Star and Planet Formation

10-13-2005

Opening Discussion

Have you seen anything interesting in the news?

Should we send an orbiter to Uranus or Neptune? Question of the value of knowledge. Should other things be priorities? How long would it take? Cost relative to putting men on the Moon. Moon counts.

What happens if 2 black holes collide?

Why is the Great Red Spot red?

Why are the moons of Jupiter so diverse and how did they come to orbit Jupiter?

What are these storms on those planets? Do you have lightning or precipitation?

More Minute Essays

Can looking at a solar eclipse blind you?
I skate at the skating rink on Tuesday nights.
General information about HST.
We know a lot about Jupiter and its moons from Galileo. We are learning a lot about Saturn and its moons. There are calls to send a lander/orbiter to Europa to investigate the possibility of an ocean there.

The Nebular Theory

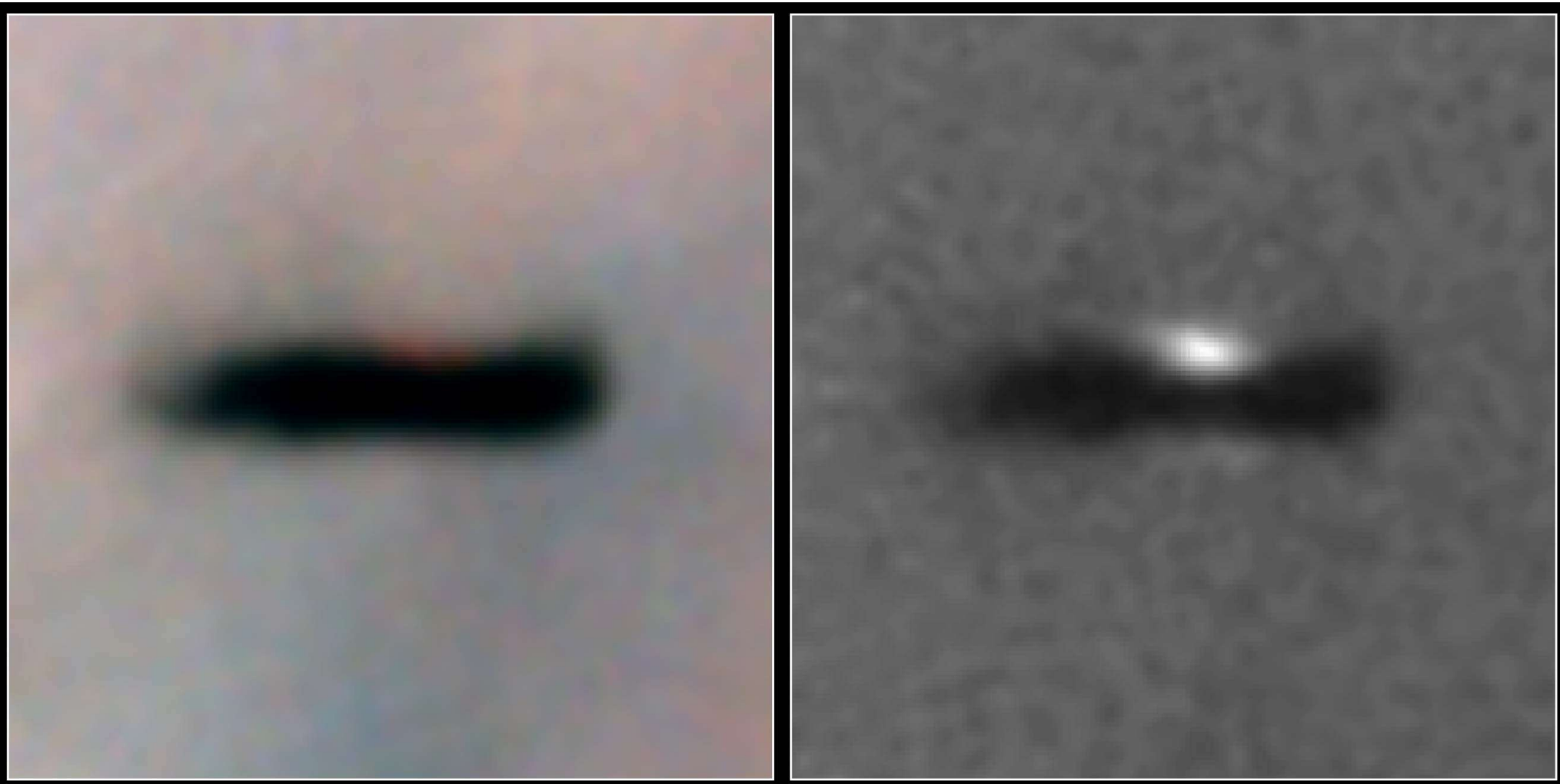
The accepted model of stellar and planet formation begins if a large cloud of gas and dust, a nebula.

