Deciphering the regolith properties of small bodies from numerical modeling

*Yun Zhang[1]

1. UCA, OCA, CNRS, Lagrange, Nice, France

Surfaces of small bodies experience a wide range of processes that alter their local and global characteristics. Numerical modeling allows us to investigate these processes and decipher the history and physical properties of small bodies from their surface characteristics. I will present an overview of our recent investigations based on numerical modeling and give some examples below.
For objects whose surfaces have been characterized in detail by spacecrafts, e.g., Ryugu by Hayabusa2 (JAXA) and Bennu by OSIRIS-REx (NASA), comparisons with numerical modeling can be used to shed some light on the formation of these surface features. For instance, some surface local mass movement features in the downslope direction were detected on asteroid Bennu [1]. This direction and color variation analyses suggest that these mass movements occurred at times close to the current spin-period regime, which may result from YORP rotational accelerations. We carried out a numerical study using the soft-sphere discrete element modeling (SSDEM) to test Bennu’s structural evolution under the YORP spin-up effect. The current surface slope, the recent surface mass movement, and the old surface age of the equatorial bulge are used as constraints to shed some light on Bennu’s surface properties and internal structure.
Direct interaction with a small body surface is the most effective way to understand the regolith mechanical properties and behavior in the actual gravitational environment. The outcome also provides precious opportunities to interpret the results using numerical modeling. For instance, the experiment performed by the Hayabusa2 Small Carry-on Impactor (SCI) on asteroid Ryugu in April 2019 offers the first opportunity for a direct confrontation of cratering on small bodies with numerical modeling [2]. We conducted SCI-like cratering tests using a hybrid Smooth Particle Hydrodynamics (SPH) and SSDEM framework. The preliminary results show that regolith near the SCI-cratering region should have little cohesion in order to match the crater morphology.
In an indirect way, the regolith properties can also be inferred for some small bodies that are at the limit of maintaining their structural stability. For instance, there are dozens of fast-rotating asteroids that require material cohesion to keep their integrity. With comprehensive numerical exploration, we can derive the minimum required amount of cohesion of their regolith and the corresponding grain size distribution.
Connecting the regolith properties with other observational data can help to reveal the formation mechanism of small bodies. For instance, our numerical modeling showed that the lack of apparent cometary activity of the interstellar object 1I/‘Oumuamua can be explained by the way its surface was built during its formation through a close encounter with its host star in another planetary system [3].

Reference: [1] Jawin et al. (2020) JGR: Planets, 125, e2020JE006475. [2] Arakawa M. et al. (2020) Science, 368: 67–71. [3] Zhang & Lin (2020) Nature Astronomy, 4, 852–860.

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