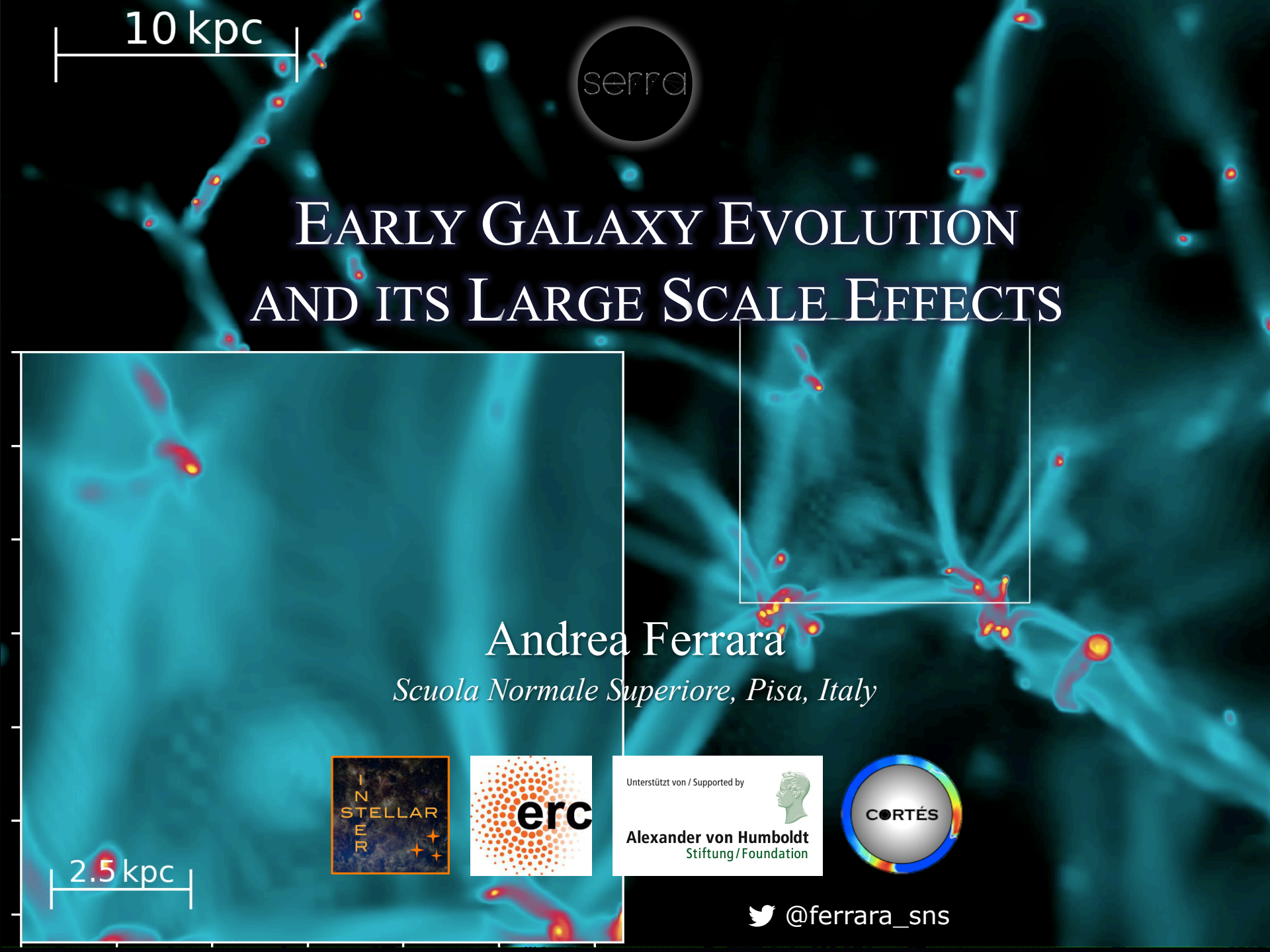

Early Galaxy Evolution and its Large Scale Effects

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Scuola Normale Superiore, Pisa, Italy

Unterstützt von / Supported by
Alexander von Humboldt Stiftung/Foundation

@ferrara_sns

Sequence of events

At z=1000 the Universe has cooled down to 3000 K. Hydrogen becomes neutral ("Recombination").

At z < 40 the first "PopIII" star (clusters)/small galaxies form.

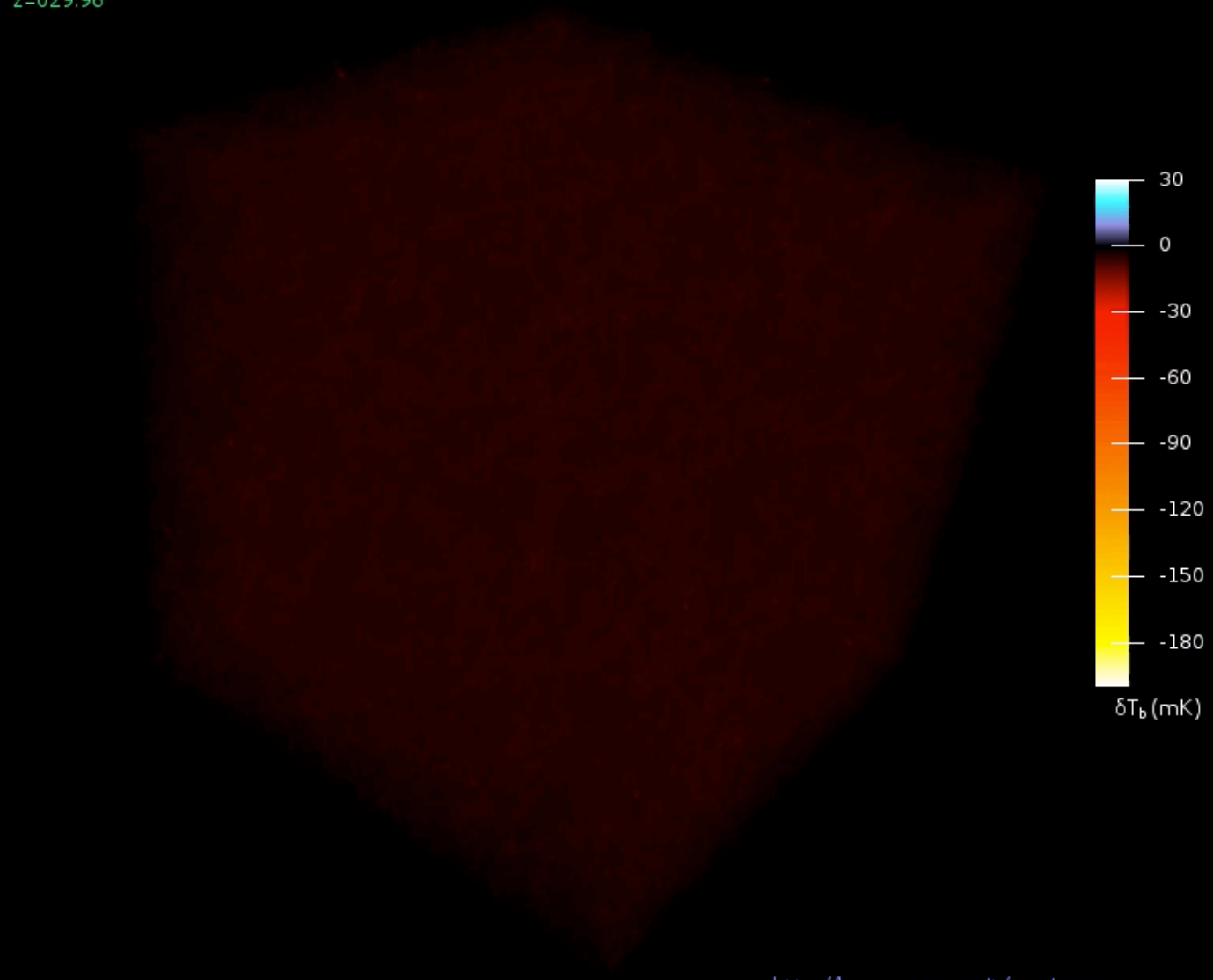
At z ~ 6-15 these gradually photo-ionize the hydrogen in the IGM ("Reionization").

