Department of Physics and Astronomy

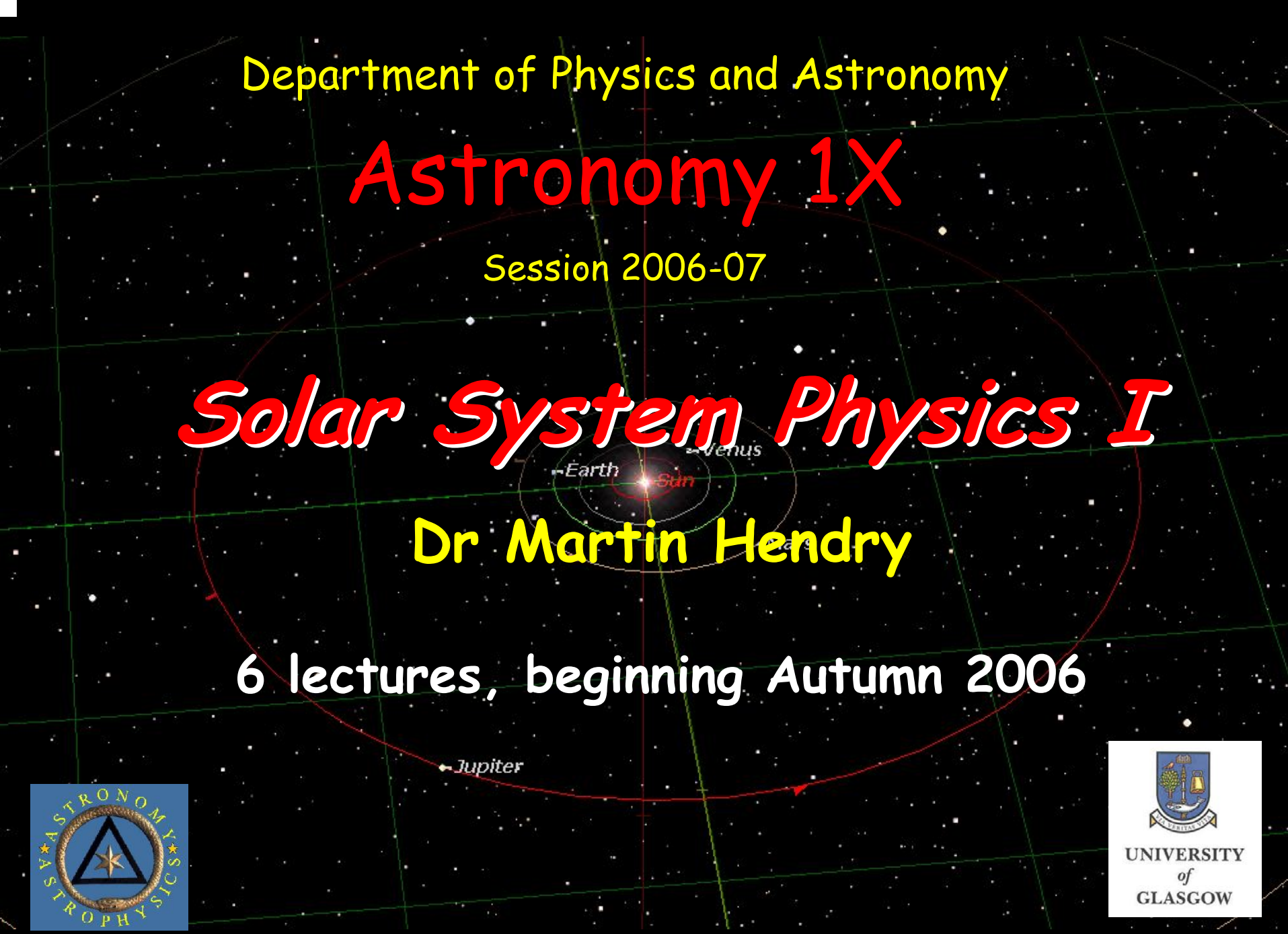
Astronomy 1X

Session 2006-07

Solar System Physics I

Dr Martin Hendry

6 lectures, beginning Autumn 2006



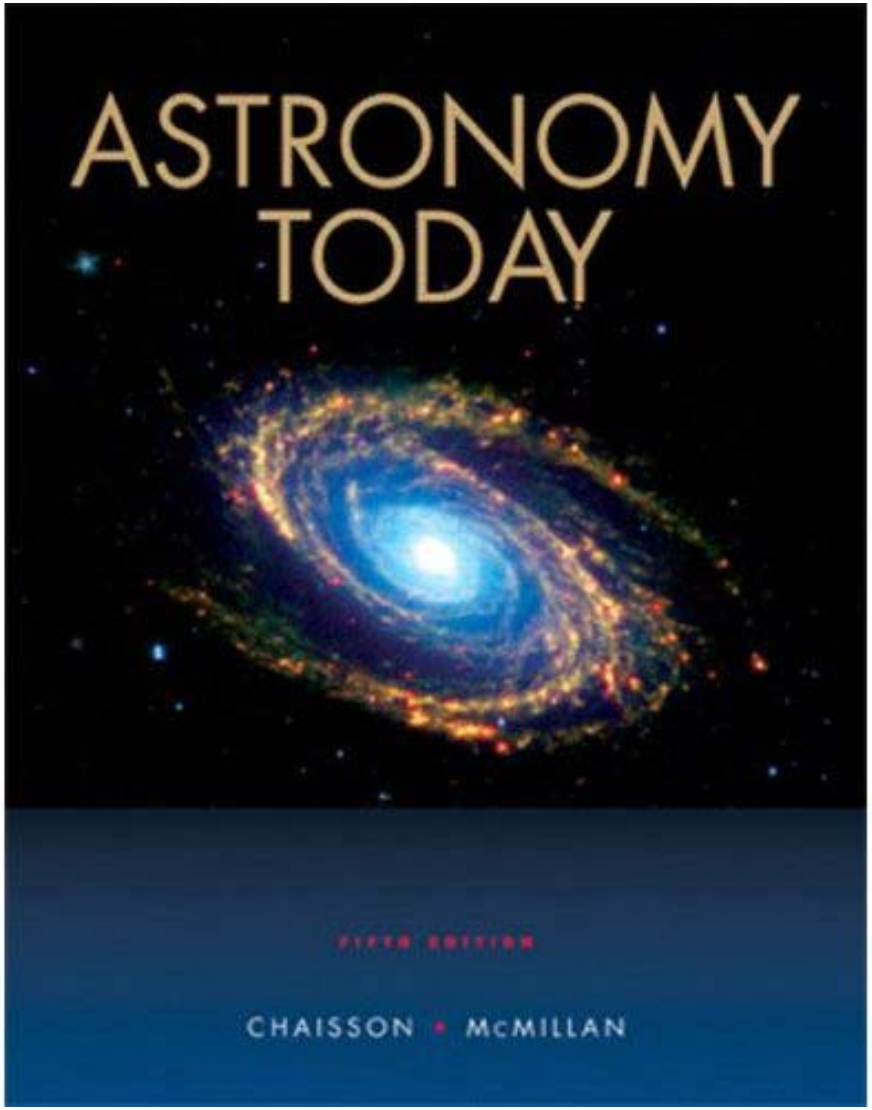
UNIVERSITY of GLASGOW

Dr Martin Hendry

- Room 607, Kelvin Building
- email: martin@astro.gla.ac.uk
- Tel: ext 5685
- Office hours: no formal time

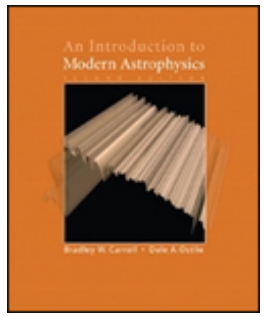
Course webpages: access via A1X moodle site

http://moodle.gla.ac.uk/physics/moodle/



Course Textbook available as a **special package** from the University Bookshop:

Includes additional chapters from Carroll & Ostlie which are **essential** *to A1X,Y*



Cost £49.99

Includes access to online learning resources for Astronomy Today

Astronomy A1X 2006-07
Solar System Physics I – Lecture Plan

Introductory Tour of the Solar System — 1 lecture

- Qualitative description of the Sun, planets, moons and minor bodies, contrasting Jovian and terrestrial planets
- Vital statistics
- Overview of Solar System formation

Gravitation and Solar System physics — 1.5 lectures

- Newton's law of gravitation and link to A1X Dynamical Astronomy
- Surface gravity and escape velocity
- Tidal forces

Astronomy A1X 2006-07
Solar System Physics I – Lecture Plan

The physics of planetary atmospheres — 1.5 lectures

- The ideal gas law and velocity of gases
- Hydrostatic equilibrium and atmospheric scale heights

The Jovian planets and their moons — 2 lectures

- Internal and atmospheric structure and composition
- Ring systems and Roche stability
- Physical properties of the main satellites
- Case studies: Titan and the Galilean moons

Lecture 1: A Tour of the Solar System

Some vital statistics:-

The Solar System consists of:-

- the Sun,
- its **8** planets,
- their moons,
- dwarf planets, asteroids and comets,
- the 'Solar wind'

- Astronomers have studied the motions of the Sun, Moon and planets for thousands of years (see A1X Positional Astronomy).

Retrograde motion

Lecture 1: A Tour of the Solar System

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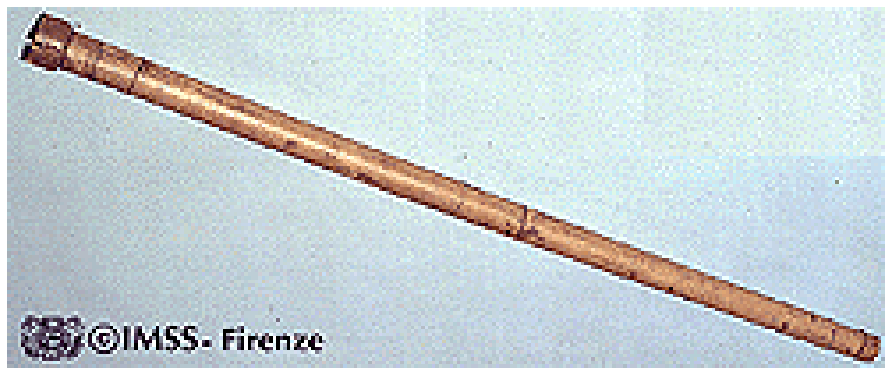
- Astronomers have studied the motions of the Sun, Moon and planets for thousands of years (see A1X Positional Astronomy).

- Before the invention of the telescope, however, we knew almost nothing about their true nature

The Observations of Galileo

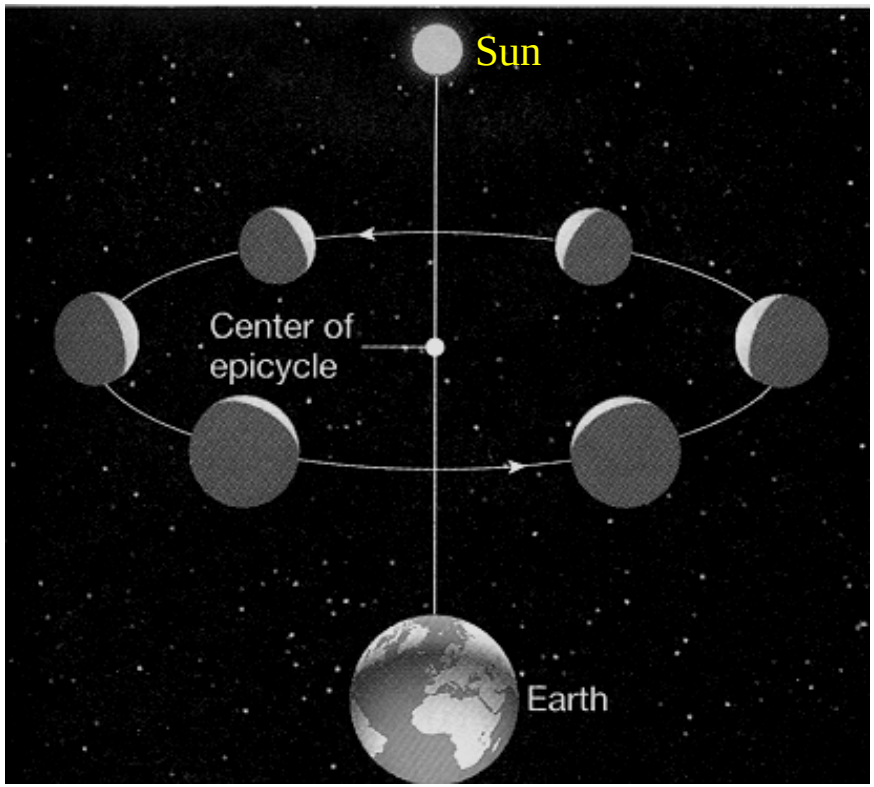
Galileo Galilei:
(1564 – 1642)



The Observations of Galileo

In 1609 observed phases of Venus

Geocentric model



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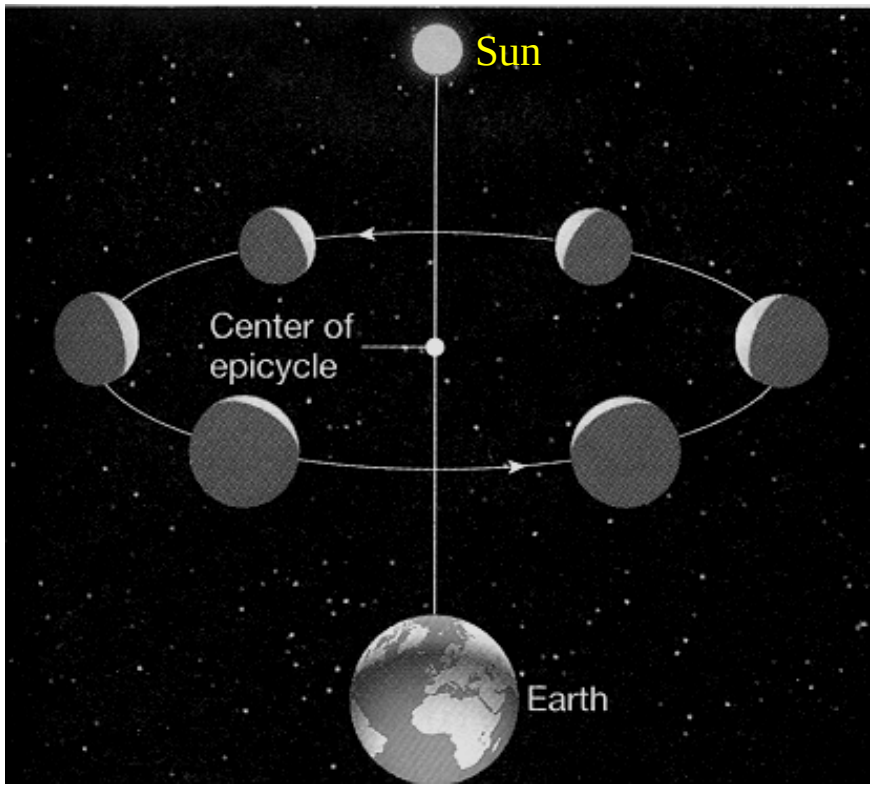
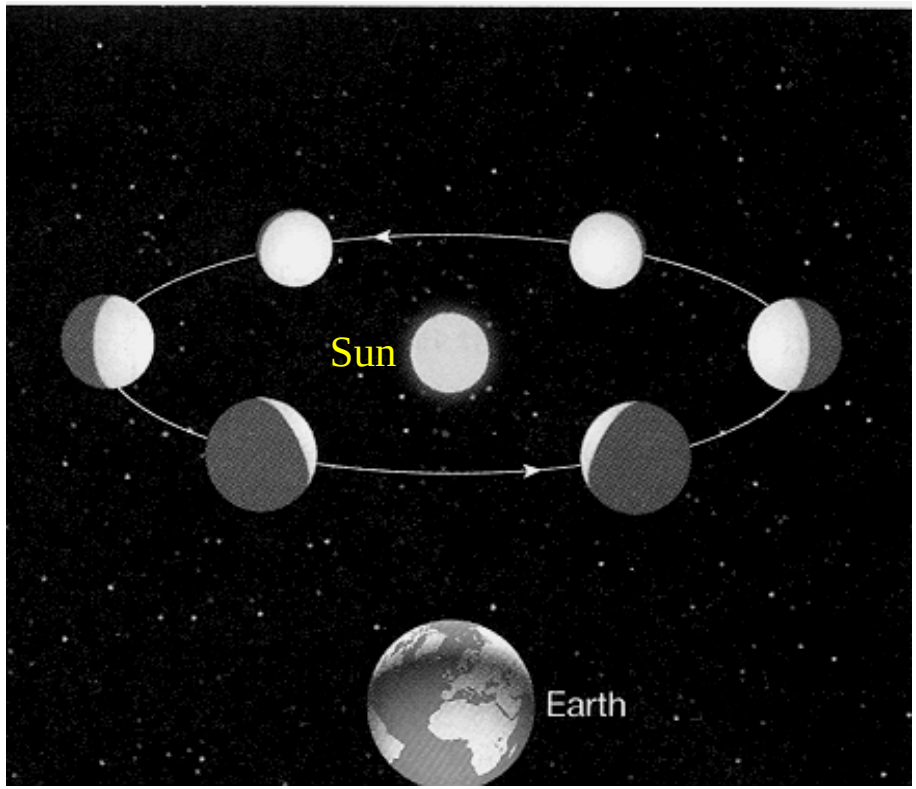


Heliocentric model



The Observations of Galileo

Phases of Venus impossible to explain in geocentric model

Clear evidence that the Earth went round the Sun, and not the other way round

Lecture 1: A Tour of the Solar System

The Sun: some vital statistics:-

The Sun is a star: a ball of (mainly) hydrogen gas,
700,000 km in radius (about 100 Earth radii)

Earth, to scale

Lecture 1: A Tour of the Solar System

The Sun: some vital statistics:-

The Sun is a star: a ball of (mainly) hydrogen gas, 700,000 km in radius (about 100 Earth radii)

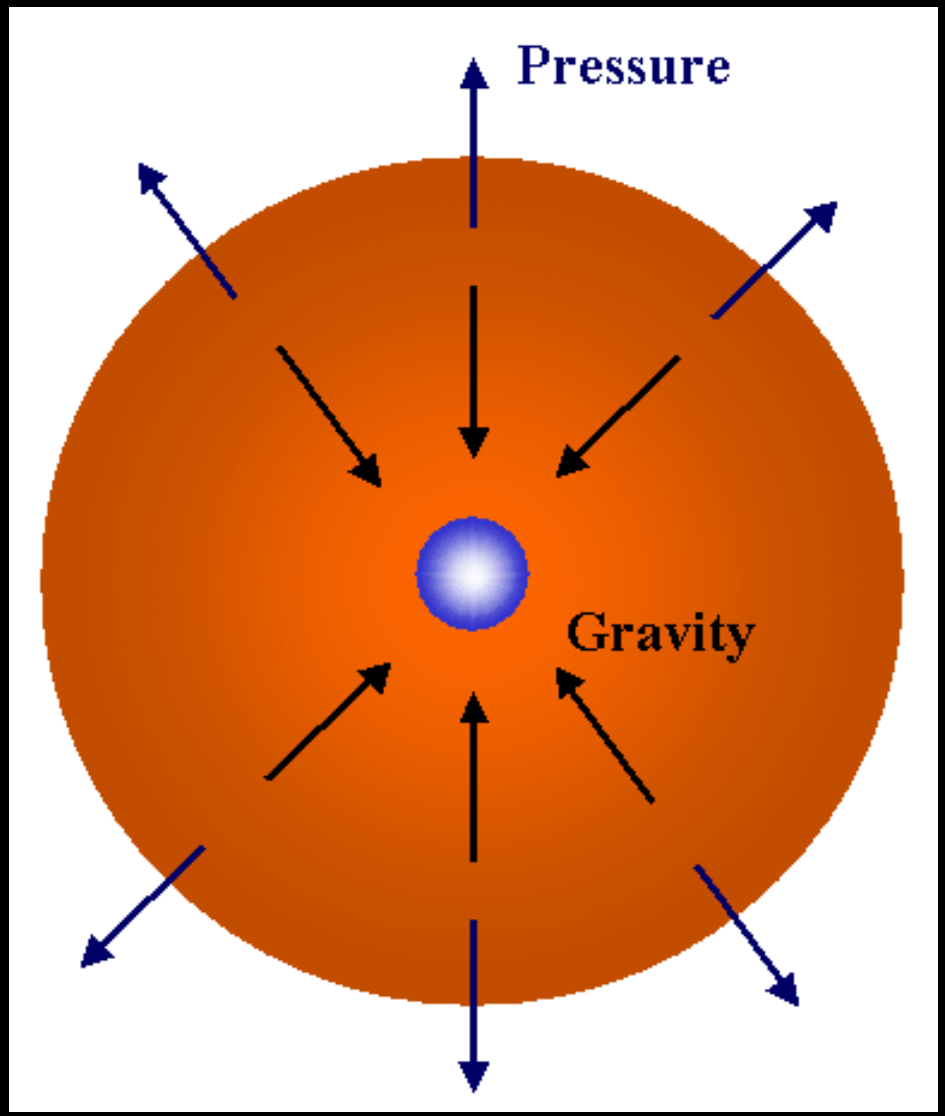
It generates heat and light through **nuclear fusion**:

