Dynamical impact bombardment chronology of the terrestrial planets from 4.5 Ga to 3.5 Ga.

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We report the intensity and effects of early impacts on the terrestrial planets by combining dynamical N-body and Monte Carlo simulations to determine impact probability, impact velocities, and expected mass addition onto the terrestrial planets from three planetesimal sources after the formation of the Moon. These are: planetesimals left over from primary accretion, the hypothetical E-belt, and comets arriving from the outer solar system. We present for the first time a robust estimate of the amount of cometary material striking the terrestrial planets during a late episode of planetesimal-driven giant planet migration. The background mass augmentation from small leftover planetesimals to the Earth and Mars is far lower than the estimates based on the abundance of highly-siderophile elements in their mantles and terrestrial tungsten isotopes. This supports that both planets were struck well after their formation by single large bodies that delivered most of their HSEs. The Moon and Mars suffer a proportionally much higher amount of cometary accretion than Venus and the Earth; for the Moon this contribution could be gleaned in its D/H ratio and Xe isotopes. We calculate the lunar, martian and mercurian chronologies using the impacts recorded onto the planets from dynamical simulations and present fits to the impact chronologies that are valid from 4.5 Ga to ca. 3.7 Ga, beyond which low-number statistics in the dynamical simulations aversely affect the impact flux. The dynamical lunar chronology thus obtained does not match both the calibrated Neukum and Werner chronologies: the calculated crater density at each epoch after 4.4 Ga is much lower than what these calibrated chronologies predict. For Mars the match with the calibrated Werner chronology is very good, so that the poor agreement for the Moon has no easy explanation. Increasing the E-belt mass to match the lunar calibrated chronology would violate the martian one. For Mercury we present a theoretical chronology only. Neither of our dynamical chronologies match that of Neukum; its decline is too steep. The dynamical lunar and martian chronologies are also different from each other, so one cannot apply the usual extrapolation from one body to the other.