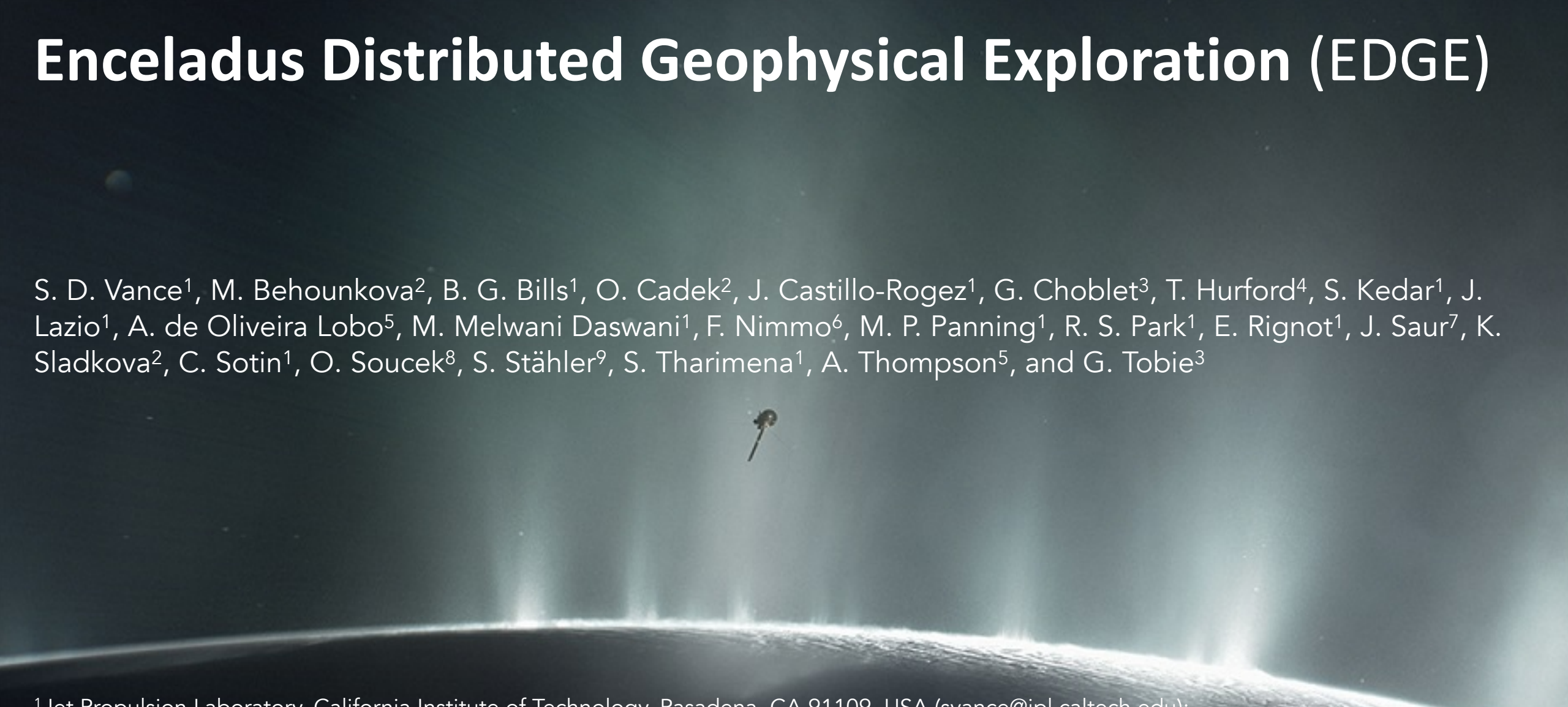
Enceladus Distributed Geophysical Exploration (EDGE)

S. D. Vance[1], M. Behounkova[2], B. G. Bills[1], O. Cadek[2], J. Castillo-Rogez[1], G. Choblet[3], T. Hurford[4], S. Kedar[1], J. Lazio[1], A. de Oliveira Lobo[5], M. Melwani Daswani[1], F. Nimmo[6], M. P. Panning[1], R. S. Park[1], E. Rignot[1], J. Saur[7], K. Sladkova[2], C. Sotin[1], O. Soucek[8], S. Stähler[9], S. Tharimena[1], A. Thompson[5], and G. Tobie[3]



[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA (svance@jpl.caltech.edu); [2]Charles University, Faculty of Mathematics and Physics, Department of Geophysics, Prague, Czech Republic; [3]Laboratoire de Planétologie et Géodynamique, Université de Nantes, France; [4]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA; [5]California Institute of Technology, Pasadena, CA, USA; [6]Department of Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, California, USA; [7]Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany; [8]Mathematical Institute of Charles University, Prague, Czech Republic; [9]Institute for Geophysics, ETH Zu□rich, Zu□rich, Switzerland.

