

CHORUS :

Candidates of Lyman continuum galaxies at $z=3.3$ and 4.9
selected from CHORUS narrow-band data

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HSC project 194

Contents

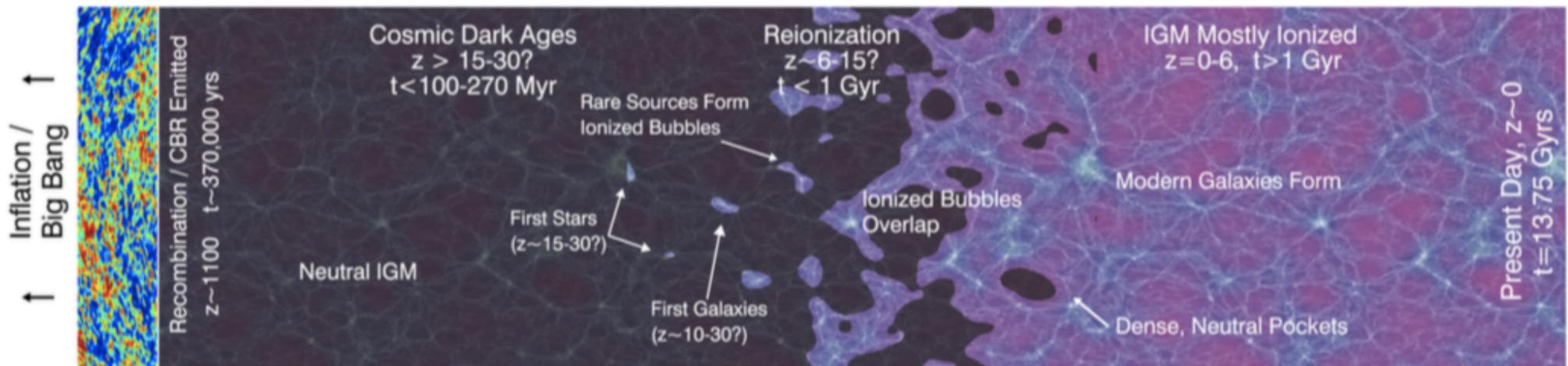
- Introduction
 - Cosmic Reionization
 - Escape fraction of Ionizing photons
 - Direct observation of escape LyC photons
- Data and Sample
 - CHORUS
 - Sample selection
- Results
- Discussion
- Summary

Introduction

Cosmic Reionization

- Phase transition from the neutral state to the ionized state in the IGM
- Reionization process is completed by $z \sim 6$
- Ionizing radiation from star-forming galaxies and/or active galactic nuclei is supposed to be responsible for the sources of cosmic reionization

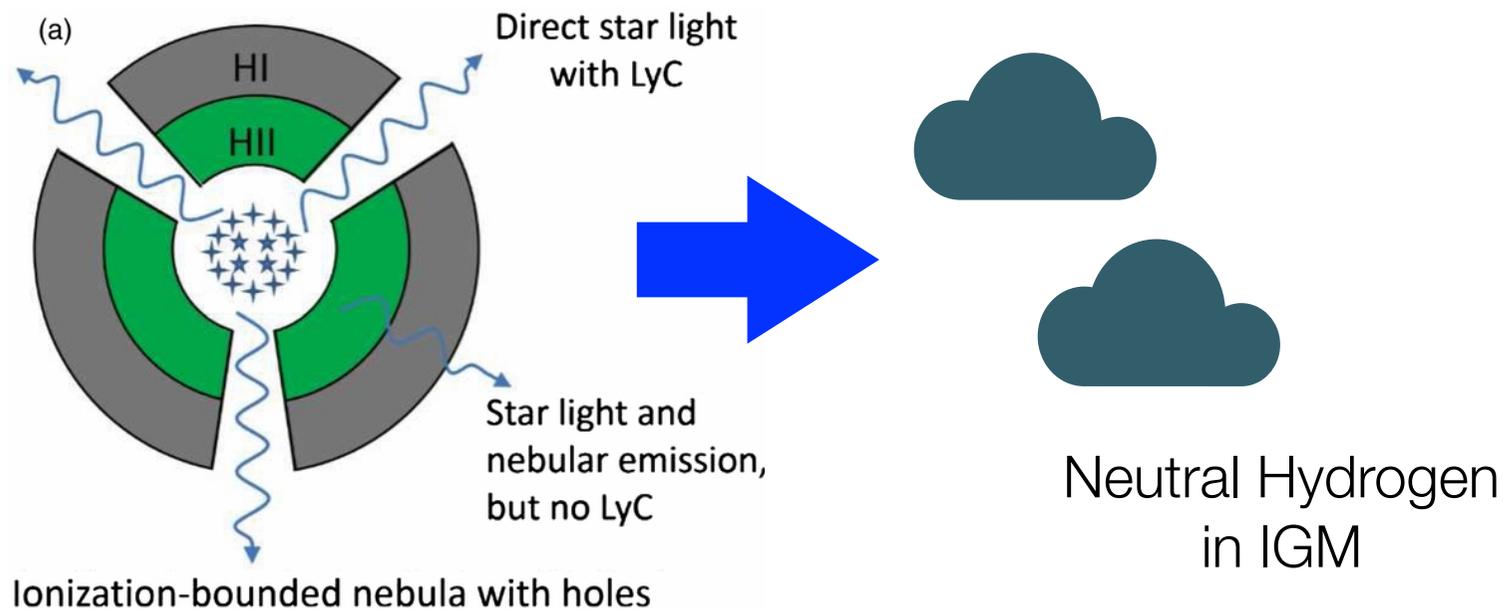
Robertson+10



Introduction

Escape fraction of ionizing photons

- The fraction of ionizing photons (Lyman continuum; LyC, $\lambda_{\text{rest}} < 912\text{\AA}$) which escape from galaxies into the surrounding IGM
- One of the key parameters to understand the sources of cosmic reionization

