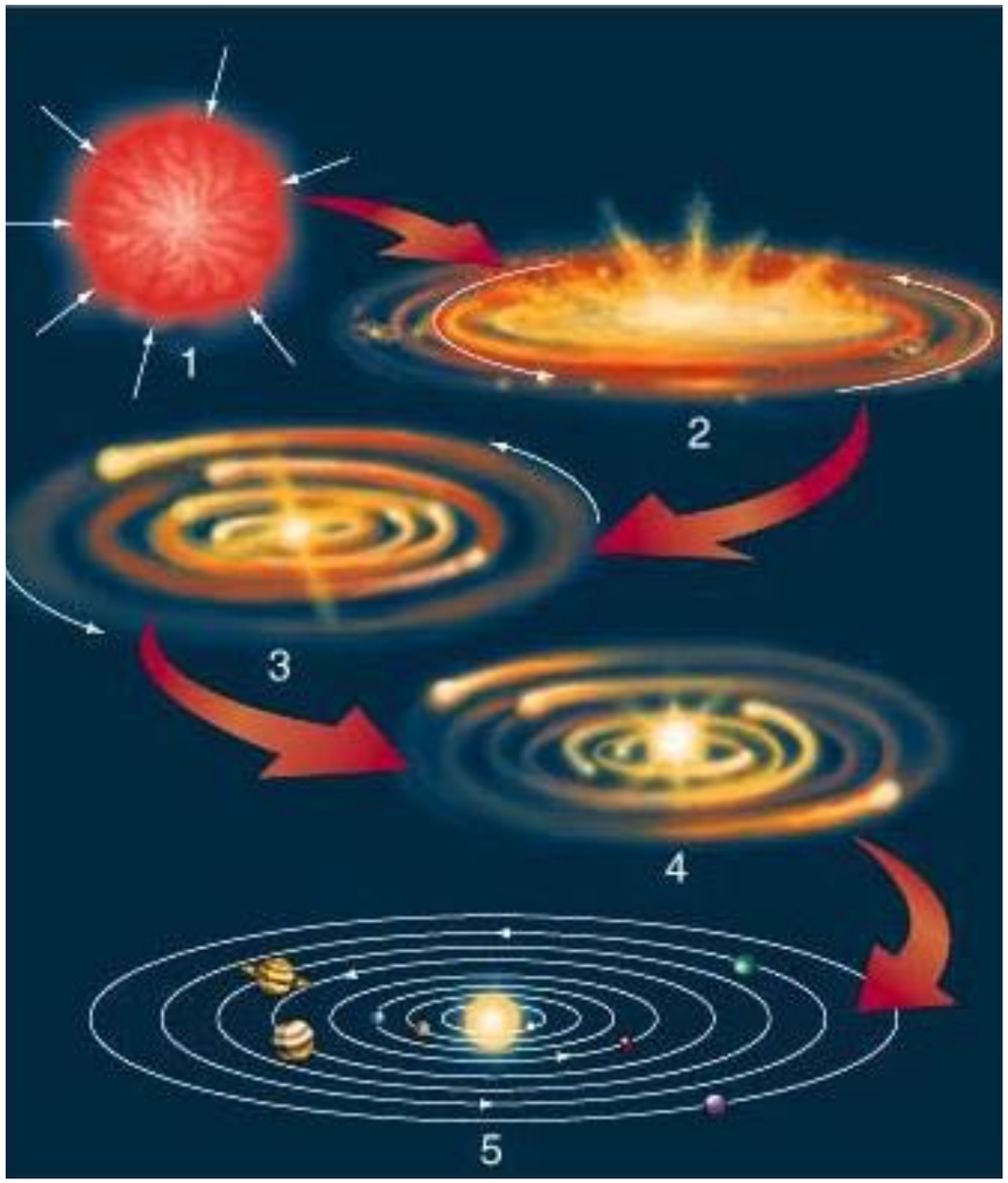
Today

- Solar System
  - contents
  - formation

- Homework due



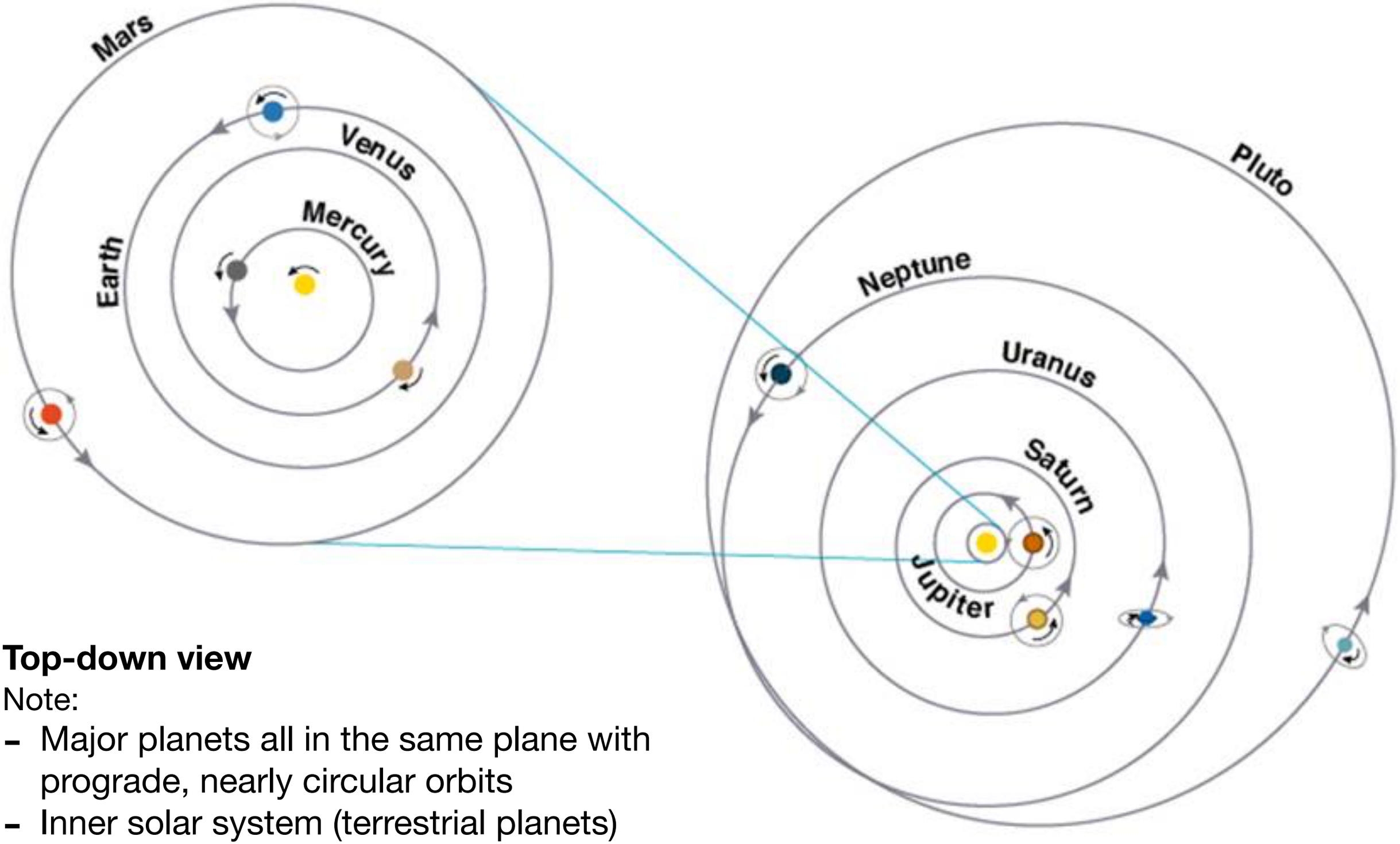
Contents of the Solar System

- The Sun
- Major Planets
  - Terrestrial: Mercury, Venus, Earth, Mars
  - Jovian planets: Jupiter, Saturn
  - Ice Giants: Uranus, Neptune

  } Gas Giants
- Moons
- Dwarf Planets
  - KBOs/TNOs: Pluto, Quaoar, Eris, Sedna...
- Asteroids

  KBO: Kuiper Belt Object
  TNO: Trans-Neptunian Object
  } same thing
- Comets
  - misc. dust, meteoroids, solar wind particles...

Layout of the Solar System



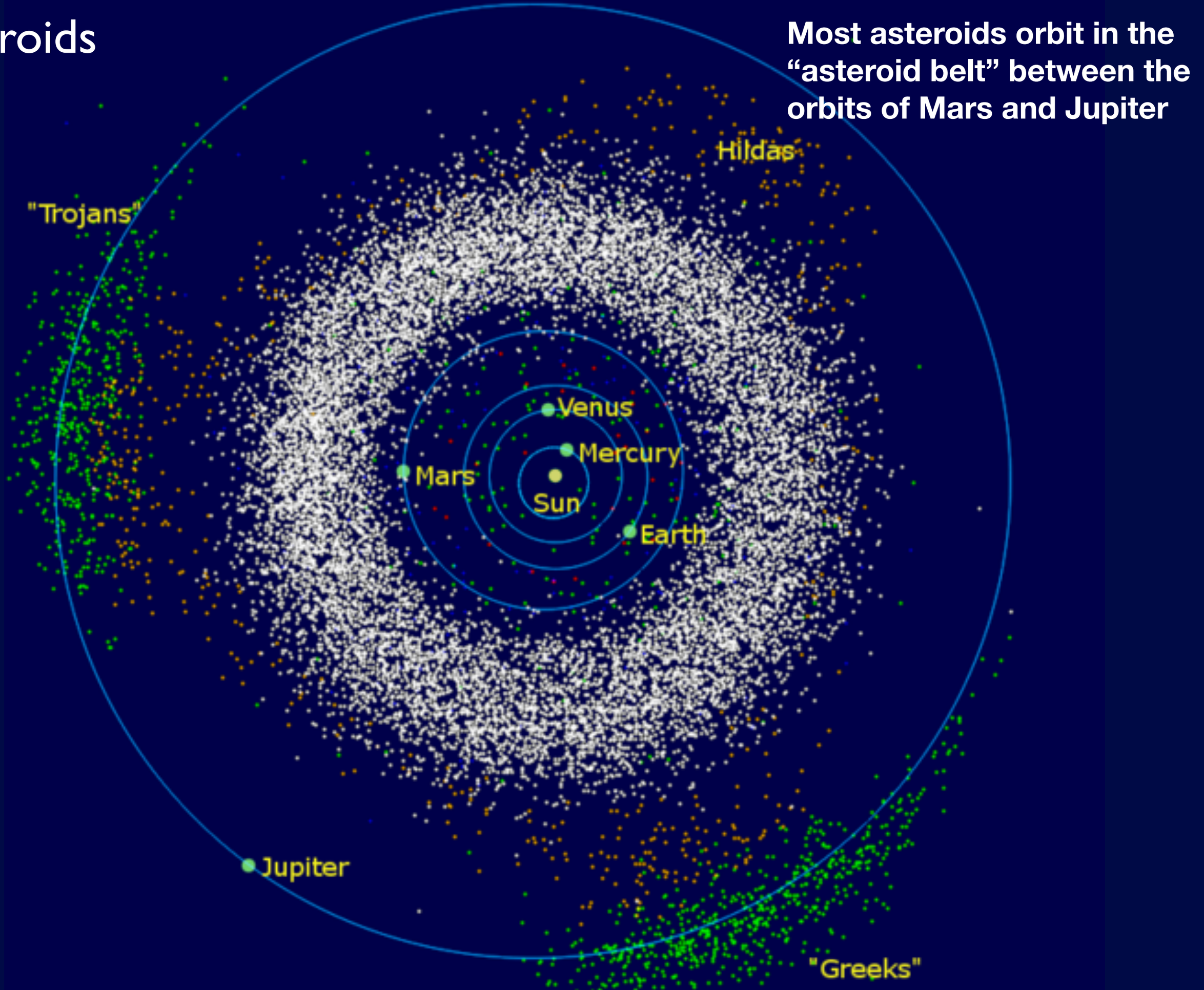
Top-down view

Note:

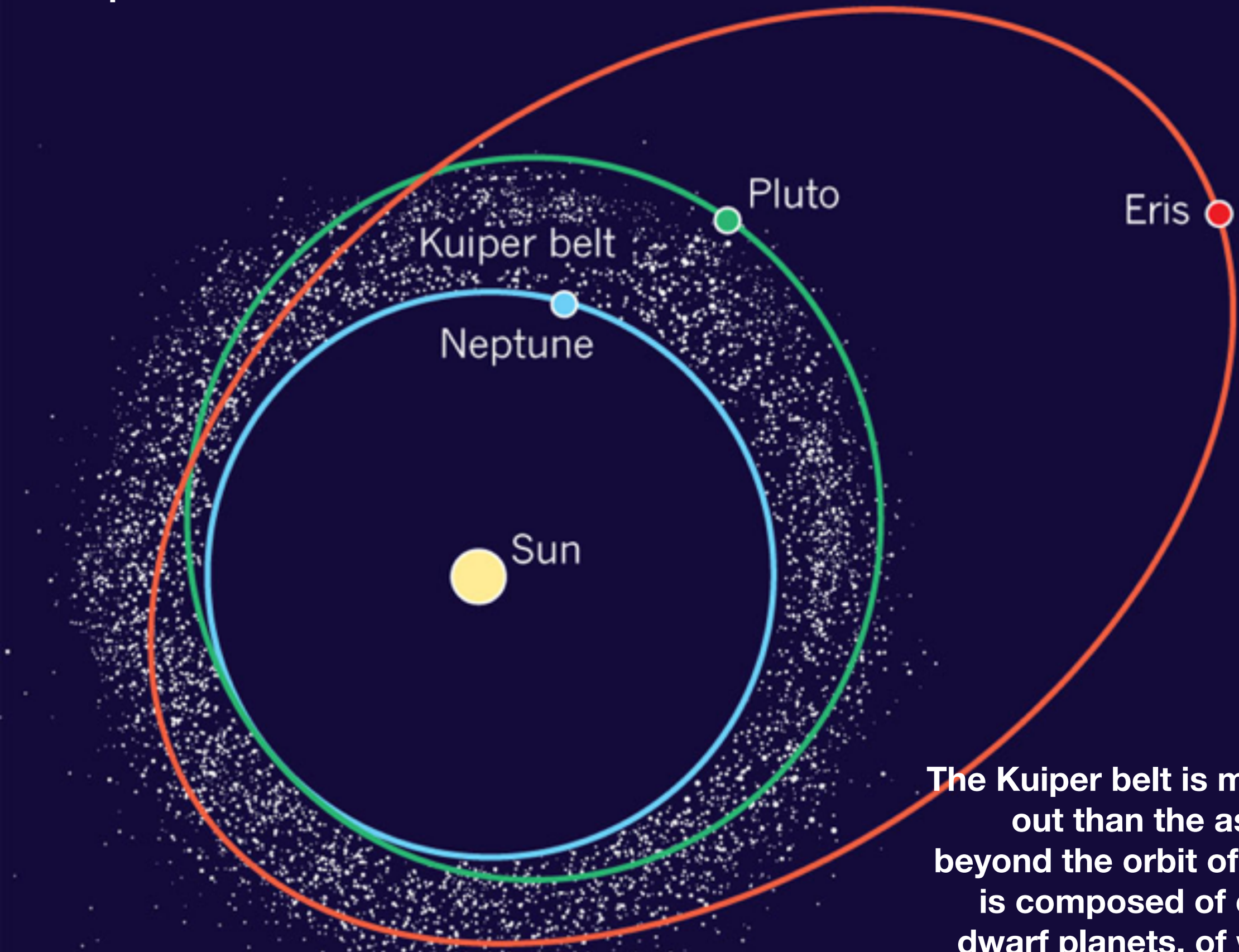
- Major planets all in the same plane with prograde, nearly circular orbits
- Inner solar system (terrestrial planets) much more compact than outer solar system (gas giants)

