PDC2015
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IAA-PDC-04-06

A DIRECT OBSERVATION THE ASTEROID'S STRUCTURE FROM DEEP INTERIOR TO REGOLITH: WHY AND HOW DO IT?

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Keywords: *ASTEROID'S STRUCTURE, RADAR, SOUNDING, REOLITH, DEEP INTERIOR*

ABSTRACT

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 and 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. Radar operating from a spacecraft is the only technique capable of achieving this science objec-tive of characterizing the internal structure and heterogeneity from submetric to global scale for the benefit of science as well as for planetary defence 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 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 maps surface and sub-surface backscattering coefficient.

Bistatic tomography radar and high frequency radar are proposed to instrument the AIDA/AIM mission (ESA). This is a unique opportunity to estimate regolith rearrangement in the impact area.

This paper reviews the benefits of direct measurement of the asteroid interior. Then the radar concepts for both deep interior and near surface sounding are shown.

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