First Unbiased Estimates of the Metallicity and Star-Formation Activity of Lyman Alpha Emitters

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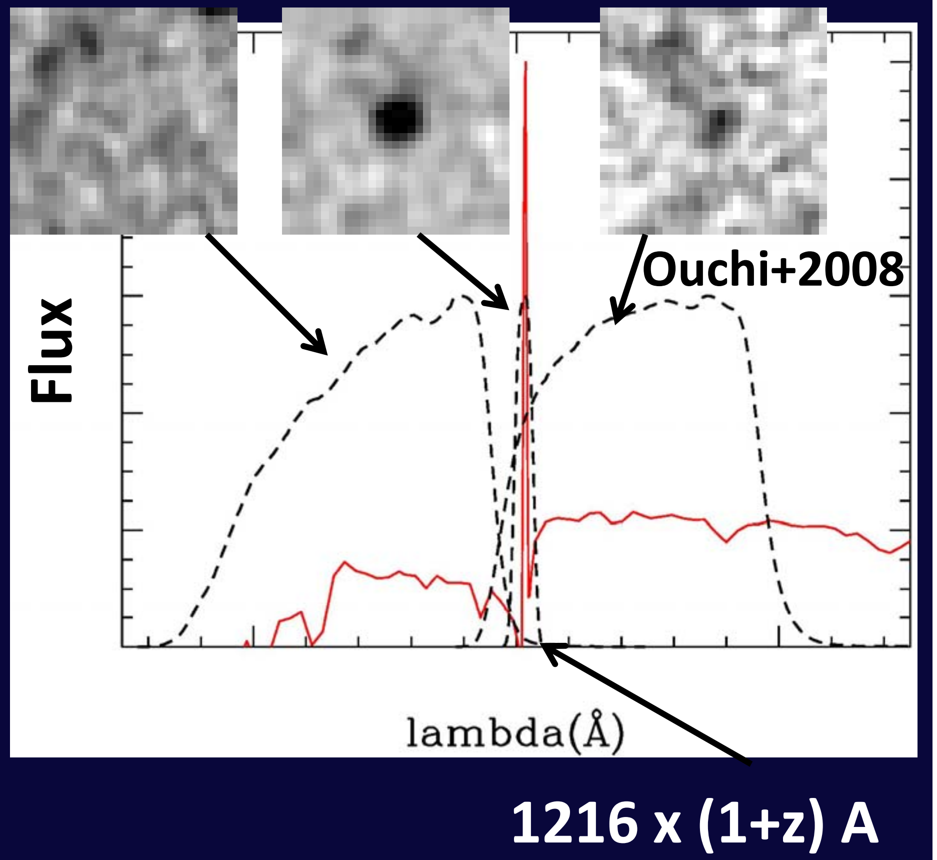
Lyman Alpha Emitters (LAEs)

- Galaxies with strong Lyα emission, faint UV continua
  - young, low-mass, and actively star-forming
  - → promising candidates of building blocks of future massive galaxies
  - → clues to solve the mystery of galaxy formation/evolution



1. Introduction

Unsolved problems about LAEs

□ No reliable measurements of SFR and metallicity

- Combinations of nebular emission → detailed measurements
- At z>3, spectroscopy of nebular emission(and Hα) is very difficult
- SED fitting is frequently used, but has some problems (e.g., metallicity degenerates with age; Ono+2010a)

