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CENTRE DE RECHERCHE ASTROPHYSIQUE DE LYON

Lya production and escape from high-redshift (simulated) galaxies and their CGM

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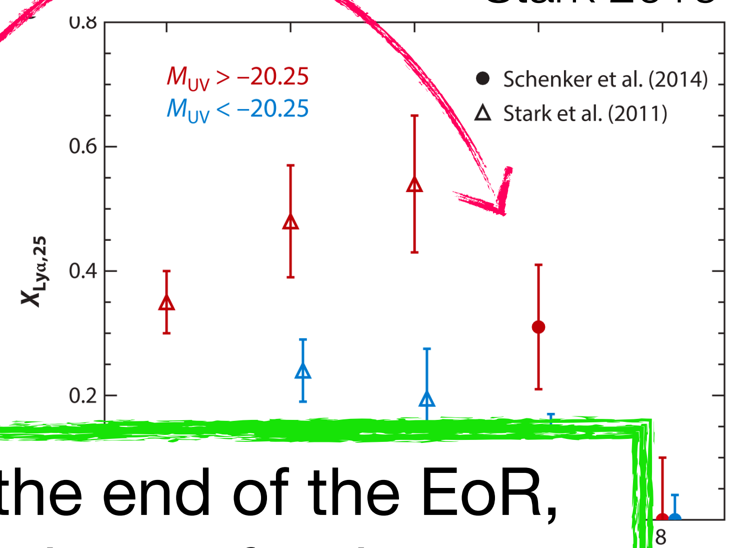
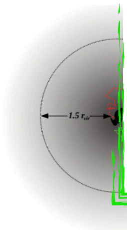
LAEs as probes of reionisation

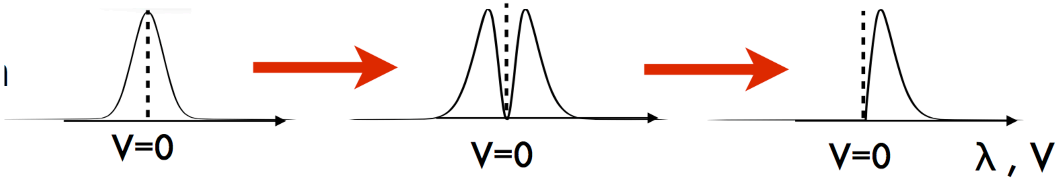
A partially neutral IGM will reduce the visibility of LAEs



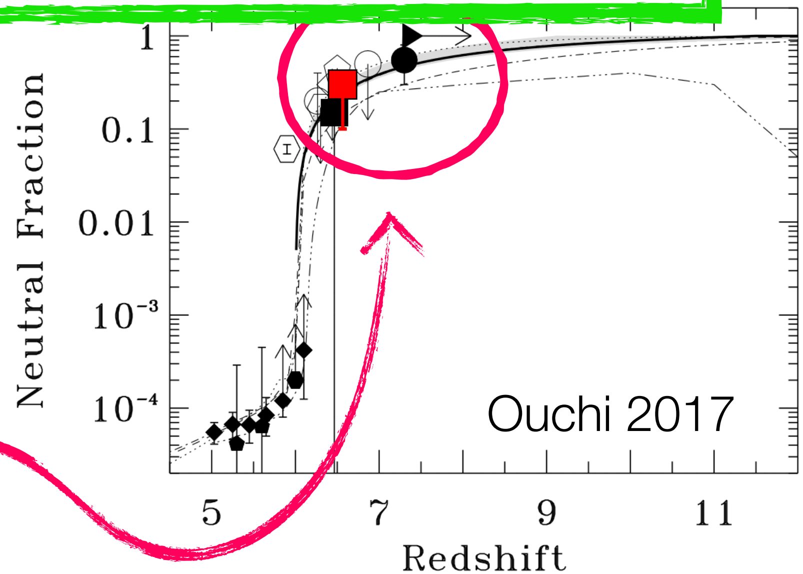
Intrinsic emission → **ISM** → **IGM** → **observer**



LAEs may tell us something about the end of the EoR, but we need to understand them better for that.

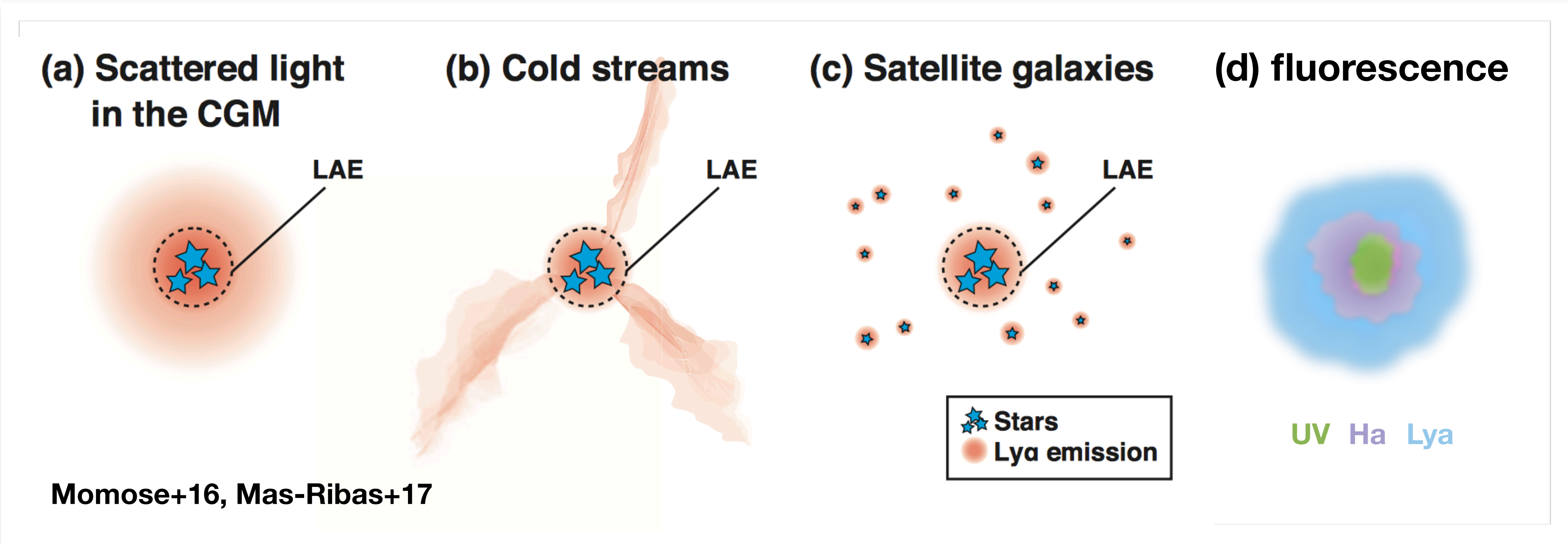


A partially neutral IGM will boost the clustering signal of LAEs



(see also Garel+12,15,16)

Extended Lya halos around (high-z) galaxies: Can they tell us about feedback ?

