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# Modelling of the inner gas and dust coma of comet 67P/Churyumov-Gerasimenko using ROSINA/COPS and OSIRIS data - First results

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## 1 Introduction

The physics of the outflow above the surface of comets is somewhat complex. Ice sublimating into vacuum forms a non-equilibrium boundary layer, the "Knudsen layer" (Kn-layer), with a scale height of ~20 mean free paths. If the production rate is low, the Kn-layer becomes infinitely thick and the velocity distribution function (VDF) remains strongly non-Maxwellian. Thus our preferred method for gas dynamics simulations of the coma is Direct Simulation Monte Carlo DSMC. Here we report on the first results of models of the outflow from the Rosetta target, comet 67P/Churyumov-Gerasimenko (C-G). Our aims are to (1) determine the gas flow-field of $H_2O$ and $CO_2$ in the innermost coma and compare the results to the in-situ measurements of the ROSINA/COPS instrument (2) produce artificial images of the dust brightnesses that can be compared to the OSIRIS cameras. The comparison with ROSINA/COPS and OSIRIS data help to constrain the initial conditions of the simulations and thus yield information on the surface processes.

## 2 Boundary Conditions

The calculations have been performed using the nucleus shape model "SHAP4S" of [3]. Surface temperatures have been defined using a simple 1-D thermal model (including insolation, shadowing, thermal emission, sublimation initially neglecting conduction) computed for each facet of the shape model. The DSMC program used is PDSC$^{++}$ [2] which is a 3-D implementation based on work by Wu and co-workers. An unstructured grid is used. The simulation domain extends out to 10 km from the centre of the nucleus. Dust particles are assumed to be spherical and at rest on the surface of the nucleus. The procedure is then (1) calculation of a steady state solution for the gas field, (2) dust particle tracking in the gas field to get a dust particle distribution function, (3) scattering of the sun light on the dust particles and (4) line of sight integration to produce dust brightnesses and gas column densities to make predictions for other experiments.

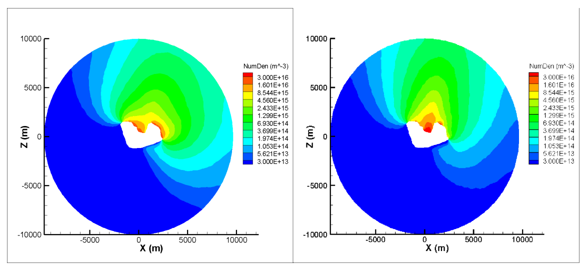


Figure 1: The gas velocity in the x-z plane of the 3D model of outflow from C-G at 3.4 AU. The sun is in the $+x$ direction and a half Maxwellian VDF was used on the comet surface. The axes are given in metres.

## 3 Gas Simulations

Figure 1 shows the number density of the outflow from C-G simulated at a heliocentric distance of 3.4 AU. A homogeneous (purely insolation driven with a gas production rate of 1.6 kg s$^{-1}$) and inhomogeneous

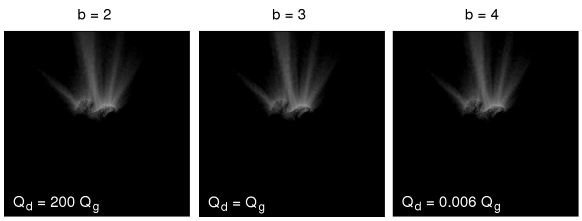


Figure 2: Artificial images composed for the viewing geometry of Rosetta on the $5.9.2014$ at $9{:}20$ UTC for different values of $b$ and $Q_d/Q_g$. The images are on a log. scale for the radiance in W m$^{-2}$ nm$^{-1}$ sr$^{-1}$ from $10^{-7}$ to $10^{-4}$.

case (increased activity is assumed in the Hapi and Hathor regions of the nucleus resulting in a gas production rate of $2.6$ kg s$^{-1}$) is shown here. The 3D gas results lay the basis for the comparison with the ROSINA/COPS data we have performed.

## 4 Dust Simulations

To calculate the dust distribution in the coma we assume test particles in the gas field without any back coupling. The motion of the dust is driven by the drag force resulting from the gas flow. We assume a quadratic drag force with a velocity and temperature-dependent drag coefficient. We also take into account the gravitational force of the nucleus on the dust. From the 3D dust density distribution of $40$ size bins we perform a line of sight integration.

## 5 Scattering

For the scattering of the dust, we use Mie theory for spherical particles using the algorithm of [4]. Under the assumption of zero optical depth, the observed radiance can be summed and compared to the expected radiance of a column of dust with a specified size distribution for which we adopt a power law distribution $n(r) \sim r^{-b}$, where $n$ is the number of particles of radius $r$. Figure 2 shows first results of this calculation for different values $b$ and gas to dust mass ratios $Q_d/Q_g$.

## 6 Conclusions

Our DSMC and dust codes have been used to study a variety of models for the gas & dust distributions of comet C-G. The codes use an unstructured grid and can provide global values for gas & dust density, velocity and temperature out to $10$ km from the nucleus. Our results can be compared with the in-situ measurements of ROSINA/COPS and the OSIRIS data. The presentation will show the improved quality of the fits using inhomogeneous emission for the August-September 2014 time frame.

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