

# TODAY

- SOLAR SYSTEM OVERVIEW
- SOLAR SYSTEM FORMATION

# EVENTS

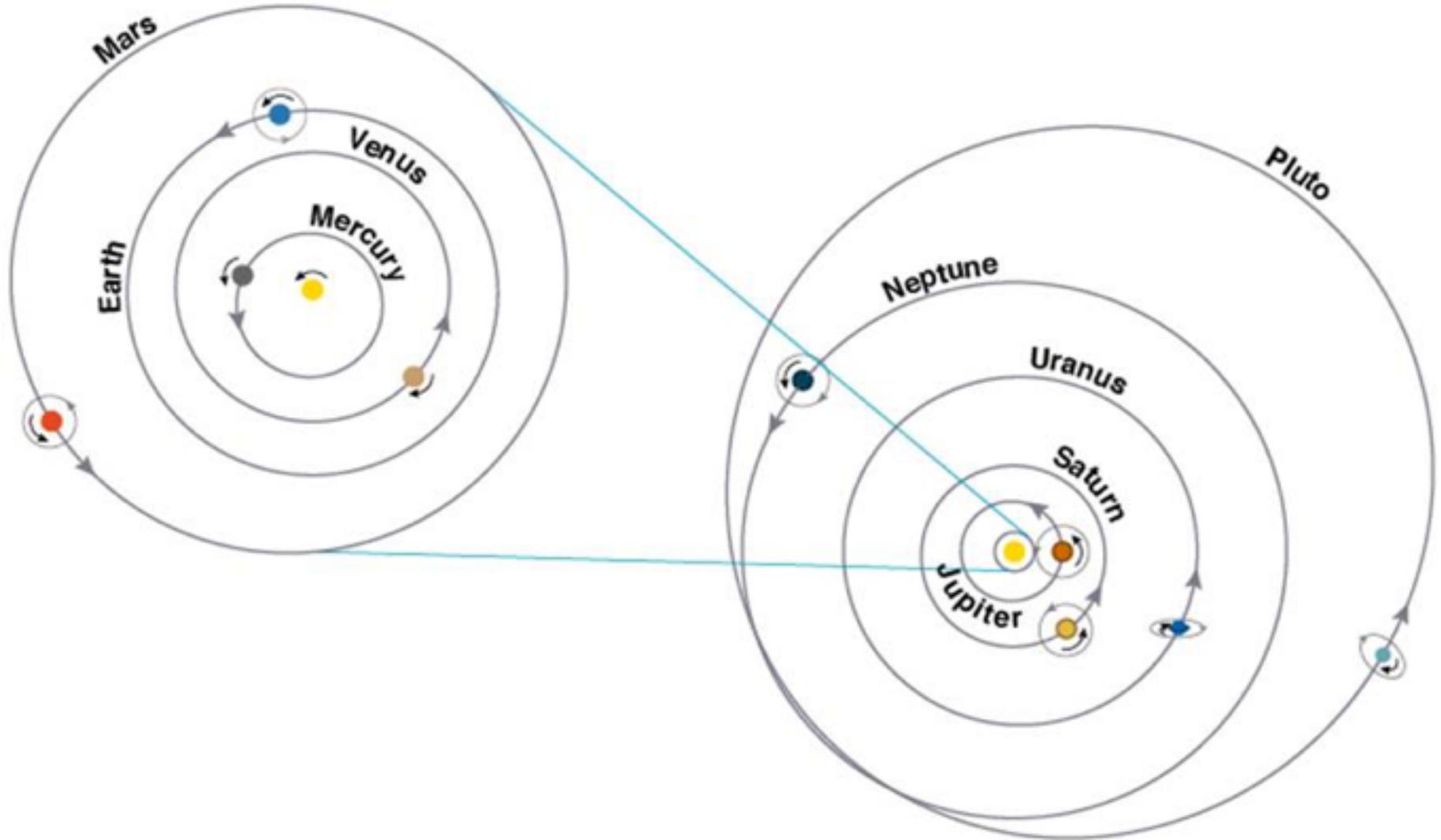
- HOMEWORK DUE THU FEB 26 (NEXT TIME)
- DR. PAWLOWSKI SUBSTITUTES
  - (PROF. MCGAUGH VISITING YALE)

# Contents of the Solar System

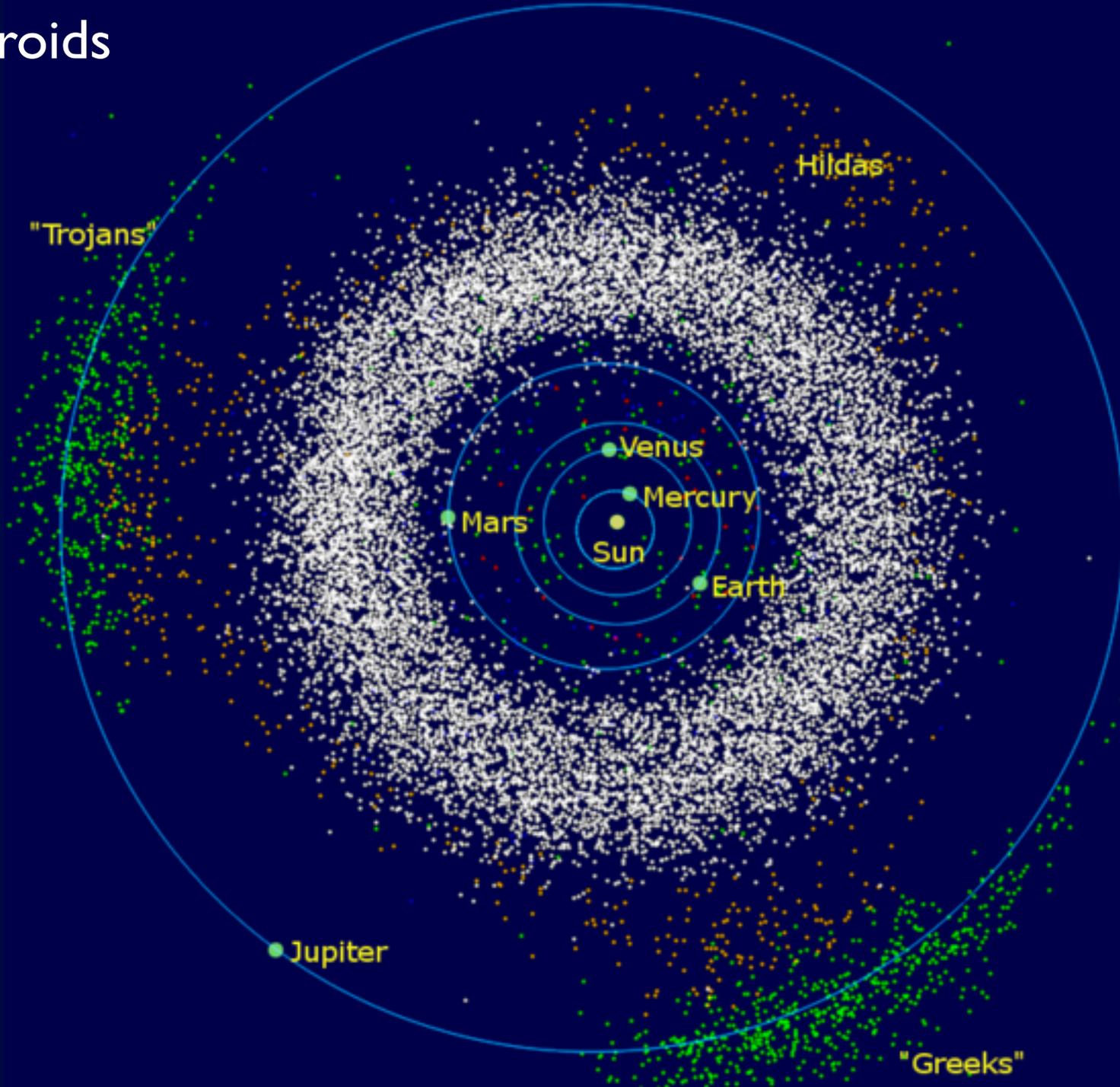
- The Sun
- Major Planets
  - Terrestrial: Mercury, Venus, Earth, Mars
  - Jovian planets: Jupiter, Saturn
  - Ice Giants: Uranus, Neptune

} Gas Giants
- Moons
- Dwarf Planet
  - KBOs: Pluto, Quaoar, Eris, Sedna...
- Asteroids
- Comets
  - misc. dust, meteoroids, solar wind particles...

