NASA's James Webb Space Telescope:
Observations of Stellar Occultations by Minor Bodies and Rings

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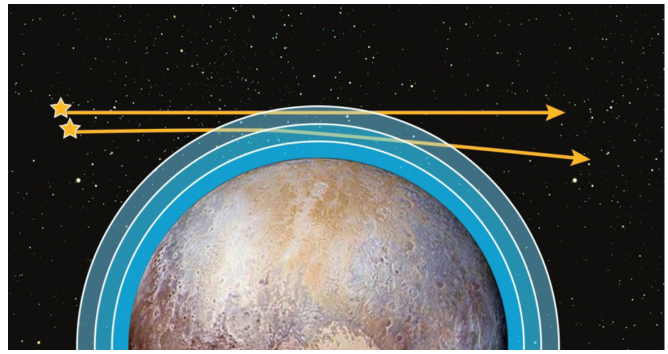
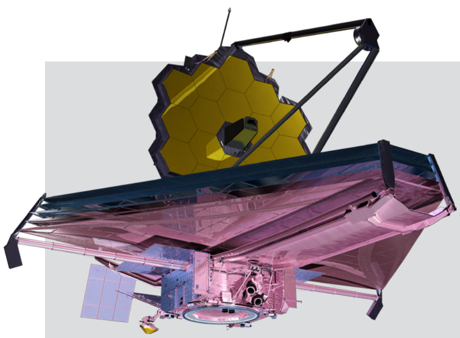
Stellar occultations are a powerful method for obtaining high-precision measurements of the shape, size, and geometric albedo of minor bodies. They can also be used to identify and characterize satellites, rings, and atmospheres. For the larger ring systems of the giant planets, stellar occultations enable characterization of the ring structure. Due to its position at the Earth-Sun L2 point, JWST will be able to observe stellar occultations not visible from Earth, enabling additional opportunities to characterize small bodies and ring systems. However, any events that are observed will be limited to a single chord.



Artist's depiction of a stellar occultation by Pluto's atmosphere. (NASA/JHUAPL/SwRI)



Target of opportunity (ToO) observations come in two flavors: disruptive and non-disruptive, the difference being whether the ToO is activated 14 days prior to the execution date. Disruptive ToOs activated less than 3 days prior to program execution will incur a 30-minute overhead. Only a few disruptive ToO programs will be accepted in each cycle due to the effect on JWST scheduling. Knowledge of the JWST observatory ephemeris is expected to be accurate to ~100 km 30 days out, so occultation ToO observations can in principle be activated more than 14 days before the event, thus avoiding the overhead penalty.

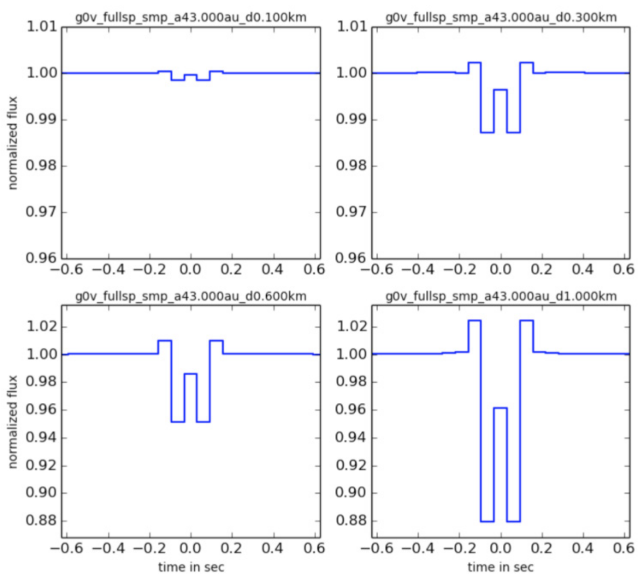
NIRCam Time Series Imaging. The NIRCam instrument in time-series imaging mode provides diffraction-limited imaging for stellar occultations using a 64 x 64 pixel subarray (2" and 4" on a side in the short- and long-wavelength channels, respectively) and a frame time of 50 msec. NIRCam also provides a wide range of filters from 0.7-5 µm that allow, for example, selection of the optimal filter to minimize reflected light from the object. Guaranteed Time Observations (GTO) program 1271 presents an example of NIRCam time series observations of a stellar occultation by a TNO.

