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Weathering Effects on the Icy Saturnian Moons: UVIS Results

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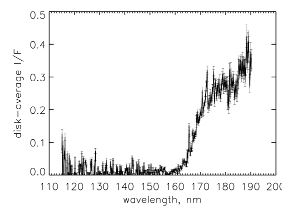
1. Introduction

The icy moons of Saturn orbit within a dynamic environment, the effects of which leave fingerprints on the surfaces of the moons. We explore the interactions between the moons and their environments by studying UV spectra and images. Prior to Cassini, the icy moons of Saturn had not been studied in the far-UV (FUV). The ultraviolet is an important wavelength regime for studying the effects of space weathering processes, because primarily the uppermost layers of the regolith and grains are sensed. Here we present FUV results from observations by the Cassini Ultraviolet Imaging Spectrograph (UVIS).

The FUV spectra of the icy Saturnian moons all show the strong signature of water ice, an absorption edge near 165 nm (e.g., [1][2]) (see Fig. 1). As a result, the spectra of the moons are generally bright longward of 165 nm and dark shortward of 165 nm. The moons are all darker than pure water ice at λ>165 nm, indicating that their surfaces are hosts to agents that absorb (darken) in the ultraviolet – if not at VNIR wavelengths.

1.1 Cassini UVIS

The Cassini UVIS [3] uses two-dimensional CODACON detectors to provide simultaneous spectral and one-dimensional spatial images. The second spatial dimension is acquired by slewing the UVIS slit across the target body. The far-UV channel of UVIS covers the 111.5-191.2 nm range. The detector format is 1024 spectral pixels by 64 spatial pixels. Each spectral pixel is 0.25 mrad and each spatial pixel is 1 mrad projected on the sky; the low-resolution slit has a spectral resolution of 0.48 nm and spatial IFOV of 1.5 mrad in the spectral dimension the high-resolution slit has a spatial IFOV of 0.75 mrad in the spectral dimension and spectral resolution of 0.275 nm.



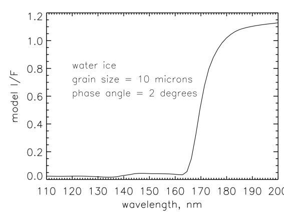


Figure 1. *Upper:* A sample disk-integrated UVIS spectrum of Enceladus (phase angle 2°). *Lower:* Model of pure water ice. Note that the spectral shapes are very similar, but the Enceladus is much darker than the pure water ice. From [2].

2. Weathering processes & UVIS results

There are many weathering processes that act on the satellite surfaces in the Saturnian system, including bombardment by photons, charged and neutral particles, and ice grains. Each is expected to exhibit a particular weathering patterns on the surfaces of the moons.

Enceladus and its south polar plume are the source of the broad E-ring [4], within which the other moons orbit. Dynamical modeling of the E-ring grains [5] have shown that, due to the eccentricities of the grains' orbits, those at the orbit of Mimas overtake Mimas in its orbit and are expected to bombard or coat the trailing hemisphere, while at Tethys and the other satellites exterior to Enceladus, the E-ring grains impact primarily the satellite leading hemispheres. E-ring grains impact/sandblast or coat the surfaces. The exact bombardment pattern of these grains is not completely known. The solution for their orbits depends on factors such as their initial rate of speed, charging history, etc. Since the latitudinal extent (vertical profile) of the E ring is much greater than that of the moons, it is our expectation that there are grain trajectories to at least reach the polar regions of the moons. The brightening effects of E-ring grain accretion have been seen at visible wavelengths (e.g., [6][7]). UVIS results show a brightening at the longer FUV wavelengths, consistent with the presence of increased amounts of pure water ice, in regions expected to accumulate E-ring grains.

Plasma and low-energy (below about 1 MeV) electrons preferentially impact the trailing hemispheres of the moons, just as the ions do. This corotating cold plasma is expected to bombard in a "bulls-eye" shape on the trailing hemisphere. However, because of their retrograde drifts in the dipole field of Saturn, electrons above about 1 MeV preferentially bombard the leading hemisphere of Mimas and Tethys [9][8]. The interaction between these high-energy electrons and the icy surface is believed to be the source of a significant thermal anomaly on Mimas [10] as well as a visible color pattern, where the surface is relatively blue on the leading hemisphere in a lens-shape matching the electron bombardment region [8].

Electrons and ions that are energetic enough to reach the ice can produce hydrogen peroxide (e.g., [11][12]). Hydrogen peroxide is known to be an effective UV absorber (e.g., [13][14]); we explore whether H_2O_2 may play a role as a darkening agent in the Saturn system. At Enceladus, NH_3 may be important in darkening the surface in the FUV [2]; Enceladus has a very steep UV absorption edge, similar to that of NH_3, and it is thought that NH_3 in the plume is redeposited on the surface. The other moons have less-steep spectral slopes in the near-UV–visible region, which may mean that H_2O_2 is important. We look for UV spectral trends across the surfaces of the moons to understand the exogenic processes and their effects.

Acknowledgements

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