FIRST RESULTS FROM THE FAINT INFRARED GRISM SURVEY (FIGS): FIRST SIMULTANEOUS DETECTION OF Lyα EMISSION AND LYMAN BREAK FROM A GALAXY AT z = 7.51

V. Tilvi1, N. Pirzkal2, S. Malhotra1, S. L. Finkelstein3, J. E. Rhoads1, R. Windhorst1, N. A. Grogan2, A. Koekemoer2, N. L. Zakamska4,5, R. Ryan6, L. Christensen6, N. Hathi1, J. Pharo8, B. Joshi1, H. Yang9, C. Gronwall8,9, A. Cimatti10, J. Walsh11, R. O’Connell12, A. Straughn13, G. Ostlin14, B. Rothberg15, R. C. Livermore3, P. Hibon16, and Jonathan P. Gardner13

1 School of Earth & Space Exploration, Arizona State University, Tempe, AZ 85287, USA
2 Space Telescope Science Institute, Baltimore, MD 21218, USA
3 Department of Astronomy, The University of Texas at Austin, Austin, TX 78712, USA
4 Deborah Lunder and Alan Ezekowitz Founders’ Circle Member, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, USA
5 Department of Physics & Astronomy, Johns Hopkins University, Bloomberg Center, 3400 N. Charles Street, Baltimore, MD 21218, USA
6 1 Dark Cosmology Centre, Niels Bohr Institute, University of Copenhagen, Juliane Marias Vej 30, DK-2100 Copenhagen, Denmark
7 Aix Marseille Universit, CNRS, LAM (Laboratoire dAstrophysique de Marseille) UMR 7326, F-13388, Marseille, France
8 Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA 16802, USA
9 Institute for Gravitation and the Cosmos, The Pennsylvania State University, University Park, PA 16802, USA
10 Dipartimento di Fisica e Astronomia, Università di Bologna, Alma Mater Studiorum, viale Berti Pichat 6/2, I-40127 Bologna, Italy
11 European Southern Observatory, Karl-Schwarzschild Strasse 2, D-85748 Garching, Germany
12 Department of Astronomy, University of Virginia, Charlottesville, VA 22904-4323, USA
13 Astrophysics Science Division, Goddard Space Flight Center, Code 665, Greenbelt, MD 20771, USA
14 Department of Astronomy, Stockholm University, Oscar Klein Center, AlbaNova, Stockholm SE-106 91, Sweden
15 Large Binocular Observatory, Tuscon, AZ 85721, USA
16 Gemini South Observatory, Casilla 603, La Serena, Chile

Received 2016 April 22; revised 2016 July 4; accepted 2016 July 12; published 2016 August 5

ABSTRACT

Galaxies at high redshifts are a valuable tool for studying cosmic dawn, therefore it is crucial to reliably identify these galaxies. Here, we present an unambiguous and first simultaneous detection of both the Lyα emission and the Lyman break from a z = 7.512 ± 0.004 galaxy, observed in the Faint Infrared Grism Survey (FIGS). These spectra, taken with the G102 grism on the Hubble Space Telescope (HST), show a significant emission line detection (6σ) in two observational position angles (PAs), with Lyα line flux of 1.06 ± 0.19 × 10^-17 erg s^-1 cm^-2. The line flux is nearly a factor of four higher than that in the archival MOSFIRE spectroscopic observations. This is consistent with other recent observations, implying that ground-based near-infrared spectroscopy underestimates the total emission line fluxes, and if confirmed, can have strong implications for reionization studies that are based on ground-based Lyα measurements. A 4σ detection of the NV line in one PA also suggests a weak active galactic nucleus (AGN), and if confirmed, would make this source the highest-redshift AGN yet found. These observations from HST thus clearly demonstrate the sensitivity of the FIGS survey, and the capability of grism spectroscopy for studying the epoch of reionization.

Key words: dark ages, reionization, first stars – early universe – galaxies: high-redshift – intergalactic medium

1. INTRODUCTION

To gain a complete understanding of the early universe, it is crucial to reliably identify high-redshift galaxies, because the formation and evolution of the earliest galaxies and the ionization of the intergalactic medium (IGM) during the epoch of reionization are deeply intertwined. The current consensus is that the IGM is mostly ionized at z < 7 (Fan et al. 2002; Malhotra & Rhoads 2004), and therefore the process of reionization must have occurred at z ≳ 7, where the IGM is expected to be significantly neutral. This is also consistent with recent Planck results (Planck Collaboration et al. 2015), which find an electron scattering optical depth equivalent to an instantaneous reionization event at z ≈ 8.8.

