Emergence of homochirality in complex media

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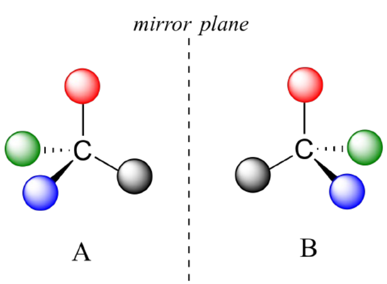

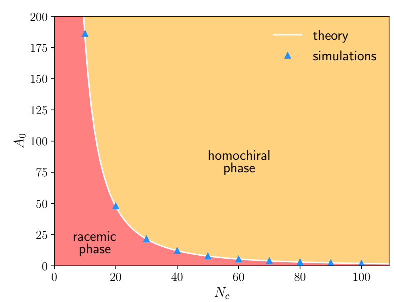

Left: illustration of the mirror symmetry between two chiral enantiomers. Right: phase diagram in the plane (N_c the number of chiral species, and A_0 the injection of energy) [1].

Résumé

Homochirality, also called biological asymmetry, is a long-standing problem in the research on the origins of life. Many mechanisms have been proposed to explain it, but none is fully accepted by the community. It is important to progress on this issue because homochirality could be an important biomarker for the detection of life outside Earth, and it is also a central issue in model experiments designed to mimic the complexification of living matter. The pioneering paper by Frank in 1953 presented a simple mathematical model based on autocatalytic reactions, which provides an amplification mechanism leading to homochirality. The model is rather simple because it contains only a few species and assumes a well-mixed environment. These two hypotheses do not fit well with experiments in prebiotic chemistry, which typically involve a large number of species and non-well-mixed systems.

In a previous work of the group, we have introduced a generalization of Frank's model containing a large number of chiral species [1]. This study shows that homochirality can emerge robustly in a large class of autocatalytic chemical networks, provided the network is large enough (in terms of the number of its chiral species) and driven sufficiently far from equilibrium.

In this project, we propose to build models for the homochirality emergence by including spatial inhomogeneities and repulsive interactions between molecules. Our model will also introduce new methods to take into account the chemical complexity of prebiotic systems, which comes from having a large number of species involved together in autocatalytic cycles [2], with unknown kinetics and topology.

[1] Emergence of homochirality in large molecular systems, G. Laurent, D. Lacoste, and P. Gaspard, Proc. Natl. Acad. Sci. U.S.A., 118, (2021)

[2] Universal motifs and the diversity of autocatalytic systems, A. Blokhuis, D. D. Lacoste, and P. Nghe, PNAS, 117, 25230 (2020).

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