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# Spectral simulations of 67P/Churyumov-Gerasimenko in the range of VIRTIS/Rosetta

**S. Erard** (1), C. Leyrat (1), D. Bockelée-Morvan (1), S. Jacquinod (1), A. Gicquel (1), Th. Encrenaz (1), J. Crovisier (1), A. Raponi (2), M. Ciarniello (2), F. Capaccioni (2), G.Filacchione (2)
(1) LESIA, Observatoire de Paris/CNRS, France (2) IAPS/INAF, Rome, Italy (stephane.erard@obspm.fr)

## Abstract

Spectral radiance from 67P is estimated as a function of Sun distance. The goal is to optimize the functioning parameters for the VIRTIS observations during the comet phase, starting June 2014.

## 1. Introduction

The International Rosetta mission is ESA's cornerstone mission dedicated to small bodies of the solar System. The spacecraft will reach its main target, comet 67P/Churyumov-Gerasimenko, in June 2014. VIRTIS (Visible Infrared and Thermal Imaging Spectrometer) is one of the remote sensing instruments on board the orbiter. It uses two optical heads (-M, -H), respectively dedicated to the VIS-NIR imaging spectroscopy (0.3-1.05 and 1-5 µm) and infrared spectroscopy (2-5 µm). VIRTIS-M has imaging capacities but the standard resolution of a grating spectrometer ($\lambda/\Delta\lambda \sim 300$), allowing mapping of the nucleus and coma. VIRTIS-H is a point spectrometer with higher resolution ($\lambda/\Delta\lambda$ up to 3000), more adapted to the physical study of the coma. Spacecraft operations at the comet are currently being defined. The VIRTIS team has developed a system of physical simulations to help optimize the observation program. It will also serve as a basis to interpret the signal during the observation phase.

## 2. Nucleus simulation

A NIR spectro-photometric model of the nucleus has been derived from a previous model of Mercury [1]. The input parameters are the Sun distance, the observation angles, and a surface temperature. The nucleus reflectance spectrum is modeled by a straight line fit to Tempel-1 measurements by the Deep Impact mission (similar to [2]), with level from the most recent radiometric calibration (Groussin, pers. comm. 2012). Photometric variations are derived from Hapke's phase function fit on this data set [3]. Two different reflectance levels are used to encompass a reasonable range of surface brightness. This includes average reflectance of 67P as well as surface variations. Possible ice patches are also modeled from Tempel-1, by using the same model spectra with addition of 4% ice features (proportions derived by [4]). During the signal analysis phase, this may be derived using either laboratory measurements or intimate and intraparticle mixtures modeling [9]. The reflected radiance level is then derived by multiplying by a solar spectrum (from [6]) convolved at adequate resolution and scaled to the requested distance. Spectral emissivity is derived from the modeled hemispherical reflectance (in the Lommel-Seeliger approximation). Thermal emission is the product of this emissivity and a black body function, using an average temperature inside the Field of View. The modeled radiance is the sum of the reflected and emitted contributions (Fig. 1).

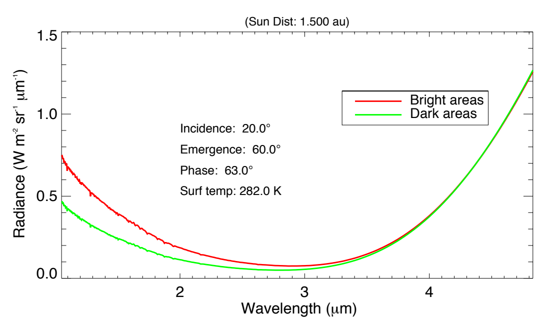


Fig. 1: Nucleus simulation of the Tempel-1/Deep impact configuration (resolution and range are similar to VIRTIS-M_IR)

The temperature itself can be set manually (as in Fig. 1) or can be computed using a thermophysical model of surfaces [5]. The physical temperature structure of any airless body results from a balance between solar insolation, heat transport within the subsurface and re-radiation outward. We use a 1-D thermal model able to compute the temperature distribution as a function of depth, local time, and geographic location, Local topography is accounted for by using the nucleus shape model from [7]. This model takes into account local variations of the insolation on both diurnal and seasonal timescales, using a specific thermal inertia, heat capacity and bond albedo. Surface temperatures that can be measured from the long wavelengths of VIRTIS spectra can thus be computed for any local time (Fig. 2).