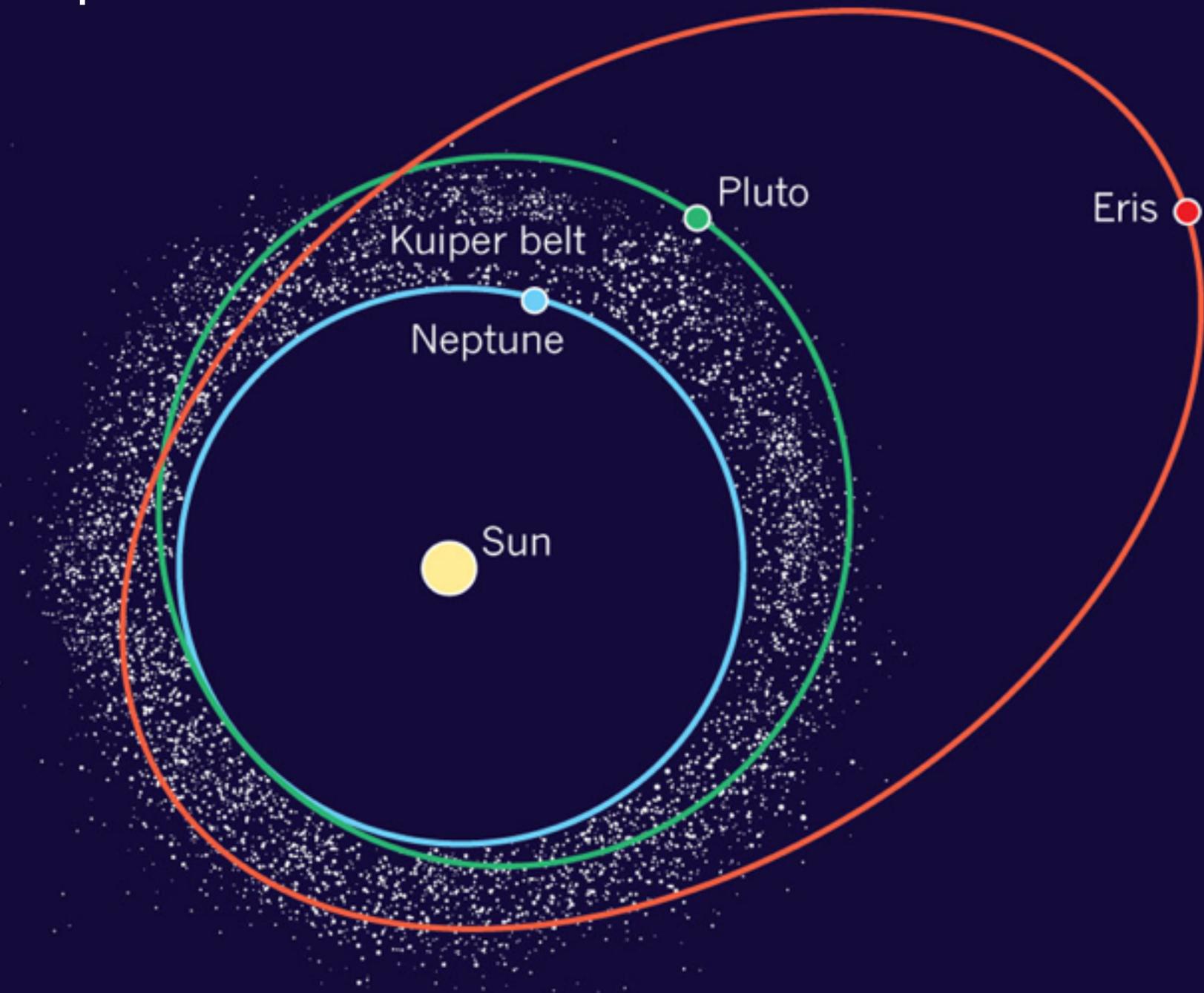
# Layout of the Solar System

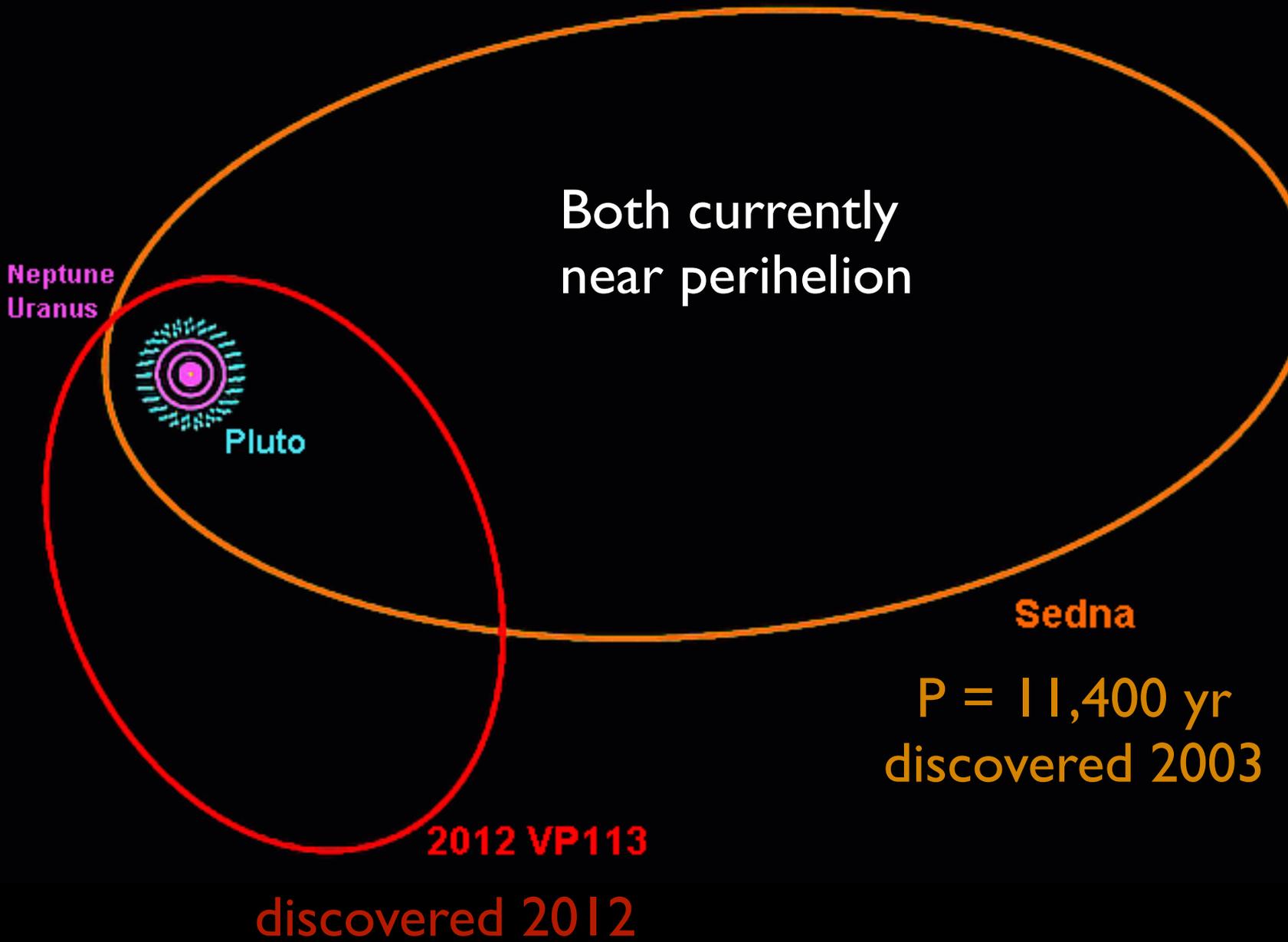


# Asteroids

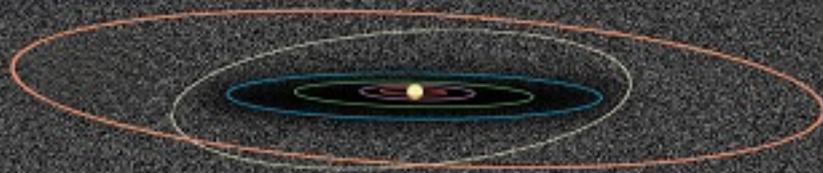


# Kuiper belt



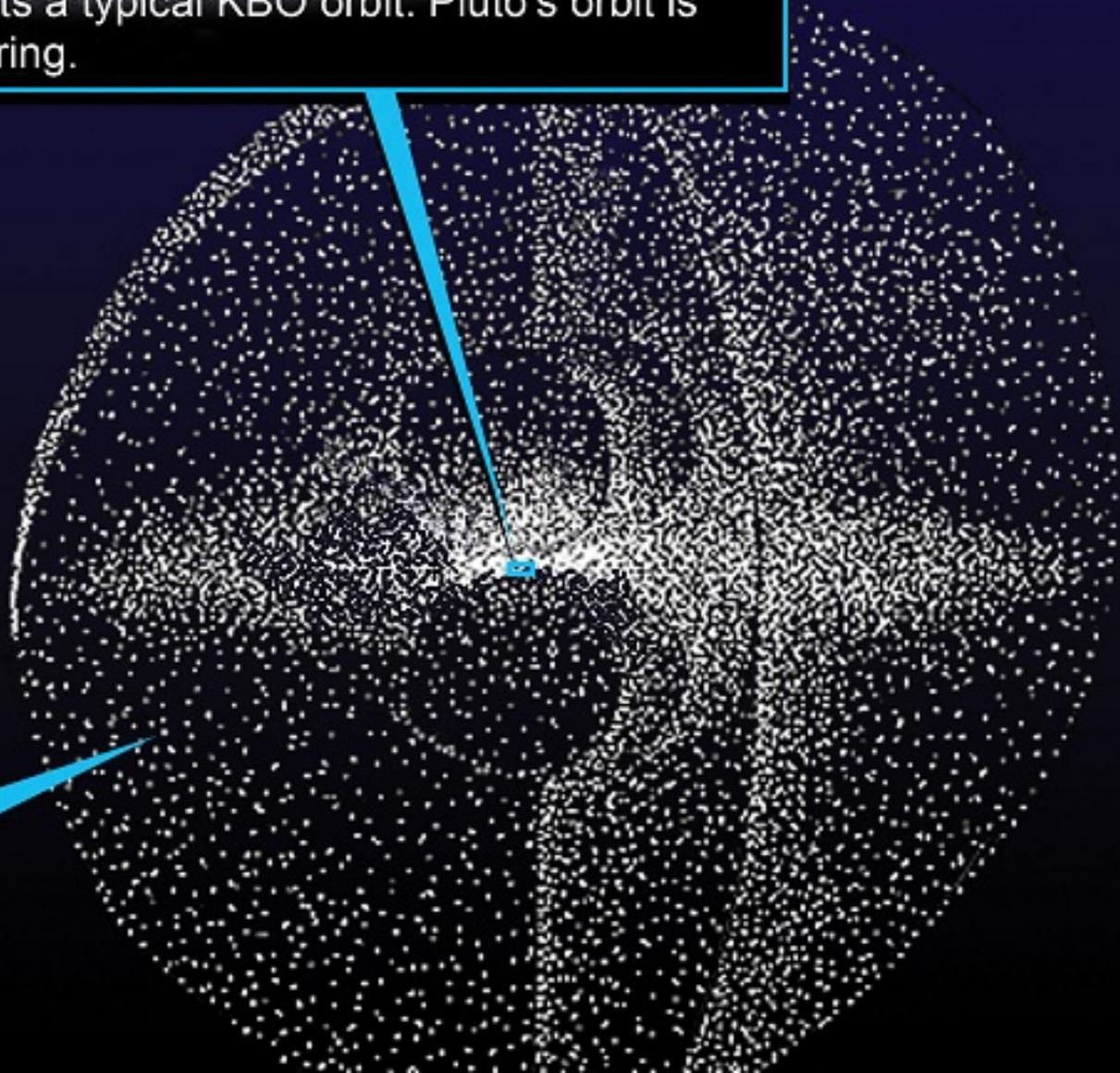


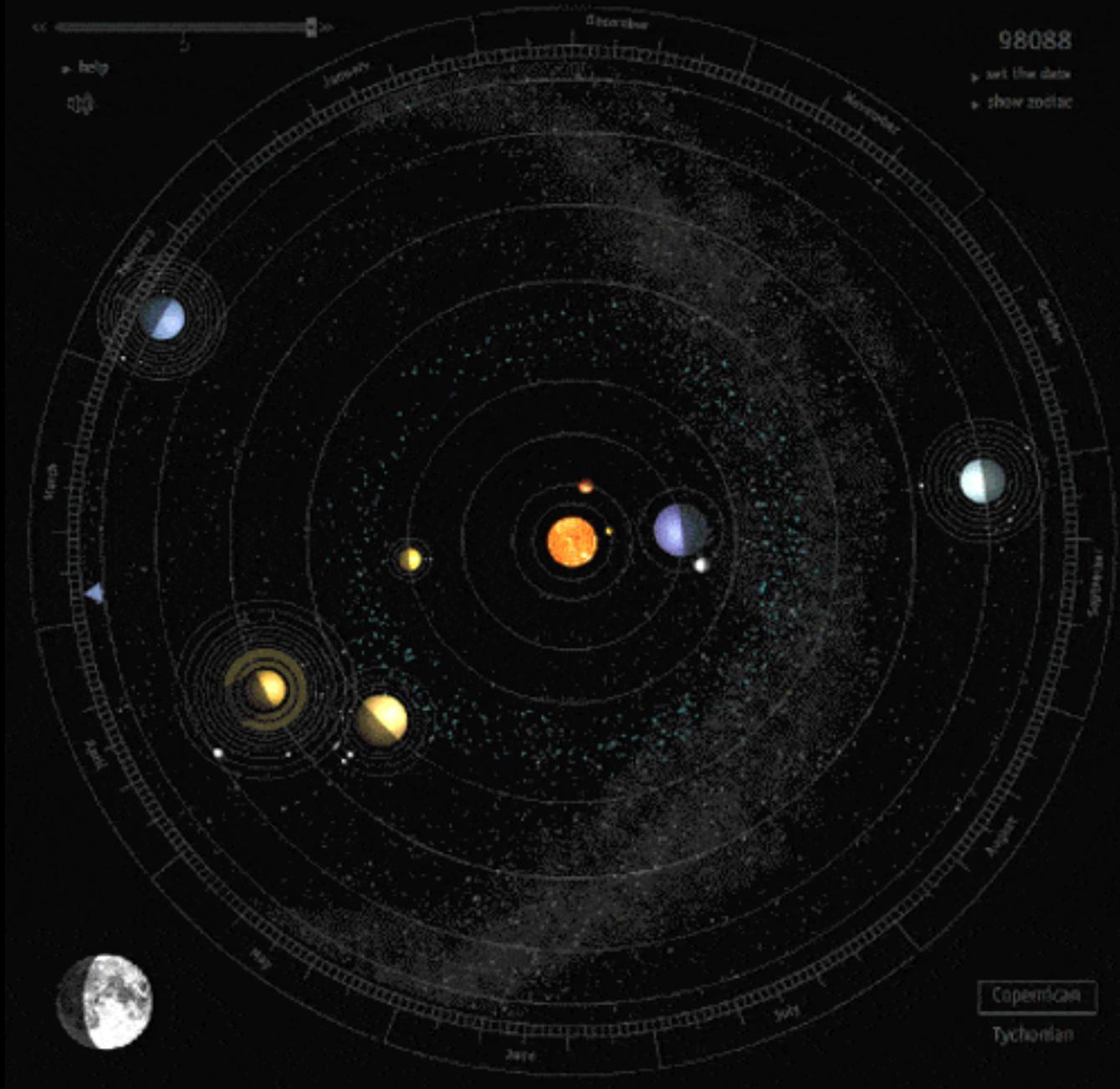
Kuiper Belt



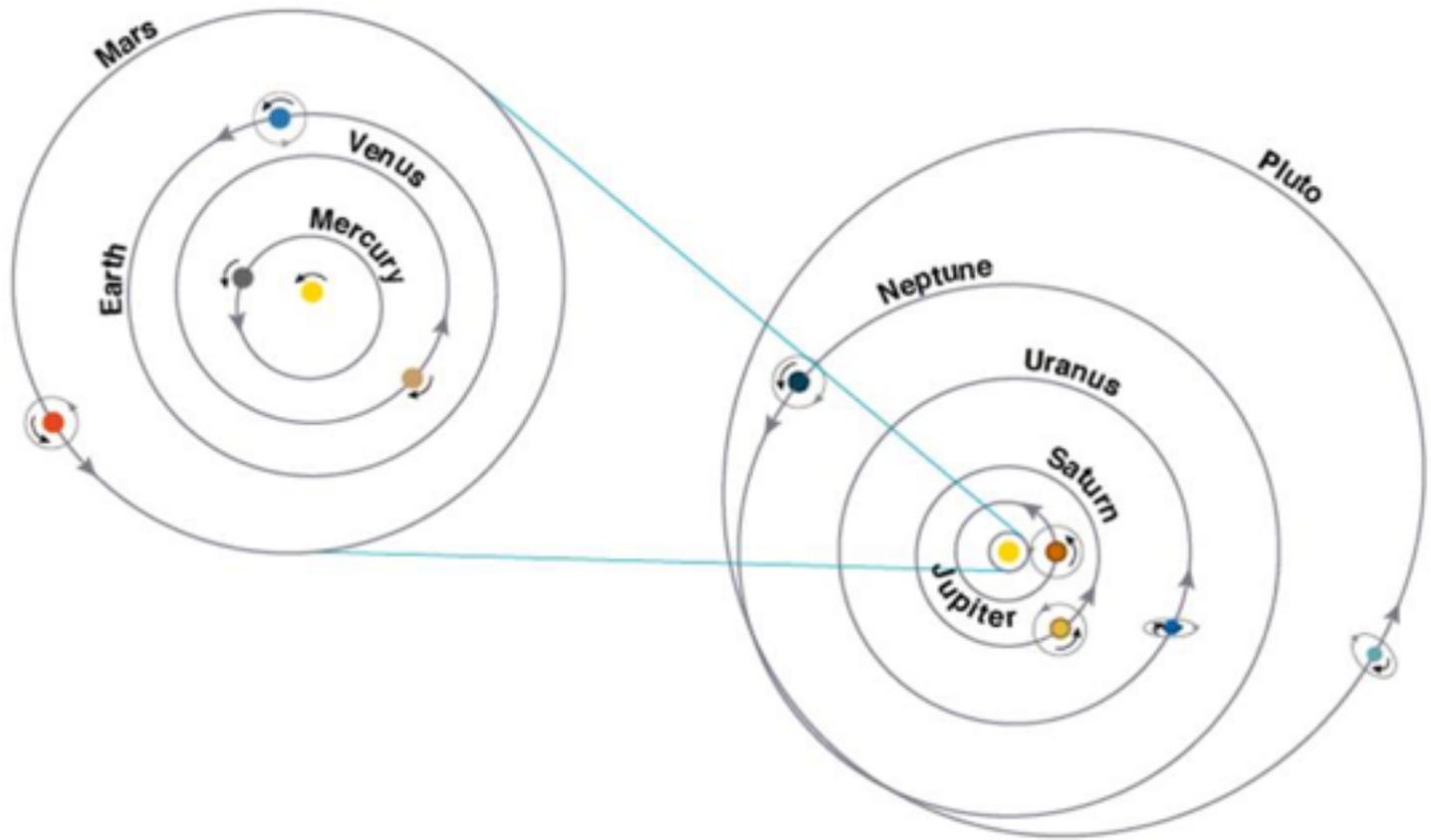
The orange track represents a typical KBO orbit. Pluto's orbit is represented by the yellow ring.