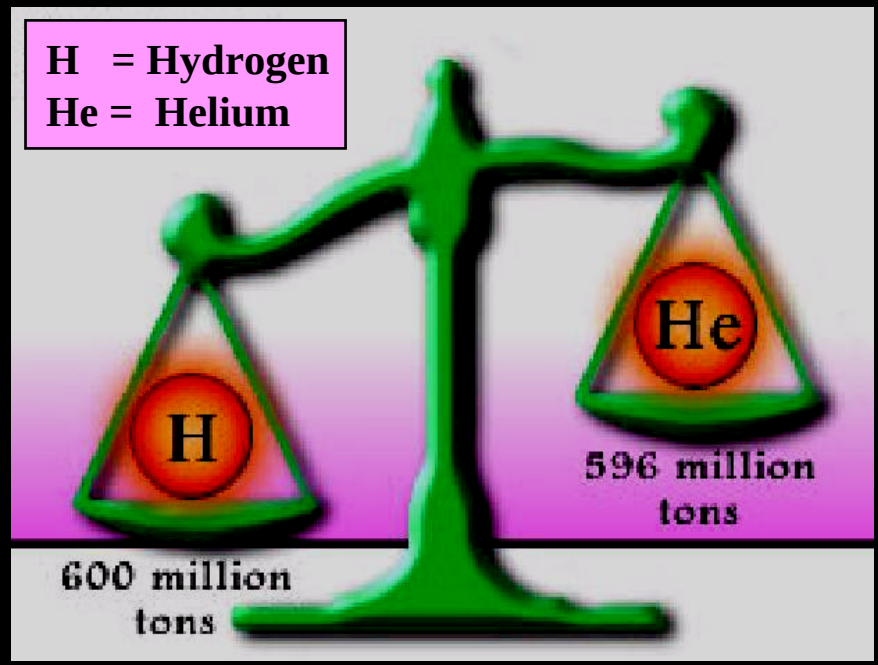
Surface temperature = 5800K

Central temperature = 15 million K

Balance (hydrostatic equilibrium) maintained between *pressure* and *gravity*

Hydrogen fusion – fuelling a star's nuclear furnace





$$E = mc^2$$

Lecture 1: A Tour of the Solar System

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Surface temperature = 5800K

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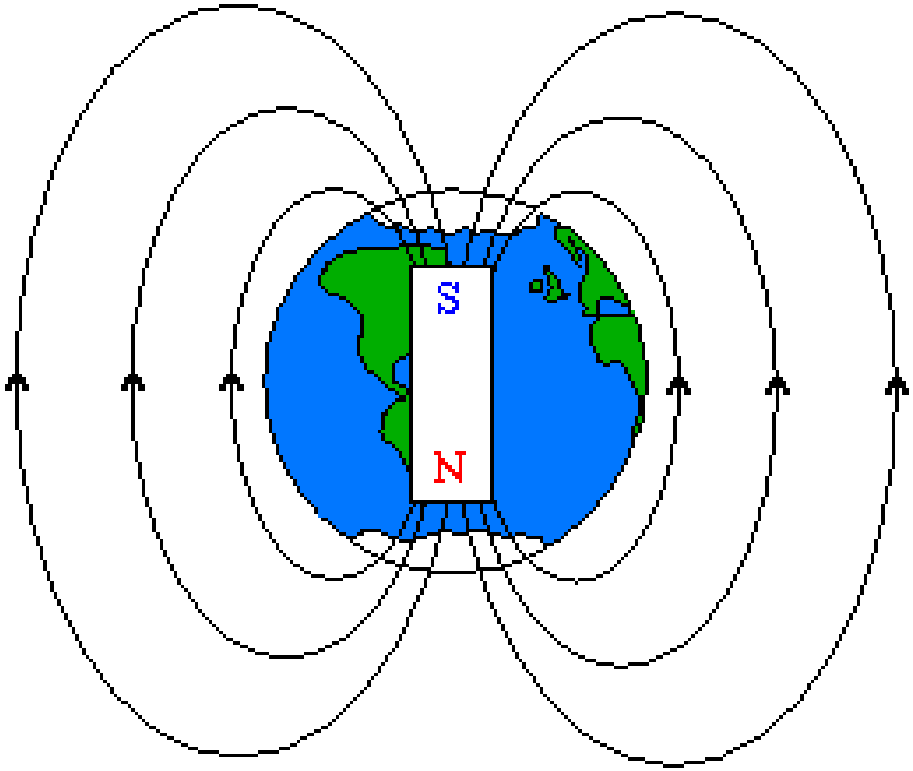
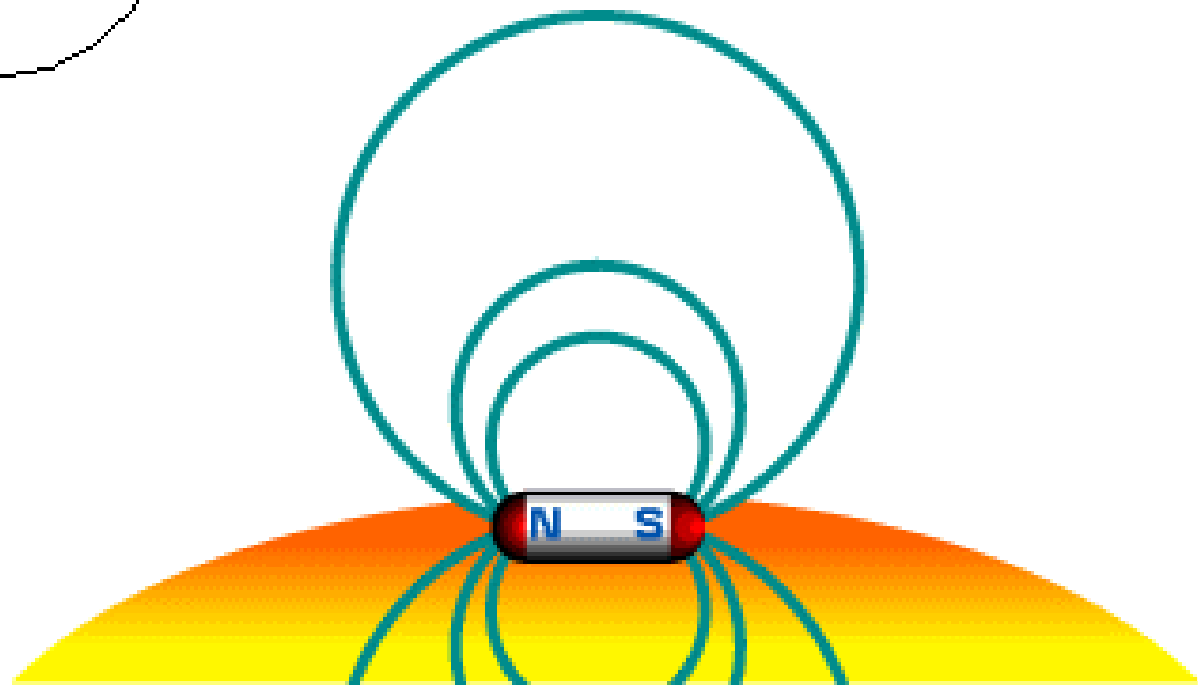
Balance (hydrostatic equilibrium) maintained between

pressure and *gravity*

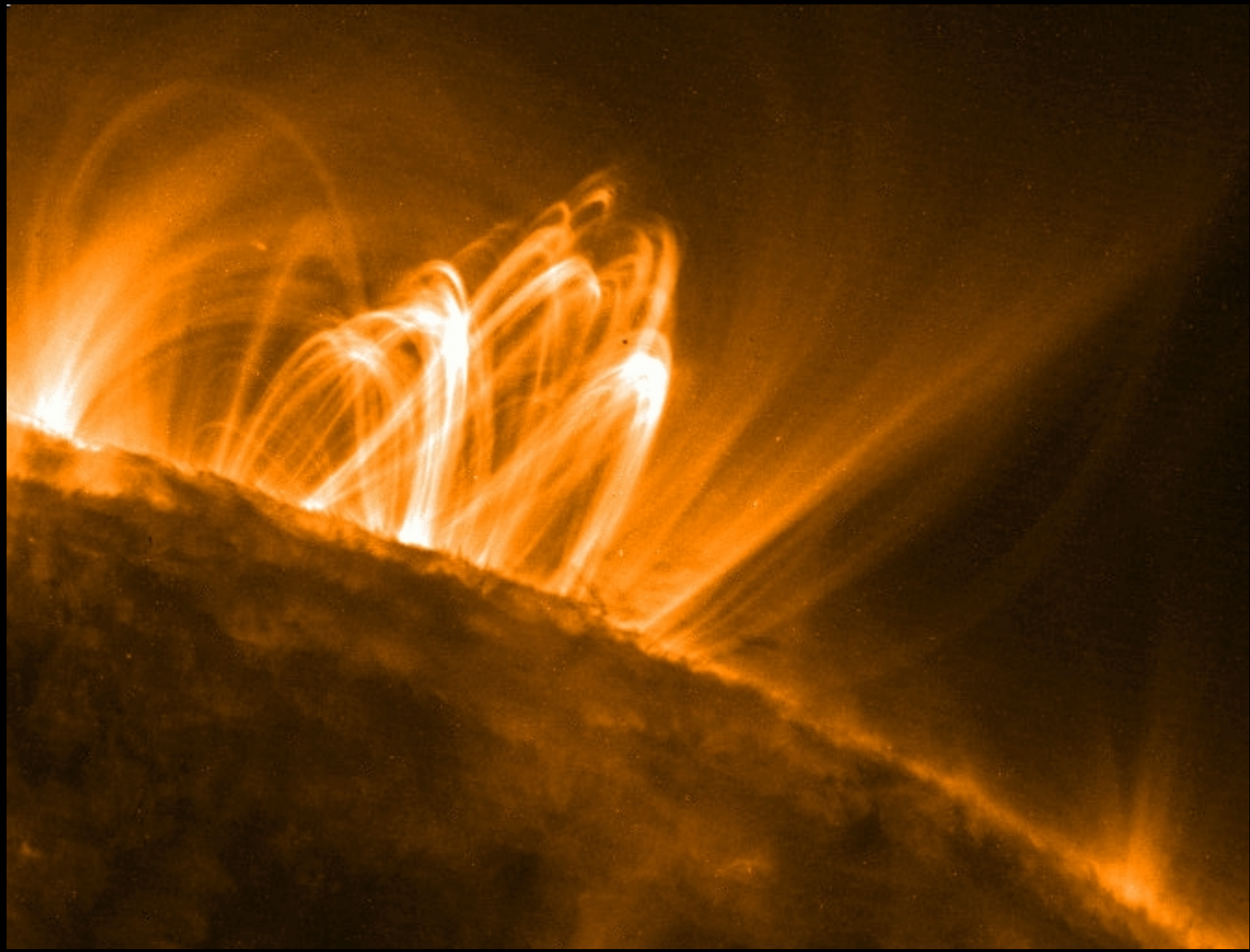
The Sun's outer atmosphere, or *corona*, is very hot (several million K) – heated by twisting of the Sun's magnetic field?...

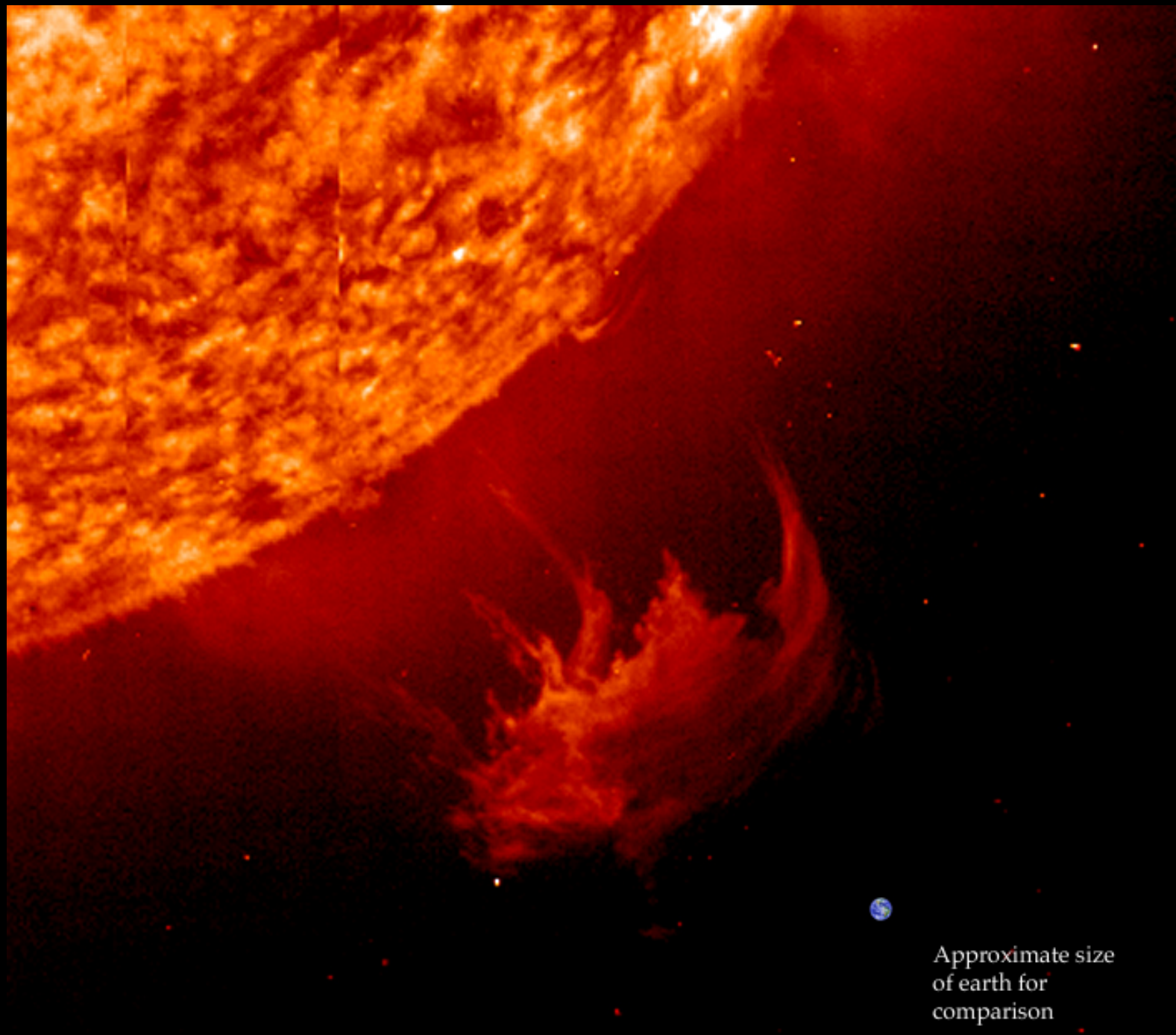


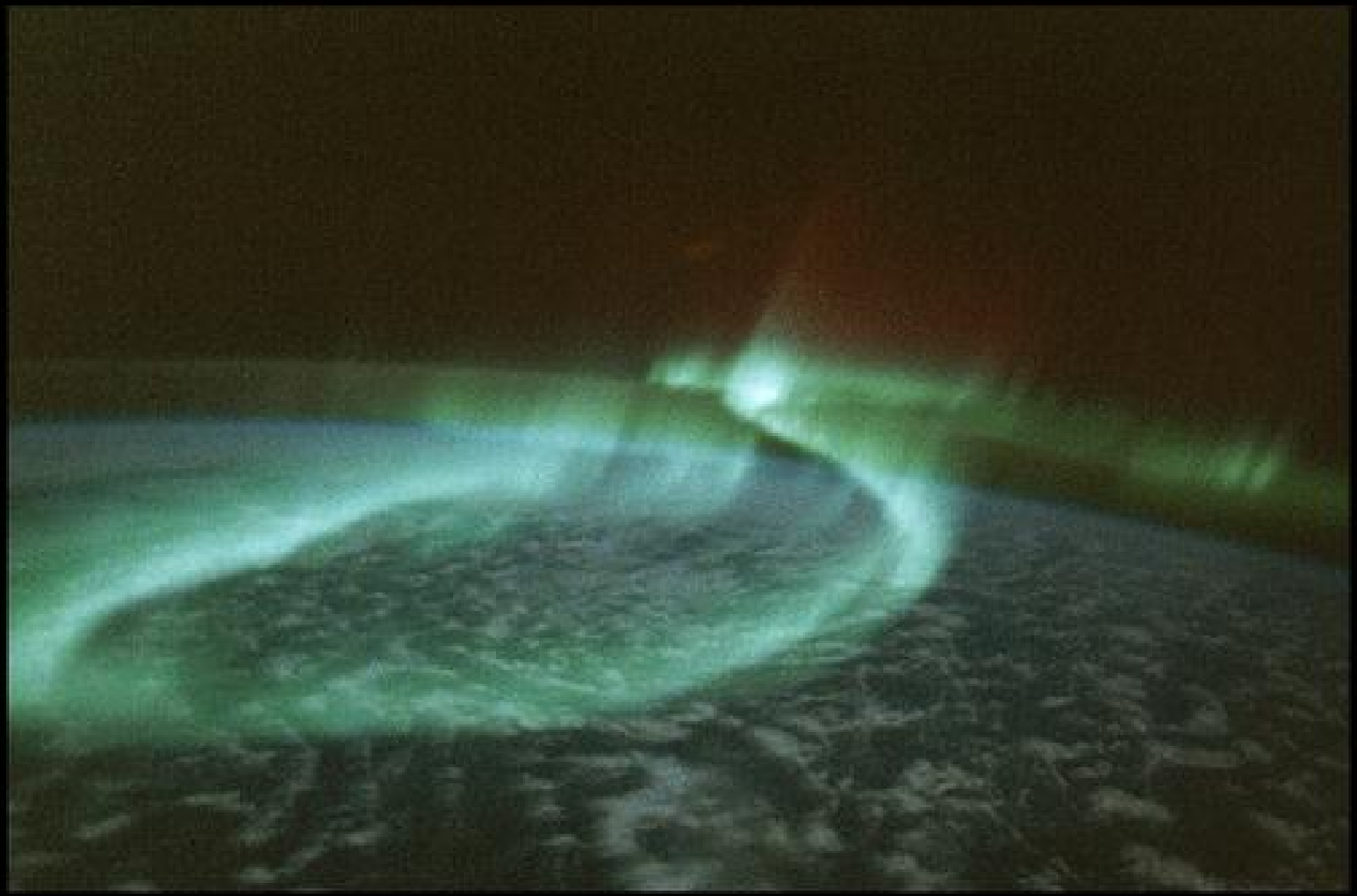
Earth’s magnetic field



Magnetic fields on the sun




Approximate size
of earth for
comparison



Lecture 1: A Tour of the Solar System

The Planets: some vital statistics:-

Name	Diameter* (Earth=1)	Mass (Earth=1)	Mean distance from the Sun
Mercury	4880 km (0.383)	3.302×10^{23} kg (0.055)	5.79×10^{7} km (0.387 AU)
Venus	12104 km (0.949)	4.869×10^{24} kg (0.815)	1.082×10^{8} km (0.723 AU)
Earth	12756 km (1.000)	5.974×10^{24} kg (1.000)	1.496×10^{8} km (1.000 AU)
Mars	6794 km (0.533)	6.418×10^{23} kg (0.107)	2.279×10^{8} km (1.524 AU)
Jupiter	142984 km (11.209)	1.899×10^{27} kg (317.8)	7.783×10^{8} km (5.203 AU)
Saturn	120536 km (9.449)	5.685×10^{26} kg (95.16)	1.432×10^{9} km (9.572 AU)
Uranus	51118 km (4.007)	8.682×10^{25} kg (14.53)	2.871×10^{9} km (19.194 AU)
Neptune	49528 km (3.883)	1.024×10^{26} kg (17.15)	4.498×10^{9} km (30.066 AU)
Pluto	~2300 km (0.18)	1.3×10^{22} kg (0.0021)	5.915×10^{9} km (39.537 AU)

* Equatorial diameter

See also table 6.1 in Astronomy Today

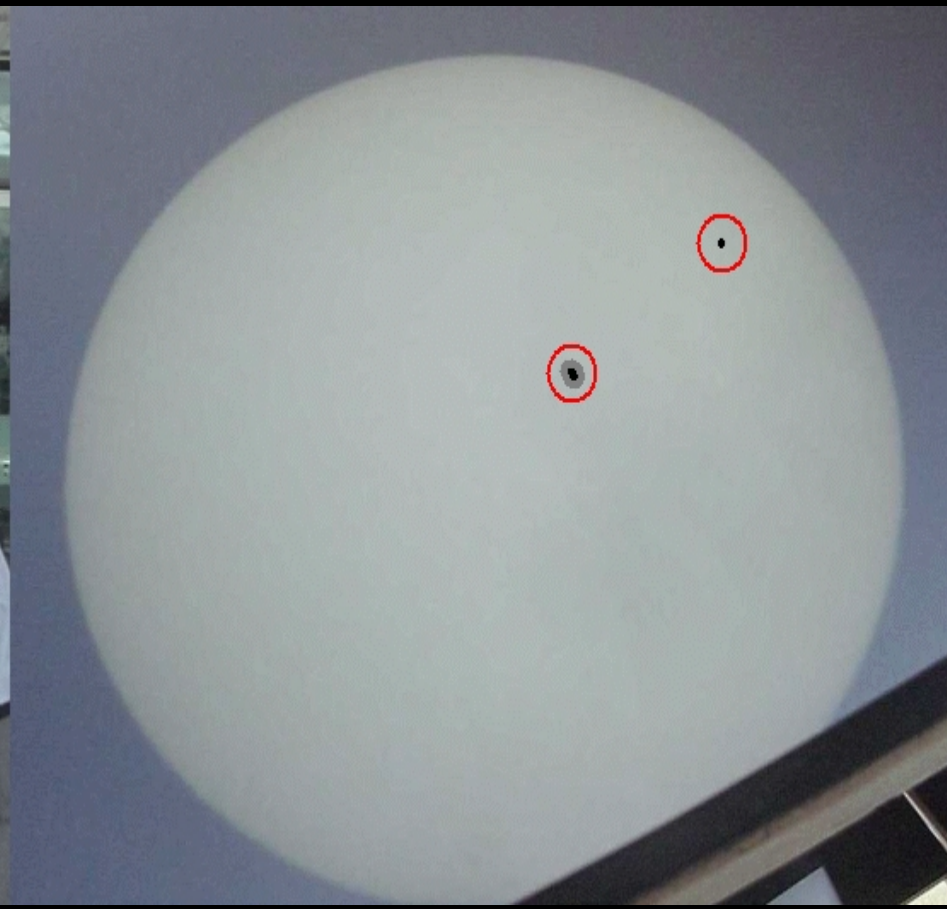
Lecture 1: A Tour of the Solar System

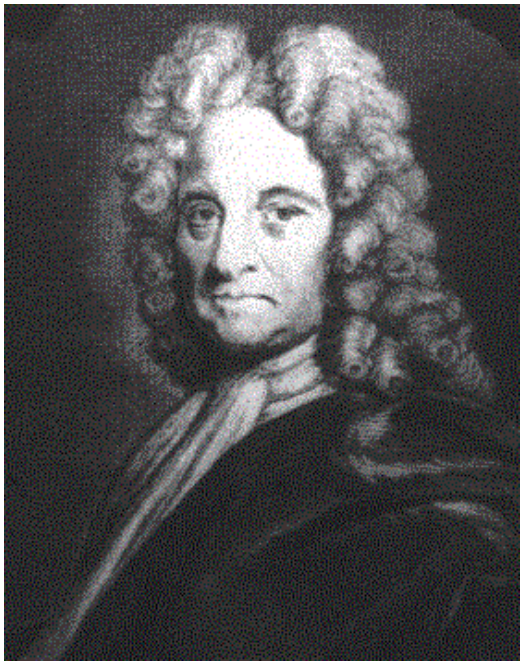
Mean Earth – Sun distance = **Astronomical Unit**

