Planning Small Body Observations with JWST

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SBAG
January 14-16, 2013

on behalf of 7 billion current Earthlings, ~10,000 future observers, ~1000 engineers and technicians, ~100 scientists worldwide, 3 space agencies
Planning your Solar System Observations with the James Webb Space Telescope

- Provide, via the JWST Project members:
  - current instrument specifications and observing modes
  - observatory capabilities (brightness limits, moving targets, tracking, and others)
  - preliminary case studies from JWST SO-DRM

**Goal:** fully engage Solar System community and provide tools they need to begin planning their observations with JWST

14 October 2012, Reno, Nevada
AAS Division for Planetary Sciences Meeting
JWST Vital Stats

- General Observatory: 5 years required; 10 years goal
- Diameter of primary mirror: 21.3 feet (6.5 meters)
- Number of primary mirror segments: 18
- Sunshield: 5 layer, 69.5 feet by 46.5 feet (21.2 meters by 14.2 meters)
- Orbit: 930,000 miles (1.5 million kilometers) from Earth
- Operating temperature: Below 50 Kelvin (−370° Fahrenheit)
- Four Science Instruments covering 0.6–28.8 microns
  - Filtered Imaging
  - Spectroscopy – Slit, Integral Field, Grism/Prism
  - Coronagraphy – Traditional Lyot + Four Quadrant Phase Masks
  - Aperture Mask Interferometry – Non-Redundant Mask (NRM)
# JWST Instrumentation