Image:phys.org

Study Goals

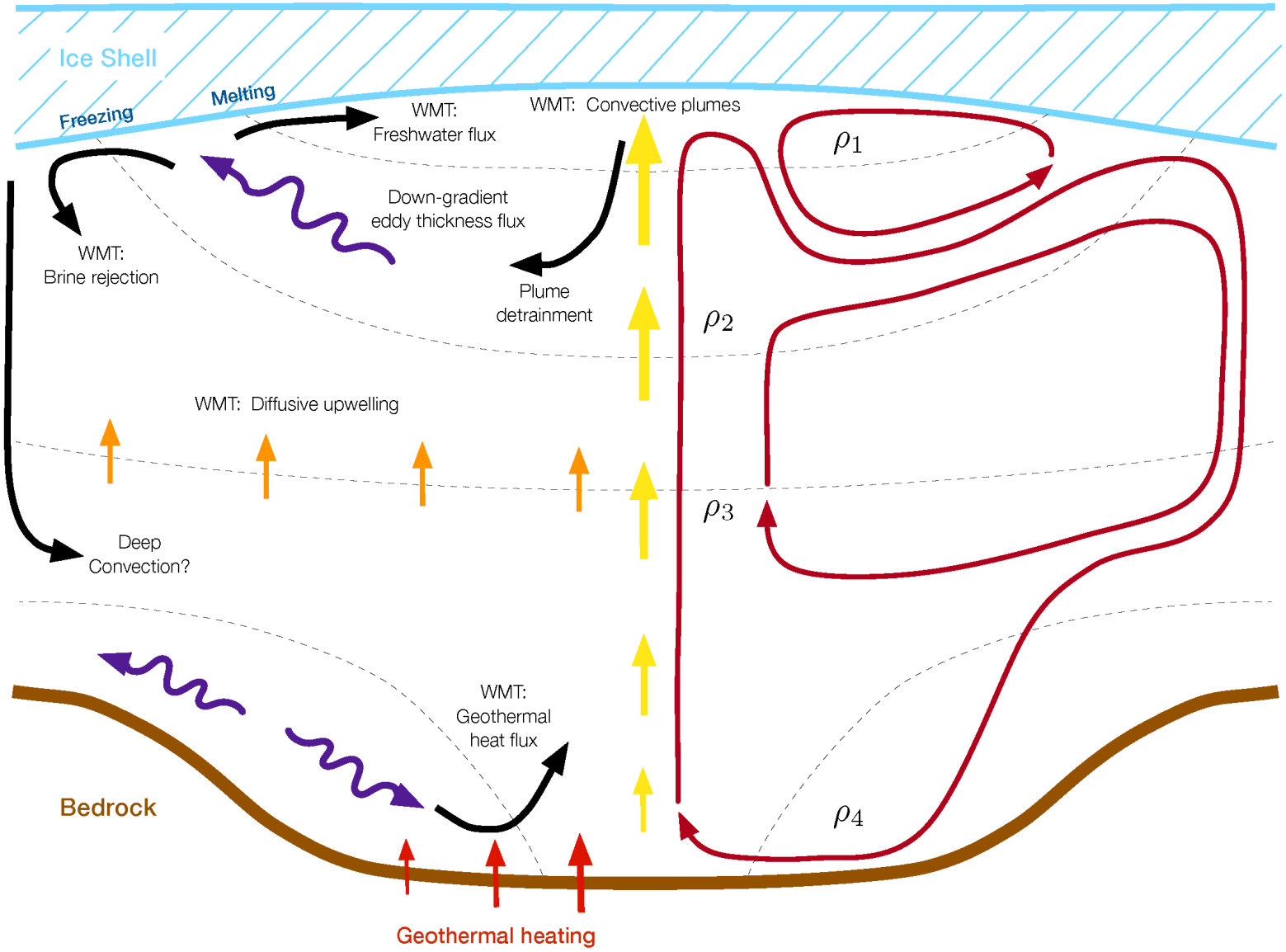
- Assess needed geophysical measurements for habitability context in future searches for life on Enceladus
- Evaluate benefits of different architectures:
  - Orbital, single or dual
  - Landed, single or networked
  - Combined orbiter and lander

