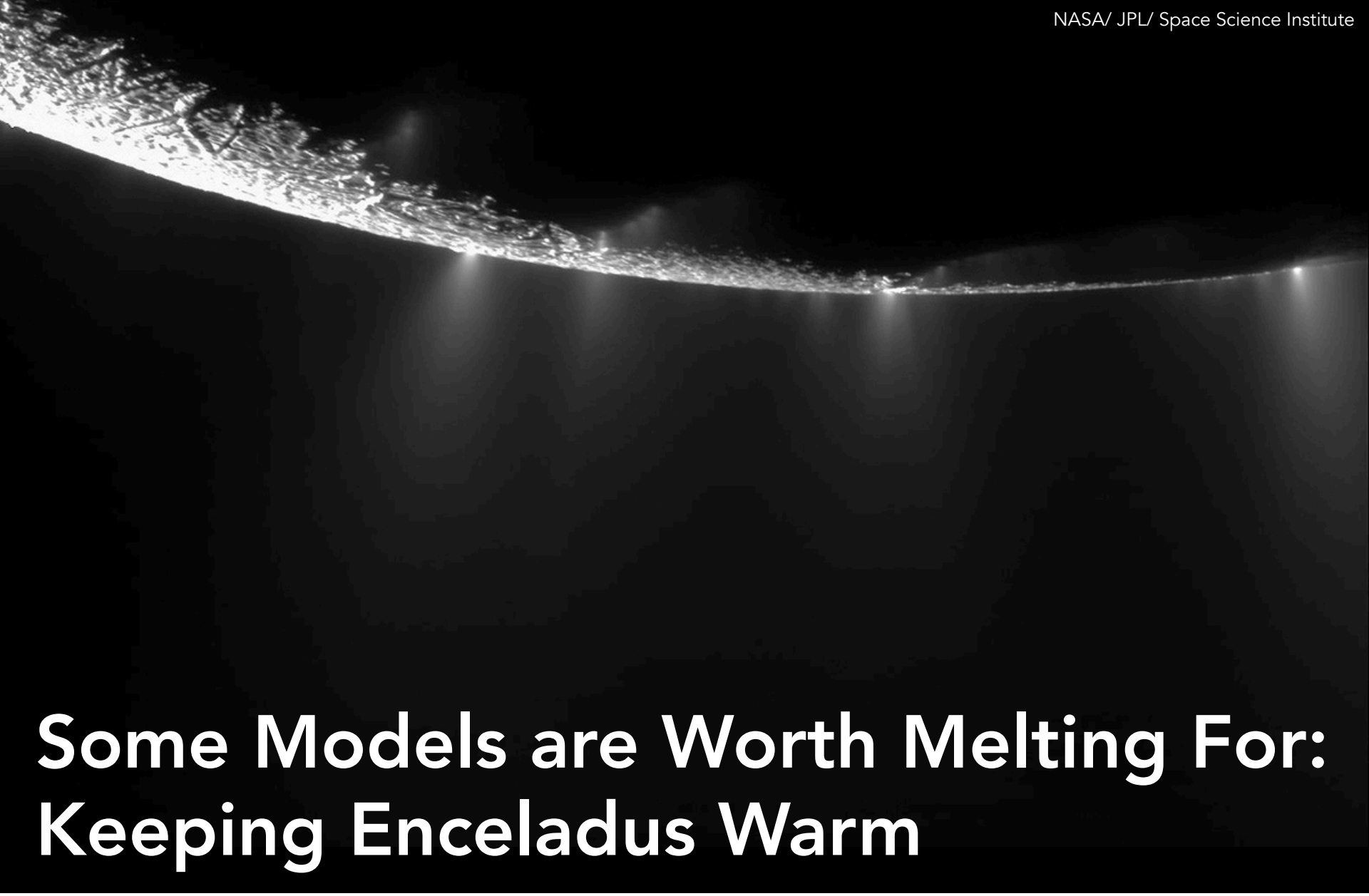


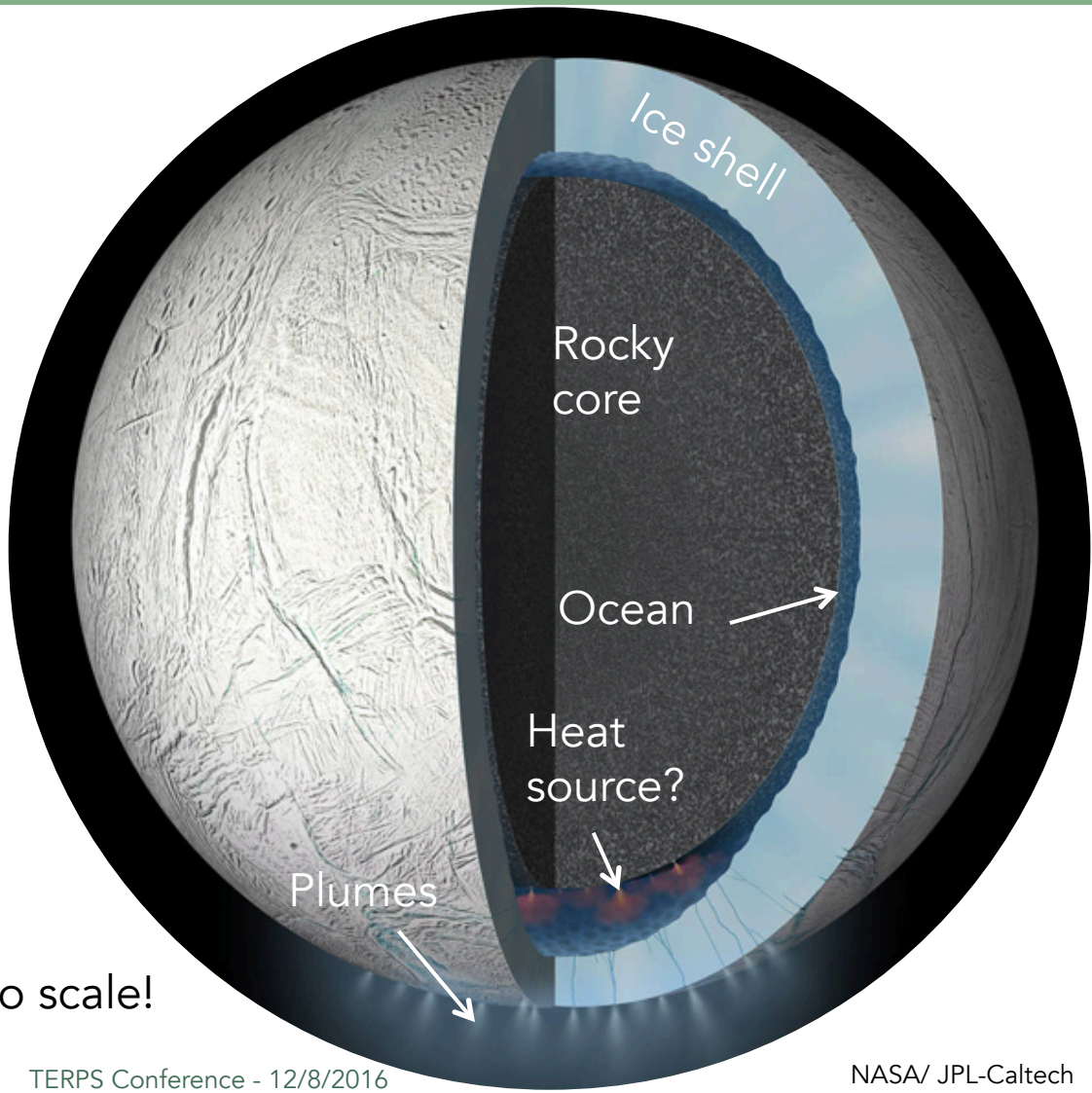
Some Models are Worth Melting For: Keeping Enceladus Warm

Rebecca Levy

Based on the paper by Travis and Schubert (2015)

Heat Sources on Enceladus

- How to maintain a liquid ocean?
- What kind of heat source is needed?
  - Tidal Dissipative Heating (TDH): steady-state and episodic

