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# Latitudinal variations in Titan's atmosphere: UVIS observations of three simultaneous stellar occultations

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## Abstract

Titan's atmosphere features extensive upper-atmosphere photochemistry and large-scale circulation that distributes photochemical products throughout the atmosphere. Cassini's Ultraviolet Imaging Spectrograph (UVIS) is uniquely able to probe Titan's mesosphere *and* thermosphere through observation of stellar occultations, which can be used to retrieve detailed profiles of molecular abundances with altitude. In this work, we present results from a triple stellar occultation. As Titan occulted Orion's belt, we were able to measure altitude profiles for three latitudes simultaneously. This gives us the unique opportunity to observe how abundances vary with both latitude and altitude, allowing us to place further constraints on chemistry and circulation models of Titan's atmosphere.

## 1. Introduction

Titan, Saturn's largest moon, has a thick atmosphere featuring extensive organic chemistry. Over 20 species, with masses up to 78 Da, have been definitively identified from a variety of ground-based and spacecraft observations of Titan's atmosphere [8], while unidentified negative ions have been detected with masses up to 10,000 Da/q [4]. After initial formation in the thermosphere, molecules experience downward transport and their distributions are strongly influenced by Titan's global circulation patterns, which vary with season. Generally, Titan's atmosphere has a single large Hadley cell that extends all the way from the summer pole to the winter pole.

Occultations allow us to measure detailed profiles of molecular abundance with altitude. Previous UVIS observations have measured vertical density profiles of $N_2$, $CH_4$, $C_2H_2$, $C_2H_4$, $C_4H_2$, HCN, $HC_3N$, and $C_6H_6$ for altitudes ∼400–1200 km [1; 2; 3; 9; 10]. However, each occultation has sampled only one location at a time.

Previous observations of Titan's atmosphere have revealed that many species have abundances that vary with latitude. The Atacama Large Millimeter/submm Array (ALMA) has been used to map several polar species in Titan's atmosphere (e.g. $C_2H_5CN$ [6], $C_2H_3CN$ [11], isotopologues of $HC_3N$ [5]). However, ALMA is limited in that it cannot observe species without a dipole moment. Cassini CIRS has been used to map latitudinal abundance variations in the stratosphere (e.g. [7],[12]), while the INMS can measure abundances in the thermosphere (e.g. [13]). UVIS observations give us the unique opportunity to measure abundances of hydrocarbons throughout Titan's mesosphere and thermosphere. In this work, we present an occultation of Orion's belt, allowing us to observe molecular abundance profiles at three latitudes simultaneously.

With these UVIS observations, we can see spectral signatures of many small organic molecules, as well as an extinction layer due to haze. Observing the behavior of haze precursor molecules along with the haze layer structure will give us a greater understanding of how Titan's photochemistry and atmospheric dynamics interact to produce the observed haze behavior.

## 2. Observations

In this work, we present analysis of Cassini UVIS observations of Titan occulting the three stars of Orion's belt. The observations occurred during flyby T116 on 1 February 2016. The stars Alnitak ($\zeta$ Orionis), Alnilam ($\epsilon$ Orionis), and Mintaka ($\delta$ Orionis) passed behind Titan's atmosphere at longitude near 70°E and latitudes of 15°N, 28°N, and 40°N, respectively. EUV and FUV observations were conducted simultaneously. The EUV channel probes the density profiles of $N_2$ and $CH_4$, while the FUV channel is sensitive to $CH_4$, other organics, and aerosol haze particles. These observations allow us to measure the latitude and altitude dependence of abundances of different species.

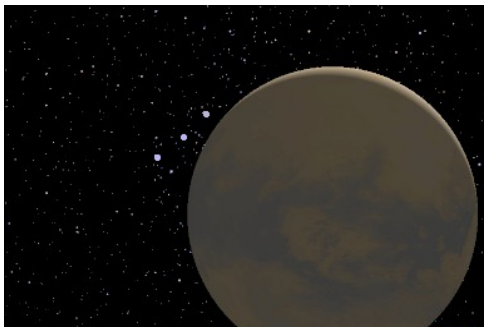

Figure 1: Cassini's view during our observations: Titan occulting Orion's belt at longitude 70°E and latitudes 15°N, 28°N, and 40°N
(Adapted from *https://space.jpl.nasa.gov/* simulation)

## 3. Summary and Conclusions

We present altitude profiles of haze and a variety of small organic molecules in Titan's atmosphere derived from Cassini UVIS observations of stellar occultations. Uniquely, we observed Titan occulting the three stars of Orion's belt, allowing us to measure altitude profiles at three latitudes simultaneously. Thus, we have been able to learn how the composition of Titan's atmosphere varies with both latitude and altitude at northern mid-latitudes near the northern summer solstice.

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