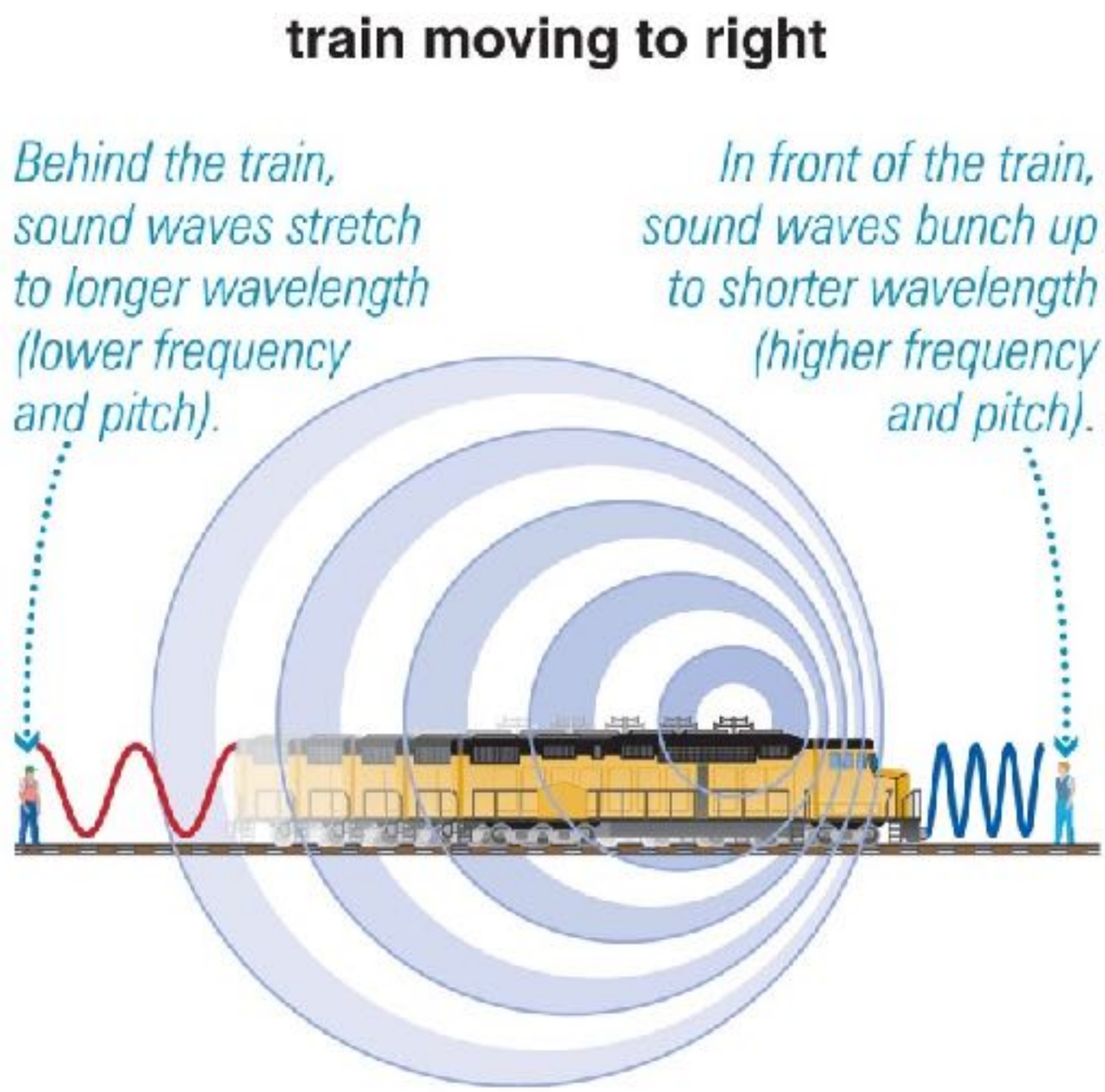
Today

- Doppler Effect
- Telescopes
- Solar System Overview

Next time

- Homework 3 Due

The Doppler Effect



b For a moving train, the sound you hear depends on whether the train is moving toward you or away from you.

Doppler Effect for Light

- Motion away -> redshift
- Motion towards -> blueshift

$$\frac{\text{wavelength shift}}{\text{wavelength}} \rightarrow \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{v}{c} \leftarrow \frac{\text{speed}}{\text{speed of light}}$$

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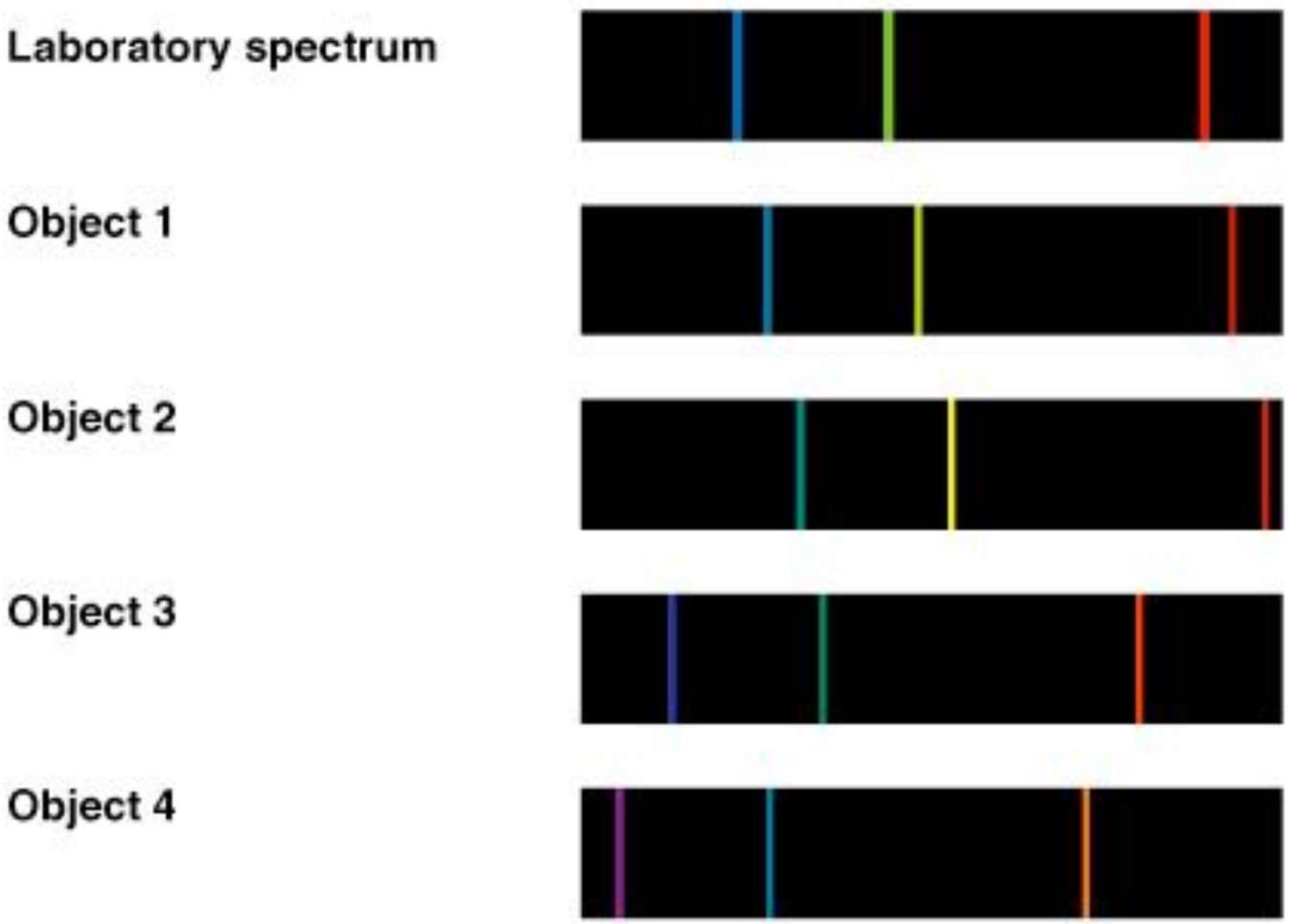
Measuring the Shift



Stationary

Moving Away

Away Faster

redshift

Moving Toward

Toward Faster

blueshift

- We generally measure the Doppler effect from shifts in the wavelengths of spectral lines.

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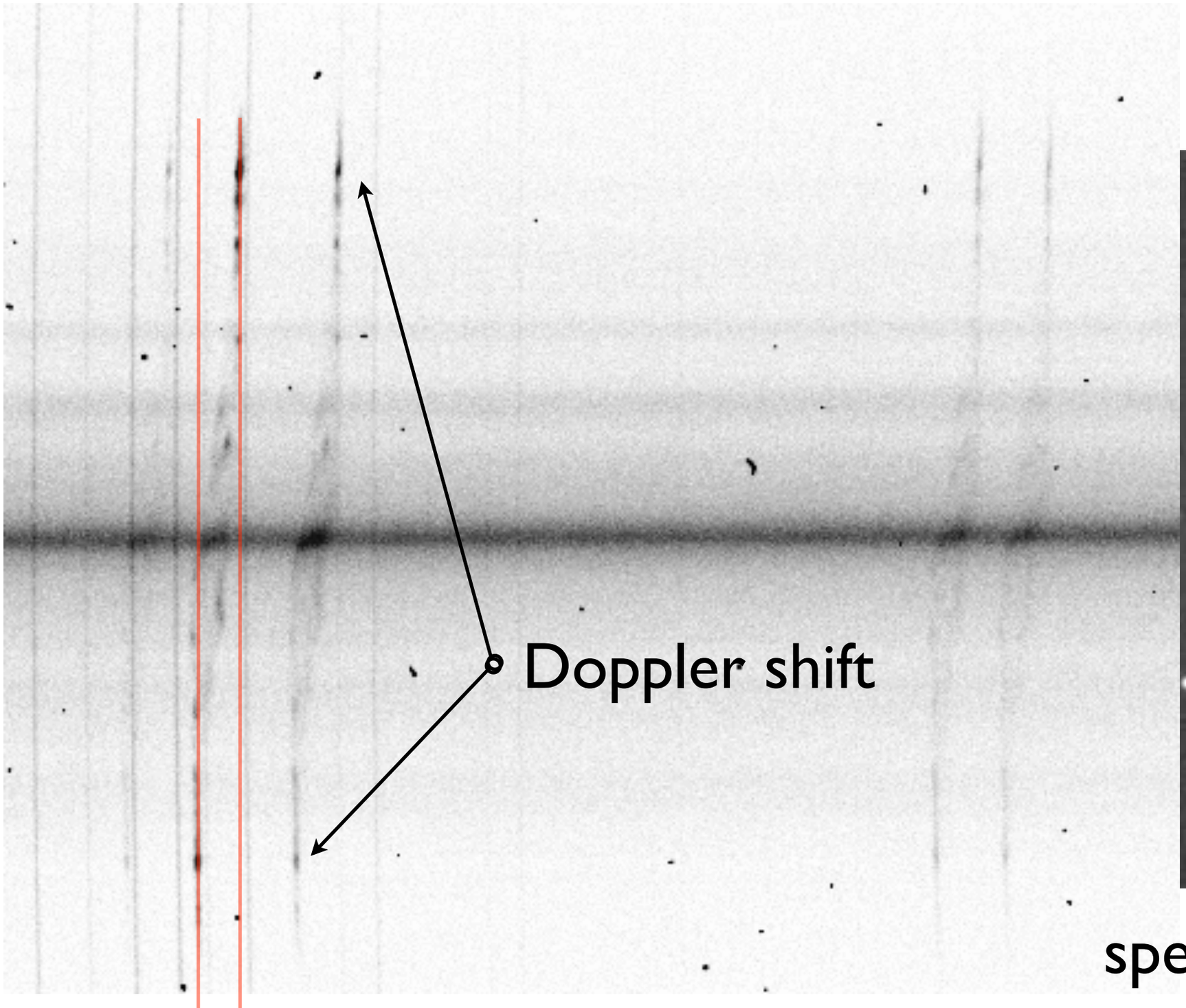
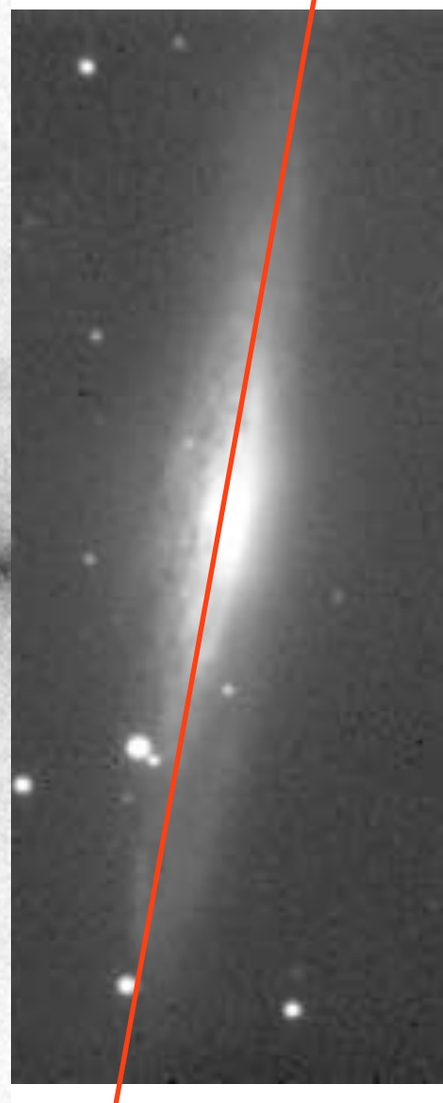
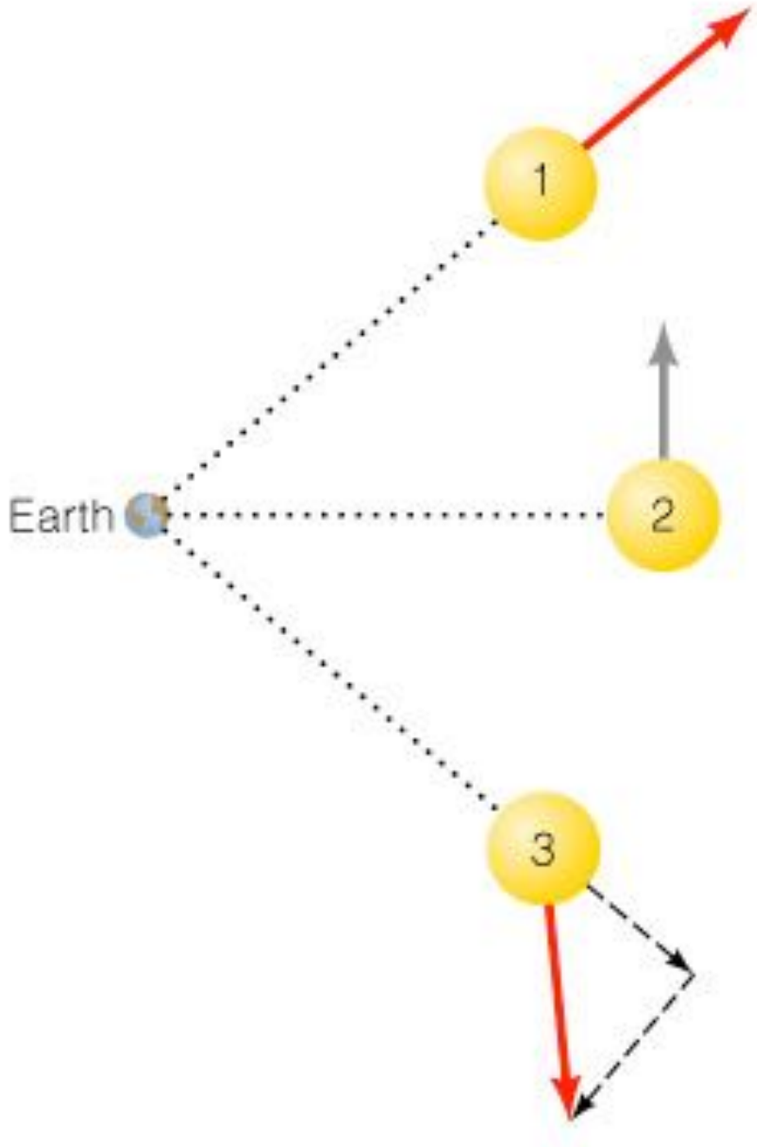
Spectrum


position along slit
Doppler shift
$\Delta\lambda$
wavelength


spectrograph slit

Doppler shift tells us ONLY about the part of an object's motion toward or away from us (along our line of sight).



