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LABORATORY AND NUMERICAL EXPERIMENTS OF IMPACT GENERATED WAVES IN AGGLOMERATED ASTEROIDS

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ABSTRACT

Asteroids and small bodies of the Solar System are thought to be agglomerates of irregular boulders, therefore cataloged as granular media and they can be considered as rubble or gravel piles. Impacts on their surface could produce seismic waves that propagate in the interior of these bodies, thus causing modifications in the internal distribution of rocks and ejections of particles and dust, resulting in a cometary-type comma. The impacts could be used to impart linear momentum to deflect an incoming asteroid.

We present laboratory experiments and numerical simulations on the propagation of impact-induced seismic waves in granular media. The influence of a static compression on wave propagation is studied to mimic the pressure variations induced by selfgravity in the asteroid interior.

Granular material such as sand, gravel, glass spheres and marbles is placed into a 50x50x50-cm acrylic cubic box (Fig. 1). Pressure inside the box is controlled by a movable sidewall with a

hydraulic jack (and monitored by 2 pressure sensors). Impacts are generated on the upper face of the box through a small hole. Projectile velocity ranges from a few meter per second of free-falling 40 gr spheres to a hundred meter per second of 15 gr pellet CO_2 gunshot. Impact velocities are deduced from a chronometer and high-speed cameras recording from outside the box. A set of piezoelectric pressure sensors and accelerometers are placed at several depths inside the granular material to detect the mechanical wave.

Impact generated waves are studied by estimating velocity, attenuation and energy transmission. The dependency of these parameters with the impact energy, the properties of the granular material and static pressure are analyzed.

In parallel, we have been performing numerical simulations to study similar processes. The simulations are performed with ESyS-Particle, a software that implements the Discrete Element Method. In a first set up, we numerically mimic the experiment described above. The mechanical properties of the granular materials and the projectiles as well as the projectile impact velocity are varied in a wide range of values. Numerical results regarding velocity, attenuation and energy transmission are compared with experimental ones.

In a second set of numerical experiments, a spherical, isolated asteroid, maintained by selfgravity is impacted on the surface. For these set of simulations, a new implementation of ESyS-particle, which includes selfgravity among the particles, is being used. The propagation of impact induced seismic waves into the interior is studied as well the ejection of low-velocity particles from the entire surface. The efficiency on imparting linear and angular momentum is estimated for different initial conditions.

These results are relevant to understand the outcomes of impacts in rubble/gravel pile asteroids. In particular, they could be useful to discuss the feasibility of the kinematic impactor alternative to deflect an incoming hazardous asteroid, as it will be tested in the projected NASA DART mission. Another application of these results is related to the ejection of low-velocity dust (~1 m/s) from the so-called Activated Asteroids.

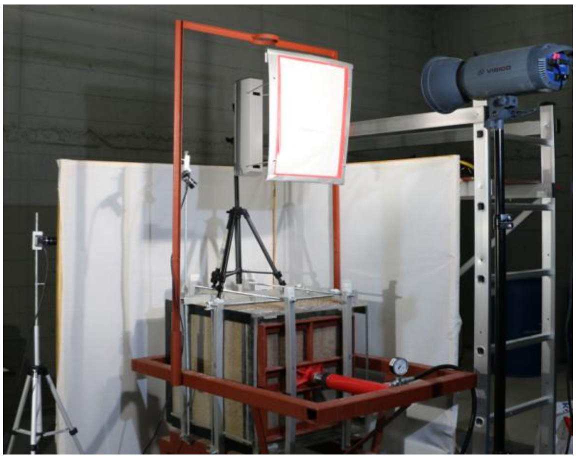

Figure 1. Experimental set up.

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