JuRa:
The Juventas Radar on Hera to fathom Didymoon

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Asteroids' internal structure and composition:

Despite some highly successful space missions to NEOs, their internal structure remains largely unknown: there is some evidence that an aggregate structure covered by regolith is very common for medium size bodies, but there are no direct observations. The size distribution of the constitutive blocks is unknown: is it fine dust, sand, pebbles or larger blocks? The observed spatial variability of the regolith is not fully explained and the mechanical behavior of granular materials in a low gravity environment remains difficult to model (Herique et al. ASR 2018).

After several asteroid orbiting missions, these crucial and yet basic questions remain open. Direct measurements are needed to answer these questions, which are of main interest for planetary defense. Therefore, the modeling of regolith structure and its mechanical reaction is crucial for any interaction of a spacecraft with a NEO and especially for a deflection mission. Knowledge about the regolith's' vertical structure is needed to model thermal behavior and thus Yarkowsky and YORP accelerations. Determination of the global structure is a way to test stability conditions and evolution scenarios. There is no way to determine this from ground-based observations.

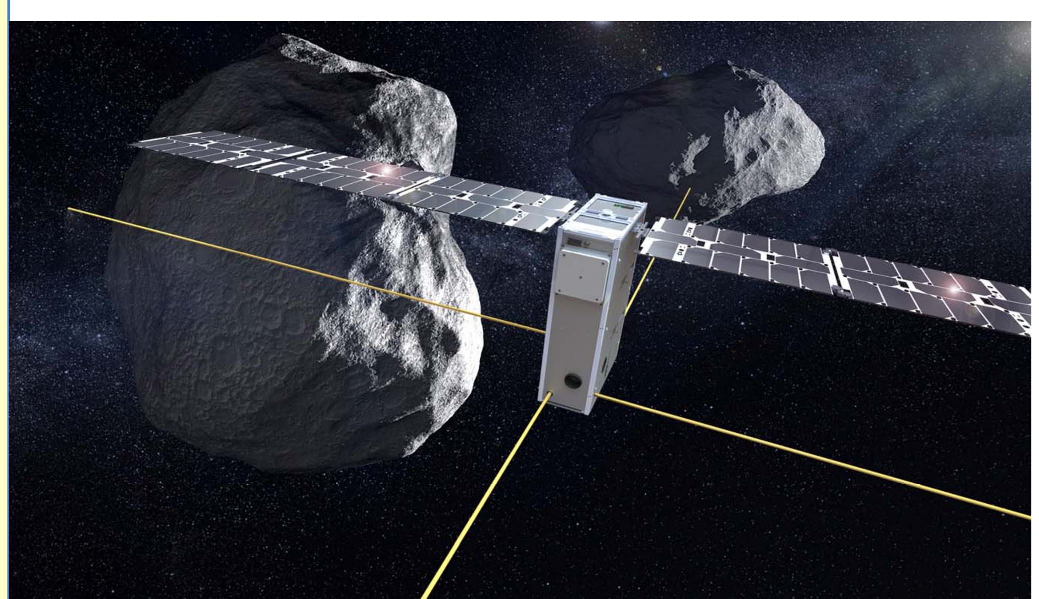
A Radar operating at distance from a spacecraft is the most mature instrument capable of achieving this science objective of characterizing the internal structure and heterogeneity from sub-metric to global scale, for the benefit of science as well as for planetary defense or exploration.

Didymos, HERA and Juventas

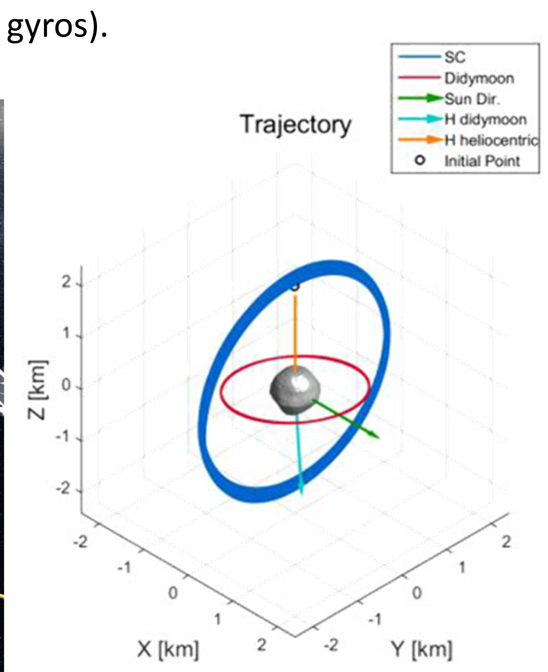
September 26, 2022, **DART/NASA** successfully impacted Dymorphos -the moonlet of Didymos NEA binary system- allowing to quantify the mechanical response of the body, mainly from ground-based observation (A. F. Cheng et al., 2016).

