A Monte Carlo type simulation toolbox for solar system small body dynamics

Daniel Kastinen, Johan Kero
Swedish Institute of Space Physics (IRF), Box 812, SE-98128 Kiruna, Sweden (dankas-1@student.ltu.se)

Introduction

The dynamics of small bodies in the solar system form a theoretical basis to study meteoroid streams and their connected meteor showers. The perhaps most missed feature in current models is the ability to easily connect programs with different functionalities. We believe this is the main reason why many contemporary techniques such as Monte Carlo simulations of meteoroid streams, orbital stability analysis, and so on, have not yet been combined. We have thus started development of a toolbox able to showcase the power of a software capable of these actions. The software is designed in a modular fashion, where one master program has the ability to call several independent modules. The parent bodies can be hand-picked, or generated from probability distributions like the Pan-STARRS Synthetic Solar System Model. This enables a wide re-use of the tools developed. To study mass propagation we use the toolbox in a statistical manner propagating a distribution of possibilities rather than relying on single assumptions. The distributions currently implemented represent orbital elements, sublimation distance, density, size, and surface activity. The software integrate ejected particles and examines close encounters with the Earth.

Results

Simulations include perturbations from all major planets, radiation pressure, and the Poynting–Robertson effect. Validations of the software was done by simulating a known and observed meteor shower, the 2011 October Draconids [1]. The simulation was performed by ejecting material from comet 21P/Giacobini-Zinner between 1866 and 1907 and propagating the material until 2020. The results of the prediction is shown in Fig. 1. To further demonstrate the statistical approach, several probabilistic results using this validation run has been calculated. One example is shown in Fig 2 where the most probable encounter rate of simulated particles is displayed as a function of solar longitude and particle mass. The ejected mass distribution was logarithmically uniform. In addition, we have used cluster analysis and time tracing of meteoroid streams to compare several orbital similarity functions, the so-called D-criteria and previously untested natural metrics [2].

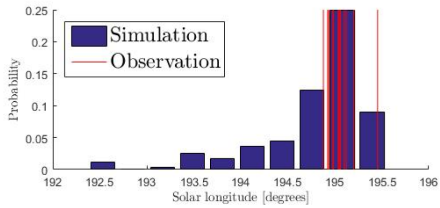

Figure 1: Simulation of the 2011 October Draconids.

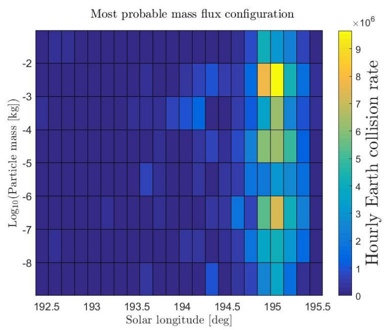

Figure 2: Simulation of the 2011 October Draconids mass flux propagation efficiency.

References

[1] Kero, J., Fujiwara, Y., Abo, M., Szasz, C and Nakamura, T. MNRAS, 424:1799-1806, 2012.

[2] Kholshevnikov, K. V. and Vassiliev, N. N., Celestial Mechanics and Dynamical Astronomy, 89:119-125, 2004.