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Born-big TNOs and the shallow size distribution of faint objects in the Edgeworth—Kuiper belt

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1. Introduction

1.1 ALICANDEP

ALICANDEP (Asteroid-LIke Collisional ANd Dynamical Evolution Package) is a collisional evolution code [1] including a) statistical elimination of objects by dynamical effects within the frame of a disc that migrates and is excited dynamically, and b) the dynamical migration of objects within the disc itself, as described by the Nice model [2]. The model meets the Nice model requirements and matches available current observables (the existence of Pluto and the rest of dwarf planets in the region; the number of objects larger than 100 km in different dynamical populations and the corresponding size distributions, as found by the Canadian France Ecliptic Plane Survey, CFEPS [3,4])

1.2 Faint TNOs surveys

The CFEPS has found overall absolute magnitude power—law differential distributions around q_1~5 for bright TNOs down to an equivalent size around 100 km. On the other hand, [4] found that the cumulative luminosity distribution for R magnitudes above 24.3 is $\alpha_2=0.3^{+0.3}_{-0.2}$, corresponding to an incremental size (D) distribution ($dN=A\cdot D^{-q2}dD$) exponent $q_2=2.5^{+1.5}_{-1.0}$ at bodies smaller than some 100 km. In an independent search by [5], a change in the slope in the TNOs distribution around 60 km was found, turning into a shallower power—law exponent ~1.9 at smaller sizes (down to some 10 km).

2. Methodology and results

We performed numerical simulations with ALICANDEP, exploring a wide parameter space of boundary conditions that fulfill the Nice model requirements and match current observables. According to our simulations, the current break size for the overall TNOs populations is at 90—150 km. A slightly smaller estimation results if restricted to the Classical Main Belt, ranging 70—120 km. Due to collisional evolution, the transition is smooth and spreads over a few tens of km. We noticed that variations in the initial break size (changing from 50 to 150 km) have only slight effects on the setting of the post-evolution break size.

Initial size distributions for bodies larger than the break size should have been close to current ones. In fact, this range of the distribution is far from collisional equilibrium and is closely related to the original one.

Interesting results are obtained when varying the initial distribution for objects smaller than the break size. 1) Any initial slope with $q_1<3$ gives reasonable values for the total initial mass and matches current observables in the TNOs populations (small bodies are not able to alter the size distribution and number of their larger siblings). 2) Differences are found in the evolved populations of objects smaller than the break size, depending on their initial distribution. Analysing the size distributions obtained in the case of shallow power—laws (q_2 from 0.5 to 2) for the initial populations of small bodies (below 100 km) a plateau forms in the range 30—100 km, followed by the onset of the typical equilibrium size distribution (Fig. 1). An average slope ~2 is calculated in that range, in agreement with observational results [5] and [6].

3. Discussion and conclusions

As a typical behaviour of collisionally relaxed systems, if a system has enough mass and time to evolve, the collisional cascade produces an equilibrium size distribution (close to q_2=3.5) even if no mass is present initially below any given size. Nevertheless, in the case of TNOs, collisional evolution was damped by dynamical instability at the beginning of the Late Heavy Bombardment (LHB) phase. During that period, 99% of the mass was ejected out of the region, stopping the collisional evolution and fossilizing the size distributions at its end.

The study of the evolution of the TNOs populations by ALICANDEP finds an explanation to observational results [5] and [6] as the combined effect of a very shallow initial distribution of bodies smaller than the break size and the onset of the LHB phase that froze collisional evolution at that time. Therefore, most of the mass was initially in large objects and the paucity of objects smaller than the break size was only partially compensated by the collisional evolution of larger objects until turned off by the onset of the LHB phase.

This result tends to confirm the hypothesis that planetesimal formation favoured objects not smaller than some ~100 km, not only in the case of the asteroid belt [7], but also in the outer solar system.

4. Figures

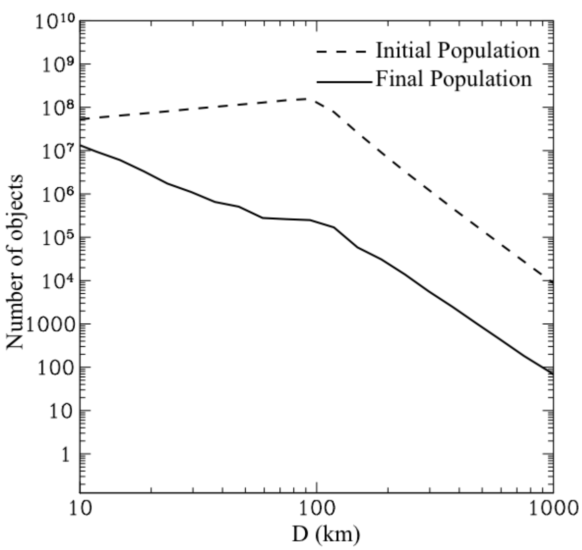

Figure 1: The evolved incremental size distribution from an initial power—law distribution (q_1=0.5) for bodies smaller than 100 km.

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