NASA's James Webb Space Telescope:
Observations of Trans-Neptunian Objects

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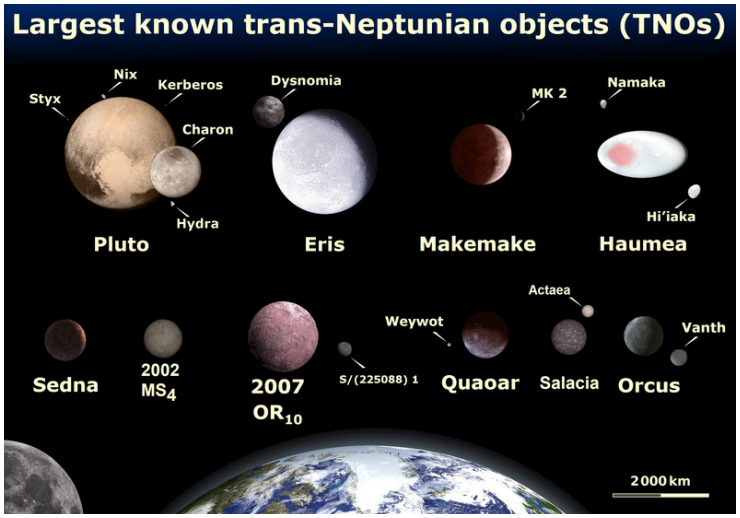
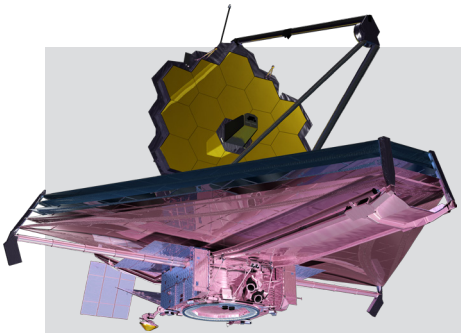


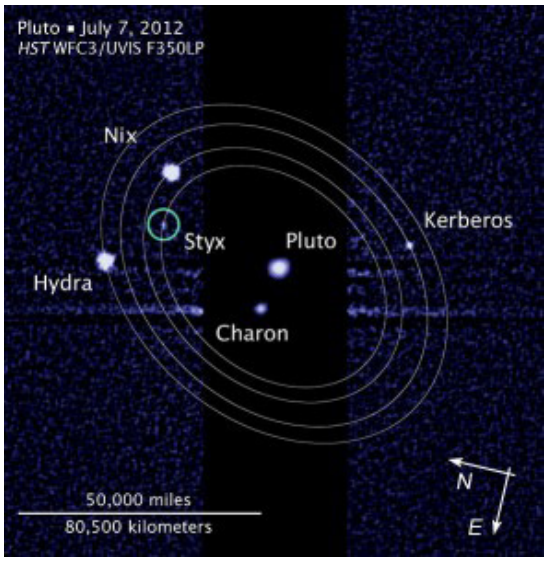
Studies of Trans-Neptunian Objects (TNOs), small icy worlds with semi-major axes >30 AU, provide valuable information on the chemical and dynamical evolution of the solar system. TNOs are incredibly diverse in terms of size, color, albedo, surface composition, binarity, and orbit, but many previous studies were limited by the faintness of these targets, caused primarily by their very large heliocentric distances.

Spectral observations of even intermediate-sized TNOs (diameters of ~500 km) are nearly impossible with ground-based facilities. Near-infrared spectral observations, critical for characterizing surface compositions, will for the first time be enabled by JWST and the NIRSpec instrument over the full near-infrared range (1-5 μm). Spectral observations across different dynamical classes will probe the chemical composition of the primordial Kuiper Belt as a function of heliocentric distance and provide the first information on the surface compositions of small TNOs. Images taken with the NIRCam instrument (1-5 μm) will enable color measurements for TNOs too small to observe with NIRSpec and has sufficient spatial resolution for resolving binary TNOs in tight orbits. Imaging observations in the mid-infrared (5-28.5 μm) with the MIRI instrument will enable observations of TNOs at the shortest wavelengths of the thermal regime.



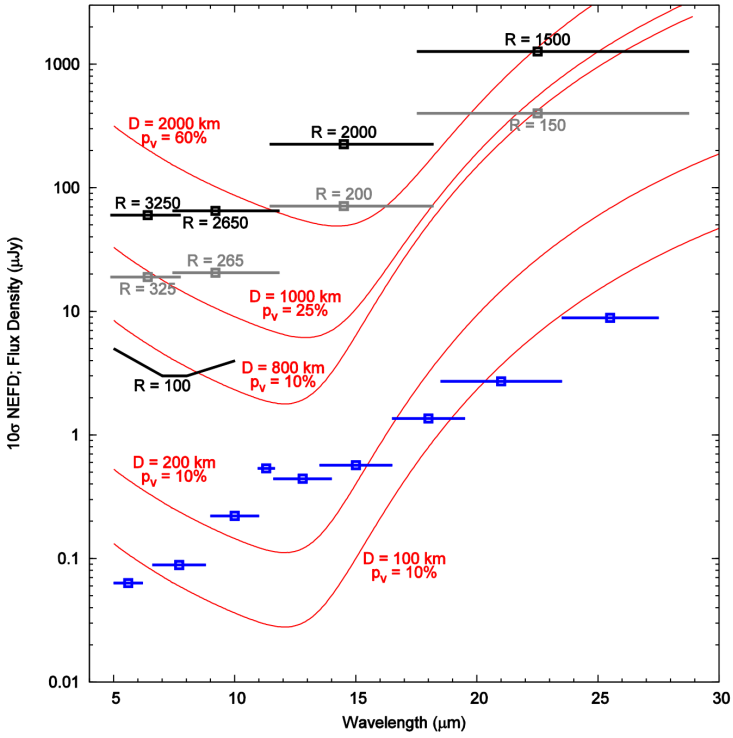
There are five Guaranteed Time Observation (GTO) programs covering imaging and spectroscopy of TNOs. Their program IDs are 1191, 1231, 1254, 1272, and 1273. They make use of the MIRI LRS, MIRI MRS, MIRI imaging, and NIRSpec IFU observing modes. More information about the individual programs can be found in the documentation (jwst-docs.stsci.edu) on the page titled "JWST GTO Observation Specifications." APT files for these programs can be obtained by opening APT, selecting File->Retrieve from STScI->Retrieve using Proposal ID, and entering the proposal ID number.

