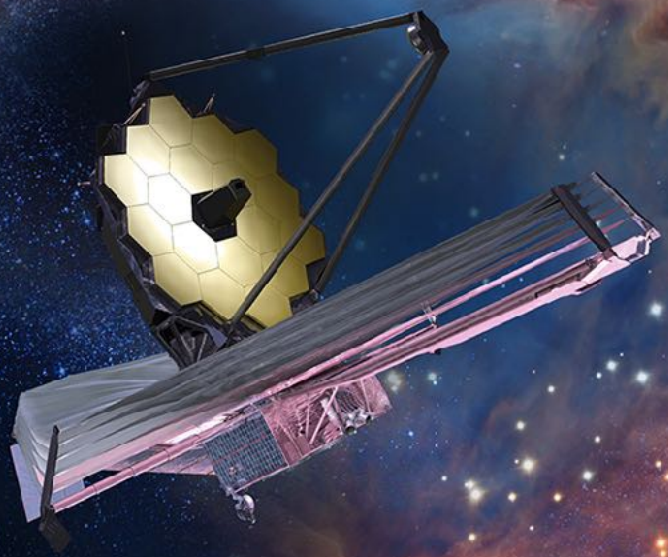
Exoplanet Science with the James Webb Space Telescope



Knicole Colón
JWST Deputy Project Scientist for Exoplanet Science
NASA Goddard Space Flight Center

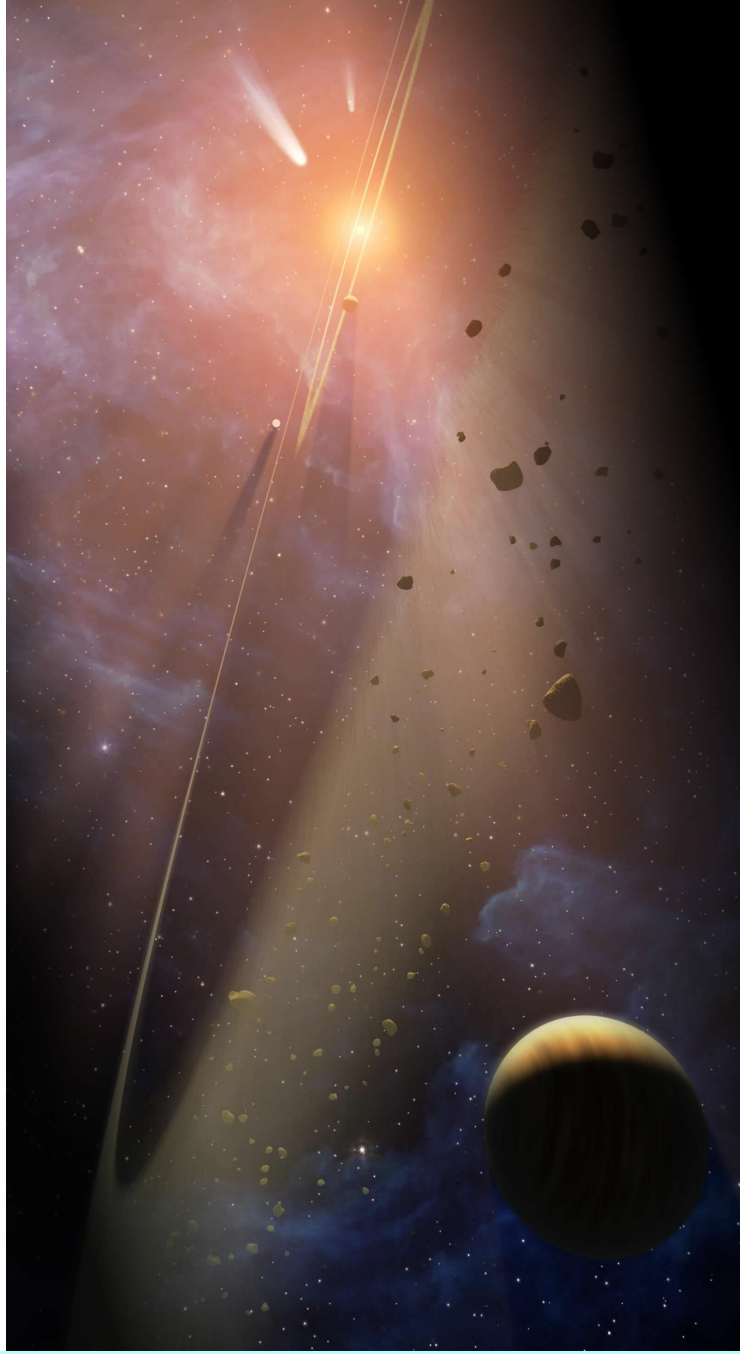
ARIEL: Science, Mission & Community 2020 Conference
16 January 2020

WEBB JAMES WEBB SPACE TELESCOPE

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

Integration, Test, Launch, Commissioning and Science

JWST sunshield deployment (Oct. 2019). Credit: NASA / Chris Gunn

Ariane 5 ECA launch vehicle. Credit: Arianespace

Slide courtesy Jane Rigby

Some Remaining I&T Activities*

Slide courtesy Eric Smith

- 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.

https://www.nasa.gov/feature/goddard/2019/nasa-s-james-webb-space-telescope-clears-critical-sunshield-deployment-testing

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

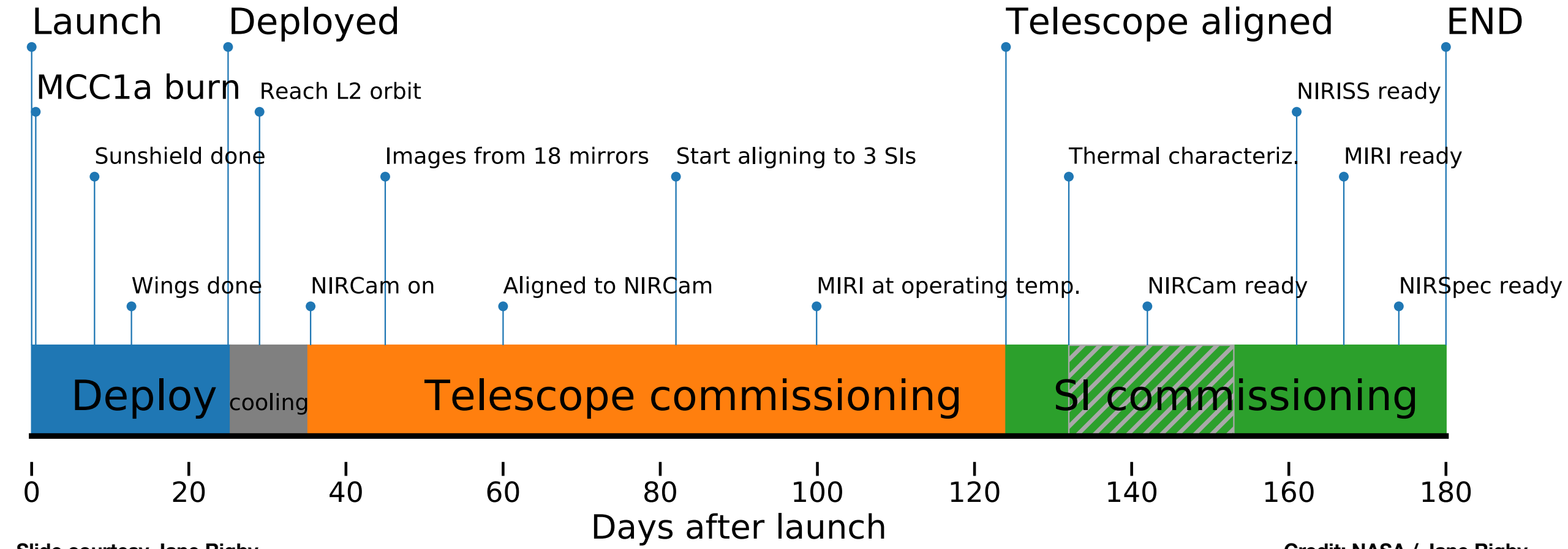
It will undergo a month long 1.5 million km journey to its destination at the second Lagrange point

Photo credit: ESA

ESPACE/Optique Vidéo du CSG - P PIRON

Commissioning JWST

This is a complex, 6 month process.