□ A solution is …

- to observe lower-z LAEs

→ Nebular emission can be obtained from the ground

- At z<2, Lyα is not observable from the ground

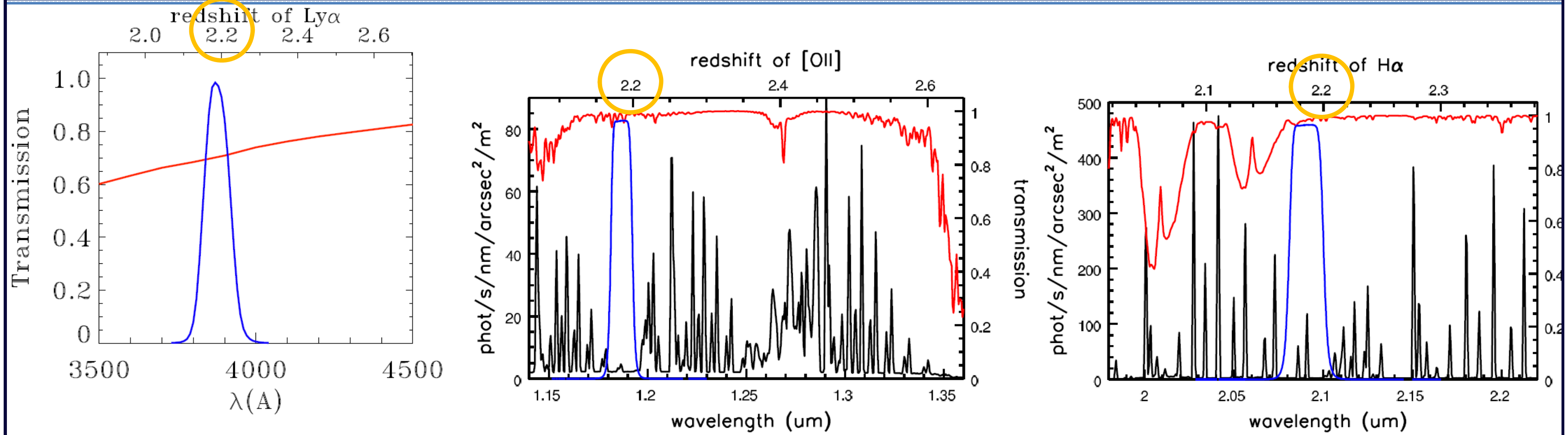
→ LAEs at z=2-3 are good targets !

1. Introduction

Outline of our study

☐ Focus on LAEs at z=2.2

NB387	NB118	NB209
Lyα	[OII]	Hα (+[NII])



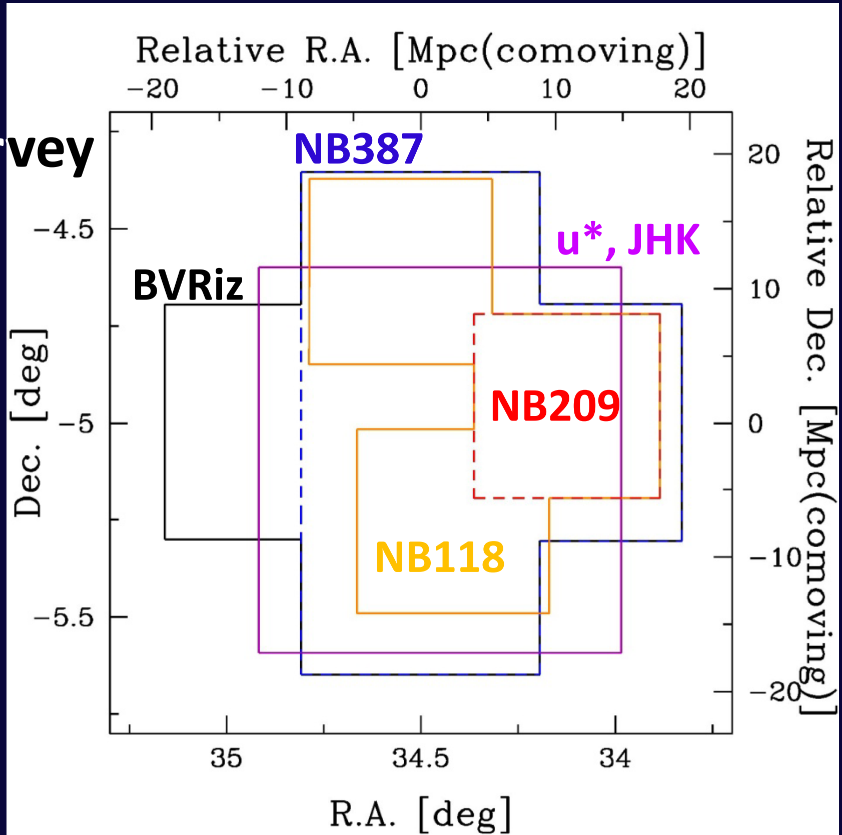
Blue : Narrowband　　© Ouchi, Lee
Red : Transmission of the atmosphere
Black : OH-airglow

