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Retrieval of HCN Concentrations from Cassini/VIMS Limb Observations of the Titan's Upper Atmosphere

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Abstract

Vertical profiles of hydrogen cyanide (HCN) have been retrieved from Cassini/VIMS limb observations in the region from 600 to 1100 km of the Titan's atmosphere by analyzing the 3 μm emission. HCN concentrations show a very good correlation with solar zenith angles, for different latitudes and local times. This would indicate that HCN is in (or close to) photochemical equilibrium in the sounded region.

1. Introduction

The 600-1100 km altitude range of the Titan atmosphere is where photochemical and nucleation processes lead to the production of heavy molecules that, through sedimentation and coagulation, originate the lower atmosphere aerosols.
The hydrogen cyanide (HCN), produced by photochemical reactions, is thought to play an important role in the chemistry of those regions and in determining the thermal structure of Titan's thermosphere[1]. Since the HCN distribution in this region is poorly known, new measurements of this species can improve our understanding of the chemical processes and thermal structure of the thermosphere.
Different observations in the infrared, from space borne and ground based instrumentation, have been used to retrieve HCN concentrations in the Titan atmosphere. More recently, the Cassini mission has provided an extensive dataset of HCN in Titan's atmosphere by using various instruments. The Composite Infra-Red Spectrometer (CIRS) has taken nadir and limb observations providing HCN concentrations from the surface up to about 500 km[2]. Another instrument on Cassini, the Ion and Neutral Mass Spectrometer (INMS), has measured HCN in the thermosphere above altitudes of 1000-1100 km[3]. HCN abundances have also been retrieved from UVIS (Ultraviolet Imaging Spectrometer) measurements during the two stellar occultations in the southern and northern hemisphere[4].
Finally, we report here measurements of HCN concentrations in Titan's upper atmosphere retrieved from the Cassini Visual Infrared Mapping Spectrometer (VIMS) limb observations in the 3.0 μm spectral region and in the 600-1100 km altitude range.

2. Analysis

VIMS is a multi-channel mapping spectrometer on board Cassini working in the 0.35–5.1 μm wavelength range. The Cassini mission was designed to have many close encounters with Titan. During these encounters VIMS took several observations at the limb of the moon with moderate spatial resolution but with pretty good altitude coverage up to atmospheric levels above 1,000 Km from the surface. Even if the spectral resolution of VIMS is moderate (about 16 nm in that part of the spectral range), the emission band of HCN at 3 μm is very well defined. HCN emissions are related to its ν_3 band and its photochemical process has been well described by Geballe et al. in their 2003 paper [5] about the Titan atmospheric emissions around 3 microns. This spectral signature has been already analyzed from ground-based telescopes [5,6], but this study is the first based on high spatial resolution observations (30 km in average).
As the daytime HCN emission exhibits large values up to about 1100 km, vanishing at nighttime at very low altitudes, daytime emissions in the thermosphere have been supposed to originate under non-LTE

conditions. Then a sophisticated non-LTE model of HCN energy levels has been developed in order to retrieve the HCN abundance from the spectra measured by VIMS[7]. A line-by-line inversion code [8], adapted to Titan from one used for Earth data retrieving, has been applied to a VIMS dataset of spectra profiles obtained in limb viewing geometry, covering a wide range of latitudes and solar zenith angles.

3. Summary and Conclusions

The radiances, spectrally integrated on the 3.0 μm HCN emission band, show a monotonically decrease with the altitude. HCN profiles were retrieved from the 22 spectra collections with solar zenith angles (Sun illumination angle respect to the normal to the surface at the geometrical coordinates relative to the tangent altitude under observation) smaller than 80º. HCN was retrieved simultaneously with C2H2+C2H6. The mean HCN concentration retrieved has a maximum value of $5x10^8$ molecules/cm^3 around 700 km and decreases monotonically above with an average scale height of about 170 km, reaching a value of $7x10^7$ molecules/cm^3 at 1050 km. The densities retrieved from the 22 spectra collections show a 1-sigma variability larger than the noise, and hence suggests that they are real changes. The HCN density shows a clear dependency with solar zenith angle, larger HCN for weaker illumination, in the SZA=40-80º interval at altitudes above 800 km. It suggests that the HCN distribution in these regions is mainly controlled by photochemical processes rather than by dynamics.

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