SYNP 1: New Trends in Nonequilibrium Physics: Conservation Laws and Nonreciprocal Interactions

Time: Thursday 15:00–17:45 Location: H 0105

Invited Talk SYNP 1.1 Thu 15:00 H 0105
Universality classes of nonequilibrium phase transitions with conservation constraints — •Walter Zimmermann — Theoretische Physik, Universität Bayreuth, Germany

Nonequilibrium phase transitions in various biological and soft matter systems with conservation constraints have recently attracted considerable attention. The mechanisms for these systems are as diverse as the systems themselves. However, they share systems spanning properties near the transitions described by universal models, as emphasized in the talk. In 1950, the Ginzburg-Landau equation (GLE) was formulated for the phase transition from normal to superconductivity. Since 1969, a large number of nonequilibrium phase transitions (bifurcations) with unconserved order parameters near their onset are described by the universal GLE, also known as envelope or amplitude equation, or by its generalization to oscillatory transitions (bifurcations) [1,2]. Using a new generalized perturbation technique applied to conserved system-specific and phenomenological models, one finds the Cahn-Hilliard (CH) class for non-oscillatory transitions and the universal CHEOPS model for oscillatory transitions (induced by nonreciprocal interactions). They are complementary to the previous universal unconserved models [1,2]. The main focus of the talk is on the fascinating solution behavior of these universal models and intermediate transport equations, as well as an intriguing secondary transition unknown from classical unconserved order parameter fields.

[1] I. Aranson, L. Kramer, Rev. Mod. Phys. 74, 99 (2002); [2] M. C. Cross, P. C. Hohenberg, Rev. Mod. Phys. 65, 851 (1993).

Invited Talk SYNP 1.2 Thu 15:30 H 0105
The many faces of living chiral crystals — •Nikta Fakhri — Maasachusetts Institute of Technology, Cambridge, USA

Emergent nonreciprocal interactions can generate self-organized states of matter that are impossible to realize in equilibrium. Here, by combining experiments, simulations, and theory, we demonstrate that nonreciprocal solids composed of living starfish embryos can spontaneously transition between stable static and oscillatory states. The two states are distinguished by the relative dominance of two distinct microscopic mechanisms of chiral symmetry breaking, namely the spinning of individual embryos, and the precession of their axis of rotation. We show that the oscillatory state is characterized by long wavelength optical vibrational modes, and can be selectively excited using external mechanical perturbations. Analysis of coupling between vibrational modes reveals that excitable nonreciprocal solids constitute a distinct class of tunable active metamaterials.

Invited Talk SYNP 1.3 Thu 16:00 H 0105
Non-reciprocal pattern formation of conserved fields — •Fridtjof Brauns[1] and M Cristina Marchetti[2] — [1]Kavli Institute for Theoretical Physics, University of California Santa Barbara, Santa Barbara, CA 93106, USA — [2]University of California Santa Barbara, Santa Barbara, CA 93106, USA

Spatio-temporal patterns in nonlinear oscillatory and excitable media have been studied extensively in systems lacking conserved quantities. More recently, pattern formation of conserved fields has come into focus, including mass-conserving reaction–diffusion systems and viscoelastic active gels. Here, we show that models for these systems can be mapped to a common “normal form”, a minimal non-reciprocal Cahn–Hilliard (NRCH) model, that can be seen as a spatially extended generalization of the FitzHugh–Nagumo model, providing a unifying dynamical-systems perspective. We show that this class of systems is identified by a characteristic dispersion relation, where the bands of unstable and propagating modes meet in an exceptional point at the bifurcation marking the onset of propagating structures (bands or droplets). The minimal NRCH model exhibits a surprisingly rich set of behaviors, including a new mechanism for interrupted coarsening that does not select a preferred wavelength and transversal undulations of wave fronts in two dimensions. Insight into these traveling structures is gained from the local dispersion relation at interfaces far away from the homogeneous steady state. This generalizes the mode coalescence mechanism for emergence of temporal order recently studied in nonreciprocally coupled systems without conserved fields.

15 min. break

Invited Talk SYNP 1.4 Thu 16:45 H 0105
Phase transitions and fluctuations of nonreciprocal systems — •Sarah A.M. Loos — DAMTP, University of Cambridge, Cambridge, UK

Reciprocity is a hallmark of thermal equilibrium, but ubiquitously broken in far-from-equilibrium systems. I will give some insights into how nonreciprocal interactions can fundamentally affect the phases and fluctuations of many-body systems. Using a two-dimensional XY model, where spins interact only with neighbours within their ‘vision cones’, we show how nonreciprocity can lead to true long-range order and directional propagation of defects [1]. In binary fluids, nonreciprocal coupling between fluid components can cause the emergence of travelling waves through PT symmetry-breaking phase transitions. Using a nonreciprocal field theory, we show that fluctuations not only inflate, as in equilibrium criticality, but also develop an asymptotically increasing time-reversal asymmetry [2-4]. The formation of dissipative patterns and the emergence of irreversible fluctuations can both be attributed to a mechanism of mode coupling in the vicinity of critical exception points, which manifests itself in actively propelled interface dynamics [4].

[1] SL, Klapp & Martynec, Phys. Rev. Lett. 130, 198301 (2023)
[2] Suchanek, Kroy & SL, Phys. Rev. Lett. 131, 258302 (2023)
[3] Suchanek, Kroy & SL, Phys. Rev. E 108, 064123 (2023)
[4] Suchanek, Kroy & SL, Phys. Rev. E 108, 064610 (2023)

Invited Talk SYNP 1.5 Thu 17:15 H 0105
Chiral matters — •William Irvine — University of Chicago

The properties of materials, including their structure, shape, rheological response and mechanical stability arise spontaneously from the interactions between elementary building blocks. In passive materials these are often reciprocal, energy conserving and subject to thermal fluctuations. I will discuss the physics of out-of-equilibrium solids and fluids built out of mechanically spinning components. These active materials which blur the line between solid and fluid, spontaneously exhibit phenomena from chiral surface waves, to perling instabilities, to dislocation motility and crystal-whorl states. These rich and lively dynamics enable inference of the rheological properties of these odd materials which include odd stress, odd viscosity and odd elasticity. If time permits I will demonstrate how spinning fluids from within in three-dimensions, naturally leads to new effects, particularly at intermediate Reynolds numbers, when fluid inertia plays a role in dynamics.