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Preliminary Albedo and Thermal Inertia Maps of Mimas

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Abstract

We derive the first, preliminary, maps of thermal inertia and bolometric Bond albedo of Mimas' thermally anomalous "PacMan" region. The albedo and thermal inertias derived are consistent with those previously published. The maps show thermal inertia may be highest towards the center of the anomalous region at low latitudes.

1. Introduction

In 2011 observations by Cassini's Composite Infrared Spectrometer (CIRS) of Mimas revealed a previously known thermal anomaly [1]. The anomalous region is located at low latitudes on Mimas' leading hemisphere and presents as a region of lower daytime surface temperatures (and higher nighttime ones) than its surroundings [Figure 1]. It forms a lens-shape region, with a sharp V-shaped boundary at 0° N and 180° W. It is this shape that resulted in the anomaly being called PacMan, after the 1980's video game icon! The surface of the anomalous region appears uniform in visible light maps, but as a dark lens-shape in IR/UV color ratio maps [Figure 1, 2]. The bolometric Bond albedo is shown to be consistent between the anomalous and non-anomalous regions (0.49–0.70, [1]). Variations in Mimas' thermal inertia were shown to be the cause of the thermal anomaly (66 ± 23 J m^{-2} K^{-1} $s^{-1/2}$ inside the anomaly and <16 J m^{-2} K^{-1} $s^{-1/2}$ outside of it).

The location of thermal anomaly and dark region of IR/UV color are spatially correlated with the region preferentially bombarded by high-energy electrons on Mimas [1, 2, 3]. These electrons are able to alter the surface to centimeter depths, the same depths probed by diurnal surface temperature variations. It is believed that these electrons are modifying Mimas' surface, sintering grains together (increasing their thermal conductivity and hence thermal inertia) and altering their scattering centers [4]. Subsequently to the discovery of this anomaly on Mimas similar ones were discovered on Tethys [Figure 1, 4] and Dione [5].

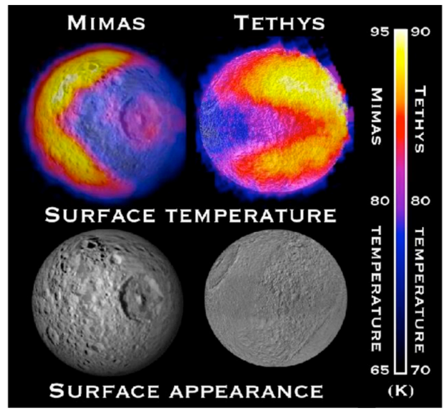

Figure 1 – Top: Surface temperatures on Mimas (left) and Tethys (right) reveal regions of anomalously cool daytime temperatures located at low latitudes on their leading hemispheres. Bottom: The regions appear almost the same as their surroundings in visible light maps. [PIA16198]

2. New Surface Temperature Maps

We use resolved CIRS data taken of Mimas to map Mimas' surface temperature. Specifically, we use CIRS focal plane 3 (FP3, 600 to 1100 cm^{-1}) observations from Cassini orbits 12 (2005/08/02, evening), 126 (2010/02/13, day), 139 (2010/10/16, night), 144 (2011/01/31, day), and 167 (2012/06/05, night and morning coverage). We also use observations from CIRS focal plane 1 (10 to 600 cm^{-1}) from Cassini orbit 126 (2010/02/13, day and night). Analysis of data from orbit 167 has not previously been presented.

Examples of daytime surface temperatures derived from these observations are given in Figure 2. The results are binned into 10° latitude and 10° longitude bins, and show the best-fitting blackbody temperature to the observed CIRS radiances (following the method of [5]). The results clearly show the region around the sub-solar point is much cooler in the anomalous region than on the trailing hemisphere.

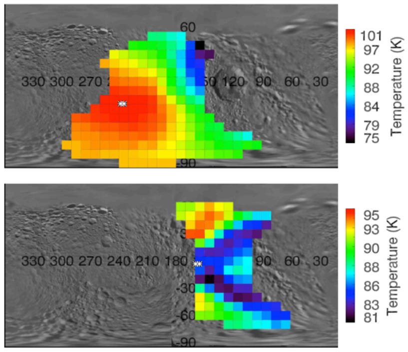

Figure 2 – Daytime surface temperatures of Mimas derived from two CIRS FP3 scans that started at 2005/08/02 02:03:52 (top) and 2010/02/13 20:02:17 (bottom). The white stars indicate the sub-solar point.

3. Preliminary Thermal Inertia and Bolometric Bond Albedo maps

We compared the derived surface temperatures to those predicted by a 1-D thermal model [6] using the geometry of each encounter and a range of albedo and thermal inertia values. In each bin all the albedos able to provide an adequate model fit to the different temperatures observed are averaged, and the mean one assumed for that bin. The standard deviation of these values is also found to provide a measure of the spread of the values. This process is repeated for the thermal inertia, and then the resulting values mapped [c.f. 4]. These preliminary results are shown in Figures 3 and 4. The albedos and thermal inertias found, both inside and outside of the anomalous region, are consistent with those previously published [1]. However, these maps provide the first clear picture of how these values vary across the region, with the highest thermal inertias being at low latitudes towards the center of the anomaly.

4. Summary

We have produced preliminary maps of thermal inertia and bolometric albedo for Mimas. More work is required to include all resolved CIRS observations, to maximize the maps' surface coverage.

Acknowledgements

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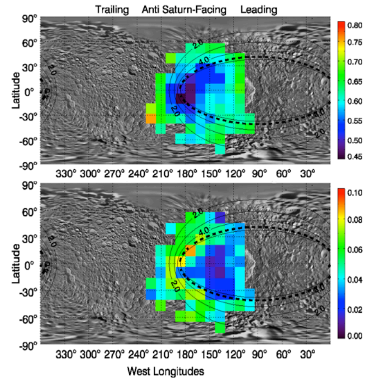

Figure 3 – New maps of Mimas' bolometric Bond albedo (top) and its standard deviation (bottom). Overlaid are contours of energetic electron power deposited into the surface per unit area (MeV cm^{-2} s^{-1}) determined using updated results from Cassini/MIMI. The best fitting contour to the IR/UV color ratio anomaly boundary is given by the dashed line at 5.6 $\times 10^4$ MeV cm^{-2} s^{-1}.

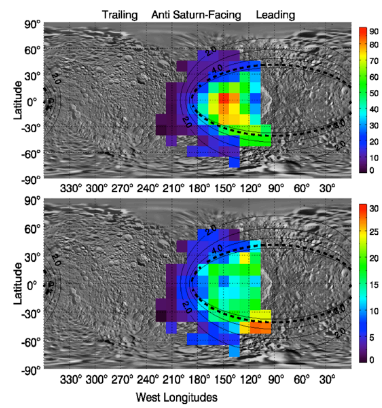

Figure 4 – New maps of Mimas' thermal inertia (in J m^{-2} K^{-1} $s^{-1/2}$) (top) and its standard deviation (bottom). Contours are the same as describe in Figure 3.

References

[1] Howett et al., Icarus 216, 221-226, 2011. [2] Schenk et al. Icarus 211, 740-757, 2011. [3] Nordheim et al. Icarus 286, 56-68, 2017, [4] Schaible et al. Icarus 285, 211-233, 2017. [5] Howett et al., Icarus 221, 1084-1088, 2012. [6] Howett et al., Icarus 241, 239-247, 2014, [7] Spencer, Icarus 83, 27-38, 1989.