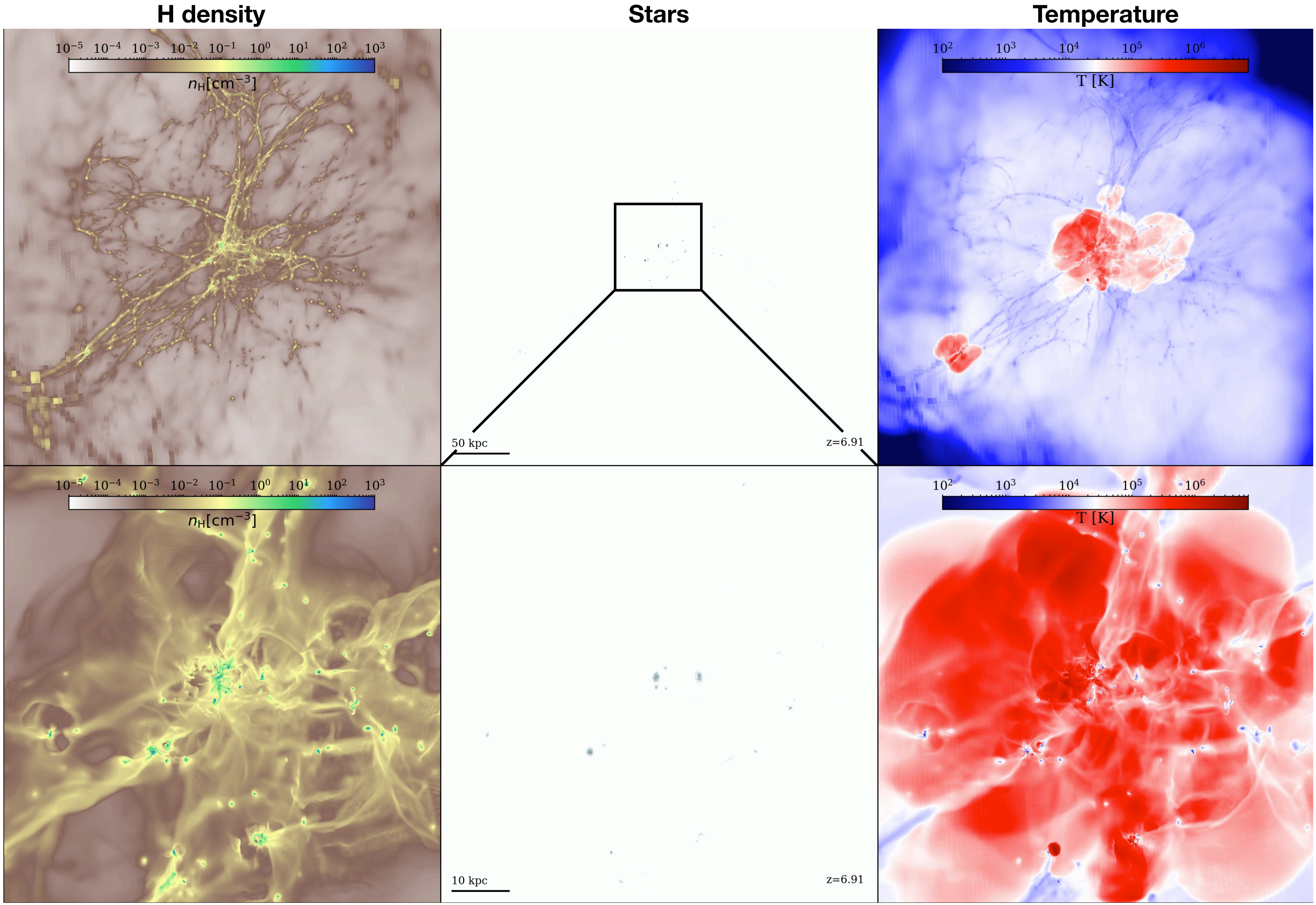


We need to build a quantitative theory for *all* these scenarios, which relates detailed Lya observables to physical properties of galaxies and their CGM. Simulations may help.
In return, LAHs may set radically new constraints on feedback.

I. Simulation of a typical LAE

Predicting Lya emission from simulated galaxies

- **Full Radiation-hydrodynamics** : stellar ionising radiation is emitted by star particles and propagated on the fly -> the simulation *predicts* Lya emissivity from recombinations and collisions in all cells.
- **High resolution** (~15pc): resolve everywhere the cooling time + resolve small-scale ISM structure (escape channels).
- High-resolution **subgrid models** for feedback and star formation (Kimm+16,17)
- **Lya RT** in post-processing: Emit photons from all luminous cells and follow their scattering with the Monte Carlo code RASCAS (Michel-Dansac et al., soon submitted and public)
- **Dust model** from metallicity & HI distributions (*Laursen+09*)



M_{halo} = 5.5 10^{10} M_{sun}, DM particles ~10^4 M_{sun}, star particles ~10^3 M_{sun}, dx ~15pc

