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# 3D+t Mathematical Simulation of the Dusty-Gas Cometary Atmosphere (Application to the Comet 103P/Hartley 2)

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## Abstract

We report the results of application of our 3D+t dust-gas coma model to a model nucleus which shape and dimensions close to those of 103P/Hartley 2 nucleus and conditions at the moment of closest approach i.e. at 13:59:47.31 UTC on 4 November 2010 (1.064 AU from the Sun). We assume various cases of gas and dust production of the nucleus taking into account available observational data.

## 1. Introduction

The Deep Impact flyby spacecraft encountered comet 103P/Hartley 2 in the frame of an Extrasolar Planet Observation and Deep Impact Extended Investigation (EPOXI) mission. Observations of the comet were carried out for 2 months on approach (5 September to 4 November) and for 3 weeks on departure (4 to 26 November), during which more than ten thousand images and spectra were obtained [1]. We apply our 3D+t dust-gas coma model [4] to a simplified nucleus of 103P/Hartley 2 and conditions at the moment of closest approach in order to calibrate the model on the available experimental data.

## 2. The Model

The present 3D+t model was already applied for simulations of the dusty-gas coma of the comet 67P/Churyumov-Gerasimenko over a range of probable conditions at the time of rendezvous with Rosetta spacecraft (i.e. at r~3 AU) [4].

### 2.1 Modeling methods

A multi-species 3D+t gas model is based on: (1) gas-dynamic approach – the numerical integration of the Navier–Stokes equations combined with a locally plane-parallel solution of the collisional Boltzmann equation for the nonequilibrium near-surface Knudsen layer (BE-NSE) [3]; and (2) kinetic approach - the direct simulation Monte–Carlo (DSMC) method. In the region close to the nucleus we use quasi-steady approximation. For the dust coma two approaches are used as well. (1) Fluid approach - the Dust Multi Fluid method (DMF); and (2) stochastic approach - the Dust Monte-Carlo (DMC) [2]. The DMC method allows not only to obtain the spatial distributions of dust but also to trace the individual trajectories of grains. We assume that dust grains are spherical moving under influence of three forces: the nucleus gravitational force, gas coma aerodynamic force, and solar radiation pressure force, and consider the full mass range of ejectable grains.

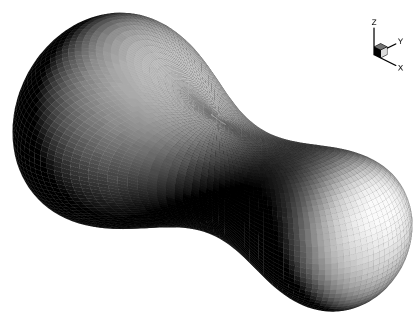


Figure 1: The shape of the model nucleus.

### 2.2 Nucleus model

We approximate the nucleus of 103P/Hartley 2 by an axisymmetric analytical shape shown in Fig.1. The surface of the nucleus is ice-dust mixture characterized by the icy area fraction $f$ ($f$=const - “homogeneous” nucleus, $f$≠const - “inhomogeneous” nucleus). The surface flux of volatile components consists of a fraction $a_0$ distributed uniformly over the surface, and a fraction $(1-a_0)$ distributed over the sunlit surface in proportion to its illumination. The upward flux of $H_2O$ at each point is computed from sublimation energy budget equation. A nightside (and shadow) an internal heat transfer free parameter is introduced to simulate a heat flux from the nucleus interior at points in shadow. At each point and each size, the dust mass flux is proportional to the gas mass flux.

## 2. Results

The largest part of our simulations are made in a range of probable conditions at the moment of closest approach to 103P/Hartley 2 (i.e. 1.064 AU from the Sun). The results of simulation illustrate the complex structure of gas and dust coma (see example on Fig.2 and Fig.3). It strongly depends on surface distribution of gas and dust fluxes. For the given rotation period (~18h), the dust distribution in the inner coma is essentially time dependent.

The simulation showed that (a) in large parts of the dust coma, grain trajectory crossings occur and thus the dust distribution cannot be characterized by unique velocity vector; (b) a wealth of trajectories ending in surface impacts are found, producing sizable fluxes of grains of a large range of sizes; (c) the dust coma at any size is structured, but the structures are not similar to the gas coma structures, nor simply related to the surface activity; (d) when computing the dust coma the asphericity of the gravity field must be taken into account.

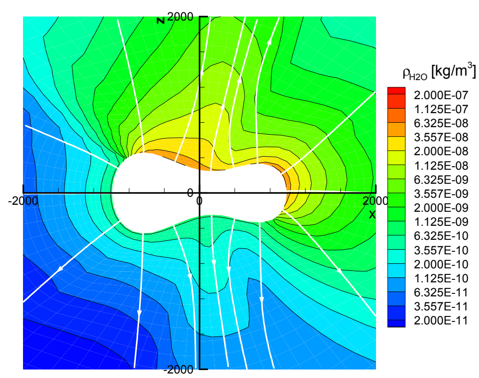


Figure 2: Isocontours of water density and flowlines.

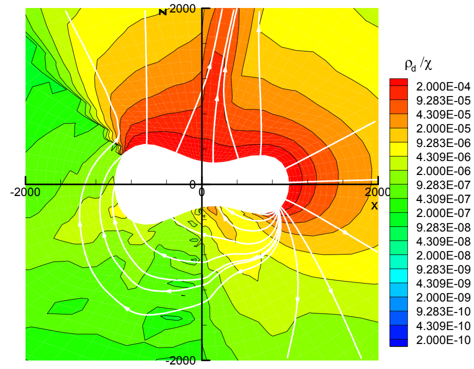


Figure 3: Isocontours of dust density and flowlines.

## References

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