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Giant Planet Formation and Evolution with a Self-consistent Treatment of the Heavy Elements

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Abstract

In the standard model for giant planet formation, the planetary growth begins with the accretion of solids (heavy elements) followed by a buildup of a gaseous atmosphere as more solids are accreted, and finally, by a rapid gas accretion. The interaction of the solids with the gaseous envelope determines the subsequent planetary growth and the final internal structure. In this work, we present a new formation and evolution model for giant planets, based on the stellar evolution toolkit Modules for Experiments in Stellar Astrophysics (MESA). We include routines that treat planetesimal ablation, the deposition of heavy elements (including composition gradients), and gas accretion, and are able to model the planetary growth from early stages, and evolve it to present-day. The effect of envelope enrichment on the planetary growth, evolution and structure are computed self-consistently. First, we compare our results to standard models where all the solids are assumed to join the core, leaving a pure H-He envelope. We next consider different planetesimal compositions and sizes, various treatments of mixing in the envelope as well as different mixing-length coefficients, and investigate their effect on the inferred evolution and internal structure of the planet.