

"Metal enrichment in the CGM around high-z merging galaxies"

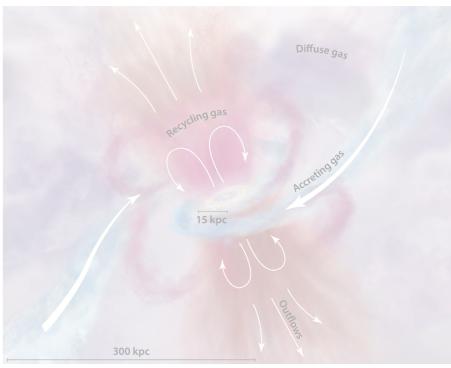
(Di Cesare et al., in prep)

Claudia Di Cesare

in collaboration with:

Michele Ginolfi (UniFi, Italy); Luca Graziani (Sapienza, Italy);
Raffaella Schneider (Sapienza, Italy);
Michael Romano (NCBJ,Poland)



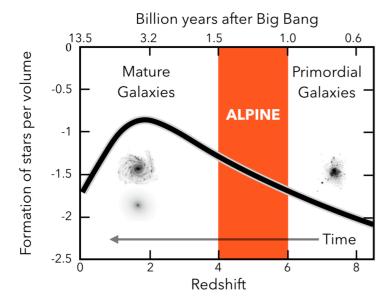


Tumlinson+2017

"Metal enrichment in the CGM around high-z merging galaxies"

4 < z < 6

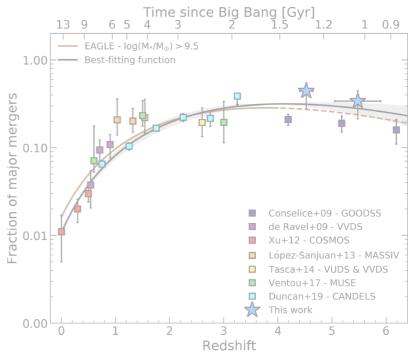
post Epoch of Reionization



credits: ALPINE collab.

[CII] 158 μm rest-frame

fraction interacting systems increase from the Local to high-z Universe





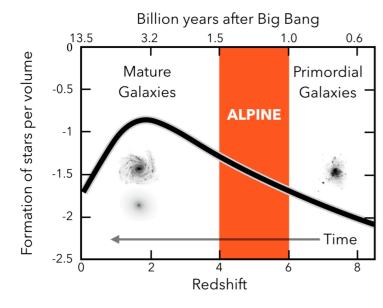
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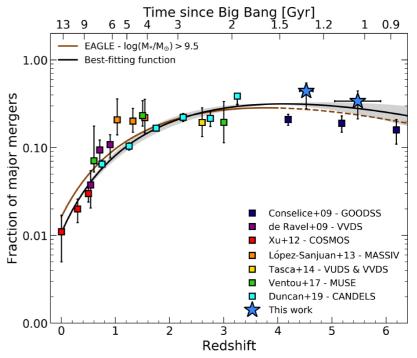
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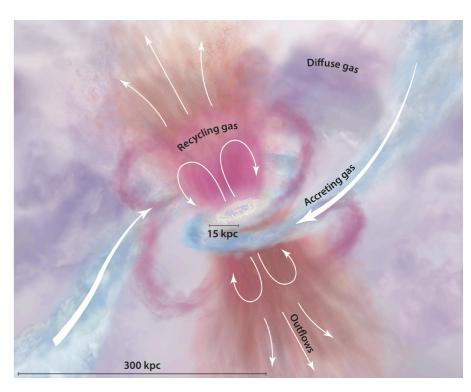
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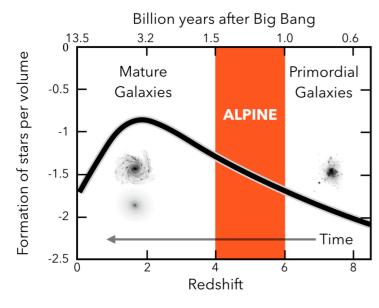
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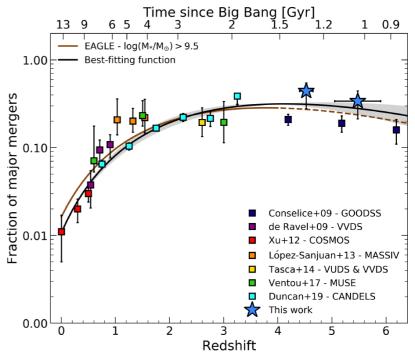
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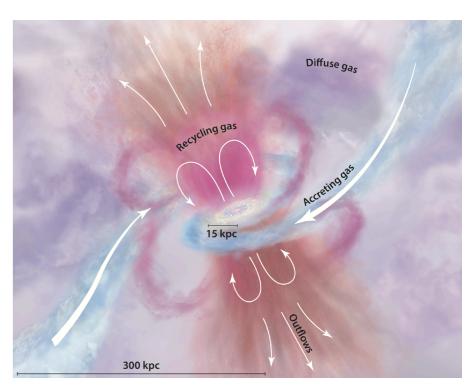
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fraction interacting systems increase from the Local to high-z Universe