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Science Requirement</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NIRCam</strong></td>
<td>Wide field, deep imaging</td>
<td>Two 2.2’ x 2.2’ SW</td>
</tr>
<tr>
<td>Univ. Az/LMATC</td>
<td>• 0.6 µm - 2.3 µm (SW)</td>
<td>Two 2.2’ x 2.2’ LW</td>
</tr>
<tr>
<td></td>
<td>• 2.4 µm - 5.0 µm (LW)</td>
<td>Coronagraph</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dual filter wheel</td>
</tr>
<tr>
<td><strong>NIRSpec</strong></td>
<td>Multi-object spectroscopy</td>
<td>9.7 Sq arcmin Ω + IFU + slits</td>
</tr>
<tr>
<td>ESA/Astrium</td>
<td>• 0.6 µm - 5.0 µm</td>
<td>100 selectable targets: MSA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=100, 1000, 3000</td>
</tr>
<tr>
<td><strong>MIRI</strong></td>
<td>Mid-infrared imaging</td>
<td>1.9’ x1.4’ with coronagraph</td>
</tr>
<tr>
<td>ESA/UKATC/JPL</td>
<td>• 5 µm - 27 µm</td>
<td>Filter wheel</td>
</tr>
<tr>
<td></td>
<td>Mid-infrared spectroscopy</td>
<td>3.7”x3.7” – 7.1”x7.1” IFU</td>
</tr>
<tr>
<td></td>
<td>• 4.9 µm - 28.8 µm</td>
<td>IFU=3000 - 2250</td>
</tr>
<tr>
<td><strong>FGS/NIRISS</strong></td>
<td>Fine Guidance Sensor</td>
<td>Two 2.3’ x 2.3’</td>
</tr>
<tr>
<td>CSA</td>
<td>0.8 µm - 5.0 µm</td>
<td>2.2’ x 2.2’</td>
</tr>
<tr>
<td></td>
<td>Near IR Imaging Slitless Spectrometer,</td>
<td>R=150, 700 with coronagraph</td>
</tr>
<tr>
<td></td>
<td>• 1.6 µm - 4.9 µm</td>
<td></td>
</tr>
</tbody>
</table>
# JWST Imaging Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Instrument</th>
<th>Wavelength (microns)</th>
<th>Pixel Scale (arcsec)</th>
<th>Full-Array* Field of View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>NIRCam*</td>
<td>0.6 – 2.3</td>
<td>0.032</td>
<td>2.2 x 2.2'</td>
</tr>
<tr>
<td></td>
<td>NIRCam*</td>
<td>2.4 – 5.0</td>
<td>0.065</td>
<td>2.2 x 2.2'</td>
</tr>
<tr>
<td></td>
<td>NIRISS</td>
<td>0.9 – 5.0</td>
<td>0.065</td>
<td>2.2 x 2.2'</td>
</tr>
<tr>
<td></td>
<td>MIRI*</td>
<td>5.0 – 28</td>
<td>0.11</td>
<td>1.23 x 1.88'</td>
</tr>
<tr>
<td>Aperture Mask Interferometry</td>
<td>NIRISS</td>
<td>3.8 – 4.8</td>
<td>0.065</td>
<td>-----</td>
</tr>
<tr>
<td>Coronography</td>
<td>NIRCam</td>
<td>0.6 – 2.3</td>
<td>0.032</td>
<td>20 x 20''</td>
</tr>
<tr>
<td></td>
<td>NIRCam</td>
<td>2.4 – 5.0</td>
<td>0.065</td>
<td>20 x 20''</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>10.65</td>
<td>0.11</td>
<td>24 x 24''</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>11.4</td>
<td>0.11</td>
<td>24 x 24''</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>15.5</td>
<td>0.11</td>
<td>24 x 24''</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>23</td>
<td>0.11</td>
<td>30 x 30''</td>
</tr>
</tbody>
</table>
JWST Spectroscopy Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Instrument</th>
<th>Wavelength (microns)</th>
<th>Resolving Power (λ/Δλ)</th>
<th>Field of View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slitless Spectroscopy</td>
<td>NIRISS</td>
<td>1.0 – 2.5</td>
<td>150</td>
<td>2.2’ x 2.2’</td>
</tr>
<tr>
<td></td>
<td>NIRISS</td>
<td>0.6 – 2.5</td>
<td>700</td>
<td>single object</td>
</tr>
<tr>
<td></td>
<td>NIRCam</td>
<td>2.4 – 5.0</td>
<td>2000</td>
<td>2.2’ x 2.2’</td>
</tr>
<tr>
<td>Multi-Object Spectroscopy</td>
<td>NIRSpec</td>
<td>0.6 – 5.0</td>
<td>100, 1000, 2700</td>
<td>3.4’ x 3.4’ with 250k 0.2 x 0.5” microshutters</td>
</tr>
<tr>
<td>Single Slit Spectroscopy</td>
<td>NIRSpec</td>
<td>0.6 – 5.0</td>
<td>100, 1000, 2700</td>
<td>slit widths 0.4” x 3.8” 0.2” x 3.3” 1.6” x 1.6”</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>5.0 – ~14.0</td>
<td>~100 at 7.5 microns</td>
<td>0.6” x 5.5” slit</td>
</tr>
<tr>
<td>Integral Field Spectroscopy</td>
<td>NIRSpec</td>
<td>0.6 – 5.0</td>
<td>100, 1000, 2700</td>
<td>3.0” x 3.0”</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>5.0 – 7.7</td>
<td>3500</td>
<td>3.0” x 3.9”</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>7.7 – 11.9</td>
<td>2800</td>
<td>3.5” x 4.4”</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>11.9 – 18.3</td>
<td>2700</td>
<td>5.2” x 6.2”</td>
</tr>
<tr>
<td></td>
<td>MIRI</td>
<td>18.3 – 28.8</td>
<td>2200</td>
<td>6.7” x 7.7”</td>
</tr>
</tbody>
</table>
Science Operations Design Reference Mission (SODRM)

1. Asteroids – NIRSpec & MIRI slit spectroscopy
2. Bright Comets – NIRSpec & MIRI IFU, NIRCam imaging
3. Ice Giants – NIRSpec & MIRI IFU, NIRCam, MIRI Imaging
4. Icy Dwarf Planets – NIRSpec spectroscopy, MIRI 25μm imaging
5. KBOs – NIRSpec slit spectroscopy, NIRCam & MIRI imaging
6. Mars – NIRSpec & MIRI IFU spectroscopy
7. Outer Planet Satellites – NIRSpec & MIRI slit spectroscopy
8. Periodic Comets – NIRSpec & MIRI slit spectroscopy

