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The sky distribution of TNOs as seen by HST

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Abstract

We present the results of the deepest all sky survey for Solar System objects. By focusing on archival data taken with HST/ACS our survey has led to the discovery of 43 Trans-neptunian objects (TNOs) and 1 centaur between 0° and 20° from the ecliptic.

Every pointing in this survey has been calibrated for detection efficiency, allowing us to accurately constrain the number of objects in the outer Solar System.

We finish by emphasizing new opportunities enabled by this approach to other existing telescopic spacecraft data from HST, Spitzer and STEREO.

1. Introduction

TNOs are what is left of the same planetesimals from which the planets in the Solar System formed. By studying their statistical properties we are offered a unique opportunity for testing theories of the growth and collisional history of planetesimals and the dynamical evolution of the giant planets [6, 8]. The study of the orbital distribution of TNOs has shown the existence of multiple distinct dynamical populations [7, 2] with different colors [3] and size distributions [1].

Larger objects in the TNO population have been discovered in bright ecliptic surveys. The bulk of our understanding of the trans-neptunian space is based on studies of these objects. However, small (∼50 km) TNOs contain significant clues about the formation of the Solar System. The size distribution of objects at this size, and in particular the size at which the size distribution undergoes a change in slope, records the collisional history and intrinsic strength of the TNO population [9].

Given the importance of studying smaller TNOs (R>25 and even R>27) we use the unique opportunity the Hubble Space Telescope (HST) presents in finding TNOs across the entire sky. Observations made with HST are deep, with a single 500 second exposure with the Advanced Camera for Surveys (ACS) reaching ∼27th magnitude, depending on the bandpass. This implies that faint TNOs appear serendipitously in a large fraction of all HST images, including fields both on and off the ecliptic. The HST archive, therefore, offers the opportunity to probe the history of the Solar System by measuring the properties of faint TNOs at a wide range of ecliptic latitudes. Furthermore, its superior angular resolution permits an accurate estimate of an object's orbital parameters, improving the identification of dynamical classes with only a few detections.

2. Results

We have found 44 outer solar system objects so far. Their orbits, generally, do not differ from previously known objects' orbits (See Figure 1 and 2). In [5] we searched 1.65 sq deg to a limiting magnitude R∼26 between 5° and 20° off the ecliptic, finding 29 TNOs and 1 centaur. The orbital constraint on distance and inclination imposed by an HST detection is usually enough to estimate whether an object is dynamically excited (hot) or not (cold).

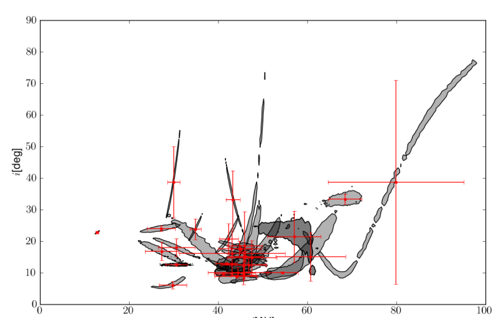

Figure 1: Distance versus inclination $1-\sigma$ probability contour for each one of the objects found in [5].

By modeling the inclination distribution and the luminosity function of both hot and cold TNOs for every pointing in our survey we can estimate the inclination distribution for new discoveries. In Figure 3 we use the detections in [5] to compare it to the observed inclination distribution probability. Our best fit gives a

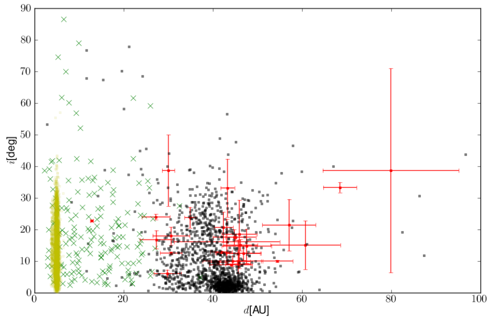

Figure 2: Distance on 01/01/11 versus inclination. Outer solar system objects (a>30AU, black squares), centaurs (green crosses) and Jupiter trojans (yellow dots) as defined by JPL are shown for comparison.

dynamically excited width of $\sigma_h = 16.5^{\circ}{}^{+4.5}_{-3.5}$, very close to the value derived by [2] for much brighter objects discovered on the ecliptic. This is an indication that smaller objects have the same inclination distribution as their larger analogs.

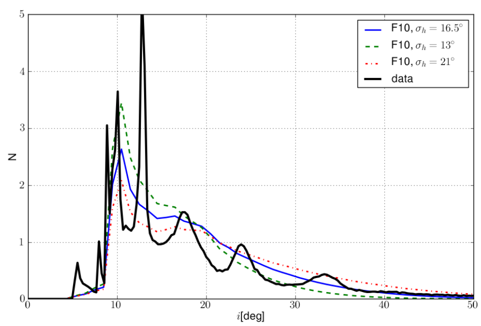

Figure 3: The inclination probability distribution for all objects in [5] is shown as a continuous black line. The best fit for $\sigma_h = 16.5^{\circ}$ is shown as a blue solid line. The limits for the $1-\sigma$ confidence level are also shown as a dashed green line and a dashed-dotted red line ($\sigma_h = 13^{\circ},\ 21^{\circ}$ respectively).

3. Conclusions and Future

We will continue our successful archival program by harvesting TNOs from data taken with the visible and infrared HST/WFC3 instrument. We estimate we will discover ∼100 new TNOs down to 10 km. (2) We will measure the V-NIR colors for ∼30 faint TNOs. We will test whether TNO surface colors are collisionally-derived (if all small TNOs have neutral/blue colors) or compositionally intrinsic (a range of colors for these smallest TNOs).

The tools we have developed to face the challenges of this project are now mature enough to be applied to data from other space and ground based facilities. This will be useful for transforming other orbiting observatories into the prime tools for studying the Solar System. We are involved in surveys for other Solar System populations using Spitzer and STEREO data, originally taken with very different scientific motivations.

We stress the importance of archiving astronomical data and making it easy to find, access and analyze. Having the tools for analyzing these large datasets will be a necessity in this new era of massive data collection from synoptic surveys and multi-wavelength space telescopes.

Acknowledgements

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