EPSC Abstracts
Vol. 6, EPSC-DPS2011-1563, 2011
EPSC-DPS Joint Meeting 2011

Composition and Grain Sizes of Dark Material in Saturn's Icy Satellites and Rings

Roger N. Clark(1), Dale P. Cruikshank(2), Cristina Dalle Ore(2), Ralf Jaumann(3), Robert H. Brown(4), John M. Curchin(1), Todd M. Hoefen(1), Katrin Stephan(3), Bonnie J. Buratti(5), Gianrico Filacchione(6), Kevin H. Baines(5), and Philip D. Nicholson (7)
(1) U.S. Geological Survey, Denver, CO, USA, (2) NASA Ames Research Center, Moffett Field, CA, USA, (3) German Aerospace Center (DLR), Berlin, Germany, (4) University of Arizona, Tucson, AZ, (5) Jet Propulsion Laboratory, Pasadena, CA, USA, (6) INAF-IASF, Italy, (7) Cornell University, Ithaca, NY, USA. (rclark@usgs.gov / FAX 303-236-3200)

Abstract

Cassini VIMS has acquired spectra of spatially resolved icy satellites and the rings of Saturn for over 6 years. The VIMS data provide a mixture space of ice and contaminants. In particular, the close Rev 49 fly-by of Iapetus provided spectra of the purest patches of dark material in the Saturn system as well as mixtures with ice. We have studied the spectral properties of the icy satellites and rings, modeling both the ice grain size distribution, the dark contaminants and their grain sizes. Modeling included nano-phase to micron-sized and larger particles and the effects of diffraction and Rayleigh absorption. We find that a simple and consistent explanation for the dark material includes nano-phase metallic iron and iron oxides. Carbon and tholins may also be present but are not spectrally dominant.

1. Introduction

Cassini VIMS spectra of the icy satellites and rings of Saturn show several unusual properties [e.g., 1, 2, 3], including relatively reduced 5-µm reflectance, reduced 3.1-µm Fresnel ice reflectance, reduced 2.6-µm reflectance, asymmetric-long 2-µm water absorption, low 1.5 / 2.0-µm ice band depth ratios, an unusual rise in reflectance toward shorter wavelengths, and a UV absorption. Dark material, most prominent on Iapetus, shows relatively linear red slope from 0.35 to 2.5 µm [Figure 8 in reference 1], but as the dark material becomes less abundant in more ice-rich regions, a blue peak becomes apparent in the spectra.

These unusual spectral structures point to several conditions. Fine-grained ice produces the reduced reflectances and band asymmetries discussed above. Sub-micron ice grains are common in the inner Saturn system, where such grains comprise the E-ring. Nevertheless, the spectral evidence shows sub-micron sized ice grains extend out to Phoebe. Modelling of the ice spectra therefore must include the effects of sub-micron ice grains, but what about the dark material?

2. Modeling

We assembled optical constants for ice, amorphous carbon, hydrogenated amorphous carbon (HAC) tholins, metallic iron, and nano-hematite to model VIMS spectra (Figure 1).

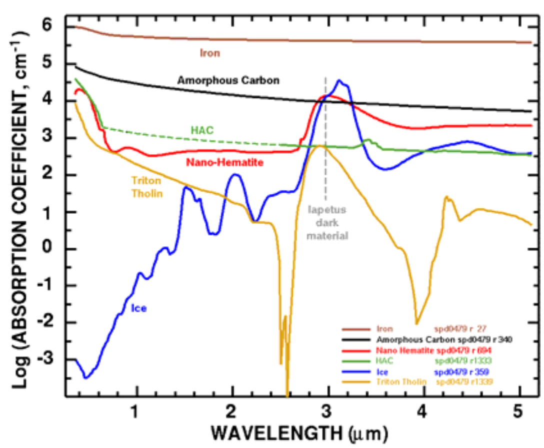

Figure 1. Absorption coefficients for various materials. See [3] for sources. The position of the water absorption in the Iapetus dark material is indicated.

