LOTIDE

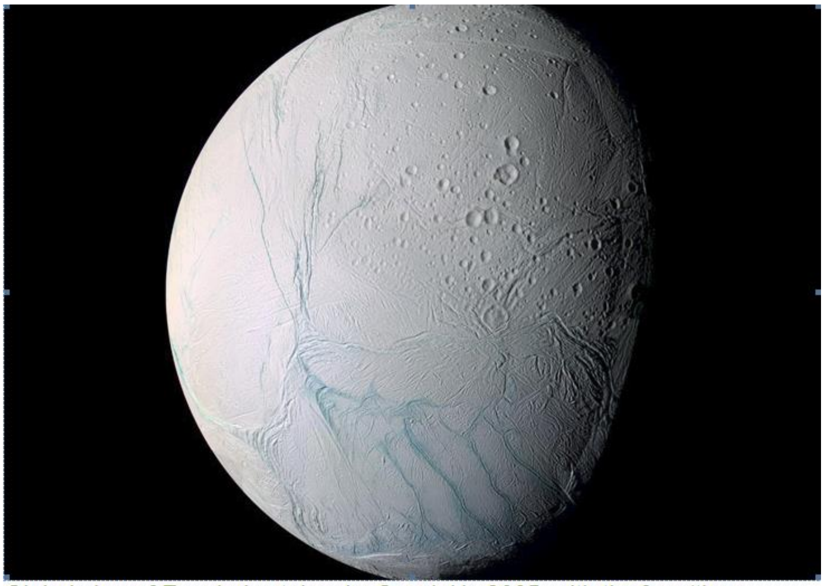
Localized Tidal Heating on Enceladus

DURATION
15/12/2014 - 15/03/2017

BUDGET
150 000€

PROJECT DESCRIPTION

For more than two centuries after its discovery, Saturn's moon Enceladus was only known as one among five mid-size satellites between the main ring system and the gigantic moon Titan.
In 2004, the arrival of the Cassini spacecraft in the Saturn system changes the whole picture. In a series of close flybys, the Cassini orbiter observes stupendous geologic activity in the south pole area.
Four long parallel cracks crossing the polar region, nicknamed `tiger stripes', are anomalously warm and emit jets that form a gigantic plume of water vapor and icy particles.
Even better, the presence of salt in the plume as well as the analysis of gravity data point to the existence of an underground ocean.
Enceladus becomes the first known icy world with deep-seated geologic activity.



Global view of Enceladus taken by Cassini in 2005, with the four 'tiger stripes' visible (in blue) at the bottom of the picture.
Credit: NASA/JPL/Space Science Institute.

Our research project addresses the question of the heat engine behind this geologic activity. At the present day, tidal forces due to the non-circular orbit are the only plausible cause of highly anomalous heating in the crust, as demonstrated by the volcanism on Jupiter's moon Io. This mechanism, however, is not fully understood: the power output is too small (by up to a factor 10) and the heat transport to the surface is too efficient, resulting in the freezing of the subsurface ocean and the end of geologic activity. Classical computations of tidal dissipation are based on an approach designed for much larger satellites such as Europa, where gravity dominates elastic effects (the crust follows the deformation of the ocean) so that tidal deformations are not much affected by lateral crustal inhomogeneities. However, Enceladus is small and its surface gravity is weak so that elasticity dominates gravity. Furthermore geologic activity is only present at the south pole, probably above a local underground sea located under a thinner and weaker crust.

As a primary objective, we will test the hypothesis that tidal dissipation is greatly enhanced by local bending of a thinner crust in the south polar region, and compare it with the global heat flow extracted from Cassini data. We propose a new method - thin shell theory - for the computation of localized tidal dissipation in Enceladus. Up to now, thin shell theory has only been used to predict elastic deformations, stresses and tectonics in a uniform crust. Instead, we will apply to Enceladus the theory of thin shells with variable thickness and depth-dependent rheology that we recently developed for larger satellites. In comparison with fully three-dimensional viscoelastic models, the thin shell approach is much faster, which is a major advantage when studying thermal and orbital evolution. Besides investigating the problem of the missing heat, the project will be useful in a more general way by providing the scientific community with a new and quick method to compute tidal dissipation in icy satellites with highly heterogeneous crusts. The project will disseminate its results through scientific papers, conferences, and public software.

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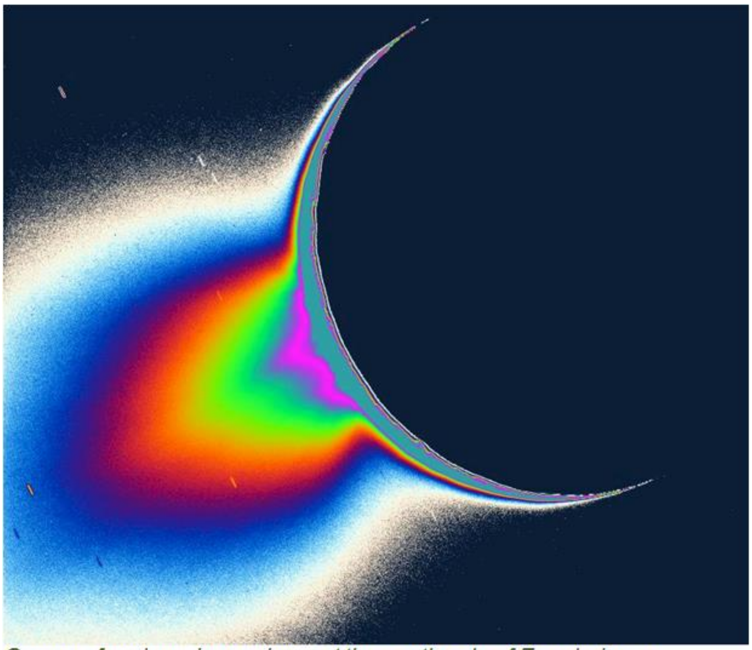
This project is of great interest to all scientists studying Enceladus. Tidal dissipation is not only responsible for the plume and the tectonics at the south pole, but also plays a fundamental role in the thermal evolution of the whole body. Most importantly, understanding Enceladus' heat engine means that we will know whether it is a long-lasting feature guaranteeing the permanent existence of a subsurface ocean. Thanks to the direct sampling by Enceladus' geysers, we have already learned that this putative ocean is made of salty water containing organic molecules. A long-lived ocean is a possible habitable zone for microbial life, making Enceladus one of the best locations when looking for extraterrestrial life, especially that ocean samples could be brought back to Earth without landing on Enceladus. Tidal heating is thus directly relevant to the question of the origin of life in the solar system, which is the most important topic in planetology for society in general.

Enceladus is also an example case of what might occur on other icy worlds. Recent observations have detected similar geologic activity on the Galilean moon Europa, namely a transient plume of water vapor above the south pole. In the solar system, other icy moons are probably inactive at the present time, but their surfaces bear the mark of past tectonic alterations. The two Galilean moons Ganymede and Callisto are of special interest because they are the targets of the next large-class ESA mission called JUICE (Jupiter Icy Moons Explorer), which has as a primary mission theme the `emergence of habitable worlds around gas giants'. As an ESA member, Belgium plays an important in that mission. Finally, the interest for Enceladus, both among scientists and in the general public, will rise at an especially high level in 2015 because of the three new flybys by the Cassini spacecraft. While scientists are eager for new data to test their theories, the general public is fascinated by space missions exploring these extraterrestrial worlds.



Geysers forming a huge plume at the south pole of Enceladus on November 27, 2005 (false colors).
Credit: NASA/JPL/Space Science Institute.

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