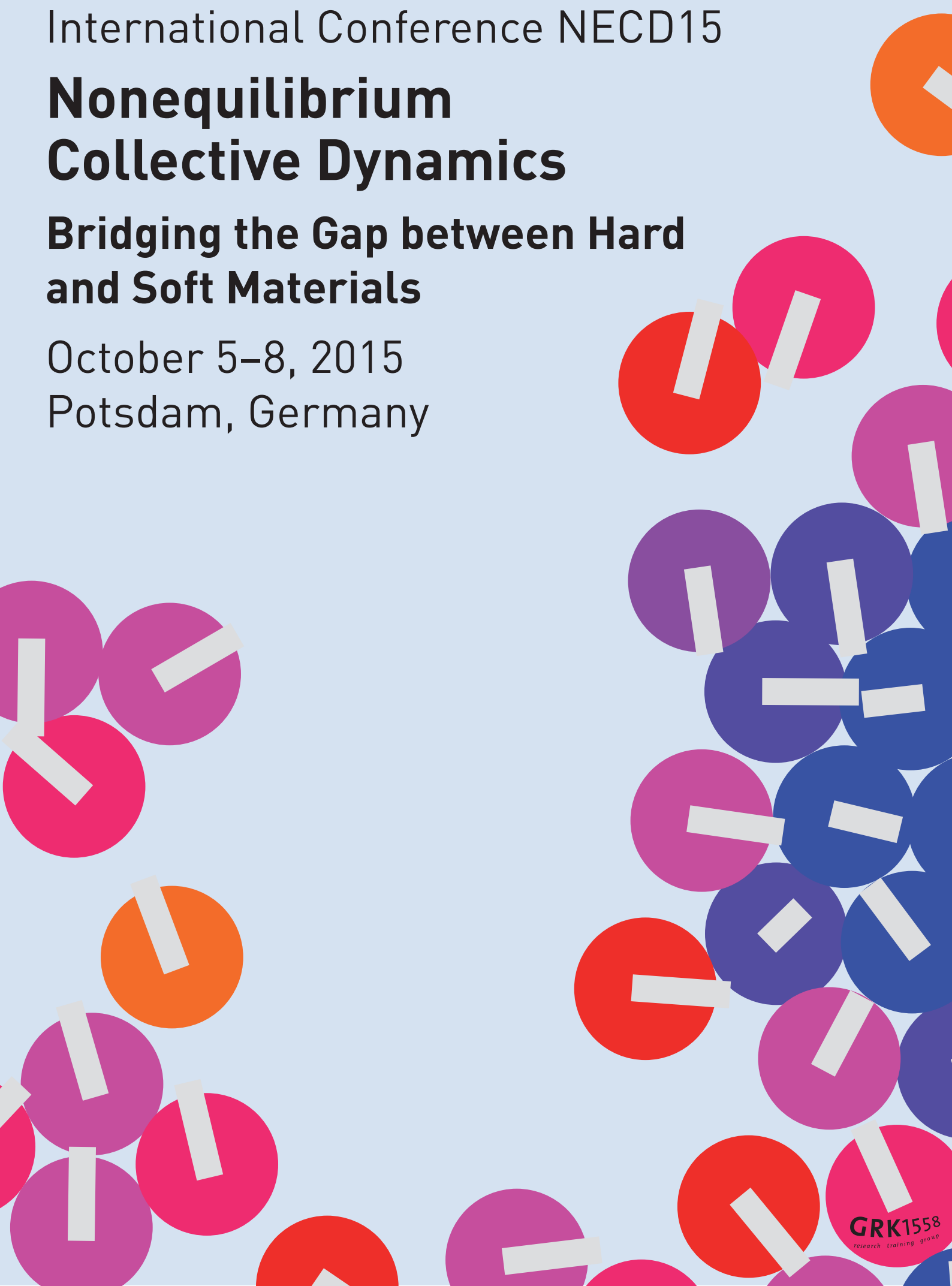
International Conference NECD15

Nonequilibrium Collective Dynamics

Bridging the Gap between Hard and Soft Materials

October 5–8, 2015
Potsdam, Germany



International Conference NECD15

Nonequilibrium Collective Dynamics

Bridging the Gap between Hard and Soft Materials

October 5 – 8, 2015

Potsdam, Germany

An Event of the
Research Training Group GRK 1558
"Nonequilibrium Collective Dynamics in
Condensed Matter and Biological Systems"

Scientific and Organization Committee

Holger Stark (chairman)
Sabine Klapp (co-chairwoman)
Carsten Beta
Markus Bär
Andreas Knorr
Julia Eckert
Jan-Timm Kuhr
Rodrigo Lugo-Frías
Oliver Pohl
Kilian Kuhla

Venue

Venue of the NECD15 conference is the hotel "Seminaris Seehotel" in Potsdam, Germany. Potsdam is located about 30 km southwest of the center of Berlin. It can easily be reached by public transport from the both airports (TXL and SXF) of Berlin. Further information is available on the conference homepage (www.itp.tu-berlin.de/necd15).

Scope

Collective dynamics under nonequilibrium conditions is ubiquitous in natural processes and technology. It greatly influences all fields of science, ranging from physics, chemistry and biology to engineering. Different approaches to study nonequilibrium collective dynamics have been developed in different disciplines, in particular in hard and soft condensed matter and biological physics. The conference NECD15 aims at bringing together specialists in these fields and to stimulate an intensive exchange of methods and ideas among them.

Contents

Monday, October 5

8:50 – 9:00	Holger Stark (Technische Universität Berlin) Opening remarks
9:00 – 9:35	Petra Schwille (MPI Martinsried) Spatial Control of Protein Pattern and Gradient Formation
9:35 – 10:10	Karsten Kruse (Universität des Saarlands, Saarbrücken) Collective effects of molecular motors and passive cross-linkers
10:10 – 10:30	Marcus J. B. Hauser (Otto-von-Guericke-Universität Magdeburg) Migratory behaviour of *Physarum polycephalum* microplasmodia
Coffee break	
11:00 – 11:35	Eberhard Bodenschatz (MPI Göttingen) Self-Oscillations of the Cytoskeleton of Chemotacticoeba
11:35 – 11:55	Marius Hintsche (Universität Potsdam) Quantifying the chemotactic response of *Pseudomonas putida*
11:55 – 12:15	Johannes Blaschke (Technische Universität Berlin) Simulating the Swimming Dynamics of *Trypanosoma brucei* in Crowded Environments
Lunch	
2:00 – 2:35	Hugues Chaté (CEA Saclay) Phase and microphase separation in active matter
2:35 – 3:10	Thomas Speck (Johannes-Gutenberg-Universität Mainz) Active Brownian particles: effective equilibrium vs. genuine non-equilibrium
3:10 – 3:30	Jakob Löber (Technische Universität Berlin) Modeling crawling cell motility
Coffee break	
4:00 – 4:35	Masaki Sano (University of Tokyo) Interaction and Collective Dynamics of Self-Propelled Particles
4:35 – 4:55	Sebastian Heidenreich (PTB Berlin) Hydrodynamic length scale selection in mesoscale turbulence
4:55 – 5:15	Jaideep Katuri (MPI Stuttgart) Synthetic microswimmers near surfaces and their collective behavior
6:00 – open	Poster session and buffet

