EPSC Abstracts
Vol. 11, EPSC2017-266, 2017
European Planetary Science Congress 2017

Laboratory spectral reflectance studies aimed at providing clues to composition of refractory phases of comet 67P/CG's nucleus

L.V. Moroz (1,2), K. Markus (1,2), G. Arnold (2), D. Henckel (2), D. Kappel (2), U. Schade (3), M. Ciarniello (4), B. Rousseau (5), E. Quirico (6), B. Schmitt (6), F. Capaccioni (4), D. Bockelee-Morvan (5), G. Filacchione (4), S. Erard (5), C. Leyrat (5), A. Longobardo (4) and the VIRTIS Science Team
(1) Institute of Earth and Environmental Science, University of Potsdam, Potsdam, Germany (Liubov.Moroz@dlr.de), (2) German Aerospace Center (DLR), Berlin, Germany, (3) HZB for Materials and Energy, Berlin, Germany, (4) INAF-IAPS, Rome, Italy, (5) LESIA-Observatoire de Paris, Meudon, France, (6) Universite Grenoble Alpes, IPAG, Grenoble, France.

Abstract

We present 0.3-5 µm reflectance spectra of well-characterized powdered crystalline materials (Fe-sulfides, Mg-silicates), natural complex hydrocarbons and their mixtures that can serve as spectral analogues of comet 67P/CG's refractory phases. We study the ability of Fe-sulfides to suppress absorption bands of other cometary refractory components and to affect spectral slopes and reflectance values of the 67P/CG surface at different wavelengths from the near-UV to the IR. We investigate 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 reflectance spectra of 67P/CG.

1. Introduction

Visible and InfraRed 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 refractories 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 [2,3]. Fine-grained opaques (Fe-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. To derive compositional information from VIRTIS spectra of the 67P surface, it is important to understand possible spectral contributions of relevant refractory phases to the reflectance curves of the comet surface.

2. Samples and Methods

Fe-sulfides used here include three terrestrial pyrrhotites ($Fe_{1-x}S$) and a troilite (FeS) from troilite nodules of the Muonionalusta iron meteorite. Bulk samples were crushed, ground and dry-sieved to several size fractions. Two sets of ortho- and clinoenstatites ($En_{\sim 100}$) were synthesized by K. Markus and R. Housley. Synthetic Fe-free forsterites and diopsides were provided by R. Housley. The samples were chemically and mineralogically characterized. The well-characterized kerite sample PAM#42 (#8450 in [3]; H/C(at.)=1.15) was used as a spectral analogue for cometary macromolecular refractory organic material. Troilite and pyrrhotite <25 µm separates were mechanically mixed with the kerite <25 µm separate. A similar set of orthoenstatite-pyrrhotite mixtures was prepared as well. Optical microscopy and SEM/BSE imaging of thin sections and ImageJ software were employed to characterize grain size distribution of mineral and kerite powders, as well as the mixtures. Analysis of the measured reflectance spectra and microscopic images showed that the desired state of mixing was not achieved, especially for kerite-sulfide mixtures. The second set of mixtures was prepared by manual grinding of the original mixtures in an agate mortar. Biconical reflectance spectra (0.3-18 µm) were acquired at Planetary Spectroscopy Laboratory (DLR, Berlin) in vacuum at *i*=*e*=15° using a Bruker VERTEX 80v FTIR-spectrometer equipped with a Bruker variable angle reflectance accessory.

3. Results and Conclusions

All powders of Mg-silicates used in this study are very bright, spectrally flat and nearly featureless in the visible and near-infrared. Steep near-UV drop-off is observed in all spectra despite very low contents of Fe and other transition elements.

Fe-sulfide powders are spectrally diverse in terms of reflectance and spectral slopes, and no specific spectral differences exist between pyrrhotites and troilite. Analysis of microscopic images suggests that the observed spectral diversity is associated with particle size variations rather than compositional ones. Overall reflectance of all samples decreases with decreasing particle size, as expected.

Reflectance spectra of fine-grained kerite-sulfide and orthoenstatite-sulfide intimate mixtures show that fine-grained Fe-sulfides (troilite and pyrrhotite) are very efficient darkening agents from the near-UV to IR, which can explain the very low IR reflectance of the 67P nucleus. Coarse-grained sulfides are much less effective darkening agents than fine-grained ones.

Our results 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.

The shape of VIRTIS reflectance spectra of 67P/CG's nucleus in the visible spectral range is consistent with the presence of organics containing polyaromatic hydrocarbons together with fine-grained Fe-sulfides (troilite and/or pyrrhotite). The above three conclusions are consistent with those obtained by [4] based on their spectral studies of coal-pyrrhotite and coal-pyrrhotite-silicate mixtures.

Analysis of reflectance spectra of kerite-sulfide mixtures shows that Fe-sulfides intimately mixed with other phases significantly influence shapes and relative contrasts of absorption bands of other species.

Despite the very low IR reflectance of 67P, the band contrast of its broad complex absorption centered near 3.2 µm is rather significant. This suggests that the carriers of the individual absorption bands contributing to this feature likely possess very intense absorption bands in this spectral range.

The broad absorption feature in 67P surface spectra shows fine structure (Figure 1), in particular, several reflectance minima whose positions coincide with those of aromatic C-H stretch (3.275 µm), CH_3 antisymmetric stretch (3.375 µm), CH_2 antisymmetric stretch (3.42 µm), and CH_3 symmetric stretch (3.48 µm) [3]. If the band assignments are correct, then the observed relative contrasts might imply higher content of aromatic C-H and higher CH_3/CH_2 ratio in 67P organics compared to the kerite sample used in this study, which has carbon aromaticity (*fa*) of 0.5 [3]. Further work is needed to clarify which species contribute to the broad complex 3.2-µm band in the VIRTIS spectra.

Acknowledgements

We thank I. Büttner for assistance in sample preparation and R. Housley for kindly providing his synthetic silicate powders. L.V.M. and K.M. acknowledge the DFG grant MO 3007/1-1.

References

[1] Capaccioni, F. et al.: Science, Vol. 347, 628, 2015.

[2] Quirico, E. et al.: Icarus, Vol. 272, 32-47, 2016.

[3] Moroz, L.V. et al.: Icarus, Vol. 134, 253-268, 1998.

[4] Rousseau, B. et al.: COMETS 2016, 14-16 November 2016, Toulouse, France.

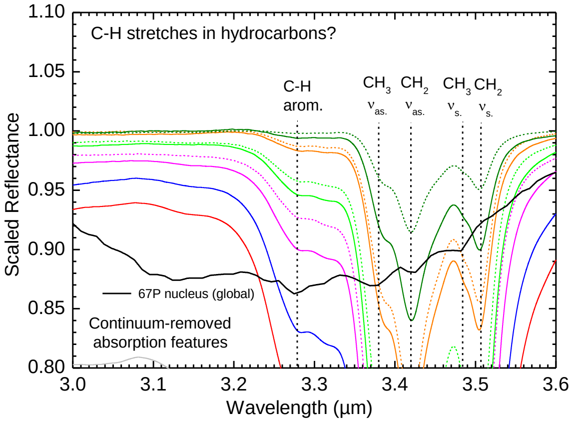

Figure 1: Continuum-removed absorption features of kerite-sulfide mixtures and in an average VIRTIS-M surface spectrum after geometric and thermal correction. Solid lines – kerite-pyrrhotite mixtures; dotted lines – kerite-troilite mixtures. Kerite volume percentages in the mixtures: red – 95; blue – 90; magenta – 80; green – 70; orange – 50; olive – 30.