149,597,870 km

1 A.U. = 107 solar diameters

May 7th 2003: Transit of Mercury

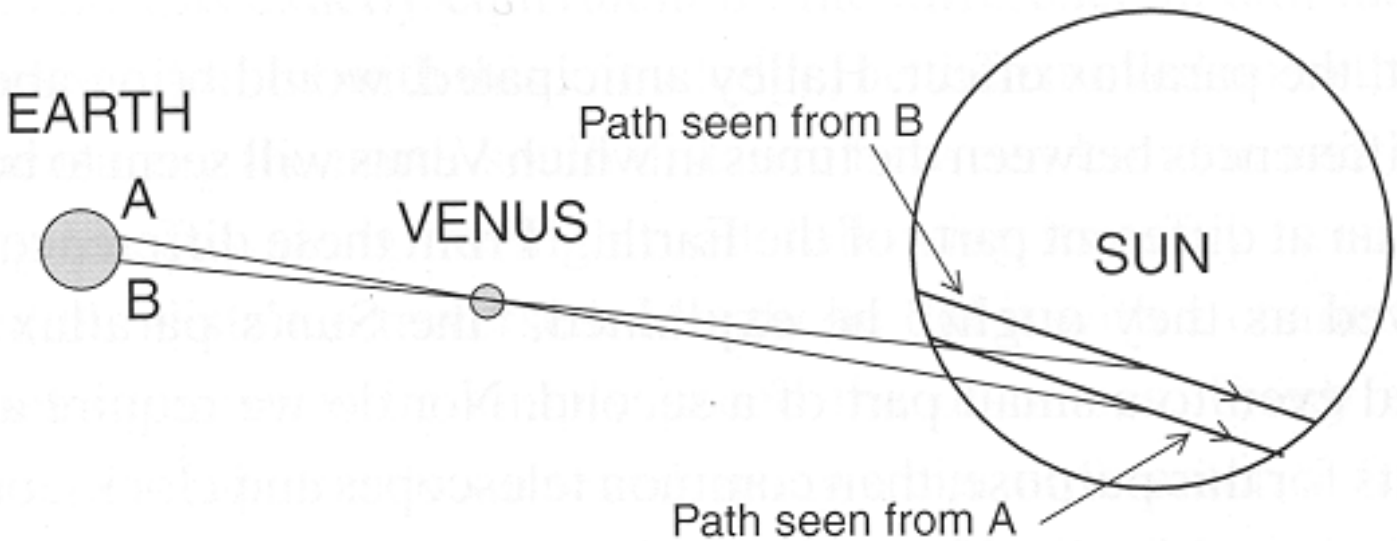


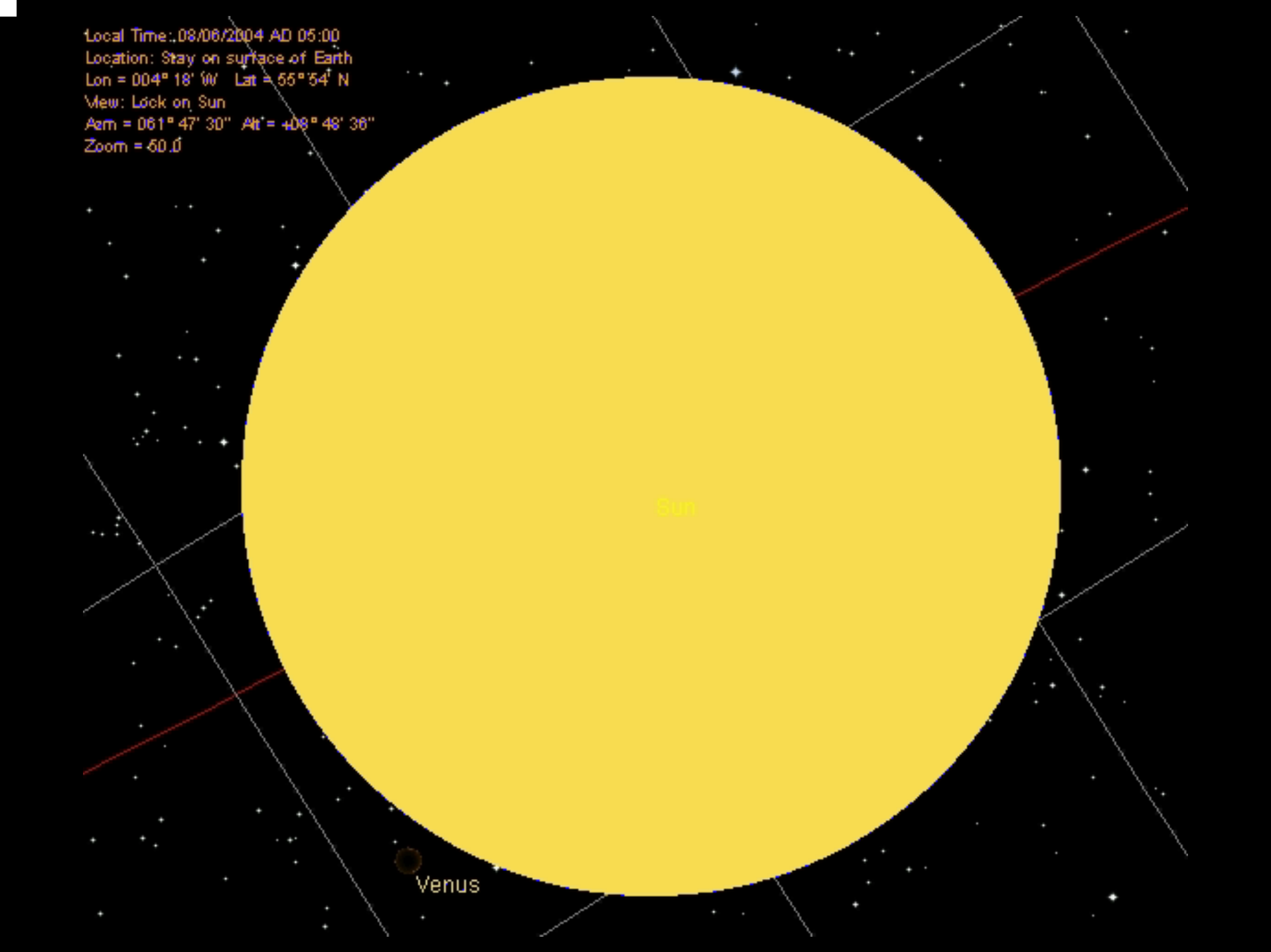


Edmond Halley
(1656 - 1742)

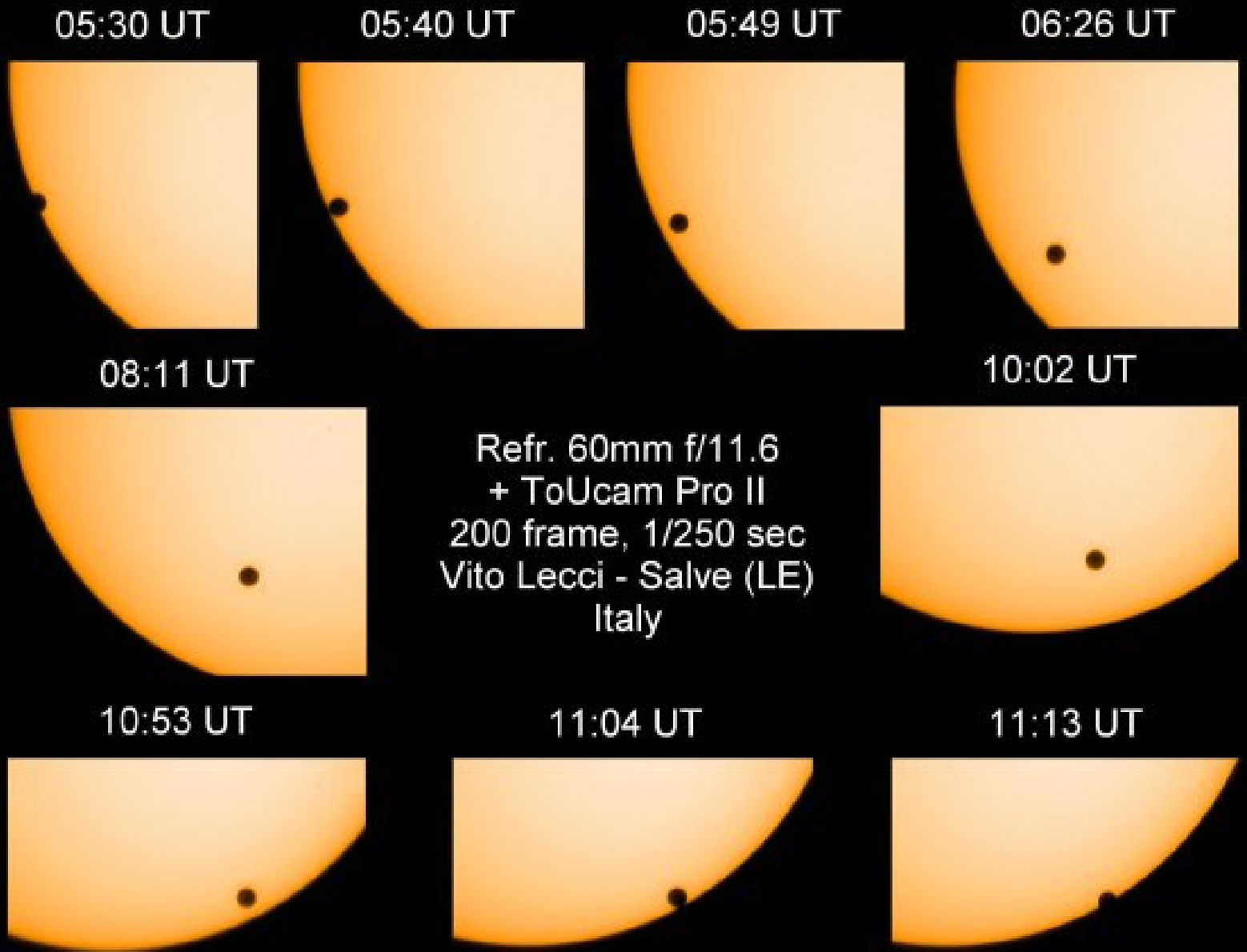
In 1716 Halley presented a paper, appealing to astronomers around the world to observe the Venus transits of 1761 and 1769

He predicted the astronomical unit could be measured to an accuracy of better than 1%




Local Time: 08/06/2004 AD 05:00
Location: Stay on surface of Earth
Lon = 004° 18' W Lat = 55° 54' N
View: Lock on Sun
Azm = 061° 47' 30" Alt = +08° 48' 36"
Zoom = 60.0
Sun
Venus

Venus transit - 08 June 2004



Kepler
A Search For Habitable Planets
NASA's first mission capable of finding Earth-size and smaller planets
Kepler mission
(launch 2008?)

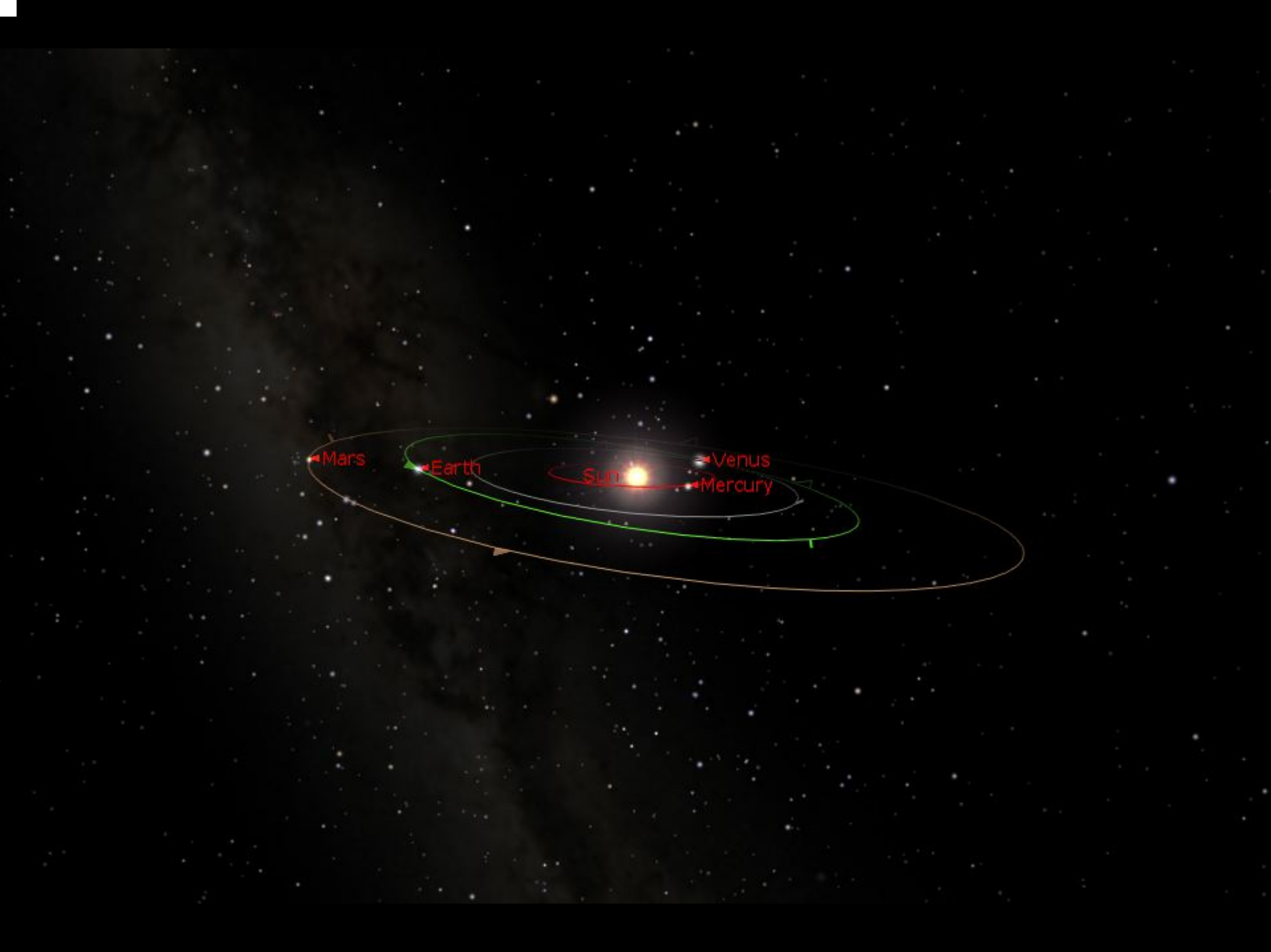
Lecture 1: A Tour of the Solar System

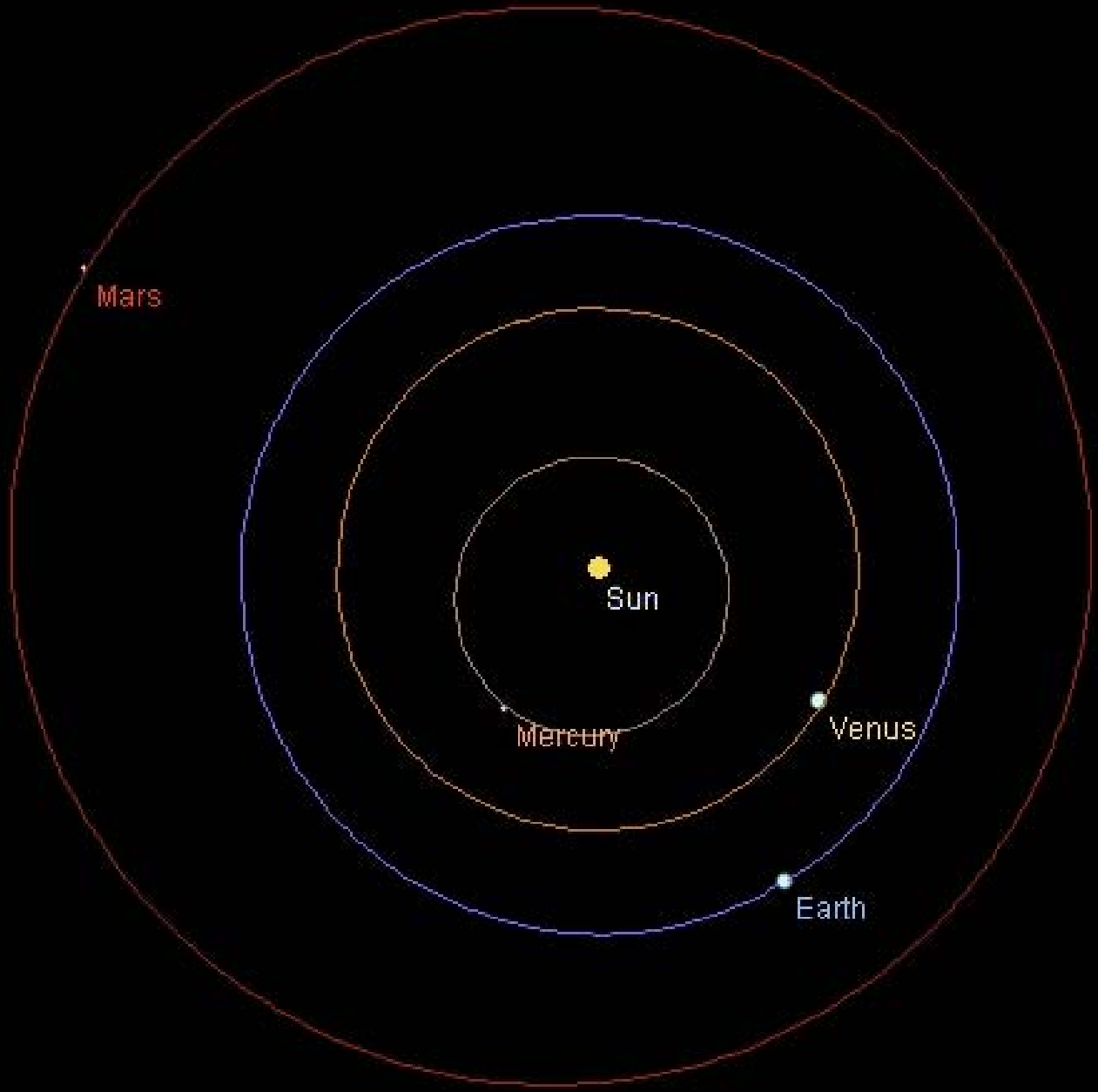
Mean Earth – Sun distance = **Astronomical Unit**

149,597,870 km

1 A.U. = 107 solar diameters

The orbits of the planets are ellipses (see A1X Dynamical Astronomy) and lie in, or close to, a plane – the ecliptic.


Mars
Earth
Sun
Venus
Mercury


Mars
Sun
Mercury
Venus
Earth

Lecture 1: A Tour of the Solar System

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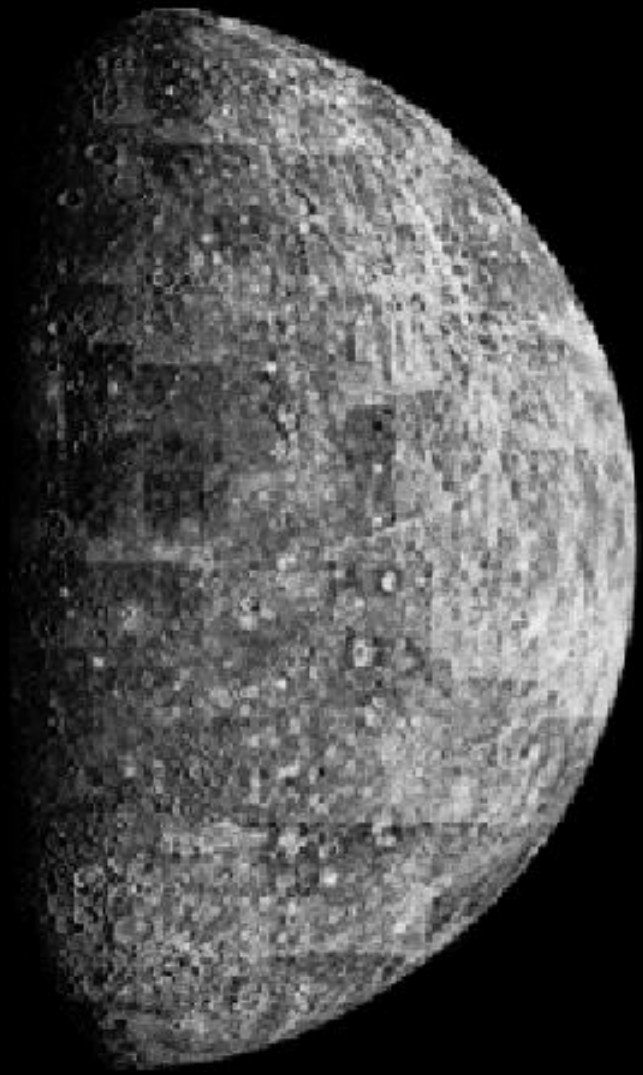
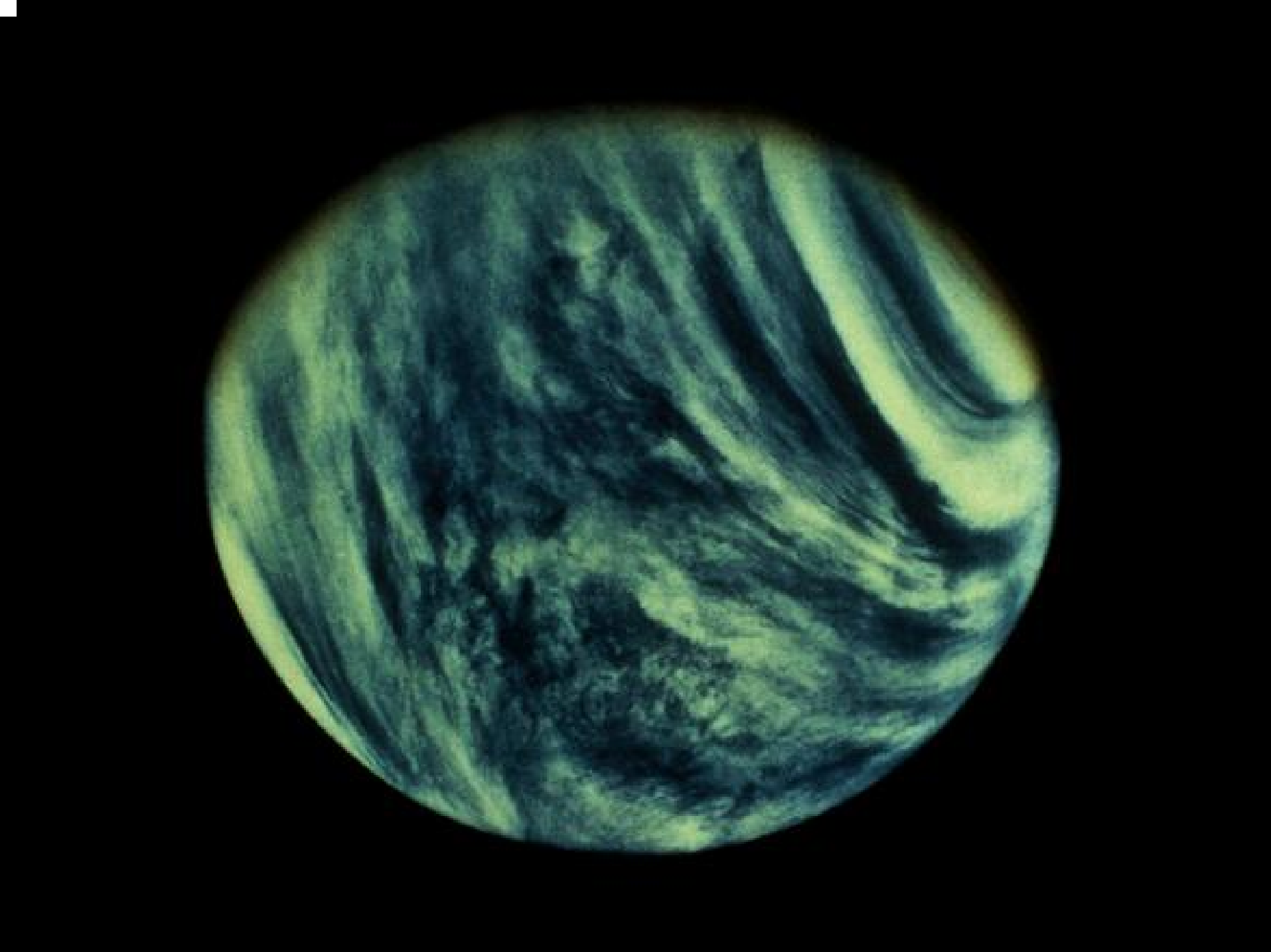
The orbits of the planets are ellipses (see A1X Dynamical Astronomy) and lie in, or close to, a plane – the ecliptic.