Lyα emission from star-forming galaxies offers a unique probe of reionization. This is because Lyα flux is attenuated by the neutral hydrogen in the IGM as Lyα photons are resonantly scattered out of the line of sight when passing through a neutral IGM. This should result in a decrease in Lyα-emitting galaxy counts at z > 6 (Rhoads & Malhotra 2001; Hu et al. 2002; Malhotra & Rhoads 2004). In addition to being a probe of reionization, galaxies in the early universe likely contributed significantly to the reionization process (McLure et al. 2010; Oesch et al. 2010; Finkelstein et al. 2012; Robertson et al. 2013; Bouwens et al. 2015; Finkelstein et al. 2015). Furthermore, the z > 6 universe provides the best chance to discover pristine galaxies (Sobral et al. 2015), therefore the identification of high-z galaxies is essential for gaining critical insight into the early universe.

In recent years, significant progress has been made toward identifying hundreds of galaxy candidates at z > 7, using extremely deep imaging observations from the Hubble Space Telescope (HST; e.g., Bouwens et al. 2015; Finkelstein et al. 2015, and references therein). These galaxy candidates, referred to as “Lyman break” galaxies (LBGs), are primarily selected based on the Lyα break at 1216 Å, caused by the intervening neutral hydrogen in the IGM. While there have been several spectroscopic follow-up observations of z > 7 LBGs, only a handful of galaxies have yielded spectroscopic redshifts via detection of either the Lyα emission line (e.g., Vanzella et al. 2011; Ono et al. 2012; Shibuya et al. 2012;
Galaxy searches at $z > 7$ have also been carried out using a narrowband imaging technique in which galaxies are pre-selected to have a strong Ly$\alpha$ line (known as Ly$\alpha$-emitting galaxies; LAEs). This technique has been successfully employed to identify many LAE candidates out to $z > 7.5$ (e.g., Hibon et al. 2010; Tilvi et al. 2010; Clément et al. 2012; Krug et al. 2012).

Despite spectroscopic successes at $z < 7$, spectroscopic confirmations of a large sample of galaxies at $z > 7$ have been challenging. Recent studies, based on spectroscopic observations of $z > 7$ galaxies, have claimed a precipitous drop in the observed number of Ly$\alpha$ emitting galaxies among LBGs (Carauna et al. 2012; Treu et al. 2013; Faisst et al. 2014; Schenker et al. 2014; Tilvi et al. 2014). However, it is not obvious whether the dominant factor behind the nondetection of expected Ly$\alpha$ emission is due to small-number statistics, evolving galaxy properties, an observational selection bias, or increasing neutral hydrogen at $z > 7$. These issues are further complicated by the presence of abundant atmospheric night sky lines at near-infrared wavelengths, contaminating emission lines in the ground-based spectra.

Fortunately, many of the above issues can be circumvented using space-based slitless grism spectroscopy (e.g., Malhotra et al. 2005; Brammer et al. 2012; van Dokkum et al. 2013; Schmidt et al. 2014; Treu et al. 2015) because it eliminates the near-infrared atmospheric contamination. Recently, Schmidt et al. (2016) have found several $z > 7$ candidates using the grism data obtained from the Grism Lens-Amplified Survey from Space (Treu et al. 2015). Furthermore, spectroscopic redshifts have been measured using a continuum detection of the Lyman break (Rhoads et al. 2013; Oesch et al. 2016) even in the absence of a Ly$\alpha$ line. This is critical because while there are other emission lines available for measuring redshifts (see, e.g., Stark et al. 2016, and references therein), they are much weaker compared to the Ly$\alpha$ line, and therefore continuum Lyman break detection provides a promising tool for measuring spectroscopic redshifts during the epoch of reionization.

Here we present the first results from the Faint Infrared Grism Survey (FIGS; S. Malhotra et al., in preparation), currently the most sensitive G102 grism survey. In this paper, we present the G102 slitless grism spectroscopic observations of FIGS_GN1_1292, a $z = 7.51$ galaxy in the GOODS-N (GN1) field, which has a ground-based spectroscopic redshift based on the Ly$\alpha$ emission line detection. Using the HST grism observations, this is now the highest-redshift galaxy that has simultaneous detection of a Ly$\alpha$ emission line and a continuum Lyman break. In Section 2 we present our observations and spectral extraction. In Section 3 we present our results, and compare our observations to those from the ground, and in Section 4 we summarize our conclusions. Throughout this paper, we use AB magnitudes, and $\Lambda$CDM cosmology with $H_0 = 70.0$ km s$^{-1}$ Mpc$^{-1}$, $\Omega_m = 0.27$, and $\Omega_\Lambda = 0.73$.

