



SECRETS OF THE SOLAR SYSTEM

S³-06

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AMNH After-School Program

AMERICAN
MUSEUM OF
NATURAL
HISTORY



Outline

Giant Planets

- Latest missions
- Rings

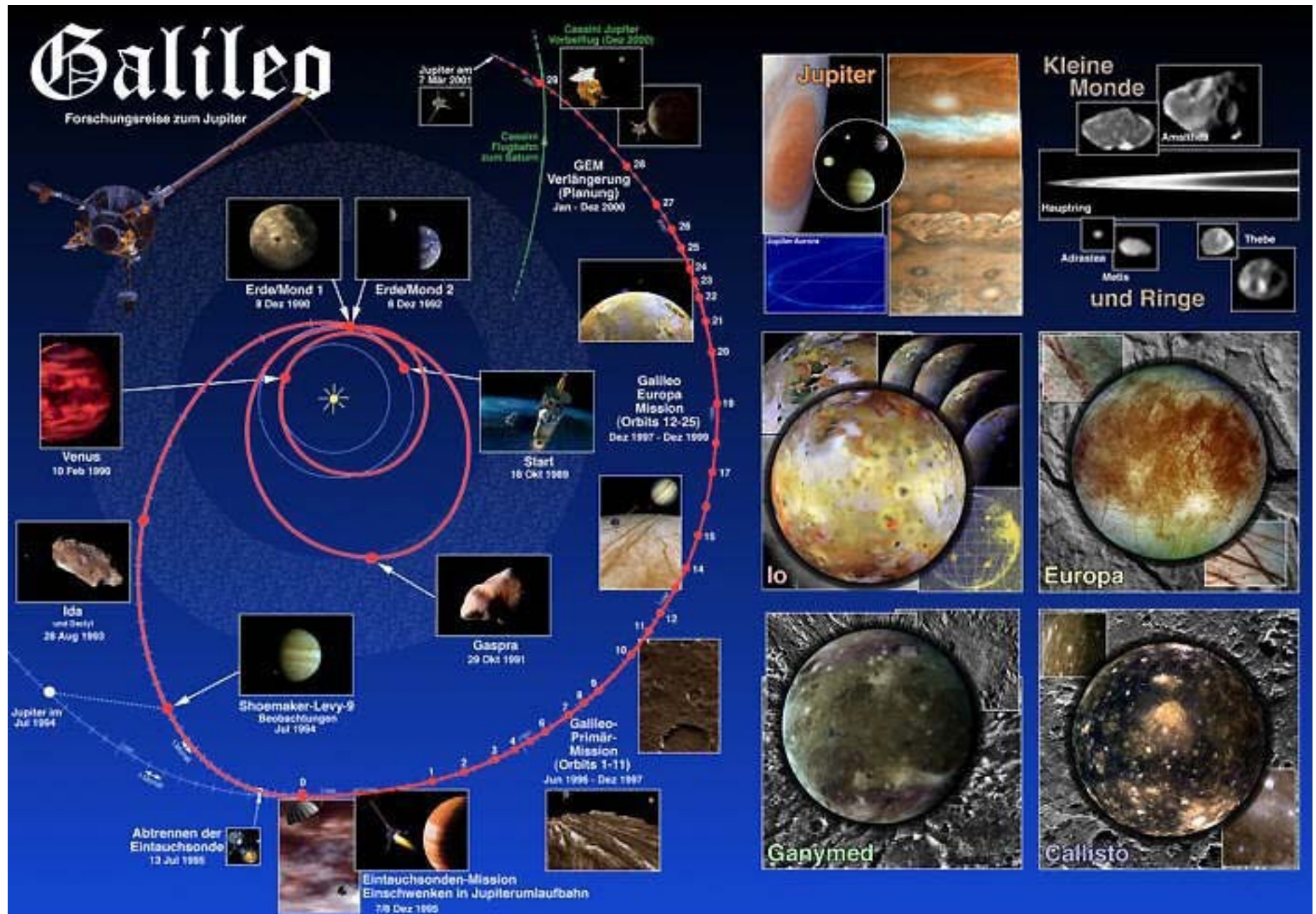
Terrestrial Planets

- Atmospheres
- Surfaces

The Earth-Moon system

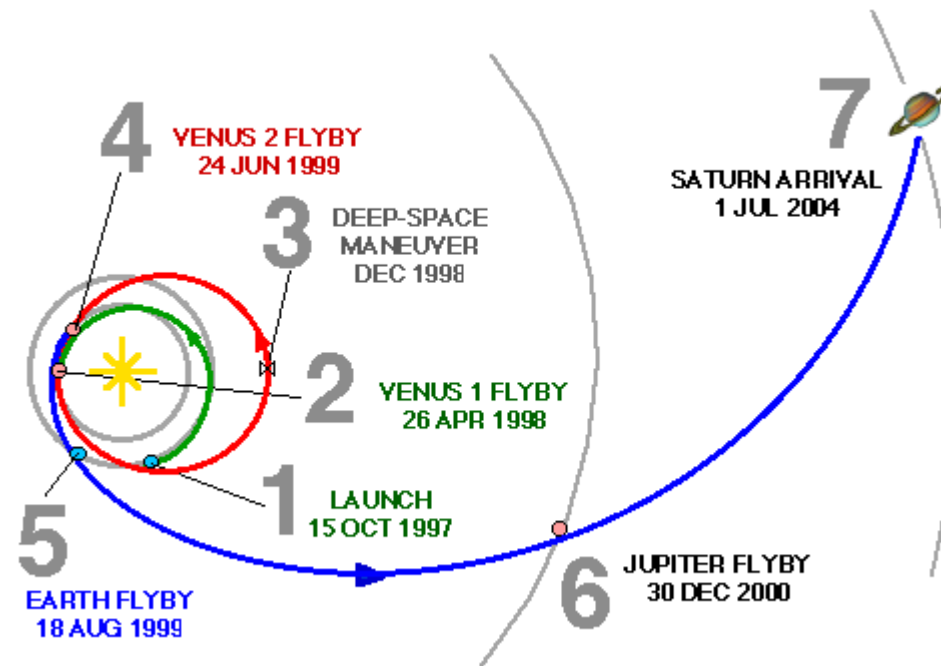
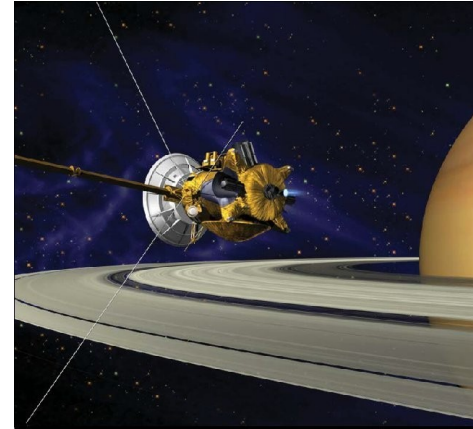
- Tidal Locking

