Mapping the deep: The past and future promise of transneptunian surveys

M. Bannister[1,2]

[1]University of Victoria, 3800 Finnerty Rd, Victoria, BC V8P 5C2, Canada
[2]NRC-Herzberg, 5071 West Saanich Rd, Victoria, BC V9E 2E7, Canada

Exploring the populations and structure of the outer Solar System requires us to examine the sky. The improving sophistication of astronomical techniques have brought us in the last century from painstaking naked-eye examination of photographic plates to identify moving sources, to supercomputer-powered image subtraction that can pull moving sources from the depths of the Galactic plane. Such advances in our ability to discover new objects have allowed us to build an understanding of the Solar System's distant populations.

The continued effort to survey the sky for new discoveries has explored the phase space of much of the transneptunian (TNO) size distribution. At the largest end, from wide-field surveys with small-to-medium optical telescopes in both North and Southern Hemispheres, the dwarf planets are now complete to $m \sim 19.5$ (Schwamb et al. 2014) and nearing completion to $m \sim 21.5$. Infrared surveys such as WISE have constrained the absence of a brown dwarf or large gas giant planet such that there can be no Saturn out to 28,000 au and no Jupiter out to 82,000 au (Luhman 2014). Similarly, pulsar timing measurements exclude line-of-sight shifts of the Solar System's barycentre due to any lurking giant planet (Verbiest et al. 2008); such timing measurements will only be improved by the Square Kilometre Array's all-sky decadal measurements of pulsars (Seto & Cooray 2007). The smaller, more abundant TNOs have been slowly constrained by surveys on larger facilities (as listed in Kavelaars et al and Petit et al. 2008): their part of the size distribution has a clear change in slope near H of 7 (Fraser et al. 2014). Characterisation of objects for their size, albedo, thermal properties and density has followed more slowly: Spitzer and Herschel have given us thermal properties; broad-band photometric surveys have shown that the colours of TNOs present distinct surface classes, ranging from the reddest in the Solar System to fully neutral reflectors; while large-aperture and space-based optical examination of the abundant binaries in the trans-Neptunian populations have offered insight into the formation processes of planetesimals. We are left today with a remnant of the primordial planetesimal disk that somehow escaped intact, and a dynamically-excited population, many of which are captured into a filigree of mean-motion resonances with Neptune.

Trying to model the history of the Solar System to reach the present-day state, with its fine nuances of dynamical structure and uneven population ratios, requires accurate knowledge of the present-day populations. Every survey of the sky points at a particular region of orbital phase space; every aperture chosen as a survey tool specifies which part of the TNO size distribution will be measured. Such biases are straightforward to characterise, but they must be considered. There remains a persistent reliance on use of the Minor Planet Center's catalogue of TNOs as a representative sample of the underlying population. The unconsidered use of such a catalogue that interweaves many surveys' biases can lead to incorrect validation of models of the Solar System's history. Using only the TNO population distribution derived from fully characterised surveys is critical for models trying to reproduce the current outer Solar System.

The hallmark of TNO surveys for decades now has been the discovery of entirely new populations. Will future surveys continue to reveal such surprises? What remains to explore? Fortunately, the need for abundant new discoveries, both further down the size distribution and in particular populations, including the remaining distant system, has been well recognised by the community. Occultation surveys offer the promise of exquisite constraints on the size distribution, particularly of smaller objects. In the infrared, the WISE mission continues in the form of NEOWISE, which may offer limits on objects large and warm enough to be visible at short λ. Optical surveys continue at $m \sim 21$ to ensure sky coverage is complete (Pan-STARRS). Significant new wide-field cameras on 4+ metre optical telescopes have recently come online, as well as time becoming more accessible to conduct large surveys as existing facilities mature: DECam on CTIO, Suprime/HyperSuprimeCam on Subaru, MegaPrime on CFHT and the Magellan 6.5 m. Efforts with these facilities include work to describe the Centaur size distribution (Schlichting et al.), add new Sednas to describe the inner Oort cloud (Trujillo and Sheppard 2014), and obtain precision estimates of the resonant populations in the Kuiper belt (Outer Solar System Origins Survey). These surveys are now ramping up, so a swathe of new discoveries can be anticipated in the coming year. The far future holds the promise from LSST to reach $m_r \sim 26$ on the whole southern sky.