Subaru 20th Anniversary Symposium

SILVERRUSH. IX.
Lyα Intensity Mapping with SFGs at $z = 5.7$ and 6.6: Lyα Emission Extended at > 150 ckpc Beyond the Virial-Radius Scale of Galaxy DMHs

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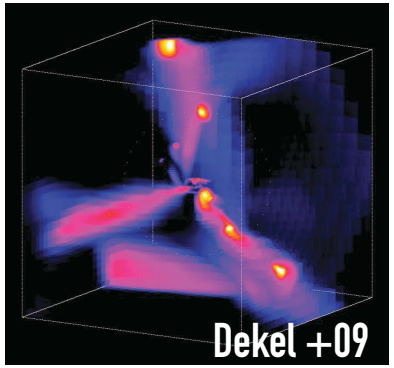
Intergalactic Medium: IGM

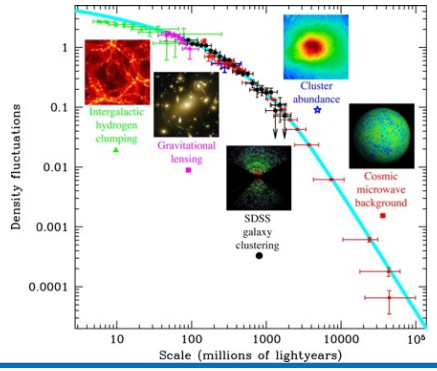
Galaxy evolution

- Gas inflow
- Outflow from galaxies



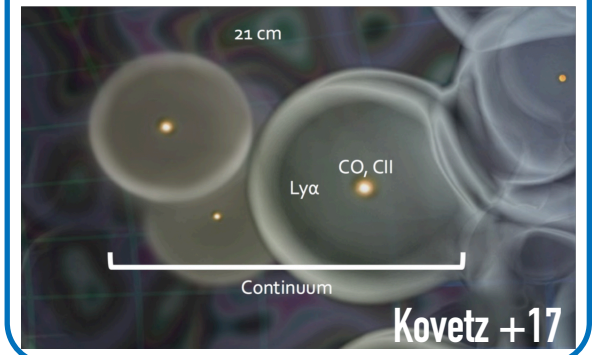
Cosmology

- Large scale structure
- Less bias compared to galaxies



Reionization

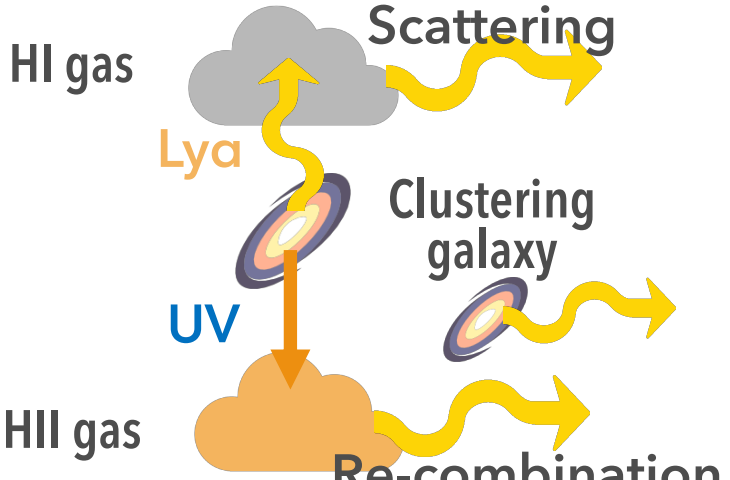
- "Bubbles"of ionized gas



Observation of IGM

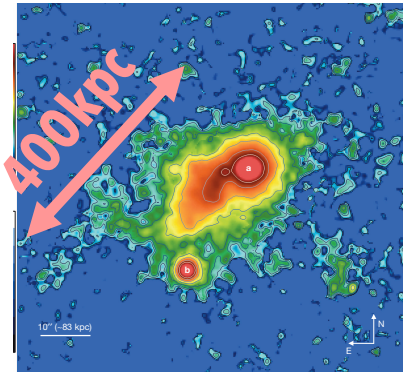
➤ Lyman-α (Lyα)

- ◆ Strongest UV emission
  - High-z Lyα→ Optical
- ◆ Resonance line
  - Scattered by the IGM