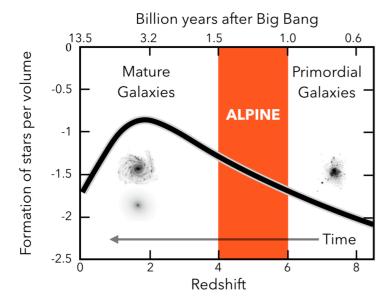
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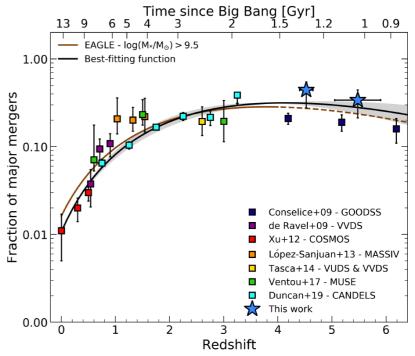
4 < z < 6

post Epoch of Reionization



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fraction interacting systems increase from the Local to high-z Universe



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)



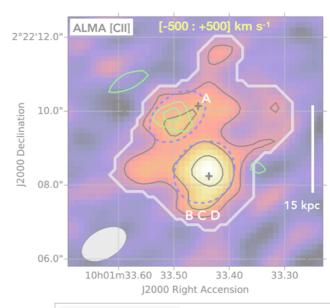
118 main sequence galaxies at $4.4 \le z \le 5.9$ with dust continuum (23) and [CII] measurements (75)

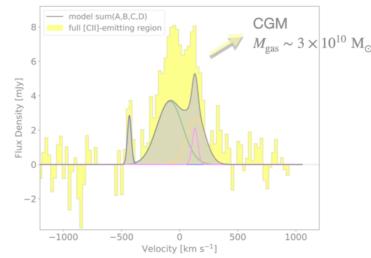
<u>Ginolfi+2020b</u>:

major merging system at z \sim 4.57 [CII] emission from CGM up to \sim 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

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8



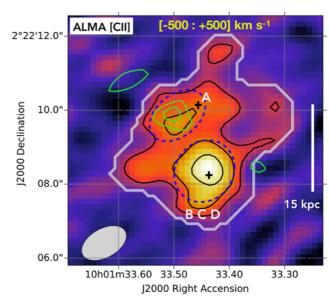
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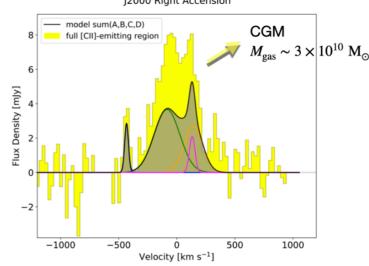
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major merging system at z ~ 4.57 [CII] emission from CGM up to ~30 kpc — 50% of total flux between the galaxies

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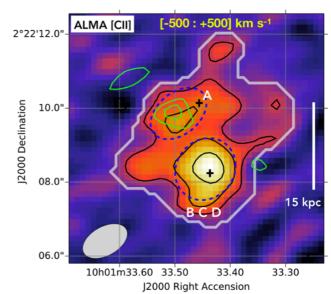
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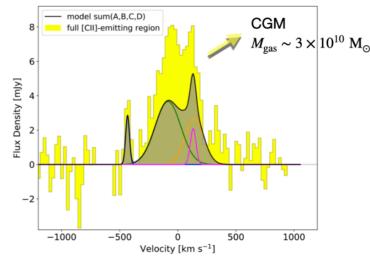
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1. candidates selection

(Romano+2021)

