ICE – HYDROCARBON INTERACTIONS UNDER TITAN-LIKE CONDITIONS: IMPLICATIONS FOR THE CARBON CYCLE ON TITAN.

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Introduction: The Cassini spacecraft has been orbiting in the Saturn system since July 2004. Remote sensing instruments have discovered dunes, river beds, lakes, seas, impact craters, mountains and cryovolcanic features [e.g. 1 - 7]. Titan's activity is somehow similar to that of Earth with methane and ethane playing the role of water and ice that of silicates. In Titan's surface condition (P=1.5 bar, T=92-94 K), methane and ethane are in the liquid phase (Fig. 1). In addition, the Visual and Infrared Mapping Spectrometer (VIMS) acquired infrared spectra of Ontario Lacus, located in the south pole area, which are best explained if the lake is composed of a mixture of liquid ethane and methane [8]. As it is the case for water on Earth, the partial pressure of methane in Titan's atmosphere is too low for it to remain in the liquid phase. The Cassini data raise several question that require laboratory experiments:

- How hydrocarbons flow on and within an icy crust?
- Do hydrocarbons react with ice and what compounds are formed?
- What is the composition of Titan's surface that can match the infrared spectra?

These questions have led us to set up a Titan chamber where we can study the interaction between hydrocarbons and an icy substrate.

Experimental setup: A reservoir of liquid methane (Fig. 2) is within a nitrogen–cooled tank.. The temperature of the reservoir is controlled within 1 K. It is usually set at 90 K, which is a few degrees above the freezing point. Methane gas comes from a tank through a 0.76 mm ID capillary where the pressure is set to either 20 or 30 psi (1.38 or 2.07 bar). As it arrives in the reservoir, methane vapour liquefies and a capillary 0.5 mm ID carries the liquid methane which forms drops at the tip which fall on the copper boat filled with ice (Fig. 3).

The ice substrate is prepared in the copper boat with Nano-pure double destilled water in a -80°C freezer. The sample is allowed to freeze in an isolation chamber to ensure no formation of secondary ice (frost) on the surface.

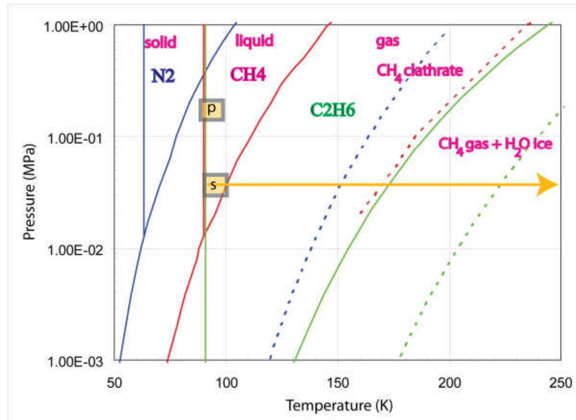

Figure 1: *Stability domain of nitrogen (blue), methane (red) and ethane (green) in a (P,T) plane.The dashed lines show the stability of the different clathrates. The orange rectangles show the conditions in the reservoir (p) and on the stage (s). The arrow shows the evolution when the stage heats up at the end of each experiment.*

The Titan environmental chamber is pumped out to remove water vapour and dry nitrogen is introduced. Liquid nitrogen flows through tubes to cool the methane reservoir and the experimental platform (stage). Temperature sensors are placed at different locations and monitored during the experiment. The reservoir temperature is adjusted for the specific experimental protocol. The stage temperature is allowed to cool to 250 K before introducing the ice sample below the capillary outlet. Dry nitrogen is continually purged through the chamber to minimize condensation of atmospheric water on the cold surfaces. After closing the chamber door, with a 6" silica viewing window, the internal pressure is reduced to 0.5 bar and the methane gas is allowed to flow into the reservoir. The temperature of the stage is maintained at 88 K and the reservoir temperature is set to 90 K but fluctuates by approximately 1 kelvin. A camera is set up outside the chamber and can monitor the experiment through the window.

