Saturn's Titan: Reports Suggesting Surface Activity from Cassini VIMS and Radar Observatons.

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Introduction: Instruments on the Cassini Saturn Orbiter have been observing the surface of the satellite Titan since the spacecraft entered Saturn orbit in mid 2004. The Visual and Infrared Mapping Spectrometer (VIMS) has returned images of the same surface units on Titan at selected wavelengths on repeated flybys during the Cassini orbital tour. We have previously reported that a region near 26°S, 78°W exhibits changes consistent with surface activity (1). This result was based on spectrophotometric analysis of VIMS images at eight infrared wavelenths ($0.93<\lambda<4.95$ µm). The region was imaged at (2.02 µm) on eight separate epochs and at three of these epochs the region was about twice as reflective as it was on the other five epochs. A spectrophotometric ratio of the eight VIMS bandpasses where the region appeared most reflective compared to where it was not reflective found that addition of ammonia frost could explain the observed change. Since ammonia is not found on Titan's surface, but is expected to be in Titan's interior, we considered these changes to be consistent with surface activity. Here, we report photometric changes at another region on Titan at 10°S, 140°W. Hereafter, we refer to (26°S, 78°W) as Case 1 and (10°S, 140°W) as Case 2. These findings suggest that Titan exhibits intermittent surface changes consistent with present volcanic activity.

The Observations: In Case 2, the region was observed on four occasions (Tb-Dec13/2004, T8-Oct27/2005, T10-Jan15/2006, T12-Mar18/2006). For each apparition we measured the I/F of 26 points on Titan's surface at different angles of incidence (i), emission (e) and phase (θ). In order to address the brightness change of the surface units with respect to viewing geometry (the photometric function) of any given point we measured the I/F of each of the 26 points the four epochs. Thus, four I/F measurements were obtained for each pointsat a distict i, e, θ.

To first order, the reflectance of a spherical surface unit varies as $I/F(\theta) \sim \cos(i)/(\cos(i)+\cos(e))$. Essentially, I/F will decrease as i, e, and θ increase and if the combination of i,e,θ increases I/F will decrease(2). We found this general rule to be true for 14 of the 26 points on the surface. For the purpose of this discussion we call this 'expected photometric behavior'. A typical example of this expected photometric behavior is shown in Fig. 1.

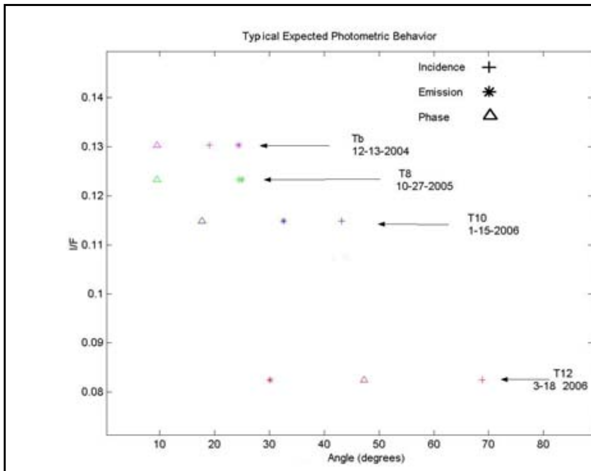

Fig. 1. Typical example of expected photometric behavior. In this instance I/F decreases as the combined i e, θ increase.

However, for 12 of the 26 points under investigation the change in I/F with respect to i, e, θ did not exhibit normal (expected) photometric behavior. In these instances, I/F was higher in instances where i, e, θ was also high. A typical example of this 'unexpected photometric behavior' is shown in Figure 2. This behavior is not predicted by photometric theory and is not observed in laboratory investigations of the angular scattering properties of solid materials regardless of grain size.

Significantly, the 12 points that exhibit this unexpected photometric behavior are located near each other on Titan's surface centered at ~10°S, 140°W. The 14 points that exhibit expected photometric behavior surround these 12 points. The points that show the unexpected photometric behavior are shown in the left panel of Figure 3. The points that show the expected photometric behavior are shown in the right panel. The most reasonable interpretation of these results is that the surface changed between the differing epochs at the locations defined by the points that exhibit unexpected photometric behavior; it was more reflective in 2004.

