TIDAL RESPONSE OF TITAN'S INTERIOR MODELS CONSISTENT WITH CASSINI-DERIVED CONSTRAINTS. J. C. Castillo-Rogez[1] and J. I. Lunine[2], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena 91109, CA, Julie.C.Castillo@jpl.nasa.gov; [2]Astronomy Department, Cornell University, 402 Space Science Building, Ithaca 14853, NY, JLunine@astro.cornell.edu.

Introduction: The gravity science experiments led by the *Cassini* radio science team at Titan have yielded important constraints on Titan's interior structure, in the form of the mean moment of inertia [1]. Cassini data also provide the possibility of constraining the tidal Love number k_2 [2]. Tidal Love numbers are functions not only of the density profile, but of the mechanical properties of the interior. Thus k_2 is a key constraint on the internal structure, which then traces back to the formation and thermal evolution of the satellite. In particular, that information would be extremely helpful to distinguish between the different models proposed so far to explain the relatively large moment of inertia [1]. One "mixed ice-rock" model [3] interprets this information as evidence for limited ice melting and separation of the rock phase from the ice. An alternative "hydrated core" model [4] suggests that the water is in the form of water of hydration, i.e., trapped in the silicate structure as a consequence of an early phase of aqueous alteration. Each model implies very different assumptions on the formation of Titan: slow and late accretion in the former case, rapid and/or early accretion, involving short-lived radioisotope heating in the latter. The goal of this paper is to identify to what extent the tidal Love number, as well as the dissipation factor if it can be measured, can help distinguish between the two models.

Interior Models: The two models are sketched in Figure 1. These interpretations of the moment of inertia do not bring direct constraints on the presence or absence of a deep ocean. However, other observations – geological [5], Schumann resonance [6], and dynamical [7] – suggest the presence of a 50 to 100 km thick shell overlaying a deep ocean.

For these two models we used a new, laboratory-based dissipation model [11, 12] accounting for material anelasticity. This is a major diference with previous calculation of Titan's Love number [2] that have assumed that Titan's material response to tidal forcing can be approximated with the Maxwell model.

The hydrated core model [4] includes an FeS-Fe core, a large mantle of hydrated silicates that is in the process of dehydrating, a small (<150 km) high-pressure layer [8], a thick ocean with a density increased by leaching from the rock as a consequence of aqueous alteration [9], and an outer icy shell. The density of the ocean is uncertain as it depends on the thermal and redox conditions during hydrothermal activity

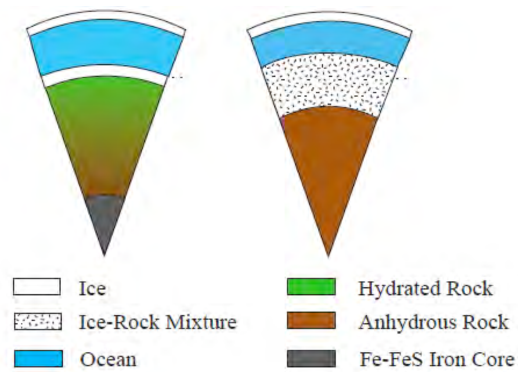

Figure 1. The two interior models proposed so far to interpret the moment of inertia data inferred by [1]. Left: Hydrated core model by [3]. Right: Partially molten model [4]. The laver thicknesses are about to scale.

and the role of CO_2 and ammonia in determining the resulting chemistry. In absence of constraints we range the density of the ocean between a lower bound assuming a pure water ice composition, and an upper bound assuming saturation of the ocean in sulfur-rich species.

The "mixed ice-rock" model is stratified into an anhydrous rocky core, a thick layer of ice mixed with rock, and an icy water shell that may contain a deep ocean. That type of interior structure would have to rely on convection in the ice-rock layer in order to promote rapid heat transfer and limit melting. This aspect remains to be modeled and account for the impact of tidal dissipation considering that the low-viscosity promoting solid state convection in the ice-rock layer is likely to imply increased dissipation and promote rapid decay of Titan's eccentricity.

A key difference between the two models is the density that should be expected for the deep ocean, if present. Castillo et al. [10] showed, in the case of Europa, that the dependence of the tidal Love numbers on the ocean density is a factor five greater than the dependence of these parameters on the outer shell thickness. In the case of the hydrated core model, the ocean is thick and and its density is large. In the case of the mixed ice-rock model, little enrichment of the ocean in impurities is expected. The presence of ammonia may actually decrease somewhat the density, assuming that this model is viable when including a few percent ammonia (which has not been studied in detail yet).