Tuesday, October 6

9:00 – 9:35	Jérémie Palacci (University of California San Diego) Emergent properties in experimental systems with synthetic micro-swimmers
9:35 – 10:10	Ramin Golestanian (University of Oxford) Collective Chemotaxis of Colloidal and Living Active Matter
10:10 – 10:30	Celia Lozano (MPI Stuttgart) Dynamics of Microswimmers with Space-Dependent Self-Propulsion
Coffee break	
11:00 – 11:35	Jürgen Horbach (Heinrich-Heine-Universität Düsseldorf) Directed Site Percolation Roots in the Formation of Shear Bands
11:35 – 11:55	Pietro Tierno (University of Barcelona) Excluded Volume Causes Integer and Fractional Plateaus in Colloidal Ratchet Currents
11:55 – 12:15	Nicolas Rivas (University of Twente, Enschede) Collective oscillations in vibrated granular media
Lunch	
2:00 – 2:35	Henri Orland (CEA Saclay) The search for transition paths
2:35 – 3:10	Jonathan Keeling (University of St Andrews) Non-equilibrium phases of matter-light systems
3:10 – 3:30	Arthur Straube (Humboldt-Universität zu Berlin) Microscopic dynamics of synchronization in driven colloids
Coffee break	
4:00 – 4:35	Martijn Wubs (Technical University of Denmark, Kgs. Lyngby) Non-classical plasmonics with and without hard walls
4:35 – 4:55	Lina Jaurigue (Technische Universität Berlin) Timing jitter in passively mode-locked semiconductor lasers: a semi-analytic approach
4:55 – 5:15	Philipp Strasberg (Technische Universität Berlin) Physics and thermodynamics of information processing at the nanoscale
6:00 – open	Poster session and buffet

Wednesday, October 7

9:00 – 9:35	Seth Fraden (Brandeis University, Waltham) Microfluidic Networks of Oscillatory Chemical Reactions
9:35 – 9:55	Michiel Hermes (University of Edinburgh) Unstable and chaotic flow in shear thickening suspensions
9:55 – 10:15	Philipp Kanehl (Technische Universität Berlin) Dense Colloidal Suspensions in Microfluidic Flow: Size Segregation and Velocity Oscillations
Coffee break	
11:00 – 11:35	Michael P. Brenner (Harvard University) Towards Artificial Living Materials
11:35 – 11:55	Ehsan Irani (Georg-August-Universität Göttingen) Rheology of Particulate Systems with Attractive Interactions: Effect of Thermal Fluctuations and Dissipation
11:55 – 12:15	Rodrigo Lugo-Frías (Technische Universität Berlin) Shear-induced oscillatory states in binary mixtures of hard anisotropic particles
Lunch	
2:00 – 2:35	Knut Drescher (MPI Marburg) Dynamics in bacterial biofilm communities
2:35 – 3:10	Pascal Silberzan (Institut Curie, Paris) Confined and shaped monolayers
3:10 – 3:30	Pierre A. Haas (University of Cambridge) How a *Volvox* Embryo Turns Itself Inside Out
Coffee break	
4:00 – 4:35	Stephan Grill (TU Dresden / MPI Dresden) Actomyosin Force Generation and Pattern Formation
4:35 – 4:55	Gabriel Seiden (MPI Dresden / Weizmann Institute, Rehovot) The tongue as an excitable medium
4:55 – 5:15	Robert Grossmann (PTB Berlin) Large-scale synchronization of diffusively and superdiffusively moving oscillators
6:30 – 9:30	Conference dinner on a boat on the river Havel

Thursday, October 8

9:00 – 9:35	Philippe Peyla (University Grenoble Alpes) Role of hydrodynamic interactions in phototactic algal suspensions
9:35 – 10:10	Suzanne Fielding (Durham University) Phase behaviour and hydrodynamics of active suspensions
10:10 – 10:30	Raphael Jeanneret (University of Warwick) Dancing with *Chlamydomonas*
Coffee break	
11:00 – 11:35	Alexander Mikhailov (FHI Berlin) Hydrodynamic Collective Effects of Active Protein Machines
11:35 – 11:55	Matthew Dennison (Technische Universität Berlin) Collective effects of hydrodynamic dipoles: enhancing particle diffusion
11:55 – 12:15	Thomas Ihle (Ernst-Moritz-Arndt Universität Greifswald) Kinetic theory of self-driven particles: Invasion waves and correlation effects
Lunch	
2:00 – 2:35	Herbert Levine (Rice University, Houston) Cell motility, from the individual to the collective
2:35 – 2:55	Erik Bernitt (Universität Bremen) Actin Waves in Fibroblasts: Noise-induced Circular Dorsal Ruffles
2:55 – 3:15	Dirk Kulawiak (Technische Universität Berlin) Reproducing contact inhibition of locomotion probabilities of colliding cells migrating on micro-patterned substrates
Coffee break	
3:45 – 4:20	Raymond Kapral (University of Toronto) Collective dynamics of chemically-active sphere dimer motors
4:20 – 4:55	Peter Keim (Universität Konstanz) Kibble-Zurek mechanism in colloidal monolayers: spontaneous symmetry breaking out of equilibrium
4:55	Holger Stark (Technische Universität Berlin) Closing remarks

Posters: Hard Matter

Poster 1	Anke Zimmermann (Technische Universität Berlin) Two dimensional optical spectroscopy of Coulomb coupled colloidal quantum dots
Poster 2	Kilian Kuhla (Technische Universität Berlin) Spatio-temporal propagation of nonclassical light in a coupled quantum dot-waveguide system
Poster 3	Mirco Kolarczik (Technische Universität Berlin) Identification of Crossed Excitons and Observation of Exciton Dynamics in Dot-in-a-Well Structures
Poster 4	Sebastian Restrepo (Technische Universität Berlin) Aspects of the Relationship between Non-Markovianity and Time-Dependent Driving
Poster 5	T. Sverre Theuerholz (Technische Universität Berlin) Metal-semiconductor hybrids: Influence of the Förster coupling between the two quantum dots

Posters: Soft Matter

Poster 6	Abhrajit Laskar (Institute of Mathematical Sciences Chennai) Micro-hydrodynamics of Active Filament
Poster 7	Alexander Ziepke (Technische Universität Berlin) Front Propagation in Sinusoidally Modulated Channels and Tubes
Poster 8	Andrea Fortini (University of Surrey) Non-equilibrium size segregation in evaporating films of colloidal mixtures
Poster 9	Andrea Fortini (University of Surrey) Superadiabatic Forces in Brownian Many-Body Dynamics
Poster 10	Arash Azhand (Technische Universität Berlin) Modulated Filament Structures in a Confined Non-Equilibrium Chemical System: Experiment, Simulation, and Theory
Poster 11	Artur Erbe (Helmholtz-Zentrum Dresden-Rossendorf) Field-controlled phase transitions between two-dimensional assemblies of magnetic Janus particles
Poster 12	Arzu B. Yener (Technische Universität Berlin) Double layer formation of driven magnetic Janus like particles
Poster 13	Dalila Vescovi (University of Twente) Simple shear flows of frictionless, hard and soft spheres
Poster 14	Ellen Fischermeier (Universität Erlangen-Nürnberg) Nonequilibrium Dynamical States in Driven Colloids

Poster 15 — Felix Winterhalter (Universität Erlangen-Nürnberg)
Fluctuating Lattice Boltzmann simulations of microswimmers

Poster 16 — Francisca Guzman-Lastra (Heinrich-Heine-Universität Düsseldorf)
Fission and fusion scenarios for magnetic microswimmer clusters

Poster 17 — Henning Reinken (Technische Universität Berlin)
Inhomogeneous flow induced dynamics of nematic colloidal binary mixtures

Poster 18 — Jaeoh Shin (MPI Dresden)
Polymer looping in crowded solutions of active particles

Poster 19 — Johann Hansing (Freie Universität Berlin)
The effect of hydrodynamics and electrostatics on particle diffusion in polymer networks

Poster 20 — Josua Grawitter (Technische Universität Berlin)
Dynamical density functional theory for mixtures of active and passive colloids

Poster 21 — Karol Makuch (University of Warsaw)
Transport coefficients of suspensions of spherical particles

Poster 22 — Maria Zeitz (Technische Universität Berlin)
Active particles in complex environments

Poster 23 — Maciej Majka (Jagiellonian University)
Non-Gaussian polymers described by alpha-stable chain statistics: Model, effective interactions in binary mixtures and application to on-surface separation

Poster 24 — Pablo de Castro (King's College London)
Nonequilibrium dynamics of Polydisperse Lattice-Gas

