

OUR SOLAR SYSTEM

Chapter

23

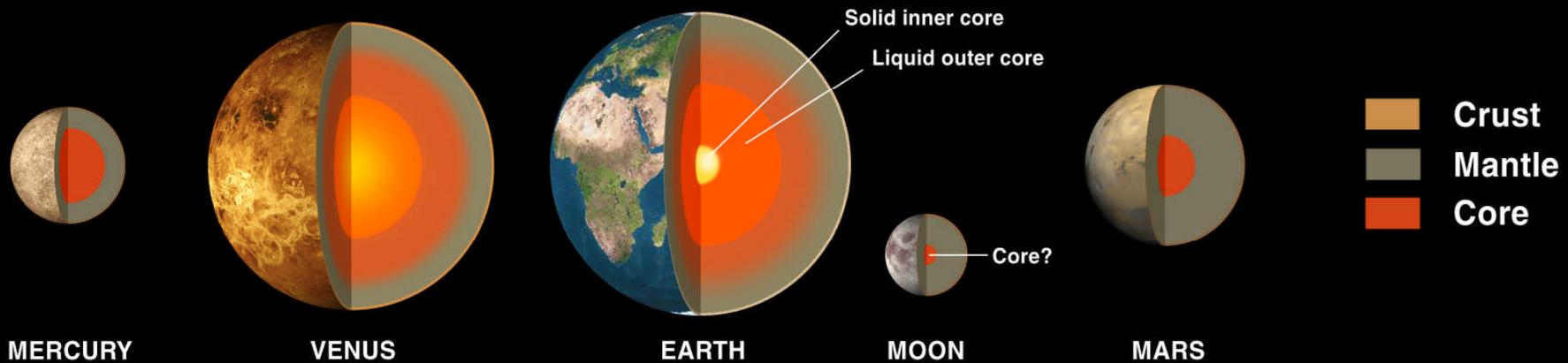




23.1 The Solar System

The Planets: An Overview

- ◆ The terrestrial planets are planets that are small and rocky—Mercury, Venus, Earth, and Mars.

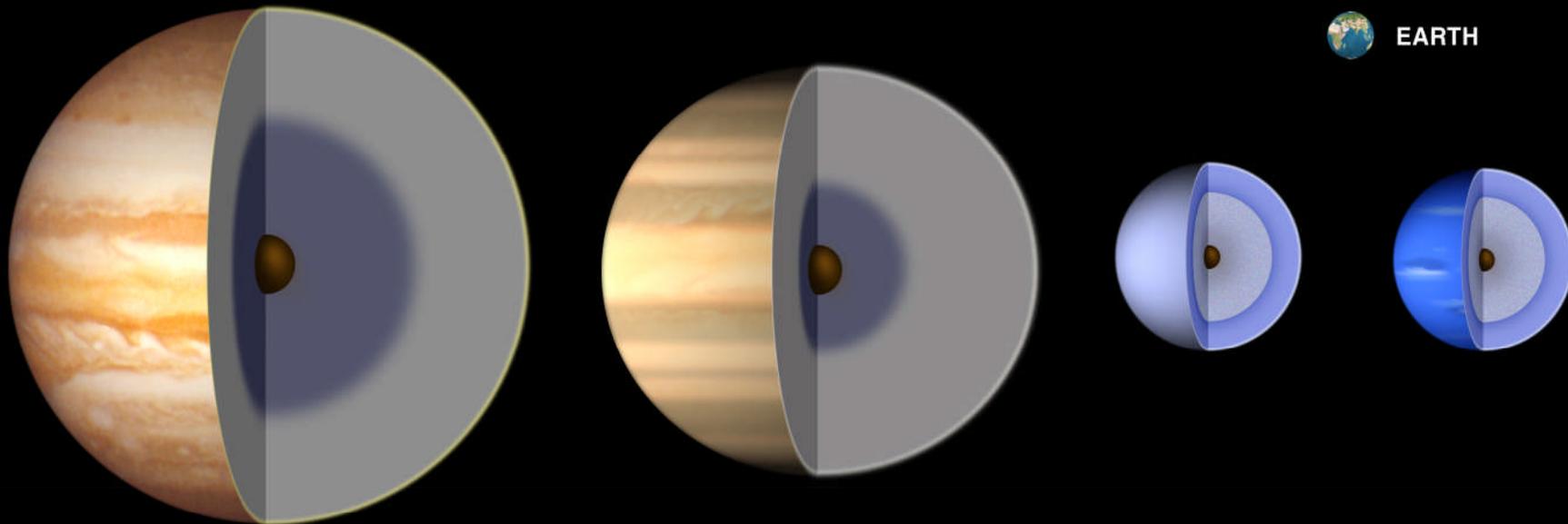


23.1 The Solar System

The Planets: An Overview

- ◆ **The Jovian planets are the huge gas giants—Jupiter, Saturn, Uranus, and Neptune.**

Jovian planets



JUPITER

SATURN

URANUS

NEPTUNE

EARTH

■ Molecular hydrogen

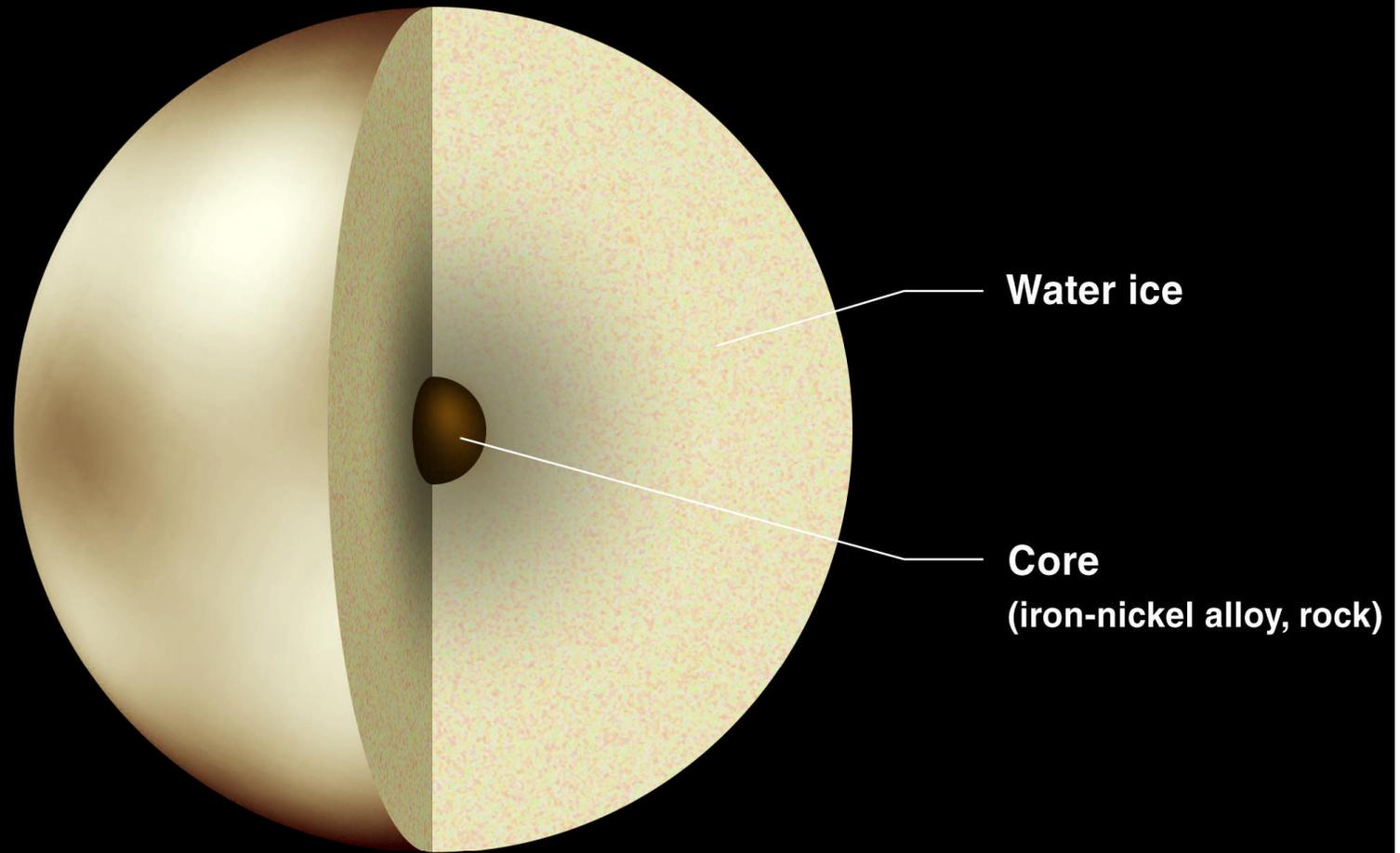
■ Metallic hydrogen

■ Hydrogen, helium, methane gas

■ Mantle (water, ammonia, methane ices)

■ Core (rock, ice)

23.1



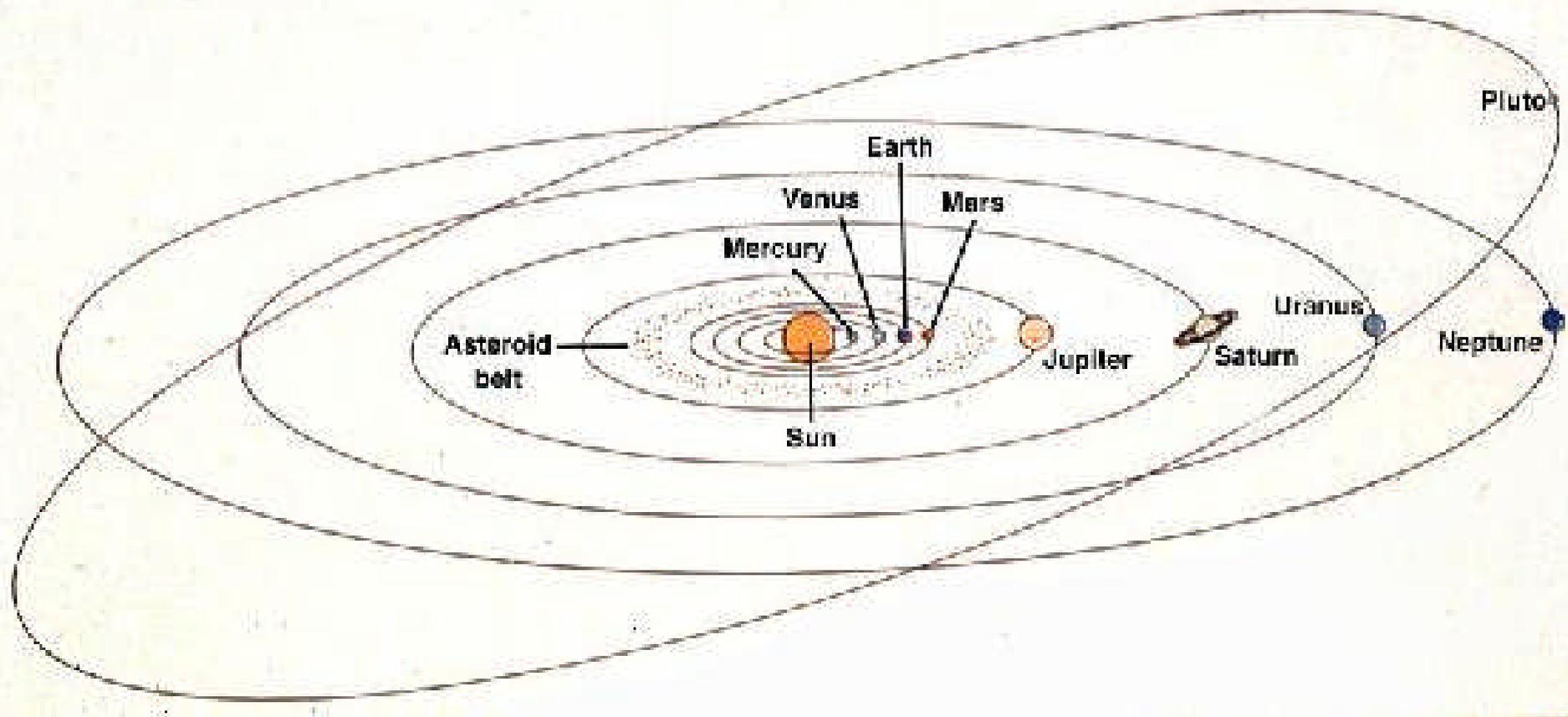
PLUTO

- ◆ Pluto does not fit into either the Jovian or the terrestrial category.

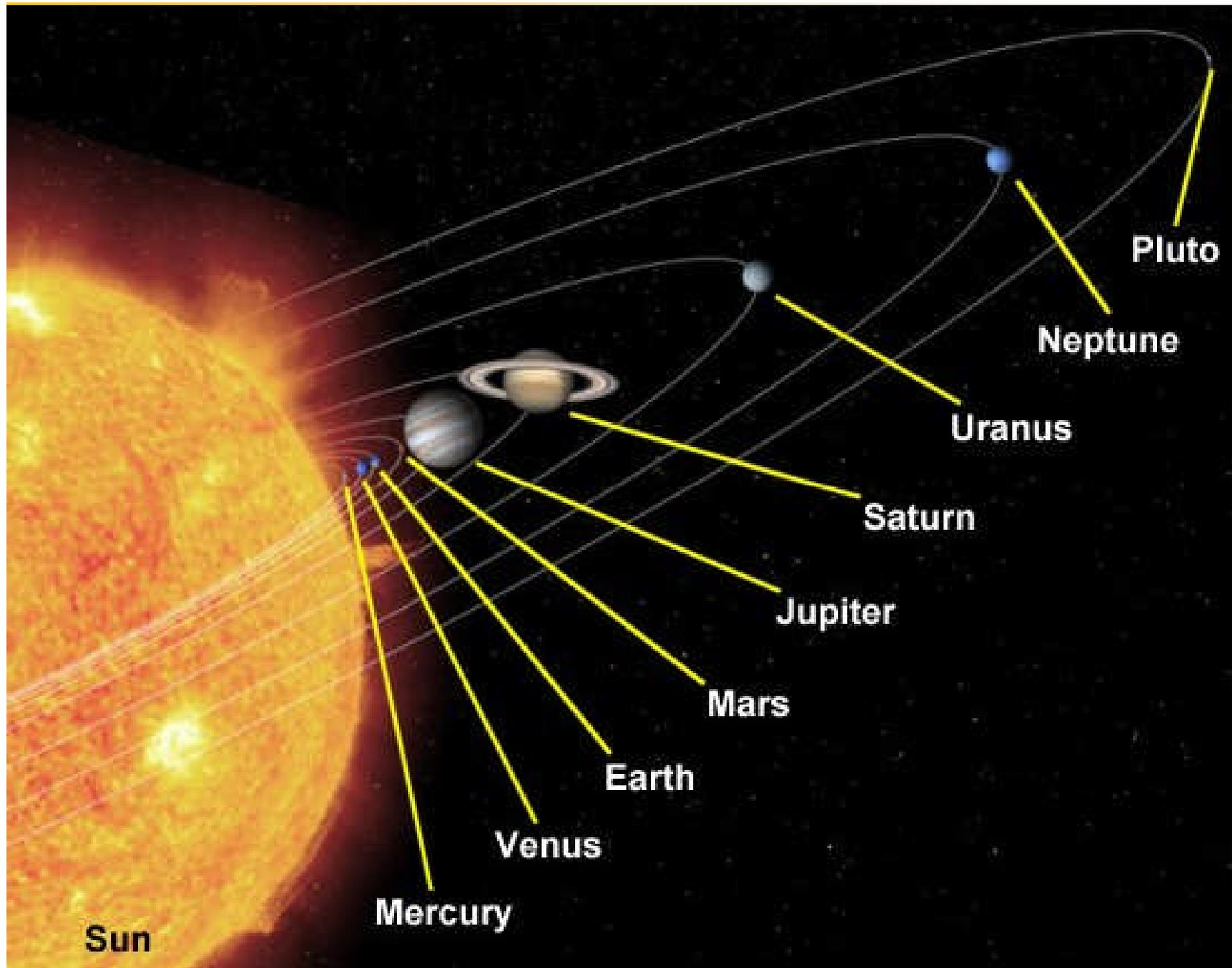
Note:

Pluto used to be known as the furthest planet from the Sun. It has now been reclassified by the International Astronomical Union as a dwarf planet, because although it is spherical and orbits the sun, it shares its orbit with many smaller bodies.

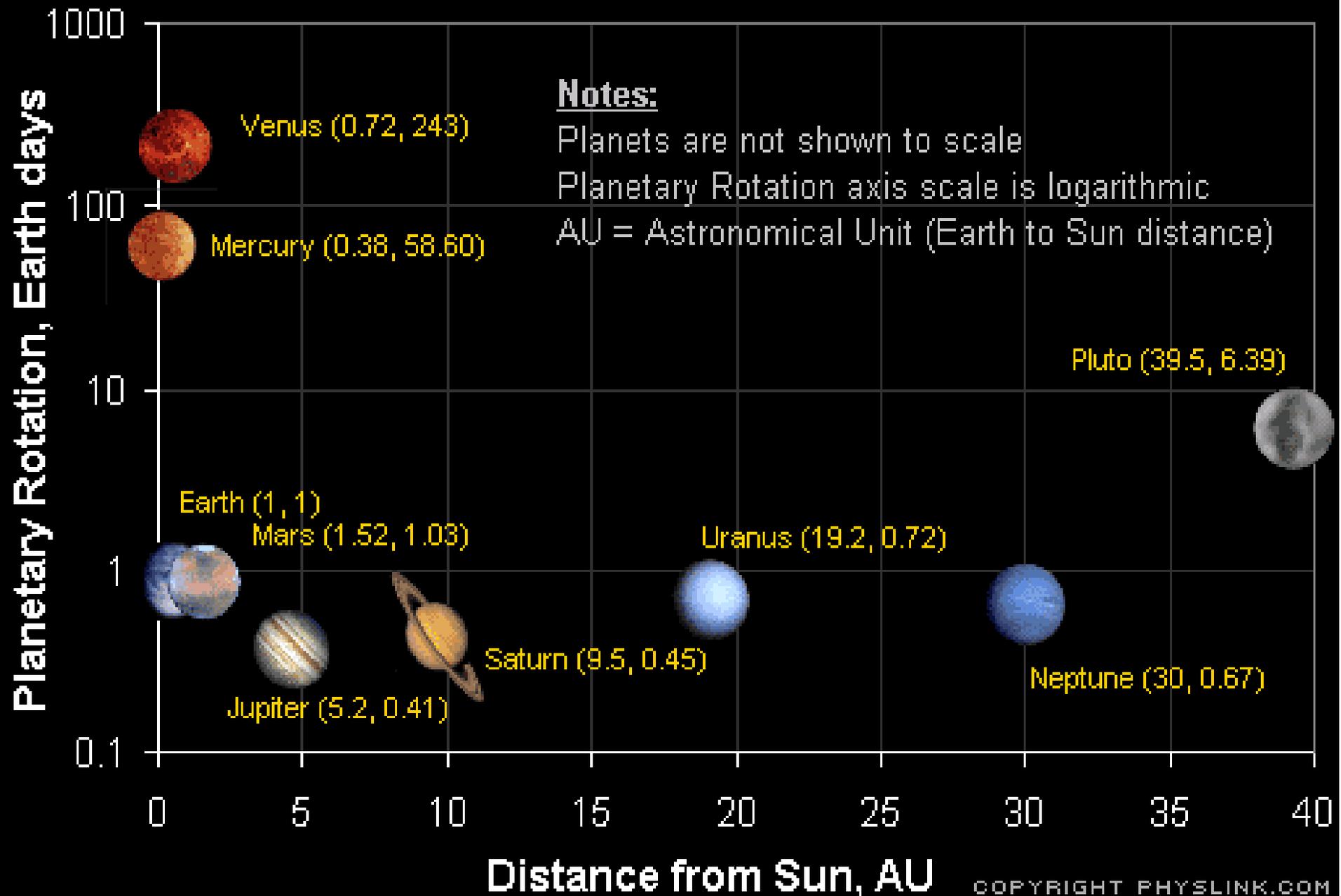
Orbits of the Planets







Planetary Rotation Periods vs Distance from the Sun



23.1 The Solar System

The Planets: An Overview

- ◆ **Size is the most obvious difference between the terrestrial and Jovian planets.**
- ◆ **Density, chemical makeup, and rate of rotation are other ways in which the two groups of planets differ.**

Planetary Data

Table 1 Planetary Data

Planet	Average Distance from Sun		Period of Revolution	Orbital Velocity km/s	Period of Rotation	Diameter (km)	Relative Mass (Earth = 1)	Average Density (g/cm ³)	Number of Known Satellites*
	AU	Millions of km							
Mercury	0.39	58	88 ^d	47.5	59 ^d	4878	0.06	5.4	0
Venus	0.72	108	225 ^d	35.0	244 ^d	12,104	0.82	5.2	0
Earth	1.00	150	365.25 ^d	29.8	23 ^h 56 ^m 04 ^s	12,756	1.00	5.5	1
Mars	1.52	228	687 ^d	24.1	24 ^h 37 ^m 23 ^s	6794	0.11	3.9	2
Jupiter	5.20	778	12 ^{yr}	13.1	9 ^h 50 ^m	143,884	317.87	1.3	63
Saturn	9.54	1427	29.5 ^{yr}	9.6	10 ^h 14 ^m	120,536	95.14	0.7	31
Uranus	19.18	2870	84 ^{yr}	6.8	17 ^h 14 ^m	51,118	14.56	1.2	25
Neptune	30.06	4497	165 ^{yr}	5.3	16 ^h 03 ^m	50,530	17.21	1.7	13
Pluto	39.44	5900	248 ^{yr}	4.7	6.4 ^d	approx. 2300	0.002	1.8	1

*Includes all satellites discovered as of March 2004.

