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IN-SITU DETERMINATION OF THERMAL INERTIA ON NEAR EARTH ASTEROID (162173) RYUGU USING MARA - THE MASCOT RADIOMETER

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1. Introduction

On October 3rd, 2018 the Hayabusa2 spacecraft [1] delivered the MASCOT lander [2] to the surface of near Earth asteroid (162173) Ryugu, where it operated for 17 hours and 7 min. Ryugu has a diameter of 850-880 m, a geometric geometric albedo between 0.045 ± 0.002 at 0.55 µm and is classified as a Cb taxonomic type [3]. During the surface mission, MASCOT investigated a site located at geophysical coordinates 22.22 ± 0.05°S, 317.26 ± 0.07°E using its magnetometer, near infrared spectrometer, optical camera [4], and radiometer [5].

The MASCOT radiometer MARA [5] obtained surface brightness temperature measurements at the site for a full day-night cycle. Because the scene observed by MARA was also imaged by the optical camera important context information was obtained. MARA observed a rock formation of approximately 60 cm diameter. The rock has a relatively rough surface and appears angular to subangular.

2. Data and Modelling

MARA obtained surface brightness temperature measurements in 6 wavelength bands, but only the 8-12 µm and >3 µm sensors have sufficiently high signal to noise for modeling nighttime temperatures. Surface brightness temperature uncertainties for these filters are estimated to be <2 K at the 2-σ level. The data obtained by MARA is shown in Fig 1a), where surface brightness temperature as determined using the 8-12 µm channel is shown in black together with the 2-σ uncertainty interval in gray

Surface temperatures have been modeled using an asteroid surface thermal model (ASTM) [6] solving the one-dimensional heat conduction equation for a given surface thermal inertia, albedo, emissivity, insolation, and thermal radiation from the surrounding terrain. Emissivity has been varied between 0.9 and 1 and insolation was varied to account for all possible orientations of the surface in the field of view. Re-radiation from the surroundings was taken into account by estimating the view factor to the surrounding environment, which radiates at temperatures assumed to be equal to the observed brightness temperature. View factors have been varied between 0and 0.08 as derived from a regional terrain model.

The best fitting thermal model is shown in red in Fig. 1a). While it is an excellent fit to the nighttime data it overestimates the daytime temperatures. Using a spherical crater roughness model [7] the modeled flux can be reduced to match the observation. However, for a thorough analysis of the daytime data, a detailed digital terrain model is necessary. We furthermore model the possible presence of a dust layer using a two-layer model with a low thermal inertia layer covering a higher thermal inertia layer (Fig 1b). However we find that even a very fine dust layer deforms the temperature evolution in a way that is incompatible with the observation, and the deformation increases with assumed rock thermal inertia.

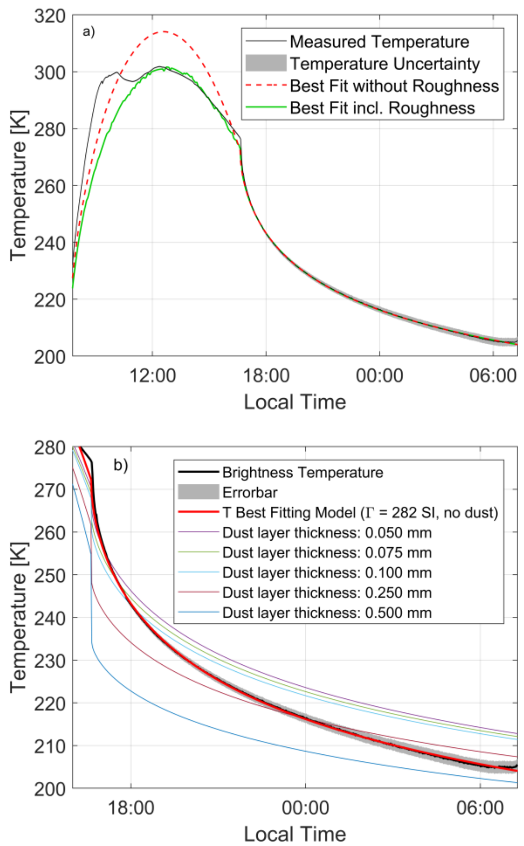

Figure 1: **a)** Surface brightness temperatures as a function of local time measured by the MARA 8-12 μm filter indicating the 2-σ confidence limits by shades. Best fitting thermal model is shown in red. **b)** Results for a 2 layer thermal model, a top layer of 25 J m^{-2} K^{-1} $s^{-1/2}$ with variable thickness and a bottom layer of 400 J m^{-2} K^{-1} $s^{-1/2}$

3. Results

Varying the surface orientation, emissivity, and re-radiation, the admissible thermal inertia ranges from 247 to 375 J m^{-2} K^{-1} $s^{-1/2}$, with a best fitting value of 282 J m^{-2} K^{-1} $s^{-1/2}$. These estimates represent a conservative upper limit for the thermal inertia as an emissivity lower than 0.9 or larger than assumed energy input from the surrounding terrain would result in even lower thermal inertia.

4. Discussion

The thermal inertia values determined here are compatible with prior global estimates derived from telescopic observations and the Hayabusa2 spacecraft [8,9], but much lower than expected from measurements on meteorites in our collections. Comparing the observed thermal inertia with models of thermal conductivity as a function of porosity [10,11], while assuming a heat capacity and grain density typical for C chondrites, we estimate the thermal conductivity of the observed boulder to be 0.06 and 0.16 W/mK a high porosity of 28 – 55 %. While Ryugu appears to be deficient of dust and a thermal model of a dust layer does not fit our observation, we cannot exclude that the high porosity zone is limited to an outer layer of the boulder. Yet, these in-situ results indicate that an asteroid with a relatively low thermal inertia of 200-300 J m^{-2} K^{-1} $s^{-1/2}$ can have surface dominated by large, highly porous boulders.

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