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: Foffi
e-mail: frank.smallenburg@universite-paris-saclay.fr Phone number:
Web page: https://www.lps.u-psud.fr
Internship location: LPS, Orsay

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

Self-assembly of granular binary mixtures

Granular materials [1] can be defined as large assemblies of macroscopic (≥ 10 μm) fundamental units (i.e. the grains). When external energy is supplied to these systems they can attain a non-equilibrium stationary 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 specific setup granular NESSs can exhibit properties that resemble the ones of a fluid at equilibrium or genuine non-equilibrum effects such as convective motion, violation of energy equipartition and size segregation.

In this project, you will focus on self-assembly of granular binary mixtures. Hard spheres of two different sizes undergoing thermal motion have revealed to form a wide range of different phases including periodic and aperiodic crystals [2]. With the experimental setup available at LPS (see Fig. 1a), we are able to realize a macroscopic version of this type of systems using grains vibrated on a substrate. This allows us to study how athermal motion influences crystallization phenomena. Depending on your interest, your project can be focused more on the simulations, or more on the experiments. Questions of interest in this study will include: How driving and dissipation mechanisms affect the stability of granular crystals? Can we observe new phases which genuinely emerge from non-equilibrium effects? Are there features of granular self-assembly which manifest at the macroscopic scale the underlying irreversible dynamics?

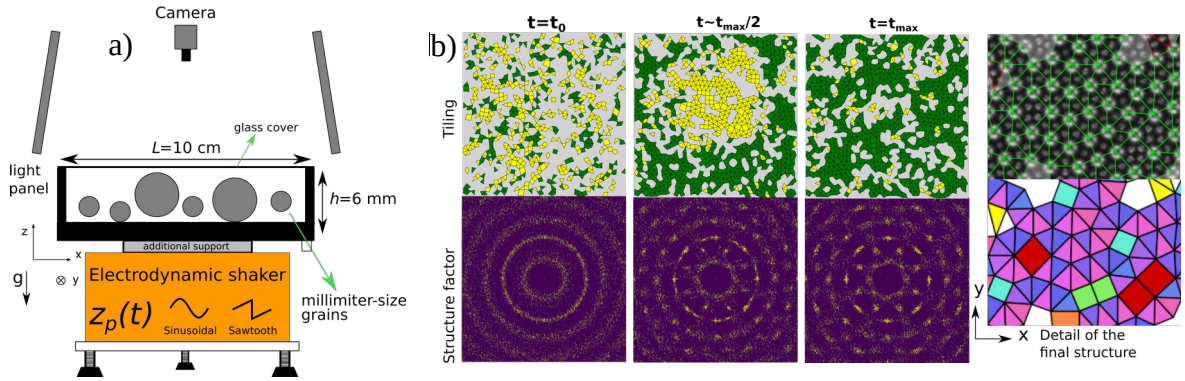

Fig1: a) Graphical scheme of the experimental apparatus available at LPS. It consists of an alluminuum plate placed on top of an electrodynamic shaker which supplies the external driving. b) Example of a granular aperiodic crystal we realized in the lab and relative analysis. Starting from a liquild-like structure, it spontaneously self-assembles when the system is subjected to vertical vibrations.

[1]: H. M. Jaeger, S. R. Nagel, and R. P. Behringer, *Rev. Mod. Phys.* **68**, 1259 (1996)
[2]: E. Fayen, M. Impéror-Clerc, L. Filion, G. Foffi, and F. Smallenburg, *Soft Matter* **19**, 2654 (2023)
[3]: A. Plati, R. Maire, E. Fayen, F. Boulogne, F. Restagno, F. Smallenburg, G. Foffi, arXiv:2307.01643

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