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Dynamics of aspherical dust for the GIADA experiment in the coma of 67P/Churyumov- Gerasimenko: I. Comparison with the spherical approximation

S. Ivanovski (1), V. Zakharov (2, 3), J.-F. Crifo (4), V. Della Corte (5), M. Fulle (6) and A. Rotundi (5)
(1) Osservatorio Astronomico di Capodimonte, Naples, Italy, (2) LESIA, Observatoire de Paris, Paris, France, (3) Gordien Strato S. A. R. L. Verrieres le Buisson, France, (4) LATMOS, CNRS, Guyancourt, France, (5) University of Parthenope, Naples, Italy, (6) Osservatorio Astronomico di Trieste, Trieste, Italy, (stavro@na.astro.it / Fax: +39 081456710)

Abstract

We report the recent advances in developing of the model of aspherical dust grain dynamics [1] in the cometary atmosphere of 67P/Churyumov- Gerasimenko. The present model is aimed to support the scientific objectives of GIADA *in-situ* experiment [2] on board of the ESA ROSETTA probe and will provide predictions on the real dust cometary grains. The currently used 3D+t models [3, 4] assume sphericity of the grains but the dynamics of aspherical grains can be very different from spherical [5].At this stage we study grains moving under the influence of two forces: aerodynamic and gravitational and discuss the distinctions between the aspherical and the spherical approximations.

1. Introduction

The recent advent of space-based dust detectors open the possibility to measure individual dust grain mass, number density and velocity in the immediate vicinity of a cometary nucleus. The GIADA (Grain Impact Analyzer and Dust Accumulator) instrument [2], on board of the ESA ROSETTA probe, is on its way to comet 67P/Churyumov- Gerasimenko and will perform such measurements. GIADA will also get the number and the momentum of the particles emitted from the nucleus. GIADA will measure the optical cross section and the mass of each in situ detected grain. Cometary grains are not spheres. Based on their shapes and orientation, an averaged value of their cross section vs. a fixed mass can be defined. By measuring the mass of many grains over a sampled optical cross section, GIADA will provide data of the optical cross section distribution vs. dust mass. Therefore the output of the instrument is of a fundamental importance for coma dynamical models used to interpret all dust data collected during the ROSETTA mission.

The currently used state-of-the-art model [3] of dust dynamics is based on the Dust Monte-Carlo (DMC) simulation technique proposed in [4]. This multicomponent, three-dimensional, time-dependent model considers the full mass range of ejectable grains moving under influence of aerodynamic, gravitational and solar forces. The simplifying assumption of the model is the grain sphericity. Here, we consider motion of axially symmetric ellipsoids with different aspect ratios in a spherically symmetric expansion of a pure gas. The present work is one of the series intended to understand the real behavior of the dust grains in the cometary atmosphere and is aimed to study the differences between the spherical and aspherical models of dust in the coma of 67P/ Churyumov-Gerasimenko.

2. The Model

We assume that dust grains are homogeneous, isothermal bodies of axial symmetric ellipsoidal shape with convex polygonal surface. The grains are moving under influence of two forces: aerodynamic and gravitational. It is assumed that presence of dust does not affect on the gas flow. The gas distribution (density, velocity, temperature) in the coma is given by an adiabatic spherical expansion of perfect gas. In the range of gas production rates of interest the mean free path of the gas molecules is much larger than the grain size, therefore for calculation of aerodynamic force acting on the grains we use free molecular expressions. Gravitational field is also assumed spherical. On the initial surface we postulate the distribution function of ejection velocity and the distribution function of initial orientation of the grains. Then we trace the trajectories of a number of grains from the surface. From this data we derive an average trajectory and dispersion around it. The goodness of spherical grain approximation is evaluated from deviation of the spherical grain trajectory from the averaged trajectory of aspherical grains expressed in terms of dispersion.

3. The Results

In contrast to the spherical grain model aspherical grains experience not only longitudinal force (i.e. drag) but also transverse force (i.e. lift) and torque. It is convenient to represent aerodynamic force in the form of dimensionless aerodynamic coefficients (drag, lift etc.) to dynamic pressure. They have strong variation with respect to the grain's orientation alpha in the full range of flow conditions. For example, Fig. 1

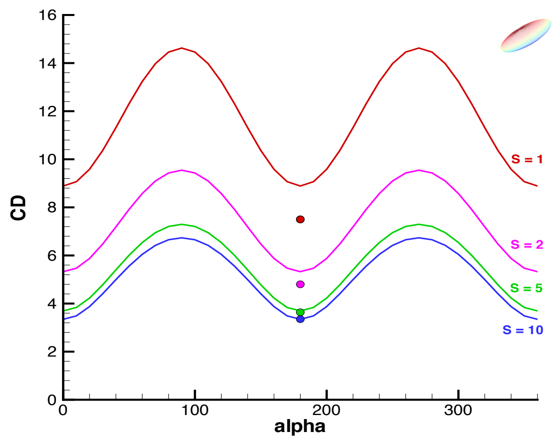

Figure 1: Drag coefficients for an ellipsoid (dots are for sphere).

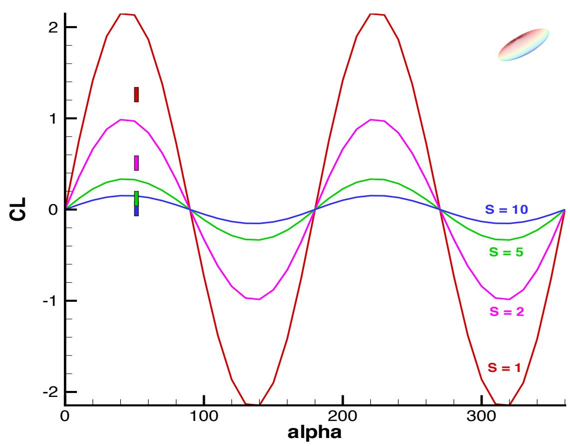

Figure 2: Lift coefficients for an ellipsoid (rectangles are for the plate).

shows comparison of the drag coefficient for a spherical and an ellipsoid shape grains. The difference increases for low speed regime (mol. speed ratio S < 5). The comparison of the lift coefficient for a plate and an ellipsoid is shown in Fig. 2. Our results also show that for different initial orientations, the velocity along the trajectory of the identical aspherical grains changes significantly (Fig. 3).

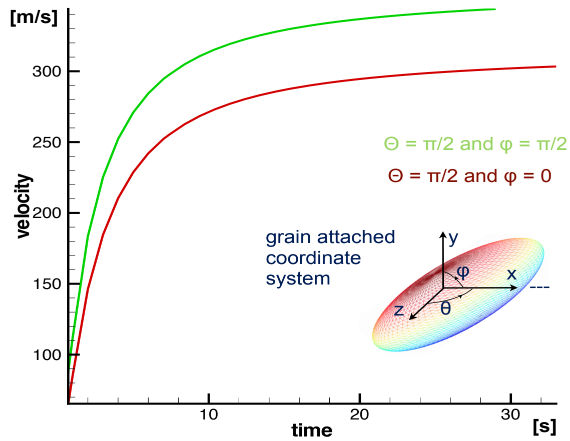

Figure 3: Velocity of an ellipsoid along the trajectories time for different initial orientation.

4. Future Work

The next step in the development of 3D+t aspherical dust dynamics model is to implement a more realistic distribution of gas and gravity and to study a variety of more realistic shapes for the dust grains . Our aim is to derive the 3D+t space density and velocity distribution of the aspherical grains.

5. Acknowledgements

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