EPSC Abstracts
Vol. 12, EPSC2018-856, 2018
European Planetary Science Congress 2018

Tidal response of Venus-like planets: Interior structure, composition and rotational evolution

Caroline Dumoulin (1), Emeline Bolmont (2), Gabriel Tobie (1), Olivier Verhoeven (1), Pascal Rosenblatt (3) and Nicolas Rambaux (4)

(1) Laboratoire de Planétologie et Géodynamique, Université de Nantes, UMR-CNRS 6112, France (2) Laboratoire AIM Paris-Saclay, CEA/Irfu Université Paris Diderot CNRS/INSU, Gif-sur-Yvette, France (3) Géoazur - Université Nice Sphia-Antipolis, France (4) Université Pierre et Marie Curie, Institut de Mécanique Céleste et Calcul des Ephémérides, Paris, France (caroline.dumoulin@univ-nantes.fr)

Venus rotates very slowly on its axis in a retrograde direction, opposite to that of most other bodies in the Solar System. This peculiar configuration is likely the result of a progressive despinning driven by tidal torques exerted by both the rocky interior and the massive atmospheric layers [1, 2]. A variety of rocky exoplanets in the habitable zone of their stars may experience tidal interactions comparable to Venus [3]. It has been shown that the competition between gravitational and thermal tides determine the final equilibrium configuration of the planet [2, 3]. However, the models developed to study these competitive processes considered simplified formulation for the internal tides.

We compute the tidal response of Venus' interior assuming various mantle compositions and temperature profiles representative of different scenarios of Venus' formation and evolution. The mantle density and seismic velocities are modeled from thermodynamical equilibria of mantle minerals and used to predict the moment of inertia, Love numbers and tide phase lag characterizing the signature of the internal structure in the gravity field. The viscoelasticity of the mantle is parameterized using an Andrade rheology. From the models considered here, the moment of inertia lies in the range of 0.327 to 0.342, corresponding to a core radius of 2900 to 3450 km. We show that both composition and rheology of the mantle strongly influence the tidal response of the interior. The amplitude of tidal deformation (k_2) is mostly sensitive to the interior composition (mantle mineralogy and iron core size), while the mantle viscosity mostly controlled the tidal dissipation function (Q).

Moreover, we show that, due to the anelasticity effects, the possibility of a completely solid metal core inside Venus cannot be ruled out based on the available estimate of k_2 from the Magellan mission [4]. A Love number k_2 lower than 0.27 would indicate the presence of a fully solid iron core while, for larger values, solutions with an entirely or partially liquid core are possible. Precise determination of the Love numbers, k_2 and h_2, together with an estimate of the tidal phase lag, by a future exploration mission will allow determining the state and size of the core, as well as the composition and viscosity of the mantle. These measurements will provide useful constraints for determining the most probable evolution scenario of Venus.

In order to test the influence of interior composition and state on the rotational evolution of Venus, we implement the computation of interior tidal response (k_2, Q) together with a parameterization of thermal atmospheric tides in an orbital code [5]. We investigate which initial conditions, interior composition and thermal state can reproduce the present-day rotational state. As a prospective study for Venus-like exoplanets, we then perform similar calculations for planets with different initial orbital configuration, various atmospheric mass (more or less massive than Venus'), mantle iron content and internal temperature. The goal of this study is to quantify how sensitive is the tidal evolution of Venus-like planets to the interior and atmospheric properties.

References

[1] Correia, A. C. M. & Laskar, J. 2001, Nature, 411, 767

[2] Auclair-Desrotour, P., Laskar, J., Mathis, S. & Correia, A. C. M. 2017. Astronomy & Astrophysics, 603, id.A108, 5 pp.

[3] Leconte, J., Wu, H., Menou, K., & Murray, N. 2015, Science, 347, 632

[4] Konopliv, A., & Yoder, C. 1996, Geophys. Res. Lett., 23, 1857–1860

[5] Bolmont, E., Gallet, F., Mathis, S., Charbonnel, C., Amard, L. & Alibert, Y. Astronomy & Astrophysics, 604, id.A113, 13 pp.