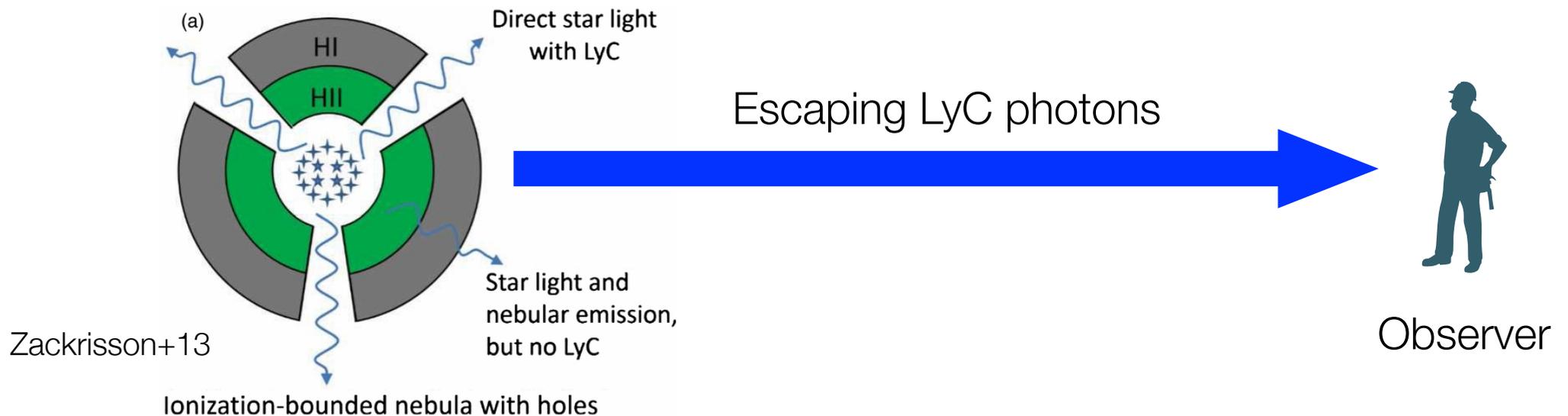


Introduction

Escape fraction of ionizing photons

- The escape fraction of LyC, $f_{\text{esc,LyC}}$, is estimated by the following formula, (Steidel+10)

$$f_{\text{esc,LyC}} = \frac{(f_{\text{LyC}}/f_{\text{UV}})_{\text{obs}}}{(f_{\text{LyC}}/f_{\text{UV}})_{\text{int}}} \exp(\tau_{\text{IGM},900}) 10^{-0.4A_{\text{UV}}}$$