Ice thickness variations have been inferred from *Cassini* measurements

These imply lateral transport as melting and refreezing affect overturning circulation

Want to determine properties in the ocean and transport to the surface

Couple these to modeling of composition and thermal evolution
(e.g, Malamud and Prialnik 2016, Melwani-Daswani et al., in prep.)



Lobo et al., in prep.

Key contextual questions addressed by geophysical measurements to assess the astrobiological potential:

1. **How is tidal dissipation distributed between the icy crust, ocean, or rocky core?**
2. **Why does the North Pole differ from the South Pole?**
3. **What is the spatial occurrence of ongoing high-temperature water-rock interactions.**
4. **What is the mass exchange, through melting and crystallization, between the ocean and the ice shell?**
5. **What is the rate of delivery of any oxidants from the surface into the ocean?**
6. **How are materials at the ice-ocean interface fractionated ice formation and melt processes?**
7. **How, and to what extent, does the ocean transport materials to the ice-ocean interface and toward the icy surface?**

1 Tidal Distribution | 2 Polar Differences | 3 Hydrothermal Distribution | 4 Mass Exchange

5 Oxidant Flux | 6 Ice Fractionation | 7 Ocean Transport

Science questions	Science areas	Measurements
How and where is tidal dissipation distributed in Enceladus?	Ice crust, ocean, rocky core	Thermal, seismic, gravity, LiDAR, tilt
What characterizes the dichotomy between the North and South Polar terrains, and what is it caused by?	Ice crust, ocean, rocky core, active features	Gravity, stereo mapping, thermal mapping, seismic, ,
How prevalent is ongoing water-rock interaction, and where does it occur?	Ocean, rocky core, active features	Seismic, EM Sounding
What is the composition, structure and thermal state of Enceladus' rocky interior? How porous is it?	Rocky core	Seismic, gravity
What is the ocean's extent and composition? What are the ocean's dynamics and structure?	Ocean, active features, ice shell	Seismic, EM sounding
What are the physical conditions at the plumes? What is the thermal output and structure around the plume sources?	Active features, ice shell	Stereo mapping, thermal mapping, InSAR, LiDAR, seismic
What are the composition, extent, density, temperature , dynamics and structure of the ice shell?	Ice shell	Seismic

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InSAR, LiDAR

Constrain the horizontal and vertical motions of ice and opening of fissures where plume jets originate; help detect active rifts and the presence of grounded areas; and provide constraints on deriving the thickness of the icy crust.

Repeat-pass over the same terrains
InSAR- mm precision
LiDAR altimetry- 10s of cm [16]
Laser altimetry could also aid a gravity investigation.

Thermal/Topographic Mapping

Mapping topographic features and thermal output with greater spatial coverage and resolution than Cassini would aid understanding heat distribution and active features in the ice.

Electromagnetic Sounding
Infer the ocean thickness and conductivity
Unlike Jupiter, no tilt of Saturn's intrinsic magnetic field with respect to its spin axis.

Externally excited oscillations of the magnetic field due to Enceladus' plume variability, magnetospheric variability and Enceladus' small eccentricity might be utilized.

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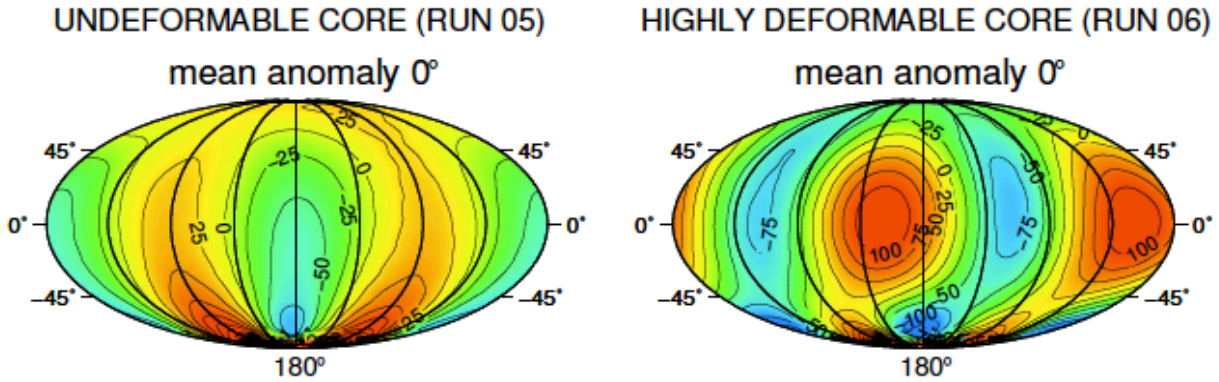
Gravity

