Cometary dust: Rosetta update and connection with meteoroids

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Introduction

While the presence of dust particles in cometary tails was already suspected in the first half of the 19th century, dust particles have been progressively been remotely studied in comae, tails and and trails from the solar light they scatter and from their infrared emission [e.g. 1,2]. Remarkable results have been obtained through space missions, and especially Rosetta long-duration rendezvous with comet 67P/Churyumov-Gerasimenko. This review will focus on the composition and physical properties of cometary dust, and on the evolution of dust particles and debris from comets to the zodiacal cloud and meteorites.

Cometary dust, Rosetta discoveries and evidences

From the flybys of 1P/Halley in 1986 to the beginning of Rosetta mission in 2014, our understanding of the properties of dust in comets has progressed thanks to a few flybys (including Stardust samples return), to remote observations of bright comets, and to theoretical and experimental simulations [3-5]. The Rosetta mission has typically discovered smooth dust-covered terrains and dune-like structures on the surface of the nucleus [6] and huge (decimetres size-range) dust clumps on bound orbits [7]. The nucleus was found to be richer in dust than in ices and extremely porous [7-9]. Rosetta has also provided evidence (though microscope and AFM imaging of collected dust) for a heterogeneity in dust particles morphologies, with large (10s to 100s μm size-range) fluffy dust aggregates (with different packing densities) of irregular, sub-micron-sized grains, the size distribution and fractal dimension of which was estimated [10-12]. Fragmentation (from impacts, evaporation of semi-volatile organics, and/or electrostatic tension) may also take place. Dust composition, as derived from Rosetta and Philae lander, favours the presence of silicates and iron sulphides, and of a significant amount of non-volatile organics, likely complex mixtures of carbon-hydrogen, oxygen-hydrogen and nitrogen-hydrogen groups, including compounds not previously detected in comets [12-14].

From comets to Earth

Dust particles released from nuclei in filaments, jets, tails and trails contribute to the replenishment of the zodiacal cloud, the main sources in the inner interplanetary medium being comets and asteroids [e.g. 15]. Depending on the β ratio of radiation pressure to gravity forces, the smallest particles ($\beta>0.5$) are pushed away by solar radiation pressure, while the intermediate ones ($0.1<\beta<0.5$) ones spiral towards the Sun under Poynting-Robertson effect. From inversion of line-of-sight integrated polarization data, changes in dust local properties with solar distance, possibly induced by evaporation processes or collisions, have been detected in the symmetry plane of the zodiacal cloud below 1.5 au [15,16]. Modelling with mixtures of dust particles (0.2 to 200 μm size-range, aggregates and compact) suggests that these heliocentric changes correspond to a progressive disappearance of solid organics towards the Sun and that a significant proportion of zodiacal dust originates from comets, in good agreement with dynamical computations [17,18]. It may be added that the properties of some interplanetary dust particles collected in the stratosphere (IDPs) and of ultra-carbonaceous Antarctic micrometeorites (UCAMMs) are comparable to those of cometary dust. Finally, the Rosetta ground-truth now allows us to speculate about the evolution of the early Earth: since fluffy aggregates are expected to be more resistant to atmospheric ablation than compact ones, cometary dust particles could, during a heavy bombardment epoch, have enriched the Earth's surface in complex organic compounds.

References

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