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w. Jeremy Blaizot

Accretion powered Lyα blobs using radiation hydrodynamics

observatoire de Lyon

ELIXIR

Lyα blobs - LABs

Extended Lyα nebulae at high redshifts (z=2-3)

The LAB debate started in 2000

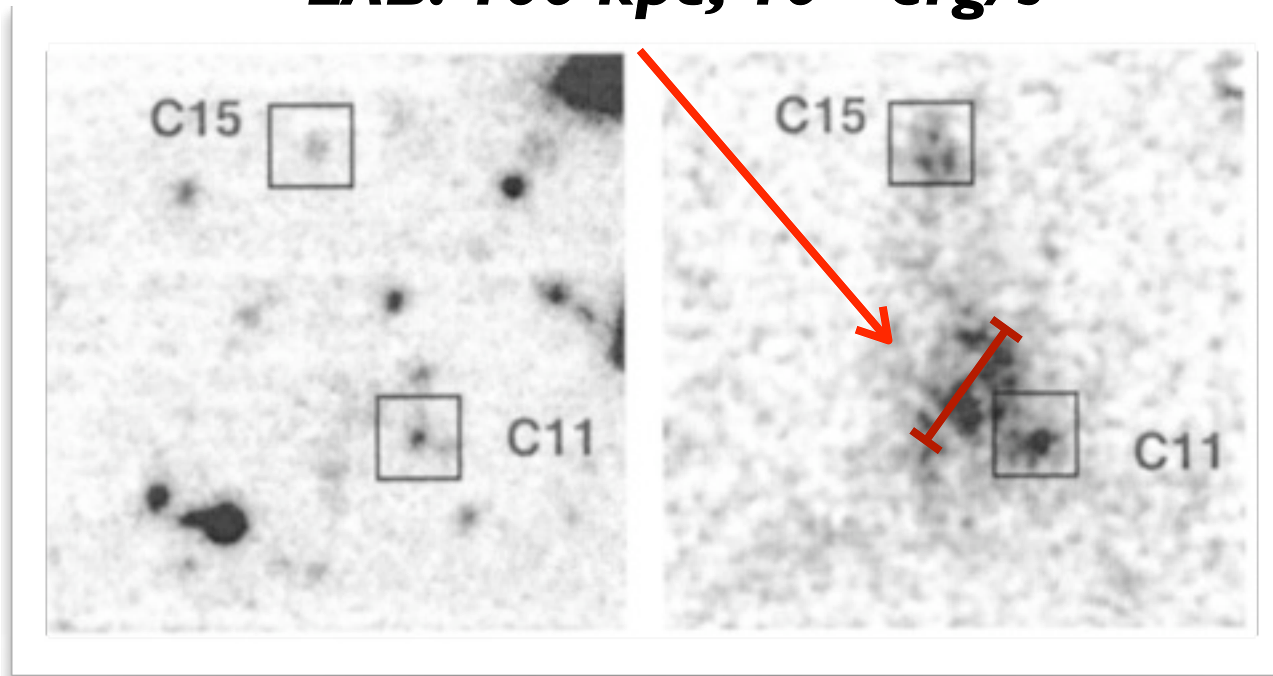
Usually found in overdense regions

They're not so many - yet
~15 giant LABs (>100 kpc)
~200 LABs (>30 kpc)

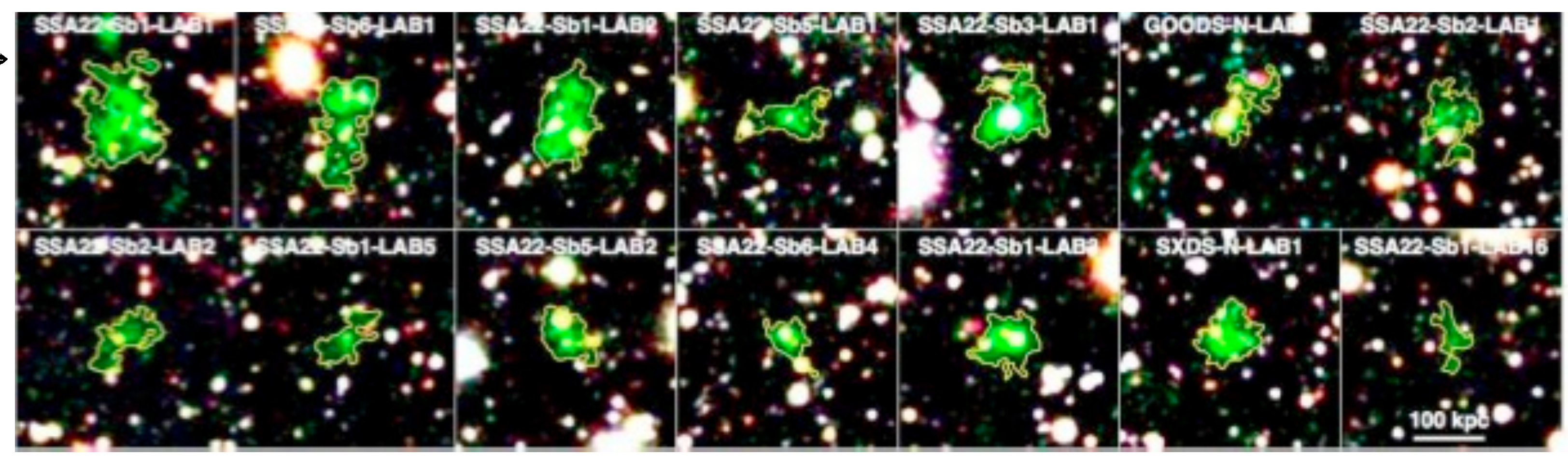
The mystery is:
What drives the emission?

Some LABs are even more mysterious - they contain no visible galaxies

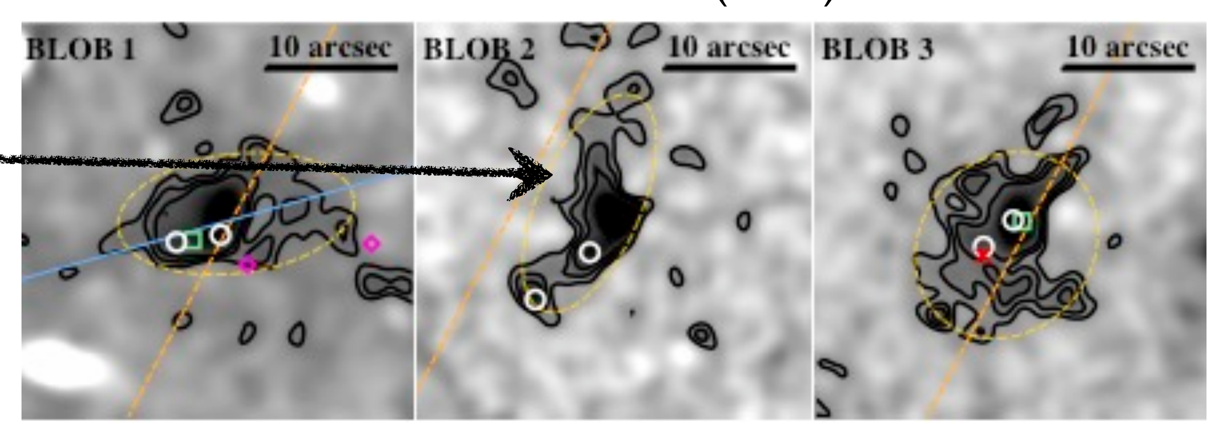
LAB: 100 kpc, 10^{44} erg/s



Steidel et. al. (2000)



Matsuda et. al. (2010)



Erb et. al. (2011)

