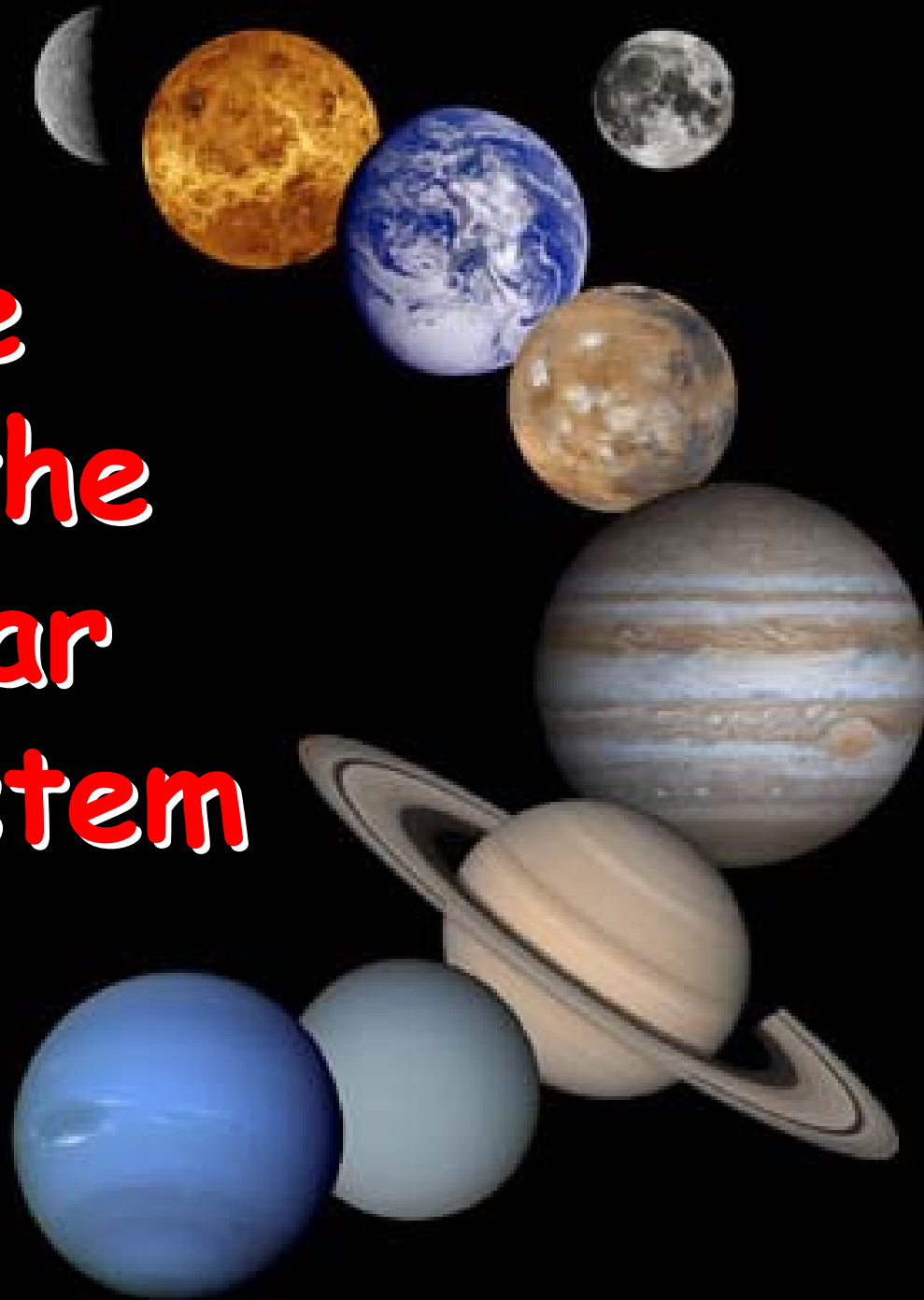


Life in the Solar System

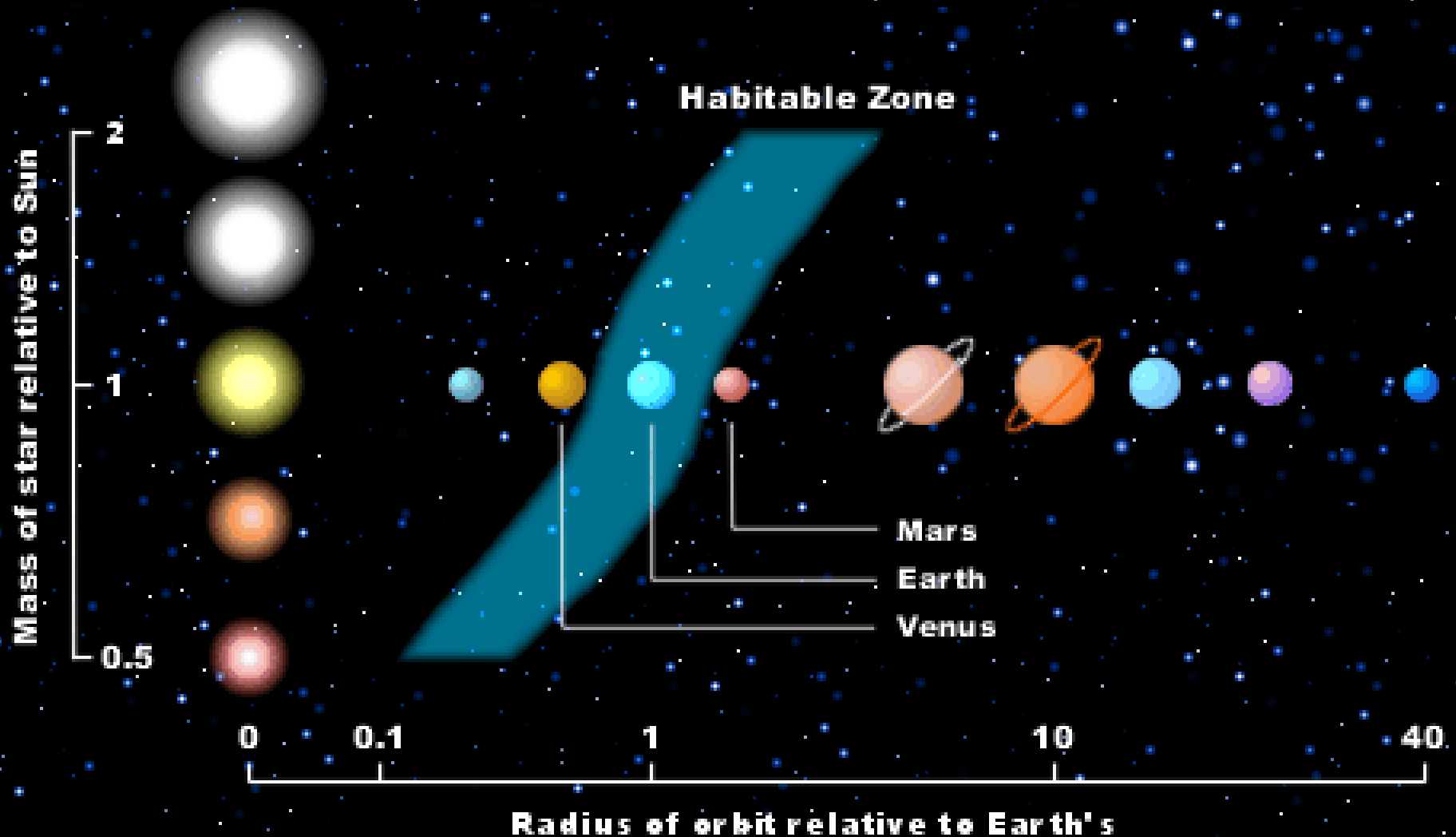


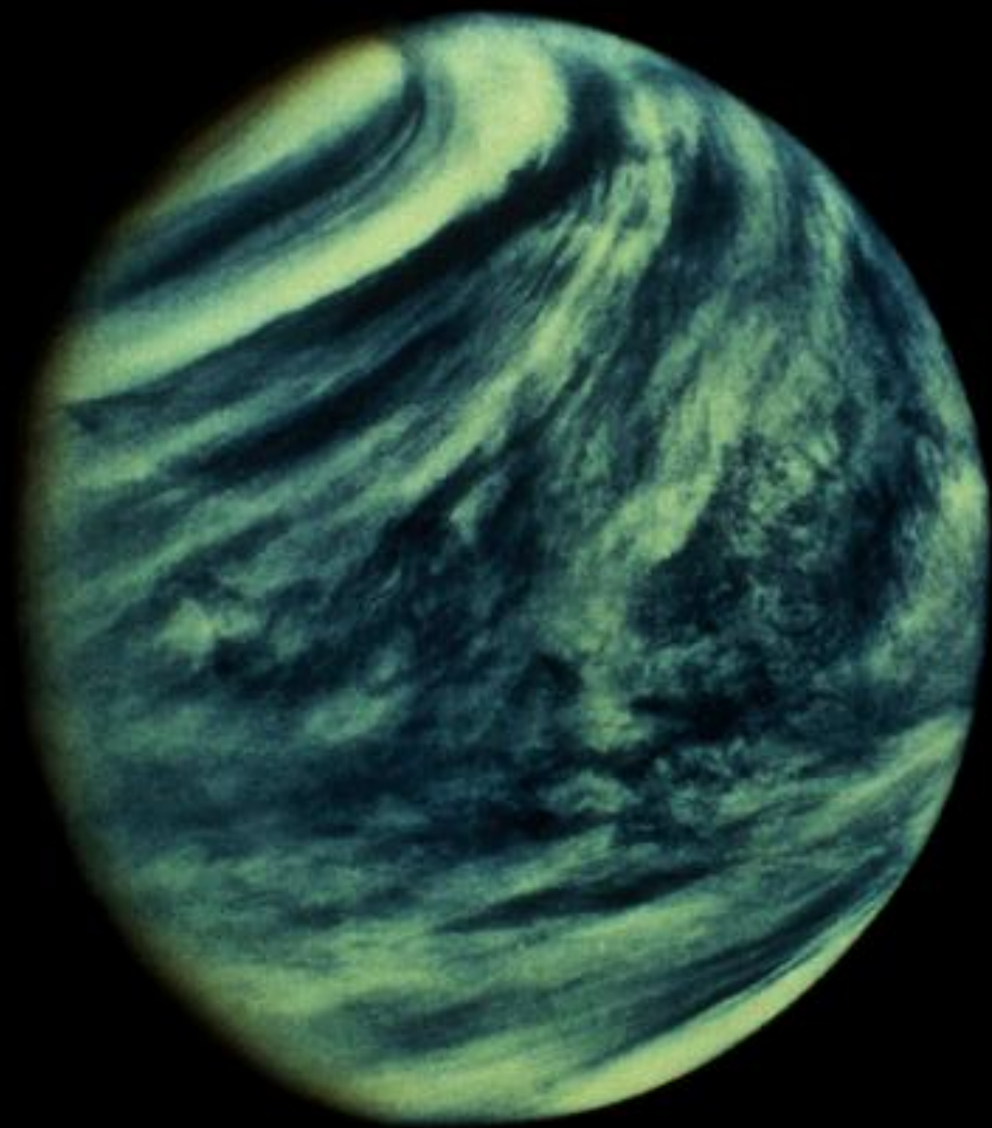
UNIVERSITY
of
GLASGOW



Life in the
Cosmos:
Jan 2006

Life in the Solar System







Venus Vital Statistics:

Surface temperature 450K

Atmosphere almost 100% CO₂

Pressure 90 times Earth's

Sulphuric Acid Rain

**Thick crust leads to regular
volcanic resurfacing**

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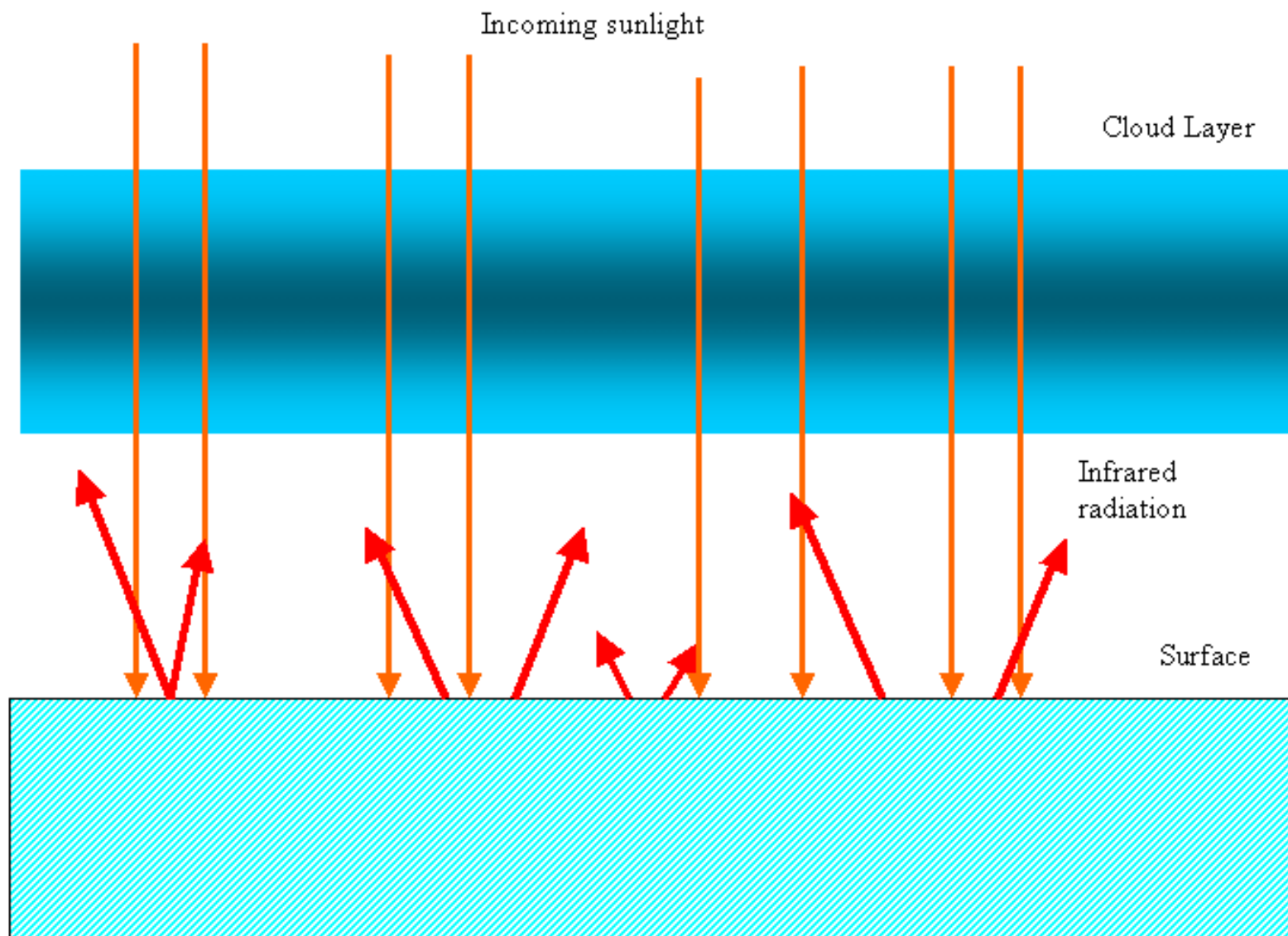
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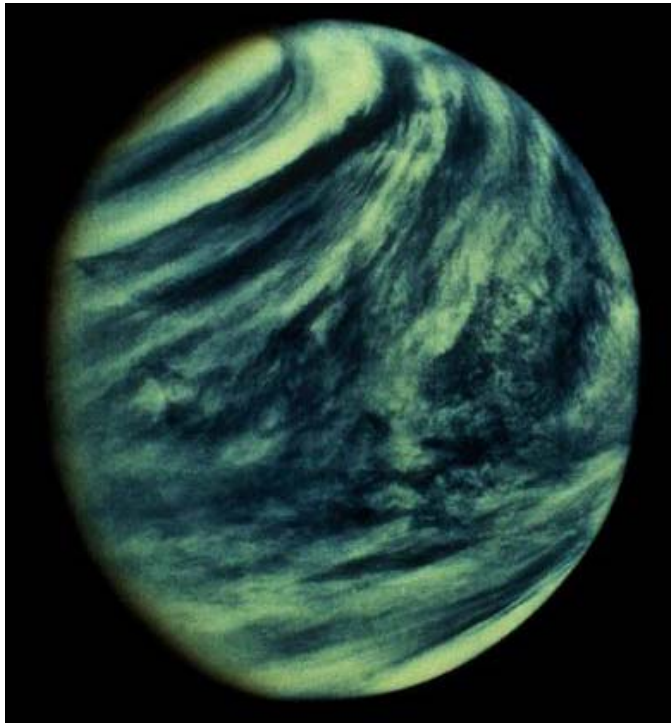
Runaway Greenhouse Effect



Our nearest neighbour: Venus

Since Venus formed in approximately the same part of the solar system as Earth, why did it end up with so little water?

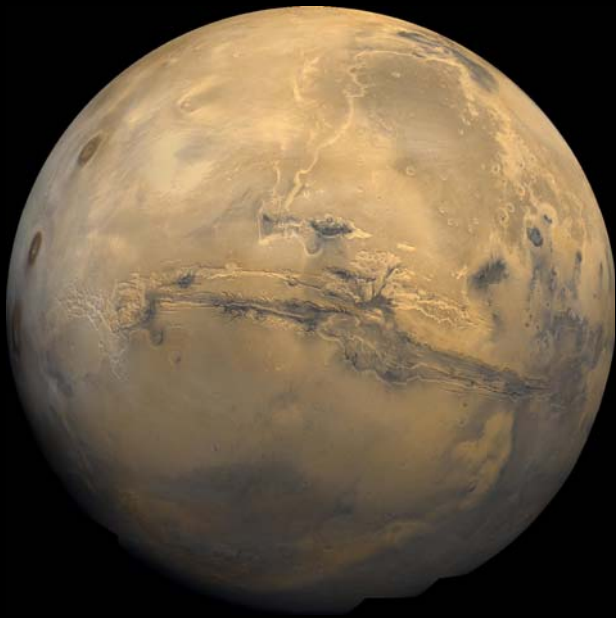
Water enters atmosphere by outgassing or arrival of comets.



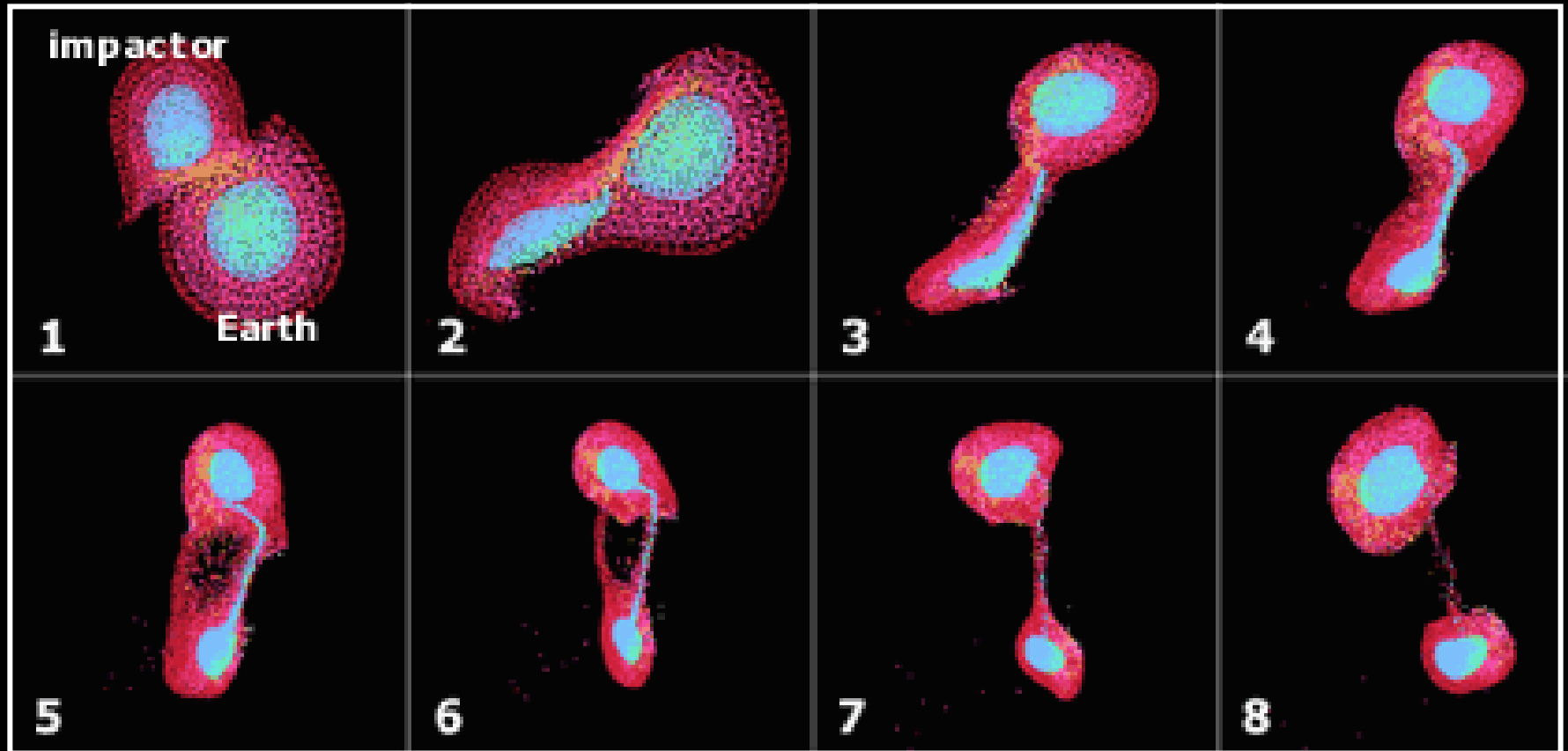
Most likely possibility – because Venus is nearer Sun, and hotter, water never condensed from atmosphere

