Full-wave Radar Tomography for Astrophysics: Interior structure of small body vs. carrier effects

Yusuf Oluwatoki Yusuf[1,2], Astrid Dufaure [2], Liisa-Ida Sorsa[1], Christelle Eyraud[2], Sampsa Pursiainen[1]

[1] Computing Sciences, Tampere University (TAU), P.O. Box 692, 33101, Tampere, Finland

[2] Aix-Marseille Univ., CNRS, Centrale Marseille, Institut Fresnel, Marseille, France

There are over $27,313$ known Near Earth Asteroids (NEAs), i.e., asteroids within 4.488×10^7 km from Earth, out of which $1,254$ are on risk list according to ESA's Near Earth Object Coordination Centre (NEOCC). Hence, advancing the knowledge of mineral composition, interior structure, and potential threats of planetary bodies is very important and has been the motivation behind space explorations over years. The first space mission to observe the deep interior of a small Solar System Body (sSSB) was Comet Nucleus Sounding Experiment by Radio Transmission (CONSERT) by European Space Agency's (ESA's) Rosetta mission which rendezvoused comet 67P/Churyumov–Gerasimenko in 2014. ESA will continue Radar Tomography (RT) exploration as a part of the HERA mission [2, 3], the European component of AIDA (Asteroid Impact and Deflection Assessment), whose Juventas Radar (JuRa) [1] carried by a CubeSat with the same name (Juventas CubeSat), will perform RT measurements with the asteroid moon of the binary asteroid Didymos as its target. Reconstructing an SSSB's interior permittivity distribution (structure) via RT is an ill-posed inverse problem and utilising the full-waveform approach, i.e., maintaining the complete wavefield information of the forward simulation, is essential with respect to the reconstruction quality.

In this presentation, we examine the goals of JuRa by applying the methods of Ground penetrating radar (GPR) modelling and inversion in the presence of noisy signal which necessitates filtering with methods such as Truncated singular value decomposition (TSVD) and robust inversion of incomplete spectral data, e.g., through sampling and error marginalisation. We utilise these techniques in numerical simulations with a complex test domain (containing a stratified surface layer, voids and cracks) and laboratory experiments with an analogue object. Based on the aforementioned, we estimate the feasibility of the JuRa experiment under mission-based payload and instrument constraints such as the 60 MHz centre frequency, 20 MHz bandwidth, and monostatic signal configuration with regards to its aim of detecting subsurface structure of the asteroid Didymos.

[1] Alain Herique, Dirk Plettemeier, Hannah Goldberg, and Wlodek Kofman. Jura: the juventas radar on hera to fathom didymoon. In *European Planetary Science Congress*, pages EPSC2020–595, 2020.

[2] Alain Herique, Dirk Plettemeier, Wlodek W Kofman, Yves Rogez, and Hannah Goldberg. Direct observations of didymos' regolith and internal structure with lfr radar on juventas cubesat for esa hera mission. In *AGU Fall Meeting Abstracts*, volume 2019, pages NH51C–0789, 2019.

[3] Patrick Michel, Michael Küppers, and Ian Carnelli. The hera mission: European component of the esa-nasa aida mission to a binary asteroid. *42nd COSPAR Scientific Assembly*, 42:B1–1, 2018.

Acknowledgements: This work was supported by the Academy of Finland Centre of Excellence in Inverse Modelling and Imaging, 2018-2025.