EXPECTED CONSTRAINTS ON RHEA'S INTERIOR FROM CASSINI.

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Introduction: We model the interior of Rhea based on observational constraints and the results from geodynamical models available in the literature. Ten main types of models are defined, depending on the presence or absence of a high-pressure ice layer (ice II), and the extent of separation of the rock component from the volatiles. We present degree-two gravity components computed for each of these models in order to assess which properties of the interior are likely to be inferred from Cassini radio science measurements scheduled on November 26, 2005 [1].

State of Knowledge: Rhea is a medium-sized icy satellite with a radius (R) of 718 km and a mean density of 1240±36 kg/m^3 [2]. Photogeology observations by Voyager show no recent geological activity expressed at its surface [3] and high crater density versus little resurfacing (especially for craters smaller than 30 km in diameter). The presence of smooth plains material close to the equator indicates that the satellites has undergone partial resurfacing in a later stage. Compressive features are also identified by [4] as megaridges and megascarps developed posterior to the formation of the cratered terrains.

Thermal evolution models published in the '80s conclude that the energy budget of Saturn's medium-sized satellite does not allow for important melting of the satellite (*e.g.*, [5, 6]), apart from the outermost 10 to 100 km [5]. Models including ammonia hydrates and salts of chondritic origin mixed with water (*e.g.*, [7, 8]) conclude to more melting and advanced partial differentiation.

We consider ten different models that differ by (a) the extent of differentiation, (b) the rock phase density, ranging from 2700 kg/m^3 to 3600 kg/m^3, depending on the degree of hydration, (c) the presence of absence of ice II. The pressure and temperature [5] inside Rhea are suitable for ice II to crystallize and this might be in part responsible for compression features identified at the surface of the satellite [4]. However, the relationship between these features and ice II crystallization is not clearly understood, and the presence of this high-pressure ice component has been questioned by [5]. Models are presented in Figure 1. These models do not include a metallic core as thermal evolution studies concur that not enough energy was available for separation of metals from the rock component.

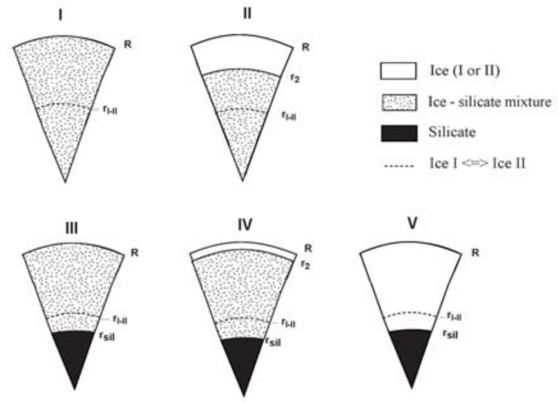

Fig 1. Models of Rhea's interior.

Interior Modeling: We compute ice I density profile after the equation of state presented in [9] using temperature profile calculated by [5]. As ice II equation of state if poorly known, we set its density to 1200 kg/m^3, based on the different sources of information available in the literature. Self-compression in the rock phase component is negligible. Further details about Rhea's interior modeling is presented in [10].

Results: Degree-two gravity coefficient C_{22} are computed assuming hydrostatic equilibrium, as suggested by [1]. We plot C_{22} as a function of the rocky core radius for models containing ice II and for a rock density of 3200 kg/m^3 in Figure 2. Results are compared to the predicted errors on the measurement of C_{22} simulated by [1]: an absolute accuracy of $1\text{x}10^{-6}$ to $7\text{x}10^{-6}$, *i.e.*, a relative accuracy of 0.5 to 3.5%. Figure 2 also encloses the error bar on the calculation of C_{22}, due to uncertainties on the density profile. The latter are due to the poor knowledge of the equation of state of ice II and of the temperature profile.

- If $2.63\text{x}10^{-4} \leq C_{22} \leq 2.80\text{x}10^{-4}$: the body is undifferentiated. This implies that there has not been enough energy available during the history of this satellite to allow for melting of the ice phase and the consequent segregation of the rocky material, and to balance heat transfer through subsolidus convection. This also provides some constraint on the presence and the role of ammonia hydrates and other contaminants.

