

Cruising the Solar System

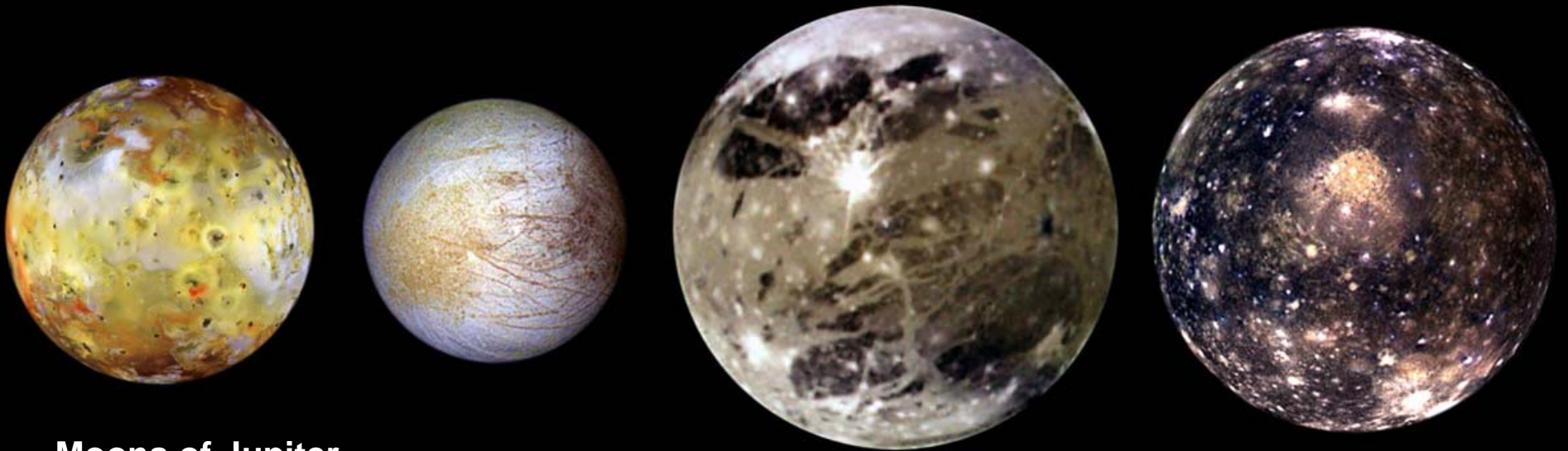
Postcards from the Planets



Philip Stooke

NASA and other space agencies have been exploring the solar system for 50 years

What have we learned from recent missions?



Moons of Jupiter

Planets used to 'belong' to astronomers...

...but now they are studied mostly by geologists.

Some planets are very active

(volcanoes and 'quakes', or erosion by wind and water)

Others never changed since they formed

(so... just craters)

Some started out active but soon stopped

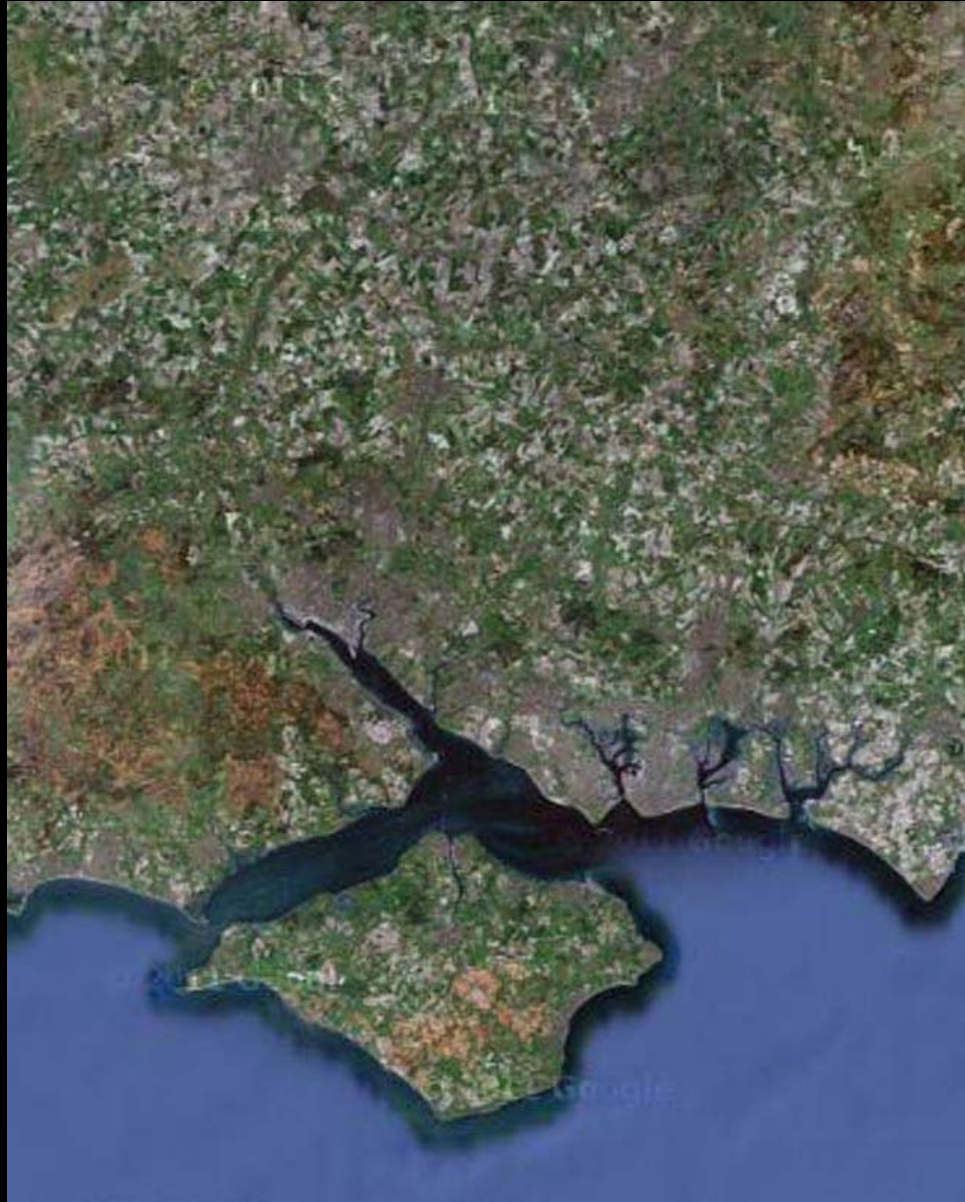
(they took early retirement)

Looking back at Earth - as we begin our cosmic cruise



Earth: continents and oceans

Water is apparent everywhere – clouds, rivers, lakes and oceans



Zoom in and life becomes visible
– from plants to roads and cities



Earth: volcanoes and craters

Violent events have shaped our world

Volcanic eruptions, asteroid impacts, continents moving and pushing up mountains



Kamchatka



Manicouagan, Quebec

Earth: rivers and glaciers

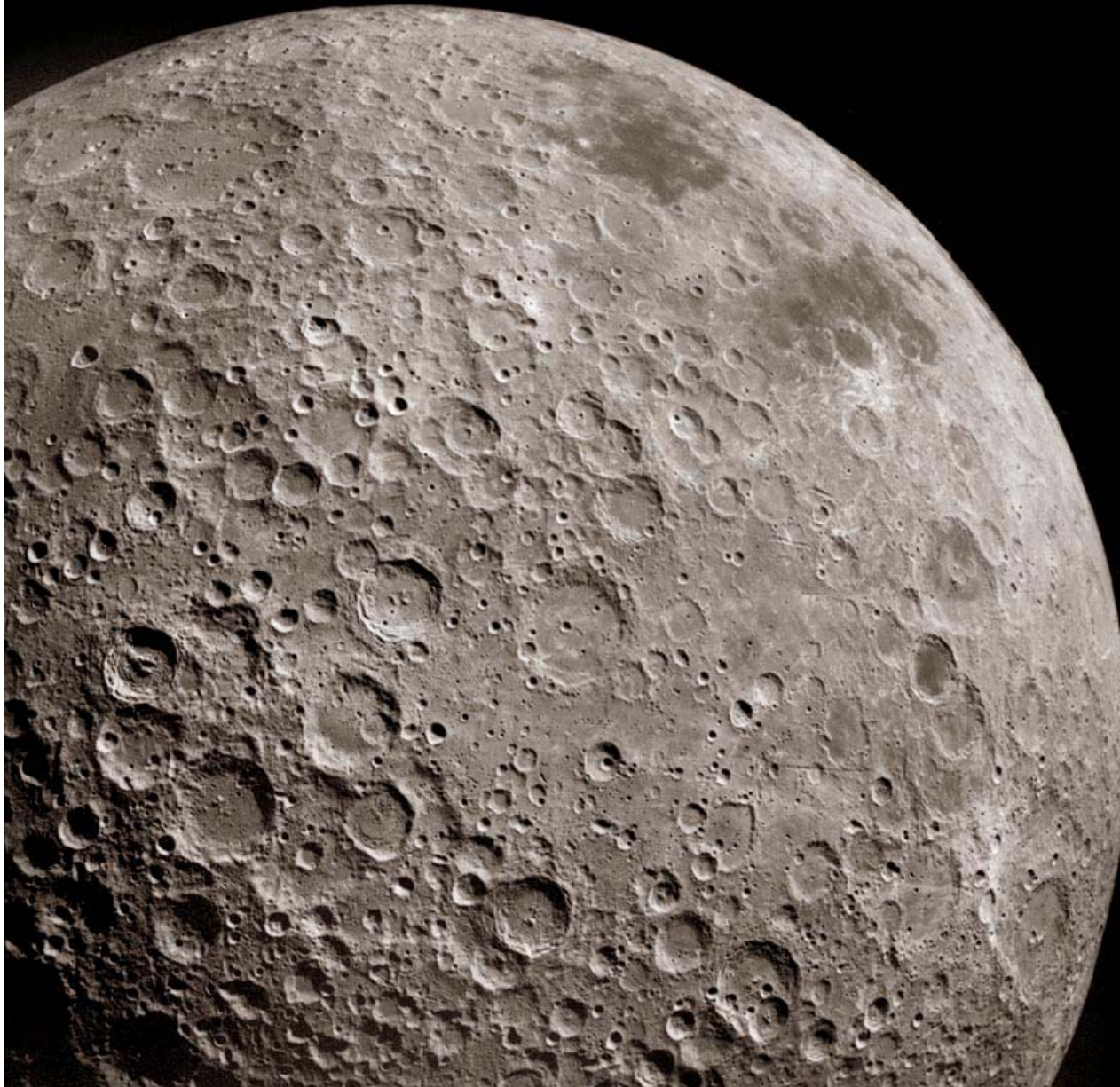


Water, always on the move, erodes the land so very few really ancient rocks remain.

We live on a dynamic planet – but what are the neighbors like?



The Moon – first port of call



A very different world.

Millions of craters, not the few seen on Earth.

Volcanoes and lava flows long ago, but now cold and inactive.

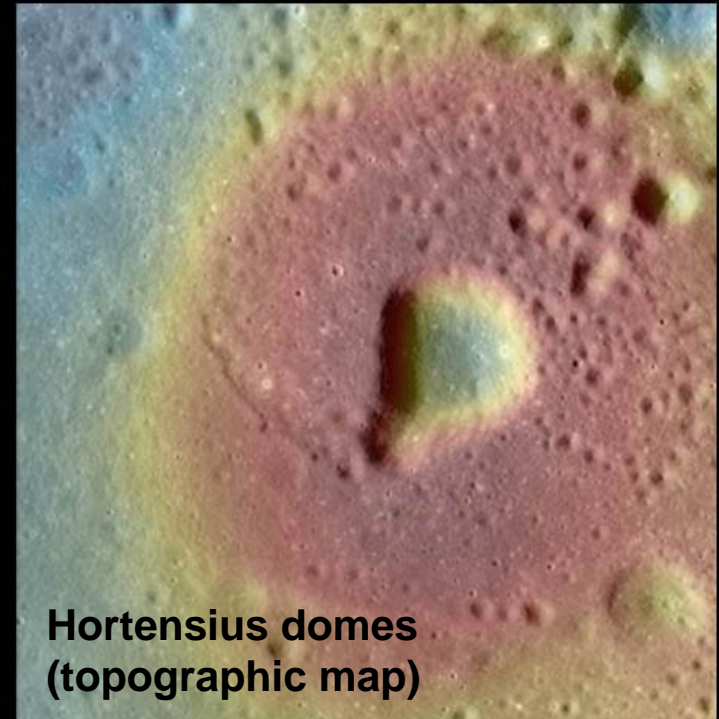
The Moon is like a geological museum.

One lesson: Earth had similar craters in the past.

The Moon – old volcanoes and lava flows



Prinz lava channels

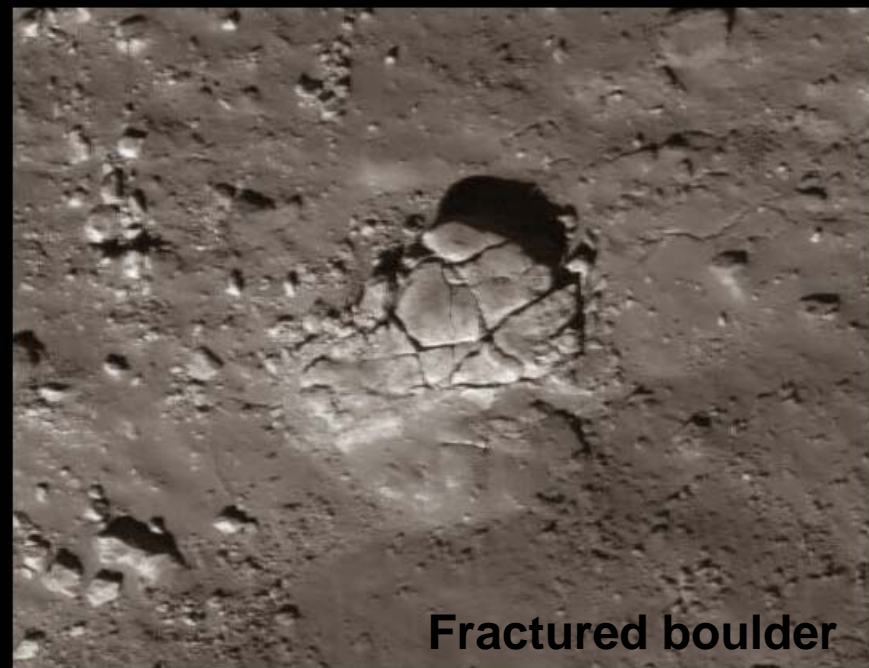
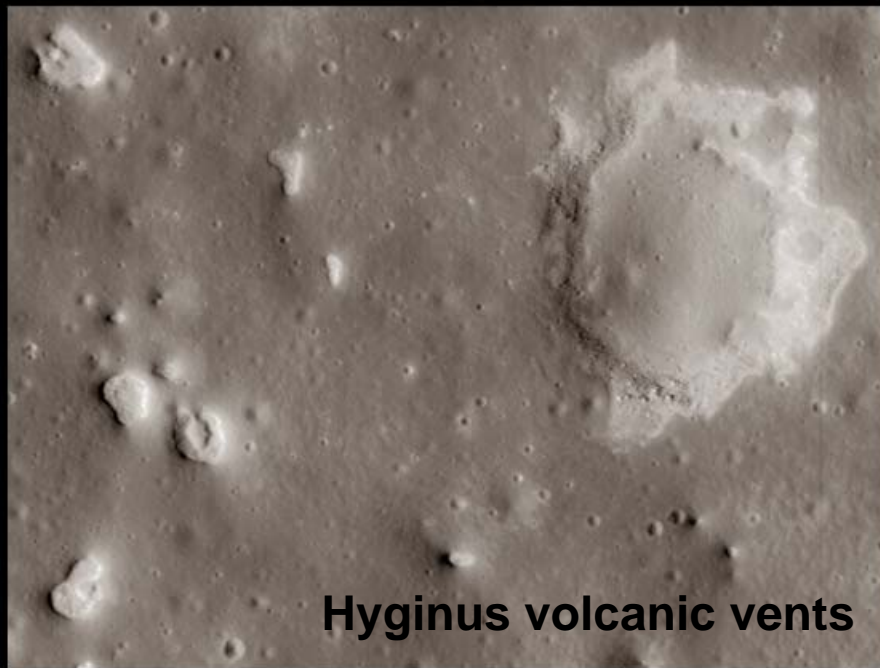


Hortensius domes
(topographic map)



Cinder cones

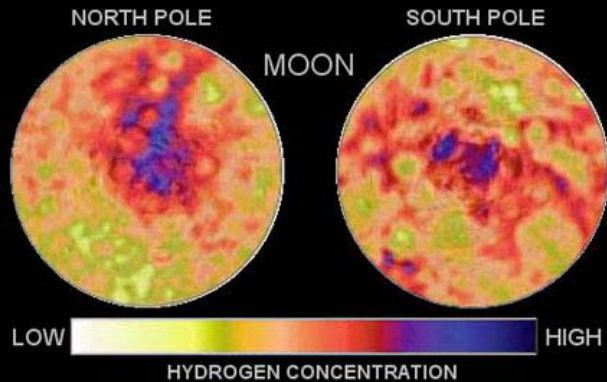
Lunar Reconnaissance Orbiter images



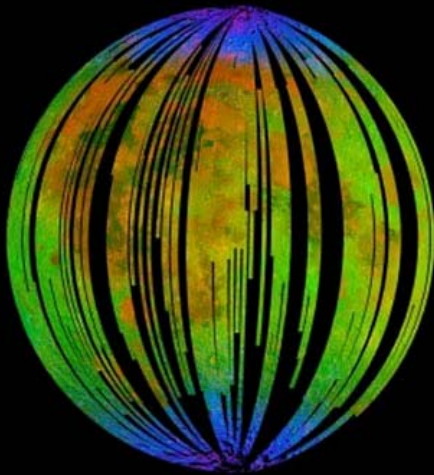
Water on the Moon

The Moon has no water... or so we used to say. Now we see that ice is found in shadows in craters at the poles

