Pilot Survey for Lyman Alpha Emitters at z=7.1

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Abstract

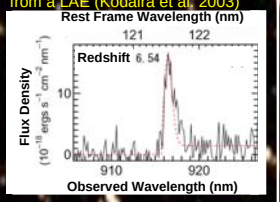
We have challenged a narrowband survey for Lyman alpha emitters (LAEs) at z = 7.1, the highest redshift in optical ever observed, using 8.2m Subaru Telescope at the summit of Mt. Mauna Kea, Hawaii. To select out the LAE candidates, we conducted imaging observation using the custom-made narrowband filter centered at λc = 9800 Å with bandpass $\Delta\lambda$ ~ 100 Å, located between the last optical window of OH airglow corresponding to z = 7.1 Lyman alpha emission. The target regions were the Subaru Deep Field (SDF) and center of CL1520 field, in which we already have very deep broadband (i' and z') images taken in previous observation. After the rigorous data reduction, we obtained 45 and 52 LAE candidates in the SDF and CL1520, respectively. We carried out a follow-up multi-object spectroscopy using a high dispersion grisms. Unfortunately, we could not identify any Lyman alpha emission on the obtained spectra, mainly due to the bad observing conditions. We discuss the estimated probability to discover such a rare high-z object based on the density and luminosity evolution of LAEs as well as the outline of our future wide-field z=7.0 LAE survey.

1. Lyman α Emitters (LAEs)

Lyman α Emitters (LAEs) are galaxies such as:
1. found at high redshift (z = 3 – 6.6)
   → primeval forming galaxy in early Universe
2. actively forming stars emitting Lyα line
3. chemically unevolved
   → not dusty yet → easier to detect Lyα line

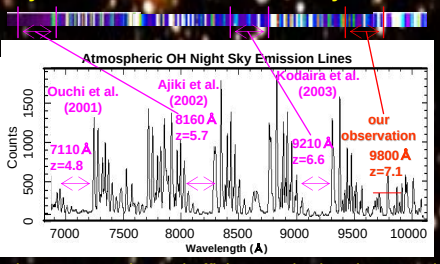
By studying LAEs statistically, we can investigate:
1. galaxy formation processes in early Universe
2. characteristics of intergalactic medium (IGM)
3. galactic superwind mechanism

An example of Lyα emission line from a LAE (Kodaira et al. 2003)

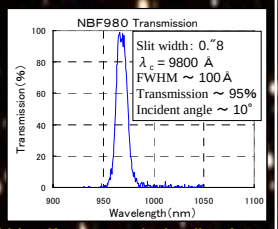


2. Narrowband Filter

Lyα Emitter Narrowband Survey to Date



Transmission of Our Custom-made Filter



The most popular and efficient method to detect and identify Lyα emission line from LAEs is narrowband survey. We had a narrowband filter specially designed that covers the last optical window of OH airglow (9750-9850 Å) corresponding to 7.0 < z < 7.1, which is the highest redshift and most distant Universe ever observed.

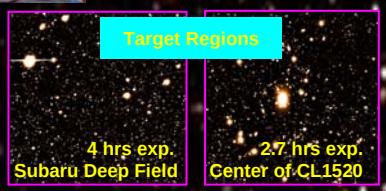
3. Imaging Observation

8.2m Subaru Telescope
Seeing ~ 1.″0-1.″2
May 2003

Limiting Mags (in AB, 2σ, 3.″0 φ)

	SDF	CL1520
i'	27.30	26.45
z'	26.40	24.74
NB980	24.24	24.05

Target Regions



4. LAE Candidates Selection

① For objects brighter than NB980 limiting magnitude (in AB, 2σ, 3.″0 φ), we applied following selection criteria:

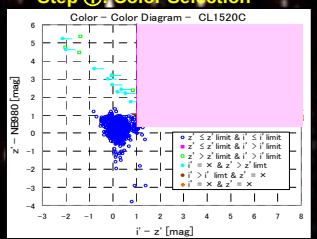
1. If $z' \le z'_{limit}$ & $i' \le i'_{limit}$, and
   ・If satisfies $z' - NB980 > 3\sigma$ (= 0.4) & $z' - i' > 1.0$, → LAE Candidates
   ・If not, → those are not LAEs.
2. If $z' \le z'_{limit}$ & $i' > i'_{limit}$ → LAE Candidates
3. If $z' > z'_{limit}$ & $i' \le i'_{limit}$ → not LAE
4. If $z' > z'_{limit}$ & $i' > i'_{limit}$ → LAE Candidates

② We visually looked at i', z', & NB980 images of all the LAE candidates selected in step ①, and judged if they look like objects bright at NB980.

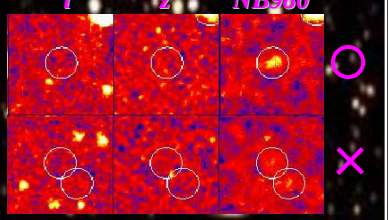
Finally, we obtained 45 & 52 LAE candidates in SDF & CL1520, respectively.

