Laboratory Experiments Exploring the Properties of Titan's Liquids

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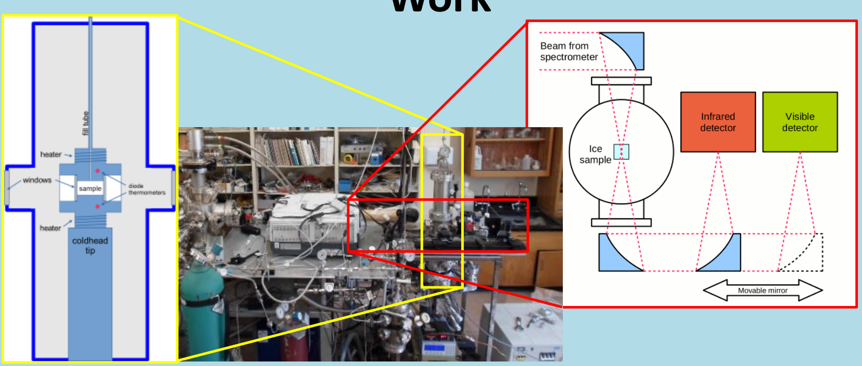
Motivation

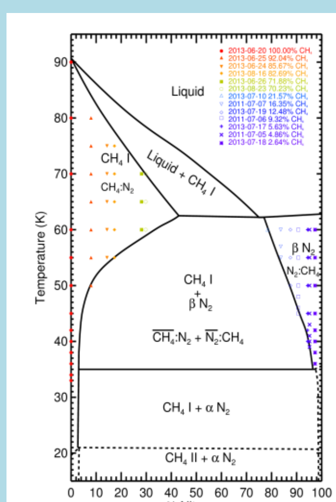
- Although both methane and ethane have been detected in the lakes and seas of Titan, the exact proportions remain undetermined.
- The temperature and pressure of Titan's atmosphere supports a "hydrologic" cycle of methane with ice, as well as liquid and vapor transport across the surface and through the atmosphere.
- Both pure methane and pure ethane freeze at approximately 91 K, but little is known about how methane and ethane interact at low temperatures; therefore we have studied their physical and spectral properties from 70-95 K.

Experimental Setup and Previous Work

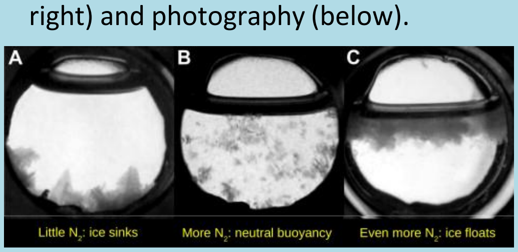


Astrophysical Ices Laboratory at Northern Arizona University. Center: Photo of laboratory setup. Left: Schematic of the cell and sample setup. Right: Schematic of transmission spectroscopy through the cell.

- Within the laboratory setup (above) [1,2,3], volatile ices are condensed within an enclosed cell (above left). Cooling is provided by closed-cycle helium refrigerators, within vacuum chambers for insulation. Mass spectrometers are capable of monitoring changes in composition.
- Cryogenic ice samples are studied via various analytical techniques including visible and infrared transmission spectroscopy (above right) and photography (below).

