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The CoPhyLab L-Experiments

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Abstract

The **Co**met **Phy**sics **Lab**oratory (CoPhyLab) is an international research program to investigate the physics of comets. The aim of the project is to run long-term experiments under realistic conditions in order to get an understanding of the physics of comets. Finding correct analogue materials and sample compositions is of prime importance. A further aim is to create samples that behave in a way similar to real comets, mainly by becoming active when under radiation by an artificial sun.

1. Introduction

The understanding of the physics of comets requires the measurement of multiple physical parameters under realistic conditions. For example, CoPhyLab will investigate thermal properties and optical properties like the albedo and reflectance. The activity will be monitored by multiple high-speed cameras for 3D-particle tracking. The physical strength of the samples will also be measured using a penetrometer. Finally the outgasing will be monitored using a mass spectrometer and a scale that measures the total weight of the sample over the duration of the experiment. All measurements will be done simultaneously in one chamber with the same sample.
The sample will be kept below $100\,\mathbf{K}$ and at a pressure around $10^{-6}\,\mathbf{mbar}$ to ensure stable conditions. The surface of the sample will be heated by a solar simulator to trigger activity of the sample.

2. Technical implementation

One of the biggest difficulties is the measurement of the surface temperature. A direct measurement with a thermal sensor is not possible, because it would lose contact when the surface undergoes sublimation. Further the sensor would alter the physical properties of the surface. The use of an infrared camera also has limitations at temperatures below $200\,\mathbf{K}$. Therefore the temperature has to be measured indirectly. The chamber will include a **Ma**scot **Ra**diometer (MARA) sensor, which can measure the temperature with six thermopiles. This method works at temperatures down to $100\,\mathbf{K}$ but needs to be calibrated at low temperatures. This calibration will be done using the scale and pure water-ice samples. The temperature can be calculated using the Hertz-Knudsen-Formula [2]

$$Z = \alpha \cdot p_s \cdot \sqrt{\frac{m}{2\pi k_B T_O}} - p_g(T_g) \cdot \sqrt{\frac{m}{2\pi k_B T_g}} \quad (1)$$

with

- Z = sublimation rate
- α = sublimation-s coefficient
- T_O = surface temperature
- T_g = gas temperature
- p_s = sublimation pressure
- p_g = gas pressure
- m = molecular mass
- k_B = Stefan-Boltzmann Constant

The sublimation coefficient describes the difference between the theoretical and measured sublimation rate Z [1]. If all parameters are known, this formula can be inverted to calculate the surface temperature from the sublimation rate measured by the scale. A further benefit of the scale is,that due to its resolution of $12\,\mathbf{Hz}$ it can detect outbursts and dust release.

2.1. The cooling system

The scale, although being really useful, brings some challenges with it. First, it has to be far away enough from cold parts, as it does not work at low temperatures. Second, it requires that the sample is cooled, but the cooling system cannot be in contact with the scale. If there is a direct connection, the scale would measure the amount of nitrogen in the system. This cannot be monitored accurately and therefore a calibration is not possible. To avoid this drawback the cooling has to be done by radiation only and therefore big surfaces are needed. The solution we opted for is to use a donut shaped nitrogen tank. The sample holder is then connected to the scale via a tube that goes through the donut hole. The setup is shown in figure 1. The main cooling system and the sample are surrounded by a cooling shield, which is cooled with liquid nitrogen. This structure also holds the penetrometer and the MARA sensor.

2.2. The chamber construction

The construction of the chamber has to host all the experiments inside the chamber and still be flexible to be adapted over the time of the project. Furthermore the chamber has to hit a restricted pricepoint, so the production by a company has to be as standard as possible. Due to these reasons the chamber has a rectangular shape and a size of $1700 \times 740 \times 740\,\mathbf{mm^3}$. All the experiments should be independent from each another, so each one has own flanges and mounting points. It is possible to run every selection of experiments without any compromises. Thus, the chamber has to be able to do this the chamber has fifty flanges in total, which range from $16\,\mathbf{mm}$ to $250\,\mathbf{mm}$ and also two quick-release doors to transfer the samples in and out the chamber and for cleaning and construction work inside.

3. Summary and Conclusions

As part of the CoPhyLab project we are constructing a comet simulation chamber, which will house fourteen different experiments. All can be run at the same time independently. The chamber houses a special cooling system, which is based exclusively on radiation, due to the fact that it has to be contactless in order for the scale to work. This allows the measurement of the surface temperature and the monitoring of outbursts and activity. The chamber is equipped with fifty flanges, which are specific to each experiment.

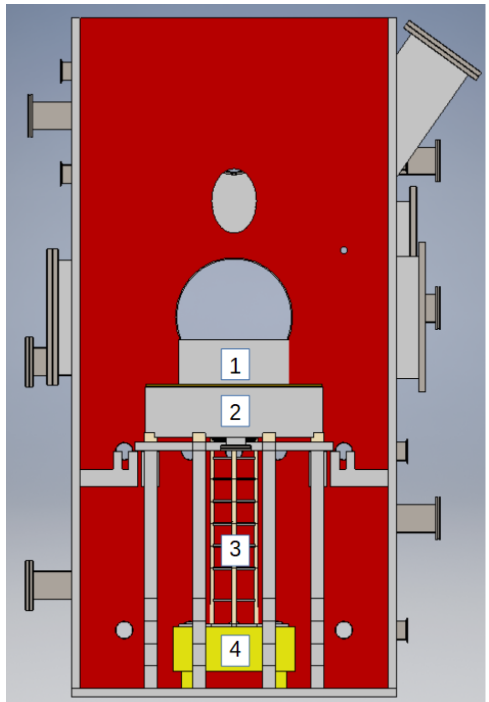

Figure 1: View of the chamber's interior (Info: The colour is for contrast. The chamber is not painted.) 1: Sample, 2: Nitrogen Donut, 3: TECAPEEK Spacer, 4: Scale

Acknowledgements

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