23.1 The Solar System

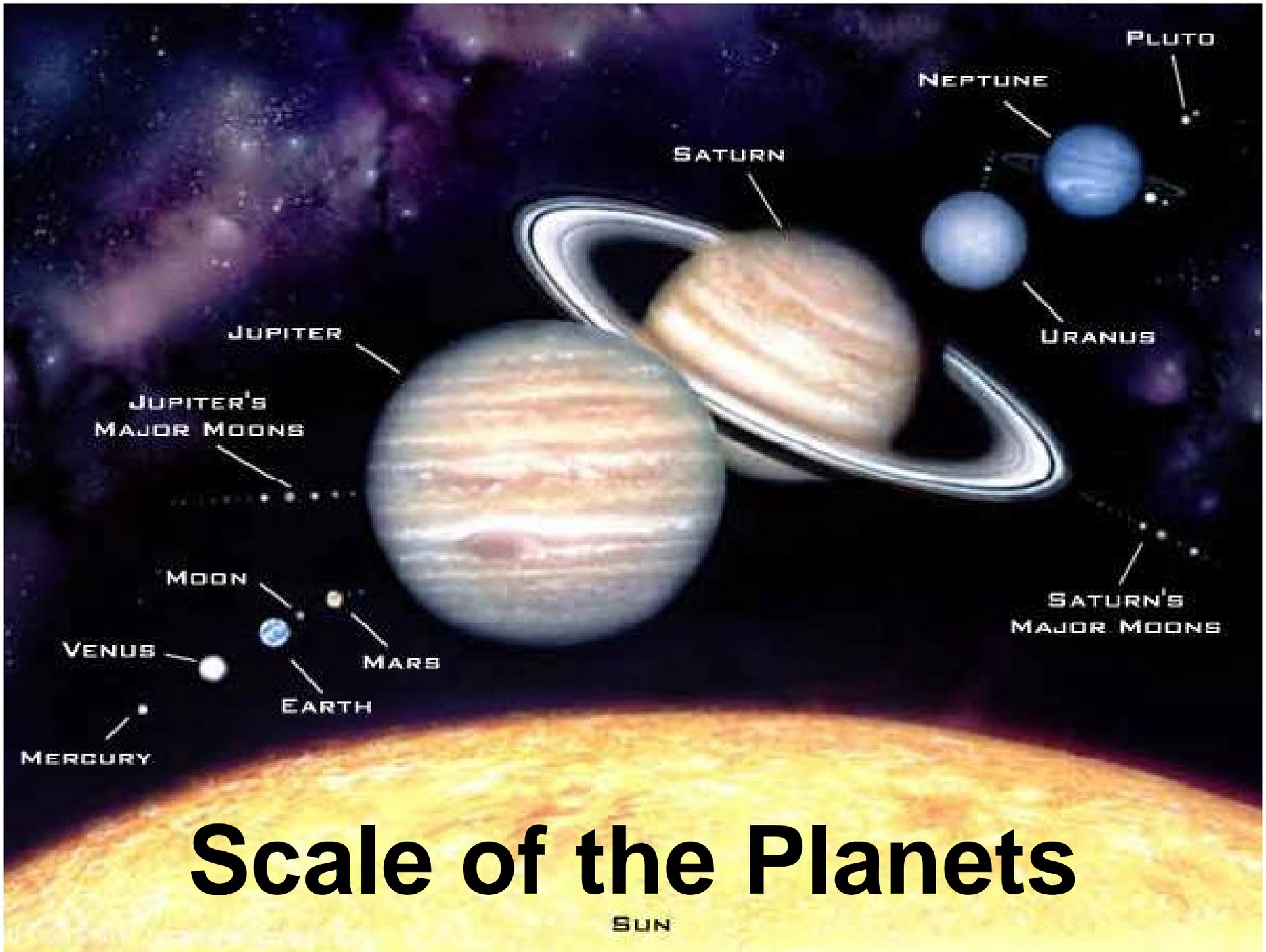
The Planets: An Overview

- ◆ **The Interiors of the Planets**
 - **The substances that make up the planets are divided into three groups: gases, rocks, and ices.**

23.1 The Solar System

The Planets: An Overview

- ◆ **The Atmosphere of the Planets**
 - **The Jovian planets have very thick atmospheres of hydrogen, helium, methane, and ammonia.**
 - **By contrast, the terrestrial planets, including Earth, have meager atmospheres at best.**



Moons of . . .

Earth



Moon

Mars

Phobos

Deimos

Jupiter



Io



Europa



Ganymede



Callisto

+ at least
24 smaller
moons

Saturn

- Mimas
- Enceladas
- Tethys
- Dione
- Rhea



Titan

- Hyperion
- Iapetus
- Phoebe

+ at least
21 smaller
moons

Uranus

- Puck
- Miranda
- Ariel
- Umbriel
- Titania
- Oberon

+ at least
15 smaller
moons

Neptune



Triton

- Nereid

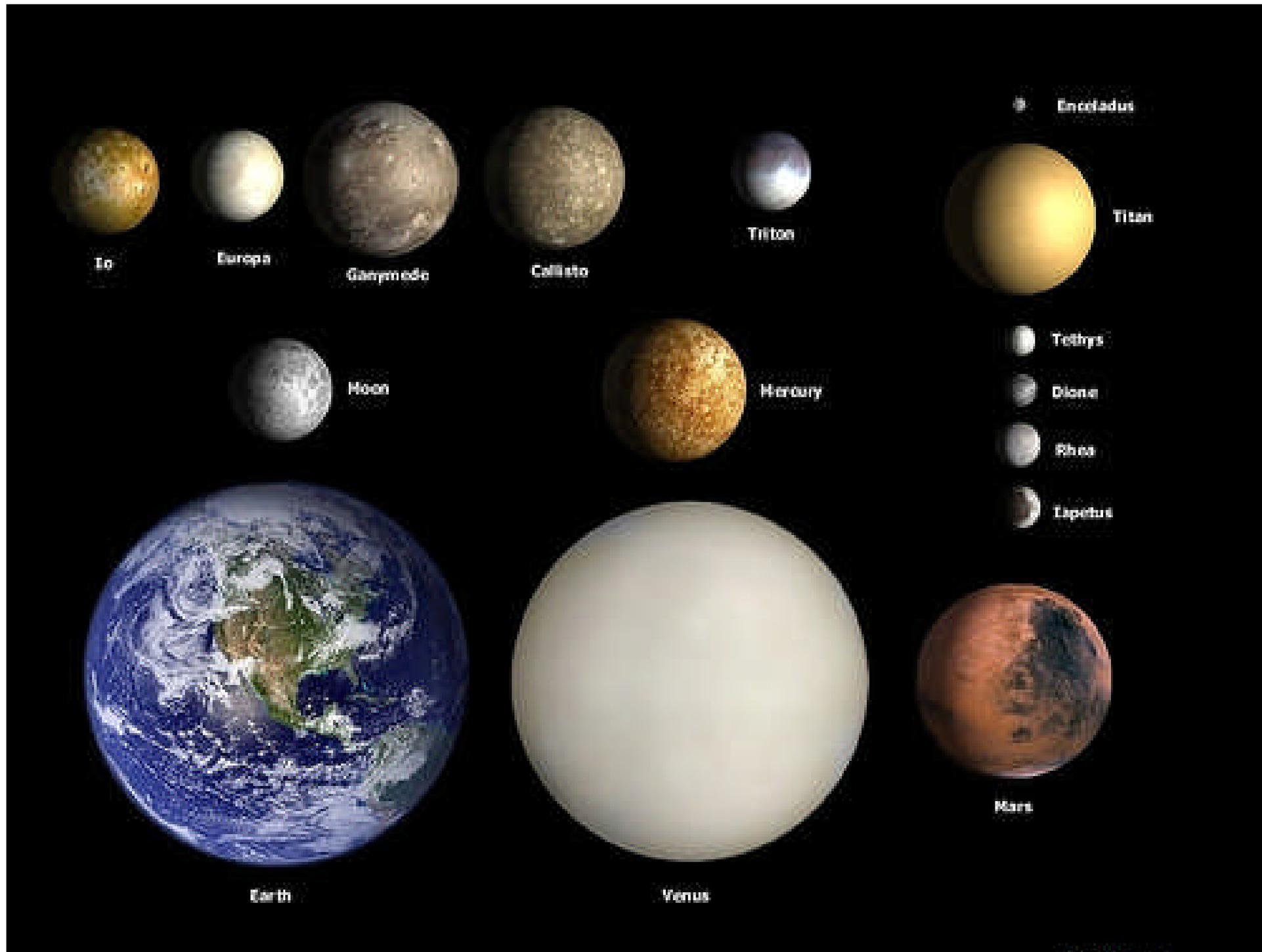
+ at least
6 smaller
moons

Pluto

- Charon

Earth





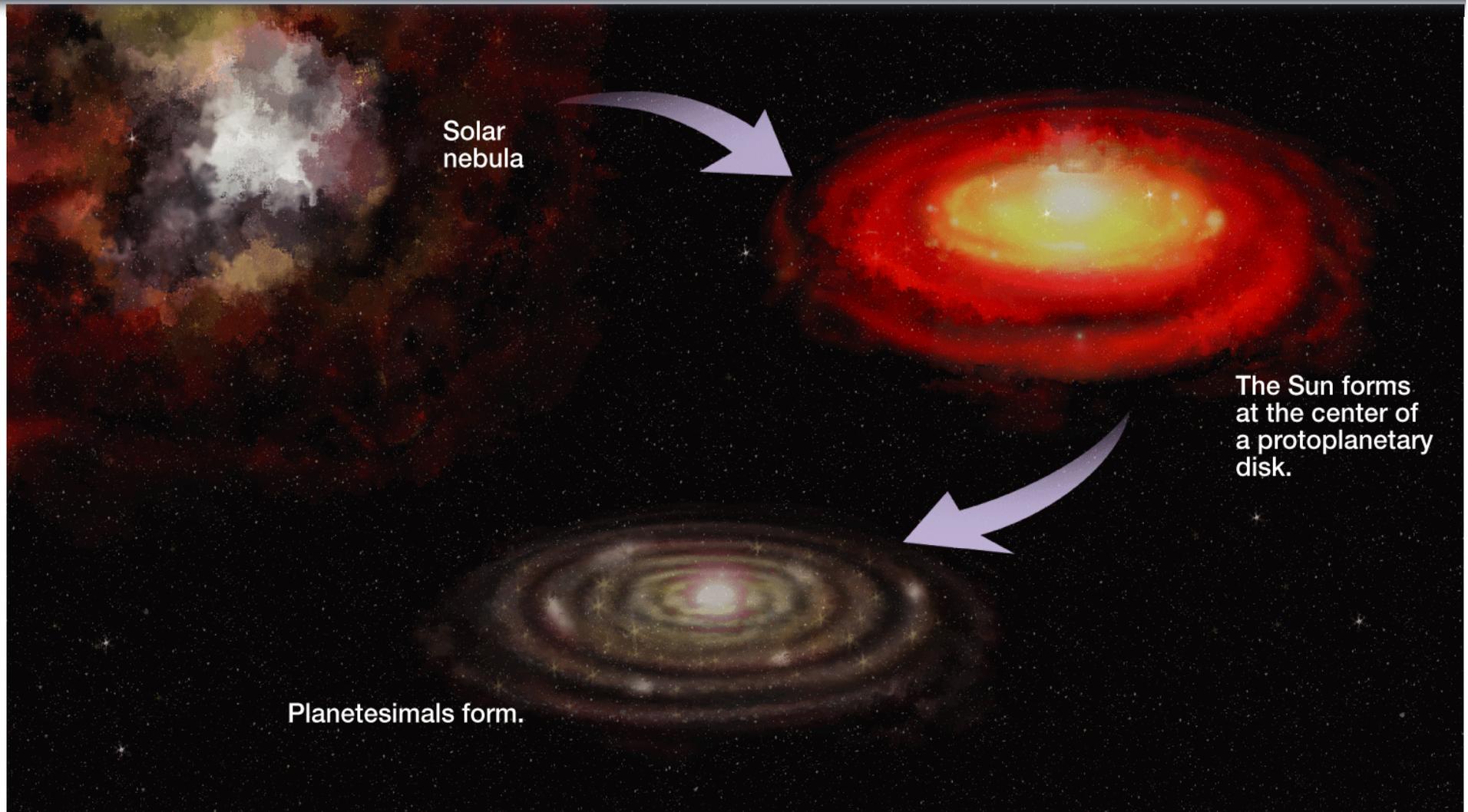
23.1 The Solar System

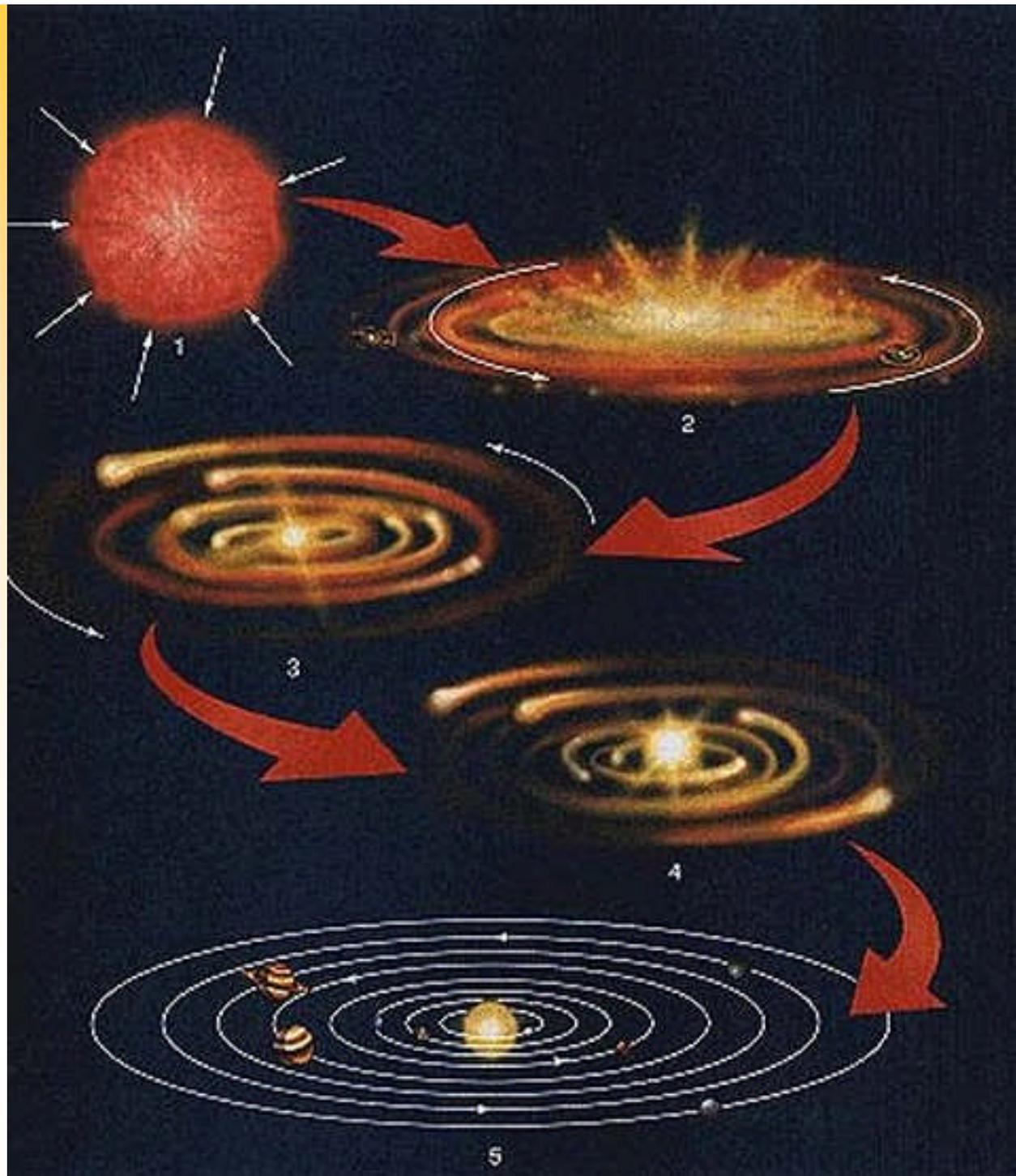
Formation of the Solar System

◆ Nebular Theory

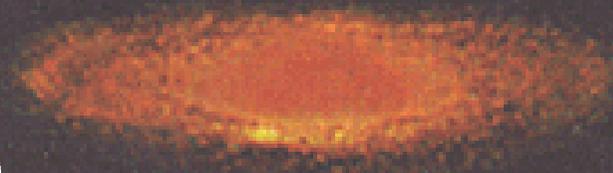
- A nebula is a cloud of gas and/or dust in space.
- According to the nebular theory, the sun and planets formed from a rotating disk of dust and gases.

Formation of the Universe

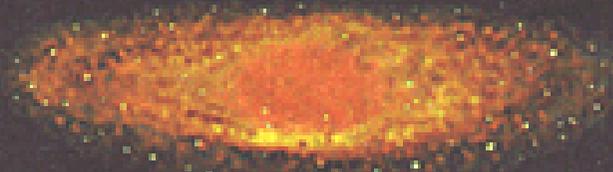




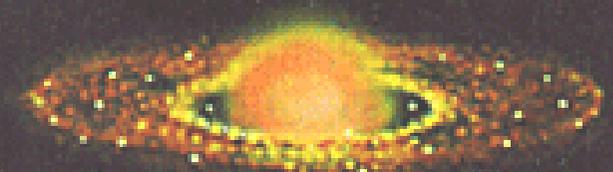
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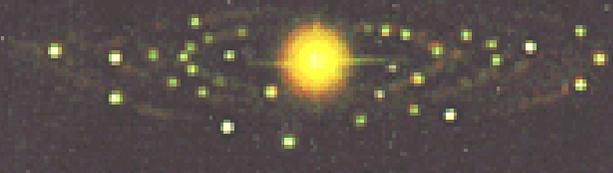
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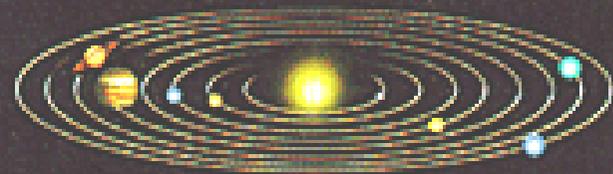
(d)



(e)



(f)



23.1 The Solar System

Formation of the Solar System

◆ Planetesimals

- **Planetesimals are small, irregularly shaped bodies formed by colliding matter.**

Disk of gas and dust
spinning around young Sun

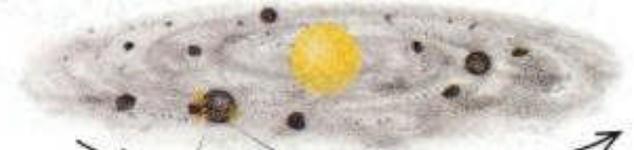


Dust grains

A



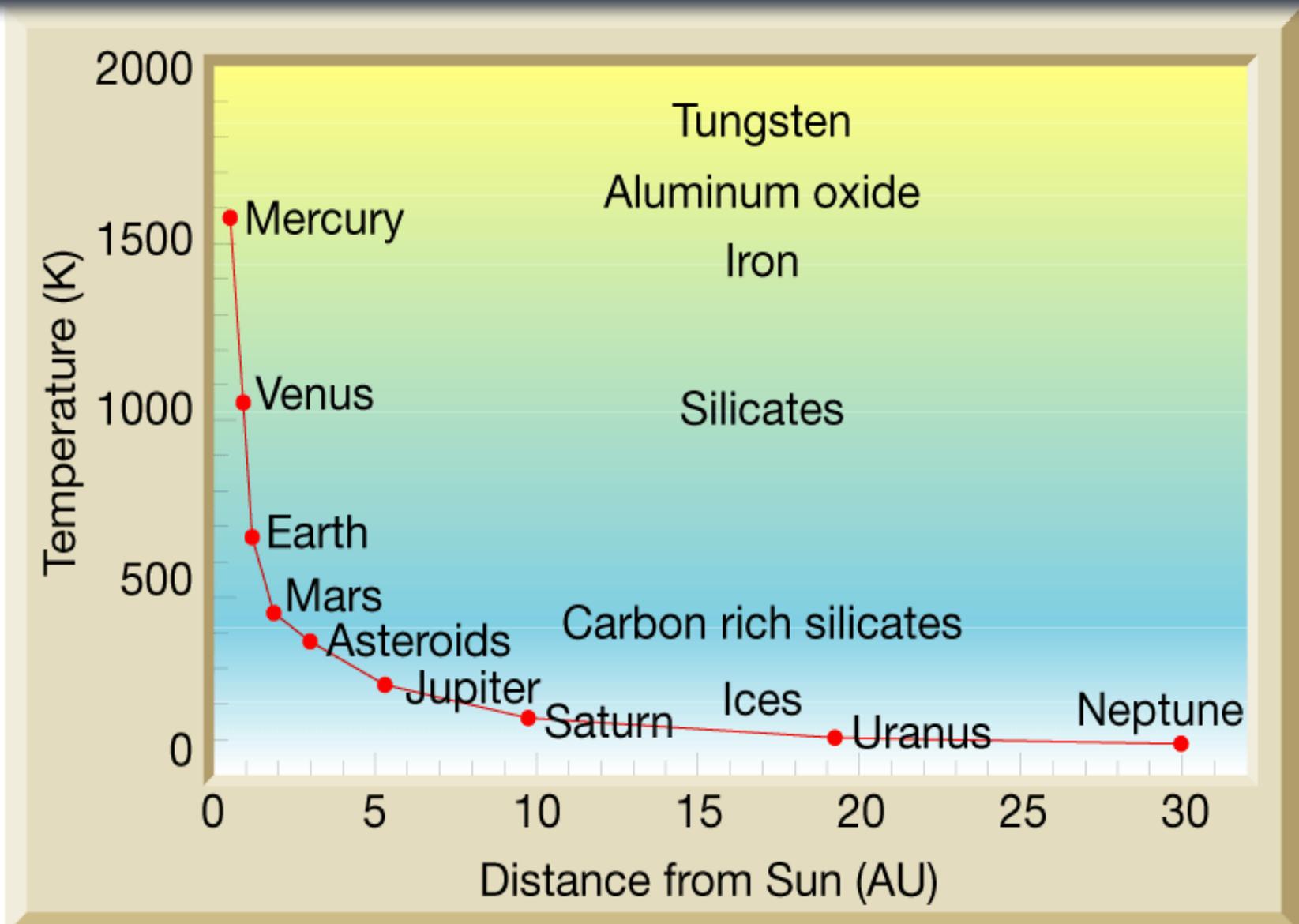
Dust grains clump
into planetesimals



Planetesimals collide
and collect into planets

B

Planetary Composition, Distance from the Sun, and Melting Point



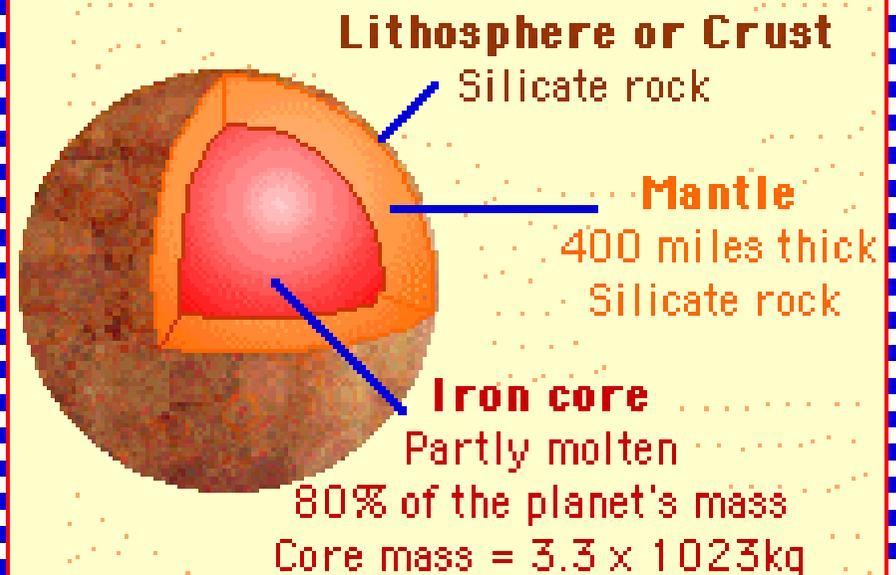


Mercury

Mercury's Surface



Inside Mercury



23.2 The Terrestrial Planets

Mercury: The Innermost Planet

- ◆ **Mercury is the innermost and second smallest planet; it is hardly larger than Earth's moon.**
- ◆ **Surface Features**
 - **Mercury has cratered highlands, much like the moon, and vast smooth terrains that resemble maria.**

