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Internal structure of small asteroids by N-body numerical simulations of non-spherical fragment shapes

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Abstract

The internal structure of asteroids and comets is fundamentally unknown due to difficulties in sounding their interiors. The measurements carried on by space probes and the observations of binary asteroids (optical and radar) have allowed acceptable estimates of the masses of only a few asteroids. From their sizes and shape models estimates of their bulk densities are derived. Such bulk densities are usually smaller than the values corresponding to typical densities of meteorites with compositions matching spectroscopical observations of the surfaces of those asteroids, rising doubts about the actual composition and structure of their interiors [1]. Similar arguments –but with much larger uncertainties- hold for comets.

The interpretation of such low bulk densities is that part of the volume inside some of those objects is occupied by voids in between the coherent components forming their global structures, qualifying them as gravitational aggregates (also, “rubble-piles”). The origin of such bodies is clearly related to former catastrophic or gradual [2] disruptions. Moreover, numerical simulations of the collisional evolution of the asteroid belt predict that most of the bodies between some hundreds of meters and about 100 km should be gravitational aggregates [3]. The situation is a little fuzzier in the case of comets.

1. Methodology.

In this work we go one step beyond the standard spherical approximation for the shapes of single components of gravitational aggregates. Firstly we try to reproduce the internal structure of some of the asteroids with best known physical characteristics (mass, size, shape, spin rate). Secondly, we investigate the dynamics of the components of gravitational aggregates under different initial conditions corresponding to the event forming the final object and to the circumstances of shattering of the parent body. We perform that by means of numerical simulations that produce irregularly shaped asteroid components. Simulations are performed by the soft-sphere discrete element model PKDGRAV code that manages the N-body gravitational problem and accounts for collisions and friction between components. In order to create non-spherical shapes for the fragments constituting our synthetic asteroids, groups of spherical particles –the basic elements of the PKDGRAV code- are clumped together and forced to keep their mutual distance constant so they can be handled and behave like rigid bodies. We draw at random mass and shape distributions for the components of each synthetic aggregate from the corresponding distributions found in a set of laboratory shattering experiments performed at NASA-Ames facilities (S. José, CA, U.S.A.) in July 2013 [4].

Considering an arbitrary number of such irregular components and different mass spectra, we allow for self collapse by mutual gravitational interactions, starting from disperse initial space configurations and angular momenta. By varying the density of components we try to get gravitational aggregates with observable physical characteristics.

2. Results.

In this way we obtain families of qualitatively similar shapes and we are able to reproduce the best density estimates available for the two parts of asteroid Itokawa [5]. According to our simulations, the formation of small body structures so-called “contact binaries” (Itokawa, Toutatis, Castalia, Comet Borrelly, …) would be a natural outcome of gravitational reaccumulation rather than the collapse of binary systems. As a consequence of our simulation results, we also point out the possibility that current bulk densities for asteroids with poorly determined shapes may be overestimated.

References

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