Oort Cloud





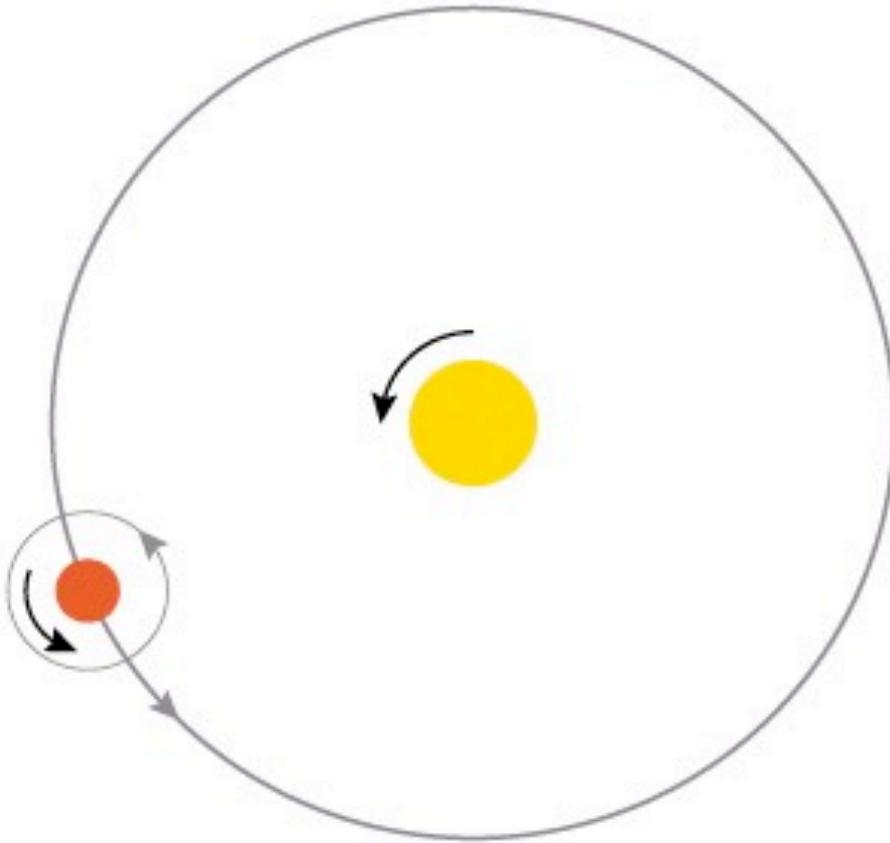
<http://popperfont.net/2012/11/13/the-ultimate-solar-system-animated-gif/>



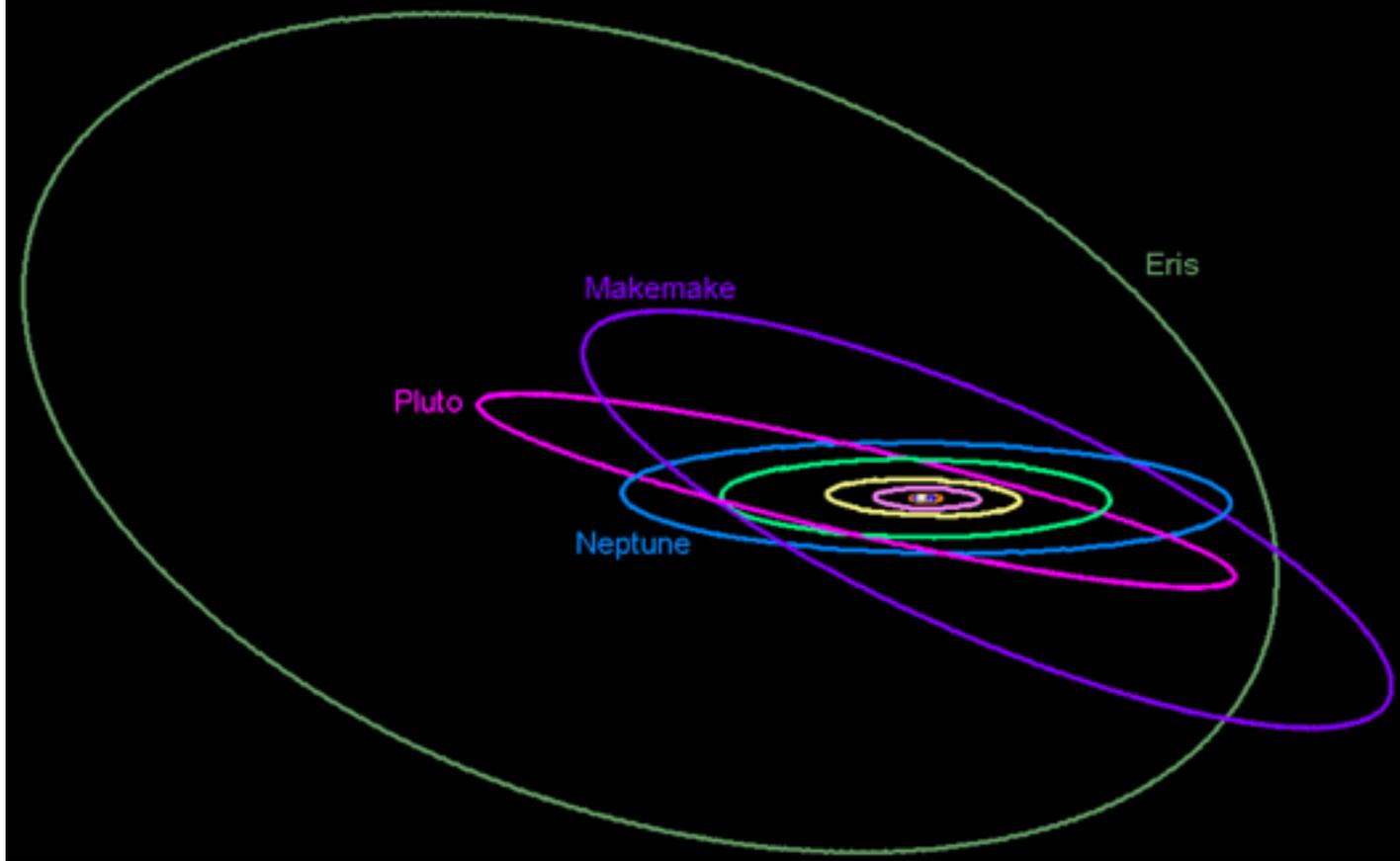
There are eight major planets with nearly circular orbits.

The planets all orbit in the same direction in nearly the same plane.

# Motion of Large Bodies



- All large bodies in the solar system orbit in the same direction and in nearly the same plane.
- Most also rotate in that direction.
  - “*prograde*”

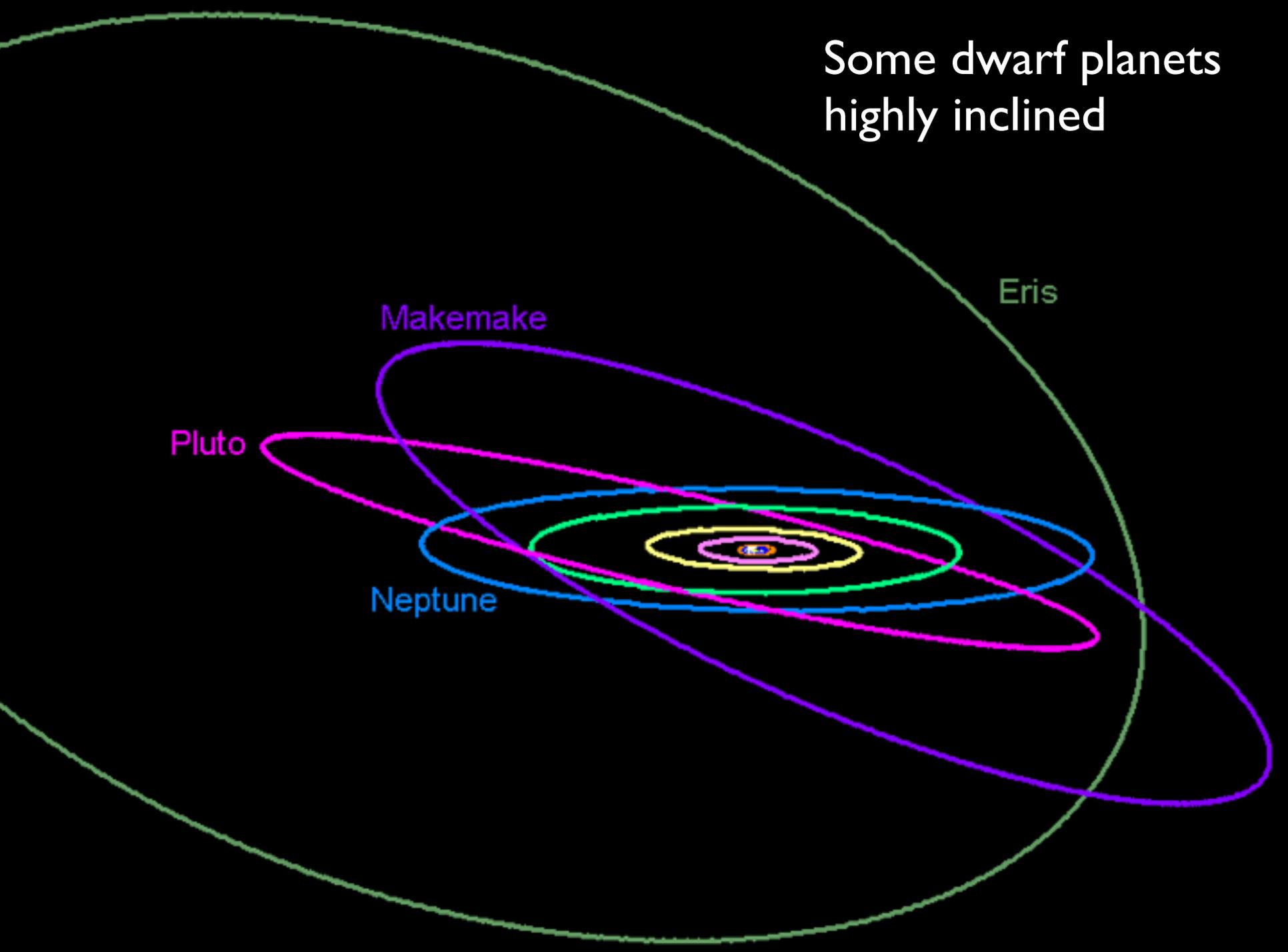


Dwarf planets are smaller than the major planets and some have quite elliptical orbits.

Most dwarf planets & asteroids also revolve prograde.

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

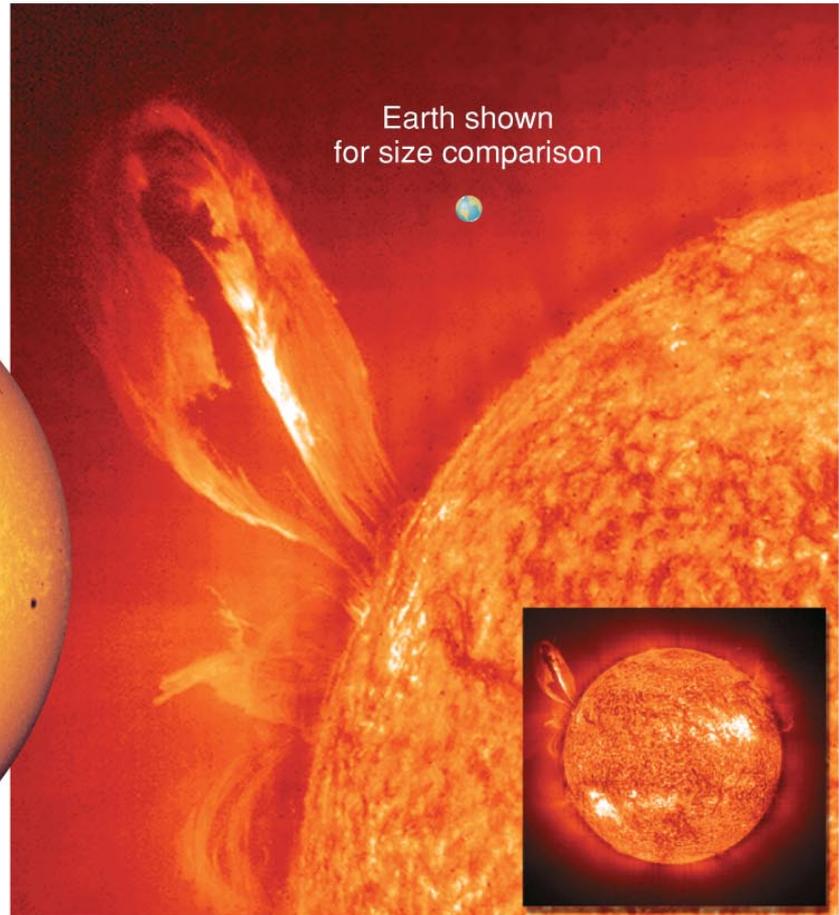
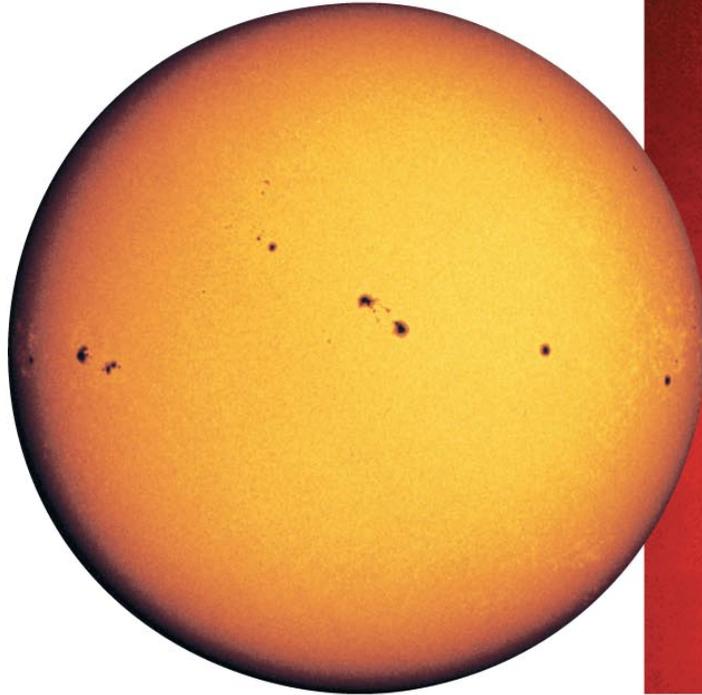
Some dwarf planets  
highly inclined



