JWST NIRCam Time Series Observations

Tom Greene (NASA Ames)
E. Schlawin (UA)
& UA / STScI NIRCam team:
D. Kelly, J. Stansberry,

ETEO w/JWST
July 10, 2017
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 \( R = \frac{\lambda}{\Delta \lambda} \sim 1500 \)
- 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 Jdox)

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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No Short Wavelength Spectroscopic Capabilities in Cycle 1

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

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NIRCam TSOs
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 CO₂ 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
NIRCam Spectral Coverage & Resolution

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 and diffraction at longer wavelengths ($\lambda \gtrsim 4 \mu m$).
Module A (TSO) Spectral Saturation Values

<table>
<thead>
<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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<tbody>
<tr>
<td>2.5</td>
<td>4.3</td>
<td>4.2</td>
<td>F322W2</td>
</tr>
<tr>
<td>2.7</td>
<td>4.4</td>
<td>4.4</td>
<td>F322W2</td>
</tr>
<tr>
<td>2.9</td>
<td>4.3</td>
<td>4.3</td>
<td>F322W2</td>
</tr>
<tr>
<td>3.1</td>
<td>4.1</td>
<td>4.1</td>
<td>F322W2</td>
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<td>3.7</td>
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<tr>
<td>4.1</td>
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<td>4.9</td>
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<td>2.4</td>
<td>F444W</td>
</tr>
</tbody>
</table>

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

Select subarray size based on the following criteria:

1. **Is $\text{mag} > \text{bright limit} + 0.75$?**
   - **Yes** → 2048 x 64
     - 4 Outputs
   - **No** → 2048 x 256
     - 1 or 4 Outputs

2. **Want > 128 subarray?**
   - **Yes** → 2048 x 128
     - 1 or 4 Outputs
   - **No** → 2048 x 256
     - 1 or 4 Outputs

3. **Is $\text{mag} > \text{bright limit} + 1.5$?**
   - **Yes** → 2048 x 256
     - 1 or 4 Outputs
   - **No** → 2048 x 256
     - 1 or 4 Outputs
Select Detector Readout Parameters

- RAPID exceeds data limit?
  - Y: RAPID Ngroups > limit?
    - Y: BRIGHT1 > limits?
      - Y: BRIGHT 2 > limits?
        - Y: Set # groups from:
          - host star brightness
          - mode saturation limit
          - subarray size
          - # of outputs
        - N: BRIGHT2
      - N: BRIGHT1
    - N: RAPID
  - N: RAPID

- 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
• 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.aplx)**

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<thead>
<tr>
<th>Number</th>
<th>Status</th>
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<tbody>
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<td>UNKNOWN</td>
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</tbody>
</table>

- **Instrument**: NIRCAM
- **Template**: NIRCam Grism Time Series
- **Target**: 3 WASP–80

<table>
<thead>
<tr>
<th>Visit Splitting</th>
<th>Number of Visits</th>
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</thead>
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<tr>
<td>65.0 Arcsec</td>
<td></td>
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</tbody>
</table>

**Splitting Distance**

- **Duration (secs)**: 19717 / 32495

**Data volume: 25,122 MB**

## Target Acquisition Parameters

<table>
<thead>
<tr>
<th>Target ACQ</th>
<th>Acq Target</th>
<th>Acq Subarray</th>
<th>Acq Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same Target as Observation</td>
<td>SUB32TATSGRISM</td>
<td>F335M</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Acq Readout Pattern</th>
<th>Acq Groups/Int</th>
<th>Acq Integrations/Exp</th>
<th>Acq Total Integrations</th>
<th>Acq Total Exposure Time</th>
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</thead>
<tbody>
<tr>
<td>RAPID</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0.087</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**

<table>
<thead>
<tr>
<th>Groups/Int</th>
<th>Integrations/Exp</th>
<th>Total Integrations</th>
<th>Total Exposure Time</th>
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<tbody>
<tr>
<td>BRIGHT1</td>
<td>6</td>
<td>1331</td>
<td>1331</td>
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</table>
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

- 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