Asteroids

Most asteroids orbit in the "asteroid belt" between the orbits of Mars and Jupiter

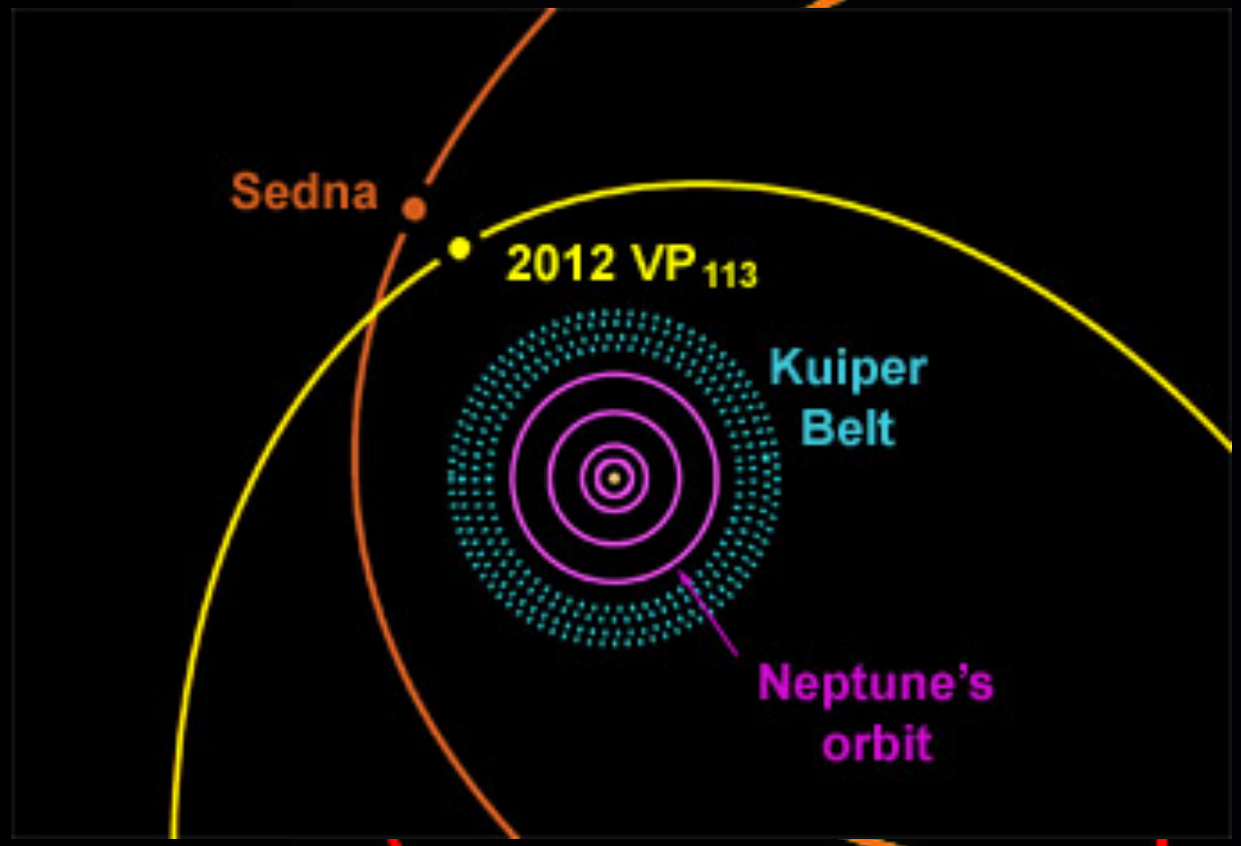


Kuiper belt



The Kuiper belt is much farther out than the asteroid belt, beyond the orbit of Neptune. It is composed of comets and dwarf planets, of which Pluto was the first example

**The Kuiper belt appears to have an outer edge,
but there are a few dwarf planets further out**



Both Sedna &
Biden are currently
near perihelion

what're the odds?
Think about
Kepler's Laws

Sedna

P = 11,400 yr
discovered 2003

2012 VP113

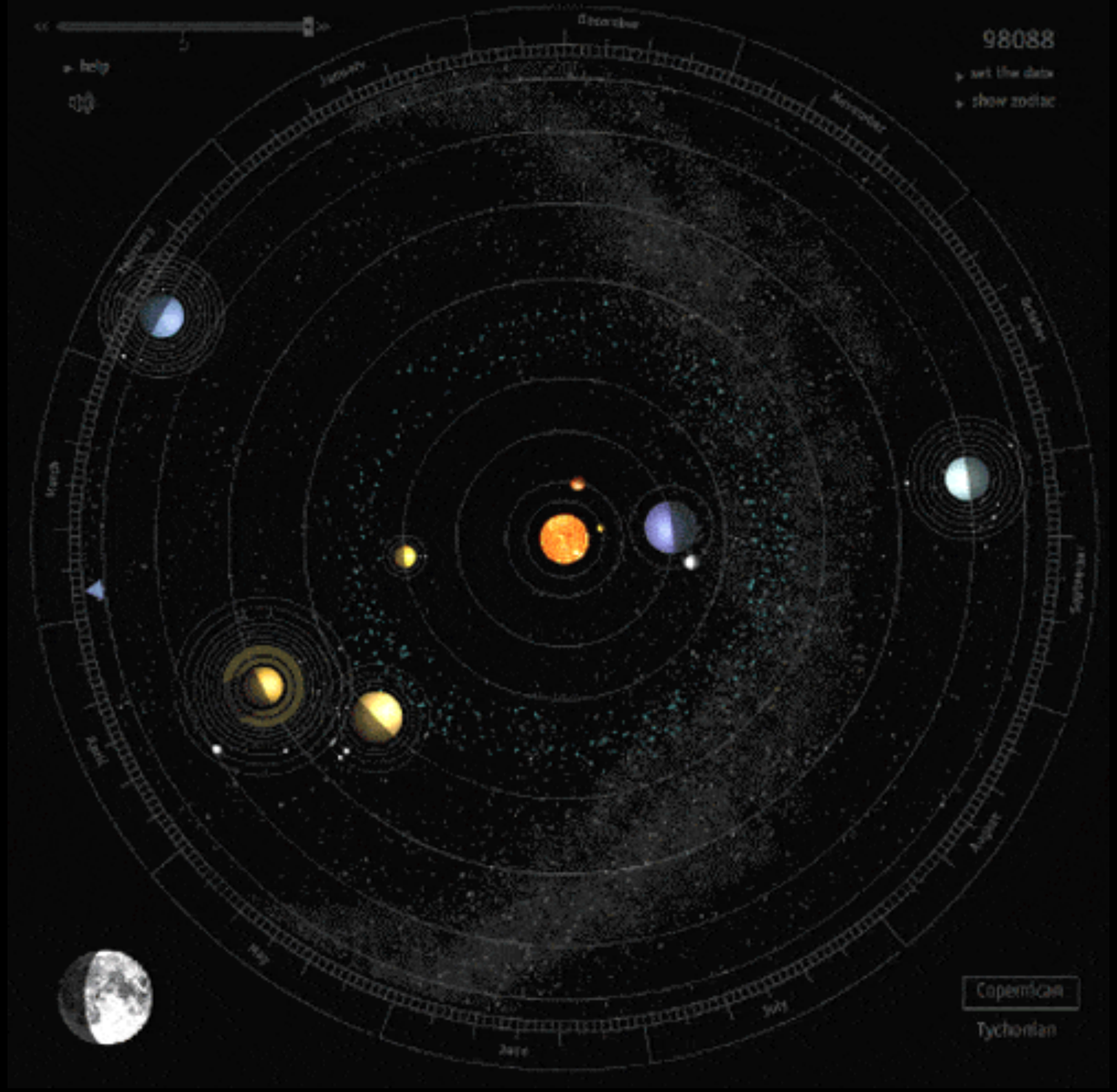
discovered 2012 (nicknamed "Biden")

Kuiper Belt

The orange track represents a typical KBO orbit. Pluto's orbit is represented by the yellow ring.

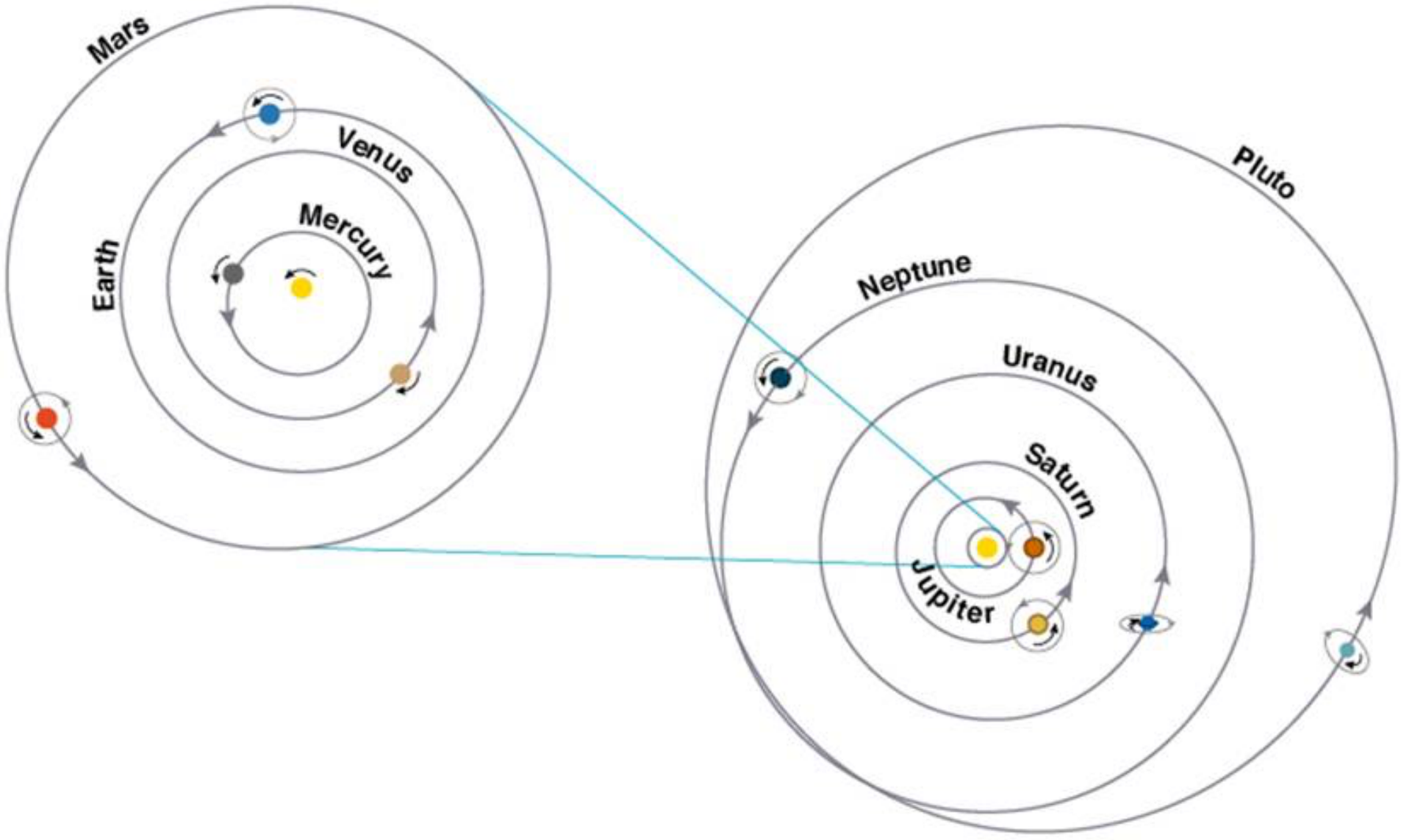
The Oort cloud is a diffuse sphere of comets far beyond the edge of the Kuiper belt

Oort Cloud



http://popperfont.net/2012/11/13/the-ultimate-solar-system-animated-gif/

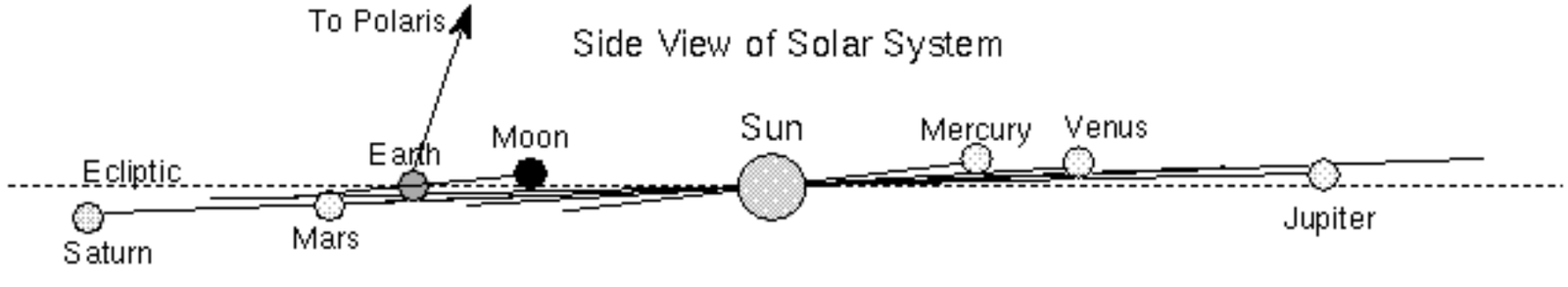
top view:

