Planet Formation

10/30/2009

Opening Discussion

- http://www.youtube.com/watch?v=yOAl0enE7kI
- Have you seen anything interesting in the news?
- What did we talk about last class?
- http://www.nytimes.com/2009/10/29/science/space/
- http://en.wikipedia.org/wiki/Jupiter

Where We Left Off

- Protostar surrounded by a disk of material.
- The structure of the disk explains much of the orderly motions in our Solar System.
  - The orbits of the planets have to all go in the same direction as the Sun spins.
  - The rotations of the planets will tend to also go this direction as the greater amount of material on the outside has more angular momentum.
  - The giant planets should also have their own disks around them that form their moons.

Contents of the Disk

- The disk is mostly hydrogen and helium. About 98% by mass.
- The other 2% is a combination of metals, rocks, and hydrogen compounds.

	Metals	Rocks	H Compounds	H and He
Condensation Temp	1000-1600K	500-1300K	<150K	Never
Relative Abundance	0.20%	0.40%	1.40%	98.00%

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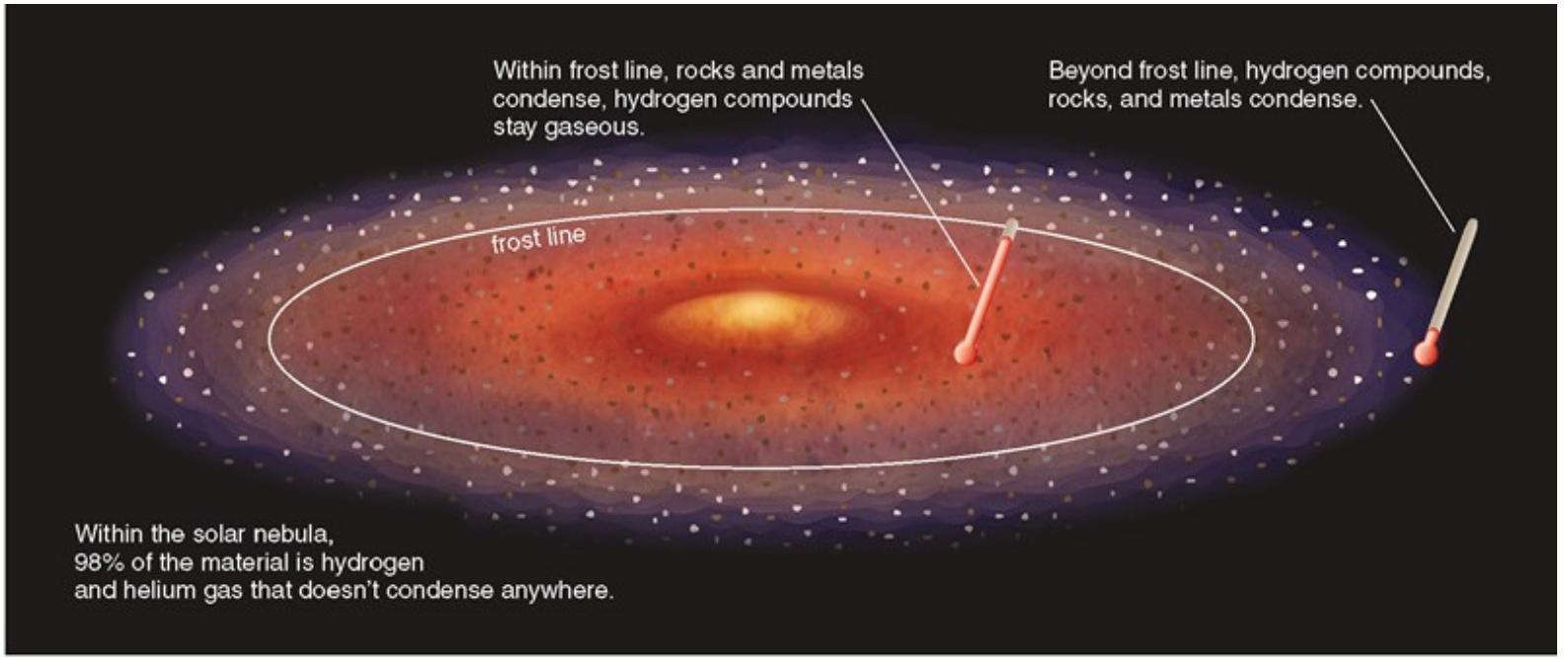

Safronov Model

- The standard model of planet formation was developed by Victor Safronov who envisioned flakes of material sticking to one another to form larger pieces which continue to grow through a process called accretion.
- Depending on distance from the Sun and disk temperature more or less material would condense and the accretion process would progress differently.
- Much work has been done on this model to work out various details. It works very well for the terrestrial planets.

Runaway and Oligarchic Growth

- Early during accretion, bodies only grow based on their cross-section. Once they get large enough their gravity starts to pull things toward them and their growth rates increase.
- This leads to runaway growth where the first body to reach a certain size “wins” because it starts to grow even faster.
- Bodies can only sweep up material that it within a certain range so you get oligarchic growth where a few bodies reach the size of protoplanets and have little left to accrete.

Final Stages

- This leaves us with a few bodies between the size of the Moon and Mars.
- Over time they perturb one another and the orbits begin to intersect.
- After a period of violent collisions, you are left with a set of final planets.

Jovian Planets

- Nothing we have discussed so far involves hydrogen and helium gas. Since the Jovian planets are made mostly of these materials we need another step for them.
- Under the standard model, once an embryo reaches about 10 Earth masses, it can hold onto the gas in the nebula. This enhances growth that leads to a runaway process that is stopped only when material is exhausted.
- There are problems with this model. There is evidence that Jupiter formed very quickly. Also, measurements of core sizes don't agree well.

Giant Instability Model

- An alternative model is that proposed by Alan Boss where gravitational instabilities lead to collapse of regions of the disk.
- This requires that the disk have a sufficient density and/or be sufficiently cold. It isn't clear if disks meet these criteria. Simulations can't currently produce stable protoplanets.
- If this did happen it could form Jupiter and Saturn very quickly (less than 1 million years). It would also agree better with core measurements.

Nice Model

- The core accretion model has gain additional support from the development of the Nice model which explains many other features of the solar system.
  - Uranus and Neptune form closer in.
  - Outer Solar System goes through rapid evolution after about a half billion years when Jupiter and Saturn cross 2:1 resonance.
  - Fallout includes late, heavy bombardment.

Solar Wind

- In the end, the Sun begins to fuse and develops a strong solar wind that blows away the solar nebula.
- This would terminate the growth of the giant planets and signals other changes in the dynamics of the early solar system that we haven't really talked about.

The Sun's Rotation

- The early Sun should have been spinning very fast, being at the center of the collapse.
- The current Sun spins quite slowly, about once each month.
- Magnetic field transfers angular momentum to gas which is then blown away.

Minute Essay

- Do you have a laptop that you could bring to class for course evaluations at the end of the semester?
- Remember to turn in assignment #3 before you leave.