A CASSINI ISS SEARCH FOR REGOLITH-TEXTURE VARIATIONS ON TETHYS.

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Introduction: On October 28, 2004 the Cassini spacecraft flew within 255,500km of Saturn's heavily-craterd icy moon, Tethys. The ISS[1] Narrow Angle Camera (NAC) obtained its first closeup multi-color images of Tethys at a Voyager-comparable spatial resolution of 1.5 km/pixel. The imaging sequence provided 23 NAC images covering 10 NAC color-filter bandpasses (ranging from 338nm to 930nm wavelengths), as well as a Wide Angle Camera (WAC), 3-color (BGR) image set. The images show whole-disk views of Tethys' trailing hemisphere viewed at a phase angle of 50° and with a sub-spacecraft point of (22°N, 270°W). At the spatial resolution of our NAC images, Tethys' 1060 km diameter presents a disk-size of about 350 pixels. Among the images returned are nine frames obtained through NAC polarization-filters at three different spectral bandpasses (UV3: 341nm, GRN: 569nm, and MT2: 727nm, respectively). In the present study, we use these polarization images to search for possible variations in the microscopic texture of regolith on Tethys.

To date, little is known about the polarization properties of surface materials on the icy satellites of Saturn, especially at moderate to large phase angles that cannot be observed from Earth. Our new Cassini images provide the first-ever measurements of Tethys' linear polarization at 50° phase. It is known from laboratory experiments on particulate surfaces[2] and radiative transfer models[3] that the linear polarization of a particulate surface depends on the albedos and optical constants of its constituent grains, the distribution of grain-sizes, and their microscopic texture.

From Voyager and telescopic observations of Tethys, it is known that Tethys has an average visual geometric albedo of 0.9. Voyager images revealed that, at optical wavelengths, the albedos and colors of terrains on Tethys vary by 10-15% over large (approximately sub-hemispheric) size-scales[4], but the albedo variations are broadly diffuse and do not appear to be correlated to any particular topographic or geological features. Tethys' trailing hemisphere, seen in our Cassini images, is known to be brighter and slightly bluer than the leading hemisphere[4]. However, on size-scales of individual geological features like impact craters, the surface of Tethys is photometrically bland. Thus, in the present study, we expect that if local-scale polarization heterogeneities are found on size-scales over which the surface is photometrically bland, they may identify local variations in microscopic texture or grain-size.

Data Set and Image Processing: The ISS NAC camera is equipped with two tandem filter wheels, each containing 12 filter slots[1]. NAC polarization images are obtained at a single broadband wavelength as a three-image set by combining each of three polarization filters on Filter Wheel #1 with a single color filter on Filter Wheel #2. The NAC polarizer filters (P0, P60, and P120) are oriented at approximately 0°, 60°, and 120° from the camera Y-axis (the vertical direction in the images), respectively. By resolving the separate polarized intensities in the direction of the electric vector components in the camera X-Y plane, the intensities from the three separate polarization frames can be combined to produce a linear-polarization image and an image of the total intensity of scattered light.

In the present study, we first radiometrically calibrated the UV3, GRN, and MT2 polarization frames using the ISS Team's CISSCAL program. Then, for each polarization image-triplet, we spatially co-registered the P0 and P120 images to the corresponding P60 frame. The co-registered triplet was then combined to produce a single linear-polarization image and a corresponding total-intensity frame for the given wavelength.

The next step was to photometrically correct each total-intensity image so that the image DN values are scaled to local albedo or normal reflectance, r_n, (i.e. the estimated bidrectional reflectance, taken in this study, to be at 0° emission angle, and 5° incidence and phase angle). For this purpose, we employed a Hapke photometric model[3] in which we fixed all model parameters except the particle single-scattering albedo (SSA) to published values for Rhea[5]. For each spectral bandpass, we adjusted the corresponding model value of average single scattering albedo to best predict (in a least-squares sense) the disk-resolved variations of brightness with photometric geometry in each of our intensity images (see Table 1). We then applied our wavelength-dependent Hapke model to convert our intensity images into albedo images. An example of the MT2 albedo image is shown in Fig. 1a, and the corersponding MT2 polarization image is shown in Fig.1b.

Results: We first measured average, whole-disk values of normal albedo and corresponding polarization for each bandpass, excluding incidence angles greater than 75°. Table 1 lists our mean values plus-or-minus one standard deviation. The average whole-disk albedo increases with increasing wavelength, and there is a corresponding decrease in linear-polarization. The inverse correlation of linear-polarization with spectral albedo is a well-known phenomenon called the Umov effect [6]. It occurs because of the preferential tendency of high-albedo particles to produce multiply-scattered

photons with randomized electric fields that dilute the singly-scattered (i.e. polarized) contribution of light scattered from the surface.