Mission to Jupiter: Galileo





Mission to Saturn: Cassini





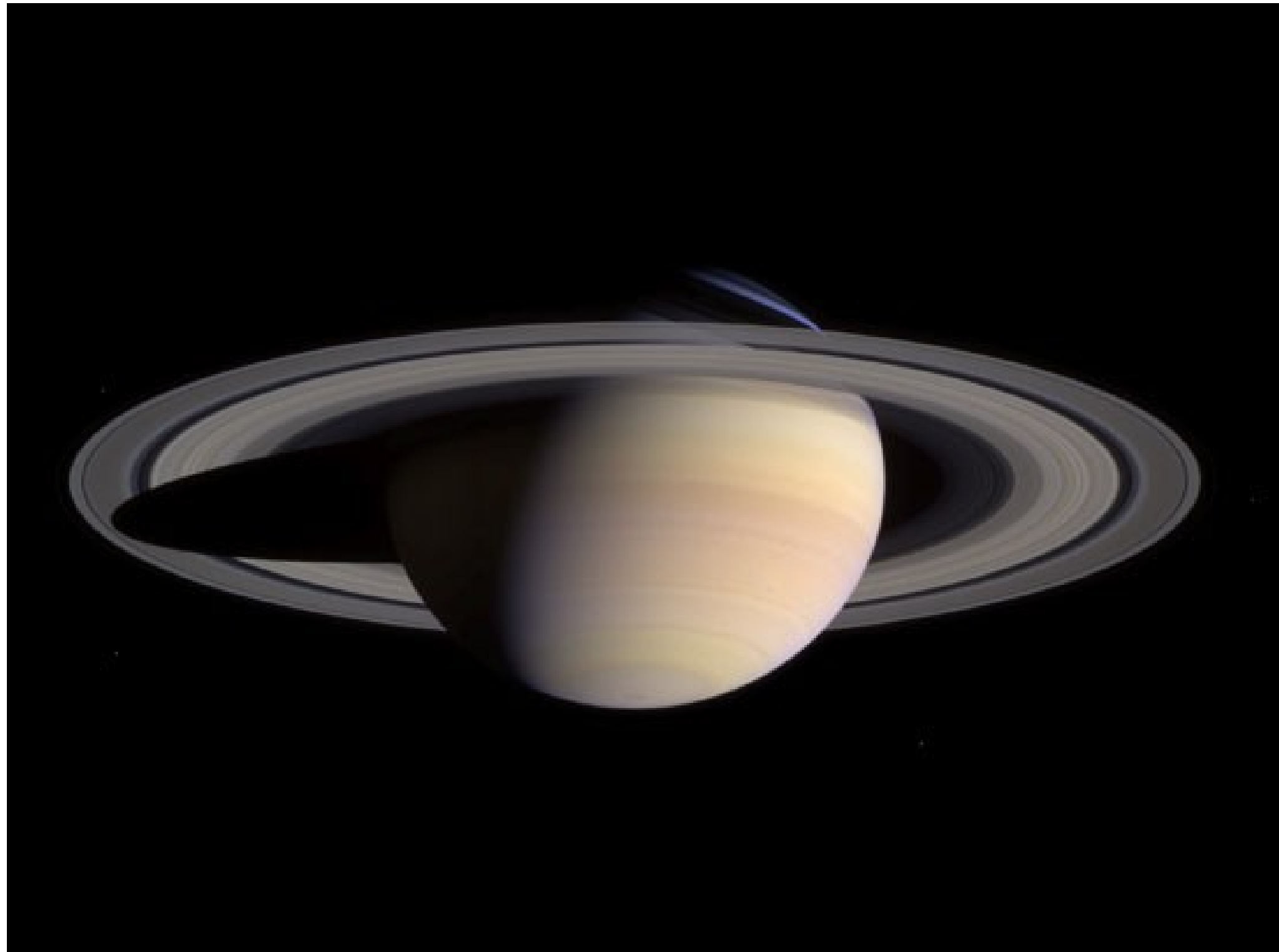
**IO WITH JUPITER
BACKDROP**

YEAR: 2001

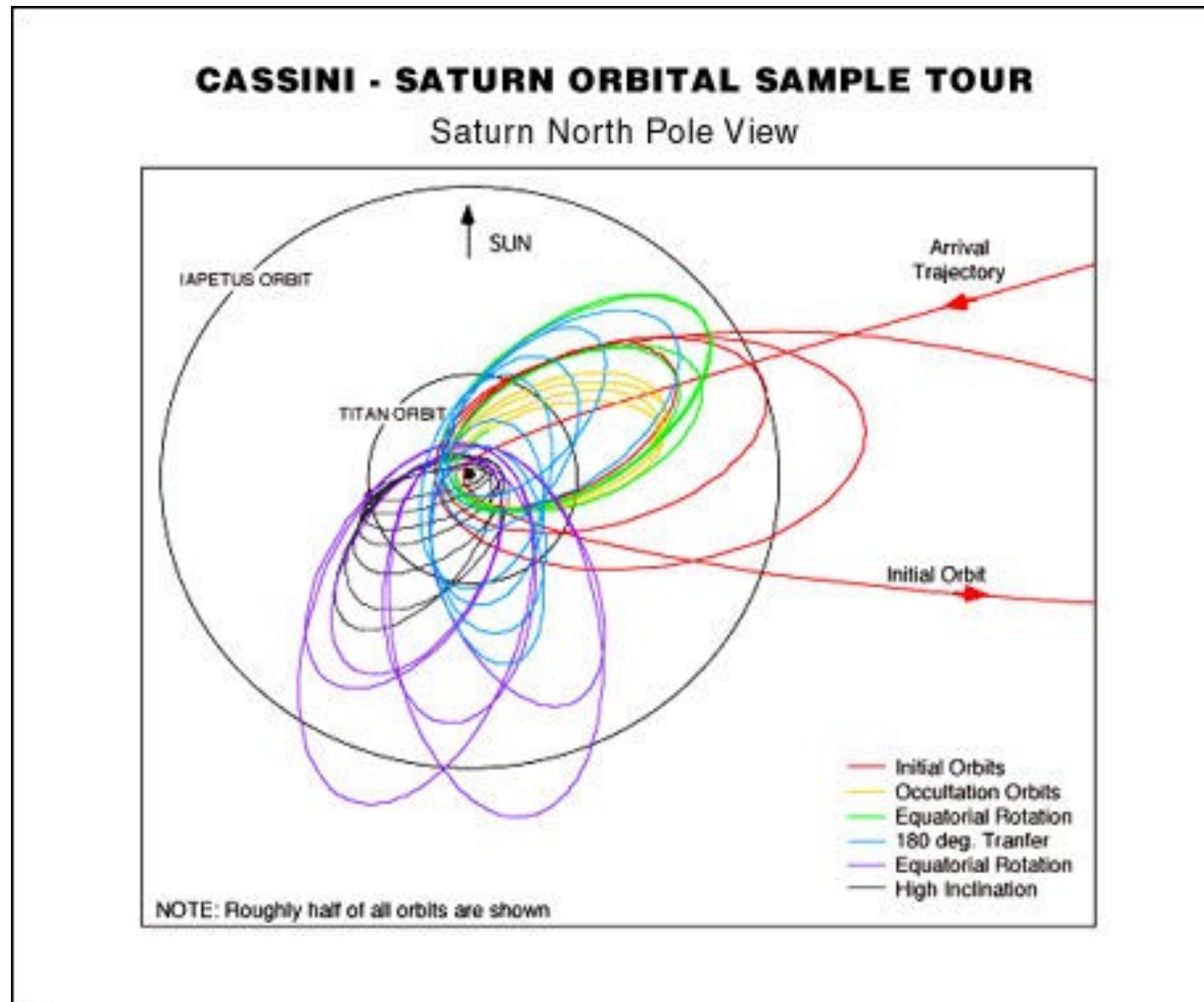
MISSION: CASSINI

TARGET: JUPITER / IO

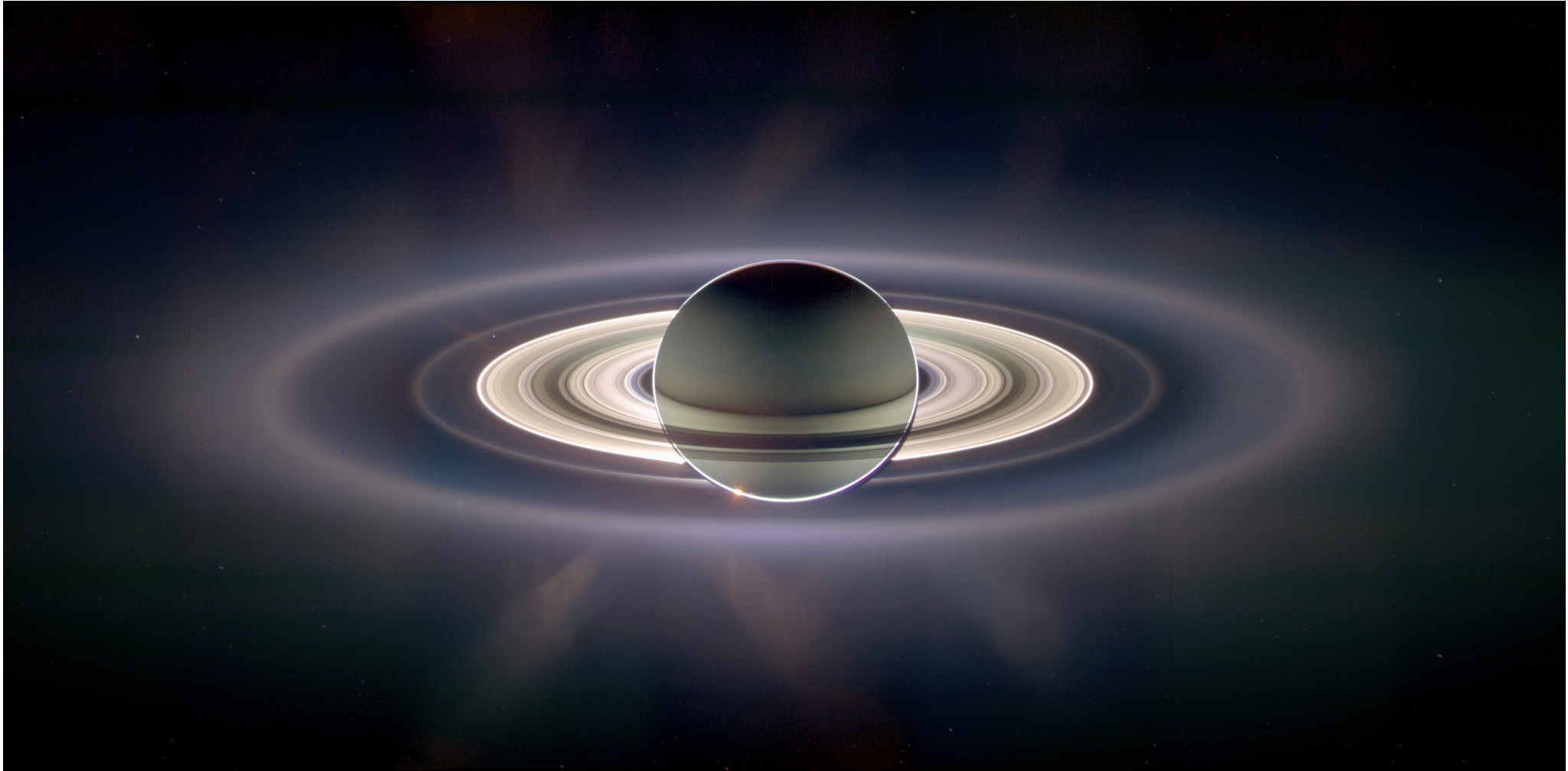
The moon Io captured against Jupiter and crossing into
Jupiter's night side.



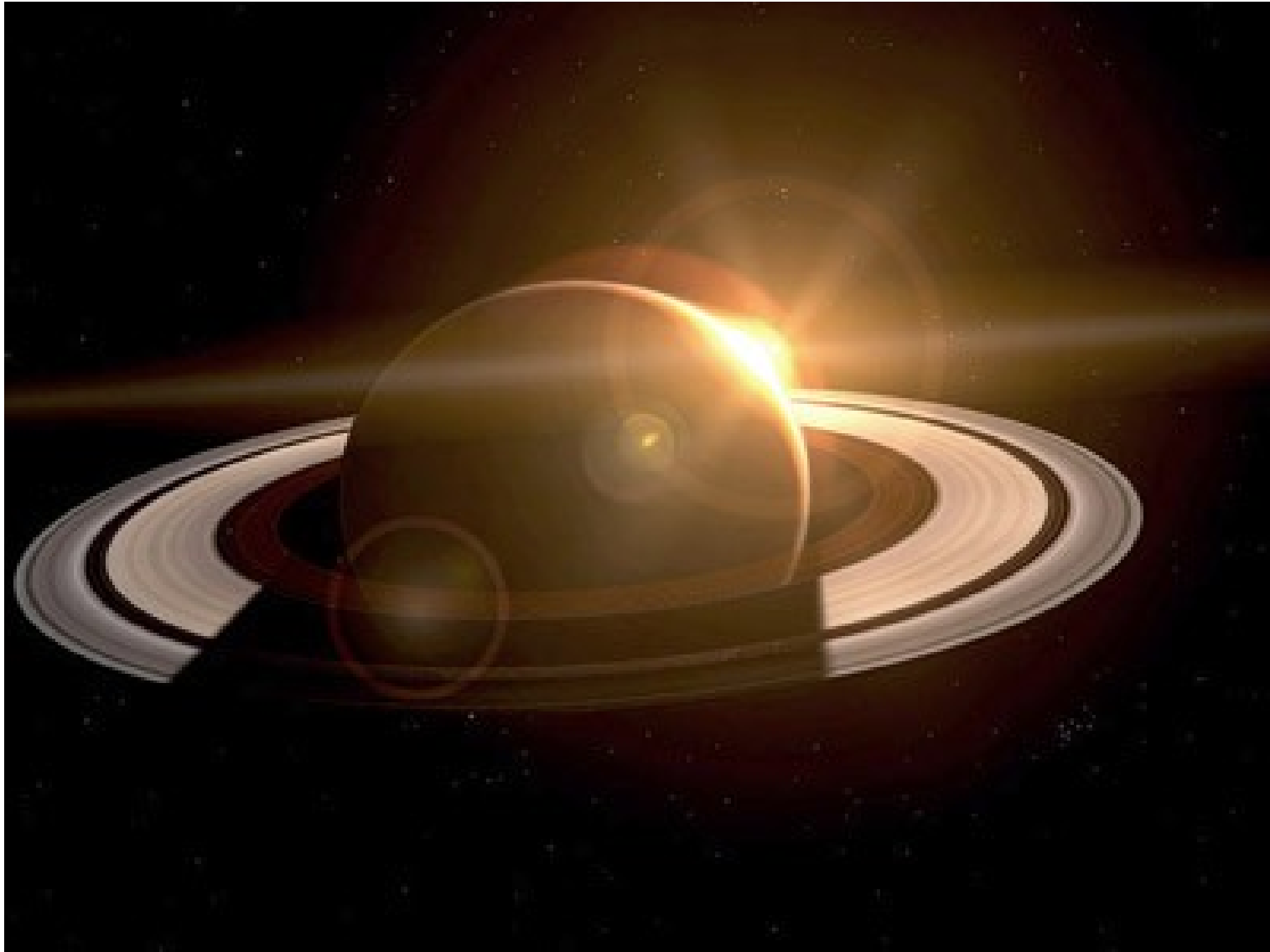
Cassini orbiting Saturn



Ringshine

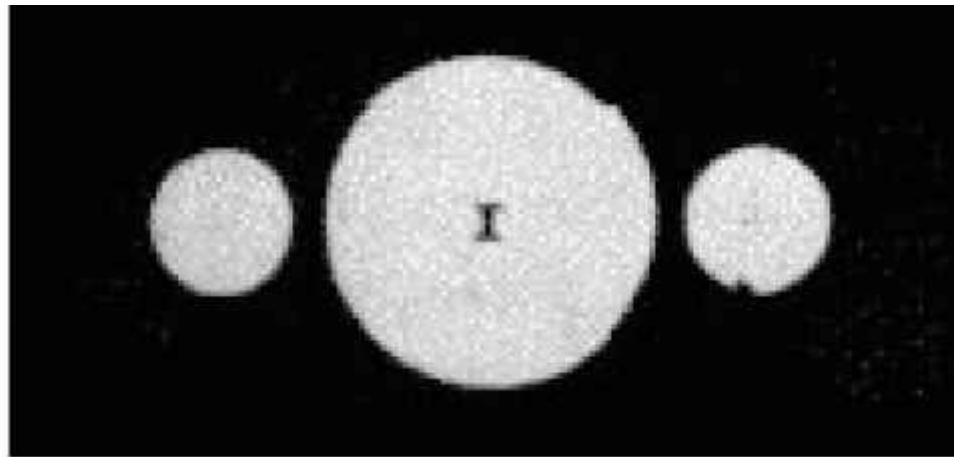


Planetary Rings



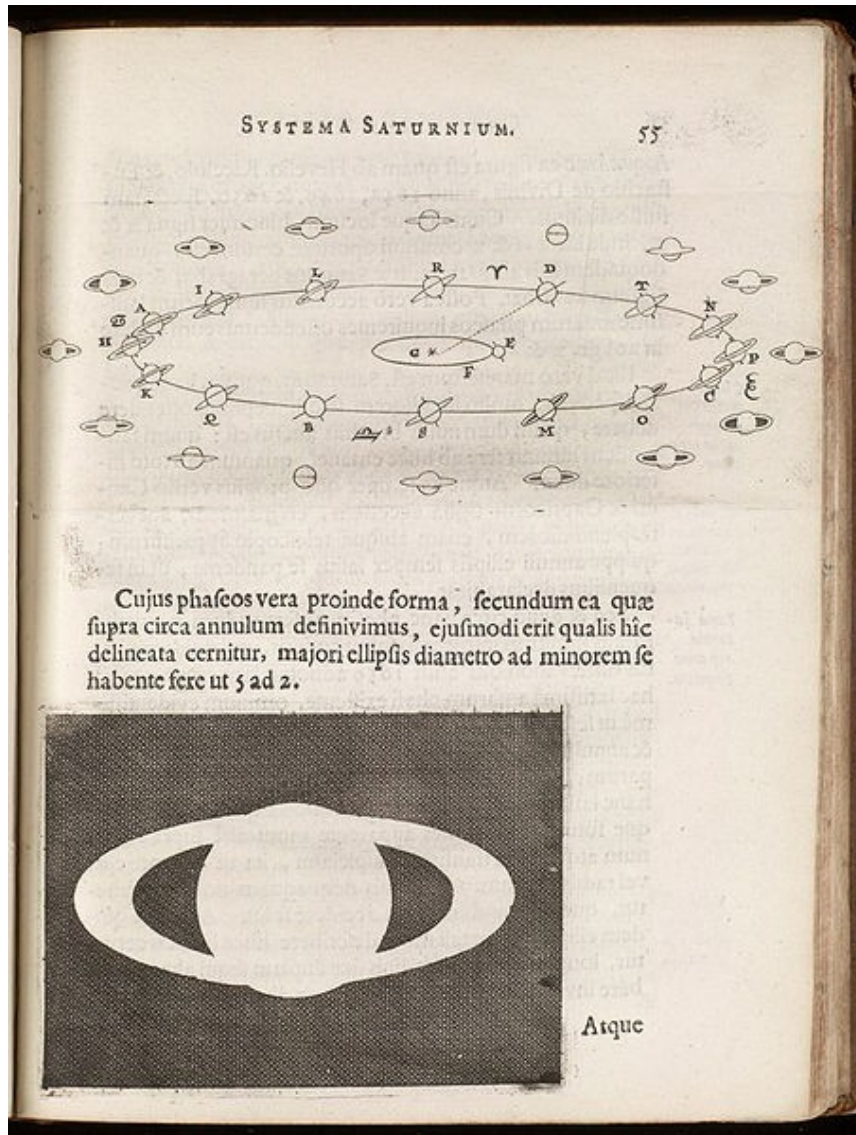
Planetary Rings

Galileo's drawing, 1610.

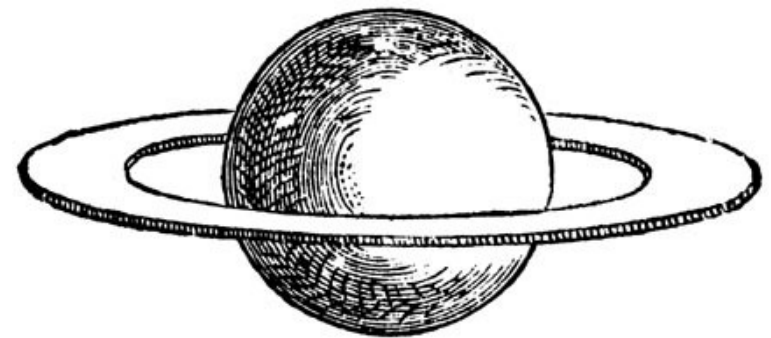


"I do not know what to say in a case
so surprising, so unlooked for, so novel."

Planetary Rings



Huygens's drawings, 1659.

