EXPLORING THE IMPACT OF THERMAL SEGREGATION ON DIONE THROUGH A BOLOMETRIC BOND ALBEDO MAP. D. G. Blackburn[1], B. J. Buratti[2], E. G. Rivera-Valentin[3] [1]NASA Postdoctoral Program Fellow, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., M/S 183-401, Pasadena, CA 91109, David.G.Blackburn@jpl.nasa.gov, [2]Jet Propulsion Laboratory, California Institute of Technology, [3]Arkansas Center for Space and Planetary Sciences, University of Arkansas.

Introduction: Next to Iapetus, Dione exhibits the greatest albedo dichotomy of any object in the solar system. The origin of the leading/trailing differences on Iapetus is most likely exogenically placed low-albedo particles from Saturn's Phoebe ring [1], modified by subsequent thermal transport [2]. In this study, we explore whether the dichotomy on Dione, which is also thought to be exogenically created by the E-ring of Saturn [3,4,5], can be sustained by a thermal transport mechanism. Ultimately, our goal is to know whether this mechanism is a general one in creating albedo dichotomies in the solar system.

Figure 1 Cropped image (N1549193167_1) of Dione from *Cassini* ISS clear filter at 0.13 degrees solar phase angle (approximately the geometric albedo) highlighting the albedo dichotomy within the trailing hemisphere alone. A wide range of phase angles from the Cassini tour (~0-140°) made acquiring the phase integrals and determining the geometric albedo possible.

Dione's leading hemisphere is heavily cratered and uniformly bright, typical of other saturnian satellites such as Rhea; however, its trailing hemisphere is covered with darker, fractured terrain. Across the trailing side is a much brighter chasm than the surrounding terrain that traces an arc across the hemisphere (Fig. 1). The bolometric Bond albedoes of the leading and trailing hemispheres are 0.63 and 0.37 [6], respectively. This albedo range should produce a difference in surface temperatures and sublimation rates for water ice, which over geologic time could create a thermal segregation effect, similar to Iapetus [2]. Sublimation may leave behind a lag deposit made up of impurities either endogenic or exogenic in origin, that slowly darkens the surface over geologic time. Thermal segregation, though, would also need some triggering event and/or ongoing process that would cause the trailing hemisphere to diverge from the leading (such as E-ring interaction).

In order to investigate thermal segregation, we produced a bolometric Bond albedo map of the surface of Dione in order to accurately model thermal processes. The *Cassini* spacecraft provides a wealth of solar phase angles to derive the necessary phase integrals, along with the ability from the VIMS and ISS instruments to include 99% of the total radiated power of the solar spectrum.

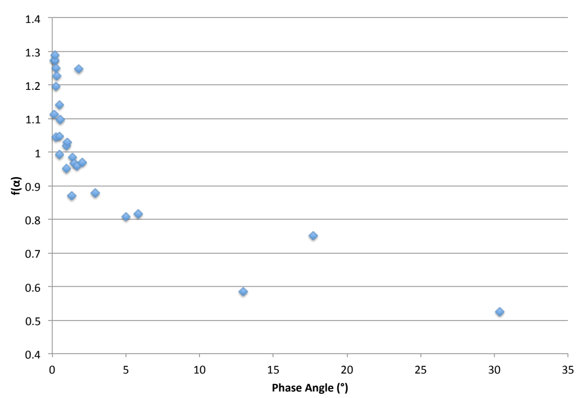

Figure 2 Surface phase function *f(α)* for the dark terrain, showing the profound opposition surge.

Methods: *Bolometric Bond albedo map.* The bolometric Bond albedo is integrated over all wavelengths, taking into account the intensity of the solar flux at each wavelength and is vital to producing accurate daytime surface temperatures within a thermal model. It is defined as:

$$A_B = \frac{\int_0^\infty q(\lambda)p(\lambda)F(\lambda)d\lambda}{\int_0^\infty F(\lambda)d\lambda}$$

where q is the phase integral, p is the geometric albedo, F is the intensity of the solar flux, and λ is wavelength. Using a similar process to Blackburn et al. [7], *Cassini* VIMS and ISS were coupled to provide a wavelength range from 0.2 – 5.2 microns. A lunar-Lambert photometric function [5,8] was employed with a scaling factor *A* of 0.87. For both the VIMS-IR bands and the ISS clear filter, surface phase functions were built (Fig. 2) in order to correct the images to normal reflectance; the mosaics were then transformed into the geometric albedo (Fig. 3-4). The relationship between the phase integrals and geometric albedo was determined from Pitman *et al*. [6]. The bolometric Bond albedo from the ISS clear filter images was folded in with the *Cassini* VIMS-IR observations to obtain the full spectral range of interest.

