

Investigating the composition of dark material on Iapetus. Richard J. Cartwright¹, Chloe B. Beddingfield^{1,2}, D. Alex Patthoff³, Dale P. Cruikshank⁴, Tom A. Nordheim⁵, and Joshua P. Emery⁶. ¹SETI Institute, Mountain View, CA (rcartwright@seti.org), ²NASA Ames Research Center, ³Planetary Science Institute, ⁴University of Central Florida, ⁵Jet Propulsion Laboratory, California Institute of Technology, ⁶Northern Arizona University.

Background and Motivation: The Saturnian moon Iapetus displays a striking hemispherical dichotomy in albedo, with a dark, H₂O ice-poor leading hemisphere and a bright, H₂O ice-rich trailing side [e.g., 1]. Much of Iapetus' surface has been mantled by dust grains that likely originated on the Saturnian irregular satellite Phoebe [e.g., 2].

Data collected by Cassini's Imaging Science Subsystem (ISS) revealed Iapetus' heavily cratered surface [3], which may have experienced global stress events (see LPSC 2022 presentations by Beddingfield et al. and Patthoff et al.). Cassini also collected data using the IR channel of the Visual and Infrared Mapping Spectrometer (VIMS, 0.85 – 5.1 μ m), identifying weak and broad absorption bands between 3.2 and 3.5 μ m that could result from C-H stretching modes of hydrocarbons [e.g., 4,5]. The spectral signatures of other organic-related features are mostly absent from the VIMS data, possibly because the relatively low resolving power of VIMS (R, 50 – 300) obscures subtle absorption features that are comparable in width or narrower than the spacing of its spectral channels (16.6 nm) [6]. To search for subtle features and more fully characterize the composition of Iapetus' dark material, we are collecting and analyzing new ground-based, near-infrared spectra of Iapetus.

Observations and Data Reduction: We observed Iapetus using the SpeX spectrograph on NASA's Infrared Telescope Facility (IRTF) [7], collecting data on ten different nights in 2020 and 2021 (*Table 1*). We utilized the short cross-dispersed mode (SXD, 0.7 – 2.55 μ m) of SpeX with the 0.8" slit, achieving an average R of 750. Iapetus was observed over a range of moderate airmass (1.3 – 1.8), with relatively good seeing for Maunakea (0.4 – 1.1"), and under clear skies or thin haze. On each night, the spectrograph slit was oriented with the parallactic angle before collecting data. Telluric correction was performed by dividing Iapetus spectra by nearby G-type stars, each observed at similar airmass (± 0.1): HD 190617 (G2V) in 2020, and HD 198395 (G2V) and HD 197818 (G1V) in 2021.

Collected spectra were calibrated and extracted using the Spextool data reduction suite [8], along with custom programs. After extraction, individual 2-minute exposures from each night were coadded to increase signal-to-noise (S/N, 100 – 250 at 2.2 μ m). Total integration times (t_{int}) are summarized in Table 1.

Table 1: IRTF/SpeX observations of Iapetus.

Spectrum Number	Sub-Obs. Long. (°)	Sub-Obs. Lat. (°)	UT Date	UT Time (mid-expos)	t_{int} (min)
1	36.26	6.15	6/27/20	10:00	20
2	46.18	6.20	6/29/20	13:45	20
3	96.73	6.46	7/10/20	13:30	20
4	113.47	2.49	5/30/20	14:10	24
5	122.58	2.51	6/01/21	14:10	60
6	155.65	6.78	7/23/20	8:00	32
7	188.11	6.94	7/30/20	8:35	28
8	213.73	2.75	6/21/21	12:10	28
9	232.06	2.82	6/25/21	12:00	28
10	325.15	5.85	6/11/20	10:55	24

Results: The collected SpeX data clearly show the hemispherical asymmetry between Iapetus' leading and trailing hemispheres (*Figure 1*). Spectra collected over

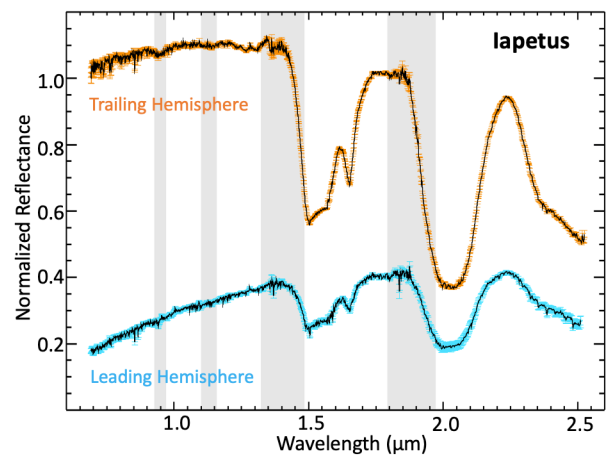


Figure 1: Grand average IRTF/SpeX spectra of Iapetus' trailing (orange) and leading (blue) hemispheres, normalized to 1 at 1.75 μ m and offset vertically for clarity. Gray-toned zones highlight wavelength regions with increased telluric absorption.

