Simulating Wide-Field Slitless Spectroscopy with JWST/NIRISS

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The background of this poster is a simulated direct image of the lensing galaxy cluster MACS J0647+7015. This color composite combines F090W, F150W, and F200W images. The exposure time is one hour per filter. Photometry and redshifts are from the CLASH catalog (Postman et al. 2012). Direct images were constructed for each of the six NIRISS filters available for WFSS.

To the CLASH catalog were added 180 high-redshift galaxies with a uniform, random distribution of redshift ($6 < z < 15$) and magnitude ($26.4 < F200W < 28.4$) and a Gaussian distribution of shapes. (The FWHM distribution has $\mu = 3$ and $\sigma = 1$ pixels in each dimension, with a minimum FWHM of 2.2 pixels.)

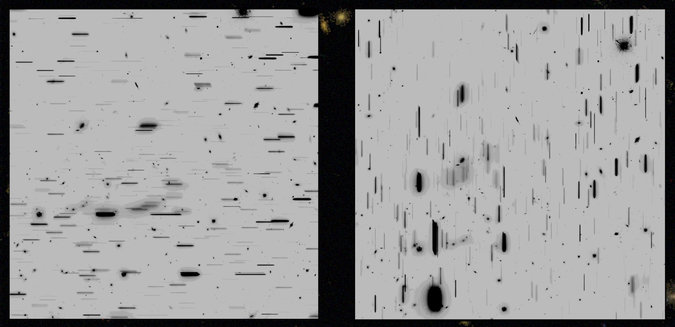

Figure 1. Simulated GR150R (left; disperses onto rows on the detector) and GR150C (right; disperses onto columns) images of the CLASH field through the F200W filter. Exposure time is 10 hours. No bad pixels, cosmic rays, background, flat-field irregularities, or edge effects are included. Dispersed images were constructed for each of the six NIRISS filters and for both grisms.

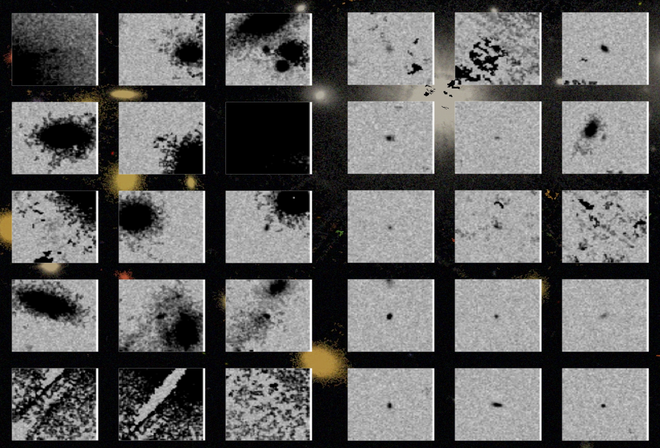

Figure 2. Using Source Extractor (Bertin & Arnouts 1996), we identified 7200 galaxies in the F200W image, including 165 of the 180 high-z galaxies. The 15 missing galaxies (left panel) fall on bright foreground objects. 15 of the 165 detected galaxies are shown in the right panel. We combined these galaxies with 835 foreground galaxies to produce a catalog of 1000 objects.

The Near Infrared Imager and Slitless Spectrograph (NIRISS) aboard the *James Webb Space Telescope (JWST)* will offer wide-field slitless spectroscopy (WFSS) with a resolving power $R = 150$ over the wavelength range 0.8 to 2.25 μm. In this band, NIRISS will be sensitive to Lyα emission and continuum breaks from galaxies with redshifts $6 < z < 17$. To explore its ability to observe such high-redshift galaxies, we have modeled a NIRISS observation of the massive galaxy cluster MACS J0647+7015 and analyzed the synthetic images using standard software tools. In this poster, we present the results of our analysis.

NIRISS is provided to the JWST project by the Canadian Space Agency under the leadership of René Doyon of the Université de Montréal. The prime contractor is COM DEV Canada.

Galaxy continua are derived from CLASH redshifts and photometry. Emission lines were added based on correlations between the line equivalent width and specific SFR, mass, redshift, and reddening. High-redshift galaxies have power-law rest-frame UV continua. 70% have Lyα emission lines with an exponential equivalent-width distribution, while 30% have no Lyα.

For each galaxy in the catalog, we used the aXe software package (Kümmel et al. 2009) to extract and calibrate the spectra from each combination of filter and grism.