Measure the static low-degree gravity potential and its time variations. Assuming a gravity signal of tens of μGal tidal Love number k_2~0.03, it is not possible to measure the diurnal response of Enceladus with multiple flybys.

An orbiter mission is the best way to achieve gravity measurements. Single- or multiple-flyby missions with 10 km closest approach at relative surface velocities V >5 km s^{-1} would not suffice for measuring the degree-2 variation gravitational potential because the corresponding velocity perturbations ($\Delta v \sim 2r\Delta g/V$) would be in the range of tens of μm/s or even less.

Perturbations sensed by an orbiter (V<0.2 km/s at 100 km) would be measurable by currently available radio science systems.

Gravity anomaly at the surface in μGal: Effect of the core



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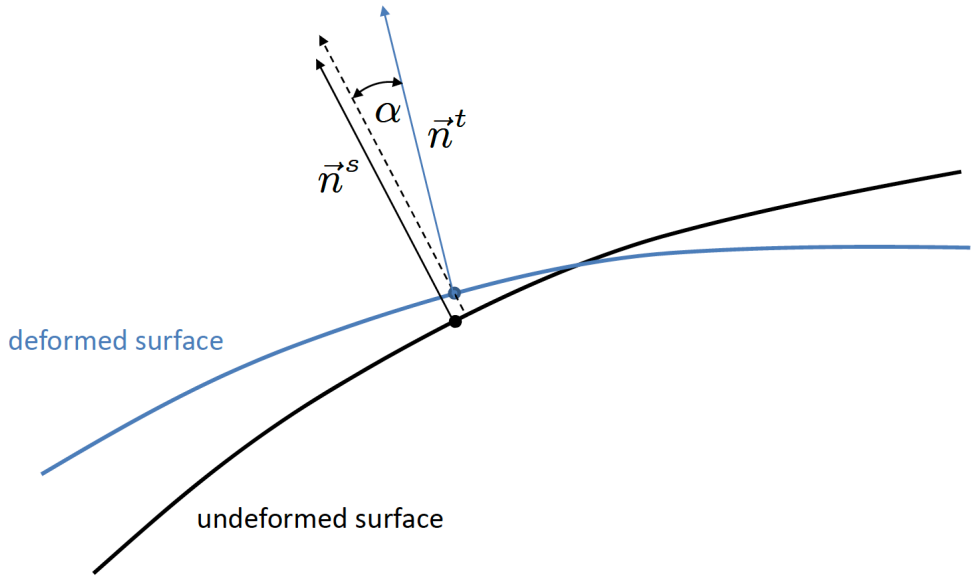
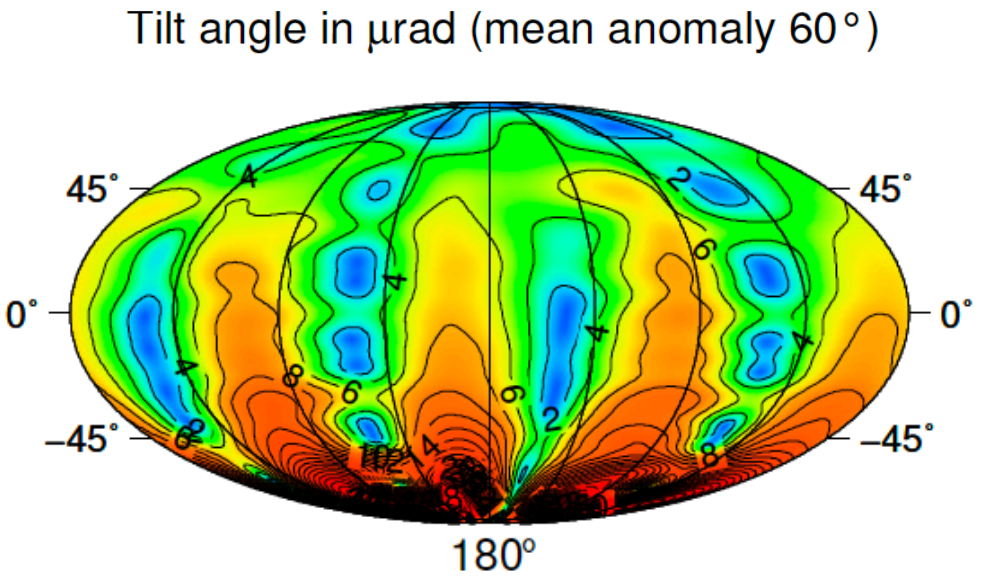
Tilt