Water molecules were then broken up by sunlight – hydrogen escaped into space

**Formation of the Moon:
Impact from Mars-sized
planetesimal during first
billion years.**

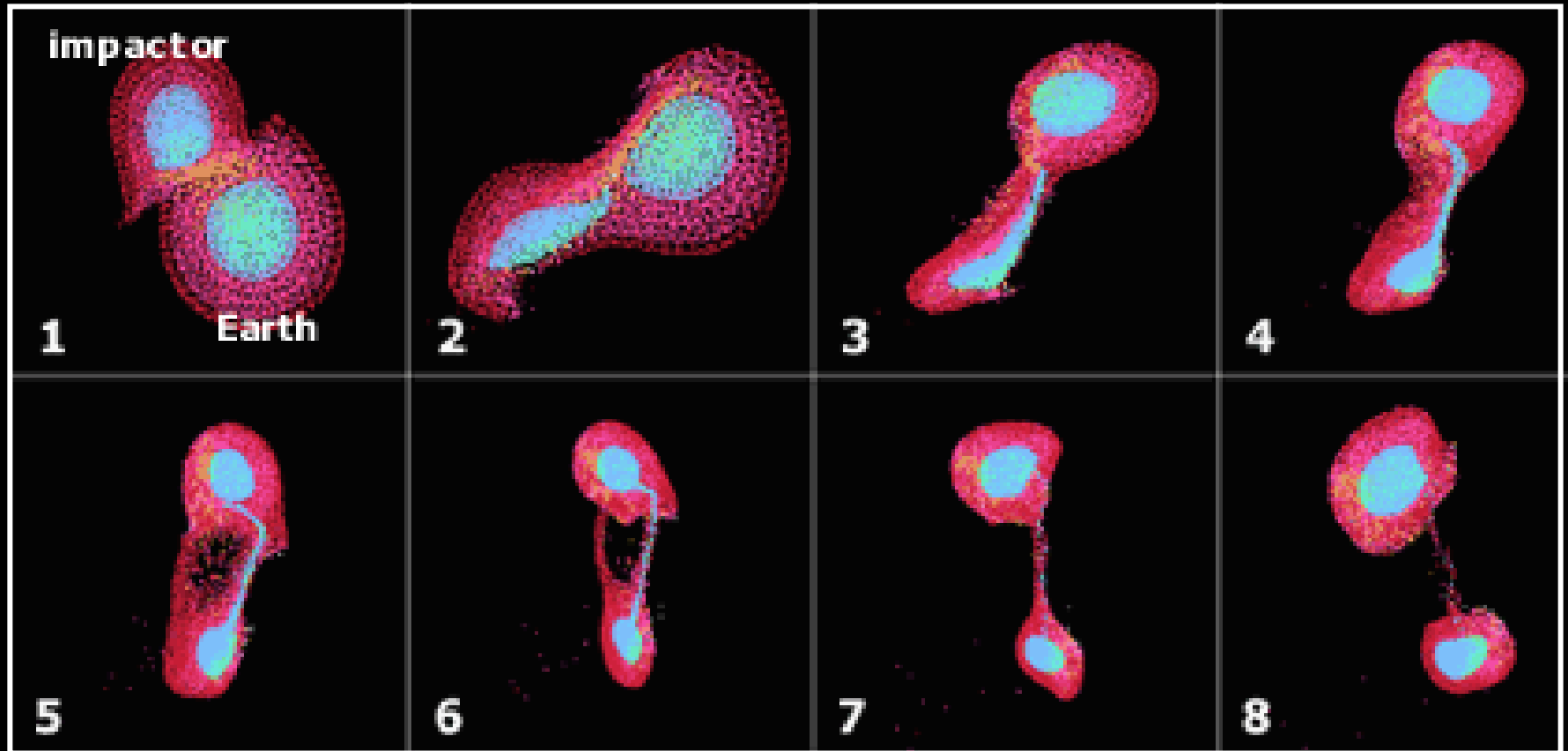


Simulations of Lunar formation

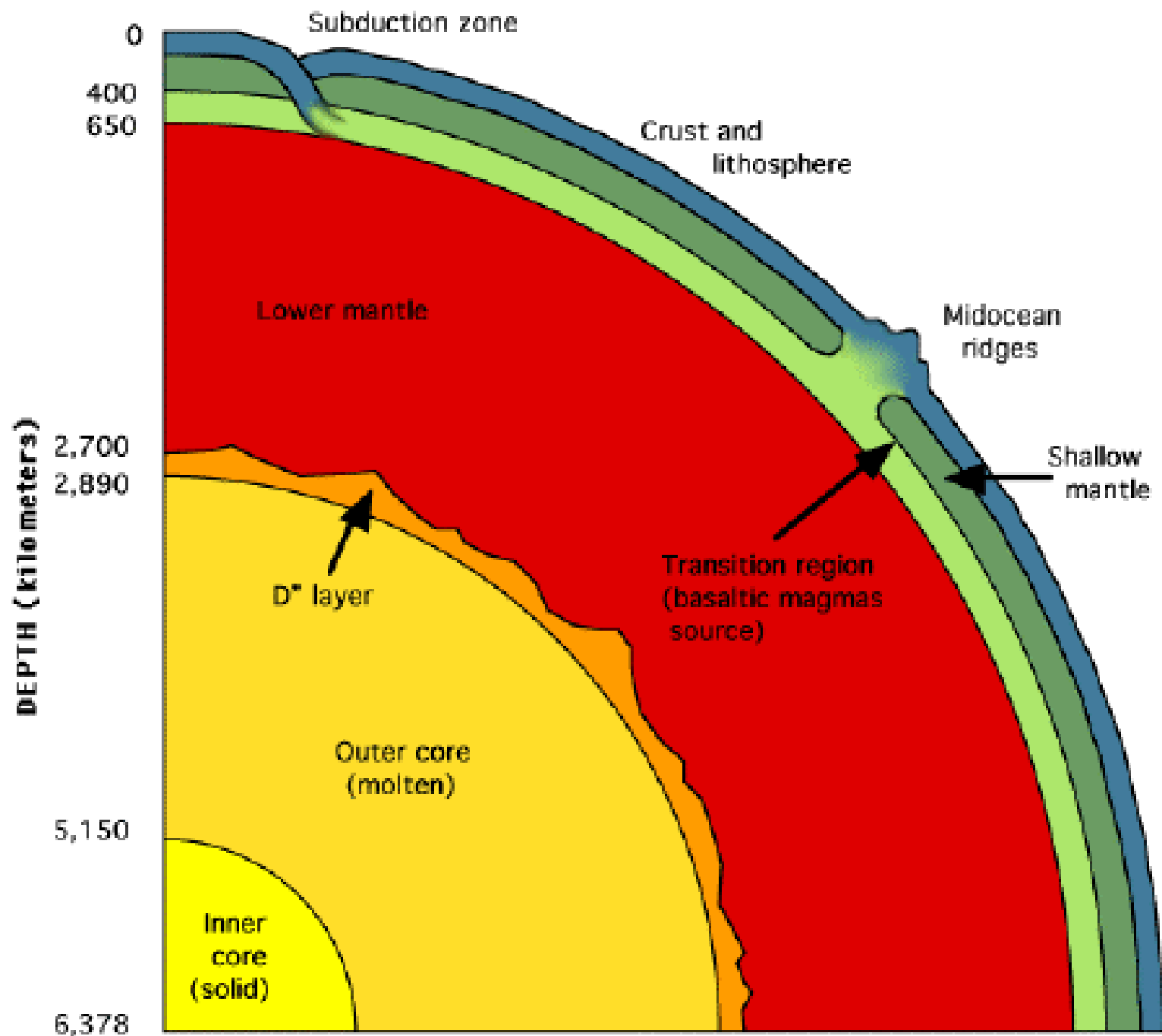


Alistair Cameron: Harvard College Observatory

Simulations of Lunar formation



Alistair Cameron: Harvard College Observatory



Impact energy = 1 million million megatons



Impact energy = 1 million million megatons

20 billion cubic kilometres of the
crust sprayed into space

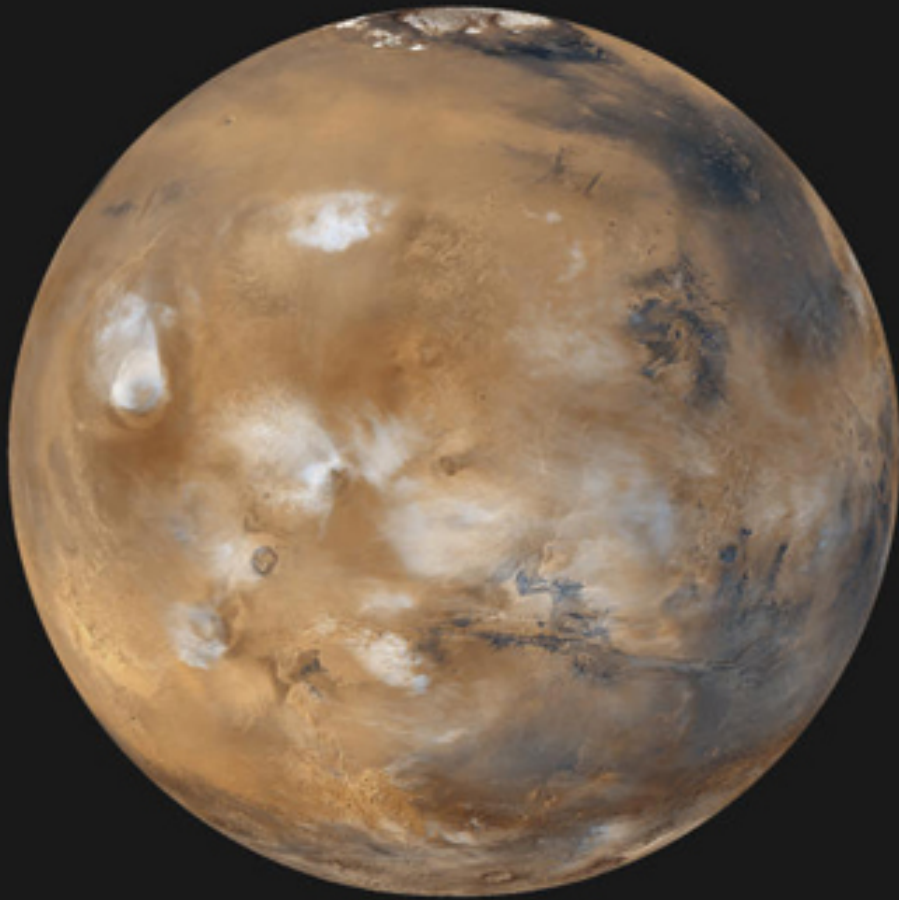
Atmosphere ejected into space

Ring of material coalesces into Moon

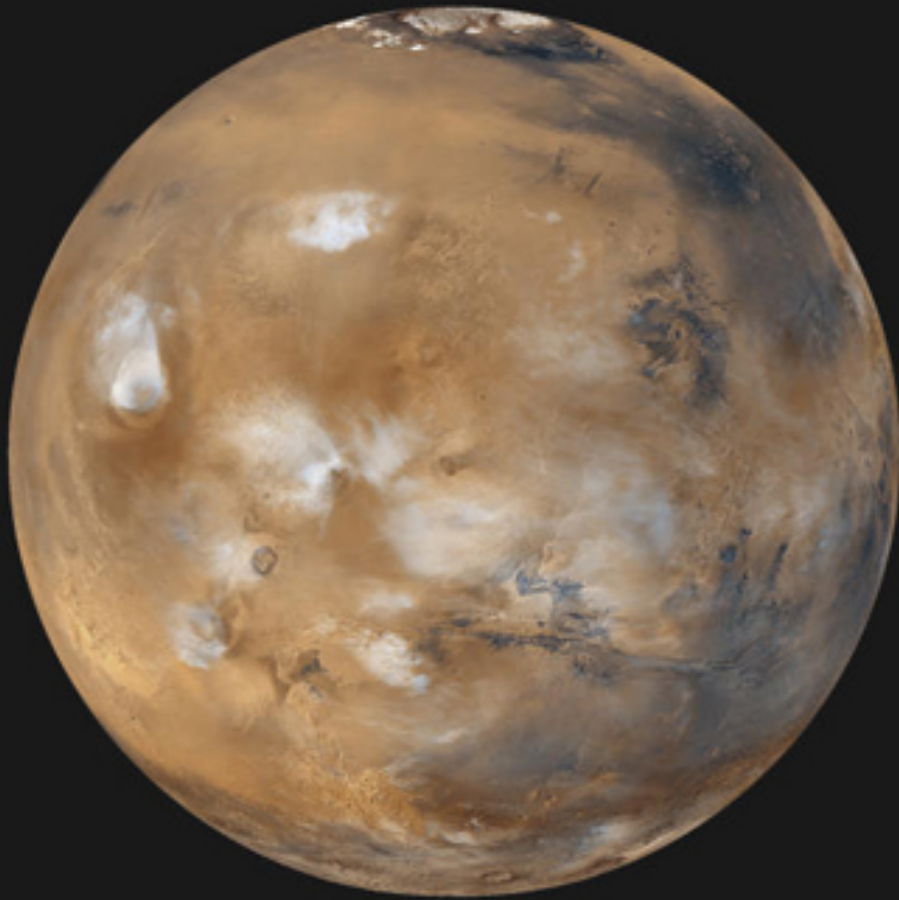




Is there life on Mars?...



Is there life on Mars?...



MARS ATTACKS!

Life on Mars?

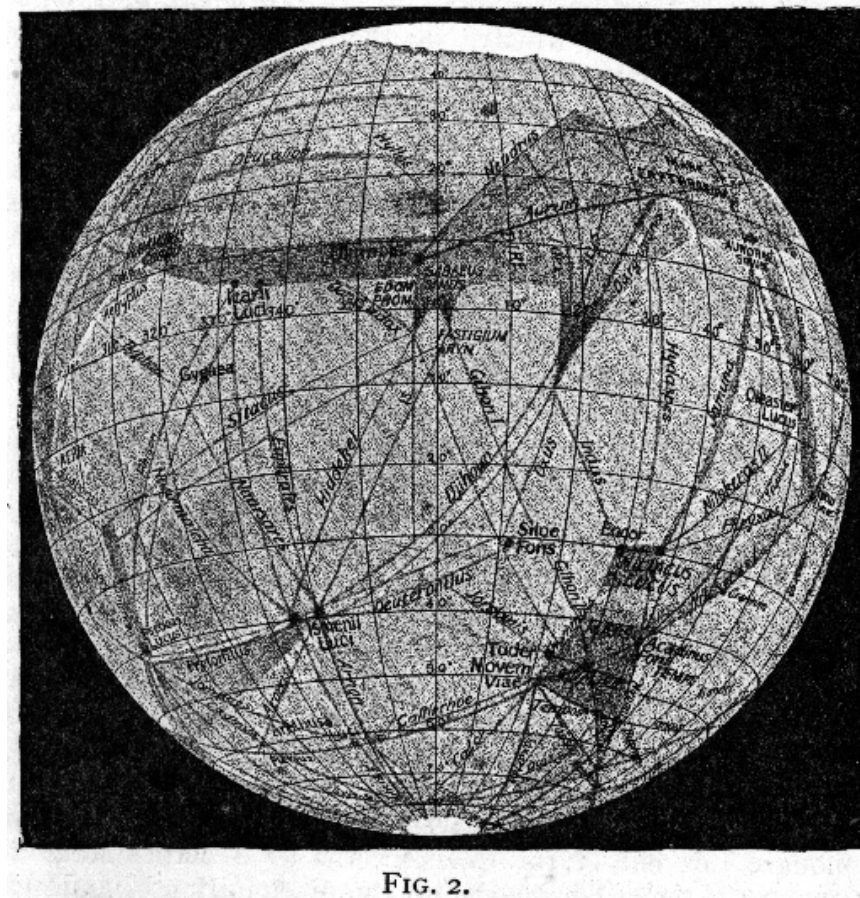
↖ The planet Mars lies tantalisingly close to the habitable zone. Could it harbour life? First look for *water*.

↖ Early observations (from the end of the 19th century) showed polar caps, whose size varies through the Martian year.



Mars from Hubble Space Telescope Mars from Global Surveyor; image NASA/JPL/MSSS

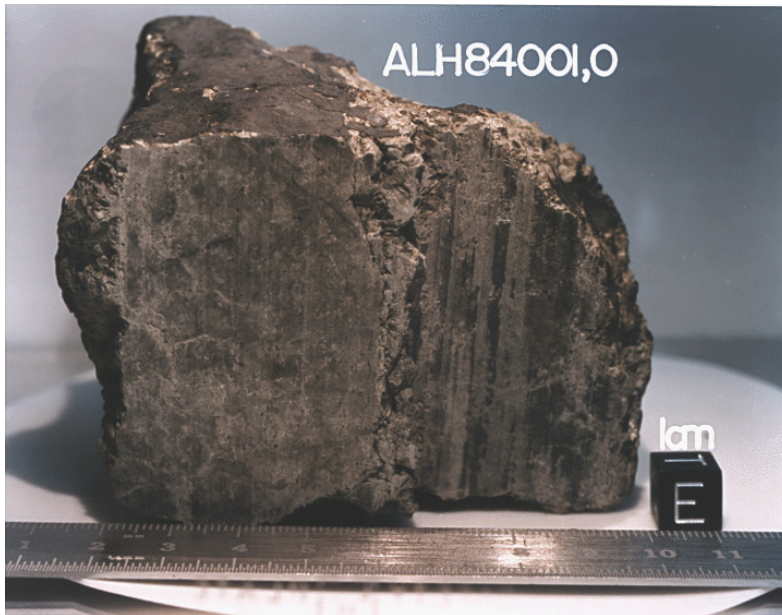
- ✚ Schiaparelli, in 1877, described channels or ‘canali’ on Mars
- ✚ Percival Lowell, a famous 19th century astronomer, claimed to have observed ‘canals’ on Mars - a claim which was later proved wrong by spacecraft observations



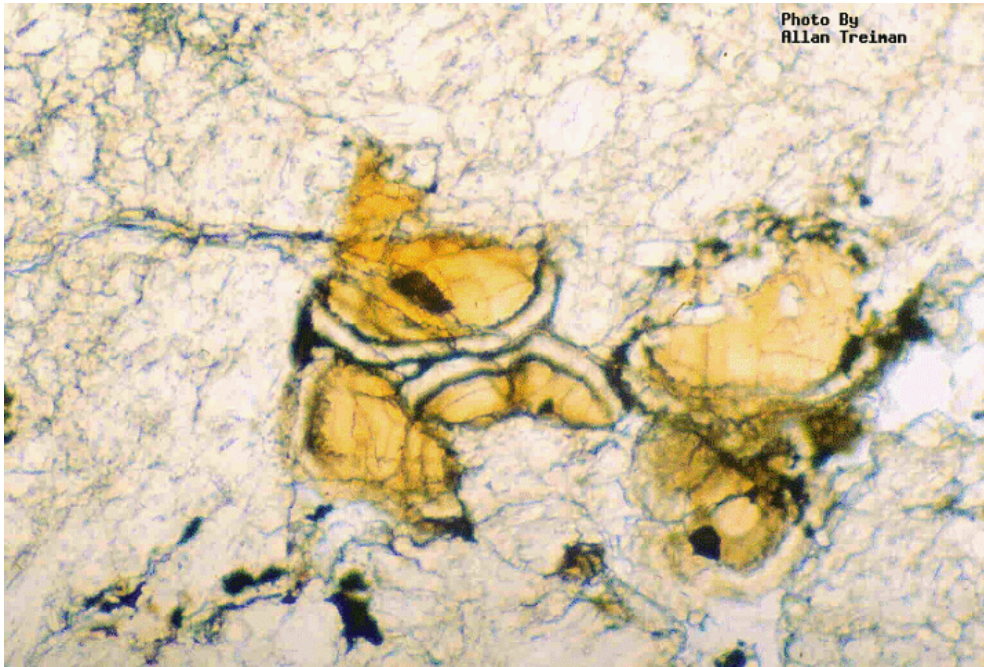
Martian Meteorites

Of the 22,000 or so meteorites that have been discovered on Earth, only 26 have been identified as originating from the planet Mars

These rare meteorites created a stir throughout the world when NASA announced in August 1996 that evidence of microfossils may be present in one of these Mars meteorites, found in Antarctica



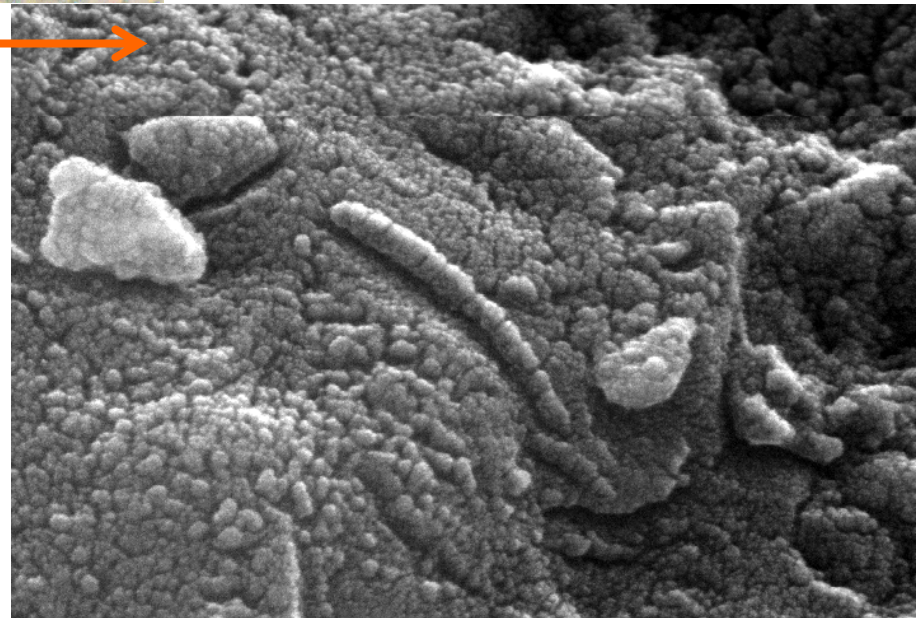
The team found unusual compounds - iron sulphides and magnetite - that can be produced by anaerobic bacteria and other organisms on Earth



The possible evidence of life in ALH 84001 was all found in and around carbonate mineral globules

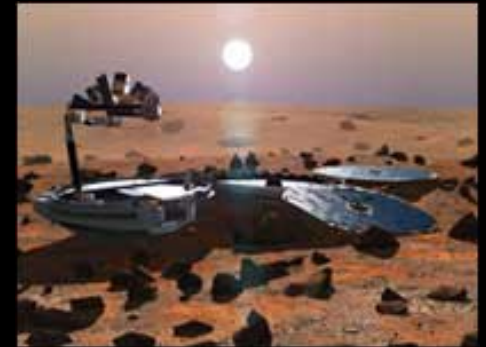
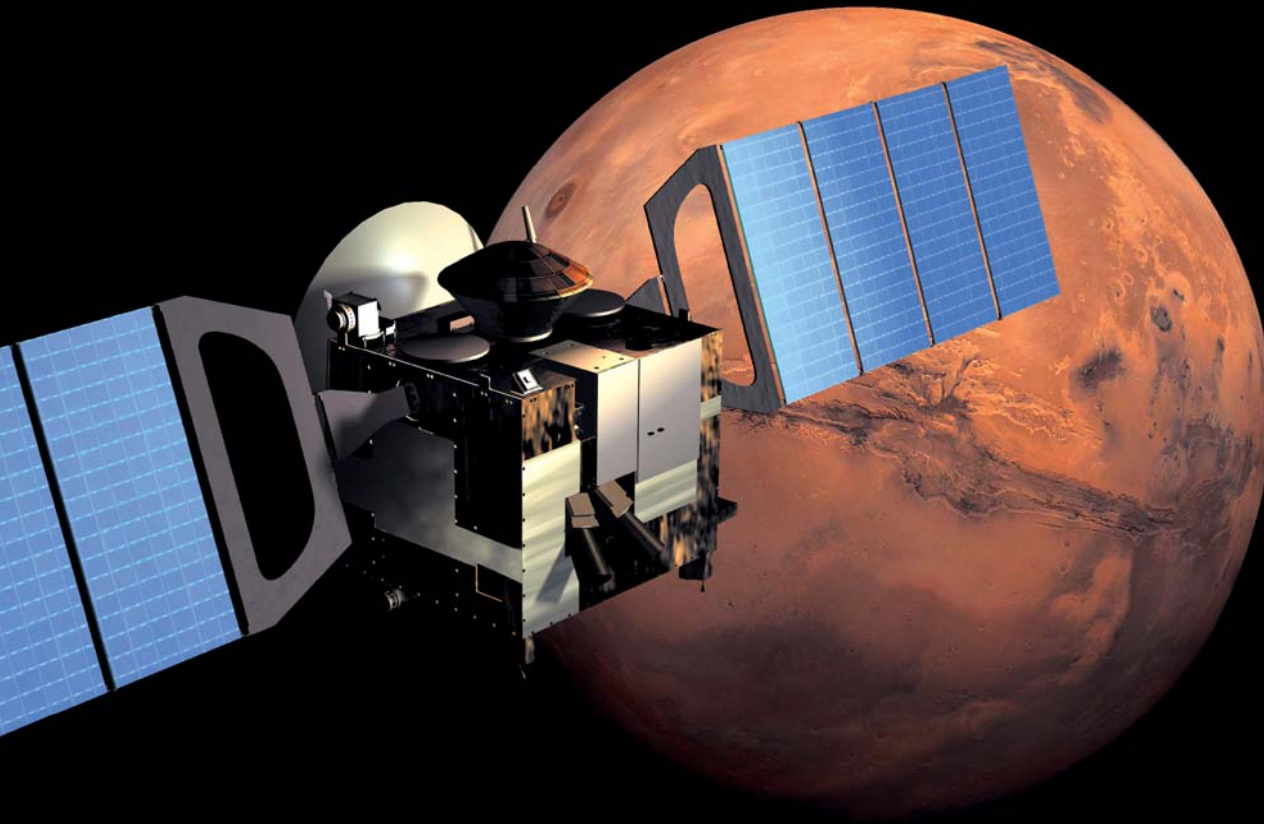
← 0.5mm →

Scanning electron microscope image, showing bacteria-like structures



Mars 2004:

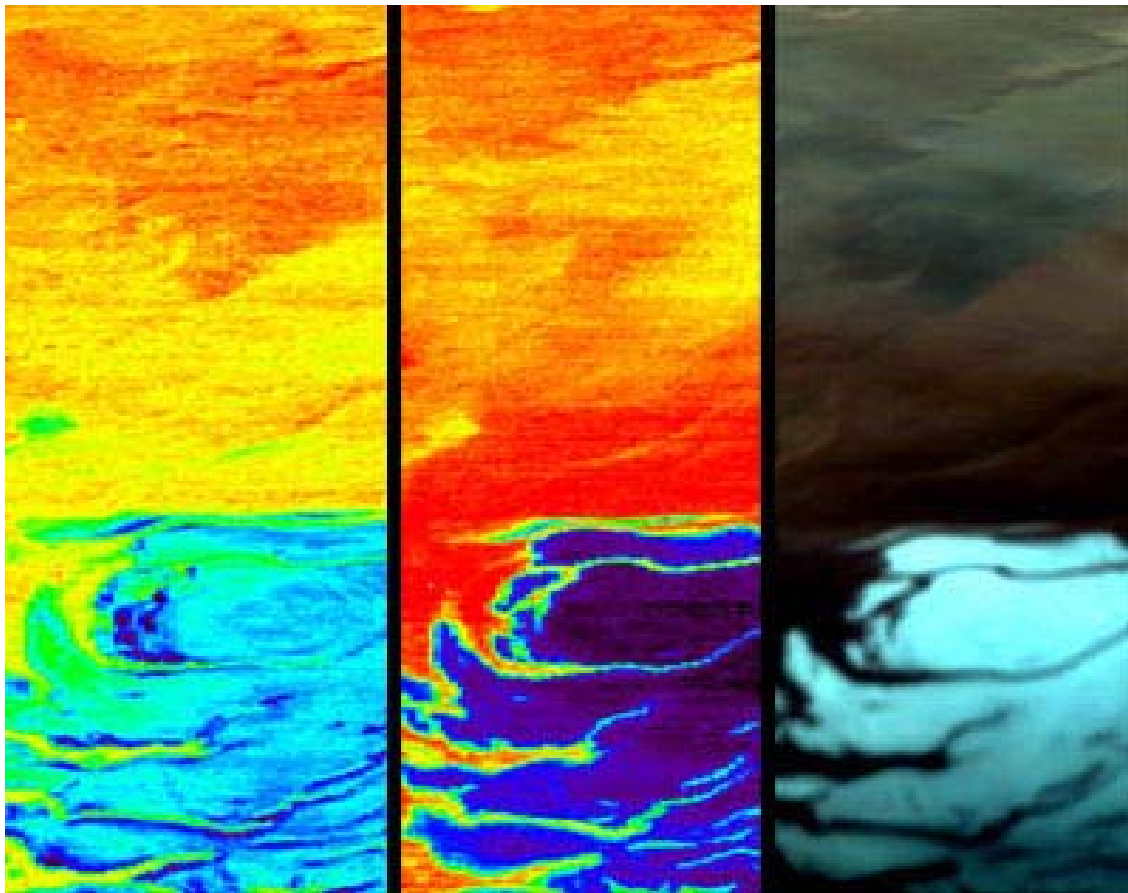
- Mars Express (+ Beagle 2)
- Spirit + Opportunity



Mars Express
Orbiter detects
water ice at the
South Pole of Mars.

Jan 23rd 2004:

Mars Express
Orbiter detects
water ice at the
South Pole of Mars.

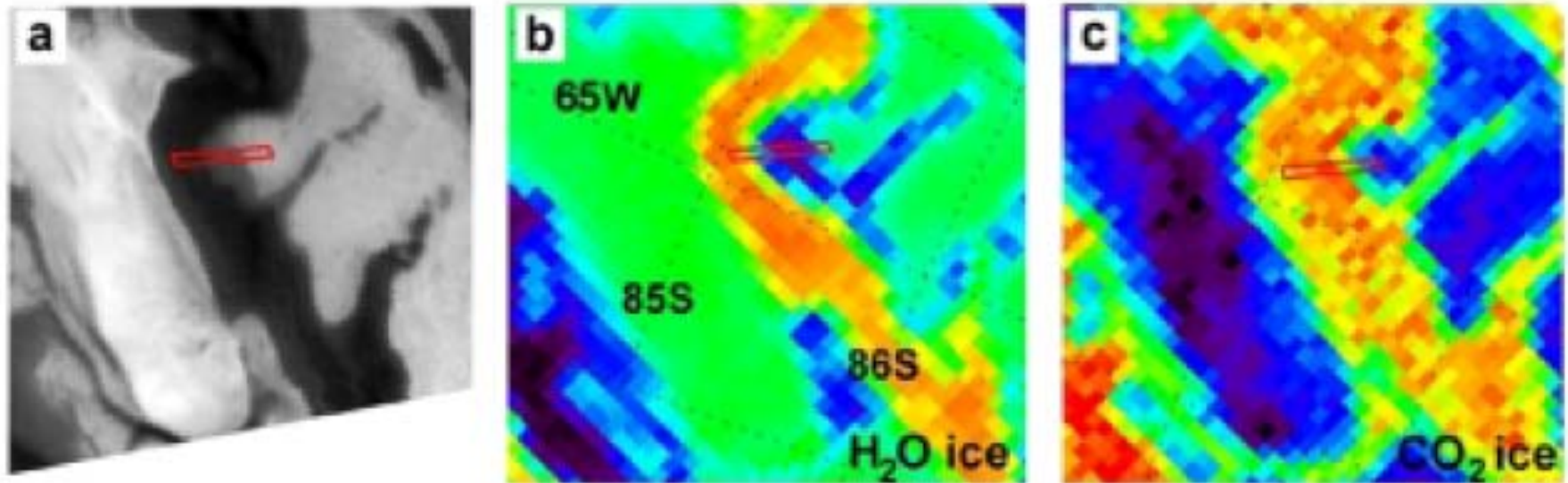


↑
H₂O

↑
CO₂

↑
Visible light

Water Ice at South Pole



Date: 31 Mar 2004

Satellite: Mars Express

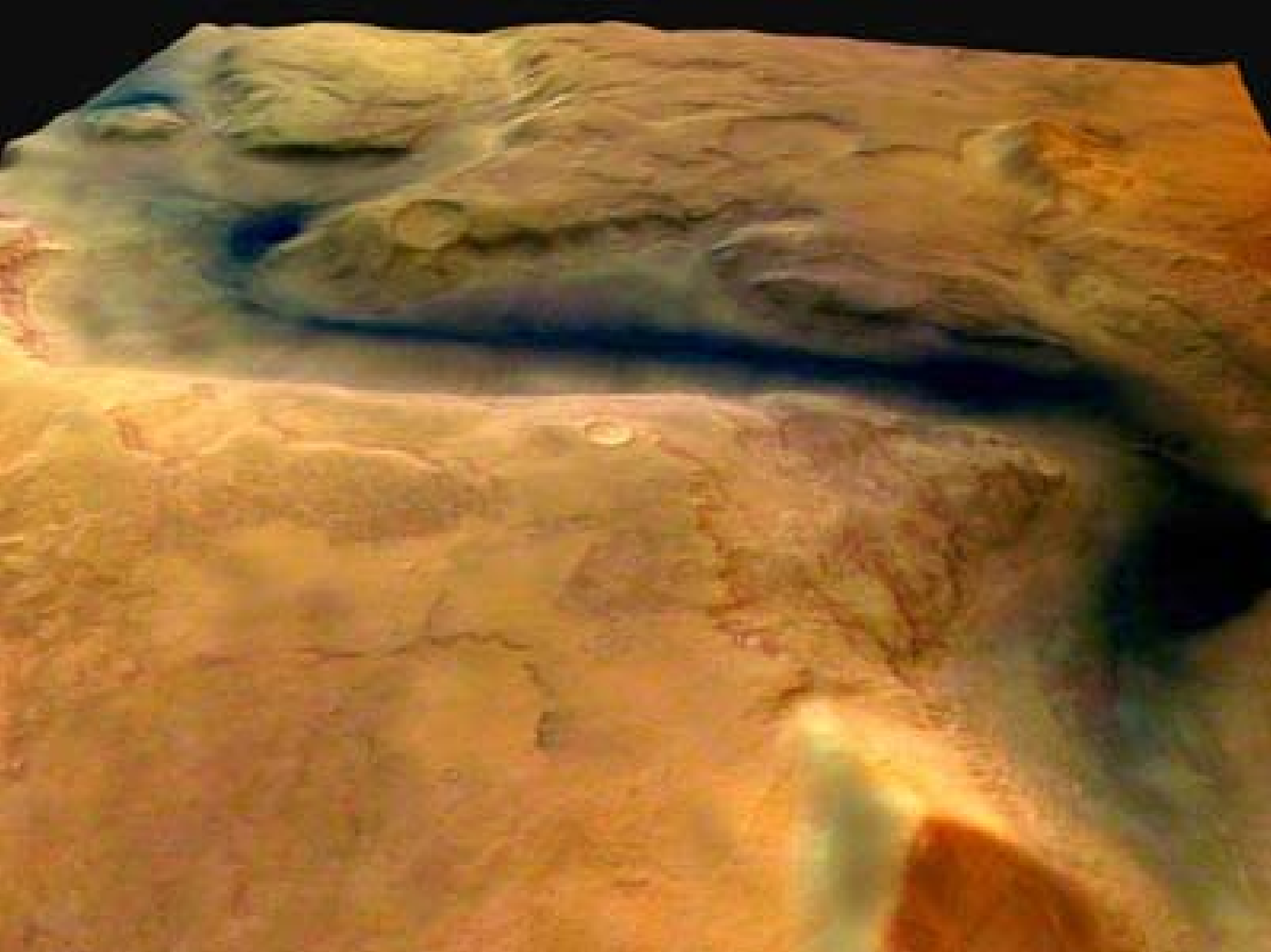
Depicts: Water Ice

Copyright: ESA/IAS

A - Image obtained by Mars Global surveyor (NASA/JPL/MSSS) highlighting the polar zone

