DY 81: Nonlinear Dynamics, Synchronization, Chaos II

Time: Friday 10:00–12:30 Location: BH-N 243

DY 81.1 Fri 10:00 BH-N 243

Phase coherence and intermittency of a turbulent field based on a system of coupled oscillators — •José-Agustín Arguedas-Leiva and Michael Wilczek — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Deutschland

Intermittency, i.e. a non-self-similar scale dependence of fluctuations, is a hallmark of fully developed turbulence. In turbulent flows, velocity fluctuations display Gaussian large-scale statistics with a transition to non-Gaussian statistics on smaller scales. For a Gaussian random field, the Fourier modes are statistically independent. Conversely, it can been shown that Fourier modes with random phases produce approximately Gaussian real-space statistics under quite general conditions. Non-Gaussianity and phase coherence are therefore intimately related. This motivates our study of intermittency in a turbulent flow as a scale-dependent coherence phenomenon of the Fourier phases. To better understand the relation between real-space intermittency and spectral-space coherence, a simple coupled oscillator model is proposed, which is reminiscent of the spectral-space formulation of the Navier-Stokes equations, in which sets of three phases are coupled in so-called triads. By studying this model we show that the three-oscillator probability density functions (PDFs) can be completely identified in terms of triad PDFs. Furthermore, a convenient parametrization allows for quantitative description of each triad's PDF using only one parameter. Using this parameter, we can isolate each triad's contribution to the real-space statistics, thereby establishing a relation between phase coherence phenomena and real-space intermittency.

DY 81.2 Fri 10:15 BH-N 243

Memristive Devices in a Chua Circuit: Comprizing Memory and deterministic Chaos — •Tom Birkoben[1], Mirko Hansen[1], Martin Ziegler[1], Karlheinz Ochs[2], Enver Solan[2], and Hermann Kohlstedt[1] — [1]Chair of Nanoelectronics, Faculty for Electrical Engineering and Information Technology, Kiel University, Germany — [2]Chair of Digital Communication Systems, Department of Electrical Engineering and Information Science, Ruhr University Bochum, Germany

Chua's circuit consists at least of one non-linear electronic device, a locally active resistor and three energy-storage elements. The circuit attracts considerable interest because it allows the study of a variety of chaos related phenomena, such as double scroll attractors and bifurcation diagrams. Here we present experimental results of a Chua circuit compromising real memristive double barrier $Nb/Al/Al_2O_3/Nb_xO_y/Au$ junctions. The devices are forming free and the I-V curves are characterized by an analog switching mechanism with a typical R_{off}/R_{on} ratio of about 100 at 0.7 V. Besides inserting a single memristive device in parallel to Chua's diode, the diode was replaced by two anti-parallel connected memristive devices. In this way, multiple scroll attractors were obtained. The dynamics of the system were characterized by chaotic oscillations interrupted by minute long time intervals in which the oscillations were suppressed. The results will be discussed in the framework of time series measurements and compared to simulations in LTSpice.

DY 81.3 Fri 10:30 BH-N 243

Control of multistability of driven nonlinear oscillators by two-frequency forcing — •Ferenc Hegedus[1], Werner Lauterborn[2], Ulrich Parlitz[3], and Robert Mettin[2] — [1]Department of Hydrodynamic Systems, Budapest University of Technology and Economics, Budapest, Hungary — [2]Drittes Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany — [3]Research Group Biomedical Physics, Max Planck Institute for Dynamics and Self-Organization and Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Göttingen, Germany

One of the main challenges of applied nonlinear science is the non-feedback control of multistability, that is, how to force a system to settle down onto a pre-selected attractor. In the present study, a novel approach for solving this control task is presented for sinusoidally driven nonlinear oscillators, which is suitable to target attractors directly (only with limited constraints). The method is based on the observation, that, for example, a period-2 attractor can be continuously transformed into a period-3 orbit (and vice versa) by applying a second, sinusoidal component to the driving (with suitable tuning of the excitation amplitudes). The pair of commensurate frequencies used for dual-frequency driving has to be properly chosen according to the periods of the transformed orbits.

DY 81.4 Fri 10:45 BH-N 243

Dynamics in ensembles of excitable units with global repulsive coupling — •Michael Zaks — Humboldt Universität zu Berlin, Institut für Physik

We consider ensembles build from excitable elements. In contrast to oscillators, isolated excitable units feature no oscillatory dynamics but stay at rest. Excitability means that for finite-size disturbances relaxation to the equilibrium is preceded by a large-scale excursion in the phase space. Description of this property, shared e.g. by many cortical cells, can be reduced to dynamics on the circle: the so-called "active rotator". Attractive coupling draws together an ensemble of excitable elements: stability of the equilibrium is enhanced. In contrast, repulsive coupling (an example is delivered by inhibitory neurons), weakens stability. Under sufficiently strong repulsion the equilibrium gets destabilized, and the large-scale oscillations commence: the formerly quiescent system acquires dynamics that completely owes to the interactions. For an ensemble of identical active rotators with global repulsive coupling the onset of oscillations occurs via the global event: the transcritical heteroclinic bifurcation. The number of unstable states of equilibrium, involved in the bifurcation, exponentially grows with the size of the ensemble. This transition gives rise to a large amount of stable periodic motions; moreover, if the coupling to the global field is restricted to the first Fourier harmonics of the rotator phase, the Strogatz-Watanabe phenomenon takes place, and the attracting periodic states fill high-dimensional continua. We discuss collective oscillations both for small ensemble of excitable units and in the thermodynamical limit.

