What We Don't Know About Europa

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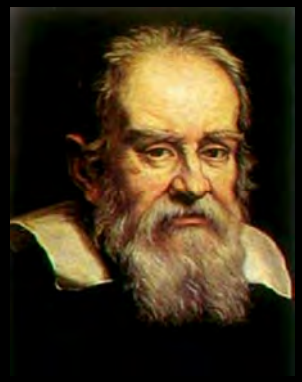
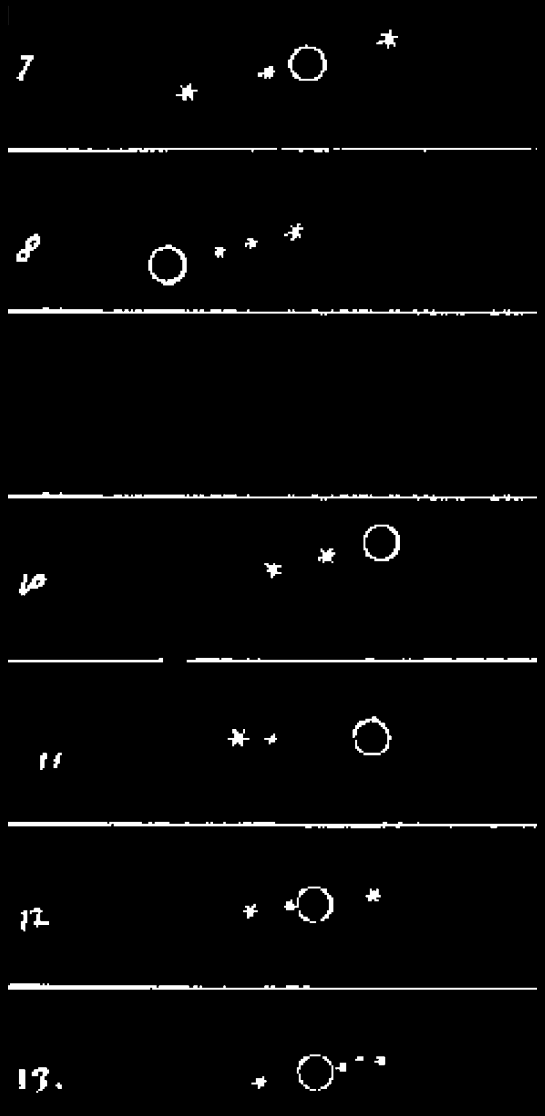
The Galilean Satellites: January 1610

