

The overview of our search for Lyman-alpha emitters and absorbers at $z=3.1$

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- Overdensity
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- EW distribution

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1. Introduction

Our observational study;

The $z=3.1$ high-density region of Lyman-alpha emitters in “SSA22-field”

wide-area (1.4 deg^2) and deep narrow-band surveys with Suprime-Cam of Subaru Telescope

Our aim;

- Characterize the Overdensity of Original High-Density Region (Steidel et al., 2003; Hayashino et al., 2004)
- Properties of LAEs as a Function of Local Density (Environment)
→ This talk
- Search and build a new sample of Lyman-alpha Blobs
→ Matsuda's talk (next day)

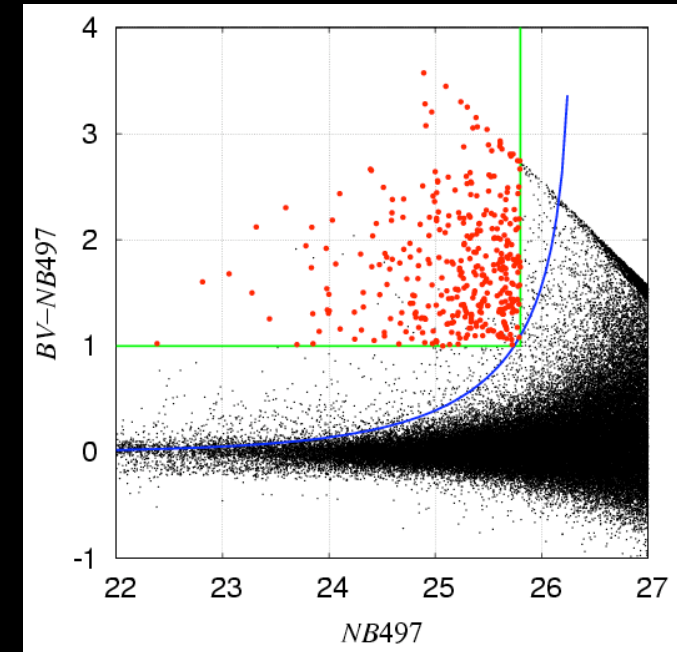
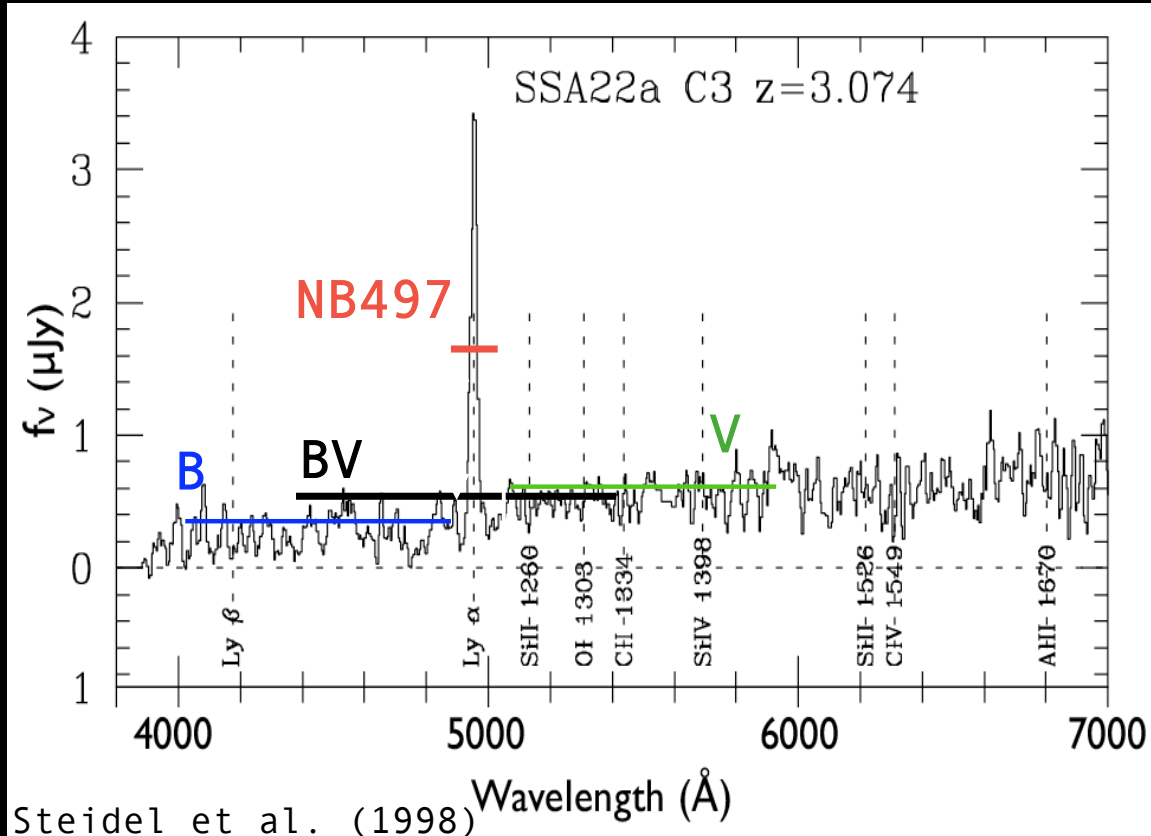
Summary of the data

	Exp-time B	Exp-time V	Exp-time NB	NB497 Sensitivity	Image size
	(hour)	(hour)	(hour)	After reddening correction 5σ ($2''\phi$)	After combined (arcsec)
SSA22 -Sb1	1.5	1.5	7.0	26.331	1.0
Sb2	1.0	1.0	5.5	26.251	1.0
Sb3	1.0	1.0	5.5	26.229	1.0
Sb4	1.0	1.1	5.5	25.867	1.2
Sb5	1.0	1.0	5.5	26.109	1.0
Sb6	1.25	1.25	5.5	26.274	1.0
Sb7	1.0	1.0	5.5	26.148	1.0

We obtained ~ 1.4 deg² homogeneous data.

