

# Cross-Correlation Ly $\alpha$ Intensity Mapping with $z=5.7$ and $6.6$ LAEs: Investigating Diffuse Ly $\alpha$ Emission in the Extremely Large Scale at $\sim 30-1000$ kpc

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1 Introduction

2 Methods

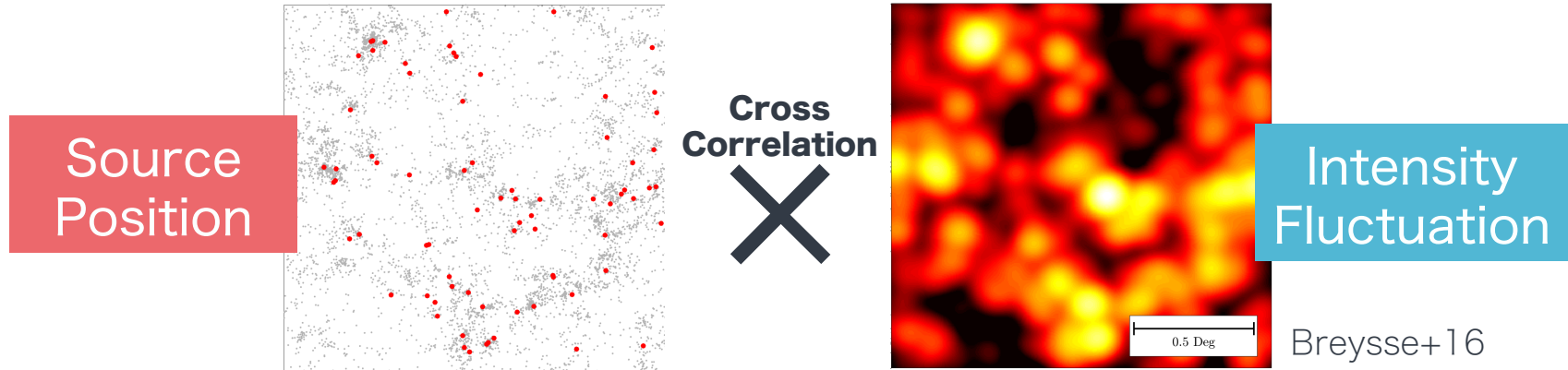
3 Results

4 Discussion

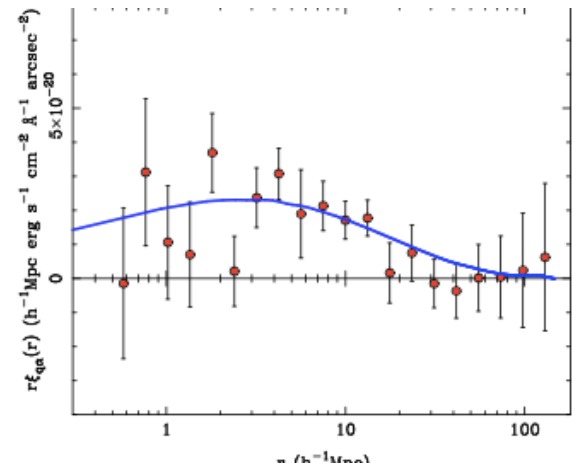
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& Summary

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# Cross-Correlation Line Intensity Mapping



- Correlating with galaxies whose redshifts are known, we can remove the background and foreground contaminations.
- e.g. Croft +16
  - QSOs  $\times$  Ly $\alpha$  cross correlation
  - Detect large scale signal



