A SUBARU SEARCH FOR LYMANα EMITTERS AT Z=5.8 WITH AN INTERMEDIATE-BAND FILTER

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ABSTRACT

We present the results of a survey for Lyα emitters at z = 5.8 using a new intermediate-band filter centered at λc = 8275 Å with ΔλFWHM ≈ 340 Å (i.e., the spectroscopic resolution is R ≈ 23) with a combination with a traditional narrow-band centered at λc ≈ 8150 Å with ΔλFWHM ≈ 120 Å (R ≈ 68). Our observations were made with use of the Subaru Prime Focus Camera, Suprime-Cam, on the 8.2 m Subaru telescope in a sky area surrounding the high redshift quasar, SDSSp J104433.04−012522.2 at z = 5.74, covering an effective sky area with ≈ 720 arcmin². In this survey, we have found four Lyα-emitter candidates from the intermediate-band image (z ≈ 5.8 with Δz ≈ 0.3). Combined with our previous results based on the NB816 imaging, we discuss the star formation activity in galaxies between z ≈ 5.7 and z ≈ 5.9.

1. INTRODUCTION

Probing the star formation activity in galactic or sub-galactic systems at high redshift is essentially important for understanding of the formation and early evolution of galaxies. This is also important to investigate major sources of the cosmic reionization (e.g., Loeb & Barkana 2001). Recent optical deep surveys and their optical spectroscopic follow-up observations have revealed more than two dozens of such star forming galaxies beyond z = 5 (e.g., Hu et al. 2002, 2004; Kodaira et al. 2003; Santos et al. 2003; see for a review Taniguchi et al. 2003b, and Spinrad 2003). In an attempt to find star-forming objects at z ≈ 5.7, we made an optical deep imaging survey in a sky area around the SDSS quasar, SDSSp J104433.04−012502.2 (Ajiki et al. 2003). In this survey, we found 20 Lyα emitter (LAE) candidates at z ≈ 5.7. Two of them were confirmed as real LAEs at z = 5.69 (Ajiki et al. 2002) and at z = 5.66 (Taniguchi et al. 2003a) based on their optical spectroscopy. In this survey, the narrowband filter NB816 (λc = 8150 Å with ΔλFWHM = 120 Å) was used to select LAEs at z ≈ 5.7. In addition to this narrowband filter, we also used a new intermediate-band filter IA827 (λc = 8275 Å with ΔλFWHM = 340 Å) (Hayashino et al. 2001; Taniguchi 2001; Taniguchi et al. 2003b) in the same observing run. Using the IA827 filter, we are able to search for LAEs in the very luminous part of the Lyα luminosity function at z ≈ 5.8 in a very large volume. This intermediate-band filter is one of a series of intermediate-band filters, called the IA filter system, dedicated to the Suprime-Cam on the 8.2 m Subaru telescope (e.g., Taniguchi 2001; see also Fujita et al. 2003). The scientific merits of the IA filter system are described in Taniguchi (2001), see for some spectacular results with a similar composite filter system, COMBO-17, Wolf et al. (2003).

In this paper, we report new results on our deep imaging survey for LAEs at z ≈ 5.8 with use of the intermediate-band filter, IA827. We adopt a flat universe with Ω_matter = 0.3, Ω_lambda = 0.7, and h_70 = 1 where h_70 = H_0/(70 km s⁻¹ Mpc⁻¹). Magnitudes are given in the AB system throughout this paper.

2. OBSERVATIONS AND DATA REDUCTION

2.1. Observations

We have carried out a very deep optical imaging survey for faint LAEs in the field surrounding the quasar SDSSp J104433.04−012502:2 at redshift 5.74 (Fan et al. 2000; Djorgovski et al. 2001; Goodrich et al. 2001), using the prime-focus wide-field camera, Suprime-Cam (Miyazaki et al. 2002) on the 8.2 m Subaru Telescope (Kaifu et al. 2000) on Mauna Kea. Suprime-Cam consists of ten 2k×4k CCD chips and provides a very wide field of view, 34′×27′ (0.202 arcsec pixel⁻¹).

