MODELLING GRAVITATIONAL ACCRETION: OBSERVABLE POLYDISPERSITY AT THE SURFACE VS REAL POLYDISPERSITY. PRELIMINARY RESULTS

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By means of 3D N-Body Contact Dynamics (CD) simulations, we simulate the gravitational accretion of polydispersed grains initially distributed homogeneously inside a spherical cloud. We aim to measure the resulting free surface Particle Size Distribution (PSD) and compare it to the PSD prescribed for the whole system. Our preliminary results show that the resulting aggregate exhibits a similar spatial homogeneous distribution of grains as the initial cloud, meaning that the accretion process does not modify the initial spatial distribution of grains. This implies that, in our simulations, the measured PSD of the free surface is similar to the nominal PSD of the entire granular system only because the initial cloud is also spatially homogeneous.

Our simulations also demonstrate the applicability of the CD method to the simulation of "increasingly realistic" granular asteroids.

Introduction As we understand today, a 'granular asteroid' or 'gravitational aggregate' is a naturally occurring, celestial body that is formed by a conglomeration of discrete, solid components that are held together by their own gravitational, cohesive and adhesive forces [1]. In the last couple of decades, some of these asteroids have been visited by different space missions and some of the first pieces of information that are received about them have the form of images. These images allow us to see their shapes and their surfaces along with the PSD of the regolith that covers them.

Analysis of the gravitational field produced by the asteroid and its spin state, together with some assumptions about the material density and internal porosity have provided some insights about their internal structure. In the best case scenario, some things can be said about the bulk density, cohesive strength and angle of friction which provide some insight into its structural strength and stability. However, a clear picture of its interior cannot be obtained because it is simply hidden.

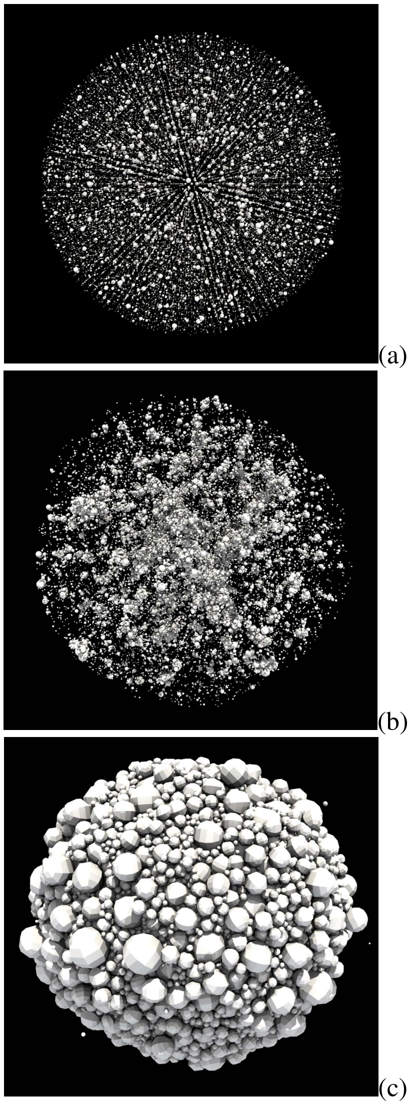

Figure 1: Accretion evolution of the polydisperse grains cloud, initial (a), intermediate (b) and final (c) states.

In this research we have tried to recreate the accretion process of a granular system that is large enough to form a small, asteroid-size gravitational aggregate. We have varied the particle size distribution of the particles so that a wide range of values is covered. After accretion, we measured the size distribution of the particles that are observable on their surfaces. This provides us with information about the PSD of the observable surface that could result from an accretion process and how close or not it is to the nominal PSD of the entire system.

Numerical Procedure For the simulations, we use the Contact Dynamics method, a class of "Non-Smooth" Discrete Element Method (DEM) [1]. In contrast to the "Smooth" DEM, also called Soft-Sphere DEM (SS-DEM), in the CD method the contact laws are expressed

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[1] Definition reached after discussions among Derek Richardson, Adriano Campo-Bagatín, Patrick Michel, Masatoshi Hirabayashi, Michael Nolan and Paul Sánchez.

in terms of mutual exclusions. On the other hand, solid friction between grains is implemented without introducing elastic regularisation or viscous damping. The contact forces and grain velocities are found simultaneously by using an iterative nonlinear Gauss-Seidel algorithm. An implicit time integration scheme is used which ensures unconditional numerical stability of calculations.

