THE DIRECTIONAL SCATTERING PROPERTIES OF IAPETUS' SURFACE. D. G. Blackburn[1], B. J. Buratti[2], R. Ulrich[3], J. A. Mosher[2], [1] Arkansas Ctr. for Space and Planetary Sci., University of Arkansas, 202 Field House, Fayetteville, AR 72701, dgblackb@uark.edu, [2] Jet Propulsion Laboratory, California Institute of Technology, Los Angeles, CA 91001, [3] Chemical Engr. Depart., University of Arkansas, 3149 Bell, Fayetteville, AR 72701.

Introduction: In the saturnian system, Iapetus exhibits the most extreme variations in albedo of the satellites, with an extremely dark, leading hemisphere and a much brighter, trailing hemisphere. In light of this unique variation and due to the limited previous work, Iapetus is a prime target for a photometric study of the changes in brightness with phase angle. Observations obtained by the *Cassini* Visual Infrared Mapping Spectrometer over the portion of the solar spectrum that includes 99% of the radiated power and over a full range of solar phase angles provide an unprecedented opportunity to study the photometric and thermal properties of icy satellites. Since the bolometric Bond albedo describes the energy balance on a planetary surface, measurements obtained over 99% of the solar spectrum is significant. For the case of Iapetus, this opportunity is particularly compelling because thermal segregation is believed to help create and sustain its unusual albedo dichotomy [1,2]. As a first step in understanding the thermal properties of Iapetus, we have calculated the phase integrals of Iapetus between 0.36 and 5.12 μm. The phase integral, which is a numerical representation of the directional scattering properties of a planet or satellite, is also the ratio between the Bond albedo, which is crucial for thermal modeling and energy balance, and the geometric albedo. In this study, we took advantage of the phase angle and wavelength coverage of *Cassini*'s VIMS instrument to produce the first phase integrals calculated directly from solar phase curves of the leading side and to estimate the phase integrals for the trailing side. We also explored the wavelength dependence of the phase integrals and the dependence of the phase integrals on the geometric albedo. Given the large albedo differences on Iapetus, this exercise also affords a prime opportunity to study the effects of albedo and wavelength on the phase curves of airless bodies.

Data analysis: We used all available non-proprietary VIMS cubes of Iapetus that captured a full disk and performed disk-integrated photometry at every band of the VIMS instrument (96 for VIMS–VIS and 256 for VIMS–IR). From the available solar phase angle coverage (~0–10º, 40–150º), we calculated the phase integral directly by definition [3,4]:

$$q = 2\int_0^{\pi} \phi(\alpha)\sin(\alpha)d\alpha$$

where q is the phase integral; $\phi(\alpha)$ is the normalized disk-integrated brightness; and α is the solar phase angle. The phase integral describes the directional scattering properties of a planetary body; in effect it is the ''beam pattern" of the object.

Results: To illustrate the relationship between geometric albedo and phase integral clearly, we chose to plot the phase integral versus geometric albedo (Fig. 1) at each band of the VIMS instrument for both the leading (pluses) and trailing (circles) hemispheres and to compare our results for Iapetus with the findings of the other saturnian icy satellites by Pitman *et al.* [5]. Plotting the Pitman *et al.* [5] data onto Figure 1 revealed highly linear trends, and we chose to use a linear best-fit line that included both the visible and near-infrared to represent the slopes of Enceladus, Tethys, Dione, Mimas, and Rhea in relation to Iapetus.

Discussion and Summary: It is well known that generally for a planetary body the phase integral increases with geometric albedo while the intensity of the opposition surge effect decreases with increasing geometric albedo [4], and our results conform to that trend. This relationship is expected, because as the albedo increases, the degree of multiple scattering, which tends to be more isotropic than single scattered radiation, also increases. These multiple-scattered photons tend to make the phase curve more ''Lambertian", which increases the area under the normalized integrated phase curve. Multiple scattering also isotropizes the single scattering phase function and partly illuminates primary shadows: both effects increase the area under the normalized integrated phase curve.

Although most of the increase in the phase integral is from an increased geometric albedo, another component is from additional effects of illuminated shadows caused by rough features and the properties of the surface – particle size and shape, for example – which affect the single particle phase function [6]. This texture difference clearly alters the slope between the leading the trailing hemispheres.