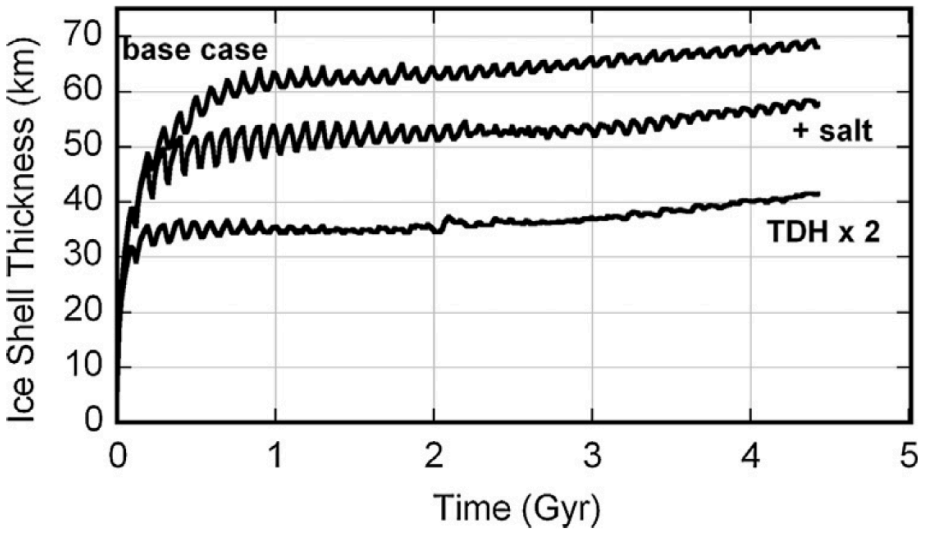


Note: Layers not to scale!

NASA/ JPL-Caltech

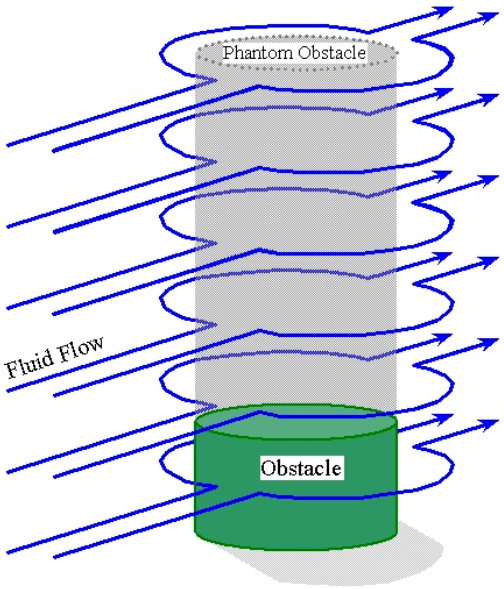
Results of Travis & Schubert

- Long Term (4.5 Gyr) Simulations
  - ~20 km depth ocean sustained indefinitely
- Short Term (100 Myr) Simulations
  - Polar oceans
  - Global oceans not sustained
- Is rotation important?



Taylor-Proudman Columns

- An obstacle in a rotating fluid acts like a barrier at all heights
- Acts like drag force on rising object (Moore & Saffman 1968)

