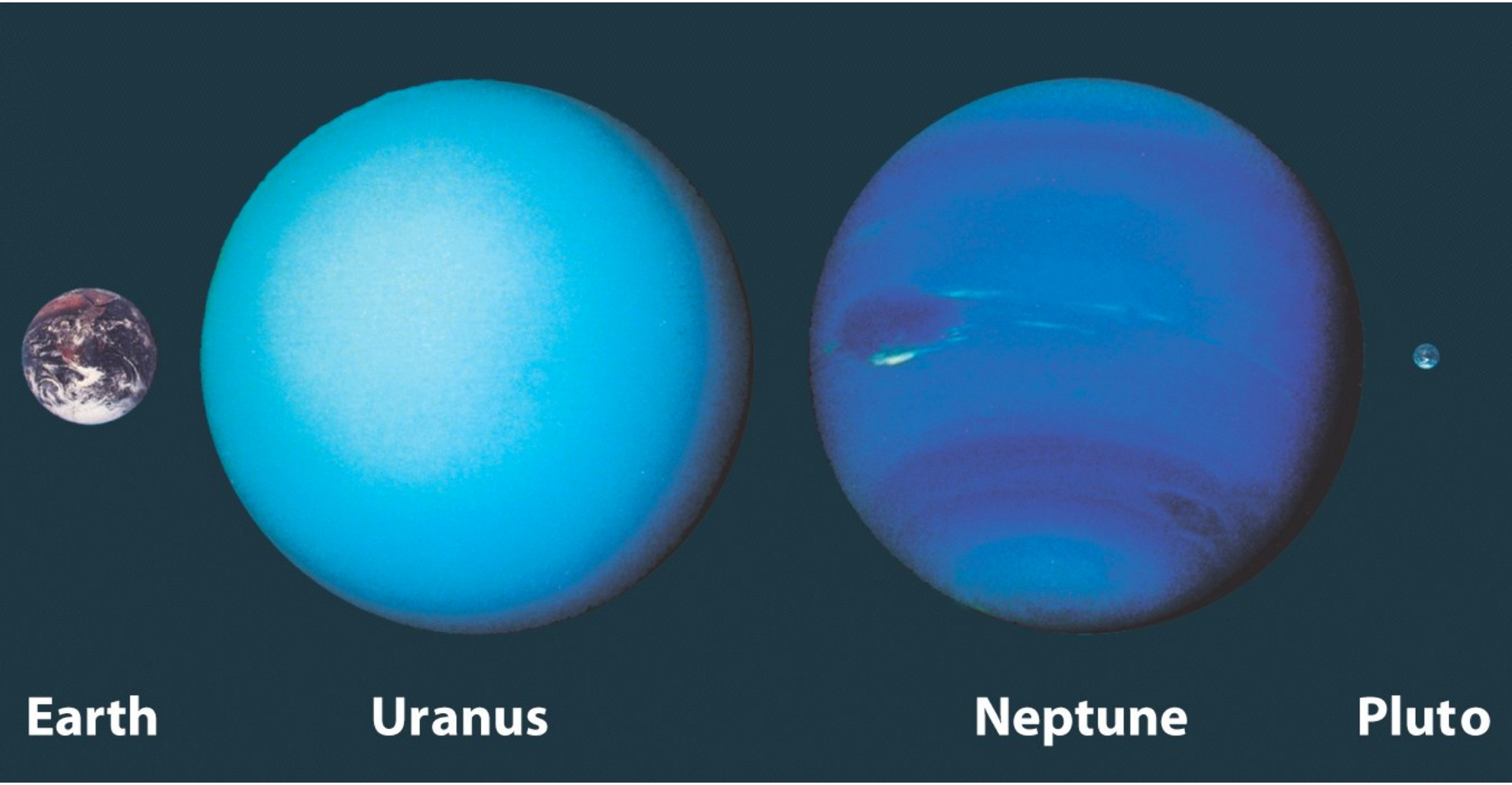
The Outer Worlds



Chapter Sixteen

ASTR 111 – 003 **Fall 2006**
Lecture 13 Nov. 27, 2006

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn

Ch16: Outer World
Ch17: Vagabonds of Solar System

Update to Textbook

- 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 now called “dwarf planet”
- Ceres, the largest asteroid, is also now classified as “dwarf planet”
- 2003 UB, once proposed as 10th planet, is also a “dward planet”

