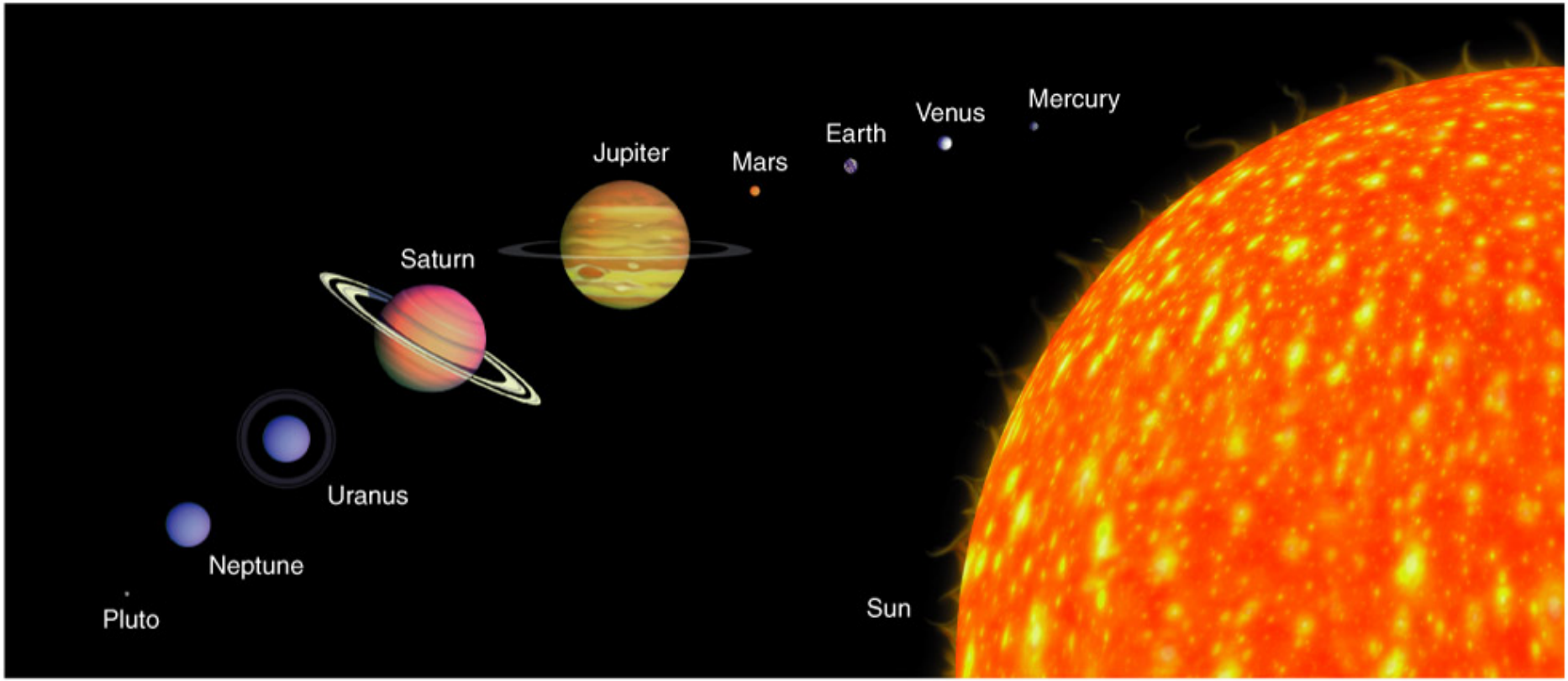
Our Planetary System (Chapter 7)

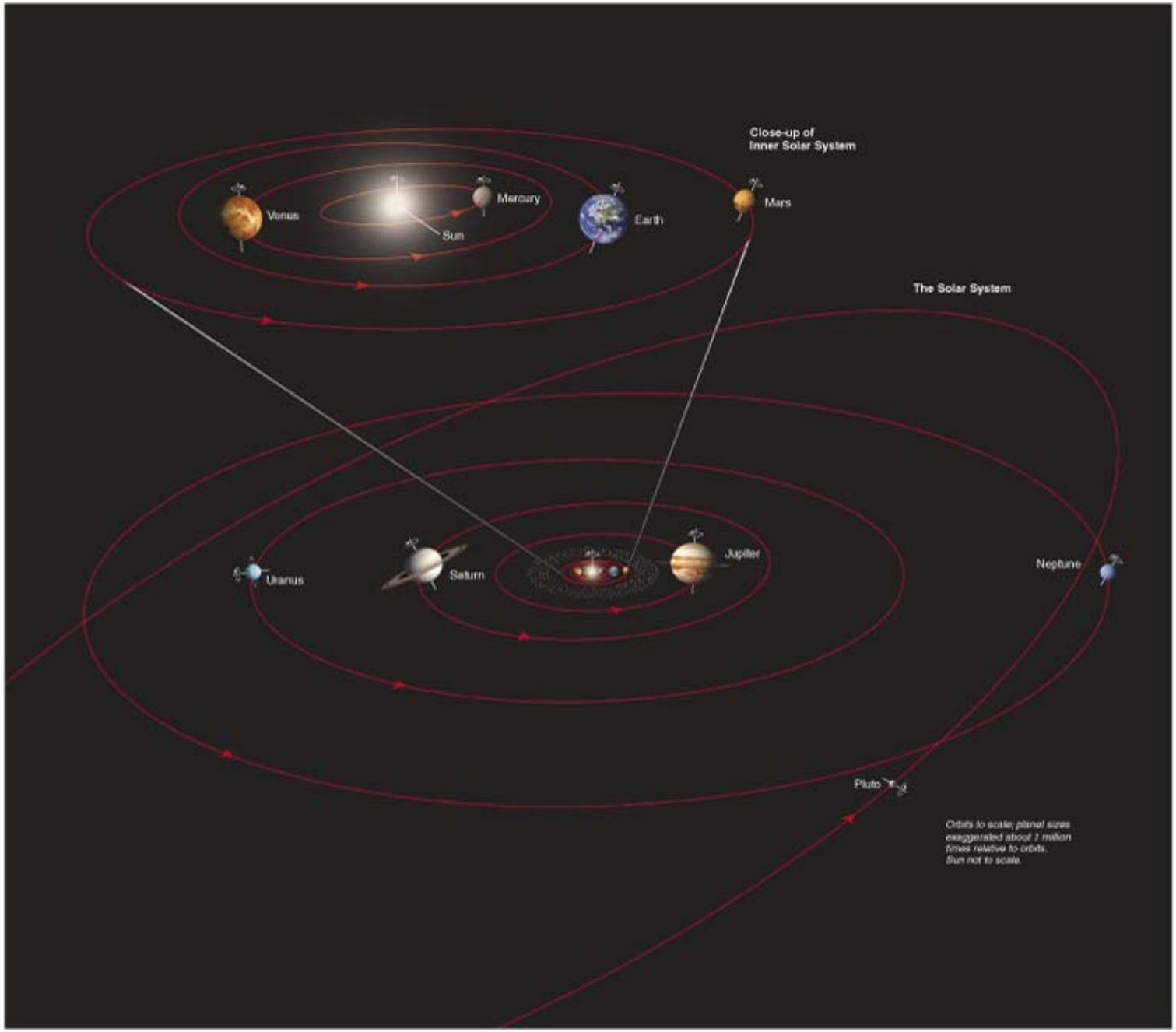


Based on Chapter 7

- This material will be useful for understanding Chapters 8, 9, 10, 11, and 12 on “Formation of the solar system”, “Planetary geology”, “Planetary atmospheres”, “Jovian planet systems”, and “Remnants of ice and rock”
- Chapters 3 and 6 on “The orbits of the planets” and “Telescopes” will be useful for understanding this chapter

Goals for Learning

- How do planets rotate on their axes and orbit the Sun?
- What are the planets made of?
- What other classes of objects are there in the solar system?



Orbits mostly lie in the same flat plane

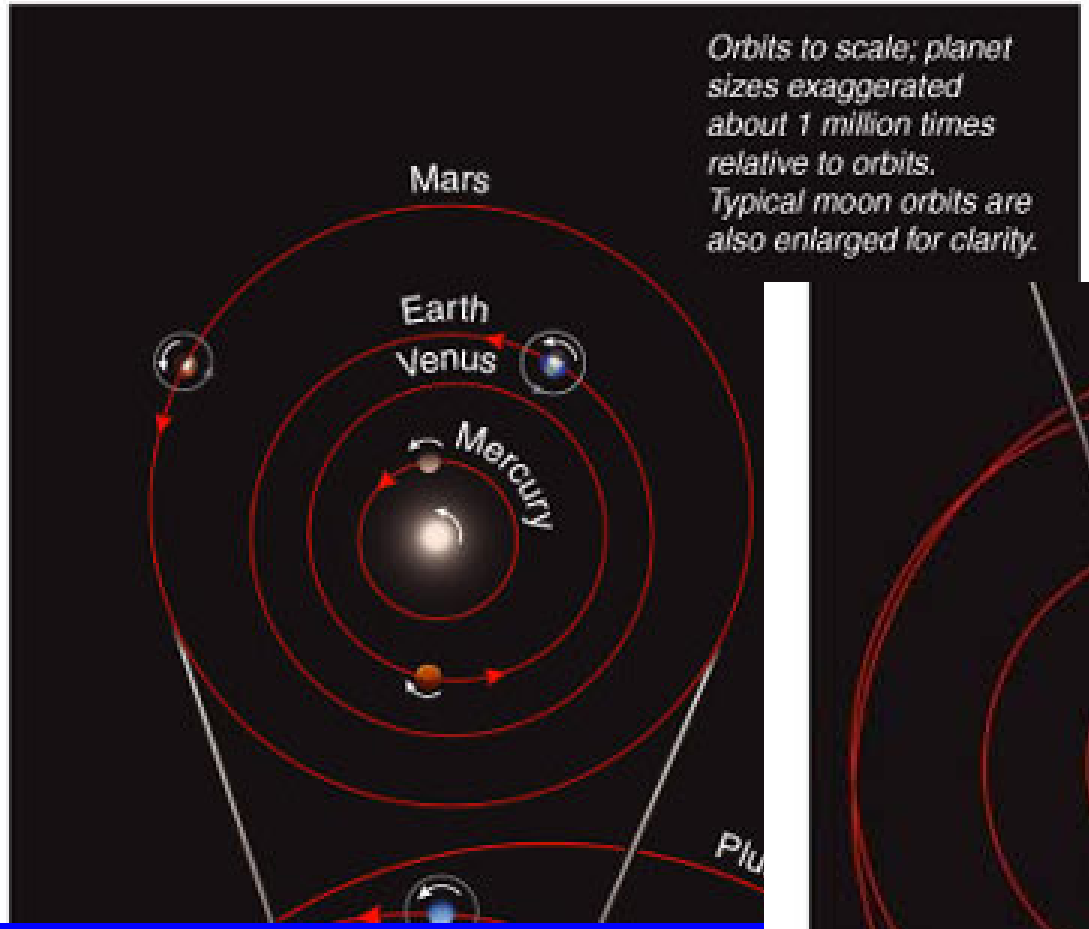
All planets go around the Sun in the same direction

