

**COMPARISON OF TIDAL DISSIPATION MODELS TO GLOBAL DISTRIBUTION OF ACTIVE IONIAN VOLCANOES FROM GALILEO PPR AND NEW HORIZONS LEISA.** J. A. Rathbun<sup>1</sup>, and J. R. Spencer<sup>2</sup>, <sup>1</sup>Planetary Science Institute (1700 E. Fort Lowell, Tucson, AZ 85719 [rathbun@psi.edu](mailto:rathbun@psi.edu)), <sup>2</sup>Southwest Research Institute (1050 Walnut St., Suite 400, Boulder, CO 80302, USA).

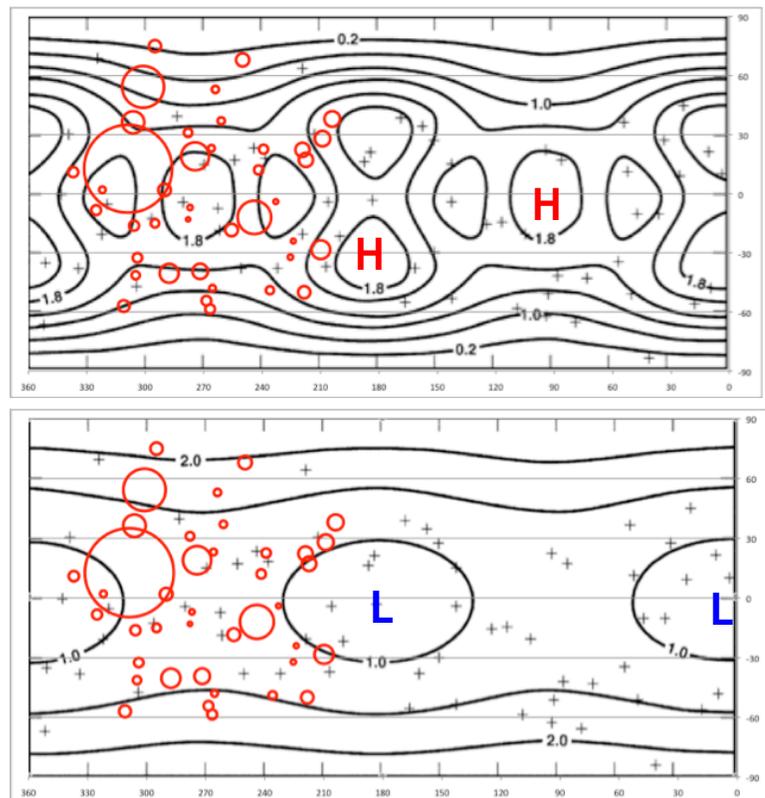
**Introduction:** Tidal heating is the major contributor to active surface geology in the outer Solar System, and yet its mechanism is not completely understood. Io's volcanoes are the clearest signature of tidal heating and measurements of the total heat output and how it varies in space and time are useful constraints on tidal heating. [1] compared the locations of hotspots detected by the Galileo Near-Infrared Mapping Spectrometer (NIMS) to the spatial variation of heat flow predicted by two end-member models. They found that the distribution of hotspots is more consistent with the heating occurring in the asthenosphere rather than the mantle. [2] also demonstrated that clustering of hotspots supports a dominant role for asthenospheric heating. Current measurements of the strength of tidal heating [3,4,5] are more than twice as large as the upper limit modeled [6], suggesting that Io's heat flow varies over time. Only [5] have attempted to investigate the temporal variability of the heat flow.

Most previous studies were limited by available data to considering each volcano equally. However, measurements of heat flow and power output from individual Ionian volcanoes from the Galileo Photopolarimeter-Radiometer (PPR) [3], NIMS [7,8], and ground-based telescopes [9,10] vary by several orders of magnitude. Each of these volcanoes, then, is an expression of different amounts of heat being transported to Io's surface. Furthermore, these earlier studies looked at all hotspots observed on Io, regardless of the time the hotspot was observed. Since volcanic activity varies on Io, using all known active volcanoes may not represent the actual heat output at one time.

More recently, [11] examined the thermal emission from 240 volcanoes to quantify the magnitude and distribution of their volcanic heat flow. They found peaks in thermal emission at 315 W and 105 W with a minimum at 200 W, suggesting a shift to the east from predicted heat flow due to tidal heating in the asthenosphere. Howev-

er, many of the thermal emission quantities they use are model dependent.

**PPR:** Because it is sensitive to long wavelengths, where most heat is radiated, the PPR dataset is the only dataset that can be directly compared to tidal dissipation models without any assumptions. [3] present measurements for approximately one hundred volcano observations. We compare these powers directly to the heat flow predictions of [12]. This direct comparison, while not global, makes no assumptions and uses only direct measurements. Figure 1 is a preliminary comparison of these data, showing the power output measured by PPR with circle area proportional to power,



**Figure 1: Locations of hotspots detected by PPR (red circles) and from NIMS during the early phase of the Galileo mission (plus signs; [1]) overlaid on the end-member model heat flows from [12]. The area of the circles indicate the average power output measured by PPR. These figures demonstrate that the nighttime PPR data favor the asthenosphere model of heat flow (top) and do not match the mantle heating model (bottom). An H indicates an area with high heat flow and an L indicates low heat flow.**

overlaid on end-member model heat flows from [12] with plus signs indicating Galileo NIMS observed hotspots [1].

