MPIDS Seminar

Self-organized dynamics of cilia and flagella in the presence of noise

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Cilia and flagella represent a model system for the physics of living matter that is accessible to quantitative study of emergent dynamics from local interactions, as well as mechanical and chemical signaling for robust behavior in the presence of noise.

In a first part of my talk, I will discuss flagellar synchronization by mutual hydro-mechanical coupling. Using a framework of Lagrangian mechanics of active systems, we first develop a theory of the beating flagellum as a noisy limit-cycle oscillator, which is fully calibrated by experimental data. In collaboration with experimental collaboration partners, we directly measure non-equilibrium fluctuations of flagellar limit-cycle oscillations [1] and show how external mechanical forces change speed and shape of the flagellar beat, induce dynamic bifurcations, or even stall the beat reversibly [2]. This flagellar load-response represents a key prerequisite for flagellar synchronization. As an application, we discuss mechanisms for in-phase and anti-phase synchronization in the model organism Chlamydomonas.

In a second part, I will shortly present a theory of sperm chemotaxis, i.e. the directed navigation of flagellated sperm cells in concentration gradients of signaling molecules released by the egg. Molecular shot noise corrupts concentration measurements at physiological concentrations, resulting in signal-to-noise ratios below one. We show that dynamic switching between different steering modes optimally balances the risk of amplifying noise and thus exploits sparse information optimally. This provides a rational for the recent experimental observation of decision making in sperm chemotaxis [3].

[1] R. Ma, G.S. Klindt, I.-H. Riedel-Kruse, F. Jülicher, B.M. Friedrich: Active phase and amplitude fluctuations of flagellar beating, Phys. Rev. Lett.113, 2014

[2] G.S. Klindt, C. Ruloff, C. Wagner, B.M. Friedrich, Load-response of the flagellar beat, Phys. Rev. Lett. 117, 2016

[3] J.F. Jikeli et al.: Sperm navigation along helical paths in 3D chemoattractant landscapes, Nature Communications 6, 2015

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MPIDS, Prandtl lecture hall, building AI,
Am Faßberg 11, Göttingen

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