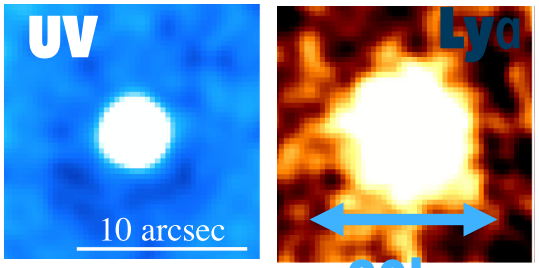
Extended Lyα Emission

Enormous Lyα Nebulae

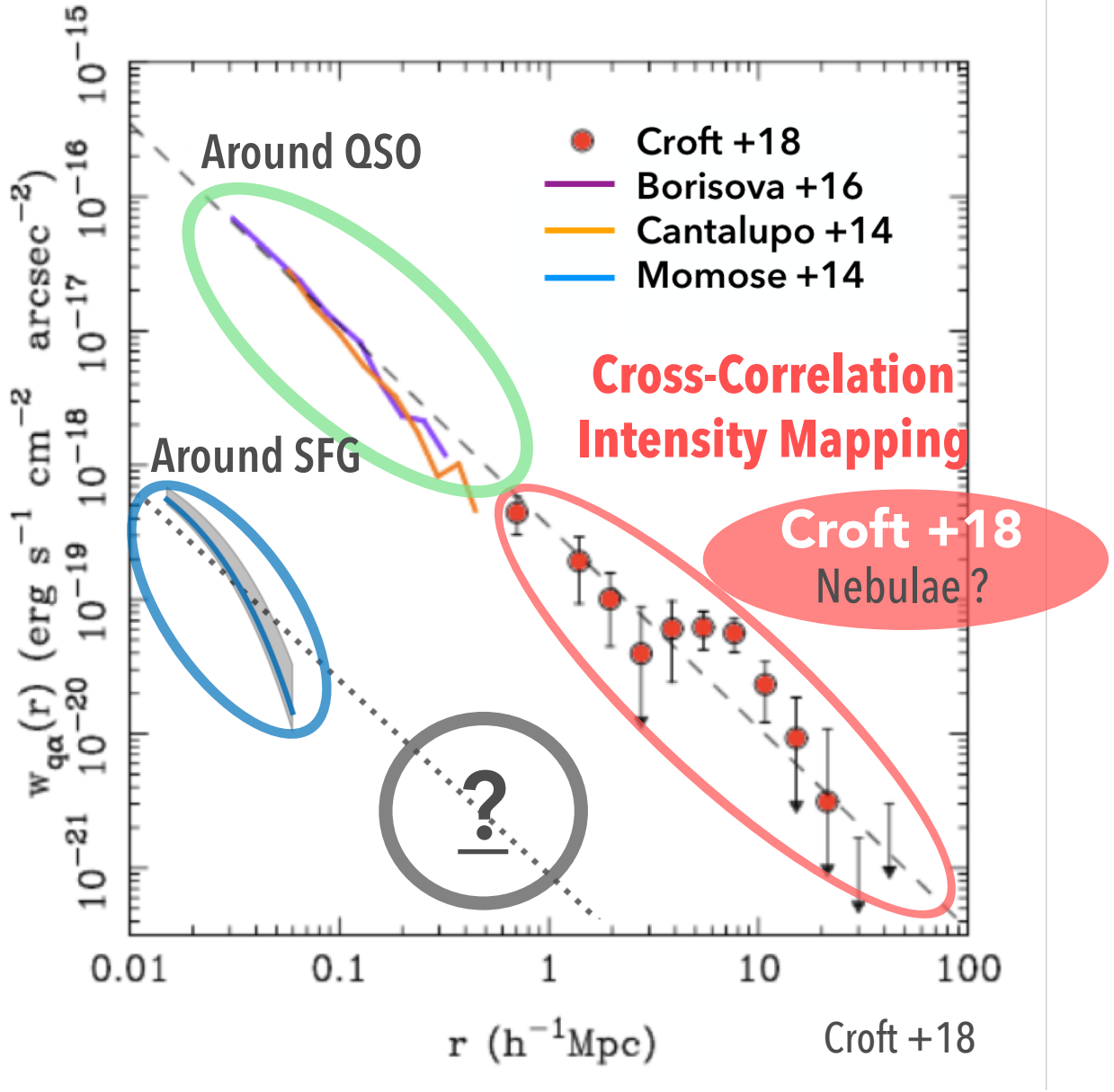


Cantalupo +14

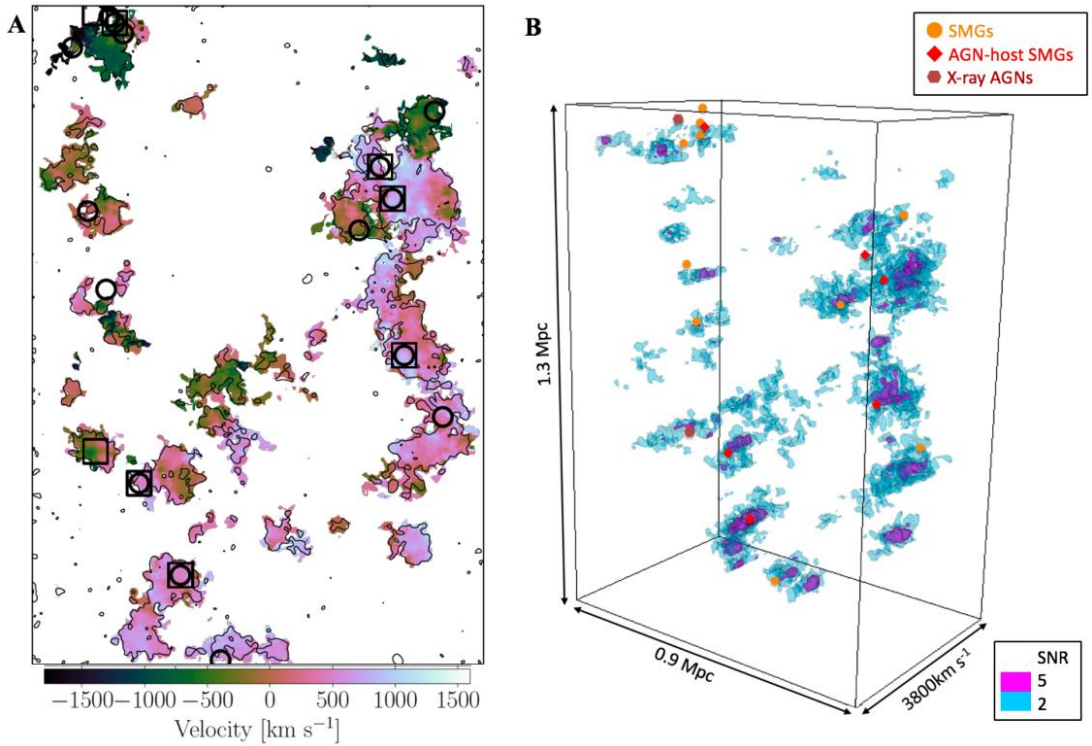
Lyman-α Halo



Momose +14



"General" IGM picture: NOT peculiar area



- Umehata+19
  - Lyα emission from IGM filaments extended to ~1pMpc
  - MUSE + ALMA + Subaru (SC)
  - Proto-cluster region

Very biased region in the universe

This study

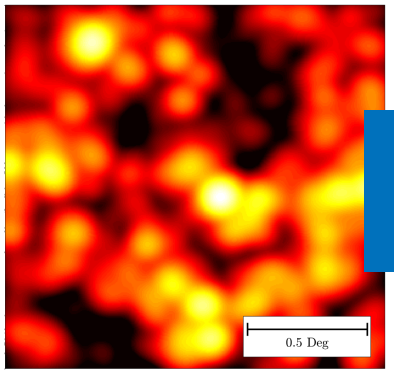
IGM picture at "normal" region around star forming galaxies (LAEs)