maximum doppler effect

no doppler effect

intermediate case

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Telescopes

- Telescopes collect more light than our eyes ⇒ **light-collecting area**

- Telescopes can see more detail than our eyes ⇒ **angular resolution** (magnification)

- Telescopes/instruments can record light more sensitively than our eyes, and detect electromagnetic radiation that is invisible to our eyes (e.g., infrared, ultraviolet)

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Bigger is better

1. Larger light-collecting area

   can see fainter things

2. Better angular resolution

   can see smaller things

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Bigger is better

For a telescope with mirror of diameter D,

can see fainter: $b^{-1} \propto D^2$

with higher resolution: $\theta \propto \frac{\lambda}{D}$

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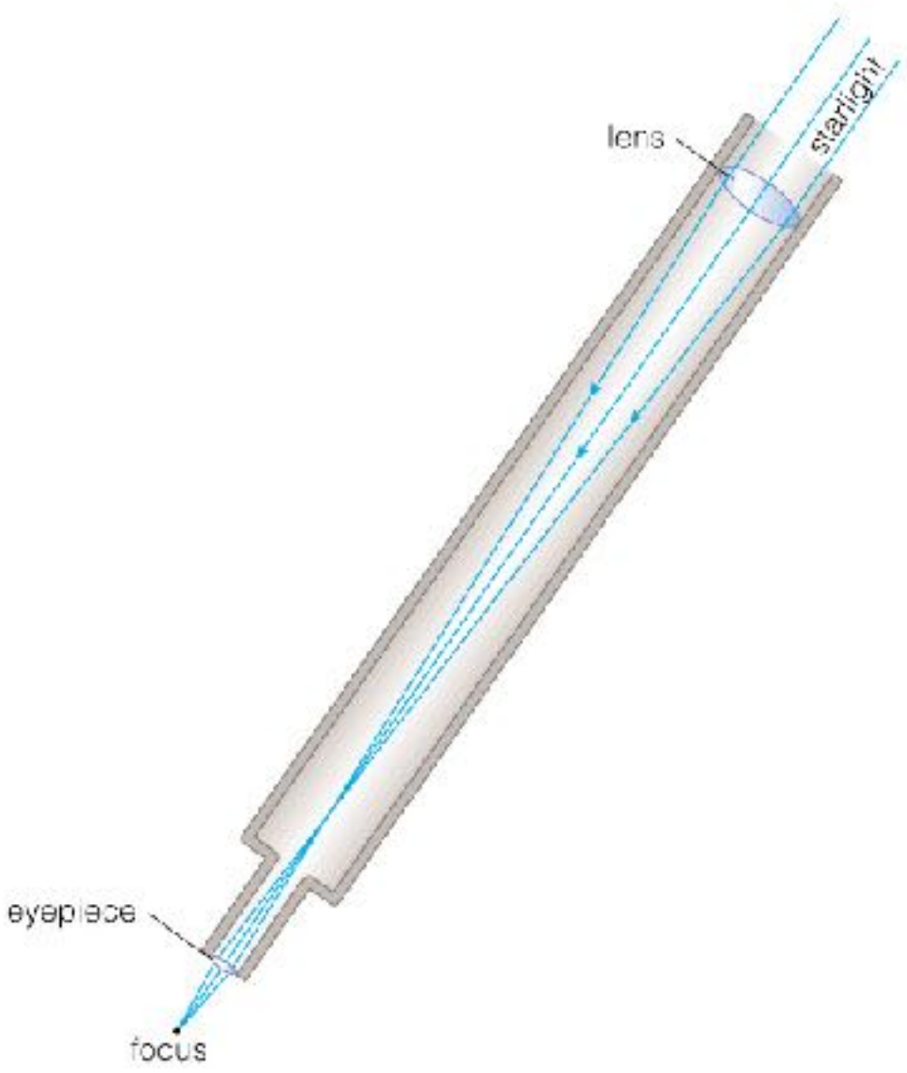
Basic Telescope Design

- Refracting: lenses



Refracting telescope

Yerkes 1-m refractor

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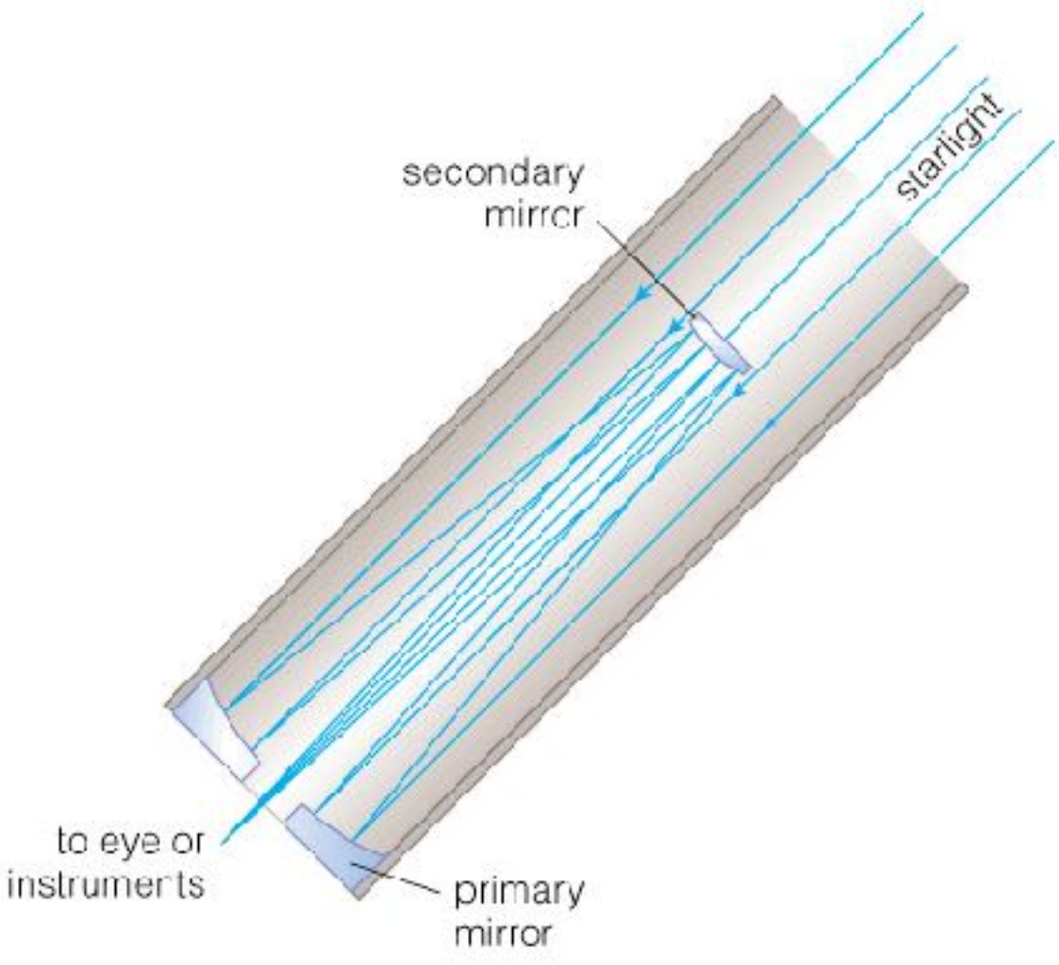
Basic Telescope Design

- Reflecting: mirrors
- Most research telescopes today are reflectors



Reflecting telescope

Gemini North 8-m

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Advantages of telescopes in space

Hubble

Chandra

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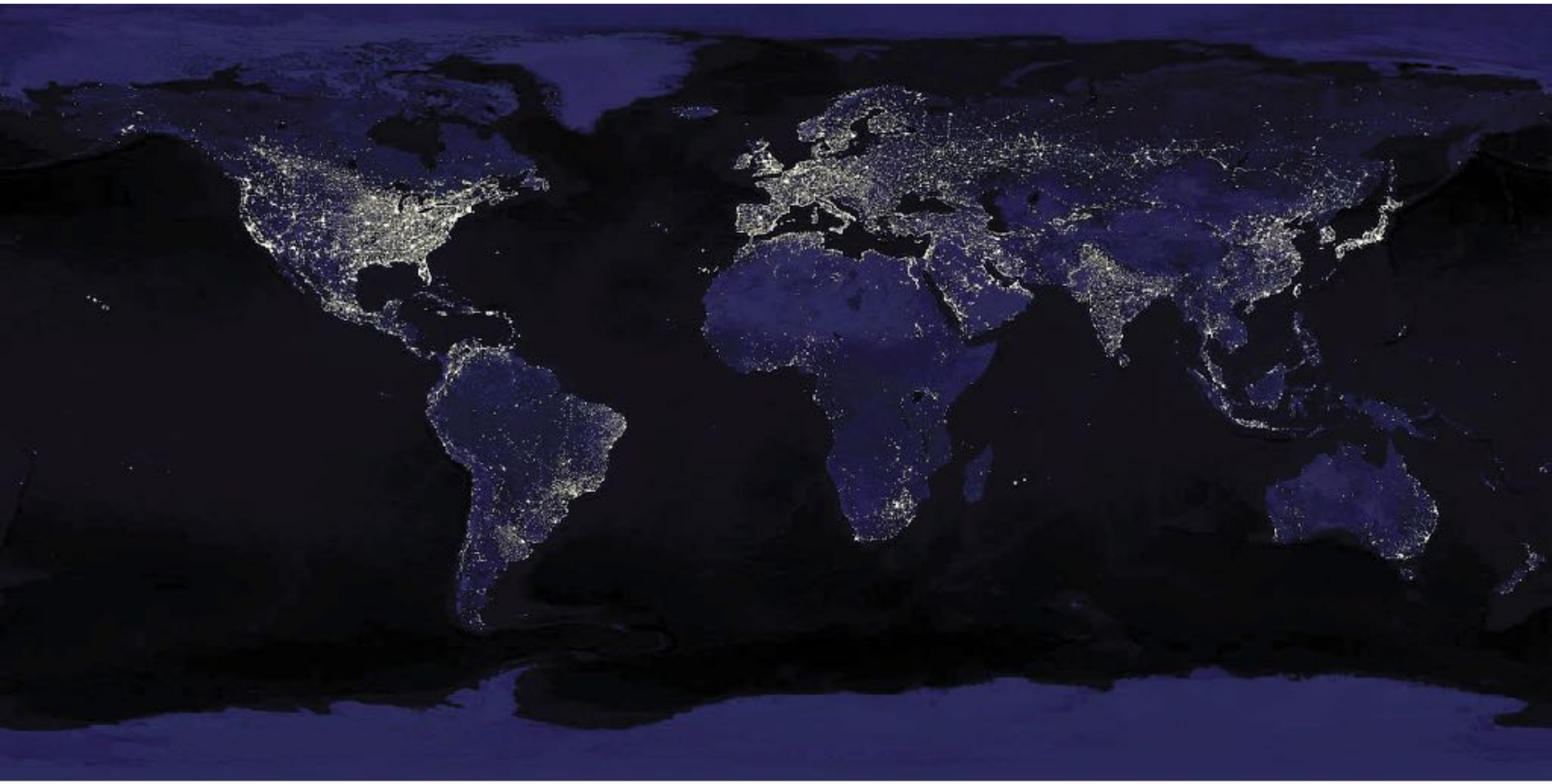
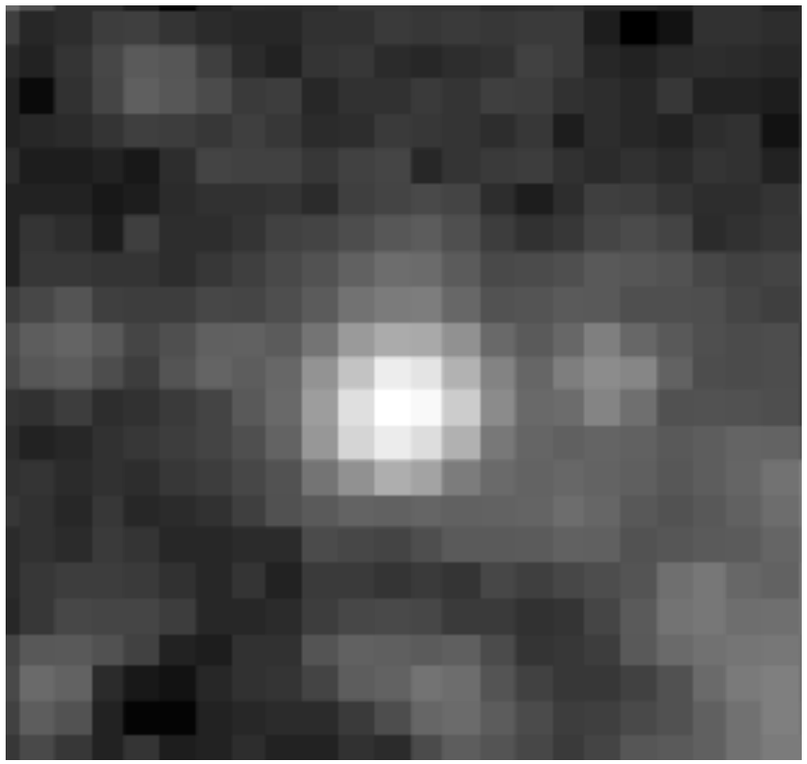
Observing problems due to Earth's atmosphere