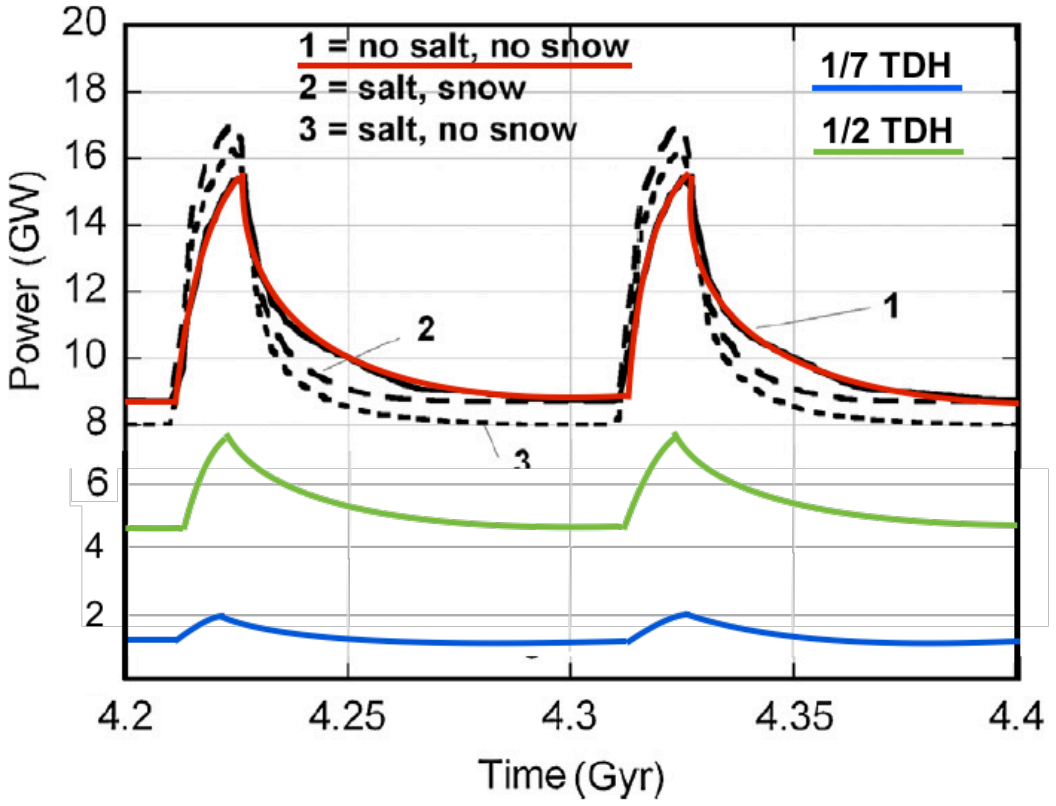


CSU Spin Tank Team

Y. van Halder

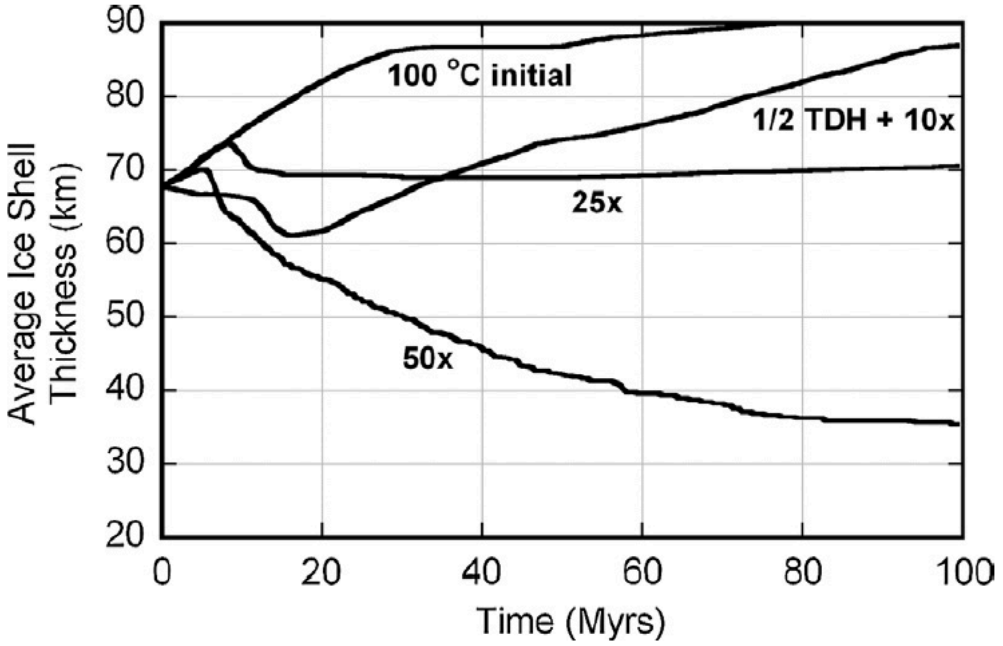
Magnitude of the Effect

- Balance forces on rising packet
  - Assumptions: size of packet
- Drag increases rise time by a factor of 7!
  - Looks like TDH which is 1/7 as efficient



