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 augmentation onto the terrestrial planets from three sources after the formation of the Moon [1]. These sources are: planetesimals left over from primary accretion and 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 an episode of planetesimal-driven giant planet migration. 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. 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 late mass augmentation. 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 (**Figure 1**). The dynamical lunar chronology thus obtained agrees reasonably well with the Werner [4] chronology, but not with that of Neukum [5]. For Mars the match with the calibrated Werner chronology is also very good. For Mercury we present a theoretical chronology only. Neither of our dynamical chronologies match that of Neukum. The dynamical lunar and martian chronologies are also somewhat different from each other, so that the usual extrapolation from one body to the other does not apply. The dynamical chronology curves displayed here result in surface ages up to 150 Myr older on the Moon and on Mars at certain epochs compared to the Neukum chronology. This has implications for the interpretation of the geological evolution of these bodies.

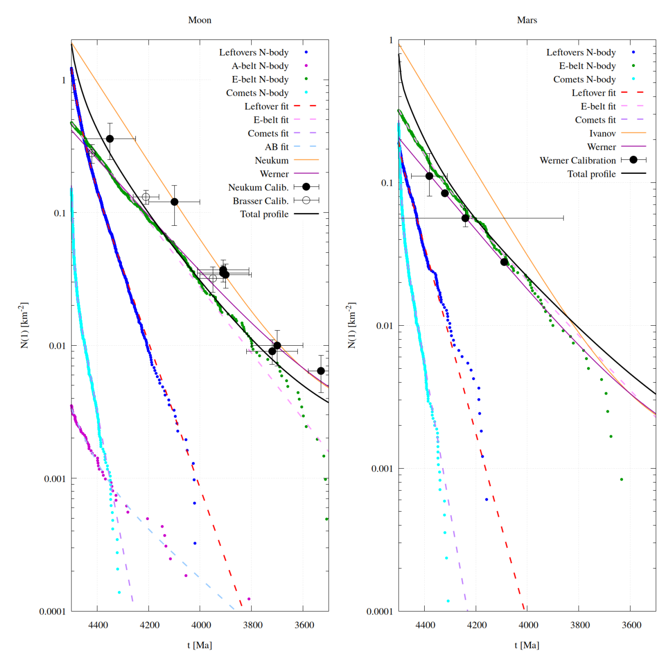

Figure 1. Lunar chronology (left) and martian chronology (right) from a combination of dynamical and Monte Carlo simulations. The three reservoirs are the comets from the outer solar system, leftover planetesimals and the E-belt with the best fits. The calibrated Werner and Neukum chronologies are shown separately as solid lines. The contribution from the main belt is included based on simulations from [2]. The filled circle data points are calibrations from [3]. The open circles are an attempt by us at a new, albeit somewhat provisional, calibration.

Bibliography

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