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Inner coma dust properties from polarization models

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Abstract

Polarimetric observations of comets may be used to infer dust properties within comae through simulations. Recent progresses, in search for analogues for porous irregular cometary particles and in numerical simulations with such particles, are expected to provide a better understanding of the near-nucleus environment of Rosetta cometary target.

1. Introduction

1.1 Rosetta mission

The Rosetta spacecraft is expected to rendezvous with comet 67P/Churyumov-Gerasimenko (C-G) in May 2013. It will progressively approach its nucleus, in order to release the Philae lander in November 2013, from an altitude smaller than 10 km. A better estimation of the properties of dust particles in the inner part of the coma is mandatory, not only to optimize data acquisition sequences for onboard dust experiments, e.g., MIDAS [14], but also to provide a better assessment of the near-nucleus environment.

1.2 Low cometary densities

The bulk density of dust particles in the coma of 1P/Halley has been estimated, from a comparison between local brightness data and dust impacts during the Giotto mission, to be about 100 kg m^{-3} [2, 10]. Such a low value, together with further evidence provided by Stardust images of dust impacts on aluminium foils and arero

gel cells [5], suggests the presence of fluffy aggregates of smaller grains in the coma. Cometary nuclei also have low densities [e.g., 11]. From mass estimation through non-gravitational forces induced by ices sublimation on a rotating nucleus, densities are estimated to be within a 100-1000 kg m^{-3} range. This indirect approach has been validated through

comets 9P/Tempel 1 and 103P/Harley 2 flybys. The density of C-G, expected to be about 370 kg m^{-3} [8], suggests a significant porosity of the nucleus interior, to be probed by Rosetta CONSERT experiment [6].

1.3 Volcanic ashes as porous analogues

In preparation of the Rosetta mission, very porous particles have been searched for laboratory measurements of the permittivity dependence upon the density, on a large range of frequencies of interest for Rosetta radiometric experiments. Volcanic ashes were found to be irregular and porous enough to provide good analogues [1]. The particles, corresponding to various sizes (10-500 μm range), originate from Etna volcano and from Nasa analogues for Martian and lunar regoliths, which are also built up from pyroclastic deposits.

2. Dust properties from polarimetry

2.1 Polarimetric observations of comets

Numerous polarimetric measurements of solar light scattered by dust in cometary comae have been obtained. The linear polarization depends upon observational conditions (phase angle, wavelength), and upon the dust particles properties. Cometary phase curves are typical of irregular dust particles, with a size greater than the wavelength (see, e.g., [7]). Changes noticed in the coma, such a decrease in polarization (at a fixed phase angle and wavelength) in the innermost coma of 1P/Halley [10], are attributed to local changes in the dust properties.

2.2 Polarimetric observations of C-G

Polarimetric observations during the last return of C-G suggest its coma to be dominated by large grains originating from one hemisphere before perihelion passage and by small grains from the other hemisphere after perihelion [4]. Observational data

are indeed interpreted through experimental simulations (with, e.g., PROGRA2 experiments) on various dust samples, with mixtures of magnesio-ferrosilica and carbon providing interesting analogues [3]. Numerical simulations, with aggregates of spherical or spheroidal grains [9], provide complementary satisfactory interpretations.

2.3 Updated numerical simulations

Since low cometary densities suggest very high porosities, it may be assumed that cometary dust is build up of aggregates of porous (instead of compact) grains, comparable to volcanic ashes. Stochastic models for non-spherical irregular porous particles shaped as volcanic ashes have been recently developed, using the concept of concave hull transformation and Gaussian random spheres [12, 13]. Numerical simulations with such particles, through parallel computations with the discrete-dipole approximation, are to be used to improve, together with comparisons with experimental simulations, previous numerical simulations, and to lead to a better estimation of the physical properties of dust in the coma of comet C-G. The model will also allow the inclusion of water ice, to tentatively interpret the above-mentioned decrease in polarization in innermost comae, where water ice might survive after ejection from the nucleus.

3. Summary

An elaborate modelling of the properties of the dust particles to be encountered by Rosetta spacecraft in the cometary coma is proposed. It relies on recent numerical simulations of polarimetric properties of irregular porous particles, such as volcanic ashes. Such particles are good analogues for cometary dust particles, which are not only very porous, but rich in silicates, carbonaceous matter, and possibly ices in the innermost coma.

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