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Identification of Acetylene on Titan's Surface

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Abstract

Titan's atmosphere is opaque in the near infrared and the composition of surface remains difficult to access from space and is still poorly constrained. Photochemical models suggest that most of the organic compounds formed in the atmosphere are heavy enough to condensate and build up at the surface in liquid and solid states over a geological timescale. Here we report evidence of solid acetylene (C_2H_2) on Titan's surface using Cassini Visual and Infrared Mapping Spectrometer (VIMS) data. C_2H_2 should be one of the most abundant organic molecules in the atmosphere according to chemistry models. By comparing VIMS observations and laboratory measurements of solid C_2H_2, we identify a specific absorption at 1.55 µm that is widespread over Titan, but is particularly strong in the brightest terrains.

1. Introduction

Saturn's moon Titan possesses a thick atmosphere that is mainly composed of N_2 (98%), CH_4 (2 % overall, but 4.9% close to the surface) and less than 1% of minor species, mostly hydrocarbons [1]. According to photochemical models, the dissociation of N_2 and CH_4 forms a plethora of complex hydrocarbons and nitriles in the atmosphere. In particular, models predict a net creation of C_2H_2 approximately 125-2000 times larger than for any other hydrocarbon and nitriles produced in the atmosphere. Over the geological time scale, a C_2H_2 solid layer, a few hundred meters thick could have formed on the surface of Titan [2]. But despite its predicted high abundance, so far, C_2H_2 has not been unambiguously detected on Titan's surface. Here we present an analysis of Titan's infrared spectra to search for the presence of solid C_2H_2 on the surface.

2. Methods

In our study, we use a high-resolution laboratory spectrum (4 cm^{-1}) of solid C_2H_2 acquired in the 1-2.2 µm wavelength range [3] to compare with VIMS' Titan spectra. Convolved to the VIMS spectral resolution (~300), the laboratory data show that C_2H_2 exhibits a strong absorption band at 1.55 µm that should be detectable in the Titan spectrum and in fact is present. We know of no other organic or nitrile candidate that possesses such a localized and strong absorption feature at 1.55 µm.

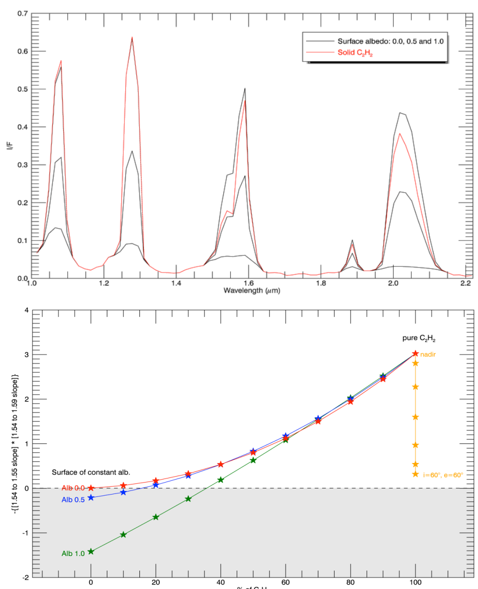

Figure 1: a) Spectra of C_2H_2 (red) mixed with neutral albedo compared to spectra of constant albedo ranging from 0 to 1 (black), at the VIMS resolution and seen through the atmosphere of Titan.

We use our Radiative Transfer (RT) model to simulate Titan's spectra at the VIMS spectral resolution (Fig. 1a) and thus evaluate the "C_2H_2 index" in the cases of uniform surface albedos, linearly mixed with our laboratory spectrum of solid C_2H_2 (from 10% to pure C_2H_2). Those - calculations were performed with the nominal model for the atmospheric gases [4][5] and aerosols with zero incidence and emergence angles. The impact of the geometry has also been tested in the limits of validity of the plane parallel approximation (~60° in incidence and emergence) for the pure C_2H_2 case. These calculations of the "C_2H_2 index" are summarized in Fig. 1b.

4. Results/Discussion

We show three global maps of Titan showing a mosaic of VIMS images at 2.01 µm (Fig. 2a), a map that presents the value of the index (Fig. 2b), and a map with the 1-sigma errors on the index due to intrinsic noise in VIMS data (Fig. 2c). For all these maps, pixels with incidence and emergence angles greater than 60° were excluded to stay in the validity domain of the RT computations of the C_2H_2 index. For the detection map (Fig. 2b), pixels with a negative and slightly positive index (up to 0.014 following the maximum possible index found in the case of uniform albedos) are characteristic of uniform surface albedo and only positive index greater than 0.014, associated with a deep band at 1.55 µm, are plotted. Finally, pixels with index values lower than their 1-sigma error are also excluded.

As a result, we see potential presence of C_2H_2 almost everywhere in our study area (Fig. 2b). Since C_2H_2 likely is produced everywhere in the atmosphere and observations show that its atmospheric abundance is quite uniform within the +/-60° latitude band, it is not surprising to find evidence of its ubiquitous sedimentation on the surface of these regions. The highest C_2H_2 indices are strongly correlated with bright terrains, fully consistent with the fact that C_2H_2 has a high albedo, especially at 1.59 µm. With a weaker signature, we also found some presence of C_2H_2 in dark areas, but with less obvious correlation with albedo. Thus, even if C_2H_2 is present almost everywhere, the spatial distribution of the intensity of its spectral signature is not homogeneous, indicating that surface processes responsible for its segregation or masking may be at work.

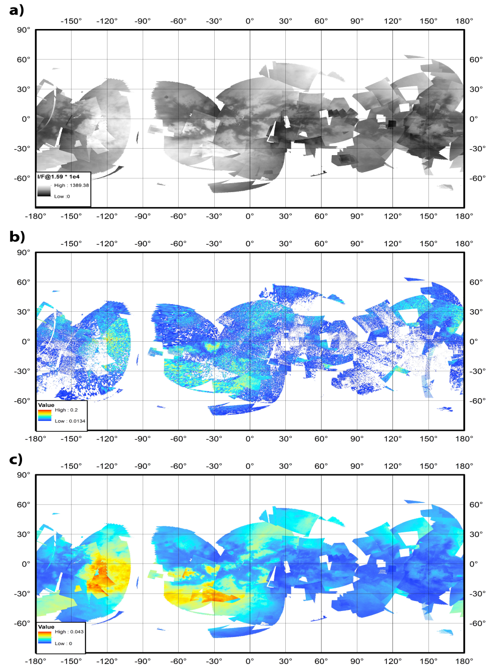

Figure 2: a) 1.59 µm map of Titan of the investigated areas where the surface has been illuminated and viewed at less than 60° angles. b) Acetylene detection map for a criterion value exceeding a 0.0134 threshold determined from Radiative Transfer simulations applied to laboratory spectra. c) A map showing the calculated errors on the slope criterion values due to the intrinsic noise in the VIMS data

Acknowledgements

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