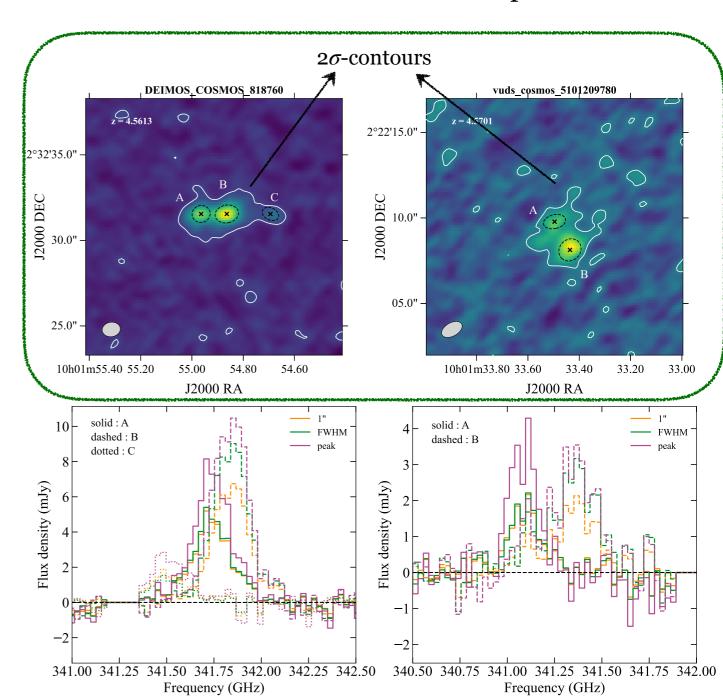
Source	z_1	z_2	Δv	r_p	$\mu_{[CII]}$	μ_K
(1)	(2)	(3)	$[\text{km s}^{-1}]$ (4)	[kpc]	(6)	(7)
CG_38	5.5731	5.5698	152.3	2.7	1.8	_
DC_308643	4.5238	4.5221	92.3	3.0	1.2	_
DC_372292	5.1345	5.1374	144.0	1.8	2.7	2.9
DC_378903	5.4311	5.4293	94.5	0.9	1.9	_
DC_417567	5.6676	5.6700	106.7	5.3	2.1	_
DC_422677	4.4361	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

$$r_p > 4 \, kpc$$

$$1 < \mu_K < 4$$

2. ALMA data reduction and analysis

2.1 total moment zero maps



10

1. candidates selection

(Romano+2021)