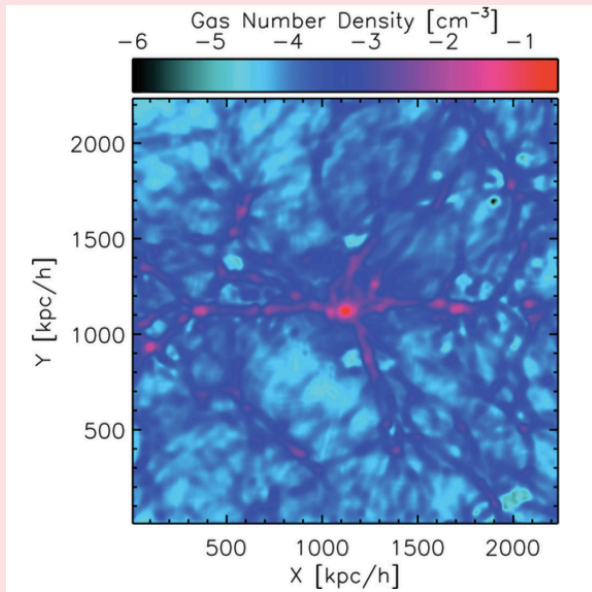
# What we can derive ?

## LAEs × Ly $\alpha$ Cross Correlation

□ Large scale

$\lesssim \sim 100\text{kpc}$

→ **IGM**



Jeerson-Daniel +12

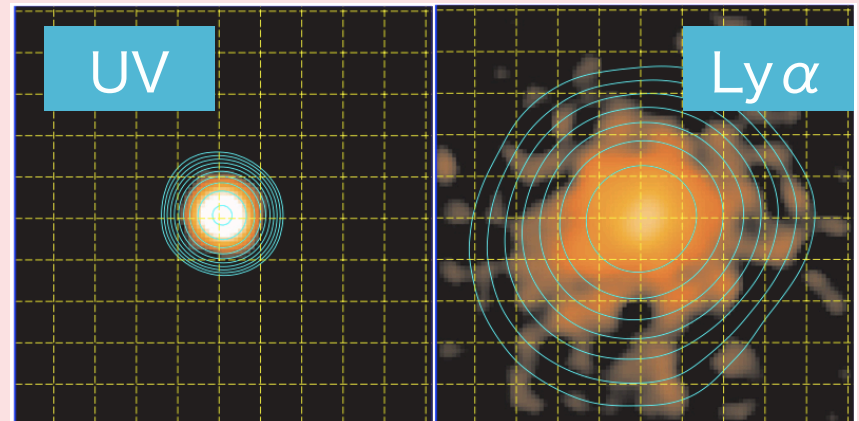
□ Intermediate scale

$\sim 10$  to  $\sim 100\text{kpc}$

→ **CGM**

ex. )

Lyman Alpha Halo(LAH)



Steidel+11

# Subaru Hyper Suprime-Cam Survey

Area : 4 deg<sup>2</sup>



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UD COSMOS  
~2deg<sup>2</sup>

UD SXDS  
~2deg<sup>2</sup>

Source position

**z = 5.7 LAEs**  
(N = 425)

×

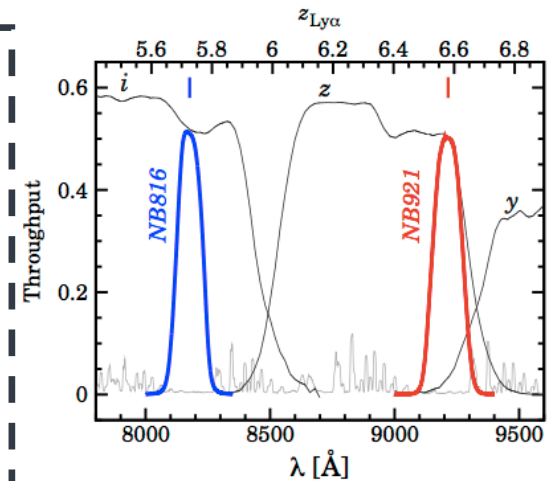
Intensity

**NB816**  
Image

**z = 6.6 LAEs**  
(N = 396)

×

**NB921**  
Image



# Cross-Correlation

These data are not open for public. Sorry.