In this survey, we used the intermediate-band filter, IA827, centered at 8275 Å with a passband of ΔλFWHM = 340 Å; the wavelength coverage corresponds to the redshift range of 5.66−5.94 for Lyα emission; note that the central wavelength of IA827 filter varies within 25 Å with the positions on the filter, causing an uncertainty in the redshift range of the objects.
estimate within $\Delta z \simeq 0.02$. We also used broad-band filters, $B$, $R_C$, $I_C$, and $z'$, and the narrow-band filter, $NB816$, centered at 8150 Å with a passband of $\Delta \lambda_{\text{FWHM}} = 120$ Å; the wavelength corresponds to the redshift range of 5.65–5.75 for Ly$\alpha$ emission (see Ajiki et al. 2003). The total-response (filter, optics, and atmosphere transmission and CCD sensitivity are taken into account) curves of the filter bands used in our observations are shown in Figure 1. A summary of the imaging observations is given in Table 1. All observations were done under photometric conditions, and the seeing was between 0′′7 and 1′′4 during the observing run. Spectrophotometric standard stars used in the flux calibration for $IA827$ are HZ 21 (Oke 1990), and PG 1034+001 (Massey et al. 1988). The detailed flux calibration for the $B$, $R_C$, $I_C$, and $NB816$ data and data reduction procedures are given in Ajiki et al. (2003).

The total size of the reduced field is 32.0′′ × 25.2′′ ≈ 807 arcmin$^2$. After masking the regions contaminated by fringes and bright stars, our actual survey area is ≈ 720 arcmin$^2$ (see Ajiki et al. 2003). The volume probed by the $IA827$ imaging has (co-moving) transverse dimensions of 4.0 × 10$^4$ $h_0^{-2}$ Mpc$^2$, and the FWHM of the filter corresponds to a co-moving depth along the line of sight of 123 $h_0^{-1}$ Mpc ($z_{\text{min}} \approx 5.66$ and $z_{\text{max}} \approx 5.94$; note that these values are average of 13 different position on the $IA827$ filter). Therefore, a total volume of 5.0 × 10$^5$ $h_0^{-3}$ Mpc$^3$ is probed in our $IA827$ image.

2.2. Source Detection and Photometry

Source detection and photometry were performed using SExtractor version 2.2.2 (Bertin & Arnouts 1996) in the double image mode. A source is selected as a 13-pixel connection above the 2 σ noise level on the $IA827$ image. Photometry was performed with a 2.8 arcsec diameter aperture for each band image after matching image size of the data of each band with the $R_C$-band data (1.4 arcsec). The limiting magnitudes are $IA827 = 25.6$, $NB816 = 26.0$, $B = 26.6$, $R_C = 26.2$, $I_C = 25.9$, and $z' = 25.3$ for a 3σ detection with a 2.8 arcsec diameter aperture. In the above source detection, we find ~ 34,000 sources down to $IA827 = 25.6$.

3. RESULTS

3.1. Selection of $IA827$-Excess Objects

Since the effective wavelength of the $IA827$ filter is 8275 Å, we use a continuum band $I827$ evaluated from a linear combination of $f_{IA827} = 0.64f_{I_C} + 0.36f_{z'}$ where $f_{I_C}$ and $f_{z'}$ are the fluxes at $I_C$ and $z'$ bands, respectively. A 3σ limit of $I827$ is ≈ 26.0 in a 2.8 arcsec diameter aperture.

When we select $IA827$-excess objects, we should be careful because objects at $z \sim 5.6$ with no emission line could be selected as nominal $IA827$-excess objects. This is due to that the absorption by intergalactic neutral hydrogen causes the strong continuum depression at $\lambda \sim 8000$ Å for objects at $z \sim 5.6$. In order to exclude such contamination in our selection procedure of $IA827$-excess objects, we investigate the effect of continuum depression for high-$z$ LAEs with different Ly$\alpha$ emission-line equivalent widths ($EW = 0, 100, 300, \text{and } 500$ Å) as a function of redshift; $5.0 \leq z \leq 6.0)$. The results are shown in Figure 2. In these estimates, we use the average optical depth derived by Madau et al. (1996). Figure 2 shows that even objects at $z \sim 5.6$ with no emission line have $IA827$ excesses as much as $I827 - IA827 \sim 0.5$ mag. We also note that the redshift range of detectable LAEs depends on EW (see section 4.2).

