Surface alteration of Saturn's icy satellites by high-energy electron bombardment. C. J. A. Howett[1], J. R. Spencer[1], C. Paranicas[2] and P. Schenk[3], [1]Southwest Research Institute, Suite 300, Boulder, Colorado 80302, USA., *howett@boulder.swri.edu*, [2]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, Maryland 20723, [3] Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, Texas 77058, USA.

Introduction: In 2010 Cassini had its closest fly-by of Saturn's innermost classical icy satellite, Mimas. Mimas' surface temperatures, as derived from observations made during this flyby by Cassini's Composite Infrared Spectrometer (CIRS), showed an abrupt change in Mimas' surface temperatures: a sharp V-shaped boundary (~15 km wide), with an apex centered close to the anti-Saturn point, separates warmer and ~15 K cooler daytime surface temperatures on Mimas' leading hemisphere (Fig.1). The anomaly, due to its shape similarity with the 1980's video icon, was dubbed "Pac-Man". Subtle differences in surface color had previously been observed in the same region [1], however the visible albedo inside and outside of the anomalous region appears to be similar [Fig. 1]. We used a 1-D thermal model [2], additionally constrained by CIRS nighttime temperature mapping, to show that changes in Mimas' surface inertia are responsible for the observed surface temperature variation [3].

Thermal anomalies on Tethys and Dione: Subsequently to the discovery of the thermal anomaly on Mimas another as been discovered on Tethys [4]. The thermal anomaly on Tethys has a similar shape to that of Mimas, occuring at low latitudes on Tethys' leading hemisphere [Fig. 1]. However, Tethys' thermal anomaly covers a smaller latitudinal extent than Mimas'. Further analysis has shown that the cause of both the Tethys and Mimas thermal anomalies is the same: an abupt increase in its surface thermal inertia.

Our mapping of Dione's surface temperature, as derived from CIRS observations, does not show any dramatic variations across the surface, unlike Mimas and Tethys. However, recently produced maps of Dione's thermal inertia do show a slight increase at low latitudes on its leading hemisphere. The region, shown in Fig. 2, is more strongly confined to equatorial latitudes than both Mimas and Tethys.

Surface Alteration: The anomalously high thermal inertia regions on Mimas, Tethys and Dione have different latitudinal extents but they all occur at mid- to low-latitudes on their leading hemispheres. This is the same region that high-energy electrons (MeV) preferentially bombarded their surfaces [3, 4, Fig. 2]. We believe that this bombardment modifies the surface, resulting in the high thermal inertias observed. Absorption of the electrons by the surface probably causes water ice molecules to be mobilized, increasing the contact areas between the ice grains, thus increasing

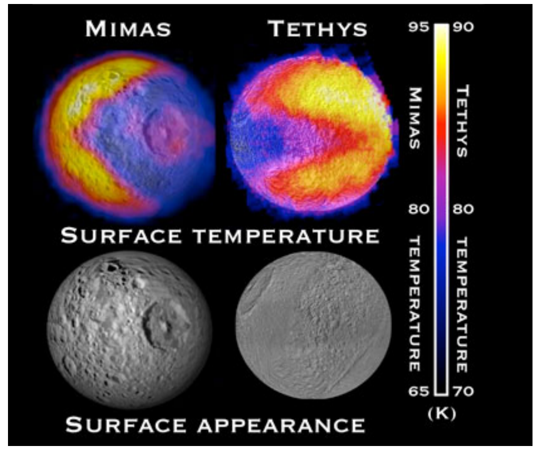

Fig. 1 Surface temperatures of Mimas and Tethys, showing their "PacMan" thermal anomalies, compared to their visible surface appearance.

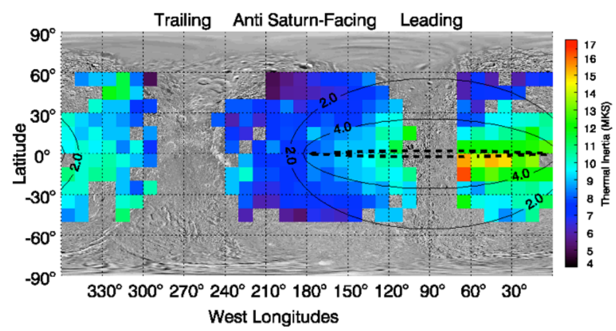

Fig. 2 Thermal inertia map of Dione showing an increase at low latitudes on its leading hemisphere. The contours show the predicted high-energy (MeV) electron flux onto Dione ($\log_{10}$ MeV cm^{-2} s^{-1}). The dotted contour, given for reference, indicates the location of the electron flux contour found to best fit the boundary of Tethys' thermally anomalous region (4.25 $\log_{10}$ MeV cm^{-2} s^{-1}).

the thermal conductivity and hence thermal inertia [3].

