DY 4: Statistical physics in biological systems II (joint session DY/BP)

Time: Monday 14:00–16:45 Location: HÜL 386

Invited Talk DY 4.1 Mon 14:00 HÜL 386

Mechanisms of tissue maintenance: a laboratory for statistical physics — •Benjamin Simons — Cavendish Laboratory, JJ Thomson Avenue, Cambridge, UK

In adult organisms, many tissues are maintained and repaired by stem cells, which divide and differentiate to generate more specialized progeny. The mechanisms that control the balance between self-renewal and differentiation promise fundamental insights into the origin and design of multi-cellular organisms. However, stem cells are often difficult to distinguish from their more differentiated progeny, and resolving these mechanisms has proved challenging. Drawing upon the results of inducible genetic labeling studies and concepts from statistical physics, we demonstrate how scaling behaviour of *clone* size distributions and spontaneous patterning phenomena reveal signatures of stochastic stem and progenitor cell fate. As well as providing insight into the molecular regulatory mechanisms controlling the maintenance, repair and regeneration of adult tissues, these results identify common organizational principles of tissue architecture.

DY 4.2 Mon 14:30 HÜL 386

A novel transition path sampling approach to assess multiple-state transition networks — •Jutta Rogal and Peter Bolhuis — Van 't Hoff Institute for Molecular Sciences, University of Amsterdam, Nieuwe Achtergracht 166, 1018 WV Amsterdam, The Netherlands

The dynamical properties of complex systems are often characterized by the existence of several (meta)stable states separated by large free energy barriers. Examples for such complex systems are omnipresent throughout nature varying from conformational changes in biological relevant molecules to phase transitions as well as many chemical reactions. The long time dynamical behavior of these systems is usually determined by transitions between the stable states. However, the sampling of such transition networks is often severely hampered by the high free energy barriers between the states making it unfeasible to use regular molecular dynamics simulations.

Transition path sampling (TPS) has been successfully applied to study such rare events, but is limited to processes between two distinct stable states. Here, we extend TPS to include multiple stable states. Combining this approach with transition interface sampling and replica exchange ideas, we not only improve sampling efficiency, but also access kinetics, mechanisms and free energies of all possible transitions within the system in one single simulation.

DY 4.3 Mon 14:45 HÜL 386

A stochastic model for tumor growth with immunization — •Thomas Bose and Steffen Trimper — Institut für Physik, Martin-Luther-Universität Halle, Germany

Much effort has been spent on revealing the mechanisms of tumor evolution. Based on these findings, we analyze tumor growth and the interaction of cancer cells with the immune system.

A deterministic component as well as a random nature is attributed to the tumor-immune interaction. More specifically, we study a stochastic model for tumor cell growth with both, a multiplicative and an additive noise term as well as cross-correlations in between. The noise includes a finite correlation time. Whereas the death rate within the logistic model is altered by a deterministic term characterizing immunization, the birth rate is assumed to be stochastically changed due to internal growth processes leading to a multiplicative internal noise. Additionally the system is subjected to an external additive noise which mimics the influence of the environment of the tumor including the stochastic elements of the immune response. The stationary probability distribution is derived to analyze the influence of finite correlation time, the immunization rate and the strength of the cross-correlation on the different steady states. Furthermore, the mean-first passage time is calculated in order to find out under which conditions the tumor can suffer extinction under the effect of correlated noise and the degree of immunization. We relate our results to a three-phase model describing tumor evolution in living organisms with an intact immune system.

DY 4.4 Mon 15:00 HÜL 386

Complex dynamics of a population submitted to changing environment — •Michel Droz[1], Ioana Bena[1], Janusz Szwabinski[1,2], and Andrzej Pękalski[2] — [1]Département de Physique Théorique, Université de Genève, quai E. Ansermet 24, 1211 Genève 4, Switzerland — [2]Institute of Theoretical Physics, University of Wrocław, pl. M. Borna 9, 50-204 Wrocław, Poland

The dynamics of a model for single-species population submitted to changing environment is studied both analytically and numerically. Different types of environment modifications are considered: periodic and abrupt (catastrophic). The delicate interplay between the different time-scale processes results in a complex dynamic for the system. The conditions for the existence of a phase transition "extinct-alive" as a function of the selection pressure and the mutation rate are discussed. Moreover, the effect of the delay in response to the changing environment on the population's survival is also investigated.

15 min. break.

DY 4.5 Mon 15:30 HÜL 386

Active Dynamics of a Particle with Energetic Shot Noise — •Jessica Strefler[1], Werner Ebeling[1], Ewa Gudowska-Nowak[2], and Lutz Schimansky-Geier[1] — [1]Institut für Physik, Humboldt-Universität Berlin — [2]Institute of Physics, Jagiellonian University, Krakow, Poland

We study the dynamics of a simple model of moving animals. We focus on the influence of stochastic energy supply modeled as shot noise on one particle in two spacial dimensions. We assume that a particle is supplied at discrete times with packets of energy which are stored in an internal energy depot. The energy of this depot is subsequently converted into kinetic energy. If enough energy is supplied the particle moves actively with a nonzero mean velocity. For this model we find two regimes which exhibit different velocity distributions and qualitatively different trajectories. We study deterministic and stochastic bifurcations of different dynamical regimes. In the adiabatic Gaussian limit we derive an analytical solution for the velocity distribution.

