DY 44: Pattern Formation I

Time: Wednesday 10:00–13:00 Location: BH-N 334

Invited Talk DY 44.1 Wed 10:00 BH-N 334

Self-organisation and positioning of sub-cellular protein clusters — •Sean M. Murray — Max Planck Institute for Terrestrial Microbiology, Marburg, Germany

Many cellular processes require proteins to be precisely positioned within the cell. In some cases this can be attributed to passive mechanisms such as recruitment by other proteins in the cell or by exploiting the curvature of the membrane. However, in bacteria, active self-positioning is likely to play a role in multiple processes, including the positioning of the future division site and cytoplasmic protein clusters. How can such dynamic clusters be formed and positioned? Here, we present a model for the self-organization and positioning of dynamic protein clusters into regularly repeating patterns based on a phase-locked Turing pattern. A single peak in the concentration is always positioned at the midpoint of the model cell and two peaks are positioned at the midpoint of each half. Furthermore, domain growth results in peak-splitting and pattern doubling. We argue that the model may explain the regular positioning of the highly conserved Structural Maintenance of Chromosomes (SMC) complexes on the bacterial nucleoid and provides an attractive mechanism for the self-positioning of dynamic protein clusters in other systems.

We also briefly present recent results on the role this mechanism may play in bacterial chromosome segregation.

DY 44.2 Wed 10:30 BH-N 334

Active phase separation: A generic approach — •Fabian Bergmann, Lisa Rapp, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Many non-equilibrium systems with conservation constraints show self-organization phenomena resembling classic phase separation: from cell polarization to cell populations communicating via chemotaxis, and from dense active Brownian particles to mussels in ecology. We identify this behavior as kinetic phase separation and suggest for its generic description near onset a Cahn-Hilliard (CH) model [J. Chem. Phys. **28**, 258 (1958)]. We introduce a general perturbative reduction scheme to establish the mathematical link between the proposed generic CH equation and system-specific models. We show this explicitely for two examples - cell polarization and chemotactic cells. The comparison of the cell polarization model to its approximation by the CH model veryfies the valitity of our generic approach. We thus suggest the CH equation as a generic model for phase separation applicable to many systems both in and outside of equilibrium.

DY 44.3 Wed 10:45 BH-N 334

Active Phase Separation vs Pattern Formation in Conserved Systems — •Lisa Rapp, Fabian Bergmann, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth

Active phase separation takes place in non-equilibrium systems such as during cell polarization or in active colloidal particle suspensions. These systems are typically described by conserved order parameters. Surprisingly, however, these conserved systems can also show spatially periodic patterns. We formulate the criteria for this transition from phase separation to periodic patterns in terms of a generic Cahn-Hilliard model and a recent model for cell polarization. In addition, the nonlinear properties of spatially periodic patterns in conserved systems are characterized.

DY 44.4 Wed 11:00 BH-N 334

Interrupted coarsening in a generalized Cahn-Hillard model with long-range interactions — •Simon Villain-Guillot and Mahdi Mcheik — Laboratoire Ondes et Matière d Aquitaine, Université de Bordeaux, 351 Cours de la Libération F-33405 Talence Cedex

The Cahn-Hilliard equation describes the dynamics of phase separation in the conservative case. This process is driven by the minimization of the free energy, especially of its interfacial part, during the Ostwald ripening, or coarsening. In 1D however, the lower energy state that should end the dynamics is very slow to reach. This is even more critical when the Cahn-Hilliard dynamics is modified to take into account long range interaction terms. A dynamical criterion proposed by Misbah and Politi [3] predict the interuption of the coarsening process and the stabilazation of a microstructured pattern.

We have explored a model where the Cahn Hilliard dynamics is coupled with a diffusion equation of a surfactant that favors interfaces. This scenario enables to speed up the dynamics and favors various pattern formation or micro-structuration.

References

[1] When does coarsening occur in the dynamics of one-dimensional fronts? P.Politi and C. Misbah, Phys. Rev. Lett. 92, 090601 (2004).

15 min. break

Invited Talk DY 44.5 Wed 11:30 BH-N 334

Spatial heterogeneities shape collective behavior of the signaling amoeboid cells — •Azam Gholami — Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Dictyostelium discoideum organism, naturally occurring in forest soil, is an important model system for the study of chemotaxis, cell differentiation, and morphogenesis. We present novel experimental results on pattern formation of signaling Dictyostelium discoideum amoeba in the presence of a periodic array of millimeter-sized pillars. We observe concentric cAMP waves that initiate almost synchronously at the posts and propagate outwards. These waves have higher frequency than the other firing centers and dominate the system dynamics. The cells respond chemotactically to these circular waves and stream towards the pillars, forming periodic Voronoi domains that reflect the periodicity of the underlying lattice. These experiments are crucial to understand the signaling mechanism of Dictyostelium cells that experience external obstacles in its natural habitat. We expect our observations to be generic to other excitable media governed by reaction-diffusion dynamics, where spatial heterogeneities can significantly influence the wave generation process.

