ULTRAVIOLET MEASUREMENTS OF THE SURFACES OF THE ICY SATURNIAN SATELLITES.

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Introduction: The Cassini mission has provided a unique opportunity to make high-resolution, multi-spectral measurements of Saturn's icy moons, to investigate their surface compositions, processes and evolution. Here we present results from the Ultraviolet Imaing Spectrograph (UVIS). This instrument allows for the first measurements of the icy satellites in the extreme ultraviolet (EUV) to far-ultraviolet (FUV) wavelength range.

The icy satellites of the Saturn system exhibit a remarkable amount of variability: Dark, battered Phoebe orbiting at a distant 200 R_S, black-and-white Iapetus, the wispy streaks of Dione, cratered Rhea and Mimas, bright Tethys and geologically active Enceladus. Phoebe, Iapetus and Hyperion all orbit laregely outside Saturn's magnetosphere, while Mimas, Enceladus, Dione Tethys and Rhea all orbit within the magnetosphere. Furthermore, Mimas, Enceladus, Tethys, Dione and Rhea all orbit within the E-ring – so the extent of exogenic effects on these icy satellites is wide-ranging.

Goals of Investigation. After 3 years in orbit around Saturn, we present a comprehensive overview of UVIS results from Phoebe, Tethys, Dione, Iapetus, Mimas, Enceladus and Rhea, focusing on surface investigations. We expect that the UV signatures of these icy satellites are strongly influenced not only by their composition, but by external effects and magnetospheric environments. We study the EUV-FUV reflectance spectra to learn about the surface composition, map out water ice grain size variations, investigate effects of possible coating by E-ring grains, examine disk-resolved and hemispheric compositional and brightness variations, and investigate the presence of radiation products such as O_3 and H_2O_2.

Instrument and Datasets: We present results from Cassini's December 31, 2004 flyby of Iapetus and the June 11, 2004 flyby of Phoebe. The range to Phoebe (radius=107 km) at closest-approach was 2068 km, while the Iapetus closest-approach distance was 124,000 km. Data from the inner icy satellites have been acquired on many close flybys, including Mimas on August 2, 2005 (47,000 km), Enceladus on July 14, 2005 (175 km), Tethys on September 15, 2005 (3200 km), Dione on October 11, 2005 (1000 km), Rhea on November 26 2005 (500 km) and Hyperion on September 26, 2005 (514 km).

The Cassini UVIS [1] uses two-dimensional CODACON detectors to provide simultaneous spectral and one-dimensional spatial images. Two spectrographic channels provide images and spectra in the EUV (563-1182 Å) and FUV (1115-1912 Å) ranges. 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 UVIS has three selectable slits. The high-resolution slit is 0.75 mrad wide for the FUV channel (1.0 mrad for the EUV channel), the low-resolution slit is 1.5 mrad wide for the FUV channel (2.0 mrad wide for the EUV channel) and the occultation slit is 8.0 mrad wide for both the FUV and EUV channels. The high- and low-resolution slits have spectral widths of 2.75 Å and 4.8 Å, respectively, in both the FUV and EUV channels, while the occultation slit has spectral widths of 24.9 Å and 19.4 Å in the FUV and EUV slits, respectively. The FUV low-resolution slit illuminates 6 spectral pixels, and the EUV low resolution slit has 5. Two-dimensional spatial maps are built up by using motion of the spacecraft to scan the UVIS slit across the body (Fig. 1).

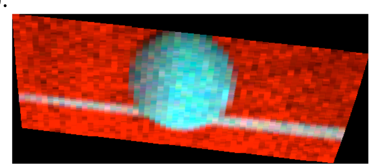

Fig. 1. FUV image of Rhea, shown with the rings in the background. Brightness variations due to surface features are visible. Red = Ly-α (1216 Å), blue=1600-1800 Å, green=1800-1900 Å.

Results:

Reflectance Spectra. The reflectance spectrum is obtained by ratioing the raw spectrum, with background subtracted, to a solar spectrum. We define reflectance as

$$r = I/F = P/(S/\pi)$$

where P is the calibrated signal from the satellite with background subtracted, in kR/Å. The solar flux is denoted by S, where $S=\pi F$. We use the solar data as measured by SOLSTICE on the SORCE spacecraft [2] at the appropriate solar longitude for the day of each observations scaled to the heliocentric distance of the moon on the day of the observation.

The FUV reflectance spectra of all of the icy Saturnian exhibit the strong water ice absorption feature at 165 nm. Sample spectra of Enceladus and Tethys are shown in Fig. 2. Overplotted are spectral models including water ice only. The model simulates the large absorption feature, but does not accurately fit the data at wavelengths <1600 Å or at wavelengths >1800 Å. We investigate the possible sources of these discrepancies.

