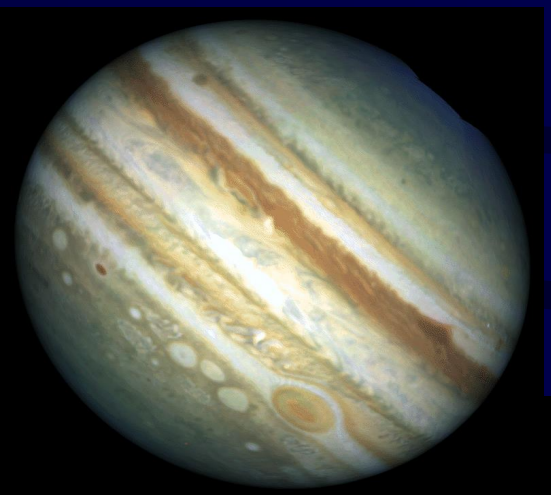
Jovians & Solar System Formation

The Jovian Planets

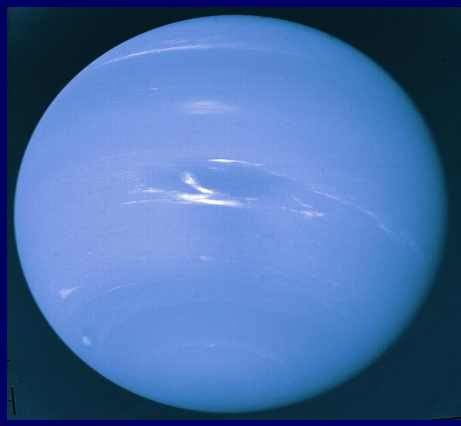


Jupiter

Saturn

Uranus

Neptune



Comparison

- **Terrestrial**
  - close to the Sun
  - closely spaced orbits
  - small radii
  - small masses
  - predominantly rocky
  - high density
  - solid surface
  - few moons
  - no rings

- **Jovian**
  - far from the Sun
  - widely spaced orbits
  - large radii
  - large masses
  - predominantly gaseous
  - low density
  - no solid surface
  - many moons
  - many rings

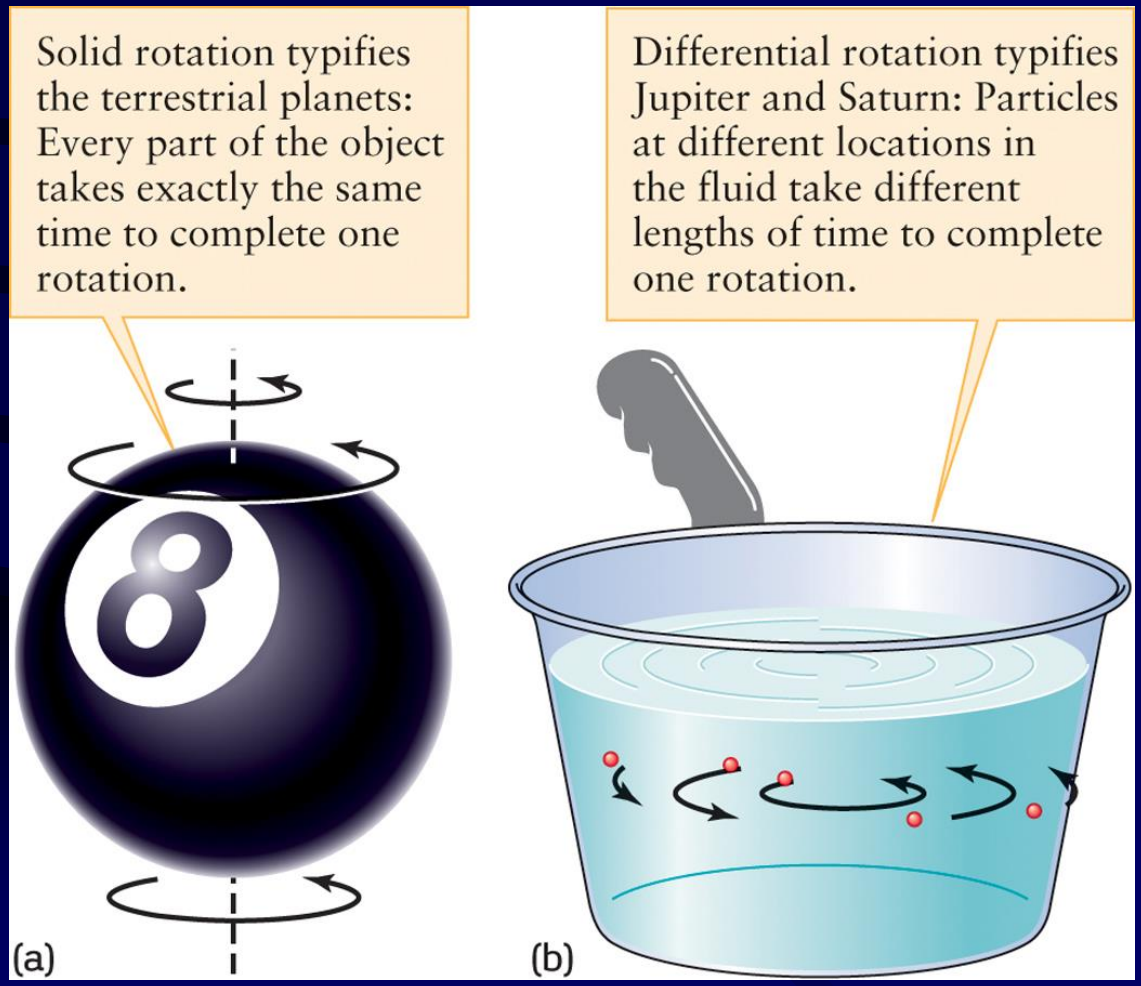
History

- **Jupiter and Saturn** known to the ancients
  - Galileo observed 4 moons of Jupiter and Saturn's rings, Huygens discovered Saturn's Titan in 1655
- **Uranus**
  - Discovered telescopically by William Herschel in 1781 (actually barely visible to naked eye)
- **Neptune**
  - Predicted from observed perturbations of Uranus's orbit: Adams (1845) and Leverrier (1846)
  - Observed by Galle (1846)
  - Discovery great triumph for computational astronomy/physics

