

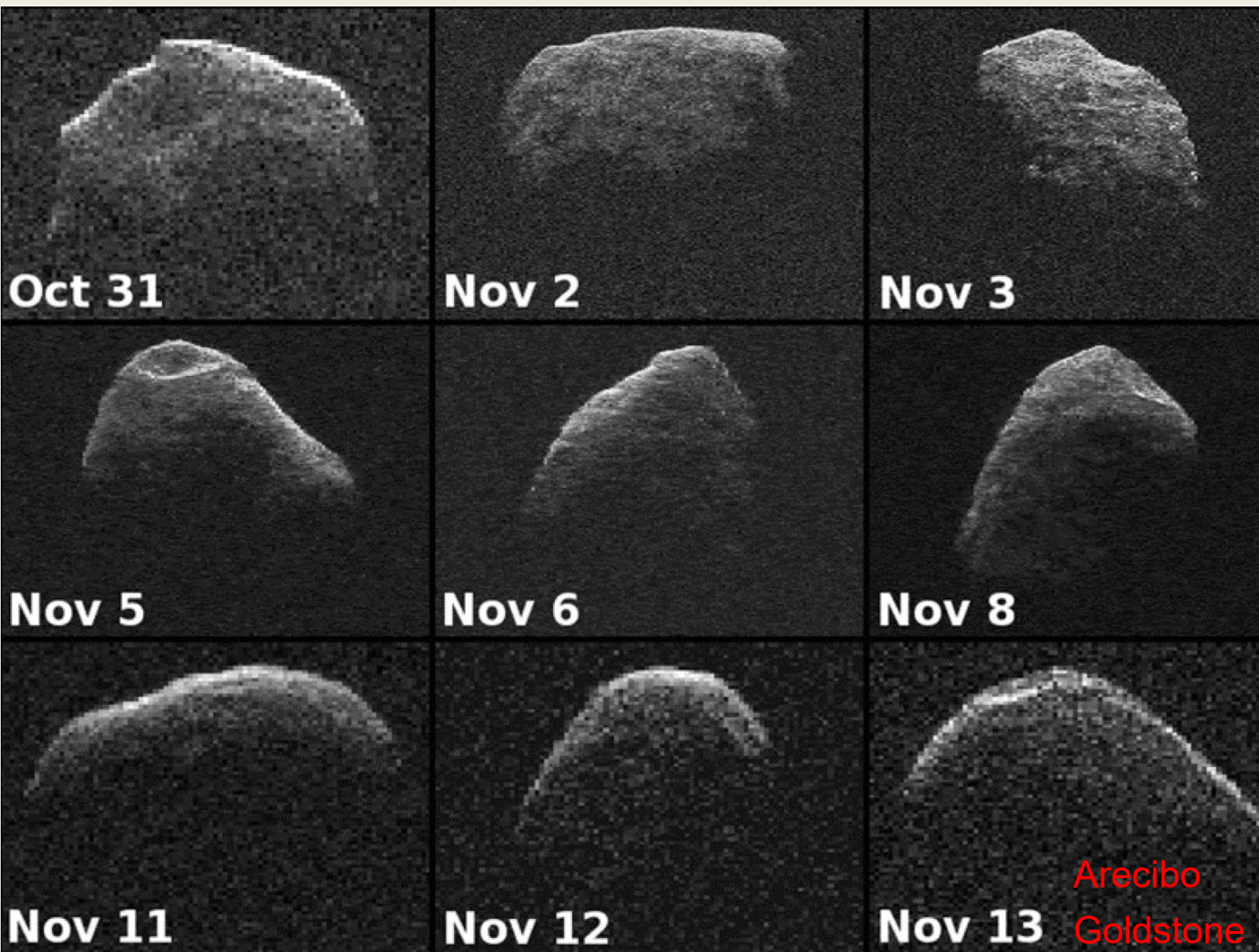


Bistatic radar observation of Apophis asteroid

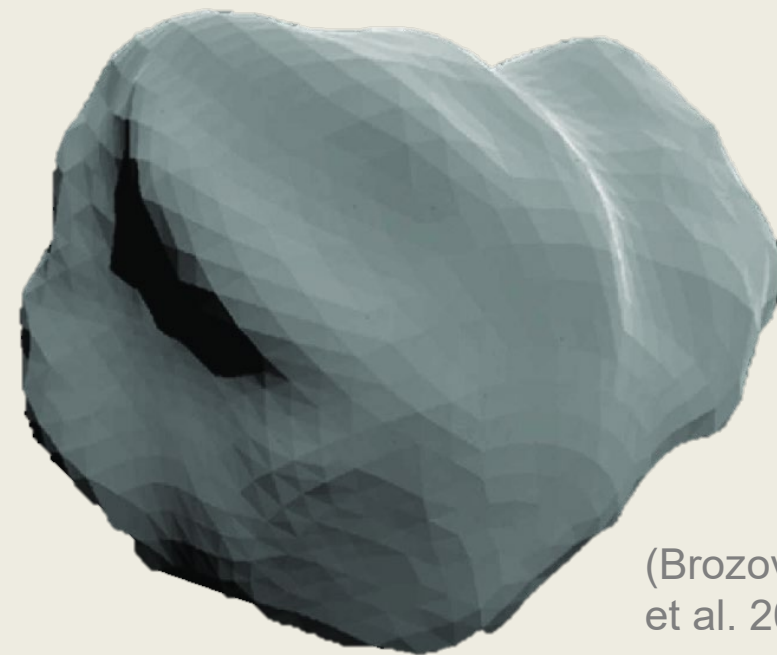
Alain Herique

University Grenoble Alpes France

99942 Apophis - 2029



