PROPOSITION DE STAGE / INTERNSHIP PROJECT

Nom du Laboratoire / Institute: Institut Lumière Matière (ILM), LYON (http://ilm.univ-lyon1.fr/)
Equipe / Team : Modélisation de la Matière Condensée et Interfaces (MMCI)
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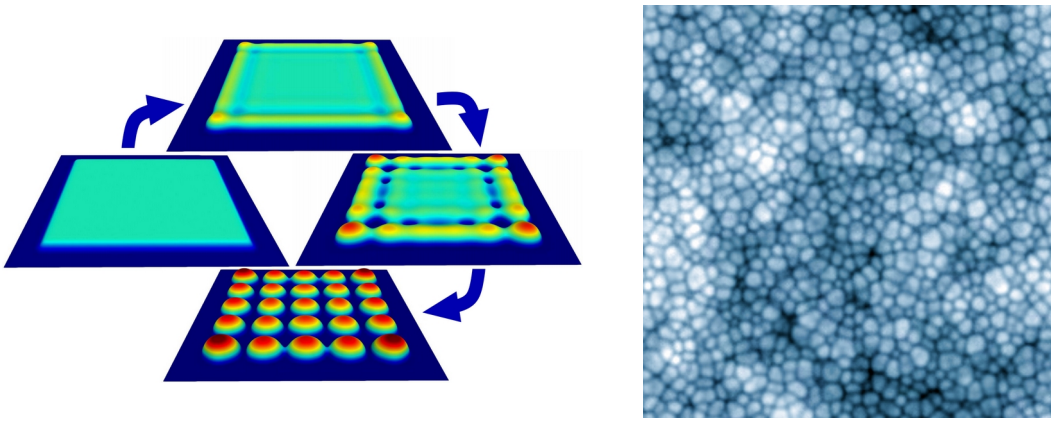
Niveau / Level: **Master 2**
Intitulé du stage / Title : **Controlling morphogenesis in non-equilibrium systems**
Possibilité de thèse / possibility of PhD : **yes**

Mots clés / Keywords: Nonlinear Dynamics, Non-equilibrium Physics, Machine Learning, Control theory

Résumé / Summary:
Instabilities in non-equilibrium and nonlinear physics give rise to a wide variety of spatial organizations of matter, ranging from simple periodic structures to complex spatio-temporal chaos. These structures can be used to design specific patterns, such as periodic patterns of dots, or stripes (see Figure and Ref.[1]). Such an approach, knon as auto-organization, has been very successful in the past decades because it allowed one to form complex self-assembled micro- and nano-structures at solid surfaces, or in soft-matter systems without having to sculpt directly the surfaces by means of some sophisticated tools. However, within this approach, a given pattern can only be obtained by a trial-and-error process, where one has to change the physical ingredients in various ways, and see what emerges.

Recent advances of control theory and Machine Learning methods now open possibilities for a novel approach [2], which includes not only the physical non-equilibrium system but also the agent that acts on the system. These approaches allows one to find an optimal strategy to reach a given pattern. These optimal straetegies obey some elegant variational principles and propose novel types of criticality and universality in non-equilibrium systems.

In this internship, we will explore startegies for driving instabilities towards pre-defined patterns by means of an external macroscopic time-dependent driving force (such as temperature or an electric field). We will work with universal model equations that describe non-equilibrium systems (such as, e.g., the Kuramoto-Sivashinsky equation, see Figure). Our ultimate theoretical goal is to understand in which sense universality can emerge in the control of non-equilibrium and nonlinear systems. Depending on the student, the internship project could be based on Machine-Learning approaches or on analytical approaches, or a combination of the two.



Left : Spontaneous formation of ordered dots from solid-state dewetting[1] ; Right :Spatio-temporal cellular chaos emerging from Kuramoto-Sivashinsky equation in 2 dimensions (J. Muñoz-García, Madrid)

References :
[1] for a recent example, see : Stress-Induced Acceleration and Ordering in Solid-State Dewetting, F Boccardo, F Rovaris, A Tripathi, F Montalenti, O Pierre-Louis, Physical Review Letters 128 (2), 026101 (2022).
[2] Controlling the shape of small clusters with and without macroscopic fields, F. Boccardo and O. Pierre-Louis, Phys. Rev. Lett. 128, 256102 (2022).