23.2 The Terrestrial Planets

◆ Surface Temperatures

- **Mercury has the greatest temperature extremes of any planet.**



Venus



23.2 The Terrestrial Planets

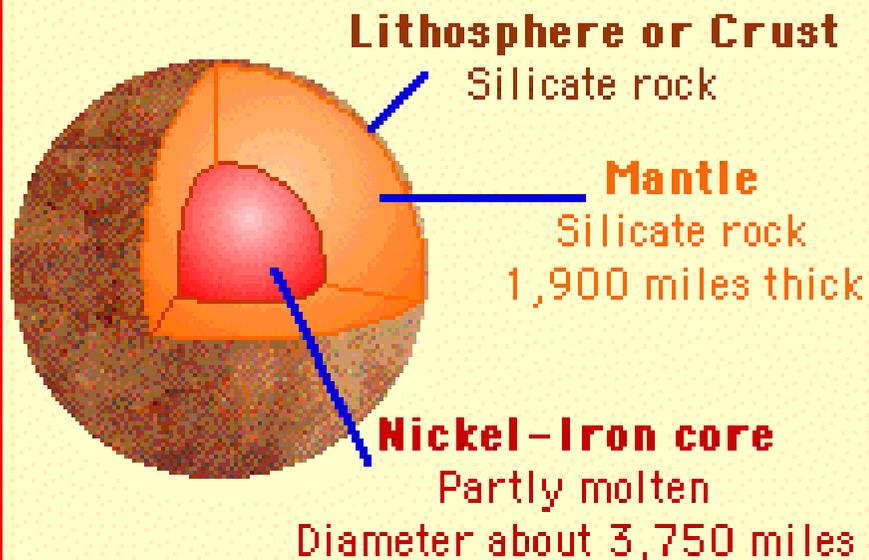
Venus: The Veiled Planet

- ◆ **Surface Temperatures**
 - **The surface temperature of Venus reaches 475°C, and its atmosphere is 97 percent carbon dioxide.**

Venus



Inside Venus



23.2 The Terrestrial Planets

Venus: The Veiled Planet

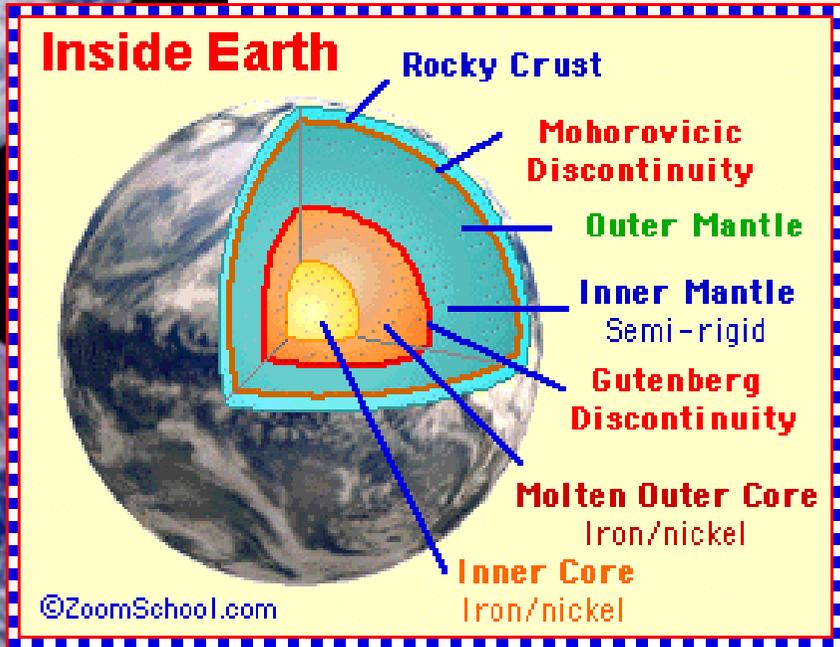
- ◆ **Venus is similar to Earth in size, density, mass, and location in the solar system. Thus, it has been referred to as “Earth’s twin.”**

23.2 The Terrestrial Planets

Venus: The Veiled Planet

◆ Surface Features

- Venus is covered in thick clouds that visible light cannot penetrate.
- About 80 percent of Venus's surface consists of plains covered by volcanic flow.



Mars



23.2 The Terrestrial Planets

Mars: The Red Planet

◆ The Martian Atmosphere

- The Martian atmosphere has only 1 percent of the density of Earth's.
- Although the atmosphere of Mars is very thin, extensive dust storms occur and may cause the color changes observed from Earth.

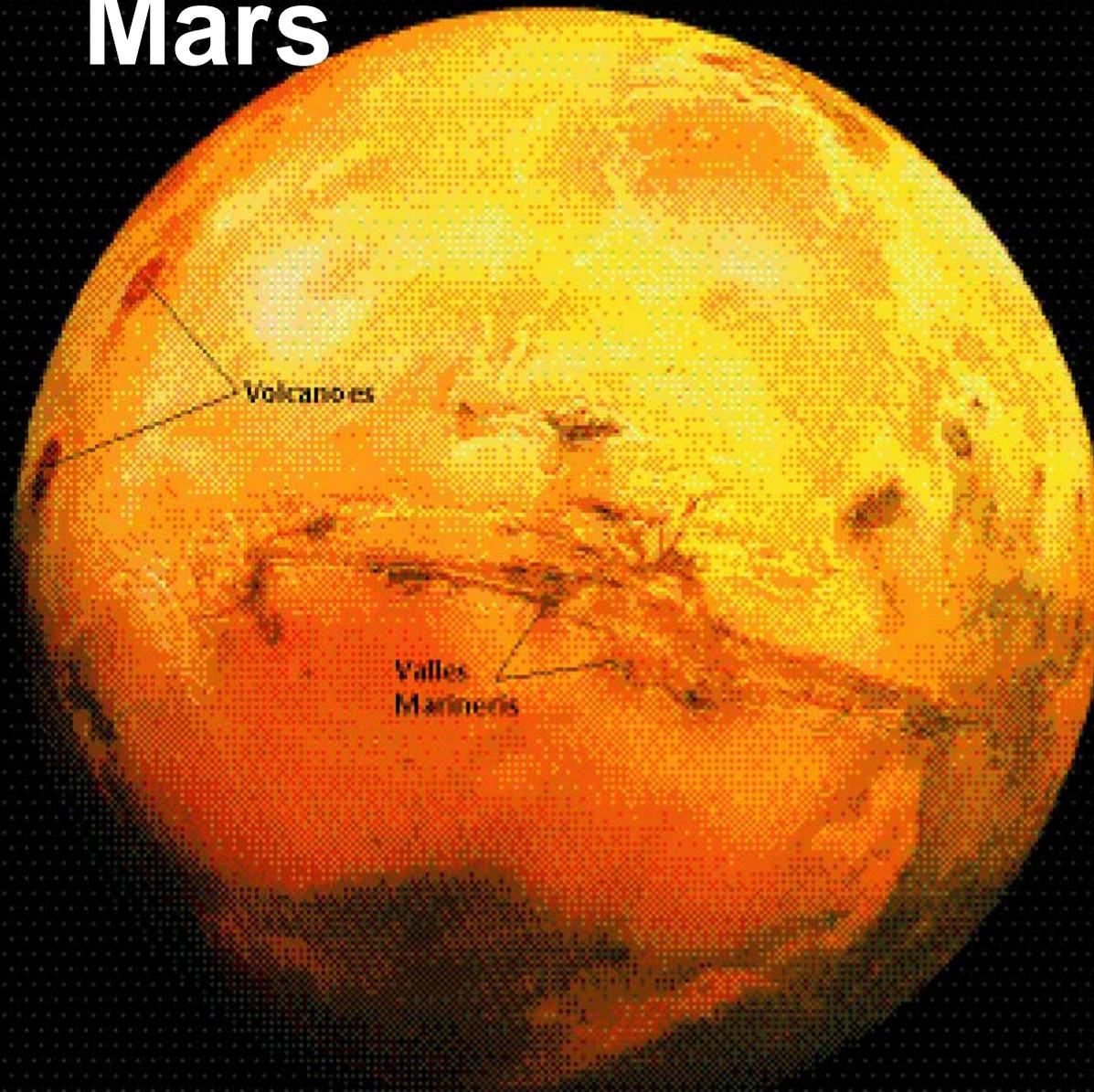
23.2 The Terrestrial Planets

Mars: The Red Planet

◆ Surface Features

- **Most Martian surface features are old by Earth standards. The highly cratered southern hemisphere is probably 3.5 billion to 4.5 billion years old.**

Mars



Mars Near Opposition
1995-2005



1995



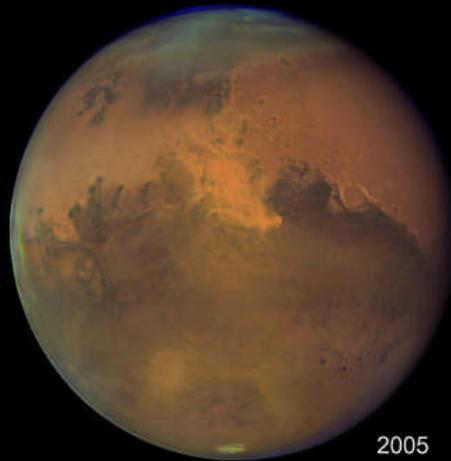
1997



1999



2001



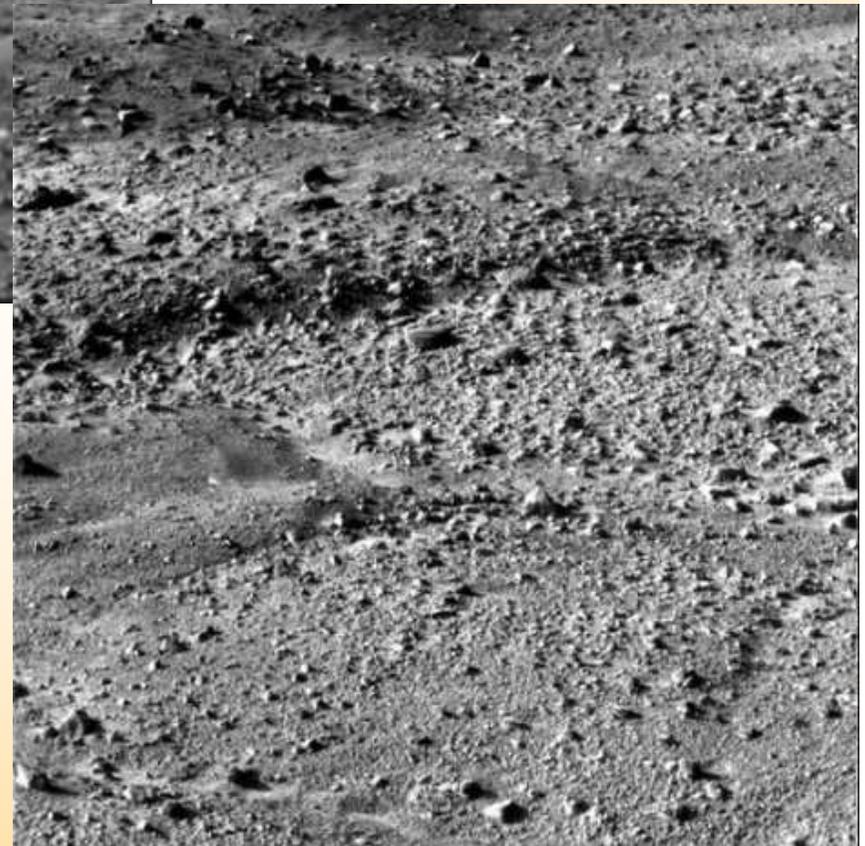
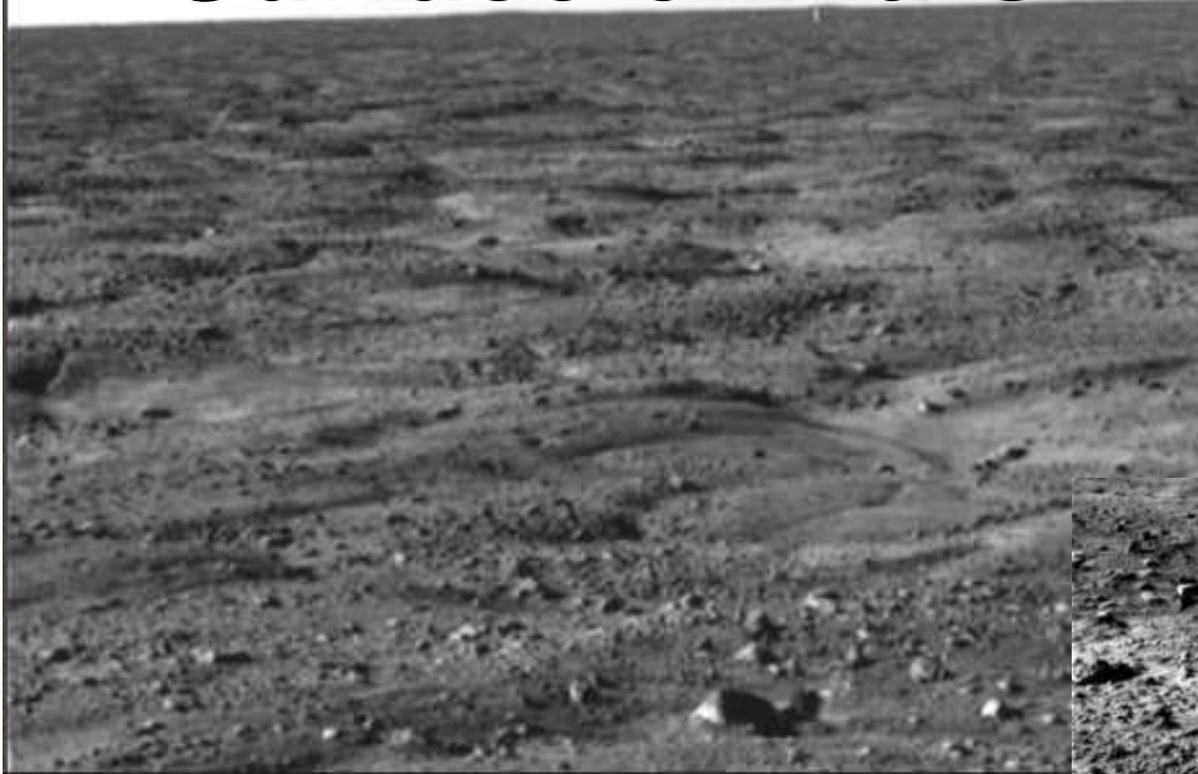
2005



2003

Hubble
Heritage

Surface of Mars in polar region





Moons of Mars: Phobos and Deimos

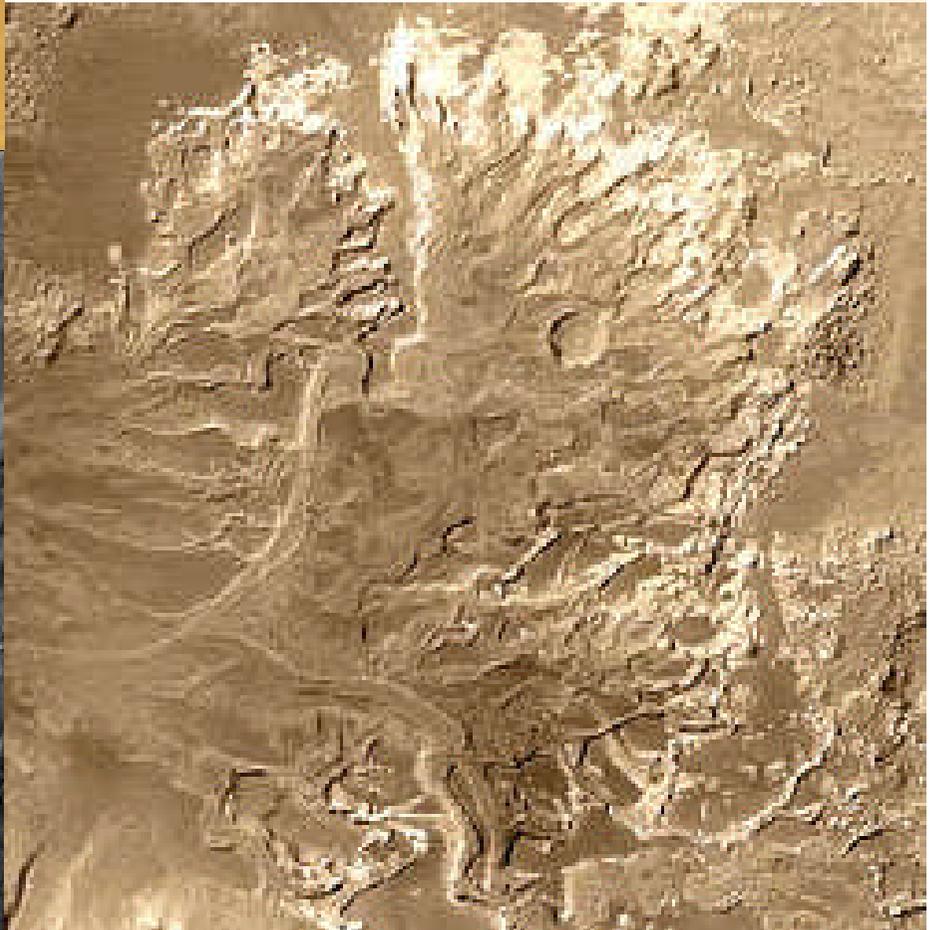
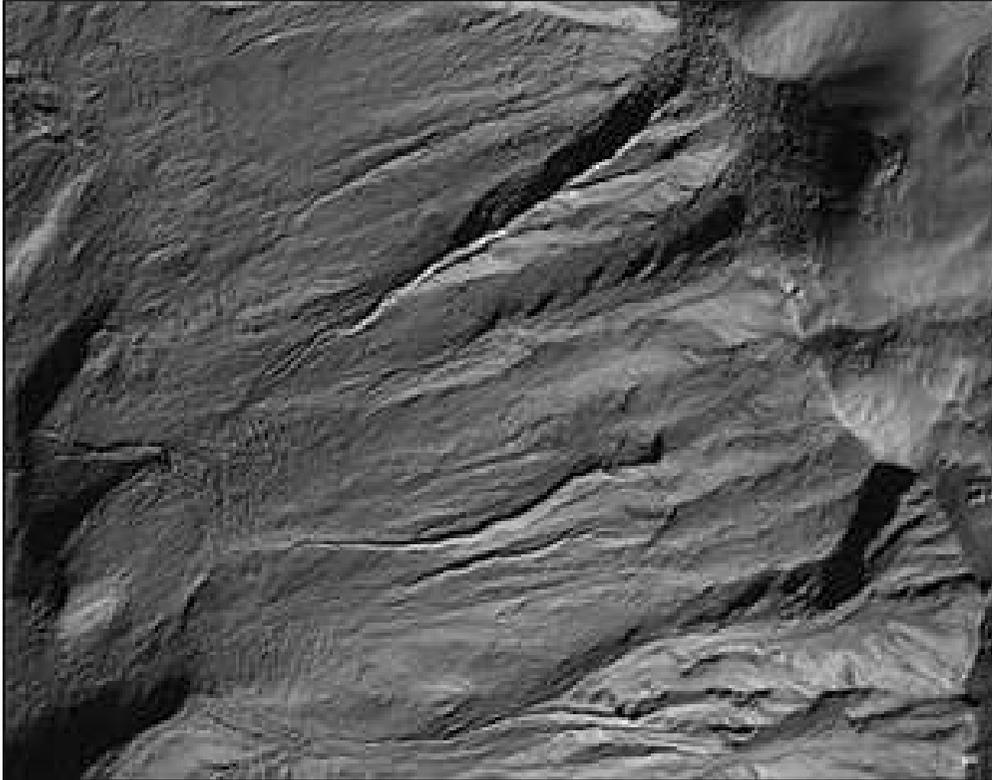
23.2 The Terrestrial Planets

Water on Mars

- **Some areas of Mars exhibit drainage patterns similar to those created by streams on Earth.**
- **Images from the Mars Global Surveyor indicate that groundwater has recently migrated to the surface.**

Although predominantly red due to the high quantities of *iron oxide* on the surface, ice-caps can be seen at both poles similar in nature to our Arctic and Antarctic. These are however composed mostly of *dry ice* (frozen carbon dioxide as opposed to water), although in the north it is known that the dry ice turns to a gas during the summer, leaving some water ice behind, but it is not known whether this happens in the south.

