COMPOSITIONAL MAPS OF 67P/CG NUCLEUS BY ROSETTA/VIRTIS-M G. Filacchione[1], F. Capaccioni[1], F. Tosi[1], S. Erard[2], M. C. De Sanctis[1], M. Ciarniello[1], A. Raponi[1], E. Palomba[1], M. T. Capria[1], G. Piccioni[1], C. Leyrat[2], D. Bockelée-Morvan[2], P. Drossart[2], G. Arnold[3], R. Jaumann[3], M. A. Barucci[2], W.-H. Ip[4], T. B. McCord[5], B. Schmitt[6], E. Quirico[6], P. Beck[6], A. Longobardo[1], R. Noschese[1], M. Cartacci[1], A. Cicchetti[1], R. Politi[1], F. Henry[2], S. Jacquinod[2] and Rosetta VIRTIS team, [1]IAPS-INAF, via del Fosso del Cavaliere, 100, 00133, Rome, Italy, [2]LESIA Observatoire de Paris/ CNRS/UPMC/Université Paris-Diderot, Meudon, France, [3]German Aerospace Center DLR Berlin, Germany, [4]NCU National Central University of Taiwan, Jhongli, Taiwan, [5]Bear Fight Institute, Winthrop, WA, United States, [6] IPAG, Université Grenoble Alpes / CNRS, Grenoble, France.

Introduction: The Visible InfraRed Thermal Imaging Spectrometer, VIRTIS [1] onboard ESA's Rosetta mission has completed two extensive mapping campaigns of the 67P/Churyumov-Gerasimenko comet nucleus in August-September 2014. After calibration and geometrical projection on nucleus shape model, VIRTIS data were processed to retrieve the distribution of several spectral indicators (spectral slopes, organic material band depths) from which compositional maps are built. Apart from being appropriate to map surface composition, those indicators allow us to correlate them with local morphological features (patches, boulders, scarps, terraces, active areas) and thermal properties [2].

VIRTIS-M instrument: The mapping unit of the instrument relies on a Shafer-Offner optical design and performs imaging spectroscopy in the 0.25-5.1 μm spectral range across 864 channels resulting in a spectral sampling of 1.8 nm/band for wavelengths below 1 μm and 9.7 nm/band between 1-5 μm. The instrument has a 3.7 deg FOV and uses 256 samples with an IFOV of 250 μrad. A CCD and a MCT detector actively cooled to T=85 K are used as focal planes [1].

Nucleus Observations: During the orbiter prelanding phase two different nucleus mapping campaigns have been completed by VIRTIS-M: 1) in August 2014, during MTP006 period, when the spacecraft was orbiting between 50-100 km distance from the nucleus with 25°-40° solar phase angle. In this period a large number of observations have been executed at constant solar phase (about 30°) allowing us to reduce the effect of photometric corrections on surface's mosaics; 2) in September 2014, during MTP007, when the spacecraft was at about 30 km distance with 60°-70° solar phase angle. In these two periods, VIRTIS-M onground resolution was about 12-25 and 7.5 m/pixel, respectively. The MTP007 campaign was designed to achieve more detailed observations of the five preselected Philae landing sites, although in worse illumination conditions with respect to the MTP006. As a general strategy, we have implemented an observation scheme which foresees a high level of redundancy and consists in the observation of each illuminated point on the surface for more than one time at different local times in order to mitigate the effects of the expected compositional differences, local topography and the highly irregular double-lobed shape of the comet's nucleus. A total of 156 and 46 hyperspectral cubes, corresponding to more than 2.168.000 and 1.073.000 spectra, were acquired in MTP006 and MTP007, respectively. As shown in Fig 1, CG nucleus reflectance spectra are characterized by a low reflectance (normal albedo 6%), a strong reddening (up to $2 \cdot 10^{-3}$ μm^{-1}) between 0.5-0.8 μm followed by a less intense reddening in the infrared range and by a wide absorption at 3.2 μm caused by the presence of organic material and OH which appears widespread across the entire nucleus surface. From these two datasets we have derived compositional maps by using specific VIS-IR spectral indicators [3] adapted to the CG spectral characteristics, namely: 0.5-0.8, 1-1.5, 1.5-2.5 μm spectral slopes and 3.2 μm band depth.

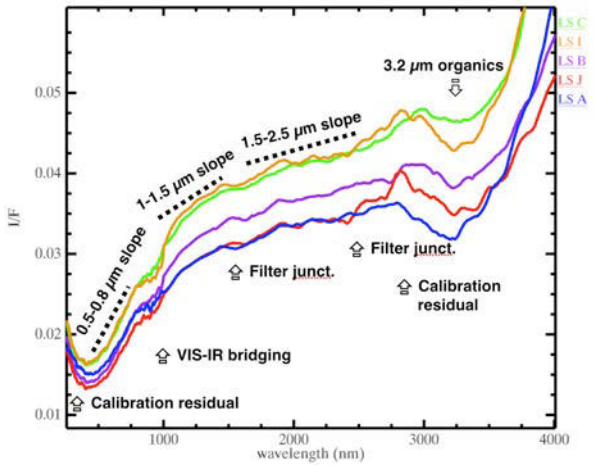

Fig 1. CG average reflectance spectra on the five proposed Philae's landing sites (LS A to C). The 4-5 μm spectral range being affected by surface thermal emission is not shown.