Comparison to Paper Results

- Paper examines ½ TDH + 10x initial heating
  - Thin ocean could barely survive
  - This does not have episodic TDH, would help maintain ocean



Summary

- Rotation could be important if the rising heat packets are sufficiently large
- The fluid dynamics of the ocean are complicated
- TDH only supports polar oceans
  - Most observations call for global oceans
  - May also not be enough to keep liquid if rotation is important
- Heating to keep Enceladus liquid is an open question

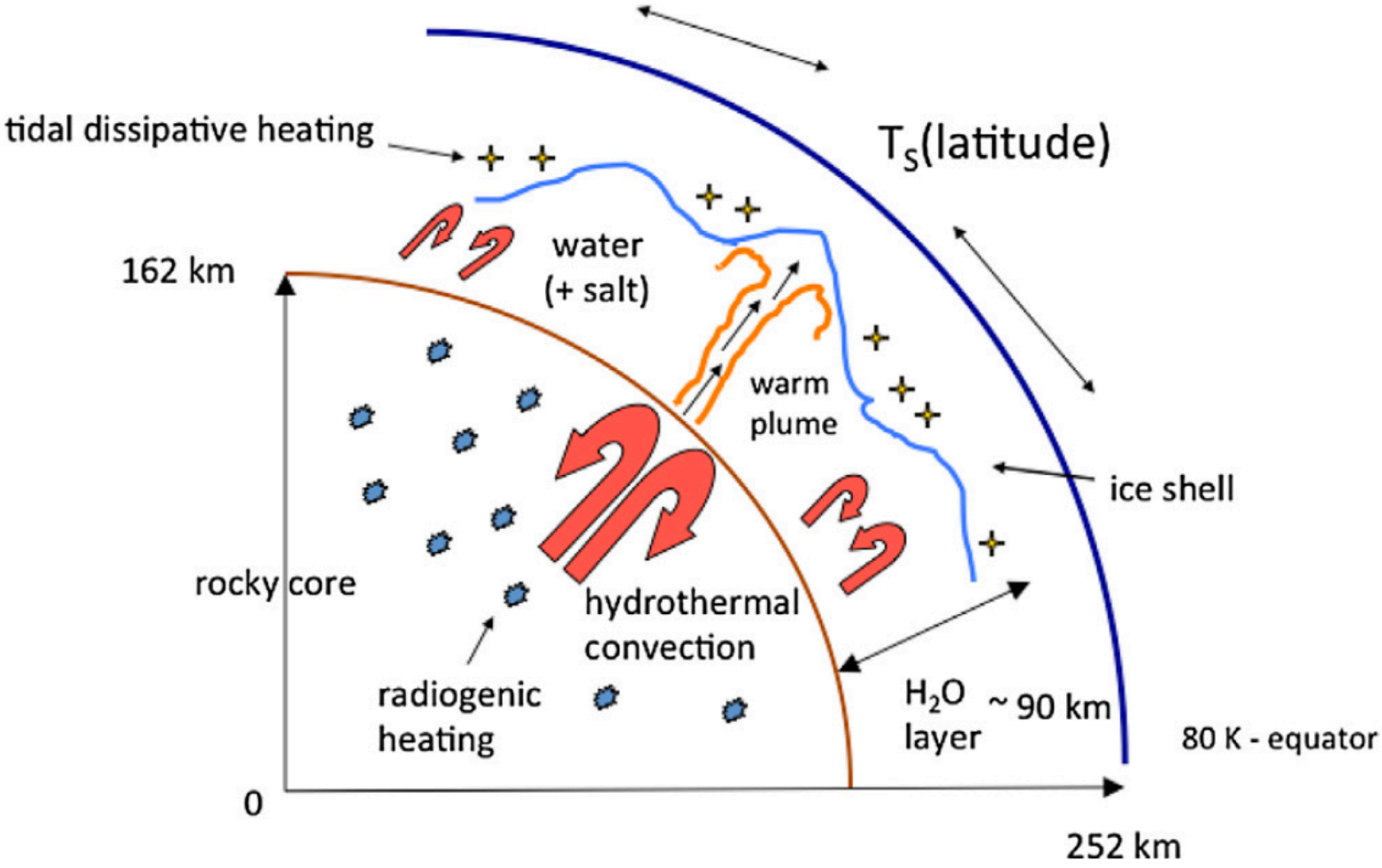
Extra Slides