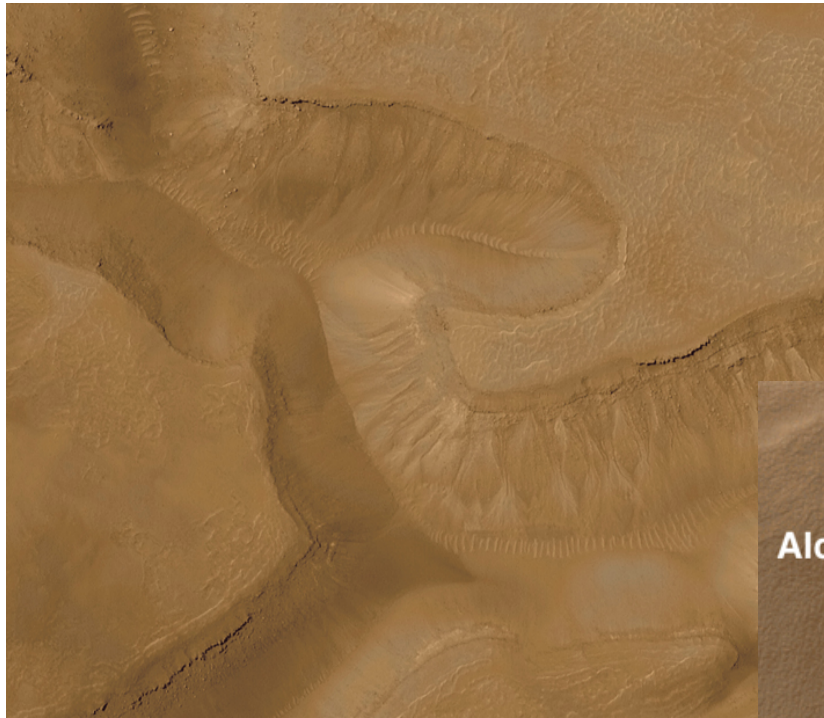
B - Chart of the same area showing the abundance of water ice identified with OMEGA

C - Even area for the CO₂ ice

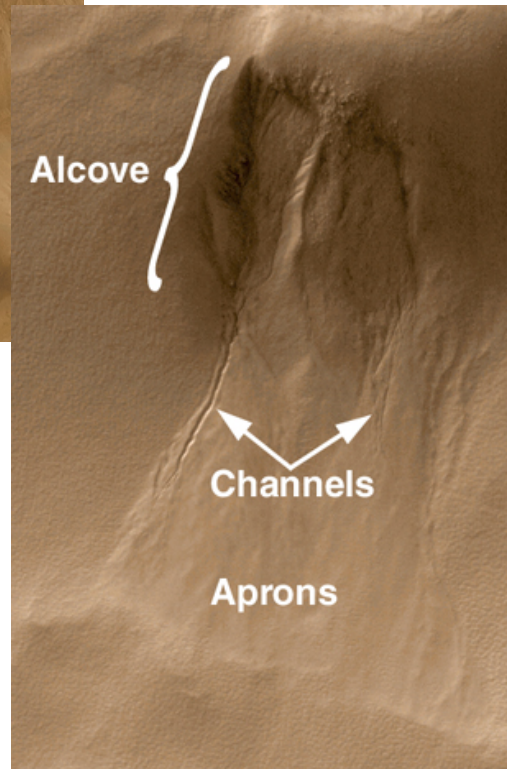


Water on Mars

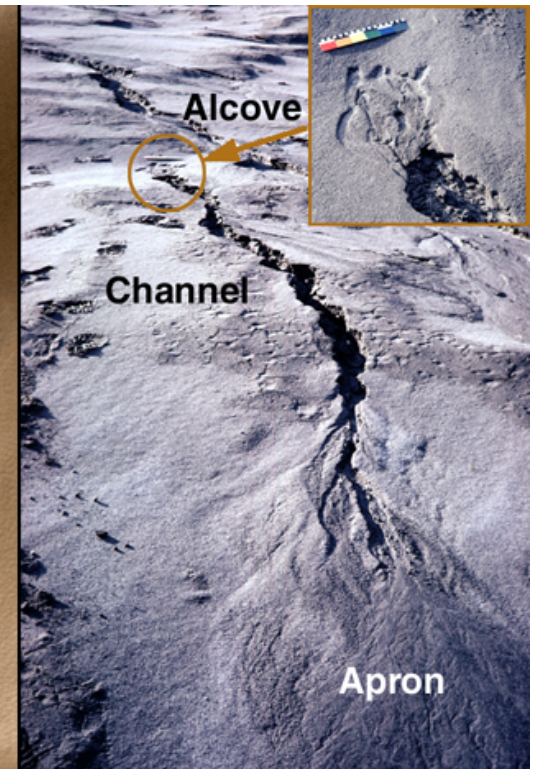
Images suggest flowing water on Mars in the past

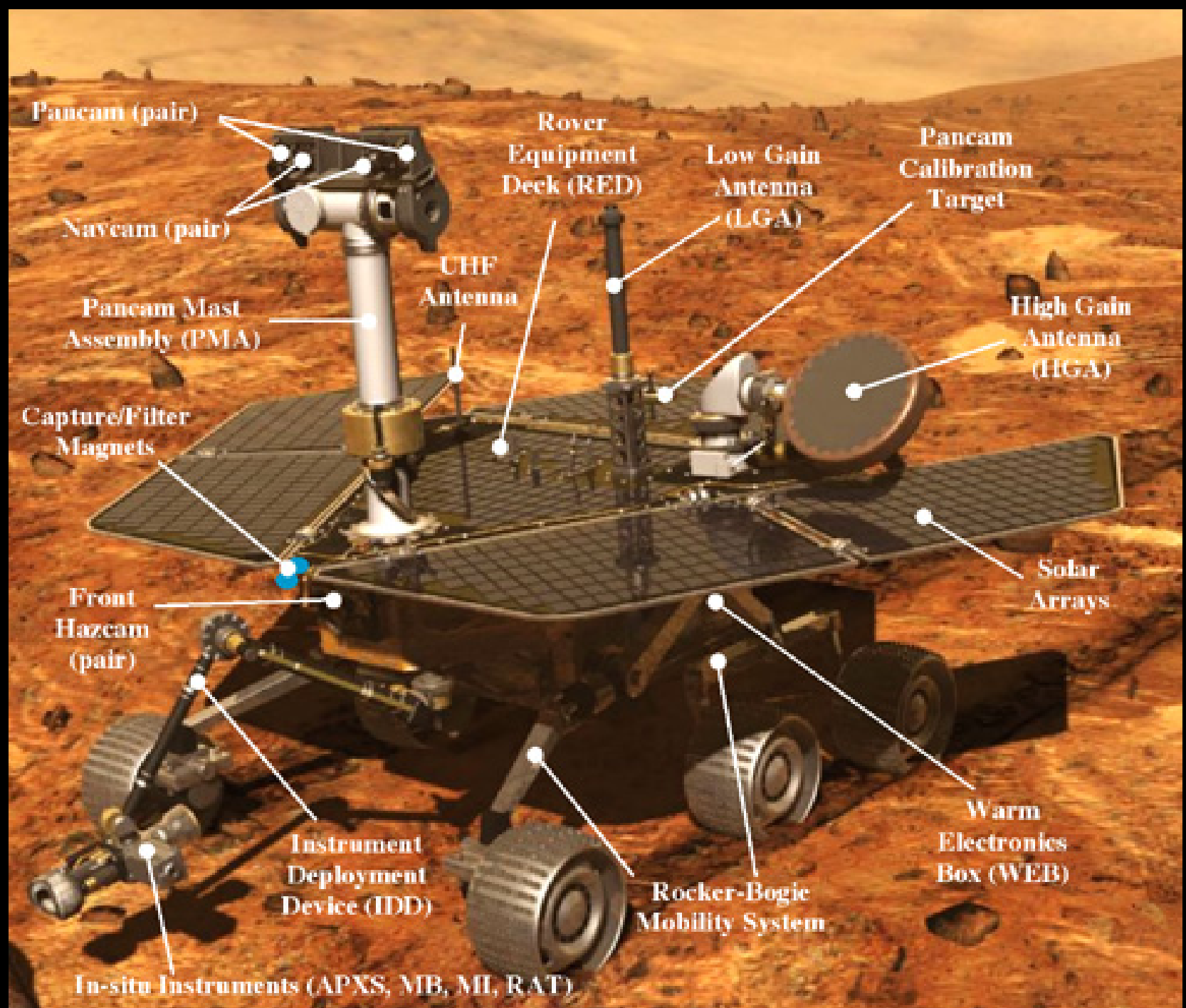


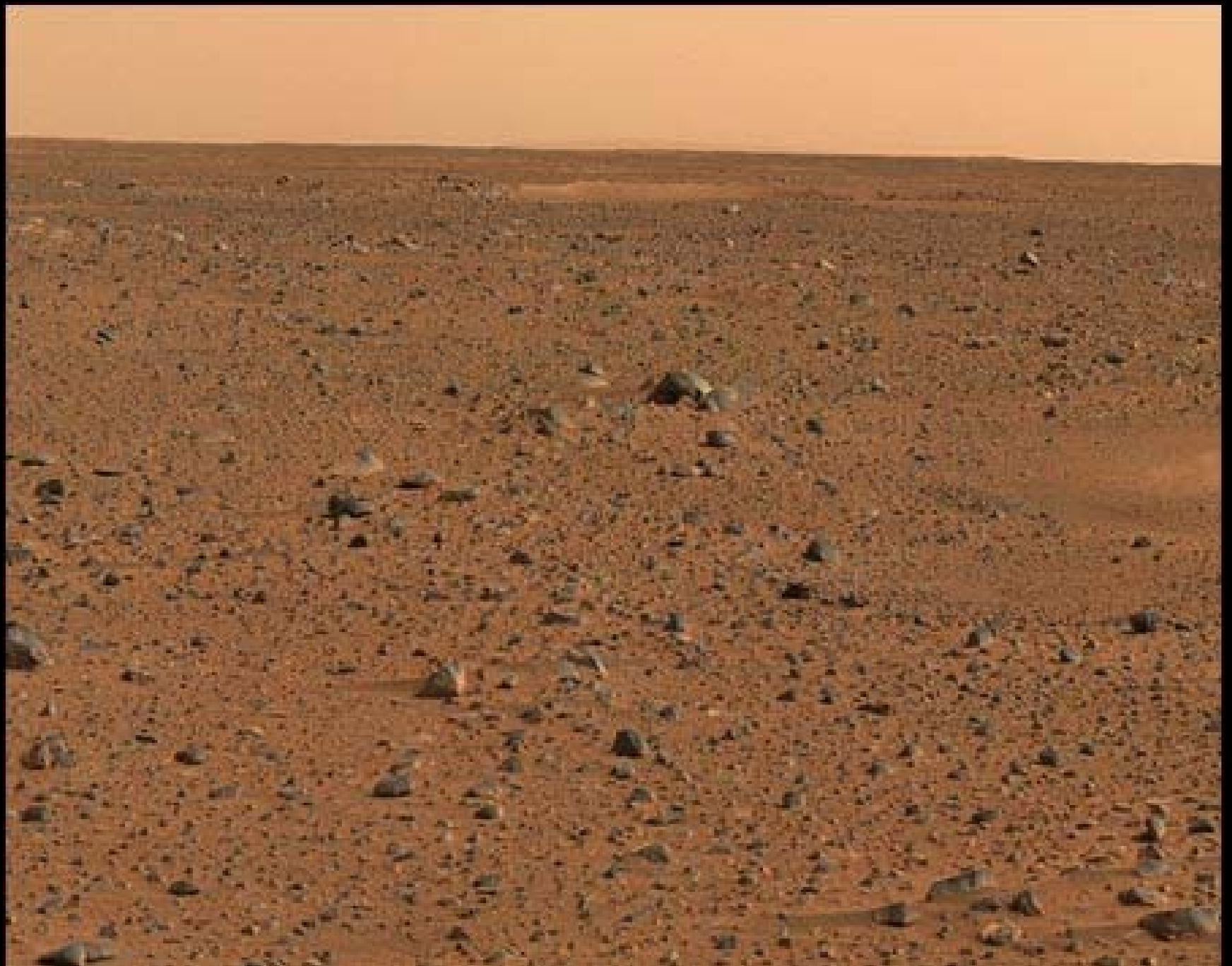
Mars



Earth









Mars Exploration Rover Mission

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+ Rovers Home

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+ SUMMARY

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+ PRESS KITS

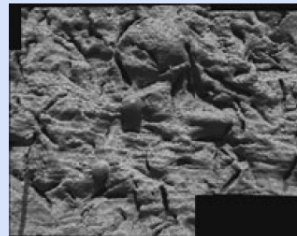
+ FACT SHEETS

+ IMAGE GALLERY

Press Releases

March 02, 2004

Opportunity Rover Finds Strong Evidence Meridiani Planum Was Wet



This image, taken by Opportunity's microscopic imager, shows a portion of the rock outcrop at Meridiani Planum, Mars, dubbed "Guadalupe."

[View Opportunity images from this press release](#)

Scientists have concluded the part of Mars that NASA's Opportunity rover is exploring was soaking wet in the past.

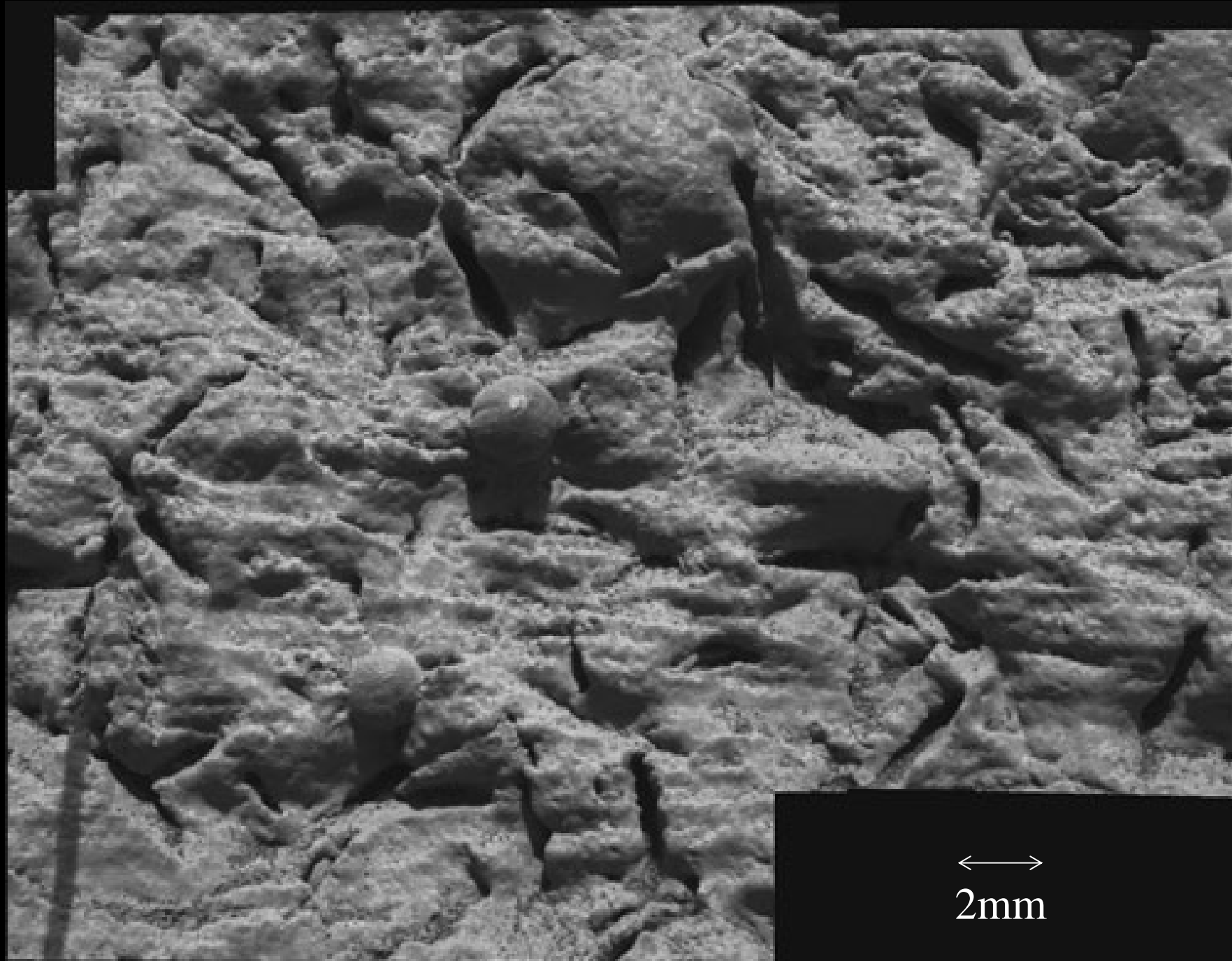
Evidence the rover found in a rock outcrop led scientists to the conclusion. Clues from the rocks' composition, such as the presence of sulfates, and the rocks' physical appearance, such as niches where crystals grew, helped make the case for a watery history.

"Liquid water once flowed through these rocks. It changed their texture, and it changed their chemistry," said Dr. Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for the science instruments on Opportunity and its twin, Spirit. "We've been able to read the tell-tale clues the water left behind, giving us confidence in that conclusion."

Dr. James Garvin, lead scientist for Mars and lunar exploration at NASA Headquarters, Washington, said, "NASA launched the Mars Exploration Rover mission specifically to check whether at least one part of Mars ever had a persistently wet environment that could possibly have been hospitable to life. Today we have strong evidence for an exciting answer: Yes."

Opportunity has more work ahead. It will try to determine whether, besides being exposed to water after they formed, the rocks may have originally been laid down by minerals precipitating out of solution at the bottom of a salty lake or sea.

The first views Opportunity sent of its landing site in Mars' Meridiani Planum region five weeks ago delighted researchers at NASA's Jet Propulsion Laboratory, Pasadena, Calif., because of the good fortune to have the spacecraft arrive next to an exposed slice of bedrock on the inner slope of a small crater.





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Press Releases

March 05, 2004

Volcanic Rock in Mars' Gusev Crater Hints at Past Water



This image shows a hole drilled by Spirit in the rock dubbed "Humphrey."

[View Spirit images from this press release](#)

[View Opportunity images from this press release](#)

NASA's Spirit has found hints of a water history in a rock at Mars' Gusev Crater, but it is a very different type of rock than those in which NASA's Opportunity found clues to a wet past on the opposite side of the planet.

A dark volcanic rock dubbed "Humphrey," about 60 centimeters (2 feet) tall, shows bright material in interior crevices and cracks that looks like minerals crystallized out of water, Dr. Ray Arvidson of Washington University, St. Louis, reported at a NASA news briefing today at NASA's Jet Propulsion Laboratory, Pasadena, Calif. He is the deputy principal investigator for the rovers' science instruments.

"If we found this rock on Earth, we would say it is a volcanic rock that had a little fluid moving through it," Arvidson said. If this interpretation is correct, the fluid -- water with minerals dissolved in it -- may have been carried in the original magma that formed the rock or may have

interacted with the rock later, he said.

The clues appear in an interior exposure of "Humphrey" where Spirit's rock abrasion tool scraped away the rock's surface to a depth of 2 millimeters (.08 inch). To gain more confidence that the bright material seen in cracks and pores is not dust that has intruded from the surface over the millenia, scientists intend to have Spirit grind more deeply into another dark rock, not yet selected. The bright material is not debris from the grinding process, said Stephen Gorevan of Honeybee Robotics, New York, lead scientist for the abrasion tool.

The amount of water suggested by the possible crystals in "Humphrey" is far less than what is indicated by the minerals and structures that Opportunity has revealed in rocks at Meridiani. Rover scientists announced the Opportunity findings earlier this week.







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Press Releases

March 23, 2004

Standing Body of Water Left Its Mark in Mars Rocks

NASA's Opportunity rover has demonstrated some rocks on Mars probably formed as deposits at the bottom of a body of gently flowing saltwater.

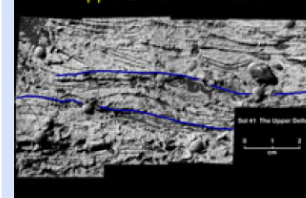
"We think Opportunity is parked on what was once the shoreline of a salty sea on Mars," said Dr. Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for the science payload on Opportunity and its twin Mars Exploration Rover, Spirit.

Clues gathered so far do not tell how long or how long ago liquid water covered the area. To gather more evidence, the rover's controllers plan to send Opportunity out across a plain toward a thicker exposure of rocks in the wall of a crater.

NASA's Associate Administrator for Space Science Dr. Ed Weiler said, "This dramatic confirmation of standing water in Mars' history builds on a progression of discoveries about that most Earthlike of alien planets. This result gives us impetus to expand our ambitious program of exploring Mars to learn whether microbes have ever lived there and, ultimately, whether we can."

"Bedding patterns in some finely layered rocks indicate the sand-sized grains of sediment that eventually bonded together were shaped into ripples by water at least five centimeters (two inches) deep, possibly much deeper, and flowing at a speed of 10 to 50 centimeters (four to 20 inches) per second," said Dr. John Grotzinger, rover science-team member from the Massachusetts Institute of Technology, Cambridge, Mass.

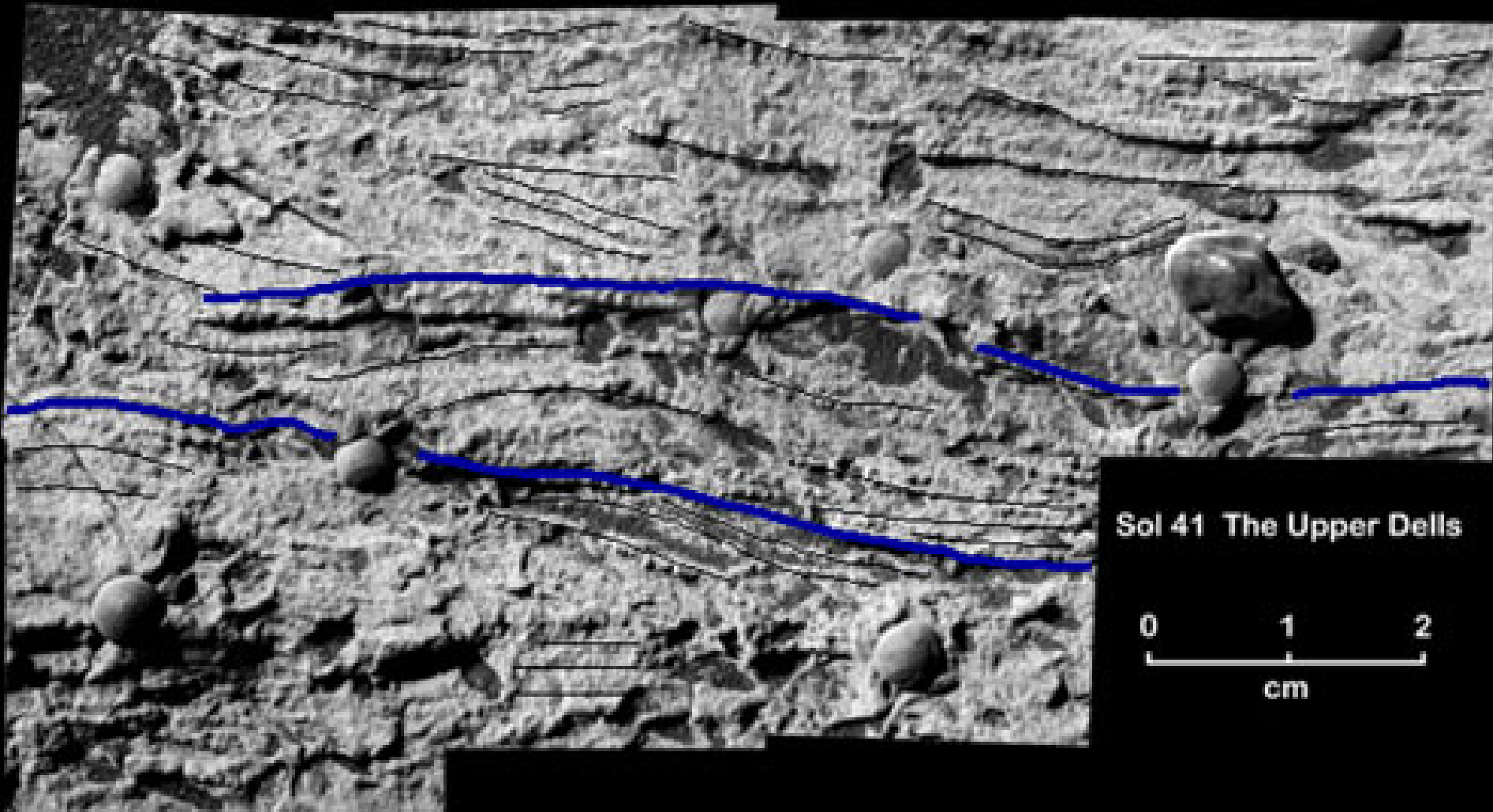
Upper Dells MI Mosaic

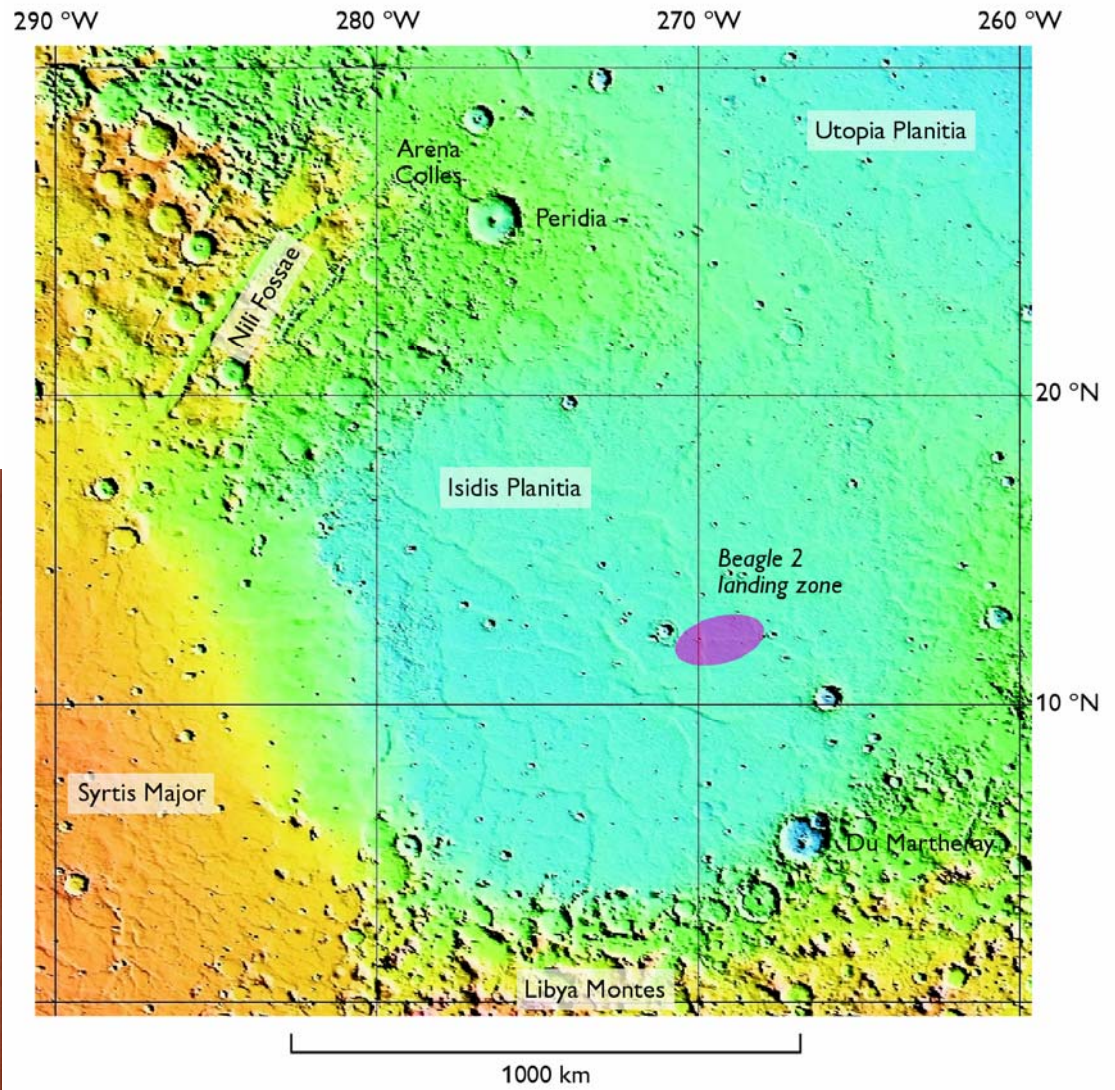
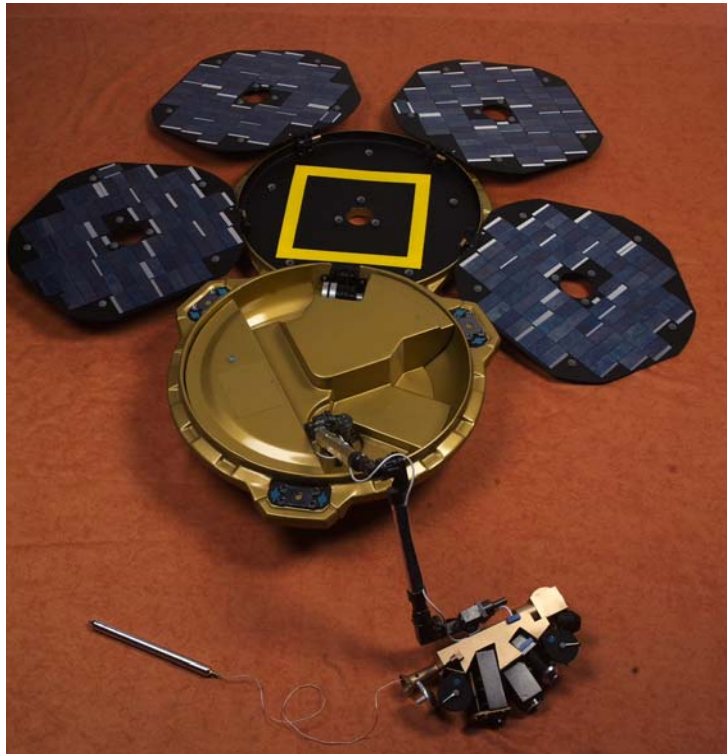
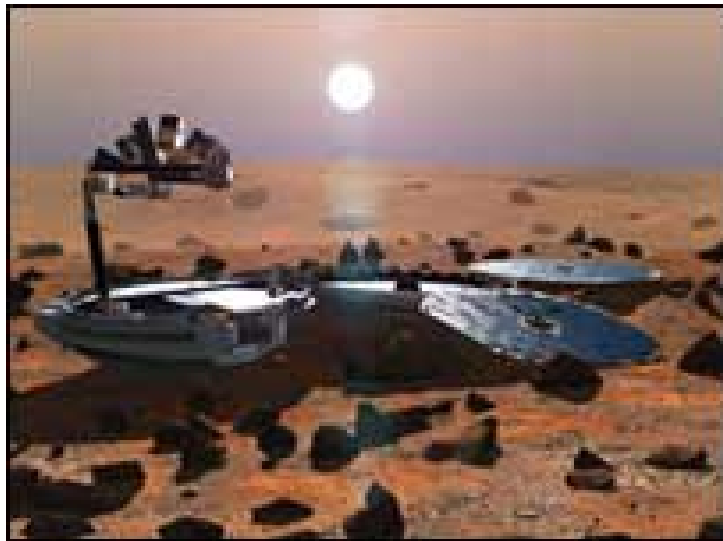


