Understanding the extended [CII] halo and its implications for LIM with cosmological zoomed simulations

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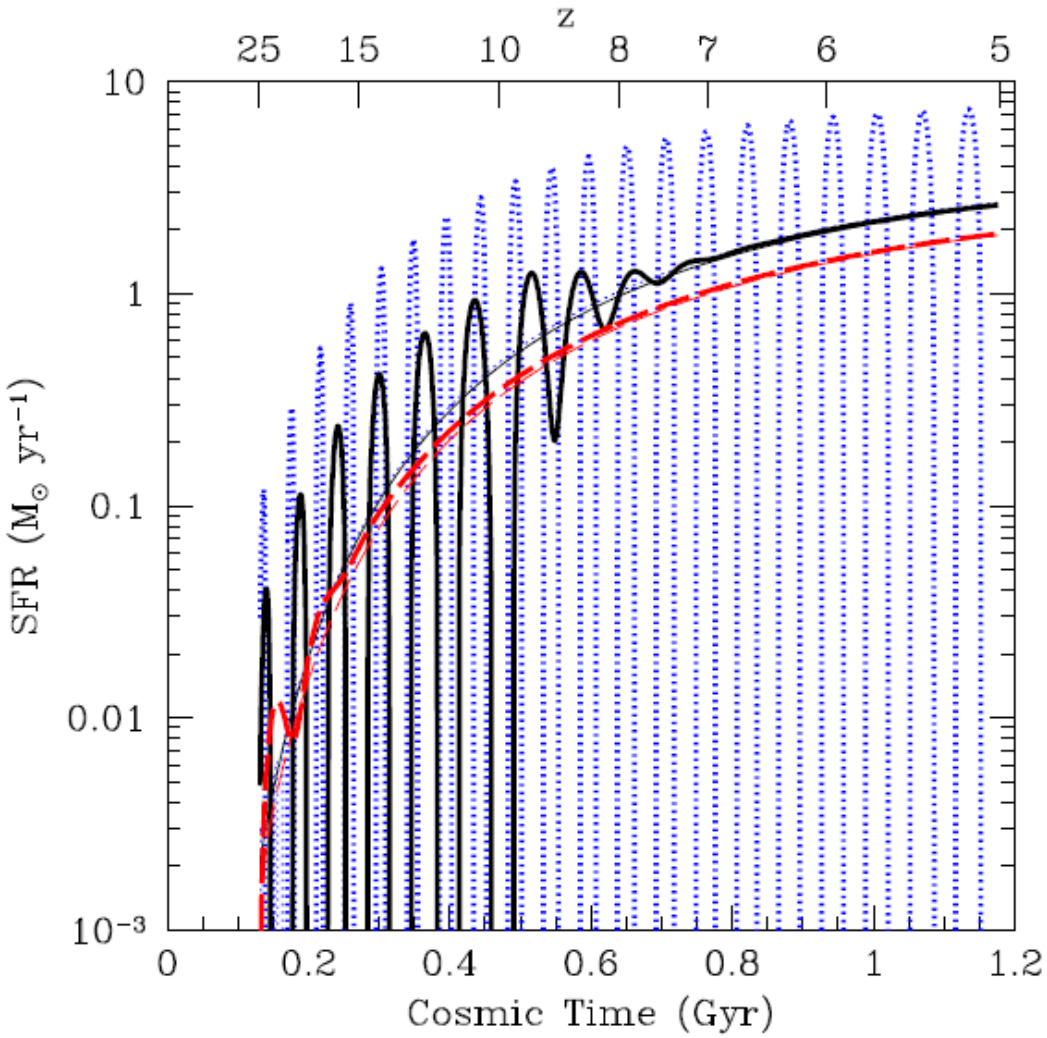
LIM25, Annecy, France

June 4, 2025

Image credit: Aaron M. Geller, Northwestern, CIERA + IT-RCDS

[CII] Line intensity mapping (LIM) to study high-z galaxy evolution

- Evolving picture of the high-z cosmic star formation and galaxy evolution
- Overabundance of bright galaxies and prevalence of starburst in cosmic dawn—a scenario that can be explained by the *bursty star formation*
- Feedback mechanisms of bursty star formation can potentially explain the ~10kpc scale *extended [CII] emission* in 4<z<6 galaxies



