Evolution of the early Solar system in terms of Big History and Global Evolution

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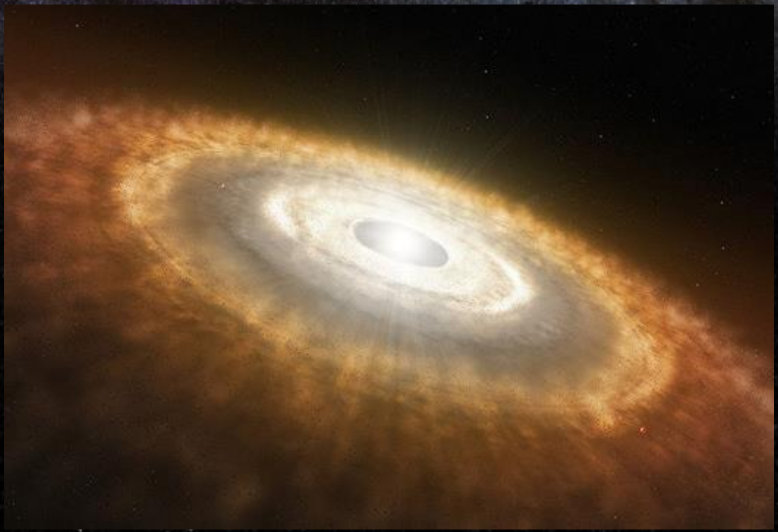
Epochs of the early history of the Solar system in evolutionary terms

- The epoch of **formation of 'order from chaos'** - the formation of protosun and protoplanetary disk from the Solar nebula (about 1 mln years after the collapse of the protosun cloud)
- The epoch of **struggle for resources** – formation of solid matter, planet embryos and primary planets (about 10–50 mln years after the collapse)
- The epoch of **planet migrations and catastrophes** – about 600–700 mln years after the collapse (i.e. 3.9–3.8 billion years ago)
- **Late Heavy Bombardment** by planetesimals and meteorites of the planets and their satellites (lasted for about 900 mln until 3.2 billion years ago)

Formation of proto-solar system from the cloud of gas and dust

- The age of the Solar system ≈ 4.6 billion years.
- The Sun and planets were formed as a result of condensation of a giant gas-and-dust cloud of molecular hydrogen and its gravitational collapse.



A trigger was needed to launch the condensation process.
A possible trigger: shock waves from a supernova in relative proximity to a proto-solar cloud (≈ 2 million years before its collapse).

General evolutionary rule:

necessity of triggering phenomena for launching the evolutionary process

- Phase transition or transformation = internal readiness of a system + a trigger. Without a trigger, a system can for a long time remain potentially ready for transformations and still no changes will occur.

Trigger in biological evolution:
the cooling (6–8 million years ago) →formation of large open spaces in the East Africa → evolution of Hominids named Dryopithecus into Hominids of the Australopithecus type.

Trigger in social evolution: a war, an involuntary resettlement or opening of the given society to the outer world (e.g., the Hawaiians with James Cook's arrival)

Protoplanetary disk and the formation of a dust subdisk

Around the young Sun there was formed a so-called *protoplanetary disk*.

~ 99% gas (mostly H2 and He)
~ 0.5 to 1.5% dust grains

gas-and-dust subdisk → planet embryos

The ratio of dust to gas in it changes by many times as compared to protoplanetary disk. The dust particles grow in size (due to adhesion and attraction).

General evolutionary rule:
importance of heterogeneity and fluctuations

- Dust is an element of *heterogeneity* in clouds of molecular hydrogen. The concentration of this solid matter launched the growth of the proto-planetary bodies and later planets.

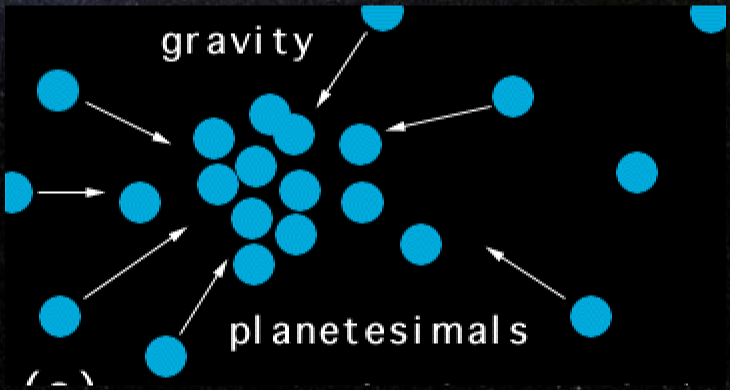
Conclusion: At all levels of Big History an evolutionary change requires the presence of ***critical heterogeneity*** to trigger the regrouping of matter or elements in the assemblage. An absolute homogeneity makes evolutionary processes impossible.

- Biological evolution: a small fluctuation/mutation → speciation.
- Social evolution: peculiar groups consisting of foreigners played an important role in the transformation of many ethnic groups.