Guiding Questions

1. How did Uranus and Neptune come to be discovered?
2. What gives Uranus its distinctive greenish-blue color?
3. Why are the clouds on Neptune so much more visible than those on Uranus?
4. Are Uranus and Neptune merely smaller versions of Jupiter and Saturn?
5. What is so unusual about the magnetic fields of Uranus and Neptune?
6. Why are the rings of Uranus and Neptune so difficult to see?
7. Do the moons of Uranus show any signs of geologic activity?
8. What makes Neptune’s moon Triton unique in the solar system?
9. Are there other planets beyond Pluto?

Uranus Data

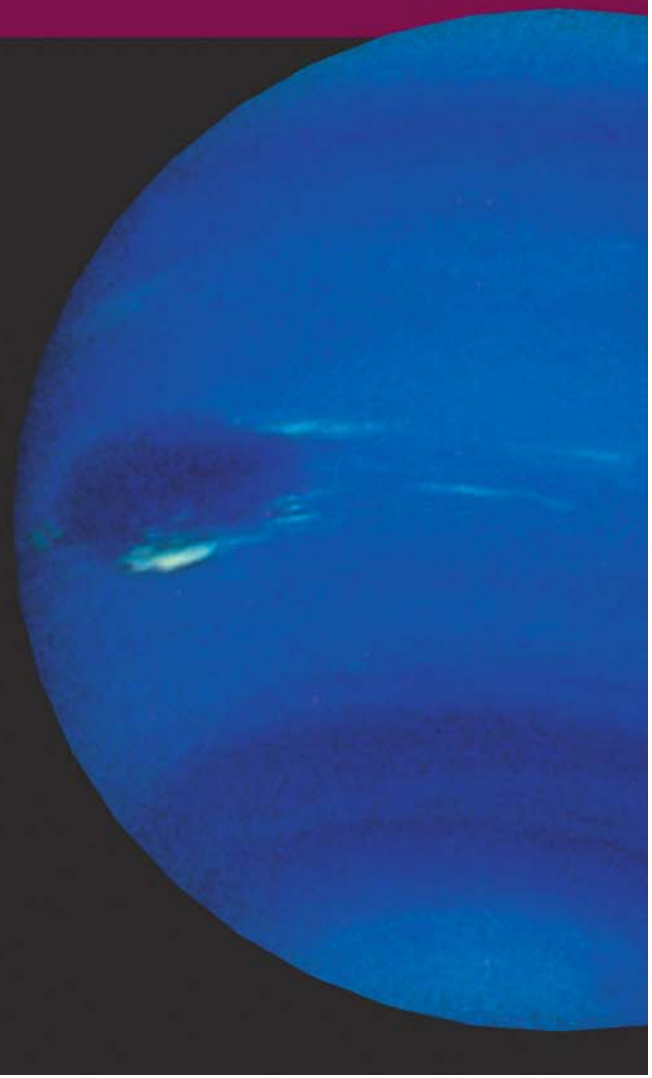
table 16-1 | Uranus Data

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)

