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# The distribution of $CO_2$ over part of the surface of Iapetus revealed from statistical clustering of a VIMS mosaic.

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## Abstract

We present a detailed study of an Iapetus mosaic of Cassini-VIMS data with high spatial resolution (0.5 x 0.5°) [5]. We analyze this set of data using a statistical clustering approach to reduce the analysis of a large number of data ($\sim 10^4$ spectra from 0.35 to 5.10 $\mu$m) to the study of seven representative groups accounting for 99.6 % of the surface covered by the original sample. We give special attention to the study of the $CO_2$ band. We find that $CO_2$ absorption is widespread over both the bright and dark regions of Iapetus' surface, and probably represents the trapping of carbon dioxide as a clathrate, hydrate, or adsorbate at the molecular level with other materials. The strength of the $CO_2$ band in the areas where both, $H_2O$- and carbon- bearing materials exist, gives support to the hypothesis that this volatile is formed on the surface of Iapetus as a product of irradiation of these two components.

## 1. Introduction

Iapetus has a near-circular orbit and is locked in synchronous rotation such that one hemisphere is permanently directed toward Saturn. Its leading hemisphere (centered on the apex of the orbital motion) has a low surface reflectance (now known to be ∼ 2% - 6%) that is ∼ 10 times less reflective than the trailing hemisphere. VIMS, the Visual and Infrared Mapping Spectrometer on the Cassini spacecraft, was designed to collect spectra for spatially resolved areas on the satellites' surfaces [1]. In 2007, Cassini approached Iapetus to a minimum distance of 1620 km, providing the highest VIMS spatial resolution data for this object during Cassini's primary mission. We present an evaluation of a set of Iapetus VIMS observations that cover part of both hemispheres around the equatorial rift (Figure1a).

## 2. Data

The data analyzed here were obtained by VIMS during the Iapetus fly-by on September 10, 2007. We selected 30 cubes among the 80 obtained during part of sequence S33 of orbit 49. A global set of 25968 spectra, covering the full range between 0.35 and 5.1 $\mu$m, was considered for building a mosaic. Co-registration of the cubes was achieved by making use of the pointing information provided by SPICE kernels, available from the Planetary Data System (PDS). Details of this process are described in [5]. After eliminating redundant information from the areas covered by multiple cubes, the final mosaic, with a spatial resolution of 6.42 km/pixel (Figure1a) is composed of 12981 spectra.

## 3. Analysis

We use a statistical approach to sort spectra with similar properties into distinct clusters ([5] and references therein). The technique is agnostic of the physical meaning of the clusters, so scientific interpretation is required as part of the subsequent evaluation of the clusters. Before applying the cluster analysis, all the spectra were normalized to 1.0 at 1.2 $\mu$m to minimize the effect of the albedo in the results ([3]). Clustering yielded 7 statistically-significant clusters containing 99.6% of the data (Figure1b) in the mosaic, each cluster is represented by an average spectrum or 'centroid' (Figure1c). The distribution of the clusters exhibits a spatial coherence when compared with the detailed geomorphology and albedo dichotomy of Iapetus. To study the $CO_2$ distribution we isolated and baselined the band (which for Iapetus is mostly centered at ∼4.25 $\mu$m) on each of the centroids. For all the centroids, the band was characterized by the center position, width and depth of the fitted Gaussian. The results are presented graphically in Figure2 together with those obtained by [2] for Iapetus (dark areas), Phoebe, Dione and Hyperion.

## 4. Results

We found that the $CO_2$ feature is present throughout the surface sampled by the mosaic. The $CO_2$ band depth on the darkest and brightest parts of the mosaic is comparable. The fact that this band is deeper in the transition zones (clusters green, yellow and orange), where both water ice and dark material are present, supports the suggestion that the $CO_2$-bearing material on Iapetus is formed as a byproduct from the dissociation of water ice and carbonaceous material, and may represent a continuous formation of $CO_2$ on the surface of Iapetus ([4] and references therein).

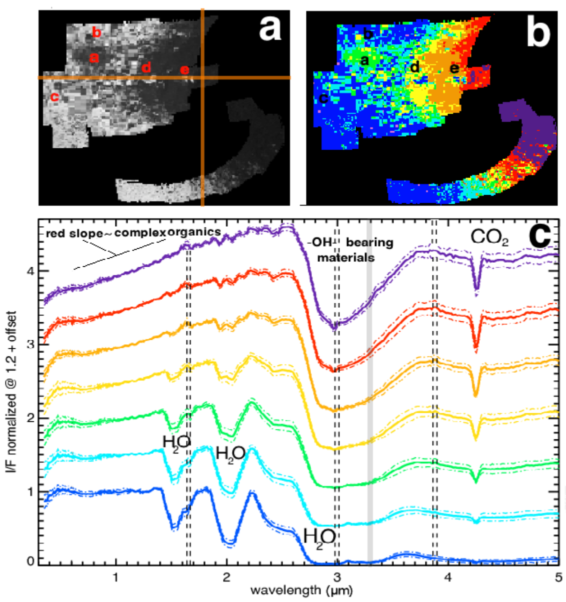


Figure 1: (a) Mosaic of data studied in this work. The orange lines mark the equator (horizontal) and the limit between the leading and trailing hemispheres. Some geographical features are labeled for comparison with panel c: [a. Dark area not named yet by the IAU; b. Baligant crater; c. Garlon crater; d. Cordova Montes; e. Sorence and Haltile Montes;]; (b) Distribution of the clusters over the mosaic; (c) Centroids representing each cluster shifted in the vertical for clarity. The color code is the same as in panel b. Some features in the spectra are labeled

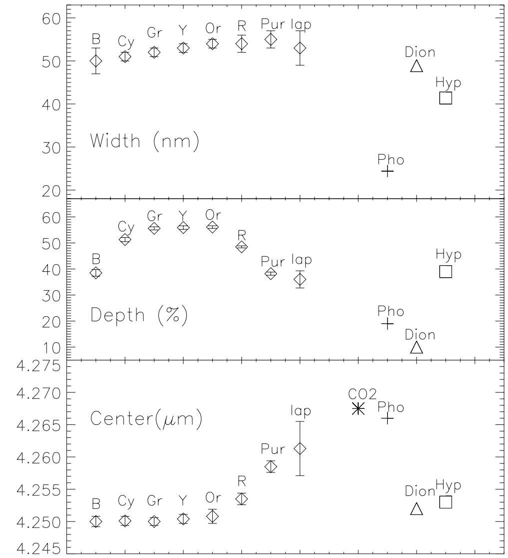


Figure 2: Study of the band of $CO_2$. From bottom to top: Center, depth and width of the band for the seven clusters of the mosaic in this work (B: blue; Cy: cyan; Gr: green; Y: yellow; Or: orange; R: red, Pur: purple; for average of the three selection of dark pixels on Iapetus (Iap) from [2]; for Phoebe (Pho), Dione (Dion) and Hyperion (Hyp) from [2]; and for pure $CO_2$ ice, ~ 80K, from [6].

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