NASA's James Webb Space Telescope:
Observing Rings and Small Satellites with JWST

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Planetary rings are of prime importance as accessible natural laboratories for disk processes, as clues to the origins and evolution of planetary systems, and as shapers as well as detectors of their planetary environments. The retinue of small moons accompanying all known ring systems are intimately connected as both sources and products, as well as shepherds and perturbers, of the rings. The James Webb Space Telescope (JWST) offers four major ways to investigate ring-moon systems with unprecedented sensitivity: **Discovering new rings and moons, time-domain science, probing ring structure with occultations, and probing ring composition with spectroscopy.**

Figure 1a of Showalter and Lissauer (2006, Science)

Figure 1b of Showalter and Lissauer (2006, Science)

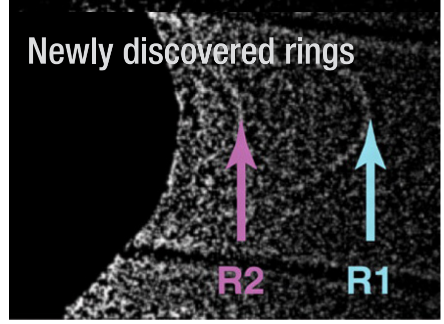
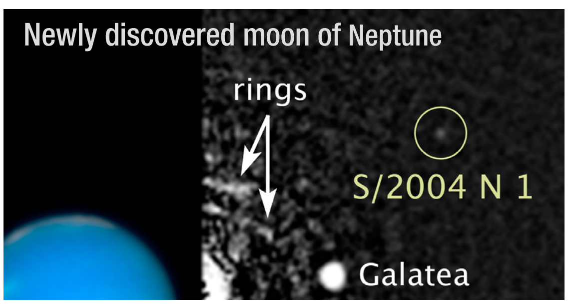


Figure 1c of Showalter and Lissauer (2006, Science)

Discovering New Rings and Moons

Small satellites and ring systems trace a system's past and provide clues to its future evolution. But in order to study these faint satellites and rings, the light from the nearby planet must be suppressed. The NIRCam instrument provides a suite of filters, some of which observe at wavelengths where atmospheric constituents, such as methane, are strongly absorbing. This increased contrast can help with the detection of small satellites close to their parent planet and faint, low-albedo rings and ring arcs. JWST is estimated to be ~2 magnitudes more sensitive than Hubble, leading to possible detections of satellites ~2 km in diameter around Neptune (Hubble discovered the smallest known Neptune satellite at ~20 km).



Cropped from a Hubble public release image.

JWST, and the NIRCam instrument in particular, will build on previous discoveries by Hubble. NIRCam's very sensitive imaging could yield discoveries of previously unknown rings and moons, similar to those made by Hubble around Neptune (Left) and Uranus (Right).

Time-Domain Science

JWST's expected mission lifetime of 5-10 years will enable a wealth of observations of long-term processes, transient phenomena, and targets of opportunity, including:

- Characterization of the chaotic orbits of satellites around Saturn, Uranus, and Pluto
- The constantly evolving ring arcs of Neptune
- Transient ring features such as the azimuthal arcs and clumps in Jupiter's rings and the ring "spokes" above Saturn's rings
- "Propeller" moons in the rings of Saturn

Saturn will be at equinox in 2025 (small ring opening angle) meaning JWST will well-placed to observe the ring "spokes" (Left) that have only been observed during equinox. (Right) Neptune's evolving ring arcs were observed by Hubble and will be easily observable with JWST.

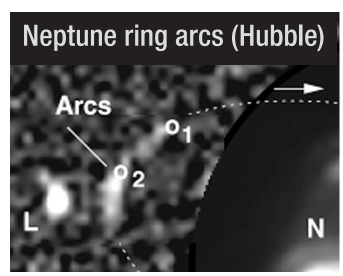


Figure 1 of Dumas et al. (1999, Nature)

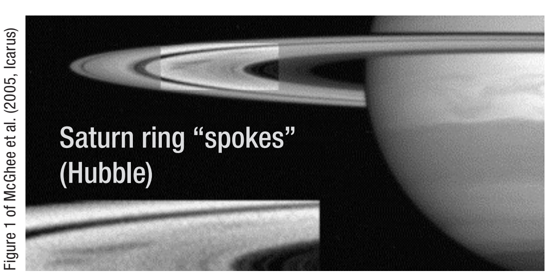


Figure 1 of McGhee et al. (2005, Icarus)