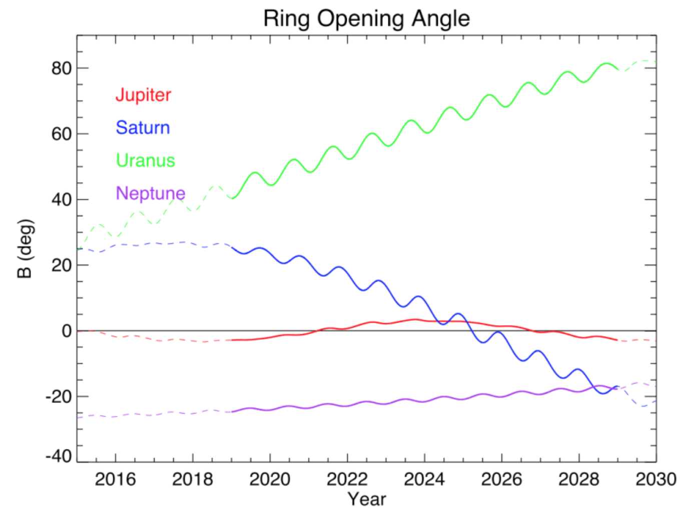
Serendipitous occultations. Serendipitous occultations of very small minor bodies could be observed using the Fine Guidance Sensor (FGS). The FGS is used for guiding and will obtain images in an 8 x 8 pixel subarray with a frame time of 64 msec. These images are expected to be downlinked, and so can be analyzed to detect occultations. FGS uses an un-filtered detector sensitive across the entire near-infrared range (0.6 – 5 µm).

The table below presents relevant information for targets that can be studied via stellar occultations, where Δ is the mean distance from the body to JWST and the parallax uncertainty is due to the expected orbital uncertainty of JWST over the course of one month (~100 km).

Body	Δ (AU)	Ang. Size	Target diameter (1000 km)	Parallax uncert. (mas)
Jupiter	4.2	45.9"	139.8	32.8
Saturn	8.5	18.9"	116.5	16.2
Uranus	18.2	3.8"	50.7	7.6
Neptune	29.0	2.3"	49.2	4.8
Pluto	38.4	82.8 mas	2.31	3.6
TNO	39.0	14.1 mas	~0.4	3.5
Centaur	16.6	8.3 mas	~0.1	8.3

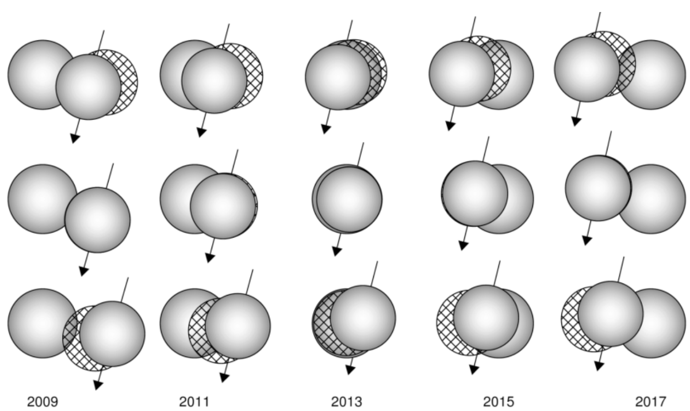
Santos-Sanz et al., 2016





Santos-Sanz et al., 2016

Occultations by rings. Observations of stellar occultations by rings can reveal very fine structures not easily observed in direct imaging and extend time baselines of time-variable structures. Among the giant planets, stellar occultations by Saturn's rings will be common during JWST's primary mission, one per year can be expected for Uranus (with a stellar K magnitude between 12 and 15), while occultations by Neptune's rings will be rare. Jupiter's rings are nearly edge-on as viewed from JWST, so occultation observations of them will be less useful than for the other outer planets. Any NIRCam filter longward of the F300M filter is ideal for increasing the contrast between the background star and Saturn's water ice-dominated rings. Observations of occultations by rings of minor bodies, such as Chariklo and Haumea, will be more challenging due to their small angular size and the difficulty of predicting the occultation track relative to the JWST orbit.



Grundy et al., 2012

Figure 1 (above left): Predicted performance. Simulated serendipitous occultation light curves using FGS for TNOs at 43 AU and diameters of 100 m (upper left), 300 m (upper right), 600 m (lower left), and 1 km (lower right). Noise not included. **Figure 2 (above right): Giant planet ring opening angles.** Solid curves cover the period from 2019-2029 for each of the giant planets. The shorter-term variability is due to the motion of the Earth. **Figure 3 (left): Mutual events.** Example of the progression of mutual events as a function of time for the TNO Sila-Nunam. The top, middle, and bottom rows show the geometry of the system at western quadrature, opposition, and eastern quadrature, respectively. North is up and East is to the left.

Mutual events. Mutual eclipses and occultations in minor body binary systems can provide information about the components' sizes, colors, shapes, and even albedo patterns. These events require a specific geometric alignment such that one component, or its shadow, passes directly in front of the other component. A binary system made of components that are large relative to the distance between them will result in longer mutual event seasons. Non-sidereal tracking is required for observing mutual events because the binary system must be tracked instead of observing a stationary star when a moving object occults it. JWST will be capable of effectively tracking binary systems found beyond the orbit of Mars.

Link to arXiv manuscript