Estimation method for sub-pixel particle abundance based on texture/photometery analysis for Hayabusa2

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Introduction: Hayabusa2 explores a C-type asteroid Ryugu. Asteroids may retain information on the early solar system. In particular, C-type asteroids may contain hydrous minerals and organics. Detailed analysis on such minerals may provide important information on the origin of life and the solar system.

Because Hayabusa2 is a sample-return mission, the decision on the sampling site on Ryugu is very important. The highest priority for landing site selection is the safety of the spacecraft. Among many requirements for safety, the requirement that needs the highest spatial resolution is the number density of sub-meter boulders. However, the resolution of images from an altitude of 20 km, where global observation will be conducted, is 2 m/pix. Even when Hayabusa2 descends to 5km of altitude, the resolution is only ~0.5 m/pix, with which smallest discernible boulders are 2 –3 meters in diameter. Because we cannot visually discern sub-meter boulders, we may have to estimate the number density of such small boulders using power-law assumption and extrapolation from the size distribution of boulders larger than 3 m. However, because the size distribution of boulders may have a cutoff in small size range, such extrapolation may lead to a large error in the number density of sub-meter boulders. In this study, we are developing a method to measure the average size of sub-pixel particles based on texture/photometry analysis in regions of interest.

Experiments: We obtained image sets with different particle sizes of basaltic sand, chosen to be 0.01-10pix in our cameras. We made analogue samples by sifting basaltic gravels from Miyake island. We conducted experiments with both single-size particles and their mixtures. In the single-size particles experiments, we used the sifted samples and changed the particle size. In the mixture experiments, we scattered 0.9-pix particles on a bed of fine particles with fixed diameter (~0.03pix) and changed the number density of 0.9 pix particles. We took pictures of the samples at a fixed phase angle (20 deg) between a camera and a lamp, simulating to images for the early phase of Hayabusa2 mission. By using the obtained image, we calculated the standard deviation, sigma, of brightness, which represents the texture of the image, for each sample and investigated the relationship between sigma and particle size.

Results: The sigma value increases with average particle size. Results from the experiments with single size particles suggests that we can estimate the mean particle sizes smaller than several pixels. More specifically, the standard deviation in image brightness significantly different among particles with diameter around 2-3 pixels, around one pixel, and smaller than a pixel. The mixture experiments indicate that sigma increases significantly with an increase of the number density of 0.9 pix particles. This suggests that even if the samples are mixtures of subpixel particles, we may be able to estimate the amount of larger particles by calculating σ.

Summary and future work: Our experimental results indicate that the standard deviation in brightness may allow us to estimate the relative abundance of the size distribution of sub-pixel particles, which had been estimated only by the extrapolation of particle size distribution of particles larger than several pixels. We will conduct experiments with mixtures of more variety of size particles and clarify quantitative

relationship between sigma and the size distribution of particle larger than 0.6 pix, which is comparable to 0.3 m for the Hayabusa2 observation.

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