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Simulation of gravitation dominated background particles in the vicinity of comet 67P/Churyumov-Gerasimenko: simulation and image analysis.

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Abstract

Images of the dust coma of comet 67P/Churyumov-Gerasimenko (hereafter 67P) contain a large amount of information about dust properties and dust dynamics in the innermost coma. However, the interpretation of the data is usually not straightforward. Numerical simulations offer an invaluable tool to test different explanatory approaches. Here we use model simulations in combination with OSIRIS image analysis to investigate the role large particles play in the first few kilometres above the nucleus surface of 67P. We present the results of a parameter study of quantities attributed to large background particles, the motion of which is dominated by gravitational forces.

1. Introduction

The global dust coma in the close vicinity of the nucleus of comet 67P has been imaged over a period of two years from August 2014 to September 2016 by the OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) cameras on ESA's Rosetta spacecraft. For our analysis we use primarily the large-scale dust coma that scatters sunlight and is thus observable by OSIRIS. Gerig et al. [2] showed that fitting the coma results indicates behaviour close to $1/r^2$ at distances > 12 km from the nucleus in reasonable agreement with theory [6]. The numerical simulations give similar behaviour. However, in the acceleration region (< ∼5 km from the surface), the numerical simulations show significant deviations from the OSIRIS observations. While the basic trend follows what might be expected from acceleration, the magnitude of the effect is not well fit by the model, indicating that additional processes may be at work. Among other explanations, large particles in bound or returning orbits around the comet nucleus may modify this behaviour by adding a background to the dynamic coma forming above the sunlit day side of the nucleus. Large particles in the millimetre size range or larger have been observed and characterised through single particle analysis in OSIRIS images and results have been published (see e.g. [1], [5]). Although those particles have been observed, it remains unclear how dominant they are in the dust coma of comet 67P and to what extent they contribute to the observed coma brightness. To further investigate this question, we use numerical simulations including gas drag and gravity to simulate the dynamic 3D dust distribution in the coma around the nucleus of 67P and then add a background coma of large gravitationally dominated particles integrated over several comet rotations.

2. Our simulation model

To simulate the gas coma in 3D around the nucleus of comet 67P we use the Direct Simulation Monte Carlo (DSMC) code PDSC++ and simulate the gas coma out to a distance of 10 km from the nucleus centre. The dust coma is then calculated on top of the gas flow field including gas drag and gravity forces. We simulate 40 size bins with sizes ranging from 8 nm to 0.3 mm and apply a weighting to our results based on a particle size distribution following a power law function of the form $n(r) \approx r^{-b}$ with n(r) being the number density, r the dust particle radius and b the power law exponent determining the steepness of the size distribution. Through a line of sight integration, taking into account observation geometry, we calculate column densities which are transformed into radiance values trough a Mie scattering model. This results in synthetic images that can be directly compared to OSIRIS images (Fig. 1 a) & b)). See also [3].
To study the influence of large gravitationally influenced particles on the coma brightness in the acceleration region, we introduce a background of large dust particles. The background is simulated by tak-

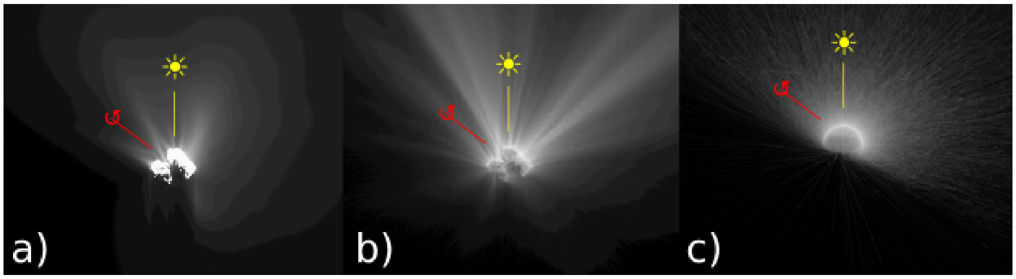

Figure 1: a) OSIRIS image WAC 2015-05-05T09.27.54; b) simulation image including gas drag and nucleus gravity (for simulation setup see [4]); c) background of gravitationally influenced large particles in a spherical model. The brightness in all three images is logarithmically enhanced and the rotation axis and the projected sun direction is indicated.

ing into account gravitational forces and nucleus rotation. Here we track particles along their Keplerian trajectories in 3D over a period of more than five full comet rotations. In this first approach we use a spherical nucleus of radius R_N = 2 km, where the simulation particles are initially placed randomly distributed over the sunlit hemisphere. A weighting using the cosine of the insolation angle can be introduced. An example of such a background simulation can be seen in Fig. 1 c).

3. Comparison of simulation data with OSIRIS images

In quantitative comparisons of simulation data with OSIRIS images using so called azimuthal average profiles (AAP) [2] we see significant deviations in the decrease of brightness in the acceleration region and the shape of the AAP on the night side of the comet.
To calculate the modelled large particle background, we have manipulated the particle size, the production rate, the ejection velocity and the initial distribution. For each model, we determine the possible contribution of large particles dominated by gravity to the dust outflow behaviour and observed coma brightness. We aim to put some constraints on the amount and the properties of large particles present in the inner coma. Preliminary results indicate, however, that gravitationally influenced large particles do not resolve the inconsistencies completely. This investigation shows to what extent analysis of image data in combination with numerical coma models can contribute to solving the question of how dominant large particles are in the innermost coma of comet 67P and adds to the ongoing discussion on the importance and magnitude of airfall on 67P.

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