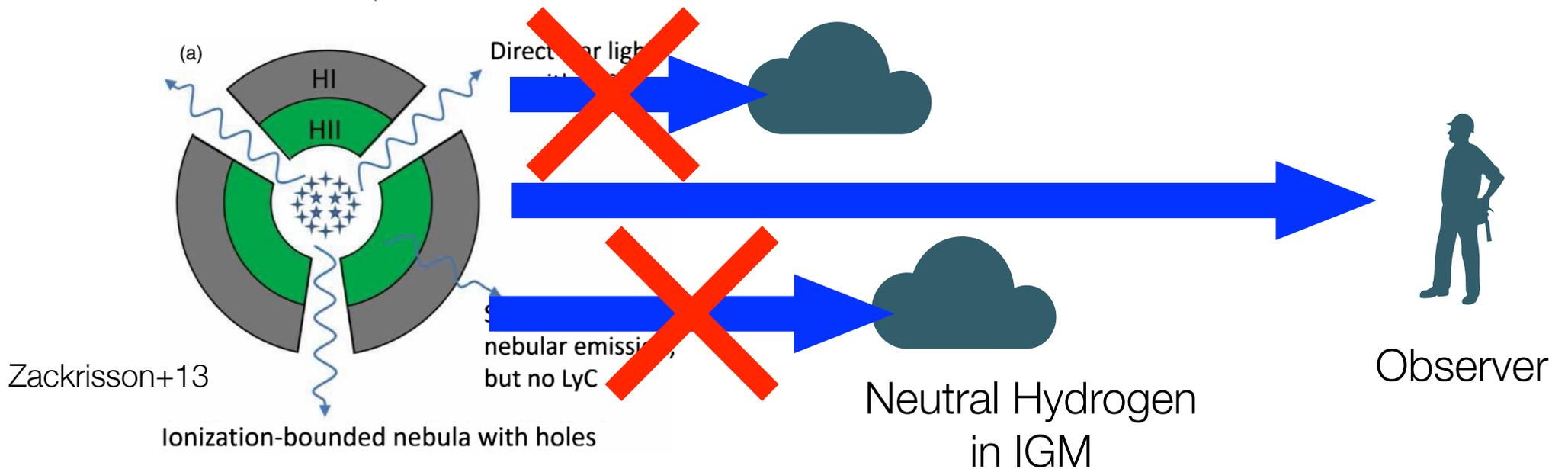


Introduction

Escape fraction of ionizing photons

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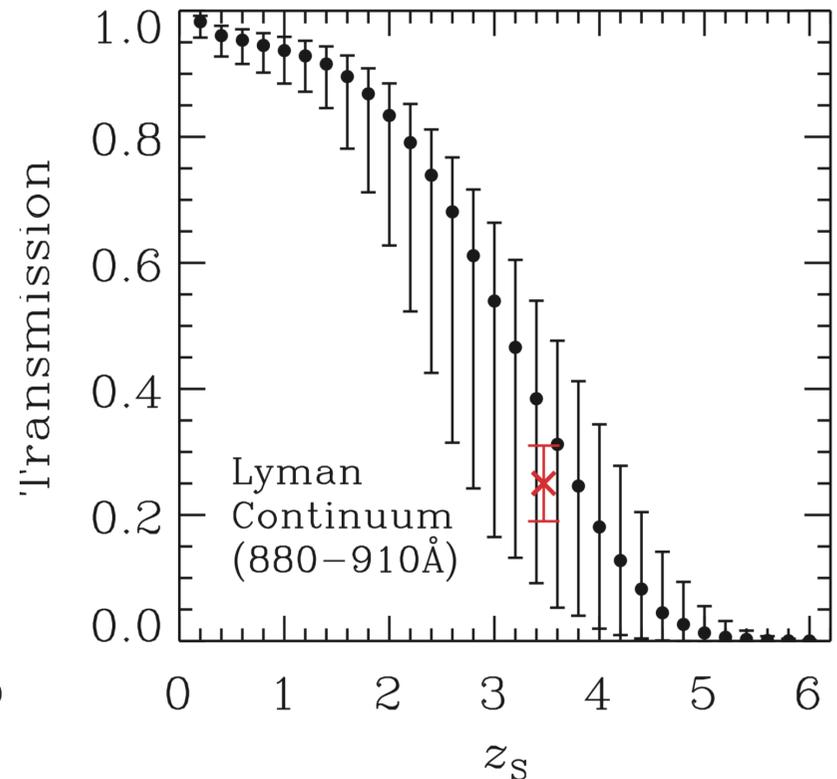
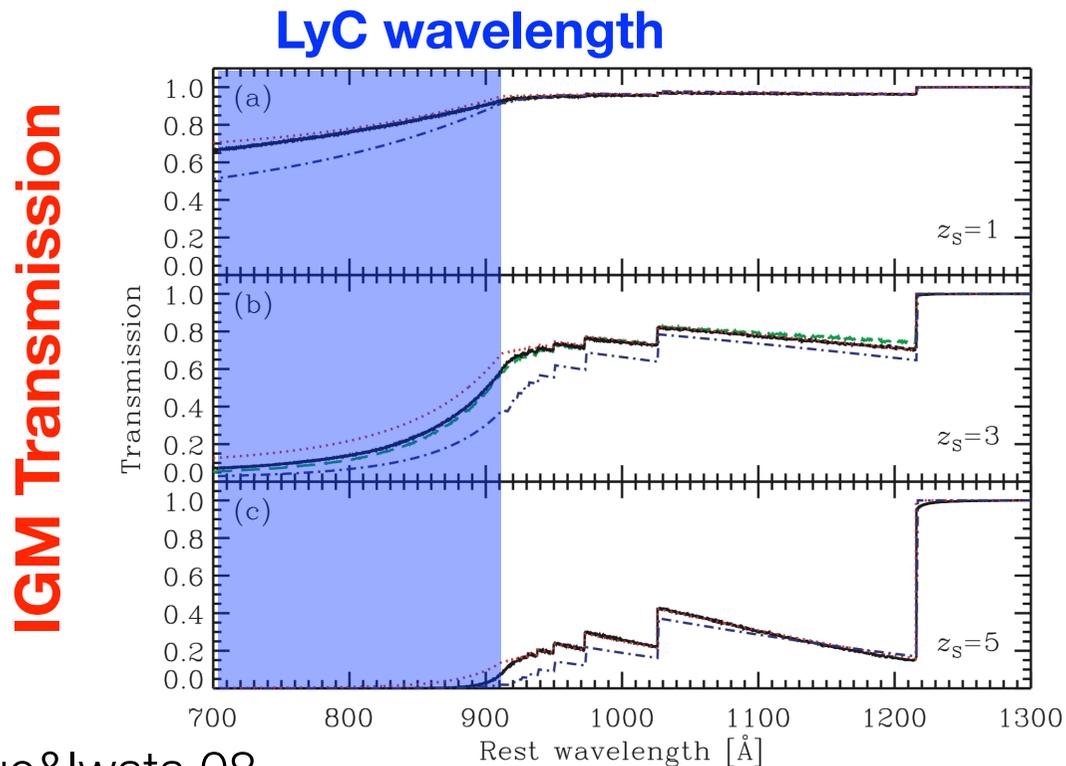
$$f_{\text{esc,LyC}} = \frac{(f_{\text{LyC}}/f_{\text{UV}})_{\text{obs}}}{(f_{\text{LyC}}/f_{\text{UV}})_{\text{int}}} \exp(\tau_{\text{IGM},900}) 10^{-0.4A_{\text{UV}}}$$



Introduction

Escape fraction of ionizing photons

- Due to the foreground IGM absorption by HI clouds, it is hard to directly measure the escape LyC photons from high- z galaxies (and almost impossible from galaxies at $z > 5$)

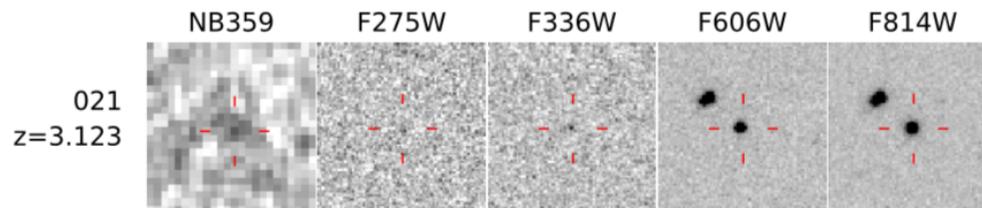
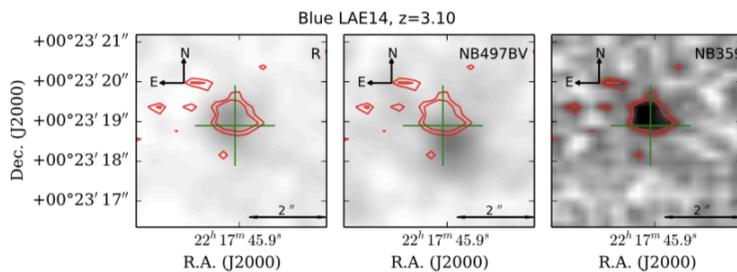