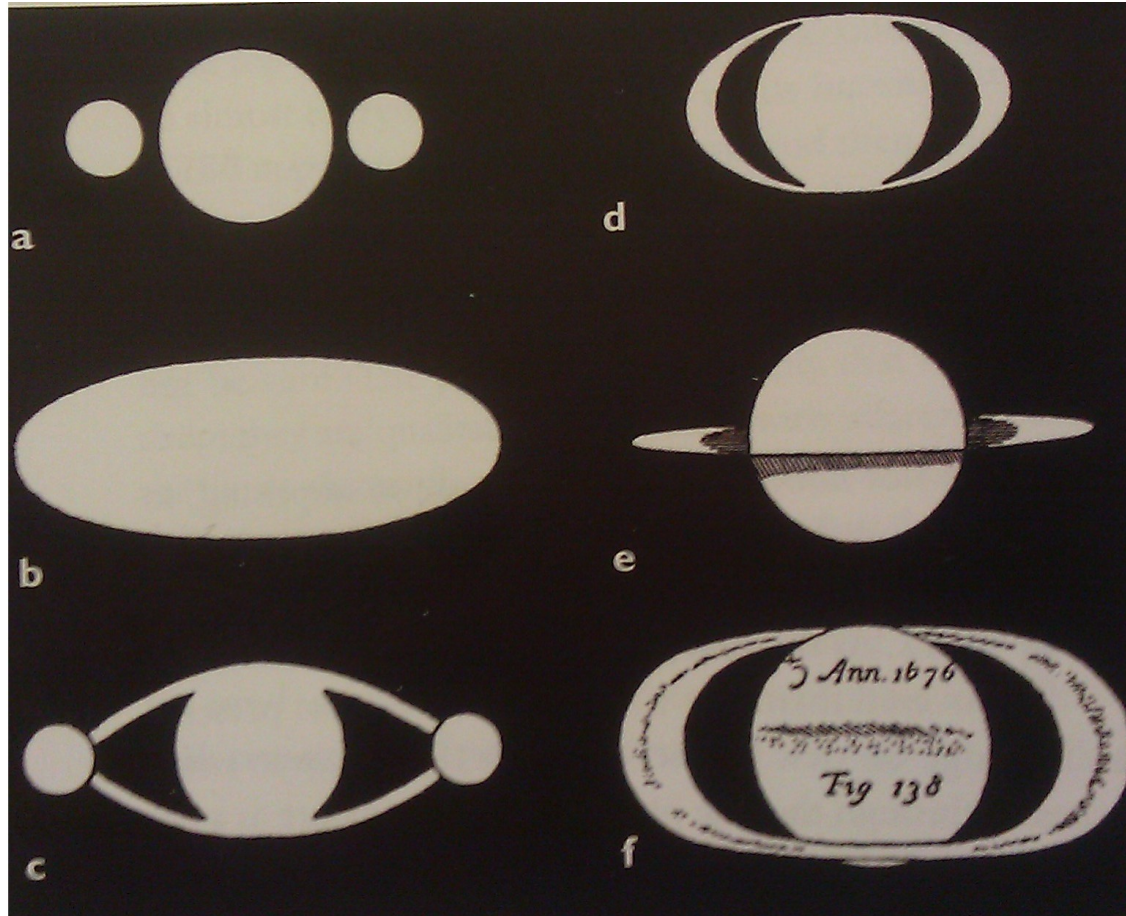


"Saturn is surrounded by a thin flat disk,
nowhere touching the planet"

Planetary Rings

Other drawings from the 17th century

Galileo, 1610



Riccioli, 1648

Gassendi, 1634

Huygens, 1655

Fontana, 1646

Cassini, 1676

Planetary Rings

What are these rings???

Solid? Liquid? Particulate?

Planetary Rings

Maxwell's proof



James Clerk Maxwell
(1831-1879)

Planetary Rings

Maxwell's proof

There are some questions in Astronomy, to which we are attracted rather on account of their peculiarity, [...] than from any direct advantage which their solution would afford to mankind.

[...] I am not aware that any practical use has been made of Saturn's Rings [...]

But when we contemplate the Rings from a purely scientific point of view, they become the most remarkable bodies in the heavens. [...] When we have actually seen that great arch swung over the equator of the planet without any visible connection, we cannot bring our minds to rest. [...] We must explain its motion on the principles of mechanics.

[...]

60 pages of calculations

[...]

[...] We conclude, therefore, that the rings must consist of disconnected particles; these may be either solid or liquid, but they must be independent. [...] The final result, therefore, of the mechanical theory is, that the only system of rings which can exist is one composed of an indefinite number of unconnected particles, revolving around the planet with different velocities according to their respective distances.

Prof. Maxwell, on the Stability of Saturn's Rings. 297

By A. Hall.

T	1859, May 29 ^h 00 ^m 77 ^s	Washington M.S.T.
Log q	9 [°] 30' 33 ^{''} 10	
μ	281 58' 10 ^{''} 7	or $\pi = 75^{\circ} 9' 46'' 1$
Ω	357 7 56 ^{''} 8	
i	95 50 56 ^{''} 8	$i = 84^{\circ} 9' 3'' 2$

Motion Retrograde.

The comet will probably be visible after its perihelion passage.

On the Stability of the Motion of Saturn's Rings; an Essay which obtained the Adams' Prize for the Year 1856, in the University of Cambridge. By J. Clerk Maxwell, M.A. late Fellow of Trinity College, Cambridge: Professor of Natural Philosophy in the Marischal College and University of Aberdeen. Cambridge: Macmillan and Co., 1859.

The following abstract of an important paper has been kindly drawn up by the Astronomer Royal for the use of the readers of the *Monthly Notices*:—

The remarkable essay of which we have given the title was published in the beginning of the present year. The subject of it is so interesting, the difficulty of treating it in its utmost generality so considerable, and the results at which the author arrives so curious, that we think a brief abstract of it will be acceptable to the readers of the *Monthly Notices*. We shall commence with a very imperfect reference to preceding investigations on the same subject.

The first to which we shall allude is Laplace's, in the *Mécanique Céleste*, livre III. chapitre vi. Laplace considers a ring of *Saturn* as a solid, the form of which is investigated as if it were fluid (a mode of treatment whose result, in respect of the form of equilibrium, is evidently good for a solid), and finds, that if the breadth and thickness of the ring are very small in comparison with its distance from *Saturn*, its section may be an ellipse; and it appears that the formula for the proportion of the axes of the ellipse admits of its being considerably flattened. But Laplace rather inclines to the supposition that there are several rings, each existing by its own proper theory. Then remarking on the appearances noticed by some observers which seem to indicate irregularities in the rings, he adds, "J'ajoute que ces inégalités sont nécessaires pour maintenir l'anneau en équilibre autour de *Saturne*," and gives an in-

C

Planetary Rings

Why only Saturn has rings?

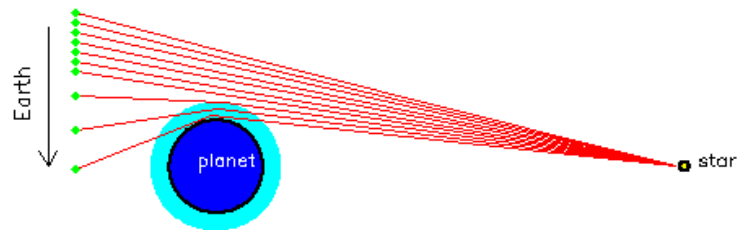
Carl Sagan

Rings of Uranus

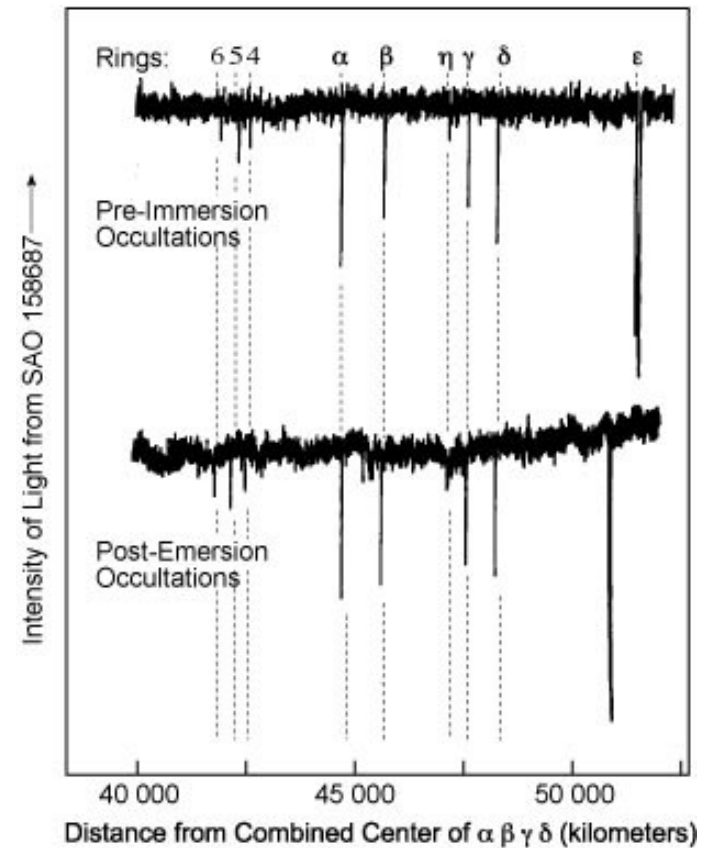
Occultations



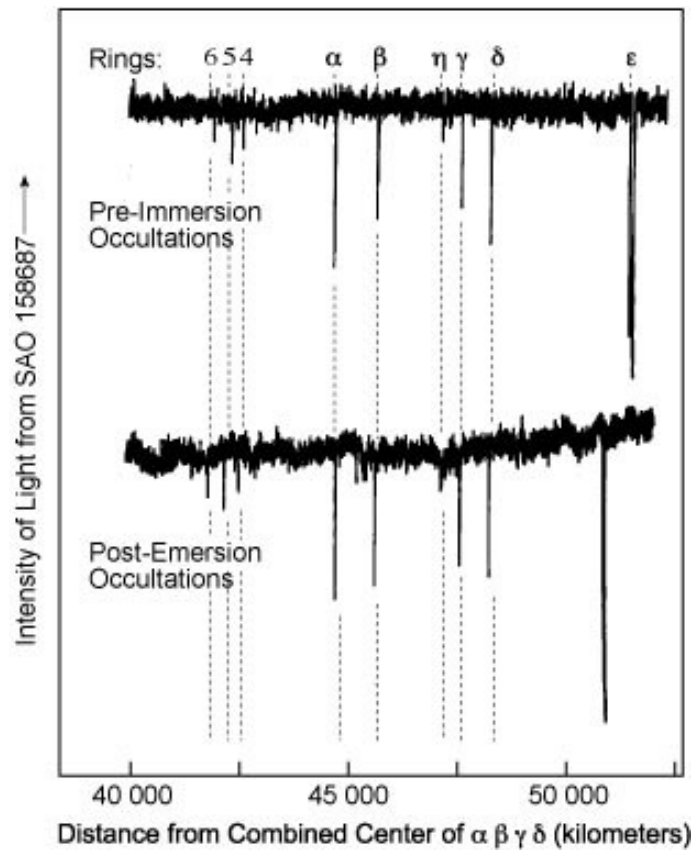
stellar occultation



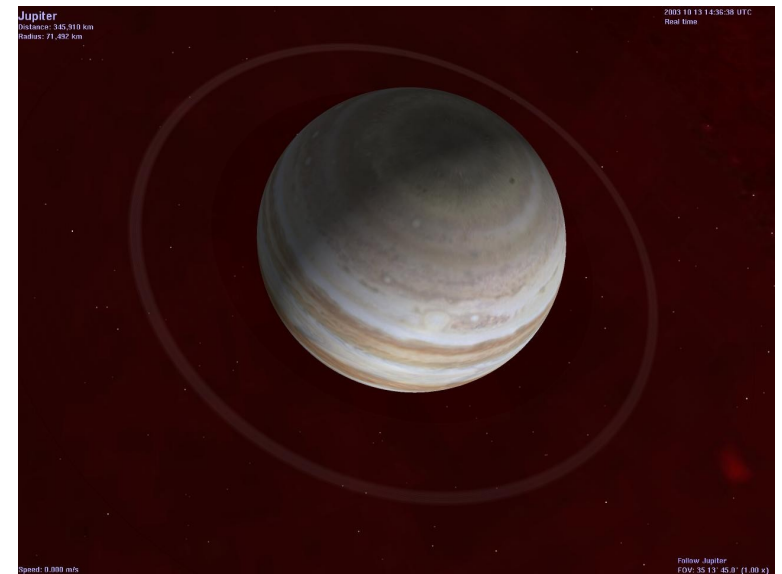
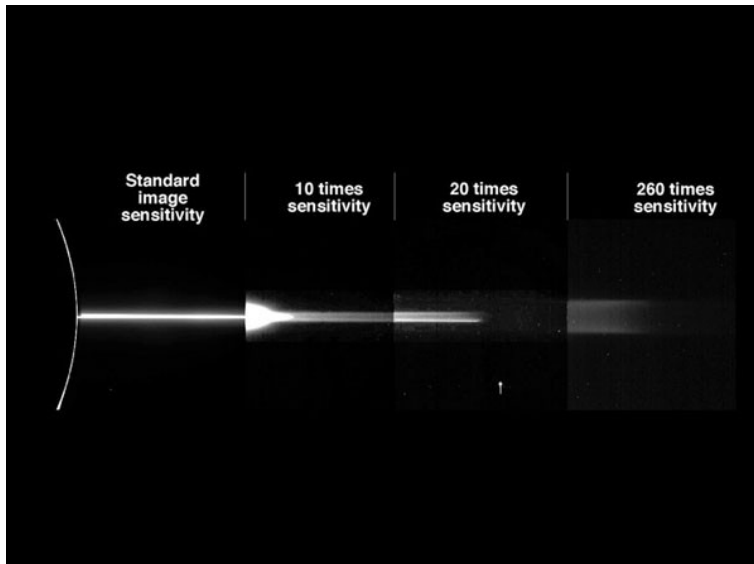
Uranus occults a star



