JWST NIRCam Time Series Observations

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ETEO w/JWST
July 10, 2017

NIRCam TSOs
Introduction

The JWST Near Infrared Camera (NIRCam) observes from 0.6 to 5.0 μm and offers imaging, coronagraphy, and grism slitless spectroscopy. NIRCam has 2 modules pointing to adjacent fields of view. Each module uses a dichroic to observe simultaneously in a short-wavelength channel (0.6–2.3 μm) and a long-wavelength channel (2.4–5.0 μm).

NIRCam has 5 observing modes for science:

- Imaging of two 2.2' × 2.2' fields separated by 44" covering 9.7 arcmin² in total
- Coronagraphic imaging at multiple wavelengths
- Wide field slitless spectroscopy (2.4–5.0 μm) using grisms with resolving power $R = \lambda/\Delta\lambda \sim 1500$
- Time series imaging (photometric monitoring)
- Grism time series (spectroscopic monitoring)

NIRCam will also obtain wavefront sensing measurements used to align and phase JWST's primary mirror.

**Focus of this talk**

From https://jwst-docs.stsci.edu/display/JTI/
NIRCam Fields of View (from STScI Jdocx)

Module A

- Coronagraph masks
- When projected on detectors
- Time series
- Spectra

Module B

- Time series imaging
- 64"
- 129"

Overlapping FOVs obtained simultaneously

- Short wavelength detectors
- Long wavelength detectors

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NIRCam modes: selectable with wheels

No Short Wavelength Spectroscopic Capabilities in Cycle 1

0.6 – 2.4 μm
Short Wavelength Channel

From OTE

Long Wavelength Channel
2.4 – 5 μm

Simultaneous SW imaging is possible!

2 LW grisms in each module provide R~1500 slitless spectroscopy:
Chose dispersion orientation and filters to suit your science
NIRCam LW Grism Spectra

Left: NIRCam spectral image of the OSIM super-continuum lamp point source taken with the LWA R grism and F444W filter during JWST instrument testing.

Right: Extracted spectrum. The continuum decreases toward longer wavelengths due to low fiber transmittance, and the broad feature near 4.27 μm is due to CO$_2$ absorption. These are artifacts of the test equipment and not NIRCam itself.

* NIRCam FOV is 2.’2 x 2.’2 with dispersion of 10 Å per 0.”065 x 0.”065 pixel
NOTE: Total spectroscopic throughput is the **product** of Grism curve and selected filter!

Figure 3. Left: Total system throughput including all OTE and NIRCam optics and the detector quantum efficiency for several NIRCam filters. The theoretical LW grism efficiency curve (shown for the A module) must be multiplied by the filter curves to produce the system throughput at each wavelength. The Module B LW grisms are anti-reflection coated on only 1 side and therefore have throughputs approximately 25% lower than the LWA grisms. Right: Grism FWHM spectral resolving power vs. wavelength for point sources, limited by pixel sampling of the PSF at shorter wavelengths ($\lambda \lesssim 4 \mu$m) and limited by the circular beam factor$^7$ and diffraction at longer wavelengths ($\lambda \gtrsim 4 \mu$m).
Module A (TSO) Spectral Saturation Values

<table>
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<tr>
<th>$\lambda$ ((\mu m))</th>
<th>$K_{sat}$ (A0V)$^c$</th>
<th>$K_{sat}$ (M2V)$^c$</th>
<th>Filter$^d$</th>
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</table>

See Greene+ (2017) JATIS article for more Module A & B saturations and sensitivity values

NIRCam can observe bright stars!

c: K-band Vega magnitudes for saturation (80% full well or 65,000 electrons) for 0.68 s integrations.
Time-series imaging is also possible

• $\lambda < 2.4 \ \mu m$ TSO imaging can be done simultaneously with either $\lambda > 2.4 \ \mu m$ imaging or spectroscopy
• SW observations can be done with weak lenses for better bright limits and potentially higher precision photometry
• Show HAT-P-18 b APT example???
Setting TSO parameters

