A Search for High Redshift Galaxies behind Gravitationally Lensing Clusters

Ota et al.2011
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2012 Feb. 15 GCOE Symposium

Outline

1. Scientific Background

- Why study distant (=high redshift) galaxies?
  - 2 motivations
- What are gravitationally lensing clusters? Why use them?

2. My Study

- A Search for high redshift galaxies by observing two lensing clusters: A2390, CL0024
- Observations, Data Analysis, Result

3. Summary

1. Scientific Background

- Why study distant (=high redshift) galaxies?
  - 2 motivations
- What are gravitationally lensing clusters?
  Why use them?

History of the Universe

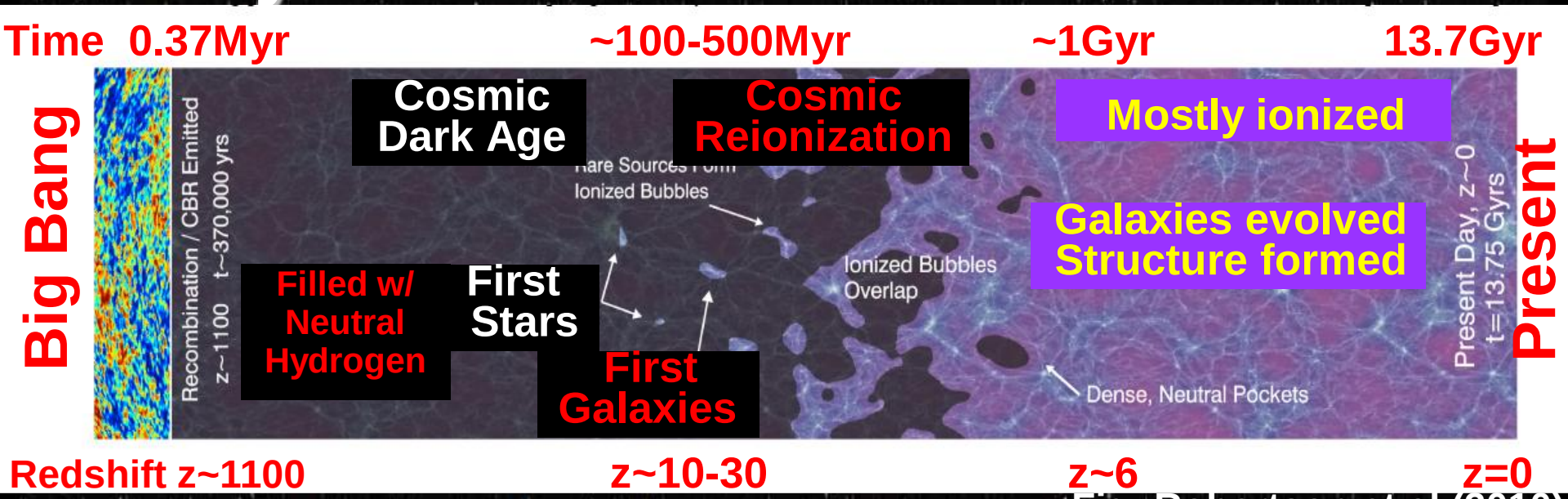


Fig: Robertson et al.(2010)

1. Studying Galaxy Evolution

- When and how the first galaxies formed?
- How galaxies evolved from the past to present?

2. Studying Reionization of the Universe

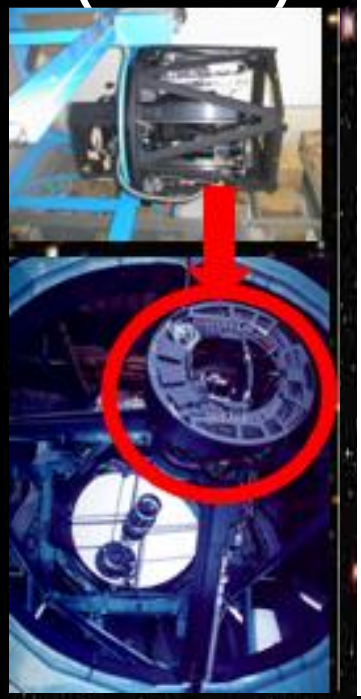
- When cosmic reionization started and ended?
- How reionization progressed in time and space?
- What are the primary source of reionization?

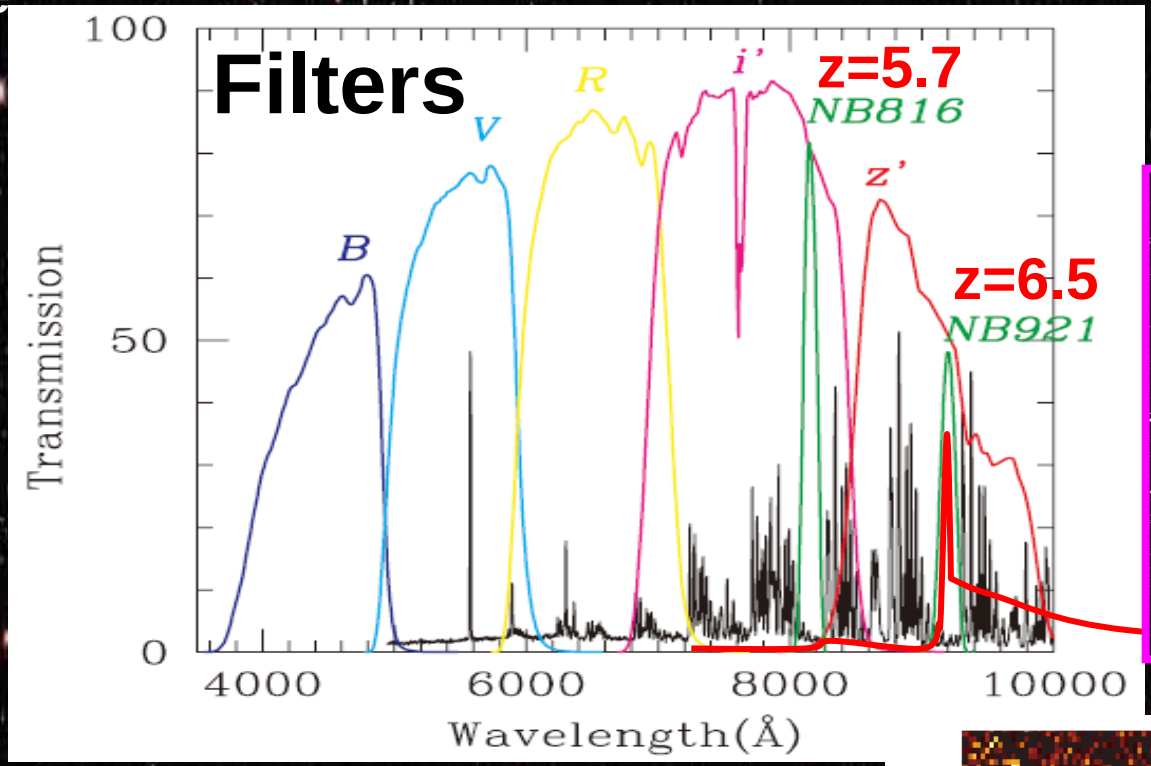
1. Studying Galaxy Evolution

- When and how the first galaxies formed?
- How galaxies evolved from the past to present?

Detecting High-z Lyα Emitting Galaxies

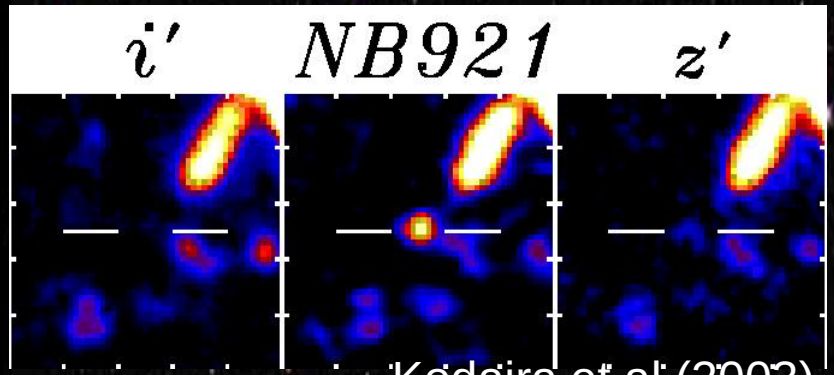
8m Telescope (Subaru)





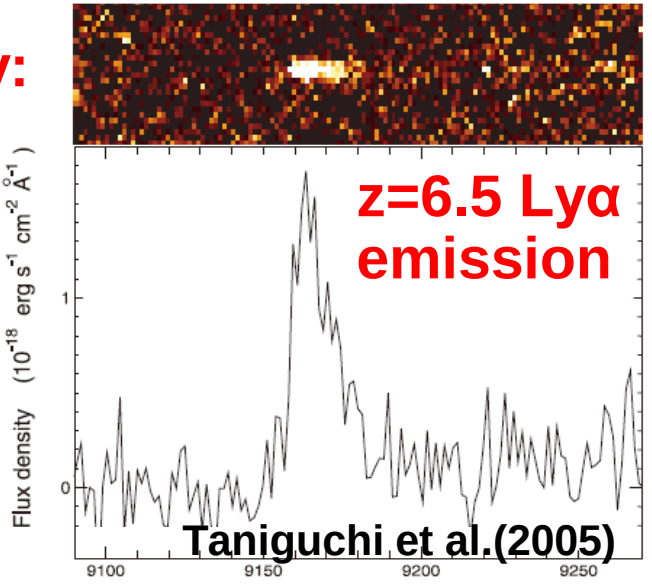
A blank sky field (Subaru Deep Field)

Imaging with filters:
Select photometric candidates



Kodaira et al.(2003)

Spectroscopy: Confirm as a real galaxy



Taniguchi et al.(2005)

When the 1st galaxies formed?