The magnitude of the thermal inertia increase between the background and the value inside the anomalous region is largest on Mimas and smallest on Dione [Fig. 3]. This follows the same pattern as the high-energy electron intensity, which decreases with distance from Saturn [Fig. 4].

Despite Enceladus' relativly intensive bombardment of high-energy electrons [Fig. 4] it is not expected that its surface will display a similar thermal anomaly, as infall from its plumes provides a high resurfacing rate. To date no such anomaly has been observed on Enceladus.

Whilst the albedo of Mimas, Tethys and Dione do vary, with reference to one another and across their surfaces (most noteably on Dione), there is no pronounced albedo change on Mimas and Dione and only a slight change on Tethys across their thermal anomaly boundaries.

Comparing the boundaries of the thermal inertia variation to contours of high-energy electron flux (e.g. Fig. 2) shows that electron energy fluxes greater than approximately 18 GeV cm^{-2} s^{-1} are required to dramatically alter the thermal inertia of an icy satellite surface [4]. It is possible that similar, currently unobserved, anomalies exist on Rhea and the Jovian icy satellites, which are also known to experience bombardment by high-energy electron fluxes [e.g. 6].

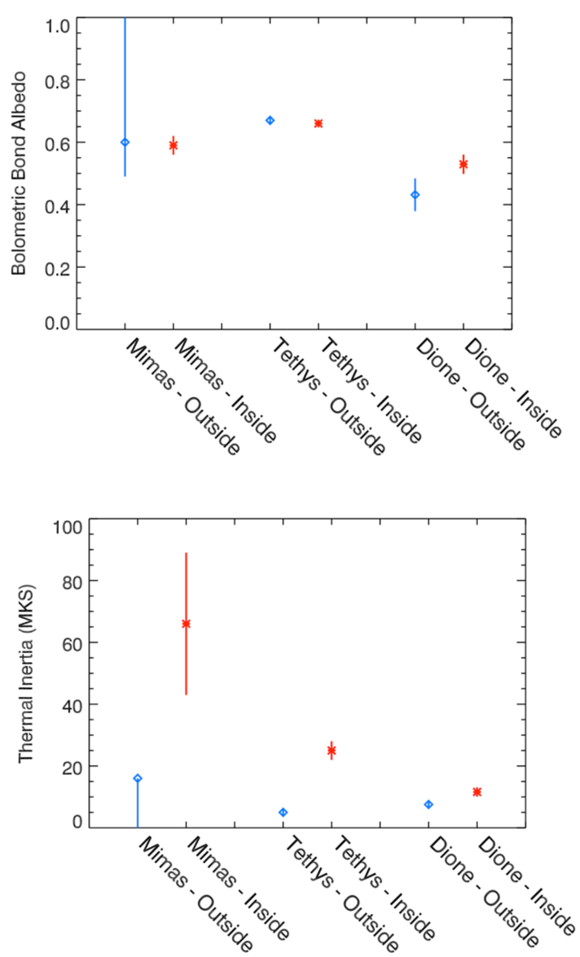

Fig. 3 The bolometric Bond albedo and thermal inertia values of Mimas, Tethys and Dione inside (red) and outside (blue) of their thermally anomalous region.

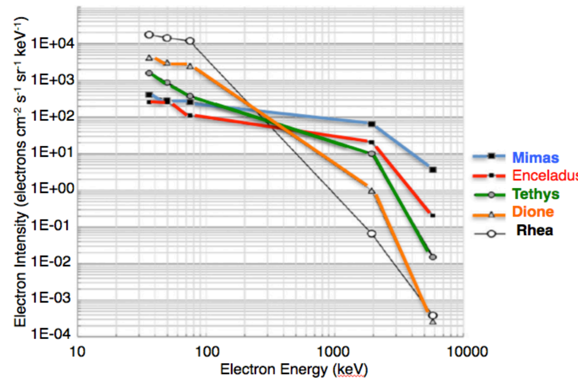

Fig. 4 The variation intensity vs. energy of electrons impacting the classical icy satellites of Saturn, adapted from Fig. 2 of [5].

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