Thermal Infrared Imager TIR on Hayabsua2 and Its In-Flight Performance using Earth-Moon Thermal Images.

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Thermal infrared imager TIR is a remote instrument on Hayabusa2 sample return mission from C-type near-Earth asteroid 162173 Ryugu, organized by Japan Aerospace Exploration Agency (JAXA) [1]. The instrument is based on the uncooled micro-bolometer array inherited from the Longwave Infrared Camera LIR on Akatsuki Venus Orbiter [2]. TIR is to observe thermal emission off the asteroid surface, and investigate its thermo-physical properties. We report here the results of in-flight performance of TIR, especially for observations of Earth and Moon.
TIR consists of the sensor unit (TIR-S) and the power supply unit (TIR-AE), along with the digital electronics (DE) for image data processing and the interface for telemetry and command. A couple of images are taken with its shutter open and close so that an effective thermal image is consequently derived by subtraction of these two images [3].
TIR covers its wide temperature from 150 to 460 K, meaning all the sunlit areas of Ryugu, and even the shadowed areas if the thermal inertia of the surface is higher than 50 [tiu = J m^{-2} $s^{-0.5}$ K^{-1}]). Field of view of TIR is 16.7° x 12.7° in horizontal and vertical directions with 328 x 248 effective pixels, with IFOV of 0.051° per pixel. This corresponds to about 17 m per pixel from the Home Position, 20 km altitude from asteroid surface. The closest view by TIR is about 1cm from the 10 m altitude during the final approach to touchdown [3].
Performance of TIR has been checked almost monthly. We controlled its temperatures by adjusting the setting points of Heater Control Electronics HCE of Hayabusa2 to investigate temperature dependency of TIR images. TIR observed the deep sky during the checks. TIR images have peripheral brightening due to thermal emission from the hood and optics of TIR. We found the lower detection temperature limit of TIR is about 150K. The effect of peripheral brightening is thoroughly reduced from TIR images by subtracting a deep sky image taken at the same temperature settings. TIR was mounted on the +Y panel of Hayabusa2 spacecraft and pointed to -Z axis. The -Z axis alignment of TIR was surveyed using the images of Earth and Moon taken before and after the Earth swing-by. Alignment of

TIR in -Z axis is checked relative to that of spacecraft, and proven within 1 or 2 pixels (0.05° or 0.10°) shifted in horizontal and vertical directions [4]. It was the unique opportunity for TIR to observe the Earth and Moon, which are the only targets with known thermo-physical properties in space before arrival at Ryugu. TIR images were taken a few minutes before the Optical Navigation Camera (ONC-T) to compare TIR and ONC-T images. In the Earth's images, Australian Continent is hotter than the surrounding ocean by 10 to 20 °C, the Antarctica is cold at around -45 to -40 °C, the southern Indian Ocean is about 0 °C. Clouds are about -45 to -30 °C. The Moon was imaged only 5 pixels in diameter, but the highest temperature can be estimated as 60 to 70 °C for the area at medium latitude. This is consistent with the estimated value for the area. The observations of Earth and Moon by TIR show that the surface temperatures are consistent with the estimated values. Thus we believe that thermal images by TIR are expected to make an essential contribution as planned for the exploration of asteroid Ryugu.

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