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The LAGER Survey

Studying Reionization with Lyα emitters

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L. Infante

Work mostly by ZhenYa Zheng, Huan Yang and Weida Hu

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OUTLINE

- Cosmic Reionization Phase Transition
- The LAGER survey
- Lyα Galaxy Selection Using NB Filters
- Spectroscopy of LAEs
- Preliminary Results

Cosmic Reionization Phase Transition

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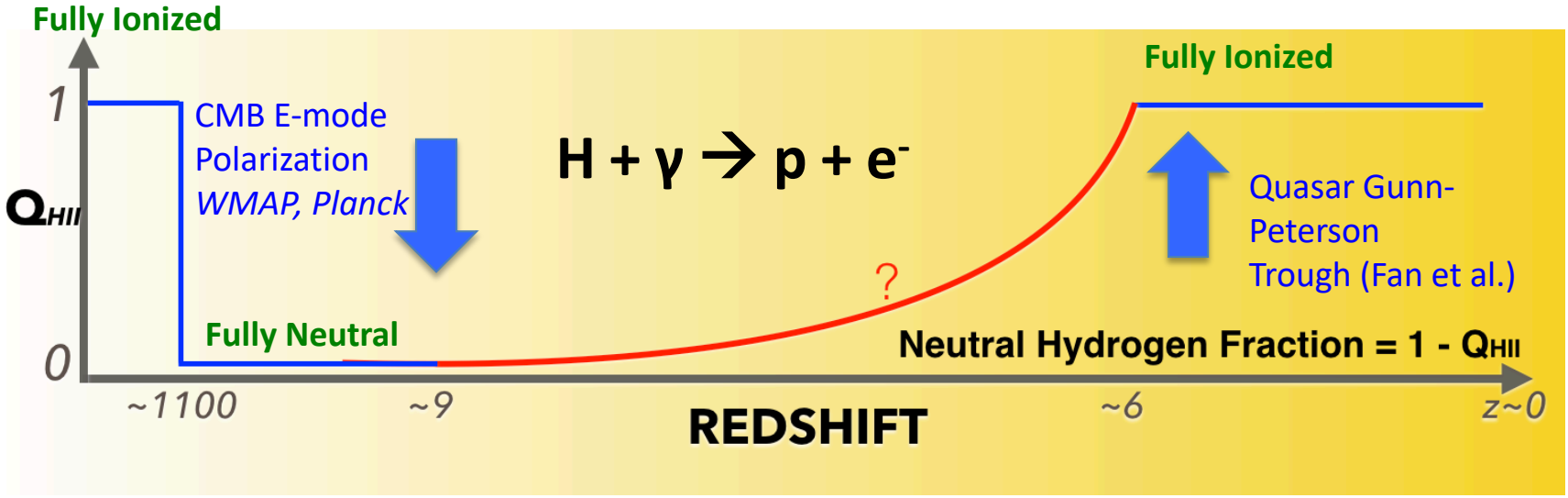
The universe changed from neutral to ionized

- UV radiation generated in this process ionized HI
- 300 and 900 million years after the Big Bang



- Stars, galaxies and black holes were formed
- However, No good physical description of this process

Lyman Alpha Galaxies in the Epoch of Reionization (LAGER)

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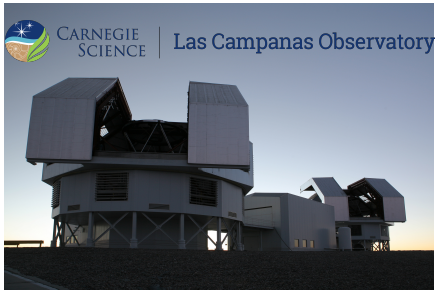
Franz Bauer (PUC), …



Why Lyα emitters?

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- Resonant scattering of Lyα photons is sensitive to neutral hydrogen in the IGM, making Lyα emitters
  - sensitive,
  - practical, and
  - powerful probe of the central phase of reionization.

Why z ~7?

Redshift z = 7 is the frontier in Lyα and reionization studies, and appears to be in the middle of reionization.

"LAGER" project

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- Deep NB Imaging with CTIO 4mt DECam (3 deg^2 FOV)
  - Optimally designed NB filter to identify Lyα lines at z ~ 7.0.
  - Long-term NOAO-Chile program to observe an area of 24 deg^2 in 8 fields (1.6 x 10^7 Mpc^3)
  - Select a few hundreds of LAEs and study reionization with the clustering properties of these Lyα sources.
- Spectroscopic follow-up with 6.5 mt Magellan Telescopes at LCO.
  - Estimate accurately the confirmation rates of LAE candidates
  - Get accurate LF
  - Use the LAEs clustering to study the ionized bubble and neutral gas fraction at z ~ 7.