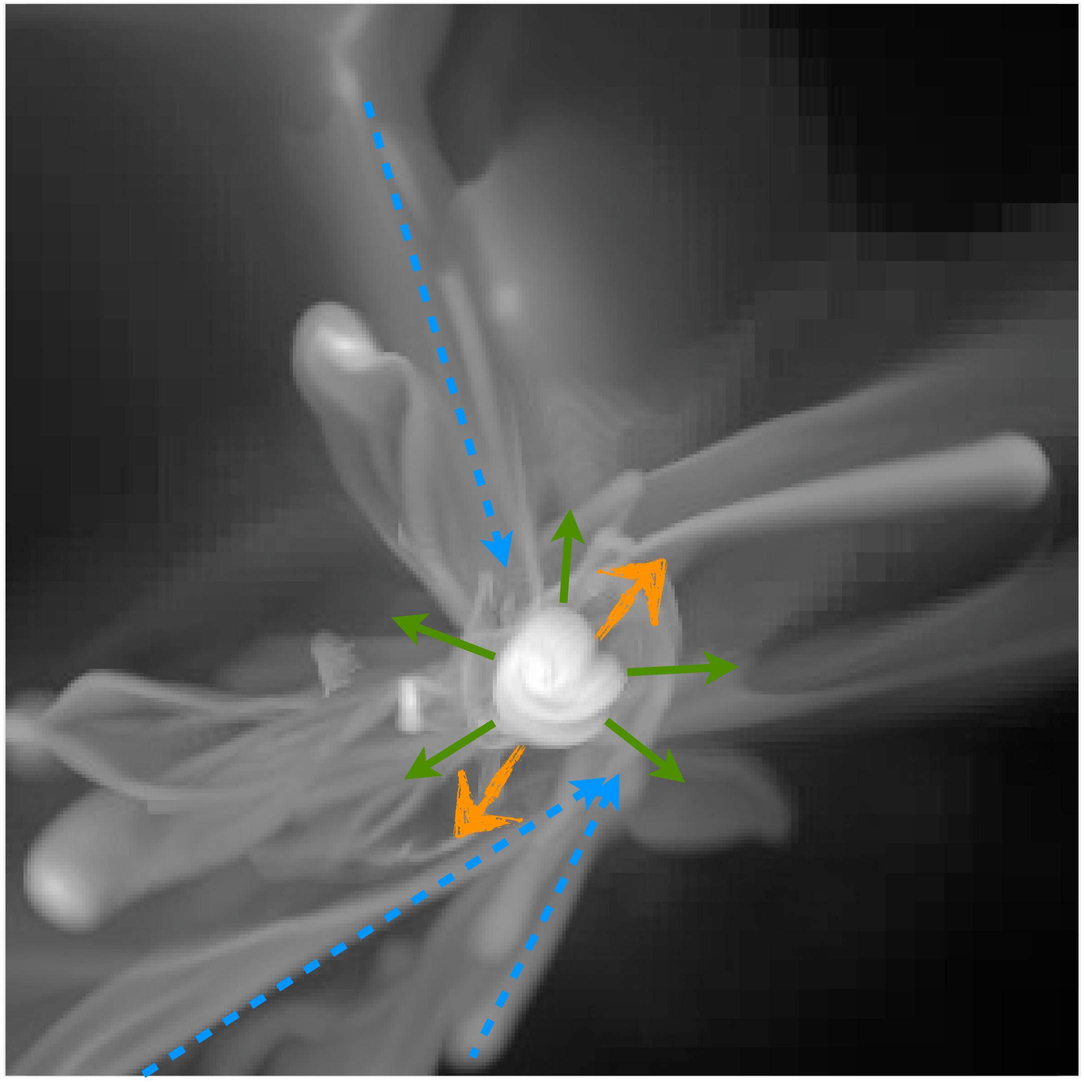
What powers Lyα blobs?

Theories and simulations

A lot of work has been done on models and simulations of LABs, yet their nature remains elusive

1:
Lya scattering
(Zheng, Laursen, Steidel)

2:
UV fluorescence
(Kollmeier, Cantalupo)



3:
SNe winds
(Taniguchi&Shioya, Ohyama, Mori)

4:
Cold accretion
(Fardal, Dijkstra, Faucher-Giguere, Goerdt, us)

Cold streams are predicted by simulations but never detected

Streams heat by gravitational dissipation and cool via Lyα emission

To simulate Lyα emission from cold accretion, one should resolve the competition between gravitational heating and Lyα cooling in the presence of an inhomogeneous UV field.

Using state-of-the-art RHD simulations, we investigate:

- **Are cold flows responsible for LABs?**
- **The observability of cold streams:**
  - **How deep do we need to go to detect those streams?**

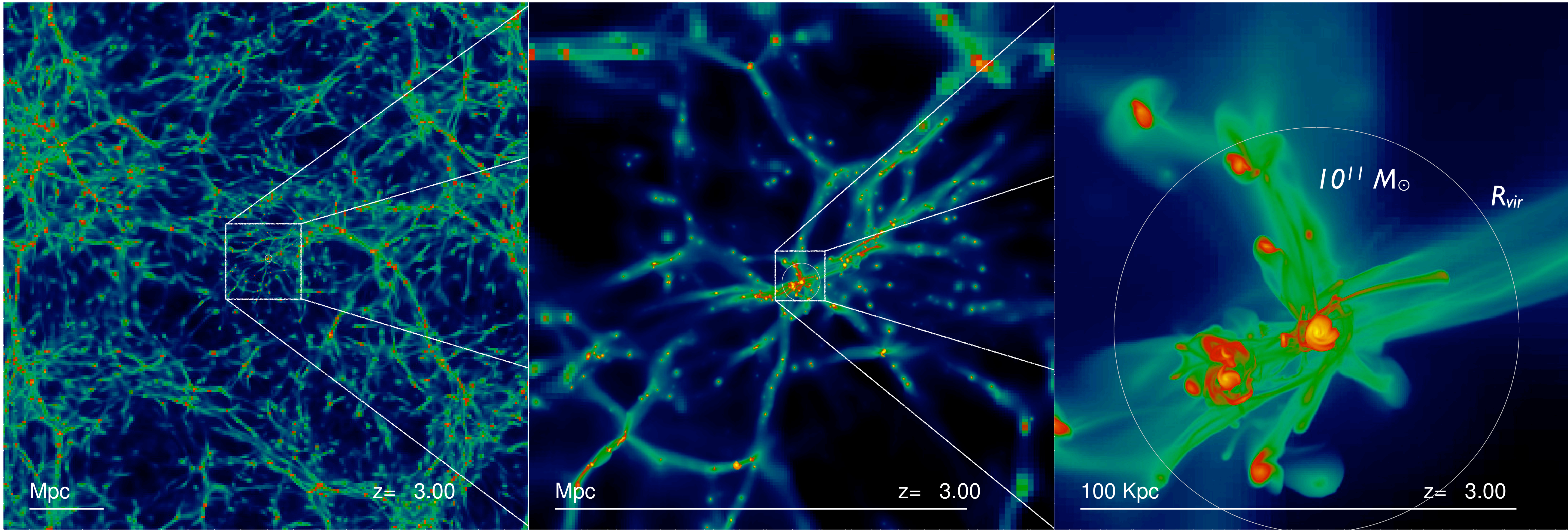
Layout

I. **Setup of simulations**

II. **Accretion properties of 3 targeted halos of very different masses**

III. **Observational predictions for 3 halos**

IV. **Comparison to observations**



Simulation setup

- **RAMSES-RT: Radiation-hydrodynamics w. non-equilibrium cooling**

- **3 cosmological zoom simulations, focusing on 3 halos at redshift 3**
  - **Halo masses:** *10^{11} / 10^{12} / 10^{13} $M_\odot$*
  - **DM mass resolution:** *10^6 / 10^7 / 5×10^7 $M_\odot$*
  - **Cell resolution:** *200 / 400 pc / 800 pc*

  - **Refinement strategy resolves streams to unprecedented levels**

- **Star formation: n_H > *1 H/cc* - ISM is exluded from Lyα analysis**
- **No stellar feedback, no metals - not important in the cold streams**

- **RT: Propagation of the UV background - proper modelling of stream cooling for the first time**