We also obtained the equivalent data in general fields with ~ 1 deg² area

LAE Detection



Robust
LAE
sample

LAE Detection Criteria

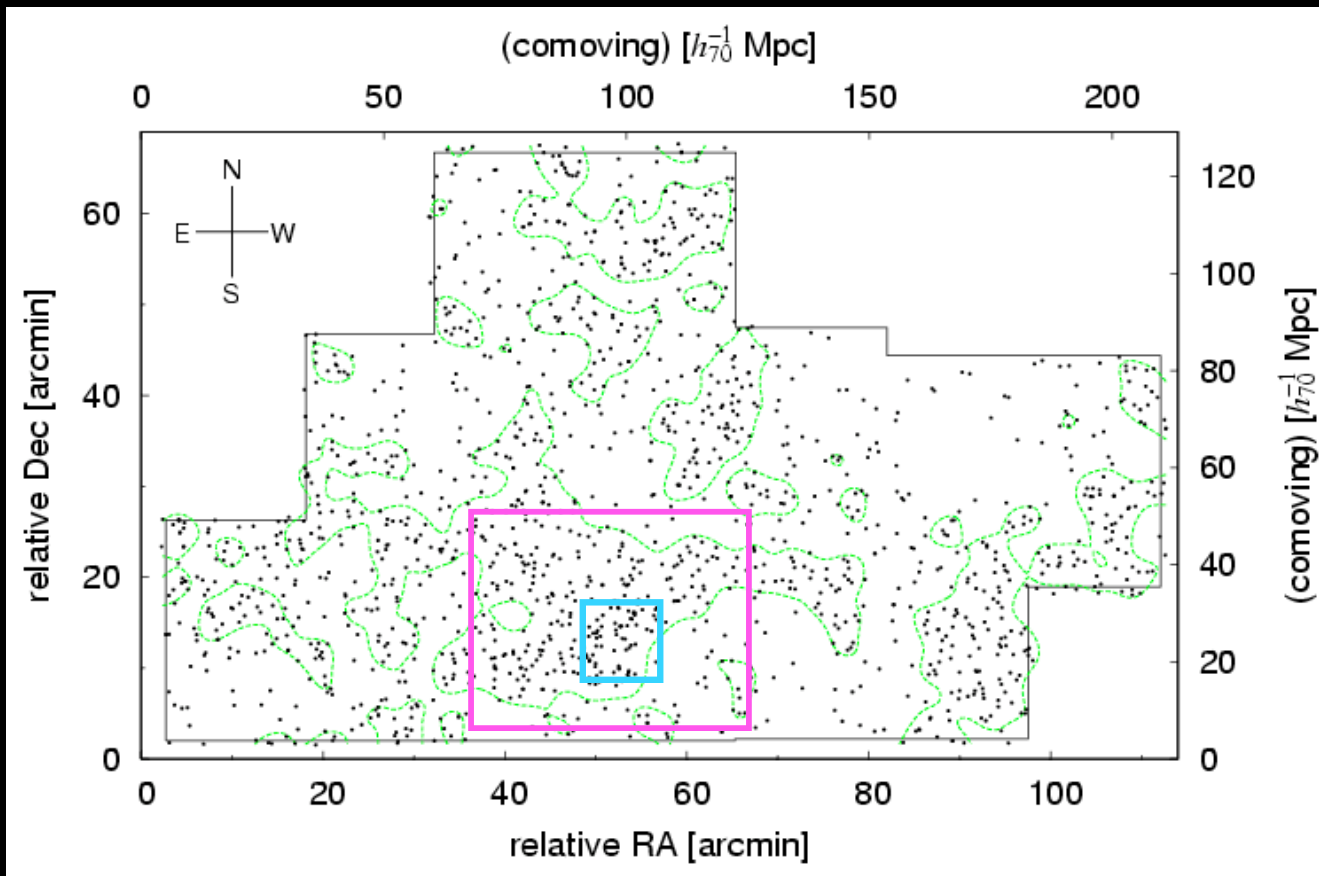
- | | |
|----------------------------------|--|
| (1) $NB497 < 25.8$ (ABmag) | (4) $V_c < 26.6$ ($S/N < 4$): $B-V_c > 0.2$ |
| (2) $BV-NB497 > 1.0$ | (5) $V_c > 26.6$ ($S/N > 4$): $BV-NB497 > 1.3$ |
| (3) $BV-NB497_{color} > 4\sigma$ | |

$$BV = (2B + V) / 3$$

2. Results: Statistical Properties

- Spatial Distribution
- Overdensity
- Angular Correlation Function
- Luminosity Function
- EW Distribution

