SYSS 1 Structure Formation and Self-Organization in non-equilibrium Systems I

Time: Thursday 09:30–13:00 Room: BAR Schö

SYSS 1.1 Thu 09:30 BAR Schö

Ferrosolitons — •Reinhard Richter[1] and Igor Barashenkov[2] — [1]Experimentalphysik 5, Universität Bayreuth, D-95440 Bayreuth, Germany — [2]University of Capetown, Rondebosch 7700, South Africa

Solitary structures in two dimensions have been mostly confined to vortices in superconductors and superfluids on one hand and dissipative solitons in nonequilibrium systems on the other. While the stability of the former is due to their nontrivial topology, the latter are believed to be stable thanks to the balance of strong dissipation and energy gain. Neither of these stabilisation principles could be at work for localised patterns on the surface of a horizontal layer of ferrofluid: this is a lossless system with no special topology. Nevertheless, we have recently discovered stable solitary spikes in the bistable regime of the Rosensweig instability [1]. These *ferrosolitons* can be generated by a local magnetic field application, or simply by mechanical perturbation of the flat surface. Their stability can be explained in part by the locking of the expanding front to the wavelength of the coexisting periodic pattern [2]. We investigate the profiles of ferrosolitons, measured by means of radioscopy [3] and analyze the locked wavefront. The ferrosolitons have oscillatory tails, which become wider as the magnetic induction is increased. We compare the measured profiles with analytical and numerical estimations.

[1] Reinhard Richter, and I.V. Barashenkov, Phys. Rev. Lett. **94** 184503-1 (2005).
[2] Y. Pomeau, Physica D (Amsterdam) **23**, 3 (1986).
[3] Reinhard Richter, and Jürgen Bläsing, Rev. Sci. Instrum. **72**, 1729 (2001).

SYSS 1.2 Thu 09:45 BAR Schö

Structure Formation by Heat - understanding and applying Thermophoresis — •Stefan Duhr, Franz Weinert, and Dieter Braun — Noether Group on Dissipative Microsystems, Applied Physics, Ludwig Maximilians Universität München, Amalienstr. 54, 80799 München, Germany

Molecules typically move from hot to cold in temperature fields, a non-equilibrium effect called thermophoresis. Compared to electrophoresis, temperatures can be applied with micrometer resolution in microfluidics, yielding an alternative to electrophoresis for biomolecule analysis. Until recently, however, theoretical understanding was poor. We report on:

o Thermophoresis of DNA and polystyrene beads is driven by solvation entropy, shown by novel microfluidic fluorescence measurements.As a result, the effective charge of molecules is inferred more robust and simple than from electrophoresis.

o Nonlinear thermophoresis reveals deviations from the Onsager foundation of thermophoresis due to a breakdown of the local equilibrium assumption. Only then, thermophoresis across a solid-water interface can crystallize colloids.

o DNA is accumulated by flow in microfluidics. Giant accumulation driven by convection is predicted for single nucleotides near volcanic seafloor vents, closing missing links in molecular evolution of life

o Water can be pumped with an infrared laser scanning microscope as a result of nonlinear thermal expansion. It allows to shrink thermophoretic field flow fractionation to microfluidic dimensions.

Website: http://www.biophysik.physik.uni-muenchen.de/Braun

SYSS 1.3 Thu 10:00 BAR Schö

Competition between traveling waves of left and right spiral vortices and their combinations with different or equal amplitudes — •Alexander Pinter, Manfred Lücke, and Christian Hoffmann — Institut für Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken, Germany

Stability, bifurcation properties, and the spatiotemporal behavior of different nonlinear combination structures of spiral vortices in the counter rotating Taylor-Couette system are investigated by full numerical simulations and by coupled amplitude equation approximations. Stable cross-spiral structures with continuously varying content of left and right spiral modes are found. They provide a stability transferring connection between the initially stable, axially counter propagating wave states of pure spirals and the axially standing waves of so-called ribbons that become stable slightly further away from onset of vortex flow.

