



Cosmogony: Formation of the solar system



Nebula Hypothesis

- A cloud of interstellar gas and/or dust collapses under its own gravity.
- During collapse gas heats up and compresses in the center.
- A protostar is formed and the rest of the gas orbits/flows around it.
 - ⇒ **accretion disk**
- Metal, rock and ice (only far from star) **condense** as gas cools.
- The dust particles collide with each other and form larger particles.
- Once the larger of these particles get big enough to have a nontrivial gravity, their growth accelerates ⇒ **Run away growth**.
- ≈1 Myrs after the nebula cooled, star generates a very strong solar wind and sweeps away the gas left in the protoplanetary nebula.
- The "**planetesimals**" would slowly collide with each other and become more massive.
- Eventually, after 10 to 100 Myrs planets are in stable orbits
 - ⇒ **solar system formed**.

First discussed by I. Kant in 1755

Cosmogony



Formation of the solar system, I

- Facts to be explained:
- planetary orbits all lie almost in the same plane, parallel to the sun's equator, almost circular
 - all planets orbit counterclockwise, in the same direction as the solar rotation
 - prograde rotation (except Venus & Neptune)
 - planets have 0.15% of the total mass, but 98% of the total angular momentum of the solar system
 - (planetary distances obey the empirical Titius-Bode law:

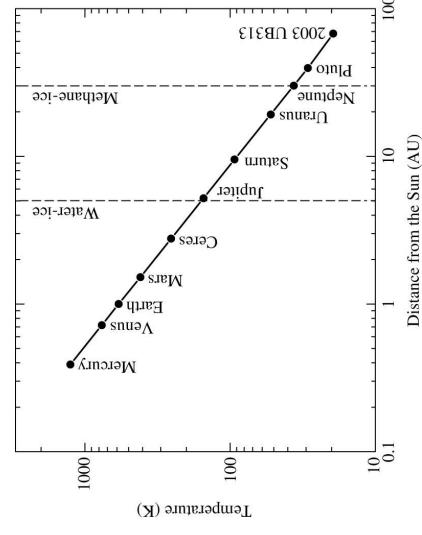
$$a_n = 0.4 + 0.32^n \quad (8.1)$$
 for $n = -\infty, 0, 1, \dots, n = 3$: asteroid belt (Ceres))
 - terrestrial and giant planets are physically and chemically different
 - satellite systems resemble miniature solar systems in structure

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Nebula Hypothesis

Condensation of dust and ices



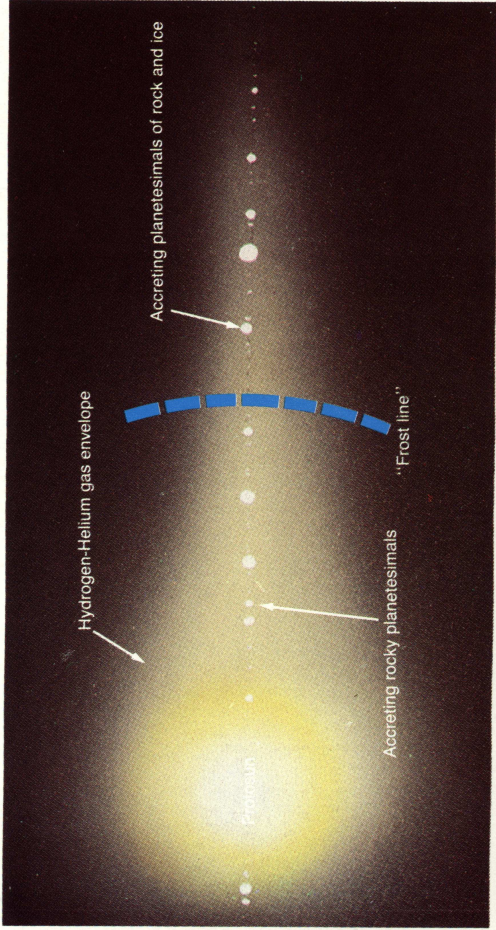
Temperature gradient in the early solar nebula (Carroll & Ostlie)

Chemical differentiation according to temperature:

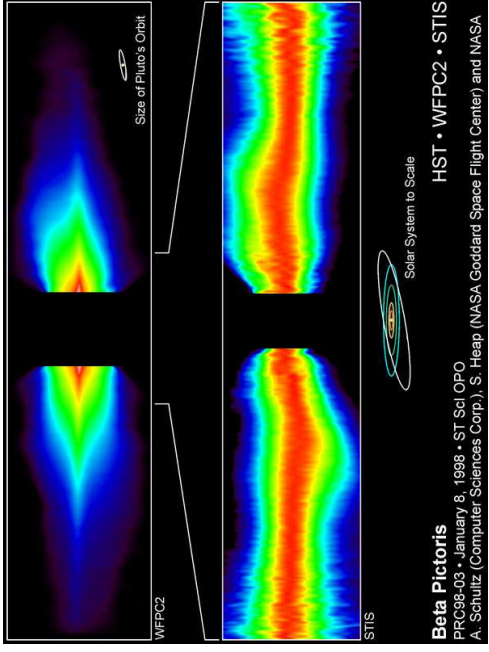
- $T > 1500\text{ K}$: Fe, Ni, CaO, AlO condense
- $1500\text{ K} > T > 1000\text{ K}$: Silicates (e.g. feldspar)
- $1000\text{ K} > T > 800\text{ K}$: FeS
- $800\text{ K} > T > 500\text{ K}$: Metallic Oxides
- $T < 150\text{ K}$: Water ice

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The frostline



Disk around the young star β Pic



"False color" image shows gradations in the brightness of the disk, which scatters the starlight.
 Warps in the disk might be caused by the gravitational pull of one or more unseen planets.