The planets divide into two groups:-

Inner *Terrestrial* planets: small, rocky — Mercury, Venus, Earth, Mars

Outer *Jovian* planets: gas giants — Jupiter, Saturn, Uranus, Neptune





Venus Vital Statistics:

Surface temperature 450K

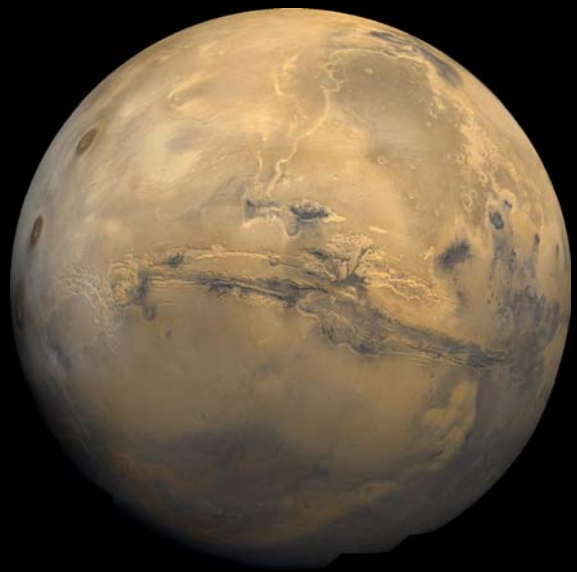
Atmosphere ~100% CO_2

Pressure 90 times Earth's

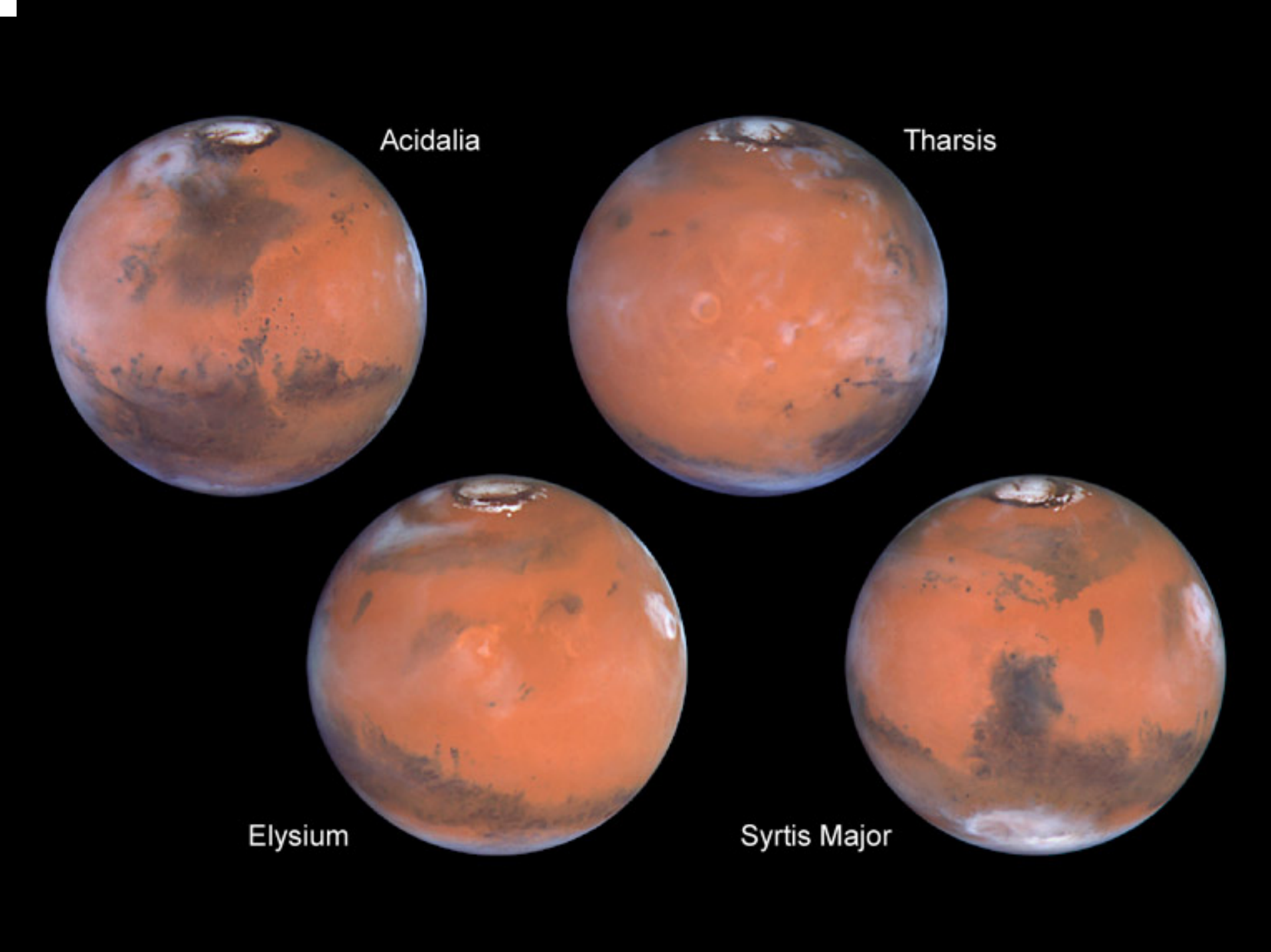
Sulphuric Acid Rain

Thick crust: regular volcanic 'resurfacing'

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

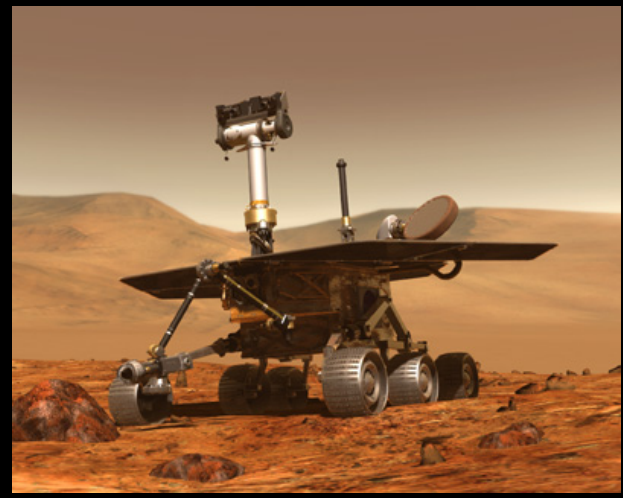


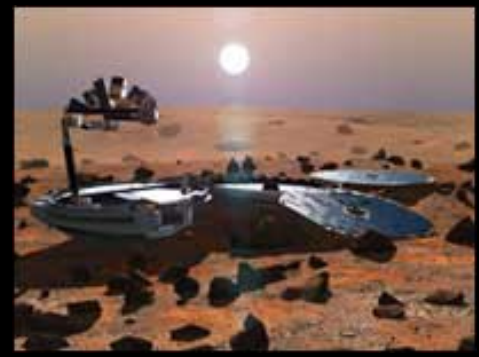
Impact energy = 1 million million megatons

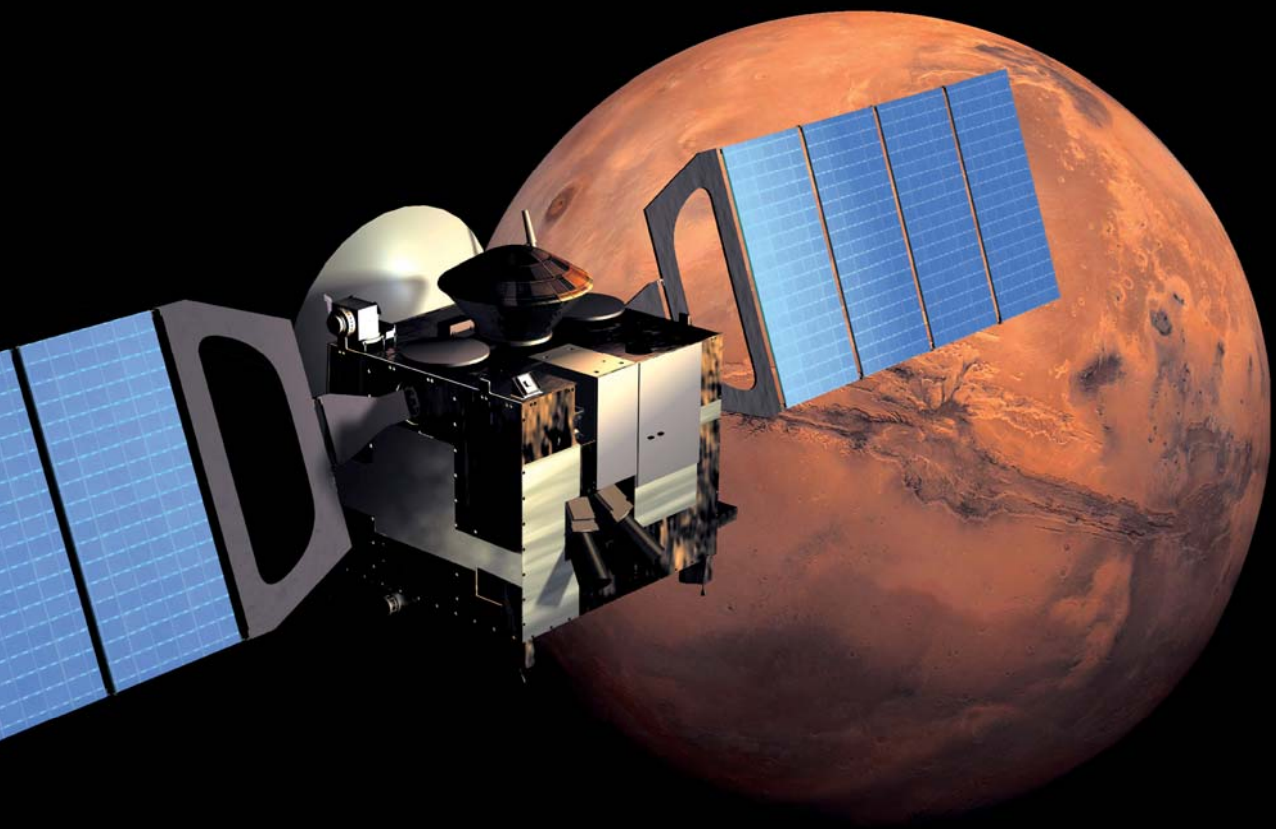

Acidalia
Tharsis
Elysium
Syrtis Major

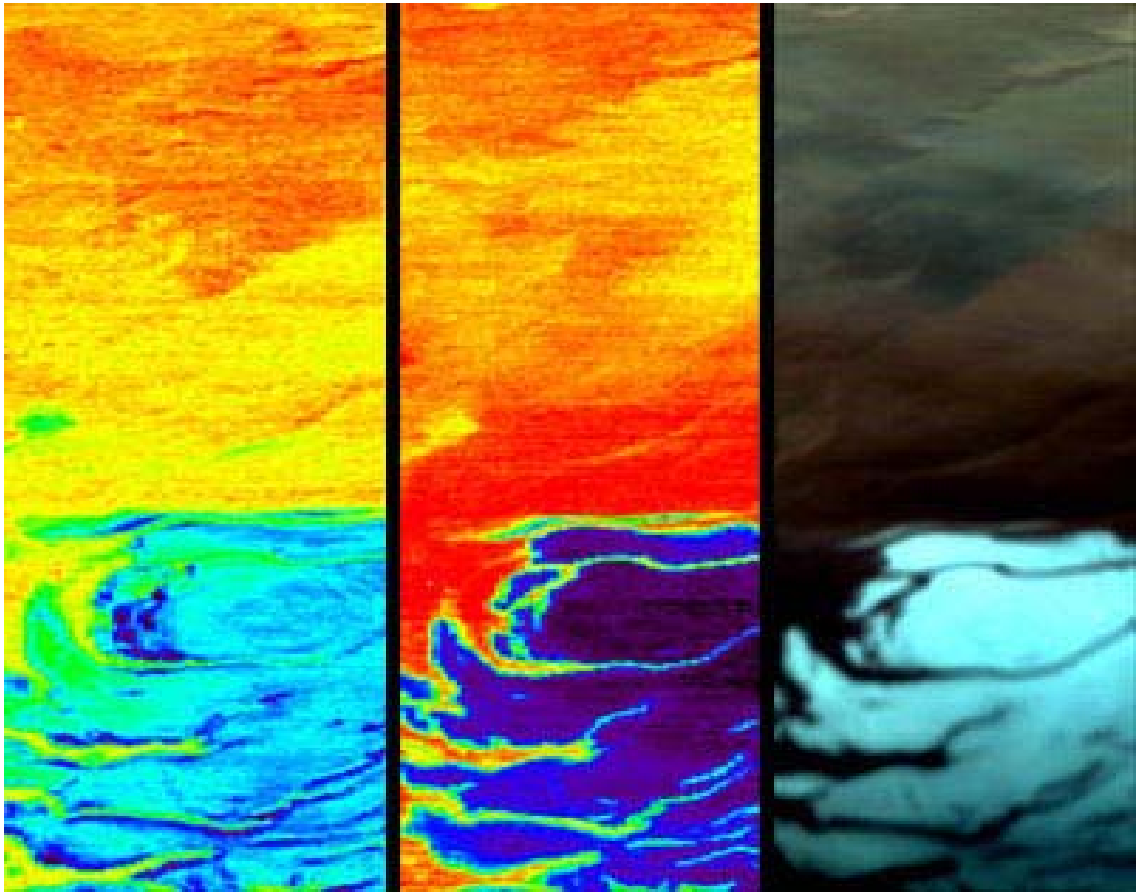
Mars 2004:

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





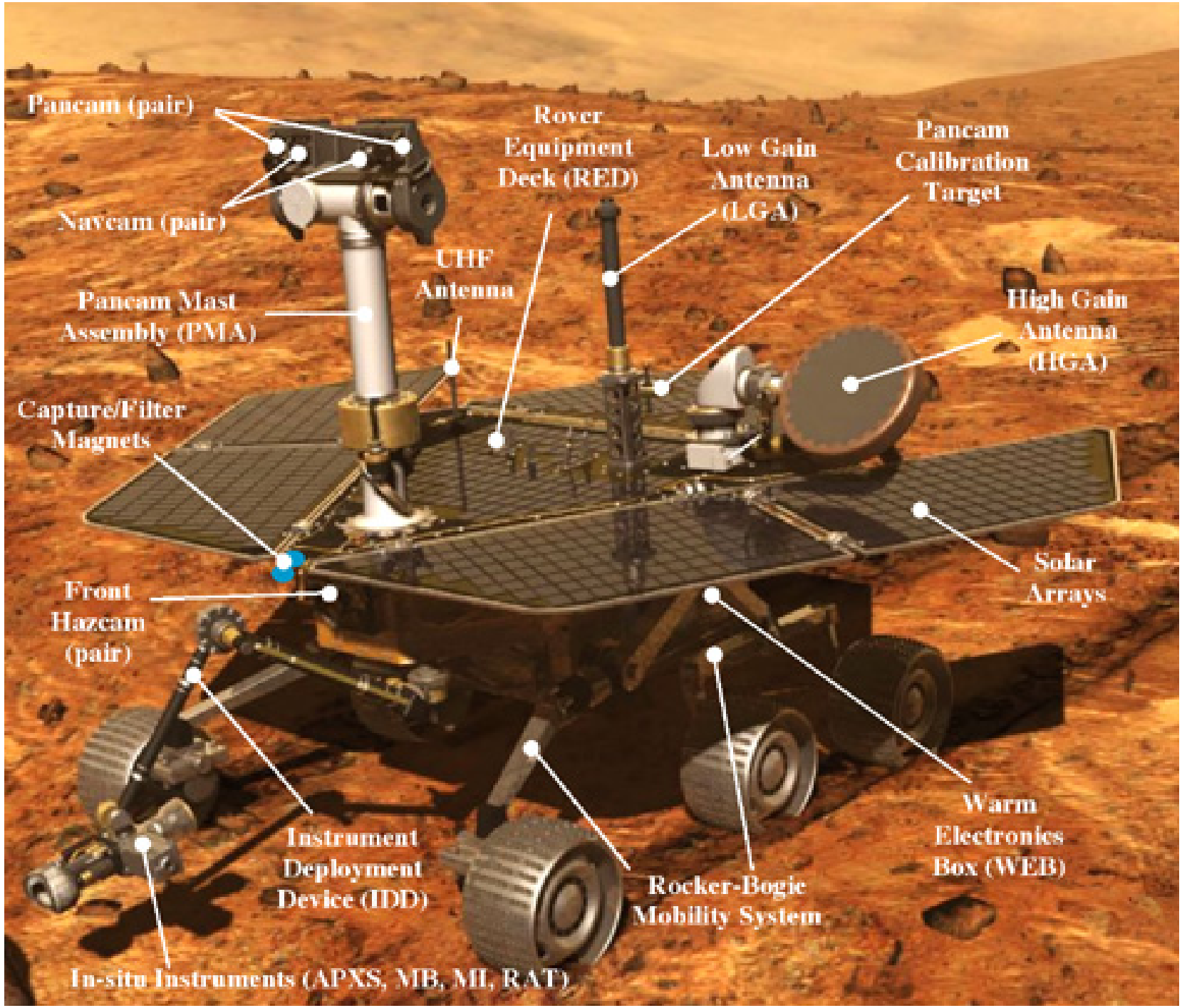


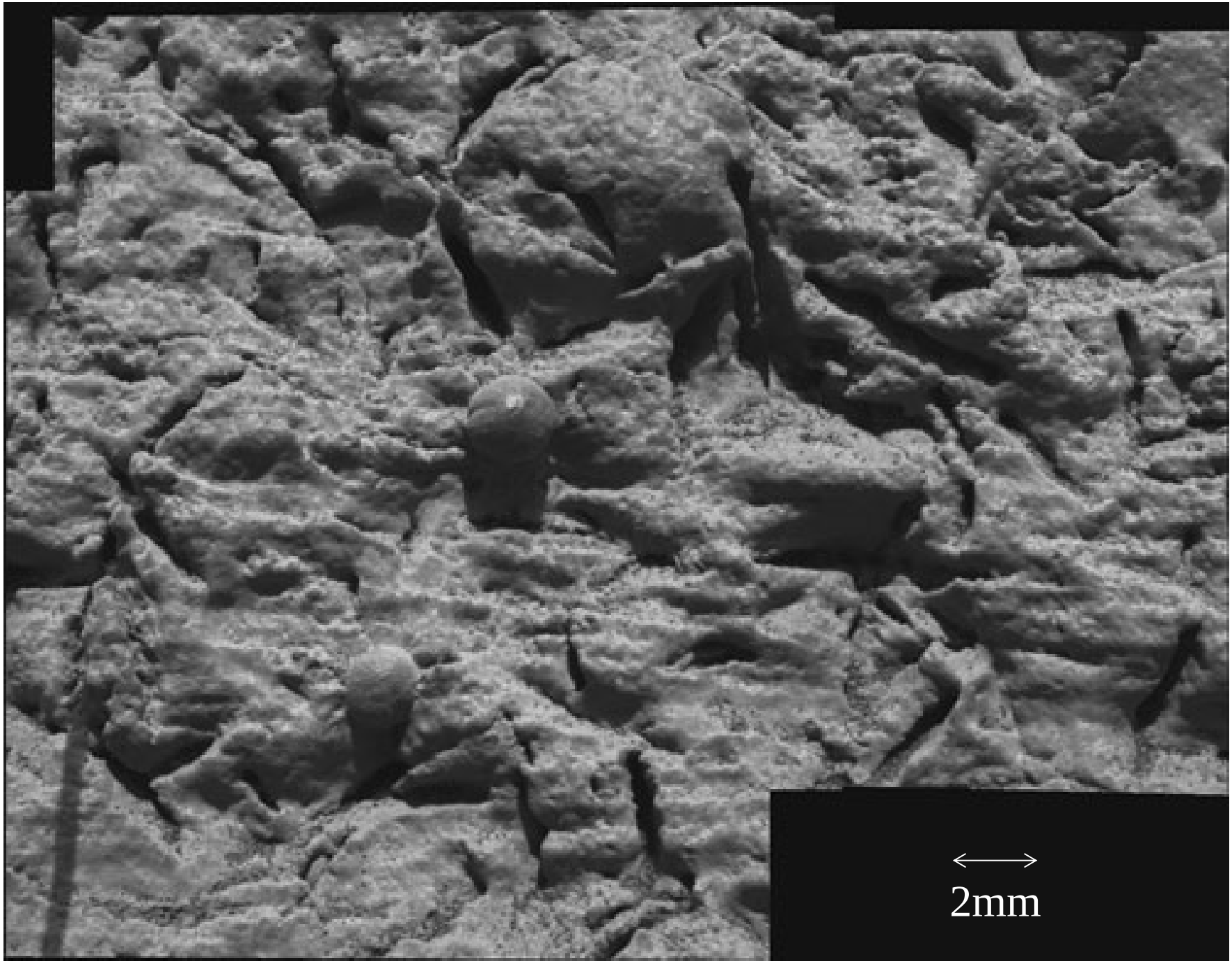


H_2O CO_2 Visible light

Jan 23rd 2004:

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


Pancam (pair)
Navcam (pair)
Rover Equipment Deck (RED)
Low Gain Antenna (LGA)
Pancam Calibration Target
UHF Antenna
Pancam Mast Assembly (PMA)
High Gain Antenna (HGA)
Capture/Filter Magnets
Solar Arrays
Front Hazcam (pair)
Instrument Deployment Device (IDD)
Rocker-Bogie Mobility System
Warm Electronics Box (WEB)
In-situ Instruments (APXS, MB, MI, RAT)


2mm

The moons of Jupiter

Galileo

Mission to Jupiter

Cassini Jupiter flyby (Dec 2000)

Jupiter on 7 Mar 2001

Cassini trajectory to Saturn

GEM extension (proposed)
Jan - Dec 2000

Earth/Moon 1
8 Dec 1990

Earth/Moon 2
8 Dec 1992

Venus
10 Feb 1990

Launch
18 Oct 1989

Galileo Europa Mission (orbits 12-25)
Dec 1997 - Dec 1999

Ida
and Dactyl
28 Aug 1993

Gaspra
29 Oct 1991

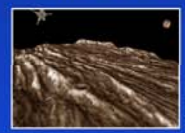
Shoemaker-Levy 9
observations
Jul 1994

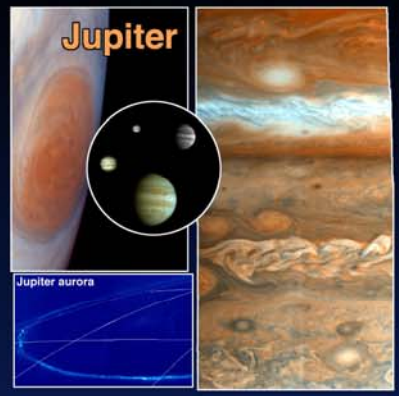
Jupiter in Jul 1994

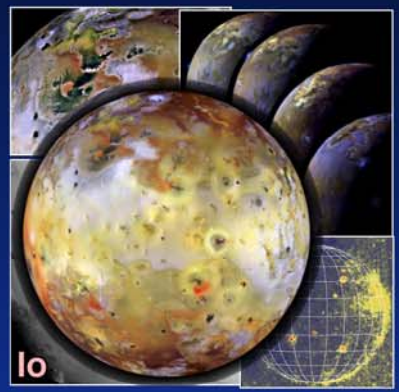
Galileo primary mission (orbits 1-11)
Jun 1996 - Dec 1997