☐ Derive SFR and Metallicity

- Hα → SFR
- [OII] + Hα → Metallicity

Data

- **Field : Subaru/XMM-Newton Deep Survey** (SXDS; Furusawa+2008)



- **Imaging Data**

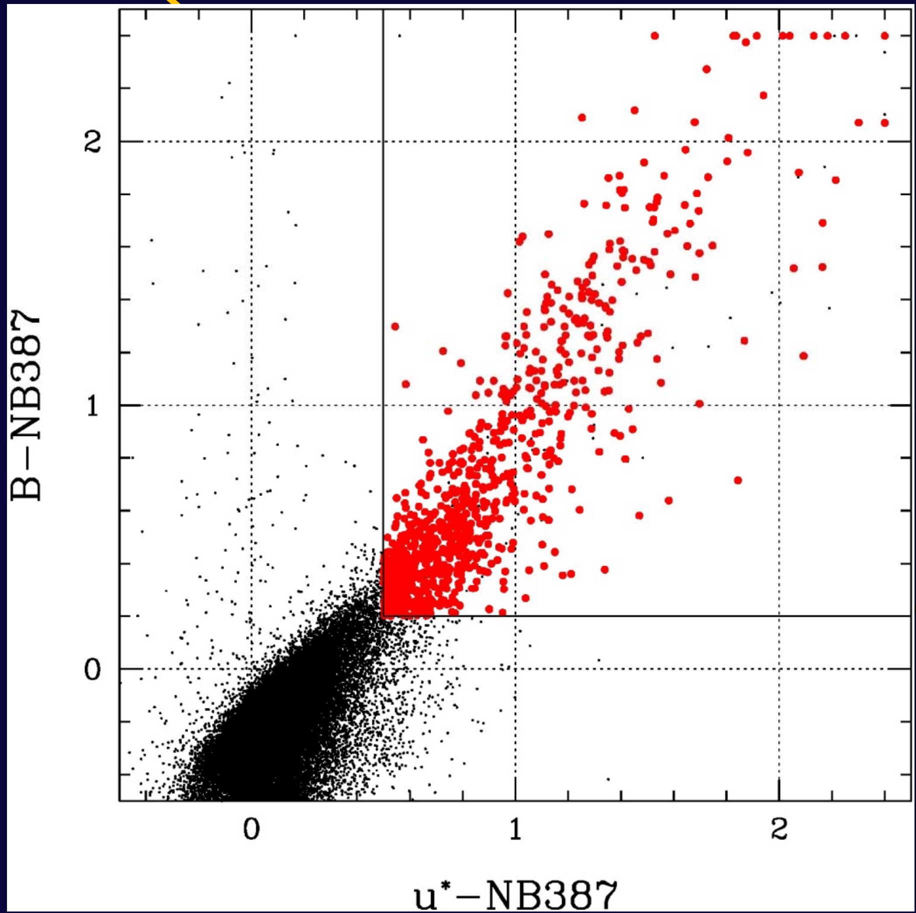
Band - Instrument, PI	Limiting mag (5σ, aper)	Area (arcmin^2)
NB387 - Suprime-Cam - Ouchi+	~25.6 AB (2.0”)	~2000
u* - CFHT/MegaCam - Foucaud+	~27.0 AB (2.0”)	~2000
BVRiz - Suprime-Cam - Furusawa+	26 - 28 AB (2.0”)	~2000
JHK - UKIRT/WFCAM - Lawrence+	~24.6 AB (2.0”)	~2000
NB118 - KPNO/NEWFIRM - Lee+	~22.6 AB (3.5”)	~1300
NB209 - KPNO/NEWFIRM - Lee+	~22.2 AB (3.5”)	~350

