The nature of $[\text{S III}]\lambda\lambda 9096,9532$ emitters at $z = 1.34$ and $1.23$

AN FangXia$^{1,2}$, ZHENG XianZhong$^2$, MENG YanZhi$^2$, CHEN Yang$^3$, WEN ZhangZheng$^5$ & LÜ GuoLiang$^1$

$^1$School of Physics and Technology, Xinjiang University, Urumqi 830046, Xinjiang, China; $^2$Purple Mountain Observatory, China Academy of Sciences, Nanjing 210008, China; $^3$Center for Astrophysics, University of Science and Technology of China, Hefei 230026, China;

A study of $[\text{S iii}]\lambda\lambda 9096,9532$ emitters at $z = 1.34$ and $1.23$ is presented using our deep narrow-band $H_2S\lambda 1$ (centered at $2.13\mu m$) imaging survey of the Extended Chandra Deep Field South (ECDFS). We combine our data with multi-wavelength data of ECDFS to build up spectral energy distributions (SEDs) from the $U$ to the $K_s$-band for emitter candidates selected with strong excess in $H_2S\lambda 1 - K_s$ and derive photometric redshifts, line luminosities, stellar masses and extinction. A sample of $14$ $[\text{S iii}]$ emitters are identified with $H_2S\lambda 1 < 22.8$ and $K_s < 24.8$ (AB) over $381$ arcmin$^2$ area, having $[\text{S iii}]$ line luminosity $L_{[\text{S III}]} = 10^{41.5-42.6}$ erg s$^{-1}$. None of the $[\text{S iii}]$ emitters is found to have X-ray counterpart in the deepest Chandra $4$ Ms observation, suggesting that they are unlikely powered by AGN. $HST/ACS$ F606W and $HST/WFC3$ F160W images show their rest-frame UV and optical morphologies. About half of the $[\text{S iii}]$ emitters are mergers and at least one third are disk-type galaxies. Nearly all $[\text{S iii}]$ emitters exhibit a prominent Balmer break in their SEDs, indicating the presence of a significant post-starburst component. Taken together, our results imply that both shock heating in post-starburst and photoionization caused by young massive stars are likely to excite strong $[\text{S iii}]$ emission lines. We conclude that the $[\text{S iii}]$ emitters in our sample are dominated by star-forming galaxies (SFGs) with stellar mass $8.7 < \log(M/M_\odot) < 9.9$.