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Image

Mask

- ◆ Bad pixel
- ◆ Cosmic ray
- ◆ S/N > 5 e.t.c...

# Cross-Correlation

These data are not open for public. Sorry.



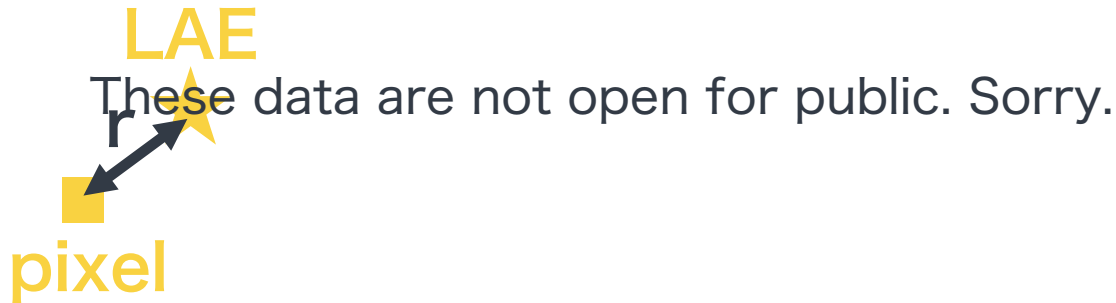
**Kakuma et al. in prep**

**Masked Image**

**Mask**

- ◆ Bad pixel
- ◆ Cosmic ray
- ◆ S/N > 5 e.t.c...

# Cross-Correlation



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Masked Image

Uncertainty :  $\sigma$   
(Systematics + Statistics)

$f$

$w = 1/\sigma^2$

$$\xi_{IM} = \left[ \frac{1}{\sum_{r,i} w_{r,i}} w_{r,i} f_{r,i} \right]_{LAE} - \left[ \frac{1}{\sum_{r,i} w_{r,i}} w_{r,i} f_{r,i} \right]_{random}$$

Correlation between random point and image



# IM Results

Errors are estimated  
by jack-knife method

$$z = 5.7$$

$$z = 6.6$$

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Detecting signals to  $\sim 1000$  kpc ??

Any systematics mimicking the signals ?

# Tests for All systematic errors

Source position

Non-LAEs

Cross  
Correlation



Intensity

NB Images  
(NB816, NB921)

Same mag  
distribution

- PSF (atmosphere, instrument)
- sky subtraction systematics
- unknown systematics

× 100 times

LAEs

$z = 5.7$



LAEs

$z = 6.6$



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Non-LAEs

Non-LAEs

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# Correlation with BB image

Source position	Cross Correlation	Intensity
$z = 5.7$ LAEs	✘	Z Image
$z = 6.6$ LAEs	✘	Y Image

**NB**       $z = 5.7$

**BB**

**NB**       $z = 6.6$

**BB**

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✓ We detected Lyman  $\alpha$  line sources

# Source profile

Subtracting Non-LAE × image  
(PSF + systematics)

300kpc  
**z = 5.7**

300kpc  
**z = 6.6**

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Extending to  
~ 300pkpc!

Two exponential components

$$\xi(r) = C_1 \exp\left(-\frac{r}{r_1}\right) + C_2 \exp\left(-\frac{r}{r_2}\right)$$

# Comparison with previous studies



**First detection ??**

Leclercq+17 (MUSE)

This plot is not open for public. Sorry.