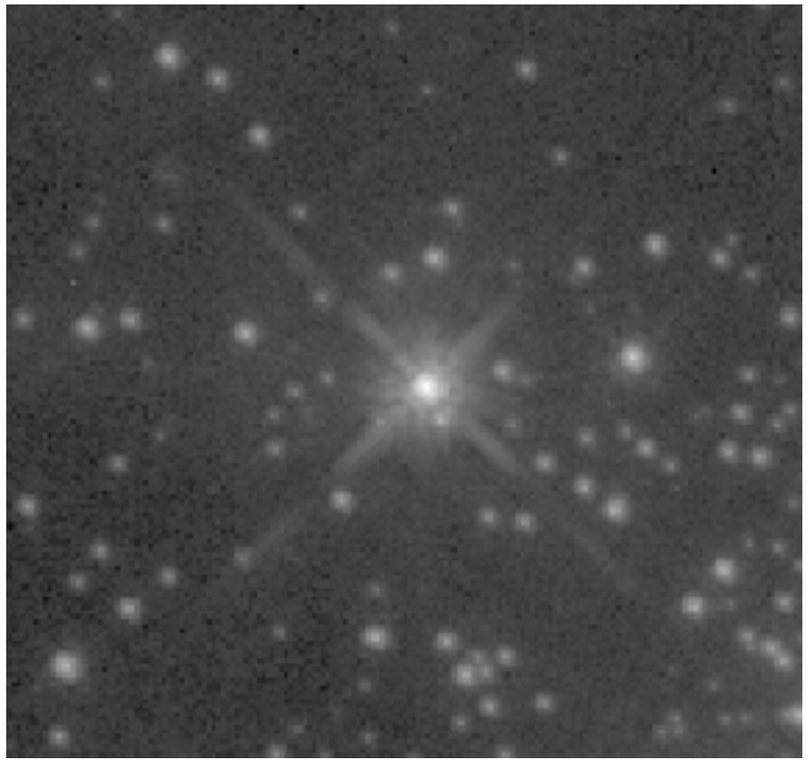
1. Light Pollution



2. Atmospheric Turbulence causes *twinkling* ⇒ blurs images (called "seeing" by astronomers).



Star viewed with ground-based telescope



View from Hubble Space Telescope

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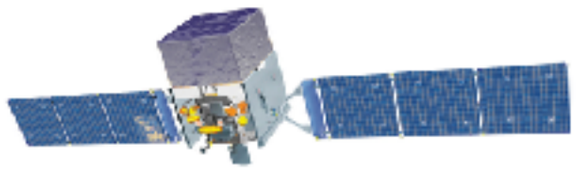
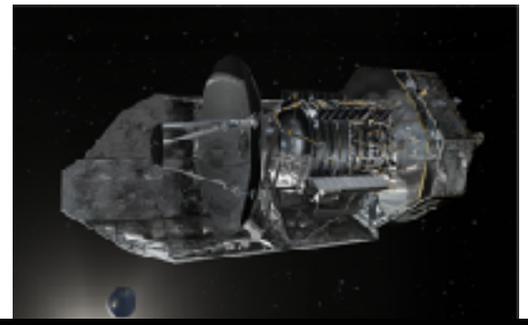
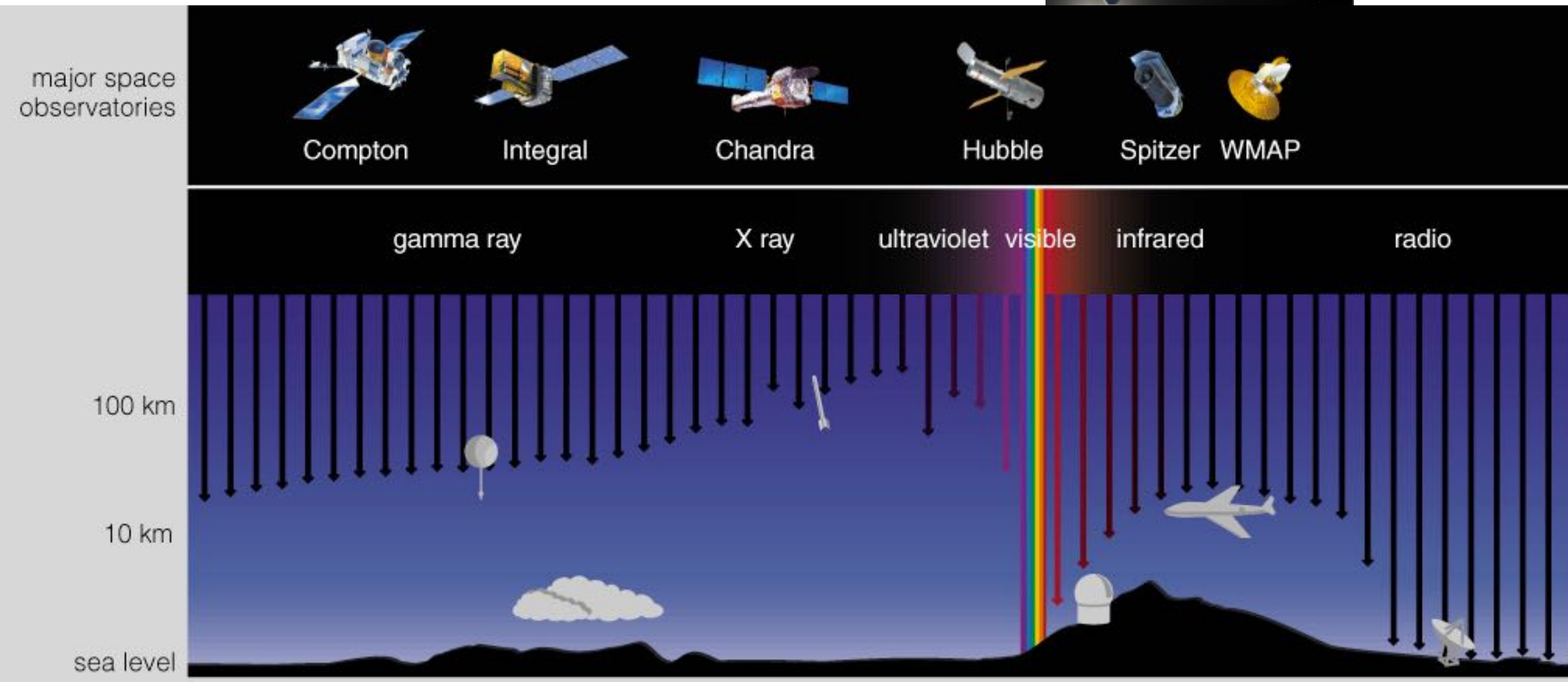
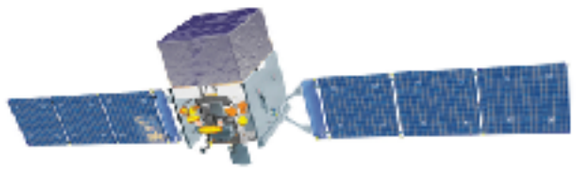
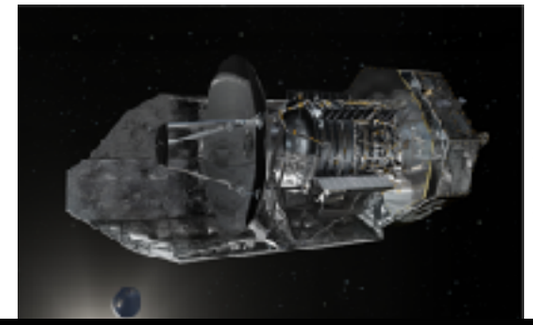
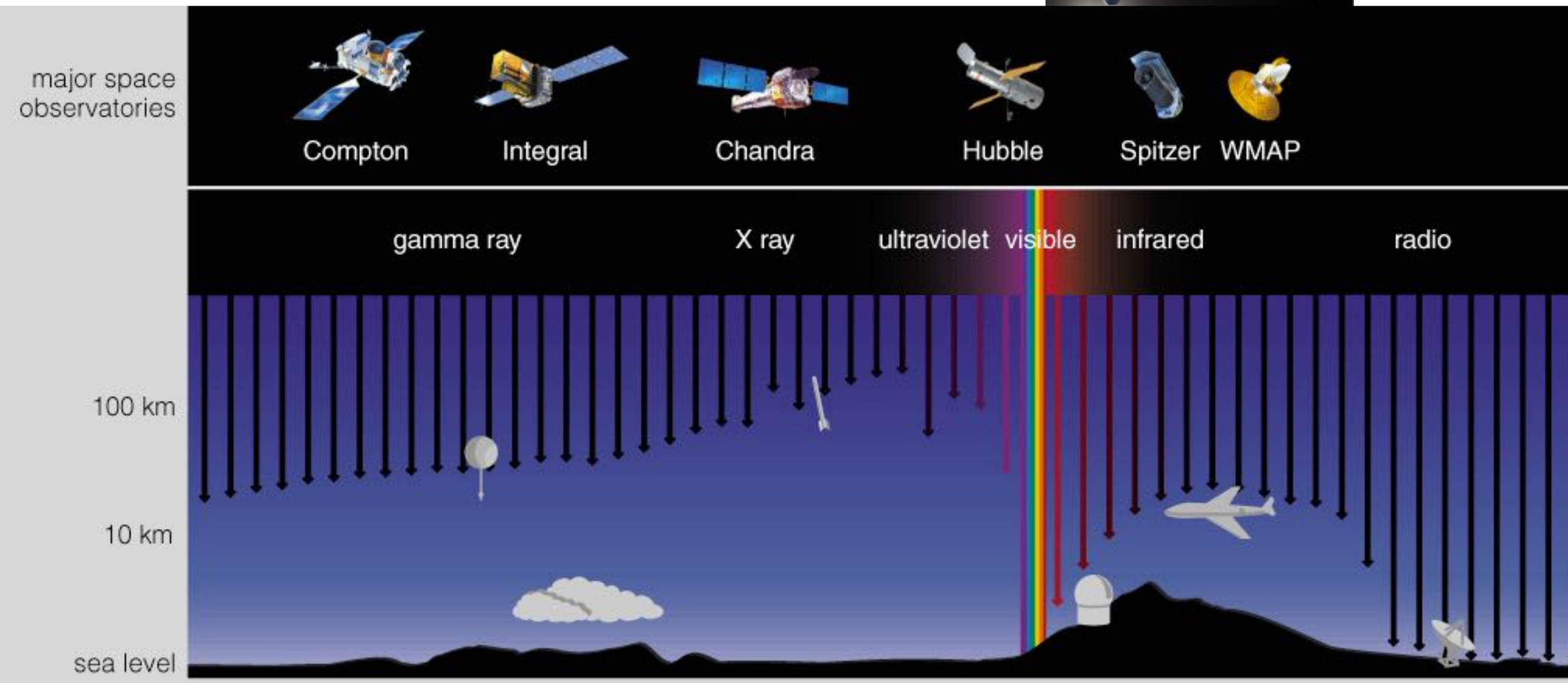
3. Atmosphere absorbs most of EM spectrum, including all UV and X ray and most infrared.

Fermi   Herschel



Telescopes in space solve all 3 problems.