Spectral Models. To model the reflectance spectra of the icy satellites, we intimate mixture models (after e.g.,[3]) We use of optical constants of water ice [4] and of candidate non-ice species. The spectral model of water ice for various grains sizes is shown in Fig. 1. Sample spectral models are shown overplotted on the satellite reflectance data in Fig. 2. The non-ice species largely are featureless in this wavelength region and do not constrain compositional models.

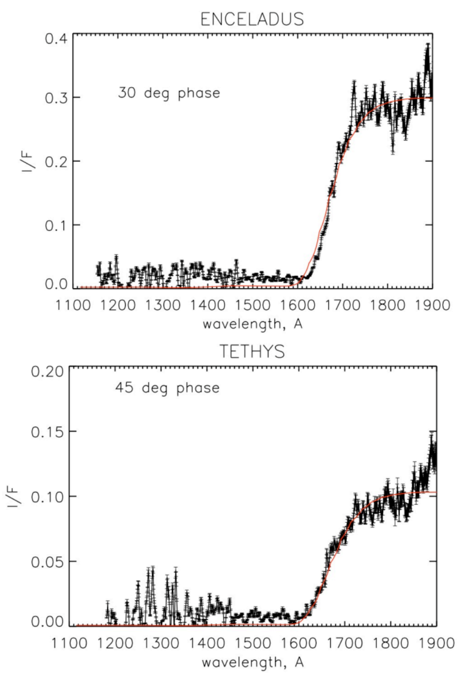

Fig. 2. Sample FUV reflectance spectra of the icy Saturnian satellites. Overplotted are spectral models of pure H_2O ice.

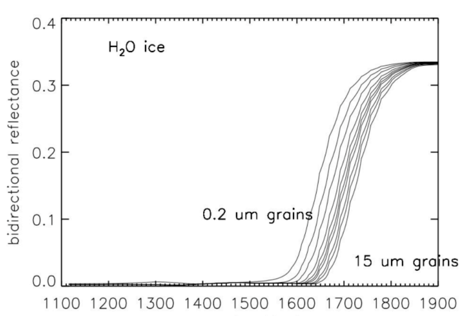

Fig. 3. Models of water ice reflectance spectra for several grain sizes, using optical constants [4].

The H_2O ice absorption feature is present even in the low latitudes of the apex region of the dark leading hemisphere of Iapetus (Fig. 4); the H_2O ice band depth increases with latitude away from the apex. Comparisons with Phoebe and Hyperion show that both of those bodies are richer in water ice that the Iapetus dark terrain. If either of those bodies is the source of the Iapetus dark material, water ice has been lost in the impact process; or, perhaps a more likely scenario is that the water ice has been lost subsequent to impact on Iapetus. We consider the idea that the dark material is warm enough at low latitudes, partly due to the slow rotation of Iapetus [5] that water ice has largely segregated from the lowest latitudes; the fact that water ice is present in the lowest, warmest latitudes suggests that the coating process is recent or ongoing.

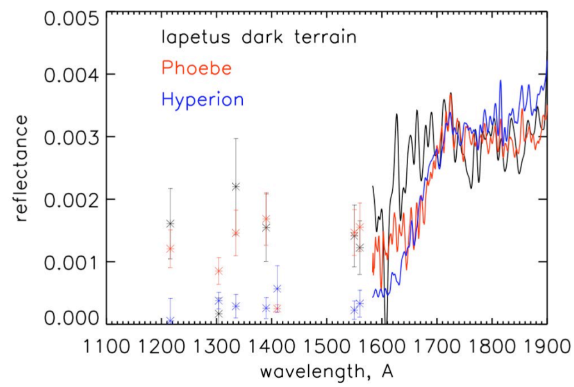

Fig. 4. Scaled reflectance spectrum of Iapetus's dark terrain (lowest latitudes) compared with disk-averaged spectra of Hyperion and Phoebe. The H_2O ice absorption feature is present even in the lowest latitudes of the dark Iapetus terrain, though it is not as strong as on Phoebe or Hyperion.

References: [1] Esposito et al. (2004) *Space Sci. Rev, 115,* 299-361. [2] McClintock et al. (2000) *Proc. SPIE, E.O.S. V, 4135*, 225-234. [3] Roush, T. L. (1994) *Icarus, 108,* 243-254. [4] Warren, S. J. (1984) *Appl.Optics, 23,* 1206-1225. [5] Spencer et al. (2005) *LPSC XXXVI*.