# A Closer Look at the Contents

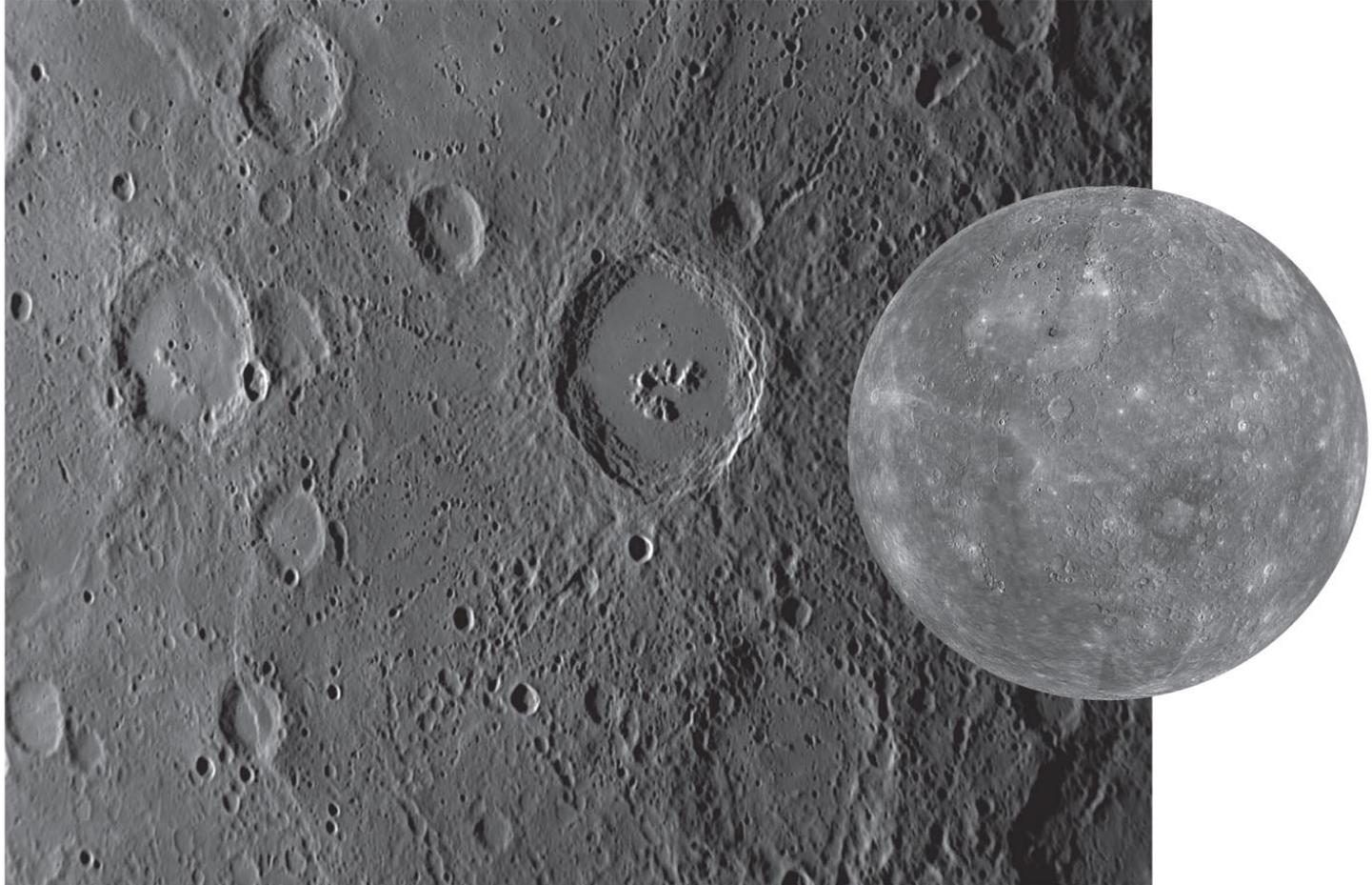
- The Sun
- Major Planets
  - Terrestrial: Mercury, Venus, Earth, Mars
  - Jovian planets: Jupiter, Saturn
  - Ice Giants: Uranus, Neptune } Gas Giants
- Moons
- Dwarf Planet
  - KBOs: Pluto, Quaoar, Eris, Sedna...
- Asteroids
- Comets
  - misc. dust, meteoroids, solar wind particles...

- The Sun



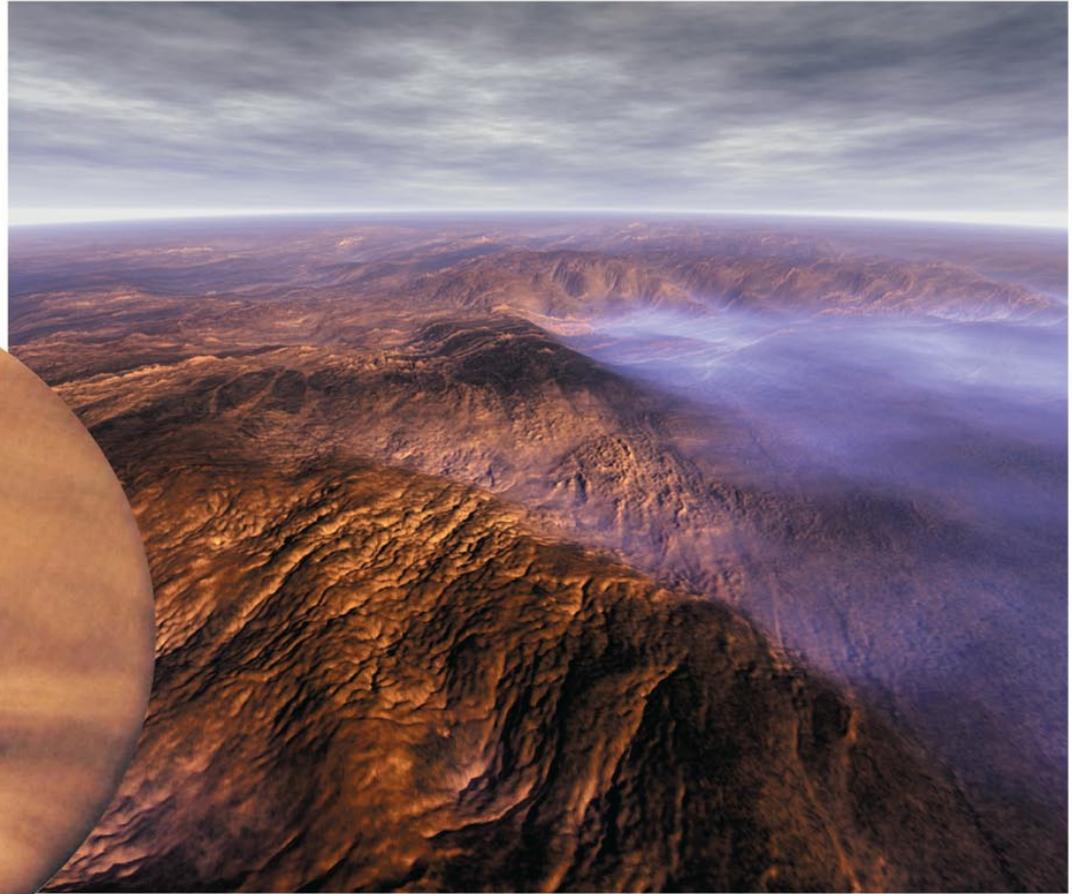
- Over 99.9% of solar system's mass
- Made mostly of H/He gas (plasma)
- Converts 4 million tons of mass into energy each second

# Mercury



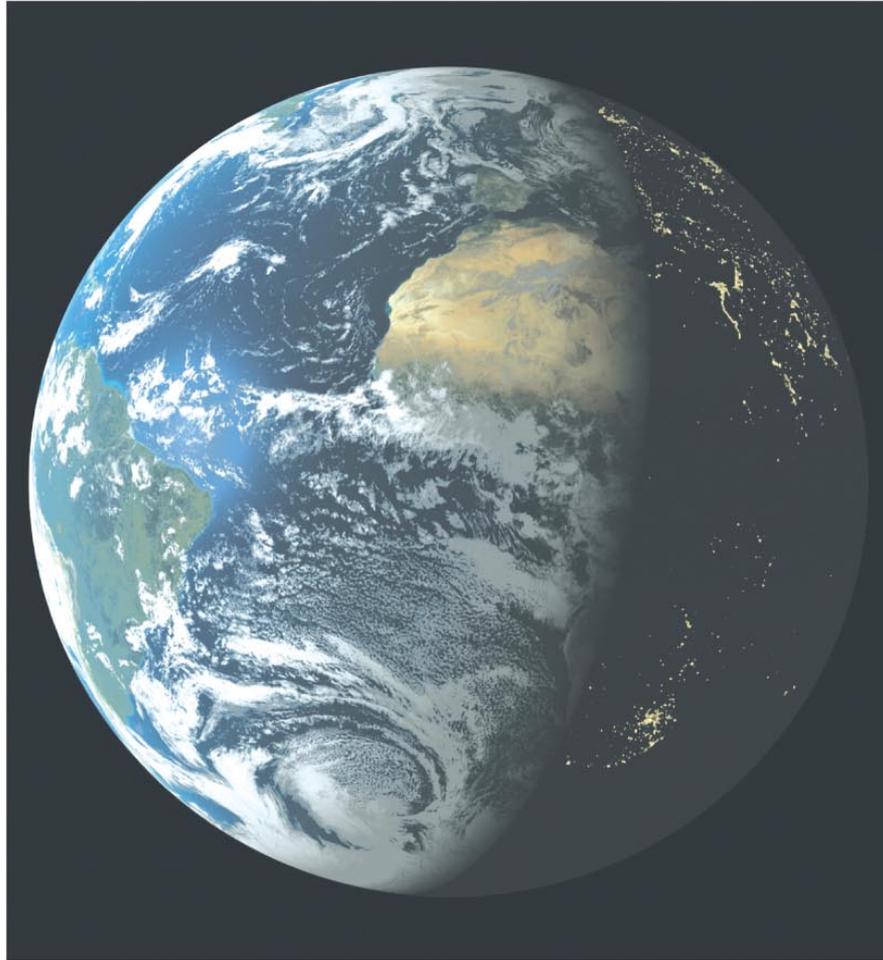
- Made of metal and rock; large iron core
- Desolate, cratered; long, tall, steep cliffs
- Very hot, very cold:  $425^{\circ}\text{C}$  (day),  $-170^{\circ}\text{C}$  (night)

# Venus



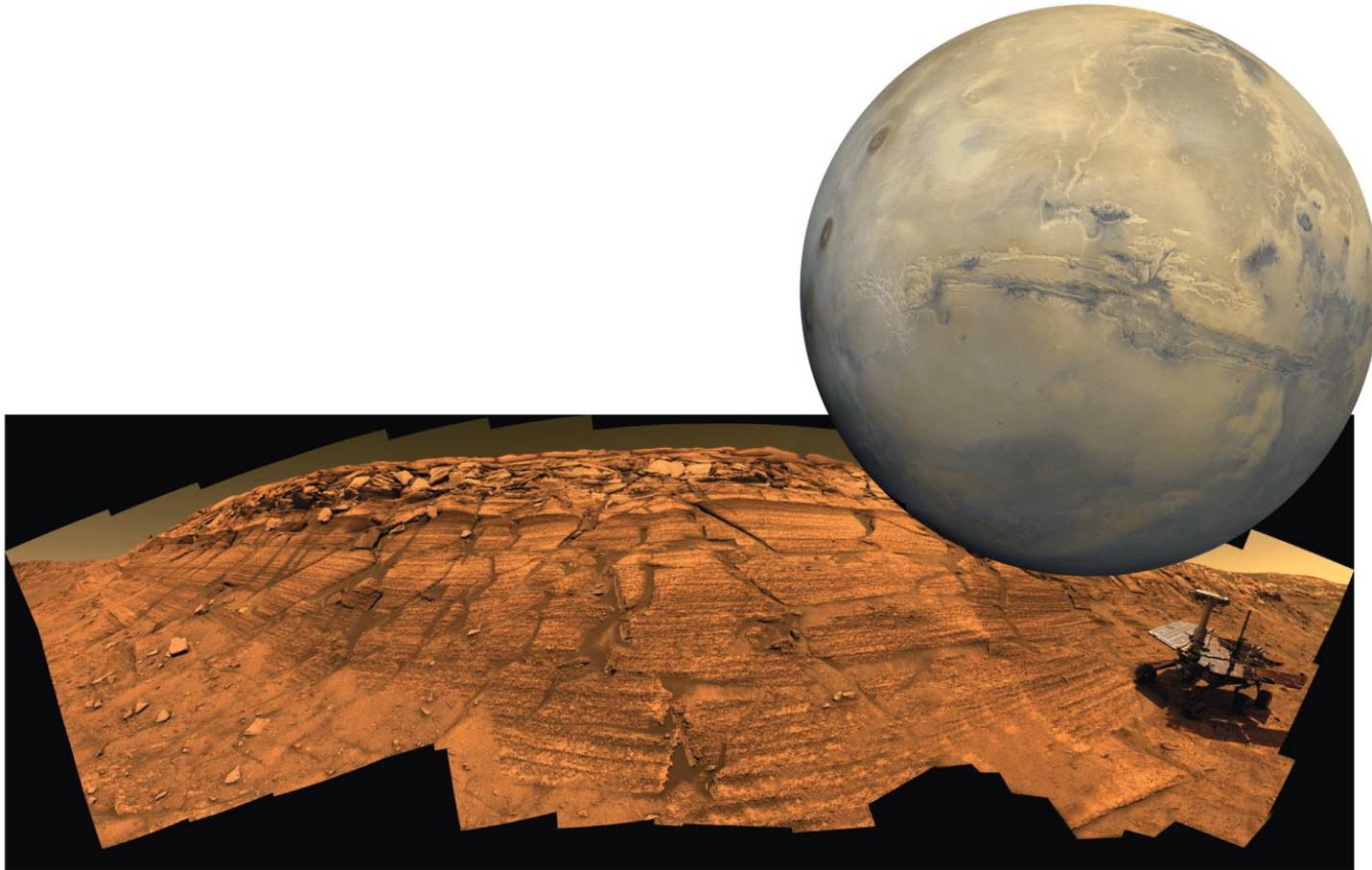
- Nearly identical in size to Earth; surface hidden by clouds
- Hellish conditions due to an extreme **greenhouse effect**
- Even hotter than Mercury: 470°C, day and night

# Earth



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

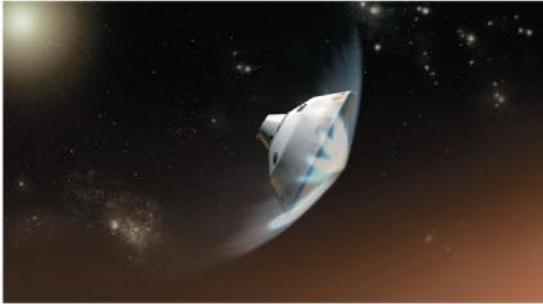
# Mars



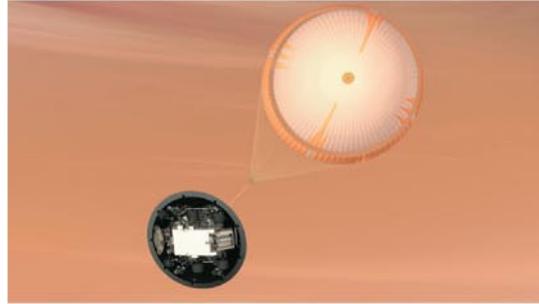
- Looks almost Earth-like, but don't go without a spacesuit!
- Giant volcanoes, a huge canyon, polar caps, more
- Water flowed in distant past; could there have been life?

