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Dust particle growth and fragmentation in the dust layer with a weak turbulence

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I studied dust sedimentation and formation of the midplane dust layer at the first stage of planet formation. I assume that the gas disk is initially in a state of laminar flow. When the dust settles at the midplane and the dust-to-gas ratio there exceeds a certain value, the dust layer becomes turbulent because of the velocity difference from the upper gas layer. The strength of the turbulence is estimated from the gravitational energy liberated as the dust particles accrete toward the star. For single-sized particles with the stopping time of 0.1 Kepler time, the turbulent strength is estimated such that the alpha parameter is of the order of 10^{-6}-10^{-5}. Under such a weak turbulence, sedimentation of the dust particles results in a strong concentration of the dust at the midplane. Consequently, in the dust layer, the gas drag effect weakens, and the radial drift velocity and mutual collision velocity of the dust particles become small. If the average dust-to-gas ratio of the whole disk is similar to the solar abundance value, the particle collision velocity does not become extremely small. For disks with the dust-to-gas ratio as large as several times the solar value, however, the maximum collision velocity cannot exceed 10 m/s. Thus, we expect that icy dust particles do not experience violent collisional destruction. I solved the coagulation equation of dust particles taking the fragmentation effect into account, and showed that icy dust particles can overcome the so-called ”fragmentation barrier” if the initial dust-to-gas ratio is large enough.

Keywords: Protoplanetary disks, Dust, Planet formation