

DY 10: Nonlinear Stochastic Systems

Time: Tuesday 9:30–12:30

Location: ZEU 160

DY 10.1 Tue 9:30 ZEU 160

Fluctuation-Driven Shifts in Selection Regimes in Population Dynamics — ●YEN TING LIN¹, HYEJIN KIM², and CHARLES DOERING³ — ¹Max Planck Institutes for the Physics of Complex Systems, Noetnitzer Str. 38, Dresden 01187, Germany — ²Department of Mathematics, Michigan State University, East Lansing, MI 48824, USA — ³Department of Mathematics, University of Michigan, Ann Arbor, Michigan 48109-1043

Demographic stochasticity is an essential feature of population dynamics. Nevertheless theoretical investigations often neglect this naturally occurring noise due to the mathematical complexity of stochastic models. This talk reports the results of analytical and computational investigations of models of competitive population dynamics, specifically the competition between species in heterogeneous environments with different phenotypes of dispersal, fully accounting for demographic stochasticity. A novel asymptotic approximation is introduced and applied to derive remarkably simple analytical forms for key statistical quantities describing the populations' dynamical evolution. The theory is verified by conventional asymptotic analysis and large-scale numerical simulations. Both dynamical mechanisms and time scales of the fluctuation-induced phenomena are identified within the theoretical approach. The analysis highlights the fundamental physical effect of the fluctuations and provides an intuitive interpretation of the complex dynamics. An interaction between stochasticity and nonlinearity is the foundation of noise-driven dynamical selection.

DY 10.2 Tue 9:45 ZEU 160

Statistical classification of small microbial food webs — ●FANNY GROLL and ALEXANDER ALTLAND — Institut für Theoretische Physik, Universität zu Köln, Germany

We identify classes of food webs with regard to their stability and species diversity. Food webs are characterised by the topology of their inter-species relations, e.g. feeding on products of metabolism of another species or competition on nutrients or via a common predator.

To gain insight into these structures we pursue a statistical approach: the starting point is the numerical implementation of food webs with given inter-species network dependence. Each species is defined by parameters determining its attributes. A whole distribution of parameter combinations is then randomly generated within biologically sensible bounds, and tested according to its temporal evolution. Individual systems evolve for some time in simulations and the outcome is monitored. Specifically, we deduce probabilities for the survival of a given number of species over distributions of network parameters at fixed network topology.

DY 10.3 Tue 10:00 ZEU 160

Stochastic switching in networks of delay-coupled oscillators — ●OTTI D'HUYS¹, THOMAS JUENGLING², and WOLFGANG KINZEL¹ — ¹Institute for Theoretical Physics, University of Wuerzburg, 97074 Wuerzburg, Germany — ²Instituto de Fisica Interdisciplinar y Sistemas Complejos, IFISC (UIB-CSIC), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain

Networks with coupling delays play an important role in various systems, such as coupled semiconductor lasers, traffic dynamics, communication networks, genetic transcription circuits or the brain. In oscillatory systems it is known that a delay induces multistability: the number of coexisting periodic orbits scales linearly with the coupling strength and the delay time.

Adding noise to the dynamics, the network switches between these coexistent orbits. For phase oscillator networks we construct a potential, which allows us to analytically compute the distribution of frequencies visited by the network and the corresponding residence times.

We find some surprising stochastic effects: with increasing delay the frequency distribution narrows, but the residence times are unaffected. With increasing coupling strength, the residence times in each orbit increase, but the number of attended orbits remains the same. Moreover, the network topology plays a crucial role: while in unidirectional rings in-phase and out-of-phase states are equally often attended, the out-of-phase states disappear for sufficiently long delays in most other networks.

DY 10.4 Tue 10:15 ZEU 160

Kolmogorov spectrum of renewable wind and solar power fluctuations — ●MEHRNAZ ANVARI¹, JOACHIM PEINKE², and MOHAMMAD REZA RAHIMI TABAR³ — ¹ForWind and Institute of Physics, Carl von Ossietzky University, 26111 Oldenburg, Germany — ²ForWind and Institute of Physics, Carl von Ossietzky University, 26111 Oldenburg, Germany — ³ForWind and Institute of Physics, Carl von Ossietzky University, 26111 Oldenburg, Germany

With increasing the contribution of renewable energies in power production, the task of reducing dynamic instability in power grids must also be addressed from the generation side, because the power delivered from such sources is spatiotemporally stochastic in nature.