Method: Cross-correlation intensity mapping

z known

Source position

Cross Correlation



not resolved

Intensity Map

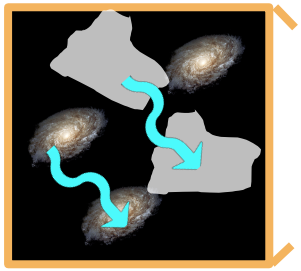
Breysse+16

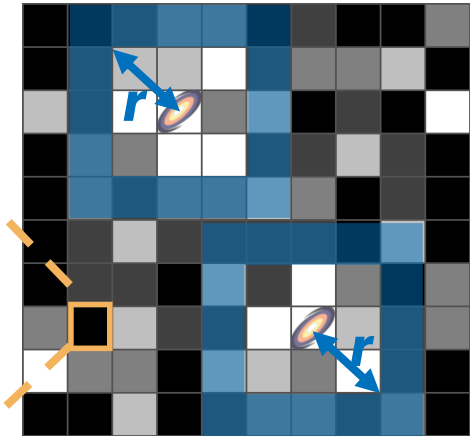
$\xi_{IM}(r)$ [erg/s/cm^2/arcsec^2]

⇨ **Intensity weighted cross-correlation function**

In this study

LAEs × **NB Image** (2D Intensity Map)



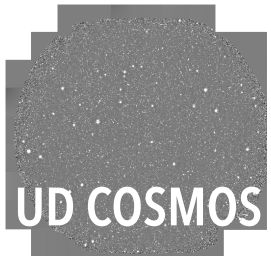


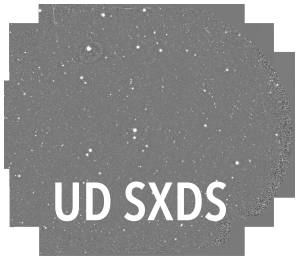
- Noise & Contamination → 0
- Diffuse Lyα emission → S/N up !