Introduction

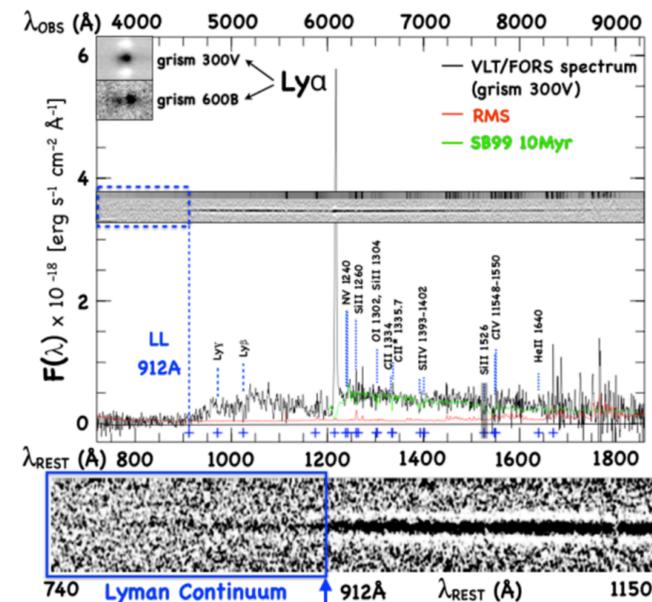
Direct observation of escaping LyC photons

- Various works reports the direct detection of LyC photons from high-z galaxies
(e.g., Iwata+09,19; Izotov+16; Micheva+17; Steidel+01, 18; Vanzella+16,18)
- The ultimate goal is to understand the escape fraction of LyC photons for high-z galaxies

Micheva+17
LAE@z=3.1



Iwata+19 SFG@z=3.1



Vanzella+18
Ion3, z=3.99

Introduction

Objective of LyC search

- There are some reports of the direct LyC detection from high- z galaxies
- The recent study finds the candidate of a LyC leaking galaxy (hereafter we call LyC Emitter, LCE) at $z \sim 4$



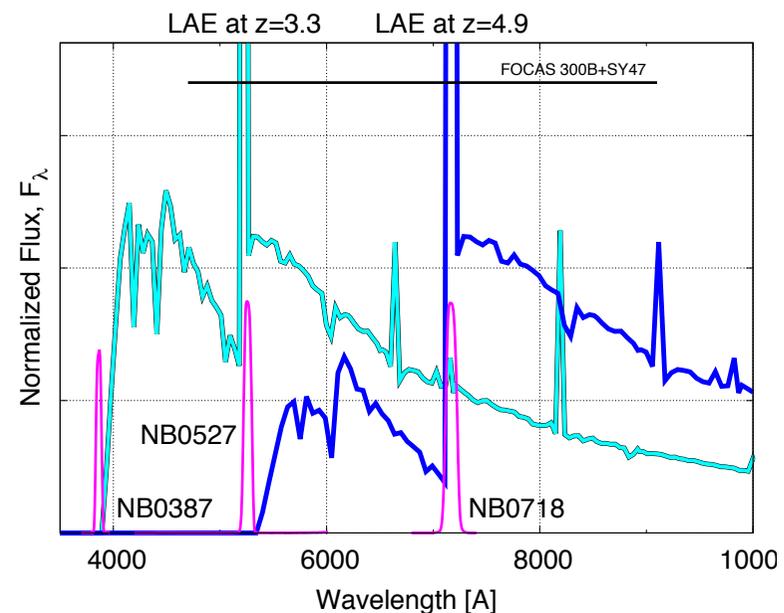
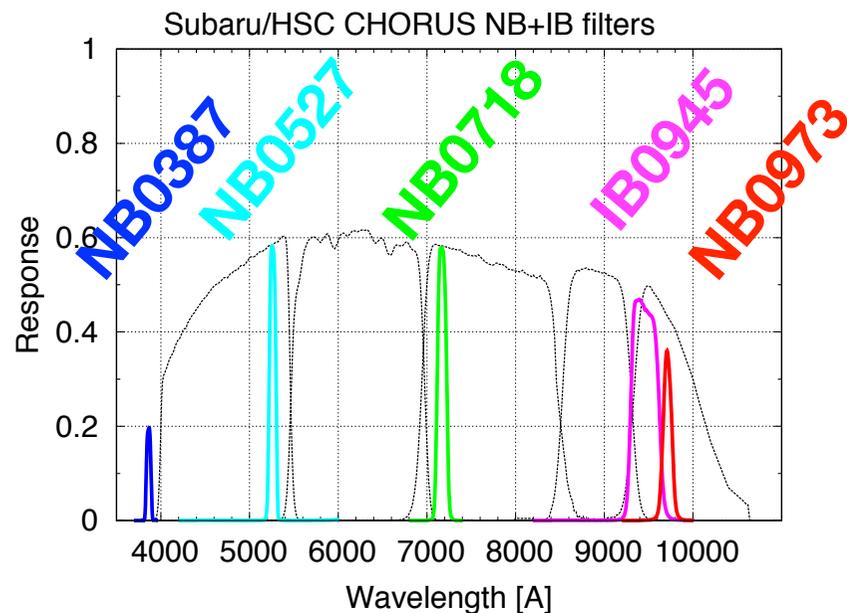
In order to increase the sample of LCEs at higher redshift, we need to conduct an ultra-wide field survey

Hyper Suprime-Cam (HSC)

Data and Sample

CHORUS project

- **C**osmic **H**ydrogen **R**eionization **U**nveiled with **S**ubaru
(PI: Akio K., Inoue; see also Poster P36)
- A survey with 4 narrow-band (NB) + 1 intermediate-band (IB) filters
- The combination of NB0387, NB0527, and NB0718 NB filters enable us to search for Ly α / LyC emission from $z=3.34$ / $z=4.93$

