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A survey of collision outcomes during planet formation: water transport and loss

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Abstract

We present results of a suite of collision simulations covering a wide range of the involved objects' parameters such as mass, projectile-to-target mass ratio, material composition, collision velocity, and collision angle. These results will aid in estimating the amount of water retained and lost in dynamical planet formation studies.

1. Introduction

It is well-established that a long sequence of collisions of protoplanetary bodies was involved in forming terrestrial planets. In particular, it is widely accepted that water-carrying planetary embryos and planetesimals from beyond the snowline – maybe even comets ([5]) – delivered a large fraction of Earth's water. Most existing planet formation studies treat those collisions as perfect inelastic merging events (e.g., [4, 6]) or apply simple fragmentation models ([1]) hereby ignoring the actual collision outcome in terms of fragmentation and water loss. As a consequence, these planet formation simulations overestimate the water content of the formed terrestrial planets – estimates range from about 30 % less water being transported to the habitable zone ([2]) to a factor of 5-10 ([3]).

2. Simulations and results

To aid the efforts of more accurately estimating the actual water transport rates to the habitable zone, we performed a number of collision simulations with our parallel 3D smooth particle hydrodynamics (SPH) code ([8, 9]) in the past (e.g., [7, 2]). The preliminary results in Figure 1 show the water loss (color-coded) after collisions of Ceres-mass objects at different collision velocities (measured in units of the mutual escape velocity) and angles (0° corresponds to a head-on collision). Note that for collision angles $\gtrsim$40° (hit-and-run collisions), the water loss is significantly lower than for eroding collisions at smaller angles and high velocity.

In order to study how the water loss additionally depends on the involved masses, projectile-to-target mass ratios, and water contents, we will present new results from a suite of several hundred collision simulations with varying parameters.

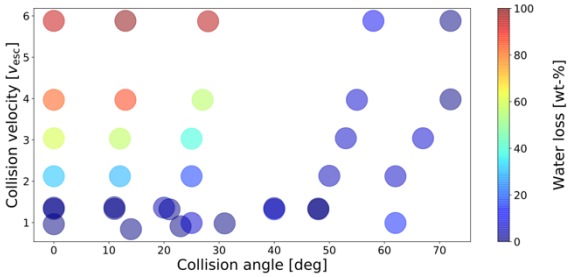

Figure 1: Water loss (color-coded) after collisions of Ceres-size objects with 30 wt-% water mass fraction. Results from SPH-simulations.

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