Data: NB image & LAE catalog from HSC

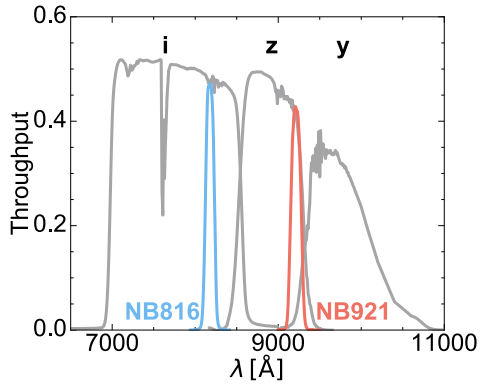
HSC-SSP

2 UD fields





2 NB filters



LAE: SHILVERRUSH catalog

Field	Area (deg^2)	m_{lim} (mag)	N_{LAE}	$\log\left(L_{\mathrm{Ly}\alpha}/[\mathrm{erg\,s^{-1}}]\right)$
(1)	(2)	(3)	(4)	(5)
NB816 ($z \sim 5.7$)				
UD-COSMOS	1.97	25.7	201	-
UD-SXDS	1.93	25.5	224	-
Total	3.9	-	425	42.0 - 43.8
NB921 ($z \sim 6.6$)				
UD-COSMOS	2.05	25.6	338	-
UD-SXDS	2.02	25.5	58	-
Total	4.07	-	396	42.3 - 44.0

Source position — **Cross Correlation** — **Intensity Map**

z = 5.7 LAEs × *NB816* Image (z=5.7 Lyα map)

z = 6.6 LAEs × *NB921* Image (z=6.6 Lyα map)

c.f. Ouchi+18, Shibuya+18

Analysis: Difficulty in observation

① Noise from low-z contaminants

- Emission from low-z objects
  - Cross-correlation → cancel out.
    But, SN goes very bad

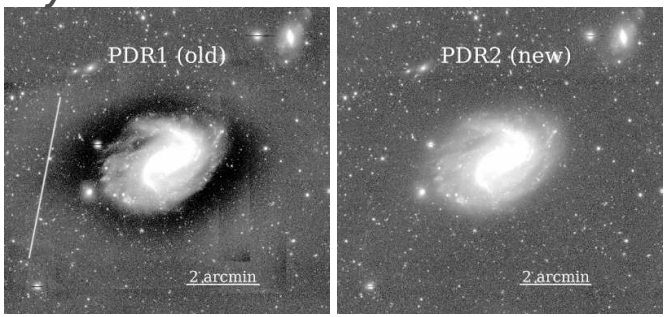
➡ Mask

② Complex systematics

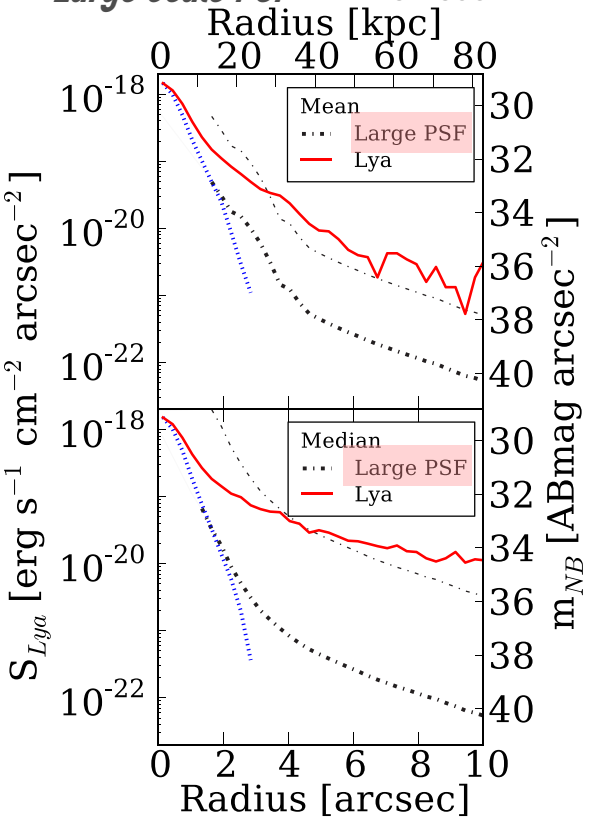
- Sky subtraction
- Point Spread Function (PSF)
  - Large scale: extends more than Gaussian ??