At z<6 galaxies form most of their stars and grow by merging.

At z<1 massive galaxy clusters are assembled.

HI 21cm Line Brightness Temperature Evolution

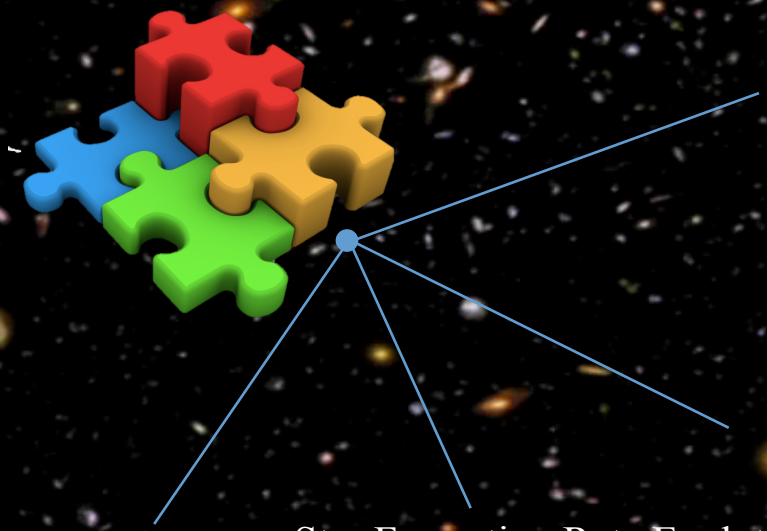
Box length=800Mpc
z=029.96



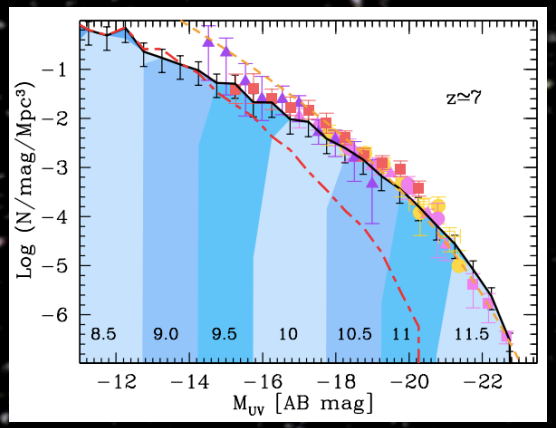
http://homepage.sns.it/mesinger


SKA
SQUARE KILOMETRE ARRAY
The world's largest radiotelescope

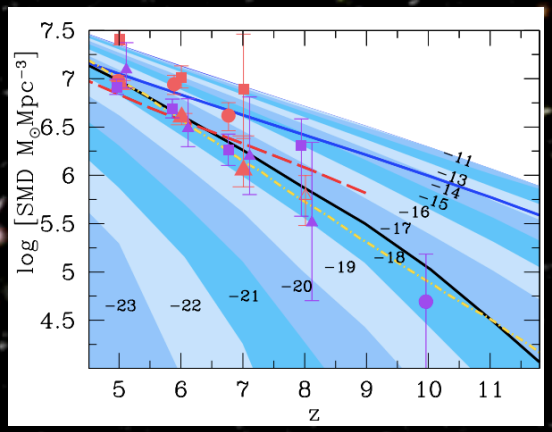
EoR Galaxies: Properties



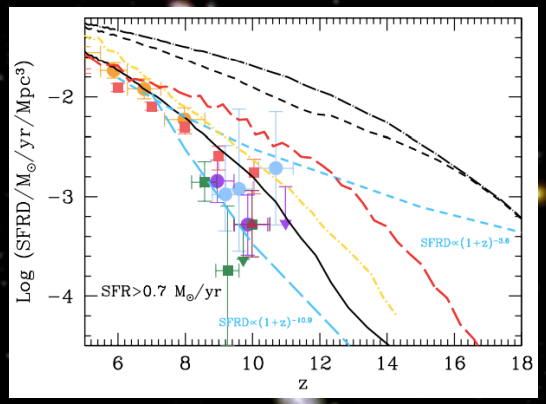
UV Luminosity Functions



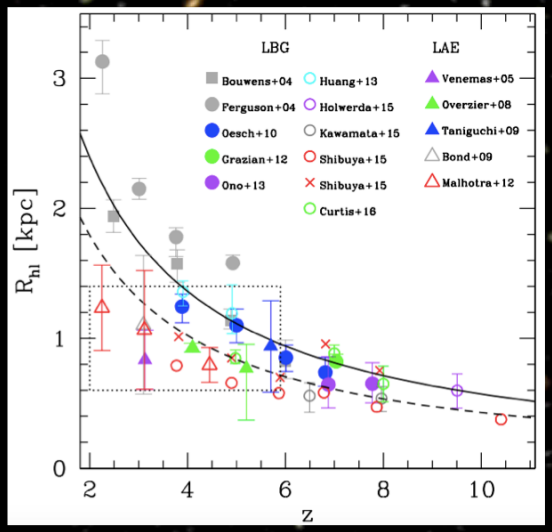
Stellar Mass Density Evolution



Star Formation Rate Evolution



