IO: THE DARK PATERAE COMPONENT OF HEAT FLOW.

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Introduction: Io is the most volcanically active body known in our Solar System. The global heat flow of Io derived from *Voyager* IRIS, IRTF and *Galileo* PPR far infrared observations is much more than predicted from tidal dissipation models [*e.g.*, 1-8]. The ground-based and spacecraft data sets compliment each other. Ground-based IRTF observations measure the daytime and eclipse hemispheric emission, span a decade in time and cover all longitudes of Io [5]. Spacecraft data yield high resolution snapshots of Io's stronger infrared sources; but without global coverage. *Galileo* NIMS highlights near infrared hot spots [*e.g.*, 9, 10]. *Galileo* SSI detected very hot spots in the visual during eclipse [*e.g.*, 11, 12]. *New Horizons* and Keck infrared observations have yielded additional data [13-16].

Global heat flow accounting. Loki Patera and other strong thermal emission sources associated with large paterae on Io have been mapped in the far infrared by *Galileo* PPR [6, 7]. Some of these detections were not quantified. In addition, other small (probably active) dark paterae were scanned by PPR, but no far infrared sources were detected.

We have examined relevant SSI images, measured the areas of dark material within dark paterae and compared these areas with mapped geologic units [*e.g.*, 17-21]. Within the context of an appropriate thermal model, these areas permit the calculation of effective temperatures. The *Galileo* SSI size distribution of paterae extends beyond the limiting spatial resolution of the infrared observations. Thus, SSI images and maps enable the construction of a thermal model to allow for small dark paterae. Moreover, a detailed model can make the important distinction between dark paterae associated with *Galileo* NIMS and SSI hot spots outside of the PPR map and dark paterae without any observed thermal emission.

Large Dark Paterae: Much of the heat flow from Io is from a few tens of relatively large, active paterae. Loki Patera, the most powerful volcanic heat source on Io, contributes approximately 10% of Io's total heat flow from much less than 1% of Io's surface [5-8]. The dark material within Loki Patera, a possible magma 'sea', has an area of ~21,500 km^2 and average model power of ~9.6 10^{12} W [8], within the range of power observed by *Galileo* PPR [6,7]. For comparison, Dazhbog Patera is the second most powerful volcanic heat source on Io. The dark material within Dazhbog Patera has an area of ~9,000 km^2 [21] and observed PPR average power of ~4 10^{12} W [7].

Small Dark Paterae: We have identified ~15 small dark paterae not detected within the region mapped by *Galileo* PPR and more than 100 (both small and large) outside this area from *Voyager* and *Galileo* data. We have inspected these dark paterae individually using the Io global mosaic created from the best imagery [17] and additional high resolution image data. Our database of dark paterae also includes those detected but not quantified by PPR and we have estimated the areas of dark material associated with each patera [*e.g.*, 18-21]. These areas of dark volcanic material range in size down to less than 100 km^2 [20]. The dark paterae considered in this work are shown in Figure 1.

Spatial Distribution of Dark Paterae: The visual images and mosaic maps of Io can be used to correct for the limited sampling of the *Voyager* IRIS and *Galileo* PPR infrared observations. Previous literature has discussed the bimodal number density of paterae and volcanic centers with respect to position [*e.g.*, 20-23]. Coincidently, Dazhbog Patera is located at a longitude near Loki Patera and thus must make a significant contribution to the observed hemispheric IRTF thermal infrared emission [*cf.*, 5, 16].

The distribution of areal density of dark material is needed for the refinement of our global thermal model. We have selected 130 dark paterae for further analysis. As expected, the areal distribution in longitude of dark material within paterae is bimodal. However, the areal surface density of dark paterae appears to be independent of latitude. The total area of dark volcanic material in other paterae (excluding Loki Patera) is ~126,500 km^2 equivalent to about six times the area of Loki Patera's dark floor. Thus, our model dark paterae (including Loki Patera) cover ~148,000 km^2 or ~0.4% of Io's surface; slightly less than the total of 0.5% for mapped 'dark patera floor' (pf$_d$) geologic units [24].