Formation of proto-planetary bodies and protoplanets

- *Condensation theory:* protoplanets formed via dust condensation.
- Theory of *successive accretion:* tiny dust particles stick together → small bodies of solid matter → larger solid objects → planetary embryos.
- Small rock fragments (from small to huge rocks) are called planetesimals.

A so-called *protoplanetary swarm of bodies*: planetesimals of various sizes collided, coalescing or splitting. The larger the body, the more resources it was able to capture. Gradually, a small 'elite' stood out (bodies of the size of the Moon or even Mercury).



General evolutionary rule:
struggle for resources and living space

- The struggle for resources - a common mechanism of selection at all levels of evolution.
- The struggle for resources is an important part of Darwin's struggle for existence in the biological world.
- Economic competition – an example of struggle for resources in social evolution.

Formation of protoplanetary system

- Until quite recently the common idea has been that all planets were formed more or less at the same time. Still at present the hypotheses gain ground that some planets may have formed earlier than other.
- Some scholars think that Jupiter formed first, with Saturn close behind, and the planets of the Earth's group formed much later; still others believe the Earth group was the first to emerge.
- There is also an interesting idea that there has existed not one but two or even more generations of primary planets. There is an opinion that being not properly formed those primary planets would explode and become the asteroid belt. Still others think that Jupiter and Saturn may have pushed the primary planets into the Sun or “ejected” them from the Solar system.
- *Thus, it took more than one attempt to form the current order of the planets in the Solar system.*

General evolutionary rule: archaic character of primary systems

Systems are not formed mature and stable. They usually undergo several reconfigurations including the cycles of destruction and re-creation. Primary systems – archaic, the superior systems - the secondary or tertiary.

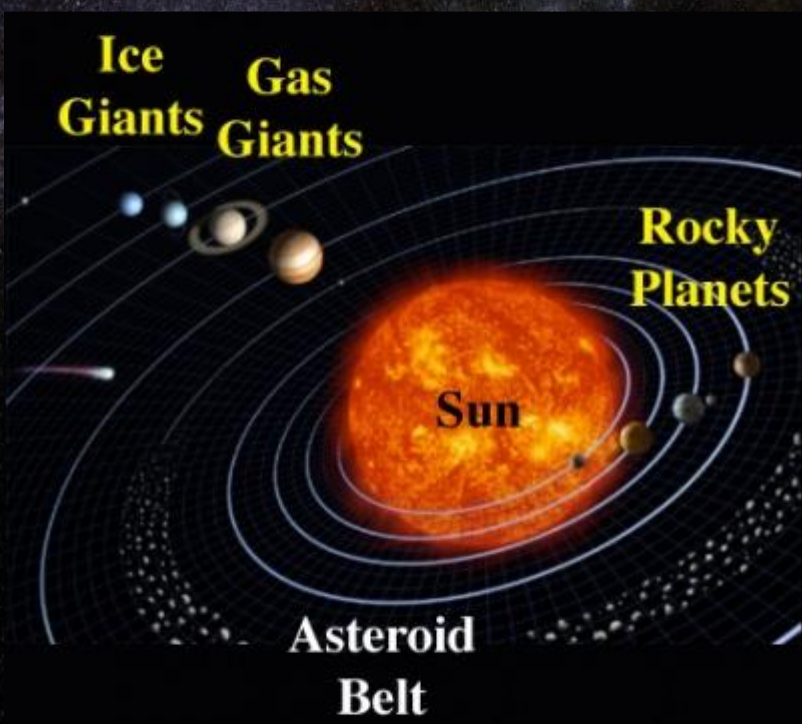
This refers to

- primary planets or stars;
- primary biological species;
- pristine states

General evolutionary rule:
law of struggle for resources

- The Solar system planets:

  - terrestrial planets (solid matter)
  - gas giants (hydrogen, helium and ice)



Hypothesis: gas giants may have been the first planets to form and have captured almost all gas, while the Earth-type planets got quite a few resources.

