07/4111 ASTEROID CENTRIFUGAL FRAGMENTATION

Type of activity: Extended Study (6 months, 35 KEUR)

Background and Motivation

While some data is available about the mineralogy and surface properties of different families of asteroids and comets we still know very little about the structure, composition and physical properties of their interior [1]. Remote observation data support the evidence that most sub-km asteroids, which tend to exhibit higher spin rate, are cohesive bodies held together by material strength while larger asteroids (km-size and more) may be loose gravitational aggregates [2]. Still, the causes for this spin rate separation (figure 1) and the relation between observed spin rates and asteroid structural features are not completely understood.

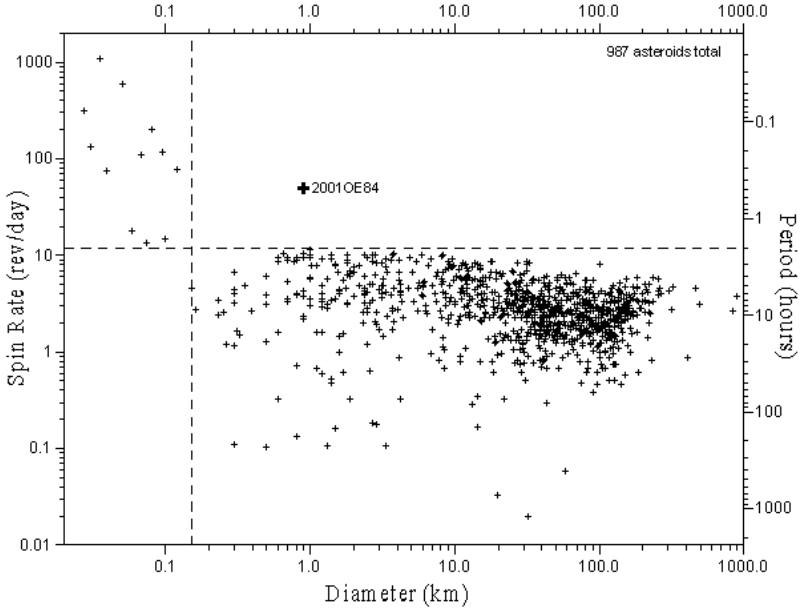

Fig.1. Relation between estimated asteroid diameter and spin rate (from ref. [2])

Clearly, an important step towards a better understanding of the asteroid interior makeup involves in situ measurements from dedicated space missions. So far, the approaches proposed in the literature are based on indirect measurements through radar tomography [3] and seismology [1] and on direct measurements through subsurface sampling [4]. While the former can only provide limited resolution measurements of the interior the latter are restricted to the outer layers of the celestial object.

A recent ESA-ACT study [5] proved the feasibility of artificially increasing the spin rate of sub-km asteroids beyond the level at which a fragmentation process is activated. This approach may provide a new tool to explore the mechanical properties of small asteroids by monitoring their response to the spin-up process. Most importantly though, once the fragmentation process is activated, a direct access to the inner layers of the fractured celestial body becomes possible providing unique scientific information on its interior. One of the most important issues to be investigated when dealing with centrifugally accelerated asteroids involves the understanding of the complex fragmentation dynamics and its dependency on the asteroid mechanical and structural properties. While it seems certain that an asteroid will experience break-up if resources are available to increase its rotation rate

indefinitely, the outcome of the fragmentation process such as the expected size of the fragments and their velocity distribution is not easy to predict. Indeed, a number of different physical phenomena characterize the system's dynamics such as deformable body dynamics and stability issues, crack activation and growth and tensional/shear stress wave propagation from abruptly relaxed boundaries after fracture onset.

While no detailed analysis has yet been conducted on purely centrifugal asteroid fragmentation dynamics, a vast amount of literature is available on collision-induced asteroid and terrestrial rock fragmentation (see for example [6]). Tidal disruption of asteroids has also been investigated [7]. Theoretical studies have been accompanied by experimental work [8] and more recently by numerical investigations based on Smoothed Particle Hydrodynamics codes (SPH) [9]. These analytical, experimental and numerical models may prove also effective in dealing with the fragmentation dynamics of centrifugally accelerated asteroids provided that all relevant physical phenomena are included in the model and material properties are carefully selected. In fact, because the properties of asteroid interiors are still poorly known, the proposed study approach is to base the analysis on a wider spectrum of material and structural properties and study their influence on the final outcome of the fragmentation process in order to gain a good understanding of the process as a whole.

Research and Study Objectives

The objectives of the study are:

- To carry out a literature review on the following main topics:

  a) Physical properties of sub-km asteroids including rotation state, expected range in material compositions and properties

  b) Fracture and fragmentation studies of asteroids due to collision and tidal encounters

  c) Main features of Smoothed Particle Hydrodynamics codes applied to brittle fragmentation

- To identify all relevant physical properties that need to be taken into account in order to investigate the fragmentation behaviour of sub-km asteroids in accordance with observation data and previous studies.

- To develop analytical and numerical models to accurately describe the centrifugally induced fragmentation dynamics of sub-km asteroids.

- To investigate the dynamical behaviour of a class of centrifugally accelerated asteroids before and after fragmentation and for different regions of the physical parameter space (e.g. asteroid size, material strength, crack distribution, initial structural damage). The output of the analysis should include the variation of geometrical and mechanical characteristics of the asteroid during the acceleration phase as well as the geometrical and dynamical characteristics of the asteroid fragments (size spectrum, linear and rotation rate distribution, fragmentation history) and their sensitivity to the variation of relevant physical parameters.

Universities and Research Centres with no space background are particularly encouraged to participate.

References

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