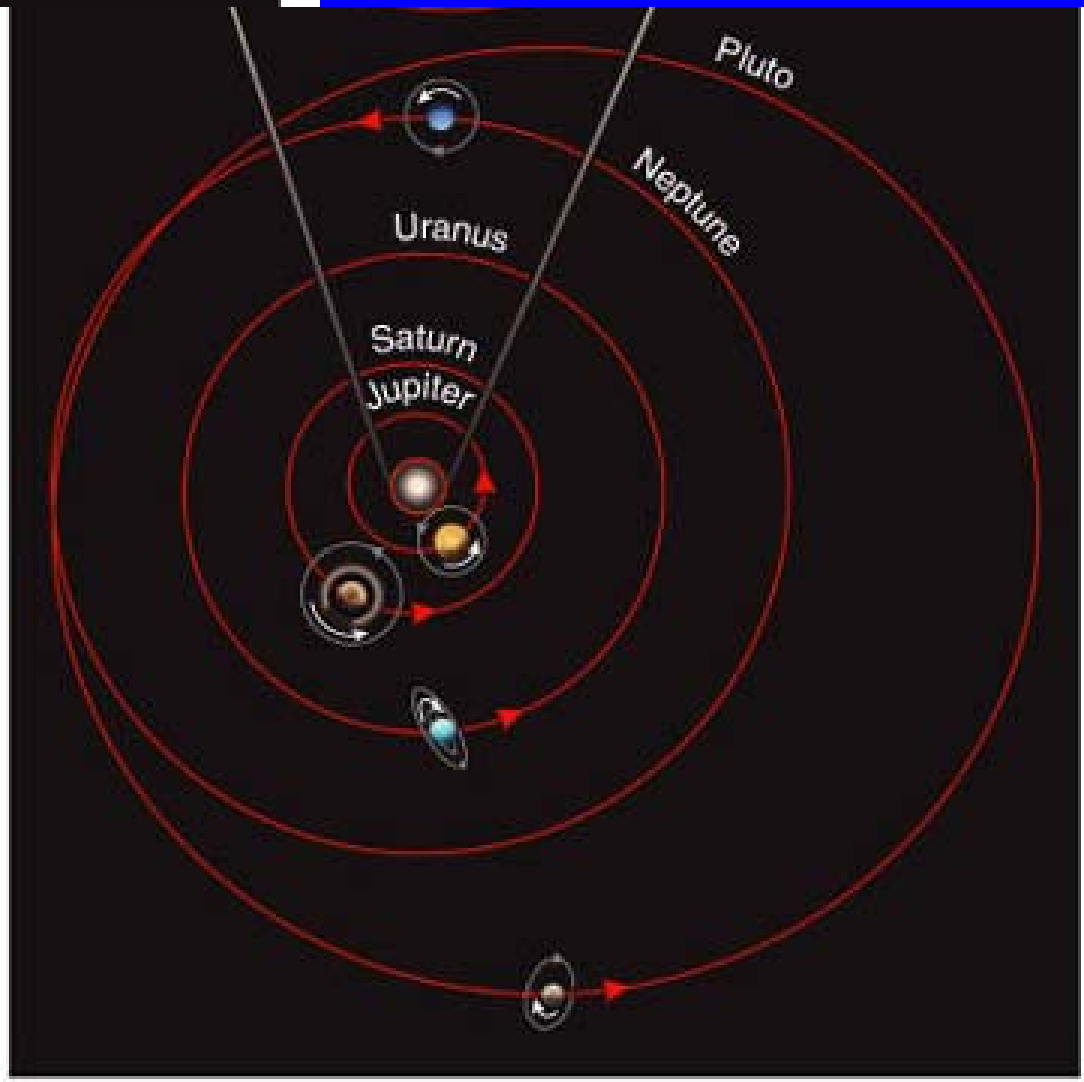
Most orbits are close to circular

Not coincidences!

Most planets rotate in the same “sense” as they orbit the Sun

Coincidence?





Planetary equators mostly lie in the same plane as their orbits

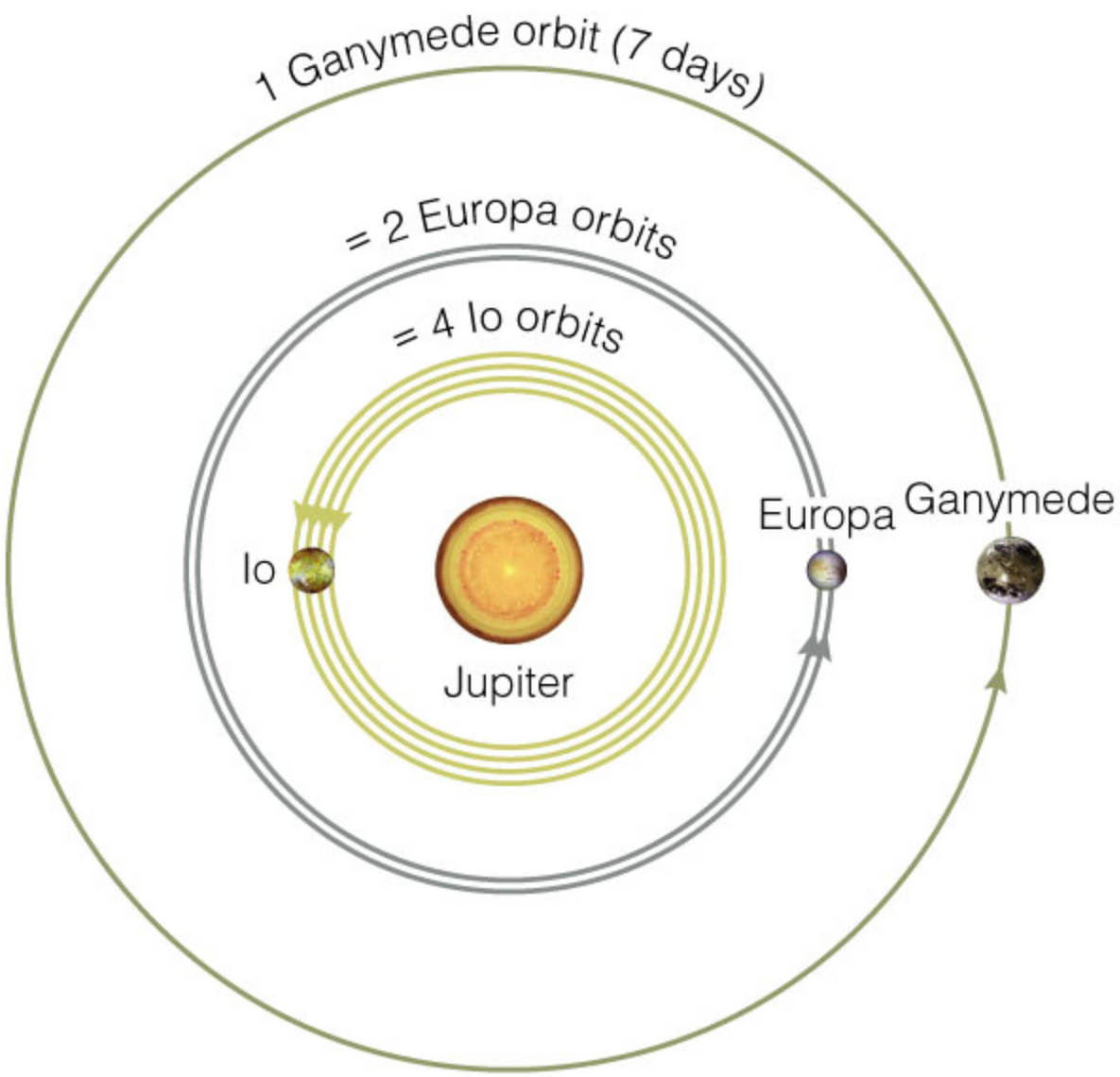
Coincidence?

- Interactive Figure: Orbital and Rotational Properties of the Planets

Rotation and Orbits of Moons

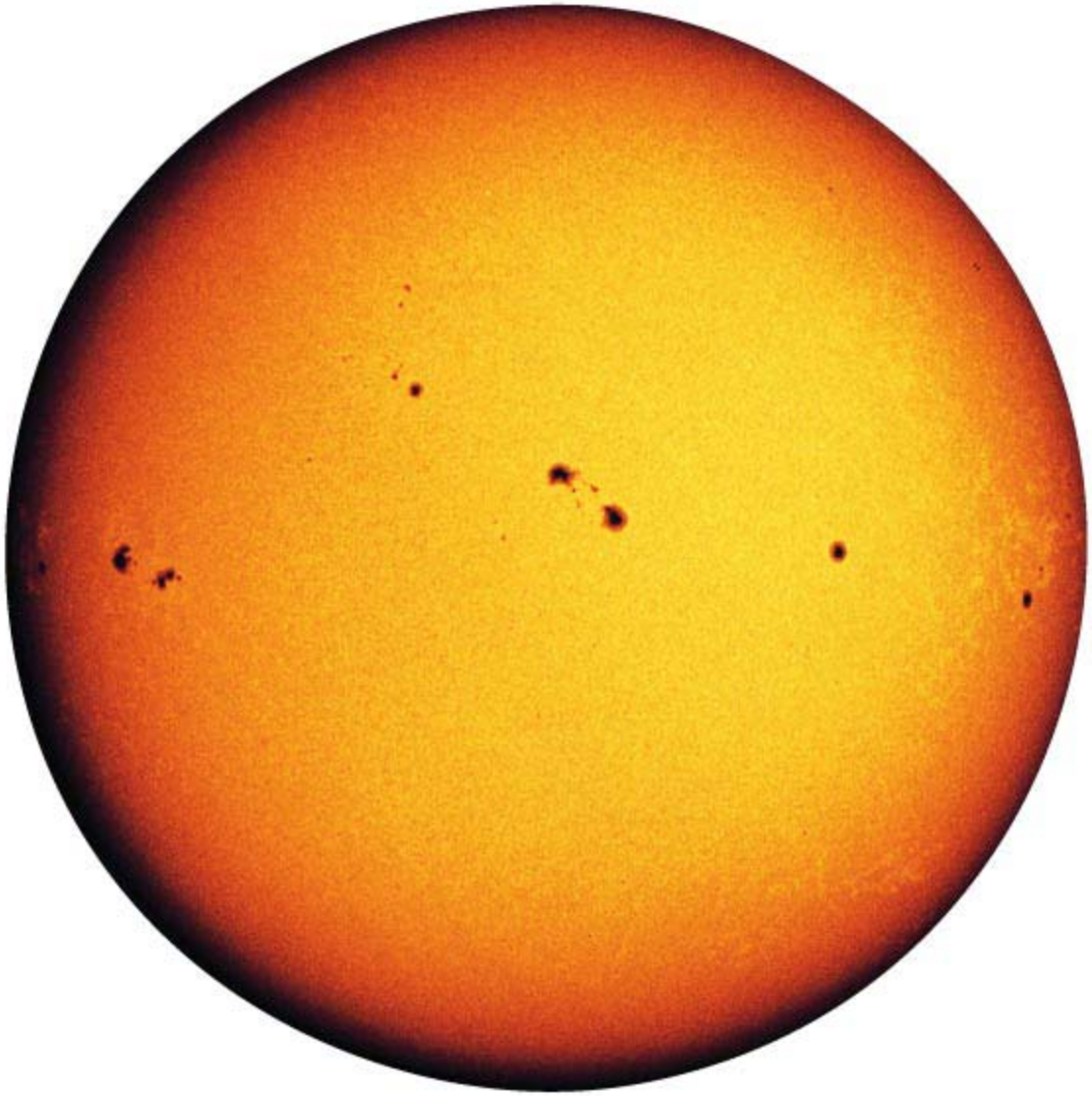
- Most moons (especially the larger ones) orbit in near-circular orbits in the same plane as the equator of their parent planet
- Most moons rotate so that their equator is in the plane of their orbit
- Most moons rotate in the same “sense” as their orbit around the parent planet

