

**DETECTION OF TRANSIENT WATER ICE ON COMET 67P/CHURYMOV-GERASIMENKO**

M.C. De Sanctis<sup>1</sup>, F. Capaccioni<sup>1</sup>, G. Filacchione<sup>1</sup>, M. Ciarniello<sup>1</sup>, A. Raponi<sup>1</sup>, F. Tosi<sup>1</sup>, B. Schmitt<sup>2</sup>, G. Arnold<sup>3</sup>, S. Erard<sup>6</sup>, D. Bockelée-Morvan<sup>6</sup>, E. Kuehr<sup>3</sup>, S. Mottola<sup>3</sup>, C. Leyrat<sup>6</sup>, E. Ammannito<sup>1,4</sup>, A. Barucci<sup>6</sup>, P. Beck<sup>5</sup>, M.T. Capria<sup>1</sup>, M. Combi<sup>7</sup>, P. Drossart<sup>6</sup>, W.-H. Ip<sup>8</sup>, T. B. McCord<sup>9</sup>, E. Quirico<sup>5</sup> and the VIRTIS Science Team,  
<sup>1</sup>Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale de Astrofisica, Rome, Italy, <sup>2</sup>Laboratoire de Planétologie de Grenoble (LPG), Grenoble, France, <sup>3</sup>German Aerospace Center DLR Berlin, Berlin, Germany, <sup>4</sup>University of California Los Angeles, Earth Planetary and Space Sciences, Los Angeles, CA-90095, USA, <sup>5</sup>University Joseph Fourier Grenoble, Grenoble, France, <sup>6</sup>LESIA-Observatoire de Paris, Meudon, France, <sup>7</sup>Space Physics Research Laboratory, The University of Michigan, Ann Arbor, USA, <sup>8</sup>National Central University, Taipei, Taiwan, <sup>9</sup>Bear Fight Institute, Winthrop, WA, USA

**Introduction:** The Visible InfraRed Thermal Imaging Spectrometer, VIRTIS [1] onboard ESA's Rosetta mission began observing the nucleus of 67P/Churyumov-Gerasimenko in August 2014. The instrument is composed of two units. VIRTIS-M, the mapping unit of the instrument, has a Shafer-Offner optical design and performs imaging spectroscopy in the 0.25-5.1  $\mu\text{m}$  spectral range across 864 channels, resulting in a spectral sampling of 1.8 nm/band for wavelengths below 1  $\mu\text{m}$  and 9.7 nm/band between 1-5  $\mu\text{m}$ . The instrument has a 3.7 deg FOV and uses 256 samples with an IFOV of 250  $\mu\text{rad}$  [1]. VIRTIS-H is the high spectral resolution unit, operating between 2-5  $\mu\text{m}$ .

**Data:** After calibration, VIRTIS-M data were analyzed to study the comet composition in great details. Comet 67P/Churyumov-Gerasimenko was observed by the Rosetta mission to be moderately active very far from the perihelion by the instruments onboard the Rosetta mission. The Visible Infrared and Thermal Imaging Spectrometer VIRTIS [1] collected high spatial and spectral resolution data [1]. Here we analyse the VIRTIS data acquired during the period August-September 2014 (3.6-3.3 AU from the Sun), with a ground spatial resolution varying between 7.5-25 m/pixel, and covering a spectral range of 0.35-5.0  $\mu\text{m}$ .

**Results:** The first reflectance spectra, taken in different areas over the illuminated regions of the comet's nucleus, show the presence of a broad absorption band at 2.9-3.6  $\mu\text{m}$ , attributed to organic compounds [2]. The same spectra showed the absence of pure water ice absorption bands, indicating an upper limit of about 1% of the water ice abundance on the surface at that resolution [2]. Those early data were acquired with a resolution of about 15-30 m/pixel. In the following observations, VIRTIS acquired data of the "neck" region with a better spatial resolution.

In some specific areas of the neck, VIRTIS observes spectral variations moving from the illuminated pixels to the shadowed areas, with a progressive change of the band around 3- $\mu\text{m}$ . This feature shows a clear shape change in the spectra with a broadening, a shift towards shorter wavelengths and a strong increase of the depth. The characteristics of the spectra showing the stronger 3- $\mu\text{m}$  band indicate the presence of water ice in addition to the organic material present on the comet surface.

Fig.1 shows the region of the neck where the ice signature has been observed and Fig. 2 shows the two spectra taken from the two marked regions, one very close to the shadow and one on the well illuminated area.

The two spectra show a clear difference around the 3- $\mu\text{m}$  spectral range. The strong 3- $\mu\text{m}$  ice band is clearly present in all the pixels located at the border of the shadow and it progressively disappears moving away from the shadow. The same regions has been observed at different comet rotations and the same phenomenon has been detected: a stronger 3- $\mu\text{m}$  ice band close to the shadows.