Furlanetto & Mirocha 2022

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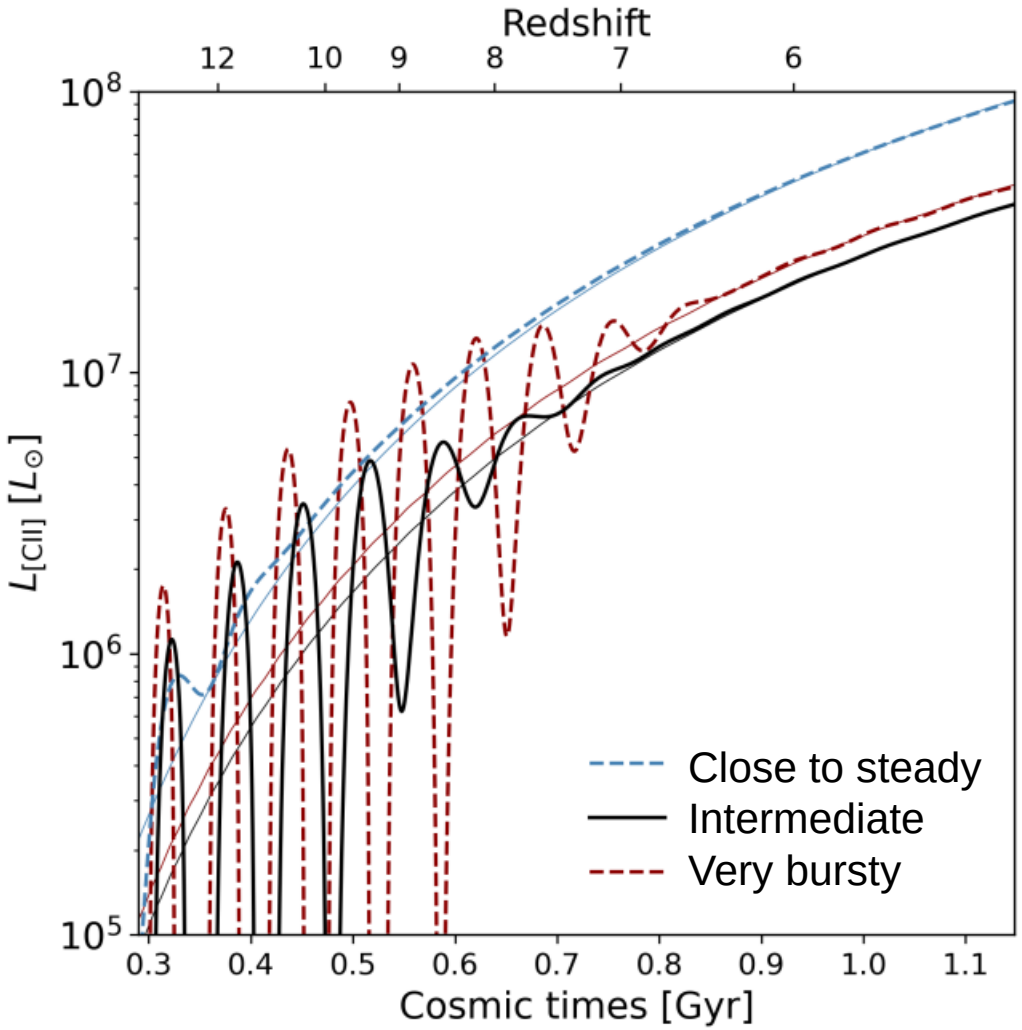
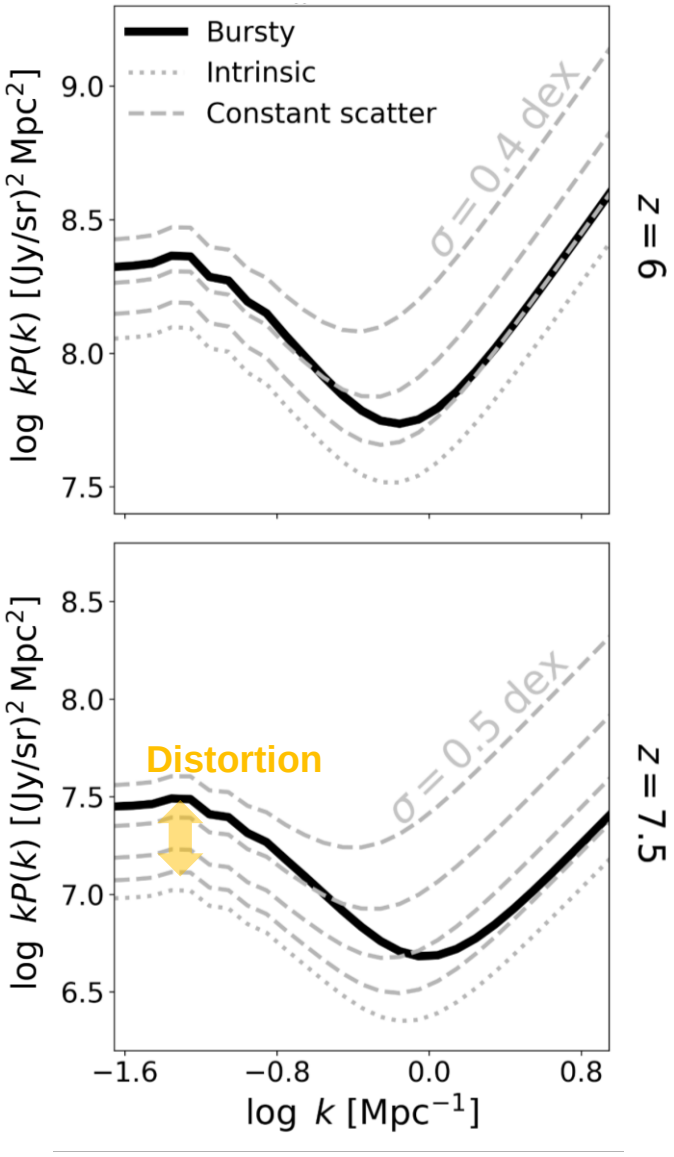


Liu et al., ApJ (2024), arXiv:2401.04204

Prevalence of high-z bursty star formation can modify the shape of [CII] LIM signals



- Bursty star formation driven by delayed supernova feedback
- This can cause halo mass dependent scatter of the [CII] luminosity
- Causes distortion of the [CII] power spectra that cannot be simply explained by a constant scatter
- Large scale, clustering power elevated, since lower mass halos that are more bursty

