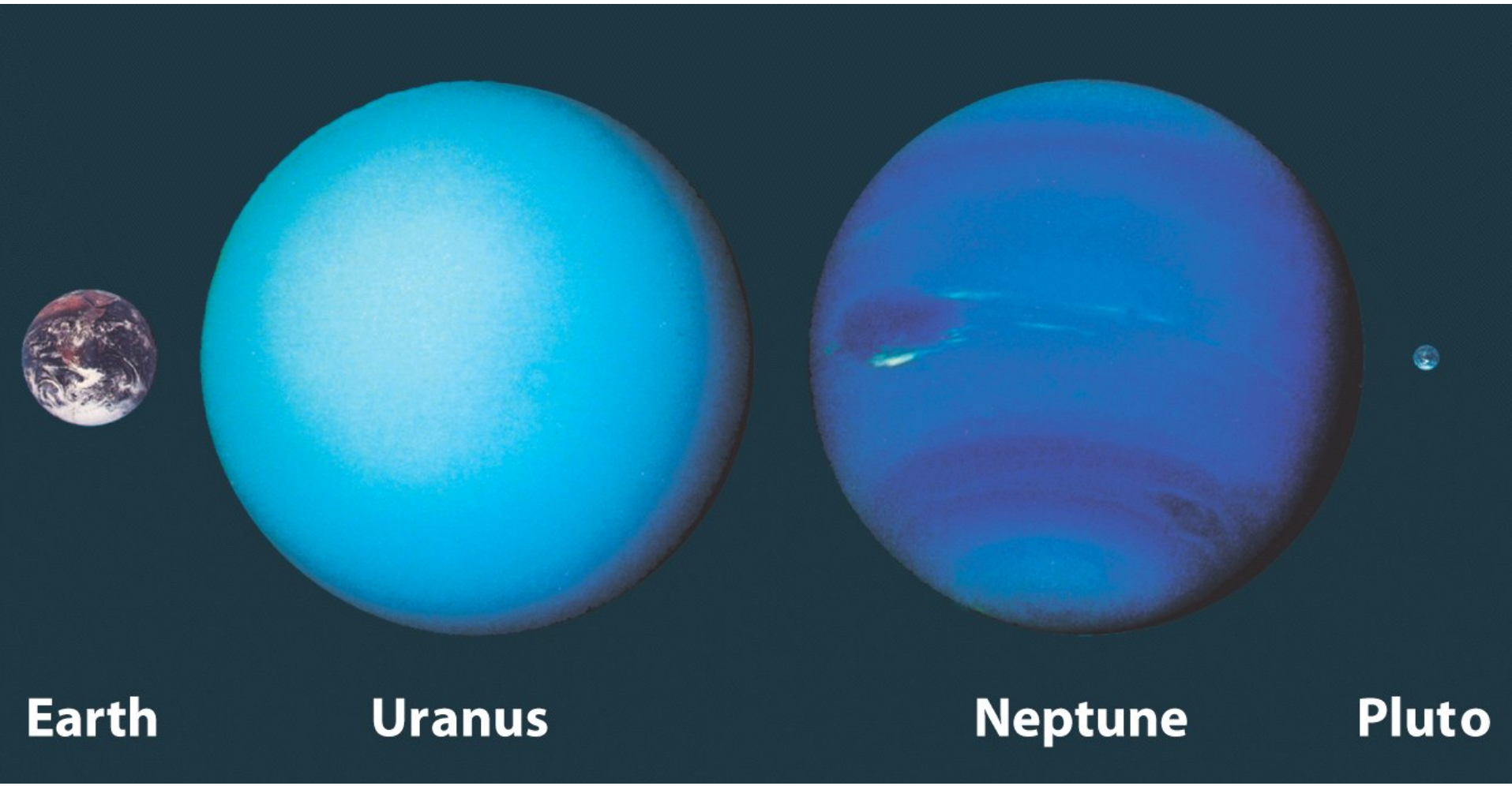
Remote Worlds



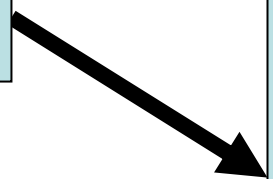
Chapter Fourten

Introduction To Modern Astronomy I: Solar System

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-15)

Sun and Life: Highlights
(Chap. 16 & 28)



Ch7: Comparative Planetology I
Ch8: Comparative Planetology II
Ch9: The Living Earth

Ch10: Our Barren Moon
Ch11: Mercury, Venus and Mars
Ch12: Jupiter and Saturn
Ch13: Satellites of Jupiter & Saturn

Ch14: Uranus, Neptune and Beyond

Ch15: Vagabonds of Solar System

Update on Pluto

- International Astronomical Union (IAU) voted on the re-definition of planets in Prague on Aug. 24, 2006.
- Pluto is no longer a planet
  - Pluto is called a “dwarf planet”
- 2003 UB, once proposed as 10th planet, is also a “dward planet”
- In this book, pluto is also called a “**trans-Neptunian object**”.
  - As of 2006, ~ 1100 such objects have been found