Rings of Uranus

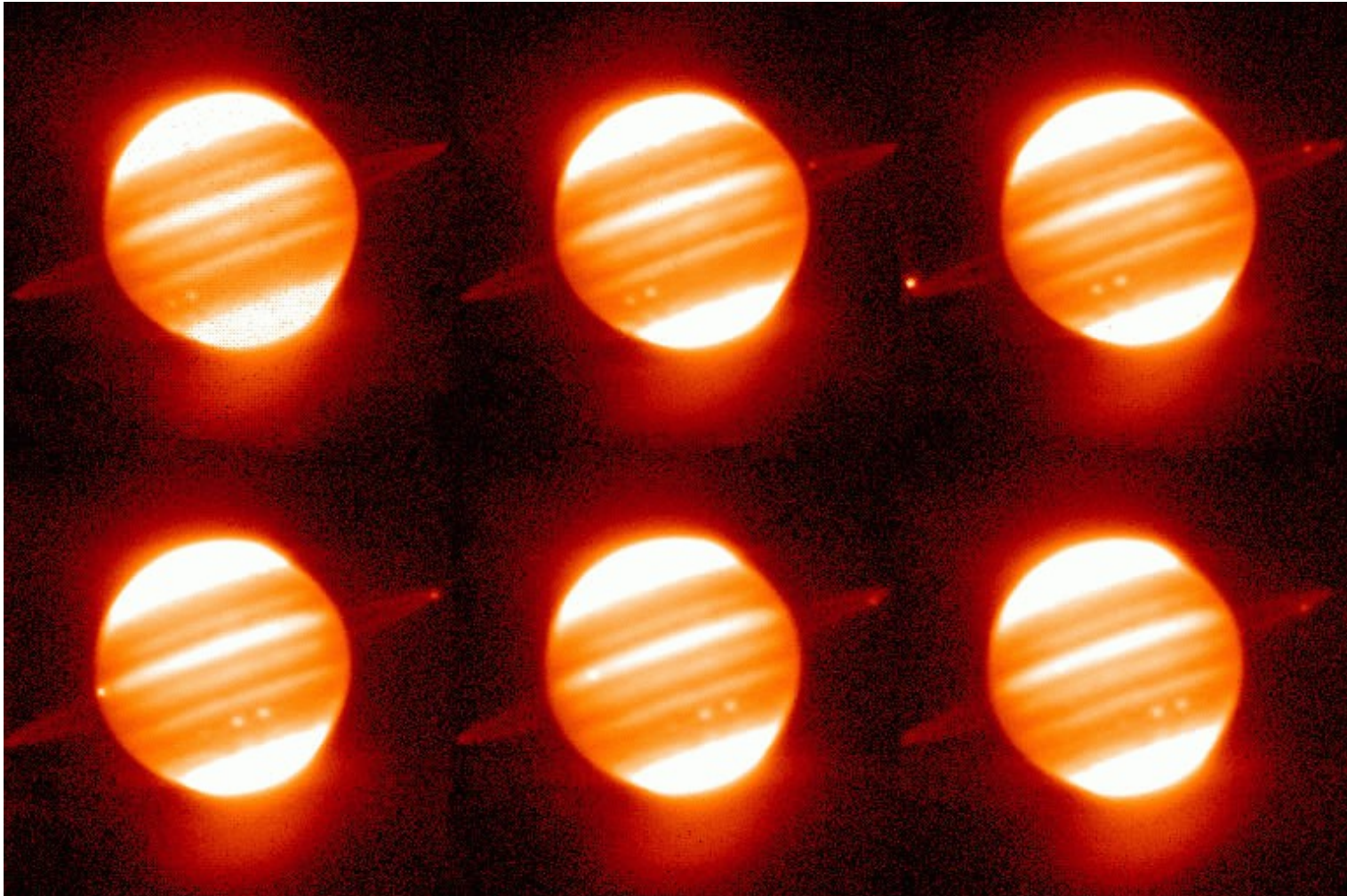


Rings of Jupiter



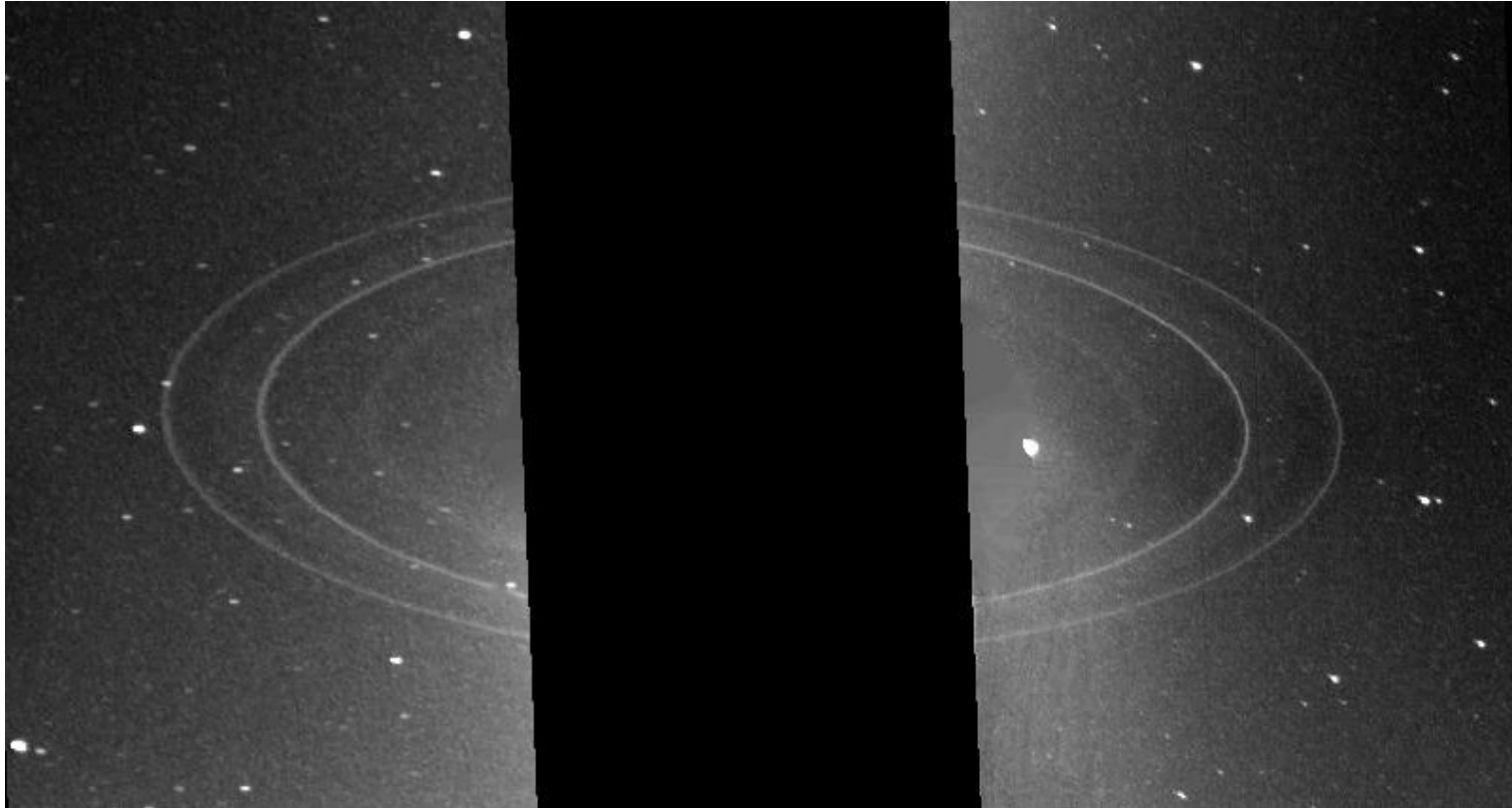
A **very faint** ring system
discovered by Voyager 1.

Rings of Jupiter



Viewed with Keck,
with a methane filter.

Rings of Neptune



A **very faint** ring system,
similar to Jupiter's rings
discovered by Voyager 2.

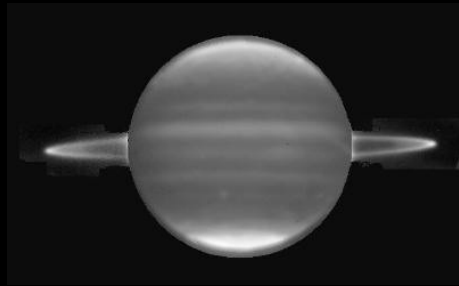
Rings of Neptune



Arcs!!!

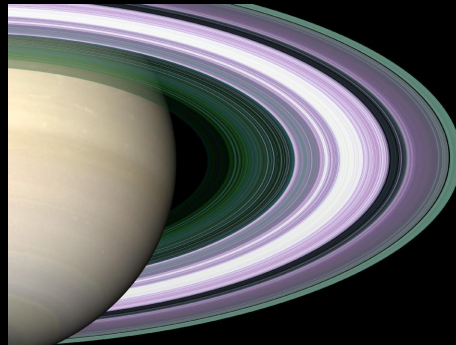
Ring Systems

Jupiter



Fine, diffuse dust,
very dark.

Saturn



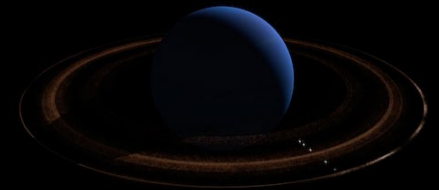
Icy boulders,
very bright.

Uranus



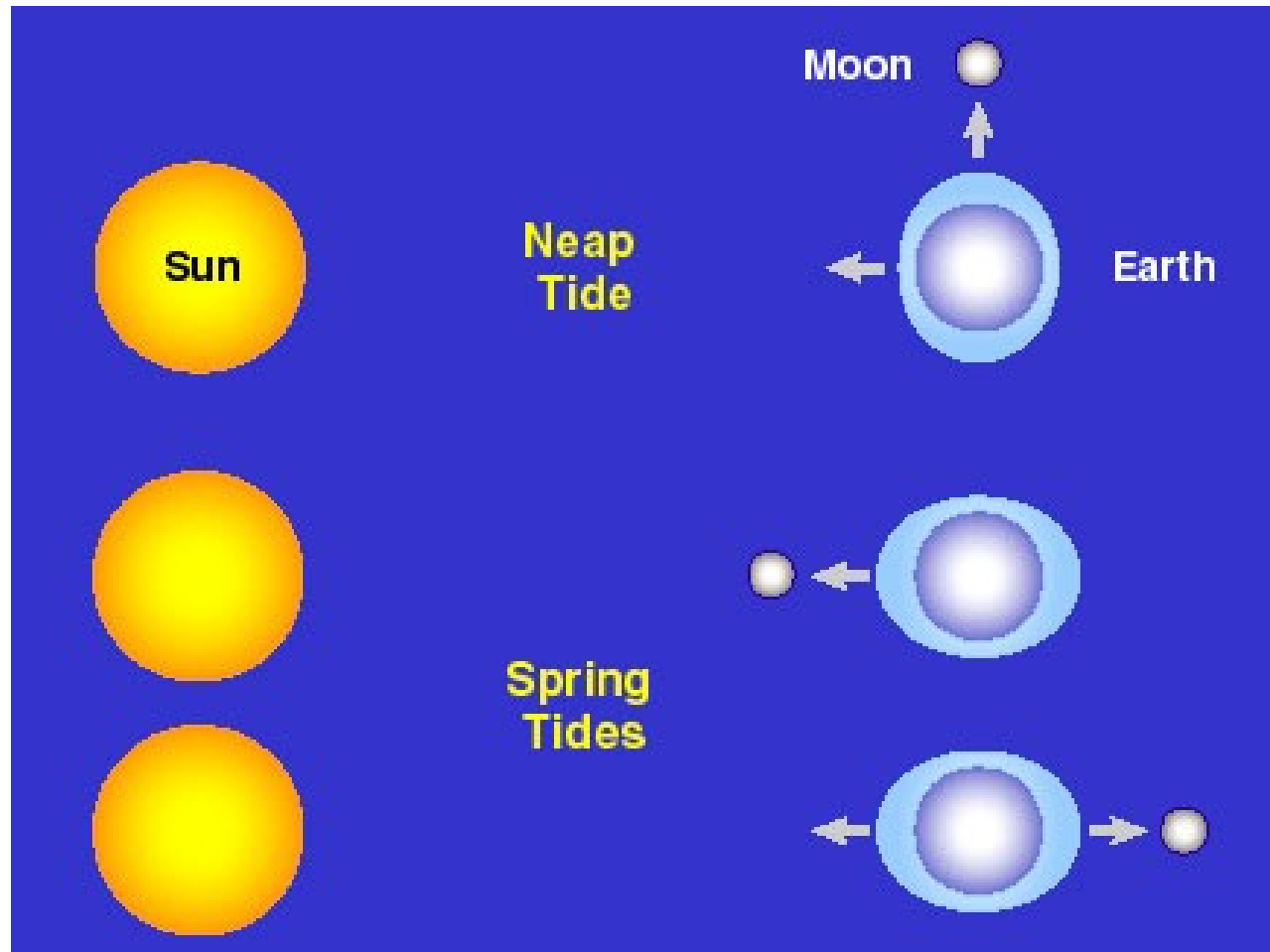
Rocky boulders,
dark.

Neptune

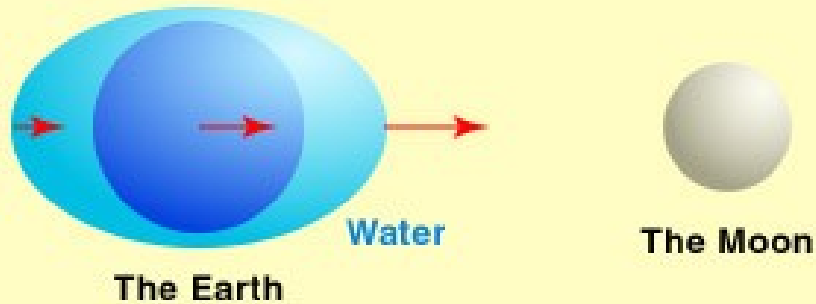


Pebbles (?)
Dark and reddish (?)

Tides



Tides



(a) Attractive Forces Exerted by the Moon



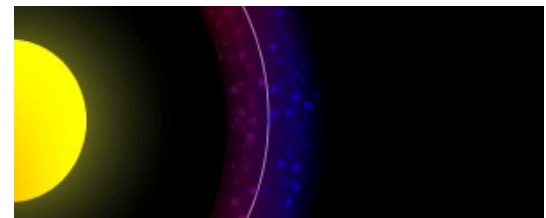
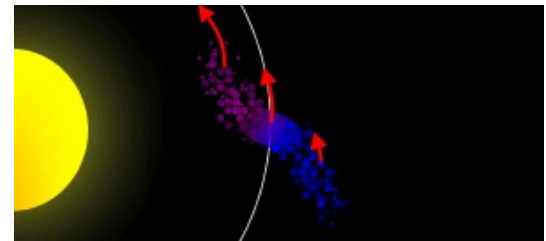
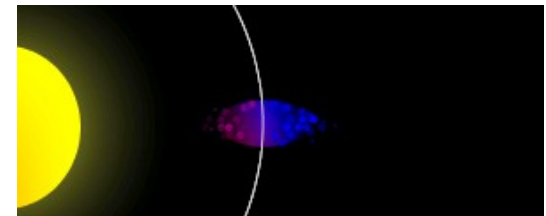
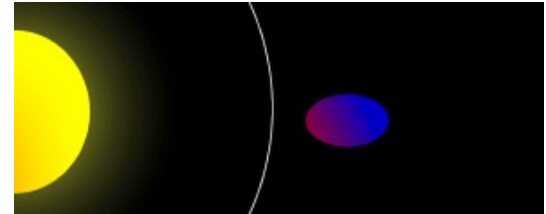
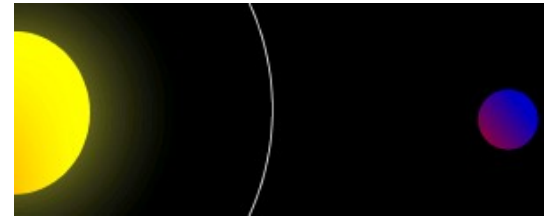
(b) Effective Forces Relative to the Earth Center

The side closer to the Moon experiences a greater pull than the side further out.

