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Laboratory simulation of Titan's lakes: developing a new experimental facility to constrain the chemical composition of Titan's liquid surfaces

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Abstract

Since the discovery of Titan lakes by Cassini in 2006, interest in predicting their composition has grown substantially. In order to simulate Titan's liquid surface, we have developed a new experimental setup named Titan's Lakes Simulation System (TiLSS) that is designed to study the composition of these lakes in equilibrium with the atmosphere. In this system, we can prepare a variety of hydrocarbon mixtures (primarily methane, ethane, and propane) in the gas phase, and condense them under Titan-simulated conditions (1.5 bar nitrogen pressure, 92 K). This experimental setup will also provide a 10 Litre volume of liquid hydrocarbons to test the operation of hardware under Titan's lakes conditions.

1. Introduction

One of the most remarkable discoveries of the Cassini-Huygens mission is the presence of hydrocarbon seas and lakes at Titan's poles [1]. While the existence of liquid methane oceans in the surface of Titan was presumed long time before Cassini-Huygens mission, the chemical composition of Titan's lakes is still not well known. The Visual and Infrared Mapping Spectrometer (VIMS) onboard the Cassini spacecraft detected ethane signatures in Ontario Lacus [2]. The detection of methane in Titan's liquid surfaces is very difficult due to the strong absorption bands of gaseous CH_4 existing in the atmosphere of Titan and the similarity between infrared spectra of liquid and gaseous Methane. Most studies aiming to determine the composition of Titan's lakes used theoretical modelling to determine this composition. Different theoretical approaches lead to important discrepancies in the predicted CH_4-C_2H_6 proportions in the equilibrium between Titan's atmosphere and surface [3] [4]. Moreover, Titan's lakes are recipients of organic products of the atmospheric photochemistry. Here also, models predicted different dissolution percentages. The need for more constraining studies of the chemical composition of Titan's lakes led to the development of TiLSS experimental platform allowing the measurement of this composition in an environment simulating the equilibrium between Titan's atmosphere and liquid surfaces.

2. Experimental setup

Figure 1 presents a schematic drawing of the Titan chamber facility. It consists of a large bell-jar high-vacuum chamber that contains a stainless steel pressure vessel. This Pressure vessel plays the role of the condenser for hydrocarbons. A Varian turbomolecular pumps out the bell jar to a pressure as low as 10^{-6} torr. Temperatures relevant to Titan's surface are reproduced using a closed-cycle helium cryostat (Cryomech AF63) and a liquid nitrogen flow through a custom cooling plate affixed to the bottom flange of the vessel. Feedthroughs in the top flange of the pressure vessel allow the injection of gaseous N_2 to pressurize the chamber to 1.5 bar pressure relevant to Titan's surface and to introduce hydrocarbons into the condenser. To analyze the chemical composition of liquid hydrocarbons, a liquid sampling valve allows taking a sample of the liquid and sending it to a SRI Gas Chromatograph (GC). Figure 2 shows a photograph of the TiLSS platform.

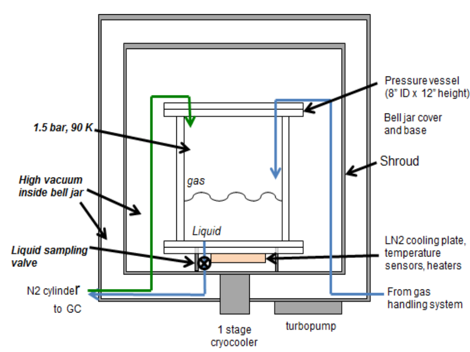

Figure 1: Schematic diagram of Titan's lakes simulation system.

Figure 2: Photograph of Titan's Lakes Simulation System TiLSS.

3. Applications

In addition to the experimental measurement of the chemical composition of the liquid-vapor equilibrium of a hydrocarbon mixture under Titan's lakes conditions, the experimental setup described here allows many other science applications. As example, the system can be used to measure the infrared spectra of mixtures of hydrocarbons and study the influence of the presence of several compounds on the infrared signatures of Methane, Ethane and Propane. These results may prove useful for quantitative interpretation of VIMS spectra of lakes.

Another key application of this chamber is towards instruments and component development, and technology maturation. Indeed, no facility to date is available for reproducing the environment of Titan's lakes with large enough volume to allow testing entire instruments and large components. This chamber is available to the community, and can be used to this end, in preparation of future instruments and missions to Titan.

4. Conclusion

An experimental setup has been designed and developed at JPL to simulate conditions existing at Titan's lakes and seas. The main goal of this experimental platform is to provide experimental control of the theoretical simulations predicting the chemical composition of Titan's lakes.

Acknowledgements

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