DY 18: Pattern Formation

Time: Tuesday 14:00–15:30 Location: H47

DY 18.1 Tue 14:00 H47

Amplitude and envelope equation for the conserved-Hopf bifurcation — •Daniel Greve[1] and Uwe Thiele[1,2] — [1]Institut für Theoretische Physik, Universität Münster, Münster, Germany — [2]Center for Nonlinear Science (CeNoS), Münster, Germany

Nonreciprocal interactions and conservation laws both play an important role in out-of-equilibrium pattern formation processes, e.g., in biochemical systems.[1,2] The generic large-scale oscillatory instability in such systems – the conserved-Hopf instability – is a central organizing element for such processes.[3,4] After classifying this instability within an extension of the Cross-Hohenberg[5] scheme, we use weakly nonlinear multi-scale analysis to obtain aclosed form (but nonlocal) slow time evolution equation for the spatiotemporal dynamics of the amplitude of fast time oscillations for thee example of two-species nonreciprocal Cahn-Hilliard models. Analytical results then reveal a universal coarsening suppression in oscillatory phase separation. Finally, we demonstrate the agreement of the two levels of description in a comparison of numerical results for the reduced and full model.

[1] A. Dinelli, J. O'Byrne, A. Curatolo, Y. Zhao, P. Sollich, and J. Tailleur, Nat. Commun. 14, 7035 (2023). [2] F. Brauns and M. C. Marchetti, Phys. Rev. X 14, 021014 (2024). [3] A. Förtsch and W. Zimmermann, (2023), talk, DPG Spring Meeting, Dresden, and A. Förtsch, Ph.D. thesis, Bayreuth (2023). [4] T. Frohoff-Hülsmann and U. Thiele, Phys. Rev. Lett. 131, 107201 (2023). [5] M. C. Cross and P. C. Hohenberg, Rev. Mod. Phys. 65, 851 (1993).

DY 18.2 Tue 14:15 H47

Wavelength selection mechanism for turbulent superstructures in Rayleigh Bénard convection — •Fabián Alvarez-Garrido and Michael Wilczek — University of Bayreuth, Bayreuth, Germany

Large-scale flow patterns coexist with small-scale turbulence in high-aspect-ratio Rayleigh-Bénard cells. These flow patterns, known as turbulent superstructures, are significantly larger than convection rolls that emerge at the onset of convection. Direct numerical simulations of the Oberbeck-Boussinesq equations reveal that the size of these structures increases with the Rayleigh number. However, the mechanism behind this increase has not been elucidated.

Small-scale turbulence plays an important role in the redistribution of heat across the system. Motivated by how the background temperature gradient profile varies between the boundary layers and the bulk, we formulate effective equations for the large scales introducing a height-dependent turbulent thermal diffusivity. A sharp increase in the diffusivity renders the boundary layers effectively thermally insulating boundaries, fundamentally modifying how the fluid exchanges heat with its surroundings. A linear stability analysis of our model shows that this change in boundary conditions goes along with a change of the type of instability, which then leads to an increased wavelength of the flow patterns. These findings provide a mechanism to understand the increasing size of turbulent superstructures.

DY 18.3 Tue 14:30 H47

Turbulence-like behavior of spot patterns mediated by defects in the context of the liquid crystal light valve experiment — •Simon Navia[1], Marcel Clerc[2], and Pedro Aguilera[2] — [1]University of Münster, Münster Germany — [2]University of Chile, Santiago, Chile

The liquid crystal light valve experiment (LCLV) with optical feedback consists of a liquid crystal cell stimulated by a voltage and a photodiode that is coupled to the intensity of the light reaching the cell, thereby creating the optical feedback loop. This experiment exhibits a variety of complex spatiotemporal phenomena. This talk presents the experimental results of the observed formation of aperiodic spatiotemporal patterns in a quasi-one-dimensional channel, characterized by power-law scaling in the temporal and spatial-spectral density of the measured light intensity, as well as in the pseudo-envelope and pseudophase. Moreover, theoretically, the system is locally described as being near nascent bistability and spatial instability, from which a simplified model could be derived. We performed numerical simulations of this simplified model which show chaotic spatiotemporal patterns and spectral densities with exponents similar to those observed in the experiment.

