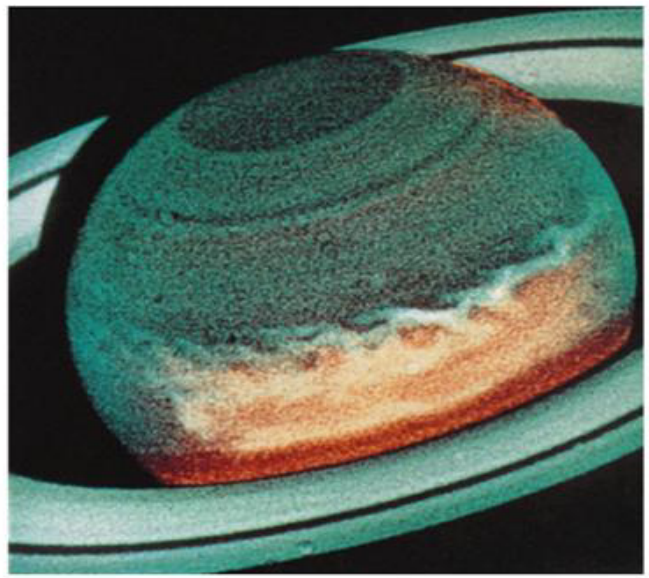
Outer Planets

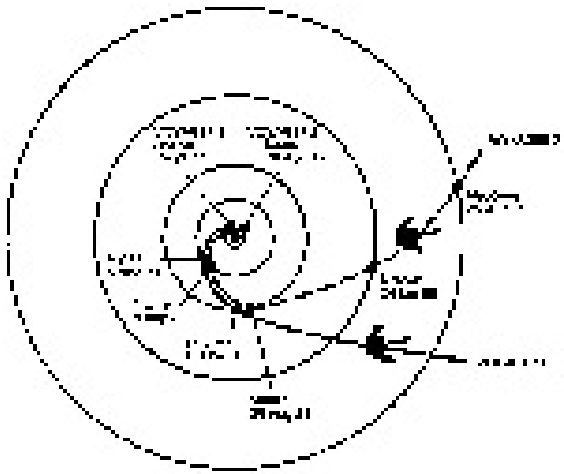
Sept. 25, 2002

- Comparative Giant Planets
- Jupiter
- Saturn
- Uranus
- Neptune
- Gravity
- Tidal Forces



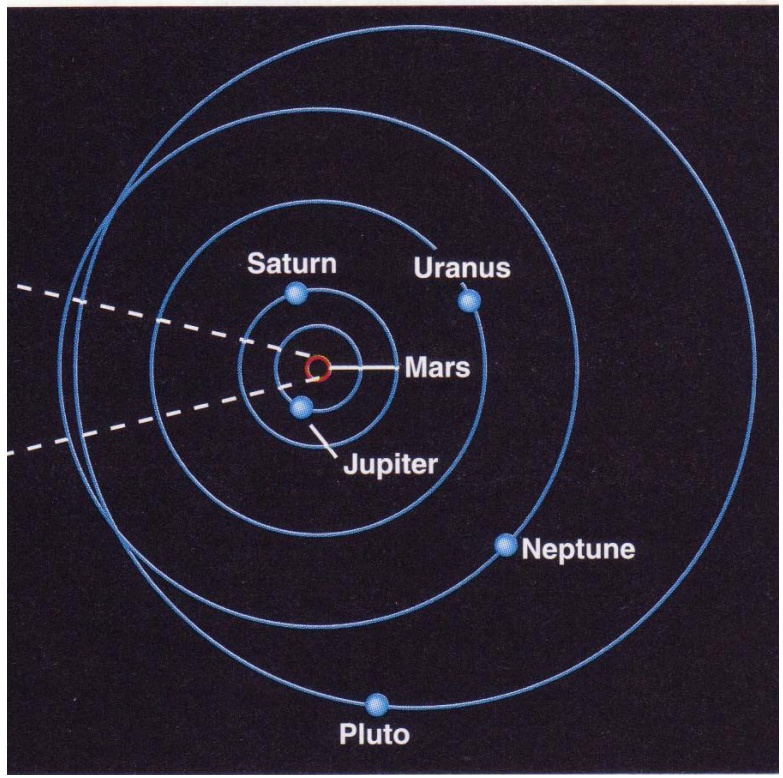
Review

- To Boldly Go
  - overview of outer planets
  - Voyager missions
  - scientific process