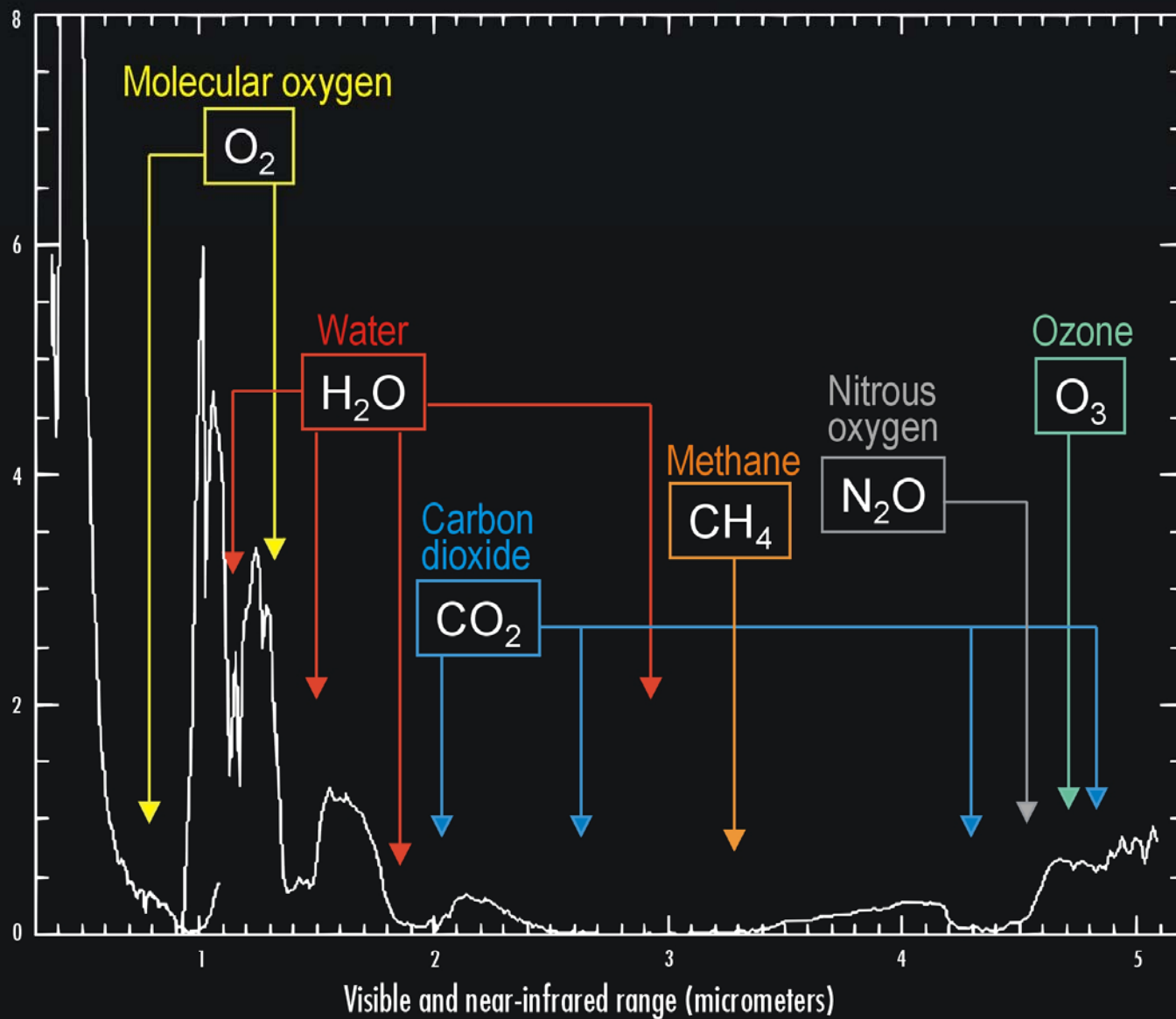
This magnified view from Opportunity of a portion of a martian rock called "Upper Dells" shows fine layers (laminae) that are truncated, discordant and at angles to each other. Interpretive black lines trace cross-lamination that indicates the sediments that formed the rock were laid down in flowing water. The interpretive blue lines point to boundaries between possible sets of cross-laminae.

[View Opportunity images from this press release](#)

Upper Dells MI Mosaic







Composition of the Earth by the Mars Express OMEGA Spectrometer
3 July, 2003

Detecting signs of life on other planets

- ✚ Many space exploration missions have been launched, with a main goal being to look for signs of life on other planets in the solar system
- ✚ One obvious question to ask - *if one such mission flew past Earth, would it detect signs of life here?*



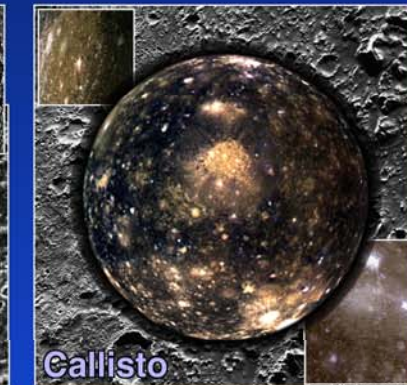
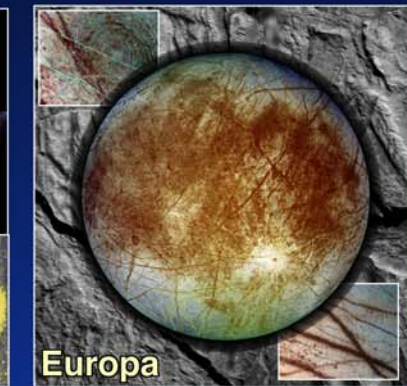
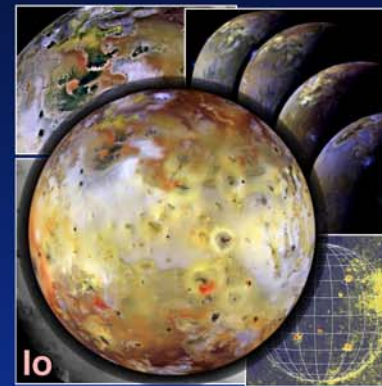
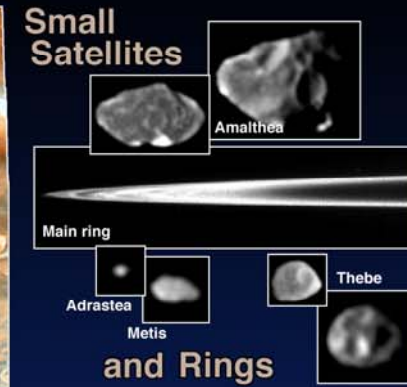
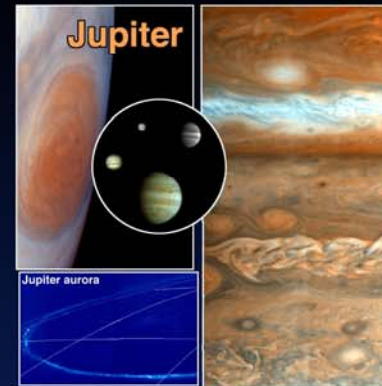
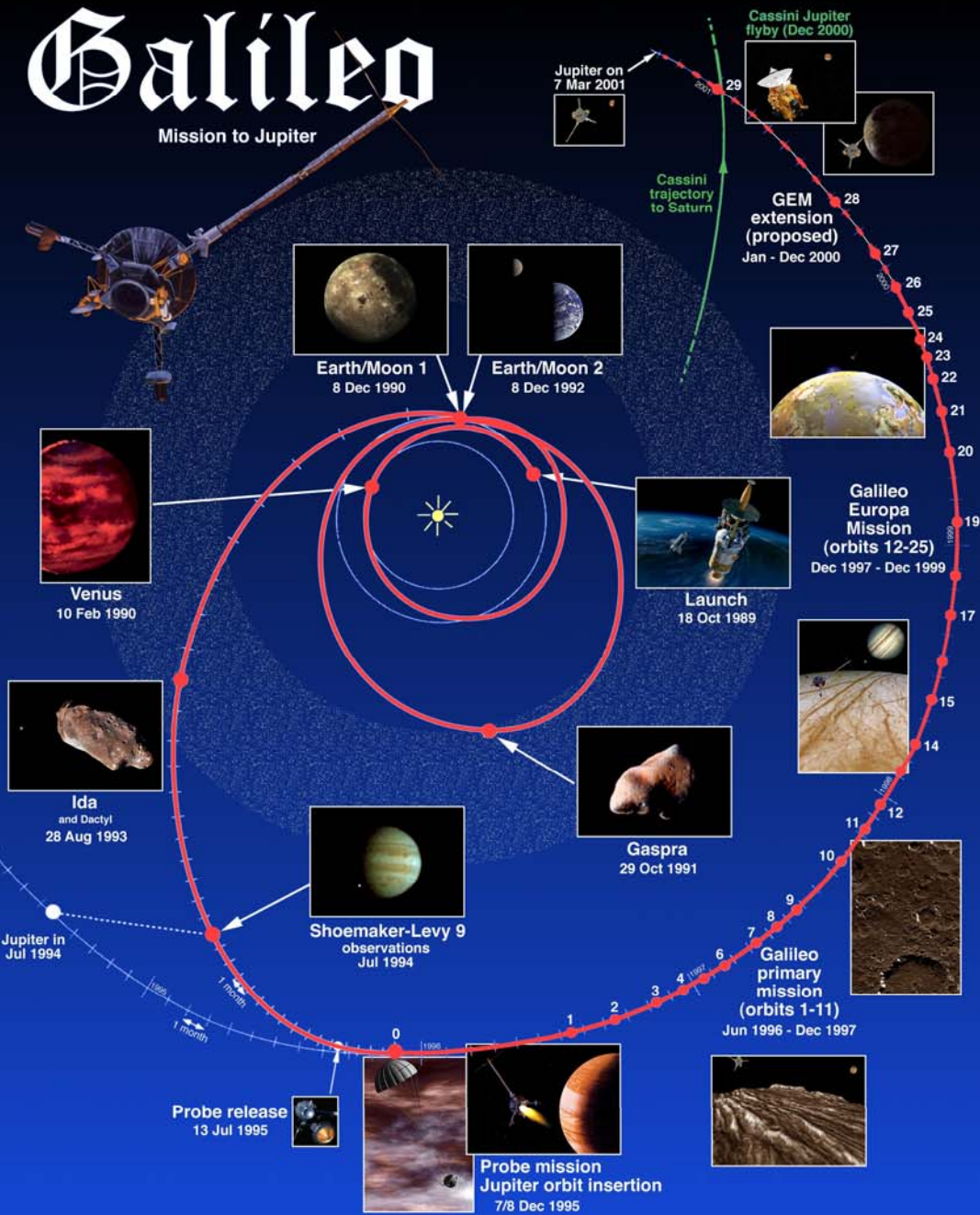
✚ This question was answered by the *Galileo mission* to Jupiter. On its way to Jupiter it also recorded data from Earth

✚ Earth flyby was at a distance of 960km, on 8th December 1990

✚ The instruments analysed Earth as if it were an unknown planet

Galileo

Mission to Jupiter



Results of Galileo flyby of Earth

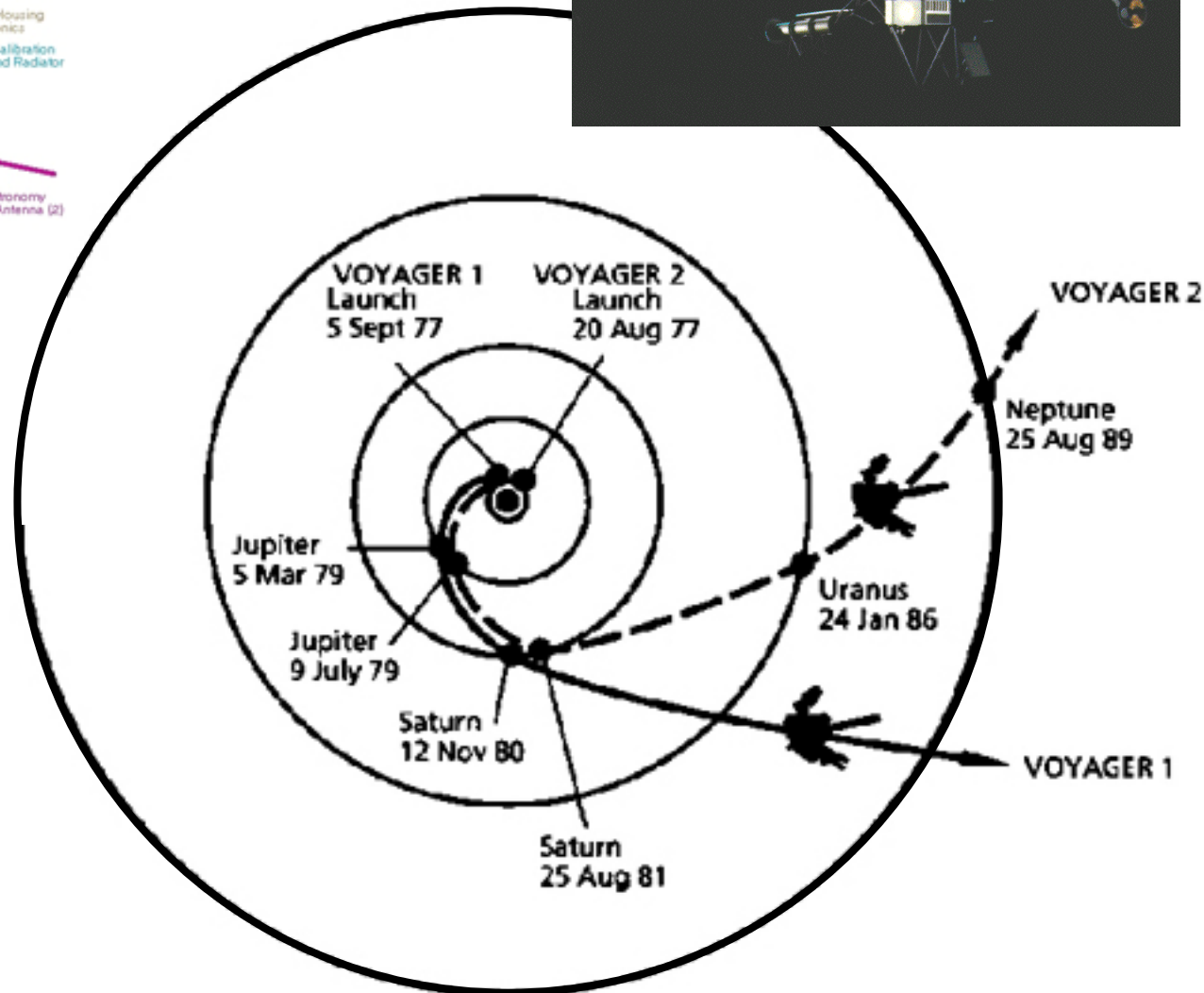
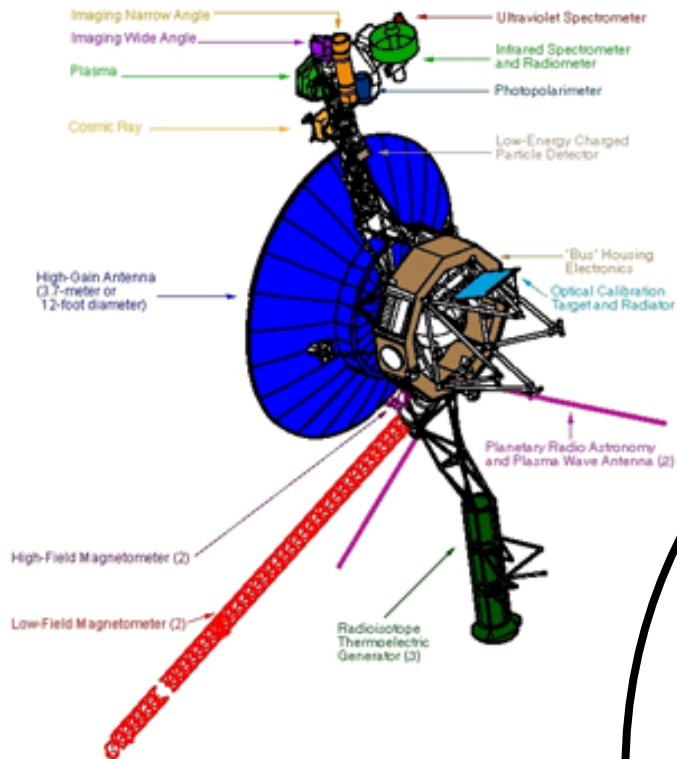
- ↖ Infrared images suggested large pools of water. Temperature measurements showed that this was liquid, not ice
- ↖ Large oxygen content found in atmosphere. Dissociation of water by sunlight not enough to explain this → biological action
- ↖ Large concentration of methane gas (CH_4), also suggesting biological activity
- ↖ Non- 'natural' radio emissions, best evidence of *intelligent life*

None of these signatures were seen from any other planetary flyby

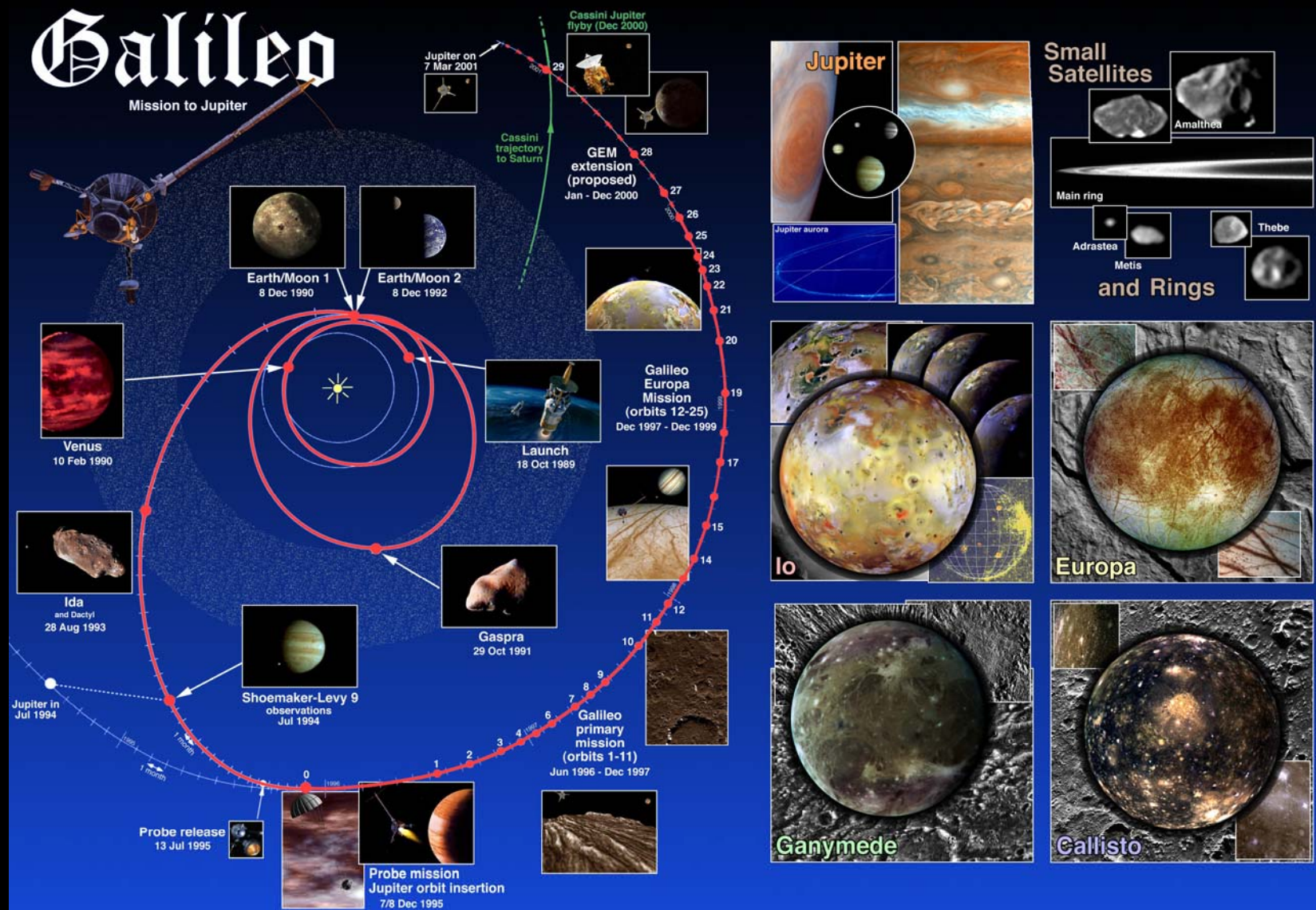
The moons of Jupiter



Voyagers 1 & 2

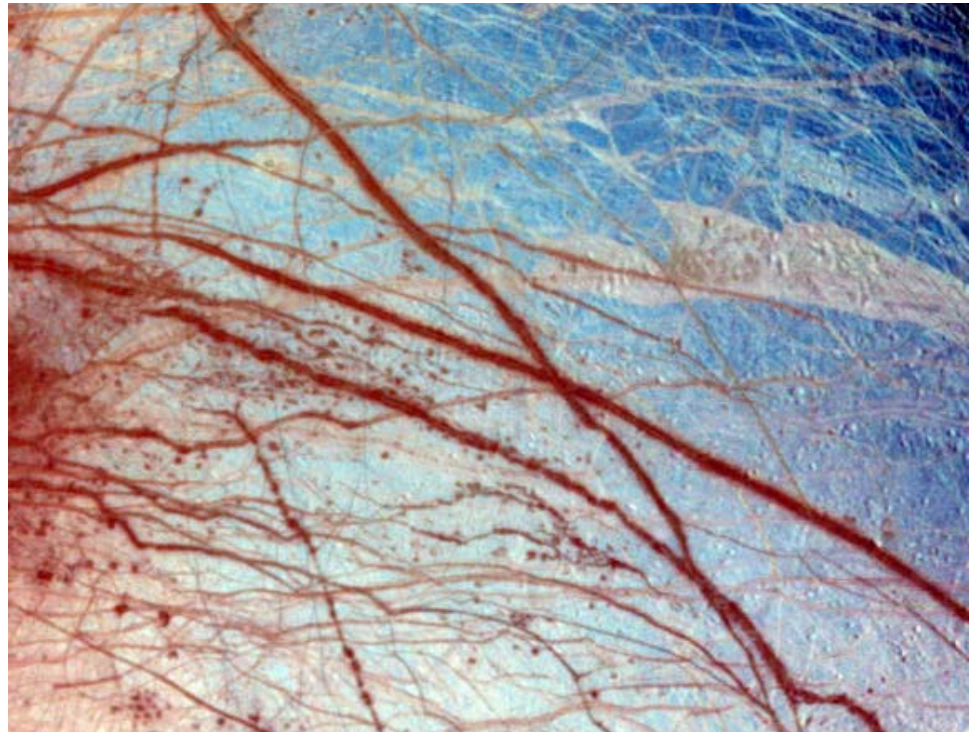
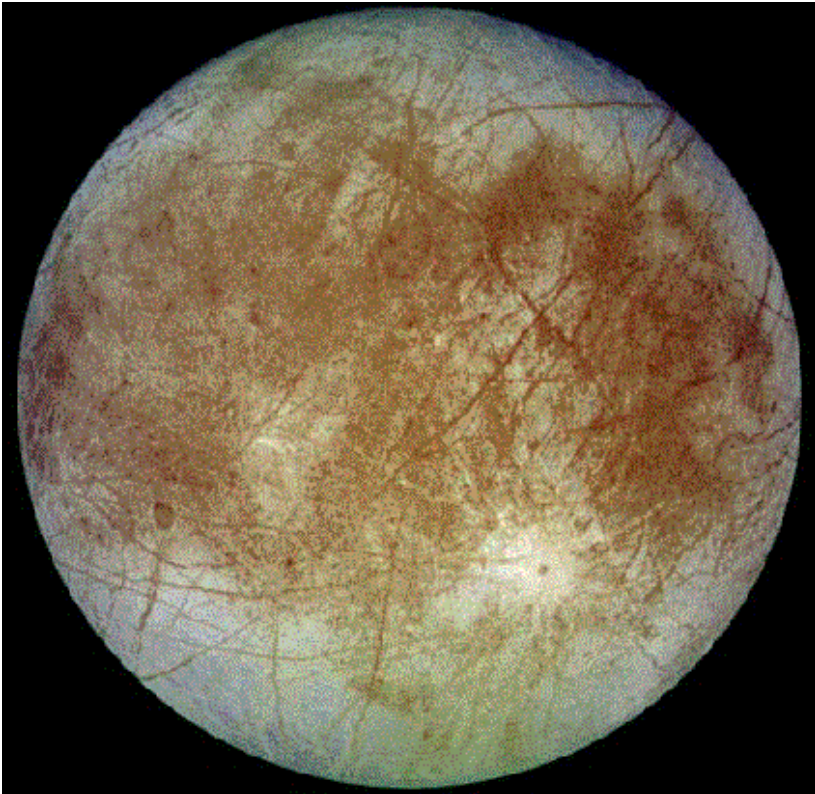