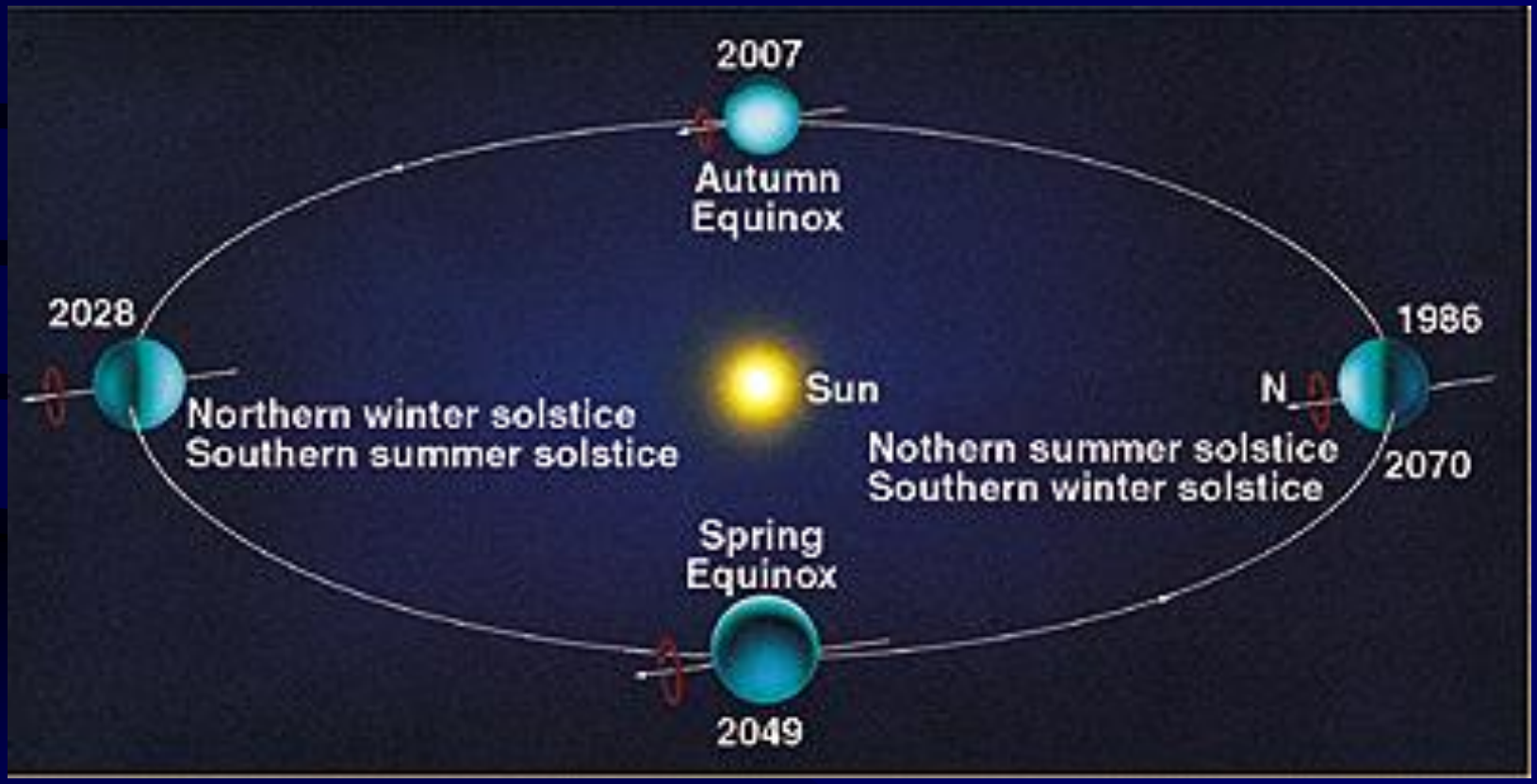
Rotation

- About 10 hours for Jupiter and Saturn; about 17 hours for Uranus and Neptune
- **Differential rotation**: rotation speed varies from point to point on the "surfaces"
  - Gaseous bodies with no solid surfaces!
  - On Jupiter, the equatorial regions rotate 6 minutes slower than polar regions
  - On Saturn the equatorial region is about 26 minutes slower
- Tilt of rotation axes:
  - Jupiter: almost none – no seasons!
  - Saturn, Neptune: about like Earth
  - Uranus: weird

Differential Rotation

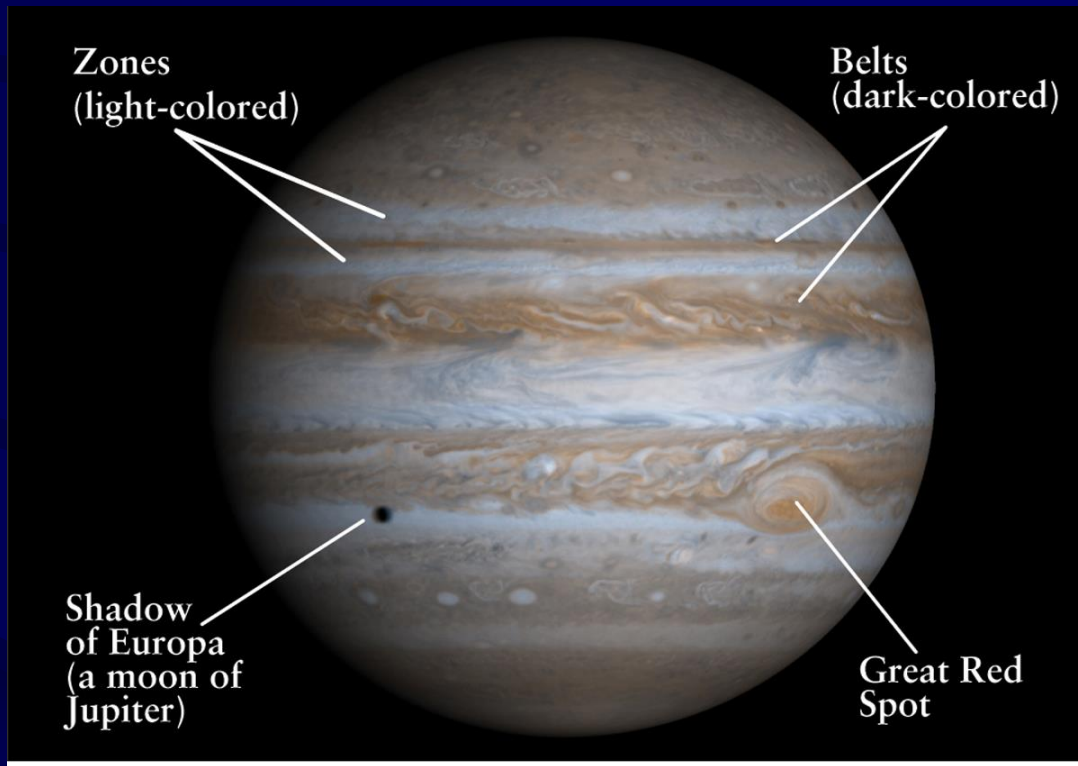


Uranus's Strange Seasons



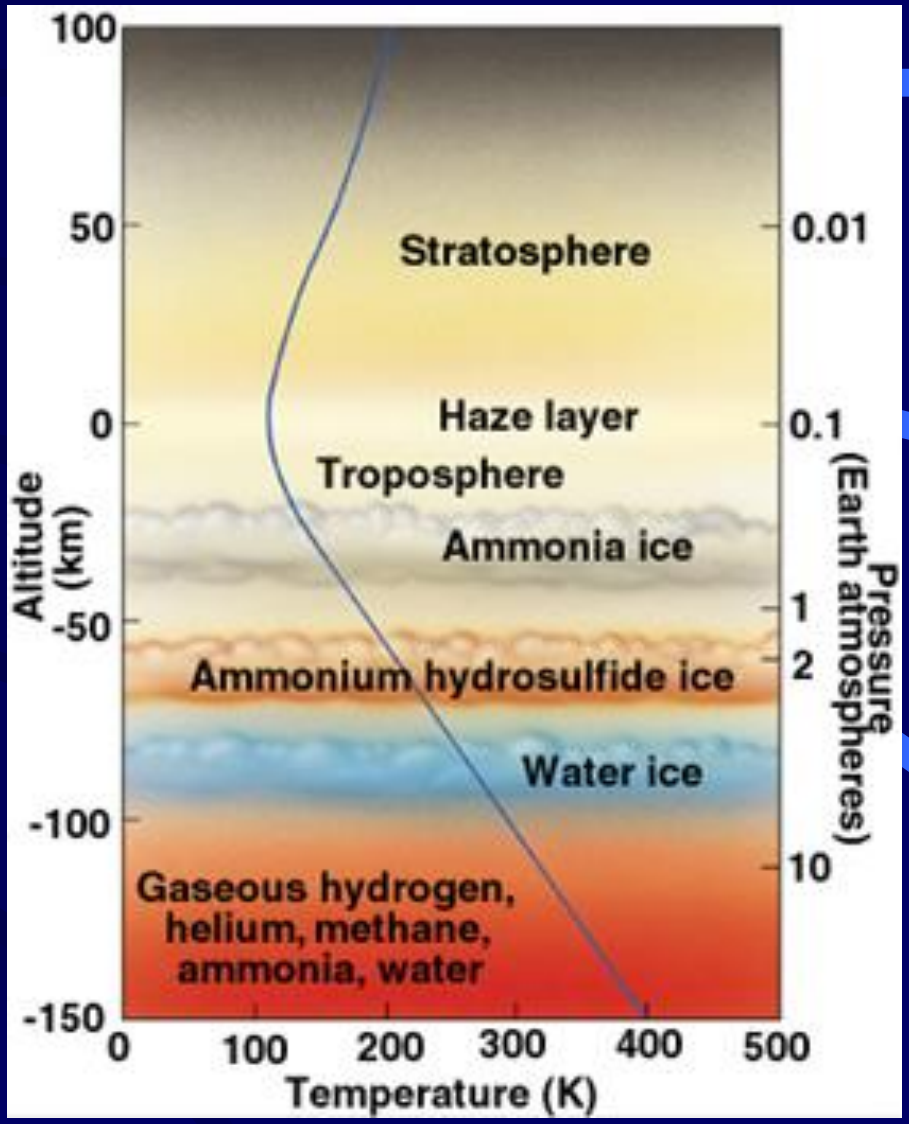
Jupiter's Atmosphere

- Cloud bands parallel to equator (rotation!)
- Great Red Spot
  - First observed in 1664 by Robert Hooke