Here we characterize the stochastic properties of the wind and solar energy sources by study their spectrum and multi-fractal exponents. The computed power spectrum from high frequency time series of solar irradiance and wind power reveals a power-law behavior with an exponent $\sim 5/3$ (Kolmogorov exponent) in the frequency domain $0.001 \text{ Hz} < f < 0.1 \text{ Hz}$, which means that the power grid is being fed by turbulent-type sources.

DY 10.5 Tue 10:30 ZEU 160

Ultra-long-tail simulation and modelling of rogue wave statistics — MARC EBERHARD¹, ●RUDOLF A. RÖMER², and AKIHIRO MARUTA³ — ¹Aston University, Birmingham, B4 7ET — ²University of Warwick, Coventry CV4 7AL, UK — ³Osaka University, 1-1 Yamadaoka, Suita, Osaka 565-0871, Japan

Optical "rogue waves" generated in fiber systems are sharp, rare and extremely high power pulses that share the main features of the devastating freak waves appearing in the ocean. In fact, rogue waves are known to occur also in plasmas, Bose-Einstein condensates and superfluid helium. Rogue waves are argued to form due to at least two mechanisms of amplification. First, a modulation instability broadens the power spectrum of the waves - and hence "amplifies" waves in frequency ranges where there were none to start with. The second amplification is then due to multiple inelastic soliton collisions. In order to describe rogue waves quantitatively, it has been shown that their probability density function depicts a typical 'L-shaped' profile, characterizing the occurrence of many small events as well as, in the horizontal part of the 'L', some very rare and extremely powerful events. What drives the formation of this 'L-shaped' PDF is not yet clear. Recently, it was argued that a third-order dispersion term might be responsible. A remarkable feature of the third-order dispersion is that the energy of the stronger soliton in most of the cases increases after the collision. Hence after multiple such collisions, the strongest soliton will have accumulated most of the energy in the system, it has become a rogue wave!

DY 10.6 Tue 10:45 ZEU 160

Critical manifold and tricritical point of nonlinear globally coupled systems with additive noise — ●RÜDIGER KÜRSTEN^{1,2} and ULRICH BEHN¹ — ¹Institut für Theoretische Physik, Universität Leipzig, Germany — ²International Max Planck Research School Mathematics in the Sciences, Leipzig, Germany

An infinite array of globally coupled overdamped constituents moving in a double-well potential under the influence of additive Gaussian white noise is closely related to a discretized version of the mean field φ^4 -Ginzburg-Landau model. The system exhibits a continuous phase transition from a symmetric phase to a symmetry broken phase [1]. The qualitative behavior is the same for higher order saturation terms φ^n , where $n \geq 6$ is even. The critical point is calculated for strong and for weak noise, these limits are also bounds for the critical point. Introducing an additional nonlinearity, such that the potential can have up to three minima, leads to richer behavior. Then the parameter space divides in three regions, a region with a symmetric phase, a region with a phase of broken symmetry and a region where both phases coexist. The region of coexistence collapses into one of the others via a discontinuous phase transition whereas the transition between the symmetric phase and the phase of broken symmetry is continuous. The tricritical point where the three regions intersect, can be calculated for strong and for weak noise. These limiting values are the optimal bounds for the tricritical point.

[1] R. Kürsten, S. Güttler, U. Behn, Phys. Rev. E **88**, 022114 (2013)

15 min break

DY 10.7 Tue 11:15 ZEU 160

Dynamical complexity in noisy coupled cubic maps — •THOMAS ZUB and STEFAN J. LINZ — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany

As far as its first bifurcation is concerned, the cubic map represents a discrete analogon to the overdamped motion of a particle in a double-well potential. The cubic map, however, possesses far richer dynamics as a function of the control parameter. In this contribution, we first study the dynamics of the cubic map with additive noise in analytical and numerical detail and compare it with the corresponding nonlinear Langevin equation. Considering two globally coupled cubic maps with additive noise, we analyze their potentially correlated dynamics as a function of the noise strength.