DY 4.6 Mon 15:45 HÜL 386

Effects of intrinsic noise on models of epidemics — •Andrew Black and Alan McKane — School of Physics and Astronomy, The University of Manchester, UK

Demographic stochasticity, i.e. intrinsic noise introduced by the random interaction of agents in indivdual-based systems, can affect their macroscopic dynamics considerably. Models which in their deterministic mean-field limit approach a fixed point, can exhibit persistent macroscopic oscillations sustained by fluctuations on the microscopic level. In the work presented here we study the effects of demographic stochasticity and external forcing on individual-based models of epidemics. We show that the fluctuations present in the unforced versions of these stochastic models can be understood in terms of noise resonating with the systems natural frequency. Analytical progress can be made by formulating the system in terms of a master equation, from which the exact power spectrum of the fluctuations is derived using a van-Kampen expansion in the inverse system size. We show that even at large amplitude of the external forcing the magnitude and frequency of the stochastic oscillations can still be determined from the unforced model.

DY 4.7 Mon 16:00 HÜL 386

Collective motion due to individual escape and pursuit response — •Pawel Romanczuk[1], Iain D. Couzin[2], and Lutz Schimansky-Geier[1] — [1]Institut für Physik, Humboldt Universität Berlin, Germany — [2]Department of Ecology and Evolutionary Biology, Princeton University, USA

Recent studies suggest that non-cooperative behavior such as cannibalism may be a driving mechanism of collective motion. Motivated by these novel results we introduce a simple model of Brownian particles interacting by biologically motivated pursuit and escape interactions. We show the onset of collective motion for both interaction types and analyze their impact on the global dynamics. We demonstrate a strong dependence of experimentally accessible macroscopic observables on the relative strength of escape and pursuit, determine the scaling of the migration speed with model parameters and present a mean field description.

DY 4.8 Mon 16:15 HÜL 386

Continuum limit of phase oscillators with delayed coupling
— •Luis G. Morelli[1,2], Saúl Ares[1], Andrew C. Oates[3], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina — [3]Max Planck Institute of Molecular Cell Biology and Genetics

Complex oscillatory systems can sometimes be described as coupled phase oscillators. Time delays can be present in the coupling when the signal propagation velocity is finite or the signals are produced and processed through many step processes. It has been shown that delayed coupling can have important and non-trivial effects on collective dynamics, affecting the collective frequency and leading to complex regimes in which multiple stable frequencies can coexist. In this contribution we consider an extended system of coupled phase oscillators with time delays in the coupling. We develop a continuum description of the system for arbitrary values of the delay and obtain an effective phase diffusion equation. Delayed coupling introduces a frequency and coupling strength renormalization in the phase diffusion equation describing the continuum oscillatory media. The solutions to the phase diffusion equation show that the effects of delayed coupling can be important both for the temporal organization of the system as for the emergent spatial patterns of oscillation. We expect that our results will be useful in a wide range of problems in which time delays are significant for the collective dynamics.

DY 4.9 Mon 16:30 HÜL 386

Pinwheel Crystallization in a Competitive Hebbian Model of Visual Cortical Development
— •Wolfgang Keil[1,2,3,4] and Fred Wolf[1,2,3,4] — [1]MPI for Dynamics and Self-Organization, Göttingen — [2]BCCN, Göttingen — [3]Georg-August-Universität, Fakultät für Physik, Göttingen — [4]IMPRS, Göttingen

The spatially complex modular architecture of the mammalian primary visual cortex is believed to reflect the requirement to smoothly map a high dimensional space of visual stimulus features to an effectively two dimensional array of neurons. Competitive Hebbian models of cortical development have been widely used to numerically study the properties of such mappings, but no analytical results about their ground states have been obtained so far. A classical example of such dimension reducing mappings is the Elastic Network Model (EN), proposed by Durbin and Mitchison (Nature (343), pp. 644-647, 1990). Here we use a perturbative approach to compute the ground states of the dynamics of orientation preference maps within this model. We find different phases as a function of the lateral intracortical interactions and external stimulus distribution properties. However, in all parameter regimes, the grounds states of the Elastic Network Model are either stripe-like, or crystalline representation of visual features. We present a complete phase diagram of the model, summarizing pattern selection. Analytical predictions are confirmed by direct numerical simulations. Our results question previous studies concluding that the EN correctly reproduces the spatially aperiodic arrangement of visual cortical processing modules.