Transfer of impact ejecta between the terrestrial planets. Brett Gladman, Joseph A. Burns. Dept. of Astronomy, Cornell University, Ithaca, NY, 14853, USA.

As more and more meteorites from the Moon and Mars are discovered, it is increasingly clear that impact fragments can escape from large bodies more easily than previously believed. These escaping fragments are then subject to the gravitational perturbations of the planets, allowing them to be transferred to a body other than the one from which they were launched. The lunar meteorites and SNC meteorites (widely accepted to be from Mars) prove the plausibility of this process.

We study the transfer dynamics by means of numerical simulations, considering the evolutions of ejecta escaping from the Moon, Mercury, and Mars. (The feasibility of impact ejection from Venus and the Earth, with their massive atmospheres, is an open question). For the case of the Moon, the escaping material has first to be followed through the stage of geocentric orbit until the particles escape to heliocentric space. In all cases, we track the material that reaches heliocentric orbit using a regularized mixed-variable-symplectic integration package developed by Levison and Duncan [1]. The particles are followed for between 2 and 20 Myr, until they impact a terrestrial planet, cross the orbit of Jupiter, or evolve to a Sun-grazing state.

The lunar ejecta problem is of interest in light of the discovery of lunar meteorites. We find that of the ejecta that just barely escapes the Earth/Moon system, slightly more than half returns to impact the Earth during 10 million years [2]. Of the Earth impacts that do occur, roughly two-thirds happen within the first 50 000 years, in agreement with the relatively young cosmic ray exposure ages of most recovered lunar meteorites. The rate of impacts is very high early on because the velocity of the escaping particles with respect to the Earth is initially low, enhancing the Earth's gravitational cross-section. Within a few Myr, the material that does not impact the Earth scatters throughout the inner solar system. Over a 10-Myr period the remaining particles continue to collide with the terrestrial planets. Many impacts with Venus, and one with Mars, are observed. We find that after a few Myr, being driven to Sun-grazing (with perihelia less than 2 solar radii) becomes a very common loss mechanism.

Material ejected from Mercury is largely re-accreted by that planet. A small fraction (10%) is driven to Venus-crossing orbits on Myr timescales, and collisions with Venus are observed. The transfer of this material to the Earth would require at least roughly 10 Myr, and would consist of a very small fraction of the launched material (in obvious contrast with the lunar case).

Martian ejecta is perhaps the most interesting in the light of the SNC meteorites. The cosmic ray exposure ages of these objects are somewhat difficult to reconcile with the dynamics. Secular resonances, which we show to be located throughout the inner solar system, are very important for establishing a relatively short timescale for the delivery of this material to the Earth. These allow fast transfers even if only very small ejection speeds off of Mars are typical.

REFERENCES: [1] Levison, H., and M. Duncan. 1994. *Icarus*, **108**, 18-36. [2] Gladman, B., J.A. Burns, and P. Lee. 1995. *LPSC XXVI*, 465-66.