Intro to Outer Planets

- Planets beyond the asteroid belt
- Gas giants
  - Jupiter
  - Saturn
- Ice giants
  - Uranus
  - Neptune
- Other
  - Pluto
- Outer planets are much further from the Sun than the inner planets



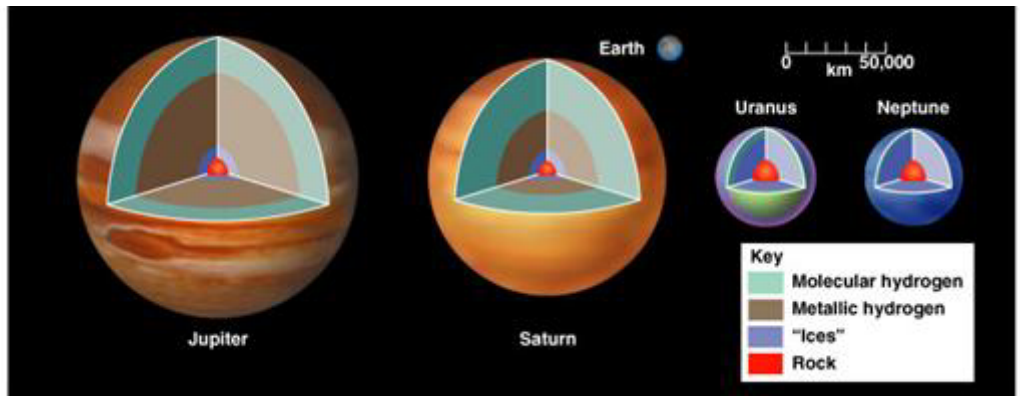
Big, Bigger, Biggest

- Uranus and Neptune
  - about 15 Earth masses
  - radii about 4 times Earth's
- Saturn
  - about 95 Earth masses
  - radius about 9.5 times Earth's
- Jupiter
  - about 318 Earth masses
  - radius about 11 times Earth's

Inner Cores

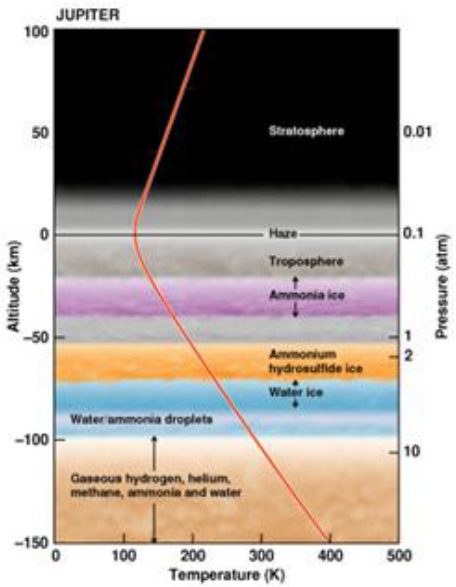
- Solid inner cores
- Jupiter & Saturn
  - metallic, liquid and gaseous hydrogen
  - still being heated by gravitational compression
- Uranus & Neptune
  - ice and more complex gases

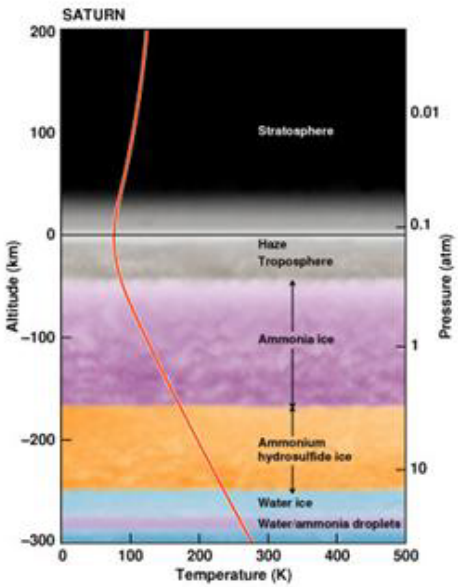
Rock
Ices
Metallic Hydrogen
Molecular Hydrogen

