Distribution of Hα emitters and Lyα emitters in the Protocluster

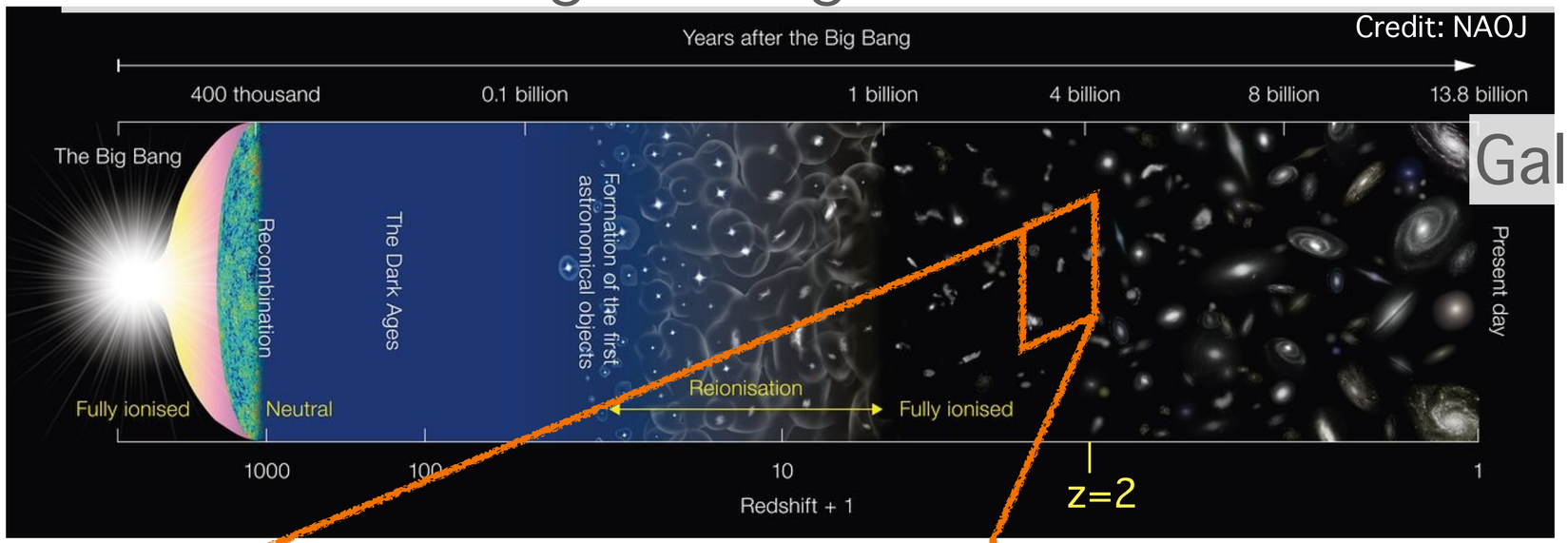
Keita Fukushima (Osaka)

Collaborators: Kentaro Nagamine (Osaka)
Yuri Oku (Osaka)
Ikkoh Shimizu (Shikoku Gakuin)
Hidenobu Yajima (Tsukuba)

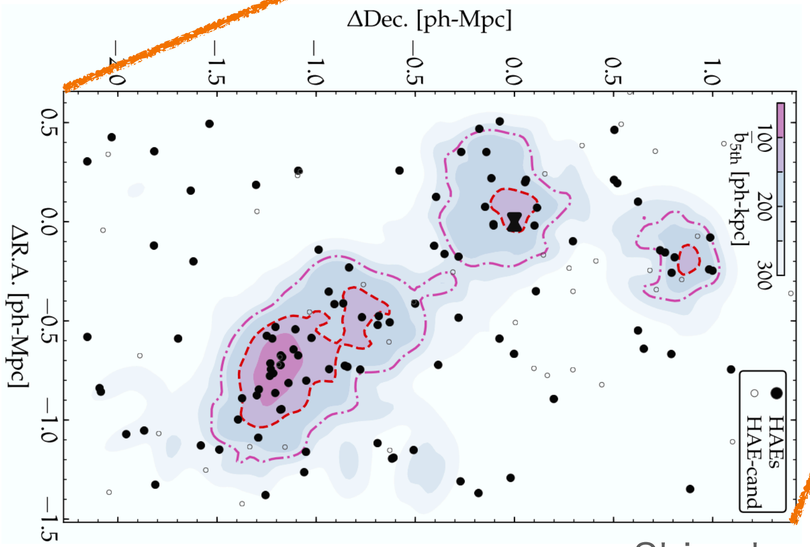
Galaxy-IGM Workshop, 16 Aug 2021

Search for ProtoCluster

Protoclusters at high redshift ($z \geq 2$) are identified as overdense regions of galaxies



Galaxies evolution

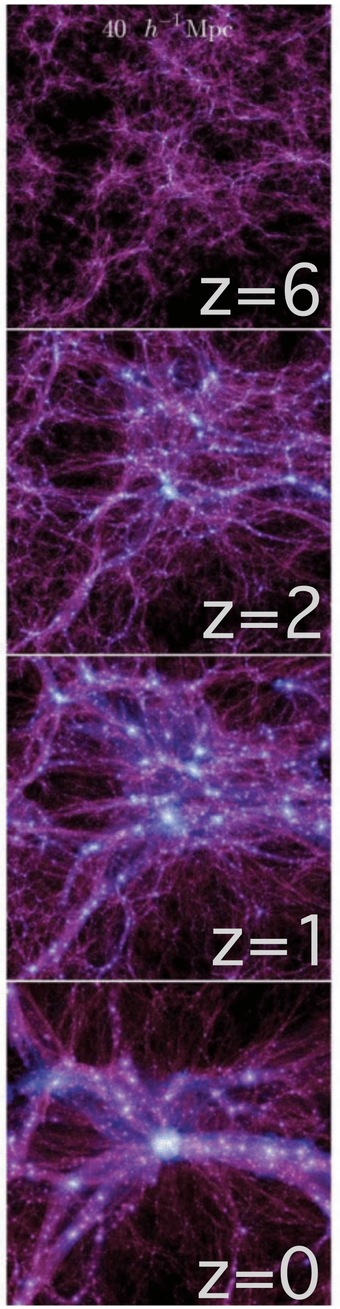


Shimakawa+18

Observations
- narrow-band survey
  - Lyα emitters : LAEs
  - Hα emitters : HAEs

Simulations
- Dark matter distributions

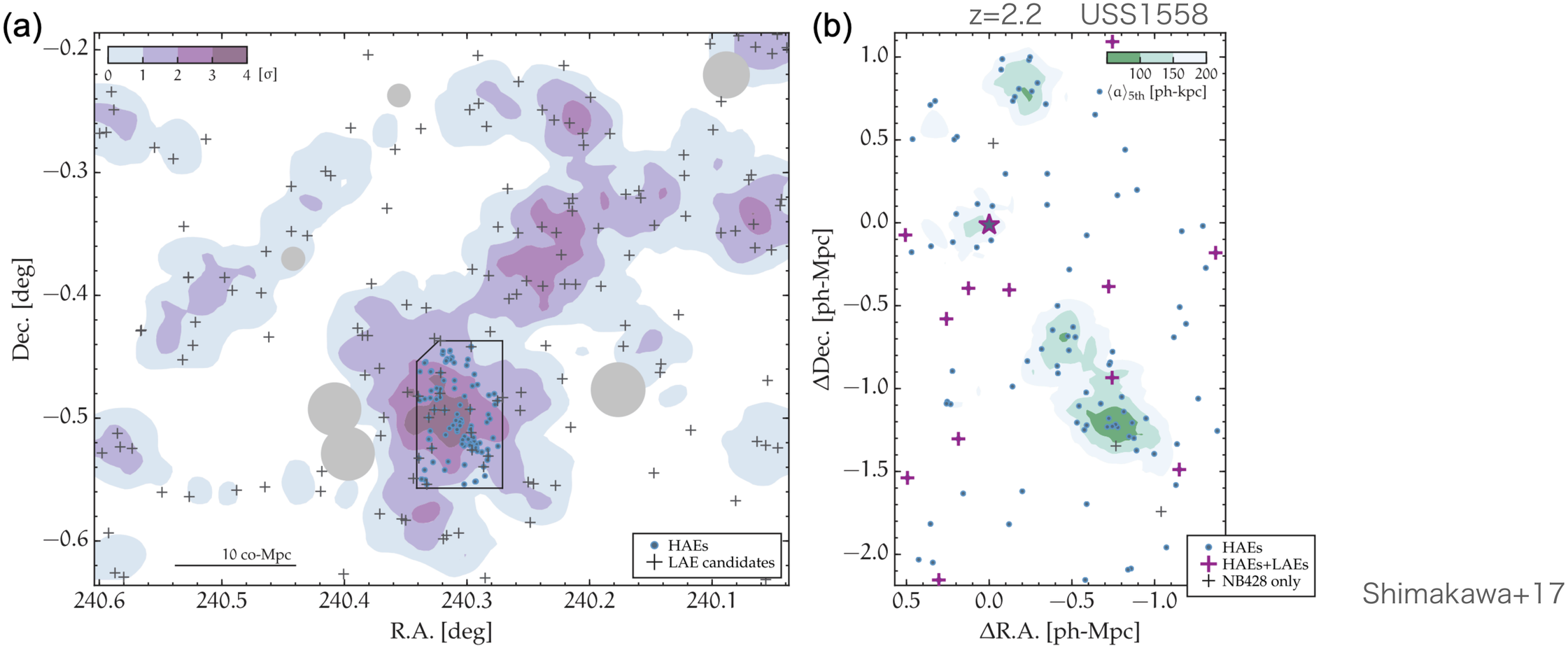
Simulations can connect galaxies and dark matter