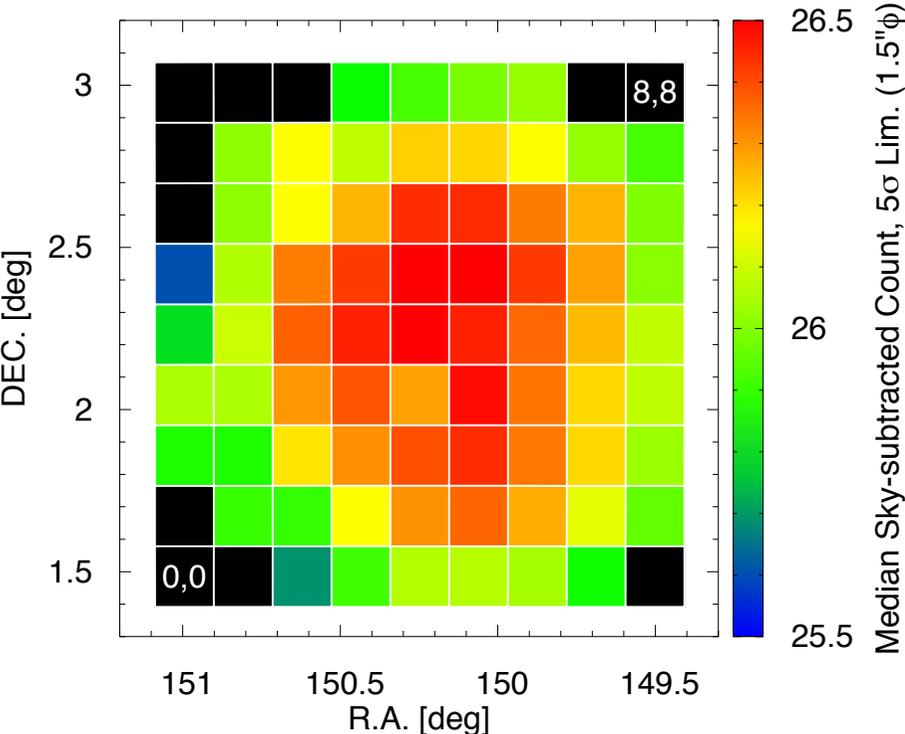


Data and Sample

CHORUS project

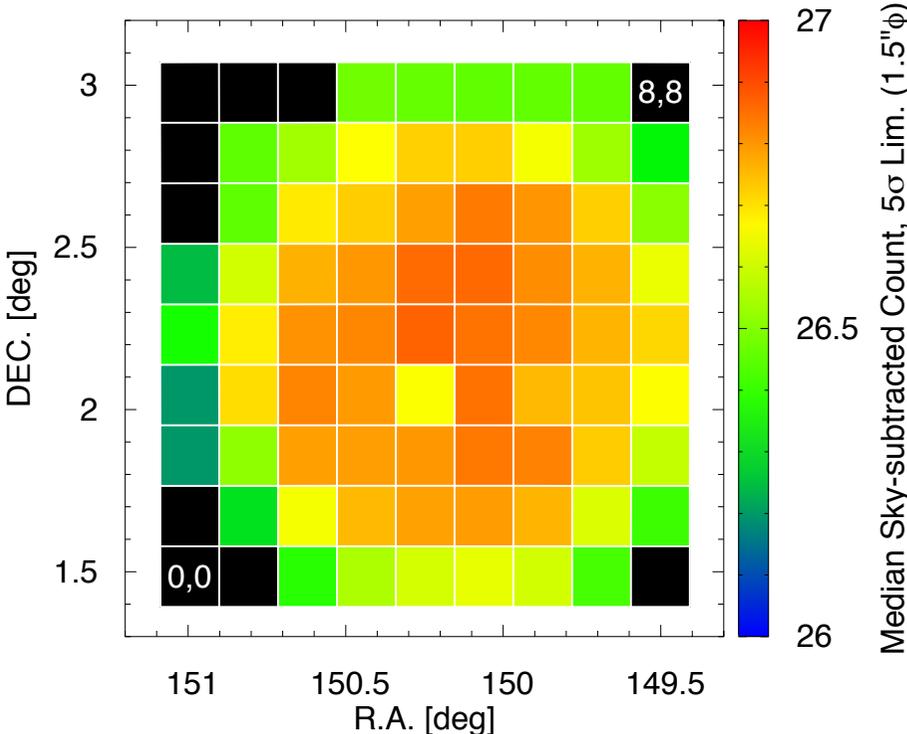
- The target field is COMOS field
- The observation has been completed

NB0387



$$m_{1.5''\phi, 5\sigma} = \underline{26.5} @\text{patch}=404$$

NB0527



$$m_{1.5''\phi, 5\sigma} = \underline{26.9} @\text{patch}=404$$

Data and Sample

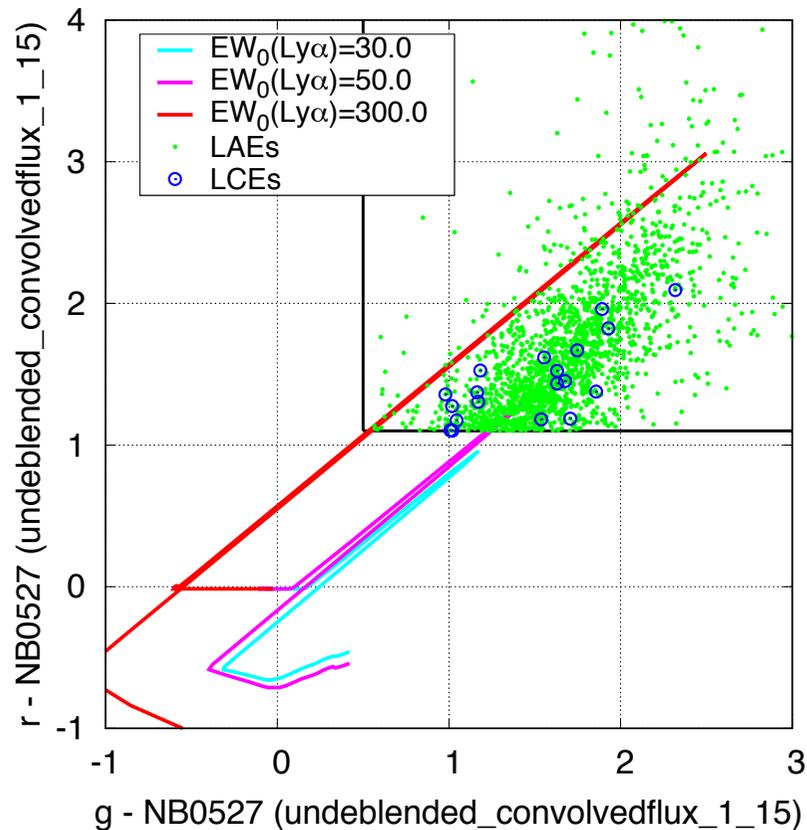
Sample selection

- **Our main purpose is to directly detect the LyC photons from $z=3.34$ and $z=4.93$**
- LyC galaxies may be missed if the sample is selected using the Lyman Break Technique
- Instead of Lyman Break, we simply select **strong NB-excess emitters**, which should be Ly α emitters with large Ly α equivalent width ($EW_0 > 50\text{\AA}$)
- Because there seems to be a significant contribution from Ly α emitters to cosmic reionization, the search for LyC from Ly α emitters is crucially important

