The Astrophysical Journal, 638:596–602, 2006 February 20

NARROWBAND SURVEY OF THE GOODS FIELDS: SEARCH FOR Lyα EMITTERS AT $z = 5.7$[1]

Masaru Ajiki,[2] Bahram Mobasher,[3,4] Yoshiaki Taniguchi,[2] Yasuhiro Shioya,[2]
Tohru Nagao,[5,6] Takashi Murayama,[2] and Shunji S. Sasaki[2]
Received 2005 August 30; accepted 2005 October 23

ABSTRACT

We present results from optical narrowband ($\lambda_c = 8150$ Å and $\Delta\lambda = 120$ Å) observations of the Great Observatories Origins Deep Survey (GOODS) fields, using Suprime-Cam on the Subaru Telescope. Using these narrowband data, we then perform a survey of Lyα emitters (LAEs) at $z \sim 5.7$. The LAE survey covers an area of $\approx$320 arcmin^2 and a comoving volume of $\simeq 8.0 \times 10^4$ Mpc^3. We found a total of 10 (GOODS-N) and 4 (GOODS-S) LAE candidates at $z \sim 5.7$. We perform a study of the spatial distribution, space density, and star formation properties of the LAEs at $z \sim 5.7$.

Subject headings: cosmology: observations — early universe — galaxies: evolution — galaxies: formation

1. INTRODUCTION

With the installation of the Advanced Camera for Surveys (ACS), the efficiency of the *Hubble Space Telescope* (*HST*) in performing wide-area and deep surveys has increased 10-fold. Such data are required to study the formation and evolution of galaxies and are essential in identifying high-redshift galaxies. Significant progress has been made in recent years in performing multi–wave band deep surveys, greatly extending the range of accessible redshifts and enhancing our knowledge of properties of galaxies out to the reionization epoch (Beckwith et al. 2003; Giavalisco et al. 2004a; Rix et al. 2004; N. Scoville et al. 2006, in preparation).

One of the general methods of selecting galaxies at high redshift is the dropout technique (e.g., Steidel et al. 1996), monitoring the Lyman break (912 Å) feature in galaxies as it moves with redshift to longer wavelengths and progressively out of the observed (shorter) passbands. Such high-z galaxies have been found in large numbers in the Great Observatories Origins Deep Survey fields (GOODS; Giavalisco et al. 2004b; Dickinson et al. 2004; Stanway et al. 2004; Bouwens et al. 2004) and are used to investigate the origin of cosmic reionization at $z \gtrsim 6$ (e.g., Barkana & Loeb 2001). Another technique for identifying high-z objects is a narrowband search for strong Lyα emitters (LAEs; e.g., Hu et al. 1998, 2002; Cowie & Hu 1998; Rhoads & Malhotra 2001; Ajiki et al. 2003; Kodaira et al. 2003; Taniguchi et al. 2005). Such narrowband surveys, conducted at selected wavelengths to avoid atmospheric emission, target emission-line galaxies at certain redshifts. Combined with broadband data to subtract the continuum, we can estimate the narrowband flux for the respective lines observed.

In this paper, we present results from a narrowband survey in the GOODS fields, searching for LAEs at $z = 5.7$. The area coverage and depth of the GOODS, combined with its multiwavelength imaging data, allow unbiased selection of a population of LAEs at high redshifts. Furthermore, the availability of deep *Spitzer Space Telescope* and *Chandra X-Ray Observatory* data, high-resolution ACS images, and ground-based optical-IR data in the GOODS fields allow a study of the nature, morphology, and star formation rate of LAEs at $z = 5.7$ and provide an unbiased sample of LAEs to compare with homogeneously selected Lyman break galaxies (LBGs) at a similar redshift. We adopt a flat universe with $\Omega_{\rm matter} = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 70$ km s^{-1} Mpc^{-1}. Throughout this paper, magnitudes are given in the AB system.

2. OBSERVATIONS AND DATA REDUCTION

2.1. *Narrowband Observations and Source Detection*

Deep narrowband surveys of the GOODS fields are performed using the Suprime-Cam (Kaifu et al. 2000; Miyazaki et al. 2002) on the 8.2 m Subaru Telescope. We use a narrowband filter, NB816, centered on 8150 Å with a width $\Delta\lambda_{\rm FWHM} = 120$ Å (Ajiki et al. 2003). This filter samples Lyα emission lines in the redshift range $z = 5.65$–5.75.

The NB816 observations of the southern (GOODS-S) field were made during 2004 February 20–22 (UT), while for the northern (GOODS-N) field, we used Subaru archival data that were taken in 2002 and 2003 April. All the NB816 observations were done under photometric conditions with a seeing between 0\.7 and 0\.9. The narrowband imaging data were reduced with the software package SDFRED (Yagi et al. 2002; Ouchi et al. 2004). The FWHM of stellar objects in the final NB816 images of the two fields is 0\.9. The limiting NB816 magnitude in both fields is NB816 ≈ 25.4 for a 5 σ detection over a 2'' diameter aperture. Deep broadband images taken by the ACS (B_{435}, V_{606}, i_{775}, and z_{850}) and ground-based near-IR data, taken as a part of the GOODS (Giavalisco et al. 2004a), are also available for these fields.

The NB816 survey covers a total area of 160 arcmin^2 in each field, corresponding to the full GOODS-ACS area (a total area of 320 arcmin^2). The transverse comoving area of the LAE survey at $z = 5.7$ is 1.8×10^3 Mpc^2. Combined with the FWHM of the filter, which has a Gaussian-like shape, this corresponds to a

[1] Based in part on data collected at Subaru Telescope and obtained from the Subaru Mitaka Okayama Kiso Archive (SMOKA) at the Astronomical Data Analysis Center, which are operated by the National Astronomical Observatory of Japan.

[2] Astronomical Institute, Graduate School of Science, Tohoku University, Aramaki, Aoba, Sendai 980-8578, Japan.