- Everything is rotating/orbiting in the same direction



A Brief Tour

- Distance from Sun
- Size
- Mass
- Composition
- Temperature
- Rings/Moons



Sun

695000 km = 108 R_E
333000 M_{Earth}

98% Hydrogen and helium

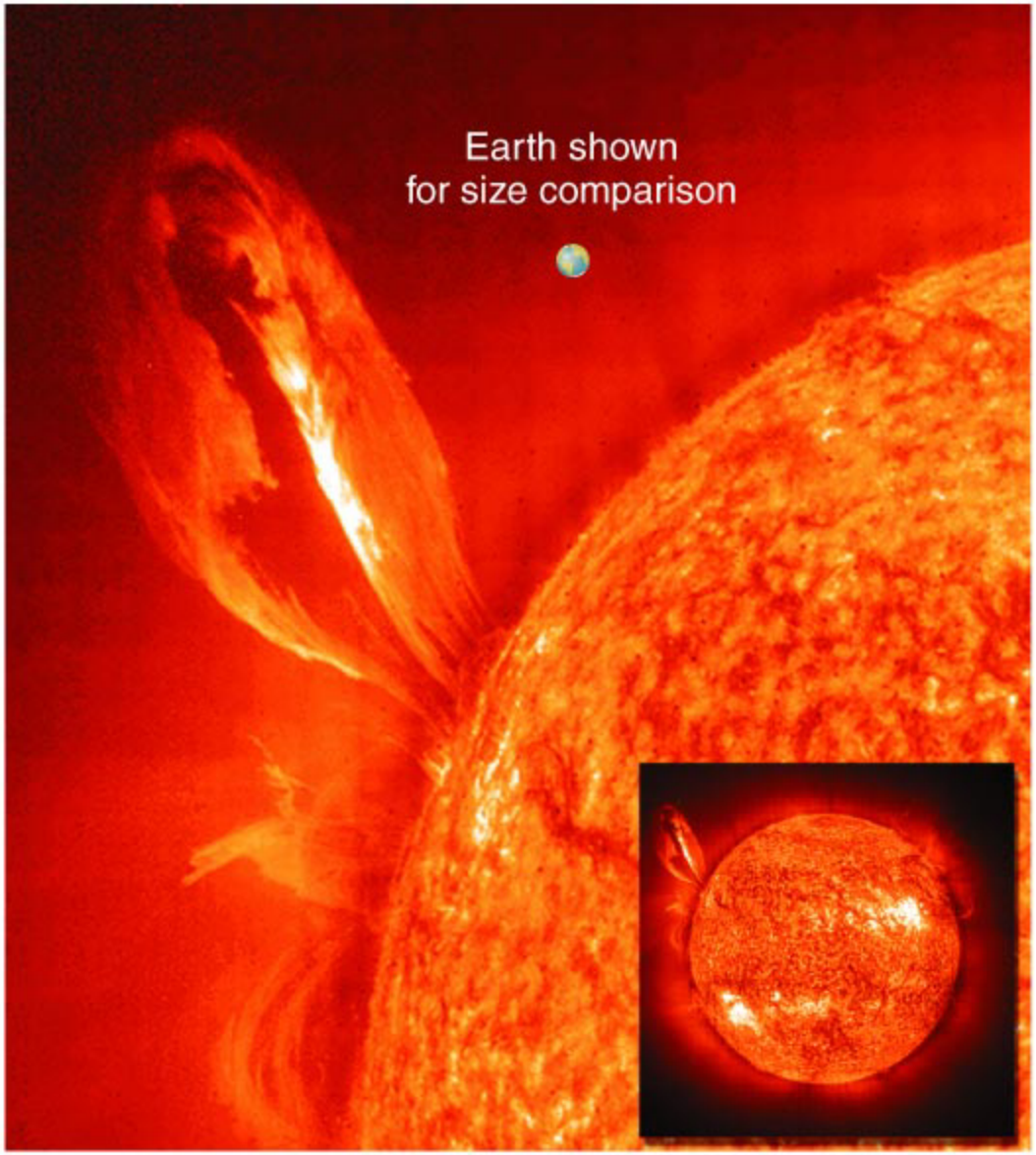
99.9% total mass of solar system

Surface = 5800K
Much hotter inside

Giant ball of gas

Gravity => orbits

Heat/light => weather and temperatures of the planets



Very dynamic, very active

Visible light doesn't vary much

UV and X-rays vary a lot

Charged particles and magnetic fields from the Sun are also important

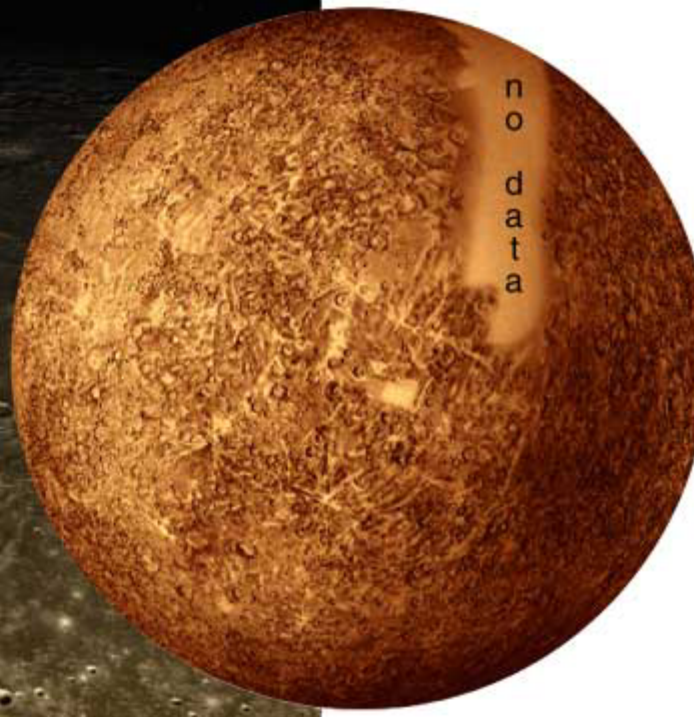
Mercury

0.39 AU
2440 km, 0.38 R_{Earth}

0.055 M_{Earth}
Rocky exterior, iron interior

700 K (day), 100 K (night)
No atmosphere

Unusual rotation
58.6 day rotation, 87.9 day orbit



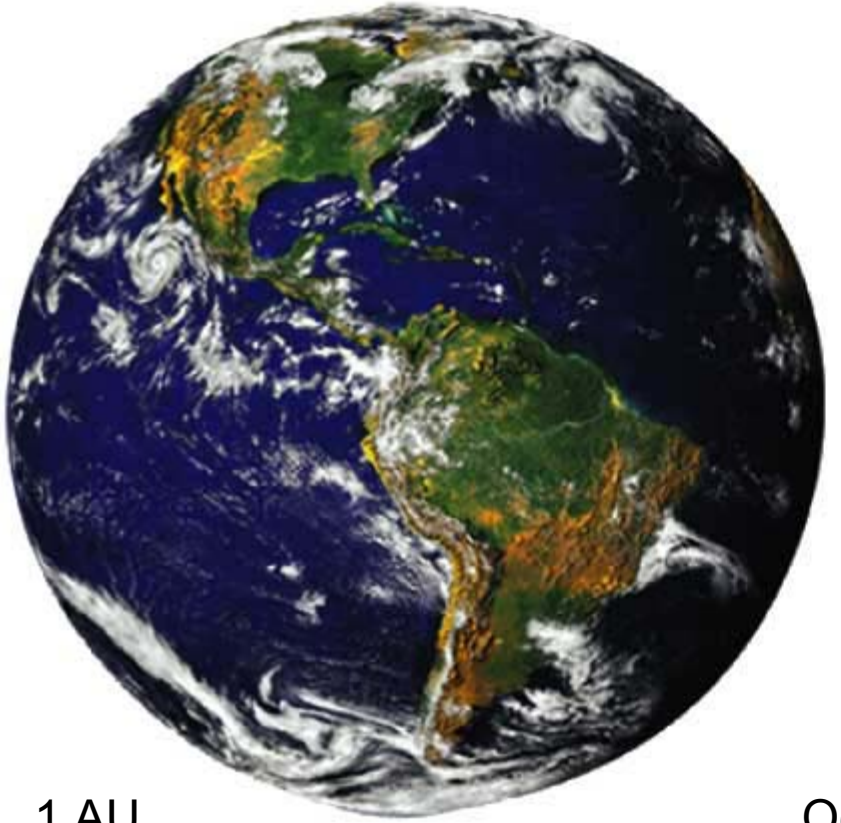
Venus

0.72 AU
6051 km, 0.98 R_{Earth}

0.82 M_{Earth}

Rocky exterior, iron interior, thick atmosphere
740K surface due to greenhouse effect No moons
Mountains, valleys, old volcanoes on surface

