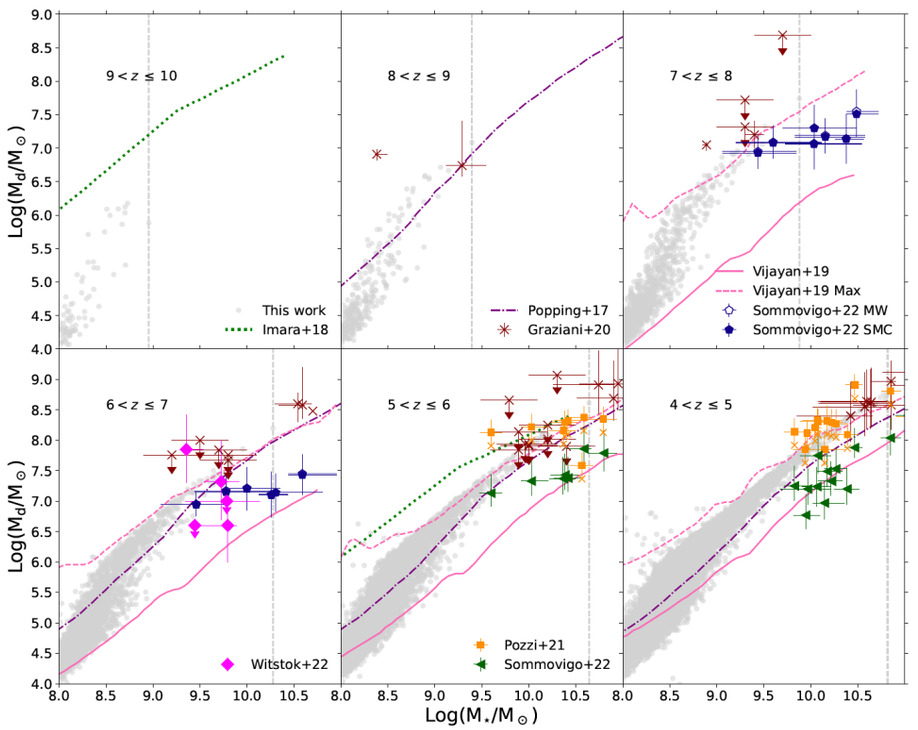
(see ***Di Cesare+2023*** for a statistical study on high-z galaxies and *Venditti+2023* for PopIII environments study using dustyGadget)

MAIN SEQUENCE OF GALAXY FORMATION



dustyGadget predictions are in global agreement with high redshift available data

