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SOME MODELS ARE WORTH MELTING FOR: KEEPING ENCELADUS WARM

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Based on the paper by Travis & Schubert (2015)

The Saturnian moon Enceladus is one of the most interesting bodies in the solar system, especially due to the large, water-rich plumes at its south pole (e.g. Porco et al. 2006). This discovery countered existing simple models predicting that Enceladus should be completely frozen. In recent years, observational evidence (e.g. Waite et al. 2009; Postberg et al. 2011; Iess et al. 2014) and chemical models (e.g. Zolotov 2007; Sekine et al. 2013) indicating a subsurface ocean has become stronger, although the extent of this ocean is debated. A number of heating mechanisms have been suggested to keep Enceladus from freezing, including radiogenic heating, exothermic chemical reactions, and tidal dissipative heating (TDH). However, neither radiogenic heating nor exothermic chemical reactions alone can keep Enceladus from freezing over timescales longer than 1.5 Gyr (Travis & Schubert 2015). A steady-state level of TDH alone would only keep Enceladus from freezing for 30 Myr (Travis & Schubert 2015). However, it has been suggested that TDH may be episodic rather than steady-state, based on observations of the plume (Waite et al. 2009). Therefore, to get a more accurate understanding of the heating mechanisms affecting Enceladus over its lifetime, it is imperative to consider all of these mechanisms in conjunction.

The simulations performed by Travis & Schubert (2015) include both steady and episodic TDH. In addition to this base case, the effects of salt in the ice, variable core permeability, and an insulating snow layer are included for some simulations. They perform both long term (4.5 Gyr) and short term (100 Myr) simulations. Their simulations show that neither steady-state nor episodic TDH alone can keep Enceladus from freezing; however, together they can sustain a liquid ocean indefinitely, even in their base case. The basic physical picture is that the short, intense, episodes of TDH (lasting for 5 Myr with a 100 Myr cycle) can heat Enceladus substantially. The runaway melting caused will partially re-freeze before the next episode of TDH, but the lower level, steady-state TDH prevents complete re-freezing. The ice shell extends down to the rocky core at the equatorial regions and is thinner in the south pole than the north. Therefore, the authors suggest that irregardless of the initial heating during formation, steady-state and episodic TDH can sustain polar oceans on Enceladus until the present time. In no case can their models sustain a global ocean.

To extend this work, I consider the effect of rotation on the results presented by Travis & Schubert (2015). Some observational evidence for a global ocean is based on perturbations to the rotation (Thomas et al. 2016). As mentioned briefly by Travis & Schubert (2015), rotational effects called Taylor-Proundman columns can form in a rotating fluid. These columns act as a drag force (Moore & Saffman 1968) on rising packets of warm fluid; this effectively reduces the efficiency of the heating mechanism on melting the ice shell and maintaining a liquid ocean. I determine the magnitude of the drag force as a result of the moon's rotation and determine the impact on the rise time and heating efficiency to understand the importance of rotation on this system. I then compare my findings to the results of Travis & Schubert (2015) to determine the impact on Enceladus' liquid ocean.

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