1 Introduction

The cosmic star formation rate density peaks at $z \sim 2 - 3$ and sharply declines to the present day $[1][3]$. The determination of physical properties of galaxies over all cosmic epochs is key to our understanding of physical processes driving the strong evolution in galaxy star formation (SF). Galaxies in the “redshift desert” $1.2 < z < 2.5$ are seldom explored with optical spectroscopies because the major emission lines are redshifted into the near-infrared (NIR), although substantial progress has been made in measuring the luminosity function $[4]$, stellar mass function $[5]$, dust extinction $[6]$ and metallicity $[7]$ of galaxy populations in this cosmic epoch. Moreover, physical conditions such as ionization state and element abundance can only be derived from important nebular emission lines such as $[O \ i]\lambda 5007$, $[N \ ii]\lambda 6584$ and $[S \ iii]\lambda 9069$. This can be done with spectroscopic surveys in the NIR with Fiber Multi Object Spectrograph on the Subaru Telescope and with NIR grisms of Wide-Field-Camara 3 (WFC3) on board the Hubble Space Telescope ($HST$), allowing to observe the $[N \ ii]$, $H\alpha$ emission lines in galaxies at $1.2 < z < 1.5$. The emission lines at longer wavelengths (for instance, $[S \ iii]$) are missed in such surveys $[8][9]$. $[S \ iii]\lambda\lambda 9096,9532$ is widely used to probe the physical conditions of galaxies and nebulae in the local universe $[10][16]$. Two major ionization stages are often observed for Sulfur, $S^+$ and $S^{++}$. $S^{++}$ becomes more abundant in high-ionization zone $[16]$, and is believed to be the dominant (often > 60%) sulfur ion in a nebula $[11]$. $S^{++}$ has three forbidden transitions at $[S \ iii]\lambda\lambda 9096,9532$ Å and $\lambda 6312$ Å. The $[S \ iii]\lambda 6312$ line is weak and sensitive to environment temperature, while the $[S \ iii]$ lines in the NIR are usually considered much stronger. These $[S \ iii]$ lines are hence often used to estimate the Sulfur abundance for low-$z$ galaxies $[1][3]$. Sulfur is one of the $\alpha$-elements and its abundance in stellar atmo-
spheres is needed for exploring galaxies formation and evolution [14]. In H\textsc{ii} regions, the intensities of [S\textsc{iii}] emission lines depend exponentially on the electron temperature [12]. The line ratios between NIR [S\textsc{iii}] and [S\textsc{ii}]\lambda 6312 Å are widely used to derive electron density and temperature in H\textsc{ii} galaxies [12] [15] [15]. In the case of photoionization, [S\textsc{iii}] is mostly yielded below 10 000 K and [S\textsc{ii}] increases until 20 000 K [16]. The abundance of [S\textsc{iii}] relative to [S\textsc{ii}] is used as an indicator of ionization conditions and the line flux ratios of them are often used to high-excitation for nearby galaxies [10]. Diaz et al. [17] pointed out that the [S\textsc{iii}] lines are weak compared to [S\textsc{ii}], [O\textsc{ii}] or [O\textsc{iii}] lines in the case of collision ionization because of the shock waves with velocities of < 100 km s\(^{-1}\) [18]. However, the shock models of Binette et al. [19] suggest that the [S\textsc{iii}] can be enhanced by high-velocity shocks (> 130 km s\(^{-1}\)), although [S\textsc{iii}]\lambda 9096,9532 is still weaker than [S\textsc{ii}]\lambda 6717,31. More research effort is needed to examine the excitation conditions of [S\textsc{iii}] in terms of photoionization versus shock heating [16] [17] [20] [21].

The [S\textsc{iii}] lines will be widely observed in upcoming NIR spectroscopic surveys. The NIR narrow-band imaging, a modest way to identify emission-line galaxies with relatively-precise redshift (\(\delta z/(1+z) \sim 1\%\)) over large sky coverage, is widely used to explore high-redshift universe [6] [22] and distinguish environments (for example, groups or clusters) traced by the emission-line galaxies [23] [24]. It is therefore important to ascertain the nature of [S\textsc{iii}] emitters at high redshifts in order to better understand the yield of these NIR narrow-band surveys.

Herein we present a sample of 14 [S\textsc{iii}]\lambda 9096,9532 emission-line galaxies at z=1.34 and 1.23 identified from our NIR narrow-band imaging survey. A careful analysis of physical properties of [S\textsc{iii}] emitters is carried out with deep multi-wavelength data in ECDFS. We describe our observation and data reduction as well as give a selection of [S\textsc{iii}] emitters. Throughout the paper we adopt a cosmology of \([\Omega_M, \Omega_{\Lambda}, h_70] = [0.7, 0.3, 1.0]\) [25]. Kroupa initial mass function (IMF) [25] and AB magnitude system [26] are used unless otherwise stated.

## 2 The Data

### 2.1 Observation and data reduction of H\textsubscript{2}S\textsubscript{1}-band data

Our survey in ECDFS (\(\alpha=03:28:45, \delta=-27:48:00\)) was carried out with WIRCam on board CFHT through the H\textsubscript{2}S\textsubscript{1} narrow-band filter (\(\lambda_c = 2.130 \mu m, \Delta \lambda = 0.0293 \mu m\)) [27]. WIRCam consists of four 2048×2048 HAWAII-2-RG detectors, providing a field of view of 20′ × 20′ and a 0.3′′ pixel scale. To cover the gaps between detectors and bad pixels, a dithering technique was adopted in our observations. The H\textsubscript{2}S\textsubscript{1} observations were made in semester 2011B with total integration time 17.24 hrs under the seeing conditions between 0.6′′ and 0.8′′.