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Narrow Band IMAGING

NB Imaging

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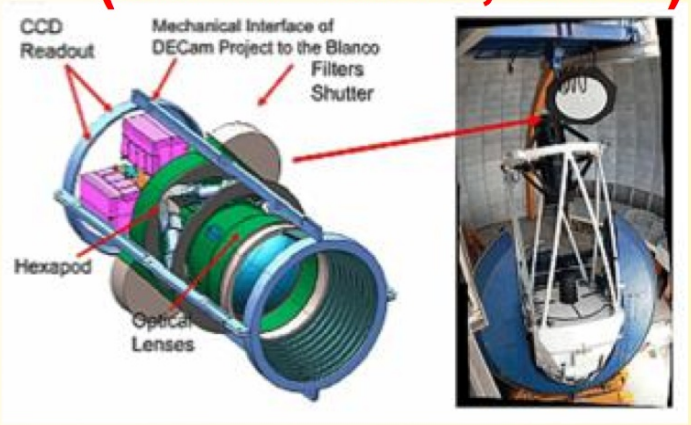
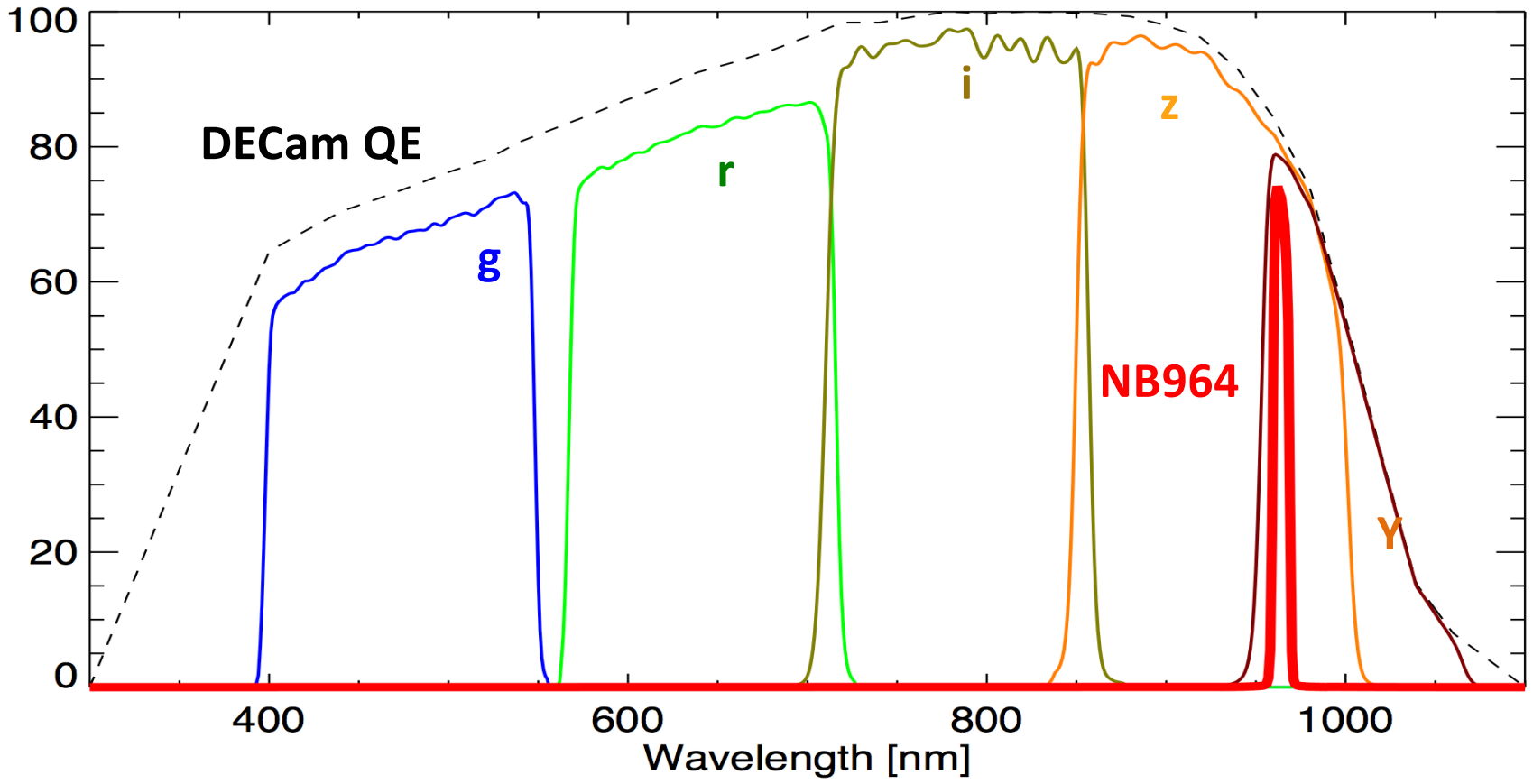
CTIO 4m Blanco Telescope
(Cerro Tololo, Chile)



Dark Energy Camera
(FOV = 3 sq-deg)

Wc = 9642 Å & FWHM = 92 Å
→ z(Lyα) = 6.93+/-0.04

NB964 Narrowband Filter



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NB964 Filter Profile vs. Sky Lines

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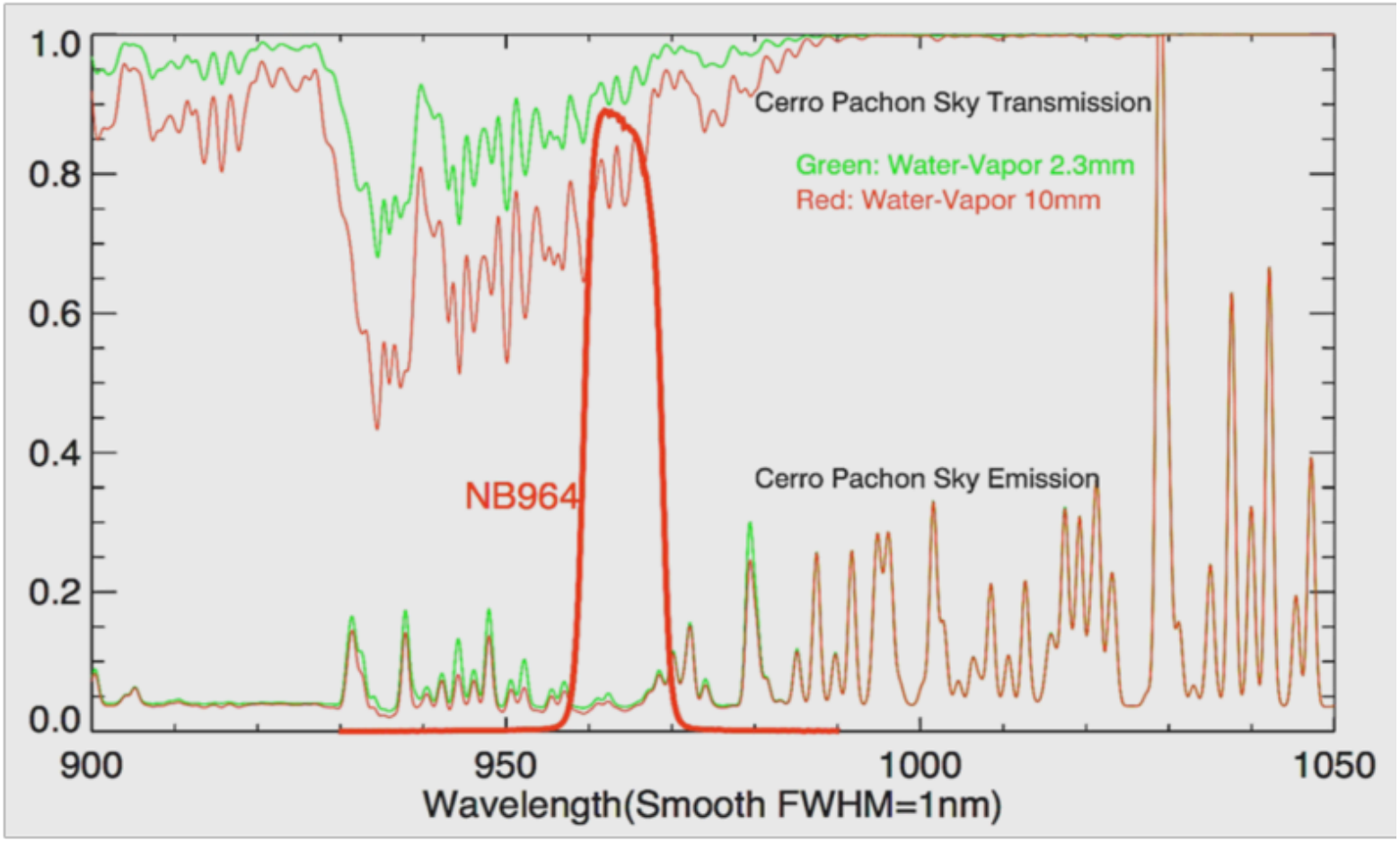