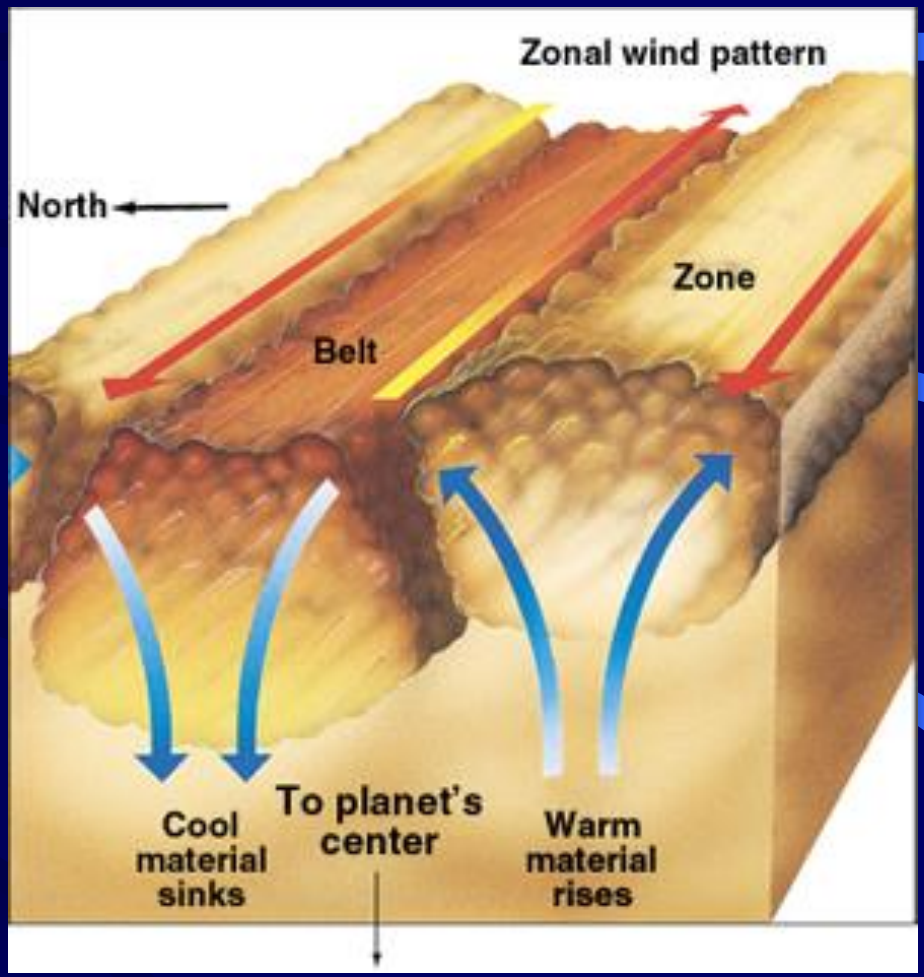
Jupiter's Atmosphere

- 86% Hydrogen, 14% Helium; some methane, water, ammonia
- Several layers of clouds: ammonia, ammonium hydrosulfide, water
- Colors mostly due to compounds of sulfur and phosphorus



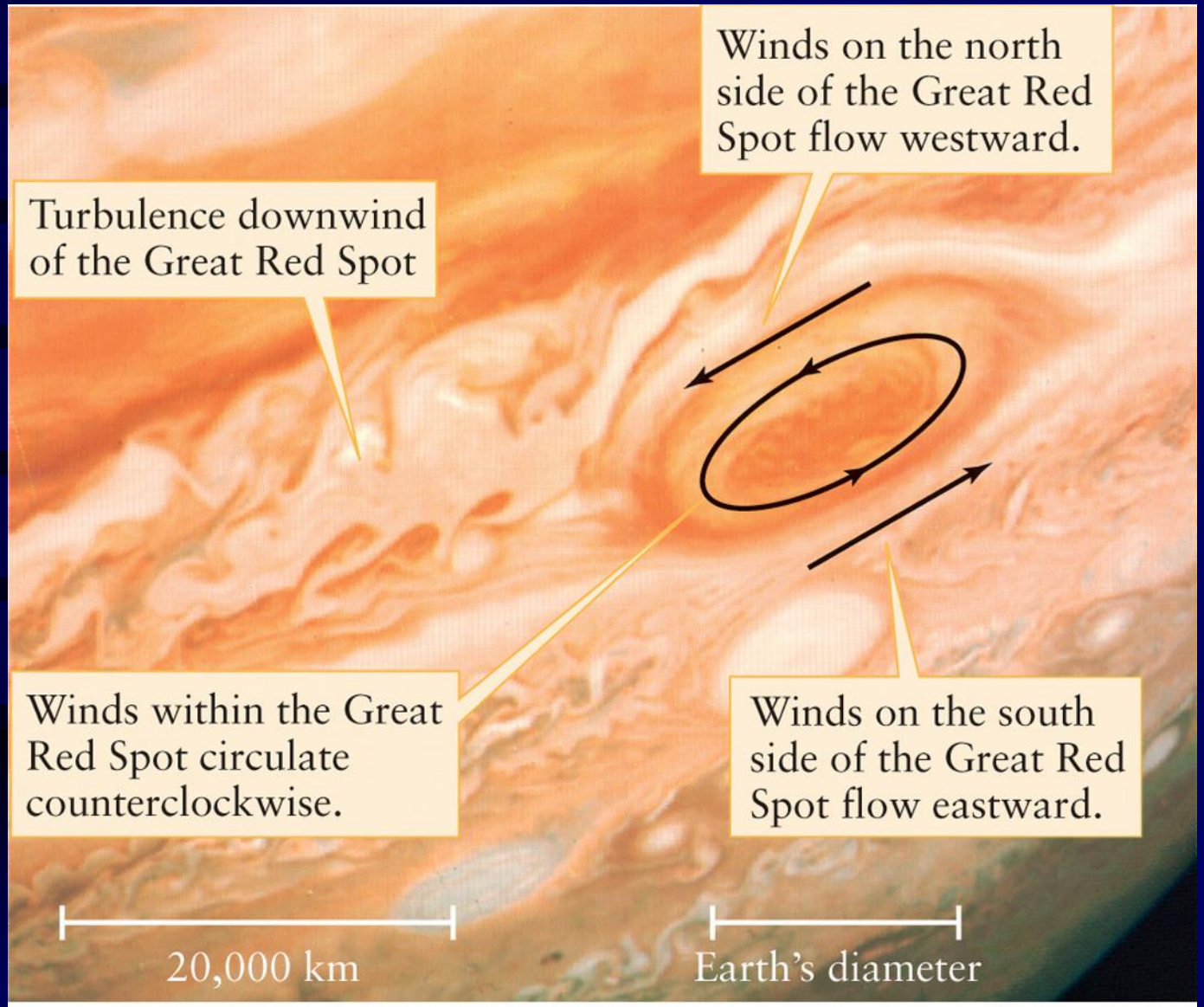
Jupiters' Bands: Zones and Belts

- **Belts:** cool, dark, sinking
- **Zones:** warm, bright, rising
- Jovian weather mostly circles the planet due to high rotation rate
- Bands exhibit east–west flow ➔**Great Red Spot** lies between regions of opposite wind flow



