OPPOSITION SURGES OF THE SATELLITES OF SATURN FROM THE *CASSINI* VISUAL INFRARED MAPPING SPECTROMETER (VIMS). B. J. Buratti[1], J. A. Mosher[1], L. Abramson[2], N. Akhter[2], R. N. Clark[3], R. H. Brown[4], K. H. Baines[1], P. D. Nicholson[5], S. DeWet[1]. [1]NASA Jet Propulsion Laboratory, California Inst. of Technology, Mailstop 183-501, Pasadena, CA 91109 (Bonnie.J.Buratti@jpl.nasa.gov), [2]Columbia University, [3]USGS Denver, [4]University of Arizona, [5]Cornell University.

Introduction: The opposition surge is the anomalous increase in brightness as an airless body becomes fully illuminated to an observer. The canonical explanation [1,2] is the disappearance of mutual shadows among regolith particles. Large surges are exhibited by fluffy surfaces, while a lack of a surge means a compact surface. The effect is particularly pronounced at solar phase angles less that about 12º. Moreover, a second surge at very small solar phase angles (<1º) seems to also be present on virtually all airless bodies. The cause of this surge may be due to coherent backscatter, an optical effect which occurs when multiply scattered photons traversing equal path lengths are scattered back to the observer at opposition [3].

Measurements of the opposition surge can be fit to models to derive physical properties of the surface. These properties can in turn be related to the collisional and impact history of the surface, and they also offer clues to other geological processes such as active volcanism and bombardment and alteration by magnetospheric particles and fine dust. Table 1 summarizes the scientific and measurement goals of the study of the opposition effect.

Table 1: The opposition surge and its meaning

Type of surge	Physical meaning	What to look for
Huge (30%) surge less than 1º	Mean free path; average particle size	Amplitude and width; wavelength dependence
"Canonical" surge > 1º	Compaction state of surface; impact and geologic history	Comparison of the slope of the phase curve and a model for the compaction state of the surface

The *Cassini* Visual and Infrared Mapping Spectrometer (VIMS) returned a data set of the opposition surge over a wavelength range extending from 0.4 to 5.1 microns. The four year nominal orbital tour and the year (so far) of the extended mission have enabled solar phase curves of unprecedented coverage and accuracy to be obtained. All the medium-sized icy satellites of Saturn have excellent coverage of the opposition surge, except Mimas (see Table 2). In addition, Dione, Rhea, and Iapetus have extraordinary measurements of the surge below 1º.

Data: Table 2 summarizes the *Cassini* VIMS coverage in solar phase angle for the medium-sized saturnian satellites. Mimas is the only satellite which does not have opposition surge observations.

Table 2 – Solar phase angle coverage

Satellite	Phase angle coverage (º)
Mimas	None
Enceladus	0.98-12.15
Tethys	0.58-11.87 (Leading)
Dione	0.13-1.88 (Trailing); 7.36-8.11 (Leading)
Rhea	0.05-10.11 (Leading)
Iapetus	0.05-3.11 (Mixed terrain)

Results: Iapetus is the best-behaved of the satellites, showing an increase in the effect at small solar phase angles as the albedo (and thus multiple scattered photons) increase, and a phase coefficient (the slope of the line) that increases with decreasing albedo for the canonical opposition surge. The latter is to be expected as primary shadows are partly illuminated by multiply scattered photons as the albedo increases. Figure 1 shows the VIMS surge data for Iapetus, while Figure 2 shows the derived phase coefficients. Moreover, Imaging Science Subsystem (ISS) images show that the coherent backscatter effect appears only in the high-albedo terrain, where multiple scattering is most significant.

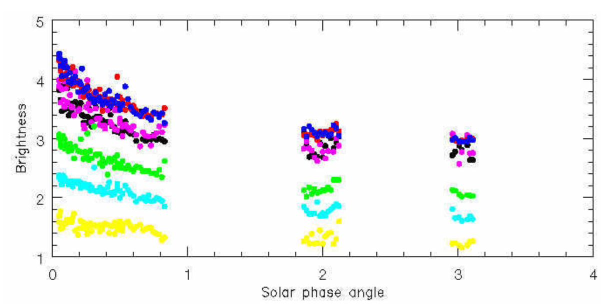

Fig. 1: The opposition solar phase curve of Iapetus from 0-3º. The data cover wavelengths from the visible to 3.5 microns in the infrared. All light is reflected.

Rhea, which has the best and most complete solar phase curve of all the satellites, doesn't show the same trend as Iapetus for the surge at very small solar phase angles (Figure 3). Similarly, Dione shows very little, if any, increase in the surge amplitude as the albedo increases.

