Our Solar System and Its Origin

How was the Solar System Formed?

A viable theory for the formation of the solar system must be

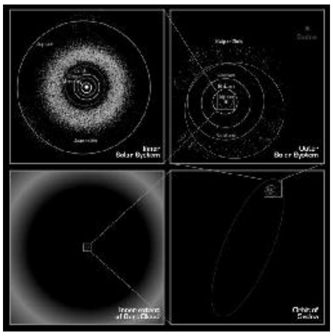
1. based on physical principles (conservation of energy, momentum, the law of gravity, the law of motions, etc.),
2. able to explain all (at least most) the observable facts with reasonable accuracy, and
3. able to explain other planetary systems.

How do we go about finding the answers?

1. **Observe:** looking for clues
2. **Guess:** come up with some explanations
3. **Test it:** see if our guess explains everything (or most of it)
4. **Try again:** if it doesn't quite work, go back to step 2.

What does the solar system look like from far away?

NASA Figure



- Sun, a star, at the center…
- Inner Planets (Mercury, Venus, Earth, Mars) ~ 1 AU
  - They are all rocky planets…
- Asteroid Belt, ~ 3 AU
- Outer Planets (Jupiter, Saturn, Neptune, Uranus), ~ 5-40 AU
  - They are all gaseous planets..
- Pluto: odd ball planet, more like a comet…
- Keiper Belt ~ 30 to 50 AU
- Oort Cloud ~ 50,000 AU
  - Where comets come from…

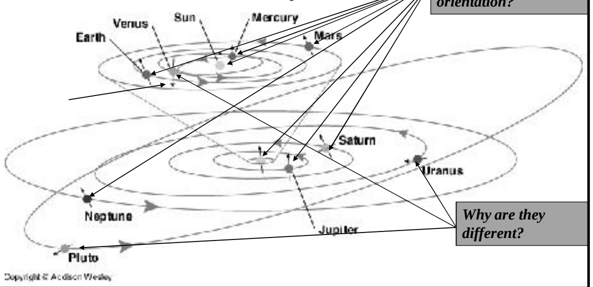
Cool link about solar system:

- http://liftoff.msfc.nasa.gov/academy/space/solarsystem/solarsystemjava.html

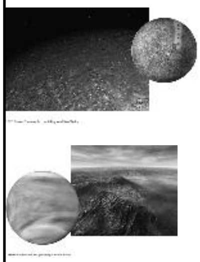
Clues - The Orbits of the Planets

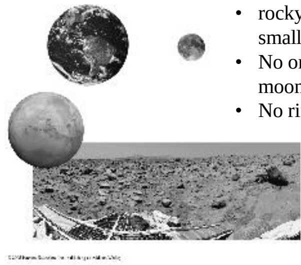
- All the planets orbit the Sun in the same direction
- The rotation axes of most of the planets and the Sun are roughly aligned with the rotation axes of their orbits.
- Orientation of Venus, Uranus, and Pluto's spin axes are not similar to that of the Sun and other planets.

Why do they spin in roughly the same orientation?



Summary - What do the inner planets look like?

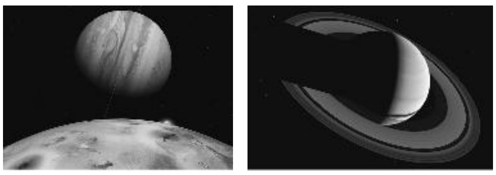




They are all…

- rocky and small!
- No or few moons
- No rings

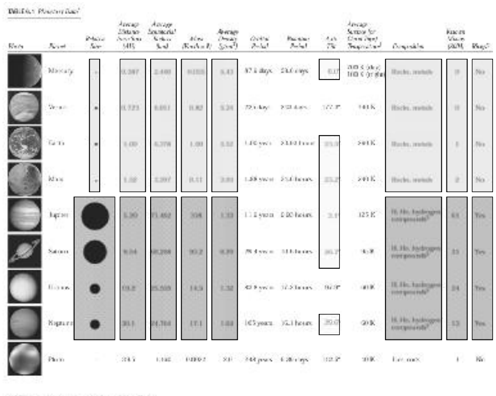
Summary - The Jovian Planets



They are all…

- gaseous and **BIG**!
- Rings
- Many moons

Quantitative Planetary Facts



Terrestrial and Jovian Planets

TABLE 6.2 *Comparison of Terrestrial and Jovian Planets*

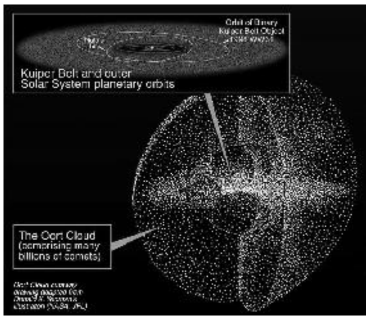
Terrestrial Planets	*Jovian Planets*
Smaller size and mass	Larger size and mass
Higher density	Lower density
Made mostly of rock and metal	Made mostly of hydrogen, helium, and hydrogen compounds
Solid surface	No solid surface
Few (if any) moons and no rings	Rings and many moons
Closer to the Sun (and closer together), with warmer surfaces	Farther from the Sun (and farther apart), with cool temperatures at cloud tops

Why?