Boylan-Kolchin+09

Distribution of HAEs & LAEs

LAEs tend to avoid high-density regions

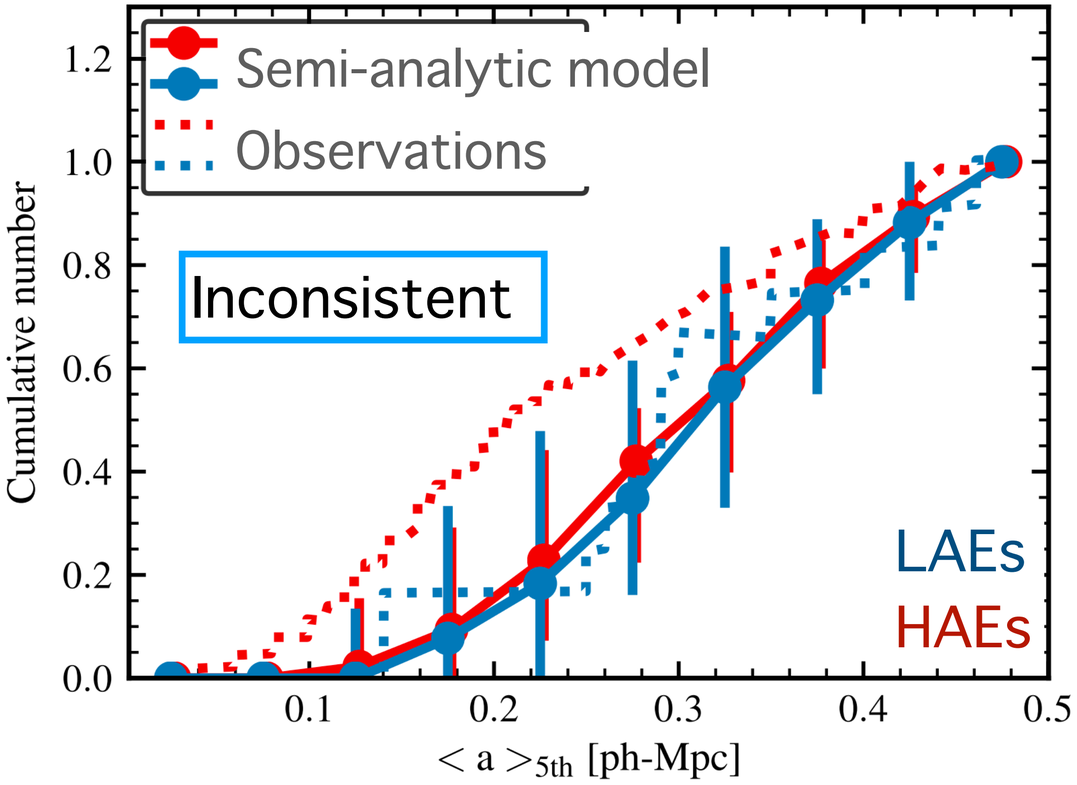


Shimakawa+17

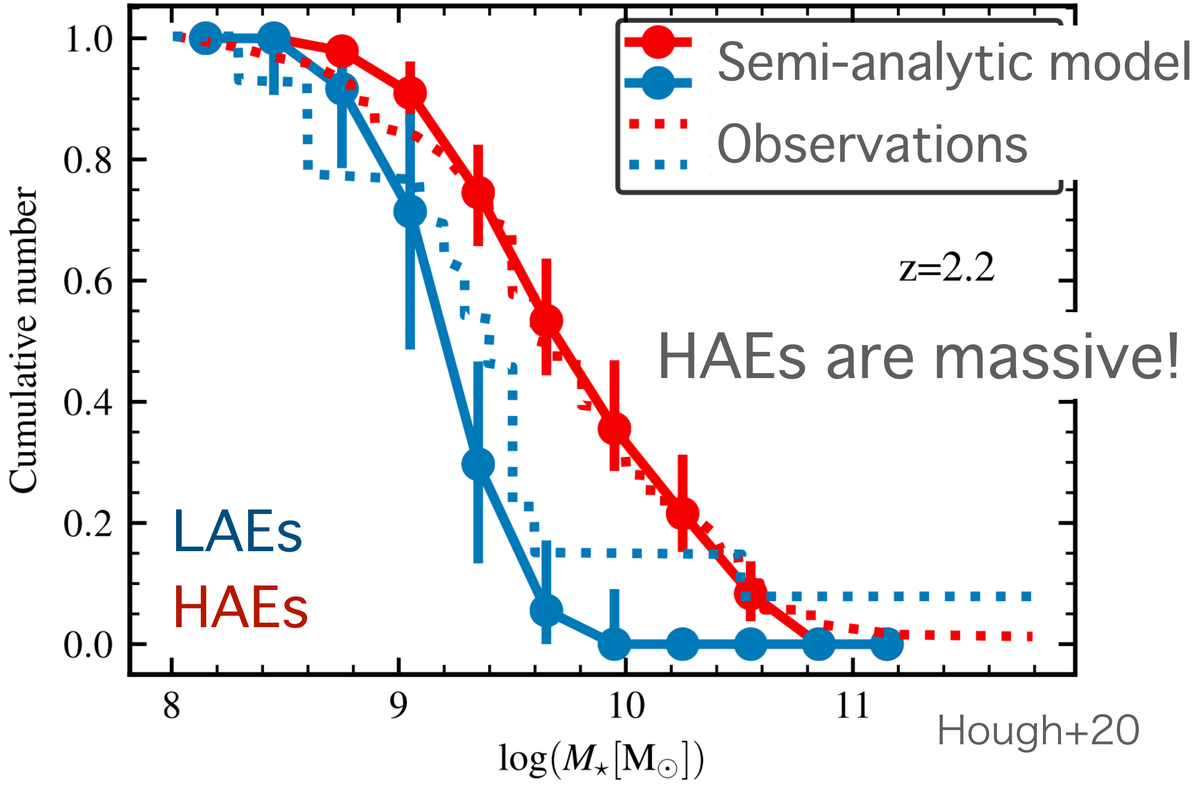
Cold, neutral gas in the protocluster prevent Lyα photons from escaping

➡ A lack of LAEs in high-density regions

Comparison with observation and Semi-analytic model



mean projected distance



agreement with observation

Observations:
Typical distance of LAEs > HAEs

Semi-analytic model:
Typical distance of LAEs ~ HAEs

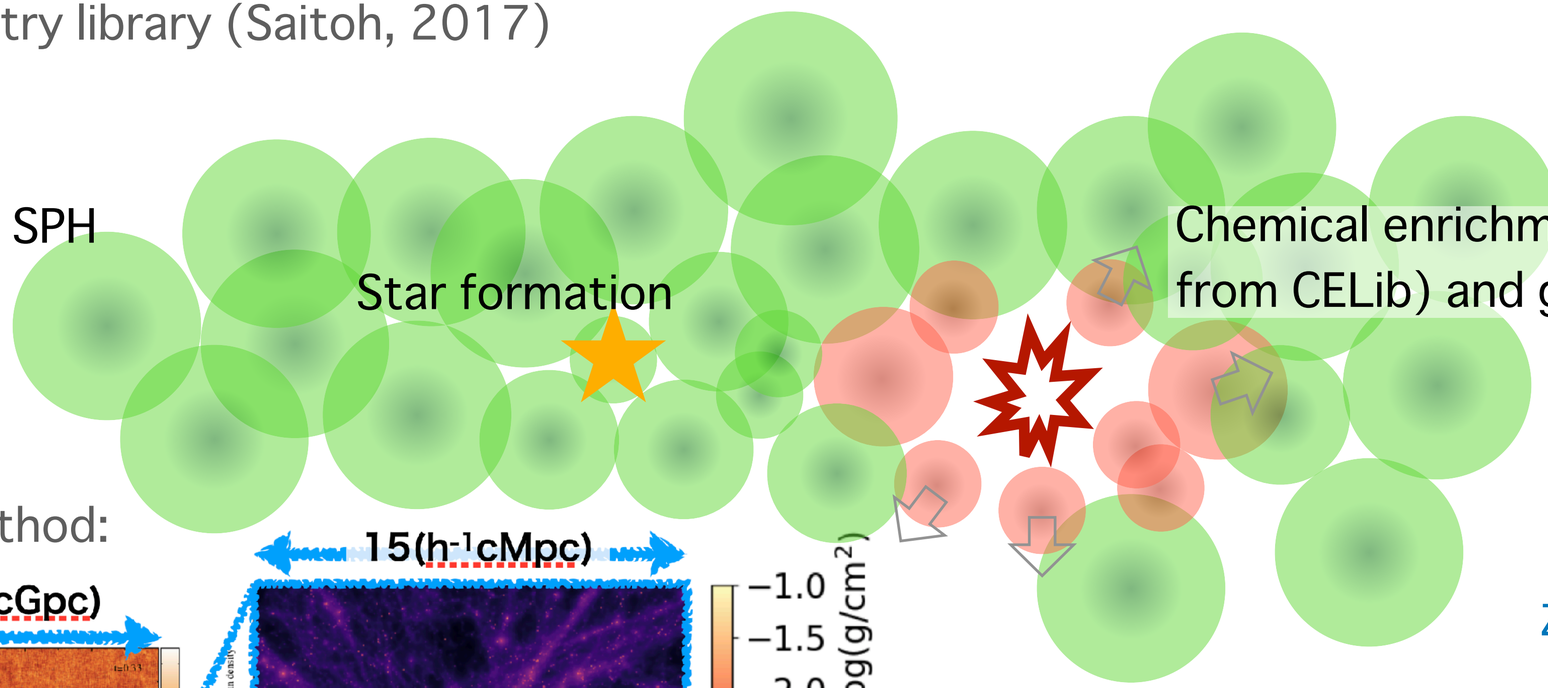
How about numerical simulations?

Methods : GADGET3-Osaka

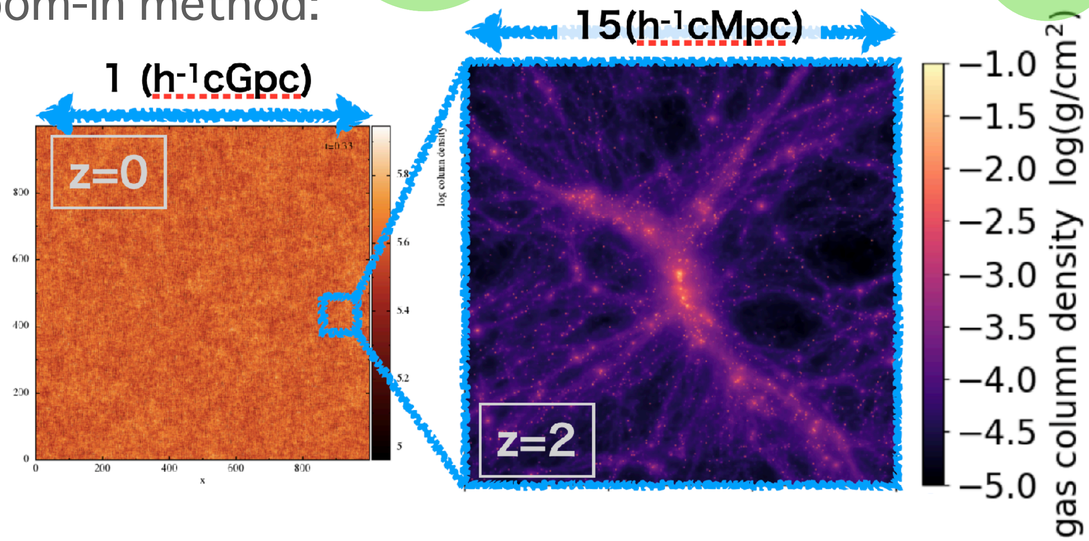
Aoyama+17, Shimizu+19

Cosmological SPH simulation code

Models : Star Formation & Thermal & Kinetic Feedback by Type Ia & II SNe, AGB stars
CELib chemistry library (Saitoh, 2017)



Zoom-in method:



Zoom volume
2.93×10^4 $(h^{-1}\mathrm{Mpc})^3$

Particle mass
$m_{DM}=1.31\times10^8\ h^{-1}M_\odot$
$m_{gas}=2.45\times10^7\ h^{-1}M_\odot$
$m_{star}=2.45\times10^7\ h^{-1}M_\odot$