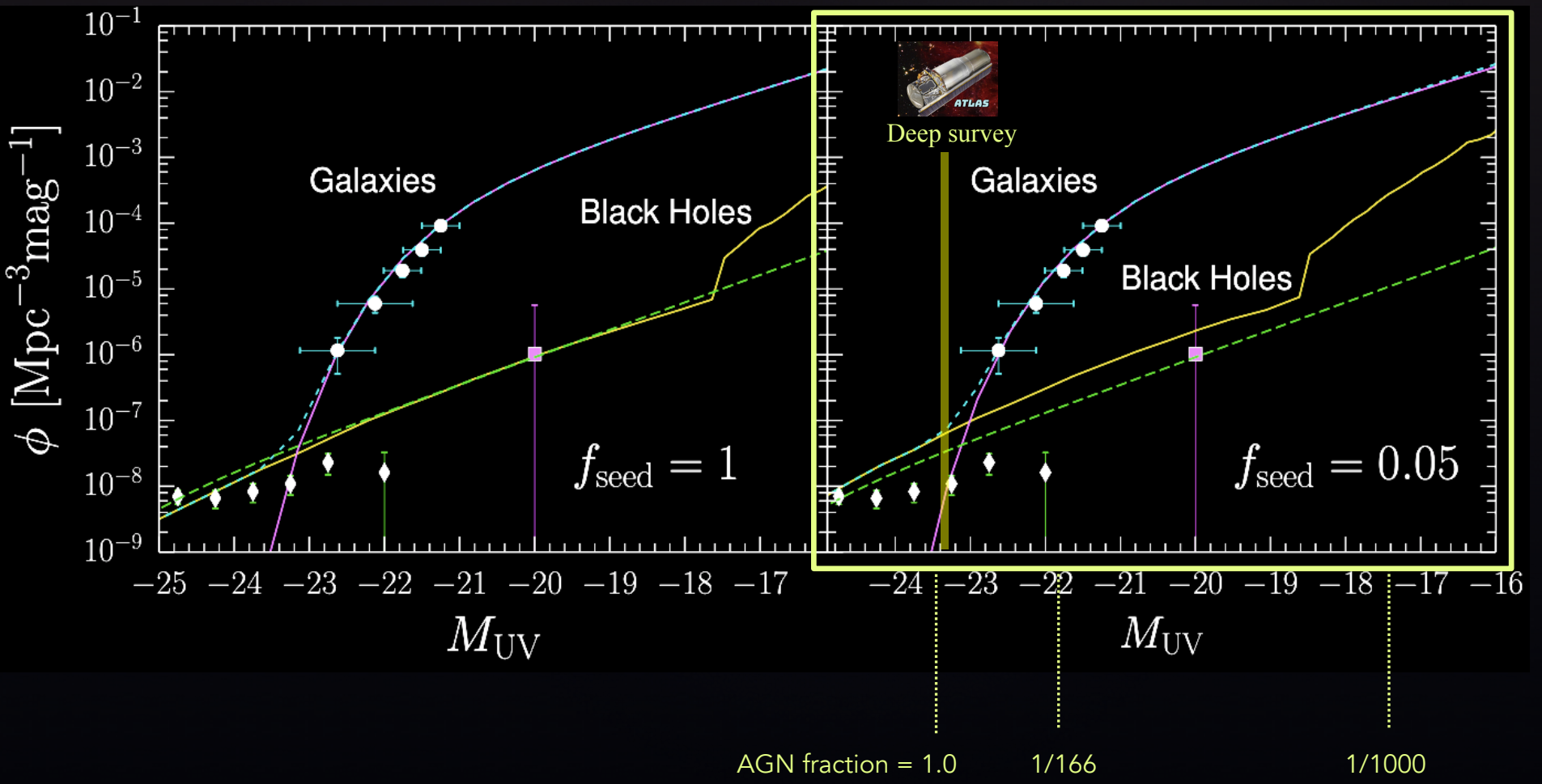
Size Evolution



For a review see:
Dayal & Ferrara 2018, Physics Reports, 780, 1

AGN in Luminous LBGs

Orofino+21

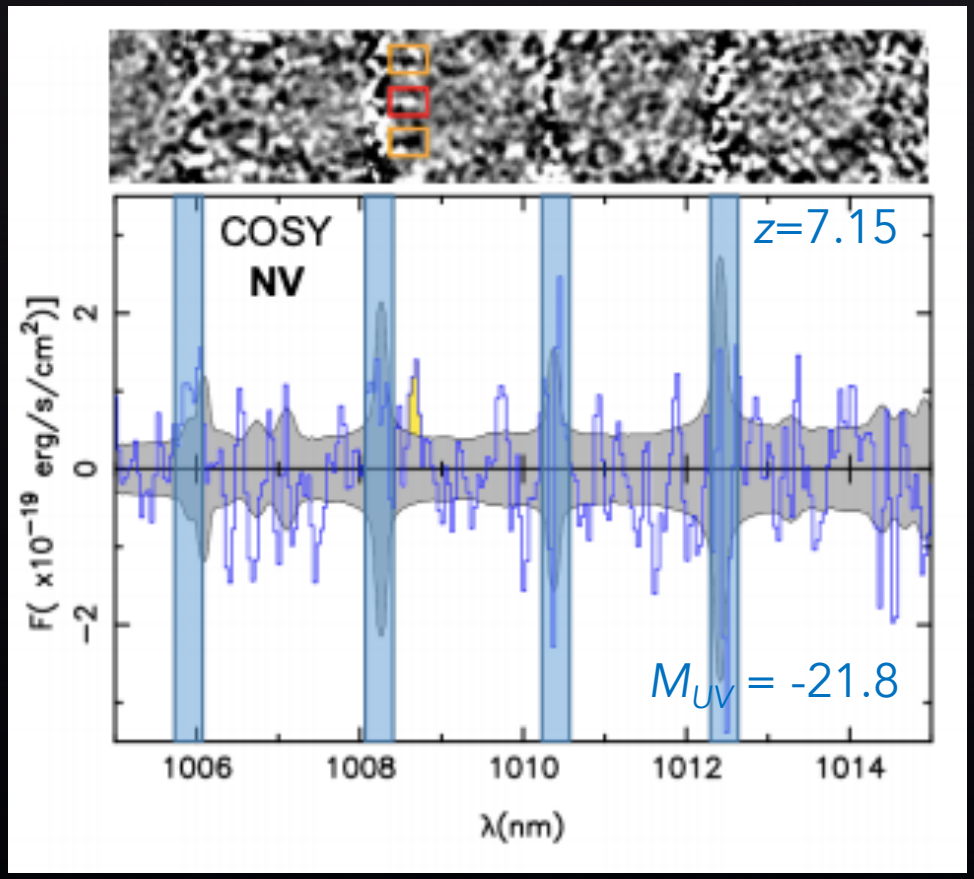


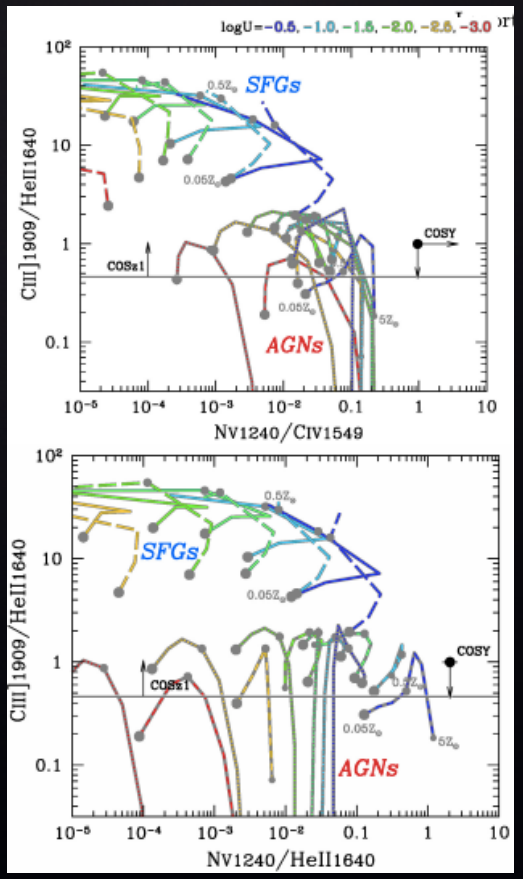
UV Lines Identify AGN

Laporte+17, Orofino+21

NV1240 Line Flux = 2.58 x 10^{-18} erg s^{-1} cm^{-2}

ATLAS Probe Deep
= 4.6 x 10^{-19} (5σ) erg s^{-1} cm^{-2}

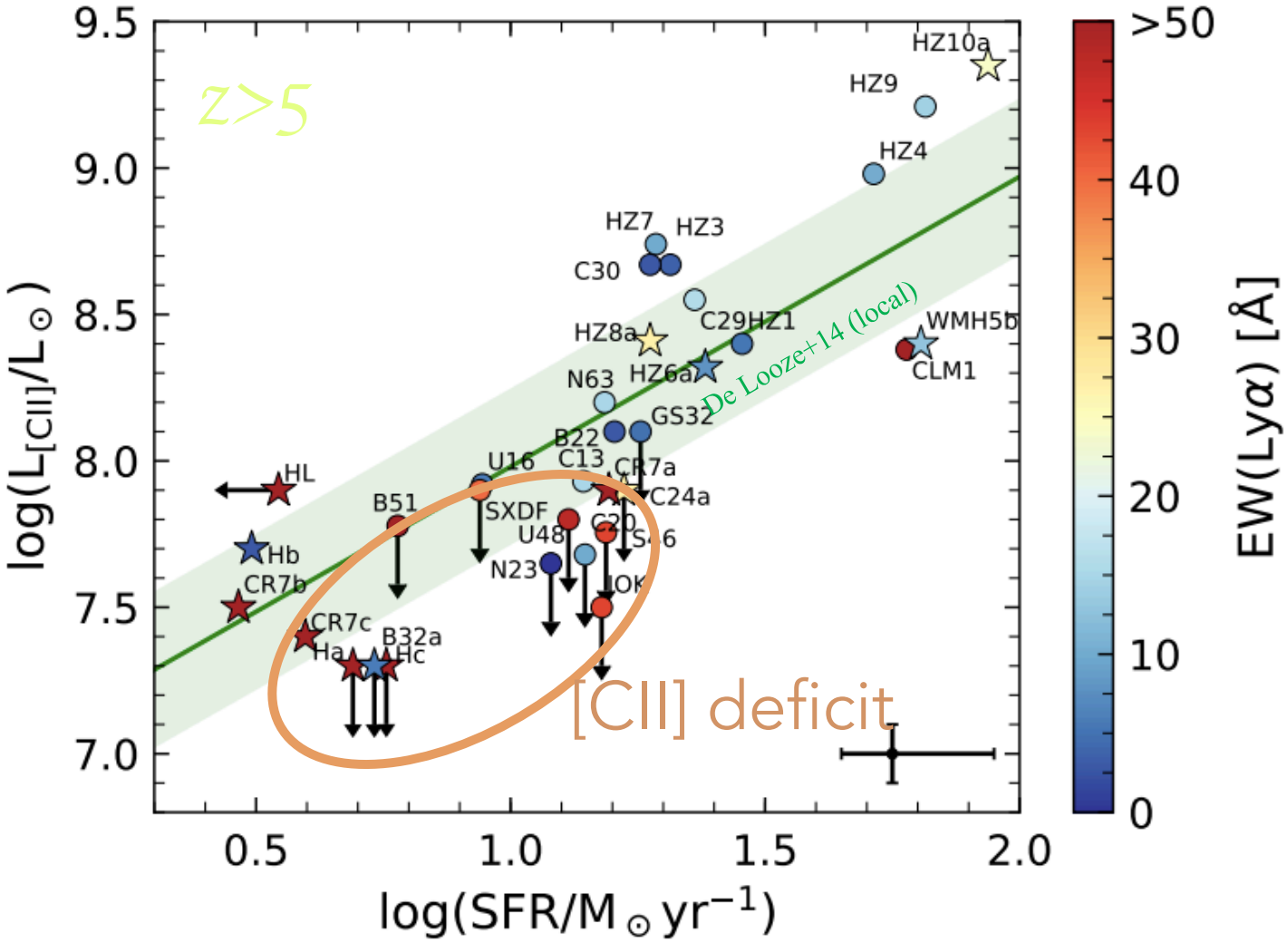





ALMA provides us with an unrivalled opportunity
to study the interstellar medium of early galaxies
Courtesy: ESO

[CII] DEFICIT

Carniani+18



LBGs @ z=6