Tilt measurements by a lander could also achieve the above goals, but would need precision of better than 2 µrad





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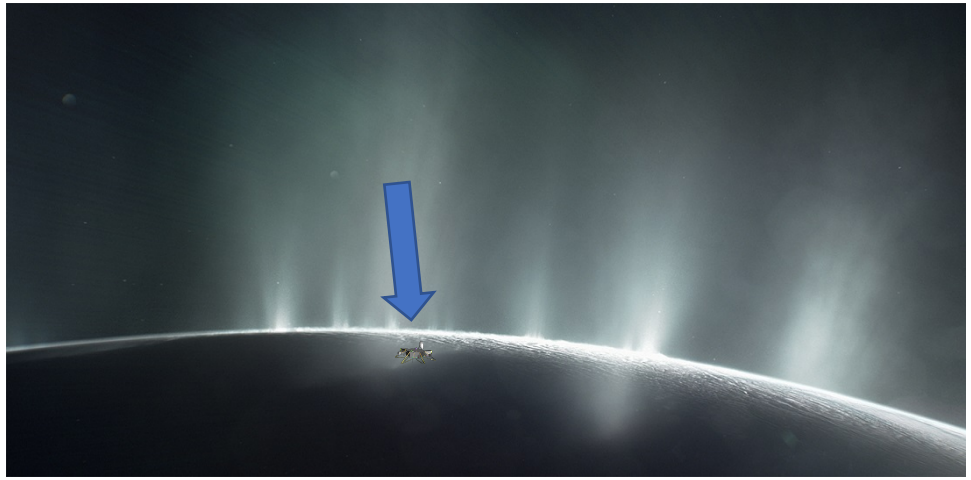
Seismology