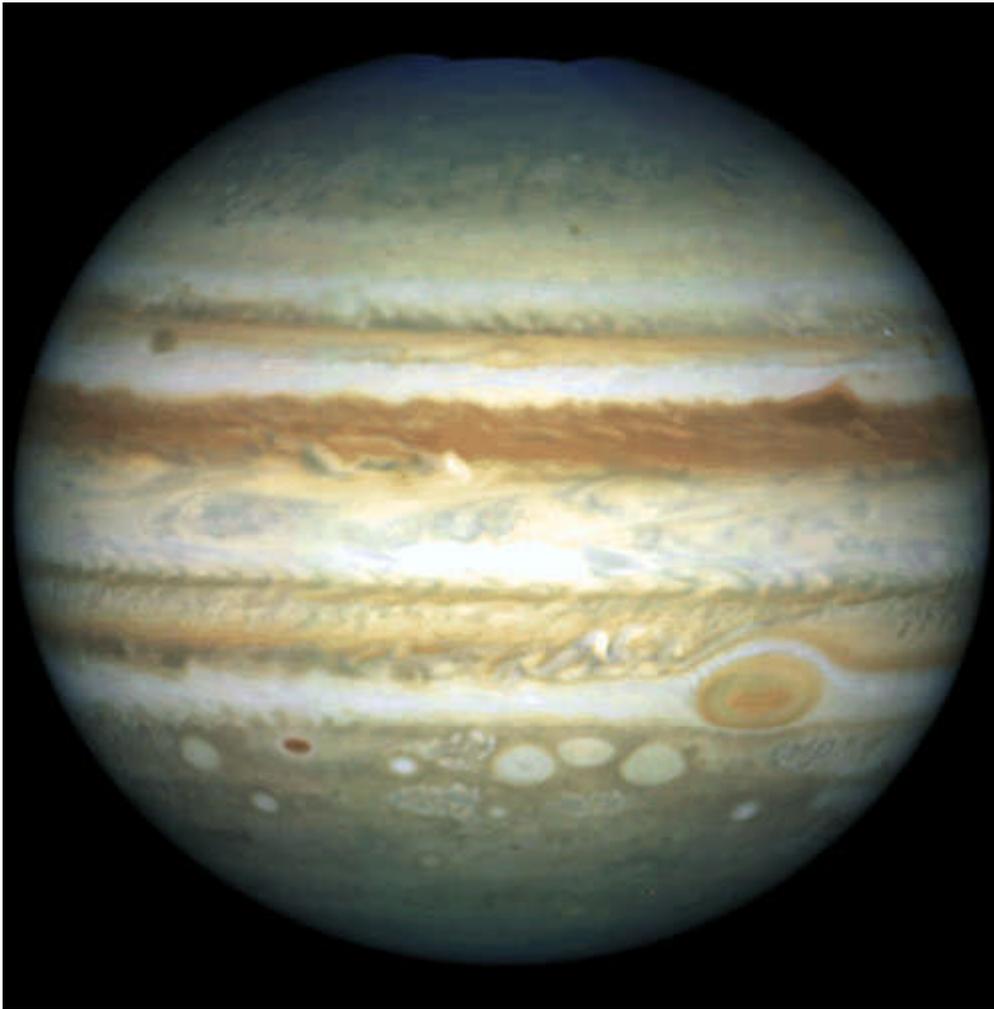
Water on Mars



23.3 The Outer Planets

Jupiter: Giant Among Planets

- ◆ **Jupiter has a mass that is 2 1/2 times greater than the mass of all the other planets and moons combined.**

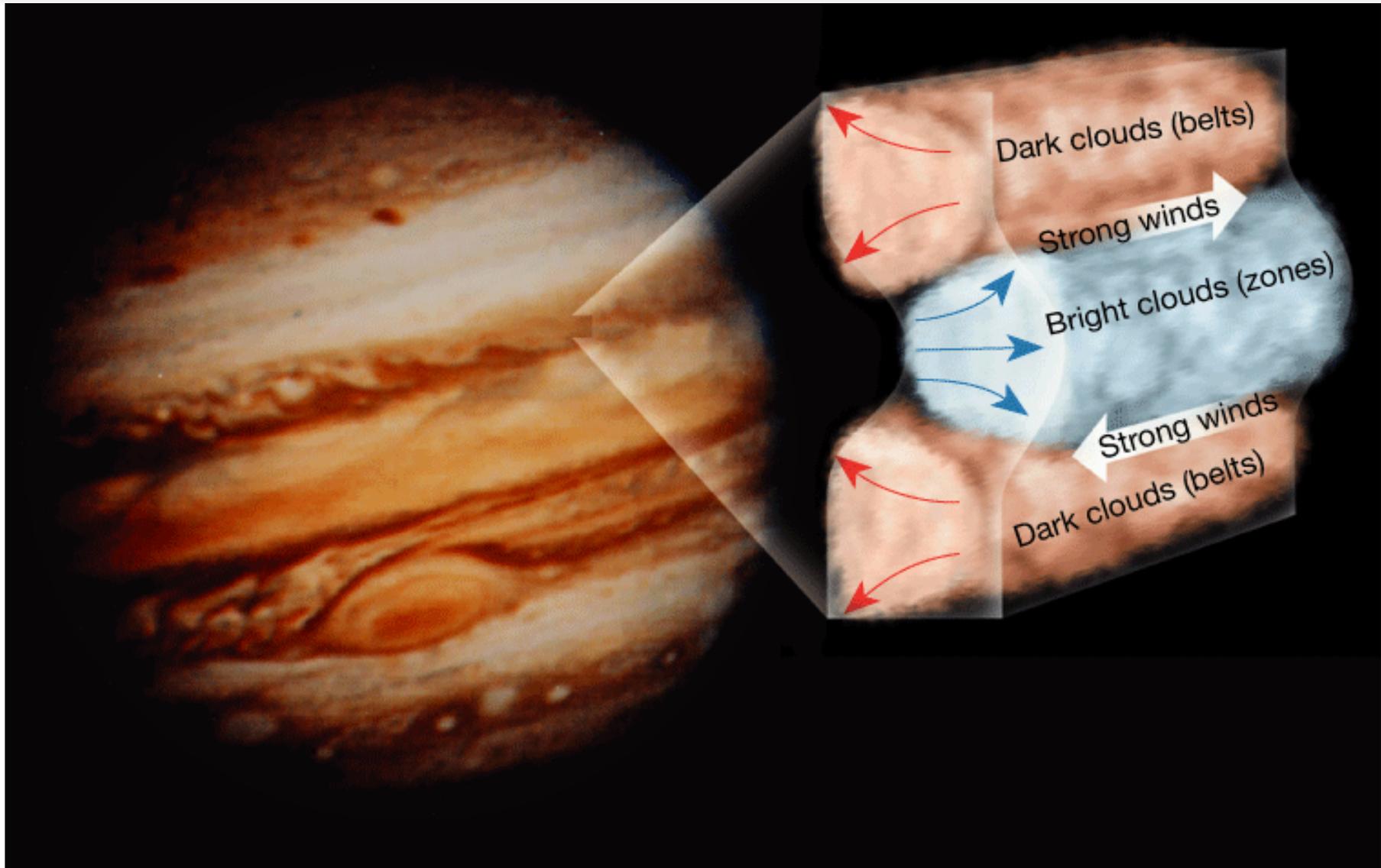


23.3 The Outer Planets

Jupiter: Giant Among Planets

- ◆ **Structure of Jupiter**
 - **Jupiter's hydrogen-helium atmosphere also contains small amounts of methane, ammonia, water, and sulfur compounds.**

Jupiter and the Great Red Spot

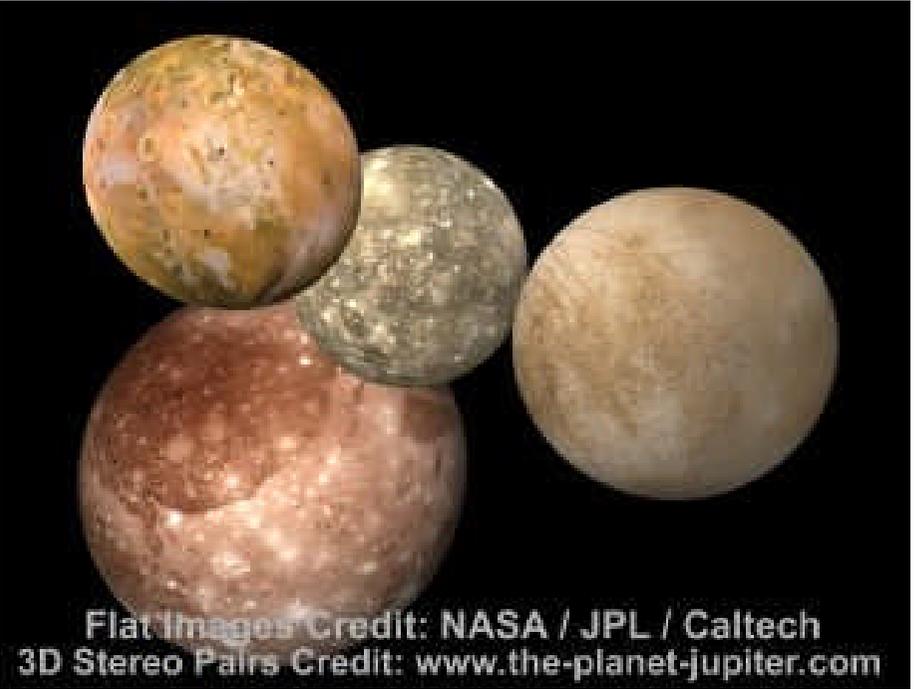


23.3 The Outer Planets

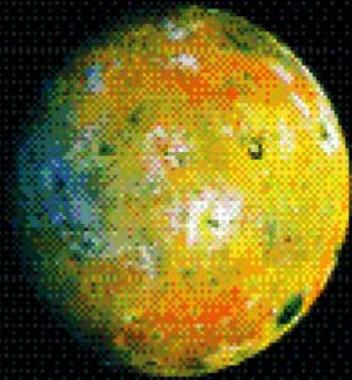
Jupiter: Giant Among Planets

◆ Jupiter's Moons

- Jupiter's satellite system, including the 28 moons discovered so far, resembles a miniature solar system.



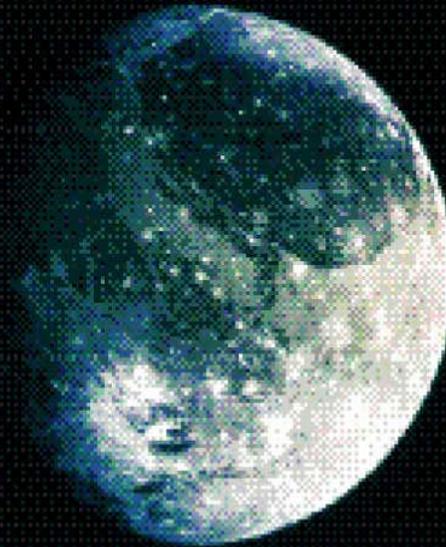
Jupiter's Largest Moons



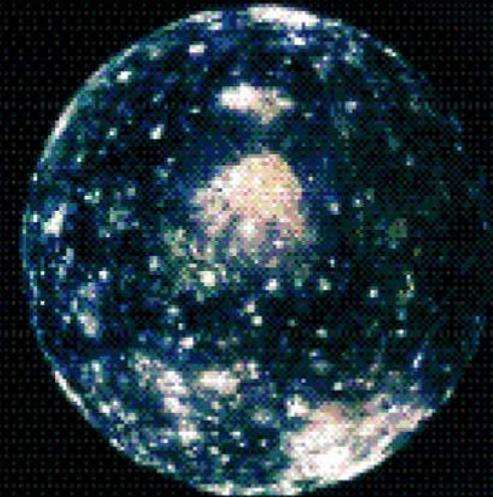
A. Io



B. Europa



C. Ganymede



D. Callisto

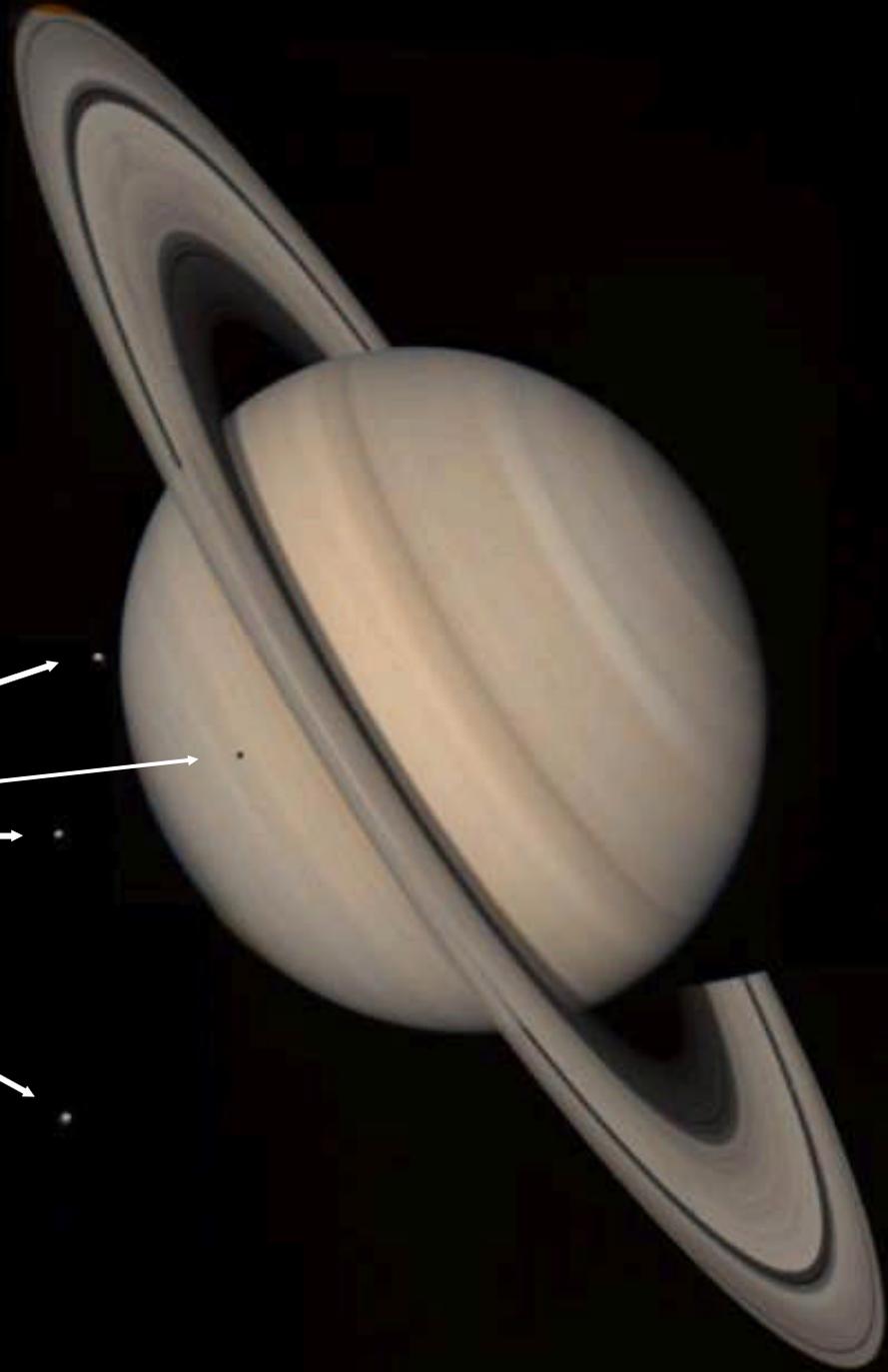
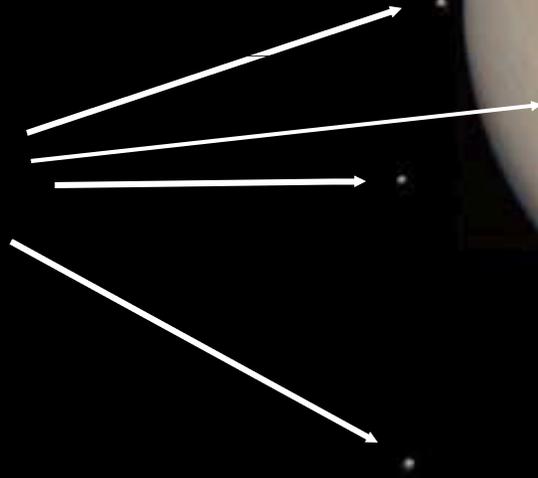
23.3 The Outer Planets

Jupiter: Giant Among Planets

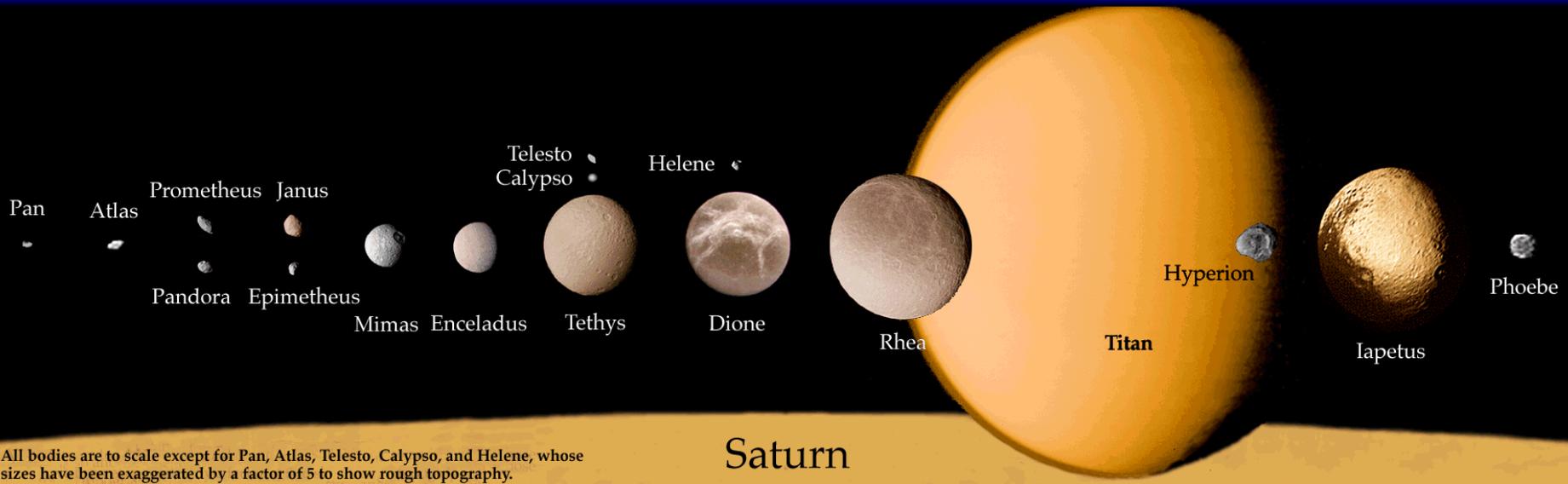
- ◆ **Jupiter's Rings**
 - **Jupiter's ring system was one of the most unexpected discoveries made by Voyager 1.**

Saturn

Moons

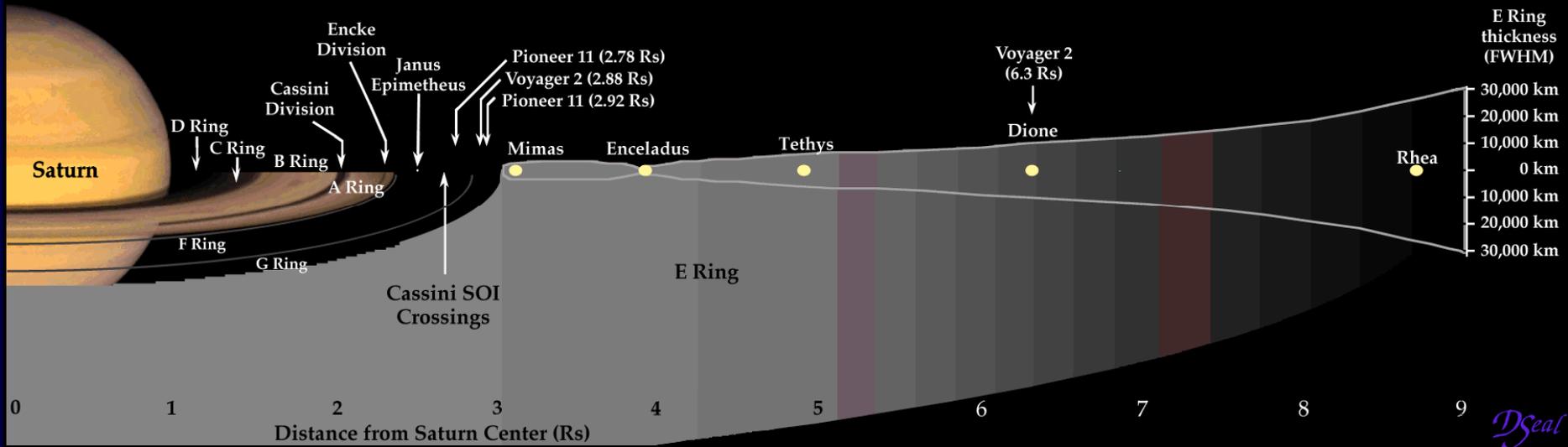


Saturn's Satellites and Ring Structure

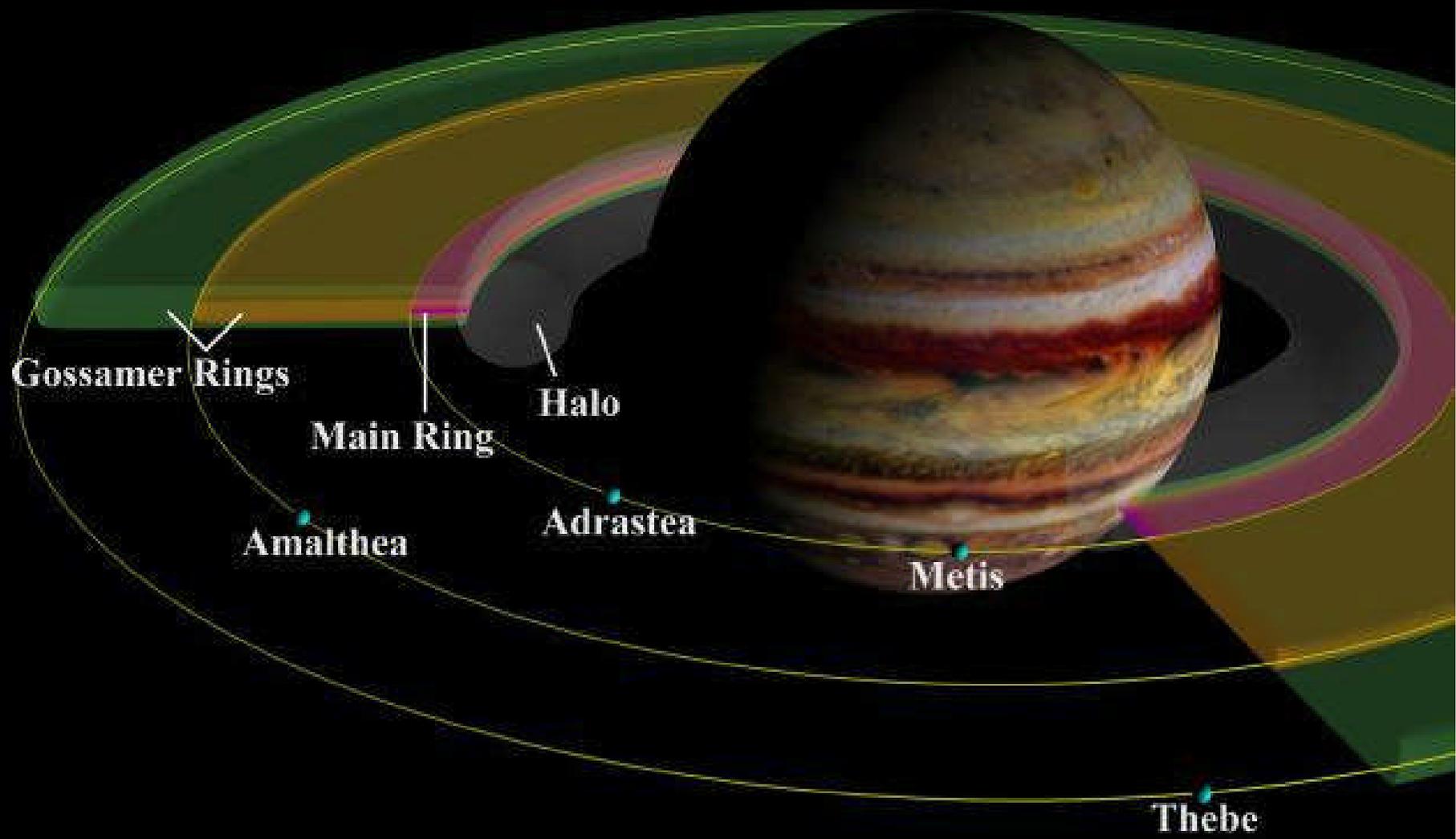


Not shown:

