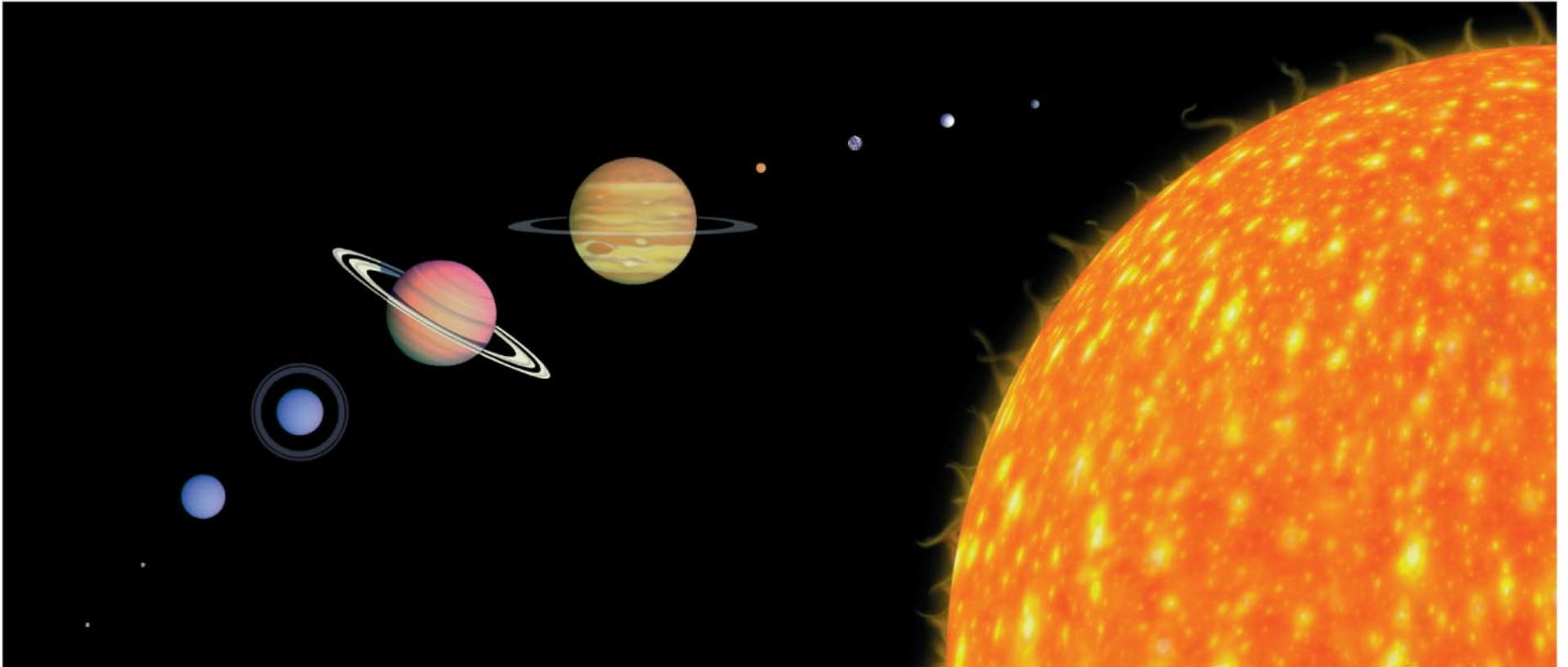
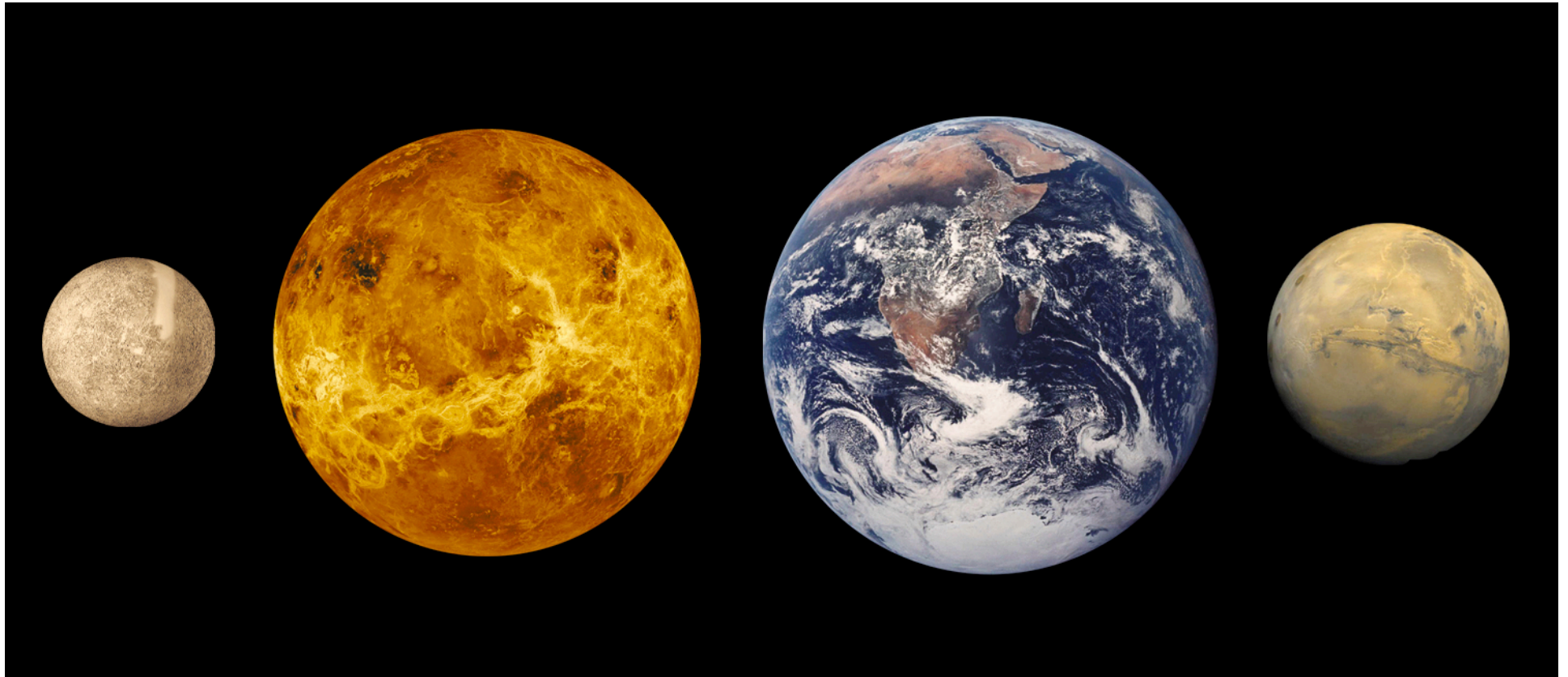


# Life in the Solar System



**Assume we need energy, liquid water, and organic materials.**

# Size Comparison of Inner Terrestrial Planets



Mercury

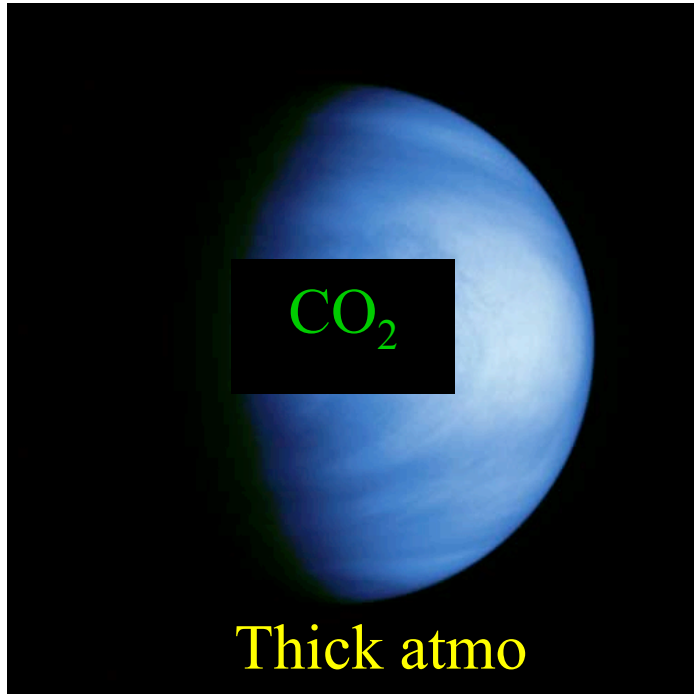
Venus

Earth

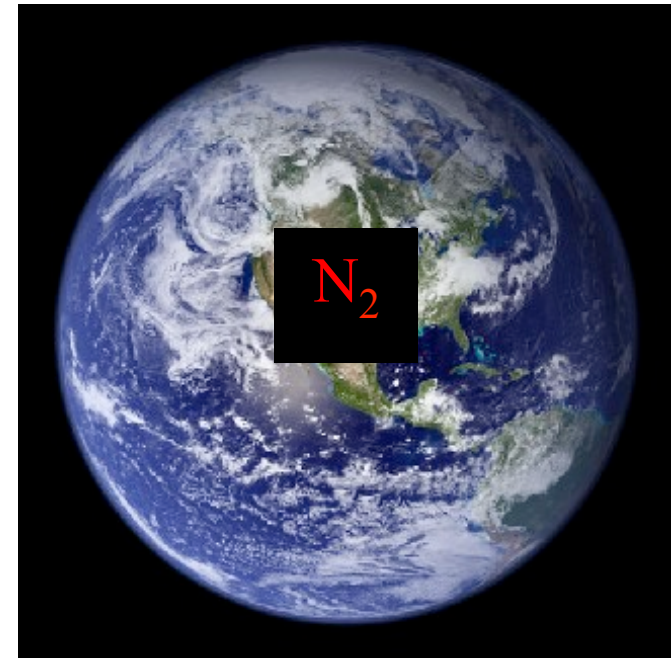
Mars

# Atmospheres

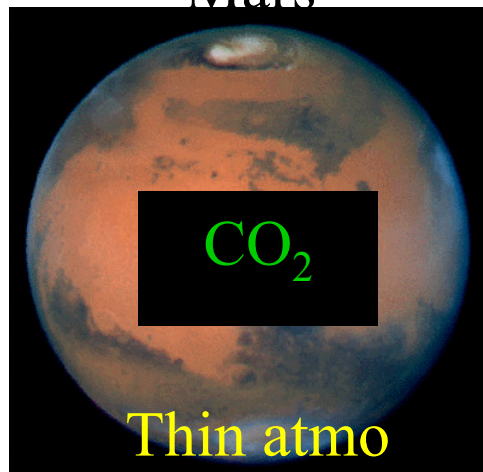
Venus



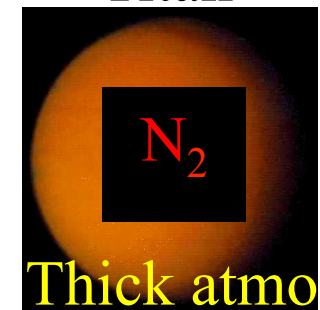
Earth



Mars



Titan



Small rocky bodies are unlikely to host life: too hot or cold for water, no protective atmosphere so too much UV and too many cosmic rays.