Uranus Data

table 16-1 | Uranus Data

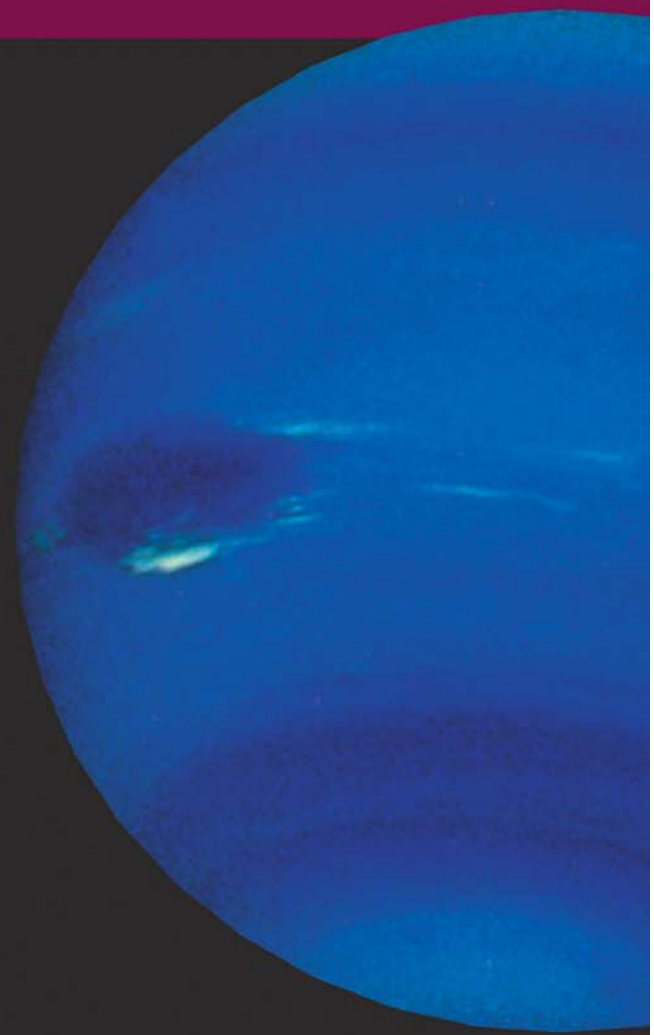
Average distance from Sun:	19.194 AU = 2.871×10^9 km
Maximum distance from Sun:	20.017 AU = 2.995×10^9 km
Minimum distance from Sun:	18.371 AU = 2.748×10^9 km
Eccentricity of orbit:	0.0429
Average orbital speed:	6.83 km/s
Orbital period:	84.099 years
Rotation period (internal):	17.24 hours
Inclination of equator to orbit:	97.86°
Inclination of orbit to ecliptic:	0.77°
Diameter:	51,118 km = 4.007 Earth diameters (equatorial)
Mass:	8.682×10^{25} kg = 14.53 Earth masses
Average density:	1318 kg/m^3
Escape speed:	21.3 km/s
Surface gravity (Earth = 1):	0.90
Albedo:	0.56
Average temperature at cloudtops:	−218°C = −360°F = 55 K
Atmospheric composition (by number of molecules):	82.5% hydrogen (H_2), 15.2% helium (He), 2.3% methane (CH_4)

Discovered in 1781 by chance, with the aid of a good telescope

Neptune Data

table 16-2 | Neptune Data

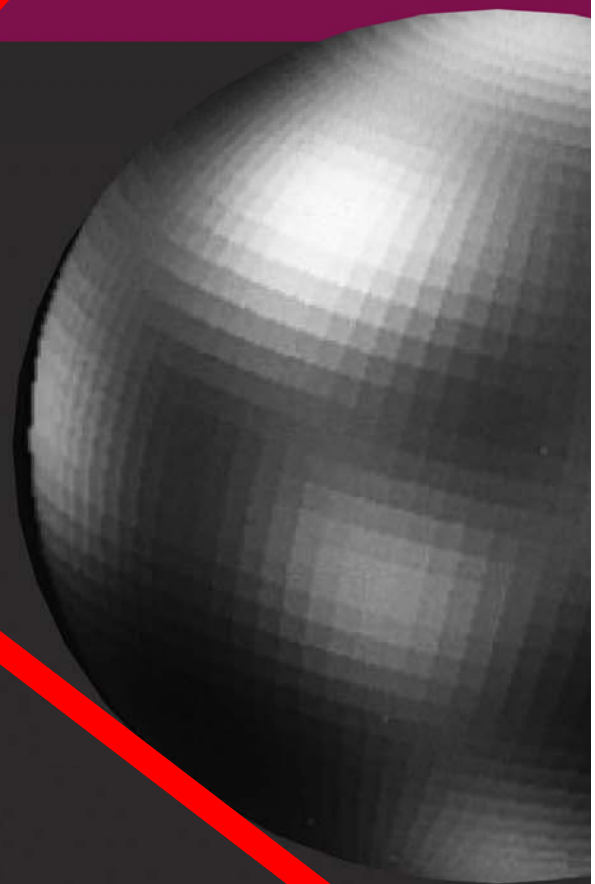
Average distance from Sun:	30.066 AU = 4.498×10^9 km
Maximum distance from Sun:	30.367 AU = 4.543×10^9 km
Minimum distance from Sun:	29.765 AU = 4.453×10^9 km
Eccentricity of orbit:	0.010
Minimum distance from Sun:	29.765 AU = 4.453×10^9 km
Eccentricity of orbit:	0.010
Average orbital speed:	5.5 km/s
Orbital period:	164.86 years
Rotation period (internal):	16.11 hours
Inclination of equator to orbit:	29.56°
Inclination of orbit to ecliptic:	1.77°
Diameter:	49,528 km = 3.883 Earth diameters (equatorial)
Mass:	1.024×10^{26} kg = 17.15 Earth masses
Average density:	1638 kg/m^3
Escape speed:	23.5 km/s
Surface gravity (Earth = 1):	1.1
Albedo:	0.51
Average temperature at cloudtops:	−218°C = −360°F = 55 K
Atmospheric composition (by number of molecules):	79% hydrogen (H_2), 18% helium (He), 3% methane (CH_4)



Discovered in 1846 by calculation, the triumph of science

Pluto Data

table 16-3	Pluto Data
Average distance from Sun:	39.537 AU = 5.915 × 10^9 km
Maximum distance from Sun:	425 AU = 7.394 × 10^9 km
Minimum distance from Sun:	29.64 AU = 4.435 × 10^9 km
Eccentricity of orbit:	0.2501
Average orbital speed:	4.7 km/s
Orbital period:	248.60 years
Rotation period:	6.387 days
Inclination of equator to orbit:	122.52°
Inclination of orbit to ecliptic:	17.146°
Diameter:	about 2 00 km = 0.18 Earth diameter
Mass:	1.3 10^{22} kg = 0.0021 Earth mass
Average density:	bout 1900 kg/m^3
Escape speed:	1.2 km/s
Surface gravity (Earth =):	0.07
bedo:	0.5
Average surface te perature:	−233°C = −387°F = 40 K