➡ Cross-correlation with "Non-LAE"

Sky subtraction Tanaka+19



Large scale PSF Momose+14



Analysis: Evaluate all systematics

$$\xi_{\mathrm{IM}}(r) = \left(\frac{1}{N}\sum_i \mu_{r;i}\right)_{\mathrm{LAE}} - \underbrace{\left(\frac{1}{N}\sum_i \mu_{r;i}\right)_{\mathrm{Non\text{-}LAE}}}_{\text{All systematics}}$$

μ : intensity
r : Separation between source and pixel
i : pixel label

Non-LAEs

- Not same redshift as LAEs (z = 5.7 or 6.6)
  - Not include Lyα emission
- Same magnitude distribution
- Similar shape

} g-dropouts (z~4) from GOLDRUSH (Ono+18)

Source position: Non-LAE (z ~ 4)

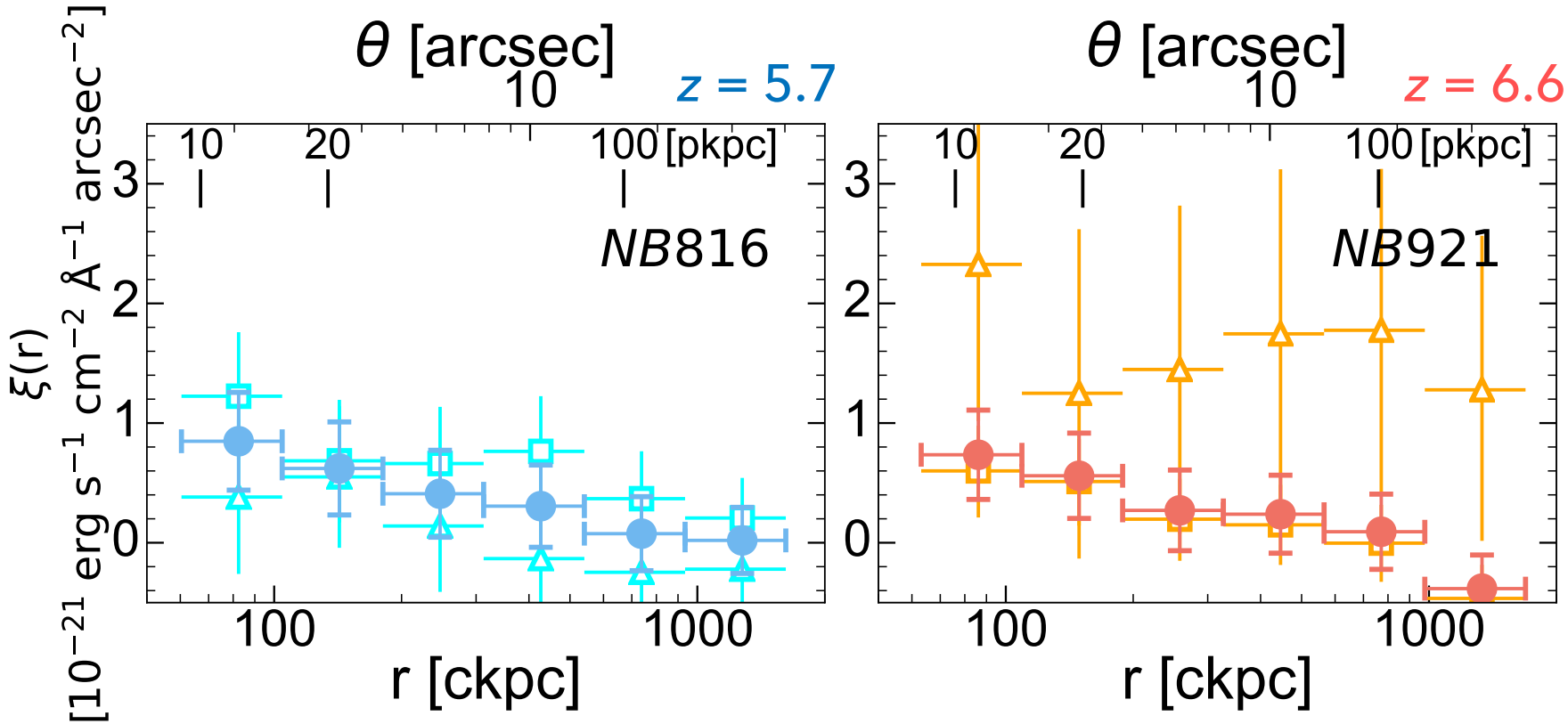
Cross Correlation: ×

Intensity Map: NB Images (*NB816, NB921*)