Large-Scale High Density Region of LAEs at $z=3.1$

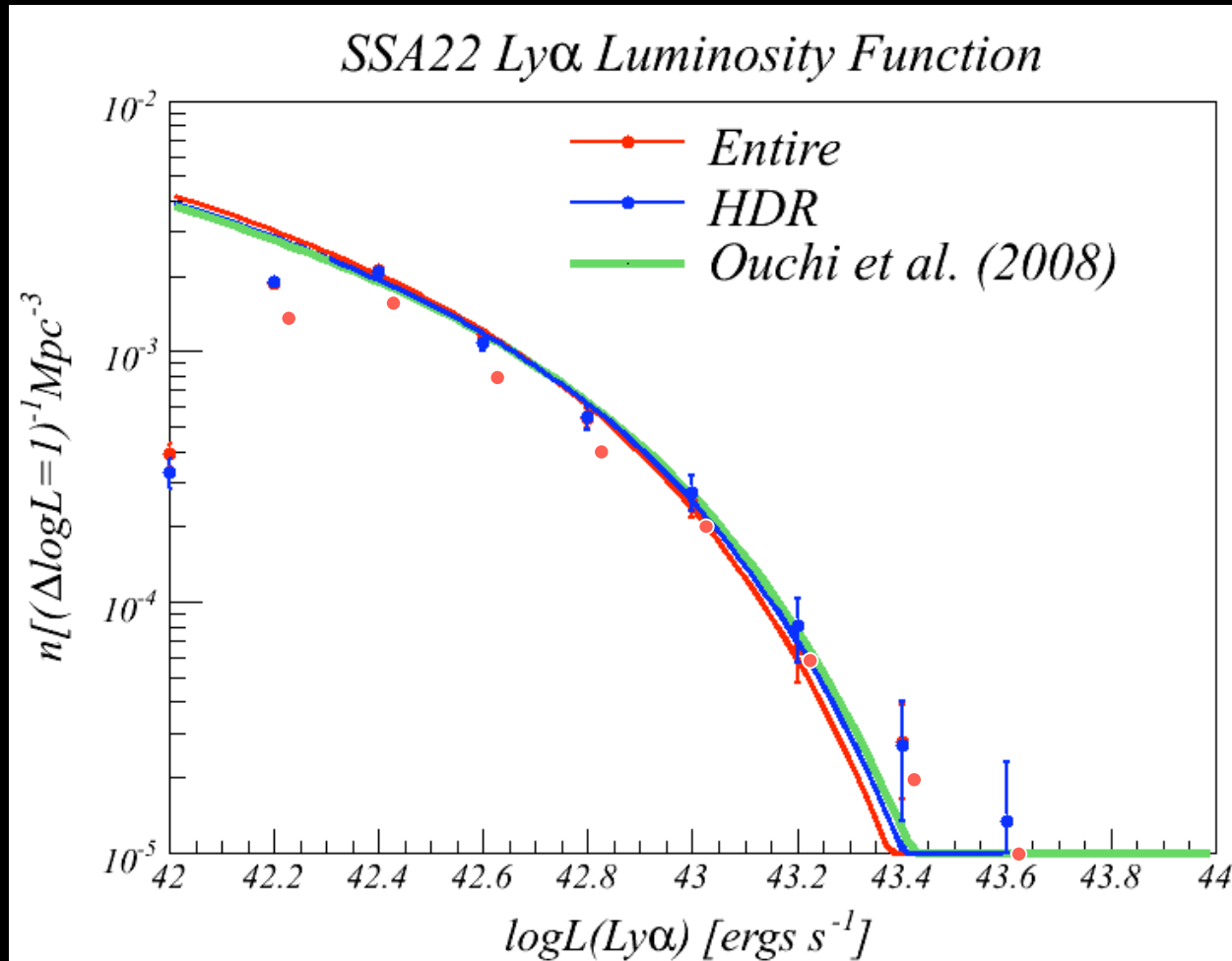


Black dots: LAEs ○ Average number density of LAEs
 Our first survey area; Sb1 Steidel's observing area

Entire field:
1412

	Num	10^{-3}Mpc^{-3}
Sb1	288	2.07
Sb2	171	1.14
Sb3	183	1.26
Sb4	187	1.15
Sb5	201	1.36
Sb6	154	0.95
Sb7	228	1.33

The shape of Luminosity Function (Lyman-alpha)



