Life Sciences as Related to Space (F)
The Evolving Chemical Universe: from proto-stars to the origin of life : Part 1 (F3.2)

THE DIVERSITY OF REFRACTORY ORGANIC MATERIAL IN COMETS

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Organic matter exists in comets (most notably in 81P/Wild 2 [Stardust], 67P/Churyomov-Gerasimenko (67P/C-G) [Rosetta], chondritic porous IDPS, and UCAMMs) and in primitive carbonaceous chondrites that likely retain some chemistry that reflects an origin in the prenatal cold molecular cloud (Alexander+2017). Heavy isotopic enrichments, 15N/14N and possibly D/H, signify preserved molecular cloud organics. In the cold outer disk, if grains are lofted above the disk mid-plane then organics likely experience significant UV processing (Ciesla+2012).

In remote sensing of comet comae, organics in the dust are considered refractory or semi-refractory. Semi-refractory organics have limited comae lifetimes and produce distributed sources of molecules (H2CO and CO). Rosetta's close passes of 67P/C-G's nucleus (10-15 km) reveals a distributed source of glycine, methyl amine and ethylamine (Altwegg+2016). Cometary samples and primitive meteorites have two types of organic matter: (1) acid-insoluble organic matter (IOM), which is a macromolecular polymer with a mixture of aromatic and aliphatic moieties, and (2) labile, soluble organics, which includes the amino acids, such as glycine (Stardust, Elsila+2009). Meteoritic IOM is robust, withstanding experimental temperatures of 1200 K (Dobrica+2011, Cody+2008). Nanoglobules are a type of IOM; they have a distinct physical structure, but often share the same chemistry as the other IOM from the same meteorite. Moderate-sized PAHs (20 C-atoms) are detected in Stardust samples (Clemett+2010). Refractory organic IOM is ubiquitous yet has a great diversity of abundances between cometary samples. IOM is in primitive chondrites, 67P/C-G (Rosetta), 81P/Wild 2 (Stardust), 1P/Halley, 26P/Grigg-Skjellerup, UCAMMs, anhydrous IDPs, and in chondritic porous IDPs (CP IDPs) and larger cluster IDPs (e.g., Fray+2016, Fomenkova+94, Busemann+09, Dobrica+2011, Dobrica+2012). 81P's refractory organic matter is of two types (De Gregorio+2011): nanoglobules of highly aromatic refractory organic matter and polyaromatic carbonyl-containing organic matter, which is similar to IOM in primitive meteorites and IDPs. Fray+2017 estimate that 50% of carbon in 67P/C-G is in IOM. 67P/C-G's organics appear to lack the soluble organic matter, aliphatic carbon, amino acids, and PAHs (Fray+2016). Other notable aspects of the diversity in IOM in cometary samples are the ranges of atomic ratios of N/C, O/C, and H/C, and the range of isotopic enrichments of 15N/14N and D/H. Aqueous and thermal processing on asteroids changes the balance of soluble to insoluble organics, and may be important for diversifying the range of OM delivered to Earth.