FULL EUROPEAN RADAR OBSERVATION OF THE BINARY ASTEROID 2005 LW3

G. Pupillo[1], S. Righini[1], R. Orosei[1], U. Bach[2], C. Bortolotti[1], S. Cicalò[3], A. Kraus[2], G. Maccaferri[1], A. Margheri[4] and M. Roma[1], [1]INAF-IRA (Via Gobetti 101, 40129 Bologna, Italy), [2]Max-Planck-Institut für Radioastronomie Auf dem Hügel 69, 53121 Bonn, Germany), [3]SpaceDyS (Via Mario Giuntini 63, 56093 Navacchio, Italy), [4]Università di Trento (Via Sommarive 14, 38123 Trento, Italy).

Introduction: Radar observations of near-Earth Objects (NEOs) are invaluable not only from a scientific point of view, but also for planetary defense and as support to space missions [1-2]. After the collapse of the Arecibo antenna in December 2021, at the moment the main operational ground-based planetary radar employed for asteroid observation is the Goldstone Solar System Radar (GSSR) in the Mojave Desert, California. The GSSR, operated by NASA – Jet Propulsion Laboratory (JPL), is installed on the 70-m DSS-14 antenna and is capable of transmitting 450 kW power [3].

To pave the way for a European radar system similar to - and in synergy with - the US one, in 2019 the European Space Agency (ESA) started the project "NEO observation concepts for radar systems", in which INAF, SpaceDyS, and the University of Helsinki were involved. The project was aimed to derive the functional requirements of a radar system, evaluate the available European assets to perform NEO radar observations and carry out some test radar campaigns, with successful experiments performed on asteroids such as 2021 AF8, 2016 AJ193, and (4660) Nereus [4-5] - all in collaboration with the NASA/JPL (DSS-14, Goldstone).

In the wake of this project, which successfully concluded in 2022, further observations were carried out to test a fully Europe-based radar system. In this work, we present the preliminary results of radar observations of asteroid 2005 LW3 performed with the multi-static radar DSS63 – Effelsberg – Medicina.

Observations and preliminary results:

Thanks to the JPL and Deep Space Network (DSN), we had the opportunity to use the 70-m

DSS-63 antenna of the Madrid Deep Space Communications Complex (MDSCC) as the transmitter. Due to the limited power available at this facility (20 kW), only a small number of targets could be selected for our experiments. On the other hand, the possibility to exploit the large 100-m Effelsberg radio telescope on the receiving side, together with the Medicina 32-m antenna (newly-renamed as Grueff Radio Telescope), provided the opportunity to achieve a higher signal-to-noise ratio and accuracy in the measurements.

Our radar observation of the potentially hazardous asteroid (PHA) 2005 LW3 was performed on November 23, 2022, during its close approach to Earth, when the NEO was at a distance of about 1.2 million km. Both the Medicina and the Effelsberg radio telescopes detected the radar echo, well resolving it in the frequency domain.

In data processing, some SW tools developed by us specifically for the asteroid observations were used, such as the Doppler compensation on time-domain data through the ephemeris-based phase-stopping technique [6].

This kind of measurement permits us to derive some important physical properties of the target. We measured a rotation period of about 4 hr (assuming an equatorial view), consistent with the Goldstone DSS-14 observations. Furthermore, the delay-Doppler images obtained by Goldstone, in addition to measuring the size of the asteroid of about 400 m, discovered that it has a satellite of approximately 50 - 100 m in diameter [7]. One of the most important achievements of our observation was the successful detection of this asteroid's satellite. The radar high-resolution spectra exhibit a narrow spike of the satellite echo, superimposed to the broader echo of the primary body (see Figure 1) [5].

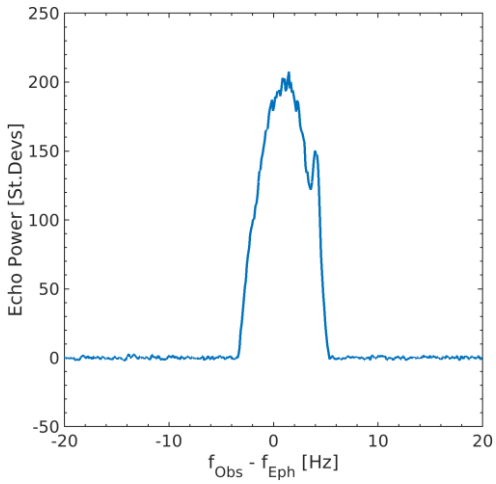

Figure 1 – Full-track integrated echo power spectrum of 2005 LW3 at 0.1 Hz frequency resolution obtained from Effelsberg data. Echo is plotted in standard deviation units of the background noise. The observed frequency in the x-axis is relative to the ephemeris-based frequency estimate of the echo from the asteroid center of mass.

Finally, the high-resolution spectra of the radar echo allowed us to obtain very accurate range-rate estimation, which can be used to significantly improve the NEO orbit knowledge.

References:

[1] Ostro S.J et al. (2002) *Asteroid Radar Astronomy* in Asteroids III, 151-168. [2] Naidu S. et al. (2016), *AJ*, 152, 1-9. [3] Rodriguez-Alvarez N. et al. (2022) *IEEE Trans. Geosci. Remote Sens.*, 60, 1-15. [4] Pupillo G. et al. (2023) *ESA - 2nd NEO and Debris Detection Conf. Proc.*, 58, 1-8. [5] Pupillo G. et al. (2023) *Remote Sens.*, (accepted) 1-22. [6] Molera Calvès G. et al. (2014) *A&A*, 564, 1-7. [7] Green D.W.E. (2022) *IAU Circular* No. 5128, 2022 December 10.