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OSIRS-REx@Bennu and Hayabusa2@Ryugu: thermal modelling of sample return mission target asteroids

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1. Asteroid thermal modelling

Asteroid observations in the thermal infrared have been been carried out since the '70s mainly to measure their sizes [1]. Essentially, these observations are obtained from space. Space surveyors such as IRAS [2], MSX [3], AKARI [4], Spitzer [5], and WISE [6] (see also [7]) have provided more than 150,000 asteroid sizes and albedos.

Moreover, thermal infrared observations allow the determination of geo-physical properties of bodies' surfaces. For instance, it is well known that rocks cool off at night more slowly than fine materials (e.g. sand) of the same compositions. This has been used to determine the rock abundance on our Moon [8] and on Mars [9] from night-time thermal infrared measurements.

A physical property that is often derived from infrared measurements is the thermal inertia of the surface [10]. This quantity measures the resistance of a body to temperature changes.. Thermal inertia can be used to estimate to estimate the grain size of the regolith [11, 12, 13], which is crucial information for sampling site selection (e.g. in the case of OSIRS-REx).

In the case of asteroids, thermal inertia controls the strength of the Yarkosvky effect, which is a secular non-gravitational perturbation on the orbit, due to the momentum imparted to the asteroid by the emission of thermal photons [14]. If the variation of the orbital semimajor axis due to the Yarkosvky effect is measured, e.g. by radar or utra-precise optical astrometry, and the body's size and thermal inertia are available, it is then possible to solve for the bulk density of the asteroid [15], which is one of the most interesting, yet unknown, properties to be determined for asteroids.

The value of the thermal inertia, together with the rotation period controls the amplitude of the day-night temperature excursions, which can reach several tens to hundred degrees on airless bodies such as asteroids [16, 10]. These temperature variations can trigger thermal fatigue [17, 18] of the surface materials leading to their failure and the production of fresh regolith.

The arrival of JAXA's Hayabusa2 at the near-Earth asteroid (162173) Ryugu and of NASA's OSIRIS-REx at (101955) Bennu this year will offer the opportunities to perform the aforementioned studies in great details on their target asteroids.

2. OSIRIS-REx & Hayabusa2

NASA's OSIRIS-REx is a sample return mission that will perform detailed infrared observations of the asteroid Bennu using OTES. This is a thermal emission Fourier-transorm spectrometer, built by P. Christiansen and collaborators at the ASU, USA, that collects hyperspectral thermal infrared data over the spectral range from 5.7 to 100 microns. OTES will be used to derive the composition and the thermophysical properties of the surface of Bennu. The main topics that OTES aims at addressing are: (1) to document the sample site spectral and compositional properties; (2) to globally map the composition of Bennu; (3) to determine regolith physical properties, such as grain size, stratification, and (4) to measure asymmetric thermal emission around the asteroid that produces the Yarkovsky effect

On the other hand, JAXA's Hayabusa2 is equipped with a thermal infrared imager (TIR) [19] based on a microbolometer array 320 x 248 pixels that will take images of Ryugu. The pass band of the detector is 8–12 microns and there are no filters. Radiance measurements are converted into temperatures via pre-flight calibration. The goal of TIR is to measure surface temperature, determine thermal inertia [20], and regolith nature. It will also be used for selection of sampling sites and for the location of MASCOT lander touch-down. The latter is also equipped with MicrOmega and MARA. The former will analyse the surface composition at micron -scale resolution; the latter is a radiometer that will measure the surface temperature at the landing site. MARA measurements are planned to be carried out along at least one day/night cycle.

OSIRS-REx and Hayabusa2 also differ in the observations modes: while the former will use different "stations" around Bennu (at 03:20 AM, 06:00 AM, 10:00 AM, 12:30 PM, 03:00 PM, 06:00 PM, 20:40 PM of local time), the latter will mostly observe the sub-solar point at nadir, i.e. from zero degree of phase angle.

OSIRIS-REx and Hayabusa2 will provide high quality data to be analysed by means of sophisticated thermal models. In some of these models, team members of these missions are implementing heat transfer taking into account the granular nature of the soil, in order to study the regolith grain size, rock abundance and stratifications.

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