Poster 25 — Peter Kalle (Technische Universität Berlin)
Controlling the dynamics of complex fluids by time-delayed feedback

Poster 26 — Sascha Gerloff (Technische Universität Berlin)
Local transport via density excitations in confined colloidal mixtures under shear flow

Poster 27 — Sebastian Ehrig (MPI Potsdam)
Active particles in confined geometries

Poster 28 — Zahra Mokhtari (Georg-August-Universität Göttingen)
Dynamics of active Brownian particles in heterogeneous media

Posters: Biological Physics

Poster 29 — Martin Falcke (Max Delbrück Center Berlin)
Concentration profiles of actin-binding molecules in motile cells

Poster 30	Oliver Pohl (Technische Universität Berlin) Inference of chemotactic strategies of *E. coli* and *Pseudomonas putida* using Kramers-Moyal coefficients
Poster 31	Robert Grossmann (Technische Universität Berlin) Vortex arrays and mesoscale turbulence of self-propelled particles
Poster 32	Sara Jabbari-Farouji (Johannes Gutenberg-Universität Mainz) A kinetic model for description of collective dynamics of magnetotactic bacteria
Poster 33	Setareh Dolati (Max Delbrück Center Berlin) Actin based cell motility: Phase field modeling of gel-like cytoskeleton and highly dynamic leading edge membrane
Poster 34	Tapan Chandra Adhyapak (Technische Universität Berlin) The Role of Rotation Induced Polymorphic Transitions during Tumbling of an *E. coli*
Poster 35	Thomas Niedermayer (PTB Berlin / MPI Potsdam) Nonequilibrium assembly of filaments: analytical results
Poster 36	Till Kranz (University of Oxford) Trail-Following in Simple Models of Bacteria

Abstracts: Talks

Spatial Control of Protein Pattern and Gradient Formation

Petra Schwille

Max Planck Institute of Biochemistry, Martinsried, Germany

Self-organization of proteins into large-scale structures is of pivotal importance for the organization of cells. The Min protein system of the bacterium *Escherichia coli* is a prime example of how pattern formation occurs via reaction-diffusion. We have previously demonstrated how Min protein patterns on flat supported membranes are influenced by membrane shape. Lately, we additionally probed the influence of membrane surface topology as a regulatory element. Using microstructured membrane-clad soft polymer substrates, Min protein patterns can be aligned. We demonstrate that Min pattern alignment starts early during pattern formation and show that macroscopic millimeter-sized areas of protein patterns of well-defined orientation can be generated. Confining the Min self-organizing system in membrane containers with constant volume, the patterns are turned into regular oscillations and stable gradients, which help to position downstream processes, such as the assembly of the bacterial divisome machinery.

Collective effects of molecular motors and passive cross-linkers

Denis Johann[1], Debajit Goswami[1], Christopher Zapp[1], Aniek Jongerius[2], Marcel Janson[2], and Karsten Kruse[1]

[1] *Saarland University, Saarbruecken, Germany*
[2] *Wageningen University, Wageningen, The Netherlands*

In eukaryotic cells, the mitotic spindle assures an even distribution of the duplicated chromosomes on to the nascent daughter cells. The scaffold of the spindle is formed by microtubules that emanate from two microtubule organizing centers leading to a bipolar structure. The assembly is kept intact through a number of cross-linking proteins including molecular motors. The motors can convert chemical energy into mechanical work and induce sliding between pairs of microtubules. Through spindles of different organisms may vary in their detailed organization, a prominent feature of many spindles are stable overlap regions of antiparallel microtubules. How these overlaps are maintained and how their size is controlled is largely an open problem. Here, we investigate the interplay of molecular motors and other cross-linking proteins that lack motor activity and study their contribution to the formation of stable overlaps. On single microtubules, we find that molecular motors and "passive" cross linkers can segregate. Microtubule pairs that are cross-linked simultaneously by both kinds of proteins can spontaneously form stable overlap regions. We discuss the underlying mechanism and show how the size of the overlap region can be regulated by changing protein concentrations.

Migratory behaviour of *Physarum polycephalum* microplasmodia

Beatrice Rodiek and Marcus J. B. Hauser

Institute of Experimental Physics, Otto von Guericke Universität Magdeburg, Magdeburg, Germany

The motility of amoeboid cells of the plasmodial slime mould *Physarum polycephalum* was studied experimentally. Analysis of their trajectories and of their mean square displacements reveal two characteristic types of behaviour that depend on the time interval τ between any pair of points along the trajectory. Whereas free migration of cells is observed for time intervals $\tau > 300$ s, at short time intervals the motility is due to changes in the cell shape induced by the peristaltic pumping of protoplasm though the cell. Freely migrating cells display persistent random motion with very long persistence times of up to ≈ 1.5 h. Superdiffusive motion typically lasts for ≈ 5 h. Whereas symmetric velocity distributions are found for short time intervals τ, the typical velocity distributions from freely migrating cells show an asymmetry, which reflects the long-lasting persistent motions. We observed that high propagation velocities are correlated with both, episodes of straight motion and an elongated cell shape. Finally, the mean squared displacement of trajectories where the cells avoided crossing their own slime trails were compared to those of freely migrating cells.

Self-Oscillations of the Cytoskeleton of Chemotactic Amoeba

Eberhard Bodenschatz

MPI-DS, Göttingen, Germany

Recently, self-oscillations of the cytoskeletal actin have been observed in *Dictyostelium*, a model system for studying chemotaxis. Here we report experimental results on the self-oscillation mechanism and the role of capping proteins and myosin II. We stimulate cells rapidly and periodically by using photo un-caging of the chemoattractant in a micro-fluidic device and measured the cellular responses. We found that the response amplitude grows with stimulation strength only in a very narrow region of stimulation, after which the response amplitude reaches a plateau. Moreover, the frequency-response is not constant but rather varies with the strength of external stimuli. To understand the underlying mechanism, we analyzed the polymerization and de-polymerization time in the single cell level. Despite of the large cell-to-cell variability, we found that the polymerization time is independent of external stimuli and the de-polymerization time is prolonged as the stimulation strength increases. Our observations explain the underlying machinery of self-oscillations, implying that the oscillation frequency of self-oscillations is determined by the binding time of capping protein. We shall also present the role of noise on the self-oscillatory behavior of cells.

This work is conducted with C. Beta, H. Hsu, J. Negrete, A. Pumir, M. Tarantola, C. Westendorf, V. Zykov and is supported by SFB 937 "Collective behavior of soft and biological matter" and the Max Planck Society.

Quantifying the chemotactic response of *Pseudomonas putida*

Marius Hintsche[1], Oliver Pohl[2], Carsten Beta[1], and Holger Stark[2]

[1] *University of Potsdam, Potsdam, Germany*
[2] *Technical University of Berlin, Berlin, Germany*

Swimming bacteria often have to navigate through chemically diverse environments. By modulating their stochastic motility pattern they can move towards or away from chemical sources. We investigate the chemotactic response of the soil bacterium *Pseudomonas putida* in gradients of aromatic hydrocarbons. Using a microfluidic assay, we measure key motility parameters like run lengths and turning angle distribution to quantify the strength of chemotactic responses in different gradient strengths. Also the influence of geometric constraints and confinement is considered.

Simulating the Swimming Dynamics of *Trypanosoma brucei* in Crowded Environments

Johannes Blaschke[1], Davod Alizadehrad[2], and Holger Stark[1]

[1] *Technische Universität Berlin, Berlin, Germany*
[2] *Forschungszentrum Jülich, Jülich, Germany*

Trypanosoma brucei is a microorganism capable of thriving in the mammalian blood stream, eventually infecting the brain resulting in sleeping sickness. Yet mammalian blood constitutes a challenging environment for parasites: in order to prosper, the parasite must constantly evade the host's immune response while moving through a densely crowded flow with highly variable flow speed. Experiments [1] have shown that the swimming motion of *T. brucei* has adapted to highly crowded environments: by virtue of a flagellum [2], which is attached to part of its cell body, the parasite oscillates its body shape. This leads to hydrodynamic swimming which is enhanced when the cell body interacts with obstacles from the environment.