• Determine how much dwell time for each object
• Set subarrays and exposure parameters
• Set SW filter: simultaneous $\lambda < 2.4$ $\mu$m imaging
• Consider target acquisition
  – Offset acquisition required for bright targets in Cycle 1
• Visibility, position angles, and spectral overlaps
• Enter values into APT
NIRCam grism time series options (APT)

- Can choose from 64, 128, 256, & 2048 x 2048 subarrays
- 1 or 4 outputs (4 for very bright stars)
- Simultaneous short wavelength imaging with weak lens to spread the light over many pixels is possible
- No dithering
- Flexible detector MULTIACCUM exposure & readout parameters
Select Subarray Size

- **mag > bright limit + 0.75?**
  - Y: 2048 x 64
  - N: 4 Outputs

- **Want > 128 subarray?**
  - Y: 2048 x 128
  - N: 1 or 4 Outputs

- **Is mag > bright limit + 1.5?**
  - Y: 2048 x 256
  - N: 1 or 4 Outputs
Select Detector Readout Parameters

- **RAPID exceeds data limit?**
  - **N**
  - **Y**

- **RAPID Ngroups > limit?**
  - **N**
  - **Y**

- **BRIGHT1 > limits?**
  - **N**
  - **Y**

- **BRIGHT 2 > limits?**
  - **N**

**Set #groups from:**
- host star brightness
- mode saturation limit
- subarray size
- # of outputs

**Set # Ints to fill dwell time**
Set SW Filter: Simultaneous $\lambda < 2.4 \, \mu m$ Imaging

Currently Available SW Filters:
- CLEAR + WLP4
- WLP8 + 182M
- WLP8 + 210M
- WLP8 + 187N
- WLP8 + 212N
Target Acquisition Note

• In Cycle 1, grism time series target acquisition is done with F335M filter, 32 x 32 subarray, and Ngroups ≥ 3
  – Saturation limit is K = 7.0 mag
• **Stars with K < 7.0 may require offset target acquisition**
  – Offset from nearby fainter star with known coordinates
• Using a narrow-band acquisition filter would allow acquiring on K < ~4.5 mag stars (likely Cycle 2 and later)
Check spectral overlap of nearby objects

We are working on an automated tool for this (NIRCam + MIRI LRS)
### APT Example: WASP-80 b F322W2

**Observation 3 of JWST Draft Proposal (NIRCam_GTO_transiting_planets_APT_ES_2015May25.apptx)**

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<td>Target</td>
<td>3 WASP-80</td>
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</table>

**Visit Splitting:**
- **Splitting Distance:** 65.0 Arcsec
- **Number of Visits:** 1

**Duration (secs):**
- **Science:** 19717
- **Total Charged:** 32495

Data volume: 25,122 MB

### Target Acquisition Parameters

<table>
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<th>Target ACQ</th>
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<tr>
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<td>Acq Groups/Int</td>
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</tbody>
</table>

### Grism Time Series Parameters

- **Subarray:** SUBGRISM256
- **No. of Output Channels:** 4
- **Exposures/Dith:** 1
- **Short Pupil+Filter:** WLP8+F210M
- **Long Pupil+Filter:** GRISMR+F322W2

**Readout Pattern:** BRIGHT1

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</table>

*Frame readout time is 1.34668*
NIRCam uses the JWST time-series data pipeline

- Users can download & re-run the pipeline with different options, additions, or removals
Future Possible Simultaneous 1 – 2 μm Spectra

- DHS elements disperse ~40% JWST’s light onto 2 NIRCam SW detectors with a small gap in-between.

- Dispersed Hartmann Sensor (DHS) elements in the SW channel of NIRCam provide 1 – 2 μm spectra using 10 sub-apertures of the JWST pupil, potentially allowing simultaneous spectra of bright stars during LW grism observations.

- This is not an approved science mode for Cycle 1; it may be approved for later cycles. There may be limitations on spectra.

See Schlawin+ (2017) PASP
The End