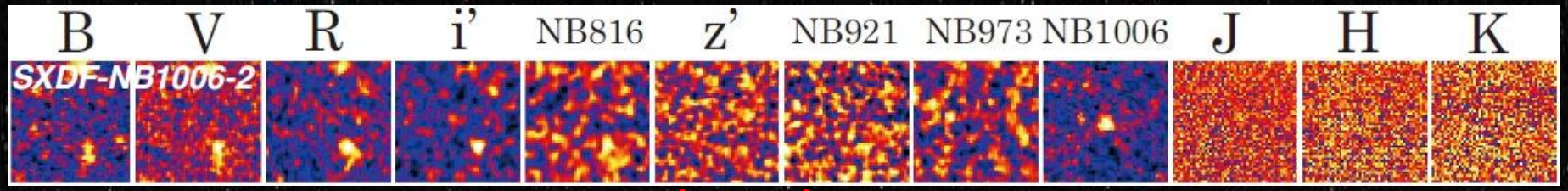
⇒ Search for the highest redshift galaxies

Galaxy Redshift Records（Spectroscopically confirmed）

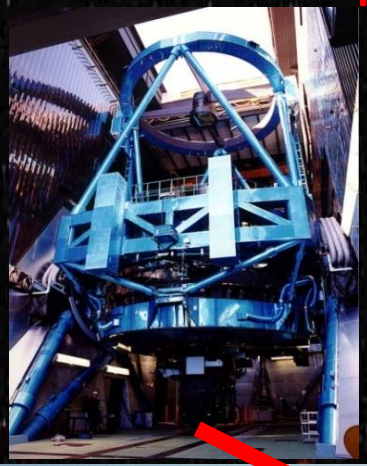
Rank	redshift	galaxy name	discoverer	released date
1	7.215	SXDF-NB1006-2	Shibuya+11	2011.12.17
2	7.213	GN-108036	Ono+12	2011.07.15
3	7.109	BDF−3299	Vanzella+11	2011.04.01
4	7.008	BDF−521	Vanzella+11	2011.04.01
5	6.972	G2_1408	Fontana+10	2010.12.20
6	6.964	IOK-1	Iye,Ota+06	2006.09.14

Blank Sky Field Searches for highest-z Lyα Emitting Galaxies

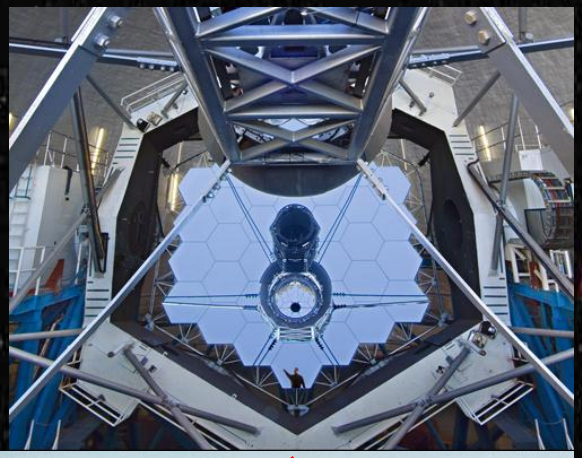
Shibuya, Kashikawa & Ota et al. 2011, submitted to *Astrophysical Journal*