Here we employ a previously developed cell body model [3,4] of *T. brucei*, and a stochastic hydrodynamic simulation technique, to investigate the effects of a crowded environments on the parasite's swimming dynamics. For channel-geometry, we find that *T. brucei*'s swimming speed is enhanced when swimming in densely packed solid obstacles, confirming experimental findings.

[1] N. Heddergott, T. Krüger, S. B. Babu, A. Wei, E. Stellamanns, S. Uppaluri, T. Pfohl, H. Stark, and M. Engstler, PLoS Pathog. **8**, e1003023 (2012).

[2] K. S. Ralston and K. L. Hill, Int. J. Parasitol. **38**, 869 (2008).

[3] D. Alizadehrad, T. Krüger, M. Engstler, and H. Stark, PLoS Comput. Biol. **11**, e1003967 (2015).

[4] S. B. Babu and H. Stark, New J. Phys. **14**, 085012 (2012).

Phase and microphase separation in active matter

Hugues Chaté

CEA – Saclay, France

It is only recently that a satisfactory global understanding of the onset of orientational order in simple models of active matter was obtained: rather than an order/disorder transition, this is best described as phase separation between a disordered gas and an ordered fluid. I will recall this, and show that the coexistence region, where chunks of the ordered fluid move in the disordered gas, can take very different aspects depending on nonlinear effects and on the nature of fluctuations.

Active Brownian particles: effective equilibrium vs. genuine non-equilibrium

Thomas Speck

Johannes Gutenberg-Universität, Mainz, Germany

A striking non-equilibrium phenomenon is the clustering and phase separation of dense, phoretically propelled colloidal particles [1,2]. The simplest model that reproduces this phase separation in computer simulations is active Brownian particles (ABPs): spherical (discoid) particles that are propelled by a constant force along an orientation that undergoes free rotational diffusion. In addition, particles interact with other particles through a, typically repulsive, pair potential. This model thus incorporates the two basic physical ingredients of micro-swimmers: volume exclusion and persistence of motion. I will discuss recent results on two aspects: First, phase separation of ABPs at sufficiently high densities strongly resembles phase separation in passive fluids and suspensions with attractive interactions, whereby the propulsion speed takes the role of an inverse temperature. Indeed, the large-scale behavior of ABPs can be mapped systematically onto an effective free energy [3] (motility-induced phase separation). Second, the non-equilibrium nature of ABPs due to their persistent motion becomes evident when considering pressure and surface tension [4]. I will introduce these concepts from the perspective of stochastic thermodynamics and discuss the numerical evidence from particle-resolved simulations.

[1] J. Palacci *et al.*, Science **339**, 936 (2013).

[2] I. Buttinoni *et al.*, Phys. Rev. Lett. **110**, 238301 (2013).

[3] T. Speck, J. Bialké, A. M. Menzel, and H. Löwen, Phys. Rev. Lett. **112**, 218304 (2014).

[4] J. Bialké, H. Löwen, and T. Speck, arXiv:1412.4601.

Modeling crawling cell motility

Jakob Löber[1], Falko Ziebert[2], and Igor S. Aranson[3]

[1] *Institut für Theoretische Physik, Technische Universität Berlin, Germany*
[2] *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany*
[3] *Materials Science Division, Argonne National Laboratory, USA*

Self-propelled motion, emerging spontaneously or in response to external cues, is a hallmark of living organisms. Self-propulsion relies on the force transfer to the surrounding. While self-propelled swimming in the bulk of liquids is fairly well characterized, many open questions remain in our understanding of self-propelled motion of cells along substrates. Here we present a phenomenological model for crawling cells based on an advected phase field model and other reaction-diffusion equations. The force transfer from the cell to the substrate is explicitly taken into account, giving rise to complex modes of cell movement such as "bipedal" motion and "stick-slip" motion. The model captures the generic structure of the traction force distribution and faithfully reproduces experimental observations, like the response of a cell on a gradient in substrate elasticity (durotaxis). Collective states of motion such as concerted rotation arises for multiple interacting cells on patterned substrates.

Interaction and Collective Dynamics of Self-Propelled Particles

Masaki Sano[1], Daiki Nishiguchi[1], Sakurako Tanida[1], and Hong-ren Jiang[2]

[1] *Department of Physics, The University of Tokyo*
[2] *Institute of Applied Mechanics, National Taiwan University*

Fluctuation and collective dynamics in active matter are attracting interests among researchers in wide fields ranging from physics to biology. Despite remarkable progress in this new field, there remain enough challenges for experimentalists to construct systems which can be tested by controlling interaction between self-propelled particles. We will introduce two experimental systems in regard to this aspect. In a system of Janus particles, we can control alignment, attractive, and repulsive interaction between particles by using induced charge under AC electric field. Several different phases are observed in this system. Hydrodynamic interaction plays important roles in mesoscopic turbulence. In biological systems, we can control the aspect ratio of self-propelled objects relatively easily. It enabled us to observe a long range nematic order in a suspension of elongated bacteria. Statistical analysis of ordering and fluctuation will be discussed.

Hydrodynamic length scale selection in mesoscale turbulence

Sebastian Heidenreich[1], Jörn Dunkel[2], Sabine H. L. Klapp[3], and Markus Bär[1]

[1] *Physikalisch Technische Bundesanstalt, Berlin, Germany*
[2] *Massachusetts Institute of Technology, Cambridge, USA*
[3] *Technical University, Berlin, Germany*

Self-sustained mesocale turbulence of bacterial suspensions presents an intriguing example for collective nonlinear behavior in biological systems. A characteristic of the collective motion is the emergence of vortices with a typical size several times larger than that of a bacterium. In the talk, we present a systematic derivation of an effective fourth-order field theory from a generic microswimmer model that allows us to predict the typical size of the vortices. We discuss the mechanism of length scale selection and for realistic parameter values, we demonstrate the fairly good agreement with recent experimental results of *Bacillus subtilis* suspensions.

Synthetic microswimmers near surfaces and their collective behavior

Jaideep Katuri[1], Juliane Simmchen[1], Laurent Helden[2], Clemens Bechinger[1, 2], and Samuel Sanchez[1, 3, 4]

[1] *Max Plank Institute for Intelligent Systems, Stuttgart, Germany*
[2] *2nd Institut für Physik, Universität Stuttgart, Stuttgart, Germany*
[3] *Institute for Bioengineering of Catalonia (IBEC), Barcelona, Spain*
[4] *Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain*

Silica particles asymmetrically coated with Pt, which move in self generated chemical gradients, are model systems in the study of active matter [1]. While there is a relatively good understanding of the motion of single active particles [2], the influence of the surfaces near which they swim is not well understood.

Natural swimmers like bacteria show interesting behaviours near surfaces that is different from their bulk properties. There is reason to believe that surface properties can have a significant influence on synthetic swimmers as they propel by phoresis, an interfacial effect.

Here, we use catalytically active spherical Janus micro-motors in order to investigate experimentally their motion on substrates of different properties. We use Total Internal Reflection Microscopy (TIRM) to estimate the height at which they swim and establish a relationship between swimming height and swimming speed. We further explore ways to modify this interaction and thereby obtain desired behaviours like directional control. Our understanding of the interaction of swimmers with the surfaces enables us to exploit surface properties to design nano-patters on the surface, much smaller than the radius of the swimmers themselves, to influence their directional behaviour.

Further, we are able to prepare and study motors of different Peclet numbers in the same system by varying the catalytic coverage using the Glancing Angle Deposition technique. We observe the emergent collective behaviours by using different ratios of these two swimmer types. We find that the clusters formed by using fast and slow swimmers in the same system are more dynamic that those reported earlier [3-5].