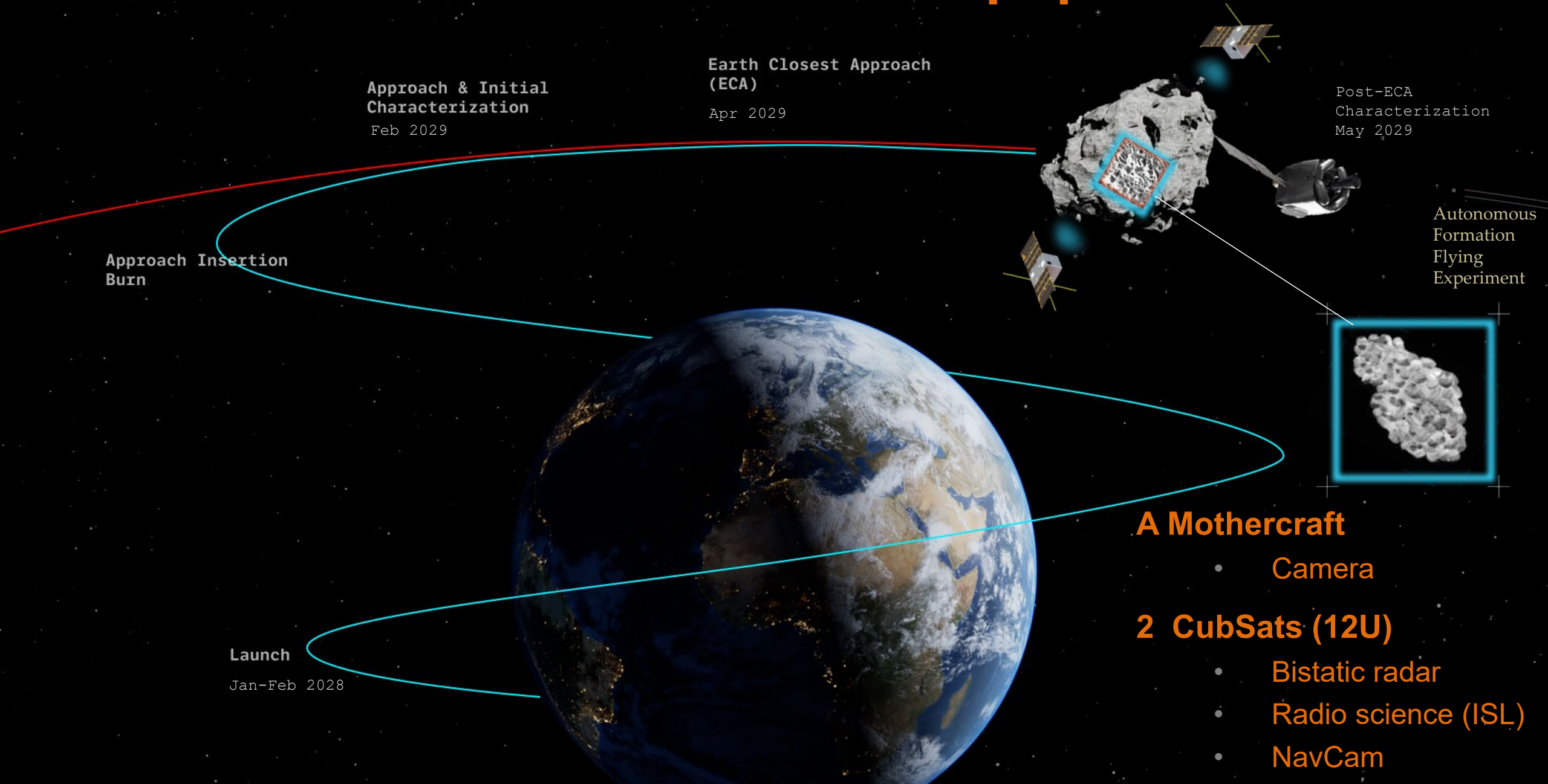
Arecibo
Goldstone



(Brozović
et al. 2018)



The Caltech Mission to Apophis



Approach & Initial
Characterization
Feb 2029

Earth Closest Approach
(ECA)
Apr 2029