Great Red Spot

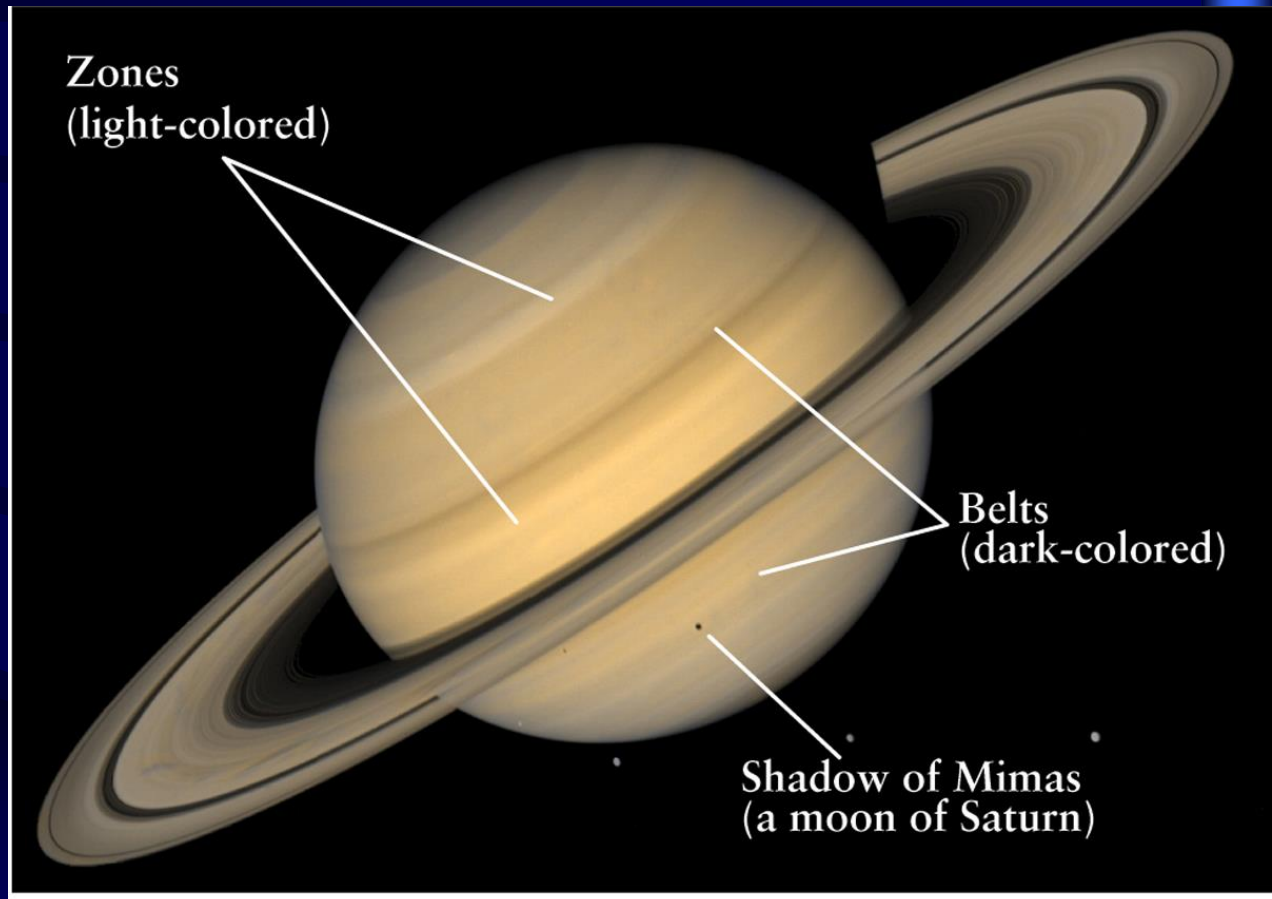
- About twice the diameter of the Earth
- A hurricane that is hundreds of years old!



NASA/JPL; adapted from A. P. Ingersoll

Saturn's Atmosphere

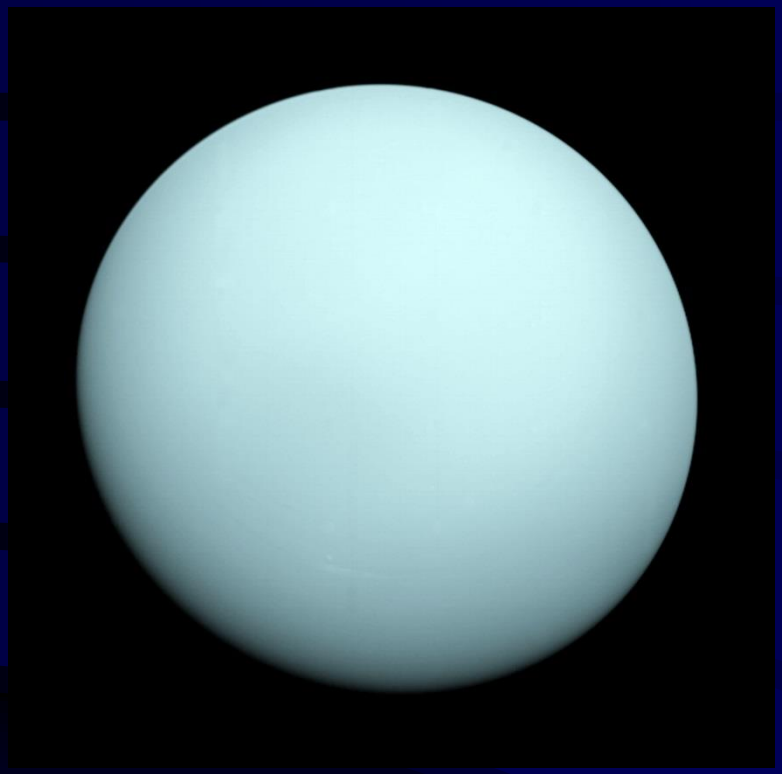
- 92% Hydrogen 7% Helium; some methane, water, ammonia
- Belt structure similar to Jupiter's, but fainter
- Storms are rarer

