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Thermal modeling of cometary analogs with CoPhyLab

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Abstract

The CoPhyLab (Comet physics Laboratory) is an international project designed to investigate the physics of comets. Part of the project is dedicated to measuring the thermal properties of cometary analogs, and more importantly, to understand the temperature and composition dependence of these properties. These properties are essential for building accurate numerical models of cometary nuclei that can be used to better understand the composition, evolution, and activity of cometary surfaces. We will present the first results of the measurements of the thermal properties of cometary analogs and discuss the consequences on our understanding of comets.

1. Introduction

The understanding of the heat propagation inside the surface of cometary nuclei is of prime importance in understanding the activity of comets. The temperatures that can be reached inside the nucleus and their diurnal/seasonal variations are essential to understand where and when the volatiles sublimate in the subsurface and produce the observed activity. Additionally, measurements of cometary nuclei by microwave radiometers [3] and infrared spectrometers can be used to constrain the composition and porosity of the subsurface when used in conjunction with numerical models of the heat propagation.

The heat propagation is strongly dependent on the thermal properties of the material, most notably the thermal conductivity and specific heat. These values have previously been measured for individual components like ice, silicates, and organics [2, 4]. Unfortunately, little is known of the thermal conductivity and specific heat of mixtures made from these individual components. We will present here the first measurements made with CoPhyLab of the thermal conductivity of mixtures of materials relevant to comets and their porosity/temperature dependence.

2. CoPhyLab

CoPhyLab comprises multiple experiments whose objectives are to expose samples to cometary conditions. To this end, samples are cooled in a vacuum chamber down to temperatures below 100K and can be heated by a solar simulator. The main CoPhyLab experiment will house 14 instruments (see presentations by Bastian Gunlach "The CoPhyLab" and Christopher Kreuzig "The CoPhyLab L-Experiments" for more details on the project). Of these experiments, two of them can be used to measure the top surface temperature of the samples, a copy of the Mascot Radiometer (MARA, [1]) and an infrared camera. Additionally, the temperature of the sample profile will be measured with thermal sensors located inside the sample.

3. Thermophysical modeling

In order to derive the thermal properties of the whole sample, a 3D thermal model is needed. The initial conditions of the samples are known (composition and temperature) and the surface and side temperature as a function of time as the sample is heated by a known solar simulator are measured.

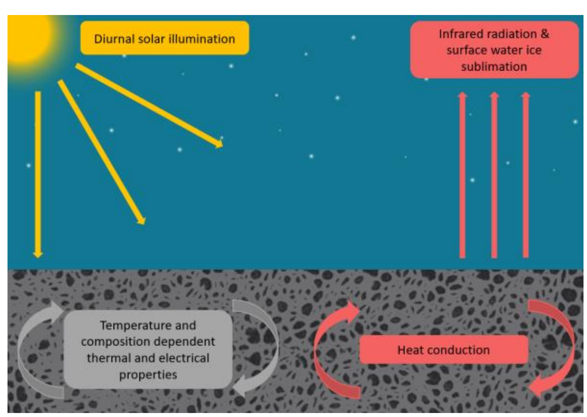

Figure 1: Schematic representation of the thermal model used for the CoPhyLab samples.

The thermal model designed for the experiment is shown in Figure 1, it takes into account heat conduction, illumination, thermal radiation and volatile sublimation. Using this model we are able to produce a temperature profile of the sample (see Figure 2). By comparing this modeled temperature to the ones measured we can constrain the average thermal properties of the sample as a function of temperature.

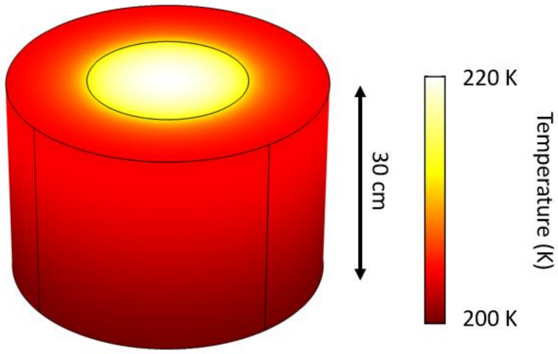

Figure 1: Example of the thermal model for a CoPhyLab sample heated from above by a solar simulator and cooled by thermal radiation

By repeating the experiments with different compositions and porosities we will be able to derive thermal property mixing laws that can be used to improve numerical thermal models of comets.

4. Samples studied

The exact list of samples that will be investigated with the CoPhyLab project has not been finalized at the time of the writing of the abstract. Individual components of interest have been identified and include ices (H_2O and CO_2), minerals (for example silica and olivine), simple organics such as carbon but also more complex ones (for example tholins).

5. Summary and Conclusions

The CoPhyLab project provides us with a unique opportunity to investigate the physics of cometary analogs. In this paper, we described how we plan to derive the thermal properties of mixtures of materials relevant to comets and try to understand the composition and temperature dependence of these thermal properties.

In order to retrieve the thermal properties from the temperature measurements of the sample accurate 3D thermal models of the samples will be built. These models will include many processes that affect the samples.

One of the final results of this work will be the derivation of mixing laws for thermal properties of materials relevant to comets. These can then be used to build more accurate thermal models of cometary nuclei and help understand the composition, structure, evolution, and activity of comets.

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