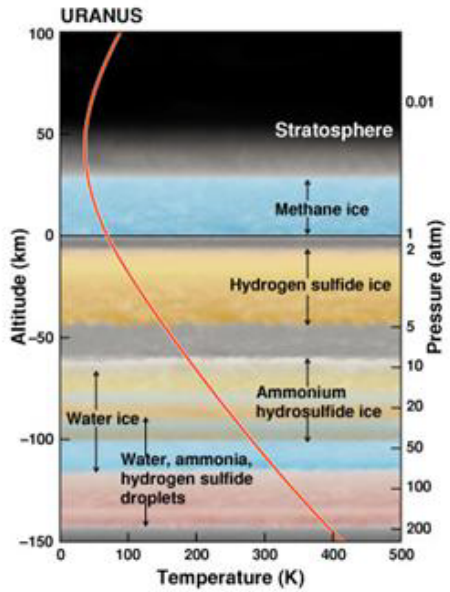


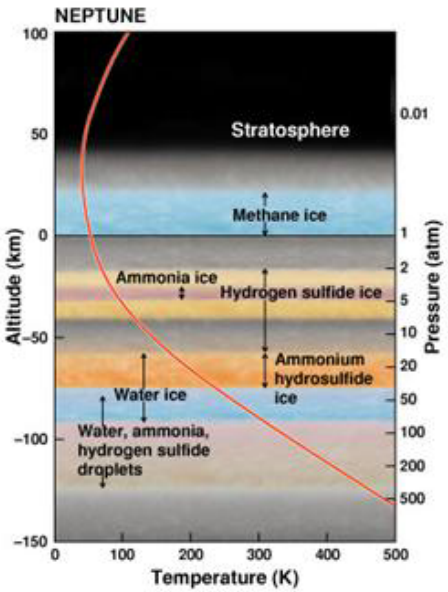
Atmospheres

- We can only see the upper atmospheres of the outer planets
- Jupiter & Saturn – light gases
- Uranus & Neptune – gases and ice



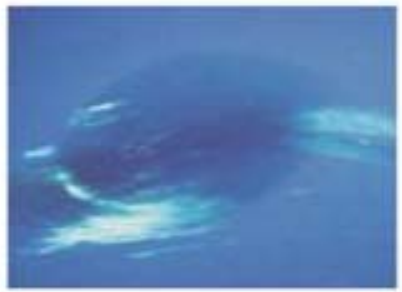






Giant Red Spot

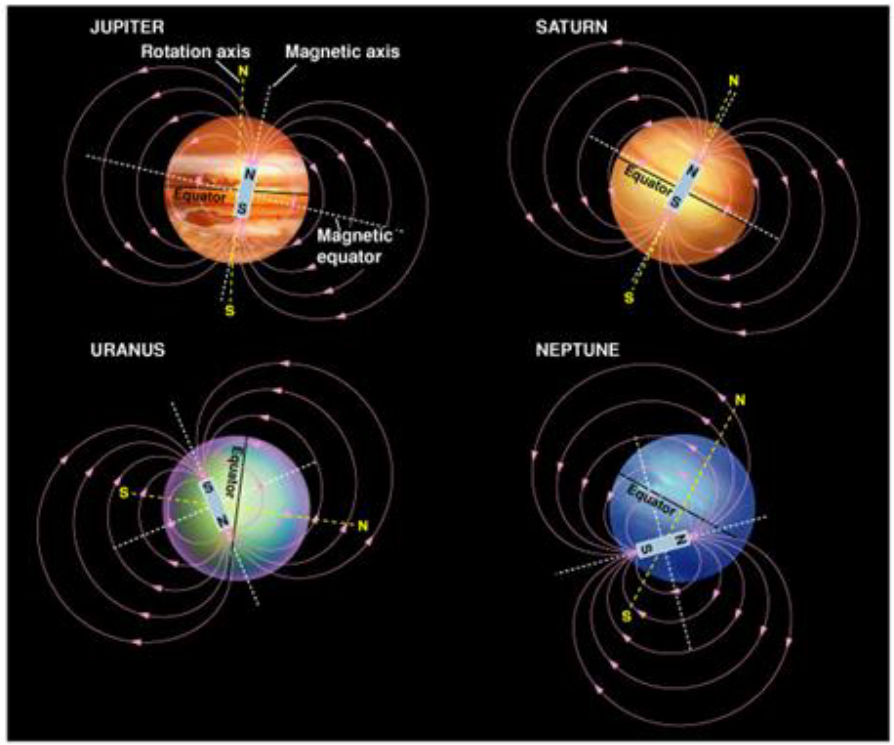
- Huge atmospheric "storm" on Jupiter
  - has existed for centuries
  - visible via telescope on Earth
  - important source of data on atmospheric behavior