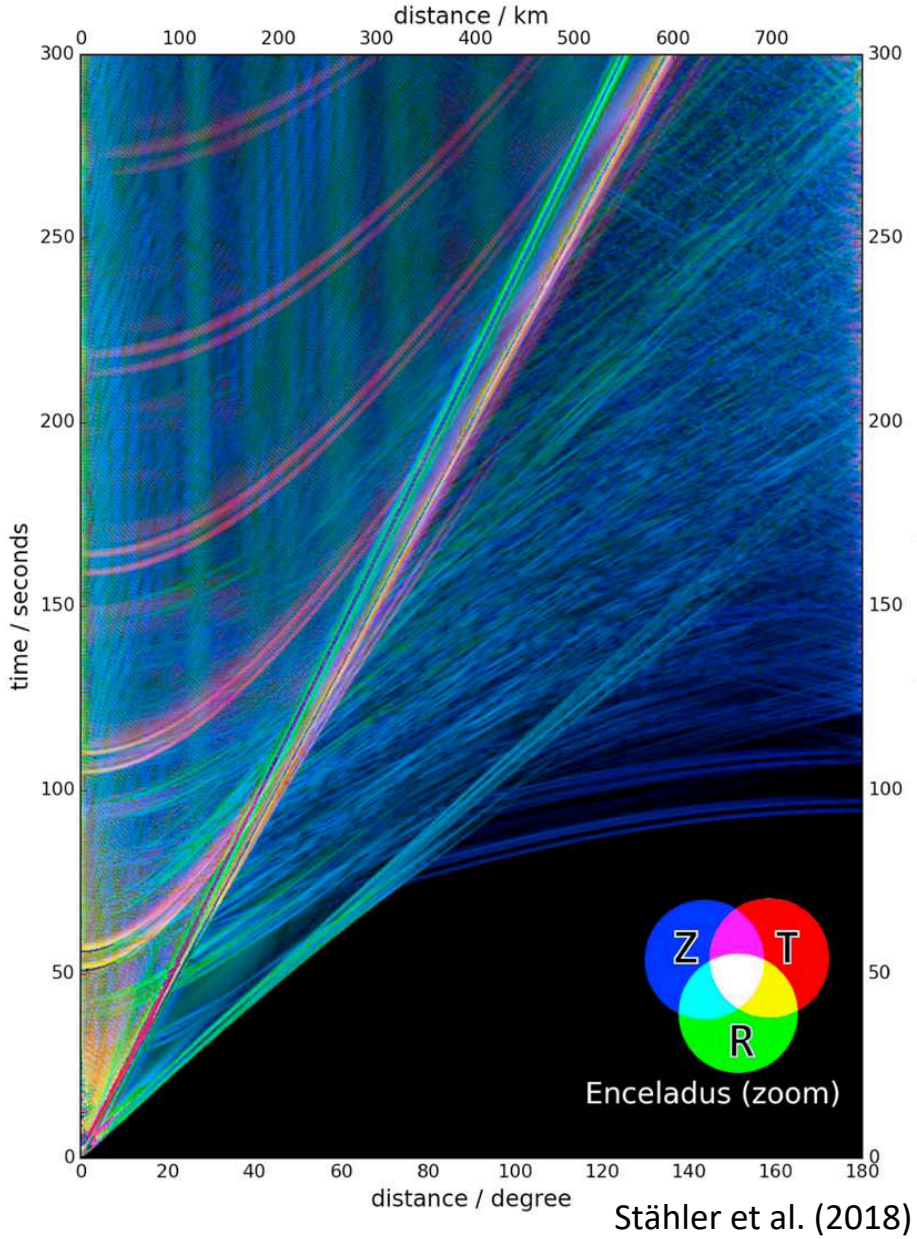
Best technique for resolving interior structure of Enceladus, highly complementary to the other techniques

A single seismometer could detect signals from anywhere on/in Enceladus

Observed plume activity indicates ample seismicity as sources for passive seismic techniques

Multi seismometers might reveal mechanics of observed fissures and fluid, gas movement in south polar plume regions





Stähler et al. (2018)