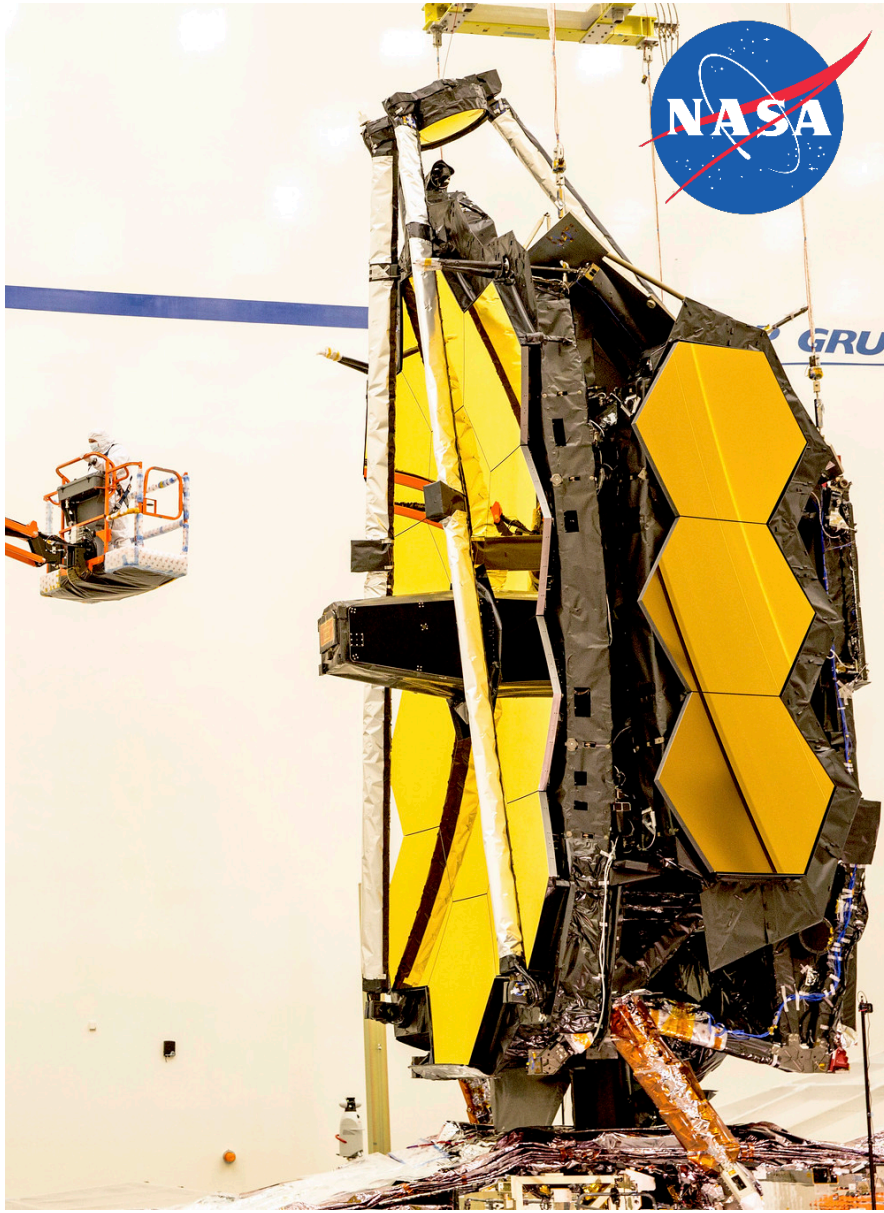
Slide courtesy Jane Rigby

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



Credit: Northrop Grumman

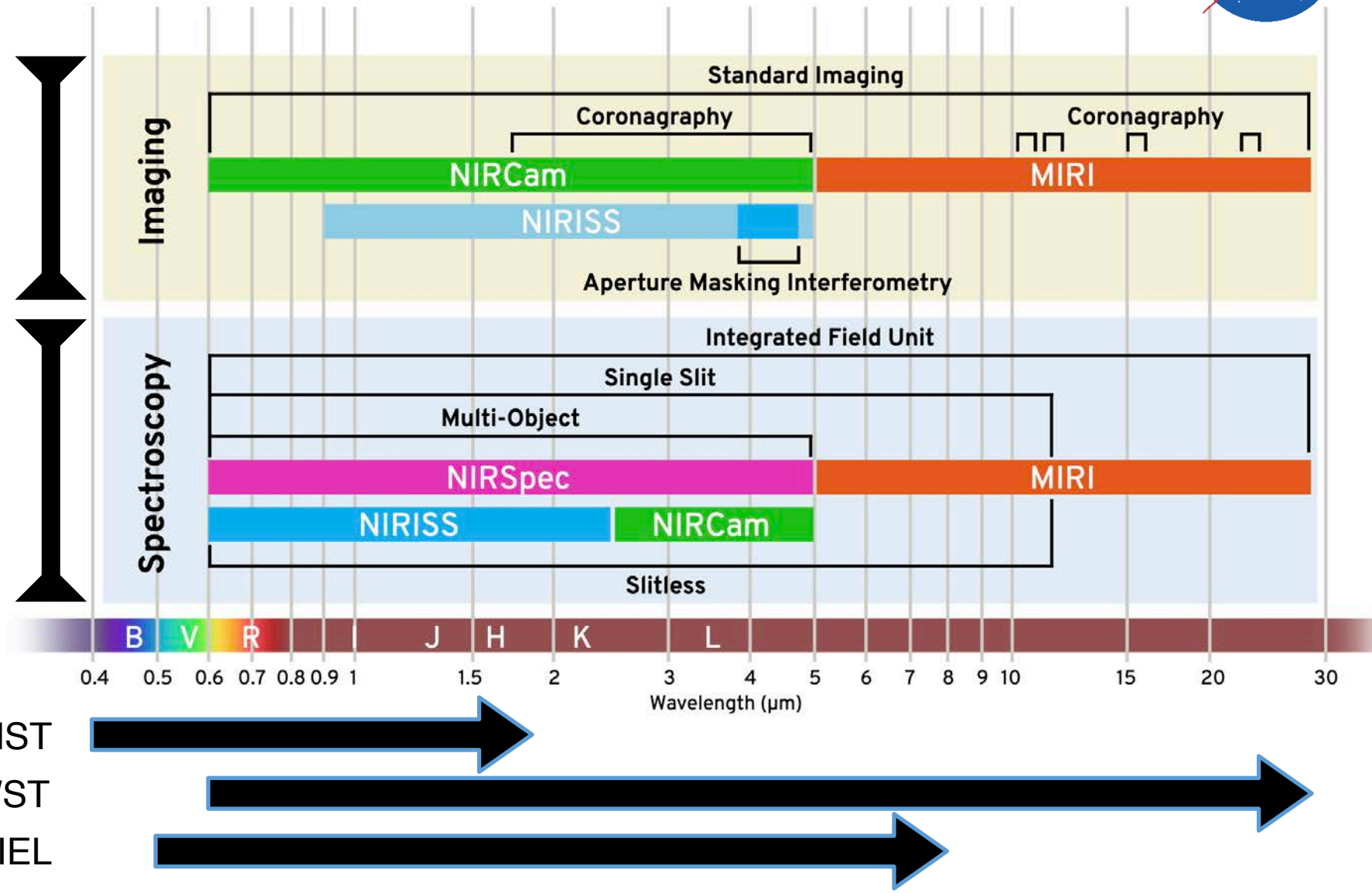
Slide courtesy Jane Rigby

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

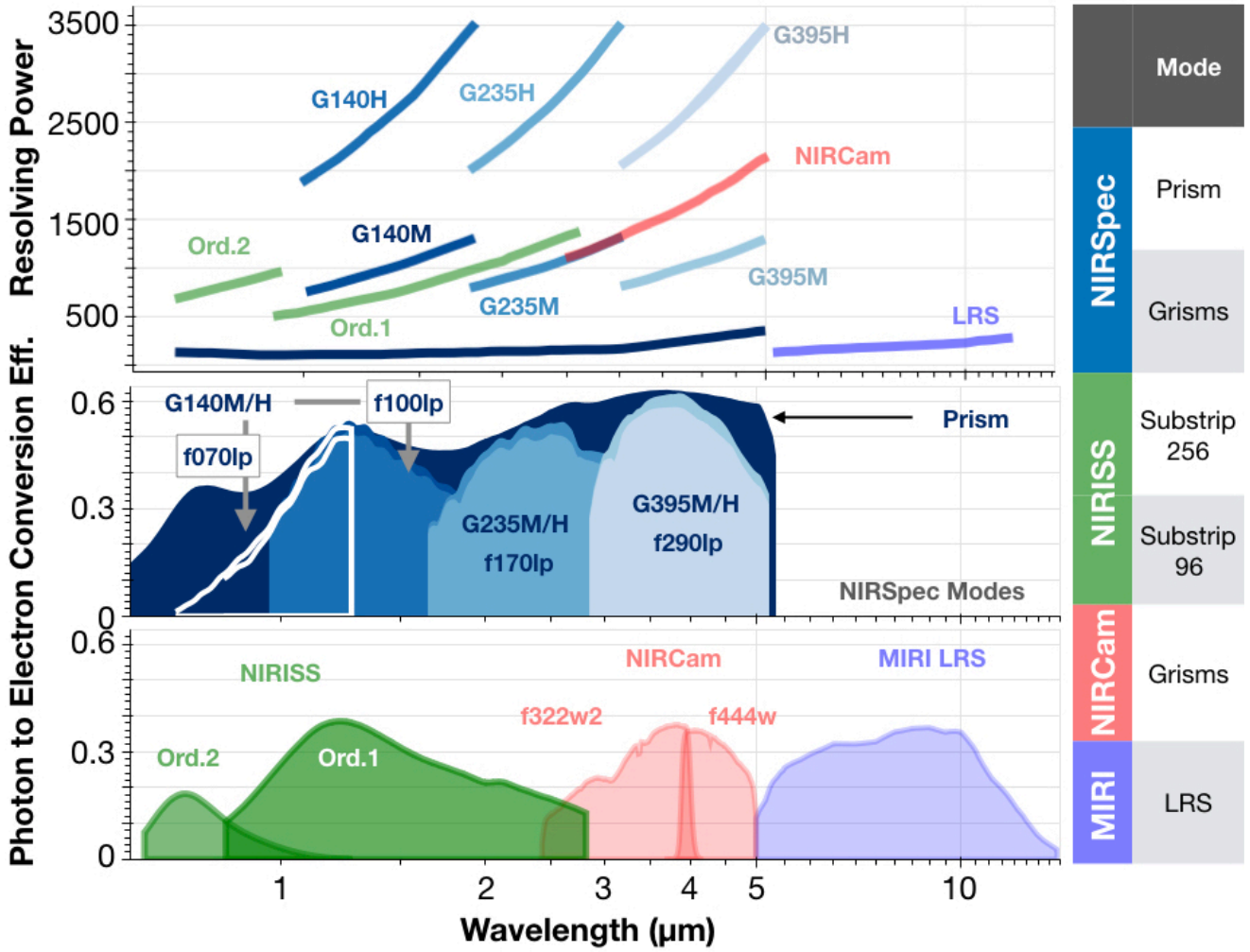


HST

JWST

ARIEL

Time Series Modes



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

	Photometry	Spectroscopy
λ ≤ 5 μm	NIRCam time-series imaging	NIRCam time-series grism spectroscopy NIRISS single object slitless spectroscopy (SOSS) NIRSpec bright object time-series spectroscopy (BOTS)
λ ≥ 5 μm	MIRI imaging	MIRI low resolution slitless spectroscopy MIRI medium resolution spectroscopy