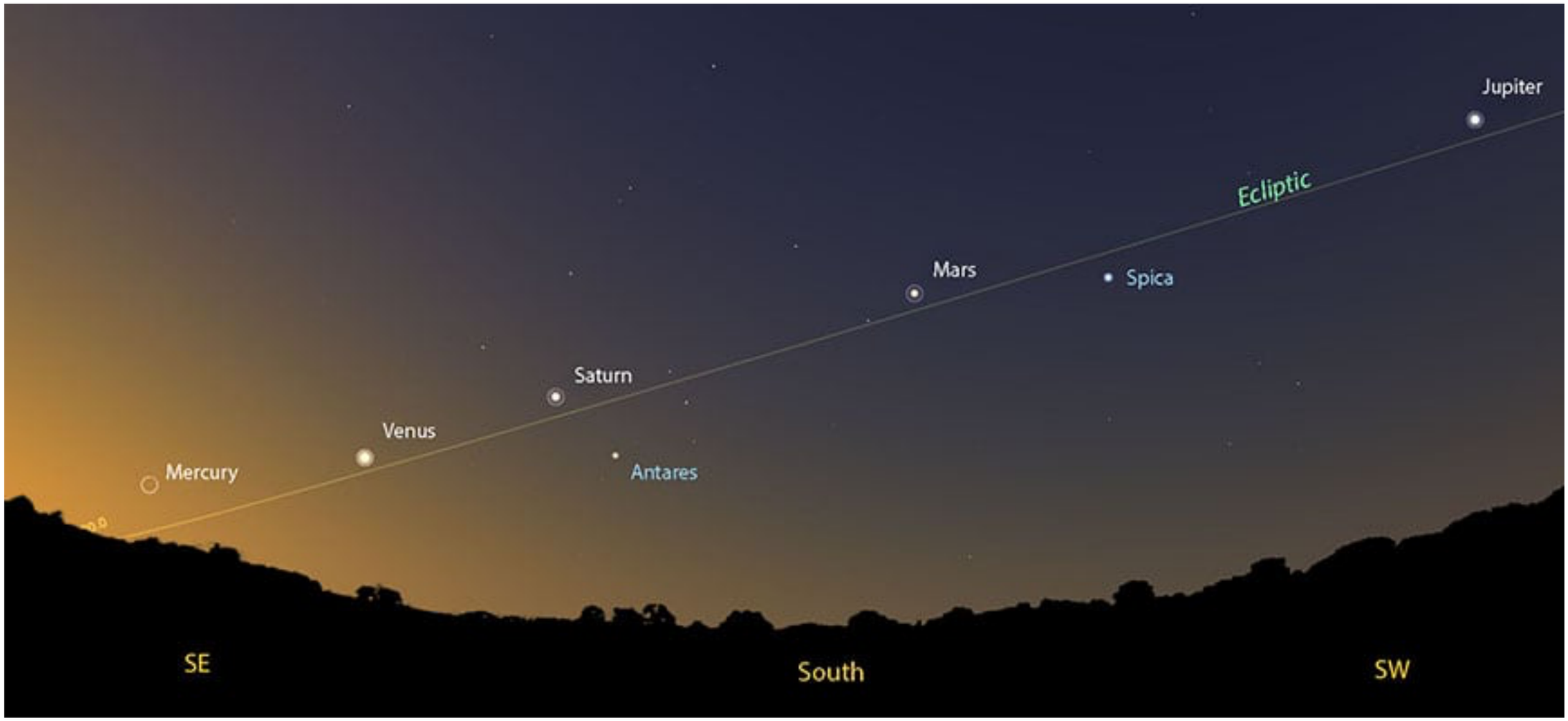


There are eight major planets with nearly circular orbits.
The planets all orbit in the same direction in nearly the same plane

Consequently, they appear along the ecliptic plane in the sky.

side view:





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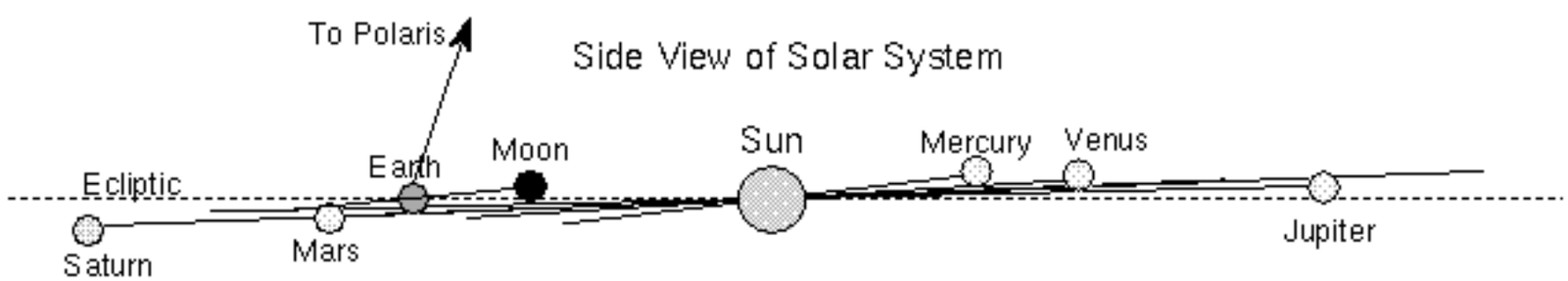
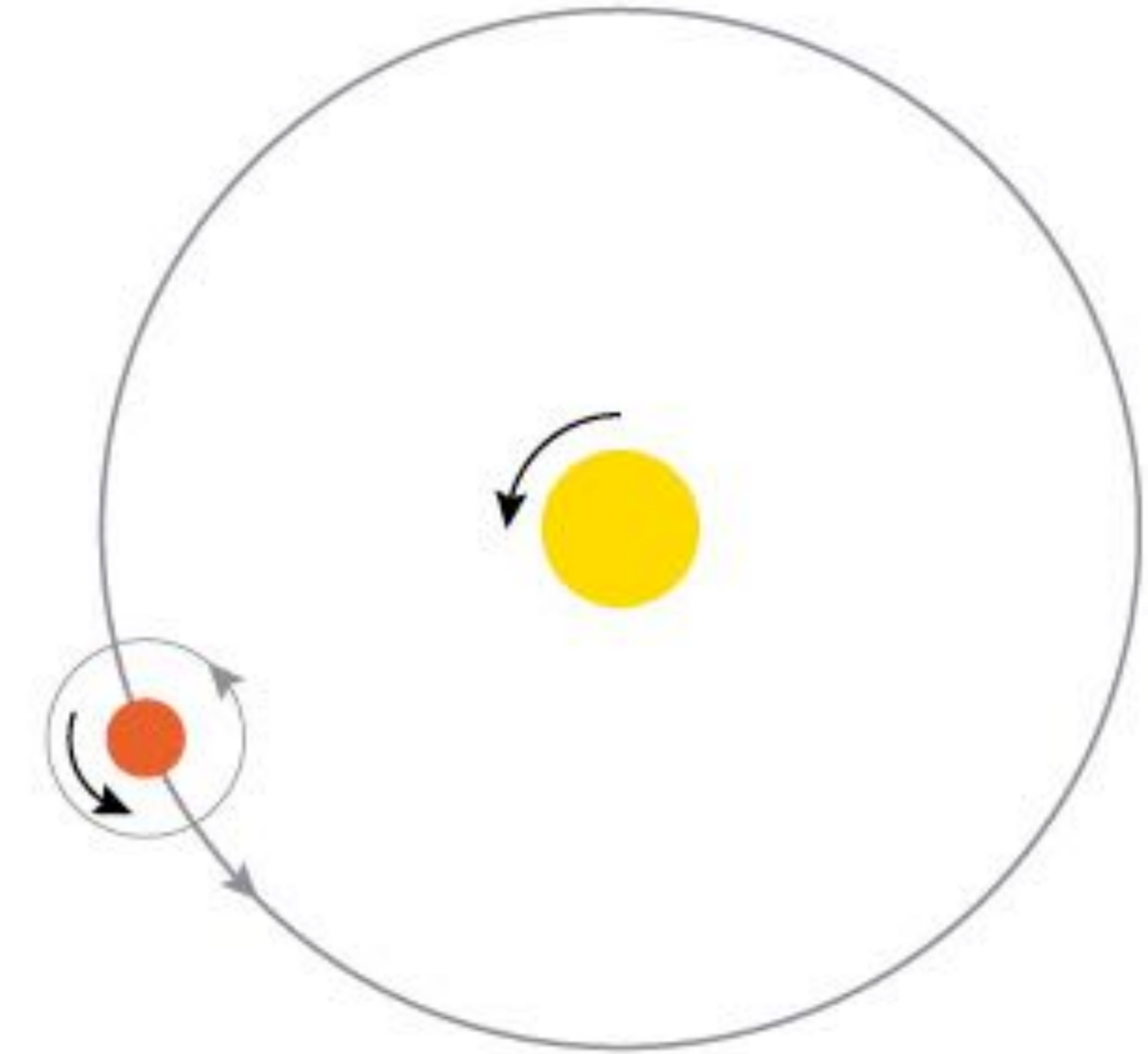
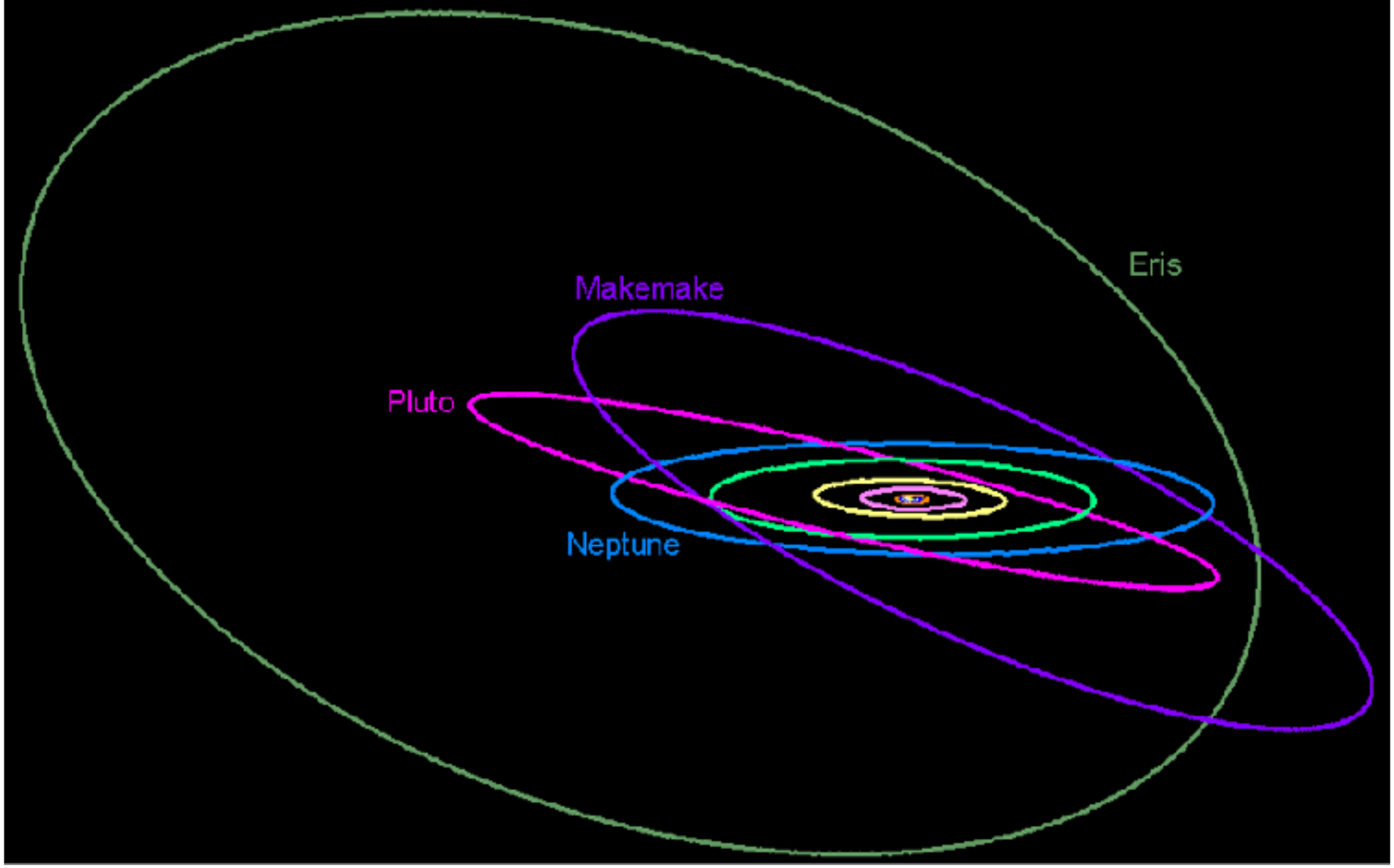


Motion of Large Bodies



- All large bodies in the solar system revolve (orbit) in the same direction in the same plane.
- Most also rotate (spin) in that direction.
  – "***prograde***"

"Right hand rule"



Dwarf planets are smaller than the major planets and some have quite elliptical orbits.

Most dwarf planets & asteroids also revolve prograde.

Comets have highly elliptical orbits; often highly inclined from the planetary plane.

