BP 44: Stochastic Dynamics of Growth Processes in Biological and Social Systems (accompanying session, joint DY/BP/SOE)

Time: Friday 10:00–12:45 Location: GÖR 226

BP 44.1 Fri 10:00 GÖR 226

Evolution of increasingly complex linear molecules — •Philipp Zimmer[1], Emanuel Gregor Worst[2], Eva Wollrab[2], Albrecht Ott[2], and Karsten Kruse[1] — [1]Universität des Saarlandes, Theoretische Biologische Physik, Postfach 151150, 66041 Saarbrücken — [2]Universität des Saarlandes, Biologische Experimentalphysik, Postfach 151150, 66041 Saarbrücken

Darwinian evolution is based on variation and selection acting on mutations, reproduction, or the metabolism of a species. These processes can only take place when the underlying system is out of thermodynamical equilibrium. For natural evolution the species as well as their relation network has continuously been gaining complexity. The conditions necessary for a steady increase in complexity are not well understood. Performing stochastic simulations as well as experiments with DNA, we analyze a chemical system consisting of autocatalytically concatenating chains. We find that, despite its inherent stochastical nature, the system evolves along a reproducible path towards states of increasing complexity if the autocatalytic activity exceeds a critical value.

BP 44.2 Fri 10:15 GÖR 226

Autocatalysis in a primordial broth — •Sabrina Scherer, Eva Wollrab, and Albrecht Ott — Biologische Experimentalphysik, Universität des Saarlandes

In many energetically driven systems non-linearities lead to pattern formation. Here we study the dynamics of a driven primordial broth, synthesized from a gas mixture of methane, ammonia and steam that is triggered by eletric discharge and heat. Using real-time mass spectrometry, we observe the generation of many hundreds of different molecules in a mass range from 50 to 1000 Dalton. The temporal course of the primordial broth reveals the spontaneous emergence and disappearance of several oligomeric groups that consist primarily of polyethylene glycol (PEG) surfactants. These oligomers appear in aperiodic oscillations. This requires stronger non-linearities than a simple autocatalytic reaction. PEG and -surfactants are well known phase-transfer catalysts, able to favour biochemical reactions by inhibiting hydrolysis. We suggest that autocatalytic phase-transfer leads to self-organizing processes in a primordial broth and enables the production of relevant biomolecules.

BP 44.3 Fri 10:30 GÖR 226

Cooperation in suddenly changing environments — •Karl Wienand[1], Jonas Cremer[2], Anna Melbinger[2], and Erwin Frey[1] — [1]Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, 80333 München, Germany — [2]UC San Diego, 9500 Gilman Dr., La Jolla, CA 92093, U.S.A.

The interdependence of evolutionary and growth dynamics shapes the evolutionary fate of populations. This is especially the case in microbial populations, where volatile population sizes and capricious environments are the rule rather than the exception. A suddenly changing carrying capacity, which periodically oscillates between abundance and scarcity of resources, represents such changing environment and causes the population size to grow and shrink. The variation in size, in turn, affects the evolutionary dynamics. Studying this complex interplay, we find most oscillating environments enhance demographic fluctuations and cooperative behavior.

BP 44.4 Fri 10:45 GÖR 226

Selection and drift in expanding bacterial colonies — •Fred Farrell[1], Bartlomiej Waclaw[1], Davide Marenduzzo[1], and Oskar Hallatschek[2] — [1]School of Physics, University of Edinburgh, Edinburgh, UK — [2]Department of Physics, University of California, Berkeley, California, USA

In an expanding population, such as a bacterial colony growing on a surface in the laboratory or in nature, evolution proceeds very differently to in a well-mixed population with a static population size. This is mostly due to the so-called founder effect, where individuals close to the expanding front of the population have a much better chance of passing their genes on to future generations than those deep within the population. Since there are relatively few of these founders, rates of genetic drift are much higher, and the probability that a beneficial mutation will fixate in the population much lower. This is important as it will impact the speed with which such a population adapts to its environment, for example developing antibiotic resistance.

I will present my work using a fairly detailed agent-based biophysical simulation model of an expanding microbial colony to estimate probabilities of fixation of beneficial mutations, and how these depend on the fitness advantage and the properties of the cells, and compare these results to analytical theories of selection in expanding populations.