We search for NB0527 / NB0718-excess emitters
and check their NB0387 / NB0527 images which correspond to LyC

Data and Sample

NB0527-excess emitters

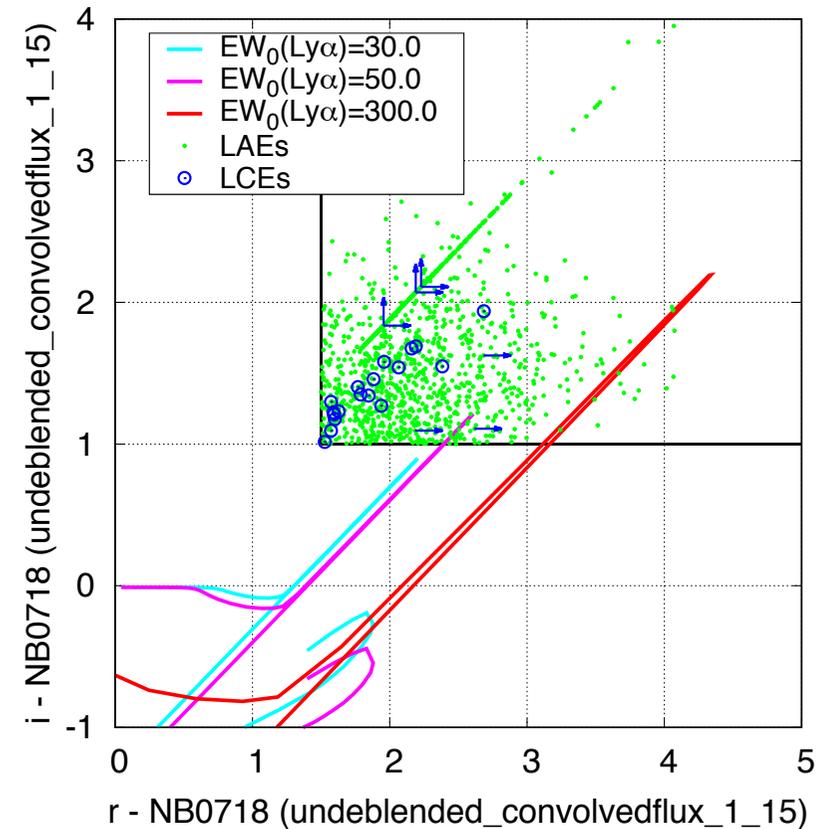


- ✓ Candidates of LAEs ($\#=2019$, Green) and LCEs ($\#=19$, Blue) at $z=3.3$
 - LCEs show the detection in NB0387 at $>3\sigma$ level
- ✓ The red, magenta, and cyan lines represent the model tracks for LAEs with $\text{EW}(\text{Ly}\alpha) = 300, 50, \text{ and } 30\text{\AA}$, respectively
 - The model tracks are calculated by using simplified spectrum + IGM absorption (Inoue+14) from $z=0.0$ to $z=6.0$

Data and Sample

NB0718-excess emitters

- ✓ Candidates of LAEs (#=1024, Green) and LCEs (#=24, Blue) at $z=4.9$
 - LCEs show the detection in NB0527 at $>3\sigma$ level
- ✓ The red, magenta, and cyan lines represent the model tracks for LAEs with $EW(Ly\alpha) = 300, 50,$ and 30\AA , respectively
 - The model track is calculated by using simplified spectrum + IGM absorption (Inoue+14) from $z=0.0$ to $z=6.0$

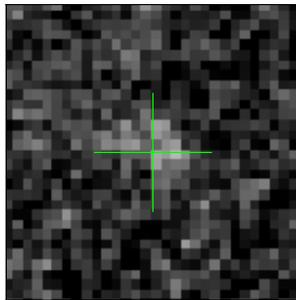


Results

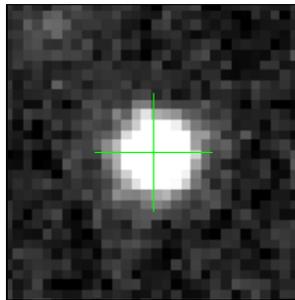
Visually checked probable candidates of LCEs

