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Cassini/VIMS methane 3.3 μm emission in Titan's upper atmosphere

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Abstract

This paper summarizes the work presented in [1]. In that work, we fulfilled a thorough analysis of Titan's methane limb emission at 3.3 μm measured by VIMS in Titan. Methane is, after nitrogen, the most abundant species in Titan's atmosphere. It plays an important role in its chemistry and energy budget and strongly emits during daytime around 3.3 μm. In Titan's upper atmosphere, where pressure is low, that emission is affected by non-local thermodynamic equilibrium. Therefore, its analysis needs from a modeling of the population of the emitting levels considering specifically the mechanisms able to excite and de-excite them. We developed a sophisticated non-LTE model that includes all known excitation mechanisms and calculates the population of 22 CH_4 vibrational levels from two isotopes. We simulated VIMS radiance and identified the bands that significantly contribute to the total measured signal. We also retrieved daytime methane abundance from 500 to 1100 km and compared our results with other measurements and results from models.

1. Introduction

The Cassini Visual-Infrared Mapping Spectrometer (VIMS) has taken observations of Titan atmosphere in the 3.3 μm spectral region during the several encounters of the Cassini spacecraft with Titan since late 2004 until present. These observations offer an unprecedented opportunity to study the middle and upper atmosphere of Titan, since the spectra show a wealth of near-infrared emissions. [2] presented a preliminary analysis of some of the observations in the CH_4 3.3 μm region. We studied the Cassini/VIMS 3.3 μm emissions in Titan's mesosphere and thermosphere in more detail. We used spectra measured at the limb to better resolve the vertical structure. The major emitter in this spectral region is CH_4 which, because of its large abundance and its rich vibrational spectra, has many weak and strong bands that contribute to these Titan's limb near-infrared emissions.

2. Data

Cassini's Visual-Infrared Mapping Spectrometer (VIMS) is an imaging spectrometer which provides measurements in cubes with up to 64×64 pixels, in the spatial field of view, and 352 wavelengths for each of these pixels in two channels, the visual (VIS) channel (0.35–1.08 μm) and the infrared (IR) channel (0.85–5.2 μm). The VIS and IR channels have spectral resolutions of 7 nm and 16 nm, respectively.

We analyzed only the spectral region around 3.3 μm taken in the IR channel. We selected spectral cubes with the smallest noise, since we were interested in the region above 400 km (where the signal is weak), covering as large as possible a latitudinal range, with a vertical resolution better than ~100 km and with phase angles lower than 60° (both to minimize the stray-light contamination and to have the largest atmospheric signal). Since the emissions we analyzed are excited by absorption of solar radiation, we only chose daytime measurements. In total, we analyzed 20 observations made during two Titan's flybys containing 4 different cubes.

3. Modeling

Our methane non-LTE model is an adaptation of the Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) code for the Earth described in [3] and calculates the non-LTE populations of 18 CH_4 vibrational levels of the main CH_4 isotope and 4 of the $^{13}CH_4$ minor isotope. We include 41 vibrational bands, out of which radiative transfer between atmospheric layers is calculated for twenty-two. We included all known collisional process, which consider the thermal relaxation of the bending modes v_2 and v_4

in collisions with N_2 and CH_4, the vibrational-thermal collisional re-distribution of vibrational quanta among the levels in a given group also in collisions with N_2 and CH_4, and the vibrational-vibrational coupling between CH_4 levels exchanging v_4, v_2, and v_3 quanta.

For the assessment of the contributing bands to the total emission and the study of the features in VIMS spectra, we used the KOPRA radiative transfer code [4] to simulate CH_4 spectral radiance in the 3.3 μm region (3150–3500 nm), included the 41 vibrational bands mentioned above and used the level populations calculated with our non-LTE model. That radiative transfer model is able to cope with non-LTE and has been widely used for the analysis of Earth limb emission.

We retrieved methane from the emission in the 3299.5–3497.9 nm interval, where there is no contamination from other atmospheric species. We used an update of the Geo-fit Multi-Target Retrieval (GMTR) system [5], which includes the Geofit Broad Band (GBB) forward model that was upgraded introducing VIMS instrumental characteristics (field of view and spectral instrumental response) along with the possibility to compute the limb radiance in non-LTE. The computed radiances were validated with the non-LTE computations made with the KOPRA radiative transfer algorithm mentioned above. The retrieval code uses the optimal estimation technique [6] and the global fit technique to retrieve the volume mixing ratios of Titan's atmospheric gases from VIMS limb radiance.

4. Summary of results

This paper is a summary of [1], which analyzes VIMS measurements of Titan's atmospheric limb emission around 3.3 μm from 500 to 1100 km. The main results from that work follow.

Titan's upper atmospheric 3.3 μm emissions mainly originate from the strong methane v_3 band. The absorption of solar energy is the major excitation process of the v_3-quanta levels above 1000 km. The distribution of the vibrational energy within levels of similar energy through collisions with N_2 is also of importance below that altitude. CH_4-CH_4 vibrational exchange of v_4-quanta affects their population below 500 km. The $\nu_3\rightarrow$ground band dominates Titan's 3.3 μm daytime limb radiance above 750 km. The $\nu_3+\nu_4\rightarrow\nu_4$ band does below that altitude and down to 300 km. The $\nu_3+\nu_2\rightarrow\nu_2$, the $2\nu_3\rightarrow\nu_3$, and the $^{13}CH_4$ $\nu_3\rightarrow$ground bands each contribute from 5 to 8% at regions below 800 km. The $\nu_3+2\nu_4\rightarrow2\nu_4$ and $\nu_2+\nu_3+\nu_4\rightarrow\nu_2+\nu_4$ bands each contribute from 2 to 5% below 650 km. Contributions from other CH_4 bands are negligible. We retrieved the CH_4 abundance from 500 to 1100 km from Cassini-VIMS daytime measurements near 3.3 μm and our results show good agreement with previous measurements and model calculations, supporting a weak deviation from well mixed values from the lower atmosphere up to 1000 km.

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References

[1] García-Comas, M., et al., Analysis of Titan CH_4 3.3 μm upper atmospheric emission as measured by Cassini/VIMS, Icarus, doi: 10.1016/j.icarus.2011.03.020, in press.

[2] Brown, R., et al., 2006. Observations in the Saturn system during approach and orbital insertion, with Cassini's Visual and Infrared Mapping Spectrometer (VIMS). Astron. Astrophys. 446, 707–716.

[3] Funke, B., et al., 2007. Analysis of nonlocal thermodynamic equilibrium CO 4.7 μm fundamental, isotopic and hot band emissions measured by the Michelson Interferometer for Passive Atmospheric Sounding on Envisat. J. Geophys. Res. 112 (D11).

[4] Stiller, G. P., et al., 2002. Sensitivity of trace gas abundances retrievals from infrared limb emission spectra to simplifying approximations in radiative transfer modelling. J. Quant. Spectrosc. Radiat. Transfer 72 (3), 249–280.

[5] Carlotti, M., et al., 2006. GMTR: Two–dimensional geo–fit multitarget retrieval model for Michelson Interferometer for Passive Atmospheric Sounding/ Environmental Satellite observations. Appl. Opt. 45 (4), 716–727.

[6] Rodgers, C. D., 2000. Inverse Methods for Atmospheric Sounding: Theory and Practice. Vol. 2 of Series on Atmospheric, Oceanic and Planetary Physics, F. W. Taylor, ed. World Scientific.