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Surface Compositions of the Icy Saturnian Moons: Clues from the Ultraviolet

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Enceladus' reflectance spectrum, while being very bright at VNIR wavelengths and consistent with a surface composed primarily of H_2O ice, is darker than predicted by pure H_2O ice spectral models at far-UV wavelengths, as measured by the Cassini Ultraviolet Imaging Spectrograph (UVIS) (Figs. 1 and 2). The visible spectrum of Enceladus is bright and featureless (Fig. 3), like pure water ice, and the near-IR spectrum has also been compared to pure water ice [1] or pure water ice plus a small amount of NH_3 hydrate [2] or NH_3 [3]. We investigate the darkness of the FUV spectrum by examining existing laboratory measurements of the optical constants and reflectance spectra of H_2O and other candidate species, and by comparing with spectral models.

We find that the low FUV reflectance of Enceladus can be explained by the presence of a small amount of NH_3 (Fig. 4) and a small amount of a tholin in addition to H_2O ice. (Optical constants for NH_3 hydrate in the UV are not available but we expect that the gross spectral properties are similar to those of NH_3 and cannot rule out the presence of NH_3 hydrate rather than NH_3.) The presence of these three species (H_2O, NH_3 and a tholin) appears to satisfy not only the FUV darkness and spectral shape, but also the visible wavelength brightness and spectral shape.

We have also modelled the solar phase curves of the Saturnian satellites using data from Cassini UVIS and VIMS. The photometric results show that the single-scatter albedos of the moons are dramatically lower in the far-UV than in the visible and NIR, supporting the spectral evidence.

We expect that ammonia in the Enceladus plume condenses in the E-ring, grains of which accumulate on and coat the surface Enceladus throughout its orbit, constantly enhancing the visible brightness of the moon and resupplying a small amount of NH_3 to the surface. We explore the potential role of ammonia and tholins in determining the UV brightness of the other icy Saturnian moons Mimas, Tethys, Dione and Rhea.

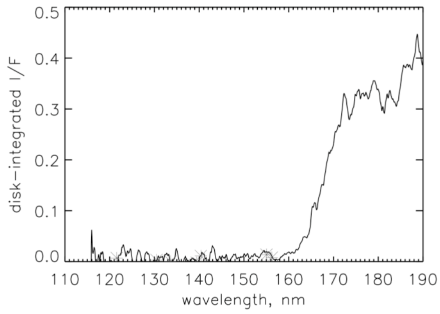

Figure 1: Far-UV reflectance spectrum of Enceladus measured by Cassini UVIS at 2° solar phase.

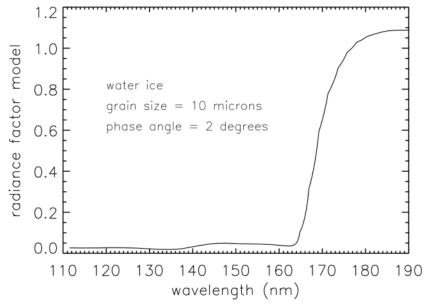

Figure 2: Model of FUV water ice reflectance spectrum at 2° phase; note that it's much brighter than the measured Enceladus spectrum in the 170 – 190 nm range.

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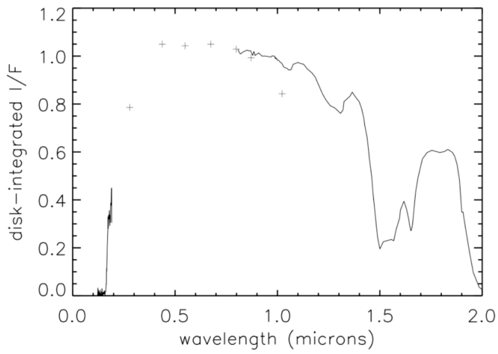

Figure 3: Composite spectrum of Enceladus at solar phase = 2°, combining UVIS data with data from [2] (0.8-2.0 mm) and [4] (plus signs).

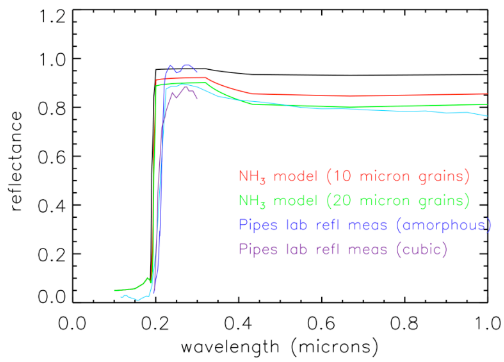

Figure 4: Ammonia ice: comparisons between Hapke models using optical constants from [5] and reflectance measurements from [6] and [7].

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