Entire:
 $\varphi^* = 2.76e-3$
 $L^* = 5.06e42$
 $\alpha = -1.5$

HDR:
 $\varphi^* = 2.44e-3$
 $L^* = 5.50e42$
 $\alpha = -1.5$

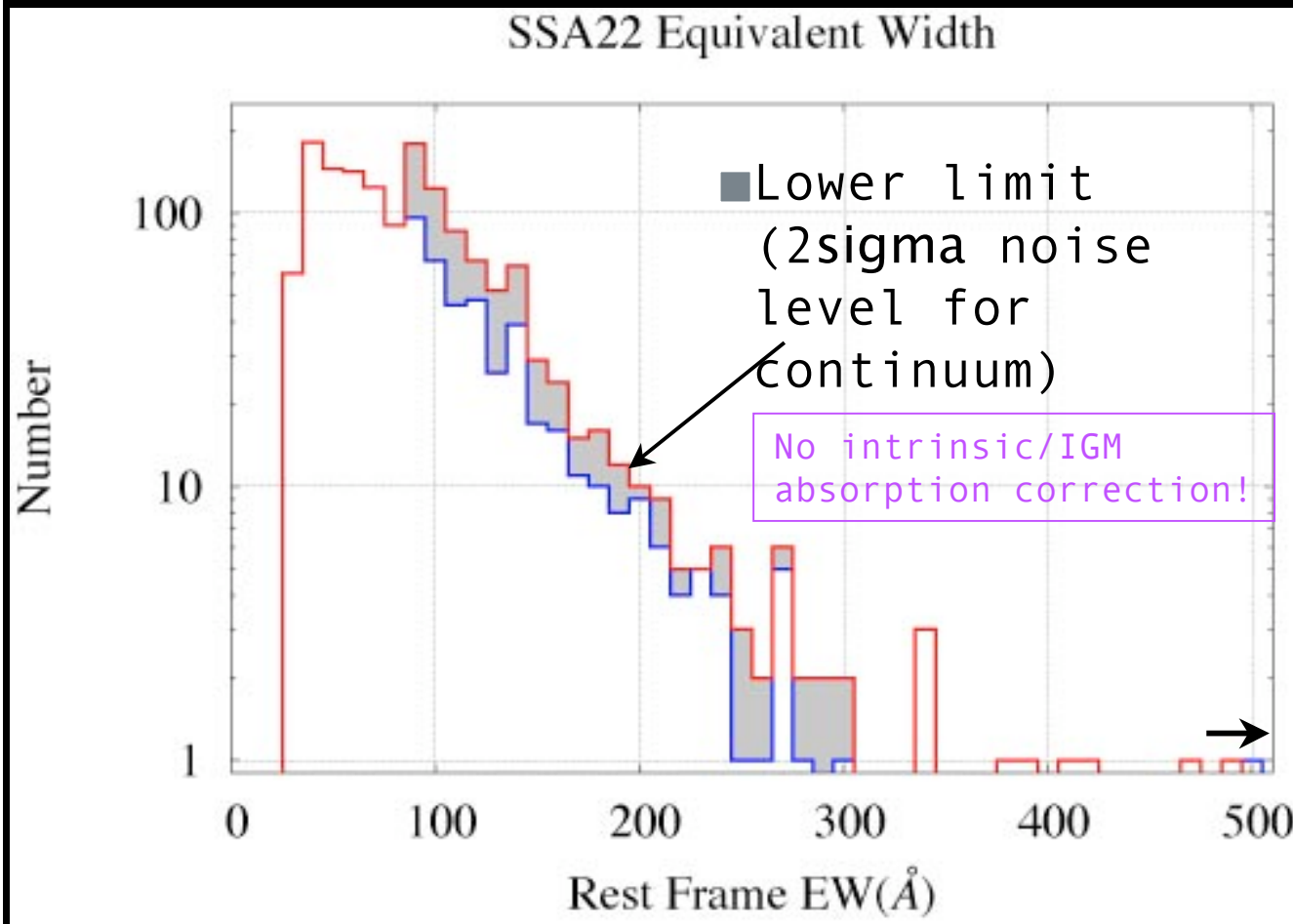
Ly α LFs
have very
similar
shape !

The vertical value is normalized at L^* in the entire region.

3. Unique Nature of SSA22 HDR

- Large EW Galaxies
- Lyman Alpha Absorbers

Very Large Equivalent-Width Objects



We find a lot of very large EW objects!

Number of objects

$EW_0 \geq 500 \text{ \AA}$ 1

$300 \leq EW_0 < 500$ 11

$200 \leq EW_0 < 300$ 45

$100 \leq EW_0 < 200$ 429

$EW_0 < 100$ 926

$EW_0 \geq 200 \text{ \AA}$ 4%

$EW_0 \geq 100 \text{ \AA}$ 35%

What are large EW objects?

1. Photoionization by UV

- A flatter slope of IMF
- Small metallicity
- Young Age (Malhotra et al.2002, Schaerer et al.2003)

