Lecture 7 Formation of the Solar System

Reading: Chapter 9 •*Quiz#2 Today*: Lecture 60 minutes, then quiz 20 minutes.

•Homework#1 will be returned on Thursday.

Origin of the Solar System

Nebular Theory

Our Solar System formed from a giant, swirling cloud of gas & dust.

Depends on two principles of Physics:

- •Newton's Law of Gravity gravitaional potential energy \Rightarrow heat
- •*Conservation of angular momentum* rotational motion is conserved

Origin of the Solar System

Our theory must explain the data

- 1. Large bodies in the Solar System have orderly motions.
- 2. There are two types of planets.
 - small, rocky terrestrial planets
 - large, hydrogen-rich Jovian planets
- 3. Asteroids & comets exist in certain regions of the Solar System
- 4. There are exceptions to these patterns.

The Solar Nebula

- The nebular theory holds that our Solar System formed out of a nebula which collapsed under its own gravity.
- observational evidence
 - We observe stars in the process of forming today.
 - The are always found within interstellar clouds of gas.



newly born stars in the Orion Nebula

Solar Nebula

The cloud of gas from which our own Solar System formed

Gravitational Collapse: A Scenario

- 1. The solar nebular was initially somewhat spherical and a few light years in diameter.
 - very cold
 - rotating slightly
- 2. It was given a "push" by some event.
 - perhaps the shock wave from a nearby supernova
- 3. As the nebula shrank, gravity increased, causing collapse.
- 4. As the nebula "falls" inward, gravitational potential energy is converted to heat.
 - Conservation of Energy
- 5. As the nebula's radius decreases, it rotates faster
 - Conservation of Angular Momentum

Angular Momentum

- **angular momentum** the momentum involved in spinning /circling = mass x velocity x radius
- **torque** anything that can cause a change in an object's angular momentum (*twisting force*)



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Conservation of Angular Momentum

• In the absence of a net torque, the total angular momentum of a system remains constant.



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Flattening of the Solar Nebula

- As the nebula collapses, clumps of gas collide & merge.
- Their random velocities average out into the nebula's direction of rotation. => Orderly motion
- The spinning nebula assumes the shape of a disk.



Collapse of the Solar Nebula

As the nebula collapses, it heats up, spins faster, and flattens.



More Support for the Nebular Theory

- We have observed disks around other stars.
- These could be new planetary systems in formation.



Orderly Motions in the Solar System

- The Sun formed in the very center of the nebula.
 - temperature & density were high enough for nuclear fusion reactions to begin
- The planets formed in the rest of the disk.
- This would explain the following:
 - all planets lie along one plane (in the disk)
 - all planets orbit in one direction (the spin direction of the disk)
 - the Sun rotates in the same direction
 - the planets would tend to rotate in this same direction
 - most moons orbit in this direction
 - most planetary orbits are near circular (collisions in the disk)

Building the Planets I: Condensation Condensation – elements & compounds began to condense (i.e. solidify) out of the nebula.... depending on temperature!



Building the Planets II: Frost Line

So only rocks & metals condensed within 3.5 AU of the Sun... the so-called *frost line*. Hydrogen compounds (ices) condensed beyond the frost line.



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Building the Planets IV: Planetesimals

Planetesimals then will:

- combine near the Sun to form rocky planets
- combine beyond the frostline to form icy planetesimals which...
- gravitationally capture H/He far from Sun to form gas planets



Building the Planets III: Accretion

Accretion -- small grains stick to one another via electromagnetic force (imagine "static electricity") until they are massive enough to attract via gravity

to form *planetesimals*.



Building the Planets V: Jovian planets and their moons

- Each gas (Jovian) planet formed its own "miniature" solar nebula. (gravitational heating and conservation of angular momentum.)
- Moons formed out of the disk.



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Building the Planets VI: Solar Wind!

Solar Wind --- charged particles streaming out from the Sun cleared away the leftover gas