Post-ECA
Characterization
May 2029

Approach Insertion
Burn

Launch
Jan-Feb 2028

Autonomous
Formation
Flying
Experiment

A Mothercraft

- Camera

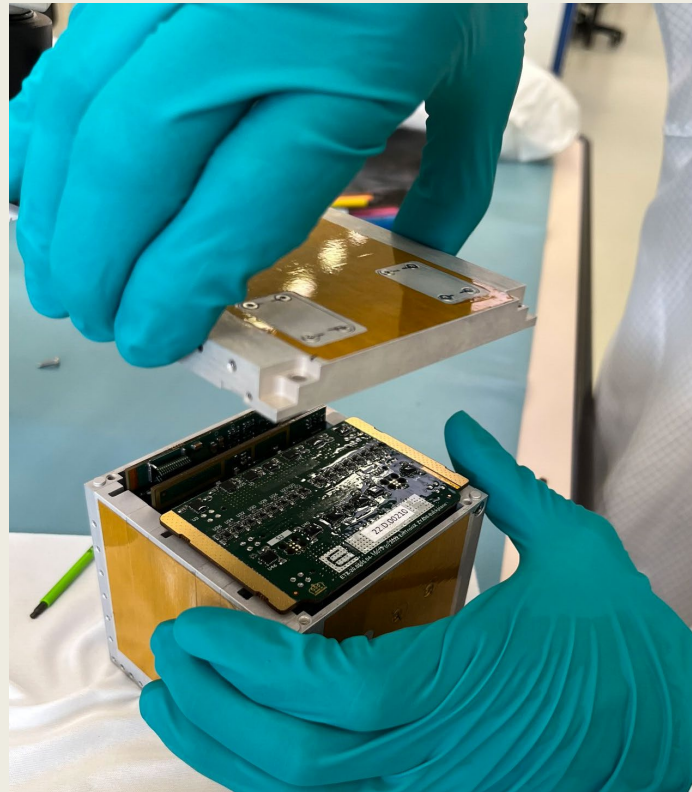
2 CubSats (12U)