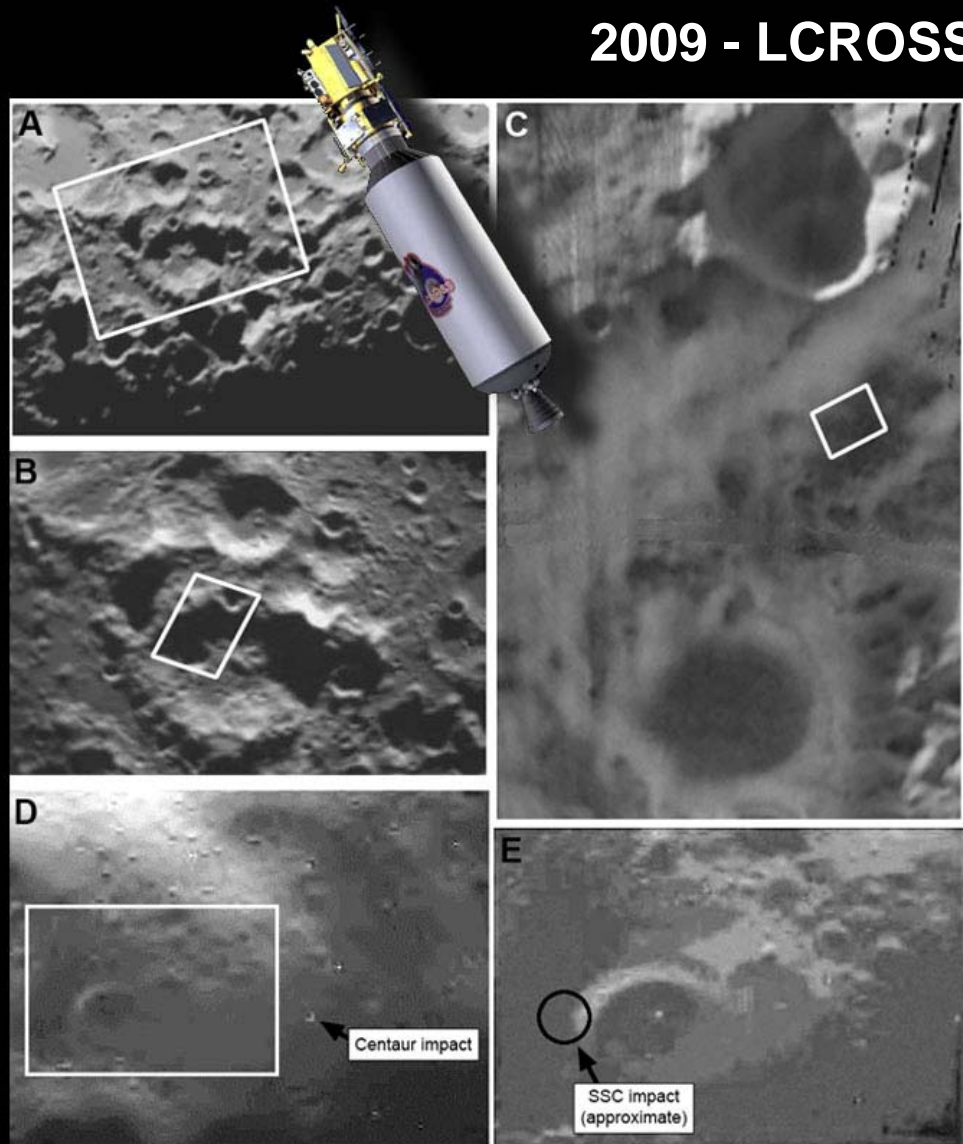
1999 – Lunar Prospector



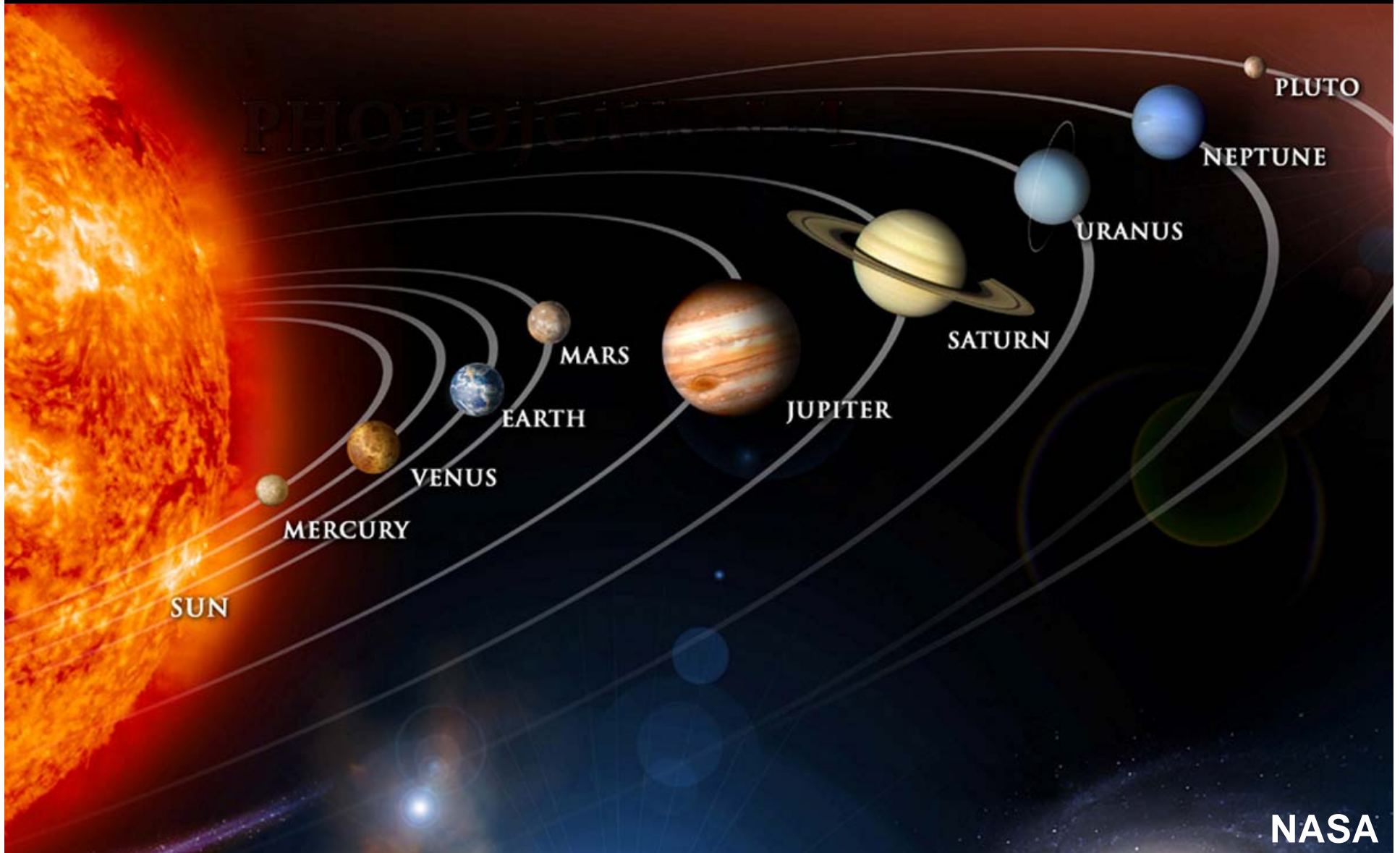
2009 – Chandrayaan 1 - MMM



2009 - LCROSS



**So Earth and the Moon are very different.
How do other worlds compare?**

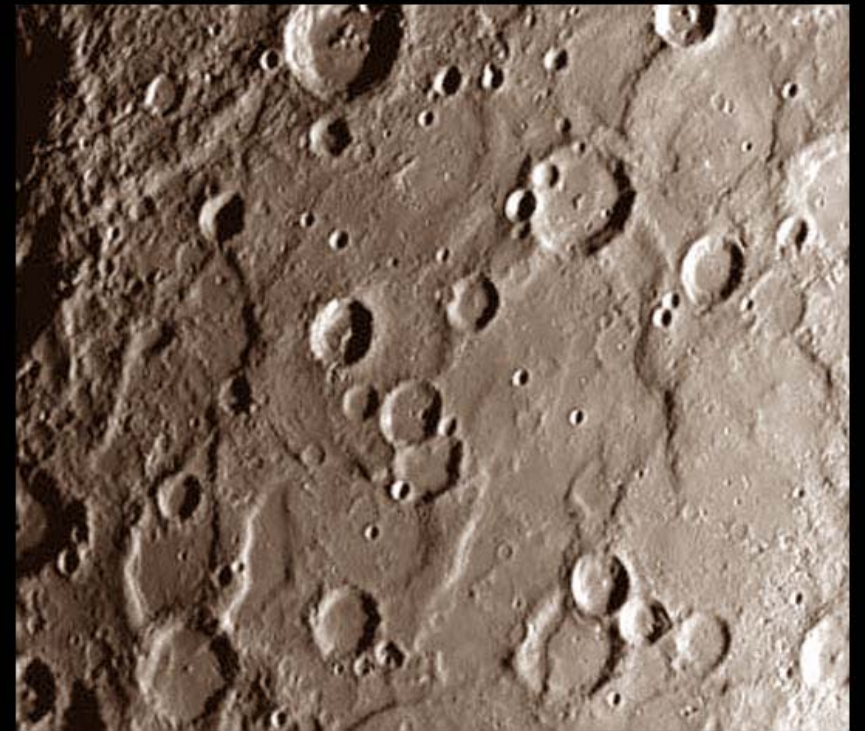


NASA

Mercury – craters and lava flows

In 1974 Mariner 10 suggested Mercury was much like the Moon.

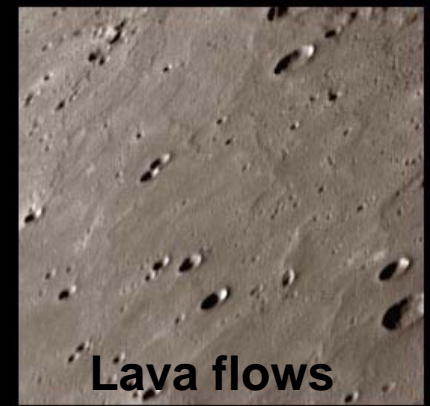
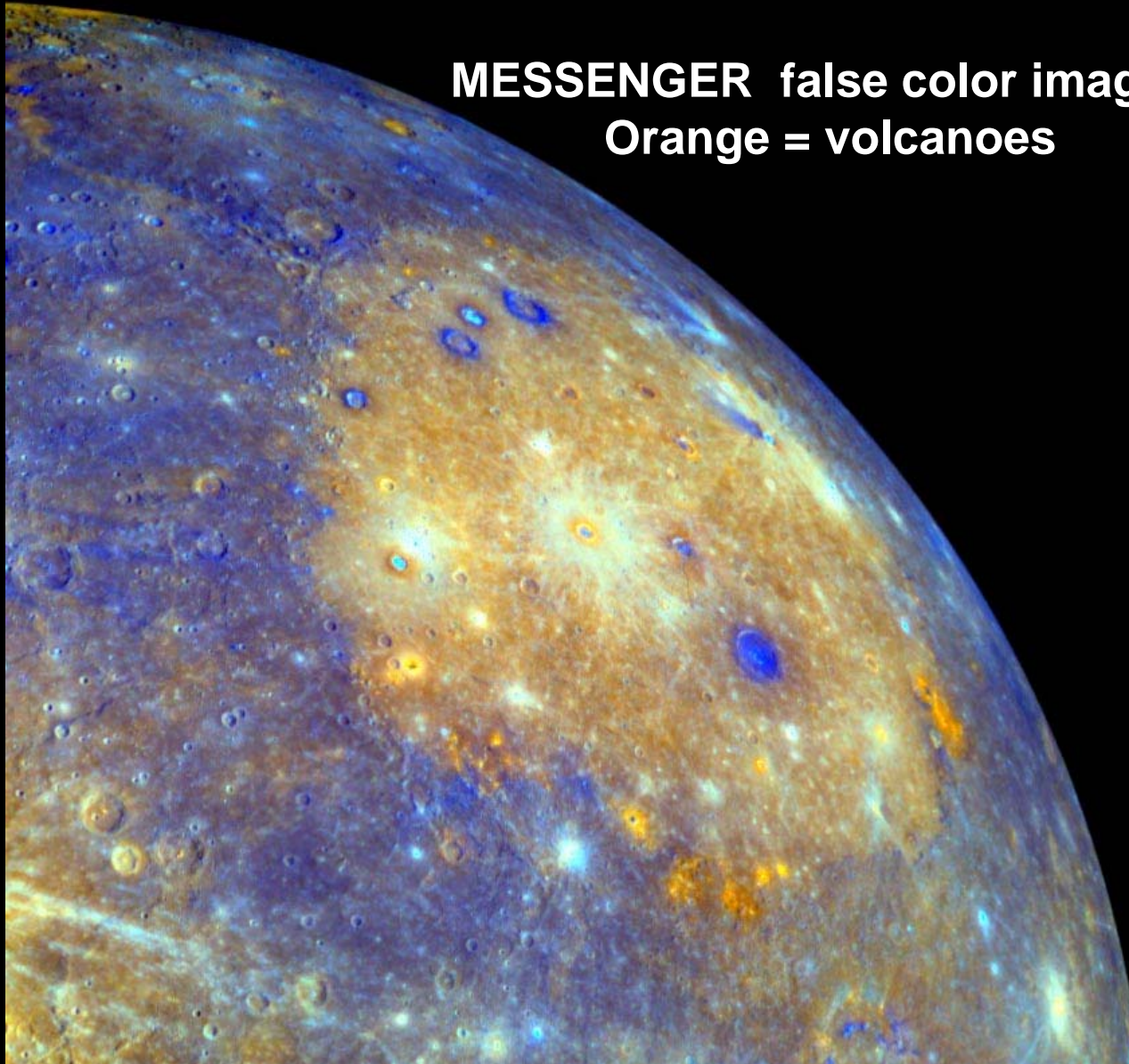
Now we have better pictures from the MESSENGER spacecraft. Mercury may have been more active than the Moon, but now it's also dead.



Mercury – volcanic ash eruptions and lava plains

They may be more extensive than on the Moon

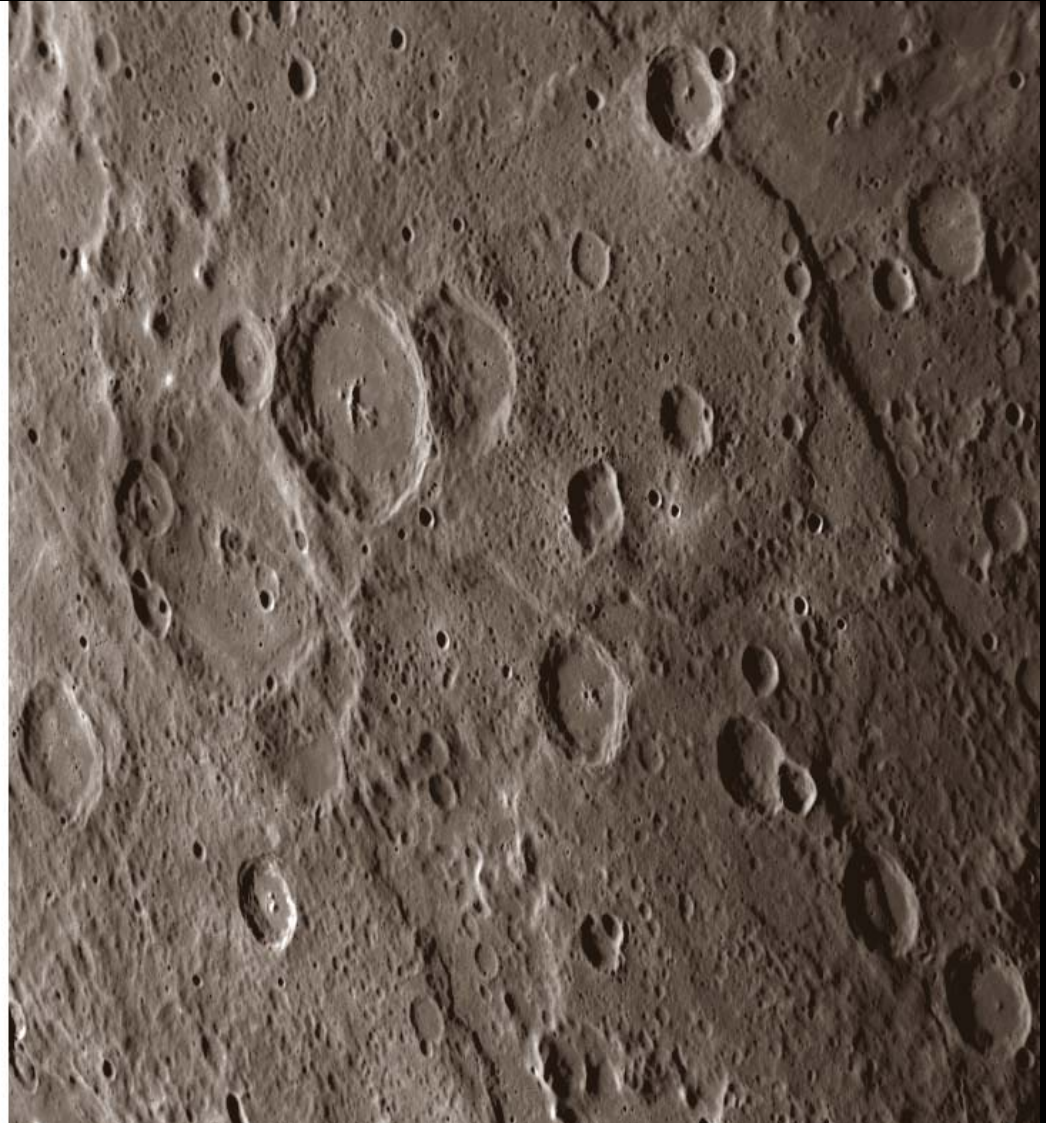
MESSENGER false color images:
Orange = volcanoes



Lava flows

Mercury – global compression: did the planet shrink?

Mercury is bigger than the Moon and may have been more active.



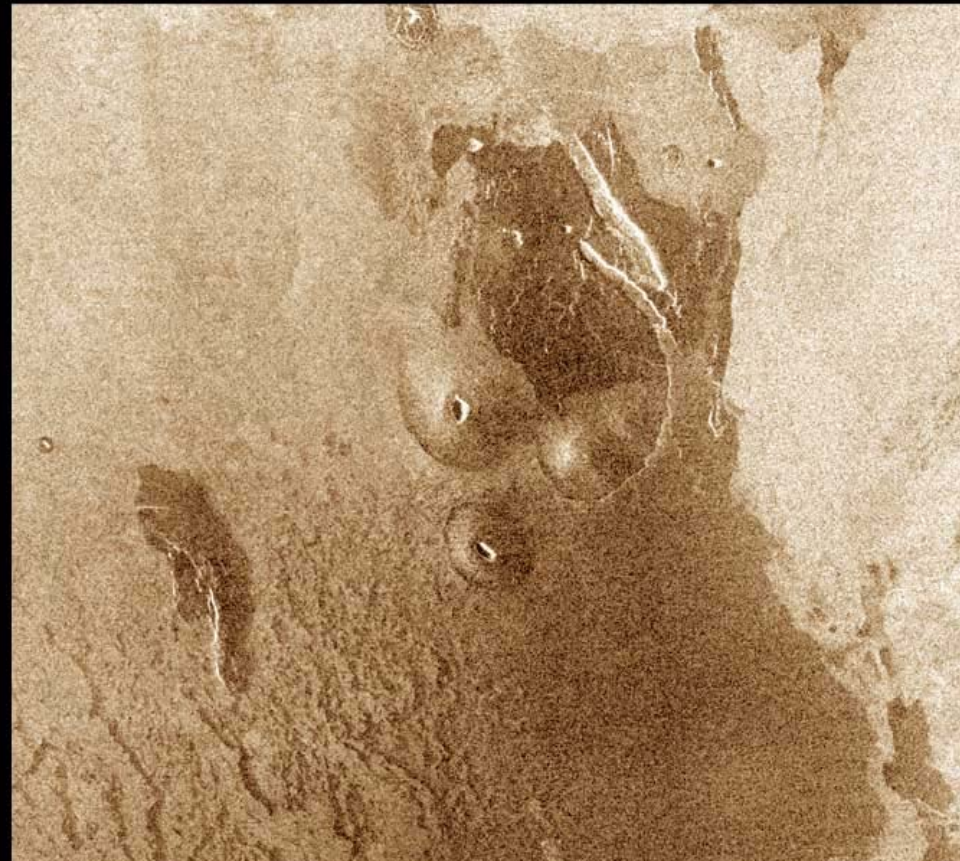
Venus – volcanoes, mountains and fractures.