Selection Criteria used in Step ①−1 are derived based on following models and assumptions.
① SED model GISSEL98 (Bruzual & Charlot 1993) ② Lyα Forest model (Madau 1995)
③ Lyα Emission: rest frame EW > 100 Å ④ amount of dust = 0

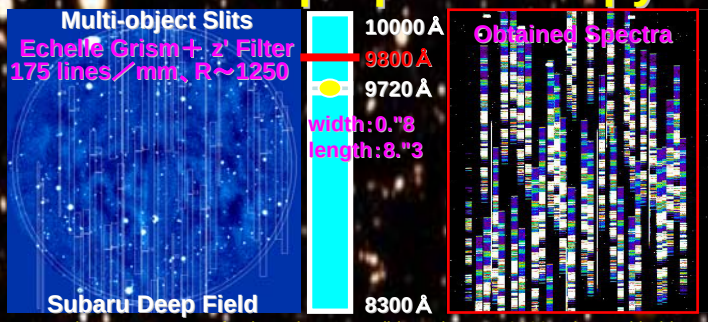
Step ①: Color Selection



Step ②: Visual Selection

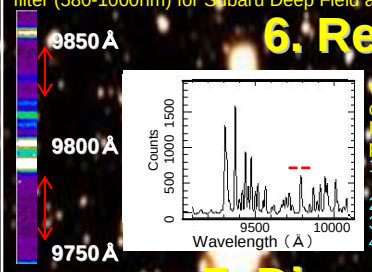


5. Follow-up Spectroscopy



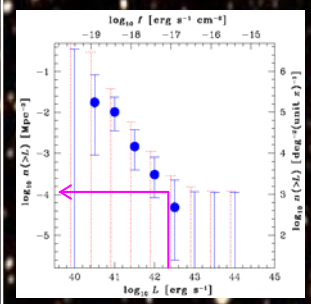
We made spectroscopy of selected LAE candidates in June 2003 using multi-object slits installed in FOCAS onboard Subaru Telescope. We used Echelle Grism (175 /mm, R～1250)+z' filter and VPH950 Grism (1095/mm, R～2500)+O58 order-cut filter (580-1000nm) for Subaru Deep Field and CL1520, respectively.

6. Result



We inspected obtained spectra one by one. However, we could not identify any Lyman alpha emission. There are 4 possible reasons in imaging observation:
1. Poor transparency and seeing (~ 1.″0 - 1.″2)
2. Lack of integration ~ 4 hours
3. Influence of OH fringing
4. Small survey volume ~ $5 \times 10^3 h^{-3} Mpc^3$

7. Discussion



Number density vs. Luminosity of z > 4.5 LAEs derived by Santos et al. (2003).

Here, we discuss how many LAEs should have been discovered by our survey. This time we covered:
Area = 28arcmin², 7.0 < z < 7.1, NB980 ≤ 24.24
which correspond to:
$\log_{10} L$ (Lyα) = 42.32 erg s^{-1}
Survey volume = $5 \times 10^3 h_{0.71}^{-3}$ Mpc³
Using the luminosity function of z > 4.5 LAEs derived by Santos et al. (2003), we estimate:
1.4 LAEs should have been detected.
Similarly, even if we could have reached NB980 = 25.0, only 4.4 LAEs would have been expected. Thus, our survey was extremely challenging and even small factors might affect the result. Due to the difficulty and slightly poor weather conditions, we this time could not find any LAEs. Learning from this result, we are now planning a larger scale survey increasing the chance to detect LAEs at z =7.0.

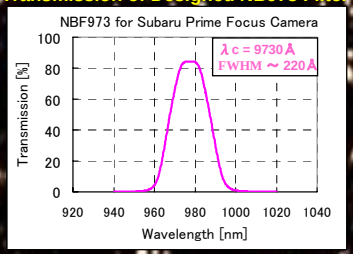
8. Upcoming Survey

Subaru Prime Focus Camera (Suprime-Cam)

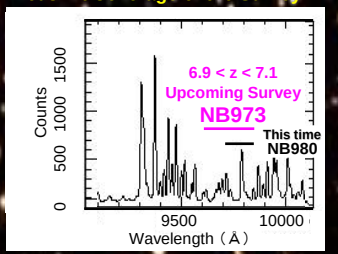
FOV: 34′×27′ (widest in the world!)

We plan to conduct Intensive Wide Field Survey for Lyman Alpha Emitters at 6.9 < z < 7.1. We intend a deeper imaging of Subaru Deep Field taking up to 36hrs integration. We survey 918 arcmin² using Suprime-Cam and newly designed filter, NBF973, with twice broader bandpass to cover larger survey volume and reduce OH fringing effects. We expect to find ~ 30 LAEs, otherwise constrain galaxy formation scenario.

Transmission of Designed NB973 Filter



Redshift Coverage of the Survey



9. References

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