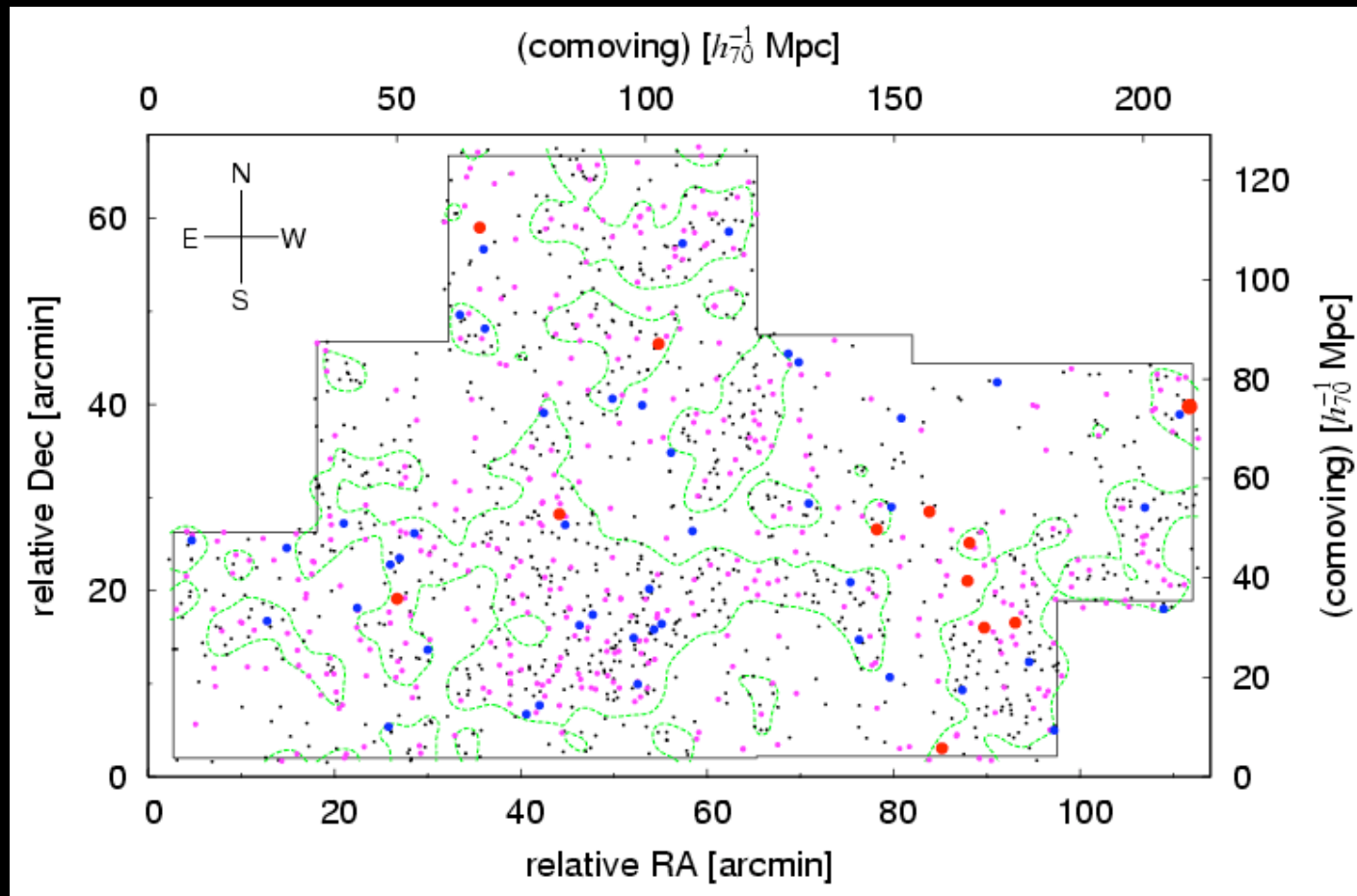
2. Cooling radiation from gravitationally heated gas in collapsed halos

3. Shock heating by starburst-driven galactic superwind

Current observational data is not enough to discriminate these possibilities

- pure Lyman-alpha clouds ? (e.g., Nilsson et al. 2006)
→ cooling collapse radiation?
- superwinds ? search for metal lines (→ ELT)
- any characteristic in clustering
/ density environment? young age / low-metal
- HeII line? → POPIII ?
(we obtained ~50 spectra with Keck/DEIMOS,
though not in this talk)