Pan	2.22 Rs	Titan	20.3 Rs
Atlas	2.28 Rs	Hyperion	24.6 Rs
Prometheus	2.31 Rs	Iapetus	59.1 Rs
Pandora	2.35 Rs	Phoebe	214.9 Rs



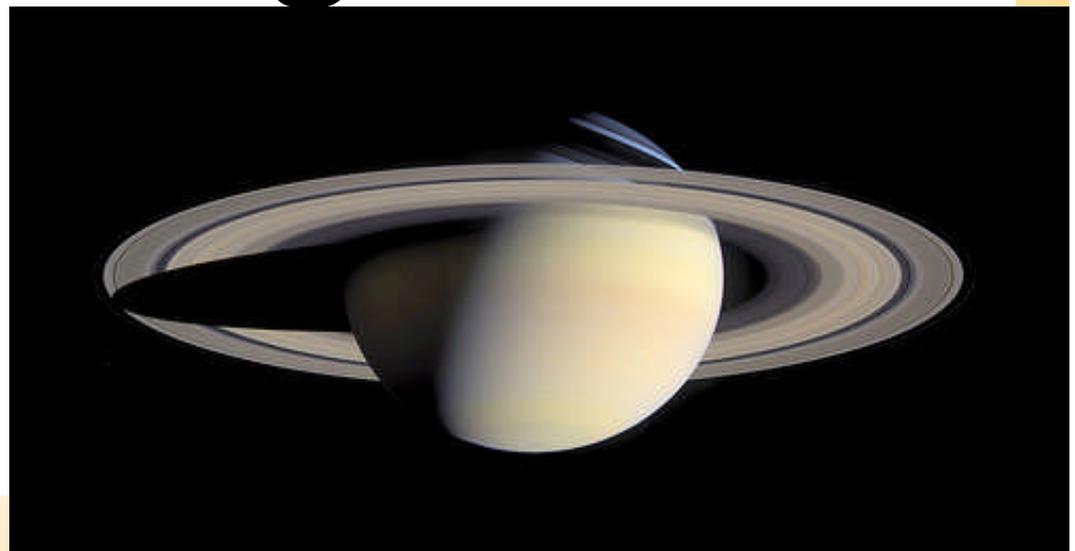
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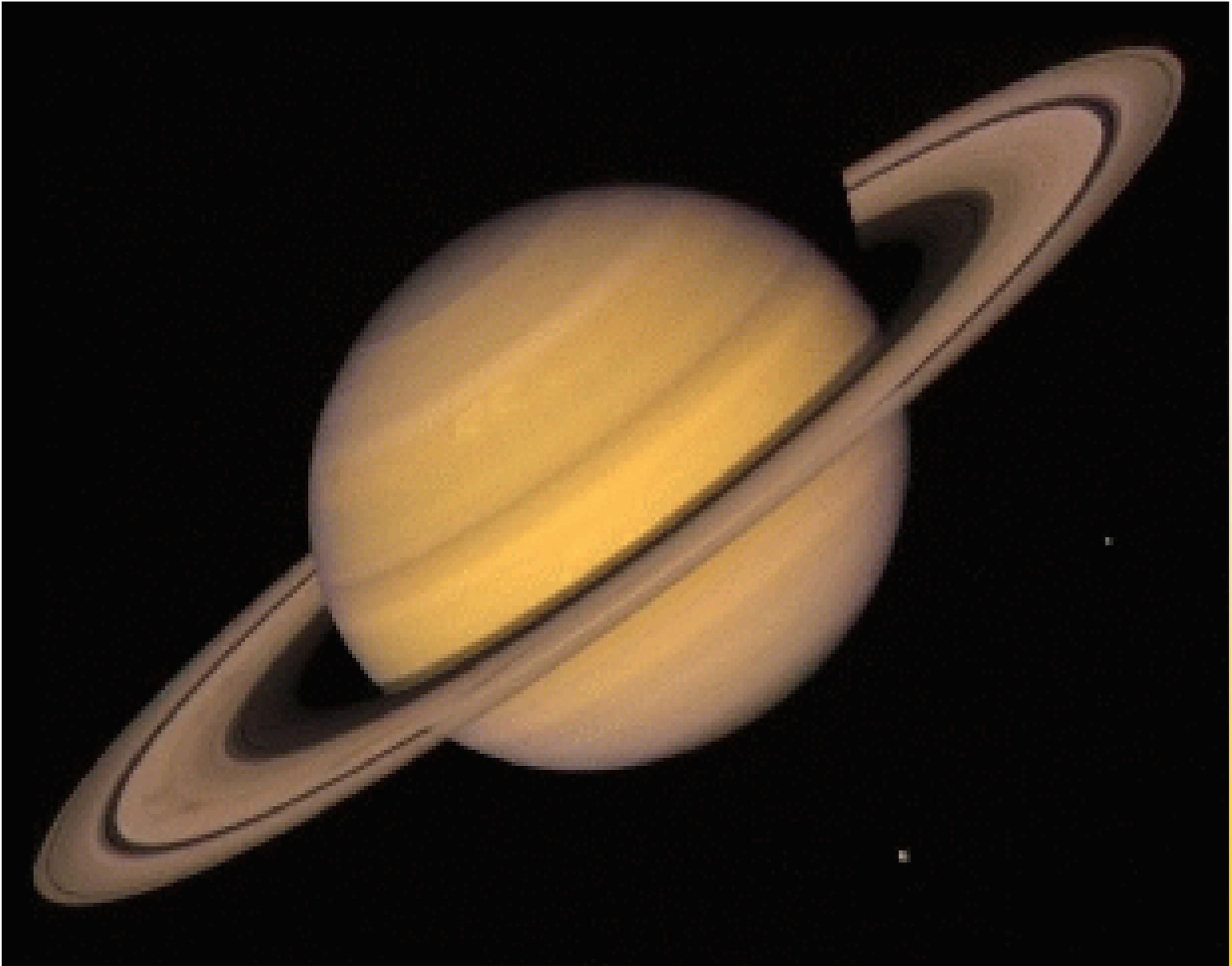


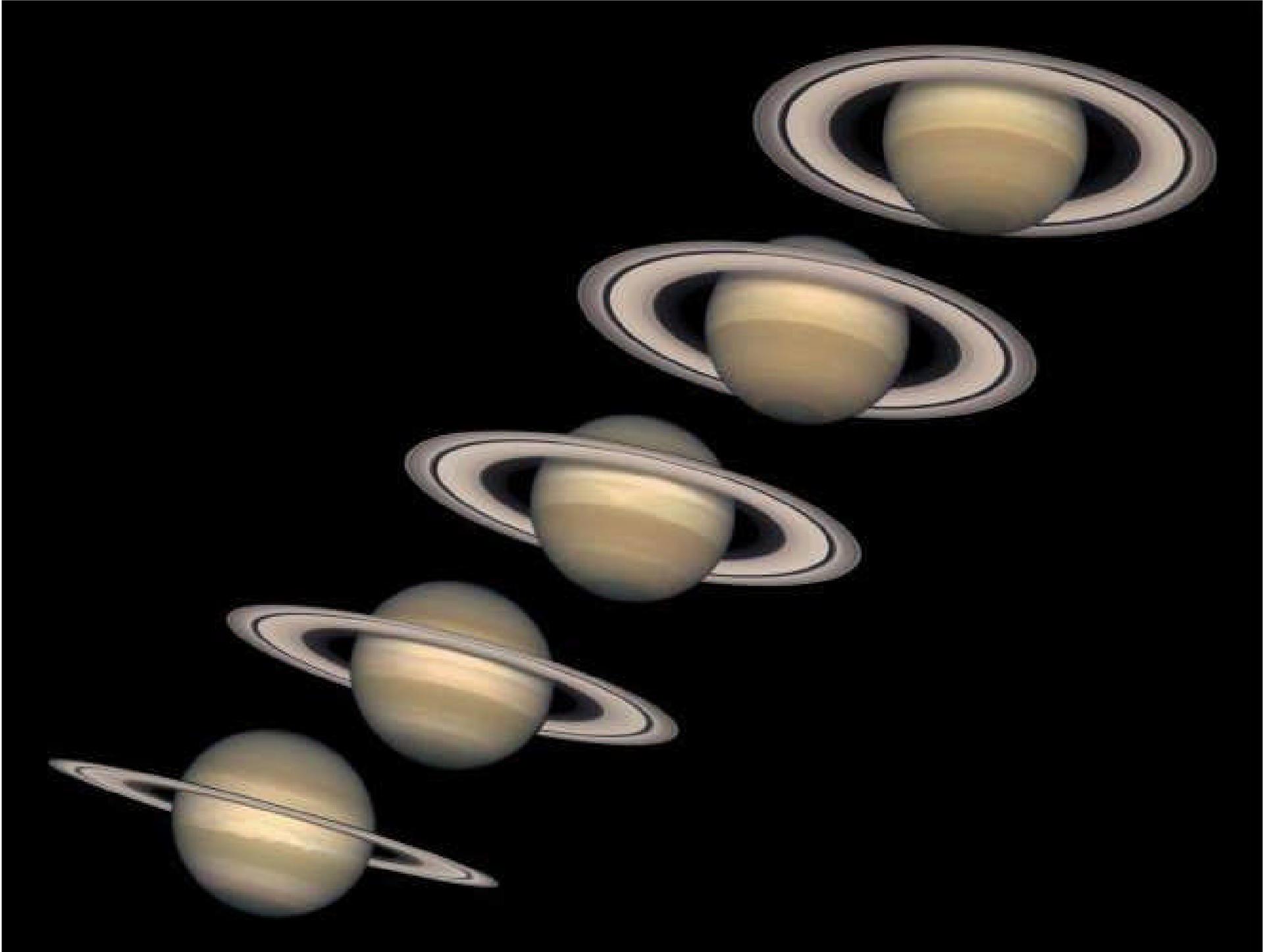
23.3 The Outer Planets

Saturn: The Elegant Planet

- ◆ The most prominent feature of Saturn is its system of rings.



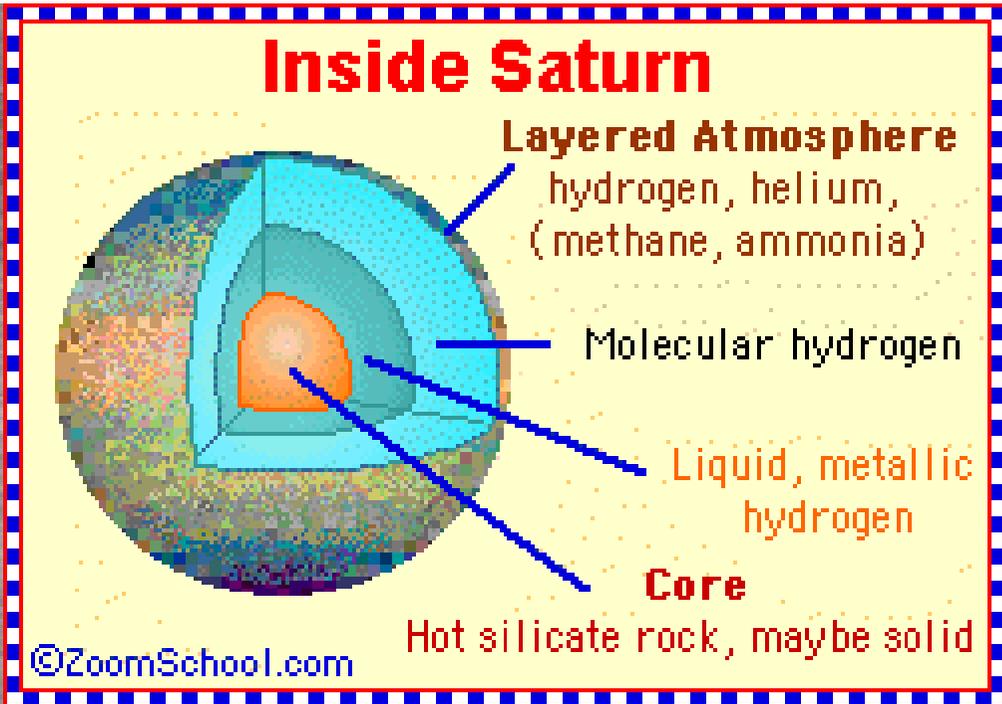
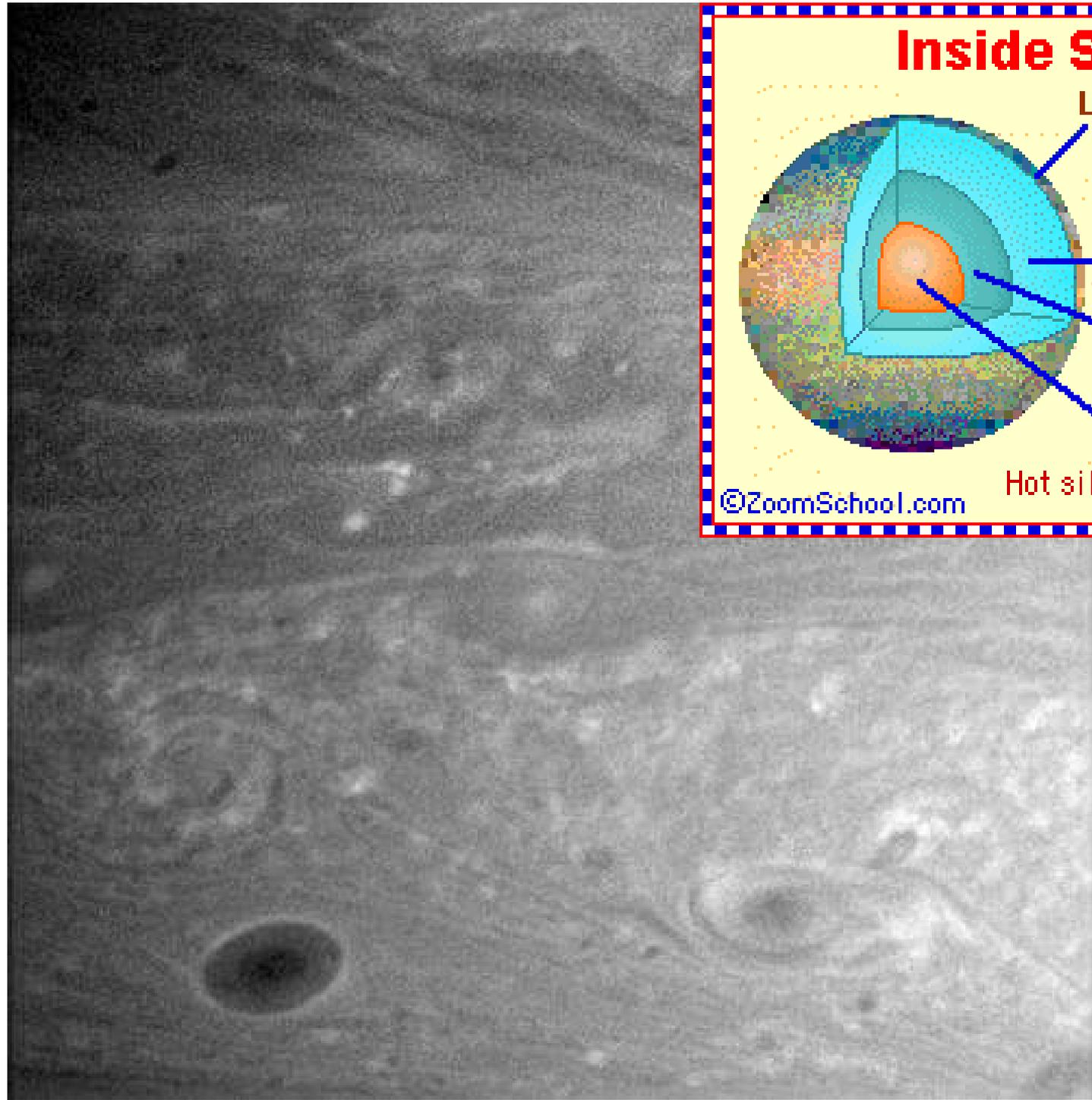




23.3 The Outer Planets

◆ Features of Saturn

- **Saturn's atmosphere is very active, with winds roaring at up to 1500 kilometers per hour.**
- **Large cyclonic "storms" similar to Jupiter's Great Red Spot, although smaller, occur in Saturn's atmosphere.**



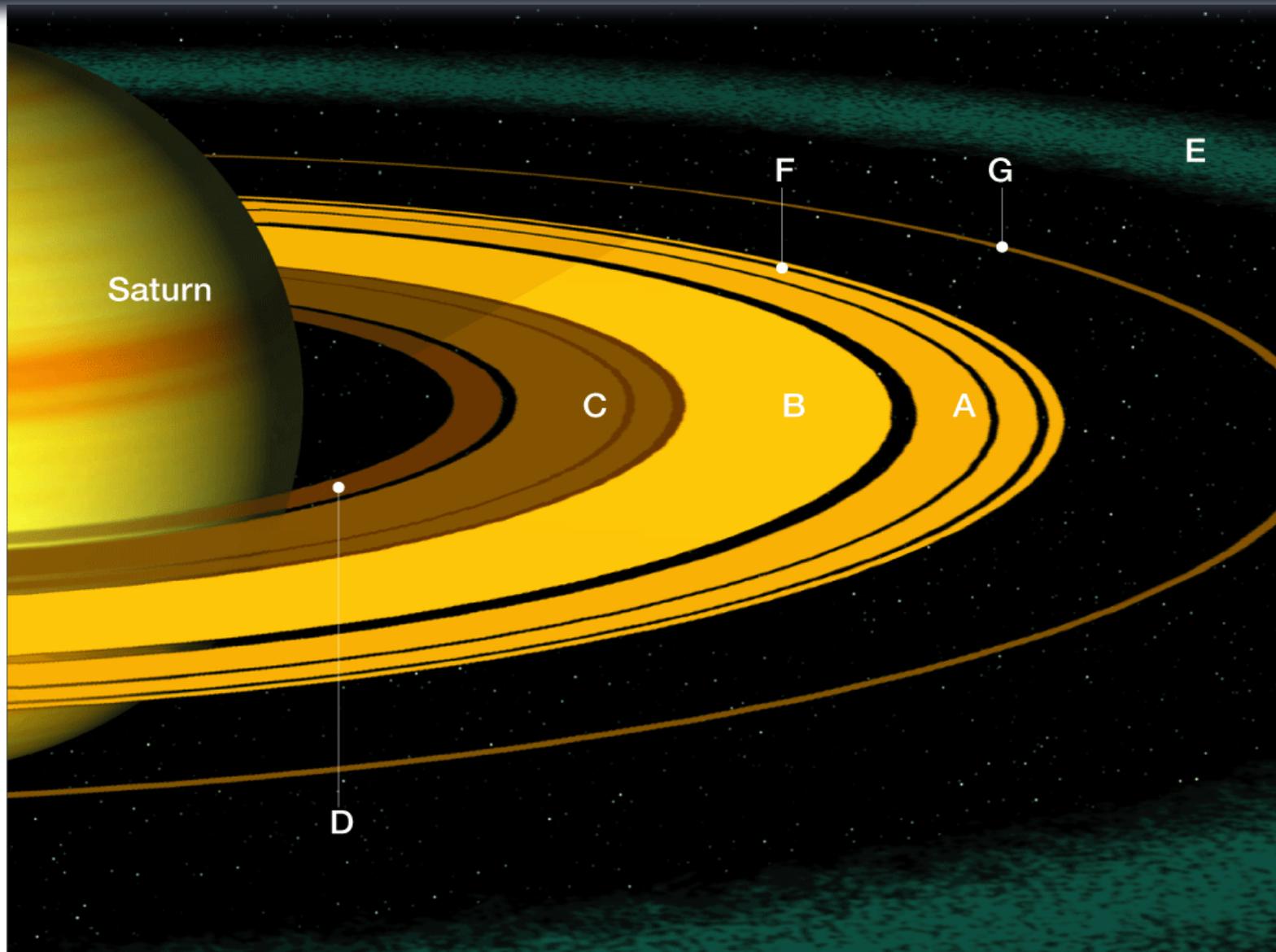
23.3 The Outer Planets

Saturn: The Elegant Planet

◆ Saturn's Rings

- **Until the discovery that Jupiter, Uranus, and Neptune have ring systems, this phenomenon was thought to be unique to Saturn.**
- **Most rings fall into one of two categories based on particle density.**

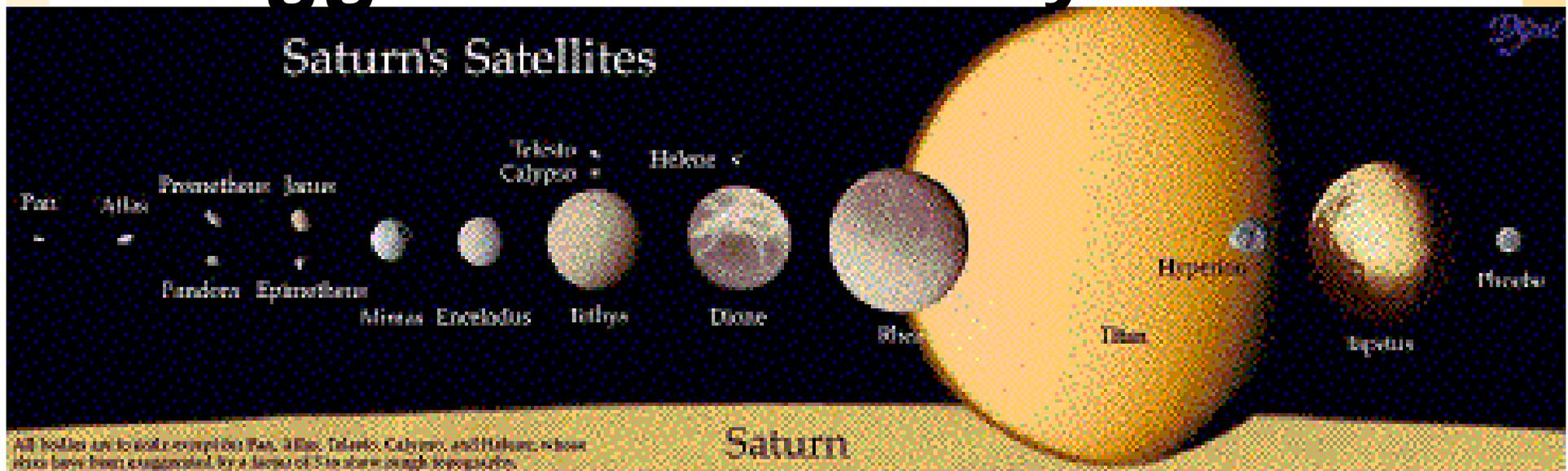
Saturn's Rings



23.3 The Outer Planets

◆ Saturn's Moons

- Saturn's satellite system consists of 31 moons.
- Titan is the largest moon, and it is bigger than Mercury.



