CHARACTERIZATION OF THE DISTRIBUTION OF THE Ly α EMITTERS IN THE 53W002 FIELD AT z = 2.4

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ABSTRACT

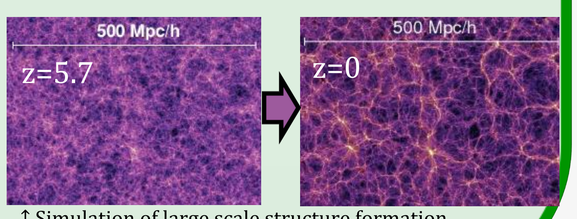
We present the results of the wide-field (31'×24') narrow band (custom-made NB413) imaging of the field around the radio galaxy 53W002 (the 53W002 field or 53W002F) with Subaru/Suprime-Cam. **We detected the 204 Ly α emitters (LAEs) at z = 2.4** down to 26 AB mag (NB413) with the rest frame equivalent width (EW_0) larger than 25 Å. We also detected the 4 Ly α blobs (LABs). The entire LAE population in the 53W002 field have the number density, EW and size distributions similar to those of other fields at z ~ 2. **We identify the significant high density region (53W002F- HDR)** that spreads over ≈ 5′ × 4′ and have the LAE number density of nearly four times as dense as the average of the entire field, while only a fraction of the objects detected by the previous medium-band survey was proved to be at z = 2.4. **Using the probability distribution function (PDF)** of mass fluctuation we evaluate its rareness probability, and **find that 53W002F-HDR is the moderately rich structure with the rareness probability of ~ 0.9 %. The distributions of the Ly α EW and luminosity in the 53W002 field show no notable environmental dependency at the scale of 10 Mpc**, which is also confirmed by using the data of the other fields. By contrast, the four LABs are all found to be located in the rims of high density regions.

I, Introduction & Aim of this study

53W002F is the field around the radio galaxy 53W002, where Pascarelle et al.(1996a,b,1998) and Keel et al.(1999) detected many LAEs at z~2.4. These previous observation, however, are insufficient because (1)the width of their used medium-band filter was too broad (correspond to z=2.3-2.42), and (2)they used the deep but limited FoV data (*HST*) or wide-field but shallow data (ground-based). So they cannot lead the definite picture of 53W002F in large scale (large scale structure, LSS).

When characterizing the structures (environments) at high-z, we should use the parameter that takes account of the cosmological structure formation rather than galaxy or mass density. For structures that have same density but lies at different redshits are not equivalent.

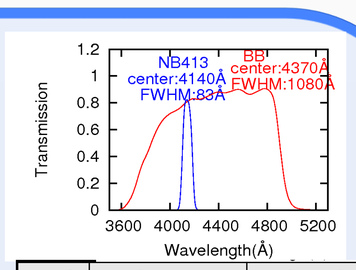
From the above, our aims are
- **clarifying the LSS traced by LAEs in 53W002F,**
- **evaluating the high density region,**
- **searching environmental dependency of LAEs**



↑ Simulation of large scale structure formation
Millennium Simulation
(http://www.mpa-garching.mpg.de/millennium/)

II, Observation & Analysis

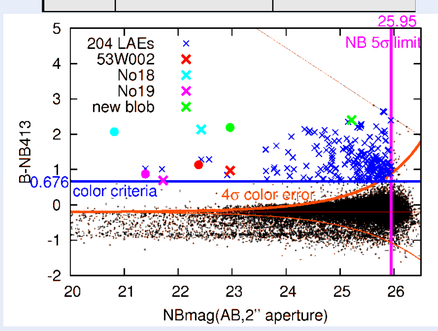
- ✓ **Instruments** : Subaru/Scam, B + NB413 filter
- ✓ **Target** : (α , δ)=($17^h14^m10^s.3$,+50°16'07'')
- ✓ **PSF** ~ 0.9''
- ✓ **Available FoV** = 707 ($arcmin^2$)
  => Volume ~ 50×40×90 Mpc^3 (comoving, @z=2.4)



Band	Total exposure(hour)	5σ detection limit(ABmag)
B	1. 0	26. 70
NB413	3. 5	25. 95

(LAE selection analysis)