# Mars

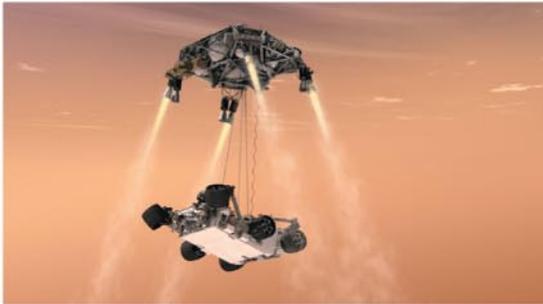
- *Curiosity* rover landed in August 2012.



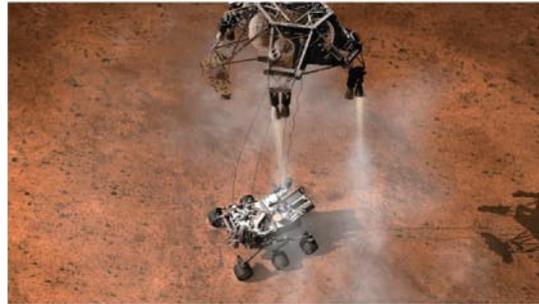
1 Friction slows spacecraft as it enters Mars atmosphere.



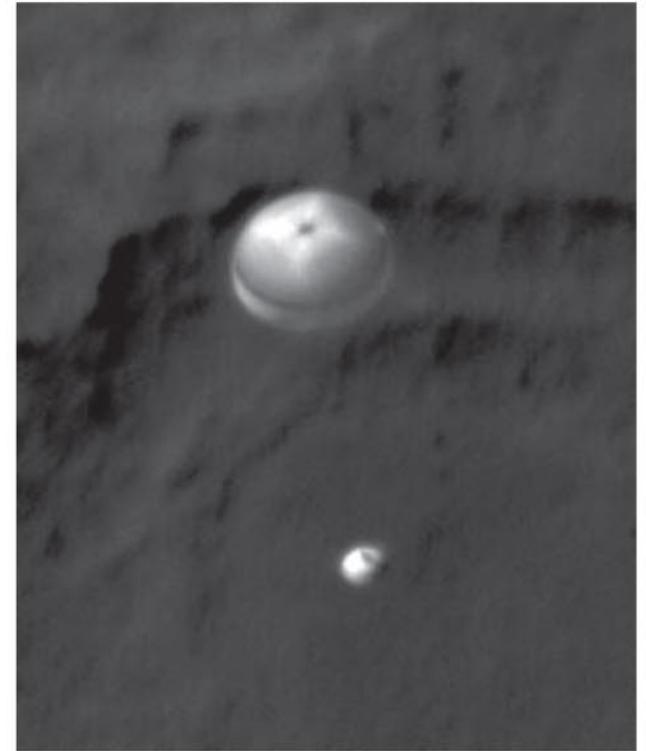
2 Parachute slows spacecraft to about 350 km/hr.



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

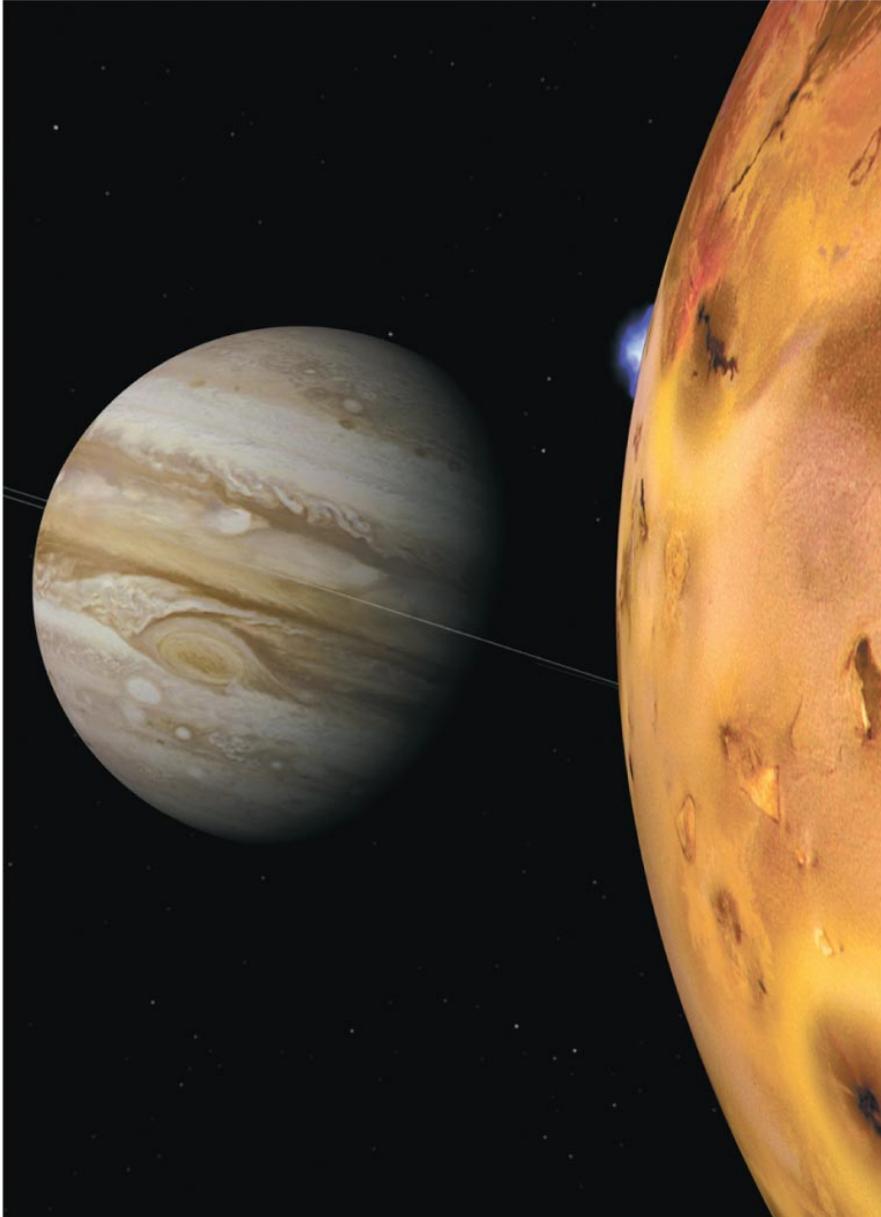


4 Tether released, the rocket heads off to crash a safe distance away.



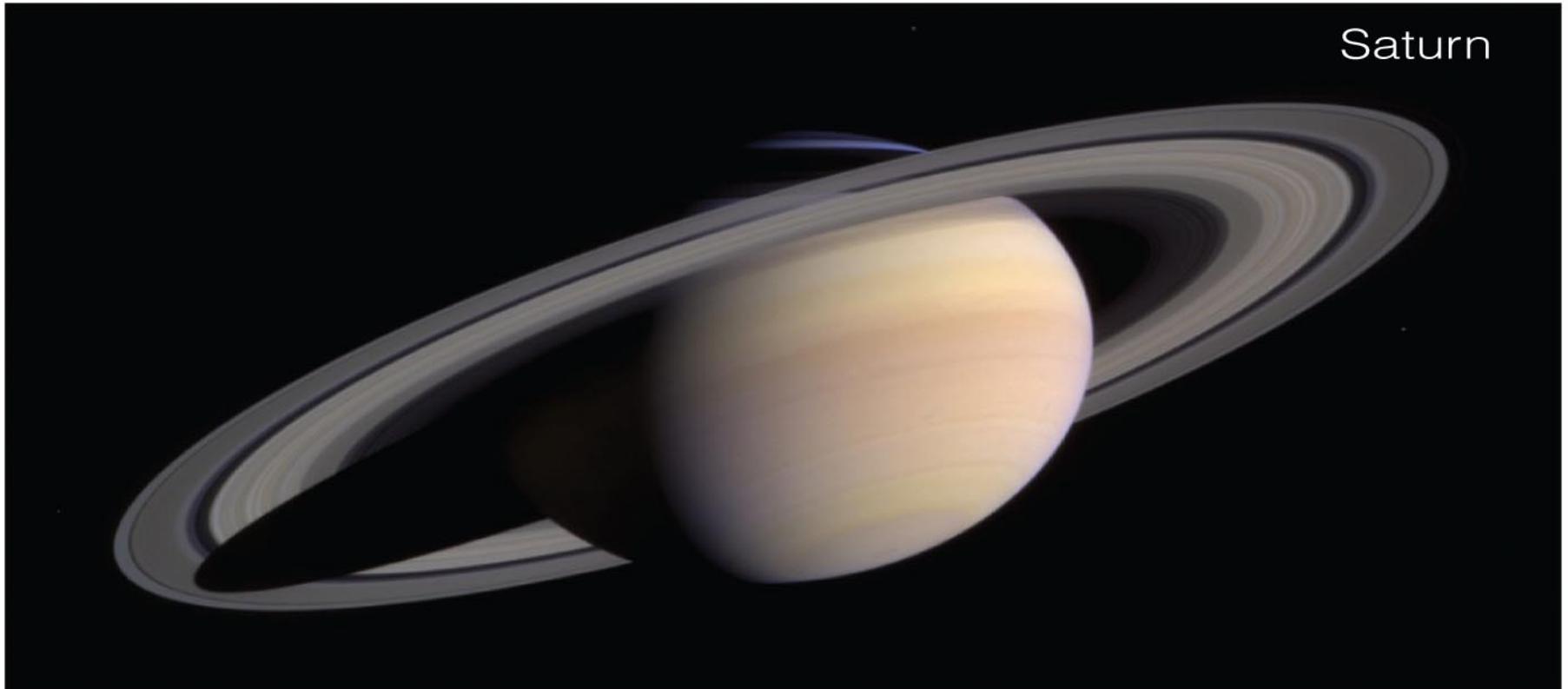
As it flew overhead, the *Mars Reconnaissance Orbiter* took this photo of the spacecraft with its parachute deployed.

# Jupiter



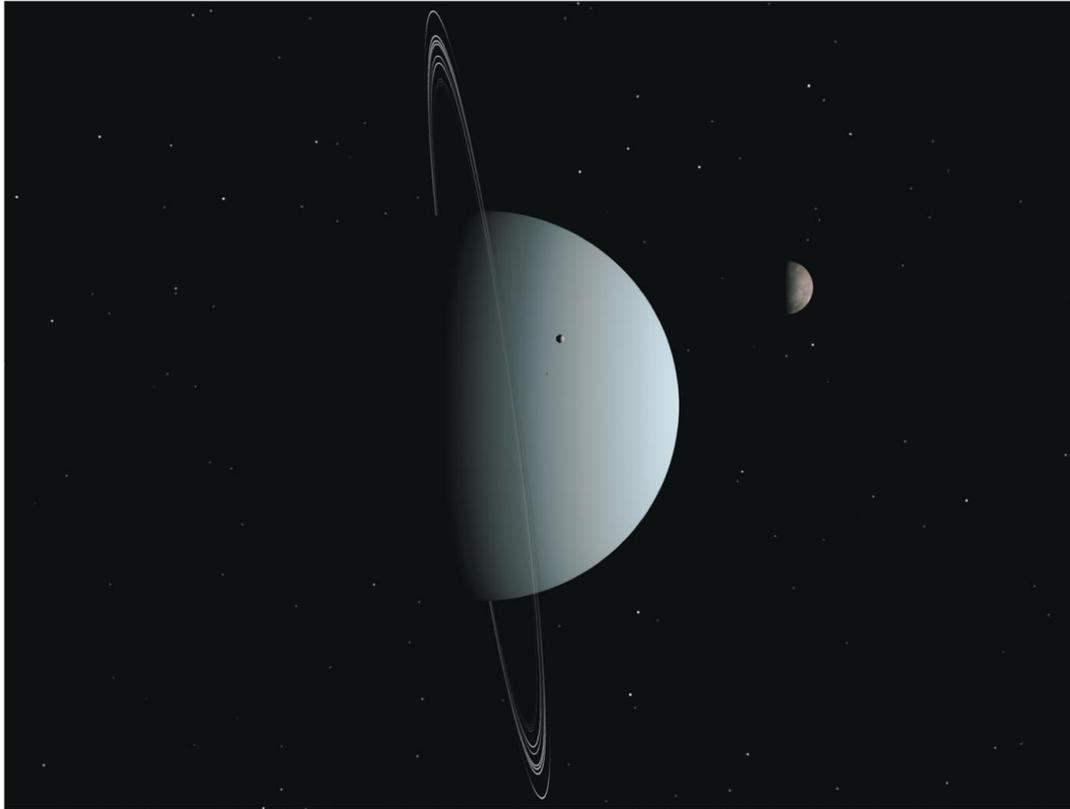
- Much farther from Sun than inner planets
- Mostly H/He; no solid surface
- 300 times more massive than Earth
- Many moons, rings

