Abstract

Giant impacts refer to the final collisions between the remaining protoplanets and planetary embryos. These impacts are the dominant physical process at the end of planet formation because of the secular resonances between the bodies after the dissipation of the gas disk. They are energetic and angular-momentum-rich events that can shape the final state of planets. In this thesis we study how such collisions modify the composition, mass, rotation period and axis of planets and form circumplanetary disks. We apply this framework in the context of the solar system planets, and study Mercury, Uranus and Neptune. In this work we use the smoothed-particle-hydrodynamics with self-gravity GASOLINE code to describe the collisions, and the BALLIC code to model the initial structure of the protoplanets. The framework is explained in the introductive Chapter 1

In Chapter 2, we study the origin of Mercury's high iron-to-rock ratio relative to the other terrestrial planets. We focus on the giant impact hypothesis and study therefore three scenarios, a giant impact, a hit-and-run and a multiple collision scenario. We investigate a large parameter space in impacter parameters, velocities, impactor's masses and compositions as well as the initial thermal state of the protoplanet to find collisions that lead to a mantle-stripping event. We find that it is difficult to form Mercury to match both its mass and composition. The multiple-collision scenario escapes the fine-tuning in the collision geometry but is constrained by the volatile-rich composition of Mercury. Mass loss is found to be more consequent if the collisions occur tight in time.

In Chapter 3 we study how giant impacts explain the differences between Uranus and Neptune. For Uranus we focus on oblique collisions that should leave its internal structure intact and at the same time form a circumplanetary disk. For Neptune we focus on head-on collisions that can deposit mass in the interior of the planet and lead to a more convective interior. We find that these massive collisions have a differentiating effect on the planets and can explain the dichotomy between them.

In Chapter 4 we discuss alternative formation scenarios for Uranus and Nep-

tune where they form by collisions of planetary embryos rather than by accreting smaller bodies as in the first stages of the core-accretion scenario. We find that the rotation periods are typically too short to match the current observations, and that the obliquities only correspond in a few cases, while no simulation can reproduce all the observed properties of the planets. We suggest that formation scenarios should consider the rotation period and obliquities as constraints to reproduce successfully planetary systems.

In Chapter 5 we discuss analogs of Mercury in the exoplanet population and characterize one metal-rich candidate, K2-106 b. The planet is found to be similar in composition to Mercury with the mean measured values. However the planet is much more massive than Mercury, and we discuss the implications and links between the solar Mercury and the extrasolar planets.

Finally we conclude that giant impacts can explain several properties of planets in the solar system, which ultimately arise from the stochasticity in the last stage of planet formation. While these collisions are expected to be a common phenomenon, the typical signatures of such events on the planets are still not well understood and open many questions to be answered for future studies, especially in the context of the ongoing and coming missions to the solar system planets.