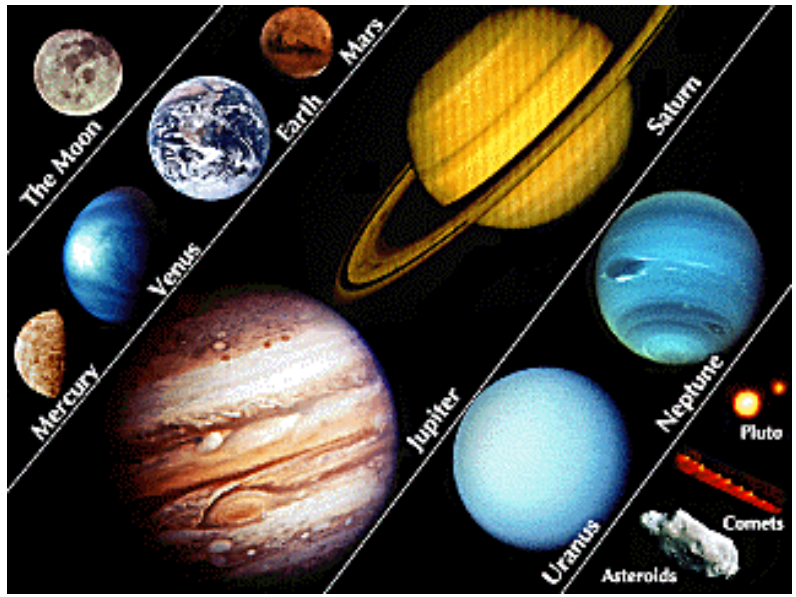
Introduction to the Solar System

Sep. 11, 2002

1) Introduction
2) Angular Momentum
3) Formation of the Solar System
4) *Cowboy Astronomer*



Review

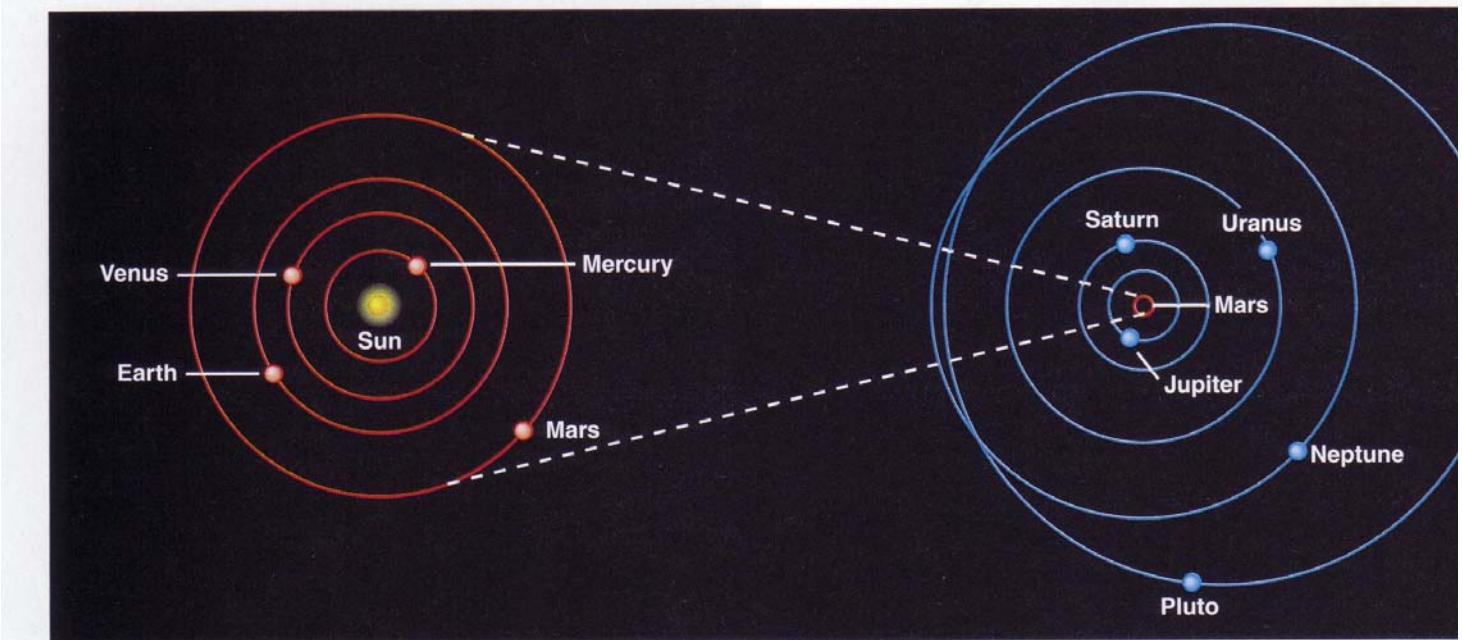
- Kepler's Laws
  - empirical description of planetary motion
- Newton's Laws
  - describe how objects behave
  - An object at rest will stay at rest, an object in motion will stay in motion
  - An unbalanced force will change an object's motion
  - For every action, there is an equal and opposite reaction
- Gravity
  - attraction of objects with mass
  - responsible for planet's and moon's orbits

