NASA's James Webb Space Telescope:

JWST Observations in the Solar System

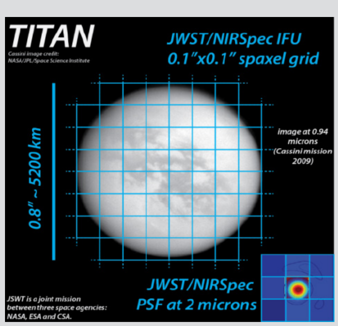
NASA's astrophysical observatories have provided many significant advances in Solar System exploration. Telescopes like Hubble and Spitzer have led directly to new discoveries and also enhanced the productivity of planetary missions. For example, monitoring of Mars has led to insights on ideal landing sites for Martian missions, and Hubble observations were critical in the discovery and determination of the flyby target for the extended phase of the New Horizons mission in early 2019. Survey missions such as IRAS and WISE have revolutionized our understanding of broad categories of solar system objects.

The James Webb Space Telescope (JWST) is poised to revolutionize many areas of astrophysical research, including Solar System Science. JWST has greater sensitivity and higher spatial resolution in the infrared compared to Hubble, and significantly higher spectral resolution in the mid-infrared compared to Spitzer. It has greater sensitivity, higher spatial resolution in the infrared, and significantly higher spectral resolution in the mid infrared. Imaging and spectroscopy (both long-slit and integral-field) will be available across the entire 0.6–28.8 micron wavelength range.

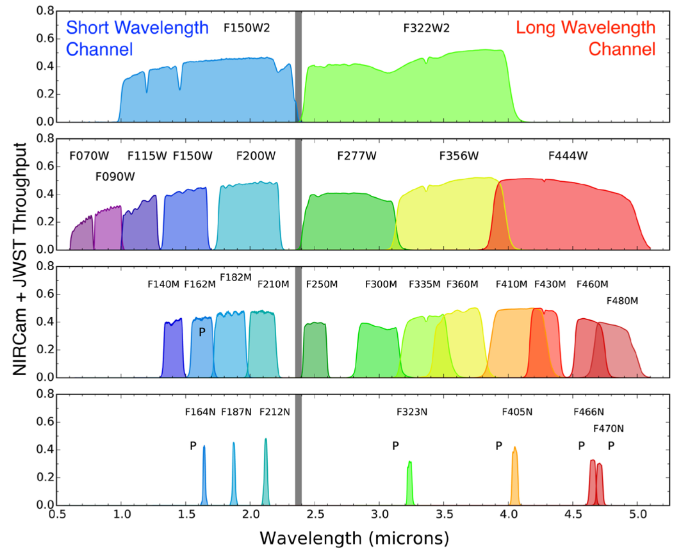
"Planetary systems and the origin of life" is one of the core science themes for JWST. For example, within the Solar System molecular inventories and surface composition of Kuiper Belt Objects and comets will provide key insight into the dynamic history of the Solar System and help constrain current theories. Global scale imaging and spectroscopy of planetary atmospheres will be used to monitor temporal variations as well as decipher dynamics and chemistry.

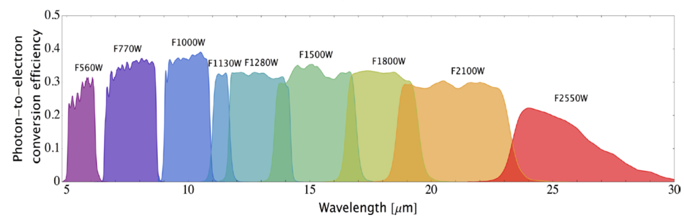
A special issue of Publications of the Astronomical Society of the Pacific contains papers that cover a wide range of Solar System science case studies. A link to all of the arXiv preprints can be found here: https://www.lpi.usra.edu/astrophysicsinvestments/HST-JWST/PASP_JWSTpapers_v2.pdf.

			# Resolution Elements		
Object	Size ('')	Size (km)	2 μm PSF	NIRSpec IFU	MIRI IFU (6.4 μm)
Mars	7	6.8e3	100	70	40
Jupiter	37	1.4e5	530	370	200
Saturn	17	1.2e5	245	170	94
Uranus	3.5	5.1e4	50	34	19
Neptune	2.2	5.0e4	31	22	12
Pluto	0.1	2.4e3	2	1	0.6



NIRSpec (1-5μm) and MIRI (5-28.8μm) offer modes that provide simultaneous spatial and spectral coverage over fields of view of a few arcseconds. The figure at left illustrates the spatial resolution of NIRSpec in such a mode. Spectral resolutions of approximately 3000 are available in both instruments.





JWST will provide many different filter options in the near-infrared with NIRCam (top) and the mid-infrared with MIRI (bottom). NIRCam acquires simultaneous exposures through two filters, one in the short- and the second in the long-wavelength channel.

Science Capability Highlights

- Important molecular (e.g. H_2O, HDO, CO, CO_2, S_2, CH_4), ice, and mineral spectral features are at wavelengths accessible with JWST but not the ground.
- Near-IR spectra or colors (composition), and mid-IR photometry (albedos, sizes), for any Kuiper belt object known today.
- Semi-annual monitoring of planetary (and satellite) weather and seasonal changes.
- Near-simultaneous mapping and spectroscopy of cometary gas and dust from 0.6 – 28.8 μm.
- Very sensitive spectral maps at R > 2000 over a 3''x3'' field and with 0.1'' spatial resolution.