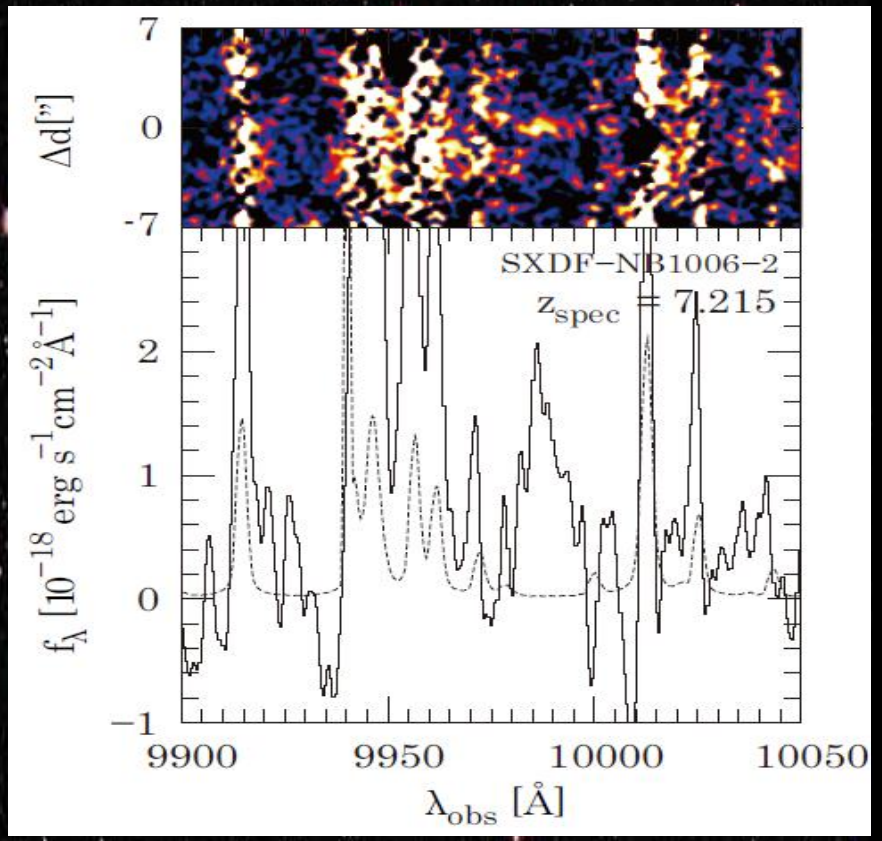
Imaging
8m Subaru Telescope



Spectroscopy (PI Ota)
10m Keck Telescope



World Record
z=7.215 Lyα emitting galaxy



~4200m Mt. Mauna Kea Hawaii

Current Redshift Frontier is z~7.2

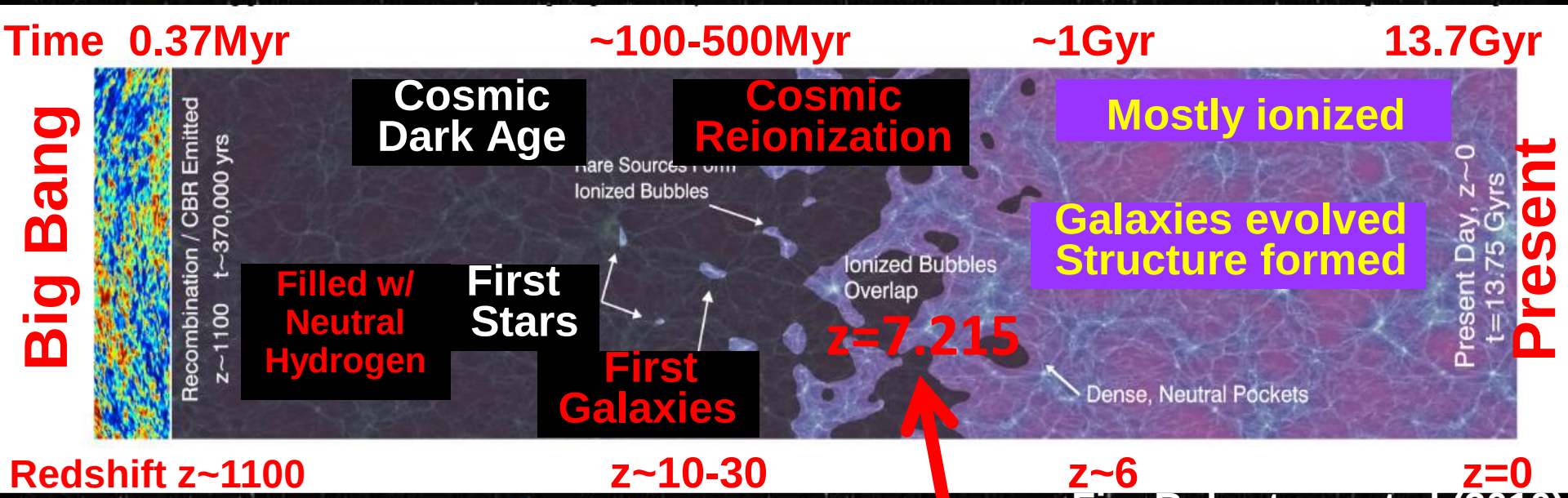
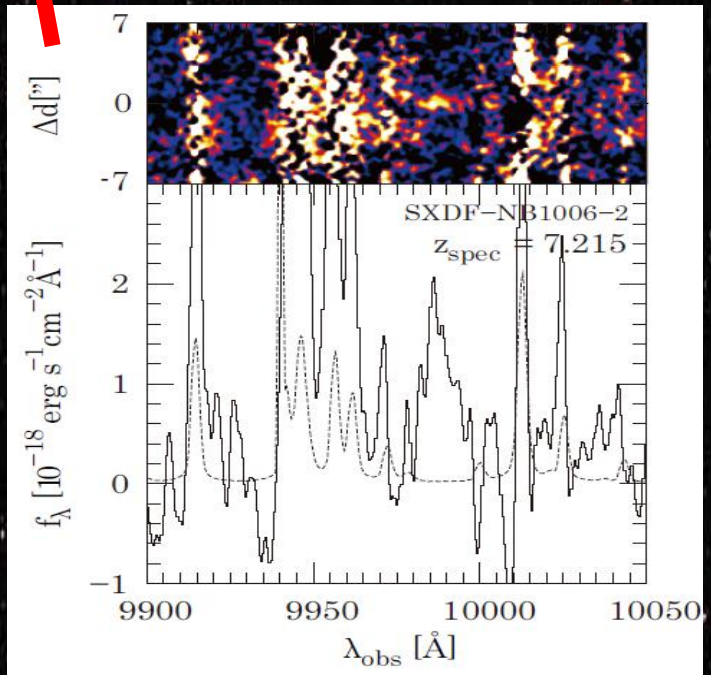


Fig: Robertson et al.(2010)

z=7.215 Lyα emitting galaxy
Currently highest redshift galaxy ever observed

What about z > 7.2?



2. Studying Reionization of the Universe

- When cosmic reionization started and ended?
- How reionization progressed in time and space?
- What are the primary source of reionization?

Lyα emission is sensitive to Cosmic Reionization

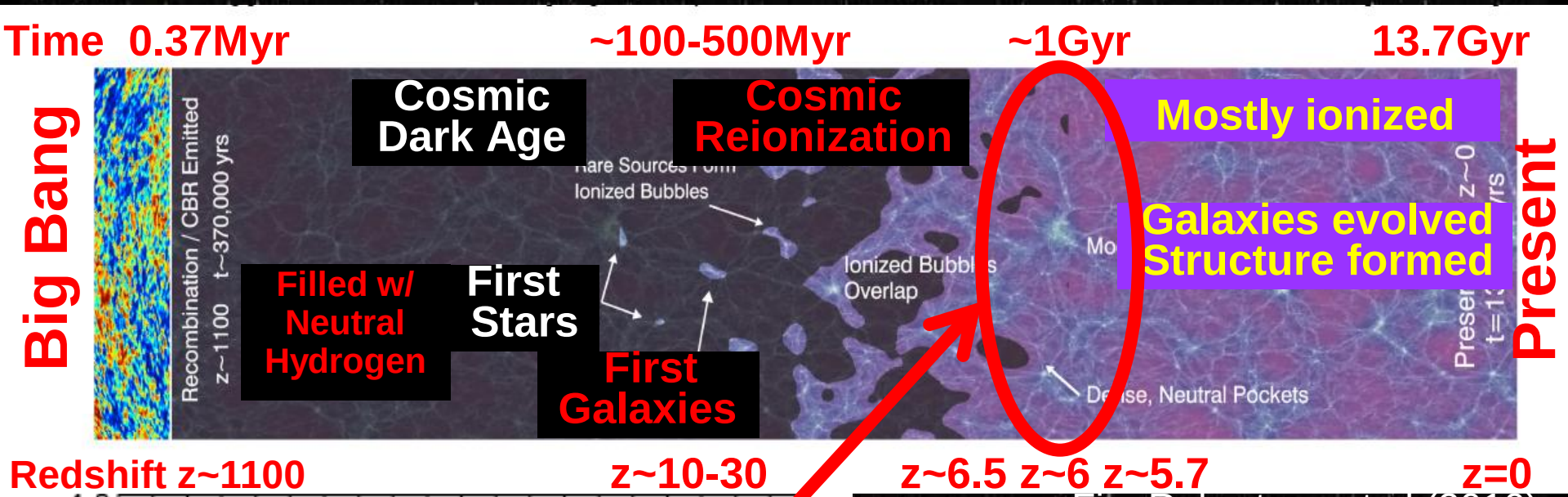
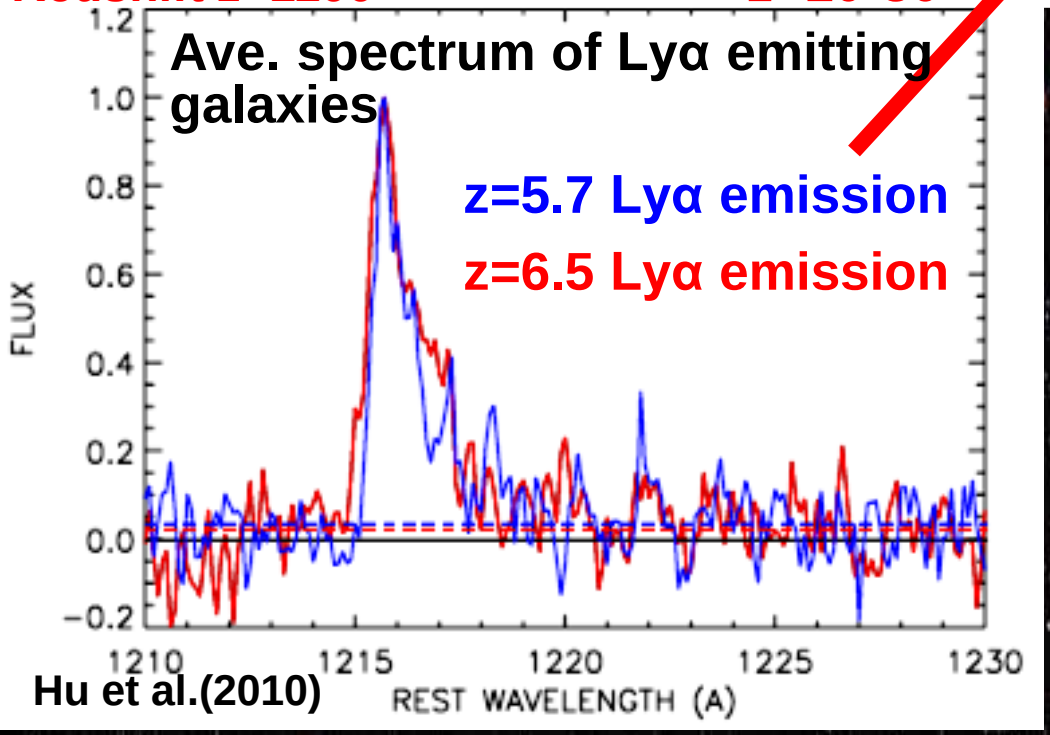


Fig: Robertson et al.(2010)



Hu et al.(2010)