Visible spectral slope maps: Compositional variability across the different regions of the nucleus is traced by means of the visible spectral slope, calculated on the best linear fit to the reflectance spectra between 0.5-0.8 μm. For each pixel the slope is sampled on a grid having 0.5° × 0.5° resolution in longitude and

latitude, averaged on all observations and then projected on a cylindrical map (see Fig. 2-3 for maps derived from MPT006 and MTP007 campaigns, respectively). With the aim to avoid oblique and distorted views, only illuminated points of the surface having incidence and emission angles lower than 80° are used in the process. A similar method is applied to derive the 3.2 µm band depth of the organic material. In Fig. 4 the 3D renderings derived from MTP006 campaign of the 0.5-0.8 µm slope and of the 3.2 µm band depth are shown projected on the nucleus shape model (version 2, courtesy ESA/Rosetta/MPS for OSIRIS Team) [4].

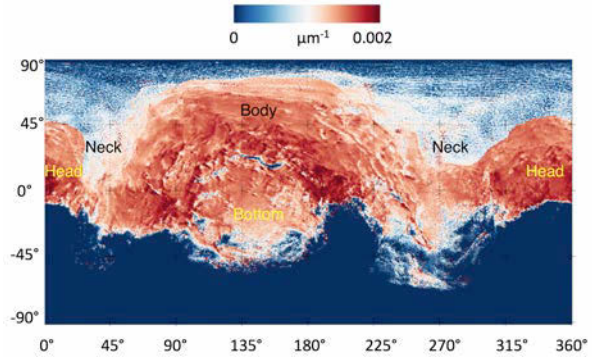

Fig 2. VIS spectral slope cylindrical map derived from MTP006 campaign data. Head, neck, body and bottom regions are indicated.

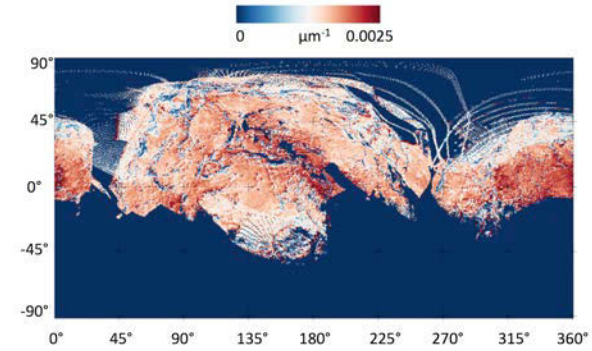

Fig 3. VIS spectral slope cylindrical map derived from MTP007 campaign data.

Results: The first compositional maps of the 67P/CG nucleus were derived by VIRTIS-M in August - September 2014 with spatial resolutions between 7.5 and 25 m/px. The surface of nucleus appears very dark having a normal albedo of 0.060 ± 0.003 at 0.55 µm [5, 6], organic materials-rich and depleted in water ice. A broad absorption, compatible with a mixture of various types of C-H and/or O-H chemical groups [7], is seen in the 2.9-3.6 µm range across the entire illuminated surface (Fig. 1). This feature is characterized by a deeper band depth on the bottom plain and head regions, whereas it is lower in active areas located on the neck (Fig. 4). Similarly, the VIS slope values are less red in the neck region and the north pole region while higher values are measured on the head and in the body regions. In summary, active areas on the neck region show less-red 0.5-0.8 µm slope and lower abundance of organic material with respect to the rest of the nucleus surface.

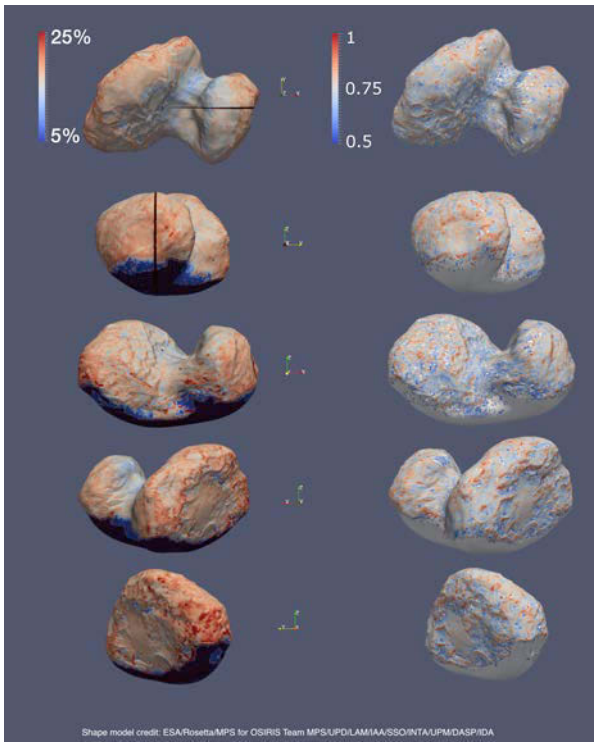

Figure 4. 3D renderings of the 0.5-0.8 µm spectral slope (left column) and 3.2 µm organics band depth (right column). Shape model courtesy by OSIRIS team. Renderings courtesy by A. Zinzi (ASDC, ASI Science Data Center, Rome, IT).

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References: [1] A. Coradini et al. (2007), *SSR 128*, 529, [2] F. Tosi et al., (2015) *LPSC XLVI abstract,* [3] G. Filacchione et al. (2013), *Icarus 220, 1064-1096,* [4] from http://sci.esa.int/rosetta/54728-shape-model-of-comet-67p/, [5] F. Capaccioni et al. (2015) *Science, in press,* [6] M. Ciarniello et al., (2015) *LPSC XLVI abstract,* [7] E. Quirico et al., (2015) *LPSC XLVI abstract.*