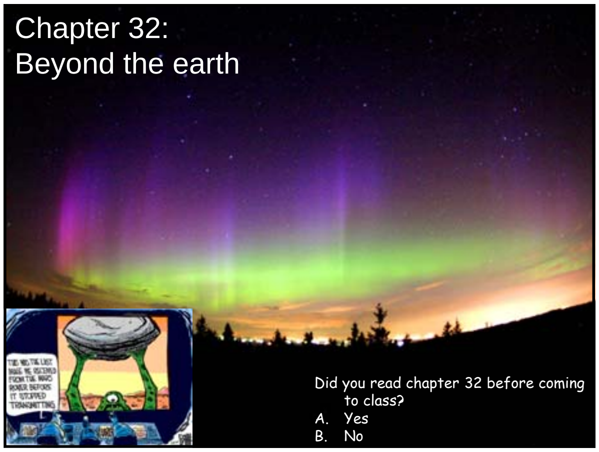


Chapter 32:
Beyond the earth

Did you read chapter 32 before coming to class?

A. Yes
B. No

Announcement

- Evaluations Pilot
- New form: http://ctlsrpilot.byu.edu/
- Once you go to this site, click on "Submit your ratings." You may be asked to log in using your BYU Net ID and password.
- Current form: http://studentratings.byu.edu/

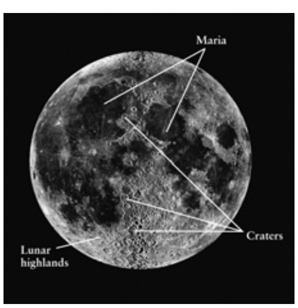
The Solar System

- Sun, planets, moons, comets, asteroids, meteoroids.
  - Sun at the center.
  - Eight planets, thousands of asteroids, and millions of comets and meteoroids orbit the sun.
  - Dozens of moons orbit the planets.

We began our study of the history of the solar system by studying the history of the earth.

The Moon hasn't had erosion and plate tectonics erase its history, so it is a good place to start

- Three types of terrain:
  - Maria
  - Highlands
  - Craters

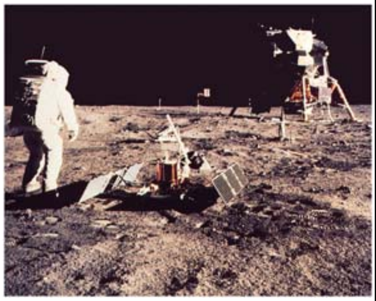


Lunar Highlands

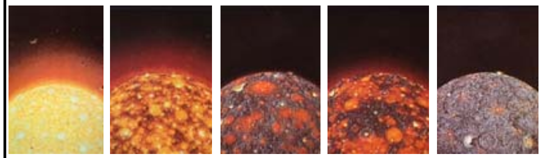
- Old, original surface
- Heavily cratered.
- Made of lighter, aluminum-rich minerals.

Maria

- Younger terrain
- Lava flows -- ancient impacts?
- Made of heavier mare basalt

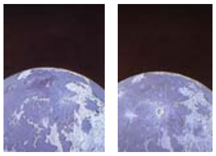


Formation of the moon



- The moon absorbed the kinetic energy of objects as the struck its surface (as well as the mass)
- Eventually it cooled off, but the cratering still continued.

Formation of the Maria



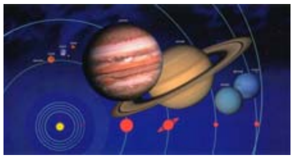
- Large impacts may have added enough energy to melt the crust and re-solidify
- Later, molten rock, perhaps reheated by radioactive decay, pushed its way through the thin crust and covered the large shallow basins.
- Some impact craters are visible on the Maria, but the rate has dramatically decreased.

How about the rest of the solar system? Some stats on the Sun

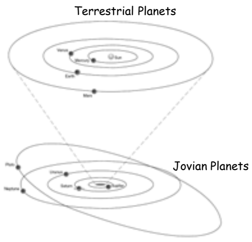
- Time for light to reach Earth
  - 8.32 minutes
- Mass ~ 2×10^{30} kg
  - ~ 333,000 more massive than the Earth
- Composition by number of atoms
  - 92.1% Hydrogen
  - 7.8% Helium
  - 0.1% everything else
- Surface temp ~ 5800 K
- Interior temp ~ 15,500,000 K
- The Sun contains more than 99.85% of the total mass of the solar system
- If you put *all* the planets in the solar system together, they would not fill up the volume of the Sun
- 110 Earths or 10 Jupiters fit across the diameter of the Sun

