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The model of aspherical dust dynamics for interpretation of the GIADA in-situ measurements in the coma of 67P/C-G

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Abstract

In order to prepare the interpretation of the GIADA *in-situ* data of Comet 67P/ Churyumov-Gerasimenko a model of dust dynamics is indispensable. The currently used 3D+t model assumes sphericity of the grains. We report the first steps in developing of the model of aspherical dust grain dynamics in the cometary atmosphere. On this stage we study the grain motion in aerodynamic force free region. The grains are convex polygonal bodies. In addition, a new approach for resolving the inverse problem is discussed, namely, based on GIADA observations, we could determine the probable location of the particles emission on the nucleus.

1. Introduction

The ESA ROSETTA space mission has been launched to make a rendezvous with the short period comet 67P/ Churyumov-Gerasimenko (67P/ C-G) and to study it from about 3.25 AU to perihelion and up to 2 AU post-perihelion. The dust monitoring is a key goal of the mission, from both scientific and operational points of view.

The GIADA (Grain Impact Analyzer and Dust Accumulator) instrument [1], on board of the ROSETTA orbiter, is aimed to analyze physical and dynamical properties of individual particles ejected from the nucleus and to monitor the dust flux and spatial distribution as a function of time. GIADA will measure the number, mass, velocity and momentum of the dust particles emitted from the nucleus.

Currently the state-of-the-art model [2] based on the Dust Monte-Carlo (DMC) simulation technique proposed in [3] is used to study the dynamics of dust grains. This model is multi-component three-dimensional time dependent. It considers the full mass range of ejectable grains moving under influence of aerodynamic, gravitational and solar forces. The simplifying assumption of the model is grain sphericity. The aim of the present work is with an aspherical model to check the goodness of spherical grain model in the coma of 67P/ Churyumov-Gerasimenko.

2. The Model

2.1. The direct problem

We assume that the grain motion is governed by three forces: aerodynamic, gravitational and solar radiation pressure. 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. The motion of aspherical grains is described by the equation:

$$m_g \frac{d\vec{v}_g}{dt} = \vec{F}_A + \vec{F}_G + \vec{F}_S + \vec{F}_I + \vec{F}_O, \quad \frac{d\vec{r}}{dt} = \vec{v}_g \quad (1)$$

Subscripts stands for aerodynamic, gravity, solar force, inertia, others, respectively. As a first step in our study we will consider a region quite distant from the nucleus (about several tens of the nucleus radius) where the aerodynamic force is negligibly small (see Fig.1). In this region, the aspherical grains are subject only to the gravity and solar force. We assume these grains homogeneous and isothermal. As gradients of the forces are much larger than characteristic size of the grains we assume at this stage that the grains are not rotating. On the initial surface in each point we postulate the distribution function of ejection velocity, distribution function of initial orientation of the grains.

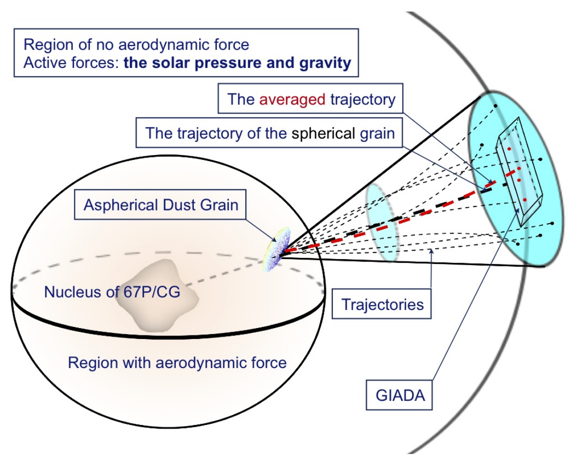

Figure 1: The model description.

Then we trace the trajectories of a number of grains from each point. 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.

2.2. The inverse problem

One of the questions to be solved when the data from GIADA *in-situ* measurements will be available is determination from which point on the nucleus the captured dust grain was ejected (so- called traceback). Having the model for the direct problem the inverse problem can be resolved in a statistical way. It looks for the most probable location on the comet nucleus from where the dust has been emitted. There is no need to solve the inverse problem in a trace-back fashion. We evaluate the probability of an ejected from the nucleus grain to enter into the instrument. The solution is a probability map for one particular family of grains emitted from the surface of the nucleus. The inverse problem is crucial for the safety of the landing operations of ROSETTA spacecraft.

3. The Results

We present the first results on comparison of spherical and apsherical grain dynamics for conditions corresponding the rendezvous of the Rosetta probe with the comet 67P/C-G. As grain shapes we use triangulated polygons approximating an ellipsoid and cuboid. Fig. 2 shows an example of trajectory spread for aspherical grains (triangulated polygon approximation of an ellipsoid) with isotropic initial orientation and a trajectory of a spherical grain. In this (very particular case) the average trajectory is straight line and it coincides with the spherical grain trajectory therefore the goodness of spherical grain approximation is good. For the first time we present the results of solution of the inverse problem for GIADA. Several positions of GIADA will be researched. As an example, Fig. 3 shows the isocontors of probabilities that the grain from this point of the surface of the nucleus (represented uniquely by the couple of the inclination and azimuthal angles) will enter in GIADA.

4. Future Work

The next step in the development of 3D+t aspherical dust dynamics model is to consider the region where aerodynamic force is present. Further, to derive the

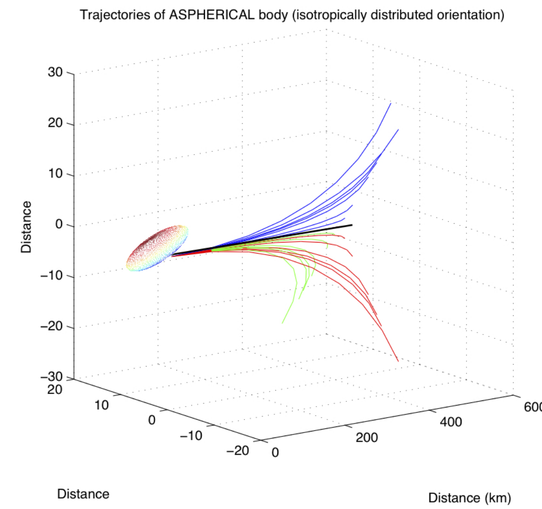

Figure 2: The dispersion (spread) of trajectories of aspherical (polygonal) grains and the averaged one.

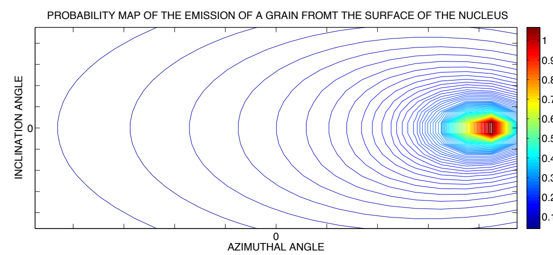

Figure 3: The distribution of the probability that the grain emitted from (θ, ϕ) will be trapped by GIADA.

3D+t space density and velocity distribution of the aspherical grains. To integrate the full coupled equations for the grain temperature and the motion of the grains from the surface for the full range of initial grain orientation at the surface. New shapes of increased sophistication, which are adequate for investigating the optical properties will be studied.

References

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