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Investigation of Titan's surface and atmosphere photometry using the VIMS instrument onboard Cassini

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Abstract

After 110 targeted flybys of Titan in a decade, the Cassini Visual and Infrared Mapping Spectrometer (VIMS) instrument acquired more than 34,000 hyperspectral cubes pointing at the surface of Titan on the dayside. Due to the strong influence of the absorbing and scattering atmosphere and of the heterogeneous viewing geometry of the flybys, retrieving Titan's surface and atmosphere normal albedo values extracted from the VIMS data remains challenging. In the present work, we aim to determine appropriate photometric functions to describe the light scattering in Titan's atmosphere, which could be used as a basis for empirical corrections or Radiative Transfer (RT) calculations to retrieve normal albedo values for the surface and the atmosphere.

1. Introduction

Titan's surface is only visible with VIMS in the infrared in 7 spectral atmospheric windows centred at 0.93, 1.08, 1.27, 1.59, 2.01, 2.7-2.8 and 5 μm [1]. Atmospheric scattering and absorption dominate Titan's spectrum at wavelengths shorter than 3 microns, while the 5 μm window has a reduced atmospheric scattering contribution to the signal recorded by VIMS [2].
We focus our study on the images acquired at the edges of each atmospheric window to determine the light scattering properties of the atmosphere. In order to explore the angular dependencies of the I/F over Titan, the entire VIMS Ta-T110 data set is decomposed into a MySQL relational database from which we extract angular and time tends on precise location or wavelength subsets. Our first fitting tests are performed on a reduced particular data set acquired at T88 to avoid time variations.

2. The T88 "EPF" observation

An "Emergence-Phase Function'' (or EPF) observation has been acquired during the T88 flyby. It consists of 25 cubes targeting the same area at a constant incidence angle of ~51^{o} and with varying emergence and phase angles (from 0 to 60^{o}).
Figure 1 shows the angular trends of the I/F with wavelength. The data clearly exhibit an increase of I/F at 5 μm at low phase angles, which is usually indicative of an opposition effect of planetary surfaces [3], already observed by Huygens/DISR [4]. In the short-wavelength windows, a "kink" and a sharp increase in the I/F are seen respectively at low and high emergence and phase angles. These effects strengthen with decreasing wavelength. They are also present in the images taken at wavelengths where the atmosphere is completely opaque, which clearly indicates that the shape of the curves is controlled by atmospheric effects. To decouple the surface-atmosphere problem, we first focus on the modelling of the atmospheric scattering and absorbing properties at the edges of the atmospheric windows.

3. Atmospheric model

Assuming that the atmosphere is a particulate medium that prevent any opposition effect, we use the simple Hapke ISMA model (Eq. 1 [3]) to take into account the effects of a multiply scattered radiation (in a plane parallel approximation). The scattering anisotropy is given by the single-scattering term of Eq. 1 (particle phase function $P_{atm}(g)$), the multiple scattering $M(\omega_0,\mu_0,\mu)$ being isotropic.

$$\frac{\mathrm{I}}{\mathrm{F}} = \frac{\omega_{0,atm}}{4}\frac{1}{\mu_0+\mu}\,[P_{atm}(g) + M(\mu_0,\mu)]\left[1 - e^{-\tau_{atm}\left(\frac{1}{\mu_0}+\frac{1}{\mu}\right)}\right] \quad (1)$$

We take into account the coupling between the haze and gas in $\omega_{0,atm}$, $P_{atm}(g)$ and τ_{atm} [5]. Because the single-scattering albedo of the gas is very low, the phase function for the total atmosphere is mainly controlled by that of the haze, for which we use a Henyey-Greenstein function with 2 lobes (*b*: size of the lobe, *c*: direction of scattering). Figure 2 shows a fit example taken at 1.14 µm as well as the $P_{atm}(g)$ parameters determined at each of the atmospheric wavelength investigated (average value of *b*~0.27+/-0.05 and *c*~-0.52+/-0.2). Our parameters fall into the “irregular particles” domain of the “*b* VS *c*” diagram [3], which seems quite consistent with the expected fractal aggregate shape of Titan’s large aerosols particles.

4. Summary

We are using the VIMS Ta-T110 data in order to determine the photometric functions of the surface and of the atmosphere. We started our study on the T88 EPF observation by fitting phase curves of atmospheric images using simple analytical laws. We found a set of parameters that are consistent with the fact that the aerosols are irregular particles, forward scattering with a rather large lobe. Future work will include the study of the other atmospheric windows to infer surface properties, and particularly the 5 µm window where the phase curve shape differs from the other.

Acknowledgements

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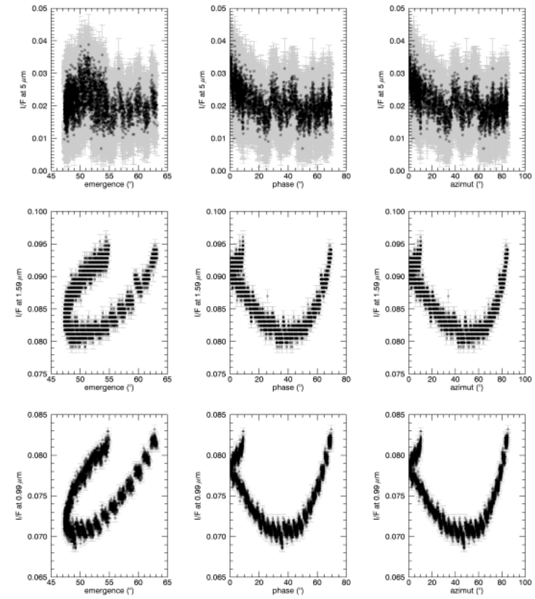

Figure 1: Angular trends of the VIMS I/F at 5 µm, 1.59 µm and 0.99 µm.

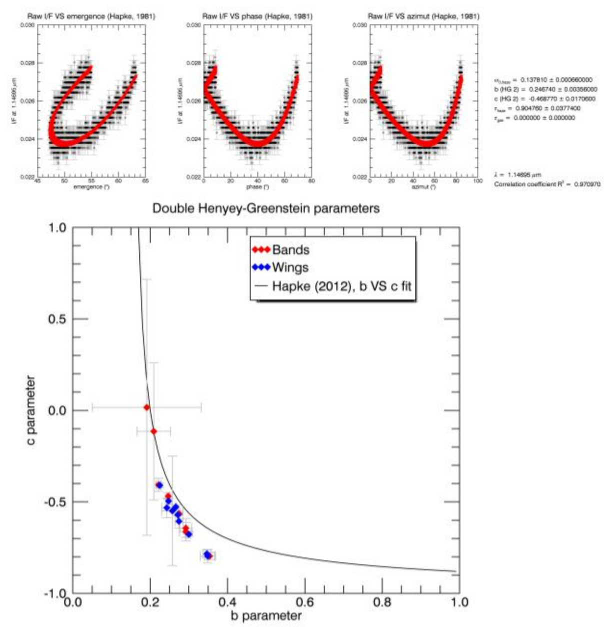

Figure 2: top: fit of the 1.14 µm data with Eq. (1). **Bottom:** Henyey-Greenstein parameters determined at each atmospheric wavelength investigated represented in the “b versus c” diagram.