- If C_{22} is close to 2.80×10^{-4}: the satellite is homogeneous, apart from slight density increase due to self-compression. This implies that conditions are not suitable for ice II to be stable.
- If $1.67 \times 10^{-4} \leq C_{22} \leq 1.90 \times 10^{-4}$: this is the indication of the presence of a rocky core, whose radius can be determined from the satellite's mass and ices densities, for a given temperature profile. The uncertainty in the measurement of C_{22} of 4×10^{-6} leads to an uncertainty in the determination of the core radius of 20 to 90 km.
- If $C_{22} \leq 1.67 \times 10^{-4}$: this indicates either that the density of the rock phase is higher than the maximum value considered in this study, or that there is separation of iron from the rock phase to form an iron core.
- In the interval between the extreme values (1.67×10^{-4} and 2.80×10^{-4}) , we have a large uncertainty in the characteristics of Rhea's internal structure, unless we choose an *a priori* model for the satellite. Further assumptions on the rock phase density and the presence or absence of ice II might be necessary to narrow the field of possible models.

We expect other observations obtained by Cassini to provide constraints on the nature of the rock component of the Saturnian satellites (*e.g.*, [11]), although it is possible that it has evolved from its original state, for example through hydrothermal metamorphism. Quantification of past extensive and compressive geological processes inferred from high-resolution imaging by Cassini will help understand endogenic processes and thermal evolution, such as the succession of partial melting and refreezing events, as well as the potential role of volatiles such as ammonia hydrates.

Conclusion. Constraining Rhea's interior from gravity measurements is crucial for understanding the thermal evolution of this satellite. Based on current information, most of the ten models cannot be distinguished from each other. However, assumptions on the density of the rock phase, presence or absence of ice II, and the degree of differentiation could allow a unique model to be determined in many cases.

These new information for Rhea will be of high interest for understanding the interior and thermal evolution of the other medium-szed satellites of Saturn.

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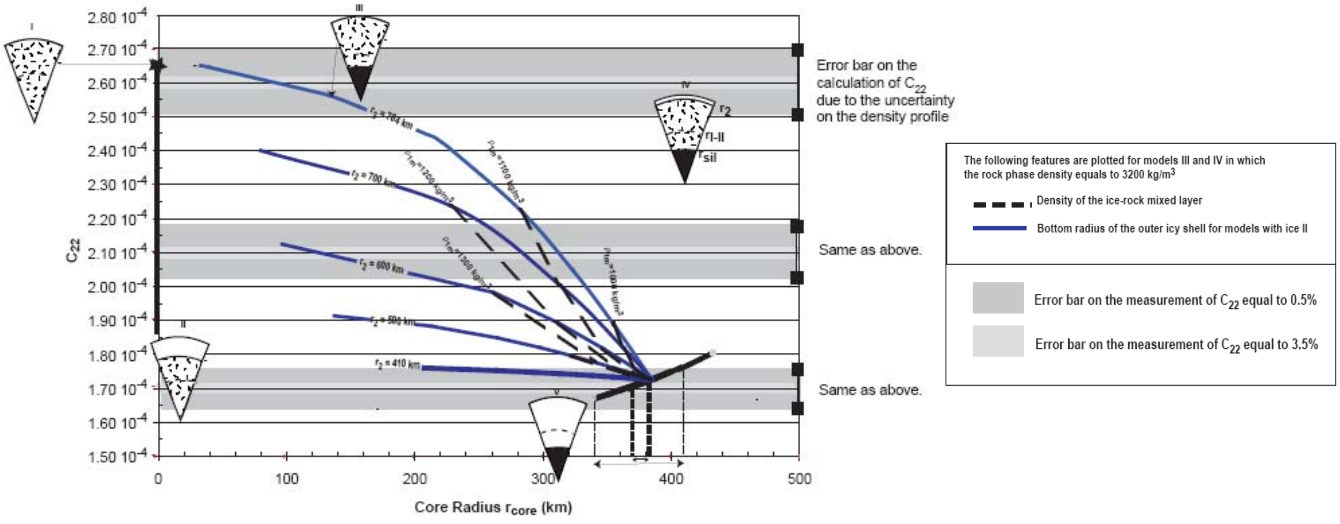

Fig. 2. Variations of C_{22} as a function of the core radius and the bottom radius of the outer icy shell.