Very Large Equivalent-Width Objects



Red circle;
 $EW_0 \geq 300 \text{ \AA}$

Blue circle;
 $200 \leq EW_0 < 300$

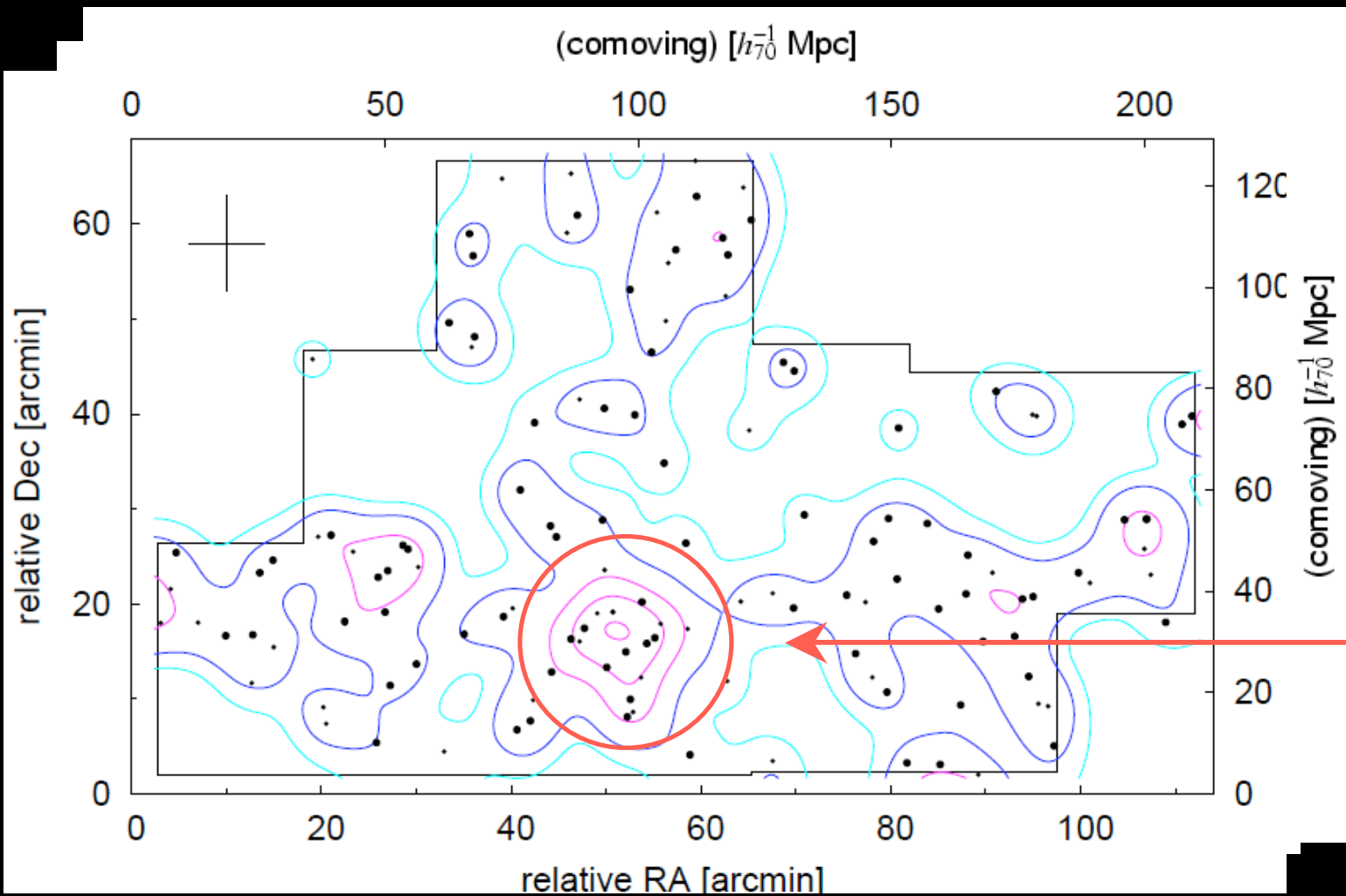
Magenta;
 $100 \leq EW_0 < 200$

$EW_0 \geq 300 \text{ \AA}$; seem to locate the outskirts of the high/low density region.

On the other hand, $200 \leq EW_0 < 300$; exist density peak of LAEs

* Include lower-limit objects due to shallow V

Density Map of Large EW ($>150\text{\AA}$) LAEs

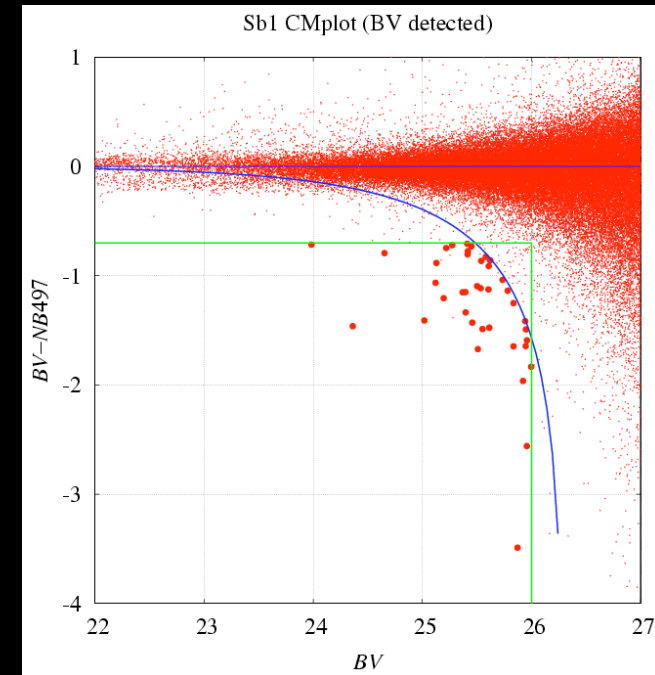
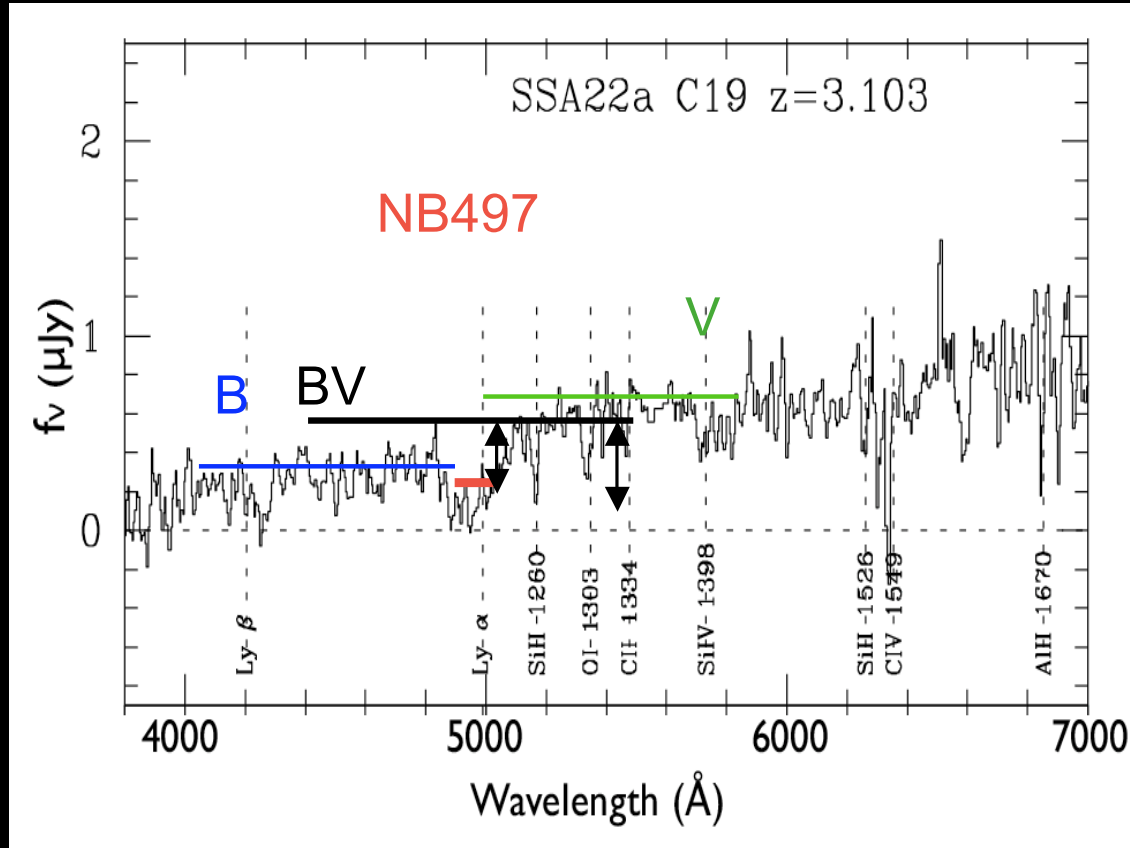


