Wide-Field Slitless Spectroscopy with NIRISS on JWST

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The Near-InfraRed Imager and Slitless Spectrograph (NIRISS) instrument on the James Webb Space Telescope (JWST) has three operation modes – (1) Wide-Field Slitless Spectroscopy (WFSS), (2) Single Object Slitless Spectroscopy (SOSS), and (3) Aperture Masking Interferometry (AMI). In the WFSS mode, NIRISS renders a spectrum for every object in the field of view with a resolving power, R=150 over the wavelength range 0.8 - 2.25 microns. The NIRISS WFSS mode is designed to enable the detection of Lyman-alpha emission lines, and the Lyman-break feature in the spectra of high redshift (z=6-17) galaxies, to probe the first ionizing sources in the early Universe. Every WFSS observation will also contain a wealth of information on the foreground objects, creating a unique resource of optical emission line spectra for the faintest galaxies at lower redshifts. The deep spectroscopic surveys using NIRISS on JWST are expected to offer interesting complementarity with the large area WFIRST surveys.

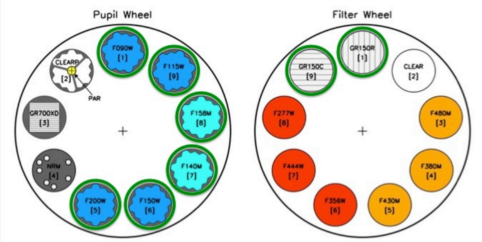

FIG 1. Two identical grisms (GR150R and GR150C) oriented with orthogonal dispersion directions are used in NIRISS to alleviate the problems with overlap of spectra in crowded fields. Each grism selected from the filter wheel is used in conjunction with a blocking filter from the pupil wheel to avoid spectral overlaps from different orders. The green circles show the active elements in the pupil wheel and filter wheel in the WFSS mode.

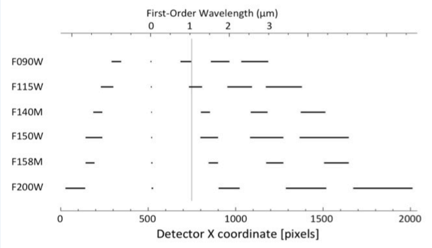

FIG 2. Relative positions of the WFSS (e.g., with GR150R grism) spectral orders for all the blocking filters in the pupil wheel for a source whose direct image is located at the detector x-coordinate=730. Spectral orders are -1, 0, 1, 2, and 3 from left to right, respectively. The lower axis has units of detector pixels, while the top axis shows first-order wavelength in microns. The direct image is located at a wavelength of 1.05 microns.

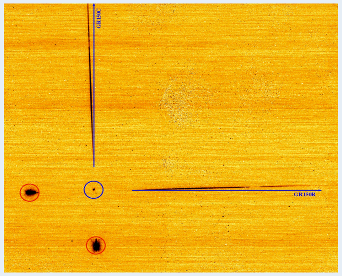

FIG 3. The trace for the GR150R and GR150C grisms obtained without any blocking filter during the cryo-vac risk reduction tests at NASA GSFC in October 2013. This combined image shows trace of both grisms, one that disperses along the columns and the other along the rows of the detector. The tilt of the trace was measured to be ≈ 1.65 degrees relative to the detector rows/columns. The blue circle shows location of the direct image, and the red circles show the zero order images.