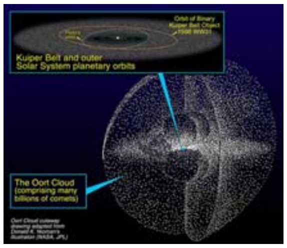
Patterns in the Planets

- The inner four planets, Mercury, Venus, Earth, and Mars are small, rocky, with hard surfaces. These are called *Terrestrial.*
- The outer four planets, Jupiter, Saturn, Uranus, and Neptune are large, gas spheres. These are called *Jovian.*
- Icy, Kuiper Belt objects at large distances (such as Pluto) fit neither category and are essentially dirty snowballs

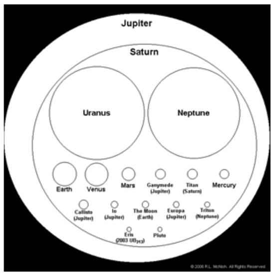


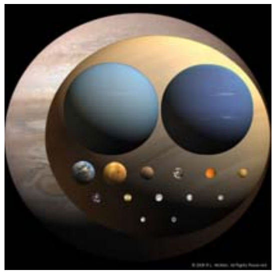
Orbital positions of the planets





Relative Sizes





Mercury

- moon-like
- rocky
- small
- very hot on sun side
- slow rotation
- Mariner 10; Messenger

Venus

- earth-like in size, density
- Rocky
- Structures
  - Faults
  - No Plate Tectonic System
- No Hydrologic System
- No Magnetic Field
- retrograde rotation
- very dense atmosphere
- Strong greenhouse effect; very hot surface
- perpetual clouds
- surface visited by Soviet probes
- surface mapped by radar (Magellan)
- ESA's Venus Express orbit insertion 11 April 2006

Mars Hydrologic & Atmospheric Systems

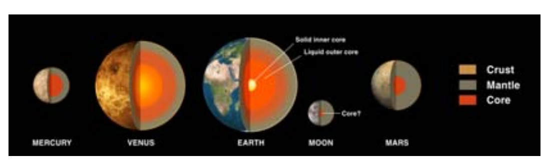
- Polar Ice Caps
  - H_2O and CO_2
  - Substantial seasonal changes in size
- Dust Storms
  - May cover the entire planet at times
- Thin Atmosphere
  - Mostly CO_2
- Evidence for periods with liquid water
  - Layered sedimentary rocks
  - "Blueberries" – concretions
  - Old river channels

Terrestrial Planets

- Atmospheres slightly different compositions
  - CO_2, N_2, O_2, or none
- Variable sizes for the cores of these planets
  - Varying densities

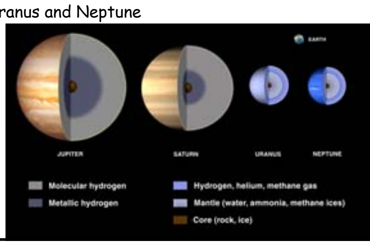
Terrestrial planets are extremely dense

- Each planet has solid core.
- Earth and perhaps Venus still have a liquid core surrounding the inner core



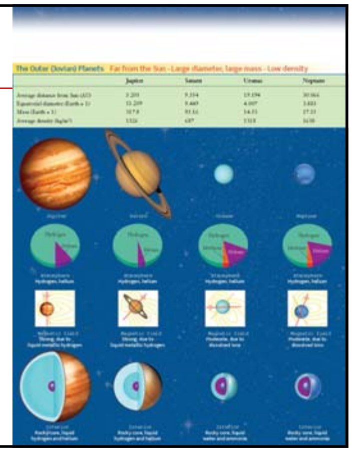
Jovian planets have extremely low densities

- Possible solid core
- Molecular and metallic hydrogen shells
  - Jupiter and Saturn
- Mantles of water and ice
  - Uranus and Neptune

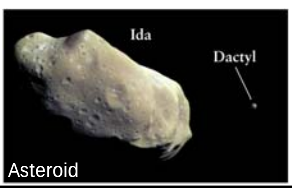


Jovian Planets

- Atmospheres consist mostly of hydrogen and helium
  - Uranus and Neptune have a little methane as well – blue color
- Varying tilts and magnetic fields
- Different cores



Smaller bodies in the solar system

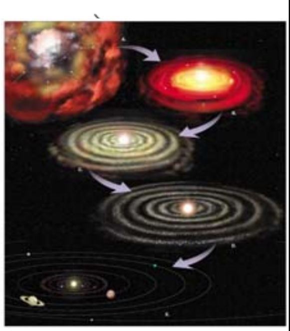


Formation of the Solar System

- Any model to explain how the solar system formed must address the following points
  1. Sun contains 99.85% of all the matter – mostly hydrogen and helium
  2. Terrestrial planets composed primarily of rocks and metals – very little hydrogen or helium - extremely small in size
  3. Jovian planets composed primarily of hydrogen and helium – very little rock and ice – giant in size
  4. All the planets orbit the Sun in the same direction
  5. All the planets orbit in nearly the same plane
  6. The smaller terrestrial planets orbit closer to the Sun then the giant Jovian planets

How did the solar system form?