15 min. break

DY 81.5 Fri 11:15 BH-N 243

Mechanism of underdrive pacing for low-energy defibrillation — •Pavel Buran, Markus Bär, and Thomas Niedermayer — Physikalisch-Technische Bundesanstalt (PTB), Berlin

Rotating excitation waves and electrical turbulence in cardiac tissue are associated with arrhythmias such as life-threatening ventricular fibrillation. Experimental studies have shown that a sequence of low-energy electrical far-field pulses is able to terminate fibrillation more gently than a single high-energy pulse. During this low-energy antifibrillation pacing (LEAP), only tissue near sufficiently large conduction heterogeneities, such as large coronary arteries, is activated. Theoretical approaches to understand LEAP have often focussed on unpinning and removal of a small number of stable spirals and suggest LEAP protocols using overdrive or underdrive pacing or combinations of it. In this talk, we demonstrate that for typical cellular models, which exhibit stable pinned spirals, the process of unpinning and drift of spirals does not appear during successful LEAP. We present an alternative mechanism of underdrive pacing, which explains both the termination of stable spirals and spatiotemporal chaos.

DY 81.6 Fri 11:30 BH-N 243

Normal and anomalous diffusion in soft Lorentz gases — •Rainer Klages[1], Sol Selene Gil Gallegos[1], Janne Solanpää[2], Mikka Sarvilahti[2], and Esa Räsänen[2] — [1]Queen Mary University of London, School of Mathematical Sciences — [2]Laboratory of Physics, Tampere University of Technology

Motivated by electronic transport in artificial graphene, we study the diffusion of point particles in a soft periodic Lorentz gas modeled by repulsive Fermi potentials on a triangular lattice. We find that the diffusion coefficient is a highly irregular function of the minimal distance between adjacent scatterers as a control parameter. Parameter regions of normal diffusion alternate with regions exhibiting superdiffusion. The latter are due to islands of periodic orbits in phase space whose origin and structure we explore in detail. The coarse functional form of the parameter-dependent diffusion coefficient is well reproduced by simple random walk models [1].

[1] R.Klages, S.S.G.Gallegos, J.Solanpää, M.Sarvilahti, E.Räsänen, submitted

DY 81.7 Fri 11:45 BH-N 243

Dependency of musical instrument forced oscillations on viscoelastic internal damping — •Rolf Bader — Institute of Systematic Musicology, University of Hamburg, Germany

A viscoelastic model for the internal damping of musical instruments is implemented within a Finite-Difference Time Domain (FDTD) method. Internal damping of wood, leather, neylon, mylar, glue or varnish strongly change the timbre of musical instruments and the precise spectrum of this damping contributes strongly to the individual instrument character. The model assumes a complex, frequency-dependent and linear stiffness in the frequency domain, which is analytically transferred into the time-domain using a Laplace transform. The resulting mass-weighted restoring force integral of the respective membrane or plate differential equation is solved using a circular buffer accumulation method for each spatial node on the geometry, which is effective, as the model is implemented on a massive parallel Graphics Processing Unit (GPU). The model is able to reproduce arbitrarily shaped internal damping frequency responses with sharp bandwidth and fast response. Due to the time-delay feedback loop of viscoelastic damping additional sidebands appear around damped partials which are caused by amplitude oscillations. The piano soundboard driven by a string is forced to vibrate with the strings frequencies as it is higher in dimensionality as well as damped stronger. The forced oscillation patterns are strongly depending on the amount of internal damping.

DY 81.8 Fri 12:00 BH-N 243

The Nature of Microtiming Deviations in Musical Performances — Mathias Sogorski[1,2], •Theo Geisel[1,2], and Viola Priesemann[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen — [2]Bernstein Center for Computational Neuroscience, Göttingen

Musical rhythms performed by humans typically show temporal fluctuations. While they have been characterized in simple rhythmic tasks in laboratory settings, it is an open question what is the nature of temporal fluctuations, when several musicians perform music jointly in all its natural complexity. To study such fluctuations in over 100 original jazz and rock/pop recordings played with and without metronome we developed a semi-automated workflow allowing the extraction of cymbal beat onsets with millisecond precision.

Analyzing the inter-beat interval (IBI) time series revealed evidence for two long-range correlated processes characterized by power laws in the IBI power spectral densities. One process dominates on short timescales ($t<8$ beats) and reflects microtiming variability in the generation of single beats. The other dominates on longer timescales and reflects slow tempo variations. Whereas the latter did not show differences between musical genres (jazz vs. rock/pop), the process on short timescales showed higher variability for jazz recordings, indicating that jazz makes stronger use of microtiming fluctuations within a measure than rock/pop. Our results elucidate principles of rhythmic performance and can inspire algorithms for artificial music generation.

DY 81.9 Fri 12:15 BH-N 243

Measuring the information dimension in chaotic scattering — •Domenico Lippolis — Institute for Applied Systems Analysis, Jiangsu University, Zhenjiang, China

Measuring the fractal dimension of a non-attracting chaotic set embedded in the phase space of an open system is, in general, a challenging task to fulfill. While the existing box-counting techniques are designed for numerical estimations, they are largely impractical for an actual experiment. In the present contribution, the information dimension of a two-dimensional chaotic saddle is alternatively estimated by means of a numerical simulation of a scattering experiment, measuring the response of a cross section to perturbations (uncertainty function), which is, in principle, realizable in the laboratory. In addition, a theoretical argument relating the estimated uncertainty dimension to the conventional information dimension is provided. Generalization to partially absorbing systems such as optical or microwave cavities is also discussed.