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The Orbit and Size-Frequency Distribution of Long Period Comets Observed by PS1

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1 Abstract

We introduce a new technique to estimate the comet nuclear size frequency distribution (SFD) that combines a cometary activity model with a survey simulation and apply it to 150 long period comets (LPC) detected by the PS1 near-Earth object survey. The debiased LPC size-frequency distribution is in agreement with previous estimates for large comets with nuclear diameter > 1km, but we measure a significant drop in the SFD slope for small objects with diameters < 1km. We infer the total mass and number of LPCs with perihelia q < 10 AU, and we estimate that the total number of 'potentially active' objects in the Oort cloud. The debiased LPC orbit distribution is broadly in agreement with expectations from contemporary dynamical models but there are discrepancies that could point towards a future ability to disentangle the relative importance of stellar perturbations and galactic tides in producing the LPC population.

2. Introduction

The size-frequency distribution (SFD) of the objects in any population provides insight into their formation and evolutionary processes. Studying the SFD for small body populations in our solar system can bridge the gap between our understanding of dust and planets in exoplanetary systems, and shed light on the formation and dynamic history of the solar system. Measuring the SFD of astroidal populations is relatively common (e.g. [1]), but determining the SFD of comets has been more challenging.

Attempts to directly measure the sizes of the comet nuclei have long been frustrated by their comae. Variability of volatile content and composition between comets make it challenging to determine their size using remote sensing observations. This is especially pronounced in dynamically new comets entering the inner solar system for the first time, which are typically bright even when they are far from the Sun because of significant coma activity driven by sublimation of CO or CO2. With in-situ results from space missions we now know that most known, active cometary nuclei are relatively small, low albedo (few percent) bodies with a mean diameter of 2.8 km [2]. However, only a dozen or so comets have been directly visited and so the SFD of cometary populations is not well known.

3 Method

We introduce a new technique to estimate the comet nuclear size frequency distribution (SFD) that combines a cometary activity model with a survey simulation and apply it to 150 long period comets (LPC) detected by the PanSTARRS1 (PS1) near-Earth object survey. We generated synthetic objects (q, e and i) according to the dynamical model of [3] and modeled the brightness using the [4] sublimation model. The objects were then distributed randomly in time several years around the PS1 survey. The efficiency of PS1 at finding LPCs was quantified by determining which synthetic comets would be detected by the PS1 survey as shown in Figure 1. The observed population of 150 LPCs was then corrected using the detection efficiency to infer the unbiased population of LPCs with q < 10 AU (see Figure 2).

4 Results

The debiased LPC size-frequency distribution is in agreement with previous estimates for large comets with nuclear diameter > 1km (e.g. [5]), but we measure a significant drop in the SFD slope for small objects with diameters < 1km. We infer the total mass and number of LPCs with perihelia q < 10 AU, and we estimate the total number of 'potentially active' ob-

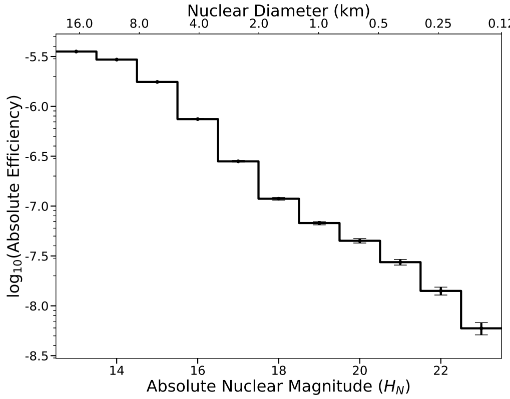

Figure 1: PS1 system absolute LPC detection efficiency as a function of absolute nuclear magnitude. The nuclear diameter (top axis) assumes a typical cometary nuclear albedo of 4%.

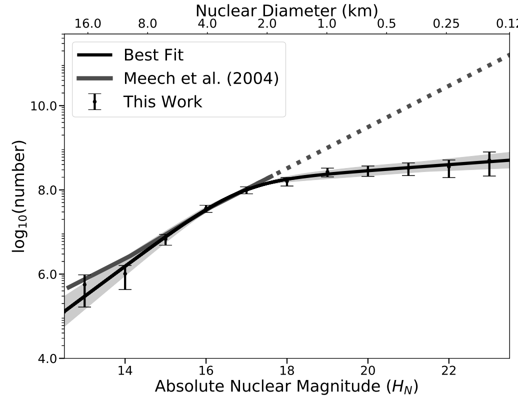

Figure 2: Bias corrected incremental absolute nuclear magnitude distribution for LPCs. The shaded gray region represents the range of solutions resulting from the least squares fit to the data. The [5] function was normalized to our debiased distribution at $H_N = 16$ and the dotted portion for $D < 2$km diameter is a simple extrapolation of their result to smaller sizes.

jects in the Oort cloud. The debiased LPC orbit distribution is broadly in agreement with expectations from contemporary dynamical models but there are discrepancies that could point towards a future ability to disentangle the relative importance of stellar perturbations and galactic tides in producing the LPC population.

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