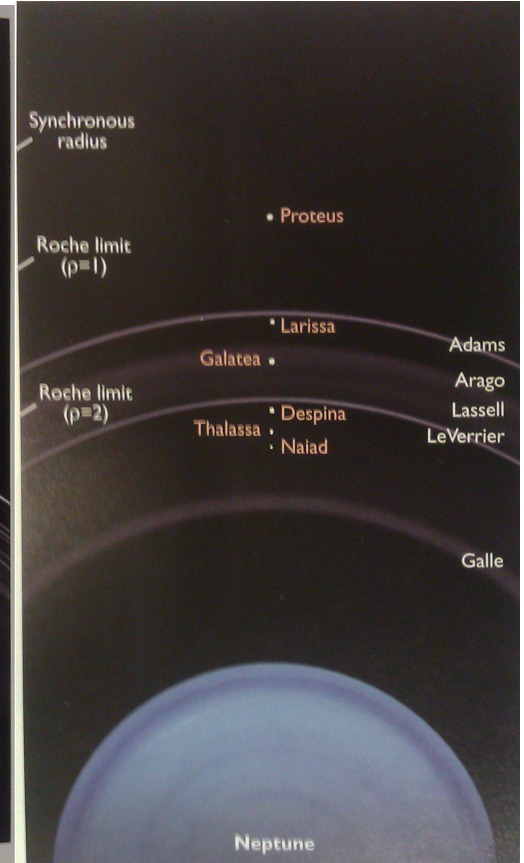
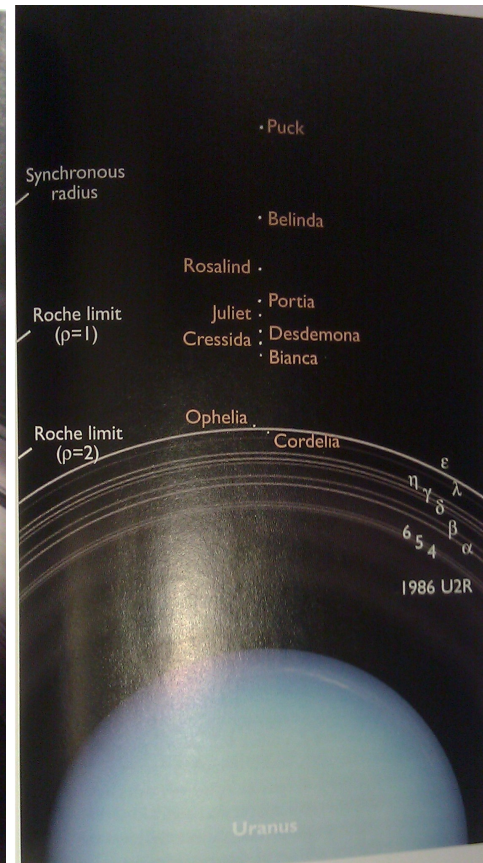
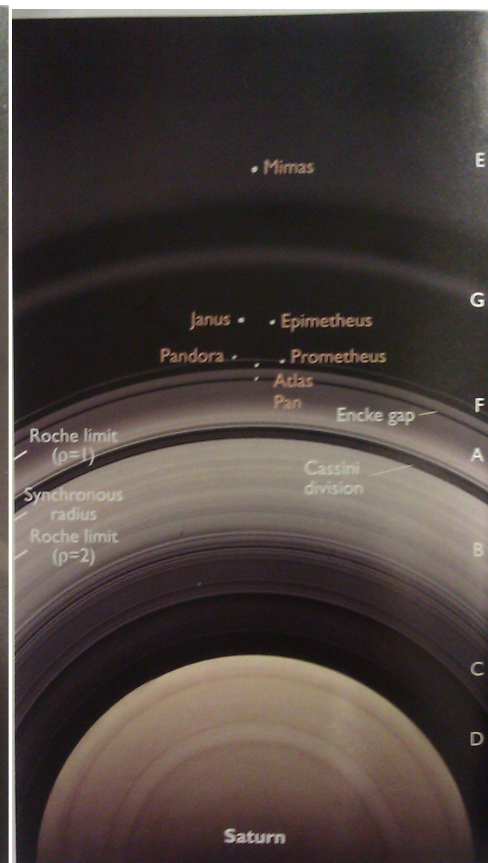
The effective result is a *differential force* we call **Tidal Force**.

Roche Limit

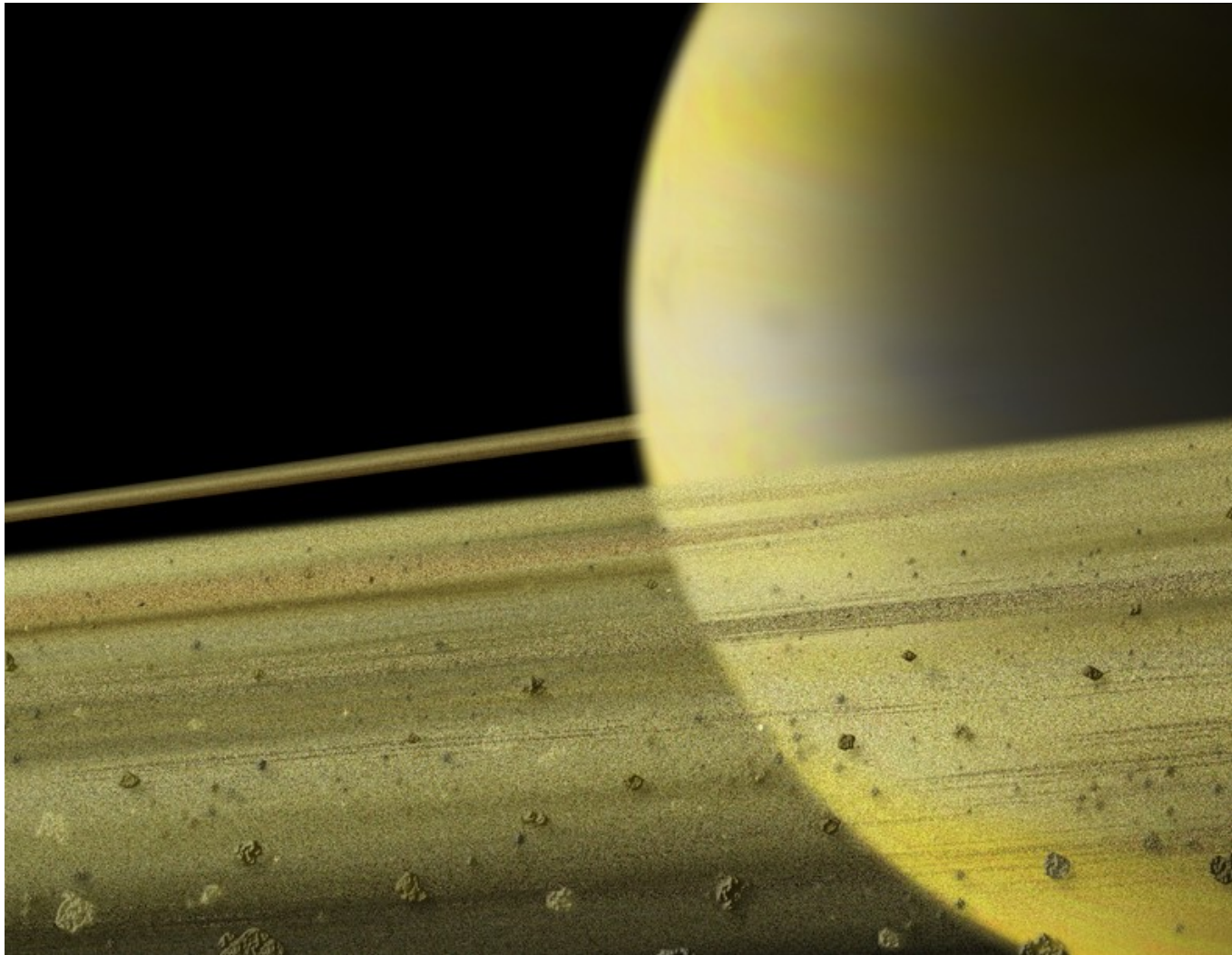
Limit where the
tidal force is **stronger** than the **internal forces**
holding the body together



All ring systems are inside their planet's Roche limit



Ring formation: Competing theories



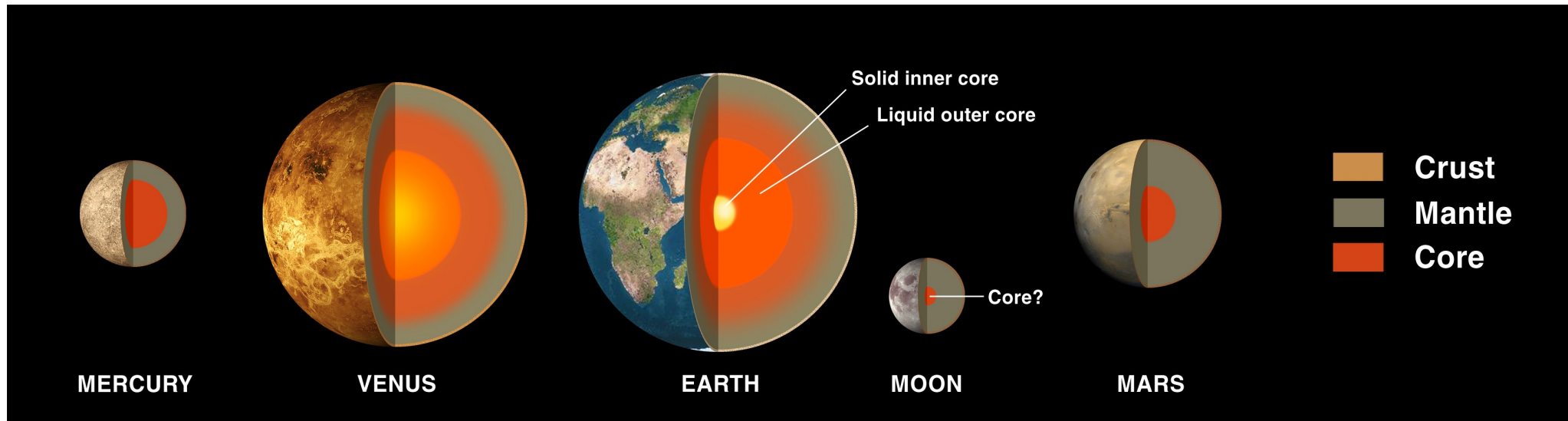
1). Moon that got too close

2). Leftover material that could not
coalesce into moons

Terrestrial Planets



Terrestrial Planets



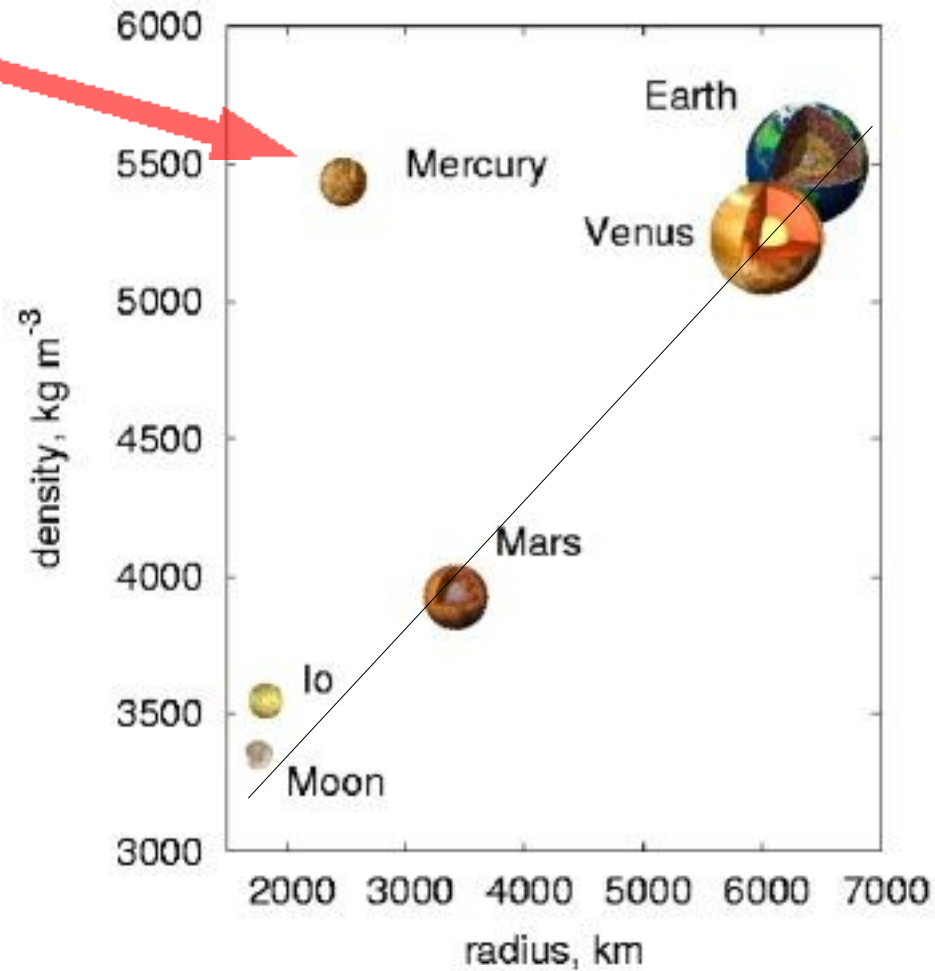
Iron-Nickel core

Silicate-rich hot mantle

Silicate-rich cold crust

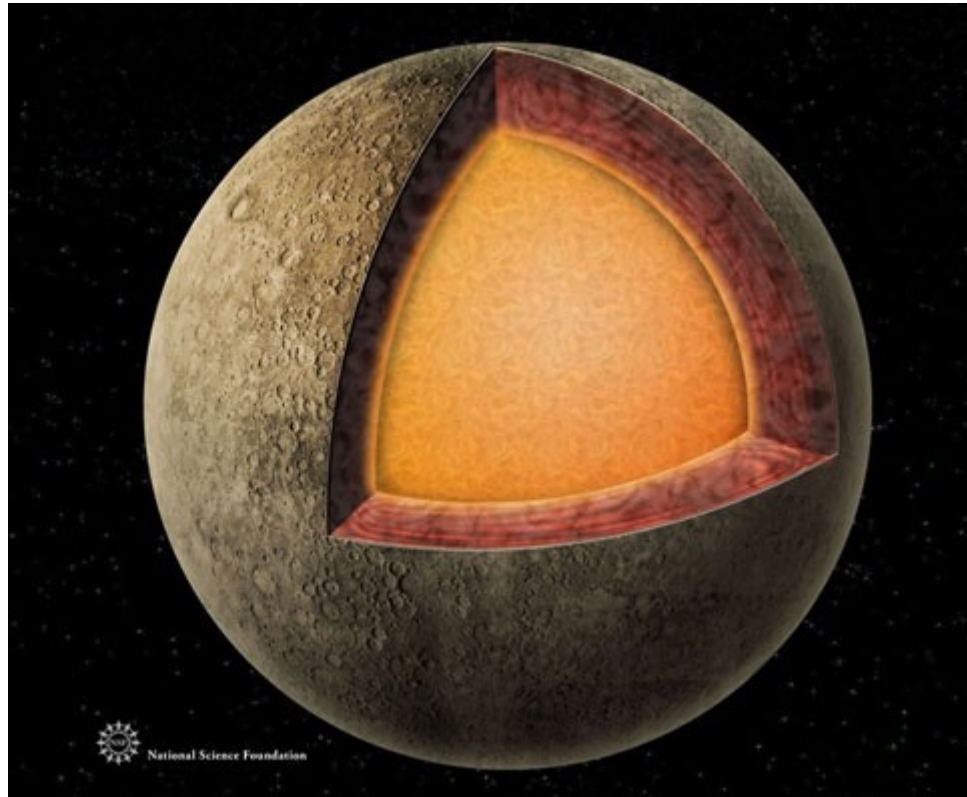
Mercury - The Iron Planet

Extreme outlier!!



