WATER ICE ABUNDANCE AND GRAIN SIZES, AND NON-ICE MATERIALS ON THE SATURNIAN SATELLITE PHOEBE FROM CASSINI/VIMS OBSERVATIONS. G. B. Hansen, S. K. Apple, and E.-J. Z. Shin-White, Department of Earth and Space Sciences, University of Washington, Box 351310, Seattle, WA 98195-1310 (ghansen@ess.washington.edu)

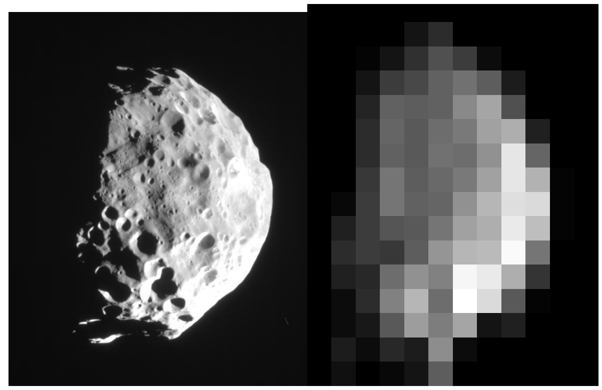
Introduction: We are working on a project to analyze the visible and infrared spectrum of the satellites of Saturn as observed by the Visual and Infrared Mapping Spectrometer (VIMS) on the Cassini orbiter. We plan to characterize the grain sizes and mixing and layering of water ice, and the characteristics of the non-ice components mixed with the ice.

The VIMS is an imaging spectrometer that generates cubes of up to 64x64 spatial coverage and 352 wavelengths (96 wavelengths 0.35-1.05 μm for VIMS-v and 256 wavelengths 0.8-5.2 μm for VIMS-ir) [1]. First we are looking at the close encounter with Phoebe, a distant satellite observed before Saturn orbit insertion {2–4]. It is in a retrograde orbit and is thought to be a captured object. We have done a critical calibration of the data set that involves careful correction of dark artifacts.

We are modeling the spectra with water ice and non-ice components, assuming linear mixing (segregated ice and non-ice terrains), which is likely considering the 3% albedo of the dark materials [5, 6]. Our first modeling effort is presented here. We derive mixing ratios and water ice grain sizes that are mapped over the surface of Phoebe at various spatial resolutions. Phoebe was observed for over two complete rotations during the encounter, so there is multiple coverage at all longitudes, although mostly at very low spatial resolution.

Observation: We have calibrated and combined a high-resolution observation by both channels of VIMS about 3.5 hours before the closest approach. There are four observations averaged, each with a spatial resolution of 15x30 km/pixel for the IR and 8 km/pixel for the VIS. The IR average is resampled with 15 km square pixels, and the VIS observation is aligned and undersampled to match this grid. Then the VIS and IR spectra are scaled to each other. A contemporaneous image from the Cassini camera is given in Figure 1(a). An image from the combined cube at a wavelength of 0.5 μm is shown in Figure 1(b). Many of the features of this low resolution image can be compared to the ISS image in Figure 1(a).

Modeling: For our model, we use precalculated bidirectional reflectances for pure water ice at grain radii from 1 μm to 1 mm (the same ones we have used for modeling the Galilean satellites [7]). These are resampled at the VIMS wavelengths and for the lighting geometries at each pixel, so we have a set of 10 grain radii at each location for the model. For linear mixing we only need an appropriate non-ice spectra and some scaling factors. The non-ice spectra is taken from some nearly ice-free locations in later observations and adjusted with the visible data in this cube. This spectrum, not including the narrow bands from other materials like CO_2 (4.25 μm), is shown in Figure 2.



(a) (b)

Figure 1. (a) Phoebe observed 3.5 hours before closest approach by the Cassini Imaging Science Subsystem (ISS). (b) VIMS image of Phoebe at 0.5 μm corresponding to the ISS image in (a).

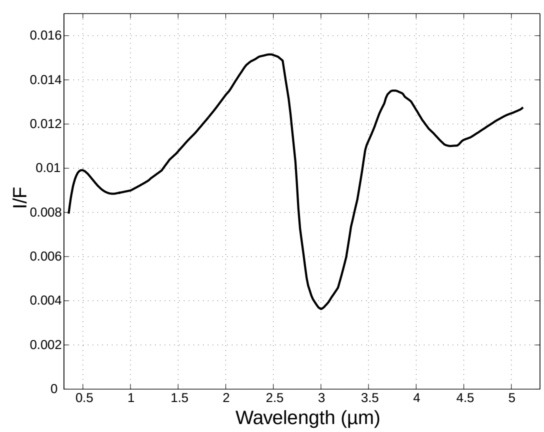


Figure 2. Non-ice spectrum for Phoebe taken from nearly ice free spectra.

The model has four parameters: the scaling for the ice and non-ice, the water ice grain size and a special short-wave scaling similar to what we used for Ganymede, effecting only below 2.5 μm. This is an approximate approach that will be refined later, as we have done for our Ganymede modeling.

Results: The ice-rich spectra could not be fitted well in general using these parameters. The ice properties are near to the best model, but the non-ice or mixing is not accurately modeled. The ice-poor spectra modeled much better as they are mostly dependent on the non-ice spectrum used, which was determined from such spectra. The spectral features of the ice are so weak in the ice-poor regions that there is no real constraint on the ice grain size (other than it must be small enough that the bands are not saturated, say <20µm radius). The fits to an ice-free and ice-rich pixel are shown in FIgure 4.