Neutral hydrogen absorbs or scatters Lyα photons

↓

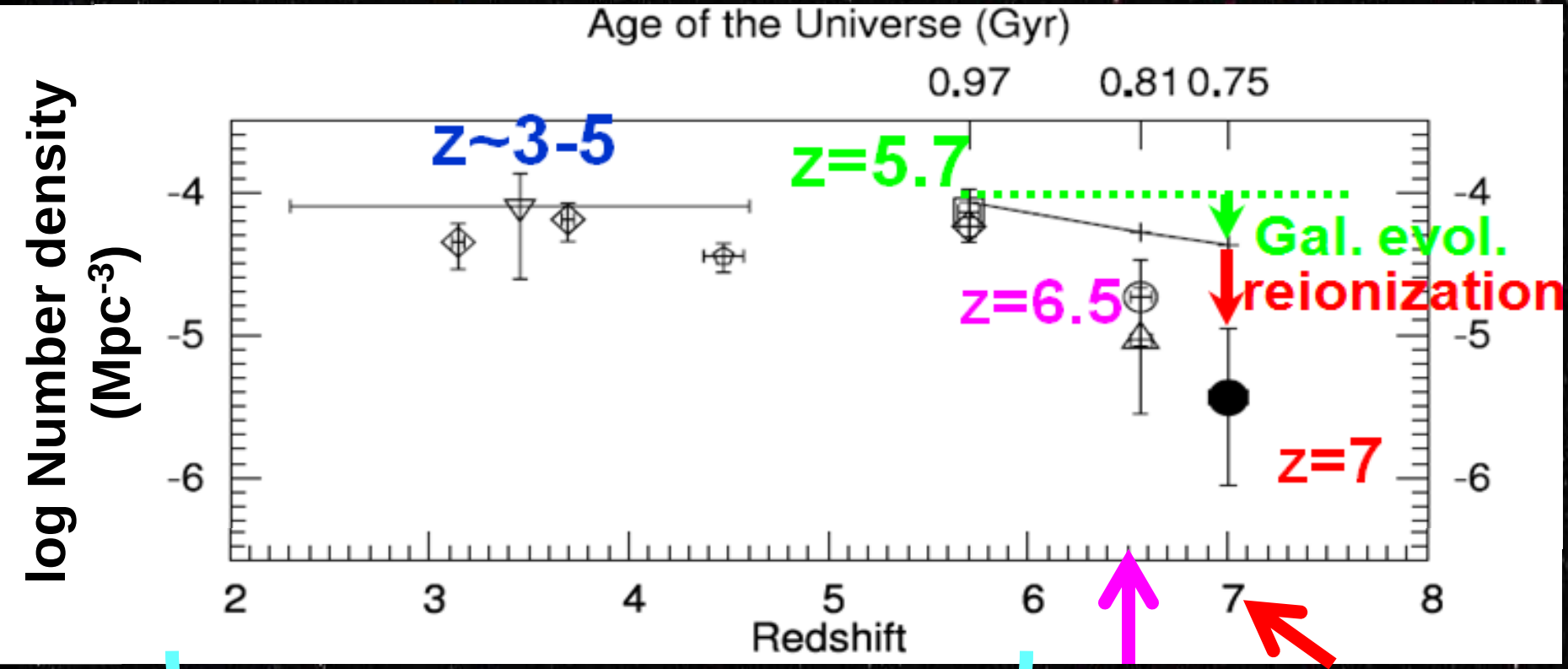
Lyα emission is attenuated if the Universe is partly neutral

↓

We can probe how neutral or reionized the Universe is with Lyα emitting galaxies

Observed number density of Lyα emitting galaxies decreases at z > 6

(due to attenuation of Lyα emission)



Universe is completely reionized

20-40% neutral

30-60% neutral

What about z > 7?