Softening length
$h = 4.07\ h^{-1}\mathrm{ckpc}$

Radiative transfer : ART²

Li+08, Yajima+12, Li+20

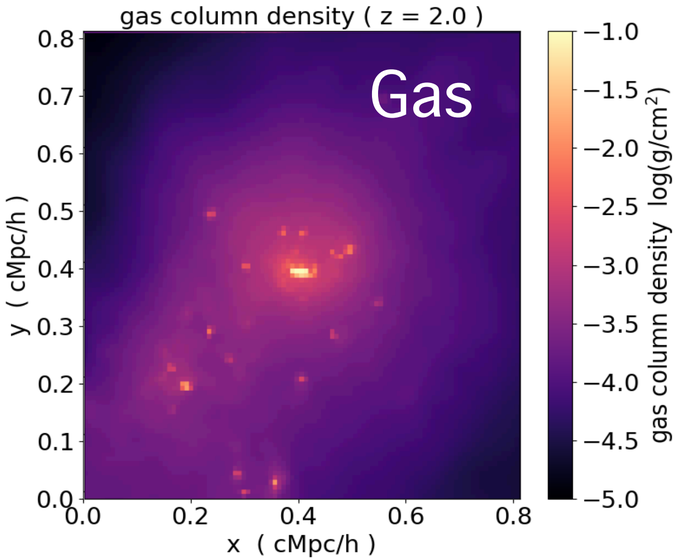
All-wavelength Radiative Transfer with Adaptive Refinement Tree

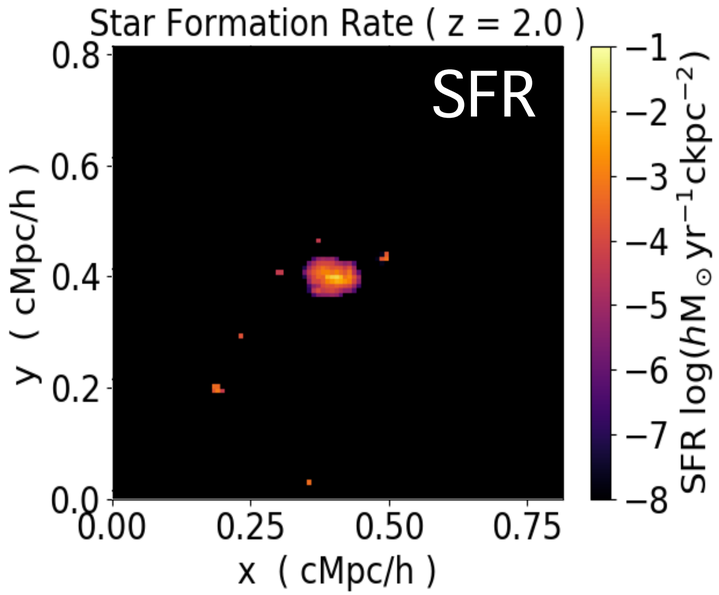
Simulation

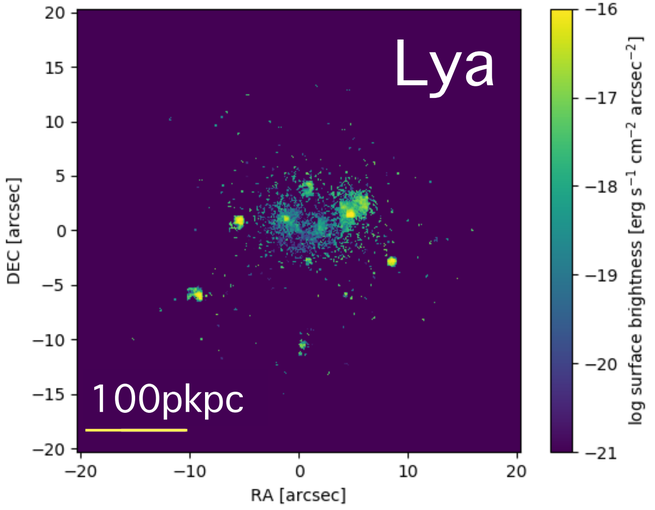
Radiation Transfer

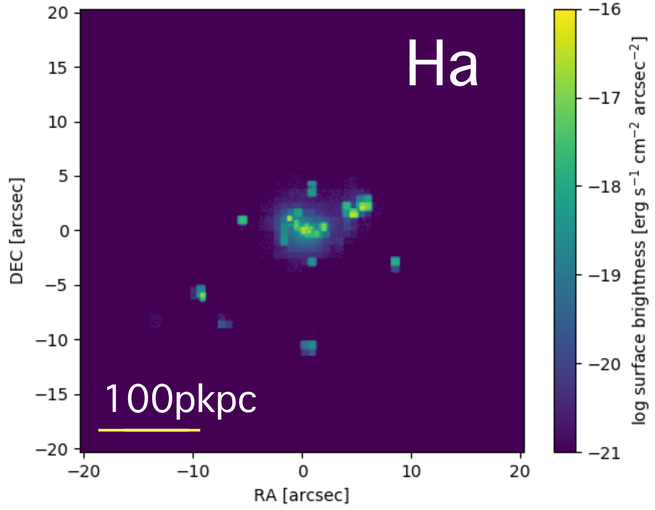
- Ionizing radiation
- Dust absorption
- Lyα
- Hα

- Updated emissivity coefficients
- Added using Cloudy (with Oku-kun)