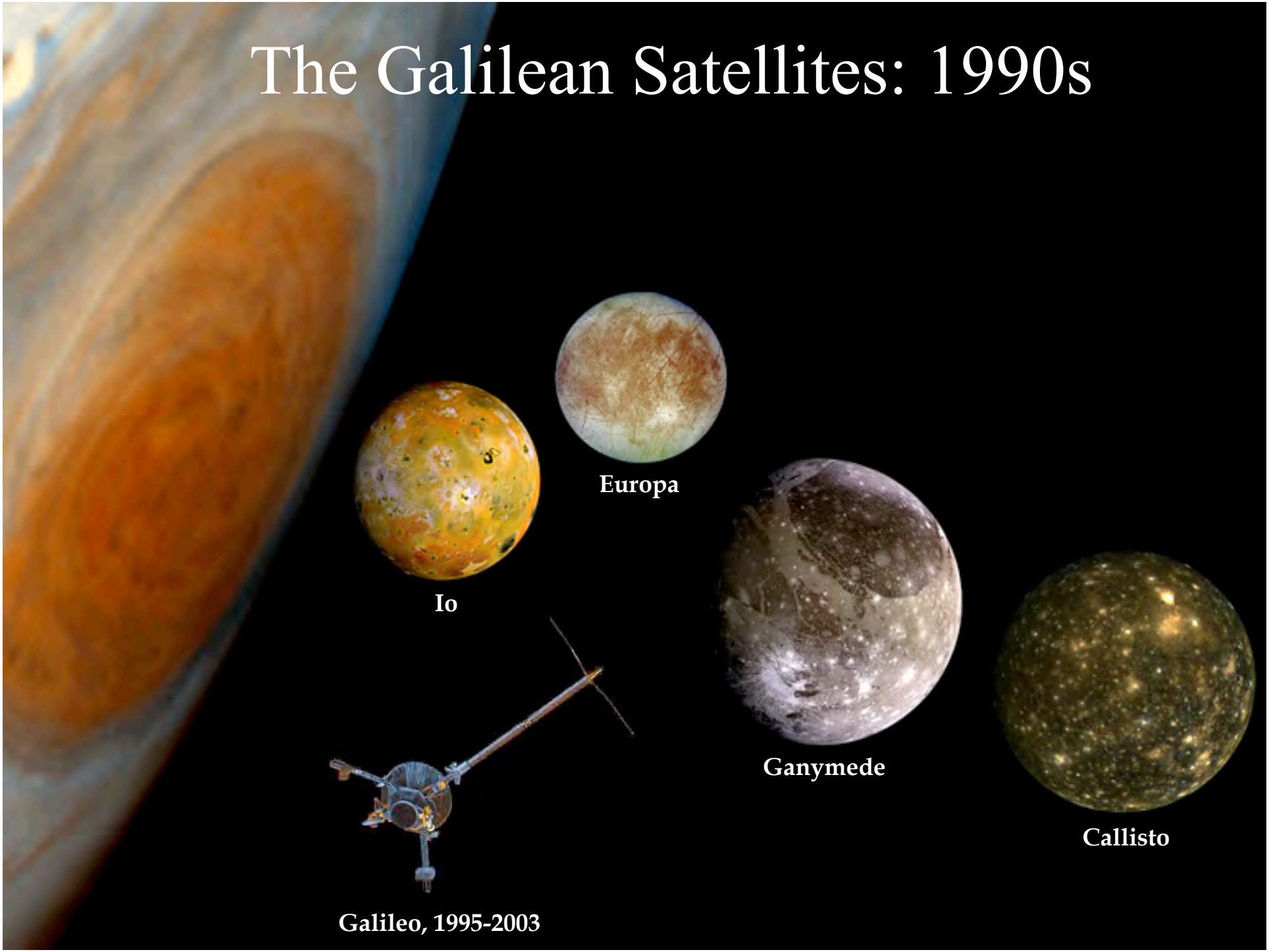


Galileo's sketches

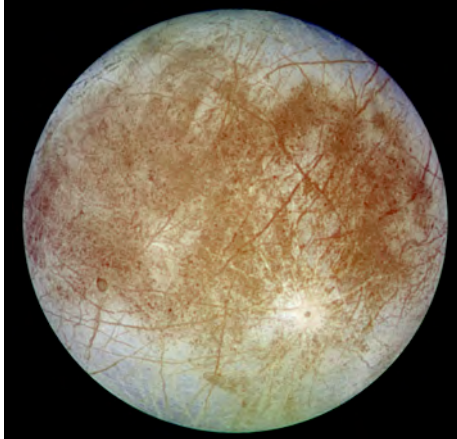


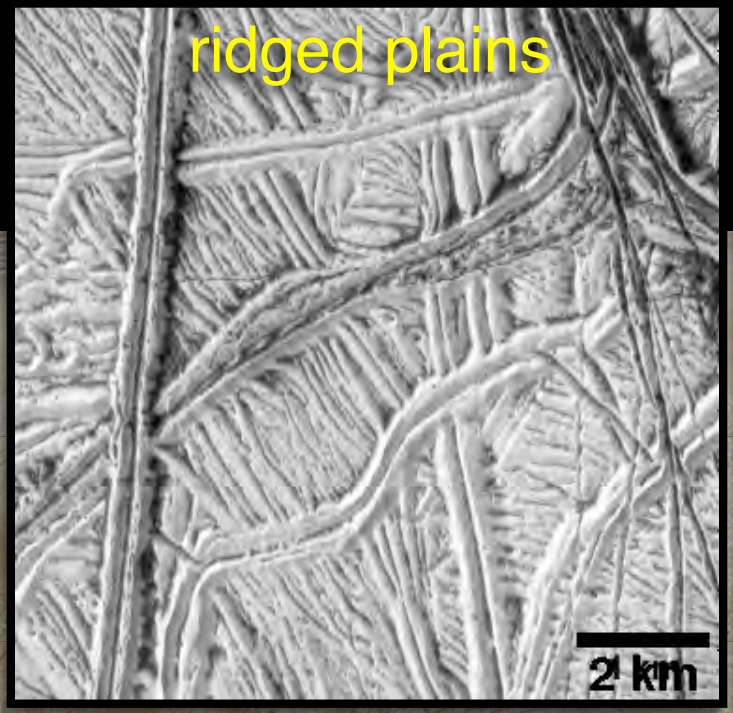
JPL Solar System Simulator

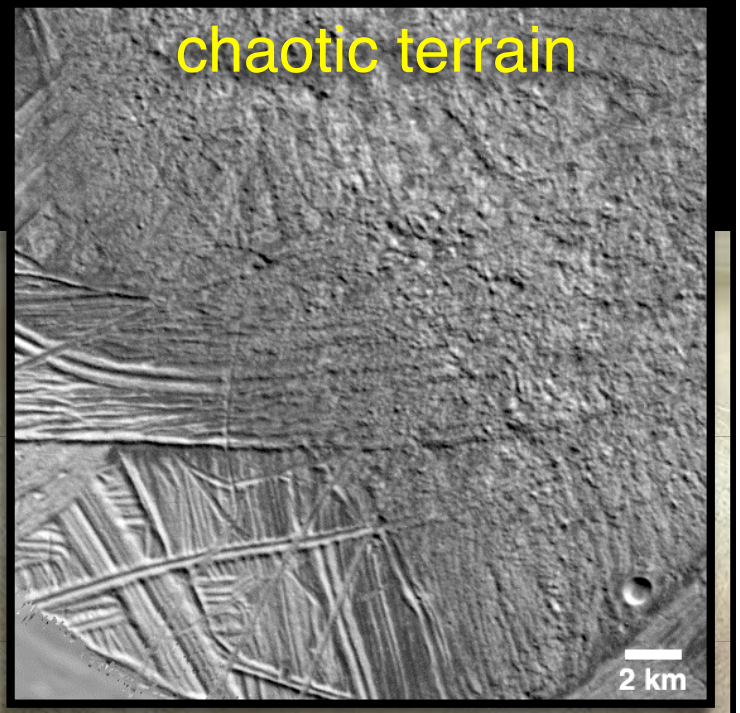
The Galilean Satellites: 1990s



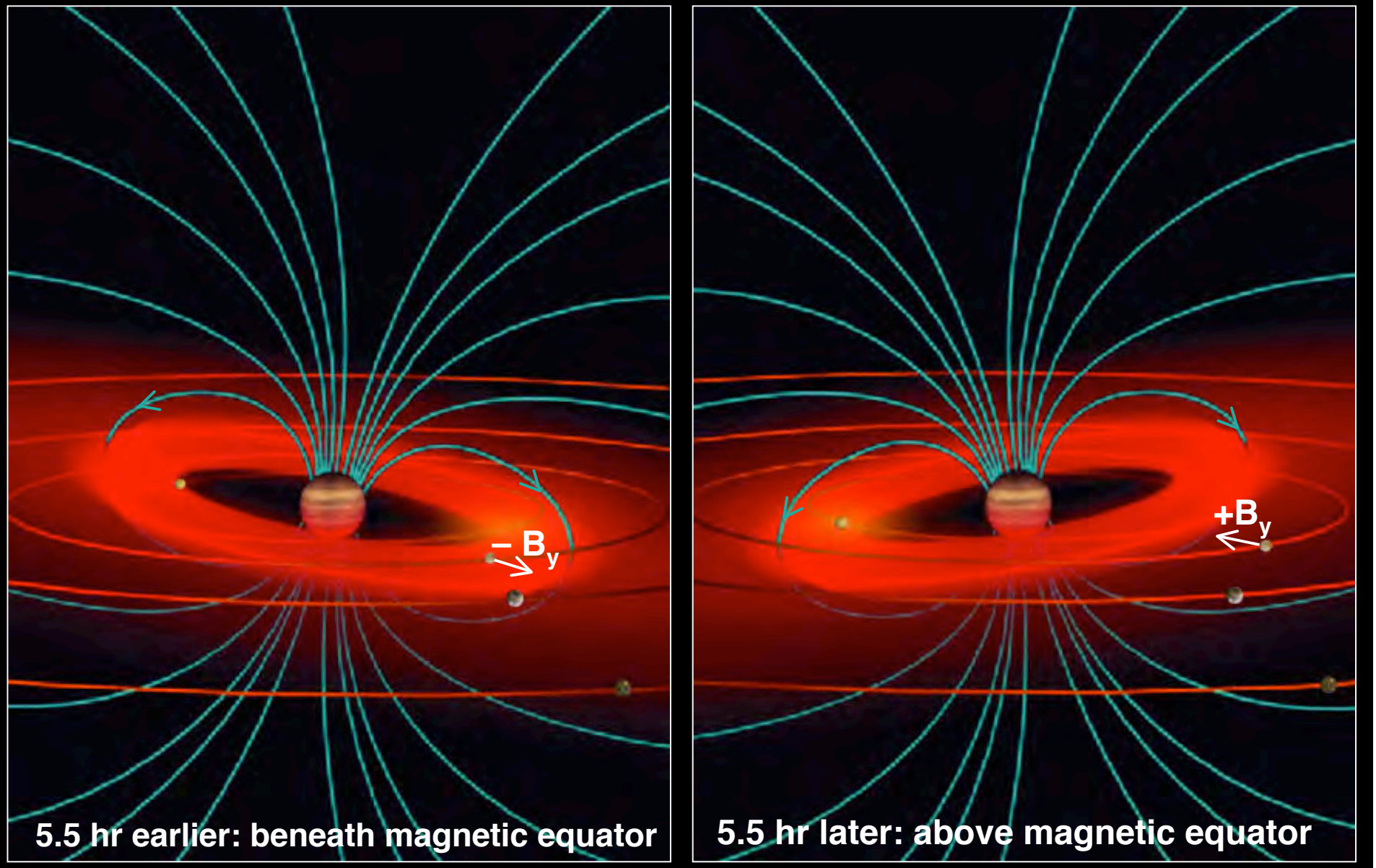
Enigmatic Europa

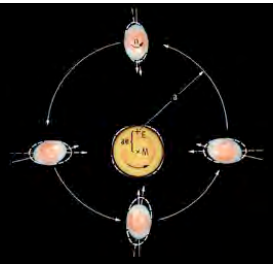




