HYDROCARBON ICES UNDER SIMULATED TITAN SURFACE CONDITIONS.

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Introduction: Saturn's moon Titan is the only body other than Earth where stable liquid has been identified on the surface. NASA Cassini RADAR discovered dark, lake-like features in the northern hemisphere of Titan [1]. Cassini-VIMS collected spectra of Titan's largest lake Ontario Lacus in the southern hemisphere of Titan. VIMS identified ethane as a major component of the lake using the 2μm atmospheric window [2]. Other hydrocarbons or nitriles may exist in liquid form in the lakes, but spectra are hard to detect because of Titan's thick atmosphere [3].

Titan has a hydrological cycle driven by methane and the surface conditions (90 K and 1.5 bar) are close to the triple point of methane, thus it can exist in different phases on Titan [4]. This study focuses on the ice phase of these hydrocarbons because it is important to understand the stability of ice layers in cases of global cooling as colder climatic periods have been suggested at geological timescales [5]. Ice layers on the surface of lakes have also been suggested via evaporative cooling of the lakes. This ice layer could be responsible for the lack of waves on the lakes [5]. We used FTIR to characterize the difference between different phases of ethane and methane, and the sublimation process of methane. It is important to understand these phases in lab as they will help us understand the geological past of Titan.

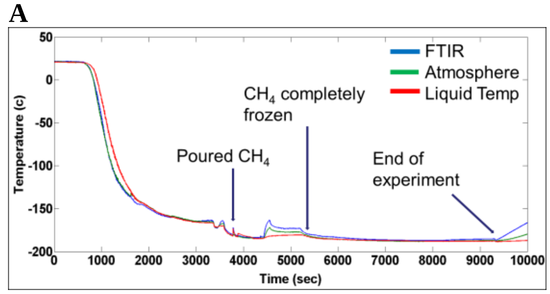
Experimental: We used our Titan simulation chamber to simulate Titan's atmosphere and surface conditions [6]. The chamber is purged with nitrogen gas before the experiment. Then, the gas is pressurized to 1.5 bar. Titan temperatures are reached by flowing liquid nitrogen through coils around the module. Once the chamber has reached relevant temperatures, hydrocarbons gas is introduced into the condenser maintained at 94 K for liquid methane and 110 K for liquid ethane. We then open the condenser and pour the liquid into the petri dish. We then continue to cool the chamber until the liquid becomes frozen (below ~ 92 K). The temperature and mass are continuously recorded during the experiment.

We used the Nicolet 6700 Smart Diffuse spectrometer with nitrogen purge gas to collect infrared spectra from 1.0 to 2.5 μm with 4cm-1 spectral resolution. This allows us to cover five of the Titan atmospheric windows at 1.19, 1.33, 1.4, 1.66, and 2.0 μm.

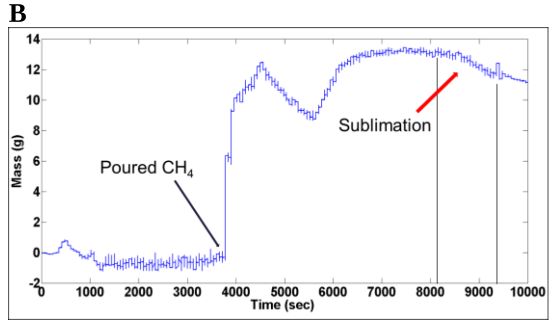
Results: A total of 7 Titan simulations of pure methane and pure ethane were run. Fig, 1 shows the temperature, mass, and FTIR spectra for a run of pure methane. At 3800 sec methane is added to the petri dish. At 5000 sec it begins to freeze and becomes completely solid at -183ºC. The mass becomes stable at 6500 sec until it starts to decrease at 8200 sec. Spectra of methane were collected during the length of the experiment. The reflectance increased from 70% to about 75% during the phase change form liquid to solid ice. In this experiment we were able to collect spectra during the transition between phases. The spectra recorded during the solid phase shows the band depth is decreasing.

Fig. 2 shows the temperature, mass, and FTIR spectra for a run of pure ethane. Ethane is dropped into the petri dish at 4000 sec, and the mass remains constant until the end of the run. There is a steady decrease in the temperature and it stabilizes until the ethane completely freezes. The formation of solid ethane ice is shown by the drop in temperature at 5000 sec. The temperature then stabilizes again until the end of the experiment. In ethane spectra a shift in reflectance of the spectra occurs with change from liquid to solid phase changes. The reflectance increases from about 67% to about 83%. However, unlike methane, the band depth in the ice spectra increases.