Fermi   Herschel

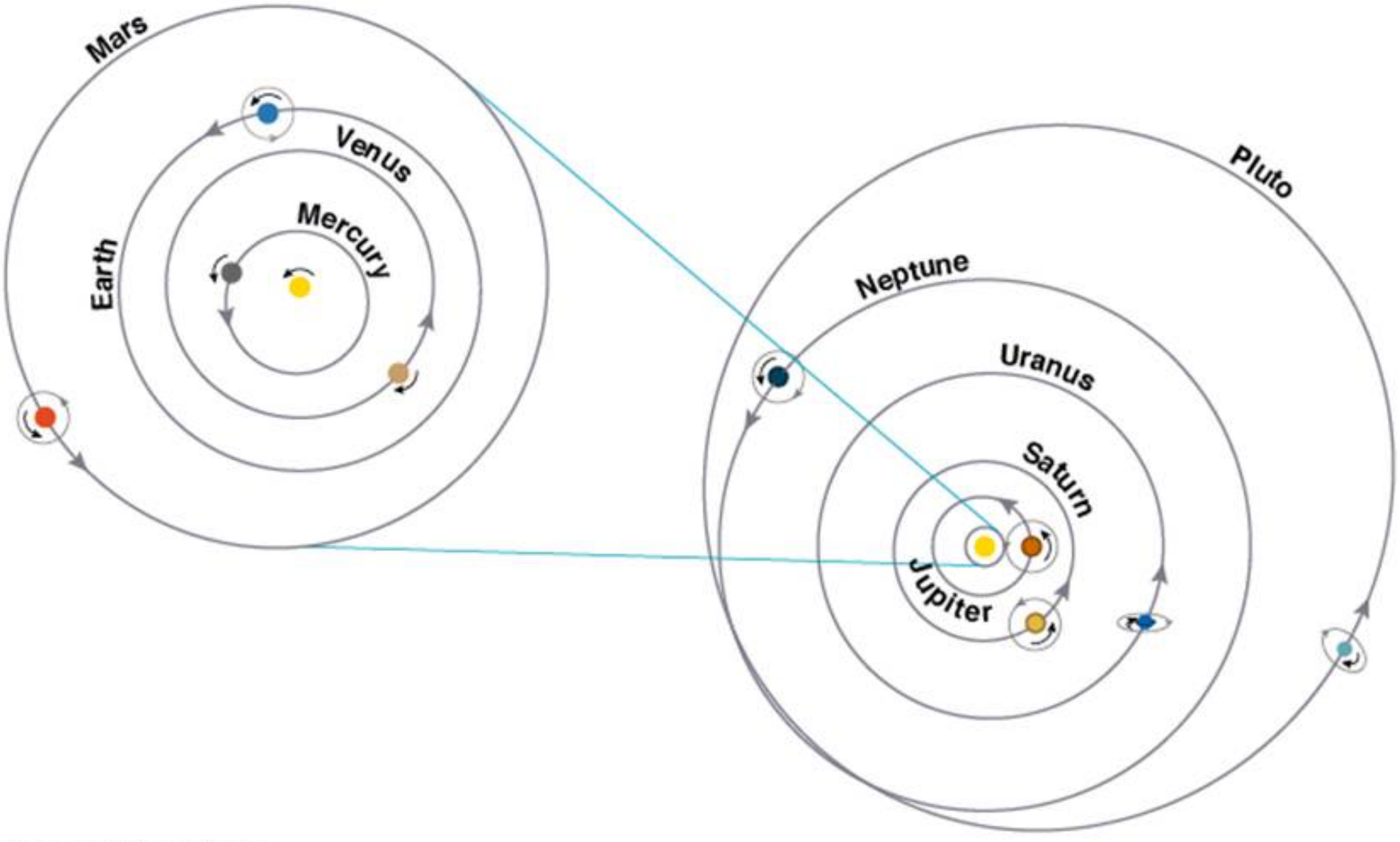


Contents of the Solar System

- 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



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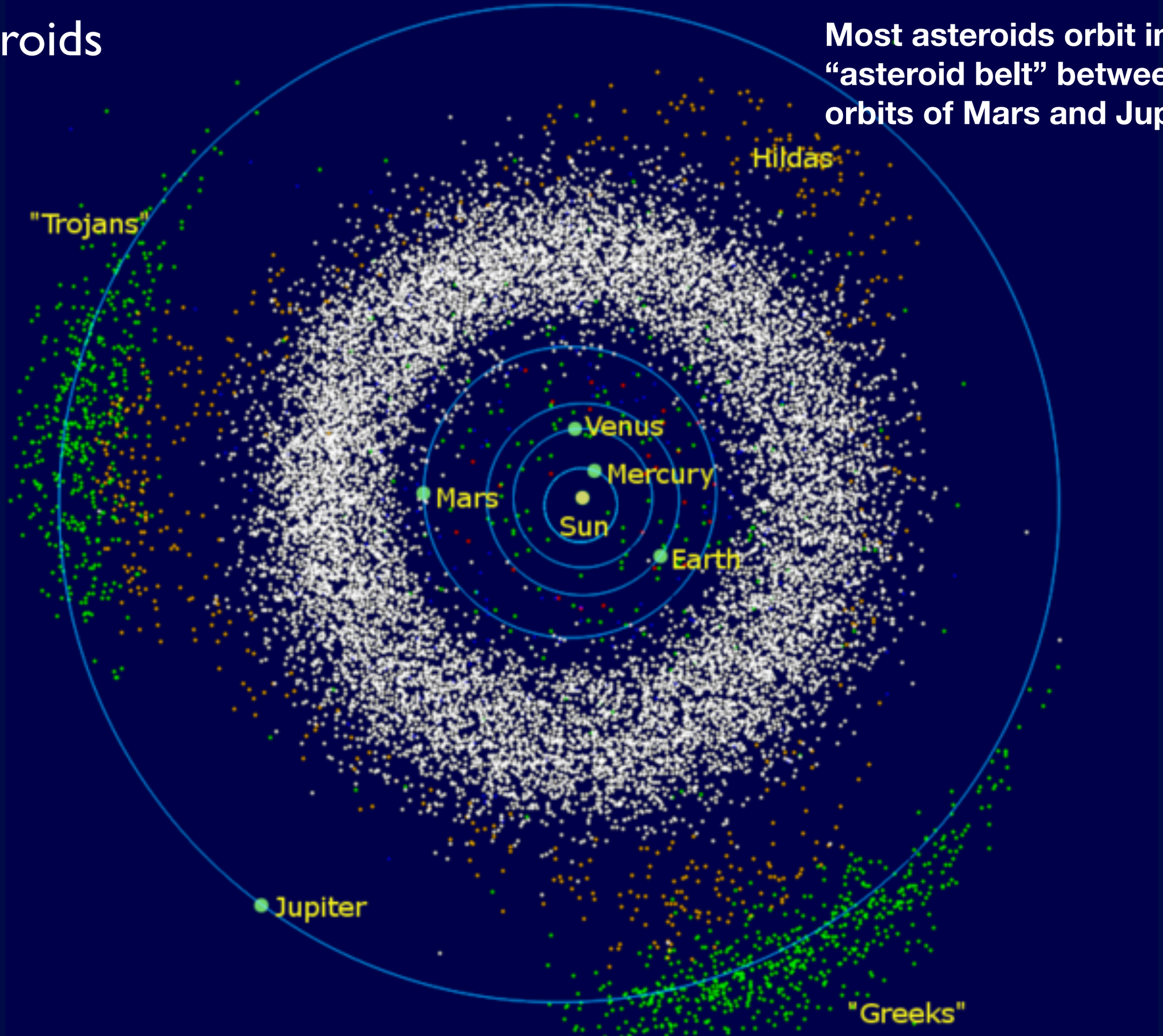
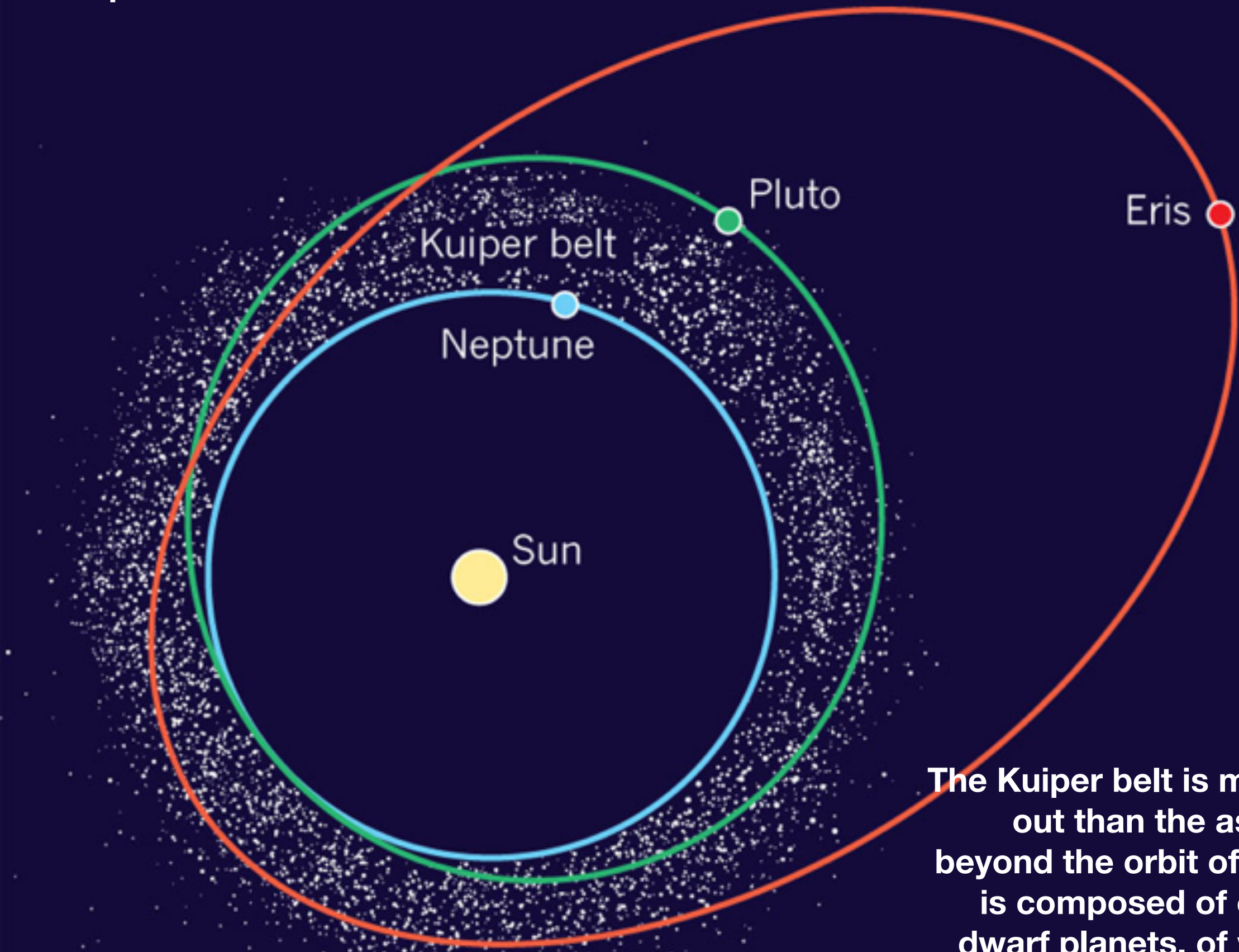
Asteroids

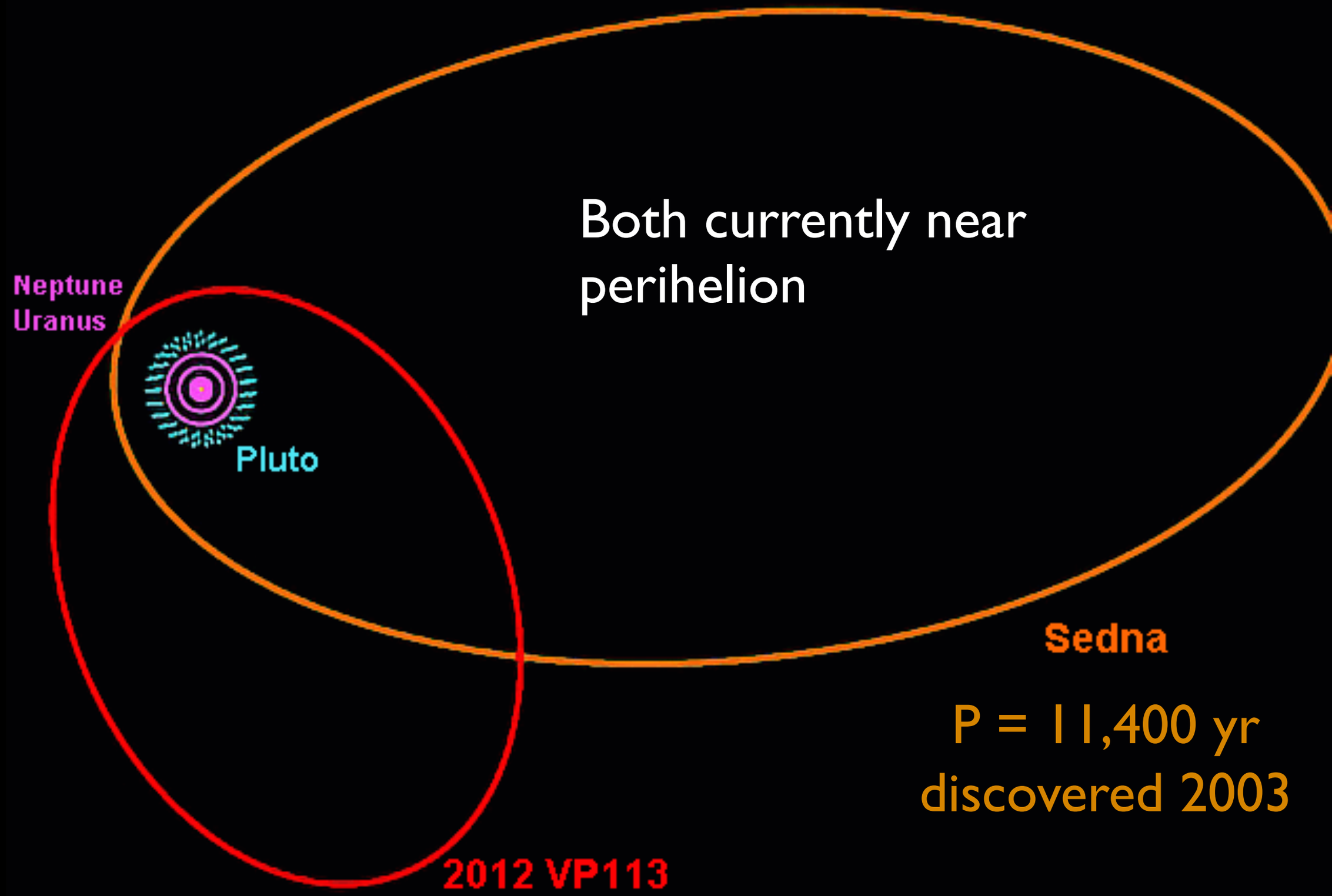
Most asteroids orbit in the "asteroid belt" between the orbits of Mars and Jupiter



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

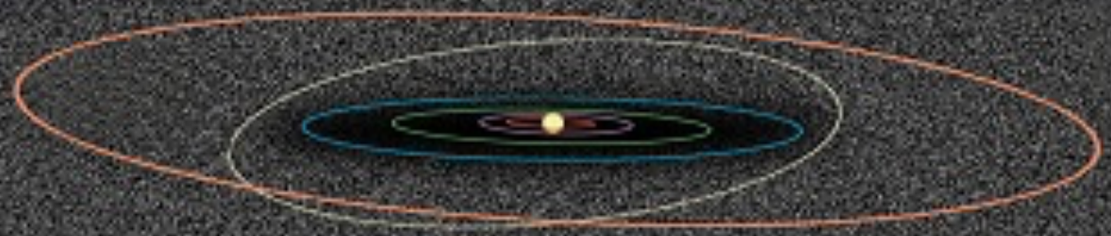


Both currently near perihelion

P = 11,400 yr
discovered 2003

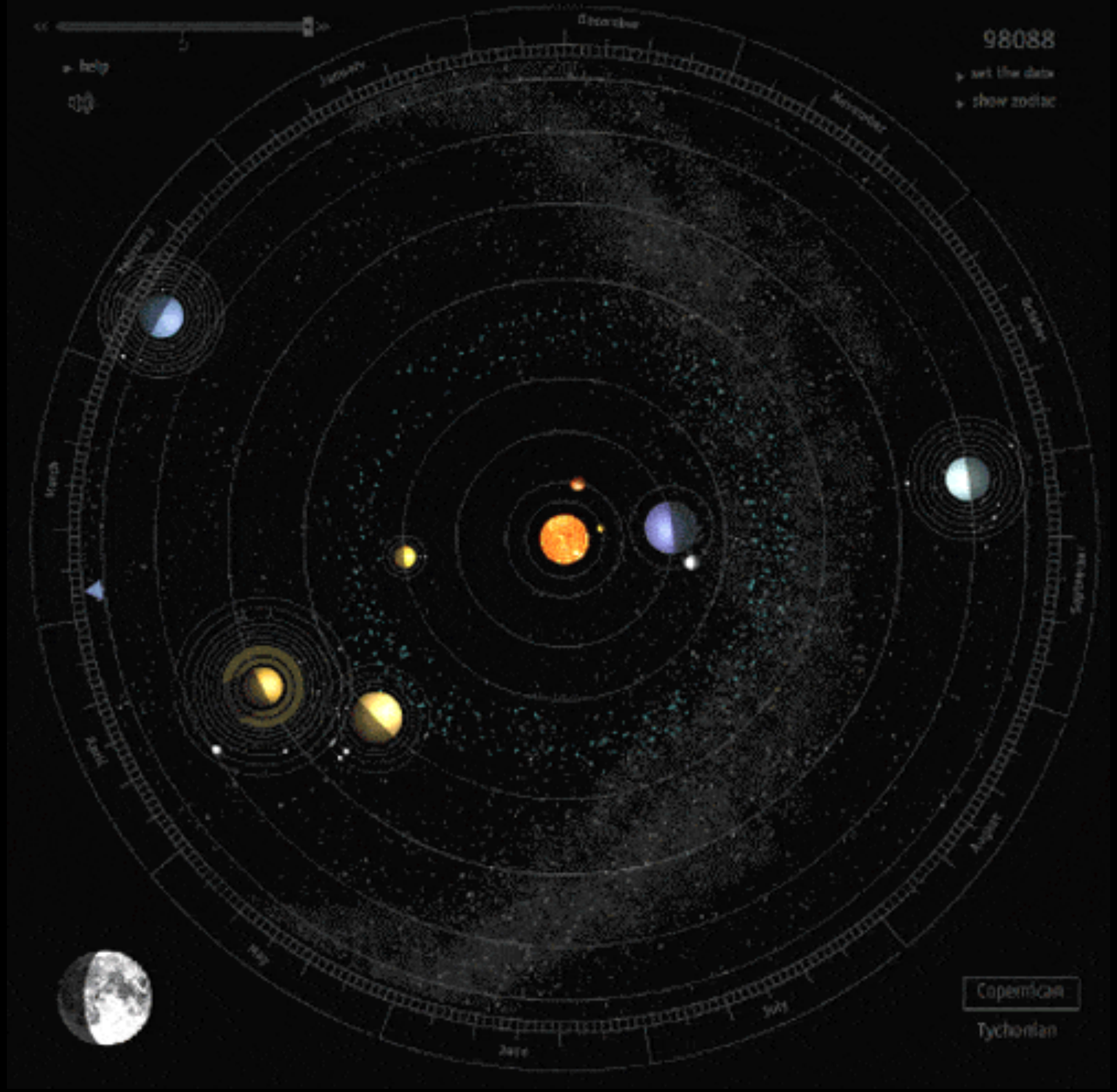
discovered 2012 (nicknamed “Biden”)

