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# Application of new methane linelists to Cassini and Earth-based data of Titan

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## Abstract

In this paper we present the improvements in our understanding of Titan's atmospheric and surface chemical composition in view of recent developments on the methane opacity, a very important parameter in simulating Titan's spectrum. In this work, we use a multi-stream radiative transfer model benefitting from the latest methane absorption coefficients available to date: theoretical predictions [1] as well as laboratory measurements [2, 3]. This code if first of all applied to the Cassini/VIMS spectro-imaging data, focusing on regions of high spectral versatility, probably related to geologically active regions. While we study the chemical composition of the ground in such regions, we also propose a re-analysis of spectral data acquired from the Earth with either ISO or ground-based facilities like VLT/NACO and VLT/ISAAC.

## 1. Introduction

The understanding of Titan's methane cycle begins with the understanding of its surface geology and atmosphere dynamics. To better constrain our knowledge of its atmospheric and surface chemical composition, we use a multi-stream radiative transfer (RT) model allowing us to retrieve Titan's surface albedo spectrum in the infrared.

It is in the scope of the ANR CH4@TITAN that our team could improve a RT model optimized for Cassini/VIMS data of Titan. Indeed, this funding enables us to participate to theoretical works on methane absorption [1] as well as to acquire new laboratory data [2,3] in conditions of pressure and temperature close to those on Saturn's main satellite.

The application of this specific model allows us to compare the improvement of such methane linelists to the modeling of Titan's surface spectrum, with respect to the older methane databases. With such an asset, we consequently propose surface spectra at several specific regions on Titan, chosen for their high albedo variability and for the variety of spectral response they show, hinting geological activity, recent or past [4]; these regions are Tui Regio (20°S, 130°W), Hotei Regio (26°S, 78°W), and Sotra Facula (15°S, 42°W). After inversion of surface spectrum and study of the chemical composition of these areas, we also propose to apply this modular RT code to other datasets, like the ISO or VLT spectra our team acquired in the last two decades.

## 2. Radiative Transfer

Our radiative transfer (RT) code is based on the SHDOM solver [5]. We aimed at a complete modularity of the code, allowing us to either achieve line-by-line or correlated-k computations. We selected a plane-parallel symbolism with a multi-stream resolution of the radiation equation, using up to 168$^{th}$ order Legendre decomposition.

On Titan, the main radiative actors are methane and aerosols. For the latter, we used at first the Huygens/DISR measurements [6] but to correctly fit the VIMS methane bands, we had to modify the optical properties of the aerosols (see [7] for details).

Regarding methane absorption, we have implemented various linelists to compare them with each other: band models [8,9], theoretical lines [1], and laboratory measurements [2,3]. As is visible on Fig. 1, the latter better reproduce the features seen in the data, in this case one VIMS spectrum acquired on April 16$^{th}$ 2005, targeting an area close to the Huygens landing site. With such a laboratory linelist, the retrieved surface albedo is nearly flat, contrary to the conclusions of older models still using [8].

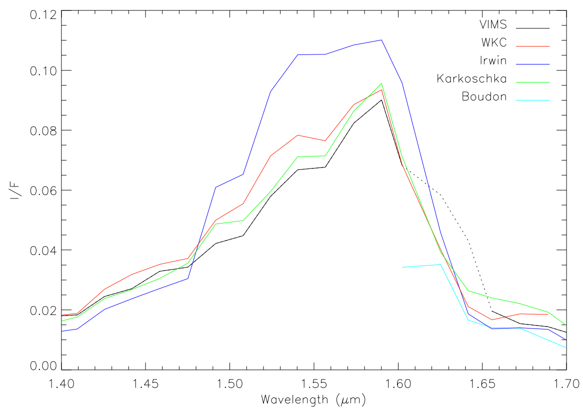


Figure 1: Comparison of methane linelists, using modified DISR aerosols and a constant surface albedo of 0.1 for all simulations. The only varying factor was the source for the methane linelist.

## 3. Applications and Overture

Choosing explicitly non-empirical methane linelists [1,2,3], as well as modified DISR aerosols [7], we applied our RT code to a set of VIMS spectra. The regions of interest include cryovolcanic candidates, as well as dune fields, mountains and lakes. The new surface albedo curves that we retrieve are indeed still compatible with dirty water ice, but their exact composition we are currently investigating by using mixtures of water ices along hydrocarbons ices and liquids, carbon dioxide and ammonia ices, tholins, and bitumens.

Nonetheless, VIMS cannot detect specific spectral signatures in the windows because of the low spectral resolution of the instrument (R=300). Our team acquired more data with a better spectral resolution, at the cost of coarser spatial resolution, using either space-borne or adaptive optics instruments. Onboard ISO, Titan was observed as a full disk with the SWS spectrometer (R=2000) in the 2.6-2.9 μm range [10] combined with a Keck II-NIRSPEC spectrum [11]. Adaptive optics also allowed us to resolve Titan's disk, when we used the VLT facilities with ISAAC (4.4-5.1μm, R=1500) in 2000 and NAOS/CONICA (2.0-2.2μm, R=700) on a spatially resolved Titan's disk [12] in 2005. The reanalysis of such data, with an improved RT code and a state-of-the-art methane description in the 1.6-10μm range, we undoubtedly improve the recognition of Titan's surface composition and the understanding of its methane cycle.

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