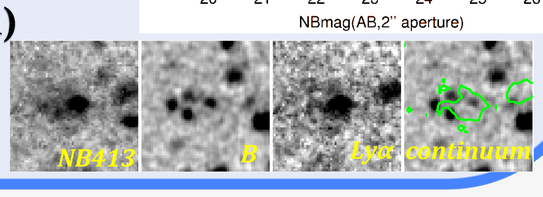
- ✓ Selection based on color-magnitude diagram
  1, NB413<25.95
  2, B-NB413>0.68(⇔EW_0 > 25Å)
  3, B-NB413>color-error(4 σ)



204 LAEs (at z=2.4)

(Ly α & continuum information)

- ✓ Using the NB413 and B images, we made the Ly α & continuum images artificially!



III, Results

1, Identification of High Density Region

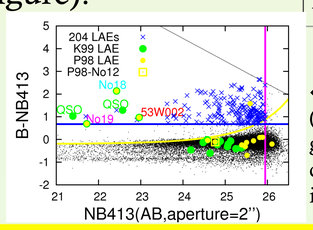
We revealed the large scael structure traced by LAEs in 53W002F clearly (see the right figure). We identified the 5' × 4' region around the most dense point as the significant high density structure (53W002F-HDR).

Their LAE number density ($4.3×10^{-3}Mpc^{-3}$) is nearly four times as dense as the mean of the entire field.

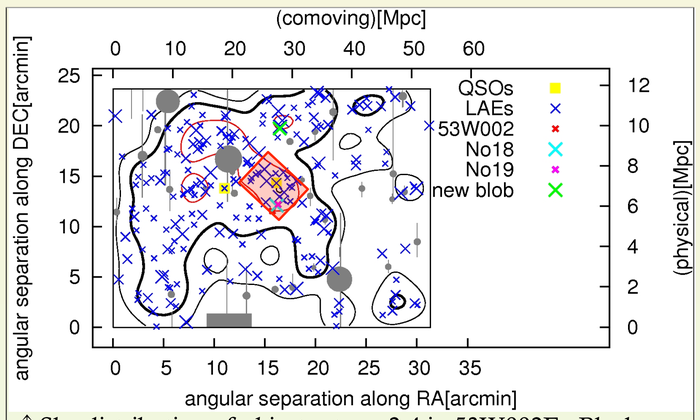
2, Difference from previous works

We compared our results with the previous LAE searches in 53W002F. Most of the LAEs previously reported are not selected in our analysis (see the bottom figure).

This may be due to the difference of the filters (previous works used medium band). Our NB413 is expected to sample the LAEs from z=2.4 thinner sheet whose depth is 90Mpc (comoving).



←The LAEs previously reported (yellow circles: Pascarelle et al. 1998, green circles: Keel et al. 1999) in our color-mag diagram. Most of them are in the featureless sequence (B-NB~0).

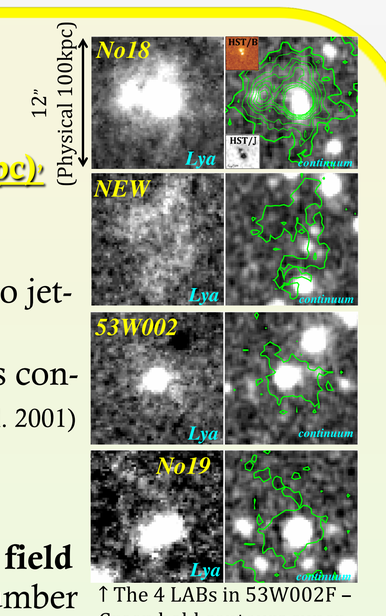


↑ Sky distribution of objects at z = 2.4 in 53W002F - Black lines correspond to contours of smoothed LAE number density: the mean (bold line), 0.5 × mean, 2 × mean (red) and 2.85 × mean of the entire field.We call the most high density region as 53W002F-HDR (orange rectangle).