SYSS 1.4 Thu 10:15 BAR Schö

Hexaroll chaos in inclined layer convection — •Will Brunner[1], Jonathan McCoy[2], Werner Pesch[3], and Eberhard Bodenschatz[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Goettingen — [2]LASSP, Department of Physics, Cornell University — [3]Physikalisches Institut, Universitaet Bayreuth

We present results from experiments in thermal convection with the aim of studying defect mediated turbulence. We induce a defect turbulent state by tilting non-Boussinesq convection 5 degrees from horizontal. This breaks the symmetry of the hexagonal pattern, producing a pattern that resembles hexarolls found in cylindrical rotating convection. We find a new type of defect complexes in addition to the expected penta-hepta defects (PHDs), where a dislocation of one sign is found in one hexagonal mode and one of opposite sign is nearby in another mode. These new defect complexes, which we term same-mode complexes (SMCs) consist of two dislocations of opposite sign in the same mode. SMCs can self-annihilate, unlike PHDs which can only annihilate pairwise. This self-annihilation gives rise to a term in the annihilation rate law that is proportional to the number of defects present. We conclude that mass action is a robust concept for dealing with reaction rates in defect turbulence, and propose that SMCs may be present in other systems where an anomalous linear annihilation rate is seen.

SYSS 1.5 Thu 10:30 BAR Schö

Bénard–convection in colloidal suspensions — •Björn Huke and Manfred Lücke — Institute for theoretical physics, Saarland University, D-66041 Saarbrücken

Colloidal suspensions differ from molecular binary mixtures like, e.g., ethanol-water by the fact that the solutal diffusion time scales are several orders of magnitudes longer: The Lewis number of the former is typically of the order of 10^{-3} to 10^{-4}. In addition they can also exhibit a Soret effect that is several orders of magnitude stronger leading to separation ratios of the order of 100.

We numerically studied the convection in a such a fluid layer heated from below for these parameters using the Galerkin method. We calculated bifurcation diagrams for roll, square, and crossroll patterns that are known to exist as stable form of convection in molecular mixtures with positive separation ratios. The stability region of these structures was investigated for selected parameter combinations. Oscillatory crossrolls and their transition into the square and stationary crossroll state were studied via a time integration of the mode equations.

Traveling waves that are an important structures in molecular fluids with negative separation ratio were also studied and found to play no role in colloids at moderate heating rates.

— 15 min. break —

SYSS 1.6 Thu 11:00 BAR Schö

Gas-Enrichment at Liquid-Wall Interfaces — •Stephan M. Dammer and Detlef Lohse — University of Twente, Physics of Fluids

Molecular dynamics simulations are performed to study the effects of dissolved gas on liquid-wall interfaces. The systems are composed of different particle species (liquid/gas/wall) that interact via Lennard-Jones potentials. Liquid-gas mixtures in contact with walls exhibit gas enrichment at the walls, which increases with increasing hydrophobicity, quantified by the contact angle which is obtained from additional simulations of droplets at walls. When compared to the gas concentration in the bulk of the liquid, for atomically smooth hydrophobic walls the observed gas enrichment can exceed more than two orders of magnitude. In the case of nanometric wall roughness gas accumulates in nano-crevices on hydrophobic walls. Close to the walls the liquid shows a layered structure which is less pronounced for increasing contact angle and which for large contact angle is considerably altered by the presence of a gas. Furthermore, we investigate the influence of the gas enrichment at hydrophobic walls on dynamical properties, such as the slip length, by nonequilibrium molecular dynamics simulations.

SYSS 1.7 Thu 11:15 BAR Schö

Xenon Dendrites: Onset and Amplitude of Sidebranches — •Oliver Wittwer and Jörg Bilgram — Laboratorium für Festkörperphysik, ETH, CH 8093 Zürich, Switzerland

The initiation of sidebranches of three dimensional xenon dendrites has been studied. The sidebranches of dendrites growing in a steady state are initiated by selective amplification of thermal noise in the region of the dendrite tip. Measurements of the amplitudes of sidebranches as a function of the distance behind the tip have been compared with theoretical predictions for non-axisymmetric needle cystals [1]. Noise initiated sidebranches start to grow 3-7 tip radii behind the tip. The sidebranches growing at the four fins are not correlated and the amplitudes measured in our experiments are in quantitative agreement with the theoretical predictions.

We have also found a second type of sidebranch initiation: External perturbations lead to sidebranches starting to grow directly at the tip. They are highly correlated at the four fins and their amplitudes are higher than the ones of noise initiated sidebranches.