Kuiper Belt

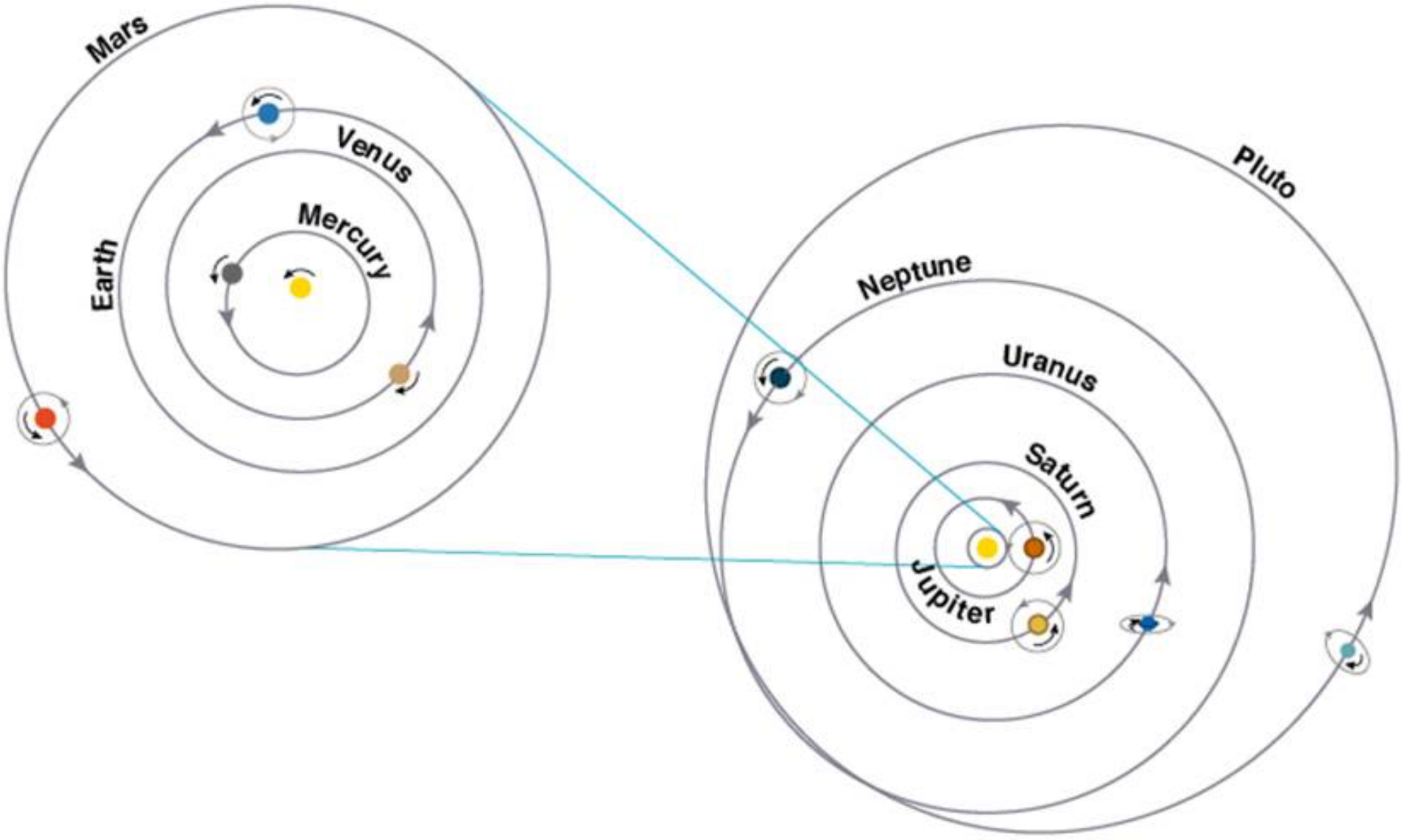


The orange track represents a typical KBO orbit. Pluto's orbit is represented by the yellow ring.

Oort Cloud



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

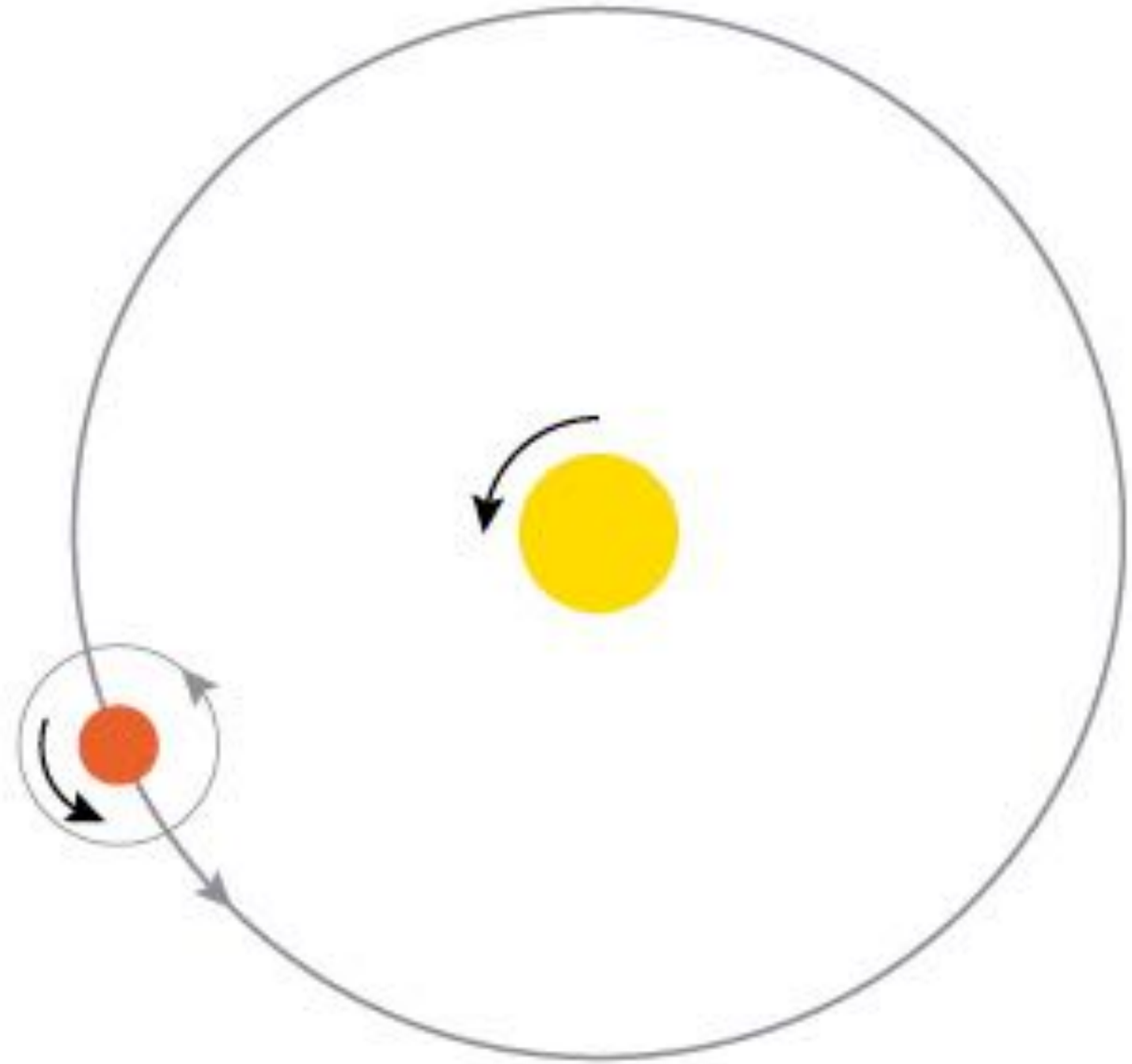


There are eight major planets with nearly circular orbits.

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

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

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***"

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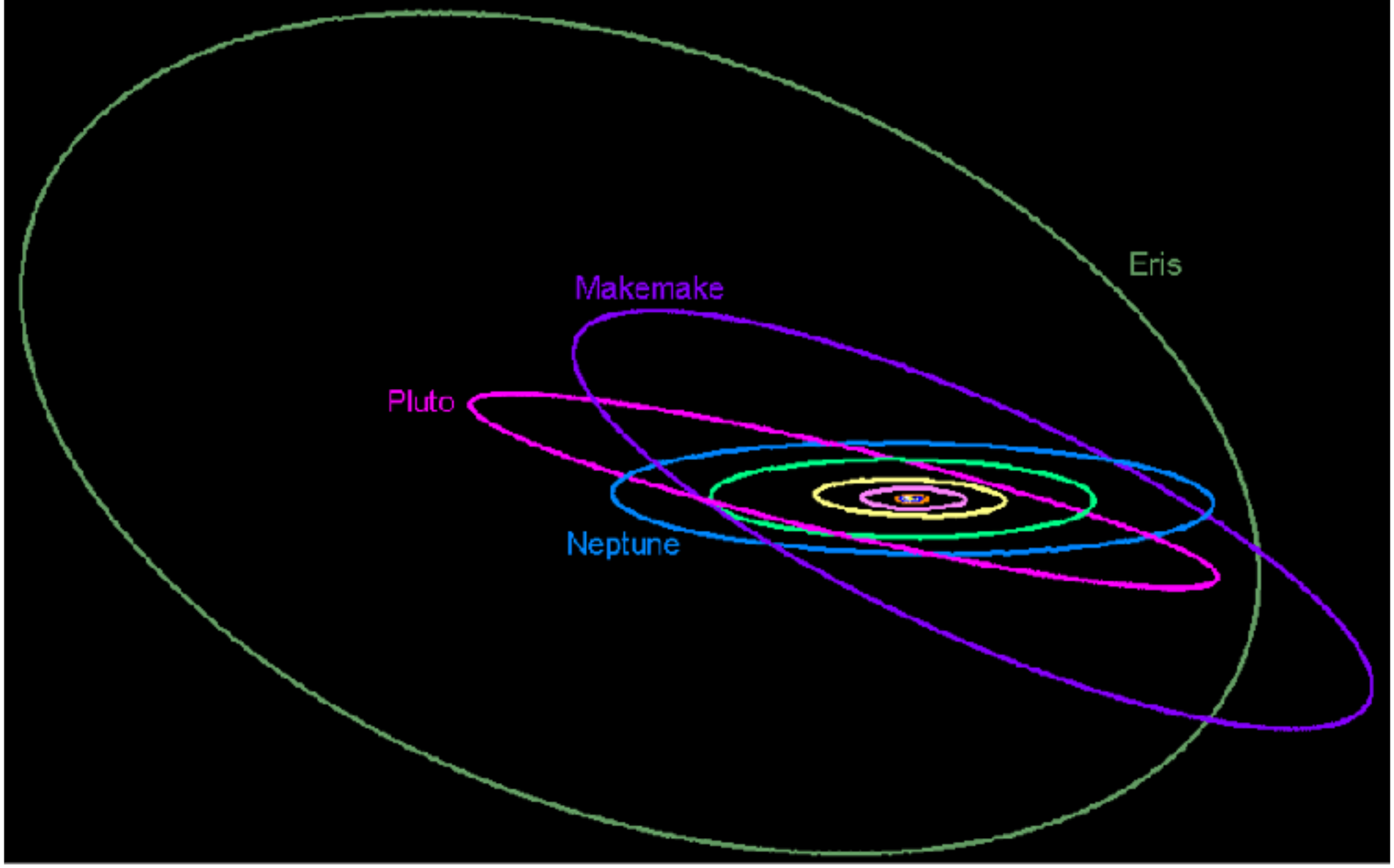


Dwarf planets are smaller than the major planets and some have quite elliptical orbits.

Most dwarf planets & asteroids also revolve prograde.