[1] arXiv:1905.08254 [pdf, other]

Deep into the structure of the first galaxies: SERRA views

A. Pallottini, A. Ferrara, D Decataldo, S. Gallerani, L. Vallini, S. Carniani, C. Behrens, M. Kohandel, S. Salvadori

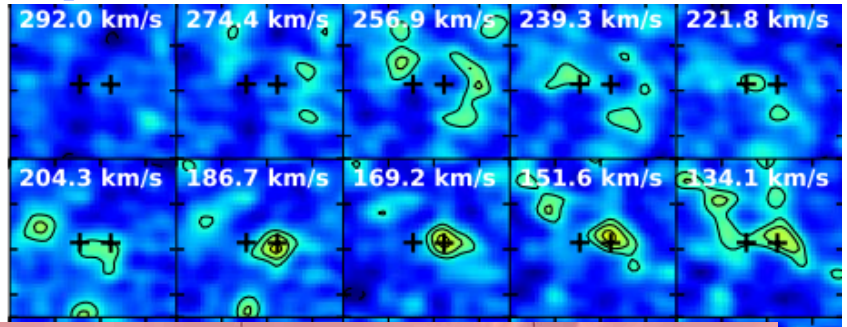
Comments: 22 pages, 14 figures, accepted by MNRAS
Subjects: **Astrophysics of Galaxies (astro-ph.GA)**; Cosmology and Nongalactic Astrophysics (astro-ph.CO)

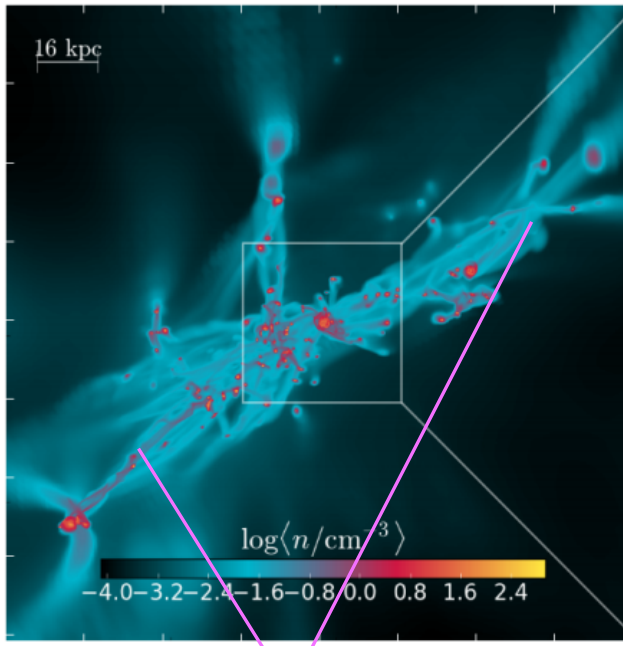
AMR zoom simulations
Spatial res = 8 pc
H_2-based SFR prescription
Non-equilibrium chemistry
Updated SN feedback model
Radiation pressure on dust
On-the-fly RT in 11 bands