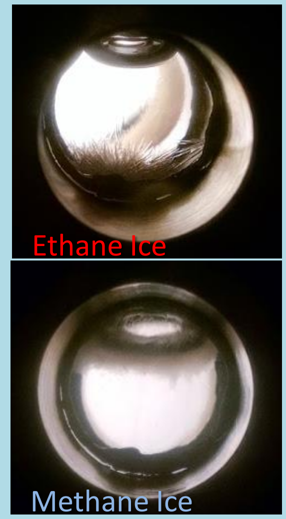


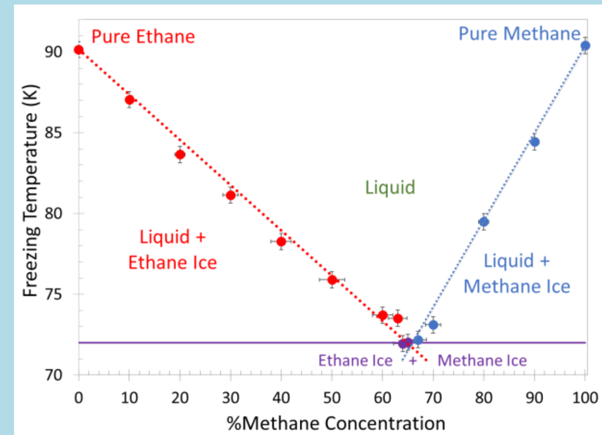
The CH_4–N_2 binary phase diagram. The symbols indicate the different set of transmission measurements performed in the Ice Lab to conduct a systematic study of the changes in CH_4–N_2 solid mixtures spectral behavior with mixing ratio and temperature. Figure and captions from [4].



In each image the sample cell is filled with $CH_4 + N_2$ held at a constant temperature for long enough to allow the ice and liquid to fully equilibrate. At 86.6 K the ice crystals sank (A), while at 80.6 K the crystals floated (C). Between 83.8 K and 84.1 K we bracketed the neutral buoyancy point of the crystals (B). Figure and caption from [5].

Freezing of the Methane-Ethane System

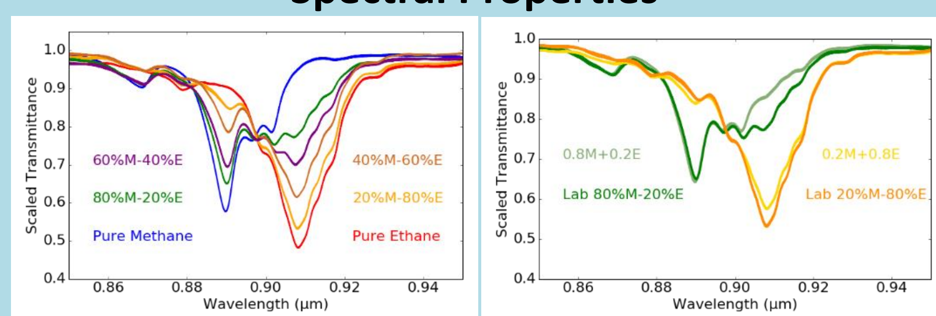




Freezing points of solutions with varying methane/ethane concentrations.

- The eutectic (lowest freezing point) occurs with 64±2% methane and 36% ethane at 72±0.5 K.
- Ethane ice freezes at the bottom of the liquid, while methane ice freezes at the top of the liquid, implying ethane ice is denser than the solution, while methane ice is less dense.

Spectral Properties



Left: Laboratory visible transmission spectra of mixtures of methane and ethane at 95 K. The methane band at 0.89 μm decreases with decreasing CH_4 concentration, while the ethane band at 0.91 μm increases with increasing C_2H_6 concentration. Right: Lab data of 80% methane and 20% methane compared with linear mixing models of the two pure species.

Implications and Future Work

- Mixing methane and ethane can suppress the freezing temperature of a solution down to 72 K (-201°C). Any mixing of these two species together will depress the freezing point of the lake below Titan's surface temperature, preventing them from freezing under current conditions.
- Spectral results demonstrate that simple linear mixing is not sufficient to understand mixtures and more work needs to be done at low temperatures.
- Current/future work includes determining the effect of nitrogen on the methane-ethane system.

References: [1] Tegler, S.C., et al. (2012) *The Astrophysical Journal*, *751,* 76. [2] Grundy, W.M., et al. (2011) *Icarus*, *212,* 941-949. [3] Hanley, J., et al. (2016) *LPSC*, Abstract #2421. [4] Protopapa, S., et al. (2015) *Icarus*, *253,* 179-188. [5] Roe, H.G. and W.M. Grundy (2012) *Icarus*, *219,* 733-736.