Neptune Data

table 16-2 | Neptune Data

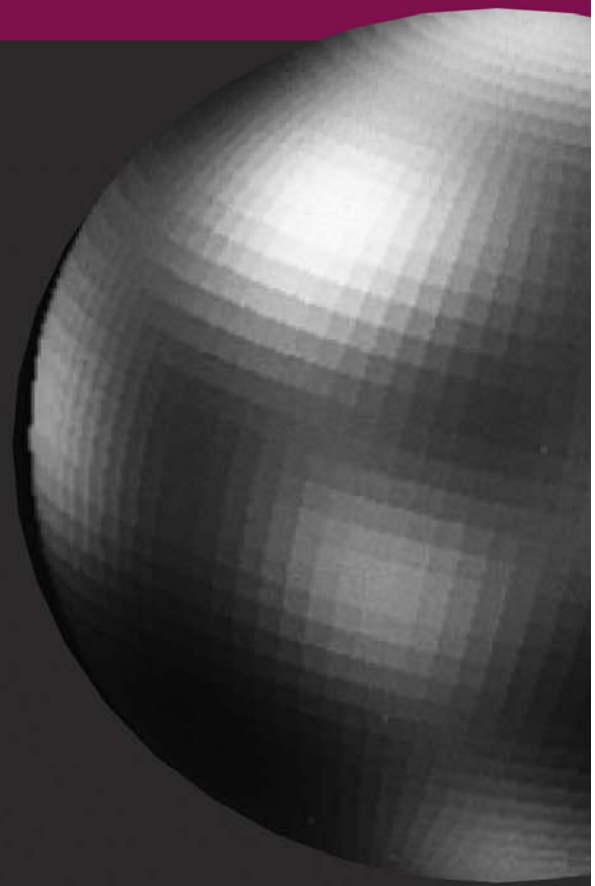
Average distance from Sun:	30.066 AU = 4.498×10^9 km
Maximum distance from Sun:	30.367 AU = 4.543×10^9 km
Minimum distance from Sun:	29.765 AU = 4.453×10^9 km
Eccentricity of orbit:	0.010
Minimum distance from Sun:	29.765 AU = 4.453×10^9 km
Eccentricity of orbit:	0.010
Average orbital speed:	5.5 km/s
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)



Pluto Data

table 16-3 | Pluto Data

Average distance from Sun:	39.537 AU = 5.915×10^9 km
Maximum distance from Sun:	49.425 AU = 7.394×10^9 km
Minimum distance from Sun:	29.649 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 2300 km = 0.18 Earth diameter
Mass:	1.3×10^{22} kg = 0.0021 Earth mass
Average density:	about 1900 kg/m^3
Escape speed:	1.2 km/s
Surface gravity (Earth = 1):	0.07
Albedo:	0.5
Average surface temperature:	−233°C = −387°F = 40 K

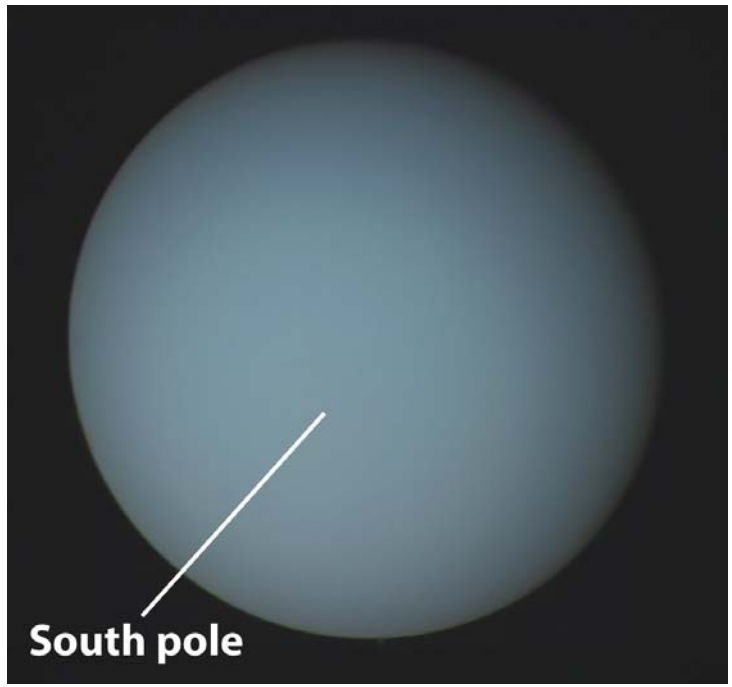


Discovery

- 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 mid-1840s
  - Slight deviations in Uranus’ orbit indicated the presence of an undiscovered planet
  - Credit shared by Le Verrier and Adams
  - A triumph of scientific reasoning