serra

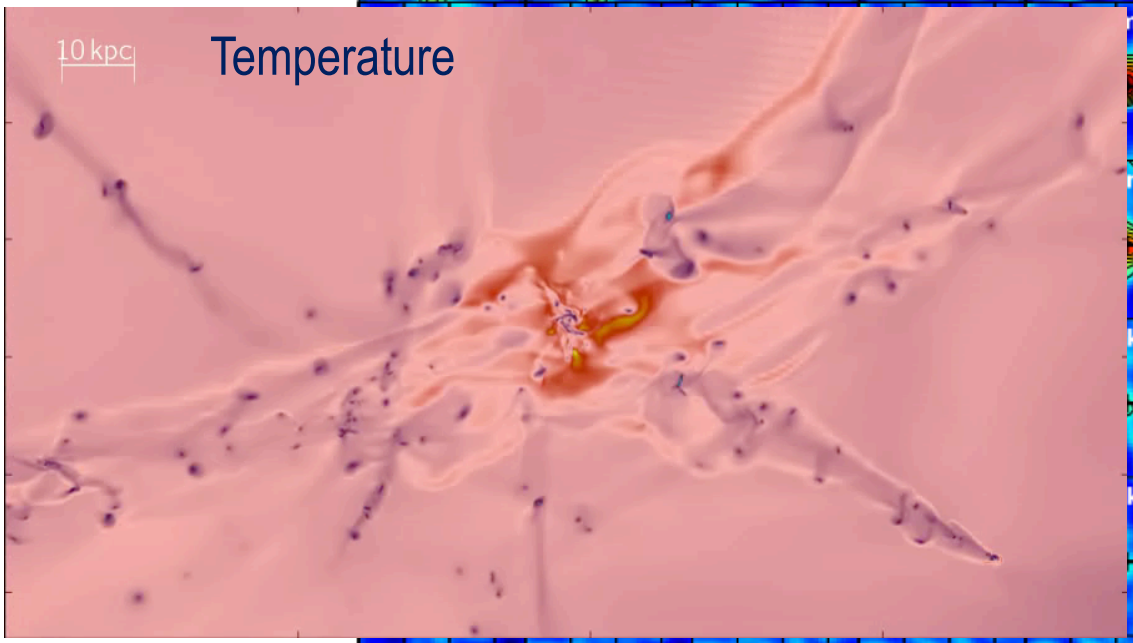
[CII] channel
map of WMH5, $z = 6.1$

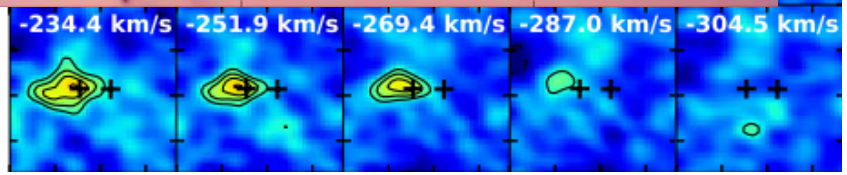
Jones+17





over-dense accreting filaments



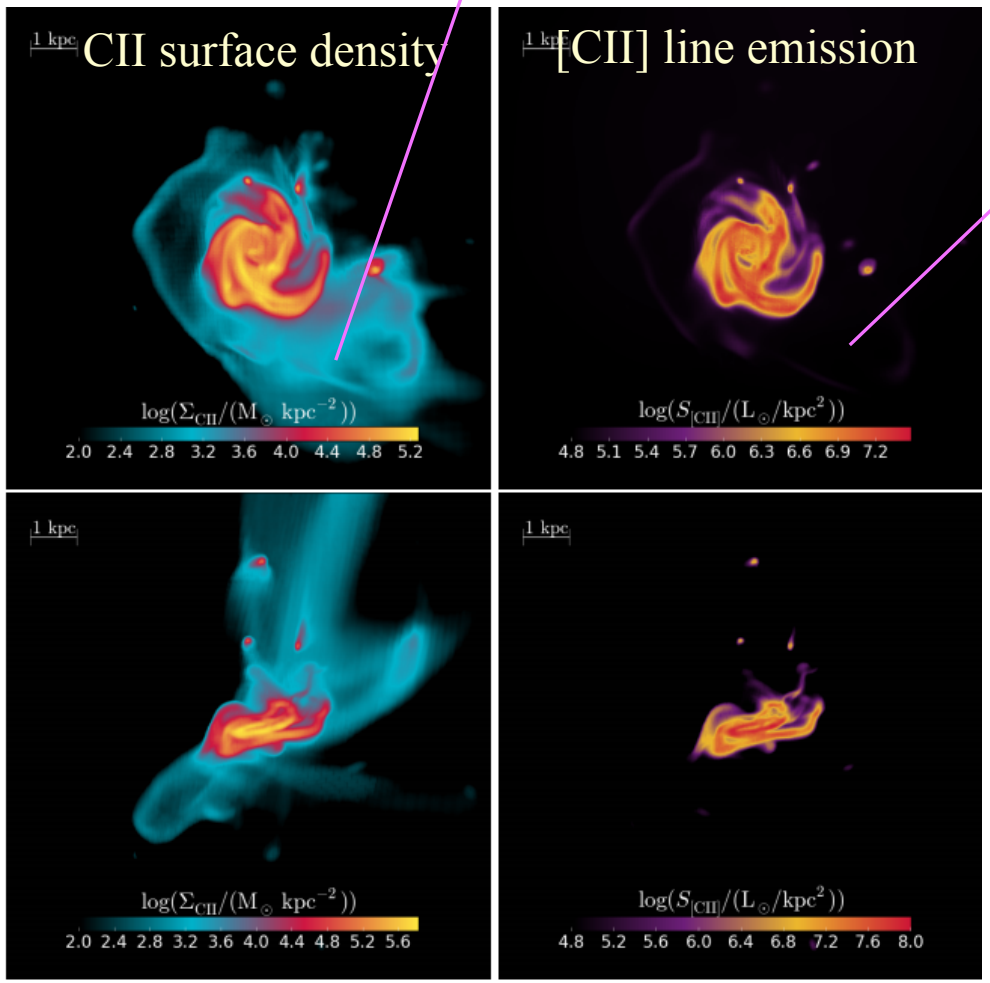


[CII] Sources (and Sinks)

⅓ of CII mass in diffuse, low-Z, weakly emitting gas (invisible due to CMB)

Face on

Edge-on



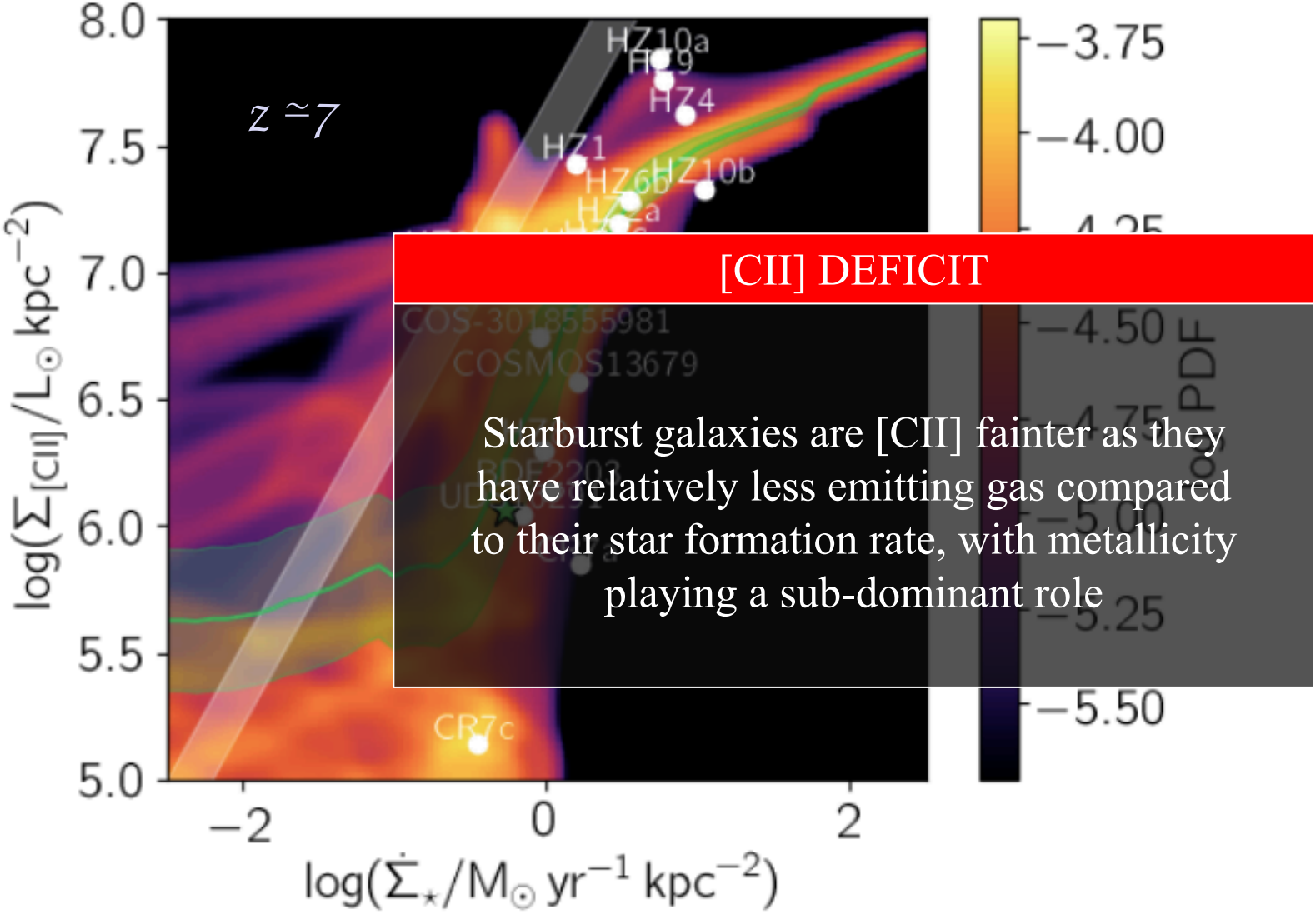
Total [CII] Luminosity
$L_{CII} = 3.5 \times 10^7\ L_\odot$