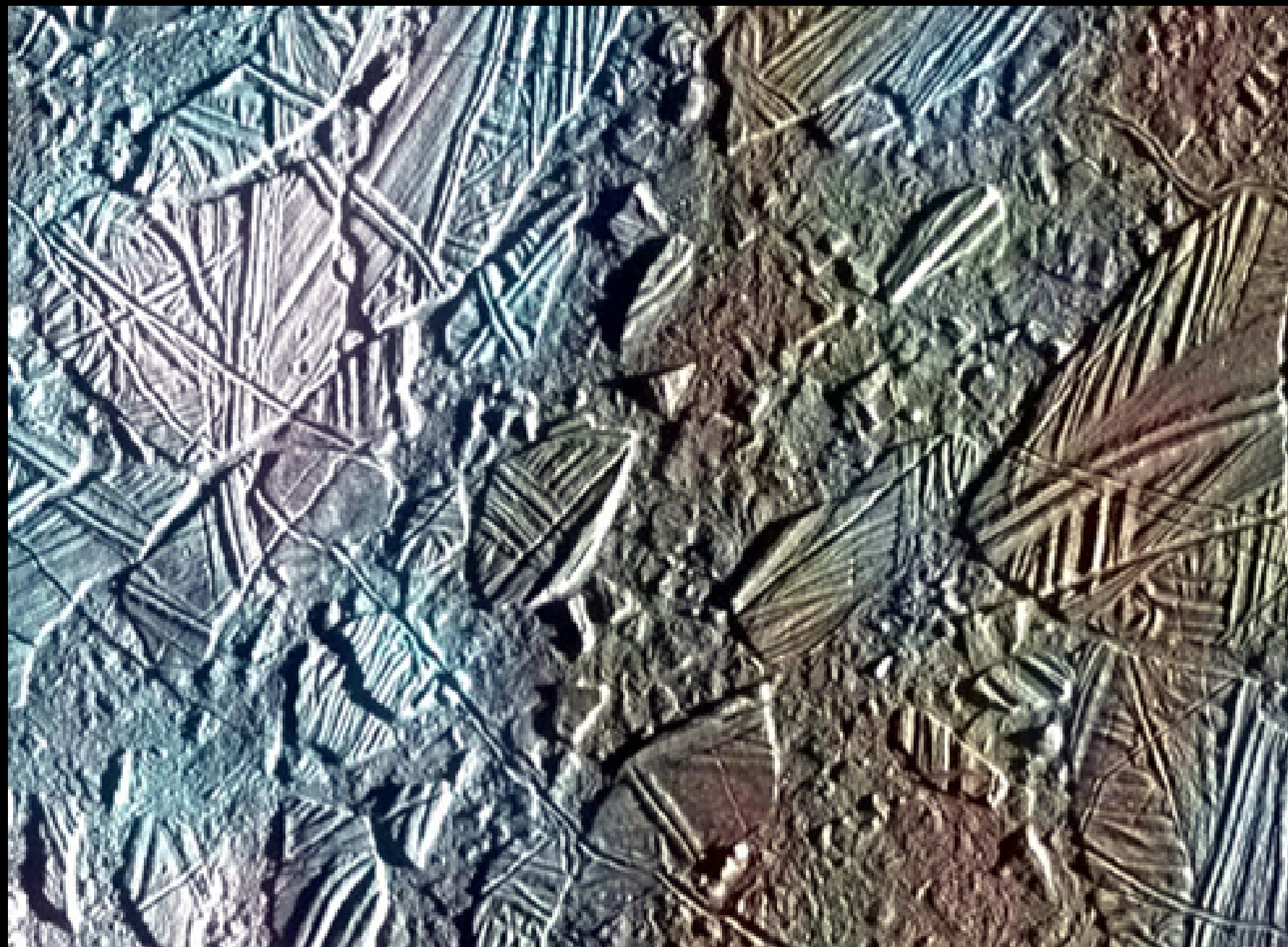
The moons of Jupiter

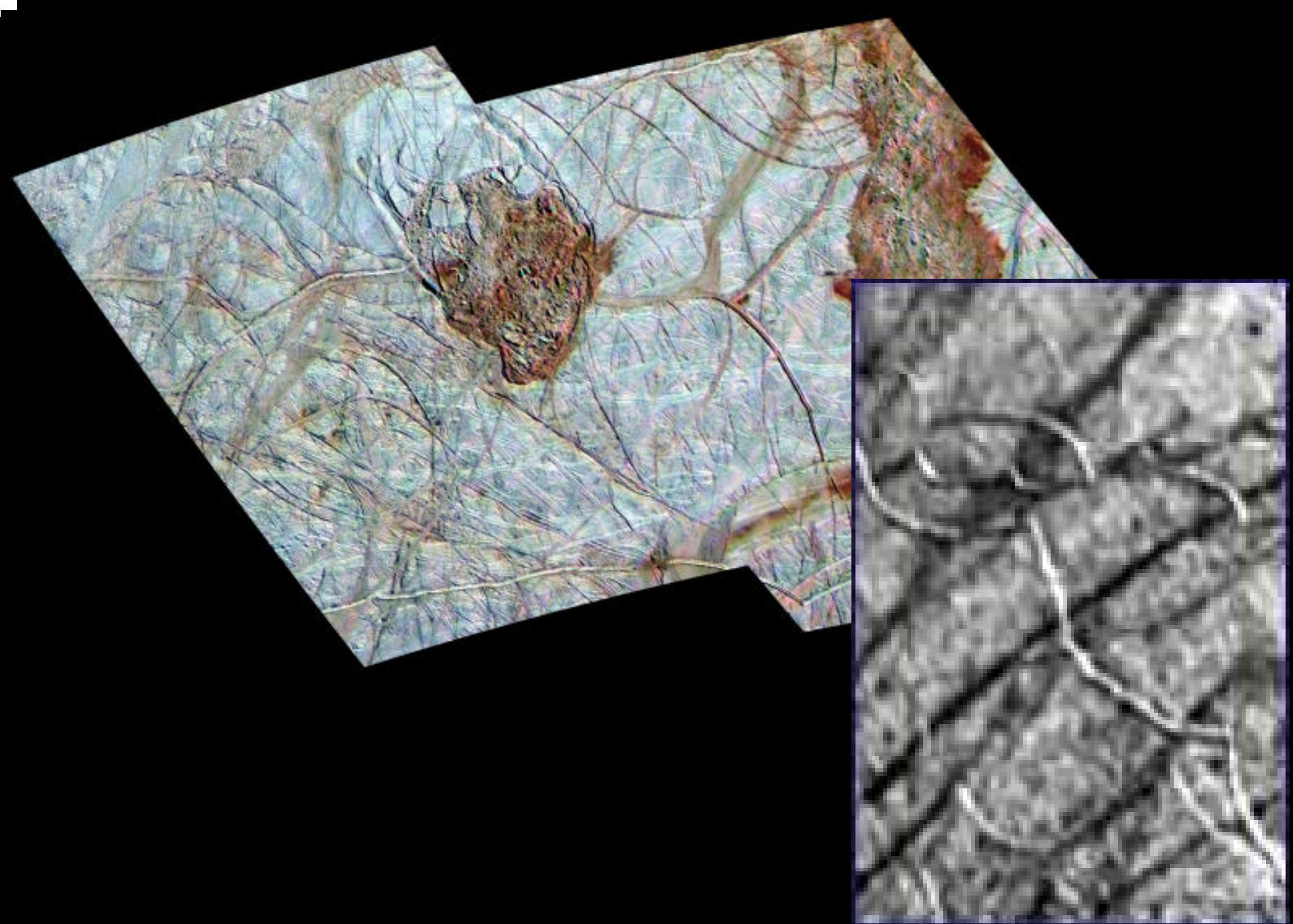


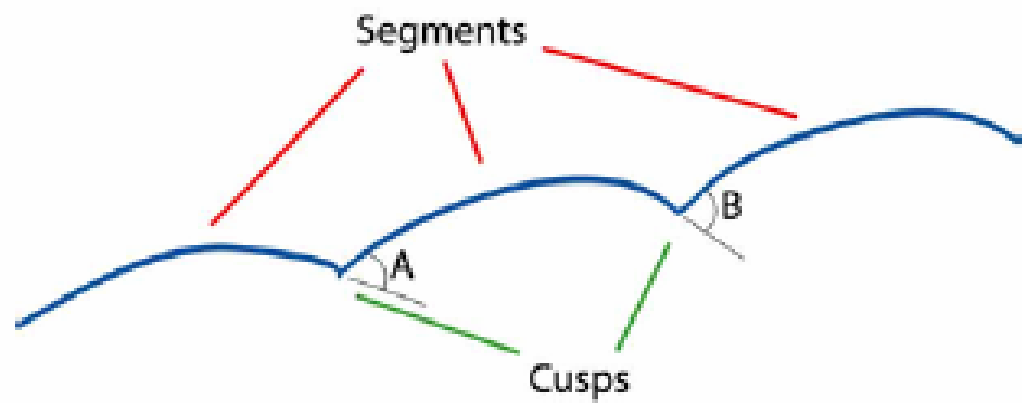
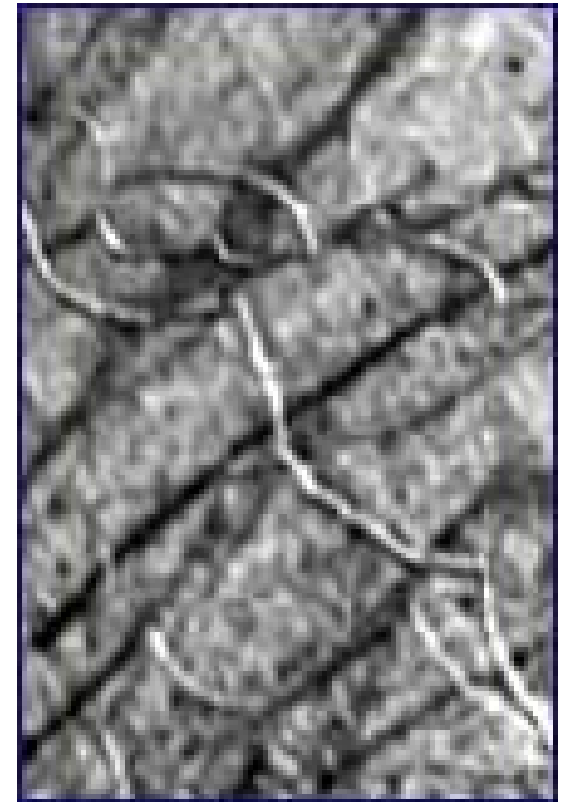
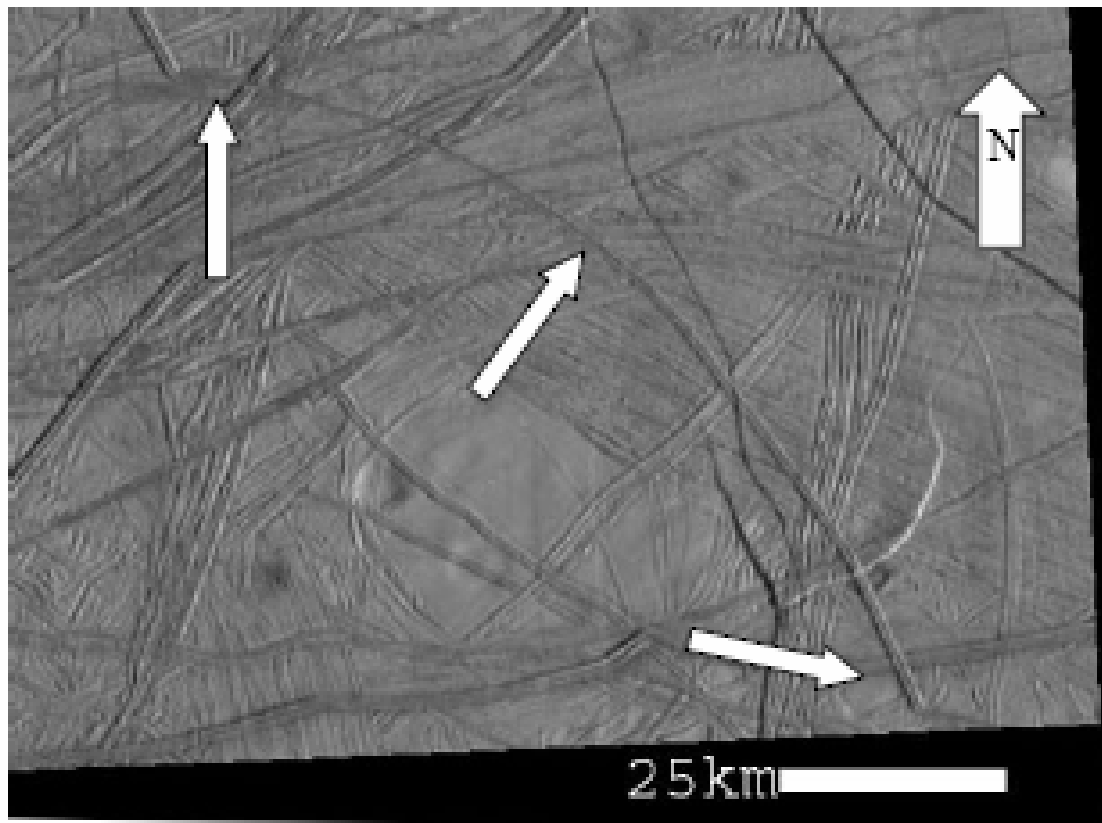
Tidal forces have a major influence on Europa

- The icy crust of the moon is covered in 'cracks' due to tidal stresses, and beneath the crust it is believed that frictional heating may result in a thin **ocean layer**

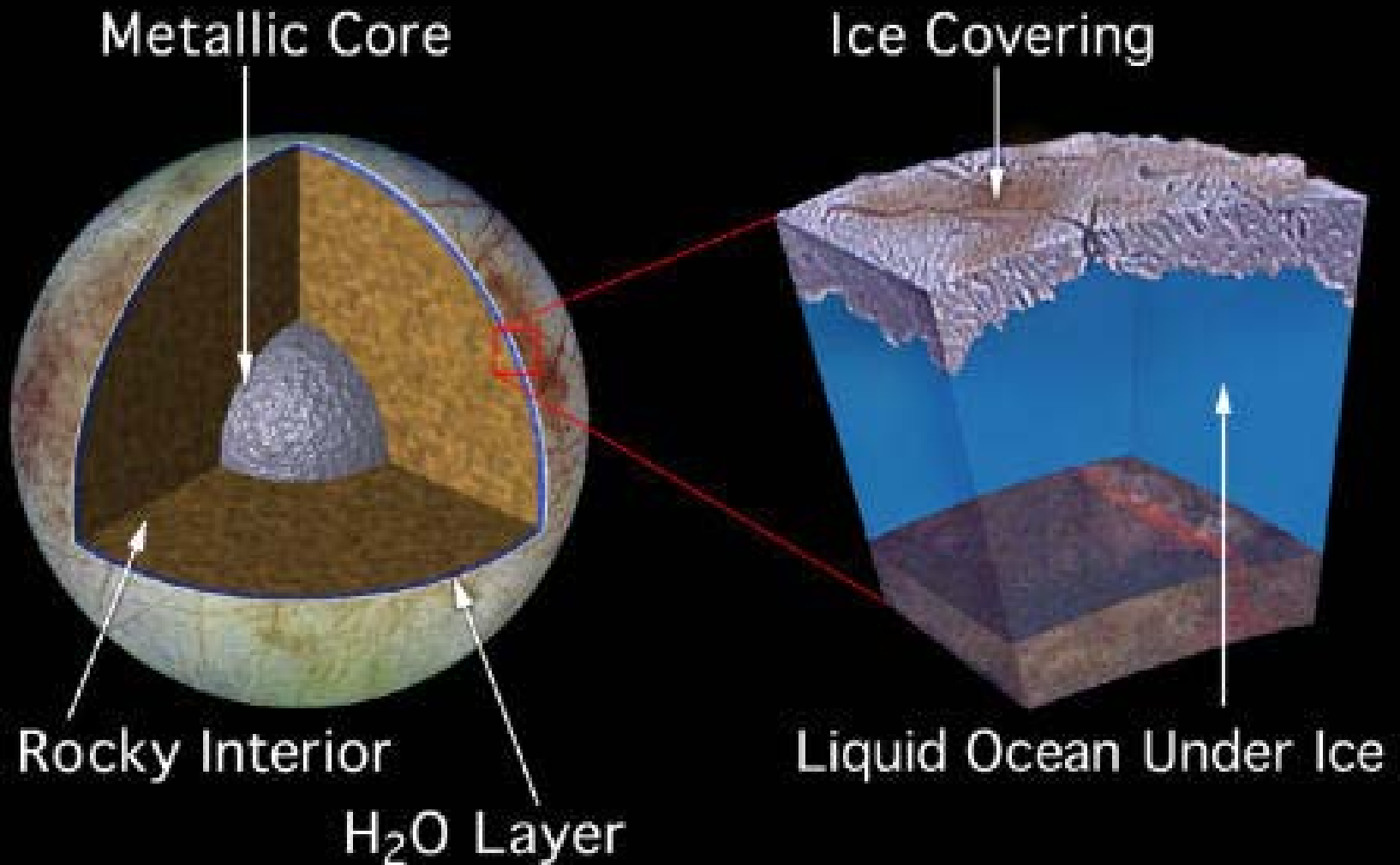


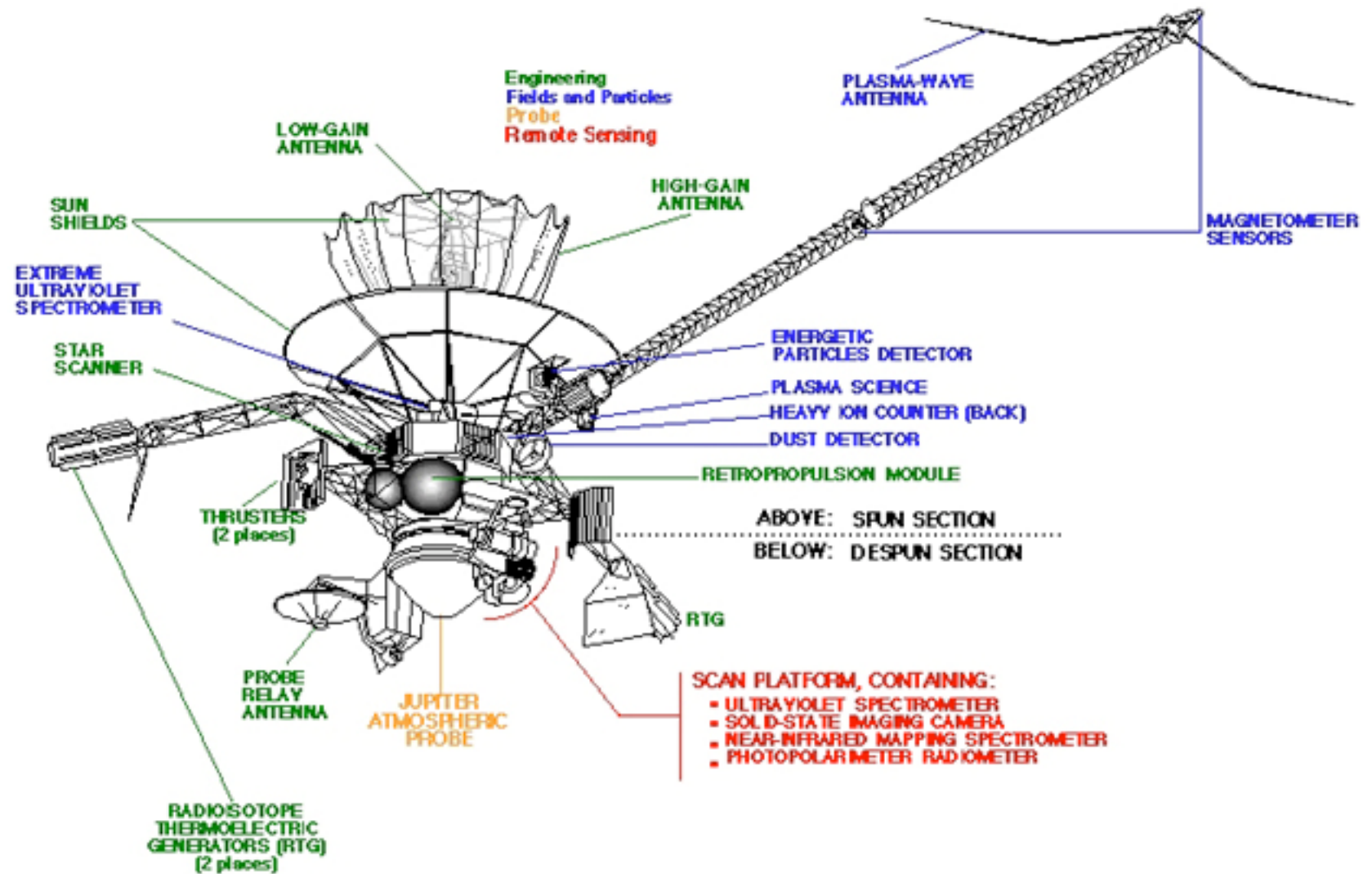






Inside Europa

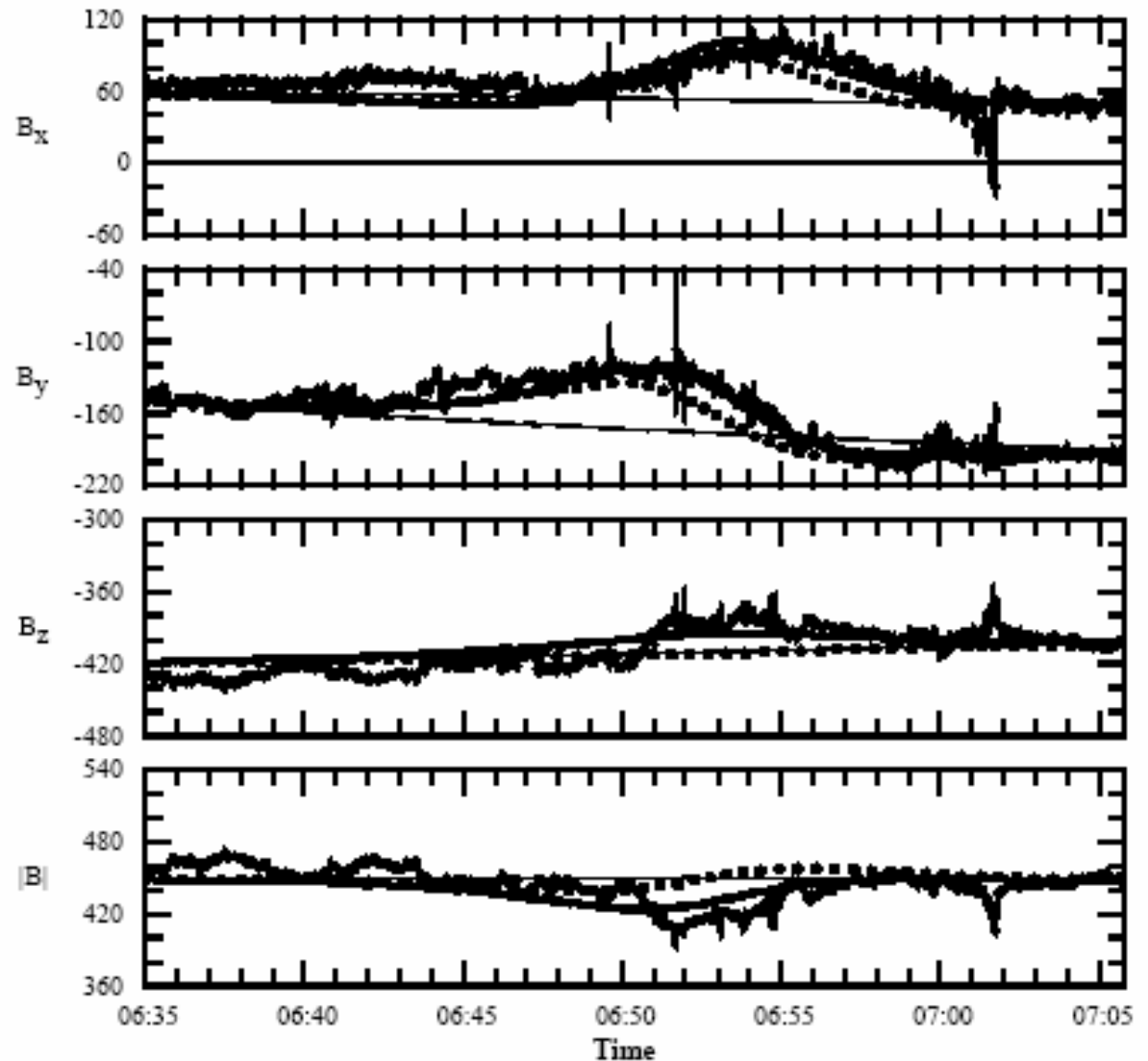




Corroborative evidence from Galileo Magnetometer measurements:

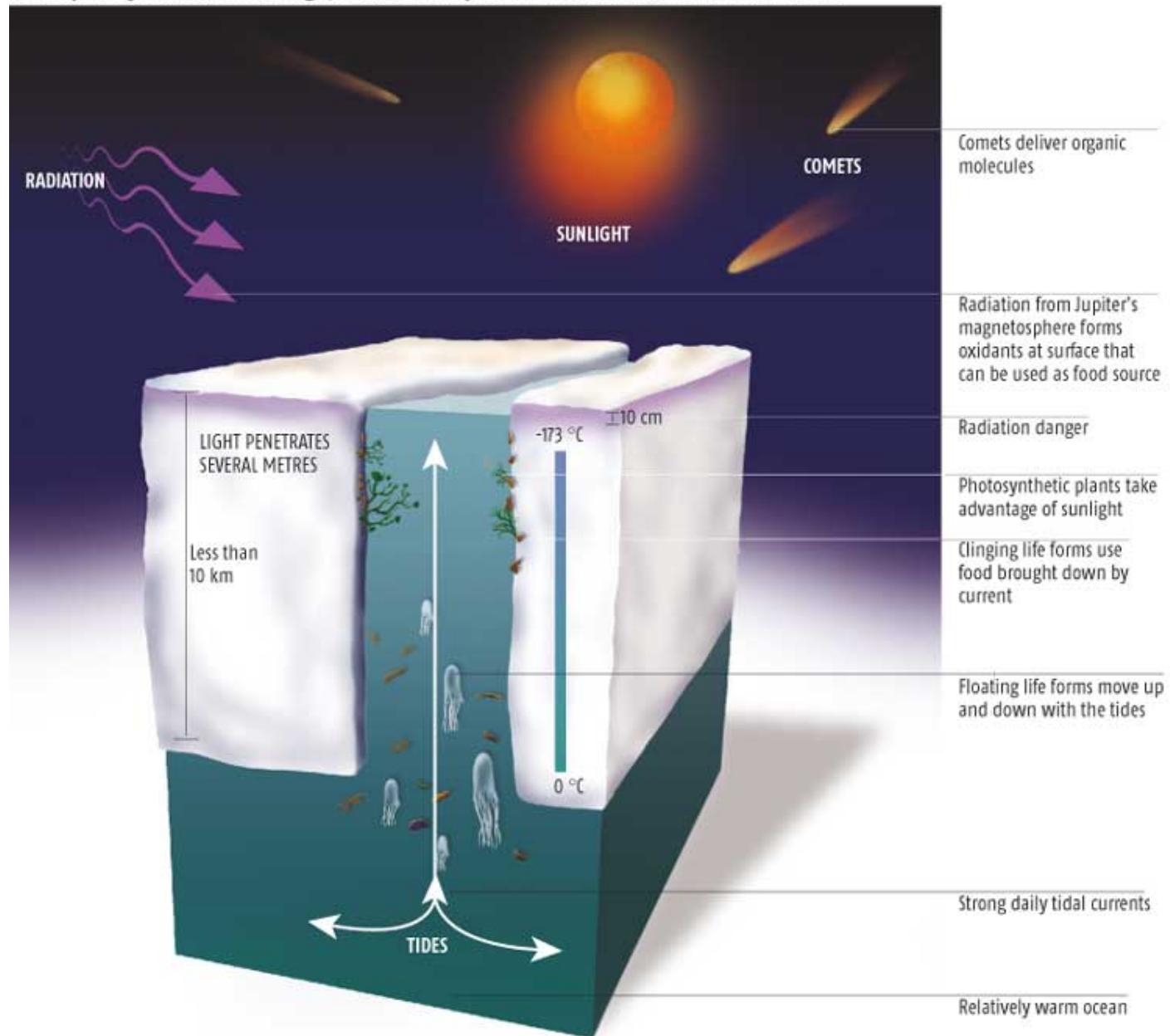
Magnetic field from
subsurface shell:

Salty Ocean?...

