Formation of Terrestrial Planets form Icy Planetesimals in a Cold Nebula

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Standard scenario of planet formation have been developed on the assumption that the primordial solar nebula is optically thin, so that H2O ice condenses only outside 2.7 AU from the Sun. The solid material is composed of only rocks at the formation region of terrestrial planets (Hayashi 1981; Hayashi et al. 1985). The inner edge of the H2O ice condensation is called snow line. The formation regions of terrestrial planets and giant planets are traditionally divided by the location of the snow line. Hayashi's disk model is called the minimum-mass solar nebula (MMSN) model, and often referred as the reference disk model of solar nebula by many followers.

However, it is widely accepted in the astronomical community that the protoplanetary disks are initially opaque owing to the floating small dust particles and become transparent only at the late stage of planetary formation. Recent models of optically thick protoplanetary disk successfully account for most properties in the observed spectral energy distributions (SEDs) (Chiang and Goldreich 1997; Chiang et al. 2001). In optically thick disks, the interior of the nebula is shadowed from direct exposure to sunlight, so that the H2O ice is prevented from sublimation even at the formation region of terrestrial planets (Chiang and Goldreich 1997; Chiang et al. 2001). As a result, dust particles are composed of the mixture of H2O ice and rocks, and the amount of dust particles is 4.2 times that of optically thin disk at the formation region of terrestrial planets.

If planetesimals are formed in such opaque protoplanetary disks, they should be mainly composed of H2O ice. We call such planetesimals icy planetesimals hereafter. Icy planetesimals can play important rolls in hydration of meteorites, water supply to terrestrial planets, formation of planetary atmospheres, formation region of giant planets which can accrete gas envelopes, etc. In this study, we aim to survey the evolutional scenarios of icy planetesimals, and examine the possibility of water supply to the terrestrial planets.