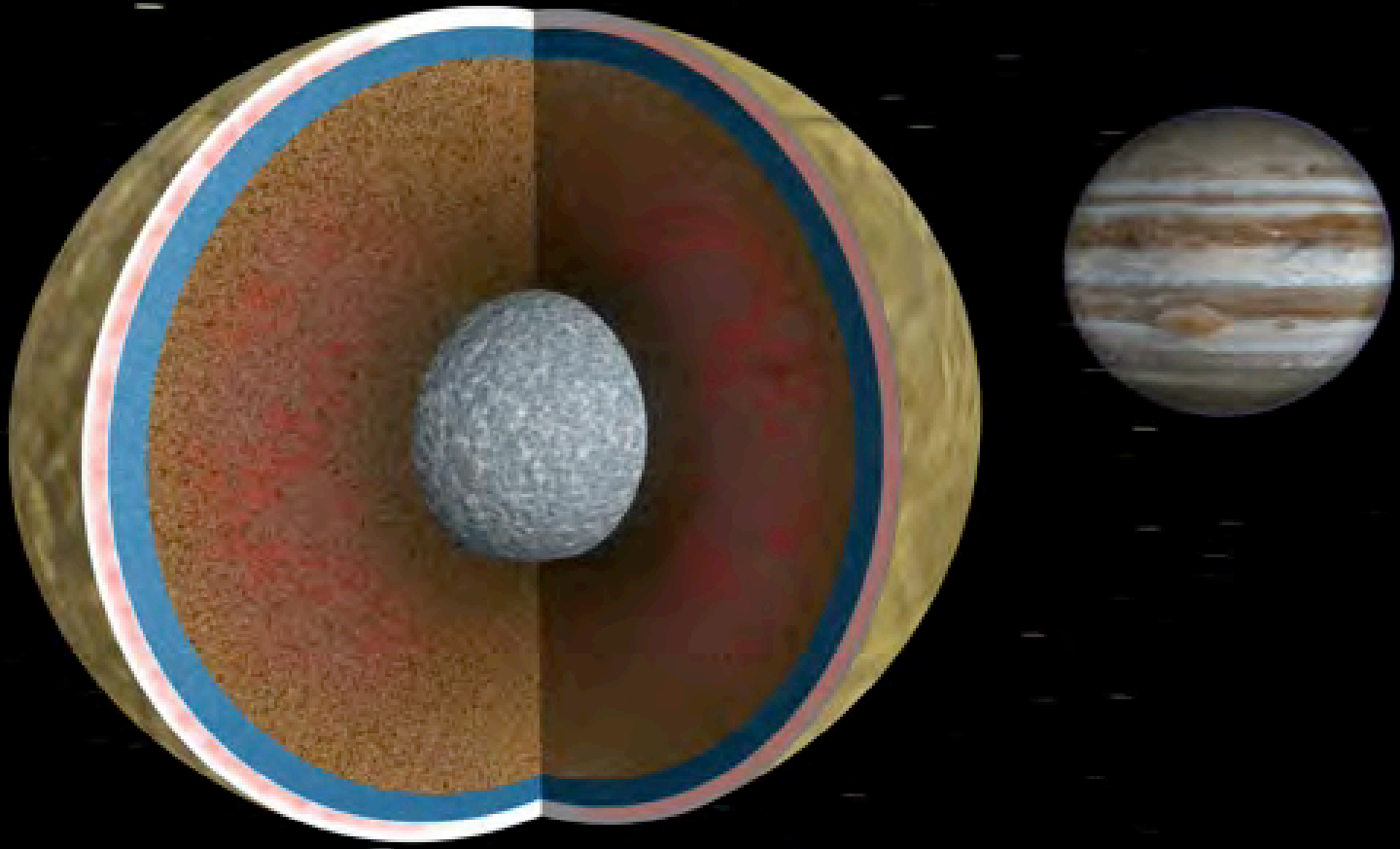


Europa's Induced Magnetic Field

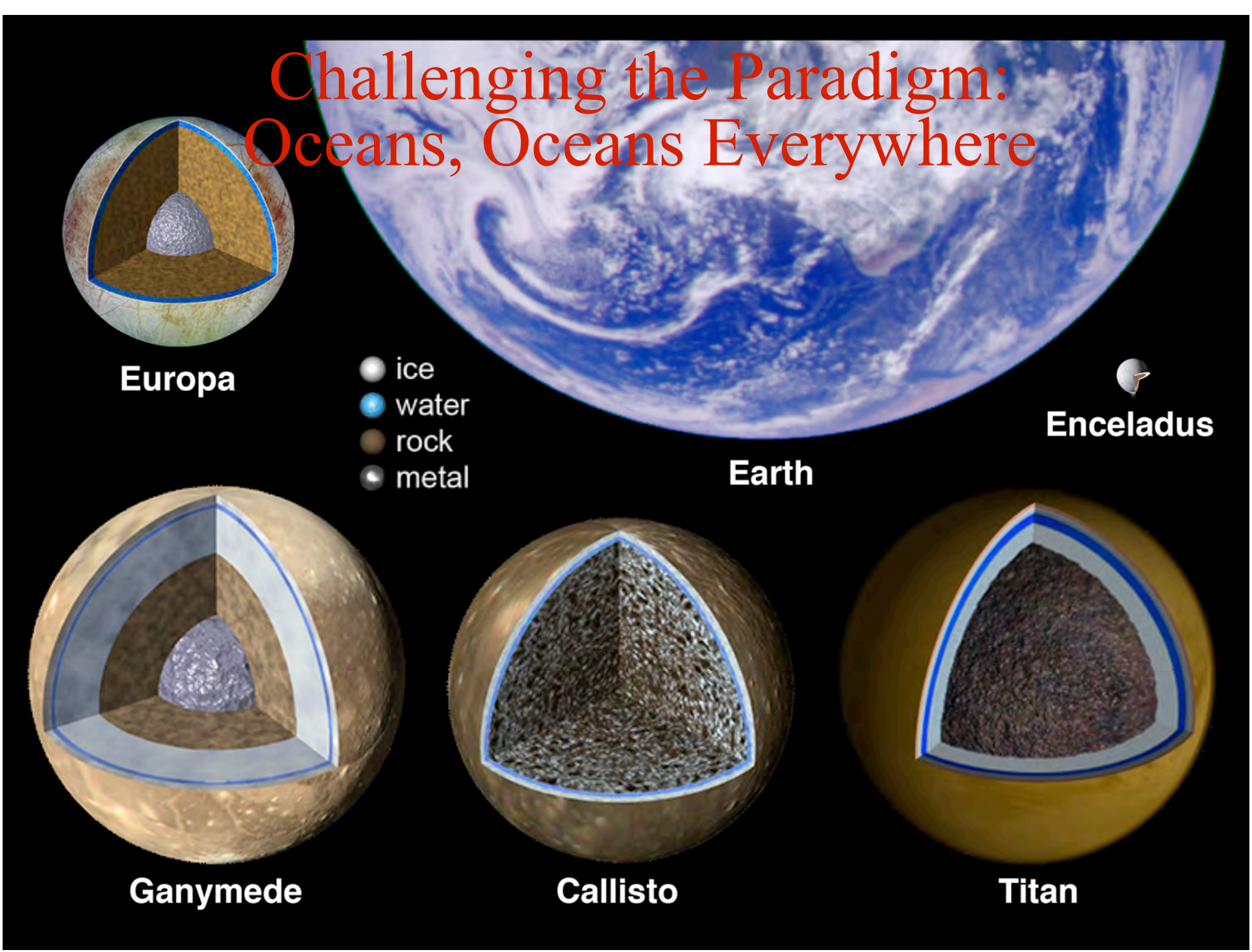




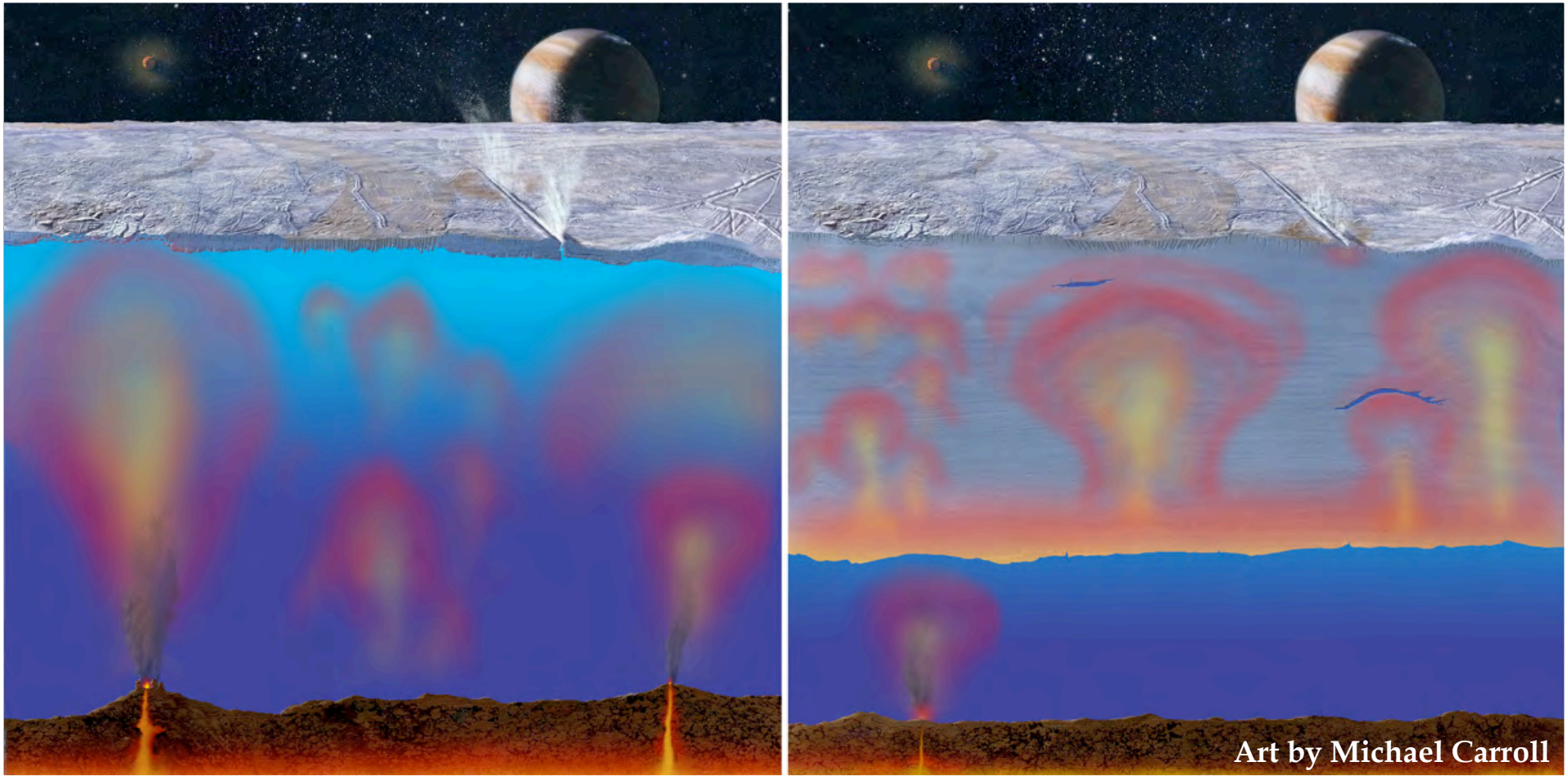
Flexing ⇒ Tidal Heating



Challenging the Paradigm: Oceans, Oceans Everywhere

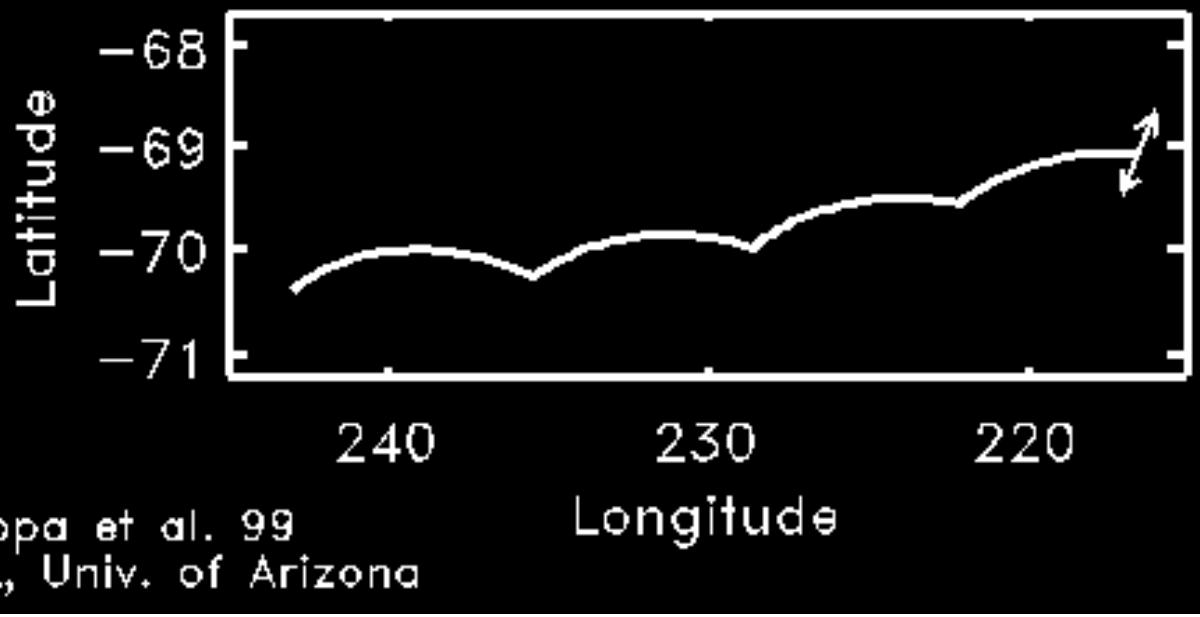


(1) What is the three-dimensional character of the icy shell?