NB964 Filter Design: Zheng, Rhoads et al. 2018

LAGER Fields

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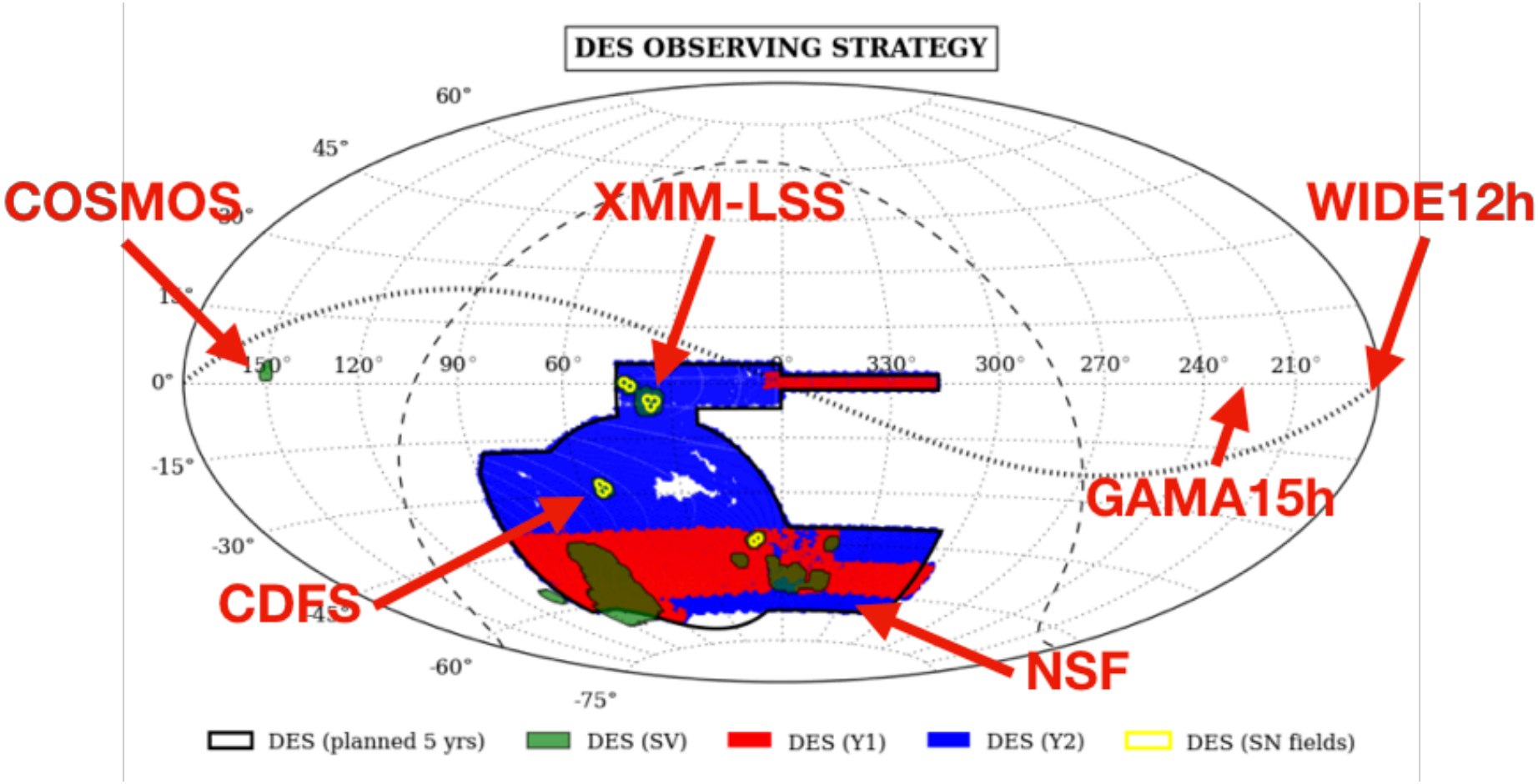

LAE Candidates at z~7

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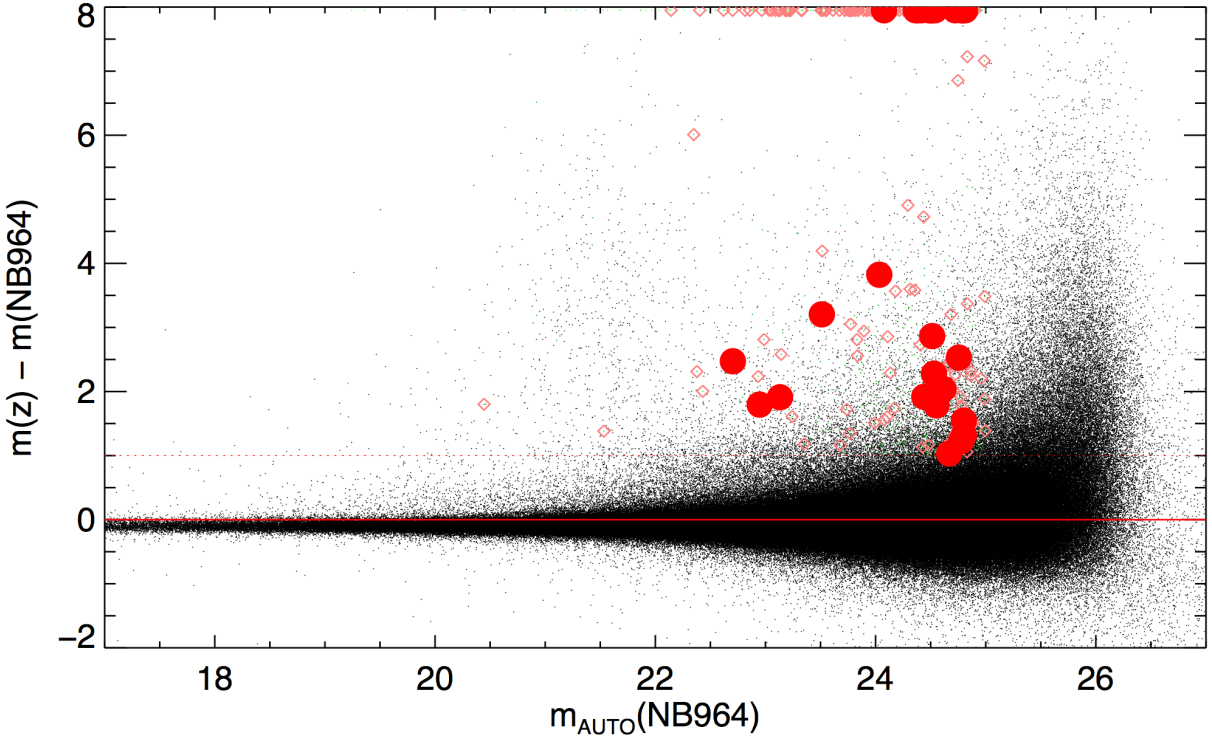
1. significant detection in NB964 image;
2. color-excess of NB964 relative to the underlying broad-band; and
3. non-detection in the bluer broadband (veto band) to filter out foreground galaxies.