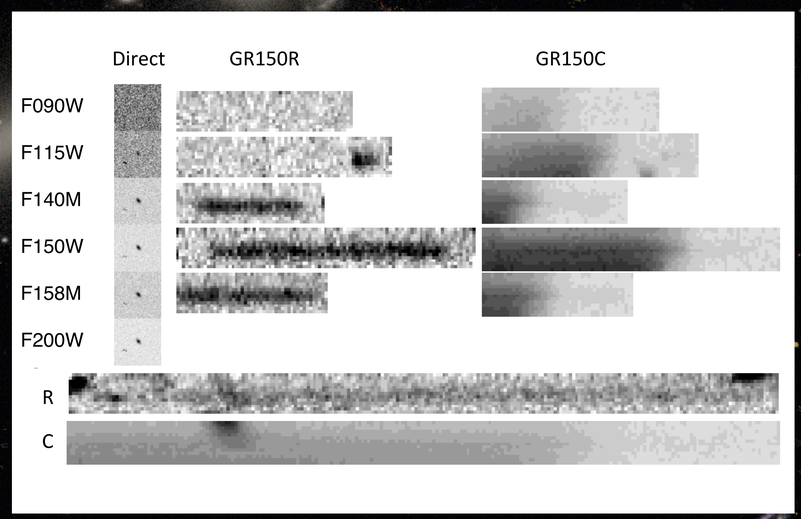

Figure 3. Having two grisms allows NIRISS to disentangle many spectral overlaps. This figure presents the direct and dispersed images of galaxy #681 obtained through each of the six NIRISS filters available for WFSS. The crosshair near the bottom of this poster marks the position of this galaxy, for which mag(F200W) = 26.4 and z = 9.3. Note the galaxy's disappearance at short wavelengths and the contamination by a foreground galaxy in the GR150C spectra.

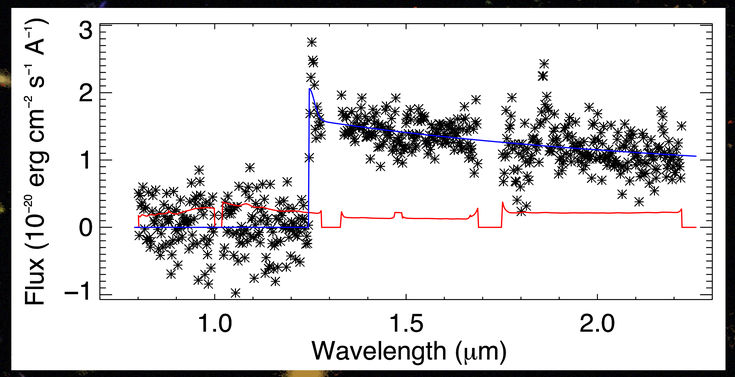

Figure 4. GR150R spectrum of the z = 9.3 galaxy #681. Black points represent the data (from all six filters), the red curve is the error array, and the blue curve is the best-fit model, which combines a power-law continuum with a Lyα emission feature.

The data were analyzed twice, first by hand and independently using an automated routine that fits each spectrum with a power-law continuum and a Lyα emission feature.

Results from Analysis by Hand

Of the full sample of 180 high-redshift objects:

- 8% were not detected by Source Extractor because they are too close to other objects. These galaxies would be missing from imaging surveys, too.
- A further 6% are so close to the field edges that their spectra are too short in either G150R or G150C to enable a proper analysis.
- This leaves 85.5% of the full sample which can be analyzed for spectral contamination.

Of the sample analyzed for spectral contamination:

- 24% do not offer a reasonable chance of measuring a redshift in either dispersion direction, either due to contamination or because the spectrum is too faint.
- 21% yield the correct redshift from one dispersion direction only.
- 55% yield the correct redshift from both dispersion directions.

Results from Automated Fits to the Extracted Spectra

Of the 165 galaxies found by Source Extractor:

- 47 spectra trigger an error or warning.
- 109 yield best-fit redshifts with errors $|z_{fit} - z| < 0.1$.
- 5 yield redshifts with large error bars that include the true redshift.
- 5 suffer from spectral overlaps that are not included in the contamination model computed by aXe.

Our analysis by hand indicates that the NIRISS data yield the correct redshift for 119 of the 165 galaxies detected by Source Extractor, while the automated routine correctly fits 109 of these galaxies. Our simulations demonstrate that WFSS with NIRISS will provide a powerful tool for the exploration of the high-redshift universe.

References: Bertin, E. & Arnouts, S. 1996, A&AS, 317, 393 • Kümmel, M., Walsh, J. R., Pirzkal, N., Kuntschner, H., & Pasquali, A.J. 2009, PASP, 121, 59 • Postman, M. et al. 2012, ApJS, 199, 25