Uranus

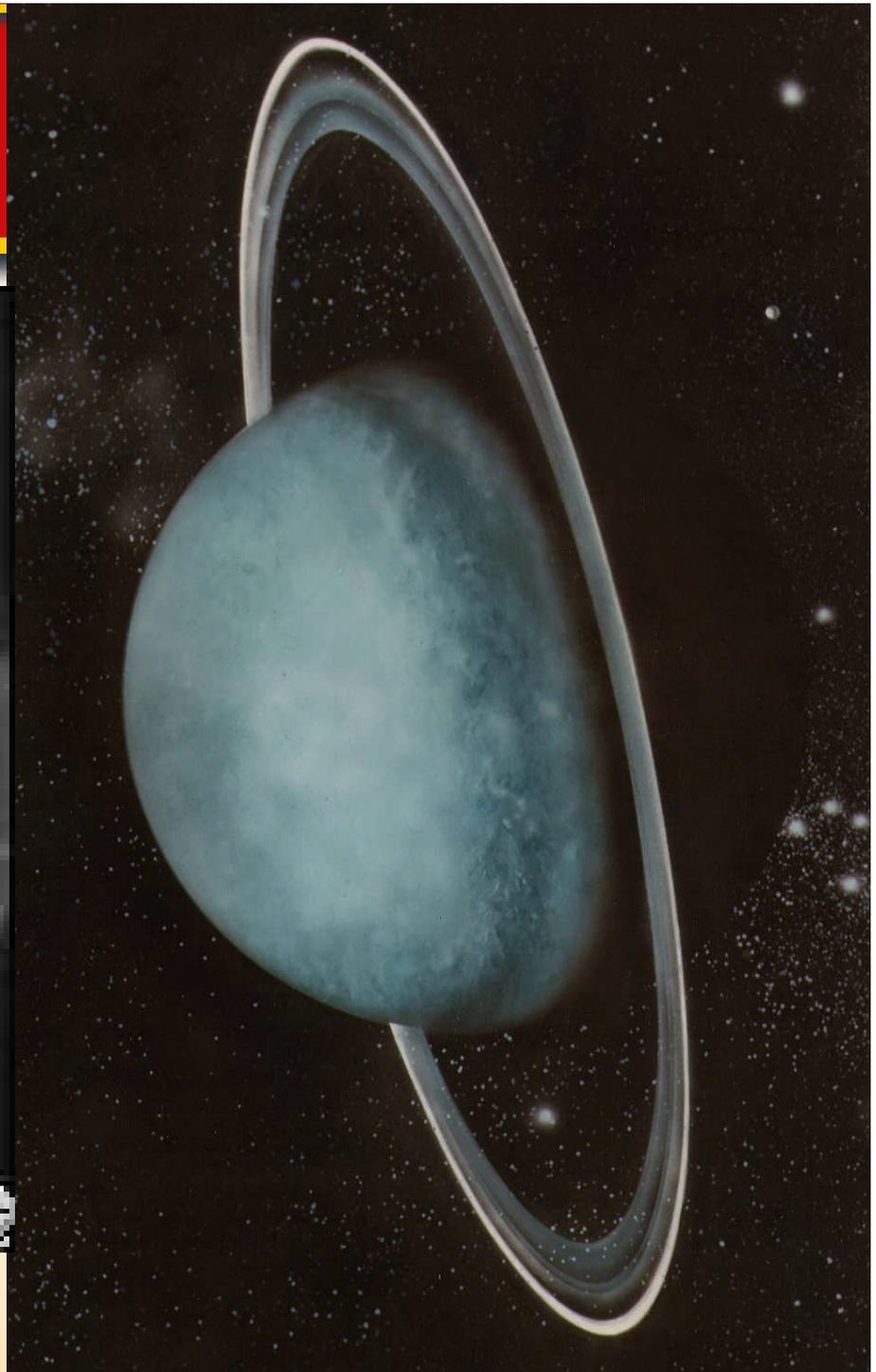
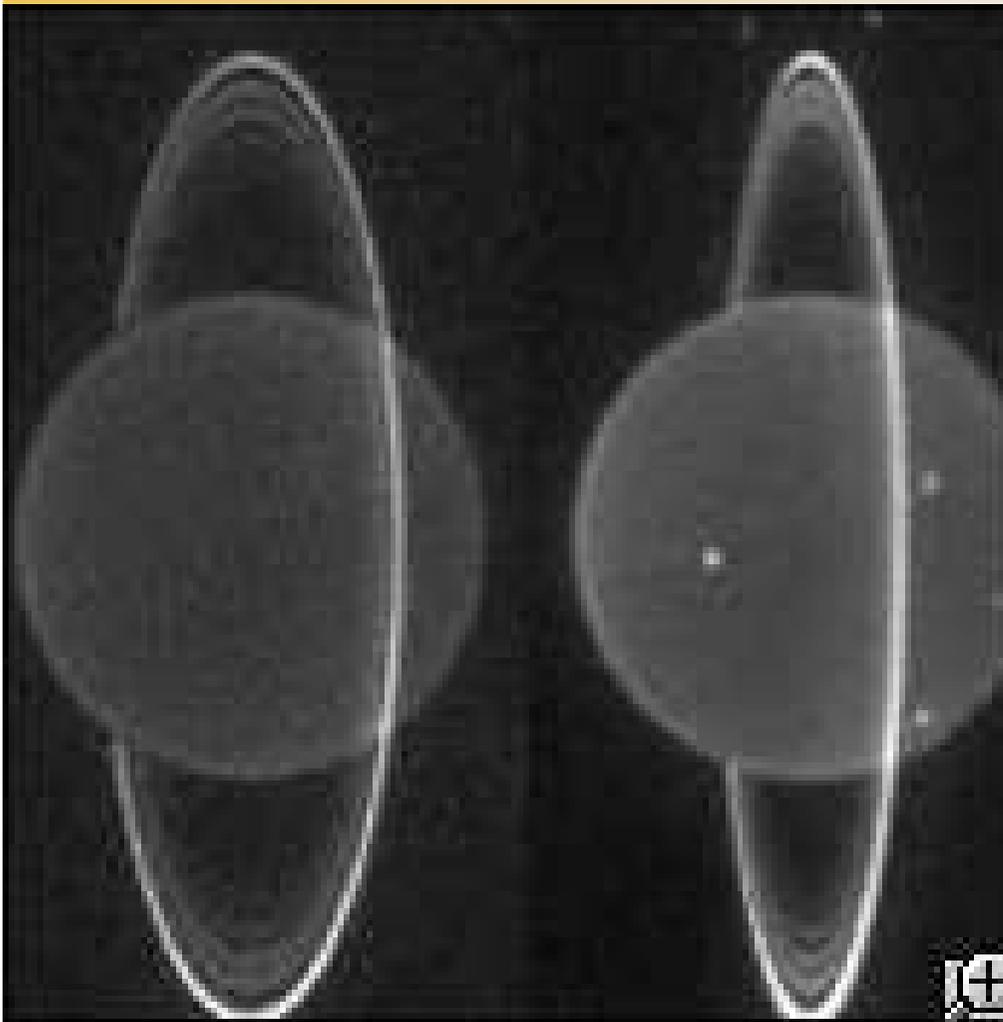


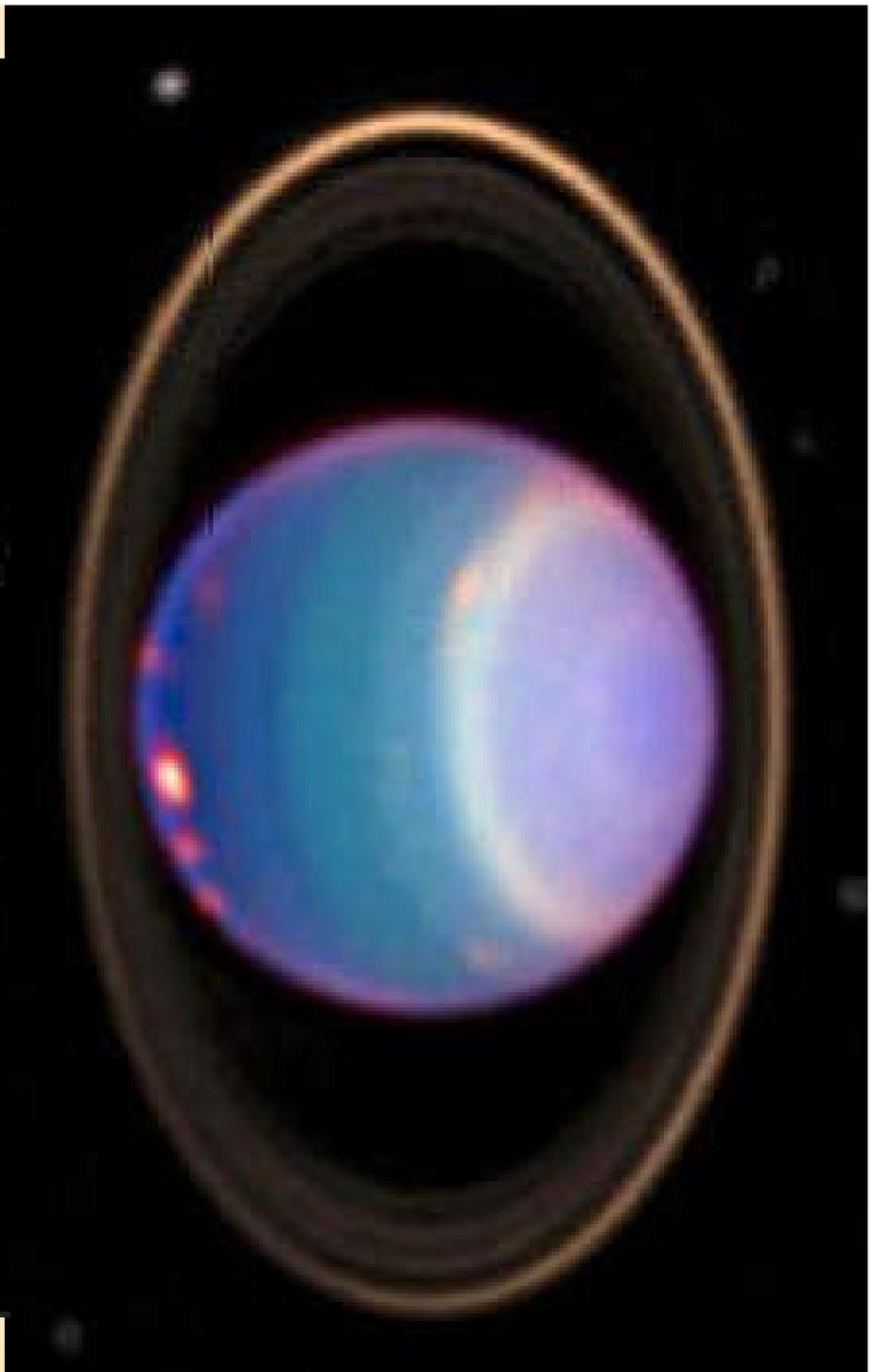
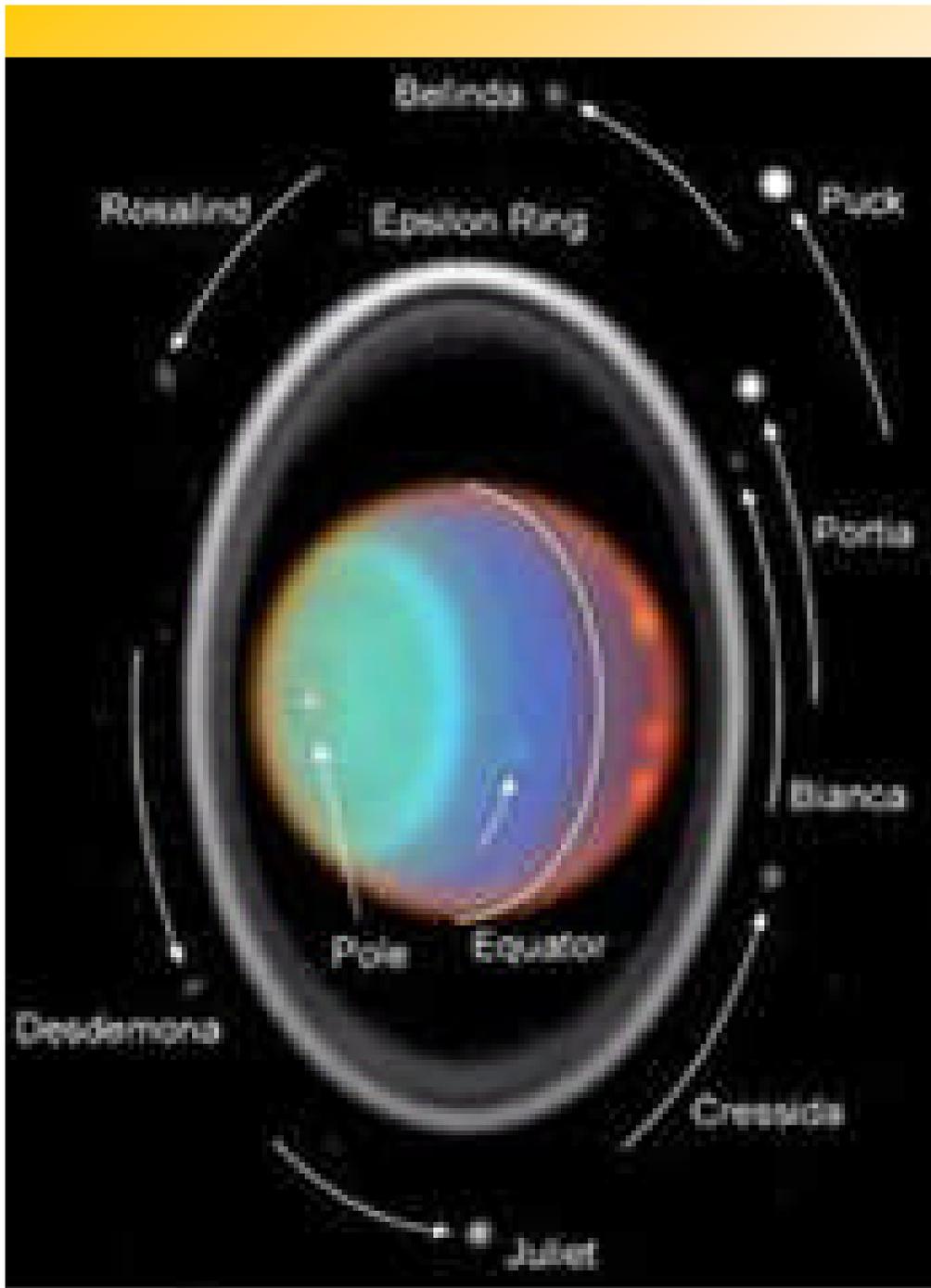
23.3 The Outer Planets

Uranus: The Sideways Planet

- ◆ **Instead of being generally perpendicular to the plane of its orbit like the other planets, Uranus's axis of rotation lies nearly parallel with the plane of its orbit.**

Uranus



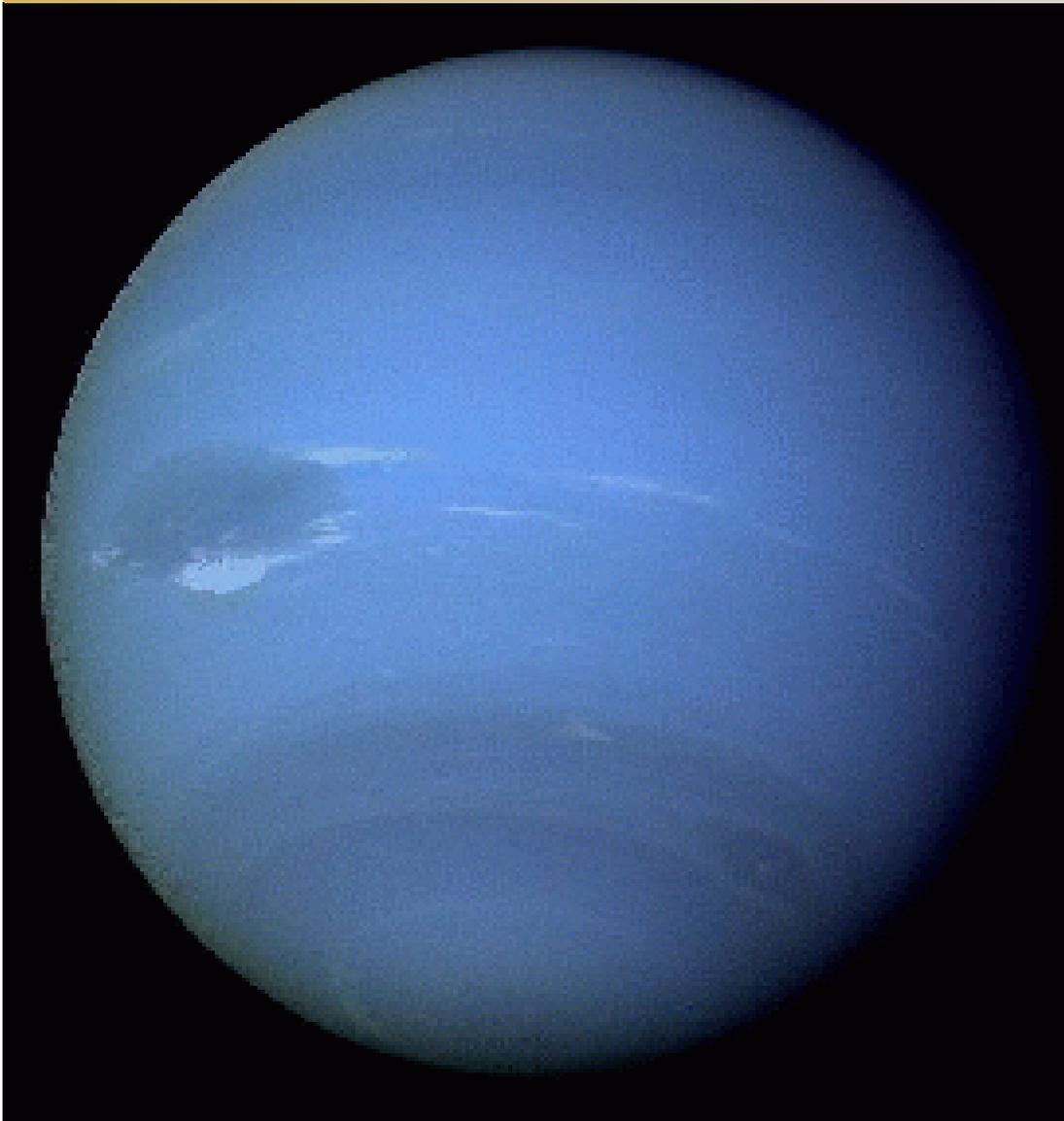


23.3 The Outer Planets

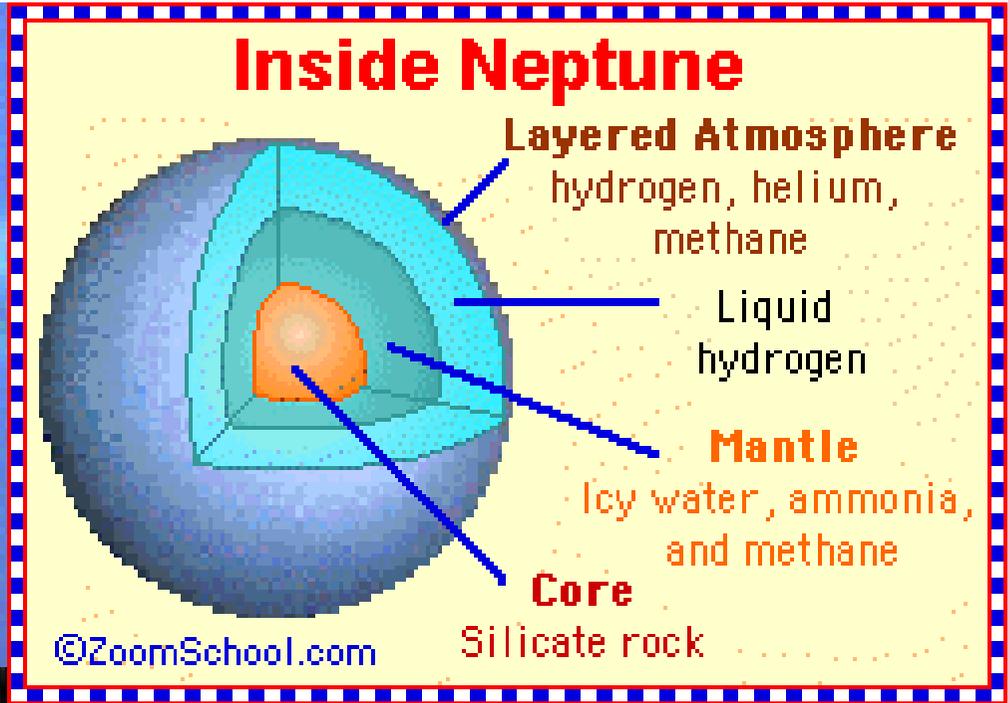
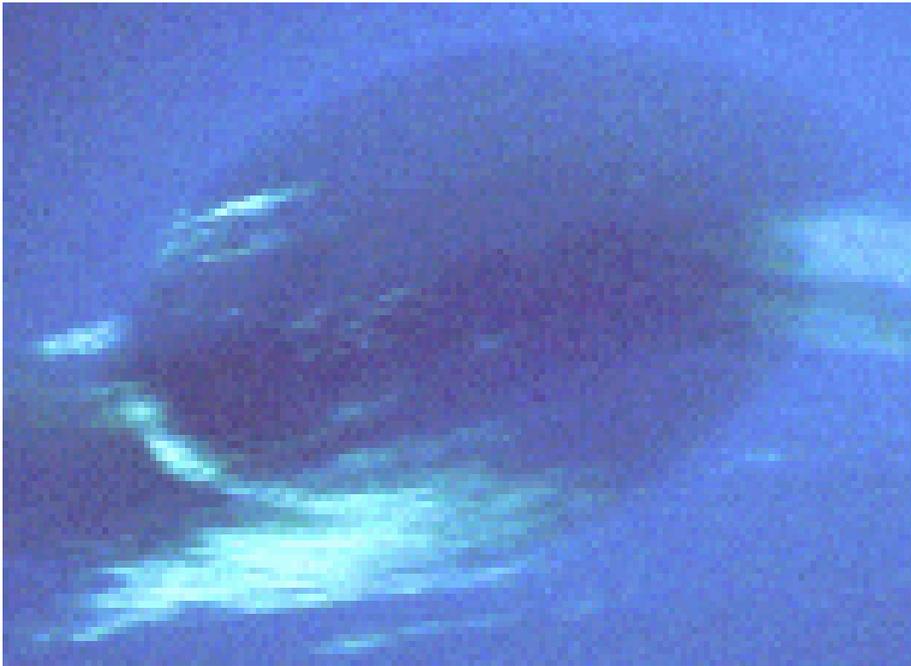
Neptune: The Windy Planet

- ◆ **Winds exceeding 1000 kilometers per hour encircle Neptune, making it one of the windiest places in the solar system.**

Neptune



Neptune's blue color is due to *methane* in the atmosphere, which absorbs red light.