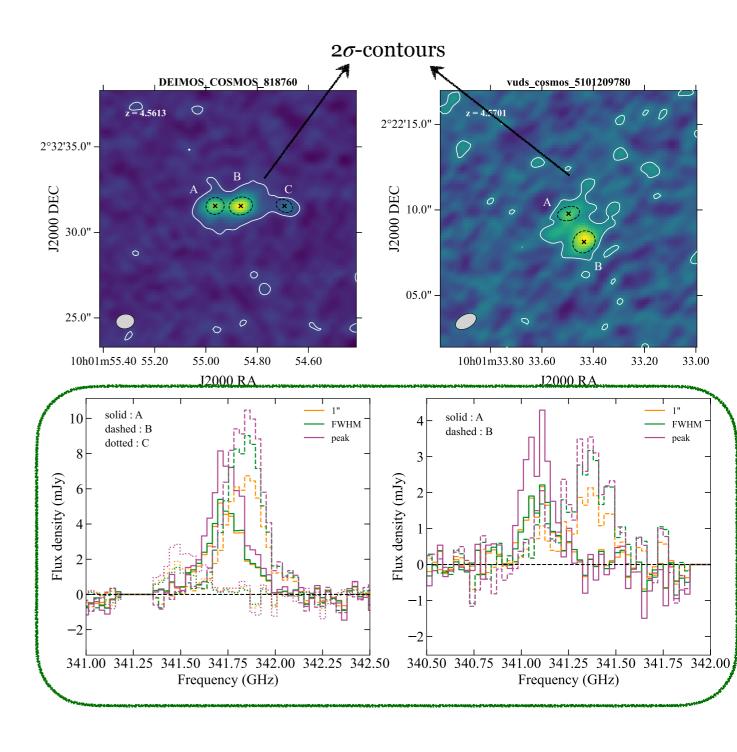
z_1	z_2	Δv	r_p	$\mu_{[ext{CII}]}$	μ_K
		$[{\rm km}{\rm s}^{-1}]$	[kpc]	•	
(2)	(3)	(4)	(5)	(6)	(7)
5.5731	5.5698	152.3	2.7	1.8	_
4.5238	4.5221	92.3	3.0	1.2	_
5.1345	5.1374	144.0	1.8	2.7	2.9
5.4311	5.4293	94.5	0.9	1.9	_
5.6676	5.6700	106.7	5.3	2.1	_
4.4361	4.4378	92.8	0.0	1.4	_
4.4914	4.4876	206.1	5.5	6.9	_
4.5122	4.5141	103.4	1.0	4.7	_
5.5731	5.5765	158.0	0.9	4.5	_
5.6834	5.6886	234.6	4.4	2.7	_
4.5244	4.5261	95.9	1.0	2.0	_
4.5288	4.5308	106.4	0.0	1.0	_
5.6802	5.6770	141.2	3.0	1.6	5.6
4.5823	4.5796	145.5	7.9	2.4	_
4.5626	4.5609	92.3	9.9	1.3	2.6
4.5076	4.5055	119.0	1.0	1.7	_
4.5547	4.5406	751.5	11.6	32.9	1.5
					_
5.1545		4.5			3.1
4.5628	4.5628	1.9	13.8	1.6	1.4
4.5210	4.5205	22.3		1.6	1.7
		217.3		4.1	2.5
4.5294	4.5293	8.9	7.2	3.0	3.7
	(2) 5.5731 4.5238 5.1345 5.4311 5.6676 4.4361 4.4914 4.5122 5.5731 5.6834 4.5244 4.5288 5.6802 4.5823 4.5626 4.5076 4.5353 5.1545 4.5628 4.5210 4.5724	(2) (3) 5.5731 5.5698 4.5238 4.5221 5.1345 5.1374 5.4311 5.4293 5.6676 5.6700 4.4361 4.4378 4.4914 4.4876 4.5122 4.5141 5.5731 5.5765 5.6834 5.6886 4.5244 4.5261 4.5288 4.5308 5.6802 5.6770 4.5823 4.5796 4.5626 4.5609 4.5076 4.5055 4.547 4.5406 4.5353 4.5315 5.1545 5.1544 4.5628 4.5628 4.5210 4.5205 4.5724 4.5684	(2) (3) [km s ⁻¹] 5.5731 5.5698 152.3 4.5238 4.5221 92.3 5.1345 5.1374 144.0 5.4311 5.4293 94.5 5.6676 5.6700 106.7 4.4361 4.4378 92.8 4.4914 4.4876 206.1 4.5122 4.5141 103.4 5.5731 5.5765 158.0 5.6834 5.6886 234.6 4.5244 4.5261 95.9 4.5288 4.5308 106.4 5.6802 5.6770 141.2 4.5823 4.5796 145.5 4.5626 4.5609 92.3 4.5076 4.5055 119.0 4.5547 4.5406 751.5 4.5353 4.5315 205.2 5.1545 5.1544 4.5 4.5210 4.5205 22.3 4.5724 4.5684 217.3	(2) (3) [km s ⁻¹] [kpc] 5.5731 5.5698 152.3 2.7 4.5238 4.5221 92.3 3.0 5.1345 5.1374 144.0 1.8 5.4311 5.4293 94.5 0.9 5.6676 5.6700 106.7 5.3 4.4361 4.4378 92.8 0.0 4.4914 4.4876 206.1 5.5 4.5122 4.5141 103.4 1.0 5.5731 5.5765 158.0 0.9 5.6834 5.6886 234.6 4.4 4.5244 4.5261 95.9 1.0 4.5288 4.5308 106.4 0.0 5.6802 5.6770 141.2 3.0 4.5823 4.5796 145.5 7.9 4.5626 4.5609 92.3 9.9 4.5076 4.5055 119.0 1.0 4.5353 4.5315 205.2 4.9 5.1545 5.154	(2) (3) [km s ⁻¹] [kpc] (6) 5.5731 5.5698 152.3 2.7 1.8 4.5238 4.5221 92.3 3.0 1.2 5.1345 5.1374 144.0 1.8 2.7 5.4311 5.4293 94.5 0.9 1.9 5.6676 5.6700 106.7 5.3 2.1 4.4361 4.4378 92.8 0.0 1.4 4.4914 4.4876 206.1 5.5 6.9 4.5122 4.5141 103.4 1.0 4.7 5.5731 5.5765 158.0 0.9 4.5 5.6834 5.6886 234.6 4.4 2.7 4.5244 4.5261 95.9 1.0 2.0 4.5288 4.5308 106.4 0.0 1.0 5.6802 5.6770 141.2 3.0 1.6 4.5823 4.5796 145.5 7.9 2.4 4.5076 4.5055 <t< td=""></t<>

