Missions to Primitive Bodies: Past, Present, and Future

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Approach

- Relationship of meteorites to asteroids and comets
- Highlights of results from primitive bodies missions
- Need for new *in situ* techniques to address Decadal Survey questions

Early thoughts on Primitive Bodies Missions – We don't need them.

- "Why bother? We have samples of cosmic material delivered to our doorsteps free of charge by God – in the form of meteorites." Harold Urey (one of founders of modern geochemistry) – ca 1965
- Urey, and others, were convinced that the in-fall of cosmic material would cover the Moon and other airless bodies with ordinary chondrites. Hard to even get approval in this era for proposals to study asteroid spectra etc. –

"You'll just see chondrites."

Post-Apollo

- “Now we have samples of the Moon delivered free of charge to our doorsteps by NASA.” Harold Urey - ca 1970
- The ‘primitive’ Moon was NOT primitive – and NOT chondritic

Telescopic Era (1970-1980)
Diversity of Asteroids

- Spectral survey – Vesta et al.
- Albedos – Matson thesis
- Connection to meteorites
- Comets – low albedos also
- Distribution of asteroid types with AU
- Mission studies looked at different types – Vesta/Ceres identified as important targets

Vesta:
First Asteroid-Meteorite Connection

The Asteroid VESTA:

Spectral Reflectivity and Compositional Implications

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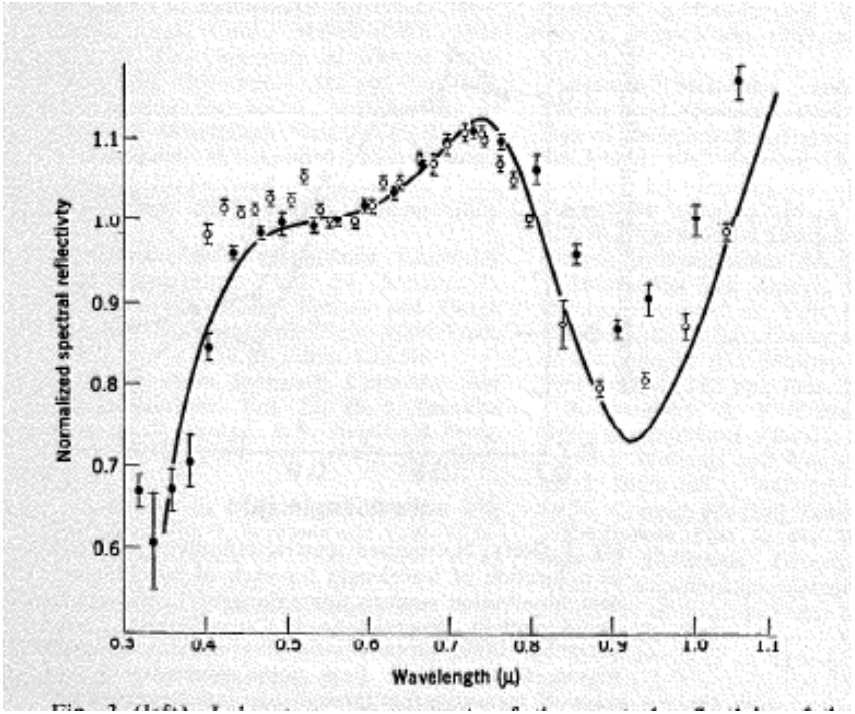
Submitted to Science April 1970