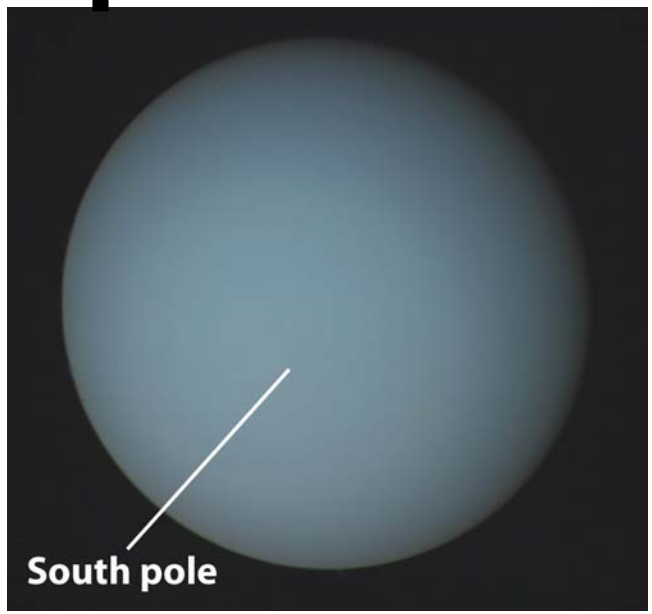


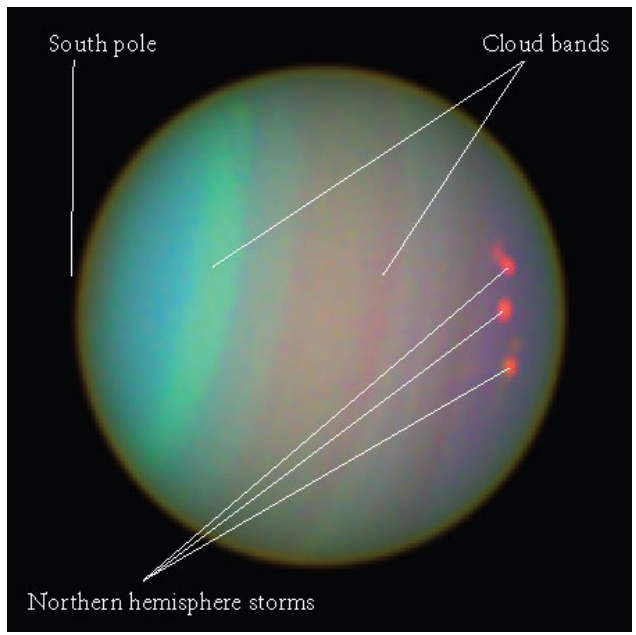
Discovery

- Other than those planets seen by naked eyes, Uranus and Neptune were discovered by telescopes
- Uranus was recognized as a planet by chance observation in 1781 by William Herschel
- Neptune's position was predicted using Newtonian laws before it was discovered in 1846
  - Slight deviations in Uranus' orbit indicated the presence of an undiscovered planet, which gravitation altered Uranus' orbit
  - The position of Neptune was predicted by Le Verrier and Adams
  - A triumph of scientific reasoning, based on the truth of Newton's law of universal graviation

Uranus: Atmosphere

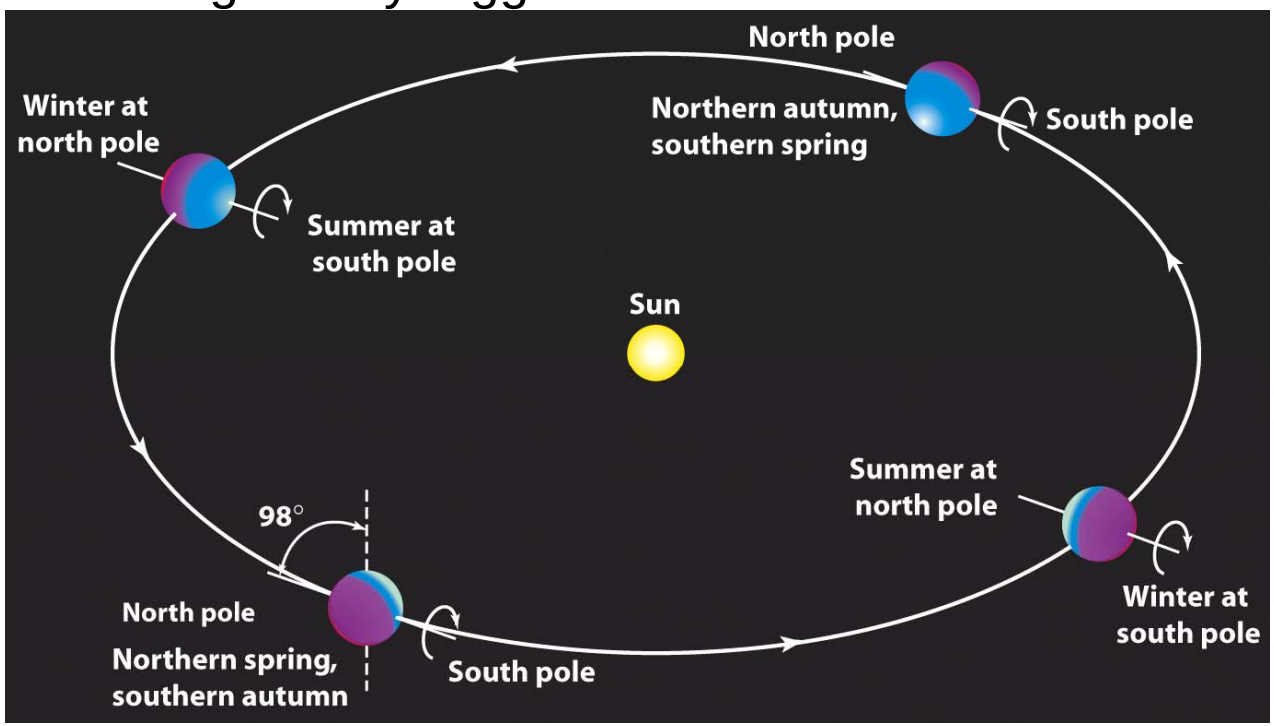
- Uranus is nearly featureless in visible light
  - Covered by atmosphere
  - Filled with **hydrocarbon haze**
- Atmosphere is primarily hydrogen (82.5%) and helium (15.2%), and 2.3% methane
- Methane absorbs red light, giving Uranus (and Neptune) their greenish-blue color
- Less cloudy than in Jupiter and Saturn; ammonia and water have precipitated out the atmosphere at the very low temperature





