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Including Cassini's Gravity Measurements from the Flybys E9, E12, E19 into Interior Structure Models of Enceladus

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Abstract

New gravity measurements confirmed that Enceladus possesses a local liquid water ocean beneath the South Polar Terrain (SPT) [2]. We will present new estimations about physical conditions at the water/rock-boundary and about geochemical processes taking place in this area.

1. Introduction

Due to the lack of proper measurements, the specific inner structure of Enceladus was unknown. There was a huge debate about Enceladus having a local or even global liquid water ocean as source of the plumes detected by Cassini [3]. Finally, Iess et al. presented the results of the gravity measurements made during three close flybys (E9, E12, E19)[2]. The authors reported the values for the largest quadrupole harmonic coefficients ($10^6 J_2 = 5435.2 \pm 34.9$, $10^6 C_{22} = 1549.8 \pm 15.6$, $1\,\sigma$) and their ratio ($J_2/C_{22} = 3.51 \pm 0.05$), which leads to a moment of inertia of around $0.335\,MR^2$ [2].

Furthermore, caused by gravity anomalies at the SPT, Iess and his colleagues concluded that a regional subsurface liquid water sea is very likely extending from the south pole to roughly 50° south latitude. It may have a thickness of about 10 km and is overlaid by an ice layer 30 to 40 km thick.

2. New Estimations

To conclude, the new findings point towards a larger rocky core than previously assumed caused by its smaller density. Prior to the study of Iess et al., the core density was assumed to be between 2 500 to 3 527.5 $kg\,m^{-3}$ [1, 4]. Therefore, the pressure at the core/liquid water-boundary is likely to be significantly lower than estimated in former studies [5]. Based on our model, the pressure should be between 20 and 30 bar, which is a pressure range quite suitable for certain terrestrial microbes to propagate. For our model, we divide Enceladus into two layers (low-density silicate core and water ice layer), whereby a parabolic liquid water reservoir is embedded into the icy layer at the southern region of the moon under a 30 to 40 km thick ice layer. Caused by the low mass of Enceladus and the resulting low radial pressure values, the density can be assumed to be constant within a certain layer.

3. Interaction between the rocky core and the water aquifer

The low-density silicate core is in direct contact to the liquid water reservoir [2]. Therefore, low temperature interactions between these layers are reasonable. One of these processes may be serpentinization. Here, mafic rocks like olivine become transformed to serpentine accompanied by the production of H_2. We will assess the ratio of mafic rocks in the core to estimate the potential H_2-production rate. However, Cassini detected H_2 in the plume material, but it seems likely that this compound was produced by "dissociation of H_2O and CO_2 through hypervelocity impact on, and reaction with, the walls of the INMS antechamber"[6]. However, H_2 is known to be a substrate for several terrestrial microbes. Therefore, if serpentinization would deliver a significant amount of H_2, then the lack of molecular hydrogen in the plume composition may be an indirect indication of extraterrestrial life within Enceladus.

4. Summary

Based on new data about Enceladus' gravity field, we will present new estimations about the physical and geochemical conditions at the core/mantle-boundary between the low density silicate core and the confirmed subsurface water aquifer. We will focus on serpentinization associated with the potential H_2-production rate.

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