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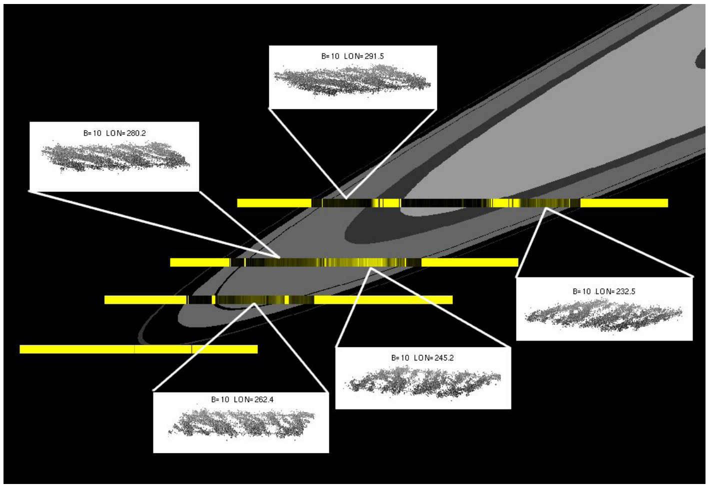
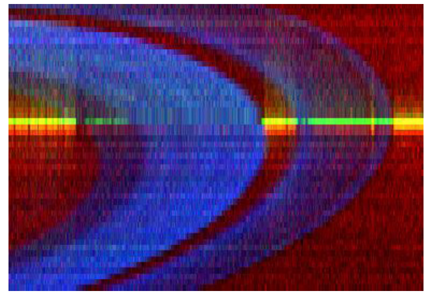
Probing Ring Structure with Occultations

Stellar occultations by rings can reveal the finer details of ring structure and can even be used to infer properties of planetary interiors by determining their precession rate around the planet. Ring systems are actually quite prevalent in the solar system: Every giant planet, the Centaur Chariklo, and the dwarf planet Haumea all have ring systems. Occultations are very powerful tools, but require a precisely known JWST orbit in order to predict events ahead of time. NIRCam time series observations will be best suited for these events with a cadence of ~20 Hz using the SUB64 subarray. NIRCam has the added bonus of imaging through two filters simultaneously, <2.3 microns and >2.4 microns.

Modified from Figure 1 of Hedman et al. (2007, AJ)



Cassini public release image



Left: Cassini observations of ring occultations revealed significant variations in ring properties as a function of azimuth, particularly in the B ring. *Above*: Cassini observation illustrating fluctuations in starlight as it passes through a ring. JWST can observe such events at a cadence of ~20 Hz with NIRCam.

Probing Ring Composition with Spectroscopy

JWST will provide clues about the origins of the satellite and ring systems of the giant planets and should help answer the question of why the Uranus and Neptune systems are so different from the Saturn system. The compositions of the small satellites and rings of the giant planets remain poorly constrained:

- Jupiter's rings are very faint and therefore difficult to study
- The Cassini VIMS instrument did not cover the 1.65 micron temperature-dependent water ice absorption feature
- Voyager 2 did not carry a spectrometer so was unable to obtain infrared spectra of the rings and small moons of Uranus and Neptune.

Using the Prism grating (R~100), the NIRSpec instrument can obtain an SNR of 10 per resolution element in 1000 seconds for a V=23.8 object.

https://arxiv.org/abs/1403.6849

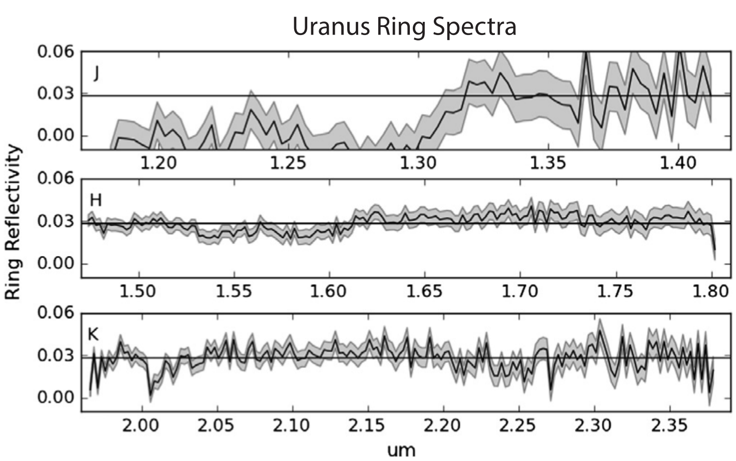
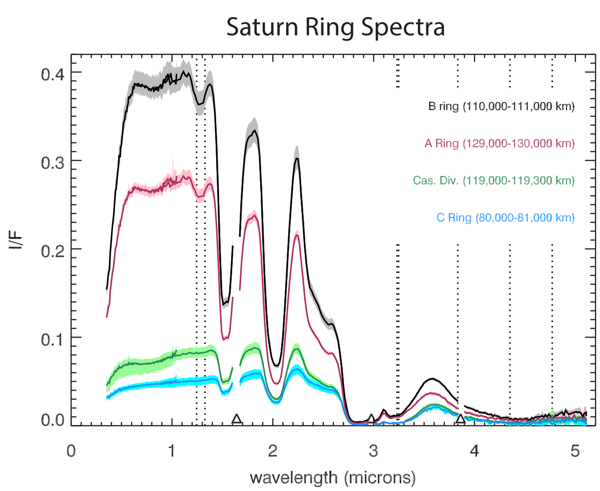


Figure 2 of de Kleer et al. (2013, Icarus 223, 105)



Modified from Figure 2 of Hedman et al. (2013, Icarus)

Ground-based spectra of Uranus' rings (Left) and Cassini VIMS spectra of Saturn's rings (Right) illustrate the diversity of ring compositions among the giant planets. The NIRSpec instrument can provide additional compositional constraints.

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