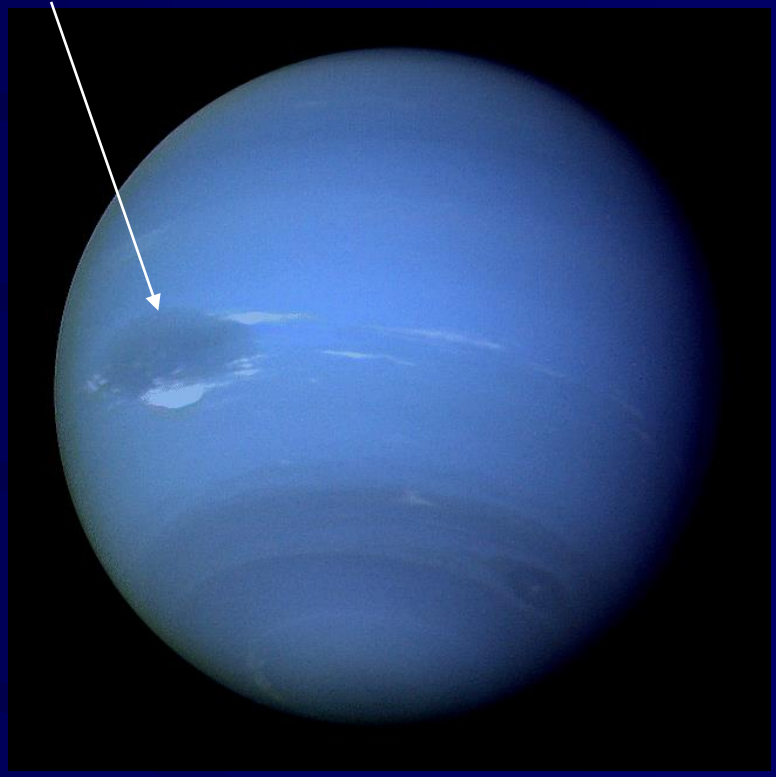


(b) Saturn

NASA/JPL

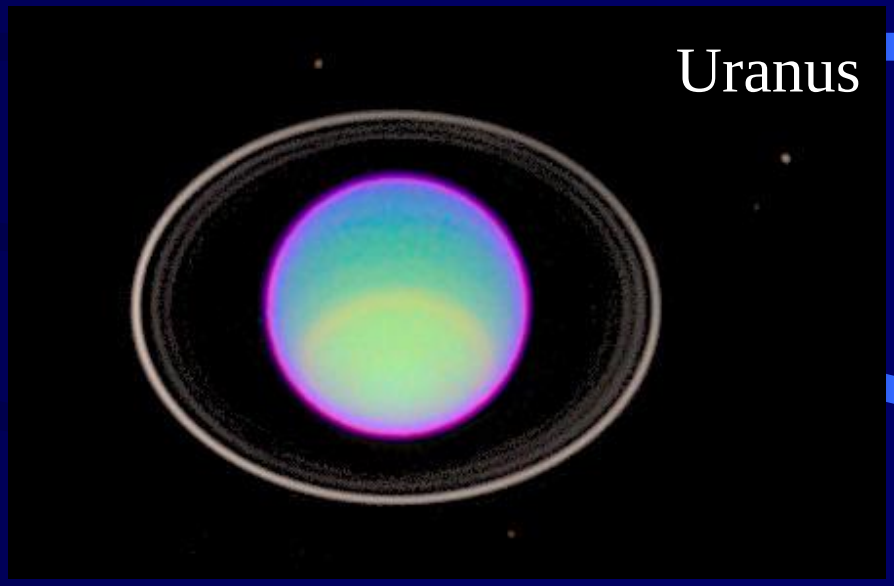
Uranus' and Neptune's Atmospheres

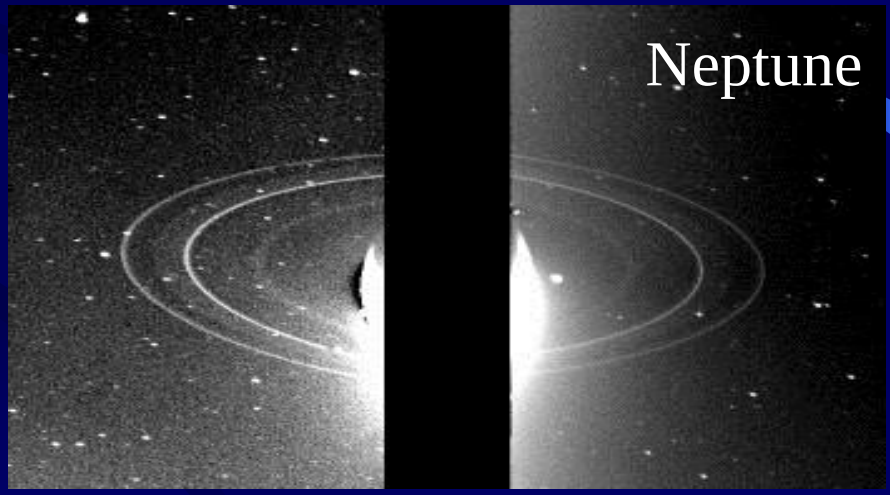




- Ammonia frozen out; more methane
  - Methane absorbs red light, leads to bluish color
- Almost no band structure on Uranus