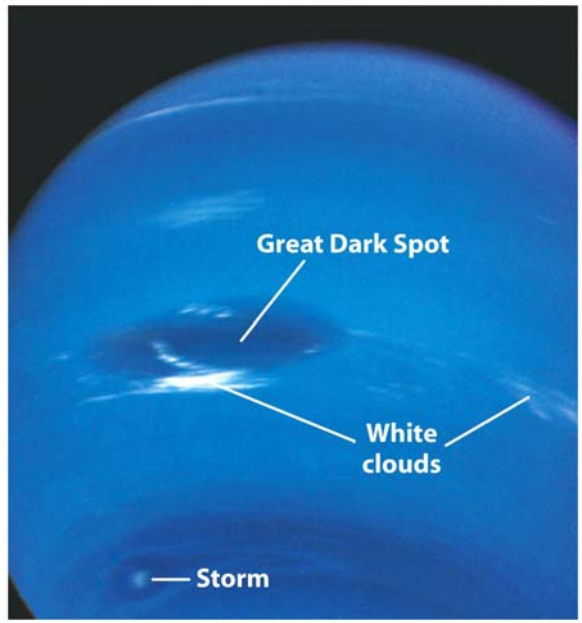
Uranus: Unusual Tilt

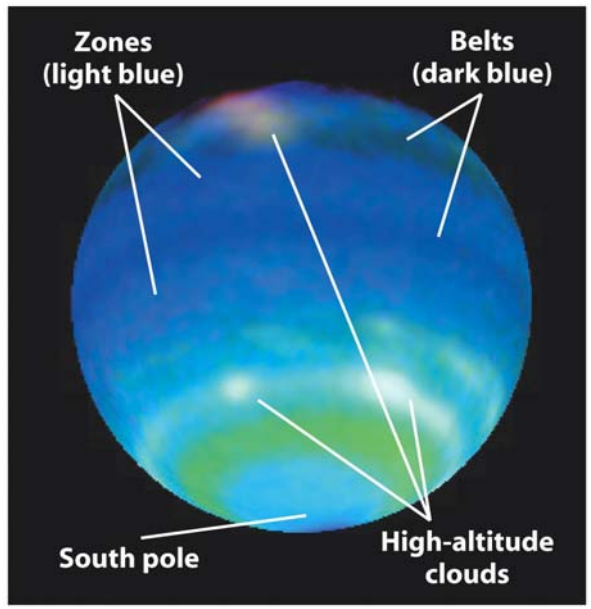
- Uranus's axis of rotation lies nearly in the plane of its orbit.
- This unusual orientation may be the result of a collision with a planet-like object early in the history of solar system. Such a collision could have knocked Uranus on its side
- Along its 84-year orbit, north and south poles alternatively point toward or away from the Sun, causing long seasons
- Seasonal changes may trigger immense storms



Neptune: Atmosphere

- Neptune has almost the same atmospheric composition as Uranus: 79% hydrogen, 18% helium, 3% methane, and almost no ammonia or water
- Unlike Uranus, Neptune has a more dynamic atmosphere
  - Neptune has the Great Dark Spot, a storm system similar to Jupiter's Great Red Spot
  - Has light zones and dark belts
  - Has high-altitude methane clouds



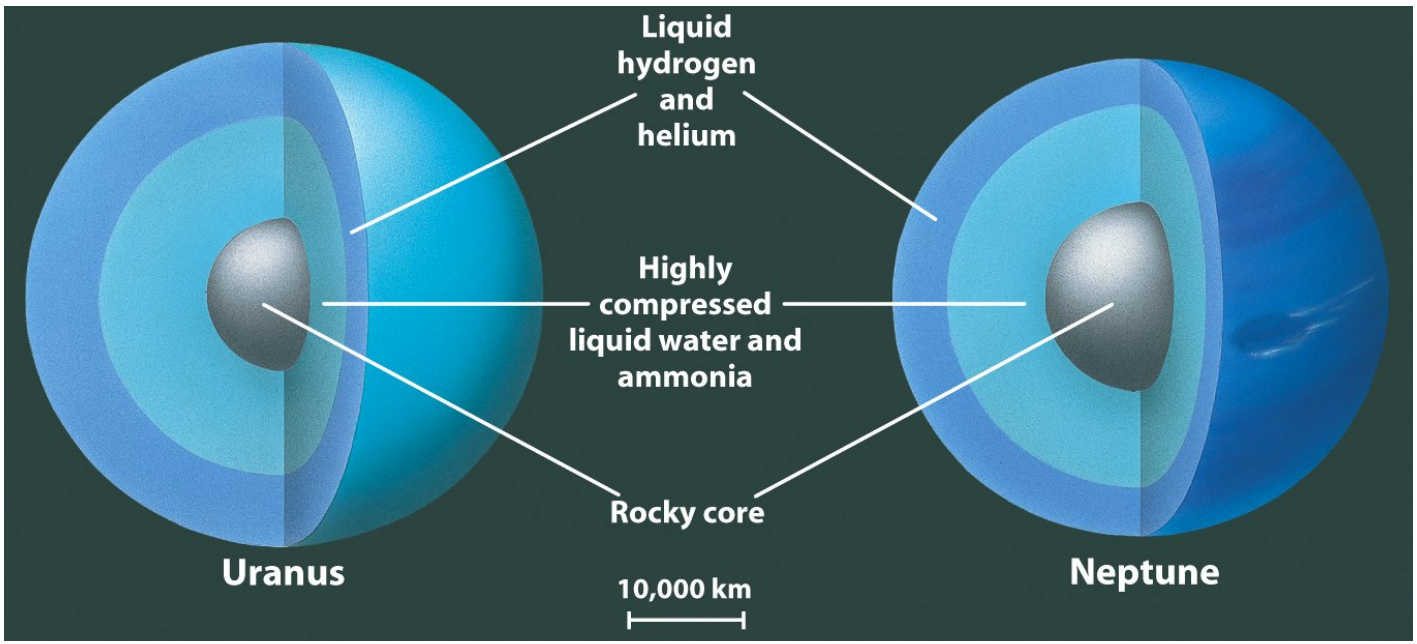


Neptune: Atmosphere

- Why does Neptune have a more dynamic atmosphere, even if it receives less sunlight than Uranus?
  - It has sufficient **internal heat**
  - Neptune is probably still **slowly contracting, converting gravitational energy that heats the planet's core**
  - Observations show that Neptune emits more energy than it receives from the Sun
  - However, Uranus radiates as much energy into space as it receives from the Sun, indicating no internal source of thermal energy

