Understanding Extraterrestrial Rock Size Distribution: An Experimental Approach

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The size-distributions of rock particles existing on extraterrestrial bodies are considered to reflect the past geological processes that have occurred on their surfaces. To statistically compare their size distributions, the power-law index, α, which is derived from fitting a power-law distribution to the cumulative size-frequency distribution (CSFD) of rocks, is frequently used [e.g., 1, 2]. This comparison is particularly important for airless bodies such as asteroids, because their surfaces are thought to effectively preserve the geologic record of several processes, including generation, fragmentation, migration, and sorting of surface rocks. For example, Chapman et al. (2002) [1] observed a steeper α value of -5 for boulders in specific regions on Eros, indicating a high abundance of boulders smaller than 10 m. This observation, coupled with a depletion of small craters (less than 200 m in diameter), suggests that additional processes may be active on the body, in addition to cratering. These could include thermal creep, electrostatic levitation and redistribution of fines, and space weathering. Thus, accurate interpretation of both the absolute and relative values of α in the CSFD is critical to understanding the geological processes on the surfaces of asteroids.

The index α is primarily derived from the analysis of surface rocks on extraterrestrial bodies. Yet, the α value has been sometimes utilized to estimate internal structures and properties, considering that internal granular materials may also follow the CSFD having the same α [3, 4]. However, recent observational results from the asteroid Ryugu and Bennu suggest the existence of subsurface layer, composed of fine-grained particles [5, 6], which may be expressed by a different α value, compared to that of the surface. Thus, how effectively the CSFD determined by surface rocks reflects the internal conditions is yet to be revealed.

In this study, we conduct laboratory experiments to investigate the consistency of α between its appearance from the surface and its true value. We prepare a granular bed with a known α value (i.e., a bed with a controlled size-frequency distribution) and observe the apparent particle size distributions obtained from the surface images obtained from the above. In addition, we investigate how the apparent surface α values can be affected by external energy input. We vibrate the granular bed, which may be one of the most common geological processes on asteroids as seismic shaking [e.g., 7], and study the resulting changes in surface rock distribution and the α-value of the CSFD.

Our laboratory experiments show that the true value of α for the granular sample and the value determined from surface images can be inconsistent, proposing that we need a careful interpretation of the α value for asteroid surfaces. Also, in the vibration experiment, we observe a significant change of surface rock distribution and a gradual shift of the α value. This suggests that the α value can be an effective indicator for understanding the evolutionary history of asteroid surfaces.

References

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