DY 28: Pattern Formation and Reaction-Diffusion Systems

Time: Tuesday 10:00–12:30 Location: ZEU 147

DY 28.1 Tue 10:00 ZEU 147

Calculating Coexistence in a two-field Phase-Field-Crystal model — •Max Philipp Holl[1] and Uwe Thiele[1,2] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Straße 9, D-48149 Münster, Germany — [2]Center for Nonlinear Science (CeNoS), Westfälische Wilhelms-Universität Münster, Corrensstr. 2, D-48149 Münster, Germany

We show that well-established numerical continuation methods can be employed to calculate the fully nonlinear phase behaviour in a range of thermodynamic systems. This method is illustrated by applying it to a two-field Phase-Field-Crystal model describing the crystallisation of a mixture of two types of colloidal particles. We compare the resulting phase diagrams containing different liquid and crystalline phases to those obtained from a one-mode approximation.

DY 28.2 Tue 10:15 ZEU 147

Oscillatory active phase separation in two-species chemotactic systems — •Andre Förtsch and Walter Zimmermann — Theoretische Physik I, Unversität Bayreuth

Two chemically interacting particle species are modelled, which are either attracted or repelled by chemicals produced by them. We show by analytical calculations and simulations, that this two-species model with a conserved particle dynamics exhibits in a wide parameter range time-dependent density modulations. This two-species system belongs to a new class of non-equilibrium phase transitions. It shows a coarsening behavior, which is fundamentally different form coarsening in common (active) phase separation. Moreover, the basic properties of these oscillatory density modulations can be described by a non-reciprocal coupling of two Cahn-Hilliard models.

DY 28.3 Tue 10:30 ZEU 147

Phase separation and time-periodic behaviour in coupled Cahn-Hilliard models — •Tobias Frohoff-Hülsmann[1], Jana Wrembel[1], and Uwe Thiele[1,2] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 9, 48149 Münster — [2]Center of Nonlinear Science (CeNoS), Westfälische Wilhelms-Universität Münster, Corrensstr. 2, 48149 Münster

The Cahn-Hilliard equation is the paradigmatic mean-field model describing phase separation in a system characterized by a single order parameter field, e.g., the concentration for binary alloys. Decreasing the underlying free energy while preserving the total mass, this equation corresponds to a conserved gradient dynamics. Two coupled Cahn-Hilliard equations are able to represent ternary systems with two conserved quantities and are the subject of our study. Using coupling terms that either preserve or break the gradient structure, we investigate how the coupling alters the system behaviour. Employing numerical path continuation we present the fully nonlinear bifurcation behaviour and trace the transitions from the uncoupled equations to the coupled model of gradient dynamics form and further to the coupled model without overall gradient dynamics form. Selected results are illustrated by exemplary time simulations.

DY 28.4 Tue 10:45 ZEU 147

Nonlinear patterns shaping the domain on which they live — •Mirko Ruppert and Walter Zimmermann — Universität Bayreuth, Bayreuth, Deutschland

Nonlinear stripe patterns in two spatial dimensions break the rotational symmetry and generically show a preferred orientation near domain boundaries, as described by the famous Newell-Whitehead-Segel (NWS) equation. We first demonstrate that, as a consequence, stripes favour rectangular over quadratic domains. We then investigate the effects of patterns ”living" in deformable domains by introducing a model coupling a generalized Swift-Hohenberg model to a generic phase field model describing the domain boundaries. If either the control parameter inside the domain (and therefore the pattern amplitude) or the coupling strength (”anchoring energy" at the boundary) are increased, the stripe pattern self-organizes the domain on which it ”lives" into anisotropic shapes. For smooth phase field variations at the domain boundaries, we simultaneously find a selection of the domain shape and the wave number of the stripe pattern. This selection shows further interesting dynamical behavior for rather steep variations of the phase field across the domain boundaries. The here-discovered feedback between the anisotropy of a pattern and its orientation at boundaries is relevant e.g. for shaken drops or biological pattern formation during development.