DY 10.8 Tue 11:30 ZEU 160

1/f noise from nonlinear stochastic differential equations driven by Lévy noise. — •RYTIS KAZAKEVIČIUS and JULIUS RUSECKAS — Institute of Theoretical Physics and Astronomy, Vilnius University, A. Gostauto 12, LT-01108 Vilnius, Lithuania

The Lévy process constitute the most general class of stable processes while the Gaussian process is their special case. The physical reason behind the Lévy non-Gaussian processes traces back to the nonhomogeneous structure of the environment, in particular, fractal or multifractal [1]. A class of nonlinear stochastic differential equations providing the power-law behavior of spectra, including $1/f$ noise, and the power-law distributions of the probability density has been proposed [2]. Usually such equations are driven by white Gaussian noise. We have generalized the nonlinear stochastic differential equations to be driven by Lévy noise instead of Gaussian noise. To preserve statistical properties of the generated signal we have changed the drift term in the equations. We have analyzed two cases when the signal is positive and when the signal can also be negative. In contrast to the equation with the Gaussian noise, the constant in the drift term is different in those two cases.

[1] T. Srokowski, Phys. Rev E **78**, 031135 (2008).

[2] B. Kaulakys, J. Ruseckas, V. Gontis and M. Alaburda, Physica A **365**, 217 (2006).

DY 10.9 Tue 11:45 ZEU 160

Spectra of delay-coupled heterogeneous noisy nonlinear oscillators — •ANDREA VÜLLINGS¹, ECHEHARD SCHÖLL¹, and BENJAMIN LINDNER^{2,3} — ¹Institut für Theoretische Physik, TU Berlin — ²Physics Department, Humboldt University Berlin — ³Bernstein Center for Computational Neuroscience Berlin

We study the spectral statistics (power and cross-spectral densities) of a small number of noisy nonlinear oscillators and derive analytical approximations for these spectra. The individual oscillators are described by the normal form of a supercritical or subcritical Hopf bifurcation supplemented by Gaussian white noise. Oscillators can be dis-

tinguished from each other by their frequency, bifurcation parameter, and noise intensity. Extending previous results from the literature, we first calculate in linear response theory the power spectral density and response function of the single oscillator in both super- and subcritical parameter. For small heterogeneous groups of oscillators ($N = 2$ or 3), which are coupled by a delayed linear term, we use a linear response ansatz to derive approximations for the power and cross-spectral densities of the oscillators within this small network. Using the theory we relate the peaks in the spectra of the homogeneous system (identical oscillators) to periodic solutions of the deterministic (noiseless) system. For two delay-coupled subcritical Hopf oscillators, we show that the coupling can enhance the coherence resonance effect, which is known to occur for the single subcritical oscillator. In the case of heterogeneous oscillators, we find that the delay-induced characteristic profile of the spectra is conserved for moderate frequency detuning.

DY 10.10 Tue 12:00 ZEU 160

Modulation of noise effects in nonlinear systems by time-delayed feedback — •PAUL GEFFERT¹, WOLFRAM JUST², ECHEHARD SCHÖLL¹, ANDREA VÜLLINGS¹, and ANNA ZAKHAROVA¹ — ¹Institut für Theoretische Physik, Technische Universität Berlin, Germany — ²Queen Mary, University of London, School of Mathematical Sciences, UK

We study noise-induced phenomena in nonlinear systems under the influence of stochastic forces and time delay, and show that they can be controlled by time-delayed feedback. In particular, we discuss coherence resonance and stochastic bifurcations in single and coupled systems described by a subcritical Hopf normal form. For the case of time delayed feedback, we derive the stationary probability distribution by means of a multiple scale perturbation expansion. By applying statistical linearization techniques, we obtain analytic expressions for the autocorrelation function of the delayed system.

DY 10.11 Tue 12:15 ZEU 160

Stochastic modelling of wind turbines' atmospheric interactions assuming a diffusion process — •BENJAMIN WAHL^{1,2}, MATTHIAS WÄCHTER², ULRIKE FEUDEL¹, and JOACHIM PEINKE² — ¹Institute for Chemistry and Biology of the Marine Environment, University of Oldenburg, Germany — ²ForWind and Institute of Physics, University of Oldenburg, Germany

The Langevin analysis has been successfully applied on single wind turbines to model the conversion from wind speed to power output with respect to the underlying turbulent dynamics. This motivates us to investigate the dynamical relationship of these quantities when they mix up from two different turbines. Therefore, we have to consider additional degrees of freedom naturally arising by the fact that the quantities of interest are measured spatially different. On the one hand the wind direction is changing over time and on the other hand the time delay of wind which is traveling from turbine to turbine is distorted due to turbulence. The split of the dynamics into a deterministic and a stochastic part should reveal a relaxation process, which we assume to exist, for instance, between two power outputs.