❖

95% of emission co-located with H_2 disk

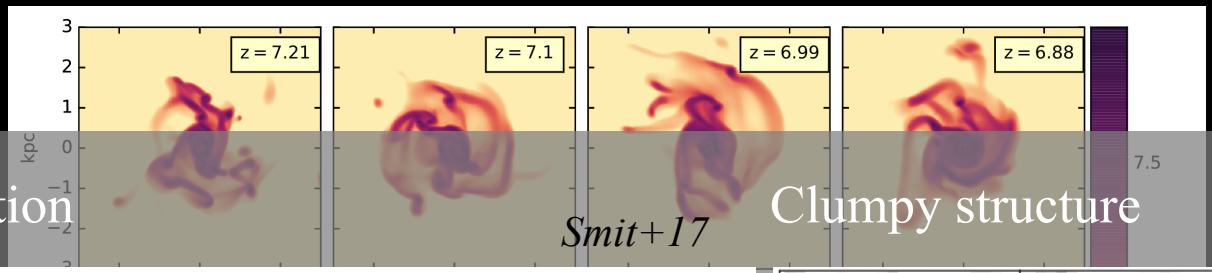
[CII] Deficit Simulated

AF+19, Pallottini+19



EARLY GALAXY ASSEMBLY

Kohandel+19, 20

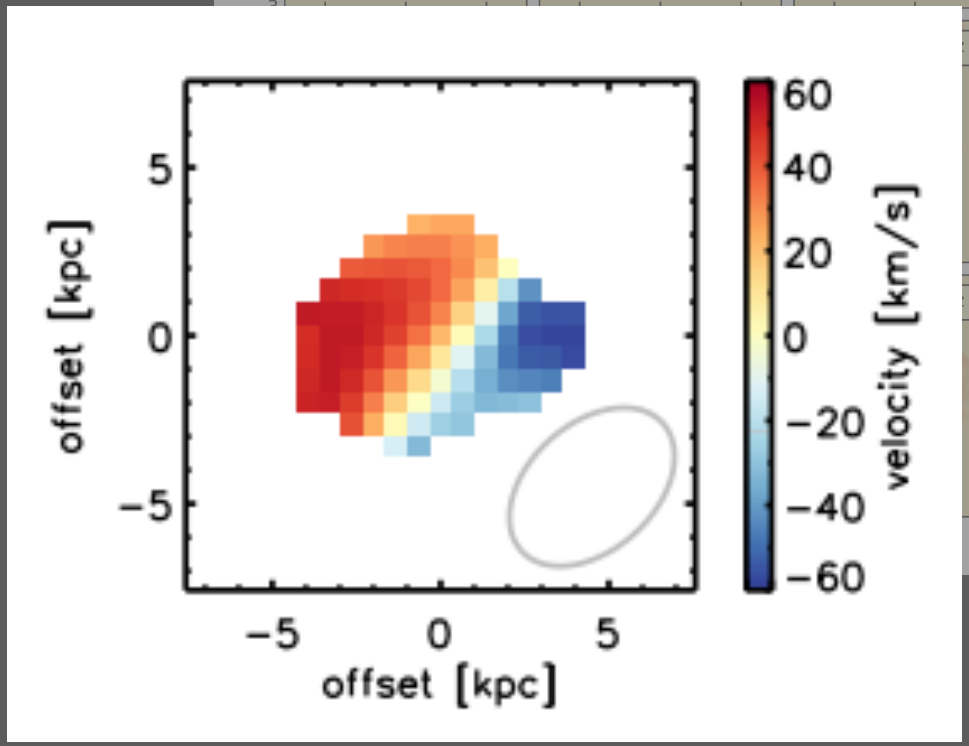


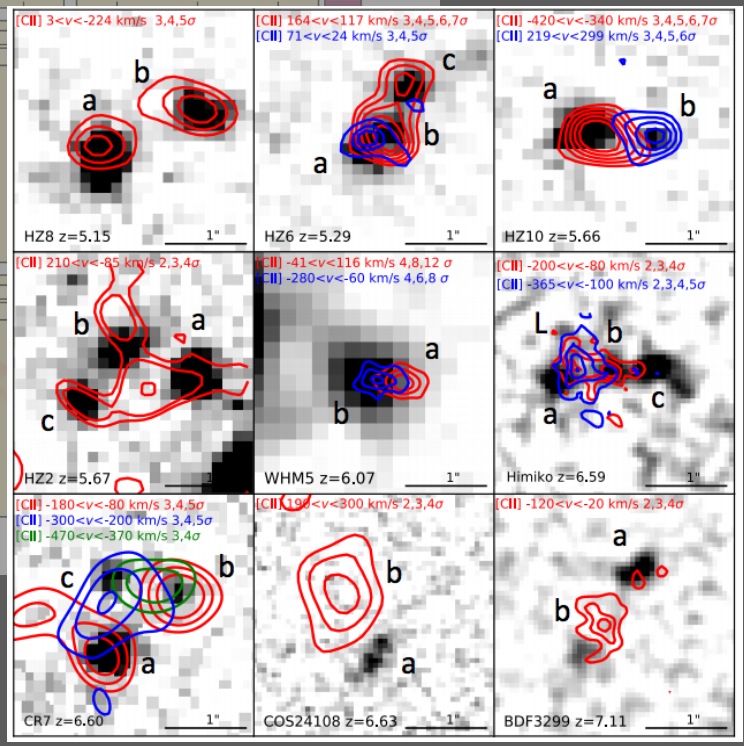
Disk rotation

Smit+17

Clumpy structure

Carniani+17



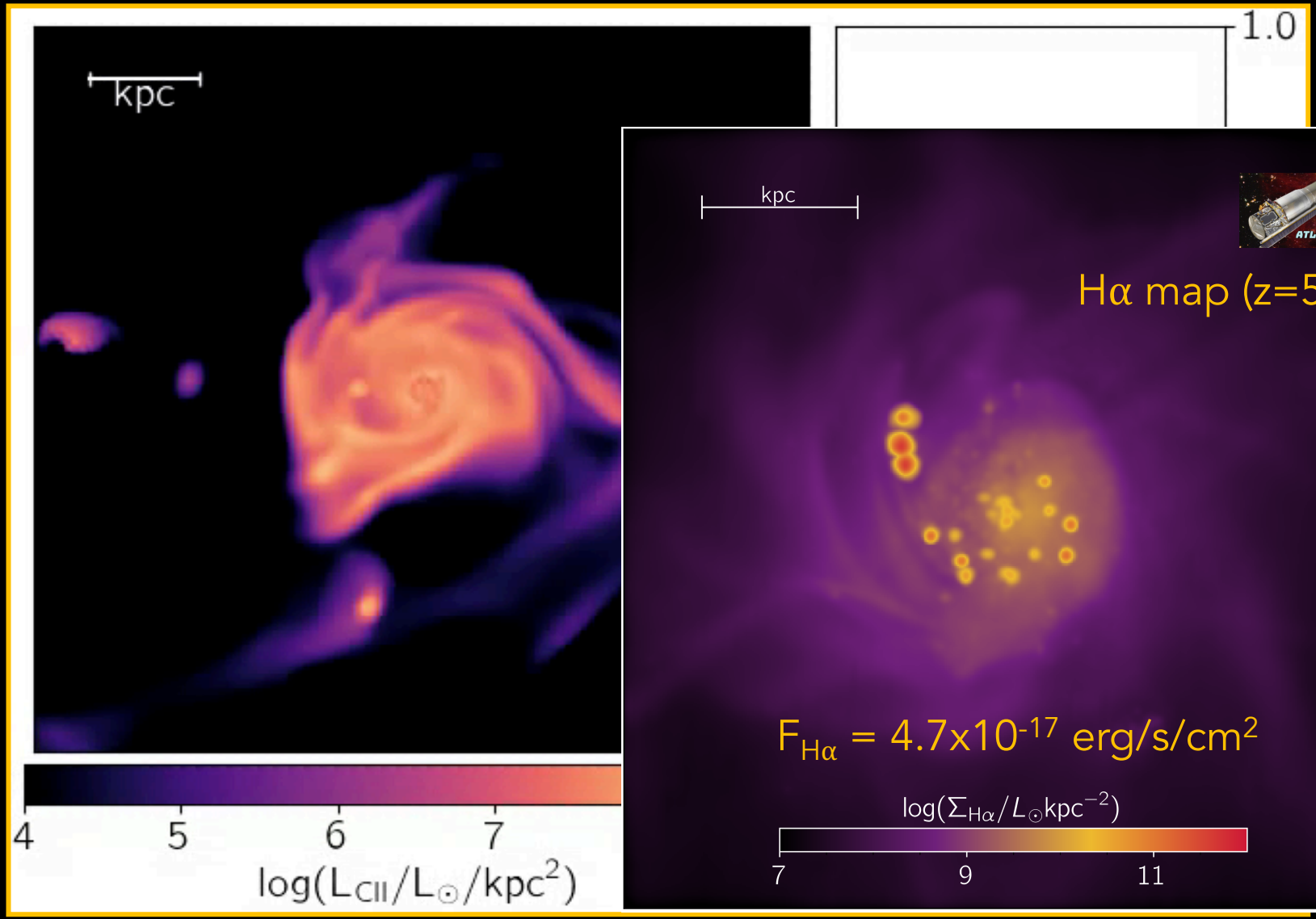


INCLINATION MATTERS

