Abstract

Without a doubt the last few decades have been a golden age for planetary science: Space missions such as Galileo, Cassini and Juno helped transform our view of Jupiter and Saturn's interiors, and the discovery of planets beyond the solar system radically changed our view of Earth's place in the universe. At the same time, these observations also raised fundamental questions about the origins of giant planets. However, what is observed today is the result of billions of years of cooling, and therefore evolution models are the essential link between formation models and observations. In this thesis, we use evolution models to learn more about the nature of gaseous planets.

Giant planets were often thought of as homogeneous balls of gas with an icy/rocky central core. However, current interior structure models of Jupiter that fit Juno data show that this view is too simplistic, and that Jupiter could have a *fuzzy* core. We investigate how this can be explained within the context of Jupiter's formation and evolution. We show that it is very challenging to explain the fuzzy core because vigorous convection develops quickly and destroys primordial composition gradients. This suggests that there are some missing pieces in our understanding of giant planets, and that processes such as core erosion, helium rain and double-diffusive convection could play an important role. One alternative to create Jupiter's fuzzy core is a collision with a planetary embryo that completely disrupted its primordial structure and mixed core material into the envelope. We present a study that investigates this scenario and show that it is feasible for certain impact and formation conditions. Beyond the solar system, the study of giant exoplanets is a great opportunity to learn more about their formation because of their diversity. It is of particular interest to understand their composition, since that can tell us something about the environments and conditions in which they were born. Because their bulk compositions cannot be observed directly, here we use evolution models to study whether current theoretical models are sufficiently constrained to make the most out of current and future observations. We demonstrate that this is not the case, and that we are at a point where theoretical uncertainties may exceed those from measurements. Evolution models are crucial for the interpretation of measurements as well as constraining formation pathways of giant planets, but they can be slow or difficult to calculate. Here, we present a framework for generating synthetic evolution tracks, and show that they provide a fast, accurate and easy-to-use alternative to full evolution calculations.

This thesis presents our contribution towards a better understanding of giant planets. However, there are still many gaps in our knowledge of how gas giants form and evolve, and in the future evolution models will play a central role in answering them. In order to make the most out of measurements of planets in- and outside of the solar system, it will be crucial that evolution models will continue to be refined.