$$r_p > 4 \, kpc$$

$$1 < \mu_K < 4$$

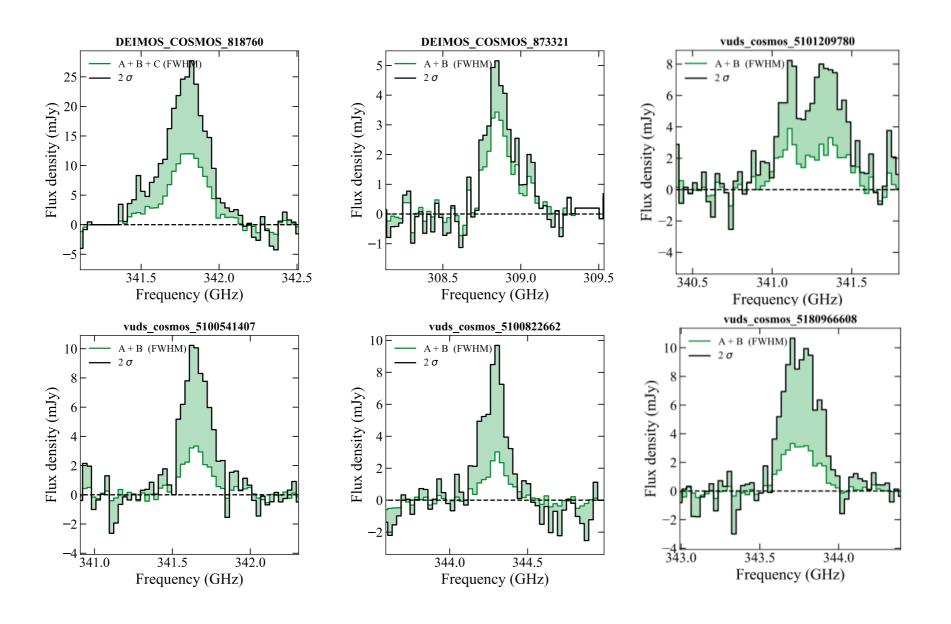
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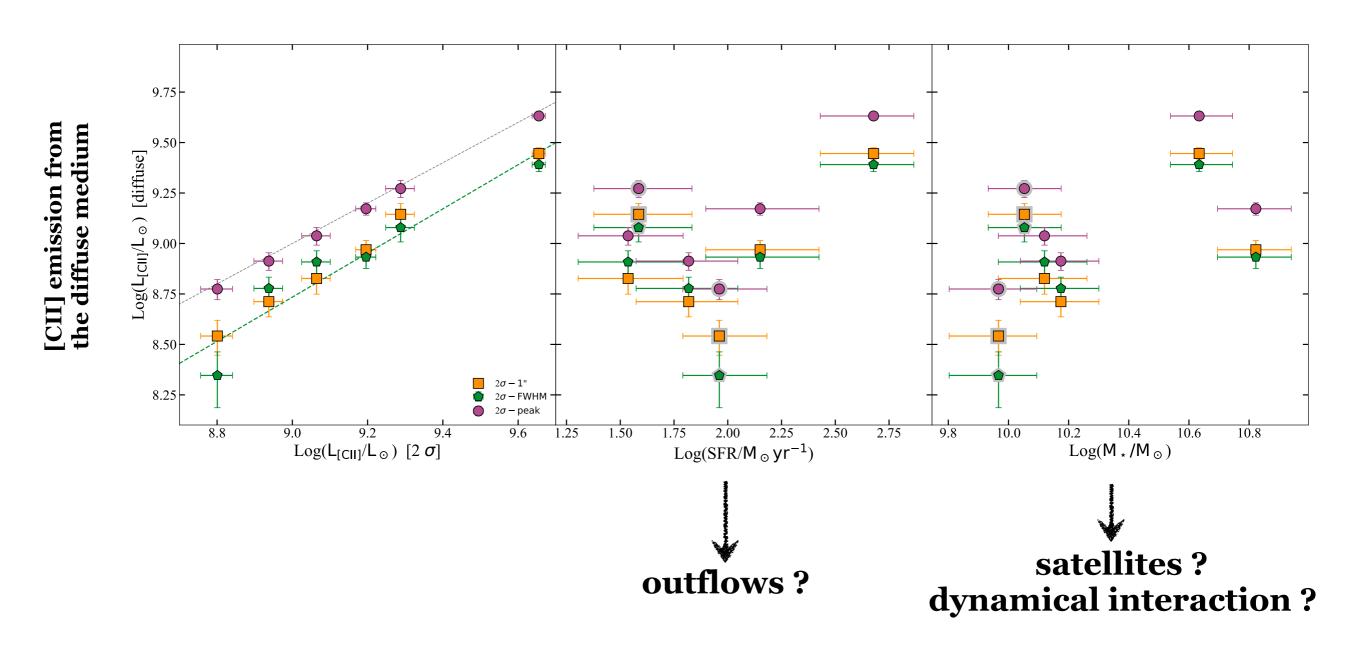
2.2 [CII] emission for each merging component from different apertures

