Thesis (B.Sc. / M.Sc.)
Pattern Formation in Chiral Active Matter

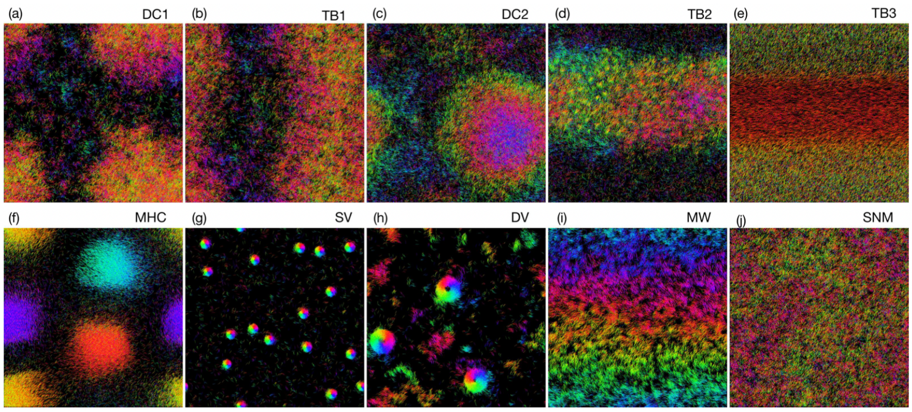

Figure 1: Examples of non-homogeneous particle dynamics of chiral active matter (see the corresponding movies in [1, 2]).

Synchronized motion of collectives of agents is a widespread phenomenon that can be encountered both in nature and in artificially manufactured systems. The most remarkable examples include bacterial swarming, flocking of birds, schooling of fish, human crowds, and robotic swarms (see [3, 4] for extensive discussions on such phenomena). It is remarkable that all these systems can exhibit similar synchronized behaviour despite the inherent diversity of the constituent agents. In order to understand what defines such behaviour, we study minimal models of collective motion. Such models often describe systems that are far from equilibrium and are referred to as active matter.

It has become a standard approach to analyse such systems with the Vicsek model in discrete time or its time continuous counterpart often referred to as an active Brownian particle model. Models of this type have been extensively analysed and a number of spatially non-homogeneous structures like large scale travelling bands or irregular high density clouds have been reported. However, these phenomena are mostly known for linear swimmers. Recently, we have presented a chiral active matter model [5] that exhibits a large variety of qualitatively similar spatially non-homogeneous regimes but for particles that perform circular motion (see Fig. 1). This project would concentrate on the investigation of the properties of each of the reported patterns, which includes particle-based modelling and continuum-based theory, i.e., with the number of particles going to infinity. The project also includes the study of the related phase transitions between spatially non-homogeneous as well as homogeneous motion.

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A potential candidate should be familiar with some of the following:

- Nonlinear dynamical systems
- Partial differential equations
- Statistical / mathematical physics
- Numerical analysis of ordinary / stochastic / partial differential equations
- C++ and MATLAB / Python

For further information, please contact Sascha H. Hauck.

References

[1] https://www.youtube.com/playlist?list=pljl7stt6ph4xdc4x5ee7xar2vm49uihvw.

[2] https://figshare.com/projects/traveling_bands_clouds_and_vortices_of_chiral_active_matter/82163.

[3] T. Vicsek and A. Zafeiris. Collective motion. *Physics Reports*, 517:71–140, 2012.

[4] Gerhard Gompper, Roland G. Winkler, Thomas Speck, Alexandre Solon, Cesare Nardini, Fernando Peruani, Hartmut Löwen, Ramin Golestanian, U. Benjamin Kaupp, Luis Alvarez, Thomas Kiørboe, Eric Lauga, Wilson C. K. Poon, Antonio DeSimone, Santiago Muinẽos Landin, Alexander Fischer, Nicola A. Soöker, Frank Cichos, Raymond Kapral, Pierre Gaspard, Marisol Ripoll, Francesc Sagues, Amin Doostmohammadi, Julia M. Yeomans, Igor S. Aranson, Clemens Bechinger, Holger Stark, Charlotte K. Hemelrijk, François J. Nedelec, Trinish Sarkar, Thibault Aryaksama, Mathilde Lacroix, Guillaume Duclos, Victor Yashunsky, Pascal Silberzan, Marino Arroyo, and Sohan Kale. The 2020 motile active matter roadmap. *Journal of Physics: Condensed Matter*, 32, 2020.

[5] Nikita Kruk, Joseé A. Carrilloand, and Heinz Koeppl. Traveling bands, clouds, and vortices of chiral active matter. *Phys. Rev. E*, 102, 2020.