[3] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218.

[4] Also at: Space Sciences Department, European Space Agency, Noordwijk, Netherlands.

[5] National Astronomical Observatory, Mitaka, Tokyo 181-8588, Japan.

[6] INAF–Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, 50125 Firenze, Italy.

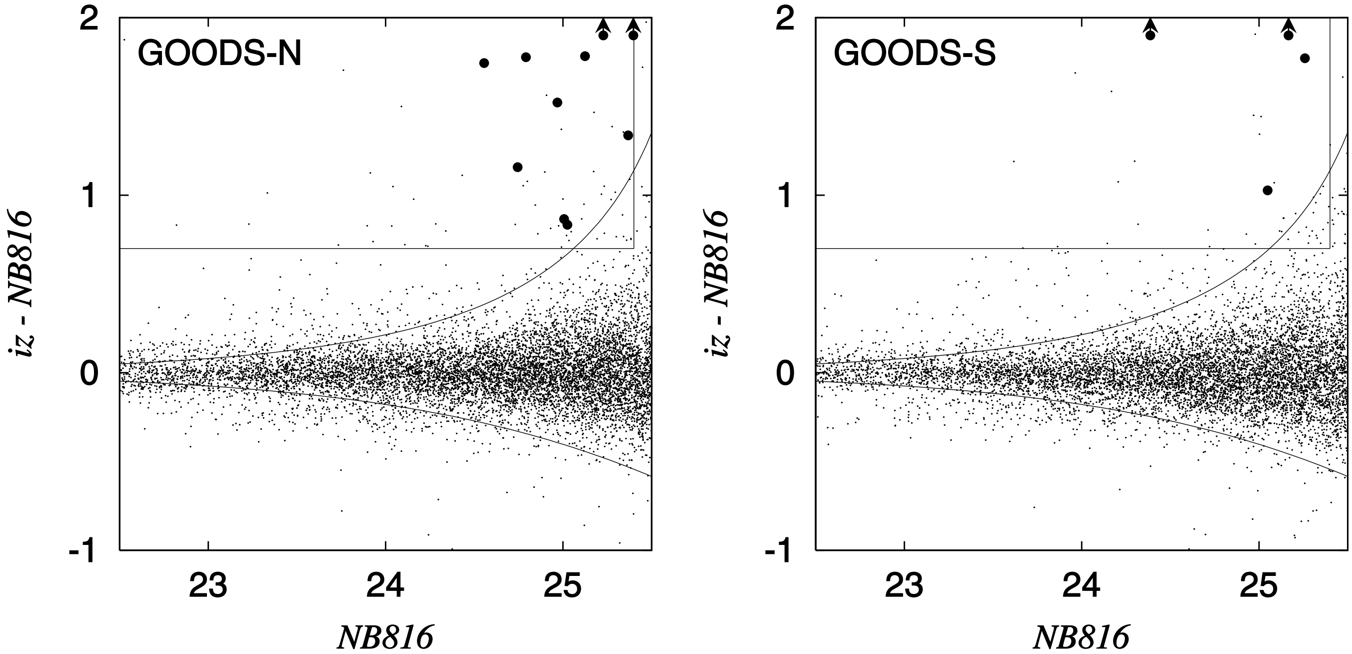

FIG. 1.—Diagram of iz − NB816 vs. NB816 in GOODS-N (*left*) and GOODS-S (*right*). Our LAE candidates are shown as filled circles. The vertical lines show the detection limit corresponding to NB816 = 25.4. The horizontal lines show the selection criterion iz − NB816 = 0.7. The curves show the 3 σ limits for iz − NB816.

comoving depth of 45 Mpc ($z_{\rm min} \approx 5.65$ to $z_{\rm max} \approx 5.75$) and a combined volume of 8.0×10^4 Mpc^3.

Source detection was performed using SExtractor, version 2.3 (Bertin & Arnouts 1996). A source is defined as a 9 pixel contiguous area above the 3 σ noise level on the NB816 image. Photometry was performed using IRAF `apphot` with a 2″ diameter aperture. To the magnitude limit of our survey, NB816 = 25.4 ($\approx$5 σ in the both fields), a total of 9600 and 8700 sources are found in the GOODS-N and GOODS-S fields, respectively.

2.2. *Selection of LAE Candidates*

The LAE candidates at $z \approx 5.7$ are identified by combining the GOODS ACS images (B_{435}, V_{606}, i_{775}, and z_{850}; Giavalisco et al. 2004a) and narrowband catalog with NB816 < 25.4. The LAEs are selected to satisfy the following criteria:

$$B_{435} > 27.5, \quad (1)$$

$$V_{606} > 27.6, \quad (2)$$

$$iz - {\rm NB816} > 0.7, \quad (3)$$

where iz is the continuum magnitude at $\lambda = 8150$ Å, estimated by linear interpolation between the i_{775} and z_{850} flux densities ($f_{iz} = 0.63 f_{i_{775}} + 0.37 f_{z_{850}}$). The first two criteria ensure that the objects at $z \approx 5.7$ are undetected (at a 2 σ noise level) in B_{435} and V_{606}, while the third condition allows selection of LAEs with a rest-frame Lyα equivalent width $\geq$17 Å. This is illustrated in Figure 1, where the LAE candidates are identified on a iz − NB816 versus NB816 color-magnitude diagram. A total of 10 (GOODS-N) and 4 (GOODS-S) LAEs at a targeted redshift of $z \sim 5.7$ are found to satisfy the above criteria. Their NB816 and broadband ACS images are shown in Figure 2 (GOODS-N) and Figure 3 (GOODS-S). Their coordinates and photometric properties are summarized in Table 1.