**a** The Moon

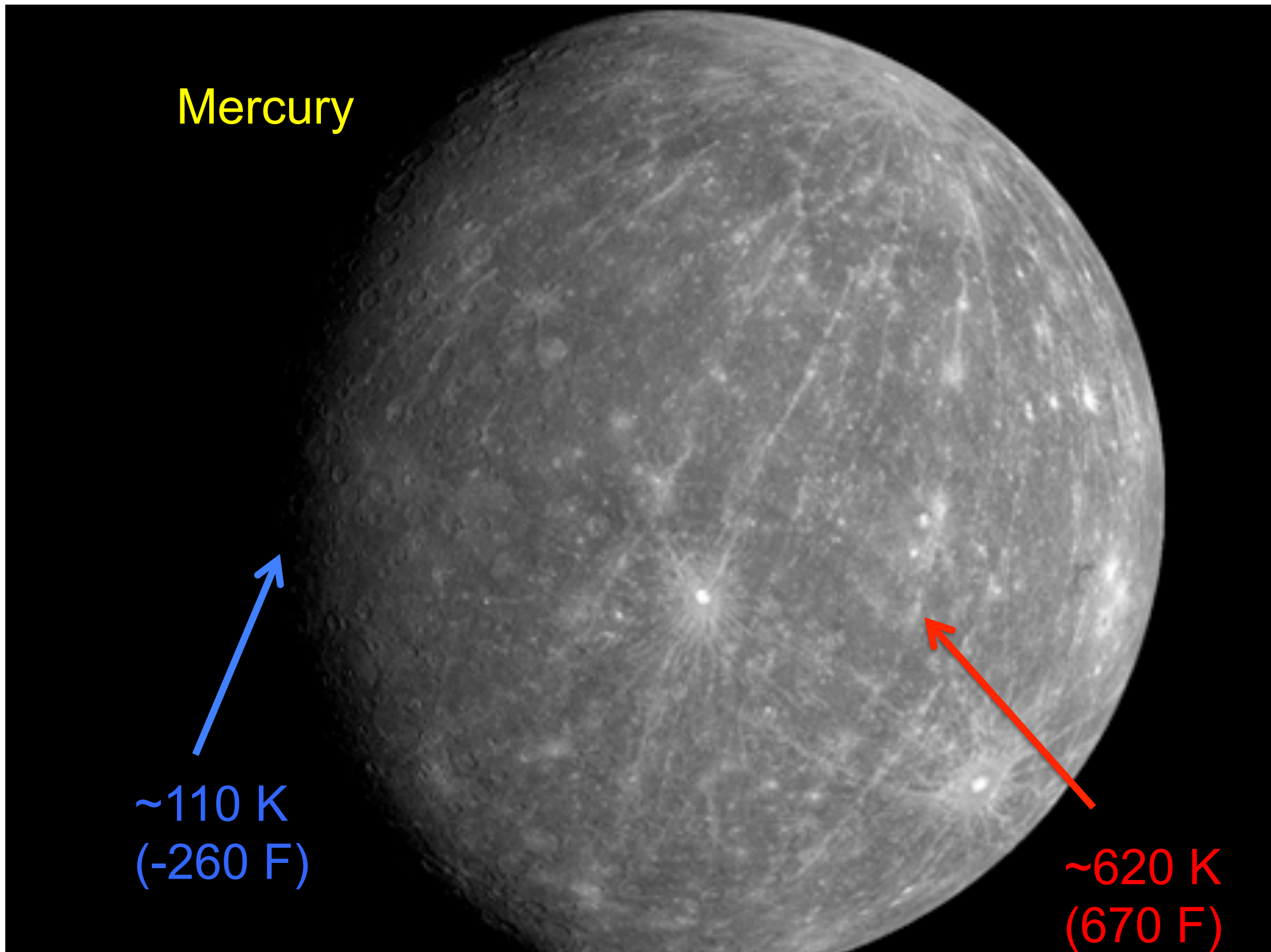


**b** Mercury

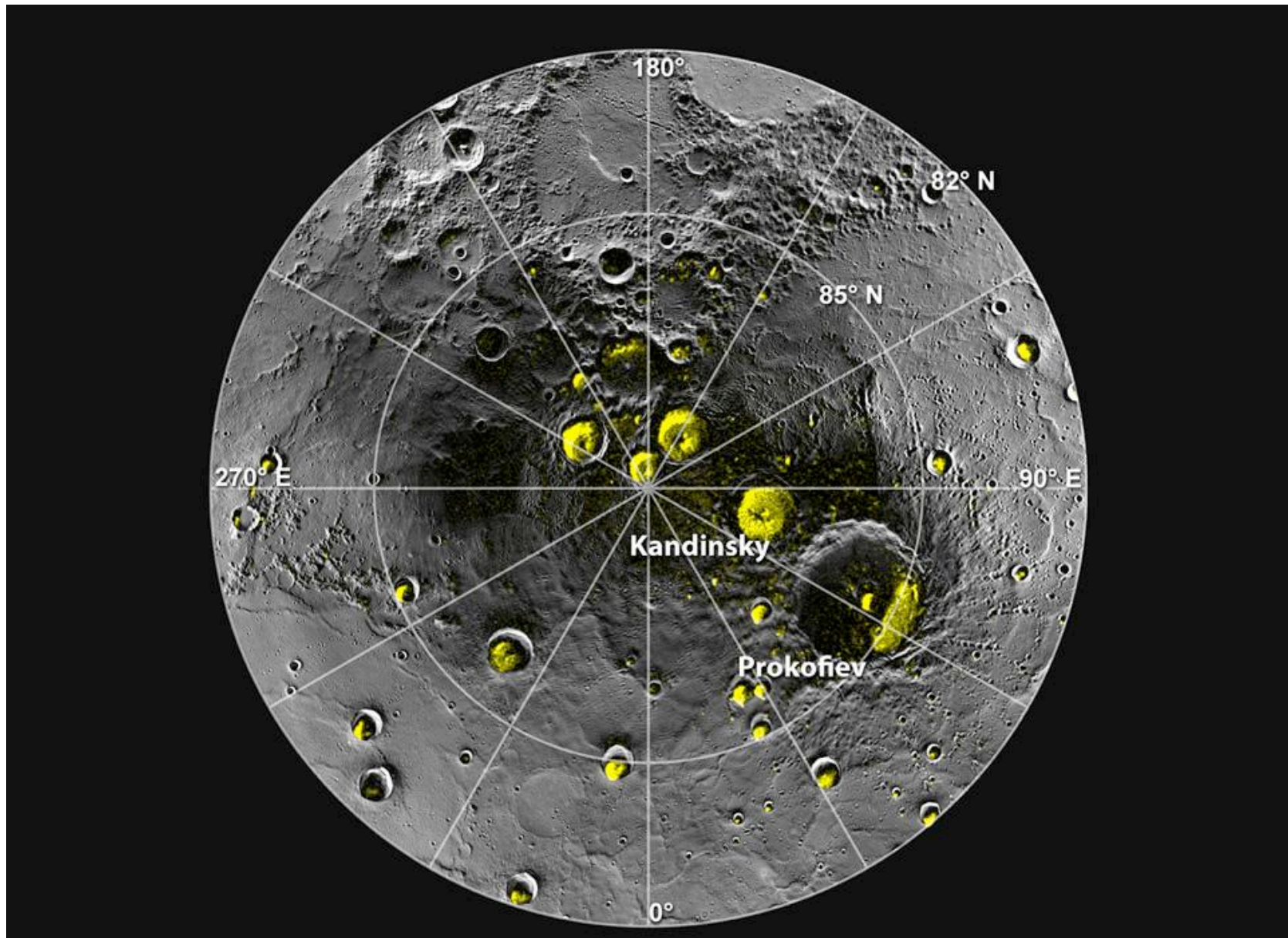
# Mercury

~110 K  
(-260 F)

~620 K  
(670 F)



Water ice discovered in permanently shadowed craters at poles of Mercury! Even in an environment as extreme as this – H<sub>2</sub>O (in ice form, not liquid) is present.



# Venus

Venus is hot (molten lead can exist on its surface!), high pressure (90 atmospheres), toxic (sulfur dioxide, ammonia clouds), and baked dry. But before the runaway Greenhouse effect took hold, 2-3 billion years ago, it might have been temperate. Today it has a thick CO<sub>2</sub> atmosphere

~750 K  
(900 F)

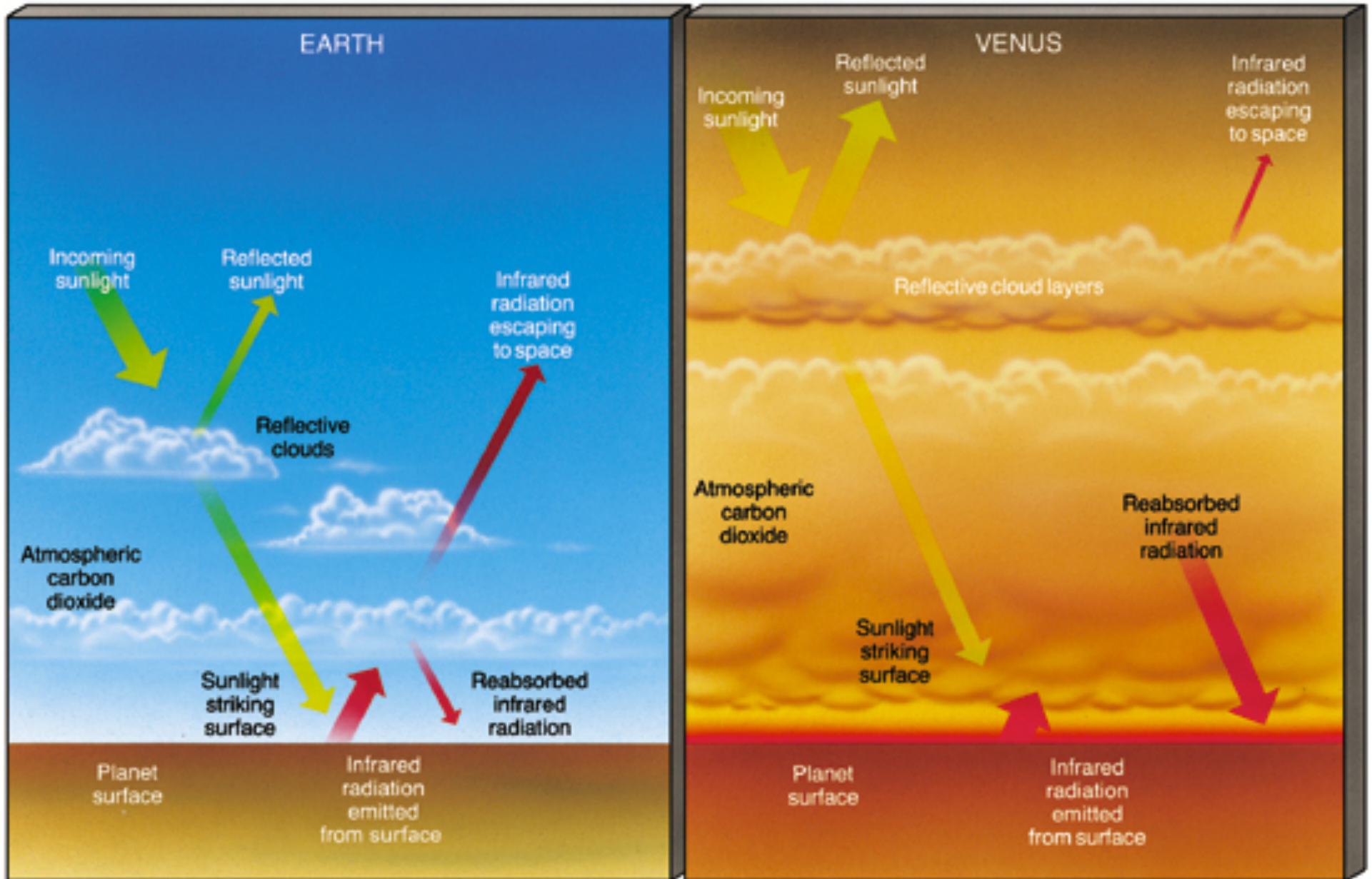




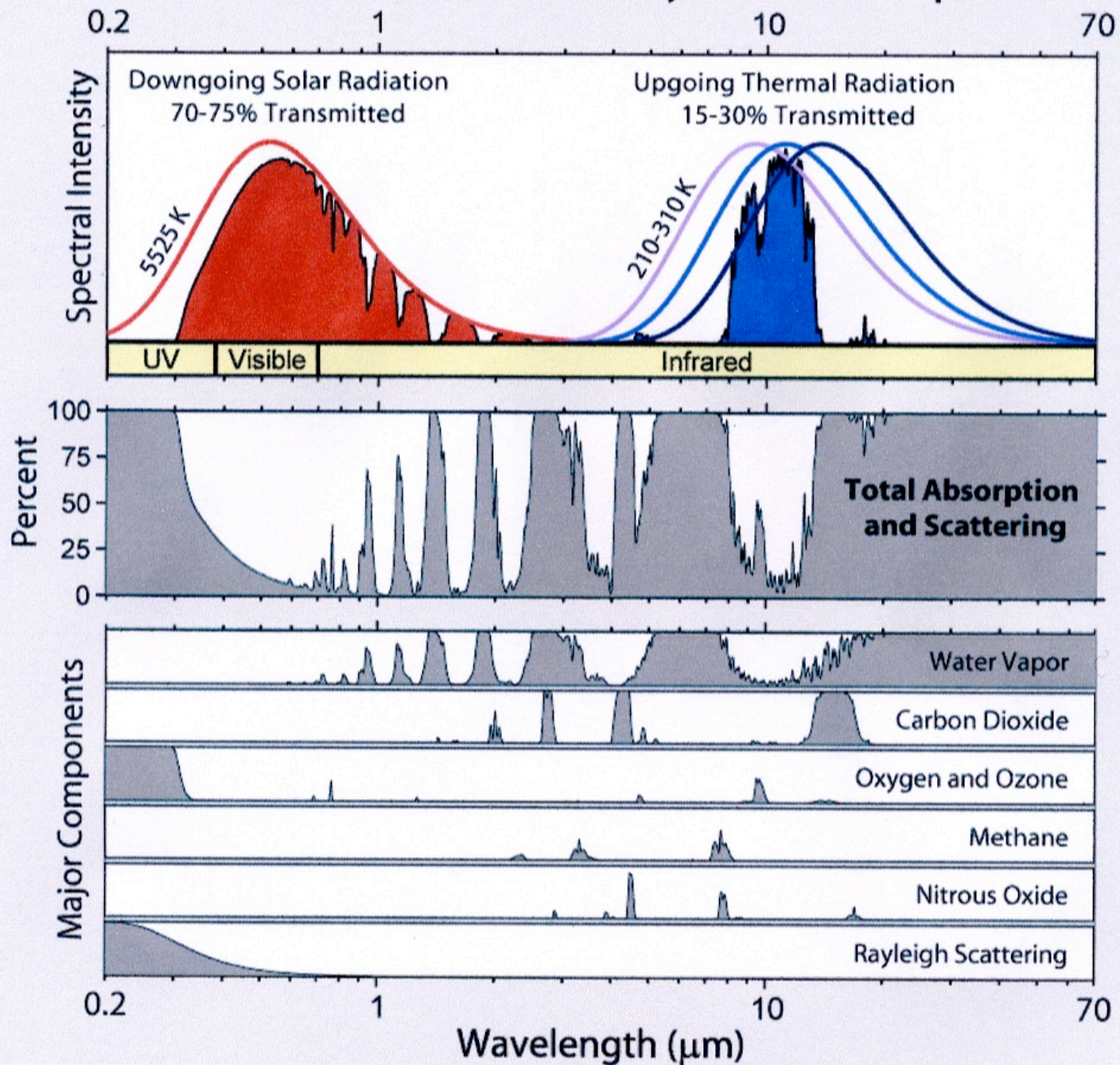
Artists conception – Venus has many volcanoes



# Greenhouse Effect

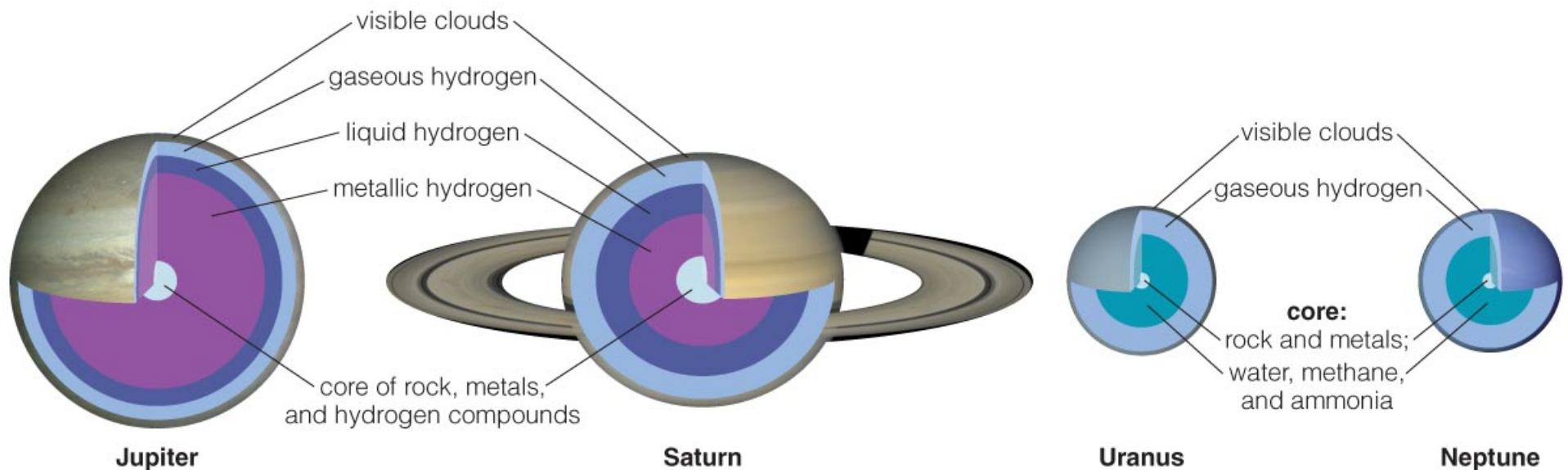


# Radiation Transmitted by the Atmosphere



# Gas Giants

Gas Giant planets are far from the Sun and cold, but the lower regions of their hydrogen-helium atmospheres are warmer. They each have rocky cores 3-5 times the mass of Earth but conditions are very extreme there – extremely high pressure, no sunlight, high temperature. Not much chance of life there.