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.

https://jwst.nasa.gov/content/forScientists/faqScientists.html
http://www.stsci.edu/files/live/sites/www/files/home/jwst/instrumentation/_documents/jwst-pocket-guide.pdf

Transiting Exoplanet Early Release Science and Guaranteed Time Observation Programs

ERS Program

See Poster by Nicolas Crouzet

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

See Poster by Nicolas Crouzet

Early Release Science Program - Status as of June 2019

Panchromatic **Transmission**

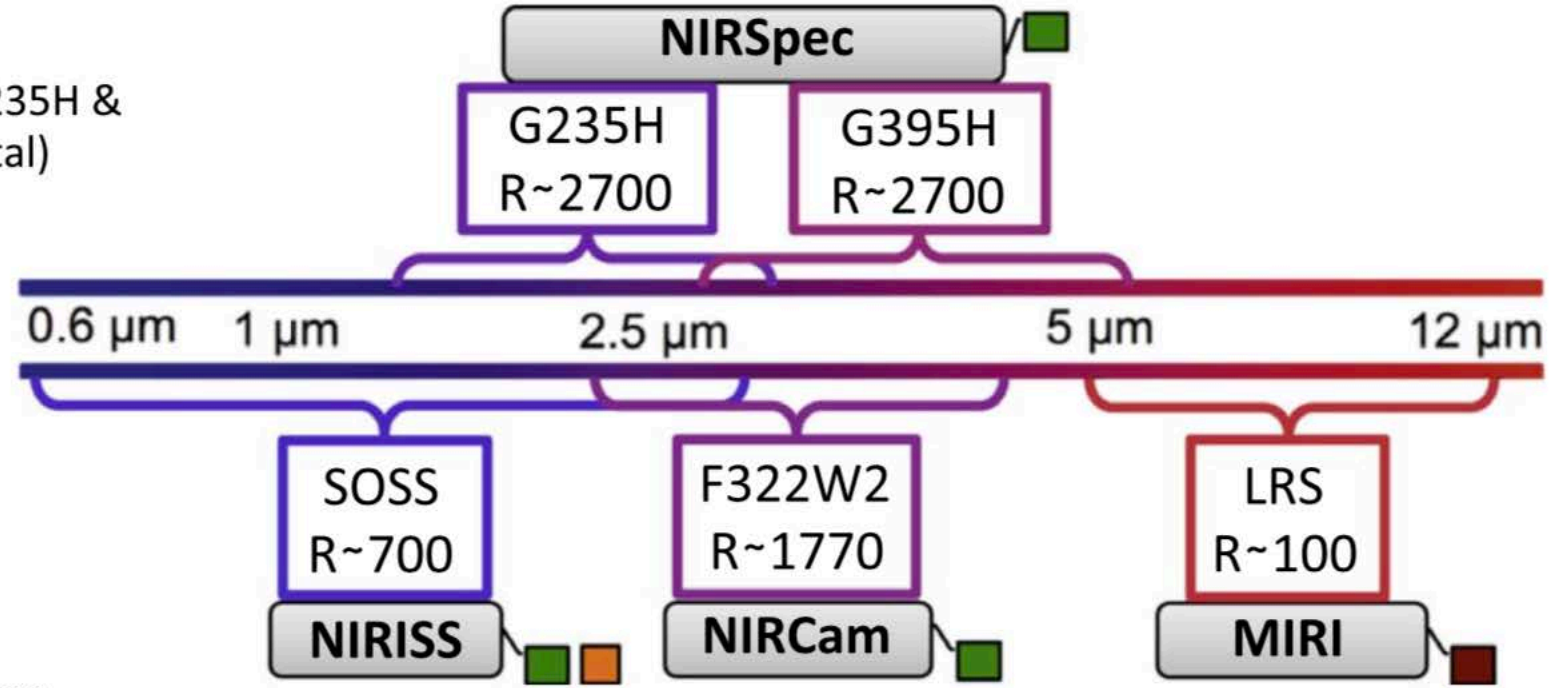
- nominal target: **WASP-79b**
- transits with NIRISS/SOSS, NIRSpec/G235H & G395H, and NIRCam/F322W2 (four total)

