Interior Structure Models of Solid Exoplanets

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The growing number of transiting planet discoveries will allow us to characterize rocky exoplanets in terms of their internal structure and atmospheric composition. This has important implications for their formation, orbital evolution, and possible habitability [1]. Mass and radius of planets transiting their host stars are provided by radial velocity and photometric observations. Structural models of solid exoplanet interiors are constructed by using equations of state for the radial density distribution, which are compliant with the thermodynamics of the high-pressure limit [2]. The radial thermal structure of low-mass exoplanets can be calculated by using a mixing length approach based on considerations that Stokes' viscous drag is locally balanced by buoyancy forces [3]. Whereas lateral variations of surface temperature do not strongly affect the thermal state of their deep interiors, the lowermost mantle is in a sluggish convection regime owing to pressure effects on viscosity [4]. However, present models of the thermal state are challenged by the imperfect knowledge of depth-dependent transport properties such as thermal conductivity and viscosity. Interior structure models of low-mass exoplanets suffer from non-uniqueness because of their unknown differentiation state, and/or the possible presence of an optically thick atmosphere, and the extrapolation of equations of state of mineral phase assemblages to extremely high pressures [5]. Further uncertainties are related to pressure-induced mantle phase transitions, the stability field of post-perovskite, the possible presence of additional high-pressure silicate phases, and the physical state of core iron alloys [6]. This has implications for mass-radius relationships as shown in Fig.1 and their usage for the characterization of low-mass exoplanets in terms of interior structure and bulk composition and the possible existence of self-sustained magnetic fields. Owing to the variable slope of mass-radius relations, planetary mean density in the upper mass range is mainly constrained by precise radius determinations, whereas mass and radius pose equally important constraints on structural models of low-mass rocky planets.

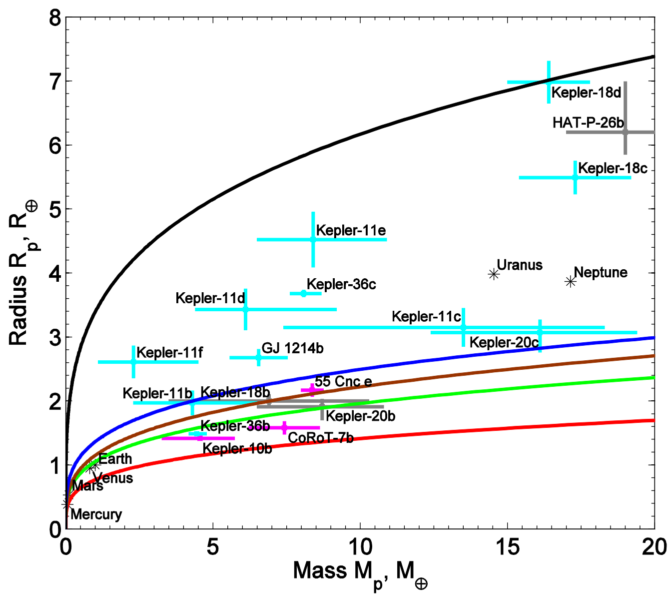

Figure 1: Mass–radius relationships of low-mass exoplanets with surface temperature ranges from 500 to 1000 K (cyan); 1000 to 1500 K (grey); 1500 to 2000 K (magenta). The model curves represent homogeneous, self-compressible solid spheres of hydrogen (black), water ice (blue), carbon (brown), silicate rock (green), and iron (red).

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