EPSC Abstracts
Vol. 10, EPSC2015-505, 2015
European Planetary Science Congress 2015

Two radars for AIM mission: A direct observation of the asteroid's structure from deep interior to regolith.

A. Herique (1), V. Ciarletti (2)

(1) Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
CNRS, IPAG, F- 38000 Grenoble, France (alain.herique@obs.ujf-grenoble.fr)

(2) UVSQ (UPSay); CNRS/INSU; LATMOS-IPSL, 11 bd d'Alembert, 78280 Guyancourt, France

Abstract

Our knowledge of the internal structure of asteroids is, so far, indirect – relying entirely on inferences from remote sensing observations of the surface, and theoretical modeling. What are the bulk properties of the regolith and deep interior? And what are the physical processes that shape their internal structures?

Direct measurements are needed to provide answers that will directly improve our ability to understand and model the mechanisms driving Near Earth Asteroids (NEA) for the benefit of science as well as for planetary defense or exploration. Radar tomography is the only technique to characterize internal structure from decimetric scale to global scale.

This paper reviews the benefits of direct measurement of the asteroid interior. Then the radar concepts for both deep interior and shallow subsurface are presented and the radar payload proposed for the AIDA/AIM mission is outlined.

1. Asteroid's internal structure

The internal structure of asteroids is still poorly known and has never been measured directly. Our knowledge is relying entirely on inferences from remote sensing observations of the surface and theoretical modeling. Is the body a monolithic piece of rock or a rubble-pile, an aggregate of boulders held together by gravity? How much porosity it contains, both in the form of micro-scale or macro-scale porosity? What is the typical size of the constituent blocs? Are these blocs homogeneous or heterogeneous? The body is covered by a regolith whose properties remain largely unknown in term of depth, size distribution and spatial variation. Is it resulting from fine particles re-accretion or from thermal fracturing? What are its coherent forces? How to model its thermal conductivity, while this parameter is so important to estimate Yarkowsky and Yorp effects?

After several asteroid orbiting missions, theses crucial and yet basic questions remain open. Direct measurements of asteroid deep interior and regolith structure are needed to better understand the asteroid accretion and dynamical evolution and to provide answers that will directly improve our ability to understand and model the mechanisms driving Near Earth Asteroids (NEA) deflection and other risk mitigation techniques. There is no way to determine this from ground-based observation.

2. Radar observation

Radar operating from a spacecraft is the only technique capable of achieving this science objective of characterizing the internal structure and heterogeneity from submetric to global scale for the benefit of science as well as for planetary defense or exploration.

The deep interior structure tomography requires low-frequency radar to penetrate throughout the complete body. The radar wave propagation delay and the received power are related to the complex dielectric permittivity (i.e to the composition and microporosity) and the small scale heterogeneities (scattering losses) while the spatial variation of the signal and the multiple paths provide information on the presence of heterogeneities (variations in composition and/or porosity), layers, ice lens. A partial coverage will provide "cuts" of the body when a dense coverage will allow a complete tomography. Two instruments concepts can be considered: a monostatic radar like

Marsis/Mars Express (ESA) that will analyze radar waves transmitted by the orbiter and received after reflection by the asteroid, its surface and its internal structures; a bistatic radar like Consert/Rosetta (ESA) that will analyze radar waves transmitted by a lander, propagated through the body and received by the orbiter.

Imaging the first ~50 meters of the subsurface with a decimetric resolution to identify layering and to reconnect surface measurements to internal structure requires a higher frequency radar on Orbiter only, like WISDOM developed for ExoMars Rover (ESA) with a frequency ranging from 300 MHz up to 2.7 GHz. At larger observation distance, this radar working in SAR mode can map surface and sub-surface backscattering coefficient. In the frame of the AIDA mission, this is a unique opportunity to estimate regolith rearrangement in the impact area.

3. AIDA/AIM Mission

Both radars are presently under study in the frame of the ESA's Asteroid Impact Monitoring mission: AIM would be a stand-alone mission or constitute the Asteroid Impact & Deflection Assessment (AIDA) with the Double Asteroid Redirection Test (DART) mission under study by APL. The AIM objective is to characterize "Didymoon", the secondary body of the binary NEA (65803) Didymos and to contribute to the evaluation of impact mitigation strategies [1].

AIM will carry Mascot2, a lander inheriting from Mascot/Hayabusa to land on Didymoon. On Mascot2 and AIM, the bistatic radar will probe the Didymoon's internal structure at 60 MHz, with a typical resolution of 30 meters to characterize the structural homogeneity of the interior. The objective is to discriminate monolithic structure vs. building blocks, to derive the possible presence of various constituting blocks and to derive an estimate of the average complex dielectric permittivity, which relates to the mineralogy and porosity of the constituting material. Assuming a full 3D coverage of the body, the radar will determine Didymoon’s 3D structure: deep layering, spatial variability of the density, of the block size distribution, of the average permittivity.

When the AIM is combined with DART, the bistatic radar will be used to characterize possible structural modification induced by DART impact. It will also support mass determination and orbit characterization with range measurements during and after descent. Finally, it will contribute to the characterization of the primary body of the Didymos system (referred to as "Didymain").

On AIM mothership, the shallow subsurface radar’s objective is to determine the structure and layering of Didymoon and Didymain shallow sub-surfaces down to a few meters with a submetric resolution. The radar also will map the spatial variation of the regolith texture which is related to the size and mineralogy of the constituting grains and macro-porosity and spatial distribution of geomorphological elements (rocks, boulders, etc) that are embedded in the subsurface.

With DART, the shallow subsurface radar is a key instrument to assess the regolith tomography before and after impact in order to characterize the crater topography, the internal structure modifications and the mass loss. It should also be able to monitor the impact ejecta, generated by the collision with the DART spacecraft, in the vicinity of the secondary asteroid in order to estimate size distribution, speed, and total mass.

It will also contribute to shape modeling, mass determination and orbital characterization with altimeter mode. And finally, more prospective objectives will be considered, such as the support to ground-based radar measurements like Arecibo or Goldstone: orbital radar measurement is indeed a unique opportunity to cross-validate ground-based NEA characterization with radar signal in the same frequency range and with better resolution, better SNR and more favorable geometry.

References

[1] Michel, P. et al. Asteroid Impact and Deflection Assessment (AIDA) Mission: Science Return and Mitigation Relevance. Planetary Defense Conference 2015., Paper IAA-PDC-15-04-01.

[2] Herique, A. et al., A direct observation of the asteroid's structure from deep interior to regolith: why and how? Planetary Defense Conference 2015, Paper IAA-PDC-15-04-06.