sum of components emission from optimal apertures



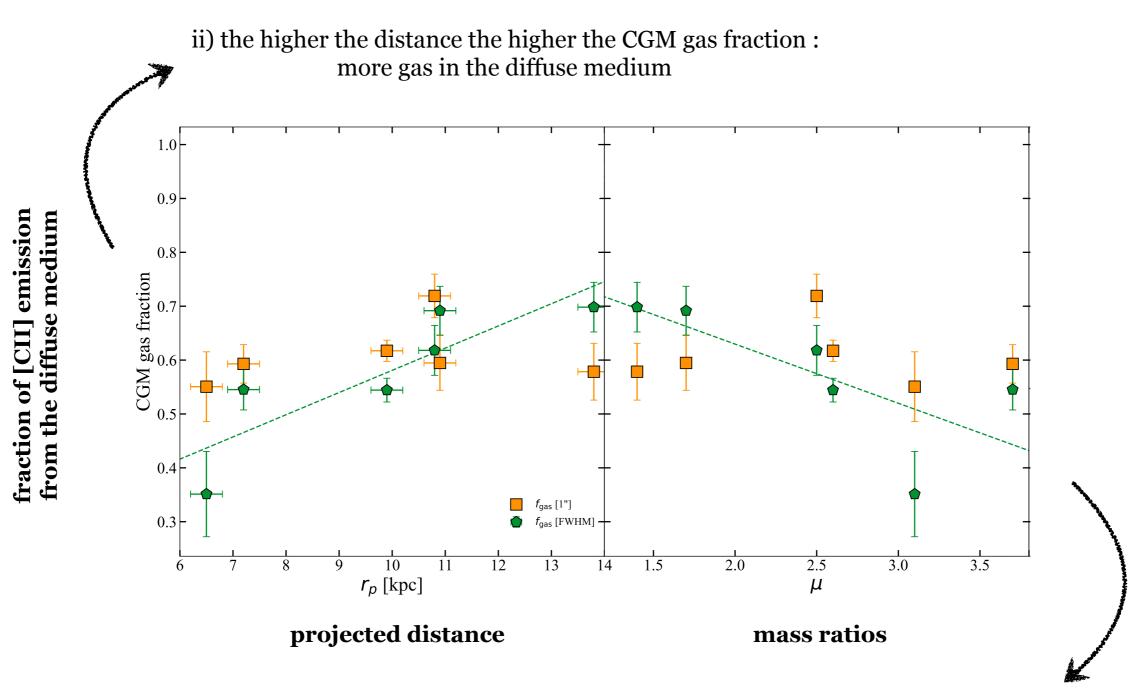
<u>qualitatively</u>: [CII] emission coming from the diffuse medium

more quantitative analysis



more quantitative analysis

i) 35%-70% emission coming from the diffuse medium



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

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wny	/ (]	o we	want to	compare	tnese	observ	/ations	with	simu	lations	
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- 1. time evolution of the merging systems
- 2. CGM emitting? or satellites galaxies we can't observe (resolution)?

SIMULATIONS

$dusty Gadget ({\tt Graziani+2020})$

[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

ΛCDM cosmology (Planck 2015) box size : 50 cMpc/h

$$m_{DM} = 3.53 \times 10^7 \,\mathrm{M}_{\odot}/\mathrm{h}$$

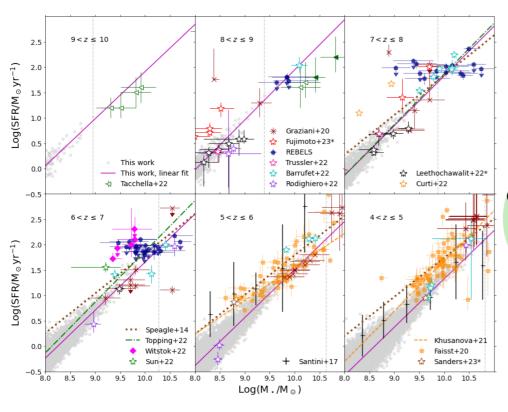
 $m_b = 5.56 \times 10^6 \,\mathrm{M}_{\odot}/\mathrm{h}$