The data was reduced using an Interactive Data Language (IDL) based pipeline called \textit{SIMPLE} (Simple Imaging and Mosaicking Pipeline) [28] [29]. The pipeline is used for flat-fielding, subtracting background, removing cosmic ray and instrumental features like crosstalk and calibrating the astrometry and photometry. Because of the rapidly varied sky color in NIR, exposures from the same dithering block (within 40 minutes) and the same detector are processed in a time and stacked into one background-subtracted science image. After that, we mosaic the four background-subtracted science images from different detectors into a frame science image. The final mosaic \(H\textsubscript{2}S\textsubscript{1}\) image has 383 arcmin\(^2\) area with integrated exposure time \(> 10\) hrs. We limited our source detection in this area, having an effective 5\(\sigma\) limiting magnitude of 22.8 mag.

### 2.2 Multi-wavelength data

The \(K_s\)-band (\(\lambda_c = 2.146 \mu m, \Delta \lambda = 0.325 \mu m\)) imaging of ECDFS was obtained with CFHT/WIRCam in semesters 2009B and 2010B [29]. The data are reduced and calibrated in the same way as we describe above for the H\textsubscript{2}S\textsubscript{1} data. The \(K_s\) image reaches a 5\(\sigma\) depth of \(K_s = 24.8\) mag in the region of \(H\textsubscript{2}S\textsubscript{1}\) source detection. Wang et al. [28] and Hsieh et al. [29] provide more details.

The multi-wavelength data we used in this work include the CFHT/WIRCam \(J\)-band data from Taiwan ECDFS Near-Infrared Survey [29]. \(U, B, V, R\) and \(I\)-band data from the Multiwavelength Survey by Yale-Chile (MUSYC) [30], \(HST/ACS F606W (V_{606})\) and F850LP (\(z_{850}\)) imaging from the Galaxy Evolution from Morphology and SEDs [31] [32], \(HST/WF3C F125W (J_{125})\) and F160W (\(H_{160}\)) imaging from the Cosmic Assembly Near-infrared Deep Extra-galactic Legacy Survey (CANDELS) [33] [34]. We summarize 12 bands data in Table 1.

### Table 1

| Camera   | Filter  | \(\lambda_c\) (Å) | FWHM (arcsec) | 5\(\sigma\) depth (AB) |
|----------|---------|------------------|---------------|-----------------------|
| CTIO     | \(U\)   | 3507             | 1.05          | 25.9                  |
|          | \(B\)   | 4600             | 1.01          | 26.5                  |
|          | \(V\)   | 5379             | 0.94          | 26.7                  |
|          | \(R\)   | 6516             | 0.83          | 26.4                  |
|          | \(I\)   | 8659             | 0.96          | 24.3                  |
| ACS      | F606W   | 5958             | 0.12          | 28.5                  |
|          | F850LP  | 9052             | 0.12          | 27.3                  |
| WFC3     | F125W   | 12493            | 0.14          | 27.2                  |
|          | F160W   | 15432            | 0.15          | 26.7                  |
| WIRCam   | \(J\)   | 12540            | 0.79          | 25.4                  |
|          | \(K_s\) | 21498            | 0.75          | 24.8                  |
|          | \(H\textsubscript{2}S\textsubscript{1}\) | 21301       | 0.80          | 22.8                  |
3 Selection of [S II] Emitters

3.1 Selection of emission-line objects

SExtractor [35] is used to detect sources and measure their fluxes in the $H_{2}S1$-band image. Our detection of a source requires a minimum of 5 contiguous pixels above 2.5σ of the background noise. Exposure map is used as weight image to reduce spurious detections in low signal-to-noise (S/N) regions. We utilize the dual-image mode in SExtractor to perform photometry in the $K_{s}$-band data. Total 8720 sources are securely detected with an S/N ratio > 5 in both $H_{2}S1$- and $K_{s}$-band images.

The emission-line candidates are selected according to the significance of their narrow-band excess, that is, their $K_{s} - H_{2}S1$ color [22, 23, 50]. A secure and significant narrow-band excess is mainly determined by the background noises of the narrow- and broad-bands, $\sigma_{H_{2}S1}$ and $\sigma_{K_{s}}$, as follows:

$$K_{s} - H_{2}S1 > \Sigma \sqrt{\sigma_{K_{s}}^{2} + \sigma_{H_{2}S1}^{2}},$$

where the right side term is the combined background noise of the two bands and $\Sigma$ is the significance factor [35]. We select emission-line candidates based upon the criterion of $\Sigma > 3$. Details can be seen in An et al. (in preparation). Moreover, an empirical rest-frame equivalent width (EW) cut of $EW > 50 \, \AA$ [57] is applied to eliminate false excess caused by photon noises for bright objects.

