Cometary Bodies – A Primer

Comet nuclei are the frozen reservoirs of dust and ices left over from the early solar nebula. The properties of the dust grains and the abundances of volatiles in cometary nuclei probe the temperatures that solar nebula materials were subjected to prior to protoplanetesimal formation. Although comets contain some of the most primitive materials in the solar system, directly observing this material is a problem because the outer layers of the parent bodies (the nuclei) have been subjected to processing mechanisms such as collisions, particle bombardment, and ultraviolet and cosmic ray irradiation. These can change the morphology or shape (but not the mineralogy) of the dust grains.

Comet Hale-Bopp / P. Michaud

The composition of small, volatile-rich icy bodies in the solar system, that have been subject to processing provides an astro-geochemical record enabling us to infer the physical conditions during the planetesimal formation epoch some 4.5 billion years ago. Among these icy "leftover bodies" are two important collections of small, planetesimal-sized objects called long- and short-period comets. Long-period comets originate in the Oört Cloud, have orbital periods ranging from several hundred to millions of years, and have diverse orbital inclinations. Oört Cloud comets probably formed near the giant planets and were gravitationally expelled by them from the early solar nebula into the Oört Cloud. Some of these comets may have originated in the trans-Neptunian region and pushed inwards to Jupiter before being scattered to the Oört Cloud. These nuclei are subject to evolutionary processing (i.e., "weathering") during their Oört Cloud "cold storage," primarily from radiation exposure in the interstellar medium. Thermal exposure from passing hot, massive O-type stars and supernovae explosions led to a devolatilization of the surfaces of the comet nuclei to depths between 1-50 meters (3-150 feet). Radiation bombardment from interstellar ultraviolet radiation and galactic cosmic rays may have polymerized the organics to create a "glue"' that holds small surface grains together to form larger aggregates. Oört Cloud comets are thought to contain mostly "pristine" solar nebula materials that are released into the coma during a perihelion passage.

Short-period comets come in two varieties. The majority, called "Jupiter Family" comets, have periods less than 20 years, small orbital inclinations, and aphelia near or beyond Jupiter. A small subset of the short-period comets are the "Halley-type" comets which have periods between 20 and 200 years, large inclinations, and are probably Oört Cloud comets perturbed into smaller orbits. Jupiter Family comets formed near Neptune and were scattered outward to create the scattered disk (dynamically "hot") population of the Kuiper Belt. Neptune's outward migration pushed other icy planetesimals outward to create the classical disk (dynamically "cold") population of the Kuiper Belt. The hot disk population is likely to scatter into Jupiter Family comet orbits. As residents of the Kuiper Belt, the Jupiter Family comets suffered collisions and are thought to have broken off of larger objects. Evolutionary mechanisms act to age the surface of these comets in a fashion similar to Oört Cloud comets; however, the effects of evolution are mitigated by the young surface age of the Kuiper Belt objects.

Once such an object becomes a Jupiter Family comet, solar radiation becomes the primary evolutionary mechanism. The lower activity of Jupiter Family comets (the production rates of coma gases and dust from the nuclear surface and from jets), compared to Oört Cloud comets, is attributed to their many close perihelion passages. Repeated periods of sublimation and re-freezing in Jupiter Family comets reduces the reservoir of volatiles possibly many feet deep in the nucleus, de-hydrogenates the surface carbonaceous grain material (leading to a lower silicate-to-amorphous carbon ratio), and alters the grain morphology (leading to larger, more solid grains).

In addition to differences in parent body evolution, there may be systematic differences in the composition of the dust contained in Oört Cloud and Jupiter Family comets. These may reflect differences in nebula temperature, the degree of radial mixing of inner nebula materials to the outer radial regions, or the extent of nebular shocks which can, for example, lead to different compositions and crystalline-to-amorphous silicate ratios between Jupiter Family and Oört Cloud comets.