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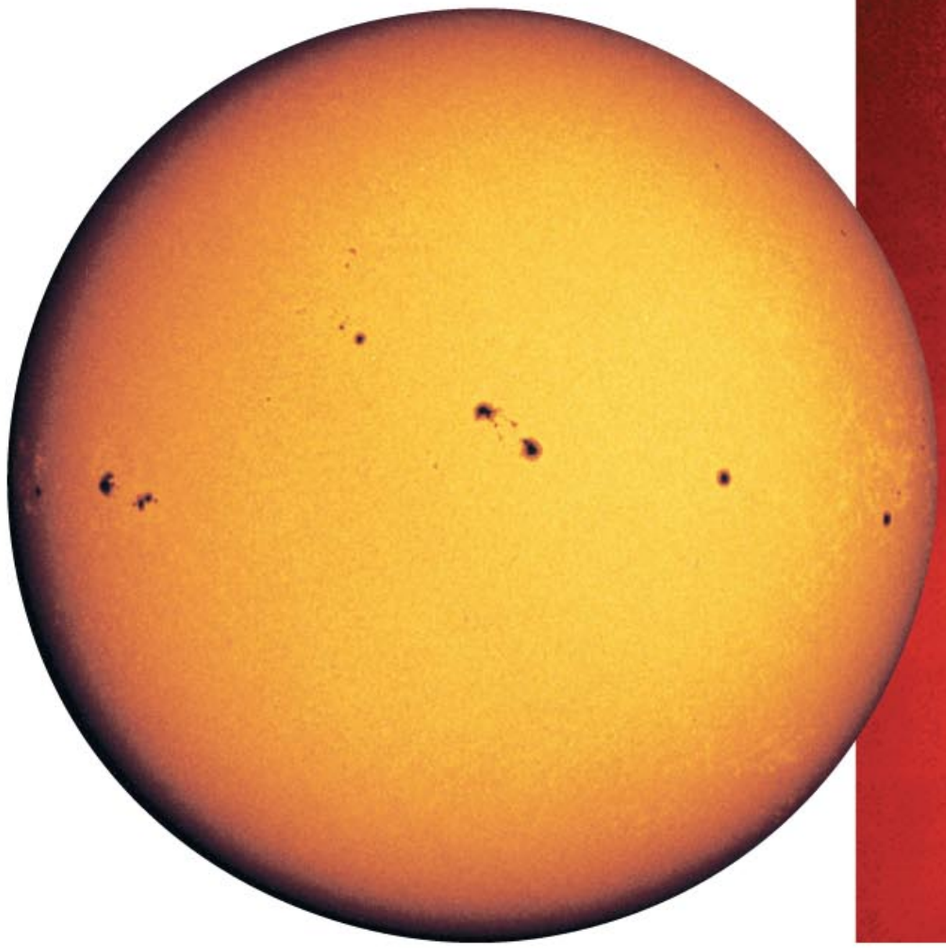
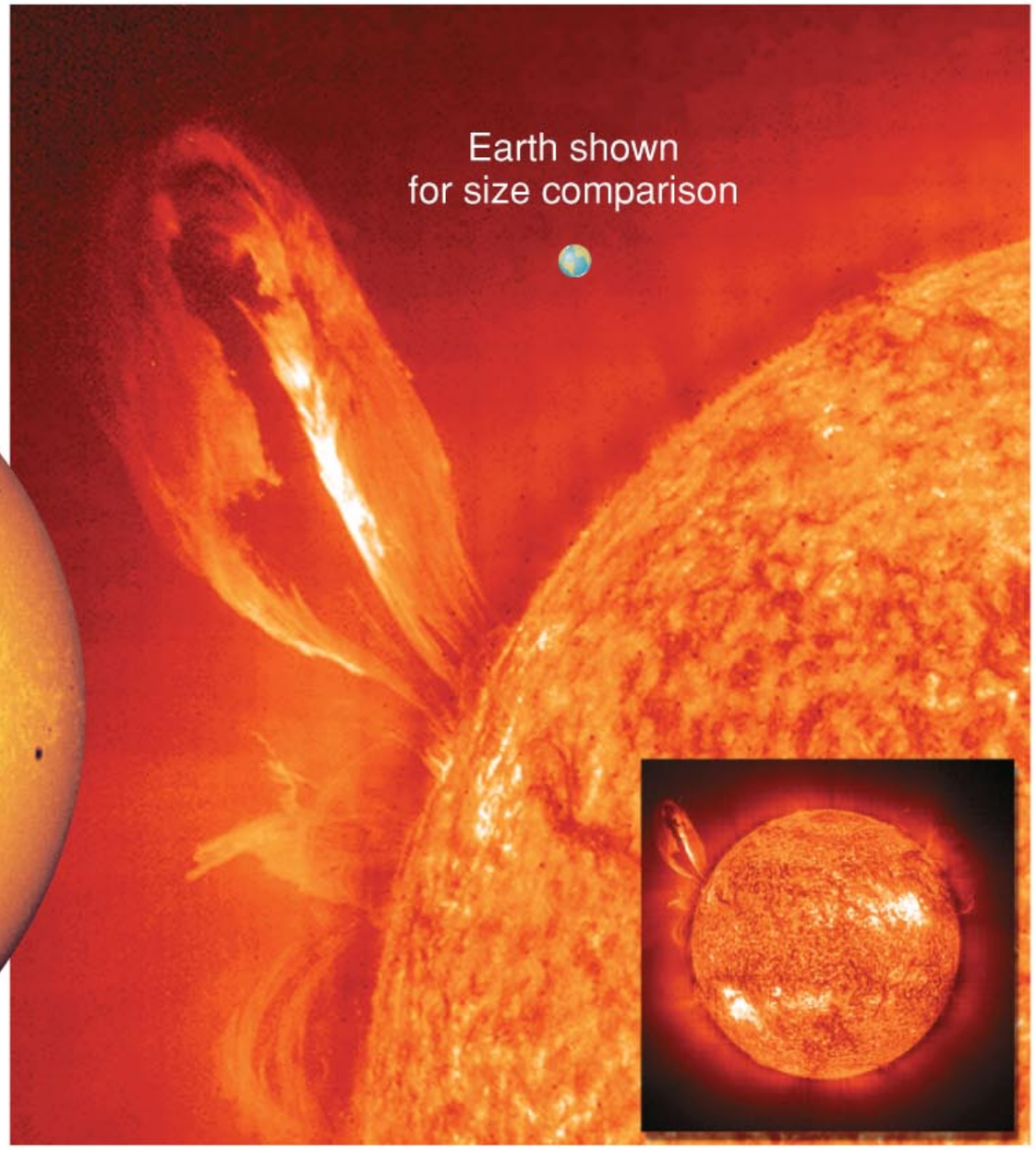
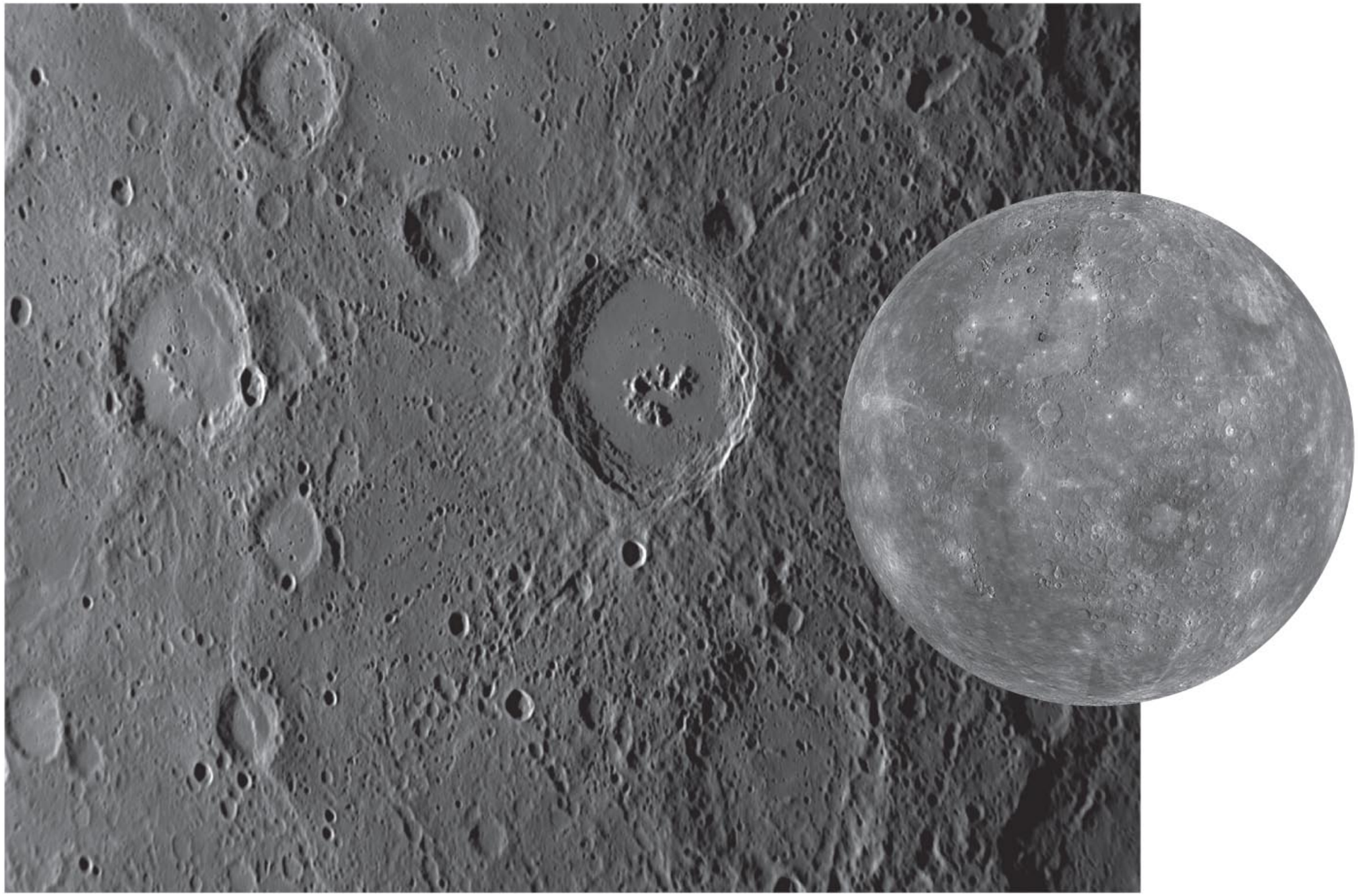
- The Sun





- Over 99.9% of solar system's mass
- Made mostly of H/He gas (plasma)
- Converts 4 million tons of mass into energy each second

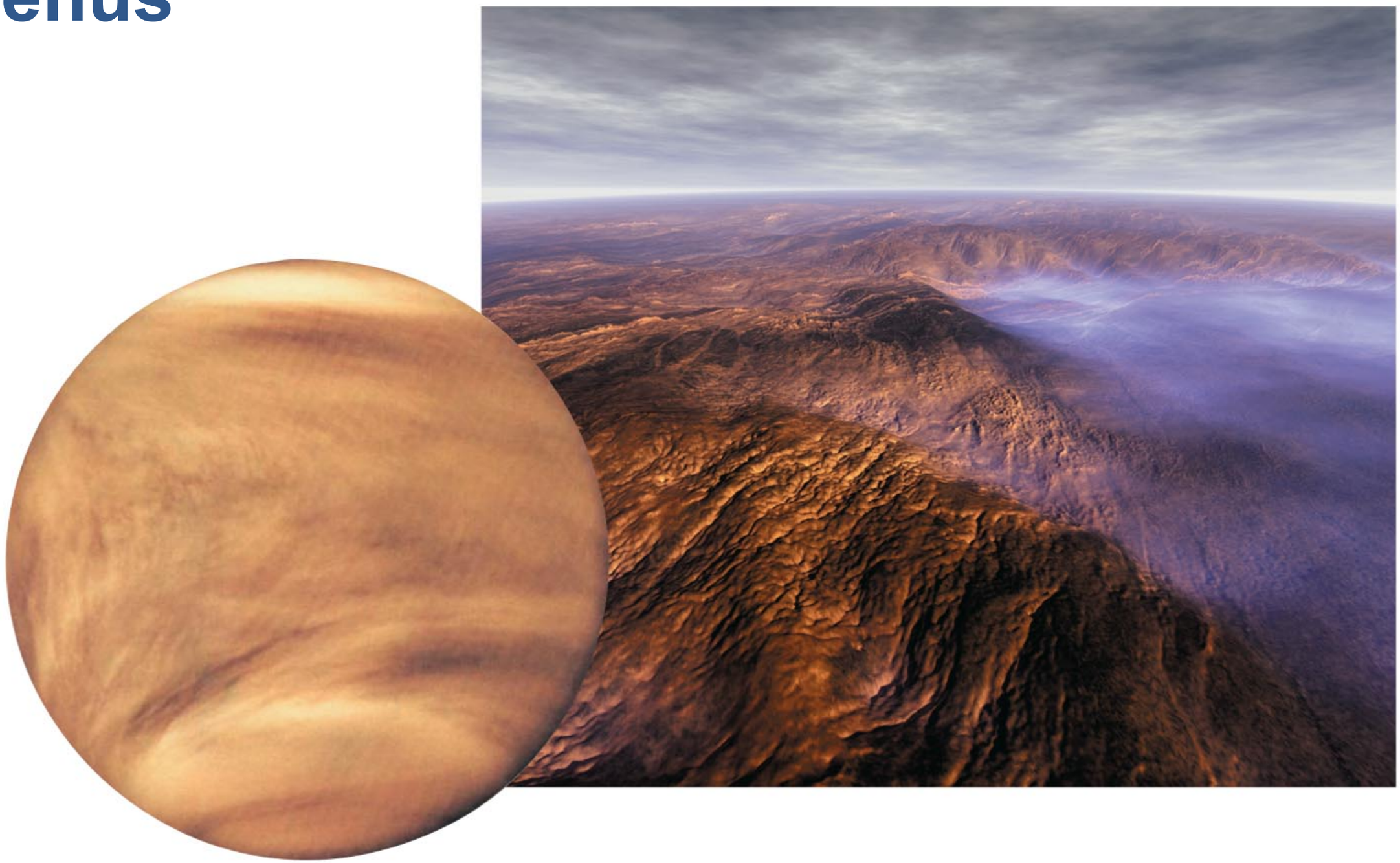
Mercury



- Made of metal and rock; large iron core
- Desolate, cratered; long, tall, steep cliffs
- Very hot, very cold: 425°C (day), –170°C (night)

