EPSC Abstracts
Vol. 10, EPSC2015-594, 2015
European Planetary Science Congress 2015

Tidal constraints on the interior of Venus

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Abstract

As a prospective study for a future exploration of Venus, we propose to systematically investigate the signature of the internal structure in the gravity field and the rotation state of Venus, through the determination of the moment of inertia and the tidal Love number.

1. Context

Although Venus is very similar in size and mass to the Earth (and therefore often referred to as its twin sister), their internal structures might differ in several ways. Indeed, the lack of plate tectonics as means to expel heat probably leads to a hotter interior for Venus. As a consequence, Venus's core should be at least partially, and maybe entirely, molten. The determination of the tidal Love number k_2 from Magellan data by [1] seems indeed to confirm the presence of a fluid core. However, there is little to constrain the core mass : Cosmochemical models ([2]) suggest core mass fractions between 23.6 and 32.0% implying a mantle mass proportionately similar to or greater than Earth's. The Venera landers returned a number of K, U and Th measurements that imply bulk ratios, and hence internal radiogenic heating rates, comparable with Earth. As the moment of inertia of the planet is not known, the first order internal structure depicted for Venus is often just a scaled version of the Earth's one. In addition, the Venus Express Mission measured a variation in the venusian length-of-day [3] that could bring information on the interior. However, the rotational models were not able to explain this large variations [4].

2. Mantle composition and core state

We test various mantle compositions, core size and density as well as temperature profiles representative of different scenarios for formation and evolution of Venus. The mantle density ρ and seismic v_P and v_S wavespeeds are computed in a consistent manner from given temperature and composition using the Perple_X program [5]. This method computes phase equilibria and uses the thermodynamics of mantle minerals developped by [6].

3. Computation of tidal deformation

The viscoelastic deformation of the planet interior under the action of periodic tidal forces are computed following the method of [7]. The Poisson equation and the equation of motions are solved for small perturbations in the frequency domain using a compressible viscoelastic rheology. The Love number k_2 and the dissipation function, Q^{-1} are computed by integrating the radial functions associated with the radial and tangential displacements, the radial and tangential stresses, and the gravitational potential, as defined by [8]. The deformation of the liquid core is assumed to be static, and the simplified formulation of [9] is thus employed.

4. Love number and moment of inertia

For a variety of interior models of Venus, the Love number, k_2, and moment of inertia factor, I/MR^2, will be computed following the method described above. The objective is to determine the sensitivity of these synthetic results to the internal structure. These synthetic data will be used to infer the measurement accuracies required on the time-varying gravitational field and the rotation state (precession rate, nutation and length of day variations) to provide useful constraints on the internal structure.

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