ORIGIN AND EVOLUTION OF ORGANIC MATTER PRESERVED IN STARDUST COMETARY AEROGEL TRACKS
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Introduction: The STARDUST spacecraft captured
dust samples from Comet 81P/Wild 2 at a relative ve-
locity of 6.1 km s\(^{-1}\) in a low density silica aerogel and
returned them to the Earth. One of the main of the sci-
entific goals established for the mission was to deter-
mine whether comets contained complex organic mate-
rials and, contingently, the nature and abundance of
this material. [1] Although contamination concerns due
to carbonaceous impurities intrinsic to the flight aerogel remain, it is generally accepted that at least a
fraction of the captured dust particles contain an
indigenous organic component. [2] However, under-
standing the nature and abundance of this material is
complicated by nature of the collection process. The
rapid dissipation of particle’s kinetic energy during its
impact and deceleration cause both the particle and
surrounding aerogel to experience an intense thermal
pulse of upwards of 2000K for a period up to several
hundred nanoseconds [3]. During this period thermal
alteration and/or destruction of organic species present
in the impacting particle are likely to occur. We have
used the technique of ultrafast two-step laser mass
spectrometry (\textit{ultra} L\textsuperscript{2}MS) [4] to investigate how
the nature and distribution of aromatic and conjugated
organic species varies between and within aerogel
cometary tracks and their associated terminal particles.

Samples: Two tracks from aerogel tile C2067 were
analyzed and we present here the results for Track 113
shown in Fig. 1(A) from STARDUST keystone
C2061,1,113,1,0. The track has a Type-B morphology
[5] likely produced by a weakly bound aggregate that
broke apart on impact. The track is characterized by a
bulbous ellipsoidal cavity extending down from the
point of impact to a base from which approximately a
dozen long slender terminal particle tracks radiate.

Methods: No specific sample preparation treatments
are required for \textit{ultra} L\textsuperscript{2}MS analysis other than the
surface to be analyzed be physically unobstructed. For
the \textit{in situ} analysis of track walls this requires manual
removal of the upper track hemisphere and overlying
aerogel. The exposed track may then be secured to the
sample analysis stage by friction mounting between
Two high transmission metal grids. Analysis of termi-
nal particles, however, cannot be analyzed \textit{in situ} due to
the exterior rind of compacted and/or melted aerogel
in which these particles are inevitably encapsulated.
This necessitated particle extraction followed by
mounting in epoxy and partially sectioning using an
ultramicrotome to expose the interior. Extracted thin-
sections provided samples for consortium mineralologi-
cal and/or isotopic characterization, while the epoxy
potted stub with the remaining sectioned particle was
used for \textit{ultra} L\textsuperscript{2}MS analysis. Although the mounting
epoxy substrate is organic it does not contribute to the
organic species observed by the \textit{ultra} L\textsuperscript{2}MS instrument
since being a macromolecular polymer it cannot be
desorbed or photoionized under the experimental con-
ditions used.

Results: Representative organic mass spectra from
both the cavity wall of Track 113 and two terminal
particles TP1 and TP3 are shown in Figs. 1(B-D). All
spectra were acquired under identical experimental
conditions. The mass peak at 106 amu present in all
three spectra corresponding to a dimethyl benzene
(CH\textsubscript{3}-C\textsubscript{6}H\textsubscript{5}CH\textsubscript{3}), however since the para-isomer xy-
lene is used as an internal mass calibrant its origin is
ambiguous and should be ignored.

Terminal Particles: The organic composition of parti-
cles TP1 and TP3 differ significantly from one to an-
other, even though mineralogically both particles are
essentially enstatite grains. This argues against con-
tamination from a common source. TP1 showed the
largest organic signal of all of the terminal particles
extracted and is characterized by a distribution of rela-
tively low weight 1-3 ring fused ring aromatic hydro-
carbons and associated alkylated homologs (\textit{Ar}-(CH\textsubscript{3})\textsubscript{n}-H). The principal peaks at 94, 128 and 178
 correspond to phenol (C\textsubscript{6}H\textsubscript{5}OH), naphthalene (C\textsubscript{10}H\textsubscript{8})
and phenanthrene (C\textsubscript{14}H\textsubscript{10}) respectively. Although the
spectral complexity is greater than that observed for
carbonaceous chondrites such as Murchison, the dom-
nant mass peaks in the main mass envelope are similar.
The outlying peak at 254 amu is likely a naphthalene
dimer produced via thermal induced free radical po-
lymerization (2\textit{Ar}-H \rightarrow 2\textit{Ar}^+ + H^+ \rightarrow \textit{Ar}_2 + H_2) during
capture. In contrast TP3 was organic poor with a
spectrum dominated by a few simple aromatics with
mass peaks at 94, 166 and 178 amu corresponding to
phenol, fluorene (C\textsubscript{14}H\textsubscript{10}) and phenanthrene.

Track Bulb: Organic species present on an \textasciitilde 300 long
section of the interior cavity wall of Track 113 demon-
strated more pronounced distribution of high mass
peaks than observed from terminal particles. Consis-
tent with previously reported analysis of STARDUST
aerogel tracks, a number of prominent odd mass spe-
cies are evident at 167, 219, 223 & 267 amu and have
been ascribed to aromatic nitriles species. [6] Several
peak series with 14 amu spacing are evident, e.g.,
\begin{align*}
  &\text{C}_2\text{H}_2\text{N}_2, \text{C}_3\text{H}_4\text{N}_2, \text{C}_4\text{H}_6\text{N}_2, \ldots \\
  &\text{C}_2\text{H}_2\text{N}_3, \text{C}_3\text{H}_4\text{N}_3, \text{C}_4\text{H}_6\text{N}_3, \ldots \\
  &\text{C}_2\text{H}_2\text{N}_4, \text{C}_3\text{H}_4\text{N}_4, \text{C}_4\text{H}_6\text{N}_4, \ldots
\end{align*}
peaks at 282, 296, 310, 324 amu, indicative of successive replacement of –H with –CH\textsubscript{2}-H. The dominant peaks at 294 and 338 amu are unusual and do not correspond to any of the simple aromatic hydrocarbons commonly observed in carbonaceous or ordinary chondrites. We are currently investigating the possibility that these species may be the by-products of the \textit{in situ} carbothermal reduction of the silica aerogel by organic matter volatilized during impact shock heating. However the absence of abundant nanophase silicon carbide (SiC), which is one of the main products of the silica carbothermal reduction, argues against this.

**Conclusions:** Organic matter is heterogeneously distributed both along aerogel tracks and between terminal particles. These differences in the distribution and abundance of organics suggest that sample contamination via a common source is not responsible for the observed results. Impact shock heating has altered, although not necessarily obscured, the organic inventory of captured cometary grains.


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**Fig 1:** \textit{ultra} L2MS analysis of Stardust Track 13; (A) Extended depth of filed optical micro-graph of Track 113 prior to analysis. The ellipsoid bulb has an equatorial diameter of ~140 \textmu m and extends into the aerogel from the initial impact point to a depth of ~600 \textmu m. The thin terminal partial tracks radiating from the bulb base extend for a further ~400-800 \textmu m. Both the red box over the lower portion of the track bulb and the two terminal particles indicated by the red circles were analyzed for organics species; (B-D) Mass spectra from the track wall (B), and terminal particles TP1 (C) and TP3 (D). All spectra were obtained under identical experimental conditions, prominent peaks are labelled according to their mass.