DY 17: Reaction-diffusion systems

Time: Wednesday 14:45–16:45 Location: ZEU 118

DY 17.1 Wed 14:45 ZEU 118

Controlling the onset of traveling pulses in reactions-diffusion systems by nonlocal feedback — •MarkusA. Dahlem[1], Felix M. Schneider[1], Jens Dreier[2], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Klinik für Neurologie, Charite, Universitätsmedizin Berlin

The onset of pulse propagation is studied in a reaction-diffusion (RD) model with control by nonlocal spatial coupling and by time-delayed feedback. We show that traveling pulses occur primarily as solutions to the RD equations while nonlocal feedback changes excitability. For certain ranges of RD and feedback parameter settings, defined as weak susceptibility and moderate control, respectively, the hybrid model can be mapped to the original RD model. This results in an effective change of RD parameters that can be expressed by algebraic functions of the control gain factor as the major control parameter. A distinctly new character is, however, added to the RD patterns outside these ranges. New patterns are obtained, for example step-wise propagation due to delay-induced oscillations. Nonlocal feedback constitutes a complementary signalling system to the classical RD mechanism of pattern formation. As a hybrid model, it combines the two major signalling systems in the brain, namely volume transmission and synaptic transmission. This theoretical model is developed in conjunction with experiments on the transition between RD pulse patterns and epileptic activity at an anatomical border.

DY 17.2 Wed 15:00 ZEU 118

Moving and breathing dissipative solitons in a three-component reaction-diffusion system — •Svetlana Gurevich and Rudolf Friedrich — Institute for Theoretical Physics, WWU Münster, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany

We are interested in the stability of the stationary localized structures (so-called dissipative solitons) in a three-component reaction-diffusion system with one activator and two inhibitors. Changing the time constants of inhibitors can lead to various destabilizations of the stationary dissipative soliton. In many cases the breathing mode becomes unstable first and the stationary dissipative soliton undergoes a bifurcation from a stationary to a breathing state. On the other hand a mode responding to a movement can be unstable first and a drift-bifurcation takes a place. Here we are interested in the interaction between these two unstable modes. This situation is analyzed performing a multiple scale perturbation expansion in the vicinity of the codim 2 bifurcation point and the corresponding amplitude equation is obtained. Also numerical simulations are carried out showing good agreement with the analytical predictions.

DY 17.3 Wed 15:15 ZEU 118

Validation of effective medium theory for heterogeneous reaction-diffusion systems — •Sergio Alonso[1], Raymond Kapral[2], and Markus Baer[1] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]University of Toronto, Toronto, Canada

Fronts and travelling waves are spatiotemporal structures observed in nonlinear chemical and biological systems. Experiments in the Belousov-Zhabotinsky reaction, catalysis and in cardiac tissue show that the properties of the waves are affected by heterogeneities and deformations which hinder the stable propagation. Numerical models usually assume spatially homogeneous systems, and do not consider any type of defect. There are, however, also models of biological processes where heterogeneous reaction-diffusion equations have been employed. Here we propose and effective medium theory for reaction-diffusion systems which relate both types of approaches. We compare the predictions of the theory with numerical simulations in different types of randomly heterogeneous media.

DY 17.4 Wed 15:30 ZEU 118

Equidistant band formation in a precipitation process — •Lukas Jahnke and Jan W. Kantelhardt — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle, Germany

Abstract: In bottom-up pattern formation approaches one aims at designing materials with nano- or microscopic 2d or 3d patterns for specific applications. We study theoretically the 3d Liesegang pattern formation process, which is based on diffusion and reactions with a nucleation threshold. It usually yields banded structures with increasing inter-band distances. We find that equidistantly spaced bands can evolve if a gradient of the nucleation threshold or a gradient in the nucleation threshold fluctuations (due to heterogeneities) are imposed on the sample. Using extended lattice gas simulations of the reaction-diffusion process we confirm the equidistant band formation. We propose experimental strategies for 3d grids of silver nano-particles in a glass matrix. Ref.: Jahnke and Kantelhardt, EPL 84 (2008) 48006.

DY 17.5 Wed 15:45 ZEU 118

Extended complex Ginzburg-Landau equation for globally coupled electrochemical systems — •Vladimir Garcia-Morales and Katharina Krischer — Technische Universität München, Physik Department E19, James-Franck Str. 1, D-85748 Garching bei München, Germany

Nonlocal interactions in spatially extended electrochemical oscillators arise because of the effect of inhomogeneities in the distribution of the electrostatic potential. We have derived a nonlocal complex Ginzburg-Landau equation (NCGLE) that accounts for this nonlocal coupling (NLC) at the vicinity of a supercritical Hopf bifurcation.

