BP 32: Evolutionary Game Theory II (joint SOE/BP/DY)

Time: Tuesday 14:00–16:15 Location: MA 001

BP 32.1 Tue 14:00 MA 001

Frequency-Dependent Selection at Rough Expanding Fronts — •Jan-Timm Kuhr and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin

Microbial colonies are a formidable model system to study longstanding questions of population dynamics, ecology, and evolutionary dynamics. Growth on surfaces naturally allows to observe range expansions, where microbes colonize new territory. The small number of reproducing individuals introduces strong demoscopic fluctuations, which interact with mutation and selection at the front.

We use generalized Eden models to explore statistical properties of multi-species range expansions, where the front's geometry and evolutionary dynamics couple to each other. In earlier work we found that irreversible mutations entail a new type of non-equilibrium phase transition accompanied by enhanced surface roughening [1].

If reproduction rates depend on local species composition, we distinguish a variety of patterns. Focusing on social dilemmas, we obtain new exponents for both kinetic roughening and the transition between global defection vs. global cooperation. This is also reflected in the dynamics of single species domains which at large times show enhanced fluctuation statistics.

[1] J.-T. Kuhr, M. Leisner, and E. Frey, New J. Phys. **13**, 113013 (2011).

BP 32.2 Tue 14:15 MA 001

Evolutionary Fitness in Variable Environments — •Anna Melbinger and Massimo Vergassola — University of California San Diego

One essential ingredient of evolutionary theory is the concept of fitness as a measure for a species' success in its living conditions. Here, we quantify the effect of environmental fluctuations onto fitness by analytical calculations on a general evolutionary model and by studying corresponding individual-based microscopic models. We demonstrate that not only larger growth rates and viabilities, but also reduced sensitivity to environmental variability substantially increases the fitness. Even for neutral evolution, variability in the growth rates plays the crucial role of strongly reducing the expected fixation times. Thereby, environmental fluctuations constitute a mechanism to account for the effective population sizes inferred from genetic data that often are much smaller than expected.

BP 32.3 Tue 14:30 MA 001

Non-selective evolution of growing populations — •Karl Wienand[1], Matthias Lechner[1], Felix Becker[2], Heinrich Jung[2], and Erwin Frey[1] — [1]Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians Universität, Munich, Germany — [2]Biozentrum, Ludwig-Maximilians Universität, Munich, Germany

Evolution results from the interplay between directed selection and non-selective effects. Most theoretical analyses of non-selective evolution rely on constant population sizes and result in some trait taking over the entire population. However, bacterial populations both in nature and in the laboratory are often observed during their exponential growth. In this work we show that, during growth, populations "freeze" to a random steady state composition. To show this, we employed theoretical models based on Pólya urns and performed experiments on two *Pseudomonas putida* strains in non-selective conditions. We found excellent agreement between experiments and theory. We were also able to elucidate the importance of initial conditions on the steady state distribution on population compositions. In particular, the initial size of the populations can tune the relative importance of initial assortment and growth as noise sources for the final distribution.

BP 32.4 Tue 14:45 MA 001

Counterintuitive findings for evolution on networks — •Laura Hindersin and Arne Traulsen — Max Planck Institute for Evolutionary Biology, Plön, Germany

How does spatial population structure affect the fixation time of a novel mutation?

In the framework of evolutionary graph theory, individuals inhabit the nodes of a network. We study the Moran birth-death process, where reproduction happens with probability proportional to fitness. The links of a node determine which other individuals can be replaced by the offspring of that individual.

Intuitively, one might assume that adding a link to a given network would always decrease fixation time. However, a simple counterexample disproves this intuition. We show analytically for small networks, that adding a link can increase the fixation time. Simulating the stochastic process on larger lattices, we find a similar result. By adding links to a 2D-lattice without boundary conditions, the fixation time can increase as well. This shows the validity of our counterintuitive result even for larger populations.

[1] Hindersin L, Traulsen A. 2014 Counterintuitive properties of the fixation time in network-structured populations. J. R. Soc. Interface 11: 20140606. http://dx.doi.org/10.1098/rsif.2014.0606

BP 32.5 Tue 15:00 MA 001

The Cost and Dynamics of Competence in *Bacillus subtilis* — •Jeffrey Power, Melih Yüksel, and Berenike Maier — Universität zu Köln, Cologne, Germany

When bacterial cells deplete all of the nutrients in their environment, they can enter a stationary growth phase. In *Bacillus subtilis*, the stationary phase is of particular interest as a fraction of a culture in the stationary phase will stochastically switch into a competent state, where cells can take up extracellular DNA. Competence presents the opportunity for the acquisition and implementation of new genes, but at the cost of a reduced growth rate.

To better understand the advantage of stochastic switching, stationary phase competition assays were carried out competing strains with various fractions of competent cells against the wild type. Flow cytometry was used to monitor changes in the mixed populations over time, and fitness advantages were quantified by means of selection coefficients. We found selection coefficients of s = 0.04(1) for the non-competent *comK* strain and s = -0.07(1) for the hypercompetent *rok* strain, indicating that competence development has a large cost.