N. of cubes: 8

statistical study on high-z galaxies

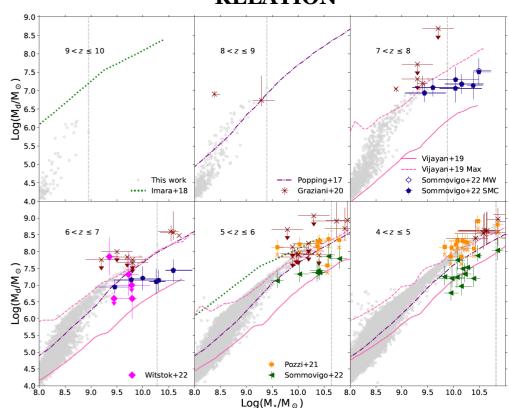
(Di Cesare+2023)

MAIN SEQUENCE OF GALAXY FORMATION



dustyGadget predictions are in **global agreement** with high redshift available data

DUST MASS STELLAR MASS RELATION



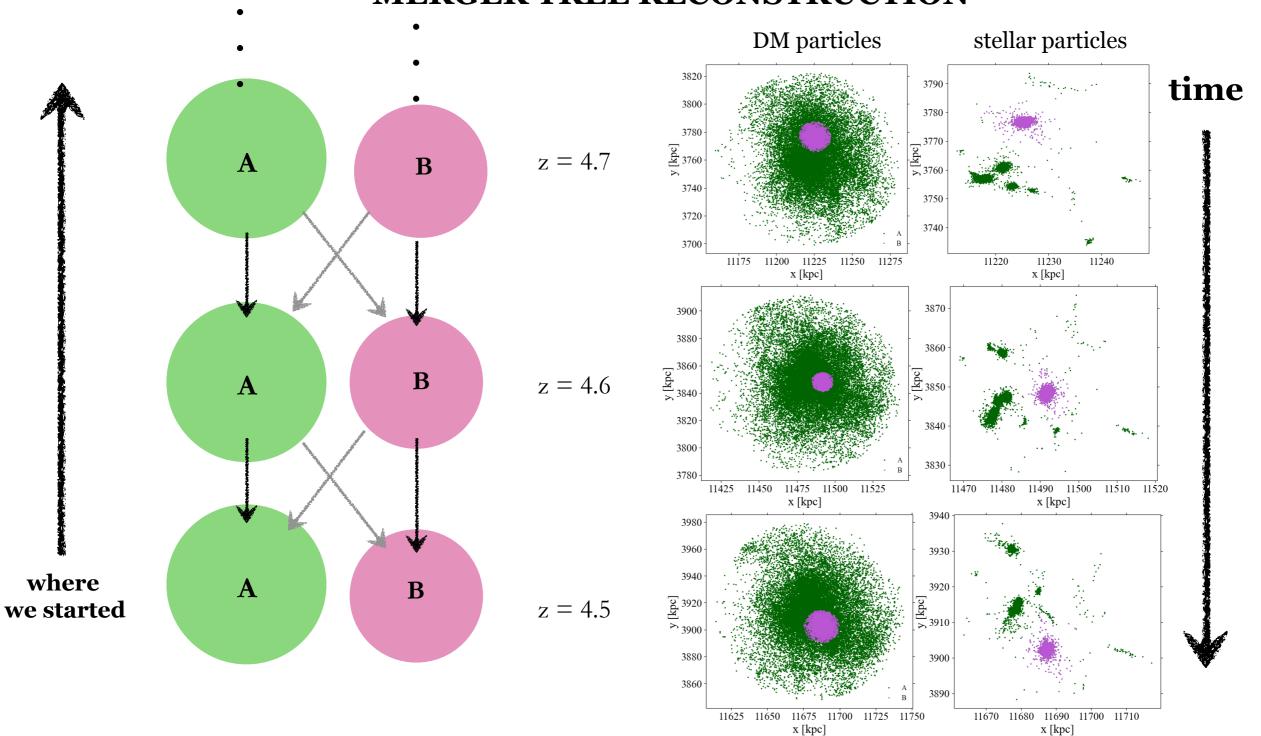
now!

