Tensile Strength of Porous Dust Aggregates in Protoplanetary Disks

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Kilometer-sized planetesimals are thought to be building blocks of planets. However, the formation process of planetesimals from submicrometer-sized dust grains in protoplanetary disks has not yet been unraveled. In this process, it has been indicated that the porous structure of dust aggregates is a key factor and it can influence the material strength of planetesimals. Here, we focus on comets, which are the most primitive bodies in our solar system and are thought to be leftover planetesimals. Their properties have been investigated by both observation and exploration. Recently, *Rosetta* reached comet 67P/Churyumov–Gerasimenko and its tensile strength was estimated.

As a first step toward constraining the formation process of planetesimals, we conducted N-body simulations considering the interaction model of dust particles (Wada et al. 2007, ApJ, 661, 320) to derive the tensile strength of porous dust aggregates and compare it with that of the comet. In our simulations, we gradually moved periodic boundaries to pull a dust aggregate, which mimics the static stretching process of porous dust aggregates. During the stretching, we measured the tensile stress at each time step. As a result of these simulations, we found that the tensile stress has the maximum value, which we define as the tensile strength of the dust aggregate. We also found that the maximum tensile stress is realized when many connections of constituent particles start to break. Then, we conducted a series of these numerical simulations with changing the initial aggregate porosity. Finally, we succeeded in deriving the tensile strength from our simulations. In addition, it is found that the derived tensile strength is reproduced by using a semi-analytic model that the tensile strength is determined by connection-breaking between constituent particles. Our model is consistent with previous experimental and numerical studies of the tensile strength (Blum & Schräpler 2004, PhRvL, 93, 115503; Blum et al. 2006, ApJ, 652, 1768; Seizinger et al. 2013, A&A, 559, A19; Gundlach et al. 2018, MNRAS, 479, 1273). The derived tensile strength of porous dust aggregates is much larger than that of the comet when the constituent particle radius is the same as the interstellar dust radius, i.e., 0.1 μm. To achieve the tensile strength of the comet, the constituent particle radius is needed to be from several to ~ 100 μm or other mechanisms to make dust aggregates fragile are needed.