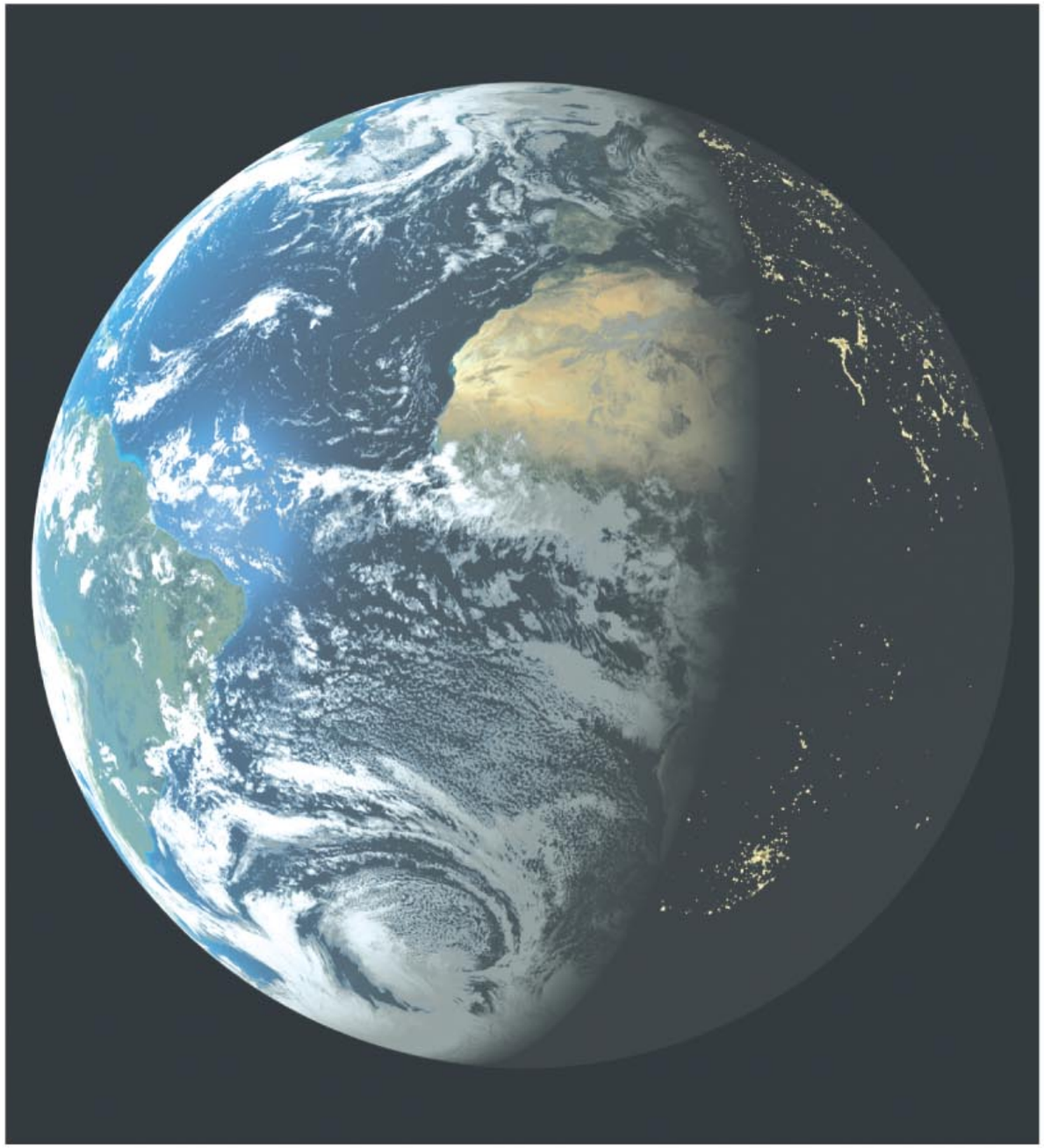
3:2 spin-orbit coupling

Venus



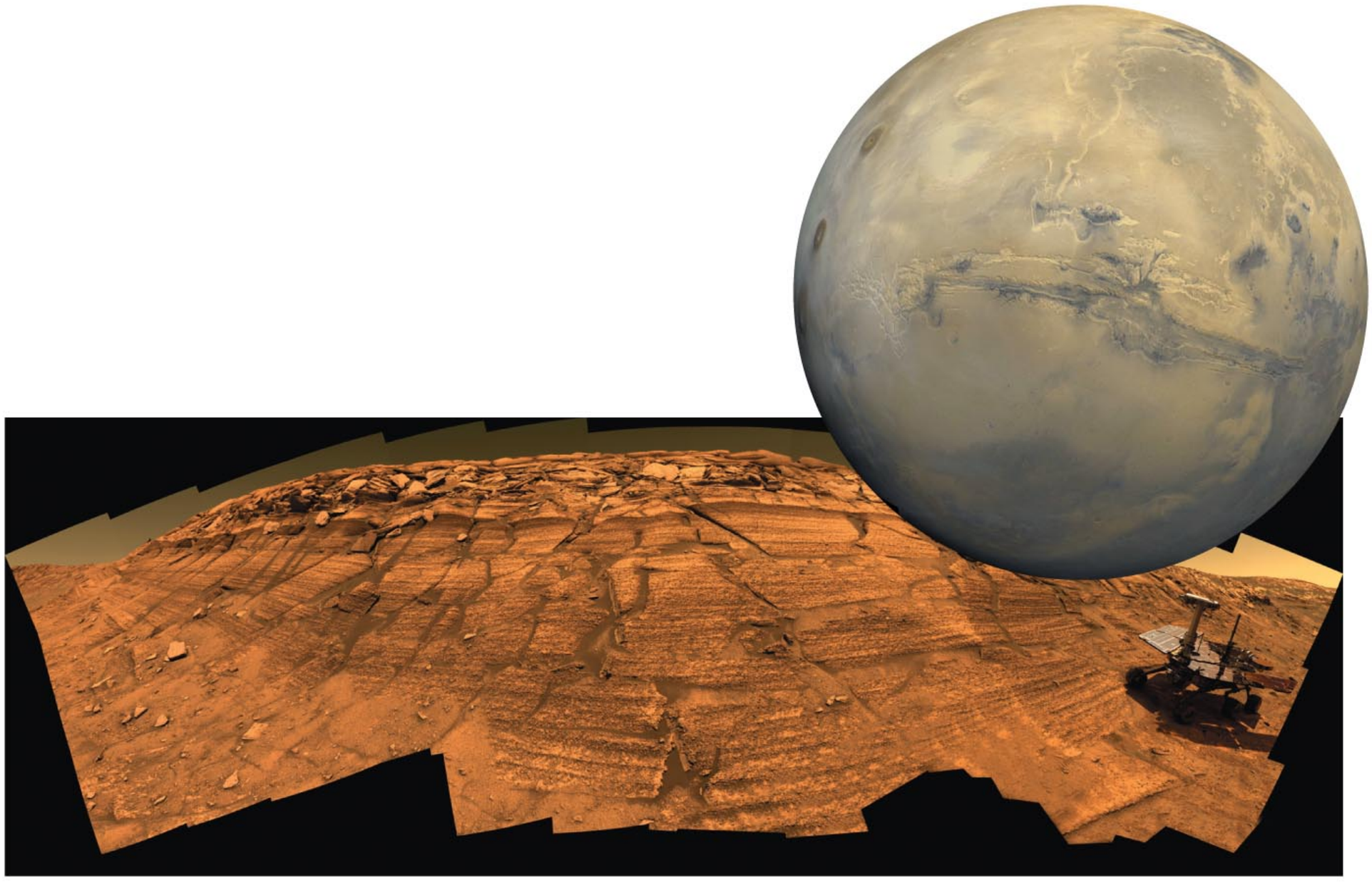
- Nearly identical in size to Earth; surface hidden by clouds
- Hellish conditions due to an extreme **greenhouse effect**
- Even hotter than Mercury: 470°C, day and night

Earth



- An oasis of life
- The only surface liquid water in the solar system
- A surprisingly large moon

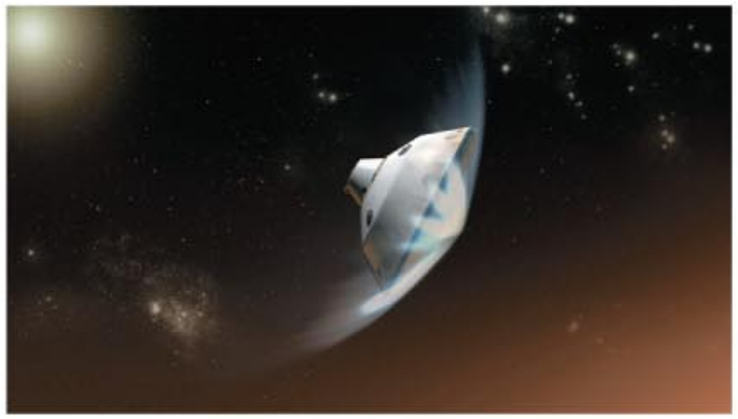
Mars



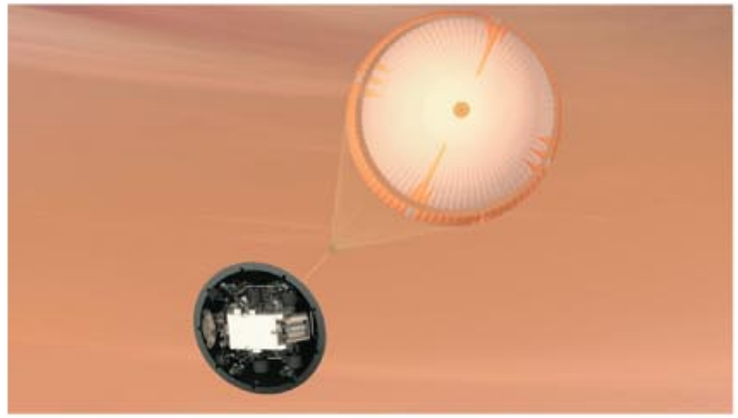
- Looks almost Earth-like, but don't go without a spacesuit!
- Giant volcanoes, a huge canyon, polar caps, more
- Water flowed in distant past; could there have been life?

Mars

- *Curiosity* rover landed in August 2012.



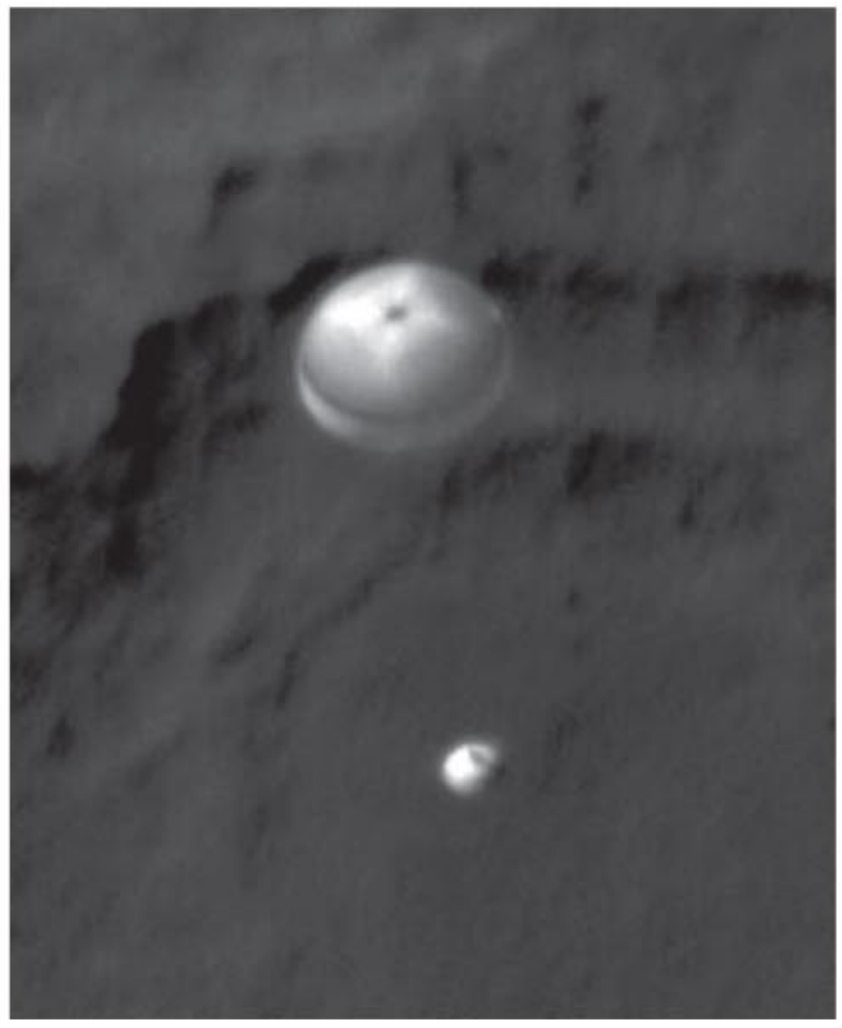
1 Friction slows spacecraft as it enters Mars atmosphere.



2 Parachute slows spacecraft to about 350 km/hr.

3 Rockets slow spacecraft to halt; "sky crane" tether lowers rover to surface.

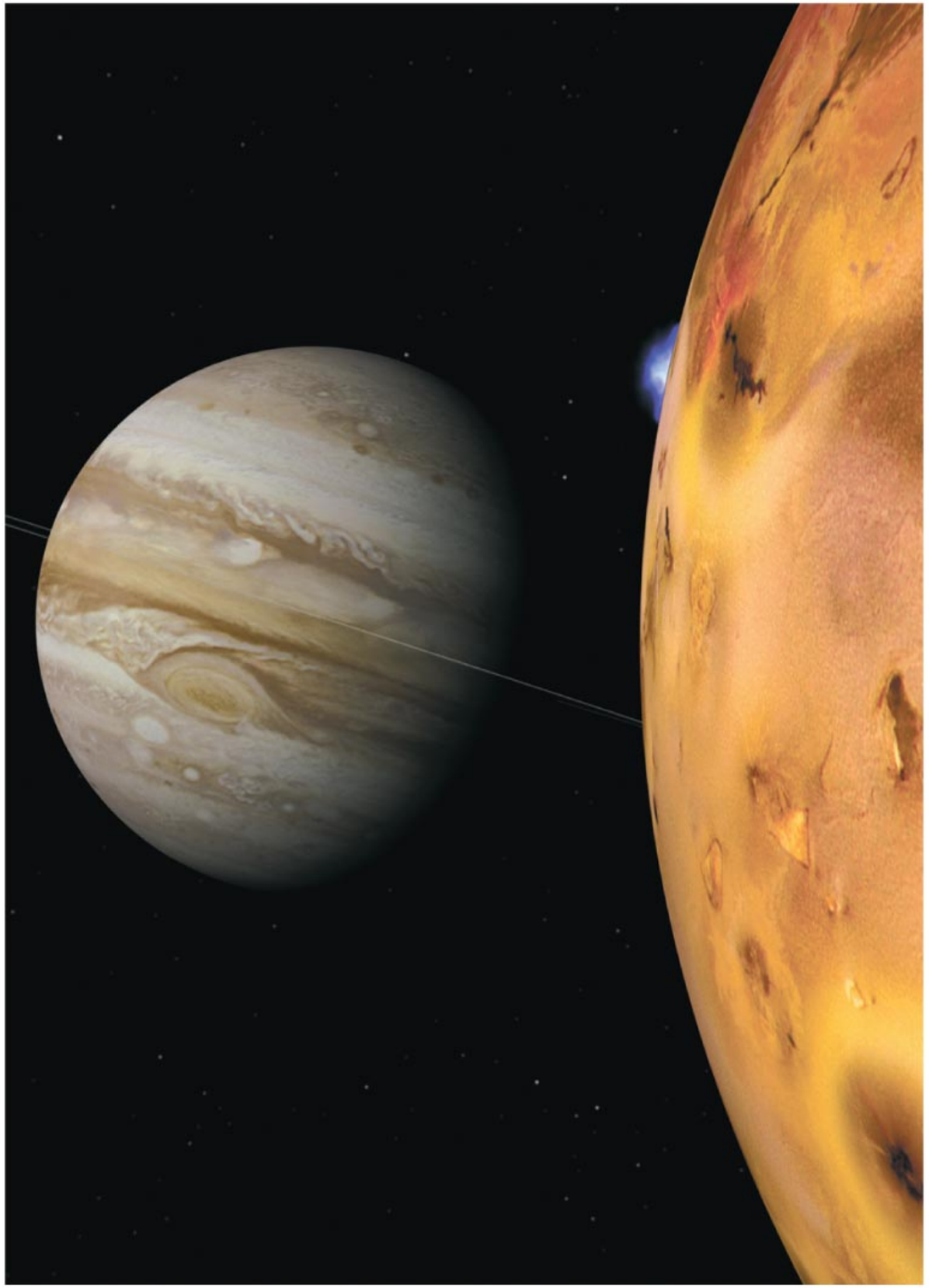
4 Tether released, the rocket heads off to crash a safe distance away.



As it flew overhead, the *Mars Reconnaissance Orbiter* took this photo of the spacecraft with its parachute deployed.

