The Mass-Depletion of the Asteroid Belt Estimated by a Lunar-Like Impact chronology Model

O. Hartmann, G. Neukum, Institute of Planetary Sciences and Remote Sensing, Department of Earth Sciences, Freie Universitaet Berlin, Germany

Introduction: The solar system has undergone a bombardment by small bodies since its existence which is documented by the impact cratering records of surfaces of its planetary bodies. The well-investigated cratering record of Earth's moon as seen in high-resolution image-investigations since the early 1960's reveals a typical size-frequency distribution (SFD), leading to an impact-chronology model proposed by [1, 2]. Comparisons of the size-frequency distribution of Near Earth Asteroids (NEA) by terrestrial-based observations of reflected sunlight and magnitude-derived diameter estimates via application of spectral models [3, 4, 5] have led to the conclusion that the Asteroid Belt acts as the primary source of projectiles impacting the surfaces of planetary bodies of the Inner Solar System [5, 2, 6, 7]. High resolution image-based investigations of crater diameter size-frequency distributions on surfaces of planetary bodies in the Jovian and Saturnian systems support this conclusion [8], but this is, however, still in discussion.

If the Asteroid Belt acts as the main contributing source for impactors for both the Inner as well as for the Outer Solar System, impact chronology models provide strong boundary conditions and time-constraints on the dynamical processes depleting the source region of the projectiles since the impact-cratering recording of planetary bodies took place due to solidified surfaces.

Method: The mass impacted on the surfaces of planetary bodies for both the Inner and Outer Solar System is estimated via lunar-like impact-chronology models derived from measurements of the size-frequency distribution of the cratering records of surfaces of planetary bodies as proposed by [1, 2]. The mapping of the crater size-frequency distribution of each planetary surface to a corresponding projectile size-frequency distribution is performed by application of an adequate scaling law as proposed by [9, 10], and refined by [11]. The mapping is performed with the assumption of an average impact velocity (Mercury: $23.6\ \mathrm{kms}^{-1}$, Venus: $19.3\ \mathrm{kms}^{-1}$, Earth: $17.8\ \mathrm{kms}^{-1}$, Moon: $14.1\ \mathrm{kms}^{-1}$, Mars: $12.4\ \mathrm{kms}^{-1}$, see [1]), an average impact angle ($\alpha_i = 45°$) and an average density of the impactor ($\varrho_{Imp} = 2.5\ \mathrm{gcm}^{-3}$), assuming a spherical shape of the projectile. For all planetary bodies of the Inner Solar System, an average surface density of $\varrho_{Surf} = 3.0\ \mathrm{gcm}^{-3}$ is assumed. To compare the size frequency-distribution of the projectiles with the size frequency-distribution of the recent Asteroid Belt, the total number of impact craters and their corresponding number of projectiles is averaged and a lunar-like size frequency-distribution fit-function is derived from this approach (Fig. 1). The size frequency-distribution of the Asteroid Belt is compared and fit to this function to extrapolate the SFD towards object's sizes the total number is incomplete due to observational constraints. With those numbers derived, an estimation of the recent total mass of the Asteroid Belt is calculated.

The derived size frequency-distribution of objects in the recent Asteroid Belt and the derived estimated total mass are compared to results taken from different approaches, as published by [12, 13, 14].

Early results and outlook: By integrating the impact-chronology model for each planetary body of the Inner Solar System over the past 4.5 Ga, the total number of impacts for the whole Inner Solar System is estimated. By application of an appropriate scaling law with proper parameters for average impact velocities, an average impact angle and average surface densities, we derive the average size frequency-distribution of impacts, and hence by application of an average density with the assumption of a spherical shape of the projectile, the total impacted mass.

Preliminary estimates of the total count of objects with diameter $D \geq 1\ \mathrm{km}$ in the recent Asteroid Main Belt ($2.0 - 3.3\ \mathrm{AU}$) are in good agreement with estimates made via different oberservational methods: $1.26 \pm 0.3 \cdot 10^6$ in this work, and $(1.2 \pm 0.5) \cdot 10^6$ by [15].

Within a projectile diameter-range of $1.0 - 1000\ \mathrm{km}$ (Ceres included) this method gives a total mass of $\mathrm{M_{belt}} \approx 3.0 \cdot 10^{21}\ \mathrm{kg}$ within the range of $2.0 - 4.2\ \mathrm{AU}$ in the Asteroid Belt. This preliminary result is also in a good agreement with results from [14], which estimate the total mass of the recent Asteroid Belt to be $\mathrm{M_{belt}} \approx 3.6 \cdot 10^{21}\ \mathrm{kg}$ from an analysis of the pertubation of the motions of the major planets by the mass of the Asteroid Belt.

Upcoming work will combine the total impact mass-estimates for both the Inner and Outer So-

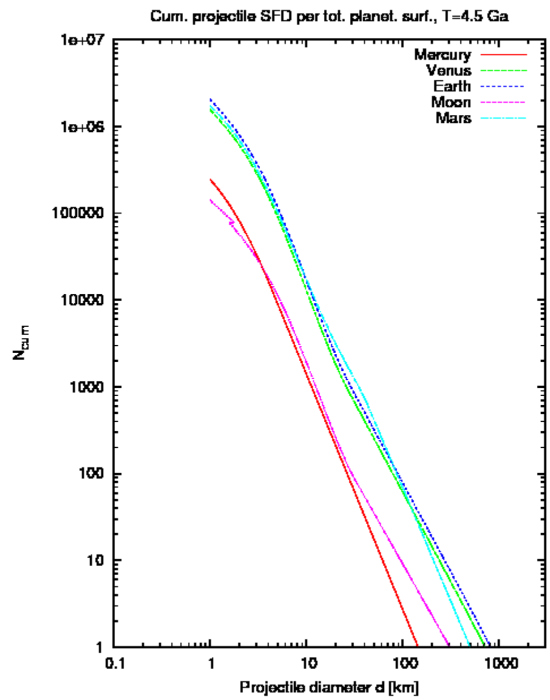

Figure 1: Cumulative SFD of the total number of impacted projectiles on surfaces of planetary bodies of the Inner Solar System for $T = 4.5$ Ga, derived from a lunar-like chronology model, as introduced by [1]. All graphs are limited to impactor-sizes ranging from $\mathrm{d} = 1.0$ km to $\mathrm{d} = 1000$ km (Ceres), the mean over the total is the fit-function for mass estimates and SFD extrapolations of the Asteroid Belt. The kinks are due to the used scaling-law and reflects the the region of impact scaling in the changing simple-to-complex regime.

lar System with estimates of the dynamical mass-depletion of the Asteroid Belt and implied time contraints, as given by the lunar-like chronology model in [1] and numerical modelling in [16].

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