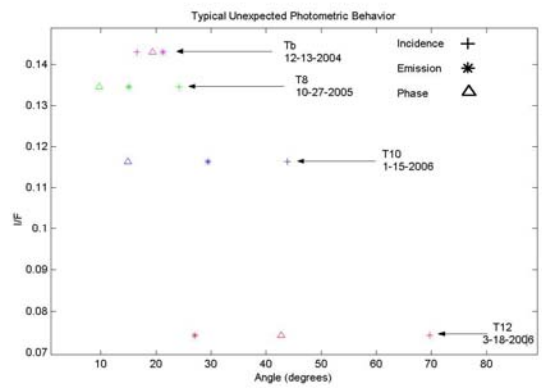

Fig 2. Typical example of unexpected photometric behavior. In this instance (T_b) I/F is higher as the combined i e, θ increease..

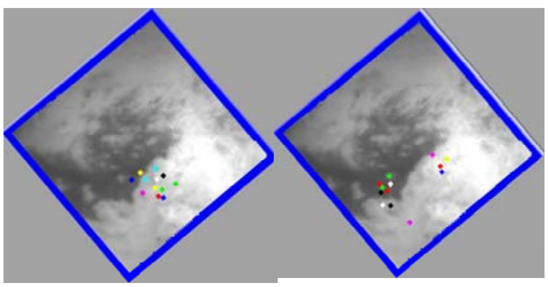

Fig 3. The left panel shows the points that exhibit unexpected photometric behavior; i,e behavior consistent with a surface change over time. The right panel shows the points that exhibit expected photometric behavior. These surround the points that changed.

Discussion: Changes in the appearance of any particular point on Titan's surface might be due to transitory atmospheric processes such as tropospheric clouds. Such clouds exhibit photometric behavior that is detectable with VIMS multiwavelength image ratioing techniques (3). We have undertaken this photometric analysis and we find that the region that shows the reflectance change on Titan's surface does not exhibit photometric properties consistent with tropospheric clouds. These changes are at or very near the surface.

To further address the cause of this change we consider Cassini Synthetic Aperture Rader (SAR) and radiometer observations of Titan(4). Cassini radar was able to observe the Case 2 environs on one flyby (T13-Apr30/2006). There are two interesting findings of the radar observations that provide insight into this matter. Comparisons between SAR and ISS images of Titan's surface have reported that generally areas that are reflective at rader wavelengths are also reflecting at infrared wavelengths. However, a region north and east of the Case 2 area exhibits the opposite behavior; it is absorbing at radar wavelengths and reflecting at infrared wavelengths. This warrants further scrutiny.

We note an additional result of interest in the SAR data. Figure 4 shows the VIMS image of the Case 2 region with a superimposed SAR image. We note that the Case 2 region (the points shown to the right of the insert) is just to the north and east of the circular feature identified in the SAR data as the crater Guabonito whose origin may be either impact or volcanic.

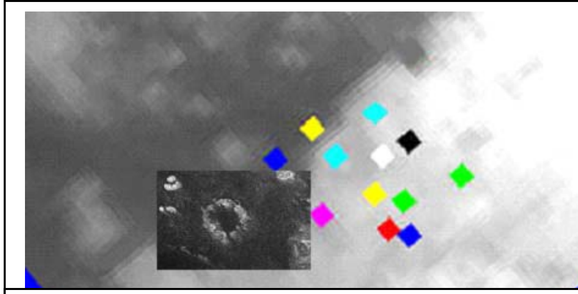

Fig 4. The SAR image if the crater Guabonito superimposed on the VIMS 2.02 µm image which included the points that exhibited the unusual intermittent change in reflectance

Conclusion: The VIMS instrument has found two instances in which selected regions on Titan's surface has become unusually reflective. These changes occur on time scales of days to months. In one instance (Case 2) the anomalously reflective region has a nearby large crater at its border as seen in SAR images. In both cases the size of reflectance variability is large, larger than Loki or Big Island of Hawaii. This is the strongest case yet for currently active surface processes on Titan. Pre Cassini, Titan was thought of as a pre-biotic earth that was frozen in time. Cassini VIMS observations now suggest that Titan is a snapshot of a episodically changing or evolving object.

References: [1] Nelson R. M. et al, LPSC 2007 Abs AAAA, , AGU 2007, Europlanets 2007. [2] Hapke, B. W. Theory of emittence and reflectance spectroscopy, p 199 and onward. [3] Griffith et al. Science, 310, 474-477(2005).[4] Stofan et al. Icarus 185, 443-456, 2006. Lopes et al. Icarus 186, 395-412, 2007. Paganelli et al, Icarus 191, 211-222, Kirk et al., DPS 2007.

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