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Clouds (in irradiated atmospheres) and their implications for interior models

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Abstract

Modeling observed planets in young open clusters and around mature stars offers a way to learn about planet formation and evolution, the link being the planetary composition [1,2]. We determine the core mass of the planet as a representative of the heavy element mass by the combination of atmosphere, structure, and evolution calculations.

Planetary opacities and clouds play an important role in this context, as they influence the atmospheric temperature-pressure profile. As an example, transmission spectroscopy indicates the presence of clouds in many gaseous planets. Using the young hot Jupiter WASP10-b as an example, we investigate the influence of different atmosphere models on the derived heavy element mass. We use atmospheric profiles with and without clouds based on semi-analytical atmosphere models [3,4]. Additionally, we look into the transition region between atmosphere and interior by using different opacities [5]. Finally, we compare our metallicity predictions to a number of planets for which spectroscopic observations exist, such as WASP-39b [6].

Overview

Giant planets are important astrophysical objects as they shape planetary systems. We aim at understanding their formation processes and evolution scenarios of planetary systems. Basic correlations such as that between the planetary heavy element mass (M_Z) and the stellar metallicity [Fe/H] [1,2] are key in this context.

In general, we determine the core mass M_{core} of the planet as a representative of the heavy element mass by the combination of atmosphere, structure, and evolution calculations. Structural models require an atmosphere model as an outer boundary condition. The atmosphere model describes the coupling between the convective interior and the stellar radiation field, acting like a bottleneck: intrinsic fluxes and fluxes from the parent star need to be processed. In particular, the radiation transport through the atmosphere influences the cooling of the planet during the evolution and thus the present interior structure. Connecting the atmosphere model to the interior model as a function of assumed intrinsic heat loss and core mass leads to the possible present structure of the planet [8,9,10]. As a consequence, the key parameter, the predicted metallicity, depends highly on the planets' thermal structure.

As a typical example for a young hot Jupiter, we investigate the transition region between atmosphere and interior of WASP-10b [7], by using different opacities, e.g. constant values or Rosseland mean opacities and their analytical fits [5]. Furthermore, we calculate atmospheric profiles with and without clouds based on a semi-analytical atmosphere model [3,4] for several planets, e.g. WASP-39b [6]. We then compare the derived key parameter, the core mass of the planet, to spectroscopic observations of giant planets.

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