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Analysis of VIMS near-IR spectra in Titan's upper atmosphere: Evidence for heavy and abundant aromatic hydrocarbons

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Abstract

Observations of Titan atmosphere made with the VIMS instrument on board the Cassini satellite show a strong limb emission around 3.3 μm at high atmospheric altitudes (above 700 km). This emission exhibits the spectral signatures of the strong CH_4 bands. A detailed analysis of the spectra reveals an additional strong emission centered at 3.28 μm and peaking at about 950 km. Here we present an analysis of this residual spectra and show that it attributed to emission from heavy aromatic hydrocarbon compounds.

1. Introduction

The Visual-Infrared Mapping Spectrometer (VIMS), part of the Cassini payload, has sounded Titan's thermosphere during many flybys. Evidence of methane fluorescence at 3.3 μm in Titan's upper atmosphere from VIMS measurements was pointed out by [5] and [3]. The 3.3 μm region has been studied in much more detail by [6] and derive accurate CH_4 density profiles from VIMS limb daytime observations near the Q and P branches by using a sophisticated CH_4 non-LTE model. More recently Dinelli et al. [4] have further analyzed these observations and discovered an emission never identified before which is not attributable to CH_4. In a subsequent step López-Puertas et al. [8] have identified this emission as attributed to polycyclic aromatic hydrocarbons (PAHs) and/or heterocyclic aromatic compounds (HACs). By using the NASA Ames PAH IR Spectroscopic Database and current models for the re-distribution of the absorbed UV energy by the PAHs in the near-IR, we have explained the unidentified spectral feature and have derived the vertical distribution of PAHs abundances in Titan's upper atmosphere. In the talk we will give details about the isolation of the emission, the discard of other potential carriers, how can we get an emission as large as that produced by the strong 3.3 μm bands of the very abundant CH_4, and the major characteristics of the derived PAHs.

2 The unidentified 3.28 μm emission

Here we analyze the data taken by VIMS on Cassini during two Titan's flybys: T34 (19 July 2007) and T35 (31 August 2007). The data were selected to cover the highest atmospheric altitudes, have the largest integration time, the best vertical resolution, and a phase angle lower than 60°. The spectral and radiometric calibration as well as more details on the observations can be found in [6, 4, 8] and references therein.

The emission between 450 km and 1250 km clearly shows the fingerprints of the CH_4 molecules, characterized by the R, Q and P branches. However, the relative intensity of these branches changes with altitude, showing very different vertical variations.

Simulations of the observed spectra with a sophisticated CH_4 non-LTE model and the CH_4 densities derived from the Q and P branches [6], show that the CH_4 emission alone cannot reproduce the excess of emission of the R-branch. When subtracted the simulated CH_4 emission from the measured radiance, an isolated emission, peaking around 3.28 μm, clearly emerges. This feature can be seen at altitudes from around 650 km up to $\sim$1300 km, exhibiting a maximum near 950 km and a secondary peak at $\sim$1200 km. Dinelli et al. [4] performed a thorough analysis discarding many potential carrier species for the unidentified feature and suggested that it could be due to emissions by aromatic compounds. A major problem was how to explain such strong emission from species or particles that should be in much smaller concentrations than methane.

3 Spectral identification and inversion of PAHs concentrations

We have studied the emission above by using the NASA Ames PAH IR Spectroscopic Database [1] and the AmesPAHdbIDLSuite set of tools [2], appropriately modified as discussed in [8]. By using current models for the re-distribution of the absorbed UV energy of the PAHs [1, 2] we have: a) explained the observed spectral feature, and b) derived the vertical distribution of PAHs abundances in Titan's upper atmosphere. These results will be discussed on the light of the measurements taken by other instruments on board Cassini and recent model simulations.

4. Summary and Conclusions

We have analyzed Cassini/VIMS limb daytime observations of Titan's upper atmosphere in the 3.3 μm region. After removing the CH_4 emission by using a sophisticated CH_4 non-LTE model [6] and the inverted CH_4 densities, we have found an emission feature that is superimposed to the CH_4 R-branch, and peaks near 3.28 μm. It is present from around 600 km until 1250 km, with a maximum intensity around 950 km [4].

We have analyzed that emission by using the NASA Ames PAH IR Spectroscopic Database and the AmesPAHdbIDLSuite tools. Based on current excitation models for PAHs, we have been able to explain very well the observed spectral feature and derive the vertical distribution of the PAHs abundance in Titan's upper atmosphere [8]. We have found that PAHs are present in large concentrations, about 2-3$\times 10^4$ particles cm^{-3} at 1000 km and extending up to about 1250 km; and are very heavy, containing about 34 carbons and a mean mass of $\sim$430 amu [8].

A very good agreement is found between these PAH concentrations and those estimated from the concentrations of heavy negative ions measured by CAPS/ELS and typical electron densities. This suggests that they are the neutral (and hence in a much larger concentration) counterpart of those heavy positive and negative ions. In consequence, we think that this finding is a major piece of evidence that supports, as suggested earlier [10, 9, 7], that the source of the main haze layer of Titan is located in the upper atmosphere [8].

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