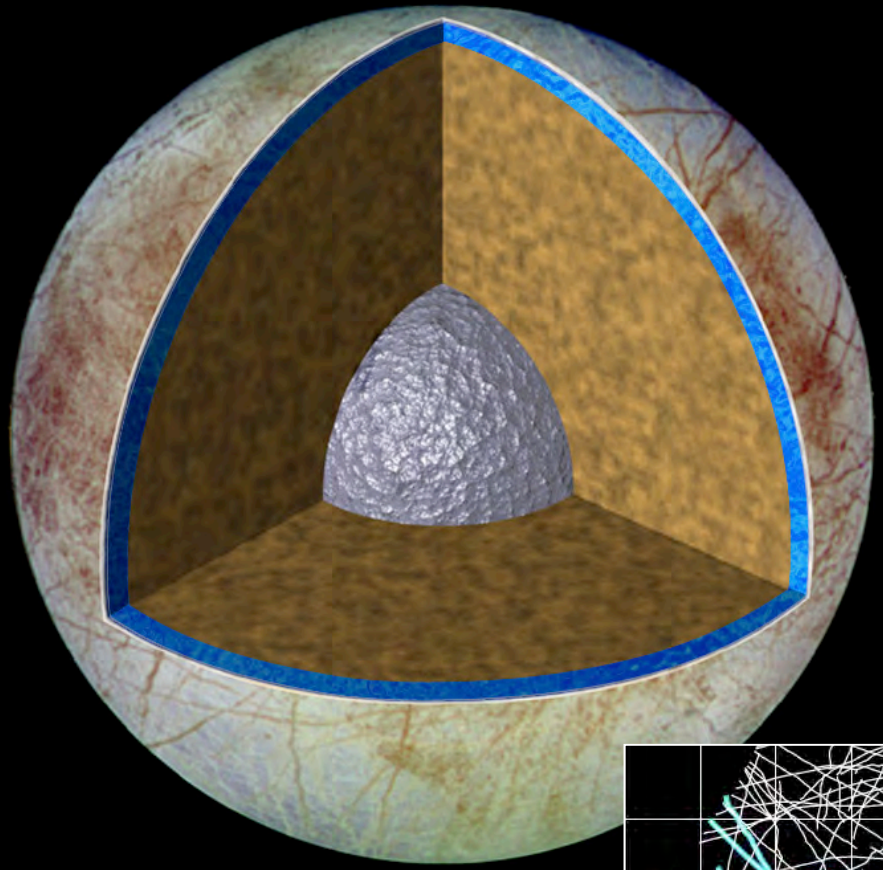


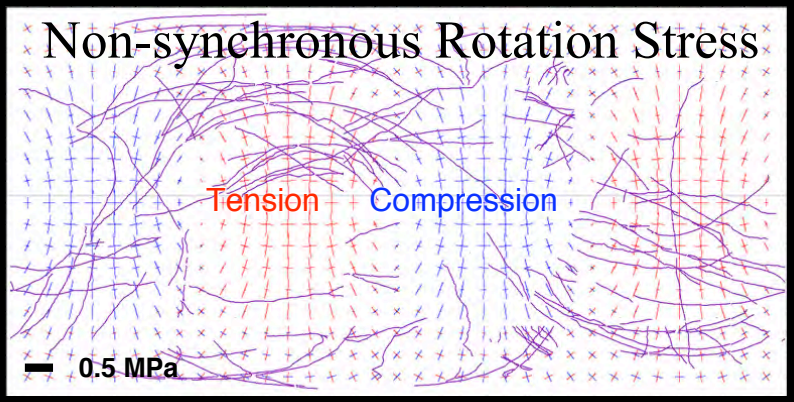
- Different implications for habitability and future exploration.
- Understanding “exchange processes” is key.

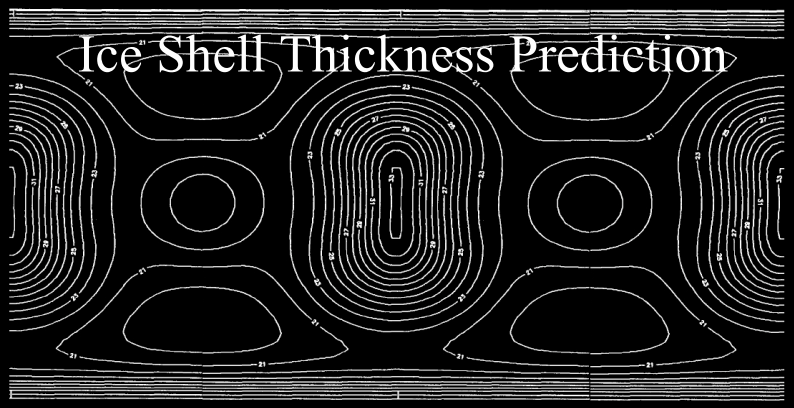
(2) What are the mechanisms of icy shell cracking?

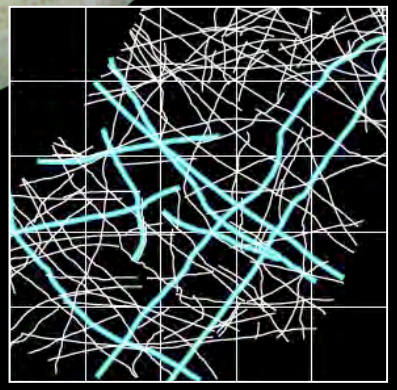


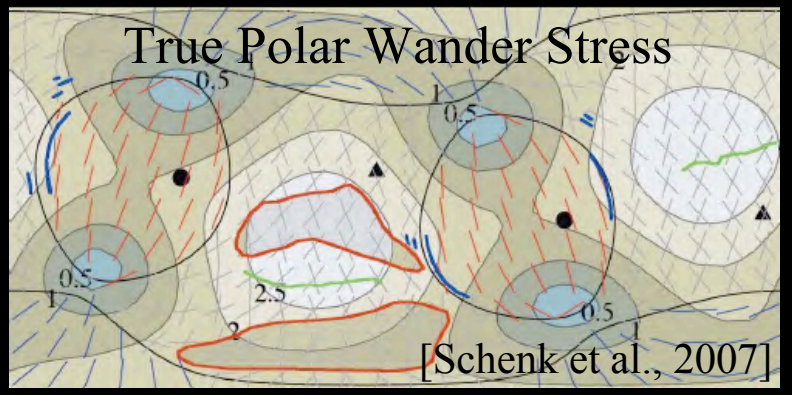
(3) What is the rotation history recorded in the icy shell?



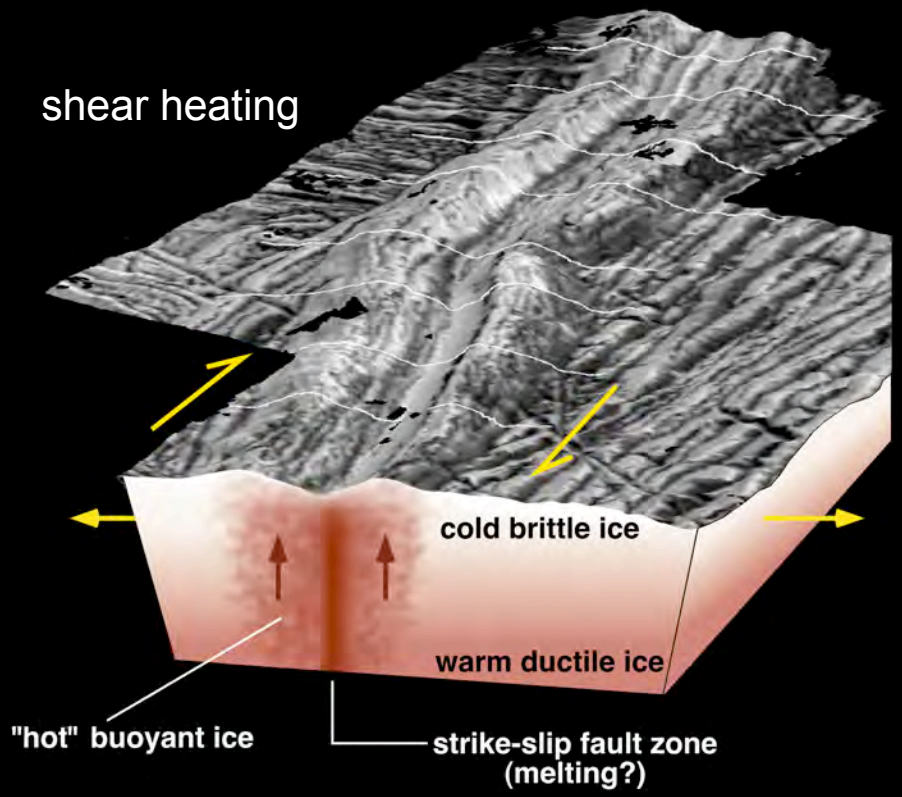


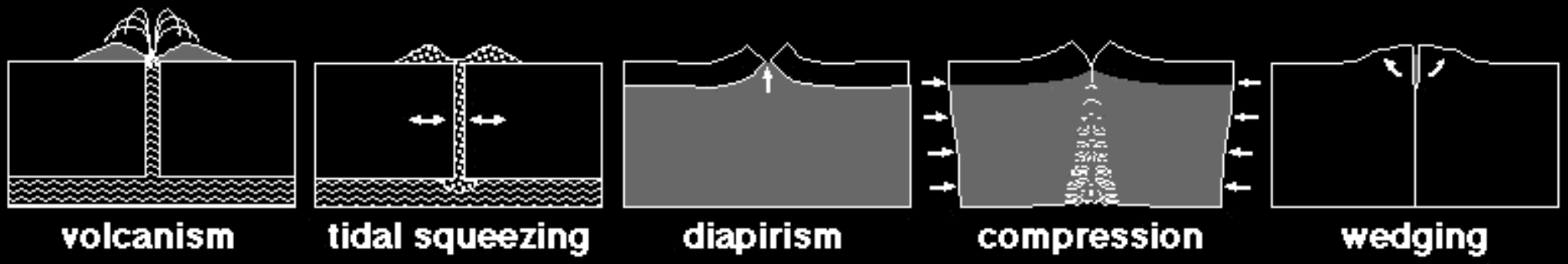




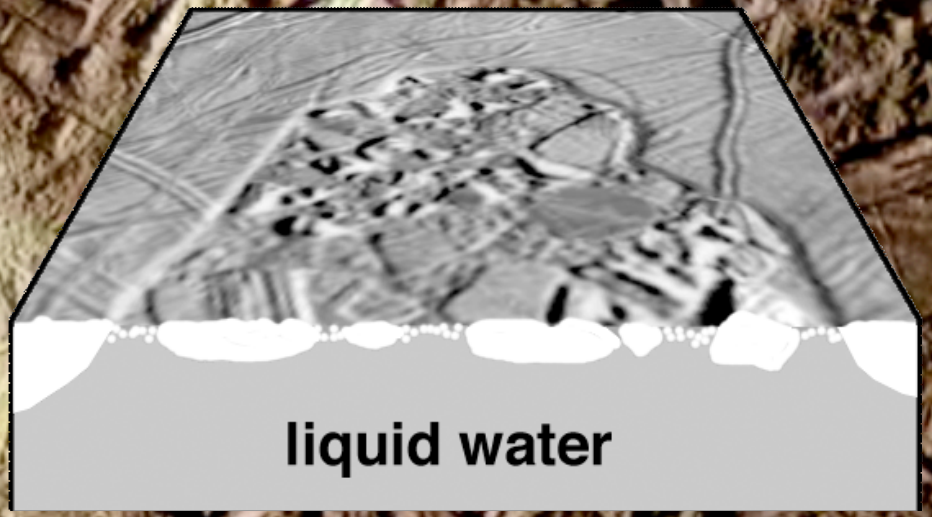


(4) How do ridges form, and is liquid water involved?