Taking our results shown in Figure 2, we adopt a selection criterion for $IA827$-excess objects, $I827 - IA827 > 0.8$, because the error of $I827 - IA827$ is $\sim 0.3$ mag for objects with $IA827 = 24.5$. Then, we select $IA827$-excess objects by using the following criteria;

$$IA827 < 24.9, \quad I827 - IA827 > 0.8, \quad I827 - IA827 > 3\sigma(I827 - IA827),$$

where

$$3\sigma(I827 - IA827) = -2.5 \log \left(1 - \sqrt{\frac{(3\sigma_{IA827})^2 + (3\sigma_{IA827})^2}{f_{IA827}}}\right).$$

The criterion, $3\sigma(I827 - IA827)$ corresponds to a line flux, $F_{\lambda} \sim 1.5 	imes 10^{-17}$ ergs s$^{-1}$ cm$^{-2}$. This line-flux limit is higher by a factor of ~ 3 than that in Ajiki et al.(2003).

In Figure 3, we show the diagram between $I827 - IA827$ and $IA827$ for the objects in the $IA827$-selected catalog together with the above criteria. There are 21 $IA827$-selected sources which satisfy the above three criteria. Note that five of the 21 objects have been also selected as $NB816$-excess objects in our previous work (Ajiki et al. 2003).

3.2. Selection of LAE Candidates

In order to select LAE candidates at $z \approx 5.8$ from our emission-line objects, we apply the same criteria as those in Ajiki et al. (2003) to all emitters; i.e.,

$$B > 26.6, \quad R_C - I_C > 1.8 \quad \text{for} \quad I_C \leq 24.8,$$

$$R_C > 26.6 \quad \text{for} \quad I_C > 24.8.$$  

These criteria enable us to select LAEs at $z \approx 5.8$ (see Ajiki et al. 2003). First, eleven of the 21 objects satisfy the criterion (5). None of the eleven objects has $I_C$ magnitude of ≤ 24.8. Therefore no object satisfies the criterion (6). Four of the eleven object satisfy the criterion (7). Finally we select 4 objects as LAE candidates at $z \approx 5.8$ by the criteria (5) and (7). Three of the 4 LAE candidates have been already selected as LAE candidates by Ajiki et al. (2003) based on their $NB816$ data. The positions and photometric properties of the four $IA827$-selected LAEs are given in Table 2. It is noted that all of our LAE candidates are undetected above 2σ level in the B- and $R_C$-band images (i.e., $B > 27.0$ and $R_C > 26.6$). The $B$, $R_C$, $I_C$, $NB816$, $IA827$, and $z'$ images of the four LAE candidates are shown in Figure 4. The comparison of results of this survey and those of using $NB816$ (Ajiki et al. 2003) are summarized in Table 3.

4. DISCUSSION

4.1. Properties of the LAE Candidates Expected from the $IA827$ and $NB816$ Data
In the previous section, we selected the 4 LAE candidates at $z \approx 5.8$ given in Table 2. All of them were also detected in our $NB816$ image. We try to estimate redshifts of the 4 LAE candidates using both the $NB816$ and $IA827$ data. In Figure 5, we show the diagram of 4 LAE candidates at $z \approx 5.8$ between $I_827 - IA827$ and $NB816 - IA827$. In this figure, we also show colors of model LAEs with $EW_{\text{obs}} = 300$ Å, 500 Å, and 1000 Å. In these models, we use the average optical depth derived by Madau et al. (1996) to estimate the absorption by intergalactic neutral hydrogen. It is found that the color of the LAE candidates at $z \approx 5.7$ above the 3 sigma detection in $IA827$ (Ajiki et al. 2003) are consistent with model LAEs at $z = 5.65 - 5.75$. It is also found that two of our 4 LAE candidates are expected to be at $z = 5.70 - 5.75$, and the other two are at $z = 5.75 - 5.77$. We can also estimate the EWs and line fluxes of our 4 LAE candidates from Figure 5. The estimated EWs, $EW_{\text{est}}$, and line fluxes, $F_{L,\text{est}}$, of our LAE candidates are given in Table 4.

4.2 Space Density of the LAEs at $z \approx 5.8$

Since we have detected the 4 LAE candidates at $z \approx 5.8$ in the volume of $5 \times 10^5 h_0^{-3} \text{Mpc}^3$, we obtain the space density of the LAE candidates at $z \approx 5.8$, $n(\text{Ly}\alpha) \simeq 8 \times 10^{-8} h_0^3 \text{Mpc}^{-3}$. This density is lower by an order of magnitude than that of our $NB816$ survey, $n(\text{Ly}\alpha) \simeq 1.1 \times 10^{-6} h_0^3 \text{Mpc}^{-3}$ at $z \approx 5.7$ (Ajiki et al. 2003), or that of Rhoads & Malhotra (2001), $n(\text{Ly}\alpha) \simeq 1.0 \times 10^{-4} \text{Mpc}^{-3}$ at $z \approx 5.70$ and $n(\text{Ly}\alpha) \simeq 6.4 \times 10^{-5} \text{Mpc}^{-3}$ at $z \approx 5.77$ (see also Rhoads et al. 2003).