Contribution #7 of the Planetary Astronomy Laboratory



Meteorites-Asteroids Albedo and Spectral Reflectance

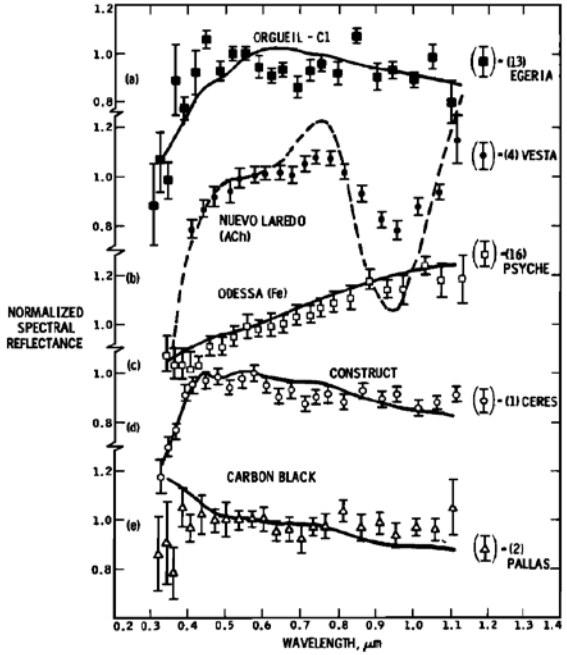


Fig. 16. Normalized spectral reflectance (0.3–1.1 μm) for five asteroids compared with laboratory reflectances of meteorites, our mixture of montmorillonite and carbon black, and pure carbon black. The asteroid spectral reflectances are from *Chapman et al.* [1973] and *McCord et al.* [1970]. The curve for Nuevo Laredo also comes from *McCord et al.* [1970].

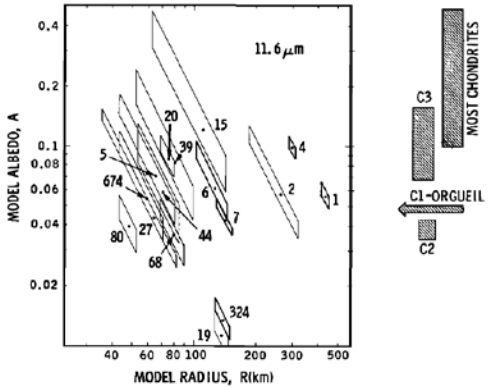


Fig. 15. Asteroid model albedos (bolometric Bond) and model radii, modified after *Matson* [1972]. The regions assigned to each asteroid represent the error limits on model parameters and 11.6-μm infrared photometry. Along the right-hand ordinate are shown the approximate ranges of meteorite reflectances taken from this study, *Adams and Filice* [1967], *Chapman and Salisbury* [1973], and *Egan et al.* [1973].

Johnson and Fanale, 1973

First Primitive Body Mission
1986: Giotto – Comet Halley

- Low albedo
- CHON particles
- D/H – not terrestrial

Asteroids

List of asteroids visited by spacecraft

From Wikipedia, the free encyclopedia

The following table lists asteroids that have been visited by spacecraft.

Name	Diameter (km)	Discovered	Spacecraft	Year(s)	Closest Approach (km)	Notes
4 Vesta	529	Mar 29, 1807	*Dawn*	2011–2012	approx. 200	Orbiting; planned to break orbit in July 2012
21 Lutetia	120×100×80	Nov 15, 1852	*Rosetta*	2010	3,162	Flyby
2867 Šteins	4.6	Nov 4, 1969	*Rosetta*	2008	800	Flyby
132524 APL	~2.5	May 9, 2002	*New Horizons*	2006	101,867	Distant flyby
25143 Itokawa	~1	Sep 26, 1998	*Hayabusa*	2005	0	Landed; returned samples to Earth
5535 Annefrank	4.0	Mar 23, 1942	*Stardust*	2002	3,079	Flyby
433 Eros	13×13×33	Aug 13, 1898	*NEAR Shoemaker*	2001	0	Landed
2685 Masursky	15-20	May 3, 1981	*Cassini*	2000	1,600,000	Distant flyby
433 Eros	13×13×33	Aug 13, 1898	*NEAR Shoemaker*	2000	35	Orbited; first asteroid studied from orbit
9969 Braille	2.2×0.6	May 27, 1992	*Deep Space 1*	1999	26	Flyby; followed by flyby of Comet Borrelly
433 Eros	13×13×33	Aug 13, 1898	*NEAR Shoemaker*	1998	3,827	Flyby
253 Mathilde	66×48×46	Nov 12, 1885	*NEAR Shoemaker*	1997	1,212	Flyby
243 Ida	56×24×21	Sep 29, 1884	*Galileo*	1993	2,390	Flyby; discovered Dactyl (moon)
951 Gaspra	18.2×10.5×8.9	Jul 30, 1916	*Galileo*	1991	1,600	Flyby; first asteroid visited by a spacecraft