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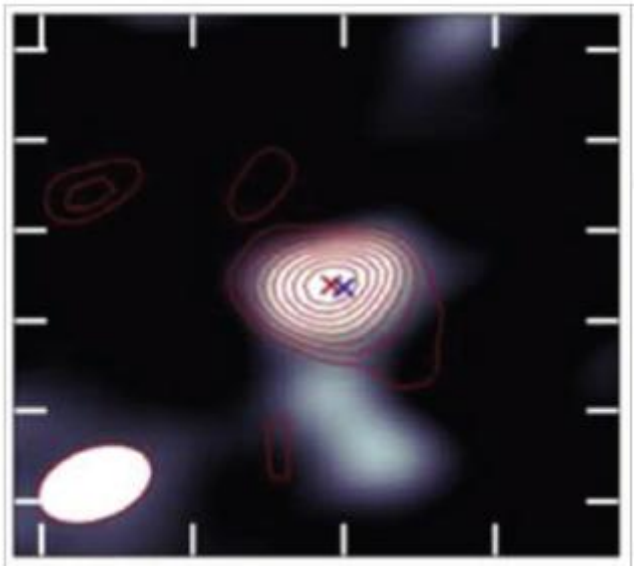
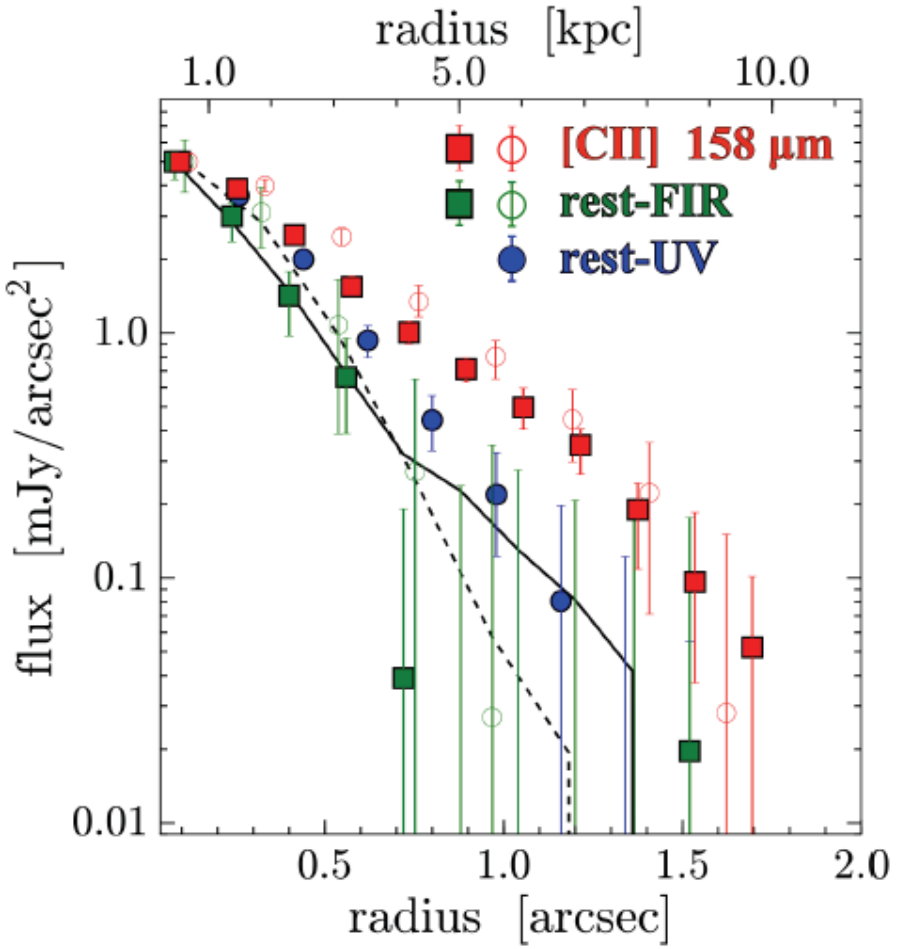
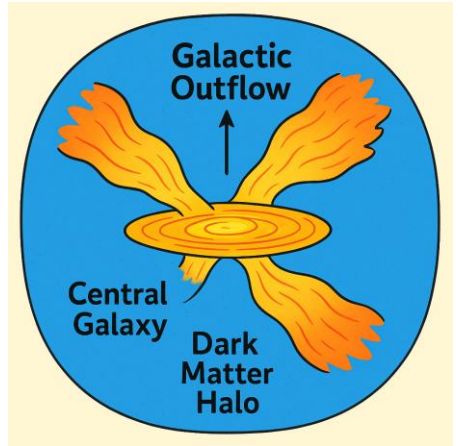
Questions remain regarding the [CII] emission in high-z galaxies





Satellite galaxies?

Outflows?

