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The challenge of fitting dust coma pattern in simulation images compared to Rosetta OSIRIS image data

Selina-Barbara Gerig (1), Raphael Marschall (2), Olga Pinzón (1), Nicolas Thomas (1), and the OSIRIS team
(1) Physikalisches Institut, Sidlerstr. 5, University of Bern, CH-3012 Bern, Switzerland, (2) International Space Science Institute (ISSI), Hallerstrasse 6, CH-3012 Bern, Switzerland
Contact: (selina-barbara.gerig@space.unibe.ch)

Abstract

We studied the differences of artificial simulation images of the inner gas and dust coma of comet 67P/Churyumov-Gerasimenko (hereafter 67P) compared to Rosetta OSIRIS images (Fig. 1). We used the identified differences to improve our simulation model (e.g. include night-side shadowing) and simultaneously gain more insight in the physical processes possibly ongoing in the innermost coma, such as fragmentation or sublimation of particles, that are not included in our simulations. We briefly describe our simulation method and our methods of image comparison.

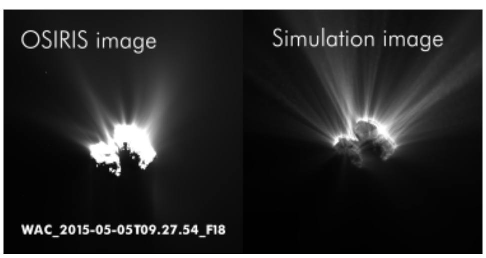

Figure 1: Example of a comparison of an OSIRIS image with the corresponding simulation image.

1. Introduction

The OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) camera system onboard the Rosetta spacecraft acquired image data of the comet nucleus and the innermost dust coma of comet 67P. While approaching the sun, ices on the comet surface sublimate and form the gas coma around the nucleus. Dust particles get accelerated away from the surface by gas drag and scatter sunlight which is caught on the images of the OSIRIS cameras. The visible dust coma on the images therefore contains information about the gas outflow, the surface source regions of the emitted gas and dust and effects of the complex shape of the nucleus. 3D numerical simulations are a powerful tool to study the behaviour of gas and dust in the inner coma of comets [1, 2]. The image data of the dust coma can be used to better constrain parameters in the simulation models. To compare OSIRIS images to artificial simulation images we found two methods to be especially suitable: We use (i) polar plots to compare the azimuthal dust distribution in the coma and (ii) azimuthal average profiles with distance to study the more general dust outflow behaviour [3].

2. The simulation model

We use the Direct Simulation Monte Carlo (DSMC) method for simulating a steady state gas flow field around comet 67P. We take into account the complex nucleus shape and simulate the gas flow to a distance of 10 km from the nucleus centre. Local surface temperatures and gas production rates are computed by solving the thermal balance equation for the different insolation angles of every surface facet. To match real production rates of 67P, we scale them by setting the effective active fraction (EAF) at the surface. The EAF can be understood as the local ice content of the surface and is a free parameter in our simulations.
To simulate the dust coma an equation of motion including gas drag and gravity from the nucleus is solved for a statistically representative number of test particles. Artificial images are computed by integrating the number densities in the simulated dust coma along the camera line-of-sight. We apply Mie scattering theory for spherical particles to calculate images in reflectance units that can be compared directly to OSIRIS images. To account for the particle size distribution we assume a power law function of the form $n(r) \propto r^{-\beta}$, with n the number of particles per dust size of radius r. A more detailed description of the model is given in [2].

3. Comparing simulation images to OSIRIS data

To compare the artificial simulation images to OSIRIS image data we use two different methods. In polar plots we analyse the reflectance values along a circle with a fixed radius around the centre of the comet nucleus in both the simulation and the OSIRIS image (Fig. 2). This allows us to check whether we are simulating the correct azimuthal dust distribution around the nucleus. It offers valuable information about the distribution of sources for gas and dust on the comet surface which is a free parameter in our simulations. To study the dynamics of dust outflow behaviour we compare profiles of azimuthal average of the simulation and the OSIRIS image. These profiles are obtained by averaging the reflectance in the images around circles with radius b and plotting the averaged reflectance R_{dust} multiplied by the distance b against distance. We found considerable deviations of the azimuthal average profiles of simulation images compared to observation data. This indicates that physical processes that are not included in the simulation model, such as fragmentation or sublimation of dust particles, might be important in the innermost coma .

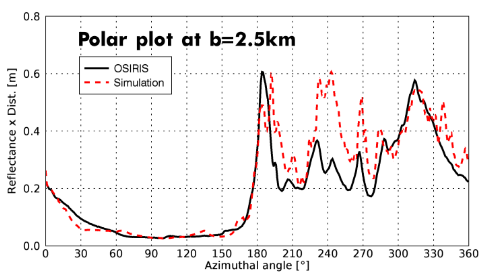

Figure 2: Comparison of the azimuthal dust distribution for the OSIRIS and simulation images in Fig. 1.

4. Results and perspectives

We have identified significant deviations in our dust simulation images compared to the OSIRIS data. The azimuthal average plots of OSIRIS images over a whole comet rotation show stronger profile variations in the dust acceleration region than the model predicts. This indicates that effects like night-side shadowing of the coma or physical processes like fragmentation or sublimation of particles might play an important role in the dust dynamics right above the comet surface. We will show the deviations between simulation and data images and focus on the most probable explanations thereof. We also discuss possible improvements of our simulation model on that basis.

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