Field	NB	Broadband	# of LAEs	
COSMOS	34hrs	Subaru Suprime-Cam	23	Zheng+2017
COSMOS	47.25hrs	Hyper Suprime-Cam	49	Hu+2019
CDFS	33.67hrs	DECam	30	

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SPECTROSCOPY

Spectroscopy

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LCO Magellan IMACS and LDSS3

z=7 confirmed LAEs

- From 2017A to 2018B (2 years), we covered 50 LAEs candidates with Magellan in total and confirmed 24 LAEs.
  - In COSMOS, 33 LAE candidates covered and 17 confirmed.
  - In CDFS, 17 LAE candidates covered and 7 confirmed.

Other

- About 10 z=5.7 and 6.5 LAEs in COSMOS are also confirmed, but we haven't paid much attention to them.
- About 100 - 200 background H-alpha, H-beta, [OIII], [OII] emitters are covered. The confirmation rate is not counted.

LyA Spectra

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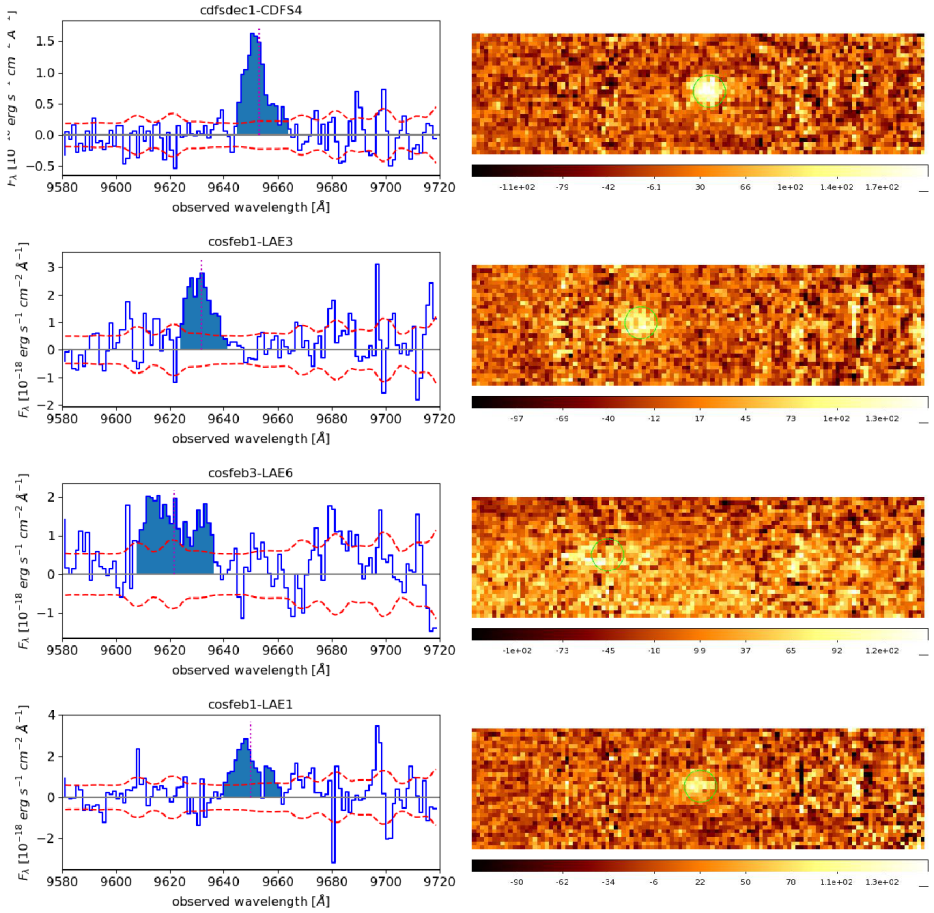