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

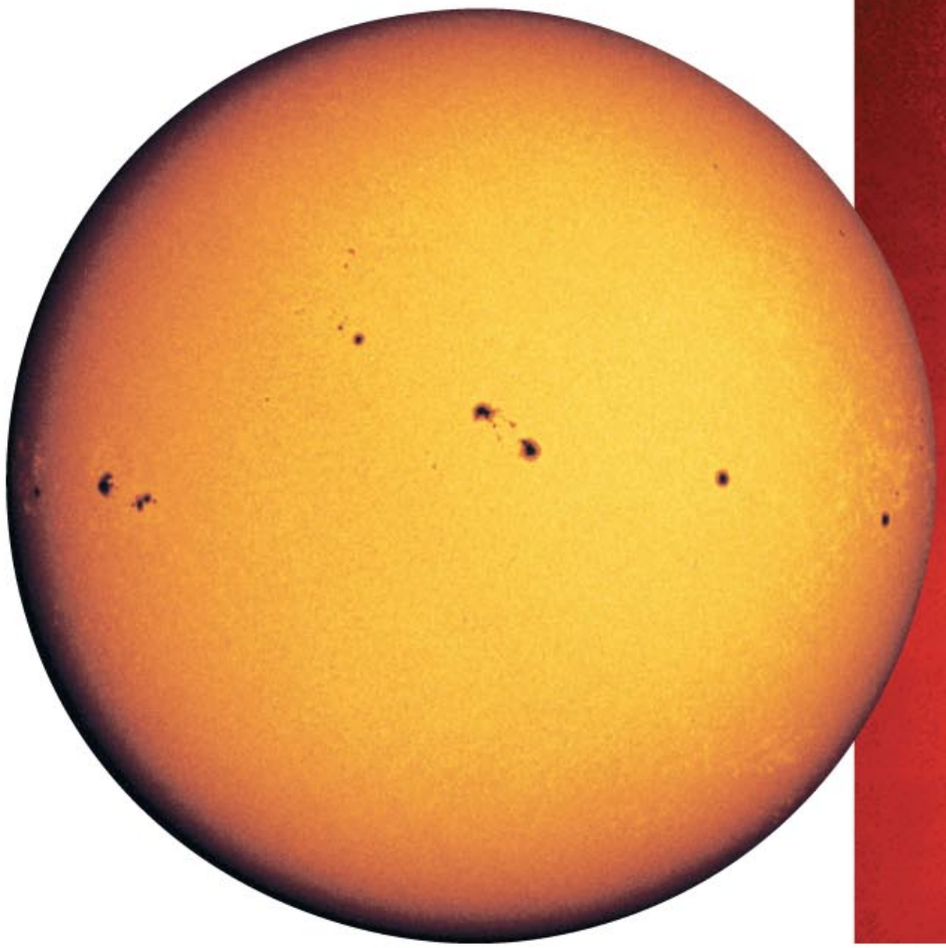
A Closer Look at the Contents

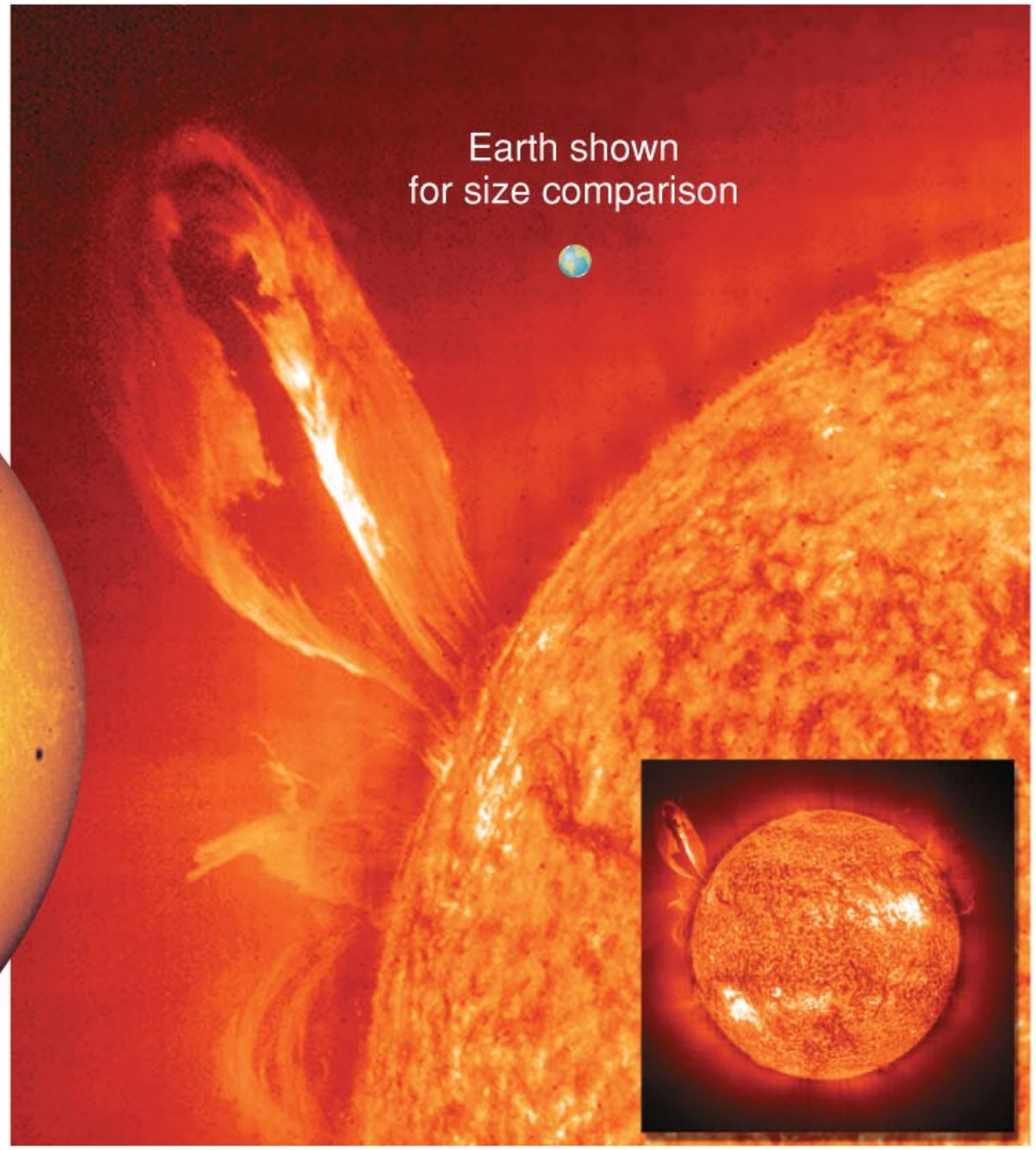
- The Sun
- Major Planets
  - Terrestrial: Mercury, Venus, Earth, Mars
  - Jovian planets: Jupiter, Saturn
  - Ice Giants: Uranus, Neptune