2. OBSERVATIONS: FIGS SURVEY

The FIGS survey is a 160-orbit G102 WFC3/grism survey, designed to obtain 40-orbit depth spectroscopic observations in two GN1 and two GOODS-S fields. To minimize contamination by overlapping spectra from nearby objects, each field was observed at five different PAs (each at an 8-orbit depth). The five PA survey strategy was found to be optimal for minimizing the contamination in the spectra of $z > 6$ sources based on aXesim simulations (see S. Malhotra et al. in preparation). The total exposure time for the 40-orbit GN1 field is 101,100 s; for the 5 individual PAs the exposure time varied from 19,300 to 21,900 s. For complete details about the FIGS survey, we refer the reader to S. Malhotra et al. (in preparation).

2.1. Two-dimensional Spectral Extraction

We used the grism extraction software package aXe$^{17}$ (Pirzkal et al. 2001; Kümmel et al. 2009) to extract individual sources. The method is similar to that of the GRism Advanced Camera for Surveys (ACS) Program for Extragalactic Surveys (Pirzkal et al. 2004), but includes additional steps that are necessary to handle the HST WFC3 infrared data of FIGS.

First, a master catalog of sources was generated using deep mosaics from the CANDELS survey (Koekemoer et al. 2011; Grogin et al. 2011) in the $z$, $J$, and $H$ bands. These mosaics also served as our absolute astrometric reference points for the FIGS F105W direct images and the associated dithered G102 exposures. They also allowed us to include the colors of sources when computing spectral contamination. Special care was taken to subtract the varying backgrounds from the individual WFC3 exposures. This includes the He i varying background (Brammer et al. 2014$^{18}$, Sabbi et al. 2015$^{19}$) and the zodiacal light background levels, and allowed for the use of up-the-ramp fitting to remove cosmic rays from individual WFC3 exposures. Two-dimensional spectra were then extracted and combined at each position angle using the aXeDrizzle feature of aXe, which also removes the sky background. The end product is a set of multi-extension FITS files that each contain the spectrum of the science object (drizzled to the native pixel scale of $0^\prime\prime.128$ per pixel, with a linearized wavelength scale), an error estimate, a spectral contamination model, and an effective exposure map. Details of the FIGS pipeline are given in N. Pirzkal et al. (in preparation).

2.2. 1D Extraction

We extracted 1D spectra of FIGS_GN1_1292 from the 2D multi-extension FITS file by summing all pixels in the spatial direction (3 pixels wide) and collapsing it to a single pixel at each wavelength. Based on our 3 and 5 pixel extraction widths, we found that a 3-pixel extraction width yields the maximum signal-to-noise ratio ($S/N$) for the Ly$\alpha$ line, and therefore in this study we use a 3-pixel ($0^\prime\prime.384$) extraction width, which is also well-matched to the FWHM ($0^\prime\prime.36$) of FIGS_GN1_1292. To convert 1D spectra from counts s$^{-1}$ to physical units (erg s$^{-1}$ cm$^{-2}$ $\AA^{-1}$), we used the following conversion: $\text{flux} = \text{flux (counts s}^{-1})/\text{sensitivity/displacement}$, where the sensitivity comes from the sensitivity function$^{20}$ provided for the WFC3 grism, and the dispersion is the wavelength dispersion at each wavelength. Our preliminary estimates of the survey depth, based on inserting and recovering simulated sources, reach the expected line flux limit of $9 \times 10^{-18}$ erg s$^{-1}$ cm$^{-2}$ (3$\sigma$) for a single PA.

$^{17}$ http://axe-info.stsci.edu/
$^{18}$ ISR WFC3 2014-03.
$^{19}$ WFC3 ISR 2015-07.
$^{20}$ WFC3_IR.G102.1st.sens.1.fits.
Figure 1. Spectra of FIGS_GN1_1292 in two PAs used in this work. Left: the top panel shows the 2D spectrum in PA = −56 (not corrected for contamination). The middle panel shows the contamination model, while the bottom panel shows the contamination-corrected 1D spectrum. The red line in the bottom panel shows the contamination level. The rectangular region in the 2D spectrum is the extraction area (3 pixels wide), and the circle represents the detected emission line. A second possible emission feature is seen near 1.055 μm in this PA. Possible interpretations of this feature are discussed in Section 3.2. The He i sky background (noted in legend) significantly varies among different PAs, decreasing the sensitivity of spectra (see Section 3.1 for details). Right: same as left panels but for the PA = −98 observations.