We can show a cluster of large EW LAEs at Sb1.

Very Interesting region!

Lyman-alpha Absorbers at
 $z=3.1$

LAA Detection



LAA Detection Criteria

- (1) $22.0 < BV < 26.2$ (ABmag)
- (2) $BV - NB497 < -0.7$
- (3) $BV - NB497_{\text{color}} > 4\sigma$ (for Sb2)

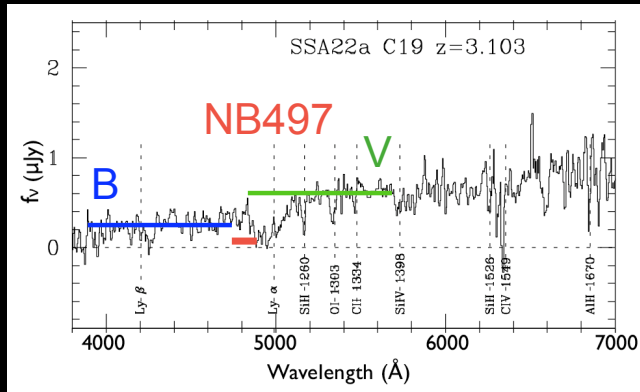
$$(4) B - NB497 < -0.3$$

$$(5) 0.4 < B - V < 3.0$$

$$(6) B > 21.0 \ \& \ V > 21.0$$

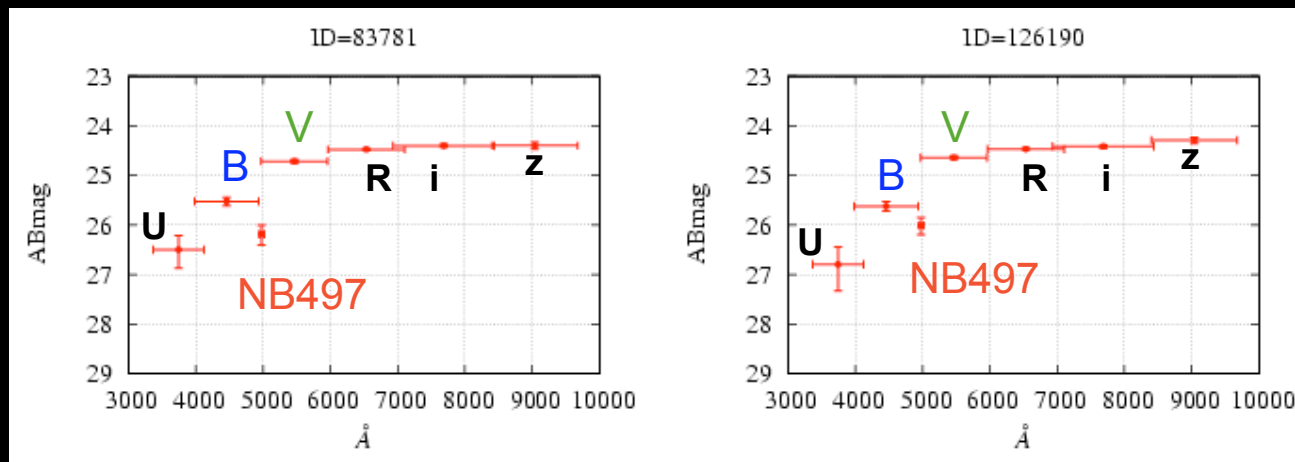
$$BV = (2B + V) / 3$$

What are the LAAs?



