IN-SITU CHARACTERIZATION OF THE DIDYMOS-DIMORPHOS DUSTY PLUME. C. Gisellu[1,2], E. Palomba[1], F. Dirri[1], A. Longobardo[1], D. Biondi[1], M. Angrisani[1,2], G. Massa[1,2], E. Nardi[2], E. Zampetti[3], D. Scaccabarozzi[4], B. Saggin[4]

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Introduction: The Asteroid Impact & Deflection Assessment (AIDA) mission is a joint project of NASA DART (Double Asteroid Redirection Test) and ESA Hera missions. It is a technology demonstration of the kinetic impactor concept to deflect a small asteroid and to characterize its physical properties.

The NASA's Double Asteroid Redirection Test (DART) impacted Dimorphos on 26th September 2022 [1]. The event was imaged by Earth-based and space telescopes showing a huge dust plume surrounding entirely the Didymos-Dimorphos system and evolving during the following days.

The dusty environment created by the impact could survive for months and, particularly for the fine particle sizes, would be mainly shaped by the solar wind. Mechanisms for resupplying new finer dusty particles to the plume should involve impacts of the Didymos surface by larger still orbiting particles. The study of the finer dusty environment present around the Didymos-Dimorphos system is actually possible by using the state of the art of a miniaturized dust sensor that is part of the instrumentation suite of the Hera space mission, the VISTA detector.

Hera is a planetary defense mission currently under development at the European Space Agency, due to launch in October 2024. Hera's main goals are the investigation of the Didymos binary system and the evaluation of the outcome of DART mission kinetic impactor test.

VISTA working principle: The instrument core is a PCM (Piezoelectric Crystal Microbalance), which is a widely used sensor for monitoring molecular contamination in space [2] and characterizing the dust composition processes in different planetary environments [3].

The frequency variations directly depends on the deposited sample mass on the crystal surface, according to Sauerbrey equation [4]:

$$\Delta f = -\frac{K_0 f^2}{A_0}\,\Delta m$$

Where K_0 is a constant dependent on the piezoelectric material, A_0 is the sensor area and f is the resonance frequency. The working principle is shown in Figure 1.

The sensing part of the instrument is composed of two quartz crystals mounted in a sandwich-like configuration, one used as a reference and the other one exposed to the external environment (i.e., the sensing crystal).

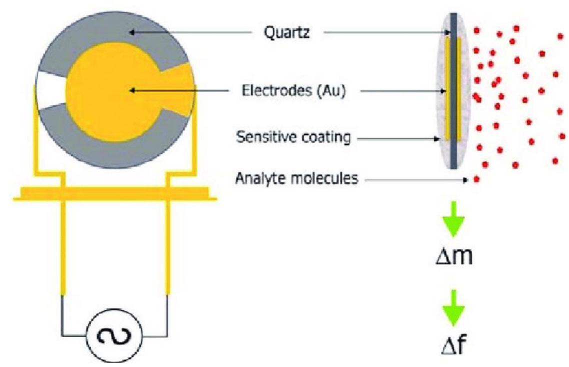

Figure 1. Working principle of a PCM. The fine dust particles are collected by the sensitive surface (AT-quartz crystals) and the deposited mass measured by frequency-mass relation.

By using customized heaters integrated on crystals surface, PCM is also capable of performing Thermo-Gravimetric Analysis (TGA), which is a widely used technique to perform thermal analysis of materials/compounds in order to detect and distinguish the volatile fraction and refractory ones by using deposition/sublimation and absorption/desorption rates [5]. VISTA can detect micron and submicron dust particles.

Dust detection: VISTA microbalance is able to characterized the finest population of the Didymos-Dimorphos plume, for particle diameters less than 10 micron [6]. As a result of dust collection in terms of collected cumulative mass a corresponding output signal (frequency) is measured (see Figure 2). This in turn translates in a sensitivity function, which links the collected mass dust to the frequency.