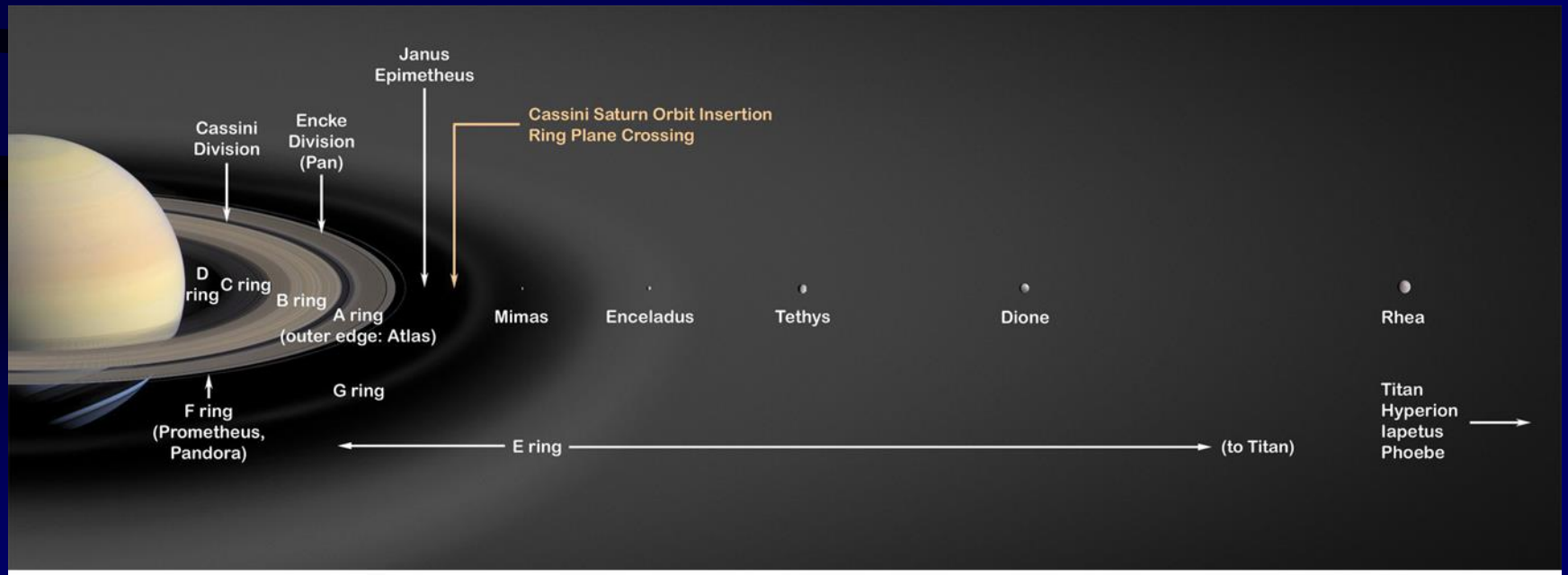
Rings



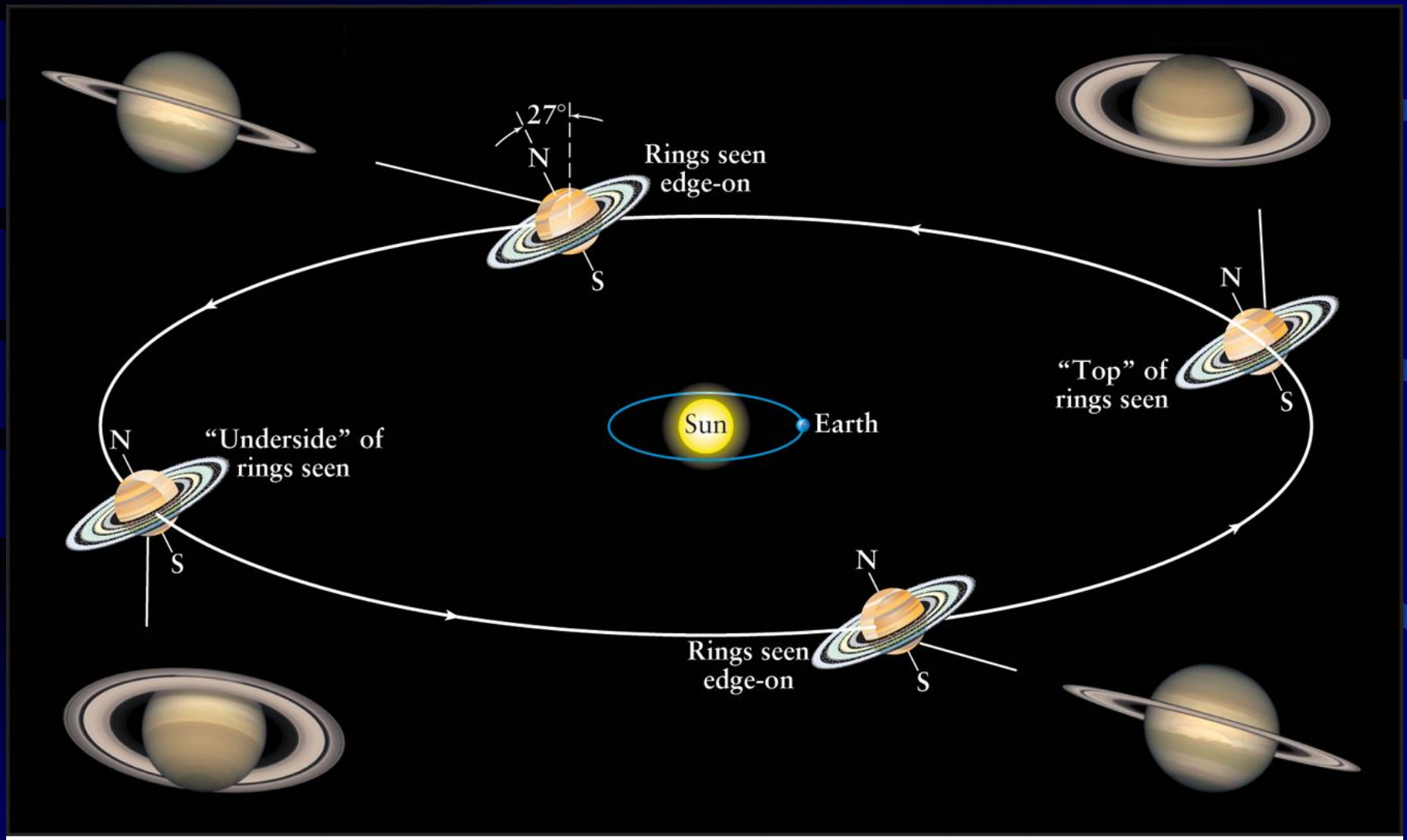


Saturn

- Rings composed of small, icy fragments, orbiting in concentric circles
- Orbits obey Kepler's laws (of course!)
  - Inner rings move faster than outer ones



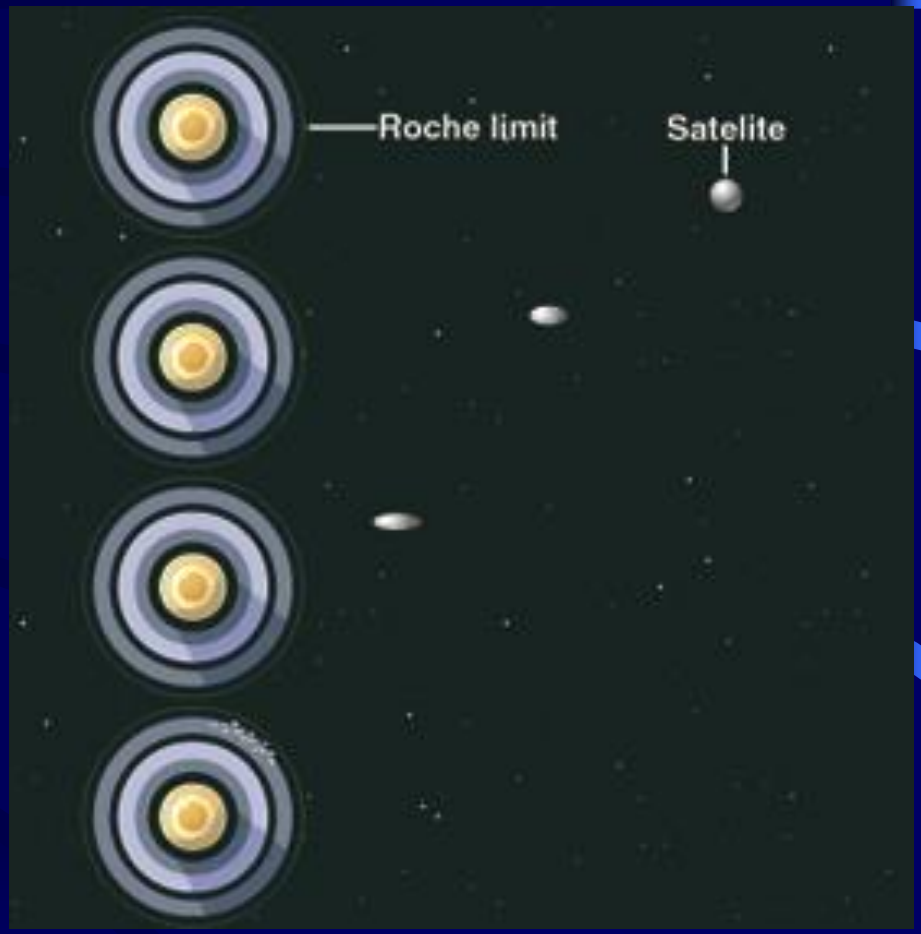
Visibility of Saturn's Rings



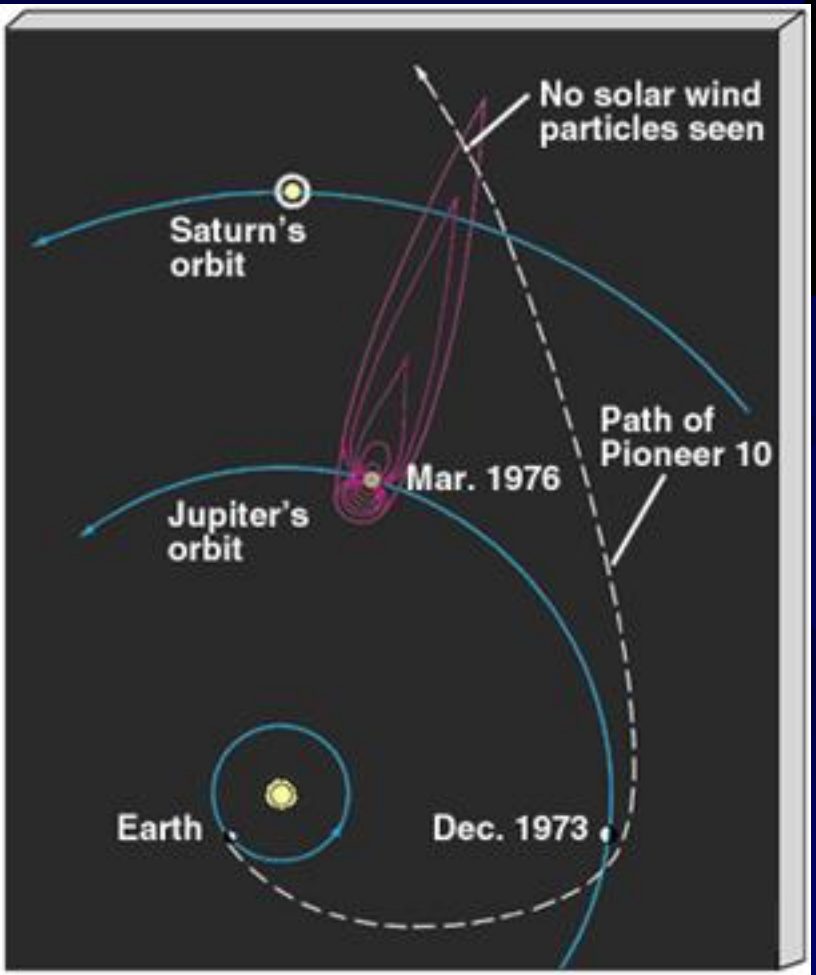
NASA and The Hubble Heritage Team/STScI/AURA/R. G. French [Wellesley College], J. Cuzzi [NASA/Ames], L. Dones [SwRI], and J. Lissauer [NASA/Ames]

How Do They Form?