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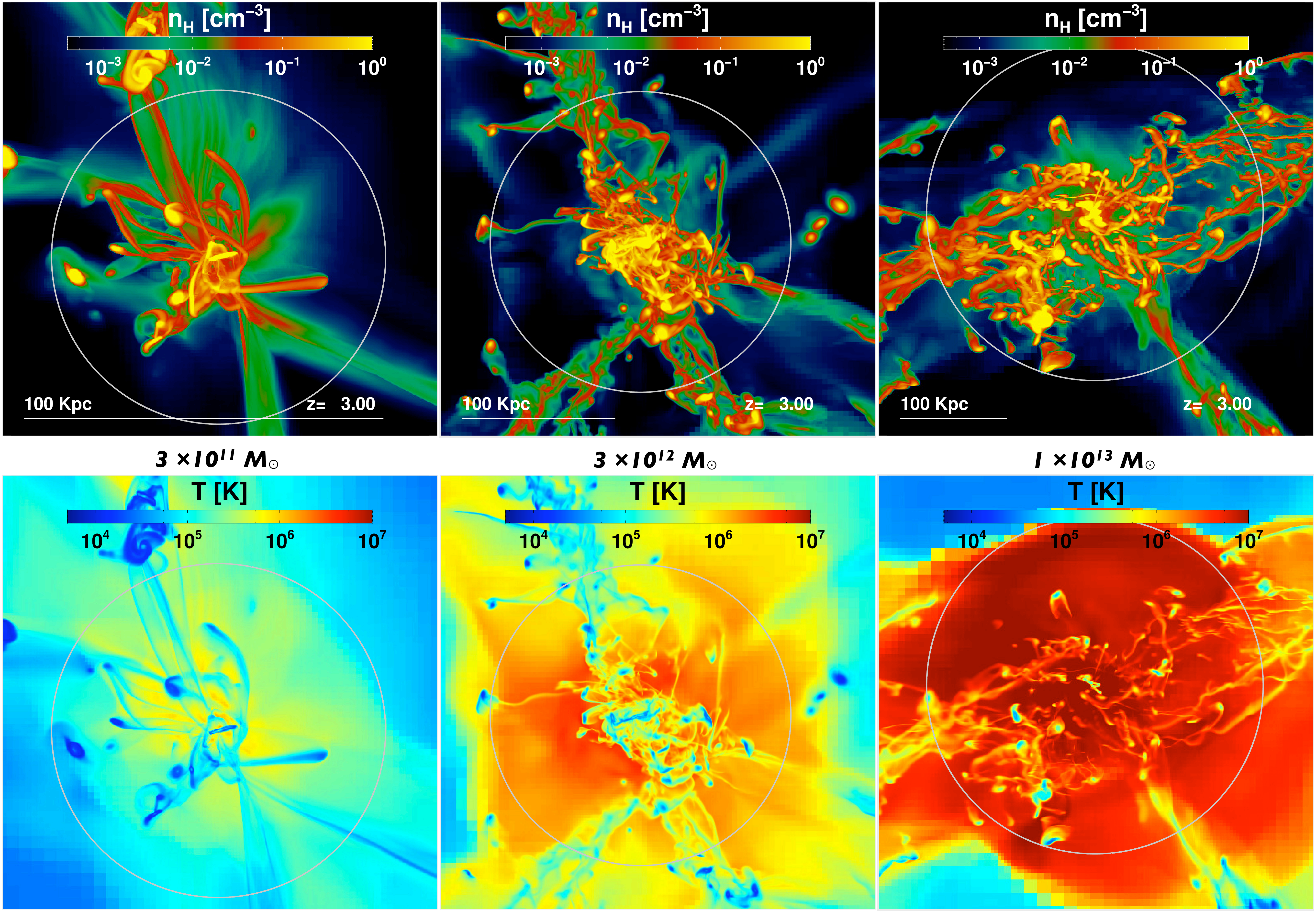
3 halos - a mass study



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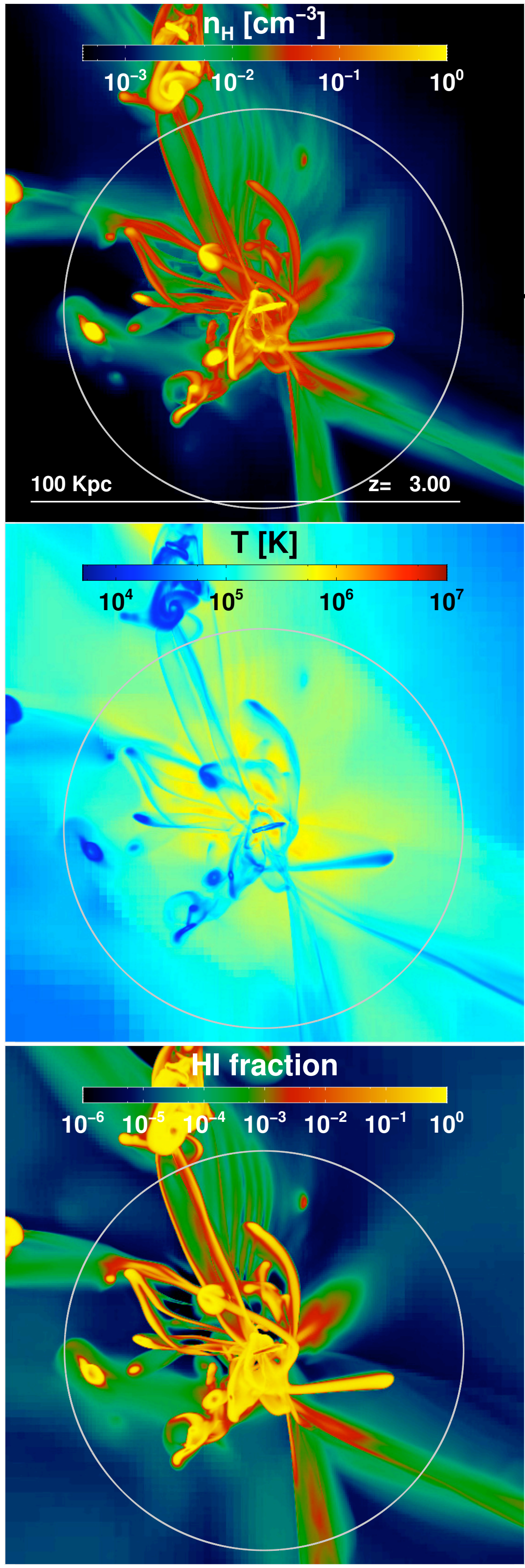
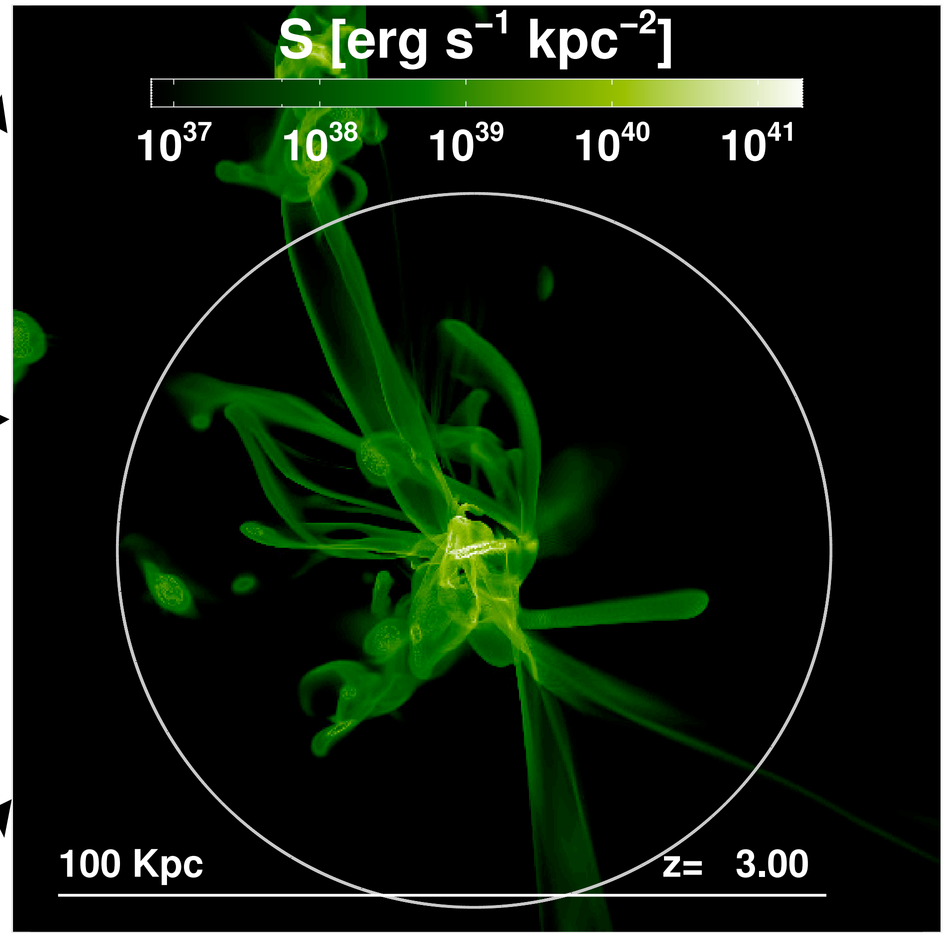
Lyα emissivity



Rest-frame Lyα surface emissivity



$$\varepsilon_{coll} = C_{Ly\alpha}(T)\; n_e\; n_{HI}\; \epsilon_{Ly\alpha}$$

$$\varepsilon_{rec} = 0.68\; \alpha^{B}_{HI}(T)\; n_e\; n_{HII}\; \epsilon_{Ly\alpha}$$

DANGER!!!

