Designing better asteroid explorers

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Recent NASA missions to asteroids have gathered important data about the early evolution of our Solar System, planet formation, and how life may have originated on Earth. These missions also provide crucial information to deflect asteroids that could hit Earth.

Missions like the OSIRIS-REx mission to Asteroid Bennu and the Hyabusa II mission to Ryugu, are often conducted by robotic explorers that send images back to Earth showing complex asteroid surfaces with cracked, perched boulders and rubble fields.

In order to better understand the behavior of asteroid material and design successful robotic explorers, researchers must first understand exactly how these explorers impact the surface of asteroids during their touchdown.

In a paper published in the journal *Icarus*, researchers in the University of Rochester's Department of Physics and Astronomy, including Alice Quillen, a professor of physics and astronomy, and Esteban Wright, a graduate student in Quillen's lab, conducted lab experiments to determine what happens when explorers and other objects touch down on complex, granular surfaces in low gravity environments. Their research provides important information in improving the accuracy of data collection on asteroids.

"Controlling the robotic explorer is paramount to mission success," Wright says. "We want to avoid a situation where the lander is stuck in its own landing site or potentially bounces off the surface and goes in an unintended direction. It may also be desirable for the explorer to skip across the surface to travel long distances."

The researchers used sand to represent an asteroid's surface in the lab. They used marbles to measure how objects impact the sandy surfaces at different angles, and filmed the marbles with high-speed video in order to track the marbles' trajectories and spin during impact with the sand.

"Granular materials like sand are usually quite absorbent upon impact," Quillen says. "Similar to a cannonball ricocheting off of water, pushed sand can act like a snow in front of a snowplow, lifting the projectile, causing it to skip off the surface."

The researchers constructed a mathematical model that includes the Froude number, a dimensionless ratio that depends on gravity, speed, and size. By scaling the model with the Froude number, the researchers were able to apply the knowledge gained from their experiments with the marbles to low gravity environments, such as those found on the surfaces of asteroids.

"We found that at velocities near the escape velocity—the velocity at which an object will escape gravitational attraction—many if not most rocks and boulders are likely to ricochet on asteroids," Wright says.

The results provide an explanation for why asteroids have strewn boulders and rocks that are perched on their surfaces, and they also influence the angle at which robotic missions will need to successfully touch down on the surface of an asteroid.

"Robotic missions that touch down on the surface of an asteroid will need to control the moment of touch down so that they don't bounce," Quillen says. "The robots can accomplish this by making their angle of impact nearly vertical, by reducing the velocity of impact to a very small value, or by making the velocity of impact large enough to form a deep crater that the robotic explorer won't bounce out of."

More information: Esteban Wright et al, Ricochets on asteroids: Experimental study of low velocity grazing impacts into granular media, *Icarus* (2020). DOI: 10.1016/j.icarus.2020.113963

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