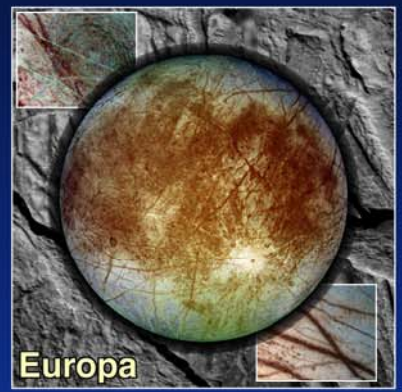
Probe release
13 Jul 1995

Probe mission
Jupiter orbit insertion
7/8 Dec 1995

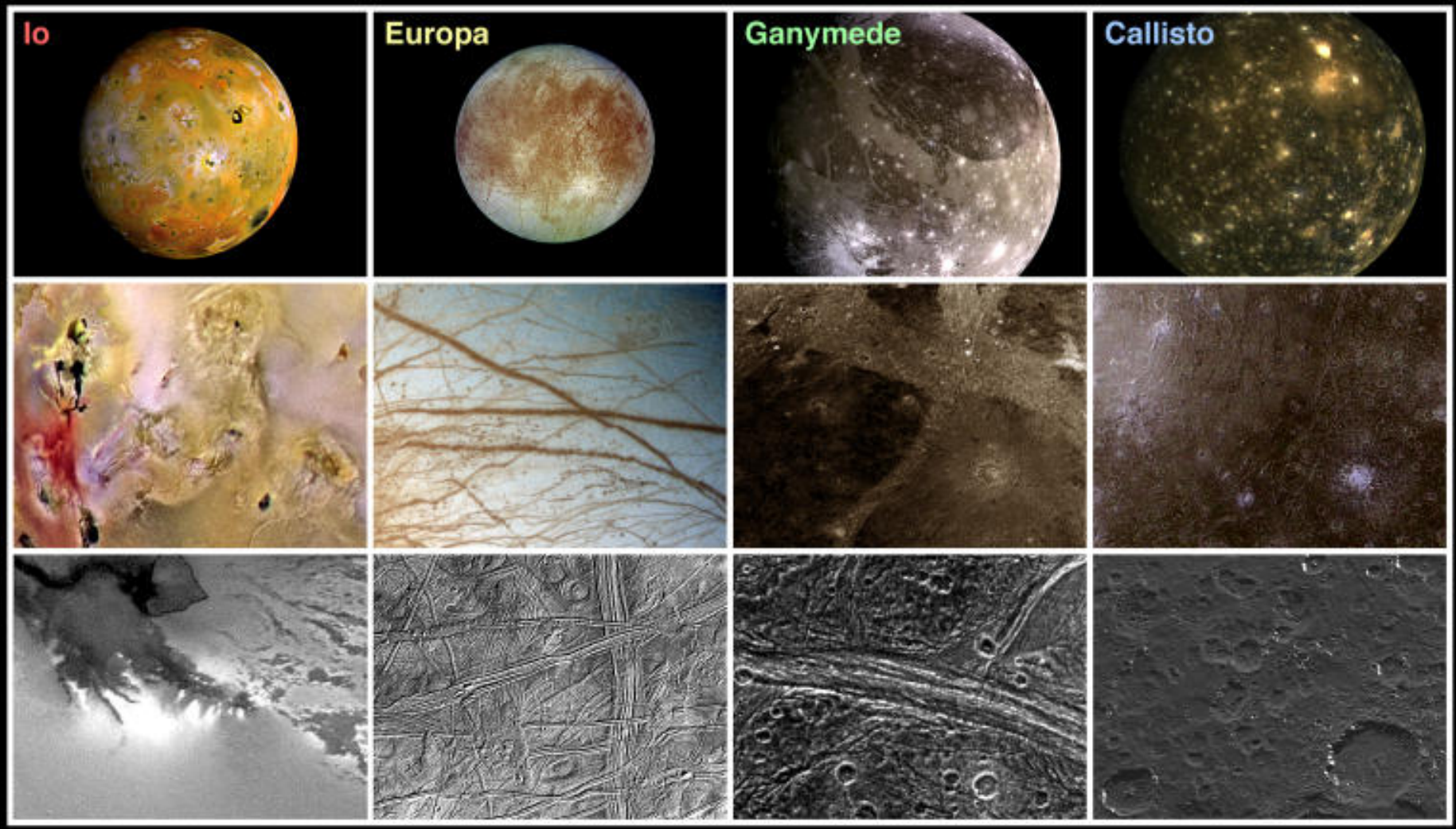


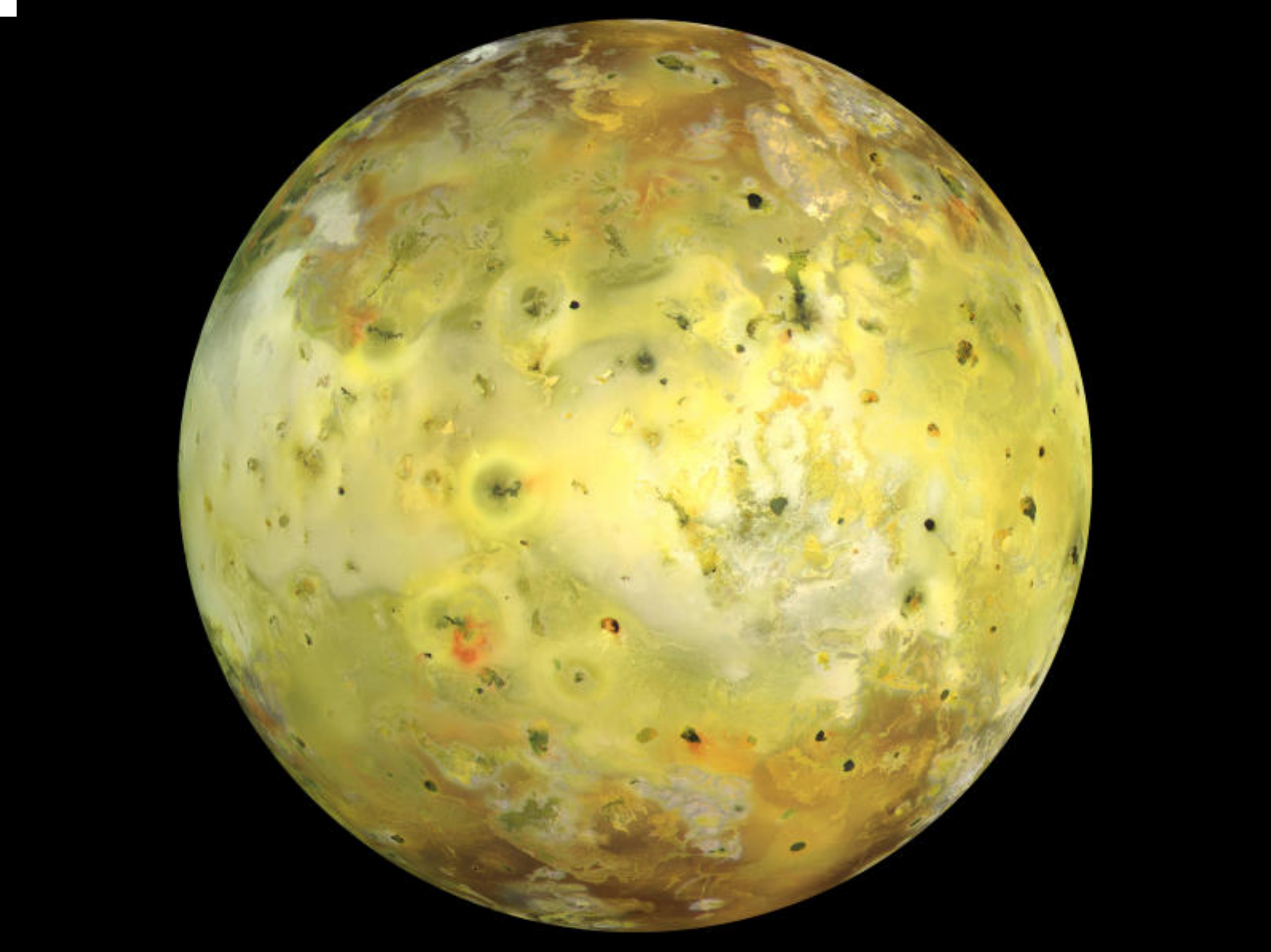


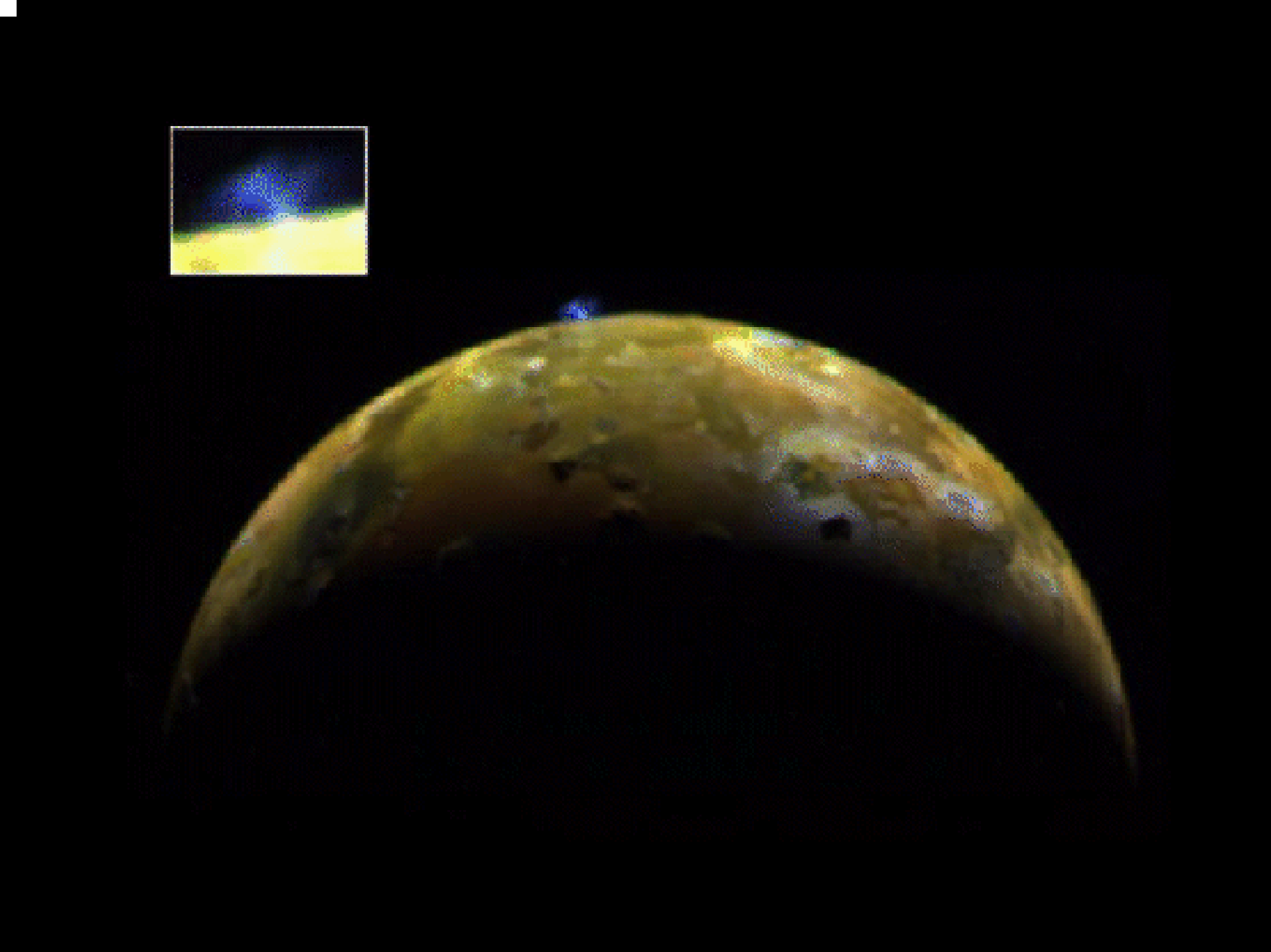


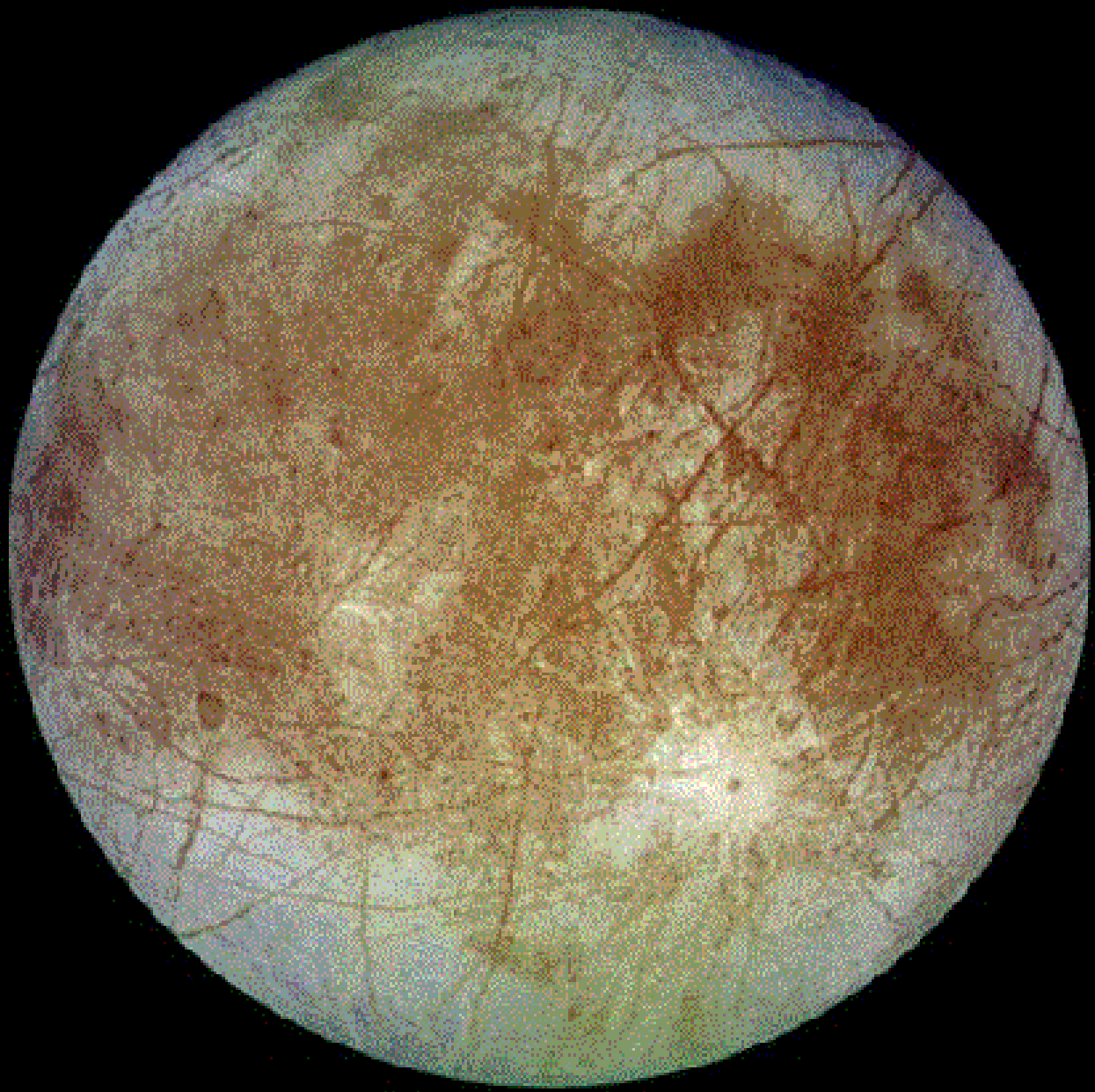