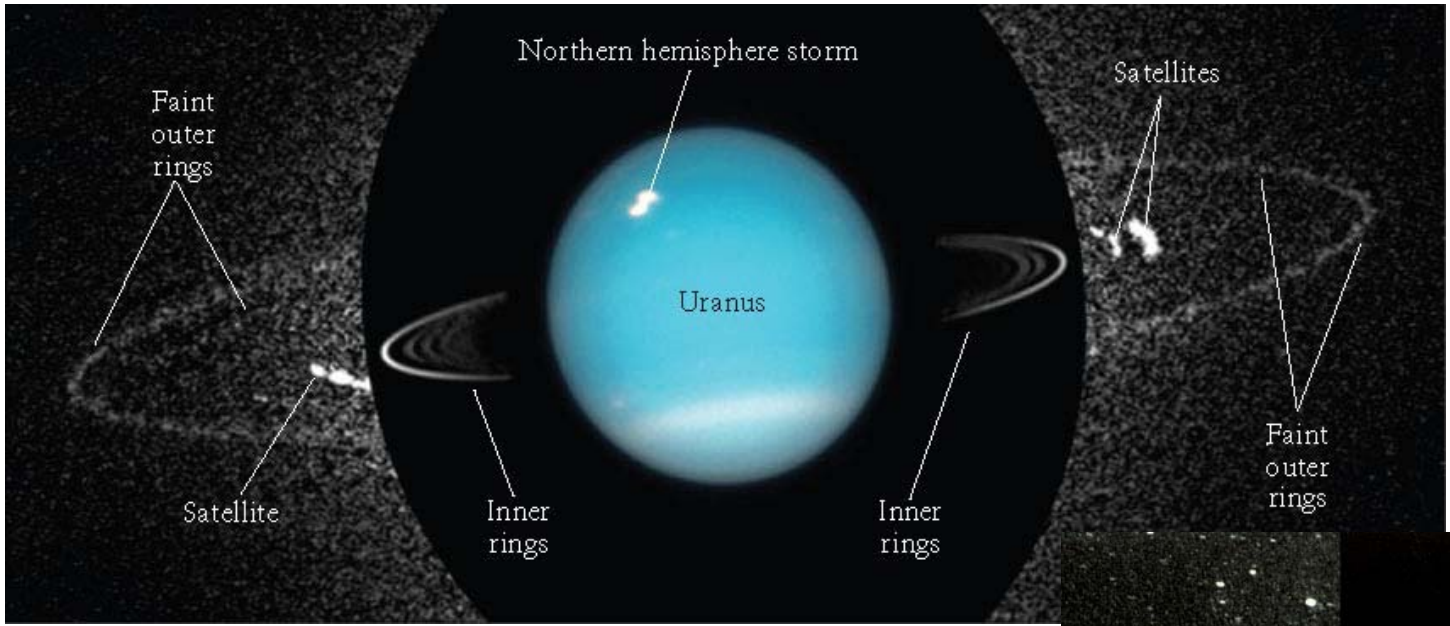
Interior Structure

- Density (~ 1500 kg/m^3) indicates a mixture of ice and rock
- Magnetic field indicates the presence of salty liquid water
- Both Uranus and Neptune may have
  - A rocky **core**
  - A **mantle** of liquid water and ammonia
  - An outer layer of **mantle** of liquid hydrogen and helium
  - A thin layer of **atmosphere** of hydrogen and helium

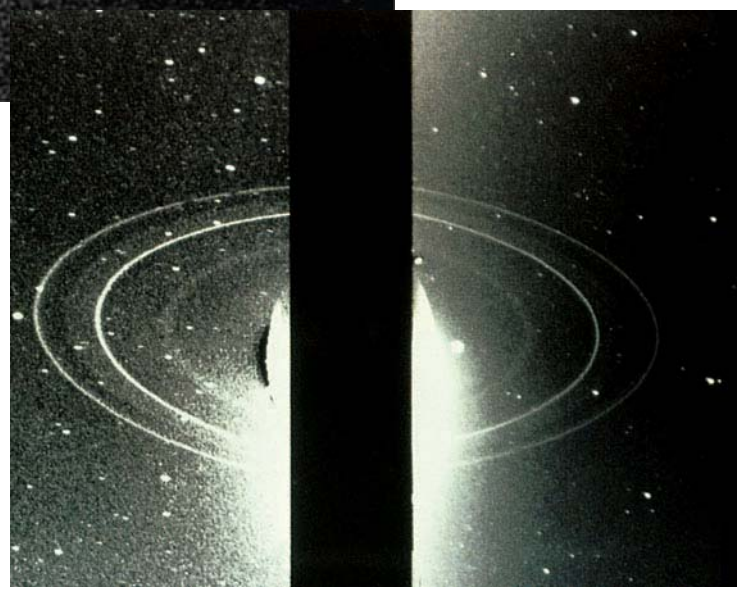


Rings

- Uranus and Neptune have thin, dark rings.