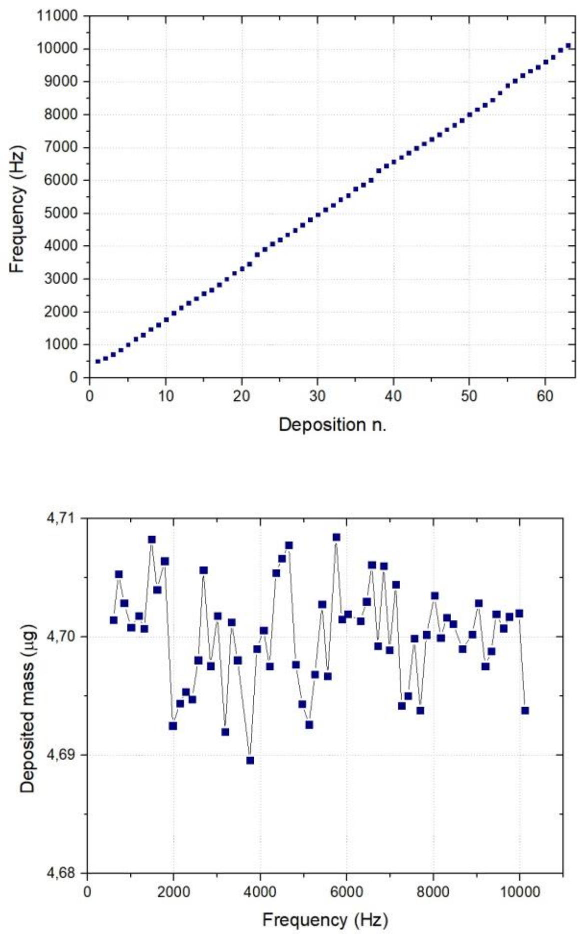

Figure 2. Frequency increase in time during deposition tests.

After the discovery of the dust around Bennu [7] and the recent improvements in the studies of active asteroids [8], it is not possible anymore to describe the dust evolution around small bodies solely by the well know physical-dynamical laws (e.g. Solar wind pressure, Poynting-Robertson, Kepler). Additional processes that could supply dust to the system could counterbalance such forces making the dust plume characterization nearly unpredictable.

The more accurate way to assess the how the fine particle population evolve in time around Didymos is to measure the dust flux mass in-situ with a dedicated sensor.

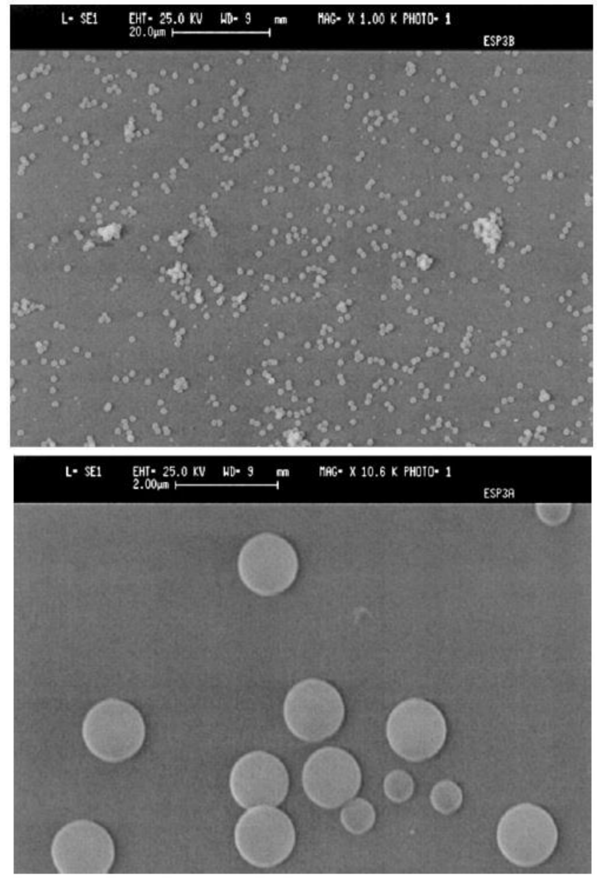

Figure 3. SEM images of the microbalance after deposition. Spherical particles of 1.2 µm diameter of silicon carbide (SiC) were used for the calibration. Some aggregates are present as shown in the top image.

References: [1] Michel et al., 2022 Planet. Sci. J. 3 160; [2] Dirri et al., 2016, AMT 9, 655–668; [3] Palomba et al., 2016, OLEB, 46 (2-3); [4] Sauerbrey 1959, Z. Phys., 155, 206-222; [5] Bargeron et al., Proc. SPIE 2261, (1994); [6] Palomba et al., 2002 Advances in Space Research 29, 8, 1155-1158; [7] Lauretta et al., 2019 Nature 568, 55–60; [8] Jewitt et al., 2015, Asteroids IV, ISBN: 978-0-816-53213-1, 221-241.