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

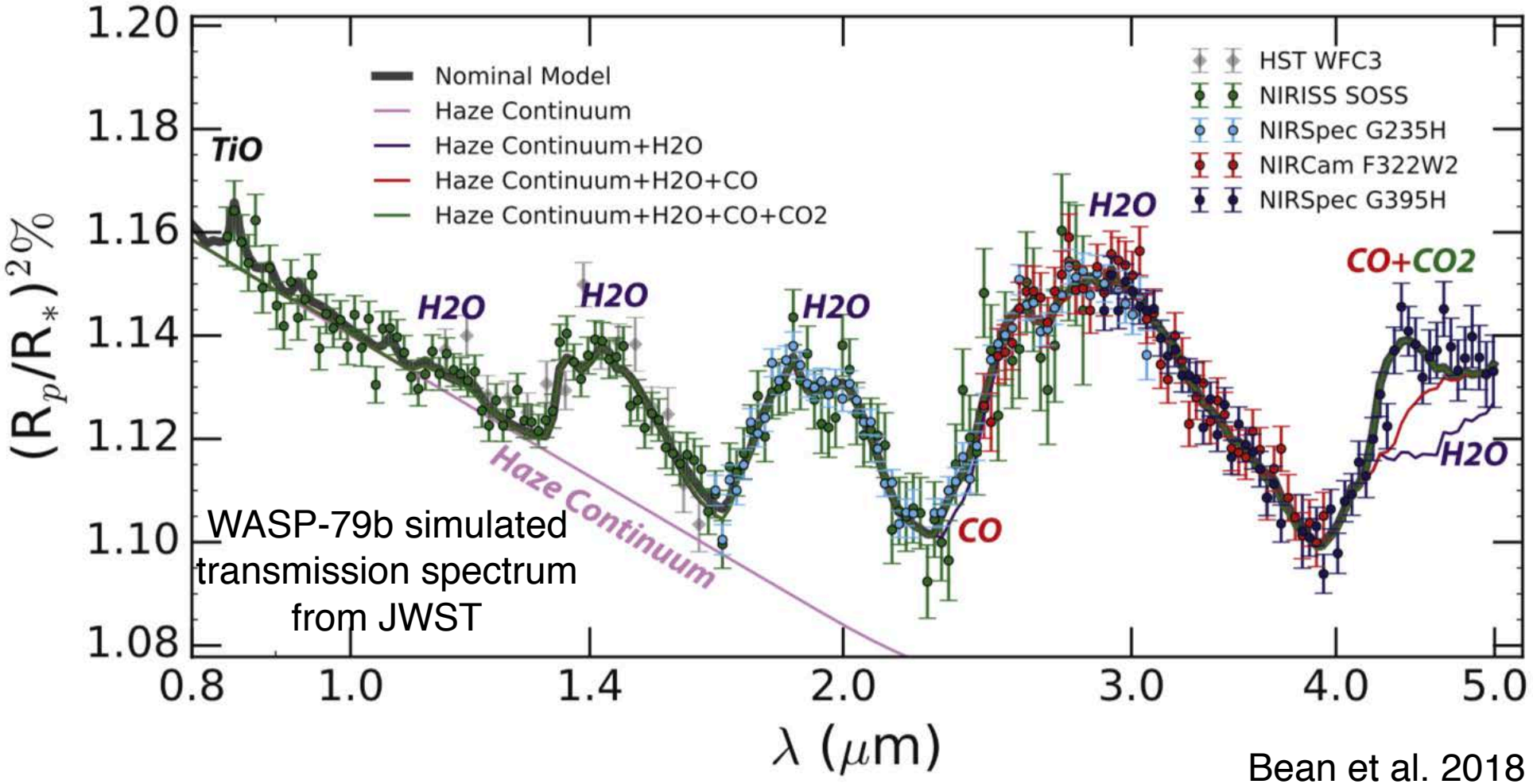


Bean et al. 2018

ERS Program

See Poster by Nicolas Crouzet

Early Release Science Program - Status as of June 2019



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

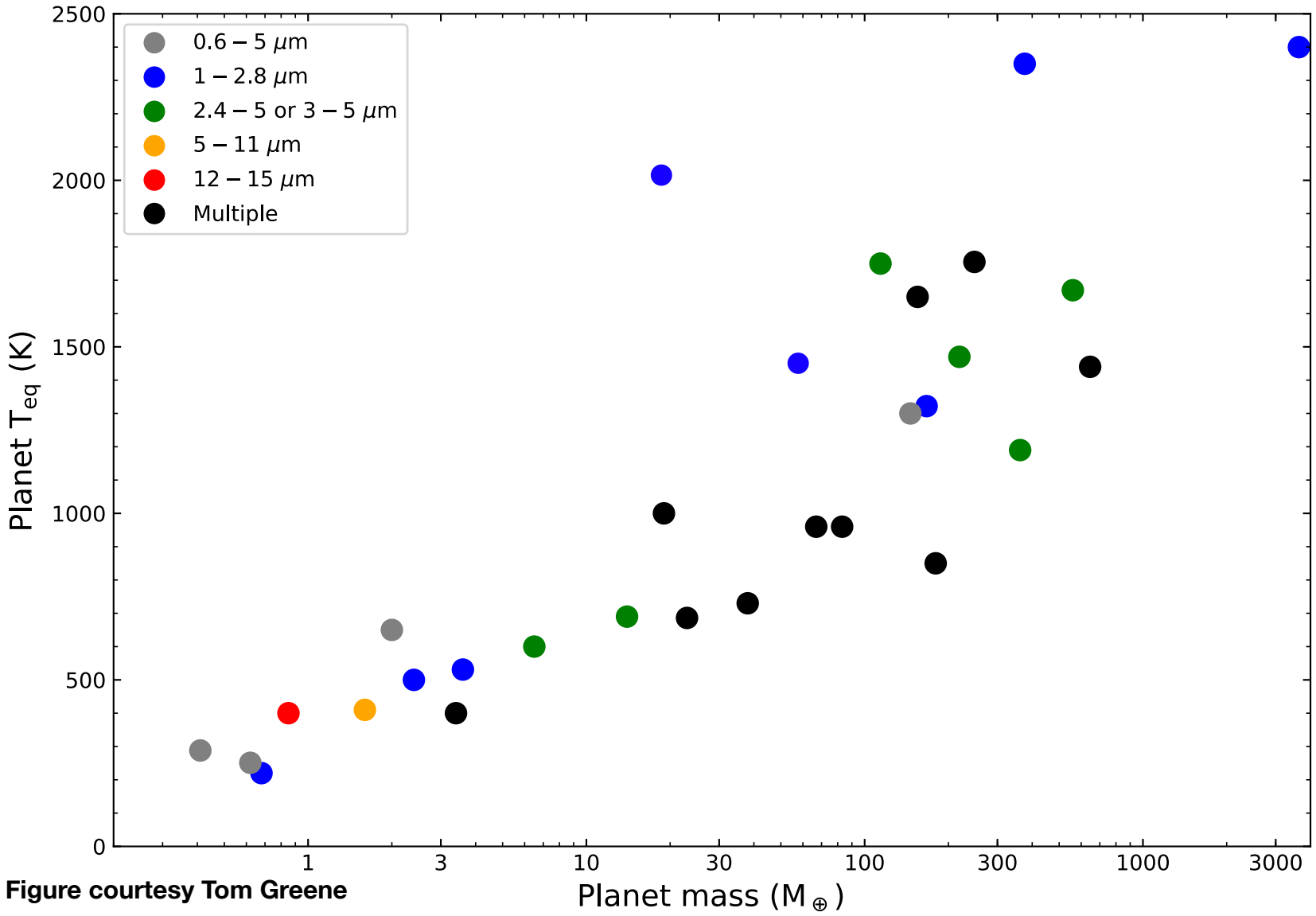


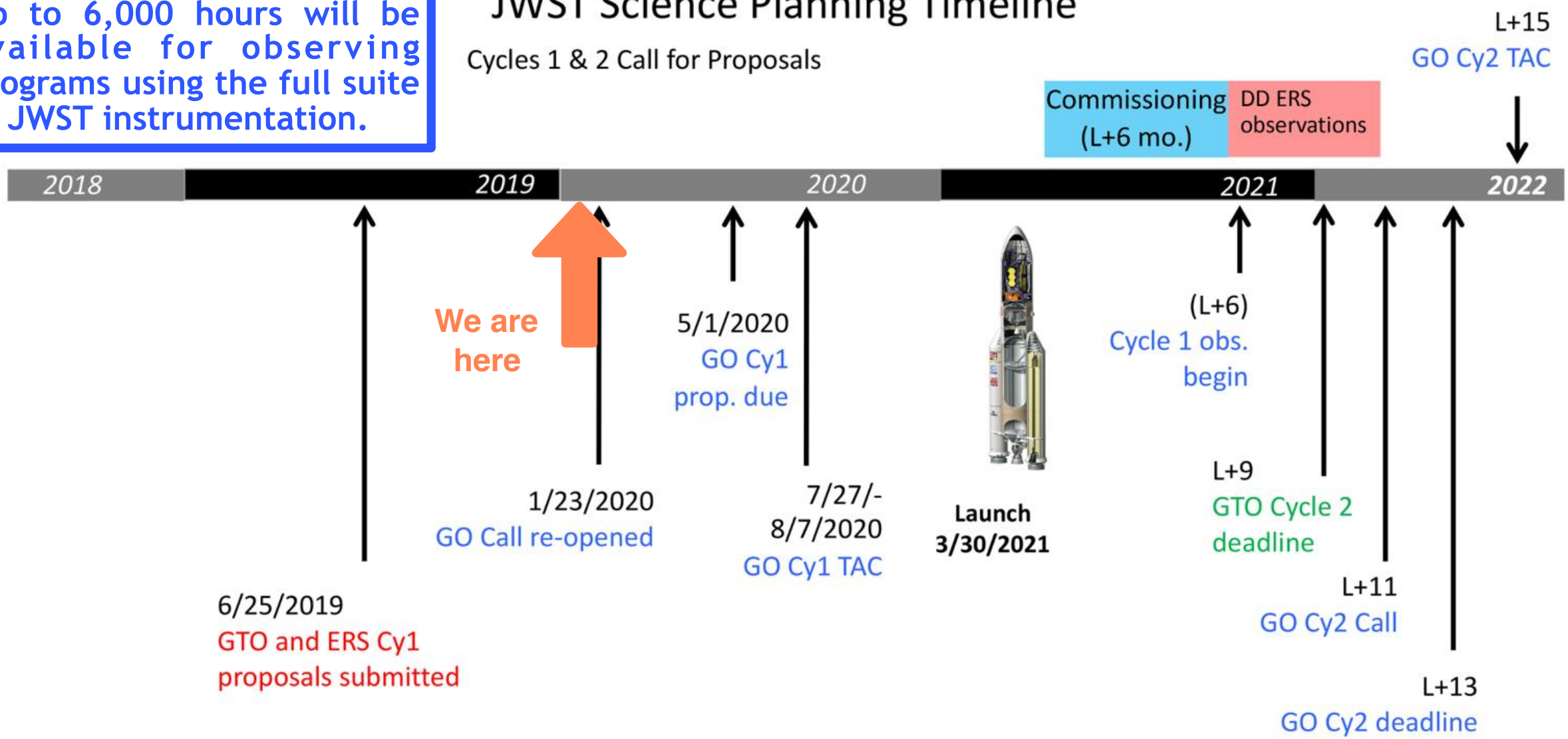
Figure courtesy Tom Greene

GJ-1132b	TRAPPIST-1b
GJ-1214b	TRAPPIST-1d
GJ-3470b	TRAPPIST-1e
GJ-357b	TRAPPIST-1f
GJ-436b	WASP-107b
HAT-P-1b	WASP-121b
HAT-P-12b	WASP-127b
HAT-P-26b	WASP-17b