The main reason for this seems to be attributed to different limits in the EW and Ly\alpha luminosity among the above surveys. The limits in the EW and Ly\alpha luminosity of our survey, $EW_{\text{obs,lim}} \approx 300$ Å and $L_{\text{Ly}\alpha,\text{lim}} \approx 1.5 \times 10^{43} \text{ergs s}^{-1}$, are much higher than those of the other surveys, $EW_{\text{obs,lim}} \approx 180$ Å and $L_{\text{Ly}\alpha,\text{lim}} \approx 5.0 \times 10^{42} \text{ergs s}^{-1}$ for that of Ajiki et al. (2003), or $EW_{\text{obs,lim}} \approx 75$ Å and $L_{\text{Ly}\alpha,\text{lim}} \approx 2.5 \times 10^{42} \text{ergs s}^{-1}$ for that of Rhoads & Malhotra (2001). Therefore, only a few objects that are selected as LAE candidates in the other surveys satisfy the limits in the EW and Ly\alpha luminosity of our survey. Actually, only four of 20 objects found in Ajiki et al. (2003) satisfy these criteria.

In Figure 6, the space density of both our LAE candidates and those found in Ajiki et al. (2003) are shown as a function of redshift together with that of Rhoads & Malhotra (2001). The redshift range for our LAE candidates is classified into two redshift intervals, $z = 5.65 - 5.75$ and $z = 5.75 - 5.77$. In the redshift estimate of our LAE candidates, we use Figure 5. Note that LAE candidates undetected in $IA827$ have redshifts between $z = 5.65$ and $z = 5.75$. It is also noted that any corrections for the detection completeness is not made for all the samples.

Although our $IA827$ filter could prove Ly\alpha emitters at $z \approx 5.7 - 5.9$, all our 4 LAE candidates lie at $z \approx 5.7 - 5.8$. Therefore, it is interesting to consider why no LAE candidates are found at $z \approx 5.8 - 5.9$. For LAEs at $z \gtrsim 5.8$, both the Ly\alpha emission and the very weak continuum depressed at wavelengths shortward of the Ly\alpha peak are recorded in the $IA827$ image. Therefore, such objects are not selected as strong $IA827$-excess objects. This effect is indeed found in our simulations shown in Figure 2. The $IA827$-excess variation in redshift are shown in Figure 2.

However, Figure 2 also shows that if LAE candidates with very large EWs such as No. 2 in Table 4 are present at $z = 5.8 - 5.9$, they could be detected as $IA827$-excess objects. Therefore, we can say that such very bright LAEs at $z = 5.8 - 5.9$ do not exist at least in our survey field.

4.3 $L_{\text{Ly}\alpha}$ Luminosity Distributions at $z = 5.7 - 5.8$

We investigate the Ly\alpha luminosities of the $z \approx 5.8$ candidates. The derived Ly\alpha luminosities of this survey range from $1.8 \times 10^{43}$ to $2.9 \times 10^{43} \text{ergs s}^{-1}$. In Figure 7, we show the number distributions of our LAE candidates as a function of Ly\alpha luminosity together with those previous LAE surveys at $z \approx 5.7$ using a narrowband filter (Ajiki et al. 2003; Rhoads & Malhotra 2001; Hu et al. 2004). The figure shows that our survey probes higher-luminosity sources with respect to the other LAE surveys at $z \approx 5.7$; see also Pascarelle et al. (1998) and Fujita et al. (2003). Since an intermediate-band can cover a wider volume than a typical narrowband filter, the use of such intermediate-band filter is useful finding higher-luminosity LAEs that are rarer than low luminosity ones.

4.4 Possibility of Large Scale Structure at $z = 5.7 - 5.8$

In Figure 8, we plot the spatial distributions the 4 LAE candidates together with those at $z \approx 5.7$ of Ajiki et al. (2003). It appears that most LAE candidates are found in the western side of the quasar SDSSp J104433.04–012502.2. In particular, there is no LAE candidate in the northeast of the quasar. Contours of the local surface density are also shown in this figure. The local surface density at position $(x, y)$ is the density averaged over the circle centered at $(x, y)$ whose radius is determined as the angular distance to 5 nearest neighbors. Note that smoothing with the top-hat filter of $\approx 3.4$ arcmin, corresponding to $\approx 8 h_0^{-1} \text{Mpc}$ at $z \approx 5.7$, is made.