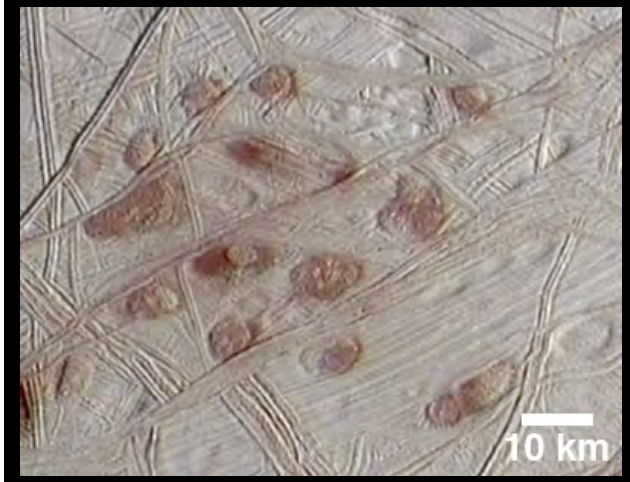
(5) How are chaos regions formed, and is liquid water involved?

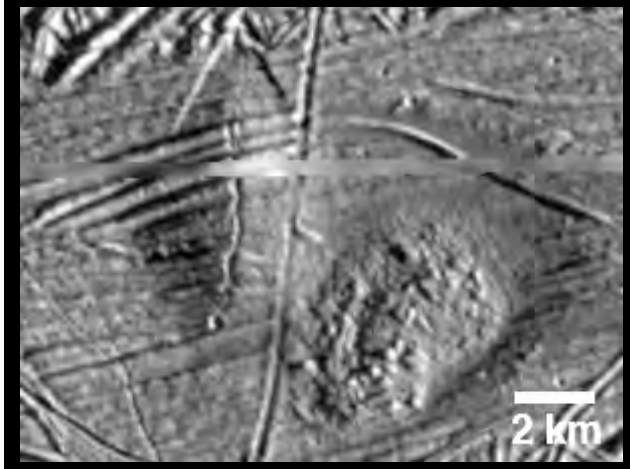


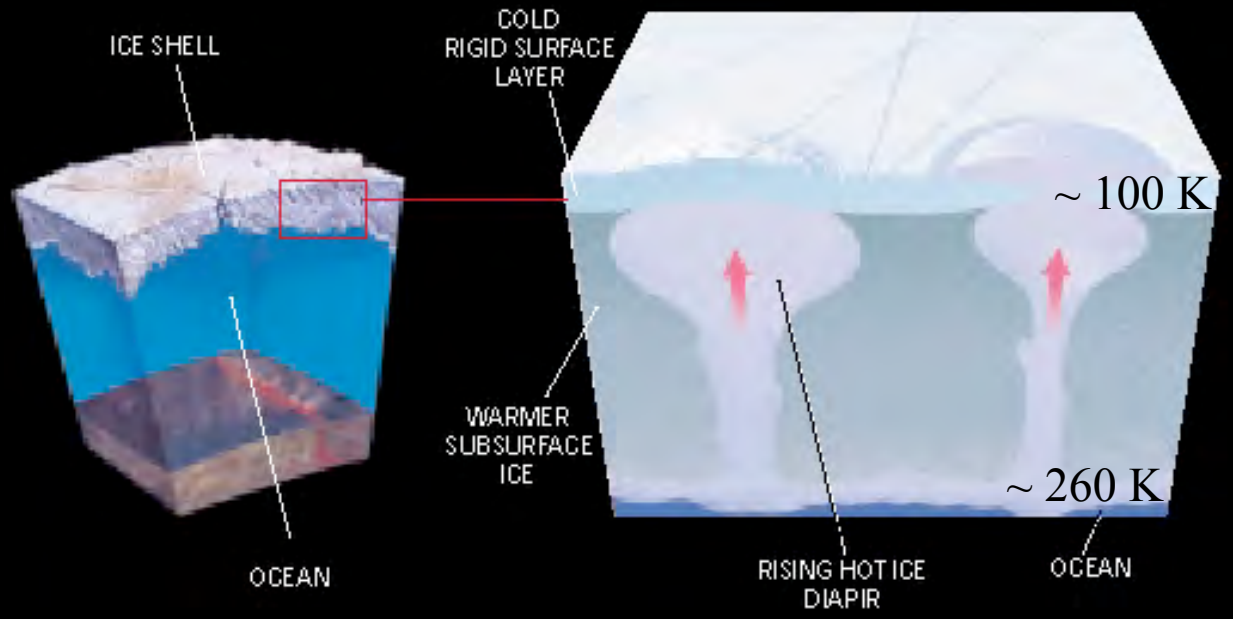
Melt-through model

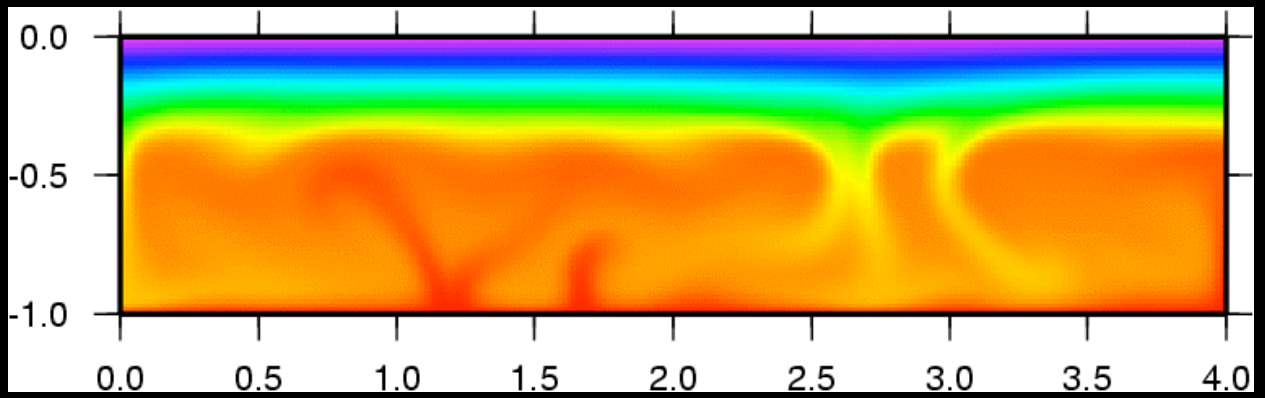
Diapirism model

(6) Is the icy shell convecting?





