Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: Ecole Doctorale EDPIF

Non-equilibrium physics of large molecular systems

In this internship, we would like to understand the properties of large molecular systems, where by that, we mean systems containing a large number of interacting chemical species [1]. The species we have in mind are inherently self-reproductive, like RNA or DNA [2]. Their replication is however never entirely precise but prone to mutations [3]. Finally the system is driven out of equilibrium by the steady supply of building blocks or fuel molecules which are free energy rich. This is a general setting which is of interest, because it contains all the elements needed to understand how chemical evolution can proceed at a molecular level. Within such a model, we would like to tackle the following questions: under what conditions can a phase transition occur in the limit where the number of species become infinite, where a phase transition could be for instance a transition from random disordered sequences to ordered and functional ones ? What kind of non-equilibrium protocol can optimally yield sequences with a certain functionality ?
Building such a theoretical framework would be useful to understand in particular *in vitro* experiments on directed evolution, in which the goal is precisely to build molecules with a well defined functionality using molecular programs. Experiments of this kind are being done in the group of Y. Rondelez at Gulliver. This project should also benefit from interactions with a group of researchers from the lab or from nearby institutes and interested in closely related topics : Z. Zeravic and Y. Rondelez (Gulliver), P. Nghe (LBC lab) and O. Rivoire (Collège de France).
The main skills which are required for this internship are statistical physics, including stochastic processes, and an interest for the biology-chemistry and biology-physics interfaces.

References :
[1] Emergence of homochirality in large molecular systems, G. Laurent, D. L. and P. Gaspard, under review (2020).
[2] Universal motifs and the diversity of autocatalytic systems, A. Blokhuis, D. L. and P. Nghe, PNAS (2020) :
https://www.pnas.org/content/early/2020/09/25/2013527117
[3] Selection dynamics in transient compartmentalization, A. Blokhuis, D. L., P. Nghe and L. Peliti, Phys. Rev. Lett., 120, 158101 (2018).