On disk-resolved local size-scales, our UV3 and GRN polarization images did not reveal any local polarization differences that could be distinguished from statistical noise or small spatial registration errors. However, as shown in Fig. 1b, spatially-coherent regional variations can be found in the MT2 polarization image above the level of statistical noise and registration errors. They appear as pair of diffuse, quasi-parallel, N-S trending bands of material with smaller polarization than adjacent materials. Comparison to the albedo image (Fig. 1a) shows that there is no clear correlation of the polarization bands to obvious albedo patterns or local geological features.

Conclusions: We have found no detectable evidence for textural variations on size-scales comparable to individual geological features, like crater walls and floors – on these size scales, the surface texture of Tethys appears to be uniform. However, the possible origin of the banded pattern in the polarization image is a mystery. However, the fact that the polarization features appear only in the MT2 filter, at a wavelength for which the surface materials are almost perfectly scattering (i.e. have albedos closest to unity) suggests that they are caused not by textural differences in regolith materials, but rather by very subtle albedo variations that are too small to be detected in our albedo image. The broad, diffuse appearance of the bands, and the absence of any obvious spatial correlation to a visible or geological feature suggests that it may be exogenic in origin – a mechanism that has been previously proposed to account for hemisphereic albedo and color variations seen in Voyager data[4].

References: [1] Porco, C.C et al, (2004) *Space Science Reviews* ***115***, 363-497. [2] Geake, J. and A. Dollfus (1986). *Mon. Not. Roy. Astr. Soc.* ***218***, 75-91. [3] Hapke, B. (1993) *Theory of Reflectance and Emittance Spectroscopy*, Cambridge Univ. Press, 455pp. [4] Buratti, B. et al. (1990) *Icarus* ***87*,** 339-357. [5] Verbiscer, A. and J. Veverka (1989) *Icarus* ***82***, 336-353, [6] Umov, N. (1905) *Phys. Z.* ***6*,** 674-676.

Table 1: *Mean Whole-disk Albedo of Tethys and Polarization at 50° Phase from ISS Images.*

Filter	***Polarization***	r_n	***SSA***
UV3 (341nm)	0.037±.0.008	0.79±.0.14	0.951
GRN (569nm)	0.024±.0.005	1.17±.0.19	0.998
MT2 (727nm)	0.0085±.0.0062	1.20±.0.21	1.000

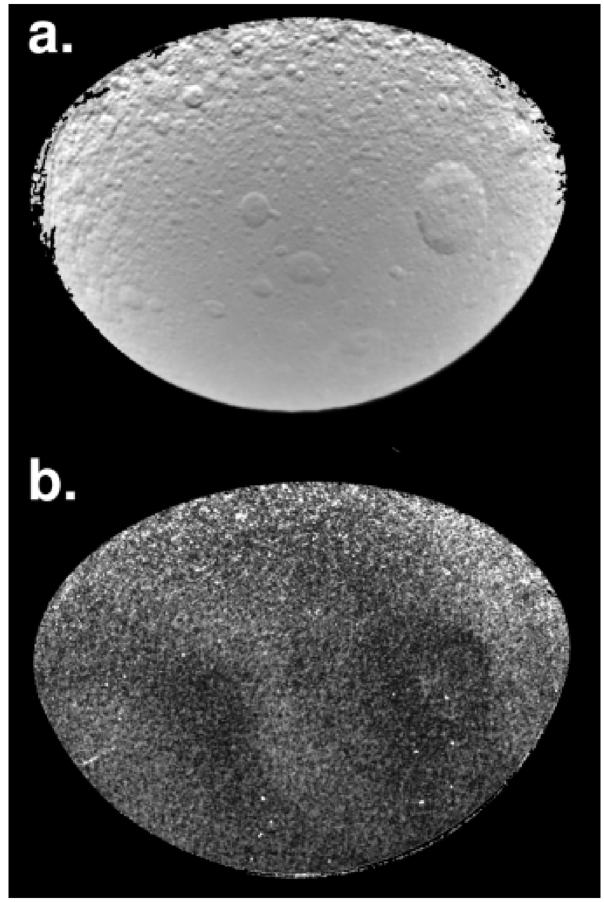

Fig. 1: a) MT2 albedo image of Tethys obtained by shading-correction of the MT2 intensity image. Incidence angles greater than 75° have been cropped out. Noth is ~30° CW from top. b) MT2 polarization image corresponding to (a). DN is linearly-scaled to the percent polarization. Dark areas identify features with-lower-polarization.