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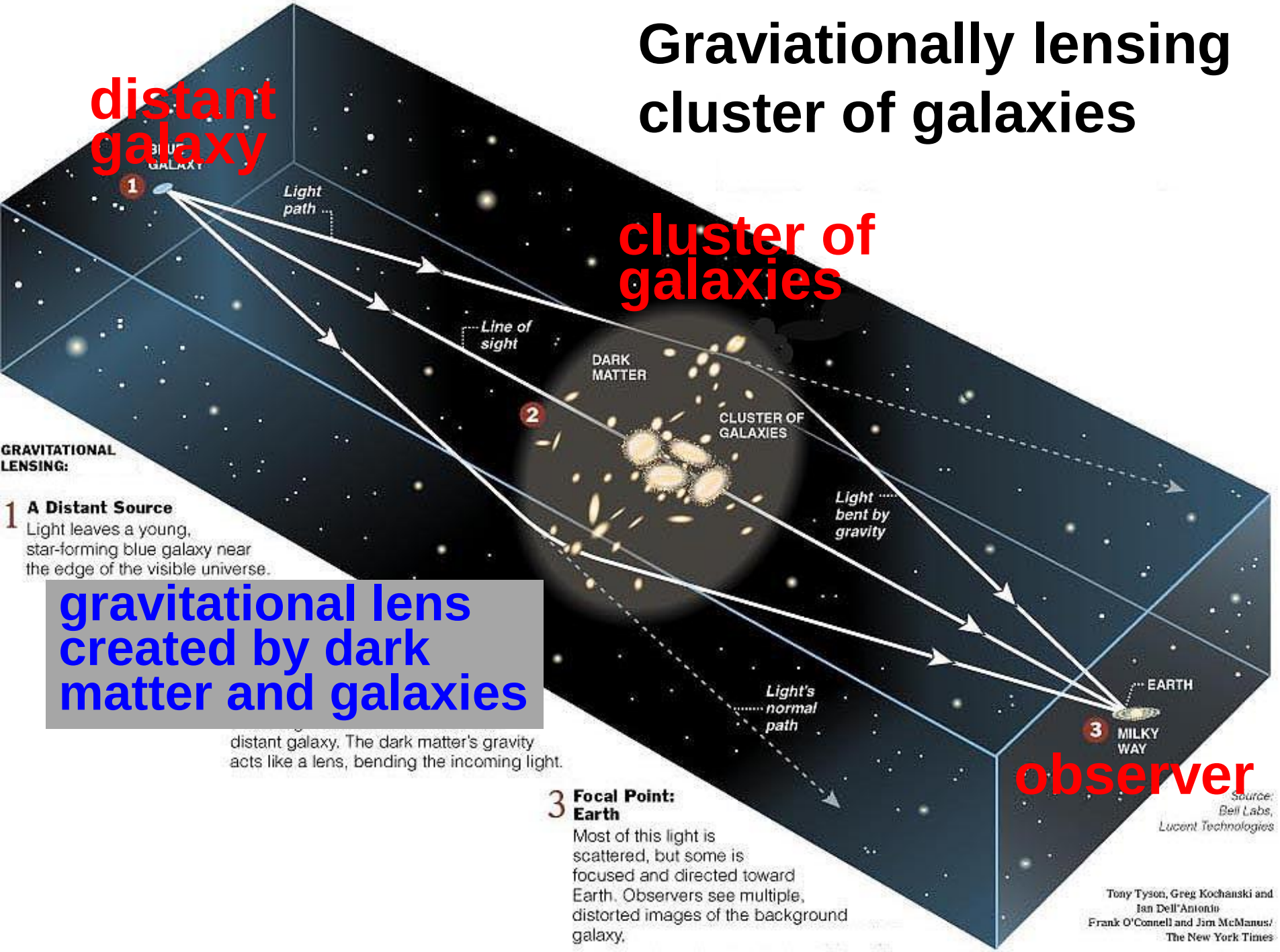
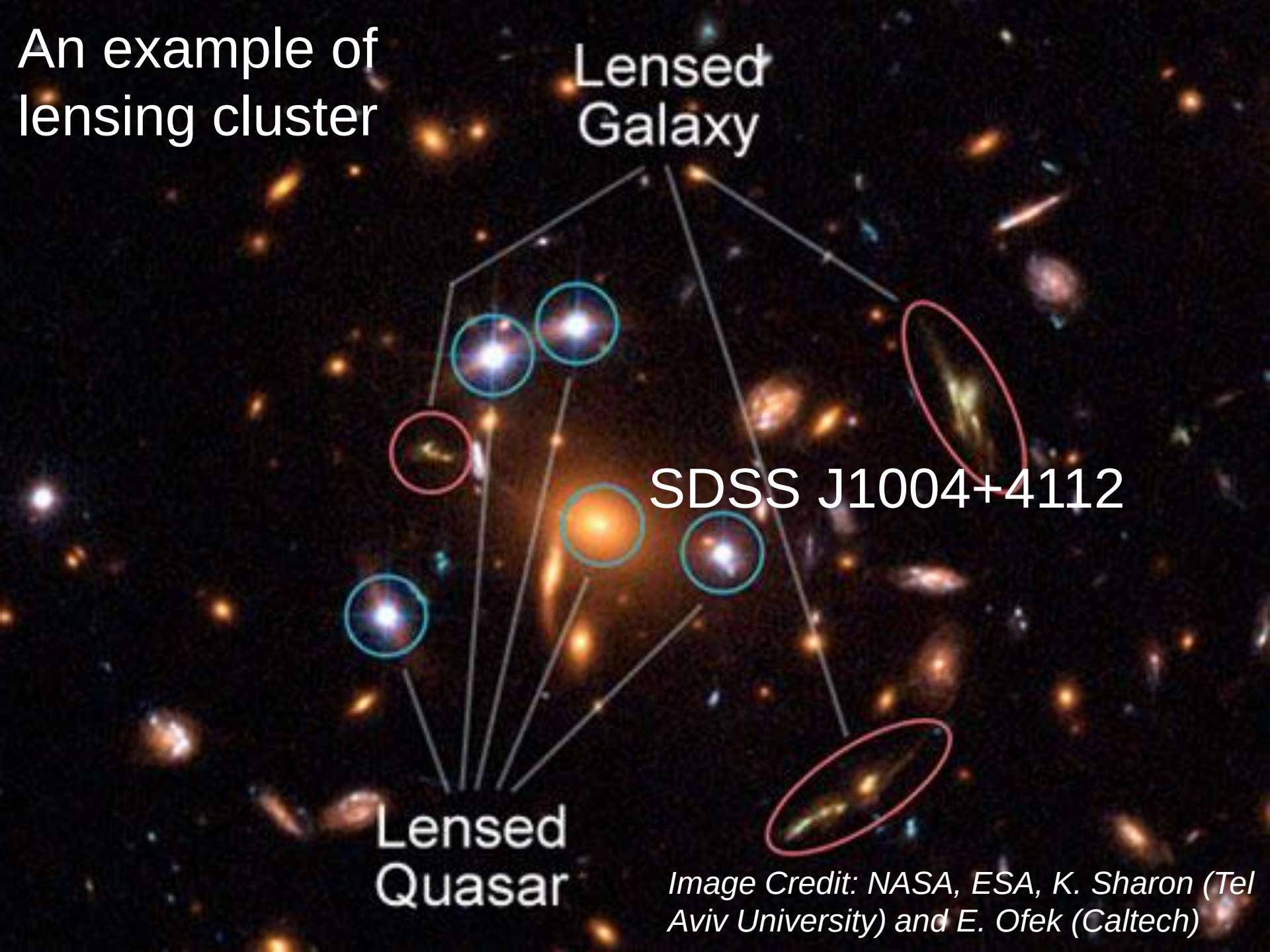
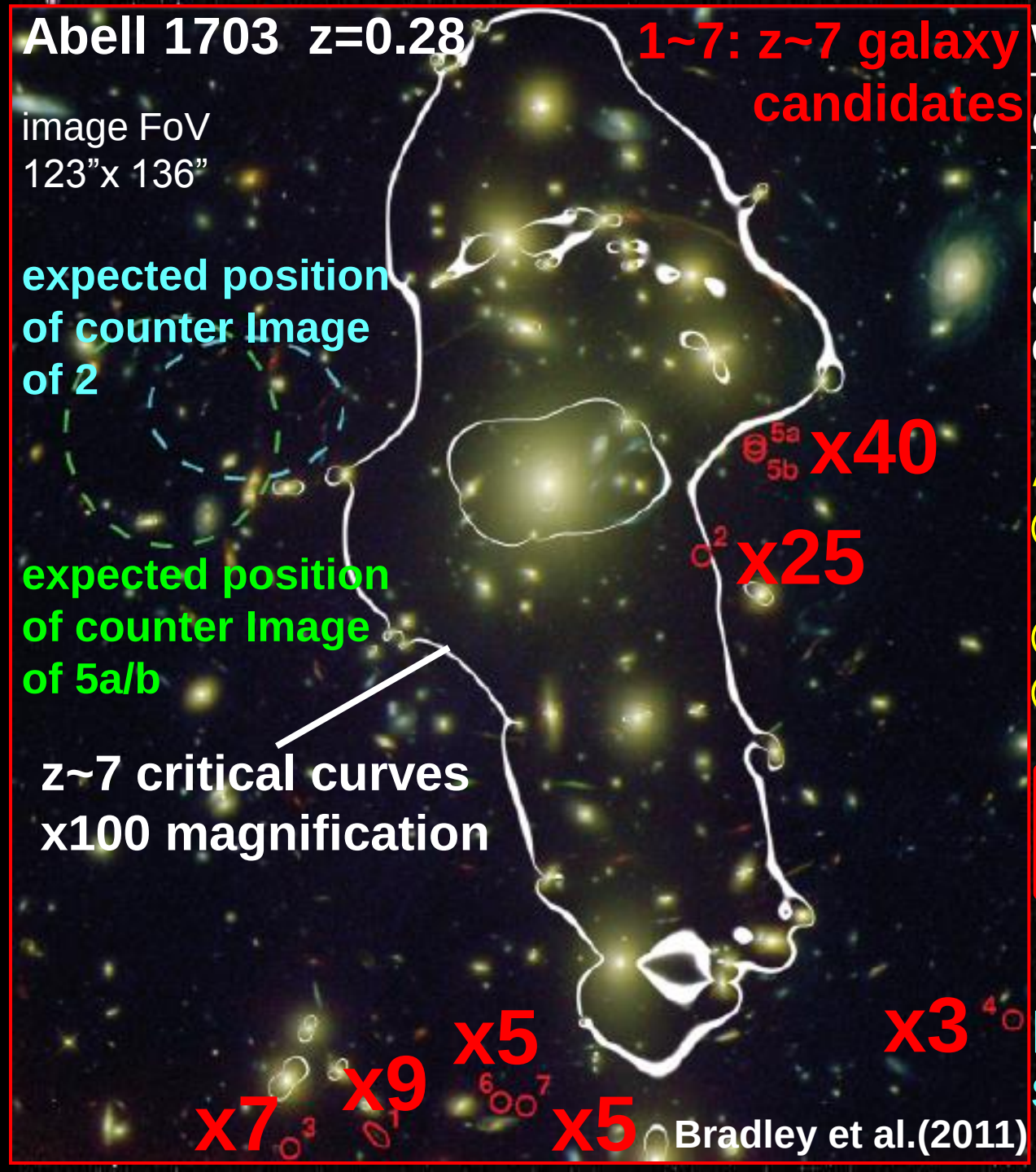
  Why use them?

Graviationally lensing cluster of galaxies




An example of lensing cluster
Lensed Galaxy
SDSS J1004+4112
Lensed Quasar
Image Credit: NASA, ESA, K. Sharon (Tel Aviv University) and E. Ofek (Caltech)



Why use lensing cluster?

Fluxes of background objects are boosted depending on (X,Y,z)

Advantages:

①deep imaging with short observing time

②spectroscopy is easier

③multiple lensed images

Powerful tool to detect distant faint galaxies

Drawback:

