NASA's James Webb Space Telescope:
Observations of the Giant Planets

The James Webb Space Telescope (JWST) offers unprecedented observing opportunities in the near- and mid-infrared for the planets Jupiter, Saturn, Uranus, and Neptune. Potential groundbreaking investigations of these planets include such studies as mapping H_3^+ emission to study auroral processes, tracking atmospheric dynamics in the aftermath of impact events, and more. Additional fields of investigation are showcased here.

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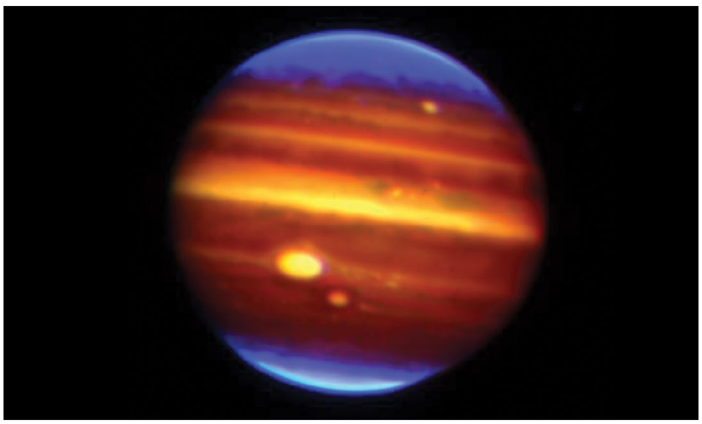
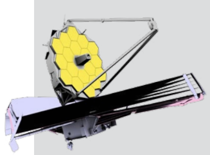


JWST will provide spatial resolution comparable to the largest ground-based telescopes, with ~600 resolution elements across the Jovian disk at 2 μm (~300 at 5 μm), and at wavelengths accessible only from space. Near-infrared view of Jupiter from UKIRT, courtesy of P. Irwin. Red: Fe II (1.644 μm) Green: Brackett γ (2.17 μm) Blue: 2.27 μm.

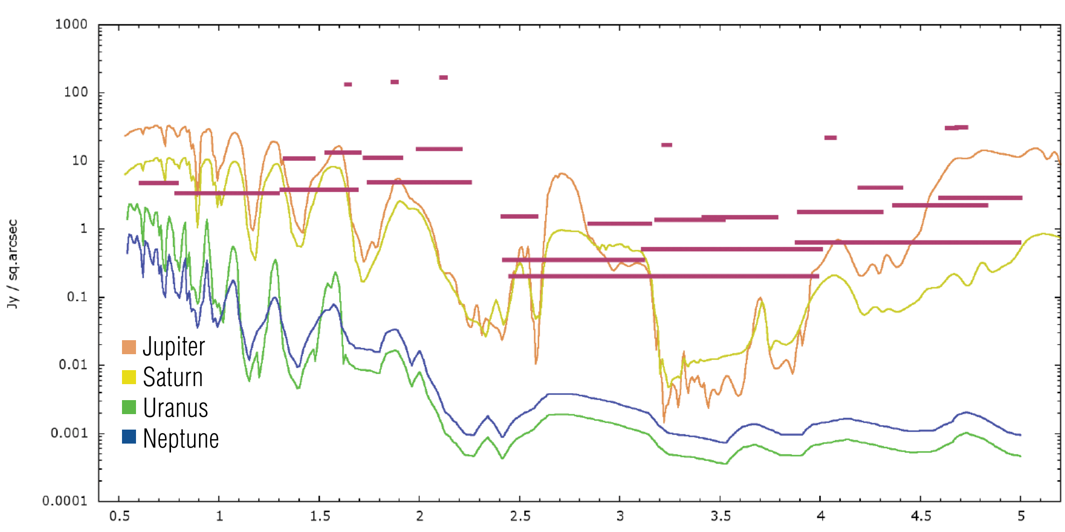
Reflected and thermally emitted light from the four giant planets is attenuated by methane to a degree that varies greatly across the near-IR spectrum. JWST observations can take advantage of this to probe to different depths in these atmospheres and engage in such investigations as the following:

- Mapping the vertical and horizontal cloud structures (including major storm systems) and their evolution, with finer detail than previously possible.
- High-resolution mapping of the latitudinal variation in the methane abundance on Uranus and Neptune to explore its implications for global circulation.
- Comparing near-simultaneous reflected-light and thermal imagery to study the thermo-chemical processes behind different features.



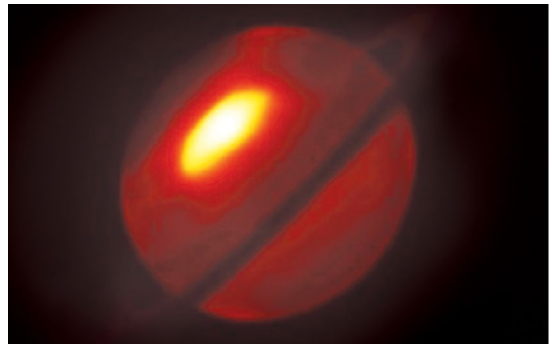
Observability windows for the giant planets span ~50 days and occur approximately every six months. All four giant planets can be observed using the highest spectral-resolution modes of NIRSpec (R=2700) and MIRI ($2000 < R < 3700$), delivering very high signal-to-noise data in short exposures. Due to the brightness of these targets, sub-array readout patterns are being implemented for all JWST instruments to decrease the minimum exposure time and raise the saturation limits. This will enable observations of even these very bright objects over much of the JWST spectral range, as shown below.