A very active planet under its cloudy atmosphere.

Volcanoes are probably still erupting.



NASA's Magellan spacecraft made these radar images of lava flows and volcanoes



Venus – craters and channels

Very few craters – all the old ones were covered by the lava. Channels up to thousands of miles long, cut by lava (too hot for water)



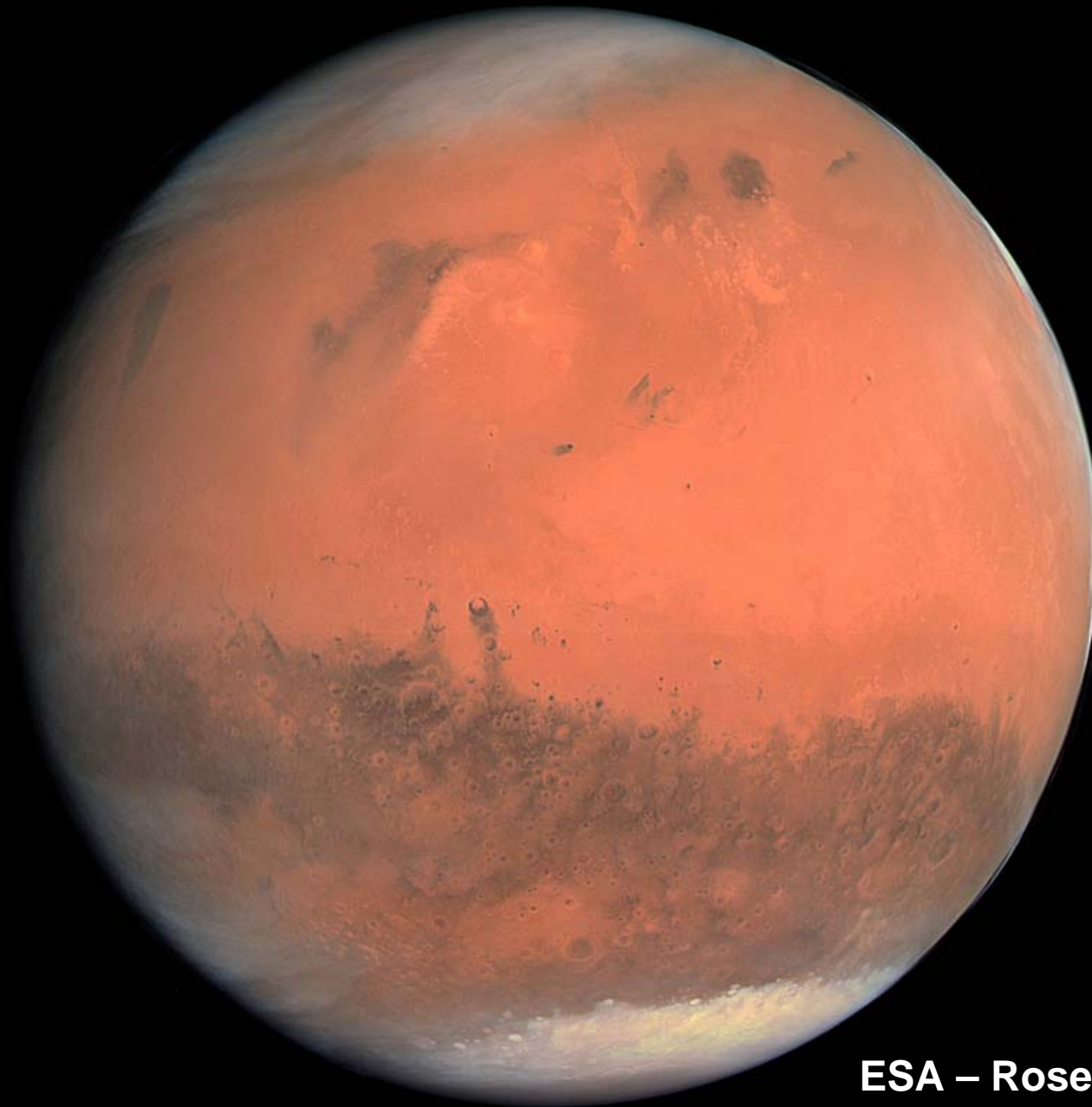
Venus from the surface - a stifling desert

Venus is slightly smaller than Earth, almost as active, but less eroded because it's too hot for liquid water.



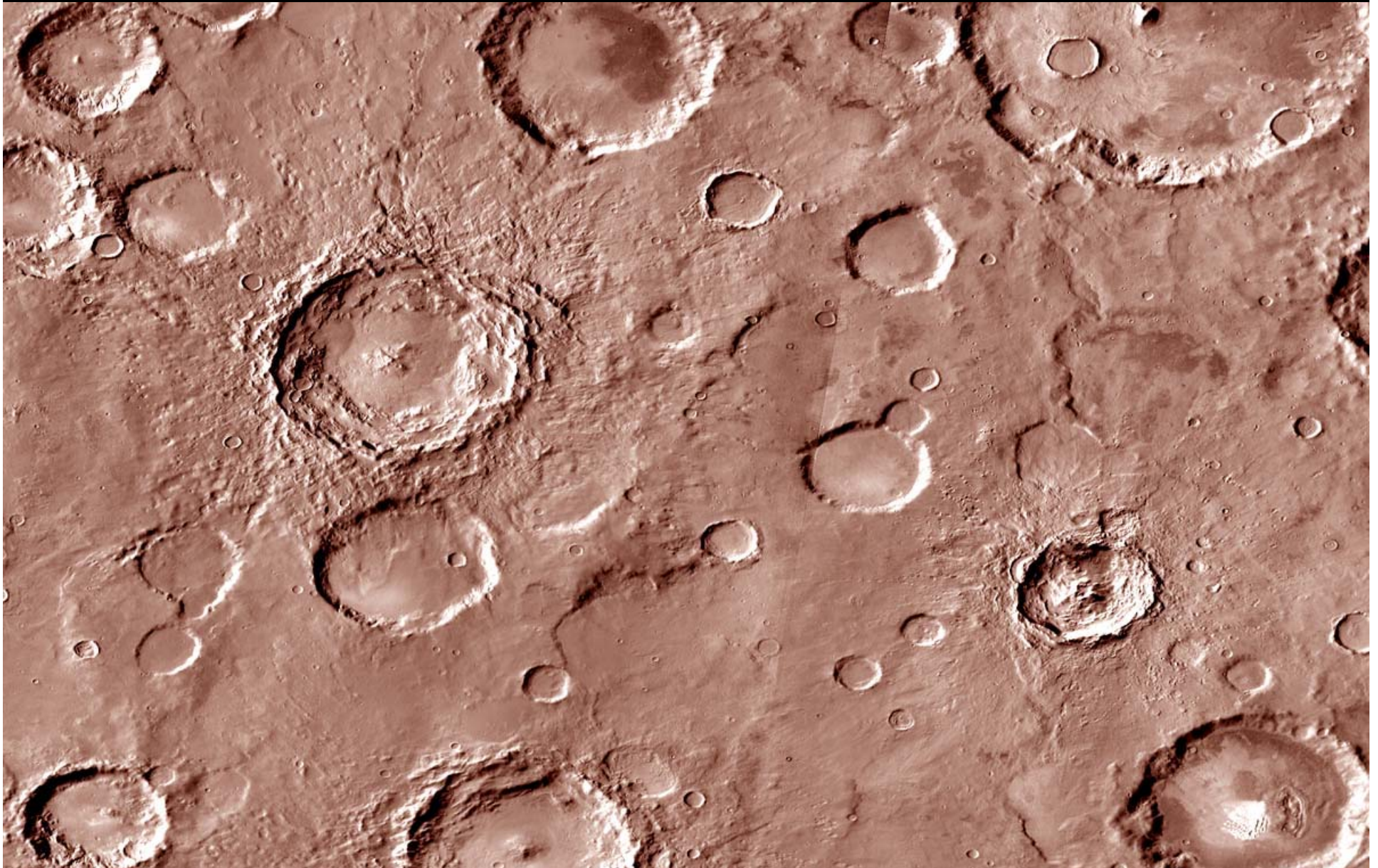
**Soviet
Venera
images**

Mars – intermediate in size and activity

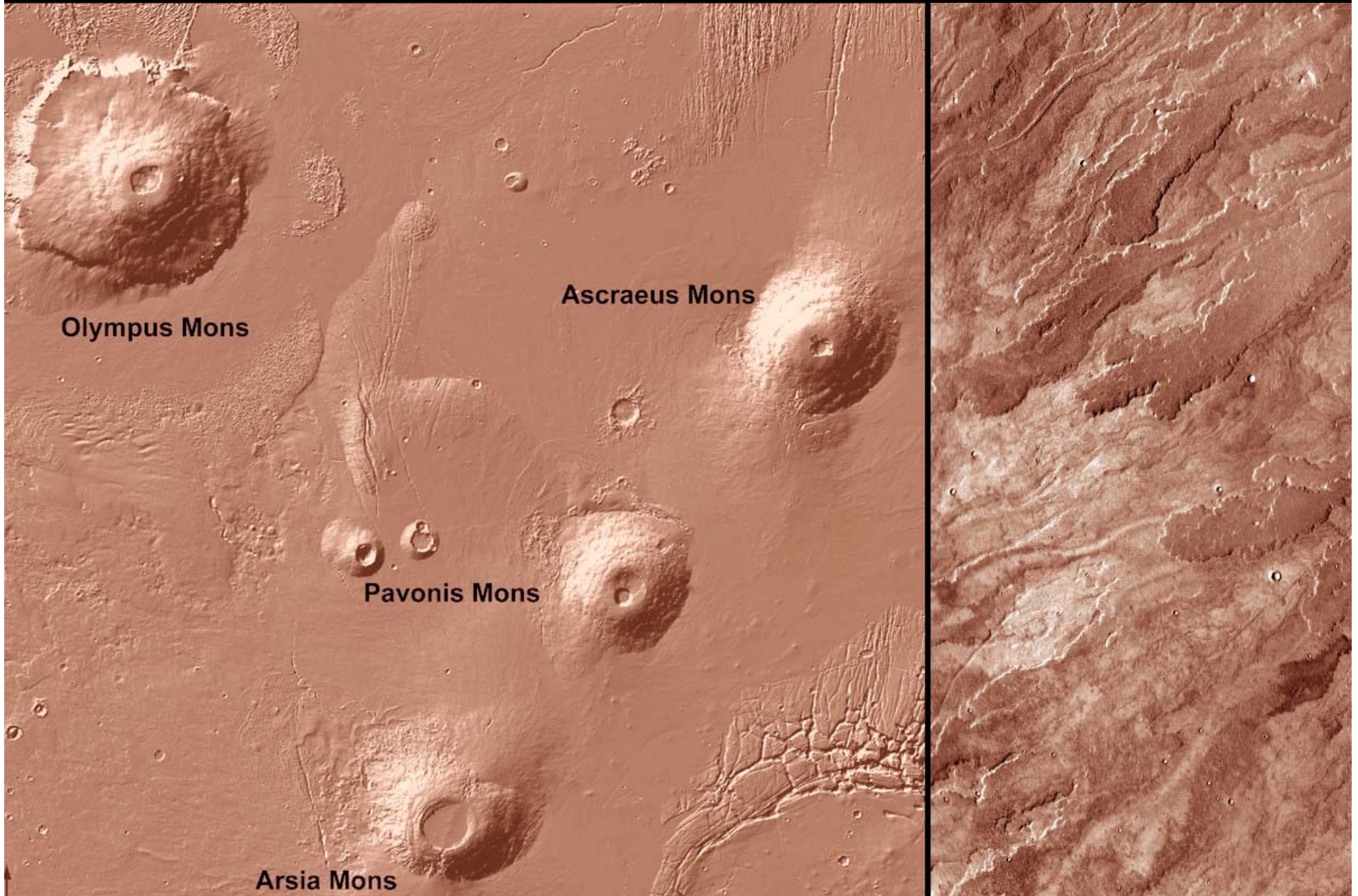


ESA – Rosetta image

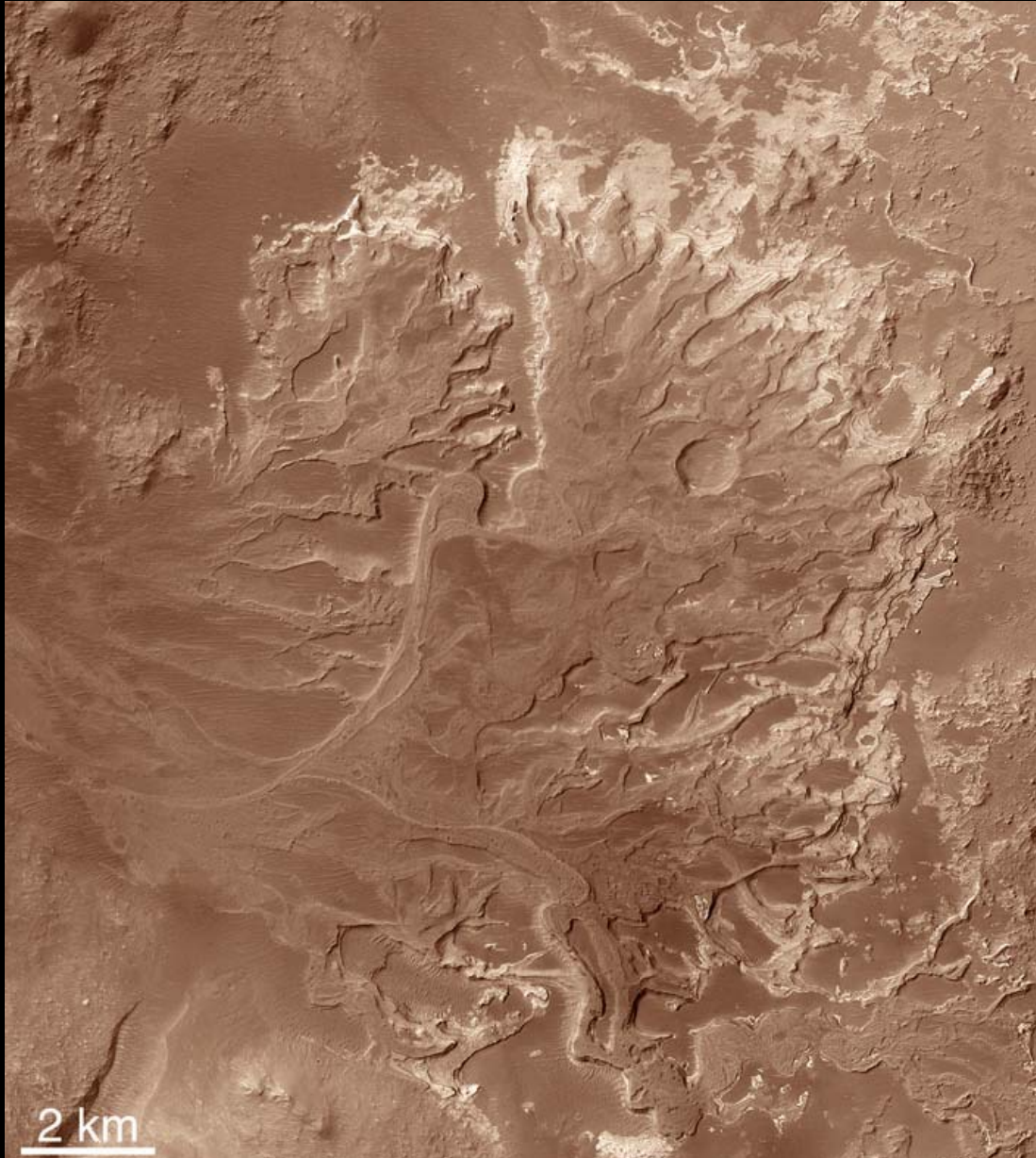
Mars – plenty of craters, but more eroded than on the Moon



Mars – giant volcanoes, lava flows, possibly some activity even now



Mars – dry river beds? Mars was wet in the past.
Now it's too cold for water but still has plenty of ice.



