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Tidally heated convection in Enceladus' ice shell: Implications for the South Pole thermal activity

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Abstract

Observations by Cassini have revealed that Enceladus' south pole is highly active, with jets of icy particles and water vapor emanating from narrow tectonic ridges, called the tiger stripes [1]. This jet activity is associated to a very high thermal emission mainly focused along the tectonic ridges [2]. Heat power required to sustain such an activity is probably related to the dissipation of mechanical energy due to tidal forces exerted by Saturn. However, the magnitude of the observed heat power as well as the concentration of activity in the south polar region remain problematic. Models of tidal friction in the ice shell indicates that a liquid water layer must exist between the rocky core and the ice shell in order to generate sufficient tidal flexing [e.g. 3,4]. However, the long term stability of this liquid reservoir as well as the mechanism concentrating the heat release along narrow ridges at the south pole remain problematic.

A variety of models have been developed these last years to better understand the coupling between heat generation and transport on Enceladus. Three main mechanisms of heat production are proposed: shear heating on tidally-displaced faults [3], volumetrically-distributed viscous deformation in a convective ice shell [4,5], turbulent dissipation associated with strong tidal oceanic flow [6]. For the heat transport, four mechanisms are considered: conduction through the ice, solid-state convection [e.g. 5,7], circulation of water vapor [e.g. 3,8] and flow of liquid water [9]. Shear heating and vapor transport along faults, which are by nature very local processes, seem a priori more compatible with the south polar activity, which is strongly localized along the tiger stripes. However, generating large tidal motions along the faults remains physically difficult and heat transport by vapor can be efficient only in very porous media. An alternative solution may be dissipation in a broader region within a convective ice shell. The main problem with this model is to explain the concentration of heat release in a very narrow region. Recent advances in the modeling of thermal convection and tidal dissipation in a 3D geometry [5,10, 11] permits us now to test this hypothesis in more details.

After reviewing the different mechanisms proposed for the heat production and transport on Enceladus, I will present recent results on the 3D modeling of tidally-heated convection in Enceladus' ice shell and will discuss the implications of coupled thermal convection and tidal dissipation for the present-day activity of Enceladus.

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