The international ISSI team "Comet 67P/Churyumov-Gerasimenko Surface Composition as a Playground for Radiative Transfer Modeling and Laboratory Measurements". M. Ciarniello[1], P. Beck[2], G. Filacchione[1], L. V. Moroz[3,4], C. Pilorget[5], A. Pommerol[6], E. Quirico[2], A. Raponi[1], S. Schröder[3], V. Vinogradoff[1], D. Kappel[3], I. Istiqomah[2], B. Rousseau[7], V. Mennella[8]

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Introduction: The Rosetta mission provided unprecedented information about 67P/Churyumov-Gerasimenko (hereafter 67P/C-G) nucleus properties and evolution along its orbit around the Sun. The composition of cometary nuclei is considered as representative of the composition of the outer regions of the early solar nebula [1, 2] and is a direct proxy to constrain the physical conditions of the early phases of the Solar System. Remote sensing observations at visible-infrared (VIS-IR) wavelengths of the nucleus of comet 67P/C-G performed by VIRTIS [3] and OSIRIS [4] aboard the Rosetta mission have revealed a surface ubiquitously covered by low-albedo material [5,6], characterized by the presence of refractory and semi-volatile organics and dark opaque phases [5, 7]. However, a quantitative determination of the physical properties (grain size, porosity) and chemical composition of the surface regolith, from spectrophotometric analysis, is still missing.

The surface composition of 67P/C-G will be investigated within an international team hosted by ISSI (International Space Science Institute, Bern, CH), taking advantage of available and dedicated laboratory reflectance measurements of cometary analogue samples and radiative transfer models [8, 9, 10, 11]. The convergence between models and measurements will allow us to provide a thorough characterization of 67P/C-G surface**.** At the same time, the comparison of theoretical predictions with results from laboratory reflectance spectroscopy on powders of analogue materials give us the possibility to constrain the capability of the radiative transfer models to characterize sample composition (endmember abundances and mixing modalities) and physical properties.

The surface composition of 67P/C-G from remote sensing data: The large amount of data produced by the VIRTIS instrument allowed to put constraints on the composition of 67P/C-G material by means of comparison with lab measurements and radiative transfer models. Below we summarize the main results achieved so far and indicate some key questions that still represent open points.

67P/C-G composition from lab measurements. Nucleus surface spectrophotometric properties have been interpreted in terms of composition by [5, 7, 12] as a mixture of refractory polyaromatic and aliphatic organic materials, fine grained opaque materials (Fe-sulfides, Fe-Ni alloys) and a semivolatile component (ammonium-bearing species and carboxylic acids), however the different proportions of the various end-members are not yet determined**.**

67P/C-G composition from spectral modelling. So far, no definitive spectral un-mixing for the 67P/C-G average dark terrain from radiative transfer modeling has been produced. Nonetheless, Hapke theory has been successfully applied to derive volatiles abundances (H_2O and CO_2) [13, 14, 15, 16] mixed to the average low albedo material. However, the low albedo material itself may hide a certain amount of water ice**.**

Key questions:

- What is the relative proportion of the fine grained opaque materials and organic compounds?
- How are the organic materials and opaque phase mixed?
- What is the typical grain size of the different endmembers?
- What is the porosity of the surface?
- What is the amount of water ice mixed within the low albedo material and how does this contribute to the shape of the 3.2 μm organic feature?

Radiative transfer models: The available and future reflectance measurements of cometary analogues provide the perfect input for testing widely applied radiative transfer models in particulate media such as the Hapke model [8] and the Shkuratov model [9]. In fact, the capability of the models to correctly describe the medium and the light scattering process, and their sensitivity to the physical properties of the investigated materials, is yet a matter of investigation [10, 17, 18, 19, 20].

Key questions:

- How can these models be extended outside the geometric optics regime (treatment of sub-micron and micron-sized particles)?
- How sensitive are these models to the particle surface texture?
- How does regolith porosity affect the spectrophotometric output?

- Are the models able to reproduce surface scattering of opaque phases?
- Are the models able to simulate the spectrophotometric output of mixtures of high and low albedo materials?

Planned activity: The activity of the ISSI team will be focused on two major subjects**:** *Retrieval of 67P/C-G surface composition* and *Test and improvement of radiative transfer models in particulate media***.** The project will benefit from the *interplay between remote sensing measurements, radiative transfer simulations and laboratory measurements (Fig.1).*

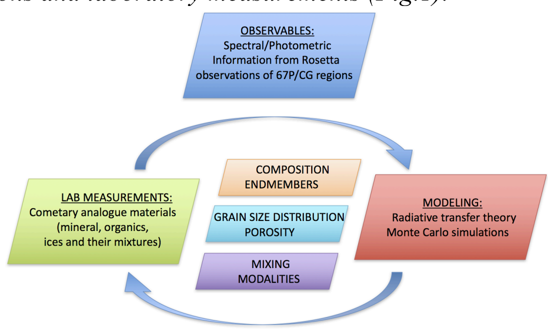

Figure 1. Scheme of the project workflow

Below, the main steps of the proposed project are indicated.

Retrieval of 67P/C-G surface composition

- Compilation of typical 67P/C-G surface VIS-IR reflectance spectra over specific regions of interest across the surface.
- Collection of existing spectral reflectance measurements of cometary analogue materials already available from team members and public spectral libraries.
- Measurements of spectral reflectance and optical constants of single endmembers of cometary analogue materials: relevant minerals, refractory and semi-volatile organic compounds and H_2O and CO_2 ices, with various grain sizes and porosities.
- Measurements of spectral reflectance of mixtures of cometary analogue materials with controlled grain size distribution, endmember abundances and porosities.
- Spectral simulation of mixtures by means of radiative transfer models.
- Best-fitting of 67P/C-G nucleus spectra with those of laboratory mixtures and/or from radiative transfer simulations.

Test and improvement of radiative transfer models in particulate media

- Comparison of the measured spectral reflectance of single endmembers and mixtures with known composition, grain size distribution and porosity, with simulated spectral reflectance. Validate model results by checking the capability to infer grain size, endmember abundances, optical properties and porosities.
- Model the contribution from small particles (submicron and micron-sized grains) in materials with multidisperse grain size distributions.

Team meetings

The team will meet for two one-week meetings at ISSI Bern. *The first meeting was scheduled for February 19-23, 2018.*

Laboratory facilities: Team members have access to the following laboratory facilities, where reflectance spectroscopy measurements and sample characterization will be performed: 1) PSL (Planetary Spectroscopy Laboratory) at the DLR Institute of Planetary Research, Berlin Germany; 2) Laboratory for Outflow Studies of Sublimating icy materials (LOSSy) of the Bern University, Switzerland; 3) Laboratory for Cold Surfaces Spectrocopy, Institut de Planétologie et d'Astrophysique de Grenoble, France.

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Additional Information: The activity of the team can be followed on a dedicated webpage at the link http://www.issibern.ch/teams/churgerasim/.

Acknowledgements: the ISSI international team "Comet 67P/Churyumov-Gerasimenko Surface Composition as a Playground for Radiative Transfer Modeling and Laboratory Measurements", number 397, thanks ISSI-Switzerland for the scientific, logistic and financial support provided to project.