Eberswalde – fossil delta

Warrego Valles – dry stream beds



Moons of Mars - too small to be active, or even round

Most worlds less than 500 km across don't have enough gravity to make themselves spherical

Phobos – 25 km across

Deimos – 15 km across



Mars Reconnaissance Orbiter images

The inner planets tell a nice simple story:

Small worlds are less active, large worlds are more active

Early retirement

Still going strong



Moon

Mercury

Mars

Venus

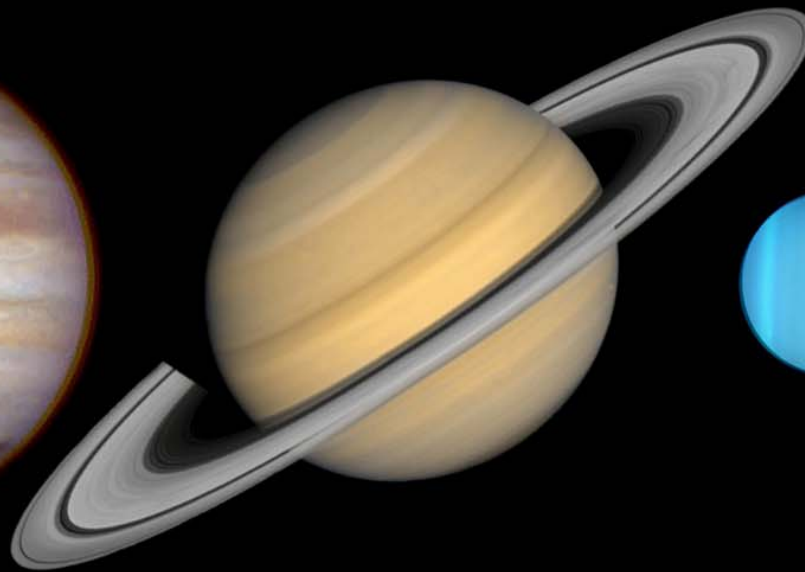
Earth

Giant planets – great balls of gas

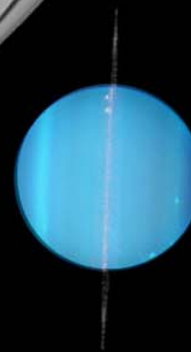
They all have solid rocky cores like Earth itself.
They all have rings, but only Saturn's are easy to see.
They all have lots of moons



Jupiter



Saturn



Uranus

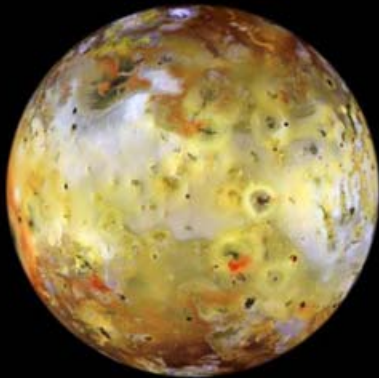


Neptune

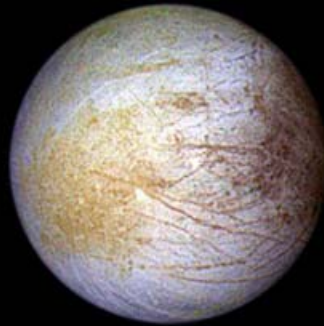
Moons of Jupiter

Scientists once feared they would be boring

Io



Europa



Ganymede



Callisto



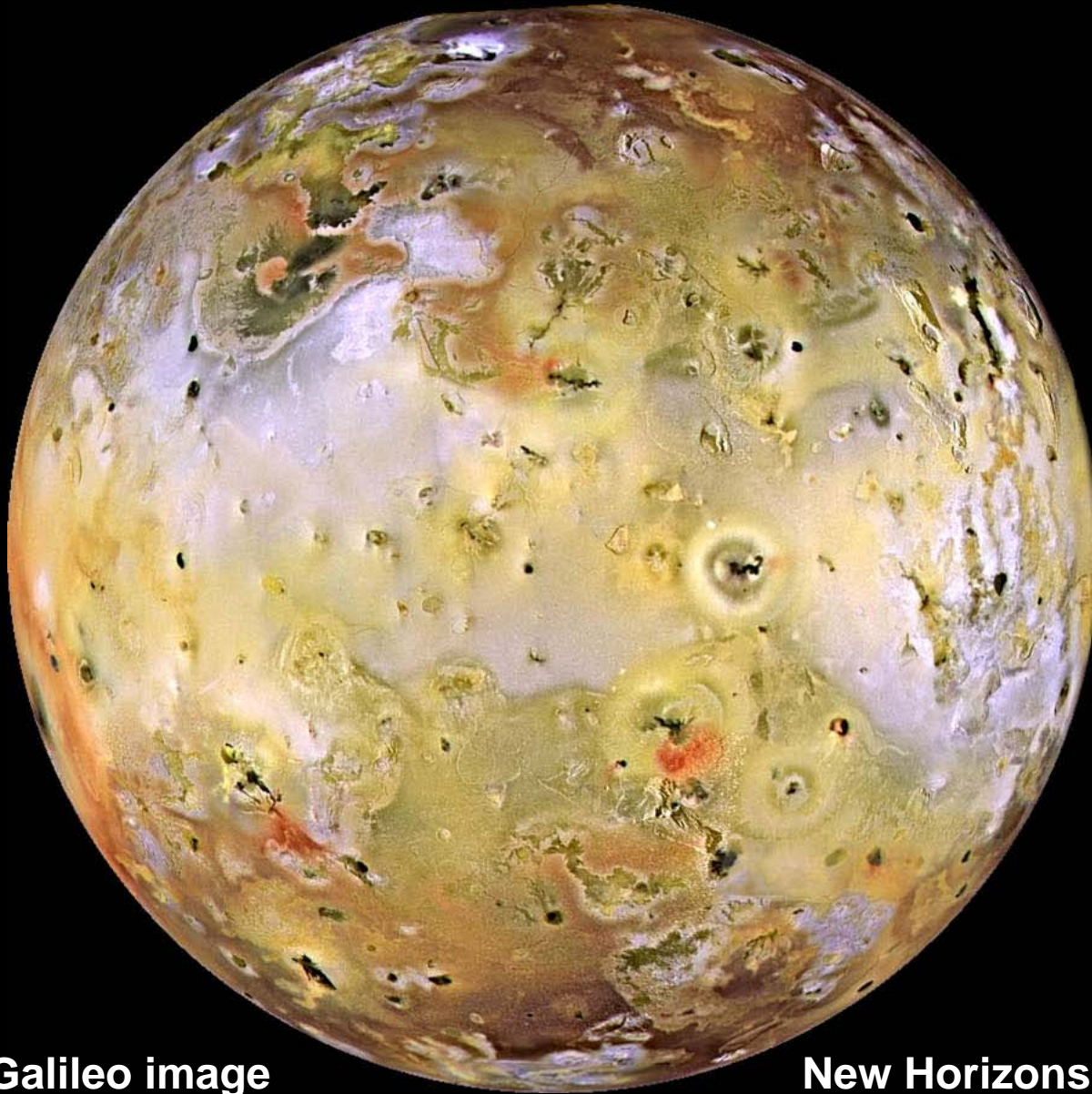
Closest to Jupiter

Most distant

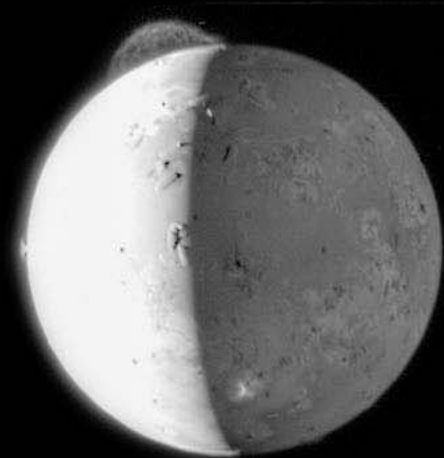


Io – covered with active volcanoes

Io is heated by Jupiter's gravity – by strong tides in its rocky body

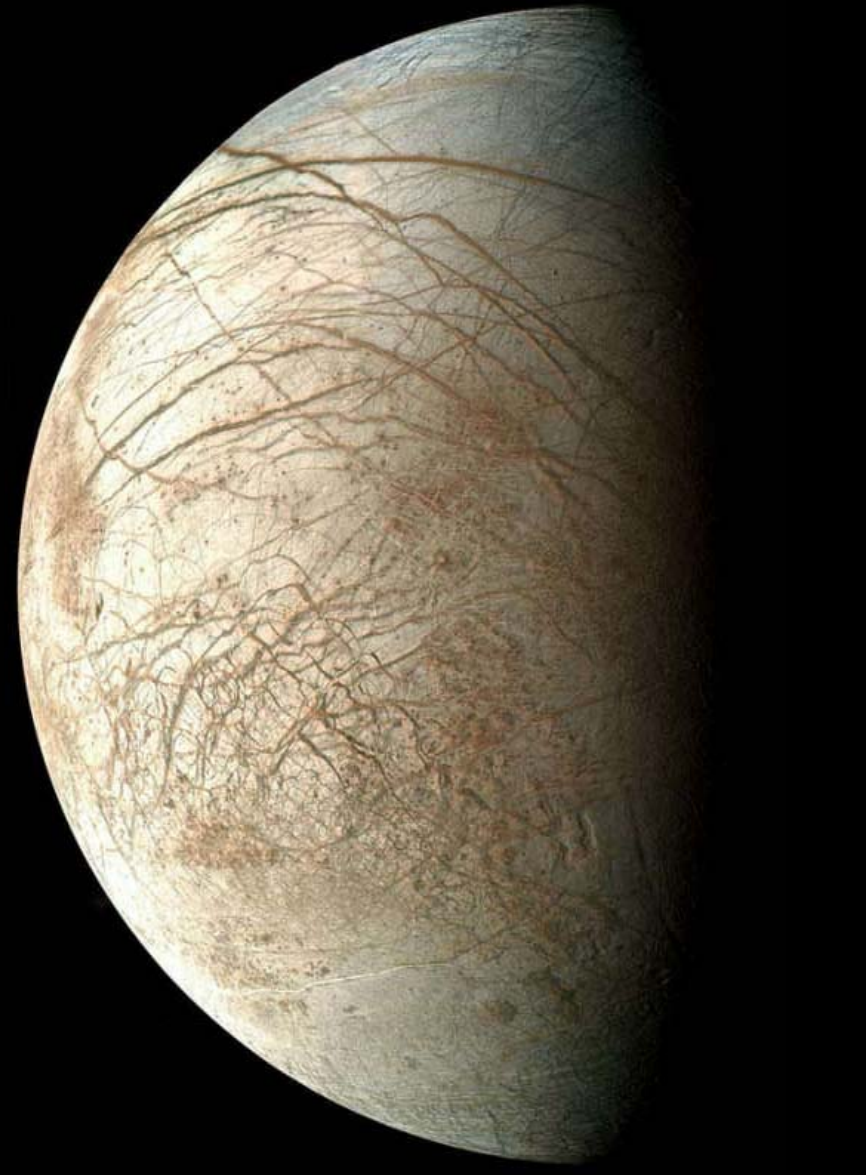


Galileo image



New Horizons images

Europa – Ice floating on a global ocean? Very few craters.
A young, active surface on a world smaller than our Moon



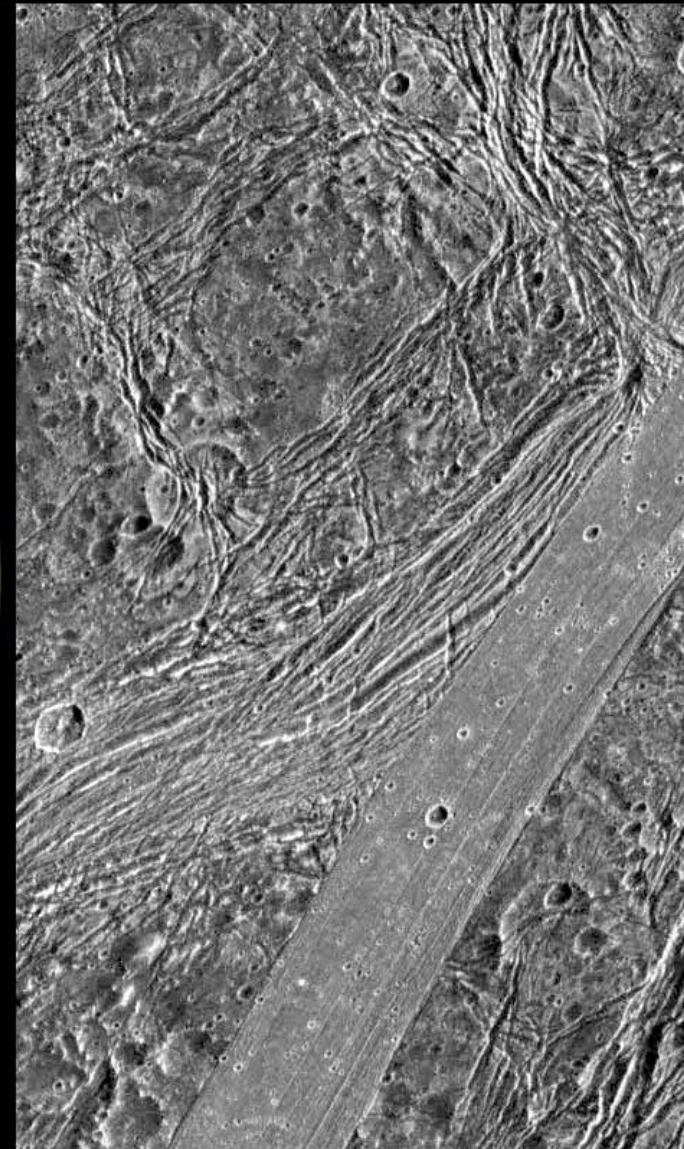
Ganymede – the biggest moon of all, bigger than Mercury.

A fractured surface and a magnetic field – maybe an ocean deep inside.

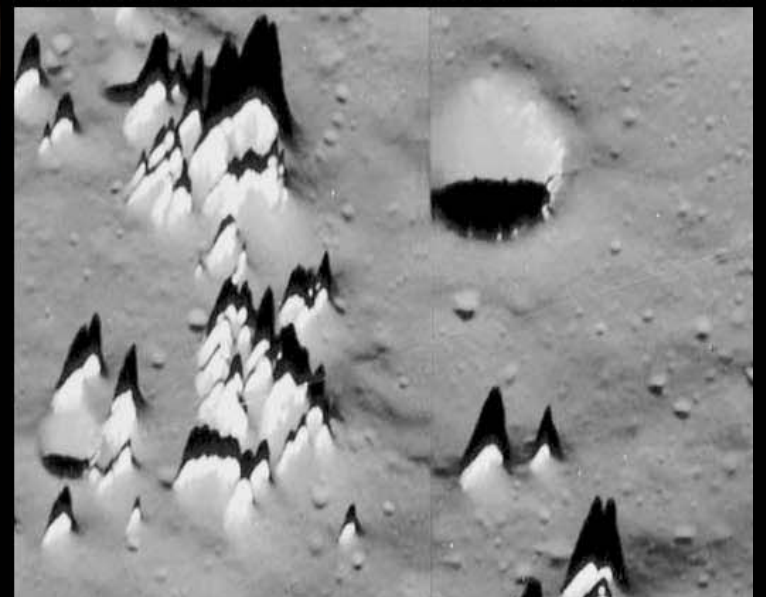
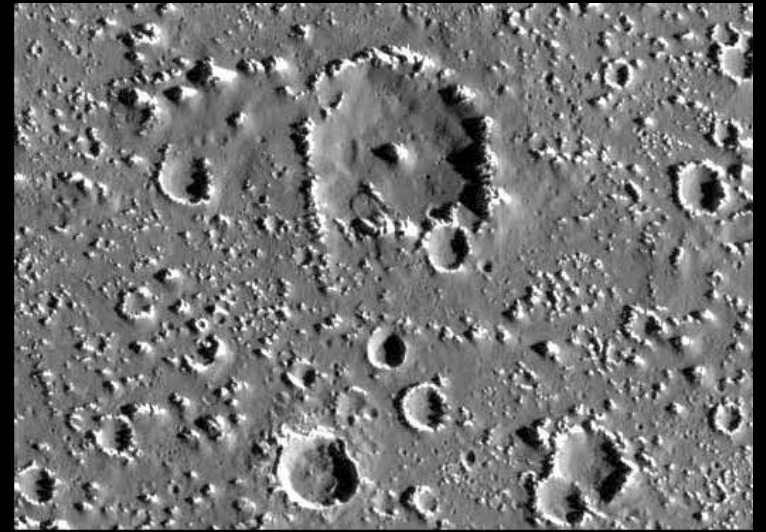
Not as active as Europa, but it's been busy.



Galileo images



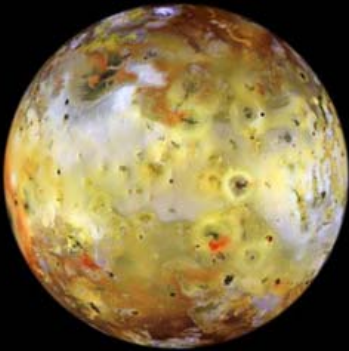
Callisto — wall-to-wall craters, huge concentric ring structures, bizarre ice spires - is the sun evaporating a surface of dirty ice?
No fractures, no internal heat, another retired moon.



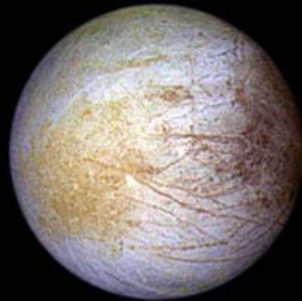
What pattern of activity?

Close to Jupiter, very active - far from Jupiter, not active
(Jupiter is the source of the energy)

Io



Europa



Ganymede



Callisto

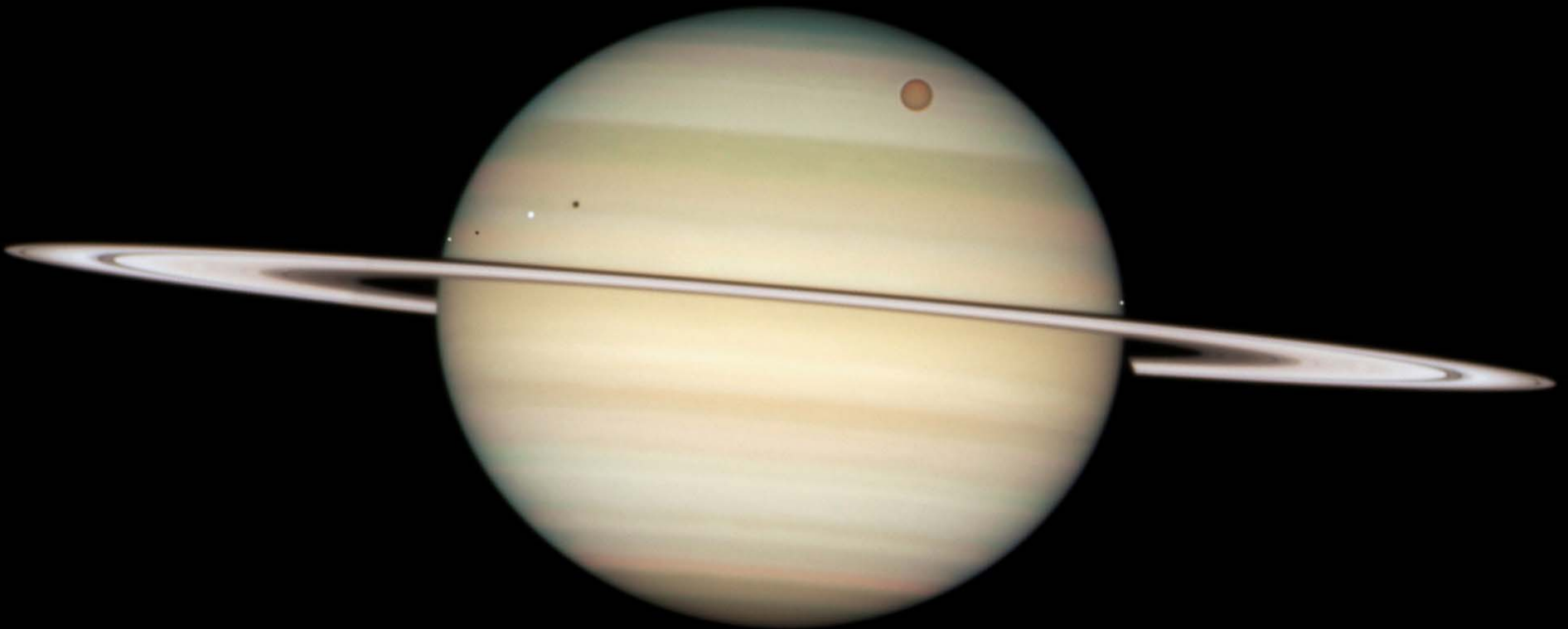


Closest to Jupiter

Most distant

Saturn – bright rings and many moons.

