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FORMATION OF TERRESTRIAL PLANETS AND THE ORIGIN OF WATER ON EARTH

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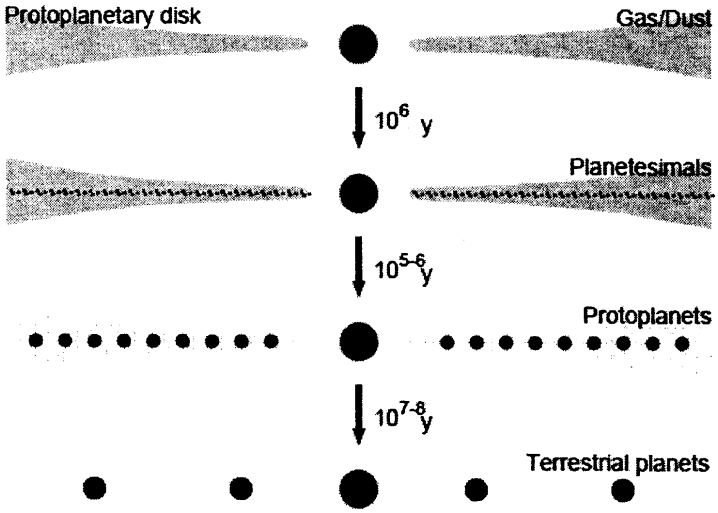
The standard scenario of terrestrial planet formation consists of three stages: (1) dust to planetesimals, (2) planetesimals to protoplanets, and (3) protoplanets to planets. The first stage is the formation of planetesimals (~10^{15}kg) from dust via the gravitational instability of the dust layer or binary coagulation of dust grains in the protoplanetary disk. In the second stage, planetesimals grow by collisions. The growth mode is initially runaway growth where larger planetesimals grow faster than smaller ones. Protoplanets are formed through runaway growth of planetesimals. When the mass of protoplanets exceeds the critical mass, the growth mode shifts to oligarchic growth. In the oligarchic growth stage, protoplanets grow in the orderly mode in which their mass ratios tend to be unity, while keeping the orbital separation by orbital repulsion. As a result, at the end of the second stage, protoplanets with the isolation mass (~10^{23}-10^{24}kg) are formed with the orbital separation proportional to their Hill radii. The final stage is giant impacts among protoplanets with clearing of residual planetesimals. The time scales of each stage are estimated as (1)10^6years, (2) 10^5-10^6years, and (3) 10^7-10^8years, respectively. The Earth accretes water since its formation in the form of planetesimals and protoplanets. In a leading hypothesis, the bulk of Earth's water comes from the asteroid belt in the form of protoplanets. In the present paper, we review the current scenario of terrestrial planet formation and discuss the delivery mechanism of water to the Earth.



The standard scenario of terrestrial planet formation.

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