- Also, Giant Dark Spot on Neptune

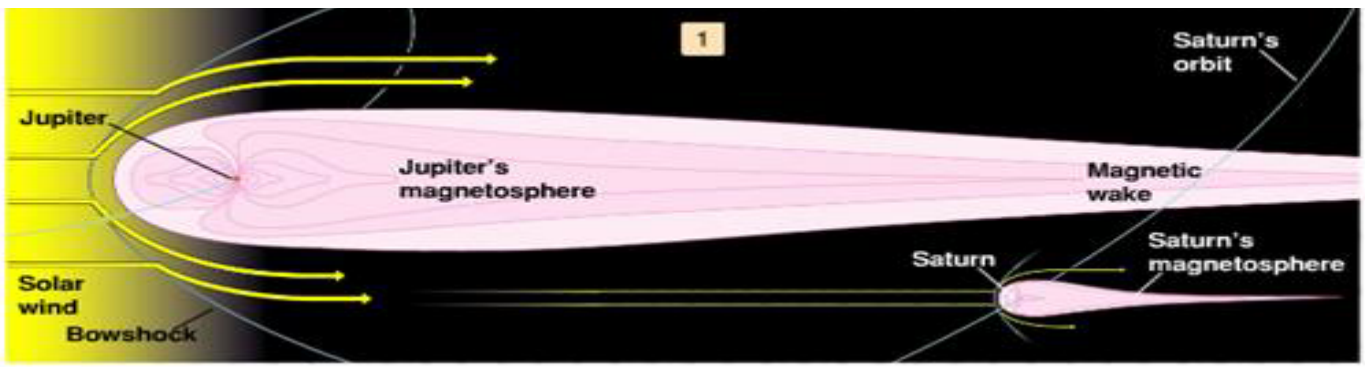
Magnetic Fields

- The outer planets have strong magnetic fields
- Some of them are offset and tilted
  - compared to axis of rotation
- These magnetic fields have effects over a very large space



Synchrotron Radiation

- Charged particles moving in a magnetic field emit electromagnetic radiation
  - often in the form of radio waves
- Solar wind is composed of charged particles kicked out of the Sun
- The interaction of the solar wind and planetary magnetic fields:
  - changes the magnetic fields
  - emits synchrotron radiation

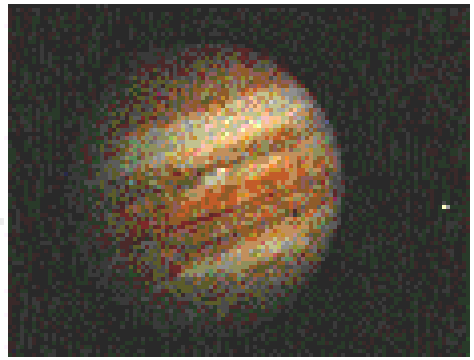


Comparative Giants

	Jupiter	Saturn	Uranus	Neptune
Distance (AU)	5.2	9.5	19.2	30.1
Period (years)	11.9	29.5	84.1	164.8
Diameter (km)	142,800	120,540	51,200	49,500
Mass (Earth=1)	318	95	14	17
Density (g/cm^3)	1.3	0.7	1.2	1.6
Rotation (hours)	9.9	10.7	17.2	16.1
Axis Tilt	3°	27°	98°	29°