# Saturn



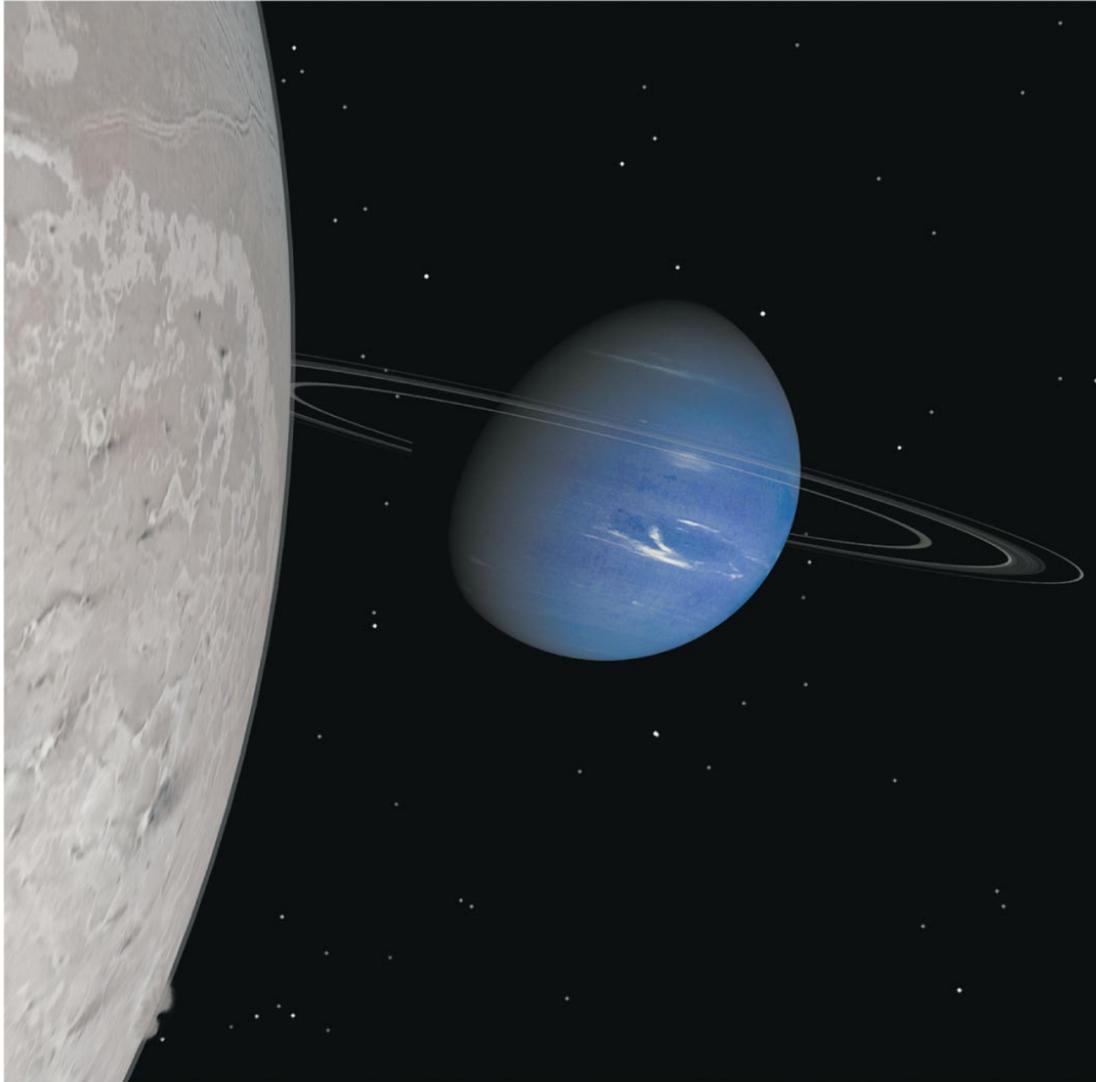
- Giant and gaseous like Jupiter
- Spectacular rings
- Many moons, including cloudy Titan

# Uranus



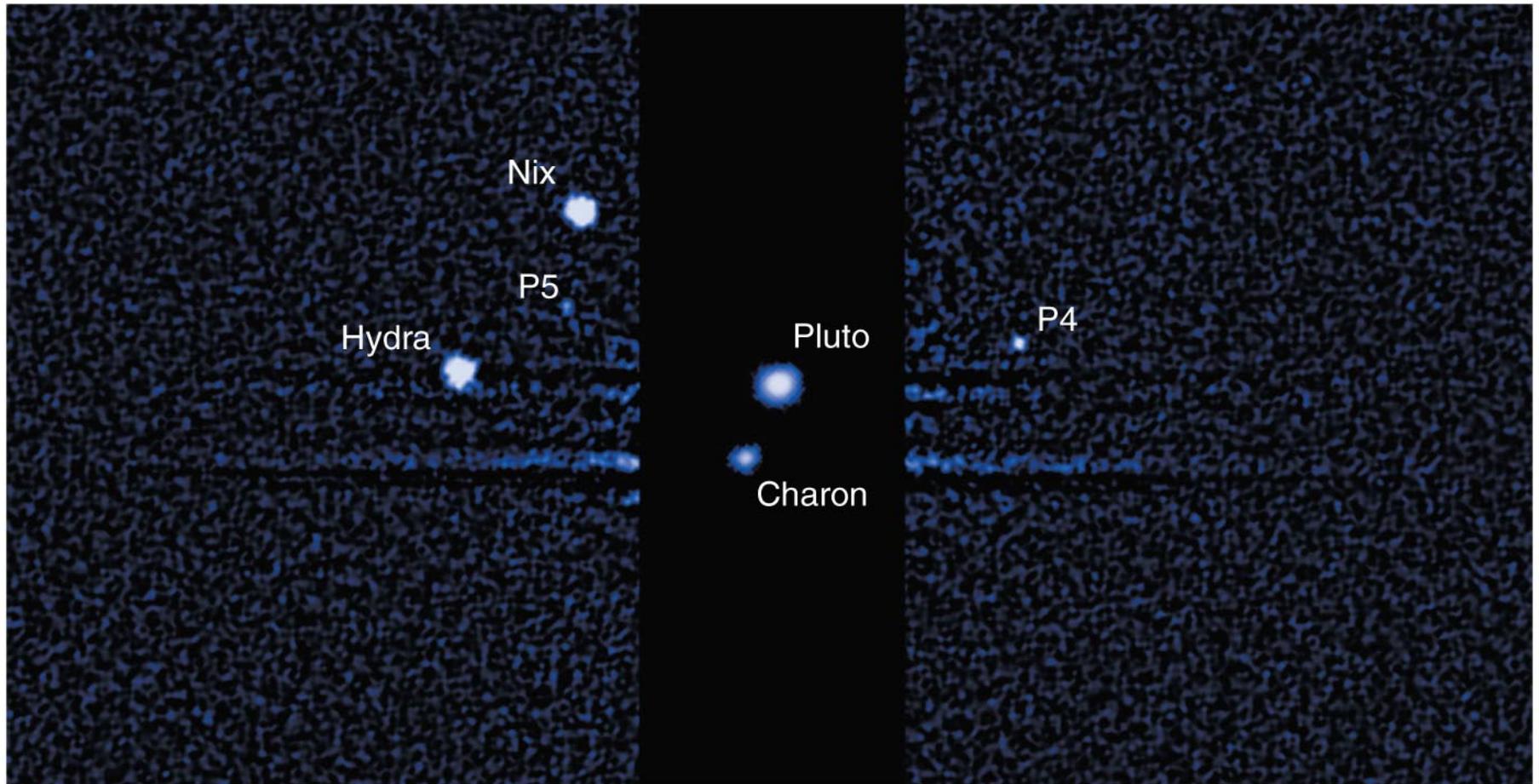
- Smaller than Jupiter/Saturn; much larger than Earth
- Made of H/He gas and **hydrogen compounds** (H<sub>2</sub>O, NH<sub>3</sub>, CH<sub>4</sub>)
- Extreme axis tilt
- Moons and rings