- Miscellaneous debris
- Moons or other small bodies torn apart by tidal forces
- Roche limit – distance inside of which an object held together by gravity will be pulled apart



Magnetospheres



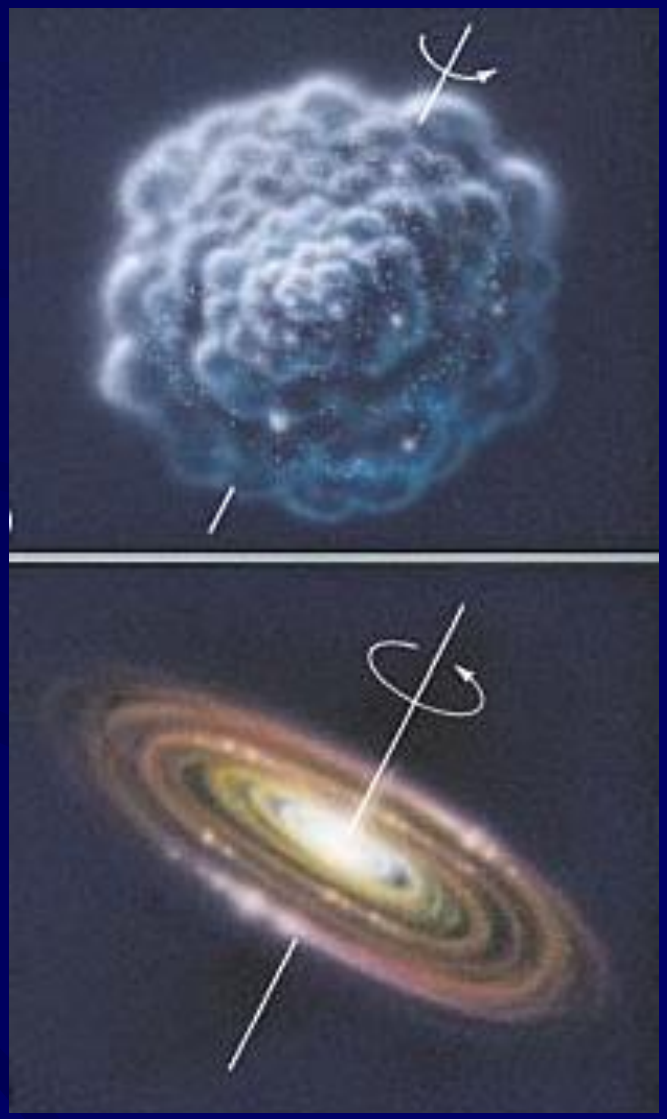
Jupiter Aurora
Hubble Space Telescope • STIS

- Very strong – Jupiter's extends past the orbit of Saturn!
- Indicate the presence of conducting cores

Aurora Borealis and Australis on Saturn

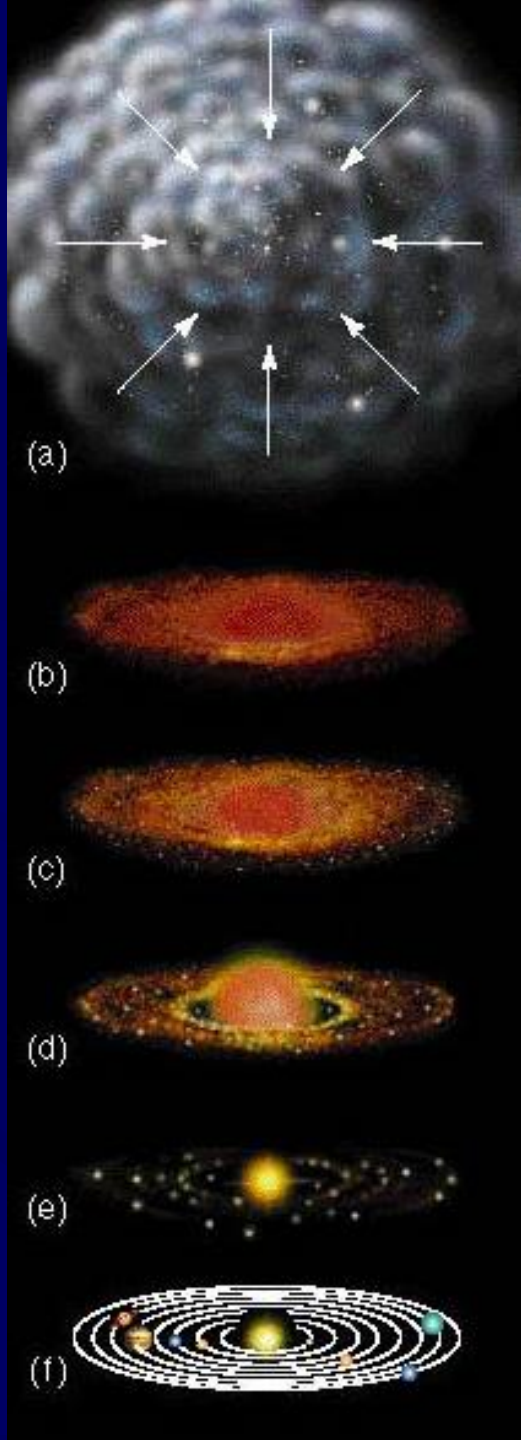
Formation of the Solar System

- Condenses from a rotating cloud of gas and dust
  - Conservation of angular momentum flattens it
- Dust helps cool the nebula and acts as seeds for the clumping of matter

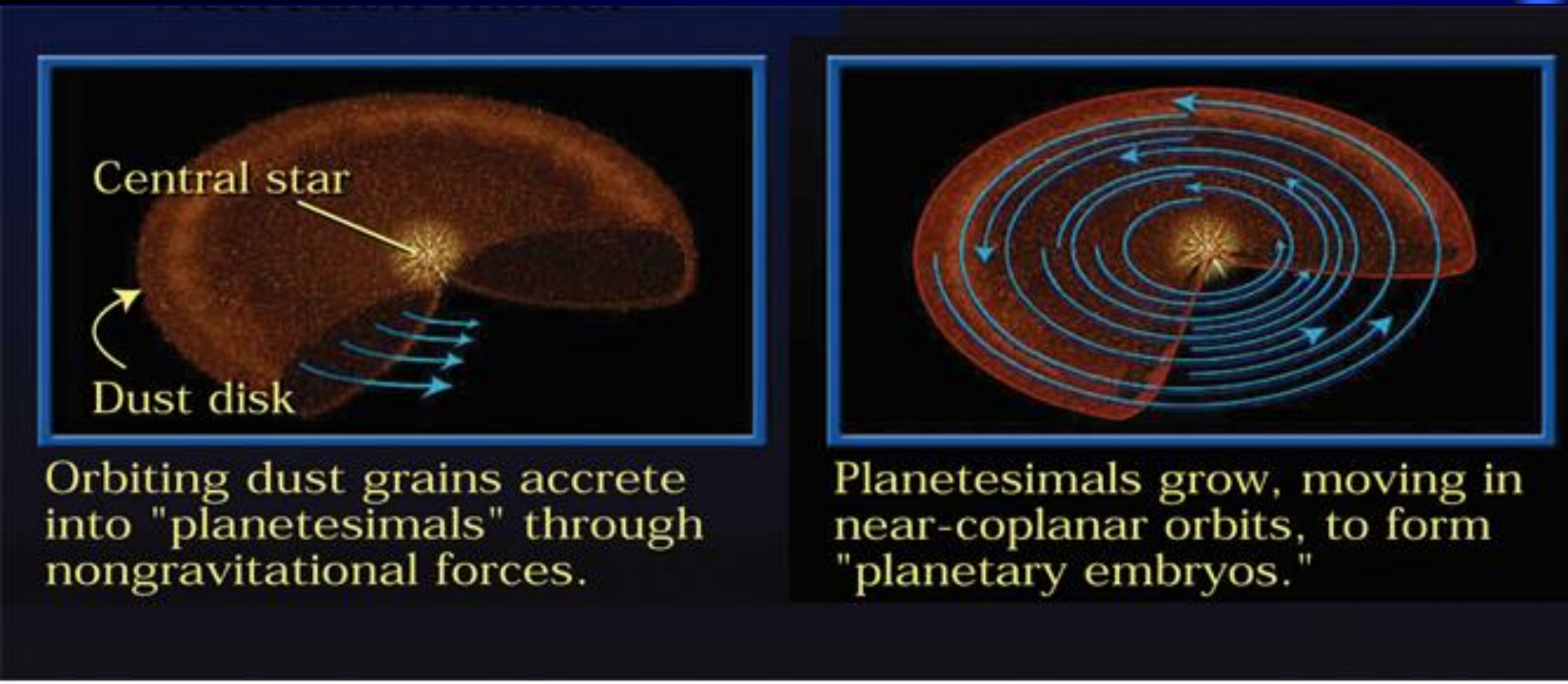


Formation of Planets

- Orbiting dust – planitesimals
- Planitesimals collide
- Different elements form in different regions due to temperature
- Asteroids
- Remaining gas