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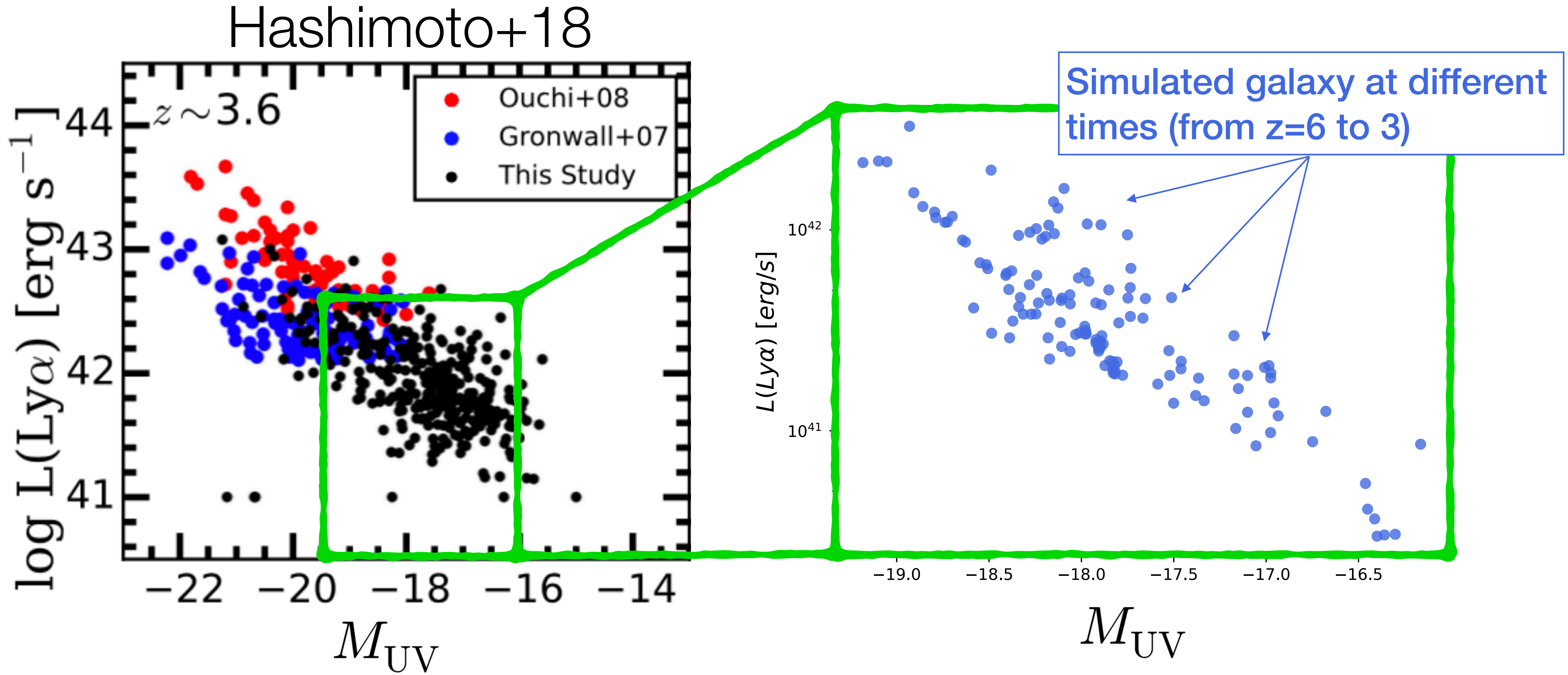
Our simulated galaxy is a typical LAE as observed by Wisotzki+16 and Leclercq+18

Stellar mass goes from **~10^8M$_{sun}$ to ~10^9M$_{sun}$**
SFR grows from **~0.1 to ~10 M$_{sun}$/yr**



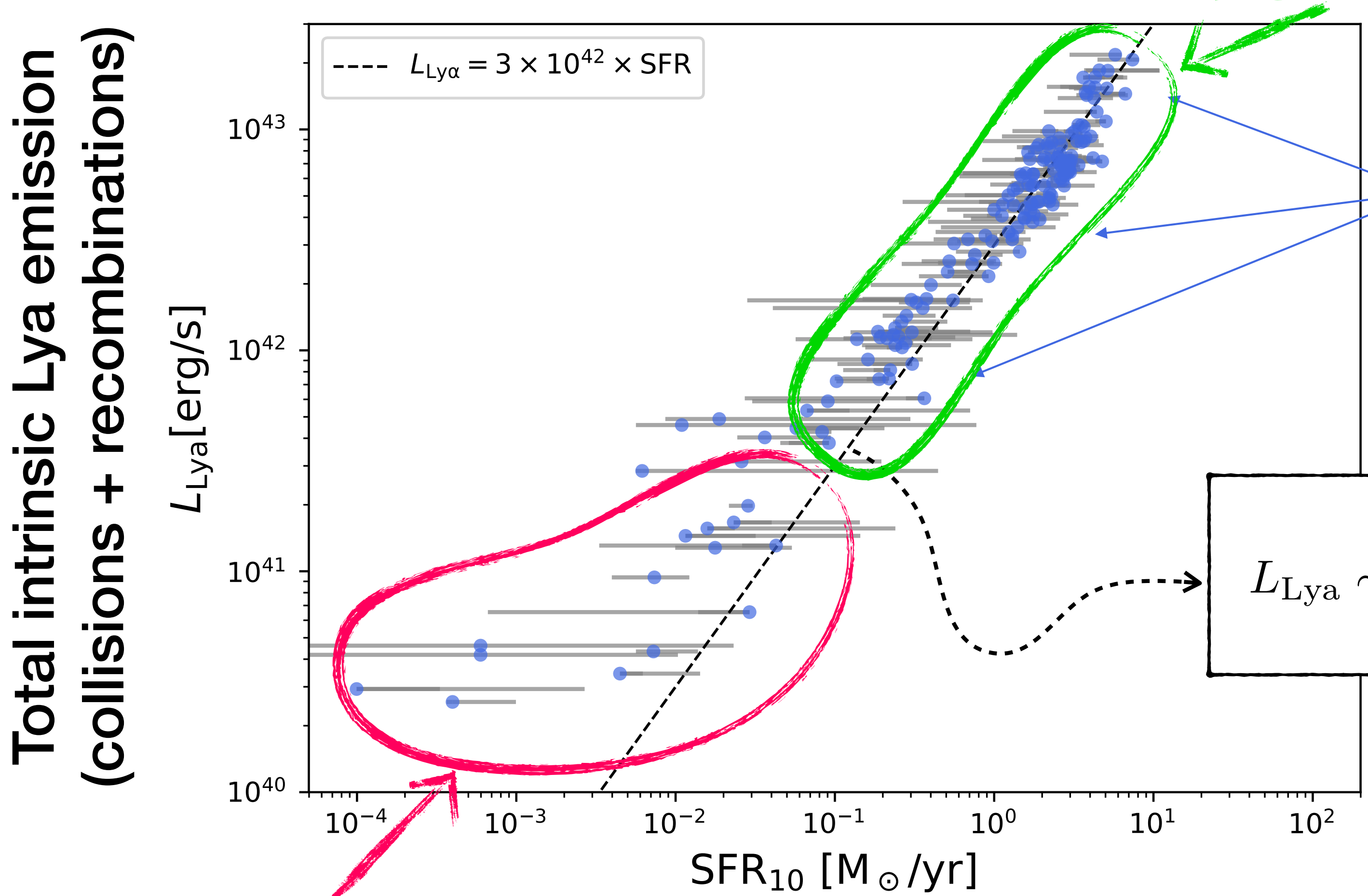
Other properties (EW, UV slope, UV size…) agree well too.

II. Lya production and escape in high-z galaxies

How much is **emitted**, how much **escapes**, how much **scatters** ?
Where is it **emitted**, from where does it **escape**, where does it **scatter** ?

