Using Dust Shed from Asteroids as Microsamples to Link Remote Measurements with Meteorite Classes

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Introduction & Summary

• Given the diversity of asteroids, it is impossible to consider returning samples from each one
• Dust particles are abundant around asteroids
• Primary minerals and organic materials can be measured by in situ dust detector instruments
• These particles can be used to classify the parent body as an ordinary chondrite, basaltic achondrite, or other class of meteorite
• Such instruments could provide direct links to known meteorite groups without returning the samples to terrestrial laboratories
The importance of asteroids

- Building blocks of terrestrial, habitable worlds
- Incubator and delivery mechanism for organic molecules
- Tracers of dynamics, including planetary migration
- Meteorite parent bodies, providing direct evidence of early solar system history
- Interesting to other communities (planetary defense, ISRU, human exploration)

Dust as microsamples

- Dust detectors use particle impact to measure mass, velocity and directionality
- Dust analyzers add a mass spectrometer to analyze the impact-generated plasma cloud

- PUMA aboard VEGA 1 and 2 flew by comet P/Halley in 1986; particles are a mixture of silicates and organic material
- Cassini CDA \( (m/\Delta m \sim 30) \) identified salts in Enceladus plume, \( (\text{SiO}_2) \) particles embedded in Saturn’s E ring, and IDPs
- New analyzers have larger detectors and higher mass resolution \( (m/\Delta m > 200) \) recognizable particle compositions and mineralogies
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- New analyzers have larger detectors and higher mass resolution ($m/Δm > 200$) → recognizable particle compositions and mineralogies

Table 4. Chemical composition of Fe-rich particles. $N$, number of spectra.

<table>
<thead>
<tr>
<th></th>
<th>PUMA-1</th>
<th>PUMA-2</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$N$</td>
<td>$N$ with Ni (%)</td>
</tr>
<tr>
<td>Metal ($\text{Fe}/\text{S} &gt; 10.0$; Fe/$\text{Si} &gt; 10.0$)</td>
<td>21</td>
<td>43 8</td>
</tr>
<tr>
<td>Sulfides ($\text{Fe}/\text{S} &lt; 10.0$; $\text{Si}/\text{Si} &gt; 5.0$)</td>
<td>35</td>
<td>26 10</td>
</tr>
<tr>
<td>Silicates ($\text{Fe}/\text{Si} &lt; 10.0$; $\text{Si}/\text{Si} &gt; 5.0$)</td>
<td>15</td>
<td>40 4</td>
</tr>
<tr>
<td>Other</td>
<td>50</td>
<td>34 11</td>
</tr>
</tbody>
</table>

H$^+$  C$^+$  Fe$^+$  Rh$^+$  O$^+$
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- Cassini CDA \((m/\Delta m \sim 30)\) identified salts in Enceladus plume, \((\text{SiO}_2)\) particles embedded in Saturn’s E ring, and IDPs
- Next generation (SUDA, IDEX) has larger detectors and higher mass resolution \((m/\Delta m > 200)\) \(\rightarrow\) recognizable particle compositions and mineralogies

Linking microsamples to meteorites

- Combination of phase abundance (silicates, Fe-Ni metal, sulfides, phosphates, oxides) and mineral composition (Fe/Mg) distinguishes major meteorite groups
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![Diagram showing classification of meteorites]

- How many particles are needed to link to a class?
  - **100s to 1000s**
**Linking microsamples to meteorites**

- How many particles are needed to link to a class?
  - 100s to 1000s
- Hayabusa returned 1087 monomineralic particles, was that enough to link to an LL chondrite (in the absence of other evidence)?
  - Yes
  - But not for Stardust (n=34)

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**Microsample density**

- Dust clouds are small particles lost from the asteroid primarily by micrometeorite impacts
- Structure of the dust cloud is created by asymmetry in the micrometeorite sources

Ejecta cloud structure (particles/m³) for 10-km body with grains a > 50 nm
Density is enhanced on the apex side, decreases with heliocentric distance
Microsample density

- 100’s to 1000’s of particles could feasibly be encountered during flybys
- Highest impact rates would be encountered for
  - close flybys
  - smaller heliocentric distances
  - larger bodies

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- These particles can be used to classify the parent body as an ordinary chondrite, basaltic achondrite, or other class of meteorite
- Such instruments could provide direct links to known meteorite groups without returning the samples to terrestrial laboratories
- Missions are being developed that will take advantage of the opportunities provided by measuring asteroid dust, particularly in combination with other instruments