First S-Asteroid Encounters – Main Belt Galileo

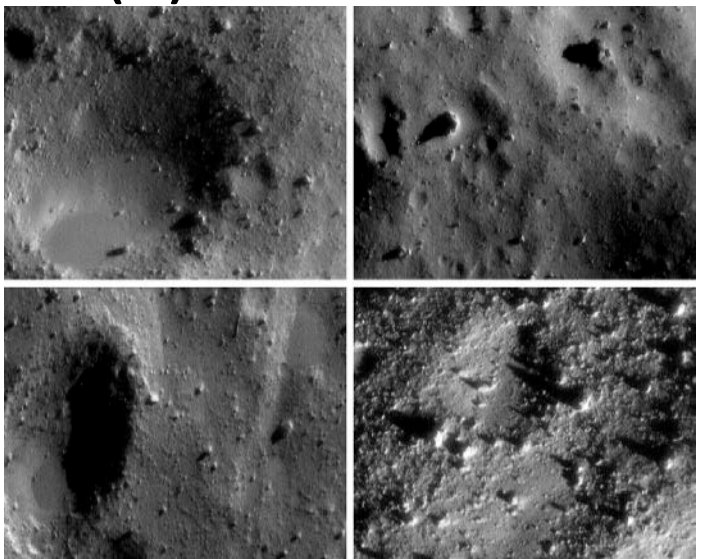
- Gaspra – 1991

- Ida – 1993
  - Discovery of Dacty, first confirmed asteroid moon

NEAR – Shoemaker
NEO's

- Flyby Mathilde (C) – 1997
  - Low porosities of asteroids ~50%

- First Orbiter/Lander: Eros (S) - 2000



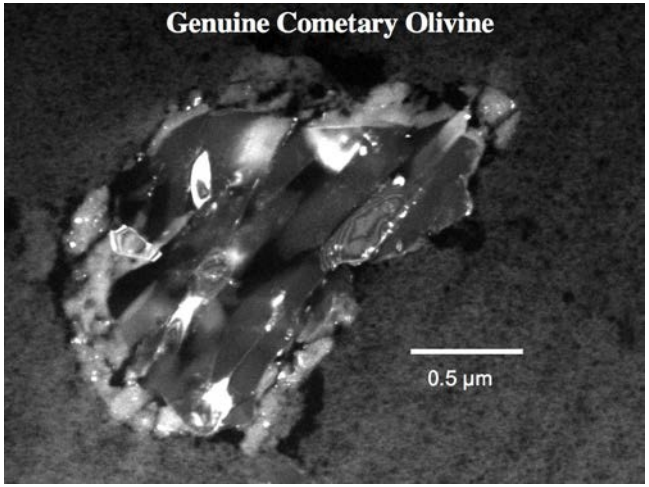
Deep Space 1
First Ion Drive Planetary Mission

