Master 2 internship proposal

Physique et Mécanique des Milieux Hétérogènes

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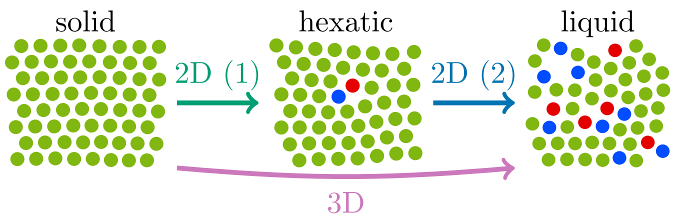
Internship location: PMMH, Sorbonne Université (Jussieu), 7 quai Saint-Bernard, Paris 5^{e}
PhD opportunity: No
Possibility of M1 internship: Yes

Tracking topological defects dynamics in active matter

At equilibrium, the KTHNY theory predicts that melting from a two-dimensional ordered solid to a disordered liquid proceeds in two successive transitions via an intermediate hexatic phase, unique to two dimensions [1]. These transitions are driven by the creation of topological defects in the ordered structure, which are such that no smooth transformation can restore order. Active materials (*e.g.* driven colloids, cells, organisms) are nonequilibrium systems whose components consume energy to generate forces and which generically display emergent collective flows [2], yet may be structurally ordered. Melting in these systems was shown to be consistent with the equilibrium two-step scenario, yet it was highlighted that defects appear in complex and dynamic clusters [3, 4].



The first goal of this internship is to build a tracking algorithm of topological defects in systems of self-propelled particles based on the classification of Ref. [4]. To this effect we will define a hierarchy indicating which small simple defects compose larger more complex defects, and use it to track the evolution of defects between consecutive simulation frames. The second goal is to characterise the individual dynamics of defects, using single-particle two-time correlations functions, and their collective dynamics, through the comparison with two-particle correlation functions [5].

References

[1] B. I. Halperin and D. R. Nelson, "Theory of two-dimensional melting", *Phys. Rev. Lett.* **41**, 121 (1978).

[2] Y.-E. Keta, R. L. Jack, and L. Berthier, "Disordered collective motion in dense assemblies of persistent particles", *Phys. Rev. Lett.* **129**, 048002 (2022).

[3] J. U. Klamser, S. C. Kapfer, and W. Krauth, "Thermodynamic phases in two-dimensional active matter", *Nat. Commun.* **9**, 5045 (2018).

[4] P. Digregorio, D. Levis, L. F. Cugliandolo, G. Gonnella, and I. Pagonabarraga, "Unified analysis of topological defects in 2D systems of active and passive disks", *Soft Matter* **18**, 566 (2022).

[5] Y.-E. Keta, J. U. Klamser, R. L. Jack, and L. Berthier, "Emerging mesoscale flows and chaotic advection in dense active matter", *Phys. Rev. Lett.* **132**, 218301 (2024).

Expected skills: This project in mainly numerical thus the prospective student should be proficient with either Python, C++, CUDA, or Julia. Knowledge in molecular dynamics simulation, (nonequilibrium) statistical physics, and stochastic processes is welcome but not mandatory.