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Probing Titan's Upper Atmosphere: Observations from Cassini UVIS

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Abstract

We use stellar occultation measurements from the Cassini UVIS instrument to determine the vertical profile of hydrocarbons and tholins in the upper Titan atmosphere. These measurements reveal spatial and seasonal variations in species densities, and improve our understanding of how photochemical processes convert methane (CH_4) into heavier hydrocarbons. These reactions directly result in the observed density profiles and also, through transport, the layers of haze seen lower in the atmosphere.

1. Introduction

Perhaps the first thing one notices about Titan is its unusual atmosphere, obscuring the surface of the moon with orange haze and producing a surface pressure even higher than that of Earth's. This atmosphere has evolved into its current state through complex photochemical processes [6], involving nitrogen (N_2), the dominant molecular species in the atmosphere, as well as methane (CH_4). Some have seen this current mixture as being analogous to the early Earth's, as it certainly provides a rich abundance of hydrocarbons the like from which early life may have arisen [1, 3]. In order to even begin to answer such questions, however, and attempt to envision the Earth or Titan as it existed in the past, we must have a better understanding of the processes that shape the atmosphere we observe today.

1.1 The Cassini UVIS Instrument

The Ultraviolet Imaging Spectrograph (UVIS) instrument onboard Cassini has provided an abundance of flyby data since Saturn orbital insertion in 2004 [2]. These observations range from studies of emission properties of the Saturn and Titan atmospheres to solar and stellar occultation events through the upper atmosphere of Titan. These stellar occultation data sets in particular provide a rare look at the vertical atmospheric structure of Titan down to 400 km, as UVIS is a unique Cassini instrument that can probe this region directly. This region is extremely important to photochemistry within the atmosphere, as it is where the vast majority of energy from UV photons is absorbed, driving the formation of heavier hydrocarbons.

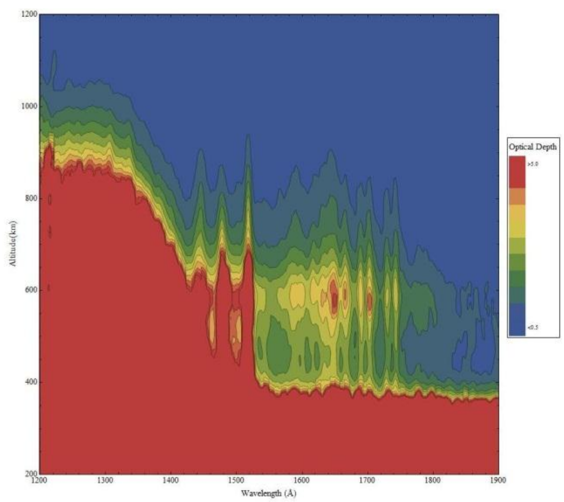

Figure 1: Optical depth profile with altitude for ingress Titan flyby during T47. Contour lines describe intervals of 0.5 in optical depth, from 0.5 to 5.0. Features correspond to hydrocarbon absorption lines – the broad feature around 1300Å is due to CH_4, while the sharper peaks indicate C_2H_2, C_2H_4, C_4H_2, and others. Below 400 km the bulk of the FUV spectrum is absorbed out by tholins.

2. Retrieval Method

Line of sight abundances for each hydrocarbon species are computed using the relevant cross sections. Best fit parameters are found through a least squares fit algorithm, utilizing Rodgers [4]. Local density profiles are calculated using a vertical inversion method, with the atmosphere assumed to be spherically symmetric along the line of sight. Often the results from this inversion have amplification of noise, an effect that is minimized by use of Tikhonov regularization [5] in order to produce a smooth profile.

3. Results and Discussion

The vertical profiles of hydrocarbon species show high variability both spatially and seasonally on Titan. Further reduction of stellar occultation data sets will allow for more precise resolution of this variability, but possible trends in the current six occultations seem to indicate distinct differences between high/low latitudes, and between occultation measurements taken years apart (2004 and 2008) at the same latitude region.

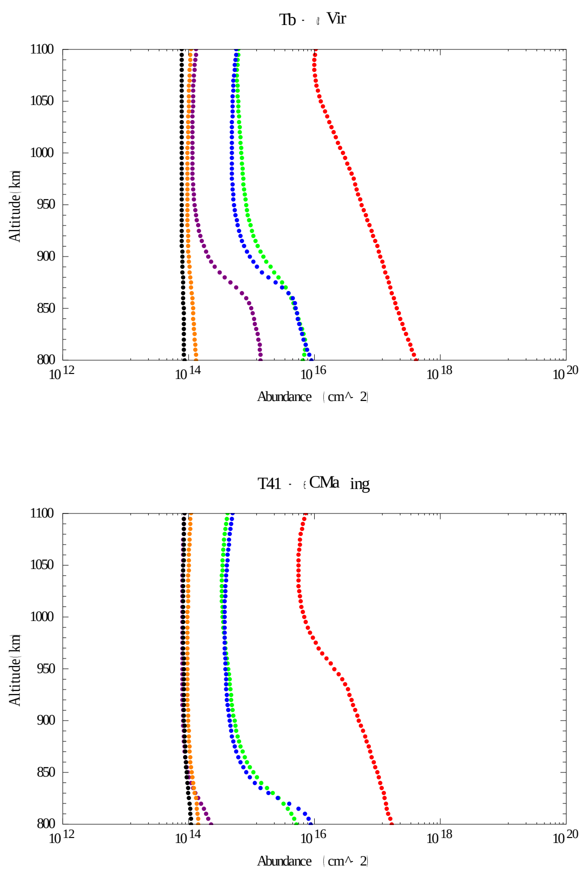

Figure 2: Examples of hydrocarbon line of sight abundances extracted from optical depth data for stellar occultations during Titan flybys Tb and T41. Colors are assigned for CH_4 (red), C_2H_2 (green), C_2H_4 (blue), C_4H_2 (purple), C_6H_6 (orange), and tholins (black).

4. Conclusions

The higher order hydrocarbons C_2H_2, C_2H_4, and C_4H_2 show distinct layered structure with significant differences in thickness and altitude, possibly dependent on latitude and season. This vertical structure, with layer thickness as narrow as about 25km, may be related to temperature dependent chemistry. The retrieved distributions of hydrocarbon species can be used to test future models of global transport in Titan's upper atmosphere, and may help explain how the compounds produced there eventually trickle down to the lower atmosphere and surface.

Acknowledgements

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