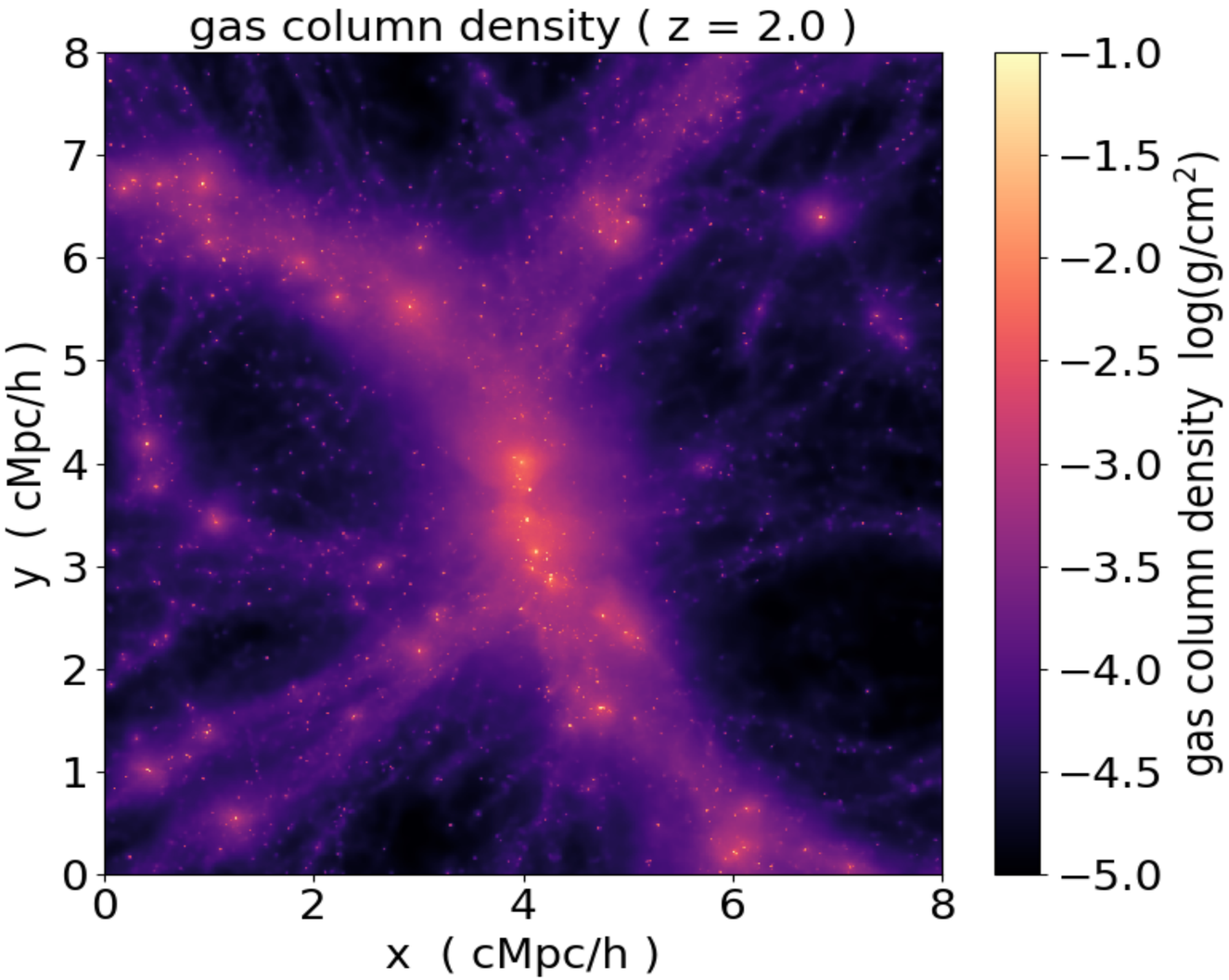




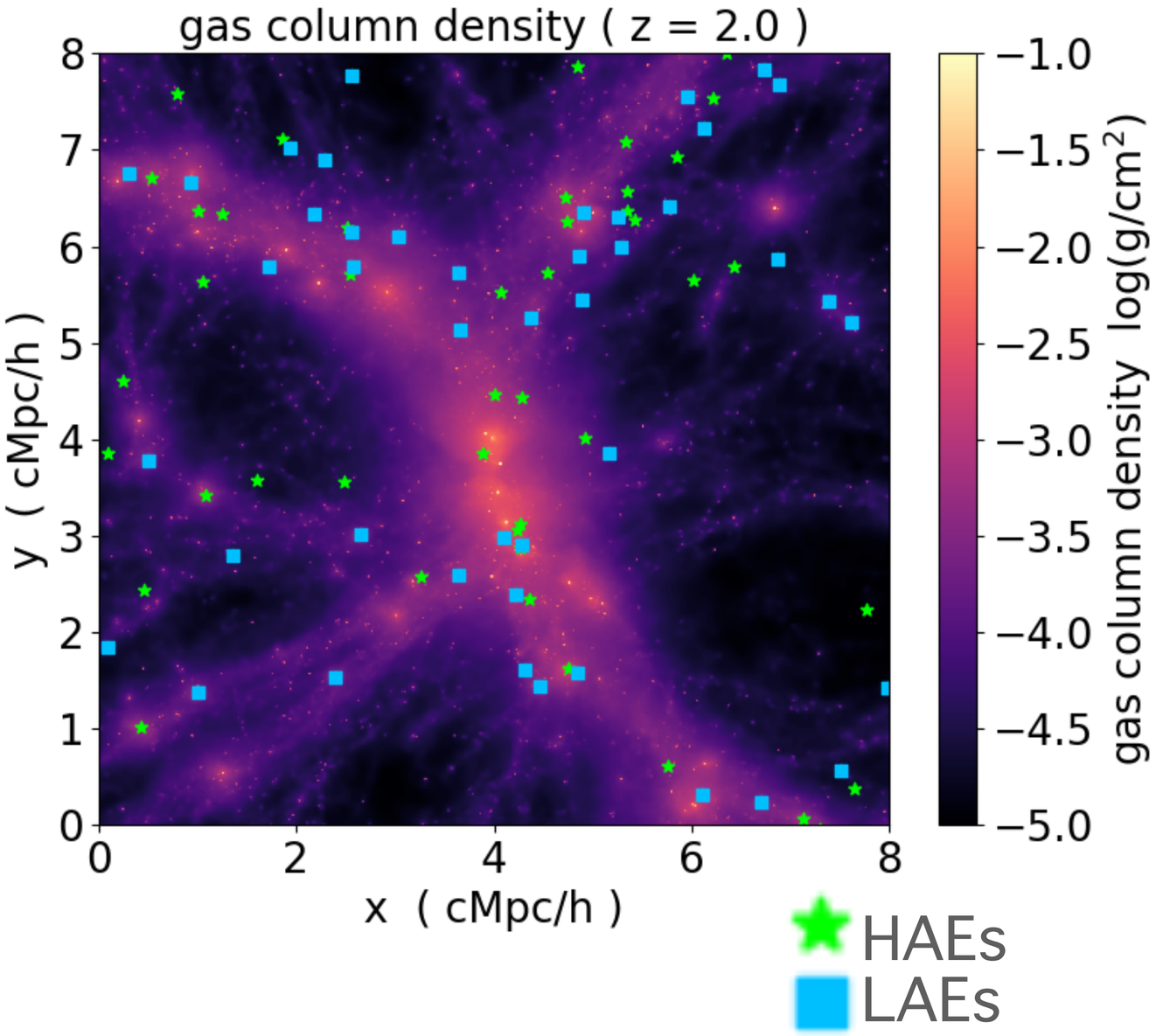




Spatial distribution of HAEs and LAEs



Spatial distribution of HAEs and LAEs



Threshold:

HAEs : $L_{H\alpha} > 4.35\times10^{41}$ erg s^{-1}

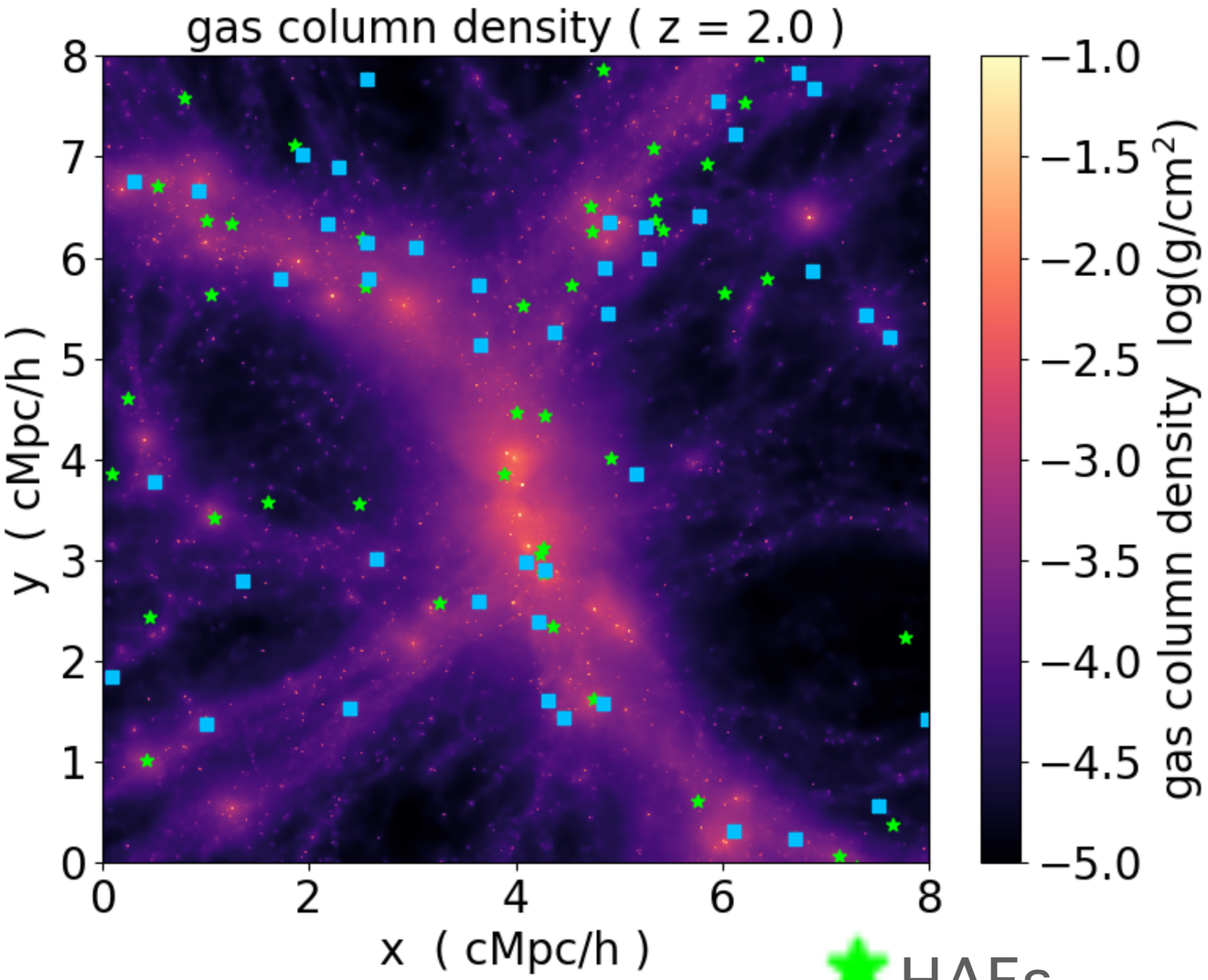
LAEs : $L_{H\alpha} > 4.35\times10^{41}$ erg s^{-1}

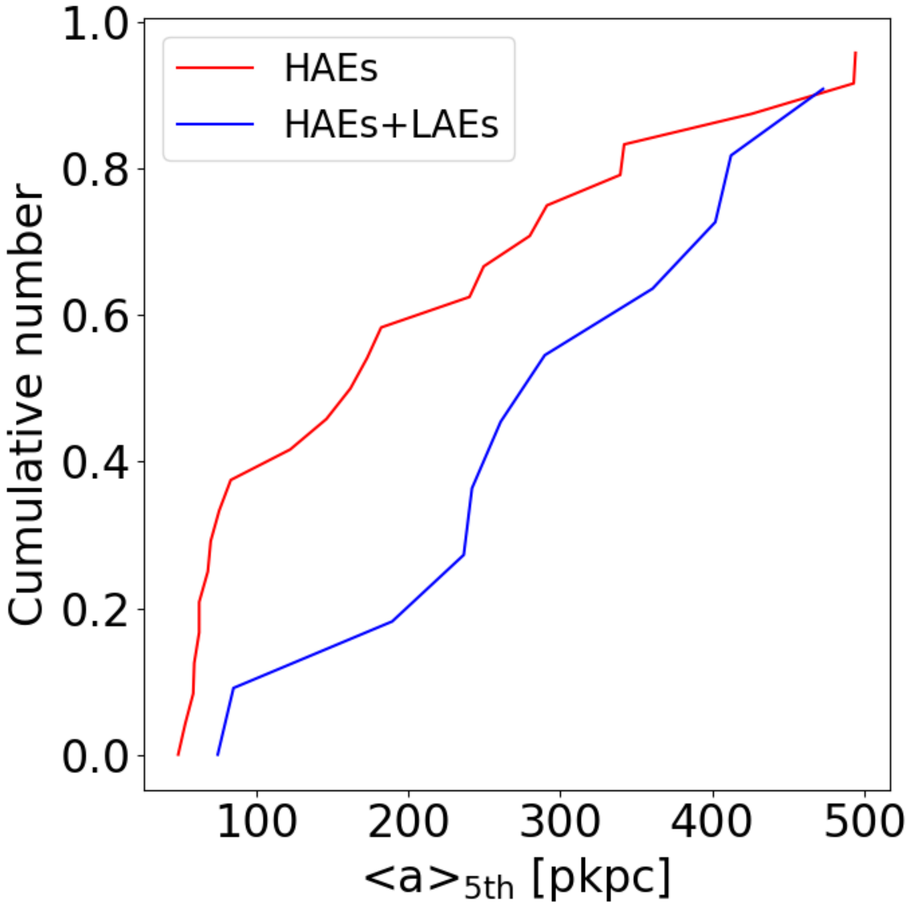
$L_{Ly\alpha} > 4.4\times10^{41}$ erg s^{-1}

(Same as Shimakawa+17)

HAE appears to be in a denser region than LAE.