The code used for these simulations is called LMGC90, developed at the University of Montpellier. The code is capable of modelling large numbers of particles with a wide variety of shapes and sizes [2, 3]. Self-gravity is calculated through an Open-Source Python library called pytreegrav [4]. In this routine, a kd-tree is implemented through the Barnes-Hut method [5] for computing the combined gravitational field and/or potential of the grains. The package implements also OpenMP multithreading. Our numerical sample is composed of 44338 spherical grains uniformly distributed by volume fraction between $d_{min} = 1.5$m and $d_{max} = 16$m and density $\rho = 2500\ kg/m^3$. The grains are randomly placed on a square network of size $0.5 d_{max}$ inside a sphere of diameter $D_i \simeq 504$ m, that we will refer as the size of the "granular cloud" (see Fig. 1(a)). Friction between grains is fixed to 0.3, and particle velocities are set to zero at the beginning of the simulations.

Results Figs.1(a) to 1(c) shows different snapshots taken during the accretion of the spherical and polydisperse cloud. At the end of the accretion process, in absence of inter-grain cohesion and anisotropic shape of the grain or anisotropic shape of the initial cloud, the shape of the aggregate is spherical with a diameter $D_f \simeq 54$ m; Fig.1(c). In order to understand whether the accretion process modifies the PSD of the particles in space, we divide the initial cloud and the final aggregate in concentric shells and calculate their individual PSDs as illustrated in Fig.2(a). The normalised PSD of each shell, as well as the initial and final states are shown in Fig 2(b). We also show on this figure the PSD of the entirety of the accreted body. We observe that all the PSDs are nearly identical, suggesting that no segregation occurs during or due to the accretion process. This is, the accretion process preserves the spatial distribution of the original cloud. In this specific case, the PSD of the surface (immediately after accretion is finished) is representative of the PSD of the hidden interior. However, this happens because the cloud was homogeneous by construction and this might not represent a realistic scenario. Unfortunately, there is no experimental data about the spatial particle distribution of the debris after an asteroid collision.

Discussion In the absence of information about a "typical" debris field after the collision of two asteroids, if one exists, homogeneity is a good first approximation, but this is a strong assumption. In this case, our simulations show that the original PSD of the surface of an asteroid, before it is modified by other phenomena (thermal fracturing, impacts, surface flows, particle shedding), would be representative of the PSD in the interior. However, in general, the PSD of the unmodified surface would be representative only of the outer regions of the initial grain cloud.

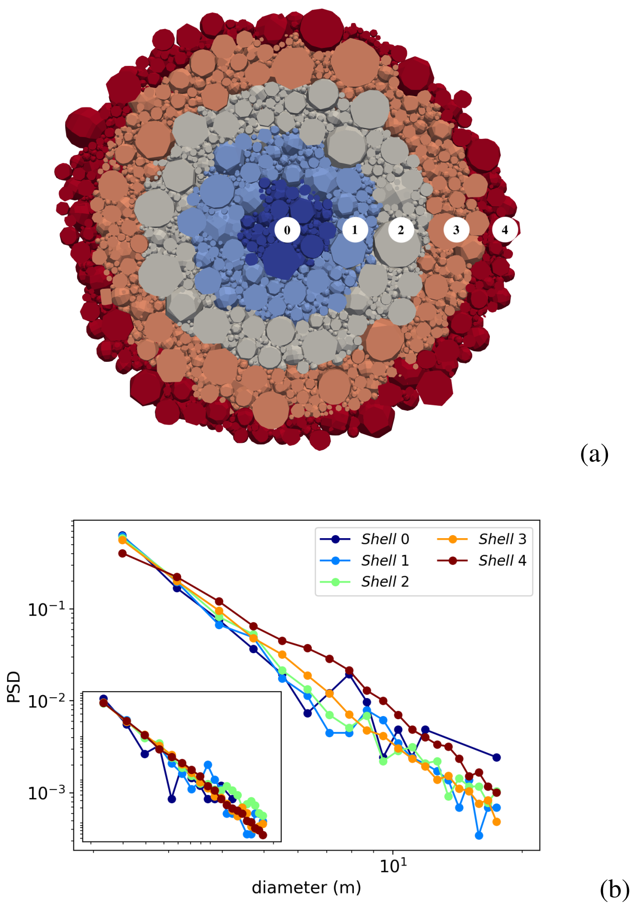

Figure 2: (a) Cross section of the granular asteroid divided in shells. (b) Normalised PSD per shell at the end of accretion and in the initial cloud (inset).

In order to support this last point, work is currently in progress on larger polydispersities and also with clouds with different initial segregation levels. These results will be presented at the conference.

References

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