Correlation of Granular Impact with Asteroid Impact

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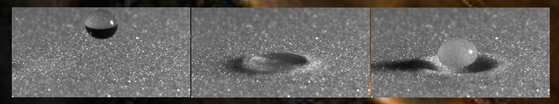
Introduction

Impact of a liquid drop on granular surface like sand beach or ground in backyard is quite familiar to all of us. Except being angry to the splashed mud on the pants, however, few people paid attention to the detailed mechanism of this process. In previous work, people showed contradictive results when explaining the power law of the impact process considering energy distribution and momentum transfer. By exploring the nature of this process, we surprisingly found that the power law we discovered is highly corresponded to the asteroid impact in planetary science. This study built up a revolutionary correlation of granular impact with asteroid impact, which further enabled researchers to look into or even mimic the gorgeous universal process in lab.

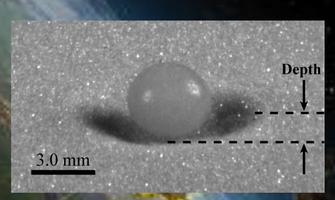
Methods

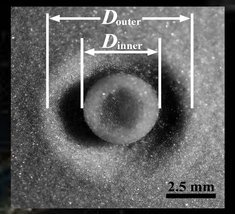
The experiment was very simple: water drop was generated from needle that powered by syringe pump and released for free falling. The impact occurred on a cup of glass beads with smooth surface. The impact process was recorded by High Speed Camera and the morphology of the generated crater was scanned with laser profilometer.



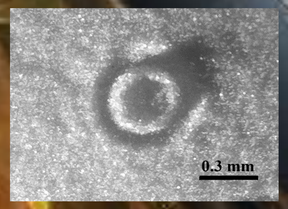
Observation

Two simple craters are shown in figures below. Two diameters are defined whereas only outer diameter is studied. The depth is measured when the bottom is visible under the bouncing ball.

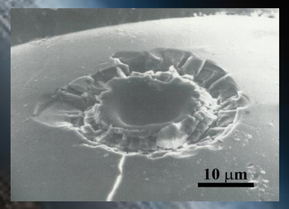




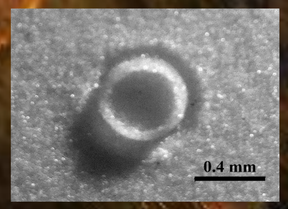
There are various of different crater morphologies from granular impact. Obvious similarity is found by comparing experimental results with meteor impact residues, shown in a gallery below.



3.06 mm, 100 μm, 1.3 cm

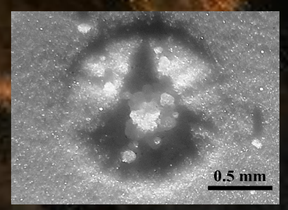


lunar microcrater (Apollo 11)

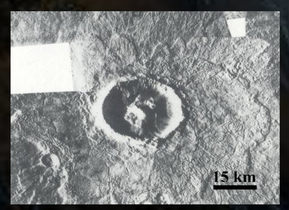


3.06 mm, 100 μm, 1.9 cm

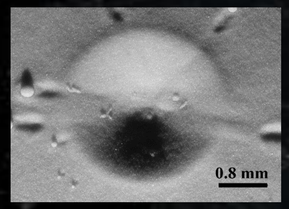
Gosses Bluff crater, Australia



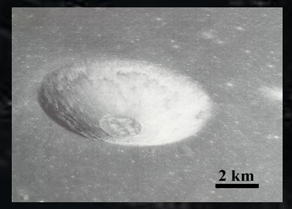
3.06 mm, 100 μm, 116.8 cm (hydrophobic)



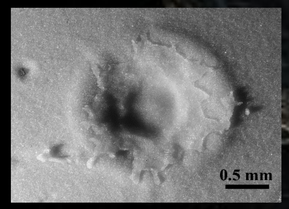
Martian crater, Arandes (Viking Orbiter)



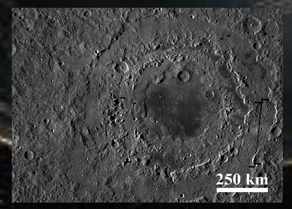
4.6 mm, 100 μm,10 m



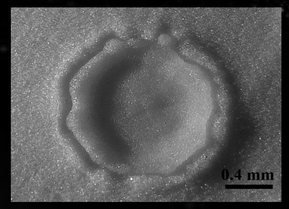
lunar crater, AS10-29-4253



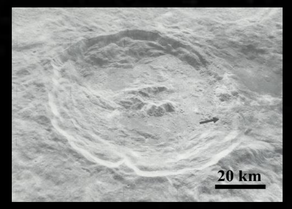
3.86 mm, 100 μm,5 m



Mare Orientale (Lunar Reconnaissance Orbiter)



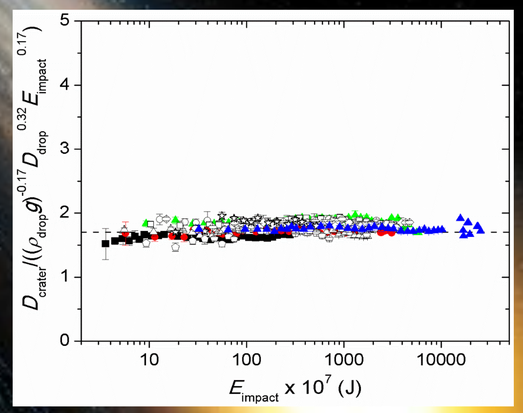
3.86 mm, 100 μm,122 cm



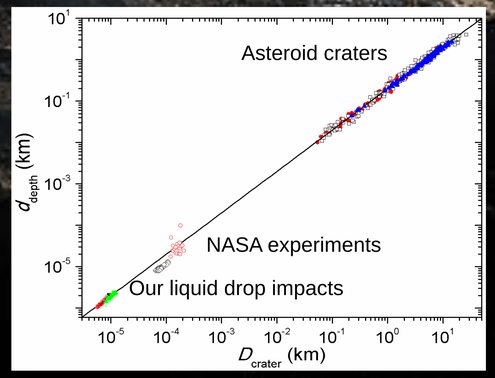
lunar crater, King, AS16-Mo488

Result

By plotting scaled outer diameter vs. impact energy, which the scale is supported by meteor impact research, we conclude that the granular impact follows same scaling low as asteroid impact.



Further, despite the diversity of the inner residue and the huge difference of impact energy (about 10^{20} total), we plot the crater depth vs. crater diameter. The slope is about five. The solid ball impact result from NASA is also included.



Based on the analysis and comparison of these two crucial plots, the physics of granular impact and asteroid impact are now closely related. Due to the lack of observation of asteroid impact it is hard to analyze the mechanism of asteroid impact directly. However, for future work, the process of granular impact will be studied, and is hence expected to fill the gap of our understanding of the universe.

Selected Reference

1. Katsuragi, H. Morphology Scaling of Drop Impact onto a Granular Layer. *Phys. Rev. Lett*. **104**, 218001 (2010)
2. Nefzaoui, E. & Skurtys, O. Impact of a liquid drop on a granular medium: Inertia, viscosity and surface tension effects on the drop deformation. *Exp. Therm. Fluid Sci.* **41**, 43-50 (2012)
3. Daniels, K.E., Coppock, J.E. & Behringer, R.P. Dynamics of meteor impacts. *Chaos* **14**, S4 (2014)

Acknowledgement

This work is funded by the University of Minnesota Undergraduate Research Opportunity Program (UROP)