

INFRARED MONITORING OF LIQUID/SOLID HYDROCARBONS UNDER TITAN SIMULATED CONDITIONS. T. Cornet¹, S.S. Magar², A. Luspay-Kuti², F.C. Wasiak², V. Chevrier², W.D.D.P. Welivitiya², L. Roe², O. Bourgeois¹, S. Le Mouélic¹, ¹Laboratoire de Planétologie et Géodynamique, 2 Rue de la Houssinière BP92208, 44322 Nantes Cedex, France. ²Arkansas Center for Space and Planetary Sciences, 202 Field House, University of Arkansas, Fayetteville, AR 72701 USA. (thomas.cornet@univ-nantes.fr).

Introduction

Titan possesses a thick and opaque atmosphere mainly composed of nitrogen and methane. Atmospheric methane is photodissociated and produces various hydrocarbons such as its first photochemical product, ethane, and several other hydrocarbons (such as acetylene, benzene, HCN, ...) that can fall onto the surface [1]. Due to Titan's surface pressure and temperature conditions (1.5 bar, 90 - 95 K), methane and ethane are metastable on the surface, forming lakes and seas seen in Cassini images of Titan [2], while other hydrocarbons are solid. Some of them can be dissolved in liquids and/or cover Titan's surface [1].

Therefore, we aim at investigating the infrared properties of Titan relevant materials under Titan conditions. To reach Titan's surface conditions, we use the Titan Module developed at the University of Arkansas and presented in Wasiak et al. [3]. First of all, we get infrared spectra of liquid methane, ethane and mixtures to characterize infrared properties of Titan's liquids. Then, we investigate the infrared properties of hydrocarbon ices. Spectra are then quantitatively analyzed and used to emphasize the presence or absence of these compounds during evaporation/sublimation processes, which are also quantified using a continuous mass monitoring [4].

Data acquisition and methods

The Titan Module is equipped with a Nicolet FTIR 6700 Smart Diffuse spectrometer with N₂ purge gas. Infrared spectra are acquired *in situ* via a fiber optics operating from 1.0 to 2.6 μm and with a spectral resolution of 4 cm^{-1} . This spectral range unfortunately does not include 2 of the 7 atmospheric windows identified by the Cassini VIMS imaging spectrometer [5], centered at 2.7-2.8 and 5 μm , where tentative compositional mappings have been realized [6, 7, 8, 9]. However, it covers 4 other atmospheric windows, of which the 2 μm window, that has been previously used to detect ethane in Ontario Lacus using VIMS spectra [10].

The Titan Module is first purged with N₂ gas to simulate Titan's atmosphere bulk composition and atmospheric pressure (1.5 bar), and cooled with liquid nitrogen through coils until Titan's surface temperature range (90-95 K) is reached. The samples are then precipitated into a sample pan continuously weighed to record the loss of mass over time. Once the samples are in the pan, they are monitored using the FTIR. Liquid methane, ethane, mixtures and acetylene ice infrared data have been acquired under Titan's conditions, except for the acetylene data that have been acquired at higher temperatures. Some spectra of these compounds are shown in Fig. 1 and are offset for clarity.

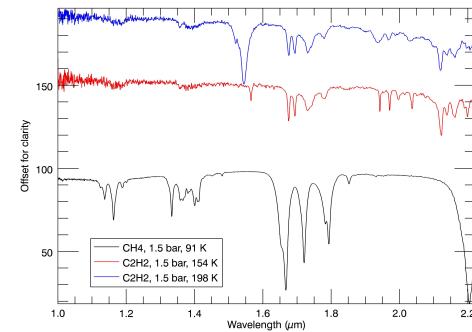


Figure 1: Infrared spectra of selected Titan relevant materials.

Interpretation of the spectra

Absorption bands, where the signal recorded by the FTIR is lower, are detected in each spectrum and allow the potential identification of a given compound. Identified methane absorption bands are centered at 1.16, 1.33, 1.41, 1.66, 1.72, 1.79 and 1.85 μm , in agreement with Clark et al. [11]. Ethane and methane-ethane mixture data are still in processing and are therefore not represented in Fig. 1.

Numerous acetylene absorption bands have been detected. Their presence, position and shape depend on the temperature. We investigated a wide range of temperatures (between 154 and 214 K) to identify the infrared properties of acetylene ice and liquid. The identified absorption bands are centered at 1.56, 1.67, 1.69, 1.73, 1.77, 1.94, 1.97, 1.99, 2.03, 2.11, 2.14, 2.16 and 2.20 μm at 154 K (solid acetylene). Other bands are present at 1.52, 1.53, and 1.54 μm (the latter being the strongest) at temperatures closer to the acetylene liquid range (between 189 and 195 K at 1.5 bar) and thus potentially corresponding to the liquid state of acetylene. Further work is needed to fully understand the spectral behavior of acetylene. Besides, regarding storage purposes, acetylene is mixed with acetone, of which absorption band position have to be taken into account.