3. RESULTS AND DISCUSSION

3.1. Line Detection

As can be seen in Figure 1, the emission line is clearly visible in both the 2D and 1D spectra in two PAs. This object has a previous ground-based Keck/MOSFIRE spectroscopic redshift of \( z = 7.5078 \pm 0.0004 \), based on a faint Ly\( \alpha \) line detection (Finkelstein et al. 2013).

For this galaxy, while there are five different PAs available from the FIGS data, three of the PAs (Figure 2) are significantly affected by varying He i background (noted in legends). The three PAs where the line is not detected have He i backgrounds that are nearly \( 10 \times \) higher. This elevated He i background\(^{21} \) does not vary significantly during the FIGS grism integrations, thanks to our survey design where we obtained direct imaging observations at the beginning or end of each orbit when the He i background was expected to be highest and most variable. Thus we do not gain in S/N in the stacked spectra (Section 3.3), we use data from only two PAs in this study.

3.2. Possible Detection of NV

In PA = −56, in addition to the Ly\( \alpha \) line at \( \lambda \sim 1.03 \) μm, there is another significant line (\( f_{\text{line}} = 0.91 \pm 0.21 \times 10^{-17} \) erg s\(^{-1}\) cm\(^{-2}\)) at \( \lambda \sim 1.055 \) μm, with a spatial offset of \( \sim 0''1 \), perpendicular to the dispersion direction. This line, however, is not detected in PA = −98. Our careful inspection of the 2D spectrum in PA = −56 did not yield any 0th, 1st, or 2nd order contamination from other sources; our contamination models already include contamination from these orders.

Furthermore, inspection of 1D spectra of contaminating sources does not show any strong emission line that could potentially produce the tentative NV line at \( \lambda \sim 1.055 \) μm in PA = −56. Inspection of the ground-based spectrum found a marginal detection (2.5\( \sigma \)) at \( \lambda \sim 1.055 \) μm, however, with a slightly larger spatial offset from the Ly\( \alpha \) axis. Thus, based on the offsets seen in the 2D grism and MOSFIRE spectra and the RGB image (Figure 3), it is possible that this line is NV(\( \lambda 1240 \)), a high ionization line, and a signature of an (weak) active galactic nucleus (AGN; e.g., Hamann & Ferland 1999), off-centered from the Ly\( \alpha \)-emitting region. Furthermore, it is also possible that the NV emission is enhanced via resonant scattering of Ly\( \alpha \) photons (e.g., Wang et al. 2010). Such off-axis emission from AGN reflection clouds has been seen before at lower redshifts (Windhorst et al. 1998), and it is argued that such off-axis emission could be missed in spectroscopy due to different PAs in both ground-based and space-based spectroscopy.

In addition, we performed simulations by inserting and recovering artificial lines in the 2D spectra, and found that about 5\% of the time, a line as bright as the tentative NV line will remain undetected at \( <1\sigma \) significance. Stronger conclusions will likely depend on deeper G141 grism data in the GN1 field. However, if the observed NV line is real, that would make this the highest-redshift AGN, and would support the idea that the (weak) AGNs might help clear the surrounding neutral hydrogen around galaxies during the epoch of reionization, making them visible in the Ly\( \alpha \) emission.

3.3. Emission Line Properties

To increase the S/N of FIGS_GN1_1292 spectra, we combined the two PAs (from Figure 1) to get average 2D and 1D spectra (Figure 4). As can be seen the emission line appears well-detected in both 2D and 1D, and the emission line

21 It is possible that our background noise is underestimated; however, this does not change our conclusions in this paper.
wavelength (shown with a vertical dashed line) matches very well with the ground-based spectrum.