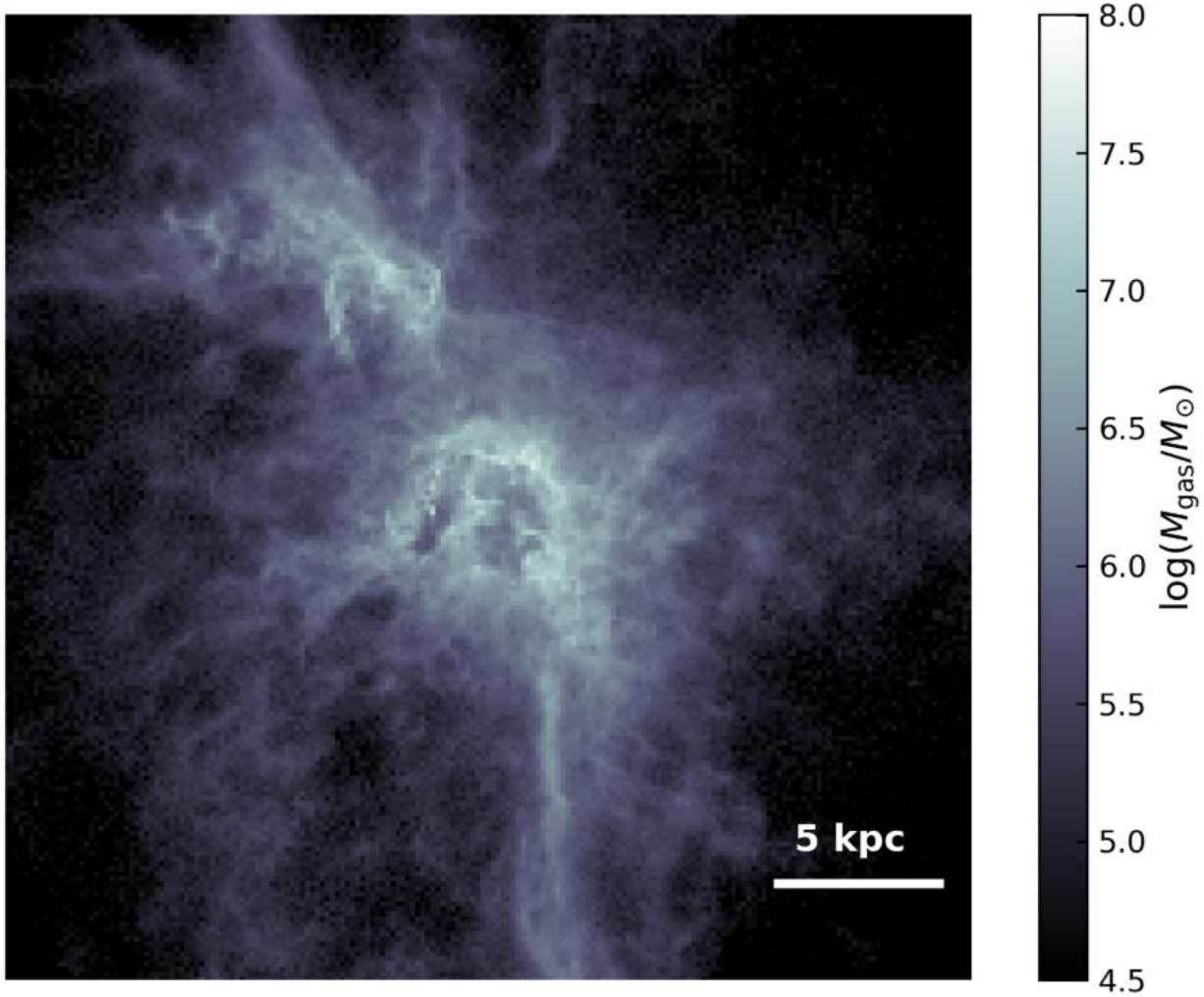


Fujimoto+19+20

High-resolution simulation is appropriate for understanding the extended [CII] emission

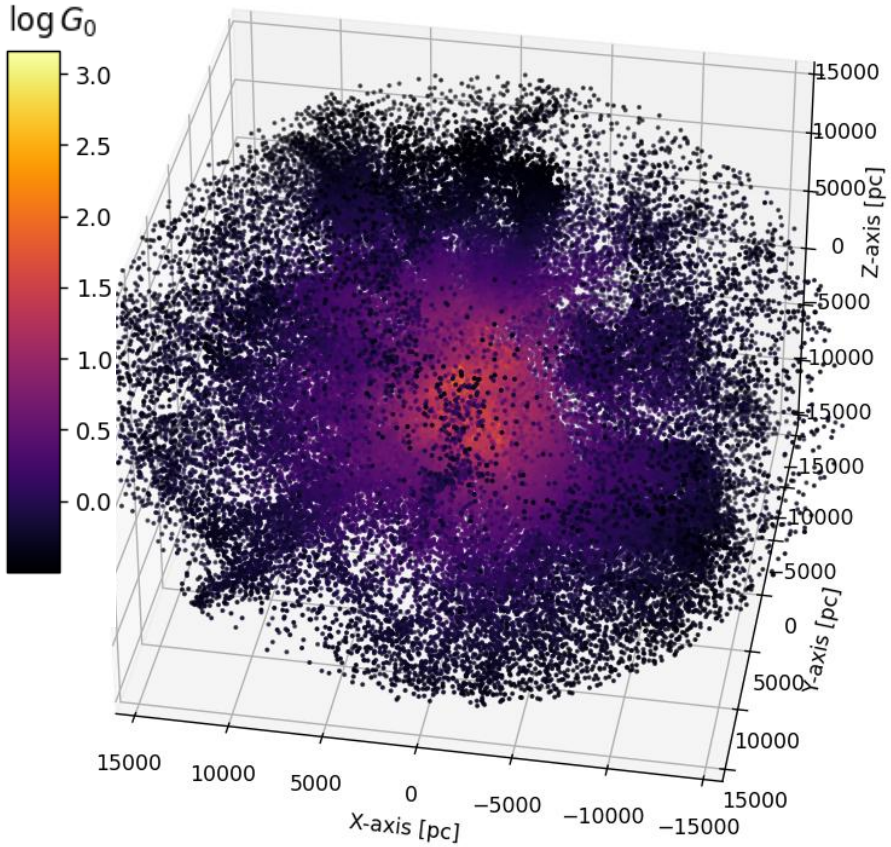
- FIRE-2 cosmological zoom-in simulations of z > 5 galaxies
- Resolved ISM, star formation, and multi-channel stellar feedback
- Halos with resolutions m_baryon ~ 1e2—1e4 M_sun and < 1 pc (densest gas)
- FIRE-2 galaxies are chosen to match the redshift, stellar mass, and SFR of ALMA galaxies