Note the short rotation times

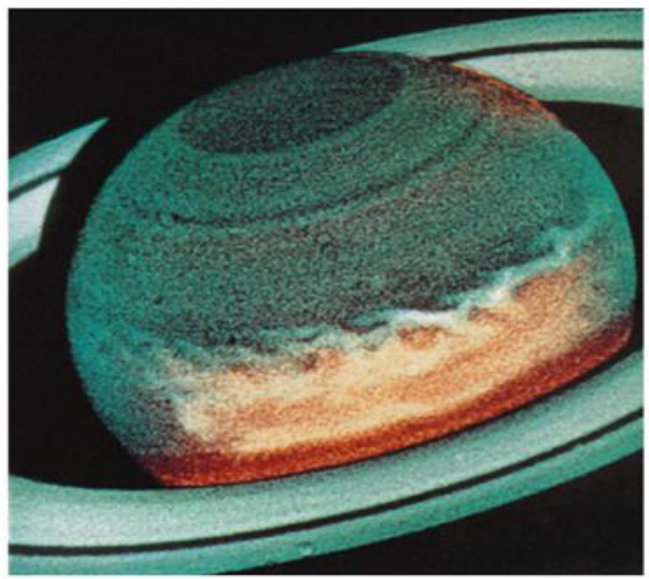
Jupiter



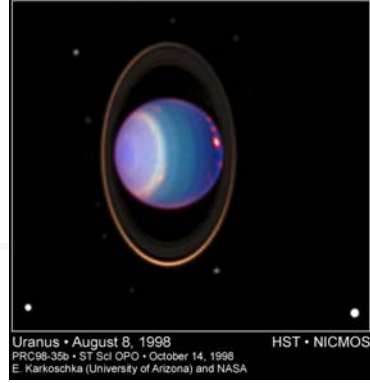
- Largest of the planets
- Composition similar to Sun
  - mostly hydrogen, helium, some other gases, little rock
- Gravity is very strong
- At least 30 moons and small ring system
- Turbulent atmosphere
- Fast moving "surface" speed
  - 28,000 miles/hr (Earth=1040 miles/hr)

Saturn

- Second largest planet
- Less dense than Jupiter
- Magnificent ring system
- Mostly hydrogen and helium
- At least 28 moons



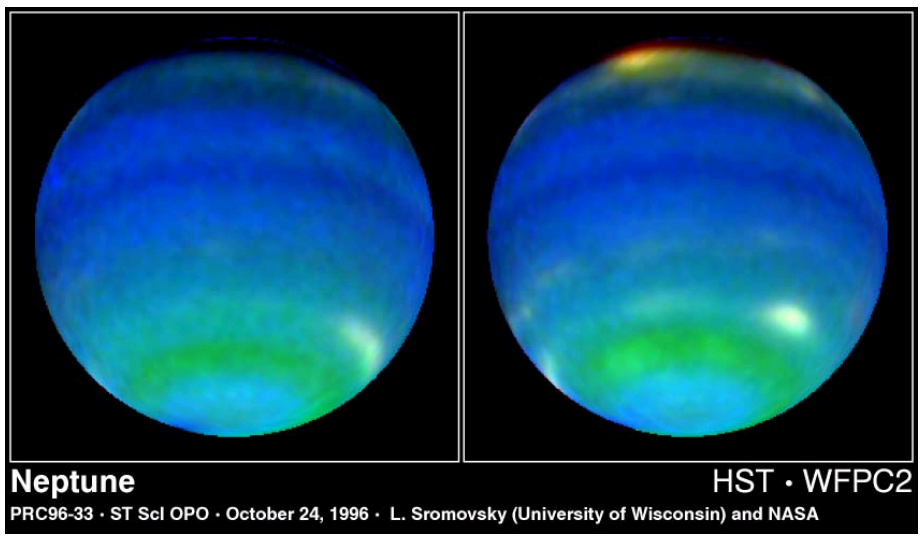
Uranus



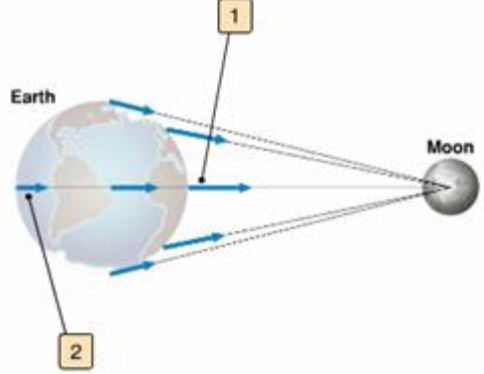
- Composed of gases with more methane and ammonia, much in the form of "ice"
- Axis of rotation is tipped over
  - tilted at 98°
  - possibly caused by collision with another large body
  - makes for a strange "day"
- At least 21 moons & a ring system
- Twice as far from the Sun as Saturn

Neptune

- Similar in composition as Uranus
- At least 8 moons and a ring system
- Discovered by its effect on the motion of Uranus