The Pieces of the Solar System

- The Sun
- The Inner Planets
  - Mercury, Venus, Earth, Mars
- The Outer Planets
  - Jupiter, Saturn, Uranus, Neptune, Pluto
- Also,
  - moons
  - asteroids
  - rings
  - comets

Pieces of the Solar System (cont)

- All planets rotate around the Sun the same direction
- They mostly lie in a single plane
  - Mercury and Pluto are somewhat tilted



Inner Planets

- The inner planets all have solid surfaces and heavy inner core
- Mercury

  - small, closest to the Sun, very hot and very cold
- Venus

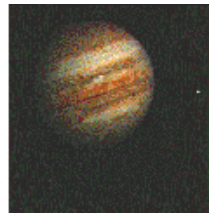
  - almost Earth-size, very dense atmosphere, very hot
- Earth

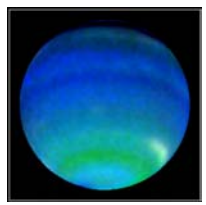
- Mars

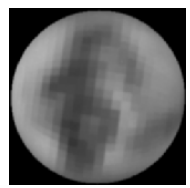
  - smaller than Earth, thin atmosphere, cold, two moons

Outer Planets

- Mostly gas – hydrogen and helium
- Jupiter
  - largest planet, 300 times mass of Earth, 1400 times its size, 28 moons and rings, several active moons
- Saturn
  - 100 times Earth's mass, 30 moons rings
- Uranus
  - larger than Earth, includes methane, axis is tipped over
- Neptune
  - larger than Earth, like Uranus
- Pluto
  - smallest, farthest planet, least known







Angular Momentum

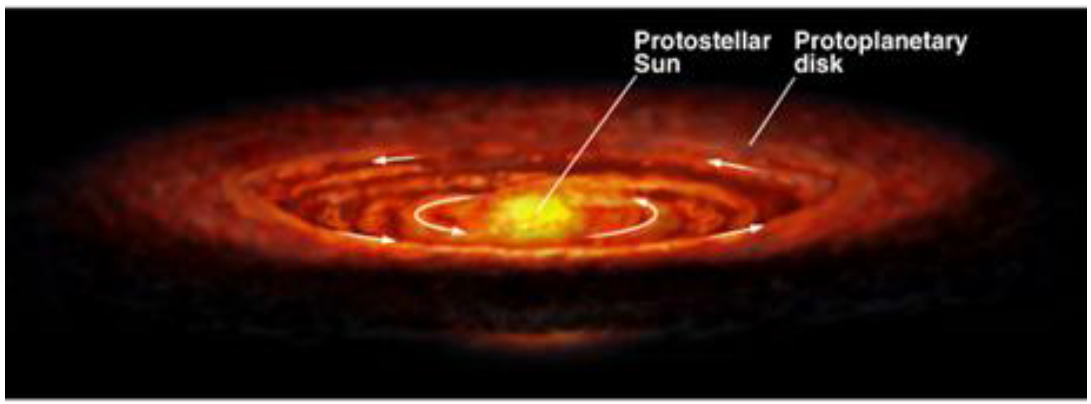
- A measure of how something is rotating
- Depends upon
  - speed of rotation
    - faster rotation means more angular momentum
  - amount of mass
    - more mass means more angular momentum
  - distribution of mass
    - mass farther from axis of rotation means more angular momentum