There are 140 objects meeting the selection criteria of $\Sigma > 3$ and $EW > 50 \, \AA$. These objects could potentially be emitters of any emission-line between Paα at $z = 0.14$ and Lyα at $z = 16.52$. We derive photometric redshifts (photo-$z$) for the 140 objects. Among them, 33 are found to have spectroscopic redshift (spec-$z$) from the MUSYC catalog [38].

3.2 Identification of [S II] emitters

We use 12 bands data as listed in Table 1 to measure fluxes and construct SEDs for the selected 140 emission-line objects. Only 72 of 140 have $J_{125}$ and $H_{160}$ data because CANDELS observations cover the central part of ECDFS, that is, the GOODS-South region. The aperture-matched photometry of the 12 bands data are given in Table 2 in units of AB magnitude. We use these matched colors to establish SEDs for 140 sample targets.

The software tool EAZY (Easy and Accurate Redshifts from Yale) [39] is used to derive photo-$z$ from SEDs. The $K_{s}$ magnitude is taken as Bayesian prior. From the previous studies, we know that the NIR selected emission-line objects are mostly, if not all, SFGs [22, 30, 41]. A library of templates is chosen particularly suitable for the SFGs, including five templates generated based on the PÈGASE population synthesis models [42] and calibrated with synthetic photometry from semi-analytic models and one template of young ($t = 50$ Myr) and dusty ($A_{V} = 2.75$) starburst [39]. The combination of these templates is able to provide models spanning a broad range of galaxies ages and the PÈGASE models provide a self-consistent treatment of emission lines [42]. We adopt "z-peak", the peak with the highest integrated probability in redshift probability function, as our photo-$z$.

A total of 17 emitter candidates have the photo-$z$ ~ 1.34 and 1.23, corresponding to $[S\, II]\lambda9096,9532$ lines. The relatively high abundance of $[S\, II]$ was not reported by other surveys [3, 37, 40, 41]. We show the best-fit SEDs obtained by EAZY in the run of photometric redshifts as well as the observed $U$, $N393$ ($\lambda_{c} = 0.393 \mu$m) (Hao et al. in preparation), $V_{606}$ and $K_{s}$-band image stamps of 17 $[S\, II]$ emission-line candidates in Figure 1. We individually inspected the SEDs and the image stamps of 17 $[S\, II]$ emission-line candidates and found that three objects had no detection in the $U$-band while a secure signal is shown in the N393-band. The fitted SEDs of these three objects were higher than upper limit of the $U$-band. The inconsistence between the upper limit of the $U$-band and the chosen model for the three objects is because the upper limits were not taken into account in SED fitting of EAZY. This inconsistence suggests that the objects should locate at a higher redshift and drop out in the $U$-band because of Lyman Break [43]. The three objects are labeled as "U-band dropout" in Figure 1. We numbered the other 14 $[S\, II]$ emission-line candidates and found two emitters, $S_{9S}$ and $S_{9N}$, having similar color and separated by ~ 1″-2″, indicating that they are in the same merger system. We report that only two objects, $S_{5}$ and $S_{8}$, are $[S\, II]_{\lambda9532}$ emitters (photo-$z$ ~ 1.23) and the $S_{5}$ is confirmed by spec-$z$. Finally, we have identified 12 $[S\, II]_{\lambda9096}$ (two in one merger system) and two $[S\, II]_{\lambda9532}$ emitters at $z = 1.34$ and $z = 1.23$, respectively (refer to Table 3).