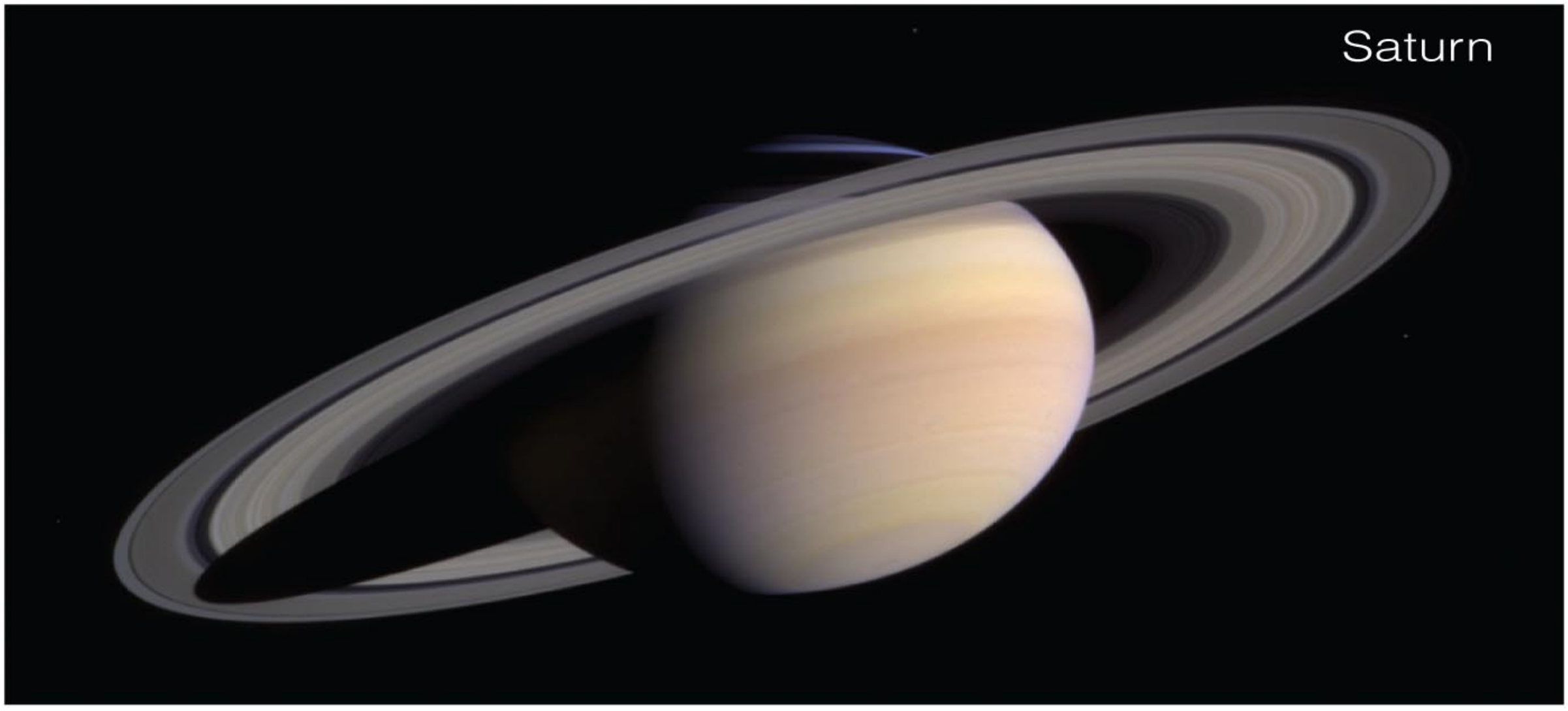
http://www.jpl.nasa.gov/video/details.php?id=1001 1:00 mark

Jupiter



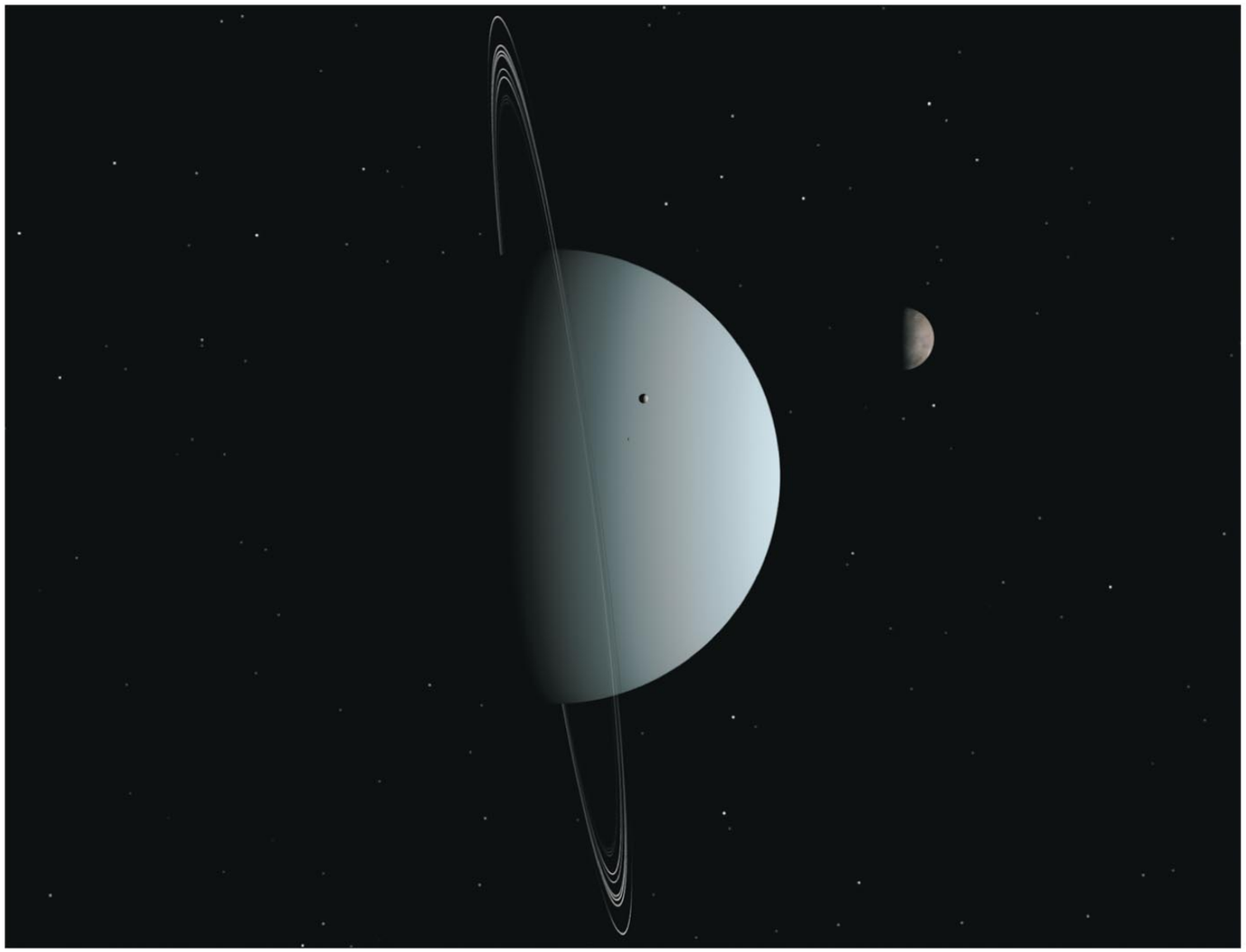
- Much farther from Sun than inner planets
- Mostly H/He; no solid surface
- 300 times more massive than Earth
- Many moons, rings

Saturn



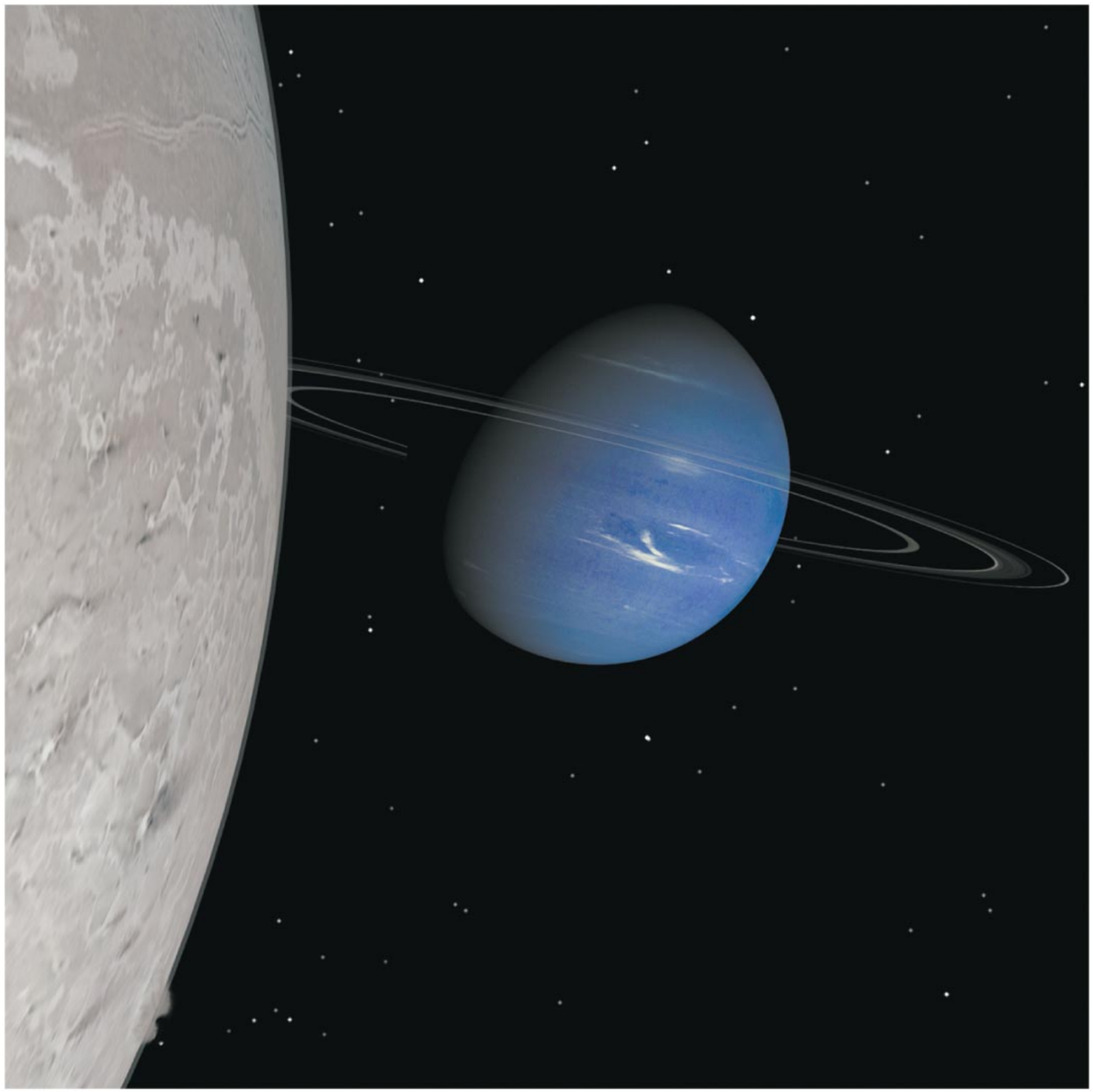
- Giant and gaseous like Jupiter
- Spectacular rings
- Many moons, including cloudy Titan

Uranus



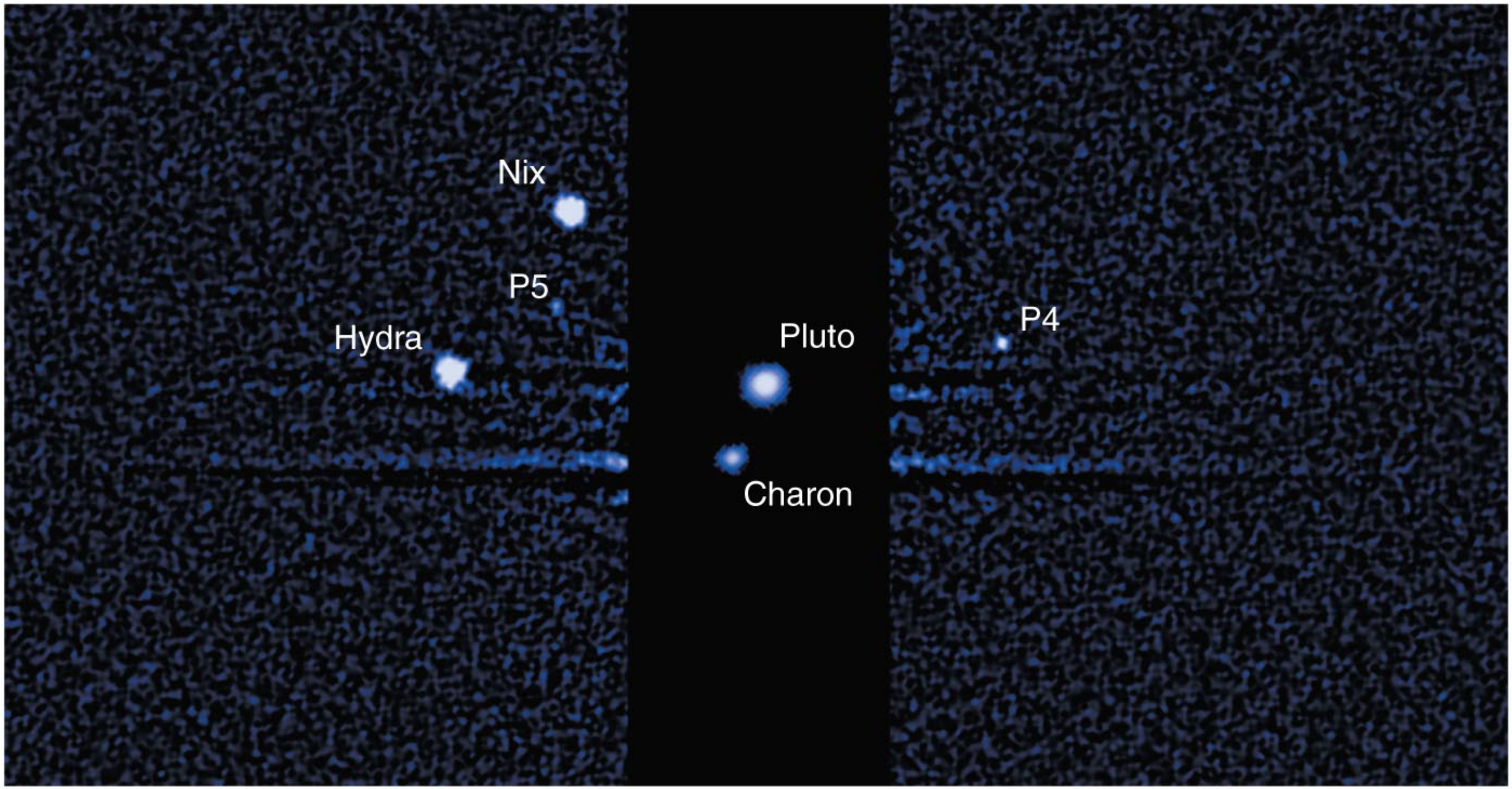
- Smaller than Jupiter/Saturn; much larger than Earth
- Made of H/He gas and **hydrogen compounds** (H_2O, NH_3, CH_4)
- Extreme axis tilt
- Moons and rings

Neptune



- Similar to Uranus (except for axis tilt)
- Many moons (including Triton)