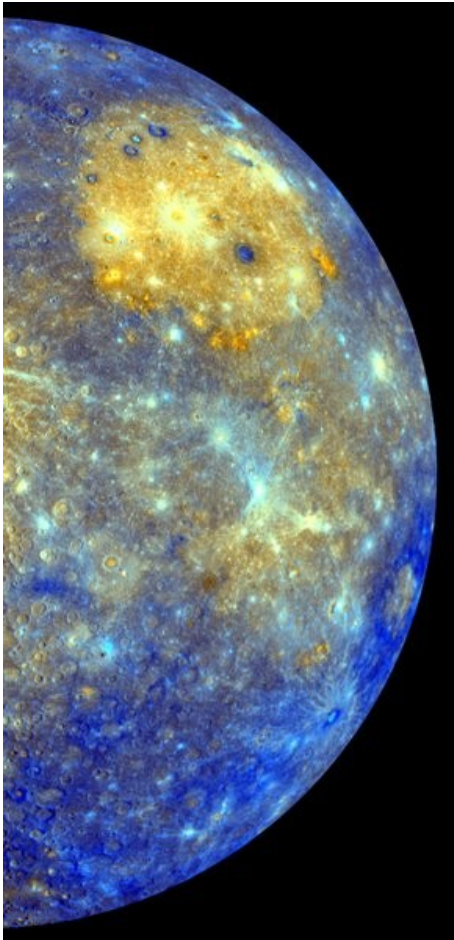
A naked metal ball

Mercury's core accounts for 60% of the planet's mass.

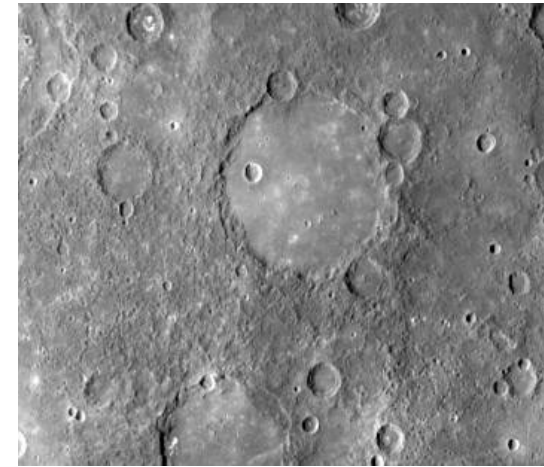


A collision probably stripped the silicate mantle,
leaving just the iron core behind.

Another giant collision in Mercury



Caloris Basin

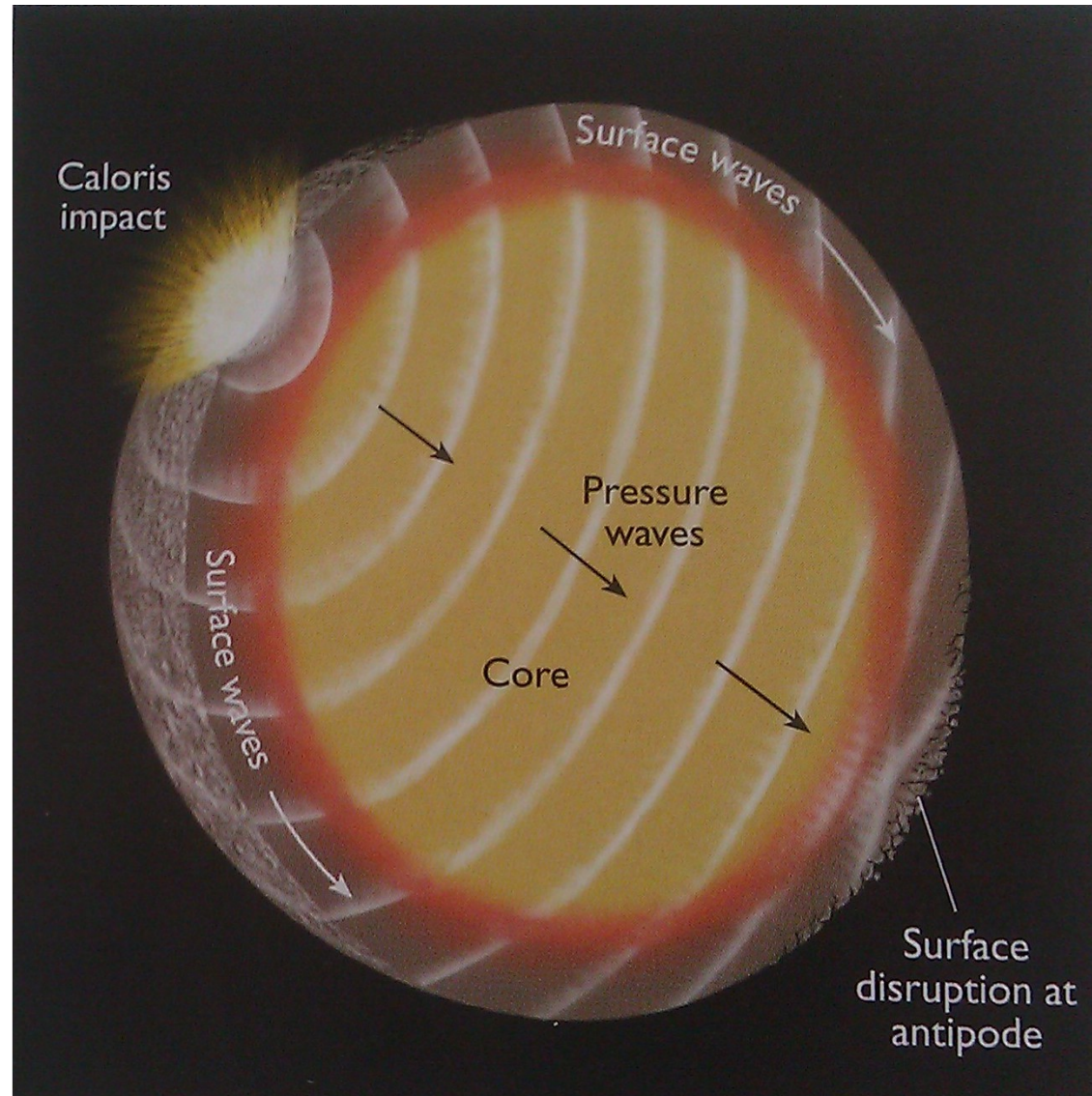


Typical Mercurian terrain

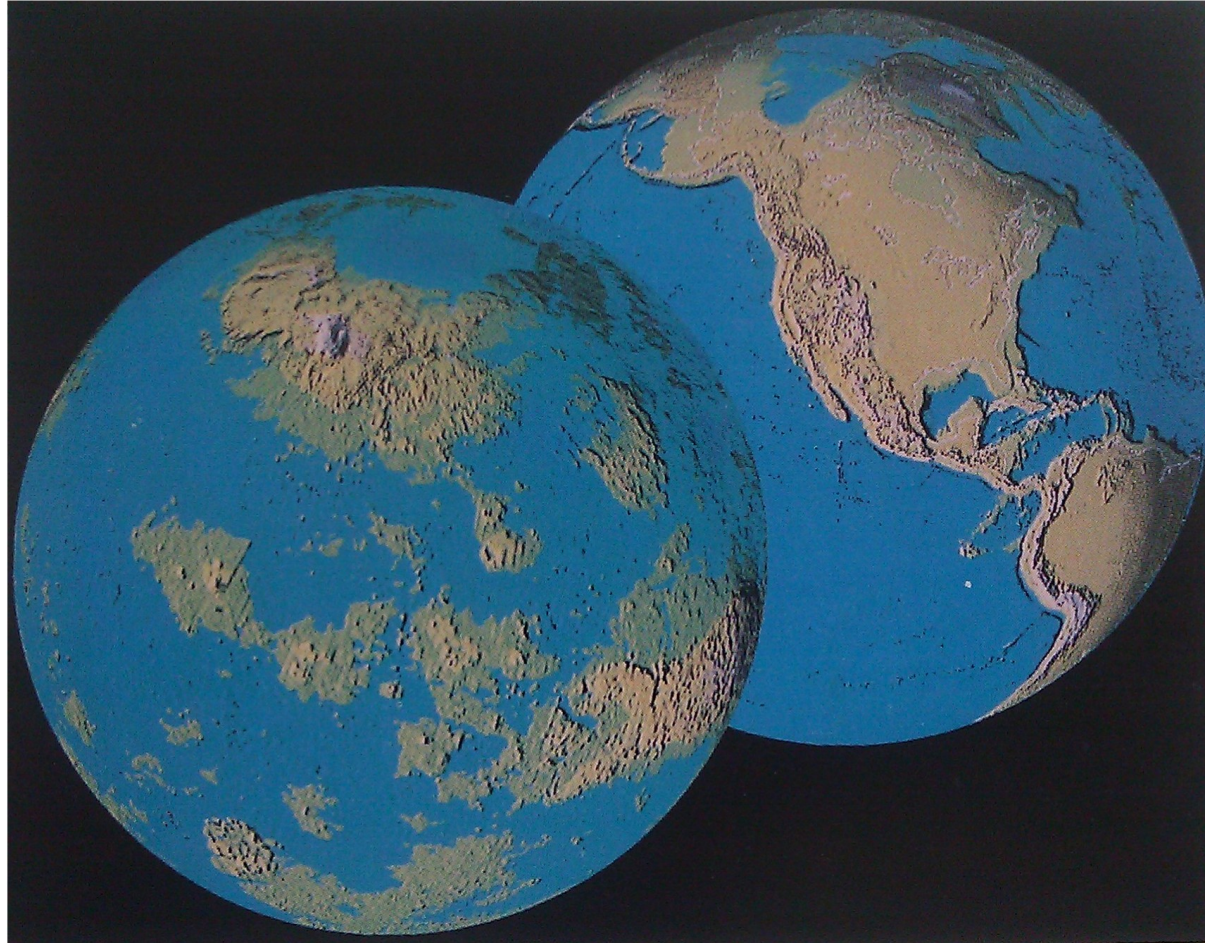


"Weird Terrain" at
Caloris' antipode

Travelling seismic waves



Venus - Earth's twin



Similar mass and radius.

Venus - Earth's **evil** twin

Very different surface and atmosphere



Pressure at surface: 92 atmospheres

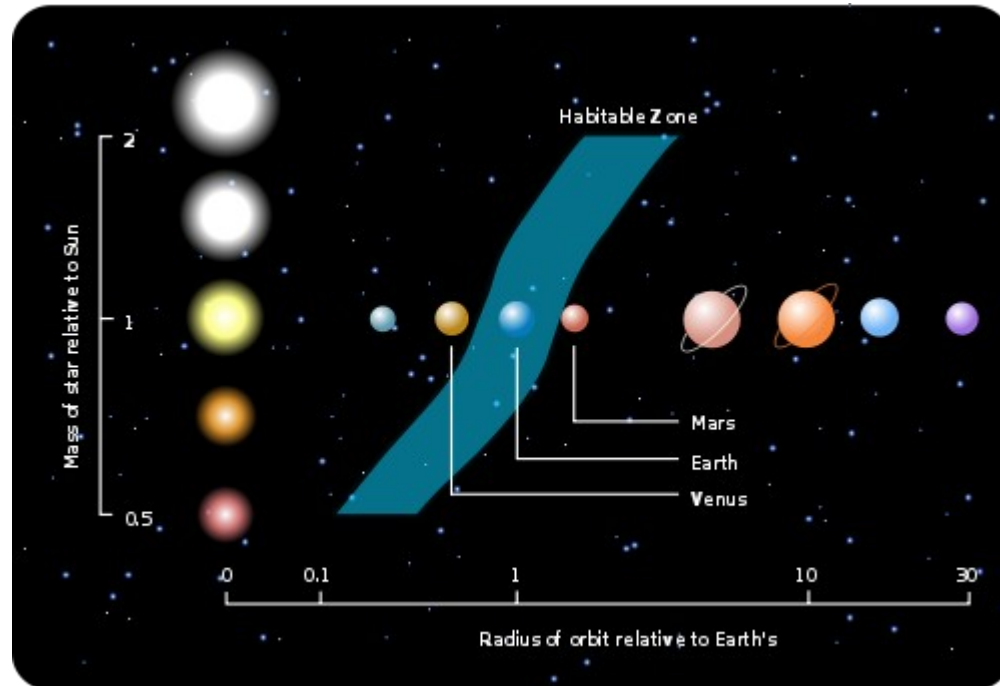
Temperature at surface: 736 K

A crushing thick atmosphere,
and temperatures high enough to melt lead

Two worlds, so similar, yet so different!

Why??

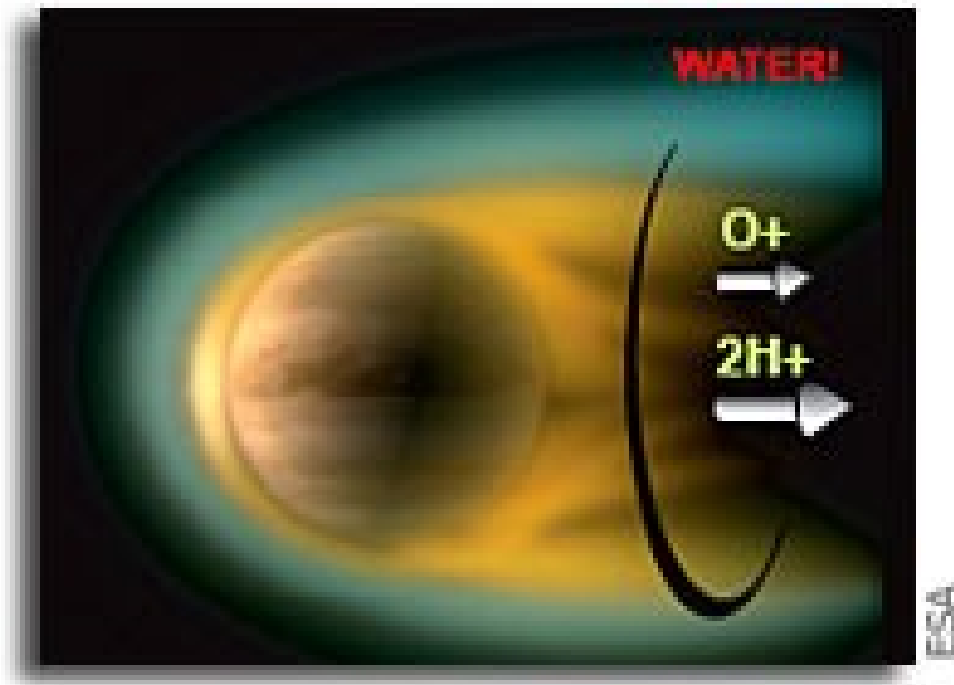
The Habitable Zone



Earth is within the habitable zone.
Venus is not.