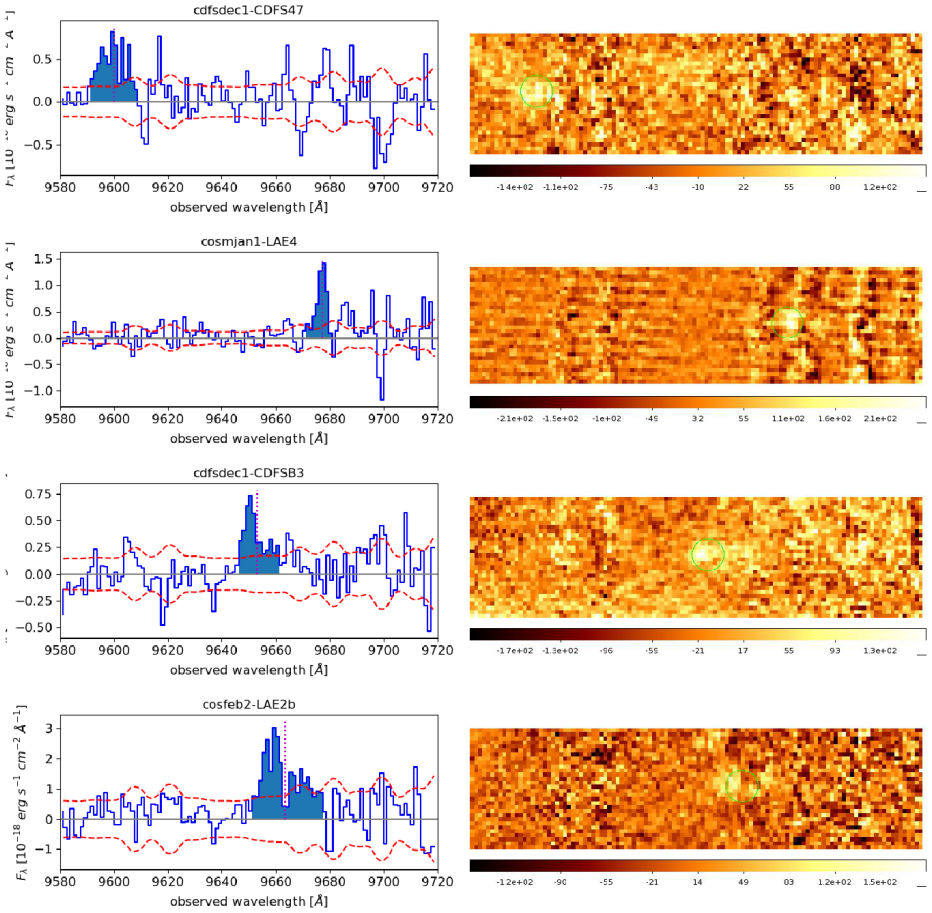

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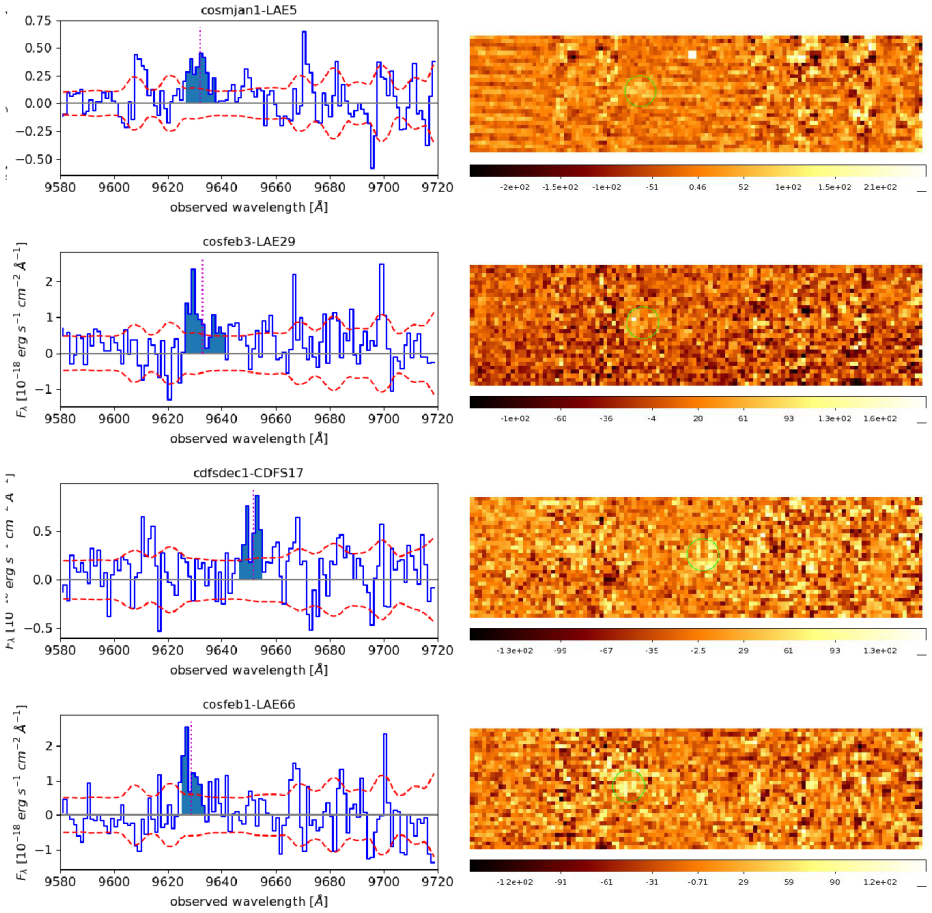

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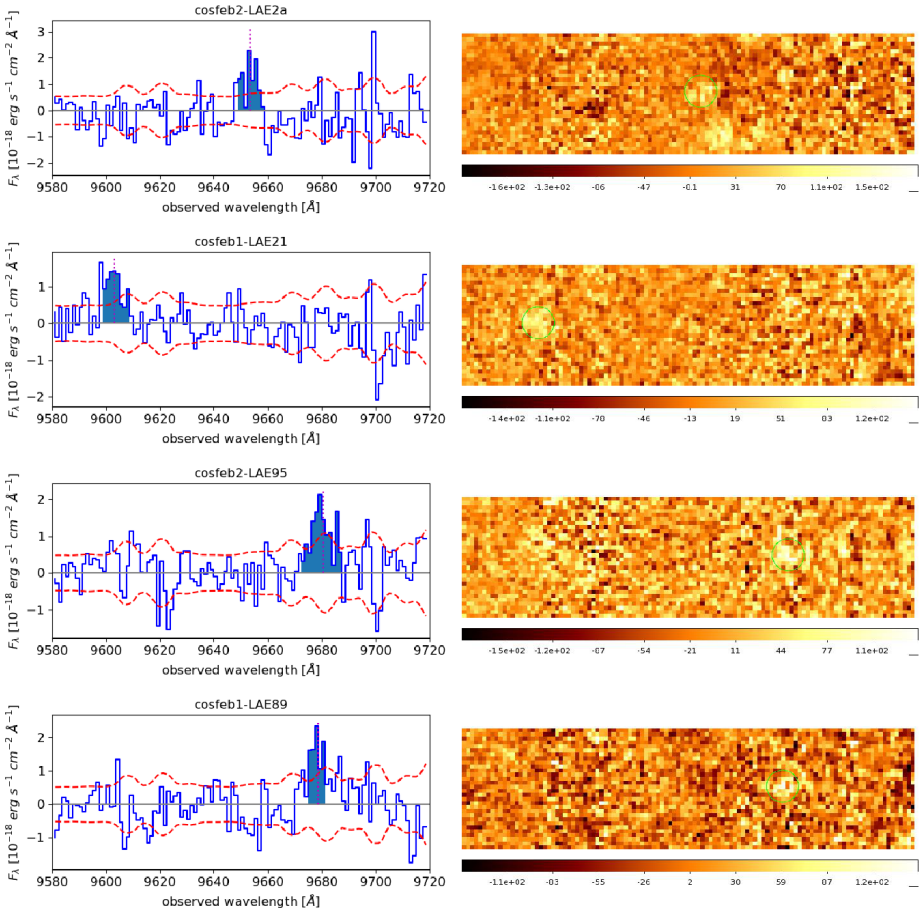