- Bistatic radar
- Radio science (ISL)
- NavCam

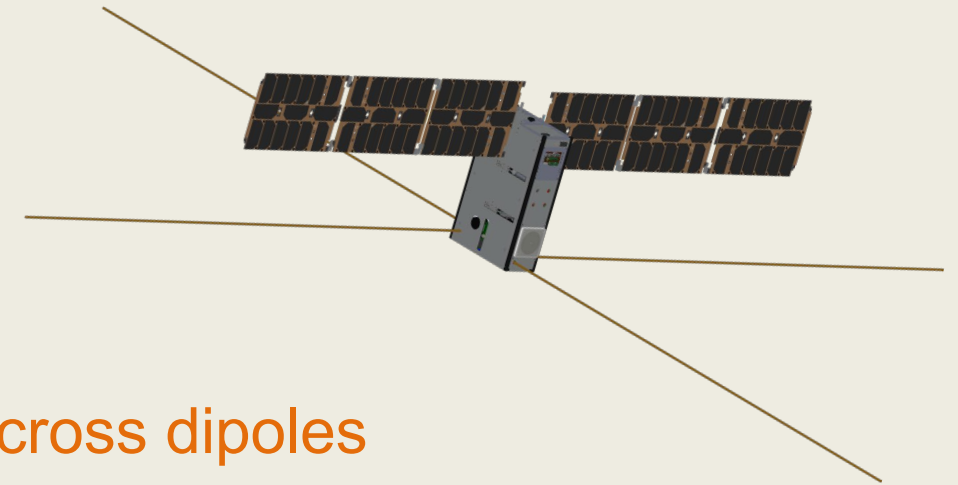
JuRa / HERA heritage



Electronics 1U / 1kg



2 cross dipoles
4 deployable booms
1.26 m & 65 g 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



3D Tomography - Internal structure

Bring out the aggregate structure

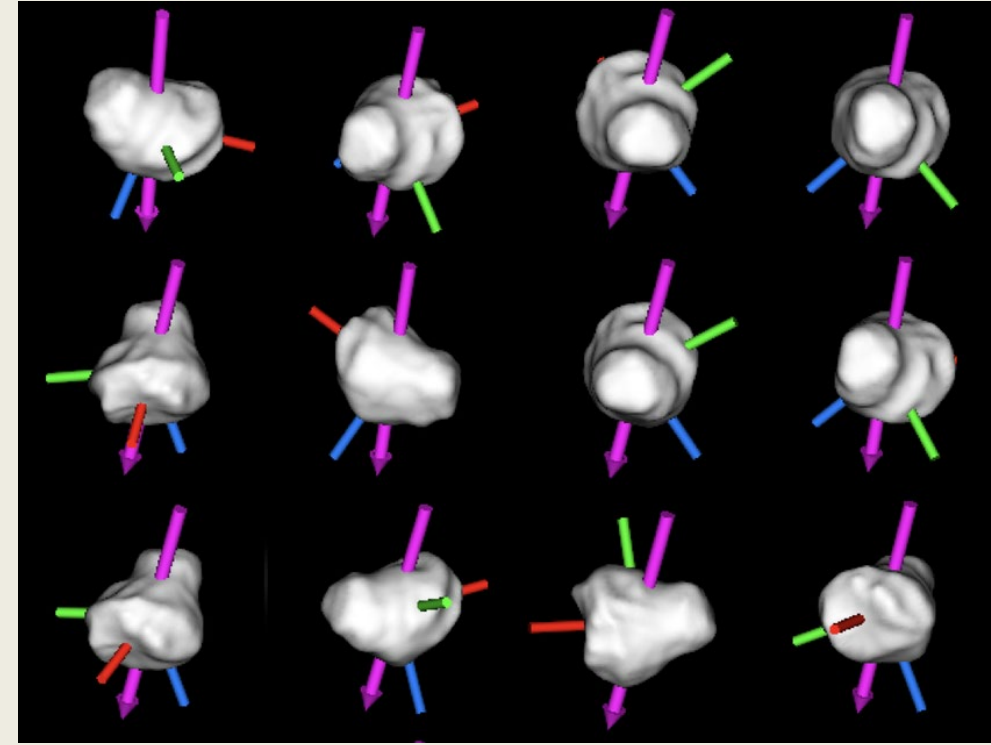
Identify internal structure: layers, voids, sub-aggregate

Identify large scale structure / variation of density

Characterize the smaller scales from sigma null
map its spatial variation

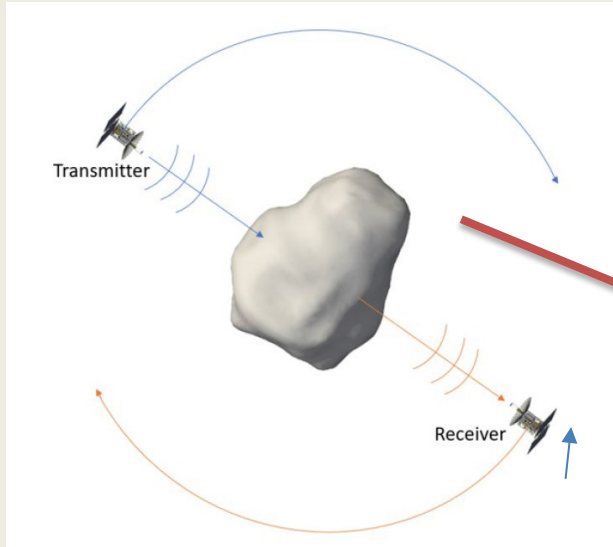
Average permittivity and its spatial variations

