Science Objectives for a Mission Concept to Enceladus: the **Astrobiology Exploration at Enceladus** (AXE)

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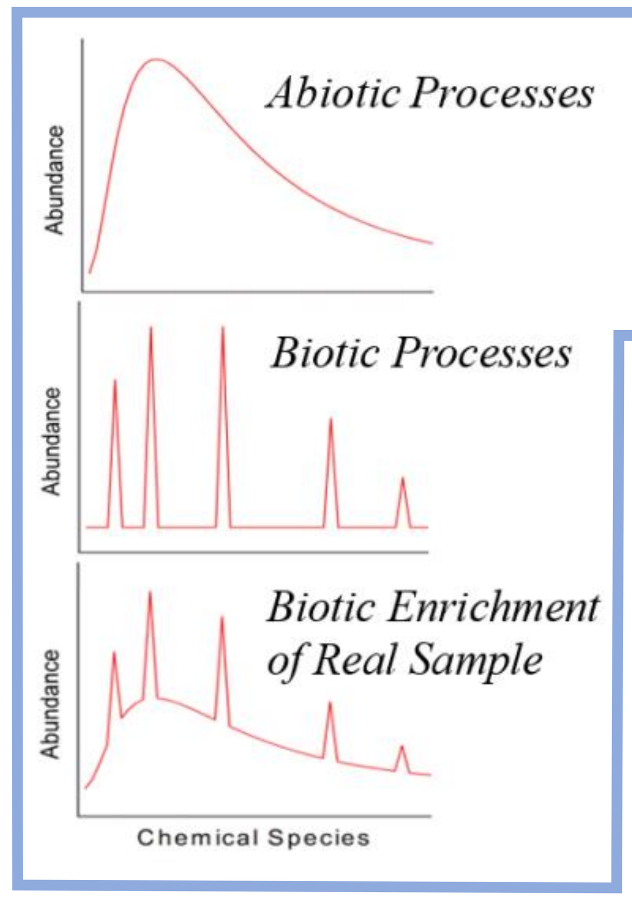


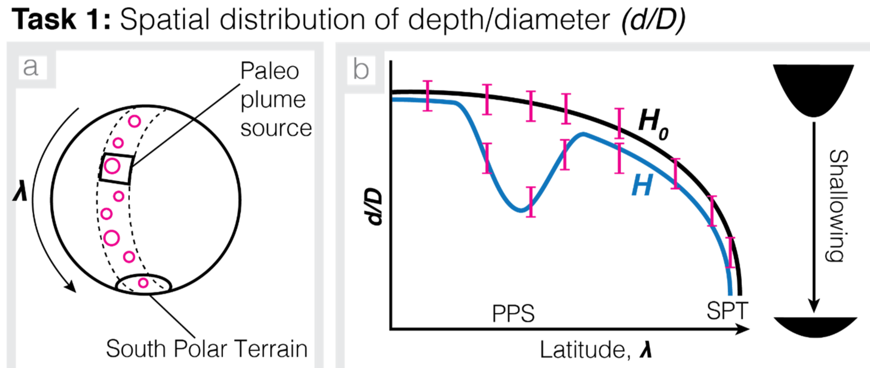
- **Objective 1:** Cassini's analysis of plume composition hints at complex organic chemistry but remains ambiguous due to past technological limitations (Postberg et al. 2018). New *in situ* chemical analysis of the plume could discern the origin of such organic material and provide evidence for biological activity (left), if present.

- **Objective 2:** While thought to be in a dynamic steady state (e.g. Beuthe et al. 2016, Čadek et al. 2019), Enceladus' power budget is unknown (total tidal heating vs total emitted heat; e.g. Hemingway & Mittal 2019). Whether its ocean is permanent or transient is thus an open question.
- If there is a mismatch in power conducted out of the ice shell and power produced by tidal heating (after accounting for other sources such as insolation), Enceladus may be rapidly freezing/melting.

