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Modeling of the seismic response of models of asteroids based on the normal modes summation method

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The knowledge of the geophysical properties of an asteroid is a key point for the development of a possible mitigation technique. This technique involves studies about the surface and sub-surface of Near Earth Objects, and for this reason, operations of seismological investigations are proposed (Ball et al., 2004). It is then necessary to constraint the sensibility of future adapted seismometers. We present simulations of seismograms of the seismic response of spherical models of asteroids impacted by a projectile, based upon a normal-mode summation method (e.g. Lognonné and Clévédé, 2002), to determine such requirements.

The Don Quichotte ESA mission involves the impact of a 400 kg projectile at 10 km/s (e.g. Ball et al., 2004) on the surface of a NEO. After this impact, seismic waves propagate within the asteroid. We compute seismic waves based upon the free-oscillations summation technique. Because of the small size of the asteroids, these normal modes are found in the 0.1-300 Hz bandwidth. They are computed for an angular order up to 500 and frequency of 30 Hz or 150 Hz.

As a second step, assuming that a seismometer is located every 5° of epicentral distance, we compute the 36 maximum values of acceleration on half of the asteroid (because the models are spherically symmetric). To accomplish this, the normal modes are summed, knowing that a vertical impact will excite spheroidal modes only (spheroidal modes correspond to Rayleigh surface waves with combined P and SV polarization). A horizontal impact will induce both spherical and toroidal modes (toroidal modes are linked to the Love surface waves with SH polarization).

The results are used to explore the effect of the reverberation of the subsurface layers. The normal modes computed very strongly depend on the properties of the layers since bifurcations can be observed with the surface-wave type modes, probably associated to modes trapped at the layers boundaries.

The amplitude of acceleration with respect to impact exhibits a decrease and a refocusing of the surface waves that varies as 1/sqrt(sinθ) with θ as the epicentral distance of the seismometers. The peak amplitude is then located at the antipode of the source, and strongly depends on the intensity of the source. The highest accelerations computed for our models are depending on the assumed direction of the force of the source. Although these results are useful to define the highest acceleration a seismometer could measure after the impact, they will be strongly dependent on the asphericity of the asteroid. The simulation of synthetic seismograms in several frequency bands have allowed to define an optimal frequency band for the extraction of data of the internal structure of kilometre-sized asteroids.

Further studies will therefore aim to model wave propagation based on fully three-dimensional numerical techniques such as the spectral-element method (SEM, e.g. Komatitsch et al., 2005), and the diffraction from both the surface and the interior will be analyzed.

References:

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