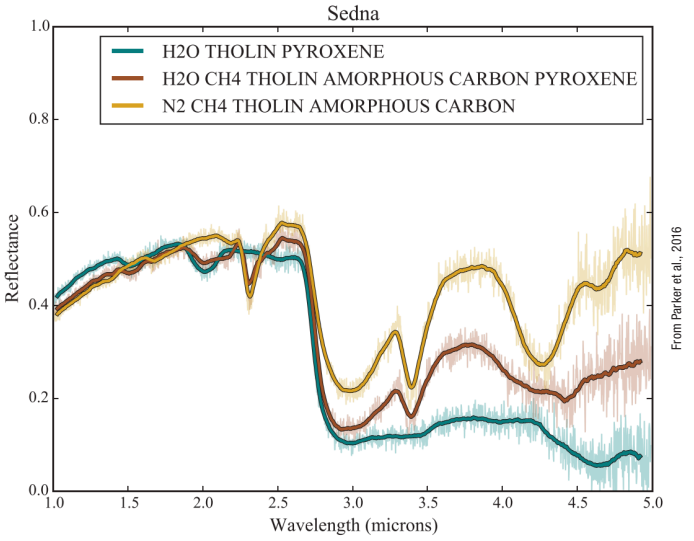
Binary discovery and characterization. The NIRCam instrument will provide a comparable PSF FWHM (0.066" at 2 μm) as HST does in the UV and visible with WFC3/UVIS, and significantly sharper images at its shortest filter (0.03" at 0.7 μm). NIRCam will provide near-IR color measurements of binary components, enabling tests of theories of binary formation through comparison of the colors of the individual components. NIRCam also observes the same field of view in two different wavelength ranges simultaneously, <2.35 μm and >2.4 μm. Users select one filter in each wavelength range. Unfortunately, the MIRI PSF is too large except at the shortest wavelengths (0.22" at 5.6 μm) to separate all but the widest of known binaries. At the longest mid-infrared wavelengths, even Pluto and Charon will not be well resolved.



Possible near-IR studies of TNOs. The following near-infrared observations would vastly expand our understanding of the compositions of TNOs.

- NIRSpec observations from 3-5 μm may uncover currently undetected ices on dwarf planets and large TNOs, including N2 on Eris, Sedna and Makemake, and CH4, NH3, ethane and other hydrocarbons on objects like Quaoar and Varuna.
- Complex irradiation products (tholins) and silicates are used extensively in modeling TNO reflectance spectra but have never been directly detected. NIRSpec can help break the degeneracy between organic- and silicate-dominated surfaces, and between organics-rich or depleted in nitrogen.
- NIRSpec observations could well confirm the presence of methanol on the surfaces of TNOs. This ice has previously been used to explain the red coloration of some TNOs, but the 2.27 μm absorption feature has yet to be confirmed in ground-based spectra except for a few of the brightest Centaurs.
- NIRCam photometry of faint objects can help distinguish between silicate-, organic-, and water-dominated surfaces among TNOs too small to observe spectroscopically. All TNOs with diameters >100 km are potential targets. By using NIRSpec observations of brighter targets, it should be possible to make excellent use of NIRCam colors to confidently extrapolate compositions to smaller TNOs.





Possible mid-IR studies of TNOs. At a typical TNO surface temperature of ~50 K, the peak thermal emission is at ~100 μm, well beyond the long-wavelength cutoff of MIRI (28.5 μm). However, the thermal slope at the MIRI wavelengths is very sensitive to surface temperature. Measurements using the MIRI 18, 21, and 25.5 μm filters can give very precise (<1 K) temperature measurements, helping to break the degeneracy between albedo and the beaming parameter in thermophysical models. Some large TNOs, such as Eris and Makemake, have anomalous thermal emission at the short wavelengths; follow-up with MIRI could help explain these mysterious emissions. By combining MIRI and ALMA measurements (the latter on the red side of the thermal peak) very precise size and albedo measurements could be made for TNOs not already characterized using Herschel or Spitzer.

Figure 1 (above): TNOs with NIRSpec. Simulated, 10,000-second, medium-resolution NIRSpec spectra of Sedna (D~995 km, r~85 AU) with three different hypothetical surface compositions. **Figure 2 (left): TNOs with MIRI.** Sensitivity of MIRI LRS (R=100), MIRI MRS (black/grey), and MIRI imaging (blue). Flux density of hypothetical TNOs with the listed properties are shown in red.

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

Link to arXiv manuscript