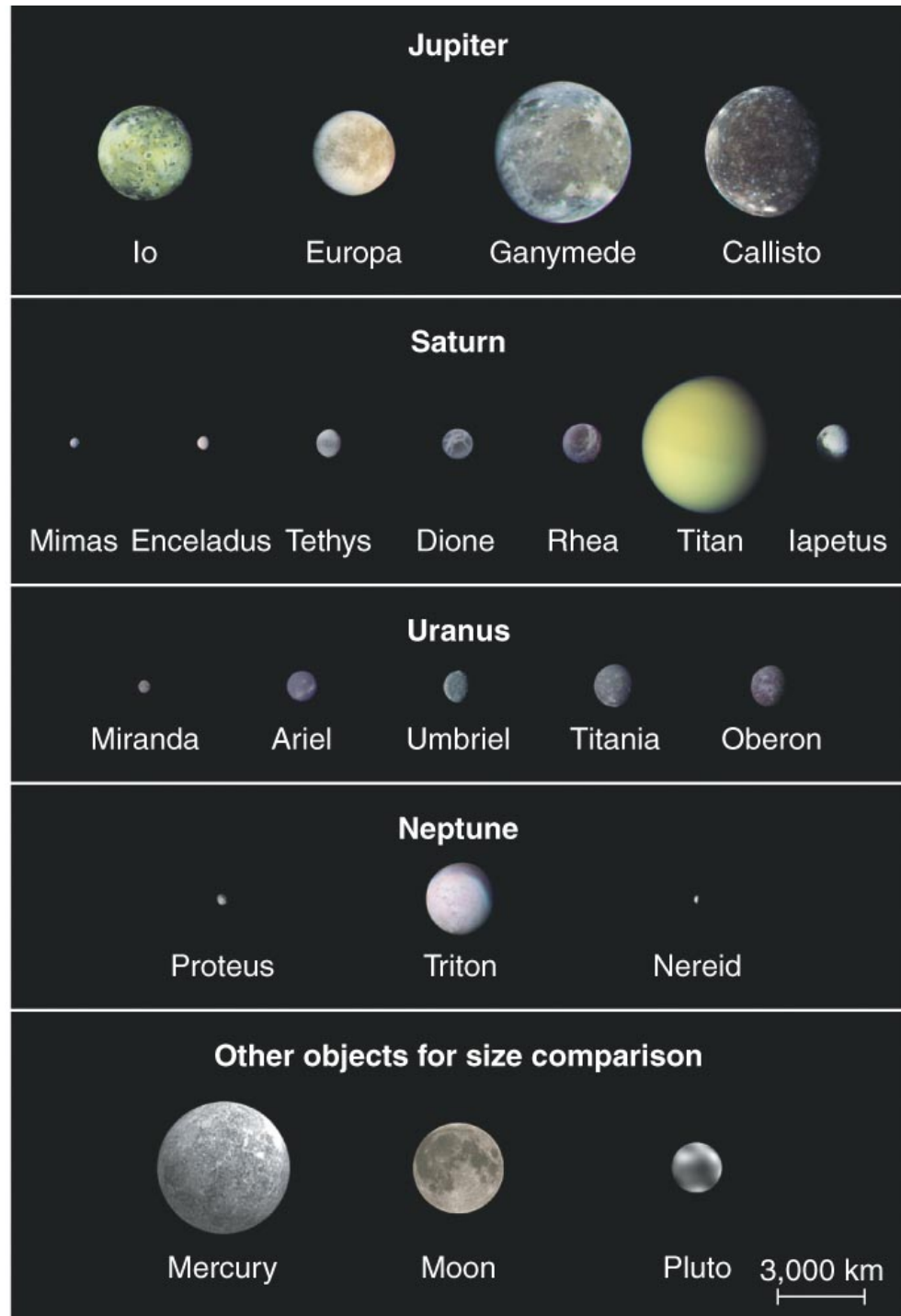


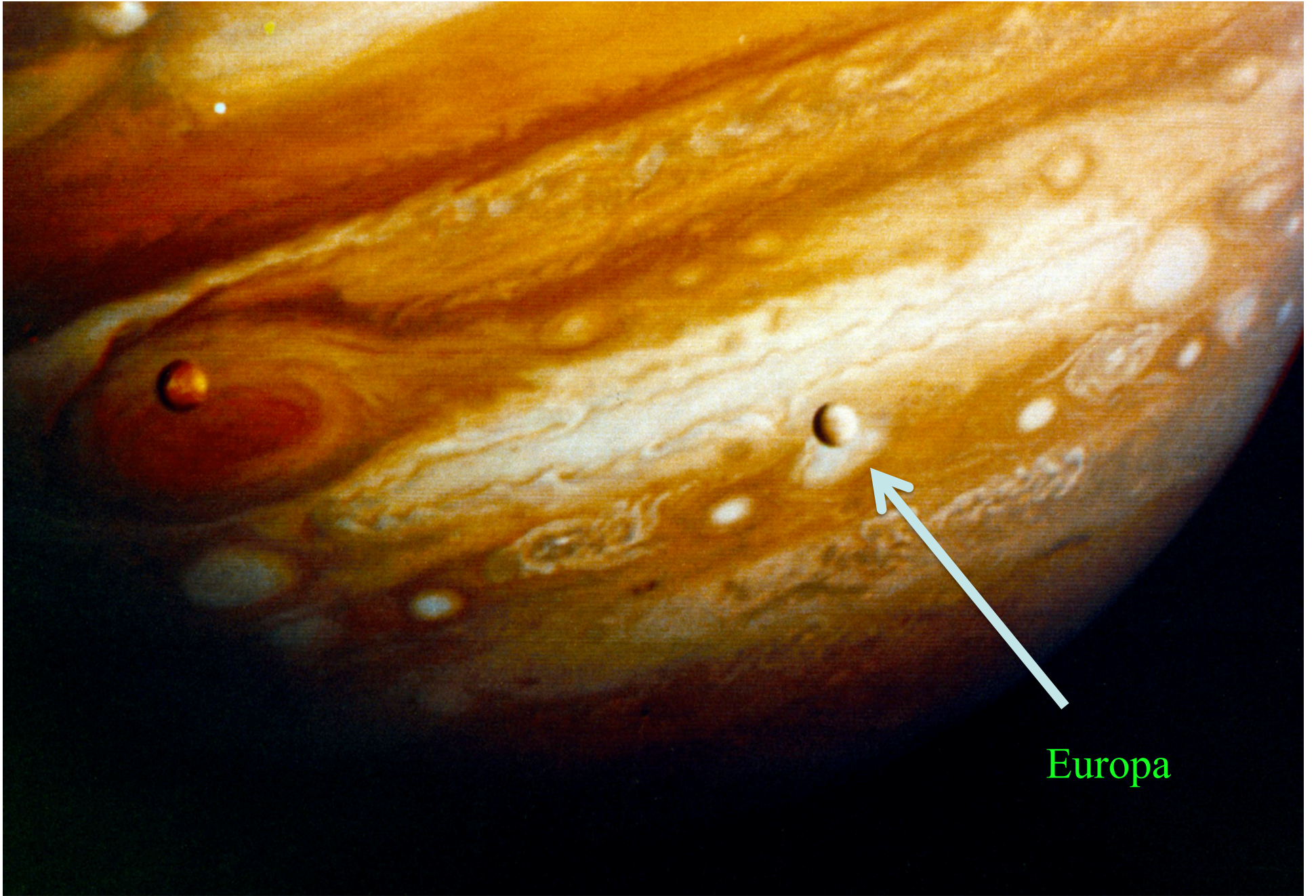
# Moons of Gas Giants

The moons of the giant planets are very distinctive “worlds” in their own right.

Some have atmospheres and geological activity, others are heated by tidal effects or from radioactivity in their cores.

As many as a **dozen** might have water kept liquid under pressure below a rocky or icy surface. Tiny Enceladus is only 500 km across yet has geysers that jet water into space.





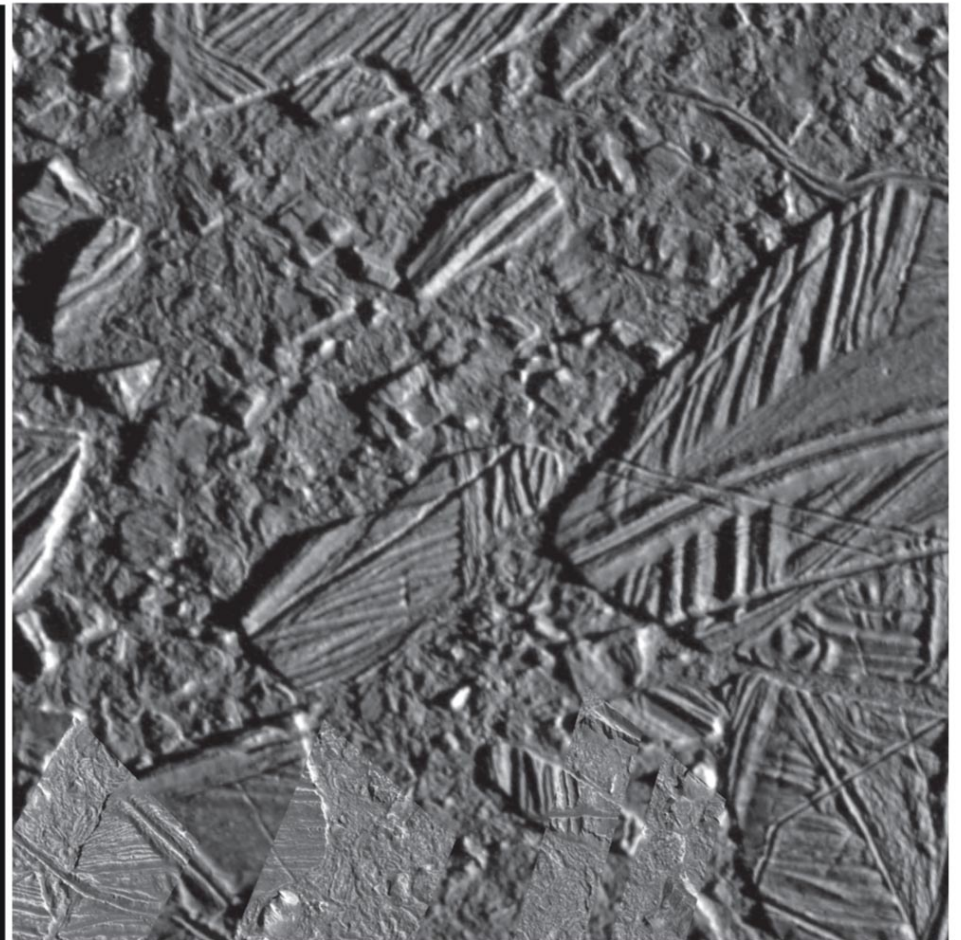
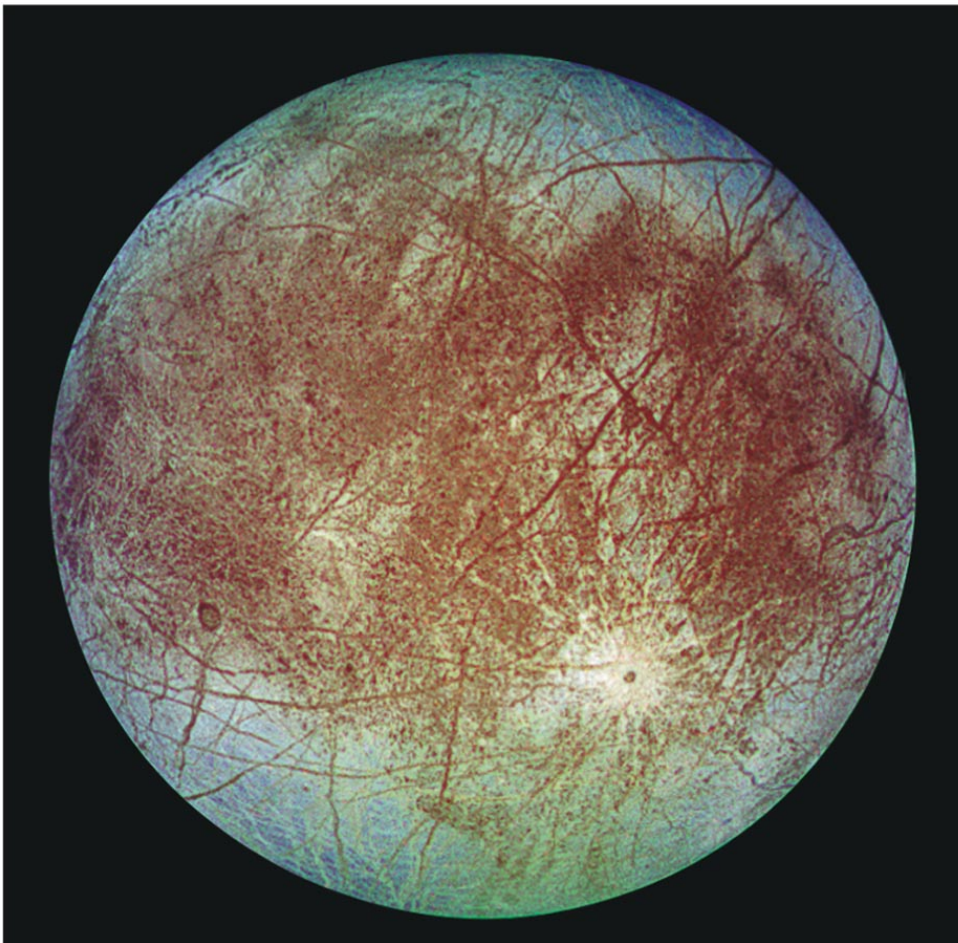
Photograph by Astronomical Society of the Pacific

