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

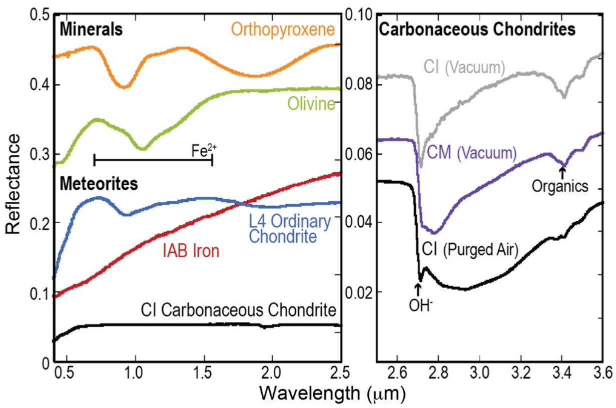
B. A. Cohen, J. A. Richardson
NASA Goddard Space Flight Center, Greenbelt MD 20771
(Barbara.A.Cohen@nasa.gov
J. R. Szalay
Princeton University, Princeton, NJ 08544
A. S. Rivkin, R. E. Klima, C. M. Ernst, N. L. Chabot
Applied Physics Laboratory, Johns Hopkins University, Laurel MD 20723
Z. Sternovsky and M. Horányi
University of Colorado, Boulder CO 80303

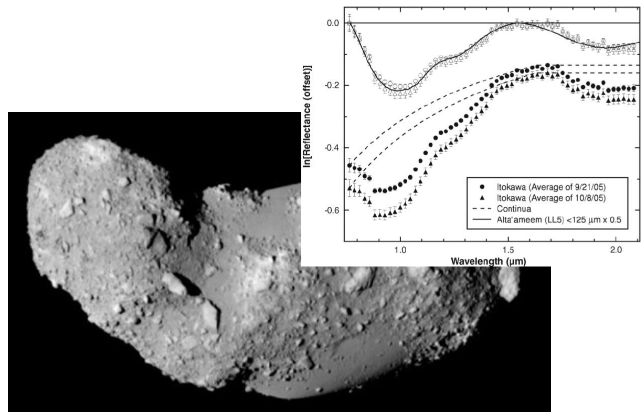
Introduction & Summary

- 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)

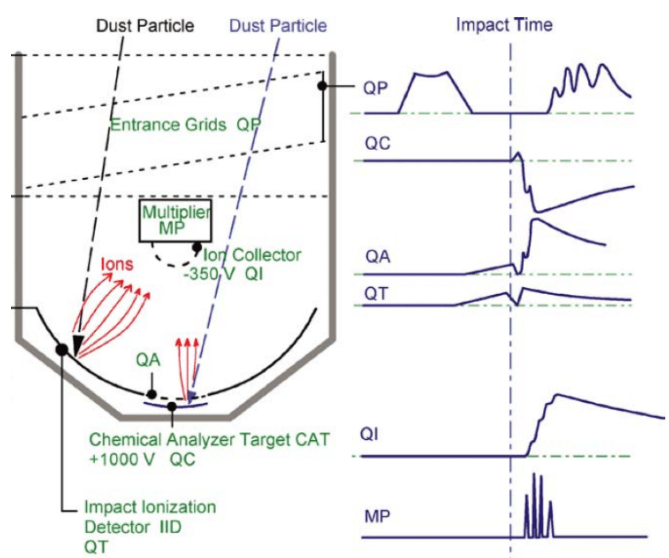




Dust as microsamples

- ***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/Δm* ~ 30) identified salts in Enceladus plume, (SiO_2) particles embedded in Saturn's E ring, and IDPs
- New analyzers have larger detectors and higher mass resolution (*m/Δm* > 200) → recognizable particle compositions and mineralogies



Impact onto small target (CAT)

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/Δm* ~ 30) identified salts in Enceladus plume, (SiO_2) particles embedded in Saturn's E ring, and IDPs
- New analyzers have larger detectors and higher mass resolution (*m/Δm* > 200) → recognizable particle compositions and mineralogies

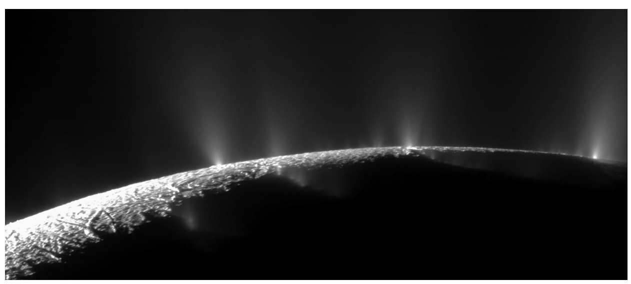
Table 4. Chemical composition of Fe-rich particles. *N*, number of spectra.

