Boston University Physics Colloquium

Fluctuations, Response, Entropy and “Temperature” in Granular Packings

To understand the mechanical response of granular materials, one needs a theoretical approach that can bridge the gap between microscopic, grain-level quantities and macroscopic, collective properties. Fluctuations are inherently related to the number of microscopic states available under a given set of macroscopic parameters. In equilibrium thermodynamics, the microcanonical entropy, or its derivatives in other ensembles, is the measure used to calculate fluctuations and response. In disordered systems such as spin glasses, the concept of complexity has been used to understand collective properties. In mean-field models, free-energy minima are separated by barriers that diverge in the thermodynamic limit, and one can in principle count the number of states unambiguously. Can we identify a physical variable in granular materials that is conserved under any local dynamics, and therefore leads to a definition of complexity? For mechanically stable packings, there is a topological conservation law that allows us to define the analog of complexity. In this talk, I will describe a framework for calculating stress fluctuations in frictional and frictionless granular packings, based on a model calculation of complexity, and compare the predictions of our theory to experiments and simulations.

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