Kohandel+19, 20

[CII] map

[CII] line profile

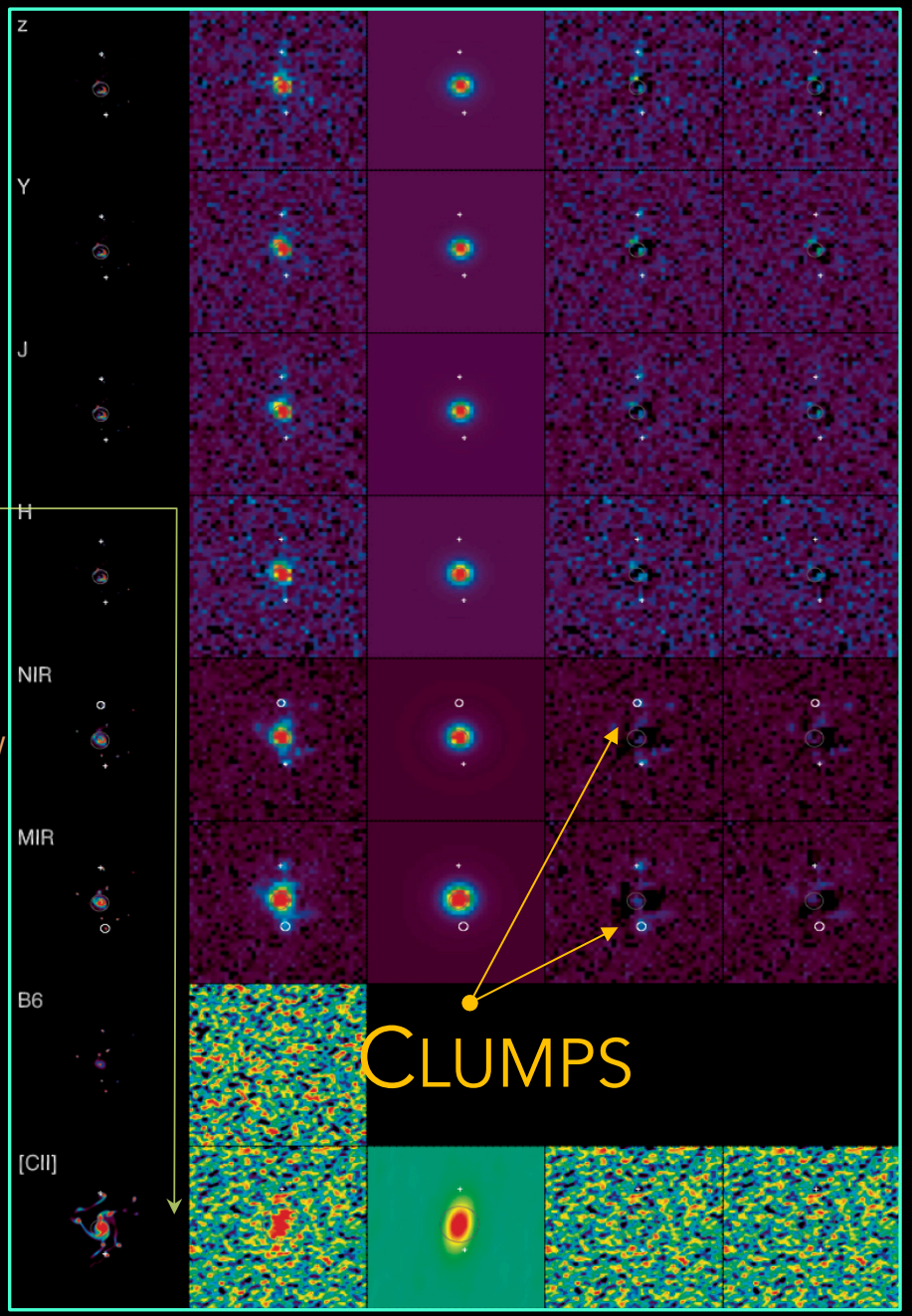


CLUMPS OR SATELLITES?

[CII] more extended than stars/dust

Clumpy disks
Predictions for a z=6 LBG
combining JWST & ALMA

Pallottini+19, Zanella+20



HST/ACS F850LP

HST/WFC3 F105W

HST/WFC3 F125W

HST/WFC3 F160W

JWST/NIRCam F444W

JWST/MIRI F770W

ALMA Band 6 cont.

