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Effects of Multiple Planetary Encounters on Kuiper Belt Objects

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1. Introduction

Nowadays many attempts are made to establish a qualitative and a quantitative connection between Kuiper Belt Population and Jupiter Family Comets. Basically, this can be thought as a diffusion process throughout the outer Solar System due to multiple close encounters with the giant planets. But, following the path of a body in such a process is not an easy task to be approached analytically nor numerically, because the motion is very chaotic and spread over a long time. A statistical approach seems to be a reasonable way and is the purpose of this paper.

2. Description of the method and results

The method is based on a Monte Carlo simulation of a virtual population originating in the source regions beyond Neptune which are supposed to deliver objects in unstable Neptune-crossing orbits – characterized by weak dynamical instabilities (Duncan et al. 1995). Our scattering engine is solely based upon planetary close encounters, so we have to assume that the initial population is already driven to the Neptune-crossing orbits by pumping up their eccentricities. Between encounters the orbits are supposed to be keplerian ones, but animated by a synthetic secular drift in the longitudes of their node and perihelion. The outcomes of close encounters are derived using Öpik's formalism (Öpik 1976) combined with our own analytical expressions describing in a complete manner the post-encounter orbital changes. This allows us to follow the evolutionary paths of about 4000 test particles until their end-state occurs. The main results of our simulation are summarized below.

Each object has experienced on average between 200-700 planetary close encounters on their entire lifetime. These encounters took place mainly in Neptune-crossing orbits and afterwards in the transition region to the Uranus-crossing orbits, and this is because the objects spend most of their lifetimes in these regions. These objects do not achieve much higher orbital inclinations, a retrograde orbit being rarely observed among the population.

The distribution of the end-states is as follows: about 22% of the population collide with one of the giant planets (mainly Jupiter) and 78% leave the Solar System on a hyperbolic or on a very elongated orbit. A very small percentage experienced a Sun-grazing end-state as an outcome of a close encounter. The average survival time of these transient bodies is about 100 My.

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Around 42% of the population reach a perihelion distance less than 2.5 AU, becoming an active Jupiter Family Comet (41%) or a Halley-type Comet (1%), accordingly with the classification given in (Levison et al. 1994).

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