 NATIONAL  
GEOGRAPHIC

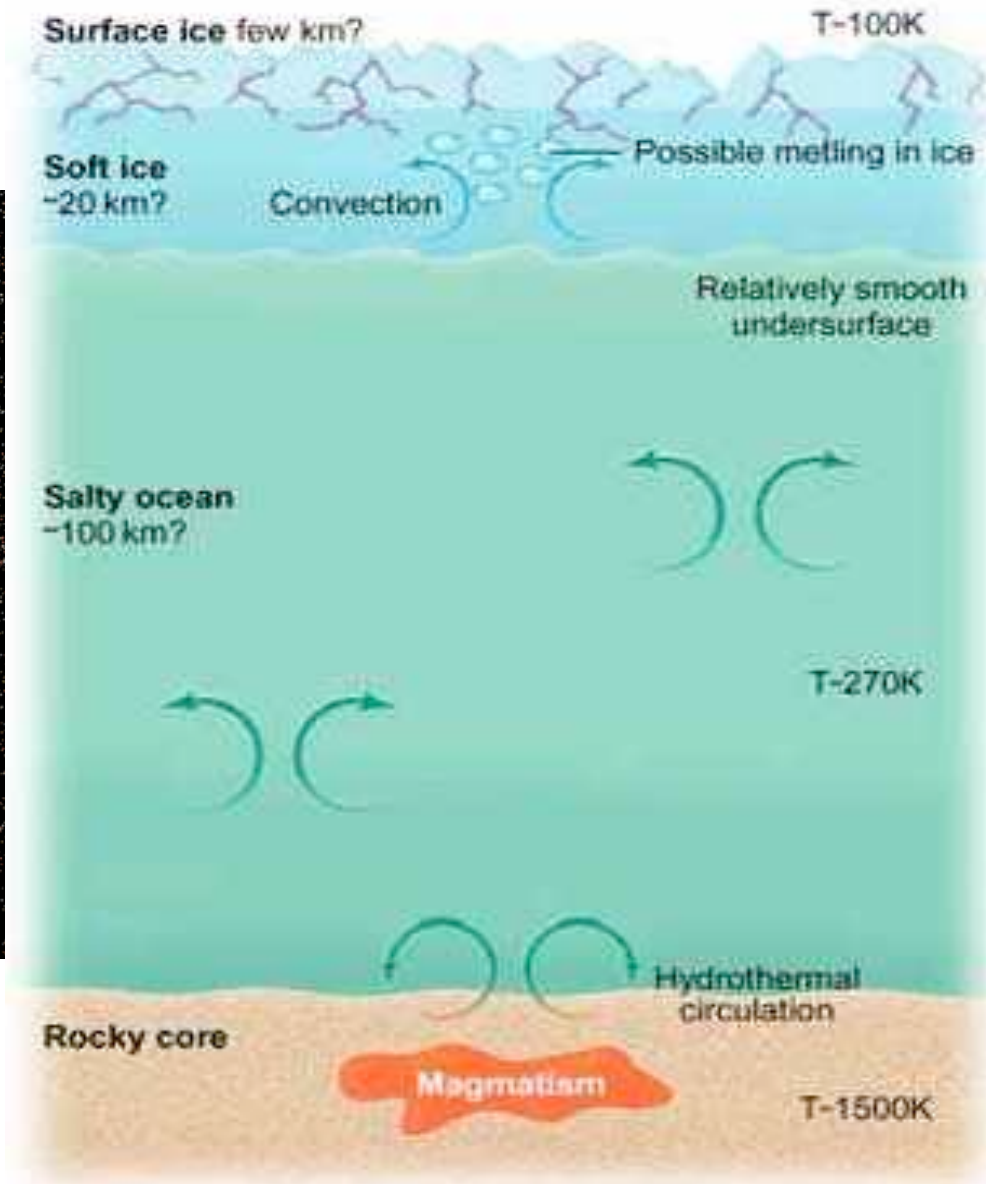
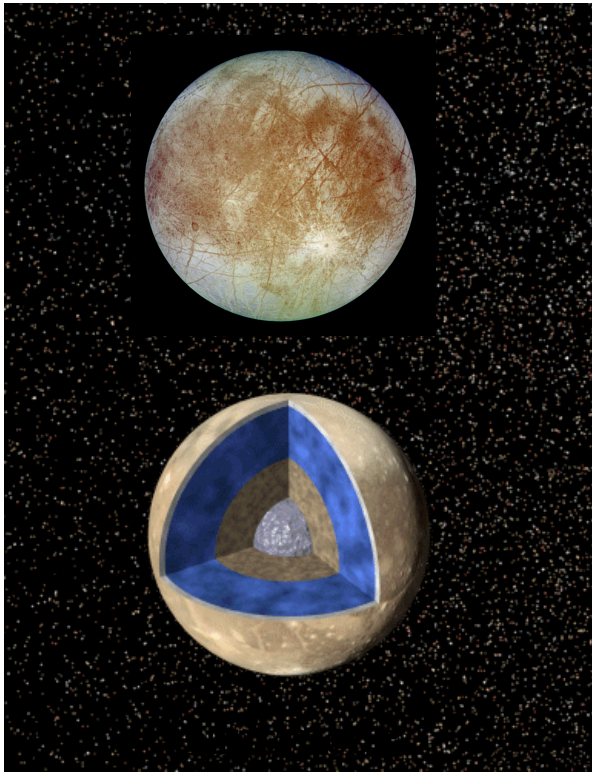
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# Europa

This Galilean moon of Jupiter is the closest thing in the solar system to another water world. An icy crust covers an ocean.