- To better constraint physical modeling of tidal effect and stability conditions
- To improve mechanics of granular material under low gravity
- To prepare any interaction with a spacecraft

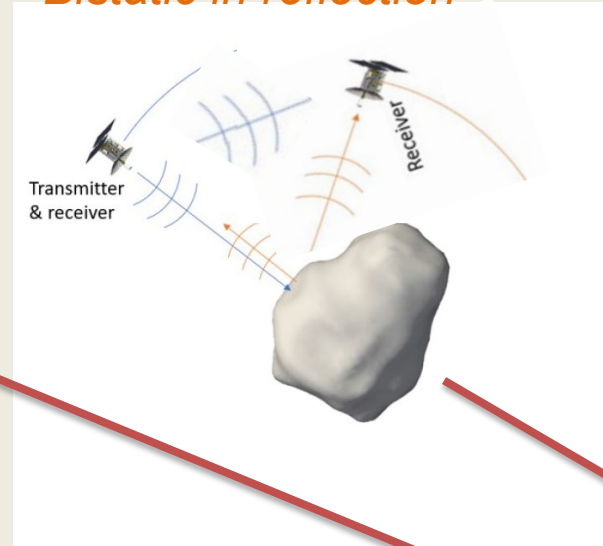


Alternation of 3 Radar modes

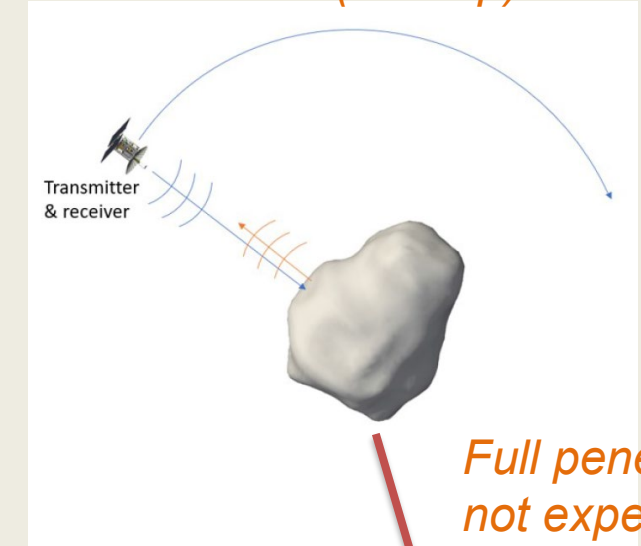
Bistatic in transmission



Bistatic in reflection



Monostatic (backup)



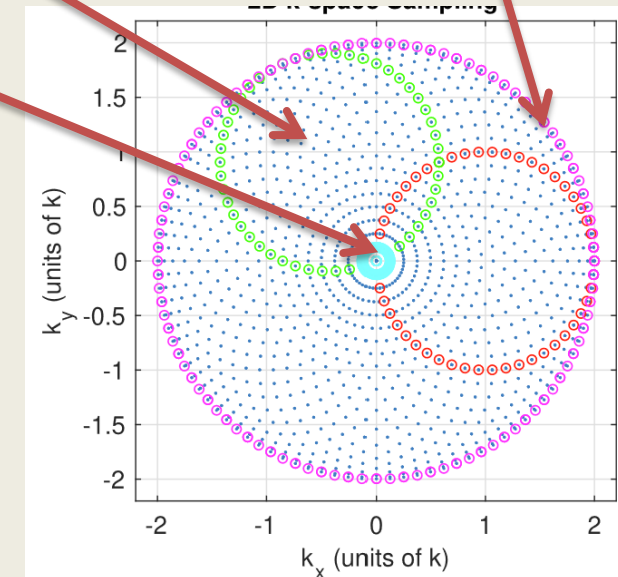
*Full penetration
not expected*

*Absolute average permittivity measurement
Projection tomography (low scattering)*