Operator splitting may give severe underestimate

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Operator splitting and hydrodynamics

De-compose the hydro-equations into parts that are easy to deal with

$$\partial_t(E) + \partial_x(E+P)u = \Gamma(\rho,T) - \Lambda(\rho,T)$$

Advection **Chemistry (cooling)**

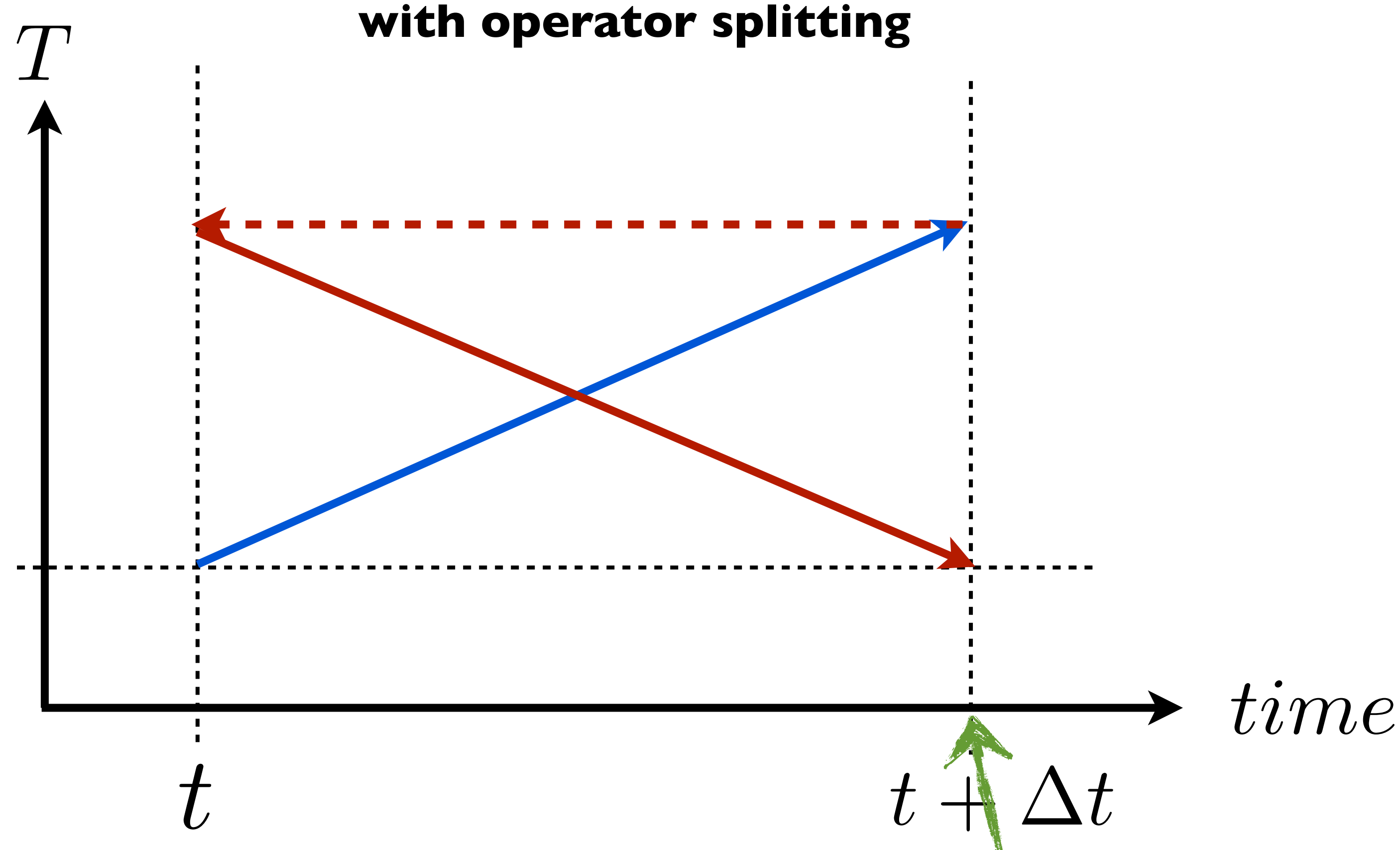
O. Splitting →

$$\partial_t E + \nabla \cdot \mathbf{u}(E+P) = 0$$

and

$$\partial_t(E) = \Gamma(\rho,T) - \Lambda(\rho,T)$$

Equilibrium between advection and cooling with operator splitting



The RAMSES output is always here!

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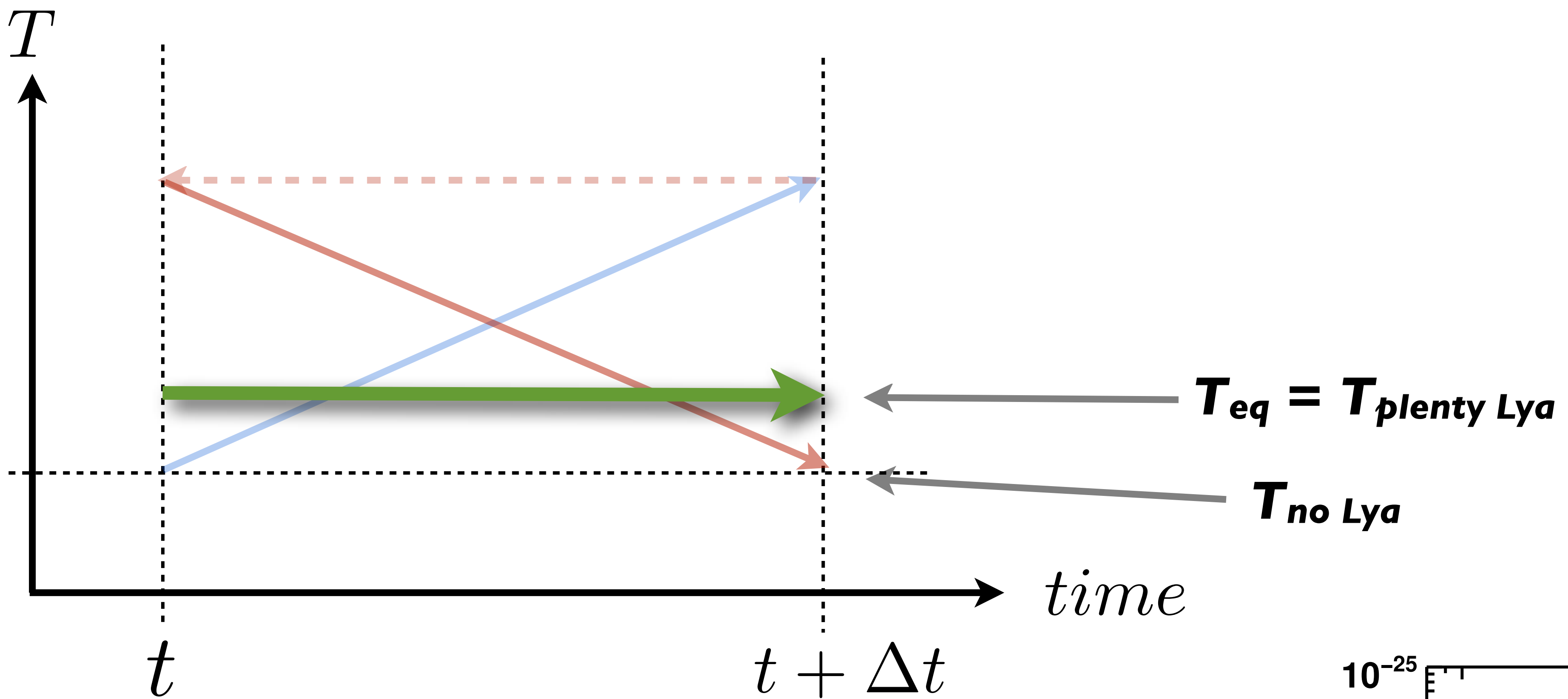
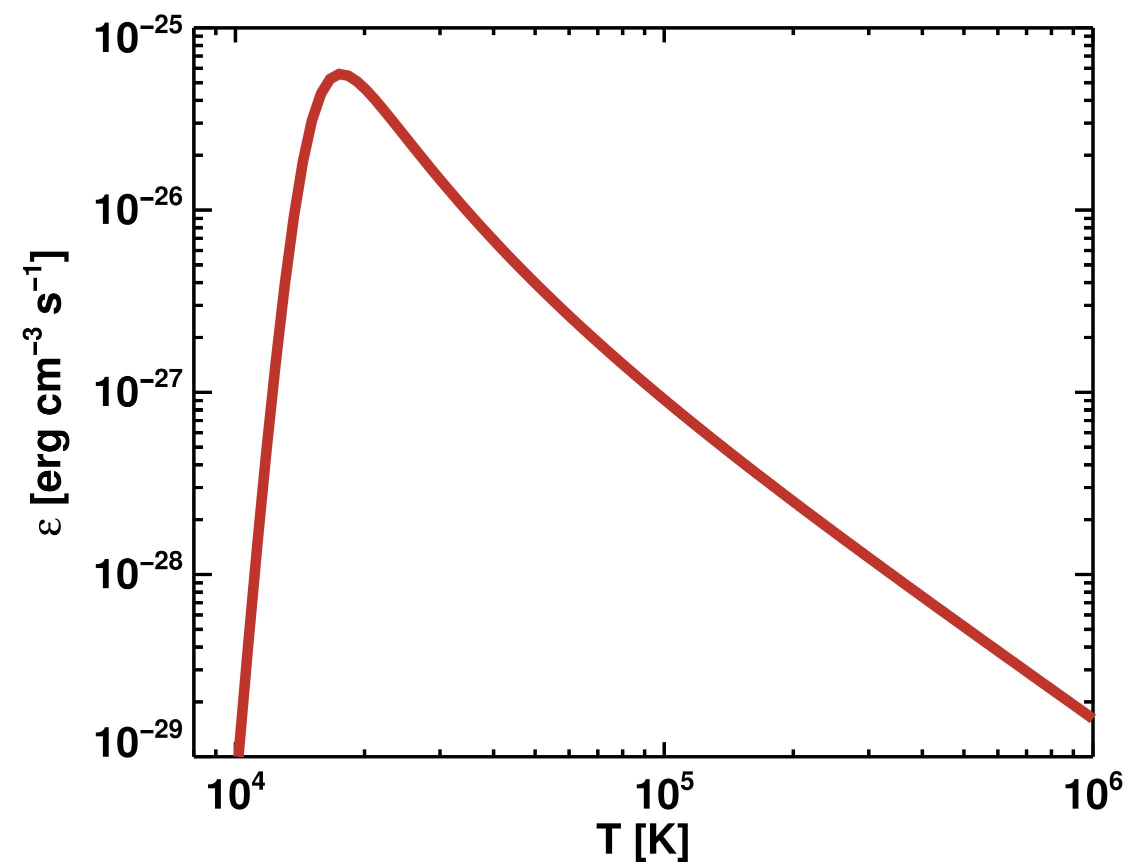
Operator splitting and hydrodynamics