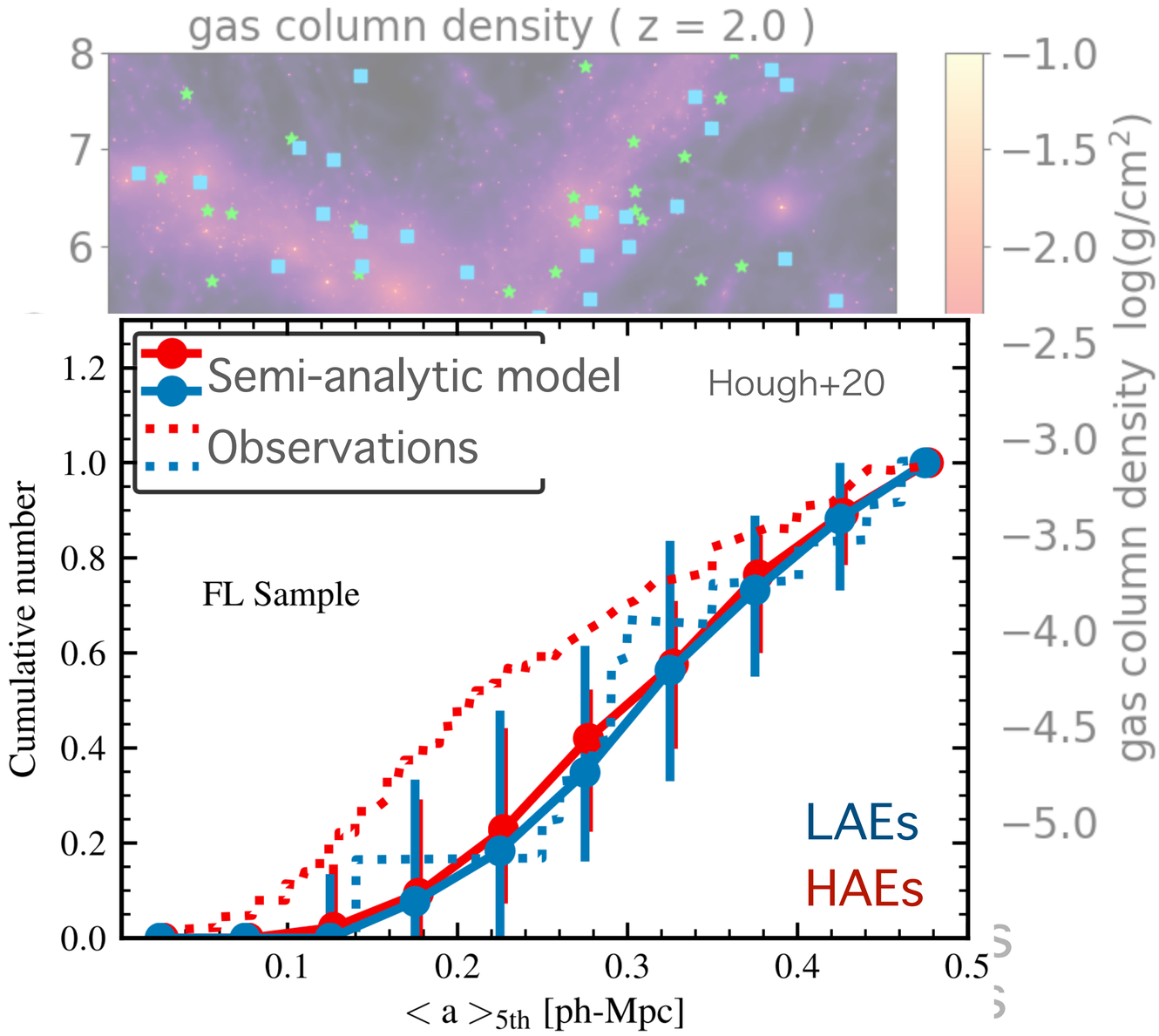
Mean projected distance of HAEs and LAEs

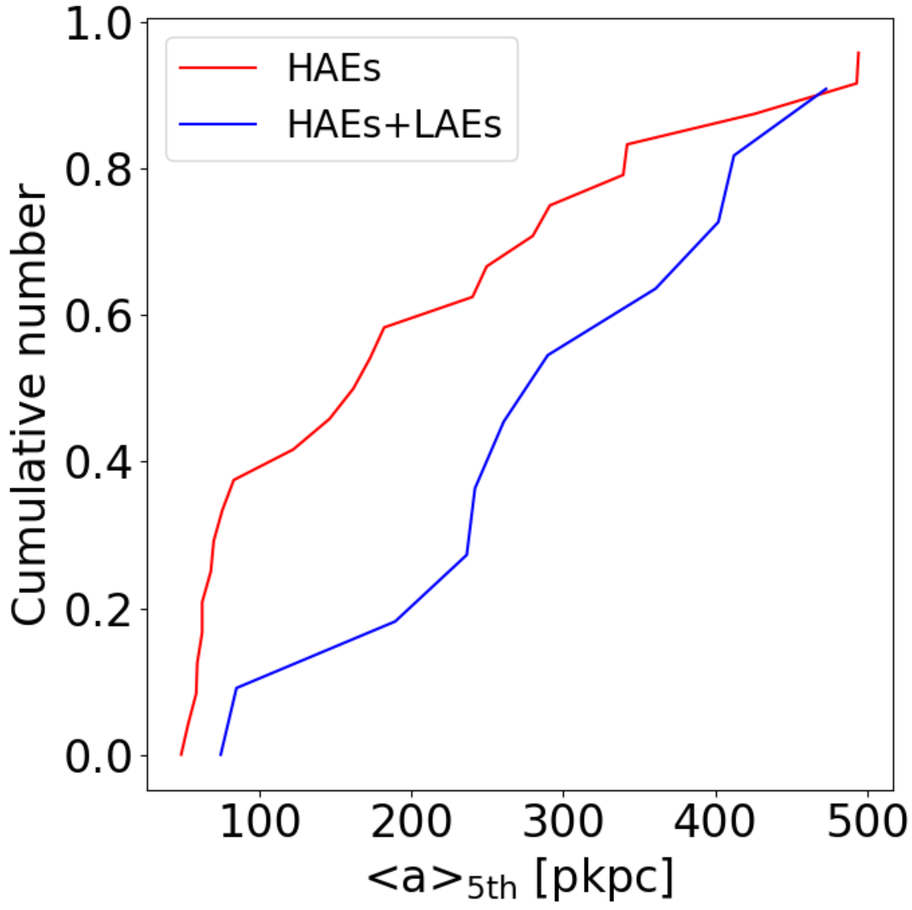




HAE appears to be in a denser region than LAE.

Mean projected distance of HAEs and LAEs

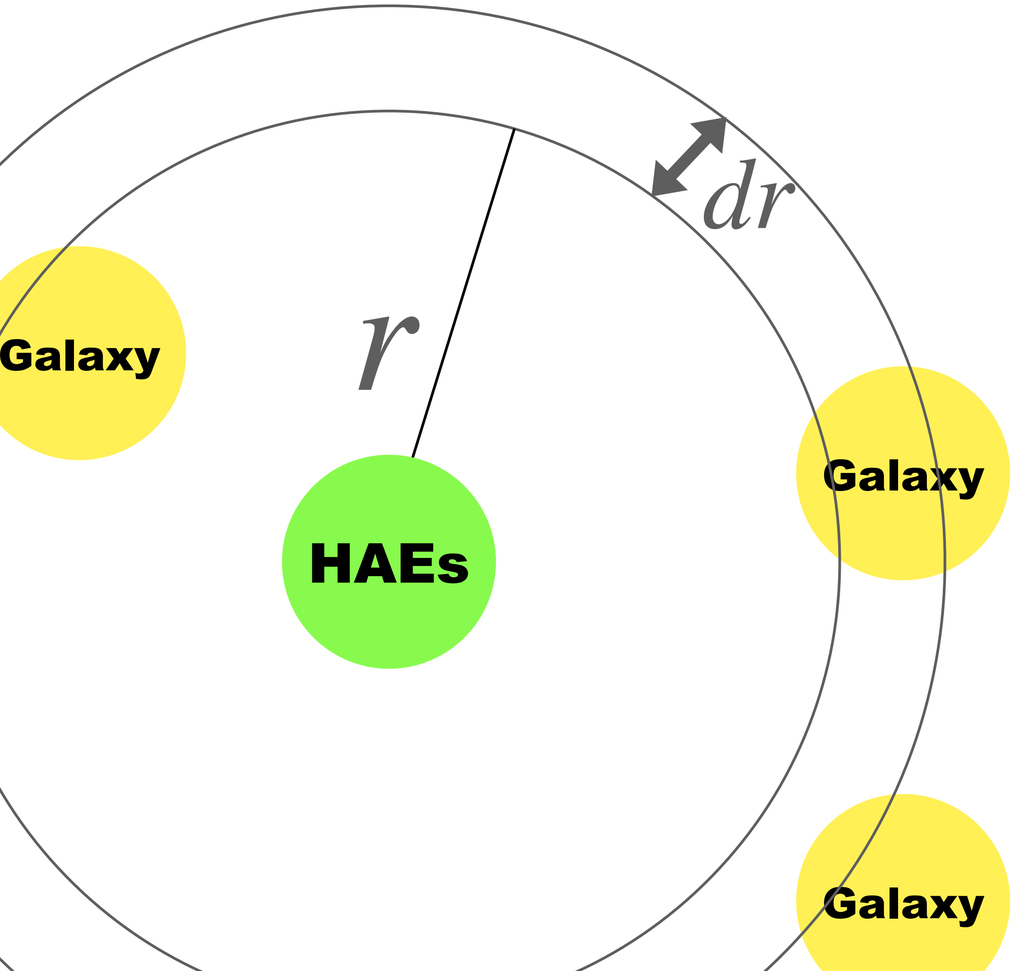




It's consistent with observation.