It is important to estimate the fraction of contaminants in our LAE survey. From spectroscopic observations of a sample of 23 LAE candidates at $z \sim 5.7$, identified in a narrowband survey, Hu et al. (2004) found that four are interlopers (two are [O II] and Hα emitters, one is a red star [NB816 − $z' > 0.2$], and one is a source with no discernible spectral features).[7] Since none of our LAE candidates have red NB816 − z_{850} colors, similar to what is expected for stars, our LAE survey is expected to be free from contamination by red stars. This, combined with the fact that the B- and V-band data here are deeper than those of Hu et al. (2004) by $\sim$1 mag, we expect a contamination rate of <14% for our sample of LAEs here.

3. RESULTS

3.1. *Number Density and Lyα Luminosities of LAE Candidates*

Using the estimated survey volume for each field, 4.0×10^4 Mpc^3, and the number of LAE candidates found at $z \approx 5.7$, we estimate LAE space densities of $n({\rm LAE}) \simeq 2.5 \times 10^{-4}$ and $\simeq 1.0 \times 10^{-4}$ Mpc^{-3} for GOODS-N and GOODS-S, respectively. The total space density in the combined GOODS fields is then $n({\rm LAE}) \simeq 1.7 \times 10^{-4}$ Mpc^{-3}. The space density of LAEs in the GOODS-S field is lower by a factor of 2.5 than that in the GOODS-N field. Spatial distributions of the LAE candidates are shown in Figure 4.

In Table 2, we list the Lyα luminosities for our sample of LAE candidates, assuming them to be at $z = 5.70$, with the Lyα shifted to the central wavelength of the NB816 filter. The Lyα luminosities range from $\approx 4.2 \times 10^{42}$ to $\approx 1.2 \times 10^{43}$ ergs s^{-1}. These values correspond to L_*–$3L_*$ of the Lyα luminosity

[7] Hu et al. (2004) used the following criteria for selecting their LAE candidates: (1) NB816 < 25.05, (2) I_c − NB816 > 0.7, (3) undetected in the B and V images, and (4) $r' - z' > 1.8$.

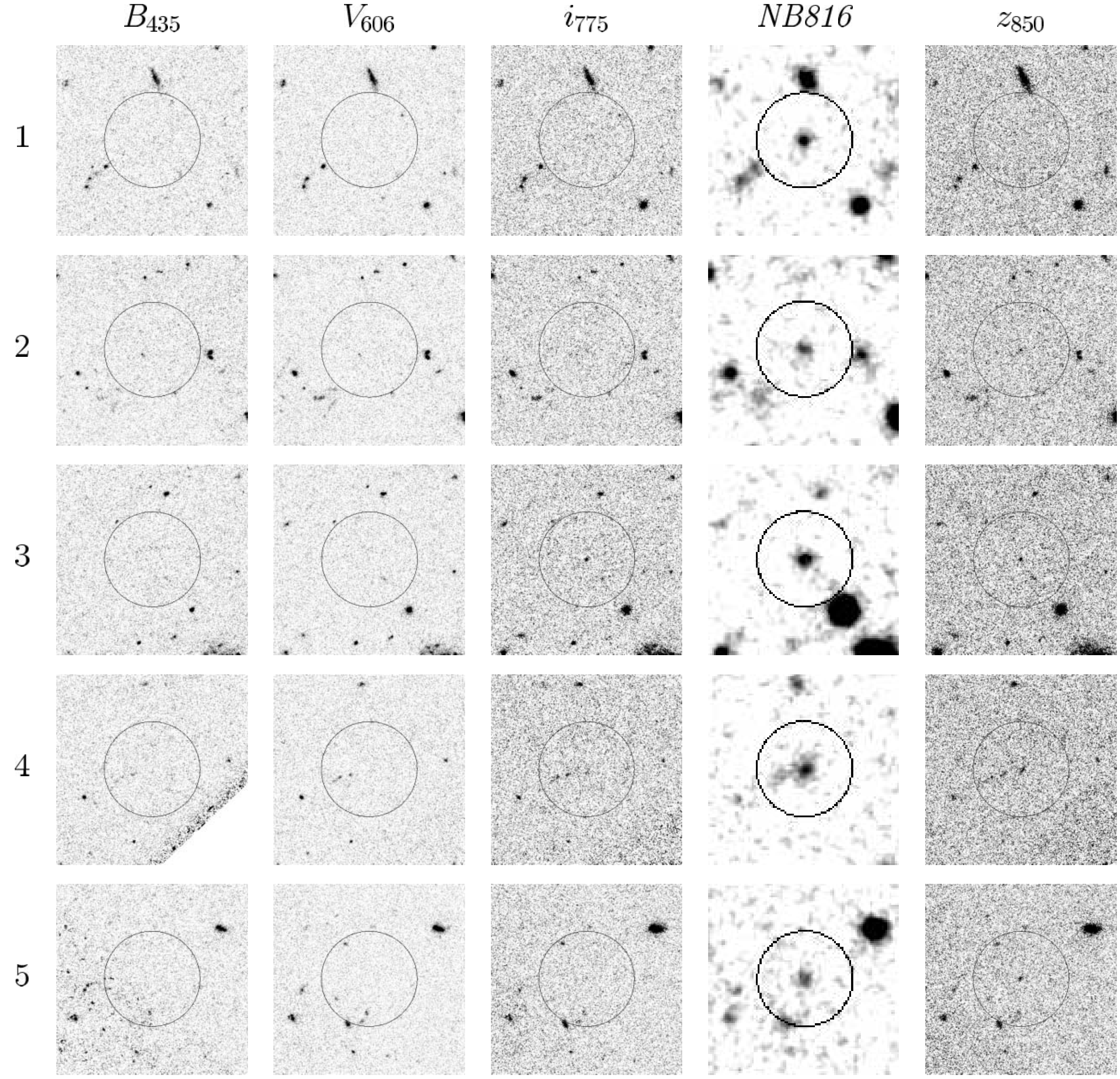

FIG. 2.—Broadband and NB816 images of our LAE candidates at $z \approx 5.7$ in GOODS-N. Each box is 12″ on a side (north is up and east is left). Each circle has a 3″ radius.