HD-149026b	WASP-18b
HD-189733b	WASP-43b
HD-209458b	WASP-52b
L98-59c	WASP-69b
L98-59d	WASP-77Ab
TOI-193.01	WASP-79b
TOI-736.01	WASP-80b

Proposal Timeline & Resources

Up to 6,000 hours will be available for observing programs using the full suite of JWST instrumentation.

JWST Science Planning Timeline



Proposal Planning, Performance, and More: https://jwst-docs.stsci.edu/

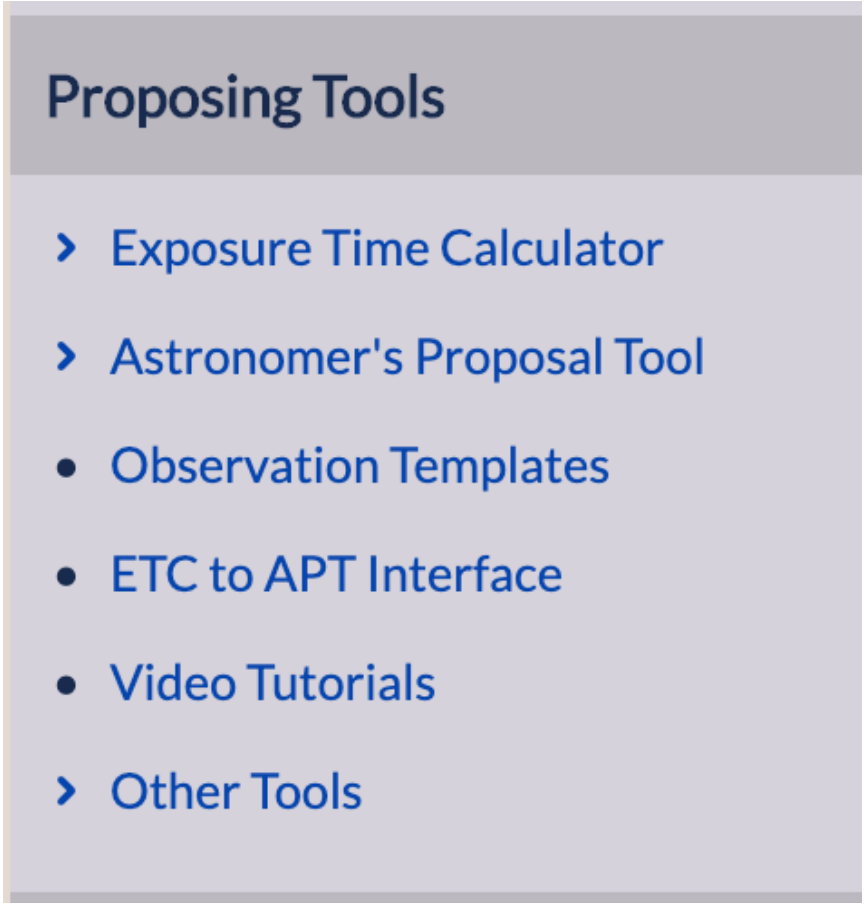
http://www.stsci.edu/jwst/science-planning/calls-for-proposals-and-policy

Proposal Resources

From STScI:

+ *Master Class Workshop Materials*
+ *Webinars*

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



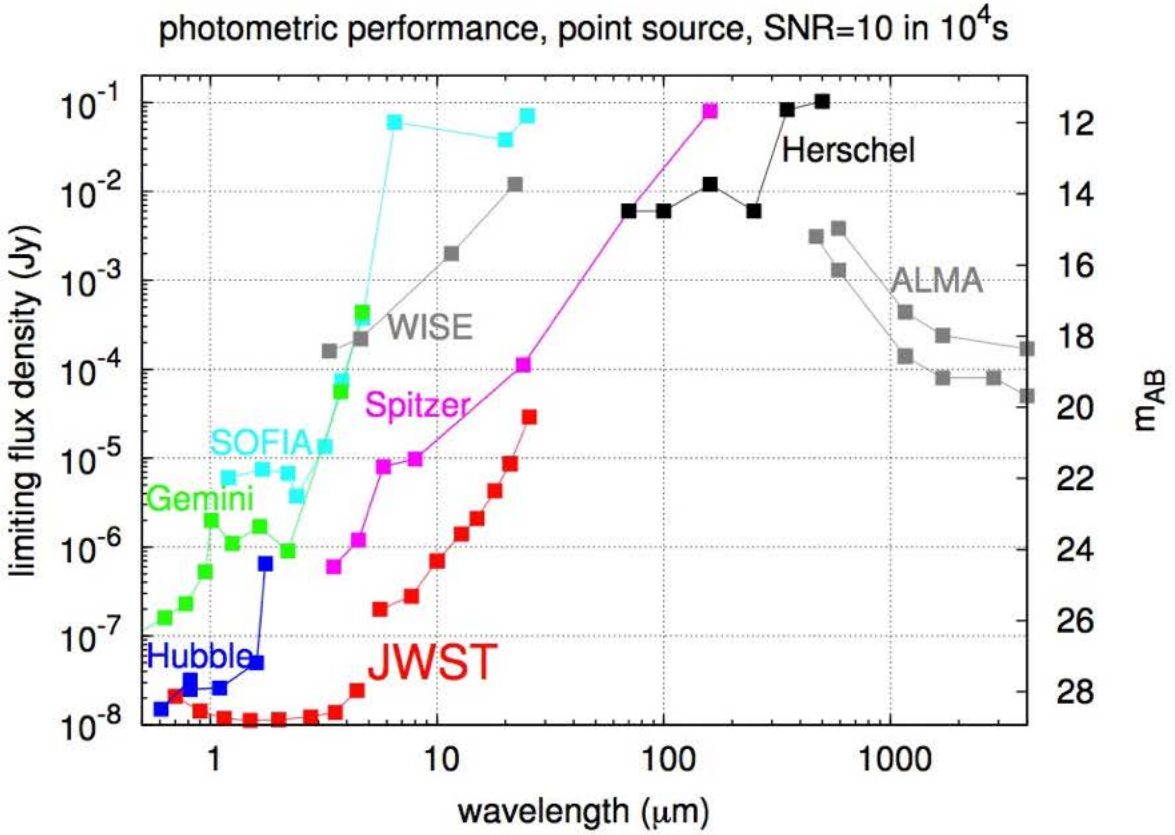
Take Home Points

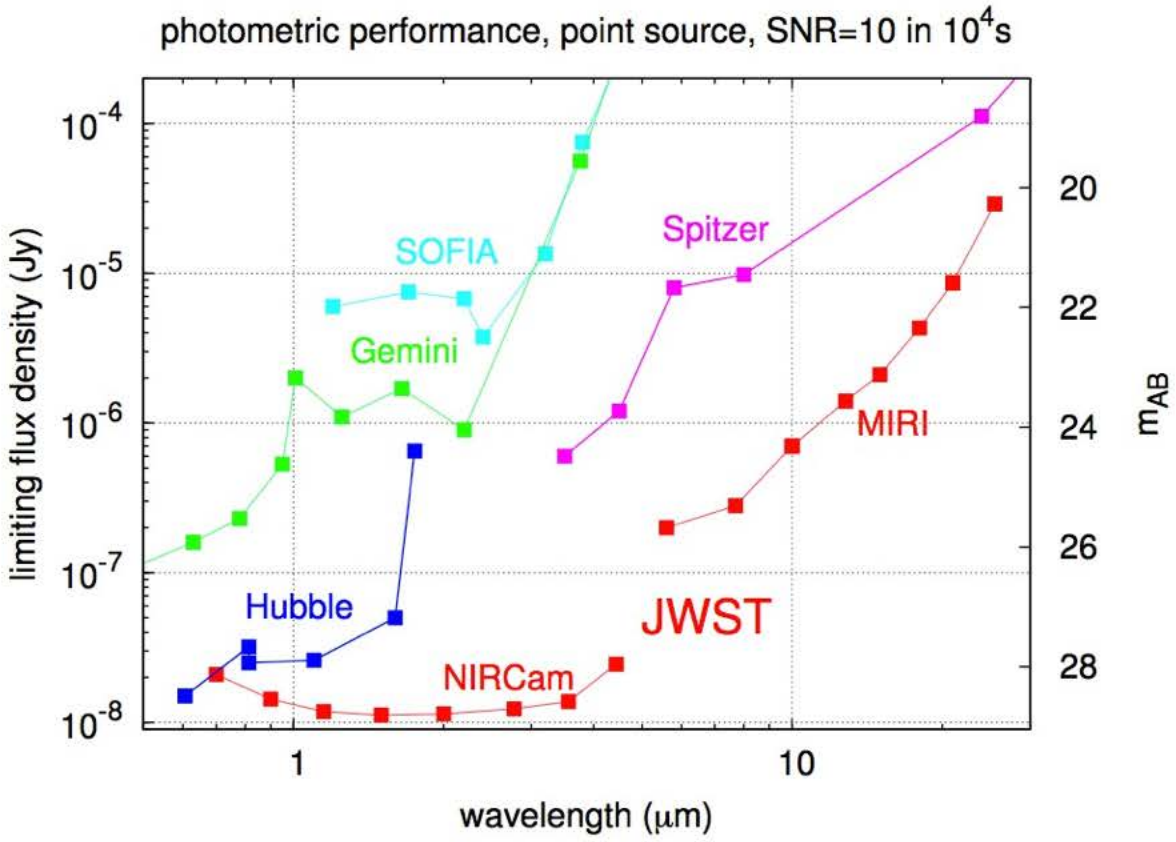
- JWST will provide a new view of exoplanet atmospheres thanks to its wavelength coverage and sensitivity.
- Early Release Science Observations are designed to test instrument capabilities early in the mission beyond standard commissioning and calibration activities.
- Guaranteed Time Observations will 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