Iapetus' leading hemisphere are redder at shorter wavelengths (< 1.4 μ m), and their 1.52- μ m and 2.02- μ m H₂O ice bands are notably weaker. Between 2.1 and 2.5 μ m, the SpeX spectra display a suite of subtle absorption bands that are stronger in the spectra collected over Iapetus' leading hemisphere (*Figure 2*). One of these subtle features, centered near 2.3855 μ m (hereafter referred to as the "2.39- μ m" band), is stronger on Iapetus' leading side and at transitional longitudes, and it is weaker in spectrum number 9, collected over

Iapetus' trailing side (*Figure 3*). These measurements indicate that the 2.39- μm band may be associated with dark material and is weaker in regions rich in H_2O ice. Furthermore, the 2.39- μm band does not align with any prominent telluric or stellar feature. The width of the 2.39- μm band (0.005 – 0.01 μm) is narrower than the spacing of VIMS' channels (*Figure 4*), possibly explaining its non-detection in the Cassini dataset.

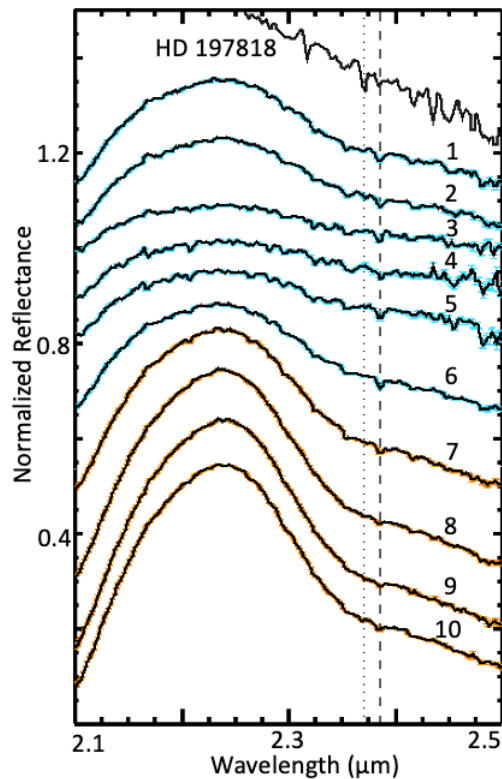


Figure 2: IRTF/SpeX spectra collected over Iapetus' leading (blue) and trailing (orange) hemispheres, normalized to 1 at 1.75 μm and offset vertically (numbers above each spectrum correspond to Table 1). The central wavelength of the 2.39- μm band (dashed line) is separated by 0.01 to 0.015 μm from a nearby telluric CH_4 band (dotted line) present in the spectrum of HD 197818 (black).

Discussion: Organics and Fe-bearing material have both been implicated in the composition of Iapetus' dark material [e.g., 4,5,9]. The detection of CO_2 on Iapetus [10] corroborates the presence of carbonaceous material. In terms of the 2.39- μm feature, hydrated methane and ethylene display absorption bands between 2.38 and 2.39 μm [11,12], as does HCN ice [13]. Similarly, hydrated Fe/Mg-bearing carbonates display bands near 2.39 μm [e.g., 14]. Consequently, C-rich material in the form of organics or metal-rich carbonates could explain the presence of the 2.39- μm band, and perhaps other subtle features between 2.1 and 2.5 μm .

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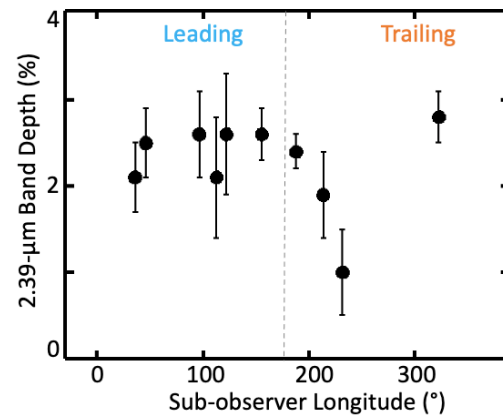


Figure 3: Continuum-divided 2.39- μm band depth measurements and 1σ uncertainties. Spectrum numbers shown in Table 1 and Figure 2 increase from left to right.

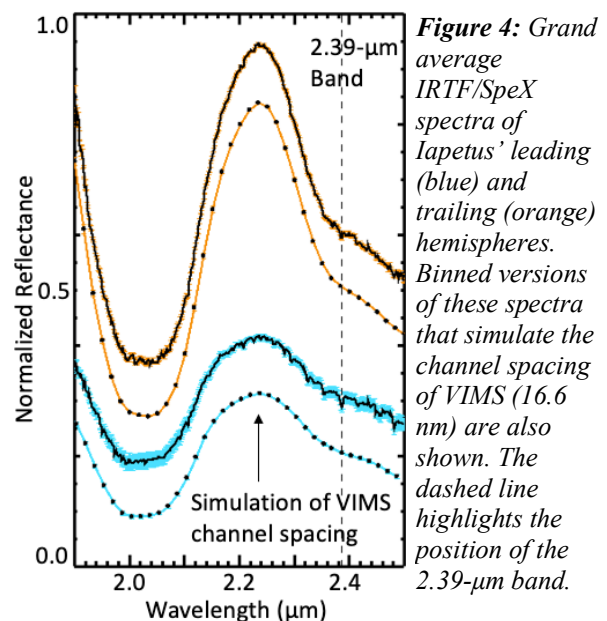


Figure 4: Grand average IRTF/SpeX spectra of Iapetus' leading (blue) and trailing (orange) hemispheres. Binned versions of these spectra that simulate the channel spacing of VIMS (16.6 nm) are also shown. The dashed line highlights the position of the 2.39- μm band.

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