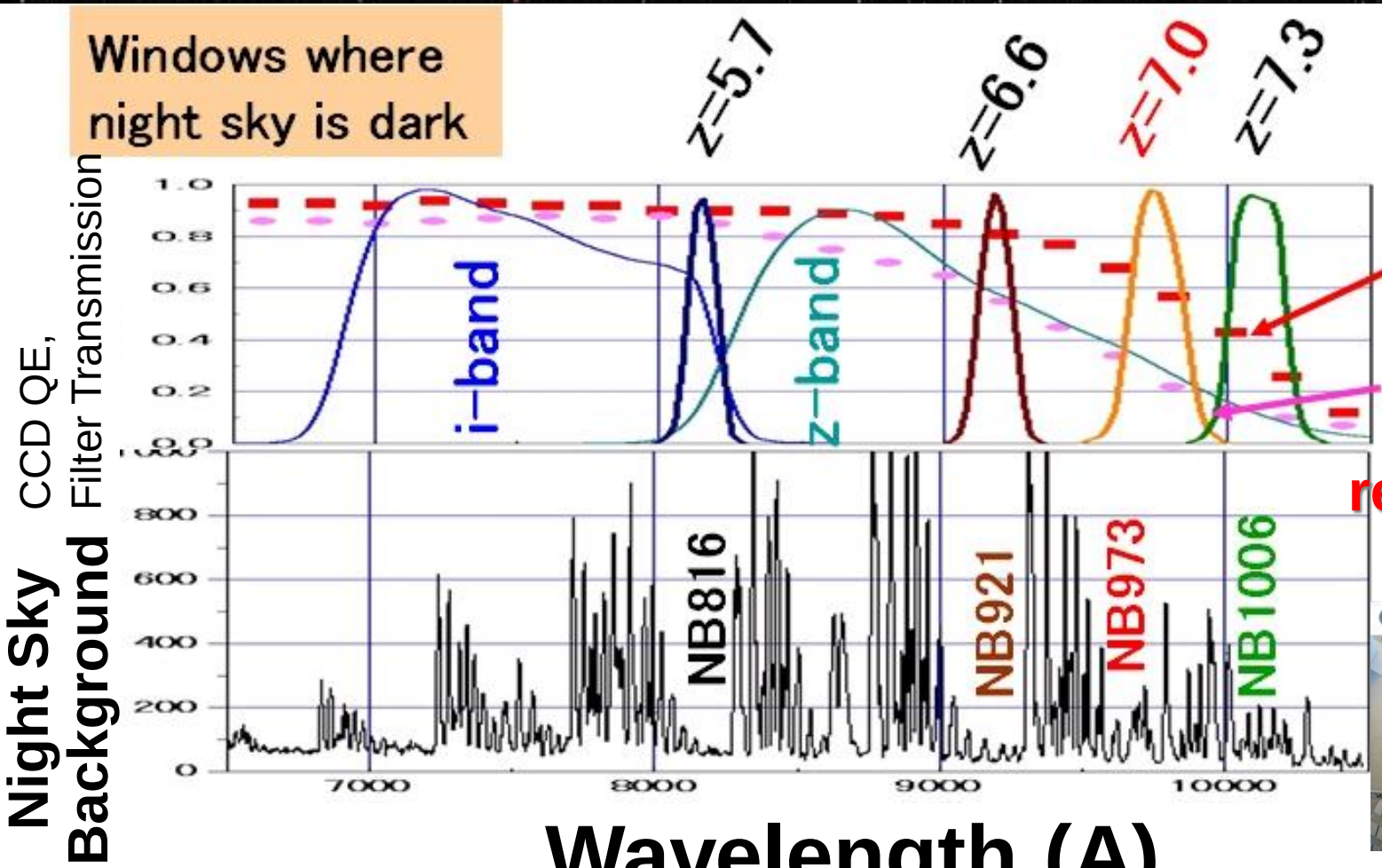
Survey area is very small

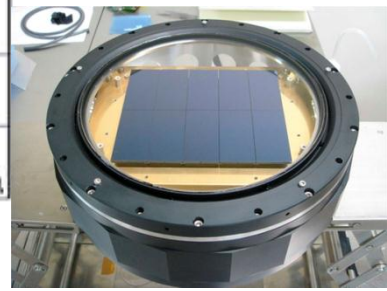
2. My Study

- A Search for high redshift galaxies by observing two lensing clusters: A2390, CL0024
- Observation, Data Analysis, Result

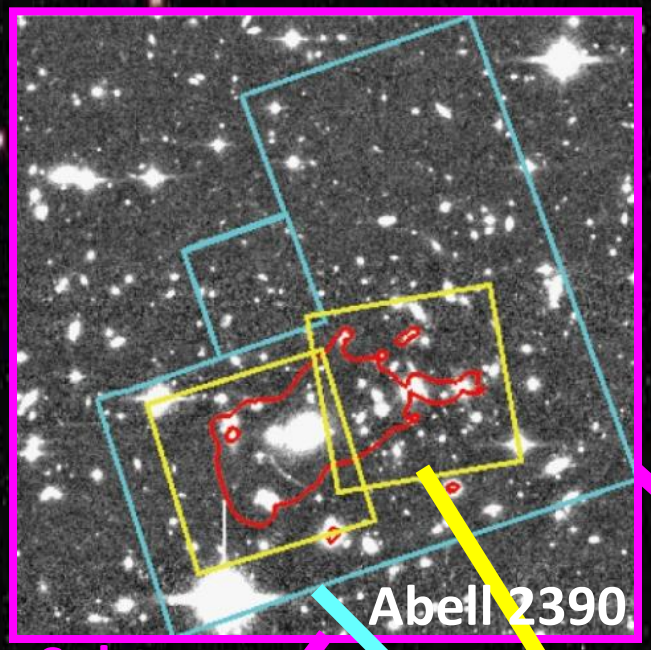
Target of study: z=7.3 Lyα emitting galaxies