Earth



Moon
Sizes to scale
Distance should be 1 m apart

1 AU
6378 km, 1 R_{Earth}
1 M_{Earth}
Rocky exterior, iron interior

Oceans and atmosphere
290 K
1 large moon (relatively large)
Life

Mars

1.52 AU

3397 km, 0.53 R_{Earth}

0.11 M_{Earth}

Rocky exterior, iron interior

220 K surface

Thin atmosphere

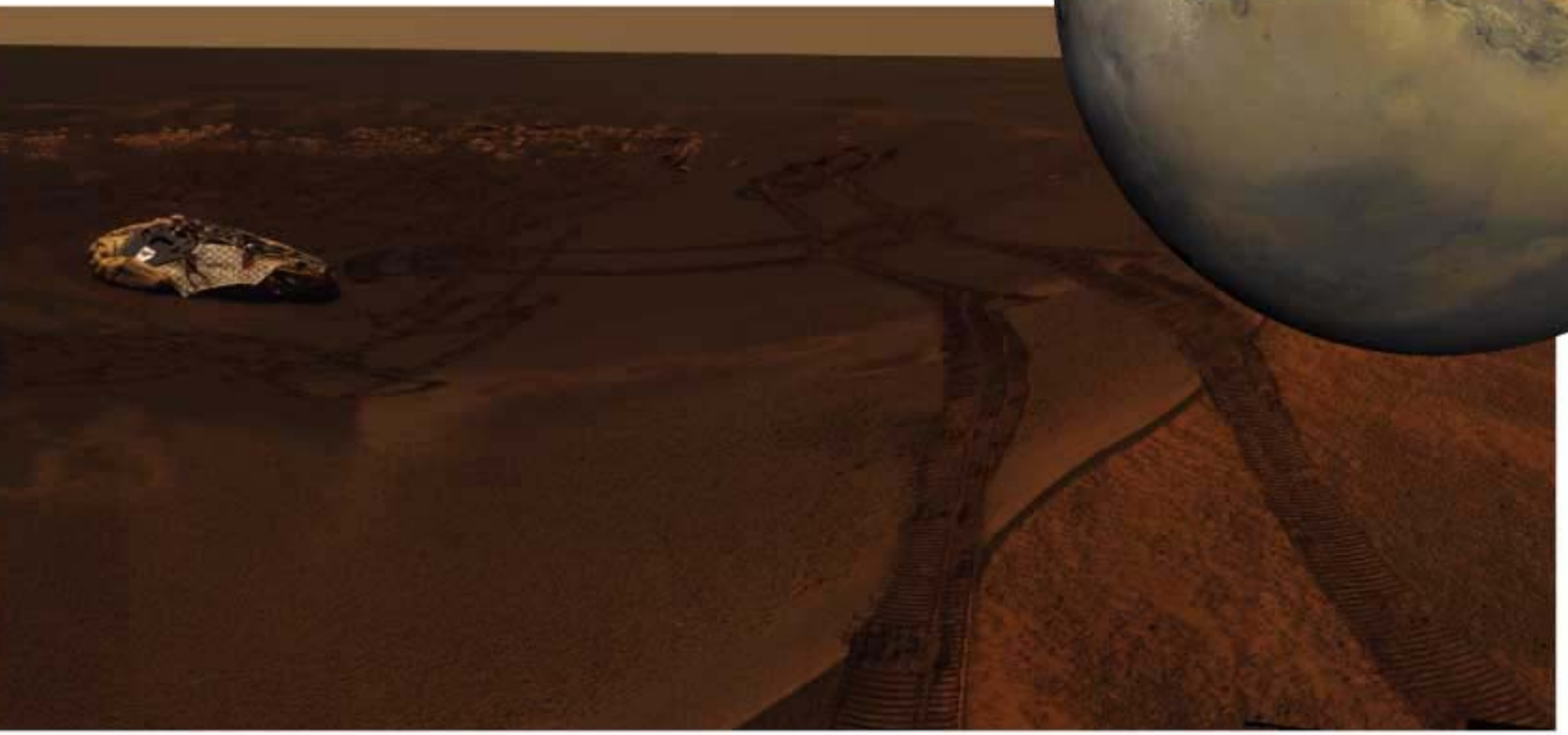
Past liquid water

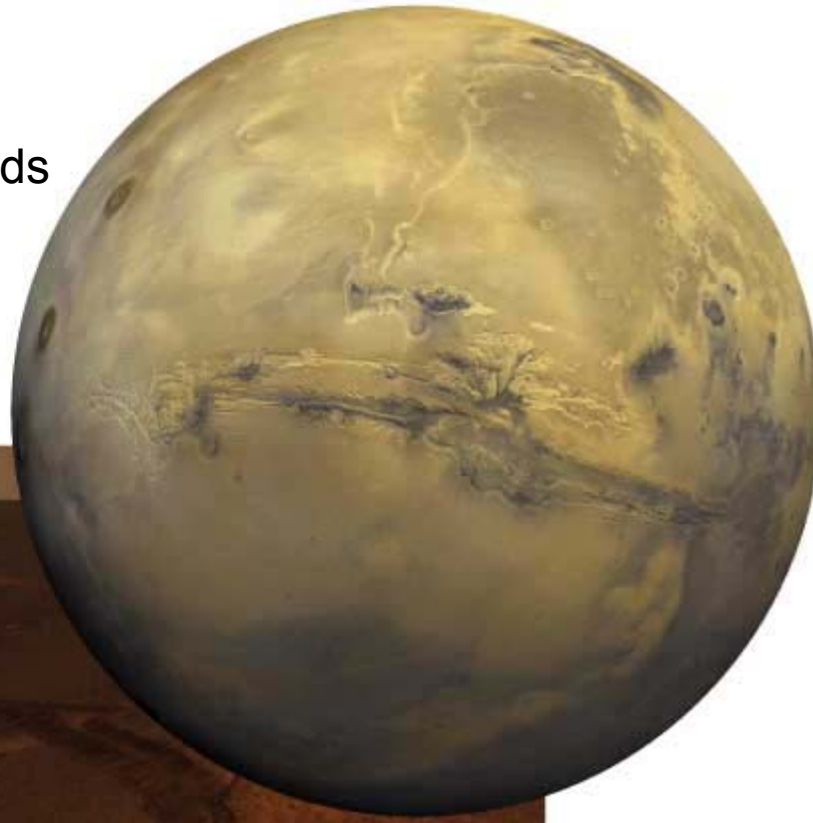
Flood channels, riverbeds

Old volcanoes

Polar ice caps

2 small moons





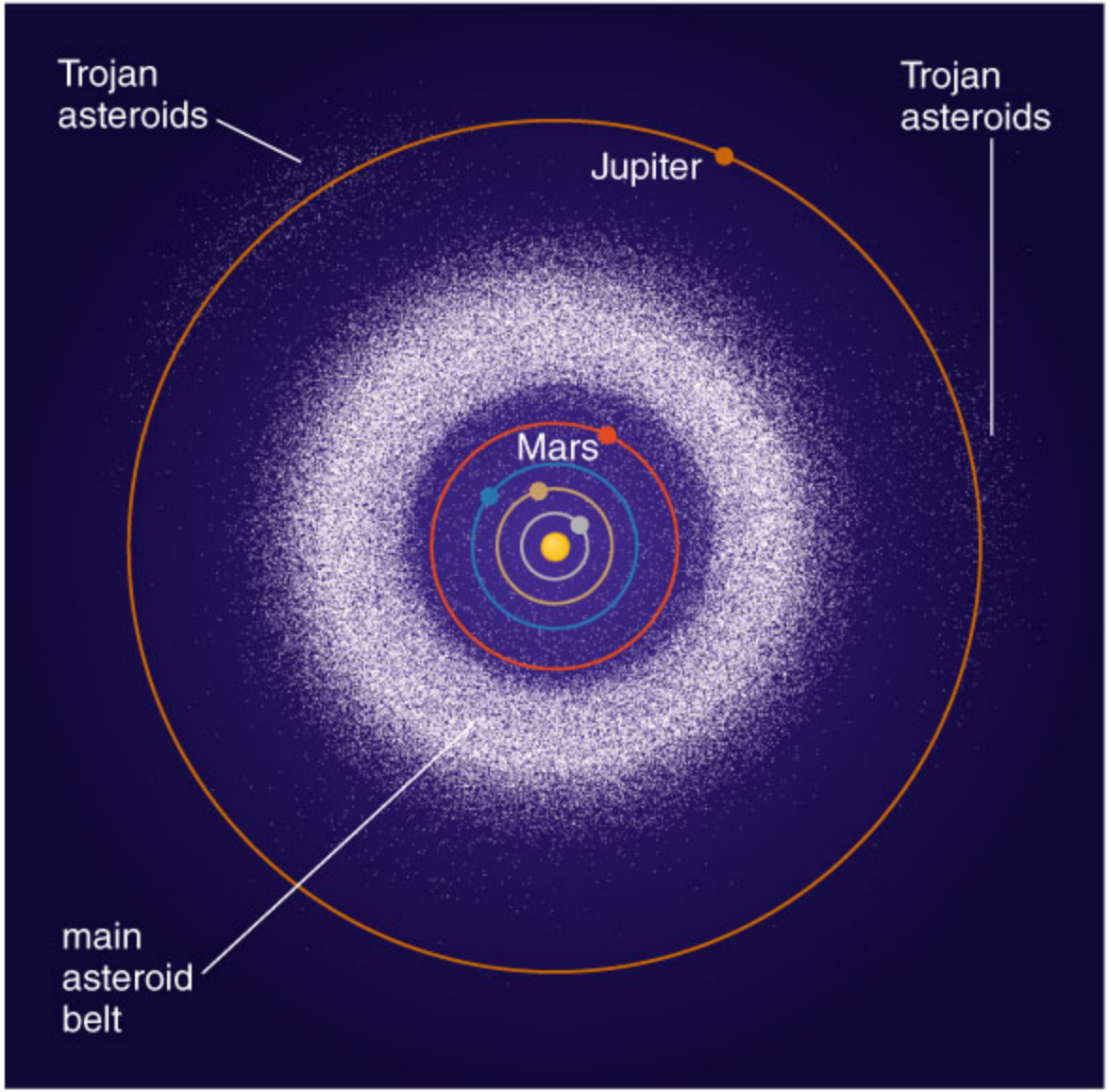
Past life? Present life?

These surfaces have been affected by flowing water

- A – Mercury, Mars
- B – Venus, Earth, Moon
- C – Earth, Mars
- D – Venus, Moon, Mars

These bodies have atmospheres

- A – Venus, Moon, Mars
- B – Mercury, Earth, Mars
- C – Mercury, Moon, Earth
- D – Venus, Earth, Mars