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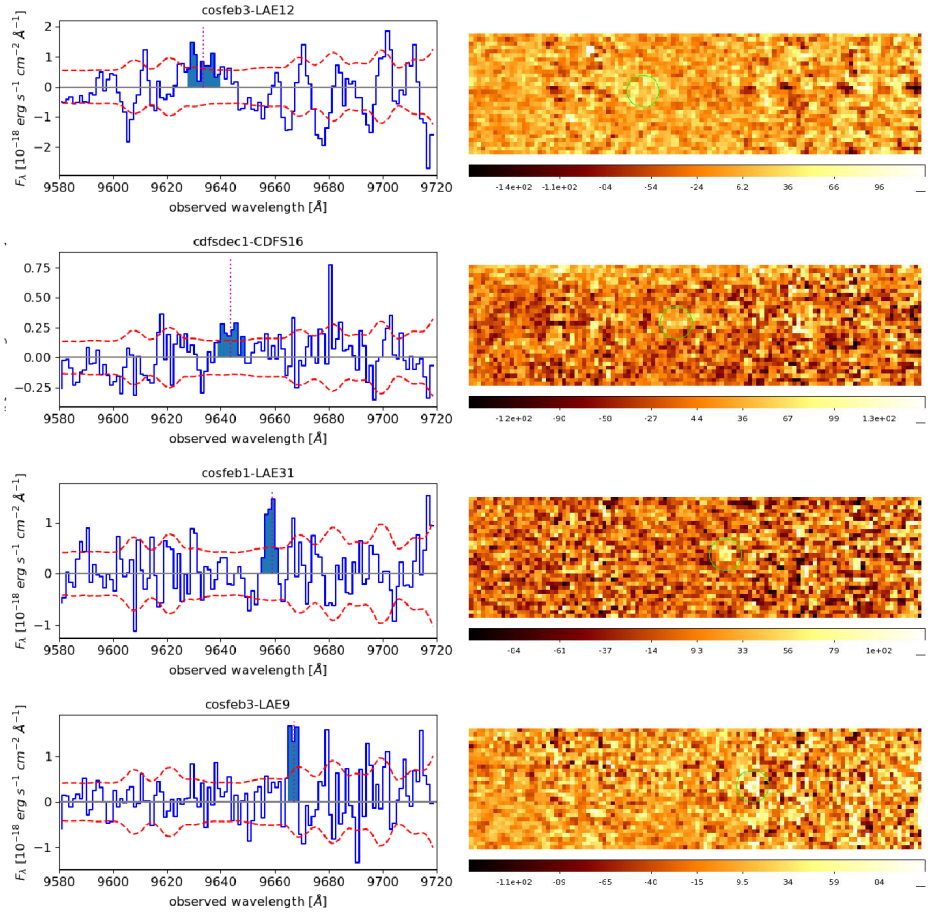
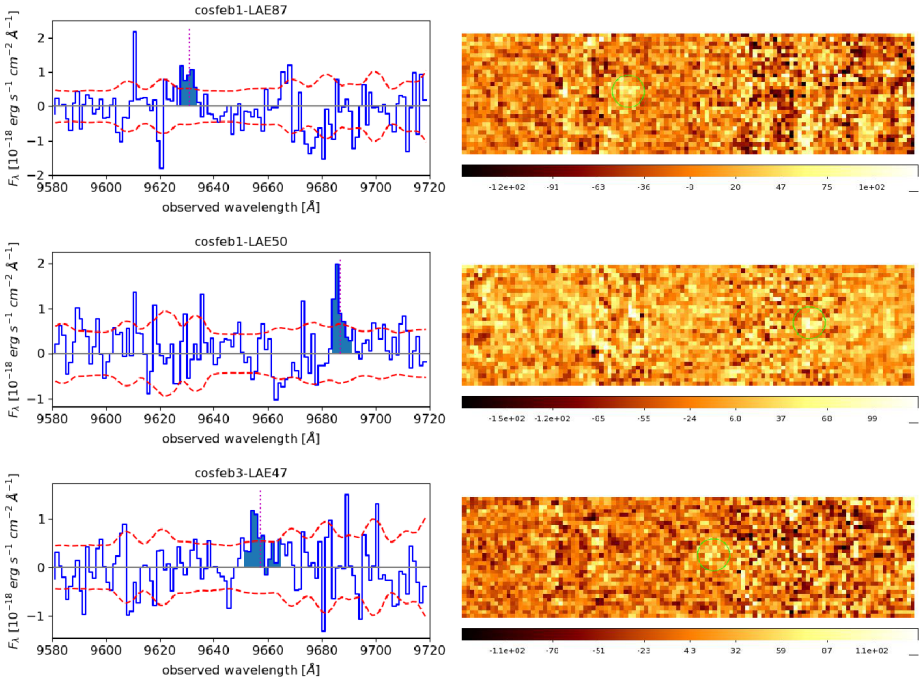

cosfeb3-LAE12
cdfsdec1-CDFS16
cosfeb1-LAE31
cosfeb3-LAE9
observed wavelength [Å]



