The Giant Planets

- Beyond Mars and the asteroids are the giant or Jovian planets
  - Jupiter, Saturn, Uranus, Neptune
  - Pluto is part of the outer solar system but will be considered with the moons of the Jovian planets
- These planets are dramatically different from the terrestrial planets
- The Jovian planets formed much farther from Sun in a much cooler environment
  - Volatile materials remained frozen
  - Planets retained significantly more solid material
  - Larger mass allowed these planets to retain the primordial hydrogen and helium
  - Chemistry became reducing rather than oxydyzing
    - Many compounds of hydrogen

Exploration of the Outer Solar System

- Six spacecraft have explored the solar system past the asteroid belt
- Challenges of these flights are many
  - Distances are huge, flight times are years
  - Communication is difficult, light hours away
    - Spacecraft must be able to carry out instructions and handle problems independently
    - Require large antennae and powerful transmitters
  - Solar power is insufficient
    - Nuclear power
- The first spacecraft to the outer solar system were Pioneers 10 and 11, launched in 1972 and 1973
  - Missions were to see if the asteroid belt could be safely navigated and if spacecraft could survive the radiation in the magnetosphere of Jupiter

Current Positions of the Jovian Planets

- Oct. 5, 2001

Voyager Missions

- Voyager 1 reached Jupiter in 1979 and went on to Saturn in 1980
- Voyager 2 reached Jupiter four months later
  - Reached Saturn in 1981
  - Reached Uranus in 1986
  - Reached Neptune in 1989
- The Voyager missions took advantage of the alignment of the outer planets
  - Used gravity slings to direct Voyager to the next planet
  - Happens once every 175 years
- Movie shows the positions of the planets once a year from 1977 to 1990
The Galileo Spacecraft

- The Galileo spacecraft arrived at Jupiter in December, 1995
  - On December 7, 1995, Galileo released a probe that descended into the Jovian atmosphere
    - Probe survived for 57 minutes and reached a depth of 200 km and was blown 500 km by Jupiter’s winds
    - Two hours later Galileo fired its retro rockets and entered orbit around Jupiter
  - Galileo had encounters with several of Jupiter’s moons (more later)

The Cassini Spacecraft

- The Cassini mission is a collaboration of NASA, European Space Agency, Italian Space Agency
- Cassini will study Saturn and its moons
- Cassini was launched October 15, 1997
- Cassini will arrive at Saturn in 2004 and will deploy the probe Huygens on the moon Titan

Basic Characteristics

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance (AU)</th>
<th>Period (y)</th>
<th>Diameter (km)</th>
<th>Mass (Earth=1)</th>
<th>Density (g/cm³)</th>
<th>Rotation (h)</th>
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</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>5.2</td>
<td>11.9</td>
<td>142,800</td>
<td>318</td>
<td>1.3</td>
<td>9.9</td>
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<tr>
<td>Saturn</td>
<td>9.5</td>
<td>29.5</td>
<td>120,540</td>
<td>95</td>
<td>0.7</td>
<td>10.7</td>
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<tr>
<td>Uranus</td>
<td>19.2</td>
<td>84.1</td>
<td>51,200</td>
<td>14</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Neptune</td>
<td>30.1</td>
<td>164.8</td>
<td>49,500</td>
<td>17</td>
<td>1.6</td>
<td>16.1</td>
</tr>
</tbody>
</table>

Appearance

- When we look at the giant planets we see only their atmospheres that are composed mainly of hydrogen and helium
  - Jupiter and Saturn have an upper cloud deck of ammonia crystal (N₂H₄)
  - Neptune has an upper cloud deck of methane (CH₄)
  - Uranus seems to be deep and featureless
- Jupiter is colorful and dynamic
  - The atmosphere has permanent features
    - Bands
    - Great Red Spot
**Rotation**

- The rotation of each of the giant planets is determined using its magnetic field
  - At 9 h 56 m Jupiter has the shortest rotation time of any planet
  - The other giant planets have similar rotation times
- The tilt of the rotation axis from being perpendicular to the orbit plane causes seasons
  - Jupiter at 3 degrees has no seasons
  - Saturn and Neptune have tilts around 28 degrees
    - Similar to the terrestrial planets but more slowly
  - Uranus is bizarre with a 98 degree tilt!

**The Bizarre Season of Uranus**

- The axis of rotation of Uranus is almost in the plane of the orbit of Uranus around the Sun
- Causes bizarre seasons

**Composition and Structure**

- The giant planets all have similar structures
  - Small rocky core (iron, silicon, oxygen)
  - Layer of ice (compounds of carbon, nitrogen, oxygen with hydrogen)
  - Layer of metallic hydrogen
  - Layer of molecular hydrogen
- For Jupiter and Saturn, only a few percent of their mass is in the core
- For Uranus and Neptune, most of their mass resides in the core

**Internal Heat Sources**

- The giant planets were strongly heated when they were formed
- Jupiter has the largest internal heat source resulting from the primordial formation of the planet
  - Emits as much heat as it receives from the Sun
- Saturn has half the internal heat of Jupiter but one quarter the mass
  - Saturn generates heat by having drops of liquid helium sink toward the core releasing gravitational energy
- Uranus has no internal heat
- Neptune has a small amount of internal heat
  - Neptune has about the same temperature at Uranus although it is farther from the Sun
Magnetic Fields

- Each of the giant planets has a strong magnetic field created by electric currents in its rapidly spinning interior
- These magnetic fields generate magnetospheres
  - Regions where the planetary magnetic field dominates the interplanetary magnetic field
- High speed electrons caught in these magnetospheres emit synchrotron radiation and emit radio waves

Atmospheres of the Jovian Planets

- Hydrogen and helium dominate the atmospheres of the Jovian planets
  - Saturn has less helium because of the precipitation of helium that contributes to Saturn’s internal energy
- The visible layer of Jupiter and Saturn consists of ammonia
- The visible layer of Uranus is methane
  - Featureless
- Neptune has a layer of condensed methane and clear gases above
  - Gives a blue color similar to Earth
- One puzzle is the colors of Jupiter and Saturn
  - Should be white
  - Photochemistry

Winds and Weather

- The thick atmospheres of the Jovian planets are fundamentally different from the terrestrial planets
  - The Jovian planets spin faster
  - There is no solid surface to impede motion of the atmosphere
  - Except for Uranus, internal heat causes convection currents
  - Features tend to coalesce into bands
    - Bands can move with different speeds
- On Uranus, the seasonal changes are small

Storms

- Superimposed on the regular atmospheric motion are many storms
  - Great Red Spot of Jupiter
    - Seems to be permanent high pressure area
    - Other large features have been observed to change and coalesce
  - Neptune’s Great Dark Spot
    - Has been observed to fade and reappear