A FIRE-2 galaxy at z = 6



Modeling the [CII] emission in FIRE-2 galaxies

SKIRT: 3D radiative transfer

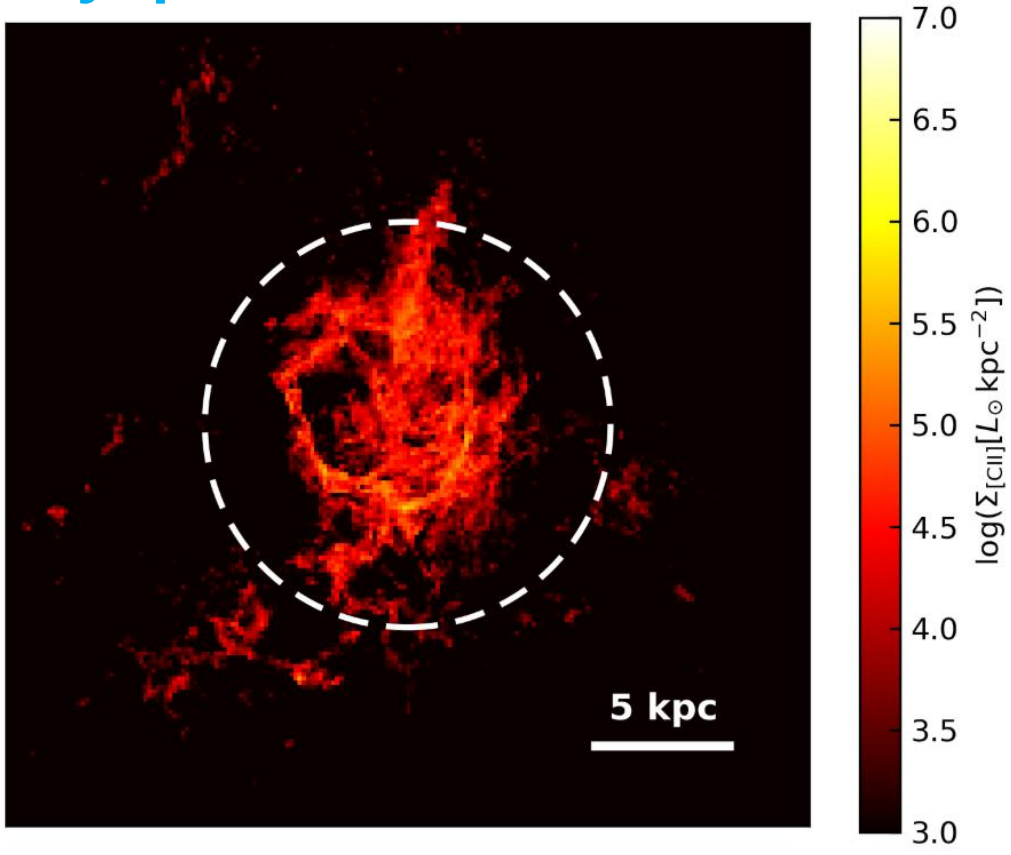


Product of radiative transfer
→ Interstellar radiation field intensity of individual gas clouds