function by Ajiki et al. (2003; $L_* = 4.1 \pm 0.4 \times 10^{42}$ ergs s^{-1}). In Figure 5 (*top*), we show the distribution of Lyα luminosities for our 14 LAE candidates. We compare our results with those of the previous LAE surveys at $z = 5.7$ (Rhoads & Malhotra 2001; Ajiki et al. 2003; Hu et al. 2004; Fig. 5, *bottom*). It is clear that the number density of our sample of LAEs with Lyα luminosities of $\approx 5 \times 10^{42}$ ergs s^{-1} is higher (by a factor of ~ 5) than those of the other surveys. This seems to be attributed to the relatively deeper completeness limit for our survey [$L_{\rm lim}({\rm Ly}\alpha) \simeq 4.8 \times 10^{42}$ ergs s^{-1} corresponding to NB816 = 25.4] compared to the previous studies, including Rhoads & Malhotra [2001; $L_{\rm lim}({\rm Ly}\alpha) \simeq 5.3 \times 10^{42}$ ergs s^{-1}], Ajiki et al. [2003; $L_{\rm lim}({\rm Ly}\alpha) \simeq 7.0 \times 10^{42}$ ergs s^{-1}], and Hu et al. [2004; $L_{\rm lim}({\rm Ly}\alpha) \simeq 6.6 \times 10^{42}$ ergs s^{-1}]. The extra depth enables our survey to include more LAEs with Lyα luminosities of $\sim(4$ to $-6) \times 10^{42}$ ergs s^{-1} than in the previous surveys. We also note that for luminosity [$L({\rm Ly}\alpha) > 7 \times 10^{42}$ ergs s^{-1}], the number density of our combined (GOODS-N and GOODS-S) sample is higher than that of Rhoads & Malhotra (2001) by a factor of ≈ 2 while lower than those of Ajiki et al. (2003) and Hu et al. (2004) by a similar factor.

3.2. *Star Formation Rates*

Using the LAE luminosities, we now estimate their corresponding star formation rates (SFRs), using the relation (Kennicutt 1998; Brocklehurst 1971)

$$ {\rm SFR}({\rm Ly}\alpha) = 9.1 \times 10^{-43} L({\rm Ly}\alpha)\ M_\odot\ {\rm yr}^{-1}. \quad (4) $$

Here $L({\rm Ly}\alpha)$ is in units of ergs per second and we assume a Salpeter initial mass function with $(m_{\rm lower}, m_{\rm upper}) = (0.1\ M_\odot, 100\ M_\odot)$. The results are given in column (3) of Table 2. We note that the SFR derived here can be underestimated due to the

