DY 16: Pattern Formation

Time: Wednesday 9:30–12:15 Location: H46

Invited Talk DY 16.1 Wed 9:30 H46

Dynamics of thin sheets: Crumpling, wrinkling and cracking — •Pascal Damman — Universite de Mons, Mons, Belgium

Thin elastic sheets are mechanically unstable to boundary or substrate-induced compressive loads. Moderate compression results in regular wrinkling while further confinement can lead to crumpling/folding or blistering. Close inspection of a simple candy wrap reveals that these patterns are universal and often coexist in the same object. These regions of stress focusing are often considered as a hindrance for technological applications, acting as nucleation points for mechanical failure. Conversely, they can be exploited constructively to build tailored 3D thin structures and to understand how the mechanical forces shape living systems, i.e., the morphogenesis.

This talk will be focused on the emergence of complex patterns for confined thin sheets. Two physical models will be described: the curtain model (i.e., a sheet confined at one edge) and the Euler buckling of a sheet resting on a soft foundation.

DY 16.2 Wed 10:00 H46

Patterned ground in permafrost: an experimental study — •Antoine Fourrière and Lucas Goehring — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Deutschland

Permafrost experiences annual freezing and thawing cycles. Differential frost heave results in the slow and natural emergence of periodic patterns at the surface of these soils. Due to the very long timescales involved, i.e. 1 to several thousand of years, field measurements can hardly provide the data needed to distinguish between the different theoretical ideas that could explain this pattern formation process. In particular, the physical mechanisms that link small-scale dynamics, such as cryosuction of water through a porous medium or the expansion of a frozen fringe, to meter-scale patterned ground are still an issue and have to be adressed. Here we present experimental work that mimics the initial stages of patterned ground formation in permafrost. We observe the evolution of surface topography for a granulate volume of $20 \times 20 \times 10$ cm during several freeze-thaw cycles. The particle size distribution and the water fraction are varied. Surface modulation is observed for particular composition of the soil. The temperature evolution $T(z,t)$ inside the sample is modelled in the framework of the Stefan problem. By comparing the model results with the measured temperature profile, simple ideas like the evolution of the freezing front and the presence of a frozen fringe can be tested.

DY 16.3 Wed 10:15 H46

Selection theory of free crystal growth in convective systems — •Martin von Kurnatowski and Klaus Kassner — Otto-von-Guericke-University Magdeburg, Department of Theoretical Physics, Universitätsplatz 2, 39106 Magdeburg

The liquid-solid-interface of a crystal growing freely in its undercooled melt forms dendritic patterns. Understanding these patterns is crucial for controlling the material properties of solid substances such as metals. In the simplest models, the growth is governed by heat transport. Neglecting surface tension, one obtains a so-called Stefan problem having a parabolic solution. This zeroth-order problem does not lead to the selection of values for important system parameters that are experimentally fully determined. Capillary effects at the two-phase boundary constitute a singular perturbation selecting the length scale of the pattern.

Solution methods are usually based on the use of Green's functions [1]. However, with convection this method is normally not applicable due to the nonlinearity of the field equations. Density changes at the phase transition are a possible cause for convection. A potential flow and a Stokes flow are two simple approximations for the flow velocity field. This contribution focuses on the latter but more extended results have also been obtained. To approach the nonlinearities analytically, we use asymptotic decomposition as a powerful extension to the standard method. It yields an eigenvalue equation to be solved numerically.

[1] E. A. Brener and V. I. Melnikov, Adv. Phys. 40, p. 53-97 (1991)

DY 16.4 Wed 10:30 H46

Crystal Growth in a Channel: From Merry-Go-Round Fingers to Seesaw Dynamics — •Klaus Kassner[1], Jean-Marc Debierre[2], and Rahma Guerin[2] — [1]Otto-von-Guericke-Universität, Magdeburg — [2]Institut Matériaux Microélectronique Nanosciences de Provence, Marseille

We study three-dimensional solidification in capillaries of various cross sections (triangular, square, hexagonal, circular) by numerical simulation, using Karma's phase-field model. Besides symmetric and asymmetric steady states expected from acquaintance with the 2D case, we find a number of hitherto unknown dynamical states, some of which were quite unexpected. In particular, there is chiral symmetry breaking leading to rotation of a growing nanocrystal in a hexagonal or circular channel. This seems to be the simplest system so far in which spontaneous breaking of chiral symmetry has been observed. A general characterization of oscillatory states (including movies) and bifurcation diagrams in terms of the undercooling and system size will be given. Some chaotic states have also been observed.

15 min. break

DY 16.5 Wed 11:00 H46

Orientational selection in pattern formation — •Vanessa Weith, Alexei Krekhov, and Walter Zimmermann — Universität Bayreuth, Theoretische Physik I, 95440 Bayreuth, Germany

Spatially periodic patterns in two-dimensional isotropic systems are on large length scales orientationally disordered. Examples are lamellae in diblock copolymers with the lamellae perpendicular to substrates or stripe patterns occurring in experiments on gas convection in large aspect ratio systems.