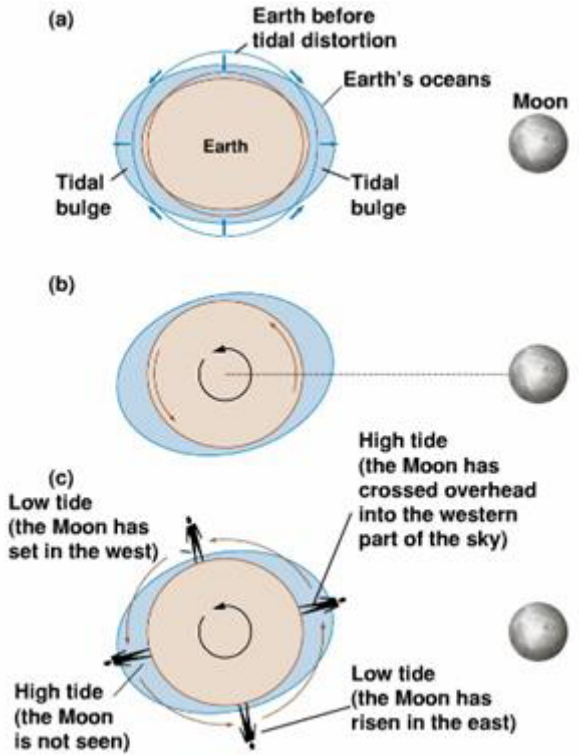


Pull of Gravity



- For large bodies which are close together, the pull of gravity will be different on different pieces of the objects
  - one side of the object is closer than the other
  - remember, the force of gravity depends upon the distance between the objects
- The force of gravity is larger on the side closer to the other object
- This can cause the object to stretch

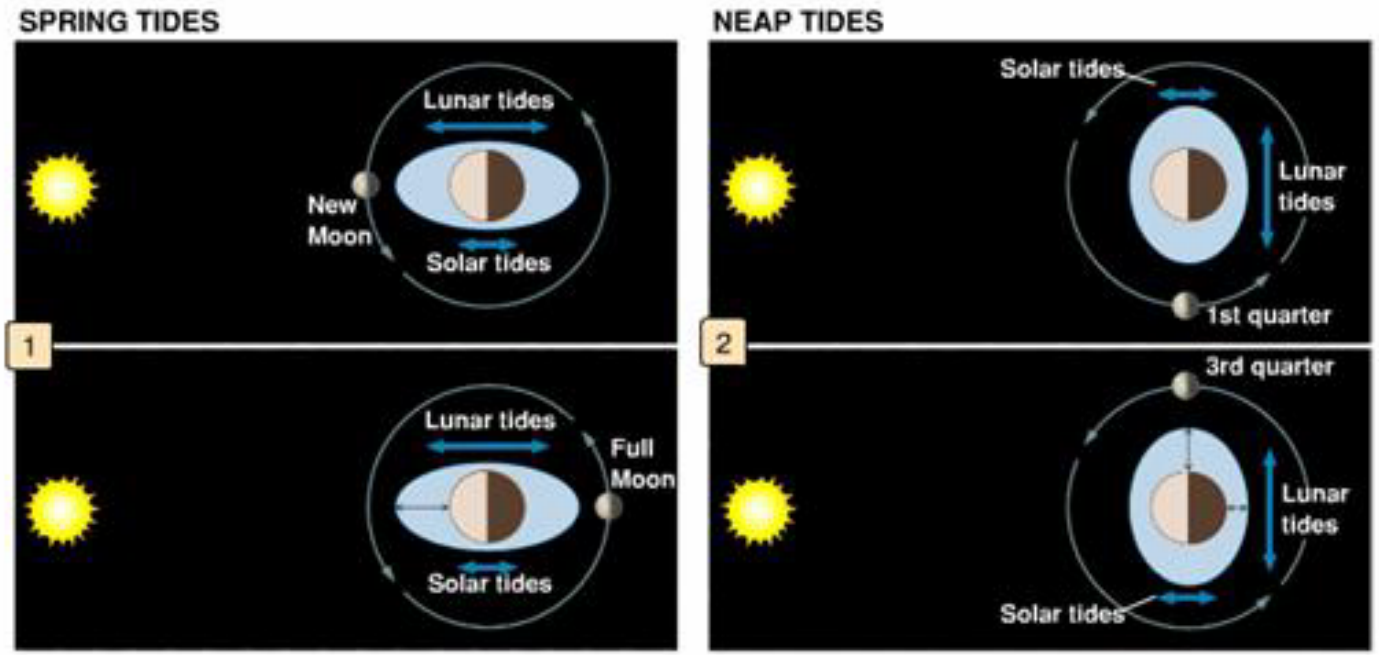
Tidal Forces



- The Moon pulls on the Earth unevenly
- This causes a flattening
- Water is more pliable than rock
  - ocean tides rise by ~1 meter
  - ground tides rise by ~30 cm
- Tides
  - high tide when Moon is above or below you
  - low tide when the Moon is off to the side
  - tides slightly lag behind Moon position

Solar and Lunar Tides

- Sun exerts tidal forces about half that of the Moon
  - sometimes they work together, other times in opposition