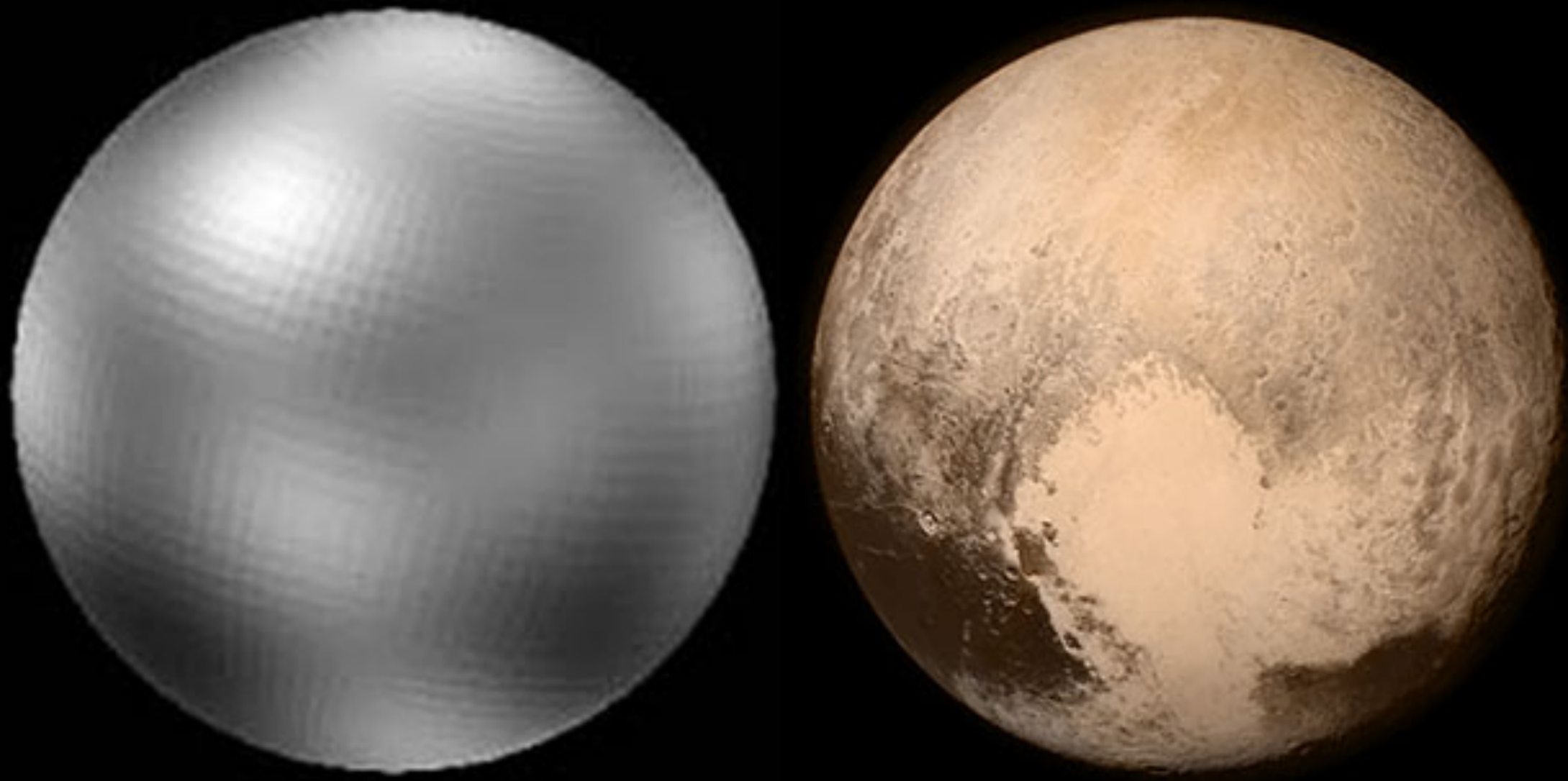
Dwarf Planets: Pluto, Eris, and more



- Much smaller than major planets
- Icy, comet-like composition
- Pluto's main moon (Charon) is of similar size

Hubble

New Horizons



1996

2015

Charon

Pluto

Selected Moons of the Solar System, with Earth for Scale

Earth
Moon

Mars
Phobos
Deimos

Asteroid Ida
Dactyl

Jupiter
Io
Europa
Ganymede
Callisto

Saturn
Mimas
Enceladus
Tethys
Dione
Rhea
Titan
Hyperion
Iapetus
Phoebe

Uranus
Puck
Miranda
Ariel
Umbriel
Titania
Oberon

Neptune
Proteus
Triton
Nereid

Pluto
Charon

Eris
Dysnomia

3000 km

Scale: 1 pixel = 25 km

Earth

Asteroids

small
irregular
rocky bodies

433 Eros - 33 × 13 km
NEAR, 2000

951 Gaspra
18.2 × 10.5 × 8.9 km
Galileo, 1991

5535 Annefrank
6.6 × 5.0 × 3.4 km
Stardust, 2002

2867 Steins
5.9 × 4.0 km
Rosetta, 2008

25143 Itokawa
0.5 × 0.3 × 0.2 km
Hayabusa, 2005

9969 Braille
2.1 × 1 × 1 km
Deep Space 1, 1999

253 Mathilde - 66 × 48 × 44 km
NEAR, 1997

Dactyl
[(243) Ida I]
1.6 × 1.2 km
Galileo, 1993

243 Ida - 58.8 × 25.4 × 18.6 km
Galileo, 1993

Comet nuclei

like asteroids, but with ice

1P/Halley - 16 × 8 × 8 km
Vega 2, 1986

9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005

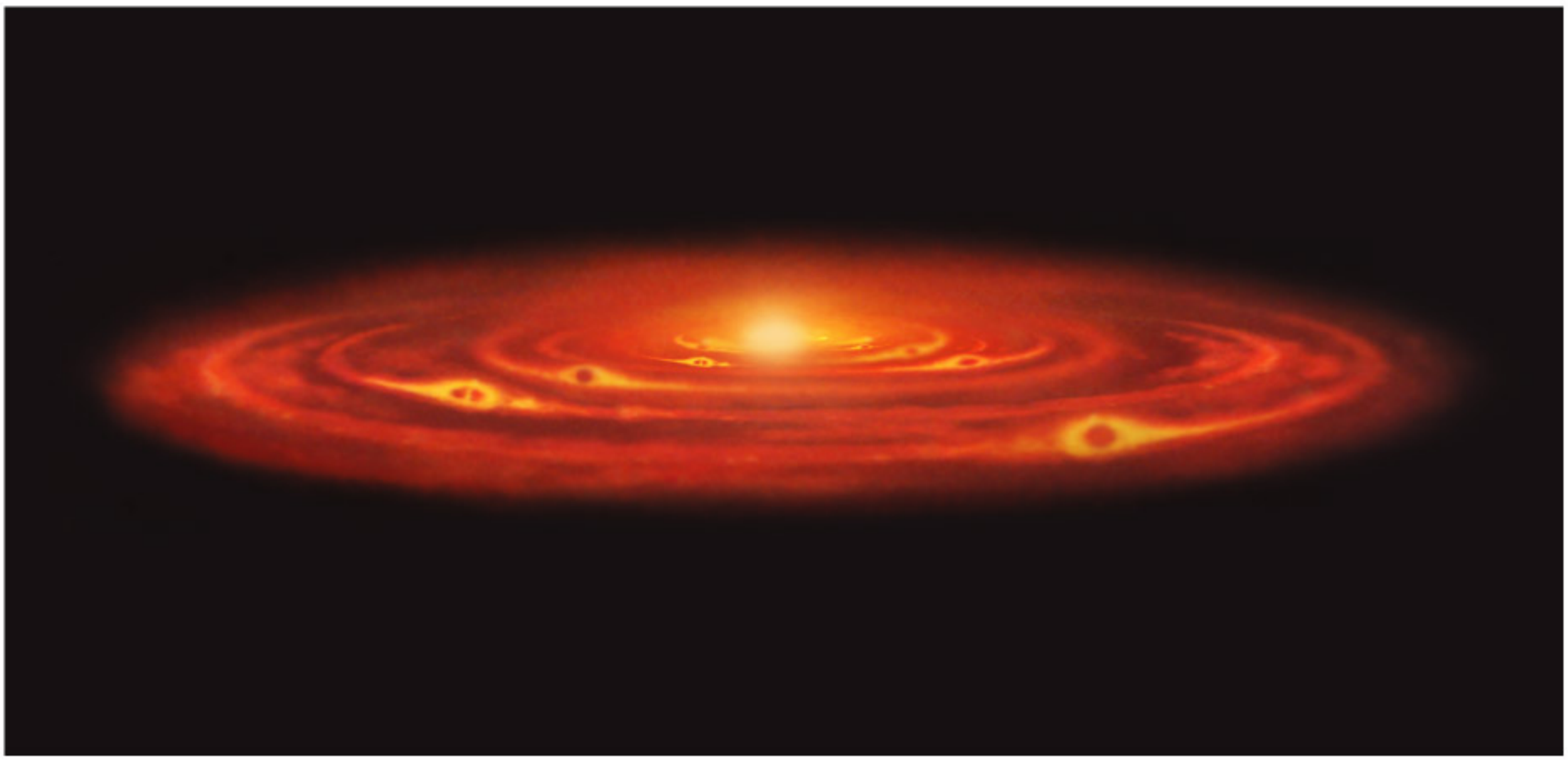
19P/Borrelly
8 × 4 km
Deep Space 1, 2001

81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004

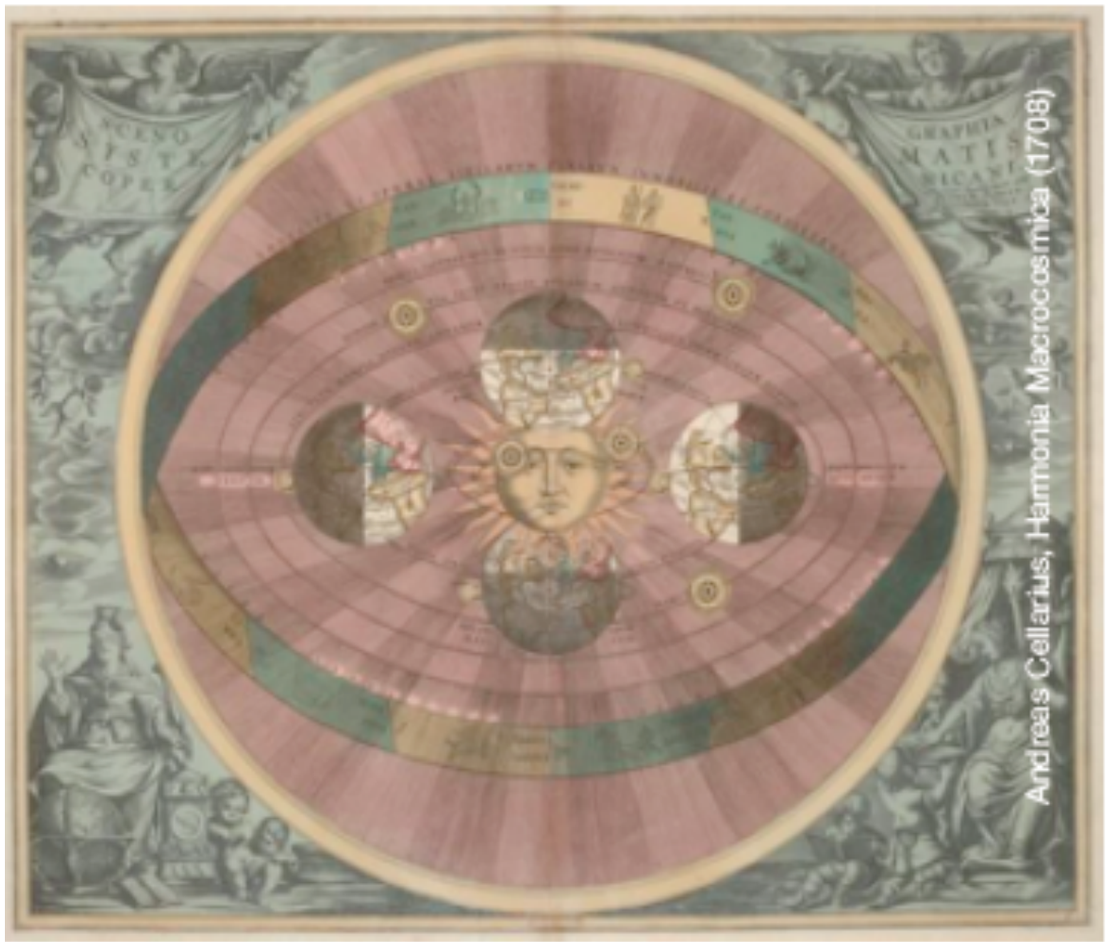
Comets ice sublimates when near the sun, forming coma & tails

Formation of the Solar System

How did these things come to be?



Why are the orbits of the planet so well aligned?
Daniel Bernoulli, 1734



What are the odds that the orbital planes of the planets are so well aligned by chance?

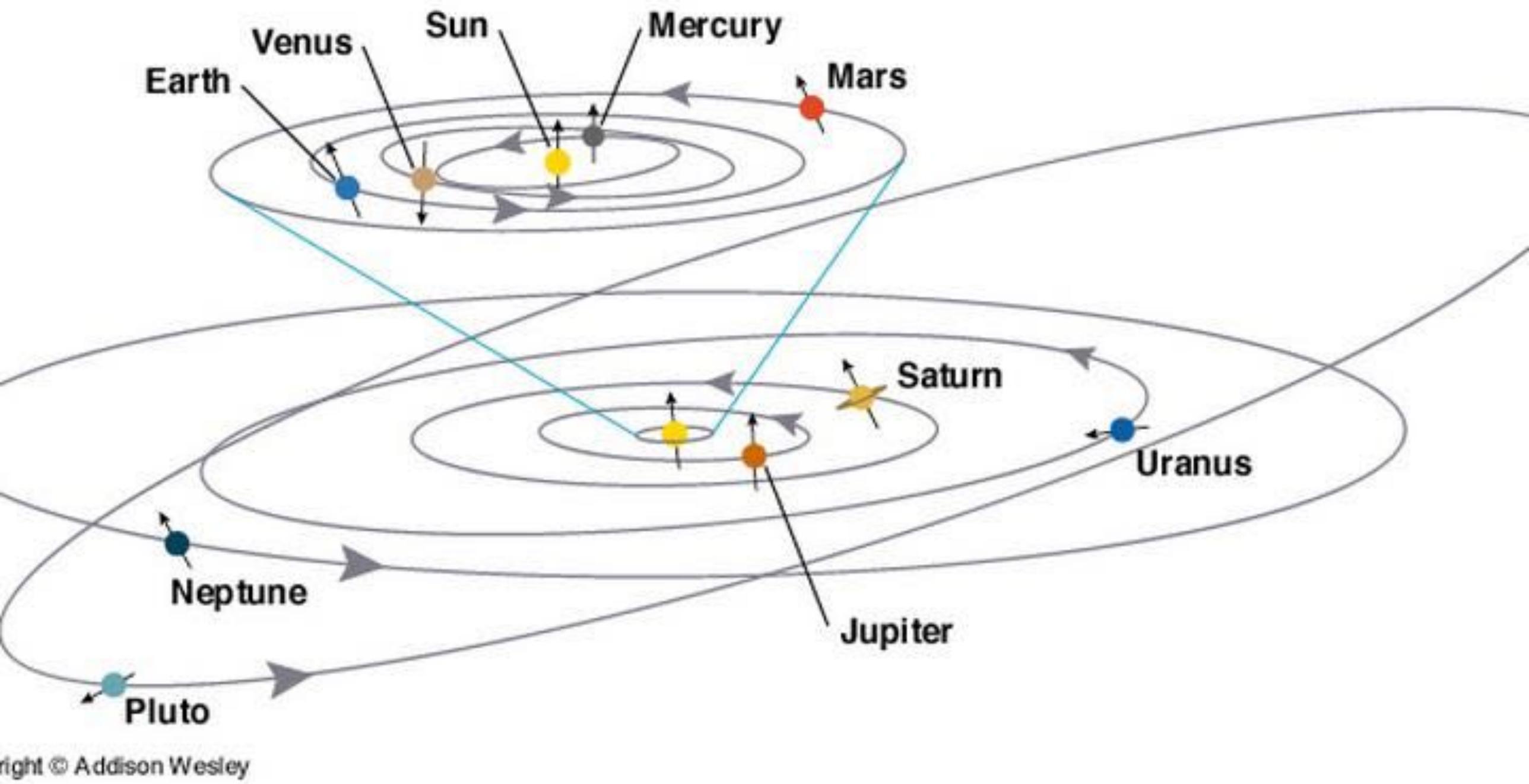
tes de ces deux Orbites. On verra par-là que cette probabilité eſt ſi petite, qu'elle doit paſſer pour une impoſſibilité morale.