} Gas Giants

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

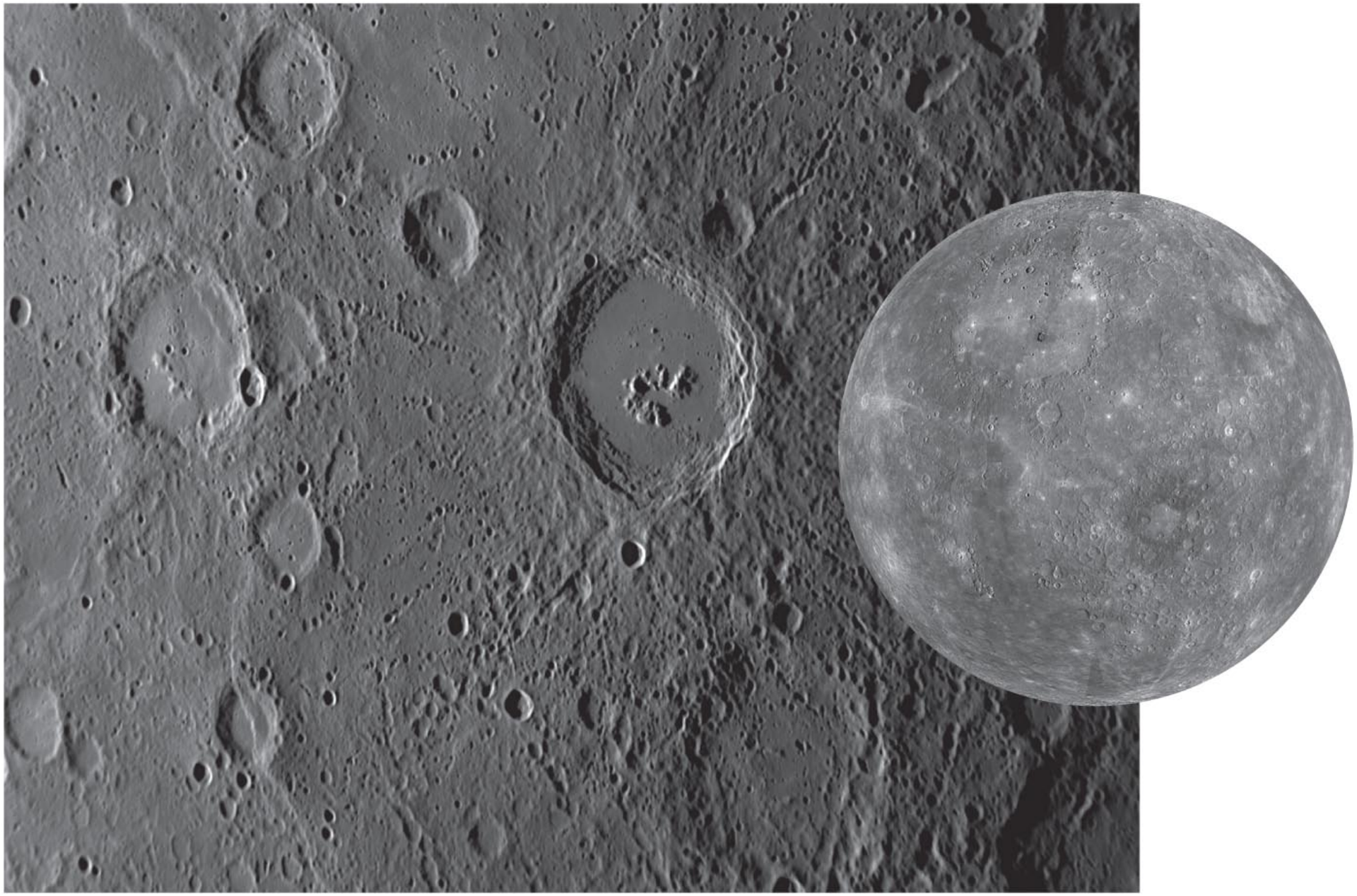
- The Sun





- 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

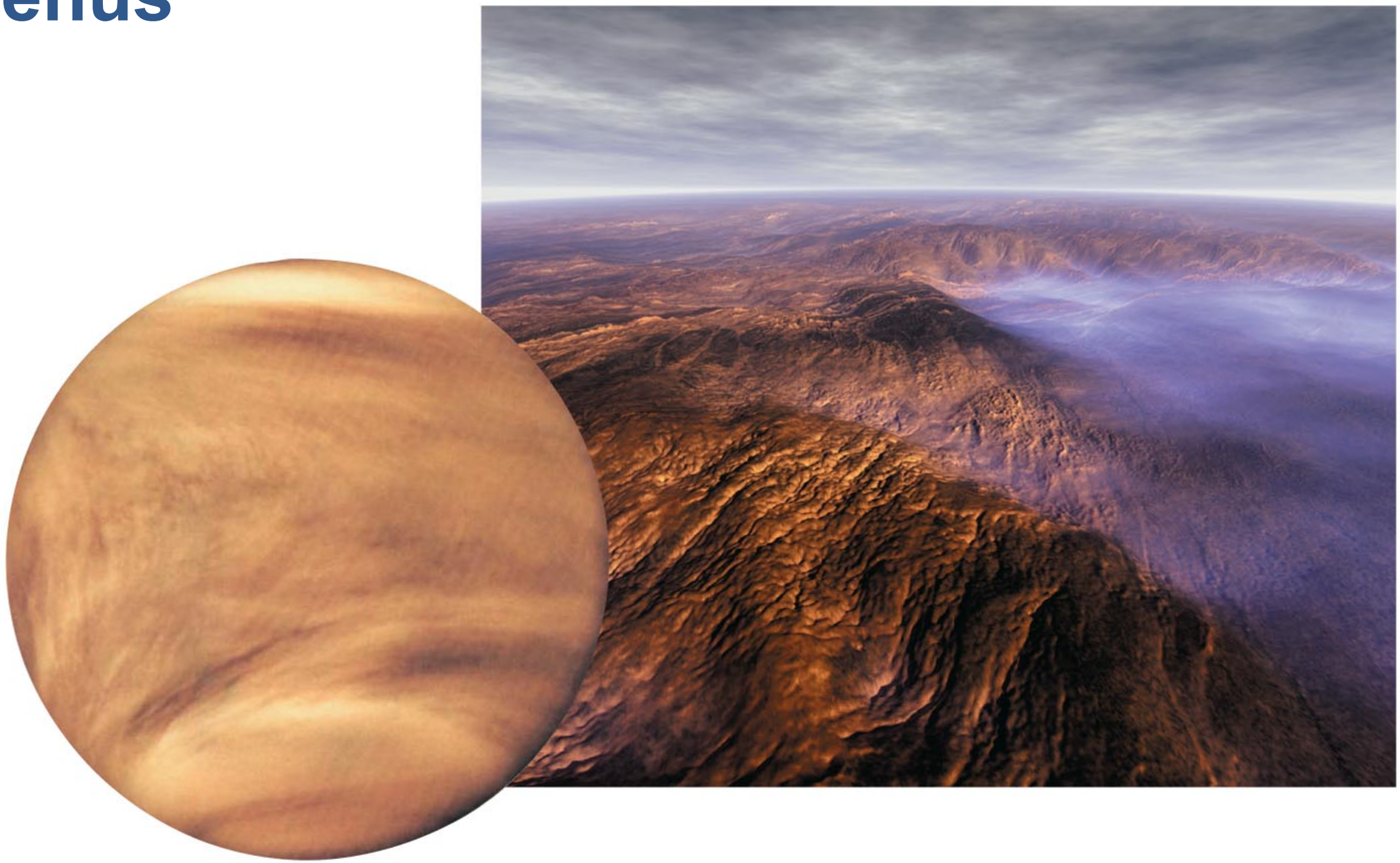
Mercury



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

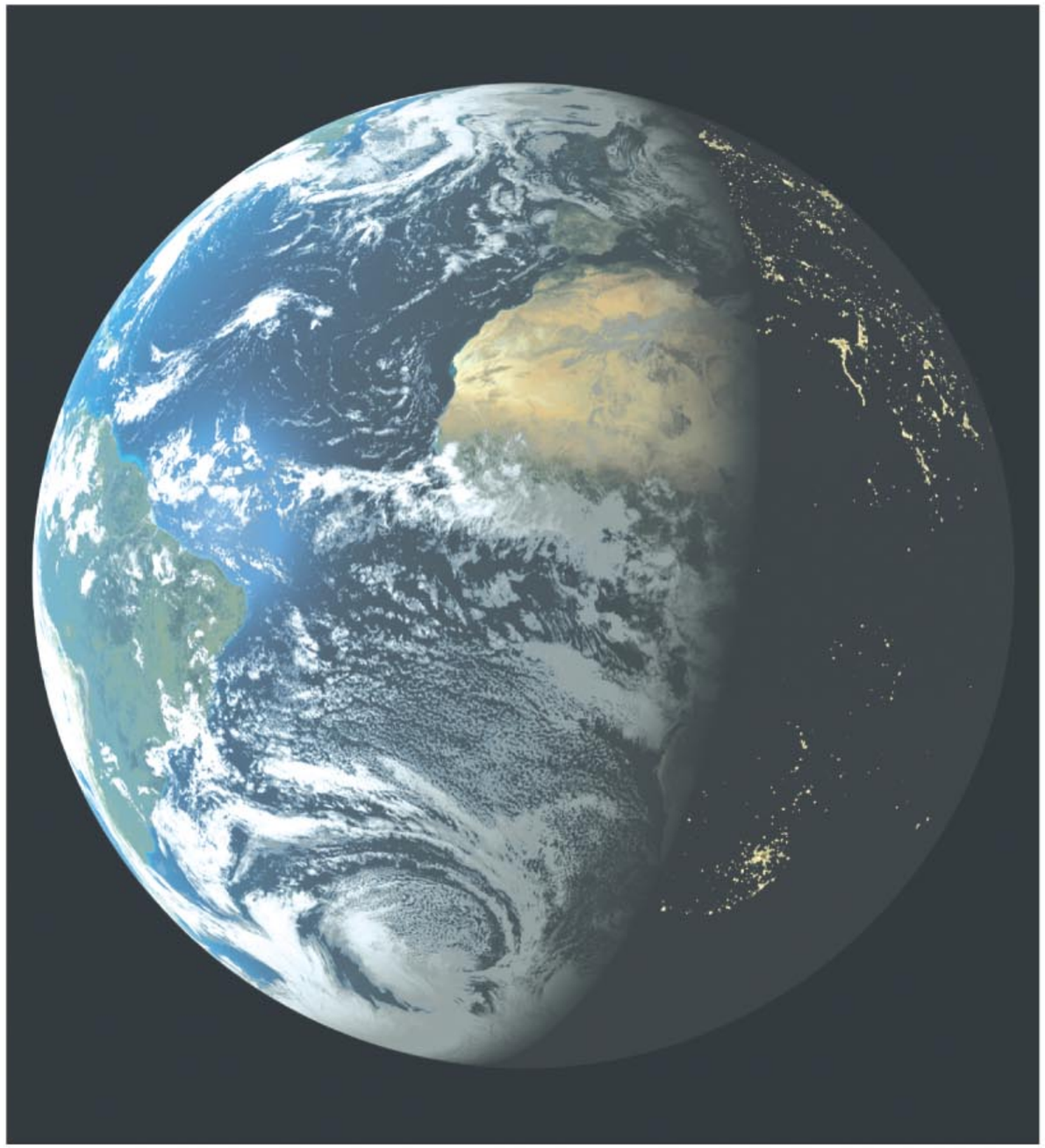
3:2 spin-orbit coupling

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

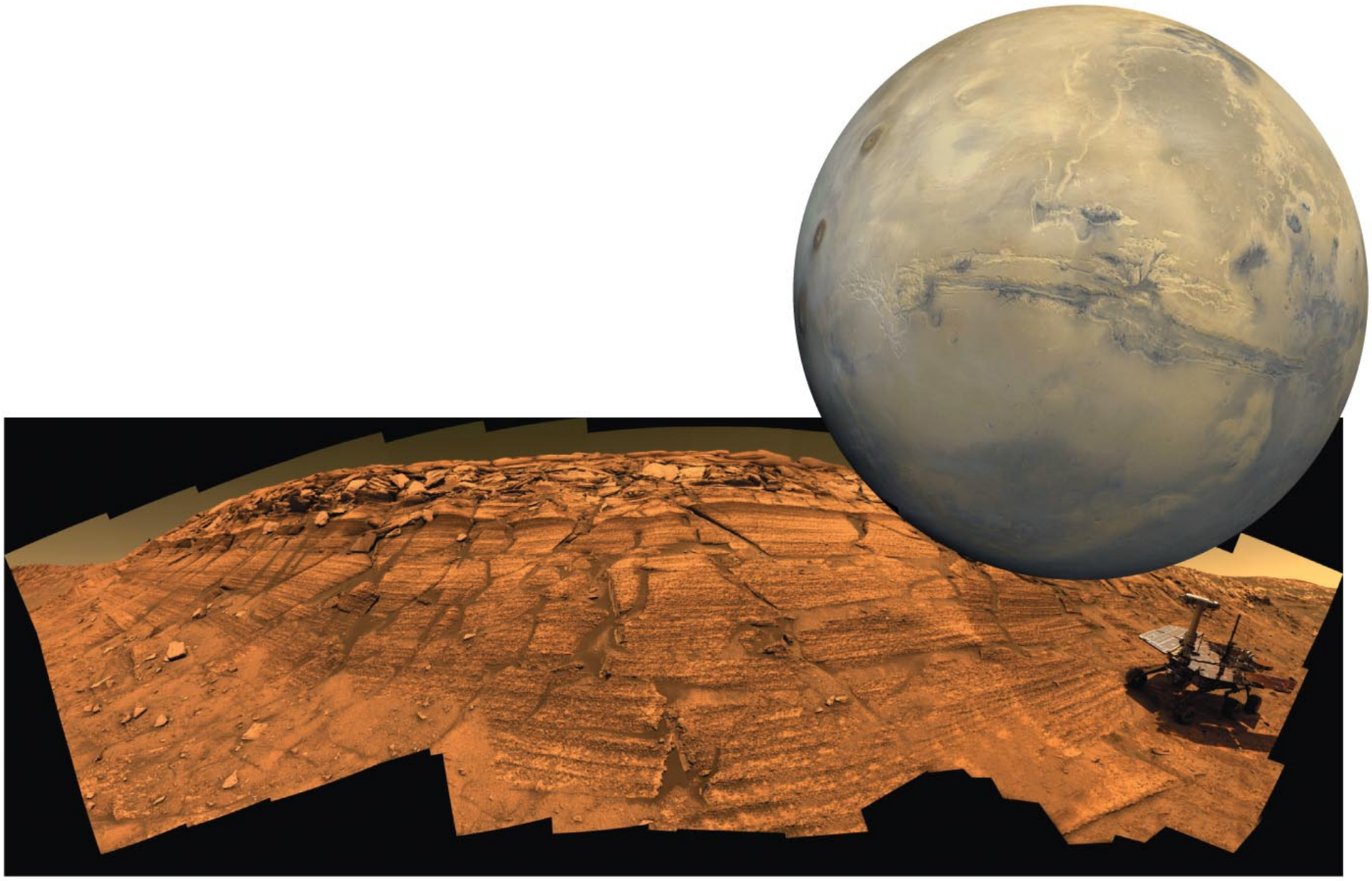
Earth



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

Except for Saturn's moon Titan

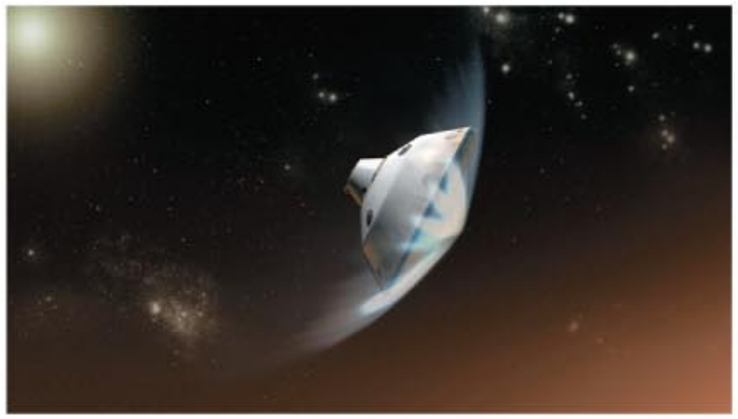
Mars



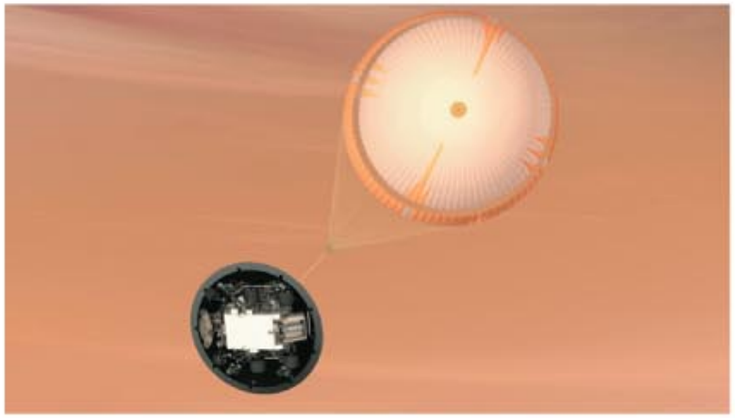
- Looks almost Earth-like, but don't go without a spacesuit!
- Giant volcanoes, a huge canyon, polar caps, more
- Water flowed in distant past; could there have been life?

Mars

- *Curiosity* rover landed in August 2012.



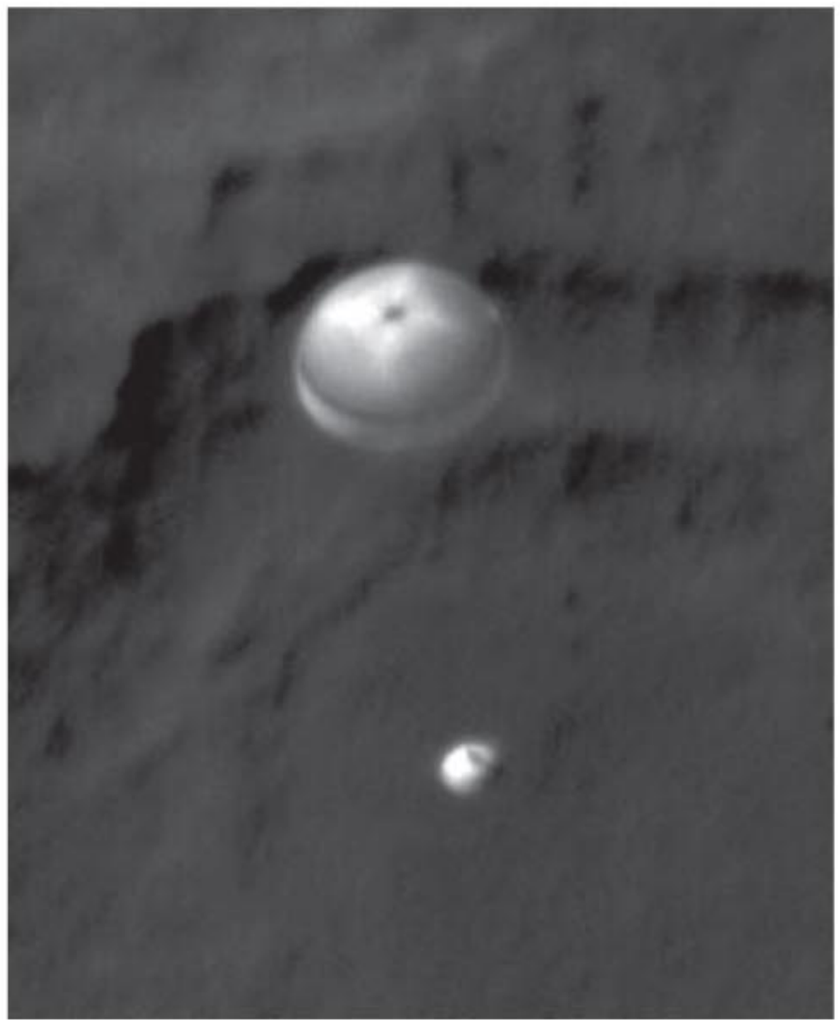
1 Friction slows spacecraft as it enters Mars atmosphere.



2 Parachute slows spacecraft to about 350 km/hr.

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

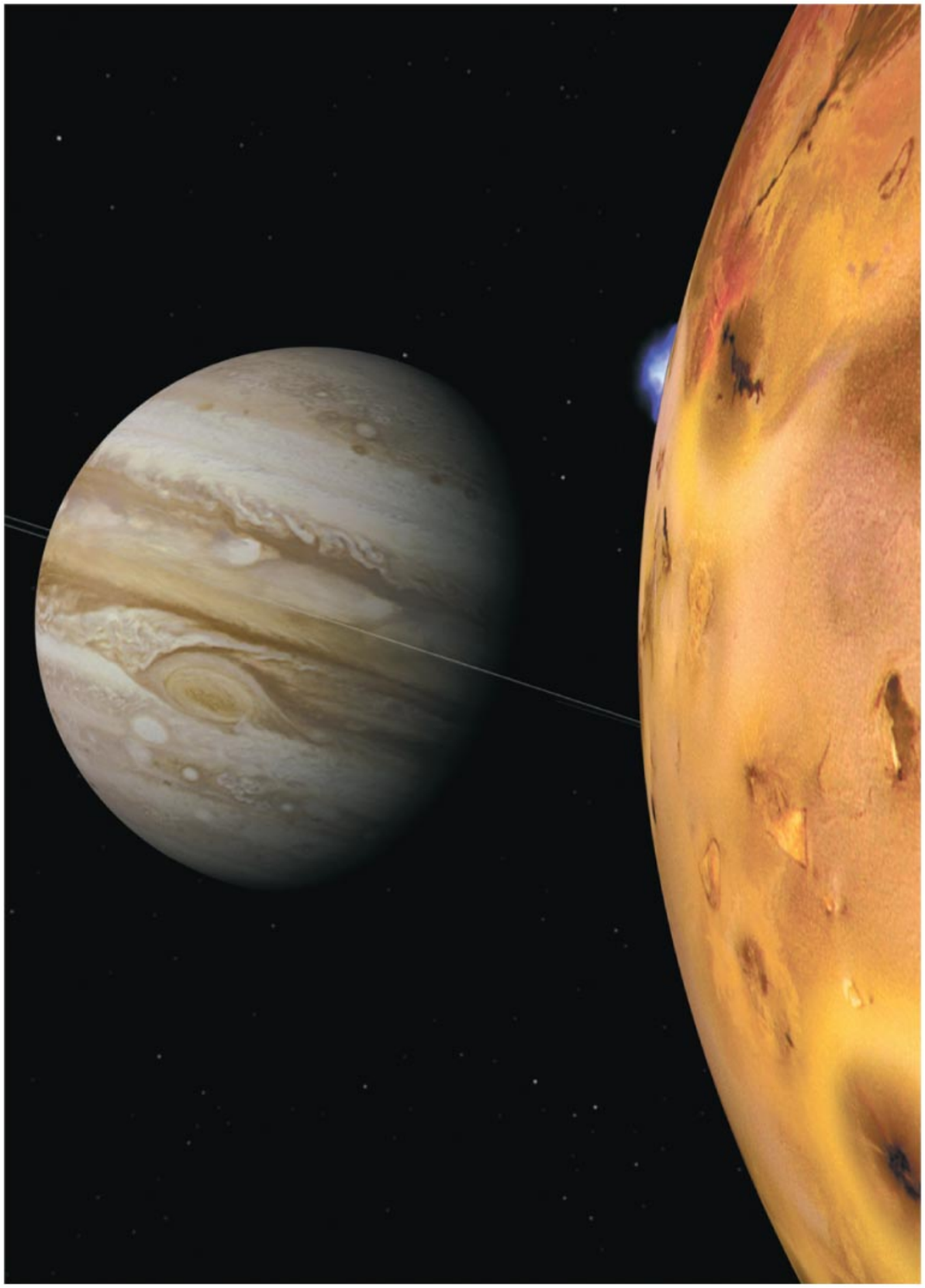
4 Tether released, the rocket heads off to crash a safe distance away.



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

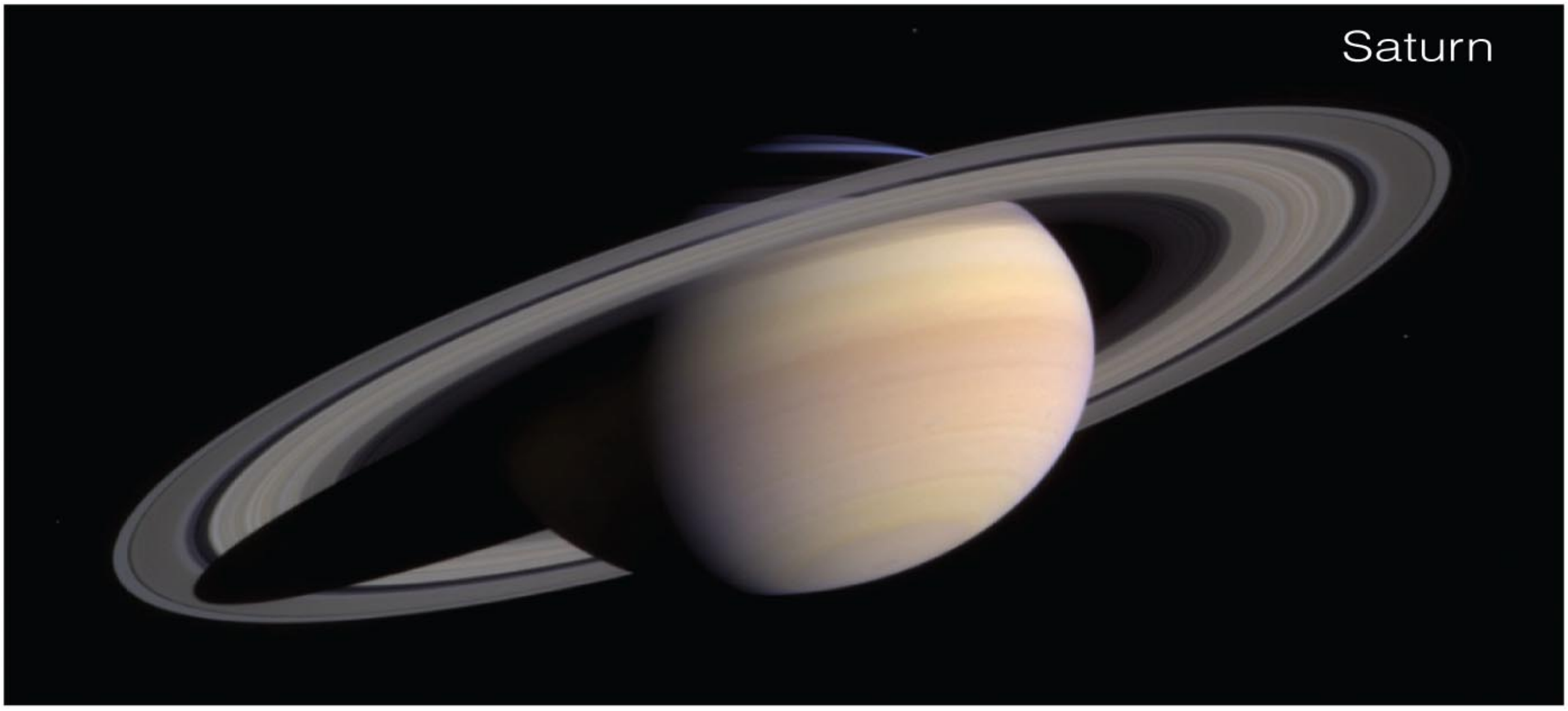
http://www.jpl.nasa.gov/video/details.php?id=1001 1:00 mark