Uranus: Atmosphere

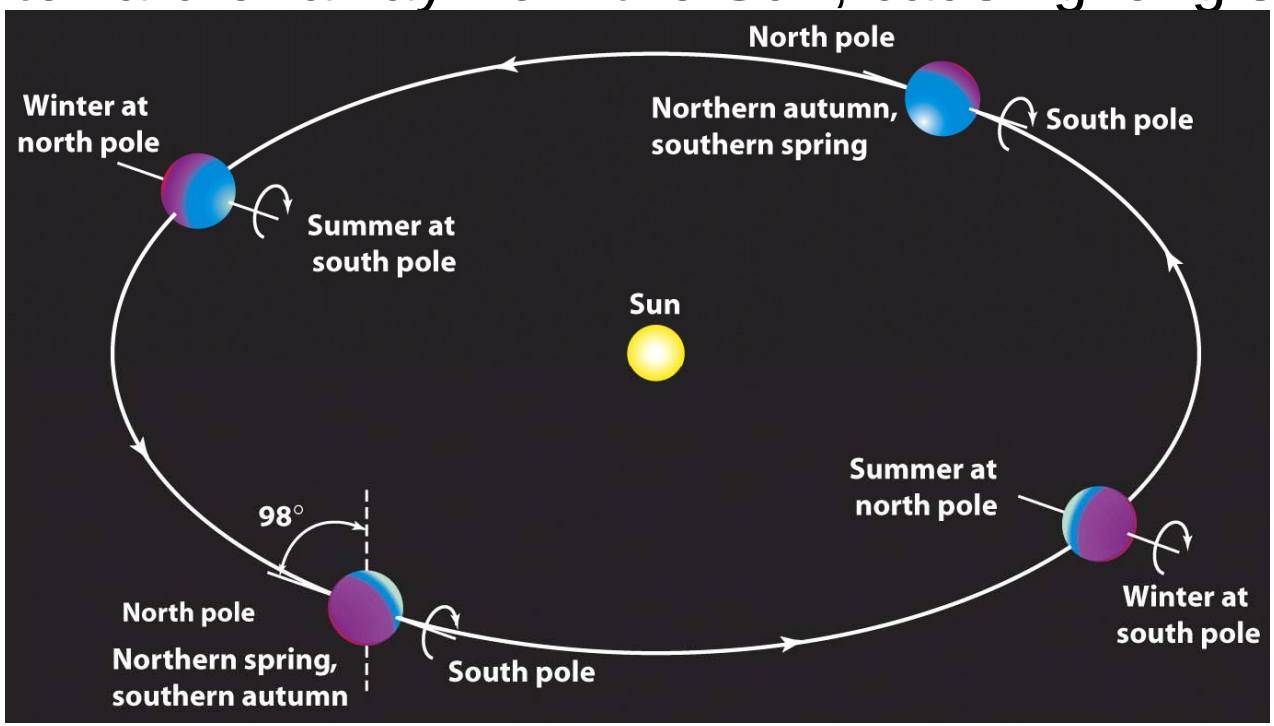
- Uranus is nearly featureless in visible light
  - Covered by atmosphere
  - No cloud
  - Enveloped by hydrocarbon haze
- Atmosphere is primarily hydrogen (82.5%) and helium (15.2%)
- Atmosphere is 2.3% methane, a relatively high percentage compared with Jupiter and Saturn



- Methane absorbs red light, giving Uranus (and Neptune) their greenish-blue color
- Due to low temperature, atmosphere lacks ammonia and water, which could make up the clouds