Global Lya budget #1
Intrinsic emission vs. SFR

Scatter due to SFH, Z, contribution of collisions



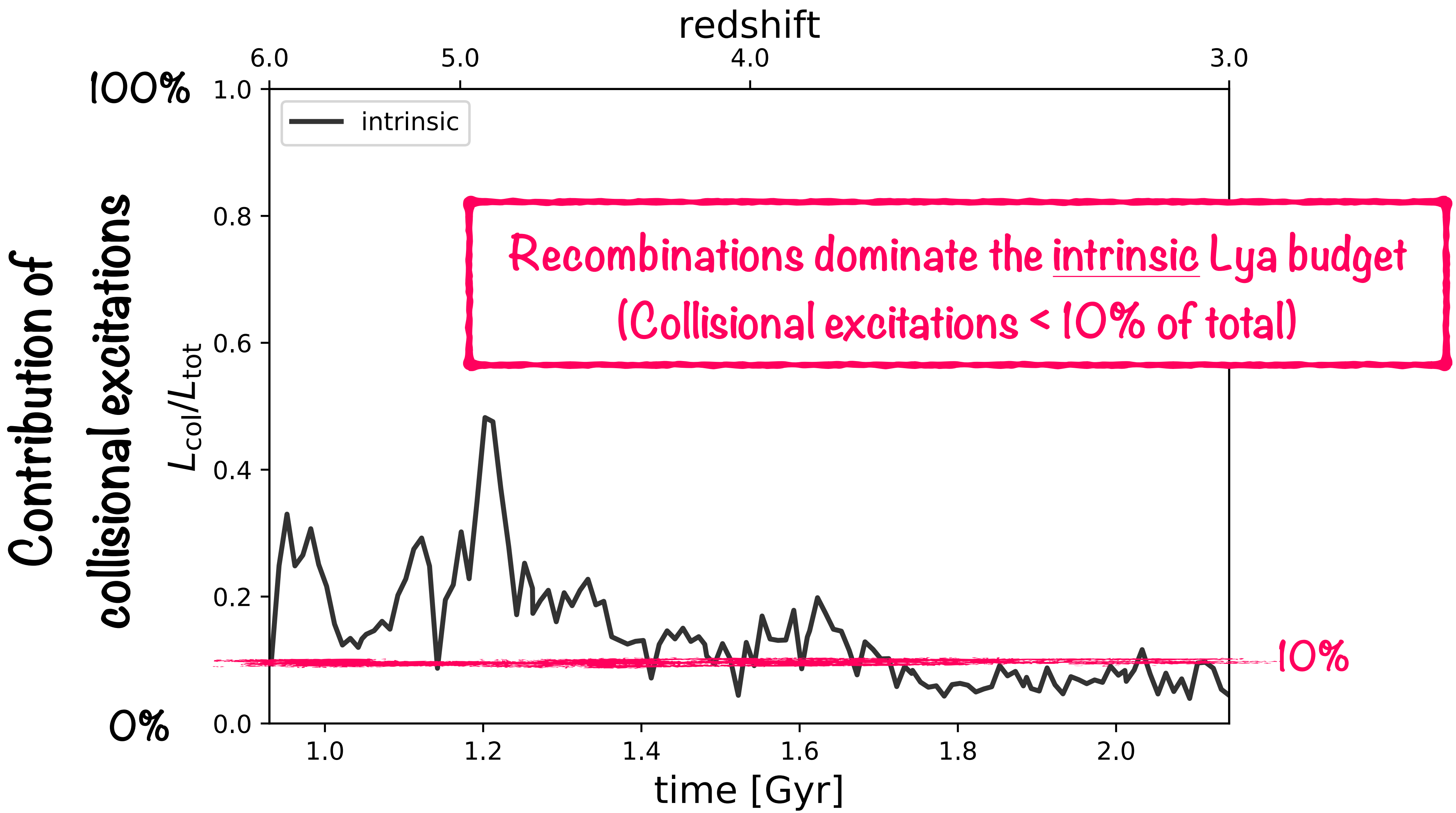
Simulated galaxy at different times (from z=8 to 3)

$$L_{\rm Lya} \sim 3\ 10^{42} \left(\frac{\rm SFR}{1\ {\rm M_\odot/yr}}\right) {\rm erg/s}$$

(BPASS w/ binaries)

Large scatter due to burstiness of star formation.

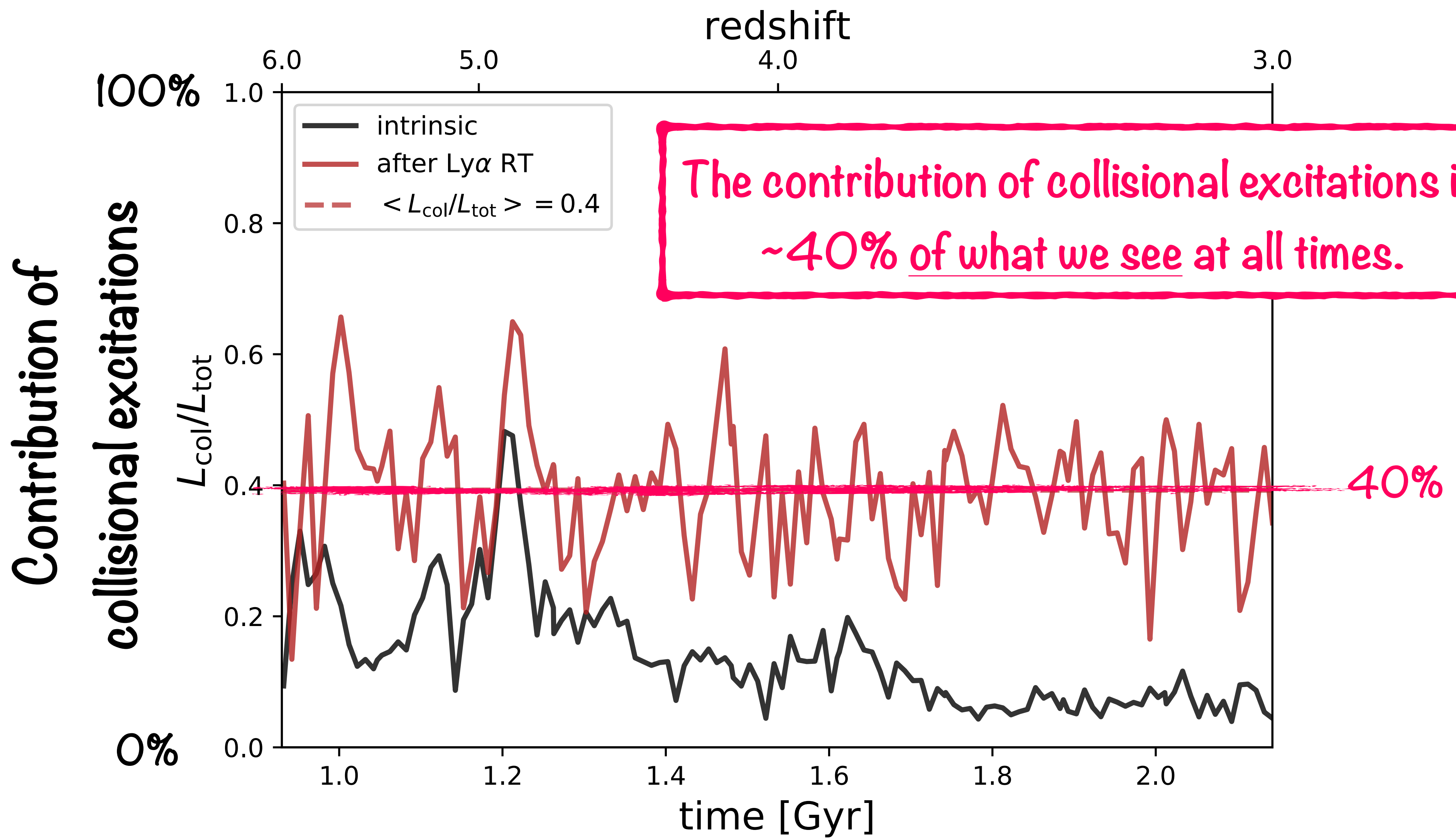
Global Lya budget #2
What is *emitted* from (simulated) galaxies



