

SPECTRAL REFLECTANCE PROPERTIES OF REFRACTORY COMPONENTS OF COMET 67P/CG'S NUCLEUS – INSIGHTS FROM LABORATORY STUDIES

L. V. Moroz^{1,2}, K. Markus^{3,2}, G. Arnold², D. Henckel², D. Kappel², U. Schade⁴, M. Ciarniello⁵, B. Rousseau⁶, E. Quirico⁷, B. Schmitt⁷, F. Capaccioni⁵, D. Bockelee-Morvan⁶, G. Filacchione⁵, S. Erard⁶, C. Leyrat⁶, A. Longobardo⁵ and the VIRTIS Science Team

¹Institute of Earth and Environmental Science, University of Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany, Liubov.Moroz@dlr.de, ²German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany, ³Institute of Planetology, University of Münster, Wilhelm-Klemm Str. 10, 48149 Münster, Germany, ⁴HZB for Materials and Energy, Albert-Einstein-Str. 15, 12489, Berlin, Germany, ⁵INAF-IAPS, Via Fosso del Cavalieri 100, 00133 Rome, Italy, ⁶LESIA, 5 place J. Janssen, 92195 Meudon, France, ⁷Univ. Grenoble Alpes, IPAG, 38000 Grenoble, France.

Introduction: Analysis of 0.25-5 μm reflectance spectra acquired by the Visible and Infra-Red Thermal Imaging Spectrometer (VIRTIS) onboard Rosetta orbiter revealed that the surface of comet 67P/CG is dark from the near-UV to the IR and is enriched in refractory phases such as organic and opaque components [1,2]. The broadness and complexity of the ubiquitous absorption feature around 3.2 μm suggest a variety of cometary organic constituents [2]. For example, complex hydrocarbons can contribute to the feature between 3.2 and 3.5 μm and to the low reflectance of the surface in the visible [2]. Relevance of natural macromolecular solids, such as solid oil bitumens (asphaltites, kerites, anthraxolites [3]) and coals as spectral analogs for the hydrocarbon part of cometary refractory organics were discussed in detail in [3, 2, 4]. Fine-grained opaque refractory phases (e.g. iron sulfides, Fe-Ni alloys) are likely responsible for the low IR reflectance and low contrast of the 3.2 μm absorption band [1, 2]. Other non-icy constituents that may contribute to spectral reflectance properties of the 67P surface include amorphous and crystalline silicates.

Results and conclusions: Here we report and discuss the 0.3-5 μm reflectance spectra of relevant Fe-sulfides (meteoritic troilite and several terrestrial pyrrhotites) ground and sieved to various particle sizes. We report the results of the synthesis, analyses, and/or spectral reflectance measurements of Fe-free low-Ca pyroxenes (ortho- and clinoenstatites), forsterites, and a high-Ca pyroxene (diopside). We present reflectance spectra of intimate mixtures of powdered Fe-sulfides with kerite (as an example of a relevant macromolecular organic solid) and synthetic orthoenstatite. We investigate and discuss the ability of Fe-sulfides to suppress absorption bands of other cometary refractory components

and to affect the spectral slopes and reflectance values of the 67P/CG surface at different wavelengths from the near-UV to the IR. Finally, we discuss the evolution of organic absorption bands as a function of sulfide content in the mixtures and the possibility for detection of individual C-H stretching bands in the VIRTIS spectra of 67P/CG. We show that spectral reflectance of the ubiquitous dark material on the surface of 67P is mostly controlled by fine-grained opaques and organic refractories, while silicate components play a less significant role and are unlikely to contribute significantly to the VIRTIS spectra and to the observed spectral variations across the 67P surface. We demonstrate that fine-grained Fe-sulfides (troilite and pyrrhotite) are effective darkening agents from the near UV to IR that can explain the very low IR reflectance of the 67P nucleus. The shape of the VIRTIS spectra in the visible range is consistent with the presence of polyaromatic-rich organics together with Fe-sulfides. Fe-sulfides intimately mixed with other components significantly influence shapes and relative contrasts of absorption bands of other phases. If real, the fine structure in the VIRTIS spectra between 3.2 and 3.5 μm could be indicative of individual C-H absorption bands in aromatic structures, methyl and methylene groups. Further work is needed to clarify which species contribute to the broad complex 3.2- μm band in the VIRTIS spectra and to the spectral shape between 1.5 and 2.5 μm .

References: [1] Capaccioni F. et al. (2015), *Science*, 347, 628. [2] Quirico E. et al. (2016), *Icarus*, 272, 32-47. [3] Moroz L.V. et al. (1998), *Icarus* 134, 253-268. [4] De Bergh C. et al. (2008). In: *The Solar System Beyond Neptune*, 483-506.