SYBS 1: Physics of Biological and Synthetic Active Matter

Time: Tuesday 9:30–12:15 Location: H 0105

Invited Talk SYBS 1.1 Tue 9:30 H 0105

Bacterial collective behaviours — •Knut Drescher — Max Planck Institute for Terrestrial Microbiology — Department of Physics, Philipps-Universität Marburg

In nature, bacteria often engage in a range of collective behaviors. In this presentation, I will demonstrate how two bacterial collective behaviors, swarming and biofilm formation, are related by physical interactions, chemical signaling, and dynamical transitions. I will show how these collective behaviors arise from cell-cell interactions, and the physiological state of individual cells. Furthermore, I will introduce new experimental methods for investigating bacterial collective behaviors.

Invited Talk SYBS 1.2 Tue 10:00 H 0105

Nonlinear dynamics of beating cilia and flagella: Swimming, steering, and synchronization — •Benjamin M. Friedrich — cfaed, TU Dresden, Dresden, Germany

Cilia and flagella represent a best-seller of nature: their regular bending waves propel cellular swimmers such as sperm cells or green alga in a liquid. In my talk, I will address the physics of flagellar swimming and how mechanical and chemical signals control biological microswimmers. In the first part, I will a present a theory of sperm chemotaxis, i.e. the directed navigation of flagellated sperm cells that follow gradients of signaling molecules released by the egg. Recent experiments revealed that sperm cells of marine invertebrates dynamically switch between two steering modes in a situation-specific manner: steering either fast or slow [1]. We argue that the measurement of a concentration gradient during chemotaxis is corrupted by noise, and compute signal-to-noise ratios below one for physiological conditions. We show that decision making between different steering modes optimally balances the risk of inadvertently steering in the wrong direction by amplifying noise, and the speed of chemotactic re-orientation. Decision making substantially increases the probability to find a target, such as an egg. In a second part, I will discuss flagellar synchronization as an emergent phenomenon in collections of several flagella, which arises from a mutual hydro-mechanical coupling [2,3].

[1] J.F. Jikeli et al. Nature Commun. 6, 2015
[2] G.S. Klindt et al. Phys. Rev. Lett. 117, 2016
[3] R. Ma et al. Phys. Rev. Lett.113, 2014

Invited Talk SYBS 1.3 Tue 10:30 H 0105

Learning to navigate in dynamic environments: animal behavior and artificial intelligence — •Antonio Celani — ICTP. Trieste, Italy

I will discuss two examples of difficult navigation tasks in highly dynamical environments. The first one is thermal soaring in birds. Birds and gliders piggyback ascending currents to fly with a reduced expenditure of energy, for example, during migration, and to extend their flying range. Flow in the thermals is highly turbulent, which poses the challenge of the orientation in strongly fluctuating environments. The second one is gravitaxis by smart microswimmers. These are self-propelled particles that can sense basic mechanical cues from their surroundings and respond to them in order to reach the highest altitude within some time horizon. We combine numerical simulations of fluid flow with reinforcement learning methods to identify strategies of navigation that can cope with potentially dangerous flow configurations and exploit favorable ones.

15 min. break

Invited Talk SYBS 1.4 Tue 11:15 H 0105

Suspensions of active colloids — •Cecile Cottin-Bizonne, Félix Ginot, Isaac Theurkauff, and Christophe Ybert — Institut Lumière Matière, Université Lyon 1, France

We experimentally explore the behavior of active suspensions of self propelled colloids. At intermediate densities we observe the formation of clusters, resulting from a permanent dynamical merging and separation of active colloids. We have characterized in depth their kinetics of formation and their dynamics which shows vivid translational and rotational motions. These experimental results are discussed in the framework of a simple statistical model that captures quantitatively the measured dynamics. This sheds some new light on the internal organization of the clusters and on the mechanisms underlying their formation. Looking further at the sedimentation profile of the active particles we derive non-equilibrium equation of state of our system. Finally in the dense regime we a observe an unexpected non-monotonic behavior of the particles with activity.

Invited Talk SYBS 1.5 Tue 11:45 H 0105

Spontaneous chiral symmetry breaking in active fluids — •Jörn Dunkel — Department of Mathematics, MIT

Recent experiments show that bacterial and other active suspensions in confined geometries can self-organize into persistent flow structures that exhibit spontaneously broken mirror symmetry. To describe these observations within a minimal theoretical framework, we consider generalized Navier-Stokes (GNS) equations that combine a generic linear instability mechanism with a conventional advective nonlinearity. This phenomenological model is analytically tractable and reproduces several experimentally observed phenomena, including spontaneous flows and viscosity reduction in active suspensions. Triad analysis and numerical simulations of the GNS equations further predict that 3D active flows can spontaneously realize chiral Beltrami vector fields that support inverse energy transport from smaller to larger scales.