# NASA's James Webb Space Telescope:
## JWST Observations in the Solar System

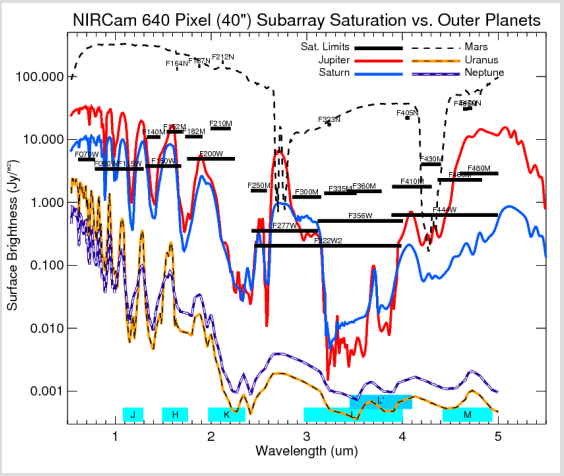
NASA's astrophysical observatories have provided many significant advances in Solar System exploration. Telescopes like Hubble and Spitzer have led directly to new discoveries and also enhanced the productivity of planetary missions. For example, monitoring of Mars has led to insights on ideal landing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

Scheduled for launch in 2018, the James Webb Space Telescope (JWST) is poised to revolutionize many areas of astrophysical research, including Solar System Science. JWST is ~100 times more powerful than the Hubble and Spitzer observatories. 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– ~ 28.5 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.

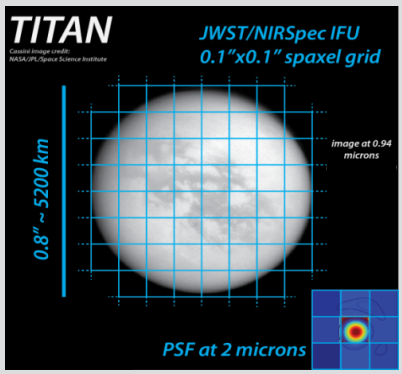
A 2014 white paper (Norwood et al., 2014) provides an overview and representative Solar System science case studies: http://www.stsci.edu/jwst/doc-archive/white-papers.

In addition, 10 community-based focus groups are examining JWST capabilities in the areas of: Asteroids, Comets, Giant Planets, Mars, Near Earth Objects, Occultations, Rings, Satellites, Titan, and Trans-Neptunian Objects. The JWST project is providing technical information to these groups to aid in their work. Detailed results from these studies will be published in a series of white papers. In the meantime, the groups are preparing 2-page flyers on their topics, which are (or will be) available from: http://www.stsci.edu/jwst/doc-archive/flyers.




JWST will be able to observe the outer planets without saturating in at least some modes. This figure shows disk-averaged spectra for the outer planets and the NIRCam saturation limits for subarrays large enough to image all of Jupiter in a single pointing. Smaller subarrays (and higher saturation limits) are available. Spectroscopic modes (with even higher limits) will be needed for Mars.

| | | | # 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 (5-28.5μm) 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.

### 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 – ~ 28.5 μm.
- Very sensitive spectral maps at R > 2000 over a 3"x3" field and with 0.1" spatial resolution.

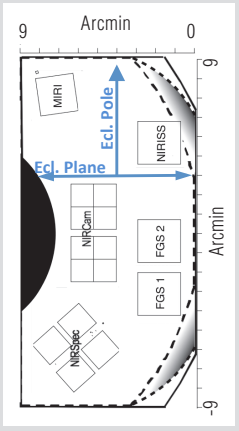
# Observatory & Capabilities

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 detectors 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). 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 – ~ 28.5 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 for observing bright targets such as the planets and brighter asteroids. Accurate scattered light performance will only be known once on-orbit testing is completed, but the fidelity of PSF models is being improved by incorporating details of mirror-segment edge figures.




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 elongations 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 pointing 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 Observer (GTO) and General Observer (GO) categories. Director's Discretionary Time will also be available, and the project is considering large-program possibilities as well. GTO target lists will be finalized prior to the GO-1 call for proposals (expected to be in late 2017). GO-1 proposals will be due in early 2018. Science operations, including execution of GO-1 programs, are expected to commence in April, 2019. Mission lifetime goal is 10 years. The fraction of time allocated for Solar System proposals will approximately reflect the fraction of the 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.

The Astronomer's Proposal Tool (APT, developed for the Hubble Space Telescope) is being expanded to support planning and submission of JWST proposals. Some APT enhancements related to planning Solar System observations are under discussion, with a goal of making them available for GO-1 proposers.

**Standard JWST Imaging Modes***

| Mode | Instrument | Wavelength (microns) | Pixel Scale (arcsec) | Field 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 – 27.5 | 0.11 | 1.23 x 1.88' |
| Aperture Mask Interferometry | NIRISS | 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.

## More Information

More information and details about JWST, observatory and instrument capabilities, and Solar System science with JWST can be found at:

jwst.nasa.gov/faq_solarsystem.html

www.stsci.edu/jwst/science/solar-system

Instrument pocket-guides, a JWST primer, and other materials are available from: www.stsci.edu/jwst/science/doc-archive

A prototype exposure-time calculator for some instrument modes is here: jwstetc.stsci.edu/etc

PSF modeling software and a PSF library can be found here: http://www.stsci.edu/jwst/software/webbpsf

**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 3.8'' 0.2 x 3.3'' 1.6 x 1.6'' |
| | MIRI | 5.0 – ~14.0 | ~100 at 7.5 microns | 0.6 x 5.5'' slit |
| IFU | NIRSpec | 0.6 – 5.0 | 100, 1000, 2700 | 3.0 x 3.0'' |
| | MIRI | 5.0 – 7.7 | 3500 | 3.0 x 3.9'' |
| | MIRI | 7.7 – 11.9 | 2800 | 3.5 x 4.4'' |
| | MIRI | 11.9 – 18.3 | 2700 | 5.2 x 6.2'' |
| | MIRI | 18.3 – 28.5 | 2200 | 6.7 x 7.7'' |