Ricochets on asteroids: experimental study of low velocity grazing impacts into granular media

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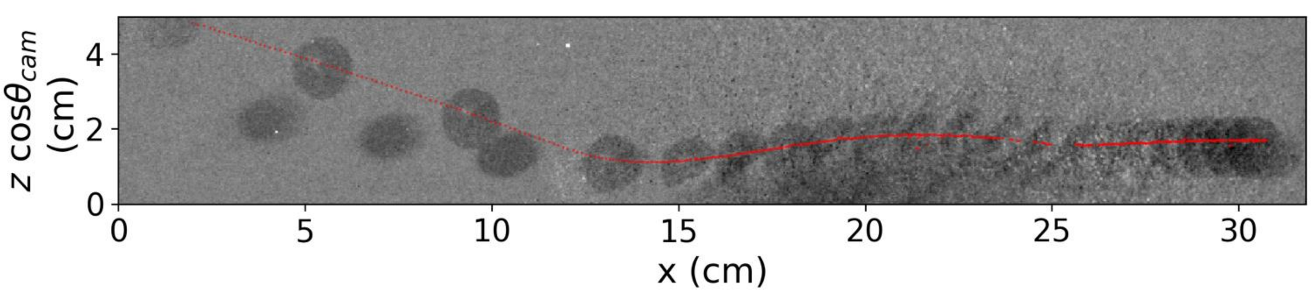
Abstract. Spin off events and impacts can eject boulders from an asteroid surface and rubble pile asteroids can accumulate from debris following a collision between large asteroids. These processes produce a population of gravitational bound objects in orbit that can impact an asteroid surface at low velocity and with a distribution of impact angles. We present laboratory experiments of low velocity spherical projectiles into a fine granular medium, sand. We delineate velocity and impact angles giving ricochets, those giving projectiles that roll-out from the impact crater and those that stop within their impact crater. With high speed camera images and fluorescent markers on the projectiles we track spin and projectile trajectories during impact. We find that the projectile only reaches a rolling without slipping condition well after the marble has reached peak penetration depth. The required friction coefficient during the penetration phase of impact is 4-5 times lower than that of the sand suggesting that the sand is fluidized near the projectile surface during penetration. We find that the critical grazing impact critical angle dividing ricochets from roll-outs, increases with increasing impact velocity. The critical angles for ricochet and for roll-out as a function of velocity can be matched by an empirical model during the rebound phase that balances a lift force against gravity. Using a dimensionless scaling argument, we estimate constraints on projectile radius, impact velocity, and impact angle that would allow projectiles on asteroids such as Eros, Ryugu, or Bennu, to ricochet or roll away from impact, finally coming to rest distant from their initial impact sites.



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