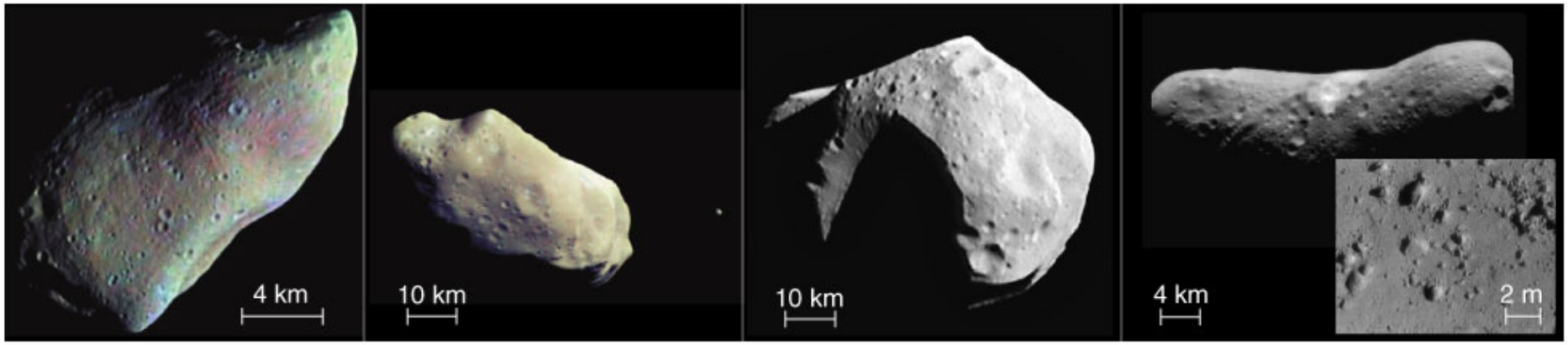


Asteroids

Most of them are much smaller than planets

A few are hundreds of km in radius

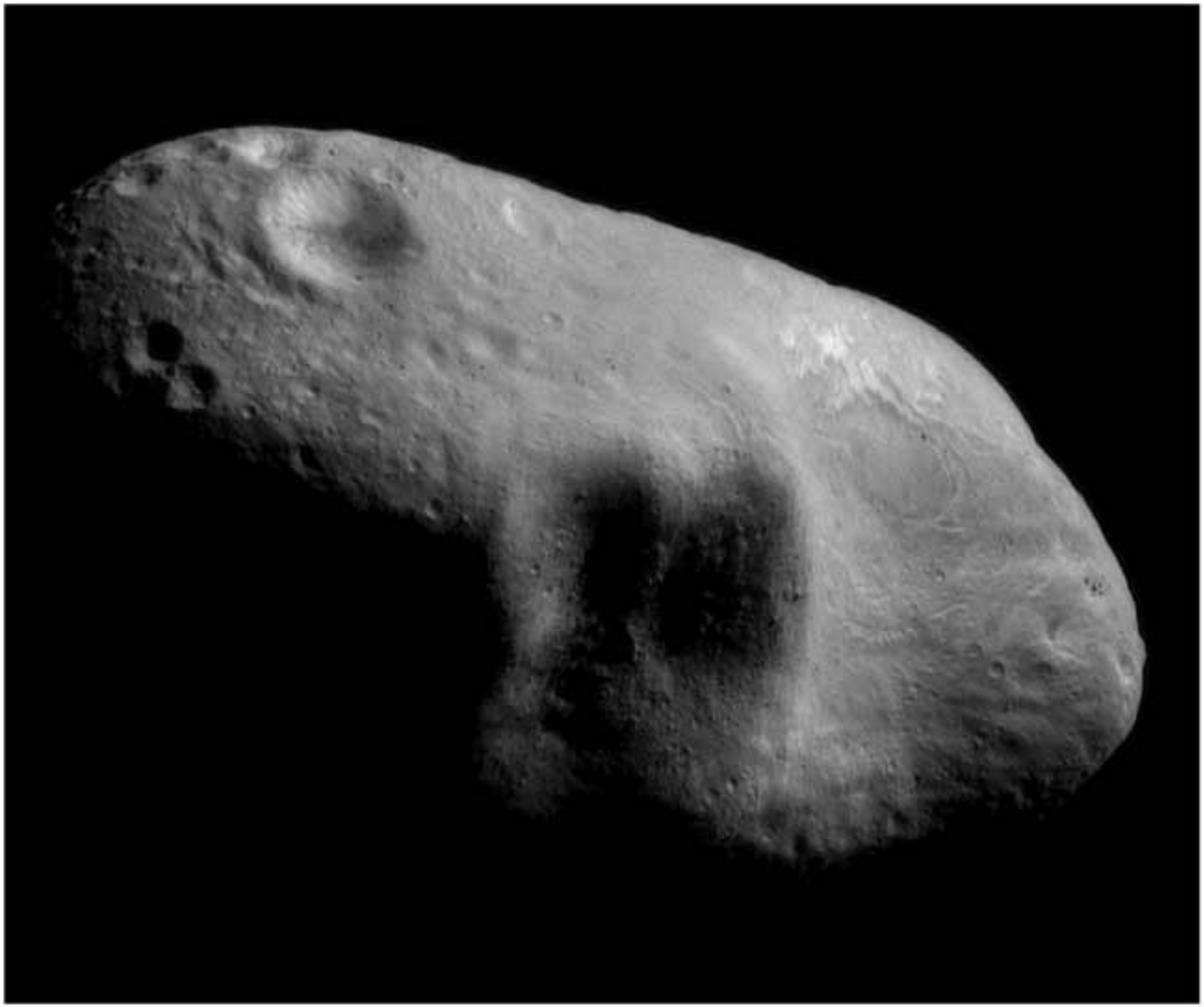
Thousands of them

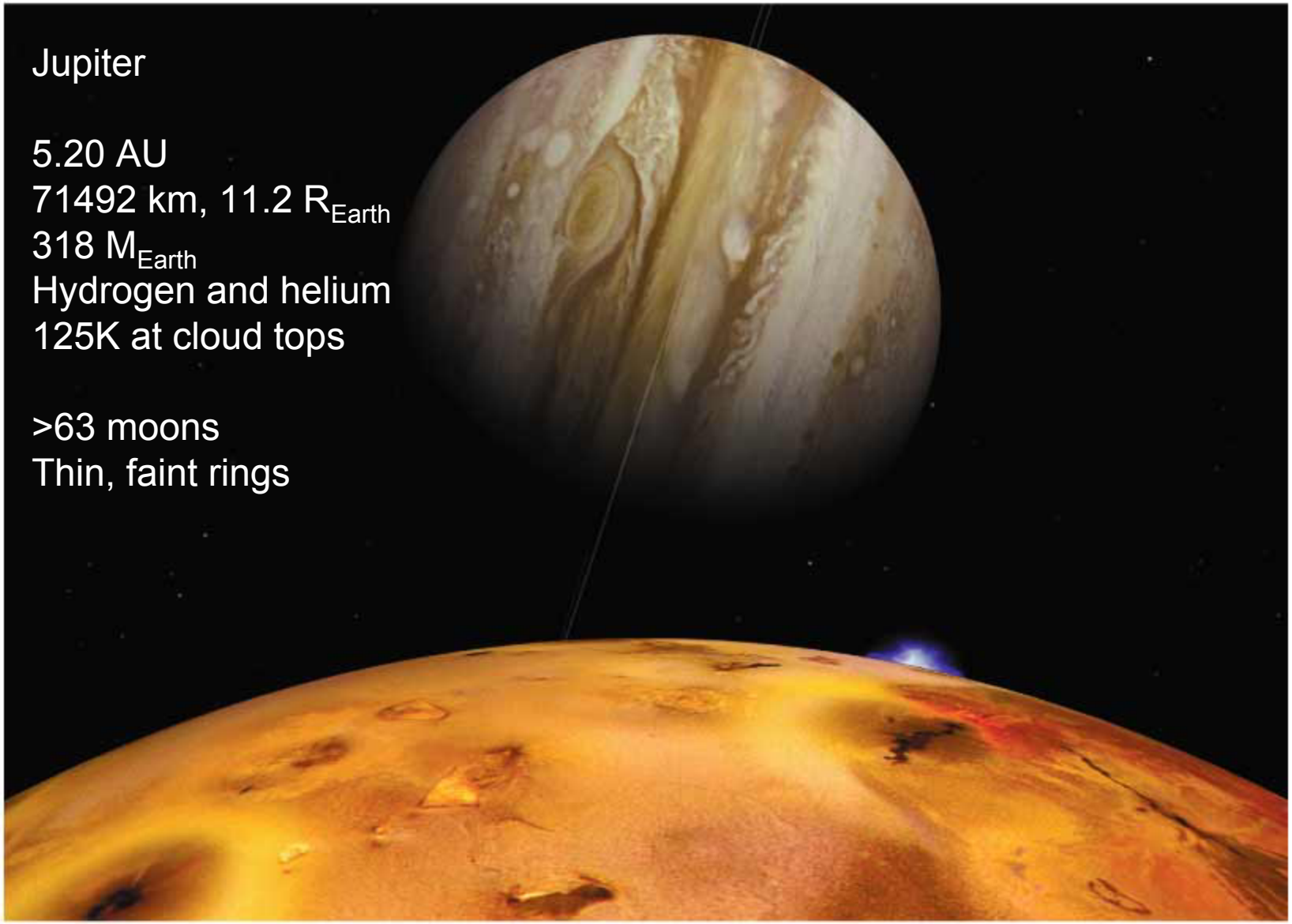


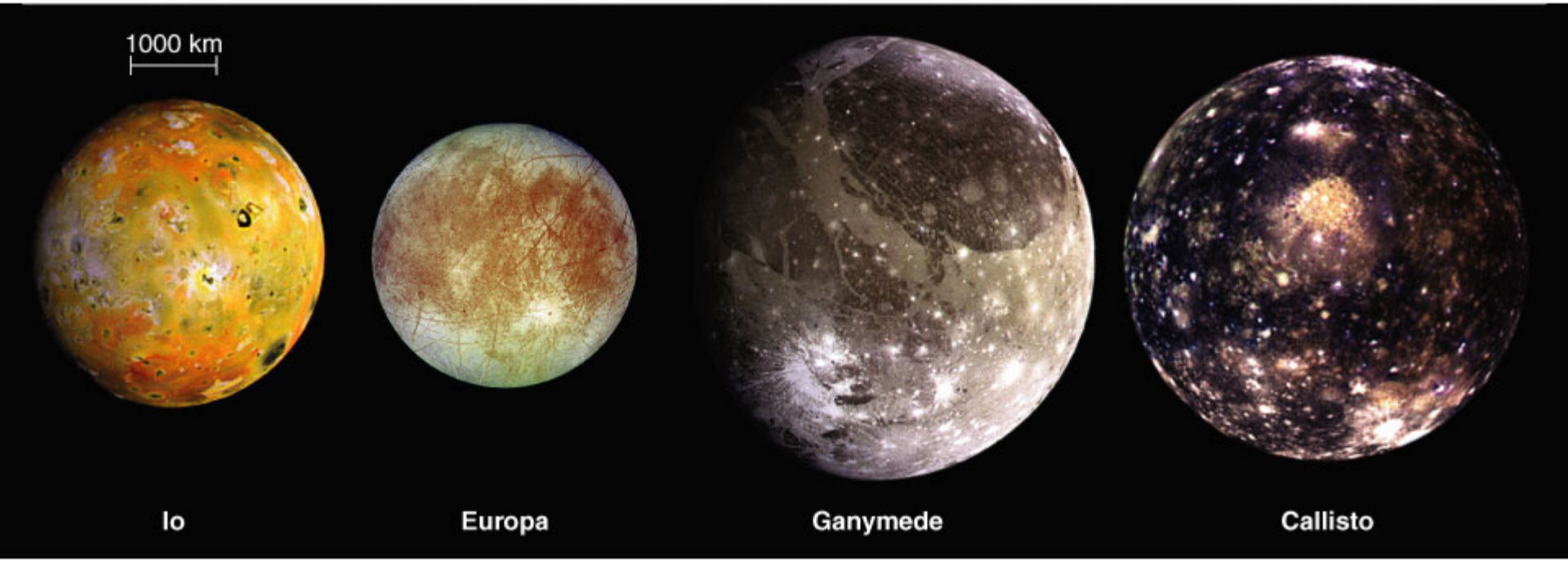
Gaspra Ida Mathilde Eros

Some asteroids – first pictures 15 years ago

Rocky exterior and interior
No atmosphere
Not shaped like a sphere
Where meteorites come from
Orbits affected by Jupiter

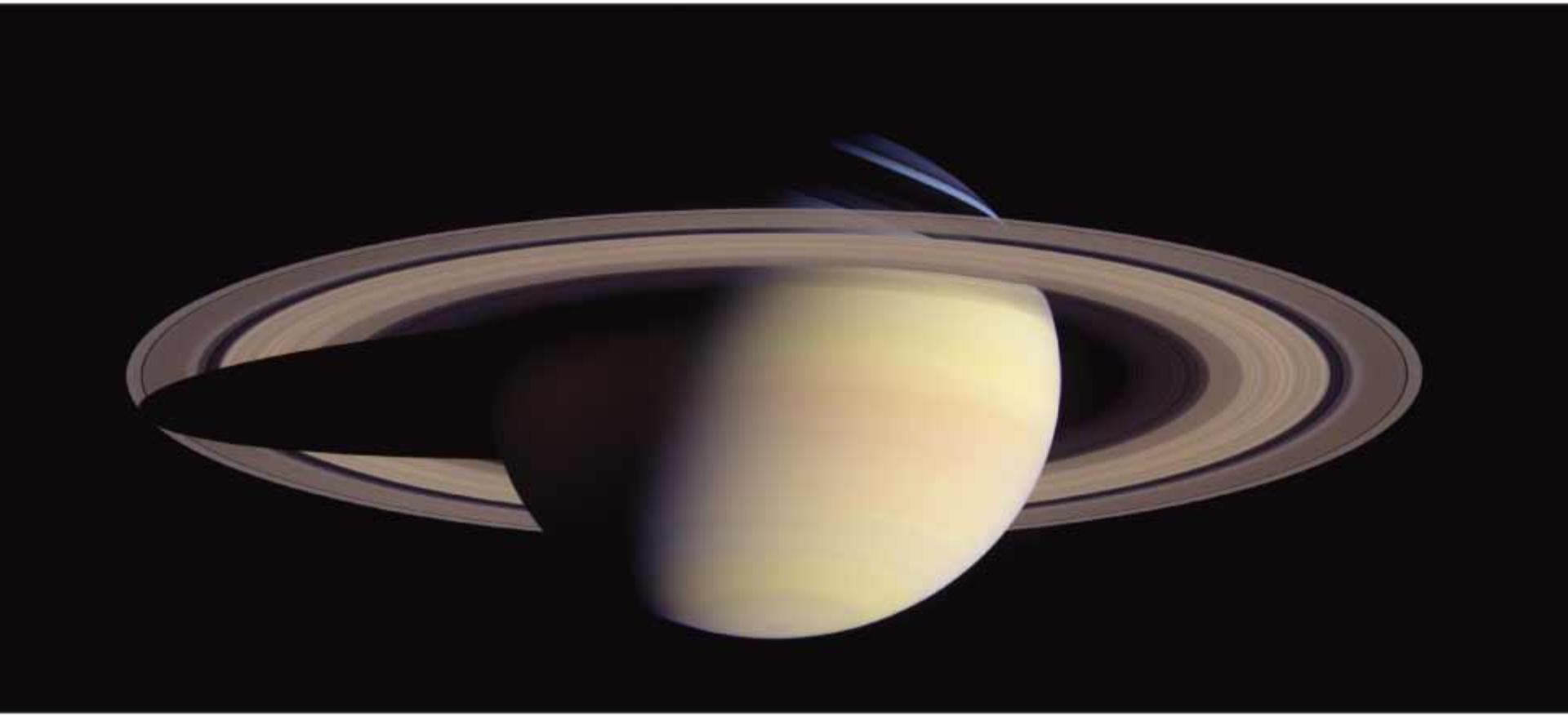






These four large moons were discovered by Galileo – the Galilean satellites
~2000 km radius
Ice/rock composition

