PDC2017
Tokyo, Japan

IAA-PDC-17-03-P18

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In-Site Determination of Asteroid Thermal Inertia using the MASCOT Radiometer

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Keywords: *Thermophysical characterization, regolith, infrared radiometer, MASCOT, AIM*

ABSTRACT

Interactions with an asteroid relevant for planetary defense, exploration, and the emerging field of asteroid mining occur first at or entirely with its top surface layers. One of the methods to characterize the asteroid's surface without disturbing the object of interest in its very sensitive microgravity environment is the radiometric determination of surface energy fluxes, and properties such as thermal inertia as well as emissivity can be constrained without introducing systemic bias. Thermal inertia provides valuable information on properties like grain size and thermal conductivity to a depth of typically a few millimeters by measuring thermal fluxes for a full asteroid rotation. Larger depth's up to a few centimeters could be probed if measurements were extended for longer periods covering a significant fraction of a seasonal cycle. The German Aerospace Center (DLR) provided the MARA radiometer to the MASCOT lander, which is a payload on JAXA's HAYABUSA2 mission to the carbonaceous near-Earth asteroid (NEA) (162173) Ryugu. The mission will investigate asteroid properties by remote sensing and by analysis of return samples to Earth, while MASCOT will be deployed from the main spacecraft and investigate the surface in situ, thus providing ground-truth measurements on small scales.

The primary science goal of MARA is to derive surface thermal inertia at the landing site by measuring surface brightness temperatures for a full asteroid rotation. In this way, complications usually encountered when interpreting dayside thermal infrared data stemming from surface roughness effects can be avoided, and MARA will retrieve thermal inertia with an expanded uncertainty (2-sigma) of 10% in its 10 cm diameter field of view. Furthermore, sub-pixel (unresolved) thermal heterogeneities can be deconvolved by incorporating data from the MASCOT imaging system, which shares the MARA field of view. As an example, we have simulated the inversion of thermal flux from a surface covered by 70% of coarse grained material of thermal inertia 620 MKS and 30 % fine grained material of thermal inertia 70 MKS. Calculations show that the uncertainty of the retrieved thermal inertia slightly increases for this test case, and 610^{+50}_{-40} MKS and 70^{+50}_{-30} MKS is obtained. While this is within the 10% uncertainty interval for the coarse grained fraction, thermal inertia for the fine grained fraction is less well constrained, but information on critical parameters such as grain size can still be obtained. MARA measurements will provide an important reference point for the Thermal Infrared Imager (TIR) of the HAYABUSA2 spacecraft, which will trace the temperature profiles of the whole surface by asteroid rotation and provide the context on a global scale. Together, the two instruments will provide a multiscale understanding of the thermophysical properties of Ryugu and its global scale surface heterogeneity. MARA is also a baseline instrument aboard the MASCOT2 lander designed for the AIM spacecraft of the joint NASA-ESA mission AIDA, and several other proposed or requested MASCOT derivates for other small solar system body missions.

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