What pattern will we find among the moons of Saturn?



NASA – Hubble Space Telescope

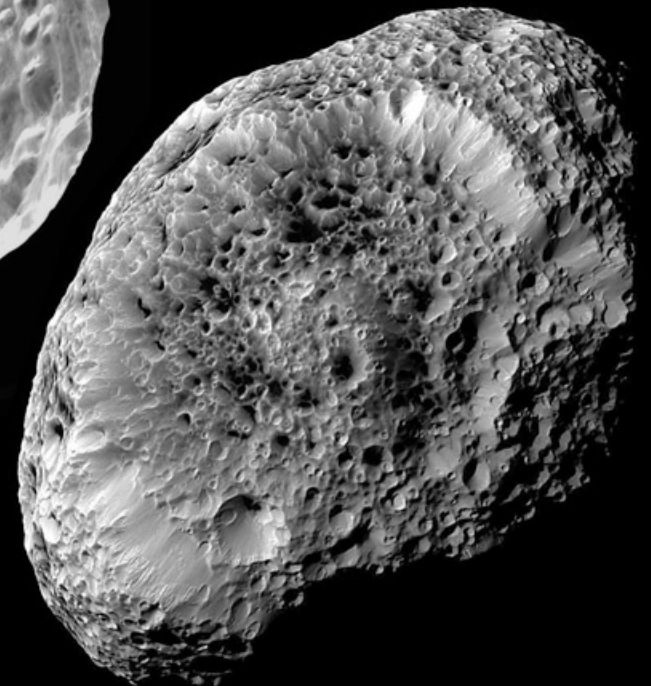
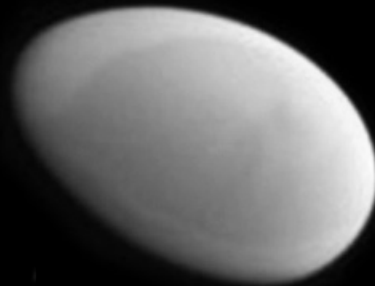
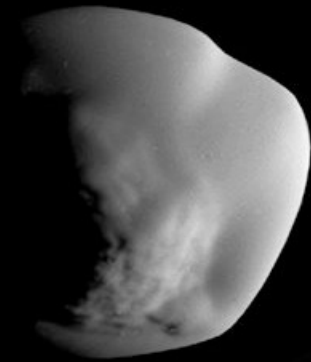
Small moons – take the rough with the smooth

Atlas

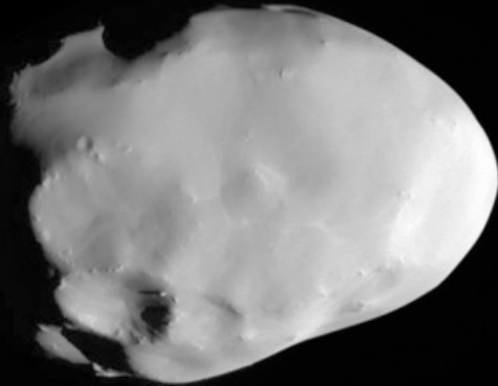
Methone

Phoebe

Hyperion

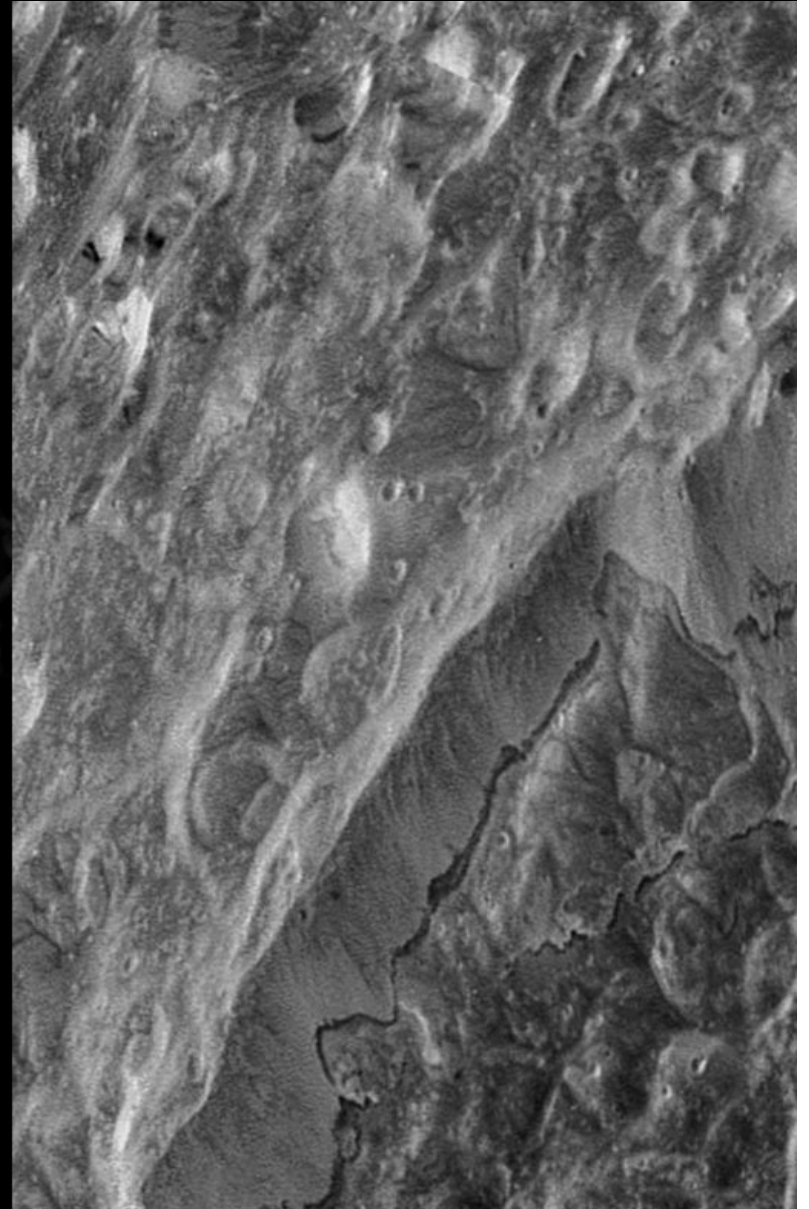
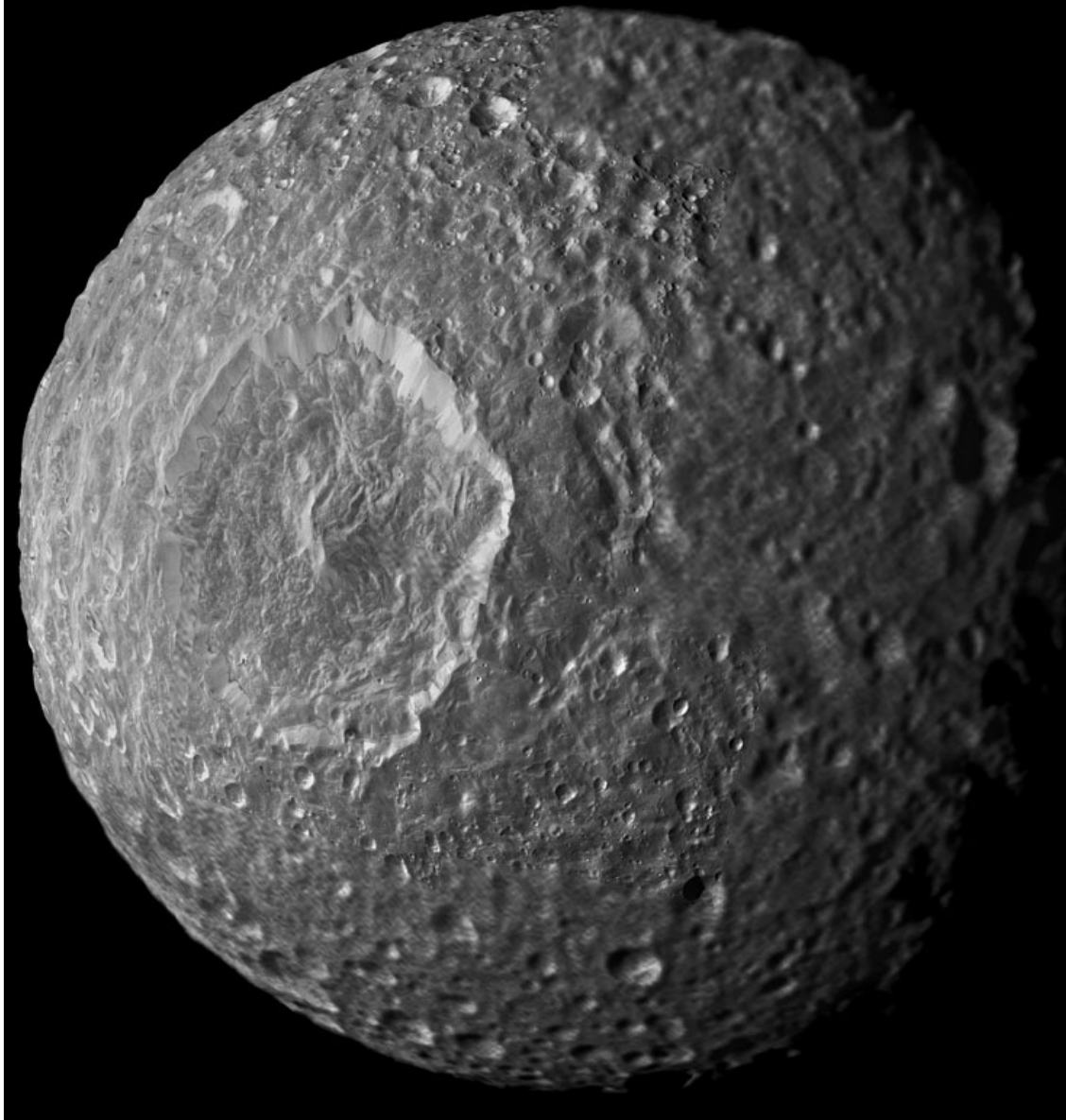


Telesto

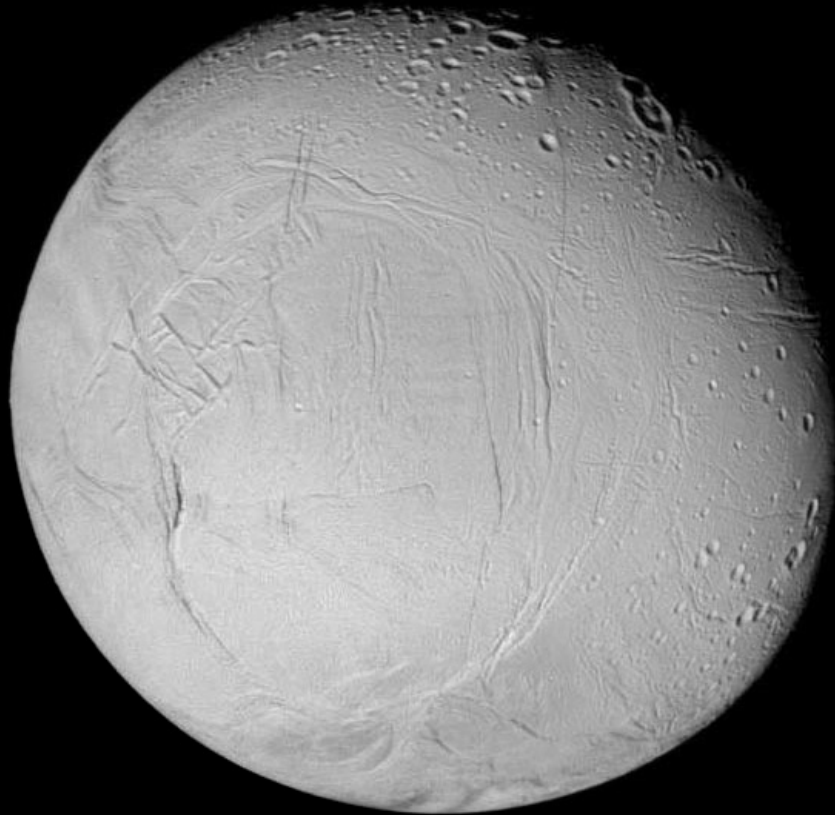


Are some moons covered with dust from the rings?

Mimas – not much happens here except impacts
-but why does the largest crater have a bathtub ring?

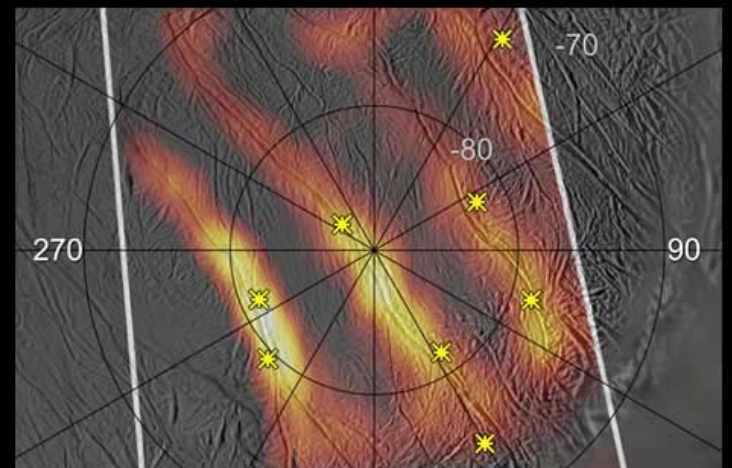
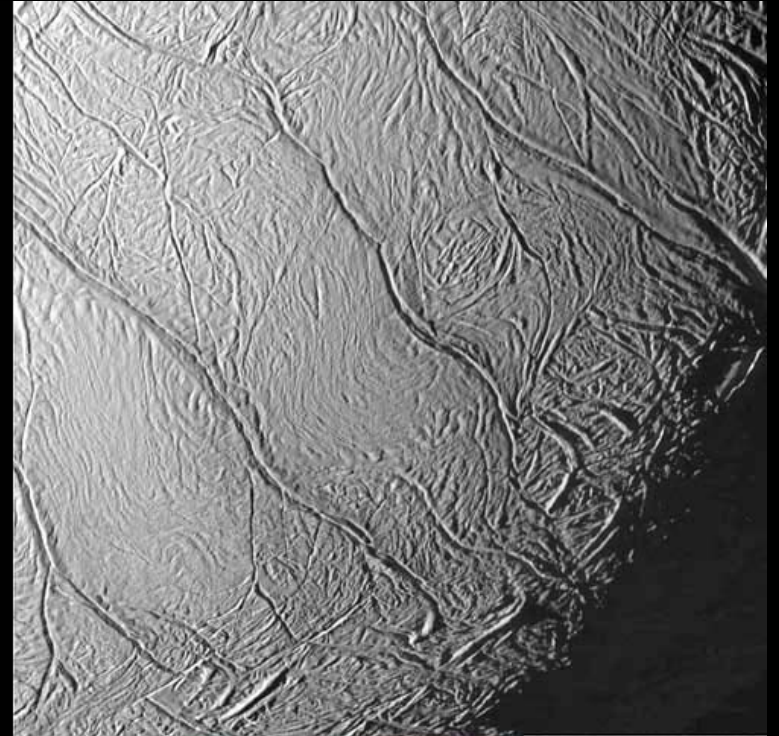
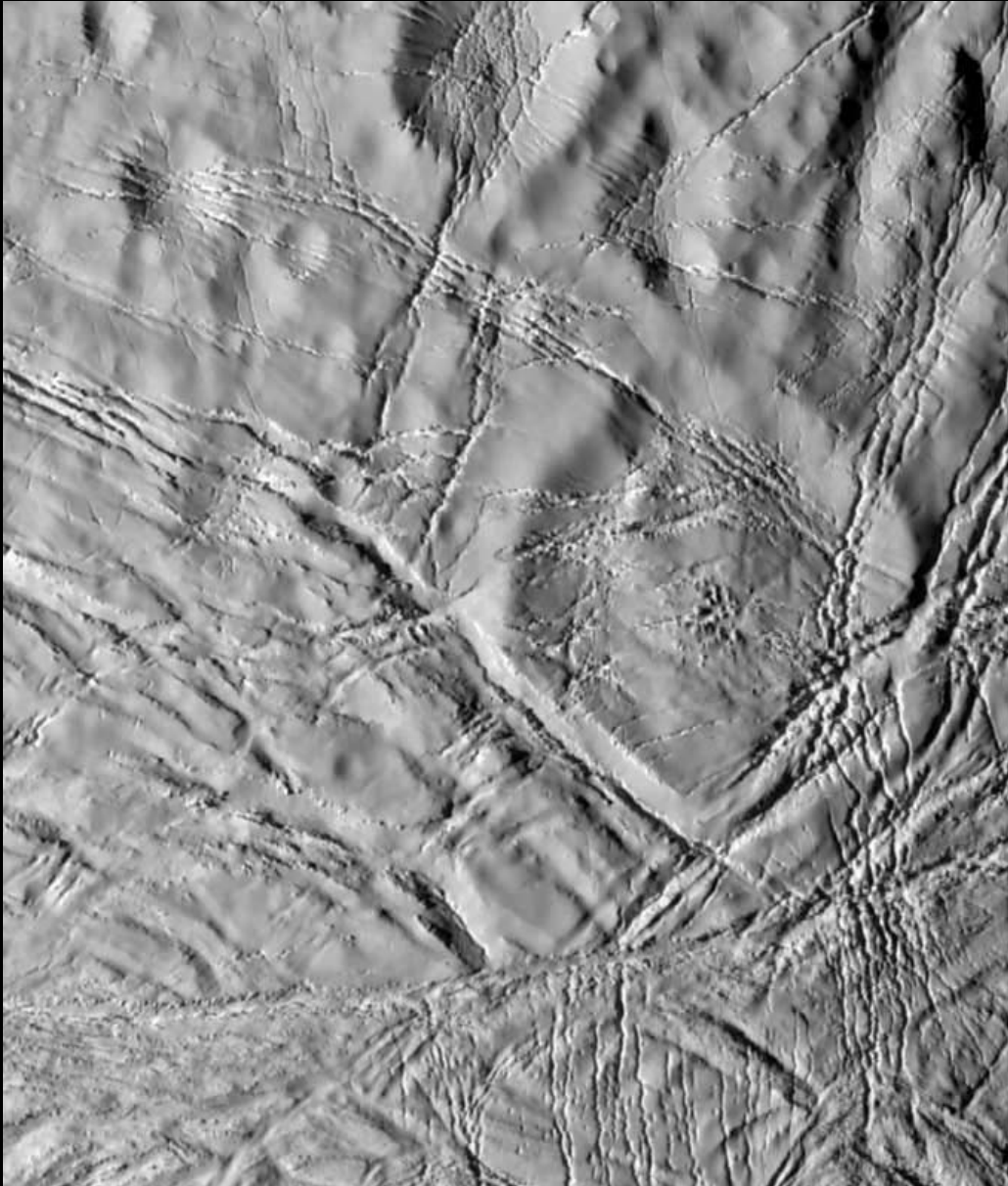


Enceladus - next door to Mimas and only 500 km across, but always active: jets of water vapor erupt from cracks at its south pole.