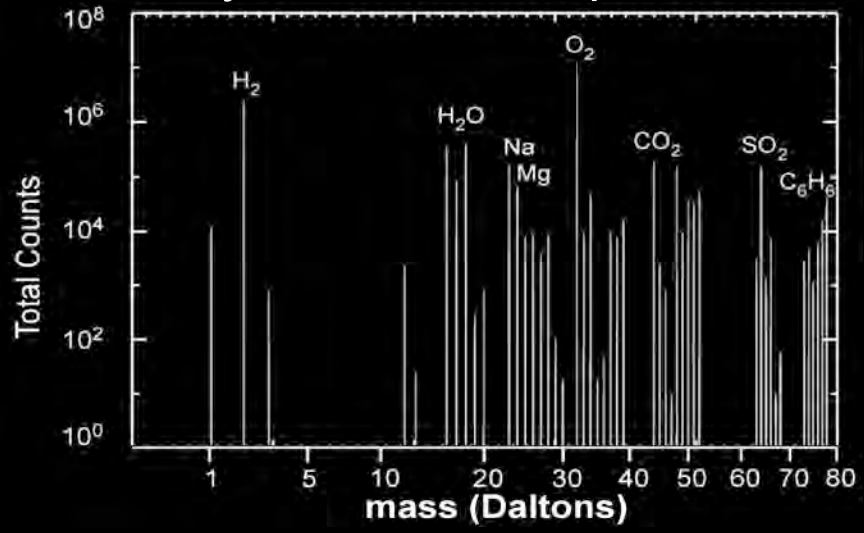


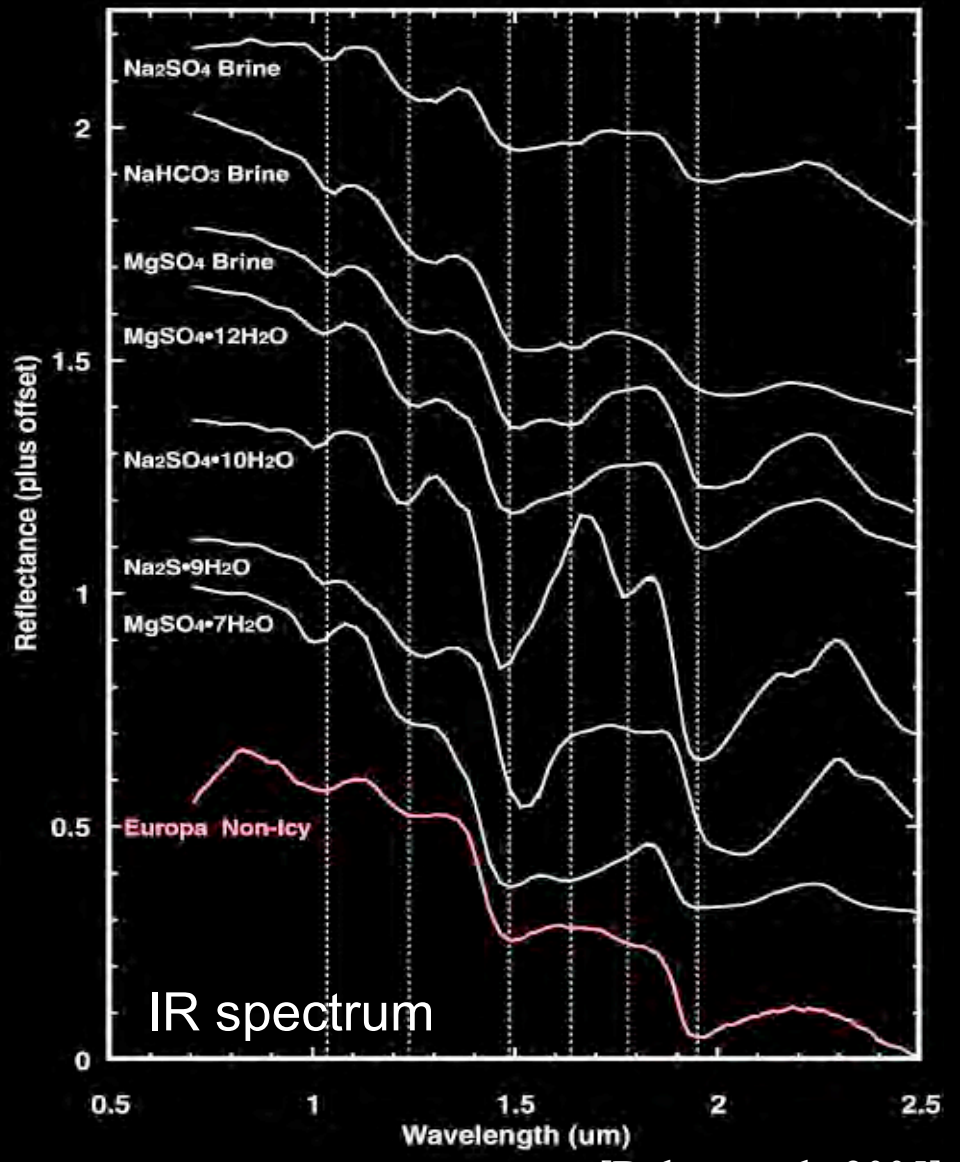


(7) What are the non-ice components of the icy shell?

- "Non-ice" material may contain hydrated salts, sulfuric acid, and sulfur.

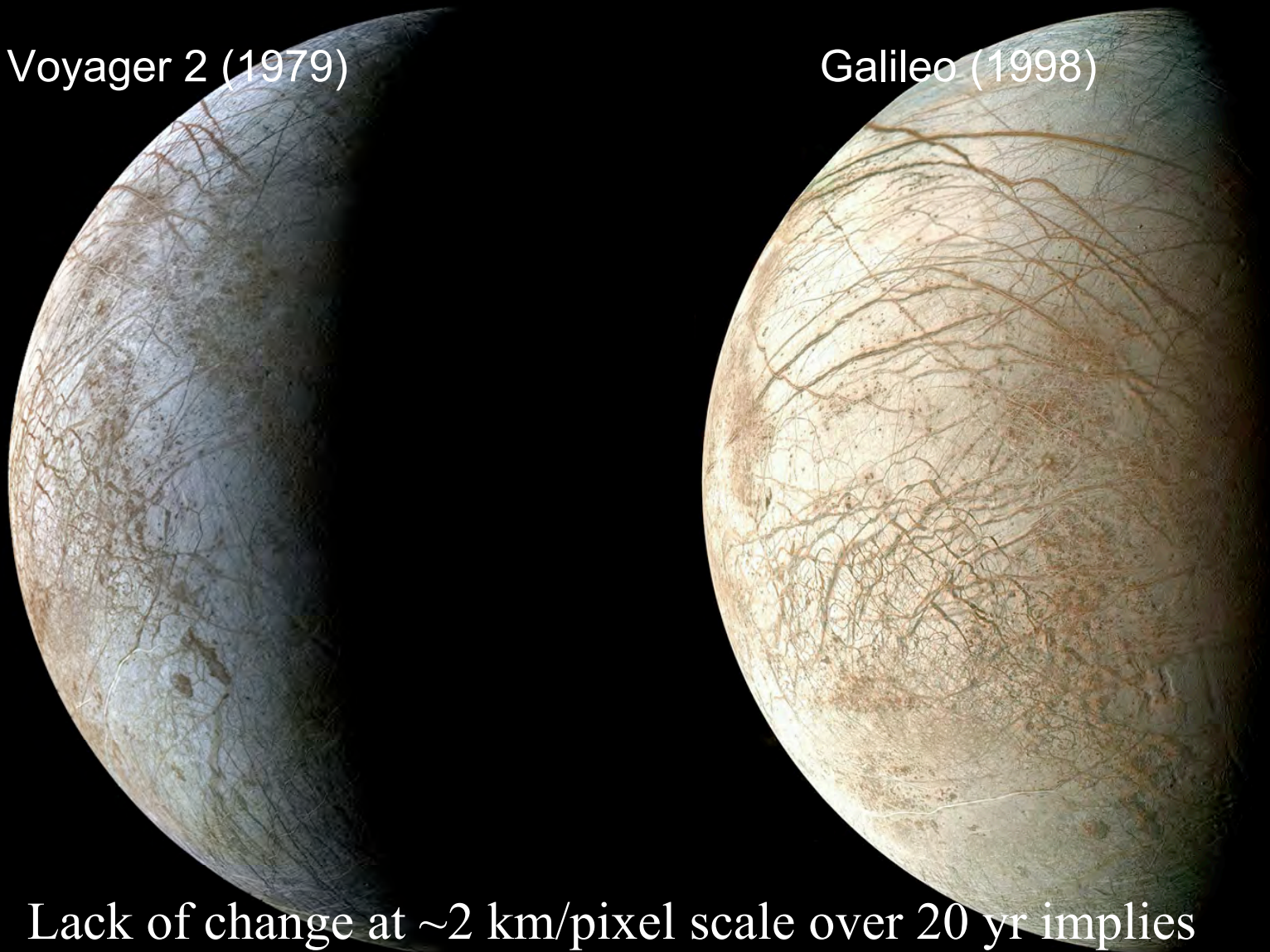
synthetic mass spectrum





[Dalton et al., 2005]

(8) How active is Europa today?

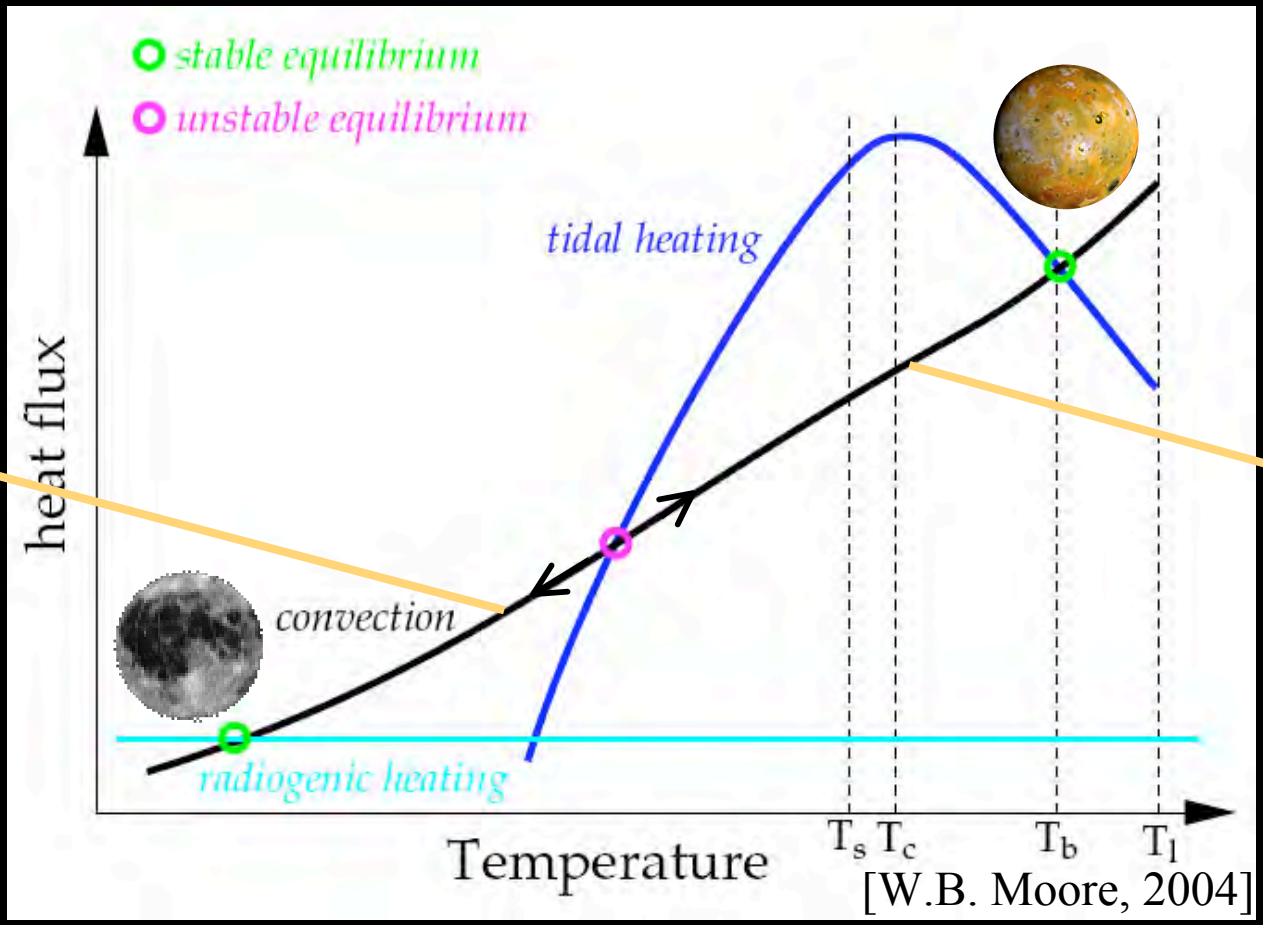


- Lack of change at ~2 km/pixel scale over 20 yr implies <1km^2/yr resurfacing rate and >30 Myr age [Phillips et al., 2000].

