Exoplanet Science with JWST

JWST will help to answer the following questions (and more!) to better understand exoplanetary systems:

- What does the composition of circumstellar disk material reveal about planet formation?
- How and where do planets form in disks?
- How do planets affect the structure of disks?
- What chemical processes take place in exoplanet atmospheres?
- What is the thermal structure of exoplanet atmospheres?
- How does the composition and structure of exoplanet atmospheres correlate with planetary or stellar parameters?
- What does the composition of exoplanet atmospheres reveal about planet formation?
The Path to Exoplanet Science with JWST
Some Remaining I&T Activities*

• System (electrical) test
• Vibration and acoustics tests
• Observatory post-environmental deployments
• Final system test
• Observatory fold and stow for launch

NOTE: *Top-level tasks to go. Many activities are associated with each of these steps.

Webb is planned to ship from California to French Guiana in late 2020

Webb is set to launch on top of ESA’s Ariane 5 in March 2021 from French Guiana

It will undergo a month long 1.5 million km journey to its destination at the second Lagrange point.
Commissioning JWST

This is a complex, 6 month process.

Launch

MCC1a burn

Sunshield done

Wings done

Deployed

Reach L2 orbit

NIRCam on

Aligned to NIRCam

Telescope aligned

Images from 18 mirrors

Start aligning to 3 SIs

NIRISS ready

Thermal characteriz.

MIRI ready

SI commissioning

MIRI at operating temp.

NIRCam ready

NIRSpec ready

END

Days after launch

0  20  40  60  80  100  120  140  160  180

Slide courtesy Jane Rigby

Credit: NASA / Jane Rigby
Starting Science with JWST

• Six months after launch, commissioning is planned to end, and science operations to begin.

• The Cycle 1 schedule will intersperse observations from GO, GTO, ERS, and calibration programs.

• Cycle 1 is just the beginning! JWST is planned to have a mission duration of 5-10 years.

GO: General Observer
GTO: Guaranteed Time Observer
ERS: Director’s Discretionary Time Early Release Science
JWST Science Instruments
Science Instruments

The four different JWST instruments cover an array of imaging and spectroscopy observing modes from optical to infrared wavelengths.

1. NIRCam
2. NIRISS
3. NIRSpec
4. MIRI
Time Series Modes

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>Photometry</th>
<th>Spectroscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5</td>
<td>NIRCam time-series imaging</td>
<td>NIRCam time-series grism spectroscopy</td>
</tr>
<tr>
<td></td>
<td>NIRS single object slitless spectroscopy (SOSS)</td>
<td>NIRS single object slitless spectroscopy (SOSS)</td>
</tr>
<tr>
<td>≥ 5</td>
<td>MIRI imaging</td>
<td>MIRI low resolution slitless spectroscopy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIRI medium resolution spectroscopy</td>
</tr>
</tbody>
</table>

https://exoctk.stsci.edu/pandexo/
https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-time-series-observations
Expected Precision

JWST will have far greater sensitivity than previous observatories, and far more sophisticated instrumentation.

**NIRCam, NIRISS, NIRSpec - HgCdTe H2RG detectors**
- heritage from HST WFC3 detectors
- expect precisions better than ~20 ppm based on HST observations

**MIRI - arsenic-doped silicon (Si:As) impurity band conduction detectors**
- heritage from Spitzer IRAC detectors
- expect precisions better than ~30-50 ppm based on Spitzer observations

*Actual noise floors will be measured during commissioning and Cycle 1.*

[Links](https://jwst.nasa.gov/content/forScientists/faqScientists.html)  
Transiting Exoplanet Early Release Science and Guaranteed Time Observation Programs
ERS Program

Early Release Science Program - Status as of June 2019

The Transiting Exoplanet Community Early Release Science Program (80.4 hours)
PI: Natalie Batalha, Co-PIs: Jacob L. Bean and Kevin B. Stevenson

• Determine the spectrophotometric timeseries performance of the key instrument modes on timescales relevant to transits for a representative range of target star brightnesses.
• Jump-start the process of developing remediation strategies for instrument-specific systematic noise.
• Provide the community a comprehensive suite of transiting exoplanet data to fully demonstrate JWST’s scientific capabilities in this area.

http://www.stsci.edu/jwst/observing-programs/approved-ers-programs
ERS Program

Early Release Science Program - Status as of June 2019

Panchromatic **Transmission**
- nominal target: **WASP-79b**
- transits with NIRISS/SOSS, NIRSpec/G235H & G395H, and NIRCam/F322W2 (four total)

**MIRI Phase Curve**
- nominal target: **WASP-43b**
- one continuous, full-orbit observation covering two secondary eclipses and one transit with MIRI/LRS

**Bright Star’s Planet Emission**
- nominal target: **WASP-18b**
- one secondary eclipse using NIRISS/SOSS

Bean et al. 2018
ERS Program

Early Release Science Program - Status as of June 2019

WASP-79b simulated transmission spectrum from JWST

Bean et al. 2018
GTO Programs

Guaranteed Time Observation Programs - Status as of June 2019

Targets:
• 28 unique exoplanets targeted
• 5 targets come from the Transiting Exoplanet Survey Satellite
• 9 targets smaller than 2 Earth radii

Observations and Modes:
• Mix of transits, eclipses, phase curves at a variety of wavelengths
• NIRCam Grism Time Series
• NIRISS Single-Object Slitless Spectroscopy
• NIRSpec Bright Object Time Series
• MIRI Imaging
• MIRI Low Resolution Spectroscopy

http://www.stsci.edu/jwst/observing-programs/approved-gto-programs
ERS & GTO Targets

Figure courtesy Tom Greene

- TRAPPIST-1b
- TRAPPIST-1d
- TRAPPIST-1e
- TRAPPIST-1f
- WASP-107b
- WASP-121b
- WASP-127b
- WASP-17b
- WASP-18b
- WASP-43b
- WASP-52b
- WASP-69b
- WASP-77Ab
- WASP-79b
- WASP-80b
Proposal Timeline & Resources
Up to 6,000 hours will be available for observing programs using the full suite of JWST instrumentation.