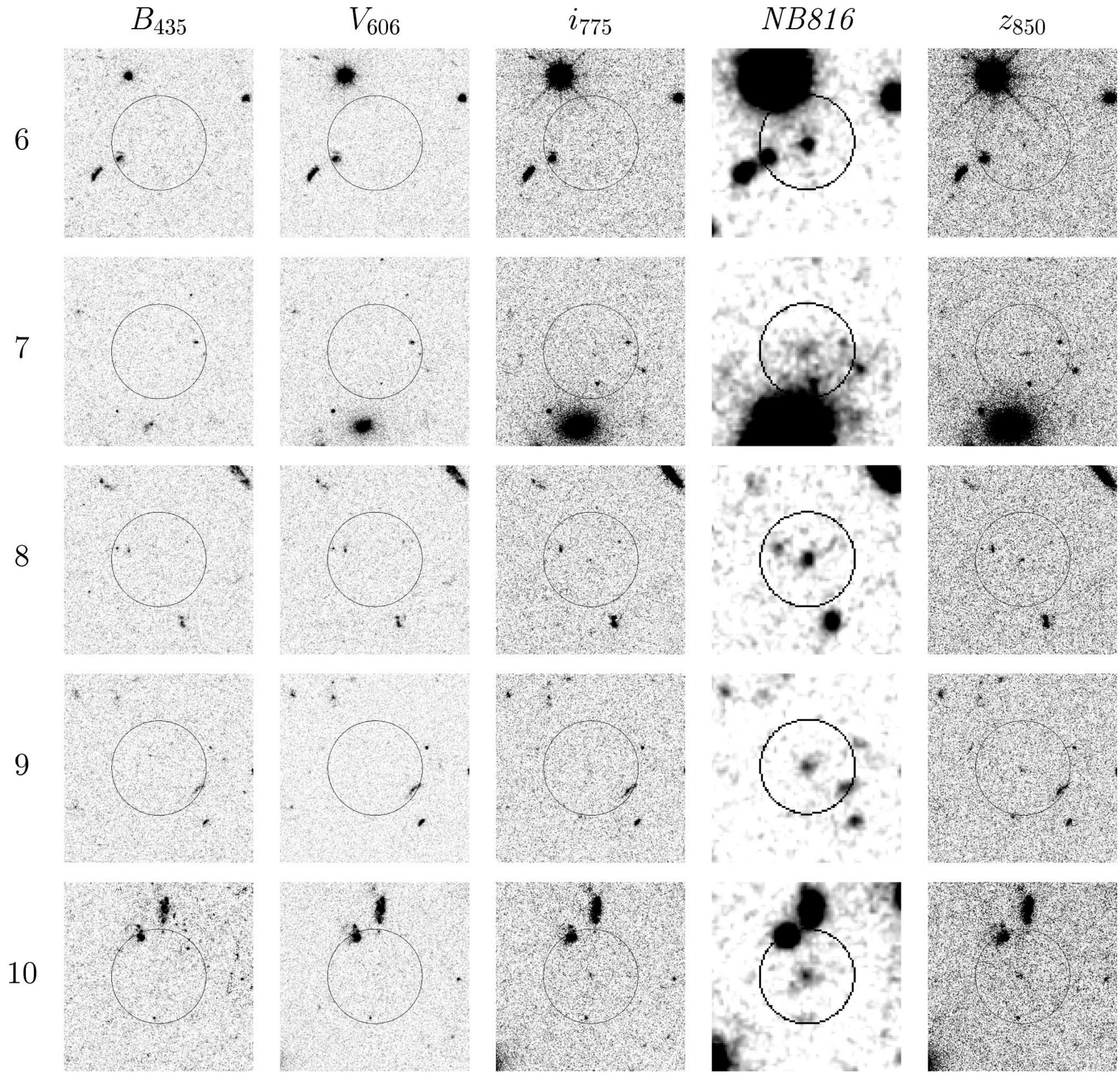

FIG. 2.—*Continued*

effect of absorption by H I gas both in the host galaxies and in the intergalactic space. The SFRs range from 4 to 11 $M_\odot$ yr^{-1} with a median of 5.2 $M_\odot$ yr^{-1}. The estimated SFRs here are comparable to those of LAEs at $z \simeq 5.7$–6.6 (e.g., Ajiki et al. 2003; Taniguchi et al. 2005).

It is instructive to examine whether the SFRs derived from Lyα luminosities here are consistent with those derived from the UV continuum luminosity from the broadband data in the GOODS. We convert the observed z_{850} magnitudes to UV continuum luminosities at $\lambda = 1360$ Å, using the relation (Kennicutt 1998; see also Madau et al. 1998)

$$\mathrm{SFR(UV)} = 1.4 \times 10^{-28} L_\nu \ M_\odot \ \mathrm{yr}^{-1}, \quad (5)$$

where L_ν is in units of ergs per second per hertz. The estimated SFRs are summarized in Table 2. Comparison between the SFRs for individual sources, estimated from SFR(Lyα) and SFR(UV) (see Fig. 6), shows that, on average, SFR(UV) is relatively higher than SFR(Lyα) for most of the LAE candidates. We also measure the average SFR ratios, $\mathrm{SFR_{total}(Ly\alpha)/SFR_{total}(UV)} = 0.71$, where $\mathrm{SFR_{total}(Ly\alpha)}$ and $\mathrm{SFR_{total}(UV)}$ are, respectively, the sum of SFR(Lyα) and SFR(UV) of all of our LAE candidates. This ratio is close to that obtained by Ajiki et al. (2003) for their sample of LAEs at $z \approx 5.7$. The lower value of SFR(Lyα) can be attributed to the effect of dust extinction and scattering by the intergalactic medium. However, some of our LAE candidates have $\mathrm{SFR(Ly\alpha)/SFR(UV)} > 1$. These are likely to be in a very early phase (<10^8 yr) of star formation activity, in which

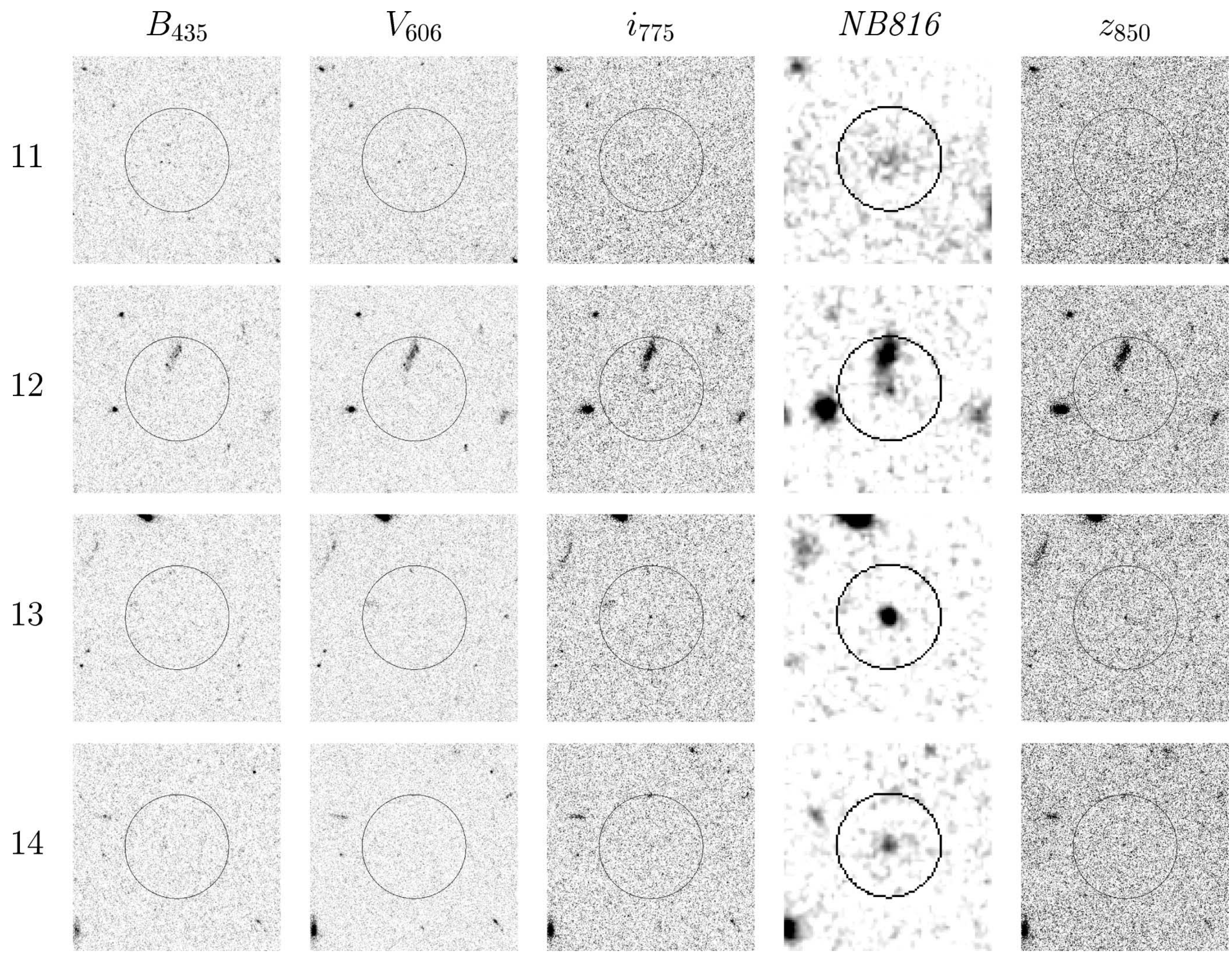

FIG. 3.—Same as Fig. 2, but in GOODS-S.