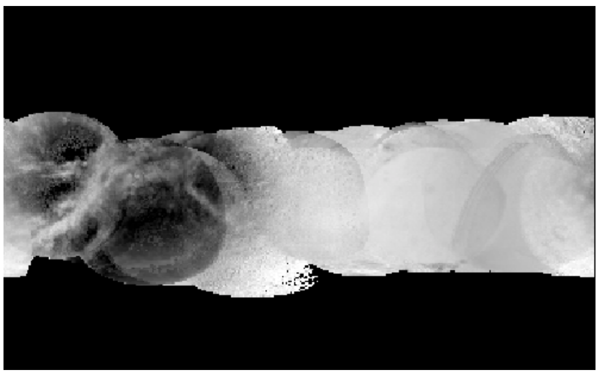

Figure 3 Geometric albedo mosaic from *Cassini* ISS clear filter (0.2-1.2 μm). Only images with phase angles less than 30 degrees and portions of images with emission and incidence angles less than 45 degrees were included to minimize the effects of cratering.

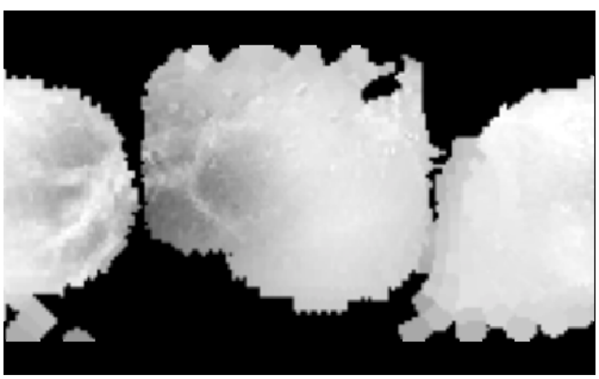

Figure 4 Geometric albedo mosaic from *Cassini* VIMS (Band 1, 0.88 μm is shown).

Thermal and sublimation model. The thermal model of Rivera-Valentin *et al*. [9] was used with the orbital parameters for Dione. Spectra from the leading and trailing hemispheres confirms the presence of water ice near the surface, so we used the Hertz-Langmuir sublimation evaporation equation for water ice.

Ballistic transport model. As Dione has no discernable atmosphere, any sublimated molecule will either ballistically hop from one location to another or have enough kinetic energy to reach escape velocity and leave the system. An analytical ballistic transport model was used from Blackburn [10] in which evaporated molecules are tracked in bulk to determine likely accumulation zones.

Results and Discussion: Albedo points for the dark and light terrain were run for example points of 0.37 and 0.63 (Table 1). The results show that the sublimation rate for the darker areas on Dione is 2.11 cm per billion years, while the brighter regions are six orders of magnitude less or completely negligible.

A comparison of the fluxes from a net accumulation map with a model of the expected darkening for sublimation and the amount of impurities present in the ice in order to form a lag deposit will be conducted. The full net accumulation map will aide in sorting out the impact on albedo from thermal segregation and environmental effects (from Saturn and E-ring).

Table 1 Model Results for Varying Albedoes

Bolometric Bond Albedo	Average Sublimation Temperature (K)	Sublimation Rate (kg m^{-2} s^{-1})
0.37	106	6.03×10^{-16}
0.63	85	5.32×10^{-22}

Future Work: Once the contribution of thermal segregation on Dione is established, other processes that shape the surface and the mass balance must also be examined. Sublimation rates will be compared with: (1) E-ring deposition, (2) ultraviolet destruction of surface ice, and (3) the destruction rate from particle bombardment from Saturn's magnetic field.

References: [1] A.J. Verbiscer et al. (2009) *Nature*, *46*, 1098-1100. [2] J.R. Spencer and T. Denk (2010), *Science*, 327, 432-435. [3] P. Schenk et al. (2011) *Icarus*, *211*, 740-757. [4] A.J. Verbiscer et al. (2007) Science, 315, 692-710. [5] B.J. Buratti et al. (1990) *Icarus*, *87*, 339-357. [6] Pitman et al. (2010) *Icarus*, *206*, 537-560. [7] D.G. Blackburn et al. (2011) *Icarus*, *212*, 329-338. [8] B.J. Buratti (1984) *Icarus*, *59*, 392-405. [9] Rivera-Valentin et al. (2011) *Icarus*, *216*, 347-358. [10] D.G. Blackburn (2011), *University of Arkansas*, PhD dissertation.

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