論文の内容の要旨

Order and fluctuations in collective dynamics of swimming bacteria

（遊泳バクテリアの集団ダイナミクスにおける秩序とゆらぎ）

氏名　西口 大貴

This dissertation is dedicated to experimental studies on collective motion of swimming bacteria from the viewpoint of nonequilibrium statistical physics. Collective motion of self-propelled elements has fascinating properties that are often different from those of orientationally-ordered equilibrium systems due to its intrinsic nonequilibrium nature. To further understand such properties, we explore emergent order and fluctuations in two major classes of collective motion: the Vicsek universality class and active turbulence.

First, we study the collective dynamics of elongated microswimmers in a very thin fluid layer between two walls by devising long, filamentous, non-tumbling bacteria. The strong confinement and the high aspect ratio of cells induce weak nematic alignment upon collision, which, for large enough density of cells, gives rise to global nematic order. This homogeneous but highly-fluctuating phase, observed on the largest experimentally-accessible scale of millimeters, exhibits the properties predicted by standard models for collective motion, especially the Vicsek-style model of polar particles with nematic alignment: true long-range nematic order and non-trivial giant number fluctuations. Therefore, our experimental system falls into the Vicsek universality class, and gives the first

experimental example of the Toner-Tu-Ramaswamy phases.

Secondly, we investigate active turbulence formed by swimming bacteria in dense suspensions. We explore how order emerges as a result of the interplay between bacterial turbulence and periodic structures. When bulk unconstrained bacterial turbulence encounters rectangular lattices of pillars, it self-organizes in vortex lattices with antiferromagnetic order. The antiferromagnetic order is the strongest and the vortices are the most stabilized in the structures with the periodicity comparable with a correlation length of unconstrained bacterial turbulence, which can be interpreted as a sort of resonance. The obtained results highlight the existence of characteristic length scale in bacterial turbulence and its importance for the emergence of order out of chaotic and fluctuating bacterial turbulence.