2. Data and Selection method

Selection of z=2.2 LAEs

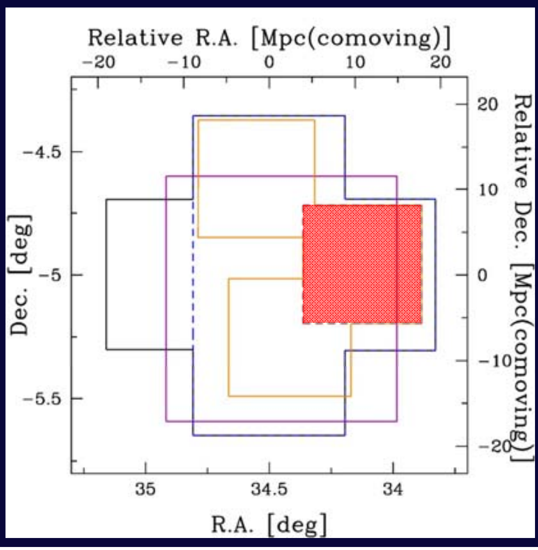
- Combination of NB387 with u* and B
  - Emitters with EW > 40A fall into this region
  - → Emitter candidates

Black : All objects (NB387)
Red : LAE candidates



- 919 candidates are found !

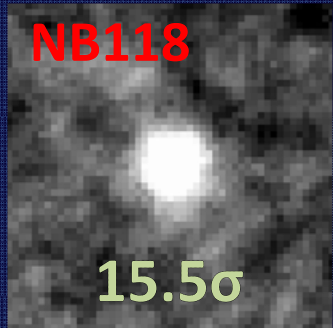
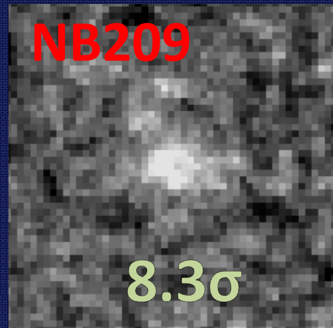
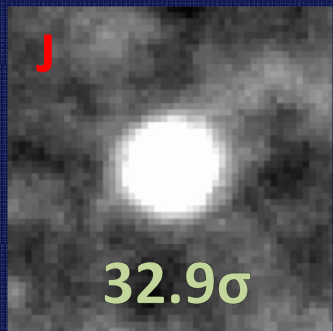
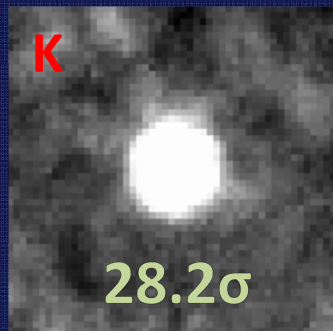
→ **105** candidates have both NB118 and NB209



Stacking of 105 objects

- Stacking images of each LAEs to increase S/N ratio and detect [OII] and Hα: "Stacking Analysis"

→ typical, and unbiased properties of LAEs

	[OII]	Hα
Narrow-band		
magnitude [3.2", AB]	24.33±0.07	23.95±0.13
Broad-band		
magnitude [3.2", AB]	24.72±0.03	24.54±0.03

First detections of [OII] & Hα from typical LAEs

- J – NB118 = **0.39 ± 0.08** → EW_{rest} (OII) = **98 (+22/-19)** A
- K – NB209 = **0.60 ± 0.14** → EW_{rest} (Hα) = **207 (+206/-90)** A

→ First detections of [OII] and Hα from typical LAEs !!

□ NB387 and u* images are also stacked in the same manner

- u* – NB387 = **0.66 ± 0.03** → EW_{rest} (Lyα) = **86 (+5/-5)** A

SFR from L(Hα)

- Hα luminosity is a good indicator of SFR (e.g., Kennicutt+1998)

	EW (A)	Luminosity (erg/s)	SFR (M_{sun}/yr)
Hα	207 (+206/-90)	(6.9 +/- 1.4) e+41*†	5.5 +/- 1.1*†
(Lyα	86 +/- 5	(1.8 +/- 0.04) e+42*	1.8 +/- 0.04*)

* Dust-Uncorrected
† [NII] is subtracted

→ typical LAEs have smaller SFRs than LBGs at high-z
(consistent with past results by SED fittings; e.g., Gawiser+2006)

- M* is derived from SED fitting (Ono+ in prep.)
  - M* = 5 x 10^8 M_{sun}

  → much smaller than other high-z populations (M*>$10^9$$M_{sun}$)

Lyα escape fraction: f_{esc}(Lyα)