Some part of this cloud begins to collapse when it becomes gravitationally unstable.

The collapsing cloud has to conserve angular momentum so extremely slow rotation becomes fast and a flattened disk of material orbits a much denser protostar.

Material in the disk clumps together to form the planets.

Evidence

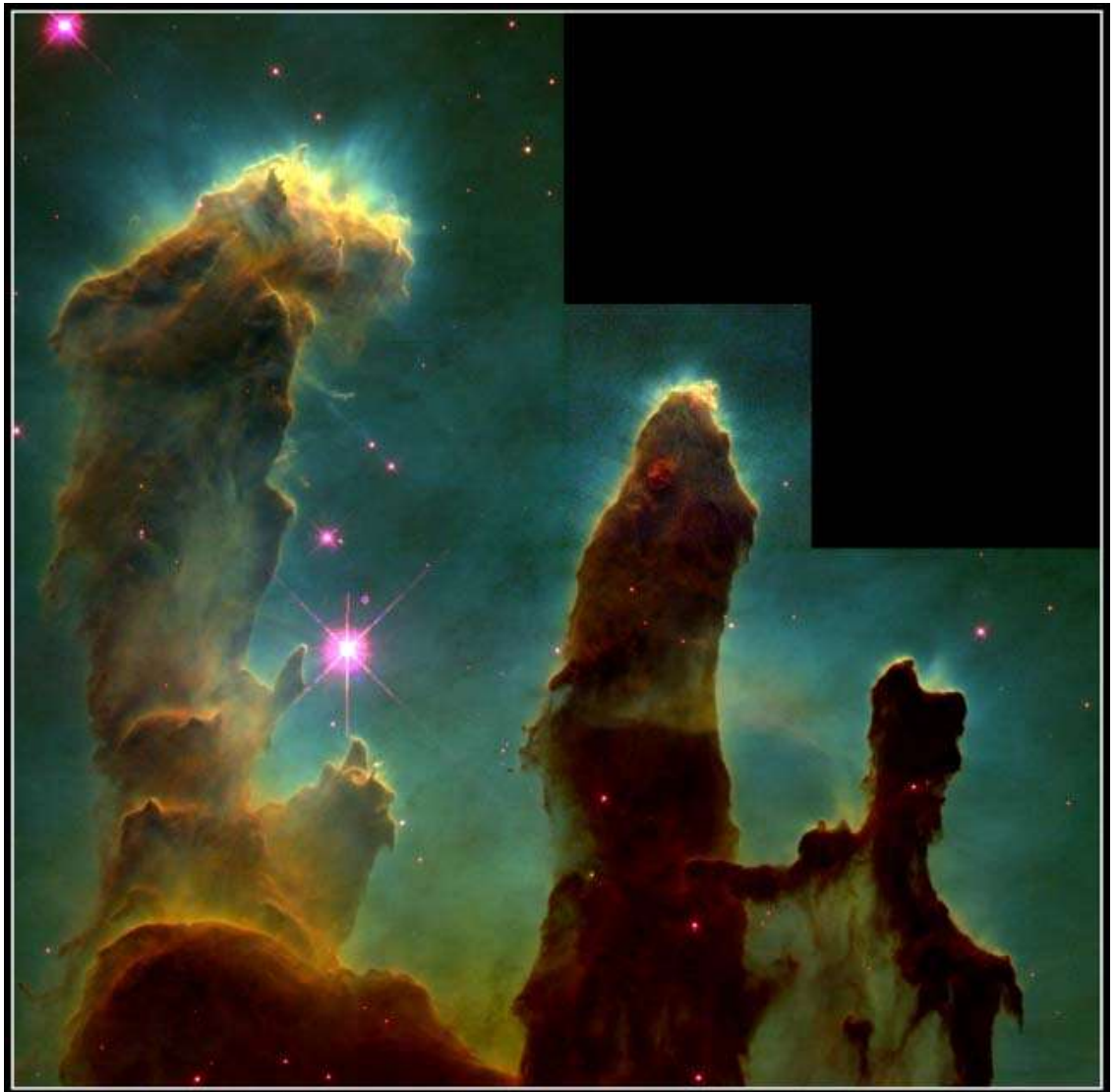


Edge-On Protoplanetary Disk · Orion Nebula

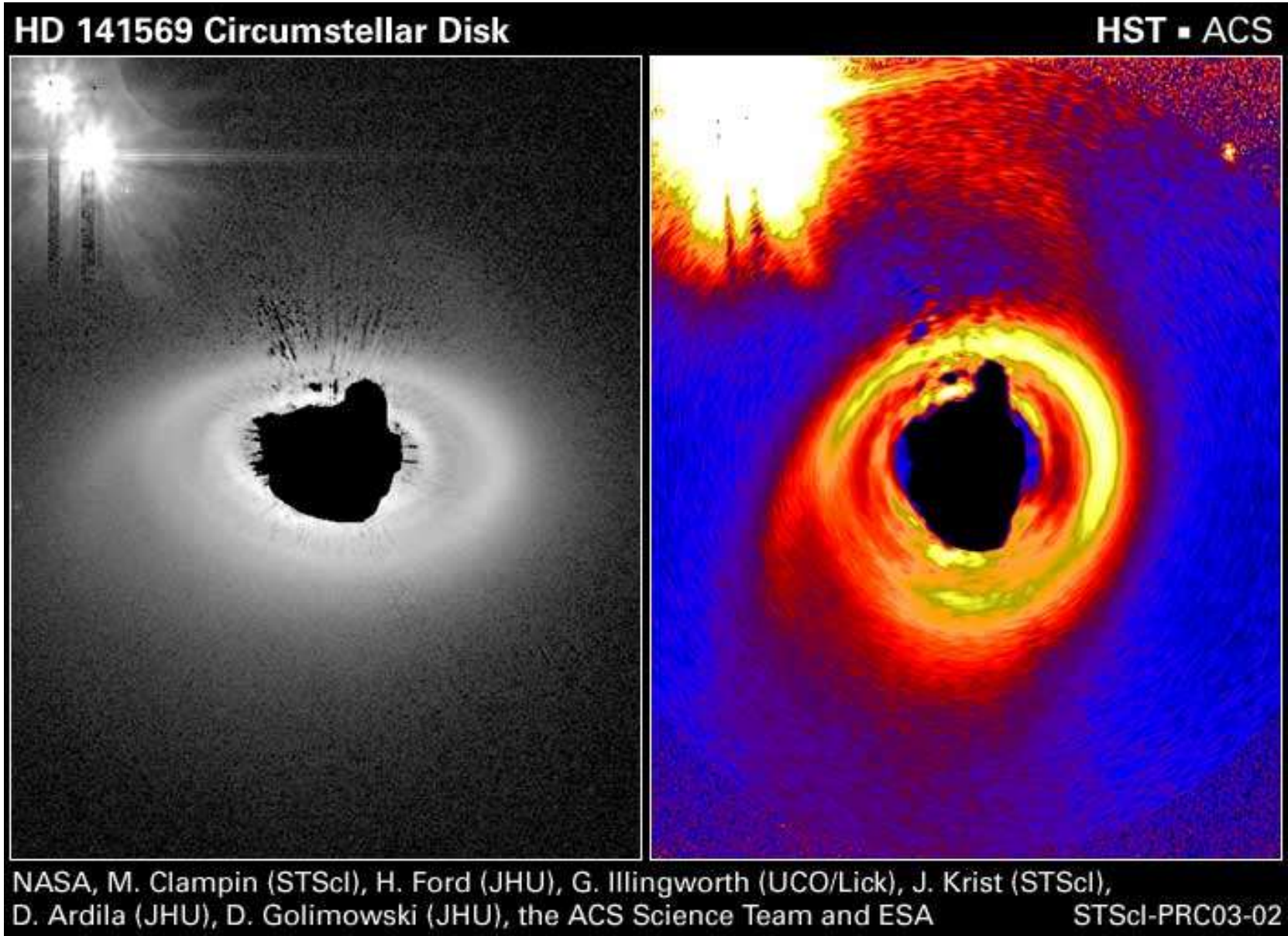
Hubble Space Telescope · Wide Field Planetary Camera 2

