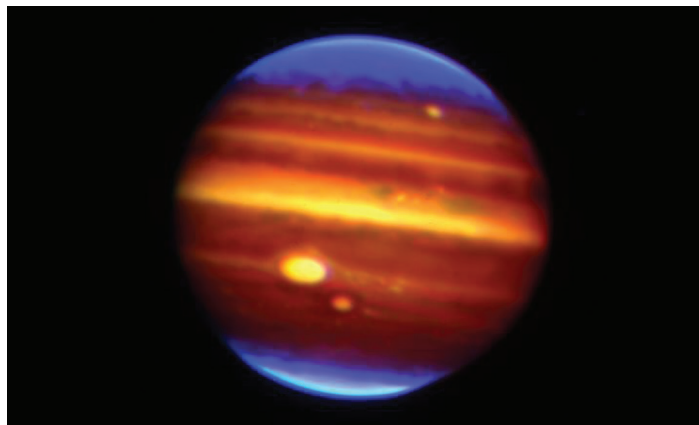




NASA's James Webb Space Telescope:

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.

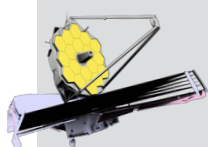


JWST will provide spatial resolution comparable to the largest ground-based telescopes, with ~600 resolution elements across the Jovian disk at 2 μ m (~300 at 5 μ m), and at wavelengths accessible only from space. The colors in the above near-infrared image of Jupiter correspond to Fe II at 1.644 μ m (red), Brackett γ at 2.17 μ m (green), and emission at 2.27 μ m (blue). (Courtesy of P. Irwin)

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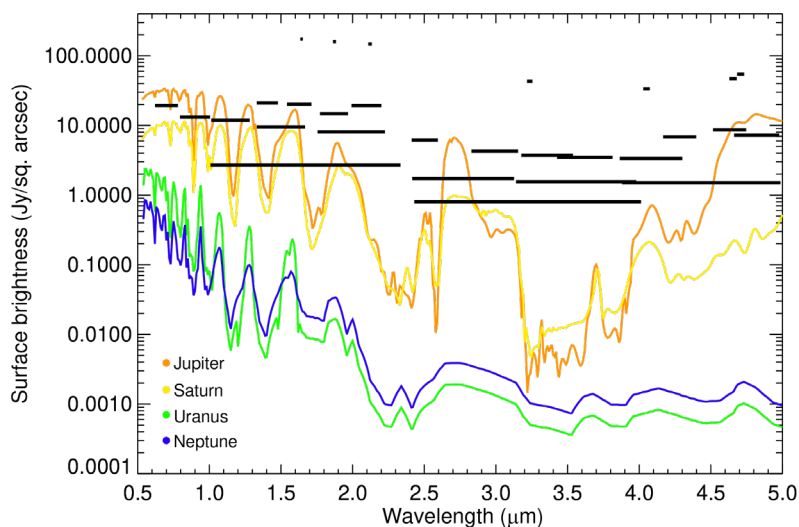
Reflected and thermally emitted light from the four giant planets is attenuated by methane to a degree that varies greatly across the near-IR spectrum. JWST observations can take advantage of this to probe to different depths in these atmospheres and engage in such investigations as the following:

- 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 resolving power modes of NIRSpec ($R=2700$) and MIRI ($2000 < R < 3700$), delivering very high signal-to-noise spectra in a short amount of time. The NIRSpec IFU and MIRI MRS have small fields of view and short readout times, but subarrays must be used for NIRCams and MIRI imaging modes. Use of small subarrays reduces the minimum exposure time and will enable observations of even these very bright objects over much of the JWST spectral range, as shown below.

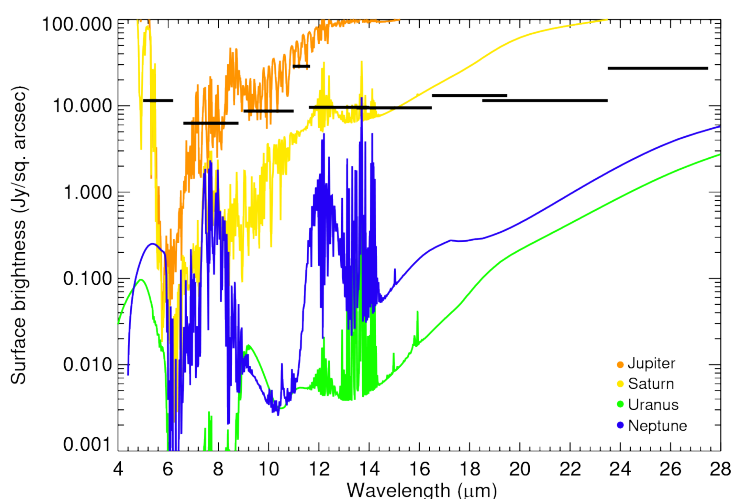
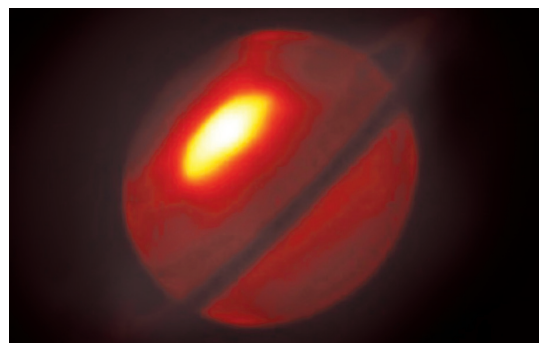
Spectra of Jupiter, Saturn, Uranus, and Neptune compared to the 1-group saturation limits of NIRCams filters, assuming 160 x 160 subarray imaging. The spectra are composited from Clark and McCord (1979), Karkoschka (1994), Encarnaz et al. (1997), Fink and Larson (1979), and Burgdorf (2008).





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

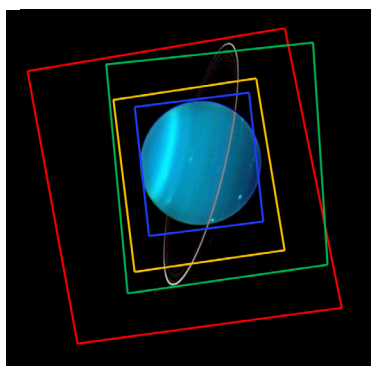
Events such as the large storm system that developed on Saturn in 2010 and the hot stratospheric "beacon" that developed after the storms dissipation (shown on the right), provide unique opportunities to deepen our understanding of processes in giant planet atmospheres. The VLT image on the right shows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



Spectra of Jupiter, Saturn, Uranus, and Neptune compared to the 1-group saturation limits of MIRI filters, assuming 64 x 64 subarray imaging. 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 photo-chemically 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 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 (MRS) will efficiently produce 2D spectral maps, even at the highest spectral resolving power possible ($R=3000$). Here, the fields of view of the four MRS channels (Channel 1 – blue; Channel 2 – yellow; Channel 3 – green; Channel 4 – red), showing their proper positions and orientations with respect to each other, are compared to the angular size of Uranus. (Infrared image of Uranus image courtesy of L. Sromovsky).



<https://arxiv.org/abs/1510.06205>

See more at jwst.stsci.edu and jwst-docs.stsci.edu