Experimentally, it is straightforward to add a global coupling (GC) to the nonlocally coupled electrochemical oscillators. GC occurs naturally in these systems, for example, when an external resistance is introduced or when part of the cell resistance is compensated, an often applied technique in electrochemical experiments.

In this talk we discuss how the NCGLE can be extended rigorously to account for the GC of electrochemical oscillators. We show that the experimental GC is also weak close to the supercritical Hopf bifurcation, having the same scaling properties as the NLC. Therefore, a center manifold reduction allows the NCGLE to be extended rigorously to account for the GC. We discuss how the interaction between NLC and GC widens the spectrum of coherent structures found in globally coupled oscillatory media and allows for wavelength selection of standing waves, stabilization of phase clusters without breaking phase invariance, and creation of heteroclinic networks connecting families of oscillatory states characterized by different spatial symmetries.

DY 17.6 Wed 16:00 ZEU 118

Generalized Recurrence Quantification analysis reveals road to turbulence in the 2D Ginzburg-Landau equation — •Angelo Facchini[1,2], Chiara Mocenni[1,2], and Antonio Vicino[1,2] — [1]Center for the Study of Complex Systems, University of Siena, Italy — [2]Department of Information Engineering, University of Siena, Italy

We use the Generalized Recurrence Plot (GRP) and the Generalized Recurrence Quantification Analysis (GRQA) (*Phys. Lett. A, 360, 545, 2007*) to investigate the pattern formed by the Complex Ginzburg-Landau Equation (CGLE)(*Rev. Mod. Phys., 74, 99, 2002*). The state of the dynamical system in steady state conditions is here represented by an image, and the application of the GRQA assign to each image a value for both ENT and DET (*A. Facchini et al, Physica D (2008), in press*). The signature of the dynamics of the CGLE is identified by the position of the image in the DET-ENT diagram. We focus on the portion of the parameter space in which there are both absolutely stable and unstable spiral wave solutions, separated by a bifurcation line (*Physica A 224, 348, 1996*). Our results show that images belonging to different stability zones are clustered in different regions of the DET-ENT diagram. By looking at the parameters value for which the position of the image jumps from a cluster to another we are able to reconstruct the bifurcation line in the DET-ENT diagram. Furthermore, before the onset of the turbulent state (cluster jump) we observe a transition region located along the reconstructed bifurcation line.

DY 17.7 Wed 16:15 ZEU 118

Diffusion-limited reactions and mortal random walkers in confined geometries — •Ingo Lohmar and Joachim Krug — Institute for Theoretical Physics, Cologne, Germany

Motivated by the diffusion-reaction kinetics on interstellar dust grains, we study a first-passage problem of mortal random walkers in a confined two-dimensional geometry. We provide an exact expression for the encounter probability of two walkers, which is evaluated in limiting cases and checked against extensive kinetic Monte Carlo simulations. We analyze the continuum limit which is approached very slowly, with corrections that vanish logarithmically with the lattice size. We then examine the influence of the shape of the lattice on the first-passage probability, where we focus on the aspect ratio dependence: Distorting the lattice always reduces the encounter probability of two walkers and can exhibit a crossover to the behavior of a genuinely one-dimensional random walk. The nature of this transition is also explained qualitatively.

DY 17.8 Wed 16:30 ZEU 118

Binding kinetics of DNA and protein targets to surface tethered probes studied with switchable DNA surfaces — •Makiko Maruyama, Wolfgang Kaiser, Erika Pringsheim, Gerhard Abstreiter, and Ulrich Rant — Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

We report on the binding kinetics of DNA and protein targets to surface immobilized probes, using the *switch*DNA sensor. The overall detection performance of a biosensor depends on the transport of target molecules from solution to the sensor and the reaction rate of the targets with the probes. The influence of analyte flow across the sensor surface and the sensor temperature on the binding response is studied and the results are compared to solution measurements.

The hybridization of 24nt DNA on the *switch*DNA sensor proceeds with outstanding efficiency; the rate constants obtained on the surface ($k > 10^5 M^{-1} s^{-1}$) correspond to values measured in solution. The results indicate that the sensor predominantly operates in the reaction-limited case for the DNA binding experiments, whereas diffusion-limited kinetics are found for the binding of streptavidin to surface-tethered biotinylated probes. The results can be rationalized by theoretically estimating the operation conditions of the sensor based on dimensionless fluidic numbers, in particular the Péclet and Damköhler numbers. The rapid reaction of the biotin-streptavidin couple ($k > 5 \times 10^6 M^{-1} s^{-1}$ in solution) leads to the formation of a target-concentration depletion zone above the sensor surface and results in mass-transport limited kinetics.