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Spectral analysis of comet's 67/P nucleus surface: expected results for VIRTIS-M onboard the Rosetta spacecraft

A. Raponi, M. Ciarniello, F. Capaccioni, G. Filacchione. INAF–IAPS, via del Fosso del Cavaliere 100, 00133, Rome, Italy, andrea.raponi@iaps.inaf.it

Abstract

The Rosetta spacecraft will encounter comet 67P/Churyumov-Gerasimenko in the second half of 2014. The present study investigates the capabilities of the VIRTIS-M imaging spectrometer [1] onboard Rosetta to detect and characterize the cometary nucleus surface composition. A radiative transfer model (Hapke [2]) is applied to a mixture of plausible endmembers to determine the spectral radiance as a function of the observing conditions. The VIRTIS-M simulator is then used to determine the expected signal to noise ratio. Finally, we determined the conditions (environmental and instrumental) required to perform abundance measurement. Four compositional endmembers for the cometary nucleus were considered: water, carbon dioxide and methanol in the state of exposed ice mixed within a dark material. As dark material we assumed the non-icy component of the Tempel1 surface as observed by Deep Impact/HRII instrument [3].

1. Introduction

The VIRTIS-M Simulator is a tool necessary to calculate the instrumental signal / noise ratio (S/N) in the IR range (1 to 5 microns) for different input signals and different observing conditions in which the spectrometer will operate during the mission. Its main aim is to obtain the optimal integration time, which allows to reach the best S/N while avoiding the saturation. The sources of noise taken into account by the simulator are the dark current (function of the integration time), the instrument background (function of the integration time and the spectrometer's temperature), and the readout noise (fixed). The IR focal plane is stabilized in temperature by an active cryocooler, while the spectrometer temperature is regulated by a passive radiator and could vary according to the S/C orientation. Although the Simulator is capable to handle variable spectrometer temperatures in this study we have assumed a nominal temperature of 135 K. Given a radiance in input, the simulator outputs the retrieved error on the signal. Moreover, given the heliocentric distance, it calculates the reflectance with its error (figure 1). The spectral analysis is performed on the reflectance spectra.

2. Simulated spectra

We examine 4 different types of ices mixtures, with abundances ranging from 1% to 10% for water, and from 1% to 5% for carbon dioxide and methanol, assuming areal or intimate mixing. Endmembers optical constants from [4-5] are used. The ices are mixed with a dark terrain, calculated from the spectra of Tempel 1 as detected from HRII [3] aboard Deep Impact. The dark terrain is a linear extrapolation in the VIRTIS-M, IR channel, spectral range derived from the average spectrum of the comet's non-icy regions [6]. The I/F spectra for the areal and intimate mixing are calculated with the Hapke model [2], assuming a rather conservative phase angle of 60° and observation geometry with the incidence angle fixed to 60° and the emission angle fixed to 0°. The radiance spectra are then obtained multiplying the derived I/F by the solar irradiance at the Earth scaled to the appropriate heliocentric distance; finally we have added the thermal emission contribution, being the surface temperature of the comet's nucleus a function of the heliocentric distance. These synthetic radiances are then used as input for the VIRTIS-M Simulator.

3. Output analysis

To assess the detectability of the endmembers we have analysed the shape of two bands for water ice (1.5 and 2 μm), one for carbon dioxide (4.2 μm) and two for methanol (3.35 and 3.6 μm) on the simulated spectra. The detection criterium is the evaluation of the error on the band area.

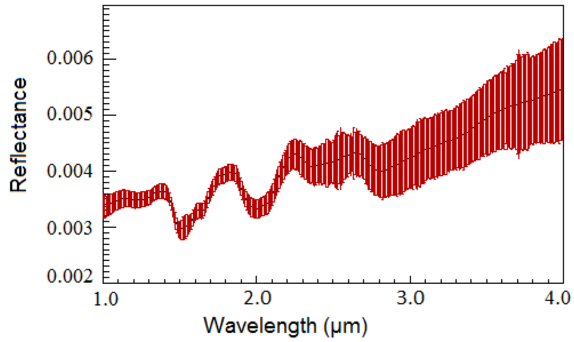

Figure 1: An example of the retrieved reflectance with error bars, obtained with the following parameters in input: heliocentric distance 2.5 AU, temperature 250 K, areal mixing, 99% dark terrain, 1% water ice, grain size 50 μm, integration time 0.5 s.

To link the detection of the bands (in term of band area) to the possibility of deriving the physical properties of the endmebers (abundance and grain size), we have generated synthetic spectra which include the instrumental noise level and then we have applied the Hapke model [2] in a similar manner as described in [7] to invert the spectrum.
Different results coming from the analysis of many spectra give a measure of the achievable accuracy (figure 2).

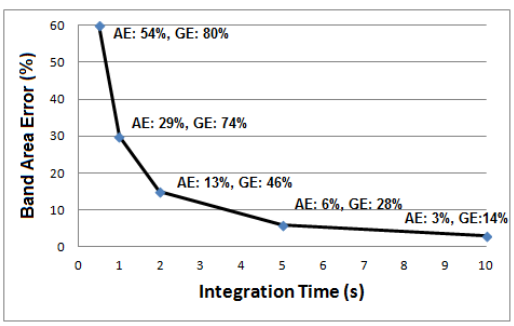

Figure 2: This plot shows the relative error on the retrieved band area for water ice versus different integration times. In this example the parameters in input include an intimate mixing with 1% water ice and grain size 50 μm (other parameters are equal to those of figure 1). For each point are indicated the relative Abundance Error (AE) and the Grain size Error (GE) as calculated from many noisy simulated spectra. The error on the abundance is always very close to the error on the band area, while the error on the grain size is always higher. In general, an integration time to which corresponds an error on the band area less than 20% could be considered optimal.

4. Results

As expected, factors that increase the detectability of a spectral feature for a given endmember are: 1) longer integration time; 2) larger endmember abundance; 3) areal mixing with the dark terrain; 4) shorter heliocentric distance. On the other hand, if the signal is too high there is the possibility to reach saturation. It is therefore necessary to identify an optimal integration time for balancing the other factors.
An integration time is considered optimal if it is far from the time at which saturation begins and if it permits a proper retrieval of endmembers properties.
For heliocentric distances between 2.5 and 3.2 AU, in general an integration time of 1 s is optimal for the detection of water ice, but a time of 5 s is required to properly detect carbon dioxide and methanol. However, 5 seconds is also a limit beyond which saturation is possible, due to the high signal of thermal emission and reflected sunlight, that prevents the detection of the bands respectively of carbon dioxide and water ice.
Close to the sun (1.5 AU) the risk of saturation is higher: in this case an integration time of 1-2 s should not be exceeded. An integration time of 0.5 s seems to be optimal in many cases. However in this case the larger thermal emission of the comet nucleus (~300 K) could pose some difficulties in the detection of the carbon dioxide feature.

Acknowledgments

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References

[1] Coradini A. et al. (2007) SSR, 128, 529-559.

[2] Hapke B. (1993) Theory of reflectance and emittance spectroscopy, Cambridge Univ. Press.

[3] Hampton D. L. et al. (2005) SSR, 117, 43-93.

[4] Warren et al., 1984, Mastrapa et al. 2008, 2009, Clark et al., 2012.

[5] Quirico et al. 1997; Trotta,1996; GhoSST service http://ghosst-prod.obs.ujf-grenoble.fr/

[6] Raponi A. et al. (2013) 44th LPSC, 1507.

[7] Ciarniello M. et al. (2011) Icarus, 214, 541-555.