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Photodesorption and Photochemistry of Titan's Aerosol Analogs

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Abstract

Titan's lower stratosphere and troposphere (lower atmosphere) receives UV-depleted longer wavelength photons. These photons are not energetic enough to cause photochemical transformations of molecules in the gas phase. However, aerosols with longer wavelength absorption could transfer that energy to other molecules resulting indirect photo-induced transformations.

1. Introduction

While Titan's upper atmosphere is photochemically very active, due to the aerosols and clouds it is often assumed that Titan's lower atmosphere is photochemically inert. However, our recent works has clearly shown that even at wavelengths that pass through the upper atmosphere unattenuated (longer than 300 nm) into the lower atmosphere, photochemistry continues to happen (Couturier-Tamburelli et al. 2014; Couturier-Tamburelli, Pietri, & Gudipati 2015; Couturier-Tamburelli et al. 2018; Gudipati et al. 2013). Acetylene, the third most abundant organic molecule in Titan's atmosphere and most abundant unsaturated hydrocarbon, cannot be photoexcited at >300 nm wavelengths, either in the gas-phase or in condensed-phase such as clouds or ice. Our goal is to understand what would happen if acetylene condenses on larger aerosols that could absorb photons reaching the lower atmosphere. Would acetylene become reactive? Indeed, our results indicate it does.

2. Results

We irradiated pure acetylene ice deposited on sapphire window at 50 K using highly de-focused (to avoid multiphoton processes) laser at 355 nm. We did not find any significant change in the infrared and ultraviolet absorption spectra of acetylene. Subsequently, we deposited ~20 nm thick acetylene ice film on a ~600 nm thick Titan's aerosol analog coated sapphire window (produced through discharge). When irradiated at 355 nm, we found significant depletion of acetylene based on infrared spectra. We have repeated similar studies at longer wavelengths, whereby the depletion effect was not as dramatic.

During these studies we have also monitored gas-phase molecular abundancies using quadrupole mass spectrometry. After careful experimentation and data analysis, we recognized that two processes work in parallel when acetylene coated Titan's aerosol analogs are bombarded with >300 nm photons: (a) photodesorption of acetylene, which accounts to about 25% of the total acetylene loss. Remaining 75% acetylene should have been chemically bonded with the aerosol.

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