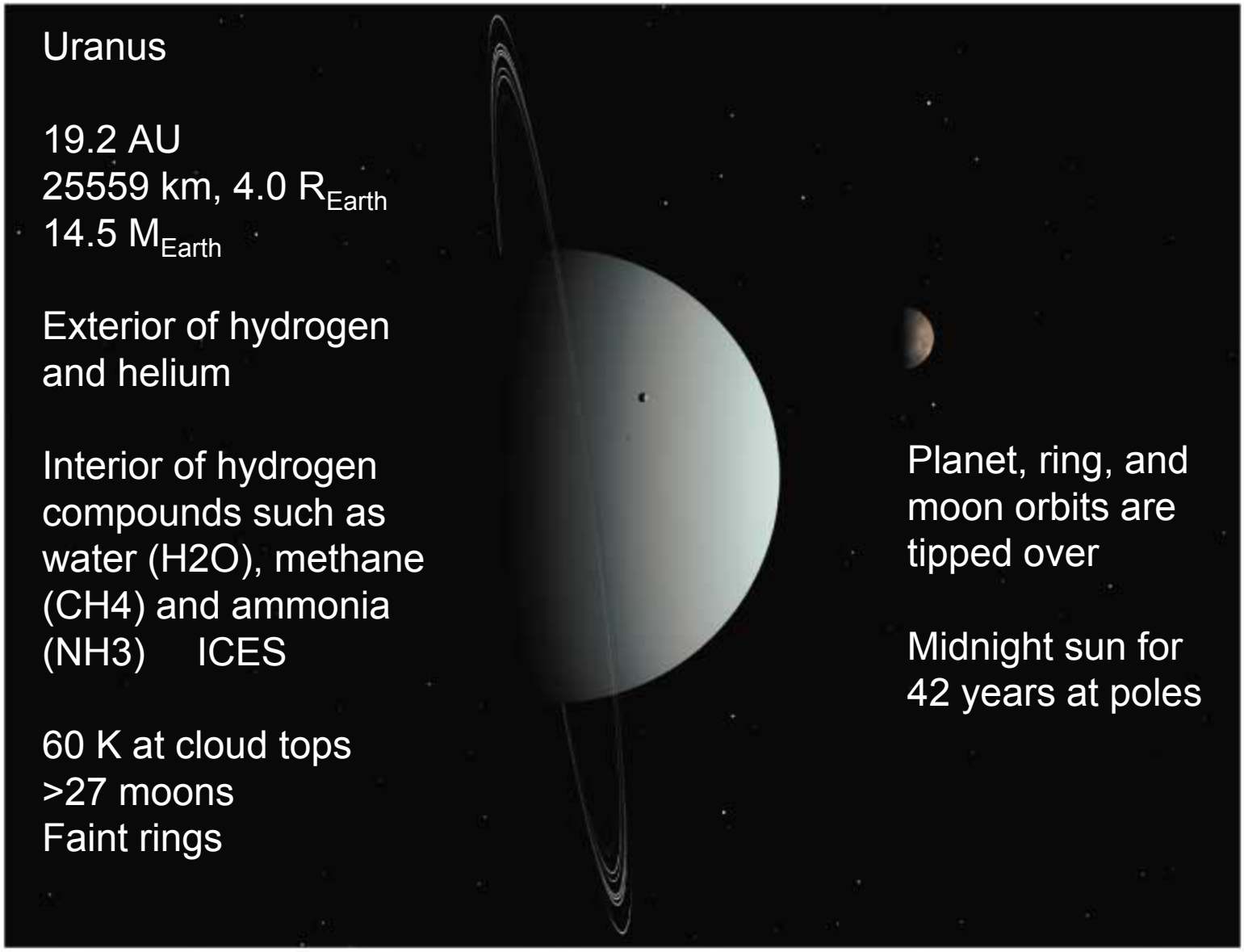
Io has active volcanoes
Europa is covered in an ice shell with a liquid water ocean below
They are worlds in their own right

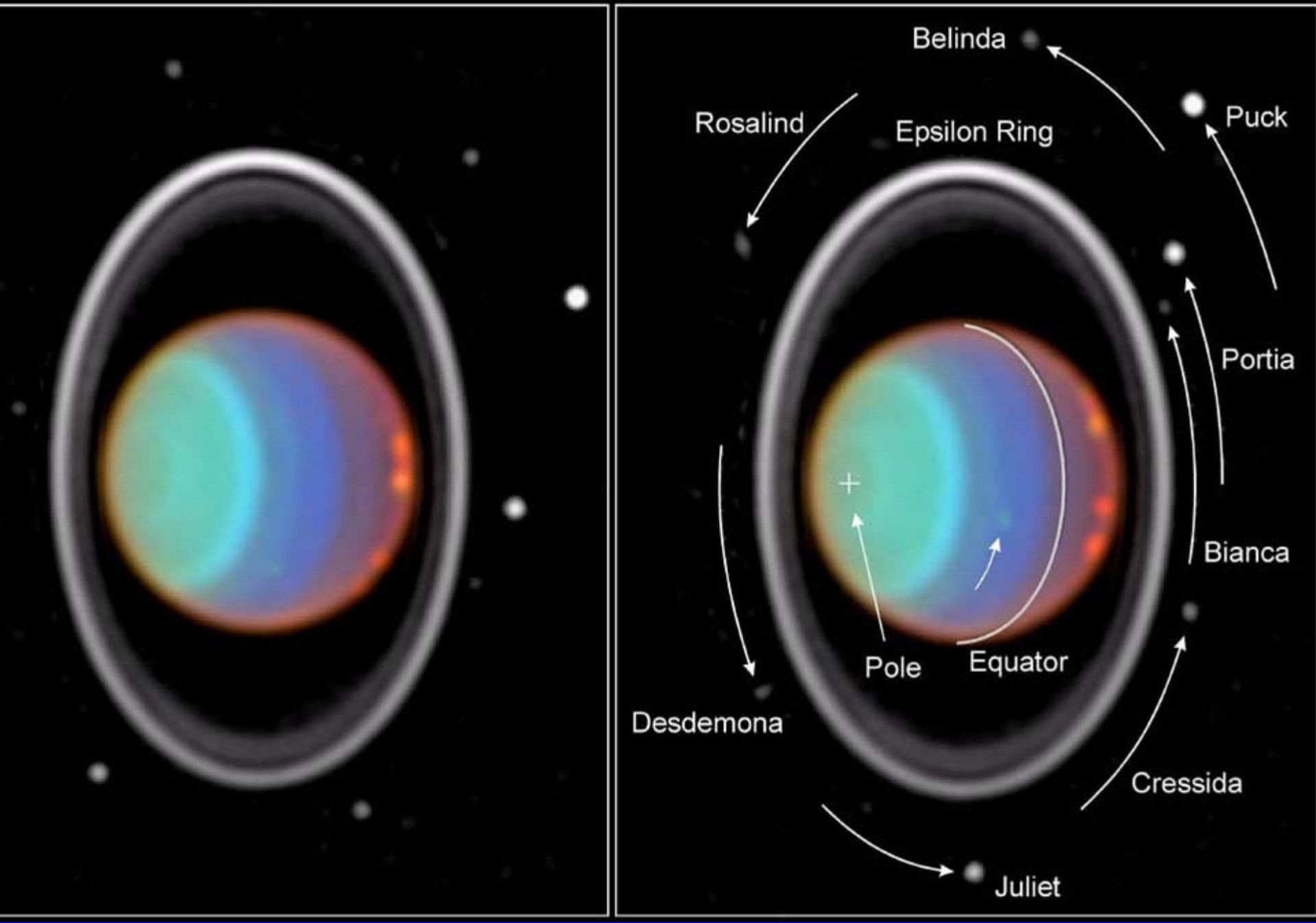


Saturn

9.54 AU
60268 km, 9.4 R_{Earth}
95.2 M_{Earth}
Hydrogen and helium

95 K at cloud tops
> 47 moons
Bright rings
Less dense than water




Belinda
Rosalind
Epsilon Ring
Puck
Portia
Bianca
Pole
Equator
Desdemona
Cressida
Juliet

Neptune

30.1 AU
24764 km, 3.9 R_{Earth}
17.1 M_{Earth}

Similar composition
to Uranus

60K at cloud tops
>13 moons
Faint rings

Its largest moon, Triton,
orbits “backwards”
around Neptune

Pluto and its largest moon, Charon

39.5 AU
Very elliptical, inclined orbit
1160 km, 0.18 R_{Earth}
0.0022 M_{Earth}

40 K surface temperature
Thin atmosphere
Ice/rock composition

Charon's radius is more than half that of Pluto – a very large moon

2 tiny moons discovered in 2005

Is Pluto a planet?

Many objects similar to Pluto have similar orbits to Pluto

Kuiper Belt Objects

These planets have rings

- A – Venus, Jupiter, Neptune
- B – Jupiter, Uranus, Neptune
- C – Mars, Saturn, Uranus
- D – Saturn, Neptune, Pluto

These planets have more than one moon

- A – Mars, Jupiter, Pluto
- B – Mercury, Saturn, Neptune
- C – Earth, Uranus, Pluto
- D – Venus, Jupiter, Saturn

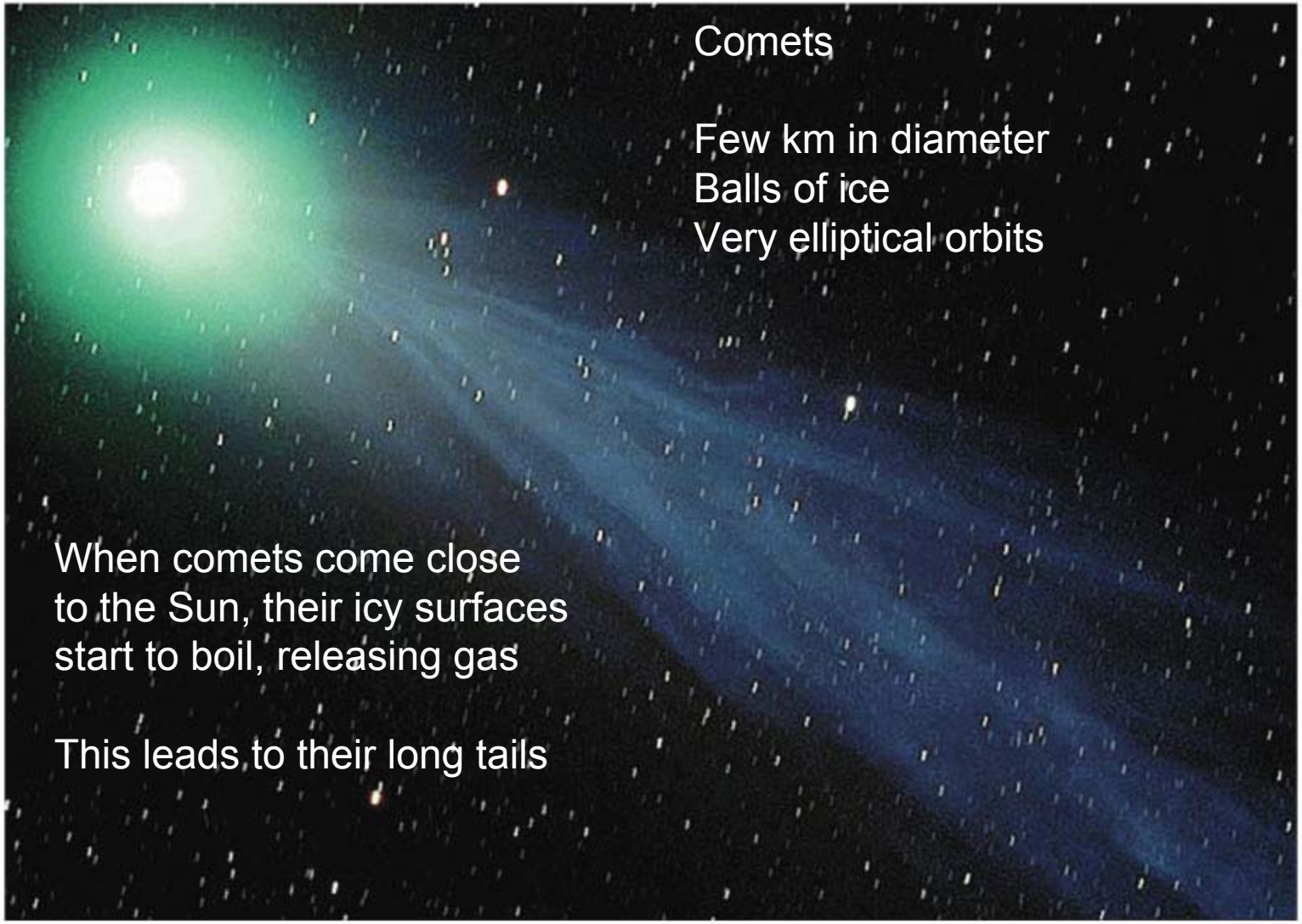
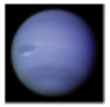


Table 7.1 Planetary Data*

Photo	Planet	Relative Size	Average Distance from Sun (AU)	Average Equatorial Radius (km)	Mass (Earth = 1)	Average Density (g/cm^3)	Orbital Period	Rotation Period	Axis Tilt	Average Surface (or Cloud Tops) Temperature†	Composition	Known Moons (2005)	Rings?
	Mercury		0.387	2,440	0.055	5.43	87.9 days	58.6 days	0.0°	700 K (day) 100 K (night)	Rocks, metals	0	No
	Venus		0.723	6,051	0.82	5.24	225 days	243 days	177.3°	740 K	Rocks, metals	0	No
	Earth		1.00	6,378	1.00	5.52	1.00 year	23.93 hours	23.5°	290 K	Rocks, metals	1	No
	Mars		1.52	3,397	0.11	3.93	1.88 years	24.6 hours	25.2°	220 K	Rocks, metals	2	No
	Jupiter		5.20	71,492	318	1.33	11.9 years	9.93 hours	3.1°	125 K	H, He, hydrogen compounds§	63	Yes
	Saturn		9.54	60,268	95.2	0.70	29.4 years	10.6 hours	26.7°	95 K	H, He, hydrogen compounds§	47	Yes
	Uranus		19.2	25,559	14.5	1.32	83.8 years	17.2 hours	97.9°	60 K	H, He, hydrogen compounds§	27	Yes
	Neptune		30.1	24,764	17.1	1.64	165 years	16.1 hours	29.6°	60 K	H, He, hydrogen compounds§	13	Yes
	Pluto		39.5	1,160	0.0022	2.0	248 years	6.39 days	112.5°	40 K	Ices, rock	1	No
	Planet X‡		67.9	1,430	?	?	560 years	?	?	?	Ices, rock	1	?