# 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

# Selected Moons of the Solar System, with Earth for Scale

Earth

Mars

Asteroid  
Ida

Jupiter

Saturn

Uranus

Neptune

Pluto

Eris

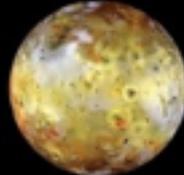


Moon

Phobos

Deimos

Dactyl



Io



Europa



Ganymede



Callisto

Mimas

Enceladus



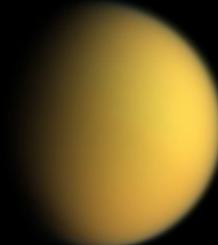
Tethys



Dione



Rhea



Titan

Hyperion



Iapetus



Phoebe

Puck

Miranda



Ariel



Umbriel



Titania



Oberon

Proteus



Triton

Nereid



Earth

Scale: 1 pixel = 25 km

# Asteroids



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



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



951 Gaspra  
18.2 × 10.5 × 8.9 km  
Galileo, 1991



433 Eros - 33 × 13 km  
NEAR, 2000



5535 Annefrank  
6.6 × 5.0 × 3.4 km  
Stardust, 2002



2867 Steins  
5.9 × 4.0 km  
Rosetta, 2008



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



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

small  
irregular  
rocky bodies

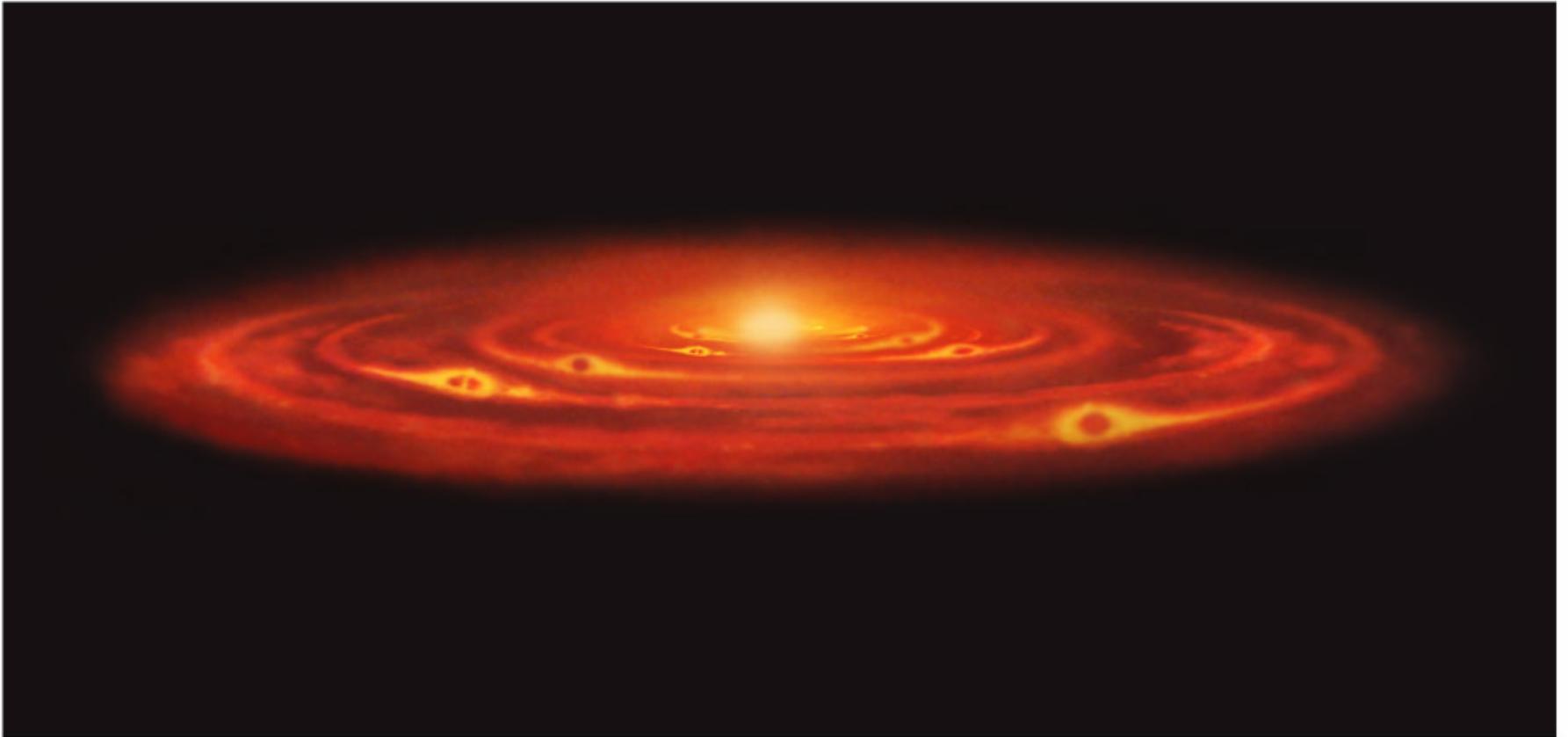


Comets

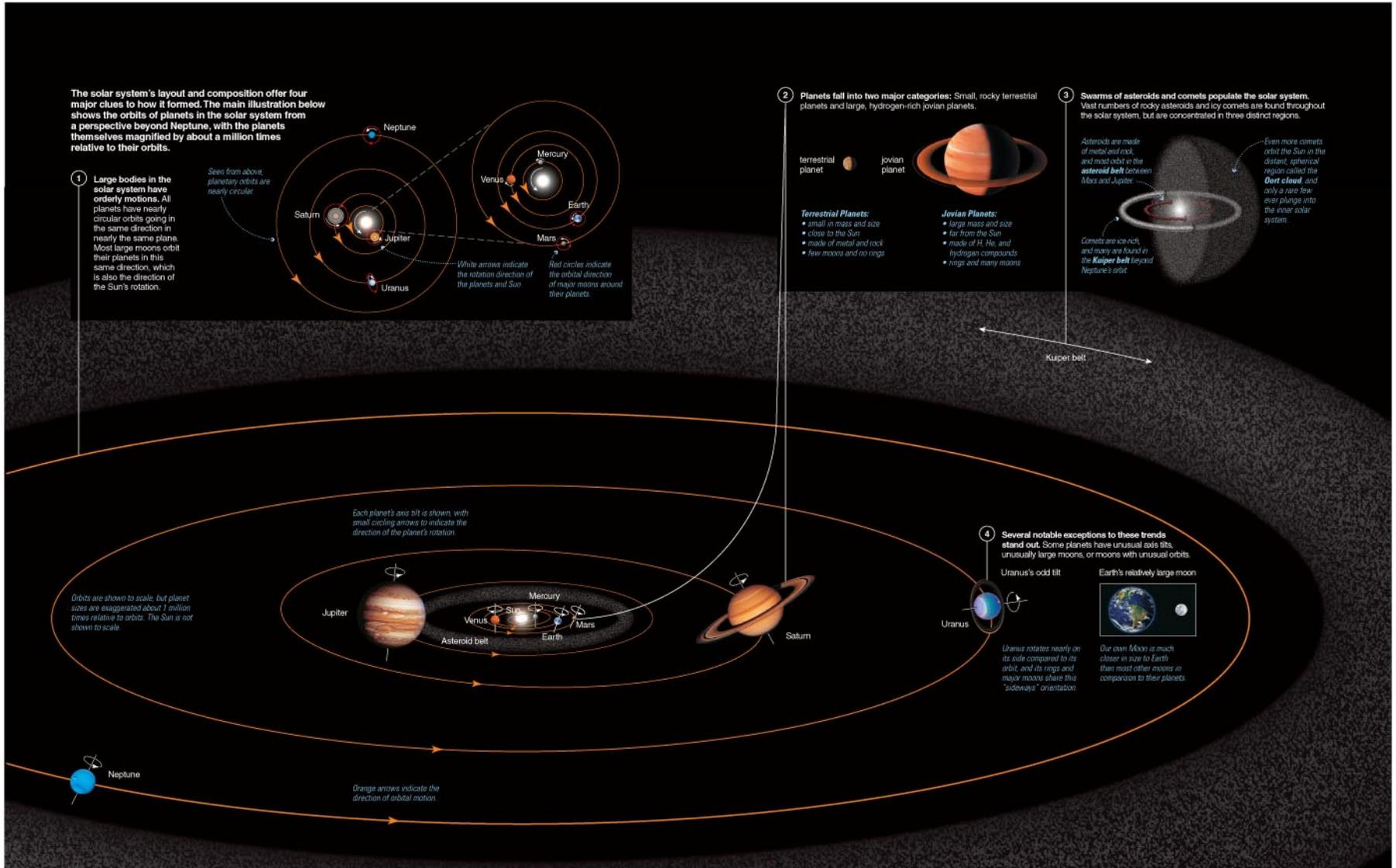
icy bodies

# Formation of the Solar System

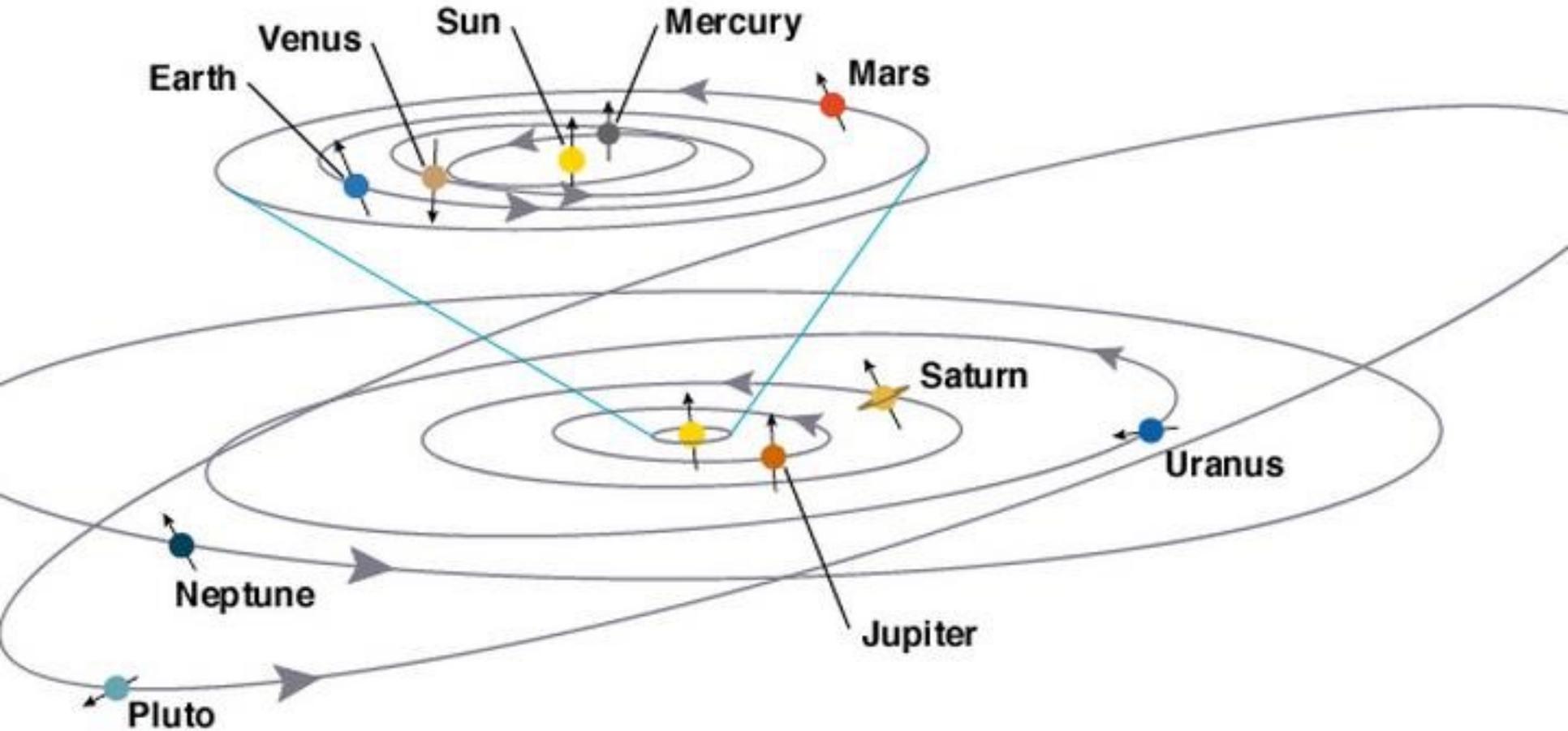
How did these things come to be?



# What features of our solar system provide clues to how it formed?



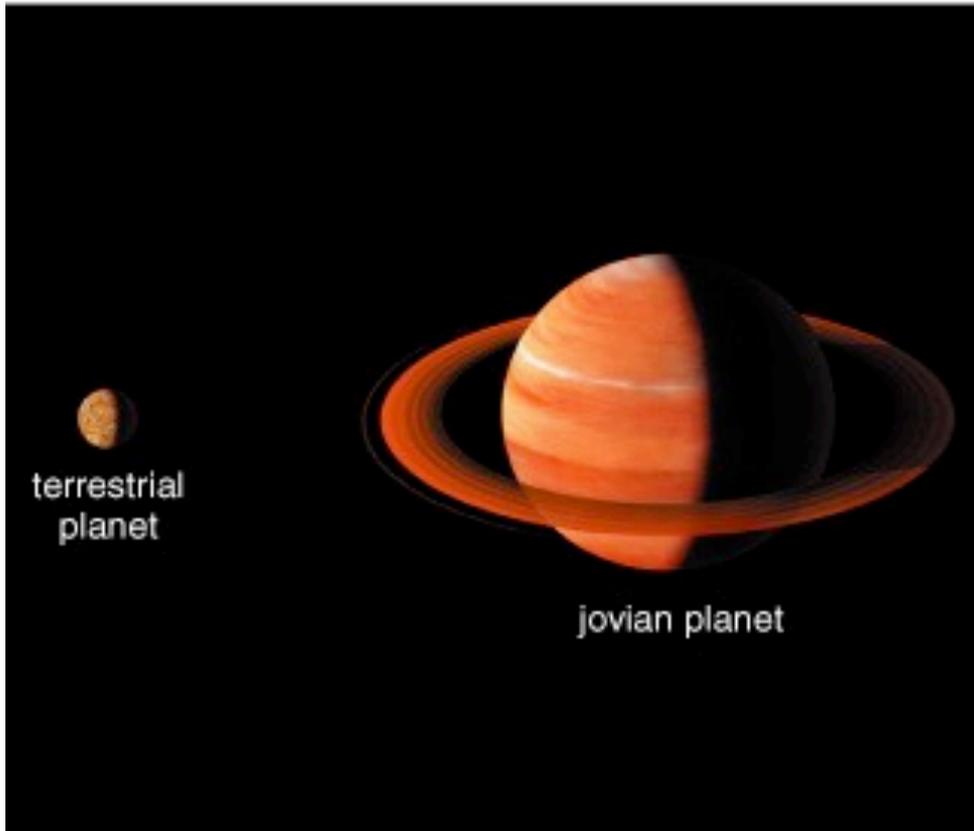
# Clues to Solar System Formation



right © Addison Wesley

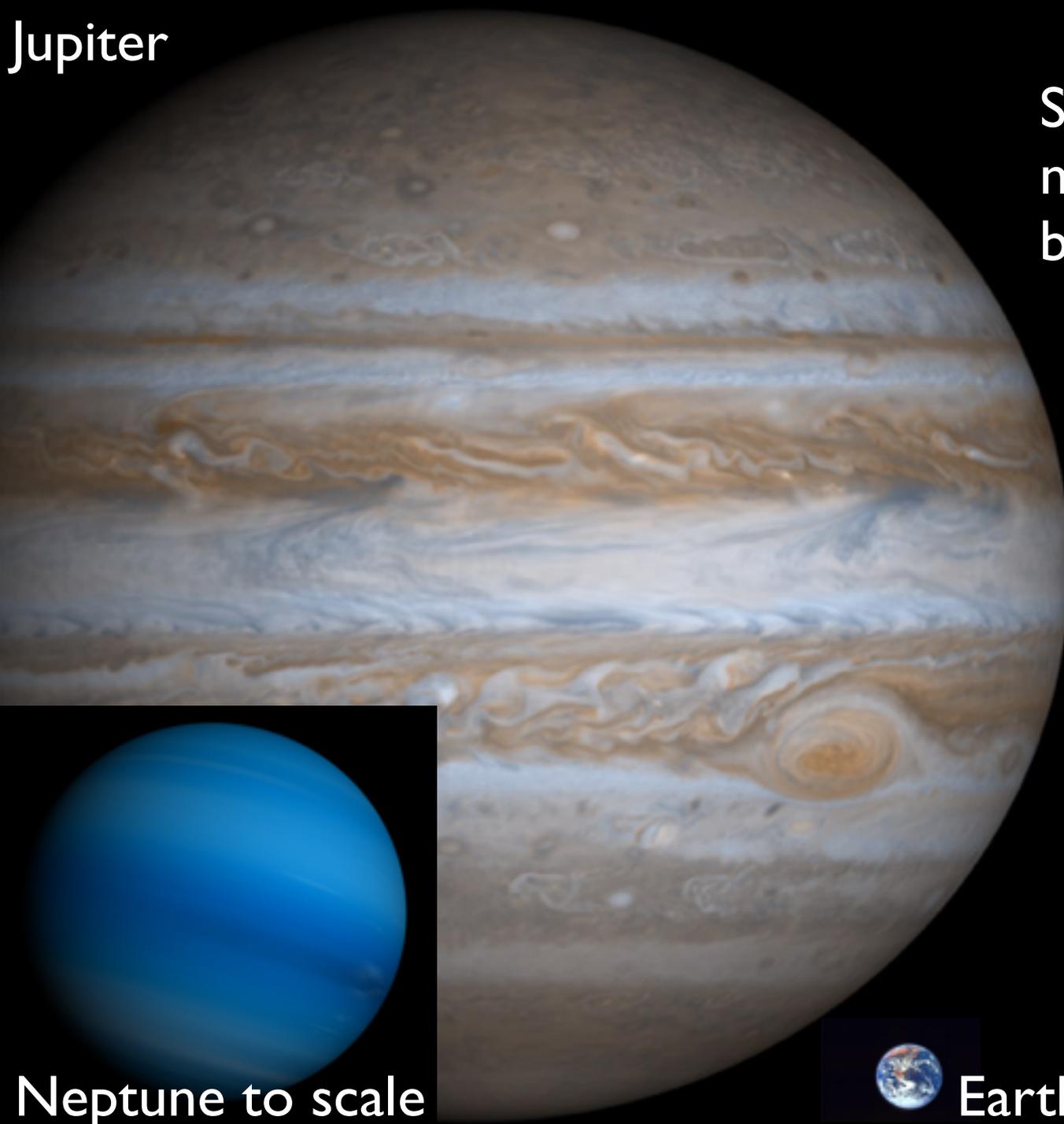
Planar, prograde motion: everything spinning in the same sense

