Experimental study of avalanche precursory events based on reproducible cycles of grain packing destabilizations.

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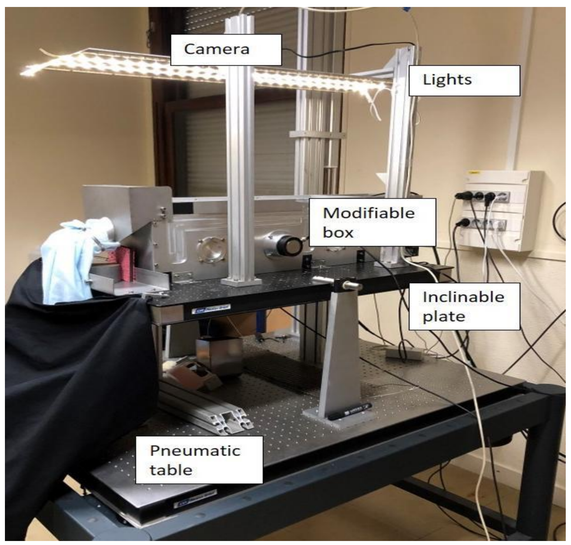
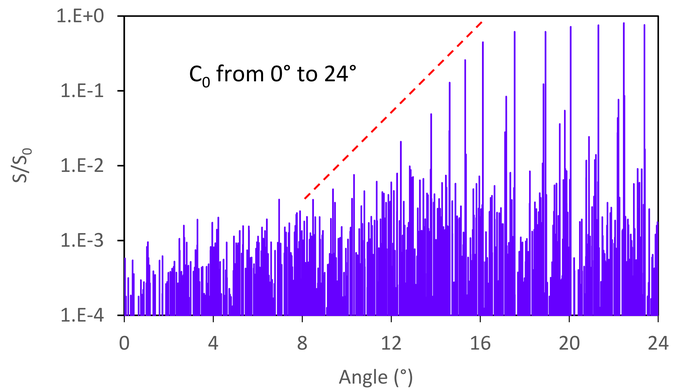
Abstract

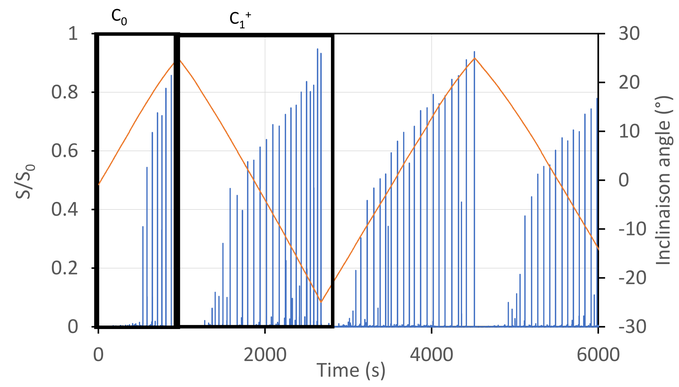
Quasi-periodic collective displacements of grains at the free surface of a tilted grain packing constitute precursors of granular avalanches. Laboratory experiments are commonly performed by slowly tilting the packing from 0° to the maximal stability angle θ_A. In these conditions, the number of precursors is too small to assess reproducible and robust statistical analyses of the precursor activity. To go beyond this limitation, we have developed a specific experimental protocol consisting of tilting the packing with successive oscillation cycles. We use a high-resolution optical camera and process the images of the packing free surface to identify precursory events during many consecutive cycles of a single packing. We observe the same behavior for all half-cycles, forth and back: appearance of the first precursors after the same variation of inclination, exponential evolution of the weak surface activity for the first precursors and linear growth of stronger surface activity for the following ones.
The experimental setup can perform multi-cycle experiments composed of an initial quarter-cycle C_0 from 0°$ to $\theta_C < \theta_A$, corresponding to a classical tilting experiment with stop before reaching avalanche, followed by a series of successive half-cycles indexed by i from + θ_C to - θ_C (C^+_i) and from -θ_C to + θ_C (C^-_i). The experimental protocol provides both reproducible precursor measurements based on large sample statistical inferences and a quasi-stationary state after one full-cycle. This approach is very promising for highlighting the effects of external parameters, including humidity and packing geometry.