Water loss

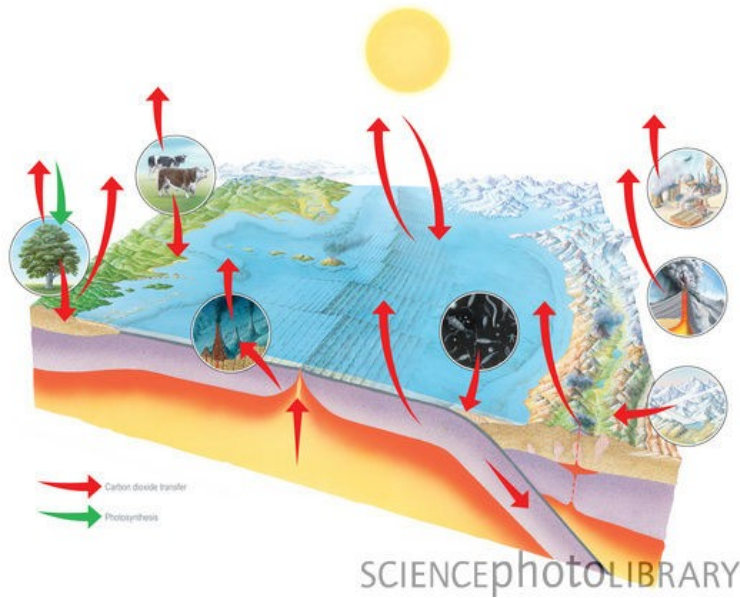
Venus is thought to have had as much water as the Earth.
But Venus is too hot to retain it.



Venus Express found evidence
of the solar wind stripping away
water from Venus' atmosphere.

Runaway greenhouse

On Earth, rain washes carbon from the atmosphere to the surface, where it gets dissolved in the oceans, and ends up as sedimentary rock.

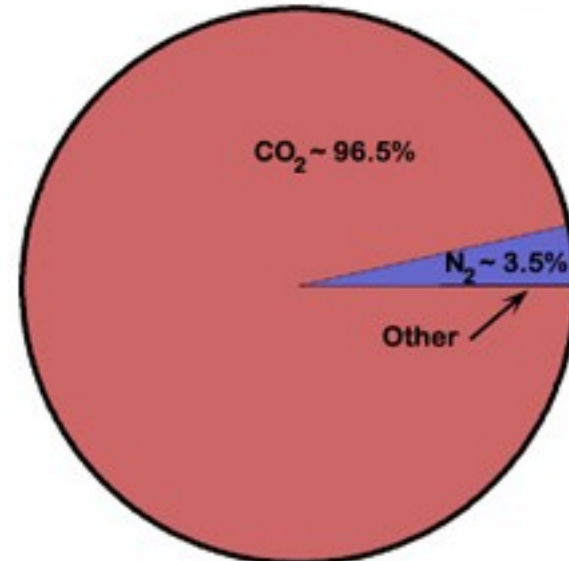


Subduction brings the carbon to the mantle.

Volcanoes bring it back to the atmosphere.

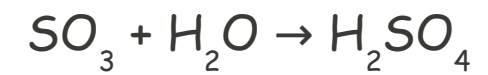
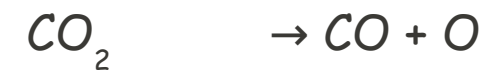
In Venus, the lack of water and tectonics means that there is no regulated carbon cycle.

All carbon ends up in the atmosphere, which is more than 95% CO_2 !!

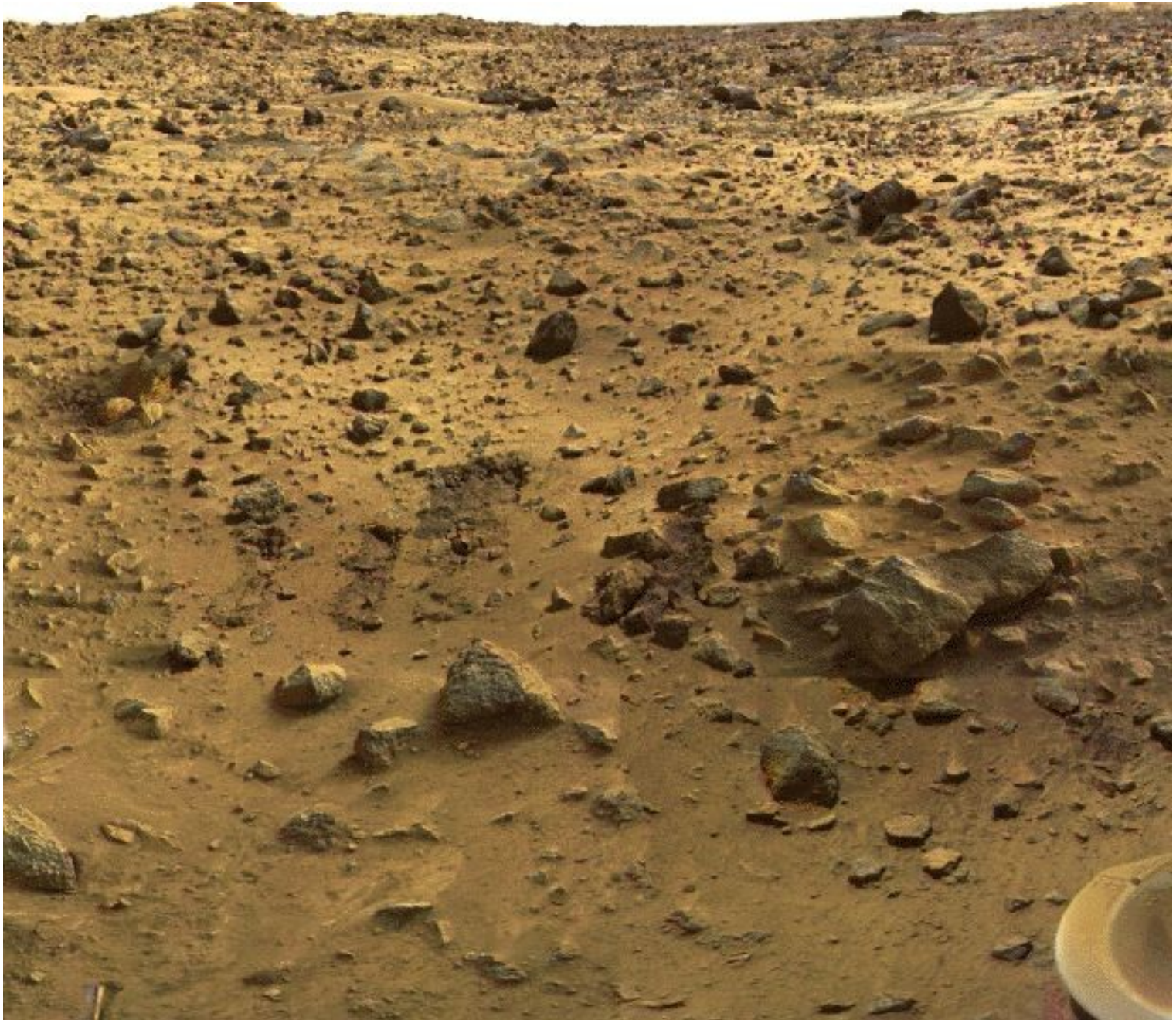


Massive resulting greenhouse effect makes Venus hotter than Mercury!

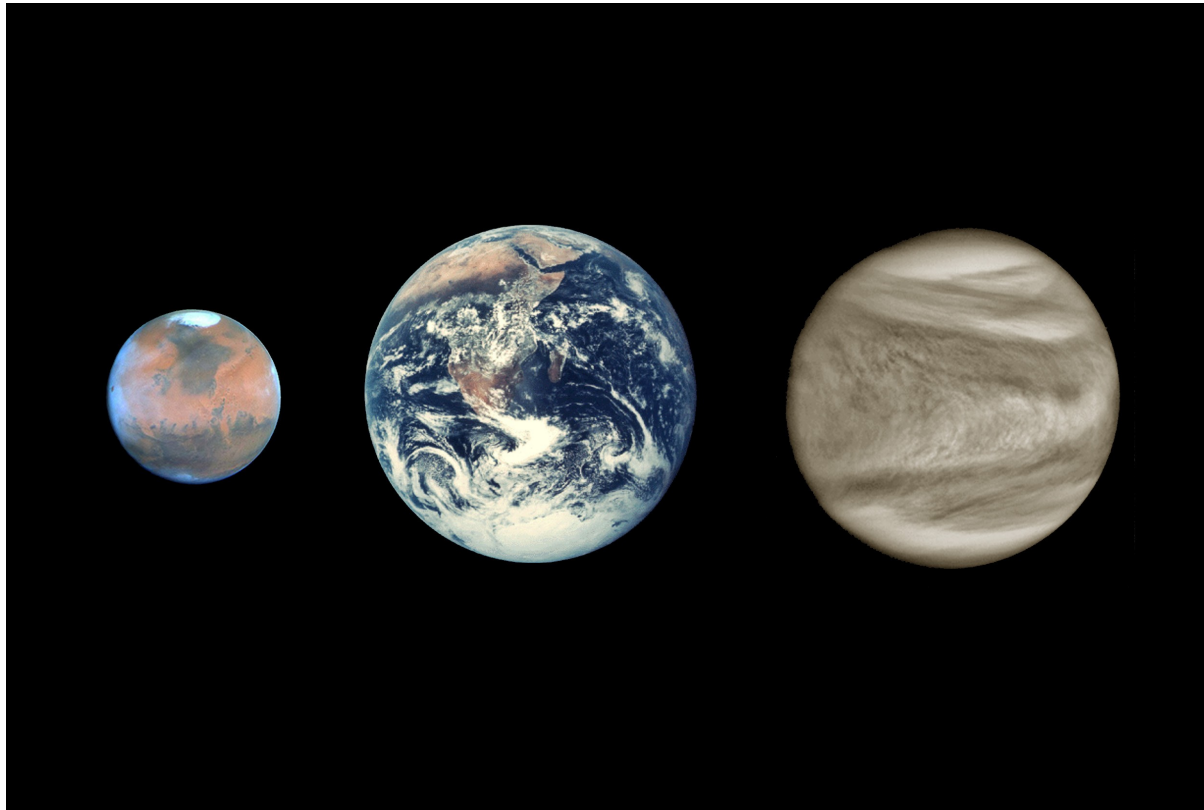
Clouds of Sulphuric Acid



Mars - The Red Planet



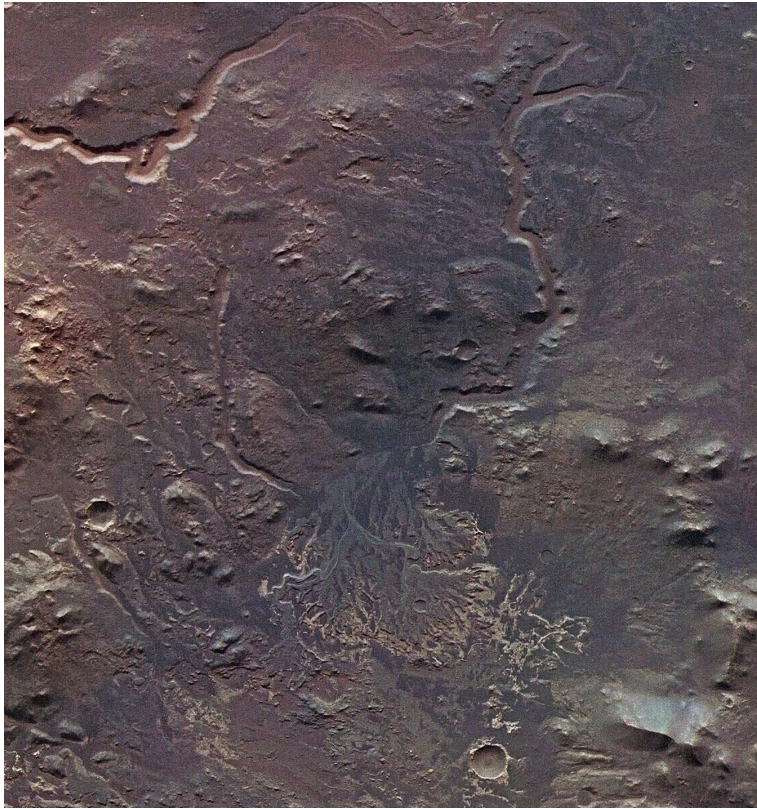
Mars is actually inside the habitable zone



But Mars is too small !!