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RESULTS so far

Number Density

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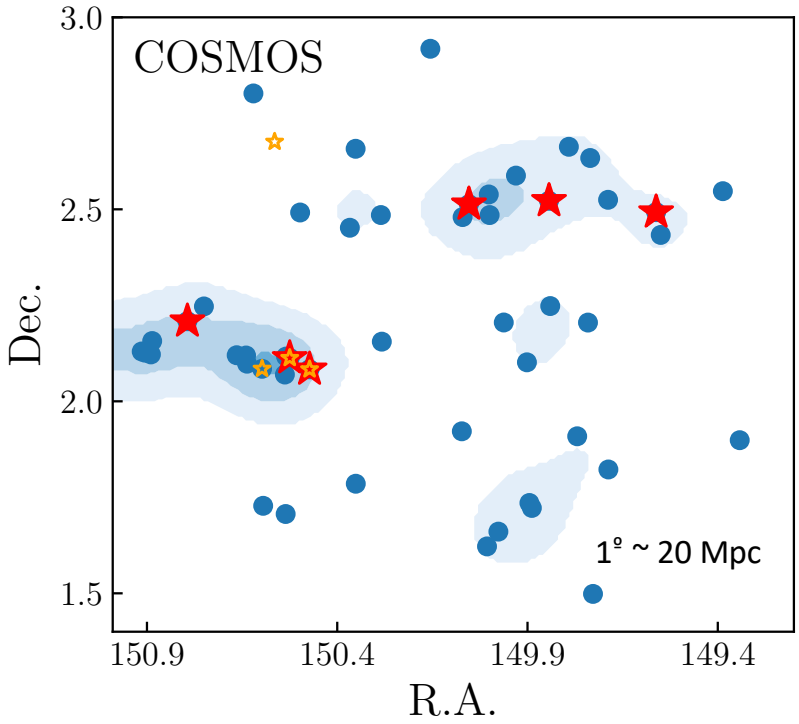
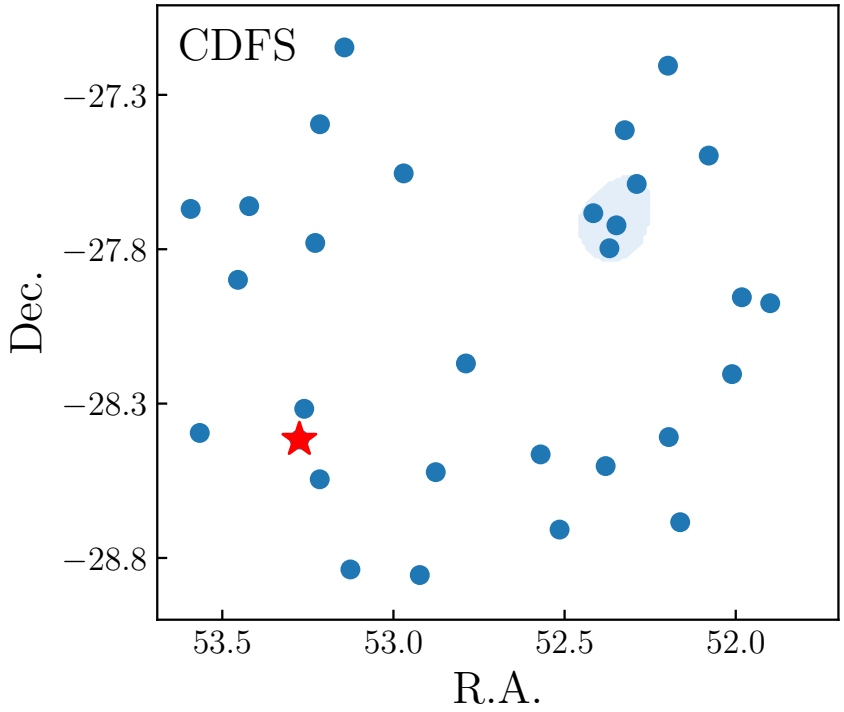
- In the LF paper, we showed
  - 49 LAEs in COSMOS and
  - 30 LAEs in CDFS.
  - Since each field is about 2 deg^2, the number of LAEs at z ~ 7 is about 20/deg^2.
- Some faint-end LAEs are excluded from the sample.
  - If we can accept a higher contamination rate, then the number of LAE candidates per sq. deg could be ~ 40/deg^2.

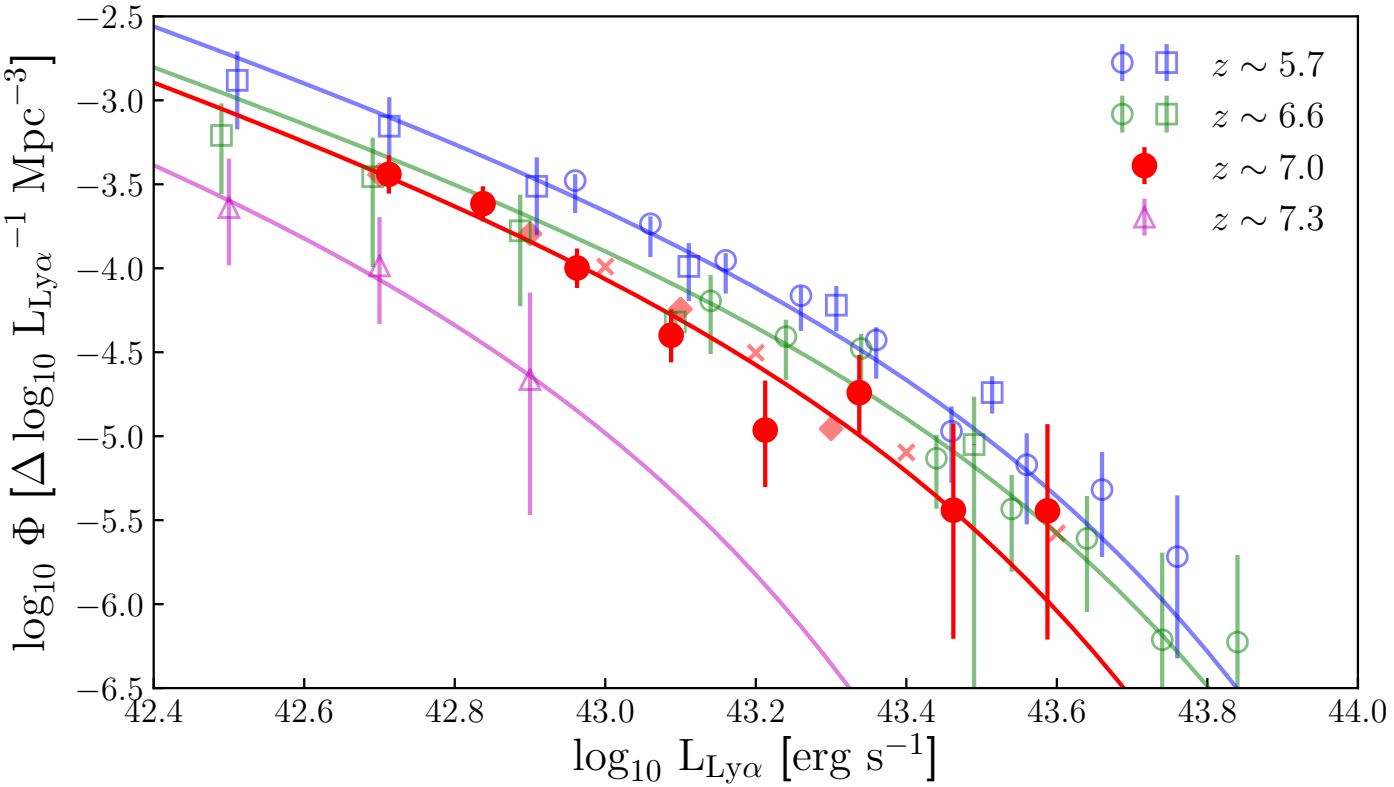
Spatial Distribution





highest redshift proto-clusters observed to date.