# 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

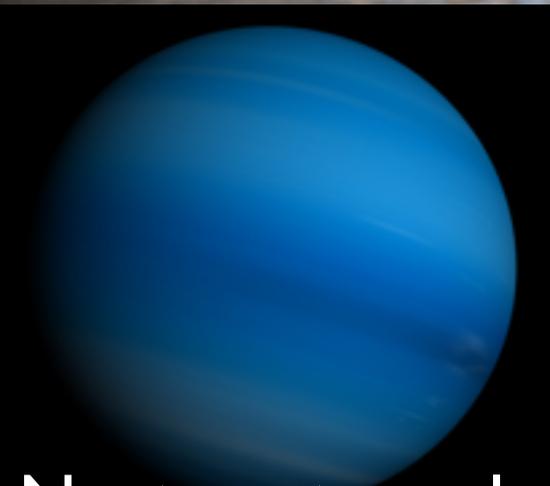


Some astronomers  
now distinguish  
between

Gas Giants  
Jupiter, Saturn

and

Ice Giants  
Uranus, Neptune

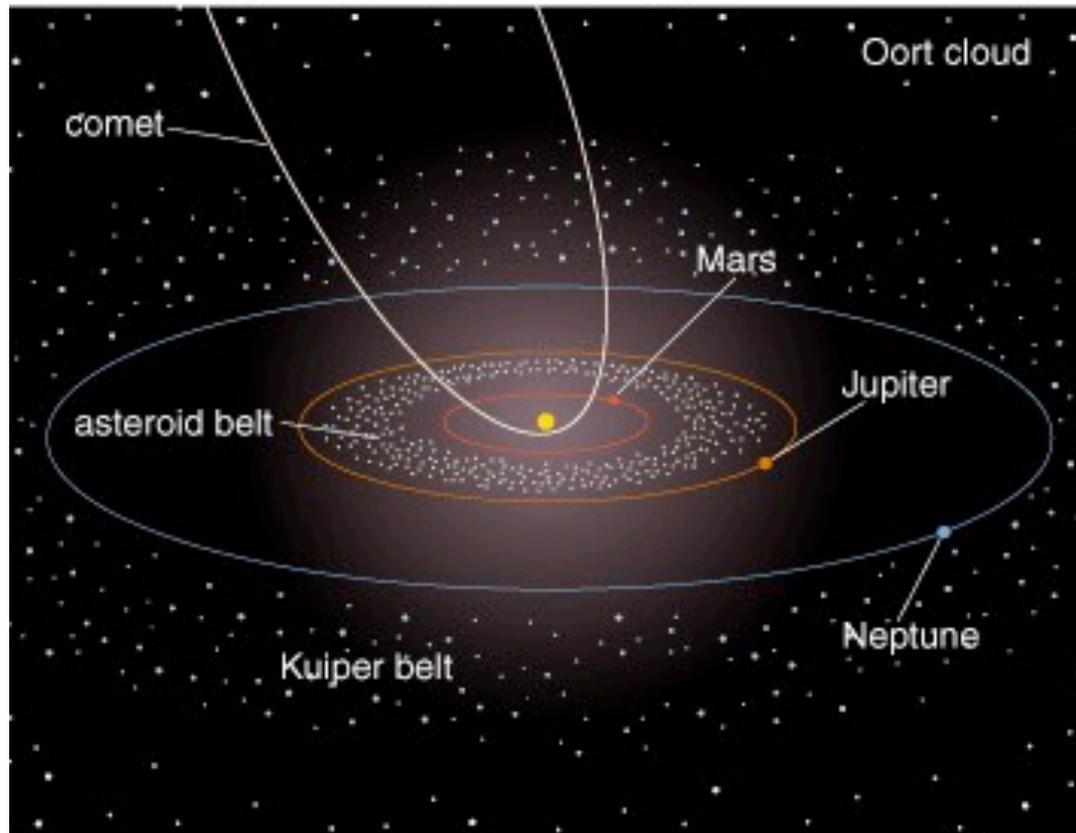


Neptune to scale



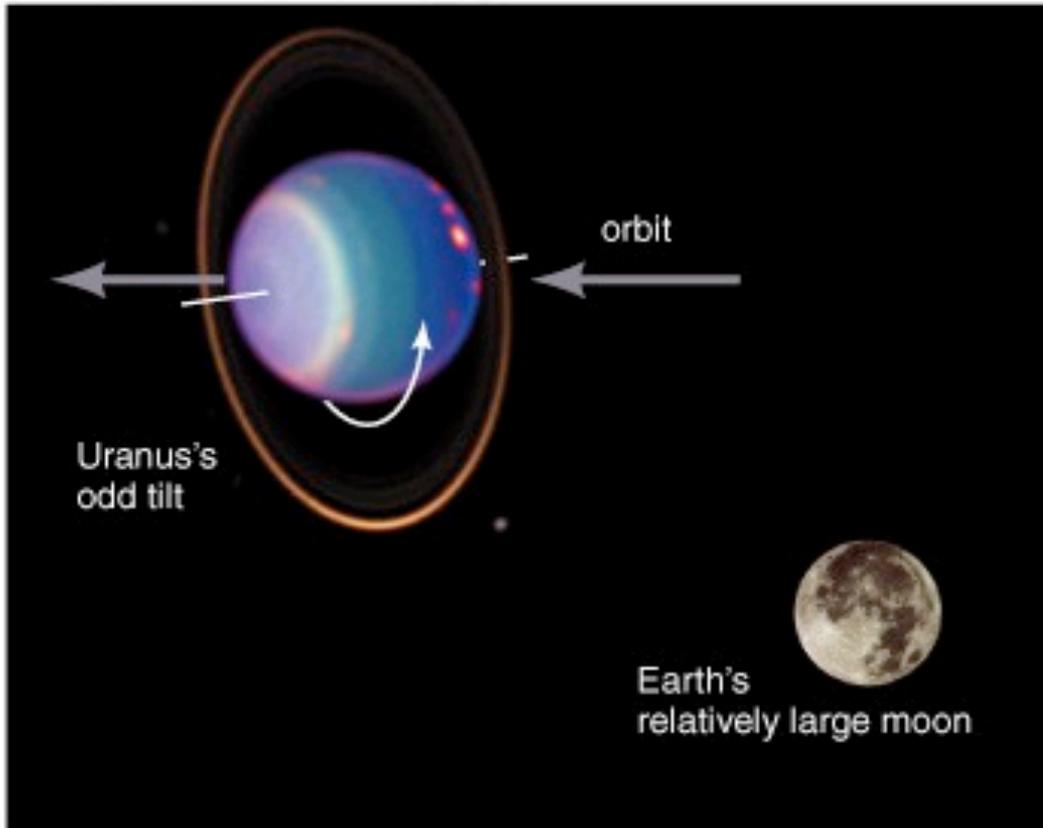
Earth to scale

# 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.

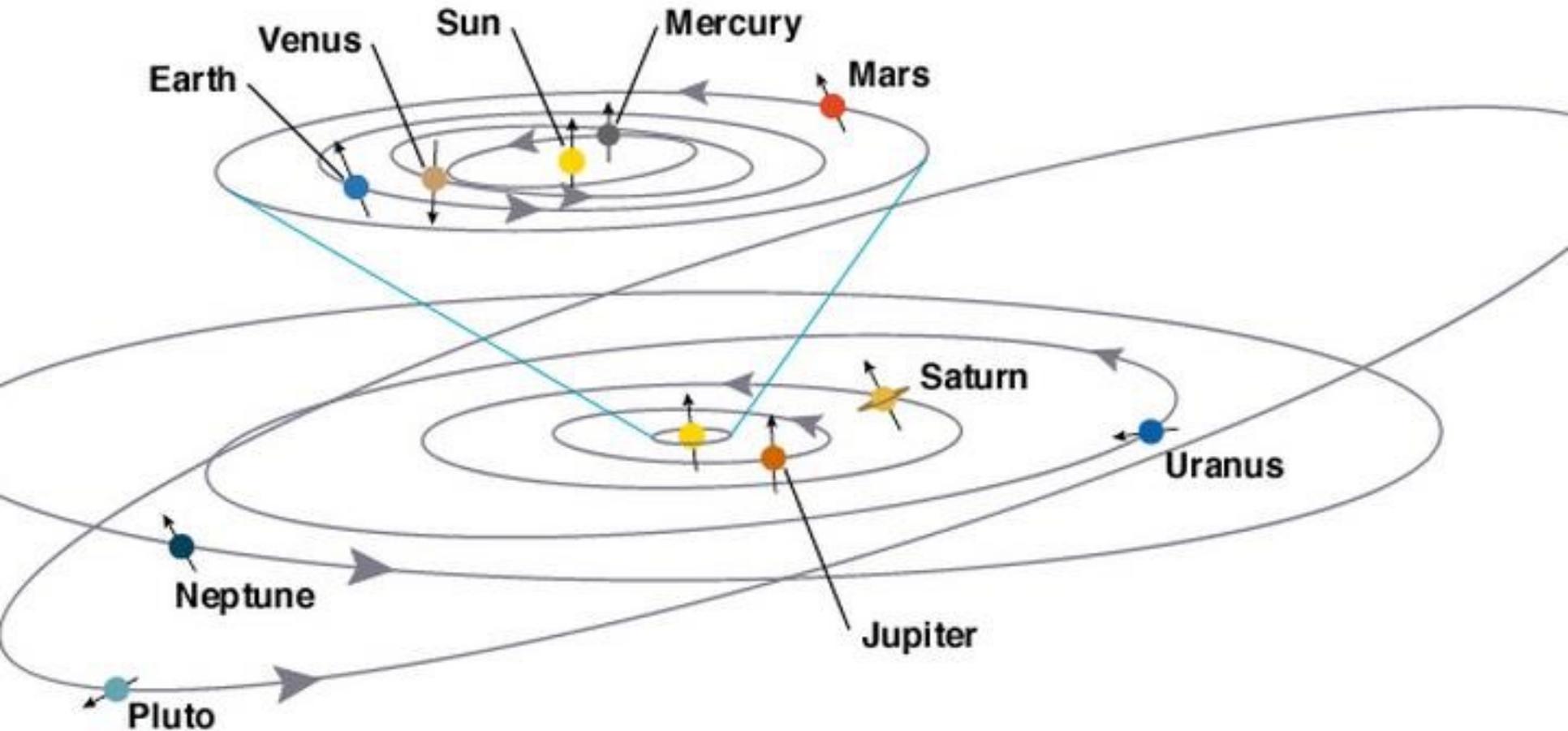
(*nebula* = cloud)

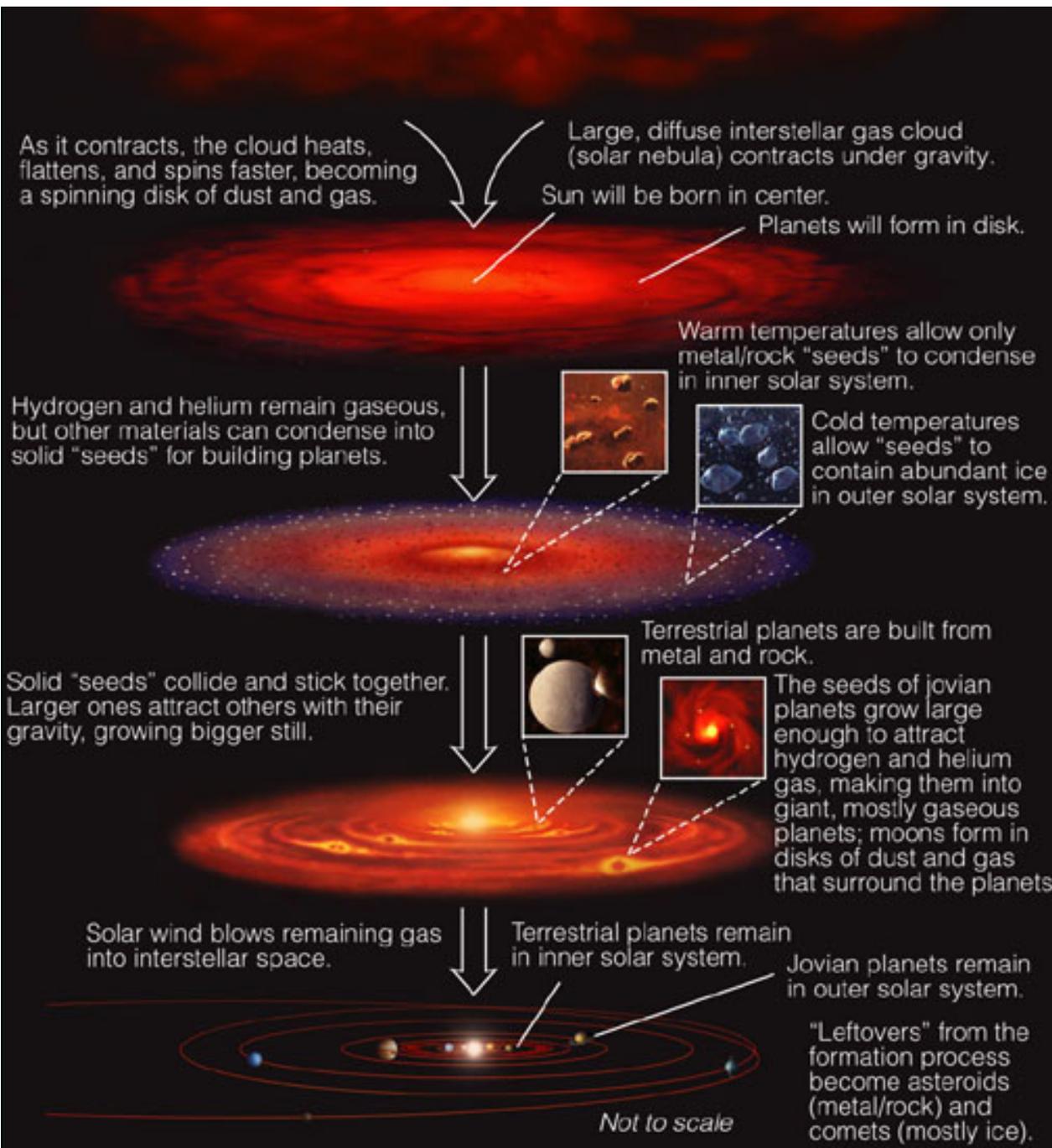
Also known as the *solar nebula* hypothesis

SS formation movie

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

# What caused the orderly patterns of motion in our solar system?





- Nebula spins up as it collapses (angular momentum conserved)
- Solid particles condense out of gas
- Particles collide; form ever larger objects
- Most mass eventually swept up into planets