Since the depth of an absorption band is directly linked to the abundance of a given compound, we computed the absorption band depths of each compound along the time, with the formula given in Massé et al. [12]. This band depth evolution with time can directly be used to constrain the presence/absence of the liquids/ices in the sample pan of the module, while it is continuously weighed to record evaporation/sublimation rates.

This use is illustrated in Fig. 2, which represents the data (FTIR, mass and temperature) recorded during a pure methane evaporation experiment (temperatures comprised between 92 and 99 K over 32 minutes, the last FTIR measurement has been taken at higher temperature). We first poured 12 g of liquid

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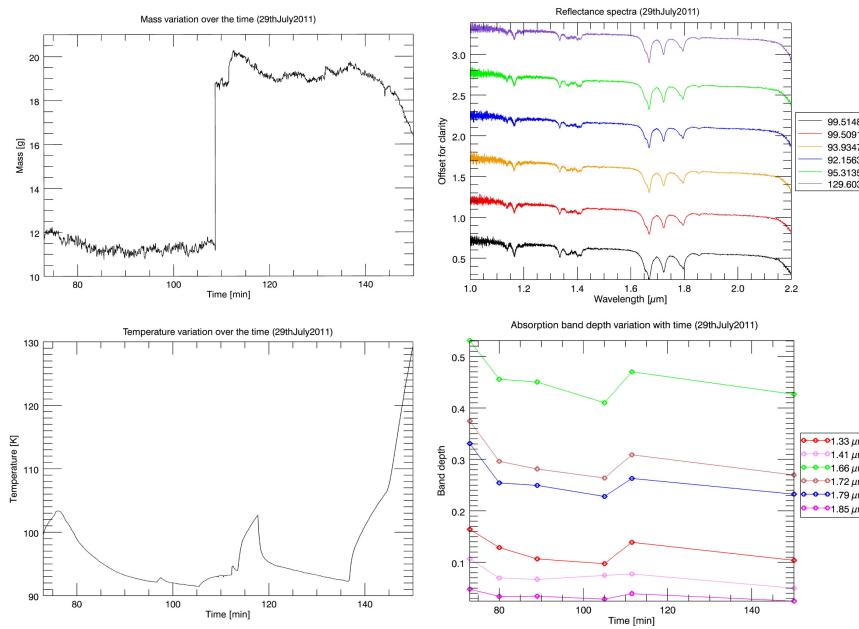


Figure 2: Example of data acquired jointly during a methane experiment. Top left: mass data. Bottom left: temperature data. Top right: FTIR data. Bottom right: absorption band depths computed using the formula of Massé et al. [12].

methane into the sample pan, about 70 min after the start of the experiment, and then two additional pours later (7 g after 109 min and 1 g right after). The band depths and the mass data are increasing during the pours and then decreasing, which proves that methane is evaporating. Because the temperatures were increasing, we had to abort the experiment before the liquid methane completely evaporated.

This monitoring will be very useful for experiments including liquid mixtures (first reported in Luspay-Kuti et al. [13]) or liquid/solid mixtures (including dissolved compounds acting as salts) to identify preferential evaporation and/or precipitation and/or crystallization of some hydrocarbons mixed together under Titan conditions. The dissolution/crystallization processes will be investigated since hydrocarbon dissolution in methane/ethane is probably an important mechanism shaping Titan's landscapes [14, 15, 16].

Discussion

The Titan Module allows to determine evaporation rates of liquids (methane, ethane and mixtures [4, 13]), under Titan surface conditions, through the continuous mass monitoring of the samples. Infrared data acquired using the FTIR implemented in the Titan Module can be used as a second checking of the evaporation/sublimation of these compounds, owing to the direct identification of the presence/absence of their absorption bands in the infrared spectra. Future work will include the quantitative determination of evaporation/sublimation rates using the infrared data, which can be checked against those determined by the mass data.

FTIR measurements used during liquid mixture experiments will allow to follow the likely preferential evaporation

of some liquids compared to others (e.g. liquid ethane compared to liquid methane). Further experiments on liquid hydrocarbons mixtures containing dissolved compounds will be useful to better constrain dissolution processes, which model the surface of Titan. Finally, such infrared laboratory measurements will be very helpful to interpret the data acquired by the VIMS imaging spectrometer onboard Cassini, in particular on the polar lakes and seas area.

Acknowledgments

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