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Modelling the H_2O outgassing of comet 67P/Churyumov-Gerasimenko using Rosetta data for July 2015

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Abstract

We aim to link the activity distribution in the inner-coma of comet 67P/Churyumov-Gerasimenko, (hereafter 67P/CG) with the composition of its nucleus. The coma is modelled with the Direct Simulation Monte Carlo (DSMC) method as a sublimation-driven flow from an H_2O-ice surface into vacuum. Multiple efforts have been made to explain the gas and dust emissions from the nucleus of comet 67P/CG [1-12]. Based on these studies, we have chosen to focus on the daily variations of number density measured by ROSINA. Our simulation results suggest that the purely insolation-driven outgassing from the nucleus with a homogeneous distribution of ice cannot explain ROSINA observations. Hence, we are currently studying the night-side contribution to the activity. A comparison with remote sensing data from MIRO and OSIRIS is also necessary in order to corroborate our previous results and better constrain the conditions at the surface. Our focus is on the period around perihelion and is therefore complementary to similar studies carried out for the November 2014 and May 2015 (equinox) periods [10].

1. Boundary Conditions

A simple thermal model for water is used [8-10] to calculate the boundary conditions at the surface for July 10, 2015. It balances the incident solar energy (as a cosine function of the incidence angle) with the energy loss through thermal emission and sublimation of water ice from the surface. The sublimation term is proportional to the effective active fraction (EAF) of the surface, which parameterizes complexities of the nucleus, such as the dust/ice ratio, penetration depth of solar radiation, erosion, etc. Variations due to thermal conductivity are neglected, since the thermal inertia for the comet has been observed to be very low [4]. Self-heating is also neglected.

2. DSMC model

The inner-gas coma is modelled using ultraSPARTS [13], which is a code that numerically simulates 3D flows of rarefied gases. The input surface mesh of the nucleus is generated with high precision after shape model SHAP7 [11] and it contains 440'596 facets. We modify the distribution of the EAF and the insolation conditions at the surface. Once the ice sublimates, a flow of gas particles is released from the nucleus into the coma until it reaches the steady-state. Our simulation domain goes up to 10 km from the nucleus centre and it has about 13 million cells.

3. Comparison with Rosetta data

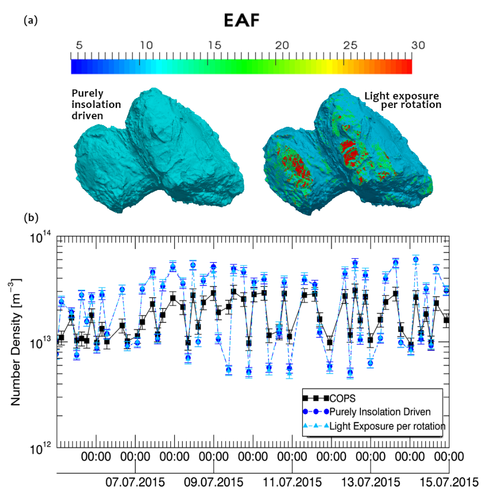

Figure 1: (a) Models with different EAF distributions. *Left*: Homogeneous everywhere. *Right*: Regions longer exposed to solar radiation in one rotation have stronger outgassing. (b) Comparison of each model to ROSINA/COPS.

Our results in Figure 1b suggest that purely insolation-driven outgassing is not sufficient to explain the ROSINA measurements on July 2015. The results follow the basic trend, but our calculations significantly overestimate the measured daily variations that arise from nucleus rotation. A multispecies case has also been tested with a mixing ratio CO_2/H_2O=2%, as measured by ROSINA/DFMS. In this case, CO_2-ice has been distributed uniformly on the nucleus and it is globally outgassing independently of solar radiation. We find that including very low night-side activity of CO_2 does not improve the fit (Figure 2). However, an artificial test where day and night sides are highly active improves the fit to the order of magnitude of the daily variations. Therefore, extended sources and/or further transport processes within the coma have to play a key role in order to explain the strong flux observed by ROSINA towards the night-side.

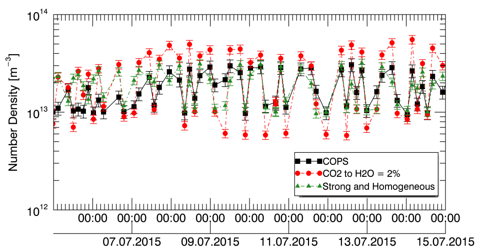

Figure 2: For the multispecies model (red) the EAF of H_2O and CO_2 are homogeneous, but insolation is not taken into account for CO_2. For the model in green, the whole surface is strongly and equally outgassing H_2O no matter the insolation conditions at the surface.

In situ measurements at high cometocentric distances (about 200 km away) cannot distinguish between subtle differences in the distributions of ice at the surface (Figures 1 and 2). This is why we must to use multi-instrument data to compare the coma structure produced by the models and the column densities, speed and temperature inferred from inverted MIRO measurements. Previous work on this issue has been done for the spring equinox [10] and we now want to use the same approach to constrain the activity one month before perihelion.

A preliminary comparison of the purely insolation-driven model in Figure 3 where gas drags dust particles [8-10] with observations taken by the OSIRIS-WAC camera also shows that the gas being driven by solar radiation alone cannot produce the dust features in the coma, especially towards the night-side. For the dayside however, it may be related to different distributions of dust over the surface.

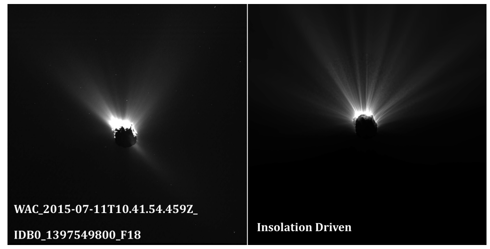

Figure 3: Comparison of the purely insolation-driven outgassing of H_2O with an OSIRIS. For both images, the sun is toward the top.

Acknowledgements

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