(9) Is the rocky mantle hot?

- Moon-like: Meager heat supply (radiogenic only).
- Io-like: Extreme tidal heating partially melts rock.

cooling by convection outpaces heating

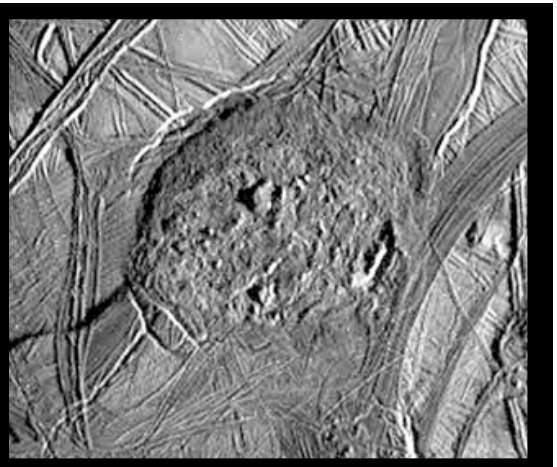


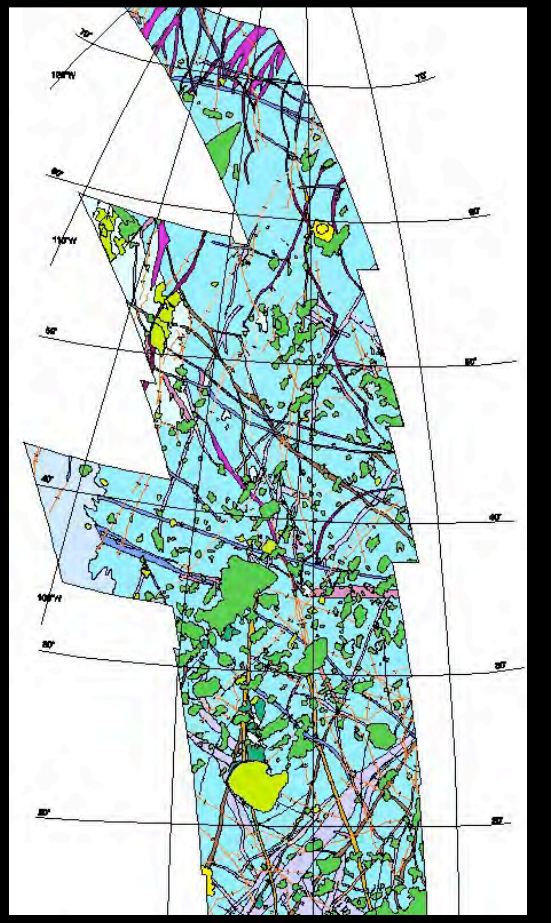
[W.B. Moore, 2004]

heating outpaces cooling by convection

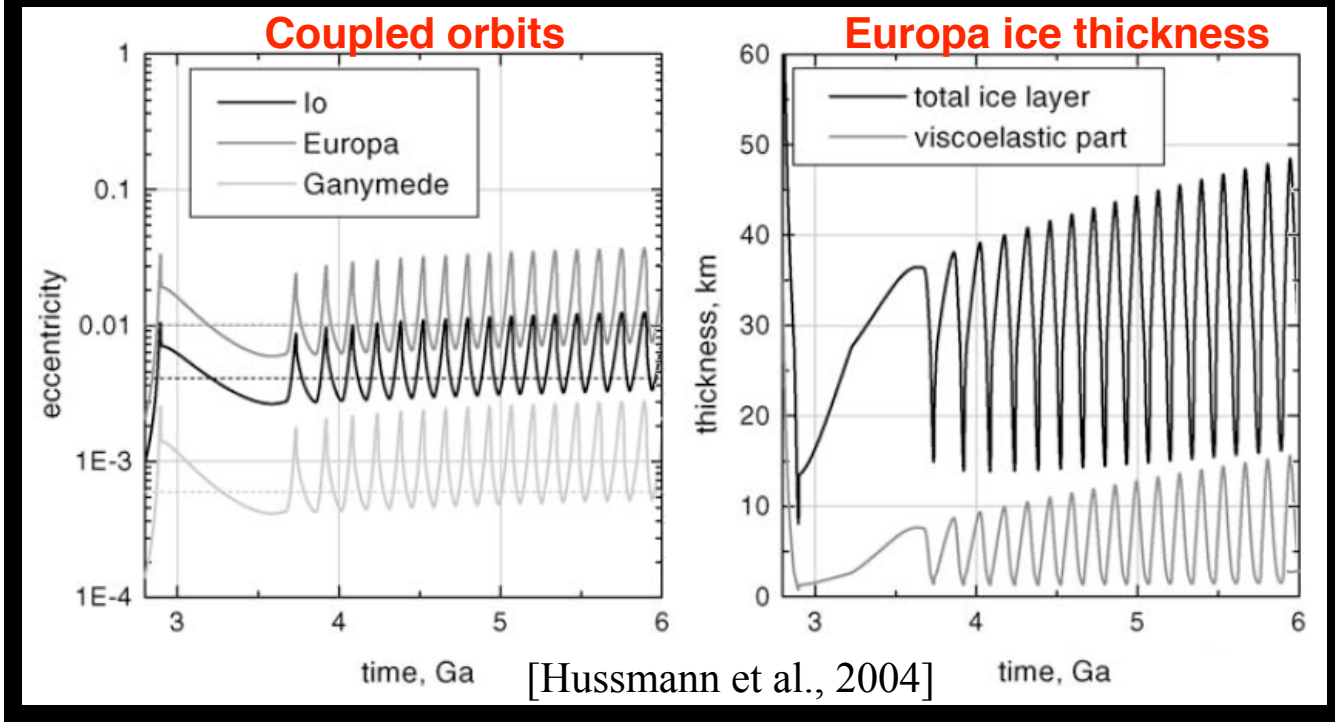
(10) Has Europa's activity changed through time?

- Mapping suggests geological changes:
  - ✧ Transition from ridged plains to chaos; waning activity.
- Strange for a surface just ~60 Myr old.
- Tidal heating and orbital evolution of the 3 resonant Galilean satellites are linked:
  - ✧ Possible cyclical tidal heating & geological activity.