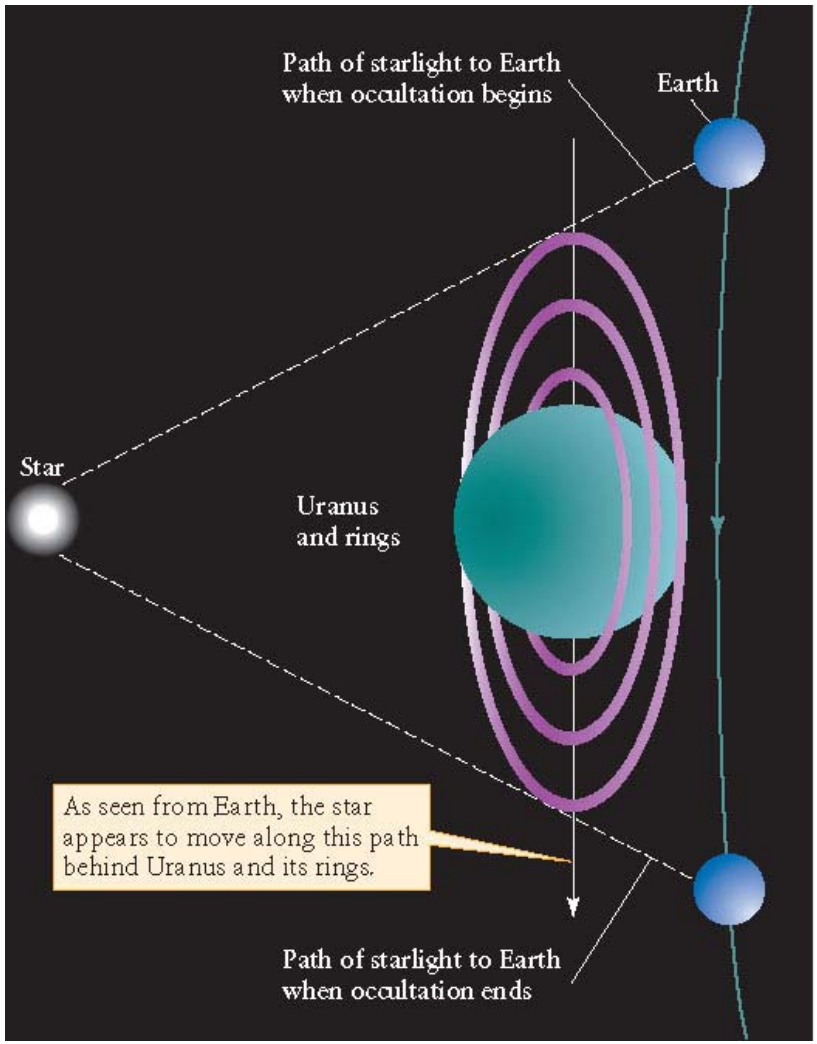
Uranus's Rings

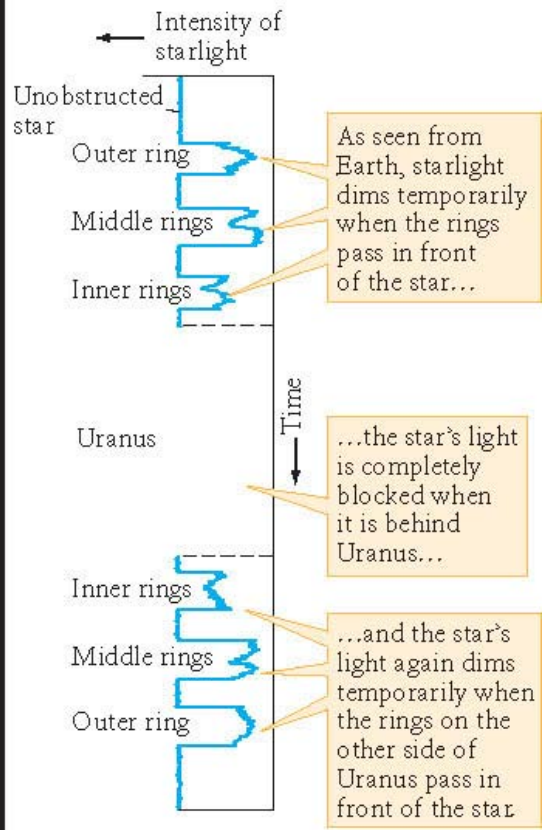


Neptune's Rings

Rings

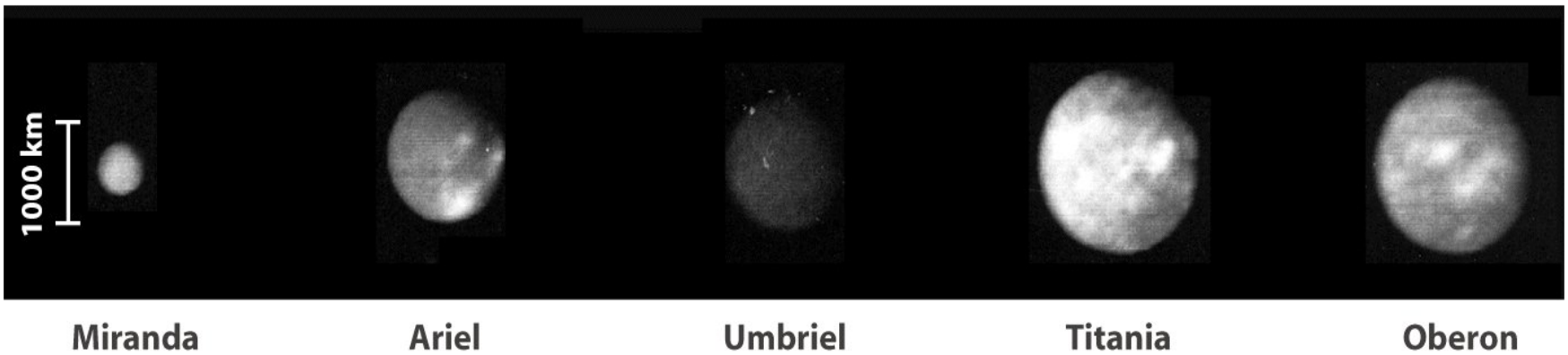
- Rings were first discovered with the so called “occultation” method in 1977





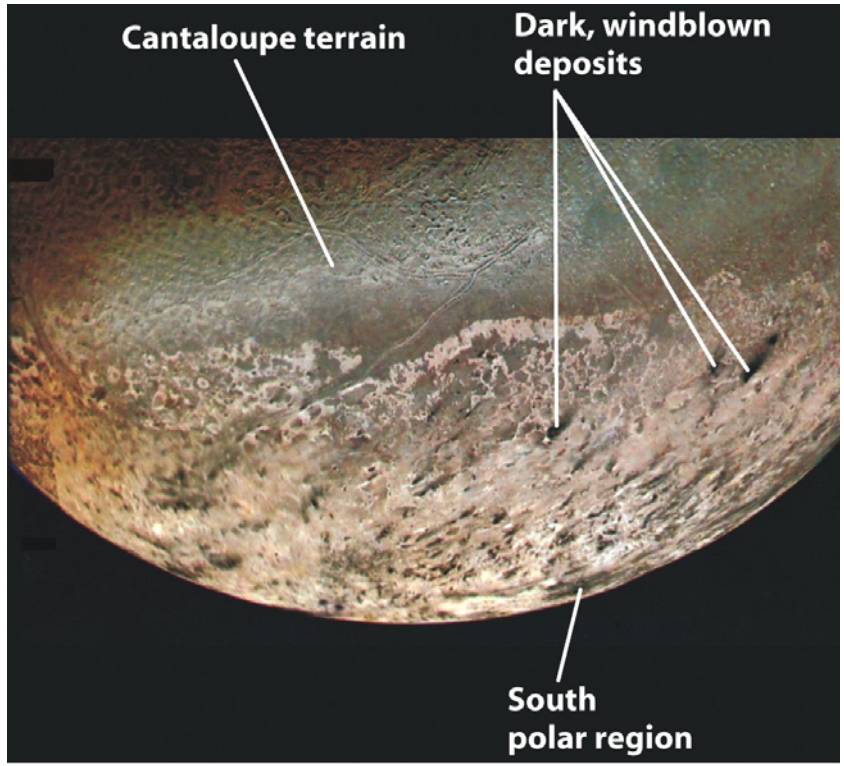
Uranus: Satellites

- Uranus has five satellites similar to the moderate-sized moons of Saturn, plus at least 22 more small satellites
- All these moons have average density around 1500 kg/m^3, consistent with a mixture of ice and rock