TABLE 1
THE LAE CANDIDATES AT $z \approx 5.7$ IN GOODS-N AND GOODS-S FIELDS

No.	α (J2000.0)	δ (J2000.0)	B_{435}	V_{606}	i_{775}	z_{850}	NB816
GOODS-N							
1	12 35 46.4	+62 12 19	29.26	99	26.91	26.91	25.12
2	12 35 58.9	+62 10 18	27.27	27.87	26.65	26.81	25.37
3	12 36 07.9	+62 08 39	27.56	28.48	26.17	28.09	24.79
4	12 36 13.4	+62 07 48	29.51	34.20	26.30	25.44	24.75
5	12 36 45.4	+62 18 03	29.07	99	28.35	26.92	25.40
6	12 36 51.6	+62 19 37	99	28.53	26.82	25.76	24.56
7	12 37 01.0	+62 21 15	99	29.13	26.10	25.54	25.03
8	12 37 17.9	+62 17 59	27.61	31.58	26.74	26.17	24.97
9	12 37 27.8	+62 11 47	99	99	27.43	99	25.23
10	12 37 35.9	+62 14 22	27.27	29.08	26.22	25.45	25.01
GOODS-S							
11	03 32 22.3	−27 56 59	27.34	27.92	28.40	26.16	25.26
12	03 32 29.4	−27 40 29	27.65	27.24	25.89	26.48	25.05
13	03 32 37.5	−27 40 57	30.36	28.93	26.90	26.87	24.39
14	03 32 52.0	−27 53 31	28.14	29.06	26.99	99	25.17

NOTES.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. The AB magnitude in a 2″ diameter is given. An entry of 99 indicates that no excess flux was measured.

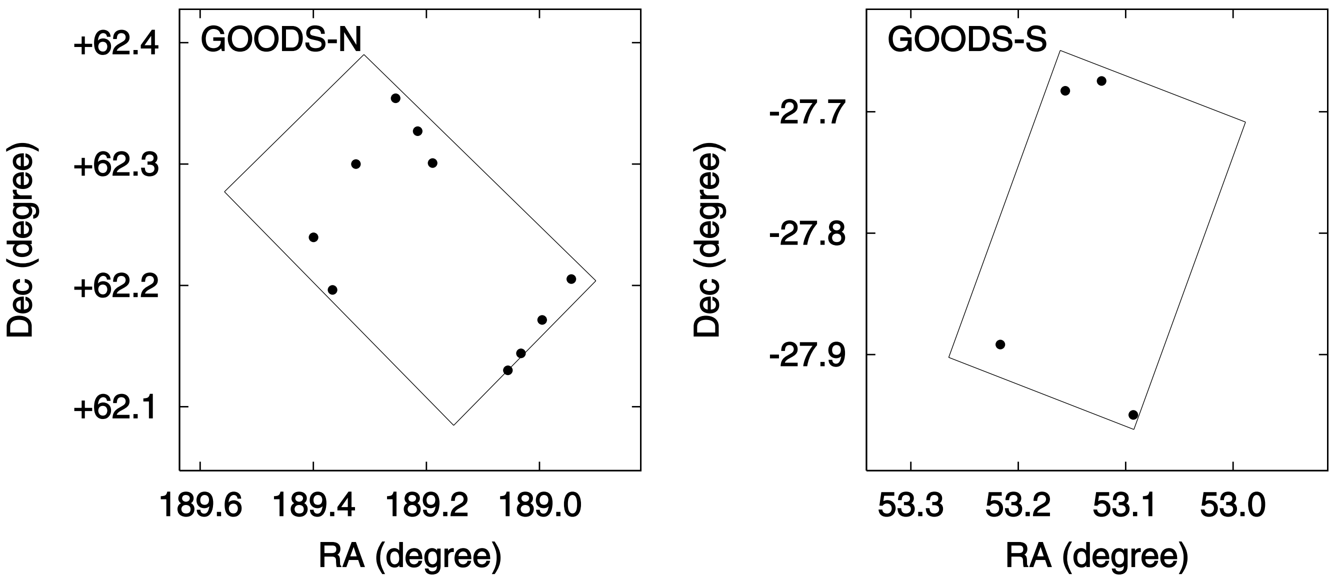

Fig. 4.—Spatial distributions of our LAE candidates in GOODS-N (*left*) and GOODS-S (*right*).