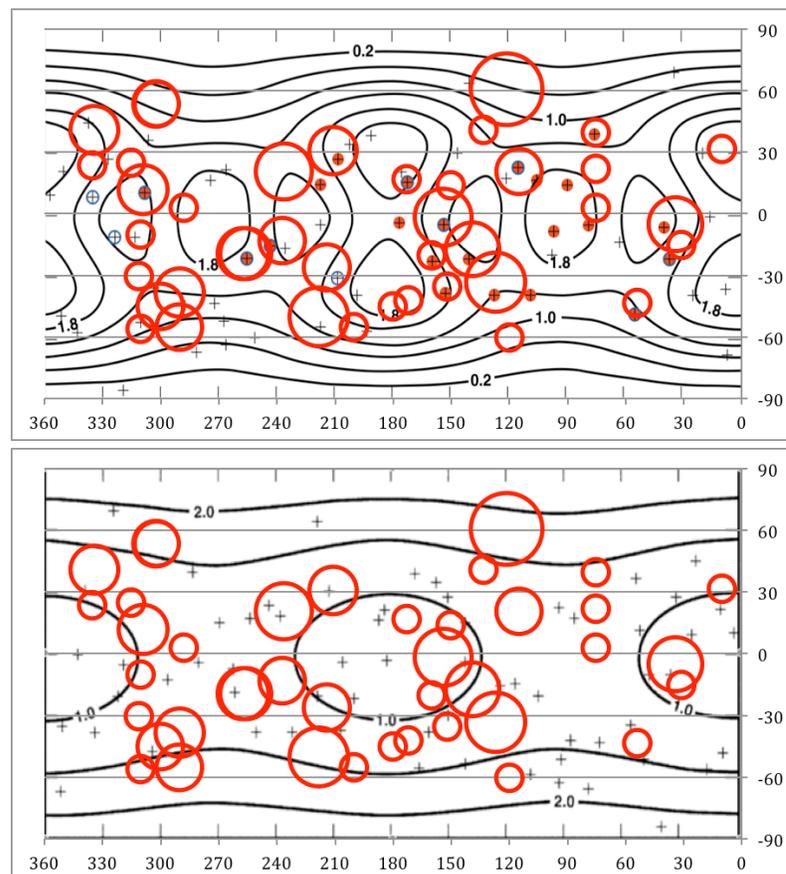
**New Horizons LEISA:** On its way to Pluto, the New Horizons spacecraft flew by the Jovian system and returned data on the Ionian volcanoes. New Horizons made its closest approach to Io at 21:57 UT on February 28, 2007, though observations were made from February 24 through March 4. Observations were made at phase angles from  $5^\circ$  to  $159^\circ$ , and two eclipses of Io by Jupiter were also observed [13]. The Linear Etalon Infrared Array (LEISA), a short-wave IR spectral imager, obtained seven 1.25-2.5-micron image cubes [13].

The New Horizons observations have much more consistent longitudinal coverage of Io than the Galileo instruments had. Because of orbital and instrumental constraints, Galileo PPR observed primarily the sub-Jupiter hemisphere [3] and Galileo NIMS primarily the anti-Jupiter hemisphere [14], so no single Galileo instrument has the longitudinal coverage of New Horizons LEISA. However, since LEISA covers a much shorter wavelength range, it is sensitive only to recent volcanic eruptions and might not be as good a tracer of heat flow.

[15] determined the location of all hotspots in the LEISA images and determined the brightness, temperature, and area, for those that were bright enough to do so. Figure 2 shows a comparison of the total output power output, calculated from those temperatures and areas, with the same heat flow models in figure 1. For those hotspots observed, but too faint to determine a temperature and area, we assume a power output of 10 GW (smaller red circles).

**Conclusions:** While figures 1 and 2 show the available data compared to the tidal heating models, they are difficult to interpret and cannot be used to quantitatively determine which model is a better match. We will construct heat flow maps for each data set by dividing the total power within a given region by the area of the chosen region. We will test three different region definitions: a simple binning by latitude and longitude into  $\sim 20$  degree square bins; defining regions based on the tidal heating prediction maps of [12]; and spherical harmonics.

**References:** [1] Lopes-Gautier, et al. (1999) *Icarus*, 140, 243-264. [2] Hamilton, C. W., et al. (2013) *Earth Planet. Sci. Lett.*, 361, 272-286. [3] Rathbun, J. A., et al. (2004) *Icarus*, 169, 127-139. [4] McEwen, et al. (1996) in *LPSC Abs.*, vol. 27, p. 843. [5] Veeder, G.J., et al., (1994) *J. Geophys. Res.* 99, 17095-17162. [6] McEwen, A.S., et al. (2004) In *Jupiter: The planet, satellites and magnetosphere*. F. Bagenal, et al. Eds. [7] Davies, A.G., et al. (2006) *Icarus*, 184, 460-477. [8] Davies, A. G. et al. (2012) *Geophys. Res. Lett.*, 39, doi:10.1029/2011GL049999. [9] Rathbun, J.A., Spencer, J.R. (2010) *Icarus*, 209, 625-630. [10] dePater, I., et al. (2014) *Icarus*, 242, 365-378. [11] Veeder et al.



**Figure 2:** Similar to Figure 1, showing locations of hotspots detected by LEISA (red circles) including the early NIMS observations and overlaid on tidal heating models.

(2012) *Icarus*, 219, 701-722. [12] Ross, M.N., et al. (1990) *Icarus*, 85, 309-325. [13] Spencer, J.R., et al. (2007). *Science*, 318, 240-243. [14] Lopes, R. M. C., et al. (2004) *Icarus*, 169, 140-174. [15] Tsang, C. C. C., et al. (2014) *J. Geophys. Res.*, 119, DOI: 10.1002/2014JE004670.