We find a weak trend with redshift: coll. excitations contribute more at higher z's

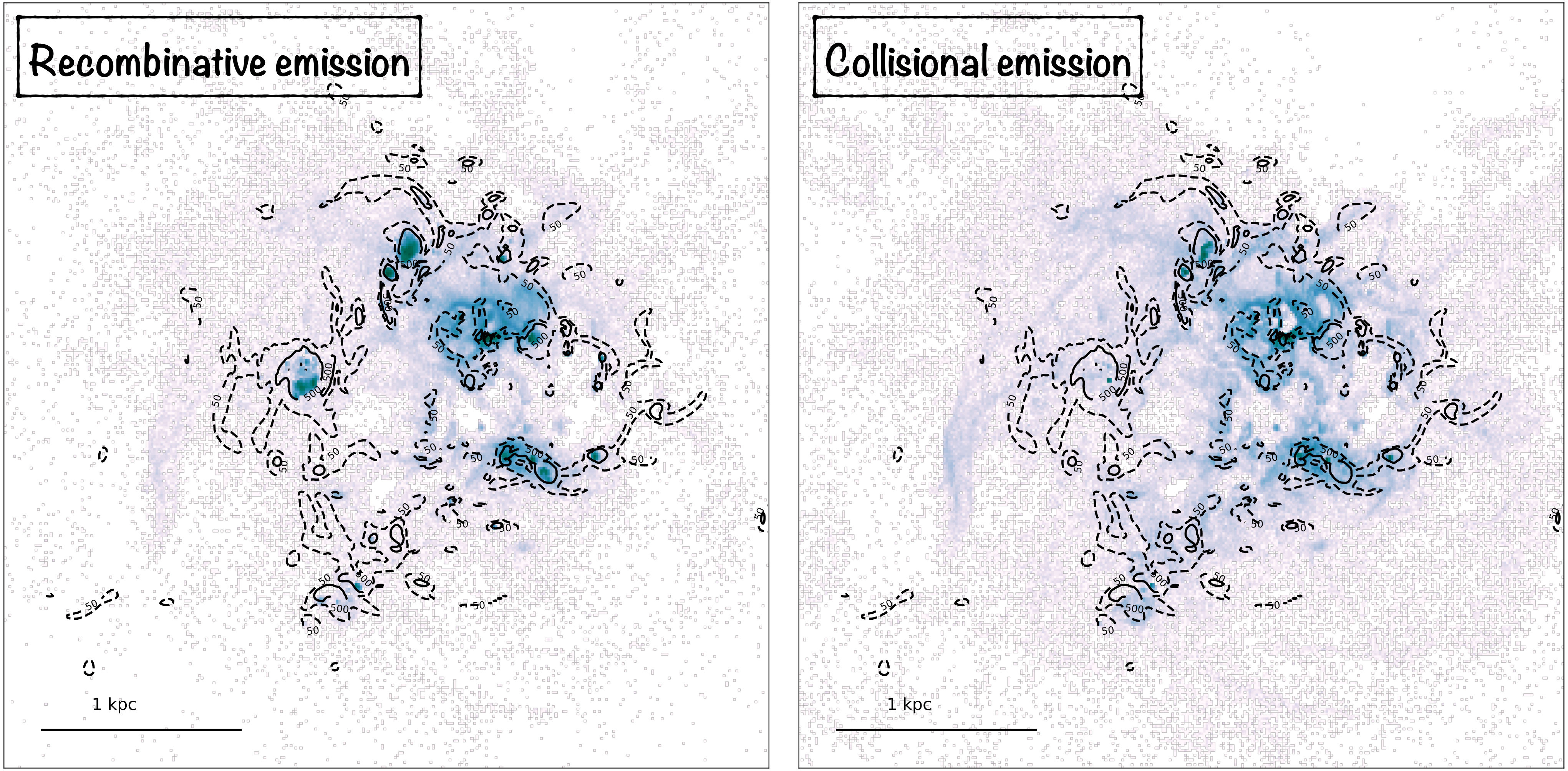
Global Lya budget #3

What is *observed* from (simulated) galaxies



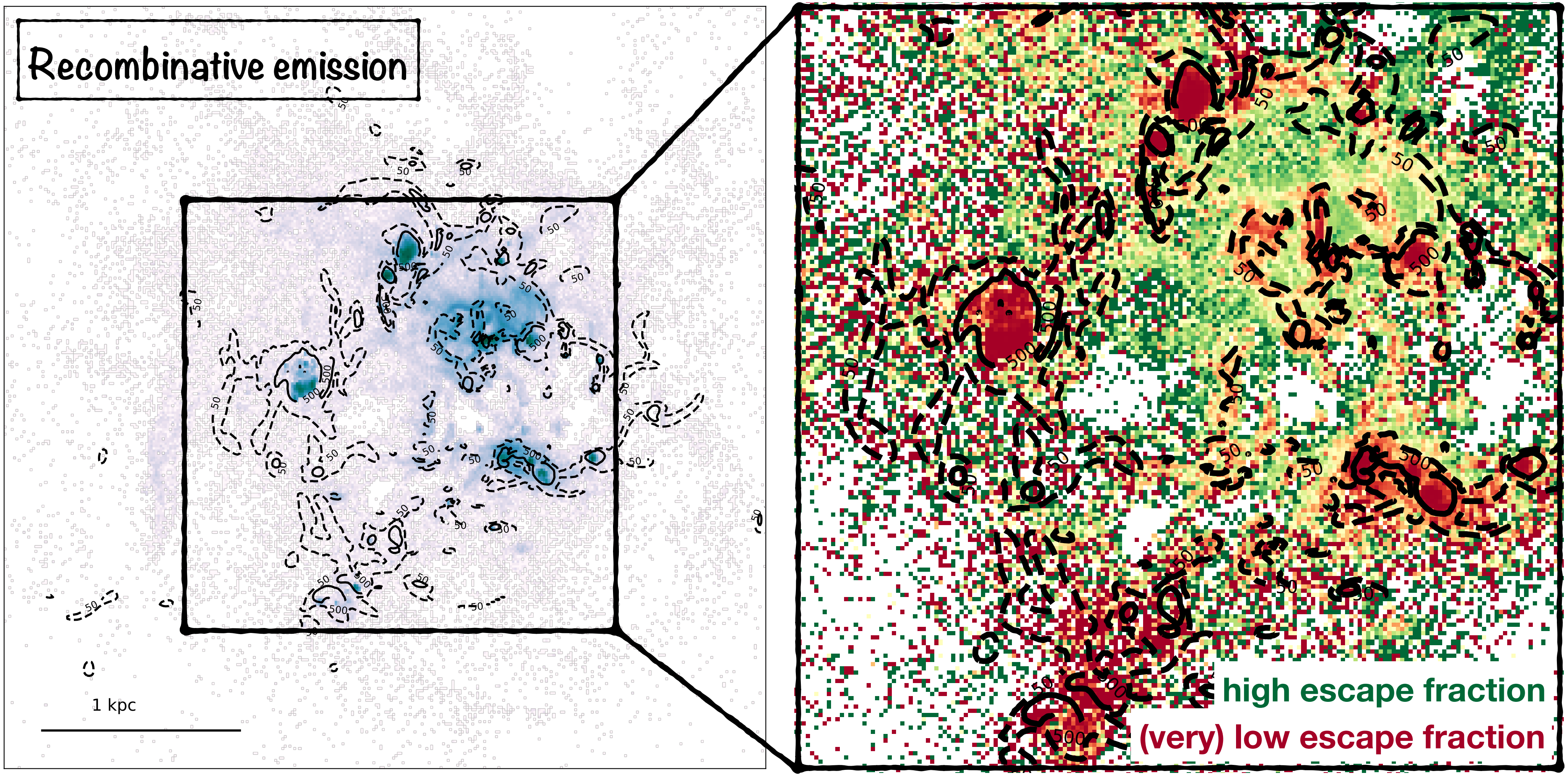
The contribution of collisional excitations is ~40% of what we see at all times.

Where are photons emitted …



Collisional emission comes from warm (~10^4K) relatively diffuse gas, whereas **recombinations** *also* come from cold and dense (100s K, nHI > 500 #/cm3) star-forming clouds.

