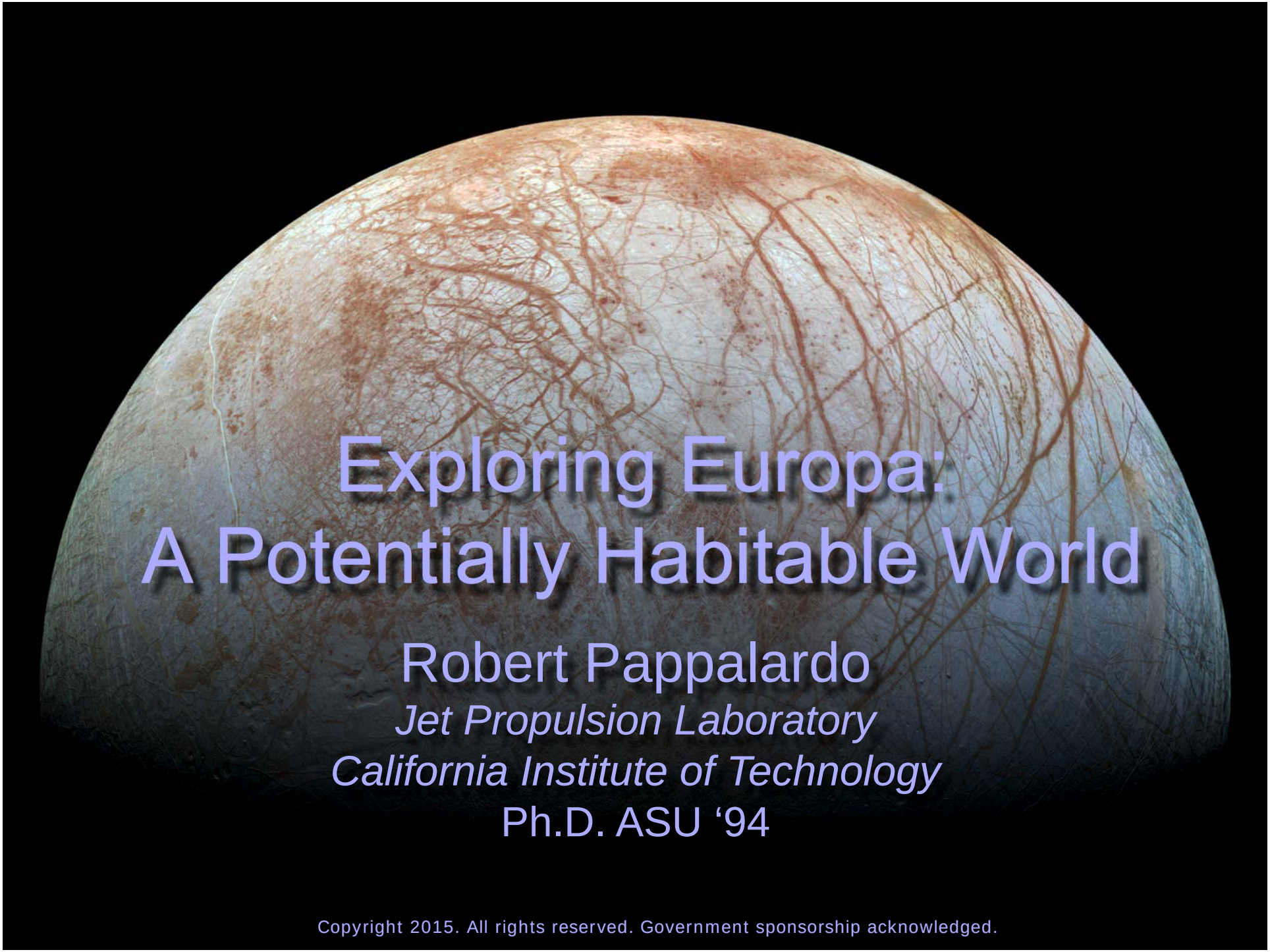


Exploring Europa: A Potentially Habitable World

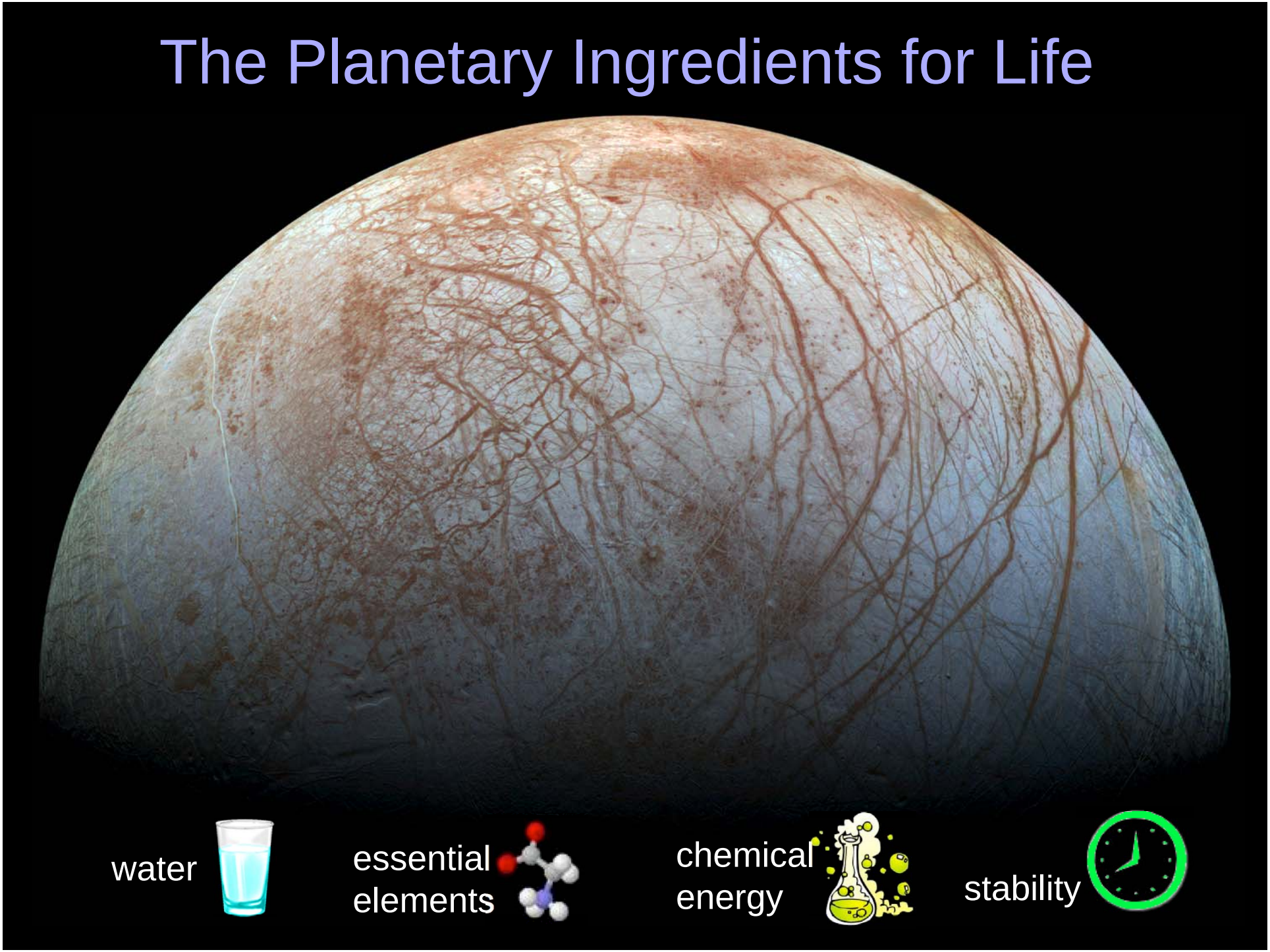
Robert Pappalardo

Jet Propulsion Laboratory

California Institute of Technology

Ph.D. ASU ‘94

