Overview of JWST and its GTO programs on star and planet formation

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on behalf of

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Largest space telescope ever built
6.5m Diameter Segmented Primary Mirror
Infrared Optimized Telescope (0.6 – 28 μm)
4 Instruments (NIRCam, NIRSpec, NIRISS, MIRI)
Passively Cooled to ~ 40K (NIRCam, NIRSpec, NIRISS)
MIRI Cooled to 7K
The JWST Mission

- JWST is a collaboration between NASA, ESA and CSA
  - Europe is guaranteed a minimum of 15% of the observing time
- Mission Lead: Goddard Space Flight Center
- Operations: Space Telescope Science Institute
- Launch May 2020 (?)
- Will be placed in an L2 orbit
- Mission Lifetime ~ 10 years
JWST Life-size Model in the Royal Hospital Kilmainham, Dublin
Near-Infrared Camera (NIRCam)
NIRCam Field of View

Module A

- coronagraph masks
- when projected on detectors

Module B

- 20"

Overlapping FOVs obtained simultaneously:
- 2.2'
- short wavelength detectors
- long wavelength detectors

44" - 42" - 129"
### At a Glance:

<table>
<thead>
<tr>
<th></th>
<th>Short Wavelength Channel</th>
<th>Long Wavelength Channel</th>
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</thead>
<tbody>
<tr>
<td>Wavelength Range</td>
<td>0.6 – 2.3 µm</td>
<td>2.4 – 5.0 µm</td>
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<tr>
<td>Nyquist Wavelength</td>
<td>2.0 µm</td>
<td>4.0 µm</td>
</tr>
<tr>
<td>Fields of View *</td>
<td>2 × 2.2' × 2.2' (with 4-5’ gaps)</td>
<td>2 × 2.2' × 2.2'</td>
</tr>
<tr>
<td>Imaging Pixels</td>
<td>8 × 2040 × 2040 pixels</td>
<td>2 × 2040 × 2040 pixels</td>
</tr>
<tr>
<td>Pixel Scale</td>
<td>0.032” / pixel</td>
<td>0.065” / pixel</td>
</tr>
<tr>
<td>Grism Slitless Spectroscopy</td>
<td>(wavefront sensing across mirror edges)</td>
<td>R = 1400 – 1800</td>
</tr>
<tr>
<td>Coronagraphy</td>
<td>round: 2.1 µm</td>
<td>round: 3.35, 4.3 µm</td>
</tr>
<tr>
<td>occulters + Lyot stops</td>
<td>bar: 1.8 – 2.2 µm</td>
<td>bar: 2.8 – 5.0 µm</td>
</tr>
</tbody>
</table>

* Two modules image adjacent fields in both channels simultaneously.

Teledyne HgCdTe H2RG detectors
Full frames are read out non-destructively every 10.74 seconds
Smallest subarray 64×64 read out in 49 ms (shortest exposure time)
NIRCam Filters  preliminary JWST OTE × NIRCam optics × dichroic × filter(s) × detector QE

Short Wavelength  F150W2
F070W  F115W  F150W  F200W  F090W
Long Wavelength  F322W2
G = supported for use with grism

F277W  F356W  F444W
G  G  G

F140M  F162M  F182M  F210M
P = in pupil wheel (includes throughput of a filter in filter wheel)

F250M  F300M  F335M  F360M  F410M  F430M  F460M
G  G  G

F480M

F164N  F187N  F212N
F323N  F405N  F466N  F470N
P  P  P  P  P

Wavelength (microns)
Near-Infrared Spectrograph (NIRSpec)
Near Infrared Spectrograph (NIRSpec)

At a glance:

NIRSpec Modes: multi-object, integral-field and slit single object and time series spectroscopy

- Detectors: Two HAWAII 2RG infrared detectors with 0.1 arcsec/pixel
- Three Spectral resolutions: ~100, ~1000, ~2700
- Wavelength coverage: 0.6 to 5.3 micron
IFU FoV: 3”x3”

Fixed slits
FoV: 0.2” x 3.2”, 0.4” x 3.65”, 1.6” x 1.6”

~250,000 micro shutters (0.2”x0.46”)

The NIRSpec focal plane and apertures. The Micro-shutter Assembly (MSA) has four quadrants of micro-shutters to create the slits for NIRSpec MOS.
Near-Infrared Imager & Slitless Spectrograph (NIRISS)
The Near-Infrared Imager and Slit-less Spectrograph (NIRISS)

At a glance:

<table>
<thead>
<tr>
<th>Detector</th>
<th>Teledyne HAWAII-2RG; HgCdTe with 5.2μm cutoff; 2048 x 2048 pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>2.2′ x 2.2′</td>
</tr>
<tr>
<td>Plate scale</td>
<td>0.065 arcsec / pixel</td>
</tr>
<tr>
<td>Pupil Wheel</td>
<td>“Blue” filters; Grism GR700XD; Aperture Mask NRM</td>
</tr>
<tr>
<td>Filter Wheel</td>
<td>“Red” filters; Grisms GR150C,R</td>
</tr>
</tbody>
</table>

Wavelength range: 0.6-5 μm
Aperture Masking Interferometry

Non-Redundant Mask (NRM) + Medium-Band “Red” Filters.