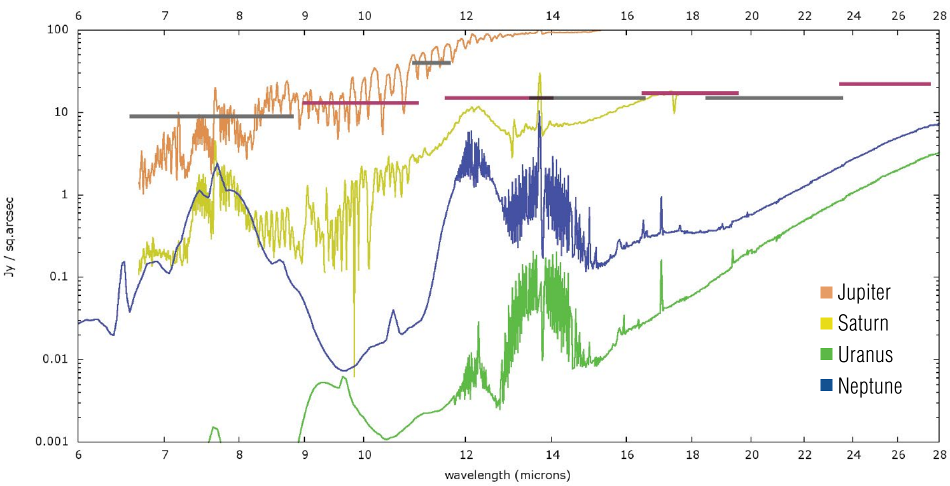
Spectra of Jupiter, Saturn, Uranus, and Neptune compared to saturation limits of NIRCam filters, assuming 640 X 640 sub-array imaging. Spectra composited from Clark and McCord (1979), Karkoschka (1994), Encrenaz (1997), Fink and Larson (1979), and Burgdorf (2008).



Ephemeral phenomena are fairly common in the atmospheres of the giant planets. These and other time variable effects driven (e.g.) by seasonal changes, will provide a rich environment for maximizing the impact of JWST's combined spatial resolution and its spectral grasp and resolution, on studies of these dynamic and complex atmospheres.

Events such as the large storm system that developed on Saturn in 2010 and the hot stratospheric "beacon" (shown here) that developed after the storm's dissipation, provide unique opportunities to deepen our understanding of processes in the giant planet atmospheres. 2011 VLT image of Saturn at 12 μm (ethane emission), courtesy of L. Fletcher.

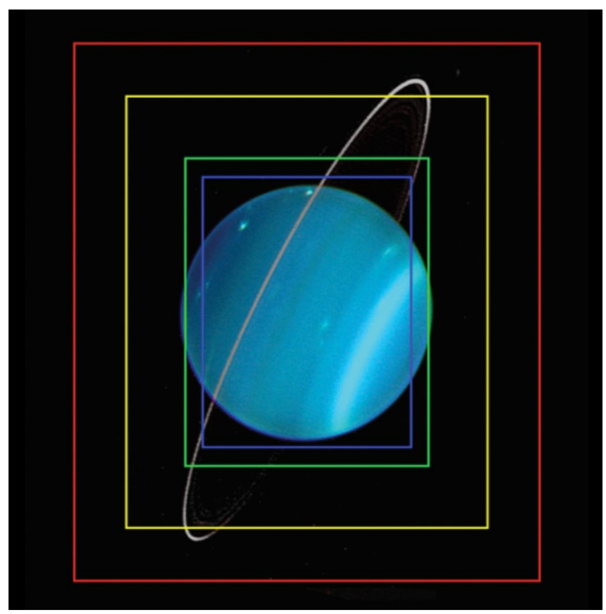




Spectra of Jupiter, Saturn, Uranus, and Neptune compared to saturation limits of MIRI filters (F560W not shown), assuming 64 x 64 sub-array imaging with minimum integration time. Jupiter/Saturn spectra are from Cassini/CIRS. Uranus/Neptune spectra are from Spitzer/IRS courtesy of G. Orton.

The mid-infrared is replete with emission features from photochemically produced hydrocarbons such as ethane and acetylene. JWST will enable mapping of this emission across the disks of Uranus and Neptune for the first time, providing insight into the thermodynamics, chemistry, and global circulation within these two atmospheres. Other stratospheric investigations on these planets include

- Detection of (or improving the upper limits for) new hydrocarbons on these planets. Ethylene and the CH_3 radical have been detected on Neptune, but not on Uranus. Benzene may be detectable on Neptune.
- Time-domain studies to clarify the observed temporal variation in stratospheric emission, and investigation of whether such changes are consequences of local weather, or tied to solar activity or the seasonal cycle.
- Mapping the distributions of oxygen-bearing species such as CO_2, CO, and H_2O to constrain the influx rates and sources of external oxygen. Such sources may include infalling ring particles, dust from satellites, Kuiper Belt objects, or cometary impacts.



The MIRI Medium-Resolution Spectrometer IFUs will efficiently produce spectral maps, even at the highest spectral resolution possible (R=3000). Here the fields of view of the four IFU bands (centered at 6.4, 9.2, 14.5, and 22.5 μm) are compared to the angular size of Uranus. Pseudo-color Uranus image (1.26, 1.62, and 2.1 μm) courtesy of L. Sromovsky.