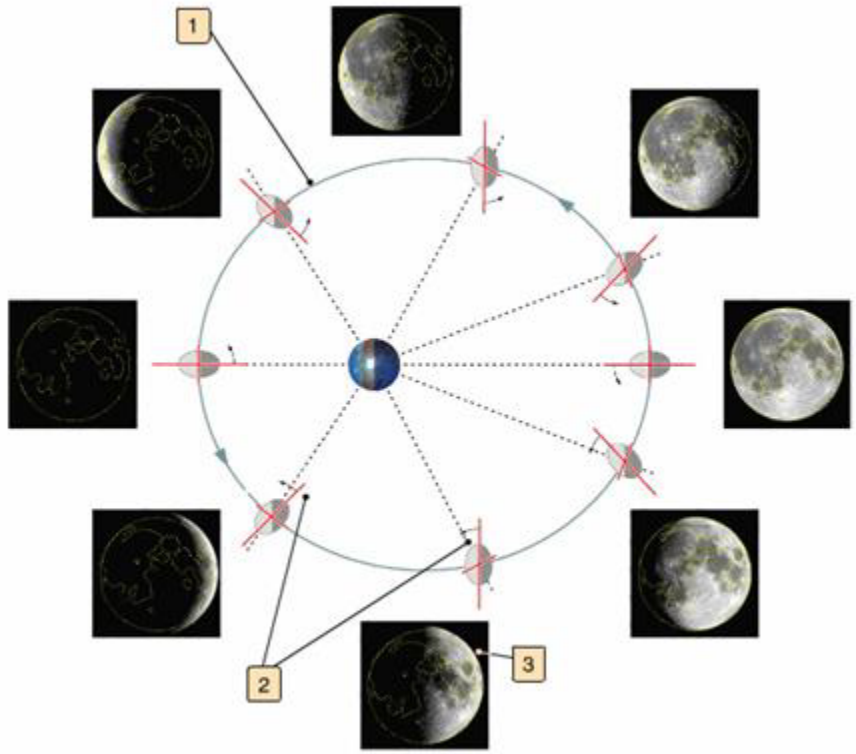


Tidal Locking

- These tidal forces slow the rotation of the bodies
  - the constant stretching causes energy loss in the form of heat
  - once the smaller body slows sufficiently, it spins at the same rate it revolves
    - no more changing tidal stretching
  - creates a tidal "bulge" facing the other body
- The objects can become locked such that the same sides always face each other
- Has happened to the Moon, would eventually happen to the Earth (50 billion years)

Tidal Rocking

- Because the Moon's orbit is elliptical, the tidal forces are uneven
- The Moon rocks back and forth slightly changing the face that we see



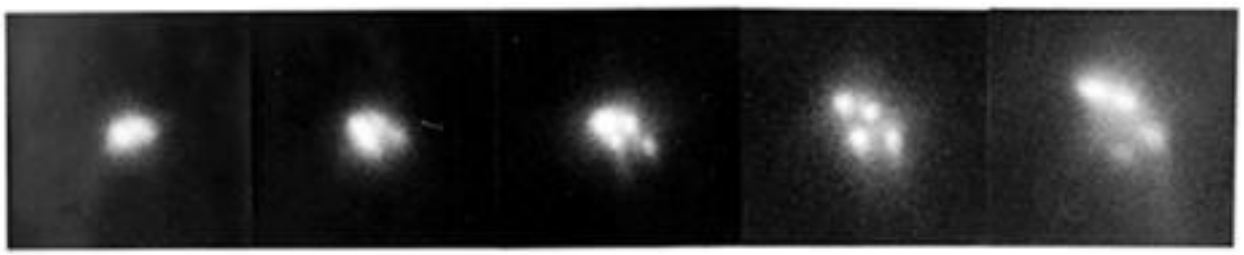
- It also changes its apparent size because of the varying distance

Spin-Orbit Resonance

- If an object has a spin and orbit which are integer (1,2,3,…) multiples of each other then it is in a "resonance"
  - it will want to stay that way
- Mercury is in a 3-2 resonance
  - it rotates 3 times for every 2 orbits
- The Moon is in a 1-1 resonance
  - it rotates once per orbit

