Tensile Strength of Porous Dust Aggregates Measured with Dust N-body Simulations

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The formation process of μm-sized dust grains into km-sized planetesimals in planet formation has several theories such as direct coalescence growth and concentration due to instability and has not yet been unraveled. It is difficult to verify the formation process because we cannot directly observe planetesimals forming in protoplanetary disks. Therefore, we focus on comets which are the most primitive bodies in our solar system and are thought to be leftover planetesimals. Comets are capable of detailed observation by spacecraft. In this work, we focused on the tensile strength of 67P/Churyumov-Gerasimenko, which is one of the comets in our solar system and was observed by the Rosetta mission.

In order to investigate whether or not the formation process of planetesimals can be restricted by their tensile strength, we conducted N-body simulations considering the interaction model of dust particles (Wada et al. 2007, ApJ, 661, 320) and investigated the tensile strength of porous dust aggregates. The initial dust aggregates were isotropically and statically compressed to simulate their formation process (Kataoka et al. 2013, A&A, 554, A4). As a result of our numerical simulations, we found that tensile stress gradually increases as tensile displacement increases, and then the tensile stress takes the maximum value. In other words, the tensile strength was obtained. We also confirmed that cutting of contacts between particles in the dust aggregates begins to occur near the maximum tensile stress. We obtained the relation that the tensile strength of dust aggregates is proportional to the 1.8 power of the initial volume filling factor, inversely proportional to the constituent particle radius, and proportional to the surface energy of the constituent material. Moreover, we succeeded in reproducing numerical simulation results by using a semi-analytical model that the tensile strength is determined by cutting of contacts between particles. It was also revealed that the constituent particle radius of comet 67P has to be about 3.3–220 μm to reproduce its tensile strength using our model. In the conventional planet formation theory, the constituent particle radius is assumed to be 0.1 μm same as the interstellar dust radius and is different from the value obtained from our model. It is necessary to reconsider theories such as the time evolution of the constituent particle radius.

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