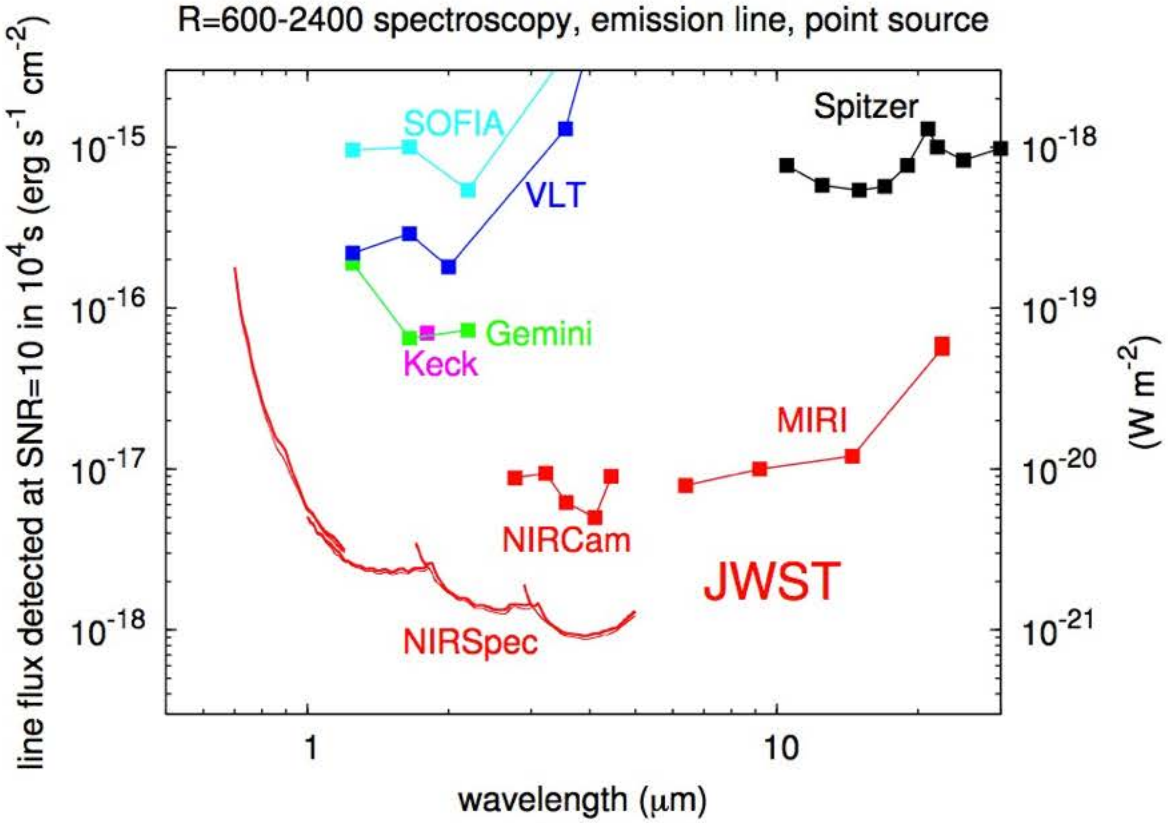
Photometric Performance

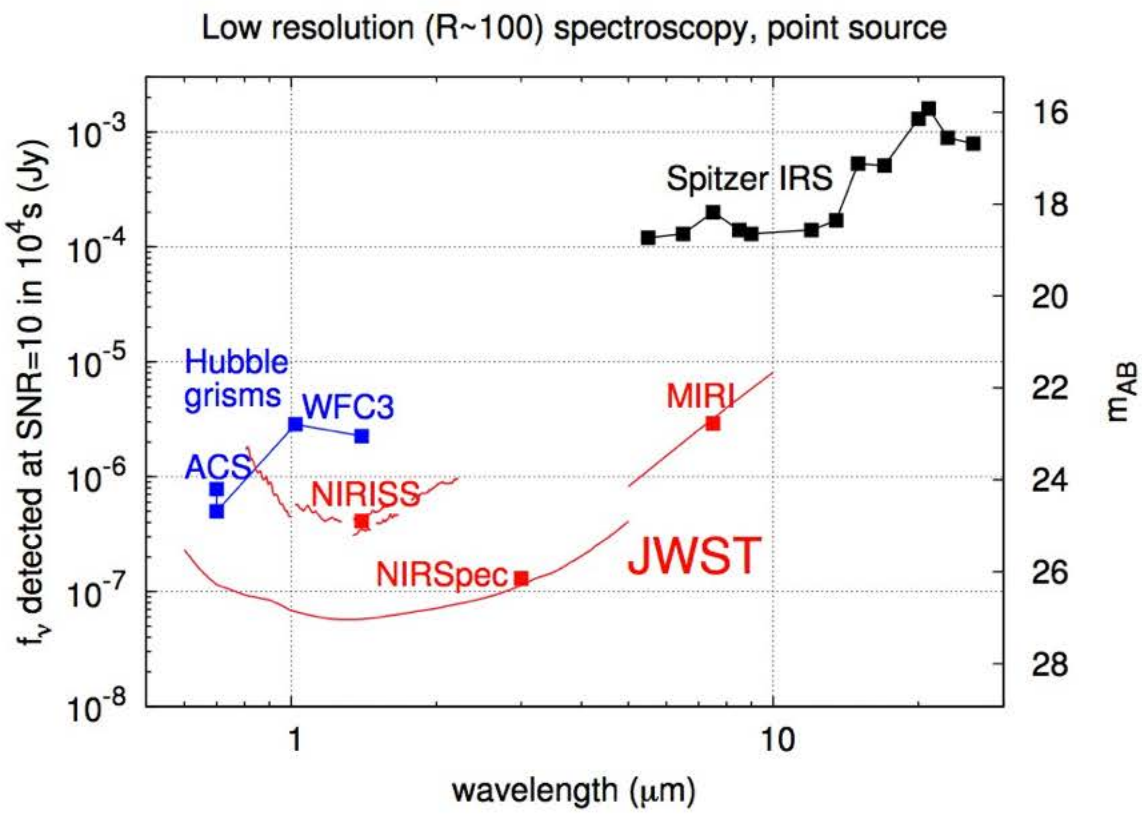




http://www.stsci.edu/jwst/about-jwst/history/historical-sensitivity-estimates

Spectroscopic Performance



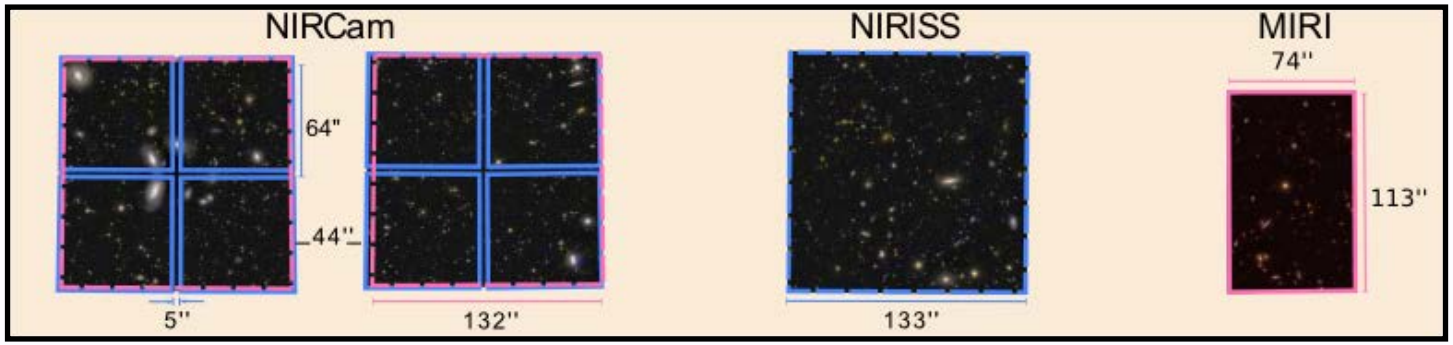


http://www.stsci.edu/jwst/about-jwst/history/historical-sensitivity-estimates

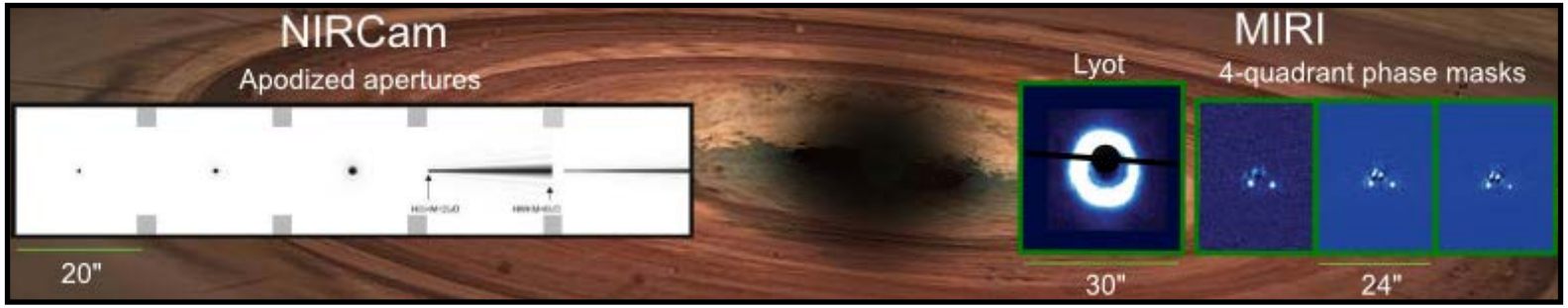
Direct Imaging of Exoplanets and Disks

Direct Imaging Modes

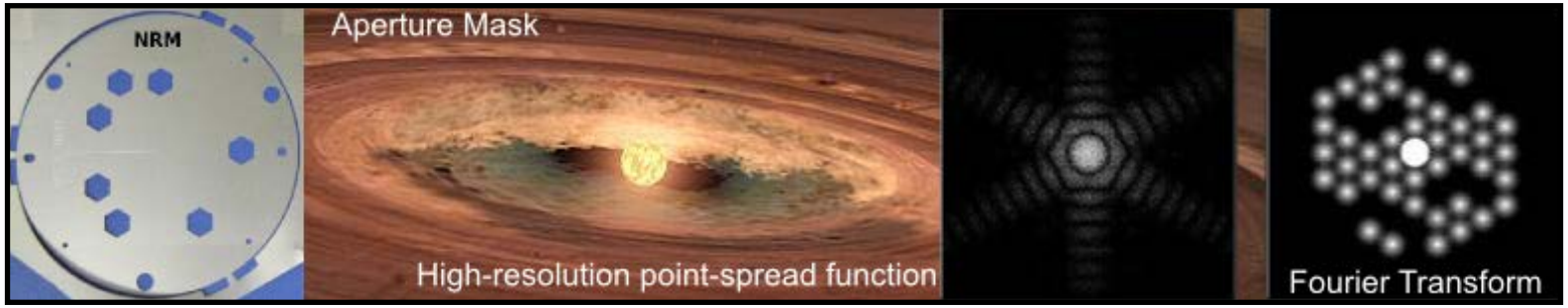
Direct Imaging with MIRI, NIRCam, NIRISS



Coronagraphy with MIRI, NIRCam



Aperture Masking Interferometry with NIRISS



http://www.stsci.edu/jwst/instrumentation/imaging-modes

ERS + GTO Programs

Early Release Science and Guaranteed Time Observation Programs - Status as of June 2019

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

ERS Program

Early Release Science Program - Status as of June 2019

High Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST

PI: Sasha Hinkley, Co-PIs: Andrew Skemer and Beth Biller

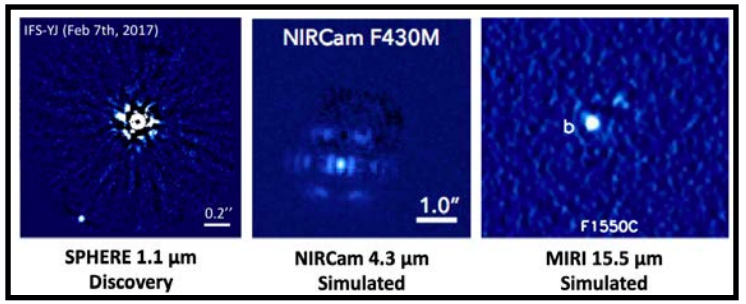
- Generate representative datasets in modes to be commonly used by the exoplanet and disk imaging communities;