BP 44.5 Fri 11:00 GÖR 226

Bacterial population genetics in antibiotic concentration gradients: Accelerated evolution of antibiotic resistance — •Philip Greulich[1,2], Bartlomiej Waclaw[2], and Rosalind Allen[2] — [1]Cavendish Laboratory, University of Cambridge, Cambridge, UK — [2]School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK

The increased emergence of antibiotic resistance poses a major threat to human health nowadays. Evolution of antibiotic resistance occurs by a sequence of mutations (mutational pathway) when bacteria are exposed to the selection pressure of an applied antibiotic. Recent experiments indicate that the spatial distribution of an antibiotic plays an important role for the evolution of antibiotic-resistant bacterial strains. I will present a stochastic model for the population genetics of bacteria growing in different spatial distributions of an antibiotic. This model reveals an intriguing interplay between the mutational pathway and the spatial structure of the drug distribution. It shows that spatial gradients in antibiotic concentrations can strongly accelerate the emergence of resistance when the mutational pathway involves a long sequence of mutants. However, gradients may slow down evolution if the pathway is short or crosses a fitness valley.

BP 44.6 Fri 11:15 GÖR 226

Evolution of the size distribution of colloidal particles: focussing, breakdown of scaling, and asymptotic distributions — •Martin Rohloff[1,2] and Jürgen Vollmer[1,2] — [1]Max Planck Institute for Dynamics and Self-Organisation (MPIDS), 37077 Göttingen, Germany — [2]Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Mechanisms underlying the synthesis of mono-disperse colloids and nanocrystals are under vivid discussion. A common feature of the recipies is the growth of an assembly of particles subjected to a flux of material, provided e.g. by a chemical reaction like the decomposition of precurser.

We present analytical and numerical studies on diffusion dominated growth of particles with a constant overall volumetric growth rate. The resulting particle growth is qualitatively different from Ostwald ripening, and it leads to narrow and non-universal asymptotic size distributions.

BP 44.7 Fri 11:30 GÖR 226

Multi-Species Range Expansions: Frequency-Dependent Selection at Rough Fronts — •Jan-Timm Kuhr and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin

Growing microbial colonies have recently been used as model systems for macroscopic colonization events, known as range expansions, since growth in the Petri dish is comparably fast and controllable.

Employing the statistical Eden model, already single-strain colonies feature remarkable properties like self-affine fronts, which have also been found in experiments. Multi-species settings promise a plethora of possible phenomena, e.g. irreversible mutations resulting in a non-equilibrium phase transition to an absorbing state [1].

Whereas a simple selective advantage entails quasi-deterministic fixation of the faster growing strain, local frequency-dependent selection gives rise to non-trivial outcomes. We focus on representations of social dilemmas, where local group selection brings about extremely rough fronts, the effects of which are neglected in other approaches.

[1] J.-T. Kuhr, M. Leisner, and E. Frey, *Range expansion with mutation and selection: dynamical phase transition in a two-species Eden model*, New J. Phys. **13**, 113013 (2011).

BP 44.8 Fri 11:45 GÖR 226

Clonal interference and Muller's ratchet in spatial habitats
— Jakub Otwinowski[1] and •Joachim Krug[2] — [1]Biology Department, University of Pennsylvania, Philadelphia, USA — [2]Institute for Theoretical Physics, University of Cologne, Cologne, Germany

Competition between independently arising beneficial mutations is enhanced in spatial populations due to the linear rather than exponential growth of the clones. The resulting fitness dynamics is analogous to a surface growth process, where new layers nucleate and spread stochastically, leading to the build up of scale-invariant roughness. This scenario differs qualitatively from the standard view of adaptation in that the speed of adaptation becomes independent of population size while the fitness variance does not, in apparent violation of Fisher's fundamental theorem. Here we exploit recent progress in the understanding of surface growth processes to obtain precise results for the universal, non-Gaussian shape of the fitness distribution for one-dimensional habitats. We then consider a version of the model where all mutations are deleterious, that is, a spatial version of Muller's ratchet. Based on an analogy to models of nonequilibrium wetting, we show that the system displays a phase transition related to directed percolation. The transition is governed by the ratio U/s^2, where U denotes the deleterious mutation rate and s the selection coefficient of mutations. For $U/s^2 > 1$ the speed of the ratchet remains finite in the limit of infinite habitat size.

