A DIRECT OBSERVATION OF THE ASTEROID'S STRUCTURE FROM DEEP INTERIOR TO REGOLITH: TWO RADARS ON THE AIM MISSION A. Herique[1] , V Ciarletti[2] and the AIM Team, [1]Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France, alain.herique@obs.ujf-grenoble.fr, [2]LATMOS/IPSL;UVSQ;UMPC, Guyancourt, France

Introduction: 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 objective 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 [1].

Low Frequency Radar: 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) [2],[3] that will analyze radar waves transmitted by a lander, propagated through the body and received by the orbiter (Figure 1). Monostatic radar requires very low frequencies in the range 10 to 20 MHz necessitating the use of large antennas and is more consuming in term of mission resources (mass, data flow), driving all the mission specification. On the other hand, bistatic radar can use slightly higher frequencies in the range 60-90 MHz, simplifying the accommodation on mission carrying a surface package. This concept is fully compliant with medium class planetary missions.

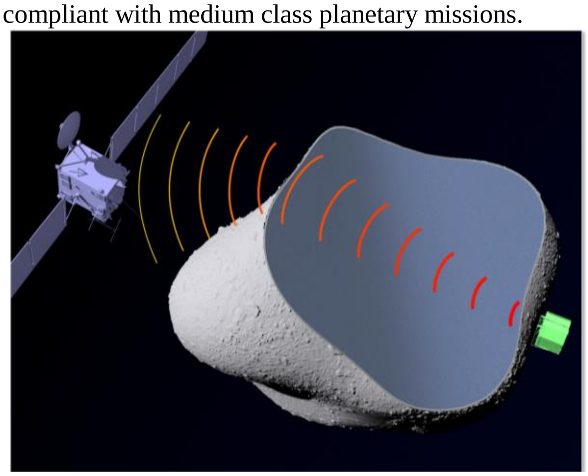

Figure 1: Illustrations of Bistatic tomographic

Hight Frequency Radar: Imaging the first tens meters of the subsurface with a metric resolution to identify layering and to reconnect surface measurements to internal structure can be achieved with a higher frequency radar on Orbiter only with a 300MHz – 800MHz frequency range typically.

An enlarged frequency range up to 3GHz, like the WISDOM radar designed and developed for the ESA ExoMars 2018 Rover mission [4] adds valuable science return contributing into the shape modeling, mass estimation, orbital parameters determination or close asteroid navigation with an altimeter mode.

AIM Mission: Bistatic tomography radar and high frequency radar are presently under phase A/B1 study in the frame of the ESA's Asteroid Impact Monitoring mission. AIM as a stand-alone mission or constituting the Asteroid Imact & Deflection Assessment (AIDA) with the Double Asteroid Redirection Test (DART) mission under study by APL is a mission to characterize "Didymoon", the secondary of the binary NEA Didymos and to contribute to the evaluation of impact mitigation strategies [5],[6].

AIM will carry Mascot2, a lander inheriting from Mascot/Hayabusa2 [6] to land on Didymoon. On Mascot2 and AIM, the bistatic will porbe the Didymoon's internal structure, with a typical resolution of 30 meters to characterize the structural homogeneity in order 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 AIM is combined with DART, the bistatic experiment will 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 (called "Didymain").

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

With DART, it 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. Then it is also a monitoring of the impact ejecta generated by the collision of 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.

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	HFR	**LFR**
Target	Regolith	Deep interior
Radar	Monostatic	Bistatic with Mascot
Signal	Step Frequency	BPSK
Heritage	WISDOM / Exomars	CONSERT / Rosetta
Wave propagation	Reflection/Scattering	Transmission
Antenna	Vivaldi	Dipoles
Tx Polarization	circular	Linear
Rx Polarization	2 linear	Circular
Penetration (m)	10 to 20	170
Resolution (m)	~2	15 - 30
Nom. BW (MHz)	300-800	50-70
Ext.. BW (MHz)	300-2500	45-75
PRF (Hz)	0.5-5	0.1-0.3
Step durat. (µs)	60	0.05
Integration	3000	261120
Tx Power (W)	20	16
Primary pow (W)	88	10 (each unit)
data rate (kbit/s)	300	5