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Temporal evolution of comet 67P/Churyumov-Gerasimenko's surface as observed by VIRTIS-M

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Abstract

We report about the seasonal evolution of 67P/Churyumov-Gerasimenko's (hereafter 67P) surface as inferred from VIRTIS-Rosetta measurements. We analyze observations performed from August 2014, when the comet was at a heliocentric distance of ~3.5 AU along the inbound part of the orbit, up to the end of the Rosetta mission in September 2016, when 67P was at ~3.8 AU outbound.

1. Introduction

The Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) [1] on board the Rosetta spacecraft acquired disk-resolved images of the nucleus of comet 67P for more than two years from August 2014 to September 2016. The observation campaigns took advantage of both the visible (VIS) and infrared (IR) channels of the instrument covering the 0.25-5.1 µm spectral range up to early May 2015 and by means of solely the VIS channel (0.25-1 µm) for the remaining part of the mission. We were able to investigate the spectral properties of 67P's surface as a function of the heliocentric distance following the comet approaching the Sun from ~3.5 AU to perihelion (~1.2 AU) and then along the outbound part of the orbit up to ~3.8 AU. Throughout this period, the surface evolution was further complicated by the combination of the relatively large orbital eccentricity, of the irregular shape of 67P's nucleus and of the inclination of its rotational axis (52° [2]), which amplify the seasonal effects.

2. Method

The long-term spectral variability of 67P's nucleus is described by means of spectral indicators as defined in [3,4]. These are computed after thermal emission removal at infrared wavelengths and reduction of reflectance spectra to single scattering albedo (SSA) [5], which minimizes observation and illumination geometry effects (Fig. 1). The spectral indicators are represented by the spectral slopes in the VIS (0.55-0.8 µm) and IR (1.2-2.0 µm) wavelength ranges, the single scattering albedo at 0.55 µm and the band area and band center of the 3.2 µm absorption feature. These quantities are projected onto latitude-longitude maps at different mission times, in order to monitor both spatial and temporal variations (Fig. 2). In parallel, the evolution of selected areas on 67P's surface is followed to monitor local variability.

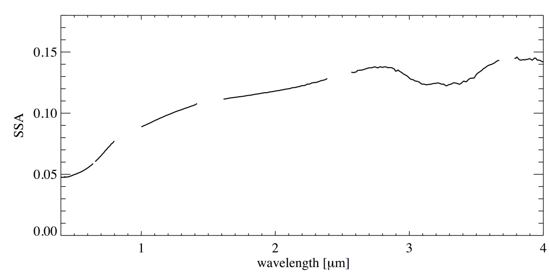

Figure. 1. Average SSA spectrum of 67P's surface. Missing parts in the curve correspond to instrumental order sorting filters and to the VIS-IR channels junction at ~1µm. 67P's spectrum has been interpreted as a mixture of refractory organics, fine-grained opaque materials (Fe-sulfides, Fe-Ni alloys) and a semi-volatile component (ammonium-bearing species and carboxylic acids) [6].

3. Preliminary results

The analysis of the VIS slope from observations taken from August 2014 to August 2016, corresponding to the Rosetta mission Medium Term Planning (MTP) observation phases from MTP006 to MTP035, indicates a progressive reduction (blueing) while the comet was approaching the Sun during the inbound orbit leg. The maximum blueing is reached in September 2015 (MTP20) just after perihelion passage (13 August 2015), followed by a slope increase (reddening) along the outbound leg. This is in agreement with the seasonal color variations reported by OSIRIS [7]. During the outbound leg of the orbit the reddening of the surface reached its maximum approximately around March-April 2016 (MTP027-MTP028), exceeding the largest values measured during the early observations on the inbound leg. Then, the VIS slope progressively decreases across the surface until the last available measurements (MTP035, ~3.8 AU outbound) to the values derived at the beginning of the observations (MTP006, ~3.5 AU, inbound).

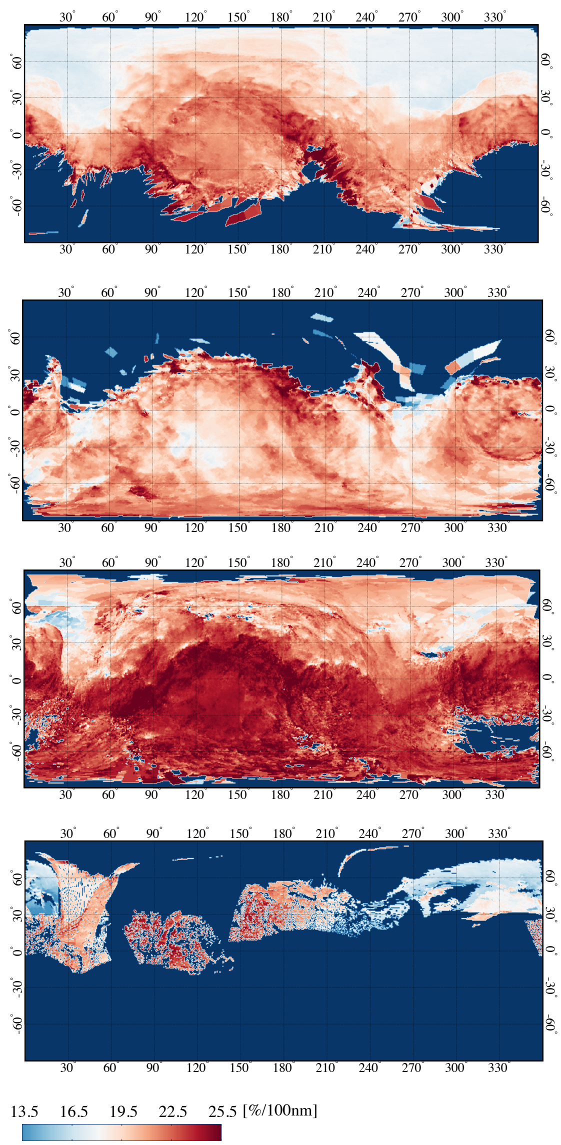

Figure 1. VIS slope maps at different observation phases from top to bottom: MTP006 (August 2014, ~3.5 AU inbound), MTP019 (August 2015, ~1.25 AU), MTP028 (April 2016, ~2.8 AU) and MTP035 (September 2016, ~3.8 AU).

These observations suggest that 67P's surface spectral properties follow a seasonal cycle related to the surface variability of the water ice content. While approaching the Sun the increasing activity removes dust from the top layers exposing the former sub-surface, which contains larger amounts of ice, and the spectra exhibit smaller VIS spectral slopes [3,4,7]. This is corroborated by the accompanying variation of the IR spectral indicators, when available [3,4]. The spectral reddening after perihelion, following the reduction of the activity, can be explained by a deposition of dust grains expelled from the Southern Hemisphere which is experiencing summer at this time, thus mantling the nucleus. Along with this, another possible mechanism, which has yet to be validated by thermophysical modeling, can be represented by a progressive depletion of the surface water ice content due to sublimation, if the timescale of replenishment from the deeper layers is larger than the sublimation rate. In this case, when the comet is at relatively large heliocentric distances (September 2016, ~3.8 AU) and the sublimation rate decreases, water ice from the interior becomes newly available on the top layers, blueing the surface again.

4. Acknowledgements

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