Correlation function $\xi(r)$

$$dN = 4\pi n r^2 dr \left(1 + \xi(r)\right)$$



dN : Number of galaxies ($M_\star \geqq 10^8 h^{-1} M_\odot$) in the shell

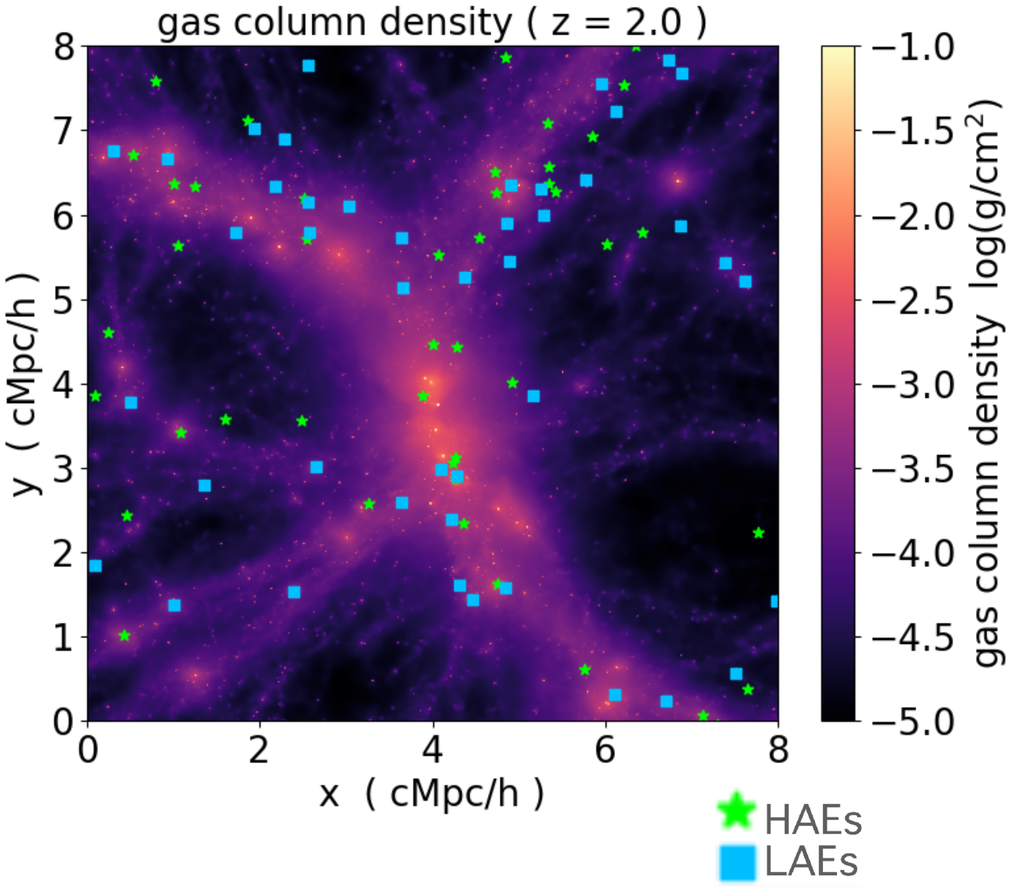
n : mean density of galaxies

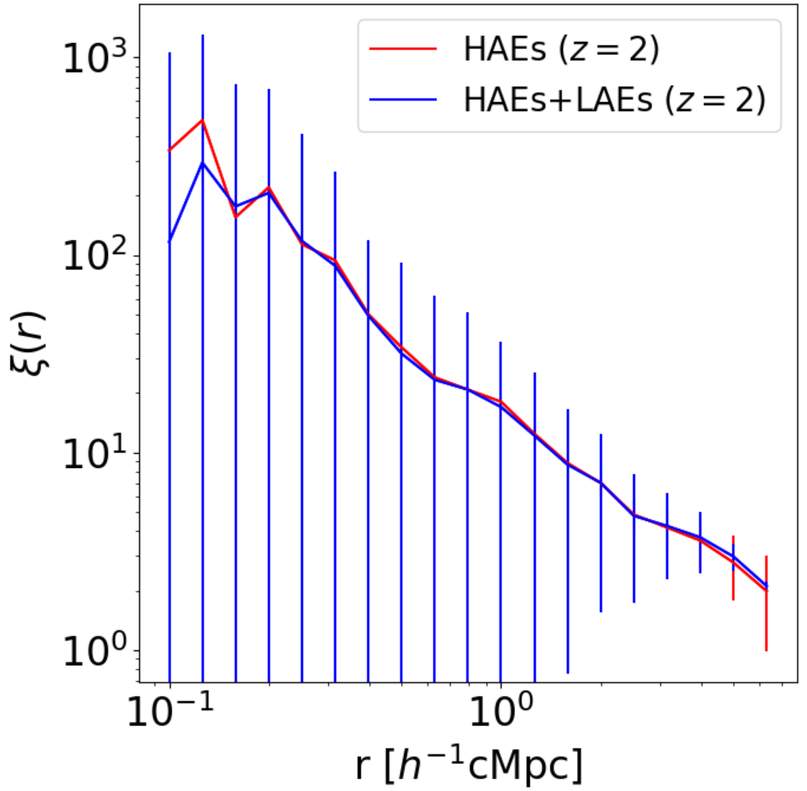
ξ=0 for random distribution,
ξ>0 for dense regions

Correlation function of HAEs and LAEs

Galaxies stellar mass thresholds:

$M_\star \geqq 10^8\, h^{-1} M_\odot$

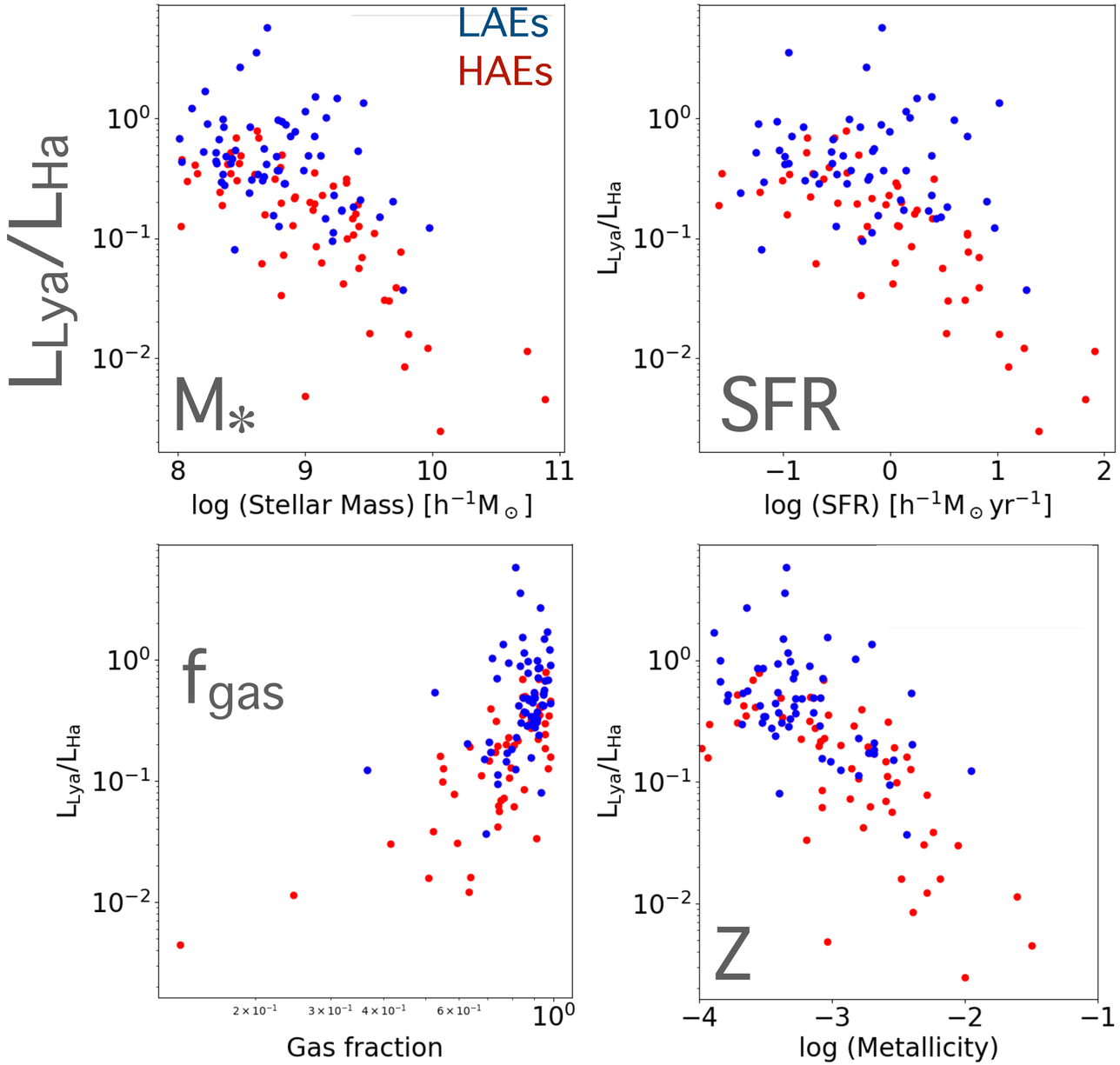


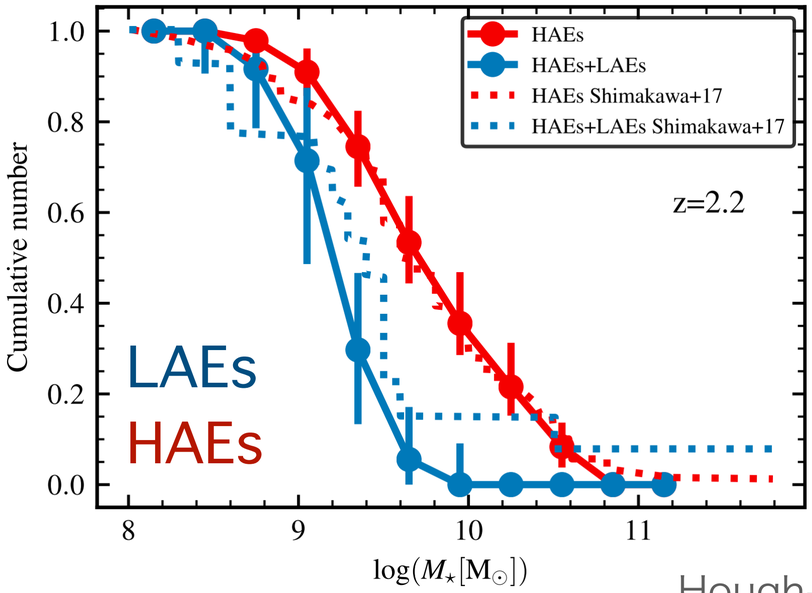


Considering the unobserved galaxies, HAEs and LAEs exist in the same high-density region.

(note: Small sample size) $N_{HAEs} = 189$ $N_{LAEs} = 131$

Difference between HAEs and LAEs





Hough+20

HAEs tend to be more massive than LAEs.

Same trend with obs. and semi-ana.

Summary

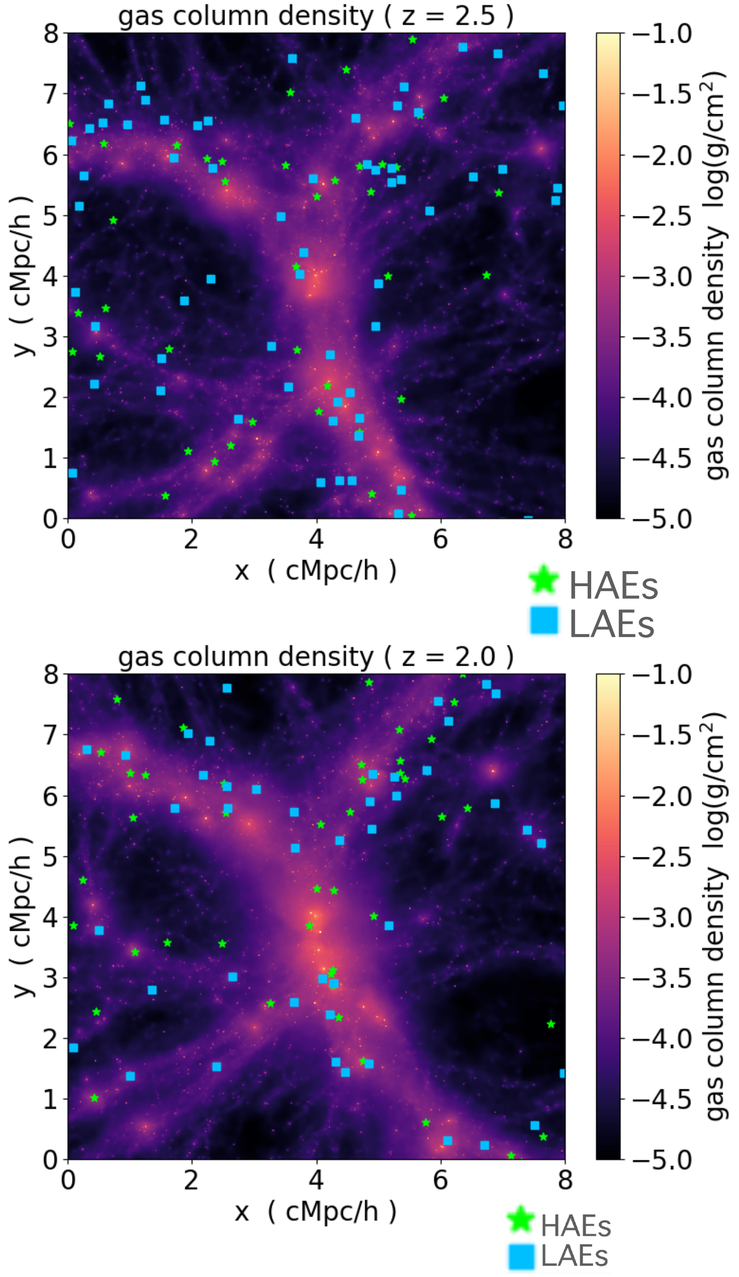
We studied the spatial distribution of HAEs and LAEs in the protoclusters. We simulated the Protocluster and solved the radiative transfer of Lyα and Hα as post-process using ART^2.