The orientational selection of the wave vector $\mathbf{q}$ of lamellae in diblock copolymers or stripe patterns in model systems can be induced by appropriate surface preparations of confining substrates. In addition we show, that the orientation of $\mathbf{q}$ of lamellae and stripe patterns can be controlled by traveling, spatially periodic modulations of the control parameter. Assuming a parallel orientation of the wave vector $\mathbf{k}$ and the velocity $\mathbf{v}$ of the modulation, we find in the case of a small velocity that the wave vector of patterns, $\mathbf{q}$, orients perpendicular to $\mathbf{v}$ and parallel to $\mathbf{v}$ in the case of larges values of $|\mathbf{v}|$.

DY 16.6 Wed 11:15 H46

Pattern formation in Cahn-Hilliard models for Langmuir-Blodgett transfer — •Markus Wilczek, Svetlana V. Gurevich, and Rudolf Friedrich — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Deutschland

Langmuir-Blodgett transfer is an established method for covering substrates with monolayer films. During the transfer, partial condensation of the monolayer can lead to the formation of patterns in different phases of the transferred monolayer. Experimental parameters like the transfer velocity influence the properties of the patterns, like the orientation and wavelength of stripes.

In this work, we investigate the pattern formation process in the framework of spinodal decomposition by means of Cahn-Hilliard models. Besides the transfer onto homogeneous substrates, the influence of prestructured substrates is studied. In particular, the occurrence of synchronization phenomena is described.

In addition, the transition between different orientations of stripe patterns is investigated, revealing the occurrence of secondary instabilities leading to certain patterns.

DY 16.7 Wed 11:30 H46

Looking beneath the surface: A study of desiccation cracks over patterned substrates — •Pawan nandakishore and Lucas Goehring — Max Planck Insititute for Dynamics and Self Organization, Goettingen, Germany

From cracks on planetary surfaces to cracks in dried paint, to cracks in microscopic thin films, contraction cracks occur at many length scales and, following linear elasticity theory these patterns should scale across these length scales. We investigate the crack patterns formed due to the presence of sinusoidal substrates and substrates with a single peak or trough. To this effect, we look at desiccated mud cracks by drying a bentonite slurry over the different substrates. The relevant parameters in this problem are the layer height, wavelength and amplitude of the substrate. We characterize the topology of the pattern, and show that an order parameter, characterized by the orientation of the cracks, behaves non monotonically. At low layer heights the crack pattern is disordered and contains wavy cracks. As the layer height is increased, a highly anisotropic crack pattern is formed when the wavelength matches the natural crack spacing of the film, or close to the layer thickness. This pattern is characterized by cracks that run parallel and perpendicular to the substrate. When the layer height is further increased the pattern becomes disordered however there are no wavy cracks present. Combining these observations from the sinusoidal substrates and the observations from the single peaks and troughs we attempt to acquire a means to decipher what lies beneath the crack pattern.

DY 16.8 Wed 11:45 H46

Revisiting the Scaling Analysis of Irreversible Aggregation Dynamics — •Jürgen Vollmer — Max Planck Insitute for Dynamics and Self-Organization, 37077 Göttingen, Germany

The analysis of the size distribution of droplets condensing on a substrate is a test ground for scaling theories. Surprisingly, a faithful description of its evolution must explicitly address microscopic nucleation and growth mechanisms of the droplets [1]. In view of this we discuss how this breaking of universality relates to other systems with vastly polydisperse droplet size distributions, like the growth of droplets in clouds.

[1] J Blaschke, T Lapp, B Hof, and J Vollmer, PRL 109, 068701 (2012).

DY 16.9 Wed 12:00 H46

Origin of Complexity in Cellular Automata — •Vladimir Garcia-Morales — Technische Universität München - Institute for Advanced Study, Lichtenbergstr. 2a, D-85748 Garching, Germany

Cellular automata (CA) constitute paradigmatic models of complexity in nature, from snowflakes, patterns in mollusc seashells and spiral waves in the Belousov- Zhabotinsky reaction to neural networks and the fundamental physical reality. A universal map encompassing all 1D deterministic first-order in time CA has been very recently derived [1]. This map is to be considered as the discrete counterpart of partial differential equations in continuum systems. The map does not depend on freely adjustable parameters and is valid for any neighborhood and alphabet size. It can be easily extended to an arbitrary number of dimensions and topologies and higher orders in time. Symmetry arguments applied to the map allow to classify all dynamical CA rules into equivalence classes and a theorem can be proved which establishes how a CA rule is constructed in terms of rules of lower range [2]. The crucial result is that the most complex CA rules can be found with a simple prescription, starting from rules possessing the symmetry upon addition modulo an integer number p, and weakly breaking this symmetry through an additional degree of freedom. It is illustrated how this mechanism is the origin of complexity in 1D CA.

[1] V. Garcia-Morales, Phys. Lett. A 376 (2012) 2645.
[2] V. Garcia-Morales, Phys. Lett. A (2012, in press), http://dx.doi.org/10.1016/j.physleta.2012.11.052