SFR(UV) values are underestimated (Schaerer 2000; see also Nagao et al. 2004, 2005). As illustrated in Figure 6 (*right*), objects with small SFR(UV) have higher SFR(Lyα)/SFR(UV) ratios. This is explained in part by selection effects in the NB816–limited sample (i.e., our survey cannot find objects below the dotted curve in the right panel of Fig. 6). However, all objects with SFR(Lyα)/SFR(UV) > 1 (i.e., an age of $<10^8$ yr) have SFR(UV) $\lesssim$ 5. This implies that the UV continuum emission of very young star-forming galaxies is too faint to be found in typical LBG surveys. The narrowband survey provides a very

TABLE 2

Lyα Luminosities and Star Formation Rates for the LAE Candidates at $z \approx 5.7$

No. (1)	L(Lyα)[a] (10^{42} ergs s^{-1}) (2)	SFR(Lyα)[b] ($M_\odot$ yr^{-1}) (3)	L_{1360}[c] (10^{28} ergs s^{-1} Hz^{-1}) (4)	SFR(UV)[d] ($M_\odot$ yr^{-1}) (5)	SFR(Lyα)/SFR(UV) (6)
GOODS-N					
1..........	5.6	5.0	3.3	4.6	1.09
2..........	4.3	3.9	3.6	5.1	0.76
3..........	8.2	7.4	<2.0	<2.8	>2.65
4..........	6.5	5.8	12.7	17.8	0.33
5..........	4.2	3.8	3.3	4.6	0.83
6..........	8.7	7.9	9.6	13.4	0.59
7..........	4.7	4.2	11.7	16.4	0.26
8..........	6.0	5.4	6.5	9.2	0.59
9..........	5.6	5.1	<2.0	<2.8	>1.81
10........	4.6	4.2	12.6	17.7	0.24
GOODS-S					
11........	4.3	3.9	6.6	9.2	0.42
12........	5.8	5.2	4.9	6.9	0.75
13........	11.6	10.5	3.4	4.8	2.17
14........	6.0	5.4	<2.0	<2.8	>1.92

[a] $\sigma \approx 0.1 \times 10^{43}$ ergs s^{-1}.
[b] $\sigma \approx 1\ M_\odot$ yr^{-1}.
[c] UV continuum luminosity at $\lambda = 1360$ Å; $\sigma \approx 2.0 \times 10^{28}$ ergs s^{-1} Hz^{-1}.
[d] $\sigma \approx 2.8\ M_\odot$ yr^{-1}.

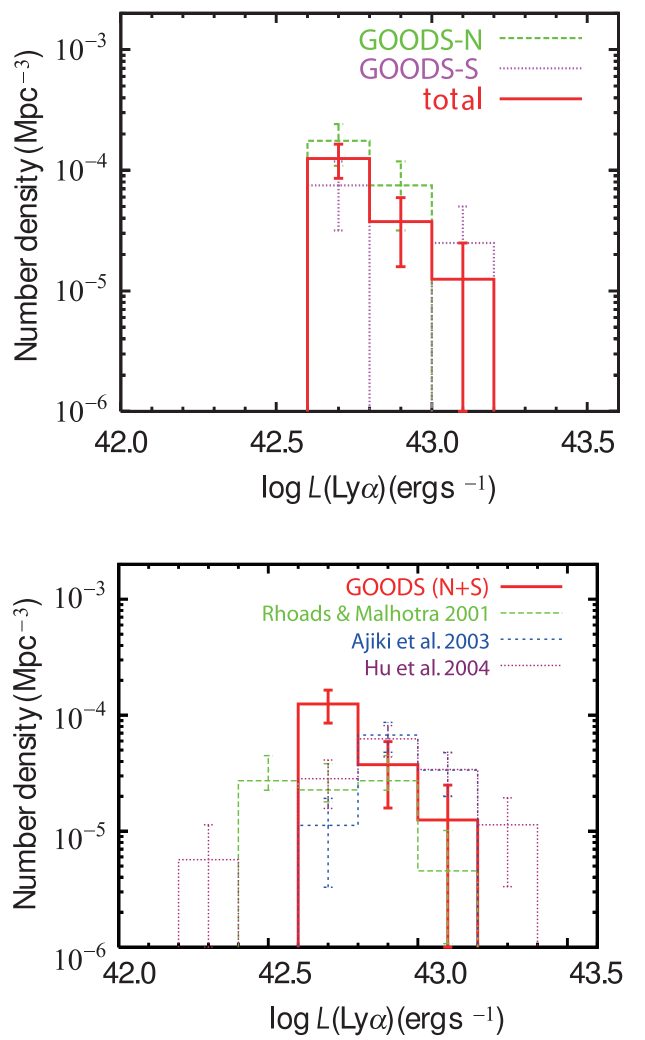

Fig. 5.—*Top*: Distribution of Lyα luminosity of our LAE candidates. *Bottom*: Our results compared with those from Rhoads & Malhotra (2001), Ajiki et al. (2003), and Hu et al. (2004).