*Appendix E gives a more complete list of planetary properties. †Surface temperatures for all objects except Jupiter, Saturn, Uranus, and Neptune, for which cloud-top temperatures are listed. §Includes water (H_2O), methane (CH_4), and ammonia (NH_3). ‡Little is known about this newly-discovered object, formally known as UB313.

Summary from textbook

List as many differences as you can between the inner planets (such as Earth) and the outer planets (such as Jupiter)

Table 7.2 Comparison of Terrestrial and Jovian Planets

Terrestrial Planets	*Jovian Planets*
Smaller size and mass	Larger size and mass
Higher density	Lower density
Made mostly of rock and metal	Made mostly of hydrogen, helium, and hydrogen compounds
Solid surface	No solid surface
Few (if any) moons and no rings	Rings and many moons
Closer to the Sun (and closer together), with warmer surfaces	Farther from the Sun (and farther apart), with cool temperatures at cloud tops

Patterns in the Solar System

- Patterns of motion (orbits and rotations)
- Two types of planets: Small, rocky inner planets and large, gas outer planets
- Many small asteroids and comets whose orbits and compositions are similar
- Exceptions to these patterns, such as Earth's large moon and Uranus's sideways tilt

Patterns of Motion

- All planetary orbits are nearly circular
- All planets orbit the Sun in the same direction: counter-clockwise as viewed from high above Earth's North Pole
- Most planets rotate in the same direction in which they orbit (counter-clockwise from above North Pole) with small axis tilts. The Sun also rotates in this direction
- Most large moons exhibit similar properties in their orbits/rotations

Two Types of Planets

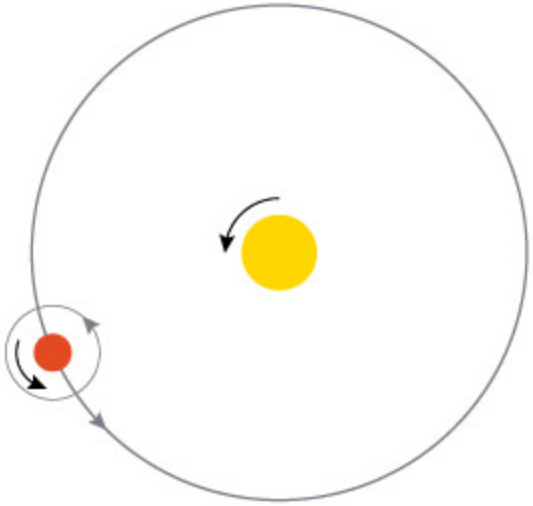
- Terrestrial planets (Mercury, Venus, Earth, Mars)
  - Small, dense, rocky exteriors, iron interiors
  - Few moons, no rings
- Jovian planets (Jupiter, Saturn, Uranus, Neptune)
  - Large, less dense, hydrogen/helium composition. Uranus and Neptune also contain lots of hydrogen compounds
  - Many moons, rings
- Pluto doesn't fit either category

Asteroids and Comets

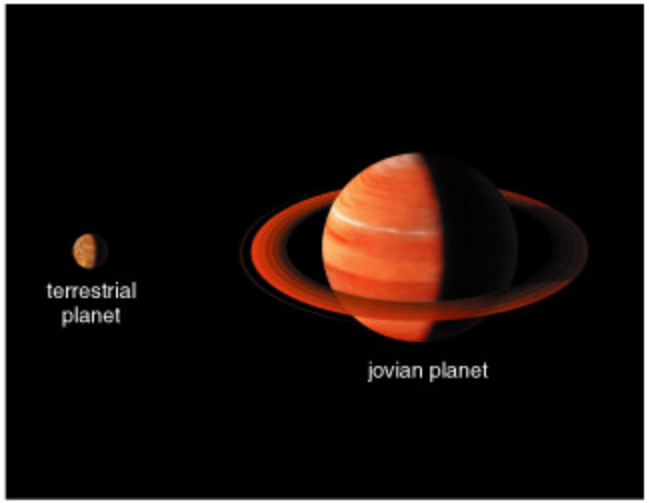
- Asteroids are small, rocky bodies that orbit the Sun. Most are found in the asteroid belt between Mars and Jupiter. There are many asteroids.
- Comets are small, icy bodies that orbit the Sun. Comets have very elliptical orbits, only becoming visible when they form tails in the inner solar system. There are many comets.

Exceptions

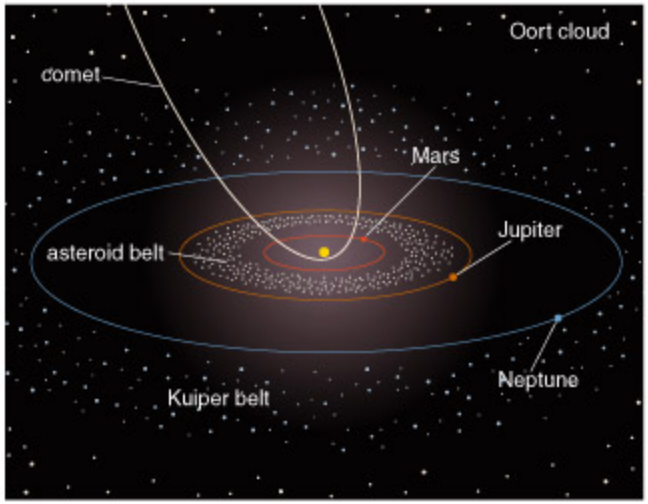
- Uranus is tilted sideways
- Earth's Moon is very large
- Venus rotates backwards
- Small moons often have backwards or inclined orbits
- Pluto isn't a terrestrial or jovian planet



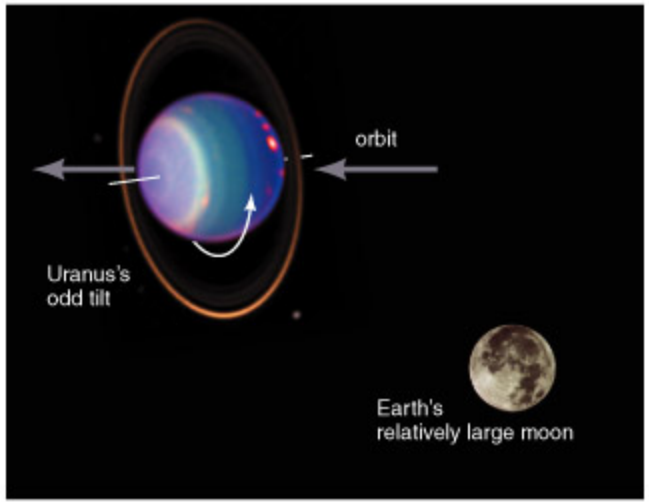
1. Large bodies in the solar system have orderly motions. All planets and most satellites have nearly circular orbits going in the same direction in nearly the same plane. The Sun and most of the planets rotate in this same direction as well.



2. The first eight planets fall into two major categories: small, rocky terrestrial planets near the Sun and large, hydrogen-rich jovian planets farther out. The jovian planets have many moons and rings made of rock and ice.



3. Swarms of asteroids and comets populate the solar system. Asteroids are concentrated in the asteroid belt, and comets populate the regions known as the Kuiper belt and the Oort cloud.



4. Several notable exceptions to these general trends stand out, such as planets with unusual axis tilts or surprisingly large moons, and moons with unusual orbits.

These four characteristics must be explained by any theory that claims to describe how the solar system was formed

Calculation Exercise

- What equation relates radius and volume for a sphere?
- Earth radius = 6.4×10^3 km = 6.4×10^6 m
- What is Earth's volume?
- Jupiter radius = 7.1×10^4 km = 7.1×10^7 m
- What is Jupiter's volume?
- How many times larger is Jupiter's radius than Earth's?
- How many times larger is Jupiter's volume than Earth's?

Calculation Exercise

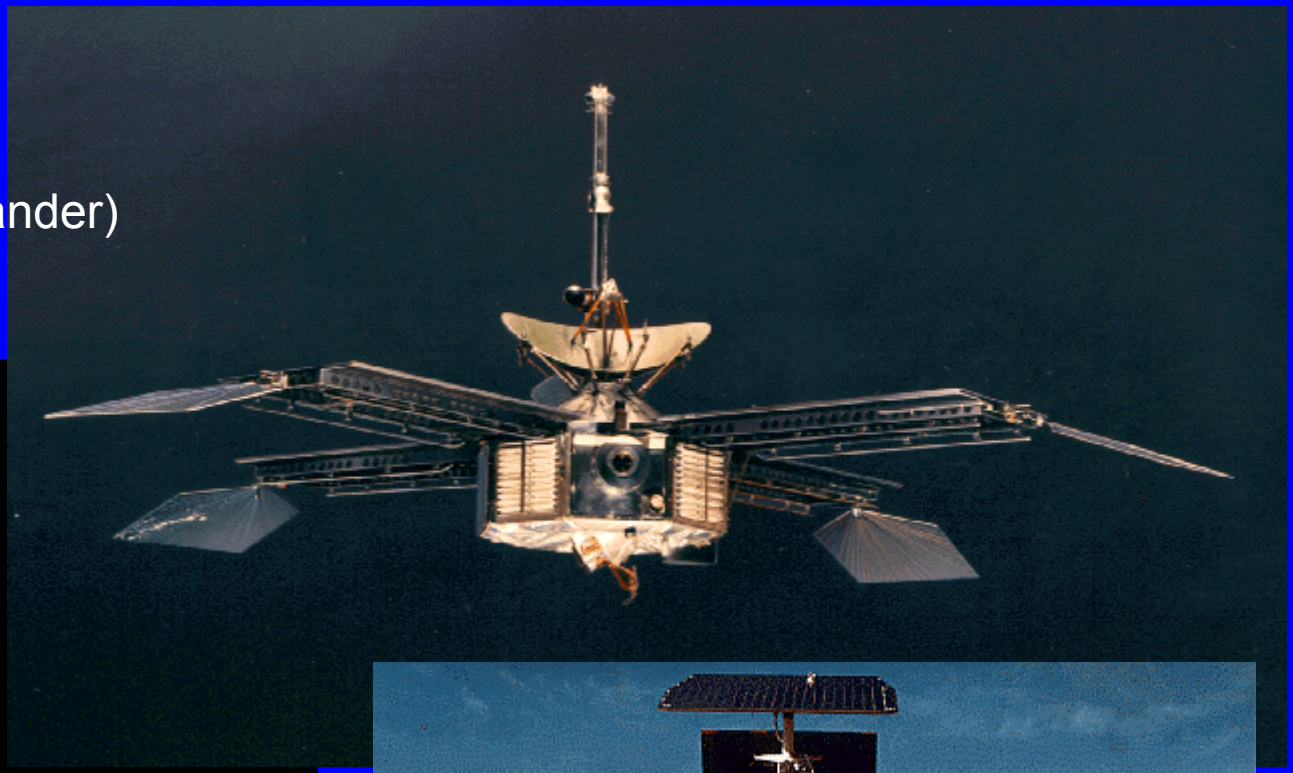
- Earth's volume = 1.1×10^{21} m^3
- Earth's density = 5.5×10^3 kg/m^3
- What is Earth's mass?
- Jupiter's volume = 1.5×10^{24} m^3
- Jupiter's density = 1.3×10^3 kg/m^3
- What is Jupiter's mass?
- How many times larger is Jupiter's mass than Earth's?

