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Modelling the H_2O outgassing from the southern hemisphere of comet 67P/Churyumov-Gerasimenko constrained by ROSINA

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Abstract

The purpose of this work is to investigate the distribution of H_2O emissions at the surface of comet 67P/Churyumov-Gerasimenko (hereafter 67P) using ROSINA's data. We therefore use direct simulation Monte Carlo (DSMC) to test different gas source distributions on the nucleus surface in order to model the coma of 67P. We then validate our surface boundary condition by comparing the simulation results for the number density to the measurements obtained by ROSINA.

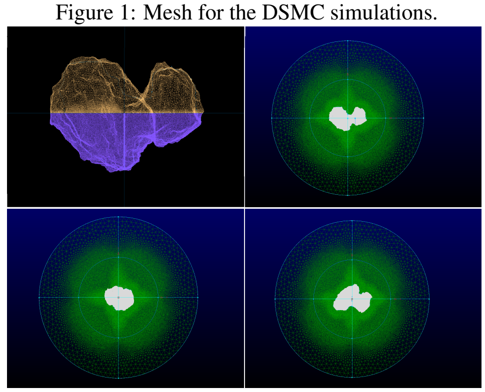
1. Introduction

Previous studies have successfully explained the H_2O activity distribution in the coma of comet 67P at the early stages of the ROSETTA mission, during summer in the northern hemisphere of the comet [1, 2, 3, 4]. These studies found that the outgassing of H_2O is driven to a large extend by insolation and the inhomogeneous distribution of H_2O on the cometary surface, with strong sources localized in the Hapi region. Cometary activity close to the perihelion has been studied by Fougere et al.[5]. Their model reproduces the evolution of the densities observed by ROSINA, which suggests a seasonal variation in the activity of the major cometary species with differences in their distribution mainly given by the illumination conditions at the surface. Based on these studies, we will utilize DSMC to link the measurements by ROSINA during July 2015 to the emission distribution at the surface and the corresponding surface morphology.

2. Modelling Approach

The inner-gas coma of comet 67P is modeled using a DSMC code, called PDSC++ [6], which numerically simulates 3D flow-fields of rarefied gas. This code requires a simulation mesh based on the shape model SHAP7 [7] and fully covers the cometary surface and its inner-coma up to 10 km with high precision as can be seen in Figure 1.

Figure 1: Mesh for the DSMC simulations.



As a first step, we use purely insolation-driven conditions for the H_2O sublimation and assume an homogeneous distribution of H_2O-ice at the surface (M1). For the second model (M2), we use the H_2O the model introduced by Marschall et al.[2] to account for the distribution of H_2O activity, which is in good agreement with the observations made by ROSINA/COPS in August and September 2014. We then add regional complexity to the input parameters in the third model (M3) in order to obtain DSMC simulations for July 2015. A description of the boundary parameters used in this work is listed in Table 1. In all our models, the temperature of H_2O-ice (T_{H2O}) is driven by solar illumination. However, the spatial distribution of the ice on the surface of 67P is given by the Effective Active Fraction (EAF), which defines the activity strength of each surface facet of the nucleus and is chosen regionally based on the observations.

Table 1: Boundary conditions for each model.

Model	T_{H2O}	EAF_{H2O}
M1	Iso-Dr	Homogeneous
M2	Iso-Dr	Active Neck
M3	Iso-Dr	Regional Distribution

3. Comparison with ROSINA

For the comparison with ROSINA data, we perform a series of DSMC simulations for the corresponding heliocentric distance and sub-solar latitude, such that each model is run for 8 different sub-solar longitudes that sample a whole rotation of the cometary nucleus. We use SPICE to calculate the geometry of each measurement made by ROSINA in time ranges close to our simulated time periods. Then, we extract the DSMC-derived value of the number density of the cell which is closer to the spacecraft location and extrapolate this value to the cometocentric distance of Rosetta. In this manner, the result of each model can be directly compared with the measurements.

4. Preliminary results

We have simulated the inner-gas coma of 67P for the spring equinox. Our DSMC results for this time period have suggested that a purely insolation-driven surface at southern latitudes is not a sufficient condition to explain the observations by ROSINA/COPS. This is shown in Figure 2, where the extrapolated DSMC-values of H_2O outgassing do not follow the behavior of the ROSINA/COPS measurements. This can be due to the contribution of the H_2O outgassing from the southern hemisphere, for which the ice sources were assumed to be equally distributed at negative latitudes on the comet. We therefore focus on the study of the key parameters that drive the H_2O outgassing at southern latitudes of the comet for a time period where most of this region is highly active.

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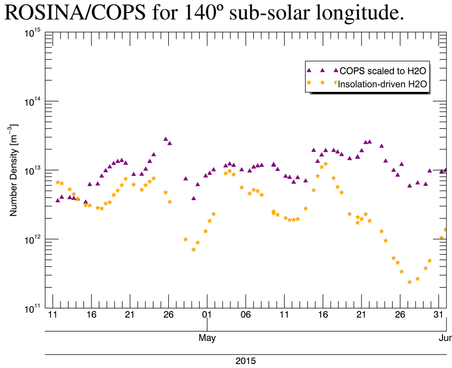
Figure 2: DSMC results for the spring equinox compared with the 10 minute average measurements by ROSINA/COPS for 140º sub-solar longitude.



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