Conservation of Angular Momentum

- Angular momentum is conserved
- If no forces act upon it, then an object's angular momentum stays the same
  - just like Newton's First Law
  - "An object at rest stays at rest, an object spinning remains spinning"
- Example: spinning ice skater
  - when the skater has her arms extended, she is spinning slowly
  - when she pulls her arms in, she starts spinning much faster

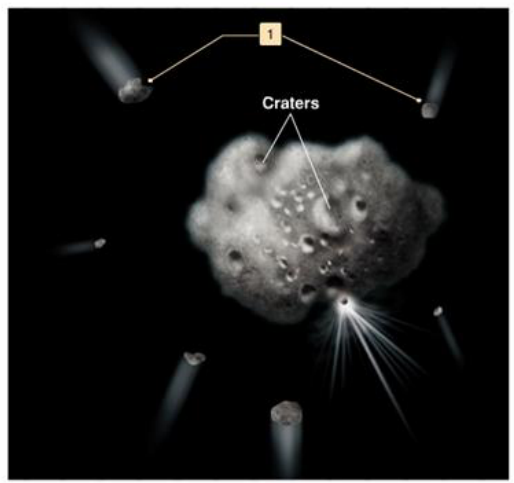
In the Early Days

- Our Solar System began as a rotating ball of gas and dust
- Gravity caused the ball to collapse into a rotating disk
  - at the center was a protostar (the beginnings of the Sun)
  - angular momentum kept it from all collapsing inward
  - called an accretion disk



Dust Got Bigger

- Slow moving particles collided and stuck together
- Eventually they got big enough
  - became planetesimals
  - about 1 kilometer diameter
  - their gravity started to attract more particles



Hot Inside, Cool on the Outside

- As the disk flattens, it gets hotter
  - collisions of gas and dust generates heat
- The inner region gets hotter than outer region
  - more mass, more collisions
  - inner region moving faster
- Two types of materials
  - refractory – can withstand higer temperatures
    - metals, rocks, etc
  - volatile – less refractory, will melt or evaporate
    - water, ice, ammonia, methane, etc
- Volatile materials don't survive in the inner region, but do in the outer region

Planetesimals Become Planets

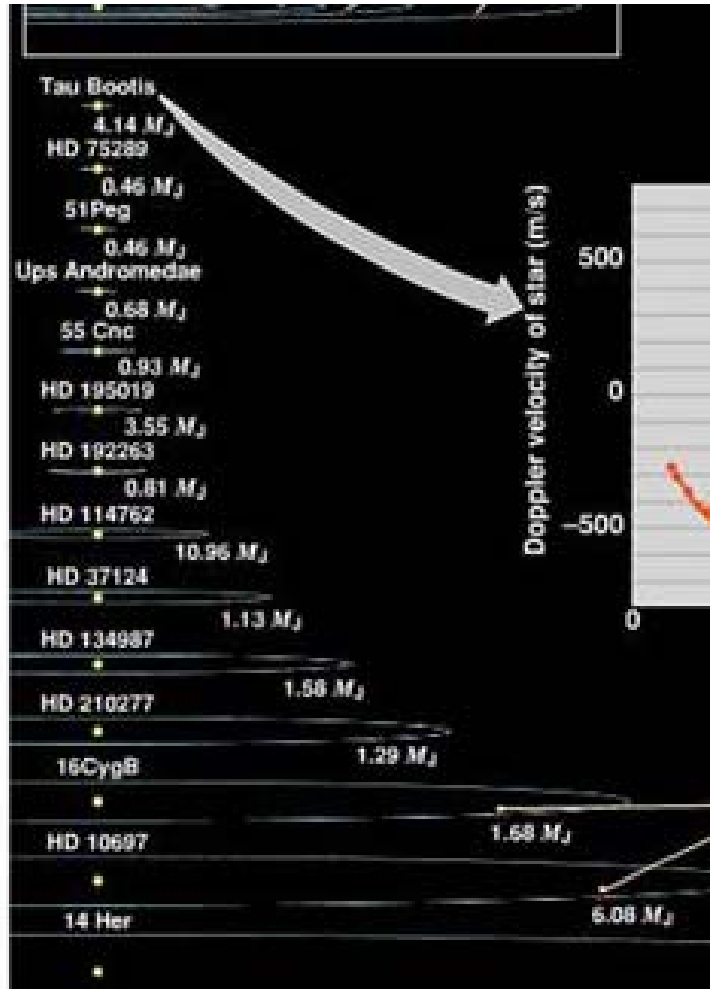
- As planetesimals gather material through gravity and collisions, they form mini-accretion disks
- Eventually they become planets
- Planets near the protostar are primarily composed of refractory materials
- Planets farther out are composed of refractory AND volatile materials
  - Gas giants made mostly of gas and ice