The Planetary Ingredients for Life



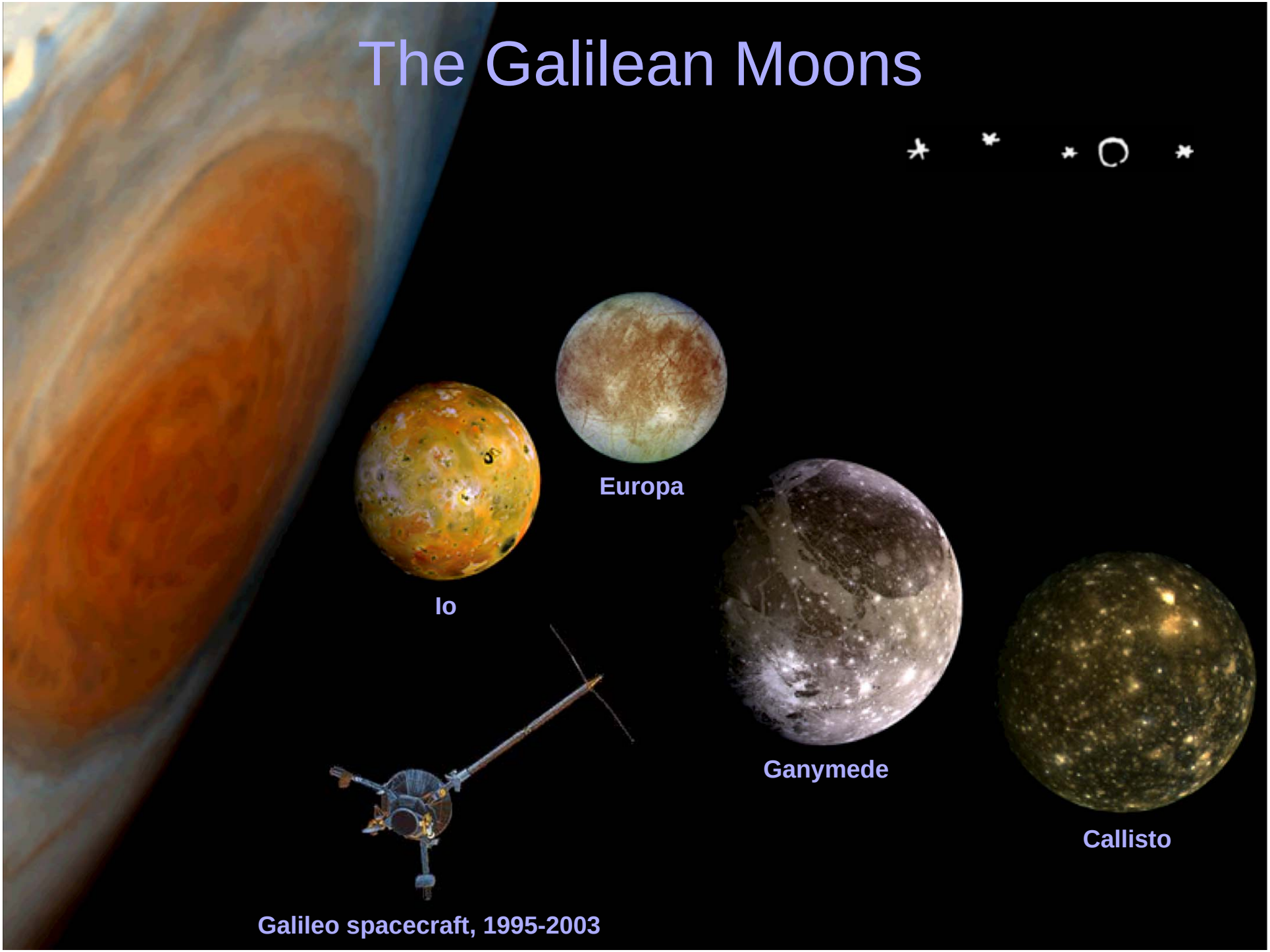
water

essential elements

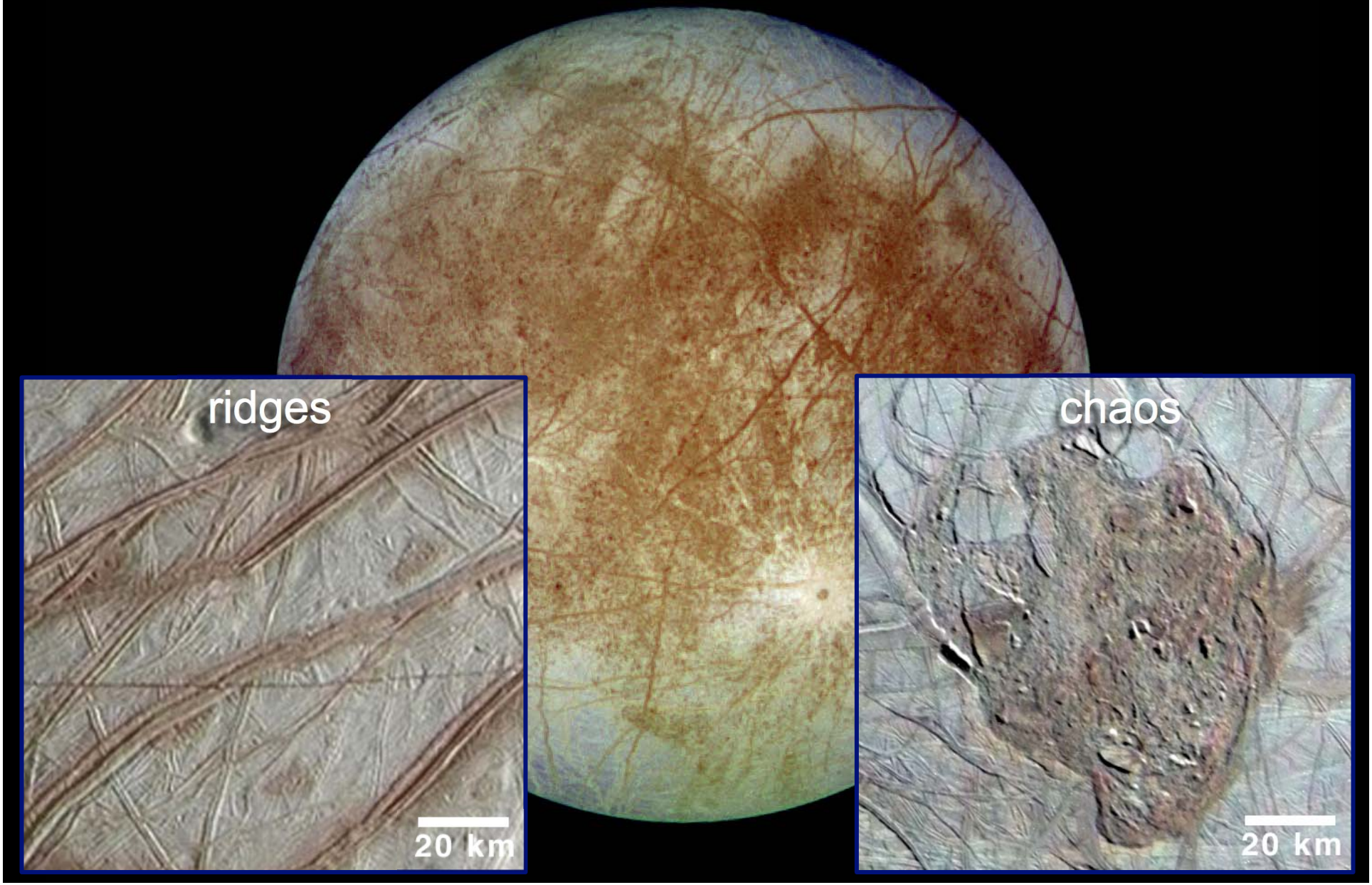
chemical energy

stability

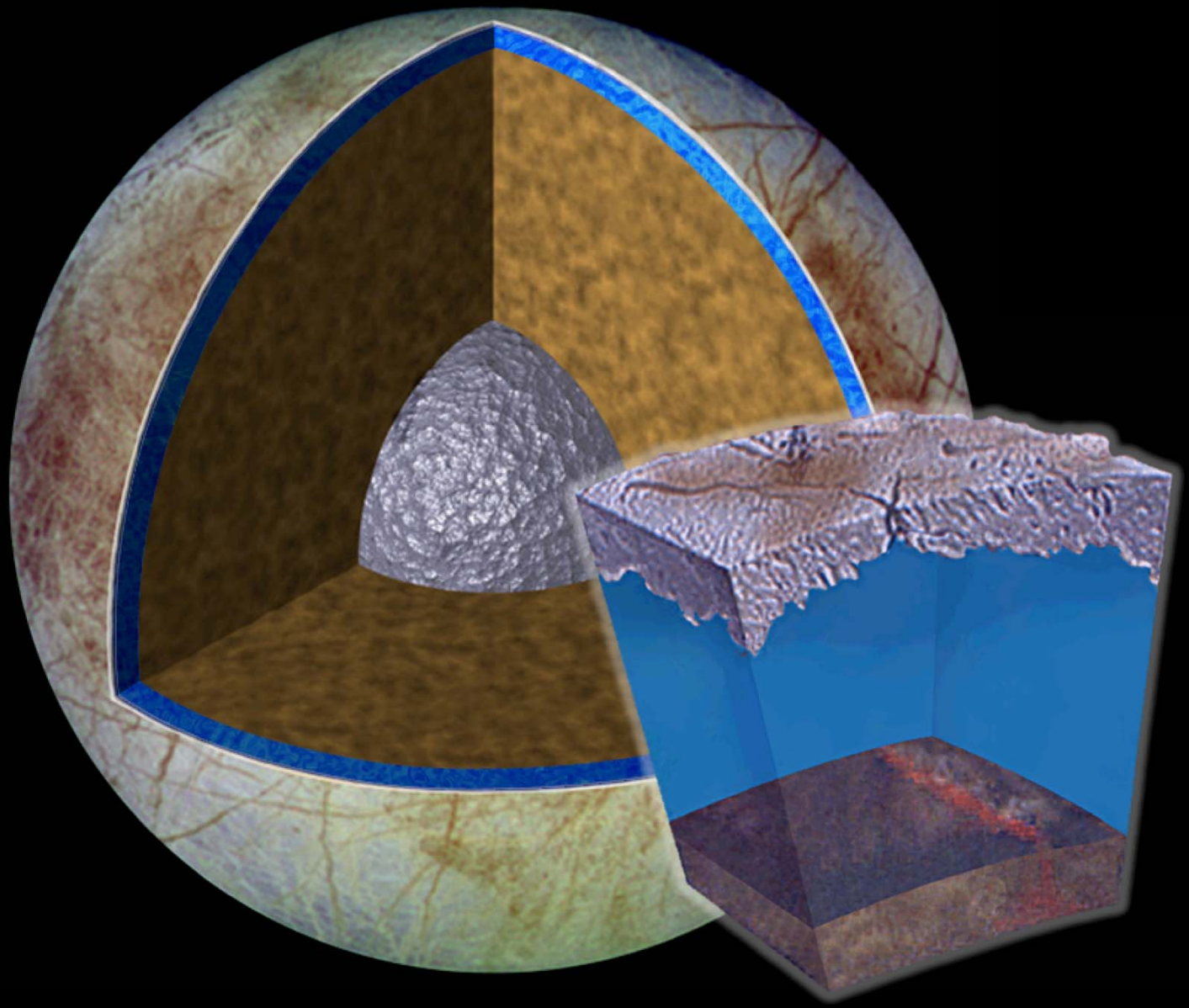
The Galilean Moons

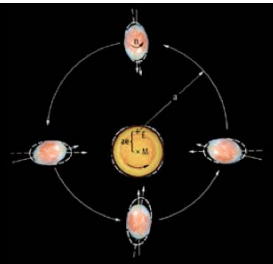


