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New Version of HEAT: Calibration and Visualization Tool for Thermal Imagers on Hayabusa2 and Hera

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Abstract

The **Hayabusa2/Hera Exploration Assistant for Thermal Imagers (HEAT)**, originally developed by Endo et al. (2017) [1], is a state-of-the-art scientific tool designed to analyze the thermal properties of asteroids. Building on previous work, such as Okada et al. (2020) [2], HEAT processes TIR data products from Hayabusa2 and will support TIRI data for respective science teams. Hayabusa2 data products are publicly available via JAXA (DARTS) [3] and NASA (PDS) [4], while Hera data products are accessible through JAXA and ESA.

HEAT offers four core functions: **Database, Conversion, Calibration, and Visualization**.

- **Hayabusa2** explored the asteroid **Ryugu**, returned samples to Earth, and is now targeting **2001 CC21** and **1998 KY26** for additional analysis to further our understanding of early solar system materials.
- **Hera** will study the binary asteroid system **Didymos-Dimorphos**, following NASA's DART impact, to evaluate asteroid deflection techniques for planetary defense

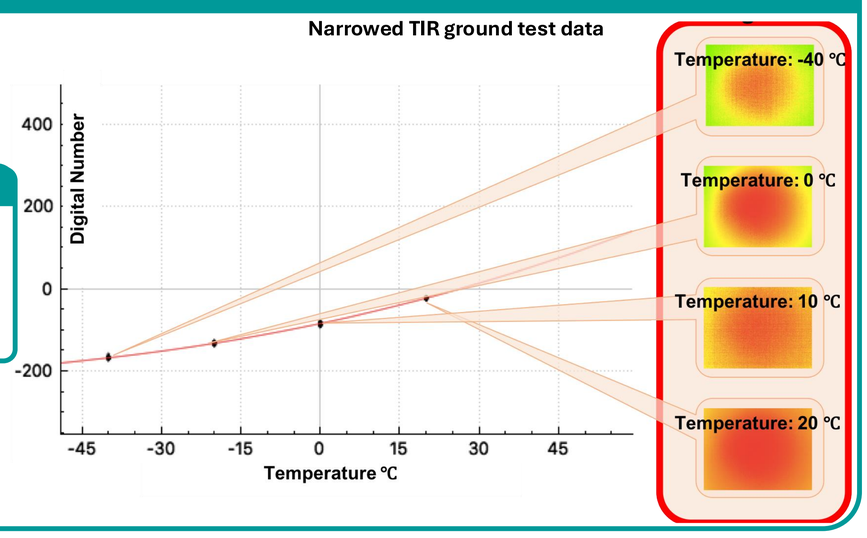
Calibration

The calibration process involves performing regression analysis on ground test data using the blackbody radiation function. Ground tests are conducted under various conditions, and the data is selected based on the observation conditions. Calibration formulas are then created to derive the calibration coefficients, A and B. These coefficients are used to convert digital numbers (DN) into temperature or radiance. The conversion is performed pixel by pixel on images captured by TIR/TIRI, which results in a lengthy processing time.

Calibration Function

$$DN = A \times F(T) + B$$

DN: Observed value of TIR
F(T): Energy flux
A, B: Calibration coefficient in the fitting

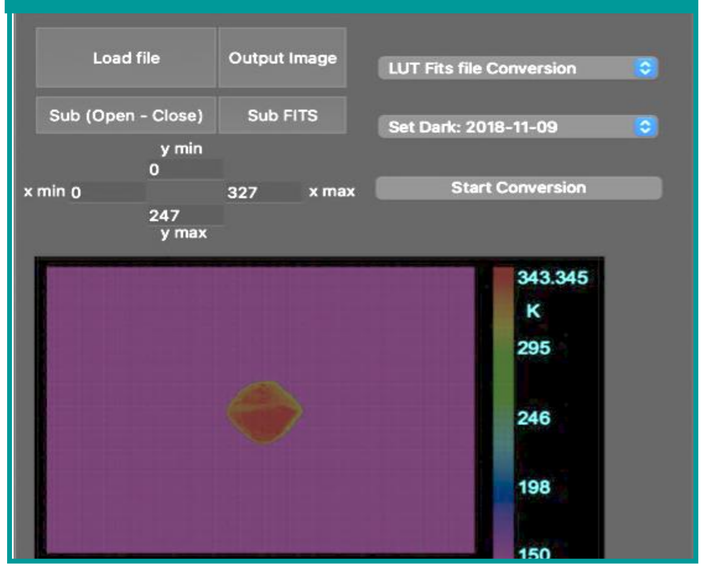


Conversion

The HEAT conversion function serves three primary functions for processing raw TIR data from Hayabusa2

