A Theoretical Study on Mechanical Properties of Aggregate Dust and Monolithic Dust: Toward a Better Understanding of Ejecta Cloud Formation

Hiroshi Kimura[1], Takayuki Hirai[1], Takaya Okamoto[1], Fumi Yoshida[1,2], Peng K. Hong[1,3], Koji Wada[1], Hiroki Senshu[1], Toshihiko Kadono[2], Eiichiro Kokubo[4], Yuki Yoshida[5], Akiko M. Nakamura[5], Sota Arakawa[6], Tomoko Arai[1], Masanori Kobayashi[1], Osamu Okudaira[1], Hiroshi Akitaya[1], Ko Ishibashi[1], Manabu Yamada[1], and Takafumi Matsui[1]

[1]*Planetary Exploration Research Center (PERC), Chiba Institute of Technology, Chiba, Japan*

[2]*University of Occupational and Environmental Health, Japan, Kitakyusyu, Japan*

[3]*PERSOL CAREER CO., LTD., Tokyo, Japan*

[4]*National Astronomical Observatory of Japan, Tokyo, Japan*

[5]*Kobe University, Kobe, Japan*

[6]*Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan*

It is natural that small airless bodies in planetary systems are major sources of dust in the zodiacal cloud and debris disks by mutual collisions and volatile sublimation. Conversely, every small airless body in the zodiacal cloud and debris disks is struck on its surface with dust continuously and such a steady bombardment of the airless body results in the formation of a so-called ejecta cloud around it, the presence of which has been identified around Jovian satellites. The formation of an ejecta cloud is directly linked to the mechanical properties of dust in the ejecta cloud, but mesoscopic physics behind the ejecta cloud formation is poorly formulated. Instead, an empirical law of macroscopic impact experiments is commonly applied to previous models of ejecta clouds, whereas there is no justification for the validity of the law in mesoscopic physics. To overcome this situation, we theoretically investigate the mechanical properties of dust in mesoscopic physics, although based on Johnson-Kendall-Roberts theory of contact mechanics, Griffith theory of fracture mechanics, and Weibull theory of flaw statistics. In this presentation, we will provide theoretical formulae for the mechanical properties of dust that are applicable to both aggregates of small grains and monoliths of any porosities. We will demonstrate how well our analytic expressions explain experimental and numerical results of mechanical properties with icy, siliceous, and carbonaceous materials in the size range from nanometers to meters.

The DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) mission will fly by several Near-Earth Asteroids (NEAs), the main target of which is the Geminid parent-body (3200) Phaethon. During their flybys, a dust analyzer named DDA (DESTINY$^+$ Dust Analyser) onboard DESTINY$^+$ will measure the mass, electric charge, velocity, and chemical composition of dust in the ejecta cloud around each NEA. Therefore, the interpretation of DESTINY$^+$/DDA in-situ data on dust in the ejecta clouds will benefit from our theoretical study, which provides a better understanding of ejecta cloud formation.