Europa's Surface

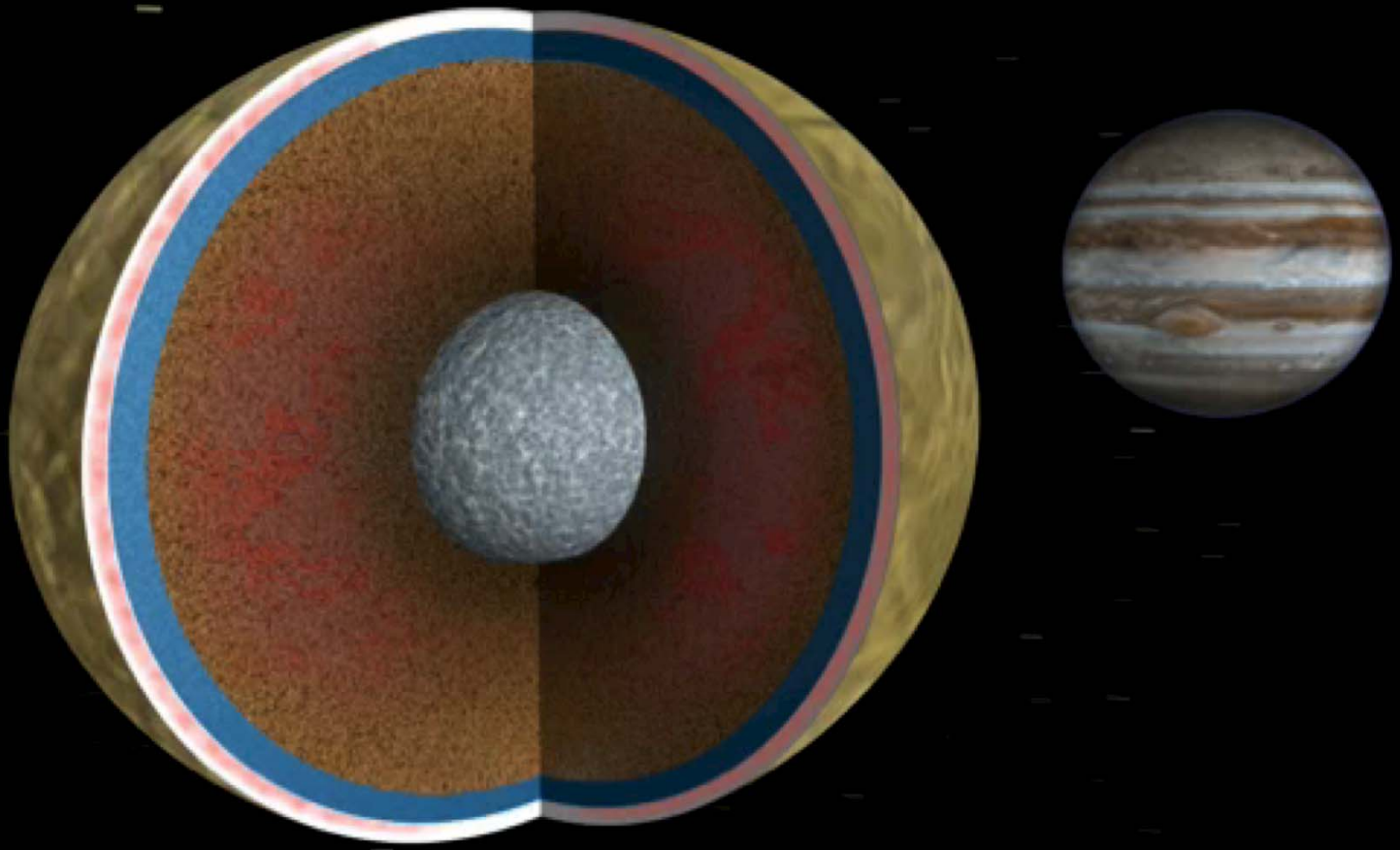


Europa's Interior

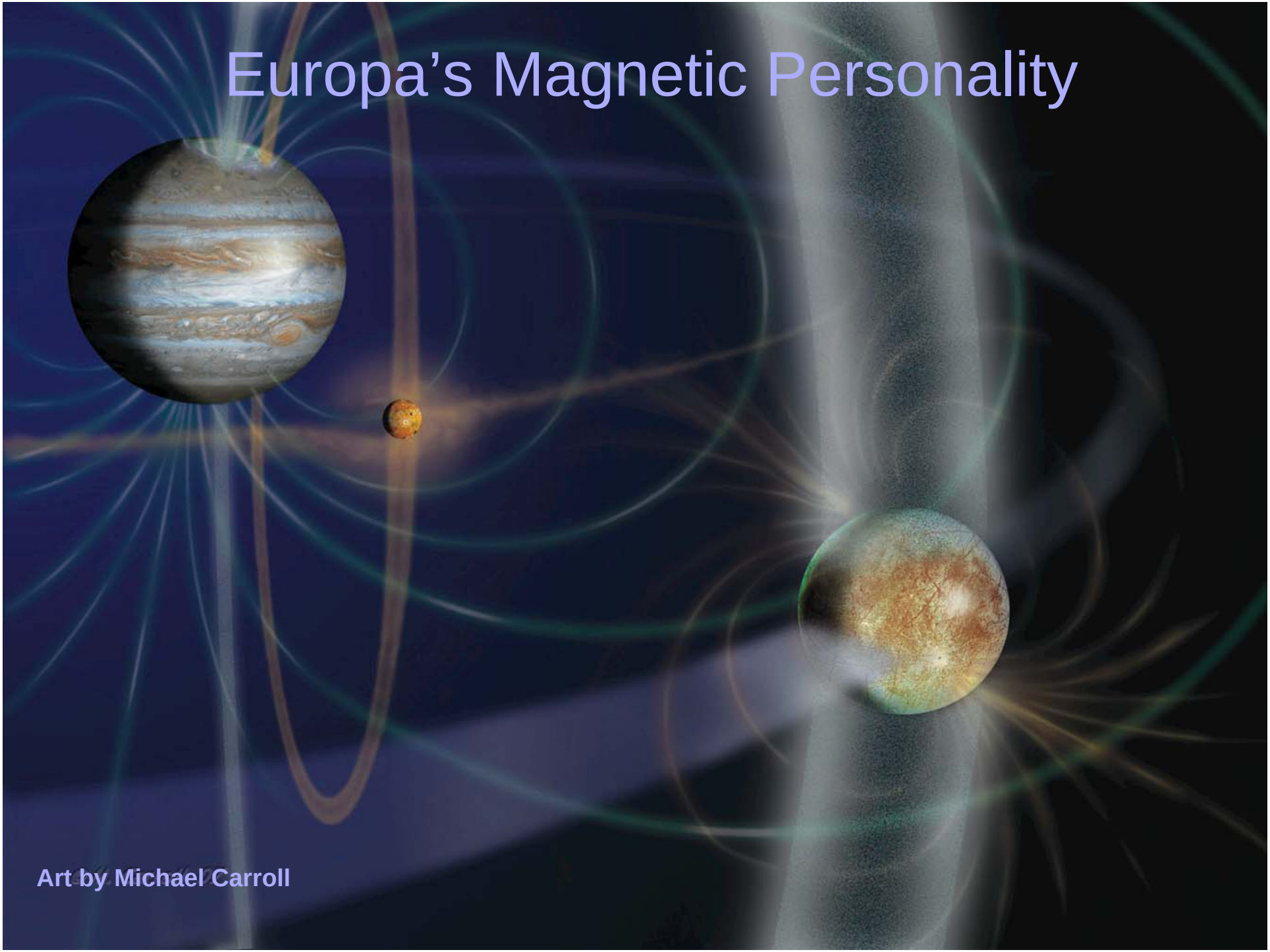




Tidal Flexing → Tidal Heating

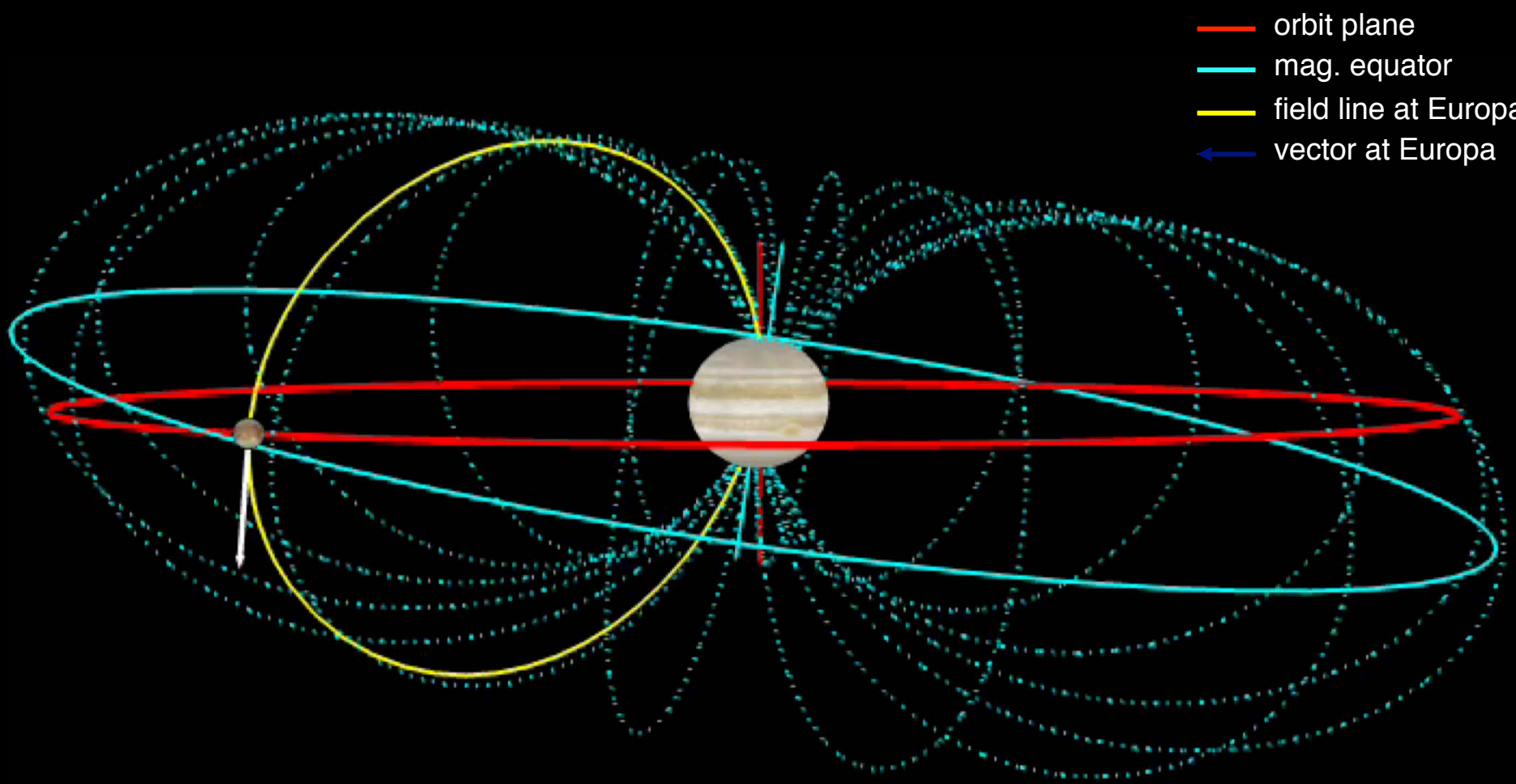


Europa’s Magnetic Personality



