JWST NIRCam Time Series Observations

ETEO w/JWST
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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 Jdox)

Module A
- coronagraph masks
- overlapping FOVs obtained simultaneously
  - 2.2'
- when projected on detectors
- Time series spectra

5.1'

Module B
- Time series imaging
- 129"
- 64"
- 64"

20"

From https://jwst-docs.stsci.edu/display/JTI/
NIRCam modes: selectable with wheels

No Short Wavelength Spectroscopic Capabilities in Cycle 1

- Short Wavelength Channel (0.6 – 2.4 μm)
  - LW grisms in each module provide R~1500 slitless spectroscopy:
    - Choose dispersion orientation and filters to suit your science

- Long Wavelength Channel (2.4 – 5 μm)
  - Simultaneous SW imaging is possible!

From OTE
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
NOTE: Total spectroscopic throughput is the **product** of Grism curve and selected filter!
## Module A (TSO) Spectral Saturation Values

<table>
<thead>
<tr>
<th>λ (μm)</th>
<th>$K_{sat}$ (A0V)&lt;sup&gt;c&lt;/sup&gt;</th>
<th>$K_{sat}$ (M2V)&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Filter&lt;sup&gt;d&lt;/sup&gt;</th>
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<tbody>
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<td>4.2</td>
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</tbody>
</table>

NIRCam can observe bright stars!

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

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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

1. **mag > bright limit + 0.75?**
   - Y: **2048 x 64**
   - N: **NIRCam TSOs**

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

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

- RAPID exceeds data limit?
- RAPID Ngroups > limit?
- BRIGHT1 > limits?
- BRIGHT 2 > limits?

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

Set # Ints to fill dwell time
Set SW Filter: Simultaneous $\lambda < 2.4 \, \mu\text{m}$ 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 $K < \sim 4.5$ mag stars (likely Cycle 2 and later)
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.aptx)

Number: 3
Status: UNKNOWN

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

Visit Splitting: 65.0 Arcsec

Duration (secs)
Science: 19717
Total Charged: 32495

Data volume: 25,122 MB

Target Acquisition Parameters

Acq Target: Same Target as Observation
Acq Subarray: SUB32TATSGRISM
Acq Filter: F335M

Acq Readout Pattern: RAPID
Acq Groups/Int: 5
Acq Integrations/Exp: 1
Acq Total Integrations: 1
Acq Total Exposure Time: 0.087

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
Groups/Int: 6
Integrations/Exp: 1331
Total Integrations: 1331
Total Exposure Time: 21509.173

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

• 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