DY 48: Pattern Formation / Reaction-Diffusion II (joint session DY/BP)

Time: Thursday 15:00–17:00 Location: ZEU 118

DY 48.1 Thu 15:00 ZEU 118

Flow Induced Instabilities in an Advected Dictyostelium Discoideum Model — •Estefania Vidal, Azam Gholami, and Eberhard Bodenschatz — Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, D-37077 Göttingen, Germany

The spirals and concentric waves of cAMP appearing during the aggregation process of the social ameba Dictyostelium Discoideum have been widely studied as an example of pattern formation in biological systems, however in the rain forest soil, the natural environment of these amebas, the constant rain washes away the signalling chemical, thus affecting the pattern formation. To simulate these environmental conditions, we studied numerically and theoretically a Reaction Diffusion model in the presence of a constant flow advection. The model, proposed by Martiel and Goldbeter, describes the dynamics of cAMP by taking its concentration as an activator and the ratio of active receptors in the cell membrane as inhibitor. Depending on the election of parameters this system can be in an oscillatory or an excitable state, and has successfully reproduce many of the experimentally observed features. We show how a Dirichlet boundary condition destabilises the system, creating a continuous influx of waves upstream which grow into train waves that fill the entire system. These phenomena, which appear due to the interaction between the Flow Induced Instability and a Hopf Bifurcation provide a novel mechanism for the creation of continuos waves in Advected Reaction Diffusion systems.

DY 48.2 Thu 15:15 ZEU 118

Localized structures in the Kuramoto-Sivashinsky-Verhulst equation in context of ion-beam eroded surfaces — •Christoph Kabelitz and Stefan Jakob Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

Pattern formation of ion-beam eroded semiconductor surfaces has received considerable attraction because of the variety of structures (from flat, rough up to periodically arranged on large scales) being experimentally observed. Besides that, also large area localized hexagonal dot patterns have being experimentally detected [1]. Using a numerically manageable extended Kuramoto-Sivashinsky equation that models the dynamics of the surface morphology of the combined erosion and redeposition processes [2, 3], such localized hexagonal structures are identified, the existence range in the parameter space is determined and the rather involved scenarios of the creation and annihilation of these structures are classified and clarified.

[1] T. Allmers, M. Donath and G. Rangelov, J. Vac. Sci. Technol. B 24, 582 (2006). [2] C. Diddens and S. J. Linz, Europhys. Lett. 104, 17010 (2013). [3] C. Diddens and S. J. Linz, Eur. Phys. J. B 88, 190 (2015).

DY 48.3 Thu 15:30 ZEU 118

Surface instabilities in vibrating thin fluid films — •Sebastian Richter[1] and Michael Bestehorn[2] — [1]Department of Theoretical Physics, BTU, 03044, Cottbus, Germany — [2]Department of Theoretical Physics, BTU, 03044, Cottbus, Germany

We investigate the spatio-temporal evolution of a thin fluid layer, which is located on a horizontal, solid substrate and is either subjected to a constant or to a time-periodic gravitational force field in normal direction. Starting with an appropriate initial state, the behavior of the liquid is simulated numerically considering both the exact problem and a long wave lubrication approximation based model obtained from the incompressible Navier-Stokes equations. The model includes inertia and viscous friction. For the case of a periodic external force, we observe the formation of time-periodic surface waves (Faraday instabilities) if the frequency and amplitude of excitation meet certain critical values. A Floquet analysis is made to determine the exact stability criteria of the linearized system. Both approaches show good agreement in the limit of a thin fluid geometry: Harmonic excitations generate patterns oscillating harmonically with the driver's frequency (ω) for low frequency ranges and subharmonically ($\omega/2$) at higher frequencies.

DY 48.4 Thu 15:45 ZEU 118

Control of competing patterns in anti-symmetrically coupled Swift-Hohenberg equations — •Maximilian Becker[1], Sina Reichelt[2], Thomas Niedermayer[1], Thomas Frenzel[2], Alexander Mielke[2], and Markus Bär[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany — [2]Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS), Berlin, Germany

The Swift-Hohenberg equation (SHE) provides a generic formulation for non-equilibrium pattern formation at a characteristic length scale. We present analytical and numerical investigations of two anti-symmetrically coupled 1d SHEs with cubic nonlinearities. A linear stability analysis of the homogeneous state reveals a wave instability in addition to the Turing instability of uncoupled SHEs. Weakly nonlinear analysis has been performed in the vicinity of the codimension-2-point of the Turing-wave instability, resulting in a set of coupled amplitude equations for Turing patterns and left- and right-traveling waves. In particular, these complex Ginzburg-Landau-type equations predict a mutual suppression of the amplitudes. In consequence, different patterns can coexist in distinct spatial regions, separated by localized interfaces. We identified specific control mechanisms for these interfaces which allow for global pattern selection. Extensive simulations of the underlying SHEs confirm our results.