- A fraction of Lyα photons that can escape from a galaxy
  - f_{esc}(Lyα) = L_{obs}(Lyα)/L_{int}(Lyα) = L_{obs}(Lyα)/(8.7xL_{int}(Hα)) = 35%

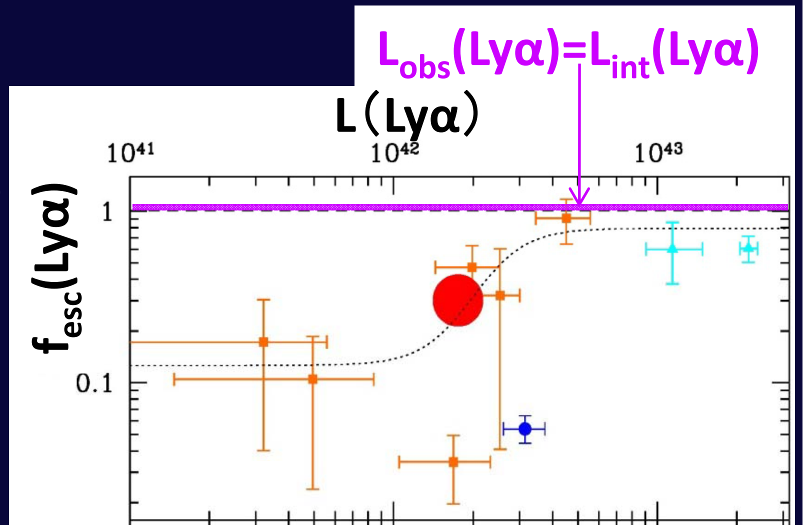
    → larger than those of HAEs and LBGs with Lyα

    + HAEs : f_{esc}(Lyα) ~ 5% (Hayes+2010)

    + LBGs : f_{esc}(Lyα) ~ 5% (Kornei+2010)

  - Brighter LAEs have larger f_{esc}(Lyα) (?)

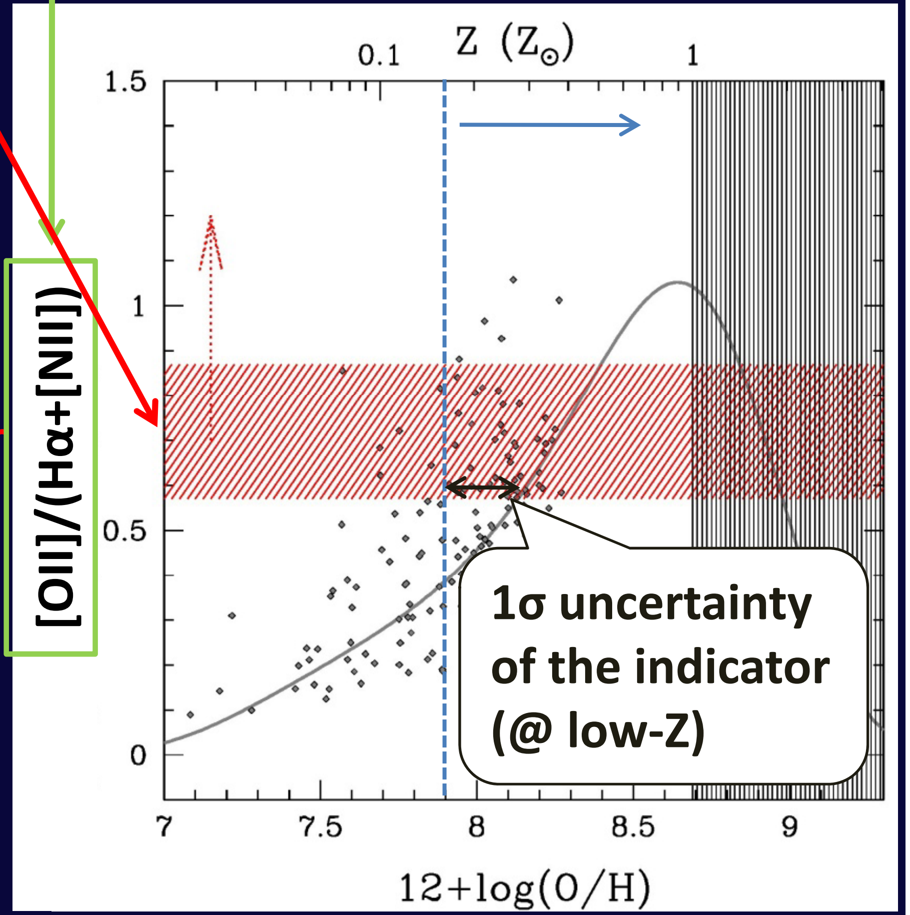
    → galaxies with higher f_{esc}(Lyα) are more easily selected as LAEs



