Abundant solar nebula solids in comets

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Comets have been proposed to consist of unprocessed interstellar materials together with a variable amount of thermally annealed interstellar grains. Recent studies of cometary solids in the laboratory have shown that comets instead consist of a wide range of materials from across the protoplanetary disk, in addition to a minor complement of interstellar materials. These advances were made possible by the return of direct samples of comet 81P/Wild 2 coma dust by the NASA Stardust mission and recent advances in microscale analytical techniques.

Isotopic studies of 'cometary' chondritic porous interplanetary dust particles (CP-IDPs) and comet 81P/Wild 2 Stardust samples show that preserved interstellar materials are more abundant in comets than in any class of meteorite. Identified interstellar materials include sub-µm-sized presolar silicates, oxides, and SiC dust grains and some fraction of the organic material that binds the samples together [1]. Presolar grain abundances reach 1 weight % in the most stardust-rich CP-IDPs, 50 x greater than in meteorites. Yet, order of magnitude variations in presolar grain abundances among CP-IDPs suggest cometary solids experienced significant variations in the degree of processing in the solar nebula.

Comets contain a suprisingly high abundance of nebular solids formed or altered at high temperatures. Comet 81P/Wild 2 samples include 10-40 µm-sized, refractory Ca-Al-rich inclusion (CAI)-, chondrule-, and ameboid olivine aggregate (AOA)-like materials [2]. The O isotopic compositions of these refractory materials are remarkably similar to their meteoritic counterparts, ranging from 5% enrichments in ^{16}O to near-terrestrial values. Comet 81P/Wild 2 and CP-IDPs also contain abundant Mg-Fe crystalline and amorphous silicates whose O isotopic compositions are also consistent with Solar System origins. Unlike meteorites, that are dominated by locally-produced materials, comets appear to be composed of materials that were formed across a wide swath of the early protoplanetary disk [2].

[1] Messenger S. et al. (2014) in: Dust in the Solar System: Properties and Origins. [2] Brownlee D. E. (2014) Ann. Rev. Earth Planet. Sci. 4 2:179–205