DUST MASS STELLAR MASS RELATION



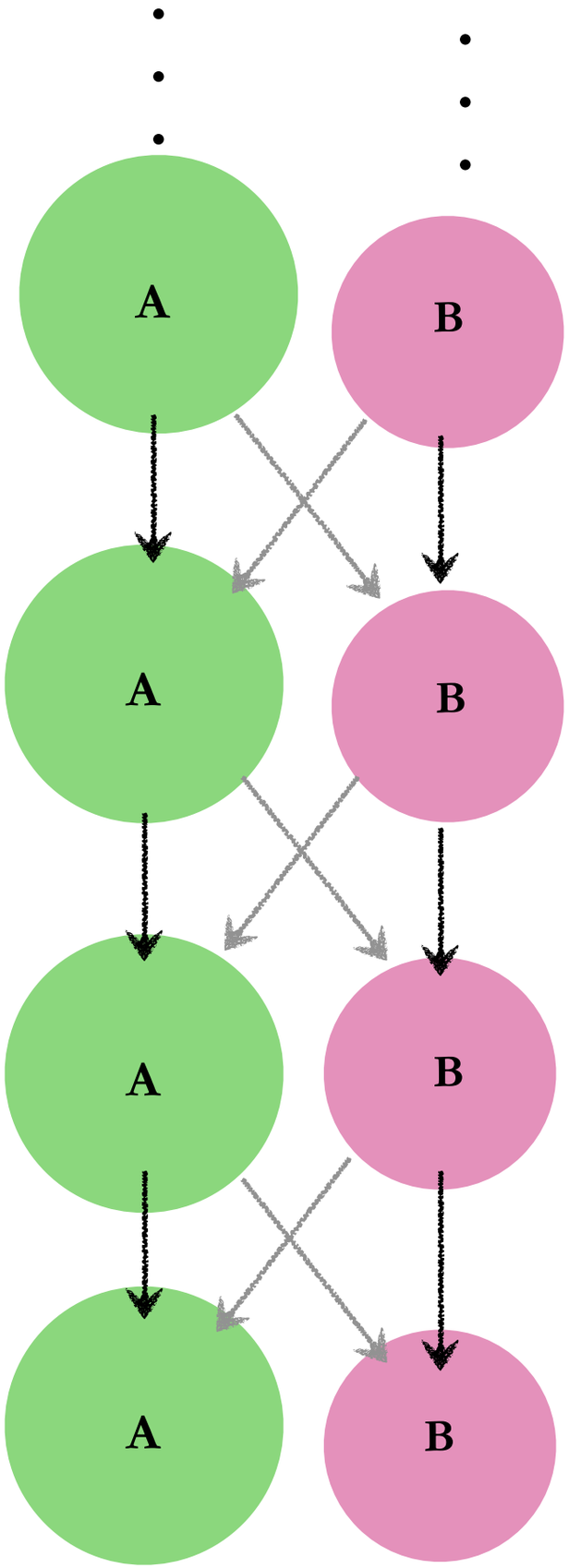
SIMULATIONS

looking for MAJOR MERGING SYSTEMS in dustyGadget

1. redshift range compatible with observations
2. cut on the stellar masses ($\mathrm{Log}(M_\star/M_\odot) \geq 10$)
3. M1/M2 ratios compatible with observations