Tidal Stresses

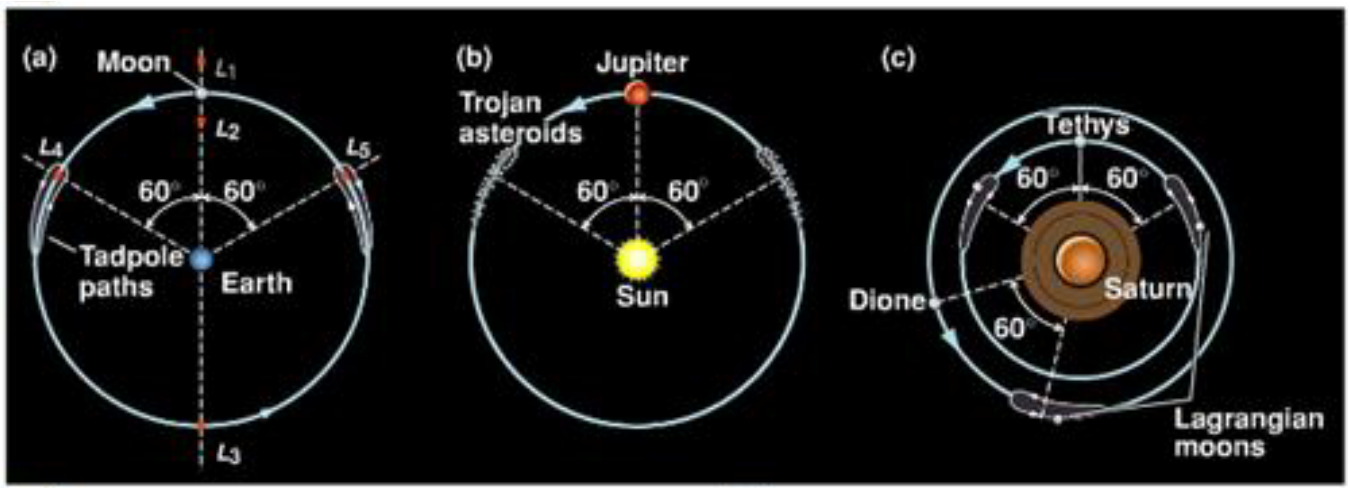
- Changing tidal stresses can cause other effects
- If stress is large enough, it can break apart an object
  - Roche limit – point at which tidal forces become stronger than self-gravity (object breaks apart)



- It generates internal heat
- Can make object volcanically active
  - Io – moon of Jupiter

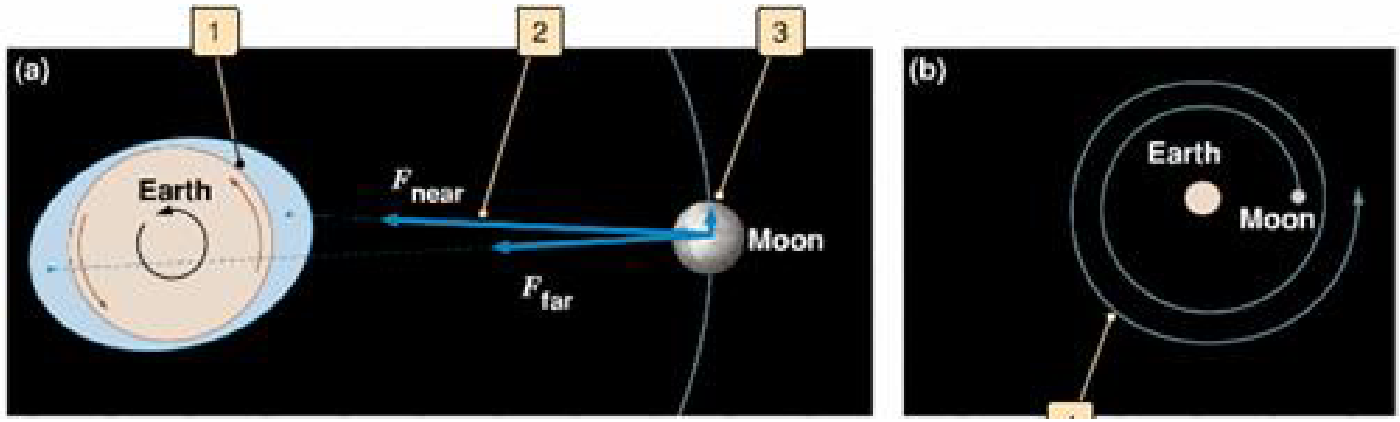
Lagrangian Points

- Two orbiting bodies can have balanced points
  - a third object at one of these points will orbit in lockstepped position with the first two
  - known as Lagrangian points
  - good places to put satellites or a space station



Acceleration of the Moon

- The Earth's tidal bulge pulls the Moon forward



- This causes the Moon to accelerate in its orbit
  - As it accelerates, it moves into a higher orbit
- The Moon is moving away from the Earth at a rate of 3.8 cm/year