All systematics

- PSF
- Sky subtraction
- Unknown systematics

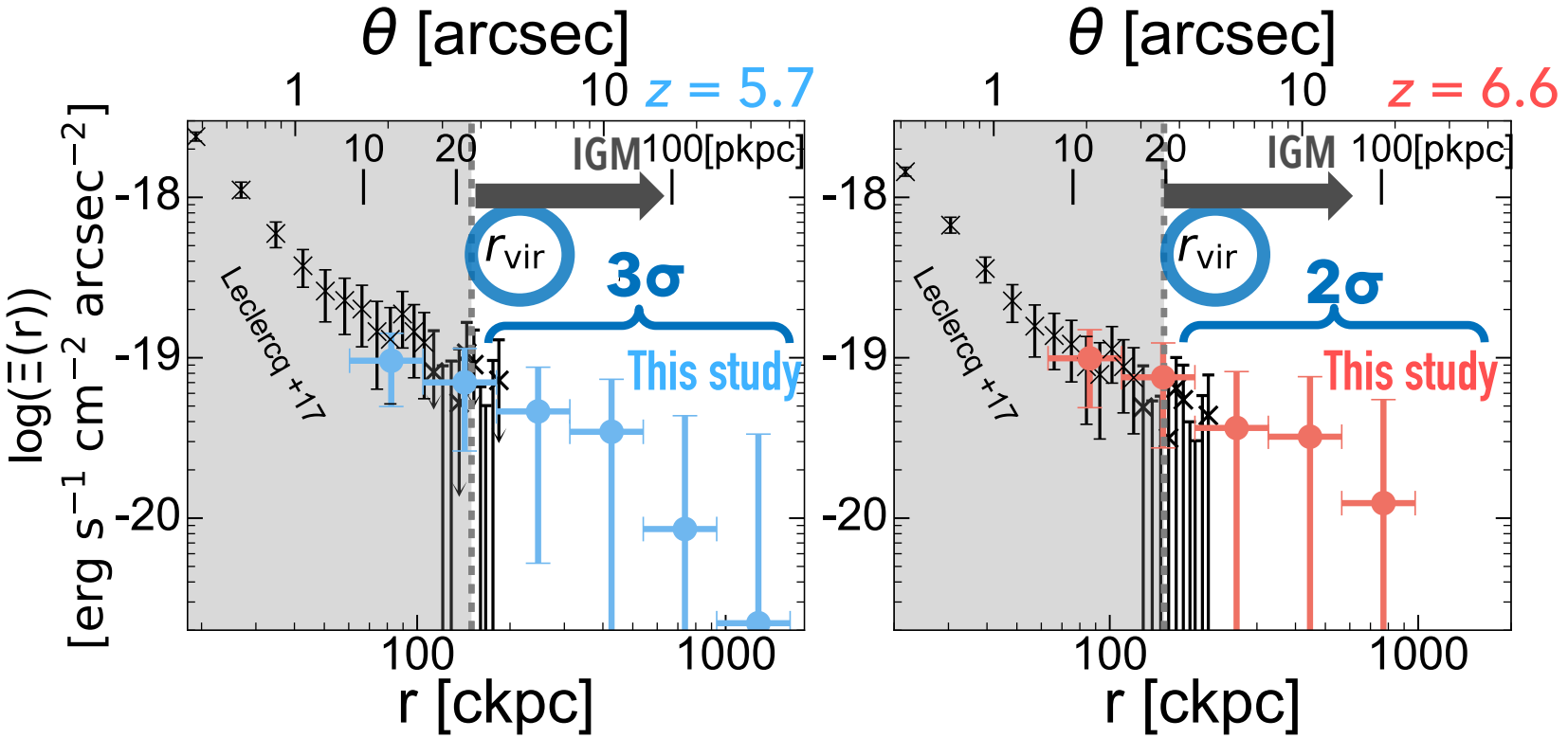
Result: Lyα cross-correlation



△ : SXDS, □: COSMOS

● : Weighted mean values of SXDS and COSMOS by the inverse values of the 1σ errors.