The spectrum of LBG

Steidel et al. 1998



The SED of our LAAs

In our simple comparison, $\sim 85\%$ of our LAA's SEDs are very similar to the spectrum of LBGs.

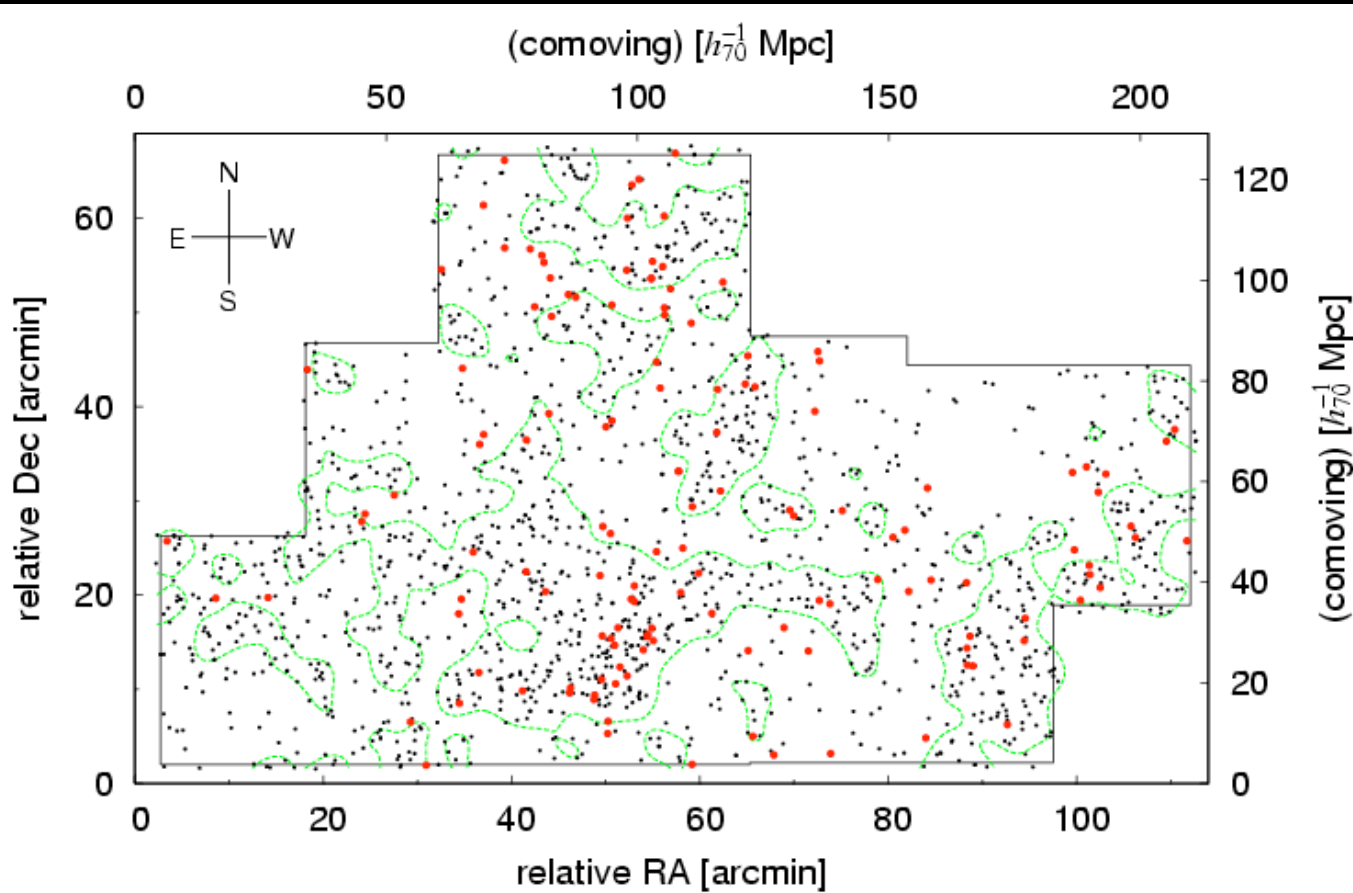
Lyman-alpha Absorbers

- LAAs density peak \leftrightarrow LAE density peak
- At the same time, LAA seem to locate at the outskirts of LAE HDR in other field

Red

circle:

LAA



Entire: **137**

	Num	10^{-4}Mpc^{-3}
Sb1	32	2.3
Sb2	22	1.5
Sb3	9	0.62
Sb4	8	0.49
Sb5	19	1.3
Sb6	16	0.98
Sb7	31	1.8

Summary

- We detected **1412 LAEs** in SSA22 region (~ 1.4 degree²).
- We found these **overdensity is very large** \sim .
- On Angular Correlation Function, LAEs show **strong clustering in entire region**, while **homogeneous distribution in HDR**.
- We found **Lyman-alpha Luminosity Functions are very similar** shape in entire region to HDR.
- We can obtain the LAEs with large EW (**$EW_0 > 200 \text{ \AA}$; 57 LAEs**). **POPIII star?**
- We also detect **137 LAAs**.

SSA22 region has various objects, so we can see the forming galaxies on time in this region.