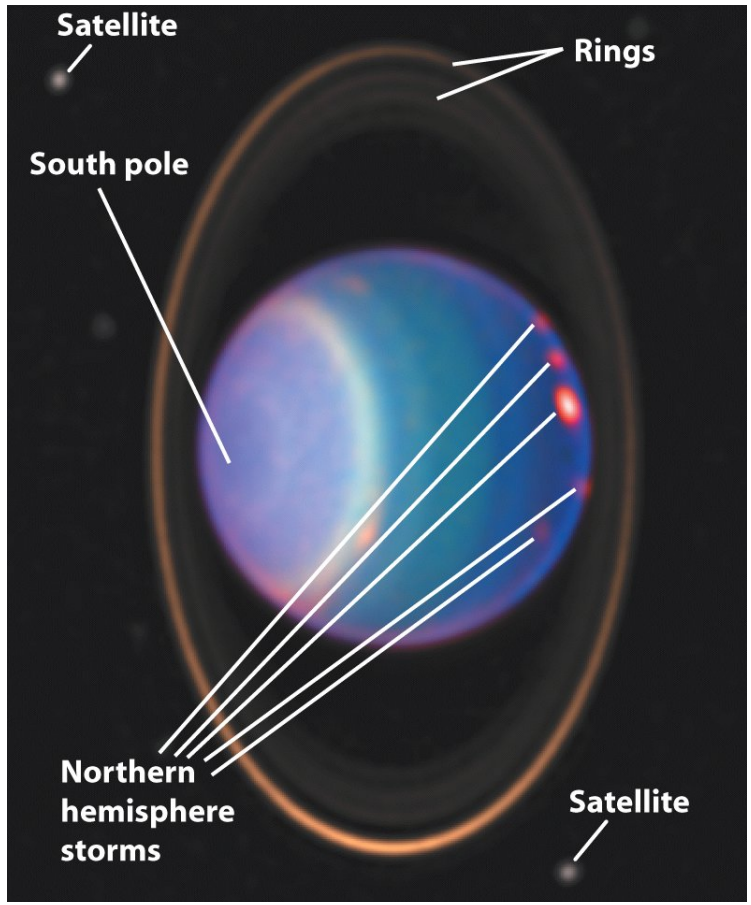
Uranus: unusual axis of rotation

- 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



Uranus: unusual axis of rotation

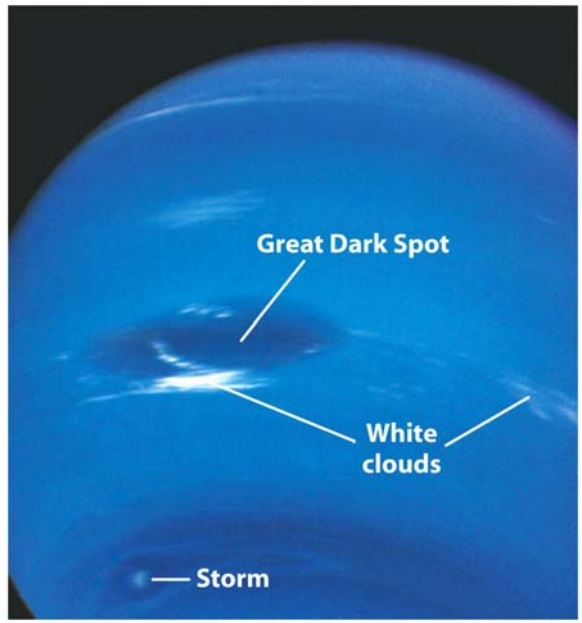
- Uranus's unusual rotation produces greatly exaggerated seasonal changes on the planet
- A season lasts almost 20 years
- When sunlight returned to northern hemisphere (1998), immense storms were triggered there

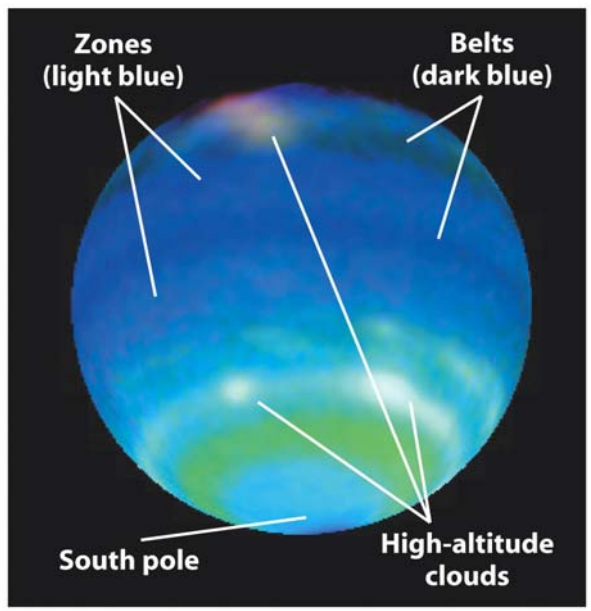


Infrared image

Neptune: Atmosphere

- Neptune has almost the same atmospheric composition as Uranus: 70% 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