This work is a fundamental start to better understanding the dynamics of the stationary phase and the evolutionary advantage of stochastically switching a population subset into a competent state.

BP 32.6 Tue 15:15 MA 001

A Two-Player Game with Linear State-Dependent Payoff Function — •Tim Herrmann[1], Mark Kirstein[2], and Katharina Fischer[3] — [1]TU Dresden — [2]TU Dresden, Chair of Managerial Economics — [3]TU Dresden, Institut für mathematische Stochastik

In classic game theory all elements of a game (set of players, set of strategies, payoff function) are static. In contrary, real-world strategic interactions are often characterized by changes of at least one of the three elements of a game over time. In our model a game with state-dependent payoff functions is analysed. The payoff function of the $(n + 1)$-st round depends linearly on the payoff of the n-th round. Thereby the structure of the game can change, e.g. from prisoner's dilemma structure to a structure, where individual rationality coincides with collective rationality. Therefore, the concepts of short-term and long-term rationality are defined. It is shown for our game with a state-dependent payoff function, that the following criteria of long-term rationality are equivalent (besides a few special cases): Pareto optimality, collective rationality and the Nash equilibrium in recursive dominant strategies. For symmetric payoff functions these three criteria of (individual and collective) long-term rationality are additionally equivalent to the collective short-term rationality. The concept of ESS is refined to absolute ESS (ESSA) and relative ESS (ESSR). It is shown that ESSA-tuples are equivalent to the above mentioned criteria for symmetric payoff functions and long-term rationality.

BP 32.7 Tue 15:30 MA 001

Evolutionary Coalitional Games — •Tadeusz Płatkowski — Faculty of Mathematics, Informatics, and Mechanics \\ University of Warsaw, Warsaw, Poland

We introduce the concept of evolutionary coalitional games played in a large population. The members of the population play a strategy chosen from a finite set, and interact in randomly formed coalitions. The interactions are described by a multiplayer strategic game. Each coalition generates a total utility, identified with the value of the coalition, and equal to the sum of the payoffs of its all members from the multiplayer game. The total utility is distributed among the coalition members, proportionally to their Shapley values. Evolution of the whole population is governed by the replicator equations. Polymorphic stationary states of the population are studied for various types of the multiplayer social dilemma games. It is argued that application of coalitional game theory solution concepts to social dilemma models of evolutionary game theory can foster cooperation in the long run.

BP 32.8 Tue 15:45 MA 001

Evolutionary games of condensates in coupled birth-death processes — •Johannes Knebel, Markus F. Weber, Torben Krüger, and Erwin Frey — Ludwig-Maximilians-Universität, München, Deutschland

Condensation phenomena occur in many systems, both in classical and quantum mechanical contexts. Typically, the entities that constitute a system collectively concentrate in one or multiple states during condensation. For example, particular strategies are selected in zero-sum games, which are generalizations of the children's game Rock-Paper-Scissors. These winning strategies can be identified with condensates.

In our work, we apply the theory of evolutionary zero-sum games to explain condensation in bosonic systems when quantum coherence is negligible. Only recently has it been shown that a driven-dissipative gas of bosons may condense not only into a single, but also into multiple non-degenerate states. This phenomenon may occur when a system of non-interacting bosons is weakly coupled to a reservoir and is driven by an external time-periodic force (Floquet system). On a mathematical level, this condensation is described by the same coupled birth-death processes that govern the dynamics of evolutionary zero-sum games. We illuminate the physical principles underlying the condensation and find that the vanishing of relative entropy production determines the condensates. Condensation proceeds exponentially fast, but the system of condensates never comes to rest: The occupation numbers of condensates oscillate, which we demonstrate for a Rock-Paper-Scissors game of condensates.

BP 32.9 Tue 16:00 MA 001

Length selection and replication in a thermal flow chamber — •Simon A. Lanzmich[1], Lorenz M. R. Keil[1], Moritz Kreysing[2], and Dieter Braun[1] — [1]Systems Biophysics, LMU Munich, Germany — [2]MPI of Molecular Cell Biology and Genetics, Dresden, Germany

The replication of long nucleic acids is central to life. On the early Earth, suitable non-equilibrium boundary conditions were required to surmount the effects of thermodynamic equilibrium such as dilution and degradation of oligonucleotides. One particularly intractable experimental finding is that short genetic polymers replicate faster and outcompete longer ones, leading to ever shorter sequences and the loss of genetic information. We show in theory and experiment that heat flux across an open chamber in submerged rock concentrates replicating oligonucleotides from a constant feeding flow and selects for longer strands. The thermal gradient triggers a complex interplay of molecular thermophoresis, external flow and laminar convection, where the latter drives strand separation and exponential replication. The measurements are understood quantitatively based on the calculation of stochastic trajectories inside the chamber using a two-dimensional random walk model. This allowed to derive lifetimes and thermal oscillation frequencies of the nucleic acids. In an intermediate range of external velocities, the superposition of flow fields retains strands of 75 bases, while strands half as long die out, inverting above dilemma of the survival of the shortest. The combined feeding, thermal cycling and positive length selection opens the door for stable molecular evolution in the long-term micro-habitat of asymmetrically heated porous rock.