1. **Pixel Coordinate Conversion**: This step adjusts the pixel coordinates of TIR and TIRI data to create calibrated images
2. **Temperature Corrections**: HEAT applies a series of temperature corrections to address variations specific to the instrument
3. **Size-of-Source Effects (SSE) Correction**:
   The SSE occurs owing to the scattering and diffraction of thermal radiation within the optical component

Conversion panel



Data Base

The database functionality is designed to manage **TIR** and **TIRI** ground test data effectively It consists of two interconnected table types:

1.Ground Test Data Table

1.Stores metadata about each test file.
2.Includes the file name and instrument temperatures for TIR and TIRI

2.Pixel Table

1.Contains detailed pixel-level data
2.Includes the file name, pixel coordinates, and DN (Digital Number) values

Visualizaton in 3D

The algorithms for data enhancement and depression detection, it is used: Laplacian smoothing and Curvature flow

Laplacian smoothing

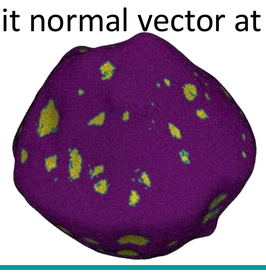
$$V_i' = V_i + \lambda \sum_{j \in N(i)} (V_j - V_i)$$

- *V*i and *V'*i represent the original and updated positions of Vertex i
- λ controls the smoothing intensity
- N (i) denotes the set of neighboring vertices of i

Curvature flow

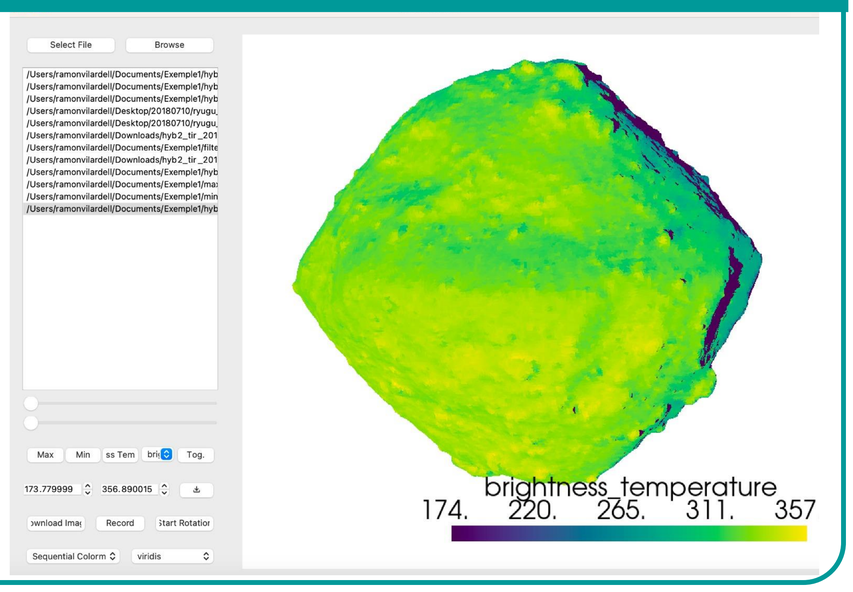
$$V_i' = V_i + \lambda H_i \mathbf{n}i$$

- *V*i and *V'*i represent the original and updated positions of vertex i
- λ controls the curvature flow rate
- *H*i represents the mean curvature at Vertex i
- ni is the unit normal vector at Vertex i



Visualizaton in 3D

The Tool allows for customizable 3D visualization with options like color map selection, model smoothing, and curvature analysis to identify features such as depressions and craters. It also offers interactive features like rotating, recording, and exporting models, as well as downloading mesh files for further analysis.



References: *[1] Okada+, Nature, Volume 579, Issue 7800, p.518-522 (2020) doi: 10.1038/s41586-020-2102-6*
[2] "DARTS", https://data.darts.isas.jaxa.jp/pub/hayabusa2/ tirbundle/browse/
[3] "PDS Small bodies Node, Asteroid/Dust Subnode", https://sbn.psi.edu/pds/resource/hayabusa2/tir.html
[4] Endo+ 2017 IEEE Aerospace Conference,pp. 1-10 (2017) doi: 10.1109/AERO.2017.7943827