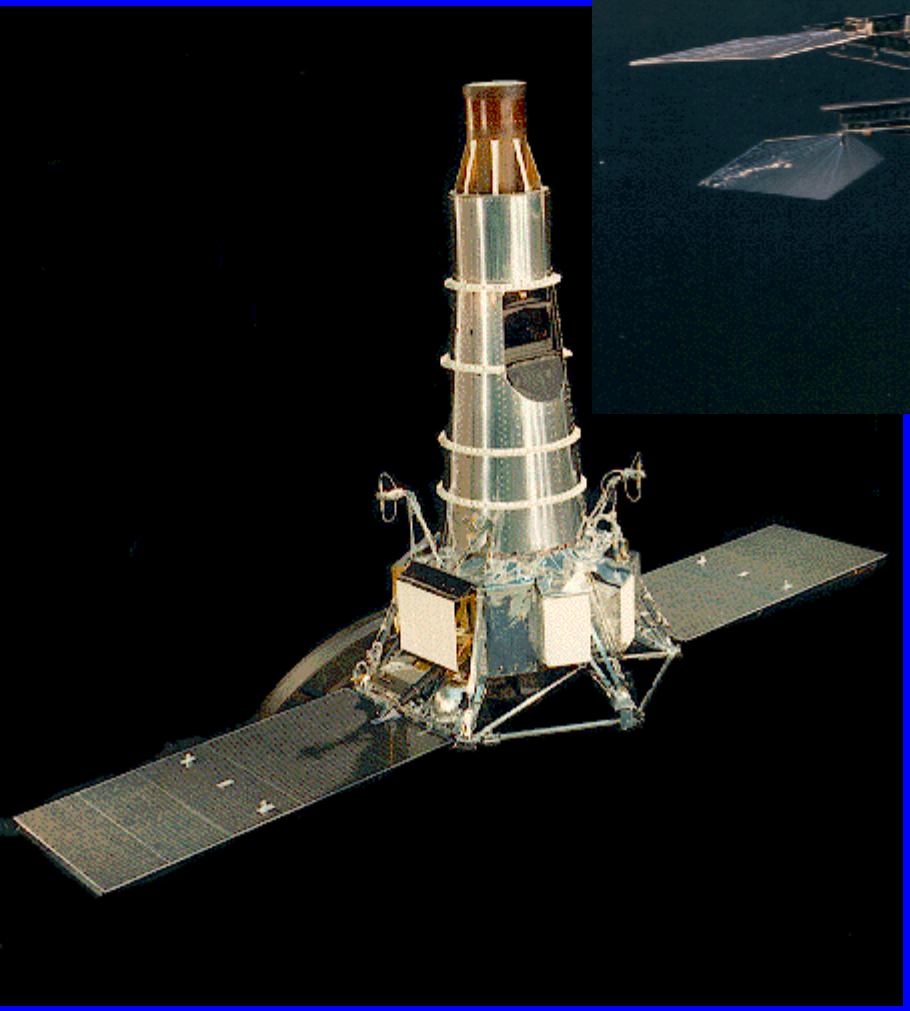
Spacecraft Exploration

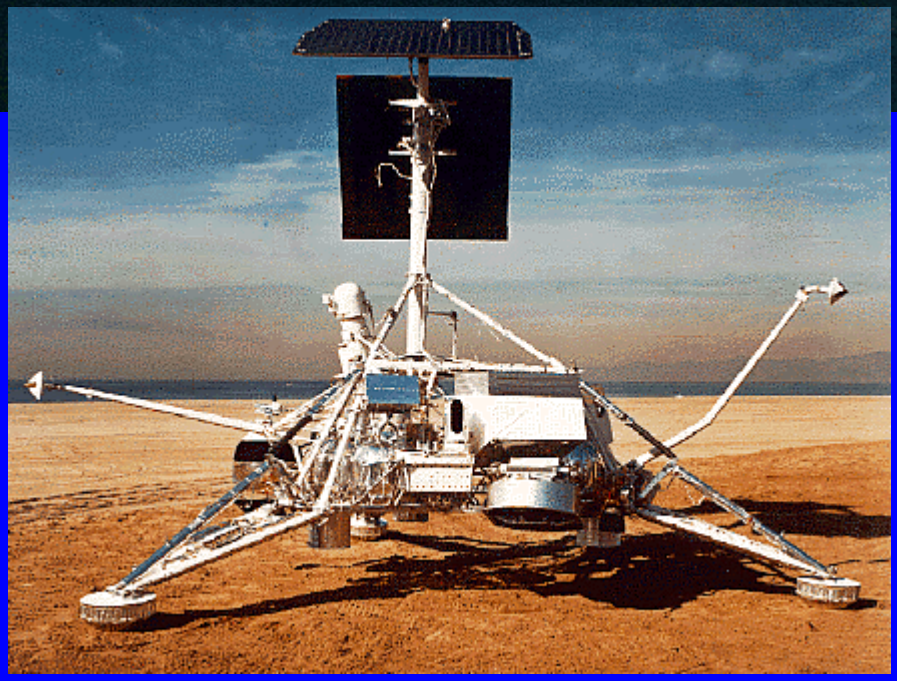
- Telescopes have limits
- What are some of the advantages of spacecraft?

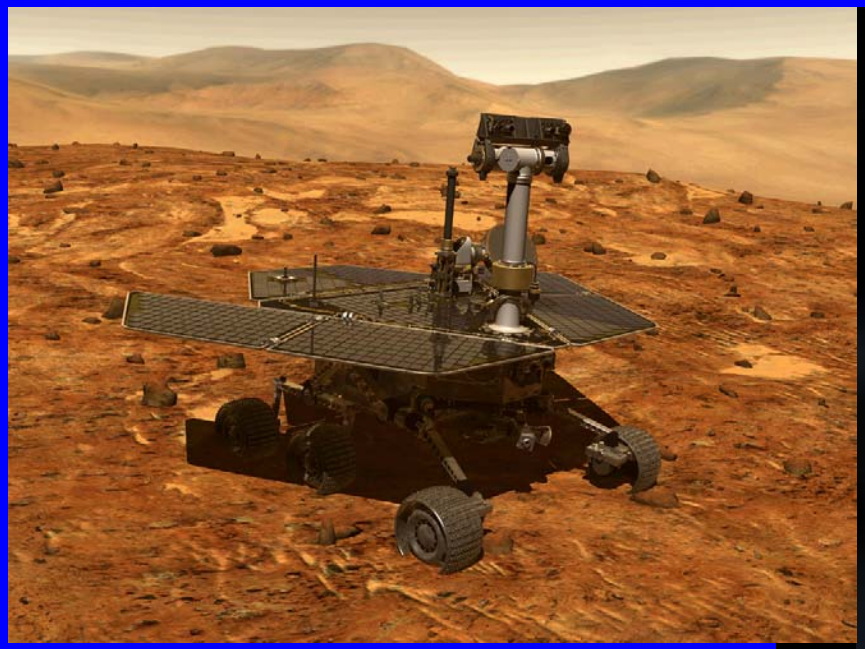
1960s spacecraft

Mariner 4 (Mars flyby)
Lunar Surveyor (Moon lander)
Ranger (Moon impactor)



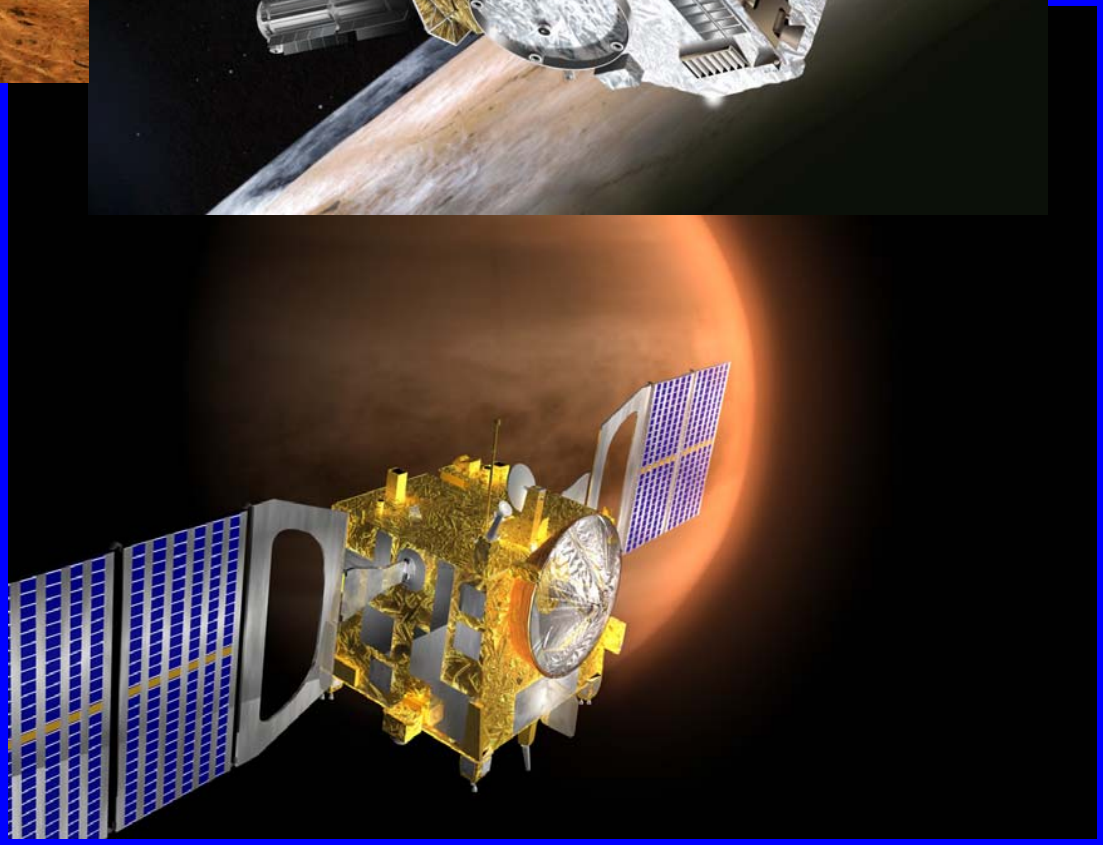






2000s spacecraft

Spirit (Mars rover)
New Horizons (Pluto flyby)
Venus Express (Venus orbiter)



Advantages of Spacecraft

- Better resolution for cameras (all wavelengths) as closer to planet
- Sometimes you just have to be there to make a measurement – there are no “telescopic rock hardness testers”
- Process a sample with a chemistry set
- Active experiments – hit something and see how it responds

Types of Spacecraft

- Flyby – Go past a planet once only
- Orbiter – Orbit a planet, repeated studies
- Lander/Probe/Rover – Touch a planet's surface/atmosphere, localized studies
- Sample return – Bring a piece back to Earth
- Human missions – Have astronauts making decisions, not a computer

Goals for Learning

- How do planets rotate on their axes and orbit the Sun?
- What are the planets made of?
- What other classes of objects are there in the solar system?

Goals for Learning

- How do planets rotate on their axes and orbit the Sun?
  - The planets orbit the Sun in the same plane and same direction
  - The rotational axes of most planets are almost perpendicular to their orbital planes
  - The rotations and orbits of many large moons behave similarly

Goals for Learning

- What are the planets made of?
  - 4 small, inner, solid planets made of metal cores and rock mantles
  - 4 large, outer, gas planets made of hydrogen outer layers and cores of rock and ice

Goals for Learning

- What other classes of objects are there in the solar system?
  - Moons: Rocky satellites of terrestrial planets, few in number, and ice satellites of jovian planets, many in number
  - Asteroids: Small rock bodies that orbit the Sun, mostly between Mars and Jupiter
  - Comets: small ice bodies that orbit the Sun, mostly in very elliptical orbits

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