Without operator splitting, the temperature might evolve more like this (and the equilibrium temperature *might* actually be *higher*):



- **Usually ok if T is slightly off**
- **But in the case of Lyα emission**
  it is not ok



- **Solution:**
  'Post-process', with really small timestep

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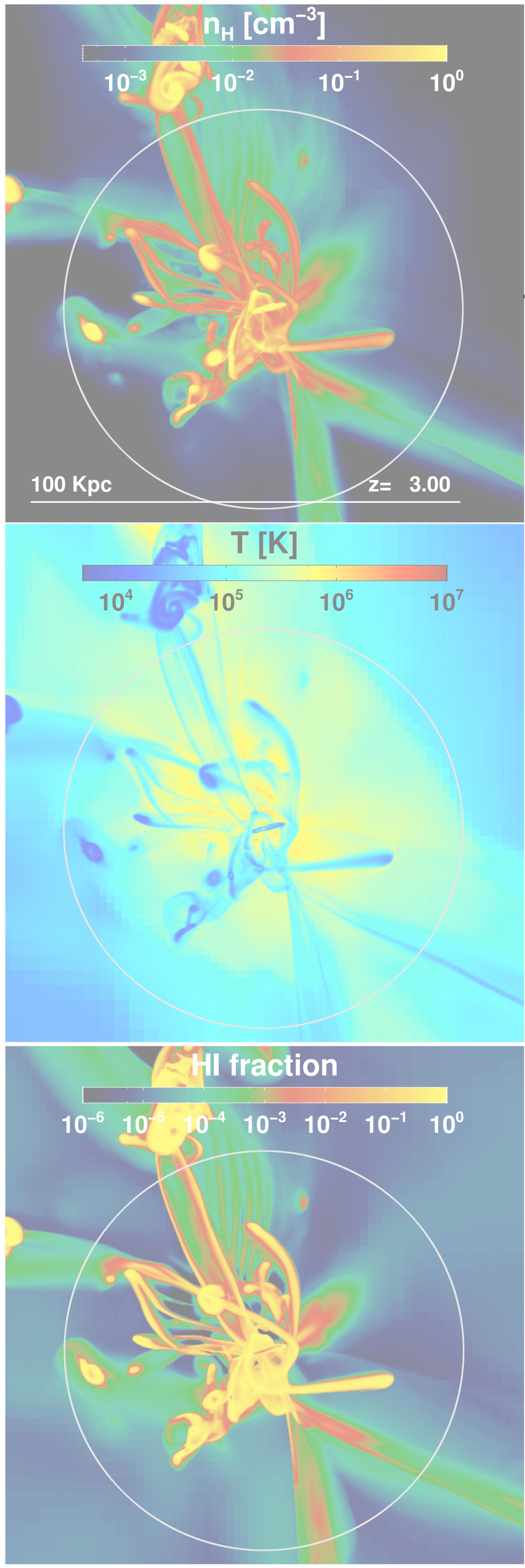
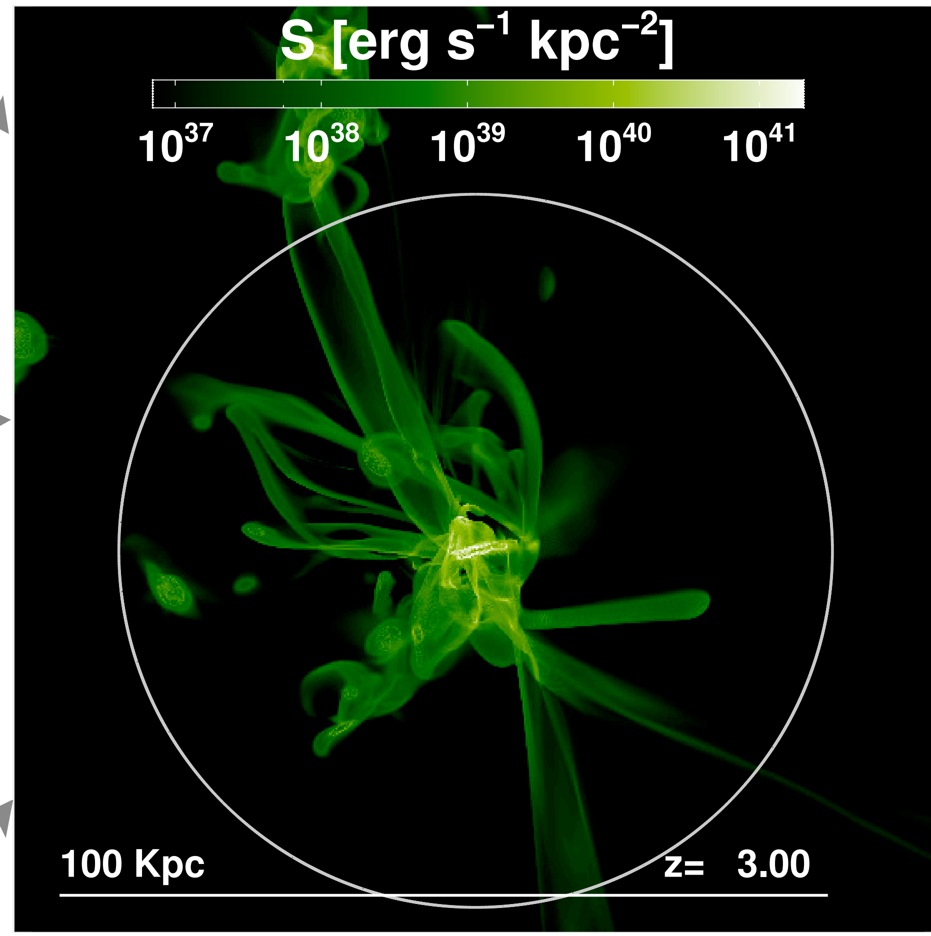
Lyα 'observations'