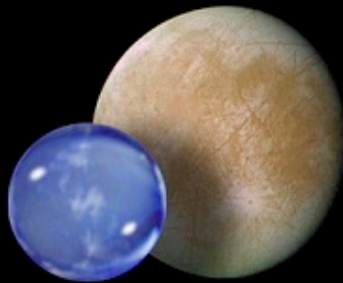


# Subsurface Ocean – Europa

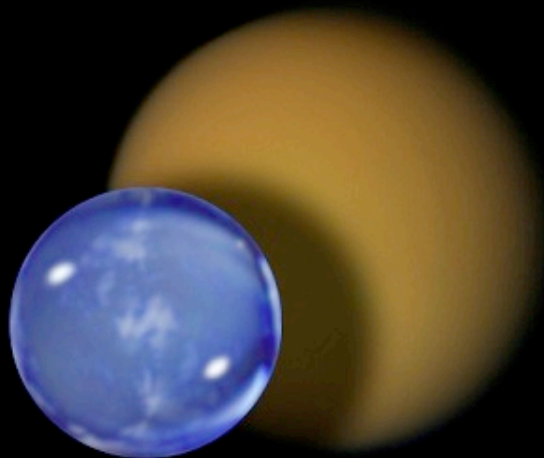


CREDIT: SCIENCE/DAVID STEVENSON

# Liquid Water in the Solar System



EUROPA



TITAN

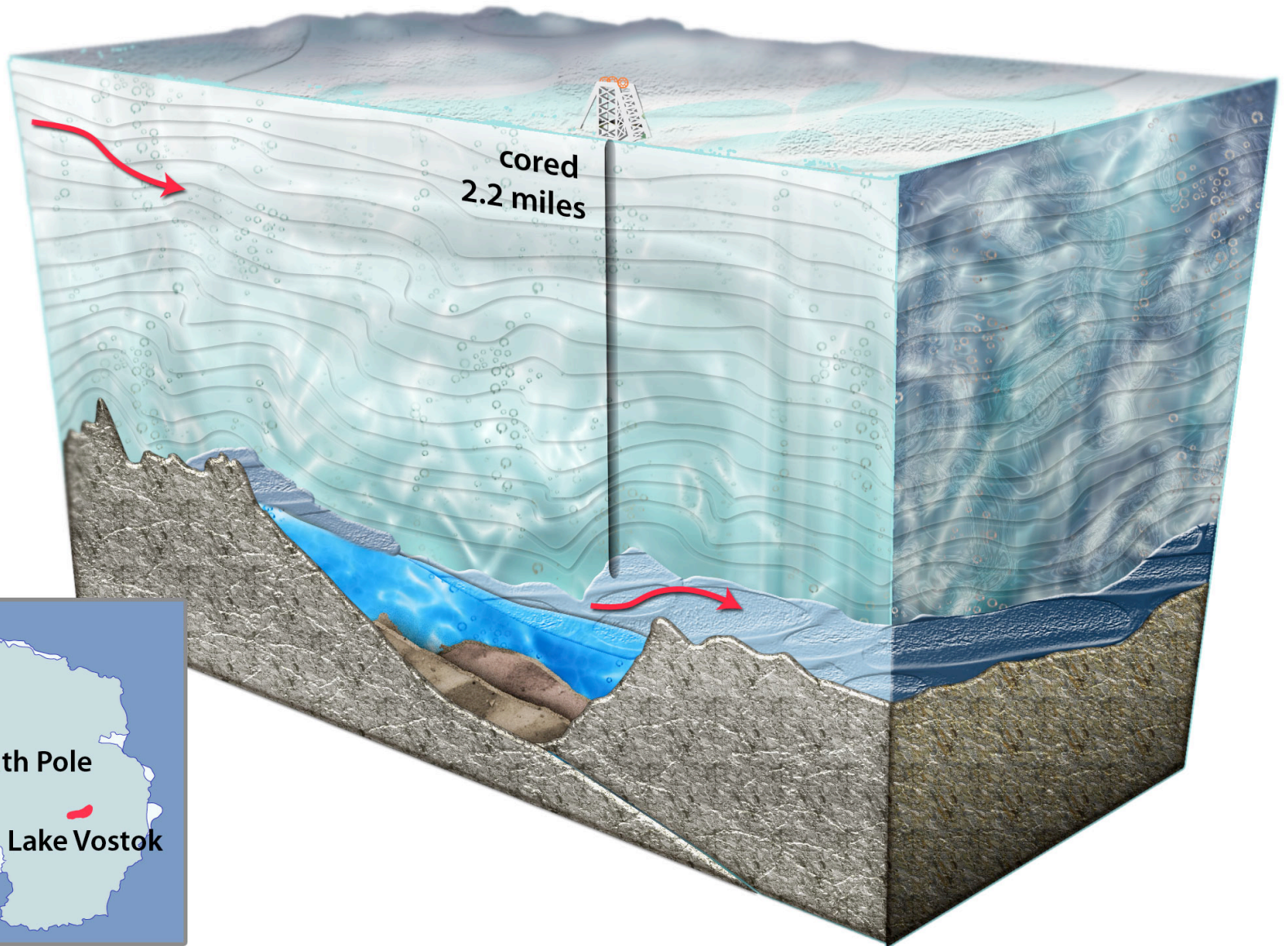


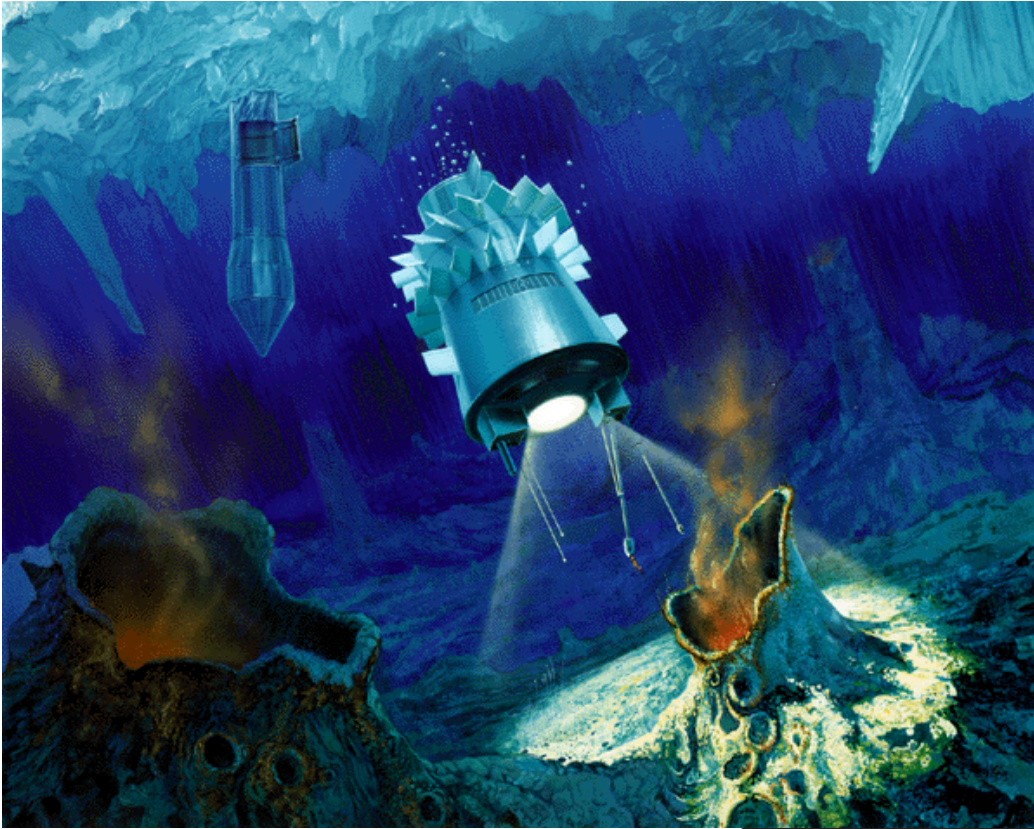
EARTH

CREDIT: PHL @ UPR Arcibo, NASA



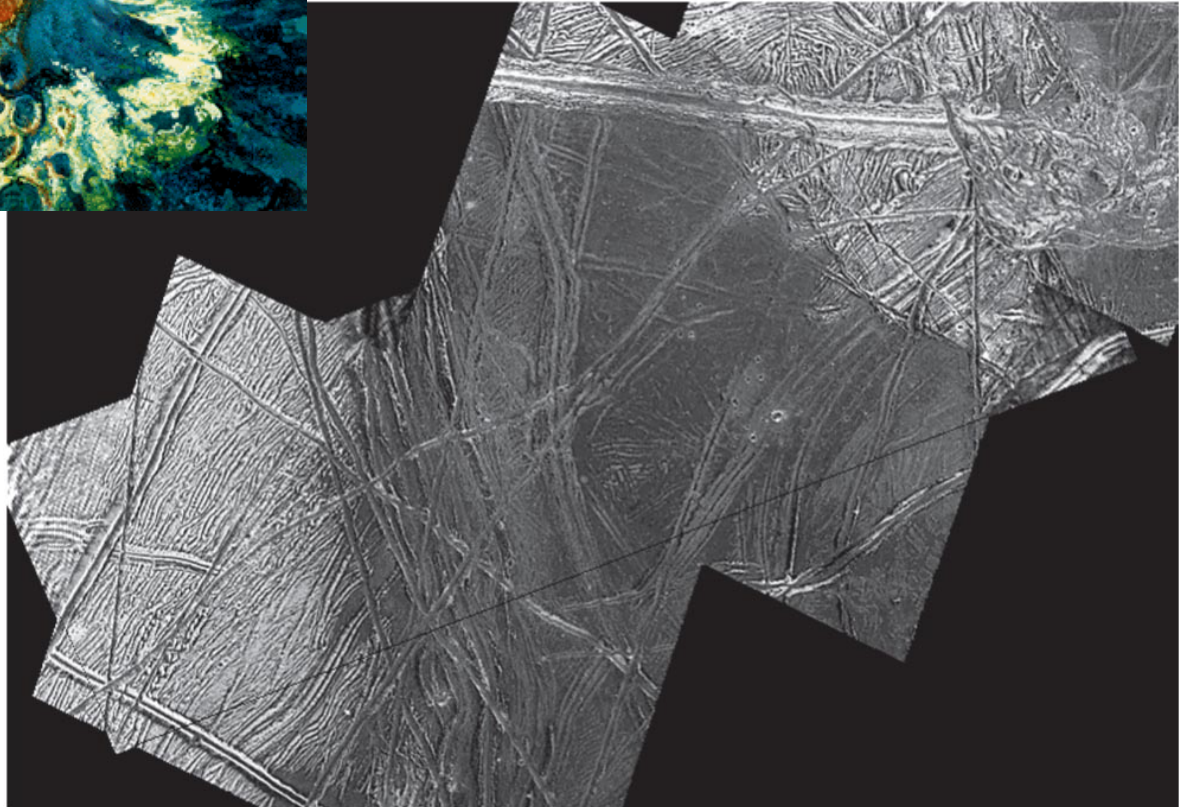
# Lake Vostok - Antarctica



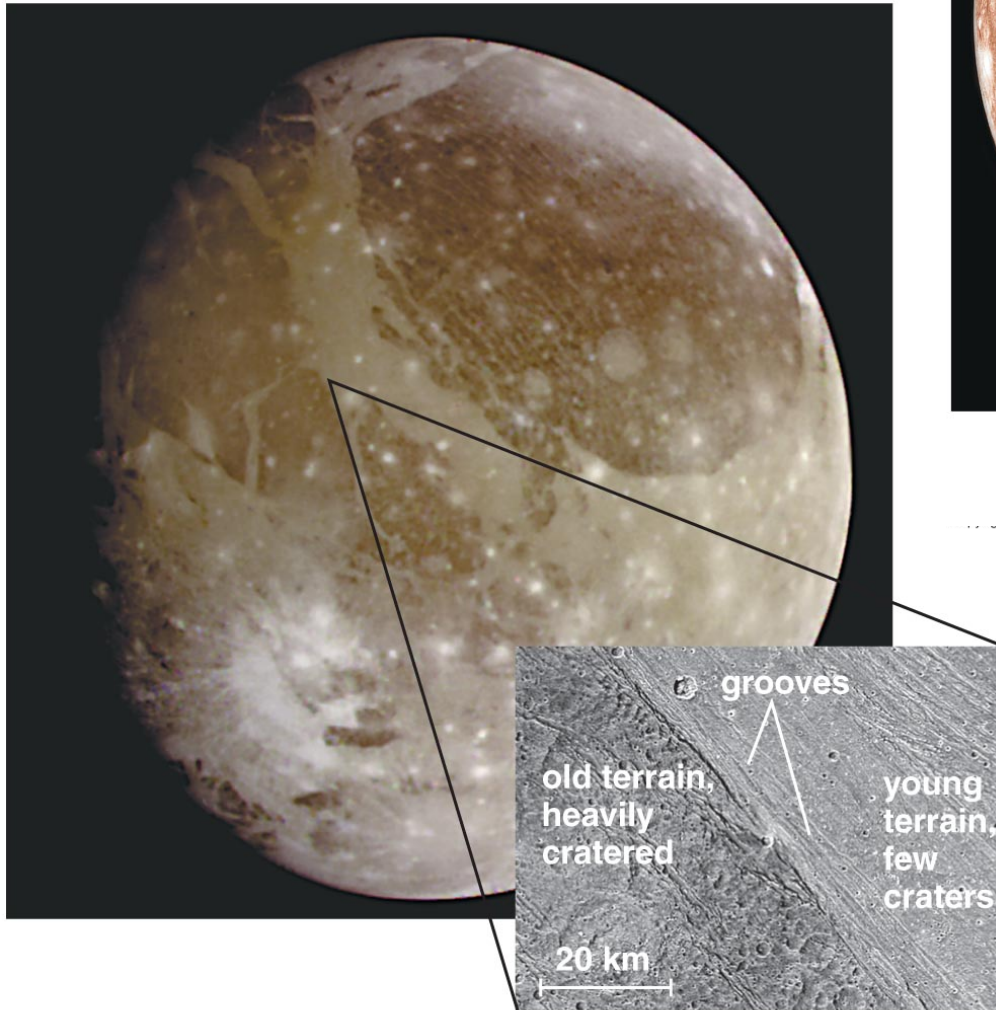
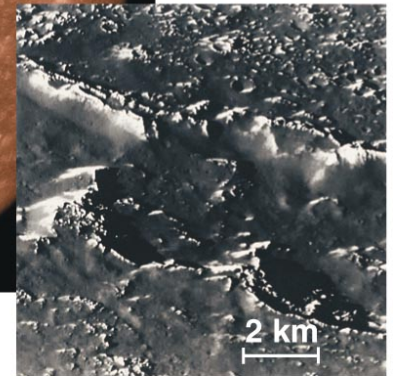
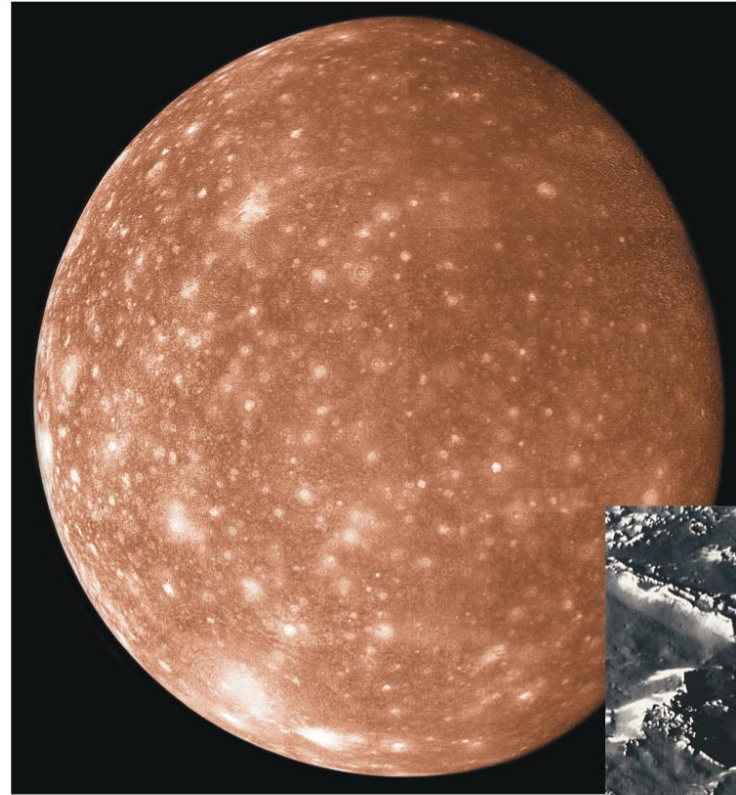


A potential mission to Europa would land on the ice pack, use heat from a nuclear reactor to melt through it, and release a hydrobot to explore the ocean.

There may be places where the crust is thin and water wells up and spreads over the surface.



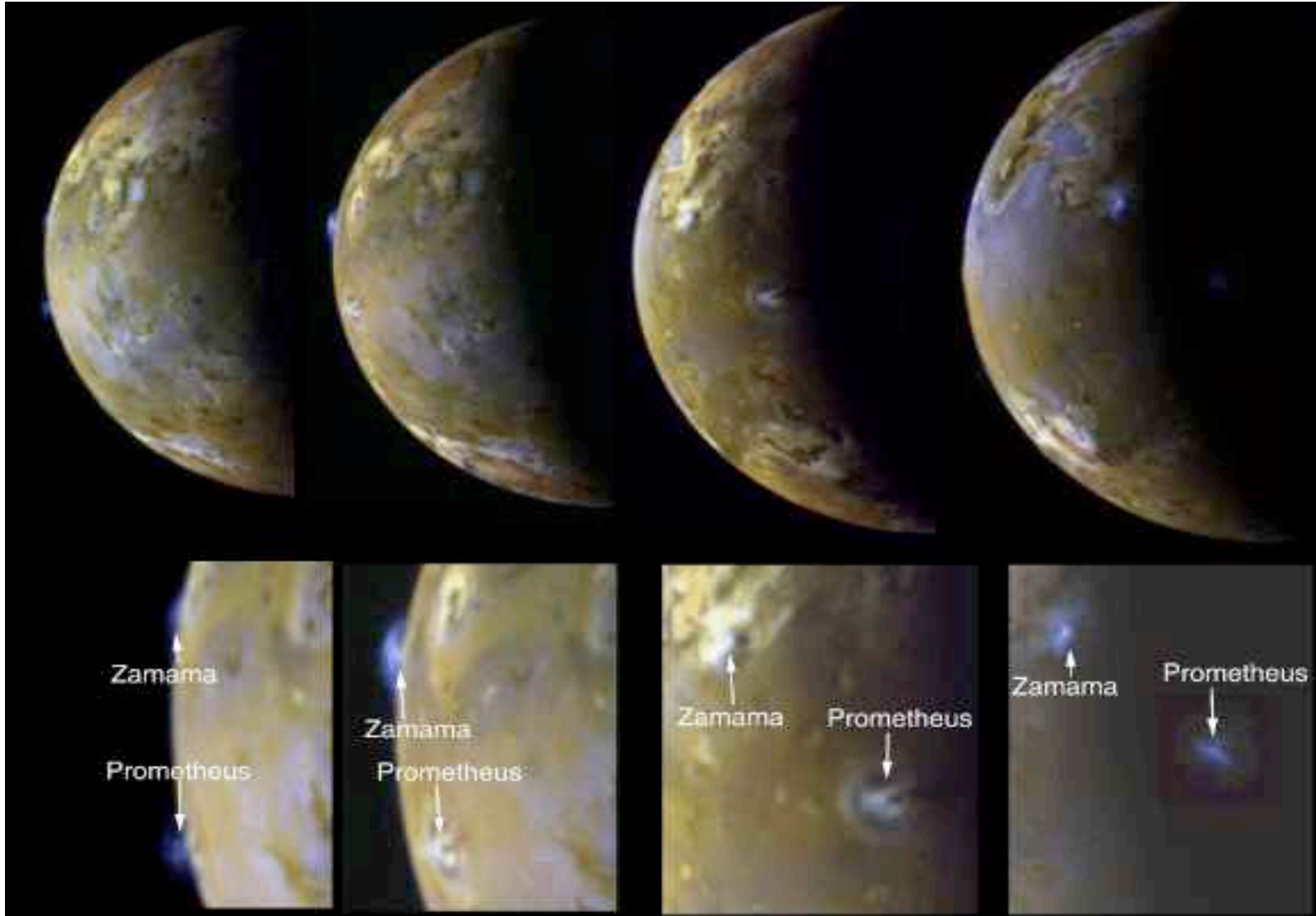
Ganymede, the largest moon in the solar system, with surface ice.



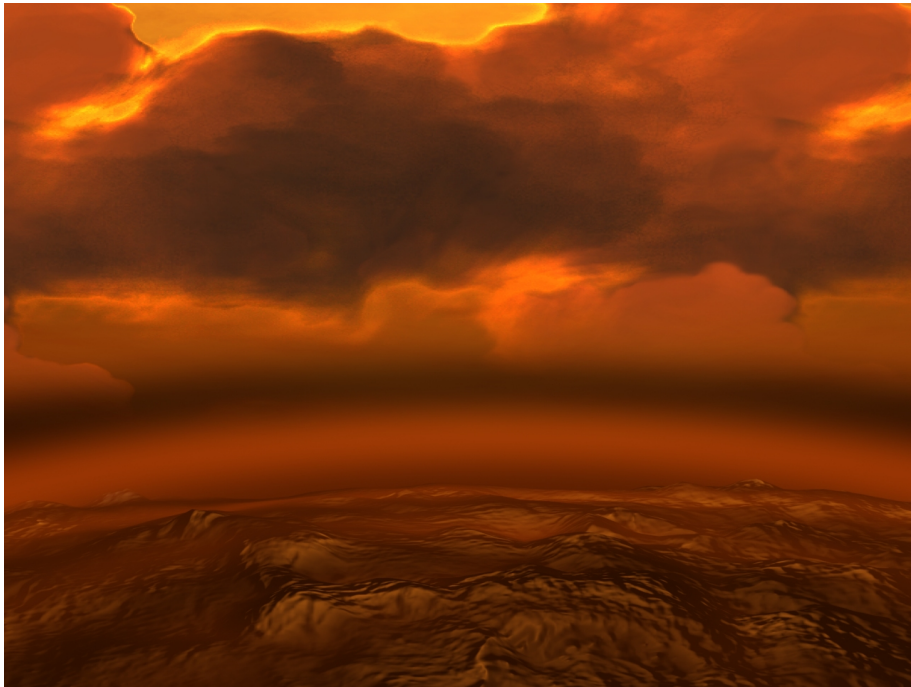
Callisto is heavily cratered, but may also have a deep buried ocean.

# Io

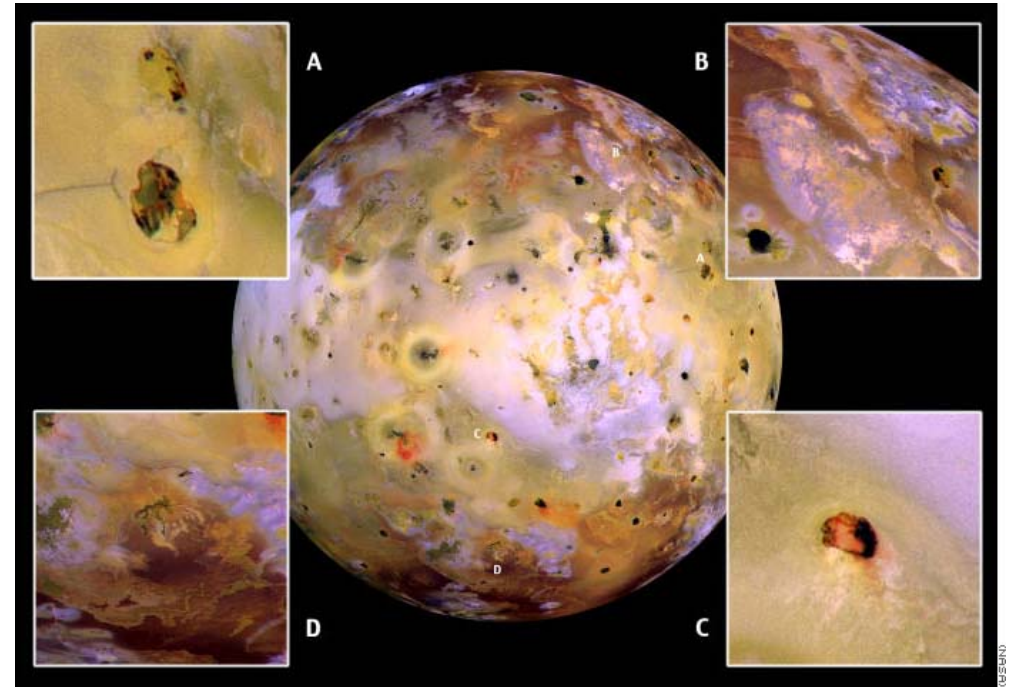
This Galilean moon of Jupiter undergoes extensive tidal heating resulting in volcanism. However, unlike Europa – surface covered in “fresh” sulfur compounds