DY 44.6 Wed 12:00 BH-N 334

Mass-conserved Excitable Waves in the interior of Giant Amoeboid Cells — •Francesc Font[1], Sven Flemming[1], Carsten Beta[2], and Sergio Alonso[2] — [1]Department of Physics, Universitat Politecnica de Catalunya, Barcelona, Spain — [2]Institute of Physics and Astronomy, Universität Potsdam, Potsdam, Germany

Spiral waves and complex patterns have been observed in the interior of Dictyostelium discoideum cells. The amoebas have typically around 10 μm length, and the waves are on the similar scale than the cell size. Recent experiments have shown that a set of similar Dictyostelium discoideum cells can fuse into a single, larger cell when exposed to repeated electric pulses. The relatively large size of the resulting cell permits a clearer observation of the wave dynamics and pattern formation within the cell domain. For a systematic characterization of the internal waves, we present a mathematical model of pattern formation in the amoeboid interior that combines noisy excitable kinetics with a mass-conservation constrain, together with a dynamic phase field for the cell shape. We will conclude by comparing numerical simulations of our model to experiments with giant amoeba Dictyostelium discoideum.

DY 44.7 Wed 12:15 BH-N 334

Spontaneous formation of target centers in D.discoideum — •Estefania Vidal-Henriquez[1], Vladimir Zykov[1], Bodenschatz Eberhard[1,2,3], and Gholami Azam[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, D-37077 Goettingen, Germany — [2]Institute for Nonlinear Dynamics, University of Goettingen, D-37073 Goettingen, Germany — [3]Laboratory of Atomic and Solid-State Physics and Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, New York 14853, USA

Dyctiostelium discoideum is a social amoeba that produces target patterns and spiral waves of cyclic AMP as a way to form multicellular aggregates when subjected to adverse environmental conditions. The stability of pacemakers at the interior of a target wave presents a modeling challenge in such organism, since in its classical description the limit cycle produces bulk (whole system) oscillations. We present a novel and robust way of producing target waves based on non-artificial conditions. Using the cell density in a discrete way, the bigger cell clusters become centers, as observed in experiments. We characterize the emission frequency of the centers and the capability of the rest of the system to react to them, depending on the cell coverage. The wave velocity is density dependent, thus producing aggregation streams. This model emphasizes the importance of external unbounded phosphodiesterase, upon which the system can change between oscillatory and excitable regimes allowing to reproduce many of the experimentally observed properties. Finally we discuss boundary conditions and the density differences necessary to artificially induce target centers.

DY 44.8 Wed 12:30 BH-N 334

Spontaneous membrane formation and self-encapsulation of active rods in an inhomogeneous motility field — •Jens Grauer[1], Hartmut Löwen[1], and Liesbeth Janssen[1,2] — [1]Institute for Theoretical Physics II: Soft Matter, Heinrich-Heine University Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany — [2]Theory of Polymers and Soft Matter, Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven, The Netherlands

We study the collective dynamics of self-propelled rods in an inhomogeneous motility field. At the interface between two regions of constant but different motility, a smectic rod layer is spontaneously created through aligning interactions between the active rods, reminiscent of an artificial membrane. This 'active membrane' engulfes rods which are locally trapped in low-motility regions and thereby further enhances the trapping efficiency by self-organization, an effect which we call 'self-encapsulation'. Our results are gained by computer simulations of self-propelled rod models confined on a sphere with a stepwise constant motility field, but the phenomenon should be observable in any geometry with sufficiently large spatial inhomogeneity. We also discuss possibilities to verify our predictions of an active membrane in a motility field in experiments of self-propelled colloidal Janus rods and vibrated granular matter.

DY 44.9 Wed 12:45 BH-N 334

Influence of fast advective flows on pattern formation of *Dictyostelium discoideum* — •Torsten Eckstein, Estefania Vidal, Albert Bae, Vladimir Zykov, Eberhard Bodenschatz, and Azam Gholami — Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

We report experimental and numerical results on pattern formation of self-organizing *Dictyostelium discoideum* cells in a microfluidic setup under a constant buffer flow. The external flow advects the signaling molecule cyclic adenosine monophosphate (cAMP) downstream, while the chemotactic cells attached to the solid substrate are not transported with the flow. At high flow velocities, elongated cAMP waves are formed that cover the whole length of the channel and propagate both parallel and perpendicular to the flow direction. While the wave period and transverse propagation velocity are constant, parallel wave velocity and the wave width increase linearly with the imposed flow. We also observe that the acquired wave shape is highly dependent on the wave generation site and the strength of the imposed flow. We compared the wave shape and velocity with numerical simulations performed using a reaction-diffusion model and found excellent agreement. These results are expected to play an important role in understanding the process of pattern formation and aggregation of *D. discoideum* that may experience fluid flows in its natural habitat.