Seasonal Variability on Saturn’s Moons Mimas and Tethys

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1. Overview & Introduction

We present far-ultraviolet (FUV) observations of Mimas and Tethys, which show evidence for likely seasonal variation in UV albedo across their surfaces. The ultraviolet is an important wavelength regime for studying the effects of photolytic and radiolytic processes, because primarily the uppermost layers of the regolith and grains are sensed in this range.

Cassini Ultraviolet Imaging Spectrograph (UVIS) [1] images (170-190 nm) of Mimas and Tethys display the brightening effects of E-ring grain accretion on Mimas’ trailing hemisphere and Tethys’ leading hemisphere. The UVIS results also suggest the presence of hydrogen peroxide, predominantly in the southern hemisphere, produced by photolysis; this is expected to be a seasonal effect as a result of enhanced UV insolation during the recently-ended southern summer. Mimas results have recently been published [3].

The FUV spectra of the icy Saturnian moons all show the strong signature of water ice, an absorption edge near 165 nm (e.g., [10][11]). As a result, the spectra of Mimas and the other moons are generally bright *longward* of 165 nm and dark *shortward* of 165 nm; in this analysis we focus on the longer-wavelength end of the H_2O absorption.

We study a Mimas dataset (February 2010) and a Tethys dataset (July 2007) taken at similar observational geometries and in similar season. The observations are centered on the anti-Saturnian hemisphere of each body.

2. Results

In Fig. 1 we show the I/F measured at wavelengths 170-190 nm. The data have been calibrated and RTG background subtracted, and have been photometrically corrected using a lunar-Lambert correction (after [2]). Figure 2 shows the dominant exogenic processes expected to affect Mimas and Tethys.

On Mimas, the albedo gradient indicates a brightening toward the trailing hemisphere, where the bulk of the E ring grains accumulate [4], and a darker leading hemisphere; this albedo gradient appears to be “tilted” such that the southern polar region is darker than the northern polar region.

On Tethys, the albedo trend is such that the leading hemisphere is brighter than the trailing hemisphere, consistent with E ring grain bombardment (Tethys’ leading hemisphere is slightly brighter than Mimas’ trailing hemisphere). On Tethys’ leading hemisphere, the southern latitudes of are significantly darker than the northern hemisphere.

3. Implications: Seasonal Variation in H_2O_2

We suggest that the UVIS images show compositional variations – namely photolytically-induced chemistry that is expected to vary across the surface seasonally. In particular, hydrogen peroxide (H_2O_2) is readily produced both by radiolysis and photolysis of ice (e.g., [5][6][7]). Peroxide is known to absorb efficiently in the UV, even in small amounts (e.g. [8]).

Using the UV solar spectrum at Saturn’s heliocentric distance, and the high-energy electron and proton distributions at Mimas [9], we modeled the formation of H_2O_2 in ice on the basis of laboratory measurements. We estimate an average Mimas surface H_2O_2 concentration from electrons and ions of only ~0.008% on the leading hemisphere, whereas by contrast on the illuminated surfaces the UV photons dominate the equilibrium and produce much higher peroxide concentrations, e.g., C_∞ ~0.13% at 45 deg latitude (taking into account the average 23% solar insolation at this latitude at the time of the measurement).

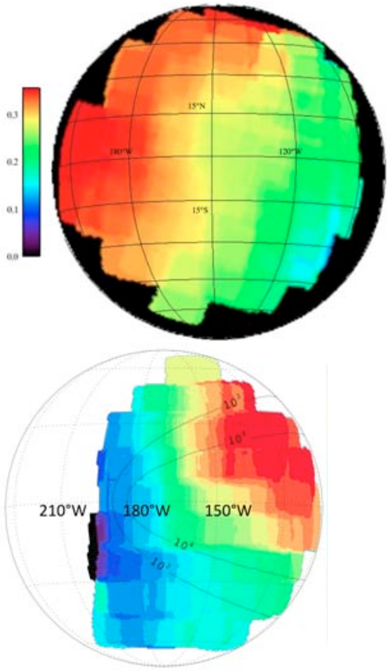

Figure 1. UV (170-190 nm) normal albedo images of Mimas (top) and Tethys (bottom). Color bars are the same for both images. Images show the anti-Saturnian hemisphere; the leading hemisphere is toward the right and the trailing hemisphere is toward the left. Data have been photometrically corrected.

We calculate the time constants to be ~8 years for unilluminated surfaces on the leading hemisphere, and, we estimate that the production timescale for H_2O_2 production is likely ~1 year. What these timescales imply is that the H_2O_2 buildup in the summer hemisphere ice occurs over about a year; once the surface moves into the fall-winter-spring period, the destruction of H_2O_2 begins to dominate, and occurs on the timescale of ~8 years. The UVIS results thus appear to be consistent with slow H_2O_2 destruction by electrons and ions in the shadowed northern latitudes during the ~7 year winter timeframe, followed by a several month recovery in peroxide during the transition to summer as surfaces are newly illuminated.

We expect that UVIS observations of Mimas and Tethys later in the Cassini tour will show a reversal in the latitudinal albedo asymmetry, as more H_2O_2 is created in the northern hemispheres and the previously-produced southern H_2O_2 is destroyed.

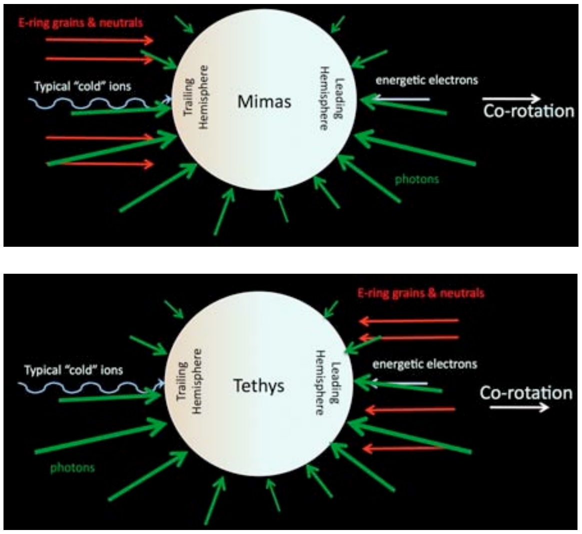

Figure 2. Schematics of the dominant exogenic processes at Mimas (top) and Tethys (bottom). The graphics are centered on the anti-Saturnian hemisphere (at 180° W); the leading hemisphere is toward the right and the trailing hemisphere is toward the left. Green arrows represent the amount of solar insolation at each latitude during southern summer; photolysis produces H_2O_2, a UV darkening agent.

References

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