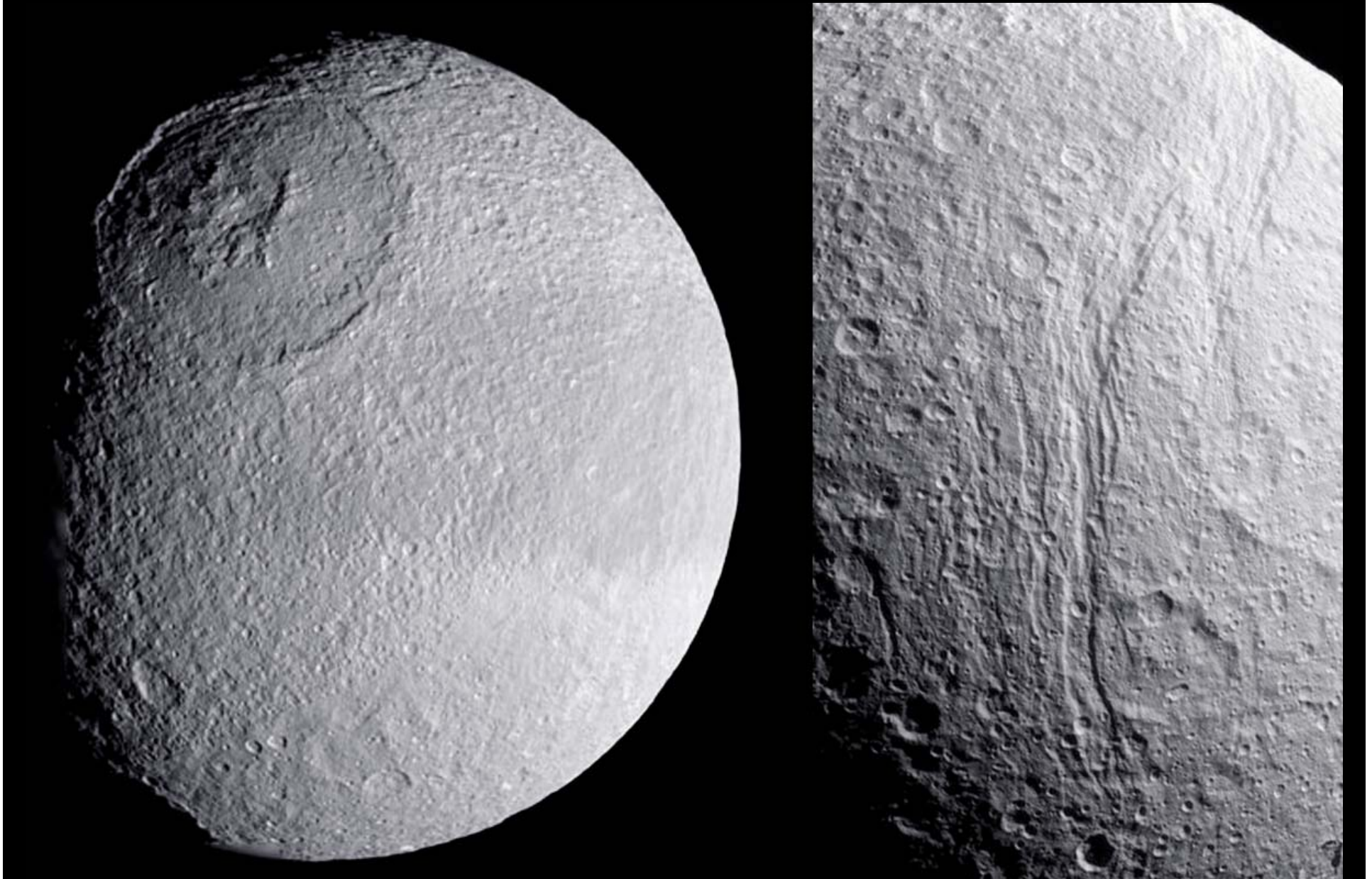


The surface has a few craters, but most areas are smooth or cracked. A very active little world.

Enceladus – a deeply fractured surface. Jets emerge from warm cracks – is there a liquid ocean underneath?

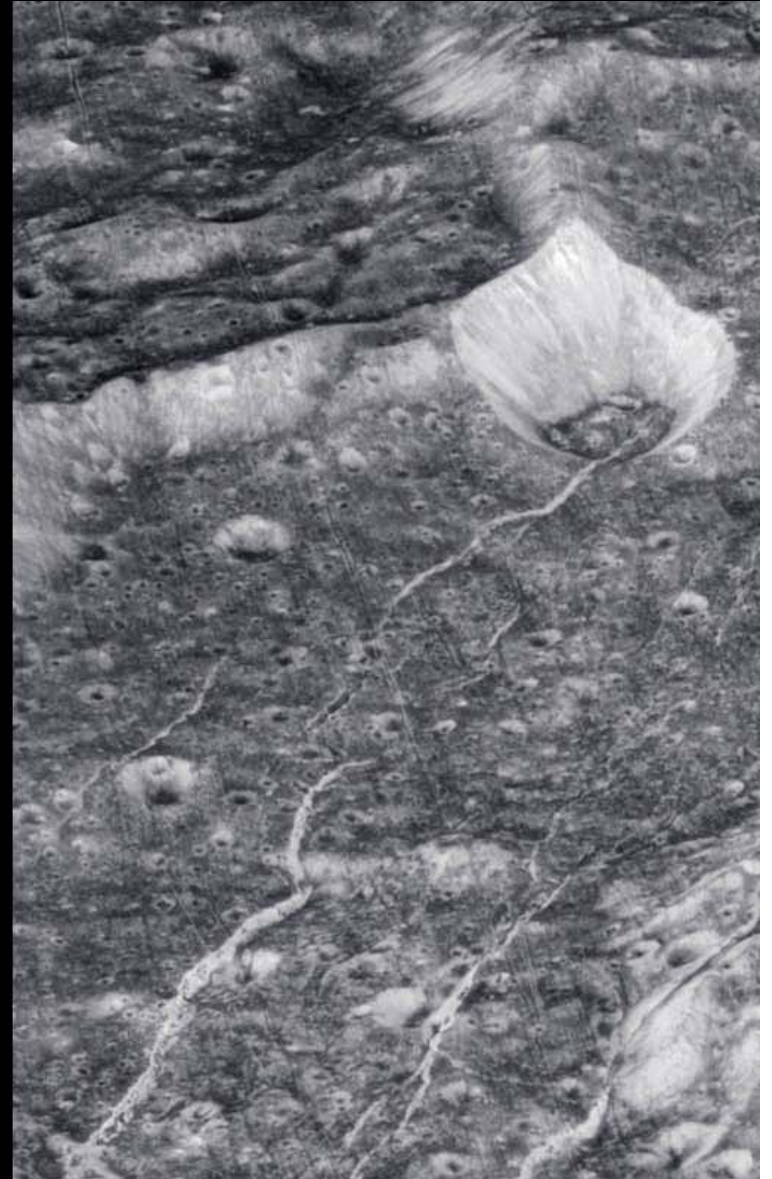


Tethys – giant crater, giant valley. All its fractures are concentrated in one place, like the East African Rift Valley



Dione – bright and dark and cracked all over.

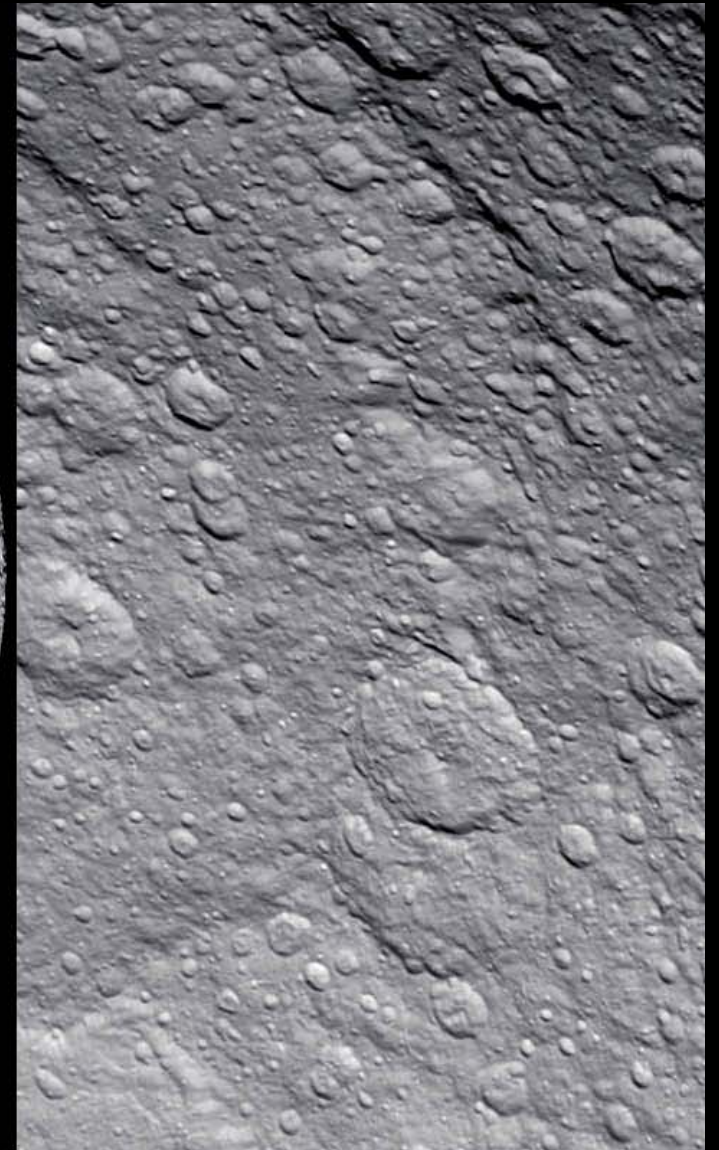
Scientists wonder if water is erupting from Dione as well, none seen yet.



Rhea – another moon that took early retirement.

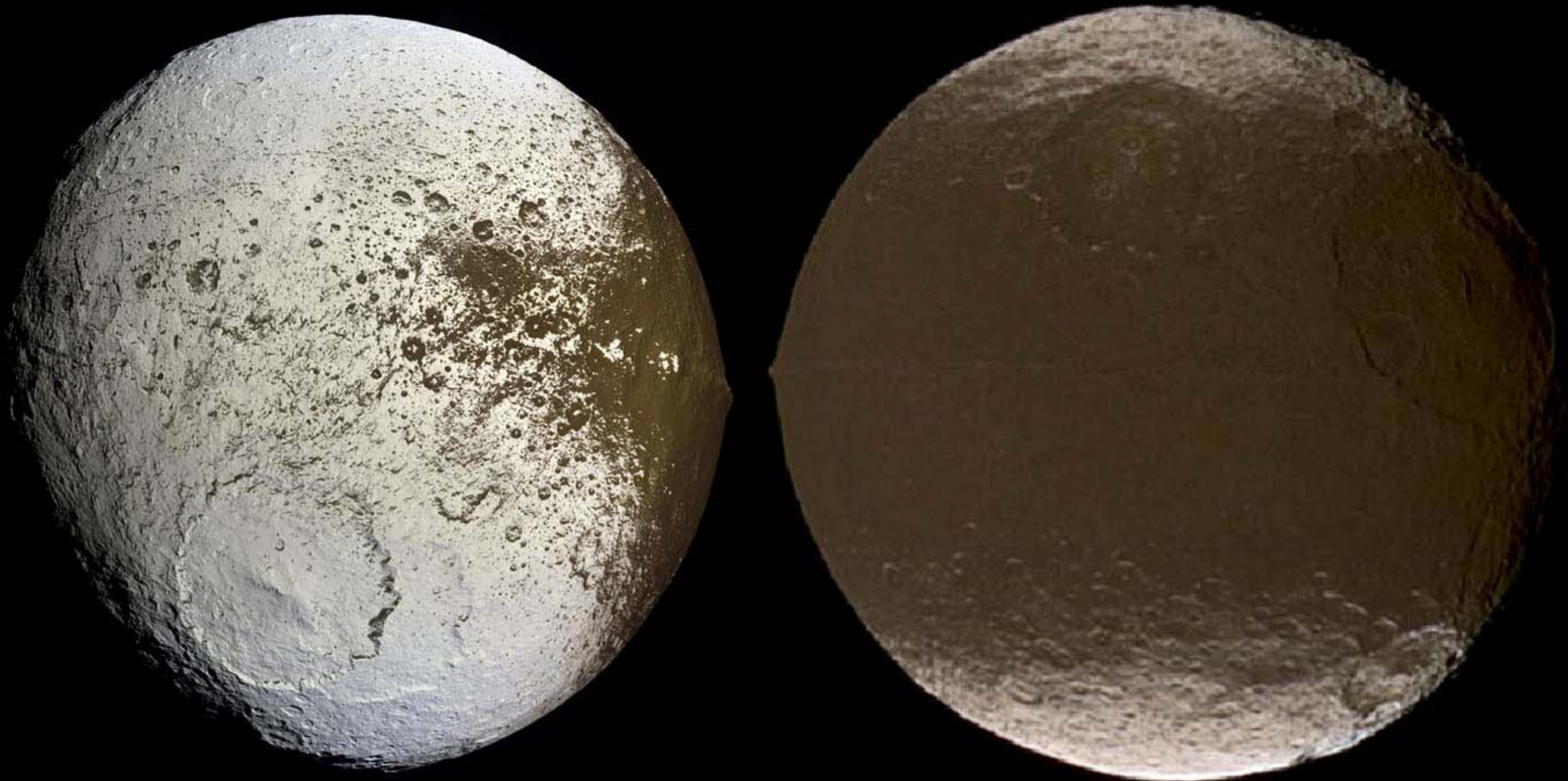
We've been moving out from Saturn – no pattern of activity yet.

But no two moons are the same.



Iapetus – taking it to extremes. The greatest contrast from one side to the other in the solar system.

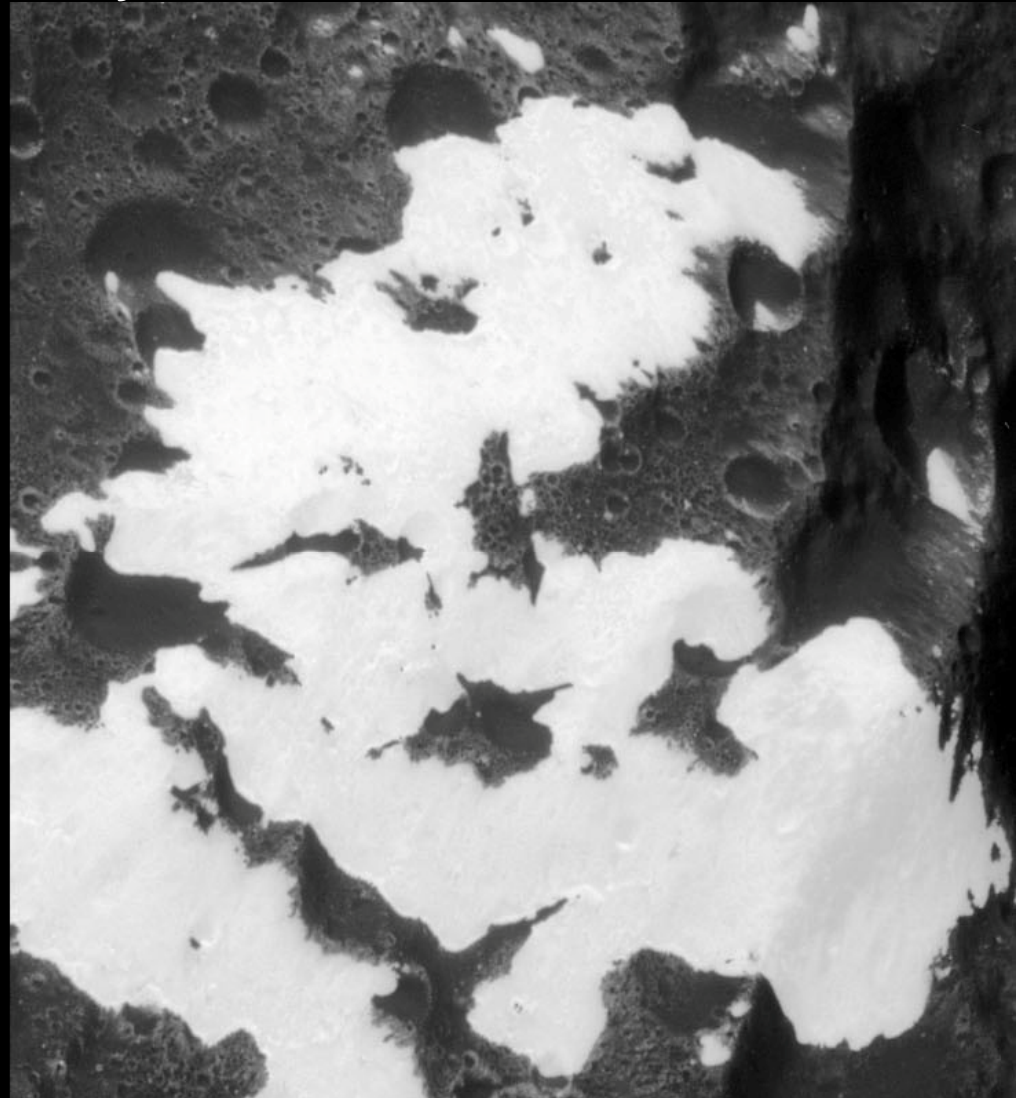
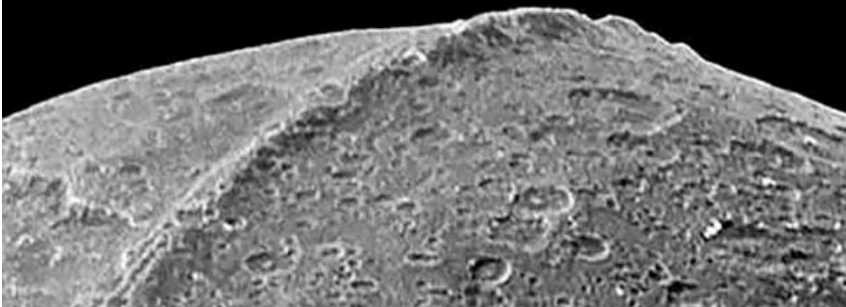
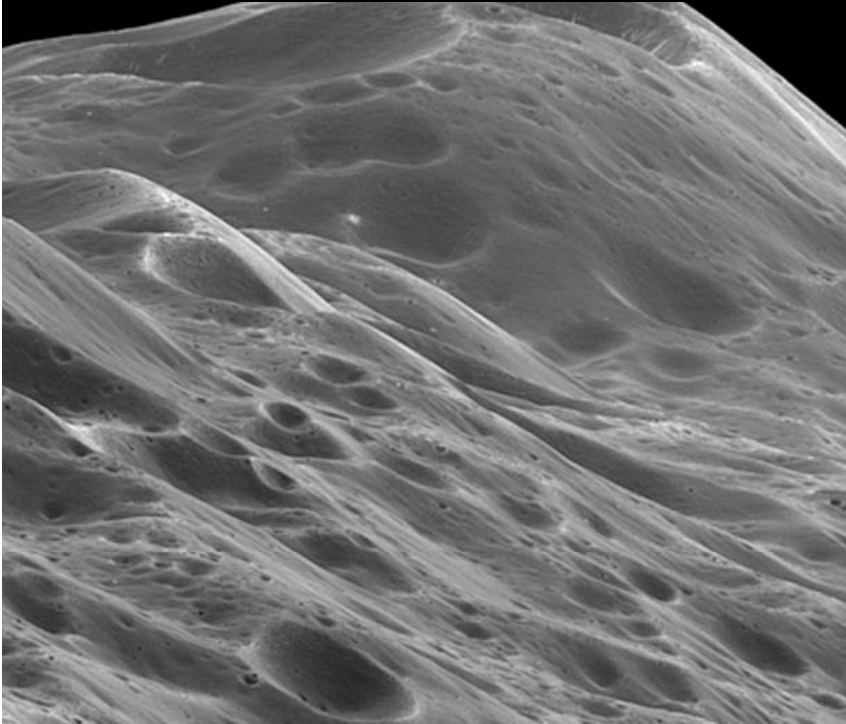
Weak sunlight evaporates ice out of the warmer dark soil. It condenses back onto the colder bright areas.



