National Aeronautics and Space Administration

FY24 R&TD Innovative Spontaneous Concepts (ISC)

Deliquescence of organic solids on Titan's surface

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Strategic Focus Area: Innovative Spontaneous Concepts

Background: Deliquescence is the process in which a solid absorbs moisture from the air, eventually transitioning from the solid to liquid phase. The process begins to occur at a relative humidity that is characteristic of the particular solid. Deliquescence has primarily been studied in salts and plays an important role in atmospheric aerosol chemistry on Earth. It has also been implicated as a possible means of forming liquid brines on the Martian surface. On Titan, the surface is dominated by solid organics, with an atmosphere of nitrogen and methane. Can a process analogous to deliquescence occur on Titan, in which solid organics absorb enough atmospheric methane to form liquid?

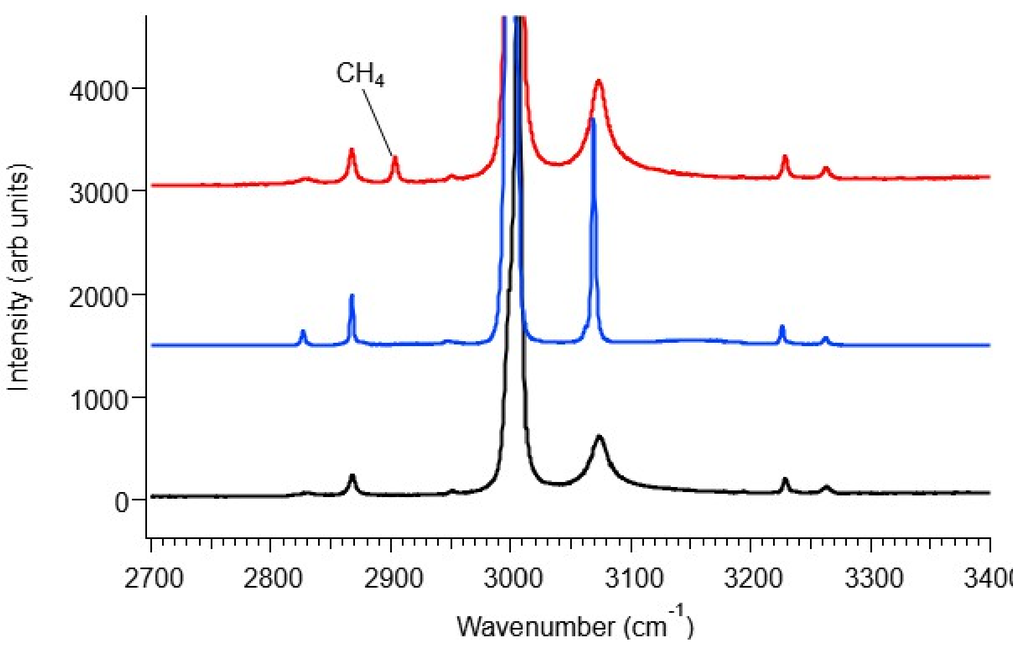

Figure 1. Raman spectra demonstrating deliquesence of ethylene by methane. Black: pure ethylene control at 105 K. Blue: Ethylene as deposited at 90 K Red: ethylene after exposure to 11% CH4 in N2 at 94 K for 1 hour. The appearance of the methane band indicates that the ethylene has begun to absorb liquid methane and deliquesce. Differences in ethylene peak width between spectra are thought to be due to changes in the crystallinity of the sample.

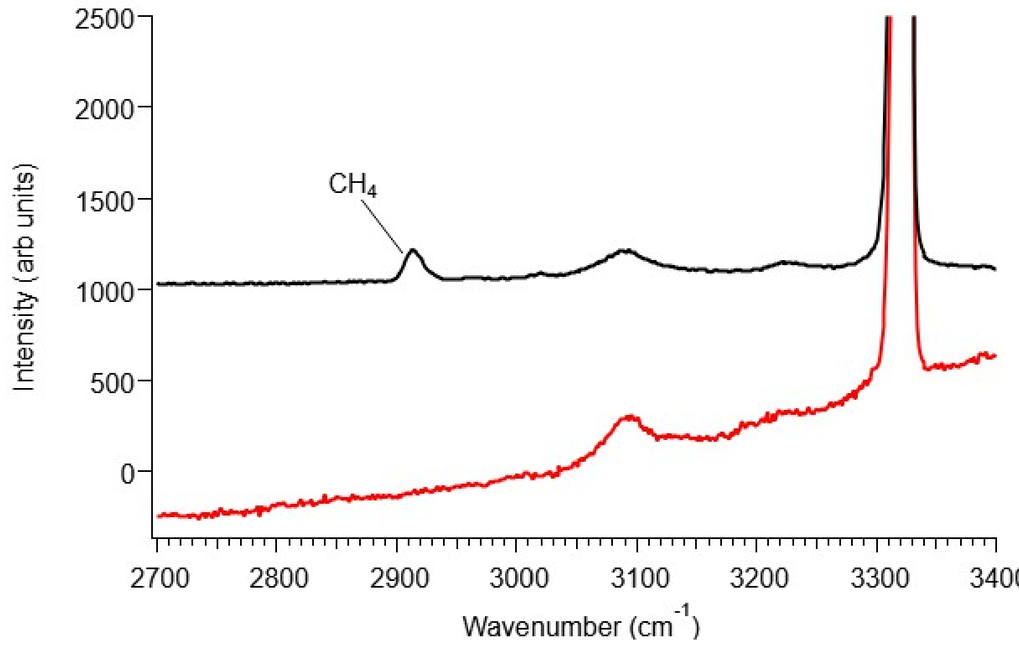

Figure 2. Raman spectrum demonstrating absorption of methane by solid acetylene. Red: solid acetylene as deposited at 90 K. Black: Acetylene after exposure to methane at 98 K. The methane band is clearly seen. The peak position of the band is distinct from gas or liquid phase methane.

Figure 3. Snapshots from timelapse imaging of ethylene deliquesence. Time proceeds from left to right. Time between images is ~100 minutes. The texture of the solid ethylene changes as the material is wetted by methane and dissolves. Methane concentration was 11% in nitrogen, at a temperature of 94 K.

Approach and Results: We used optical microscopy and micro-Raman spectroscopy to observe solid butane, acetylene ethylene particles under a range of methane humidity and temperature values. The sample was held in a liquid nitrogen cooled cryostage (Linkam 420) under N_2 gas. Gas mixtures with a well-defined methane concentration were then flowed over the sample. Raman spectra indicated some absorption of methane onto acetylene, and significant methane absorption and wetting of ethylene was observed. Time lapse imaging of solid ethylene under an 11% methane in N_2 atmosphere at 94 K showed complete deliquesence of the ethylene. No evidence for butane deliquesence was observed. Deliquesence under Titan conditions occurred over timescales of hours, similar to aqueous deliquesence timescales under terrestrial conditions.

Significance/Benefits to JPL and NASA:
Deliquescence of surface organics with methane would have a number of implications for Titan's surface. Wetting of surface materials would result in significant spectral changes, as well as optical darkening. This could be an alternate explanation for ISS observations of rainfall-induced darkening on Titan's surface. Cycles of deliquescence followed by drying (referred to as efflorescence) would alter the properties of surface organics, resulting in changes in grain size and mechanical properties. Dissolution of organic during deliquescence, followed by precipitation during subsequent drying (efflorescence), could result in induration of surface materials. This work is particularly relevant to the upcoming Dragonfly mission to Titan.

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