BP 44.9 Fri 12:00 GÖR 226

A Non-Equilibrium Phase Transition in a Biofilm Growth Model in a Fluctuating Environment
— •Florentine Mayer and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics (ASC) and Center for NanoScience (CeNs), Department of Physics, Ludwig-Maximilians-Universität München, Germany

Bacterial communities represent complex and dynamic ecological systems. They appear in the form of free-floating bacteria and biofilms in nearly all parts of our environment. They are highly relevant for human health and disease. Spatial patterns arise from heterogeneities of the underlying landscape or are self-organized by the bacterial interactions, and play an important role in maintaining species diversity. Bacteria must rapidly adapt to fluctuating environments in order to survive. In biofilms this is often achieved by phenotypic diversity, where bacteria can switch between different phenotypic states. Survival of the population can increase if each of these phenotypes is adapted to different environmental conditions.To analyze biofilm growth we set up a two-species automaton model in which growth, death and switching rates depend on the environmental conditions. These fluctuate, resulting in periodically interchanged reaction rates. Depending on the rates we find either fast extinction or thriving biofilms with intriguing spatio-temporal patterns. Close to the region of extinction patterns become self-affine, which is typical for a phase transition to an absorbing state. Employing extensive stochastic simulations we measure critical exponents of our non-equilibrium phase transition and find universal scaling behaviour characterising the universality class of our model.

BP 44.10 Fri 12:15 GÖR 226

Discrete scale invariance in growing networks
— Wei Chen[1,2,3], •Malte Schröder[4], Raissa M. D'Souza[3], Didier Sornette[5], and Jan Nagler[5,4] — [1]Chinese Academy of Sciences, Beijing — [2]Peking University, Beijing — [3]University of California, Davis — [4]MPI DS Göttingen — [5]ETH Zürich

Discrete scale invariance (DSI) arises in systems where the usual (continuous) scale invariance (for example at phase transitions) is partially broken, leading to a remarkable discrete hierarchy of resonances in the system order parameter. DSI has broad technical, physical and biological relevance, penetrating statistical physics (Potts model, Singularities), hydrodynamics, turbulence, astronomy, evolution, fracture and economics. (D. Sornette, Phys. Rep. 297, 239 (1998)).

A hierarchy of discrete micro-transitions leading up to the transition to global connectivity in models of continuous and discontinuous percolation is observed. These transitions can in some cases be observed in the relative variance of the size of the largest cluster even in the thermodynamic limit.

Depending on the model these cascades exhibit either genuine discrete scale-invariance or a generalized (novel) form. In contrast to average values, the size of the largest cluster before the phase transition is limited to integer values. This leads to a family of scaling relations that describe the behavior of the micro-transition cascade (Chen, Schröder, D'Souza, Sornette, Nagler (under review)). Our findings open up the possibility for the prediction of tipping in complex systems that are dominated by large-scale disorder.

BP 44.11 Fri 12:30 GÖR 226

Firm growth and inter-organizational flows in the Stockholm region, 1990-2003
— •Hernan Mondani[1], Petter Holme[2,3,1,4], and Fredrik Liljeros[1,4] — [1]Department of Sociology, Stockholm University, Sweden — [2]Department of Energy Science, Sungkyunkwan University, Korea — [3]IceLab, Department of Physics, Umeå University, Sweden — [4]Institute for Futures Studies, Stockholm, Sweden

Explaining the emergence of fat-tailed growth-rate distributions in terms of the action of individual agents remains an important open question in the study of socio-economic systems. Studies of organizational growth statistics are limited by the quantity and level of detail of the available information. Large databases have little or no information about the composition of each workplace, and the time-dependent variables are often reported at the level of the organization.

In this empiric study, we use Swedish register data, a quite unique individual-level longitudinal database that provides data on organizational membership of all workers in the Stockholm region, for a period of 14 years (1990-2003). With this dataset, we can analyze how individual attributes are aggregated at the organizational level, and track individual movements on a yearly basis.

We compute statistics for organizational size and growth, and look at their time evolution in the period of analysis. We further study the distribution of individual-level properties across organizations, especially the in- and out-flow of people moving between organizations.