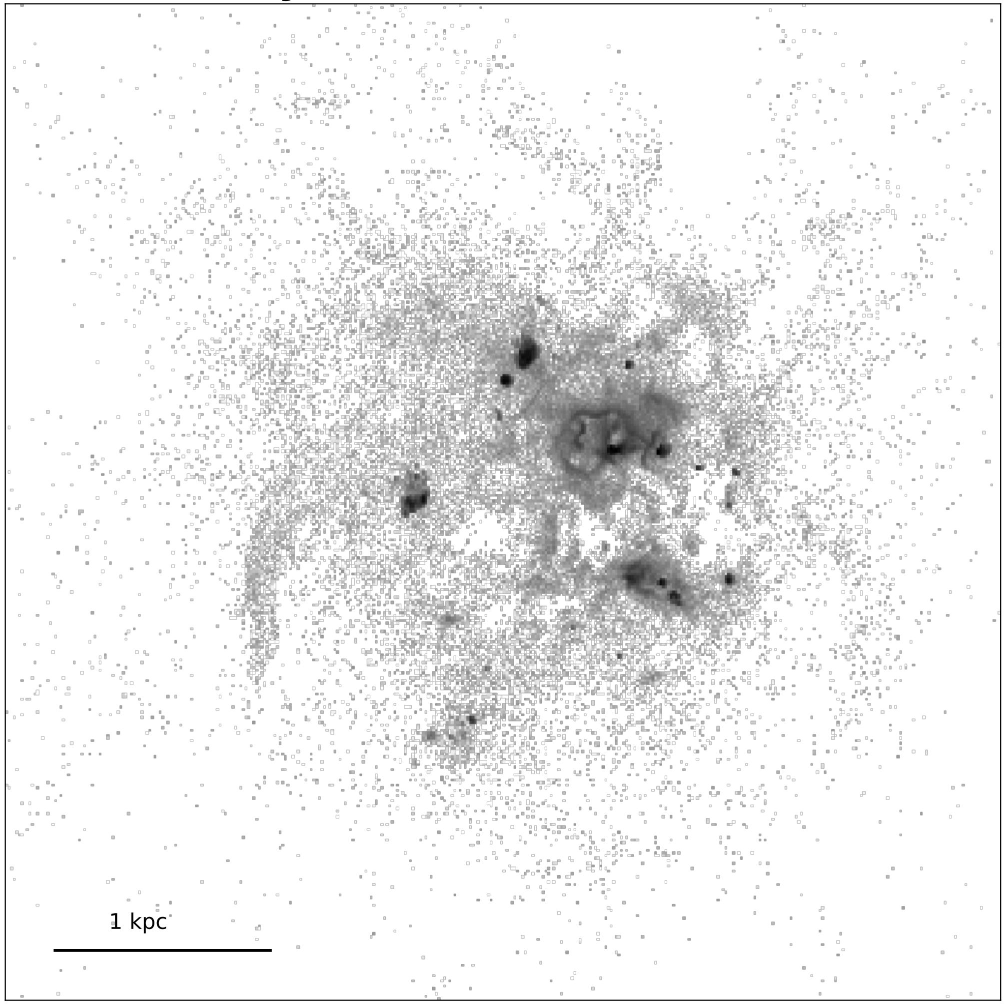
Where are photons absorbed …



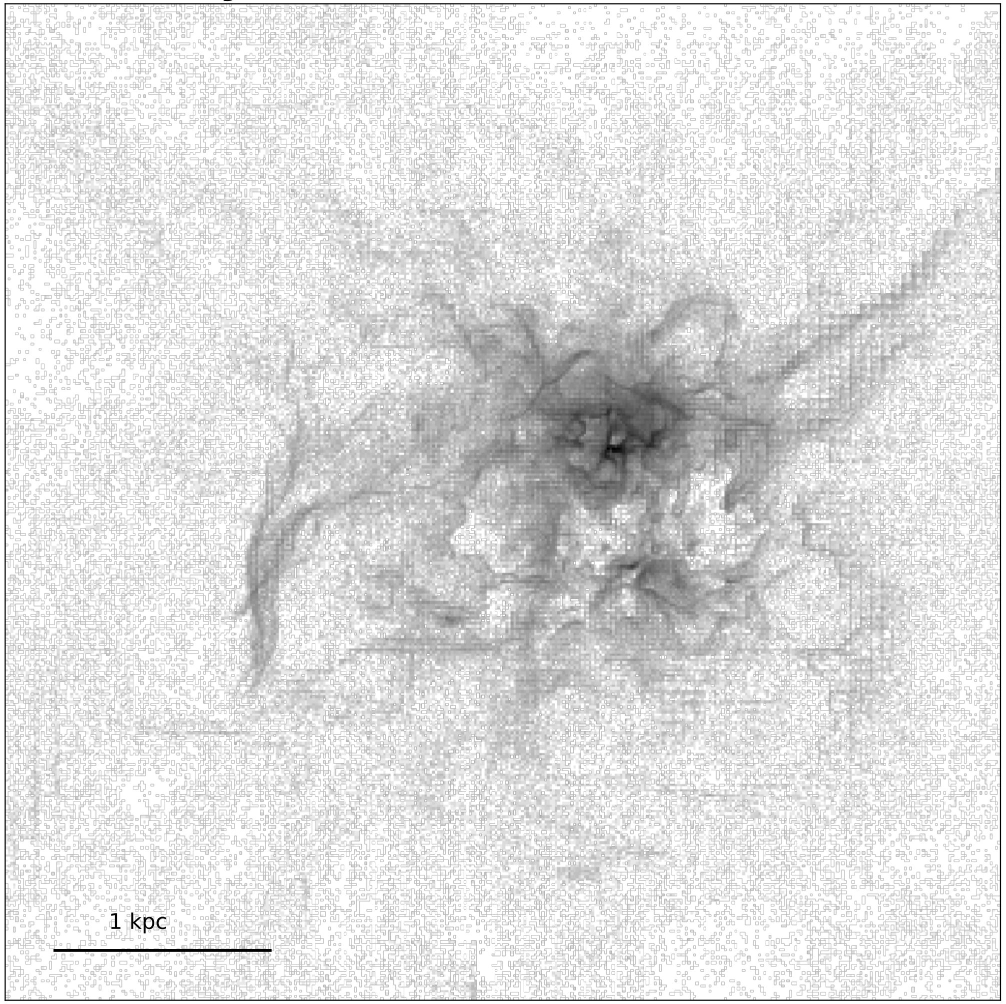
Escape from star-forming clouds is very hard before they are dispersed by SN explosions. Recombination photons are preferentially lost there.