[1] E. Brener, Phys. Rev. Lett. **71**, 3653 (1993)

SYSS 1.8 Thu 11:30 BAR Schö

Self-Organized Electrochemical Assembly of Mesoscale Silver Wires and Dendrites — •Sheng Zhong[1,2], Thomas Koch[1,2], Harald Roesner[2], Horst Hahn[2], Eberhard Nold[3], Dong Wang[4], Mu Wang[5], Stefan Walheim[2], and Thomas Schimmel[1,2] — [1]Institute of Applied Physics, University of Karlsruhe, D-76128 Karlsruhe, Germany — [2]Institute of Nanotechnology (INT), Forschungszentrum Karlsruhe, D-76021 Karlsruhe, Germany — [3]Institute for Materials Research I (IMF I), Forschungszentrum Karlsruhe, D-76021 Karlsruhe, Germany — [4]Institute for Materials Research II (IMF II), Forschungszentrum Karlsruhe, D-76021 Karlsruhe, Germany — [5]National Laboratory of Solid-State Microstructures, Nanjing University, Nanjing 21009, China

Mesoscopic metal structures attract considerable attention due to their potential application in next-generation electronic devices, such as interconnects and active components. The synthesis of these mesoscale building blocks is a crucial step towards the implementation of nanodevices. We demonstrate a novel and simple electrochemical deposition approach for the self-assembly of free-standing single-crystalline mesoscopic silver wires and regular dendritic structures from an aqueous solution without templates, additives and surfactants. The single-crystalline silver wires and structures grow spontaneously under a direct current electric field. Wire diameters down to 100 nm and wire lengths up to 150 micro meter and more are found. This simple electrodeposition system using a growth process that can be observed in situ also opens a convenient way to study the electrochemical growth mechanism in order to tailor mesostructures on this length scale.

SYSS 1.9 Thu 11:45 BAR Schö

Pattern formation in the CO + O reaction on Ir(111) surfaces under the influence of noise — •Stefan Wehner[1], Patrick Hofmann[2], Dieter Schmeisser[2], Helmut R. Brand[3], and Jürgen Küppers[1,4] — [1]Experimentalphysik III, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Angewandte Physik II, Brandenburgische Technische Universität Cottbus, 03013 Cottbus, Germany — [3]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany — [4]Max-Planck-Institut für Plasmaphysik (EURATOM Association), 85748 Garching, Germany

The rate of CO oxidation on Ir(111) surfaces exhibits bistability at $T = 500$ K in a range of the CO fraction Y in the CO + O reactant gas flux. Quadrupol mass spectrometer measurements of the CO_2 rates as a function of the noise strength imposed on Y are well reproduced by parameter-free modeling.

We present Photoelectron emission microscopy (PEEM) measurements and 2D calculations of the spatio-temporal patterns of CO and O rich domains. The role of combined multiplicative and additive noise on Y for CO and O domain wall motion and island nucleation-growth-coalescence processes is analysed.

For small noise amplitudes few islands nucleate and grow up to some 100 μm in diameter, before they merge with another island. With increasing noise amplitudes more islands nucleate. With large noise amplitudes bursts to and switching between the branches is observed. The domain wall velocity is found to be independent of the noise strength and island size.

SYSS 1.10 Thu 12:00 BAR Schö

Spatio-temporal dynamics of a fuel cell reaction system: New oscillatory mechanism, bifurcation analysis and efficiency improvement — •Nilüfer Baba[1], Jan Siegmeier[1], Antoine Bonnefont[2], and Katharina Krischer[1] — [1]Physik Department, E19, Technische Universität München, James Franck Str. 1, D - 85748 Garching bei München, Germany — [2]Laboratoire d'Electrochimie et de Chimie Physique du Corps Solide, UMR - Université Louis Pasteur - C.N.R.S. 4, rue Blaise Pascal, 67000 Strasbourg, France

Fuel cells are promising energy conversion devices and much research effort is focussed on their improvement. One considerable problem is that the fuel gas (hydrogen) is contaminated by CO when produced from methane which constitutes the main H_2 source. CO acts as a poison since it absorbs on the Pt catalyst, blocks hydrogen oxidation and reduces the efficiency.

We present a mathematical model for the $H_2/CO/Pt$ system and its bifurcation analysis. We demonstrate that the system displays a novel type of oscillations, involving a slow chemical autocatalysis of surface adsorbed species and a fast negative feedback loop involving the electric potential. The latter, however, is switched off in the presence of a high poison coverage, which enables potentiostatic oscillations in a wide parameter range. Simulations also show Turing patterns of small wavelengths. Based on these results we discuss control techniques that stabilize the system in a state where the coverage is minimized and thus the efficiency is enhanced.