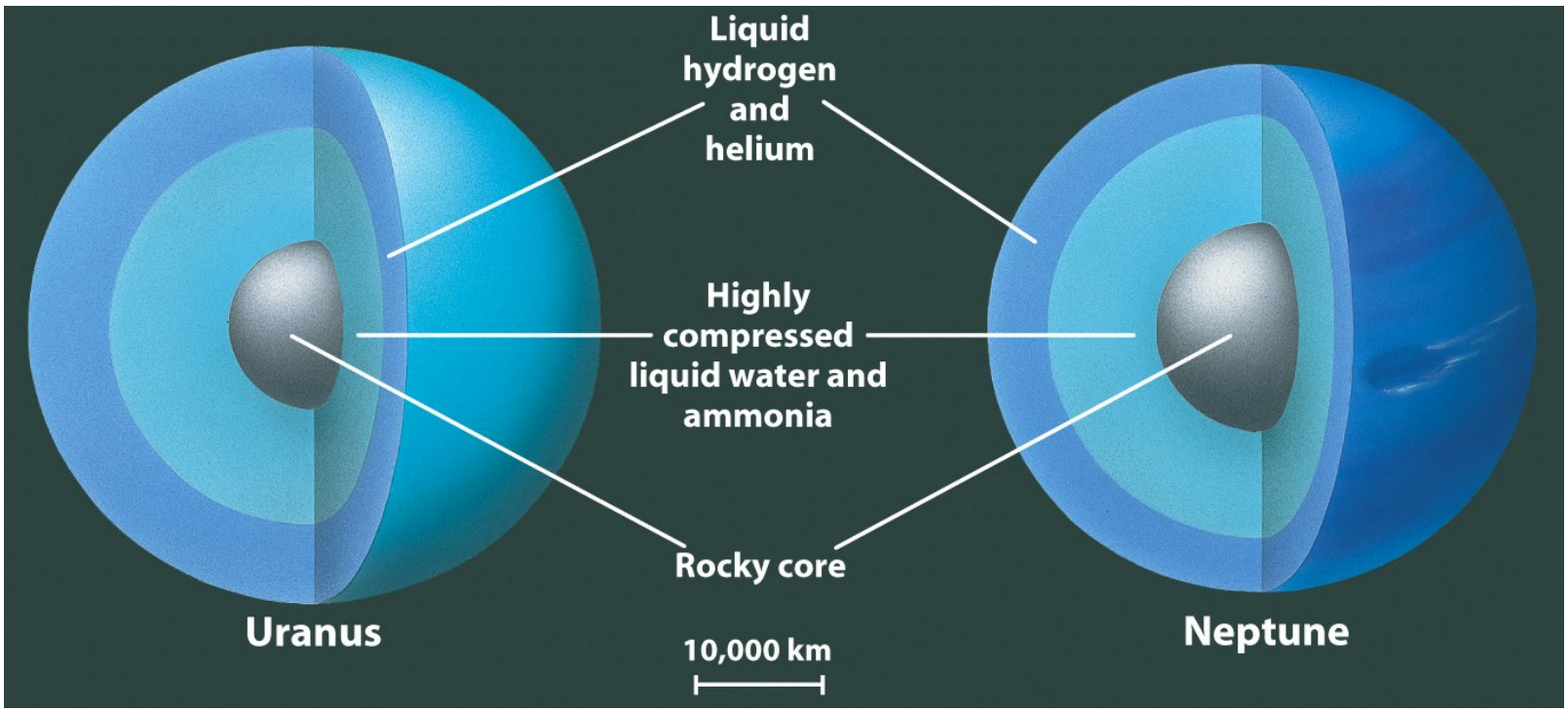


Neptune: Atmosphere

- Why does Neptune have a 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
  - Uranus radiates as much energy into space as it receives from the Sun, indicating no internal source of thermal energy

