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Laboratory experiments to simulate the formation of dust comae and size segregation on asteroids

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Abstract

Some observations of minor bodies of the Solar System have shown that granular material is present on the surfaces and maybe in the interior of these bodies. For example, m-size boulders have been observed on the surface of Itokawa as well as sand grains. Dust clouds formed after an impact has been detected in several main-belt asteroids.

Results related to the physics of Granular Media can be used to understand the physical evolution of these objects. We present some laboratory experiments devoted to study some processes relevant to these problems.

We have identified two cases where we would like to apply these experimental results, i.e.:

- Size segregation of rocks due to quakes induced by impacts onto asteroids, in particular the case of asteroid Itokawa.

- Production of dust clouds at low relative velocity due to the ejection generated by the passage of a seismic wave produced in a collision. The results would be applied to the case of the so-called "main-belt comets".

1. Introduction

1.1 "Main-belt comets" or activated asteroids

In recent years, a few objects in typical asteroidal orbits have shown some kind of activity-like appearance: they were observed with a dust coma and tail. There were the cases of 133P/Elst-Pizarro, P/2005U1 (Read), 176P/Linear and, recently, P/2008R1 (Garradd), the so-called "main-belt" comets or activated asteroids ([1]). From the observations thus far, a cometary appearance is detected due to the presence of a dust coma, however, it is not possible to draw a conclusion on whether gas is present in it or not. Therefore, it is still uncertain whether the dust activity is triggered by the sublimation of ices or by some other process. Several explanations to the phenomena have been postulated.

The alternative model presented here is based on the hypothesis that the coma is produced by dust particles being lifted by the seismic shaking produced after an impact. Even small impacts onto km-sized bodies are capable of producing a global quake which causes accelerations larger than the local gravity acceleration ([2]). The dust on the surface could be ejected at very low velocities, comparable to the escape velocity of the object, and would then escape from the object at low relative velocities or could enter into orbit around the object. In the last case, a dust cloud could be formed around the asteroid. By the influence of the solar radiation pressure, the dust particles could finally escape or re-impact the surface.

1.2 Itokawa

The images of the surface taken with the onboard instrument AMICA showed a completely different picture in comparison to the other asteroids previously visited by spacecrafts: while the other asteroids (much larger than Itokawa) have a surface with many craters and generally covered by a thick regolith layer; Itokawa shows a small number of large craters and, more strikingly, the presence of a large number of large blocks randomly distributed on most of the surface.

The distribution of boulders on the surface of Itokawa is correlated with the surface gravity. Large boulders are in the regions of high gravitational potential, while small-boulders are in the region of low gravitational potential. A size segregation or Brazil nut effects has been proposed to explain such correlation.

2. Laboratory experiments

2.1 The "Cocoa Effect"

The device used in the experimental setup is called "CQC: la Caja Que Cae", in english, "The Falling Box". It consists of an acrylic box supported by four rails fixed on a wooden and metal skeleton. In this case, the box is partially filled with different types of dust: talc, fine sand and thick sand and then dropped (free fall) from $\sim 40\ cm$, impacting the floor at a speed of $\sim 2.5\ m/s$.

The purpose of these experiments is to simulate a quake coming from below. This quake could be produced by a distant impact and the transmission of a shock through the entire object.

The box is connected to a vacuum pump to better simulate the conditions on an asteroid's surface. The process is recorded using two high speed cameras in order to measure the ejected particle's speeds.

When working with talc (grain size from 0.05 to 0.1mm), a big dust cloud is clearly seen after the fall (Fig. 1). In this case, it is calculated from the videos that talc particles can reach velocities up to 2 m/s. In case of fine sand (grain size from 0.125 to 0.25mm), a much smaller sand cloud can still be noticed. Apparently, no cloud is formed when working with thick sand (grain size from 0.5 to 1mm). In this case, as well as in the one of fine sand, velocities reached by the particles are significantly lower than in the case of talc.

We have called this phenomena the "cocoa effect", because it can be easily observed when a can of cocoa or any fine powder falls and knock the floor.

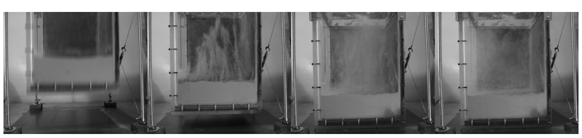

Figure 1: Sequence of photos of the production of a cloud of talc.

2.2 The "Brazil Nut Effect"

Consider a recipient with several large ball on the bottom and a larger number of smaller ones on top of it. All the balls have similar densities. After shaking the recipient for a while, the larger ball rise to the top and the small ones sink to the bottom ([3]). This is the so called size segregation due to shaking or Brazil nut effect (BNE) , because it can be easily seen when one mixes nuts of different sizes in a can; the large Brazil nuts rise to the top of the can.

Most of the experiments in the literature have considered spheric particles. We would like to investigate the effects of irregular shapes in the size segregation process.

We have used the same experimental device described above: the falling box. We fill the box with a mixture of cm-size boulders, sand and/or talc. And we repeatedly lift and release the box, simulating a sequence of quakes coming from below.

Depending on the compaction of the fine powder, the Brazil nut effect is observed or not. For fine talc, we do not observed the effect, but it is observed for coarse sand.

We plan to perform further experiments to better characterize and understand this phenomena.

3. Summary and Conclusions

The results of these experiments will be combined with the numerical simulations presented in this conference [4].

The application of these results to real cases will be the subject of further studies, but we foreseen some situations where the results presented here will be relevant:

- The internal structure of a small asteroid like Itokawa, formed as an agglomerate of m-size particles, and the relevance of the Brazil nut effect produced by repeated impacts.
- The formation of dust clouds at low escaping velocities after an impact onto a km-size asteroid.

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