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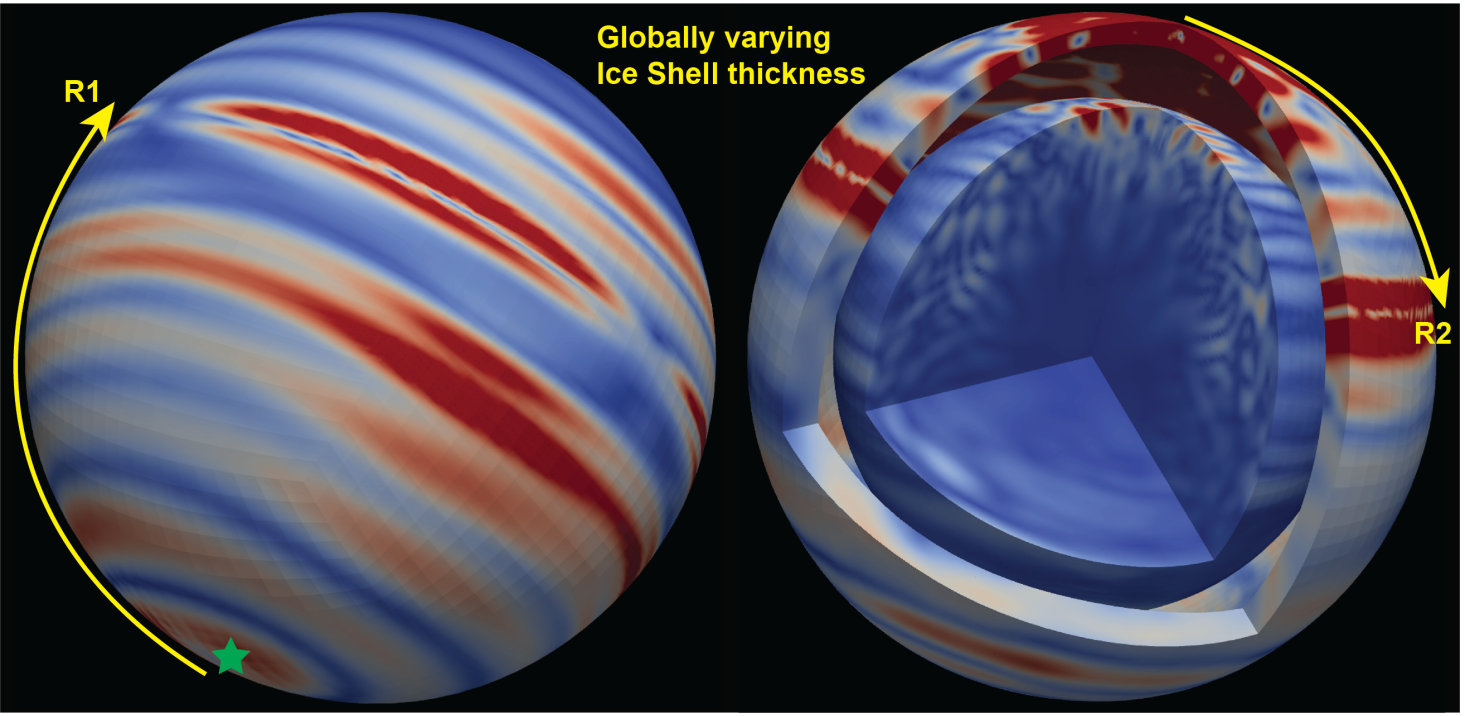
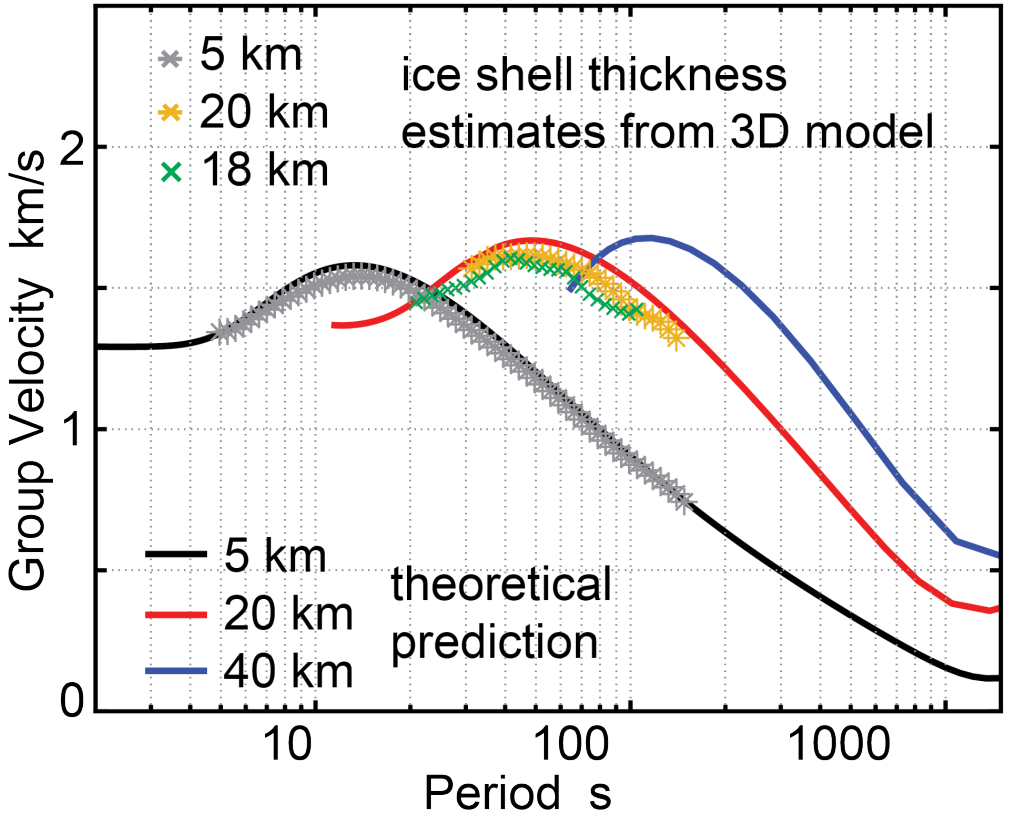
Seismology





Tharimena et al., in prep

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