Art by Michael Carroll

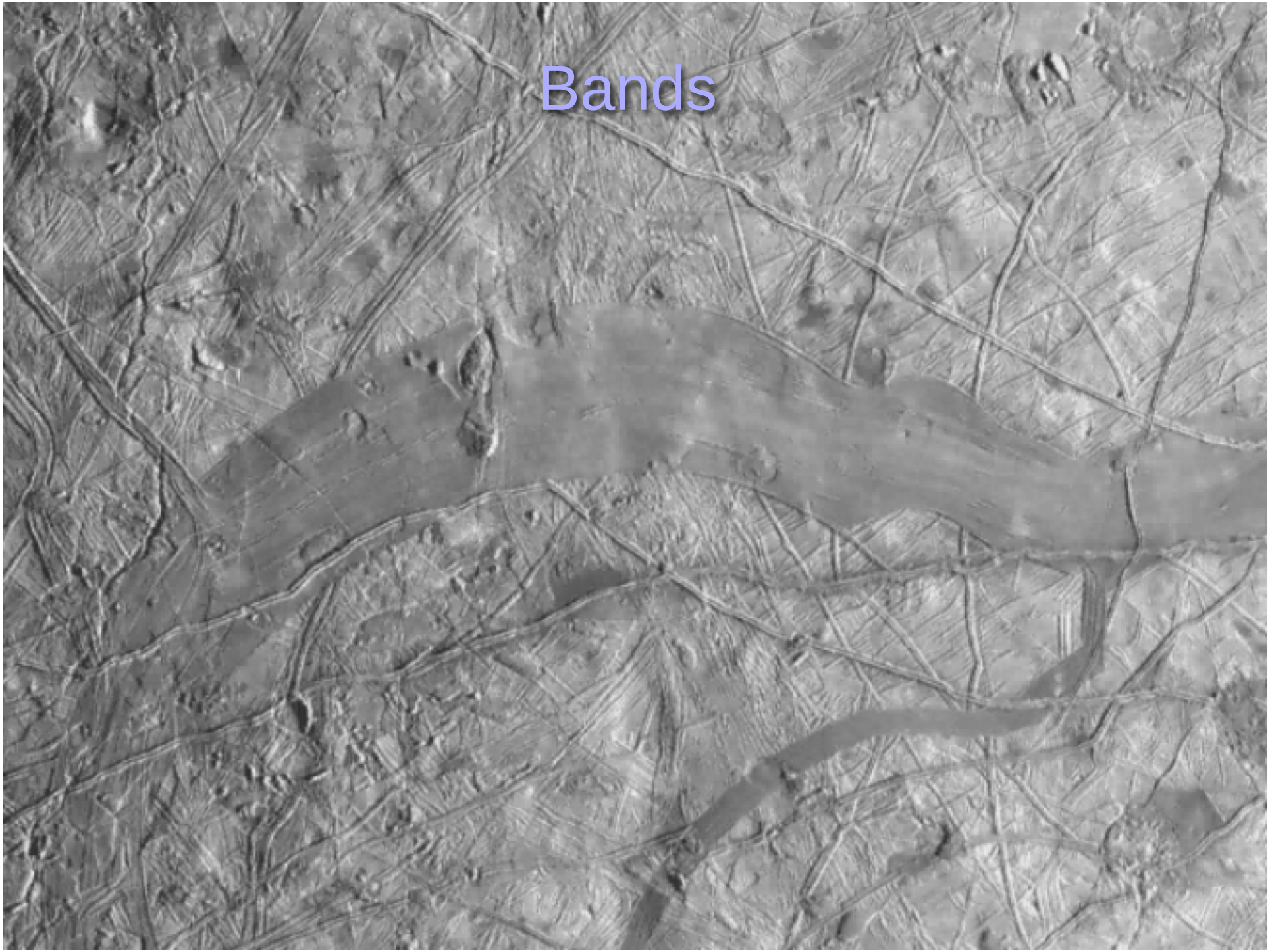
Europa's Induced Magnetic Field

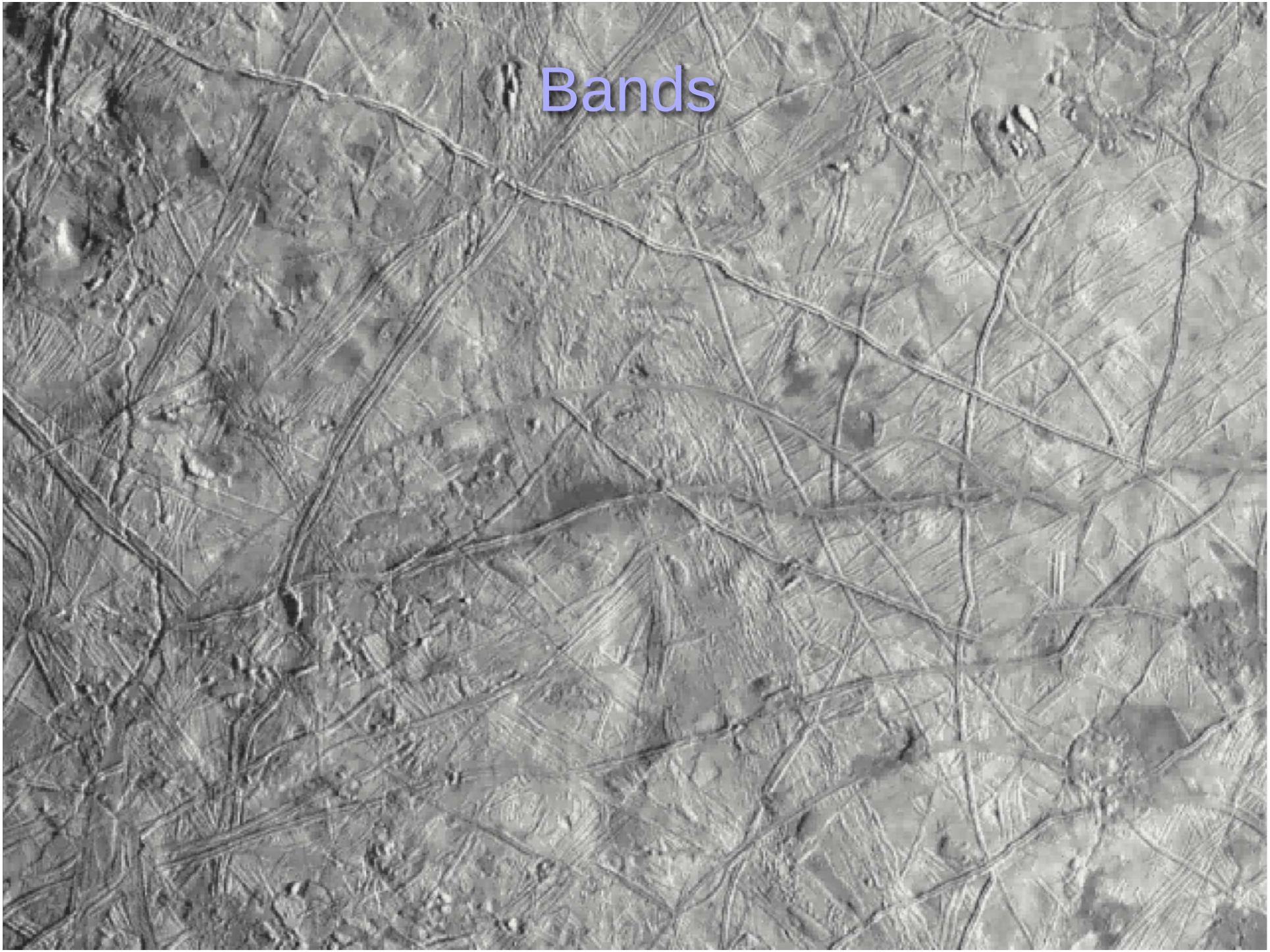


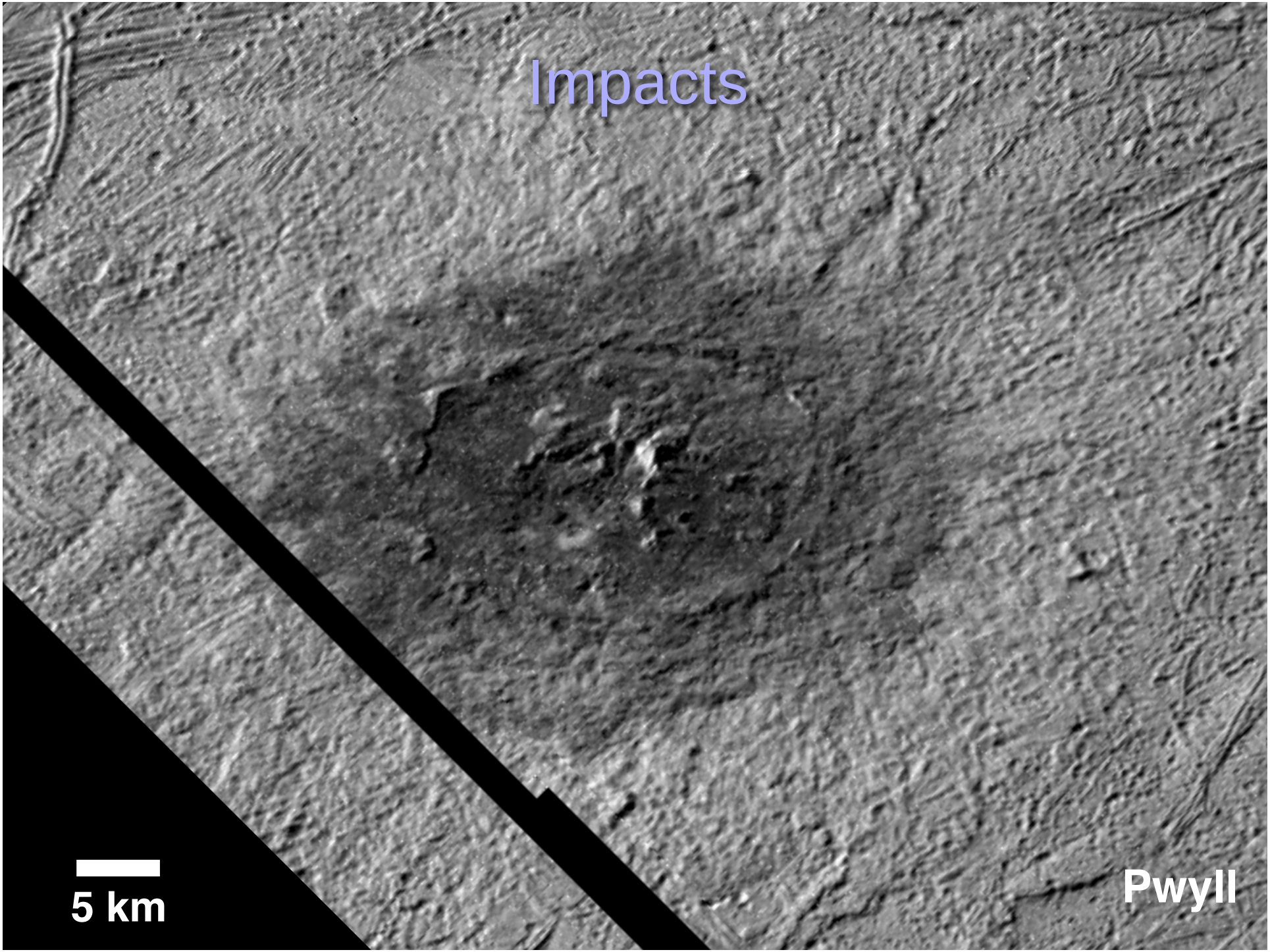
[*animation by E. Sturm using JPL's Jupiter Environment Tool*]