Narrowband filter for z=7.3 Lyα + **8m Subaru Telescope Prime Focus Camera**



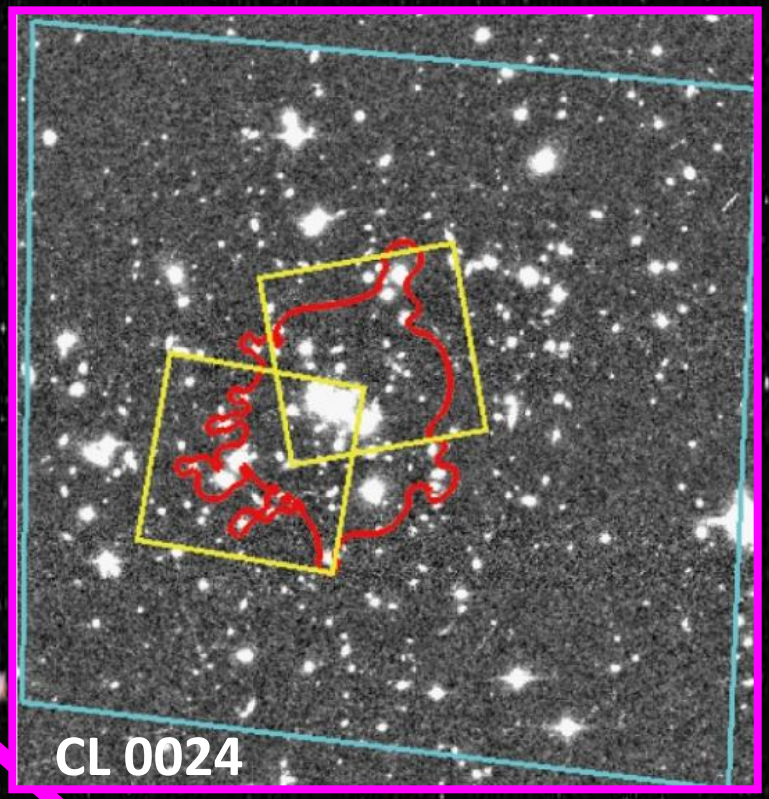


A Search for z=7.3 Lyα Emitting Galaxies behind Two Lensing Clusters



Abell 2390

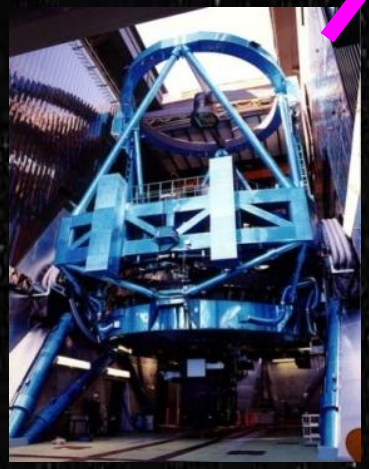
Subaru



CL 0024

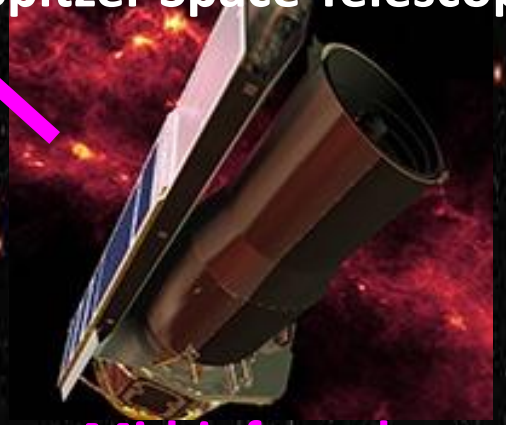
Hubble Space Telescope

Spitzer Space Telescope

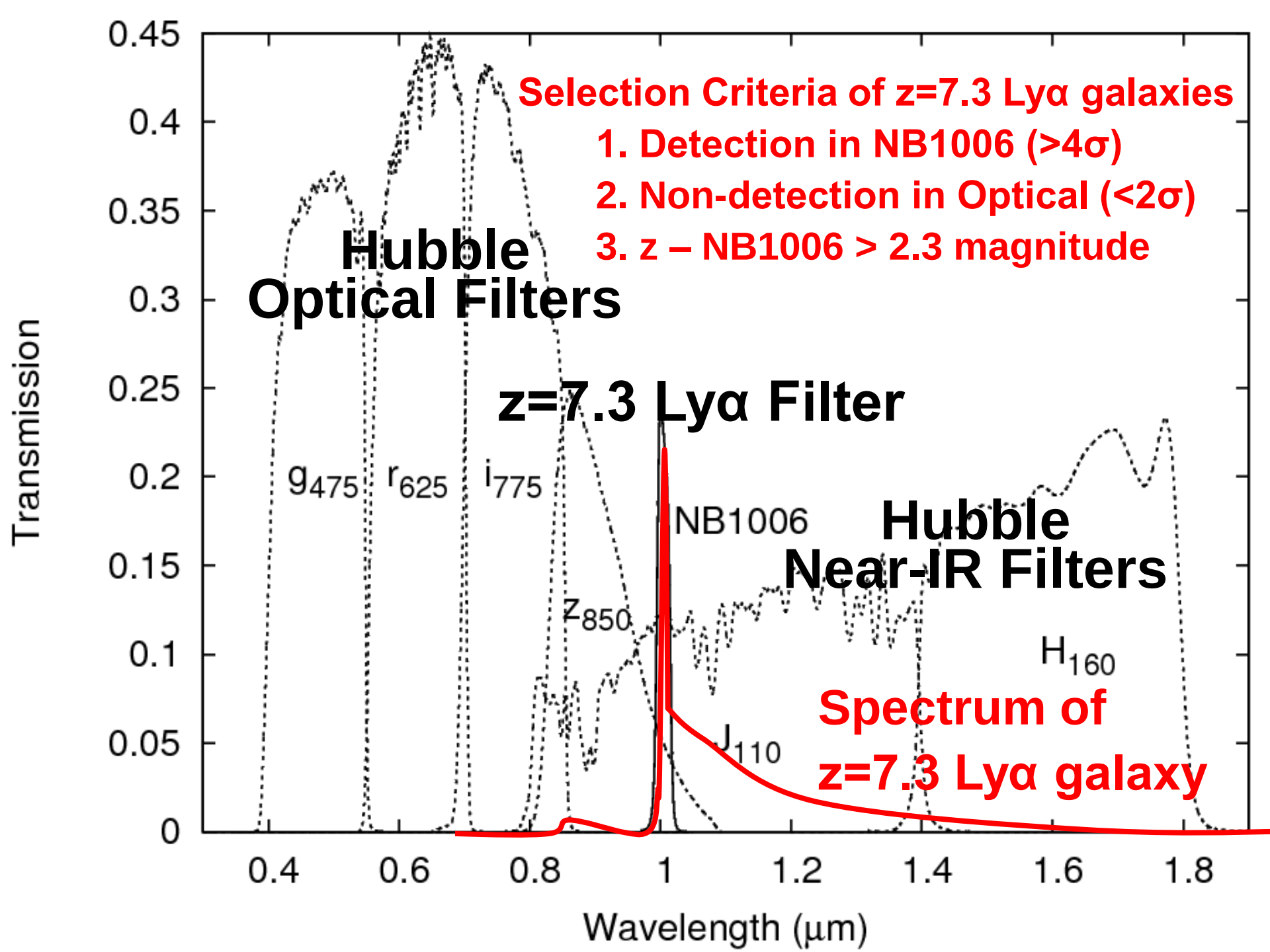


Optical NB1006

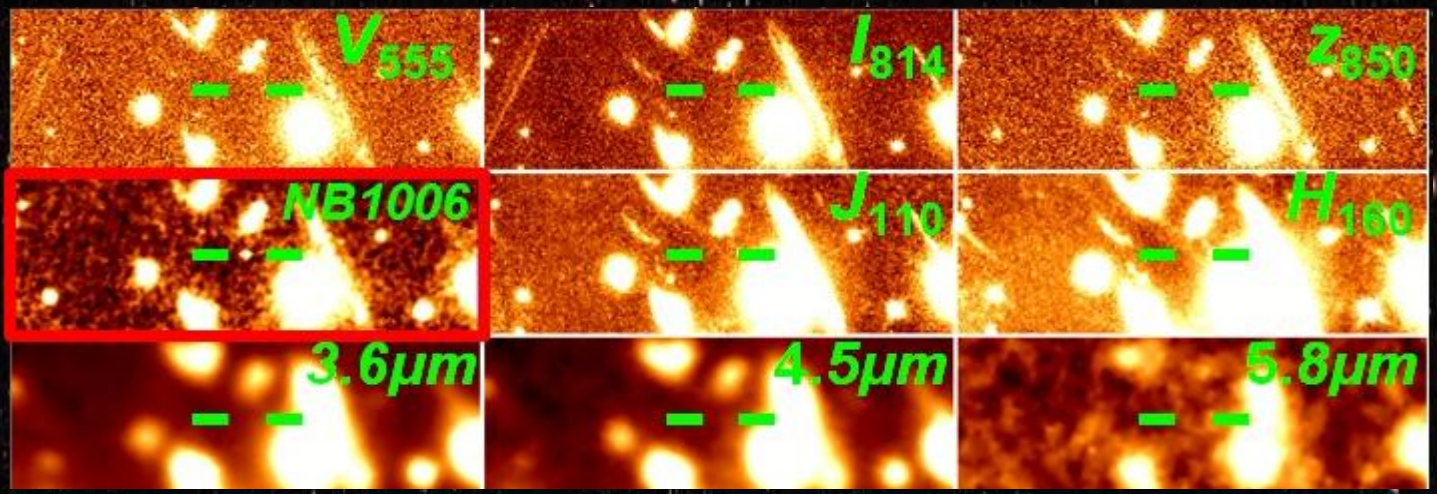
Optical, Near-infrared

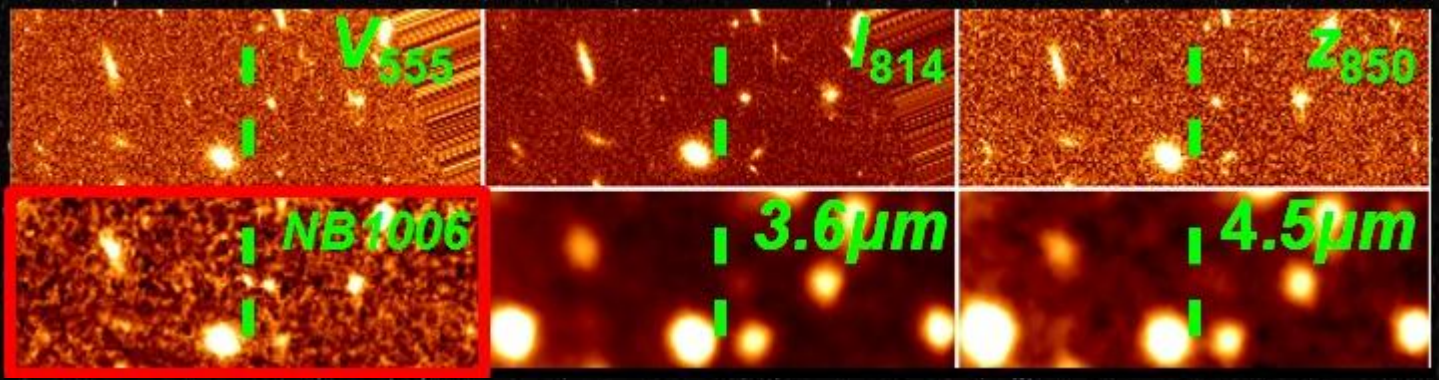


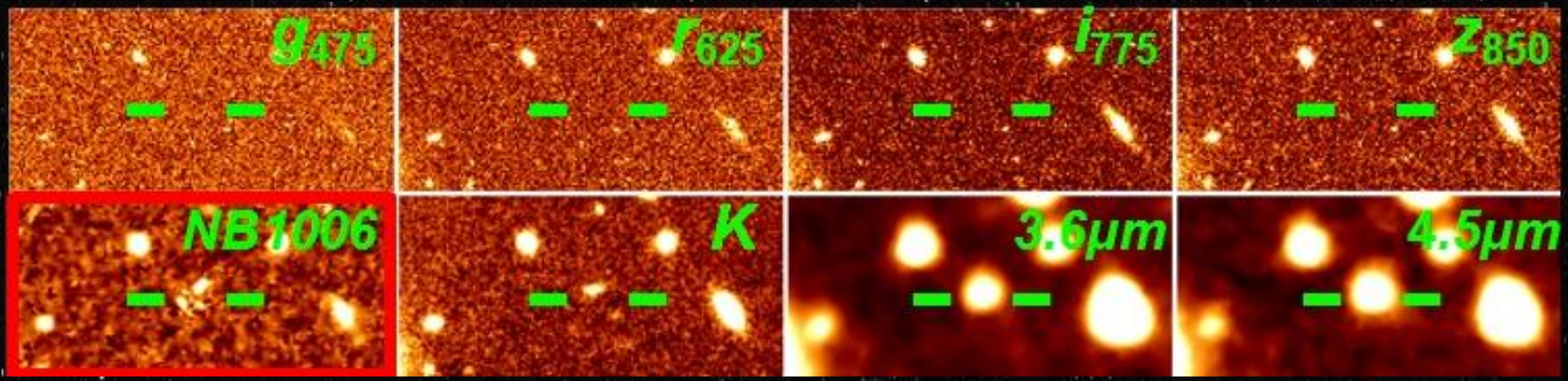
Mid-infrared


Selection Criteria of z=7.3 Lyα galaxies
1. Detection in NB1006 (>4σ)
2. Non-detection in Optical (<2σ)
3. z – NB1006 > 2.3 magnitude
Hubble
Optical Filters
z=7.3 Lyα Filter
g475
r625
i775
z850
NB1006
J110
Hubble
Near-IR Filters
H160
Spectrum of
z=7.3 Lyα galaxy
Transmission
Wavelength (μm)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