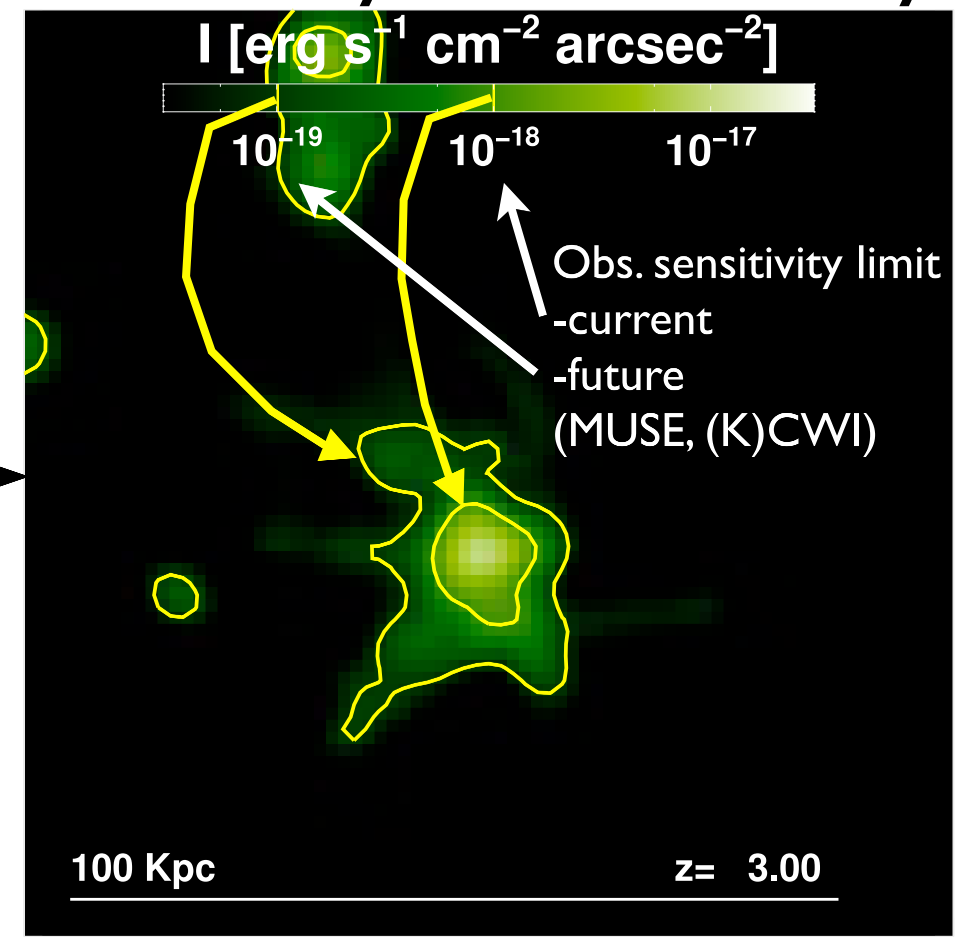
Rest-frame Lyα surface emissivity



$$\varepsilon_{coll} = C_{Ly\alpha}(T)\, n_e\, n_{HI}\, \epsilon_{Ly\alpha}$$

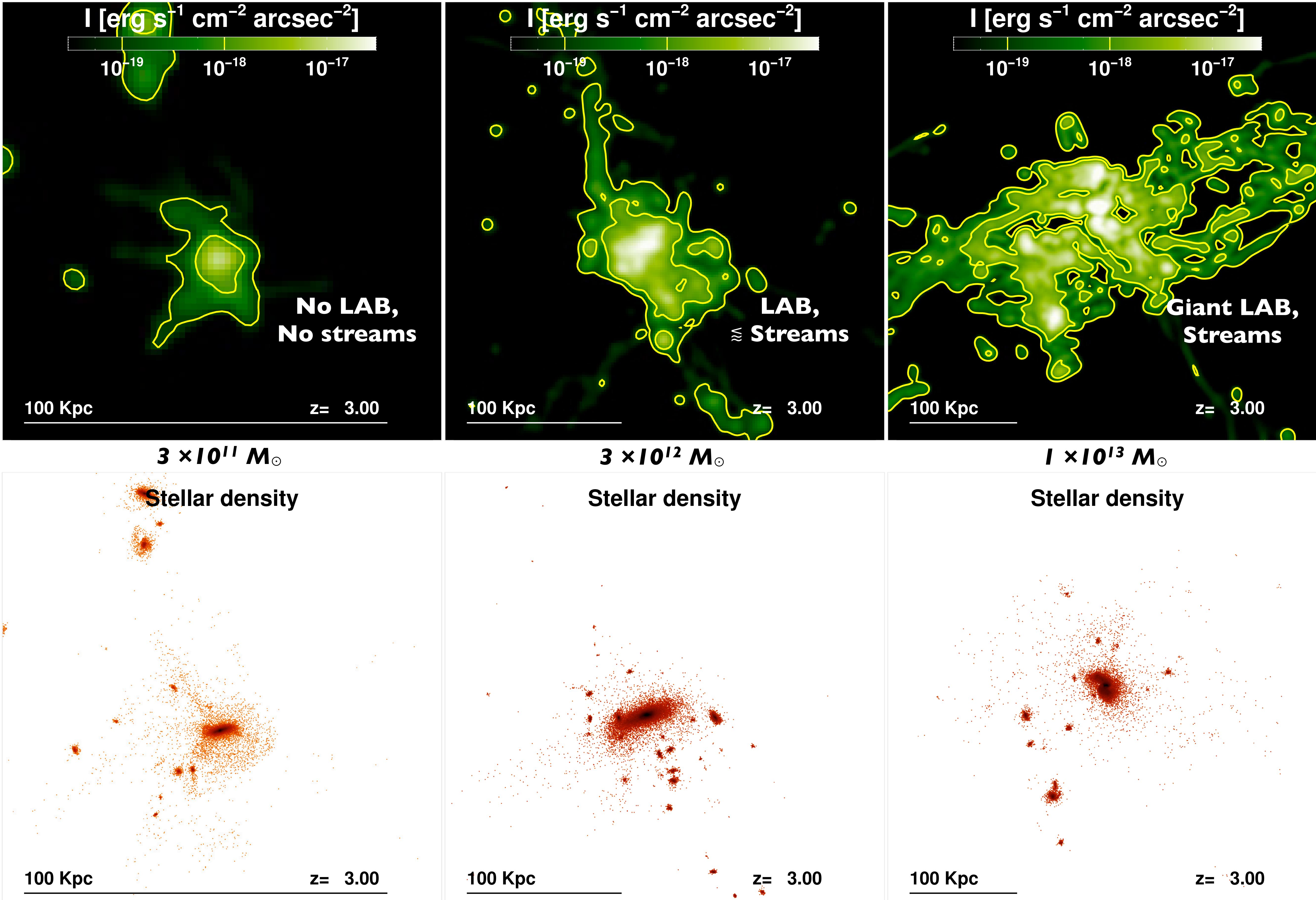
$$\varepsilon_{rec} = 0.68\, \alpha^{B}_{HI}(T)\, n_e\, n_{HII}\, \epsilon_{Ly\alpha}$$

Observed Lyα surface emissivity



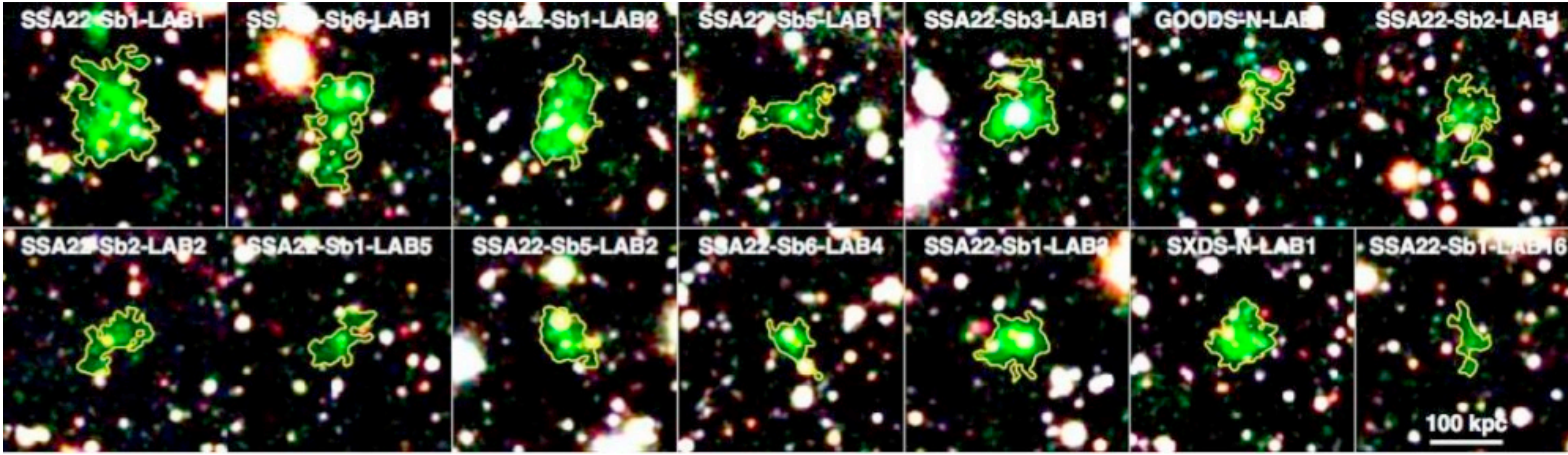
- **Luminosity distance**
- **Convolution with PSF of FWHM=0.8 arcsec**
- **Cosmic transmission f_α=0.66**

