Do we really understand the rocks that astronauts might be visiting?

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How can we know what it’s made of?

Lunar origin is established by comparing the mineralogy, the chemical composition, and the isotopic composition between meteorites and samples from the Moon collected by Apollo missions.

Most Martian meteorites are 1.3 billion years old or less, much younger than typical meteorites from asteroids which are 4.5 billion years old. They also have higher contents of volatiles than igneous meteorites. The gases trapped in the meteorites match those that Viking measured in the Martian atmosphere.
Forest City (H5 ordinary chondrite) is covered by a fusion coating. One tip has been cut off, exposing the lighter gray, speckled interior. Fusion coatings are very thin.

Below is the Gibeon (IVA) iron meteorite, showing well-developed regmaglypts (thumbprints) on the surface of the meteorite.

At the left is Allende (a CV3 carbonaceous chondrite). Patches of the fusion coating have worn off, exposing the lighter gray interior.
What do asteroids look like?

To spacecraft cameras, both asteroids and comets (when far enough away from the sun) look much like cratered rocks. Their surfaces are very dark due to long exposure to space. Humans have never seen an asteroid up close and personal.
Even smaller asteroids are not uniform

Asteroid Itokowa, target of the Japanese Hayabusa Mission
Zooming in on Itokawa, we see very different types of local terrain.
Variation persists at the local level
The First Steps of Physical Characterization are Accomplished From the Ground

| Visible | Astrometry - refine orbit and ephemerides  
| Cometary Activity - evidence of volatiles  
| Satellites - evidence of recent splitting / fresh surface material, mass determination |
| Radar  | Astrometry - very high precision orbit refinement  
| Shape Model - shape and size of asteroid  
| Surface Features - evidence of craters, boulders and surface features down to ~7 meters  
| Surface Roughness - evidence of regolith, size distribution of regolith  
| Satellites - evidence of recent splitting / fresh surface material, mass determination |
| Meteors | Detection - evidence of past volatile outgassing  
| Orbits - past history of volatile outgassing |
Observational Clues to Asteroid Properties

Visible Photometry
- **Lightcurve** - rotation period, simple shape model, non-principal axis rotation, evidence of satellites, heterogeneity of surface
- **Colors** - taxonomy, rough mineralogy
- **Phase Function** - brightness, rough size, rough albedo, evidence of regolith

Visible Spectroscopy
- **Spectroscopy** - taxonomy, mineralogy, heterogeneity of surface

Near-Infrared Spectroscopy
- **Spectroscopy** - taxonomy, mineralogy, heterogeneity of surface, albedo of dark objects

Thermal Infrared Spectroscopy
- **Spectroscopy** - mineralogy, heterogeneity of surface, albedo, size, thermal inertia, evidence of regolith

Spitzer Thermal Infrared Spectra
- For a Typical Carbonaceous NEA
Asteroids are categorized by their spectra, with the majority falling into three main groups: the C-type, S-type & M-type. These are carbon-rich, stony and metallic resp.


Each spectrum covers the spectral range from 450 nm to 2400 nm (left to right).
### Number of Known Asteroids

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
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<tbody>
<tr>
<td>1980</td>
<td>&lt; 10,000</td>
</tr>
<tr>
<td>1985</td>
<td>&lt; 12,000</td>
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<td>~ 325,000</td>
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<td>2010</td>
<td>~ 525,000</td>
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“*The Near-Earth Object Surveys and Hazard Mitigation Strategies: Interim Report*” from the NAS estimates that we have found only about 10% of the >140 m class objects as of 2010.

We have only classified about 5000 of the known asteroids.
If the goal of a manned mission is making specific measurements or emplacement and testing of specialized equipment, then that equipment will be designed for a specific set of requirements and will only work on certain types of material (e.g. spectral classes).
Asteroid classification is the basis for the exploration of the solar system.

Commercial exploitation of nearby asteroids, as well as the far future selection of asteroid resources to support independent habitats, will require prior knowledge of their composition & structure.
What do we need to do now?

- If we are going to an asteroid as the first step in a long-term plan to explore and exploit the solar system then we need to understand how to translate the spectral signatures of asteroids into knowledge of their geology.

- From previous experience, we need to visit prime examples of the specific types of spectrally characterized bodies with well instrumented spacecraft.