LF Evolution

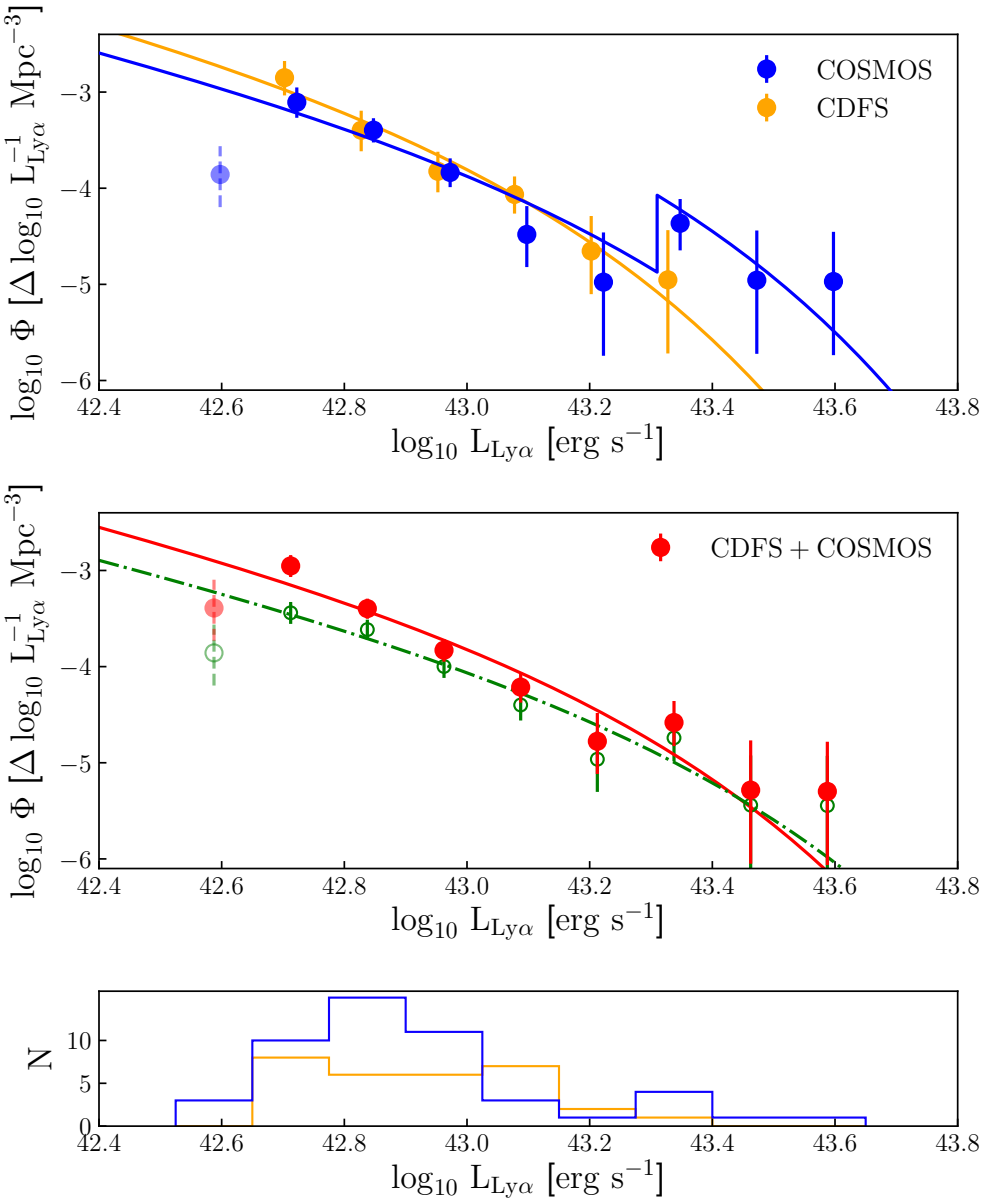


Little Evolution of Lyα LF at z ~ 3-6

(Ouchi+08, Faisst+2014, Zheng+2016, Hu+2019..)

z~5.7: Ouchi+2008 & Konno+2018
z~6.6: Ouchi+2010 & Konno+2018
z~6.9: Hu+2019, Ota+ , Itoh+2018
z~7.3: Konno+2014

LF



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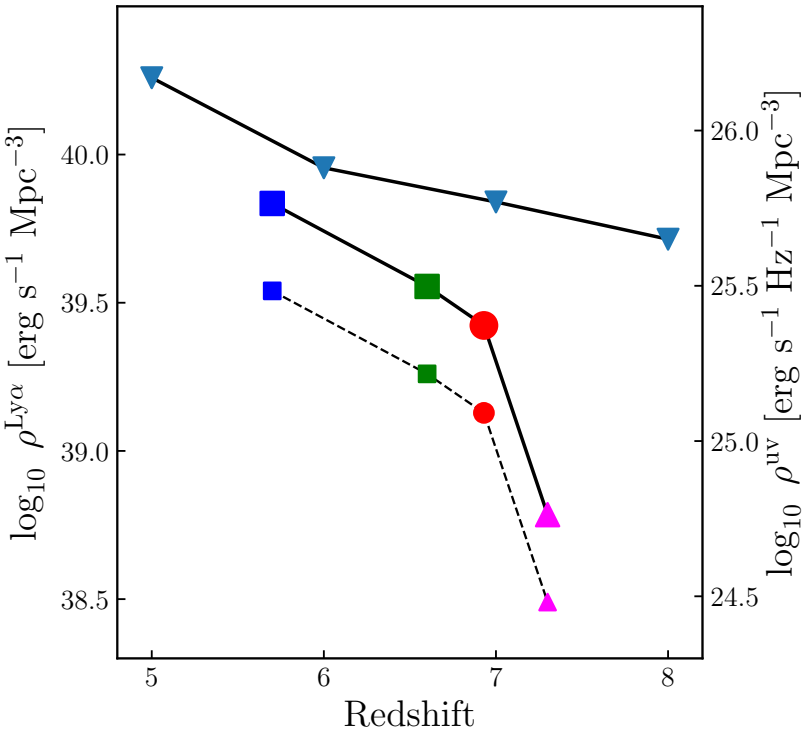
The bright-end shift

- More luminous LAEs ($L_{lya}>10^{43.3}$ erg/s) in COSMOS field! Suppoting inside-out reionization topology -> **bubbles**.
- Faint-end LFs of the two fields are similar.

Neutral Hydrogen Fraction



$$\rho^{Ly\alpha} = \kappa T^{IGM} f_{esc} \rho^{UV}$$

$$\frac{T^{IGM}_{7.0}}{T^{IGM}_{5.7}} = \frac{\rho^{Ly\alpha}_{7.0}/\rho^{Ly\alpha}_{5.7}}{\rho^{UV}_{7.0}/\rho^{UV}_{5.7}} = 0.63 \pm 0.09$$

Compare with Santos+2004 and McQuinn+2007, we conclude that $x_{\rm HI} = 0.2 - 0.5$

Summary (work in progress)

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z ~ 7

- Compiled the largest-ever sample LAEs.
  - Number density ~ 20 LAE/deg^2
  - Confirmed ~ 50% spectroscopically
- Found a bright end shift in the LF in the COSMOS field, but not in the CDF field.
- Derive a neutral hydrogen fraction x_{HI}=0.2-0.4

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THANK YOU