Galahad

Primitive Asteroid Sample Return for New Frontiers
Andy Cheng (PI) & P. Michel (Science Team)
Asteroids and Solar System Origins

- Asteroids are remnants from the beginnings of solar system formation
  - They preserve materials from the first few million years of solar system history

- Primitive asteroids are the building blocks of terrestrial planets
  - Dust accreted to form asteroid-sized planetesimals, which then accreted to form planetary embryos
  - Some of these planetesimals, or largely unaltered fragments of them, survive to the present epoch

- Primitive asteroids preserve evidence of the processes and conditions of planet formation

- Primitive asteroids delivered organics and volatiles to early Earth – but which ones, and how much?
  - What role did these organics play in the development of life?
Why asteroid sample return?

- Meteorites have provided invaluable data about origins and evolution of planetary materials, but meteorites provide biased and incomplete samples of asteroids.
- Returned samples may provide fragile material which could not survive Earth atmospheric entry intact.
- Returned samples are uncontaminated by time spent in a terrestrial environment.
- Returned samples represent the diversity of material in an asteroid, possibly including material absent from the meteorite collection.
- Sample return provides geologic context for meteorites in our collection, plus clues to the nature and the evolution of the source body.
Science Goals

- Understand origins of organic-rich solar system material
- Understand processes and conditions of habitable planet formation
  - Return samples from a body little changed from those that were assembled to form Earth, its oceans and biosphere
- Understand the population of asteroids that may someday impact Earth
Asteroid Spectral Classes

- Spectral classes are based on visible data, though interpretation is informed by IR/radar/albedos
- Three main spectral “complexes”: C, X, S
  - S complex includes Gaspra, Ida, Eros, Itokawa, Apophis…
    - Dominant type in near-Earth population
  - C complex includes Mathilde, Ceres
    - Dominant types in main belt
    - Related to carbonaceous chondrite meteorites?
  - X complex includes Nereus, metallic objects?
- Outlying D class looks like comets, Trojans, Deimos…
  - Planetary protection requirements for D-asteroid samples
Asteroid Spectral Classes

Graph showing normalized reflectance vs. wavelength (μm) for different asteroid spectral classes: D class (Bus average), T class (Bus average), C class (Bus average), and B class (Bus average).
## Select Target Possibilities Considered

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
<th>H</th>
<th>D (km)</th>
<th>P (hrs)</th>
<th>Considered By</th>
</tr>
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<tbody>
<tr>
<td>(4015) Wilson-Harrington</td>
<td>CF</td>
<td>15.99</td>
<td>~4</td>
<td>6.1</td>
<td>Marco Polo</td>
</tr>
<tr>
<td>2002 AT4</td>
<td>D</td>
<td>20.9</td>
<td>~0.4</td>
<td></td>
<td>Marco Polo</td>
</tr>
<tr>
<td>2001 SG286</td>
<td>D</td>
<td>20.9</td>
<td>~0.4</td>
<td></td>
<td>Marco Polo</td>
</tr>
<tr>
<td>(162173) 1999 JU3</td>
<td>Cg</td>
<td>19.1</td>
<td>1.0</td>
<td>7.6</td>
<td>Marco Polo</td>
</tr>
<tr>
<td>(175706) 1996 FG3</td>
<td>C (bin.)</td>
<td>17.8</td>
<td>1.4,0.4</td>
<td>3.6</td>
<td>Marco Polo</td>
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<tr>
<td>(101955) 1999 RQ36</td>
<td>B</td>
<td>20.8</td>
<td>0.6</td>
<td>4.3</td>
<td>OSIRIS (Disc.)</td>
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<tr>
<td>2001 AE2</td>
<td>T</td>
<td>19.0</td>
<td>~1.0</td>
<td></td>
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</table>
Sample Analyses

- Isotopic sample analyses will be able to:
  - Identify pre-solar materials, formed around stars other than Sun.
  - Determine isotope ratios in hydrated minerals and organics and compare them to values for terrestrial, cometary, meteoritic materials.
  - Date formation and evolution events for primitive materials, including nebular condensation, chondrule formation, impact metamorphism and aqueous alteration.

- Organic Sample Analyses
  - Search for biochemically important molecules (e.g., sugars, amino acids)
  - Understand formation and evolution of organic species

- Mineralogic Sample Analyses
  - Study thermal and aqueous alteration history of planetesimals and parent bodies
  - Establish chemical, thermal and aqueous context for interpretation of isotopic and organic analyses.
  - Comparisons of Top-Surface and “Bulk” Samples to elucidate effects of space weathering and improve understanding of asteroid spectra
Remote Sensing

- Mineralogies, colors, albedos for surface features
- Structures, densities and surface regolith distributions
  - Is the object a rubble pile?
- Geologic context of sampling site
- Payload instruments under consideration: multi-spectral visible imaging, infrared spectral mapping, sample acquisition and transfer mechanisms.