Global Heat Flow: A number of volcanic components with different properties have been identified on Io implying that different processes are at work [25-28]. For example, we have previously quantified the heat flow contribution made by large dark volcanic fields [29]. Dark volcanic fields have a single maximum in their longitudinal distribution; but dark paterae have a bimodal distribution of their heat flow.

Conclusions: The infrared observations of Io show that the thermal emission comes from a variety of sources. We have identified several dark paterae not detected within the *Galileo* PPR map. The total area of dark paterae and their surface distribution is constrained by global mosaics from *Voyager* and *Galileo* images. Altogether, dark paterae are the most significant component of the heat flow on Io. Other dark paterae yield somewhat more heat flow than either Loki Patera itself or large dark volcanic fields. Separate and detailed accounting for the thermal emission from each class of heat sources on Io within a global thermal model helps to clarify the different contributions to Io's global heat flow.

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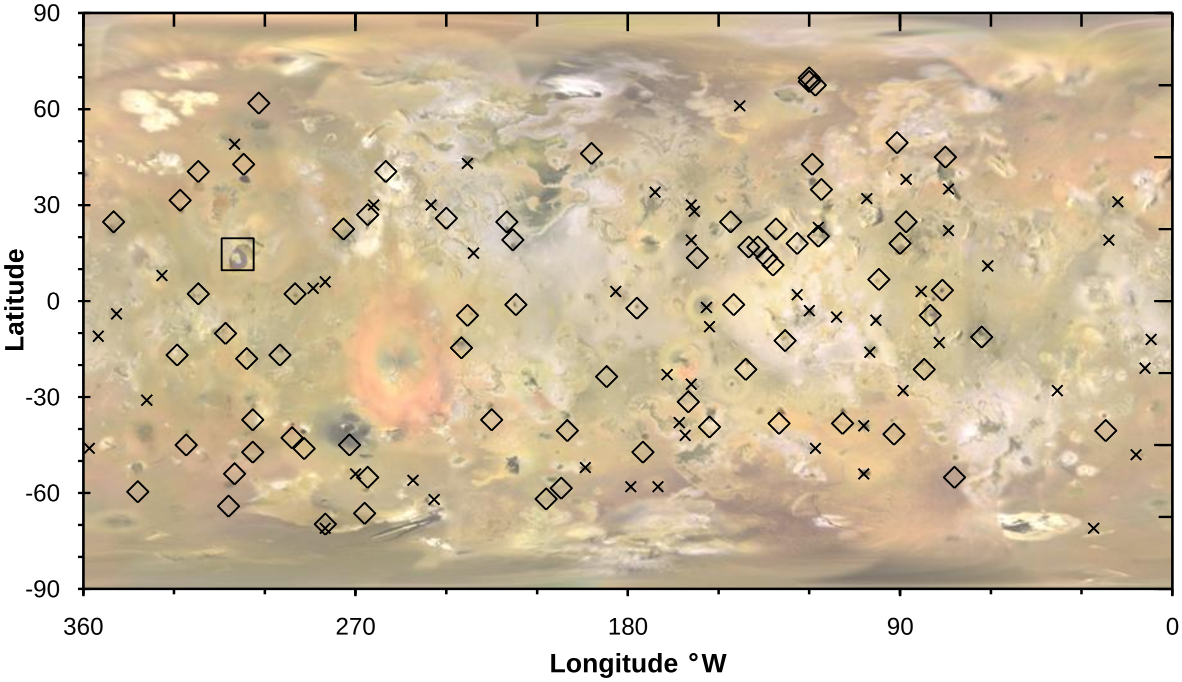

Figure 1: Locations of ionian paterae with dark floors incorporated in this study. Key: Square = Loki Patera. Diamond = active volcanic source. Cross = low temperature thermal source.