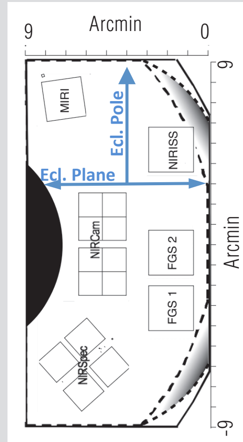
Observatory & Capabilities

After launch, JWST will enter a halo orbit around the Sun-Earth L2 point. This orbit simplifies planning and scheduling, and minimizes thermal and scattered light influences from the Earth and Moon. The 6.5m primary mirror provides diffraction-limited performance (PSF FWHM = 64mas) at 2µm. The mirror and science instruments are passively cooled to 40K by remaining in the shadow of the sunshield; the detec-tors in the mid-IR instrument are actively cooled to 6.7K.

The JWST pointing control system will track objects moving at rates of up to 30 mas/sec (adequate to follow Mars and even most near-Earth objects and long-period comets). The target ephemeris is represented as a 5th order polynomial, enabling tracking of objects (such as Io) that have large apparent accelerations. Pointing stability (and therefore image quality) for moving targets is expected to be comparable to that for fixed targets.

The four science instruments on JWST cover the wavelength range from 0.6 – 28.8 µm and offer superb imaging and spectroscopic sensitivity (see some additional detail in tables below). Subarray readouts will enable non-saturated observations of the giant planets and many bright primitive bodies in a variety of instrument modes.

Scattered light is a concern when observing in the vicinity of bright targets such as the planets and brighter asteroids. Accurate scat-tered light performance will only be known once on-orbit testing is completed, but modeling work is ongoing.



JWST science Instrument and guider fields of view as they project onto the sky. The ecliptic orientation shown is for a line-of-sight in the ecliptic plane and in the direction of observatory orbital motion about the Sun. The line of sight is restricted to solar elonga-tions of 85° – 135° (so that the telescope and instruments always remains in the shadow of the sunshield). The resulting field of regard encompasses 35% of the sky; any particular pointing falls within the field of regard twice a year. These point-ing restrictions result in continuous viewing windows of about 50 days for low-inclination targets, while a 5° cone at the ecliptic poles is continuously visible.

JWST science observations will, for the first 2.5 years, fall into Guaranteed Time Observations (GTO), Director's Discretionary Early Release Science (DD-ERS), and General Observer (GO) categories. GTO and ERS target lists will be finalized prior to the GO-1 call for proposals. The fraction of time allocated for Solar System proposals will approximately reflect the fraction of total available time requested for those proposals. The selection process is expected to be highly competitive. Analysis funding will be made available to successful US-based proposers.

Standard JWST Imaging Modes

Mode	Instrument	Wavelength (microns)	Pixel Scale (arcsec)	Feild of View
Imaging	NIRCam	0.6–2.3	0.032	2.2 x 4.4'
	NIRCam	2.4 – 5.0	0.065	2.2 x 4.4'
	NIRISS	0.9 – 5.0	0.065	2.2 x 2.2'
	MIRI	5.0 – 28.8	0.11	1.23 x 1.88'
Aperture Mask Interferometry	NIRSS	3.8 – 4.8	0.065	--------

*MIRI and NIRCam are capable of imaging in sub arrays to facilitate observations of bright objects, and coronagraphy of extra-Solar planetary systems.

JWST Spectroscopy Modes

Mode	Instrument	Wavelength (microns)	Resolving Power (λ/Δλ)	Field of View
Slitless Grism	NIRISS	1.0 – 2.5	150	2.2 x 2.2'
	NIRISS	0.6 – 2.5	700	single object
	NIRCam	2.4 – 5.0	2000	2.2 x 4.4'
Single Slit Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	slits with 0.4 x 3.7" 0.2 x 3.2" 1.6 x 1.6"
	MIRI	5.0 – ~14.0	~100 at 7.5 microns	0.5 x 4.7" slit
IFU	NIRSpec	NIRSpec	100, 1000, 2700	3.0 x 3.0"
	MIRI	4.9 – 7.7	3500	3.3 x 3.7"'
	MIRI	7.5 – 11.7	3000	4.2 x 4.8"'
	MIRI	11.5 – 18.1	2300	5.6 x 6.2"
	MIRI	17.7 – 28.5	1700	7.2 x 7.9"

More information and details about JWST, observatory and instrument capabilities, and Solar System science with JWST can be found at: **jwst-docs.stsci.edu**

An instrument pocket guide is here: **https://jwst.stsci.edu/files/live/sites/jwst/files/home/instrumentation/technical%20docu-ments/jwst-pocket-guide.pdf**

JWST science flyers are here: **jwst.stsci.edu/about-jwst/history/flyers**

The JWST Exposure Time Calculator (ETC) is here: **jwst.etc.stsci.edu**

The Astronomer's Proposal Tool (APT) can be downloaded here: **www.stsci.edu/hst/proposing/apt**

PSF modeling software and a PSF library can be found here: **https://jwst.stsci.edu/science-planning/proposal-planning-toolbox/psf-simulation-tool-webbpsf**

Images courtesy of NASA