Orange ■ : Hayes+2010
Cyan ▲ : Finkelstein+2010
Blue ● : NB209-detected LAE
Red ● : our result (stacked LAE)

Metallicity

- The ratio of [OII] and Hα+[NII] can be an indicator of metallicity
  - Combine two indicators: [OII]/Hβ and [NII]/Hα（Maiolino+2008）
  - → Empirical metallicity indicator : [OII]/(Hα+[NII])
  - [OII]/(Hα+[NII]) = 0.72 +/- 0.15
  - → $Z > \sim 0.15\, Z_{sun}$
  - → First constraint on lower-limit of metallicity for LAEs



- Typical LAEs are not so metal-poor

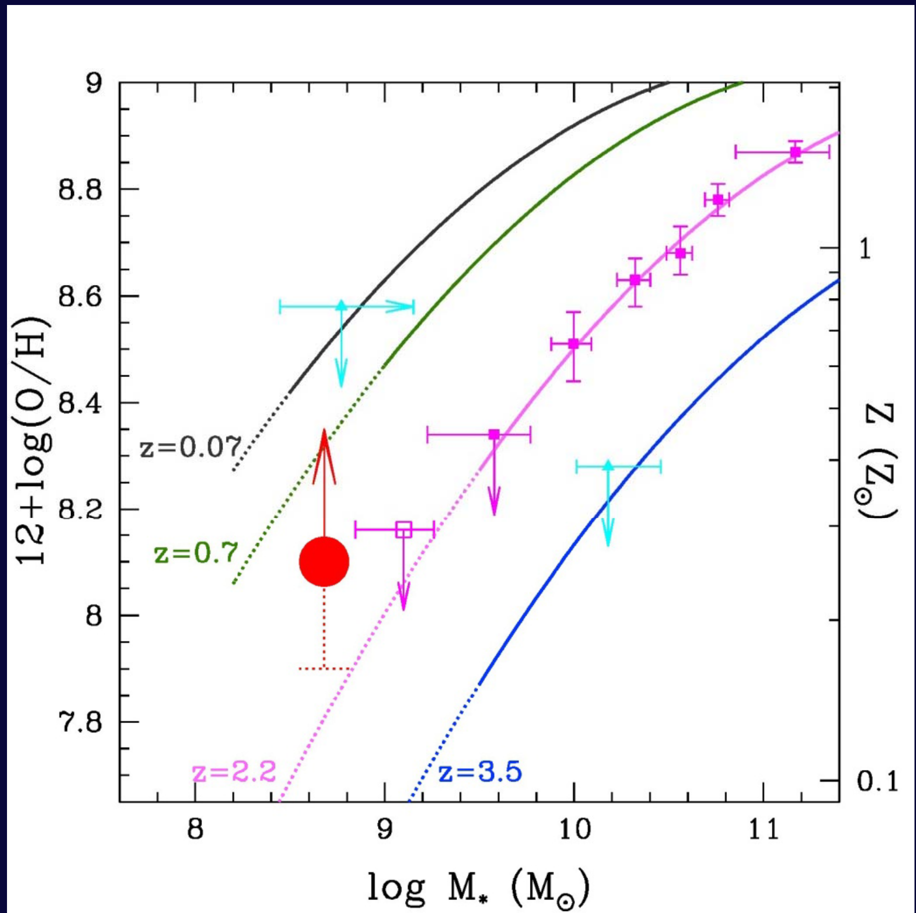
→ do not support the hypothesis that LAEs are extremely metal-poor galaxies (e.g., Schaerer 2003)

Mass-Metallicity Relation

☐ M-Z relation is known to evolve with redshift

- Our result have an offset from the M-Z relation at z~2 (Erb+2006)