23.3 The Outer Planets

Pluto: Planet X

- ◆ **Pluto's orbit is highly eccentric, causing it to occasionally travel inside the orbit of Neptune, where it resided from 1979 through February 1999.**

Pluto and its moon Charon



Dwarf Planets



Pluto



Eris



Ceres

The Dwarf Planets: Pluto, Eris, & Ceres

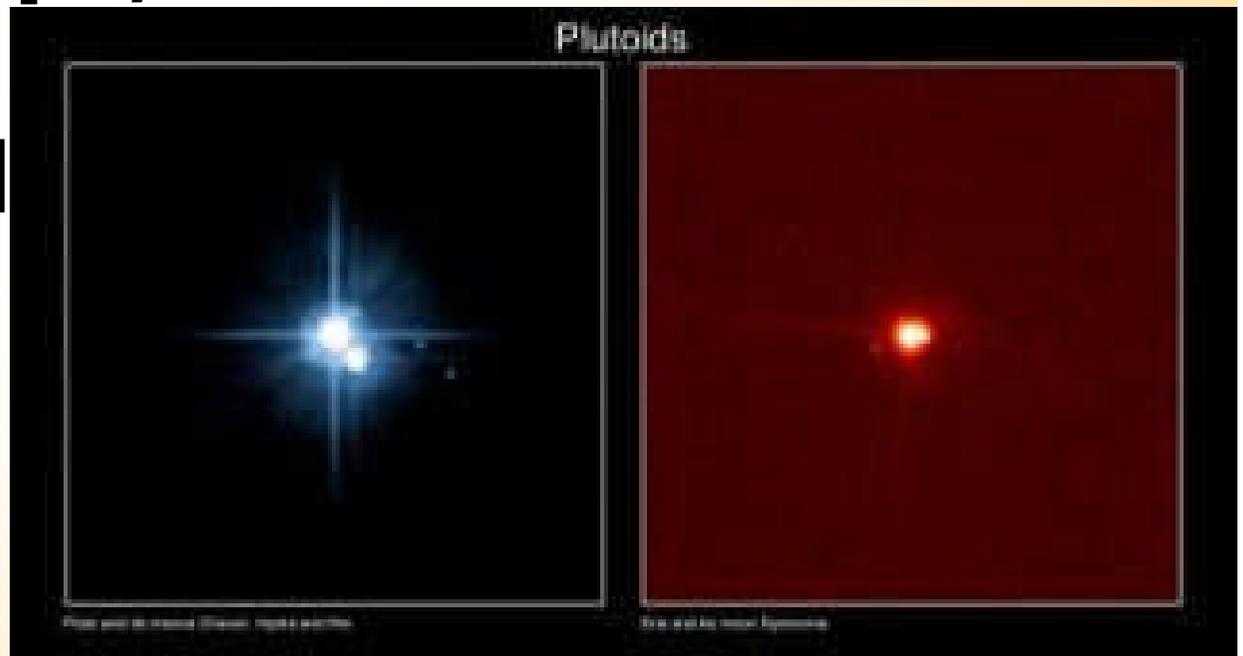
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 **Formerly planet X**

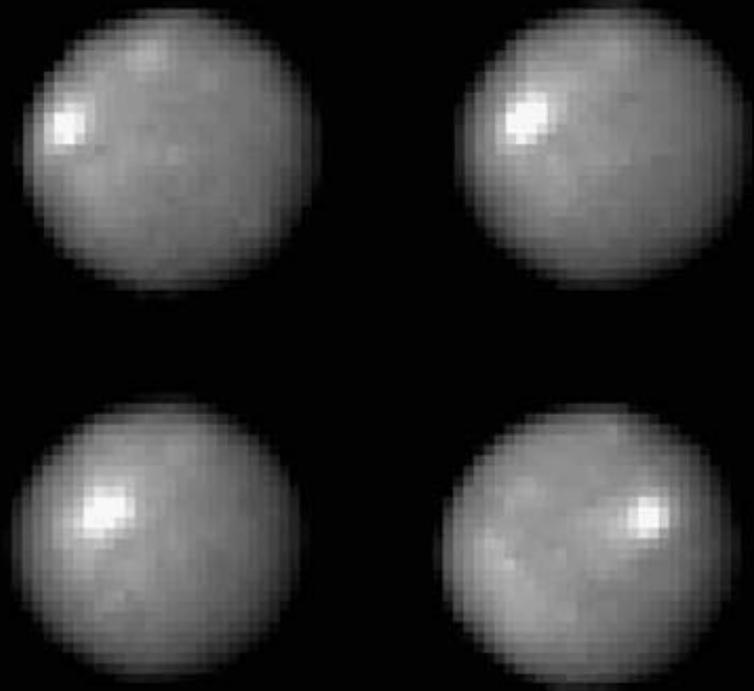
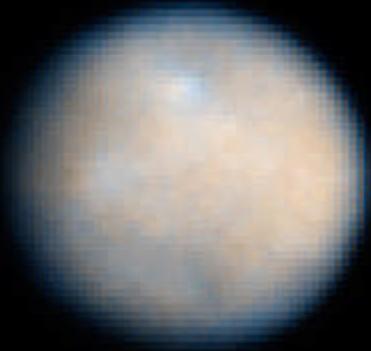
Pluto's identity crisis

**The International
Astronomical Union (IAU)
announced Pluto should now
be called a "plutoid," two
years after the organization
voted to demote Pluto to
"dwarf planet" status.**

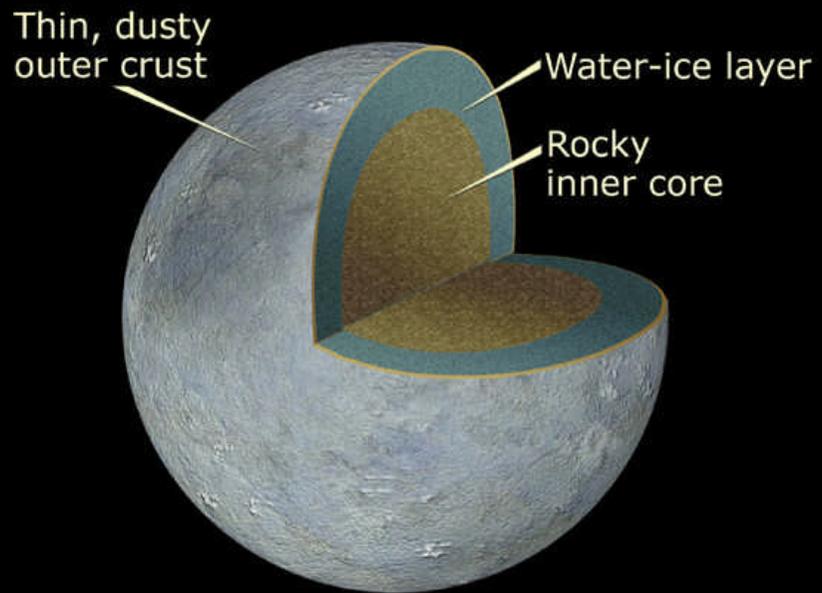
The two known and named plutoids are Pluto and Eris. Plutoids are celestial bodies in orbit around the Sun at a distance greater than that of Neptune that have sufficient mass for their self-gravity to overcome rigid body forces so that they assume a hydrostatic equilibrium (near-spherical) shape, and that have not cleared the neighborhood around their orbit.



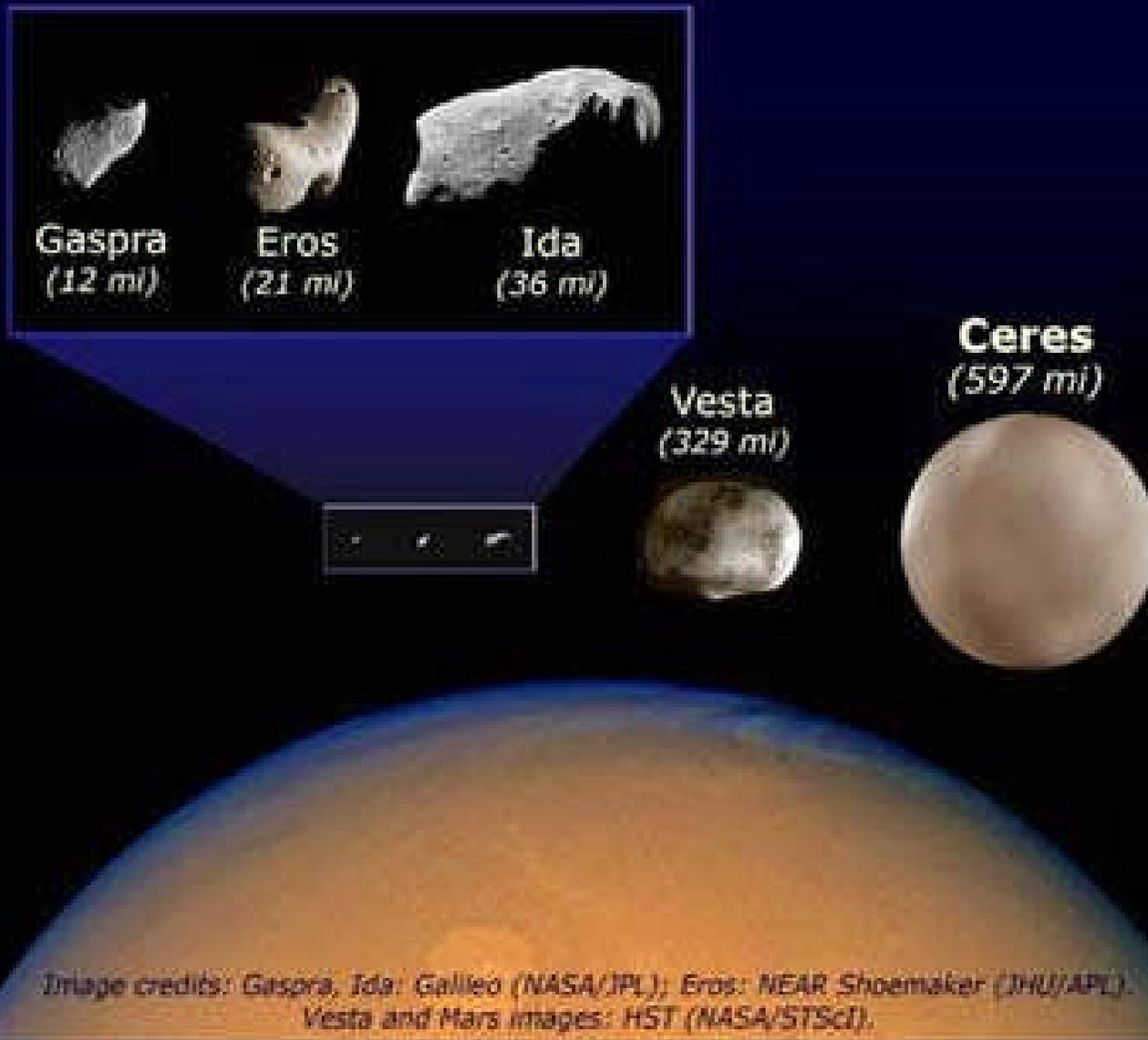
Ceres



Ceres' layers



Hubble image of Ceres, the largest asteroid in the main asteroid belt, compared with four other asteroids and Mars.
(Longest dimension for each body in parentheses.)



New Planets?

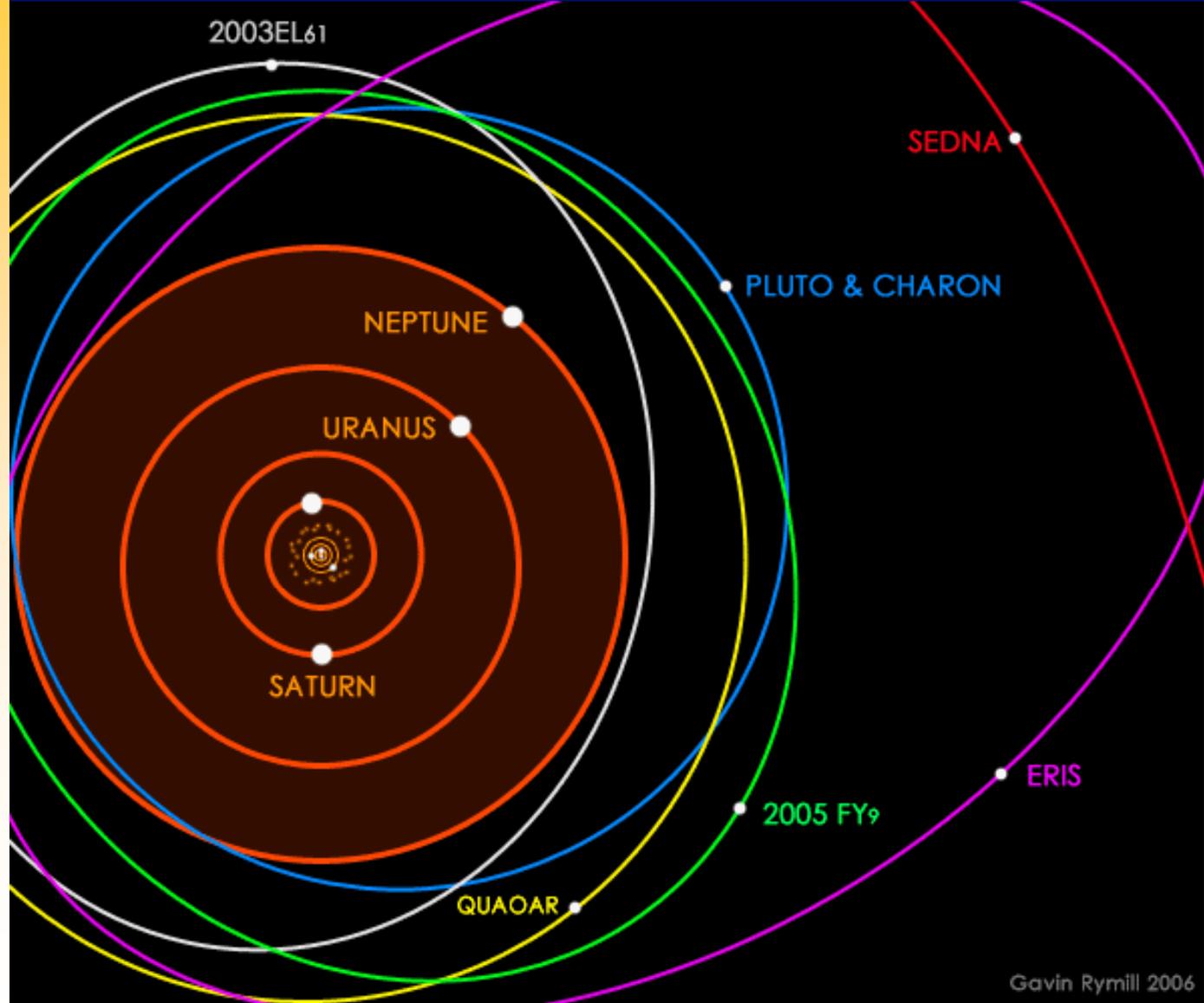
The Future of our solar system!



Sedna

In March 2004, researchers at the California Institute of technology (Caltech) discovered a body orbiting the sun that is three times further away from the Earth than Pluto. This puts it well beyond the bounds of the Kuiper Belt as far as we know, and yet it is approximately three-quarters of the size of Pluto, larger than Quaoar.

The 8 main planets' orbits (orange) shown with trans-Neptunian dwarf planets' eccentric orbits



Gavin Rymill 2006



Makemake Named the Newest Plutoid

The red methane-covered dwarf planet, formerly known as 2005 FY9 or “Easterbunny,” is named after a Polynesian creator of humanity and god of fertility.

“The orbit is not particularly strange, but the object itself is big, probably about two-thirds the size of Pluto,” said Michael E. Brown, who discovered and named Makemake (pronounced MAH-keh MAH-keh).

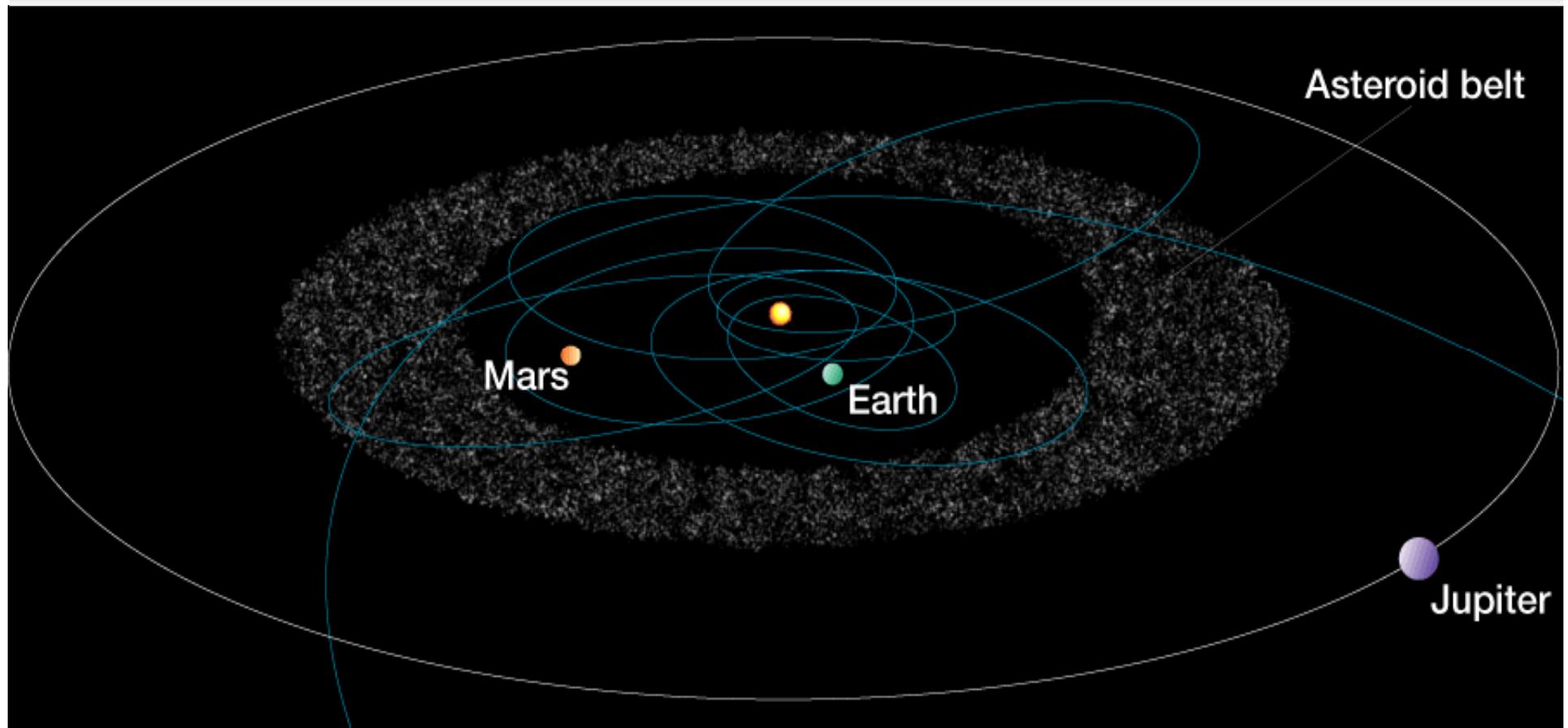
Dr. Brown said the name came to him when he was looking for a mythological god and thought of Easter Island in the South Pacific. Makemake was the chief god among people who settled the island.

