

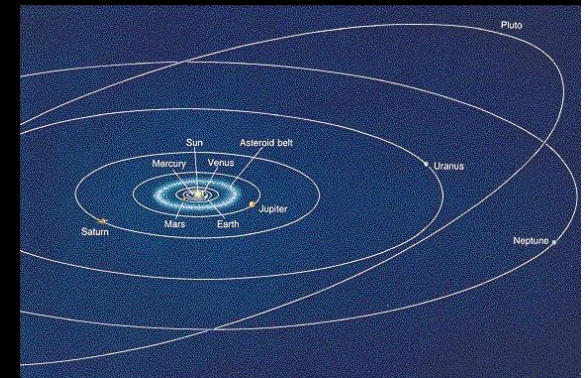
Formation of the Solar System

The story so far...

Reading: 18.1 & 18.5

Clues from the Solar System

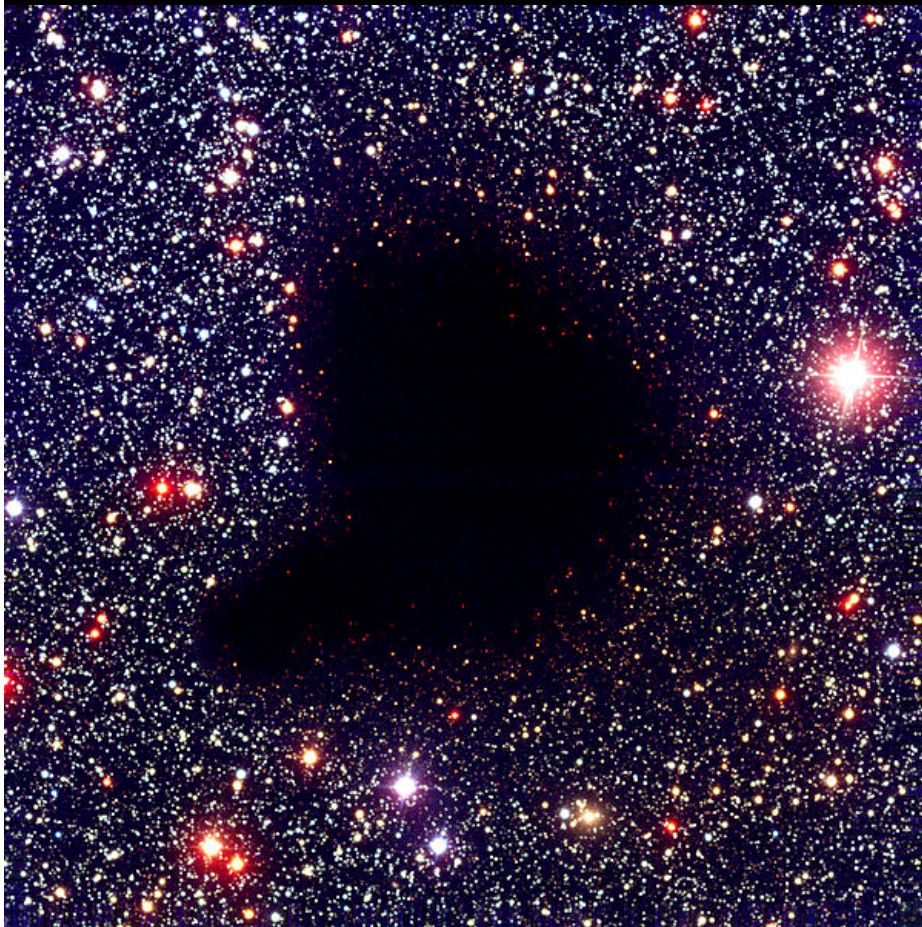
1. The orbital planes of all the planets are nearly the same, in the equatorial plane of the sun.
2. The planets all orbit the Sun in the same direction, the direction it rotates, and most rotate the same direction
3. Planetary orbits are close to circular.
4. The Sun has most of the mass of the Solar System, but not most of the angular momentum.
5. Regular satellites orbit their planets in same way



Quick Summary: the *Nebular Hypothesis*

- Giant *Molecular Cloud*
- Clumping due to gravity, and formation of *Nebular Disk* due to angular momentum.
- Inner part heated by *gravitational pressure*.
- Substances *condense* as parts of the cloud cools.
- Smaller particles collect together to form *Planetesimals*
- Solar Nebula blown away, leaving only materials that had condensed.
- Outer planets also collected gas that had not yet condensed.
- Regular satellites formed similarly around outer planets from accretion disks

Giant Molecular Cloud



Barnard 68,
Photo from ESO/VLT



Orion Nebula
Photo from ESO
VLT & MPG telescopes

Solar Nebula

Clumping due to gravity



Protoplanetary disk in the Orion Nebula.

(image taken on 29 December 1993 with the HST's Wide Field and Planetary Camera)

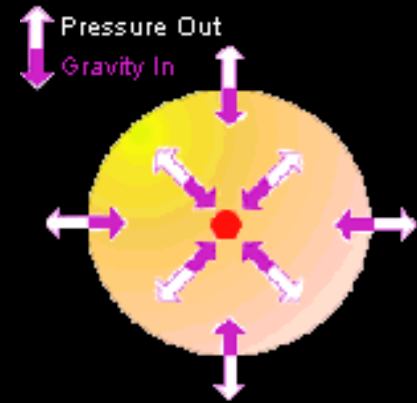


Formation of a disk due to angular momentum



Gravitational Heating...