[1]Aguilera-Rojas PJ, Clerc MG, Navia S. Opt Lett. 2024 doi: 10.1364/OL.522830.

[2]Verschueren N, Bortolozzo U, Clerc MG, Residori S. Phys Rev Lett. 2013 doi: 10.1103/PhysRevLett.110.104101.

DY 18.4 Tue 14:45 H47

Efficient formation of Turing patterns using physical interactions — •Cathelijne ter Burg, Chengjie Luo, and David Zwicker — Max Planck Institute for Dynamics and Self-Organisation, Am Fassberg 17, Gottingen 37077, Germany

Turing patterns arise when an activating and an inhibitory component drive local activation and global inhibition of their production. Physical interactions between the components can facilitate such patterns. Using a thermodynamically-consistent version of such a model, we show that physical interactions lower the energetic requirements for forming patterns of a given length scale. Stronger physical interactions thus permit pattern formation for systems that are less active. However, we also found a dynamic regime where structures of well-defined length scales evolve chaotically for very strong physical interactions. This regime emerges from an interplay of coarsening and spinodal decomposition of bulk phases. We conclude that physical interactions of intermediate strength are energetically optimal for forming stationary patterns of a well-defined length scale.

DY 18.5 Tue 15:00 H47

Numerical and Experimental Analysis of Multi-Soliton Interactions in Ultrafast Lasers — •Julia Lang and Georg Herink — Universität Bayreuth

Ultrafast lasers are excellent platforms for experimentally observing multi-soliton solutions of the nonlinear Schrödinger equation in real-time. Interactions between solitons are often neglected in common pulse propagation models. However, they generate a variety of nonlinear dynamics, which manifest in distinct soliton trajectories observed via real-time spectral interferometry. Here, we report on soliton interactions in two different classes of widely established laser systems, namely Kerr-lens mode-locked Ti:sapphire [1] and SESAM mode-locked Er:fiber [2] lasers. Laser system-specific components result in virtually opposite behaviour, i.e., in soliton attraction, repulsion and/or binding. We discuss their representations in the generalized Schrödinger equation and present one-to-one correspondences between experiment and theory.

[1] A Völkel et al. Intracavity Raman scattering couples soliton molecules with terahertz phonons. Nat Commun. 2022;13(1):2066.

[2] J. A. Lang et al. Controlling intracavity dual-comb soliton motion in a single-fiber laser. Sci Adv. 2024;10(2):eadk2290.

DY 18.6 Tue 15:15 H47

Self-similarity in 1 and 2-dimensional cellular automata — •Jens Christian Claussen — University of Birmingham, UK

Cellular automata with a localized single seed initial condition can exhibit deterministic time series with power-law scaling, which led us numerically to the identification of two universality (sub)classes within the Wolfram class IV cellular automata [1], where rule 90 (Sierpinski) and rule 150 are representatives of these classes. The generated time series can be analytically described by a tensorial Fibonacci iteration [2]. An exploration of 2-dimensional outer-totalistic cellular automata showed that fractals with more general one- or two-step self-similarity may exist, including a rule providing a triple replication, and generating a 2-dim spatial Sierpinski pattern. Here we also consider the more general question what variety of universality classes can be found, eventually extending the dynamics to more general algebraic structures. We show that in the 1-dimensional ECA case of a mod 2 dynamics indeed only the two self-similarity cases represented by rule 90 and rule 150 exist.

[1] J. Nagler and J.C.Claussen (2005) $1/f^\alpha$ spectra in elementary cellular automata and fractal signals, Phys. Rev. E 71, 067103 (2005)
[2] Time evolution of the rule 150 cellular automaton activity from a Fibonacci iteration, J. Math. Phys 49, 062701 (2008)