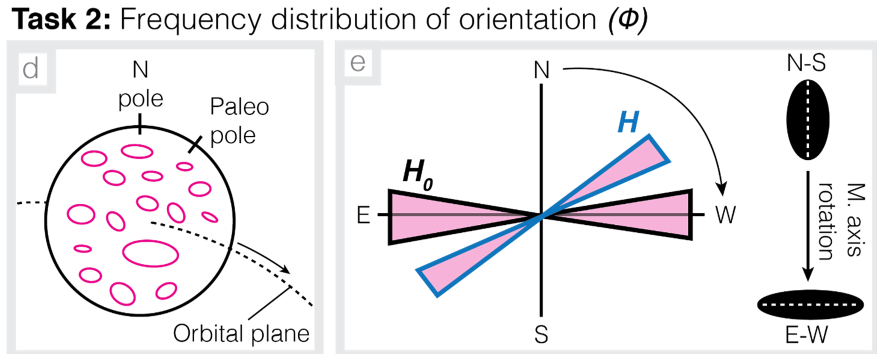
- **Objective 3:** It is unknown whether the south polar vents operate as open crevasses (Kite & Rubin 2016), point-source cryovolcanoes (Spitale et al. 2015), or some combination. In an open crevasse scenario, vent width is expected to change with orbital forcings. In a cryovolcanic scenario, negligible surface motion is expected.

- **Objective 4:** Geologic activity produced and is currently active in the South Polar Terrain (SPT). A survey of small craters (100 m to 1 km diameter) in heavily cratered terrain and ancient north polar terrain can reveal paleo plume sources (PPS) and any ice shell reorientation.
- Low depth-to-diameter (d/D) ratio of craters would indicate relatively relaxed craters or deposit of plume fallout (Spitale & Porco 2007, Kirchoff & Schenk 2009); thus a PPS (Task 1, right)
- Elliptical craters are expected to be strongly oriented along Enceladus' orbital plane (cf. Ferguson et al. 2020). A population of elliptical craters with a consistent but *different* orientation φ would indicate shell reorientation (Task 2, right; cf. Holo et al. 2018).

Task 1: Spatial distribution of depth/diameter (*d/D*)



Task 2: Frequency distribution of orientation (*Φ*)



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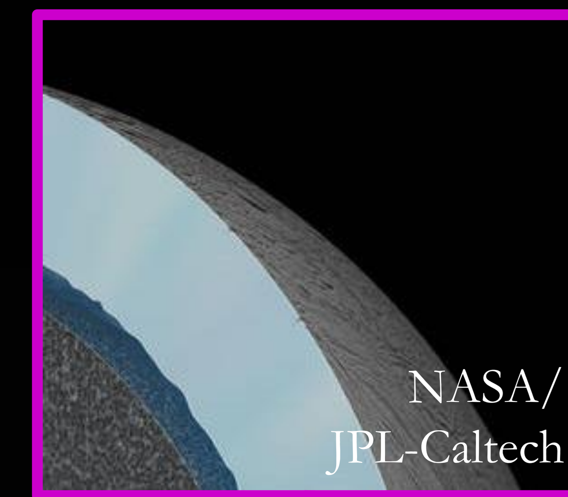
Citations: Beuthe et al. (2016) *Icarus*, *280*, 278. Čadek et al. (2019) *Icarus*, *319*, 476. Ferguson et al. (2020) *JGR: Planets*, *125*(9). Hemingway & Mittal (2019) *Icarus*, *322*, 111. Iess et al. (2013) *Science*, *344*(6179), 78. Kirchoff & Schenk (2009) *Icarus*, *202*(2), 656. Kite & Rubin (2016) *PNAS*, *113*(15), 3972. Postberg et al. (2018) *Nature*, *558*, 564. Spitale et al. (2015) *Nature*, *531*(7550), 57. Spitale & Porco (2007) *Nature*, *449*(7163), 695. Thomas et al. (2016) *Icarus*, *264*, 37.

The AXE Mission would **search for biosignatures** at Enceladus and **contextualize** these measurements through **geophysical** investigations

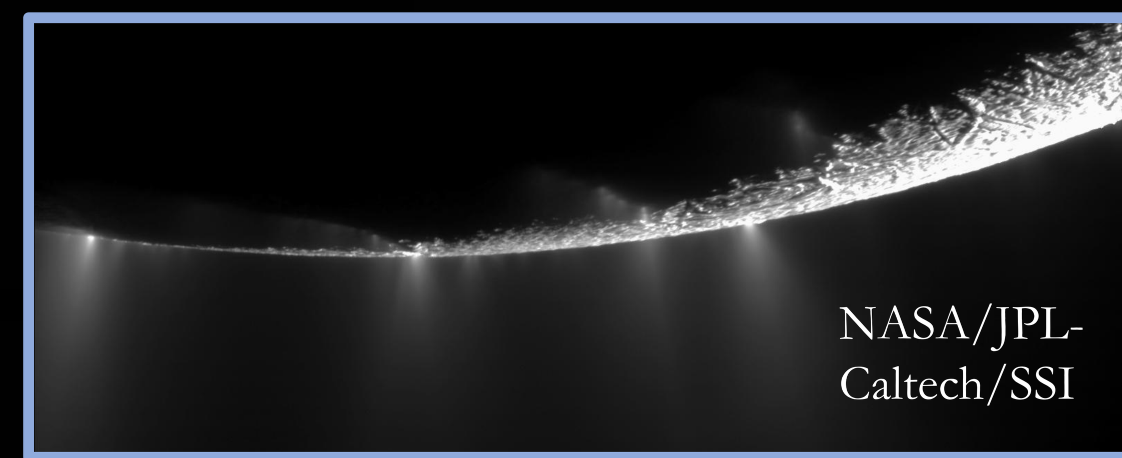
1. Are organic compounds in the plume biological in origin?

