Abstract

Stars and planets have accompanied mankind since the very beginning. Despite this long time, it was only a few decades ago that remote space missions allowed us to study the planets in the Solar System *in-situ*. This led to a golden age of planetary science, with huge advances in our understanding of our neighboring planets. Spacecraft missions to Jupiter (Galileo, Juno), Saturn (Cassini), and to some extent Uranus and Neptune (Voyager II) allow us to study their interiors in great detail. And a precise understanding of the internal structure and composition of a planet is key to understand its formation and evolution. This knowledge also helps us to better understand the properties and evolution of the Solar System. Finally, the first discovery of an exoplanet in 1995 set off a cascade of subsequent discoveries. Most of the discovered exoplanets have masses and radii similar to those of Jupiter and Neptune. It is therefore natural to study their Solar System equivalents first, and then apply this knowledge to them.

The Juno and Cassini spacecraft measured the gravitational fields of Jupiter and Saturn with unprecedented precision. This allowed us to better constrain their interiors. And indeed, we realized that the historical assumption of a distinct and presumably rocky/iron-rich core covered by a mostly gaseous envelope was probably too simple. In fact, both Jupiter and Saturn may have dilute cores. However, gravitational data alone are blind to the center of a planet. To probe the core region of a planet, one must find an additional quantity that is sensitive to that region. We have shown with empirical structure models of Jupiter that an accurate measurement of its moment of inertia can help to further constrain its core region. Because Uranus and Neptune were only visited by Voyager II in the late 1980s, their relatively large measurement uncertainties do not allow for an exhaustive description of their interiors. Not only are their gravity measurements relatively uncertain, but their exact rotation periods are also under debate. We have shown with empirical structure models that exact knowledge of their rotation periods and wind depths is crucial to better constrain their interior structure models. On the other hand, we studied which observables a future spacecraft should measure to effectively constrain their current uncertainties in rotation period and wind depth. All gaseous planets in the Solar System show evidence of non-convective regions. In the case of Uranus its luminosity and its magnetic field suggest the presence of non-convective regions. The presence of such non-convective, and therefore non-adiabatic, regions can significantly affect a planet's temperature profile, composition and cooling path. To investigate the effect of non-adiabatic regions within Uranus, we've interpreted its empirical structure models in terms of temperature and composition. We find that all considered Uranus models are partially non-convective, leading to significantly hotter and metal-rich interiors compared to fully adiabatic models.

In this thesis we collect our contributions to a better understanding of the interior structure of the gaseous planets Jupiter, Uranus and Neptune. Despite our efforts, the interior structure of our gaseous neighbors is still not fully understood and requires further research to unravel. And as questions are answered, new ones will arise.