# Could there be life in even more extreme environments?



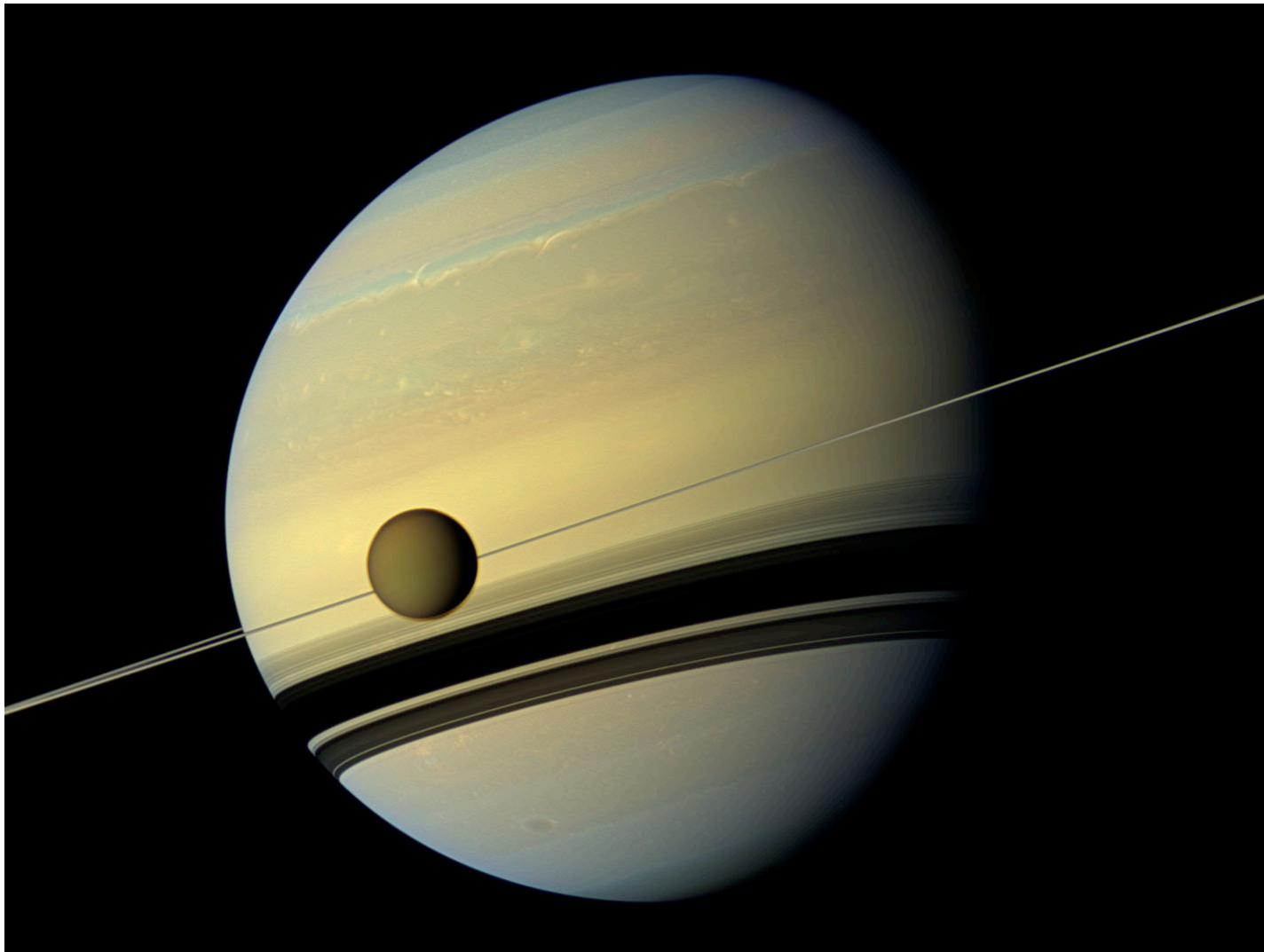
Biochemistry floating in the temperate upper regions of Venus' toxic atmosphere?

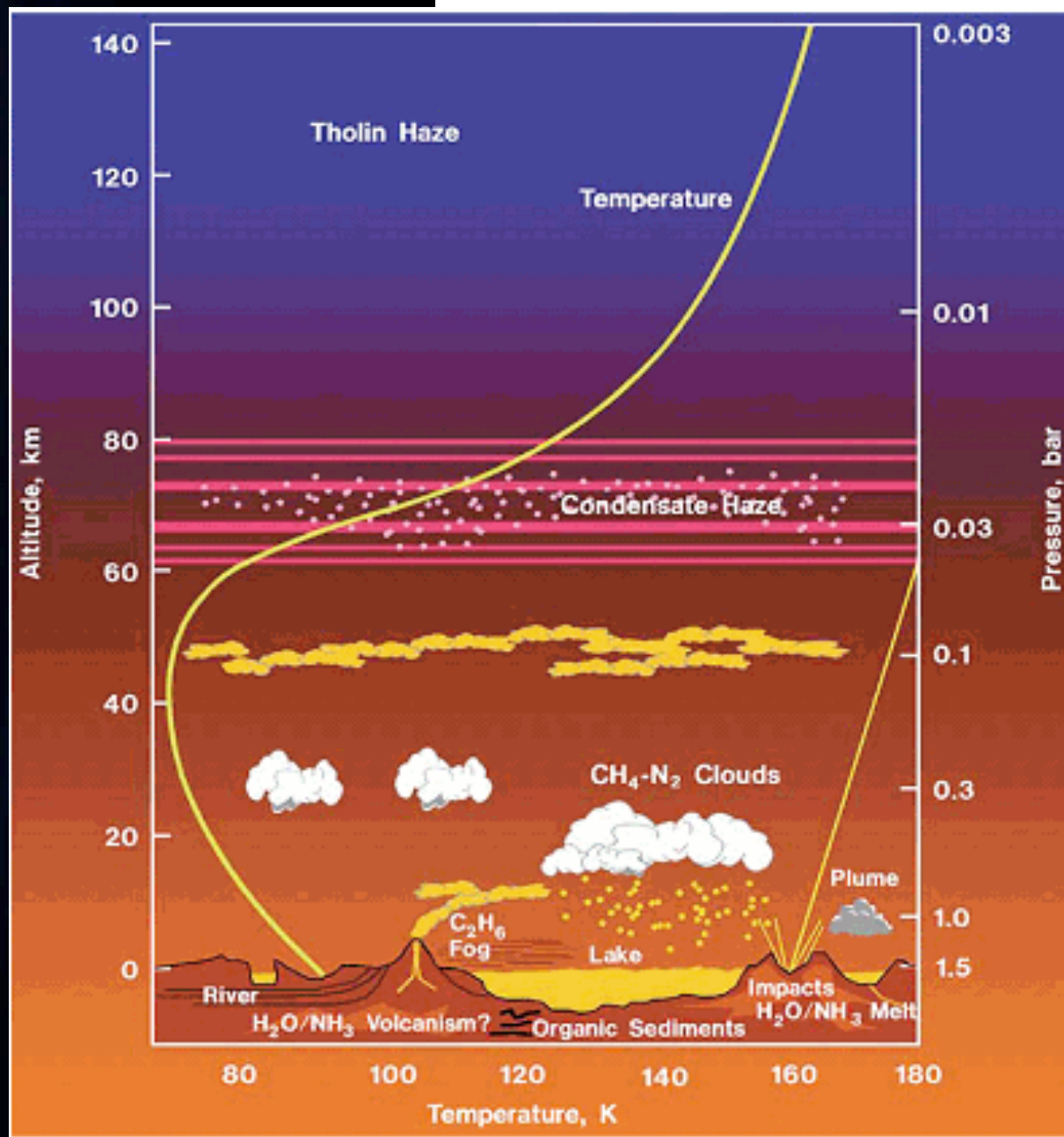


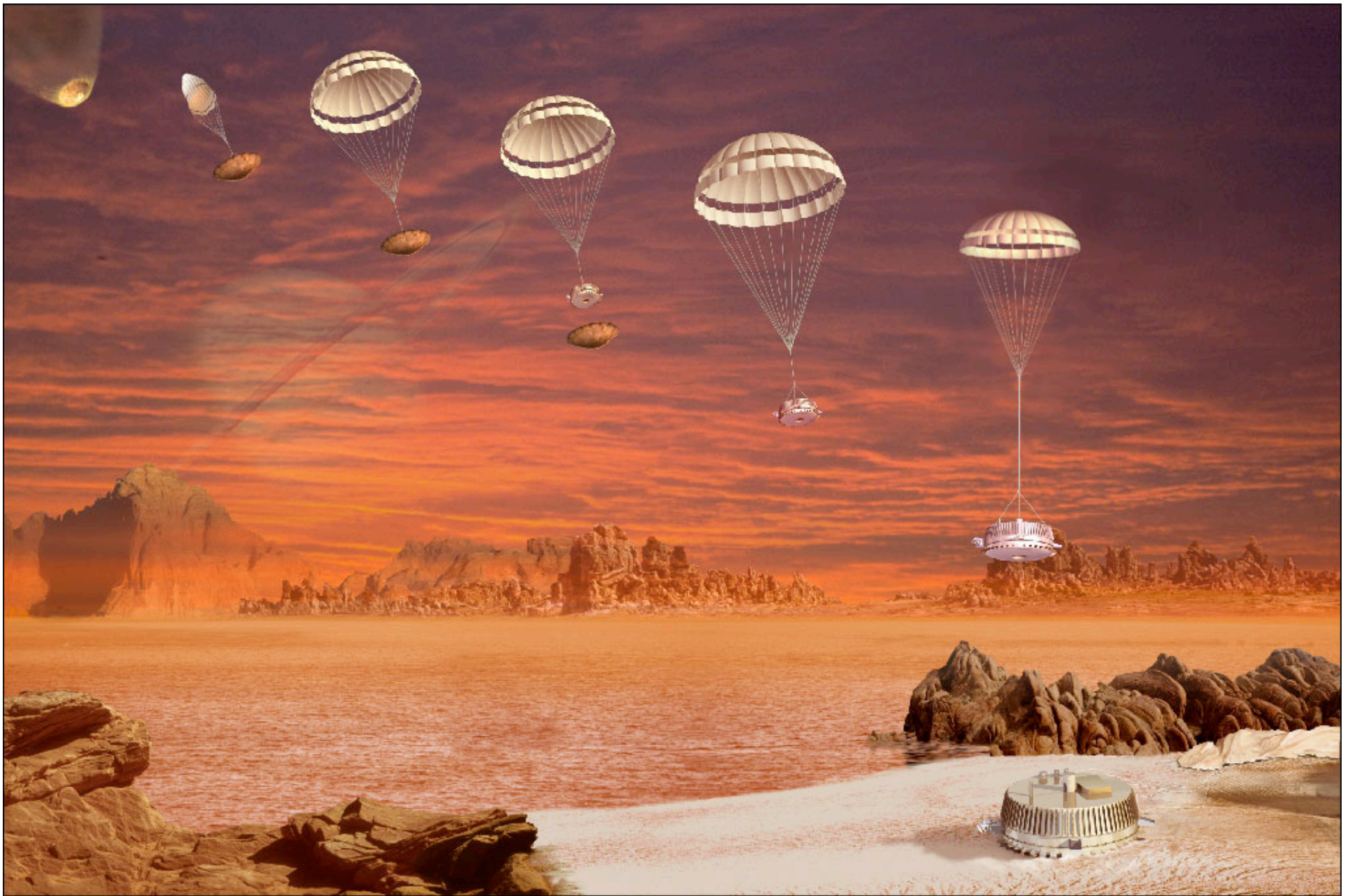
Biochemistry based on the highly active sulfur-based reactions on Io's surface?

# Titan – Largest Moon of Saturn

This large moon of Saturn has a nitrogen atmosphere thicker than the Earth's, active geology, and weathering and climate.





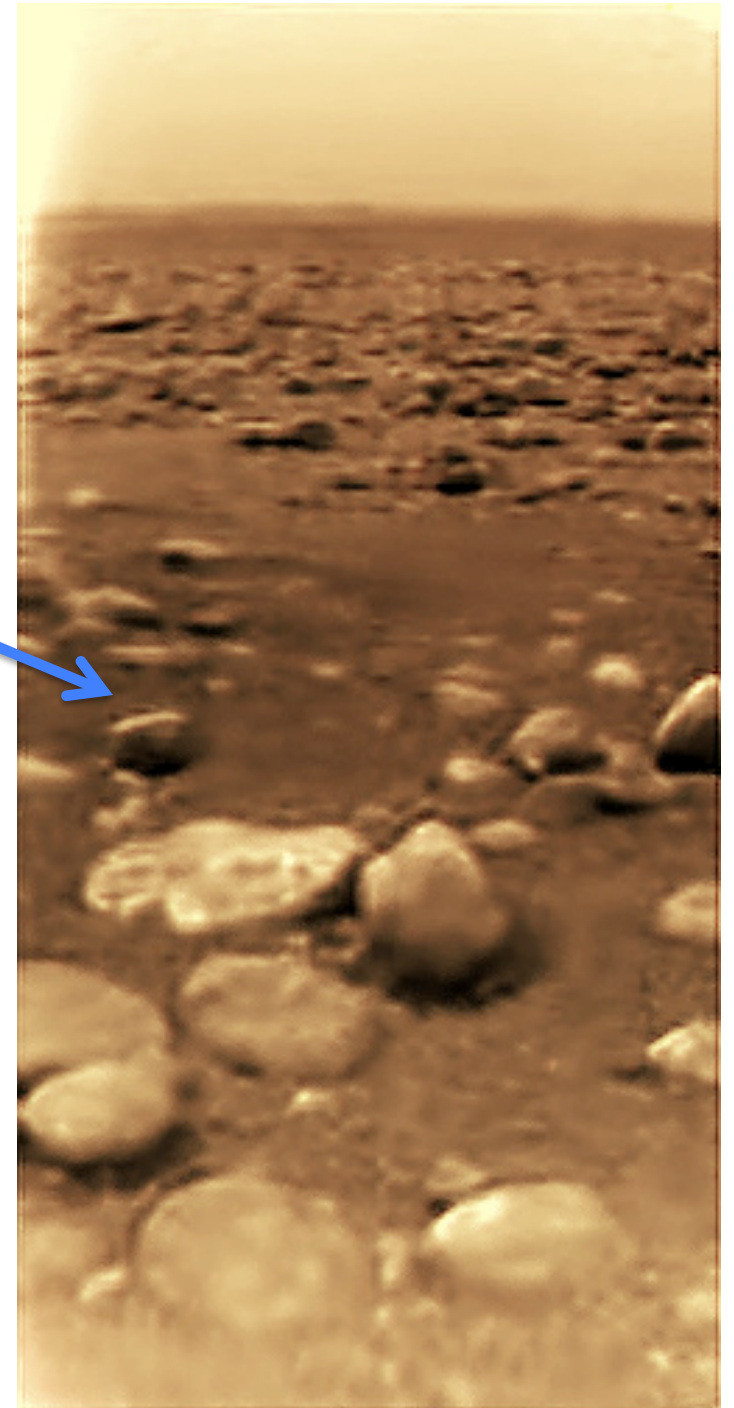
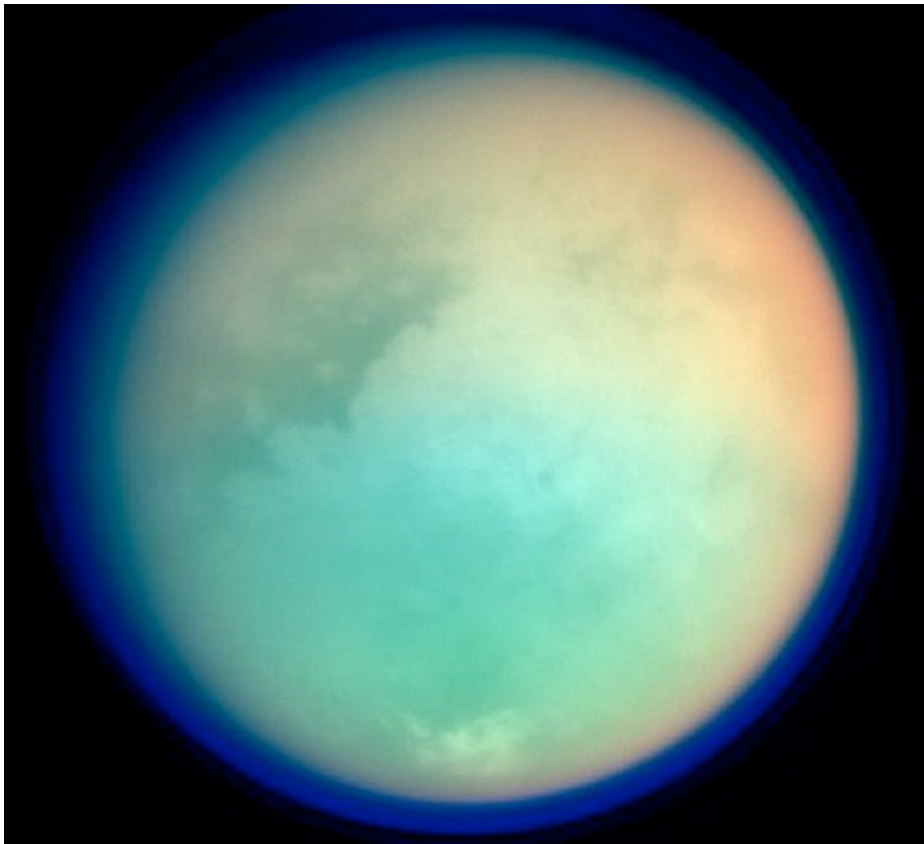