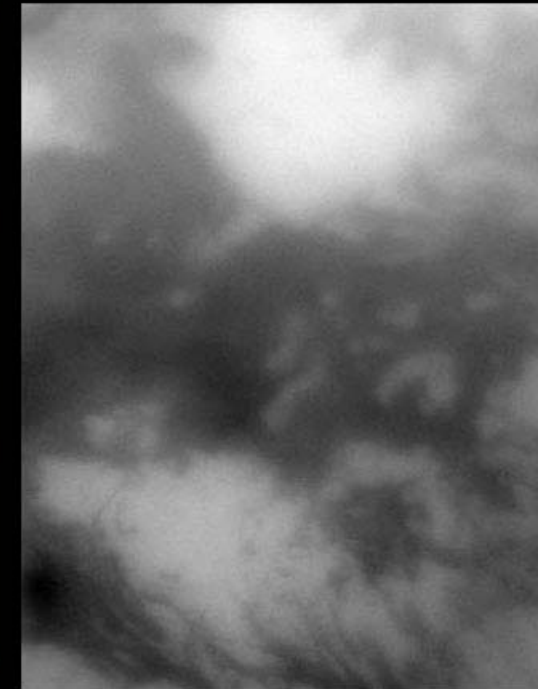
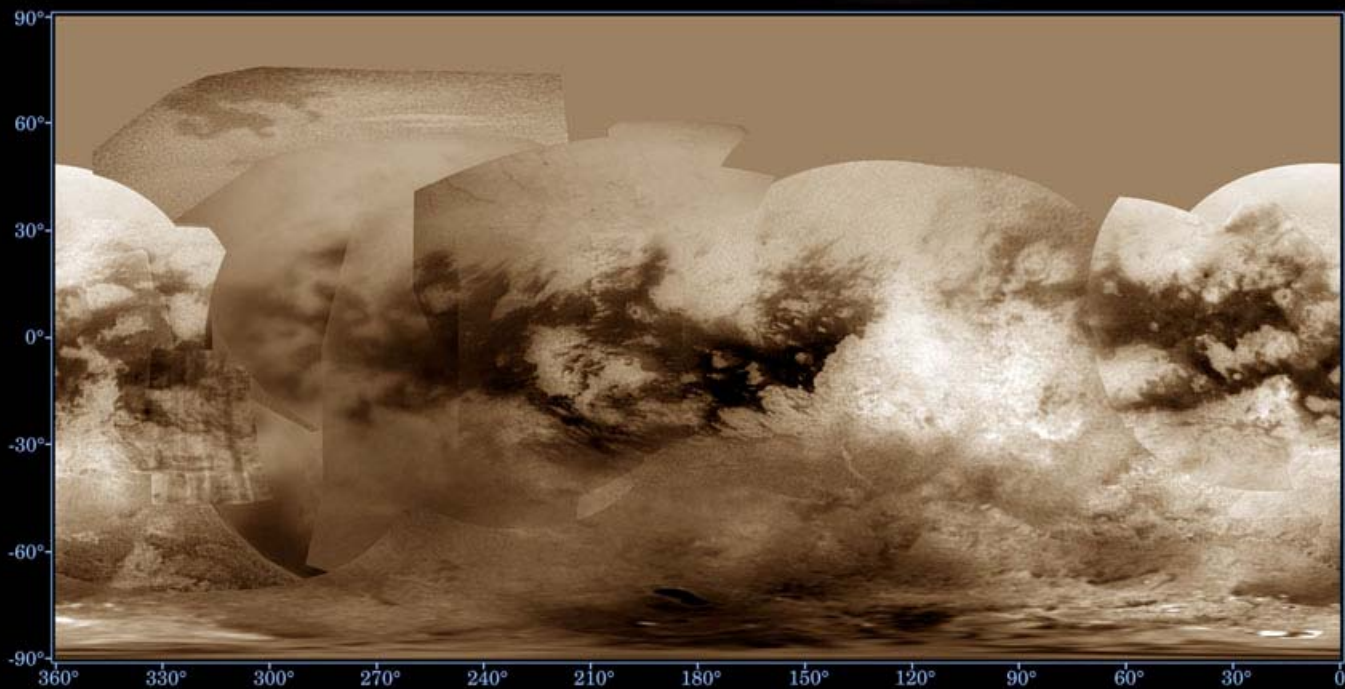
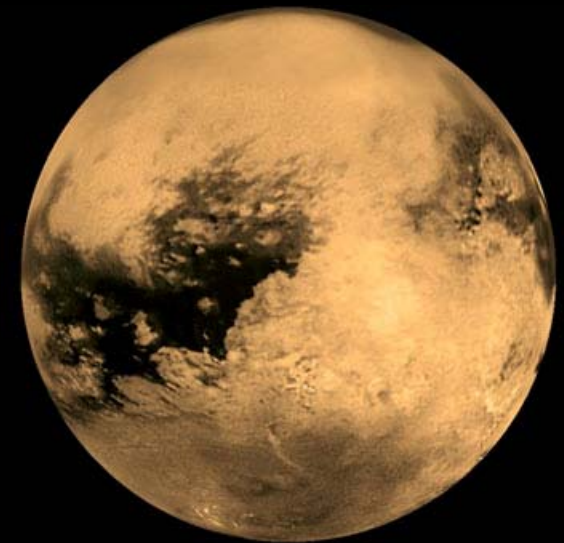
Iapetus – where did you get that ridge?

A mountain ridge 20 km high in places runs around 75% of the equator

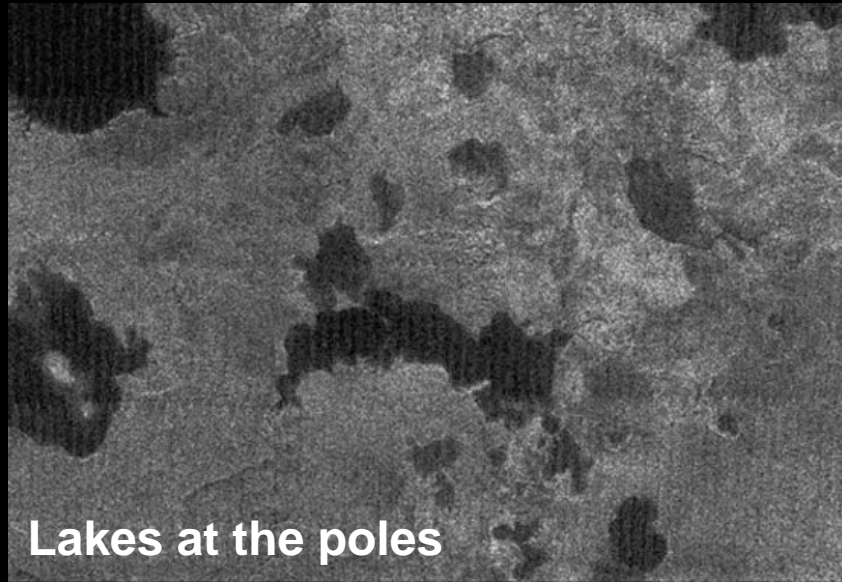
Icy blotches on one of the mountains



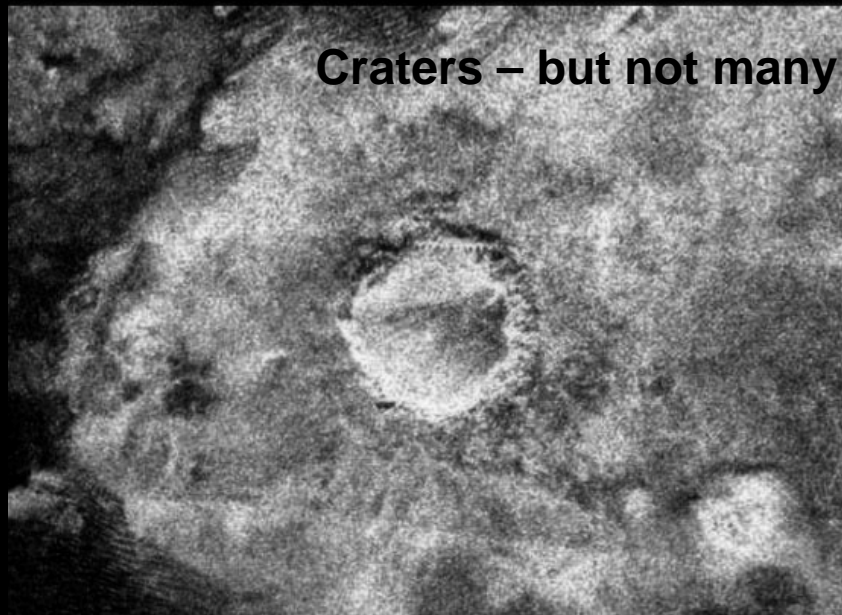
Titan – as big as Mercury, and the only moon with a thick atmosphere.



Titan – radar looks through the clouds. And what a world it sees!
– methane lakes, riverbeds, sand dunes, volcanoes – an active world.



Lakes at the poles

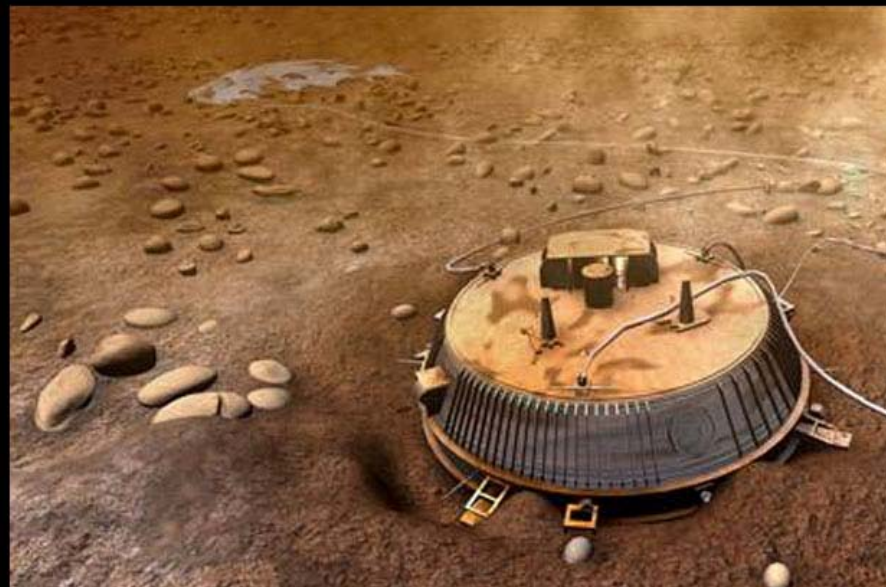
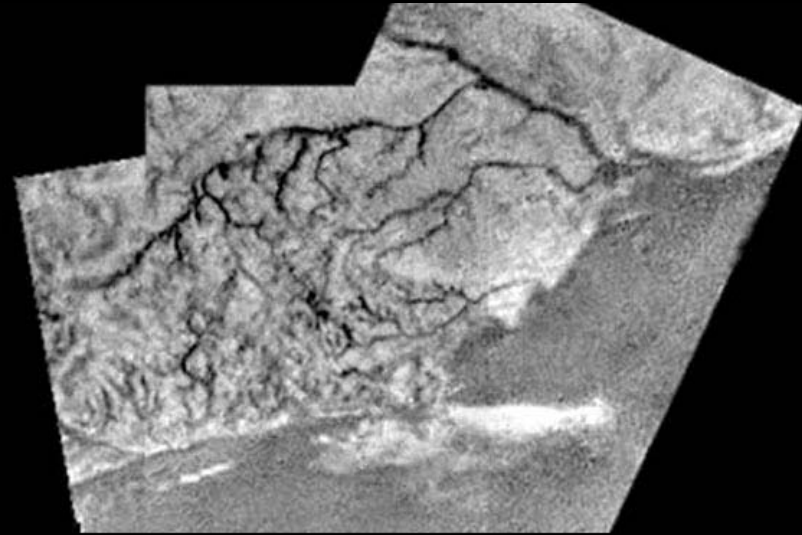


Craters – but not many



Sand dunes around the equator

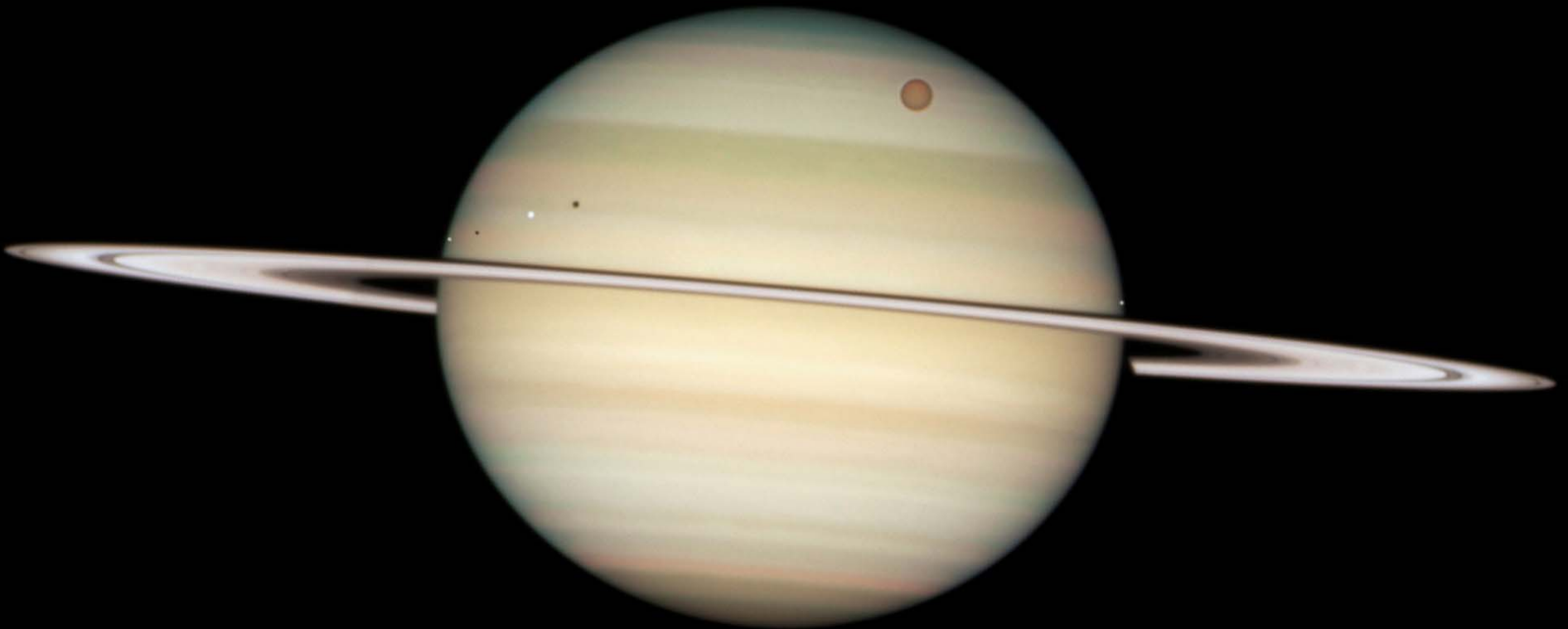
Titan – another way to see the surface – go there!
The European Space Agency's probe Huygens landed on Titan in 2005.
It saw dry riverbeds that flow with liquid methane after rainstorms.



