MODELING IO'S HEAT FLOW: CONSTRAINTS FROM GALILEO PPR. J. A. Rathbun, J. R. Spencer, *Lowell Observatory, Flagstaff AZ 86001, USA (rathbun@lowell.edu)*, L. K. Tamppari, *Jet Propulsion Laboratory, Pasadena CA 91109, USA*.

Only months after the proposal that major amounts of tidal heating occur on Io [1], the existence of such heating was spectacularly confirmed when the Voyager spacecraft observed active volcanoes on Io. However, the magnitude of the heat flow calculated from tidal dissipation models is much smaller than more direct measurements of Io's heat flow. The steady-state heat flow derived from tidal dissipation models consistent with orbital observations is less than ≈ 1.0 W/m^2 [2] while values based on surface radiance range from 1.85 to 3 W/m^2 [3]. Recently, Veeder, et al [3] found the heat flow from Io's hot spots to be 2.5 W/m^2 with the majority of the contribution from hot spots with a temperature of less than 200 K. These cooler hot spots have a larger areal extent than the hottest hot spots and, therefore, contribute more to the planetary heat flow. Here, we attempt to improve on previous heat flow estimates with higher resolution data, from the Galileo photopolarimeter-radiometer (PPR) instrument, and improved thermophysical models of the surface (table 1).

There are two components to Io's surface heat flow to consider when modeling: the heat radiated from the hot spots and the solar heat reradiated from the background surface. In earlier treatments, the background heat was approximated implicitly assuming either a null or infinite thermal inertia [3, 4, 5, 6]. This approximation can be improved by treating the surface thermophysically with a realistic, finite, thermal inertia. Our model includes thermophysical heat flow and subsurface penetration of sunlight [7]. At each time step and at each depth, the heat flow equation is solved for the temperature at the particular time and depth with an additional term for incident sunlight.

The heat radiated from the hot spots depends not only on their temperature and areal extent, but also on the time of day at the hot spot [3]. Early treatments ignored the solar contribution to the hot spot's temperatures, but Veeder et al showed that this so called "thermal pedestal effect" is important for the lower temperature hot spots. However, they assume zero thermal inertia in their calculations of this effect while a more realistic thermal inertia will decrease the effect on daytime temperatures (fig. 1).

We model the surface heat flow to match the observed thermal emission from Io. The first step is to calculate the background temperatures. This depends on the albedo, emissivity, thermal inertia, density and specific heat of each point on the surface (which we regard as fixed in time), and the heliocentric distance of Io and the subsolar point (which change from observation to observation). From these temperatures the total thermal emission can be calculated. Second, the thermal emission from the hot spots must be calculated. The temperature and areal extent of each hot spot is expected to change over time. Veeder et al found that 11 hot spot components from 5 different hot spots were necessary to match their groundbased data. They changed the temperatures and extent of these components on a yearly basis and found that significant changes occur on this timescale. The temperatures of the hot spots also changes daily due to the thermal pedestal effect. This effect depends on the albedo of the hot spot which they found to be different for most of the 11 components [3].

We further improve on existing models by modeling a disk-resolved intensity. Previous models and most ground-based observations yield only disk-integrated intensities and thus have no latitudinal information. Much of our PPR data is disk-resolved, so this refinement to the modeling is necessary to get the most information from the data. For every latitude and longitude the background temperature and resulting thermal emission is calculated. For each hot spot, its temperature and radiance are also calculated. The resulting latitude longitude maps of radiance are then remapped to an orthographic projection which simulates the viewing geometry and resolution of any observation.

In addition to previously published data [3, 8] with which our model must be consistent, Galileo PPR data provides new observational constraints on Io's heat flow. PPR obtained maps of Io's daytime and nighttime thermal emission with low spatial resolution during the nominal mission: these will mostly provide measurements of disk-integrated emission at phase angles not obtainable from Earth. During the extended mission PPR has mapped Io with sufficient resolution to spatially separate passive and volcanic thermal radiation, and on orbit I25 PPR obtained a 300 km resolution near-global map of nighttime thermal emission which will be of particular importance for constraining heat flow.

The model parameters are the albedo, thermal inertia, emissivity, density and specific heat of the surface, which can vary with latitude and longitude, and the temperature and areal extent of the hot spot components, which change with time. We will use a bolometric albedo map [9], and improved Galileo maps, to define surface units within which surface parameters will be constant. Hot spots will be defined initially using published temperatures and areas [3, 10] and changed as needed to match the observations. The heat flow from Io can be calculated simply by summing the power from each hot spot, so the heat flow as a function of time will be the final result of the modeling.

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Table 1: List of major features of our thermophysical model.

Property	Why it is necessary
disk-resolved	Some PPR data is disk-resolved
finite thermal inertia	Previous models assumed 0 or inf
thermophysical pedestal effect	Previous models either ignored pedestal effect or treated it with 0 thermal inertia

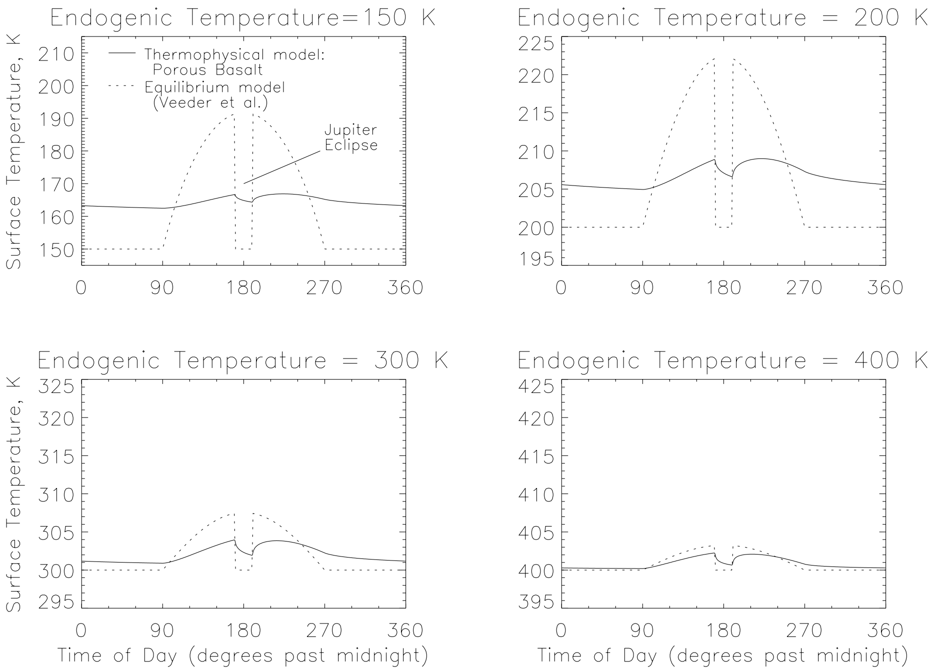

Figure 1: Temperature at a hot spot as a function of time of day, illustrating the “thermal pedestal effect”. Different plots are for different “endogenic temperatures” of hot spots (temperature in the absence of sunlight). In the equilibrium model [3] with an implied 0 thermal inertia (dotted lines) the effect is large while with a finite thermal inertia (solid lines) the effect is smaller during the day and large at night and during eclipse.