When compared with other icy satellites, the dark material has a phase integral closer to the dark surface of Phoebe (q = 0.29 ± 0.03); however, Phoebe's phase integral showed no significant wavelength dependence [7]. The slope and magnitude of our measurements for the bright, icy material on compare best to the satellites of Dione, Rhea, and Mimas [5]. The phase integrals of Rhea and Dione would be expected to be more similar to Iapetus, as these icy satellites also exhibit insignificant multiple scattering and are more lunarlike than the brighter satellites of Mimas, Tethys, and

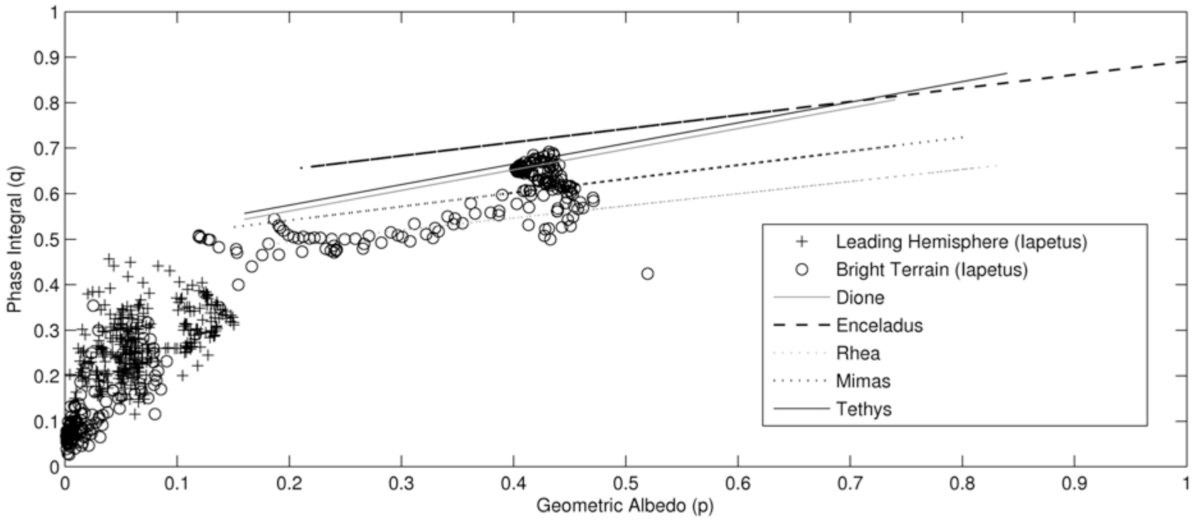

Fig. 1 Phase integral versus geometric albedo for Iapetus for the dark, leading side (pluses) and the bright, trailing side (circles). The lines are linear fits to the Pitman *et al*. [5] results for Dione, Enceladus, Rhea, Mimas, and Tethys.

Enceladus [8]; however since their geometric albedos are slightly higher, the phase integrals at each wavelength band are not as comparable. Since the albedos and morphology of Dione and Rhea are similar to the bright side of Iapetus, it is reasonable to assume that the surface texture of Dione and Rhea is also similar to the bright side of Iapetus (except perhaps for some accumulation on their surfaces of micron-sized particles from the E-ring). The dark material on Iapetus may have settled onto a moon that looked more like a ‘‘typical” icy saturnian satellite.

Compared with previous results, our phase integrals for the bright side are lower than the estimates of Morrison *et al*. [9] ($q \sim 1.3$) based on radiometry, yet Morrison used inaccurate numbers for Iapetus' radius and the average geometric albedo for the trailing side (835 km and 0.35 instead of 730 km and 0.42 [10]). Our results for the bright and dark hemispheres at 0.47 μm are 0.58 ± 0.10 and 0.20 ± 0.06, respectively, compared to the results of Squyres *et al*. [10] of ~0.9 and ~0.3. The difference in the phase integral for the bright region can be explained based on the coverage of the *Cassini* spacecraft relative to *Voyager*. *Voyager* provided excellent coverage of the north polar region [10], where geometric albedos approach 0.65, and a phase integral closer to 1 like on Europa's surface is not surprising. Our twelve high-resolution images used for disk-resolved photometry of the bright terrain centered on a region where the average geometric albedo is 0.43 near the equator, since *Cassini* had poor coverage of both poles of Iapetus. Yet, *Cassini* had better coverage of the dark region, which is of course weighted more in our approximation of the leading hemisphere since we included every cube available. However, if Iapetus follows a similar trend to the other icy satellites of Saturn [5], which is likely to be the case, then extrapolating the slope up to the highest albedo region (0.65) would produce a phase integral of ~0.7. Our results of lower phase integrals than previous findings translated into lower Bond albedos and higher temperatures in thermal models, which may have profound implications on volatile transport on Iapetus [1,11].

Further information: For more information regarding this study and a more thorough discussion of the techniques and results, see Blackburn *et al*. [12] where the full report is published. Also, using the phase integrals achieved through this study, a bolometric Bond albedo map for Iapetus was developed [13].

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