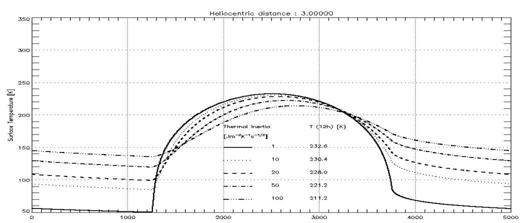


Fig. 2 Simulated surface temperature of 67P at the equator, at 3AU from the Sun.

# 3. Gaseous coma simulation

In the coma, we focus on the main two species expected to be detected by VIRTIS: $H_2O$ and $CO_2$. These species contribute mostly by fluorescent emission of their $\nu_3$ bands in the 2.67 and 4.26 µm regions respectively. Here the intensities are estimated considering IR pumping by the Sun, collisional quenching of IR bands, and radiation trapping [8]. The fundamental vibrational state is assumed to be at local thermal equilibrium. Production rates are taken from the engineering model of 67P; local density, mean velocity and mean temperature along the line of sight are retrieved from an isentropic model. Other species such as $CH_4$, OCS… also have signatures in the VIRTIS range, but may have significant intensity only close to perihelion.

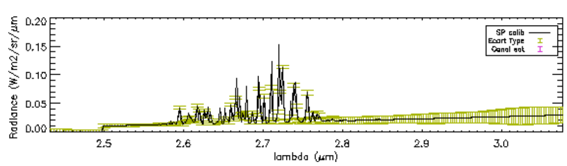


Fig. 3: $H_2O$ limb emission at perihelion, as expected from VIRTIS-H: 5 km tangent altitude, 20 s exposure time. The production rate is assumed to be $10^{28}$ mol/s.

# 3. Dust coma simulation

The particles are modeled as two-layer spherical grains with a mantle of amorphous carbon and a core of amorphous olivine in equal mass proportions. A power law size distribution is assumed with size ranging from 0.1 µm to the maximum liftable size (depending on Sun distance).

The Mie theory is used to compute the absorption coefficient of the material. Grain temperature is obtained assuming thermal equilibrium. The local density and relative contribution of each size bin to the emitted flux is derived assuming that grains move isotropically from the surface with a velocity which depends on the grain size, on the gas production rates at the surface, and on gas velocity. The observed thermal flux is simulated for limb observations at different distances from the nucleus surface. The thermal contribution of all grains is integrated along the viewing direction. This thermal continuum is then added to fluorescent emission of the gaseous species so as to obtain a complete simulated spectrum of the coma in the thermal range. In reflected light, the dust contribution is also estimated from Mie scattering.

# 4. Conclusion

These estimates of the signal are eventually fed into instrument simulators for both channels (M and H), together with the functioning conditions (temperature of the optical parts…). This allows the team to optimize the integration times (to avoid any saturation) and the expected signal-to-noise ratio (by summing consecutive frames if needed).

# Acknowledgements

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# References

[1] Erard et al 2011, PSS. [2] Groussin et al 2007, Icarus. [3] Li et al 2009, Icarus. [4] Sunshine et al 2006, Science. [5] Leyrat et al. 2011, A&A. [6] Kurucz 1997, ISO workshop. [7] Lamy et al. 2007, Sp. Sc. Rev. [8] Bockelée-Morvan 1987, A&A. [9] Ciarniello et al 2011, Icarus.