looking for MAJOR MERGING SYSTEMS in dustyGadget

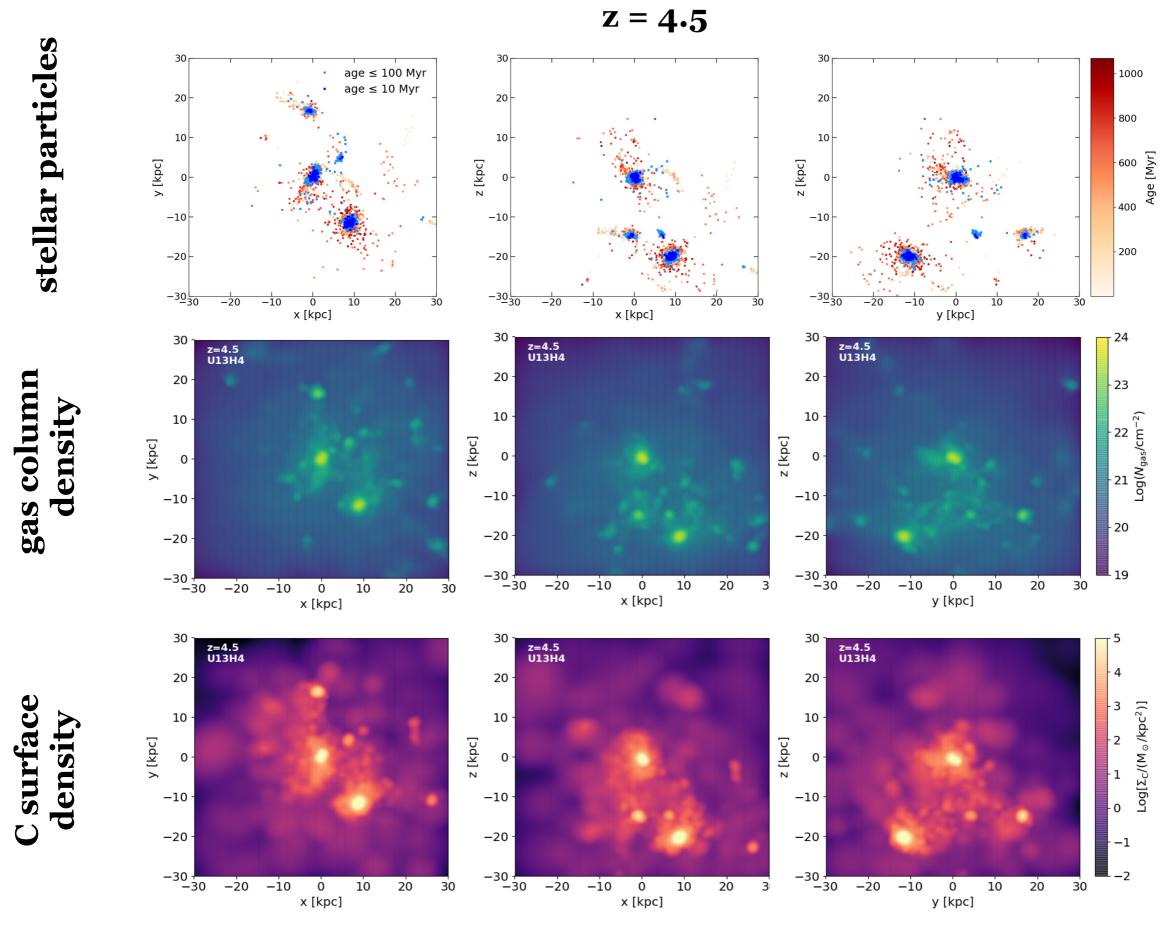
- 1. observed redshift range
- 2. cut on the stellar masses ($Log(M_{\star}/M_{\odot}) \ge 10$)
- 3. mass ratios comparable with observations

sample of 10 galaxies at z~4.5

MERGER TREE RECONSTRUCTION



- i) merger happens before in DM than baryonic matter
- ii) satellites in baryonic matter



preliminary CONCLUSIONS:

- diffuse [CII] emission from a sample of 6 interacting galaxies
- 35%-70% emission is coming from the medium *between* the galaxies
- tentative trends between the diffuse emission, physical properties ($L_{[CII]}; M_{\star}; SFR$) and the relative properties ($r_p; \mu$) of analysed systems
- merger tree reconstructions with dustyGadget
- predictions from simulations to interpret the observations

Thanks for your attention!

email: <u>claudia.dicesare@uniroma1.it</u>