Heating Mechanisms

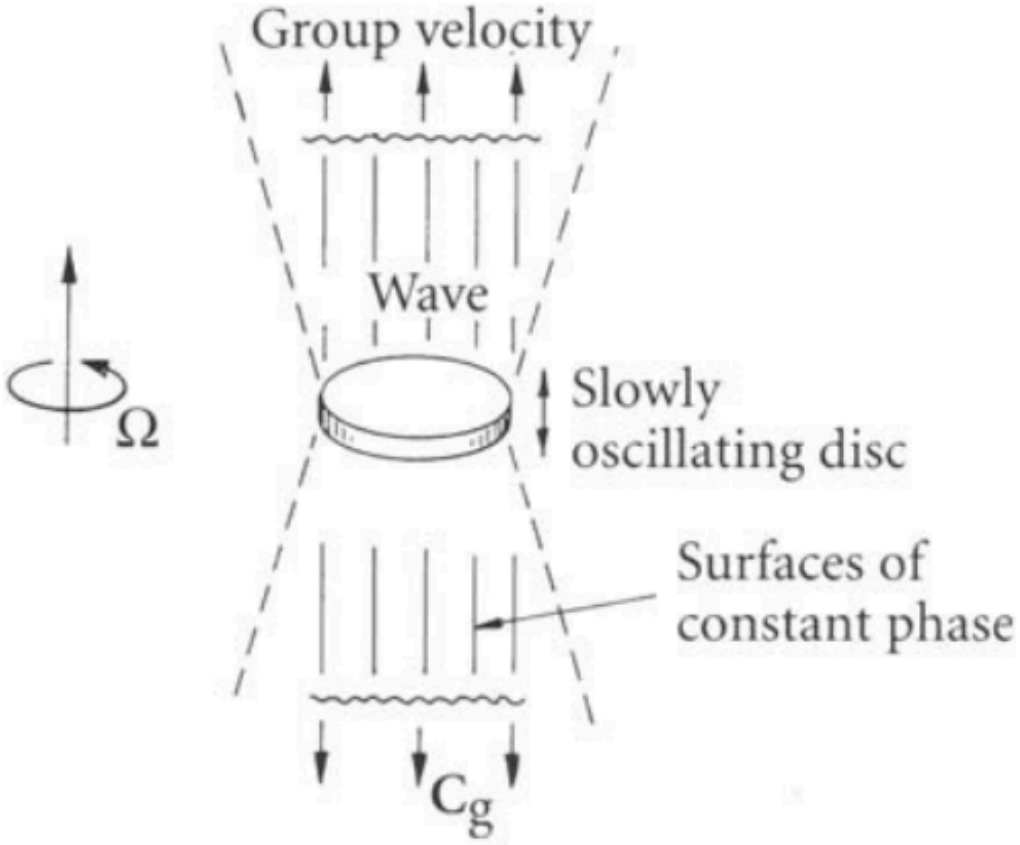
Heating Mechanism	Time to Re-freeze	Initial or on-going?
Radiogenic ^{26}Al and ^{60}Fe	< 1.5 Gyr	Initial
Exothermic chemical reactions	< 1 Gyr	Initial
Steady TDH	~ 30 Myr	On-going
Steady + Episodic TDH	Never!	On-going

- Tidal Dissipative Heating (TDH)
  - Requires an ocean
  - Steady state TDH from eccentricity of orbit
  - Evidence for episodic TDH every 100 Myr
  - Episodic burst lasting 5 Myr at 10x steady level

Interior Heat Processes



Rossby Waves and Taylor Columns



Ward (2010), Davidson (2004)