*Synchronization from maincraft (ISL)
SNR*

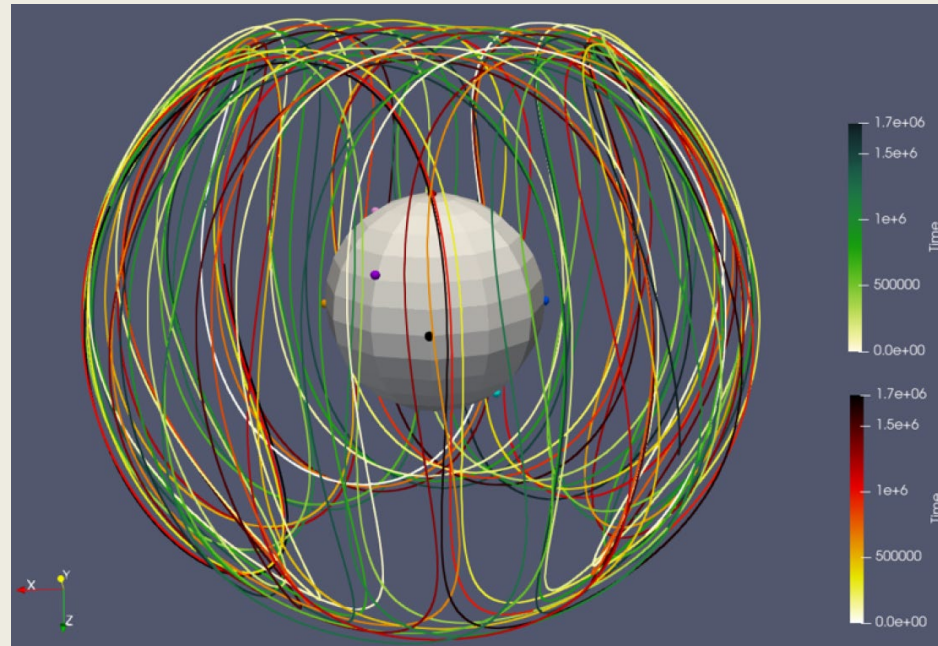
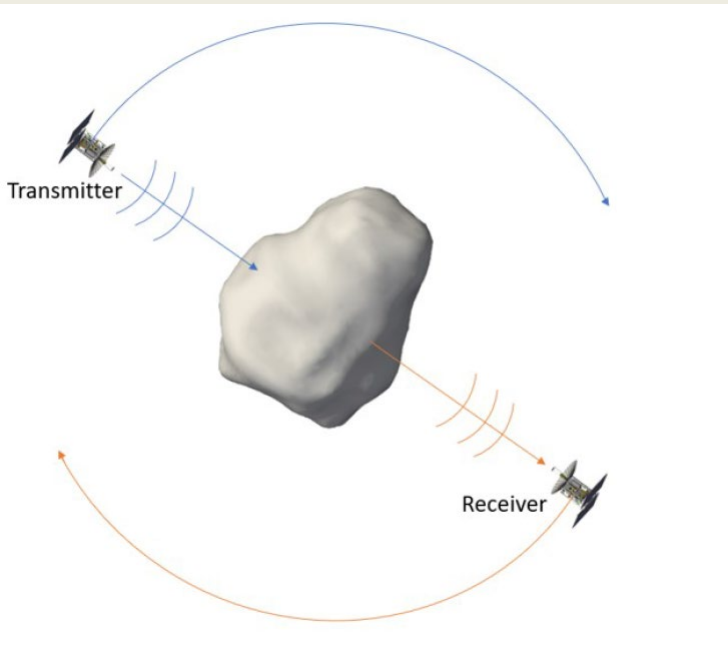
*Scattering tomography
 $\lambda/2$*