sample of 10 galaxies at z~4.5

MERGER TREE RECONSTRUCTION



$z = 4.8$

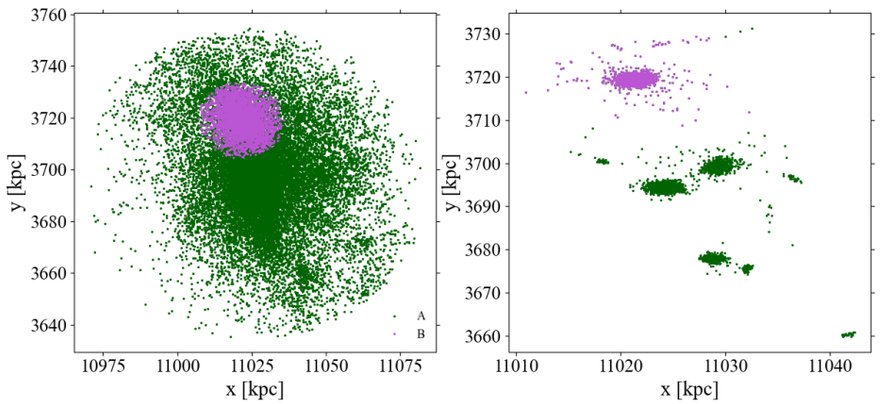
$z = 4.7$

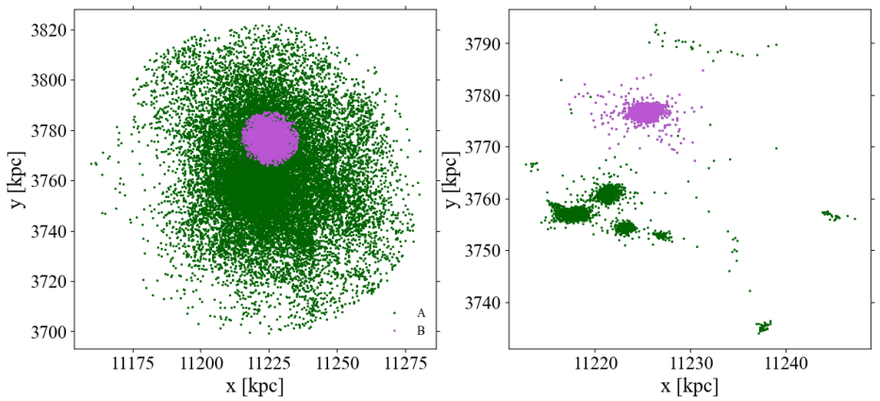
$z = 4.6$

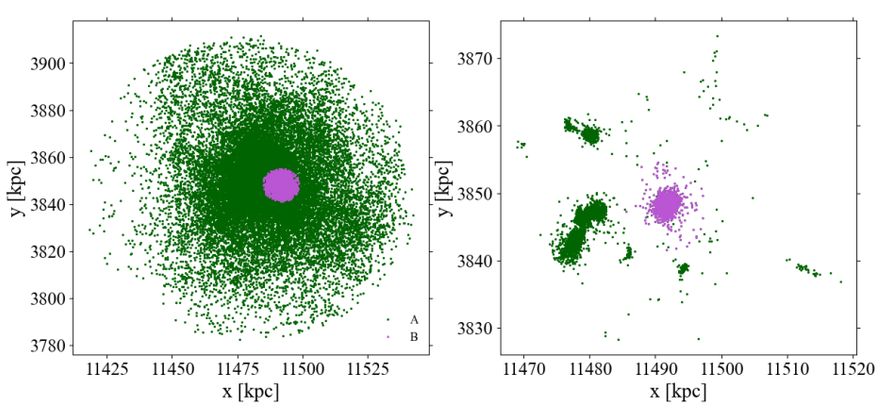
$z = 4.5$

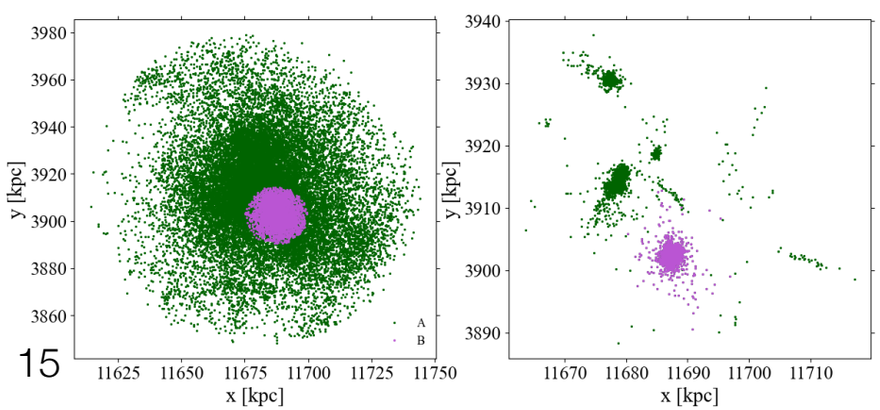
DM particles

stellar particles





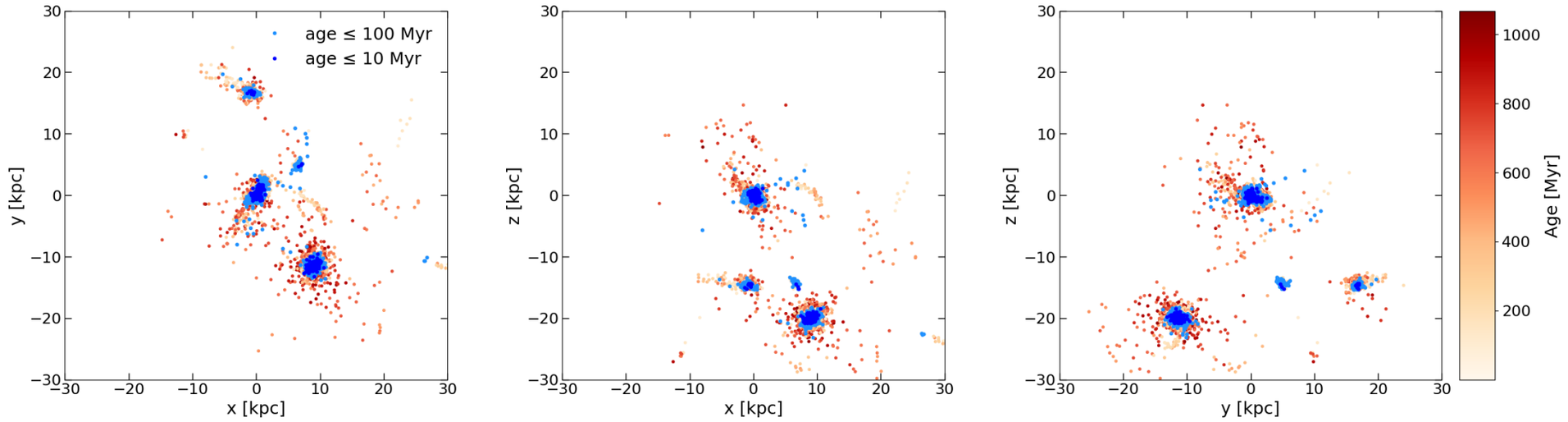




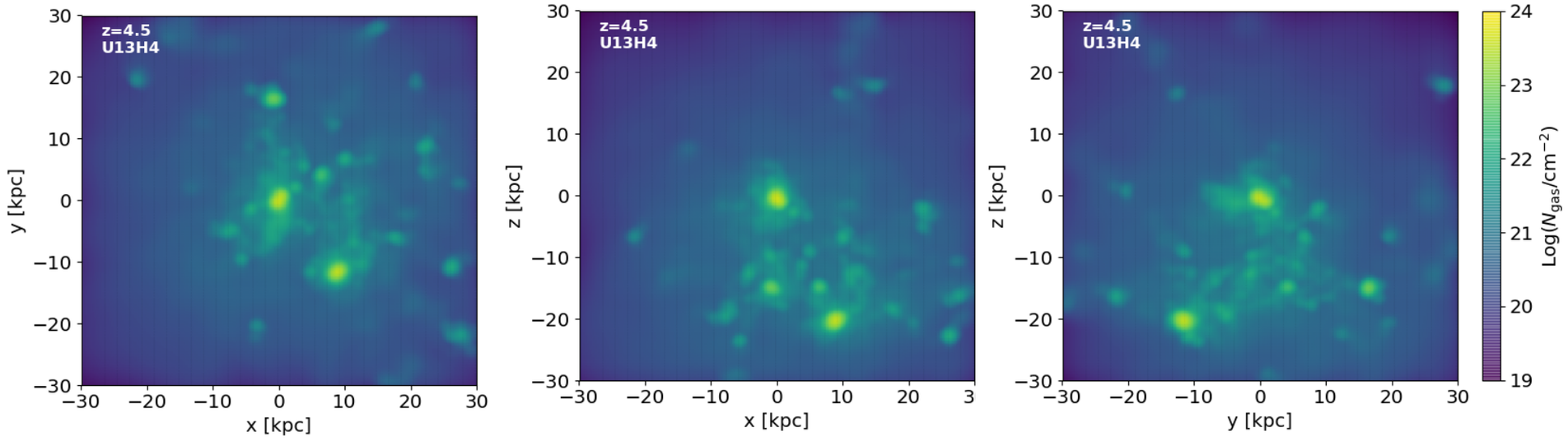
time

z = 4.5

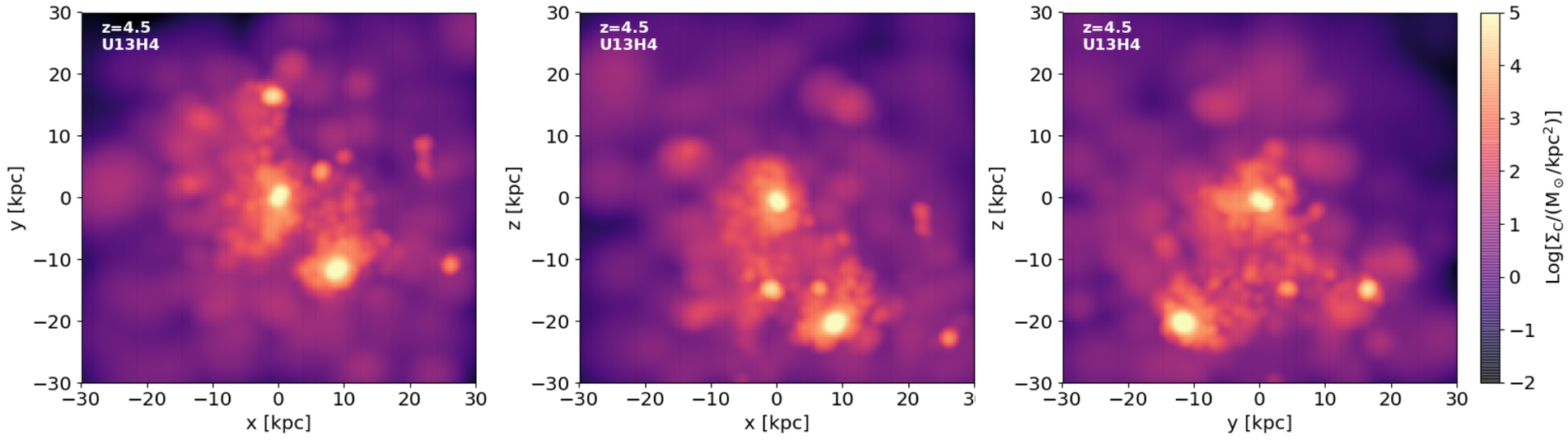
stellar particles



gas column density



C surface density



preliminary CONCLUSIONS

- diffuse [CII] emission from a sample of 6 interacting galaxies
- 30%-70% gas is coming from the medium between the galaxies
- tentative trends between the diffuse emission, the global physical properties ($L_{[CII]}$; $M_\star$; SFR) and the relative properties
- merger tree reconstructions with dustyGadget
- predictions from simulations to interpret the observations

SAPIENZA
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Thanks for your attention!

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