A



B



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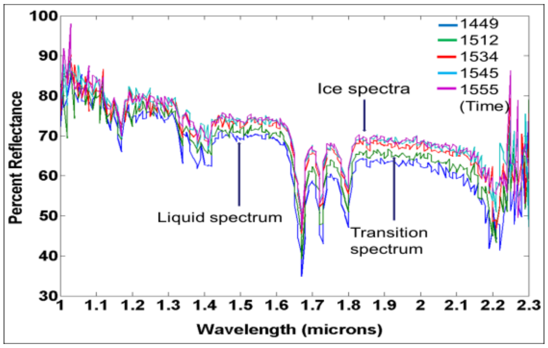

Figure 1: Freezing of liquid methane. A. Temperature versus time. B. Mass versus time. C. Infrared spectra of methane during the course of the experiment. Methane peaks are observed at three of the atmospheric windows: 1.19, 1.33, and 1.66 microns.

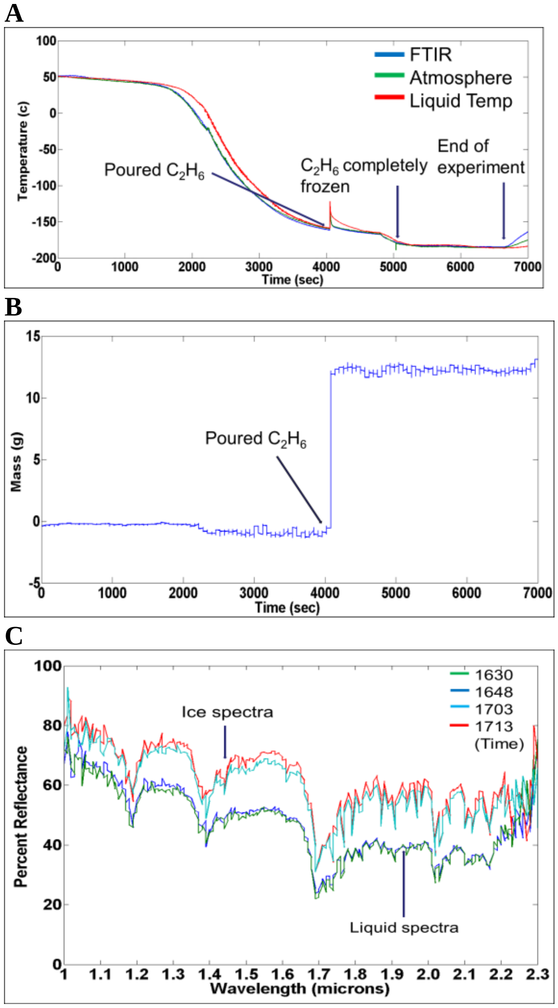

Figure 2: Freezing of liquid ethane. A.Temperature versus time. B. Mass versus time. C. Infrared spectra of ethane during the course of the experiment. Ethane peaks are observed at three of the atmospheric windows: 1.19, 1.4, 1.66, and 2.0 microns.

Discussion: When analyzing the FTIR spectra from the runs we concentrate on two features: reflectance and absorption band depth. We compare temperature and mass data to ensure a direct correlation. In theory, as a substance changes form liquid to solid the reflectance should increase. The shift is shown in the spectra of Fig. 1C and Fig. 2C. Both methane and ethane in the solid phase have a higher reflectance.

The absorption band depth is directly associated with the amount of liquid present as discussed by Singh et al. [7]. Methane is an extremely volatile hydrocarbon. In Fig. 1C ice spectra the band depth decreases probably due to methane sublimating. The mass data (Fig. 1B) also shows a decrease in the amount of methane in the petri dish. Further calculation on the sublimation rate of methane ice requires more data analysis. In Fig. 2C ice spectra of ethane the band depths increase. Due to ethane being non-volatile, it does not sublimate so the mass stays constant.

Application to Titan. Studying methane ices will help to gain a better understanding of the hydrological cycle through evaporation/sublimation rates and also to determine the physical state of the lakes on Titan. Identification of the phase of the hydrocarbons can be interpreted by experimental data. Reflectance changes can be used to interpret light and dark features found on Titan's surface by Cassini spacecraft. Although direct comparisons of brightness variations across Ontario Lacus are not possible due to the non-normal viewing angle of measurement, Ontario Lacus revealed a dark structure corresponding to the low lying and flat radar structure of the lake and shows variation in the albedo. Darkening of the lake interior at 2 microns is consistent with the lab reflectance results of liquid ethane.

Conclusion: From this study we have found that reflectance increases as the hydrocarbons change from liquid to solid ice. Methane is sublimating over time and ethane band depths increase over time.

Future Work: The sublimation rate of methane will be calculated. Also, there will be further sublimation experiments with hydrocarbon mixtures.

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References: [1] Stofan et al 2007 Icarus 185, 443-456. [2] R. H. Brown et al. Nature, 454:607– 610, 2008. [3] Moriconi et al. 2010, Icarus 210, 823-831). [4] A. Luspay-Kuti, et al. (2012) 43rdLPSC, 2408. [5] R. D. Lorenz., (1997), *GRL*, 24-22. [6] F.C. Wasiak et al. In 42nd LPSC, page 1322, 2011. [7] S. Singh, et al. (2013) 44thLPSC, 2056.