Jet

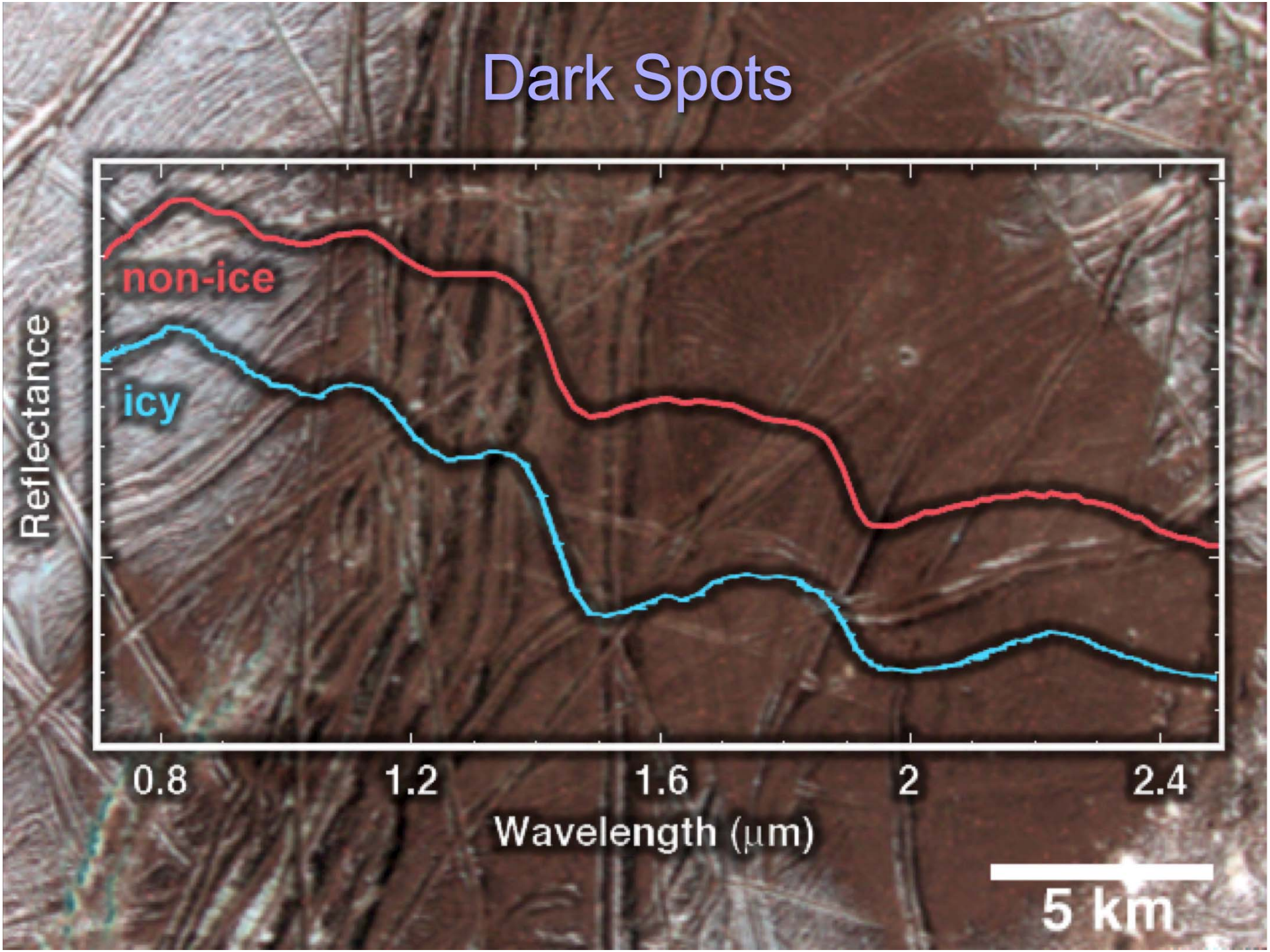

Ridges


Bands


Bands

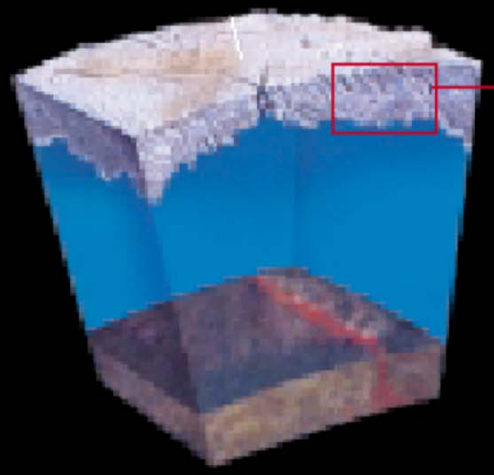

Impacts
5 km
Pwyll

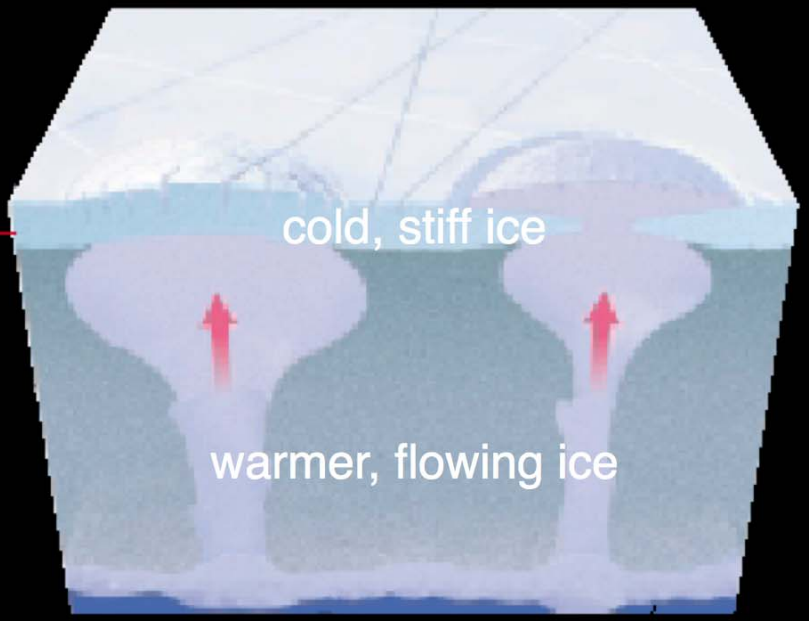

Impacts
10 km
Tyre


Dark Spots
non-ice
icy
Reflectance
0.8
1.2
1.6
2
2.4
Wavelength (μm)
5 km

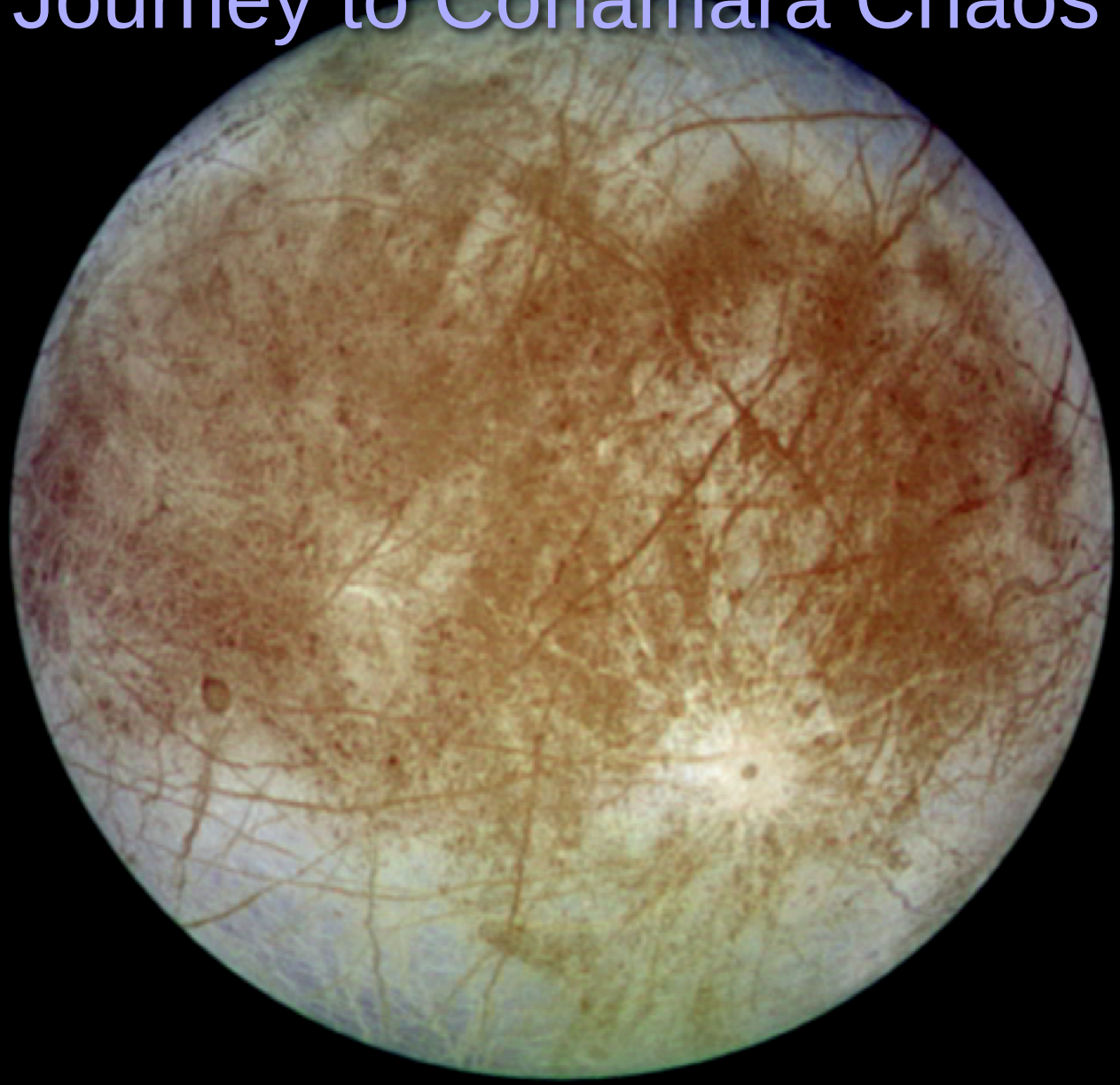

Lenticulae
Mosaic by Orion

Ice Convection





Journey to Conamara Chaos




Chaos
West
Mirage
Sun City
Glendale
Phoenix Mountains Preserve
Paradise Valley
Scottsdale
Tolleson
Phoenix
Tempe
Mesa
Guadalupe
Salt River
Mosaic by Orion