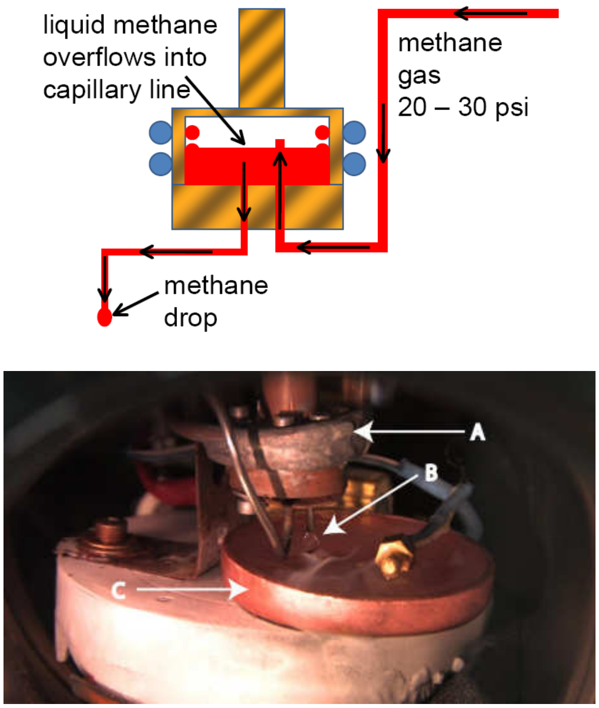

Figure 2: *The methane reservoir (top panel labeled A in the bottom picture) is in the Titan environmental chamber. The drop comes out of the capillary (B) and falls on the copper stage (4" diameter) or onto ice substrate (C).*

Results: When methane drops came into contact with an ice substrate, the interaction is similar to how water soaks into a sand matrix. Figure 3 shows how the methane darkens the ice substate as it presumeably disperses into the ices' open pore space which may be cracks in the ice sample. Then, the liquid methane fills up the depression that was carved into the ice. Experiments with positive topography have been realized and it was observed that the elevated ice gets wetted by liquid methane before the pool starts filling up. The same behavior has been observed with liquid ethane.

Once the depression is filled with liquid hydrocarbons, the formation of liquid droplets is stopped. The liquid evaporates because the temperature of the chamber is higher than the vaporizing temperature. The depression dries out before the solid (ice+liquid hydrocarbon) exhibits any change in optical properties. Then, the liquid hydrocarbons seem to evaporate from the solid ice until the ice comes back to its initial colors (top panel in Fig. 2).

Implications for Titan: Most of Titan's lakes have been observed by the Cassini radar instrument in the northern hemisphere during Titan's winter and more recently in the southern hemisphere. Only one large lake has been observed in the southern hemisphere by Cassini's optical instruments (ISS and VIMS). The present experiments suggest that Titan's subsurface must be filled with liquid hydrocarbons in both polar regions. In addition, methane was released from the subsurface when the Huygens probe landed on Titan, which suggests that Titan's subsurface is also wetted by hydrocarbons in the equatorial domains. The wetting characteristics of methane and ethane as observed by the present experiments suggest that the Titan lakes do not represent an equipotential water table [9] on Titan but rather an over-saturation of the solid ice in hydrocarbons. Further experiments will be carried out in order to investigate the optical properties of these mixtures in the infrared in order to compare with infrared spectra acquired by the VIMS instrument onboard the Cassini spacecraft [6-8].

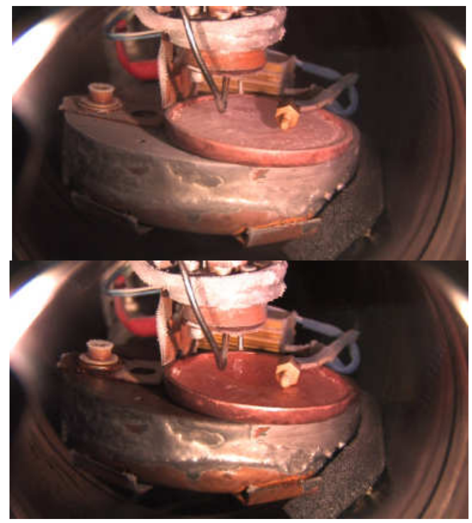

Figure 3: *When water ice (top picture) is wetted by liquid methane, the methane is absorbed in the ice and causes change in its optical properties (bottom picture).*

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References:

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