Key Results and Implications: The calculation of k_2 and the dissipation factor for an example of interior structure for the hydrated core model is presented in Figure 2. Consistently with previous calculation [10], the value of k_2 increases with increasing ocean density and is as high as 0.59 in this case – as a reference, for a pure water ocean, and neglecting the effect of pressure on the ocean density, the maximum value of k_2 is 0.48 [2]. In the case of the mixed ice-rock model, the tidal Love number can also become as large as 0.6 due to the increased deformation of low-viscosity, ice-rich layers. However, in that model the dissipation factor is between 5 and 50 for the range of viscosities for which convection is most efficient at transferring heat and keeping the interior undifferentiated. For the hydrated core model the dissipation factor remains greater than 50 (e.g., Fig. 2) and the impact of tidal dissipation on orbital evolution is expected to be limited.

We will present results obtained for a broad parametric space and discuss to what extent the accuracy expected on the *Cassini* gravity data will help discriminate between the two models.

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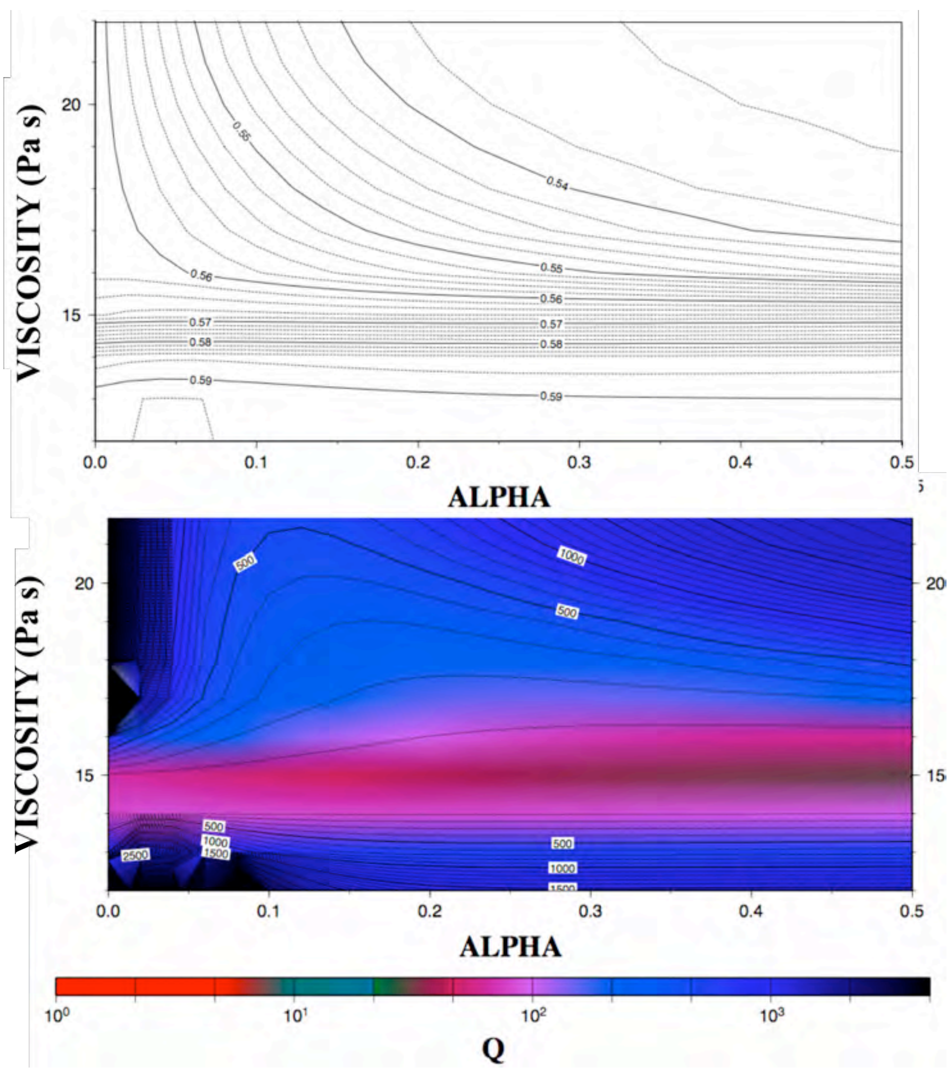

Figure 2. Tidal Love number (top) and dissipation factor (bottom) for a model of Titan with a core dominated by hydrated silicates. The results are presented as a function of the viscosity of the outer icy shell and a parameter alpha that quantified the degree of heterogeneity of the ice. Experimental measurements generally indicate that alpha is between 0.1 and 0.3 [12]. In this example, the ocean density is 1250 kg/m^3.