

Spectral modeling in the VNIR range of 67P/Churyumov-Gerasimenko nucleus from VIRTIS-M onboard Rosetta

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Abstract

Topic of this work is the analysis of the surface composition of comet 67P/Churyumov-Gerasimenko using the data obtained by the VIRTIS instrument [1] onboard the Rosetta spacecraft. We have focused on the VNIR spectral range (0.4 - 2.5 μm) which presents a nearly flat spectrum with quite uniform spectral slopes across the entire comet surface. In this work we report about the spectral modeling of CG VIS-IR spectra by means of Hapke's radiative transfer model.

1. Introduction

VIRTIS (Visible, InfraRed and Thermal Imaging Spectrometer) performs high spectral and spatial resolution observations in the VIS (0.25 - 1.0 μm) and IR (1.0 - 5.1 μm) spectral ranges.

The spectra of the comet 67P/Churyumov-Gerasimenko display a red slope over the range 0.5 to 0.8 μm with a coefficient of 5 to 25% $\text{k}\text{\AA}^{-1}$. The spectrum shows a change of the slope at $\sim 1.0 \mu\text{m}$ and displays a more neutral (1.5 to 5% $\text{k}\text{\AA}^{-1}$) spectral slope in the range 1.0 to 2.0 μm [2]. The identification of the plausible compounds from these spectra is quite challenging due to the lack of specific absorption features. For this reason we consider the presence of dark refractory materials (like Fe-bearing opaque - sulfides - minerals) which give rise to the very low reflectance observed and have neutral spectra. In addition, plausible components of the complex mixture making up the surface of 67P are the Insoluble Organic Matter (IOM) found in carbonaceous chondrites [3] which display neutral and very dark spectra in the studied spectral region. Furthermore, macromolecular organic solids also contribute to the spectrum as evidenced by the broad absorption band at 2.9 - 3.4 μm [2]. However, none

of the typical features of the spectra of the abovementioned compounds are compatible with the spectra of 67P (Fig.1), indicating that a complex mixture is required for reproducing the spectra of the nucleus surface.

Our analysis is performed using the above mentioned compounds as end-members and modeling (intimate as well as areal) mixtures taking into consideration also variable grain sizes.

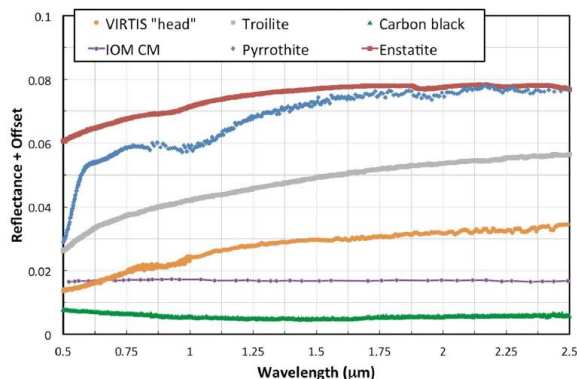


Fig. 1. The spectrum of 67P (yellow), from the "Head" region, in the spectral range 0.5 to 2.5 μm is compared to the spectra of several other compounds. The Murchison IOM is from [3], enstatite spectrum from [4], troilite and carbon black spectra from [5], and pyrrhothite spectrum from [6]. For further details see [2].

2. Method

In order to model the measured spectra we have taken into account the Hapke radiative transfer model [7] which allows to infer the composition, the abundances of the end-members and the grain size.

Calibrated spectra are cleaned from spikes and artefacts are removed. The best fit is obtained with a least square optimization algorithm, which can

account for multiple end-members, each one characterized by its own optical constants. The latter are mostly obtained by applying the methodology described in [8] to IR spectra reflectance obtained from the RELAB database.

The poissonian noise is calculated by taking into account the total raw signal in photoelectrons. Then the resulting error bars of the reflectance spectra are used to weight the different parts of the spectra during the fitting procedure. For further details on the method see [9].

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References

- [1] A. Coradini et al, SSR, Virtis: An Imaging Spectrometer for the Rosetta Mission, *Space Sci. Rev.* 128, 529–559, 2007.
- [2] F. Capaccioni, et al., The organic-rich surface of comet 67P/Churyumov-Gerasimenko as seen by VIRTIS/Rosetta, *Science* 347, 2015.
- [3] E. A. Cloutis, P. Hudon, T. Hiroi, M. J. Gaffey, P. Mann, Spectral reflectance properties of carbonaceous chondrites: 2. CM chondrites, *Icarus* 216, 309–346, 2011.
- [4] R. L. Klima, C. M. Pieters, M. D. Dyar, Spectroscopy of synthetic Mg-Fe pyroxenes I: Spin-allowed and spin forbidden crystal field bands in the visible and near-infrared, *Meteorit. Planet. Sci.* 42, 235–253, 2007.
- [5] The HoserLab Database is available at <http://psf.uwinnipeg.ca/Home.html>.

[6] The U.S. Geological Survey SpecLab Database is available at <http://speclab.cr.usgs.gov>.

[7] Hapke B., Cambridge Univ. Press., 1993, 2012

[8] Carli, C.; Ciarniello, M.; Capaccioni, F.; Serventi, G.; Sgavetti, M. Spectral variability of plagioclase- mafic mixtures (2): Investigation of the optical constant and retrieved mineral abundance dependence on particle size distribution, *Icarus*, 235, 207-219, 2014

[9] Raponi, A. PhD Thesis, arXiv:1503.08172, 2015