- Nebular Hypothesis
  - Condensing cloud of hydrogen, helium, iron, etc.
  - As cloud collapsed into protostar the rate of rotation increased and some of the gas formed a disk (like pizza dough)
  - Most of the mass collapsed in the center to form the sun
  - Density variations in outer part of disk caused some of the mass to collect into planetesimals (many miles in diameter)
  - Protoplanets swept up most of the nearby debris. There were occasional "catastrophes" when large planetesimals collided with protoplanets.
- How long ago? ~4.6 billion years



Evidence for the Nebular Hypothesis

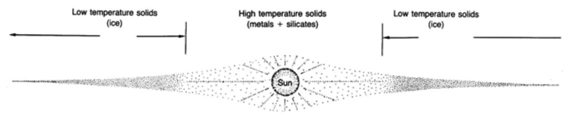
- Densest planets are nearest the sun
- Planets revolve in almost the same plane
- Most planets rotate in the same direction as they revolve (Venus and Uranus are exceptions)
- Craters exist on most planets and moons.
- Radioactive dates of earth, moon, and meteorite rocks are consistent.
- The earth still collects tons of meteoric material each day.
- We observe other solar systems in the process of formation, and their behavior seems to be consistent with this process.

In a newly-formed planetary system, where will the temperatures be highest on average?

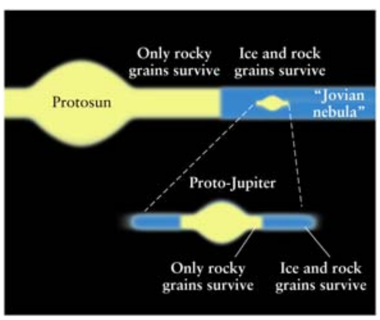
a) Near the central star
b) At intermediate distances from the star
c) At large distances from the star

Temperature & Density Determine what Kind of Planets Form

- Near the star
  - Temperatures are high
  - Light elements like hydrogen are driven off by radiation
  - Leftover, heavier elements form dense, terrestrial type planets
- At intermediate distances
  - Temperatures lower
  - Lots of gas (mostly H, He)
  - This condenses to form gas giants
- At large distances
  - Lowest temperatures & least amount of material in largest space
  - Small amounts of cold material condense to form icy objects
  - It is believed that a large belt of these objects exist, but they are difficult to observe.

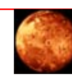


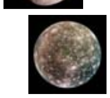
Jupiter and Saturn are "mini-solar systems"



Jupiter's Galilean Moons

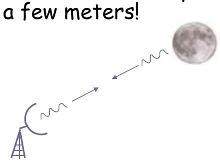
- Io
  - Volcanically active
  - High density (3.5 g/cm^3)
  - No craters
- Europa
  - Ice surface may overlie liquid water ocean
  - High density (3.0 g/cm^3)
  - No large craters, only small ones
  - Many cracks and fissures in ice surface
- Ganymede
  - Larger than Mercury
  - Lower density (1.9 g/cm^3)
  - Younger surface is cracked and healed ice
  - Old cratered terrain
- Callisto
  - Lower density (1.8 g/cm^3)
  - Old highly cratered ice surface



Finding Distances Precisely

- Within the Solar System we can often use Radar Ranging.
  - Radiation from radar travel at the speed of light
  - Measure time from transmission to detection
  - Distance = (speed of light) x (time delay) ÷ 2
- Using communication with space probes we have found distances to all planets but Pluto to within a few meters!

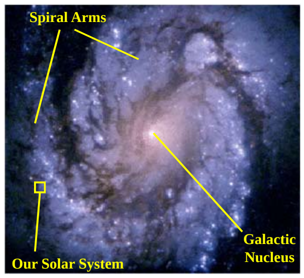


Laser Ranging to the Moon

- Laser ranging allows us to measure the distance to the moon to extreme precision. However, it is not a practical method for places we haven't visited.

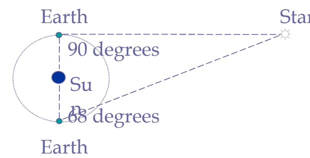

Beyond our solar system: The milky way (our galaxy)

- ~400 billion stars
- All objects visible at night with naked eye are in our own galaxy
- Diameter = 100,000 light years
- Closest Neighbor is 1,000,000 million light years



Triangulation

- Used to find distances to nearest stars.
  - Same techniques used in land surveys
- For astronomy, it builds upon the fact that we know the orbital radius of the earth very precisely.



Triangulation

- Can be used to find distances to the nearest ~10,000 stars.
- All methods of finding greater distances build on this!