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

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- Next generation (SUDA, IDEX) has larger detectors and higher mass resolution ($m/\Delta m > 200$) → 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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How many particles are needed to link to a class?
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- 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)**

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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- Missions are being developed that will take advantage of the opportunities provided by measuring asteroid dust, particularly in combination with other instruments

Main-belt and NEO Tour with Imaging and Spectroscopy