Detectability Performance of Thermal Infrared Imager TIR on Hayabusa2

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The thermal infrared imager TIR [1] onboard the JAXA’s second asteroid explorer Hayabusa2 is a thermal camera based on two-dimensional uncooled micro-bolometer array, inherited from the Longwave Infrared Camera (LIR) on Akatsuki (formerly PLANET-C) Venus climate orbiter [2]. TIR is to observe the thermal emission from the target body, C-type near-Earth asteroid 162173 Ryugu (formerly $1999JU_3$) to investigate its surface thermo-physical properties that are strongly related to representative grain size and porosity. Such information enables us to understand its formation process and surface evolution processes. The data from TIR will be used to select the landing sites for sample collection and for the surface lander and rovers both from scientific and technical viewpoints. Typical grain size derived from the thermal inertia map determined by TIR data is scientifically essential to select the suitable sites for collection by the sampling device and for the analysis of returned samples. Typical boulder abundance and predicted thermal environments are technically essential for safety and hazard-free landing operations.
TIR has been checked in flight by observations of the deep sky as backgrounds, and of the Earth and the Moon as known targets during the Earth swing-by operation campaign. The first and longest distance observation of the Earth and the Moon was carried out on 14 October 2015, at about 2×10^7 km from the Earth. There were opportunities that TIR observed the Earth and the moon 7 times before and 18 times after the Earth Swing-by on 3 December 2015. During that period, the distance changed by two orders of magnitude, and the distance dependency of TIR response is now derived for the thermal brightness of the Earth and the Moon. The dependency is inversely proportional to the square of distance, for the diameter of the Moon corresponding to 0.2 to 6 pixels of TIR images. From this trend, the detection limit (> 10 DN for the target body) is at about 1.5×10^8 km for the Moon [3].
This result indicates the possible detection of unknown asteroids closely passing by the Hayabusa2 spacecraft. For the 100 m sized asteroid of C-type (its geometric albedo ~ 0.05), the detection limit (> 10 DN) is estimated about 2×10^3 km from the spacecraft. During April to June in 2017, Hayabusa2 will be around the L5 point of the sun-earth Lagrange point, gravitationally meta-stable point, so that unknown

small bodies may be detected if they pass within such a distance. Before arrival at asteroid Ryugu which is of rounded shape and with diameter of 0.88 km, it will be detected at 1.5×10^4 km distance. Ryugu will be investigated during the approach phase and its light-curve of brightness temperature will be investigated before arrival. Around Ryugu, TIR is estimated to detect small moons encircling Ryugu at Home Position (20 km from the target asteroid) if they have diameter larger than 1 m, and their orbits are traced by continual imags taken with TIR.

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References

[1] Okada T. et al. (2016) Space Sci. Rev. doi:10.1007/ s11214-016-0286-8.
[2] Fukuhara T. et al. (2011) *Earth Planets Space,* 63, 1009-1018.
[3] Okada T. et al. (2017) Lunar Planet. Sci. Conf. 48, #1818.

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