



FY24 Topic Areas Research and Technology Development (TRTD)

# How many cracks does it take to get to the water on Enceladus?

**Principal Investigator:** Samuel M. Howell (3226) [SAMUEL.M.HOWELL@JPL.NASA.GOV]  
**Co-Investigators:** Erin Leonard (3223); Danielle Wyrick (SWRI)  
**Collaborators:** Juliana Kelley (UC Boulder); Mohit Melwani Daswani (3226); Elodie Lesage (3226)

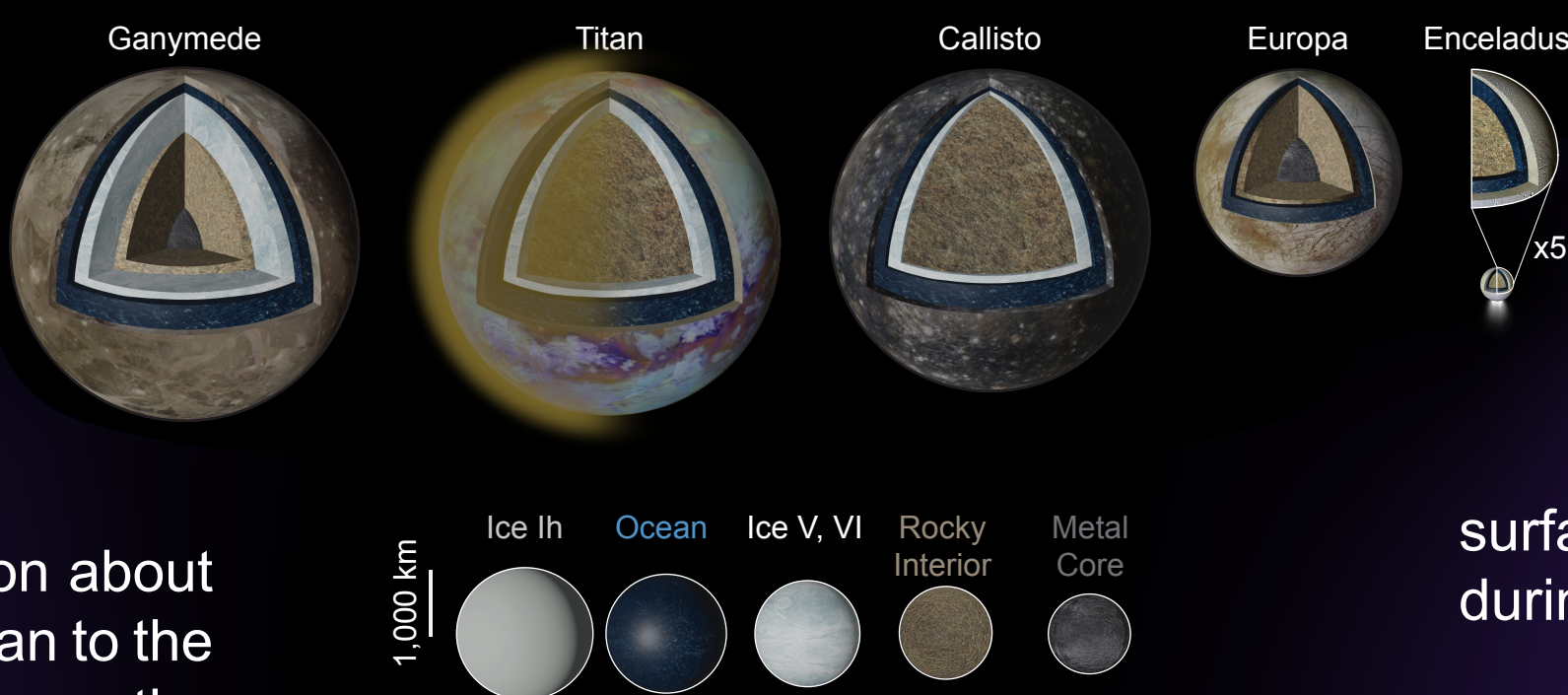
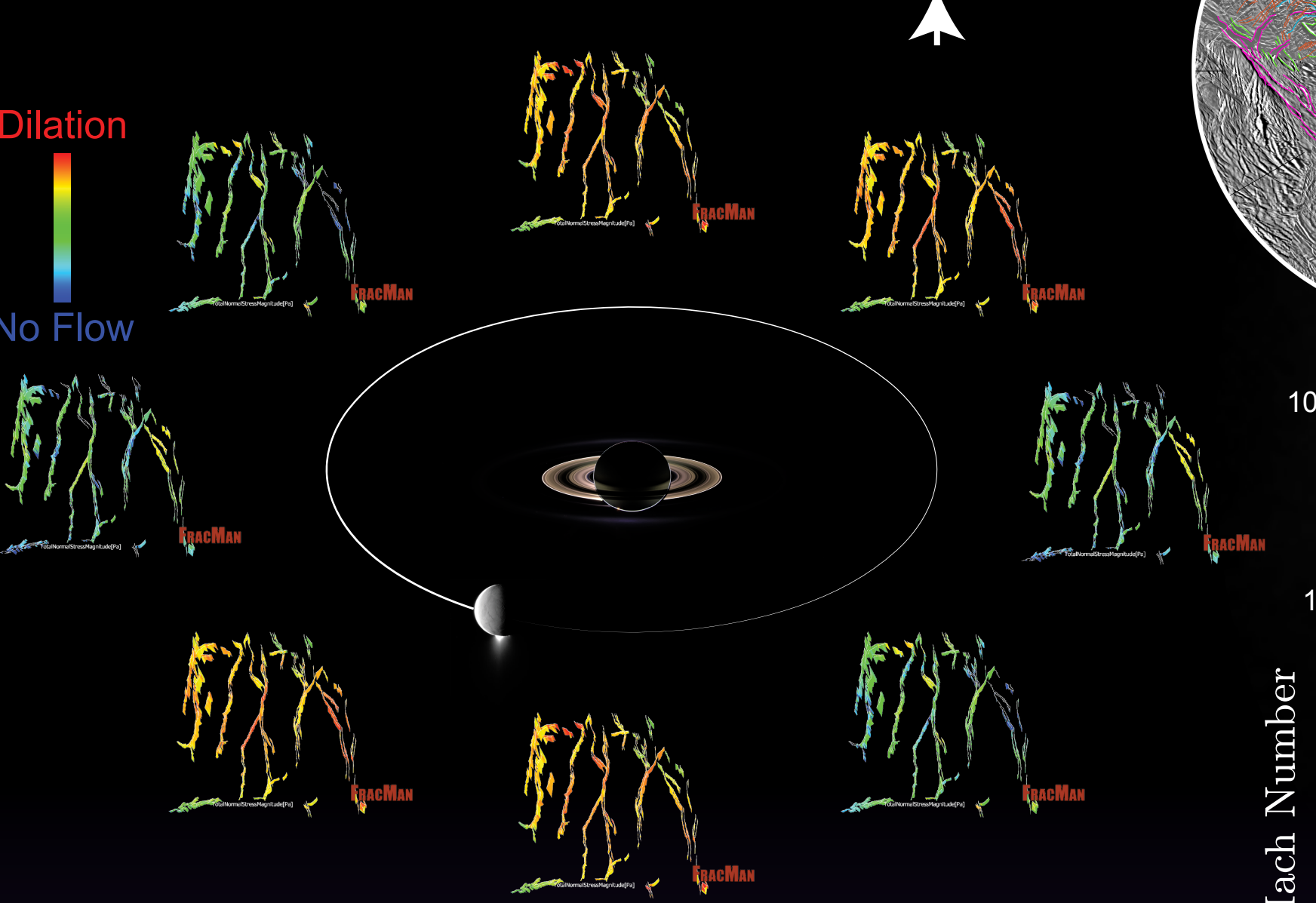
Strategic Focus Area: Ocean Worlds