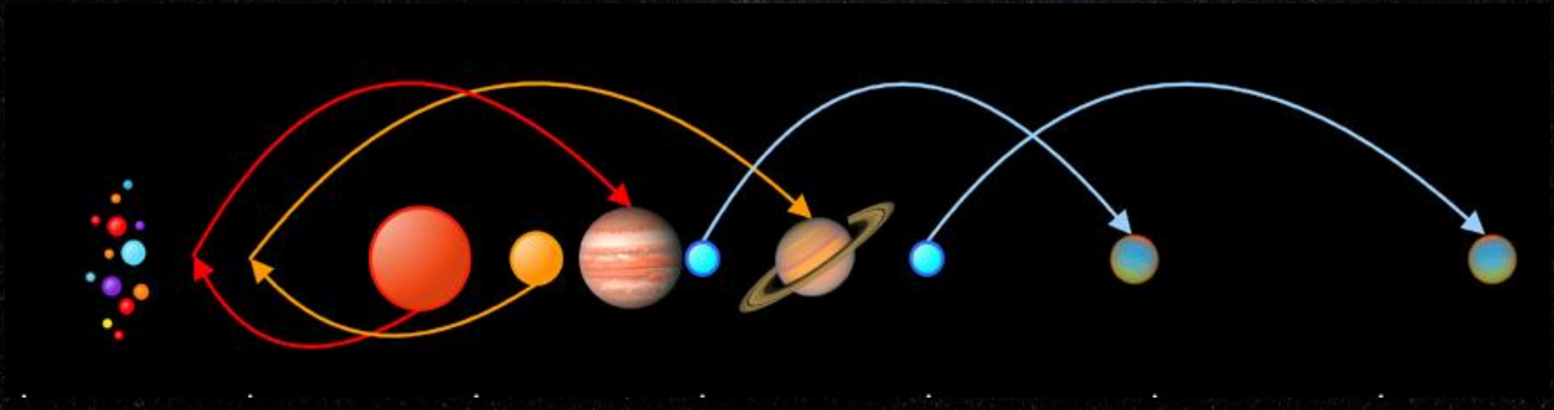
Planetary migration

It was previously thought, planets remain in the original orbits since their formation.

But recently there has become popular the opinion that the planets used to migrate over a long time.

Neptune and Uranus mutually changed the orbits since Uranus used to occupy a further position from the Sun than Neptune.

Here we again deal with the rule of ***archaic character of primary systems***.

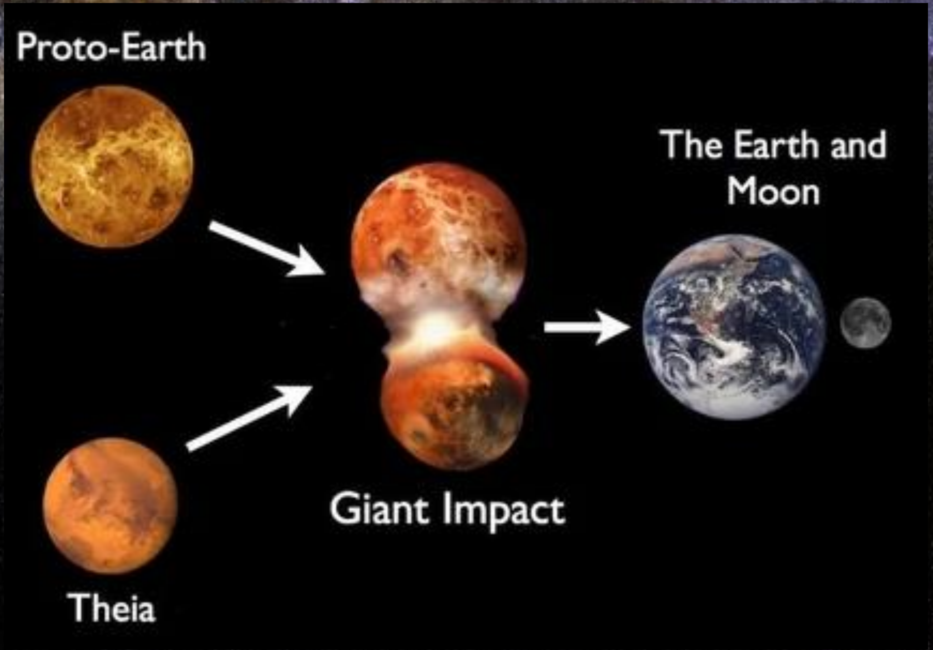


Collisions and catastrophes in the early phase of the Solar system

Two bunches of catastrophes (during the first hundred of million years).

1) Mercury used to be the satellite of Venus from which it later "escaped". This explains both Mercury's small size, more appropriate for a satellite, and the retrograde rotation of Venus.

2) Theia impact



Catastrophic pattern

- Drama is characteristic of Big History in its every stage.
- *Example*: the Cretaceous-Palaeogene extinction caused by the asteroid (Yucatan ≈ 65 mln years ago).
- Catastrophes have considerably affected the course of social evolution (e.g., the Black Death in 14th -century Europe).
- ***Catastrophes are one of the main mechanisms of selection at every Big History level.***
- Catastrophes are the triggers launching some processes, or they destruct the flawed systems and expand the evolutionary opportunities for increasing variability.

Rules, laws, and patterns of evolution

- the rule of necessity of triggering events to launch the evolutionary process;
- the rule of important heterogeneity and fluctuations;
- the law of struggle for resources and living space;
- the rule of the archaic character of primary systems;
- catastrophes as an essential mechanism of selection

But these are just a *few* evolutionary rules and laws. However, much of what we know about Big History can be traced already in its cosmic phase.

The universal character of evolution is a reality with numerous manifestations.


Thank you for your attention!