3, Ly α Blobs (LABs)

LAB selection criteria is,
isophotal area(2 σ in Ly α)
> $10arcsec^2$ (extent of ~30kpc),
⇒ **4 LABs**

Especially unique one is **No18**!!
- Morphologically, it has the two jet-like structures/two tails.
- Central core has the two knots connected with AGN.(Motohara et al. 2001)
- No18 was detected as submm source.(Smail et al. 2003)



↑ The 4 LABs in 53W002F – Green bold contours superposed on continuum images show the isophotal apertures of the Lyα image, 2σ $arcsec^{-2}$ of the background fluctuation.

4, LAE properties in the entire field

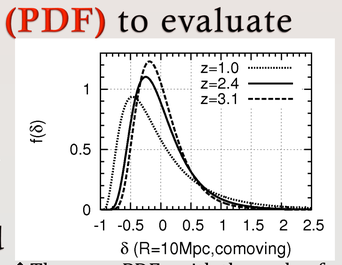
We confirmed that the LAE number density, size distribution and EW distribution is not exotic compared with other z~2 LAEs.
=> 53W002F is normal field as a whole

IV, Discussion

Here, we use **Probability Distribution Function (PDF)** to evaluate rarenesses of arbitrary structures in 53W002F.

Def :the probability of having a fluctuation in the overdensity range (δ , δ +d δ) within a sphere (radius : R) randomly located at the given redshift

- ✓ PDF for mass fluctuations is well approximated up to moderately high non-linear regime,



↑ The mass PDFs with the scale of R=10Mpc for three different cosmic epochs.

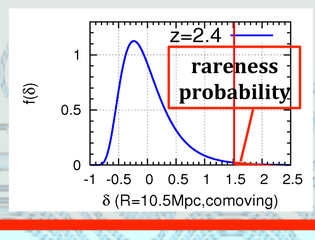
$$f_R(\delta) = \frac{(2\pi\omega_R^2)^{-1/2}}{1+\delta} exp\left[-\frac{\{\ln(1+\delta)+\omega_R^2/2\}^2}{2\omega_R^2}\right] \quad \text{with} \quad \omega_R^2 = \ln(1+\sigma_R^2)$$

1, Evaluation of the rareness of 53W002F-HDR

53W002F-HDR : $\delta_{LAE,HDR}=2.7\pm0.8 \xrightarrow{\text{LAE bias = 1.8}} \delta_{mass,HDR}=1.5\pm0.5$

Volume is equivalent to that of the sphere with R=10.5Mpc

=> calculate the probability of having δ_{mass} larger than $\delta_{mass,HDR}$ (**Rareness Probability; RP**) from PDF



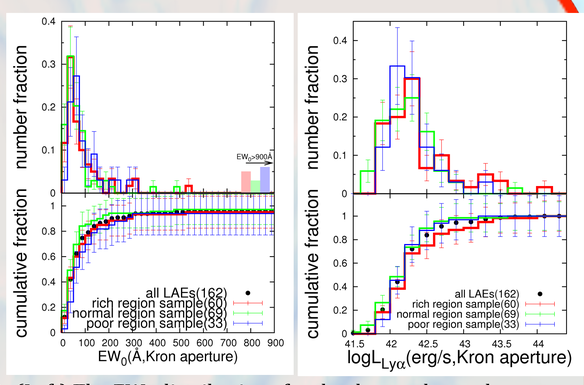
$0.9^{+2.4}_{-0.62}$ %

2, The Environmental dependency of LAEs

Environment for each LAE
: RPs in the spheres with R=10Mpc centered at each LAE

LAEs are divided into three subsamples by their environment

=>
- rich region sample : 0%<RP<12%
- normal region sample : 12%<RP<50%
- poor region sample : 50%<RP<100%



(Left) The EW_0 distributions for the three subsamples.
(Right) The Lyα luminosity distributions.
In both figures, the distributions of the three subsamples are in agreement within the error bars.

There is no notable difference in the EW and $L_{Ly\alpha}$ distributions among three subsamples, which indicate **Ly α emitting mechanism of LAEs doesn't depend on their environment**.

3, Rich regions and LABs

The RPs of the regions where the 4 LABs live
: 53W002=>10%, No18=>7.7%, No19=>7.7%, NEW=>10%
・・・**The LABs are biased to moderate dense regions (rims of high density region, rather than density peaks).**
Three of them lies in the very small area (the rim of 53W002F-HDR).