Computing spectra of ice plus various contaminants, we find that materials with absorption features will likely reveal their presence in the extensive mixture series observed by VIMS in the Saturn system (e.g. Figure 2). We find the best matches among mixture

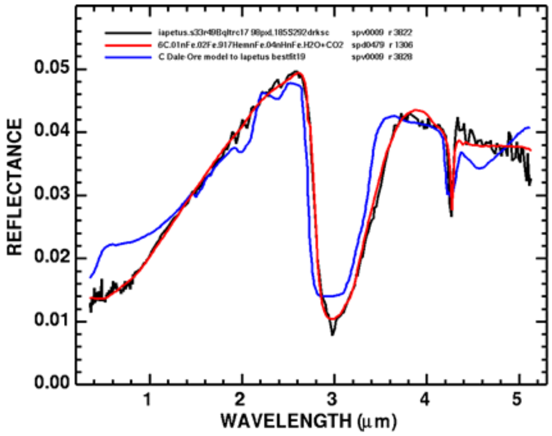

Figure 2. Modeled ice + nano iron + nano-hematite + CO_2 (red line) and ice + carbon + tholin +CO_2 (blue line) compared to a VIMS spectrum of the dark material on Iapetus.

series spectra with spectral dominance by ice + nano-iron + nano-hematite + CO_2. The position of the water absorption in tholins does not match that seen in the dark material on Iapetus whereas the adsorbed water in nano-hematite provides a good match to the position and shape of that seen in the Iapetus spectra.

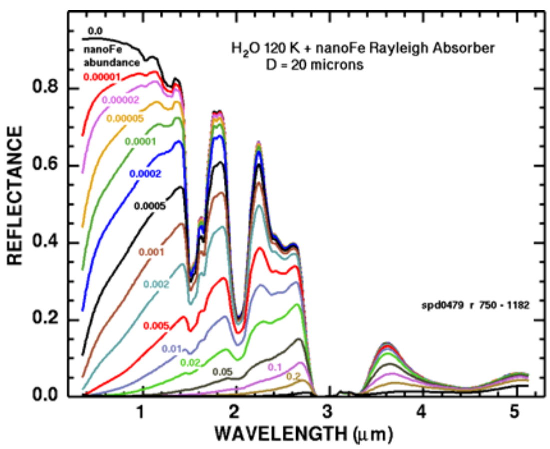

Figure 3. Model spectra of ice + nano-iron as a Rayleigh absorber.

Nano-iron in abundances of a few tens of parts-per-million in ice shows a UV absorption similar to that seen in VIMS spectra of the icy satellites and rings (Figure 3). In higher abundances, metallic iron creates a linear spectrum (Figures 2, 3) matching the observed dark material spectra.

We tested amorphous carbon as a Rayleigh absorber (Figure 4) but it exhibits a weaker UV absorption and has a shape at low abundances unlike that observed in VIMS spectra. Amorphous carbon could contribute to the linear nature of the Iapetus spectra in higher abundances, but the spectrum of carbon is flatter than that observed in spectra of Iapetus.

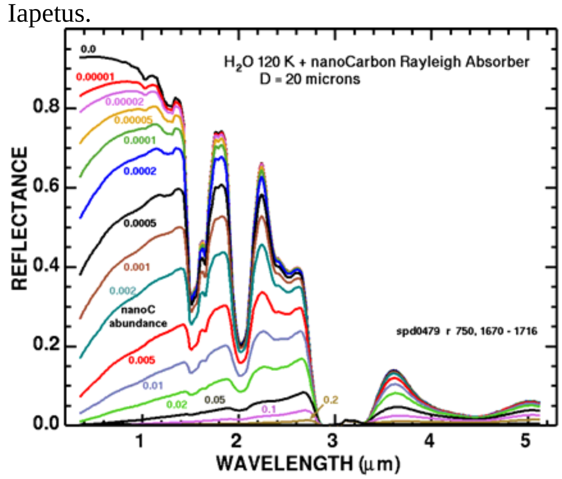

Figure 4. Ice + carbon as a Rayleigh absorber.

6. Summary and Conclusions

We find that nano-phase iron and hematite in a mixture with fine-grained ice can explain most, if not all the spectral structure in the icy surfaces data in the Saturn system. Nano-phase iron and hematite abundances are very small, and it might be possible to have larger abundances of carbon and tholins as long as the iron and hematite remains spectrally dominant.

Acknowledgements

This work was funded by the NASA Cassini project.

References

[1] Clark, R.N., *et al.*, 2008, Compositional mapping of Saturn's satellite Dione with Cassini VIMS and implications of dark material in the Saturn system, *Icarus*, **193**, p 372-386, doi:10.1016/j.icarus.2007.08.035. [2] Cuzzi, *et al.* (2009) Ring Particle Composition and Size Distribution, in *Saturn after Cassini/Huygens*, Springer, DOI 10.1007/978-1-4020-9215-2, pp. 459-509. [3] Clark, R. N., *et al.*, 2010, The Composition of Iapetus: Mapping Results from Cassini VIMS, *Icarus*, in review.