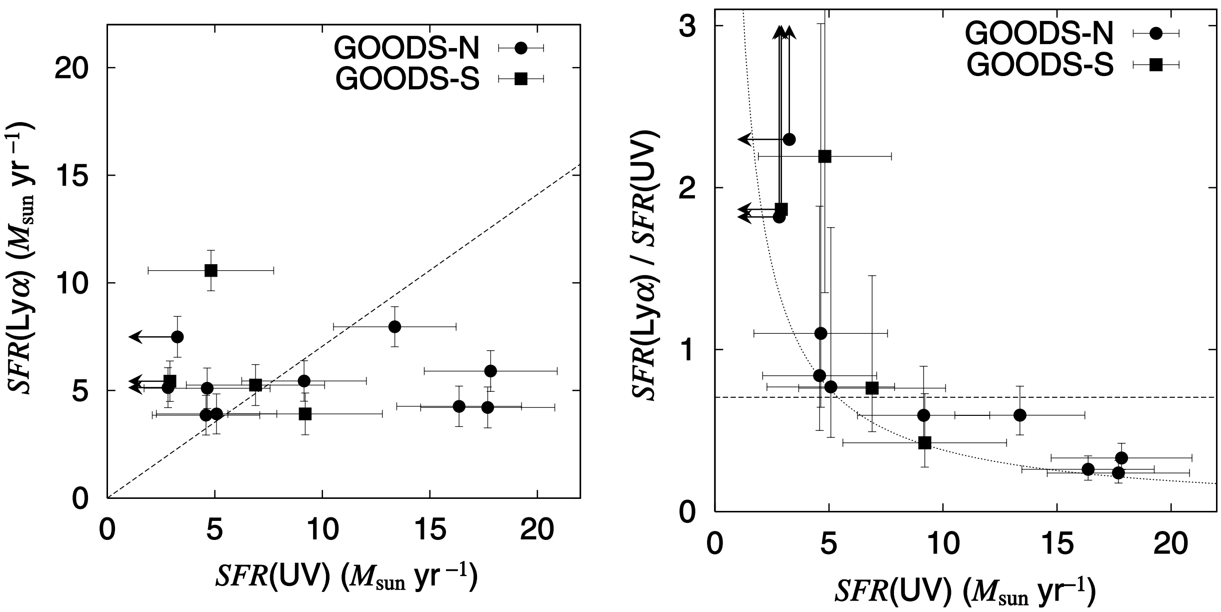

FIG. 6.—Comparison between SFR(Lyα) and SFR(UV) (*left*) and SFR(Lyα)/SFR(UV) and SFR(UV) (*right*) for 14 LAE candidates. The dashed lines in both panels show SFR(Lyα)/SFR(UV) = 0.71. The dotted curve in the right panel shows the detection limit of our survey corresponding to SFR(Lyα) = 3.8 $M_\odot$ yr^{-1}.

efficient method for investigating such very young star-forming galaxies.

4. SUMMARY

We present results from a NB816 survey in the two GOODS fields, aiming for LAE galaxies in the redshift range $z = 5.65$–5.75. We find a total of 14 LAE candidates satisfying our selection criteria. The space density of LAEs with $L(\text{Ly}\alpha) \approx 5 \times 10^{42}$ ergs s^{-1} found here (1.0×10^{-4} Mpc^{-3}) is a factor of $\sim$5 higher than in other similar surveys (Rhoads & Malhotra 2001; Ajiki et al. 2003; Hu et al. 2004), due to the relatively deeper flux limit in the present survey. Using the Lyα luminosities, we estimate the SFRs for LAEs, SFR(Lyα), to be in the range 4–11 $M_\odot$ yr^{-1}. Overall, this is smaller than the SFR estimated from rest-frame UV light [SFR(Lyα)/SFR(UV) = 0.71], due to extinction in the Lyα flux. We interpret a larger SFR(Lyα) value [i.e., SFR(Lyα)/SFR(UV) > 1], observed for a few LAEs, as due to a very early phase of star formation ($<10^8$ yr).

We would like to thank both the Subaru and *HST* staff for their invaluable help. Data reduction/analysis was in part carried out on an "sb" computer system operated by the Astronomical Data Analysis Center (ADAC) and Subaru Telescope of the National Astronomical Observatory of Japan. We also thank an anonymous referee for useful comments and suggestions. This work was financially supported in part by the Ministry of Education, Culture, Sports, Science, and Technology (10044052 and 10304013) and by the Japan Society for the Promotion of Science (JSPS; 15340059 and 17253001). M. A., S. S. S., and T. N. are JSPS fellows.

REFERENCES

Ajiki, M., et al. 2003, AJ, 126, 2091
Barkana, R., & Loeb, A. 2001, Phys. Rep., 349, 125
Beckwith, S. V. W., et al. 2003, BAAS Abstr., 202, 17.05
Bertin, E., & Arnouts, S. 1996, A&AS, 117, 393
Bouwens, R. J., et al. 2004, ApJ, 606, L25
Brocklehurst, M. 1971, MNRAS, 153, 471
Cowie, L. L., & Hu, E. M. 1998, AJ, 115, 1319
Dickinson, M., et al. 2004, ApJ, 600, L99
Giavalisco, M., et al. 2004a, ApJ, 600, L93
———. 2004b, ApJ, 600, L103
Hu, E. M., Cowie, L. L., Capak, P., McMahon, R. G., Hayashino, T., & Komiyama, Y. 2004, AJ, 127, 563
Hu, E. M., Cowie, L. L., & McMahon, R. G. 1998, ApJ, 502, L99
Hu, E. M., Cowie, L. L., McMahon, R. G., Capak, R., Iwamuro, F., Kneib, J.-P., Maihara, T., & Motohara, K. 2002, ApJ, 568, L75
Kaifu, N., et al. 2000, PASJ, 52, 1
Kennicutt, R. C., Jr. 1998, ARA&A, 36, 189
Kodaira, K., et al. 2003, PASJ, 55, L17
Madau, P., Pozzetti, L., & Dickinson, M. 1998, ApJ, 498, 106
Miyazaki, S., et al. 2002, PASJ, 54, 833
Nagao, T., et al. 2004, ApJ, 613, L9
———. 2005, ApJ, 634, 142
Ouchi, M., et al. 2004, ApJ, 611, 660
Rhoads, J. E., & Malhotra, S. 2001, ApJ, 563, L5
Rix, H., et al. 2004, ApJS, 152, 163
Schaerer, D. 2000, in Building the Galaxies: From the Primordial Universe to the Present, ed. F. Hammer et al. (Gif-sur-Yvette: Editions Frontières), 389
Stanway, E. R., Bunker, A. J., McMahon, R. G., Ellis, R. S., Treu, T., & McCarthy, P. J. 2004, ApJ, 607, 704
Steidel, C. C., Giavalisco, M., Dickinson, M., & Adelberger, K. L. 1996, AJ, 112, 352
Taniguchi, Y., et al. 2005, PASJ, 57, 165
Yagi, M., Kashikawa, N., Sekiguchi, M., Doi, M., Yasuda, N., Shimasaku, K., & Okamura, S. 2002, AJ, 123, 66

Note added in proof.—Wang et al. (ApJ, 622, L77 [2005]) also made a similar narrowband survey for LAEs at $z \simeq 5.70$–5.77 in the Chandra Deep Field South region including the GOODS-S field. They found two LAE candidates at $z \simeq 5.77$ in the GOODS-S field. These are not detected in our survey because our filter bandpass is slightly different from theirs.