REMOTE SENSING OF ASTEROIDS FROM EARTH AND SPACE. L. A. McFadden NASA, Goddard Space Flight Center. E-mail: lucy.mcfadden@nasa.gov.

Introduction: The story of the asteroid belt and its role in formation of our solar system is very different now than it was about two decades ago thanks to the complementary information provided by ground- and space-based studies including recent sample return. It was 1991 when the Galileo spacecraft made the first asteroid flyby of 951 Gaspra (1). The return of samples directly from 25143 Itokawa (2) in 2010 resulted in 9 orders of magnitude increase in the scale at which asteroids are studied!

Orbital Evolution: Asteroid orbital evolution is studied by computer simulation (3). When xenolithic material is found in returned samples we know that dynamical mixing has occurred. This information constrains models of orbital evolution. Evidence from comets suggests mixing across the entire solar system (4).

In Situ Studies: Space-based studies numbering 10's of asteroids, takes us into the realm of geology. The position of a spacecraft in orbit around an asteroid provides the most precise mass. Images are the raw data for shape models. With accurate mass and volume, the bulk density is determined contraining bulk composition and internal structure. Geological context is derived from surface morphology. Cratering is ubiquitous and crustal stresses produce ridges or graben placing limits on strength. Further, surface compositional information is determined from spectral reflectance measurements spanning ultraviolet to infrared wavelengths. Some information about mineralogy, surface texture and scattering properties become known for the top few microns of regolith (5). Gamma ray and neutron detectors probe a little deeper and reveal elemental abundances and ratios for O, Mg, Al, Si, Fe, K, Ca, among the rock-forming elements and H, C, N, Cl of the volatile elements (6).

Surveys: Thousands of asteroids are characterized by ground and space-based telescopic surveys. Spatial resolution is limited compared to *in situ* studies. Radiometric measurements combined with visual magnitude result in derived diameters for >100,000 asteroids (7). Lightcurve measurements (8) and radar imaging (9) yield rotation rate, shape and aspect ratios. The intensity of the reflected light or radar signal is proportional to the cross sectional area of the asteroid. *In situ* exploration refines and extends interpretations from telescopic surveys.

Recent Results and Future Plans: Dawn mission tells us the asteroid belt had multiple episodes of violent collisions (10) and confirms Vesta's differentiated state. Dynamical models predict that asteroids originally condensed in both the inner and outer solar system and now reside between Mars and Jupiter (11). Direct observational evidence of outer solar system material in the asteroid belt remains to be seen. Sample return missions are expected to reveal just how mixed the asteroid belt is.

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