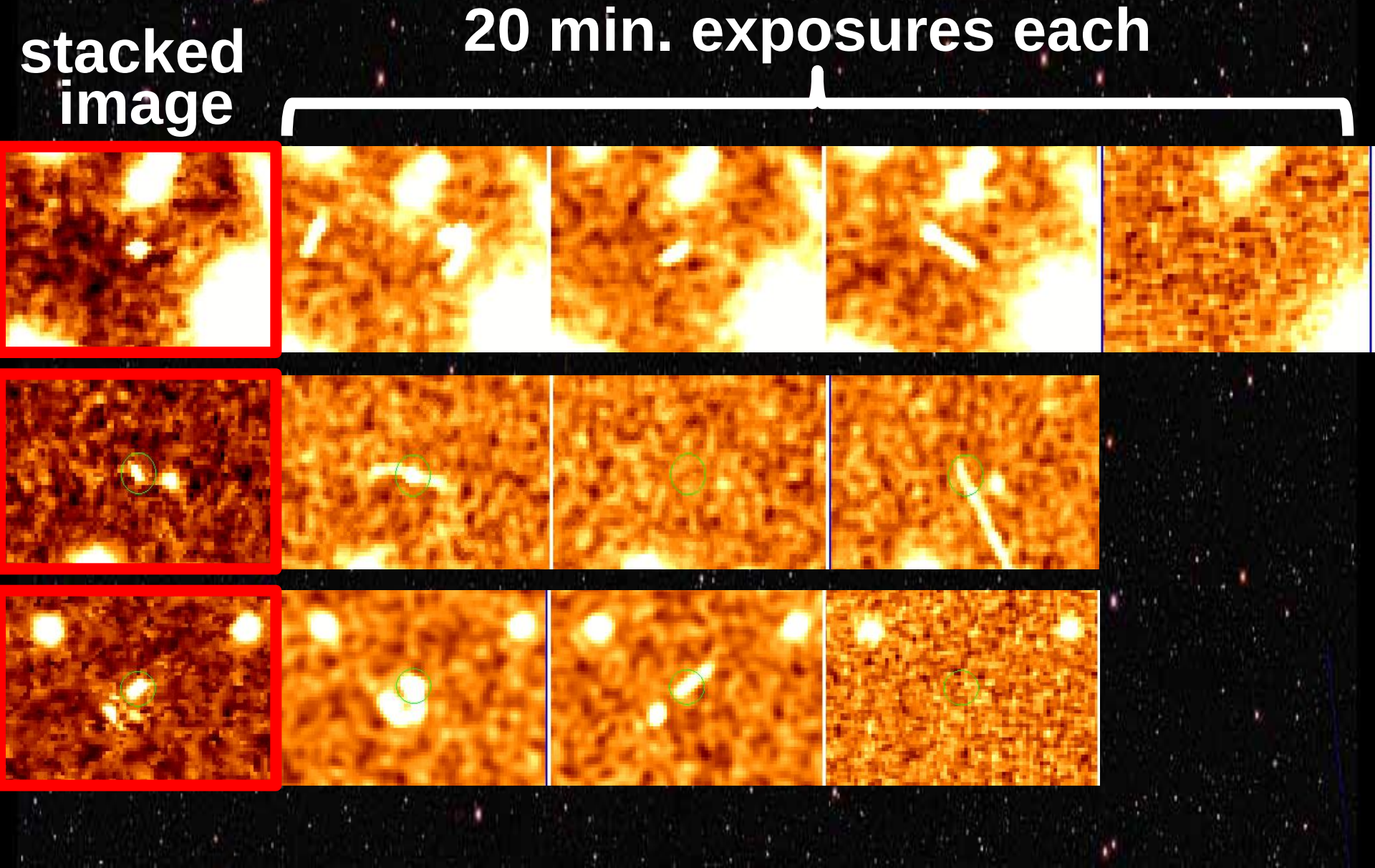
A few objects satisfied selection criteria, but …







Unfortunately, they were all found to be cosmic ray events hitting the same positions.



Next Plan: Extending to other lensing clusters

Deep multi-wavelength images are available from archive!

Hubble WFPC2, ACS Camera: Optical Images～27-28mag

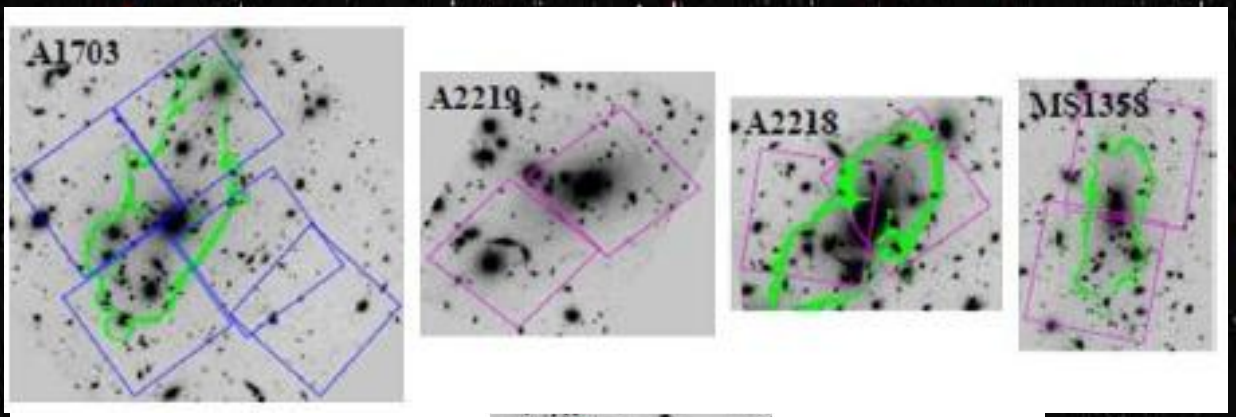
Hubble NICMOS Camera: Near-infrared Images～26-27mag

Spitzer IRAC Camera: Mid-infrared Images～24mag

Hubble

Spitzer

Optical to mid-Infrared data



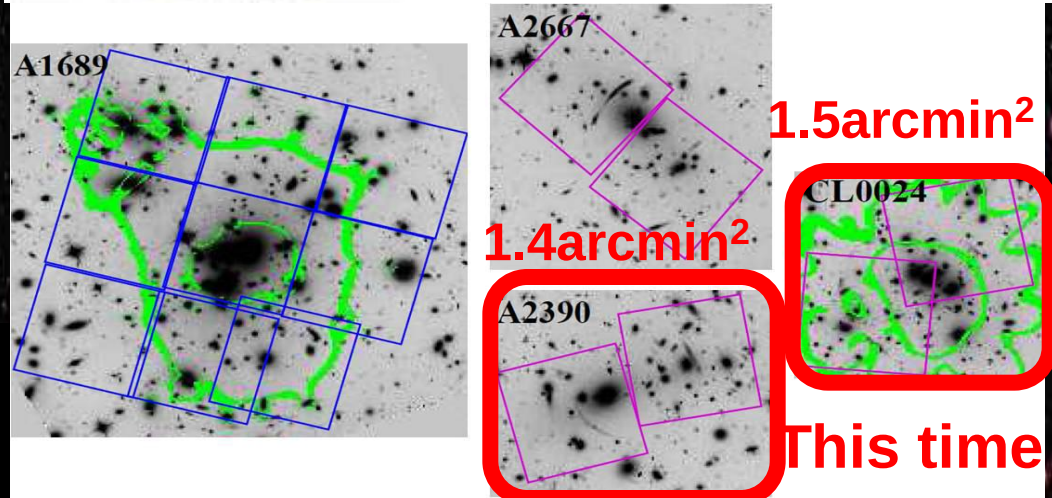


Figure: Bouwens et al.(2009)

Summary

Objectives

(1) To find galaxy at z=7.3

(2) To study cosmic reionization at z>7

Observation

I searched for z=7.3 Lyα emitting galaxies by imaging two lensing clusters A2390, CL0024

Result

I could not detect z=7.3 galaxies

Next plan

I will extend the study to other lensing clusters