A Comprehensive and Self-consistent Model of Terrestrial Planet Formation in the Solar System

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We have developed the currently most comprehensive and self-consistent approach to realistically simulate the formation of terrestrial planets. Our approach begins with simulating the collisional growth of planetesimals and continues with resolving giant impacts and the full formation of terrestrial planets. It takes into account the dynamical friction due to the debris and planetesimal disks, migration of planetesimals and embryos, and the perturbation as well as possible migration of giant planets. As the most important step toward a fully comprehensive and realistic model, our approach incorporates SPH simulations into N-body integrations in real time allowing, for the first time, collisions to be simulated accurately as they occur. Results point to several important findings. For instance, in the context of our solar system, almost all simulations produced an Earth-analog. They also demonstrated that the similarities between the size and mass of Earth and Venus are a natural outcome of the formation process, and Mars-sized planets appear in systems where the mass distribution in the planetesimal disk is non-uniform. When studying the effects of giant planets, results showed that secular resonances are the main reason that our solar system does not have Super-Earths. They are also the reason that terrestrial planets form interior to 2.1 AU. Simulations also show that the capture into resonance of migrating giant planets does not play a significant role on the formation of terrestrial planets, and while giant planets may affect the inventory of planet-forming material and water-carrying objects, especially when they migrate, they play no role in the mechanics of the formation of terrestrial planets and the transfer/transport of water to them. Formation and water delivery is merely due to the mutual interactions of planetary embryos, a process that occurs even when no giant planet exists. We will present the results of our study and discuss their applications to extrasolar planets.