A mushy source for the geysers of Enceladus

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The outer solar system may harbor life, and a promising location is Enceladus, a tiny moon of Saturn, due to its observed cryovolcanism and inferred liquid ocean. This rock-cored icy satellite has a liquid ocean covered by a thin outer ice shell (Spencer and Nimmo, 2013). Tidal heating due to Enceladus' orbital eccentricity around Saturn likely maintains the liquid ocean. At the south pole, fractures penetrate into the ice shell and emit geysers of salty ice crystals, i.e. cryovolcanoes. The goal for this project is to enhance understanding of the possible sources of the plume material. We will do this by developing a fluid mechanical model of buoyant flow, reaction and chemical transport through a porous ice region generated by partial melting from localised heating.

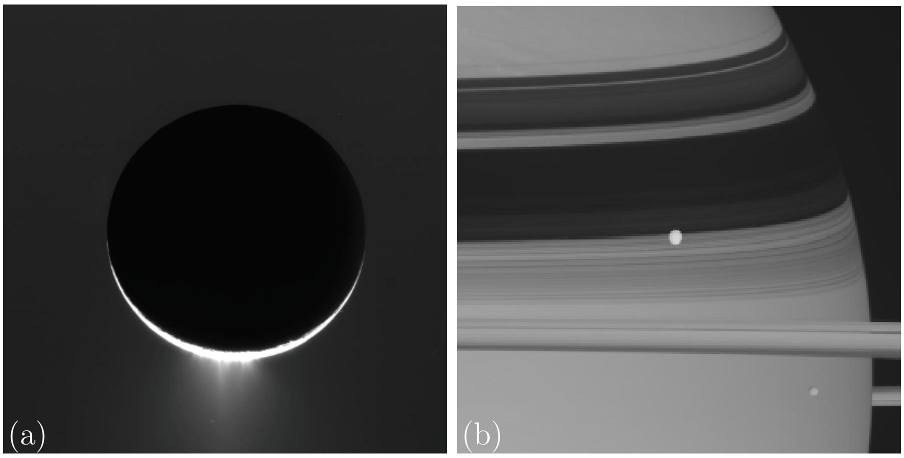

Figure 1: Two images acquired by the Cassini spacecraft: (a) plumes emanating from the south polar terrain of Enceladus. (b) Enceladus (above rings) and Mimas (below rings) in front of Saturn.

Shear heating along the fractures accounts for the observed heat flux anomaly around the south pole (Nimmo et al., 2007), and may explain the plume genesis if the shear heating is large enough to cause melting. Prevailing models have treated pure fresh ice, but the ice shell is likely a binary mixture of salts and water. Partial melting of the salt and ice mixture can result in the formation of a *mushy layer*, which is a reactive porous layer of fresh ice crystals and saline liquid brine, and allows for convection of the interstitial fluid (Wells et al., 2019). The aim of this project is to determine the extent of the mushy region generated by localised heating along fractures, and the convective salt flux that escapes. The results will help to understand whether the geysers of Enceladus are sourced from melting within the ice shell, or from a direct pathway to the liquid ocean.

Modus operandi: with a theoretical emphasis, our goal is to derive a simple fluid dynamical model of the essential processes. We will first consider plume dynamics in a narrow boundary layer around the fracture (adapting the approach of Guba and Worster (2006) to deal with a localised source of heating). Potential extensions include a detailed examination of the asymptotic structure of the flow, and/or considering complementary numerical simulations. The project will also provide an opportunity to develop understanding of continuum models for thermodynamics and flow in reactive porous media.

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