Placing Comet 81P/Wild 2 organics into context with meteoritic organic solids

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The Stardust comet sample return mission from Comet Wild 2 has provided an unprecedented opportunity to assess the organic chemistry of what may be the most primitive Solar System material. Cometary organic matter likely constitutes an extraordinarily well preserved sample of the molecular cloud material that was the source of matter from which our Solar System originated.

As members of the Organics Principal Experimental Team we have been applying an unusual, but very powerful analytical tool, scanning transmission X-ray microscopy and microspectrometry (commonly referred to as STXM) to provide a window into the complex structure of comet organic solids captured during the Stardust mission. This technique provides essential information on the molecular environments of carbon, nitrogen, and oxygen. So far we have discovered that the organic particles extracted from the Stardust aerogel collectors exhibit considerable chemical complexity and variety. STXM analysis reveals ~ four different types of organics; 1) a relative dense oxygen rich phase with moderate nitrogen that shares some similarity in organic structures to organic matter in primitive meteoritic organics (interestingly, this organic phase has been shown to have a relatively high concentration of the heavy hydrogen isotope, deuterium); 2) a fluffy or low density, highly oxygen rich organic phase; 3) a highly nitrogen rich organic phase with moderate oxygen content; and 4) an apparently liquid or solvent-soluble phase that is highly oxygen rich.

Placing these observations in context with similar studies of meteorite organic matter is extremely interesting. We have determined that the cometary organic matter (studied so far) is universally richer in both oxygen and nitrogen, with an average molecular structure that is strikingly fragile in comparison with that previously determined for meteoritic organics. In comparison, even the most primitive meteoritic organic matter has much lower oxygen content than the Stardust organic particles. In this regard, the organic matter analyzed from Comet Wild 2 meets our expectation of a Kuiper belt object, that is, we observe a delicate organic structure that has been preserved in deeply frozen state in these primordial solar system bodies. Ultimately, however, one of the most intriguing questions still remains; how is it that fragile organic matter could survive collection given that the capture velocity was 6.1 km/s! The energetic nature of the sample capture process is such that at least some material is expected to have been subjected to very high temperatures, although for a short time.

It is clear from the many observations of the particle tracks in the aerogel that more than just passive capture of particles occurred. Rather many of the tracks exhibit evidence of explosive events accompanying capture, consistent with the possibility that some of the particles contained abundant volatile material. These observations lead us to suspect that one source of the particle complexity that we observe may be *de novo* synthesis of solids through spontaneous condensation of small molecules into organic solids during the sublimation or thermally induced evaporation of cometary ices. Such a scenario is certainly plausible and may provide the only rational explanation for such chemical heterogeneity as possible contaminants are ruled out.