23.4 Minor Members of the Solar System

Asteroids: Microplanets

- ◆ **An asteroid is a small, rocky body whose diameter can range from a few hundred kilometers to less than a kilometer.**
- ◆ **Most asteroids lie between the orbits of Mars and Jupiter. They have orbital periods of three to six years.**

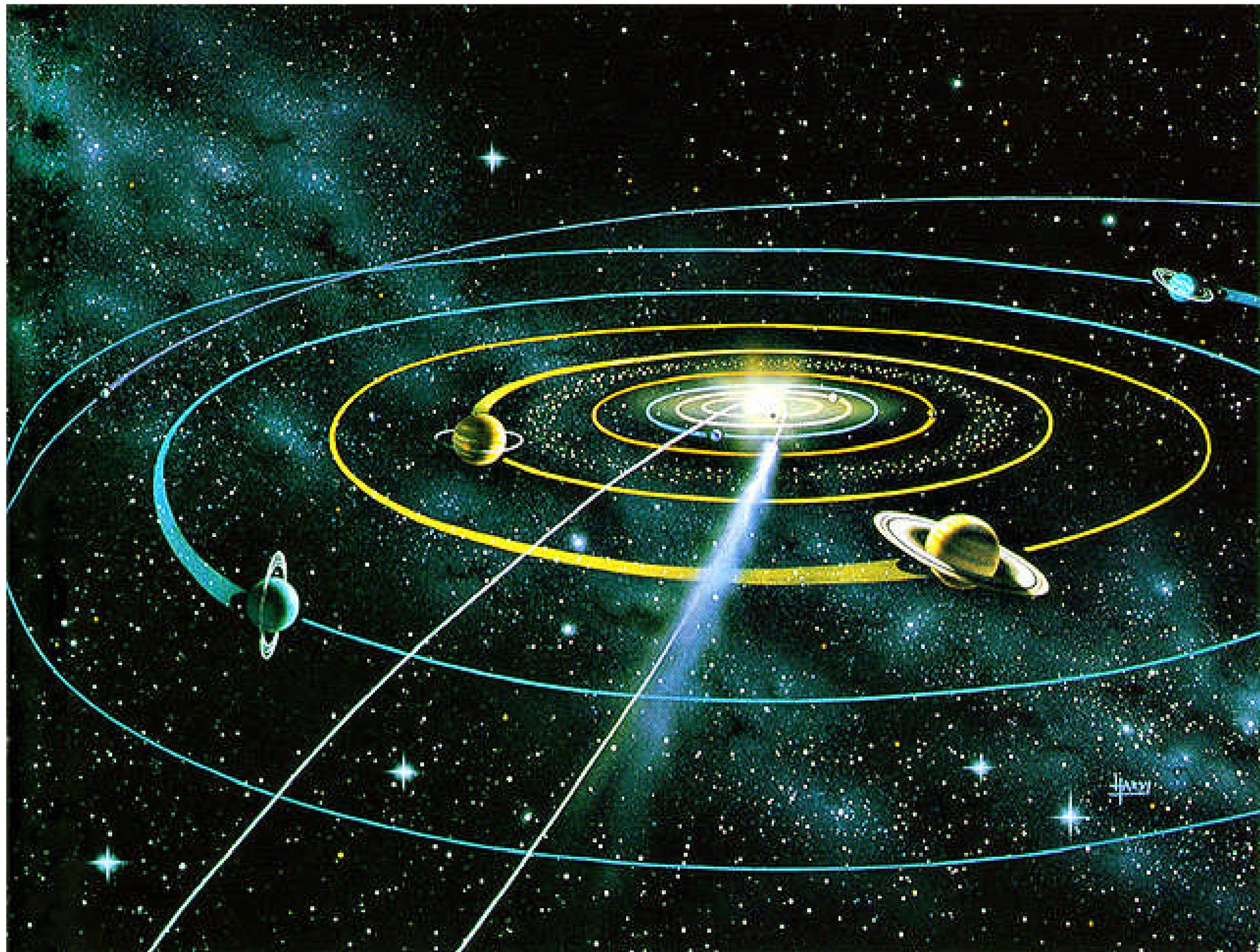
Irregular Orbits of Asteroids



23.4 Minor Members of the Solar System

Comets

- ◆ **Comets are small bodies made of rocky and metallic pieces held together by frozen gases. Comets generally revolve about the sun in elongated orbits.**

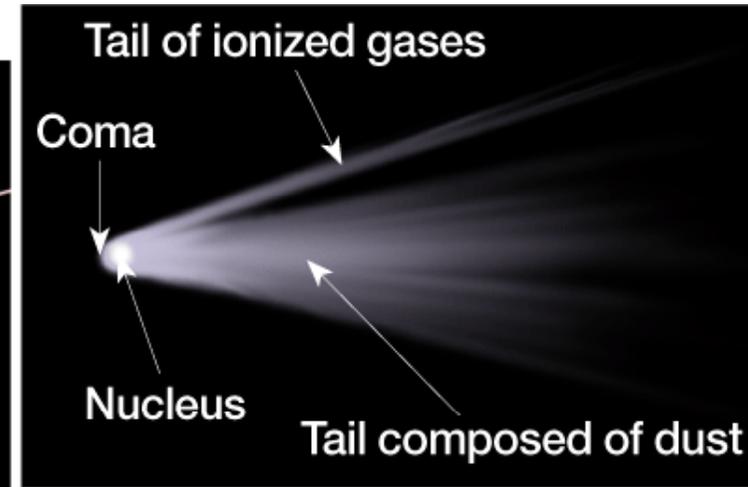
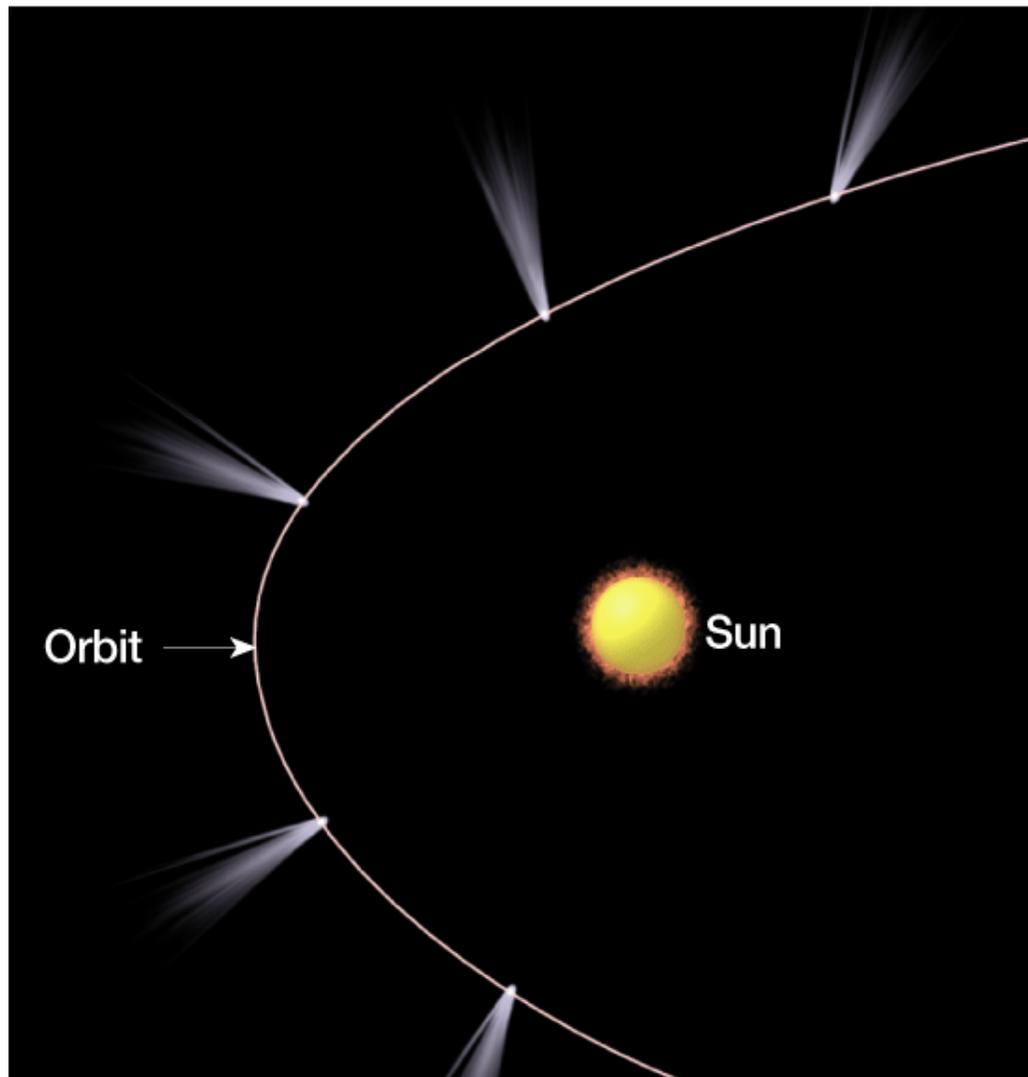


23.4 Minor Members of the Solar System

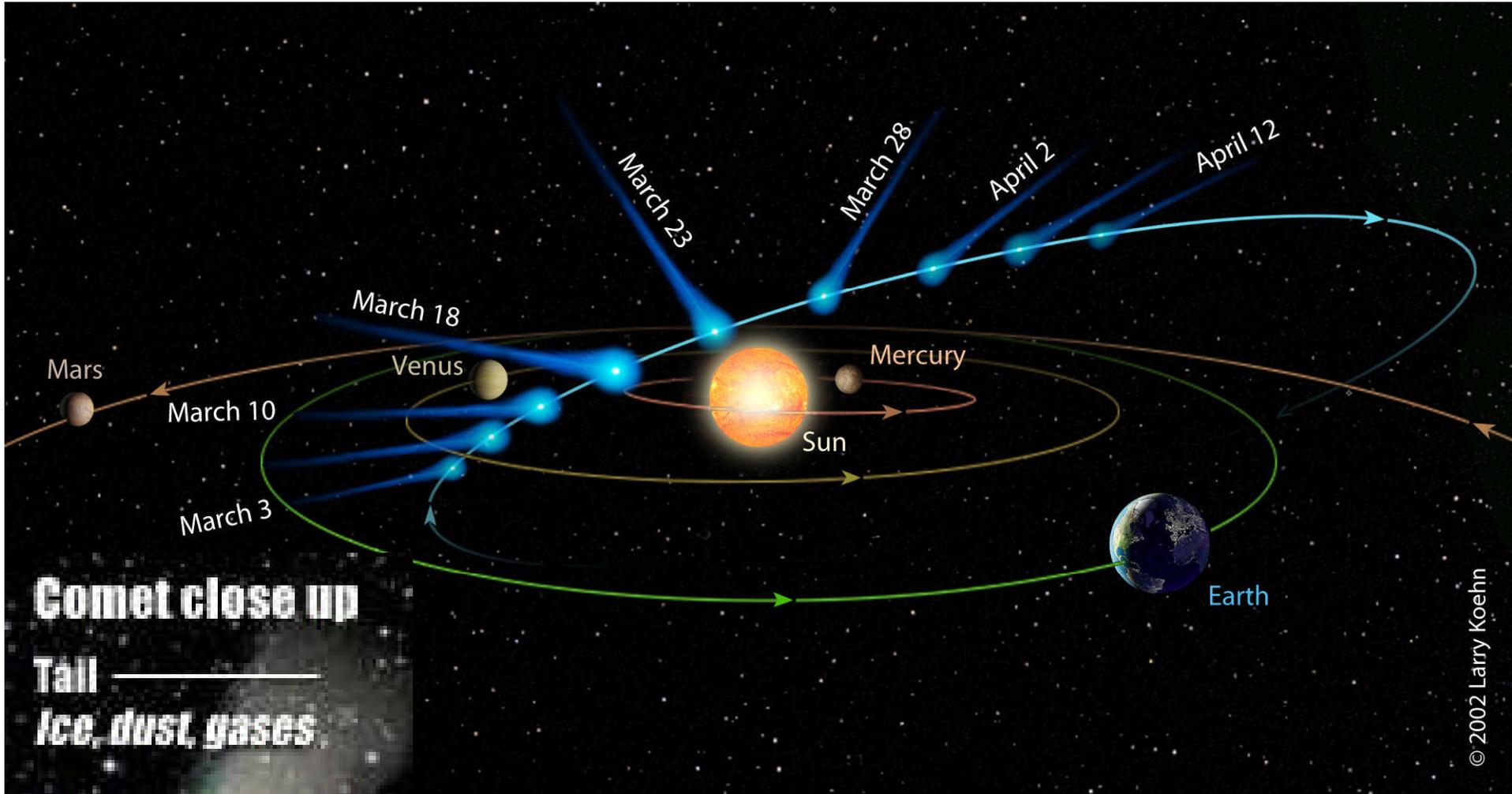
◆ Coma

- **A coma is the fuzzy, gaseous component of a comet's head.**
- **A small glowing nucleus with a diameter of only a few kilometers can sometimes be detected within a coma. As comets approach the sun, some, but not all, develop a tail that extends for millions of kilometers.**

Comet's Tail Points Away from the Sun



Enlarged view



© 2002 Larry Koehn

Comet close up

Tail
Ice, dust, gases

Coma
Core

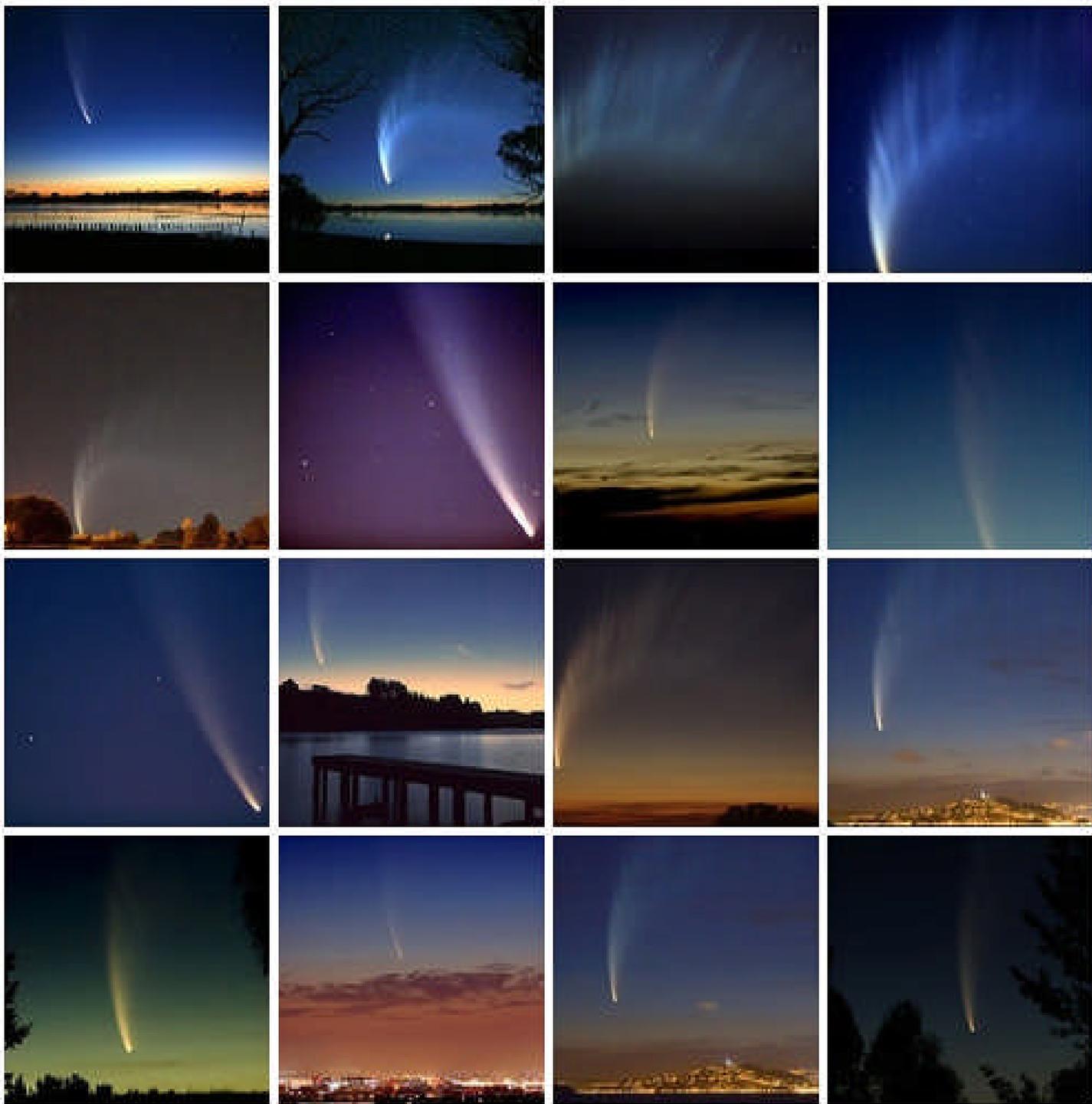


23.4 Minor Members of the Solar System

◆ Halley's Comet 1986

- The most famous short-period comet is Halley's comet. Its orbital period is 76 years.





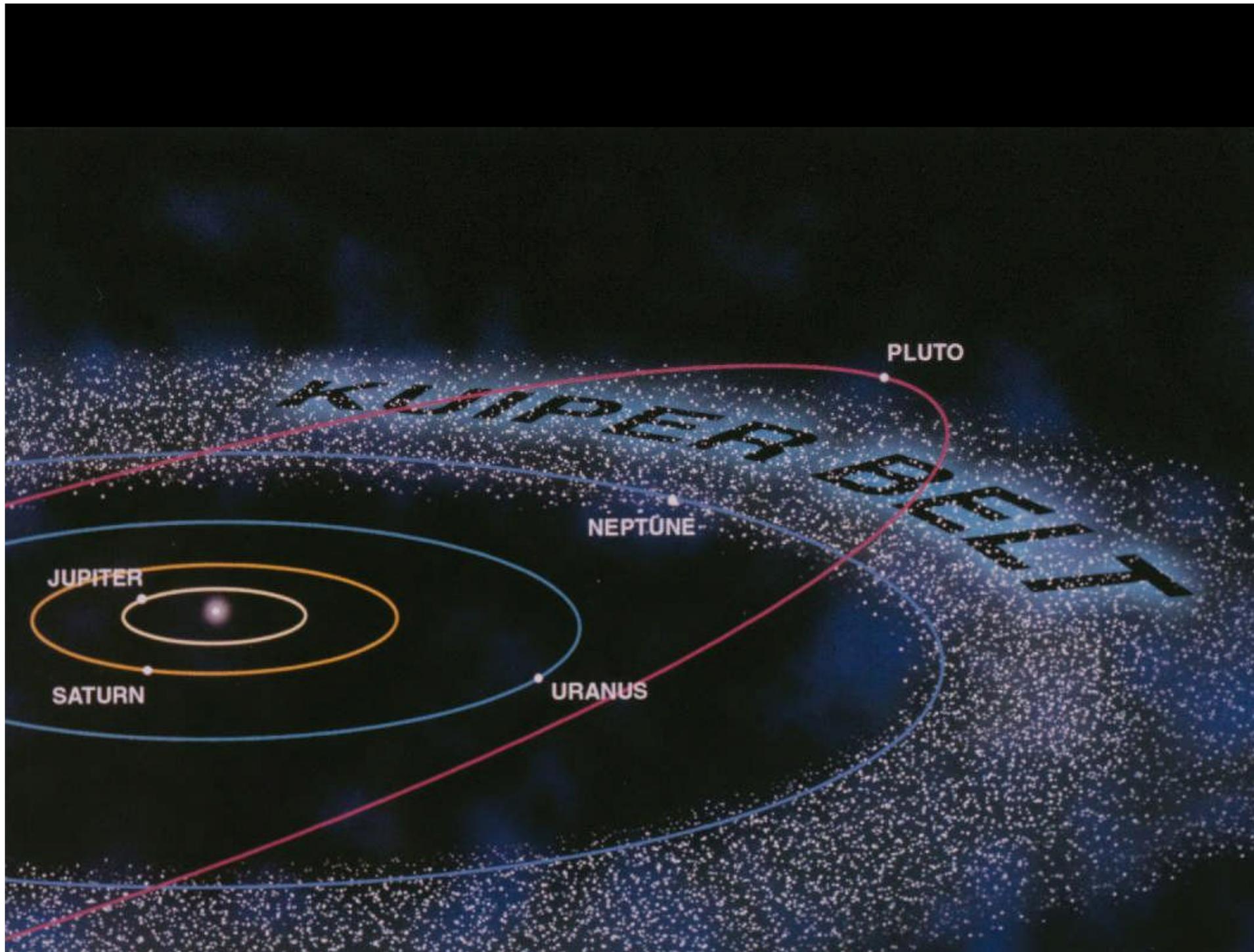
M O Z a r b t h o n e

23.4 Minor Members of the Solar System

Comets

◆ Kuiper Belt

- Like the asteroids in the inner solar system, most Kuiper belt comets move in nearly circular orbits that lie roughly in the same plane as the planets.



Largest known Kuiper Belt objects



"Xena"
(2003 UB313)



Pluto



2005 FY9



2003 EL61



Sedna



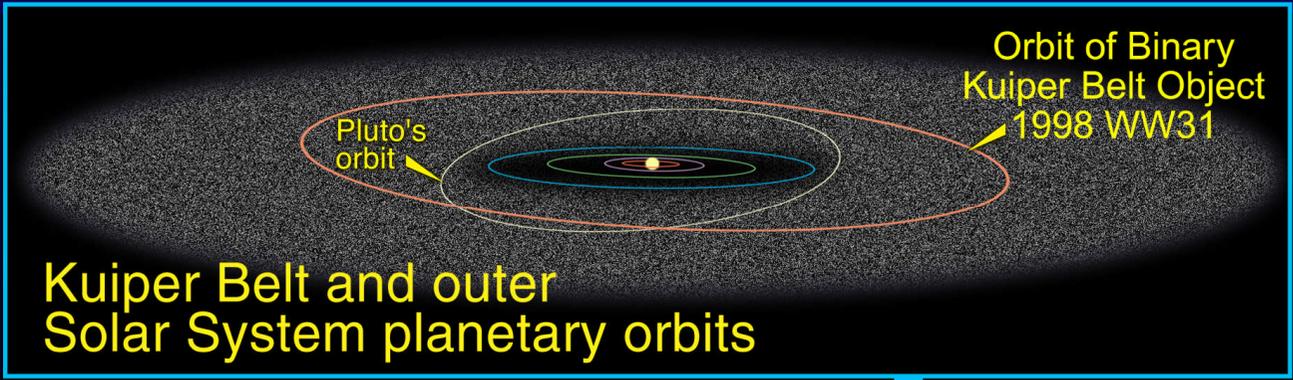
Quaoar



23.4 Minor Members of the Solar System

Comets

- ◆ **Oort Cloud**
 - **Comets with long orbital periods appear to be distributed in all directions from the sun, forming a spherical shell around the solar system called the Oort cloud.**



This is a cutaway drawing of the Oort Cloud, a spherical shell of icy objects surrounding the Solar System. It is depicted as a vast, dense field of small white and grey dots. A blue arrow points from the text box to a specific region within the cloud.

The Oort Cloud (comprising many billions of comets)

Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustration (NASA, JPL)

23.4 Minor Members of the Solar System

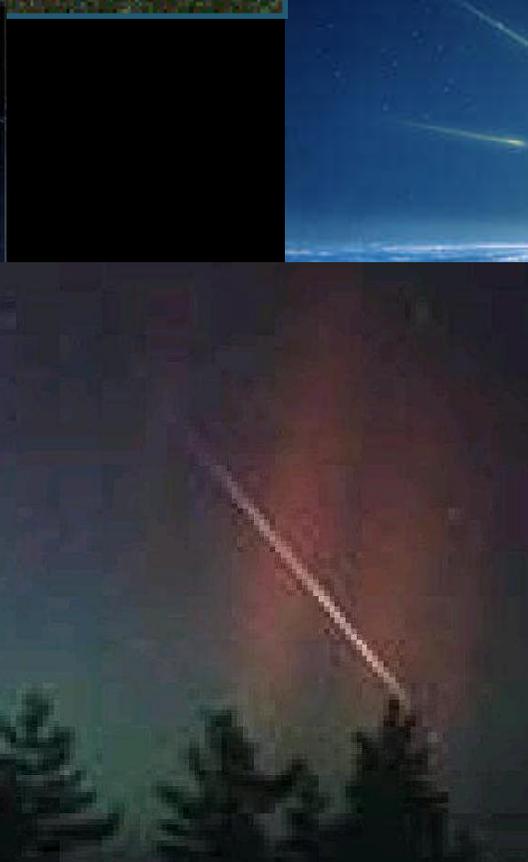
Meteoroids

- ◆ **A meteoroid is a small, solid particle that travels through space.**

23.4 Minor Members of the Solar System

Meteoroids

- ◆ **A meteor is the luminous phenomenon observed when a meteoroid enters Earth's atmosphere and burns up, popularly called a shooting star.**



Numazawa atlas@atlasphoto.com

23.4 Minor Members of the Solar System

Meteoroids

- ◆ **A meteorite is any portion of a meteoroid that reaches Earth's surface.**





Meteor lake Kaali, Estonia





Crater Lake Oregon

23.4 Minor Members of the Solar System

- ◆ **Most meteoroids originate from any one of the following three sources: (1) interplanetary debris that was not gravitationally swept up by the planets during the formation of the solar system, (2) material from the asteroid belt, or (3) the solid remains of comets that once traveled near Earth's orbit.**

Major Meteor Showers

Table 2 Major Meteor Showers

Shower	Approximate Dates	Associated Comet
Quadrantids	Jan. 4–6	
Lyrids	Apr. 20–23	Comet 1861 I
Eta	May 3–5	Halley's comet
Aquarids		
Delta	July 30	
Aquarids		
Perseids	Aug. 12	Comet 1862 III
Draconids	Oct. 7–10	Comet Giacobini-Zinner
Orionids	Oct. 20	Halley's comet
Taurids	Nov. 3–13	Comet Encke
Andromedids	Nov. 14	Comet Biela
Leonids	Nov. 18	Comet 1866 I
Geminids	Dec. 4–16	