Five years later, **ESA HERA mission** will be a unique opportunity to deeply investigate the Didymos binary system and especially its moonlet, to observe in detail the bodies, the crater and the ejecta in order to better constrain mechanical models providing a global characterization of the binary system: shape, density, dynamic properties, thermal properties and composition (P.Michel et al, 2022). The Hera mothercraft will carry two CubeSat's, Juventas and Milani. The small spacecraft Juventas will investigate the asteroids' internal structure. Information about the internal structure is crucial for science, planetary defense and exploration since our current knowledge relies entirely on inferences from remote sensing observations of the surface and theoretical modeling (Herique et al 2018). HERA will be launched in 2024 to arrive at Didymos in 2026.

Juventas is a 6U CubeSat designed as part of the HERA mission to complement its science and in-orbit demonstration objectives. The HERA spacecraft will carry two CubeSats that will be deployed after a preliminary characterization phase has completed. The Juventas mission's main scientific objective is to assess the physical and dynamical properties of Didymoon such as the interior structure and surface strength. Knowledge of these properties is necessary to characterize the DART impact and assess the outcome of the deflection test, and crucial for our understanding of the evolution of asteroids. Juventas therefore complements the HERA planetary defense demonstration mission to a binary asteroid and helps to meet its scientific and technological goals. The CubeSat payload consists of a low frequency radar (LFR), a 3-axes gravimeter, an inter-satellite radio link (ISL), a visible camera, and an IMU (accelerometers and gyros).



Juventas Cubsat



SSTO of Juventas in the Didymos synodic reference frame.

Juventas will be released from 10 km above the Didymoon surface and will autonomously enter its observational orbits.
Baseline for global observations phase is a 3.15 km Self-Stabilised Terminator Orbit (SSTO) for its high scientific return with a reduced number of operations required
In order to perform proximity observations, Juventas will enter a 2 km distance SSTO.

Science Objective	Investigation	Measurements	Instruments	Mission Phase
Gravity field of Didymoon	Gravity field at least up to degree & order 2	Deflection during orbit measured with ranging, LoS to HERA	ISL radio link	Proximity operations
	Surface gravity	Surface acceleration	Gravimeter	Surface operations
	CubeSat touchdown/bouncing	Dynamic recording of each event	IMU	Landing / Bouncing
Internal structure of Didymoon	Size characterization for the constitutive block and composition heterogeneity	Radar backscattered signal	Low frequency radar	Proximity operations
Surface properties of Didymoon	Visible imaging	Inspection of Didymoon surface features and impact crater	Visible camera	Proximity operations, Surface operations
	Surface strength measurement	Rebounds from the surface	IMU	Landing / Bouncing
(secondary) Dynamical properties of Didymoon	Orbital analysis	Orbital analysis by ranging	ISL radio link	Surface operations
	Variable surface acceleration	Surface acceleration measurements over >1 orbit	Gravimeter	Surface operations
	Attitude and Time dependent surface illumination	Attitude and time dependent surface illumination	Star tracker, sun sensors	Surface operations

JuRa radar to fathom Didymos system

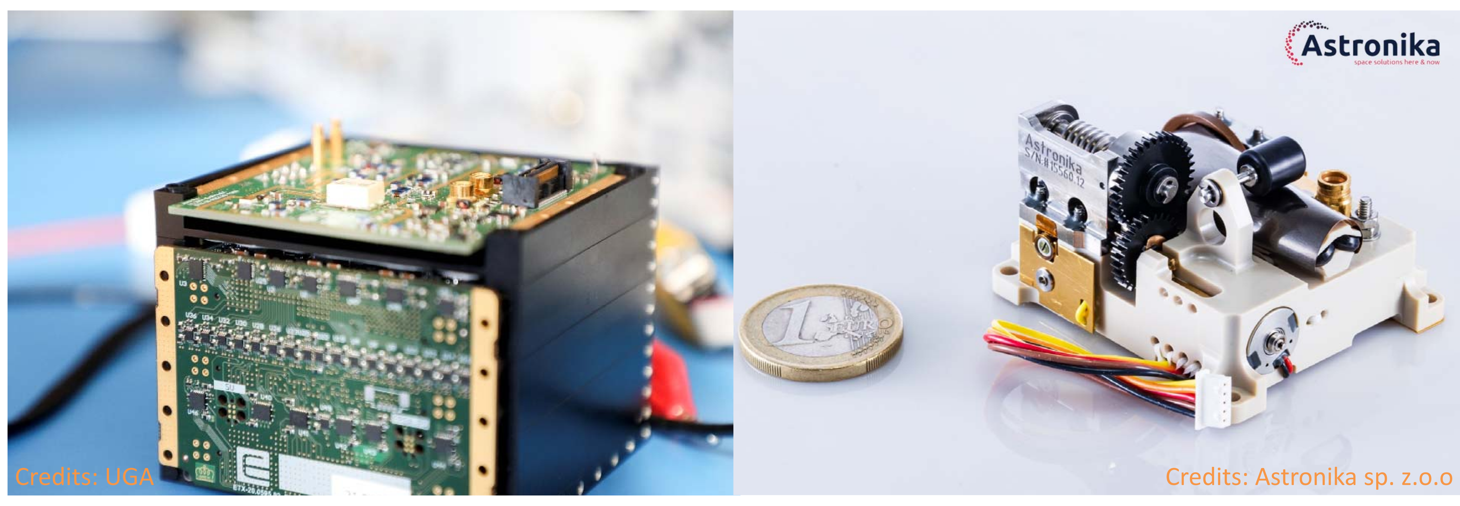
JuRa is a monostatic radar to maps the backscatter coefficient (sigma zero - σ_0) of the surface or subsurface, which quantifies the returned power per surface or volume unit. It is related to the degree of heterogeneity at the scale of the wavelength and to the dielectric contrast of heterogeneities, giving access to both, the sub-meter texture of the constituent material and larger scale structures.