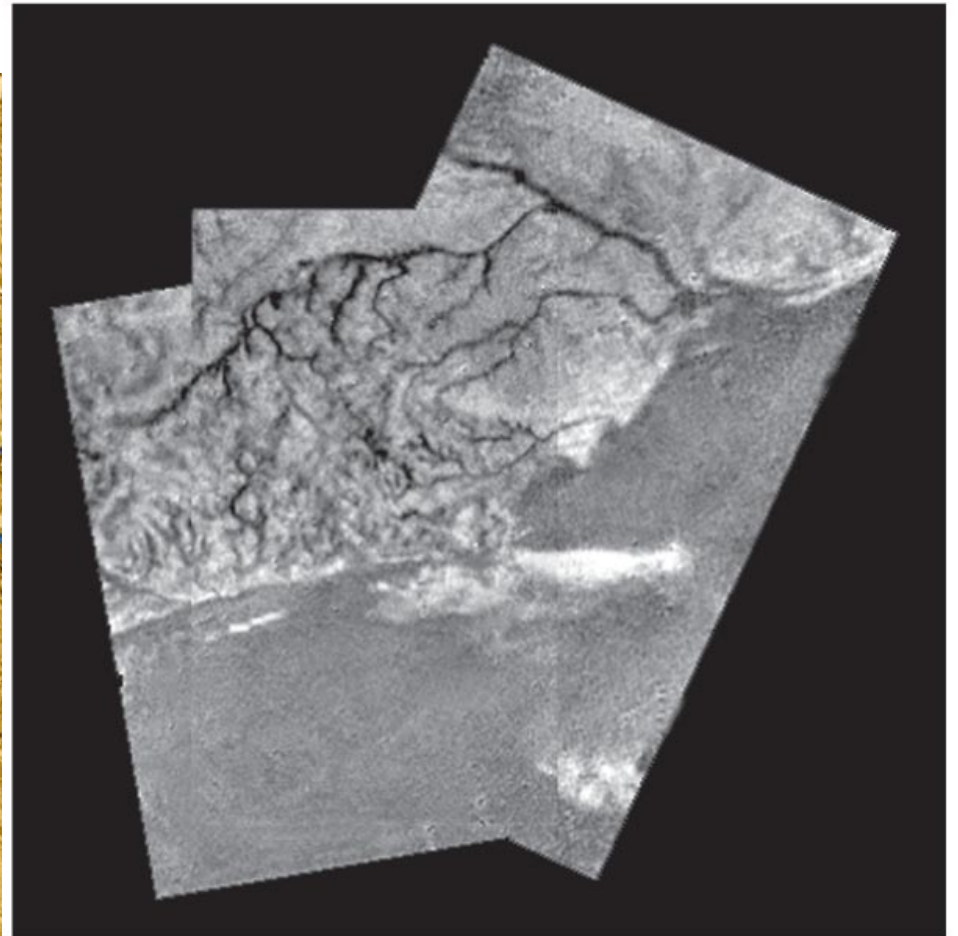
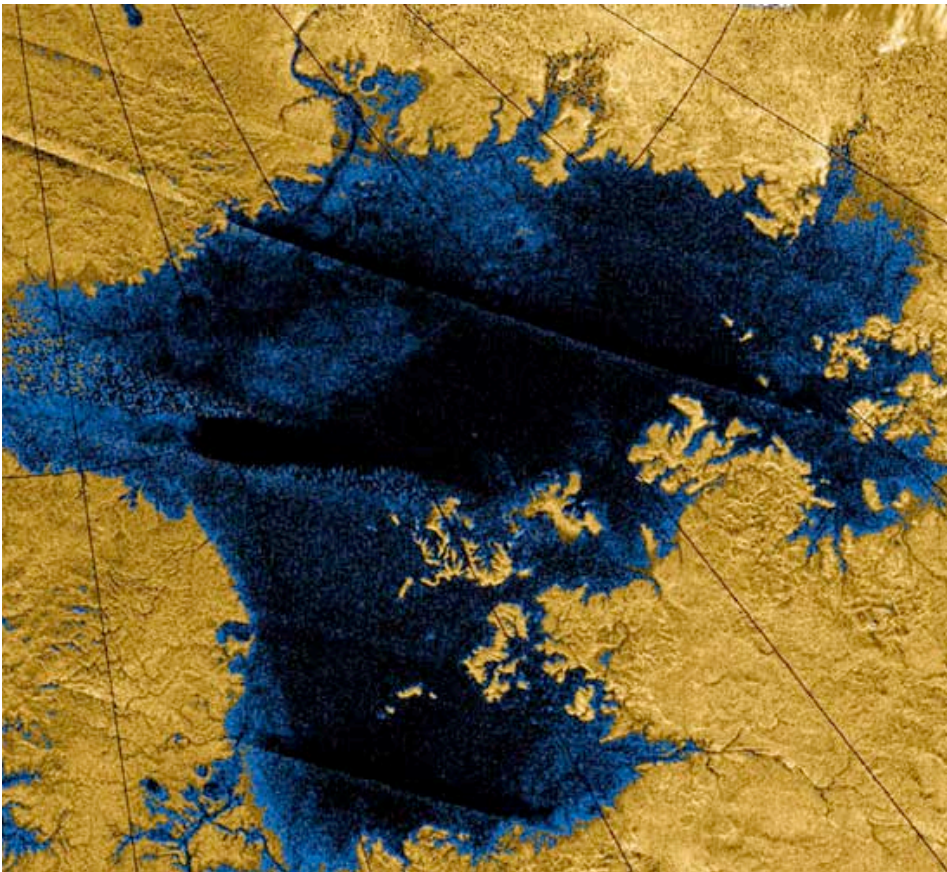
# Titan

~90 K  
(-290 F)

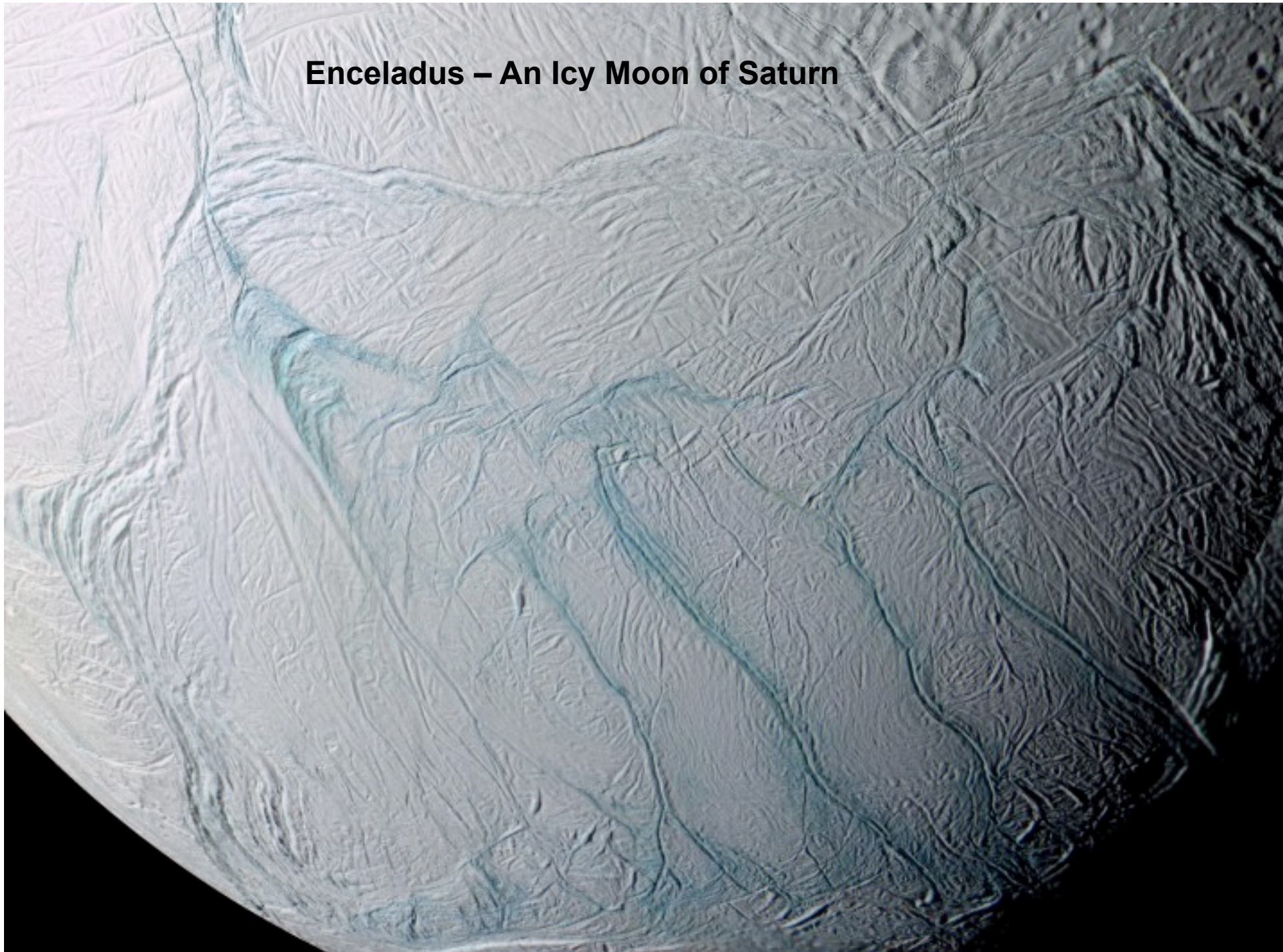
View from the Huygens  
lander, sent in late 2005.



But its nothing like Earth. The lakes and erosion features are mostly ethane and methane – complex hydrocarbon chemistry.



## Enceladus – An Icy Moon of Saturn



## Enceladus – An Icy Moon of Saturn

Cryovolcanoes =  
“Ice Volcano”