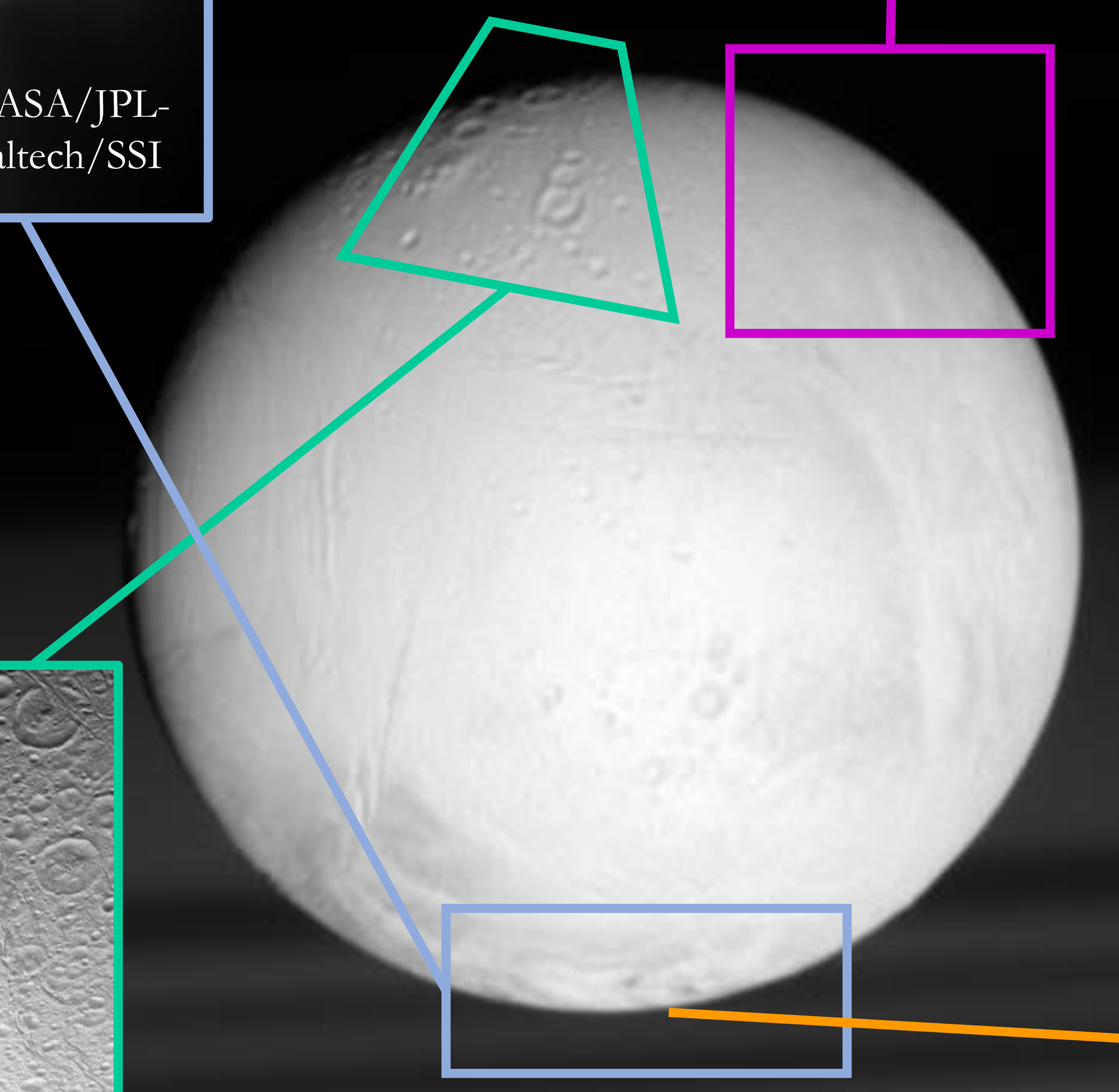
The relative distribution of organic compounds in the plume would provide evidence for biological processing, if present