- The first objective of JuRa is to characterize the moonlet's interior, to identify internal geological structure such as layers, voids and sub-aggregates, to bring out the aggregate structure and to characterize its constituent blocks in terms of size distribution and heterogeneity at from submetric to global scale.
- The second objective is to estimate the average permittivity and to monitor its spatial variation in order to retrieve information on its composition and porosity. Radar bypasses the near surface alteration by space-weathering and thermal-cycling as observed with optical remote sensing. The observation of the structure and composition of the moonlet will provide constraints on the mechanical model of the impact process.
- The same characterization applied to the main asteroid of the binary system is among the secondary objectives, to detect differences in texture and composition. When compared to the observation of the moonlet, it will constraint the model of binary system formation to discriminate between progressive versus catastrophic process and more generally on the stability conditions of the system.

Implementation: The radar consists of an electronic box and an antenna: The radar unit is sending and receiving a BPSK code modulated at 60 MHz in time sharing.
The received signal is on-board accumulated to reduce the data volume and constitutes the science measurement. The measurement is done in full linear polarization with the capacity to calculate circular polarization on board.
The electronics corresponds to 1U for 1.4kg. The antennas is constituted of 4 booms of 1.26m and 65g each.

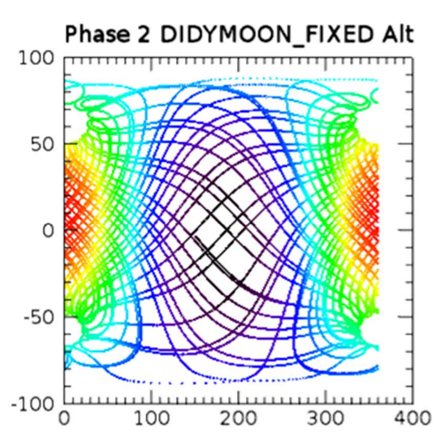
	JuRa
carrier	60 MHz
signal	BPSK
BW	20 MHz nominal 30 MHz extended
Resolution	10 – 15 m (1D)
Polarization	Full linear
Tx power	5 W
$NE\sigma_0$	Better than -50 $dB.m^2/m^2$

JuRa electronics is developed in newspace approach: The EM2 has been de-risk in 2022 with radiation, thermal vacuum, chock and EMC test.
The JuRa PFM is under test to be delivered in May 23 for integration on Juventas Cubsat . Acceptance test and Radar calibration are in progress.

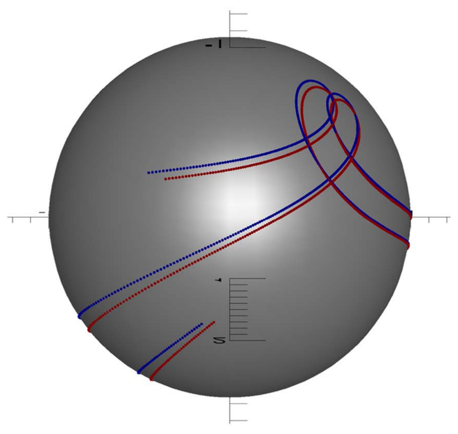


JuRa Electronics box and antenna boom

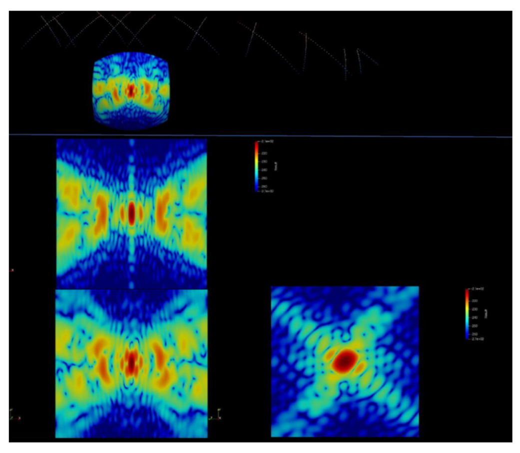
Operation scenario and processing : multipasses acquisition is required to retrieve 3D maps from Synthetic Aperture Radar processing. A typical operation scenario consists in set of acquisition along ~45 minutes arc of orbits.
The definition of the processing allows to optimize scenario of operation and to consolidate orbit requirement. The definition of optimization criteria in terms of coverage and resolution will be then introduced in the orbit optimization process.
Ground segment for operation and processing will be developed in 2024-25.



Orbits coverage



Ewald Sphere



Performances

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