### Table 2: Photometry of [S III] emitters

| ID  | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ | $M_{[S\, III]}$ |
|-----|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| $\alpha$ | 23.65 ±0.10 | 25.54 ±0.06 | 25.49 ±0.07 | 25.31 ±0.08 | 25.26 ±0.09 | 24.98 ±0.10 | 24.75 ±0.11 | 24.53 ±0.12 | 24.51 ±0.13 | 24.33 ±0.14 | 24.10 ±0.15 |
| $\beta$ | 23.59 ±0.11 | 25.53 ±0.06 | 25.46 ±0.07 | 25.31 ±0.08 | 25.26 ±0.09 | 24.98 ±0.10 | 24.75 ±0.11 | 24.53 ±0.12 | 24.51 ±0.13 | 24.33 ±0.14 | 24.10 ±0.15 |

*Table 2: Photometry of [S III] emitters.*
Figure 1 Image stamps and SEDs of [S III] emitters. Each stamp has a size of $4.5'' \times 4.5''$. The squares are the observed data points and circles are the best-fit results from EAZY [39]. The arrows show the upper limits of corresponded bands which means the source is not detected or resolved in these bands. The three U-band dropout objects are marked with a label of "U-band dropout ". The thick line shows the best-fit SED and light lines are the templates. The inset plot shows the probability distribution of derived photometric redshift.
Figure.1 (continued).
4 Properties of [S III] Emitters

We use the multi-wavelength data of ECDFS and modeled SEDs of our sample to analyze the SF activity, X-ray property, morphology, dust attenuation, stellar mass and stellar population of selected [S III] emitters. The derived properties, extinction corrected luminosity, EW, stellar mass, A_v, and morphology type, of our sample galaxies are summarized in Table 3.

4.1 Star formation activity and X-ray properties

We adopt a rest-frame color-selection technique [44] to study the SF activity in our sample galaxies. We employed the criteria of $V - J > 1.6$, $U - V > 0.49 + 0.88 \times (V - J)$ and $U - V < 1.3$ (three lines in Figure 2) to separate quiescent galaxies from SFGs, following Williams et al. [44]. We use observed $I$ ($\lambda_{850}$ instead if $I$ is not available), $J$ and $K_s$ as the rest-frame $U$, $V$ and $J$. We show our [S III] emitters and the $K_s$-selected galaxies with $1.0 < z_{\text{spec}} < 2.0$ from FIREWORKS [45] in Figure 2. The three lines in Figure 2 represent the SFGs from FIREWORKS. All of the [S III] emitters (red solid points) distribute in the locus of these blue SFGs.

The deepest X-ray data from Chandra 4 Ms observation allow the X-ray properties of our sample galaxies to be examined [45]. None of the [S III] emitters is found to have X-ray counterpart suggestive of no presence of Active Galactic Nuclei (AGN).

4.2 Morphologies

We use HST/ACS F606W imaging data to examine morphologies of our sample of 14 [S III] emission-line galaxies. This band observe the rest-frame 2546 Å and 2671 Å for $z = 1.34$ and $z = 1.23$, respectively. The HST/WF3 F160W imaging data from CANDELS show rest-frame optical morphologies for half of the sample galaxies. Here we execute a visual classification of the rest-frame UV morphologies for 14 [S III] emission-line galaxies (by An F.X, Zheng X.Z and Wen Z.Z). We found that 43% (6/14) sample galaxies appear to be merger remnants with tail, double core; 29% (4/14) are diffuse; 14% (2/14) show a readily apparent disk and the remain 14% have clumpy morphologies. We compared the rest-frame optical morphologies from CANDELS of seven [S III] emission-line galaxies in GOODS-South and found two are different from rest-frame UV morphologies. We present the F606W and F160W image stamps of these seven [S III] emission-line galaxies in Figure 3, they are S3, S4, S5, S6, S8, S9S and S9N from left to right, one can see the apparent discrepancy between rest-frame UV and rest-frame optical morphologies of S5 and S6. We argue that this discrepancy is caused by the heavily dust extinction for rest-frame UV light which is confirmed by our estimation of dust extinction as described in next subsection (refer to Table 3). Because of this heavily dust extinction, the S5 and S6 appear diffuse morphologies in rest-frame UV while they are disk galaxies as shown in rest-frame optical images. We inspected our morphological classification with F160W images for the other [S III] emission-line galaxies in the GOODS-