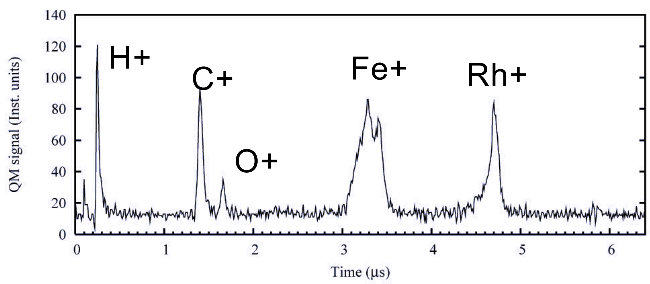
	PUMA-1		PUMA-2 *(N)*
	N	*N* with Ni (%)	
Metal (Fe/S > 10.0; Fe/Si > 10.0)	21	43	8
Sulfides (Fe/S < 10.0; S/Si > 5.0)	35	26	10
Silicates (Fe/Si < 10.0; Si/S > 5.0)	15	40	4
Other	50	34	11

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/Δm* ~ 30) identified salts in Enceladus plume, (SiO_2) particles embedded in Saturn's E ring, and IDPs
- New analyzers have larger detectors and higher mass resolution (*m/Δm* > 200) → recognizable particle compositions and mineralogies

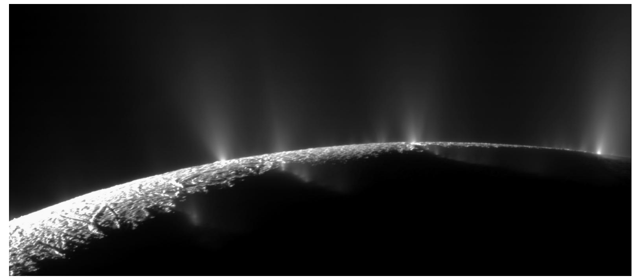


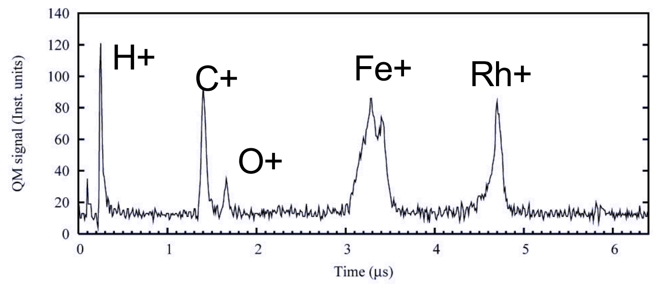


Dust as microsamples

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

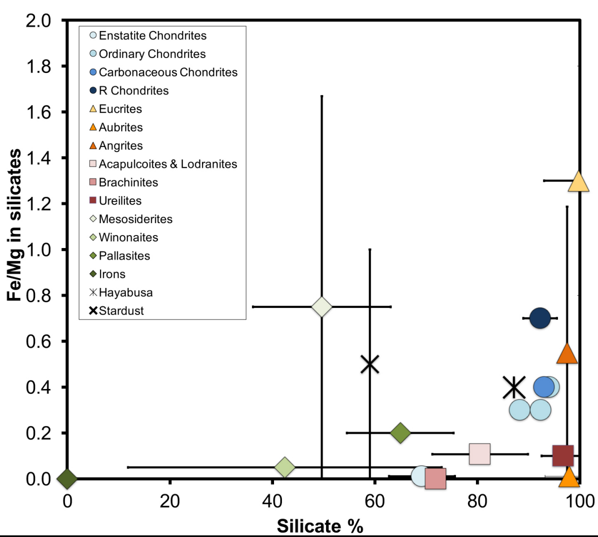
- PUMA aboard VEGA 1 and 2 flew by comet P/Halley in 1986; particles are a mixture of silicates and organic material
- Cassini CDA ($m/\Delta m$ ~ 30) identified salts in Enceladus plume, (SiO_2) particles embedded in Saturn's E ring, and IDPs
- Next generation (SUDA, IDEX) has larger detectors and higher mass resolution ($m/\Delta m$ > 200) → recognizable particle compositions and mineralogies