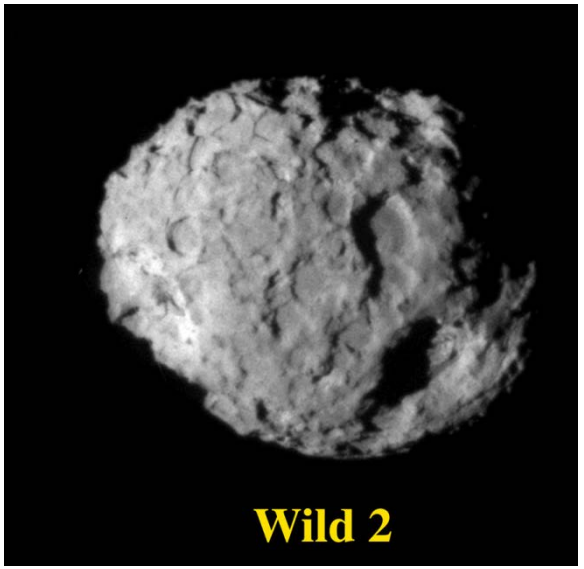
- Comet Borelly: 2001

Stardust

- NEO flyby 2003– AnneFrank

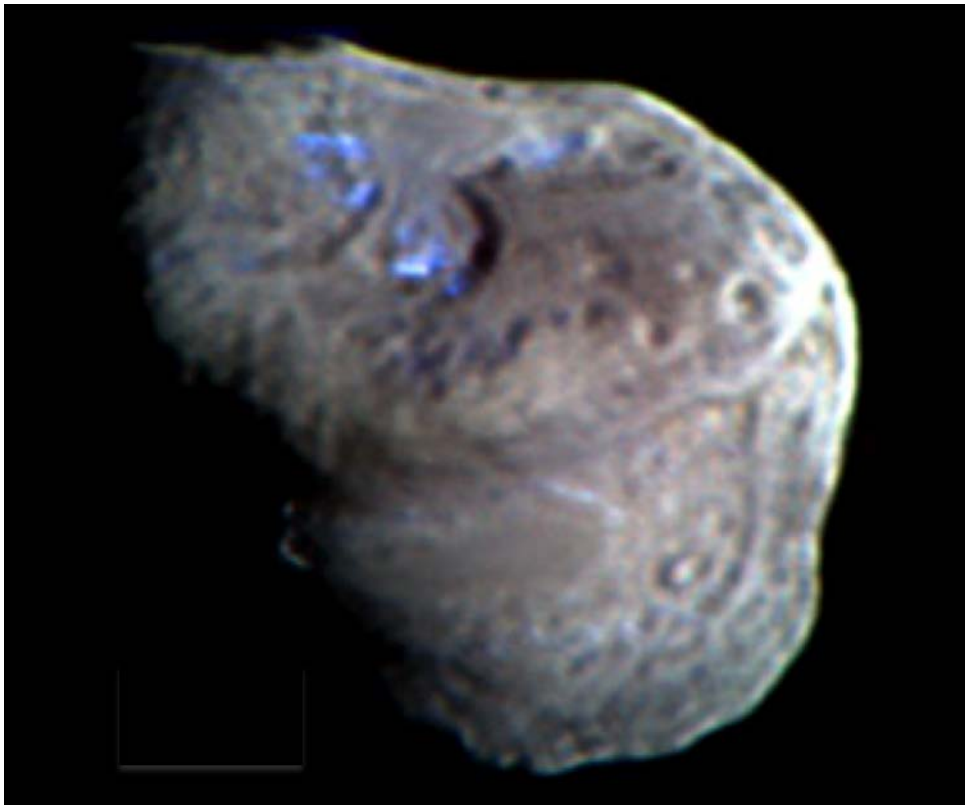
- First comet sample return – Wild 2 2006