SYSS 1.11 Thu 12:15 BAR Schö

Pulse propagation in excitable media at the edge to oscillatory kinetics. — •Grigori Bordiougov, Georg Roeder, and Harald Engel — Institut fuer Theoretische Physik, TU Berlin, Hardenbergstr. 36 10623 Berlin

Small amplitude oscillations in the wake of solitary pulses are shown to have a strong impact on the interaction between excitation pulses. Annihilation of colliding pulses is replaced by reflective collision. In addition to this soliton-like behavior we find bistability in the dispersion curve for periodic pulse trains [1]. Close to the Canard explosion in the local dynamics we observe break-up of the dispersion curve into disconnected branches accompanied by the formation of isolas [2]. Our results shed new light on the still open mechanism of the transition between trigger and phase waves in reaction-diffusion systems [3]. The reported behavior is generic for a whole class of media with an unique homogeneous steady state that undergoes a supercritical Hopf-bifurcation with Canard explosion due to well separated time scales (so-called type II excitable systems [4]).

1. G. Bordiougov et al., Phys. Rev. Lett. 90(14), 148302 (2003).

2. G. Roeder et al., Bistable dispersion relation in an excitable FitzHugh-Nagumo model, in preparation.

3. G. Bordiougov et al., From Trigger to Phase Waves and Back Again, submitted to Physica D.

4. E. Izhikevich, Int. J. of Bif. and Chaos 10 1171-1266 (2000).

SYSS 1.12 Thu 12:30 BAR Schö

Coherent structures in nonequilibrium wave dynamics — •Benno Rumpf[1], Guenter Radons[1], Alan Newell[2], and Laura Biven[3] — [1]Physics Institute, TU Chemnitz, 09107 Chemnitz, Germany — [2]Mathematics Department, University of Arizona, Tucson, Arizona, USA — [3]Max-Planck-Institut fuer Physik komplexer Systeme, 01187 Dresden, Germany

Turbulence of dispersive nonlinear waves transfers energy from a long spatial scale, where a driving force is applied, to a short viscous scale. In many physical systems, the wave amplitude is almost everywhere small, while strongly nonlinear structures with high amplitudes emerge intermittently. Our study of these coherent structures in nonequilibrium systems is based on a simple statistical analysis of a wide class of Hamiltonian wave equations. The formation of coherent structures depends critically on the thermodynamic parameters of the low-amplitude waves, and on the frequency of coherent structures.

[1] B.Rumpf, L.Biven, Weak turbulence in the Majda-McLaughlin-Tabak equation: Fluxes in wavenumber and in amplitude space, Physica D 204, 188-203, (2005)

[2] B.Rumpf, A.C.Newell, Intermittency as a consequence of turbulent transport in nonlinear systems, Phys.Rev.E 69, 026306, (2004)

[3] B.Rumpf, Intermittent movement of localized excitations of a nonlinear lattice, Phys.Rev.E 70, 016609 (2004)

[4] B.Rumpf, Simple statistical explanation for the localization of en-

ergy in nonlinear lattices with two conserved quantities, Phys.Rev.E 69, 016618 (2004)

SYSS 1.13 Thu 12:45 BAR Schö

Patterns in chaotically mixing fluid flows — •Arthur Straube and Arkady Pikovsky — University of Potsdam, Am Neuen Palais 10, PF 601553, D-14415 Potsdam

We consider a reaction-diffusion system of an activator-inhibitor type and impose a periodic in space mixing flow. We fix governing parameters in a way that ensures the stability of the homogeneous steady state in reaction-diffusion system, so that without advection no Turing patterns occur. Next, we increase the advection rate and study the influence of the flow on the stability of this state. One could expect that because the flow is mixing, it should stabilize the homogeneous state. However, the instability appears as the rate of advection increases beyond a certain threshold, which results in pattern formation. We apply the Bloch theory to find out the length-scale of the patterns, which generally do not coincide with the length-scale of the imposed flow. The mechanism of the instability can be understood from a reduced model; the results are explained by means of Lyapunov exponents. We report on two situations: (i) general case when both chemical species are advected and (ii) a partial case, when only one species is advected, which is relevant to biological applications.

Since the flow and reaction terms are generic for the effects investigated, we believe that the results hold for a variety of flows and chemical reactions.