DY 48.5 Thu 16:00 ZEU 118

Modeling collective motion and pattern formation of self-propelled rods and application to myxobacteria — Robert Grossmann[1,2], Fernando Peruani[1], and •Markus Bär[2] — [1]Universite de Nice, France — [2]Physikalisch-Technische Bundesanstalt, Germany

We study self-propelled particles with nematic velocity-alignment in two dimensions, which reverse their direction of motion repeatedly. The large-scale properties of these point-like self-propelled rods are analyzed within a hydrodynamic theory that can be systematically derived from the microscopic dynamics. Combining analytical methods and numerical continuation, we show that an entire family of elongated high-density regions, called bands, self-segregates spontaneously from a homogeneous background via two subcritical bifurcations. The reduction of the multi-particle system onto the dynamics of bands provides a unified framework to understand aggregation mechanisms and nonequilibrium phase separation in active systems with nematic velocity-alignment, e. g. the collective dynamics of rod-shaped, actively moving myxobacteria. R. Großmann, F. Peruani, and M. Bär, Phys. Rev. E 94, 050602 (2016).

DY 48.6 Thu 16:15 ZEU 118

Pattern formation in polymerizing actin flocks — •Thomas Le Goff, Benno Liebchen, and Davide Marenduzzo — School of Physics and Astronomy, University of Edinburgh, UK

F-Actin is a polymer existing in the cytoskeleton of cells and which is involved in cell motility, cell division or cell signaling. These polymers form a network which can exhibit very interesting dynamics. Particularly, actin waves usually following formation of spots were observed experimentally [1].

We propose a simple physical model based on a minimum number of ingredients to describe the appearance of these waves :(i) treadmilling - i.e. the simultaneous growth and shrinkage at the two ends of the actin fiber, (ii) polymerisation and (iii) a nematic interaction term causing fiber alignment for large concentration of F-actin. With this simple model we obtain very rich dynamics, in particular we can observe formation of spots, spirals and waves resembling the dynamics seen experimentally. Our model also allows us to make definite predictions on the mechanism underlying wave formation in vivo.

[1]T. Bretschneider, K. Anderson, M. Ecke, A. Müller-Taubenberger, B. Schroth-Diez, H. C. Ishikawa-Ankerhold, G. Gerisch, Biophys. J. 96, 2888 (2009).

DY 48.7 Thu 16:30 ZEU 118

Size matters for Nonlinear Waves and Min Protein Patterns — •Fabian Bergmann, Lisa Rapp, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Self-organization is a fundamental strategy in nature. In E. coli bacteria, for example, self-organized pole-to-pole oscillations of the Min proteins have an important function within the cell division machinery. Such pole-to-pole oscillations in living cells behave like standing waves (SW) in very small (confined) systems. In extended in vitro experiments, Min oscillations develop into nonlinear traveling waves (TW). TW patterns are also known from many other nonequilibrium systems. But is the transition from traveling waves in extended to standing waves in strongly confined systems a specific property of the Min oscillation pattern? Or is it a generic and robust universal principle of all nonlinear traveling waves that just also applies to the Min oscillations in cells?

We address this central question by imposing strong spatial confinement to a generic model for nonlinear traveling waves. Using simulations, analytical and symmetry considerations, we conclude that traveling waves inevitably change into standing waves in sufficiently small confined systems.

DY 48.8 Thu 16:45 ZEU 118

Traveling Waves in Conserved Systems — •Lisa Rapp, Fabian Bergmann, Markus Hilt, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Deutschland

Nonlinear traveling waves are one of the elementary prototype patterns that occur in various systems in nature far from thermal equilibrium. So far, their behavior has mostly been investigated in systems with an unconserved order parameter. In contrast, in systems with conserved order parameter, the Hopf-bifurcation to traveling waves is nearly unexplored (except for a first approach in Ref. [1]). The effects of conservation laws, however, may play a significant role in many pattern forming systems such as the Min protein oscillations during cell division in E.coli bacteria.

In spatially extended conserved systems, there are two distinctly different Hopf-bifurcations from a homogeneous basic state to traveling waves. On the one hand, the transition can occur via a finite wavenumber instability, similar to convection systems. On the other hand, the basic state can also become unstable towards long wavelength modes, comparable to the non-oscillatory Cahn-Hilliard model for potential systems.

We introduce a generalized Swift-Hohenberg model for conserved systems that includes both scenarios as special cases. Exploring this model and its limiting cases, we find interesting types of coarsening behavior and spatio-temporal complexity.

[1] W. Zimmermann, Physica A **237**, 575 (1997).