Solid lines : Maiolino+2008
Magenta ■ : Erb+2006,2010
Cyan ▲ : Finkelstein+2010
Red ● : our result (stacked LAE)



4. Discussion

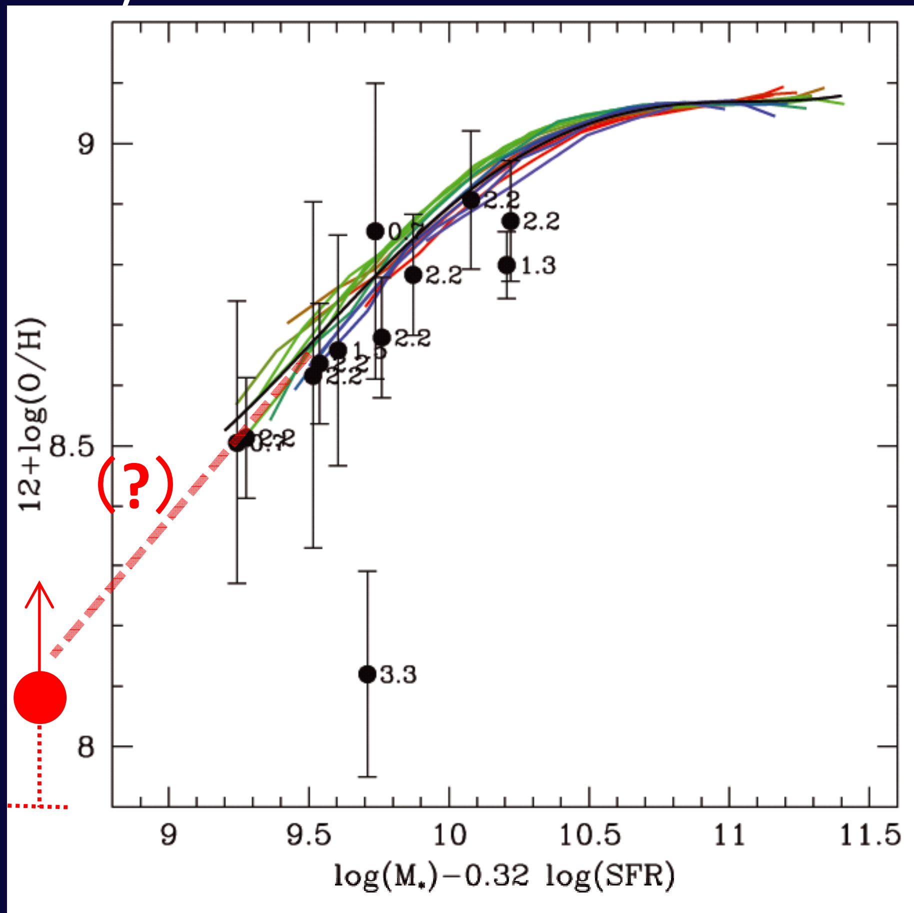
Fundamental Metallicity Relation

☐ SFR can be a key parameter to describe the M-Z relation

→ FMR (Mannucci+2010, Richard+2010)

- High SFR → low metallicity
- Our result is placed near a smooth extrapolation of the FMR

→ The offset seen in the M-Z R. may be due to small SFRs of LAEs



Solid lines : Mannucci+2010
Black dots : Mannucci+2010
Red ● : our result (stacked LAE)

Mannucci+2010

Summary and future works

- We carry out Suprime-Cam/NB387 imaging survey to find LAEs at z=2.2
  - 919 LAE candidates are selected in the SXDS field
- Stacking of 105 objects yields the first detections of [OII] and Hα from typical LAEs (NB387 < 25.6AB)
  - EW_{rest} (OII) = 98 (+22/-19) A, EW_{rest} (Hα) = 207 (+206/-90) A
  - SFR = ~6 M_{sun}/yr : much smaller than that of LBGs
  - f_{esc}(Lyα) ~ 35 % : larger than those of other populations
  - Z > ~ 0.15 Z_{sun} : larger than that inferred from the M-Z relation

  → our result supports the FMR in the lower M* side
- Keck/NIRSPEC follow-up observation will bring more information of LAEs in detail !!