Formation of Planets



NASA and A. Feild [STScI]

Differentiation of gas and terrestrial planets

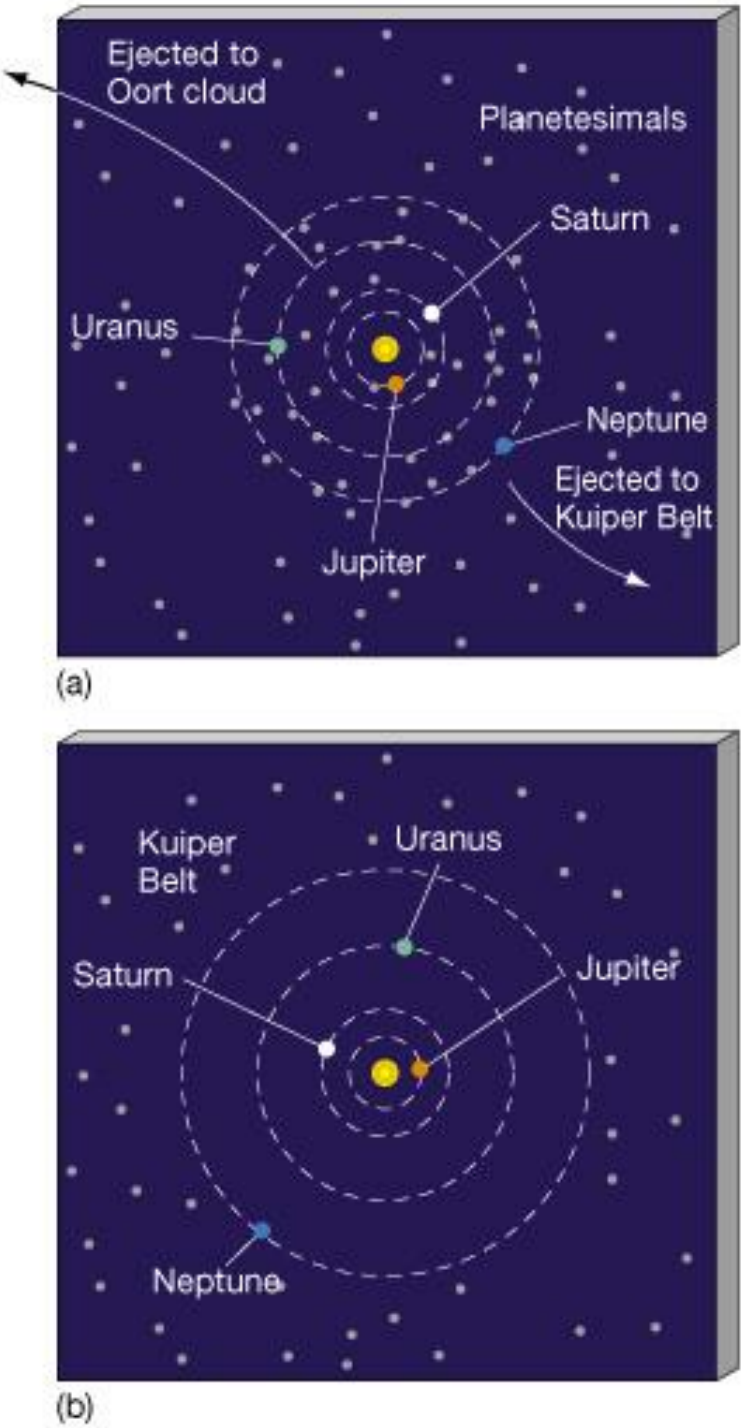
Gas-giant planets accrete gas envelopes before disk gas disappears.

Gas-giant planets scatter or accrete remaining planetesimals and embryos.

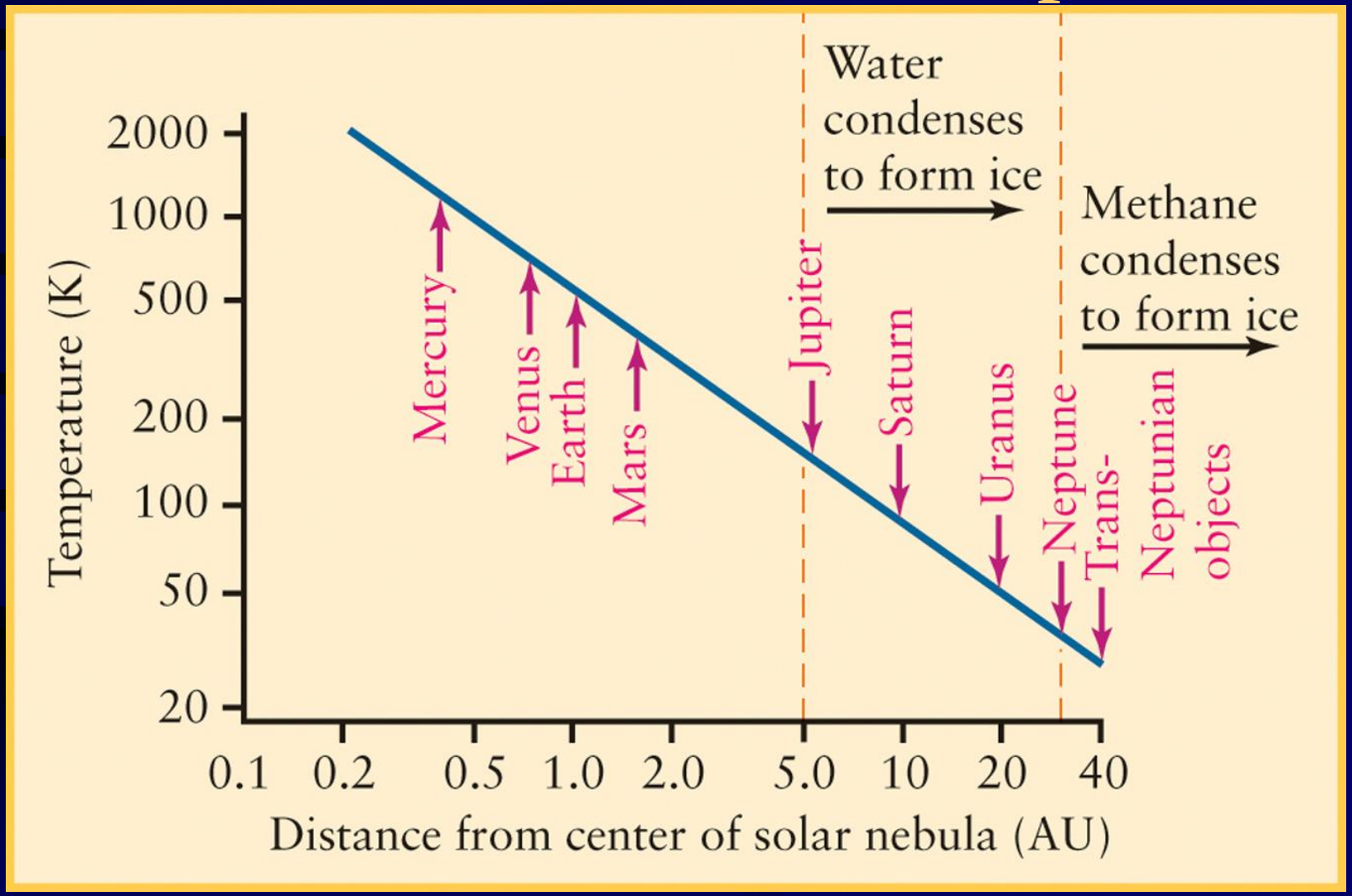
Cleaning up the Solar System

- Small objects are forced out of the inner Solar System by gravitational pull of bigger planets
- Small planetesimals collide and form planets

-- or are thrown out!



Structure of the Planets explained



Temperature and density of materials drop with distance to sun

Different formation mechanisms of terrestrial and Jovian planets

- This explains why they are of different size and material