The Kuiper Belt and the Oort Cloud

1. http://www.ifa.hawaii.edu/faculty/jewitt/KuiperBelt.htm
2. http://www.ifa.hawaii.edu/faculty/jewitt/oort.html

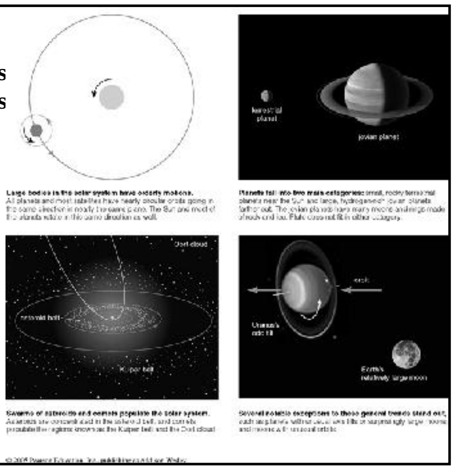
NASA Figure



Kuiper Belt
A large body of small objects orbiting (the short period comets) the Sun in a radial zone extending outward from the orbit of Neptune (30 AU) to about 50 AU. Pluto maybe the biggest of the Kuiper Belt object.

Oort Cloud
Long Period Comets (period > 200 years) seems to come mostly from a spherical region at about 50,000 AU from the Sun.

Common Characteristics and Exceptions of the Solar System



We need to be able to explain all these!

Common Characteristics and Exceptions

Table 7.3 Four Major Characteristics of the Solar System

Large bodies in the solar system have orderly motions. All planets and most satellites have nearly circular orbits going in the same direction in nearly the same plane. The Sun and most of the planets rotate in this same direction as well.

Planets fall into two main categories: small, rocky terrestrial planets near the Sun and large, hydrogen rich jovian planets farther out. The jovian planets have many moons and rings made of rock and ice.

Swarms of asteroids and comets populate the solar system. Asteroids are concentrated in the asteroid belt, and comets populate the regions known as the Kuiper belt and the Oort cloud.

Several notable exceptions to these general trends stand out, such as planets with unusual axis tilts or surprisingly large moons, and moons with unusual orbits.

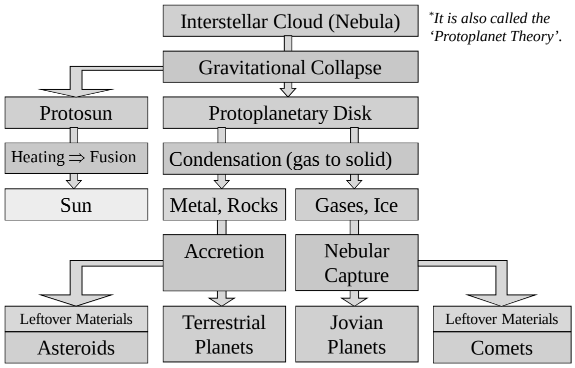
Planetary Nebula or Close Encounter?

Historically, two hypothesis were put forward to explain the formation of the solar system….

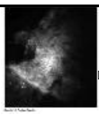
- *Gravitational Collapse of Planetary Nebula* (Latin for "cloud")
  Solar system formed form gravitational collapse of an interstellar cloud or gas
- *Close Encounter* (of the Sun *with another star*)
  Planets are formed from debris pulled out of the Sun during a close encounter with another star. But, it cannot account for
  - *The angular momentum distribution in the solar system,*
  - *Probability for such encounter is small in our neighborhood…*

The Nebular Theory* of Solar System Formation

It is also called the 'Protoplanet Theory'.



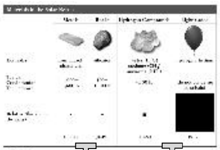
A Pictorial History

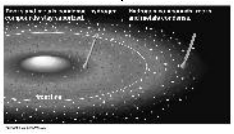


Interplanetary Cloud

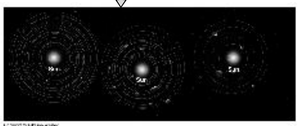
Gravitational Collapse

Condensation

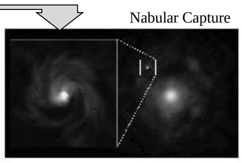




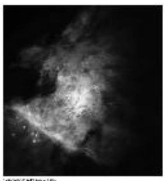
Accretion



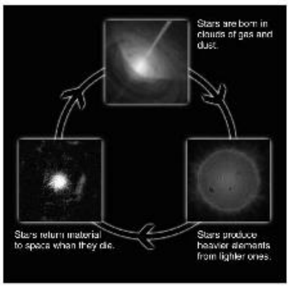
Nabular Capture



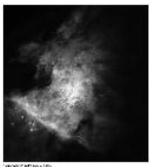
The Interstellar Clouds



- *The primordial gas after the Big Bang has very low heavy metal content (Chapter 17)…*
- *The interstellar clouds that the solar system was built from gas that has gone through several star-gas-star cycles. (Chapter 12)*



Collapse of the Solar Nebula



Gravitational Collapse

Denser region in a interstellar cloud, maybe compressed by shock waves from an exploding supernova, triggers the gravitational collapse.

1. **Heating** ⇒ Prototsun ⇒ Sun
   In-falling materials loses gravitational potential energy, which were converted into kinetic energy. The dense materials collides with each other, causing the gas to heat up. Once the temperature and density gets high enough for nuclear fusion to start, a star is born.
2. **Spinning** ⇒ Smoothing of the random motions
   Conservation of angular momentum causes the in-falling material to spin faster and faster as they get closer to the center of the collapsing cloud. ⇒ demonstration
3. **Flattening** ⇒ Protoplanetary disk. ***Check out the animation in the e-book!***
   The solar nebular flattened into a flat disk. Collision between clumps of material turns the random, chaotic motion into a orderly rotating disk.

This process explains the orderly motion of most of the solar system objects!