"We will see thence that this probability is so small, that it must to be received as a moral impossibility."

About 1 in 1 Million (10^{-6})

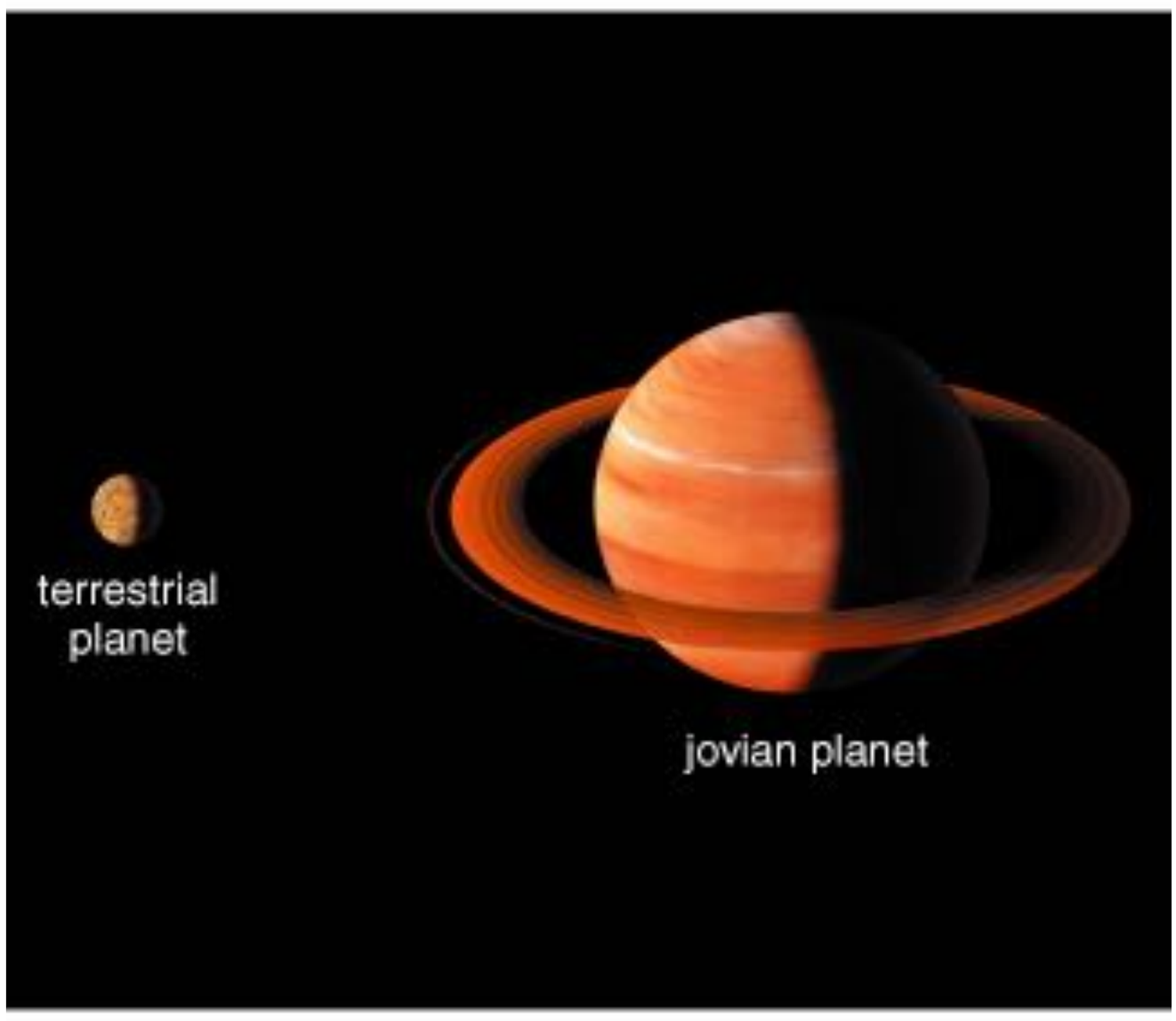
Need to explain why the solar system is so structured

Clues to Solar System Formation



Planar, prograde motion: everything spinning in the same sense

Two Major Planet Types



- Terrestrial planets are rocky, relatively small, and close to the Sun.
- Jovian planets are gaseous, larger, and farther from the Sun.

Jupiter

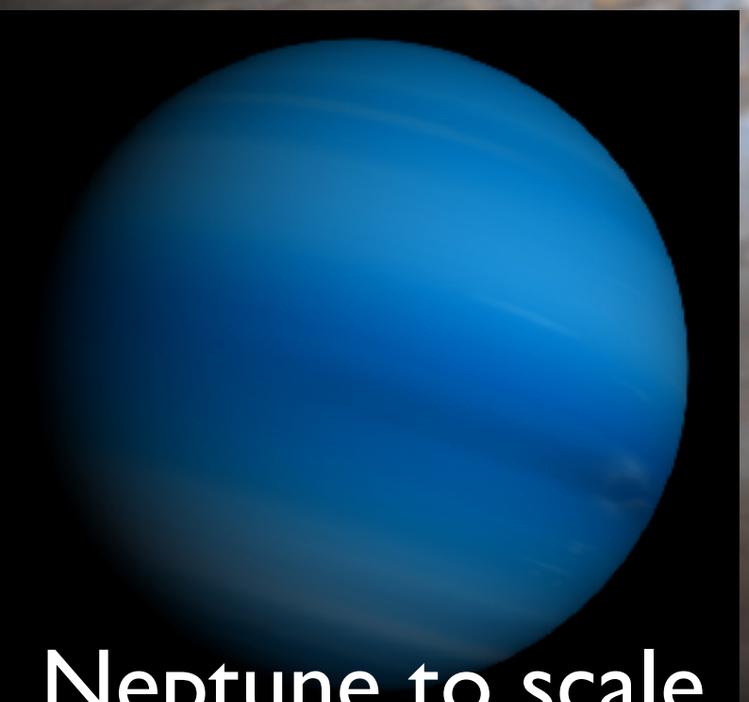
Some astronomers now distinguish between

Gas Giants
Jupiter, Saturn

and

Ice Giants
Uranus, Neptune

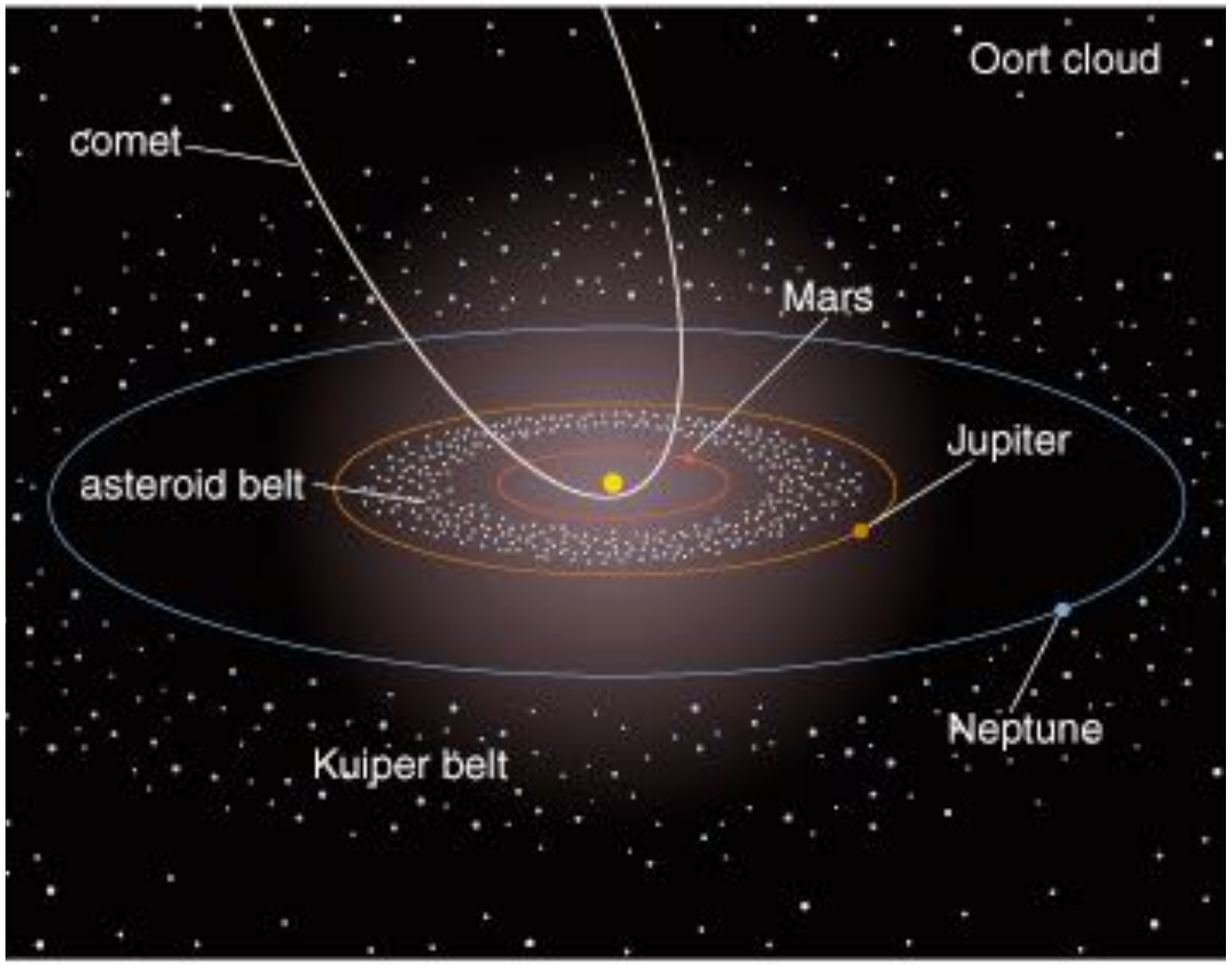
Expect more distinctions with new discoveries



Neptune to scale

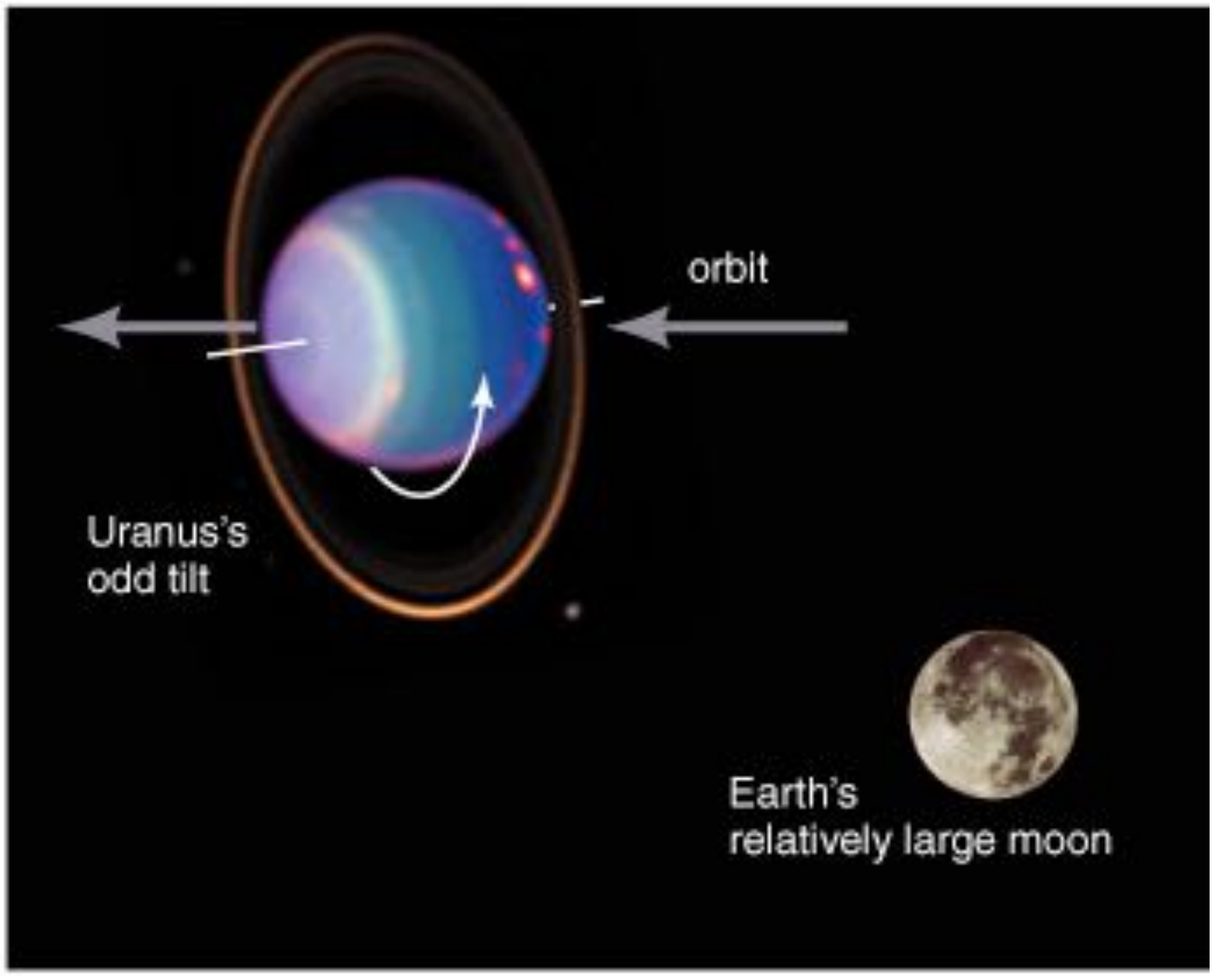
Earth to scale

Swarms of Smaller Bodies



- Many rocky asteroids and icy comets populate the solar system.
- Rocky things close to the sun
- Icy things farther out

Notable Exceptions



- Several exceptions to normal patterns need to be explained.

According to the ***nebular theory,*** our solar system formed from a giant cloud of interstellar gas.

(***nebula*** = cloud)

Also known as the ***solar nebula*** hypothesis

The dissipation of gas causes it to settle into a single plane where angular momentum is conserved

SS formation movie

http://www.spitzer.caltech.edu/video-audio/730-ssc2004-22v2-The-Evolution-of-a-Planet-Forming-Disk