

The standard scenario of solar system formation and its problems

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The solar system consists of planets, their satellites and rings, and a huge number of minor bodies. The planets can be classified into three groups: terrestrial planets (Mercury, Venus, Earth and Mars), gas giants (Jupiter and Saturn), and ice giants (Uranus and Neptune). These groups differ from one another by compositions, masses, and orbital radii. The terrestrial planets are light rocky ones with relatively small orbital radii, the gas giants are heavy planets with main components of hydrogen and helium gas in the middle of the solar system, and the ice giants are moderately massive with main components of water, methane, and ammonia ice in distant regions. These planetary orbits are nearly circular and coplanar, which suggests that the solar system was formed from a protoplanetary disk around the proto-sun.

The basic framework of the standard scenario for solar system formation was established in 1960's to 1980's. In the standard scenario, the solar system forms from a protoplanetary disk around the proto-sun that is a by-product of star formation and consists of gas and dust. The formation scenario can be divided into three stages: (1) formation of planetesimals from dust, (2) formation of protoplanets from planetesimals, and (3) formation of planets from protoplanets. In stage (1), planetesimals form from dust in the protoplanetary disk. Planetesimals are small building blocks of solid planets. Planetesimals grow by mutual collisions to protoplanets or planetary embryos in stage (2). The final stage (3) depends on a type of planets. The final stage of terrestrial planet formation is giant impacts among rocky protoplanets while sweeping residual planetesimals. Large protoplanets capture a massive gas envelope by self-gravity to become gas giant planets. Ice giants are leftover icy protoplanets that fail to become gas giants. Though the standard scenario can explain the formation of the basic structure of the solar system physically naturally, it has several serious unsolved problems such as planetesimal formation and timescale of giant planet formation. In the present talk, I review the basic elementary processes of solar system formation and discuss the problems now the standard scenario is facing.

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