## Background

Enceladus is prioritized as an Ocean Worlds flagship target and is a focal point in New Frontiers 5-7 in the current Decadal Survey. Its South Polar Terrain (SPT) "Tiger Stripes" comprise linear fractures, ejecting jets of water vapor and icy grains, forming a vast plume. While the plumes betray information about the near-surface environment, fluid transport from the ocean to the subsurface is likely to be affected by interactions between the background stress field and existing fractures and faults, mechanical stratification within the shell, ice shell rheology, compositional evolution of the fluids during transport, residence in fully and partially molten reservoirs, physical and thermal interactions between the magma and surrounding ice, surface topography, tectonic activity, and geologic history. Thus, there is a risk that measurement and spacecraft requirements rely on under-constrained assumptions about rapid (hours to days) transport timescales from the ocean to the surface and magma evolution with depth and time, as well as a risk that the geometries required for deep in situ vent exploration do not reflect physical multiphase transport and eruption. ***This work aids in understanding Enceladus as a habitable system by further constraining ocean-surface transport, and matching Cassini observables to physical predictions of the near-surface environment.***

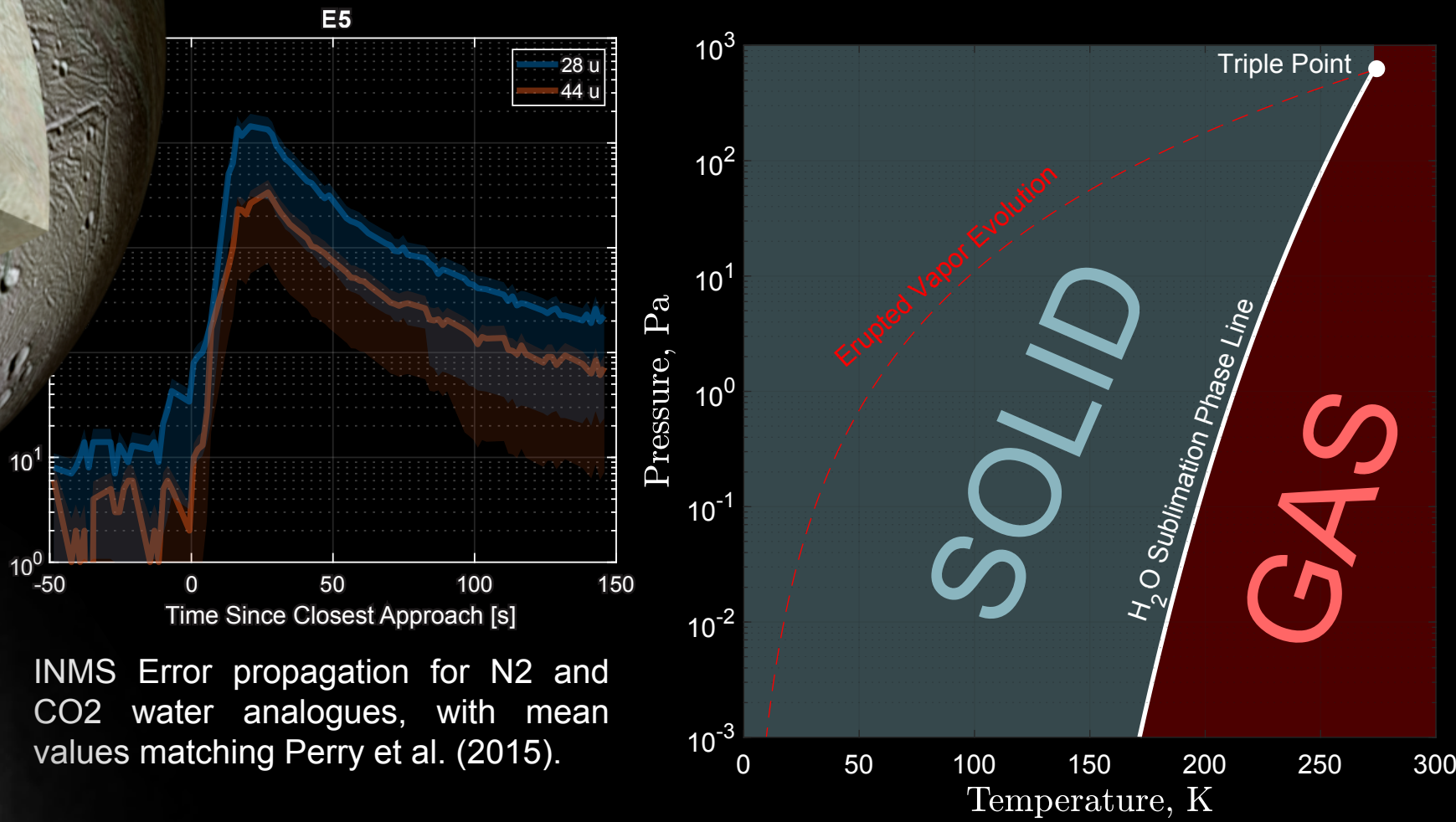
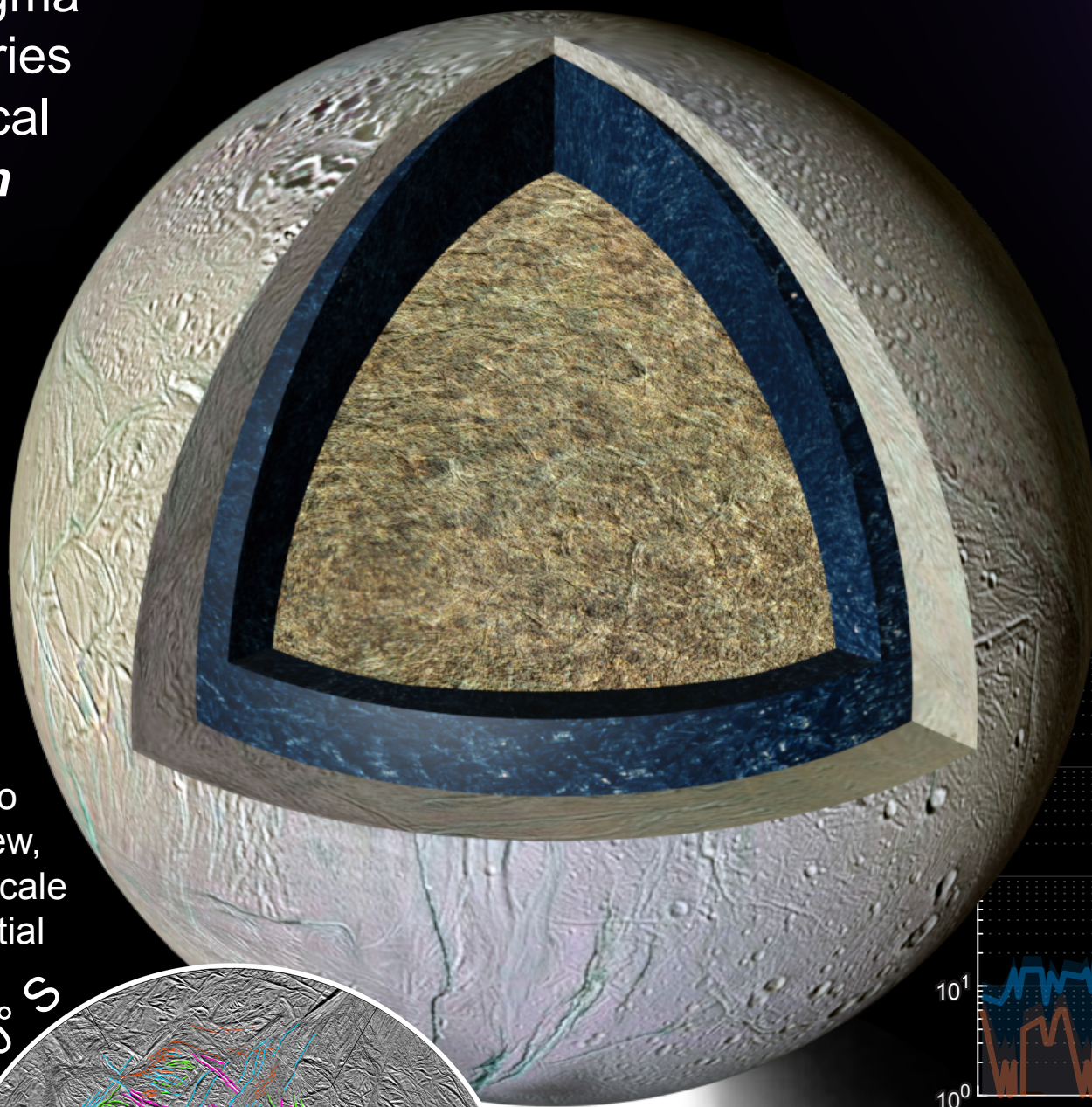
## Approach and Results

