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Multi-wavelength quantification of Io's volcanic heat flow from *Galileo* NIMS data

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Abstract

Funded by NASA's PDART Program, we are systematically processing all Io data obtained between 1996 and 2001 by the *Galileo* spacecraft Near Infrared Mapping Spectrometer (NIMS) [1]. We are deriving at-surface leaving radiances in the range 0.7 to 5.2 µm for over 1000 detections of thermal emission from Io's active volcanoes. The resulting products will be made available via NASA's Planetary Data System (PDS). Here, we report on progress in processing all suitable NIMS Io "tube" products to identify, process, and model thermal emission from Io's volcanoes.

1. Introduction

Galileo NIMS data contain the highest spatial and spectral resolution data of thermal emission from Io's active volcanoes [2] but historically have been hard to access and process. Recently, data access has been improved [3]. Now, by generating fully processed NIMS hot spot spectra, we will ensure wider planetary community access to an invaluable resource: an extensive set of Io's volcanic thermal emission spectra.

1.1 *Galileo* NIMS data

NIMS was particularly well suited to observing thermal emission from ongoing or recent high-temperature (silicate) volcanic activity [2]. The NIMS wavelength range (0.7 to 5.2 µm) meant that it was sensitive to a wide range of surface temperatures (>1000 K to ~220 K) and lava surface exposure times (seconds to days) [4]. A detailed description of NIMS Io data is found in [2]. Each NIMS product contains valuable metadata (range to target, observation time, emission angle, etc.) and each is available from the NASA Planetary Data System. NIMS Io data have a wide range of spatial resolutions, a function of range to target. Most tube data have spatial resolutions from ~100 to ~400 km/pixel. Temporal resolution of individual targets was also highly variable. During *Galileo* orbit E4, the Loki Patera region was observed 15 times in less than a day [5]. On some other orbits only single observations of Io were obtained. The maximum number of wavelengths was 408. From October 1999 wavelengths were restricted to 12 or 15 distributed across the NIMS wavelength range. These latter data are still suitable for temperature fitting. Io longitudinal coverage was highly variable over the course of the mission, with most regional (resolution ~100-300 km/pixel) and global observations (>300 km/pixel) of the anti-Jovian hemisphere.

1.2 Processing data: "tubes" and "cubes"

The NIMS Io dataset in the PDS can be summarized as follows: 190 NIMS Io "tube" observations of spectral radiance were obtained and converted into 181 "cube" products. NIMS tube hot spot data for sub-pixel sources are processed by adding spectra from two adjacent pixels (see Figure 1) in the mirror sweep direction (along a single line) to account for the NIMS point-spread function. A tube includes a 50% swath overlap, and contains accurate, unaltered radiance values. The swath overlap is removed during generation of cube products, which are re- navigated and contain the most accurate hot spot location data.

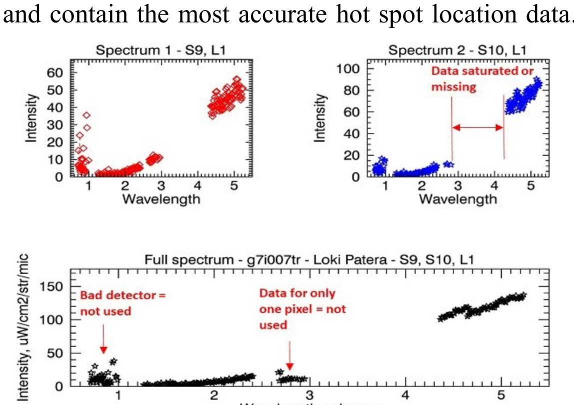

Figure 1: Example of a PDART interim product: the addition of NIMS "tube" radiance spectra (g7i007tr) of Loki Patera. The added spectrum, once anomalies are removed, is used to derive spectral radiances, temperatures, areas, and power output (see [5]).

