**1. Science aim/goal** (provide a high-level statement in 140 characters or less):
A FIR-Survey of TNOs and Related Outer Solar System Small Bodies

**(i) Scientific Importance:**

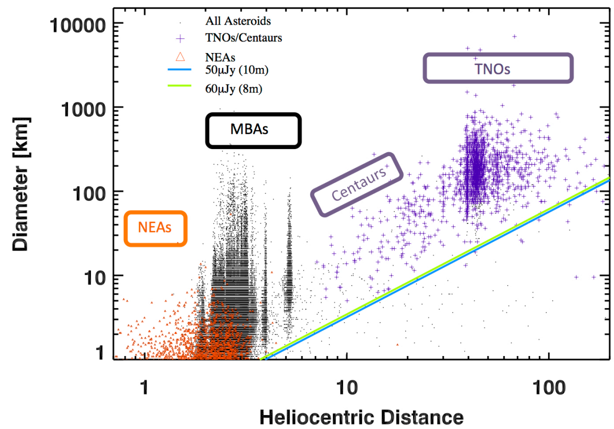
The small solar-system bodies that reside between 30 and 50 AU are referred to as the Trans Neptunian Objects, or TNOs. They comprise, in fact, the majority of small bodies within the solar system and are themselves a collection of dynamically variegated subpopulations, including Centaurs and Scattered-Disk Objects (SDOs), as well as "cold" (low-inclination and eccentricity) and "hot" (high eccentricity) classical Kuiper Belt populations (KBOs; Gladman et al. 2008). These minor planets are the reservoir of the comets that routinely visit our inner solar system, the short period comets, and so cloud the distinction between asteroids and comets. They are primordial material, unmodified by the evolution of the solar system after their emplacement and are the sources of volatile materials to the inner solar system. TNO and outer solar system small body size distributions, down to scales of 10s of km or ~ a few km (Dones et al. 2015, and ref. therein) provide tests of the formation scales of planetesimals and evolutionary models of the early Solar system. The ability to derive large quantities of size measurements is a unique value of such FIR surveys. Small bodies typically can vary in their surface reflectivity by factors of 5 or more, while surveys that detect emitted light provide reliable sizes from the flux (cf. Mainzer et al. 2011). This is important because the previous optical surveys have provided alternate size frequency distributions, based on inferences of reflectivity, indicative of competing evolution histories for these bodies (cf. Dones et al. 2015) especially at the smaller end (TNO diameters <100 km) of the size scales. Objects at TNO distances will be best detected at wavelengths near 110 μm. Shorter (~70 μm), and longer (~200 μm), wavelengths will better constrain the sizes and temperatures of the objects observed. Presently, most surveys have placed order-of-magnitude constraints on larger TNOs, with solar-system absolute magnitudes (H)<9 and sizes >100 km. Focused studies of particular objects of interest would also be possible. Study of TNOs, and interlopers into near-TNO distances from even further populations in the Oort cloud, can thus inform us about the early history of the solar system, and how its composition has evolved over the time since it was formed, but while removed from the effects of strong insolation and while the bulk of their volatiles are intact. The thermal radiation of objects from 30 to 100 AU from the Sun, with temperatures ~30-50K, provide sufficient flux at ~100 μm to probe the most interesting size scales of the outer solar system populations.

**(ii) Measurements Required:**

The main requirement is to image a large area of the sky multiple times and capture large numbers of TNOs and related outer solar system objects. A single band near 125 μm and with sensitivities ~50 μJy would reach large numbers (many thousands) and small (~20 km; Figure 1) sizes. Other bands, ~70 μm and 250 μm, with comparable sensitivities, would provide better temperature, and therefore size, constraints. The survey will have to cover the area several times so motion, ~2 arcseconds per hour (mostly parallax from the Earth's motion), can be detected and confirmed. With coverage of 4 integrations over the course of hours to days, an orbital distance can be constrained, and a repeated observation, a few months later, can establish an orbit for each object. The multiple coverage required to quantify sky motion also mitigates confusion noise.

**(iii) Uniqueness to 10µm to few mm wavelength facility:**
Only a FIR imaging survey can reach the sensitivity and the speed that may be able to meet the cadence requirements. A 10m OST can reach a 5 sigma sensitivity of ~50 µJy in ~14s of integration, and 4 repeated observations over the course of several days could allow for the coverage of 8000 square degrees of sky in ~1300 hours for a 20×20 arcmin FOV. For a quarter square degree FOV with a 10m telescope, a similar survey interval would cover roughly 20% of the sky down to sizes of ~20km (FIR imager case).

**(iv) Longevity/Durability:** (with respect to expected 2025-2030 facilities)
For bodies with ~10% albedo and 20 km in diameter at 40 AU, the visual brightness is ~27.6 $m_V$, not detectable by LSST (< 25 $m_V$) or other surveys. LSST therefore cannot compete in the characterization of outer solar system small bodies, and owing to the uncertainty in their reflectance, cannot determine their sizes with similar confidence as a thermal survey.




**3. Figure:** Sensitivity limits of small bodies as observed by a 100µm imaging survey with an 8 -10m telescope are ~60 (green line) to 50 µJy (blue line) respectively. Purple crosses represent objects from the Minor Planet Center database (3/18/17), with sizes assuming 10% albedo in thermal equilibrium with insolation, and are plotted at their semi-major axis values.

**4. Table:**

| Parameter | Unit | Required value | Desired Value | Comments |
|---|---|---|---|---|
| Wavelength/band | µm | 100 | 70, 100, 200 | Extra bands yield temp. |
| Number of targets | | >1000 | | Based on ~10% uncertainty per 10 km size bin |
| Survey area | deg.$^2$ | >1000 | 20,000 | |
| Angular resolution | arcsec | 3 | 2 | |
| Spectral resolution | $\Delta\lambda/\lambda$ | 0.3 | 0.3 | |
| Continuum Sensitivity | µJy | 50 | 10 | |
| Spectral line sensitivity | W m$^{-2}$ | NA | NA | |
| Dynamic range | | | | |
| Cadence | | 4 in 8h to 7d | 2+ epochs | |
| Any other requirement | FOV | 20×20 arcmin | ~0.25 to 1.0 sqr degrees | |

**5. Key references:** Dones et al. 2015. Space Sci Rev (2015) 197, 191.; Gladman et al. 2008, in The Solar System Beyond Neptune (Tucson, AZ: Univ. Arizona Press), 43.; Mainzer et al. 2011. NEOWISE Observations of Near-Earth Objects: Preliminary Results. ApJ. 743, 156.