PRC95-45c · ST ScI OPO · November 20, 1995 · M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

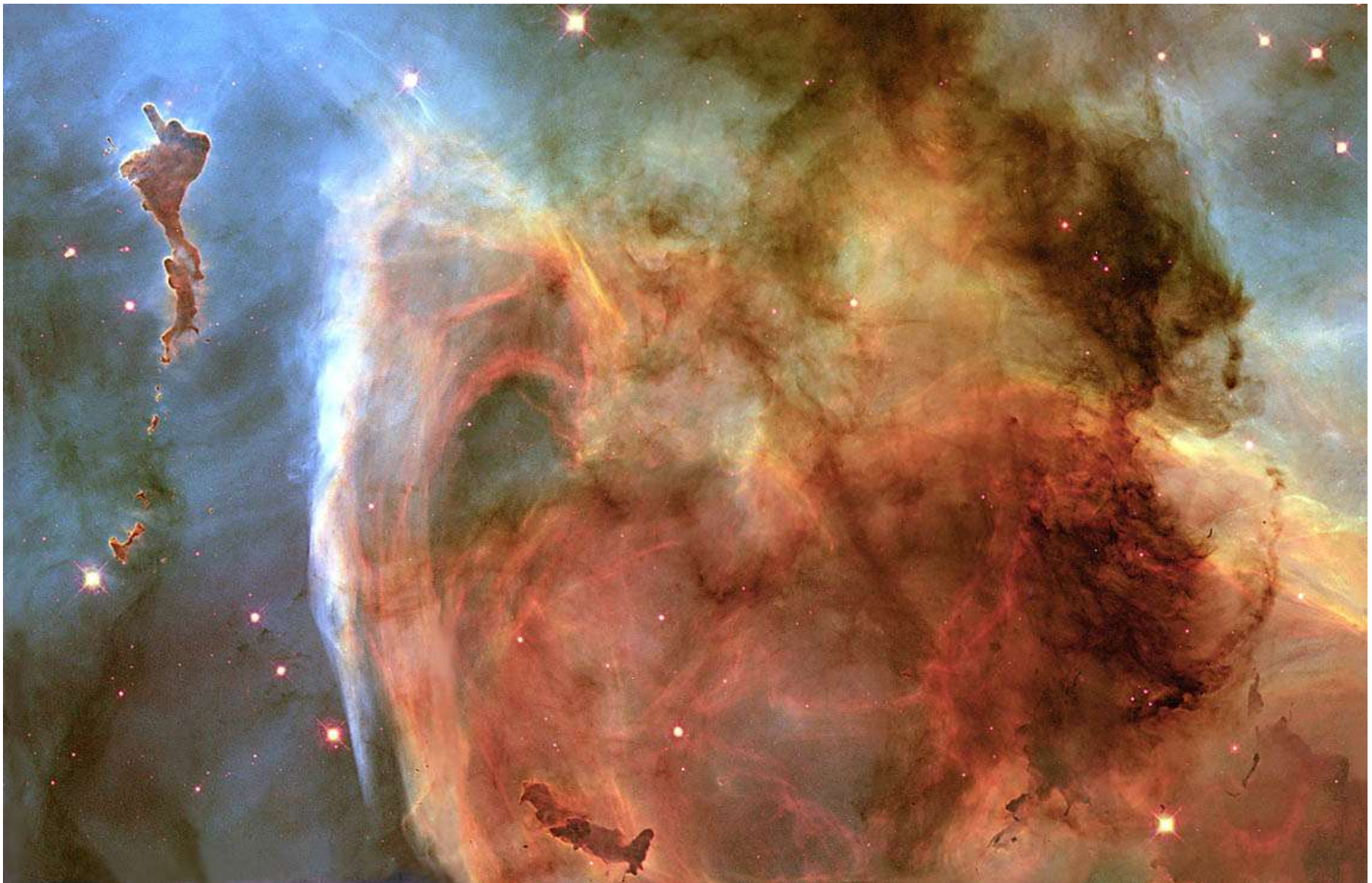
More Evidence



Still More Evidence



Another Pretty Picture



Orderly Motion

The nebular theory would predict the type of motion that we see in our Solar System where basically everything spins in the same direction.

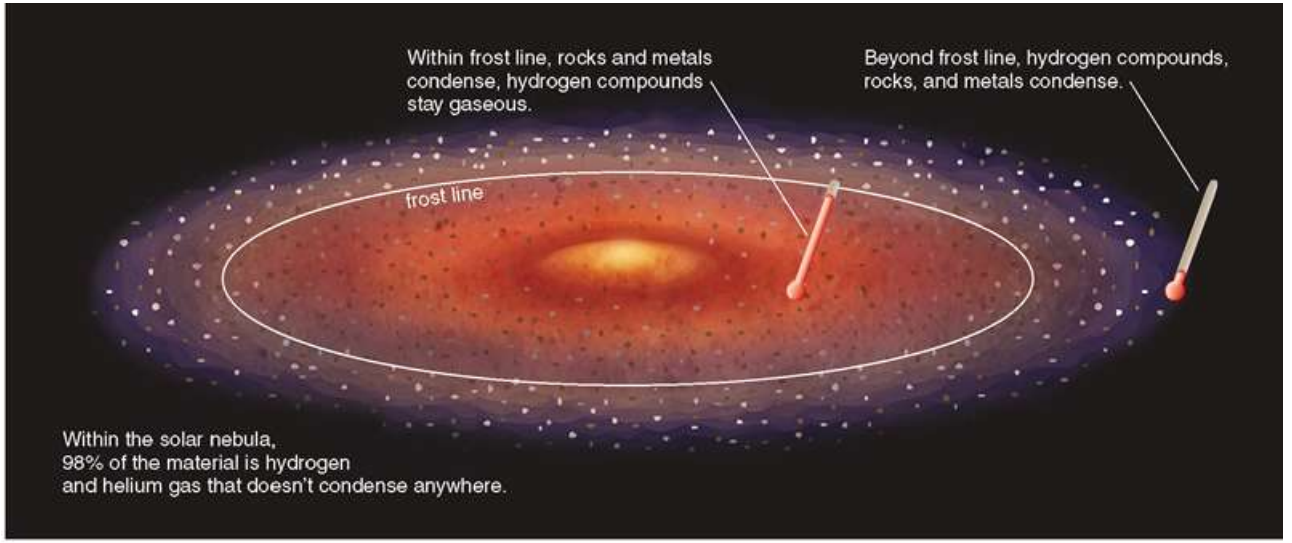
The orbits of the planets have to all go in the same direction as the Sun spins.

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.

Condensation and the Frost Line

	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%



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.

Giant 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.

Boss 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.

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.

Minute Essay

Our solar system agrees with the nebular theory very well. What observation could we make of planets around other stars that would cause us to question this theory?

Remember that next class we have a quiz and your assignment is due.