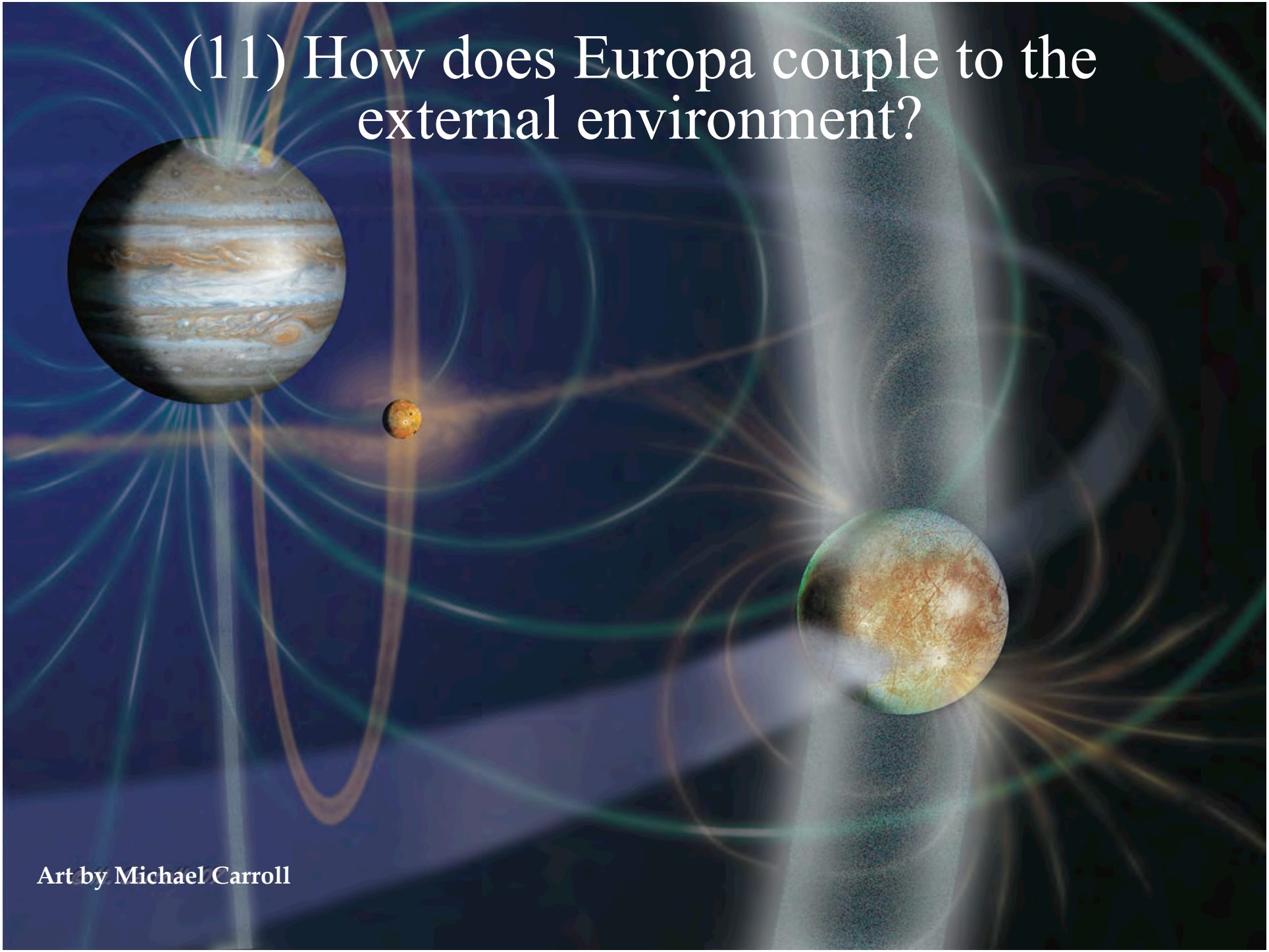


[Figueredo & Greeley, 2004]



[Hussmann et al., 2004]

(11) How does Europa couple to the external environment?

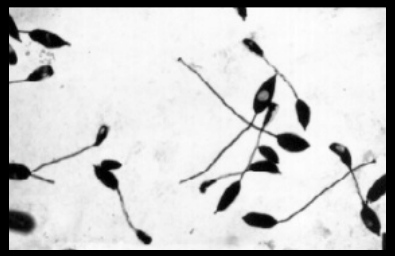


Art by Michael Carroll

(12) Is Europa's ocean habitable, and inhabited?

- Irradiation of surface H_2O creates oxidants:
  - ✧ H_2O_2 (hydrogen peroxide)
  - ✧ CH_2O (formaldehyde)
  - ✧ O_2 clathrates
- Hydrothermal activity at mantle could produce reductants
- Chemical energy availability is the most significant question regarding ocean habitability

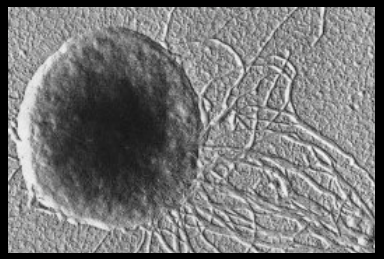
Hyphomicrobium



CH_2O oxidation:

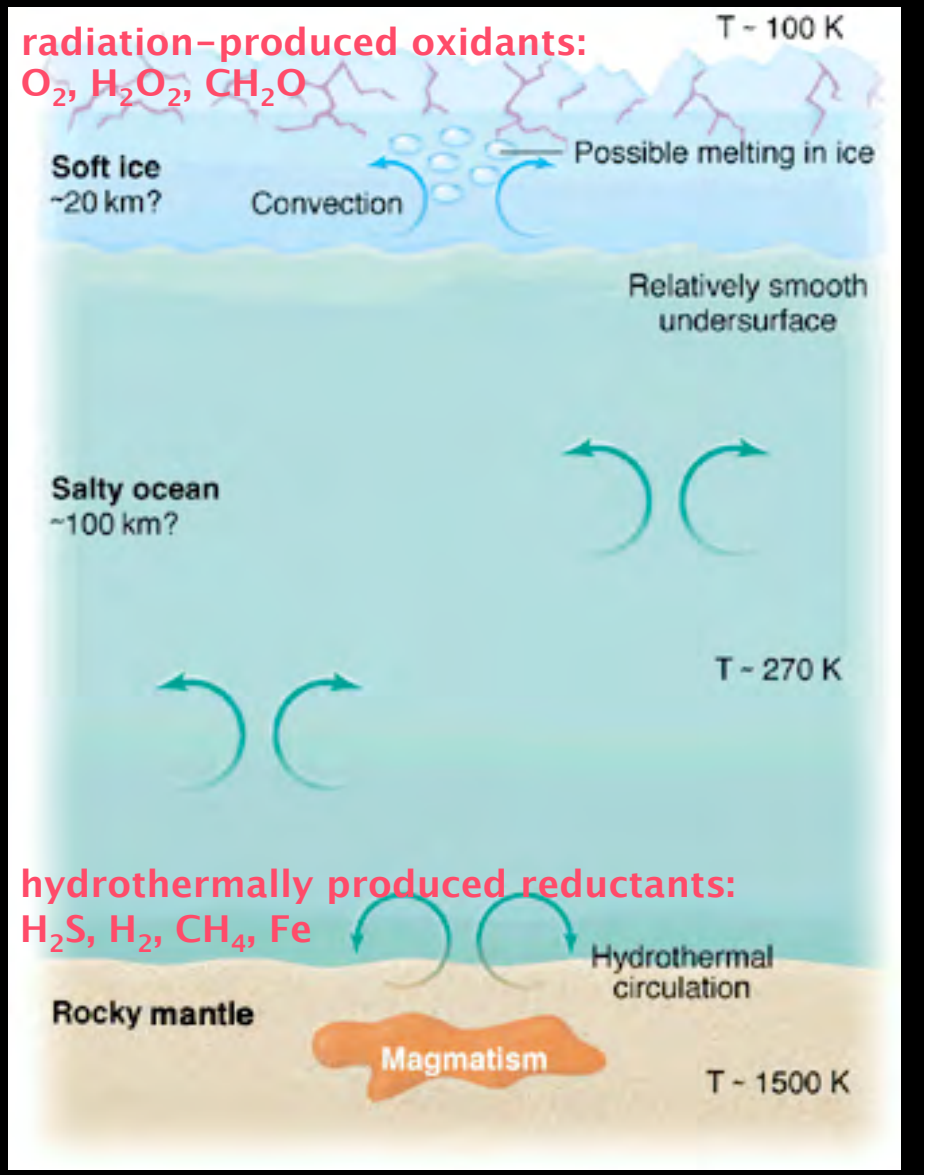
$CH_2O + O_2 \rightarrow H_2O + CO_2$

Methanococcus jannischii



Methanogenesis:

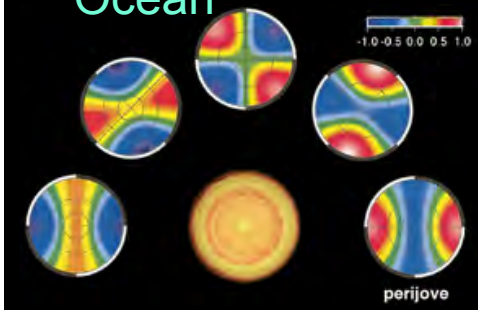
$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$



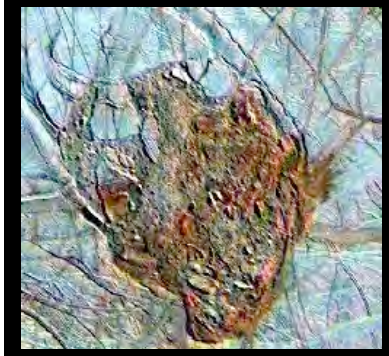
[after Stevenson, 2000]

Proposed Jupiter Europa Orbiter (JEO)
Goal: Explore Europa to Investigate Its Habitability

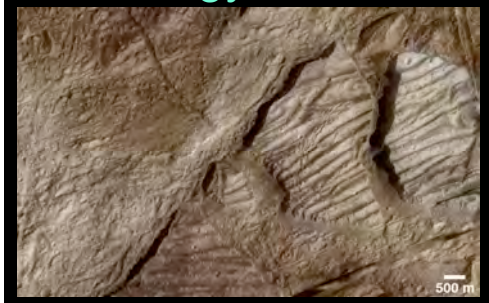
Ocean



Composition



Geology



Objectives:

A. Ocean:
Extent of the ocean and its relation to the deeper interior.

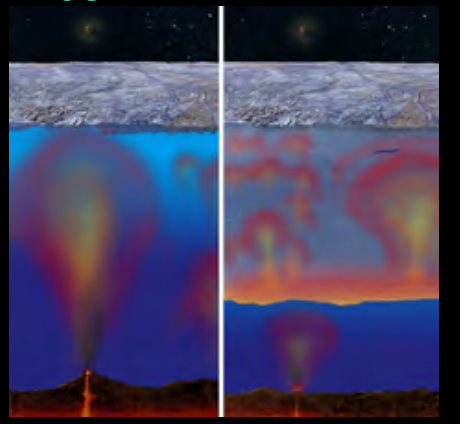
B. Ice:
Ice shell and subsurface water, and surface-ice-ocean exchange.

C. Composition:
Surface compositions and chemistry, as related to habitability.

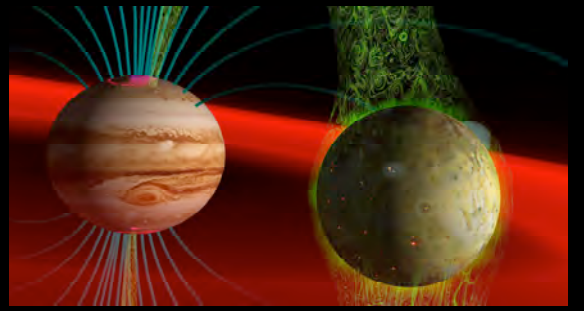
D. Geology:
Formation of surface features, current activity, and future landing sites.

E. Jupiter system:
Europa in the Jupiter system context.

Ice



Jupiter system



Proposed Europa Jupiter System Mission (EJSM)