No. 24 Spectroscopy of Lyman Break Galaxies at z~5

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Introduction

To study galaxy formation and evolution, we have been studying Lyman Break Galaxies(LBGs) at z~5. We have a sample of z~5 LBGs taken with Subaru Suprime-Cam. To confirm the validity of our photometric selection criteria and reveal the physical nature of z~5 LBGs, we have been making spectroscopic observations of these LBGs. Previous results obtained with Subaru/FOCAS were presented by Ando et al. 2004 and 2007. However the size of our spectroscopic sample is still very small. So in order to increase our spectroscopic sample and derive more detailed nature of z~5 LBGs, we made spectroscopic observations of z~5 LBGs with GMOS-N and GMOS-S. Here we present the results obtained with GMOS together with those obtained by FOCAS.

Sample

Photometric selection criteria of z~5 LBGs

- V-Ic > 1.5

and

- V-Ic > 7.0(Ic-z')+0.15

(All magnitudes are given in AB system)

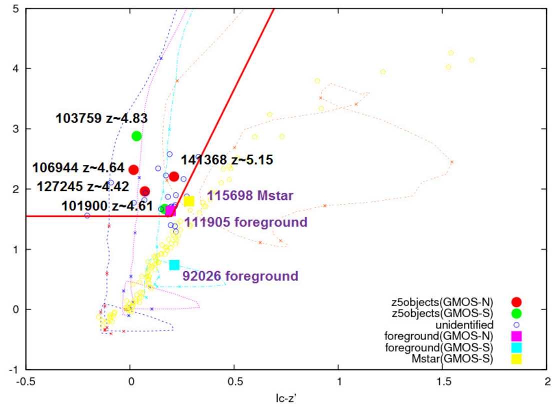


Fig. 1. Our selection criteria in color-color diagram.

Filled circles show spectroscopic identified LBGs.

Model color tracks of starforming galaxies(E(B-V) = 0.0, 0.2, 0.4) and early type galaxy are also plotted. Open pentagons represent the typical colors of galactic stars. Model spectrum of starforming galaxy is calculated with PEGASE, by assuming constant starformation history, Salpeter IMF, sub-solar metallicity, and 100Myr age. We also considered mean IGM absorption at z~5(Inoue et al. 2005).

Observations

GOODS-N and its flanking field

Instrument･･･GMOS-N

Target･･･2 masks.

Exposure Time･･･ 10 hours and 8 hours,

Slit length･･･1"×8", 1"×9"

Pixel scale･･･2.74Å/pixel×0.14"/pixel

Spectral resolution･･･8-9Å(FWHM),

seeing･･･0.7-1.0"(combined image)

J0053+1234 region

Instrument･･･GMOS-S

Target･･･1 mask.

Exposure Time･･･ 16 hours

Slit length･･･1"×3.8"

Pixel scale･･･1.37Å/pixel×0.14"/pixel

Spectral resolution･･･7-8Å(FWHM),

seeing･･･0.7-0.9"(combined image)

Results

z' band magnitude range	observed objects	identified LBGs[a]	identified foregrounds[a]	unidentified
23.5~24.0	3	2 (103759 & 101900)[b]	0	1
24.0~24.5	8	0	1 (111905)[c]	7
24.5~25.0	11	2 (106944 &127245)	0	9
25.0~	3	1 (141368)	0	2
objects not in selection window	6	0	2 (115698 & 92026)[d]	4

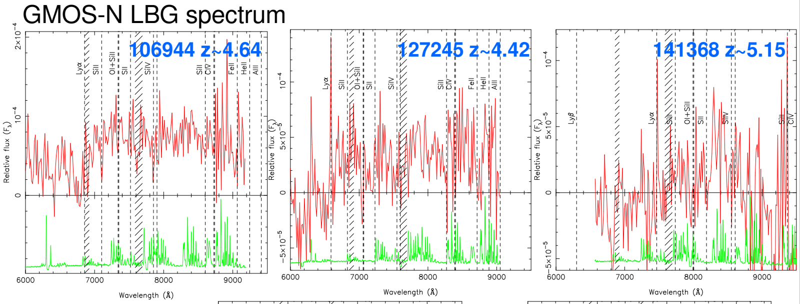
a) : The IDs in parenthesis correspond to the IDs of spectrum below.