- Deliver science enabling products to empower a broad user base to develop successful future investigations; and
- Carry out breakthrough science by characterizing exoplanets for the first 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

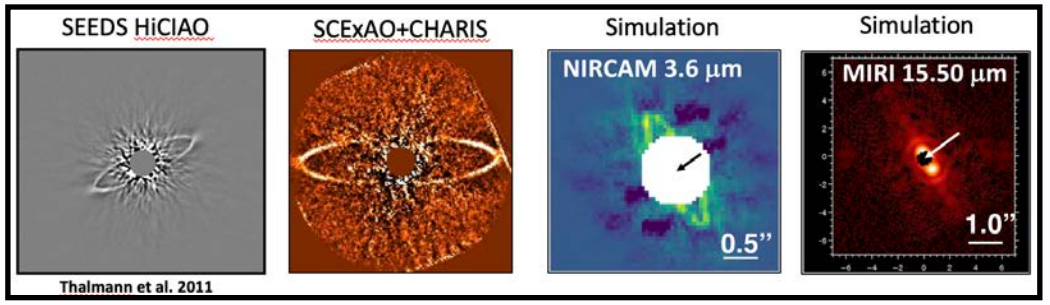
Early Release Science Program - Status as of June 2019

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



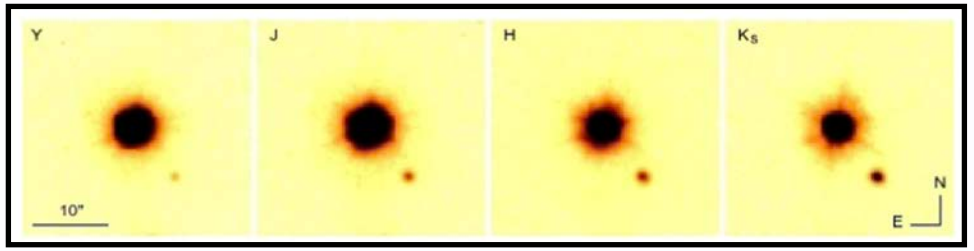
HIP 65426
Chauvin et al. 2017

HR 4796 A:
MIRI Coronagraphic Imaging
NIRCam Coronagraphic Imaging



HR 4796 A
Milli et al. 2017

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



VHS 1256
Gauza et al. 2015

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

GTO 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

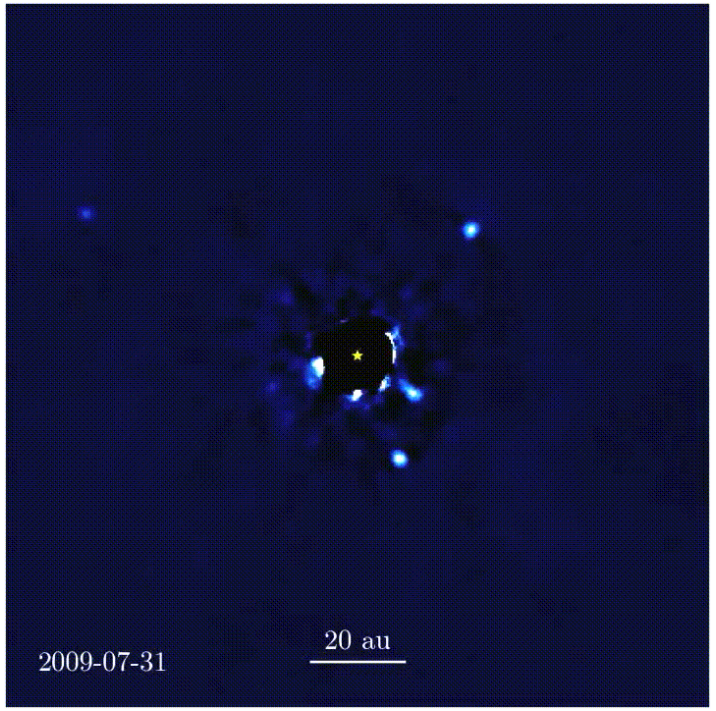
MIRI Medium Resolution Spectroscopy

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

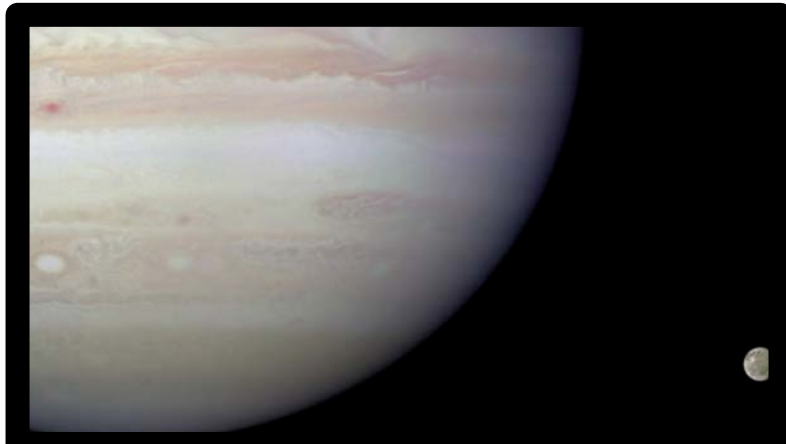
ERS Observations of the Jovian System as a Demonstration of JWST's Capabilities for Solar System Science

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