

Formation and early dynamics of planetary systems

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According to the generally accepted theories, the formation of planets takes place in protoplanetary disks. A protoplanetary disk forms from a fragment of a giant molecular cloud in the early phases of star formation. There are two competing theories for the formation of giant planets. One of these is the gravitational instability, in which a massive protoplanetary disk can be fragmented due to its own gravity. If the fragments can cool efficiently, they can collapse leading to the formation of giant planets. The biggest challenge to this theory is to ensure an effective cooling mechanism enabling the radiation of the gravitational energy released during the collapse. Further problems are that the fragments would result in too big bodies, and the formation of terrestrial planets cannot be explained.

The other, more widely accepted scenario is the planetesimal and core accretion hypothesis. According to this, the formation of the planets begins with the coagulation of the cosmic dust in the gaseous protoplanetary disk. Initially the dust consists of small, sub-micron sized particles. As the result of random collisions these particles can grow, and they are supposed to form few meter sized dust aggregates. The large dust aggregates grow further by pairwise collisions until planetesimals, bodies in the km size regime appear. The collision and growth of planetesimals leads to the formation of terrestrial planets and cores of giant planets with 10-15 Earth-mass. A planetary core accretes a gaseous envelope leading to the birth of a gas giant planet. The final architecture of a planetary system takes shape after the dispersal of the gas disk by the photo-evaporation of the star.

There are still unanswered problems in the core accretion hypothesis, too. One of these is the famous "meter size barrier", which predicts that dust aggregates cannot grow above 1 m in protoplanetary disks. The other one is the timescale problem of the growth of the planetary cores of giant planets. During these lectures possible solutions to these problems will also be presented.

The following topics will be covered: - observational evidences, the diversity of planetary systems; - a special case: characterization of the Solar System; - observation, characterization, and physics of protoplanetary accretion disks; evolution of protoplanetary disks- formation of planetesimals by coagulation of dust particles, the meter size barrier; - growth of planetesimals (runaway and oligarchic growth); - formation of terrestrial planets; - formation of giant planets; - disk-planet and planet-planet interactions, migration of planets; - early evolution and formation of planetary systems, the Nice model.