The contour map suggests that there is a high-density region in northwest side of the quasar, where the local density is higher by a factor of 3 than the average density in this field. To examine its statistical significance, we made simple simulations; we distributed 21 points randomly in the survey field and estimated the local surface density at each point. We found that 19% of 100 random distributions also show a similar high-density region. Therefore, it is difficult to conclude that there is a high-density clustering region of LAEs at $z \approx 5.7$.

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Fig. 1.— Response curves (filter, optics, atmosphere transmission, and CCD sensitivity are taken into account) of the filters used in our observations. Upper panel shows the response curves of both the NB816 and IA827 filters.
Fig. 2.— The $IA827$ excess of model LAEs with $EW_{\text{obs}} = 0\AA$, $100\AA$, $300\AA$, and $500\AA$ as a function of redshift. The horizontal line shows our selection criterion for $IA827$-excess objects.

Fig. 3.— Color-magnitude diagram between $Iz827 - IA827$ and $IA827$. All objects detected down to the apparent magnitude of $IA827 = 25.6$ in the $IA827$-selected catalog are shown. The horizontal solid line corresponds to the color of $Iz827 - IA827 = 0.8$ and the vertical solid line corresponds to the magnitude limit of $IA827 = 24.9$. Solid curves show the distribution of $3\sigma$ error.

Fig. 4.— $B$, $R_C$, $I_C$, $NB816$, $IA827$, and $z'$ images of our LAE candidates at $z \approx 5.8$. Each box is $16''$ on a side. Each circle is $4''$ radius. The numbers shown in the left column correspond to those given in the first column of Table 2.
Fig. 5.—Diagram between I\(z\)827 – I\(A\)827 and NB816 – I\(A\)827. Four I\(A\)827-selected LAEs in this study and NB816-selected LAEs in Ajiki et al. (2003) are shown. Color properties of model LAEs with \(E\_W\_\text{obs} = 300\) Å, 500 Å, and 1000 Å are also shown. The horizontal line shows our selection criterion for the I\(A\)827-excess objects. The two LAEs confirmed by our spectroscopy are marked (Ajiki et al. 2002; Taniguchi et al. 2003a). Note that none of LAE candidates found by this survey has NB816 – I\(A\)827 > 1.0.

Fig. 6.—Number densities of LAE candidates found both in this survey and in Ajiki et al. (2003) as a function of redshift are compared with those derived by Rhoads & Malhotra (2001). Note that there is no LAE candidate at \(z = 5.77–5.94\) in our survey.

Fig. 7.—Number distributions of LAE candidates found both in this survey as a function of Ly\(\alpha\) luminosity are compared with those derived by Ajiki et al. (2003), Rhoads & Malhotra (2001), and Hu et al. (2004). The Ly\(\alpha\) luminosity distribution of these surveys are estimated from their photometric catalogs.
Fig. 8.— Celestial positions of both the 4 LAE candidates at \( z \approx 5.8 \) and those at \( z \approx 5.7 \) found in Ajiki et al. (2003). Our survey area is shown by solid line. The position of SDSSp J104433.04–012502.2 is shown by “×”. The two LAEs at \( z \approx 5.7 \) confirmed by our spectroscopy are marked with open circles (Ajiki et al. 2002; Taniguchi et al. 2003a). The contours show the local surface density of the LAE candidates of \( \Sigma, 2\Sigma, \) and \( 3\Sigma \), where \( \Sigma \) is the surface density averaged over the field, \( 2.9 \times 10^{-2} \) arcmin\(^{-2}\).

**Table 1**

| Band | Obs. Date (UT)         | \( T_{\text{int}} \) (sec) | \( m_{\text{lim}} \) (AB) \( ^{b} \) | \( FWHM_{\text{star}} \) (arcsec) \( ^{c} \) |
|------|------------------------|-----------------------------|---------------------------------|---------------------------------|
| \( B \) | 2002 February 17       | 1680                        | 26.6                            | 1.2                             |
| \( R_C \) | 2002 February 15, 16  | 4800                        | 26.2                            | 1.4                             |
| \( I_C \) | 2002 February 15, 16  | 3360                        | 25.9                            | 1.2                             |
| \( z' \) | 2002 February 15, 16  | 5160                        | 25.3                            | 1.2                             |
| \( NB816 \) | 2002 February 15 - 17 | 36000                       | 26.0                            | 0.9                             |
| \( IA827 \) | 2002 February 15 , 17 | 12420                       | 25.6                            | 1.2                             |

\(^{a}\)Total integration time.