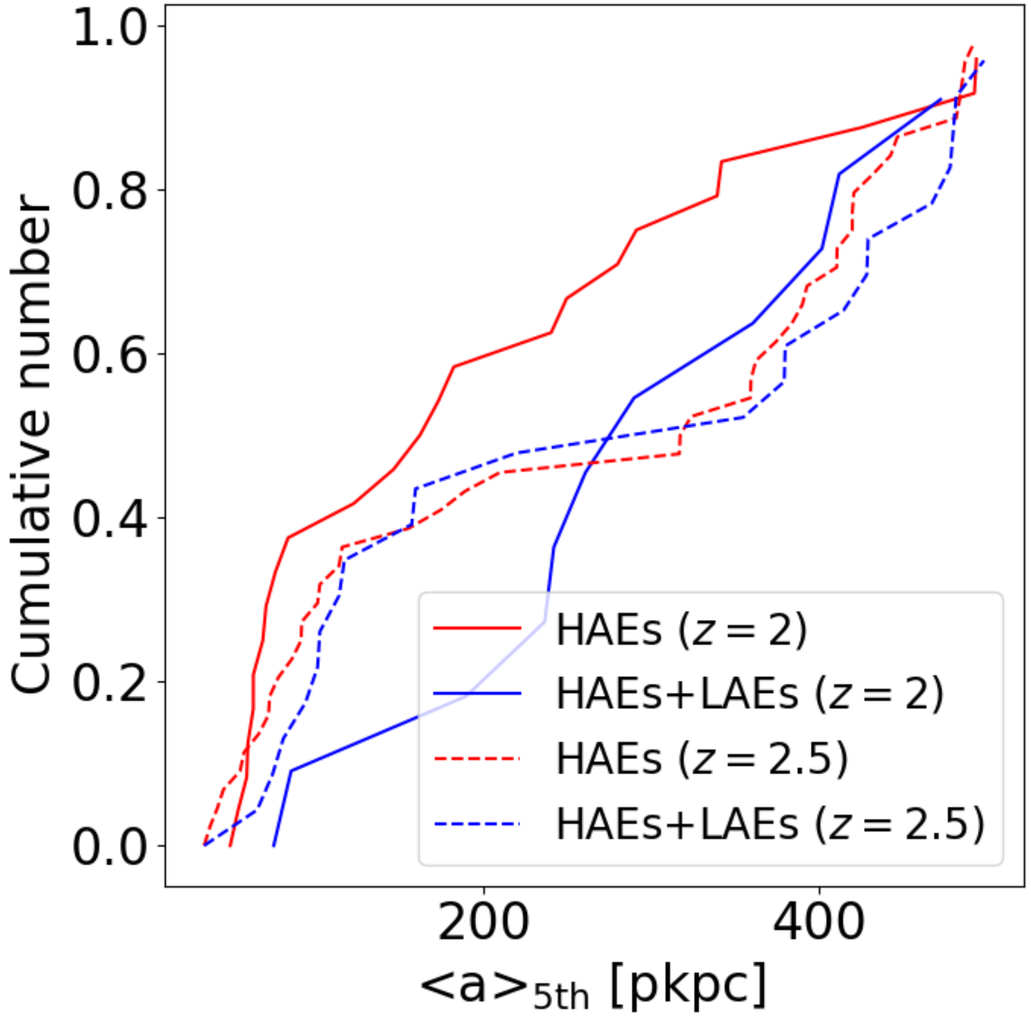
- Using the mean projected distance, HAEs appear to be more dense than LAEs.
  (Consistent with observation)
- Considering the unobserved galaxies, HAEs and LAEs may actually exist in the same density region.
- HAEs tend to be more massive than LAEs.
  (Consistent with semi-analytic model and observation)

Future work

- More detailed clustering analysis
- More samples
- Check for the presence of Lya blobs and Ha blobs

Evolution of the $\langle a \rangle_{5th}$ of HAEs and LAEs



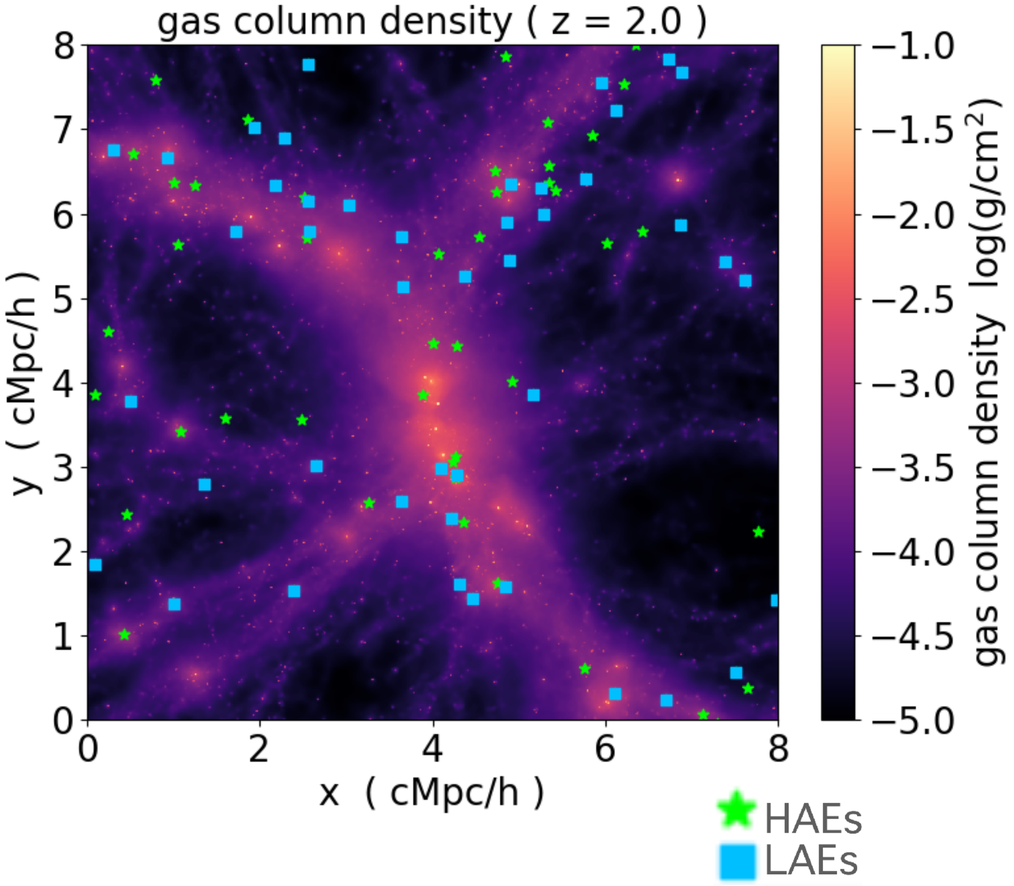


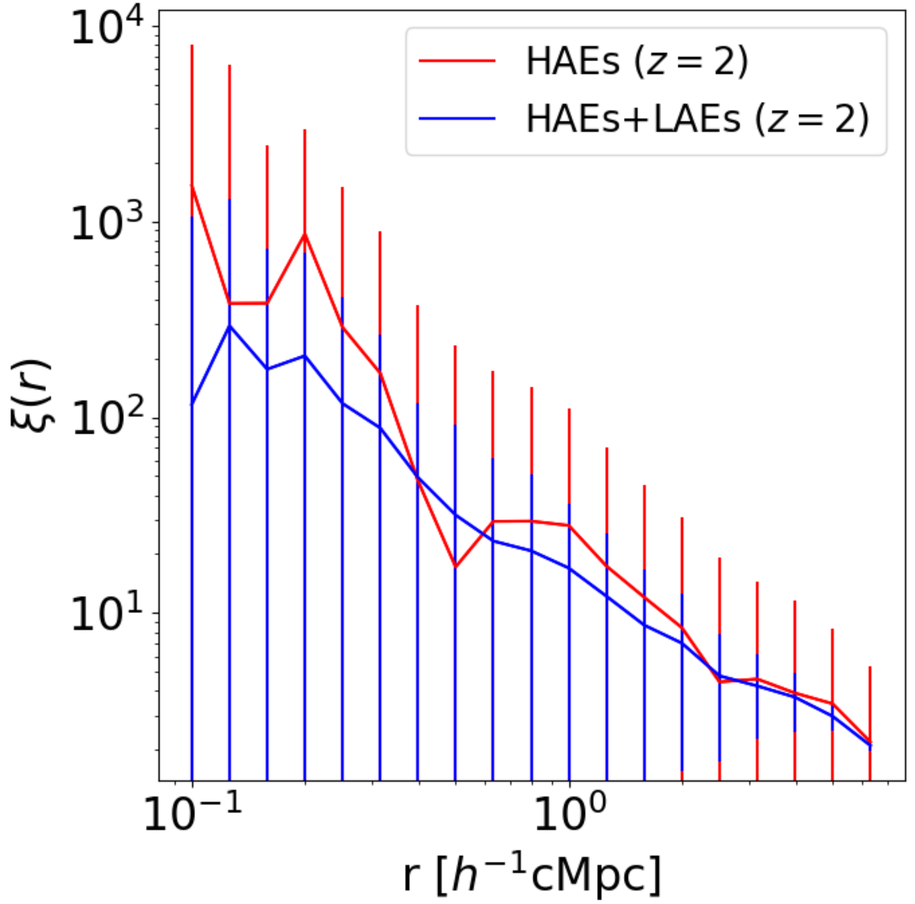
HAEs will exist in higher density areas?
(Note: Small sample size)

Correlation function of HAEs and LAEs

Galaxies stellar mass thresholds:

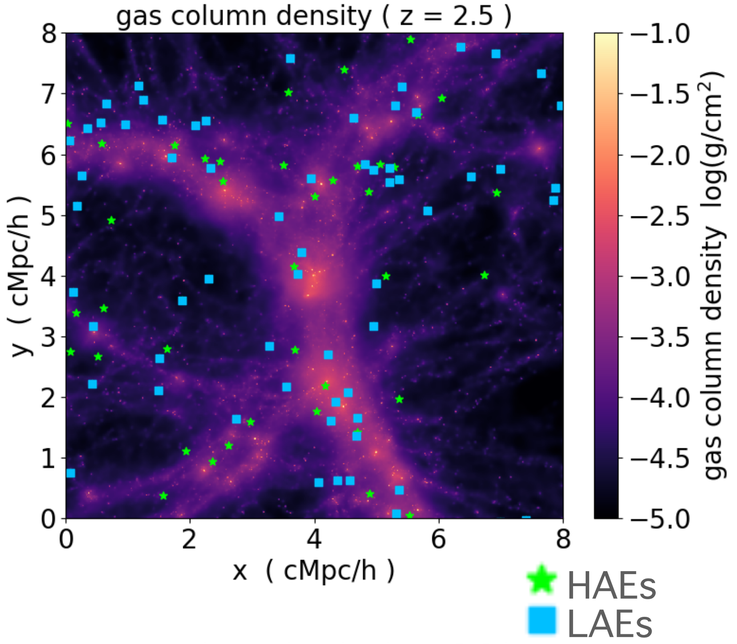
$M_\star \geqq 10^8\, h^{-1} M_\odot$

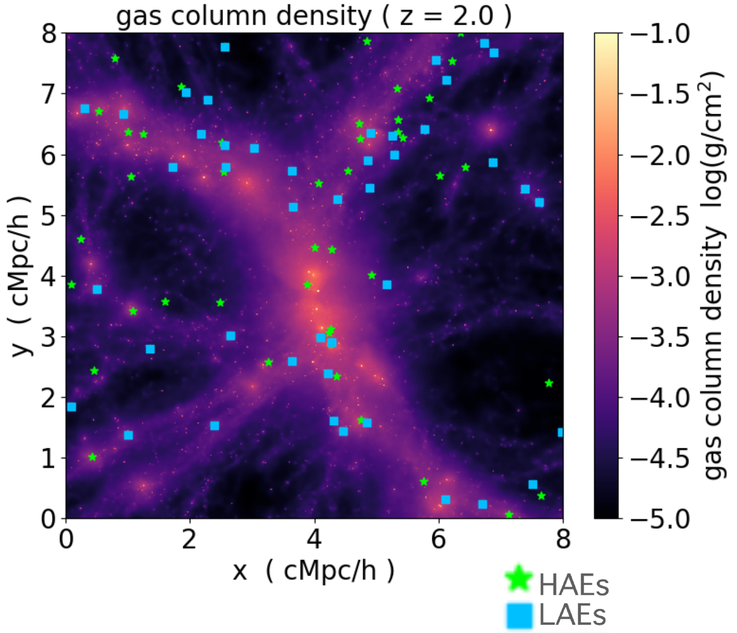


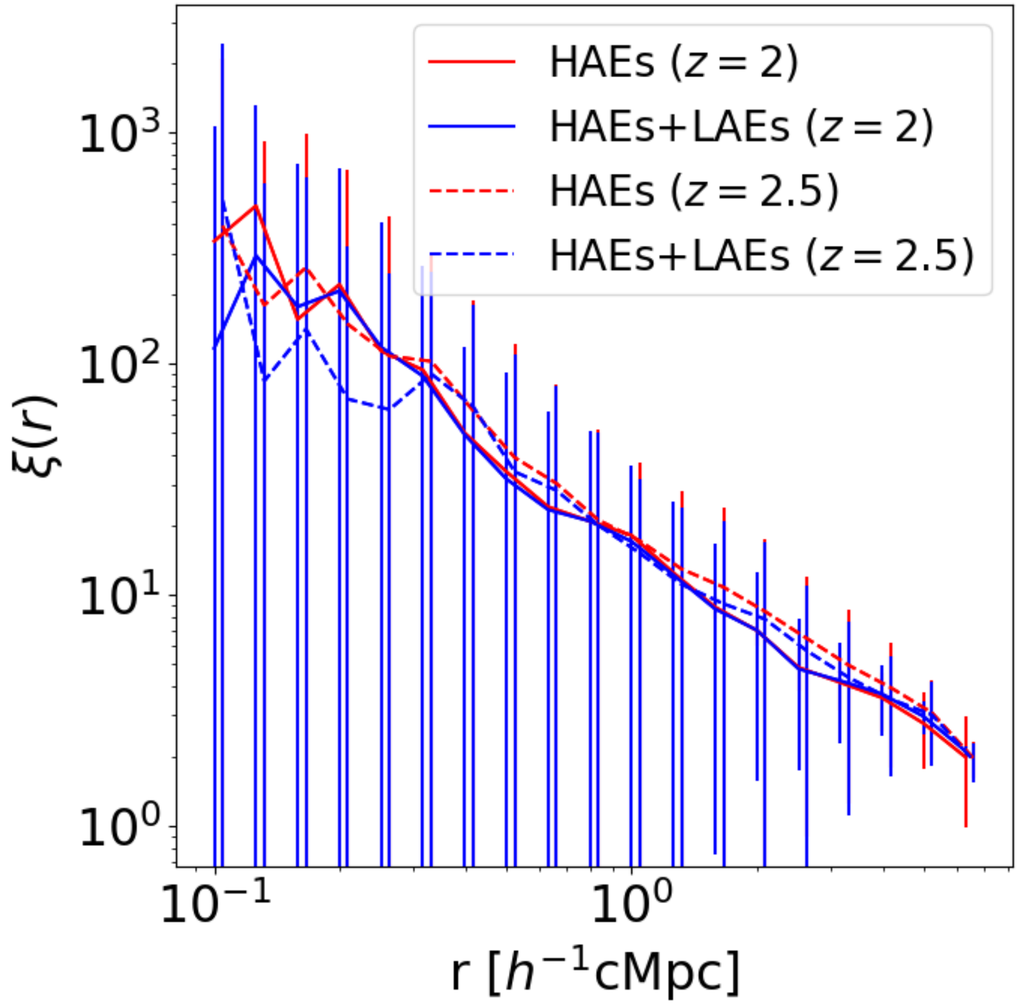


Galaxies that are HAEs but not LAEs may exist in denser regions than LAEs.

Evolution of the distribution of HAEs and LAEs

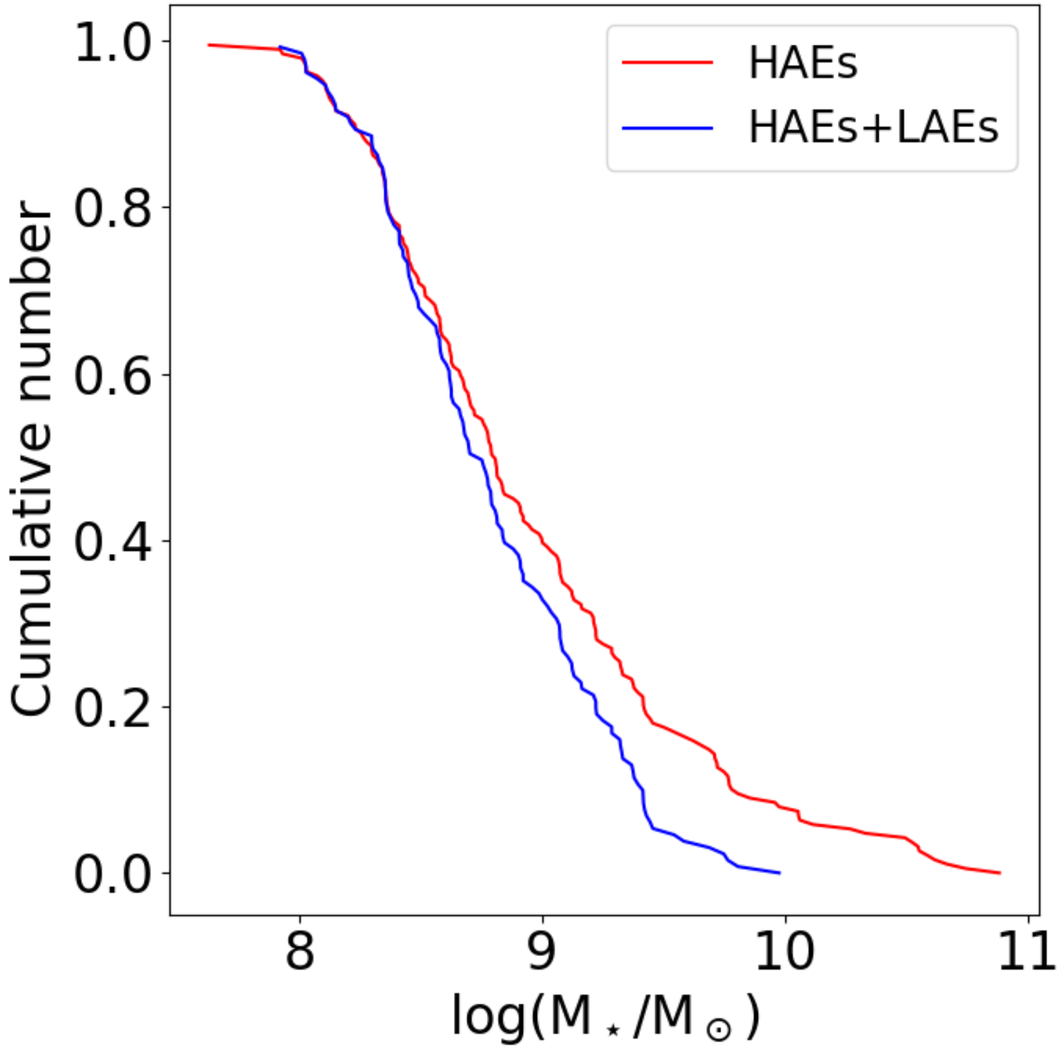


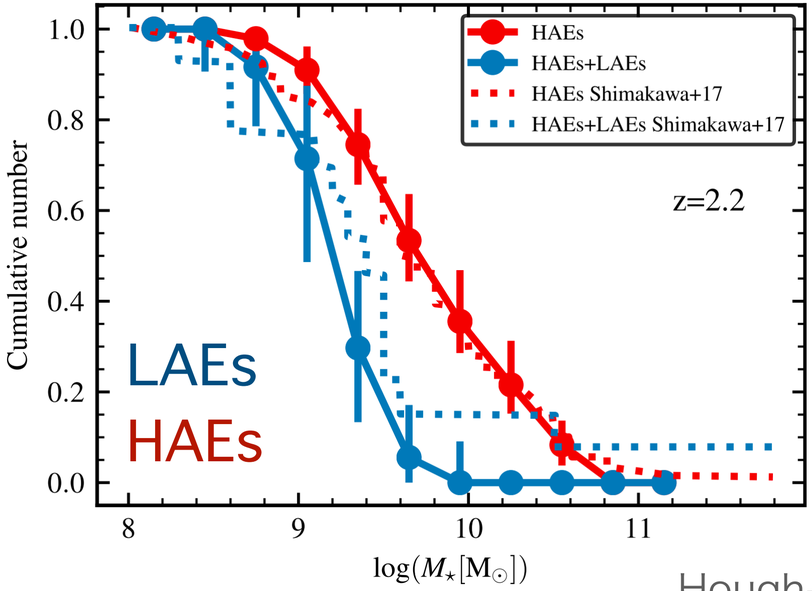




No redshift evolution?
(note: Small sample size)

Difference between HAEs and LAEs





Hough+20

HAEs tend to be more massive than LAEs.

Same trend with obs. and seni-ana.