b) : These 2 LBGs were already identified by Steidel et al. 1999

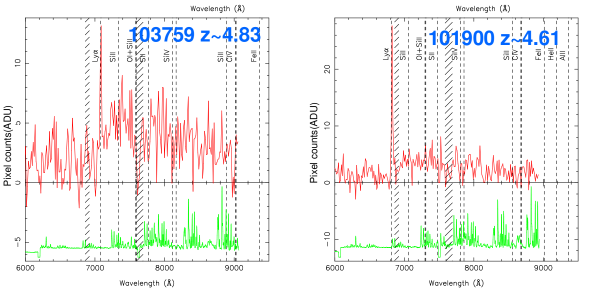
c) : This object shows an emission line around 8212Å and continuum flux at the blueward of its emission line, so this emission line is not Lyα. If this emission is [OII]3727, redshift of this object is 1.20.

d) : One is a galactic M star. The other is a z~0.41 starforming galaxy with emission lines around 6859Å(Hβ), 9262Å(Hα) and 9292Å([NII]).

GMOS-N LBG spectrum



GMOS-S LBG spectrum[a]



Properties of z~5 LBGs

ID	Redshift	EW(Lyα) (Å)	EW(LIS)[b] (Å)	z'	M1400[c]	V - Ic	Ic - z'
106944	4.64	0	-2.0±1.1	24.5	-21.6	2.3	0.02
127245	4.42	$5.0^{+5.0}_{-1.9}$	-	24.9	-21.1	2.0	0.07
141368	5.15	$5.0^{+6.0}_{-2.4}$	-	25.3	-21.1	2.2	0.21
103759	4.83	$5.1^{+3.4}_{-1.7}$	-	23.5	-22.7	2.9	0.03
101900	4.61	18^{+18}_{-6}	-	23.7	-22.4	1.7	0.17

a) : The spertra of 103759 and 101900 are not flux calibrated.

b) : EW(LIS) means the average EW of Low-ionized InterStellar absorption lines, SiII1260Å, OI+SiII1303Å,and CII1335Å.

c) : M1400 is calculated from z' band magnitude assuming β=-1. ($f_\lambda \propto \lambda^\beta$)

Discussion

Redshift Distribution

Fig. 3. shows the redshift distribution of our LBG sample. At z>4.8, strong OH night sky emission may suppress the number of spectroscopic identified LBGs.

As is seen in fig. 1, the V-Ic color of LBGs is redder at larger redshift. There seems to be a weak correlation between V-Ic color and redshift, as shown in fig. 4. The observed relation between V-Ic color and redshift is very consistent with the distribution derived from model color track. Their distribution suggests that many LBGs are in the region of 0.0<E(B-V)<0.2. It is consistent with median value of E(B-V)~0.2 from SED fitting(see Ohta and Yabe's poster(No. 27 and 30)).

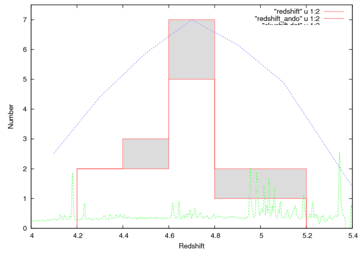


Fig. 3. The redshift distribution of observed LBGs. Gray histogram represents the LBGs identified with GMOS-N and GMOS-S, and the others represetnts the Subaru FOCAS sample. Blue dotted line is the normalized expected distribution. Green dashed line represents the sky intensity at the redshifted Lyα wavelength.

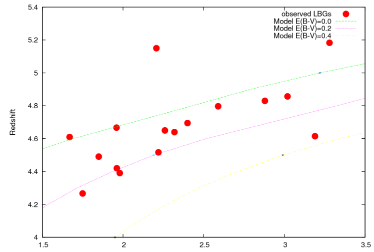


Fig. 4. Redshift versus V-Ic color. Filled circles show our spectroscopicaly identified LBGs. Green, cyan and yellow lines show the expected color-redshift relation of model spectrum of E(B-V)=0.0, 0.2, and 0.4, respectively.

Lyα EW vs UV luminosity

Fig. 5 shows rest-frame Lyα equivalent width against UVabs magnitude. The absence of UV luminous LBGs with large EW Lyα emission is seen.

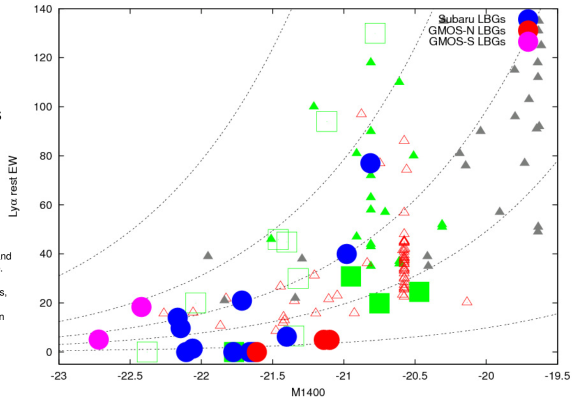


Fig. 5. Rest-frame Lyα equivalent width vs Ultraviolet absolute magnitude.