\(^{b}\)The limiting magnitude (3σ) within a 2.8 arcsec aperture.

\(^{c}\)The full width at half maximum of stellar objects in the final image.
Table 2
PHOTOMETRIC PROPERTIES OF THE LAE CANDIDATES AT $z \approx 5.8$  

| No. | $\alpha$ (J2000) | $\delta$ (J2000) | $I_C$ | $NB816$ | $IA827$ | $z^b$ | $Iz827$ | $z^{b}$ | A03 $^c$ |
|-----|------------------|------------------|-------|---------|---------|-------|---------|---------|---------|
| 1   | 10 43 48.3       | −01 23 20        | 25.7  | 23.9    | 24.5    | (25.5)| 25.7    | 7       |
| 2   | 10 43 55.5       | −01 14 18        | (26.2)| 25.0    | 24.6    | >25.7 | (26.2)  | 12      |
| 3   | 10 43 59.0       | −01 16 27        | (26.0)| 24.3    | 24.9    | >25.7 | (26.2)  | 13      |
| 4   | 10 44 01.6       | −01 42 31        | 25.0  | 24.7    | 24.2    | >25.7 | 25.2    | ⋯       |

$^a$All of our LAE candidates are undetected above 2σ level in $B$- and $R_C$-band images ($B > 27.0$ and $R_C > 26.6$).

$^b$AB magnitude in a 2.8 arcsec diameter. The magnitudes between the 2σ and 3σ detection levels are put in parentheses.

$^c$ID number in Ajiki et al. (2003).

Table 3
COMPARISON OF LAE SURVEYS IN SDSSp J1044-0125 FIELD

| Filter $^1$ | $z_c^2$ | $(z_{\text{max}}, z_{\text{min}})^3$ | $V^4$ | $EW_{0,\text{lim}}^5$ | $L_{\text{lim}}^6$ | $N_{\text{LAE}}^7$ |
|-------------|---------|-----------------------------------|-------|-----------------------|-------------------|---------------|
| $NB816$     | 5.70    | (5.65, 5.75)                      | 1.8   | 32                    | 5                 | 20            |
| $IA827$     | 5.80    | (5.66, 5.94)                      | 5.0   | 57                    | 15                | 4             |
| $NB816 \& IA827^8$ | 5.70    | (5.66, 5.75)                      | 1.7   | 57                    | 15                | 3             |

$^1$Filter name used in the survey.

$^2$Central redshift corresponding to the center of the passband.

$^3$Minimum and maximum redshift.

$^4$Co-moving volume in units of $10^3h_0^{-3}$ Mpc$^3$.

$^5$Survey limit in rest-frame equivalent width in units of Å.

$^6$Survey limit in Ly$\alpha$-luminosity in units of $10^{42}$ ergs s$^{-1}$.

$^7$Number of LAE candidates detected in the survey.

$^8$Overlap of the $NB816$ and $IA827$ surveys.

Table 4
THE ESTIMATED PROPERTIES OF LAE CANDIDATES AT $z \approx 5.8$

| No. | $NB816-IA827$ | $Iz827-IA827$ | $z_{\text{est}}$ | $EW_{\text{obs, est}}$ (Å) | $F_{L,\text{est}}$ ($10^{-17}$ ergs s$^{-1}$ cm$^{-2}$) |
|-----|---------------|---------------|------------------|----------------------------|-------------------|
| 1   | $-0.58_{-0.13}^{+0.15}$ | $1.17_{-0.32}^{+0.29}$ | 5.74  | $660_{-330}^{+590}$ | 6.3  |
| 2   | $0.41_{-0.19}^{+0.21}$  | $1.46_{-0.40}^{+0.44}$  | 5.77  | $1290_{-640}^{+4300}$ | 6.8  |
| 3   | $-0.60_{-0.19}^{+0.20}$ | $1.26_{-0.43}^{+0.48}$ | 5.74  | $810_{-500}^{+2800}$ | 4.8  |
| 4   | $0.50_{-0.14}^{+0.16}$  | $1.00_{-0.23}^{+0.23}$  | 5.77  | $500_{-190}^{+200}$ | 8.0  |