Neptune: Satellites

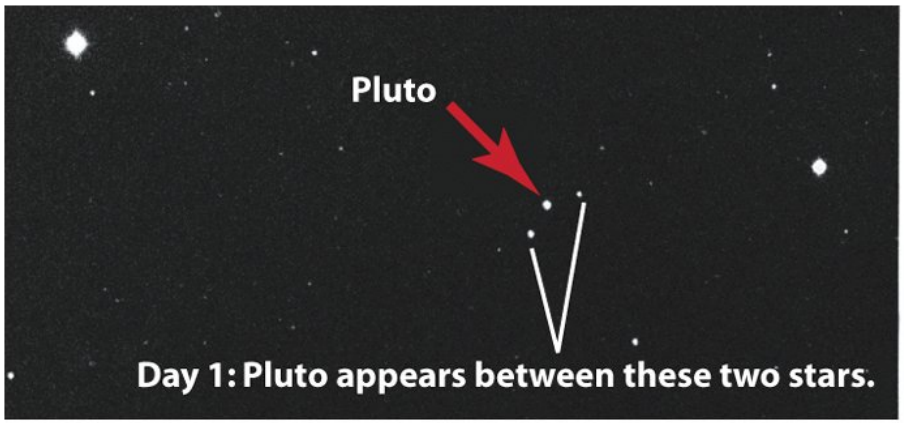
- Neptune has 13 known satellites
- Triton, the largest satellite, is comparable in size to our Moon.
- Triton has a young, icy surface indicative of tectonic activity
- The energy for this activity may have been provided by tidal heating
  - occurred when Triton was captured by Neptune's gravity into a **retrograde orbit**

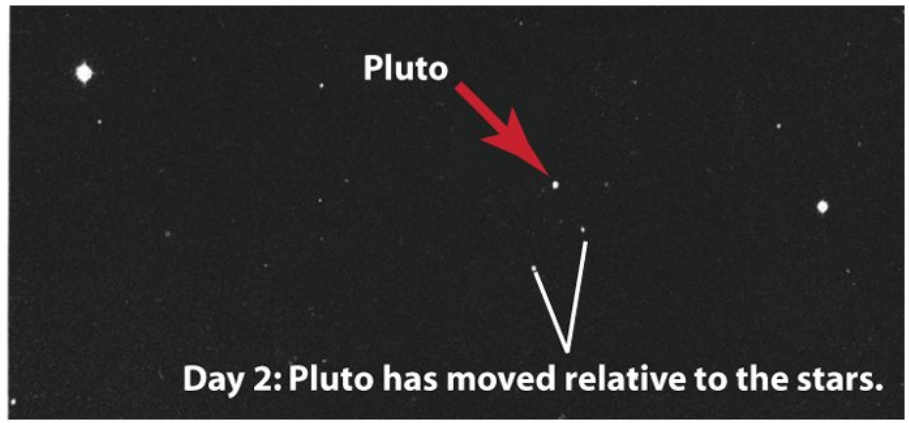


Triton

Pluto

- Pluto was discovered in 1930 after a long search for the ninth planet
- Pluto moves in a highly elliptical orbit
  - Eccentricity 0.25
  - Sometimes within the orbit of Neptune
- Pluto's orbit is steeply inclined to the plane of ecliptic (17°)



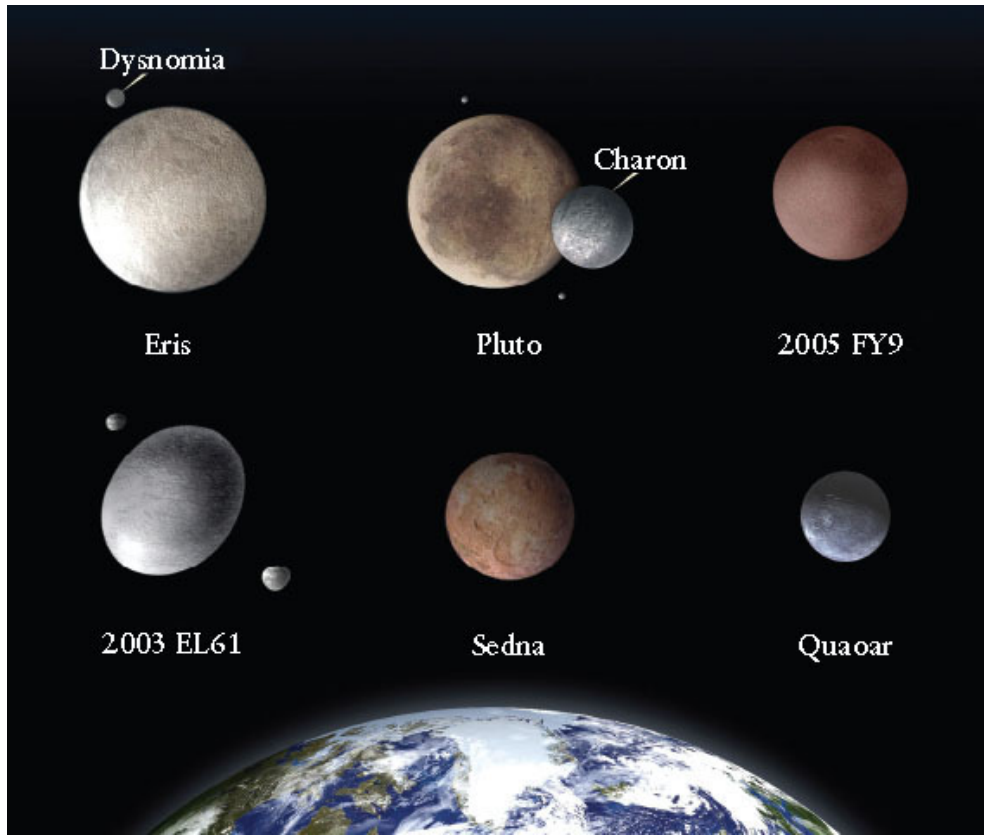


Pluto and Charon

- Pluto (2300 km) and its satellite Charon (1200 km) resembles each other in mass and size more than any other planet-satellite pair in the solar system.
- The distance is also the smallest, 19,640 km
- **Both rotate in lockstep**: Charon's orbit period is the same as its rotational period, and also the same as the Pluto's rotation period (6.3 days)
  - Both keep the same face toward each other
  - As seen from Pluto, Charon neither rises nor sets

