Symposium Nonlinear and Anomalous Transport in Complex Systems (SYNF)

jointly organized by
Section Biological Physics (PB),
Section Dynamics and Statistical Physics (DY), and
Working Group Physics of Sozio-Economic Systems (AKSOE)

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Biological, social and physical systems far from thermodynamic equilibrium typically exhibit transport phenomena that are nonlinear, anomalous and interesting. This symposium provides insight into cutting edge research on transport phenomena in various systems on a wide range of scales. The aim is to illustrate key principles, discern essential similarities, identify crucial differences and put the transport phenomena into a global perspective.

Overview of Invited Talks and Sessions

(lecture room H1)

Invited Talks

SYNF 1.1	Wed	14:45–15:15	H1	**Depolymerization of microtubules by kinesins** — •Jonathon Howard
SYNF 1.2	Wed	15:15–15:45	H1	**Hydra Molecular Network Reaches Criticality at the Symmetry-Breaking Axis-Defining Moment** — Jordi Soriano, Cyril Colombo, •Albrecht Ott
SYNF 1.3	Wed	15:45–16:15	H1	**Morphogen Transport in Epithelia** — •Tobias Bollenbach
SYNF 1.4	Wed	16:15–16:45	H1	**Flocks, Herds and Schools - Physical Models of Animal Motion** — •Udo Erdmann
SYNF 1.5	Wed	16:45–17:15	H1	**Nonlinear transport processes in large-scale ecological networks** — •Bernd Blasius

Sessions

SYNF 1.1–1.5	Wed	14:30–17:15	H1	**Nonlinear and Anomalous Transport in Complex Systems**

SYNF 1: Nonlinear and Anomalous Transport in Complex Systems

Time: Wednesday 14:30–17:15 Location: H1

Wed 14:00 H1

Introduction

Invited Talk SYNF 1.1 Wed 14:45 H1

Depolymerization of microtubules by kinesins — •Jonathon Howard — Max Planck Institute of Molecular Cell Biology & Genetics, Dresden

The kinesin superfamily are proteins with sequence similarity to the motor domain of kinesin-1, the founding member of the superfamily. Many kinesins, including kinesin-1, are motors that couple the chemical potential associated with the hydrolysis of ATP into mechanical force used to drive directed movement along a microtubule. However, cellular and genetic studies indicate that kinesins in several of the families destabilize microtubules. For example, deleting kinesin-8 leads to longer mitotic spindles, and overexpressing kinesin-13 leads to loss of cytoplasmic microtubules. To determine how destabilization occurs, we have developed single-molecule-fluorescence assays to study directly the interaction of these kinesins with microtubules. We have discovered that both kinesin are depolymerases that bind to microtubule ends and depolymerize them in an ATP-dependent manner. Kinesin-13 and kinesin-8 target to the ends by different mechanisms. Kinesin-13 uses a diffusion and capture mechanism to quickly and economically reach either end. By contrast, kinesin-8 is a highly processive and directed motor that depolymerizes longer microtubules more quickly than shorter ones, providing a feedback mechanism that can account for the role of kinesin-8 in regulating spindle size. These single-molecule studies demonstrate that kinesin proteins are not just transporters but also regulate the polymerization of the track itself.

Invited Talk SYNF 1.2 Wed 15:15 H1

Hydra Molecular Network Reaches Criticality at the Symmetry-Breaking Axis-Defining Moment — Jordi Soriano[1], Cyril Colombo[2], and •Albrecht Ott[1] — [1]Lehrstuhl Experimentalphysik 1, Universität Bayreuth, Bayeuth, Germany — [2]EADS Space Transportation, Les Muraux, France

We study biological, multicellular symmetry breaking on a hollow cell sphere as it occurs during hydra regeneration from a random cell aggregate. We show that even a weak temperature gradient directs the axis of the regenerating animal - but only if it is applied during the symmetry-breaking moment. We observe that the spatial distribution of the early expressed, head-specific gene ks1 has become scale-free and fractal at that point. We suggest the self-organized critical state to reflect long range signaling, which is required for axis definition and arises from cell next-neighbor communication.