Comparison with the MUSE LAH result

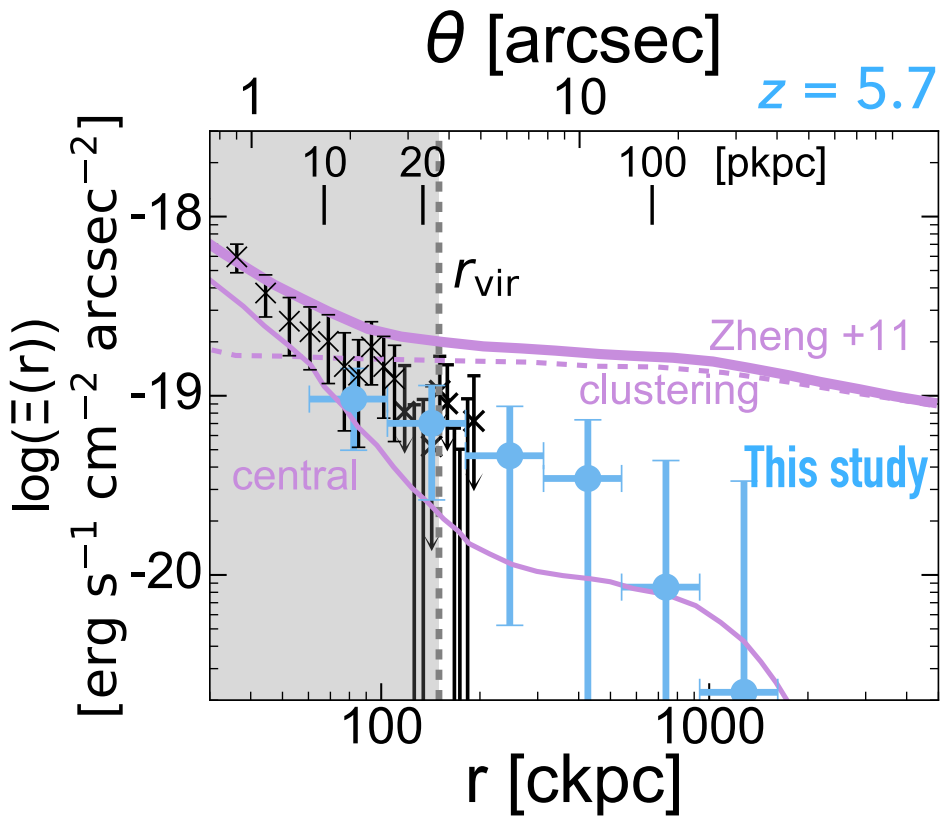


- Leclercq+17 #547
  - $z = 5.98, \log(L_{Ly\alpha}/[\mathrm{erg\ s^{-1}}]) = 42.77$
- r_{vir} : the DMH virial radius of the LAEs ($M_h \sim 10^{11} M_\odot$)

$$\Xi(r) = \xi_{\mathrm{IM}}(r) \times \mathrm{FWHM_{NB}}$$

Extending Lyα emission beyond the r_{vir} ~3 (2) σ at z = 5.7 (6.6)

Comparison with a simulation result



Zheng +11

- Radiation-hydrodynamic reionization simulation
- z = 5.7
- Lyα radial profiles of stacked LAE images
- Two main components
  - **Central**
    Star-forming regions of the LAE & scattering
  - **Clustering**
    → clustered sources around the LAE

✕ Only "Clustering"
(shape is very different)

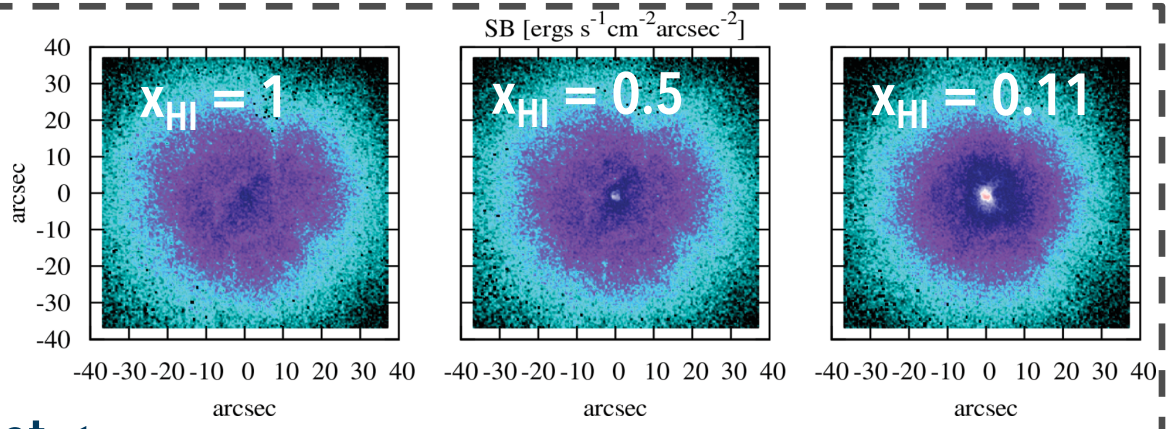
△ Only "Central"
(amplitude is not enough)