Table 3: Properties of [S III] emitters

| ID   | RA       | DEC      | log L_{SIII} (erg s^{-1}) | err log L_{SIII} (erg s^{-1}) | EW_{SIII} (Å) | A_v (mag) | log (M_*/M_⊙) | Photo-z | Spec-z | Morphology |
|------|----------|----------|----------------------------|--------------------------------|----------------|-----------|---------------|---------|--------|------------|
| S1_a | 52.939262| -27.973326| 41.89                      | 0.94                           | 637.84         | 0.91      | 9.16          | 1.35    |        | Merger     |
| S1_b | 53.239098| -27.971136| 41.76                      | 0.97                           | 630.31         | 0.00      | 9.15          | 1.34    |        | Disk       |
| S2   | 53.096191| -27.916807| 41.63                      | 0.84                           | 802.79         | 0.09      | 9.19          | 1.35    |        | Disk       |
| S3   | 53.222755| -27.859795| 41.67                      | 0.87                           | 318.84         | 0.00      | 9.63          | 1.35    |        | Disk       |
| S4   | 53.186699| -27.831648| 42.63                      | 1.17                           | 443.30         | 0.00      | 9.45          | 1.35    |        | Disk       |
| S5   | 52.993256| -27.922824| 41.55                      | 0.69                           | 365.85         | 0.00      | 9.24          | 1.35    |        | Disk       |
| S6   | 52.095090| -27.98351 | 41.77                      | 0.63                           | 190.99         | 1.20      | 9.91          | 1.35    |        | Disk       |
| S7   | 53.079136| -27.785062| 42.04                      | 0.97                           | 267.93         | 0.00      | 9.44          | 1.34    |        | Disk       |
| S8   | 53.062340| -27.747675| 41.88                      | 1.00                           | 333.47         | 0.30      | 8.92          | 1.34    |        | Disk       |
| S9   | 52.967308| -27.755555| 41.70                      | 0.89                           | 998.66         | 0.40      | 8.67          | 1.34    |        | Disk       |
| S10  | 52.993256| -27.722013| 41.59                      | 0.77                           | 452.96         | 0.29      | 9.22          | 1.34    |        | Disk       |
| S11  | 52.938370| -27.719694| 41.72                      | 0.82                           | 229.74         | 0.00      | 9.46          | 1.34    |        | Disk       |
| S12  | 53.076378| -27.663435| 41.58                      | 0.73                           | 383.50         | 0.00      | 9.18          | 1.35    |        | Disk       |

Figure 2: $U - V$ versus $V - J$ diagram of our [S III] emission-line galaxies (red solid points) and $K_s$-selected galaxies with $1.0 < z_{\text{spec}} < 2.0$ from FIREWORKS [45]. The three lines ($V - J > 1.6$, $U - V > 0.49 + 0.88 \times (V - J)$ and $U - V < 1.3$) define the separation cuts between quiescent galaxies (gray pluses in the top-left region) and SFGs (blue pluses)
South. The $S_5$ and the $S_6$ are modified to disk morphology and the classification of other five [S II] emitters are confirmed by rest-frame optical morphologies. Therefore, our classification based on rest-frame UV morphologies has large uncertainty caused by dust extinction. Moreover, the morphological parameters, Gini and $M_{50}$ coefficient [47] which are derived from rest-frame UV images, can not delineate the difference between mergers and non-mergers of our sample galaxies as Stott et al. [48] reported.

Figure 3  HST F606W (upper) and F160W (bottom) image stamps of seven [S III] emission-line galaxies at $z \sim 1.3$. Each stamp has a size of $4.5'' \times 4.5''$, corresponding to 37 kpc$\times$37 kpc at $z \sim 1.3$.

4.3 Dust extinction

We estimate dust extinction of [S II] emission-line galaxies from the best-fit SEDs as shown in Figure 1. As described above, we made use of EAZY [39] to fit SEDs with a library of six galaxy templates. One of the six templates represents a young and dusty starburst with $A_V = 2.75$ which is presented by yellow light line in Figure 1 (refer to color version in on-line journal). Other five templates represent stellar populations of different ages and their synthetic photometry are calibrated by semi-analytic models which are unable to produce extremely dusty galaxies [39,42]. Generally speaking, since stars are formed in dusty environments, the young stellar population being most affected by dust extinction. We assume that the young population comprises two parts: unattenuated and attenuated. Thus, in this model the amount of dust attenuation in the modeling of a galaxy SED can be estimated through the fraction of the dusty starburst template to the total (refer to Table 4). We calculated $A_V$ for [S II] emission-line galaxies in our sample using the best-fit templates obtained in the run of photometric redshifts as shown in Figure 1. The maximal $A_V$ in this model is limited by $A_V = 2.75$ adopted in the young and dusty starburst template. From our SED modeling we find that this limitation has little influence to our extinction estimation of [S II] emitters except one, the $S_6$, whose SED is dominated by this dusty starburst template (see Figure 1 and Table 4). We list the estimated $A_V$ of our sample in Table 3 and we do not find the correlation between our SED-derived extinction and luminosity, stellar mass or line equivalent width of [S II] emitters as other emission-line selected samples at similar redshift found [69].