LCE @ $z=3.3$

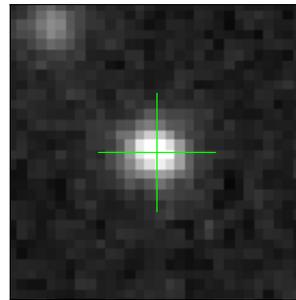
NB0387



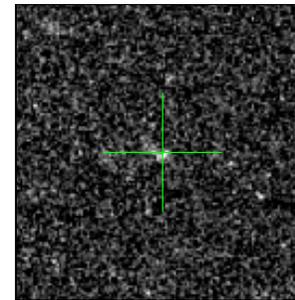
NB0527



HSC-R

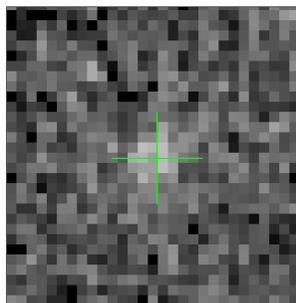


F814W

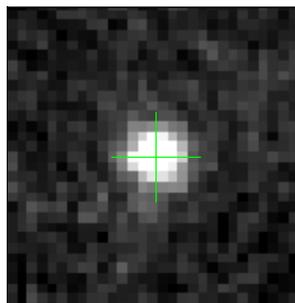


LCE @ $z=4.9$

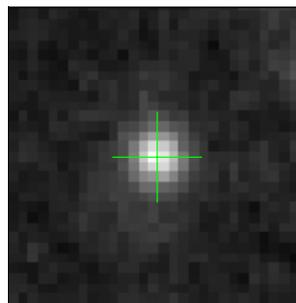
NB0527



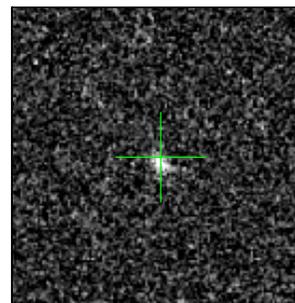
NB0718



HSC-I

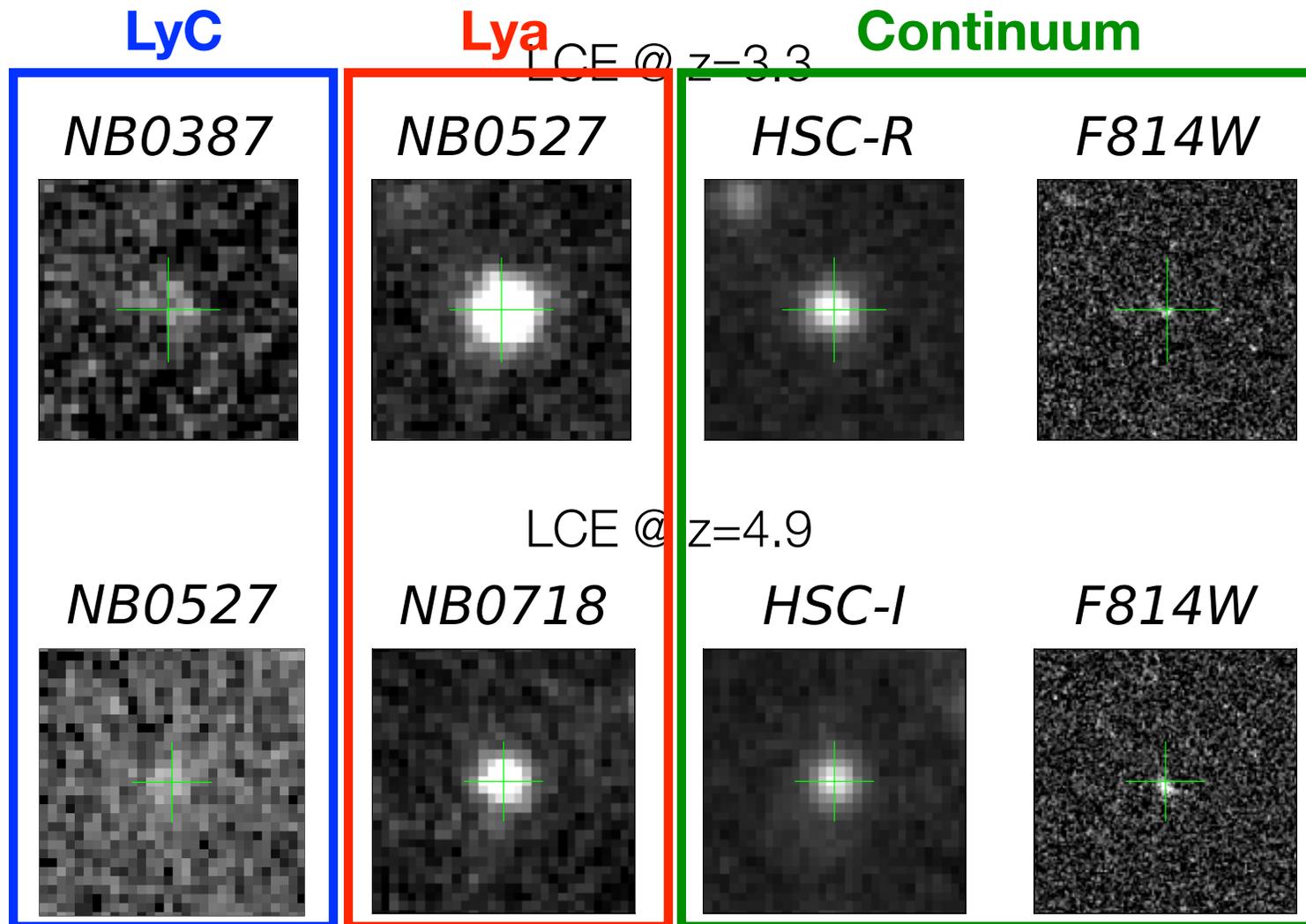


F814W



Results

Visually checked probable candidates of LCEs

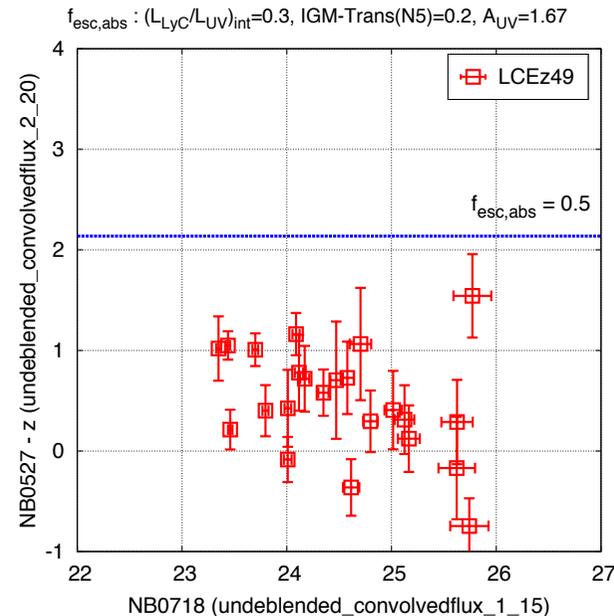
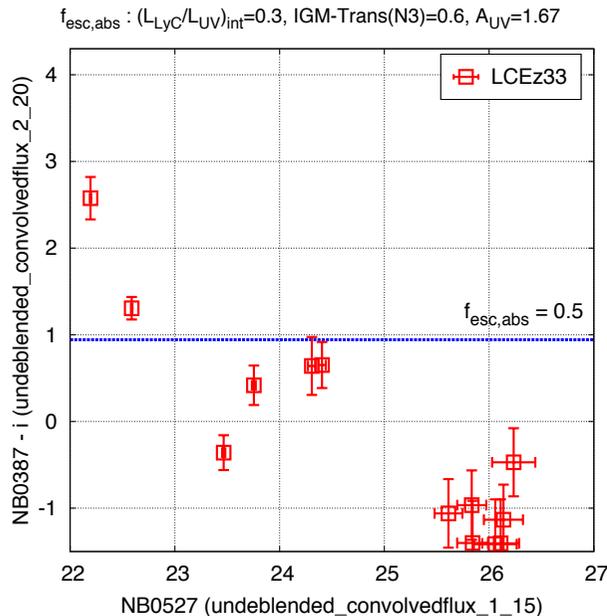