Trans-Neptunian Objects

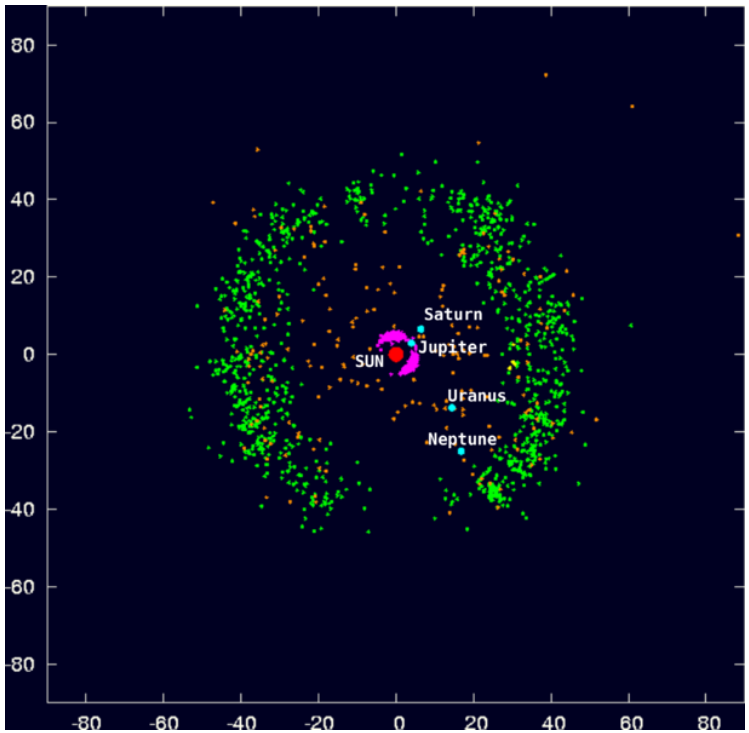
- **Trans-Neptunian objects:** objects whose orbits have semi-major axiss larger than that of Neptune.
- Pluto and Charon are now thought to be **trans-Neptunian objects**
- More than one thousand trans-Neptunian objects have been found, and at least nine of these objects have satellites of their own



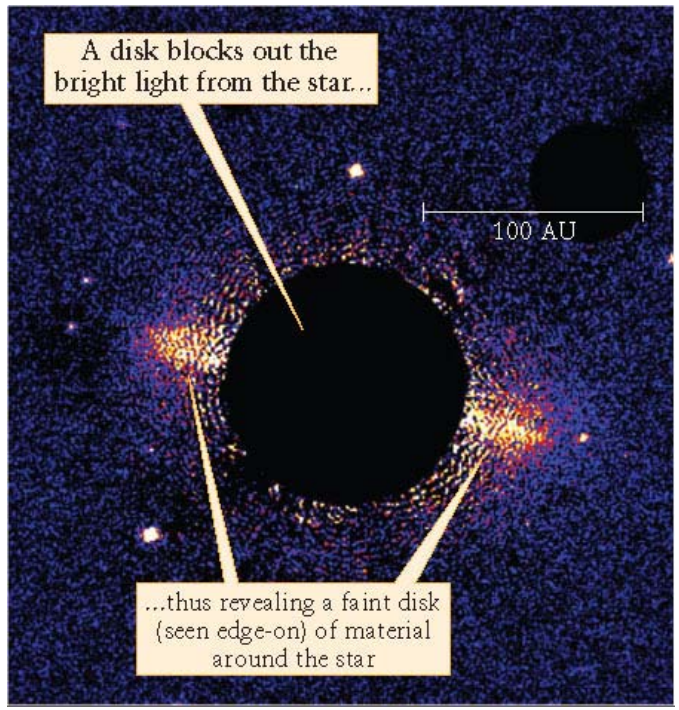
Trans-Neptunian Objects

Kuiper Belt

- **Kuiper Belt:** lies beyond the orbit of Neptune between 30 and 50 AU from the Sun
- Most trans-Neptunian objects lie within Kuiper belt.
- Kuiper belt is produced by the gravitational forces of Jovian planets



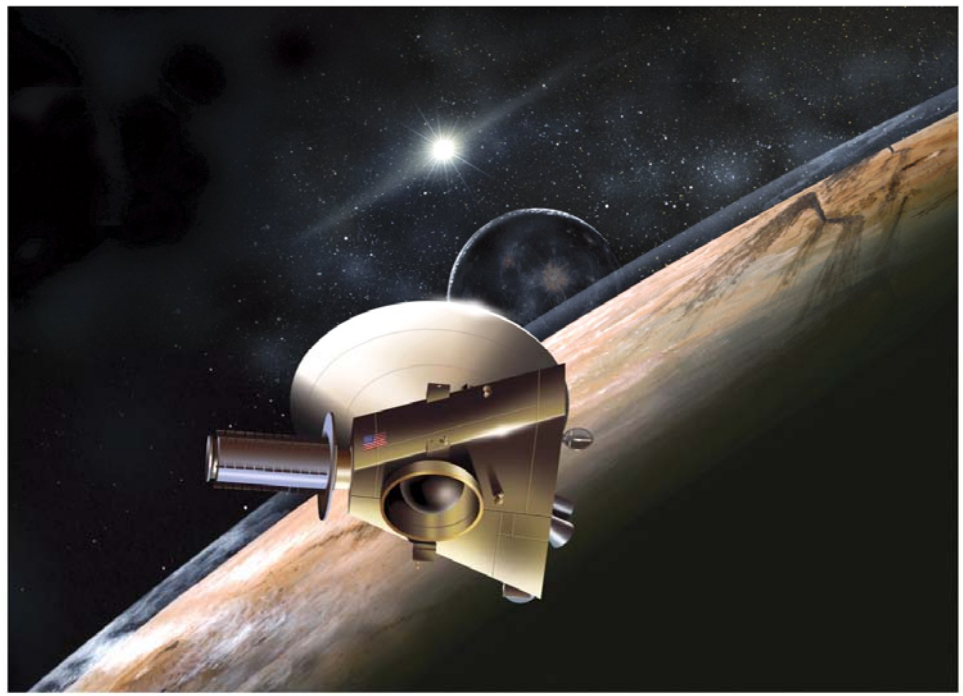
Kuiper belt



“Kuiper belt” around another star

Kuiper Belt

- NASA's **New Horizons**
  - Jan. 19, 2006: launched
  - July 2015: Pluto-Charon encounter
  - 2016-2020: Kuiper Belt Object Encounter



Final Notes on Chap. 16

- There are 10 sections in total.

- The following sections are not covered
  - 16-5 (magnetic field)

Advanced Question
Chap. 14, Q7 in P372

Explain the statement “Methane” is to Uranus’s atmosphere as water is to Earth’s atmosphere?

Advanced Question
Chap. 14, Q43 in P373

The New Horizons spacecraft will swing by Jupiter to get a boost from that planet's gravity, enabling it to reach Pluto relatively quickly. To see what would happen if this technique were not used, consider a spacecraft trajectory that is an elliptical orbit around the Sun. The perihelion of this orbit is at 1 AU from the Sun (at the Earth) and the aphelian is at 30 AU (at Pluto's position). Calculate how long it would take a spacecraft in this orbit to make the one-way trip from Earth to Pluto. Based on the information in section 14-10, how much time is saved by making a swling by Jupiter instead?