Observational predictions



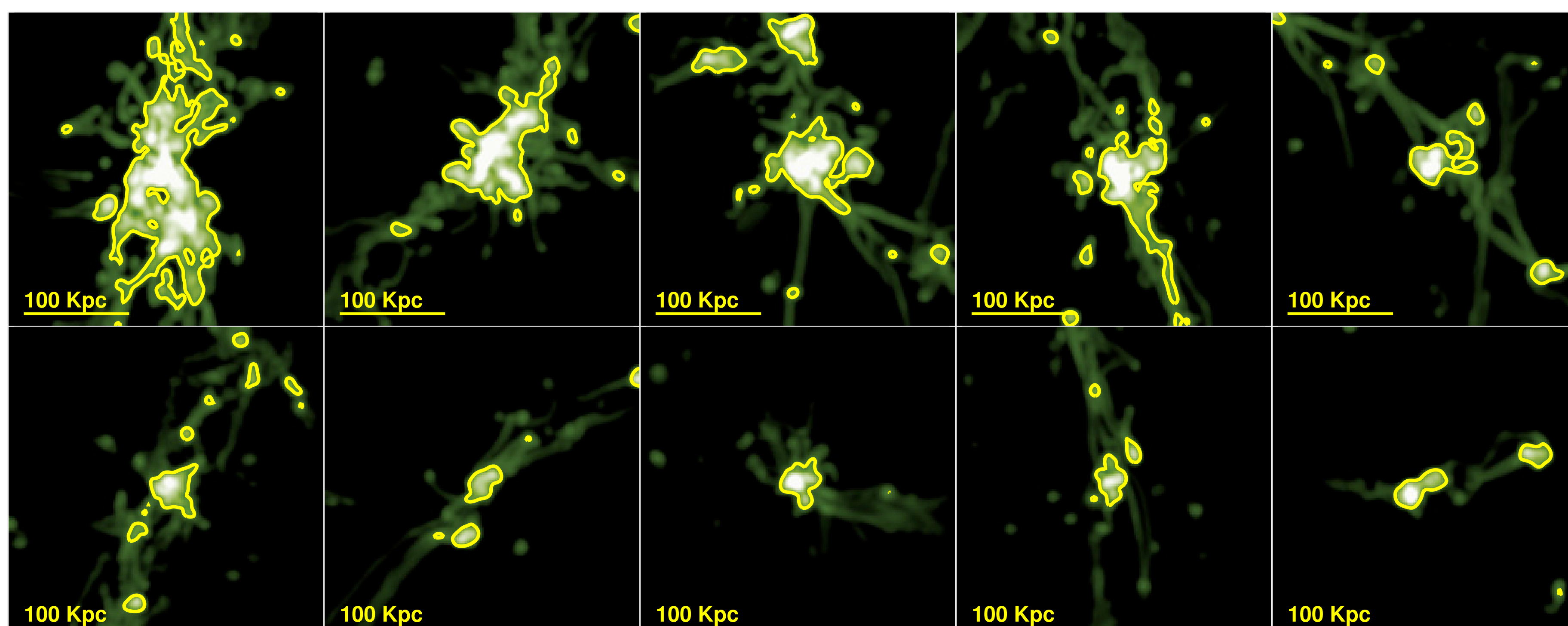
Comparison to observations

Do our LABs look like the real thing?



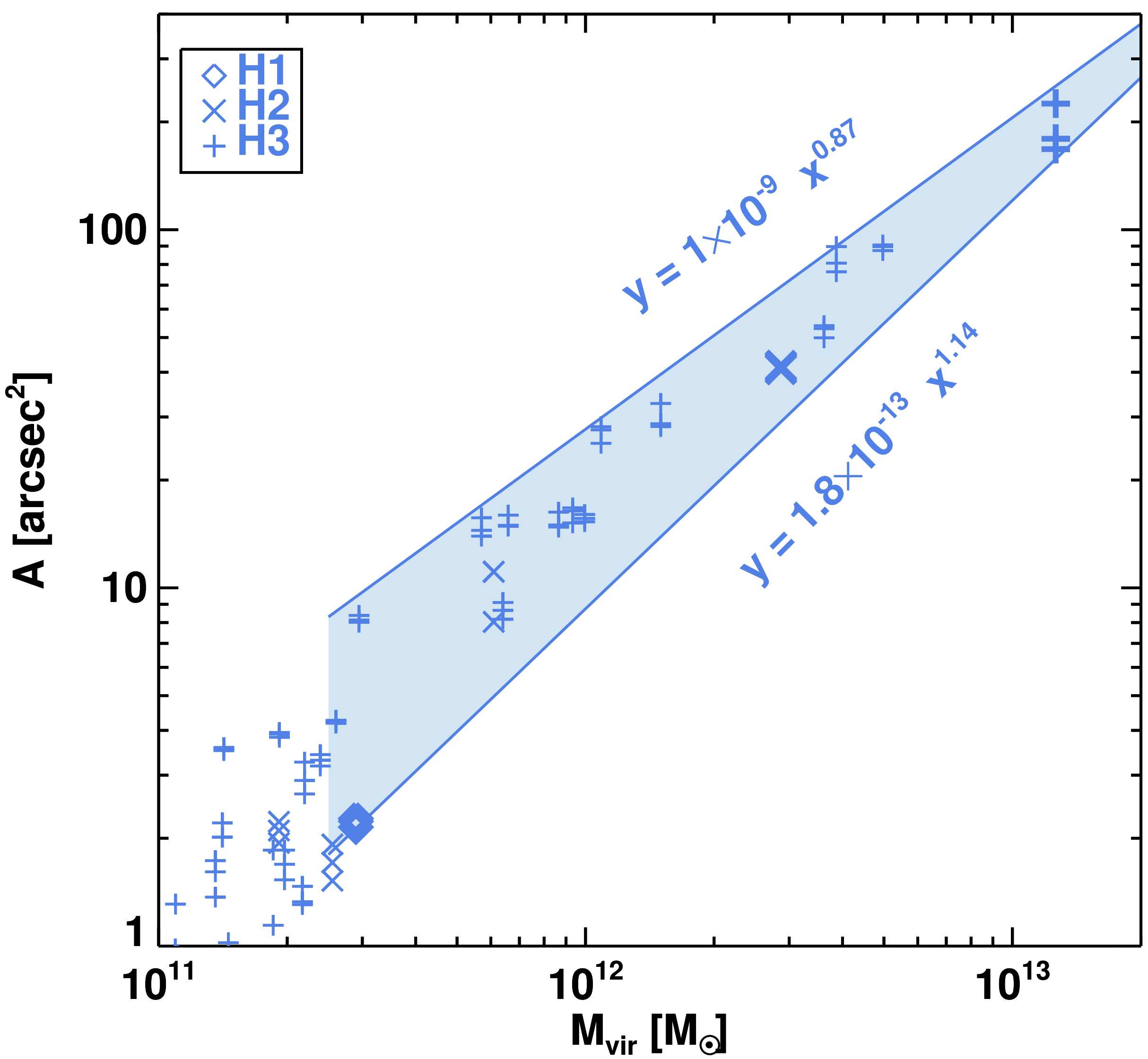
- Observations of the 14 biggest redshift 3 LABs from Matsuda et al. 2010

