Institut d'études avancées - PROJET DE COLLABORATION SCIENTIFIQUE

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Titre du projet :

Correlations and perturbation spreading in long-range interacting nonlinear oscillators

Résumé :

The project is part of a general research theme focused on transport and diffusion of energy in many-body systems characterized by different sources of complexity: *nonlinearity*, *low-dimensionality*, *long-range interactions* and *disorder*, the latter originating from random interactions and/or topology. Generally speaking, the aim is to characterize the dynamics of such systems driven out of equilibrium by external (possibly non-conservative) forces or by different thermal reservoirs exchanging energy, momentum and mass [1]. The aim of this vast, interdisciplinary research will be to illustrate generic and universal features by simple paradigmatic models in the spirit of basic statistical mechanics. Among them, systems of *classical coupled oscillators* are of particular interest as they represent a large variety of different physical problems like atomic vibrations in crystals and molecules or field modes in optics or acoustics. Methodologically, the tools entail numerical simulations and solution of simplified toy models [2].

A fairly complete understanding of transport property in low-dimensional lattices has been achieved in the recent years [1,2]. Non trivial effects like the emergence of anomalous heat diffusion in nonlinear chains and the effect of disorder (Anderson localization) have been investigated thoroughly. However, the effects of long-range interactions has so far received very little attention [3]. It is known that long-range interacting systems display peculiar features like out-of-equilibrium quasi-stationary-states, anomalous diffusion etc. What should we expect when such system interact with external reservoirs? Attempts to answer to this question will most likely open a new line of research.

As a concrete example, we will consider computationally convenient models like arrays of coupled classical particles interacting through nonlinear forces whose strength is inversely proportional to a power of their distance. The specific questions that we wish to investigate regard (i) the propagation of perturbations and (ii) the scaling properties of correlation functions. Spreading of perturbations in chaotic systems yields insight on how information propagates in presence of fluctuations [4]. A useful indicator is the co-moving Lyapunov exponent that is related to the typical speed of perturbations [5].

Other important quantities for non-equilibrium processes are the correlation functions of the fluctuations of conserved variables (e.g. energy) . In the framework of linear response theory, they are connected to measurable transport coefficients. It has recently been established that correlation functions of one-dimensional oscillator chains satisfies scaling relations in the same universality class of the celebrated Kardar-Parisi-Zhang equation [6]. One aim of the project would be to investigate numerically the dynamical scaling of such correlation functions, an issue which is yet unexplored for long-range interacting oscillators.

The research will be carried in collaboration with prof. A. Torcini and his group at the *Laboratoire de Physique Théorique et Modélisation.*

During the sojourn, the Candidate will also actively participate to the S*emestre Thématique Complexité* financed by Labex MME-DII and that will be held at the IEA during 2018. The Candidate will give some lectures for the PhD Course *Introduction to Chaos* of the *Ecole doctorale Économie, Management, Mathématiques et Physique* (EM2P) supervised by A. Torcini during that semester.

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[2] S. Lepri, R. Livi and A. Politi, *Thermal conduction in classical low-dimensional lattices* Phys. Rep. 377-1 (2003)
[2] D. Bagchi, *Thermal transport in the Fermi-Pasta-Ulam model with long-range interaction*, Phys. Rev. E 95 032102 (2017)
[3] A. Torcini , S. Lepri *Disturbance propagation in chaotic extended systems with long range coupling* Phys. Rev. E 55 R3805 (1997).
[4] G. Giacomelli et al., *Convective Lyapunov Exponents and Propagation of Correlations* Phys. Rev. Lett. 85, 3616 (2000)
[5] H. Spohn, *Fluctuating hydrodynamics for anharmonic chains*, J. Stat. Phys 154, 1191 (2014)