Proposal Planning, Performance, and More: [https://jwst-docs.stsci.edu/](https://jwst-docs.stsci.edu/)
Proposal Resources

From STScI:

+ Master Class Workshop Materials
+ Webinars

http://www.stsci.edu/jwst/news-events
https://jwst-docs.stsci.edu/

Proposing Tools

- Exposure Time Calculator
- Astronomer's Proposal Tool
  - Observation Templates
  - ETC to APT Interface
  - Video Tutorials
- Other Tools
Take Home Points

• JWST will provide a new view of exoplanet atmospheres thanks to its wavelength coverage and sensitivity.

• Early Release Science Observations are designed to test instrument capabilities early in the mission beyond standard commissioning and calibration activities.

• Guaranteed Time Observations will be scheduled over the first few cycles.

• The Cycle 1 GO Call for Proposals will come out later this month (January 2020) - many proposal tools are available now or are coming very soon.

• Propose for JWST observations! Beyond the ERS and GTO programs, there is plenty of exoplanet science to be done. Note the Cycle 1 GO deadline is 1 May 2020.

• We (myself and the JSTUC*) are here to advocate on your behalf for exoplanet science with JWST.

*current exoplanet representatives: Natalie Batalha, Tom Greene, Heather Knutson
Extra Slides
Spectroscopic Performance

http://www.stsci.edu/jwst/about-jwst/history/historical-sensitivity-estimates
Direct Imaging of Exoplanets and Disks
Direct Imaging with MIRI, NIRCam, NIRISS

Coronagraphy with MIRI, NIRCam

Aperture Masking Interferometry with NIRISS

http://www.stsci.edu/jwst/instrumentation/imaging-modes
ERS Program (PI: Sasha Hinkley / Co-PIs: Andrew Skemer and Beth Biller) - 51.7 hours

- HIP 65426 (MIRI, NIRCam, NIRISS)
- HR 4796 A (MIRI, NIRCam)
- VHS 1256 (MIRI, NIRCam, NIRSpec)

GTO Programs (multiple PIs)
- about 30 unique systems targeted

http://www.stsci.edu/jwst/observing-programs/approved-ers-programs
http://www.stsci.edu/jwst/observing-programs/approved-gto-programs
High Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST
PI: Sasha Hinkley, Co-PIs: Andrew Skemer and Beth Biller

• Generate representative datasets in modes to be commonly used by the exoplanet and disk imaging communities;
• Deliver science enabling products to empower a broad user base to develop successful future investigations; and
• Carry out breakthrough science by characterizing exoplanets for the first time over their full spectral range from 2-28 microns, and debris disk spectrophotometry out to 15 microns sampling the 3 micron water ice feature.

http://www.stsci.edu/jwst/observing-programs/approved-ers-programs
ERS Program

Early Release Science Program - Status as of June 2019

HIP 65426:
MIRI Coronagraphic Imaging
NIRCam Coronagraphic Imaging
NIRISS Aperture Masking Interferometry

HR 4796 A:
MIRI Coronagraphic Imaging
NIRCam Coronagraphic Imaging

VHS 1256:
MIRI Medium Resolution Spectroscopy
NIRCam Imaging
NIRSpec IFU Spectroscopy

http://www.stsci.edu/jwst/observing-programs/approved-ers-programs
Guaranteed Time Observation Programs - Status as of June 2019

Targets:
Nearly 30 unique systems will be observed

Observing Modes:
MIRI Coronagraphic Imaging
MIRI Imaging
MIRI Low Resolution Spectroscopy
MIRI Medium Resolution Spectroscopy
NIRCam Coronagraphic Imaging
NIRISS Aperture Masking Interferometry
NIRSpec Fixed Slit Spectroscopy
NIRSpec IFU Spectroscopy

HR 8799; Wang/Marois

http://www.stsci.edu/jwst/observing-programs/approved-gto-programs
Solar System Science
ERS Program

Early Release Science Program - Status as of June 2019

ERS Observations of the Jovian System as a Demonstration of JWST’s Capabilities for Solar System Science
PI: Imke de Pater, Co-PI: Thierry Fouchet
28.9 hours

- the Jupiter system
  - Characterize Jupiter’s cloud layers, winds, composition, auroral activity, and temperature structure;
  - Produce maps of the atmosphere and surface of volcanically-active Io and icy satellite Ganymede to constrain their thermal and atmospheric structure, and search for plumes; and
  - Characterize the ring structure, and its sources, sinks and evolution.

- MIRI: Medium Resolution Spectroscopy
- NIRCam: Imaging
- NIRISS: Aperture Masking Interferometry
- NIRSpec: IFU Spectroscopy

http://www.stsci.edu/jwst/observing-programs/approved-ers-programs
GTO Programs

Guaranteed Time Observation Programs - Status as of June 2019

- Asteroids, Comets
- Near Earth Objects (NEOs)
- Mars, Jupiter (the Great Red Spot), Europa, Saturn (and its rings and small satellites), Enceladus, Titan, Uranus, Neptune
- Trans-Neptunian Objects (TNOs)
- Kuiper Belt Objects (KBOs)

http://www.stsci.edu/jwst/observing-programs/approved-gto-programs