Invited Talk SYNF 1.3 Wed 15:45 H1

Morphogen Transport in Epithelia — •Tobias Bollenbach — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Strasse 38, 01187 Dresden, Germany — Department of Systems Biology, Harvard Medical School, 200 Longwood Avenue, Boston, MA 02115, USA

Morphogens are signaling molecules that play a key role in animal development. They spread from a restricted source into an adjacent target tissue forming a concentration gradient. The fate of cells in the target tissue is determined by the local concentration of such morphogens. Here, we study morphogen transport through the tissue using a combined theoretical and experimental approach. Recent experiments on the morphogen Decapentaplegic (Dpp) in the fruit fly *Drosophila melanogaster* provide evidence for the importance of a cellular transport mechanism that was termed "planar transcytosis". In this mechanism, morphogens are transported through the cells by repeated rounds of internalization and externalization. Starting from a microscopic description of these processes, we derive nonlinear transport equations which describe the interplay of transcytosis and passive diffusion. We find that transcytosis leads to an increased robustness of the created gradients with respect to morphogen over-expression. We further discuss the effects of spatial disorder on the steady state concentration profile and address the important question how precise the positional information encoded in a morphogen gradient can be. Finally, we relate our theoretical work to recent experiments on the kinetics and precision of morphogen gradient formation.

Invited Talk SYNF 1.4 Wed 16:15 H1

Flocks, Herds and Schools - Physical Models of Animal Motion — •Udo Erdmann — Helmholtz-Gemeinschaft Deutscher Forschungszentren, Berlin, Germany

The phenomenon of collective motion is of wide interest and therefore a lot of scientific research has been done in that field recently. Especially in biological and social systems which seem to be far from equilibrium most of the time, coherent motion of groups of individuals can be observed very often. Schools of fish, flocks of birds, groups of ants, systems of microorganisms like bacteria or cellular slime molds etc. show cooperative behavior and collective moving modes of a large group of these species. The variety of types of motion goes from translational directed motion over rotational motions up to more complex cooperative moving patterns of particles. Various approaches which try to tackle this phenomenon have been developed. In contrast of the rule-based models the talk will focus on a physicists view onto the aforementioned phenomena. The dynamics of the individuals will be modeled based on Newton's law. This reductionist type of approach finds three main ingredients which have to be put into the equations of motion of every single particle in order to obtain the main types of swarming motion. Various types of interactions are investigated. The stability of translational and rotational motion and a transition between these two types of motion will be discussed throughout the talk.

Invited Talk SYNF 1.5 Wed 16:45 H1

Nonlinear transport processes in large-scale ecological networks — •Bernd Blasius — Institut für Chemie und Biologie des Meeres, Carl-von-Ossietzky.Str. 9-11, Postfach 2503, 26111 Oldenburg

Transport processes play an important role in biological and ecological systems. Such processes increasingly take place on complex networks on global scales, where the spatial landscape is segmented into local habitat islands which are connected by long-range dispersal in a network of invasion pathways. Important examples are the geographical expansion of alien species to new habitats and the global spread of infectious diseases into a new range.

These topics are explored on several case studies. First we study the dynamics of epidemic outbreaks in networks of cities, which are coupled by transport of individuals between cities. We propose that the network topology is defined solely from the size distribution of the cities, which results in a hierarchical synchronization of the epidemic outbreaks and compares well to the dynamics observed in infectious childhood diseases. Secondly we analyze the spread of infectious diseases on adaptive networks where the travel behavior of individuals may change during the onset of an epidemic. This gives rise to a complicated interplay between a time changing network topology and the spatial epidemic state. Finally we study the migratory movement of birds between summer and winter populations on a network of intermediate stopover sites. To mimic this process we introduce a seasonal varying Markov network where the transition rates are a periodic function of time.