A Blind Search for Ly $\alpha$ Emission from Galaxies at $z = 6-8$ with Deep HST Grism Spectra

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Why Lyα Emission?

• Lyα emission is the predominate spectroscopic measure of redshift for galaxies at this epoch.
• It is important to calibrate the photometric redshift as any uncertainty in the redshift propagates through to uncertainties in the luminosity, stellar mass, star-formation rate, etc.
• Our understanding of the evolution of galaxies after the first billion years relies heavily on accurate distance measures, and this project would provide these for a large sample of galaxies at this epoch.
Why $z = 6-8$?

- $\sim 25\%$ of continuum-selected galaxies at $z=3$ have Ly $\alpha$
- $\sim 60\%$ at $z=6$
- Drops off at $z=7$
- Probe of Reionization

Ono et al 2012
Survey Area

GOODS South

GOODS North

DEIMOS MOSFIRE (completed)
MOSFIRE (proposed)
CLEAR FIGS
FIGS Program

- Four HST pointings, each with 40 orbits each with 5 different roll angles
- Continuum limit: \( J=26.5 \), line flux limit: \( 4\times10^{-18} \text{ erg/cm}^2/\text{s} \)
- Spectra for 6000 galaxies without preselection

Science Goals

- Probe reionization epoch
- Measure fraction of galaxies with high equivalent width Ly \( \alpha \) – measure neutral fraction of IGM
- Study formation processes of early type galaxies
- Study SF, dust extinction, and metallicity at \( z=1-2 \)
What is the HST G102 Grism?

- **Wavelength Range:** 8000-11500Å
- **Resolution:** R~200
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Extracting the Data

2D Grism Spectra

1D Grism Spectra

Extract using optimal extraction technique from Horne (1985)

\[ f = \frac{\sum MP(D - S)/V}{\sum MP^2/V} \]
Fitting the “Continuum”

1. Blind search for emission lines: Gaussian + Constant
2. Mask out the lines and region around them
3. Interpolate over these regions
4. Fit smoothing function to entire spectrum to get ‘continuum’
5. Subtract the continuum from original spectrum ➞ flat spectrum
Continuum Fitting of Spectra

Contamination subtracted spectra with “continuum” measure overplotted (thick line)
Flat 1D Spectra

Contamination and continuum subtracted spectra
Blind Emission Line Searching

1. Use flattened spectra and step down the wavelength array
2. Use MCMC fitting routine to fit a Gaussian
   1. 50,000 iterations and 1000 walkers for each pixel
   2. Restrict peak to be between neighboring pixels
   3. Restrict width to be 32Å < width < 72Å
   4. Fix constant = 0
   5. Do not fix flux value
   6. 68% confidence value as error in fit
3. Count as a potential line if signal-to-noise > 3 and highest SNR of surrounding pixels
Determining if the Line is Real

Method 1: Individual PA’s

- Expect 3-sigma detections in individual position angles
- Expect the same line to be found in multiple position angles
- Expect line to be found in average of these position angles
Determining if the Line is Real

Method 2: Weighted Stack of All PA’s

- Perform weighted stack of all five PA’s
- Run same line finding method to find 3 $\sigma$ lines
Determining if the Line is Real

Method 3: Fit to All PA’s Simultaneously

- Fit continuum slope for each PA separately
- Run MCMC fitting on top each of slope
- Use combined $\chi^2$ for all five PA’s
- Expect non-detection PA’s to have high error
Preliminary Results
Comparison to Photometry

Simulated SED with Measured Line Flux

Black points are Lyα flux-subtracted filter fluxes.
Ground-Based Follow-Up

- Obtain ground-based follow-up for potential emission lines to validate our line discovery method.
- Proposals accepted for HET/LRS-2 (PI Larson) and LBT/LUCI (PI Tilvi)
- Proposals submitted for Keck/MOSFIRE (PI Finkelstein) and VLT/X-SHOOTER (PI Christensen)
Future Work

• Perform completeness measure, to understand whether our data support an evolution of the Ly\(\alpha\) equivalent width distribution at \(z > 6\)
• Quantify contamination in our line identification method
• Perform same process on the CLEAR data set
• Proof of concept for JWST and WFIRST
Summary

• Need Lyα emission to measure spectroscopic redshifts at this epoch
  • Inconsistencies with photometric redshifts propagates higher error to luminosity functions – galaxy properties
• Probe of reionization – neutral state of IGM
  • Increase in number of confirmed LAE’s at z > 6
• Grism data provides spectra without pre-selection
  • Need ground-based follow-up for Lyα confirmation
• Precursor to JWST and WFIRST Grism surveys