Physical properties of dust particles in cometary comae: from clues to evidence with the Rosetta mission

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Abstract

Physical properties of dust in cometary comae have first been approached through unique flyby missions and numerous remote observations of the intensity and polarization of the solar light they scatter. Clues to size distribution, morphology, refractive index of dust particles, and to their variations within comae have been derived from polarimetric data.
The Rosetta rendezvous mission to 67P/Churyumov-Gerasimenko (hereafter 67P) is now confirming previous estimations and providing detailed evidence about the dust physical properties, through sophisticated measurements obtained in different regions of the coma and for different solar distances.

1. Clues from previous studies

1.1. In situ studies

Changes in polarization, and thus in dust properties, within 1P/Halley coma had been discovered through observations of HOPE instrument on-board the Giotto spacecraft. For a fixed phase angle, the polarization was higher in red than in blue, except in the innermost coma, increased when Giotto crossed a jet-like feature and decreased in the innermost coma [e.g. 1]. Comparing intensities of light scattered by dust and dust fluxes led us to estimate that the dust particles were very porous and dark, with densities about 100 kg m^{-3} and albedos about 0.04 [2]. More recently, the Stardust mission provided evidence for dust fragmentation during its flyby of 81P/Wild 2 [3] and for the presence of both compact grains and aggregates, impacting aluminum foils of the sample return capsule [4].

1.2. Remote observations

Numerous remote polarimetric observations in the visible and near-IR domains have shown that, in the visible, the polarization at a fixed phase angle usually increases with increasing wavelength [e.g., 5]. They have also provided, through polarimetric imaging techniques, clues to the presence of heterogeneities in the dust properties within a coma, with an increase of polarization in jet-like features and a possible decrease in near-nucleus polarimetric halos. Such trends have typically been pointed out for 67P after its 2009 perihelion passage [6] and for C/1995 O1 Hale Bopp [7], respectively.
Numerical and experimental simulations are needed to interpret polarimetric observations, over a large range of phase angles in different colors, in terms of physical properties. Numerical fitting of 1P/Halley and C/1995 O1 Hale-Bopp data suggests i) a size distribution with a power law index of about -2.9, ii) the presence of aggregates and compact particles, iii) silicates and more absorbing organics with comparable contributions [8]. Experimental simulations, as developed for low spatial-density dust samples [9], lead to satisfactory fits for fluffy aggregates of Mg-silicates, C aggregates, with some compact Mg-silicates [10]. In 67P coma at its 2009 return, the presence of rather-large slow-moving absorbing particles before perihelion, and of fluffy aggregates of submicron-sized grains in jets after perihelion, is suspected [6]. Changes from innermost to outer coma are attributed to evolution processes, related to the alteration or evaporation of material partly constituting dust particles.

2. Evidence with Rosetta mission

While Rosetta rendezvous mission is still in its escort phase, the on-board dust instruments, i.e. GIADA, COSIMA and MIDAS, have already given remarkable evidence about the physical properties of dust, together with their variations, in the inner coma of comet 67P [e.g., 11, 12]. The morphology of dust particles reveals both compact (either almost spherical or quite irregular) and flocculent (some of them most likely agglomerates at very small scales) particles. Compact particles detected by GIADA and OSIRIS range in size from 0.03 to 1 mm [11], while fluffy aggregates of sub-micron grains detected by GIADA range in size from 0.2 to 2.5 mm [13].

Rosetta thus gives evidence for a significant amount of fluffy particles in the solid material ejected by comets. Such particles would be more resistant to atmospheric entry ablation than compact ones [14], thus enabling a larger mass of cometary material enrichment on the surface of early terrestrial planets.

4. Summary and Conclusions

Rosetta mission is now providing, thanks to its dust experiments, a fabulous wealth of information about dust particles released from 67P nucleus. While results already confirm previous indirect clues, mostly derived from polarimetric observations of comets, a significant evolution may be expected, not only while the comet gets closer to the Sun, but also after it has passed its perihelion [6].

Numerous remote polarimetric observations (including HST observations) should take place later on this year, allowing us to link the properties derived from remote observations to those accurately measured in the nucleus environment.

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