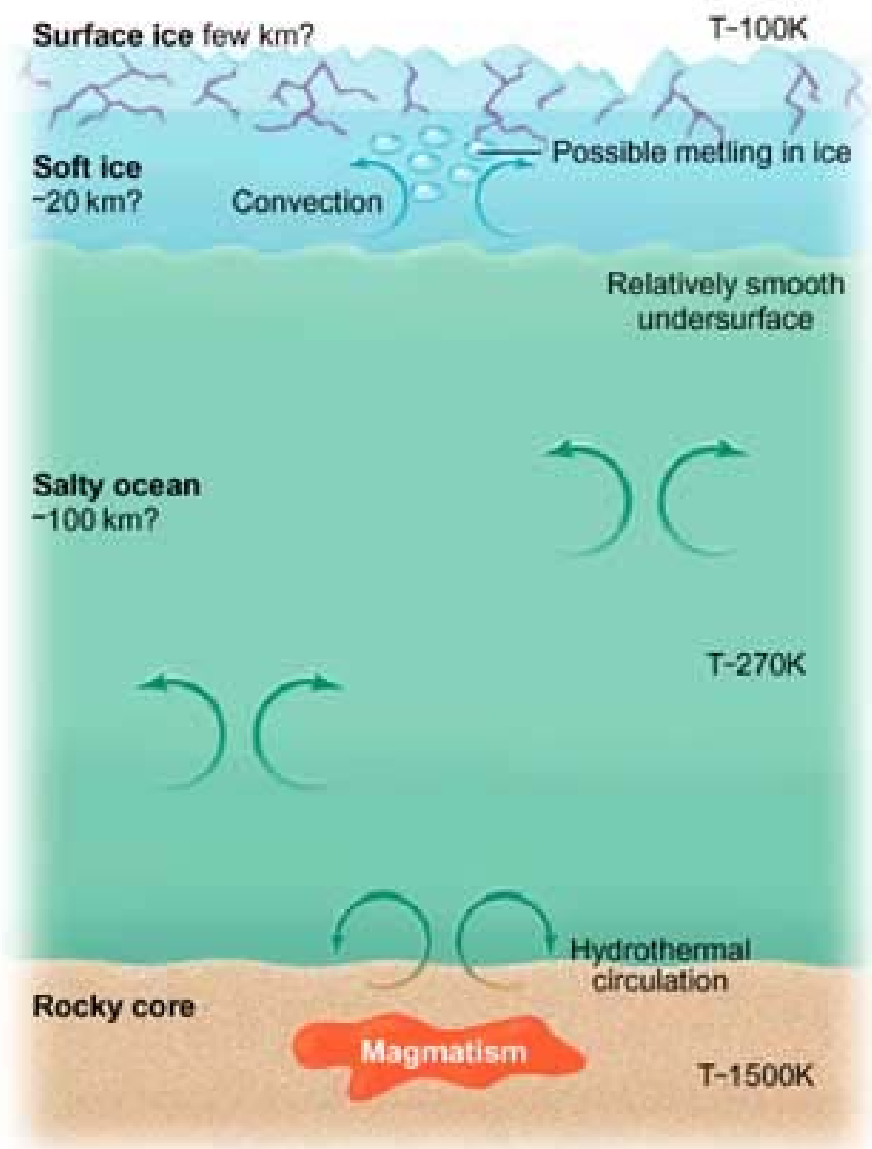


IS THERE LIFE ON EUROPA?

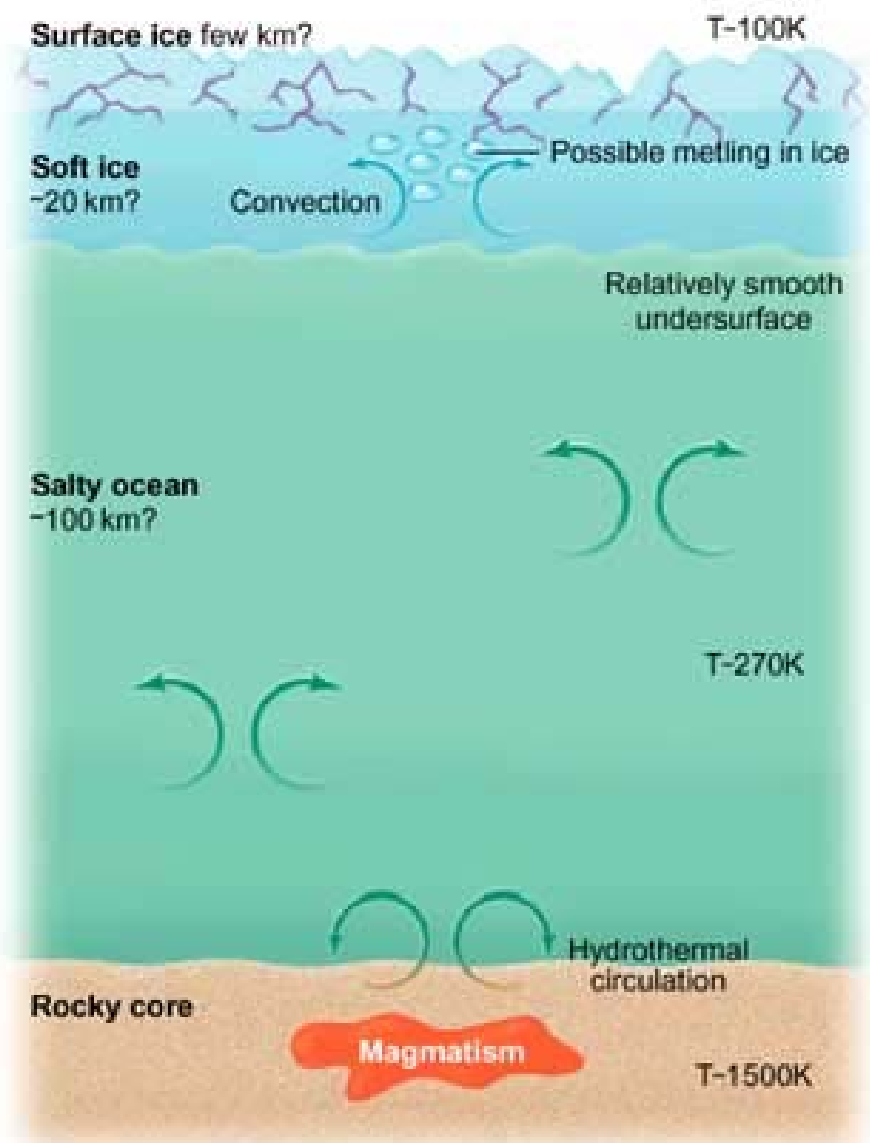
If Europa's icy crust is thin enough, cracks would provide a habitat where life could thrive



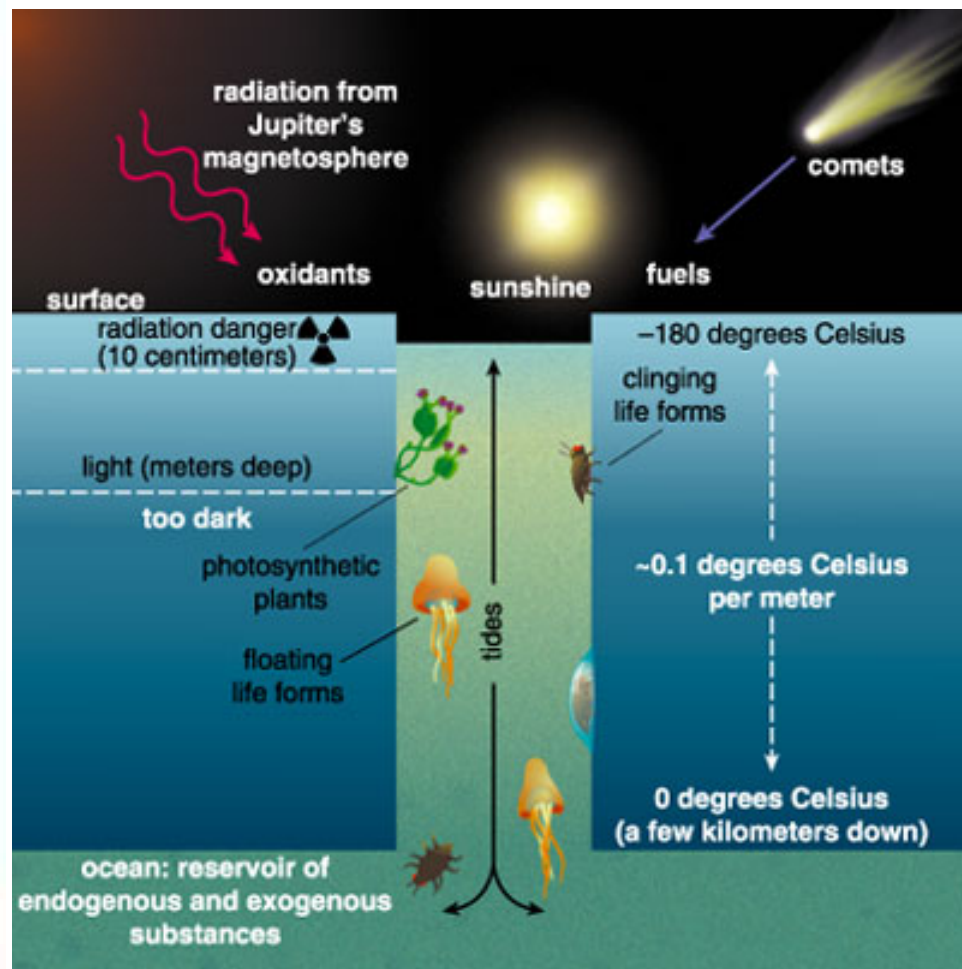
From *Science* (2002)



CREDIT: SCIENCE/DAVID STEVENSON

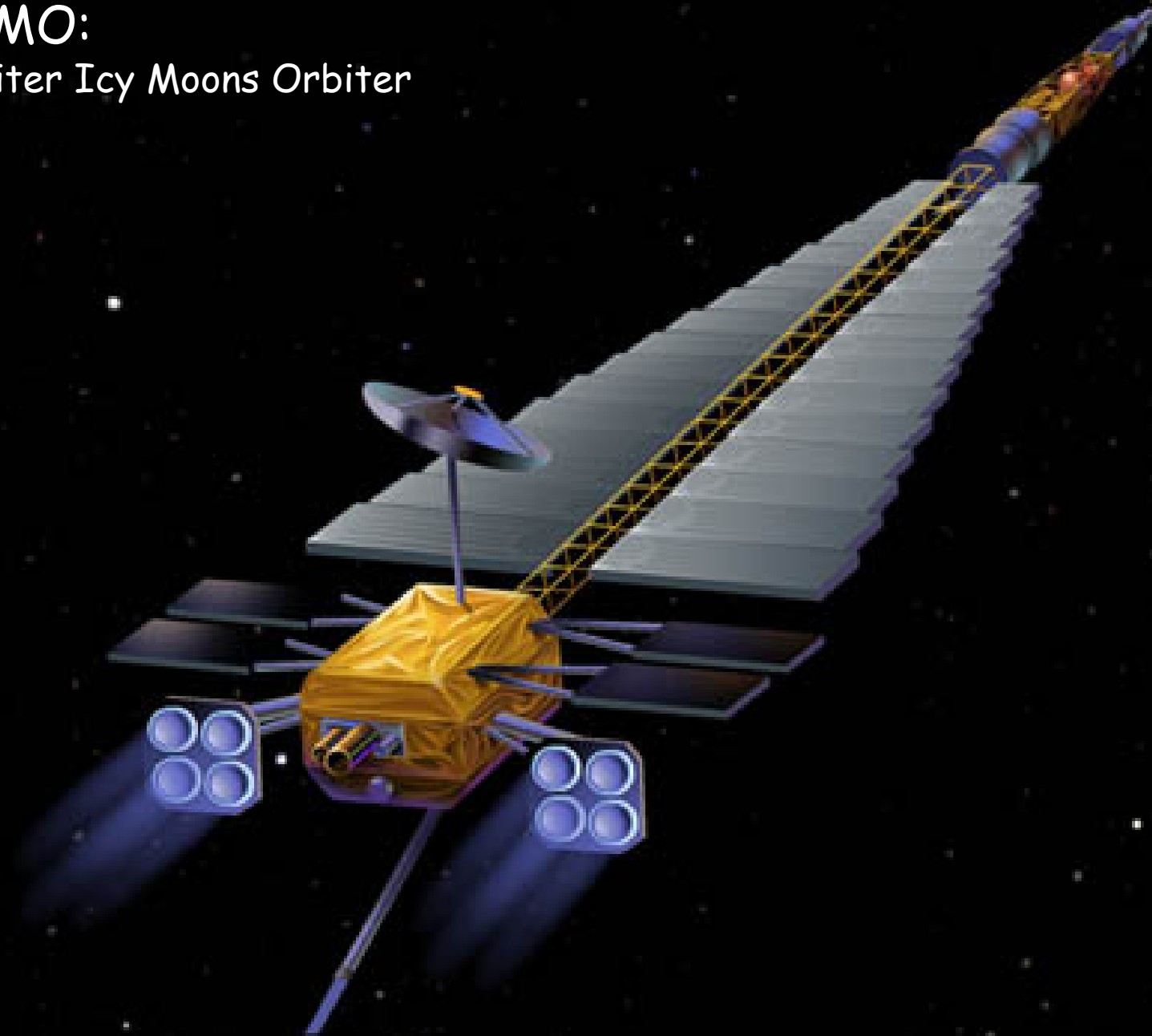


CREDIT: SCIENCE/DAVID STEVENSON



JIMO:

Jupiter Icy Moons Orbiter

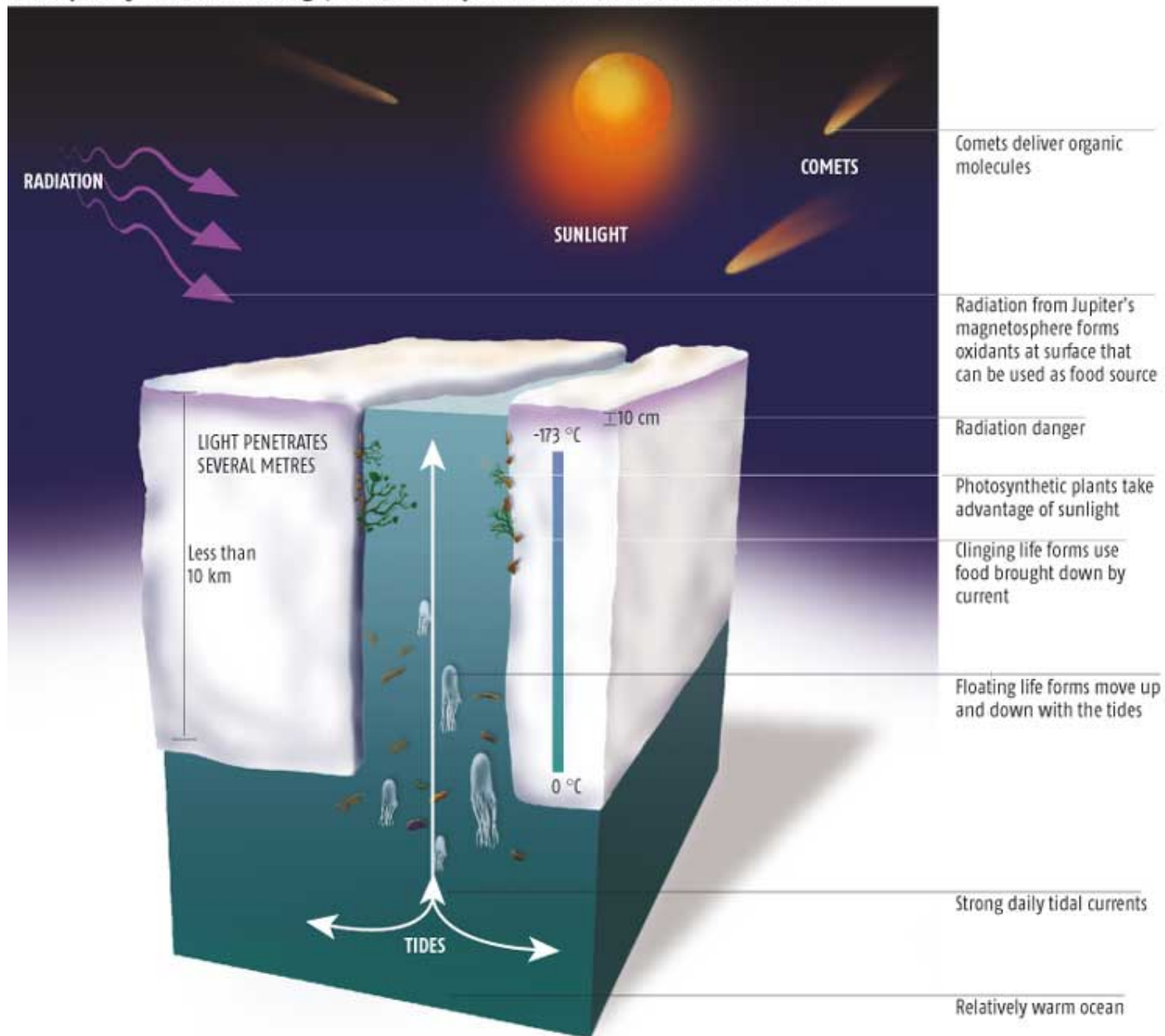


ICEPICK:
Europa lander mission



IS THERE LIFE ON EUROPA?

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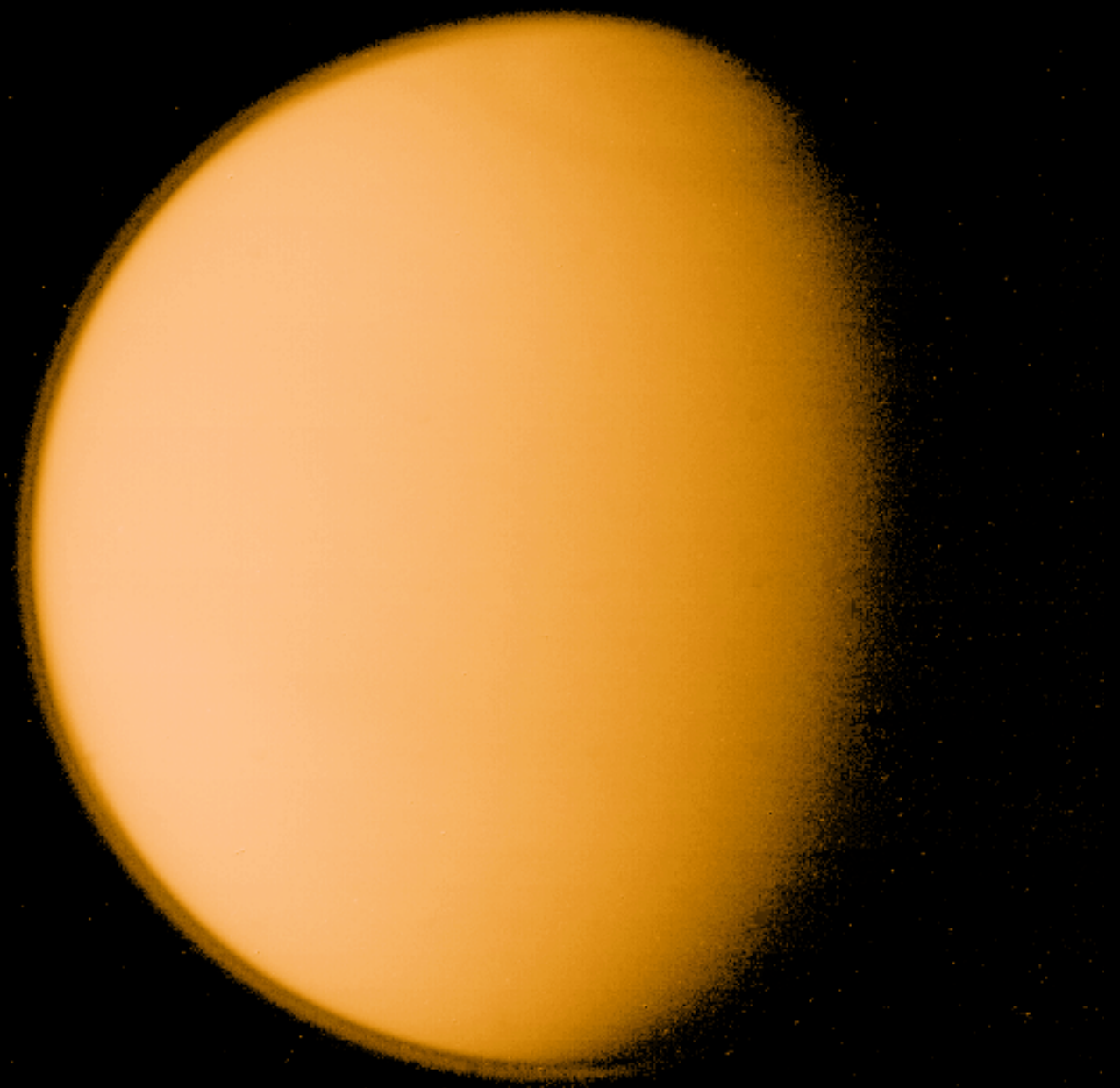
Inside Europa

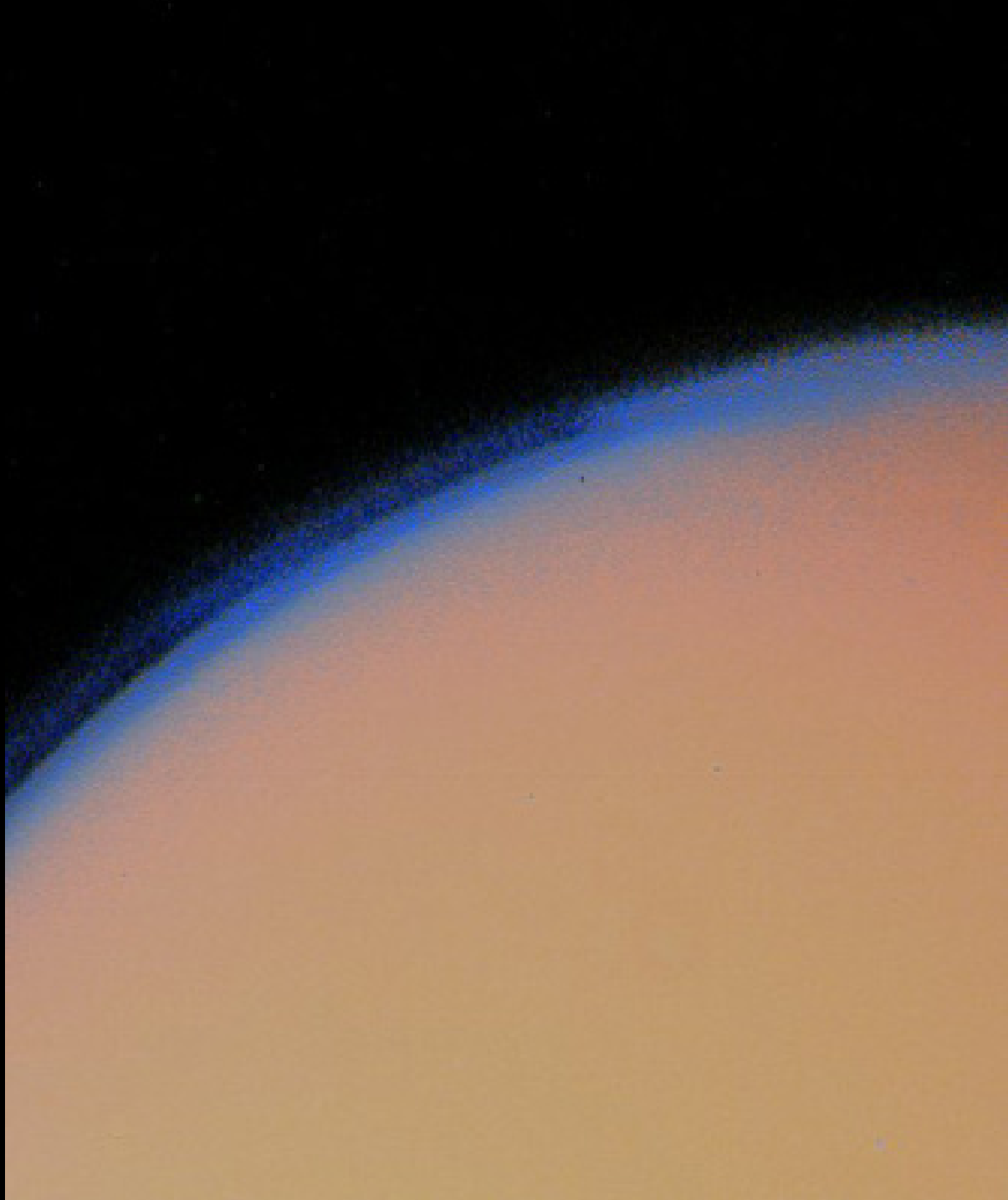


Could there be life?.....