[1] J. R. Howse *et al.*, Self-Motile Colloidal Particles: from Directed Propulsion to Random Walk, Phys. Rev. Lett. **99**(4), 048102 (2007).

[2] S. J. Ebbens and J. R. Howse, Direct Observation of the Direction of Motion for Spherical Catalytic Swimmers, Langmuir **27**(20), 12293 (2011).

[3] J. Palacci *et al.*, Living Crystals of Light-Activated Colloidal Surfers, Science **339**(6122), 936 (2013).

[4] I. Theurkauff *et al.*, Dynamic Clustering in Active Colloidal Suspensions with Chemical Signaling, Phys. Rev. Lett. **108**(26), 268303 (2012).

[5] I. Buttinoni *et al.*, Dynamical Clustering and Phase Separation in Suspensions of Self-Propelled Colloidal Particles, Phys. Rev. Lett. **110**(23), 238301 (2013).

Emergent properties in experimental systems with synthetic micro-swimmers

Jérémie Palacci

University of California, San Diego, USA

Self-propelled micro-particles are intrinsically out-of-equilibrium. This renders their physics far richer than passive colloids and can potentially give rise to the emergence of complex phenomena...

I will present a variety of non-equilibrium phenomena observed in experiments with different types of synthetic micro-swimmers: self-assembly, sensing of the environment, or effective interactions, in the absence of any potential...

Collective Chemotaxis of Colloidal and Living Active Matter

Ramin Golestanian

University of Oxford, United Kingdom

Many non-equilibrium processes that lead to motility involve a scalar field or thermodynamic potential that obeys the Poisson equation and is thus able to mediate a long-range interaction between various motile components. The long-range nature of these interactions combined with the non-equilibrium dynamics of the system can lead to a rich phenomenology that could have immense potential for applications, if we were to engineer emergent behaviours. I discuss two different systems in which chemotaxis – response to chemical gradients – leads to the emergence of nontrivial collective properties. For catalytic colloids the chemical activity that leads to the self-propulsion of each colloid also serves as a source (or sink) for a field that affects others, both positionally (attraction or repulsion) and orientationally (alignment or anti-alignment). The resulting many-body effective dynamics exhibits instabilities towards formation of cluster, patterns, asters, plasma oscillations, and spontaneous oscillations. For a system of isotropic living cells that undergo a growth/death process in addition to attractive chemotaxis, dynamical renormalization group (RG) method gives us a rich phase diagram with a novel dynamical phase transition and new exponents describing a super-diffusive transport regime. I will finish by speculating about the biological implications of the RG calculation.

Dynamics of Microswimmers with Space-Dependent Self-Propulsion

Celia Lozano[1], Borge ten Hagen[2], Hartmut Löwen[2], and Clemens Bechinger[1, 3]

[1] *Max-Planck-Institut für Intelligente Systeme, Heisenbergstrasse 3, D-70569 Stuttgart, Germany*
[2] *Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany*
[3] *2. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany*

Active Brownian particles are characterized by their ability to extract energy from their environment to perform a directed motion. While their swimming motion under bulk conditions is rather well understood, only little is known about the dynamical properties of active particles under conditions where the Péclet number (Pe) varies spatially. We present an experimental study, where active motion is achieved by diffusiophoretic forces in a binary solvent and where Pe is controlled by the local light intensity. In the presence of a one-dimensional periodic intensity pattern, we observe the accumulation/depletion of active particles in regions with low/high illumination, i.e. with small/large Pe. We study the steady state particle density variations as a function of the ratio of the persistence length of active particles and the strip width of the intensity pattern and compare our results to numerical simulations. We expect that our findings contribute to the understanding of pattern formation of chemotactic organisms in chemical gradients.

Directed Site Percolation Roots in the Formation of Shear Bands

Jürgen Horbach[1], Gaurav P. Shrivastav[1], and Pinaki Chaudhuri[2]

[1] *Theoretical Physics: Soft Matter, University of Duesseldorf, Germany*
[2] *Institute of Mathematical Sciences, Chennai, India*

The origin and growth of shear bands in glassy systems under shear has attracted much attention in recent years. Different models have been proposed to explain this phenomenon. However, there is no consensus about the microscopic origin of shear banding in glasses. We use non-equilibrium molecular dynamics simulations to study a glassforming Lennard-Jones mixture under constant shear rate in a planar Couette flow geometry. To shear the system, Lees-Edwards boundary conditions are applied and the system is coupled to a dissipative particle dynamics thermostat. At a temperature below the glass transition temperature and sufficiently low shear rates, shear bands are formed around a strain of the order of 0.1. We show that shear banding has its origin in a directed percolation transition. The shear band is a transient but long-lived flow pattern. After it has formed it grows diffusively until the whole system exhibits a uniform flow pattern with a linear velocity profile according to the Couette flow geometry.

Excluded Volume Causes Integer and Fractional Plateaus in Colloidal Ratchet Currents

Pietro Tierno[1, 2] and Thomas Fischer[3]

[1] *Estructura i Constituents de la Matèria, Universitat de Barcelona, Avenida Diagonal 647, 08028 Barcelona, Spain*
[2] *Institut de Nanociència i Nanotecnologia IN2UB, Universitat de Barcelona, 08028 Barcelona, Spain*
[3] *Institute of Physics, Universität Bayreuth, 95440 Bayreuth, Germany*

We study the collective transport of paramagnetic colloids driven above a magnetic bubble lattice by an external rotating magnetic field [1]. We measure a direct ratchet current which rises in integer and fractional steps with the field amplitude. The stepwise increase is caused by excluded volume interactions between the particles, which form composite clusters above the bubbles with mobile and immobile occupation sites. Transient energy minima located at the interstitials between the bubbles cause the colloids to hop from one composite cluster to the next with synchronous and period doubled modes of transport. The colloidal current may be polarized to make selective use of type up or type down interstitials [2].

[1] P. Tierno, T. H. Johansen, and T. M. Fischer, Phys. Rev. Lett. **99**, 038303 (2007).

[2] P. Tierno and T. M. Fischer, Phys. Rev. Lett. **112**, 048302 (2014).

Collective oscillations in vibrated granular media

Nicolas Rivas[1], Anthony R. Thornton[1], Stefan Luding[1], and Devaraj van der Meer[2]

[1] *Multi Scale Mechanics (MSM), MESA+, CTW, University of Twente, Enschede, The Netherlands*
[2] *Physics of Fluids, University of Twente, Enschede, The Netherlands*

We present simulations and a theoretical treatment of vertically vibrated granular media. The system considered is confined in a quasi-one-dimensional (column) geometry, where the vertical extension of the container is much larger than both horizontal lengths. The additional geometric constraint present in the column setup frustrates the convection state that is normally observed in wider geometries. This makes it possible to study collective oscillations of the grains with a characteristic frequency that is much lower than the frequency of energy injection. A model based on Cauchy's equations is able to predict with high accuracy the frequency of the particles' collective motion, and shows that a sufficient condition for the existence of the low-frequency mode is an inverted density profile with distinct low and high density regions. Furthermore, using a novel size-scalings analysis of the granular hydrodynamic equations we are able to study the influence of fluctuations on the oscillations. Surprisingly, for hydrodynamically equivalent systems with different number of particles the frequency of the oscillations remains invariant, while the amplitude decreases.

Invited talk Tuesday, 2:00 – 2:35

The search for transition paths

Henri Orland

IPhT, CEA-Saclay, France

Transition paths are the stochastic paths that take a system from one state to another. For instance, they can be the ensemble of paths taking a protein from a denatured state to its native state. These transition paths can be formulated as conditioned stochastic paths. They can be generated exactly by a modified Langevin equation. If there is a high barrier between the two states, the transition path time is small compared to the folding time, and one can use a short-time expansion to generate the transition paths. This approximation is tested on several examples.