DY 28.5 Tue 11:00 ZEU 147

Phase transition in a biased reaction-diffusion system — •Pratik Mullick[1,2] and Parongama Sen[2] — [1]Department of Physics and Astronomy ‘Galileo Galilei’, University of Padova, Via Francesco Marzolo 8, 35131 Padova, Italy — [2]Department of Physics, University of Calcutta, 92 APC Road, Kolkata 70009, India

Reaction diffusion systems being a prototype model for pattern formation have shown diverse applications in several complex systems. Different categories of reaction diffusion systems depends on the number and types of the reactants. The simplest is the single species reaction diffusion system generally described as as $kA \to lA$. We consider a two dimesnional lattice, on which the particles A are biased to move towards their nearest neighbours and annihilate when they arrive at the same site; $A+A \to \emptyset$. Several systems with interacting entities e.g. bacteria and antibiotics, predators and preys, individuals in a society can be studied using reaction diffusion models with a bias, which can be either positive or negative. Any nonzero bias is seen to drastically affect the behaviour of the system compared to the unbiased (diffusive) case. For positive bias, the system shows formation of dimers, which are isolated pairs of particles located in nearest neighbouring positions with no other particles around, while for negative bias a finite density of particles are seen to survive in the system. Both the quantities vanish in a power-law manner close to the diffusive limit with different exponents. The results indicate the presence of a continuous phase transition at the diffusive point.

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15 min. break

DY 28.6 Tue 11:30 ZEU 147

Pattern selection in reaction diffusion systems — Srikanth Subramanian and •Sean Murray — Max Planck Institute for Terrestrial Microbiology, Marburg, Germany

Turing's theory of pattern formation has been used to describe self-organisation in many biological, chemical and physical systems. However, while conditions sufficient for the existence of patterns are known, the nonlinear mechanisms responsible for pattern selection are not. Here, we show the physical principle of mass flow through the system has a critical role in pattern determination. In particular, mass flow, rather than growing Fourier modes, underlies the regular positioning of peaks within a pattern and is responsible for a competition instability that leads to a reduction in the number of peaks. These results also explain the coarsening and lack of peak movement observed in the limit of no mass flow, namely, in mass-conserved systems.

DY 28.7 Tue 11:45 ZEU 147

Pattern formation in confined magnetizable granular matter — •Eric Opsomer[1], Simon Merminod[2], Julien Schockmel[1], Nicolas Vandewalle[1], Michael Berhanu[3], and Eric Falcon[3] — [1]University of Liège, Liège, Belgium — [2]Brandeis University, Waltham, USA (MA) — [3]CNRS, Université Paris Diderot, Paris, France

Magnetizable granular materials can be used as model systems for the study of phase transitions, crystallization and pattern formation. Indeed, in addition to granular gases and crystalline arrangements, labyrinthine structures have been reported in confined vibrated systems were agitation is competing with magnetic repulsion between particles.

Here, we present DEM simulations of vibrated magnetizable spheres in a Hele-Shaw cell and study the impact of the gap size on the observed structures. By tuning the confinement, we recreate established experimental data and generate new structures displaying herringbone patterns.

DY 28.8 Tue 12:00 ZEU 147

Salt polygons are caused by convection — •Lucas Goehring[1], Jana Lasser[2], Marcel Ernst[2], and Joanna Nield[3] — [1]Nottingham Trent University — [2]Max Planck Institute for Dynamics

and Self-Organisation — [3]University of Southampton

From fairy circles to patterned ground and columnar joints, natural patterns spontaneously appear in many complex geophysical settings. Here, we shed light on the origins of polygonally patterned crusts of salt playa and salt pans. These beautifully regular features, approximately a meter in diameter, are found worldwide and are fundamentally important to the transport of salt and dust in arid regions. We show that they are consistent with the surface expression of buoyancy-driven convection in the porous soil beneath a salt crust. By combining quantitative results from direct field observations, analogue experiments, linear stability theory, and numerical simulations, we further determine the conditions under which salt polygons should form, as well as how their characteristic size emerges.

DY 28.9 Tue 12:15 ZEU 147

Periodic patterns emerge beyond active phase separation —

•Frederik J. Thomsen, Lisa Rapp, Fabian Bergmann, and Walter Zimmermann — Theoretische Physik, Universität Bayreuth

A generic model for a conserved order-parameter field is suggested and investigated that shows a primary transition to large-scale active phase separation. It is a first example of a nonlinear conserved system that shows a secondary bifurcation to spatially periodic patterns. The transition is hysteretic. This spatially periodic patterns show multistability, i. e. we find wavenumber bands of stable periodic patterns as in classial pattern forming systems with unconserved order parameter fields. In a certain parameter subrange this model follows a gradient dynamics. In this range and in its neighborhood homogeneous phase separated states coexist with spatially periodic patterns.