112 programs → 1.78 years total Wall-Clock time
→ 70 science, 42 calibration
Near-IR Comet Spectra

NIRSpec: 1000 sec Continuum Sensitivity

Comet Nuclei: 5 km, $p_V = 5\%$

10σ NEFD, Flux Density (μJy)

Wavelength (μm)

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NIRCam: 1 – 5 micron Colors of Small TNOs

NIRCam & FGS/TFI: 1000 sec Point-Source Sensitivity

KBOs: 45 AU, \( p_V = 10\% \)

1000 w/ D > 100 km

\[ 10\sigma \text{ NEFD, Flux Density (\(\mu\)Jy)} \]

\[ \text{Wavelength (\(\mu\)m)} \]

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MIRI Photometry: TNOs

MIRI: 10σ, 1000 sec Point-Source Sensitivity

KBOs: 40 AU, $p_\nu = 10\%$

NEFD (μJy)

Wavelength (μm)

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JWST solar system capabilities

- HST (or better) angular resolution at longer wavelengths
  - diffraction limited 6.5 telescope at 2 μm
- Zodi background limited imaging sensitivity for λ < 12 μm
  - faint objects like KBO’s, asteroids, satellites of Pluto, planetary rings
- Full coverage from 0.6 to 28 μm with imaging and spectroscopy, \( R = \lambda / \Delta \lambda = 3000 \) (chemistry and physics)
- Follows ephemeris up to at least 0.03 arcsec/sec for moving targets
  - Nonlinear tracking (JPL/HORIZONS)
- Subarray readout modes for bright objects
- Can observe all planets and satellites except Mercury, Venus, Earth, and Moon (from 85 to 135 deg from Sun)
Field of Regard

- Observatory thermal design defines the allowed Solar orientations
  - Solar elongation 85° to 135° (like Spitzer)
  - Roll ±5° about line of sight

- JWST can observe the whole sky every year while remaining continuously in the shadow of its sunshield.
  - Field of Regard is an annulus covering 35% of the sky
  - The whole sky is covered each year with small continuous viewing zones at the Ecliptic poles
Planning your Solar System Observations with JWST

The JWST team participated in the Division for Planetary Sciences Annual Meeting in Reno on October 14-19th, 2012. In addition to our booth presence, we organized a special workshop titled “Planning your Solar System Observations with JWST”. This workshop took place from 9 am to noon on Sunday October 14th, and was attended by 50 DPS members.

We discussed topics such as moving target capabilities, bright observing modes, imaging and spectroscopic sensitivities for Solar System objects, and much more. Lots of new ideas emerged at the workshop and we have noted these down and will begin evaluating after the DPS meeting. The seven presentations that were given at the meeting are all linked below:

1. Opening Remarks and Schedule
2. Proposing for HST time
3. JWST Observatory, Instrument Modes, and Specs
4. JWST Brightness Limits
5. Operations Concepts for Moving Target Observations with JWST
7. Summary, Closing Thoughts, and Next Steps

The three JWST Solar System flyers that were presented at the meeting are also available here, as well as the FAQ sheet:

1. JWST Observations in the Solar System
2. JWST Observations of Dwarf Planets
3. NIRSpec and MIRI Observations of Asteroids

More information about the AAS Division for Planetary Sciences Annual Meeting

http://www.stsci.edu/jwst/science/solar-system
44th Lunar and Planetary Science Conference
March 18-22, 2013
The Woodlands, Texas

• Peripheral Meeting Request
  • Sunday, March 17 (afternoon)
  • Same format as DPS
  • Targeted Invite List
Extra Slides
SODRM 2012 by Category

- Exoplanets
- Solar System
- Calibration
- Distant Galaxies & Cosmology
- Galactic
- Nearby Galaxies
NIRSpec: and Smaller TNOs too...

NIRSpec: 1000 sec Continuum Sensitivity

KBOs: 45 AU, $p_v = 10\%$
300 w/ D > 200 km

Space Telescope Science Institute, 2012
Oct. 1 – J. Stansberry