Simulations of MACSJ0416.1-2403 as Observed with JWST/NIRISS

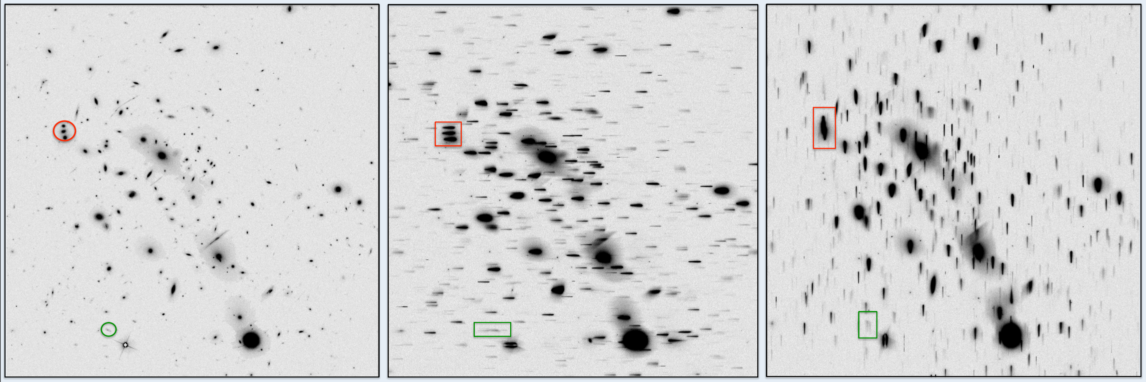

FIG 4. Simulations of the HST Frontier Fields (HFF) Cluster MACSJ0416.1-2403 as observed using the NIRISS WFSS mode on JWST, created using aXeSIM. The direct image (left) uses the F115W filter, and the dispersed images through the GR150R+F115W (middle) and GR150C+F115W (right) are shown. The image templates used in aXeSIM are the normalized cutouts from the HFF F814W images. We used the 7-band photometry available for ≈ 4000 sources in the cluster, and obtained their best-fit SEDs (including emission-lines) using the Eazy photometric redshift code (Brammer et al. 2008). These best-fit SEDs are used as input template spectra for the simulations. The direct image shows the 2.2′ x 2.2′ field of view of NIRISS with half-pixel sampling of 0.0324 arcsecs/pixel. The simulations are done using ≈ 2500s for the direct image and ≈ 25,000s for the dispersed images. The direct and dispersed images are created for all the six blocking filters crossed with the two grisms. After the spectral extraction of individual galaxies from each dispersed image, they are stitched together to yield the final spectrum covering the wavelength range from 0.8-2.2 microns. The red and green circles show two examples where the use of orthogonal dispersion allows to separate the overlapping spectra from multiple sources.

Spectra of resolved sub-structures within lensed galaxies at z=1-3

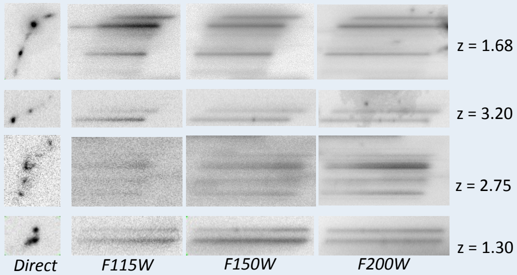

FIG 5. Examples of lensed galaxies in the MACSJ0416.1-2403 cluster with redshifts in the range z=1-3. The magnification offered by lensing offers an opportunity to study the spectral properties of resolved sub-structures (bulges, star-forming complexes, clumps) within the galaxy. The follow-up spectra of lensed arcs seen in HST images have revealed strong emission-lines ([OII], H-beta, [OIII]) that can be used to derive information about the physical conditions in the ionized gas, star formation rates, and chemical abundances (Bayliss et al. 2014). With the resolution of NIRISS (≈0.08′′ @2 microns), it will be possible to study sub-structures on physical scales of ≈ 600-700 parsecs at z=1-3 even in unlensed galaxies.

Synergy between wide-field slitless spectroscopy from JWST and WFIRST

- Slitless spectroscopy with NIRISS on JWST will allow to probe the low luminosity galaxies, while the bright end of the luminosity function will benefit from the large sky coverage of WFIRST. For galaxies within the luminosity range that can be well-studied with WFIRST, JWST will offer continuity over the same luminosities at higher redshift. The deep surveys from JWST will be essential for constraining the properties of the faint galaxies and will offer excellent synergy with the wide, shallower galaxy redshift surveys from WFIRST.
- If the NIRISS WFSS is used in "pure-parallel" observing mode, statistically significant samples of z=1-3 emission-line galaxies would be available to study the evolution of low mass, actively star-forming galaxies. The WISP program with HST/WFC3 has sucessfully demonstrated the potential of pure-parallel grism surveys to obtain emission-line spectra for galaxies brighter than ≈ 24 AB magnitude in F140W filter (Atek et al. 2010).
- NIRISS will offer spatially resolved spectroscopy for galaxies at z=1-3 allowing to proble the physical conditions in the ionized gas, derive star formation rates and metallicity. WFIRST will provide similar information for large samples of galaxies at z<0.5.

References and useful links

http://www.stsci.edu/jwst/instruments/niriss
http://axe.stsci.edu/axesim/
http://www.stsci.edu/hst/campaigns/frontier-fields/
Atek, H., et al. 2010, ApJ, 723, 104.
Brammer, G., van Dokkum, P.G., Coppi, P., 2008, ApJ, 686, 1503.
Bayliss, M. B., Rigby, J. R., et al. 2014, ApJ, 790, 144.

★ Also see the related JWST/NIRISS poster by Van Dixon & Chris Willott on Simulations of high redshift emission-line galaxies.