Momose+14

**This Study**  
**3<sup>rd</sup>**

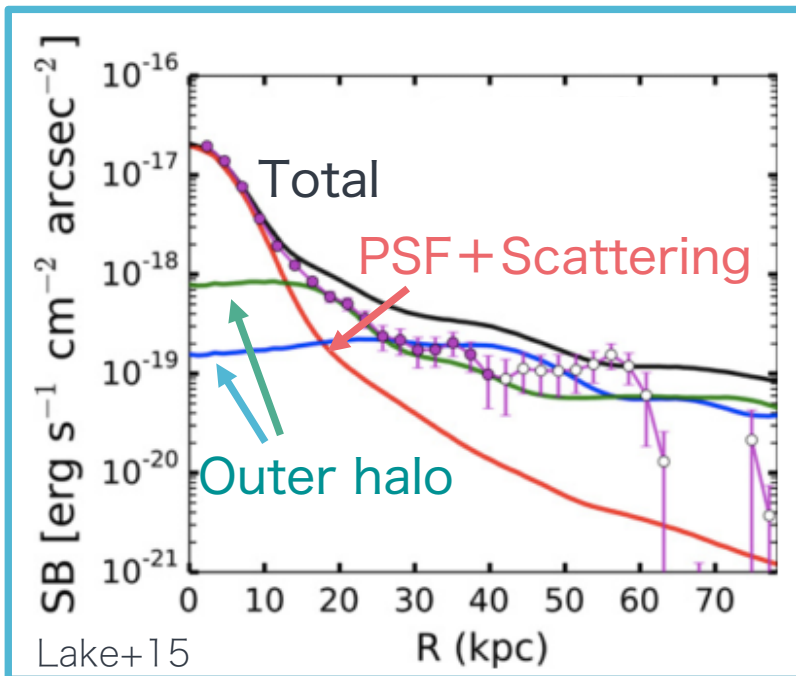
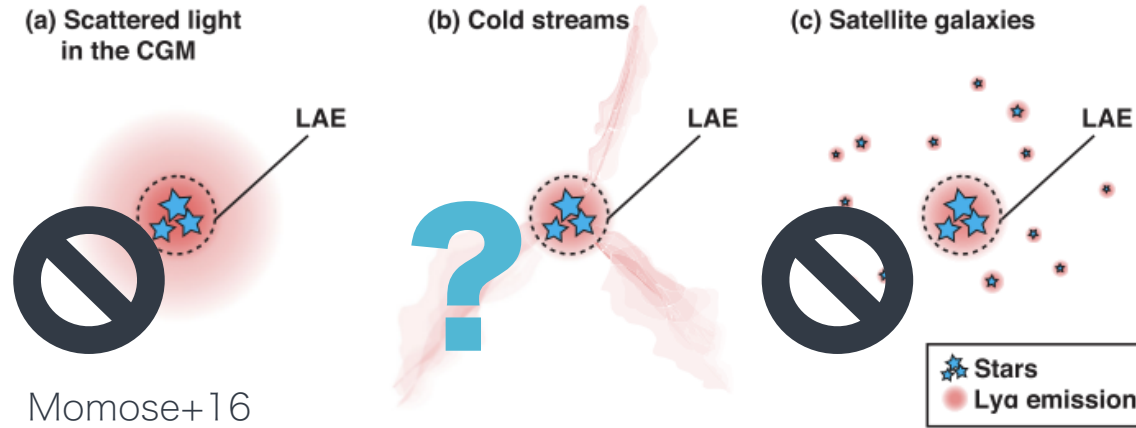
**component**  
**r ~ 140 pkpc**  
**"NEW source"**

1<sup>st</sup>  
component  
r ~ 0.4 pkpc  
"Disk like"

2<sup>nd</sup>  
component  
r ~ 6 pkpc  
"LAH"

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# The origin of the source



- ✓ Contribution from outer halo
  - cooling radiation
  - star formation
- ✓ UV signals doesn't extend.
  - We can detect the signals from cold gas streams ??

# Conclusion & Summary

- ❑ Tentative detection of **the Ly $\alpha$  sources around galaxies extending to  $\sim 300$  pkpc at  $z=5.7$  and  $6.6$  based on the Cross-Correlation Ly $\alpha$  Intensity Mapping**
  - The origin of this source may be gravitational cooling radiation.
  - We are conducting an other series of serious tests. (Stay tuned)