LINEAR POLARIZATION AND ALBEDO RECONNAISSANCE FOR REGOLITH TEXTURE ON SATURN'S MOON IAPETUS.

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Introduction: Before lunar samples were returned to Earth, it was shown that linear polarization curves and albedo measurements of the moon and asteroids could be used to predict the regolith surface texture of these bodies [1]. The prediction that lunar mare regolith is texturally similar to finely pulverized lava basalts was confirmed by returned lunar samples [2].

Our ultimate objective is to use Cassini Imaging Science Subsystem (ISS) Narrow Angle Camera (NAC) images of icy Saturnian satellites – acquired through broadband color and polarization filters – to measure the linear polarizations and corresponding albedos of icy terrains and to characterize implied surface textural properties. In this preliminary study, we demonstrate the sensitivity of ISS NAC polarization images for the analysis of icy satellite surfaces by testing if these images can detect Umov's law, a well-known inverse relationship between the linear-polarization and albedo of regolith-covered surfaces [3]. Iapetus is our test satellite because its terrain provides a broad range of albedos over which we expect linear polarization to systematically vary. In particular, we will use Cassini Regio's stark contrast with Iapetus' remaining brighter surface to demonstrate Umov's law. Our hypothesis is that the linear polarization of all materials on Iapetus will vary inversely and monotonically with their corresponding albedo.

Method: Each ISS NAC polarization observation is a three-image sequence obtained for 0, 60, and 120 degree orientations of the electric field vector, respectively. The polarization filters are used in combination with broadband color filters from a tandem filter wheel, so that changes in polarization with wavelength can be studied. Each image sequence is obtained at approximately constant phase angle. First, the images are radio-metrically calibrated so that pixel DN value represents radiance factors. Camera pointing information is updated using control points and limb locations on the satellite's surfaces. The separate images are spatially co-registered and combined using an algorithm that produces a linear polarization image and a corresponding total intensity (i.e. non-polarized) image [4].

To produce albedo images, the total intensity image must be corrected for the gradient in shading across the visible disk due to gradual systematic gradations in the incidence and emission angles. We model the photometric gradient across the disk with fits of the Minnaert photometric function:

$$r(i,e) = B_0 \cos^k(i) \cos^{k-1}(e) \qquad (1)$$

Here, r is the radiance factor, i and e are the incidence and emission angle, respectively, B_0 and k are respectively the Minnaert albedo coefficient and exponent. We use least squares to fit the Minnaert parameters to the distribution of radiance factors across the disk. Finally, we apply the least-squares Minnaert fit to rescale pixel DN values to albedo (for this purposes, values of the B_0 parameter). Once linear polarization and albedo images for Iapetus are calculated, we plot albedo and linear polarization values at corresponding image pixels.

We will focus on the polarization image sequence: N1510472386, N1510472426, and N1510472466 [3] – which will be referred to as sequence A. These were taken with a 569 nm color filter and a 633 nm filter for P0, P60, and P120, respectively.

Results: Umov's law holds for our linear polarization and albedo images of Iapetus in sequence A. From equation 1, our fitted albedo Minnaert coefficient and exponent for sequence A are: B0 = 0.00264808 +- 1.157×10^{-5} and k = 0.372497 +- 3.33×10^{-3}.

We applied the average-disk value of Minnaert k to each pixel of the intensity image to estimate pixel-by-pixel variations in the predicted values of B0.

Our albedo image (i.e. image representing values of B0) for Sequence A is shown in Fig. 1 (left). Comparison of the Iapetus albedo image to the linear polarization image (Fig. 1, right) clearly shows that, as expected, low-albedo materials covering Cassini Regio have significantly larger values of polarization than high albedo materials elsewhere on Iapetus. This relationship is shown in detail in Fig. 2, which demonstrates that Umov's Law broadly holds for all terrains visible in our Iapetus images.

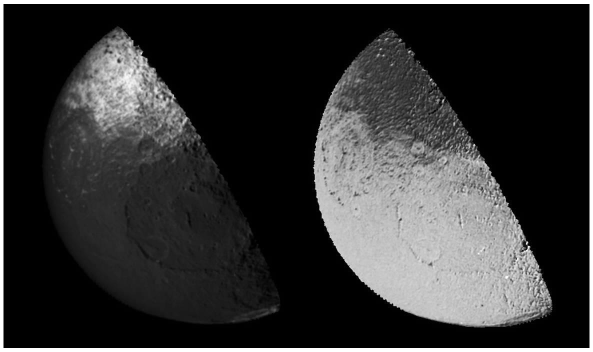

Figure 1. Iapetus A sequence. Albedo image (left) and Linear Polarization image (right). Phase angle is 84.2 degrees. We applied a large stretch to the linear polarization image to show shading differences.

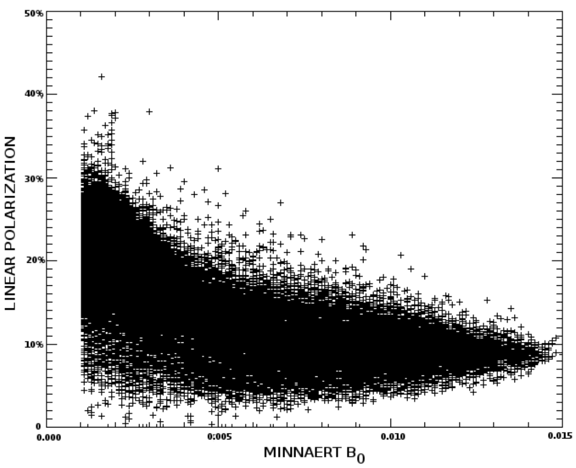

Figure 2. Iapetus A sequence: Linear Polarization vs. Minnaert B0 (Albedo) for corresponding pixels between our Albedo and Linear Polarization Images. The decreasing approximately linear trend confirms Umov's law.

Conclusions: Umov's law is confirmed by Fig. 2, where linear polarization decreases with increasing Minnaert B0. The DN pixel values of the linear polarization and albedo images in Fig. 1 are the data points in Fig. 2; thus our reduction technique produces images that accurately represent linear polarization and albedo for a given polarization sequence.

The detailed relationship between polarization and albedo appears to be relatively simple and monotonic, even though there are stark albedo contrasts across the boundary of Cassini Regio and adjacent high-albedo regions. Our preliminary interpretation is that Iapetus' regolith most likely has a fairly uniform surface texture. To verify this conclusion we will need to reproduce these measurements for image sequences at various phase angles. In particular, previous work on lunar soils [1] indicates that surface textural properties of icy terrains are more reliably estimated from the systematic variations of linear polarization with phase angle, especially at phase angles less than about 15-degrees. This will be the focus of our future analysis of linear polarization behavior of Iapetus and other icy Saturnian satellites.

References:

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