Chaos

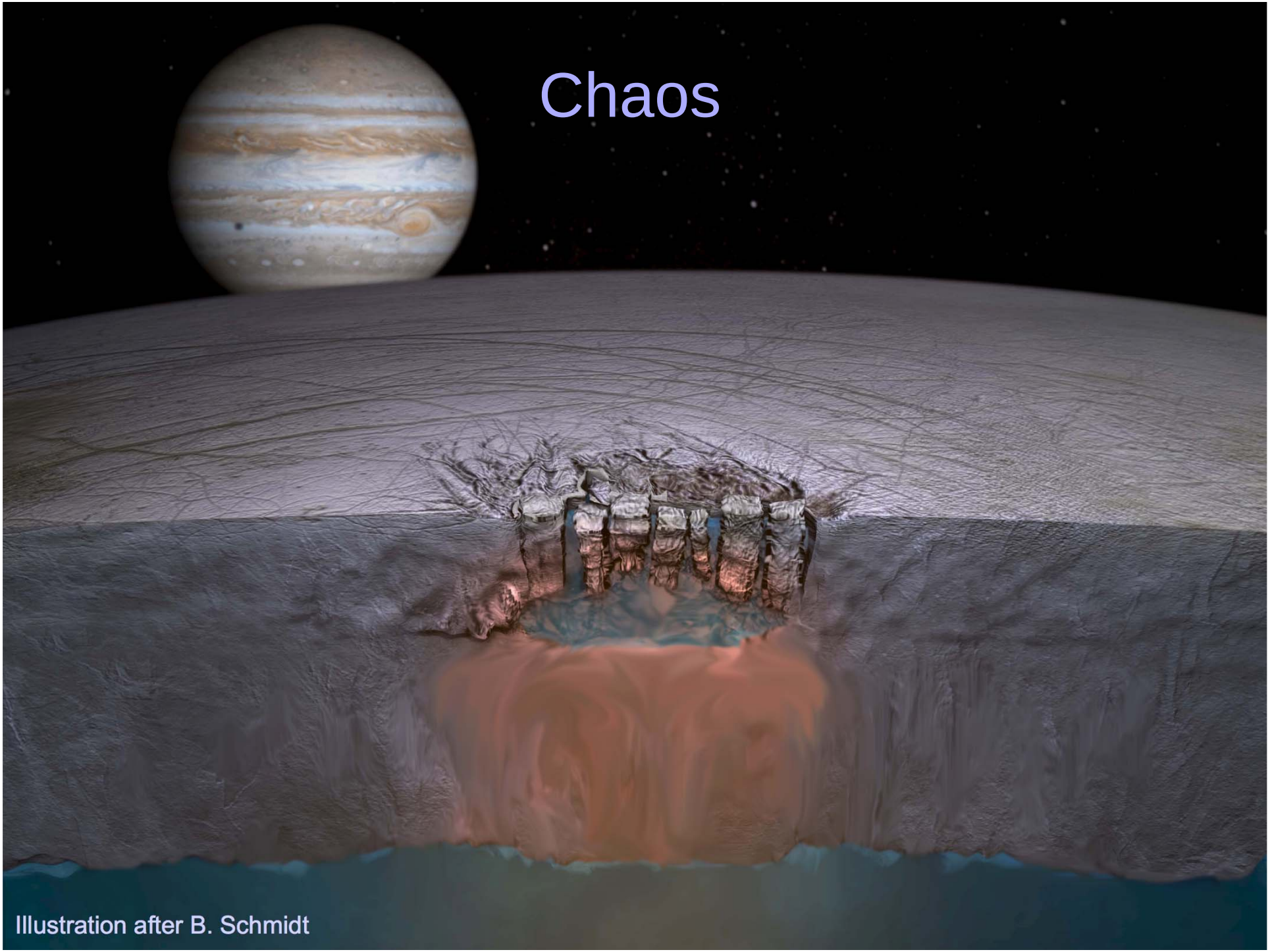
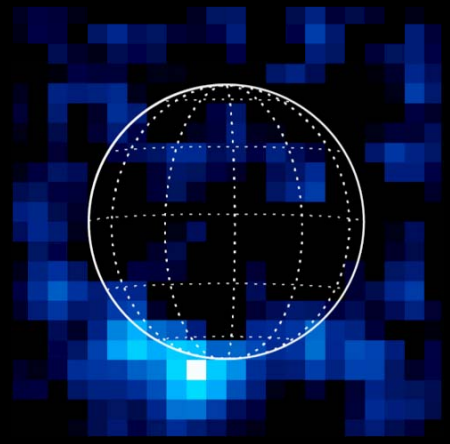


Illustration after B. Schmidt

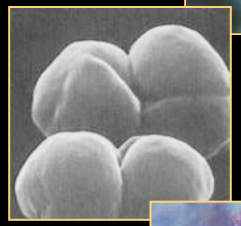
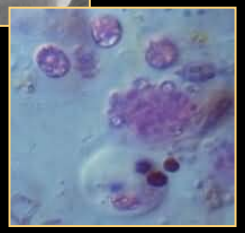
Active Plumes?



Some Reactions That Can Power Life

- Photosynthesis (plants):
  - $CO_2 + H_2O \rightarrow sugar + O_2$
- Aerobic respiration (animals):
  - $sugar + O_2 \rightarrow CO_2 + H_2O$
- Iron oxidation:
  - $2Fe^{2+} + {}^1/_2\, O_2 + 2H^+ \rightarrow 2Fe^{3+} + H_2O$
- Methanogenesis:
  - $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
- Sulfur reduction or oxidation:
  - $H_2SO_4 + 4H_2 \rightarrow H_2S + 4H_2O$
  - $CO_2 + 2H_2S \rightarrow CH_2O + 2S + H_2O$



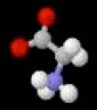




Chemosynthesis: Chemical reactions that can power life, in the absence of sunlight (without photosynthesis).

Habitability: Ingredients for Life

Water

- Probable saltwater ocean, implied by surface geology and magnetic field
- Possible lakes within the ice shell, produced by local melting



Chemistry

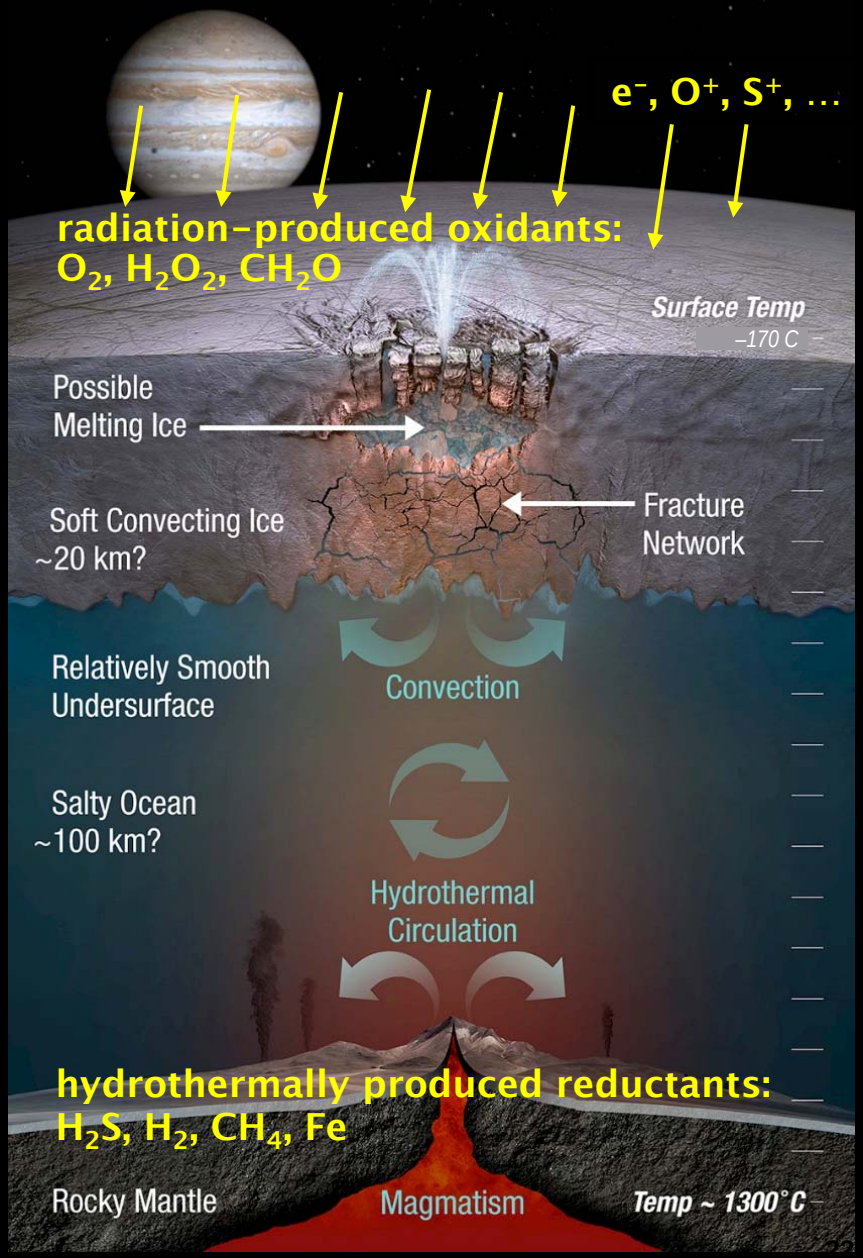
- Ocean in direct contact with mantle rock, promoting chemical leaching
- Dark red surface materials contain salts, probably from the ocean