+ FIRE-2 resolved galaxy properties

Prepared for the Cloudy photoionization simulation to get the line emissivity

Cloudy: photoionization model

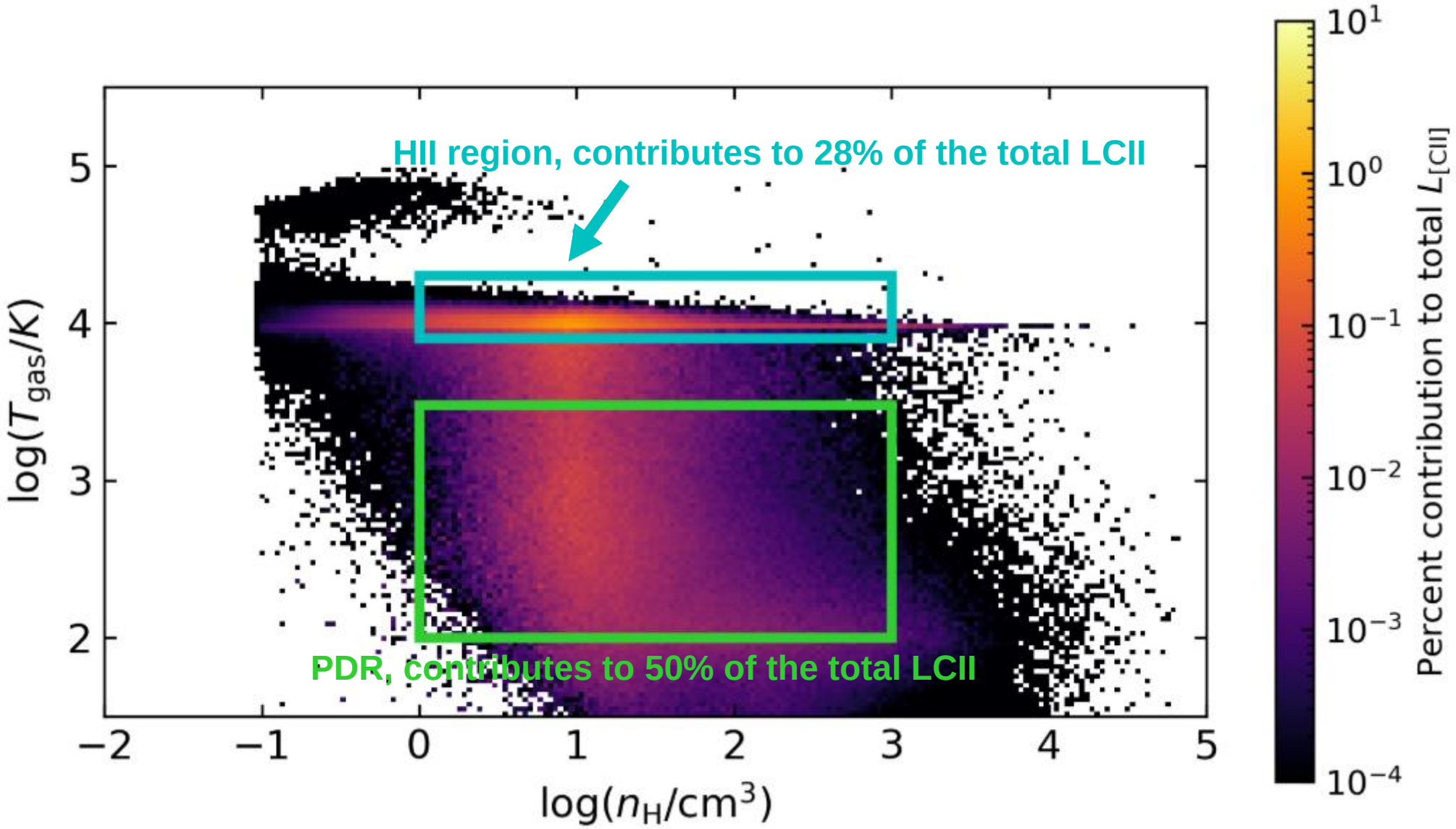


Line emissivity vs. ISM depth →
L_line of all gas clouds are integrated up to Sobolev length of local density gradient

$$L_{[\mathrm{C\,II}],\,\mathrm{cl}} = 4\pi \int_0^{R_{\mathrm{cl}}} \Lambda_{[\mathrm{C\,II}]}(x)\, x^2 \mathrm{d}x$$

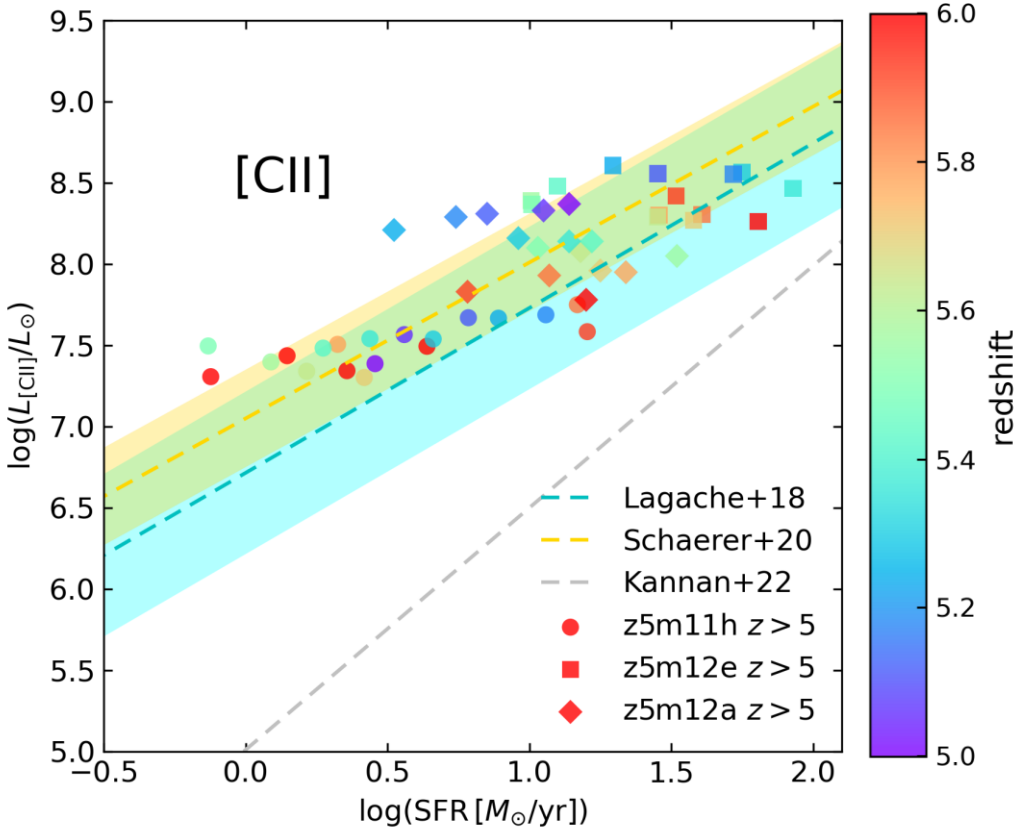
See also: Liang+24, Doğa's talk on June 3