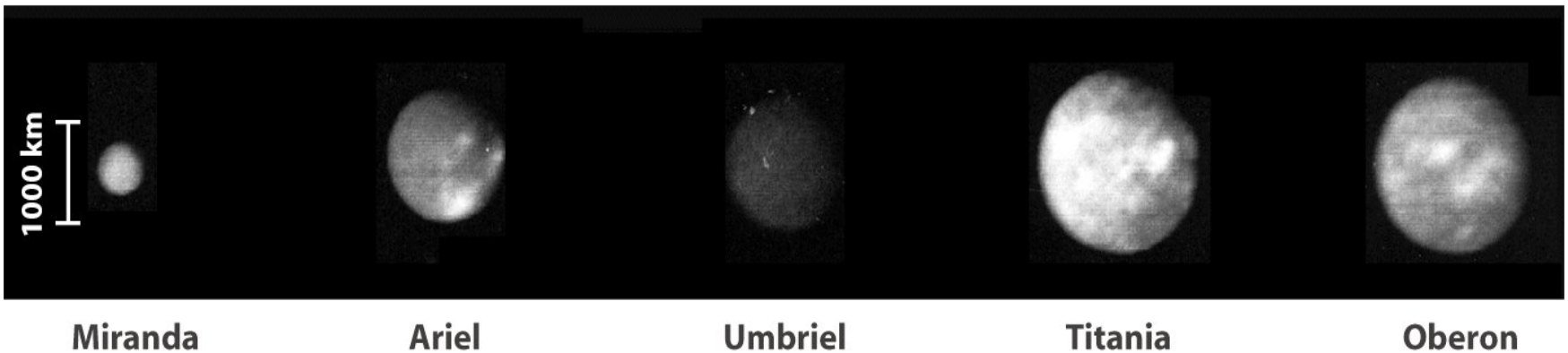
Interior Structure

- Both Uranus and Neptune may have
  - A rocky core
  - A mantle of liquid water and ammonia
  - An outer layer of liquid hydrogen and helium
  - A thin layer of atmosphere



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 km/m^3, consistent with a mixture of ice and rock



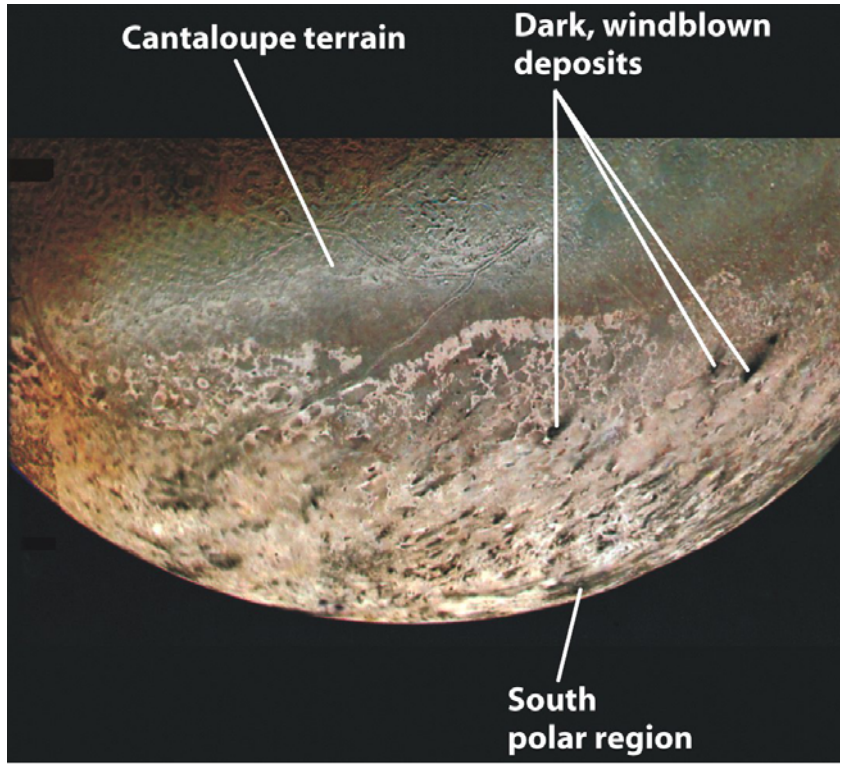
Uranus: Satellites

- Miranda shows evidence of geological activity
  - Part of surface is heavily cratered and thus ancient
  - Part of surface is dominated by parallel networks of valleys and ridges
  - The geological activity may be caused by the **gravitational tidal heating** in the past