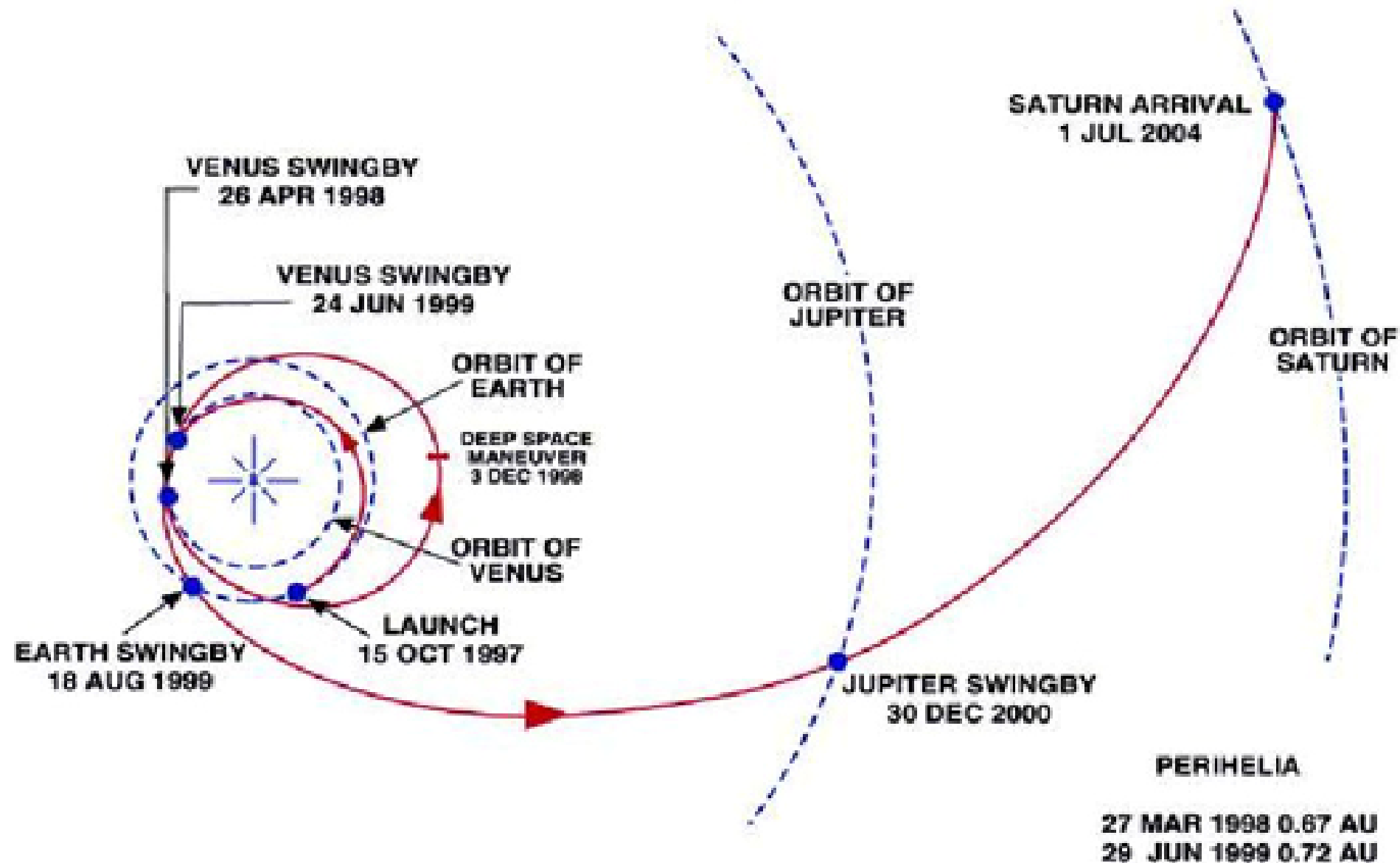




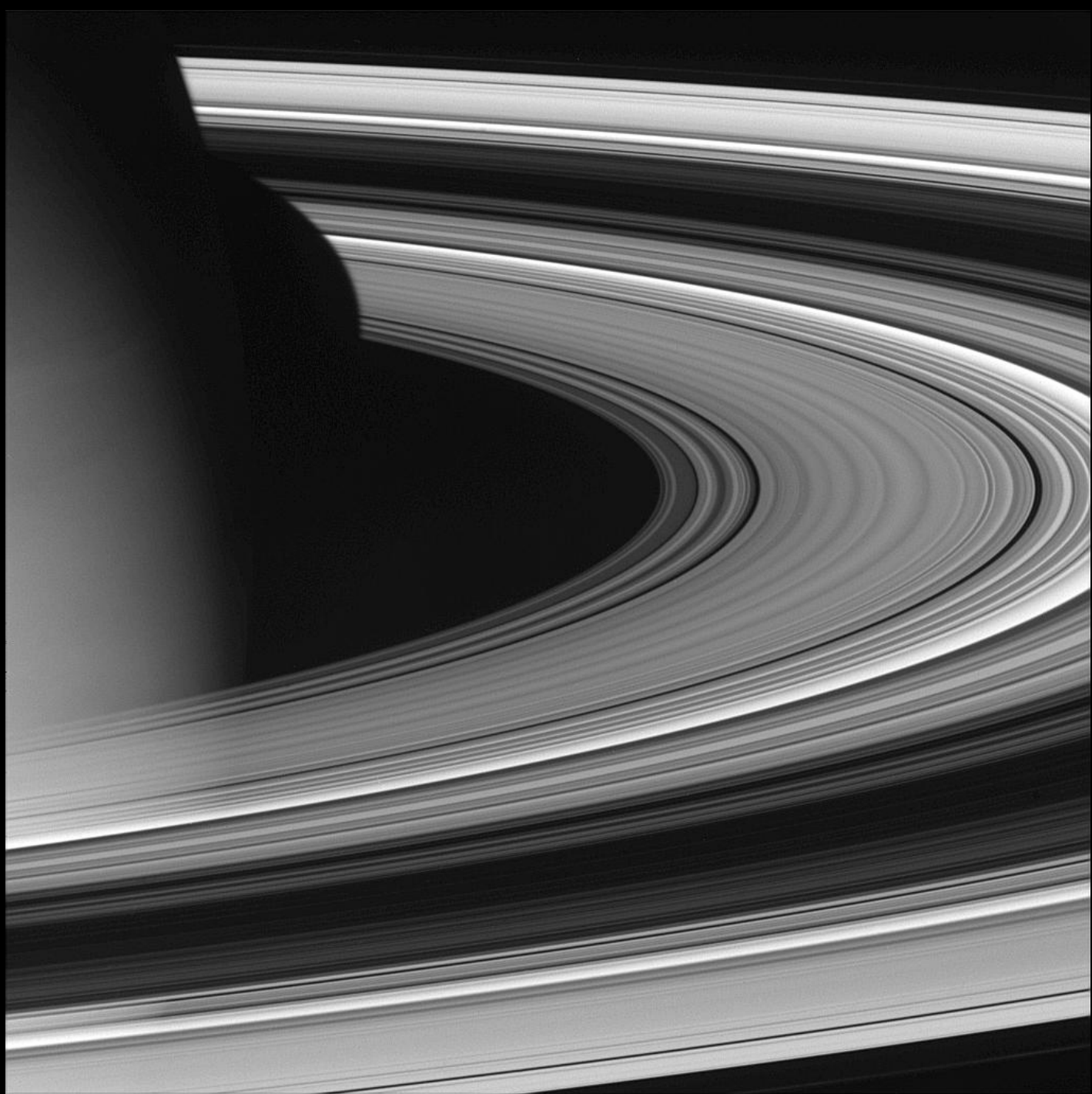
CASSINI SPACECRAFT

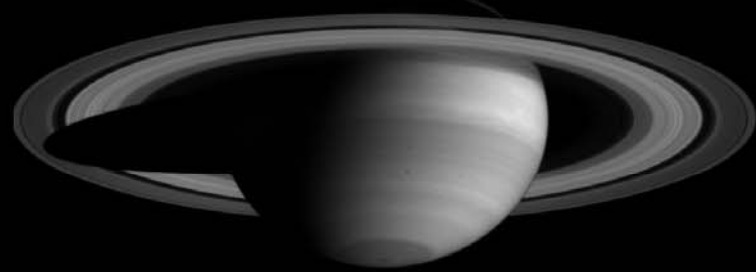
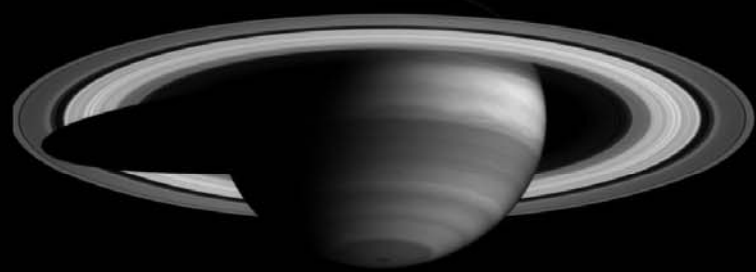


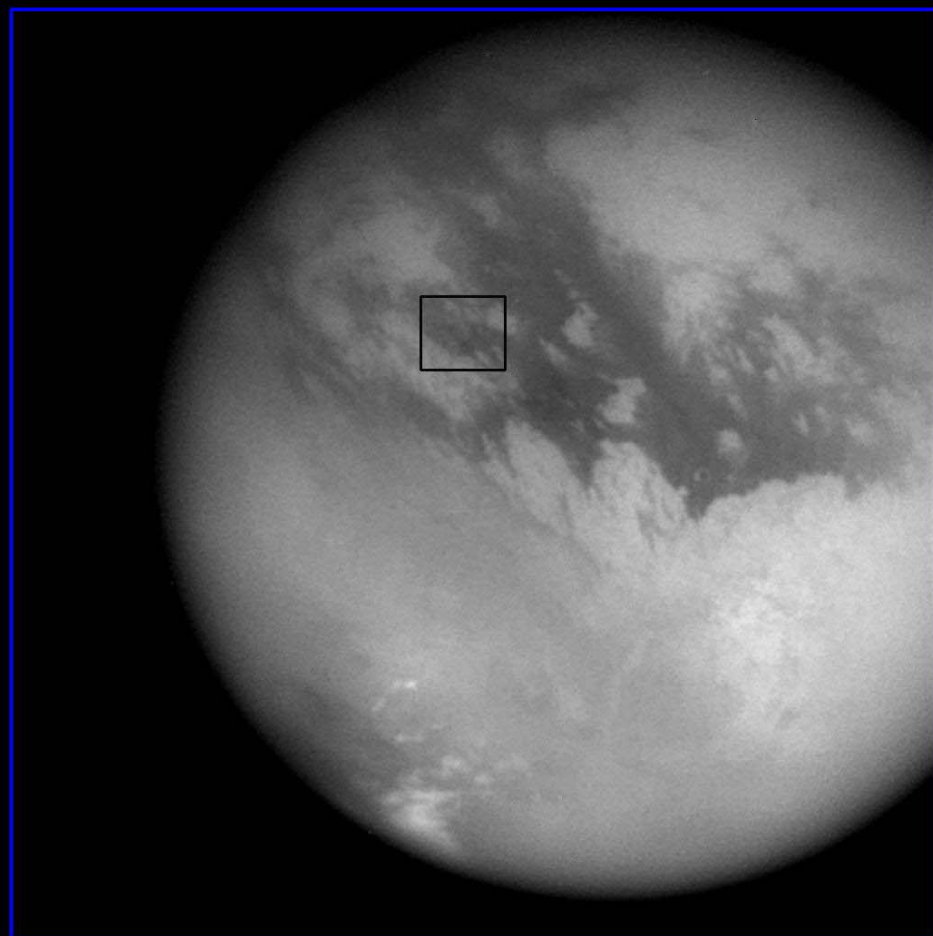
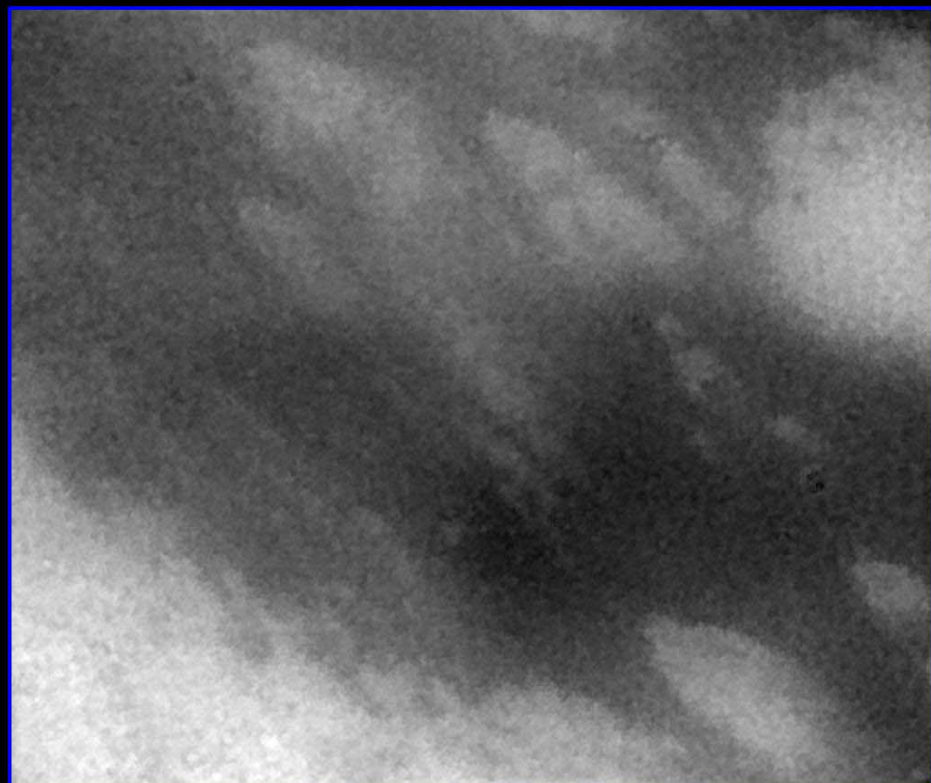
CASSINI INTERPLANETARY TRAJECTORY

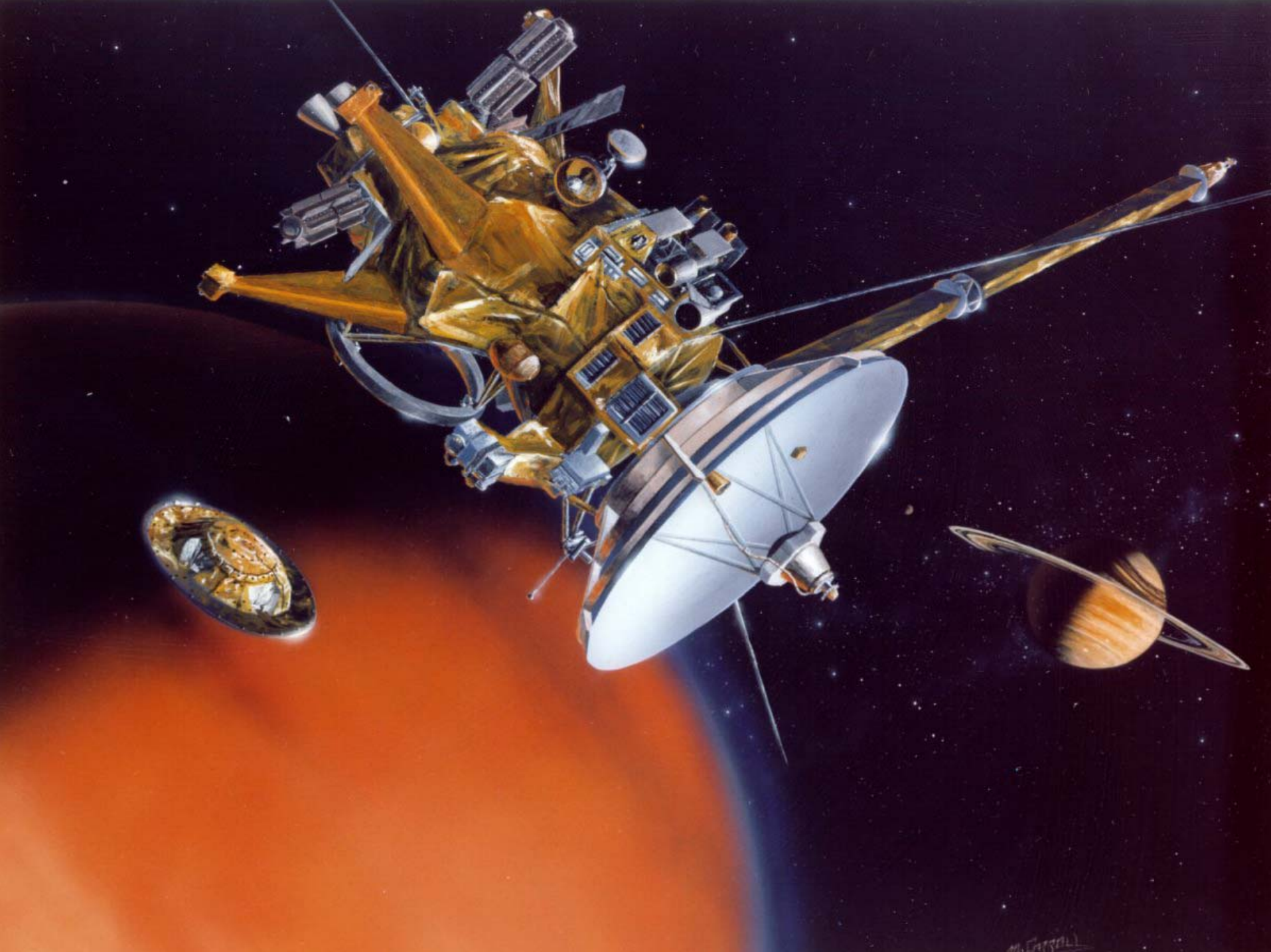


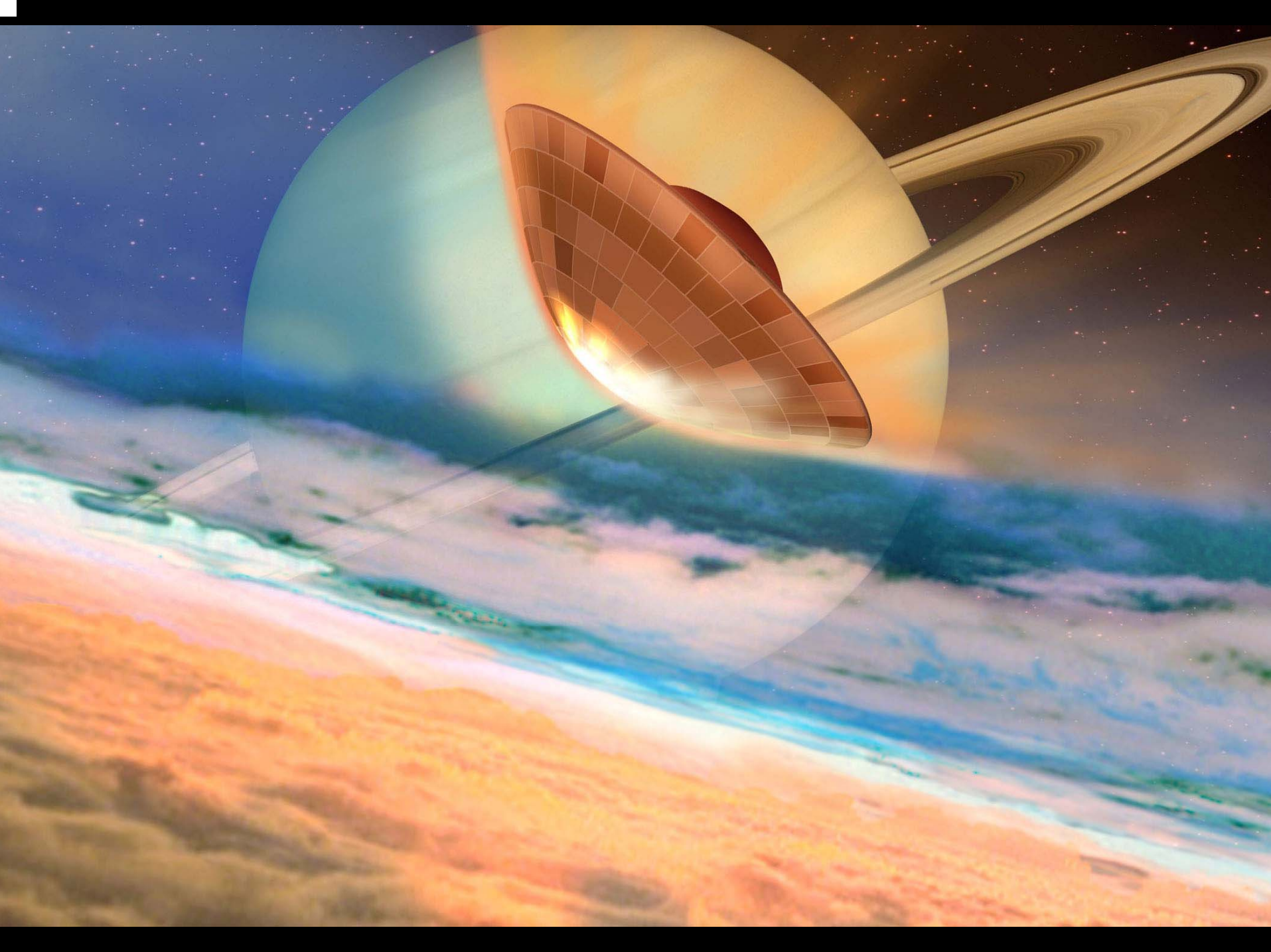


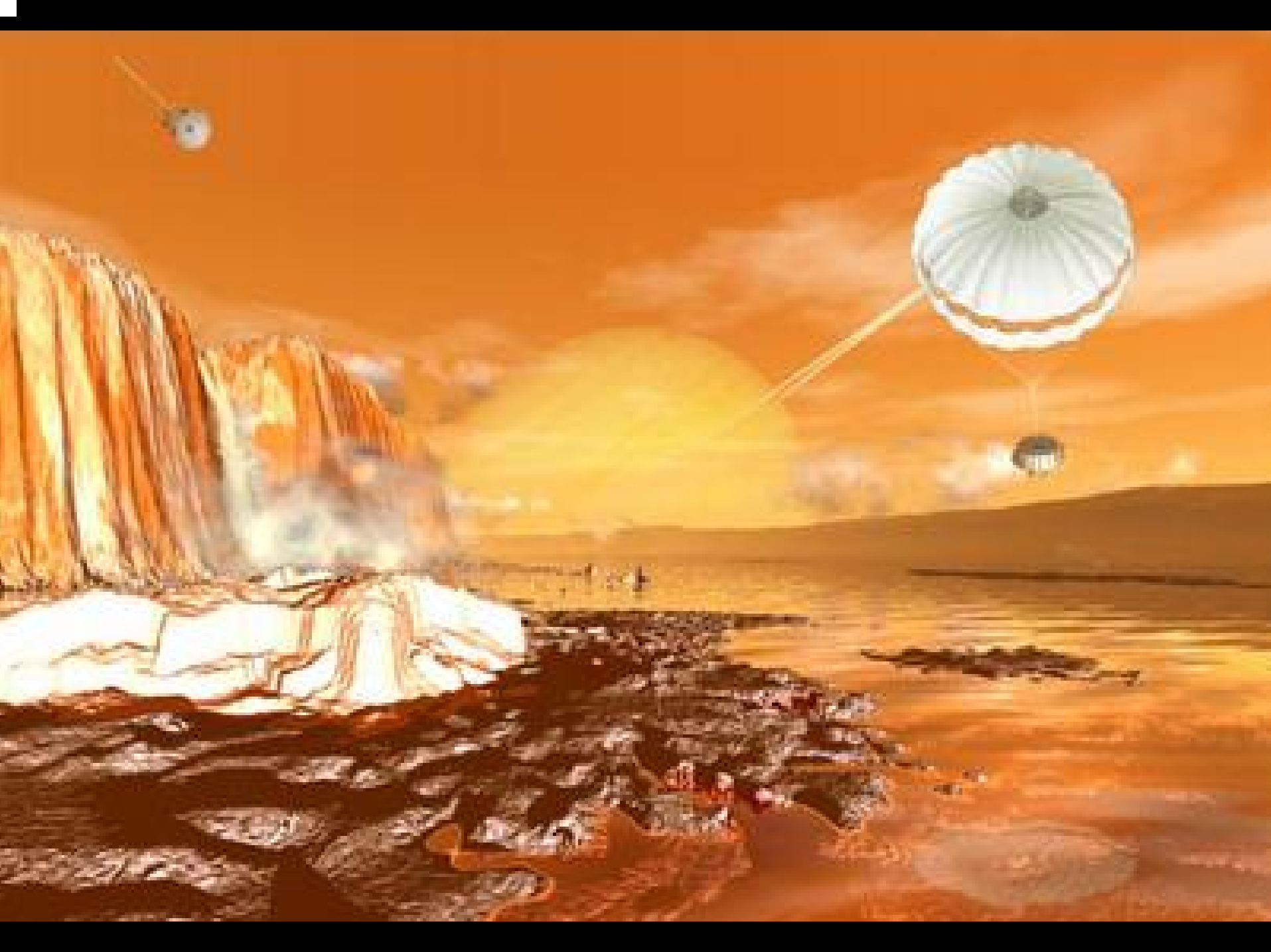


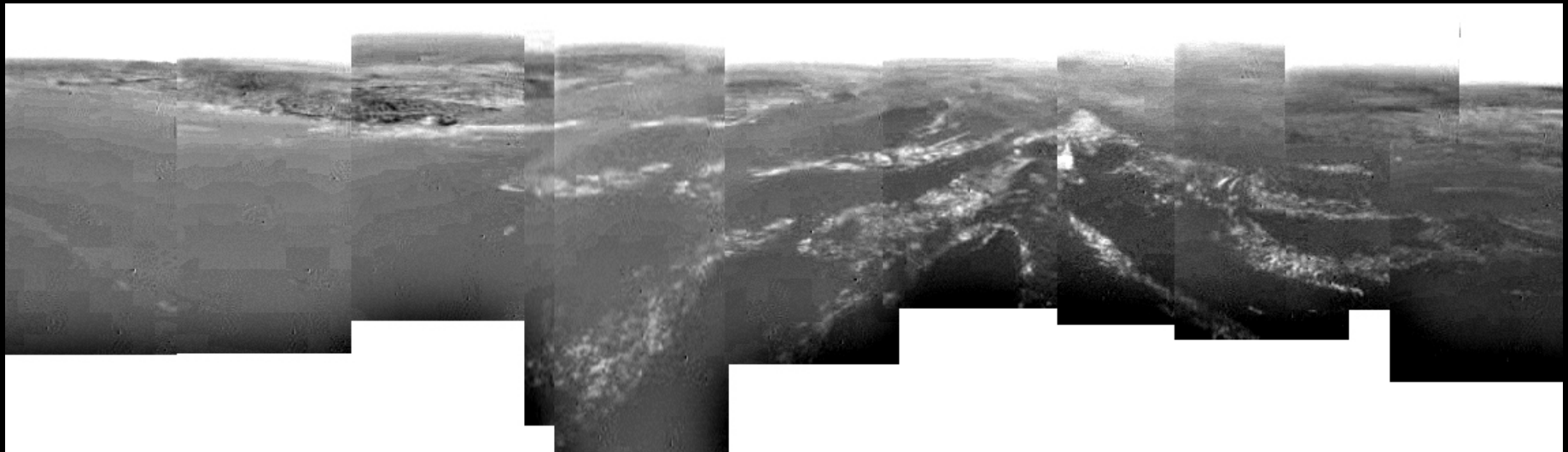
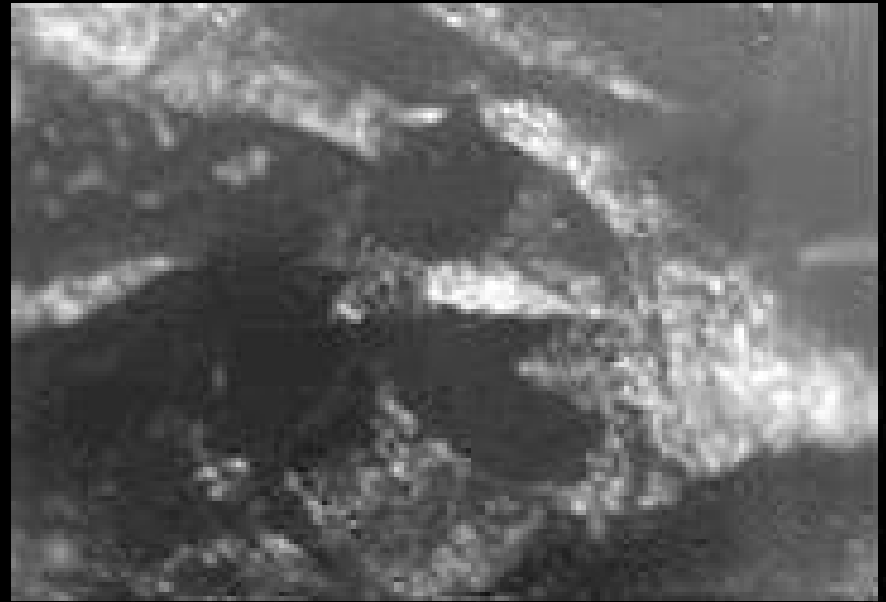


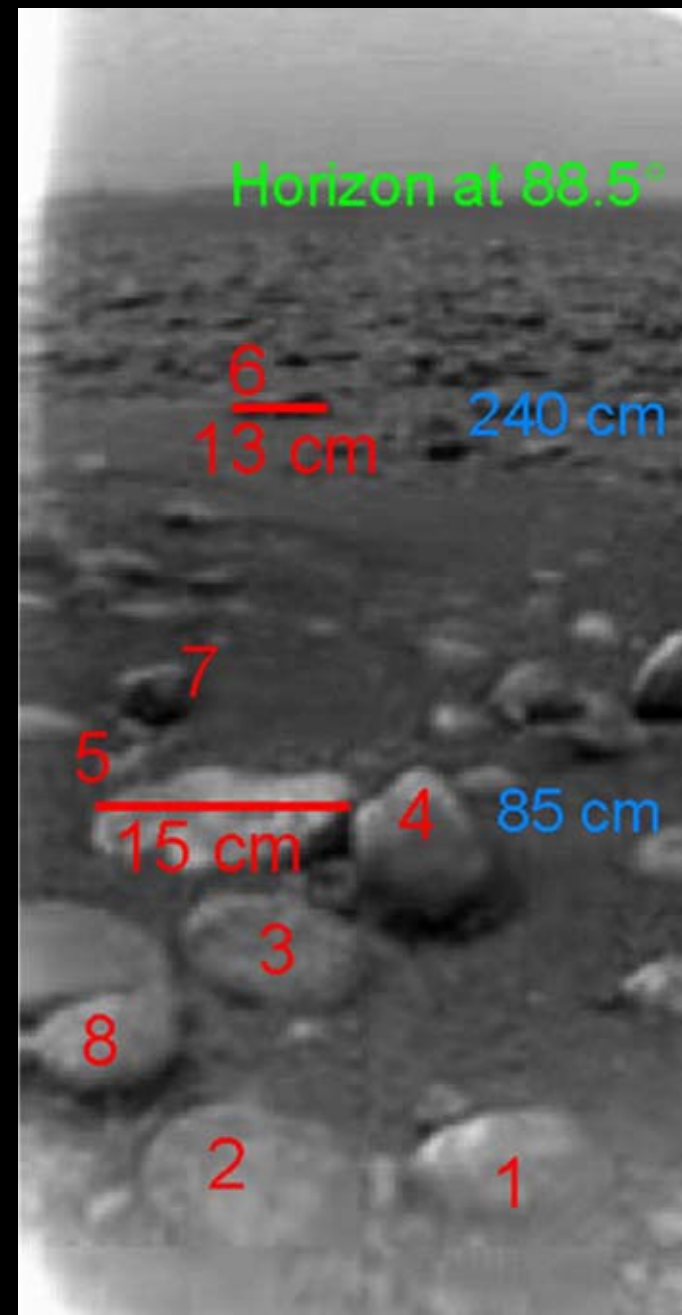
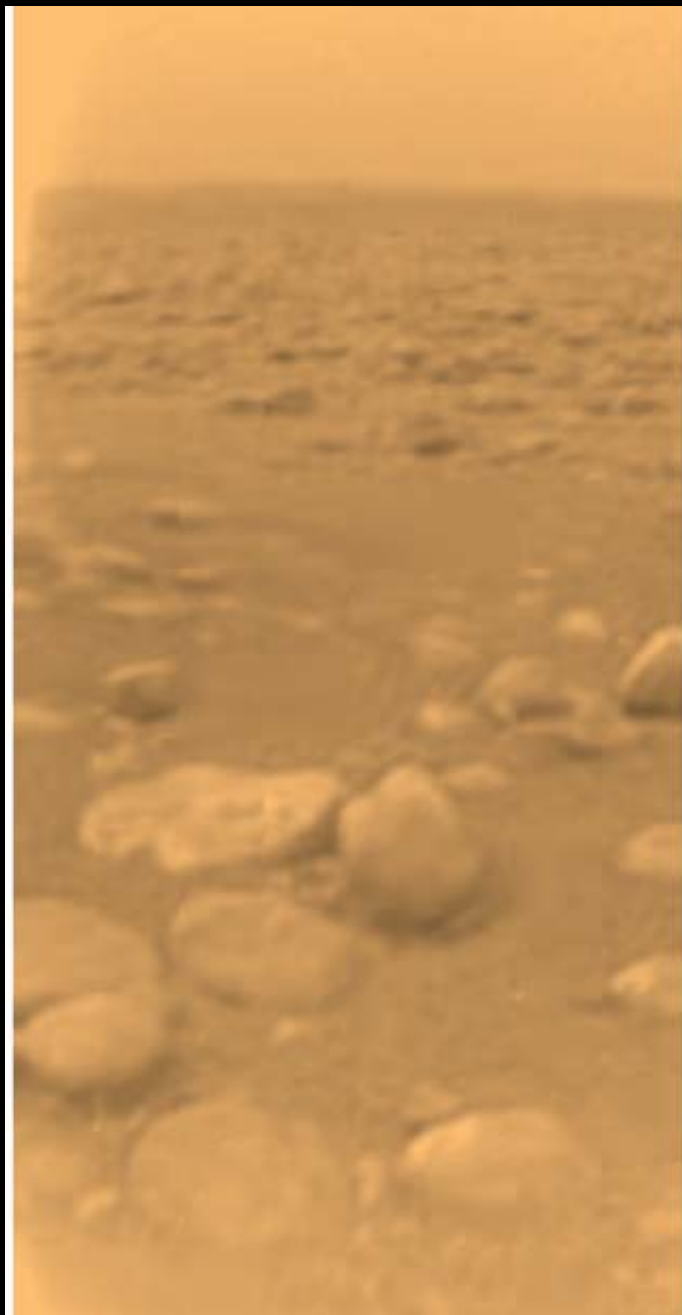












A deep space photograph showing a vast field of galaxies and stars against a black background. The galaxies are of various shapes and sizes, some appearing as bright, elongated structures, while others are more distant and faint. The stars are scattered throughout the field, some appearing as sharp points of light, while others are more diffuse. The overall scene is a representation of the vastness and complexity of the universe.