As the cube production process includes averaging radiance values from adjacent pixels in line and sample space, the resulting radiance values should not be used for quantifying thermal emission from sub-pixel sources without considerable care, which is why new, robust products are desirable. A recent analysis [6] that exclusively used cube data for extracting 3.5 µm spectral radiances underestimated the spectral radiances from Io's most powerful hot spots – Loki Patera [5] (Figure 2), Pele and Pillan [7], and Amirani [8] (Figure 3) – by up to five orders of magnitude. This was, in part, due to the incorporation of saturated (null value) 3.5 µm data. For many volcanoes, [6] generated uncertainties that are in part due to the presence of spectral anomalies caused by (for example) boom hits. The 3.5 µm radiances in [6] are often smaller, and uncertainties larger, than those previously extracted from the NIMS observations [e.g., 5, 7-9] and from InfraRed Telescope Facility (IRTF) observations [10].

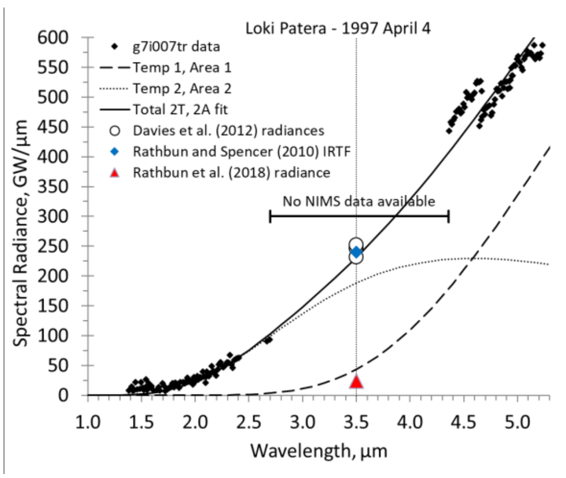

Figure 2: 2-Temp, 2-Area fit to partially-saturated NIMS "tube" data (interpolated to 3.5 µm) of Loki Patera by [5]. Blue diamond = contemporaneous IRTF data [10]. Red triangle = result from [6].

2. Production workflow

Given the variability of spectra in the NIMS dataset, with varying numbers of wavelengths, different amounts of radiation noise, other artifacts such as boom hits and excessive jitter (as examples), and effects of instrument degradation, there is no "one size fits all" methodology for fitting even nighttime data. We have instead separated the data into different classes based on their complexity and presence of anomalies and have developed a production workflow for each class. These spectra will enable robust estimates of thermal emission, tightly constraining model fits to the data. An existing database of 4.8 and 5 µm spectral radiance data (NITED – e.g., [5]) has been imported into an Interactive Display Language (IDL) structure and the full NIMS Io data collection has been ingested into IDL data structures. The entire production workflow is within the IDL environment, with results written into other IDL data structures. This allows the results to be written into any desired format for ingestion into PDS4 products, as defined using the latest PDS standards and XML product templates [11]. We are working closely with staff at the PDS on product design in order to streamline final product generation. At all stages of the workflow, careful checks are made to ensure the products generated at that stage are accurate.

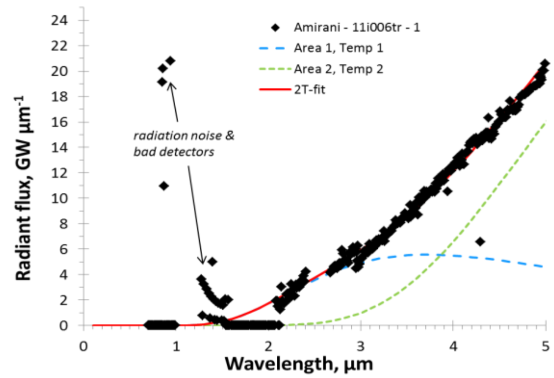

Figure 3. A 2-Temp, 2-Area fit to a NIMS Amirani spectrum obtained on 1997 Nov 7 (11i006tr) [8]. There are some problematic, anomalous data: these require careful identification and processing.

Acknowledgements

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