Phase diagram of [CII]-emitting gas

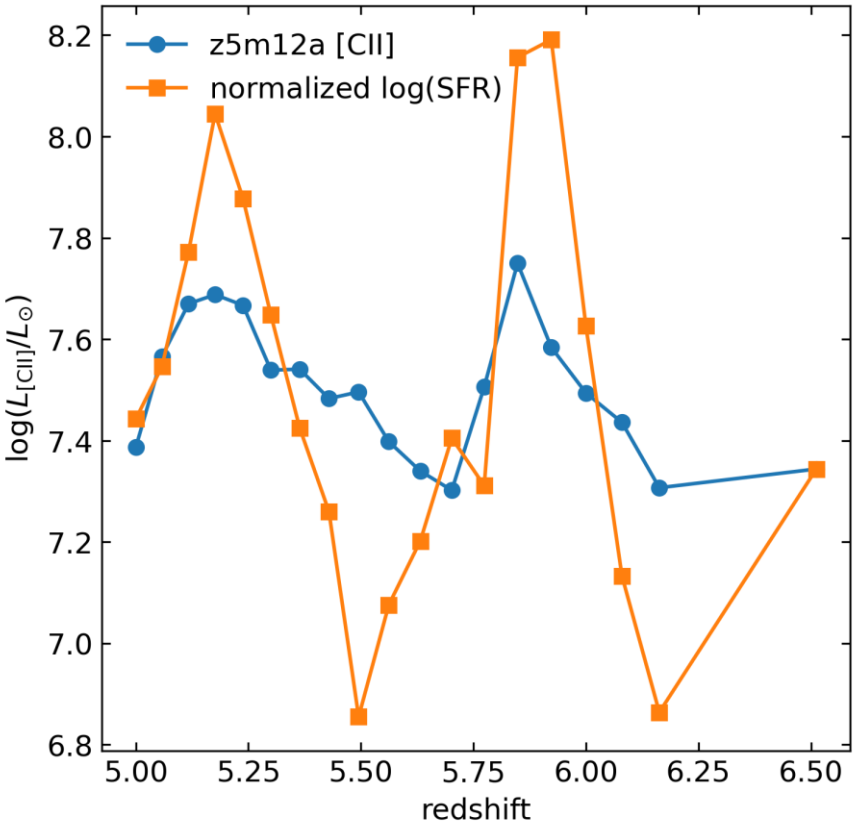


[CII] properties of FIRE-2 galaxies

L_{CII} vs SFR

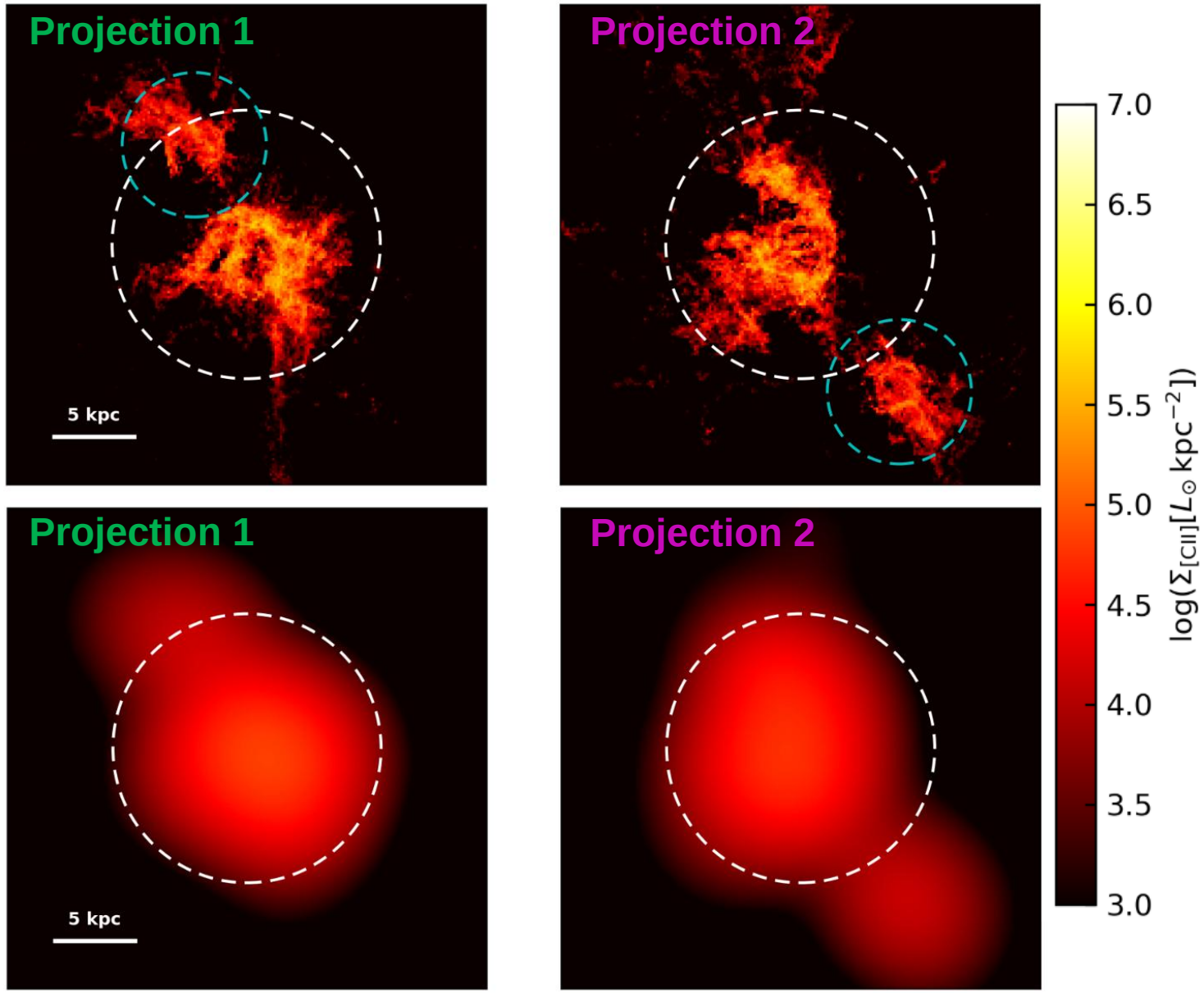


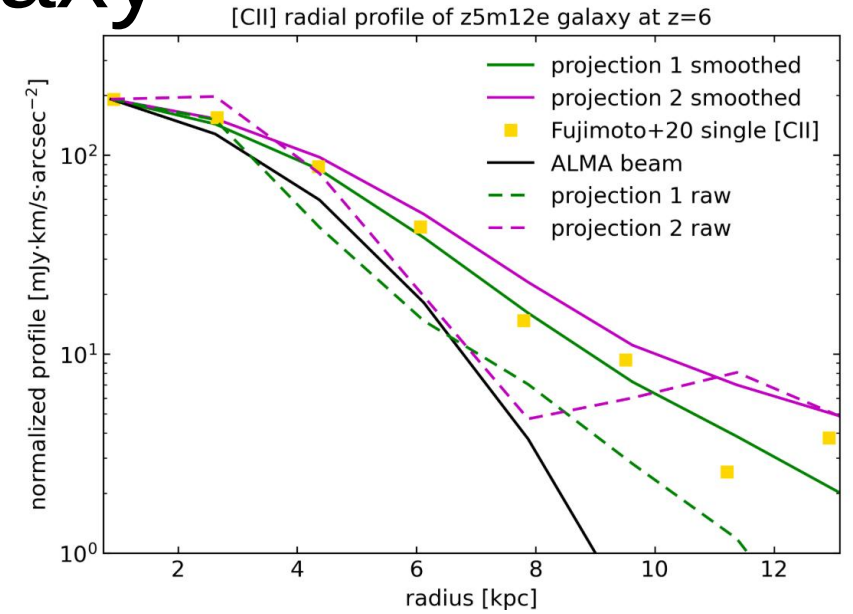
L_{CII} and SFR vs redshift



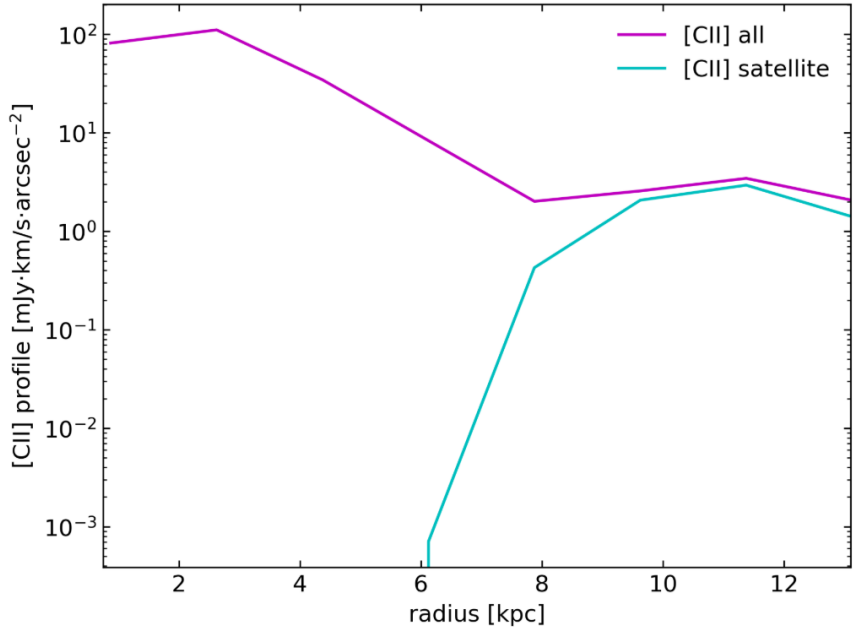
- Broadly consistent with the empirical relation
- Fluctuations of LCII and SFR vs redshift

z = 6 snapshot of a FIRE-2 galaxy





Satellite galaxy contribution to the extended emission



Summary

- The extended [CII] emission is ubiquitous in high-z galaxies, which can potentially modify the [CII] LIM signal
- Two pictures: (1) contribution by satellite galaxies, and (2) outflows driven by feedback of bursty star formation
- FIRE-2 + SKIRT + Cloudy: Satellite galaxies can contribute to the extended [CII] emission
- Varying the viewing angle can change the radius of [CII] halo