The results of the modeling are illustrated in Figure 5. The non-ice scaling is tied to its bidirectional reflectance properties and is larger on the bright limb, but there are weaker patterns correlated to the ice abundance. The ice scaling is very large near the terminator; this comes from the inaccurate lighting geometry where roughness effects are significant. Otherwise it is quite small, implying very small amounts of ice (0.5–3% spatially). The short wave scaling generally pushes the short-wave spectrum down a little in the ice-free areas and up a lot in the icy areas. The grain size defaults to 1 µm in the center (mostly ice free) and 2–10 µm elsewhere, consistent with other Saturnian satellites [8].

Discussion: The linear modeling approach shows the weak water ice bands near 1.04 and 1.25 µm. These bands are not seen in VIMS spectra of most terrains on Phoebe or Iapetus. For these small grain sizes and amounts they are very small and perhaps the VIMS calibration may be a little off here as well. In future we plan to project all these data and products on a map of Phoebe, where overlapping data can be compared and used to refine the results.

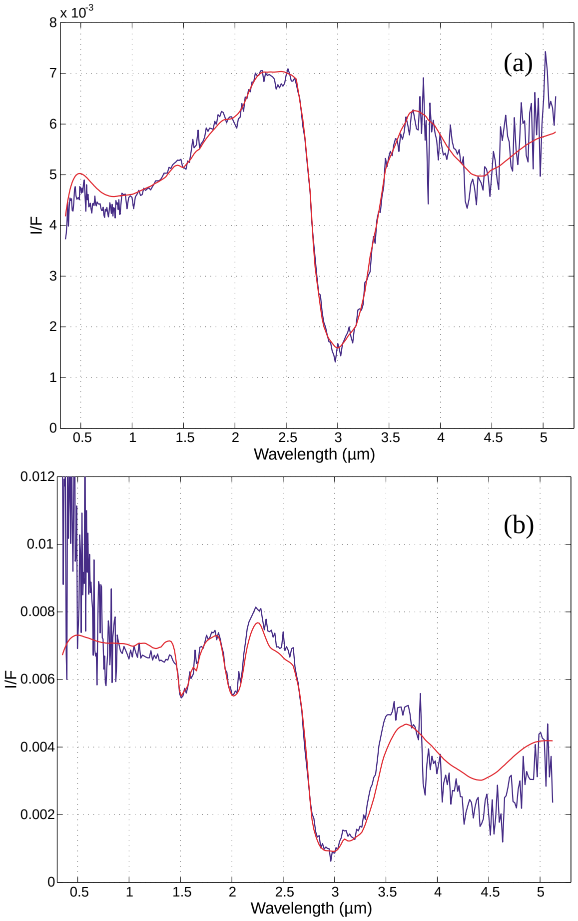


Figure 4. Example model fits for two pixels, ice-free (a) and ice-rich (b) in the Phoebe observation. The VIMS data is in blue and the model data in red.

References: [1] Brown, R. H., *et al.* (2004), *Space Sci. Rev. 115*, 111–168. [2] Clark, R. N., *et al.* (2005), *Nature 435*, 66–69. [3] Coradini, A., *et al.* (2008), *Icarus 193*, 233–251. [4] Cruikshank, D. P., *et al.* (2007), *Nature 448*, 54–56. [5] Spencer, J. R. (1987), *Icarus 69*, 297–313. [6] Spencer, J. R., *et al.* (2007), *Eos Trans. AGU 88(52)*, Abstract P22C-04. [7] Hansen G. B., and T. B. McCord (2008), *BAAS 40*, 506–507. [8] Hansen, G. B., *et al.* (2006), *Eos Trans. AGU 86*, Abstract #P11B-0124.

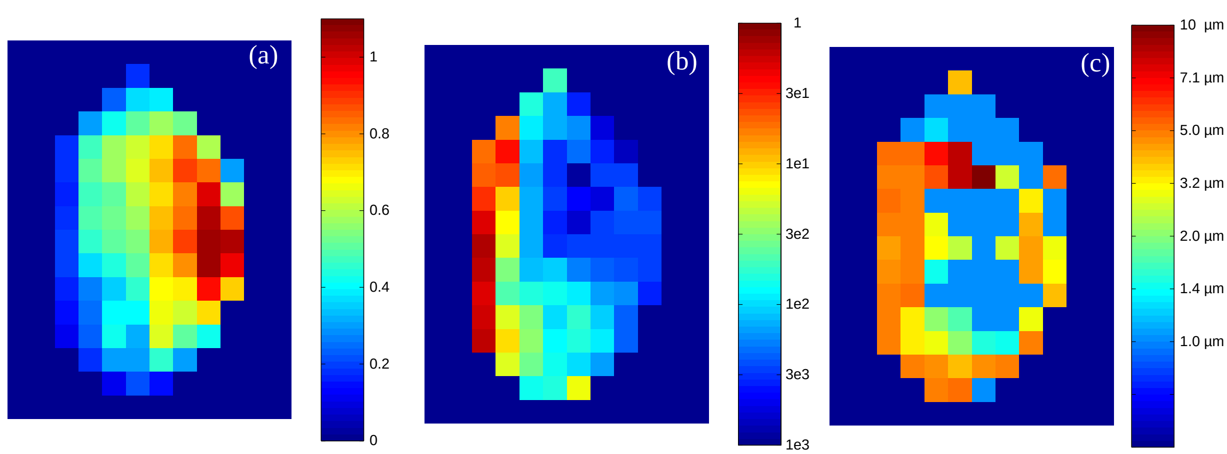


Figure 5. Maps of various model fit parameters: (a) non-ice scaling, (b) ice scaling (log), and (c) grain size (radius)