Master 2: *International Centre for Fundamental Physics*
INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Laboratoire de Physique des Solides (LPS)
CNRS identification code: UMR-8502
Internship director's surname: Restagno, Foffi
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Internship location: LPS, Orsay

Thesis possibility after internship: YES
Funding already obtained for a PhD: NO If YES, which type of funding:

Trapping mechanisms in vibrated granular matter

Granular materials [1] can be defined as large assemblies of macroscopic (≥ 10 μm) particles (i.e. the grains). When external energy is applied to these systems, they can reach a non-equilibrium steady state (NESS), where the statistical properties of the dynamics remain constant but the time-reversal symmetry is broken by forcing and dissipative mechanisms. Depending on the experimental conditions, these systems can follow equilibrium-like behaviour [2] or completely deviate from it.

In this project, you will study the behaviour of granular materials "fluidised" by mechanical vibrations and confined in different geometries. In these systems, dissipative collisions tend to cool the effective temperature of the grains in correspondence of high density fluctuations or near the walls, creating a non-trivial interplay between the confinement and the density/velocity fields.
The aim of the project is to characterise these effects in the presence of complex geometries and obstacles, with a particular focus on trapping mechanisms (Fig. 1a), i.e. the realisation of NESSs where only a sub-region of the available space is effectively explored by the grains [2,3].
We will address this problem both by molecular dynamics simulations and in the experimental setup available at LPS (see Fig. 1b-c). Depending on your interests, your project can focus more on the simulations or more on the experiments.

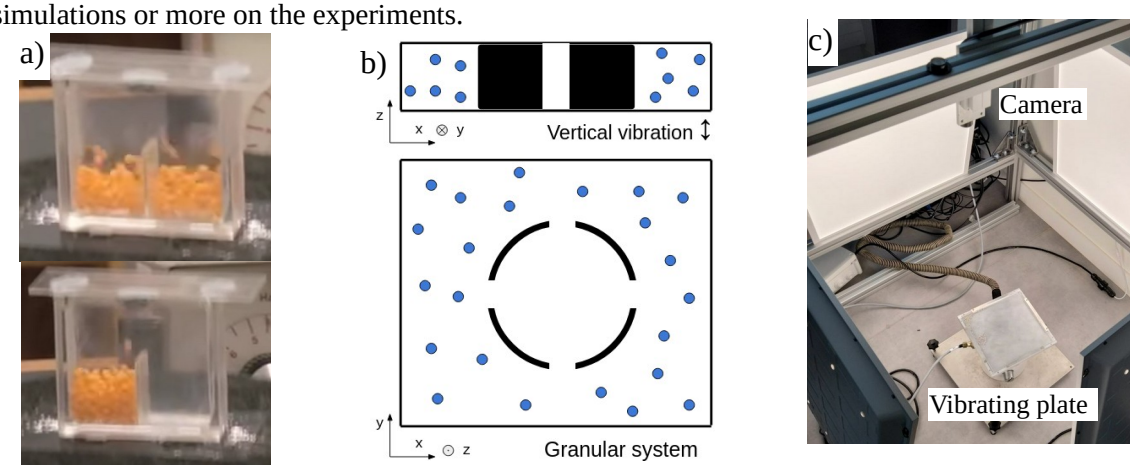

Fig1: a) Granular materials in a box with two sets vibrated on a speaker. Initially (top photo) they occupy both sets, after some vibration all the grains end up in the same compartment. Full video at [3]. b) Sketch of a quasi-2D granular system with obstacles. c) Photo of the quasi-2D experimental setup for vibrofluidized granular matter at LPS (camera and vibrating plate).

[1]: H. M. Jaeger, S. R. Nagel, and R. P. Behringer, *Rev. Mod. Phys.* **68**, 1259 (1996)
[2]: A. Plati, R. Maire, E. Fayen, F. Boulogne, F. Restagno, F. Smallenburg, and G. Foffi, Nat. Phys. **20**, 465–471 (2024)
[3]: J. Eggers Phys. Rev. Lett. **83**, 5322 (1999)
[4]: https://www.youtube.com/watch?v=SRGf0Mq2Zwg&t=224s

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: NO Soft Matter and Biological Physics: YES
Quantum Physics: NO Theoretical Physics: YES