Miranda

Neptune: Satellites

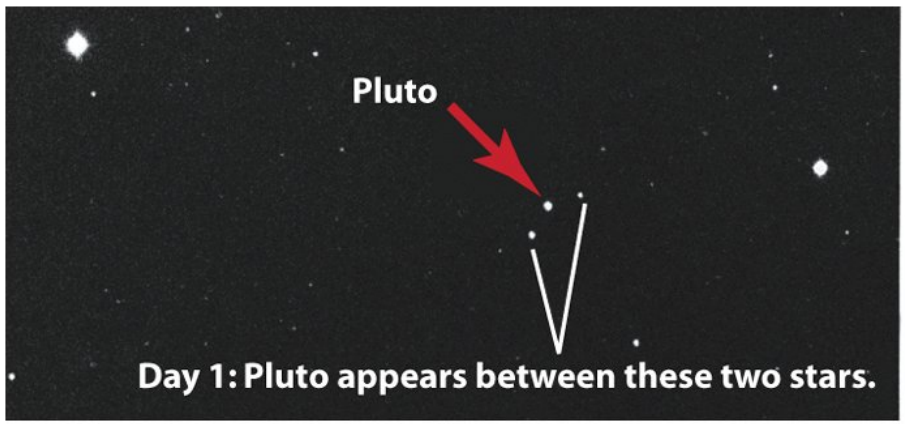
- Neptune has 13 satellites
- Triton, the largest satellite, is comparable in size to our Moon or the Galilean satellites of Jupiter
- Triton has a young, icy surface indicative of tectonic activity
- The energy for this activity may have been provided by tidal heating
  - occurred when Triton was captured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

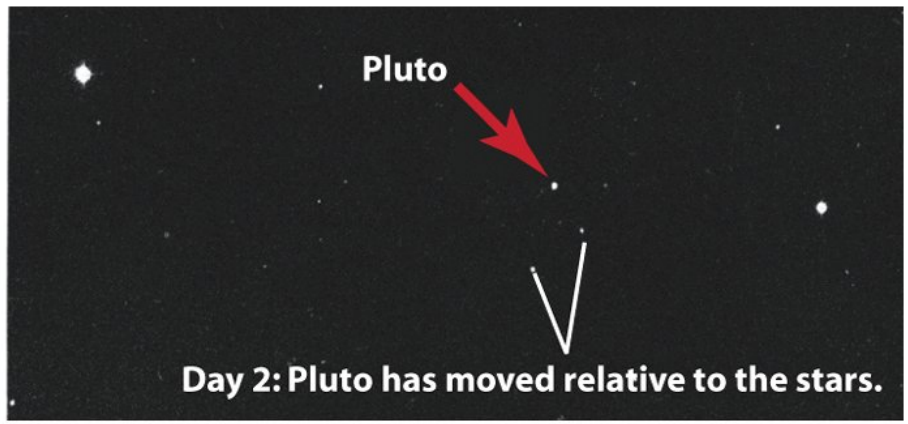


Triton

Pluto

- **Pluto is no longer a planet**
- Pluto was discovered in 1930 after a long search for the ninth planet
- Pluto mov in a highly elliptical orbit
  - Eccentricity 0.25
  - Sometimes within the orbit of Neptune
- Pluto's orbit is steeply inclined to the plane of the ecliptic





Pluto and Charon

- Pluto (2300 km) 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
- 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

Kuiper Belt

- Neptune and Charon are now thought to be **Kuiper belt objects**
- **Kuiper Belt:** lies beyond the orbit of Neptune between 30 and 500 AU from the Sun
- More than one thousand Kuiper Belt objects have been found, and at least nine of these objects have satellites of their own

•NASA's New Horizons Mission

- Jan. 19, 2006: launched
- July 2015: Pluto-Charon encounter
- 2016-2020: Kuiper Belt Object Encounter

Final Notes on Chap. 16

- There are 9 sections in total.

- The following sections are not covered
  - 16-5 (magnetic field)
  - 16-6 (thin & dark rings)