Alternative explanations for the $\lambda = 1.0347\ \mu m$ line are strongly disfavored. H$\alpha$ is ruled out by the spectral break in the FIGS spectrum while the [O $\Pi$] doublet is ruled out by the break and by the absence of a [O $\Pi$]$\lambda$4959 line in the MOSFIRE spectrum (Finkelstein et al. 2013). The [O $\Pi$]$\lambda$3727 doublet is hardest to rule out. Line asymmetry would be useful in principle, but the MOSFIRE spectrum overlaps a night sky line, precluding reliable asymmetry measurement (Finkelstein et al. 2013), and the FIGS data lack the needed spectral resolution. We highly disfavor the line being [O $\Pi$] emission due to non-detection of the [O $\Pi$] emission line at $\lambda \sim 1.39\ \mu m$ in the archival G141 grism data, and therefore favor this line being Ly$\alpha$ emission from a $z = 7.51$ galaxy.

To measure the grism line properties we used a Gaussian fitting function (MPFIT function in IDL) to the 1D spectrum, shown in Figure 4 (middle panel). We measured the Ly$\alpha$ equivalent width ($W_{Ly\alpha}$; the ratio of emission line flux to the continuum flux density) using the average continuum flux density between $\lambda = 1.07\ \mu m$ and $\lambda = 1.14\ \mu m$ (Figure 4), which yields $f_{Ly\alpha} = 2.52 \pm 0.59 \times 10^{-20}\ erg\ s^{-1}\ cm^{-2}\ A^{-1}$. Combining this measurement with the Ly$\alpha$ line flux, we get rest-frame $W_{Ly\alpha} = 49.3 \pm 8.9\ \AA$. Other physical properties are listed in Table 1.

### 3.4. Comparison of Keck/MOSFIRE and HST Grism Spectra

The bottom panel in Figure 4 shows the Keck/MOSFIRE ground-based spectrum of this source. The MOSFIRE spectrum (shown in gray) is contaminated by several OH sky line residuals, some of which are even brighter than the Ly$\alpha$ line itself, making it difficult to observe in the near-infrared part of the spectrum from the ground. The emission line at $\lambda = 1.0343\ \mu m$ (marked by the vertical dashed line) is partly contaminated by a night sky line. The space-based grism...
observations do not suffer from this issue. On the other hand, the MOSFIRE spectrum has a much higher spectral resolution, which would potentially allow distinguishing between two closely spaced lines, as well as the shape of the Ly\(\alpha\) line that tends to be asymmetric at high redshifts. With the G102 grism resolution, we cannot measure the shape of the Ly\(\alpha\) line.

The emission line wavelength in the FIGS_GN1_1292 spectrum matches very well with the ground-based Keck/MOSFIRE spectroscopic redshift from Finkelstein et al. (2013). However, there is a significant difference in the line flux, in that our grism-measured line flux is \(\sim 4\) times higher than the measurements from the MOSFIRE spectrum. A similar discrepancy has been seen before, in Masters et al. (2014), where they found that the HST/WFC3 G141 grism line fluxes were higher by a factor of \(2-4\) compared to the ground-based Magellan/FIRE measurements. A similar flux comparison between HST/ACS grism and LDSS3 found a scatter of about 0.5–2, however, with no systematics (Xia et al. 2011). In this study, while the origin of these discrepancies is not entirely clear, possible contributing factors include underestimation of contamination in grism spectra, slit-losses in ground-based spectroscopic measurements, underestimation of fluxes due to the presence of atmospheric lines and a much higher resolution of ground-based spectrographs, and uncertainties in the absolute flux calibration. For FIGS_GN1_1292 the grism flux calibrations seem to not be at fault since they agree with the flux measurements from broadband images. Whatever the cause, if emission line fluxes at near-IR wavelengths from ground-based measurements are confirmed to be underestimated, it would reduce the apparent strong redshift evolution in the Ly\(\alpha\) equivalent width distribution; a larger \(z > 7\) galaxy sample would allow firmer conclusions. Furthermore, to minimize the systematic errors in the Ly\(\alpha\) equivalent width distribution, ideally, sample galaxies should be detected in both Ly\(\alpha\) emission and the continuum, as in the case of FIGS_GN1_1292 (see below).

![Figure 4](image.png)

**Figure 4.** Top: the average of two contamination-free PAs from Figure 1 for FIGS_GN1_1292 in the GN1 field. The middle panel shows a 1D contamination-corrected spectrum, extracted using a 3-pixel wide aperture. As can be seen, the Ly\(\alpha\) emission line is clearly visible in both the 2D and 1D spectra, with wavelength \(\lambda = 1.0347 \pm 0.005\, \mu m\), consistent with the ground-based Keck/MOSFIRE spectroscopic detection (bottom panel) from Finkelstein et al. (2013). The orange horizontal line shows the sensitivity of G102, normalized to the redder continuum. The MOSFIRE spectrum shown in gray represents the native resolution while the black line shows a heavily smoothed spectrum. The FIGS HST grism spectrum also shows a clear detection of the continuum (horizontal blue line, and errors from bootstrap technique shown in shaded red region; see Section 3.5) with 5.6\(\sigma\) significance measured at \(\lambda = 1.07-1.14\, \mu m\).

