ASTEROID LIDAR FOR TOPOGRAPHY, MAPPING AND LANDING. David E. Smith[1], Xiaoli Sun[2], Erwan Mazarico[2], and Maria T. Zuber[1], [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 USA, [2]Solar System Exploration Division, NASA-GSFC Greenbelt, Maryland 20771 USA.

Introduction: Investigations of asteroids and other primitive bodies can provide insight about the physical properties of these objects, their origin, the evolution of our solar system, and potential encounters with Earth. To achieve these goals, lidar instruments are essential tools in asteroid exploration. Lidars, in concert with gravity measurements, can be used to precisely determine asteroid shape, rotational and orbital dynamics, and internal structure. An ideal asteroid lidar should be able to operate in several modes, including a long-distance survey mode, a precision global-mapping mode, a high-resolution targeted mapping mode, and real-time guidance mode for touch down.

Science Benefits: Small bodies are remnants of planetary formation, preserving constituents indicative of conditions in the early Solar System in unique, mostly pristine settings. Recent [1, 2, 3] or proposed [4] astronomic surveys of asteroids have taught us about their population, with implications for the dynamical evolution of the solar system [5, 6]. The near-Earth object (NEO) population also poses a threat of Earth impact and a better understanding of their internal structure can help developing mitigation strategies. Despite relative ease of access to spacecraft, only a handful of asteroids have been extensively surveyed [7, 8, 9, 10, 11, 12]. Robotic exploration has allowed their study as unique objects, and observations have shown the complexity and diversity of their individual conditions. In addition to information on their surface composition from spectral or nuclear instrumentation, their shape, gravity, and morphology help us understand their internal structure and the processes that have affected them, key to clarifying their origin in order to constrain planetary formation.

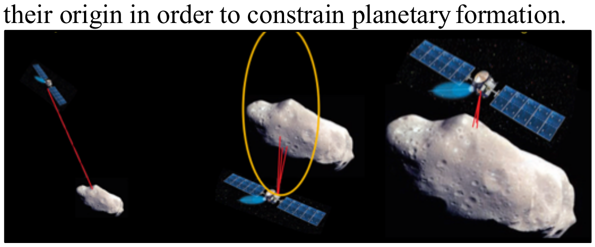

Fig 1 *shows examples of surveying, mapping from orbit, and close proximity operations.*

Typical Science Questions:

1. What is the asteroid's interior structure and its coherence?
2. What does shape and structure reveal about the body history?
3. What is the spin state?
4. Can its history be constrained?
5. Is there a signature of recent torques?
6. Was the interior disrupted from a high spin rate?

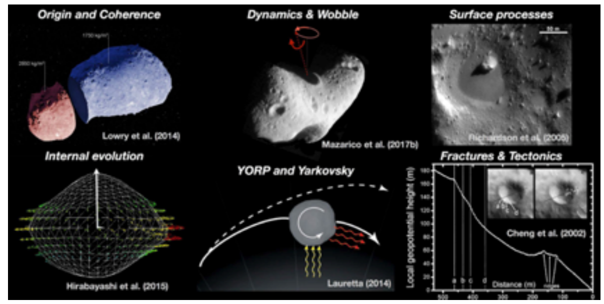

Fig 2. *Illustrates key objectives for a small-body mission. The lidar can address such topics due to its high precision, geodetic accuracy, high resolution swaths.*

Instrument Concept: We describe a miniaturized multi-function swath-mapping lidar based on return-to-zero pseudo noise (RZPN) code laser modulation and detection technique. The receiver detects the laser pulse train instead of individual laser pulses and determines the range by correlating the received signal with the RZPN kernel [13, 14]. It uses a new 2x8 pixel HgCdTe avalanche photodiode array, which gives near quantum limited receiver sensitivity and wide dynamic range from short- to mid-infrared wavelengths. Our approach enables the use of low peak-power lasers, such as fiber lasers used in terrestrial telecommunications, for long-distance measurements without aliasing.

	Conventional planetary lidar	Current and past asteroid lidar	Flash lidar	Asteroid lidar
Nominal range capability	800±600, MLA 400±200 km, MOLA 50±20 km, LOLA	15–100 km NLR 0.030–25 km, Ha. 0.5–7.5 km, OLA	1 m to 6 km, ASC	1 m to 500 km (adjustable)
Dynamic range	10^2	up to 10^6	10^7	10^{11}
Precision	0.1 to 1.0 m	0.05 to 1.0 m	0.05 to 0.2 m	0.05 to 1.0 m
Beams or Pixels	1 or 5 beams	1 beam	128x128 pixels	2x8 pixels
Normal Albedo	Yes	No, Yes	No	Yes
Laser transmitter	Nd:YAG custom built	Nd:YAG custom built	Nd:YAG custom built	Fiber lasers from telecom industry
Pulse energy	3 to 50 mJ, fixed	0.7 to 15 mJ, fixed	5 mJ, fixed	2 ∝J, programable
Pulse rate	8 to 28 Hz, fixed	1 to 100 Hz, fixed	20 Hz, fixed	2 MHz, programable
Mass	7-30 kg	5-7 kg	6-7 kg	(6 kg)
Power	17-34 W	15 19 59 W	60-70 W	(35-50 W), variable
Size	30x30x30 cm	27x32x23 cm	14x21x17 cm	20x20x10 cm

Table 1 *compares the asteroid lidar with various other lidar systems used in planetary research.*

Summary: The asteroid lidar concept provides the full range of measurements usually required in asteroid research and landing.

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