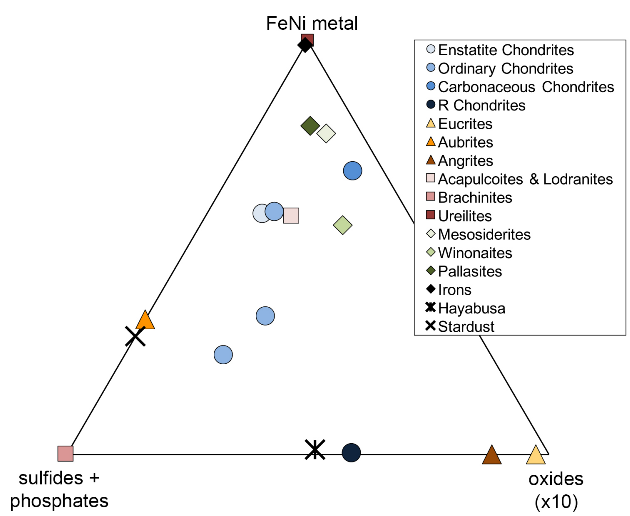




Linking microsamples to meteorites

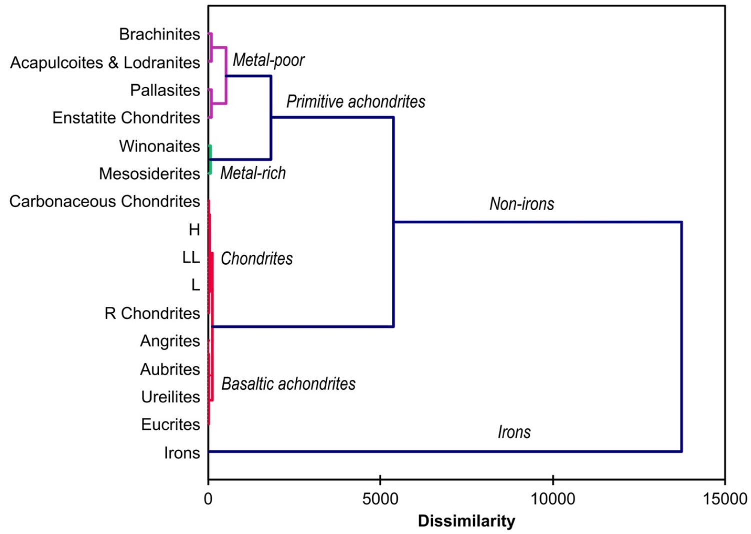
- Combination of phase abundance (silicates, Fe-Ni metal, sulfides, phosphates, oxides) and mineral composition (Fe/Mg) distinguishes major meteorite groups





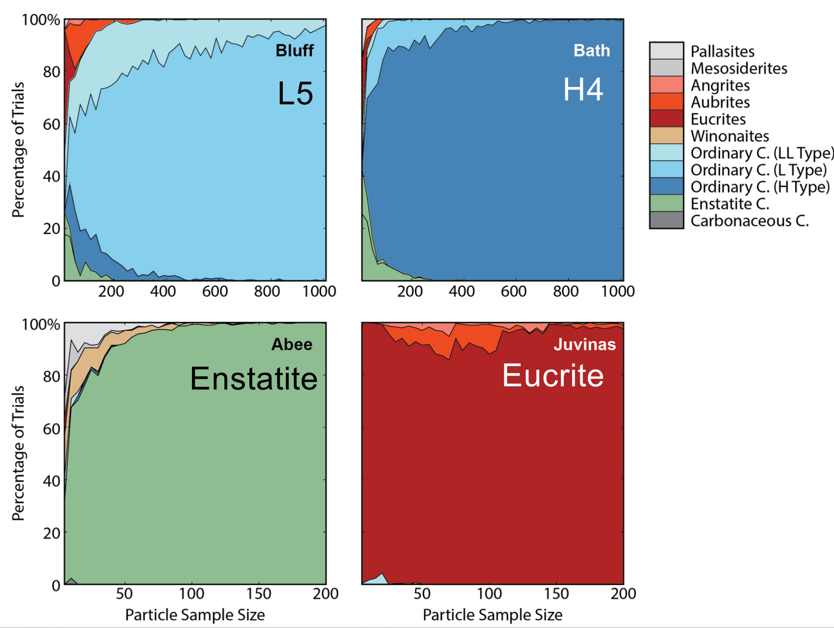
Linking microsamples to meteorites

- Combination of phase abundance (silicates, Fe-Ni metal, sulfides, phosphates, oxides) and mineral composition (Fe/Mg) distinguishes major meteorite groups