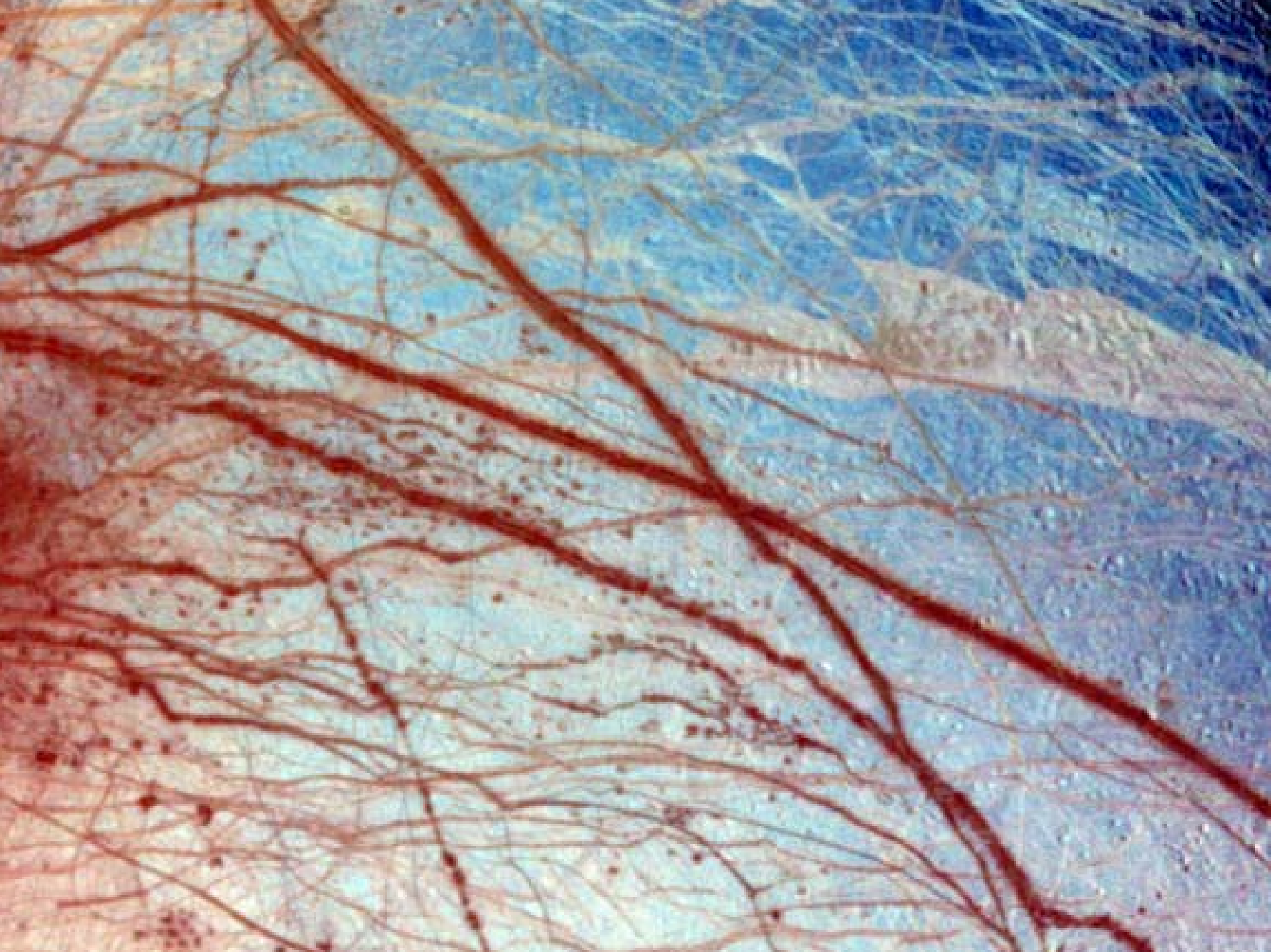
Galileo's Moons



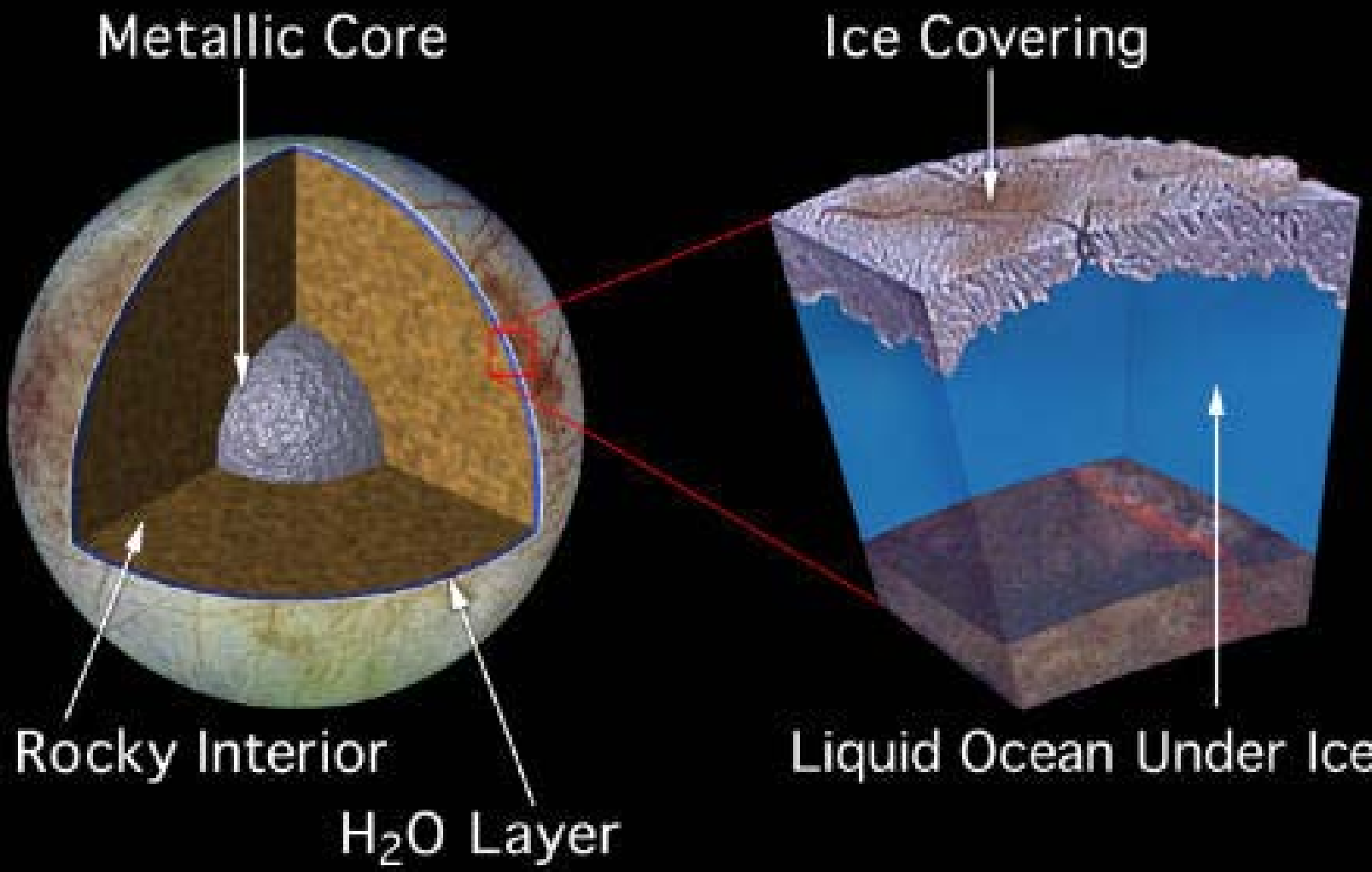








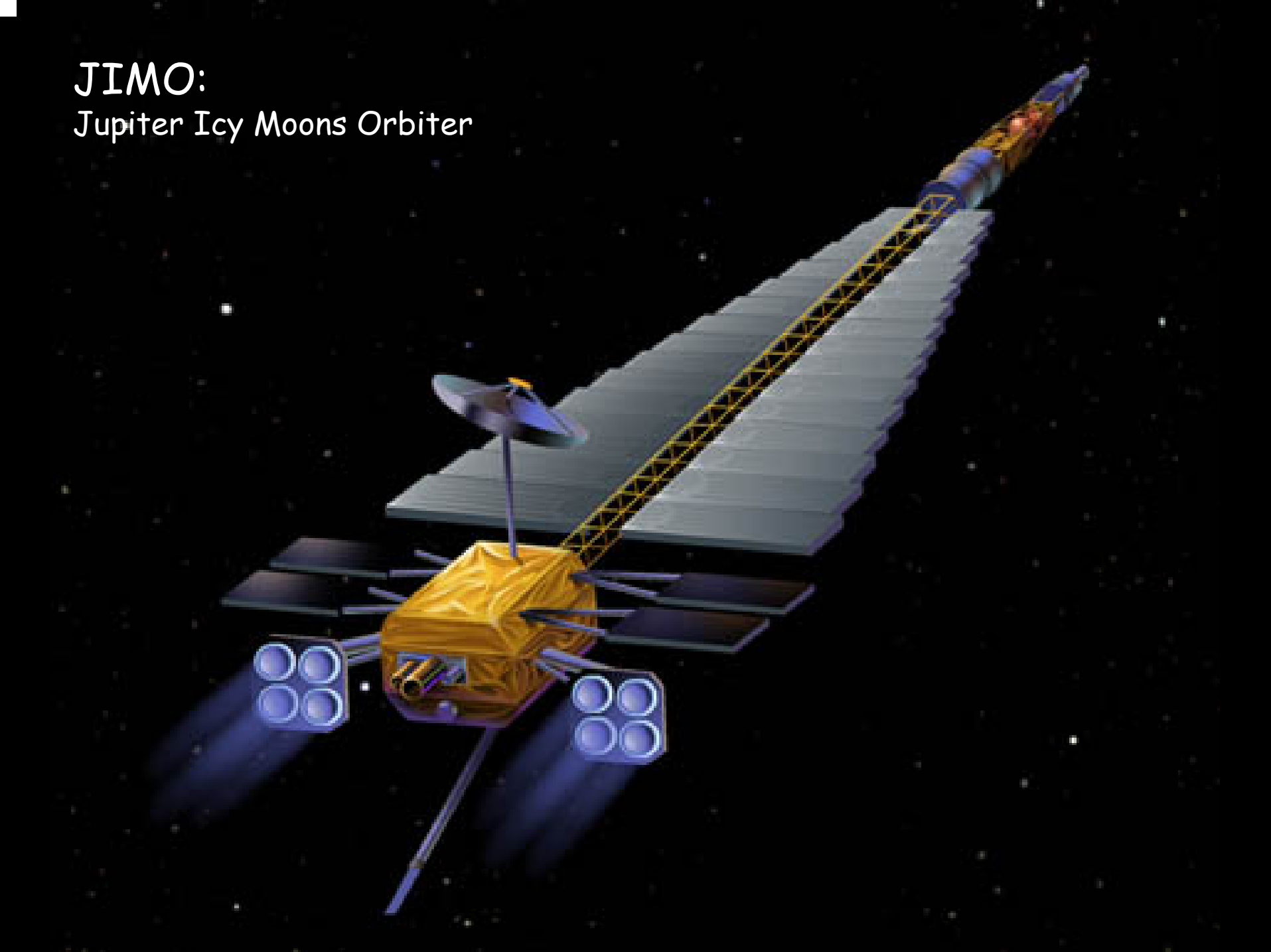
Inside Europa

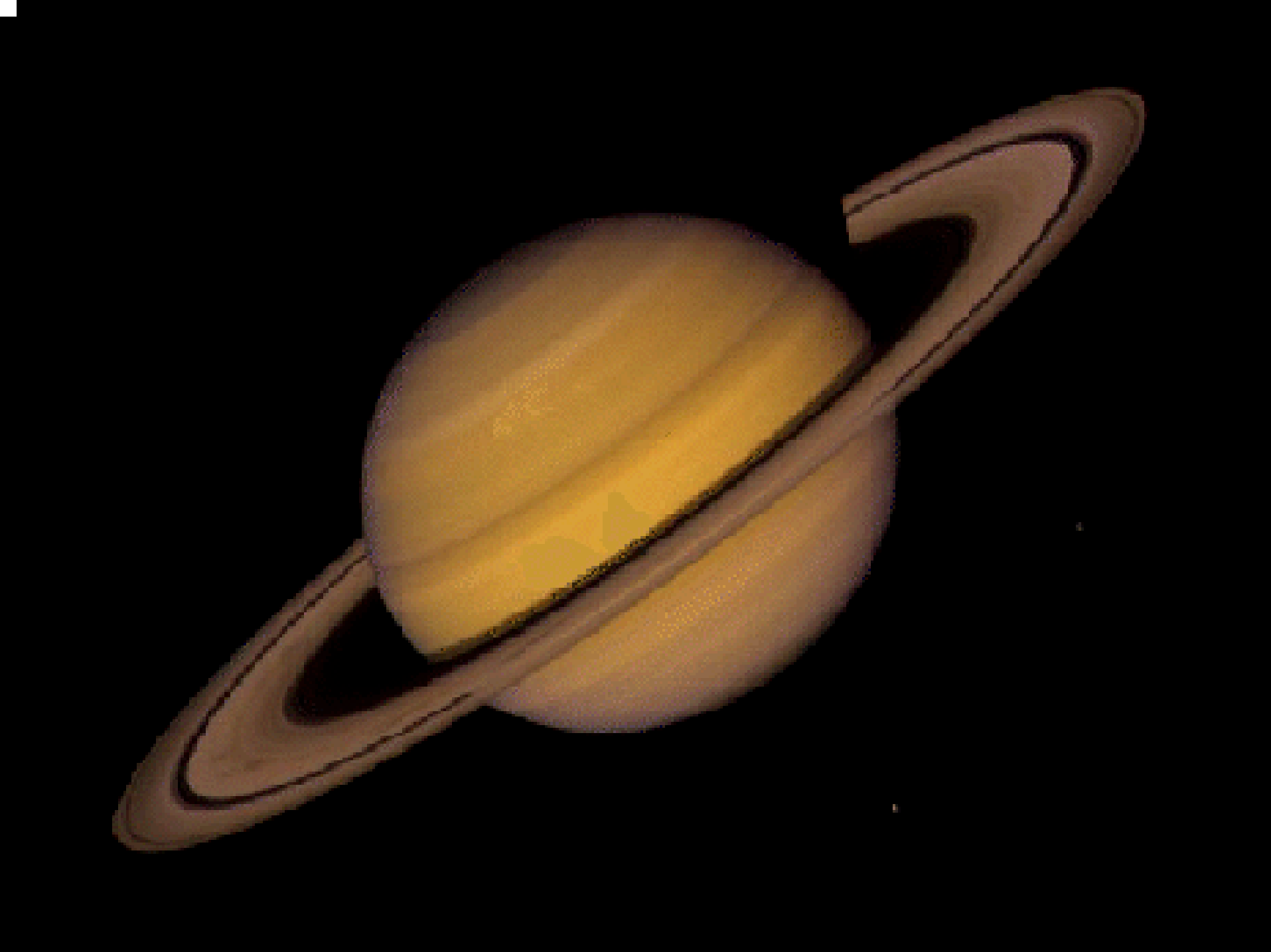


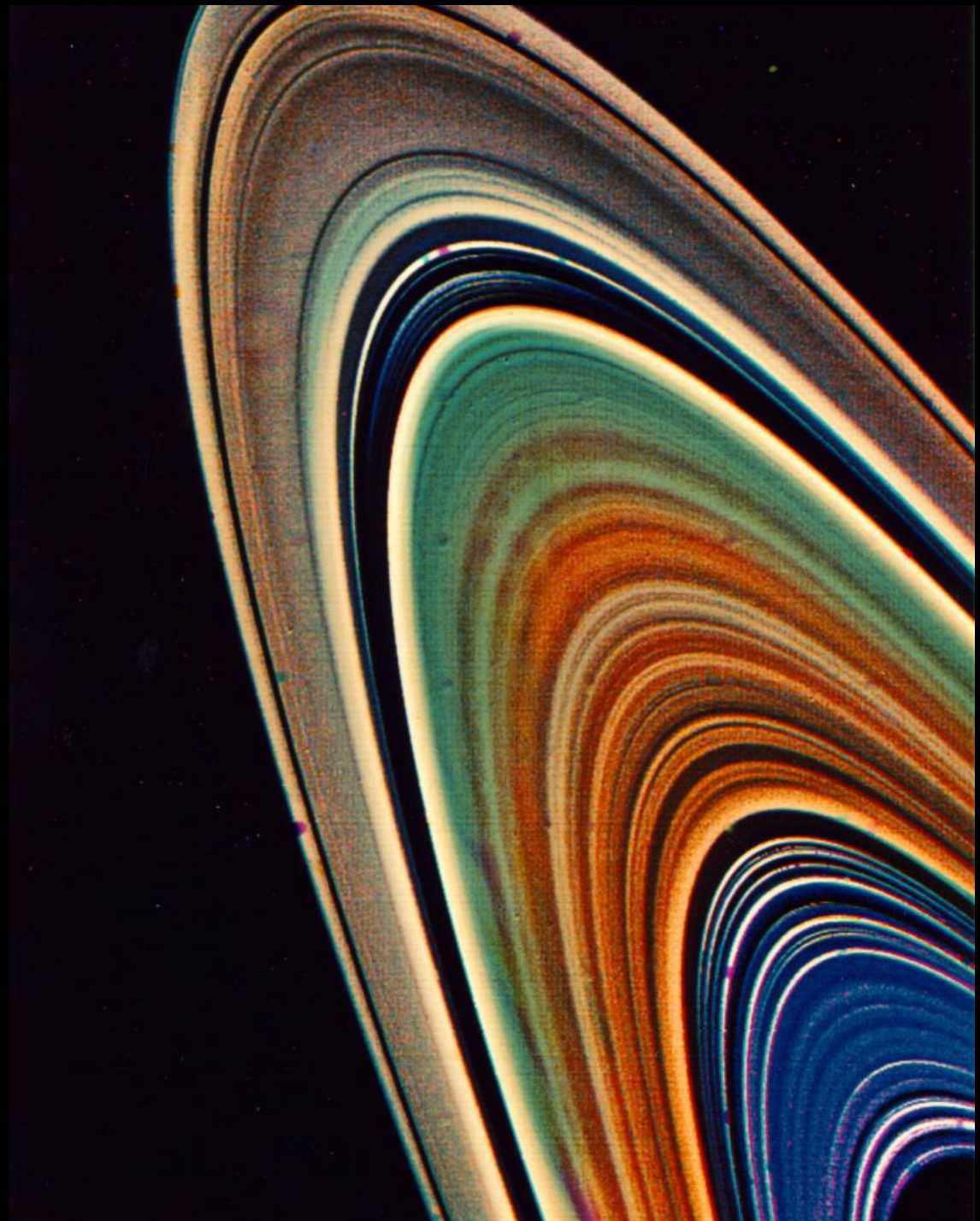
Could there be life?…..

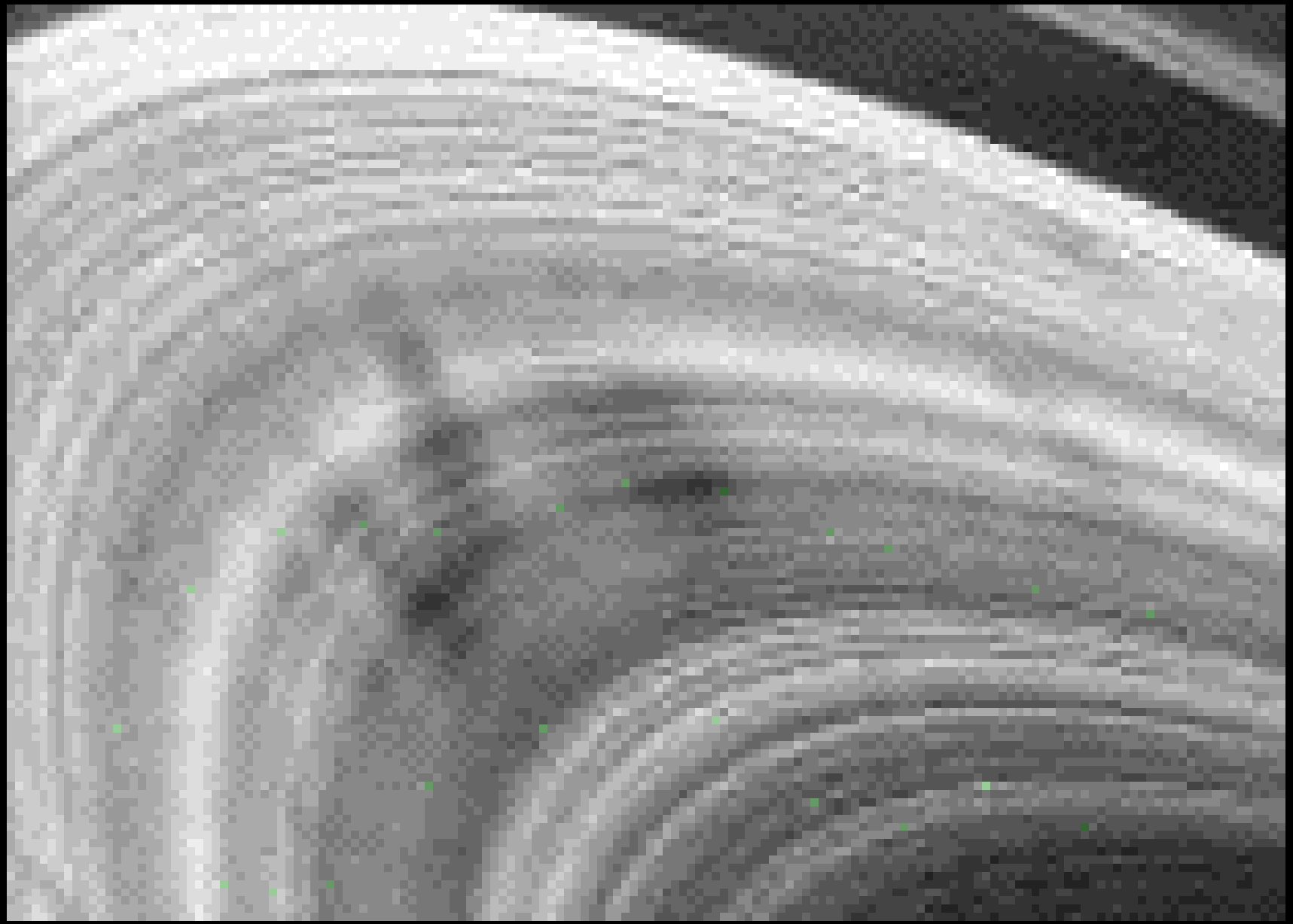
JIMO:

