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Asteroid deflection using a kinetic impactor: Insights from hypervelocity impact experiments

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Within the framework of the planned AIDA mission [1], an impactor spacecraft (DART) hits the second component of the asteroid Didymos at hypervelocity. The impact crater will be observed from the AIM spacecraft and an observation of the ejecta plume is possible [1]. This allows conclusions to be drawn about the physical properties of the target material, and the momentum transfer will be studied [1].

In preparation for this mission, hypervelocity impact experiments can provide valuable information about the outcome of an impact event as a function of impactor and target material properties and, thus, support the interpretation of the data from the DART impact. In addition, these impact experiments provide an important means to validate numerical impact simulations required to simulate large-scale impacts that cannot be studied in laboratory experiments. Impact experiments have shown that crater morphology and size, crater growth and ejecta dynamics strongly depend on the physical properties of the target material [2]. For example, porous materials like sandstone lead to a shallower and slower ejection than low-porous materials like quartzite, and the cratering efficiency is reduced in porous targets leading to a smaller amount of ejected mass [3]. These phenomena result in a reduced momentum multiplication factor (often called "beta-value"), i.e. the ratio of the change in target momentum after the impact and the momentum of the projectile is smaller for porous materials.

Hypervelocity impact experiments into target materials with different porosities and densities such as quartzite (2.9 %, 2.6 g/cm3), sandstone (25.3 %, 2 g/cm3), limestone (31 %, 1.8 g/cm3), and highly porous aerated concrete (87.5 %, 0.4 g/cm3) were conducted. Projectile velocities were varied between about 3 km/s and almost 7 km/s. A ballistic pendulum was used to measure the momentum transfer. The material strength required for scaling laws was determined for all target materials. The highest beta values were measured for the low-porous quartzite (e.g., beta $\sim$ 3 for a projectile velocity of about 4.05 km/s). Porous materials like sandstone, on the other hand, show lower beta values (e.g., beta $\sim$ 1.8 for a projectile velocity of about 4.11 km/s).

[1] Cheng A. F. et al. 2015 Acta Astronaut 115:262–269 [2] Hoerth T. et al. 2013 Meteorit Planet Sci 48:23–32
[3] Hoerth T. et al. 2015 Proc Engin 103:197–204