Non-equilibrium phases of matter-light systems

Jonathan Keeling

University of St Andrews, St Andrews, United Kingdom

Strong coupling between electromagnetic radiation and matter degrees of freedom provides a way to engineer new quasiparticles with controllable, tunable properties. This overarching concept covers many systems of current theoretical and experimental interest, from superconducting qubits in microwave cavities, to polariton and photon condensates, and cold atoms in optical cavities. Because of the light component, these new types of "quantum matter" are often far from equilibrium, and so allow for types of physics, requiring new rules for what kinds of states can occur.

I will discusses theoretical approaches to understanding the non-equilibrium phases, and phase transitions of such systems in general, and focus on two specific cases. One concerns arrays of coupled cavities, coupled to artificial atoms (superconducting qubits) [1]. Here I will discus our work on finding the non-equilibrium steady states of these systems with coherent or parametric pumping [2], and how the dynamical attractors can be quite distinct from the ground state. The second example concerns cold atoms in an optical cavity [3], and the attractors of this open dynamical system [4].

[1] A. Houck, H. Tureci, and J. Koch, Nature Phys. **8**, 292 (2012).

[2] F. Nissen *et al.*, Phys. Rev. Lett. **108**, 233603 (2012); C. Joshi and J. Keeling, Phys. Rev. A **88**, 063835 (2013); M. Schiró *et al.* arXiv:1503.04456.

[3] K. Baumann, C. Guerlin, F. Brennecke, and T. Esslinger, Nature **464**, 1301 (2010); A. Kollar *et al.*, New J. Phys. **17**, 043012 (2015).

[4] J. Keeling, M. J. Bhaseen, and B. D. Simons, Phys. Rev. Lett. **105**, 043001 (2010); M. J. Bhaseen, J. Mayoh, B. D. Simons, and J. Keeling, Phys. Rev. A **85**, 013817 (2012).

Microscopic dynamics of synchronization in driven colloids

Michael Juniper[1], Arthur Straube[2], Rut Besseling[3], Dirk Aarts[1], and Roel Dullens[1]

[1] *Department of Chemistry, Physical and Theoretical Chemistry Laboratory, University of Oxford, United Kingdom*
[2] *Department of Physics, Humboldt-Universität zu Berlin, Germany*
[3] *InProcess-LSP, Oss, The Netherlands*

Synchronization of coupled oscillators has been scrutinized for over three centuries, from Huygens' pendulum clocks to physiological rhythms. One such synchronization phenomenon, dynamic mode locking, occurs when naturally oscillating processes are driven by an externally imposed modulation. Typically only averaged or integrated properties are accessible, leaving underlying mechanisms unseen. We visualize the microscopic dynamics underlying mode locking in a colloidal model system, by using particle trajectories to produce phase portraits [Nat. Commun. **6**, 7187 (2015)]. We use this approach to examine the enhancement of mode locking in a flexible chain of magnetically coupled particles, which we ascribe to breathing modes caused by mode-locked density waves. Finally, we demonstrate that an emergent density wave in a static colloidal chain mode locks as a quasi-particle, with microscopic dynamics analogous to those seen for a single particle. Our results indicate that understanding the intricate link between emergent behaviour and microscopic dynamics is key to controlling synchronization.

Non-classical plasmonics with and without hard walls

Martijn Wubs

DTU Fotonik, Technical University of Denmark, Kgs. Lyngby, Denmark

On the surface of metals, waves can propagate with amplitudes that decay exponentially on both sides of the interface. These surface waves are a hybrid of collective oscillations of electrons and light and are called surface plasmons. Their properties are studied and engineered in the field of plasmonics. A unique property of plasmonic waveguides is their scale invariance: a twice smaller waveguide supports surface plasmons with twice smaller periods, according to classical electrodynamics [1]. This makes metal nanostructures interesting for miniaturization of optical circuits.

In the quest for smaller structures, deviations from classical electrodynamics were observed in recent experiments on individual few-nanometer particles: for example, resonances of smaller silver particles are broader and occur at higher frequencies [2], where classically no such broadening or blueshifts are expected. Further deviations are found for larger structures with nanometer-sized gaps.

Standard hydrodynamic Drude theory, a semi-classical theory that entails nonlocal optical response, predicts resonance blueshifts. It assumes, just like in classical electrodynamics, that the free electrons of the metal are strictly confined within the hard walls of the metal geometry. We generalized this theory so that also size-dependent broadening can be understood [3,4].

Until very recently, hydrodynamic theory could not explain that resonances of some metals actually shift to lower rather than to higher frequencies as sizes are reduced. By removing the hard-wall assumption from hydrodynamic Drude theory and describing spill-out of free electrons beyond the classical boundary, the different frequency shifts for different metals can now be described semiclassically for the first time [5], where previously *ab initio* methods were required.

Besides these theories, corresponding methods for the efficient computation of optical properties of metal nanostructures will be reviewed, including a method where spill-out of electrons is described as a dipole sheet on the classical metal surface [6].

[1] S. Raza *et al.*, Phys. Rev. B **88**, 115401 (2013).

[2] S. Raza *et al.*, Nanophotonics **2**, 131 (2013).

[3] N. A. Mortensen *et al.*, Nat. Commun. **5**, 3809 (2014).

[4] S. Raza *et al.*, J. Phys. Condens. Matter **27**, 183204 (2015).

[5] G. Toscano *et al.*, Nat. Commun. **6**, 7132 (2015).

[6] W. Yan *et al.*, arXiv:1504.07113.

Timing jitter in passively mode-locked semiconductor lasers: a semi-analytic approach

Lina Jaurigue[1], Eckehard Schöll[1], and Kathy Lüdge[2]

[1] *Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany*
[2] *Department of Physics, Freie Universität, Berlin, Germany*

Semiconductor passively mode-locked lasers have a relatively large timing jitter due to the absence of an external reference clock. We investigate the influence of optical feedback on the timing jitter of such devices. Using a novel semi-analytic approach we derive an expression for the dependence of the timing jitter on resonant feedback delay lengths, showing that the timing jitter scales approximately with the inverse of the resonant feedback delay time.

Physics and thermodynamics of information processing at the nanoscale

Philipp Strasberg, Javier Cerrillo, Gernot Schaller, and Tobias Brandes

TU Berlin, Berlin, Germany

Information processing, e.g., sensing, feedback, adaptation, or computation, plays an ubiquitous role in nanoscale engines or biomolecular machines. In the past, such devices were often treated by a "top-down" or "phenomenological" approach resting on arguments and idealized concepts from the thermodynamics of computation and information theory. At the moment, instead, one is more aiming at an "inclusive" or "autonomous" approach treating all relevant entities and tasks of information processing on an equal footing. In this talk we will present simple devices [1,2] highlighting the assumptions needed to obtain the ideal limit of a Maxwell demon [1] or an information driven engine [2] and we will critically discuss whether the thermodynamics of computation holds at the nanoscale [3].

[1] Strasberg, Schaller, Brandes, and Esposito, Phys. Rev. Lett. **110**, 040601 (2013).

[2] Strasberg, Schaller, Brandes, and Jarzynski, Phys. Rev. E **90**, 062107 (2014).

[3] Strasberg, Cerrillo, Schaller, and Brandes, arXiv: 1506.00894.

Microfluidic Networks of Oscillatory Chemical Reactions

Nate Tompkins, Ning Li, Irv Epstein, and Seth Fraden

Brandeis University, Waltham, USA

Several microfluidic based experimental systems of networks of non-linear chemical oscillators are presented. 2D planar arrays of oscillators with nearest neighbor coupling involving both inhibitory and excitatory species are developed, including bioinspired designs, such as Central Pattern Generators. We explore phenomena such as chemical computation, synchronization, oscillator death, and assess the number of attractors, as well as their basin of attraction, as a function of the topology of the network and the heterogeneity of the oscillators and their coupling strength.

