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Derivation of general dynamical parameters of non-spherical dust calibrated with Rosetta/GIADA measurements

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Abstract

How the knowledge on cometary dust dynamics acquired through Rosetta data can be properly applied to other comets remains a question of outstanding scientific interest. In the present study we investigate a set of dynamical parameters derived by the non-spherical dust model, mainly calibrated by Rosetta/GIADA [1] data, aiming at determining the minimum number of parameters capable to represent the key processes acting on non-spherical dust in cometary atmospheres.

1. Introduction

The unique data obtained by Rosetta in the vicinity of 67P/Churyumov-Gerasimenko (67P) helped to calibrate coma models. In particular, Rosetta in situ observations allowed to test coma models, which include additional physical parameters hardly addressed in pre-Rosetta epoch. One of them is the non-sphericity of dust particles. The irregular shape leads to changes in the particle motion (with respect to a spherical particle) due to addition of the transversal forces and rotational motion governed by the aerodynamic force. This leads to different terminal velocities of particles with the same mass, but different in shape. In a series of works based on Rosetta data we derived the rotational frequencies and velocities of the non-spherical particles in the vicinity of 67P [2-5].

[6] use a minimum number of parameters necessary to represent the key process in cometary atmospheres to find asymptotics for spherical particles motion in a spherically expanding flow. The authors introduced three universal dimensionless parameters and computed the dust terminal velocity, distance and time to acquire this velocity as a function of these parameters.

In the present work, we add the dust particle non-sphericity to the model developed by [6] to study which additional critical parameters are needed to describe the particle rotational frequency and its motion in expanding flow.

2. The model

We study the dynamics of homogeneous and isothermal non-spherical dust grains in the ideal perfect gas expansion into vacuum and ejected by a homogeneous spherical source described by its radius, mass, surface temperature and gas production rate. We assume submicron to millimeter spheroidal particles with different aspect ratios (0.1 - 10) moving under the influence of the gravitational and aerodynamic forces and torques. The latter is computed assuming a free molecular flow, which is the case for 67P coma: the minimal mean free path of the molecules is of the order of meters, i.e. much less than the considered dust grain sizes. From the same origin on the surface we trace a number of grain trajectories with different initial conditions. We assume that dust stream does not affect the gas flow. We use GIADA data [7-9] (only in the periods of the mission when such dusty-gas approximation is applicable) to compare the measured with the derived dust velocities, under the assumed non-spherical parameters.

3. Conclusion

We present asymptotic solutions for a broad range of parameters critical to describe the key process of non-spherical dust dynamics in a simplified model of gas coma. Such dimensional parameters can be used as a reference estimation of dust rotational frequencies in various cometary atmospheres that experience the considered physical conditions.

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