4.4 Stellar masses

We use the software FAST (Fitting and Assessment of Synthetic Templates) [49] to fit MA05 stellar population synthesis models [50] with an exponentially declining Star formation histories (SFHs). Our choice of SFHs guarantees consistency with most current researches [51]. The metallicity is fixed to solar ($Z = 0.02$) when fit MA05 models. The SF timescale, $\tau$, varies between 10 Myr and 10 Gyr in steps of 0.5 dex and the age is allowed to vary between 0.1 Myr and the age of the universe at the observed redshift in estimating stellar mass for our sample. Dust extinction is modeled using the Calzetti reddening law [52], with $A_V$ ranges between 0 and 3 mag in steps of 0.01 mag. Photometric redshift derived by EAZY is used as recommended by FAST [49]. Although, the two codes use different template sets, FAST can deal with this difference and obtain a reliable result of stellar mass, refer to the appendix in Kriek et al. [49]. The estimated stellar masses of our sample galaxies are $8.7 < \log(M/M_\odot) < 9.9$.

| ID | $\text{Template}_{1}$ | $\text{Template}_{2}$ | $\text{Template}_{3}$ | $\text{Template}_{4}$ | $\text{Template}_{5}$ | $\text{Template}_{6}$ |
|----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| $S_{1}$ | 0 | 10 | 56 | 1 | 0 | 27 |
| $S_{2}$ | 0 | 30 | 70 | 0 | 0 | 0 |
| $S_{3}$ | 0 | 17 | 26 | 53 | 2 | 2 |
| $S_{4}$ | 0 | 27 | 73 | 0 | 0 | 0 |
| $S_{5}$ | 0 | 10 | 86 | 1 | 0 | 3 |
| $S_{6}$ | 0 | 2 | 0 | 0 | 0 | 98 |
| $S_{7}$ | 0 | 22 | 78 | 0 | 0 | 0 |
| $S_{8}$ | 0 | 5 | 0 | 26 | 27 | 9 | 33 |
| $S_{9S}$ | 0 | 1 | 45 | 13 | 4 | 2 | 35 |
| $S_{9N}$ | 0 | 1 | 46 | 4 | 1 | 1 | 47 |
| $S_{10}$ | 0 | 28 | 60 | 1 | 0 | 11 |
| $S_{11}$ | 0 | 7 | 40 | 47 | 0 | 6 |
| $S_{12}$ | 0 | 30 | 70 | 0 | 0 | 0 |
| $S_{13}$ | 0 | 34 | 62 | 4 | 0 | 0 |

a) $\text{Template}_{1}$ to $\text{Template}_{5}$ are five templates generated based on the PÉGASE models; 
b) $\text{Template}_{6}$ is the template of young and dusty starburst.

4.5 Stellar populations

The best-fit EAZY templates, which are shown by light color lines in Figure 1, which represent the fractions of different stellar components of modeled SEDs, thus, can be used to analysis the stellar populations of our sample galaxies. We present the fractions of six templates at $\lambda = 2.146 \mu m$ for 14 modeled SEDs in Table 4. One can see that the template $\text{Temp}_{3}$, which is shown by green line in Figure 1 (refer to color version in on-line journal), is the dominant for most of modeled SEDs. From Figure 1, we see that this template has a significant Balmer break at $\sim 3650 \AA$ (redshifted to $\sim 8540 \AA$ at $z = 1.34$). The Balmer break is the typical spectra feature of A-star which represents the stellar populations with ongoing SF over sustained timescales (> 100 Myr) or the post-starburst populations 0.3-1 Gyr since the cessation of SF [43]. For the majority of modeled SEDs, the secondary contributor is the template $\text{Temp}_{2}$, which is shown by light blue line in Figure 1. This template represents a stellar component of
age around 10 Myr with blue continuum and strong emission lines \cite{53}. Moreover, the contribution from the dusty, starburst template cannot be ignored for most of modeled SEDs and we see that one of modeled SEDs (S6) is dominated by this template (refer to Figure 1 and Table 4). Despite this, from Figure 1, we see that the Balmer break and strong emission lines are the prominent features of SEDs for nearly all of the [S\textsc{ii}] emitters. This indicates that a post-starburst component in combination with a secondary young stellar component with ongoing SF is the most representative of our observed SEDs.