When a gas is compressed, with no way for heat to be released, then the temperature of the gas increases.

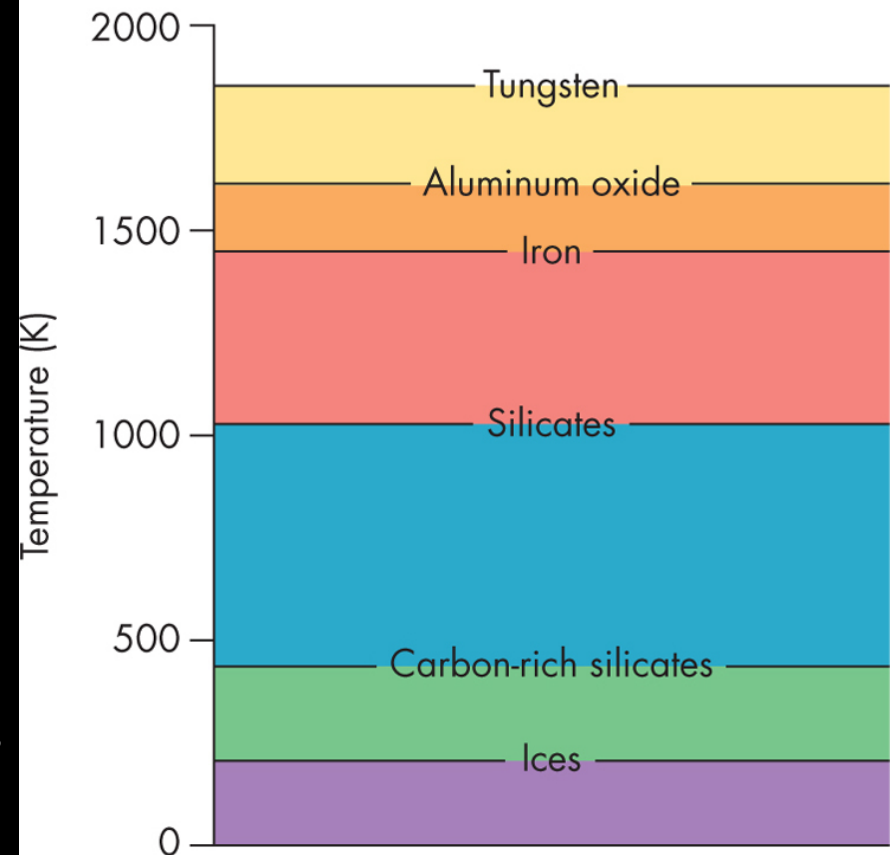


...then Condensation

Outer part of solar nebula is cooler, so everything condenses. Inner part is warmer, so lighter materials remain gas.

Condensation temperatures of various substances in Solar Nebula (Fig 18.17)

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Planet Formation

Grains of condensed material form *Planetesimals*, with sizes ranging from millimeters to kilometers.

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A Gravitational instability model:



Disk of the solar nebula is shrinking.

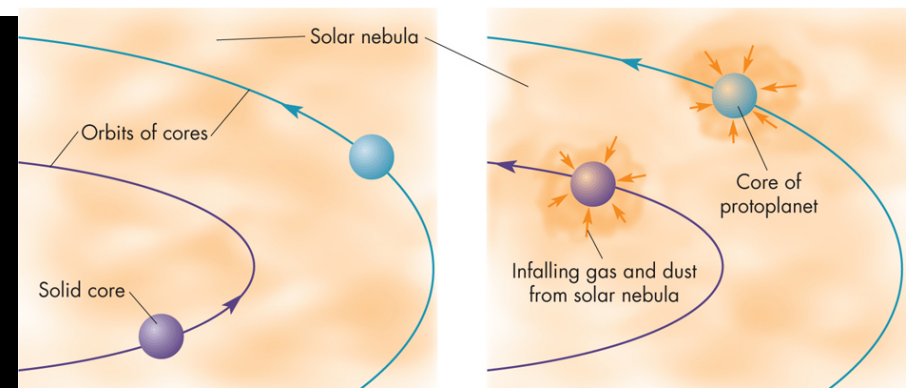
Rings form in nebula but they are unstable.

Rings collapse into protoplanets.

Planetesimals grow in size and mass through both accretion and collisions.

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B An alternative model:



Solid cores formed at the distances of the giant planet.

The cores then captured gas and dust from the surrounding solar nebula.

Bode's Law

After Mercury, the distance to the next planet is about double the distance from the previous

Planet	Distance (AU)	Difference
Mercury	0.4	-
Venus	0.7	0.3
Earth	1.0	0.3
Mars	1.5	0.6
Ceres	2.8	1.1
Jupiter	5.2	2.4
Saturn	9.5	4.7
Uranus	19.2	9.7
Neptune	30.0	???
Pluto	39.5	19.2

Mathematical formula:

$$a = 0.4 + 0.3 \cdot 2^m$$

for

$$m = -\infty, 0, 1, 2 \dots$$

measured in AU.

No complete explanation of Bode's Law, but it may involve resonances like those that influence Saturn's rings and trojan asteroids.

Also known as [Titius-Bode Law](#)

End of Solar Nebula

At about the time the temperature decreased to around 1000 K at the inner edge of the nebula, something blew the rest of the nebula away.

Possible cause:
our star turning “on”

This explains why the inner planets are rocky while the outer planets are a mix of rock and ice.

Temperature in the Solar System at various distances *at the time when condensation stopped*.
(Fig 18.18)