Where are photons seen …

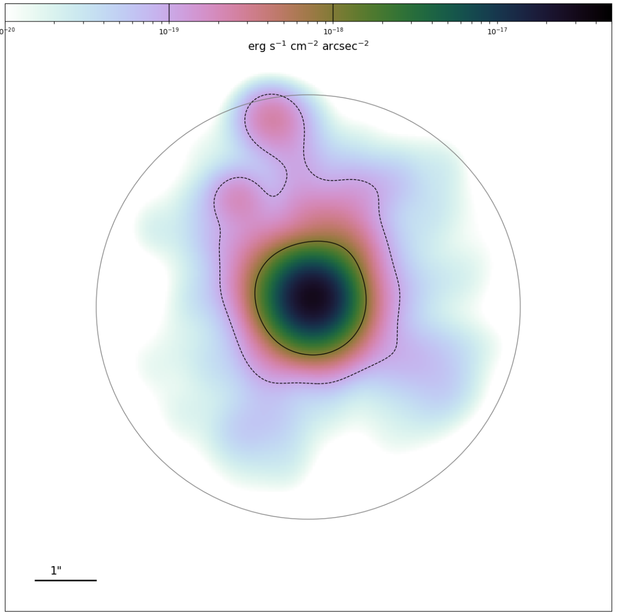
Before Lya RT

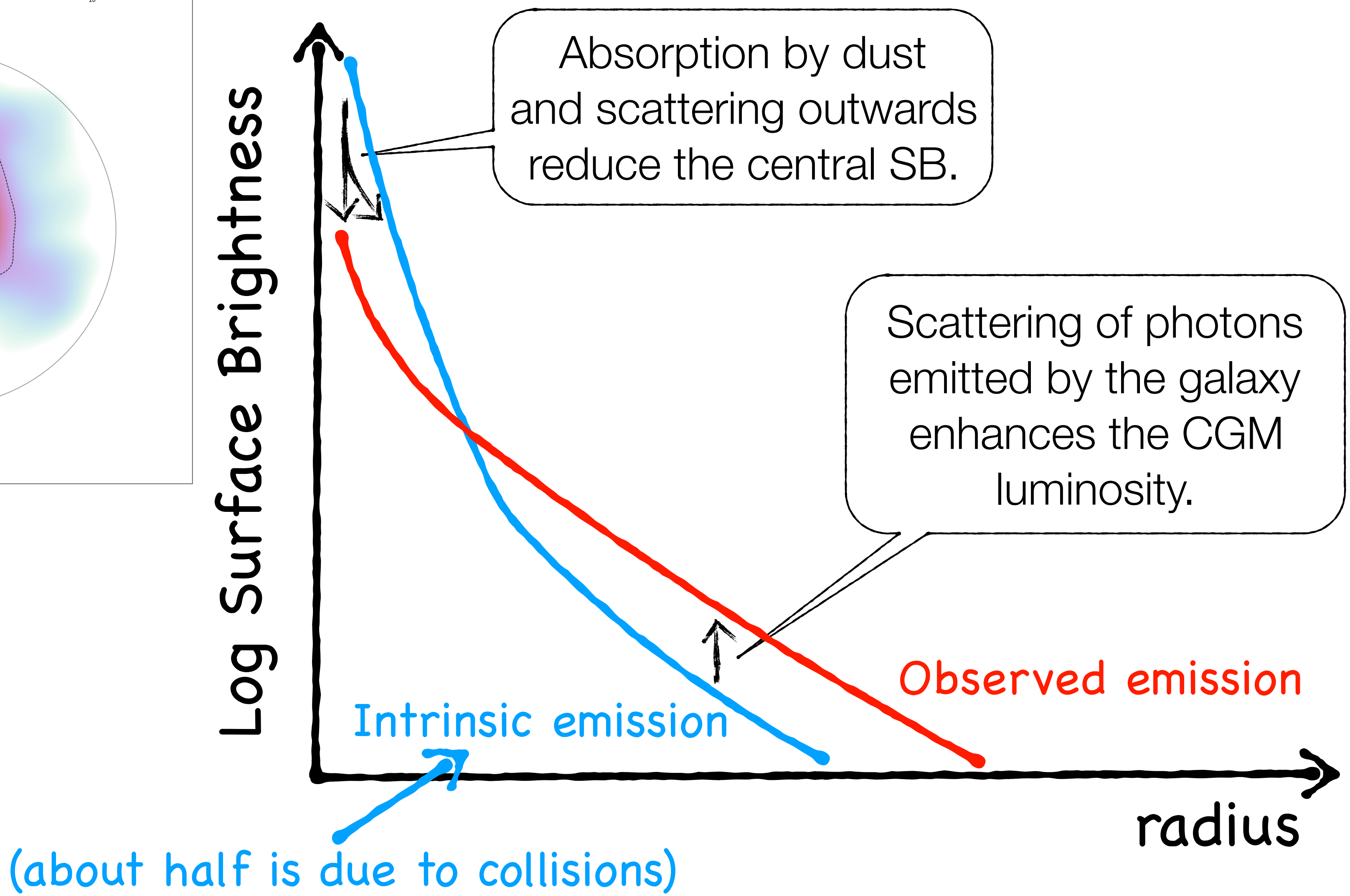


After Lya RT



What about the CGM ?

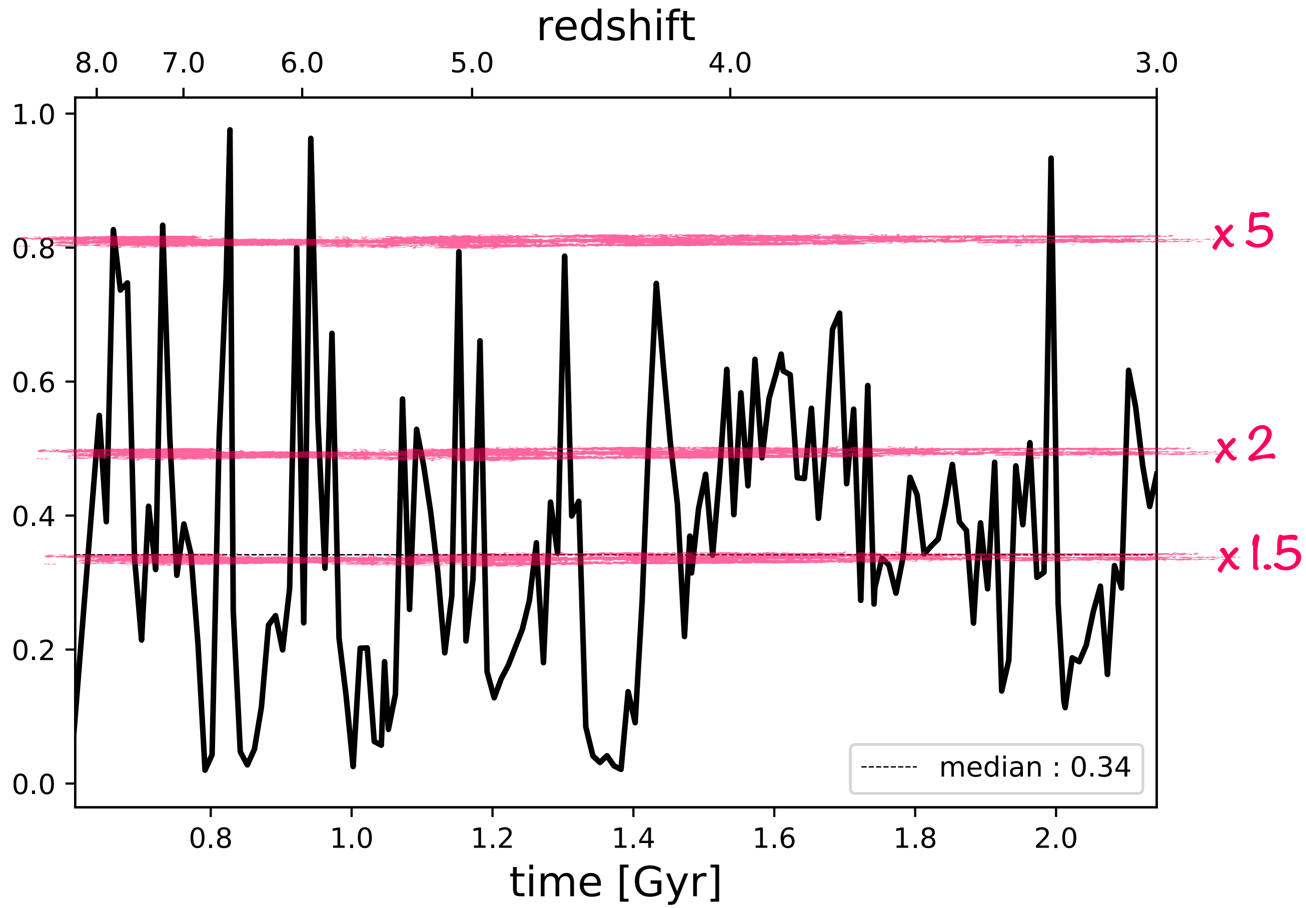




The contribution of scattering to CGM

~ 1/3rd of the CGM luminosity is scattered light produced in the central galaxy

Fraction of Lya photons seen as coming from the CGM but produced in the galaxy.



Low values mostly due to satellite galaxies (mostly not visible in continuum)

Summary

- **Cosmological RHD simulations** post-processed with Lya RT **are** beginning to be **predictive in terms of Lya emission and are in reasonable agreement with observations.**

- Fluorescence largely dominates the Lya intrinsic emission of galaxies (~90%) … BUT recombination photons have a lower escape fraction so that **collisions and recombinations contribute about equally (~40 vs. 60%) to the observed Lya emission from galaxies.**

- The **small-scale regulation of Lya escape** implies large variations of Lya apparent properties on short timescales and at small angular scales. Thus, Lya props. may not relate well to macroscopic properties (e.g. Mstar, SFR, …) [see Runnholm's talk]

- **Circum-galactic gas** emits Lya through collisions and recombinations in comparable amounts. Scattering of Lya from the central galaxy enhances its surface brightness by a factor ~ 2 with large scatter. -> we expect no strong correlation between LAH and LAE properties…

Sharing data.

NB: all codes used in this talk are or will soon be public

We are now able to construct accurate mocks (spectra, images, cubes) and are happy to distribute them.

The codes used in this talk (RAMSES, including sub-grid models, and RASCAS) are or will soon be public.