Jupiter



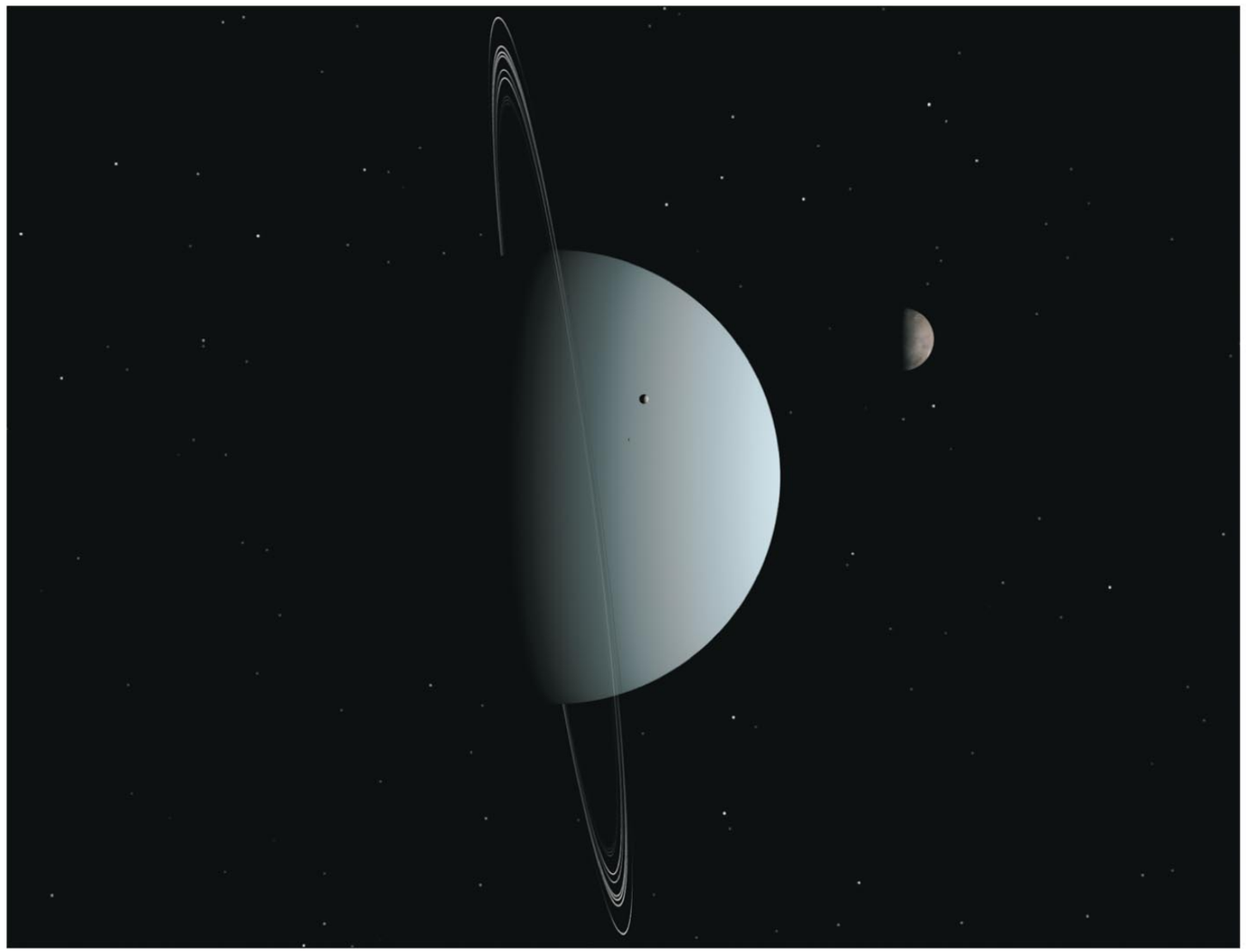
- Much farther from Sun than inner planets
- Mostly H/He; no solid surface
- 300 times more massive than Earth
- Many moons, rings

Saturn



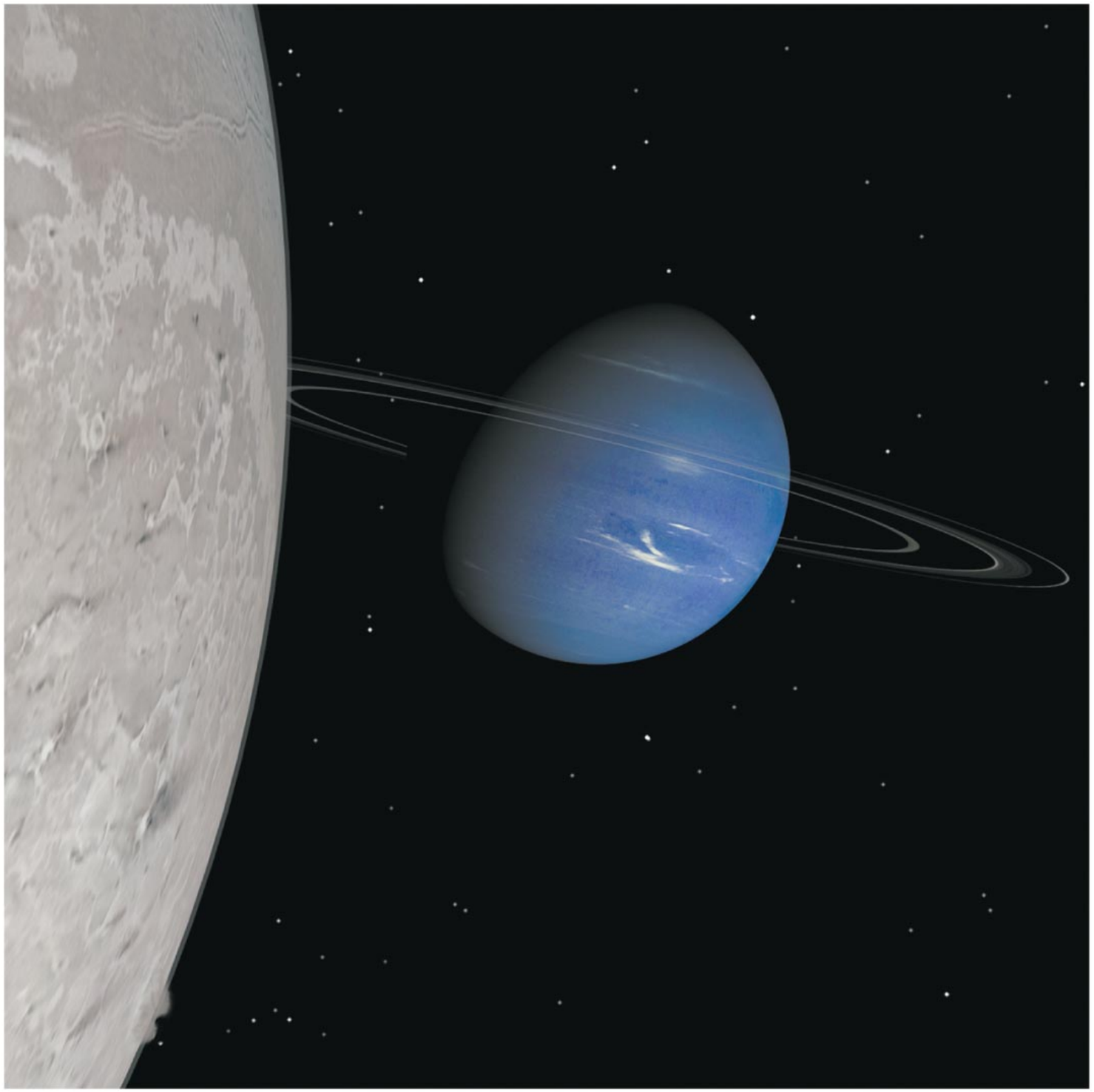
- Giant and gaseous like Jupiter
- Spectacular rings
- Many moons, including cloudy Titan

Uranus



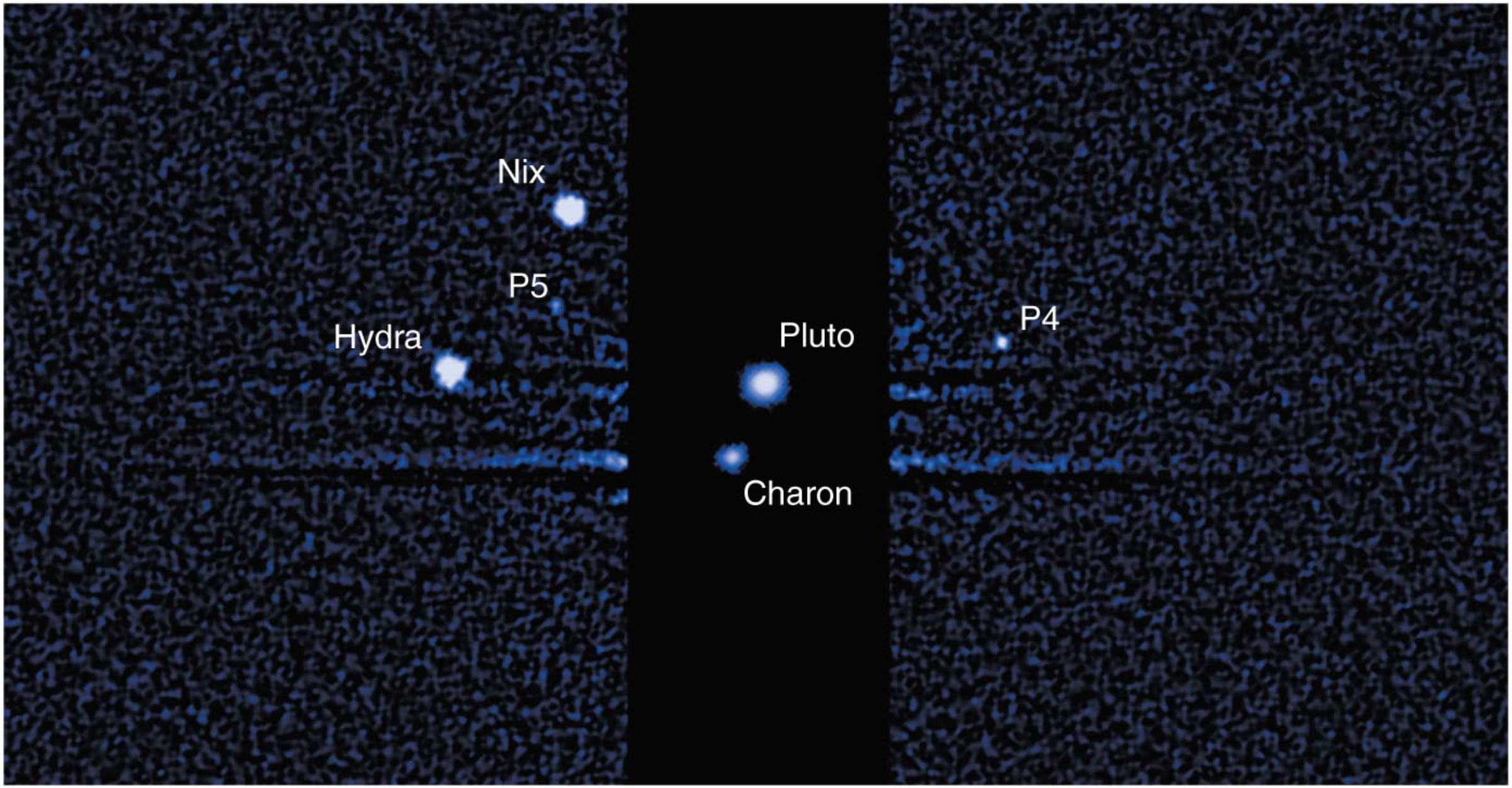
- Smaller than Jupiter/Saturn; much larger than Earth
- Made of H/He gas and **hydrogen compounds** (H_2O, NH_3, CH_4)
- Extreme axis tilt
- Moons and rings

Neptune



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

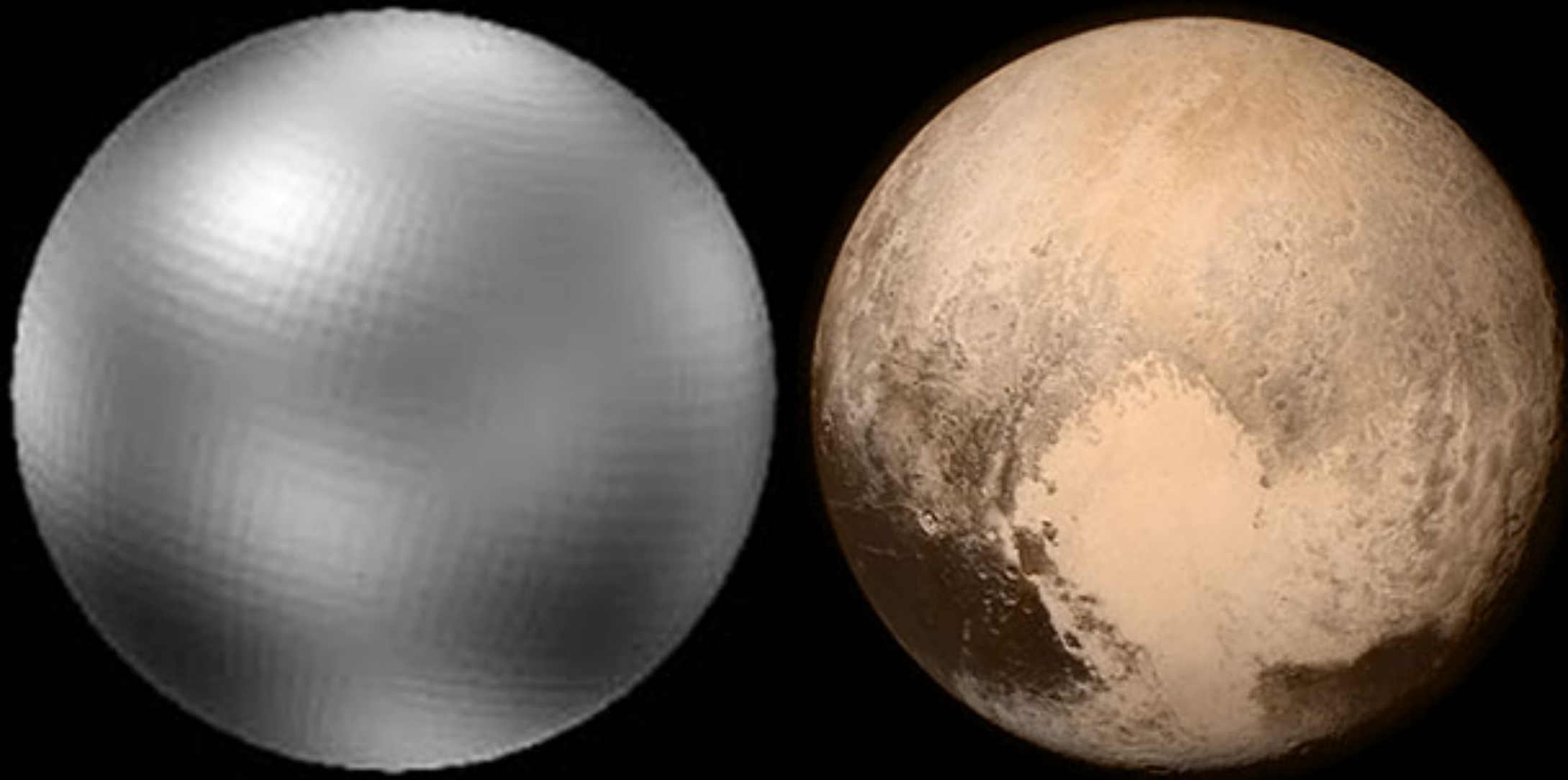
Dwarf Planets: Pluto, Eris, and more



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

Hubble

New Horizons



1996

2015