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Mind the gap: investigating why the physical and orbital properties of 'hot' and 'cold' Classical KBOs mismatch.

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Abstract

We have generated orbital parameters for 700 Classical Kuiper Belt Objects (CKBOs) and simulated their orbital evolution for 500 Myr. We have noticed that, during their orbital evolution, objects with initial orbital inclinations $\sim 5^\circ - 10^\circ$ make larger inclination excursions that others. Since the inclination variation of these objects is approximately pendulum-like, they spend more time at the extrema and less time at their (central) initial inclination, hence they are less likely to be seen there. We will discuss this phenomenon and analyze if it could be responsible for the observed inclination density gap at $i \sim 5^\circ$ of the unbiased distribution of CKBOs.

1 Introduction

Kuiper Belt Objects (KBOs), also known as Trans-Neptunian Objects (TNOs), are a vast group of icy objects orbiting the Sun in a disk-like region beyond Neptune [1]. Their orbital structure lead to several sub-classifications based on orbital parameters. Yet, it is hard to establish clear borderlines between classes. Classical Kuiper Belt Objects (CKBOs) are, roughly, those with both semi-major axes and perihelia between $\sim$ 37 and 48 AU, that are not located in any strong mean-motion resonance with Neptune [2, 3, and references therein]

The unbiased orbital inclination distribution of CKBOs indicates the existence of a density gap at inclinations $i \sim 5^\circ$. Consequently, their inclination distribution has been best described by the superposition of two different populations which may overlap but show a transition at $i \sim 5^\circ$ [4, 5, 6] — see Fig.1 a). The two populations are usually referred to as dynamically 'cold', if $i \lesssim 5^\circ$, and dynamically 'hot', if $i \gtrsim 5^\circ$ [7].

Measured physical properties, like surface colors, spectral reflectance, albedos, sizes, and frequency of binaries also relate with inclination [7, 8, 9, 10, 11, 12, and others]. Such reinforces the idea of different origins for hot and cold CKBOs whom possessed primordial differences. However, it is puzzling that color properties and orbital properties of these objects do not match. CKBOs seem to be equally red up to $i \sim 12^\circ$ and not just up to $i \sim 5^\circ$ — where maximum evidence for transition would be expected [13]. Dealing with lower statistics, albedos and binarity suggest a distinction below $i \sim 12^\circ$ but still probably above $i \sim 5^\circ$ [11, 12].

From the currently measured physical properties of CKBOs they seem to be, in fact, composed by two distinct populations but, nonetheless, these populations might be separating/overlapping at higher inclinations than the $i \sim 5^\circ$ suggested by dynamics.

2 Conjecture

In order to investigate why the physical and orbital properties of hot and cold CKBOs mismatch we have generated orbital elements for 700 CKBOs. Their inclinations are uniformly spread between 0° and 50° but the semi-major axes and perihelia have been computed using modeled distributions. We ran their orbital evolution for 500 Myr using the Bulirsh-Stoer algorithm, keeping records of the parameters each 10 kyr.

We computed the inclination minima and maxima for each object as a function of their initial inclination and median filtered those values. It is noticeable that objects with initial inclinations $\sim 5^\circ - 10^\circ$ possess a range of inclination variations $\sim 1^\circ - 2^\circ$ larger than others — see Fig.1b). Further, a statistical analysis shows that the (median) frequency distribution of the orbital inclinations of our CKBOs, during the 500 Myr, between their extrema (which we normalized to -1 and 1) shows an approximately pendulum-like behavior — see Fig.1c). Consequently, the objects will spend more time near their inclination extrema than

near their (central) initial inclinations. Since objects with initial $i \sim 5^\circ - 10^\circ$ have wider inclination variations they will be less likely to be observed close to the initial value. Hence, we hypothesize that this effect might be responsible for the observed inclination density gap at $i \sim 5^\circ$ and the apparent discrepancy between the transition of physical properties of CKBOS with inclination and the so-called dynamically hot and dynamically cold orbits.

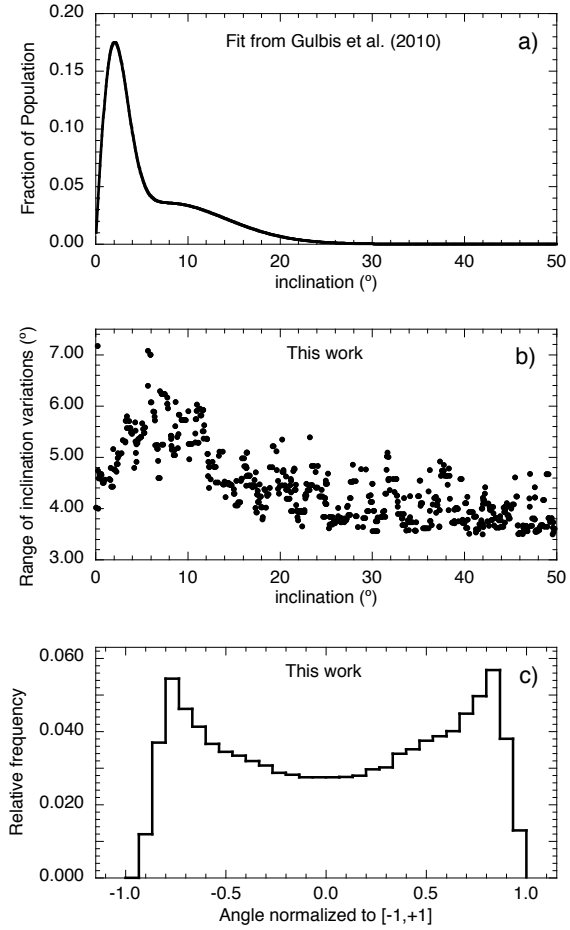

Figure 1: a) Debiased inclination distribution of CKBOs suggesting two populations. b) Median filtered range of inclination variations as a function of i during 500 Myr. c) Frequency distribution of i between their extrema (normalized to -1 and 1) during 500 Myr.

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