5 Discussion and Conclusion

We present a sizable sample of [S\textsc{ii}] emitters identified using deep $H_\text{ST}/S1$ combined with deep $K_s$ imaging data of ECDFS. The deep optical and NIR imaging data in the ECDFS are utilized to construct SEDs and then derive photometric redshift, extinction and stellar mass. Total 14 [S\textsc{ii}] emitters at $z=1.34$ and $z=1.23$ are identified with the observed [S\textsc{ii}] line flux $>2.9\times10^{-17}$ erg s$^{-1}$ cm$^{-2}$ Hz$^{-1}$. The rest-frame $U-V$ versus $V-J$ diagram shows that all of our [S\textsc{ii}] emitters are SFGs. None of our sample galaxies is detected in the Chandra 4Ms observation, although the possibility to host a Compton-thick AGN individually-undetected in the current X-ray observation can not be excluded \cite{54}. We note that the Compton-thick AGN has little influence in exciting [S\textsc{ii}] lines. We classify the morphologies of our sample based on the $HST/ACS$ F606W images, finding that most [S\textsc{ii}] emitters are mergers and disk-type galaxies. The available rest-frame optical morphologies from CANDELS confirm that the majority of classification while also revealing that the rest-frame UV morphologies of our sample are seriously affected by heavily dust extinction, particularly for objects which appear diffuse morphologies in rest-frame UV images. Although the rest-frame optical lights are less affected by dust obscuration, only half of [S\textsc{ii}] emission-line galaxies are covered by CANDELS. The dust extinction of our sample galaxies is estimated from the modeled SEDs. Our estimation is limited by $A_V=2.75$ adopted in the sixth template (refer to Table 4) and the SED-derived extinction tends to be lower than the ture case represented by the IR to UV luminosity ratio $L_{IR}/L_{UV}$. Unlike other emission-line selected samples at similar redshift, the estimated extinction of [S\textsc{ii}] emission-line galaxies appears to have no obvious correlation with luminosity, stellar mass or line equivalent width $\text{[6, 9]}$. The stellar masses of our sample galaxies are $8.7<\log(M/M_\odot)<9.9$.

The stellar population modeling shows that the Balmer break and the strong emission lines are the prominent features of SEDs for nearly all of the [S\textsc{ii}] emitters, indicating the presence of a post-starburst and an ongoing burst components \cite{43}. Thus, the photoionization caused by young O and B stars in ongoing burst and the collisional ionization because of supernova-driven shocks in post-starburst may all responsible for exciting strong [S\textsc{ii}] lines. This conclusion is consistent with the previous studies of [S\textsc{ii}] emission lines in starburst galaxies \cite{55, 56}.

Information of some important emission lines, such as [N\textsc{ii}], [S\textsc{ii}] in the redshift range, $1.0<z<1.5$, is critical to our understanding of the history of chemical evolution. The on-going James Webb Space Telescope, K-band Multi-Object Spectrograph on Very Large Telescope will provide important information of optical as well as NIR emission lines. Fundamental properties such as element abundance, metallicity and ionization state of galaxies at this redshift range can be studied and these properties will also aid researchers to reveal the buildup of heavy elements as galaxies are assembled over cosmic time and understand the cosmic reionization.

\textit{This research uses data obtained through the Telescope Access Program (TAP), which is funded by the National Astronomical Observatories and the Special Fund for Astronomy from the Ministry of Finance. This work is supported by National Basic Research Program of China (973 Program 2013CB834900) and the National Natural Science Foundation of China under No. 11063002.}
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