Discussion

Ratio of $L_{\text{LyC}}/L_{\text{UV}}$

- The assumptions for the prediction of $f_{\text{esc}}=0.5$ are
 - (1) the transparent sight-line ($\text{Trans} = 0.6$),
 - (2) the high production rate of LyC photons ($L_{\text{LyC}}/L_{\text{UV}} = 0.3$),
 - (3) the typical dust attenuation of LAEs@ $z=3.1$ ($A_{\text{UV}}=1.67$)
- It is possible that the foreground interlopers contaminate the LyC filters

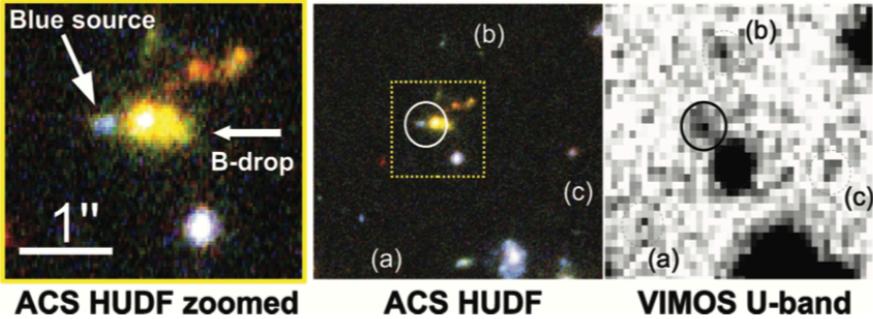
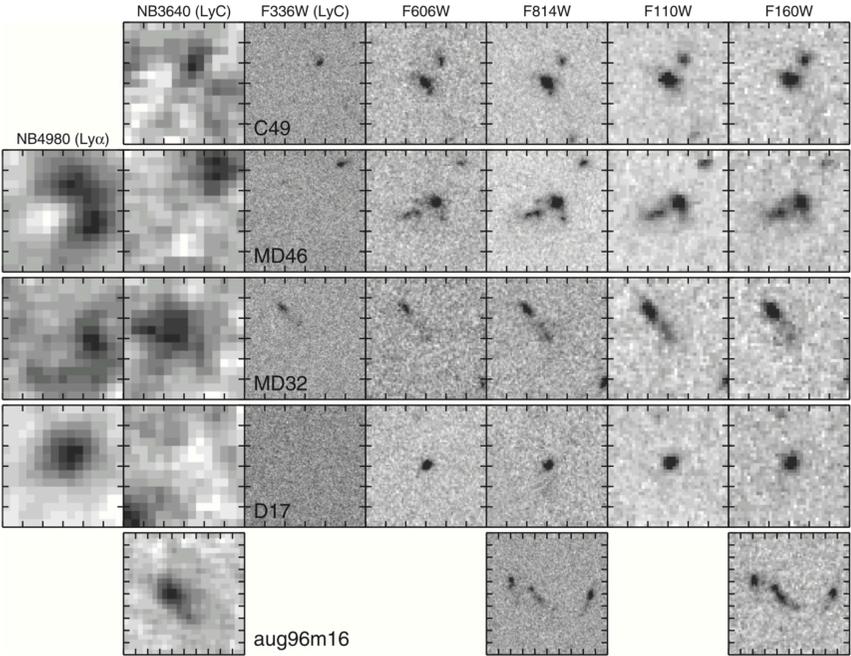

 f_{esc} increase



Discussion

Possibility of contamination

- Although we have checked the HST/F814W images, it is still possible that the foreground interlopers contaminate the NB filter (LyC) images
- We need a follow-up opt/NIR spectroscopy for our candidates and also need the detailed spectral energy distribution fitting analysis



Vanzella+10

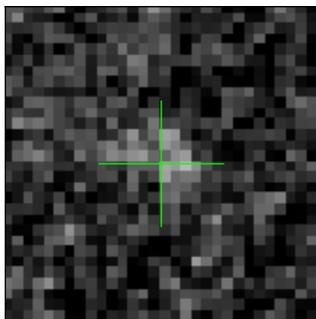
Siana+15

Summary

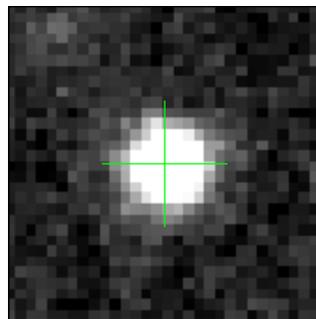
- We have searched for LyC Emitters (LCEs) at $z=3.34$ and $z=4.93$ by using CHORUS narrow-band images
- Our sample consists of NB0527/NB0718-excess emitters which are Ly α Emitters with Ly α equivalent width $> 50\text{\AA}$
- We have found some possible LCE candidates, and we need a follow-up observation
- We plan to conduct the detailed spectral energy distribution fitting analysis for our sample

LCE @ $z=3.3$

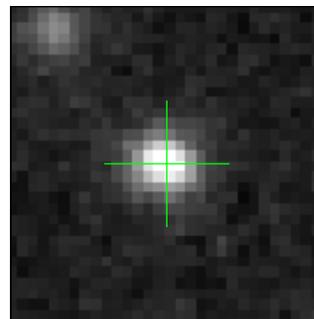
NB0387



NB0527



HSC-R



F814W

