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Photometric and spectrophotometric measurements of the CoPhyLab dust mixtures.

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Abstract:
Even as the late space exploration ESA/ROSETTA mission allowed to perform the most complete investigation of a cometary nucleus to date [1], and observations of interstellar comet 2I/Borisov hint to the pervasiveness of typical cometary properties beyond our solar system [2], our understanding of underlying physical processes occurring on surfaces of cometary nuclei remains limited.
Based on the present advances in cometary sciences, the Cometary Physics Laboratory project (hereafter CoPhyLab) is performing series of laboratory measurements and sublimation experiments to investigate thoroughly and shed further lights on these processes.
We report on the present status of photometric and spectrophotometric measurements of minerals and organics compounds mixtures at the Bern University in view of the next rounds of CoPhyLab experiments.

Introduction:
Icy small bodies of the solar system are remnants of the swarm of planetesimals that populated the protoplanetary disk, 4.57 Gyrs ago. Confined in the thermally and dynamically cold outer reaches of the system, their composition and other physical properties are a tracer for the formation and evolution processes of the solar system.
The successive space missions to cometary nuclei have gathered troves of detailled measurements and allowed a glimpse on the complexity and variability of their properties [3,4]. Extensive campaigns of comprehensive laboratory experiments are being prepared as part of the CoPhyLab project [5] in order to further unravel the physical processes cometary material experience.
As part of the CoPhyLab experiments, we are currently investigating the optical properties of mineral and organic materials (e.g. graphite, humic acid and SiO_2) using photometric and spectrophotometric measurements made at the Bern University.

Instruments and samples:
The Ice Laboratory of the Bern University has developed over the years a collection of instruments dedicated to the characterization of the physical properties of minerals, simple organic compounds and ices, with a particular expertise in the production of water ices [6].
The present investigations are focused on the characterization of the optical properties of a assortment of graphite, humic acid and SiO_2 mixtures. These mixtures will be used in a subsequent

time in sublimation experiments, as the "dust"-part of an analogue to the observed physical properties of the cometary surface materials [7]. The photometric and spectrophotometric measurements of these investigations are made with the PHIRE-2 goniometer and the MoHIS spectro-imager.

The PHIRE-2 acquires the bidirectional reflectance (hereafter BRDF) of samples across the whole hemisphere [8]. A monochromatic 250 W halogen lamp and 6 broadband filters are used to provide illumination in the visible and near-infrared domain (430-1070 nm). Light is then conveyed through an optical fibre up to the incidence arm of the goniometer, at the end of which a set of mirror, iris and lens focus the beam on the sample. The light reflected by the illuminated surface is integrated by a 1-pixel silicium detector affixed at the end of the emergence arm. The emergence arm can be equipped either with a beam-splitter setup or a 45° slanted mirror, thus allowing to investigate the sample's phase function between 10^{-3} ° and 5° and from 4° to 180° of phase angle. As the sample is installed on a rotating holder, it is thus possible to measure its BRDF across the whole hemisphere.

The MoHIS spectro-imager allows to map the spectral reflectance across samples' surfaces from 300 nm to 2500 nm, using a visible camera (a 1392x1040 pixels CCD detector, with an average image scale of 0.46 mrad.pxl^{-1}) and an infrared camera (a 320x256 pixels MCT detector, with an average image scale of 2.25 mrad.pxl^{-1}). Another halogen lamp and a gratings monochromator coupled to a 5 mm-diameter fibre bundle provide illumination of the samples' surfaces with adjustable wavelength bandpasses (as narrow as 5 nm).

The samples investigated are mixtures of synthetic graphite (CAS: 7782-42-5), humic acid (CAS: 1415-93-6) and SiO_2 (CAS:14808-60-7). The current CoPhyLab investigations are performed on a set of 10 mixtures with respective mass fractions of : 33%; (40%, 30%, 30%); (60%, 20%, 20%) and (80%, 10%, 10%), not including measurements performed on each unmixed component.
Further considerations on these mixtures shall be discussed by [9].

Data modelling:
Once acquired, the complete dataset of BRDFs of pure components and mixtures shall be modelled using the semi-empirical Hapke photometric model [10].
This modelling is done using both an elementary implementation of the Hapke model, as well as an implementation including a surface roughness correction [11], a porosity correction [12], and additional modifications discussed in [13,14]. This later implementation of the model was used previously to model the BRDF of comet 67P/ Churyumov-Gerasimenko [15].

Perspectives:
The CoPhyLab project is presently investigating the properties of minerals and organics mixtures to produce an material matching measured physical properties of cometary nuclei' surfaces, in view of upcoming sublimation experiments with the CoPhyLab sublimation chamber.
The measurements of the bidirectional reflectance and reflectance spectra of these mixtures are on-going and the results of these investigations will be presented.

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