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Apparent and real temporal variability of surface components of 67P/CG nucleus with Rosetta VIRTIS

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Abstract

The surface material of comet nucleus 67P/Churyumov-Gerasimenko contains components with a broad absorption band between 2900 and 3600 nm [1] that was revealed by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS, [2]) on the Rosetta spacecraft. Absorptions in this range of wavelengths are likely due to C-H and/or O-H chemical groups in various compounds [1, 3, 4]. In this study we investigate the distribution of this absorber across the surface of the comet nucleus, and apparent temporal variability on areas where the absorption band is the strongest.

1. Introduction

Comets are objects that probably contain components that are mostly unaltered since their formation. In addition, they may have contributed in bringing molecules such as H_2O, organics and amino acids at the surface of the planets, satellites and asteroids in the early stages of their formation. Their study is therefore important both to 1) to analyze their processes of formation, which may document the environment at the time of the formation, or even prior to the formation of the solar system, and 2) to clarify their role in the geological and biological evolution of the Earth. Organics are of premium interest, and the nucleus of comet 67P/C-G exhibits a broad and complex absorption band between 2900 and 3600 nm, with some diversity across the surface that may correspond to several types of C-H and/or O-H bonds in a variety of molecules [4]. Our objective is to determine whether apparent variations in absorption band depth in VIRTIS spectra can be indicators of present surface activity, and how much multiple scattering may enhance this effect. Cometary activity involves degasing of water vapor, which may expose materials that is otherwise masked by a top layer of dust. If water ice is present also in the subsurface, it would change the band depth, position and depth of the 2900-3600 nm absorption.

2. Data: All VIRTIS-M IR pre-landing observations

VIRTIS-M (Mapper) measures radiation in the range 0.25-5.1 µm with one detector in the visible (0.25-1. µm) and a second one in the near-infrared (1.-5.1 µm). In this study, we used all observations of the pre-landing phase, between June and December 2014 which represent approximately 10^6 spectra. These observations were designed to study the surface of the comet nucleus in order to choose a site for the lander Philae [5],. Some of these observations have been acquired after the landing. During these six months, the solar distance of the comet decreased from 3.82 and 2.76 astronomical units, resulting in an increase of the thermal emission, affecting increasingly shorter wavelengths. In this study, we focused on locations with a strong and broad absorption feature around 3 µm that were observed several times under various solar incidences, and for which the temperature was low enough to not be affected by thermal emission shorter than 3400 nm.

3. Spectral analysis: Apparent temporal variations in absorption band depth

We first calibrated VIRTIS M IR spectra in I/F (division of the measured radiance by the solar spectrum). In order to compare the variations in absorption band depth, we calculated the average I/F between 1000 and 2600 nm, except within small ranges at the edge of order sorting filter, where scattered light occurs, and we divided each spectrum by its own average I/F. This technique has the advantage of minimizing illumination effects due to the local topography, without using a digital elevation model. Figure 1 illustrates apparent variations in absorption band depth of one location observed multiple times. Its location is shown in Figure 2.

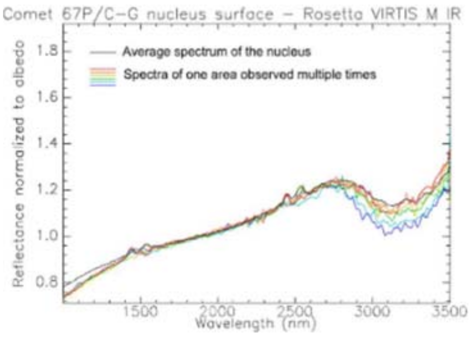

Figure 1:.Spectra of one location at the bottom of the nucleus (showed in Figure 2) where apparent variations as function of time are observed in absorption band depth between 2900 and 3600 nm.

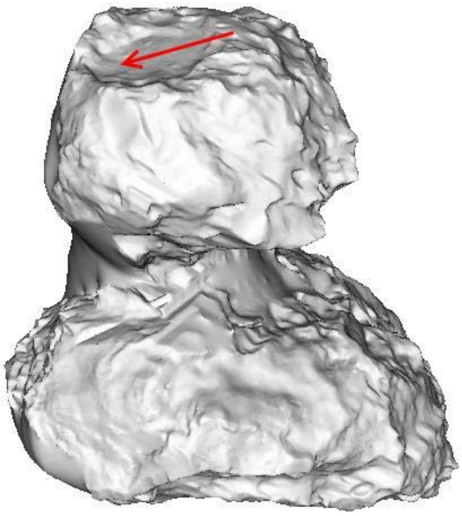

Figure 2: Shaded view of the comet nucleus shape model. The red arrow indicates one location on the head of the comet nucleus where apparent temporal variability has been observed by VIRTIS.

4. Summary and Conclusions

The area presented in this study has a stronger band than the average spectrum of the nucleus (Figure 1). However, given the high solar incidence angle and the rugged topography in the area, these apparent variations may be enhanced by multiple reflections on surrounding terrains. In addition, if the surface regolith is rough, some facets may be illuminated under low incidence angles, which may result in high diversity in surface temperatures within an area observed by one pixel, therefore we cannot exclude possible thermal emission contamination. We will investigate the amplitude of those effects in order to determine how much the observed variations in absorption band depth can be due to temporal variations of the surface material abundance. We will also determine whether this change in absorption band depth can be partially or totally attributed to water.

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