Energy

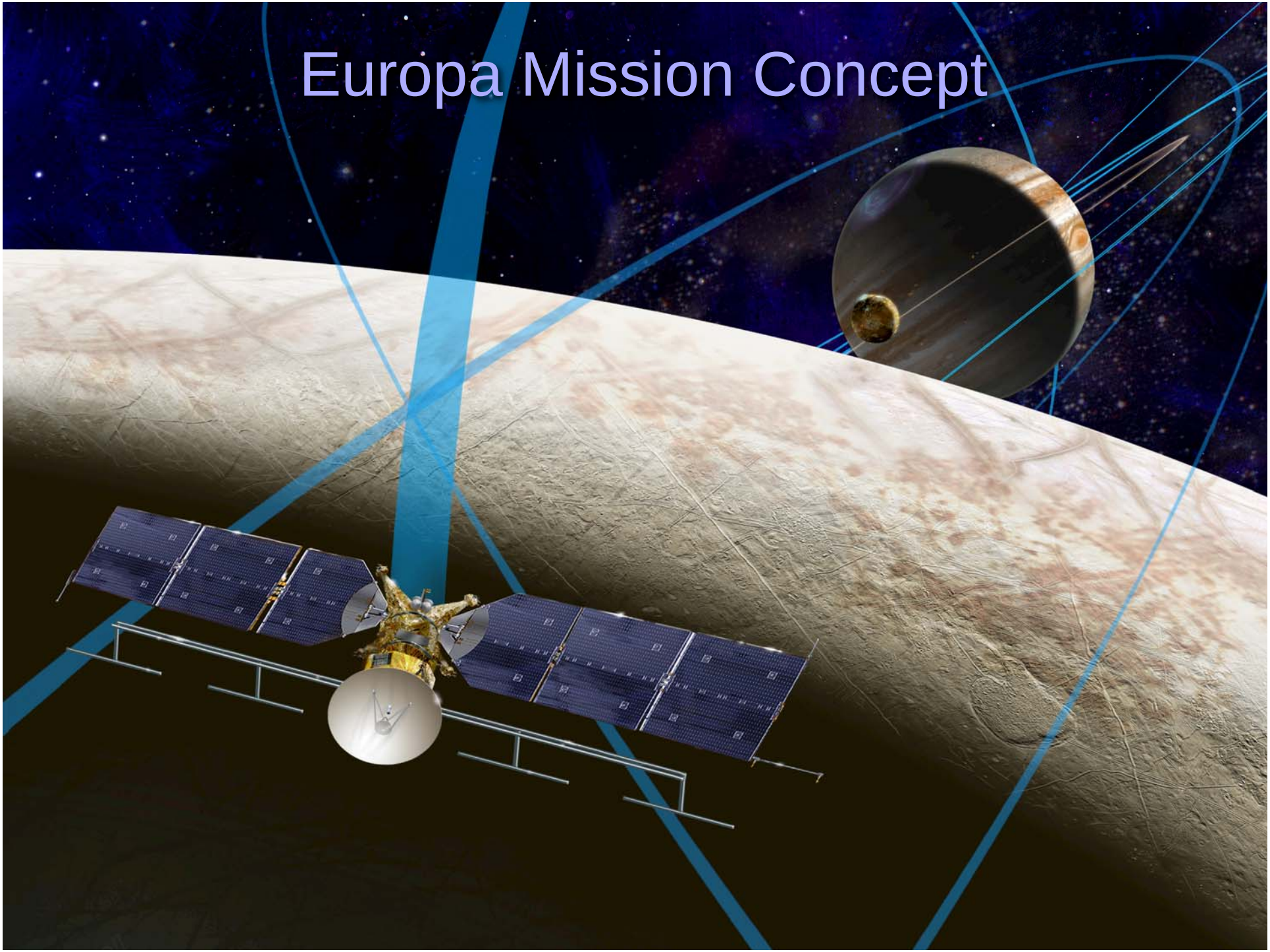
- Chemical energy could sustain life
- Surface irradiation creates oxidants
- Mantle rock-water reactions could create reductants