### Table 1

**Properties of FIGS_GN1_1292**

|        | Grism | MOSFIRE$^a$ |
|--------|-------|-------------|
| R.A., decl. | 12:36:37.913 | ... |
| \(\lambda_{\text{Ly}\alpha}(\mu m)\) | 1.0347 ± 0.005 | 1.0343 ± 0.0004 |
| \(z_{\text{Ly\alpha}}\) | 7.512 ± 0.004 | 7.5078 ± 0.0004 |
| \(z_{\text{Ly}\alpha-\text{break}}\) | 7.512 | ... |
| \(f_{\text{Ly}\alpha}(10^{-17}\text{erg s}^{-1}\text{cm}^{-2})\) | 1.06 ± 0.19 | 0.264 ± 0.034 |
| \(f_{\text{Ly\alpha}}(10^{-20}\text{erg s}^{-1}\text{cm}^{-2}\text{A}^{-1})\) | 2.52 ± 0.59 | ... |
| \(W_{\text{Ly\alpha}}\, \text{(rest)} (\AA)\) | 49.3 ± 8.9 | 7.5 ± 1.5 |
| FWHM (\AA) | 44 ± 9 | 7.7 ± 1 |
| \(L_{\text{Ly\alpha}}(10^{42}\text{erg s}^{-1})\) | 7.1 ± 1.3 | 1.77 ± 0.36 |
| \(\chi_{\text{G102}}\) (mag) | 26.7 ± 0.2 | ... |
| Ly\(\alpha\) break significance (\(\sigma\))$^b$ | 4.8 | ... |

**Notes.**

$^a$ From Finkelstein et al. (2013).

$^b$ Based on bootstrap technique (see Section 3.5).
red sides, respectively. These values yield a $Y_{F105W}$ bandpass magnitude of $26.7 \pm 0.2$ mag, in agreement with the measured magnitude from the imaging data, with $Y_{F105W} = 26.4 \pm 0.2$ mag.

To measure the Lyman break significance in the presence of asymmetric error bars, we use the upper error bar on the blue flux, and the lower error bar on the red continuum flux. This yields a Lyman break significance of 4.8$\sigma$. In addition to using the bootstrap technique, we directly measured the median fluxes on the blue and red sides. This yields $f_\lambda = 0.00 \pm 10^{-20}$ erg s$^{-1}$ cm$^{-2}$ A$^{-1}$ and $f_\lambda = 2.52 \pm 0.59 \times 10^{-20}$ erg s$^{-1}$ cm$^{-2}$ A$^{-1}$, on the blue and red sides, respectively. This yields a Lyman break significance of 2.7, somewhat lower than the bootstrap measurement, which is likely due to overestimated errors due to a non-normal flux distribution. Thus, based on the bootstrap measurements, FIGS\_GN1\_1292 is currently the most distant galaxy that has been spectroscopically confirmed using both the Ly$\alpha$ line and the Lyman break.

4. SUMMARY

Here we presented grism spectroscopy of FIGS\_GN1\_1292, the first object at $z > 7$ that has been spectroscopically confirmed using both the Ly$\alpha$ line and the Lyman break—prior to this, $z > 7$ galaxies have been confirmed using either the Ly$\alpha$ emission line or the Lyman break detection. Our accurate redshift measurement based on the continuum break detection demonstrates the value of FIGS and similar surveys for continuum observations. This is crucial because as we probe the epoch of reionization, we expect Ly$\alpha$ emission to attenuate, and therefore redshift measurements from continuum break becomes critical. Thus, our successful identification of a galaxy in the reionization epoch motivates planning for even more sensitive space-based grism surveys from upcoming missions, including the James Webb Space Telescope and the Wide Field Infrared Survey Telescope.

We thank the referee for very useful feedback that improved this manuscript. This work is based on observations taken by the FIGS program (GO 13779) with the NASA/ESA HST, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. R.A.W. acknowledges support from NASA JWS\_Interdisciplinary Scientist grant NNX14AN10G from GSFC.

REFERENCES

Bouwens, R. J., Illingworth, G. D., Oesch, P. A., et al. 2015, ApJ, 811, 140