The Sun Turns ON

- When the Sun achieved sufficient mass, it began the critical fusion reactions which provide its light output
- It also provides for a strong solar wind
  - streams of particles flowing outward from the Sun
- The solar wind swept away the interplanetary gas and dust
  - also removed the original atmospheres from the inner planets
- Secondary atmospheres develop from gases released from the planet's interior

Nothing Special

- Our solar system is not unique
- There are lots of other stars out there
  - just glance at the night sky
  - we have observed gas planets around some of them
- Some of these stars should have Earth-like planets around them
- Does that means there may be life out there?



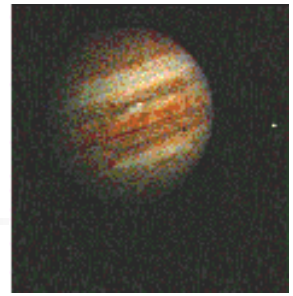
How Do We Know This?

- We were not here when the Solar System was formed and we can't watch another system form
  - so how do we know any of this?
- We have observed other systems with large planets
- We have observed protostars with accretion disks
- We use Newton's laws, solar formation models and computer simulations to see if they can describe the end result: our Solar System
- Our model is incomplete and we have a lot to learn, but it does explain a great deal

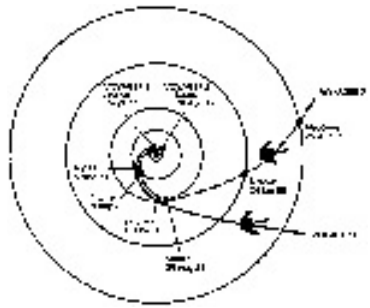
NASA Solar System Missions

- Flyby missions - satellite to pass by another object
  - quick look, but cheap
  - examples: Voyager, Mariner, Pioneer, …
- Orbiters - satellite in orbit around a planet or moon
  - more detailed studies, but not "hands-on"
  - examples: Galileo, Clementine, Magellan, …
- Landers - lander on the surface of a planet or moon
  - get rock samples and direct data, limited area can be covered
  - examples: Viking, Mars Surveyor, Mars Odyssey, …
- Manned missions - humans on the surface of a planet or moon
  - can do advanced, complicated studies/experiments, but very expensive
  - examples: Apollo 11 through Apollo 17

The Grand Tour - Voyager



- During the mid-1970's NASA sent two satellites to visit the gas giants, Jupiter and Saturn
  - The planets were aligned in such a way to make it easy
  - Voyager 1 and 2 were launched and did flybys of Jupiter
  - This was followed by flybys of Saturn
  - Voyager 2 also then went by Uranus and Neptune
- These missions were some of the most successful scientific endeavors ever
- They both continue outward towards the edge of the Solar System



The Mass of the Solar System

- By mass, the solar system is almost all Sun
- We are a very small part

Object	Percentage of Total Mass
Sun	99.80
Jupiter	0.10
Comets	0.05
All other planets	0.04
Satellites and rings	0.00005
Asteroids	0.000002
Dust	0.0000001