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Deep Ecliptic Exploration Project (DEEP) Observing Strategy

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Abstract

We present the Deep Ecliptic Exploration Project (DEEP) survey strategy including observing cadence for orbit determination, exposure times, field pointings and filter choices. The overall goal of the survey is to discover and characterize the orbits of several thousand Trans-Neptunian Objects (TNOs) using the Dark Energy Camera (DECam) on the Cerro Tololo Inter-American Observatory Blanco 4 meter telescope. We will conduct a series of exposures of a single 3 square degree DECam field-of-view over half of an observing night to achieve very deep sensitivity, about magnitude 27 using a wide VR filter which encompasses both the V and R bandpasses. Additional fields will be observed in subsequent nights to increase sky area to about 35 square degrees in the first year. In subsequent years, the fields will be re-visited to allow TNOs to be tracked for orbit determination. When complete, DEEP will be the largest survey of the outer solar system ever undertaken in terms of object numbers and will also be among the deepest.

1. Guiding Principles of the Survey

To constrain our overall survey design, we created principles derived from our science goals. The main science goals are discussed in more detail by Trilling et al. [1], but in summary are: (1) to measure the size distribution of the TNOs down to 50 km, (2) measure the colors of thousands of TNOs, (3) derive the shape distribution of TNOs from partial lightcurves, and (4) measure colors, size distribution, and shapes as a function of dynamical class and size. Additional secondary science goals are related to other populations such as the main belt asteroids, Centaurs and Trojan asteroids.

The guiding principles derived from these science goals follow. (1) Survey depth is more important than measuring color. That is because the survey's main goal is to probe small sizes and discover large numbers of objects. (2) Uniform depth per observing run per field is the most important feature of the survey. This will allow the ability to track objects consistently throughout the survey. (3) Colors will only be done after uniform depth is reached in the VR filter. This is because of the prior two principles and also because if the object's orbit is well-known, colors can be obtained in later epochs if need be. (4) We want to observe each object twice in the first year, once near opposition and once a month from opposition. Each object will then be observed in years 2 and 3 as well. The inclusion of the off-opposition observation allows for a better orbit solution with a factor 10 lower astrometric error after the survey is completed (Figure 1). (5) To track objects over the 3 years of the survey, we must expand our sky coverage as objects with different orbits disperse from their initial discovery locations (Figure 2). (6) Objects in the outer solar system are the primary goal, but science cases involving asteroids will also be probed.

2. Observing Strategy

Following the guiding principles, our observing strategy is summarized here. (1) Exposure times for individual images are 120 seconds, short enough to allow depth for asteroids by mitigating trailing loss (Jewitt, Luu and Chen [3]) but not creating undue readout overhead. (2) We chose to measure colors using VR - i. The choice of VR over r was made because of bandpass. The choice of i over g was made due to the redness of the TNOs, which favors i band depth.

Although unconventional, the VR - i color measurement should take about half the exposure time compared to a more traditional r - i measurement. (3) The actual field locations were chosen to lie along the invariable plane as defined by Souami and Souchay [4] and designed such that equal amounts of time could be spent on each field during the on-opposition and off-opposition observations.

3. Figures

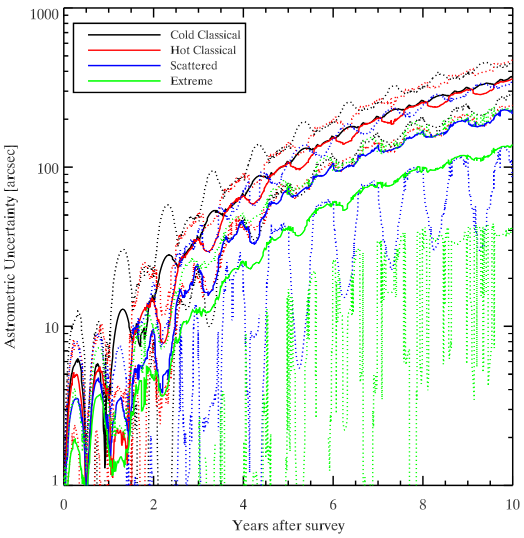

Figure 1: Astrometric uncertainty after our survey is completed for different classes of TNOs. Gaussian noise of 0.6 arcseconds was applied to objects detected in our sky coverage simulation. Orbits were then fit using the technique of Bernstein and Khushalani [2]. Solid lines mark the median orbit uncertainty while dashed lines bound the 90% confidence region for each orbit type.

References

[1] Trilling, D., et al., #319, EPSC-DPS 2019, 15–20 September 2019, Geneva, Switzerland, 2019.

[2] Bernstein, G. and Khushalani, B., AJ, 120, pp. 3323–3332, 2000.

[3] Jewitt, D., Luu, J. and Chen, J., AJ, 112, pp. 1225–1238, 1996.

[4] Souami, D. and Souchay, J., A&A, 543, A133, 2012.

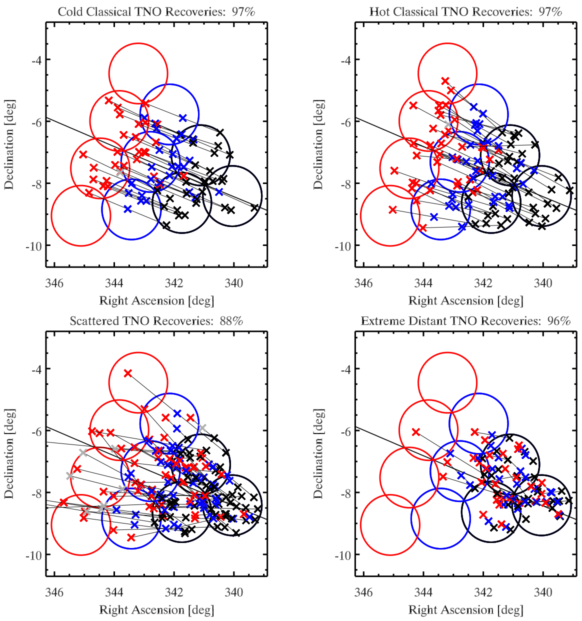

Figure 2: A visualization of our recovery efficiency is shown. Circles approximate the DECam field positions. Black fields will be imaged in Years 1–3, blue in Years 2–3 and red Year 3. Four populations of TNOs are modeled with simulated discovered objects shown as crosses with color coding for the year they are imaged (again, black, blue and red for Years 1, 2, and 3, respectively). Grey crosses represent objects that are not imaged in a given year and grey lines connect object positions across epochs. Recovery efficiency is nearly 90% or more for all classes of objects. The numbers of plotted objects are to depict orbital motion, in reality many thousands of objects were simulated and will be discovered.