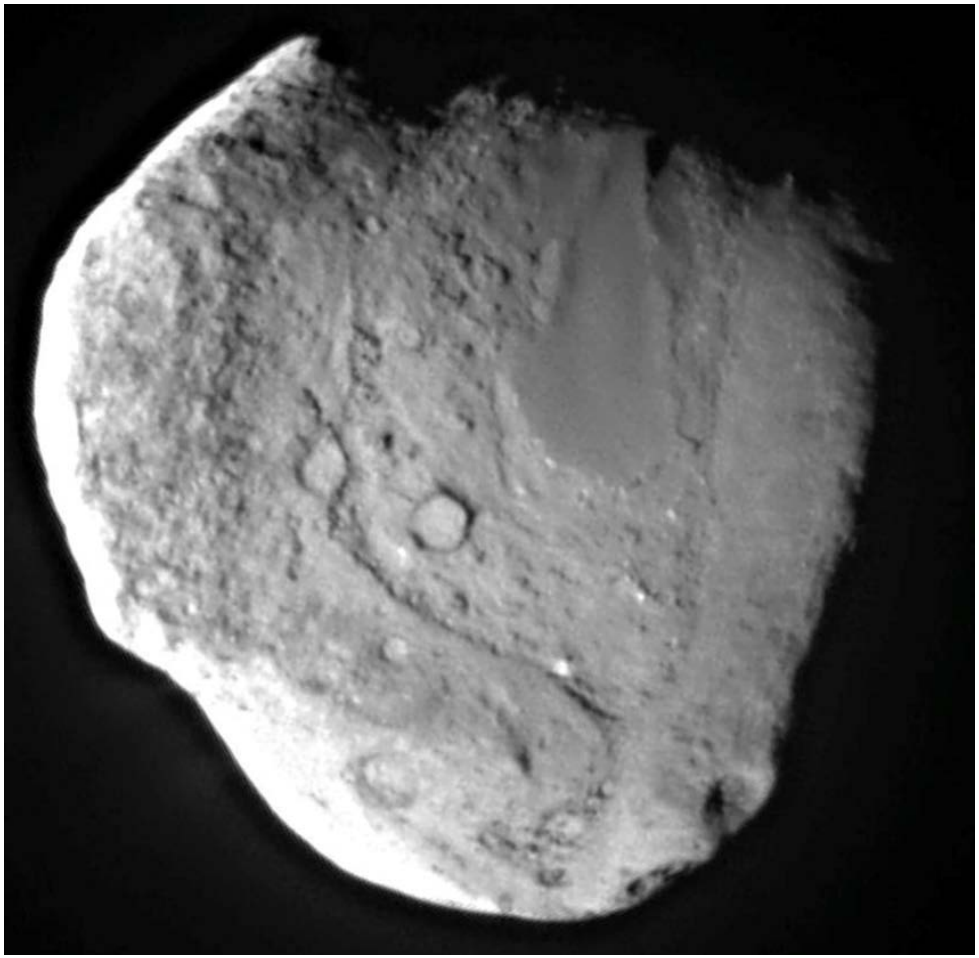


Deep Impact

- Temple 1 – 2005

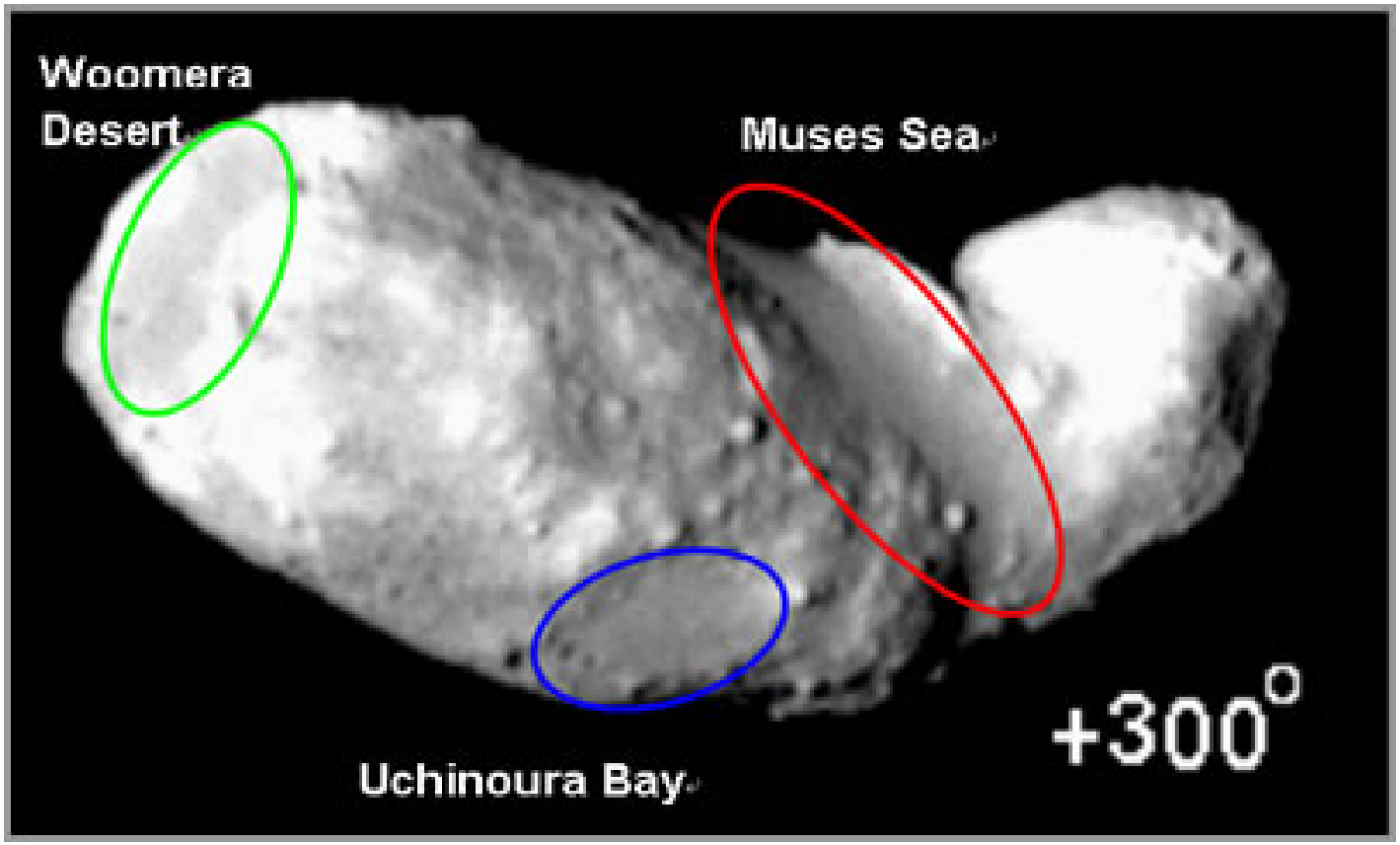


Stardust NExT: Flyby of Deep Impact Target, Temple 1 - 2011



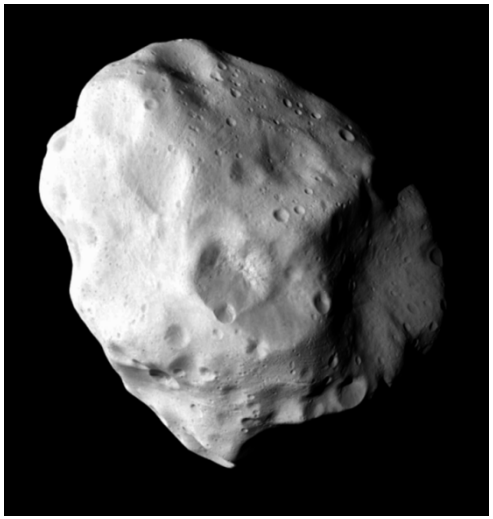
Hayabusa
First S-type NEO sample return - 2010

- Itokawa



Rosetta

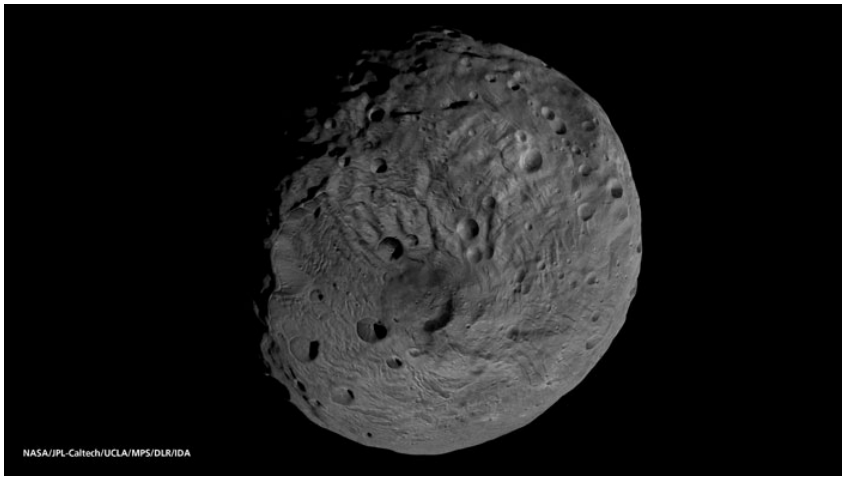
- Steins 2008 - flyby
- Lutetia 2010 – Large main belt asteroid flyby: Differentiated Asteroid?



- Comet G-M – primary target

DAWN – Vesta and Ceres
First Main Belt Asteroid Orbiter

- Vesta – currently in orbit



- Composition – Evidence for link to HED meteorites => “Effective sample return from a differentiated asteroid”

Future Missions

- Osiris-Rex: NF 3
  First C-type NEO Sample Return
- Comet Sample Return: proposed
  NF 4 mission

What have we learned?

- “Primitive” Bodies span a range of different bodies and evolutionary histories
- Dynamical re-arrangement of solar system now a major issue
- Decadal Survey
  - Recommended observations imply multiple sample returns - unlikely
  - In Situ investigations needed to address goals