Atmospheric pressure is too weak
to sustain liquid water

Evidence of a balmy past

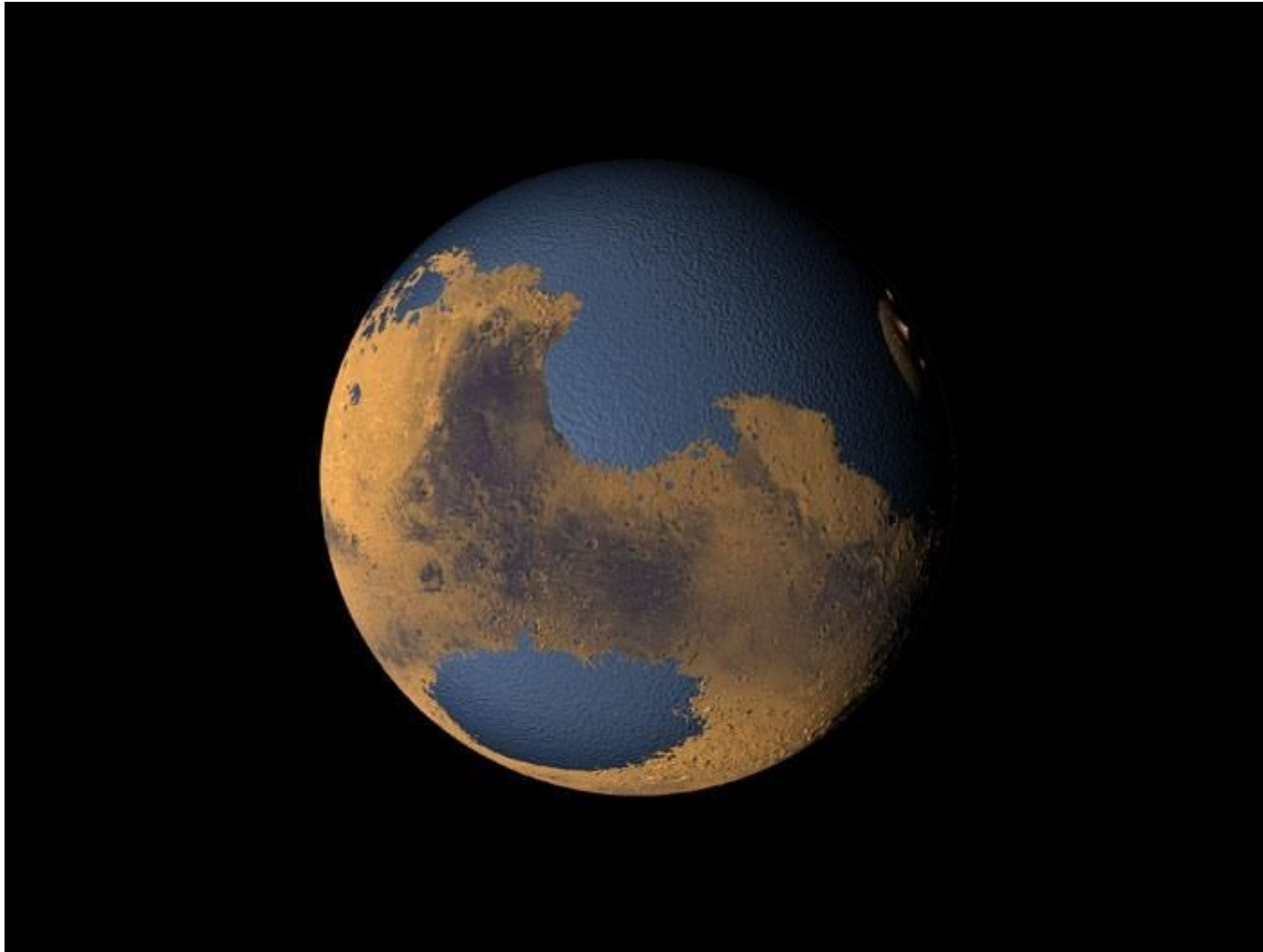


A dry river delta



An ancient riverbed

How ancient Mars may have looked like



The question is not if Mars had water.

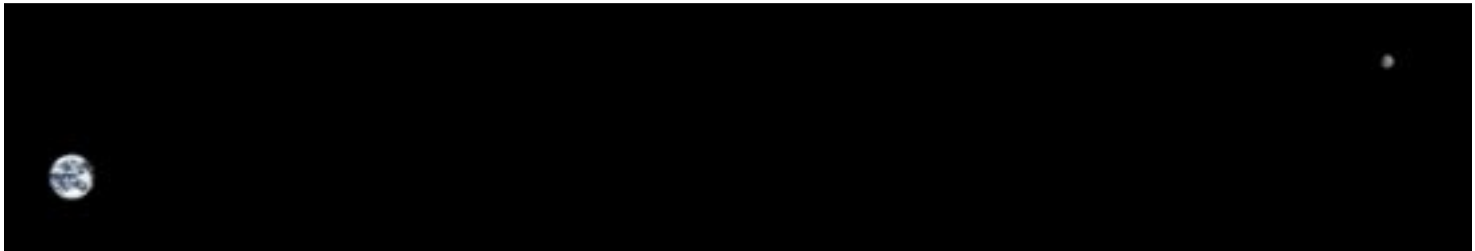
For it clearly had.

But how long did Mars "wet phase" last?

And... where did the water go?

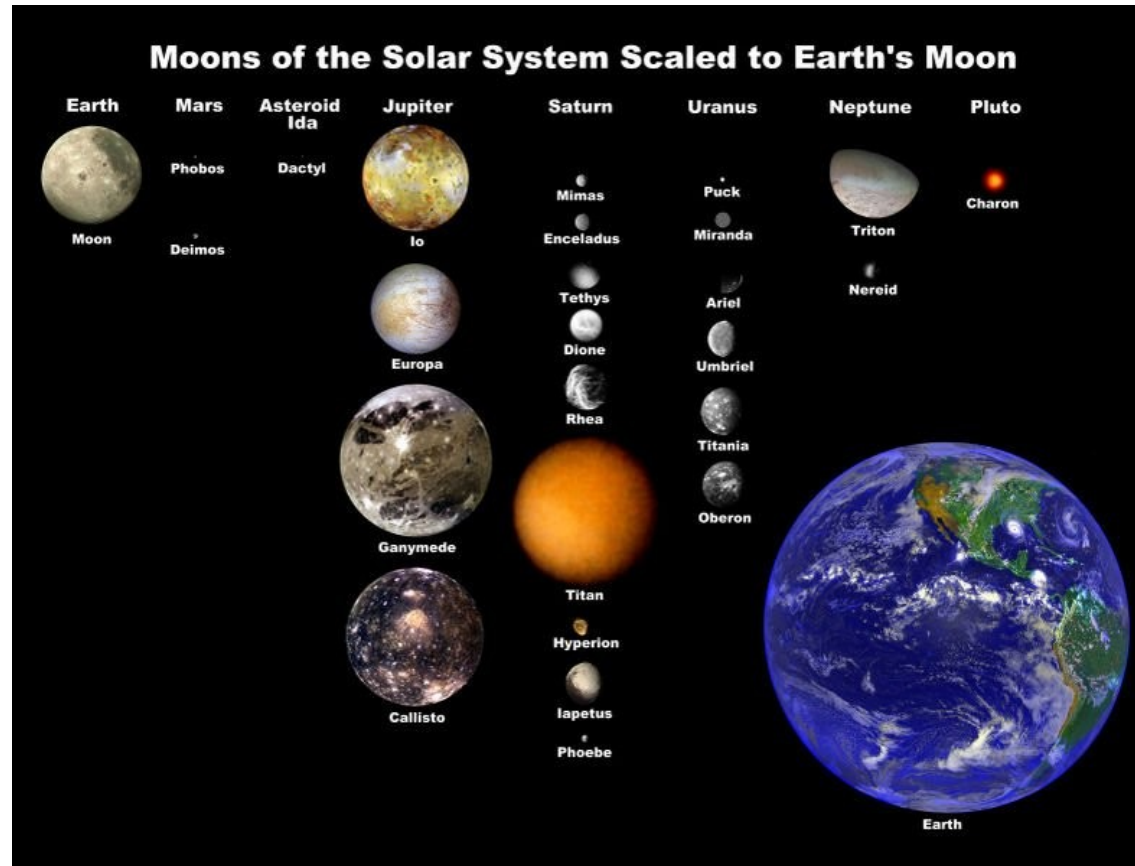
The Earth-Moon system

The Moon is a freaky big satellite compared to its parent planet



The Earth-Moon system is easily seen as a double star from Mars

Earth's giant satellite



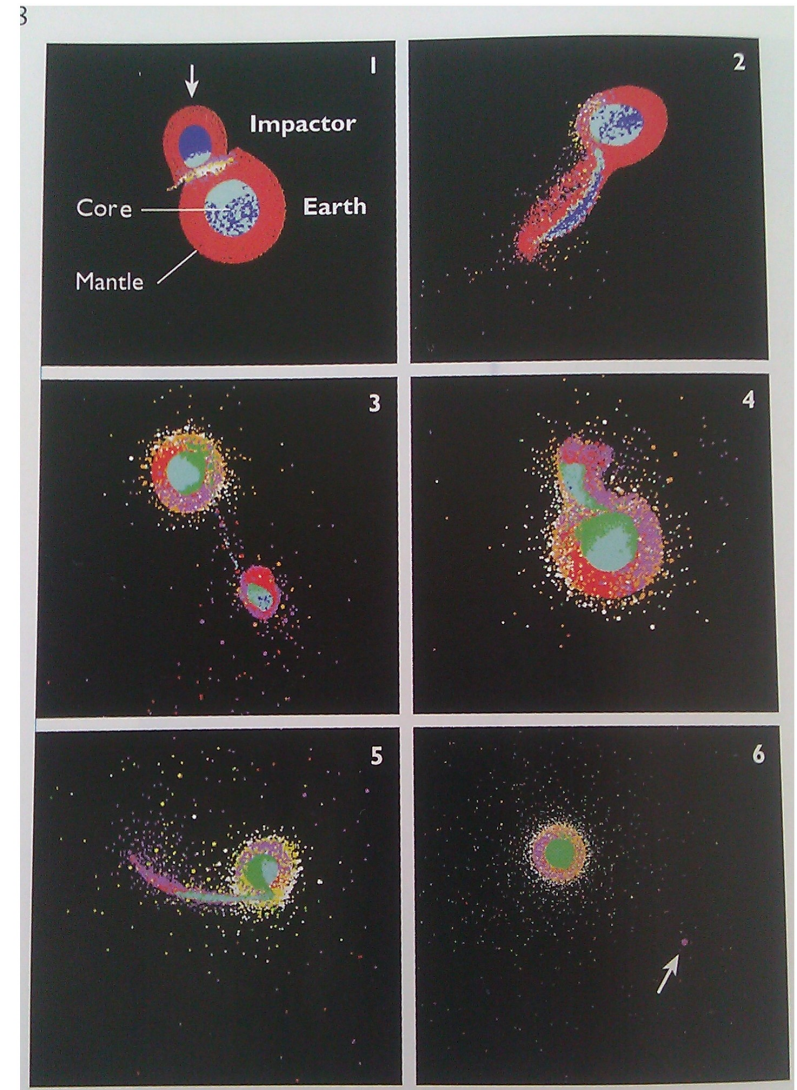
The Moon rivalizes in size
with the satellites of the giant planets

Formation

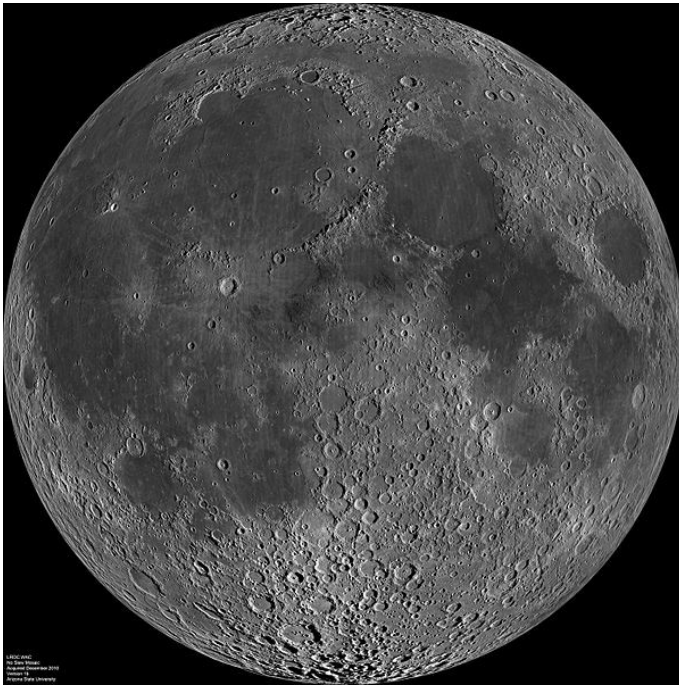
Giant impact with Mars-mass body



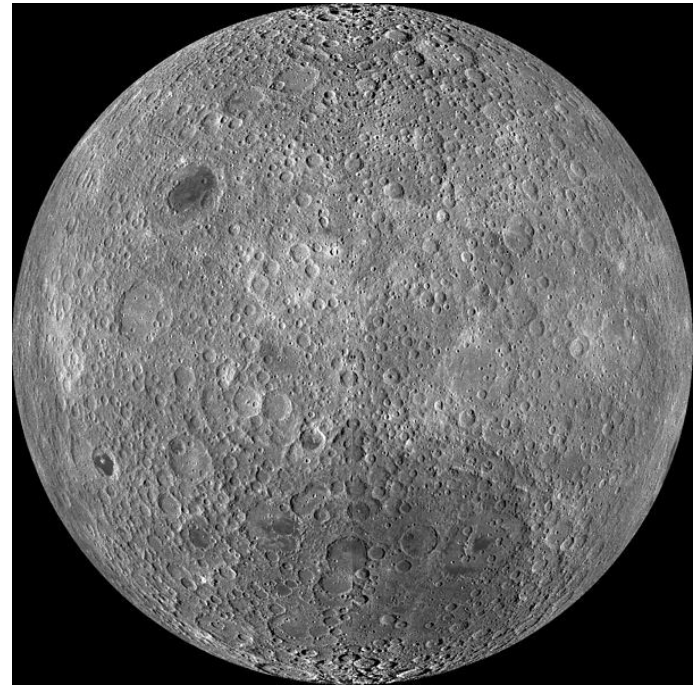
Accretion from debris in orbit



Why do we always see the same hemisphere of the Moon?



Moon's near side

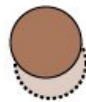
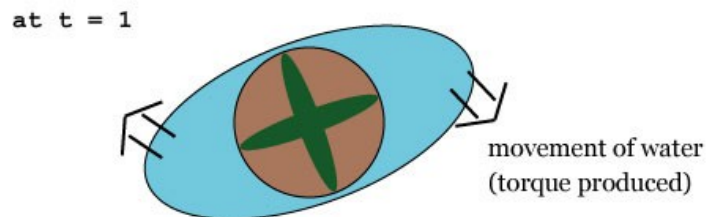
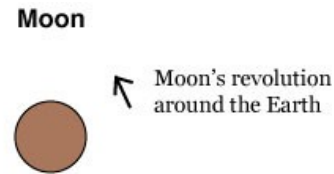
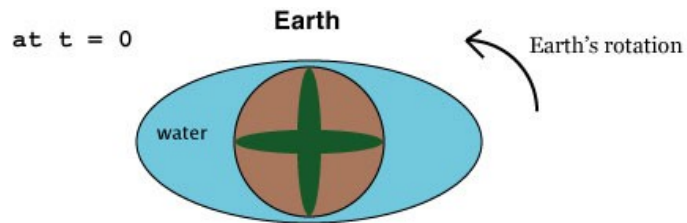


Moon's far side

Tidal locking

Earth's bulk rotates **once a day**.

Tidal bulge rotates with the
Moon's orbital period: **once a month**.



GENERATES FRICTION

Works as a **brake** that
slows down Earth's rotation

The process will continue until
Earth's rotational period
equals the
orbital period of the Moon.

(The Earth has already tidally locked
the Moon long ago.)