We are characterizing the fracture environment using physical and modeling approaches. We have identified new physical controls on near-surface eruptions and composition, and are working to characterize plume mass flux uncertainty in order to inform conceptual and numerical model development. Additionally, we have created a new, comprehensive fracture map of the SPT using globally controlled USGS mosaics at a scale of 1:250,000, mapping all linear features > 250 m in scale. We classify each potential fracture based on morphology, structural association, and predominant orientation. This initial fracture map is being used to create a two-dimensional (map view) discrete fracture network using FracMan. We apply time- and spatially-varying stress fields to the SPT that reflect the diurnal stresses generated through gravitational interaction.

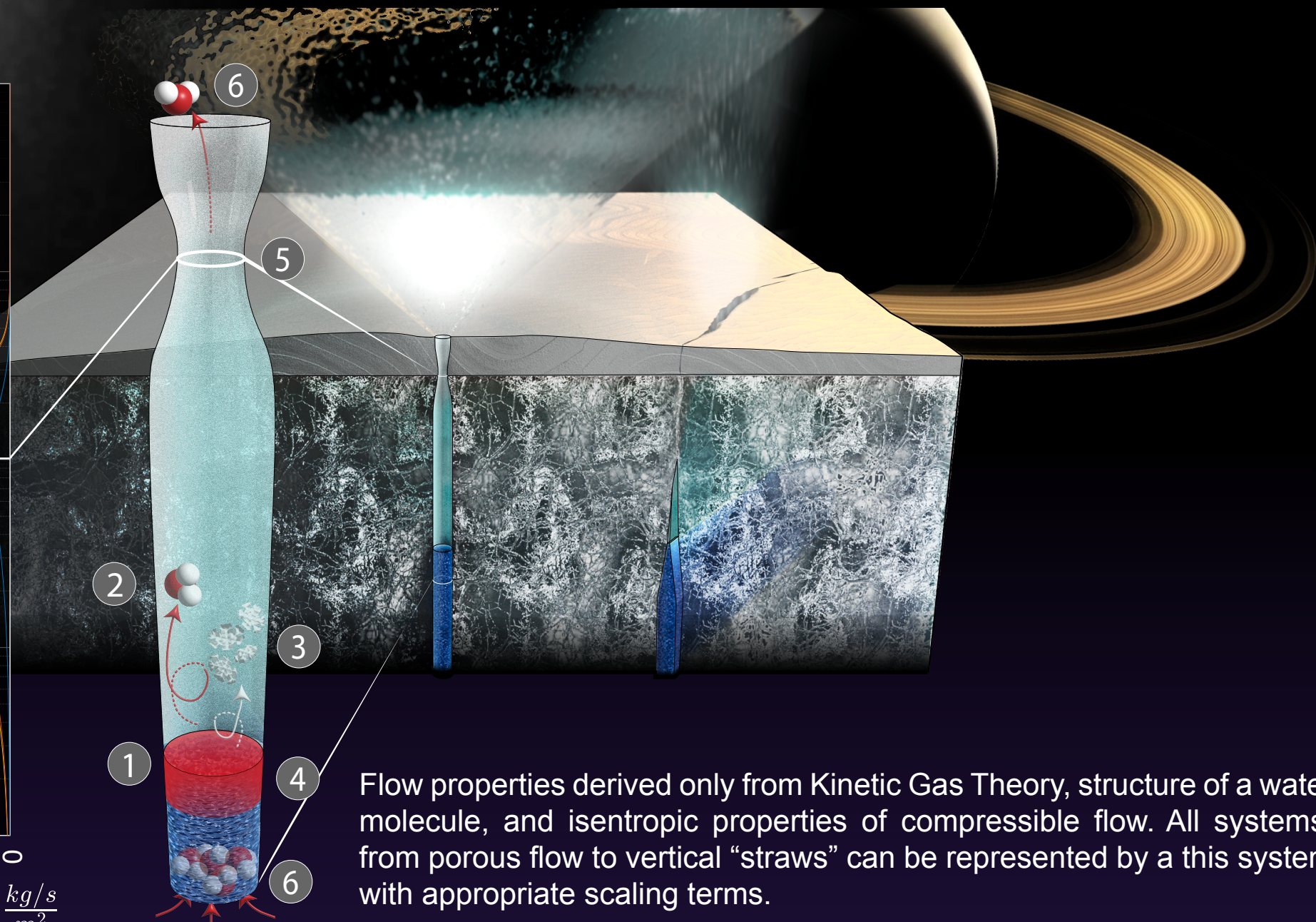


(Above) Among the most plausible Ocean Worlds, the escape of putative interior ocean water from Enceladus is benefitted by its small size and relatively low gravity.

(Below) Enceladus cross-section. Ice thickness is minimal at the poles.



The erupting water vapor emanating from the triple point phase boundary is super-cooled, and evolves through pressures and temperatures typical of the solid phase rather than gas phase. This comprises non-equilibrium flow, in which the temperature and velocities of the gas differ from that of entrained and condensed ice grains.



National Aeronautics and Space Administration

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California

www.nasa.gov

Clearance Number:  
Poster Number: RPD-159  
Copyright 2023. All rights reserved.

## Predictions

Howell et al. (in prep), Enceladus' Jet Propulsion Laboratory: Vacuum Siphon Decouples Plume Observations from Source Reservoir

1. Significant uncertainty persists in the total erupted mass flux due to high uncertainty in the plume density and paucity of constraints on material velocity.
2. Water vapor eruption at Enceladus is driven only by the partial pressure of water at the triple point connecting to the space environment to create an isostatic "vacuum siphon".
3. No special processes required to pressurize water column or vapor.
4. Icy and vapor mass flow rates do not change diurnally, only their height/kinetic energy.
5. The active vent area is uniquely to be knowable from the total plume flux.
6. The chemistry of the plume and E-ring are decoupled from the source reservoir by a phase-lag at the triple point interface.
7. Nanosilicates in the E-ring are not a reliable indicator of ongoing hydrothermal activity because their chemistry sources from this lag.
8. The material velocity, subsurface geometry, and conduit diameter of vents are not knowable from Cassini data, placing uncertainty on plume sampling and vent exploration.