Geological activity

- “Stirs the pot”
- Could provide time for life to develop



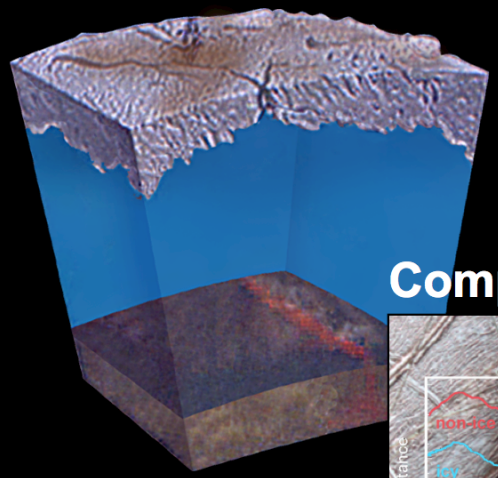
Europa Mission Concept



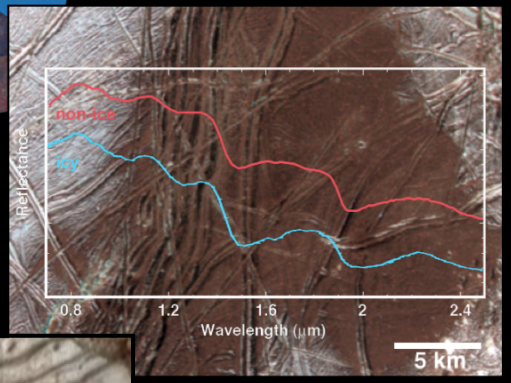
Europa Mission Science

Goal: Explore Europa to investigate its habitability

Ocean & Ice Shell

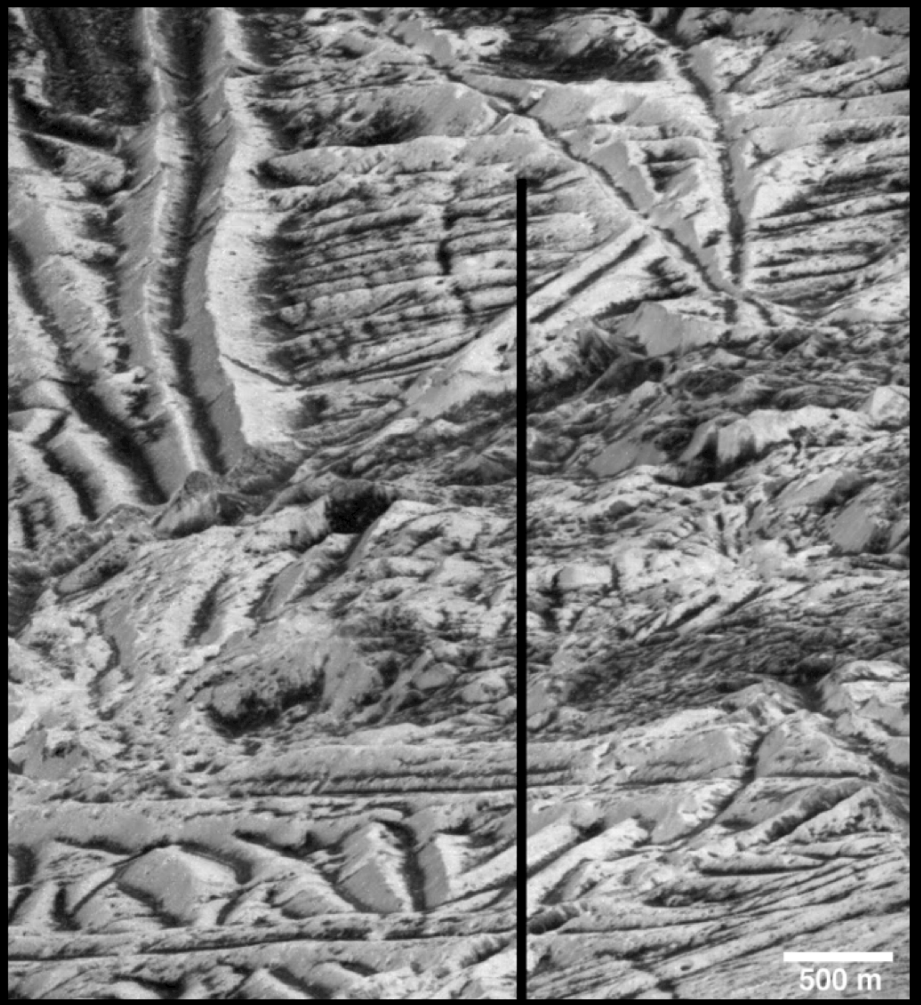


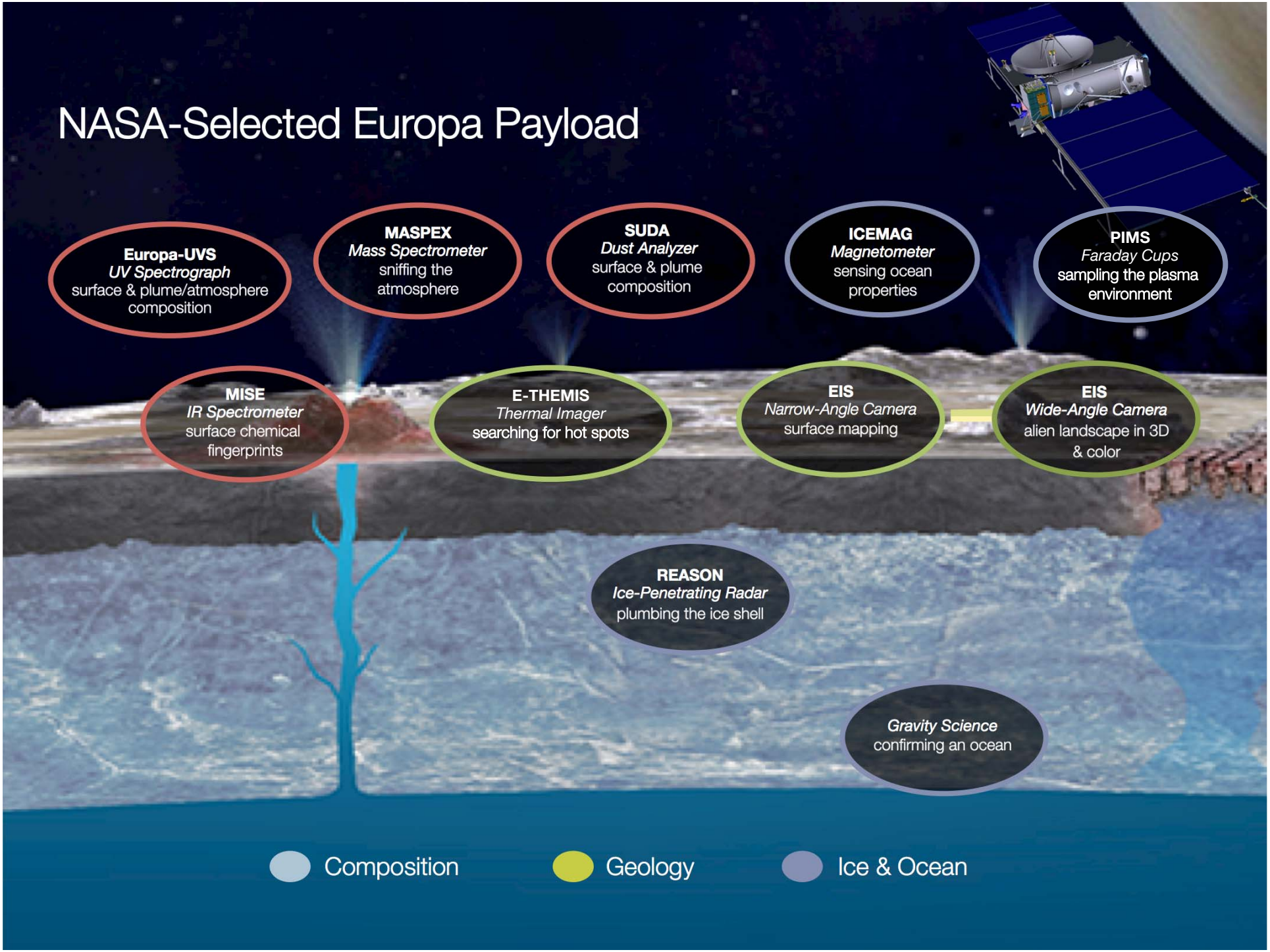
Composition



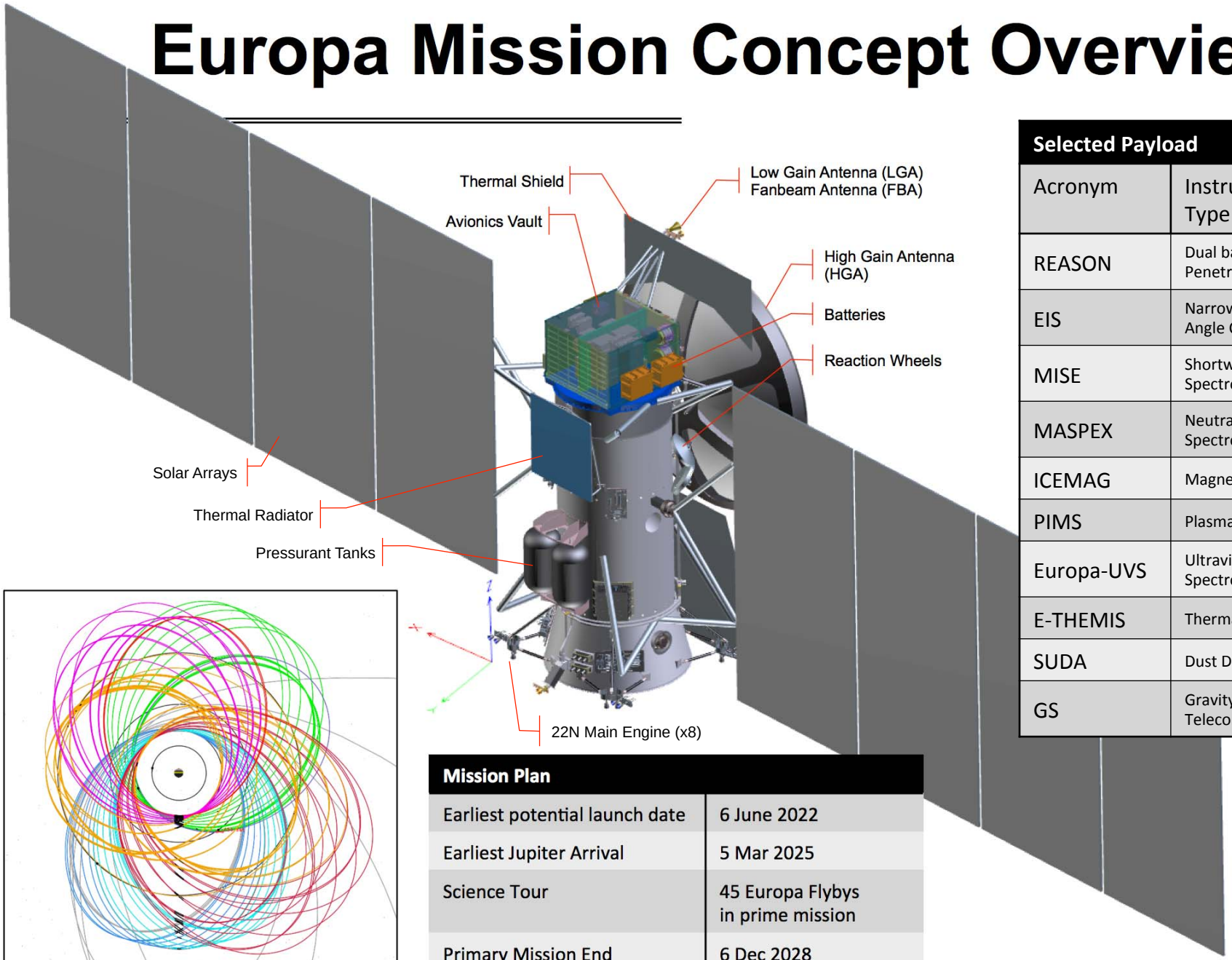
Geology

Reconnaissance




NASA-Selected Europa Payload
Europa-UVS
UV Spectrograph
surface & plume/atmosphere composition
MASPEX
Mass Spectrometer
sniffing the atmosphere
SUDA
Dust Analyzer
surface & plume composition
ICEMAG
Magnetometer
sensing ocean properties
PIMS
Faraday Cups
sampling the plasma environment
MISE
IR Spectrometer
surface chemical fingerprints
E-THEMIS
Thermal Imager
searching for hot spots
EIS
Narrow-Angle Camera
surface mapping
EIS
Wide-Angle Camera
alien landscape in 3D & color
REASON
Ice-Penetrating Radar
plumbing the ice shell
Gravity Science
confirming an ocean
Composition
Geology
Ice & Ocean

Europa Mission Concept Overview



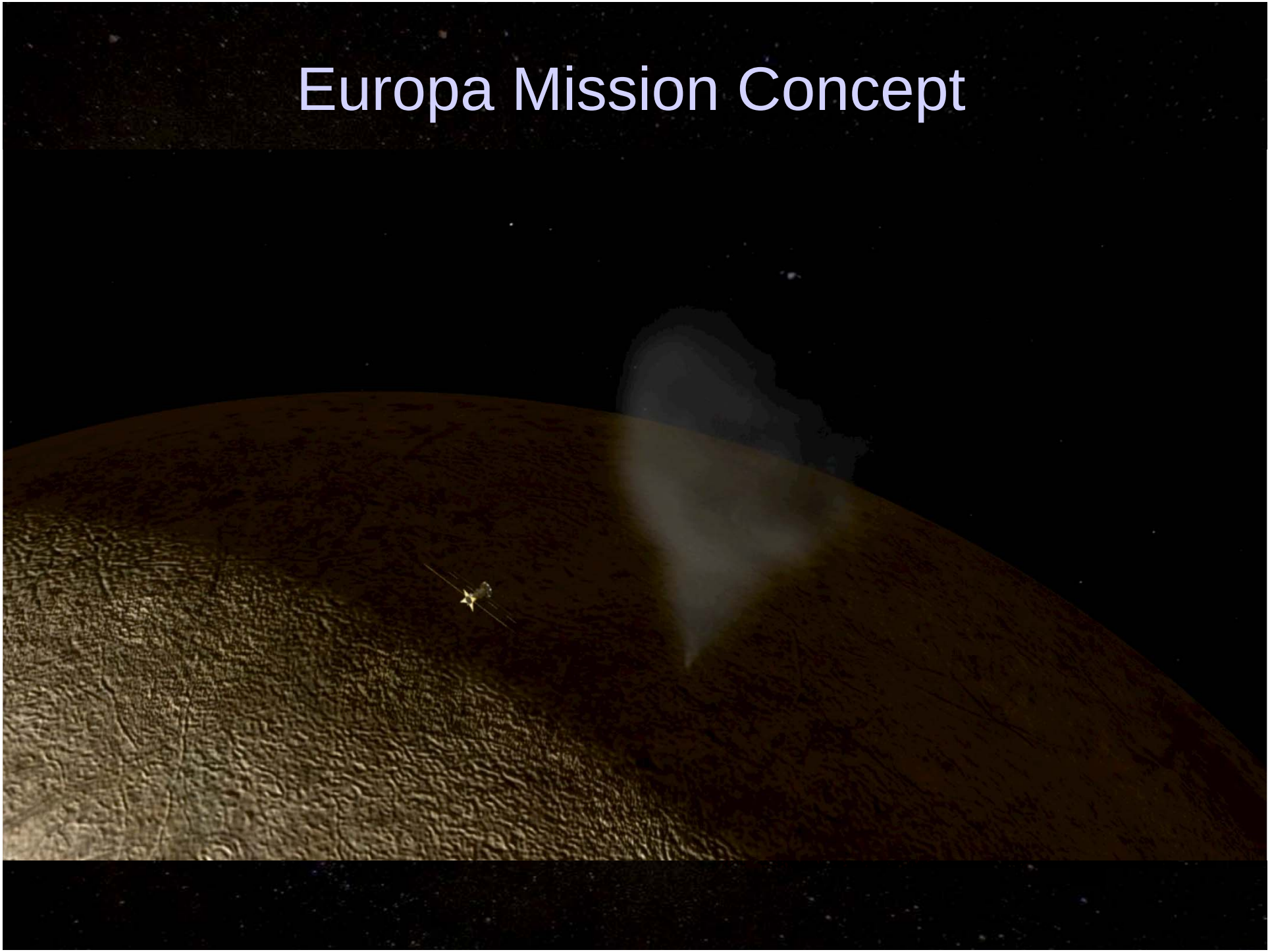
Mission Plan	
Earliest potential launch date	6 June 2022
Earliest Jupiter Arrival	5 Mar 2025
Science Tour	45 Europa Flybys in prime mission
Primary Mission End	6 Dec 2028 (Ganymede Impact)

Selected Payload	
Acronym	Instrument Type
REASON	Dual band Ice Penetrating Radar
EIS	Narrow Angle / Wide Angle Cameras
MISE	Shortwave Infrared Spectrometer
MASPEX	Neutral Mass Spectrometer
ICEMAG	Magnetometer
PIMS	Plasma Sensor
Europa-UVS	Ultraviolet Spectrograph
E-THEMIS	Thermal Imager
SUDA	Dust Detector
GS	Gravity Science via Telecom Subsystem

A Global Web of Fly-bys

- Multiple satellite gravity assists enables "global-regional coverage" of Europa from orbit around Jupiter
- Current mission design consists of 42 low-altitude flybys of Europa from Jupiter orbit over 3.5 yr
- Minimizes time in high radiation environment
- Simple repetitive operations

Europa Mission Concept



Europa Mission Concept


http://www.nasa.gov/europa