Linking microsamples to meteorites

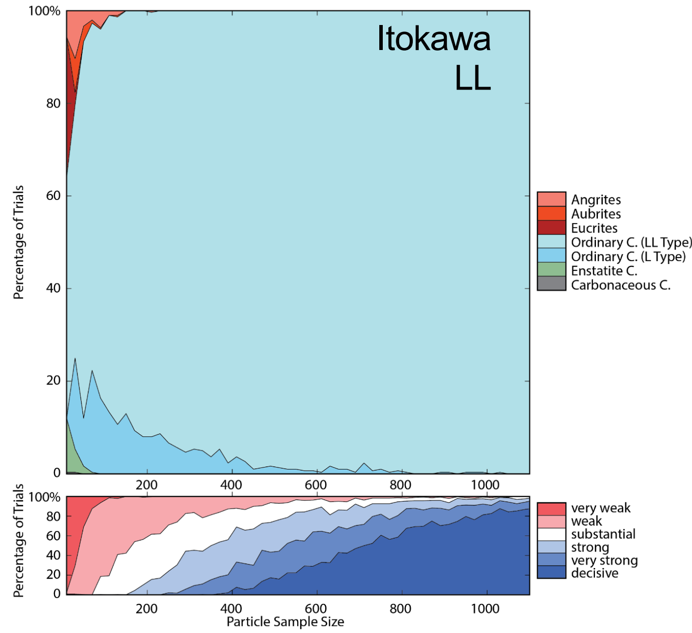
- How many particles are needed to link to a class?
- ***100s to 1000s***



Linking microsamples to meteorites

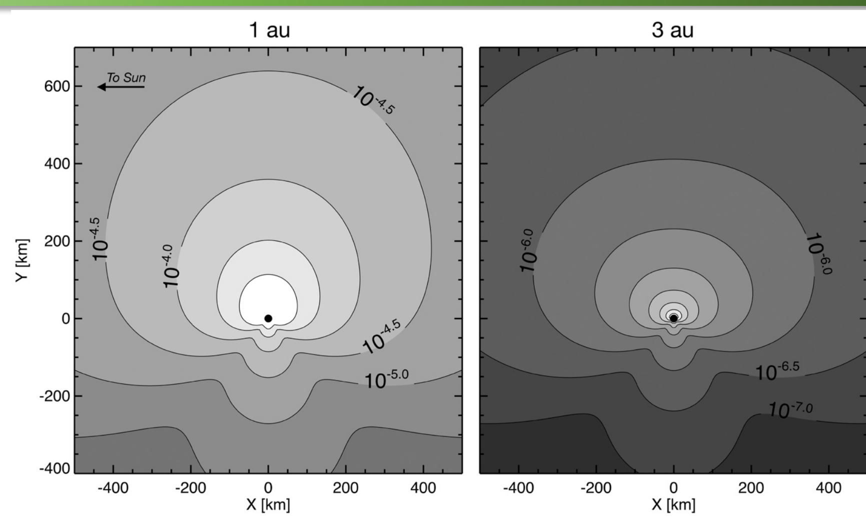
- How many particles are needed to link to a class?
- ***100s to 1000s***

- 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)*



Microsample density

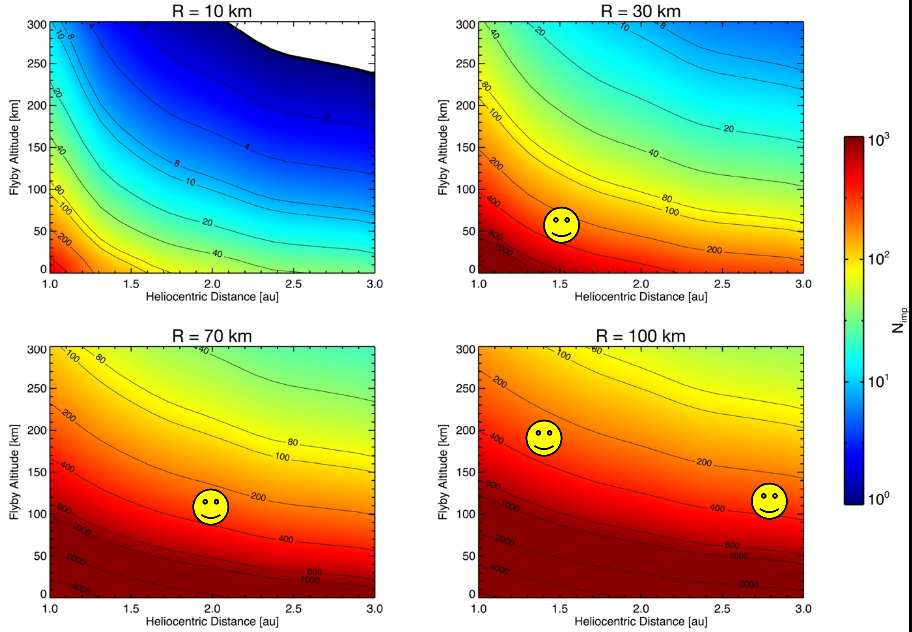
- Dust clouds are small particles lost from the asteroid primarily by **micrometeorite impacts**
- Structure of the dust cloud is created by asymmetry in the micrometeorite sources



Ejecta cloud structure (particles/m^3) 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



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

MANTIS
Main-belt and NEO Tour
with Imaging and Spectroscopy