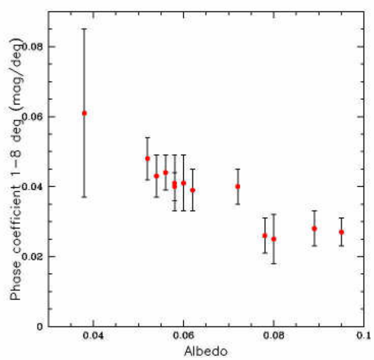

Fig. 2: The slope of the solar phase curve (the "phase coefficient") decreases as the albedo increases. This effect is expected for shadow-hiding, since bright surfaces have partly illuminated primary shadows. On the other hand, the slope of the surge at solar phase angles <1° increases with albedo, suggesting that it is a multiple scattering effect, such as coherent backscatter.

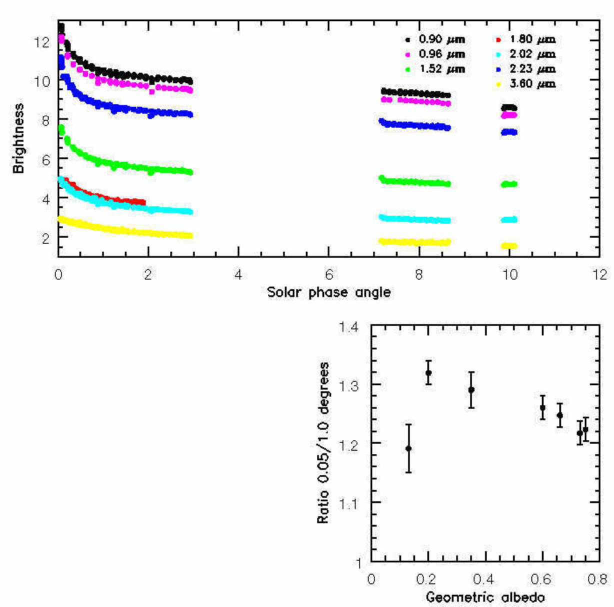

Fig. 3: The phase curve of Rhea shows a ***decrease*** in amplitude (except for the very lowest albedo), which is opposite to the trend exhibited by Iapetus.

The ISS observations of Dione had sufficient resolution such that the surge in both the bright and dark terrains could be studied (see Figure 4). Like Iapetus, the high-alebedo terrains of Dione exhibit a larger surge in the last degree of solar phase angle, but the effect is much slighter.

Discussion: The observations of "canonical" surge can be fit to a model that describes the porosity of the optically active portion of the surface in terms of void space, i.e., the fraction of space not occupied by particles (Irvine, 1966). The derived values for Tethys, Dione, Rhea, and Iapetus are in the range of 80-87%, which is comparable to that of the Moon and the Galilean satellites [4], suggesting that the pulverizing effects of collisional processes are similar for rocky and icy surfaces. The exception is Enceladus, which has a derived porosity of 5%. Although an annealed surface could exhibit such a compaction state, it is more likely that the porosity model breaks down when multiple scattering – which the model does not treat - becomes significant, as is true for Enceladus.

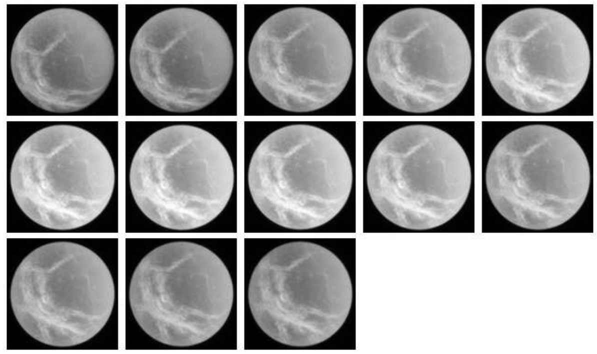

Fig. 4: ISS observations of the opposition solar phase curve for Dione. Opposition is on the left side of the middle panel. The high albedo regions show a greater surge, as is expected if the phenomenon is due to coherent backscatter, but the difference is not as great as that of Iapetus, perhaps because the albedo difference is not as great.

There is no trend in the characteristics of the surge between the leading and trailing sides of the satellites, and there is no trend with distance from Enceladus (as would be expected if particles from the E-ring were determining the character of the surge).

References: [1] W. Irvine (1966) *JGR* 71, 2931, [2] B. Hapke (1986) *Icarus* 67, 264. [3] B. Hapke (1990) *Icarus* 88, 407. [4] B. Buratti (1985). *Icarus* 61, 208.