THERMAL IMAGER TO REVEAL SURFACE PHYSICAL STATE OF ASTEROIDS.

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Introduction: Thermal imaging is a powerful tool to investigate the physical state of planetary surfaces. The first high-resolution one-rotation global thermal images of an asteroid in history have been taken by the thermal infrared imager TIR on Hayabusa2 [1]. Highly porous nature of C-type asteroid 162173 Ryugu has been discovered [2-3]. In the ESA Hera mission, thermal imaging will reveal the surface physical state of the S-type binary asteroid Didymos for the first time [2]. Understanding the physical state of Apophis is essential to investigate the influence of earth impact and the effect of deflection by impact.

TIR on Hayabusa2: TIR is a thermal imager on Hayabusa2, based on uncooled micro-bolometer with 328 x 248 effective pixels and 16° x 12° field of view. It contributed to studying thermophysical properties of C-type asteroid Ryugu. From the Home Position, 20 km from the asteroid, high-resolution one-rotation global thermal image set has been taken on 30 June 2018 for the first time. Higher-resolution thermal image set has been taken on 1 August 2018, during the Mid-Altitude Observation Campaign from the altitude of 5 km, with the spatial resolution of 4.5 m per pixel. During the later stages of descent operations for touchdowns and its rehearsal operations, and for the release of the European small lander MASCOT and the twin hopping micro-rovers MINERVA-II, those thermal images of local areas but even higher resolution have been taken at several regions, from the altitudes of 500 m to 20 m. Close-up thermal images just before touchdown below the altitude of 10 m with the spatial resolution < 1 cm per pixel. We concluded that the C-type asteroid Ryugu are made of highly porous materials that originated from the fragments of porous parent body [2]. We discovered some boulders that have thermal inertia as high as dense carbonaceous chondrites, indicating their origin from the innermost consolidated region of the parent body[2].

TIRI Instrument: TIRI is a thermal imager for the Hera mission, based on uncooled micro-bolometer array with 1024 x 768 effective pixels, and 13.3° x 10° field of view, 4 times higher spatial resolution than TIR on Hayabusa2. TIRI is a one-box instrument, consisting of the sensor unit BOL and the electronics unit SHU, with the targeted specification of the total mass of 3.5 kg, the power of 17 W, and the envelope area 190 x 250 x 260 mm (main body of 150 x 180 x 230 mm). TIRI has the functions of thermal imaging with multi-band filters [3].

An eight-point filter wheel will be implemented on TIRI: one band for close (used as a shutter), one for a wide band (8-14 μm) for thermal imaging, and the other 6 narrow bands covering 3 bands in 8-10 μm for Christensen Feature (CF) and 3 bands in 10-12 μm for Reststrahlen Feature (RF). Color ratios of multi-bands informs on composition of materials such as SiO_2 abundance in silicates, and olivine to pyroxene ration of crystalline silicates and oxides.

In the Hera mission, TIRI and other instruments will observe the binary asteroid Didymos and its moon DImorphos to characterize their surface from the altitude of 30 to 20 km. Then the Hera will descend to the lower altitude of 20 to 10 km, to investigate the surface with higher spatial resolution. The spacecraft will go down to lower altitude to conduct close-up thermal imaging with higher spatial resolution, especially for the artificial crater formed by the impact of NASA DART spacecraft.

Science objectives of TIRI: The main objectives of the Hera mission regarding Planetary Defense are to obtain information on the effect of DART impact to Dimorphos by the observation of the dimension and the excavated materials of the artificial crater, and by the precise orbital determination. TIRI will contribute to the purposes by measuring the crater dimension, the sedimentation of ejecta, and the YORP (B-YORP) effect by constructing the thermophysical model.

TIRI will take thermal images of the binary to study their surface thermal inertia and to derive their porosity of boulders and surrounding sediments. Characterizing the materials of S-type asteroids is also the main target, by comparing C-type asteroid Ryugu. Dimorphos is the smallest body ever explored by the spacecraft and interested in its surface physical state (consolidated or not) for its low gravity field. Origin of the binary should be investigated by comparing the composition and physical state.

Future mission to Apophis: Surface physical state of Apophis is similarly a key information both for planetary defense and science, so that a thermal imager should be implemented in the future missions. Thermal imaging is also applicable to flyby mission, so that it is practical even for a low-cost small missions.

References: [1] Okada T. et al. (2017) *SSR.* 208, 255-286. [2] Okada T. et al. (2020) *Nature*, 579, 518-522. [3] Shimaki Y. et al. (2020) Icarus 348, 113835. [4] Okada T. et al. (2020) LPSC, #1355