SIMULATIONS OF TITAN LAKES: POTENTIAL METHANE-ETHYLENE EVAPORITIC DEPOSITS. M. Heslart1,2, K. Farnsworth3, V. Chevrier2, E. Czapinski5, D. Laxton3, 4Department of Astronomy, University of Florida, Gainesville, FL 32611, 2Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, AR 72701. [Email: astroice7@ufl.edu].

Introduction:
Titan is the only natural satellite in the Solar System known to have a thick atmosphere and active hydrological cycle on its surface. As a result, the Cassini-Huygens mission has found strong evidence for stable lacustrine formations in its polar regions (above 60°N/S) [1]. These lakes were likely formed from the precipitation of methane (CH₄) and photochemical by-products, such as ethane (C₂H₆), derived from the UV photodissociation of CH₄ and nitrogen (N₂) in the upper atmosphere [2]. The composition of these lakes and percentage of dried versus liquid-filled lakes on the surface are uncertain [2,3]. Cassini RADAR observations and models have suggested that several hydrocarbons should be dissolved in the lakes and present in dried lake beds through atmospheric and geological processes [3-6].

Several hydrocarbons, such as ethylene (C₂H₄) and acetylene (C₂H₂), have been found to have very low solubility in cryogenic solutions through laboratory simulations [7-9]. These experiments point to hydrocarbons as probable candidates for the evaporite deposits on Titan.

Bright 5.0 micron surface observations provide strong evidence for evaporitic deposits, known as “bath-tub rings” [5]. Lake and evaporite models have proposed a variety of chemical compositions for the lakes and dry lake beds on Titan [2,10,11]. However, these models have large uncertainties that need validation from laboratory experiments. For one compositional case for evaporites, C₂H₄ has been proposed as a likely constituent formed by the evaporation of CH₄ [4]. In addition, laboratory simulations have found evidence that simulated cosmic rays irradiating C₂H₆ ices decomposed into C₂H₄ and H₂, providing a potential secondary source for the formation of C₂H₄ ice particles [12].

These studies show a high likelihood of C₂H₄ being in Titan’s lakes and lake beds. Thus, we aimed at running experiments to test for the crystallization of potential evaporites of liquid CH₄ enriched with C₂H₄ under simulated Titan conditions. The analysis of time-series Fourier transform infrared (FTIR) spectra of the liquid CH₄-C₂H₄ mixture during evaporation allows for the determination of evaporitic formation. We also assess whether C₂H₄ can be detected in the lakes and evaporitic deposits through Titan’s atmospheric windows by the Cassini Visual and Infrared Mapping Spectrometer (VIMS), shown in Fig. 1.

Methods:
The experiments were conducted in the Titan Module of the W.M. Keck Laboratory at the University of

Figure 1: Sample VIMS spectrum of Titan from the T4 flyby. The grey boxes indicates the atmospheric windows of Titan’s atmosphere centered at 1.08, 1.28, 1.60, 2.03, 2.7-2.8, and 5.0 microns with corresponding surface images. Image credit [13].

Arkansas that replicates the surface conditions of Titan [14]. The simulation chamber sustains a pressure of 1.5 bars with N₂ gas and temperatures of 90-95 K with liquid N₂. The pressure and temperatures are continuously measured with a barometer and thermocouples respectively. C₂H₄ gas is first added in the condenser to freeze followed by CH₄ gas that condenses into a liquid state. Then, the mixture is formed and reaches solution after ~10-20 minutes. Next, the liquid mixture is poured through a glass fritted filter to remove any solid particles before being deposited into a petri-dish. The chamber temperature for the C₂H₄-CH₄ experiments were kept at ~95 K since the freezing point of ethylene is 104 K, which still allows for the formation of solid particles. The mixture is probed by a Nicolet 6700 FTIR spectrometer that collected in-situ NIR spectra every 10-15 minutes during the evaporation period.

Results:
This study investigated the differences in NIR absorption features between a mixture of liquid CH₄ with dissolved C₂H₄ and the individual constituents in liquid and solid phases. They also determined the potential for the detection of some absorption features by VIMS.

Spectral comparison between the C₂H₄-CH₄ mixture and its individual components in liquid and solid states are represented in Fig. 2. There are several well-defined features for C₂H₄ and CH₄ in the mixture spectrum, which show partial freezing. The six C₂H₄ features are centered at approximately 1.67, 1.96, 1.99, 2.02, 2.11, and 2.12 μm. The CH₄ features are centered at approximately 1.63, 1.72, 1.79, and 1.85 μm. Unfortunately, C₂H₄ is unlikely to be detected in Titan lakes by VIMS since the larger C₂H₄ bands at 1.63, 2.11, and 2.12 μm j-
Conclusions and Future Work:
This study has confirmed the possibility for the formation of C$_2$H$_4$ evaporites from the evaporation of liquid CH$_4$ saturated with C$_2$H$_4$ on Titan’s surface. However, FTIR spectroscopy alone is unable to determine if any co-crystallization occurred, but remains an intriguing question. Future experiments will test other hydrocarbons (e.g. C$_2$H$_2$, CH$_3$CN) as potential evaporites in binary and ternary mixtures with CH$_4$ and C$_2$H$_4$.
These experimental observations will help us better understand the surface processes and lake bed compositions of Titan’s surface.

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Figure 2: The NIR spectrum of a stable liquid mixture of C$_2$H$_4$ dissolved in CH$_4$. Comparison with spectra of C$_2$H$_4$ ice (offset by +10%), liquid C$_2$H$_4$, and liquid CH$_4$. The red and black dashed lines represent CH$_4$ and C$_2$H$_4$ absorption bands respectively.

Figure 3: A) The time-series NIR spectra of frozen C$_2$H$_4$ saturated in liquid CH$_4$ undergoing evaporation under simulated Titan conditions (1.5 bars and 95 K). B) Same NIR spectra each offset by 30% for visual comparison. The grey and black regions designate the key absorption features of C$_2$H$_4$ and CH$_4$ respectively. The black regions show CH$_4$ loss as the CH$_4$ band depths decrease and disappear during the experiment.