ALMA 158um

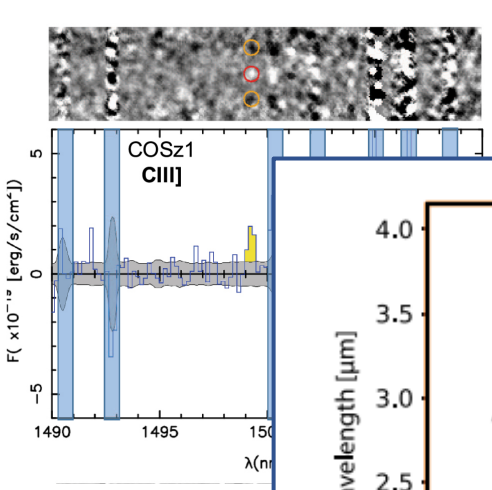
Vallini+20

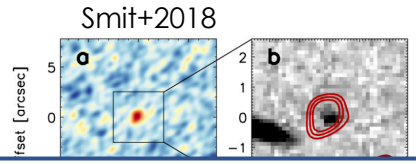
COS-3018: Combining UV AND FIR lines

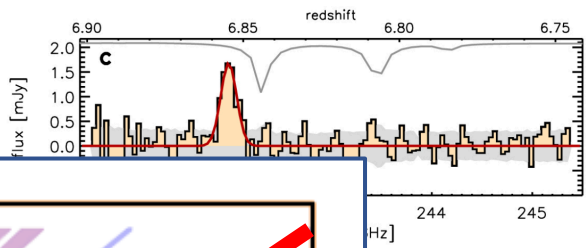
z=6.68

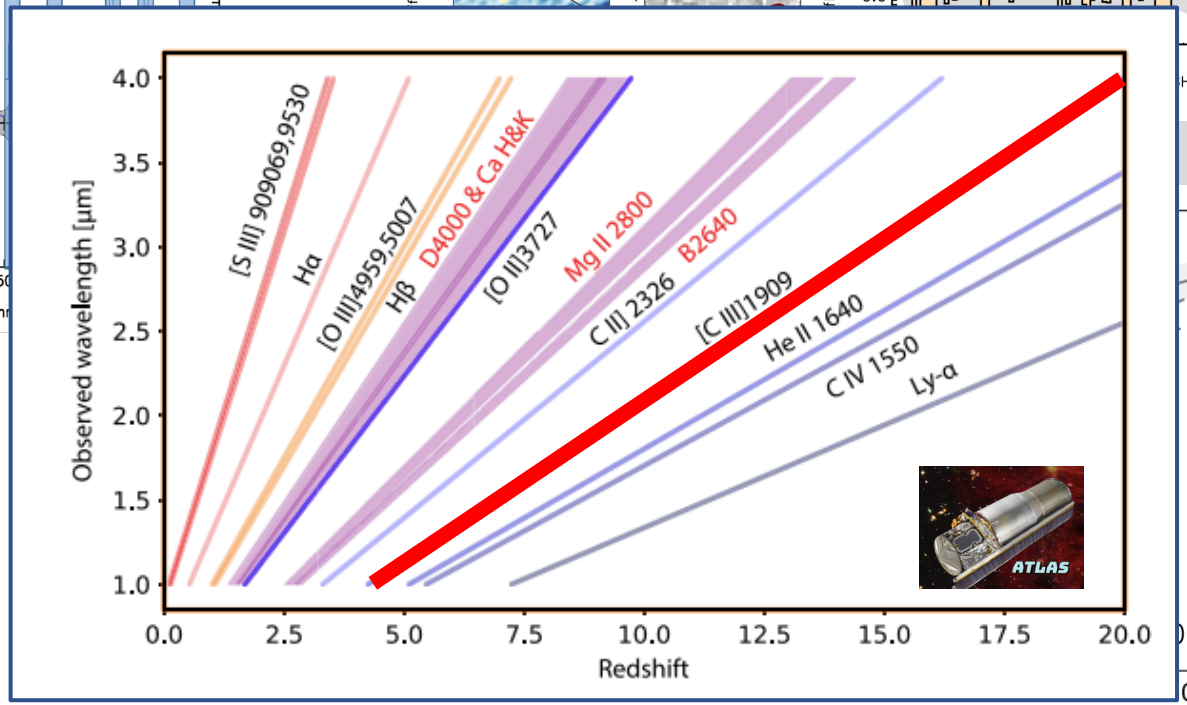
CIII] 1909 detected

[CII] detected and spatially resolved







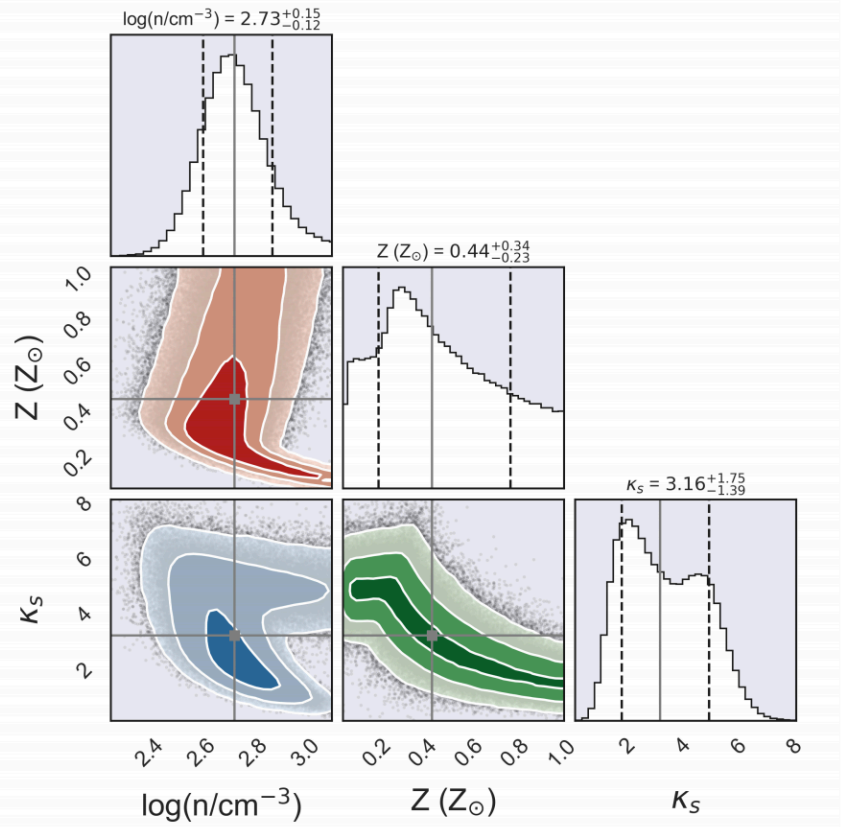


Vallini+20

COS-3018: physical properties

z=6.68

Quantity	Value	Reference
$r_{\rm UV}$ (kpc)	1.3 ± 0.1	(1)
$\rm SFR_{UV}$ ($\rm M_\odot\,yr^{-1}$)	18.9 ± 1.5	(1)
$\Sigma_{\rm SFR}$ ($\rm M_\odot\,yr^{-1}kpc^{-2}$)	3.6 ± 0.5	(1)
$L_{\rm [CII]}$ ($10^8\,L_\odot$)	4.7 ± 0.5	(2)
$r_{\rm [CII]}$ (kpc)	2.6 ± 0.5	(1)
$\Sigma_{\rm [CII]}$ ($L_\odot\,\rm kpc^{-2}$)	$(2.2 \pm 0.7) \times 10^7$	This work
$L_{\rm CIII]}$ ($L_\odot$)	$(1.9 \pm 0.4) \times 10^8$	(3)
$\Sigma_{\rm CIII]}$ ($L_\odot\,\rm kpc^{-2}$)	$(3.7 \pm 0.4) \times 10^7$	This work



COS3018

- it is a **moderate starburst galaxy** (κ_S = 3.16),
- has **sub-solar gas-phase metallicity** (Z =0.44 Z)
- has a **mean gas density** of log(n/cm^{-3}) = 2.73

GLAM!
Galaxy Line Analyzer with MCMC

Python routines developed to derive the ISM properties from observed [OIII] vs [CII] ratios in high-z galaxies

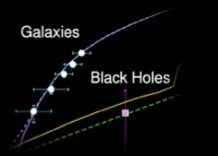
View On GitHub

GLAM (Galaxy Line Analyzer with MCMC) on GitHub
https://lvallini.github.io/MCMC_galaxyline_analyzer/

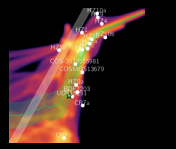
CONCLUSIONS.zip

EoR galaxies mostly studied in r.f. UV continuum or Lya line. Statistics has greatly improved.
Spectroscopy is fundamental to obtain their physical properties.

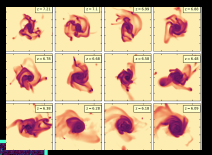
Spectroscopy is also key to infer the presence of faint AGN in LBGs

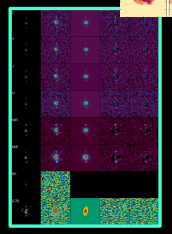


[CII] Deficit induced by starburst activity. Subdominant: metallicity & inclination;
CMB suppresses fine structure FIR emission from low density gas.



Galaxy assembly and dynamics can be quantitatively studied using spectral signatures.





Giant clumps can be detected in synergy with JWST;
In-situ or satellites? Relation with gravitational bulk motions?

Combine FIR and r.f. UV lines to study physical properties (k_s, *Z, n)* of EoR galaxies