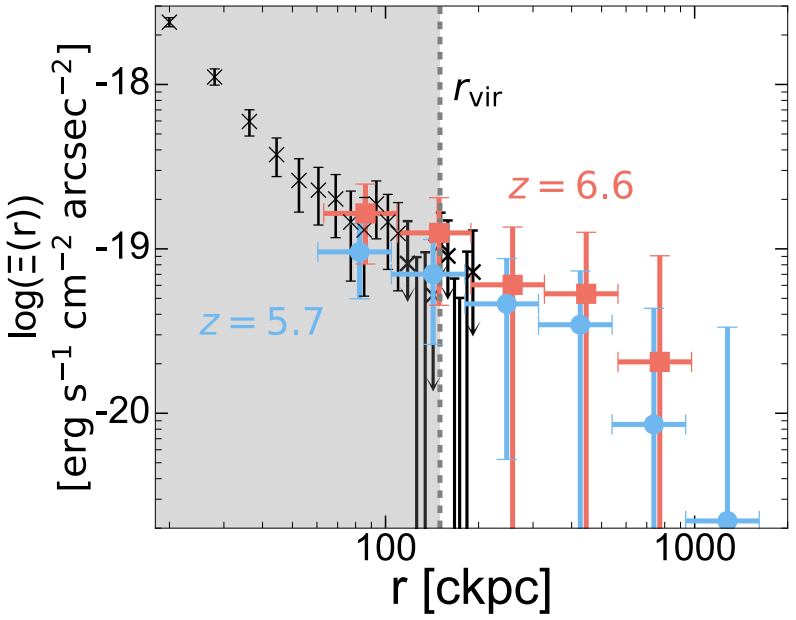
Main: "Central"
+
Other physical processes (?)

Cosmic Reionization

Jeeson-Daniel +12

Low x_{ion}
→ Scattering
→ Lya profile: flat





No significant difference

- Low SN (?)
- Need larger sample
  - New LAE sample with ML

Summary

Goal

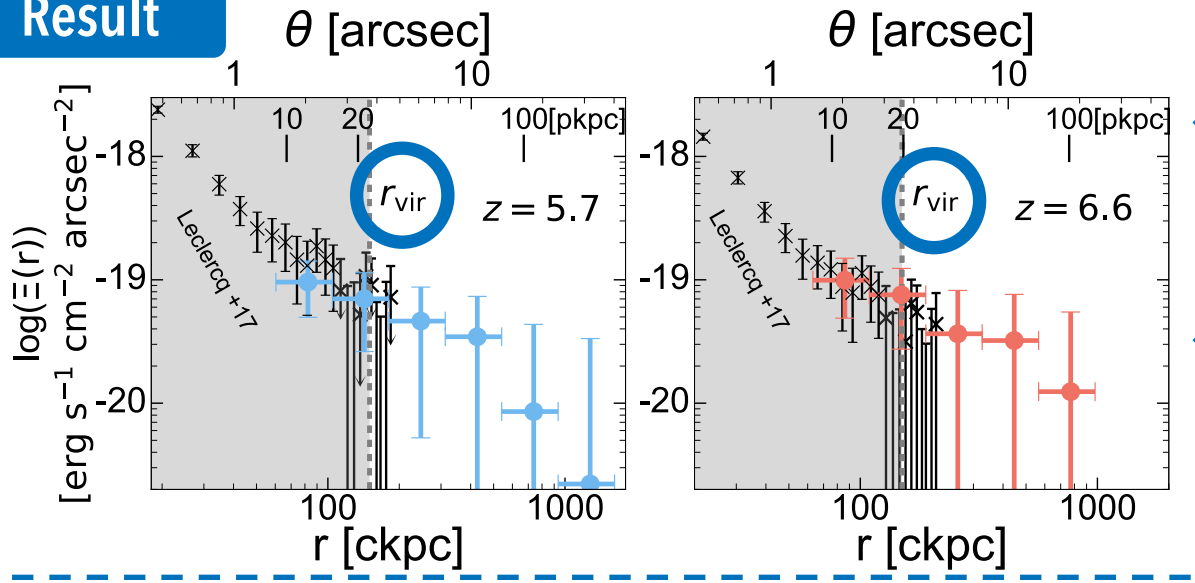
- Observe IGM around "Normal" Star-forming galaxies

Method

- Cross-correlation intensity mapping w/ LAE
- Using Subaru HSC-SSP deep & wide NB images

Source position: z = 5.7 (6.6) LAEs × Cross Correlation Intensity Map: *NB816* (*NB921*) Image

Result



- Lyα emission extends beyond r_{vir}
- Main: Scattering from central LAE + Other mechanism