# Comets – Reservoirs of Icy Water



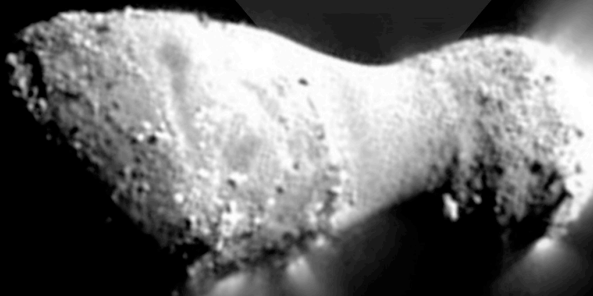
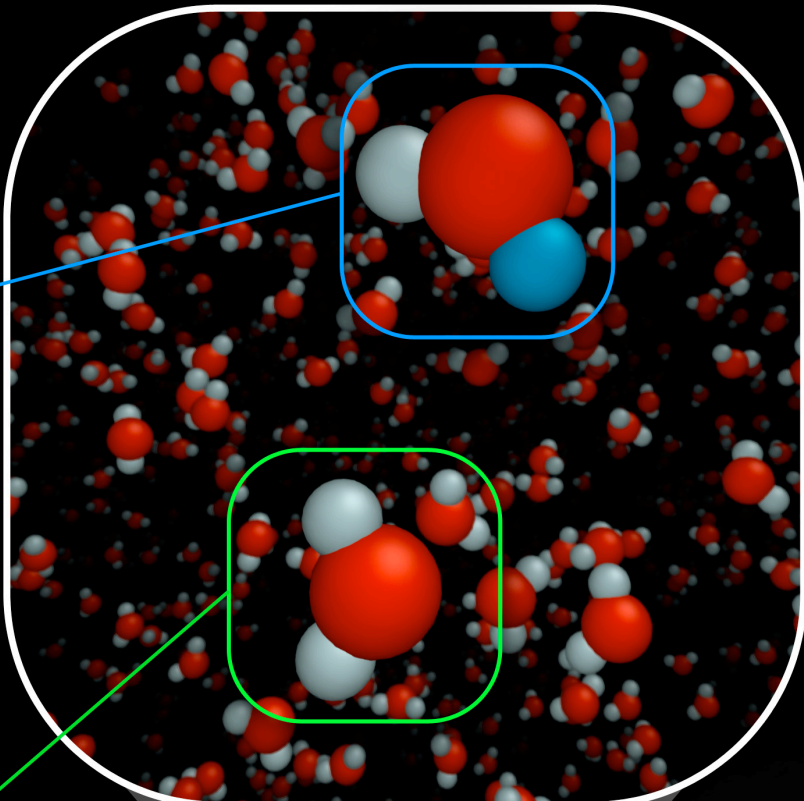
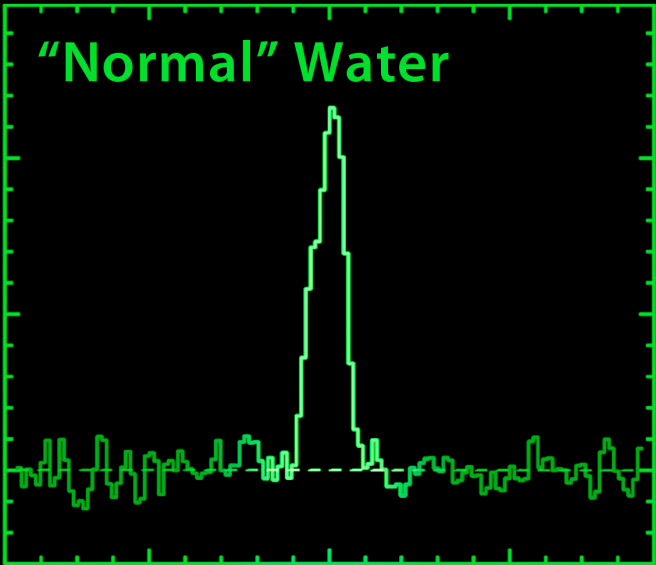
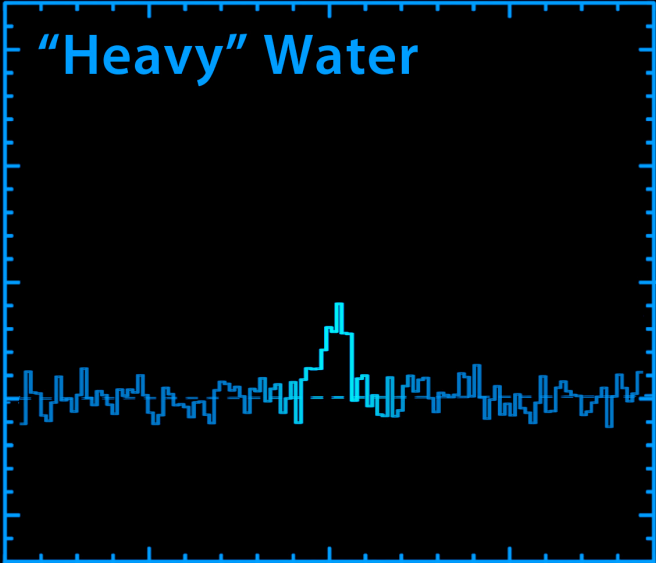
Takács - Kiss (Uni. Sydney) - Szabó (Uni. Szeged)

# Comets – Reservoirs of Icy Water



## Herschel Space Observatory



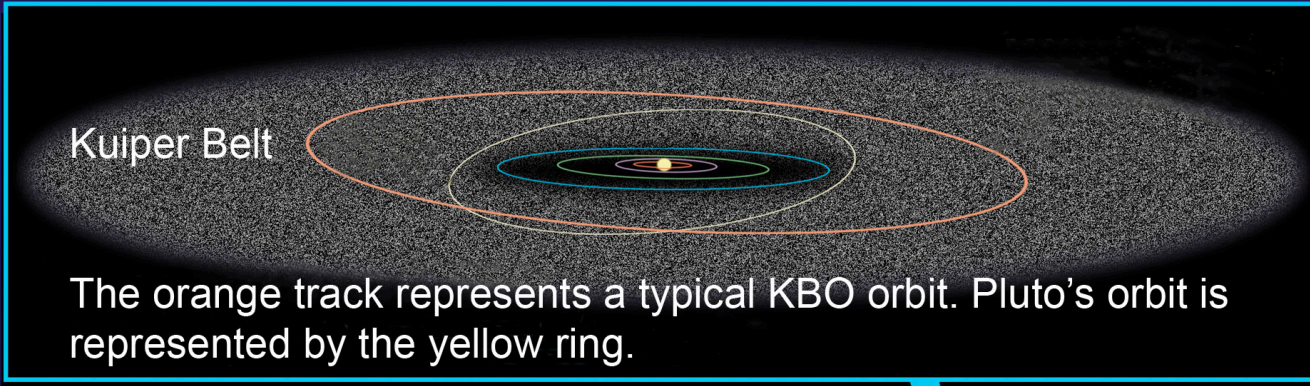
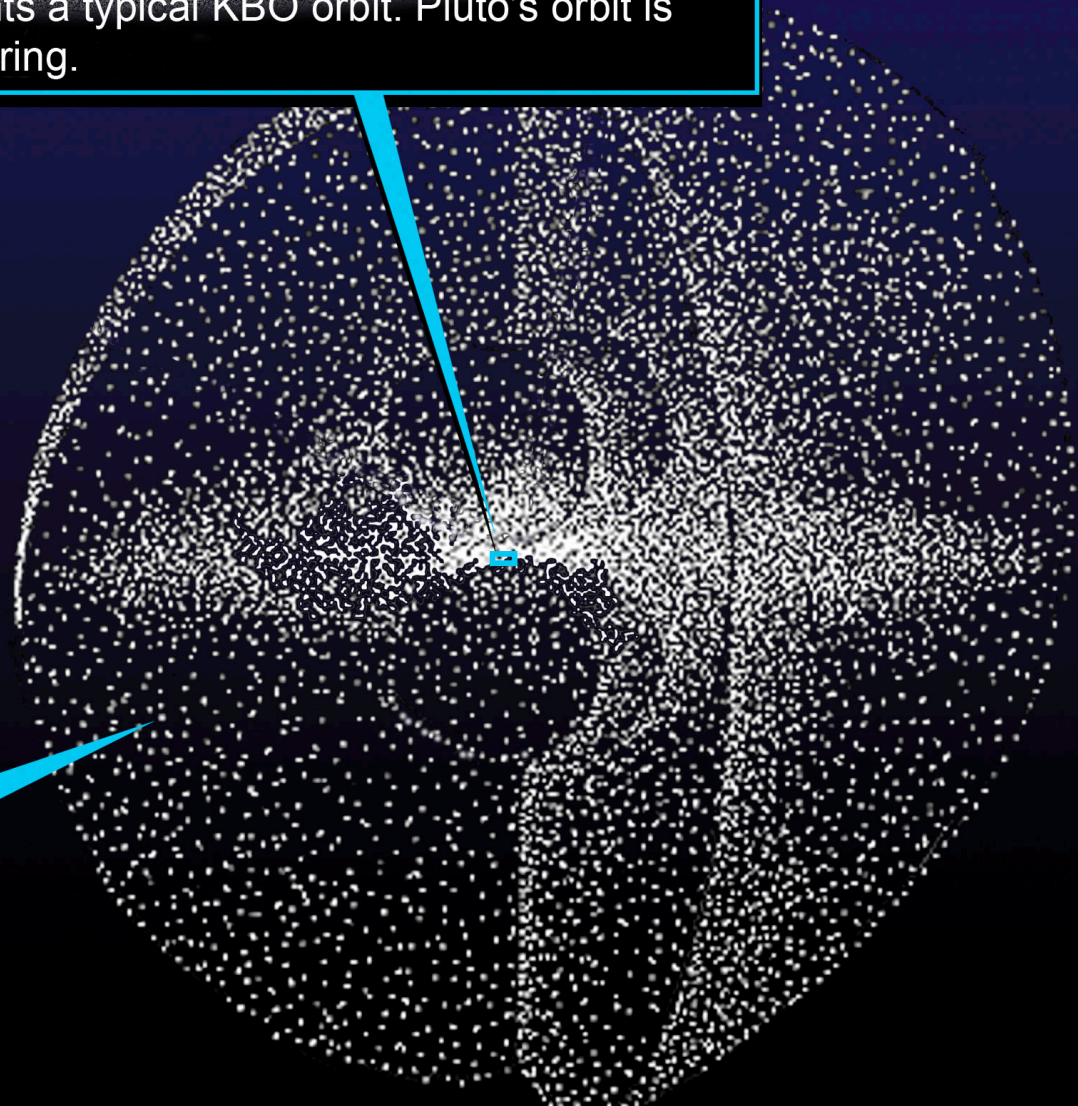




Kuiper Belt

The orange track represents a typical KBO orbit. Pluto's orbit is represented by the yellow ring.

Oort Cloud



# Asteroids – How Much H<sub>2</sub>O?



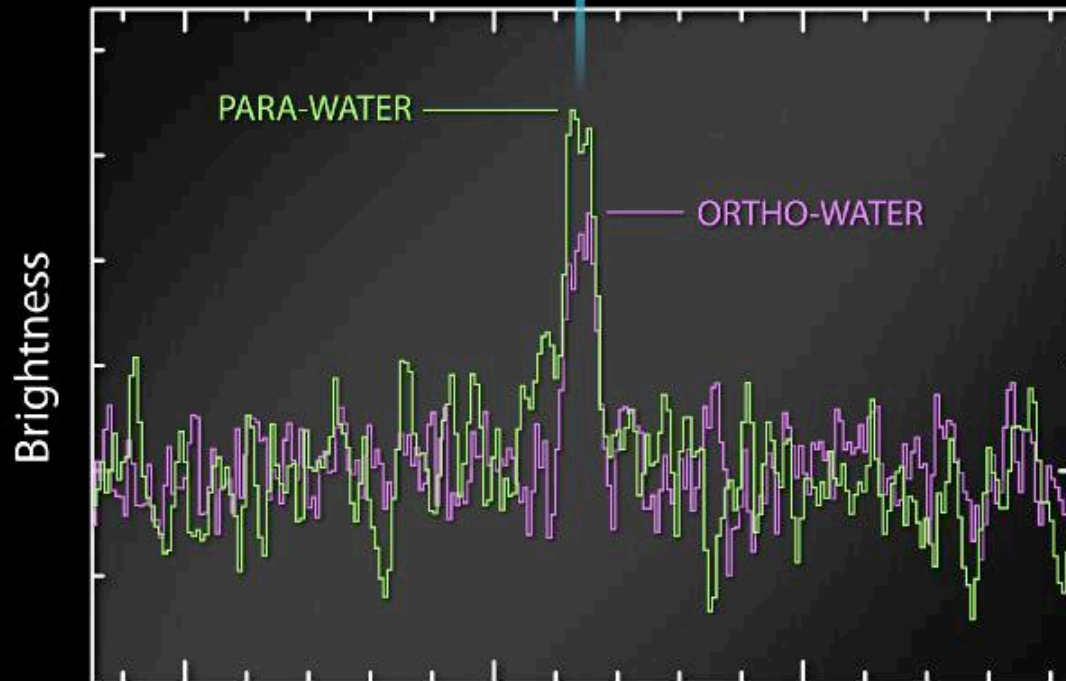
Vesta

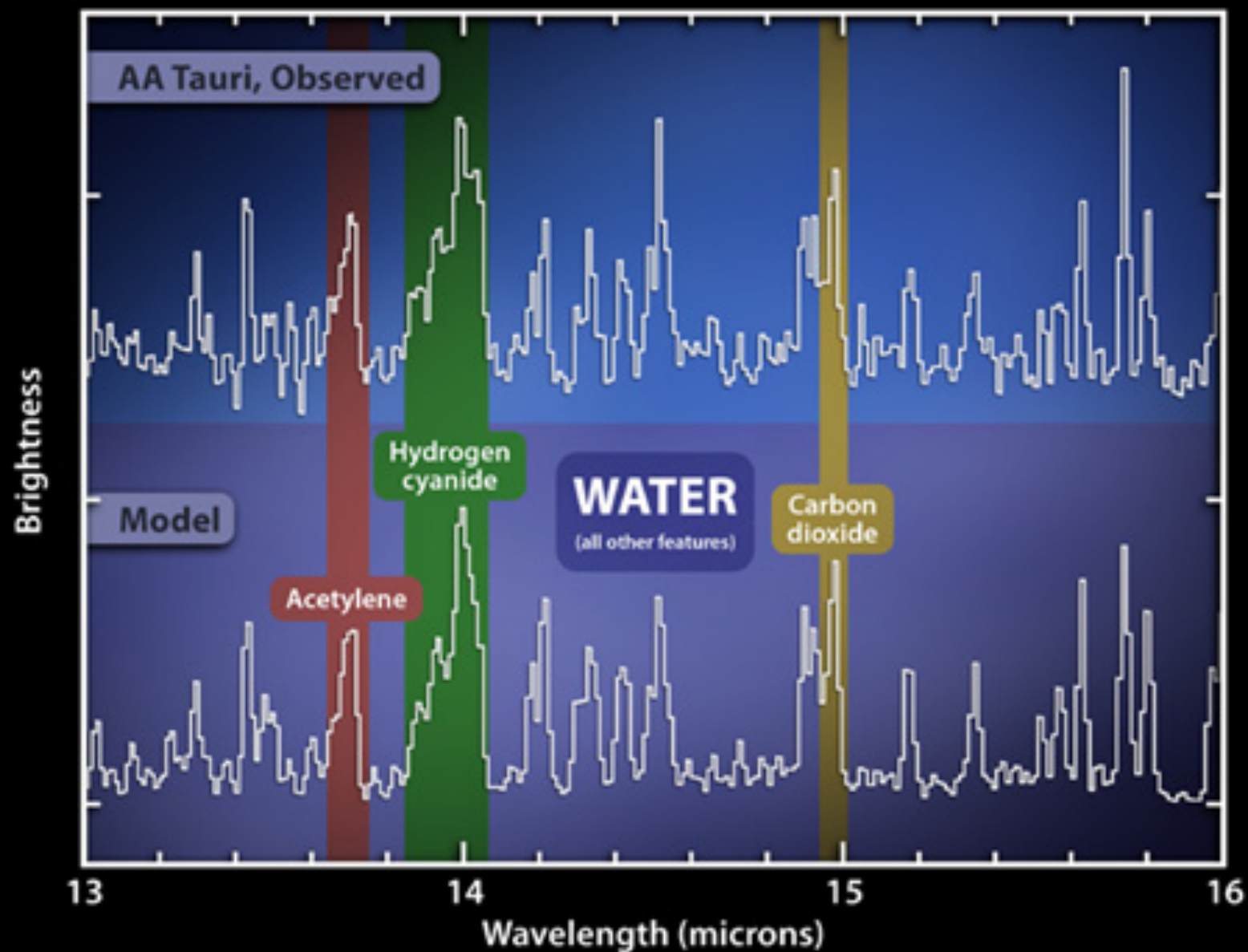
# Water in a Forming Solar System



TW Hydrae

Enough H<sub>2</sub>O to  
fill thousands of  
Earth's oceans!





Organic Molecules and Water in a Protoplanetary Disk

Spitzer Space Telescope • IRS

NASA / JPL-Caltech / J. Carr (Naval Research Laboratory)

ssc2008-06a

# Water and Organics are **COMMON** in new Solar Systems!

Star Forming Regions in Orion

