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Aspherical rotating dust dynamics for GIADA experiment in the coma of 67P/Churyumov- Gerasimenko

S. Ivanovski (1, 2), V. Zakharov (3, 4), V. Della Corte (1), F. Lucarelli (5), J. F. Crifo (6), A. Rotundi (5) and M. Fulle (7)
(1) INAF- Istituto di Astrofisica e Planetologia Spaziali (IAPS), Roma, Italy, (2) Osservatorio Astronomico di Capodimonte, Naples, Italy, (3) LESIA, Observatoire de Paris, F-92195, Meudon, France, (4) Gordien Strato S. A. R. L. Verrieres le Buisson, France, (5) University of Parthenope, Naples, Italy, (6) LATMOS, CNRS, Guyancourt, France, (7) Osservatorio Astronomico di Trieste, Trieste, Italy, (stavro.ivanovski@iaps.inaf.it / Fax: +39 0645488383)

Abstract

The recent advances of the 3D+t cometary aspherical dust model [1, 2] have been used for studying the dust dynamics in the circumnuclear coma of the comet 67P/Churyumov-Gerasimenko (67P/C-G). This model will be used for analysis of the forthcoming *in-situ* dust data collected by GIADA (Grain Impact Analyzer and Dust Accumulator) [3] on board of the ESA ROSETTA probe. In the present research we study dust grain motion driven by the aerodynamic and gravitational forces and discuss the influence of dust grain's shape. We show the differences in dust grain velocities owing to the grain shape, initial orientation and rotation. The outcomes of the model are used to forecast by means of GIPSI [4] the dust distribution seen by GIADA at some of the ROSETTA operational phases.

1. Introduction

GIADA will perform direct measurements of the velocity, momentum and optical cross section for each in situ detected grain. From this data the mass of each detected grain will be derived. In order to analyze the dust 67P/C-G coma data, a twofold process is prompted:1) data collected will serve to calibrate the coma dynamical models and 2) the coma dynamical models will reconstruct the come evolution based on interpreted instruments' data. Majority of currently published ab-initio dust models (e.g. [5, 6, 7, 8]) assume sphericity of dust grains. At the same time experimental data shows that dust grains are highly aspherical. Our work is the extension the state-of the-art 3D+t Dust Monte-Carlo (DMC) approach [5, 6] on the aspherical grains. We study the motion of grains driven by aerodynamic, gravitational and solar pressure forces for the full range of ejectable masses. The shapes of the grains are prolate and oblate ellipsoids of revolution. In general case, in the flow such grains experience a torque and starts to rotate. By introducing rotation averaged drag coefficients we elaborate the complexity owing to the aspherical dust dynamics versus the spherical dust models applied to the 67P/C-G coma. In order to assess the performance of GIADA along ESA proposed orbit at 3AU, we generated a forecast by means of GIPSI using the aspherical dust model. Since the real gas coma of 67P/C-G is still unknown for the forecast we used non-calibrated gas solutions for the spherical nucleus.

2. The Model

We consider the dynamics of homogeneous, isothermal dust grains in a gas coma of homogeneous spherical nucleus. The gas distribution (density, velocity, temperature) in the coma is taken from [9]. The shape of dust grains is ellipsoid of revolution (approximated by polygons) with various aspect ratios of axes. Three forces are considered: the nucleus gravity, the torque, the aerodynamic force and solar pressure force. We assume that dust stream does not affect the gas flow. The aerodynamic force is estimated from expressions for free molecular interaction. This assumption is reasonable since for 67P/C-G the minimal mean free path of the molecules has order of meters, while our dust grain sizes are much less than a meter. Gravitational field is assumed spherical. The motion of the dust grains is described by the sets of kinematic and dynamic equations of Euler for a rigid body. On the comet surface we postulate the distribution function of ejection velocity and the distribution function of initial orientation of the grains. From the same origin on the surface we trace a number of grain trajectories with different initial conditions. We average the drag coefficients computed for rotating grains in order to evaluate the "aerodynamic correction" which has to be introduced to already existing spherical dust expressions.

3. The Results

We present comparison of velocity and circular frequency (i.e. rotation per second) of dust grains versus the shape (oblate or prolate), size, initial orientation and ejection velocity. Fig. 1 shows the dependence of the drag coefficient for rotating prolate grain as a function of the speed ratio for cold and hot particles with specular and diffuse reflection of gas molecules σ . In the case of hot grains with specular reflection the drag coefficient raises about 40% for small speed ratios. In the case of diffuse reflection the drop of the drag is less than a half. We perform GI-

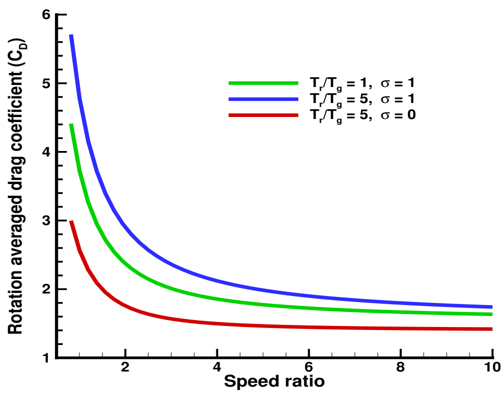

Figure 1: Rotation averaged drag coefficients as a function of the gas-dust speed ratio for a prolate grain for different fraction σ and dust temperatures.

ADA simulated measurements with GIPSI along part of the ESA prelanding COP bound orbit (time interval: 2014-10-13T11:00:00 - 2014-10-23T23:00:00) using the aspherical dust solutions. In order to have the results applicable to 67P/C-G we adjust the solutions through the dust-to-gas ratio and the total dust mass flux derived by observational data [10]. The used total gas production is 35 kg/s (CO+ H_2O) and the total dust flux is 112 kg/s for 3AU. The results show different velocity for prolate and oblate grains and similar dust rates and distribution. The temporal shift of dust collection for each of the shapes, shows that the corresponding flux is at different space locations along the orbit. The number of detected particles for prolate and oblate grains are 245 and 309, respectively.

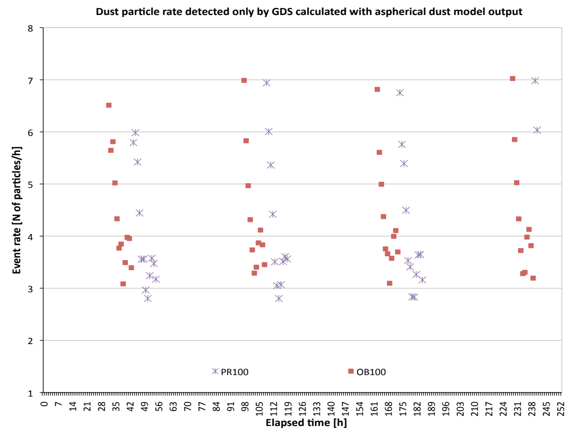

Figure 2: The dust rates of prolate and oblate 100 μm size grains (PR100 and OB100) computed by GIPSI using the aspherical dust model output with spherical nucleus gas solutions.

4. Future Work

Once data available (the second half of 2014), we plan to use realistic calibrated gas solutions for our 3D+t aspherical dust computations. Next steps also include: studying more realistic dust grain shapes and investigating the settling of the rotating grains with very irregular shapes.

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