EPSC Abstracts
Vol. 8, EPSC2013-603, 2013
European Planetary Science Congress 2013

Titan's interior from Cassini-Huygens

G. Tobie (1), R.-M. Baland (1), A. Lefevre (1), J. Monteux (1), O. Cadek (2), G. Choblet (1), G. Mitri (3)
(1) University of Nantes, CNRS, Laboratoire de Planétologie et Géodynamique de Nantes, France; (2) Charles University, Department of Geophysics, Prague, Czech Republic; (3) Istituto di Astrofisica e Planetogia Spaziali, Instituto Nazionale di Astrofisica, Roma, Italy (gabriel.tobie@univ-nantes.fr / Fax:+33-2-51125268)

Abstract

The Cassini-Huygens mission has brought many informations about Titan that can be used to infer its interior structure: the gravity field coefficients (up to degree 3, [1]), the surface shape (up to degree 6, [2]), the tidal Love number [1], the electric field [3], and the orientation of its rotation axis [4]. The measured obliquity and gravity perturbation due to tides, as well as the electric field, are lines of evidence for the presence of an internal global ocean beneath the ice surface of Titan [5,1,3]. The observed surface shape and gravity can be used to further constrain the structure of the ice shell above the internal ocean. The presence of a significant topography associated with weak gravity anomalies indicates that deflections of internal interface or lateral density variations may exist to compensate the topography.

To assess the sources of compensation, we consider interior models including interface deflections and/or density variations, which reproduces simultaneously the surface gravity and long-wavelength topography data [6]. Furthermore, in order to test the long-term mechanical stability of the internal mass anomalies, we compute the relaxation rate of each internal interface in response to surface mass load. We show that the topography can be explained either by defections of the ocean/ice interface or by density variations in an upper crust [6]. For non-perfectly compensated models of the outer ice shell, the present-day structure is stable only for a conductive layer above a relatively cold ocean (for bottom viscosity $> 10^{16}$ Pa.s, $T < 250$ K). For perfectly compensated models, a convective ice shell is stable (with a bottom viscosity lower than 10^{15} Pas) if the source of compensation is due to density variations in the upper crust (2-3 km below the surface). In this case, deep gravity anomalies are required to explain the observed geoid. Our calculations show that the high pressure ice layer cannot be the source of the residual gravity anomalies. The existence of mass anomalies in the rocky core is a most likely explanation. However, as the observed geoid and topography are mostly sensitive to the lateral structure of the outer ice shell, no information can be retrieved on the ice shell thickness, ocean density and/or size of the rocky core.

Constraints on these internal parameters can be obtained from the tidal Love number and the obliquity. To derive the possible density profile, the obliquity is computed from a Cassini state model for a satellite with an internal liquid layer, each layer having an ellipsoidal shape consistent with the measured surface shape and gravity field [7]. We show that, once the observed surface flattening is taken into account, the measured obliquity can be reproduced only for internal models with a dense ocean (between 1275 and 1350 kg.m^{-3}) above a differentiated interior with a full separation of rock and ice [7]. We obtain normalized moments of inertia between 0.31 and 0.33, significantly lower than the expected hydrostatic value (0.34). The tidal Love number is also found to be mostly sensitive to the ocean density and to a lesser extent the ice shell thickness.

By combining obliquity and tidal Love number constraints, we show that the thickness of the outer ice shell is at least 40 km and the ocean thickness is less than 100 km, with an averaged density of 1275-1350 kg.m^{-3}. Such a high density indicates that the ocean may contain a significant fraction of salts. Our calculations also imply that there is a significant difference of flattening between the surface and the ice/ocean interface. This is possible only if the ice layer is viscous enough to limit relaxation, as indicated above. This is also consistent with an ocean enriched in salts for which the crystallization point can be several tens of degree below the crystallization point of pure water system. The elevated density (> 3800 kg.m^{-3}) found for the rocky core further suggests that Titan might have a differentiated iron core. The rocky core is likely

fully dehydrated at present, suggesting warm conditions during most of its evolution. All the water contained in the deep interior has probably been expelled to the outer regions, thus potentially explaining the salt enrichments.

Acknowledgements

The research leading to these results has received funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013 Grant Agreement no. 259285), from the Conseil Régional des Pays de la Loire, France, and from the Agence Nationale de Recherche (Accretis decision n^o ANR-10-PDOC-001-01).

References

[1] Iess, L. et al., 2012. The Tides of Titan. Science, Vol 337, 457-460.

[2] Mitri, G. et al. 2013. Shape, Topography, Gravity Anomalies and Tidal Deformation of Titan, Icarus, submitted

[3] Béghin, C. et al. 2012. Analytic theory of Titan's Schumann resonance: Constraints on ionospheric conductivity and buried water ocean. Icarus, 218, 1028-1042.

[4] Stiles, B.W. et al. 2010. ERRATUM: "Determining Titan's Spin State from Cassini Radar Images". Astron. J. 139, 311. 10.1088/0004-6256/135/5/1669.

[5] Baland, R.-M. et al. 2011. Titan's obliquity as evidence of a subsurface ocean? Astronomy and Astrophysics, 530, A141.

[6] Lefevre, A. et al. 2013. Titan's outer ice shell structure and dynamics constrained by Cassini data, Icarus, submitted.

[7] Baland, R.-M. et al. 2013. Titan's internal structure inferred from its gravity field, shape and its spin state, Icarus, submitted.