SURFACE PHYSICAL STATE OF ASTEROIDS REVEALED BY THERMAL IMAGING. T. Okada¹, T. Fukuhara², M. Yoshikawa¹, and Hera-TIRI Team, ¹Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo, Sagamihara, 252-5210 Japan, okada@planet.isas.jaxa.jp, ²Rikkyo University, Tokyo, Japan.

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]. In Hera mission, thermal imaging of S-type binary asteroid Didymos is under study to investigate the surface physical state of S-type asteroid for the first time [3]. Understanding the physical state of Apophis is essential to investigate the influence of earth impact and the effect of deflection from impact.

TIR on Hayabusa2: TIR is a thermal imager on Hayabusa2, based on uncooled micro-bolometer with 328x248 effective pixels and 16° x 12° field of view. It was developed to investigate thermophysical properties of C-type asteroid Ryugu. From Home Position, 20 km from the asteroid, high-resolution one-rotation global thermal image set has been taken in 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 descent stages for touchdown and its reentry operations or for the release of the European small lander MASCOT and the twin hopping micro-rovers MINERVA-II, higher resolution but local thermal images have been taken at several areas, 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 pixels. We conclude that the C-type asteroid Ryugu are made of highly porous materials that originated from the fragments of porous parent body, and some boulders with typical thermal inertia of dense rocks might have originated from the innermost region of the parent body.

TIRI Instrument: TIRI is a proposed thermal imager for the ESA Hera mission, based on uncooled micro-bolometer array with 1024 x 768 effective pixels, and 10° x 7.5°, or 13° x 10°, indicating 5 or 4 times higher spatial resolution than TIR on Hayabusa2. TIRI is one-box instrument, consisting of the sensor unit BOL and the electronics unit SHU, with the targeted specification of the total mass < 5 kg, the power < 30 W, and the envelope area < 300 x 150 x 200 mm. TIRI has the functions of thermal imaging as well as thermal infrared multi-band imaging.

TIRI has a filter wheel for multi-band imaging, with 8 bands: one band for blank, the other band for clear (8-14 μm wide band) for thermal imaging, and the other 6 narrow bands covering 3 bands in 8-10 μm for Christensen Feature (CF) and 3 band in 10-12 μm for Reststrahlen Feature (RF). Color ratios of multi-bands indicate the composition of materials (such as SiO2 abundance in silicates, and olivine to pyroxene ration of crystalline silicates and oxides.

In Hera mission, TIRI and other instruments will observe the binary asteroid Didymos and its moon 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. Then the spacecraft will go down to the lower altitude of 10 to 5 km or lower to conduct close-up thermal imaging with higher spatial resolution.

Science objectives of TIRI: The main objectives of the Hera mission are to obtain information on the effect of impact to Didymo by DART by observing the dimension and the excavated materials of the artificial crater and the precise orbital determination, regarding planetary defense. 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.

Of course, TIRI will take the thermal images of Didymos and its moon for their surface thermal inertia, investigating the porosity of boulders and sediments. Characterizing the materials of S-type asteroids is also the main target, by comparing C-type asteroid Ryugu. Didymo 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 must be informed not only for science but for planetary defense by thermal imaging or the other methods in the future missions. Thermal imaging is applicable to flyby mission, so that it is very practical even for a low-cost mission.