7-hole aperture mask with 21 distinct (“non-redundant”) separations (“baselines”)

Michelson:
\[ \delta \theta = 0.5 \frac{\lambda}{D} \]

NIRISS AMI enables exoplanet detection at 3.8, 4.3, and 4.8 μm around stars as bright as \( M' \sim 4 \), reaching \( 10^{-4} \) contrast at separations of 70–400 milli-arcseconds. It provides lower contrast at 2.8 μm with the F277W filter.

Image reconstruction is also enabled.
Mid-Infrared Instrument (MIRI)
MIRI Details

- Imaging (74''x113'') with 9 wavebands from 5 to 28 μm
- Coronagraphic Imaging at 10.65, 11.4, 15.5 and 23 μm (24''x24'')
- Diffraction Limited at 7 microns (pixel ~ 0.11'')
- MR Spectroscopy (R~3000) using 4 IFUs: entire spectrum from 4.9 to 28.8 μm
- LR Spectroscopy (R~100) 5-10 μm (0.5''x4.7'' or slitless)
MIRI MRS (IFU)

IFU FoV:
from 3.3”x3.7” Ch1 to 7.3”x7.9” Ch4
JWST Performance

photometric performance, point source, SNR=10 in $10^4$s

limiting flux density (Jy)

wavelength (μm)

mAB
R=600-2400 spectroscopy, emission line, point source

Line flux detected at SNR=10 in 10^4 s (erg s^{-1} cm^{-2})

- SOFIA
- VLT
- Gemini
- Keck
- MIRI
- NIRCam
- NIRSpec
- Spitzer

Wavelength (μm)

W m^{-2}
MIRI EC GTO Programs on Protoplanetary Disks, Protostars and Jets

- **Protoplanetary disks** (GTO 1284). P.I.: Th. Henning (MPIA), 111.4 hrs. ~60 targets (Herbig Ae stars, T Tauri stars, brown dwarfs and young debris disks). MIRI/IFU+NIRSpec (few targets)

- **Protostars** (GTO 1282). P.I.: E. Van Dishoeck (U. Leiden), 39 hrs. 30 targets (26 low-mass and 4 high-mass embedded YSOs). MIRI/IFU + NIRSpec on 4 targets (T. Greene program)

- **Jets** (GTO 1257). P.I.: T. Ray (DIAS), 22.8 hrs. HH211. MIRI/IFU + NIRSpec + NIRCam
GTO program on Protoplanetary Disks

Aims:

- Investigate the chemical inventory in the terrestrial planet forming zone
- Follow the gas evolution into the disk dispersal stage
- Study the structure and evolution of protoplanetary and debris disks in the thermal mid-IR.
- Planet formation and presence of protoplanets.
GTO program on Protostars

Aims/Key questions:

• Main characteristics of Class 0/I protostars (accretion and ejection rates, etc.).

• Disks: Origin and location of chemical complexity. Composition and processing of ices. Gas/ice ratios.

• Protostar feedback on surroundings. Physics of jet/wind – envelope interaction (accretion on disk?).

• How do these characteristics change from low- to high-mass stars and with evolutionary stage?

SMA C0 3-2 Contours
(Jorgensen et al. 2007)
GTO program on Jets (HH 211 map)

Aims/Key questions:
• Do shock properties vary with distance from protostar? Role of UV?
• Is dust launched inside Class 0 jets?
• Is dust destroyed by shocks?
• Shock modelling along the whole flow in the MIR/FIR (+ NIR for the blue-shifted BS)
Other GTO Programs I

- Apart from our 3 GTO programs there are other 4 on Debris Disks, 1 on prestellar cores and 4 on YSOs and 2 on Protostellar Jets + 1 Cycle 0 (Ice Age) (E. Palumbo talk)

YSOs:

Other GTO Programs II

• Protostellar Binaries in Perseus. P.I.: M. Ressler (JPL). 12 hrs, MIRI/IFU (11 targets in Per.)

Protostellar Jets:


Conclusions

- JWST is on schedule for a 2020 launch
  - All instruments are now integrated with the telescope

- JWST will dominate astronomy in the next decade due to its unique capabilities!

- Start thinking about your science cases for Cycle 1!