Are we alone in the Universe?...

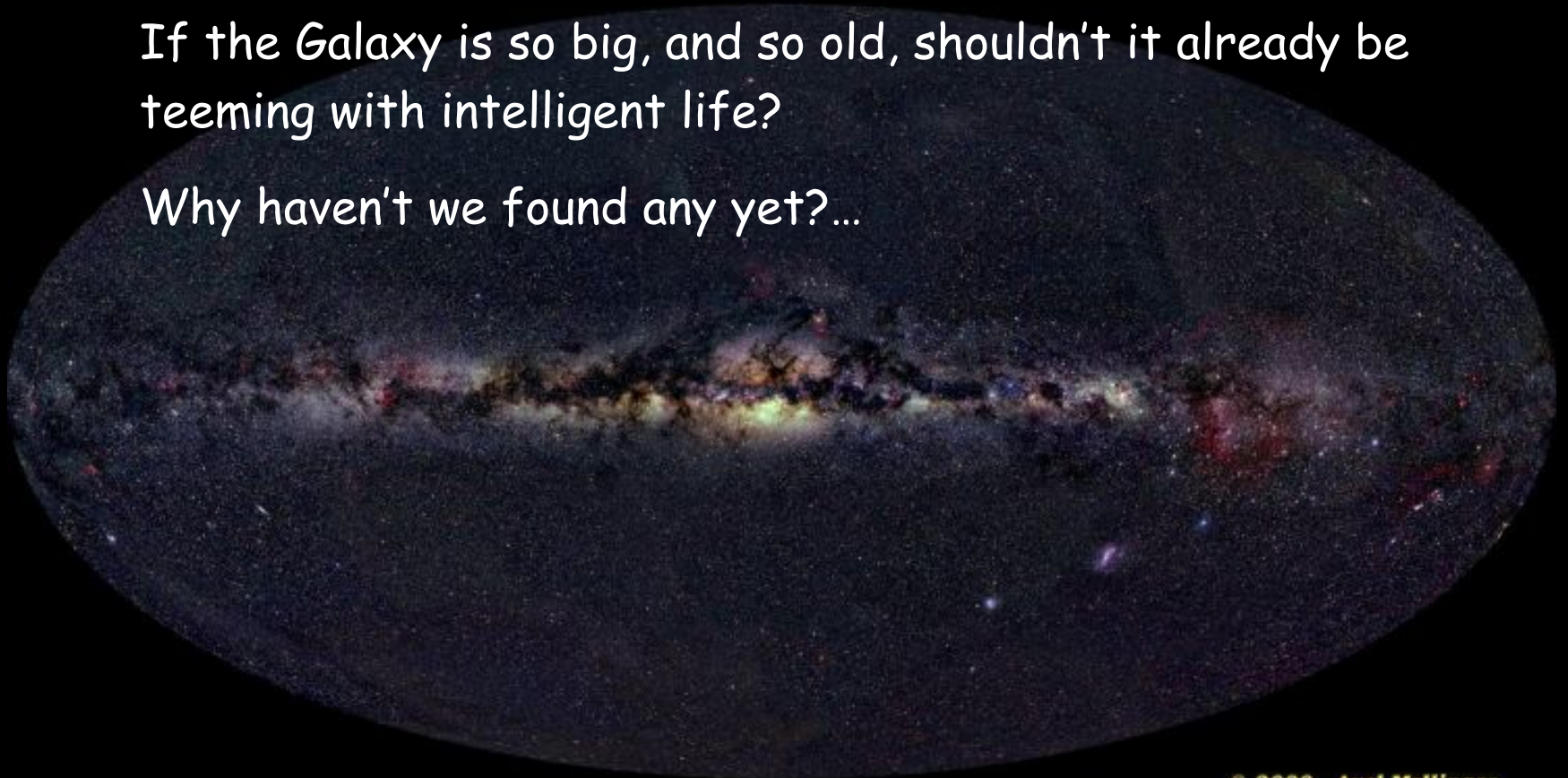
*Is life on Earth an
extraordinary accident?*

This leads us to another big question:

The Milky Way is about 10 billion years old, and contains around 100 billion stars

If the Galaxy is so big, and so old, shouldn't it already be teeming with intelligent life?

Why haven't we found any yet?...



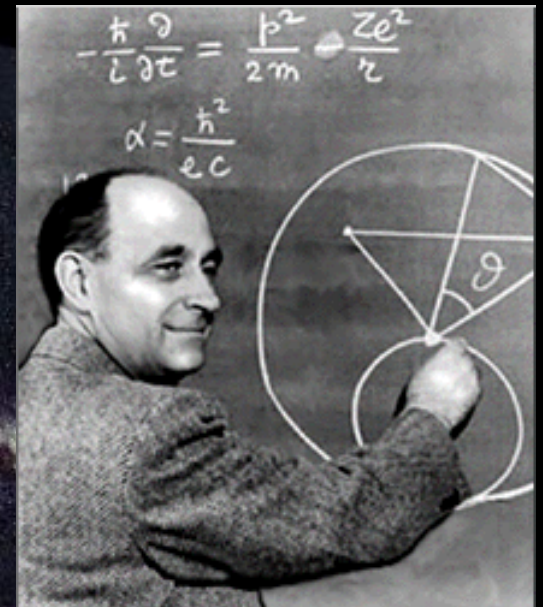
This leads us to another big question:

If the Galaxy is so big, and so old, shouldn't it already be teeming with intelligent life?

Why haven't we found any yet?...

Fermi's Paradox:

"Where is Everybody?....."

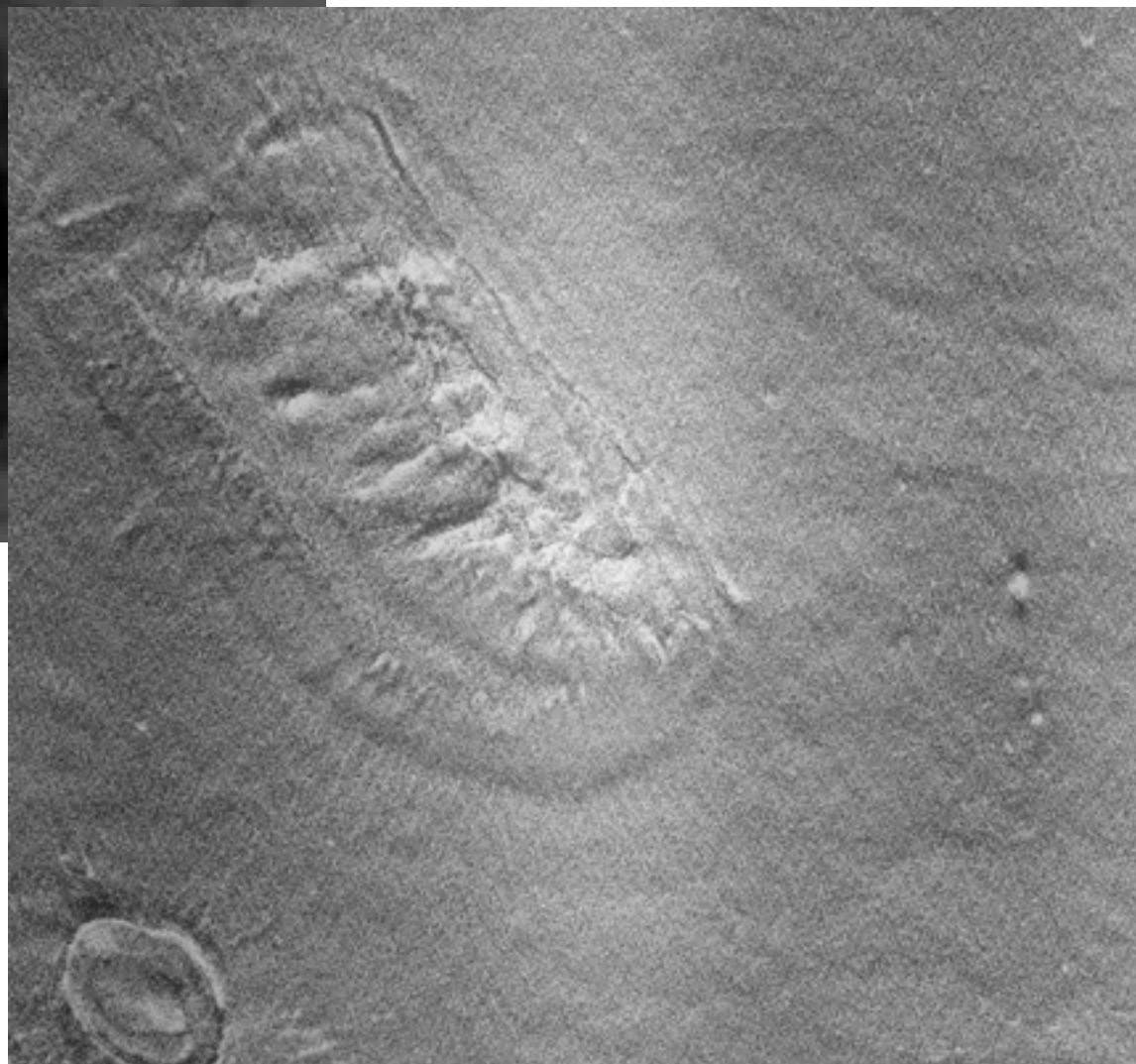


➤ They are here and are meddling in Human affairs



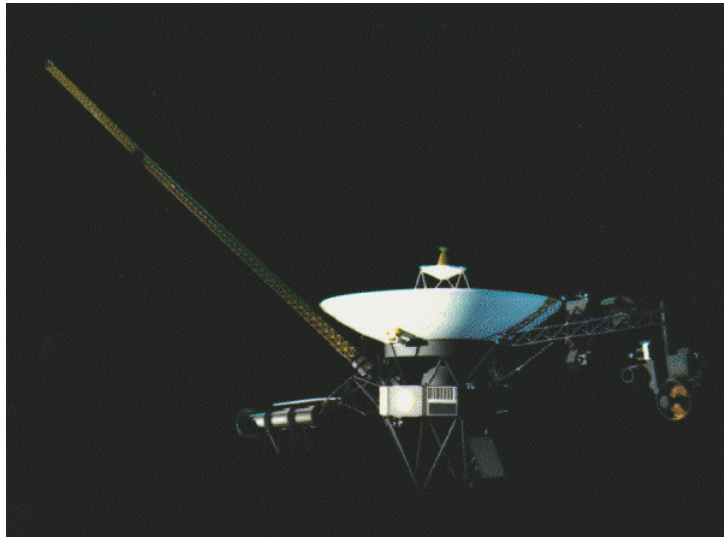
- They were here, and left evidence of their presence





They exist but have not yet communicated

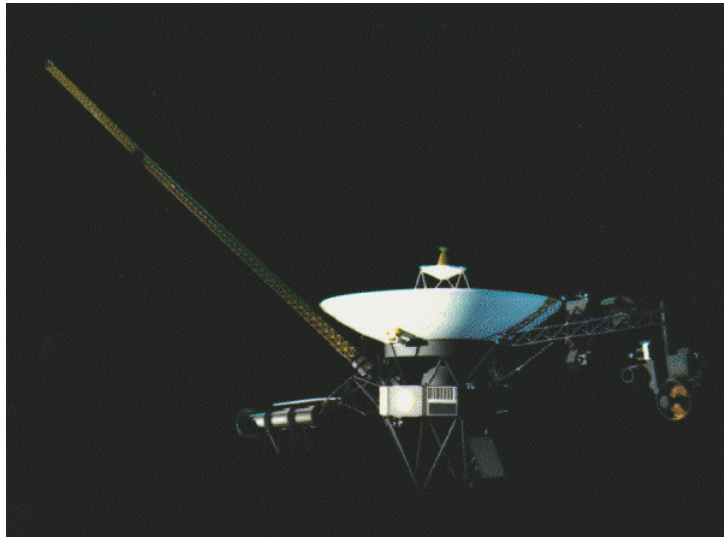
- The stars are very far away / they have not had time to reach us



Voyager 1 would take ~75000 years to reach Proxima Centauri.....

They exist but have not yet communicated

- The stars are very far away / they have not had time to reach us



Voyager 1 would take ~75000 years to reach Proxima Centauri.....

.....but this is less than 100,000th of the age of the Galaxy

They exist but have not yet communicated

➤ They stay at home...



They exist but have not yet communicated

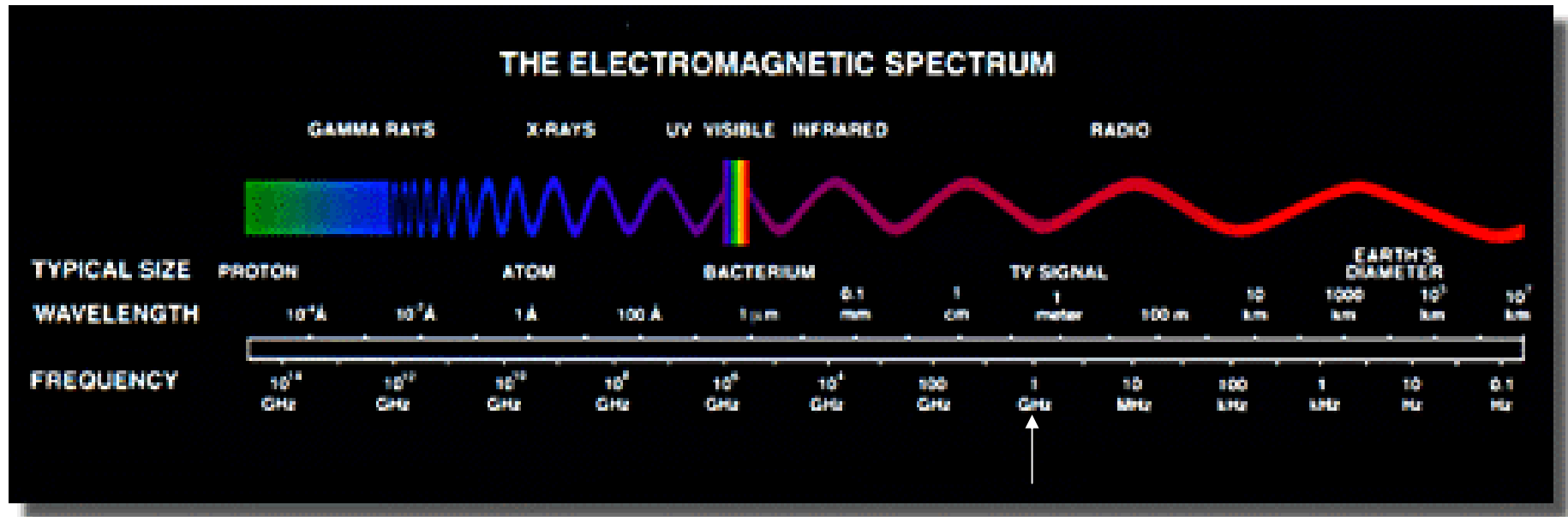
➤ They stay at home...



...and surf the net

They exist but have not yet communicated

➤ They are signalling but we don't know how to listen



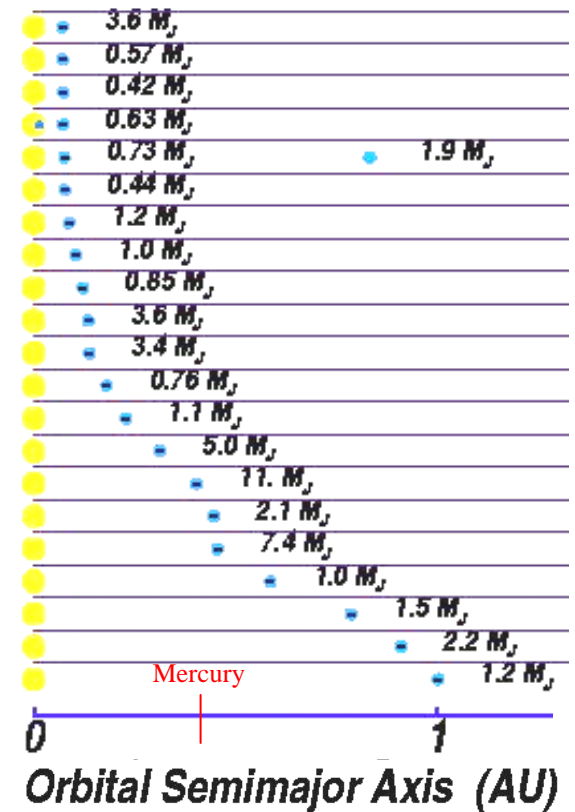
The 'Waterhole': strong H and OH emission between 1.42 GHz and 1.64 GHz

They do not exist

➤ Rocky planets are rare

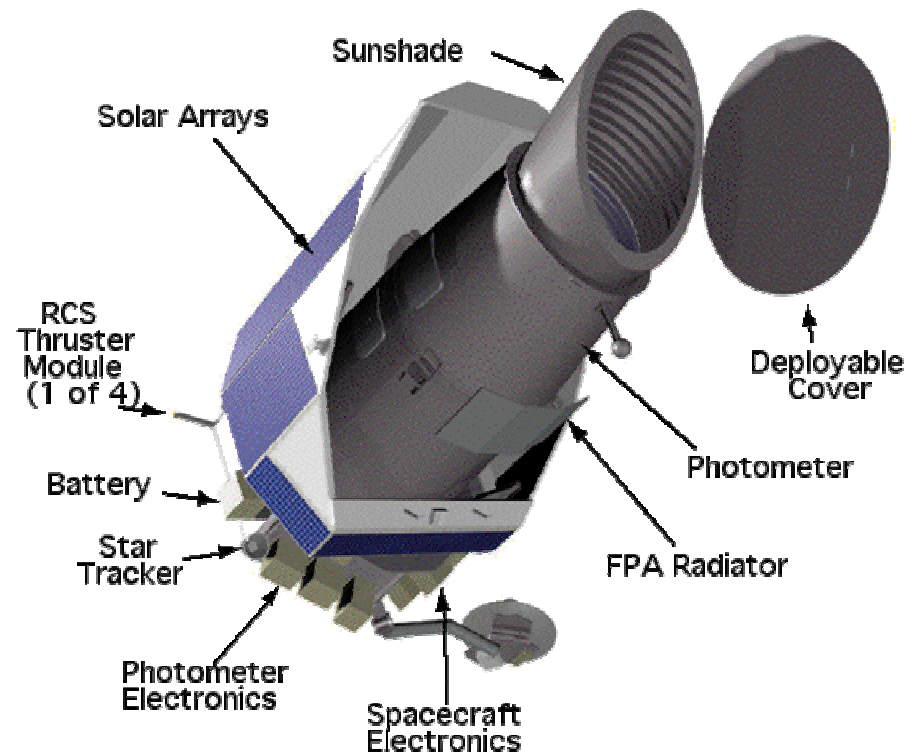


TauBoo
HD187123
HD75289
HD209458
Ups And
51Peg
HD217107
HD130322
55Cnc
GL86
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70Vir
HD37124
HD134987
IotaHor
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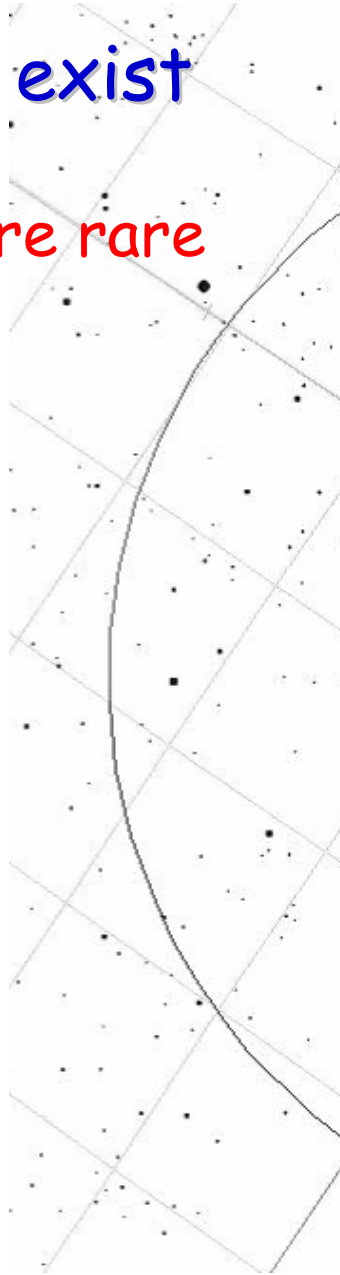
They do not exist

➤ Rocky planets are rare



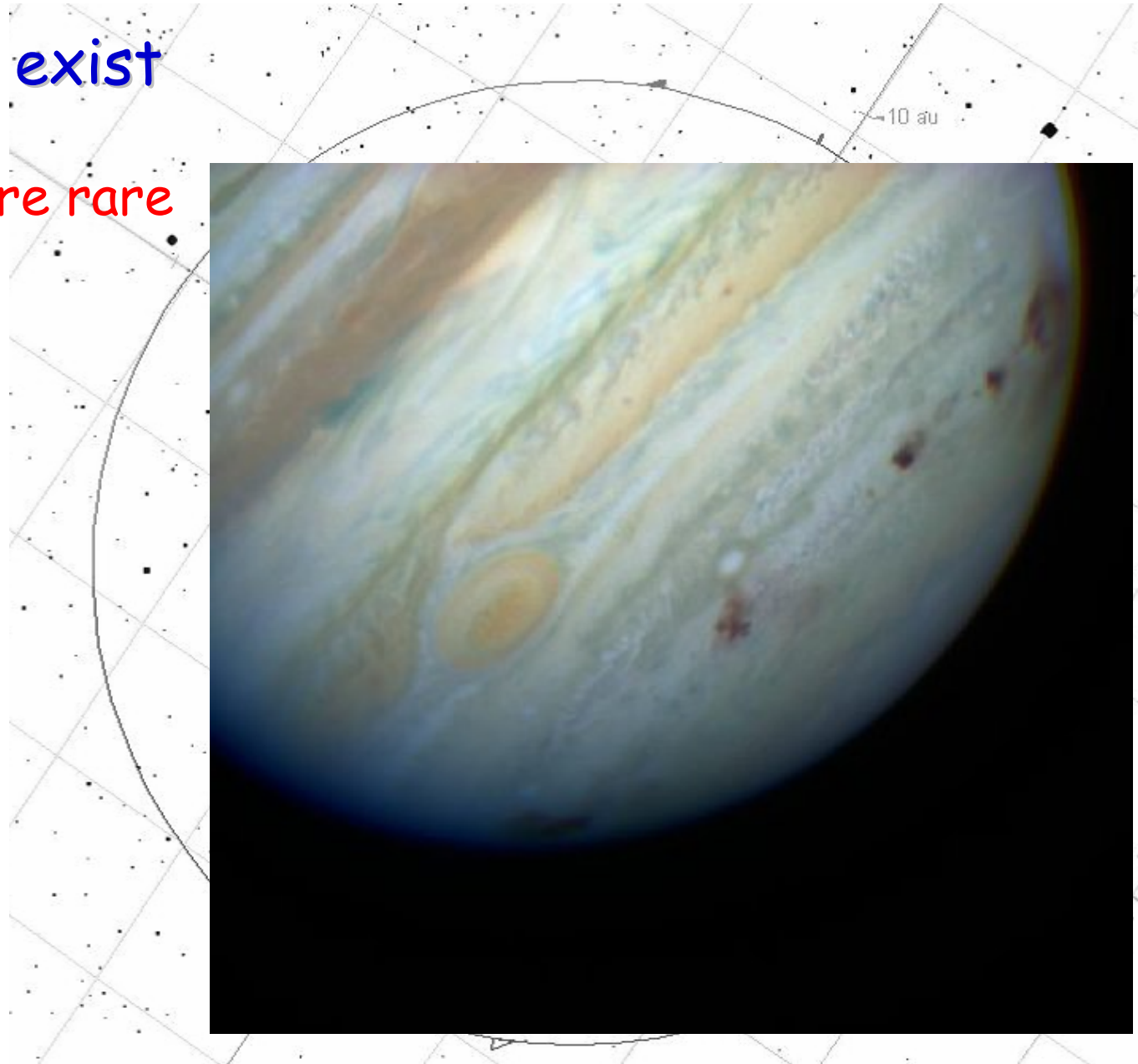
They do not exist

➤ Jupiters are rare



They do not exist

➤ Jupiters are rare









Giordano Bruno
(1548 - 1600)

*On the Infinite Universe and
worlds (1584)*

"...there is not merely one world, one earth, one sun, but as many worlds as we see bright lights around us."

"all those worlds ... contain animals and inhabitants no less than can our own earth, since those worlds have no less virtue nor a nature different from that of our earth".