Enceladus: A Hidden World

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May 1, 2014

1 Introduction

Enceladus is an icy world orbiting Saturn and, from recent observations, may be a new frontier for space exploration and astrophysical research. It is a relatively small moon with a cross sectional size of England's area. Despite its small size, it is uniquely interesting as the first body discovered to have ice jets shooting from geyser-like openings. Does Enceladus in fact have a subsurface ocean and one that is capable of hosting life? Based on direct observations and numerical analyses, it is very likely that Enceladus have a reservoir of liquid water beneath its icy crust.

2 The South Polar Region

Very little was known about Enceladus until 2005, when the Cassini-Huygens spacecraft imaged details of Enceladus' surface for the first time. Enceladus featured a region, later to be known as the 'tiger stripes,' in the southern hemisphere where water ice jets seem to be erupting from. Whereas most of Enceladus' surface is composed of granular fine ice, the site of the cryovolcanic activities are primarily composed of crystalline ice due to geological activity and higher temperature. The south polar region is also the location of a detected hemisphere, which formed from the material ejected by the jets. Analyses concluded that the atmosphere is composed of approximately 91 percent water vapor and is a major source of Saturn's E Ring. The peculiarities of these region indicates a differentiated body and the existence of a subsurface ocean inside the southern hemisphere.

3 Cryovolcanism and Internal Mechanisms

The observed cryovolcanic activities are indicative of an active interior. A form is heating mechanicsm would most likely be necessary to maintain a subsurface liquid water ocean, if such an ocean is indeed responsible for the ice jets. Tidal heating can easily be present to provide the necessary energy source that would support the ocean. Tidal forces on Enceladus arise from its interaction with

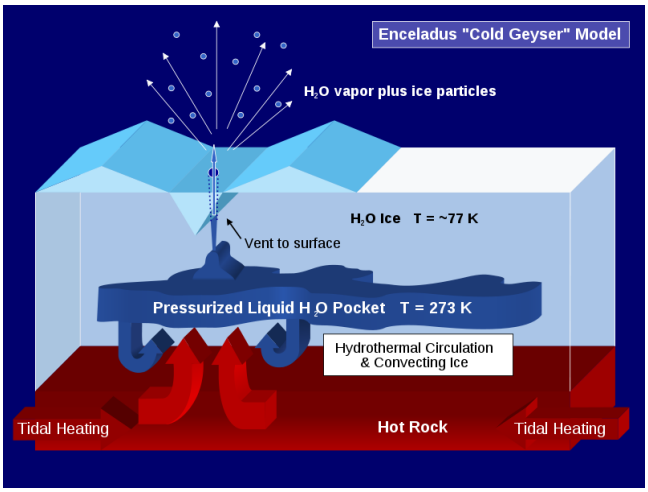

Figure 1: A schematic drawing of the possible underlying mechanisms in the interior of Enceladus. Tidal heating support a dynamic magma mantle which provides thermal circulation for a layer of liquid water ocean above and the resulting cryovolcanism. Source: wikipedia.org/wiki/Enceladus

nearby bodies such as Saturn and Dione. The thermal energy from the tidal forces can differentiate the interior by heating up the mantle, creating a bed of magma. Such an active interior generate energy circulation upwards towards the surface. Between the water ice crush and the magma mantle would be a layer in which temperatures and conditions would favor the existence of a liquid water ocean. This active ocean would in turn release energy through cracks in the form of the observed cryovolcanic activities, releasing water ice among other substances. Organic compounds such as methane, propane, acetylene, and other hydrocarbons have been detected near areas with cryovolcanic activity.

4 Gravitational Data and Analysis

Recent gravitational data analysis further supports the theory of the subsurface liquid water ocean. The Cassini-Huygens spacecraft returned values of the gravitational force acting on it during it recent Enceladus flybys. The spacecraft measured gravitational perturbations that arise from irregularities within Enceladus. Gravitational Doppler Effects induce a slightly perturbed velocity of the spacecraft and this change in velocity can be measured as radio signals from instruments on Earth. The effect can be measured with great precision - the effected velocity is small as 90 micrometers per second. From observations of a surface depression in the south polar region, there would be an expected gravitational anomaly in measurements. The measured values corresponding to the anomaly are not as relatively negative, compared to the rest of Enceladus,

as would be expected of an uniformly dense interior. The gravitational potential of a body is:

$$V = \frac{GM}{r}[1 - \sum_{l=1}^{\infty} J_{2l}\left[\frac{a}{r}\right]^{2l} P_{2l}cos(\theta)] \tag{1}$$

where $P_{2l}cos(\theta)$ are the Legendre polynomials and $J_{2l}\left[\frac{a}{r}\right]^{2l}$ are the gravitational moments of inertia. The general form of the potential, as derived as the solution to Laplace's Equation, is:

$$V = \frac{1}{a}[\sum_{l=1}^{\infty}\sum_{m=0}^{l}\left[\frac{a}{r}\right]^{l+1}(C_{lm}cos(m\phi) + S_{lm}sin(m\phi))P_l^m cos(\theta)] \tag{2}$$

where C and S are coefficients of the spherical harmonics and ϕ is the azimuthal angle denoting longitude. A ratio of $\frac{J_2}{C_{22}} = 3$ would indicate a body in hydrostatic equilibrium. The measured value of this ratio is around 3.51, which is indicative of a differentiated body. The interior of the southern hemisphere is therefore extrapolated to be approximately seven percent more dense than the surface ice. The existence of a hidden liquid water ocean in the southern hemisphere would fill the gaps of the data analyses; it is in correspondance with the values derived with the gravitational analysis and with the measured Doppler Effects.

5 Conclusion

Enceladus is looking quite promising as a frontier worth exploring. Due to observations and the aforementioned data analyses, it is highly likely that a stable liquid ocean water exists beneath the surface. The possibility of it as a host for life is also realistic since, as far as we know, there are no significant barriers from preventing it from maintaining the conditions to do so. Enceladus is a world filled with possibilities and more is to be known about it with planned future flybys and possibly even probe missions.

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