2. Is the subsurface ocean long-lived?

Discrepancies in heat production and output would indicate the ice shell (left) is rapidly melting or freezing



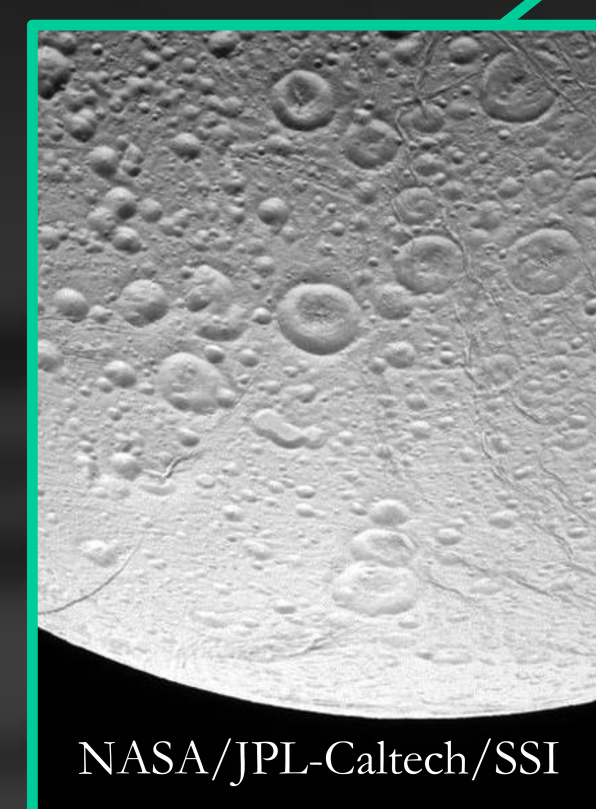


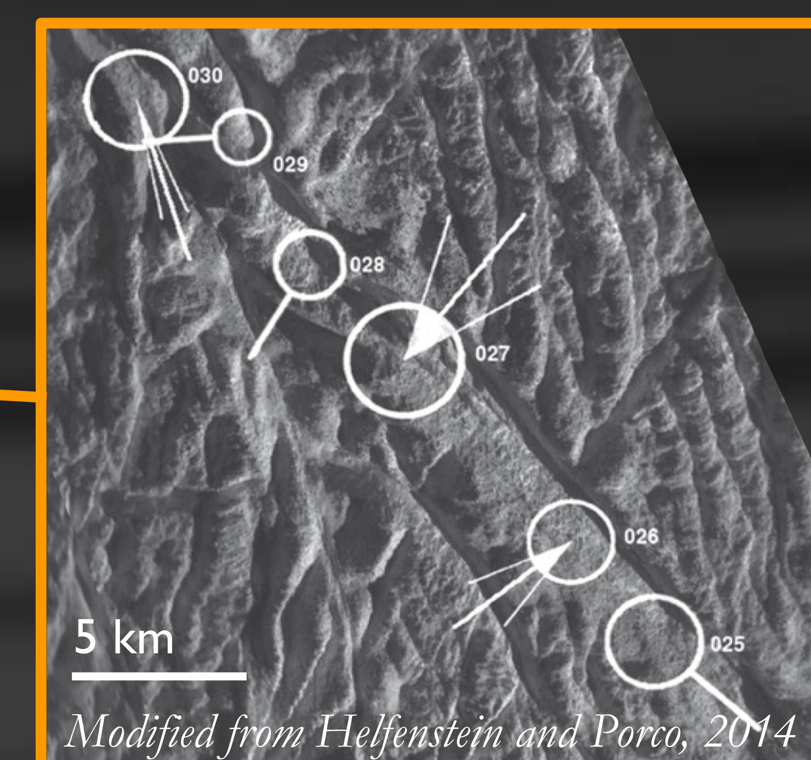
3. Are plumes mostly open crevasse boiling or explosive cryo-volcanism?

Vent (example below) morphology and any temporal variation will discern which eruption style dominates

4. Have other regions ever been as active as the South Polar Terrain?

Evidence of paleo plume sources or ice shell reorientation in heavily cratered or ancient north polar terrain (right) would indicate such past activity





Modified from Helfenstein and Porco, 2014

Image Credit: NASA/JPL-Caltech/SSI