*Synchro from direct path
Blinding from direct path*

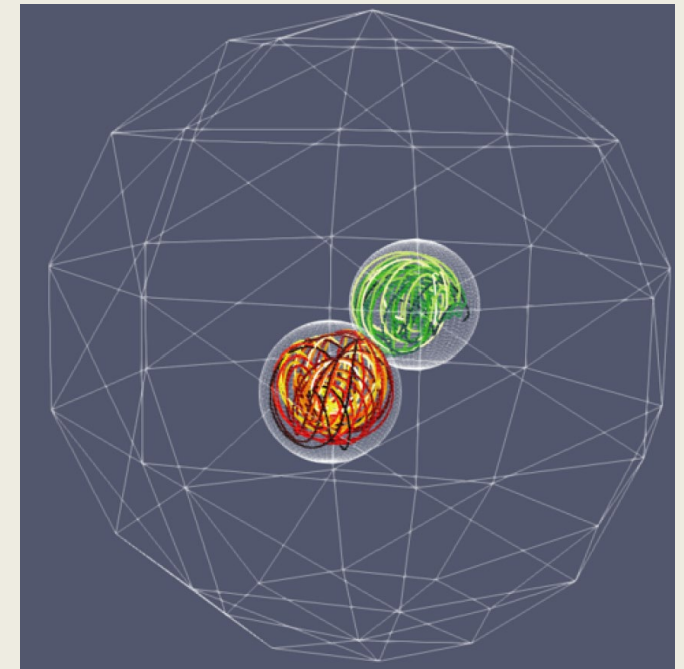


Ewald sphere coverage

- **Operation at low altitude :**
 - No plan wave approximation
 - k differs for different points in the asteroid
 - Final image : the same resolution but for different area of the Ewald sphere



Orbits of the 2 CubeSats in the body fixed frame



Eval sphere plot of the orbit for areas of Apophis

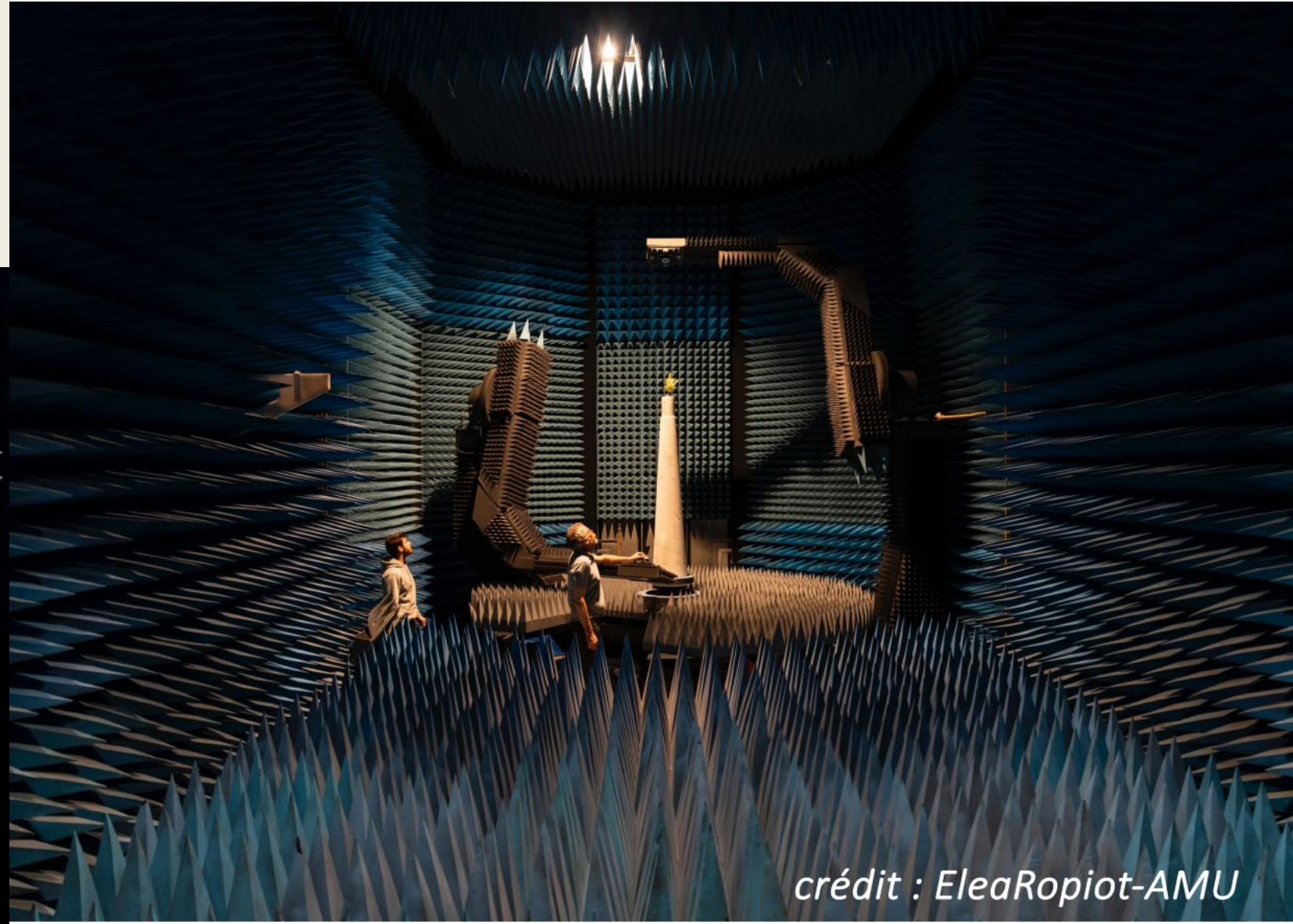
Imaging of the internal structure of an asteroid analogue from lab-measurements