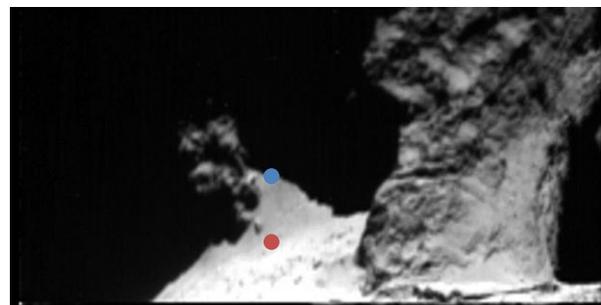


Fig.1. VIRTIS monochromatic image at 0.7- $\mu\text{m}$  of the neck region of 67P. The colored dots indicate the zones from which the spectra in Fig.2 are taken. The blue one is located very close to the shadow area.

The analysis done indicates that the maximum quantity of water ice is found very close to the shadow areas in all the observations, even if the pixels in shadows are different in each image. The observations suggest that the ice is not constant but it depends on the thermo-physical condition of the comet surface. The spectra show also different thermal emissions: the one with stronger 3- $\mu\text{m}$  band are also characterized by smaller thermal emissions. A clear anti-correlation trend of ice abundance with temperature is seen in this region of the neck, suggesting that the water ice feature is present only when the temperature is low enough to permit the stability of water ice on comet surface. Thus, we are looking at a dynamical process that implies sublimation and condensation of water ice triggered by the rapid illumination changes of the neck region. .

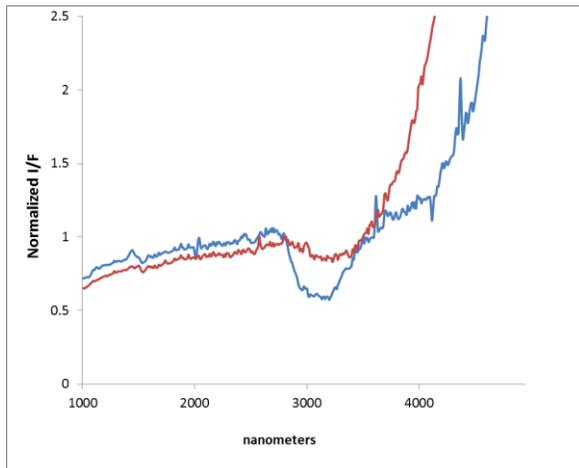


Fig.2 Two spectra taken from the region in fig.1. The red and the blue spectra correspond, respectively, to the red and blue spots in fig.1.

Two possible mechanisms for the condensation of water ice in the comet unilluminated area can be considered: the condensation of coma material (emitted gas and icy grains) onto cold spots on the nucleus [3] or condensation in the colder external layers of gas coming from subsurface sources [4,5]. Both the mechanisms can be responsible for the phenomenon we see.

**Conclusion:** Ice has been observed on other cometary surfaces [6] as patches of pure ice mixed with the non-ice component of the surface. In case of comet 9P/Tempel 1, these ice patches were not directly linked with the comet gas activity and the main sources of gases were indicated in the comet interior. On comet 67P, VIRTIS observes surface water ice

mixed with a non-ice organic rich refractory component, in a region where the localized water activity occurs [7]. Moreover, the ice signature is variable with time and illumination conditions suggesting a cyclic process of sublimation-condensation of water ice on the comet surface.

The cyclic replenishment of ice, due to the illumination changes, in the first comet layers can be the key for the strong local activity at such high heliocentric distance.

#### References:

- [1] Coradini et al. (2007) *Space Sci. Rev.* 128, 529-559. [2] Capaccioni et al. (2015) *Science*, (in press). [3] Author G. H. (1996) *LPS XXVII*, 1344–1345. [4] De Sanctis et al. (2010) *AJ*, doi:10.1088/0004-6256/140/1/1. [5] Capria et al. (2001) *Planet. Space Sci.*, 49, 907 [6] Sunshine et al. (2006) *Science* 311, 1453-1455. [7] Filacchione et al. (2015) *LPSC 2015*.

#### Acknowledgments:

The authors would like to thank the Italian Space Agency (ASI - Italy), the Centre National d'Etudes Spatiales (CNES- France), the Deutsches Zentrum für Luft- und Raumfahrt (DLR-Germany), the National Aeronautic and Space Administration (NASA-USA). VIRTIS was built by a consortium from Italy, France and Germany, under the scientific responsibility of the Istituto di Astrofisica e Planetologia Spaziali of INAF, I, which guides also the scientific operations. The VIRTIS instrument development for ESA has been funded and managed by ASI, with contributions from Observatoire de Meudon financed by CNES, F, and from DLR, D. The authors wish to thank the Rosetta Science Ground Segment and the Rosetta Mission Operations Centre for their fantastic support throughout these early phases of the mission