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A search for dwarf planets in the southern hemisphere sky

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Abstract

The population of icy objects in the distant outer regions of the Solar System beyond Neptune offer insight into the early history and evolution of the Solar System. Extensive surveys of this population have previously focussed on the Northern Hemisphere sky. We present our analysis of 9,500 square degrees of sky south of the ecliptic that have more than thirty nights of observation over five years, with an approximate limiting flux of $m(clear) \sim 19.5$. This is the largest spatial coverage of any existing southern survey for trans-Neptunian objects (TNOs). We generated this survey through an innovative analysis of the more than 500,000 images of the Siding Spring Survey, an ongoing survey for near-Earth asteroids that has been operating at the 0.5 m Uppsala telescope at Siding Spring Observatory since 2004. We discuss the limits that our results place on the dwarf planet-sized end of the TNO population distribution.

1. Introduction

The trans-Neptunian objects have been extensively surveyed in the Northern Hemisphere sky, with the detection of four dwarf planets and several other large objects. However, only minimal surveying has yet been made of the Southern Hemisphere: none of the few detections made by Moody et al [1] have subsequently been successfully re-observed for recovery and determination of their orbits, and they are considered lost. As most known large TNOs have substantial orbital inclinations of tens of degrees, a survey of the entire southern sky, far from the ecliptic, is at a possible advantage for detecting new large bright TNOs. These factors make the characterization of the bright Southern Hemisphere TNO population a high priority.

2. The Siding Spring Survey

The ANU Research School of Astronomy and Astrophysics (RSAA) has been involved for some fifteen years with the University of Arizona's NASA-funded Catalina Sky Survey South, which searches for near-Earth asteroids using the RSAA's 0.5 m Uppsala telescope at Siding Spring Observatory in northern New South Wales. This data set, the Siding Spring Survey, runs from 2004 to the present, with a cadence of 3-5 images on each 4 square degree field over ~45 minutes. This coverage repeats anywhere from the next night to several weeks to months later. Most fields have approximately six to ten observations in each field's "season": the eight months centred on the time of the year that the field is at opposition (they are predominantly observed close to quadrature, as necessary for an NEO survey). This temporal coverage was sufficiently dense to make it possible to re-analyse the data set for TNOs. This kind of analysis of an extended-length dataset, observed in a cadence quite different from a normal TNO survey, has not previously been tried for TNO detection.

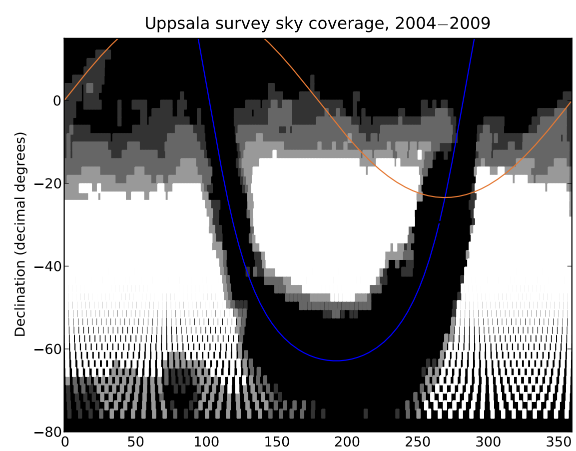

Figure 1: The sky coverage of the Siding Spring Survey, 2004-2009. White squares have 30+ nights of observation; the three shades of increasingly dark grey indicate 20-30, 10-20, and 5-10 nights of observation. Pluto is currently in the zone of galactic avoidance.

The sky coverage of this survey is comprehensive: 9,500 square degrees have more than thirty nights of observation in the period 2004-2009 (Fig. 1). Each of the 2,257 fields in this sample of the dataset has between 30 and 90 nights of observation.

The dense temporal coverage of this dataset will give detected objects orbits with extremely small errors, so initial dynamical characterisations will be possible without lengthy followup observation.

3. TNO detection analysis

A list of point sources is extracted from each image, the points corresponding to moving objects are identified, and all plausible orbits between sets of three points (the minimum required to determine an orbit) are calculated. To determine if a given source was transient, the source lists from the four images of a field on a night were compared and combined, due to the slow object motion rate and the seeing-matched plate scale of 1.2 arcsec/pixel. This introduced cutoff in heliocentric distance is intentionally close to the motion detection limit of the standard Catalina pipeline: a 15 arcsec/hr fast-moving Centaur. Plausible-orbit prefiltering was necessary to reduce the sheer quantity of potential orbits from considering sets of three of these sources. This prefilter kept bound orbits with suitable orbital parameters and quality of fit: heliocentric distance > 15 AU, a > 0, e < 1, $\chi^2 < 500$. The filtered triplet orbits were then fully fit using the `orbfit` package [2] and selected under the same criteria. This still left too large a number of potential candidates to blink visually. The dense temporal coverage meant that any object appearing on a given field would reappear within the survey's five years in many more than one triplet. We subsequently linked all permutations of two triplets into arcs and refit the arcs, to see if any arcs remained. Visual blinking could then be used to assess the validity of the arc. Cross-field followup and on-sky followup would provide final confirmation of an object.

4. Conclusion

This survey can provide the number of large bright objects in the southern sky, which can be better considered as the sky density of large TNOs, and the derivative from that, a measurement on the upper end of the luminosity function of TNOs. This constraint provides a check on existing models of TNO size distribution.

The magnitude limit of this survey is spatially varying: the individual image integration time varies between 20 seconds and 1 minute, and is increased by the observer in non-photometric conditions.

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References

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