Unstable and chaotic flow in shear thickening suspensions

Michiel Hermes, Ben M. Guy, Guilhem Poy, Wilson C. K. Poon, and Mike Cates

School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kindom

Shear thickening is a ubiquitous phenomenon in dense suspensions of hard particles. Although hydrodynamics have long been thought to be the cause of shear thickening recently theory, simulations and experiments have show that shear thickening in dense suspensions is caused by the formation of frictional contacts. Theory also predicts sigmoidal and backwards bending flow curves for a range of densities. I will show that there exist a range of stresses for which neither homogeneous flow, nor gradient or vorticity bands can be stable and thus that no stable flow is possible. I will show that the flow of corn starch is indeed unsteady for a range of stresses, as predicted by theory. I will show that there exist several regimes of unstable flow for different applied shear stress ranging from very regular to fully chaotic.

Dense Colloidal Suspensions in Microfluidic Flow: Size Segregation and Velocity Oscillations

Philipp Kanehl and Holger Stark

Institute of Theoretical Physics, TU Berlin, Germany

Colloids in suspension exhibit shear-induced migration towards regions of low viscous shear. In dense bidisperse colloidal suspensions under pressure driven flow large particles can segregate in the center of a microchannel and the suspension partially demixes [1]. In mono disperse suspensions, if the density is increased further, regular oscillations in flow velocity emerge [2].

To develop a theoretical understanding of these effects, we simulate hard spheres under pressure-driven flow in two and three dimensions using the mesoscale simulation technique of multi-particle collision dynamics. Generalizing an existing phenomenological model [3] to binary suspension, our theory accurately reproduces the segregated density profiles across the channel from our simulations. We present a detailed parameter study on how a monodisperse suspension enriches the channel center and quantitatively confirm the experimental observation that a binary colloidal mixture partially segregates into its two species. In particular, we always find a strong accumulation of large particles in the center.

Moreover, first results on velocity oscillations in suspensions near random close packing are presented. By analyzing our numerical data, we address the role of fluid permeation, colloidal friction, and channel confinement.

[1] D. Semwogerere, J. F. Morris, and E. R. Weeks, J. Fluid Mech. **581**, 437 (2007).

[2] L. Isa, R. Besseling, A. N. Morozov, and W. C. Poon, Phys. Rev. Lett. **102**, 058302 (2009).

[3] R. J. Phillips, R. C. Armstrong, R. A. Brown, A. L. Graham, and J. R. Abbott, Phys. Fluids **4**, 30 (1992).

Towards Artificial Living Materials

Michael P. Brenner

Harvard University, Cambridge, USA

Biological systems provide an inspiration for creating a new paradigm for materials synthesis. Imagine it were possible to create an inanimate material that could both perform some function, e.g. catalyze a set of reactions, and also self replicate. Changing the parameters governing such a system would allow the possibility of evolving materials with interesting properties by carrying out "mutation-selection" cycles on the functional outcomes. Although we are quite far from realizing such a vision in the laboratory, recent experimental advances in coating colloidal scale objects with specific glues (e.g. using complementary DNA strands) have suggested a set of theoretical models in which the possibilities of realizing these ideas can be explored in a controlled way. This talk will describe our ongoing efforts to explore these ideas using theory and simulation, and also small scale experiments.

Rheology of Particulate Systems with Attractive Interactions: Effect of Thermal Fluctuations and Dissipation

Ehsan Irani[1], Pinaki Chaudhuri[2], and Claus Heussinger[1]

[1] *Institute for Theoretical Physics, Georg-August University of Göttingen, Göttingen, Germany*
[2] *Institute of Mathematical Sciences, Tamil Nadu, India*

The rheology of a particulate system with attractive interactions is studied in two cases: in the presence of thermal fluctuations, and in the presence of a viscous dissipative force. In the athermal limit, attractive interactions result in a finite yield stress, an iso-static structure emerges below the jamming point and shear bands form in large enough systems. On the other hand, thermal fluctuations tend to rupture the local structure. The transition to the thermal-dominated regime is investigated and the rheology is explained in terms of the distance to the glass transition. Furthermore, the presence of the viscous force is observed to change the flow curve in a non-trivial way due to the competition between attractive and viscous force.

Shear-induced oscillatory states in binary mixtures of hard anisotropic particles

Rodrigo Lugo-Frías and Sabine H. L. Klapp

Institute of Theoretical Physics, Technical University Berlin, Berlin, Germany

Because of their interesting functional properties and technological applications, mixtures of anisotropic repulsive colloidal particles have been the subject of systematic studies over the last decade. Of particular interest is their rheological properties under the influence of external flow fields [1, 2]. In this work we study the flow induced oscillatory behavior of homogeneous and inhomogeneous binary mixtures of hard rod–like particles.

Using classical density functional theory (DFT) we develop a mesoscopic free energy functional for a binary mixture of hard rod-like particles in terms of a set of two Q-tensor order parameters, and their gradients, corresponding to each component of the system [3]. Given the equilibrium theory, we then investigate the shear-induced dynamics using an extension of the mesoscopic Doi–Hess theory [4] for different values of shear rate and concentration. Interestingly, the bulk of the system presents synchronized oscillatory states of the two components as well as in-plane symmetry breaking behavior [3]. Furthermore, we present first results of the spatial inhomogeneous response of the system.

[1] M. Golmohammadi and A. D. Rey, "Structure and phase transitions of carbonaceous mesophase binary mixtures under uniaxial extensional flow", Journal of Non-Newtonian Fluid Mechanics **165**, 698-711 (2010).

[2] C. Denniston, E. Orlandini, and J. M. Yeomnans, "Simulations of liquid crystals in Poiseuille flow", Computational and Theoretical Polymer Science **11**, 389-395 (2001).

[3] R. Lugo-Frías and S. H. L. Klapp, "Binary mixtures of hard rod-like colloids: mesoscopic equilibrium theory and shear-driven instabilities", in preparation, (2015).

[4] C. Pereira Borgmeyer and S. Hess, "Unified description of the flow alignment and viscosity in the isotropic and nematic phases of liquid crystals", Journal of Non-Equilibrium Thermodynamics **20**, 359-384 (1995).

Dynamics in bacterial biofilm communities

Knut Drescher

Max Planck Institute for Terrestrial Microbiology, Marburg, Germany

Bacteria frequently occupy densely populated surface-bound communities, known as "biofilms". It is largely unknown how bacteria organize their collective behavior inside biofilms, and how biofilms behave in natural environments. In this presentation, I will focus on how fluid physics shapes the dynamics of collective behaviors inside biofilms in geometrically complex environments. I will also show how biofilm communities avoid invasion by members of their own species and other species, to illustrate the rich interplay of bacterial cooperative behaviors in biofilm communities and physics.

Confined and shaped monolayers

Pascal Silberzan

Institut Curie, Paris, France

Cell monolayers routinely exhibit collective behaviors largely controlled by cell-cell interactions. In this context, confinement and boundary conditions play an important role in the organization and dynamics of these cell assemblies. Interestingly, many *in vivo* processes, including morphogenesis or tumor maturation, involve small populations of cells within a spatially restricted region.

We report experiments in which epithelial monolayers confined in circular disks exhibit low-frequency periodic radial displacement modes. When the boundary is removed, cells collectively migrate on the free surface. The essential characteristics of the collective dynamics in these two situations are well-accounted for by the same theoretical model in which cells are described as persistent random walkers which adapt their motion to that of their neighbors. In contrast, elongated fibroblasts that do not develop cell-cell adhesions self-organize until reaching a perfect nematic order upon confinement.

After days in culture, the confined epithelia develop a tridimensional structure in the form of a peripheral cell cord at the domain edge. Confinement by itself is therefore sufficient to induce morphogenetic-like processes including spontaneous collective pulsations, global orientation and transition from 2D to 3D.

Finally, culturing cell monolayers on cylindrical wires reveals some specific traits of the out-of-plane curvature on the dynamics and architecture of epithelia, independent on the lateral confinement.