Filled circles show our spectroscopic LBGs, and the others show the data taken from literature. Filled squares, open squares, filled triangles, and open triangles show z~5 LBGs, z~6 LBGs, z~5.7 LAEs, and z~6.6 LAEs, respectively. Dashed lines show Lyα rest EW as a function of UV absolute magnitude for a constant Lyα luminosity of 5×10^43, 2×10^43, 10^43, 5×10^42, and 10^43 erg/s from top-reft to bottom-right.

Lyα rest EW vs stellar mass, color excess, age, and starformation rate

Some objects have both spectroscopic identification and rest UV to optical SED. Fig. 6. shows the dependences of Lyα EW on stellar mass, color excess, age, and starformation rate derived from rest UV to optical SED fitting. Although the sample size is very small, more massive LBGs maight have smaller Lyα EWs and there is no relation between Lyα EW and other parameters. Note that all LBGs having both spectroscopic identification and SED have relatively weak(rest EW<20Å) Lyα emission.

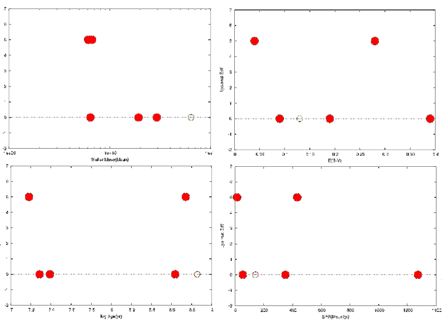


Fig. 6. Lyα rest-frame EW against stellar mass, color excess, age, and starformation rate derived from rest UV to optical SED fitting. Top-left : Lyα EW vs stellar mass. Top-right : Lyα vs E(B-V). Bottom-left : Lyα EW vs age of starformation. Bottom-right : Lyα EW vs starformation rate. Filled circles show our sample with both spectroscopic identification and SED, and open circle shows the z=5.515 LBG by Dow-Hygelund et al. 2005.

Mass-Metallicity relation

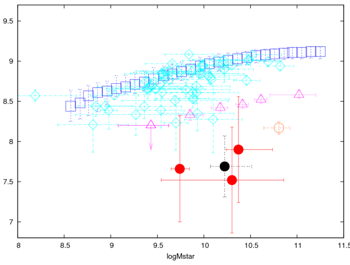


Fig. 7. Mass-Mettalicity relation at various redshift. Open squares, open diamonds and open triangles show z~0.1(tremonti et al. 2004), z~0.7(Savaglio et al. 2005), and z~2.0(Erb et al. 2006) respectively. Red filled circles show our z~5 LBG sample, black filled circle represents the average of them, and brown open circle shows the z=5.515 LBG by Dow-Hygelund et al. 2005.

Fig. 7. shows the mass-metallicity relation of z~0.1, 0.7, 2.0, and 5. The metal abundance of z~5 LBGs is calculated from the empirical relation between LIS absorption line EWs and metal abundance by Heckman et al. 1998. The stellar masses are from SED fitting. Only three LBGs have detectable LIS absorption and SED. Two objects are from FOCAS sample and the other is 106944 by GMOS-N. Although the uncertainty of this derivation is very large and the S/N of LIS absorption is very bad, it seems that the metal abundances of z~5 LBGs are smaller than those of z~2 galaxies with similar stellar mass.

Summary

We made spectroscopic observations of 25 z~5 LBG candidates in a region including GOODS-N, and J0053+1234 region with GMOS-N and GMOS-S, respectively. Five objects are identified to be z~5 LBGs (two objects were already identified by Steidel et al. 1999), and one object as a foreground contamination. We also observed objects which are not in the LBG selection window with GMOS-S, and identified two objects as foreground objects. Fig. 4. shows that LBGs of redder V-Ic color tends to have larger redshift, so this is consistent with the color track of model starforming galaxy. As shown in fig. 5. UV luminous LBGs don't show large Lyα EW. The mass-metallicity relation of our z~5 LBGs shown in fig. 7. suggests the chemical evolution of LBGs from z~5 to z~2, although the uncertainty is very large.