A. Dufaure, C. Eyraud et al 2024 , L. Sorsa et al 2022, 2023

- Analogue of an asteroid
- Microwave analogy



Itokawa
535 m

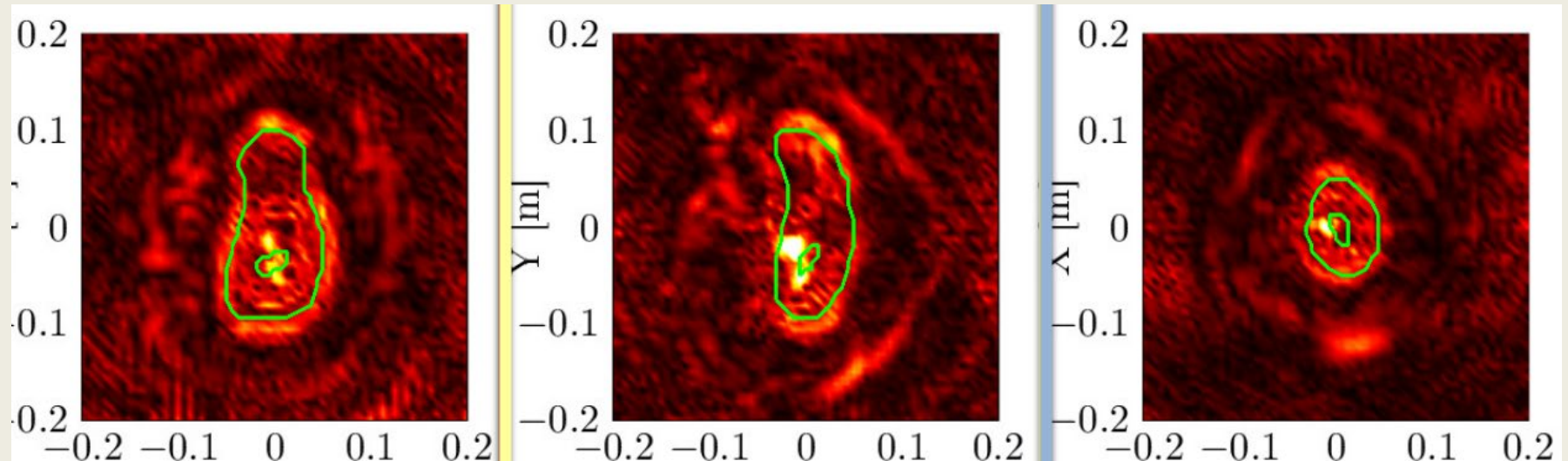
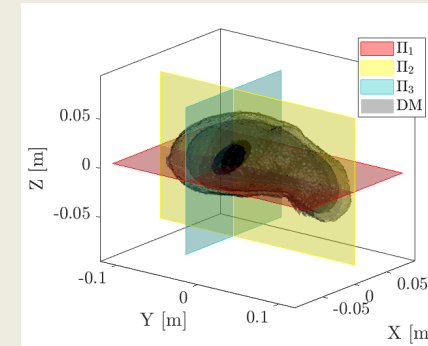


crédit : EleaRopiot-AMU

Imaging of the internal structure of an asteroid analogue from lab-measurements

A. Dufaure, C. Eyraud et al 2024 , L. Sorsa et al 2022, 2023

- Analogue of an asteroid
- Microwave analogy
- Measurements in a controlled environnement
- Structural Imaging : Pseudo inverse, PCA



Science objectives

- **Secondary objectives are more prospective:**
 - to support gravity field characterization and dynamical state determination
 - ⇒ radar ranging and interferometry
 - to evaluate the feasibility of bistatic radar experiment in transmission
 - ⇒ between spacecraft and LOFAR ground based facility



The LOFAR core (NI)