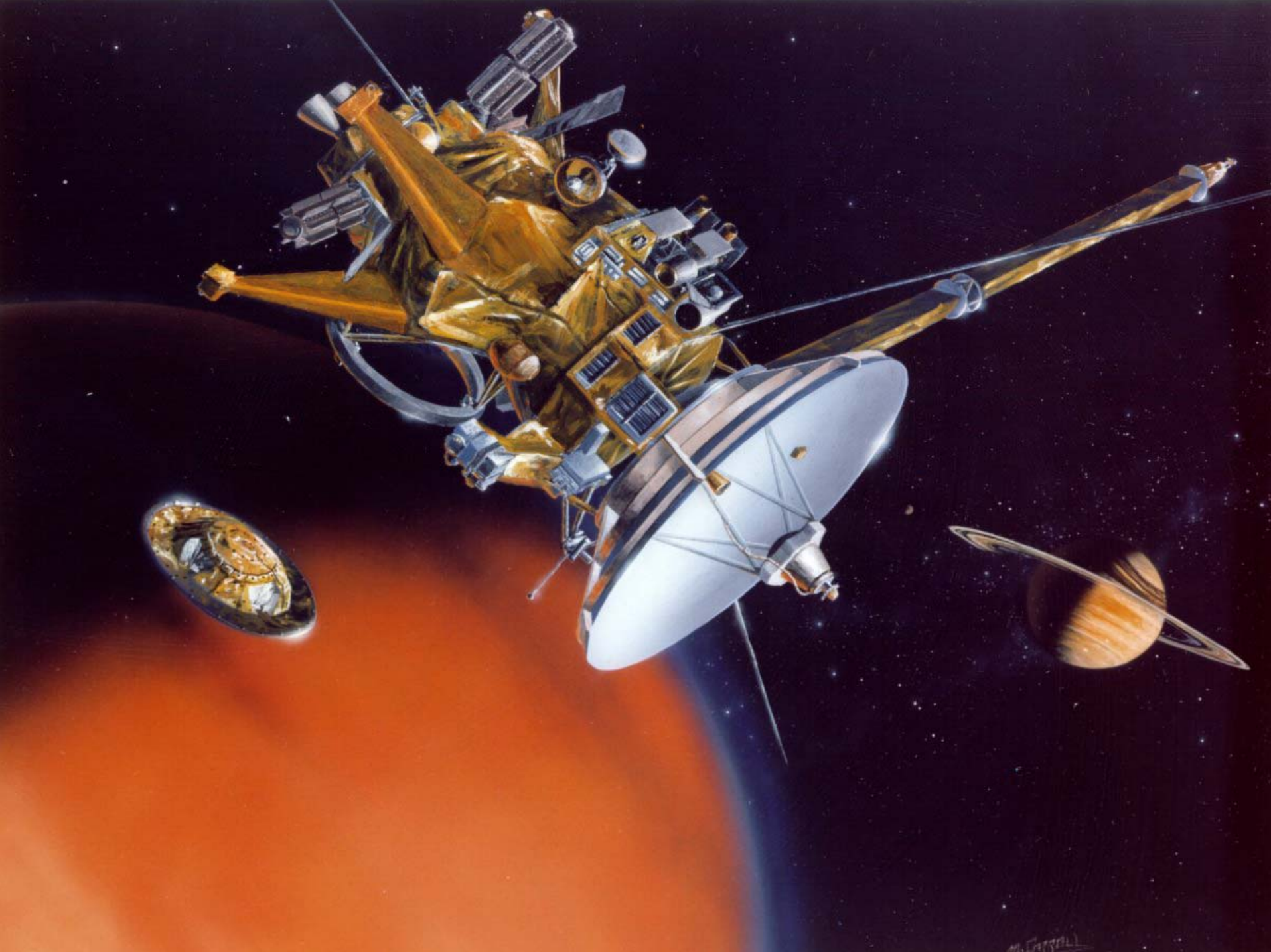
Jupiter Icy Moons Orbiter

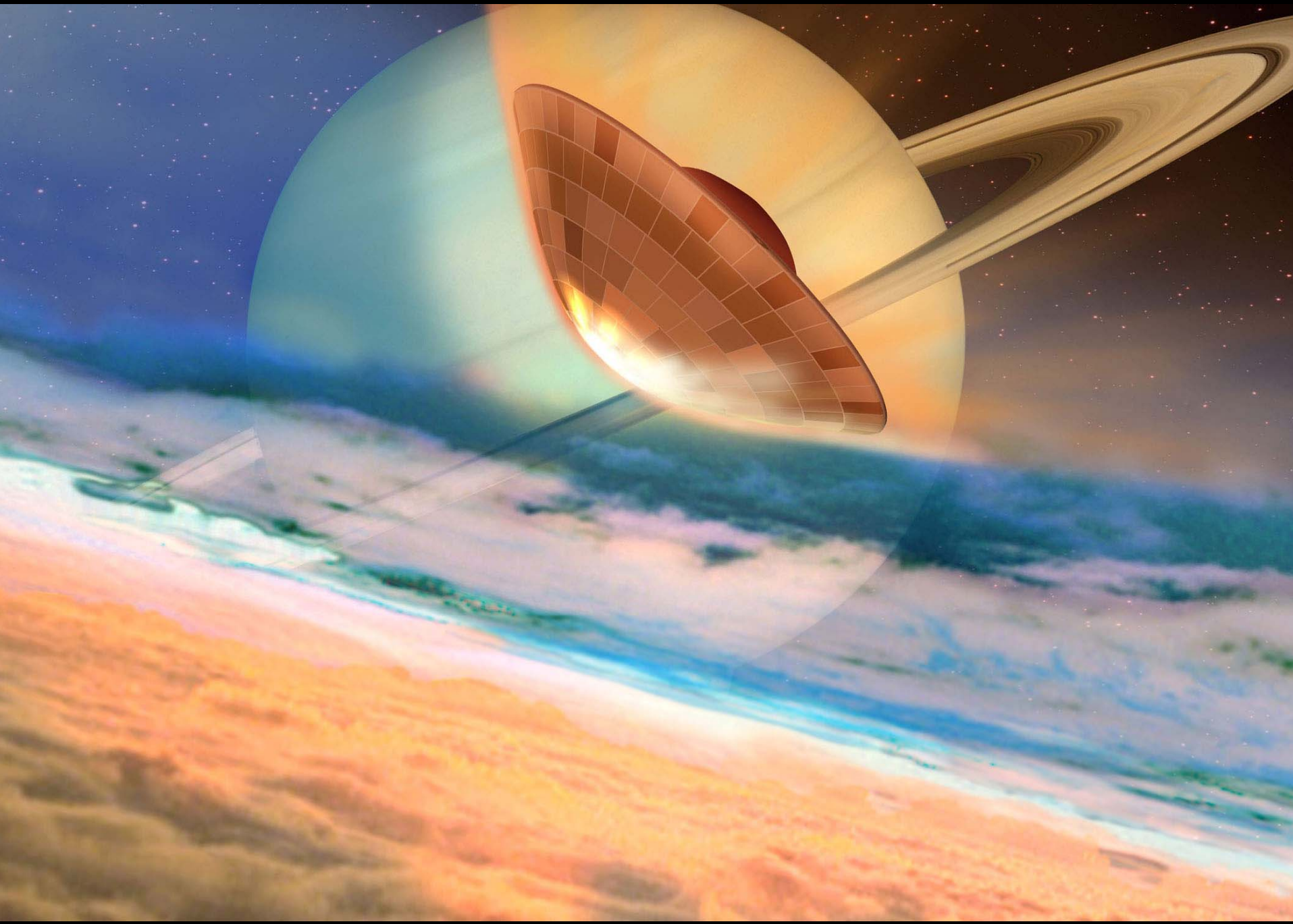


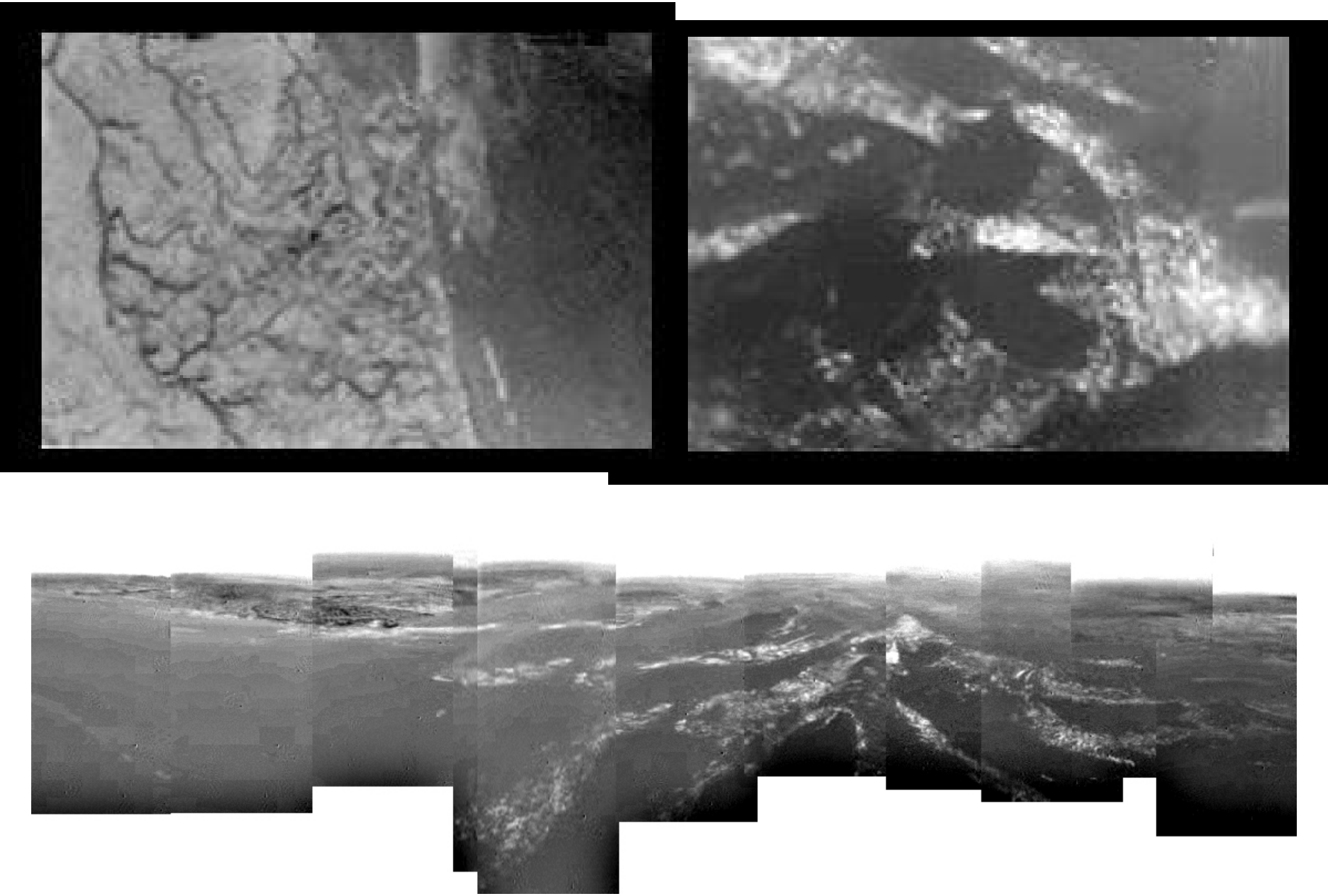


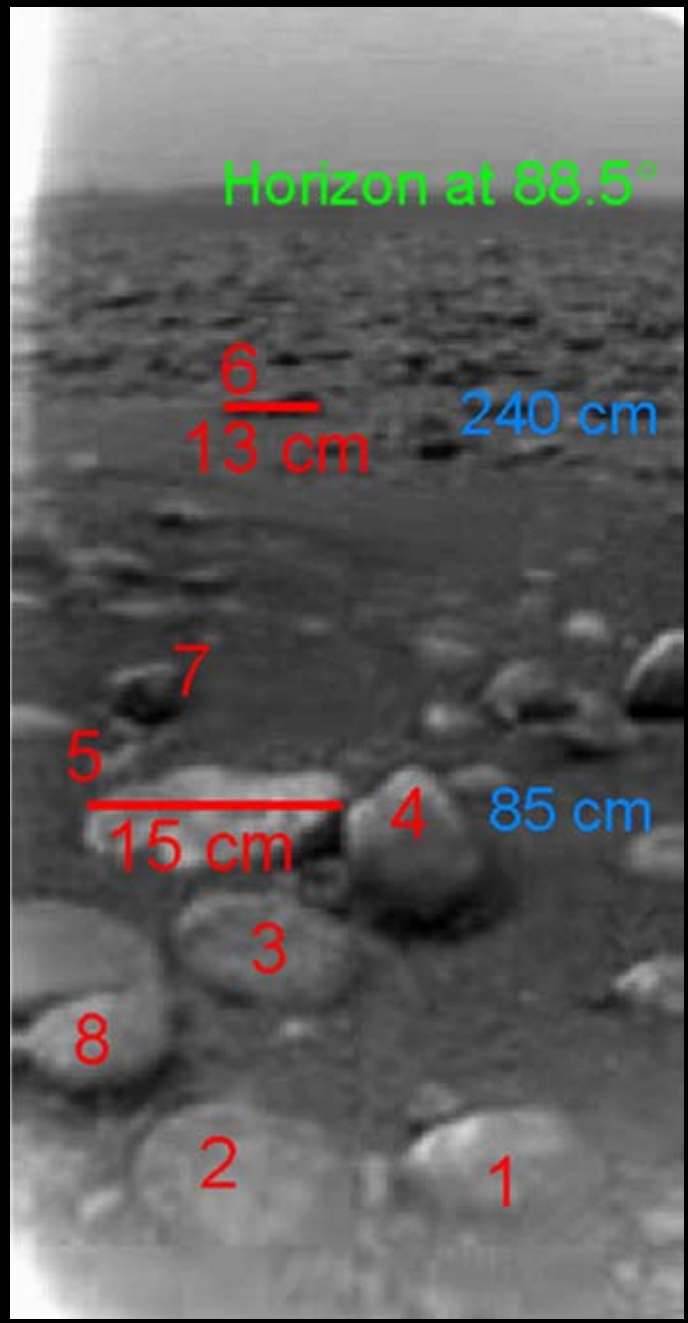


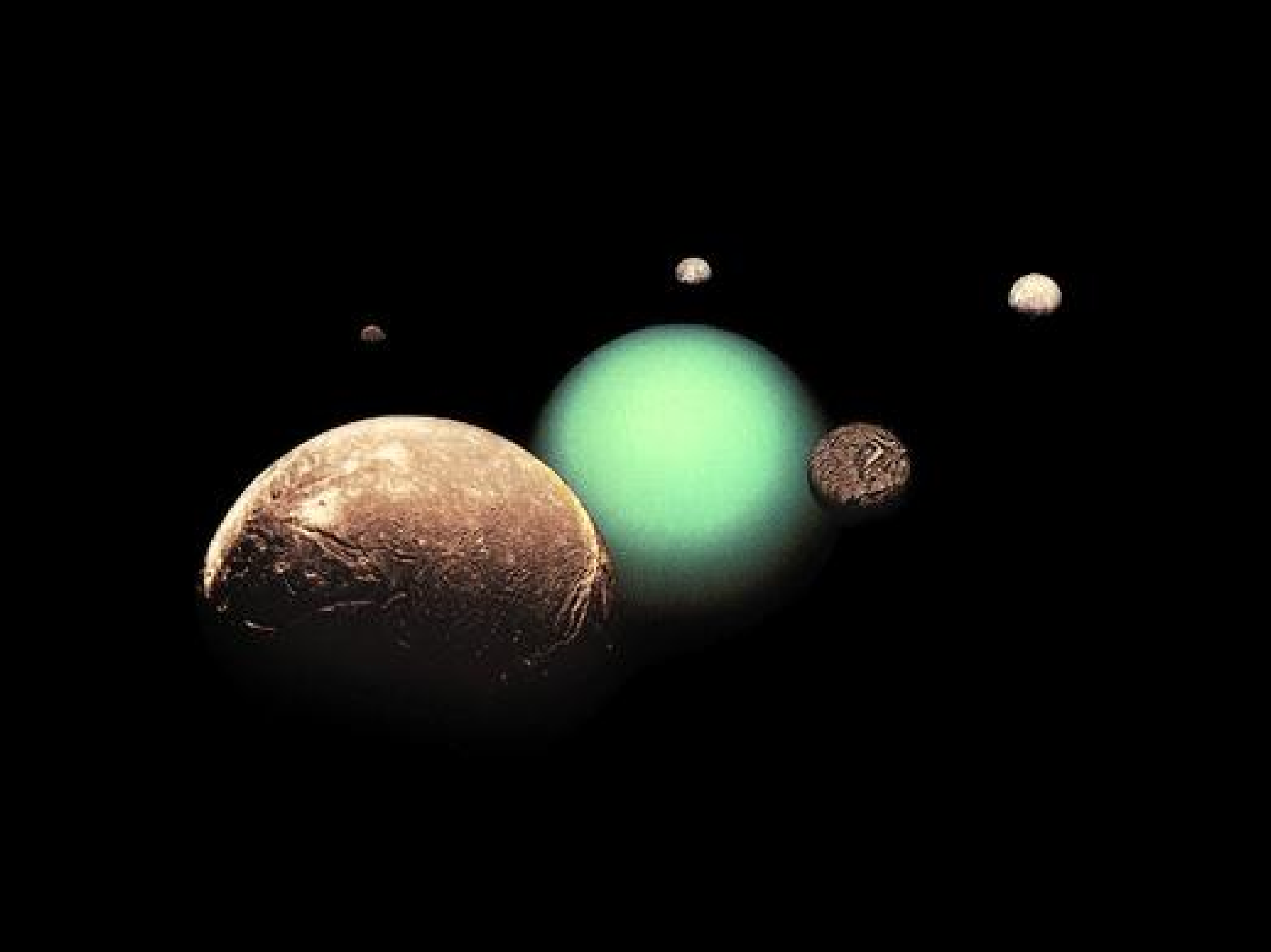


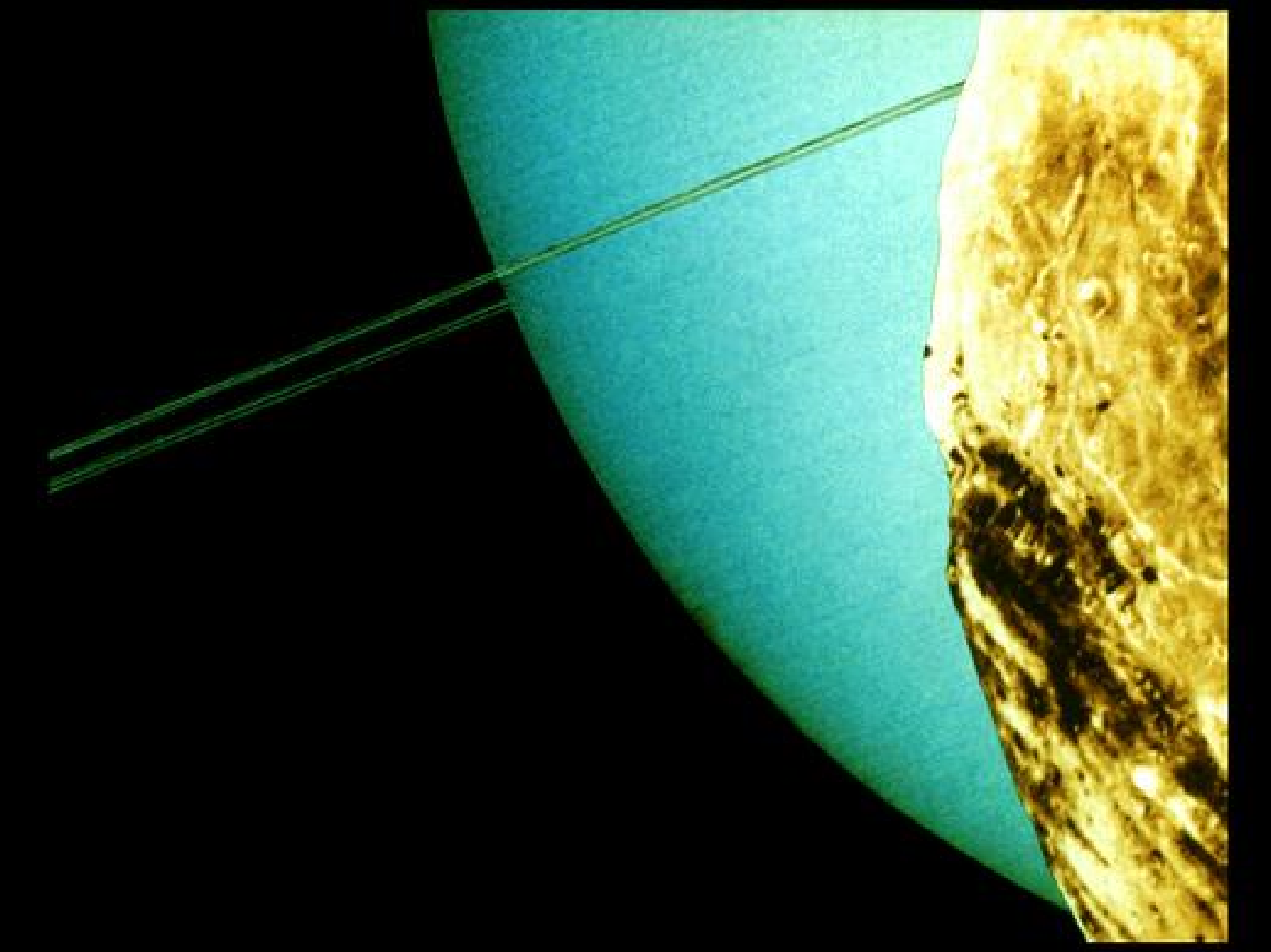


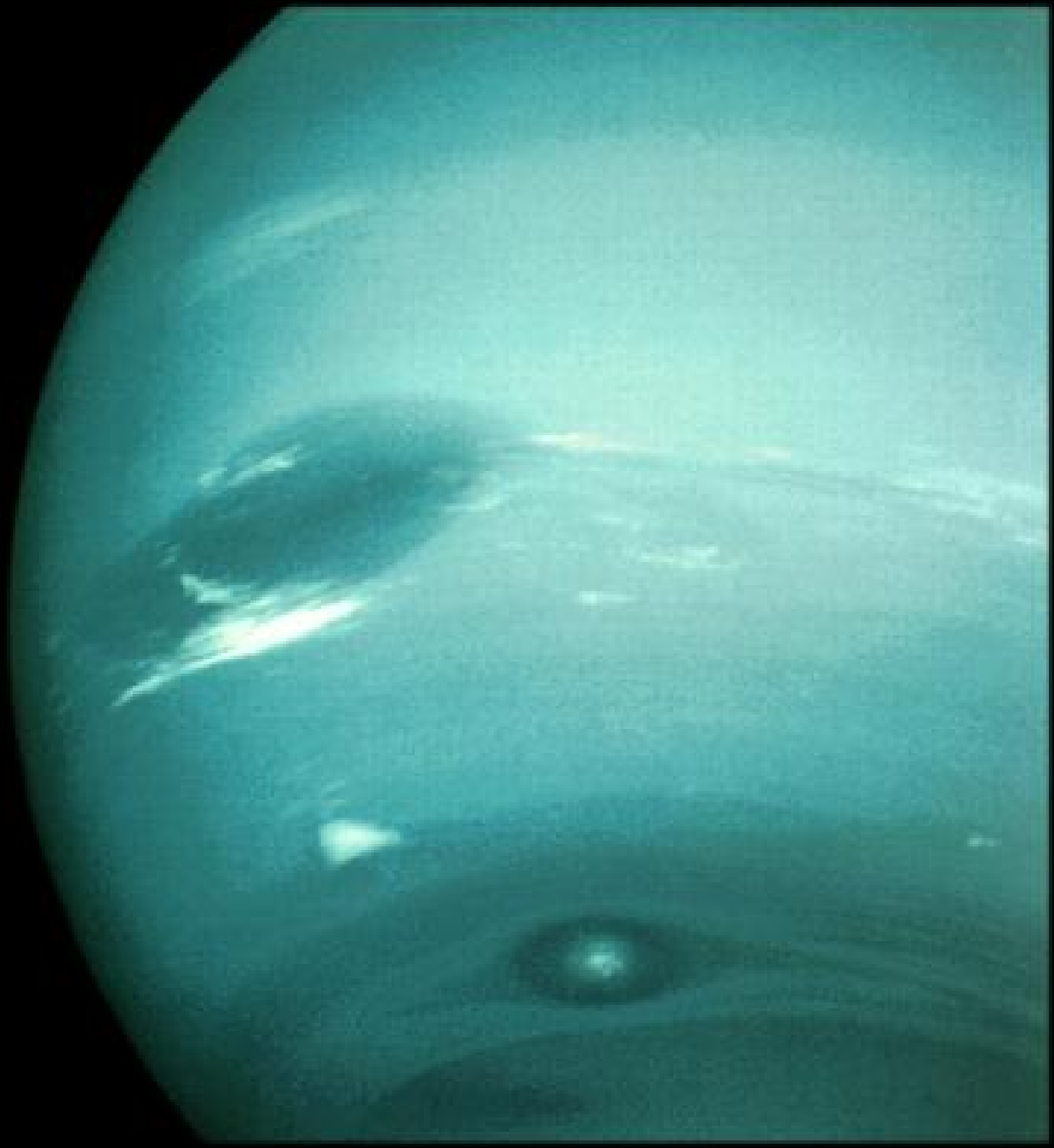





Horizon at 88.5°
6
13 cm
240 cm
7
5
15 cm
4
85 cm
3
8
2
1







Lecture 1: A Tour of the Solar System

Mean Earth – Sun distance = **Astronomical Unit**

149,597,870 km

1 A.U. = 107 solar diameters

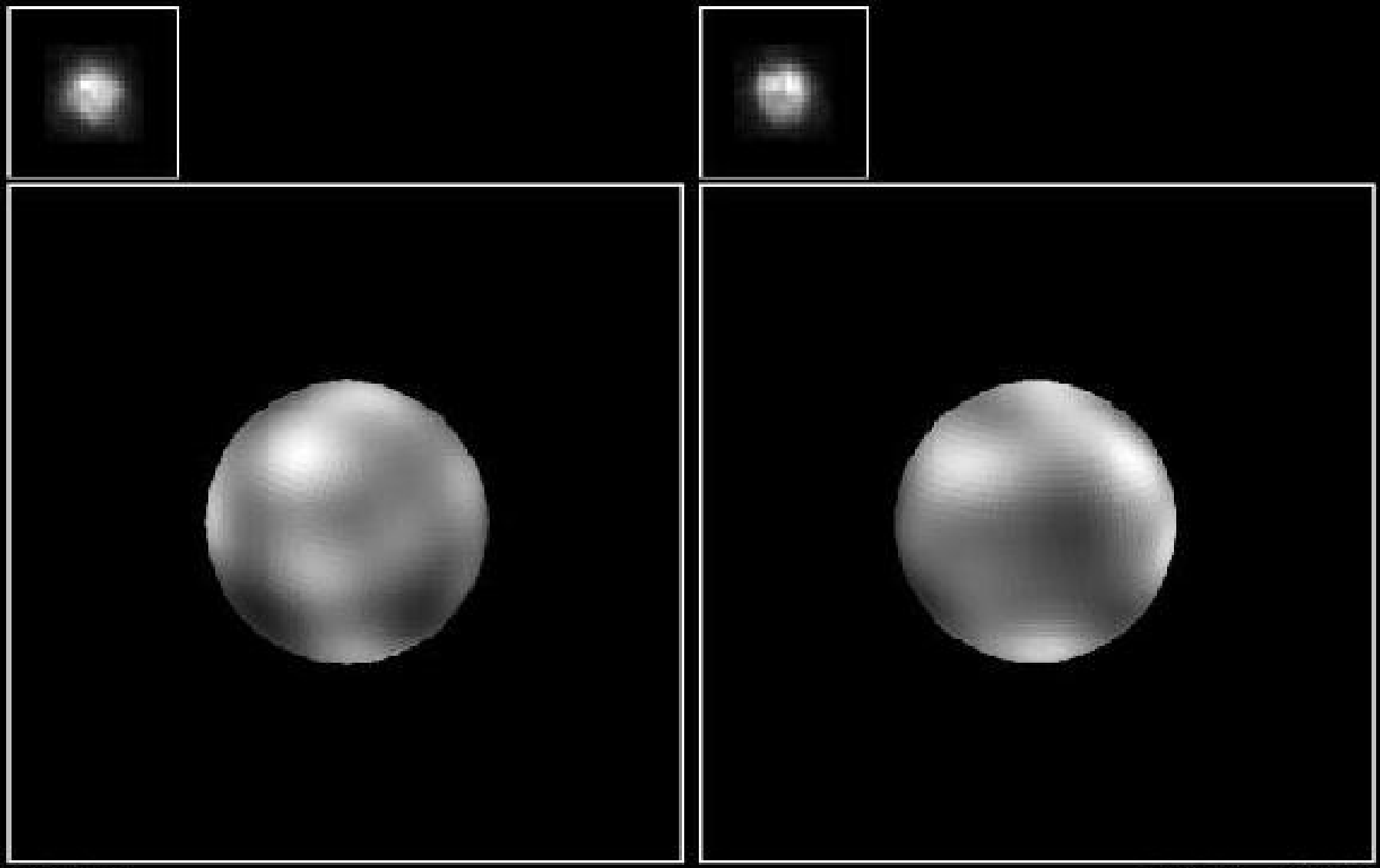
The orbits of the planets are ellipses (see A1X Dynamical Astronomy) and lie in, or close to, a plane – the ecliptic.

The planets divide into two groups:-

Inner *Terrestrial* planets: small, rocky — Mercury, Venus, Earth, Mars

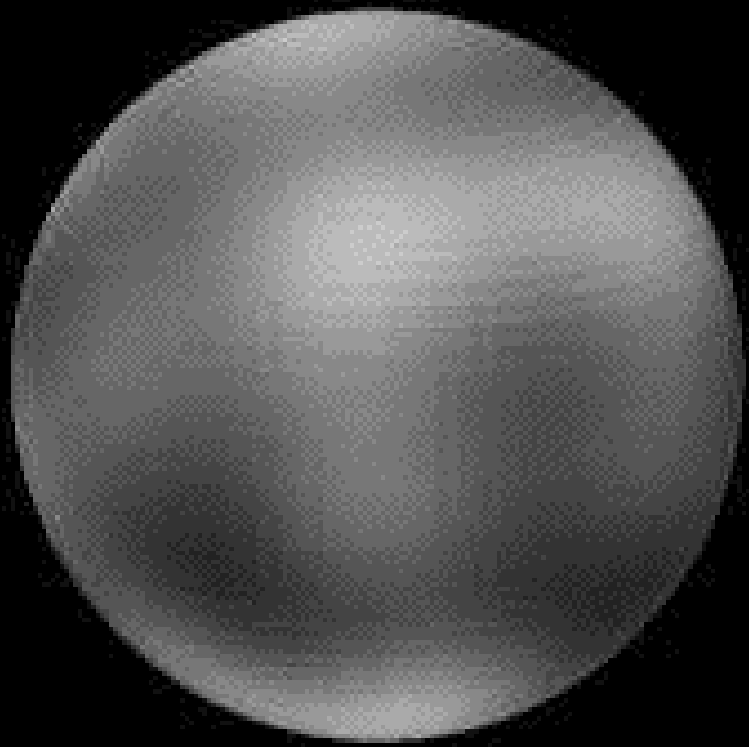
Outer *Jovian* planets: gas giants — Jupiter, Saturn, Uranus, Neptune

Pluto is a 'misfit' – Kuiper Belt object (planetesimal); together with asteroids and comets, 'debris' from formation of the Solar System.

