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The tidal response of Earth-size exoplanets: from Venus-like planets to Ocean-planets

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The amount of detected planets with size comparable to the Earth increases drastically. Most of the Earth-size planet candidates orbit at close distances from their central star, and therefore are subjected to large tidal forcing. Accurate determination of the tidal parameters of exoplanets taking into account their interior structure and rheology is essential to better constrain their rotational and orbital history, and hence their impact on climate stability and planetary habitability.

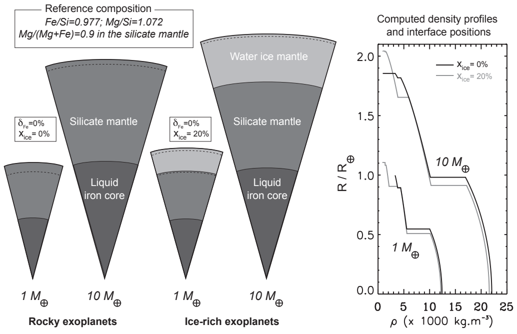

Figure 1: *Computed interior structure for a given mass and bulk composition. The bulk composition is defined relative to a reference composition corresponding to the solar value for the Fe/Si and Mg/Si ratio and to the terrestrial value for the Mg/(Mg+Fe) ratio in the silicate mantle. For rocky planets, the water ice mass ratio is 0%, while it can reach values up to 50% for ice-rich planets. For the examples shown here, an ice mass ratio of 20% is considered and planet masses of 1 and 10 M⊕ are displayed. The interior structure is divided in three main layers: ice mantle, rock mantle and iron core. The dashed lines indicate the separation between the low-pressure and high-pressure phases for both ice and silicate mantle.*

In a first study, we have computed the tidal response of rocky and ice-rich solid exoplanets for masses ranging between 0.1 and 10 Earth masses using a multilayer approach and an Andrade rheology[1] (Figure 1). We showed that the amplitude of tidal response, characterized by the gravitational Love number, k_2, is mostly controlled by self-gravitation and increases as a function of planet masses. For rocky planets, k_2 depends mostly on the relative size of the iron core, and hence on the bulk iron fraction. For ice-rich planets, the presence of outer ice layers reduces the amplitude of tidal response compared to ice-free rocky planets of similar masses. For both types of planet (rocky and ice-rich), we proposed relatively simple scaling laws to predict the potential Love number value as a function of radius, planet mass and composition. For the dissipation rate, characterized by the Q^{-1} factor, we did not find any direct control by the planet mass. The dissipation rate is mostly sensitive to the forcing frequency and to the internal viscosity, which depends on the thermal evolution of the planet, controlled by the planet mass and composition.

In this first approach, we did not consider the possible presence of external fluid envelops (dense atmosphere, magma ocean or liquid water ocean), which may significantly influence the tidal response of underlying solid interiors as well as the long-term rotation evolution of the body [2, 3]. Following the approach of [4], we compute the tidal response of the solid part by considering external fluid enveloppes of various vertical extensions and masses (Venus-like atmospheres, extended hydrogen atmosphere, liquid water oceans, magma oceans etc.). Parameterization of the global gravitational Love number (including the fluid envelop) as well as the load Love number (describing the solid response to surface loading of the fluid envelop) are then derived for various internal structures and fluid envelop configurations. This new parameterization of the Love numbers for stratified interiors is finally used to describe the tidal torques including both fluid and solid tides following the approach of [3].

References

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