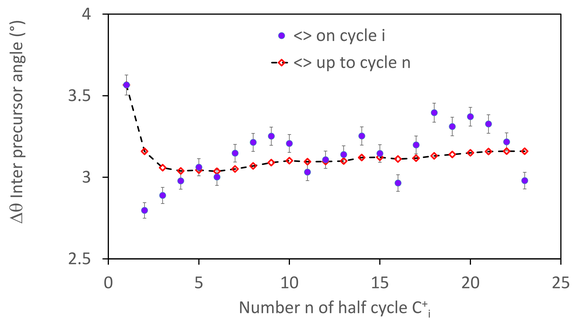
Photography of the experimental setup.



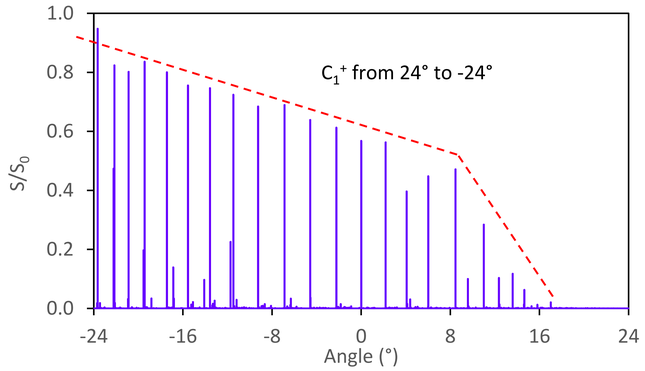
Surface activity measured for a 2~mm beads packing and θ_c=24° during the initial quarter-cycle C_0. The dashed line is an exponential approximation of the activity behavior.



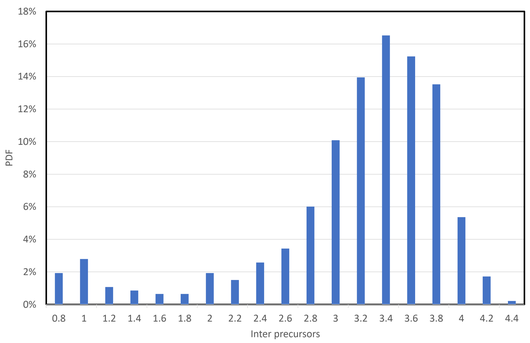
Surface activity S/S_0 measured as a function of the recording time during a multi-cycle experiment composed of 4 full-cycles (blue line)



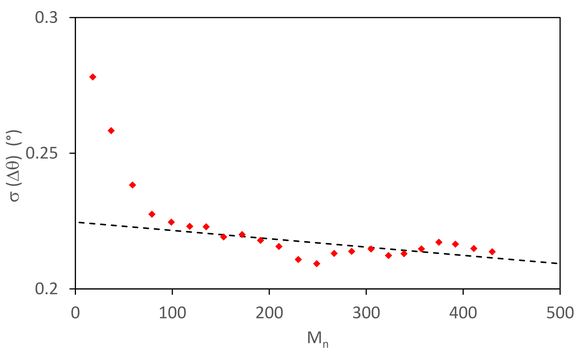
Evolution of the inter-precursor angle $\Delta\theta$ averaged (<>)on each half-cycle C^+_i (disk with its error bar) and accumulated average from 0 up to n (open diamond) versus the number n up to 23 full-cycles



Activity of the C_1 half-cycle following C_0 as a function of the inclination angle.



Distribution of the interprecursor interval $\Delta\theta$



Error bar evolution with the full number of interpercuros

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