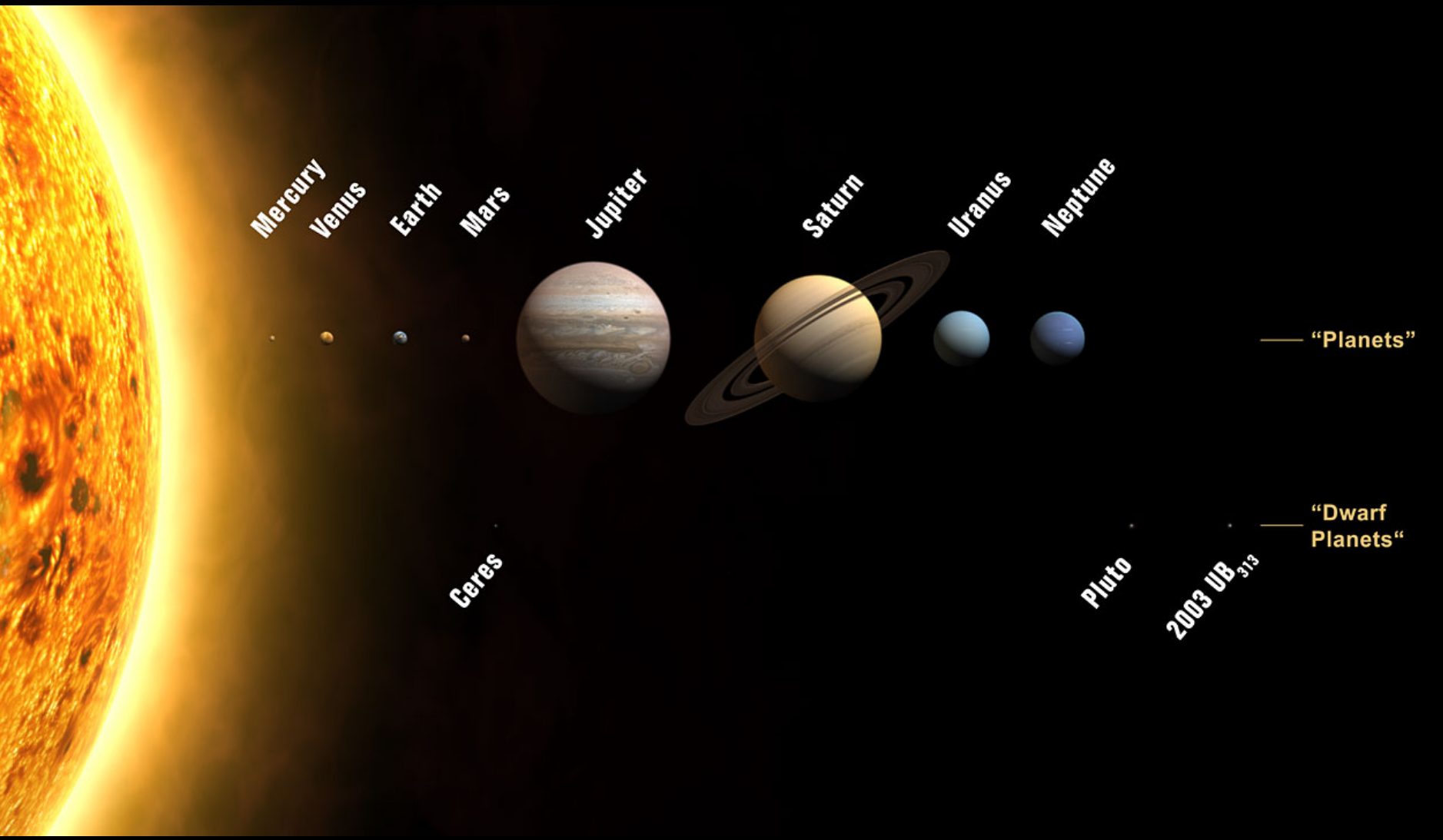


Pluto HST • FOC

PRC96-09a • ST ScI OPO • March 7, 1996 • A. Stern (SwRI), M. Buie (Lowell Obs.), NASA, ESA

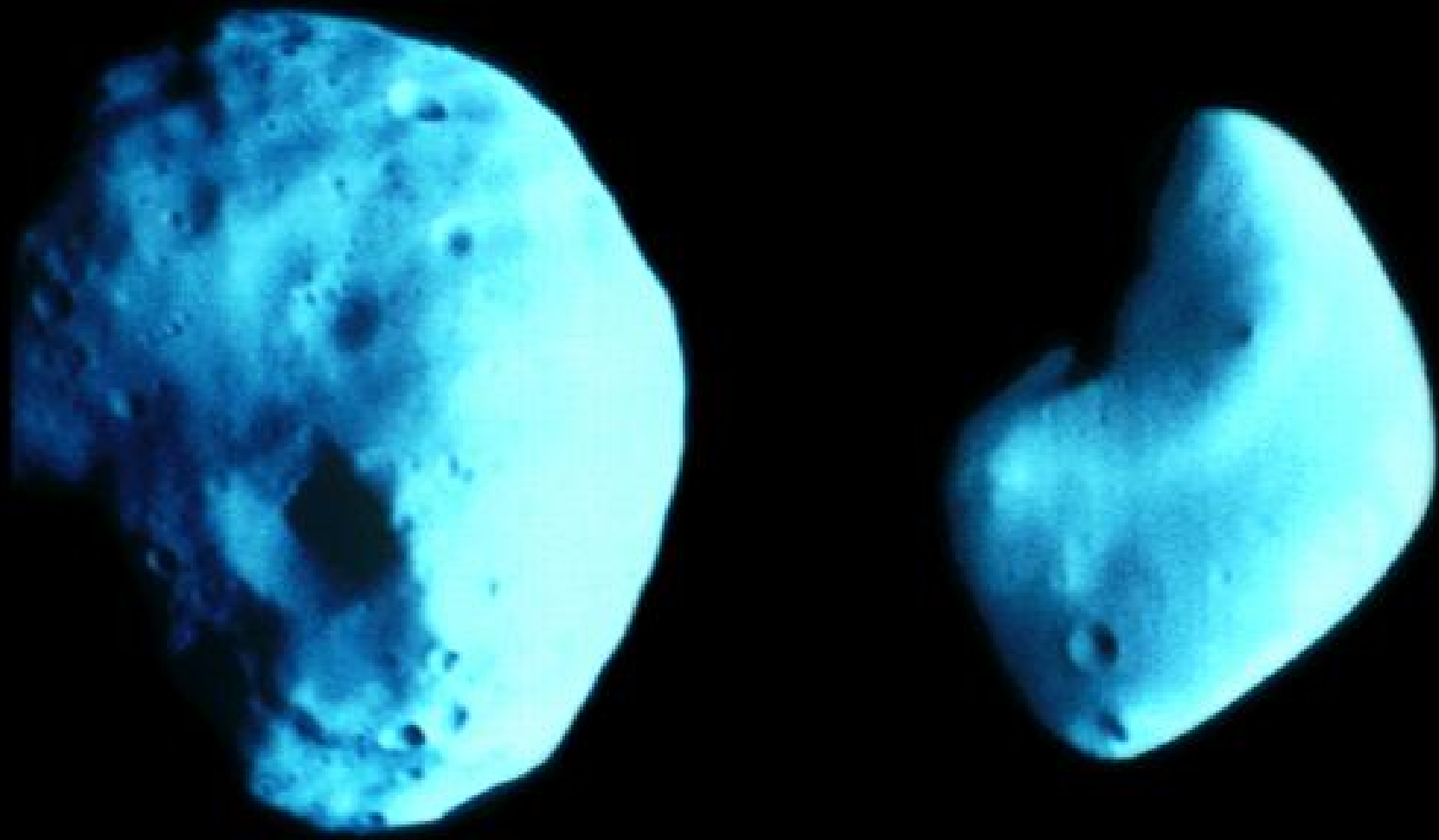


Sedna
Quaoar
Pluto
Moon
Earth


Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
"Planets"
Ceres
Pluto
2003 UB313
"Dwarf Planets"

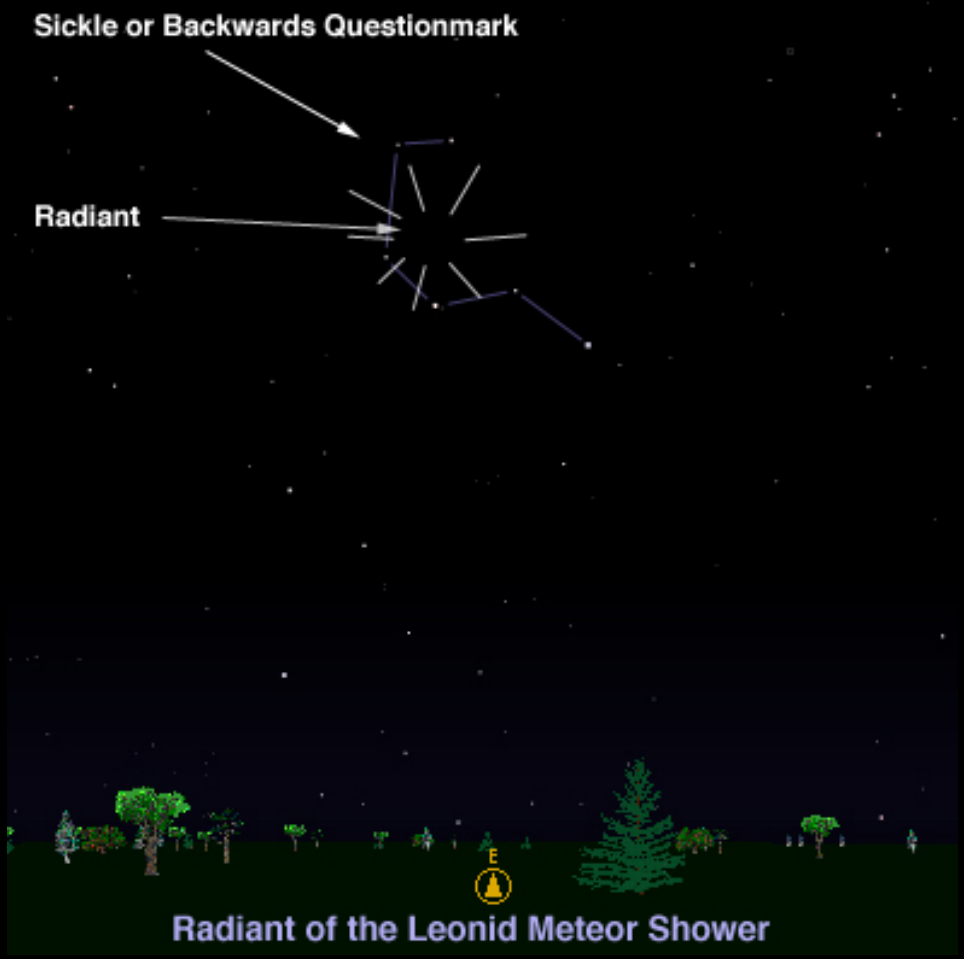
Invention of telescope led to discovery of Minor Planets or *asteroids*. Most orbit between Mars and Jupiter – ***Asteroid Belt***

'Lumps' of rock (up to 1000km across), reflecting sunlight. Only visible through a telescope



NEAR – 433 Eros
Feb 10 2000 09:10:00

Leonid Meteor Shower: Nov 17th – 18th



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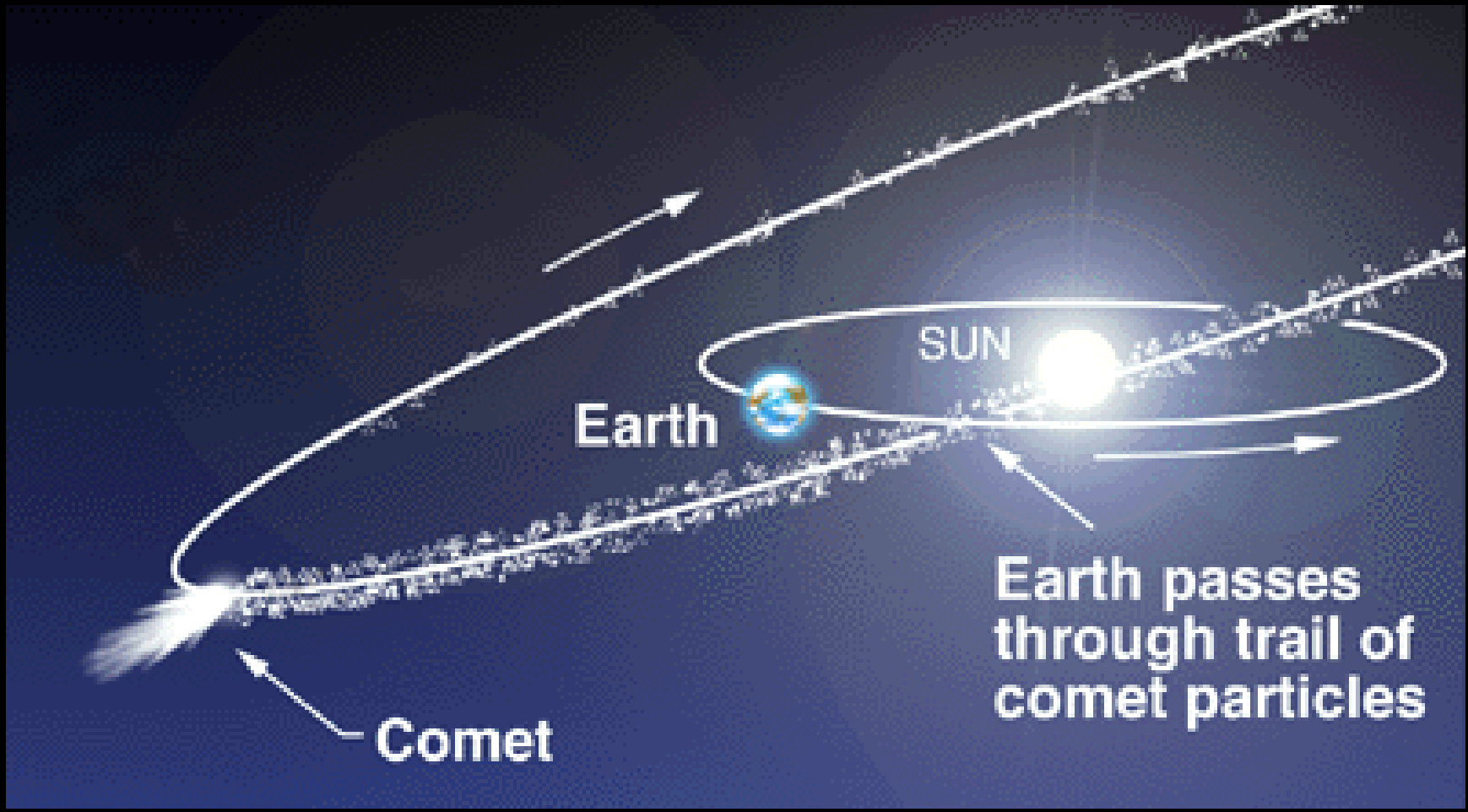
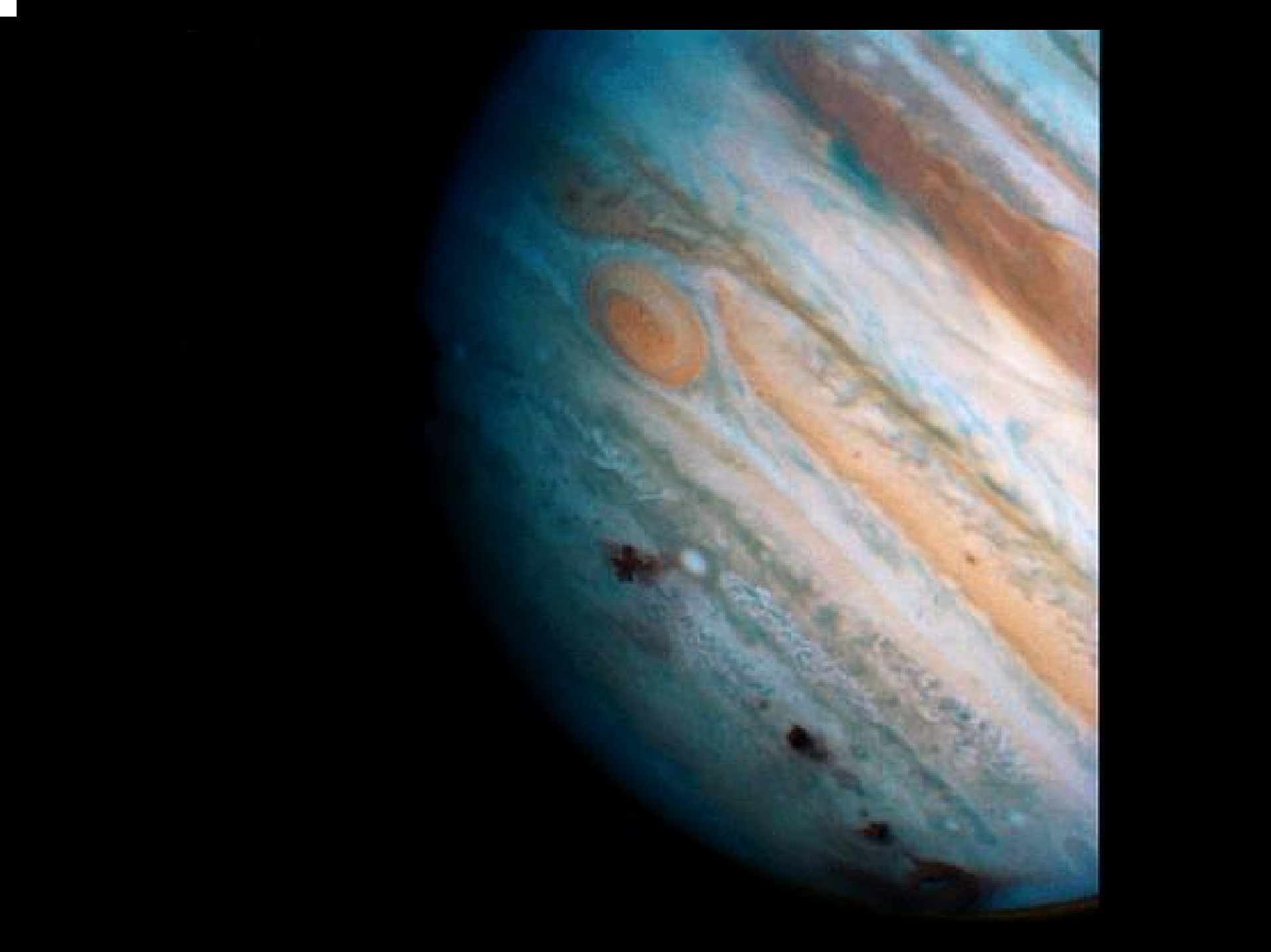
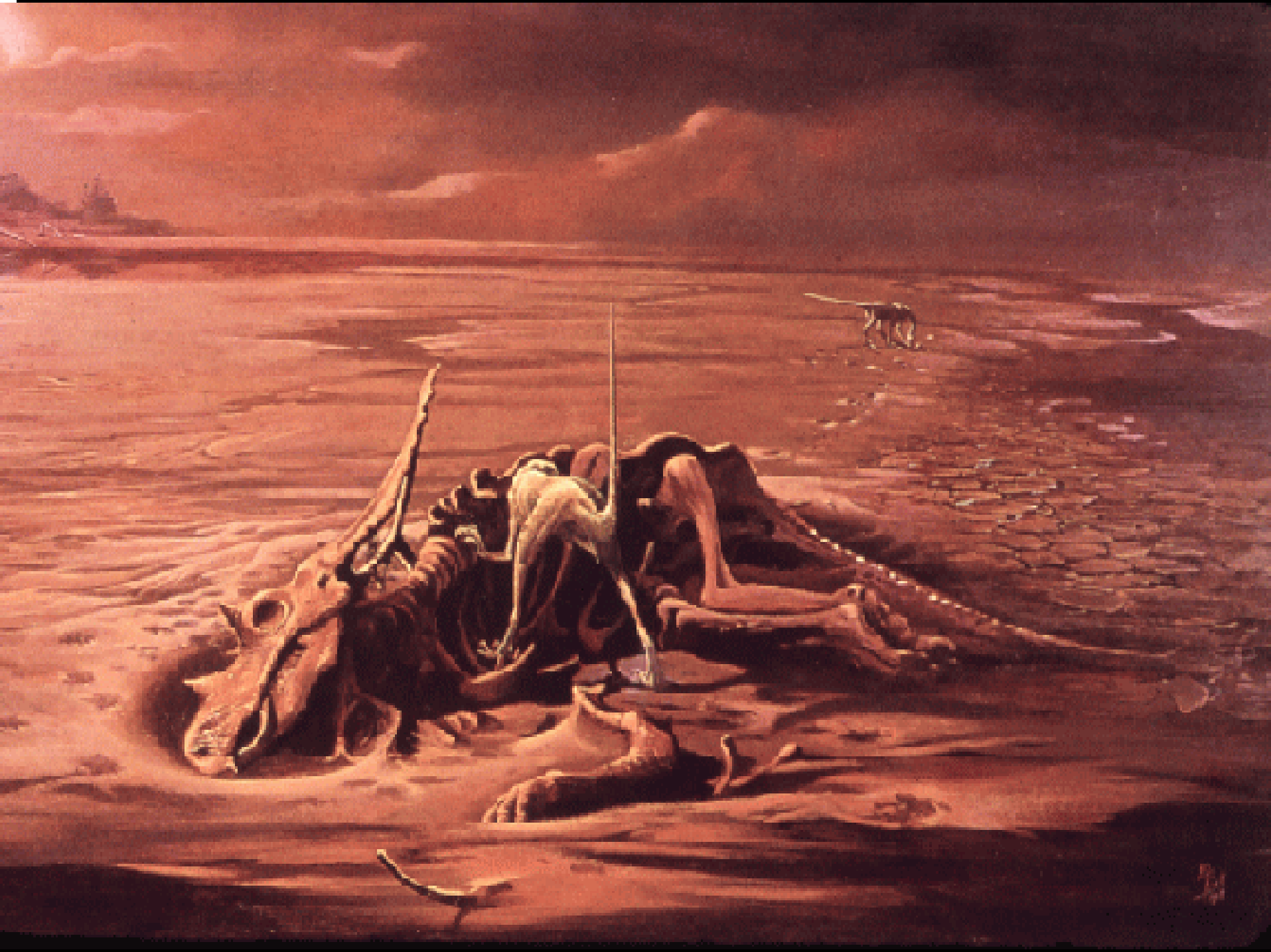


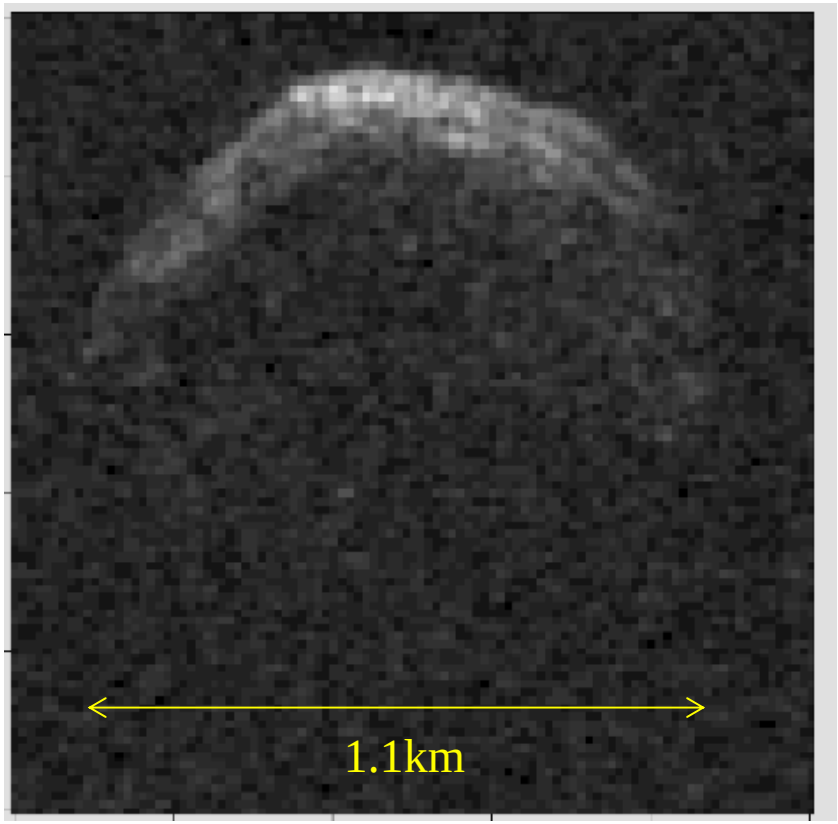




874 years till Doomsday?…

Asteroid 1950DA: 1 in 300 chance of collision with Earth on March 16th 2880

(Science, Apr 5th 2002)



Credit: Arecibo Observatory

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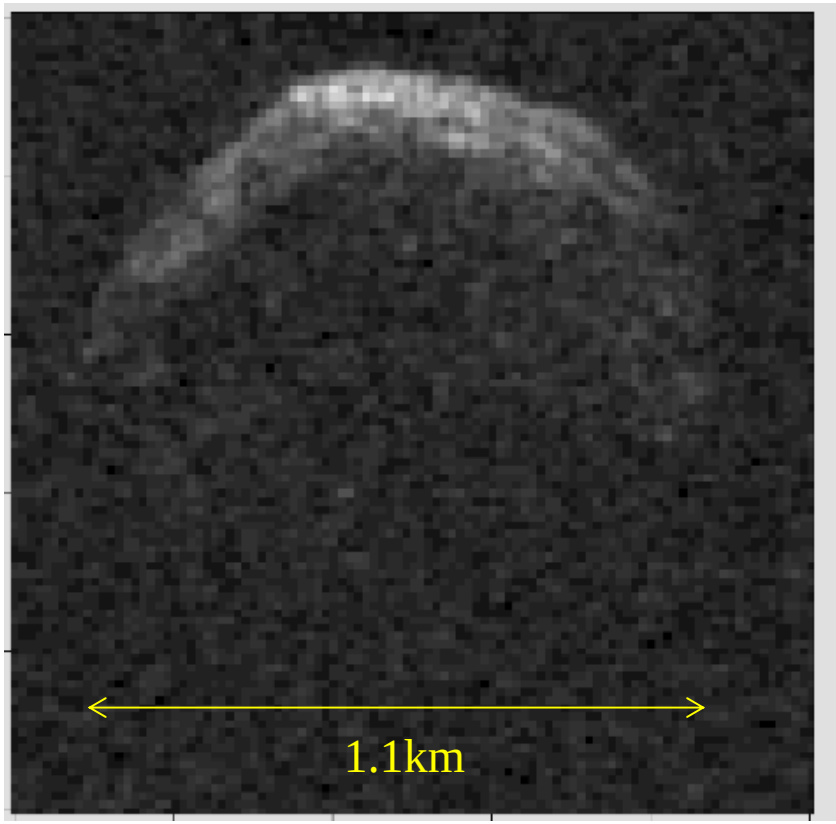

Credit: Arecibo Observatory

Need to determine the orbit of the asteroid…

…all about *gravity*