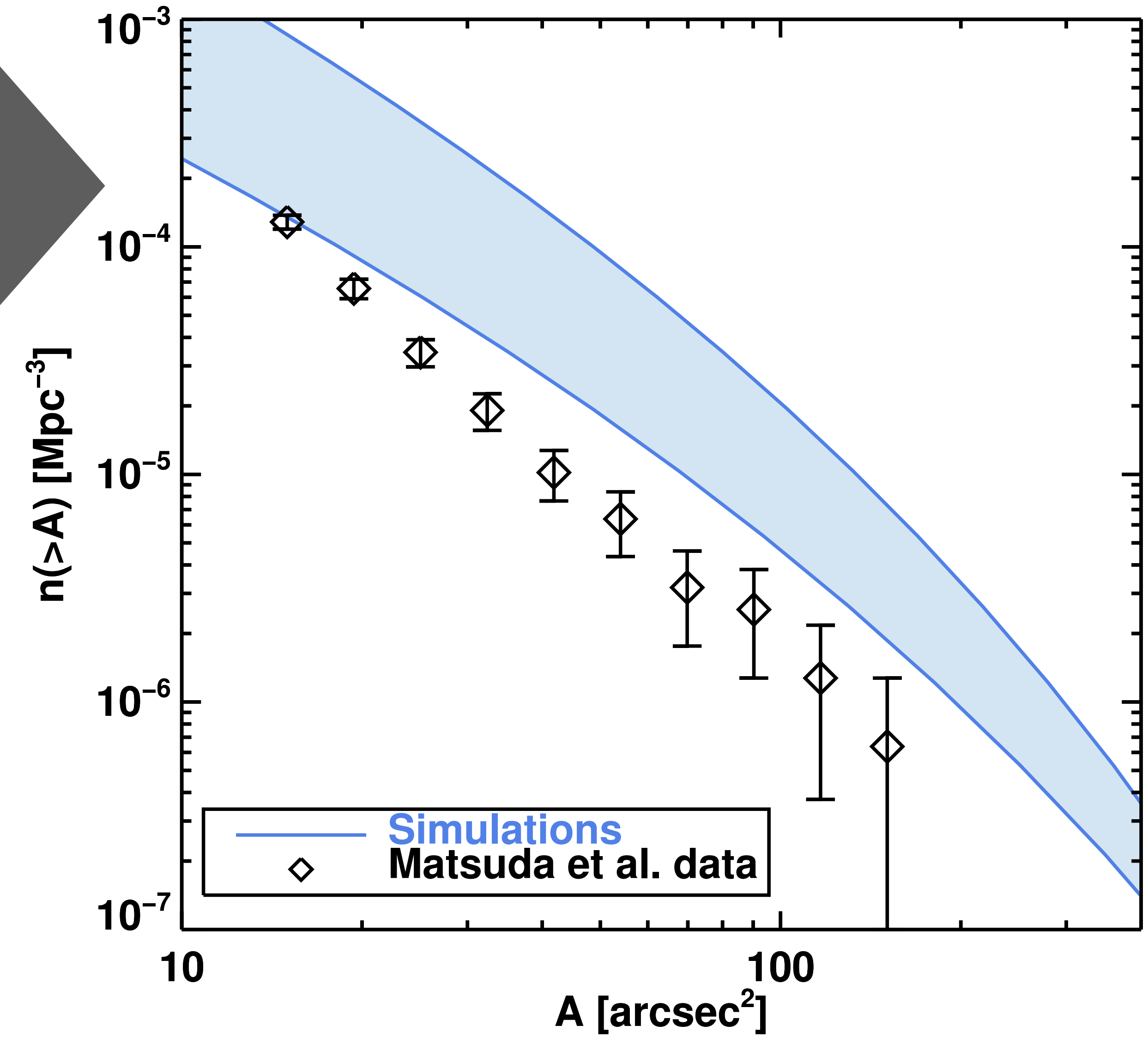
- Us, at same redshift and sensitivity



Comparison to observations

Are the statistics consistent?





- A(M) convolved with halo mass function
- Compared to 202 LABs from Matsuda et al.
- We overestimate observed areas by a factor of 2-3
  - Bad statistics, environmental effects, cosmic extinction
  - Observational uncertainties: Noise, continuum subtraction, Lyα absorbers
  - Physics: Effects of winds, metals, local UV enhancement - can all be negative

Comparison to observations

New developments!

Central Powering of the Largest Lyman-alpha Nebula is Revealed by Polarized Radiation

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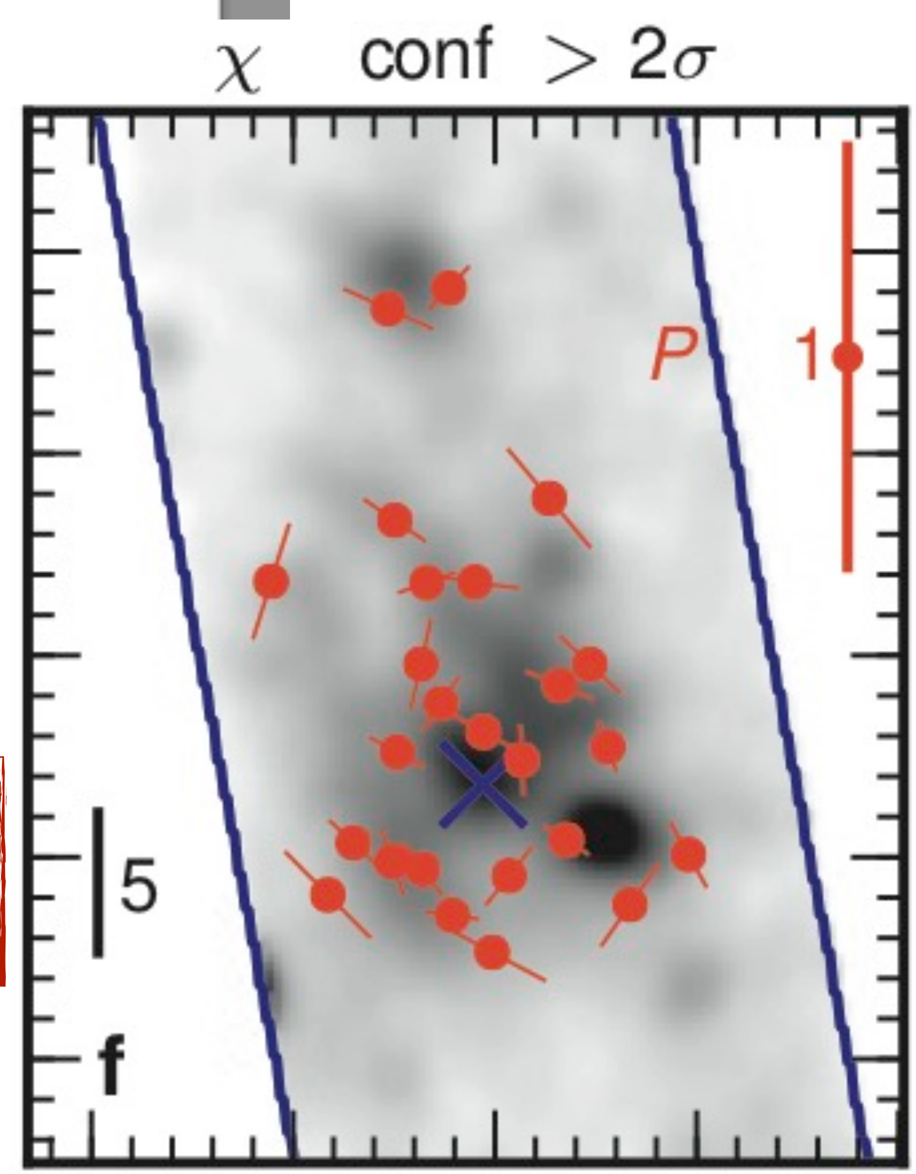
High-redshift Lyman-alpha blobs[1,2] are extended, luminous, but rare structures that appear to be associated with the highest peaks in the matter density of the Universe[3–6]. Their energy output and morphology are similar to powerful radio galaxies[7], but the source of the luminosity is unclear. Some blobs are associated with ultraviolet or infrared bright galaxies, suggesting an extreme starburst event or accretion onto a central black hole[8–10]. Another possibility is gas that is shock excited by supernovae[11,12]. However some blobs are not associated with galaxies[13,14], and may instead be heated by gas falling into a dark matter halo[15–19]. The polarization of the Lyα emission can in principle distinguish between these options[20–22], but a previous attempt to detect this signature returned a null detection[23]. Here we report on the detection of polarized Lyα from the blob LAB1[2]. Although the central region shows no measurable polarization, the polarized fraction (P) increases to $\approx$ 20 per cent at a radius of 45 kpc, forming an almost complete polarized ring. The detection of polarized radiation is inconsistent with the in situ production of Lyα photons, and we conclude that they must have been produced in the galaxies hosted within the nebula, and re-scattered by neutral hydrogen.

The Lyα emission line of neutral hydrogen is a frequently used observational tracer of evolving galaxies in the high redshift Universe. Lyα imaging surveys typically find a large number of faint unresolved objects and a small fraction of extremely luminous and spatially extended systems that are usually referred to independently as Lyman alpha blobs (LABs). The compact sources usually appear to be more ordinary star forming galaxies whereas, since their discovery, much controversy has surrounded the true nature of LABs. Because one of the possible modes of powering



Summary and conclusions

- **First fully consistent RHD simulations of accretion streams**
- **Cold streams are *on-the-verge* Lyα observable in massive halos**
- **Cold accretion can explain *most* LABs**
  - **We overpredict LAB abundance by a x2, but a number of systematic uncertainties may dig us out of that hole**
  - **Still no explanation LABs without galaxies - except by resorting to 'hidden' galaxies**

Prospectives

- **Add physics to the powering of LABs:**
  - **<u>Scattering</u>, UV photo-fluorescence, SNe/AGN winds**
  - **Comparison to polarization observations**