ESA

Saturn's moons - no obvious pattern at all

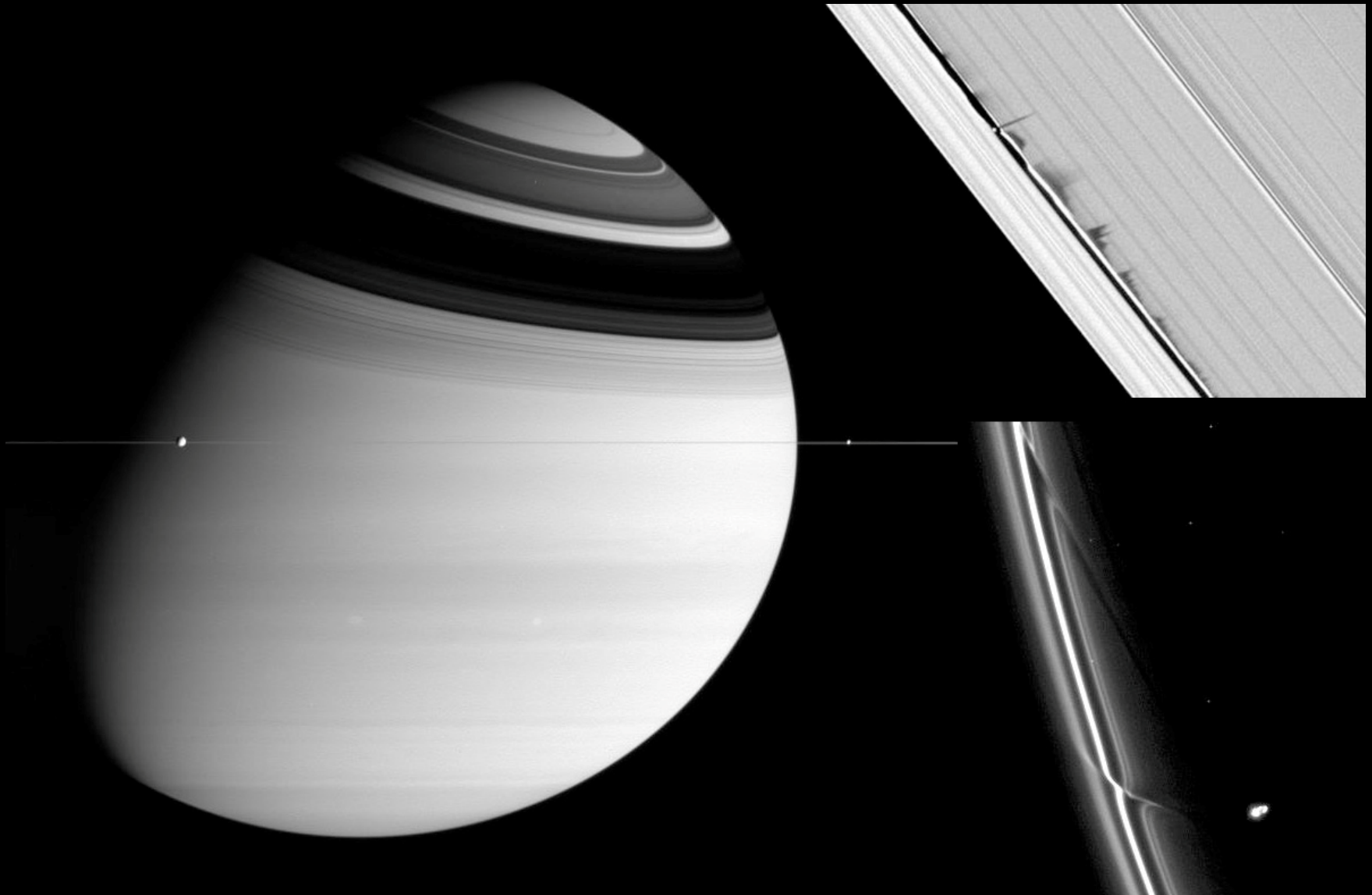
The Cassini spacecraft is still exploring Saturn



NASA – Hubble Space Telescope

Saturn's Rings put on a show

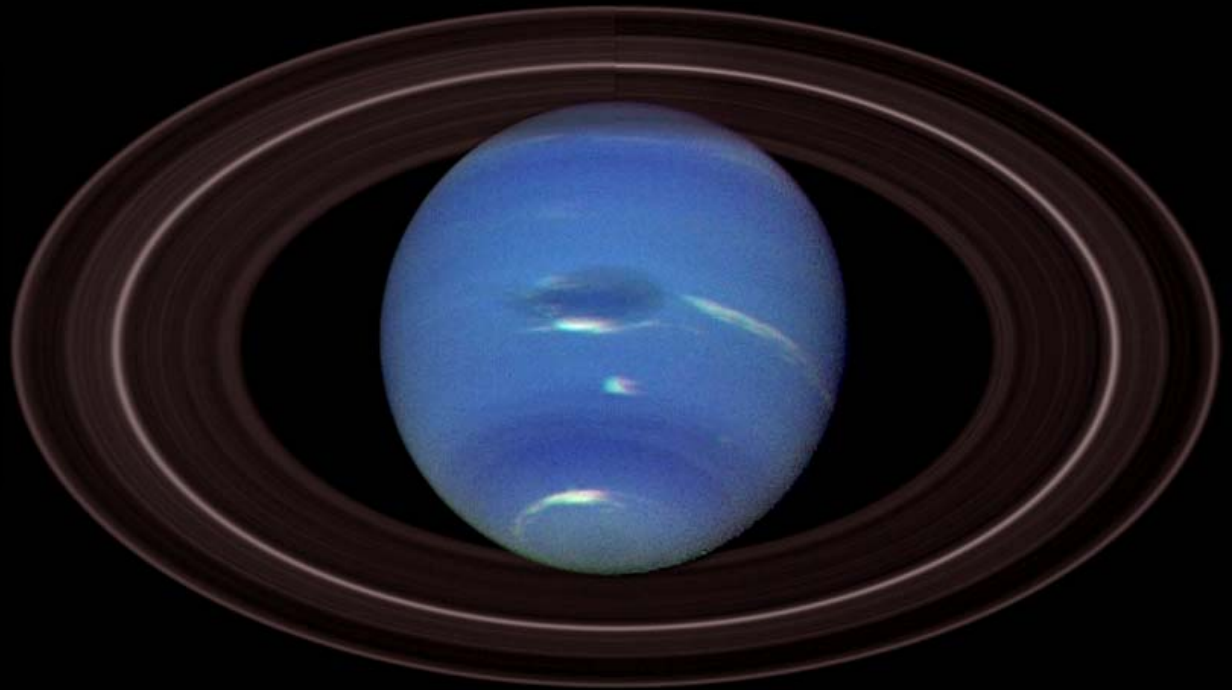
Shadows show lumps in the otherwise very flat rings.
One moon stirs up a narrow ringlet every time it comes close.



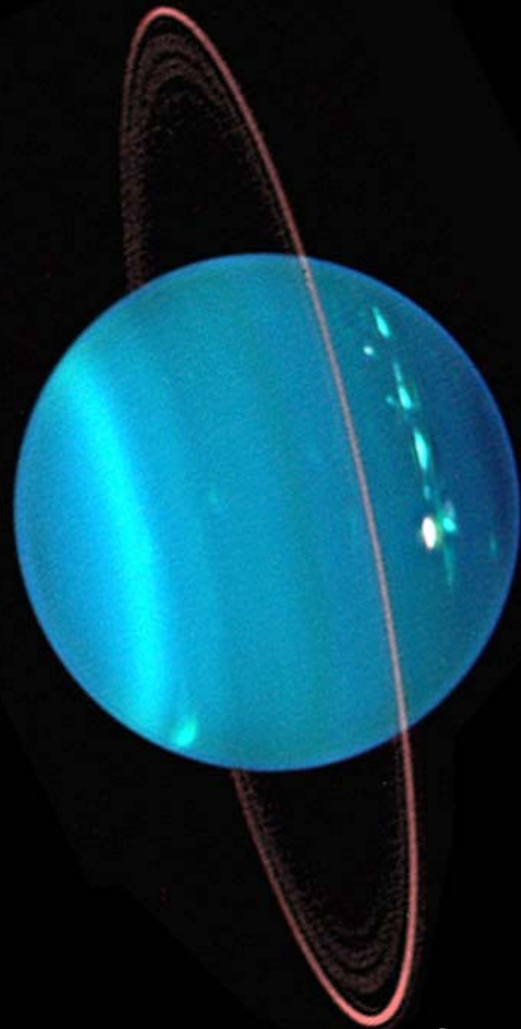
Uranus and Neptune

Gas giants, but very different from Jupiter and Saturn.
Lots of methane, not much hydrogen.

Neptune from Voyager 2



Both sets of rings have
been artificially brightened

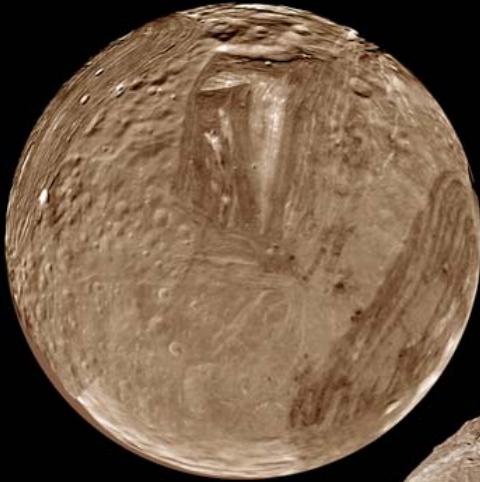


Uranus from Hubble Space Telescope

Moons of Uranus

We don't know so much about these distant worlds.
The moons closer to Uranus seem to be more active.

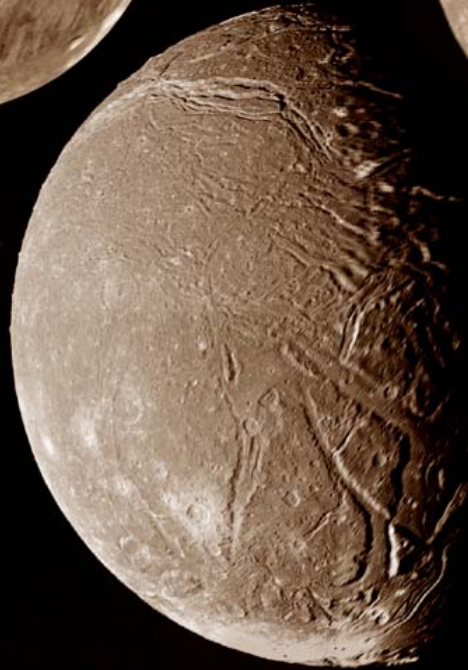
Miranda



Ariel



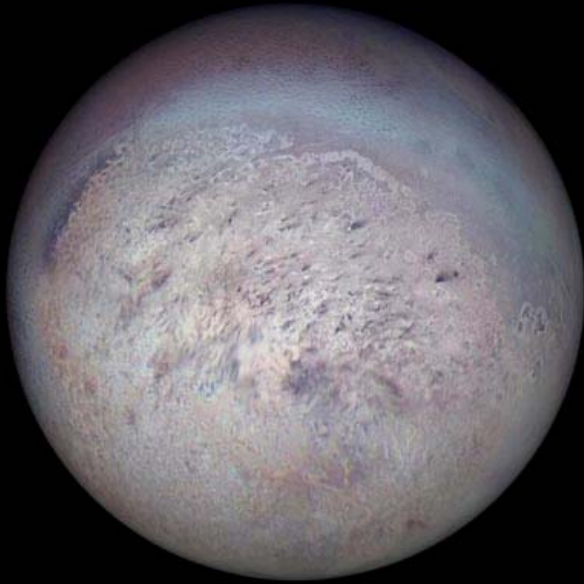
Titania



Oberon



Neptune's moon Triton – a young and active surface. Is it a cousin of Pluto heated by tides when it was captured by Neptune?



Asteroids

Remnants of the building blocks the planets were made from.
Irregular shapes come from a long history of impacts.

Gaspra

Ida

Eros



Asteroids are not all the same!

Itokawa was visited by Hayabusa, a Japanese spacecraft. It collected a soil sample and brought it back to Earth. Only 600 m long, is it a loose pile of rubble?



Lutetia, 100 km across, was imaged by Rosetta, a European spacecraft on its way to a comet. Are the lines on its surface cracks made by impacts?



JAXA

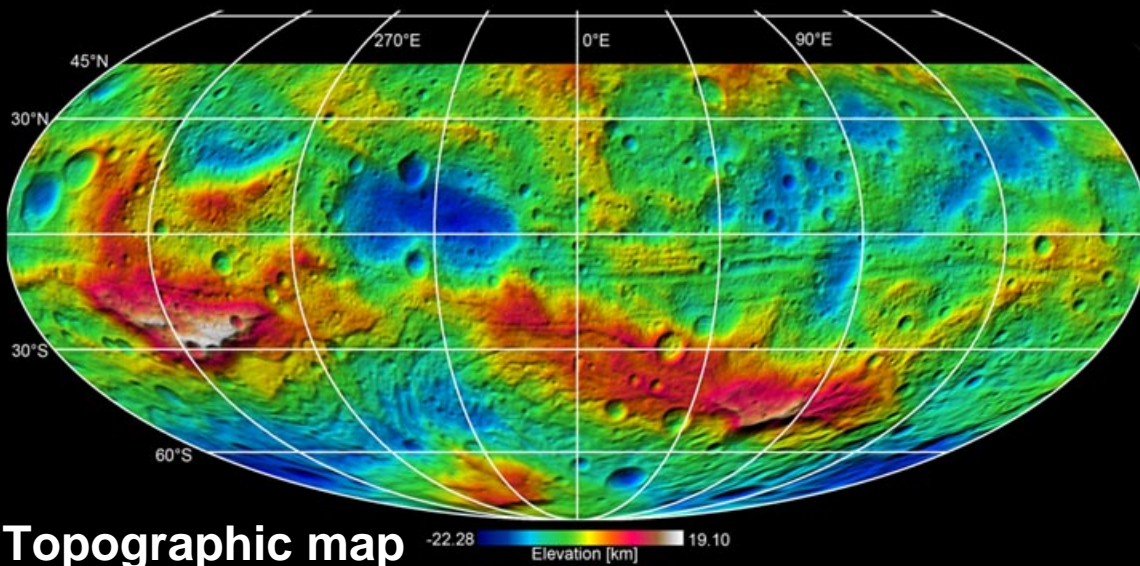
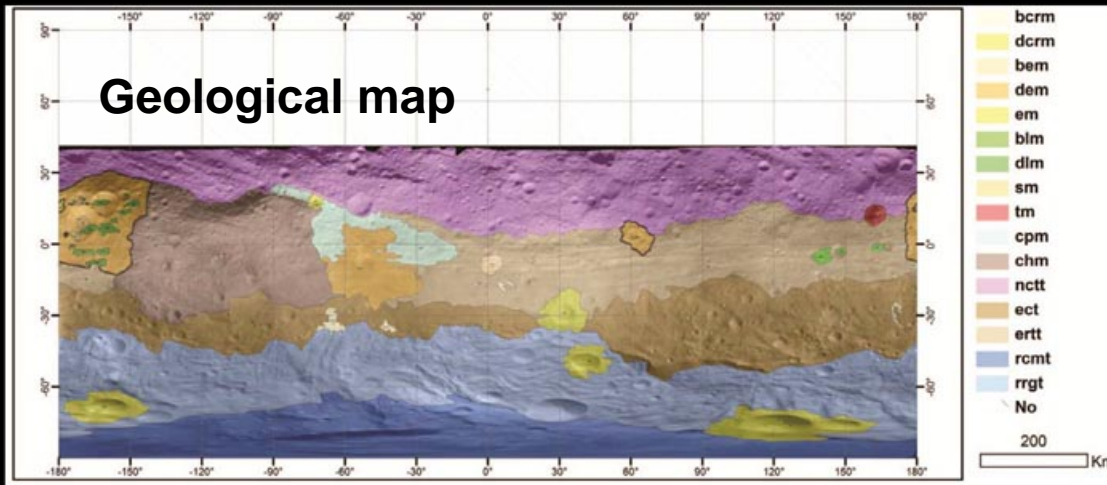
ESA

Vesta - the volcanic asteroid

One of the largest asteroids, 500 km (300 miles) across and covered with lava flows.

Pieces knocked off by impacts have come to Earth as meteorites.

The Dawn spacecraft orbited Vesta in 2011 and 2012.



Dawn images

Comets – icy cousins of asteroids.

Building blocks of most of the outer solar system.

When they approach the sun their ices evaporate into space

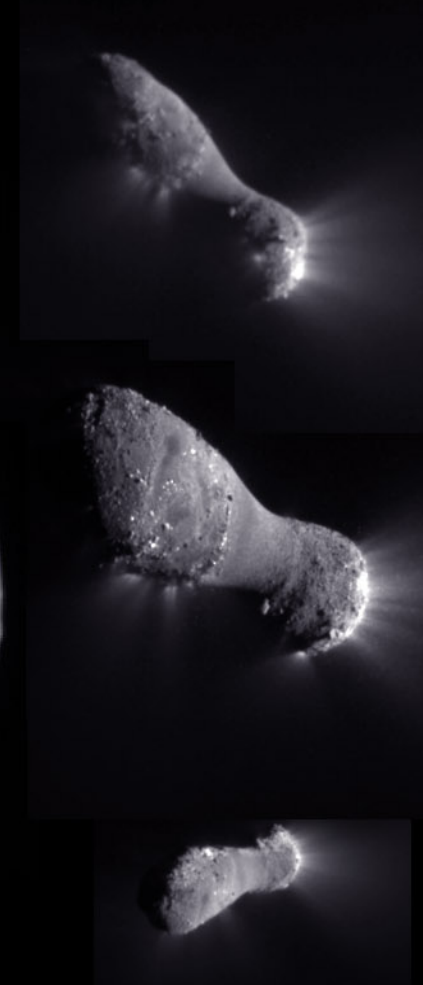
Wild 2



Tempel 1



Hartley 2

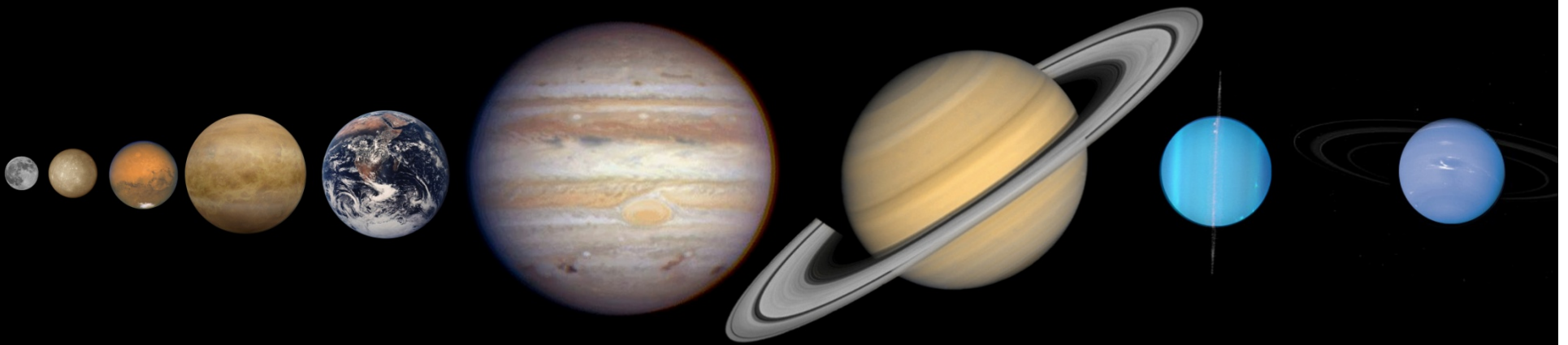


Comet Halley



The solar system is a big neighborhood
... and the neighbors are very different.

The biggest surprise of solar system exploration has been
this extraordinary diversity.



End

Thanks for your interest in the planets.

Philip Stooke