How a *Volvox* Embryo Turns Itself Inside Out

Pierre A. Haas, S. Höhn, A. R. Honerkamp-Smith, P. Khuc Trong, and Raymond E. Goldstein

Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, United Kingdom

Deformations of cell sheets pervade early animal development, but they arise from an intricate interplay of cell shape changes, cell migration, cell intercalation, and cell division. We combine theory and experiment to explore what is perhaps the simplest instance of cell sheet folding: the "inversion" process in the green alga *Volvox*, whose embryos, in a process hypothesised to be driven by cell shape changes alone, must turn themselves inside out to complete their development. We use light sheet microscopy to reveal the intriguing dynamics of this process. An elastic model, in which cell shape changes correspond to local variations of intrinsic curvature and stretches of an elastic shell, reproduces the dynamics and sheds light on the underlying mechanics of inversion.

Actomyosin Force Generation and Pattern Formation

Stephan Grill

BIOTEC, TU Dresden, Germany
MPI-PKS, Dresden, Germany
MPI-CBG, Dresden, Germany

Morphogenesis is one of the great unknowns in Biology. Much is known about molecular mechanisms of regulation, but little is known about the physical mechanisms by which an unpatterned blob of cells develops into a fully structured and formed organism. The actomyosin cortex is a thin layer underneath the cellular membrane that can self contract, which drives many of the large-scale morphogenetic rearrangements that are observed during development. How this cortex reshapes and deforms, and how such morphogenetic processes couple to regulatory biochemical pathways is largely unclear. I will discuss two emergent physical activities of the actomyosin cytoskeleton, an active contractile tension and an active torque, both of which can serve to drive flows and large-scale chiral rotations of the actomyosin cytoskeleton. I will illustrate how active tension drive flows, how molecular constituents of the cortex affect flows, and how morphogenetic patterns can be formed by coupling regulatory biochemistry to active cortical mechanics. A particular focus will be the investigation of how compressive cortical flow drives the formation of an actin filament alignment pattern for generating a cleavage furrow for cytokinesis.

The tongue as an excitable medium

Gabriel Seiden[1, 2] and Sofia Curland[2]

[1] *Max Planck Institute for the Physics of Complex Systems, Dresden, Germany*
[2] *Weizmann Institute of Science, Rehovot, Israel*

Geographic tongue (GT) is a medical condition affecting approximately 2% of the population, whereby the tiny hairlike protrusions (papillae) covering the upper part of the tongue are lost due to a slowly expanding inflammation. The resultant dynamical appearance of the tongue has striking similarities with well known out-of-equilibrium phenomena observed in excitable media, such as forest fires, cardiac dynamics and chemically driven reaction-diffusion systems. We explore the dynamics associated with GT from a dynamical systems perspective, utilizing cellular automata simulations. Our results shed light on the evolution of the inflammation and suggest a practical way to classify the severity of the condition, based on the characteristic patterns observed in GT patients.

Large-scale synchronization of diffusively and superdiffusively moving oscillators

Robert Großmann[1], Fernando Peruani[2], and Markus Bär[1]

[1] *Physikalisch-Technische Bundesanstalt, Berlin, Germany*
[2] *Universite de Nice, Nice, France*

Motivated by observations of synchronization in chemical and biological systems composed of mobile entities, we study an ensemble of random walkers carrying internal noisy phase oscillators which are synchronized among the walkers by local interactions. We consider both normal diffusive motion and superdiffusion modeled by Lévy flights. This model system is equivalent to an ensemble of moving XY spins. Due to individual mobility, the temporal dynamics is, however, inherently a nonequilibrium process. By deriving a stochastic field theory, we link microscopic and macroscopic dynamics, particularly demonstrating that this nonequilibrium system can be mapped onto an effective equilibrium system. The theory is analyzed and compared to numerical Langevin simulations revealing a defect-mediated transition from incoherence to quasi long-range order for diffusing oscillators in two dimensions. In contrast, superdiffusion suppresses the emergence of topological defects thus inducing a continuous synchronization transition to long-range order in two dimensions.

Role of hydrodynamic interactions in phototactic algal suspensions

Philippe Peyla[1], Levan Jibuti[2], Ling Qi[1], and Salima Rafaï[1]

[1] *LIPHY – CNRS- University Grenoble Alpes, Grenoble, France*
[2] *Theoretische Physik I, University of Bayreuth, Bayreuth, Germany*

Some microalgae swim toward light sources: this property is known as phototaxis. Experimentally, we use this property to control the motion of microalgae within a flow using light [1]. The combination of flow vorticity and phototaxis results in a self-concentration of algae. Intermittent light exposure allows analysis of the dynamics of this phenomenon and of its reversibility. The redispersion of concentrated algae is also studied.

In order to model this phenomenon, three-dimensional (3D) numerical simulations are performed on suspensions composed of puller-like microswimmers in a flow or in a fluid at rest. The swimmers self-orient themselves regularly in a given direction in order to mimic phototaxis [2]. Simulations reproduce very well the experiments. Simulations also predict some clustering instability due to hydrodynamic interactions between microswimmers. This phenomenon is peculiar for pullers for which collective motions are usually not observed on such a short time scale.

[1] X. Garcia, S. Rafaï, and P. Peyla, *Light control of the flow of phototactic microswimmer suspensions*, Phys. Rev. Lett. **110**, 138106 (2013).

[2] L. Jibuti, L. Qi, C. Misbah, W. Zimmermann, S. Rafaï, and P. Peyla, *Self-focusing and jet instability of a microswimmer suspension*, Phys. Rev. E **90**, 063019 (2014).

Phase behaviour and hydrodynamics of active suspensions

Suzanne Fielding

Department of Physics, Durham University, Durham, United Kingdom

The talk will be divided into two parts. In the first part we report the results of simulations of a continuum model of active fluids in two spatial dimensions, between parallel confining walls that are either static or moving at fixed relative velocity. We focus on extensile materials and find that steady shear bands, previously shown to arise ubiquitously in 1D for the active nematic phase at small (or indeed zero) shear rate, are generally replaced in 2D by more complex flow patterns that can be stationary, oscillatory, or apparently chaotic. In the second part we report the results of a recent study to simulate with hydrodynamics a suspension of active disks squirming through a Newtonian fluid. We explore numerically the full range of squirmer area fractions from dilute to close packed and show that "motility induced phase separation" (MIPS), which was recently proposed to arise generically in active matter, and which has been seen in simulations of active Brownian disks, is strongly suppressed by hydrodynamic interactions. We give an argument for why this should be the case and support it with counterpart simulations of active Brownian disks in a parameter regime that provides a closer counterpart to hydrodynamic suspensions than in previous studies.

Dancing with *Chlamydomonas*

Raphael Jeanneret, Marco Polin, and Vasily Kantsler

Department of Physics, University of Warwick

The diffusive nature of the dynamics of particles in a fluid is due to the incessant collision between the molecules composing the fluid and the particles. This classical Brownian motion is a genuine equilibrium phenomenon where both the molecular species and the embedded particles are passive components driven only by thermal fluctuations. What about the same system where a dilute dispersion of active particles is added? These self-propelled particles will indeed stir the fluid in which the particles are embedded, giving them additional momenta and leading eventually to an enhanced diffusivity.

This kind of study has already been performed, among others, by Leptos *et al.* [1], where, using direct tracking of the trajectories, they looked at the enhanced diffusivity of micron-sized polystyrene beads embedded in a dilute solution of the model motile alga *Chlamydomonas Reinhardtii*. Through this microscopic measurement, they showed that the effective diffusivity is an affine function of the concentration of microorganisms: $D_{eff} = D_0 + \alpha\phi$, where D_0 is the equilibrium diffusivity and ϕ the volumetric fraction.

Here we look at the steady-state sedimentation profile of polystyrene beads as a function of the concentration of *Chlamydomonas*. The first result is that, even in this out-of-equilibrium system, the profile of density still decays exponentially, but the typical length scale of this exponential decrease is strongly affected by the micro-organisms. Indeed, this effective gravitational length is an affine function of the concentration of algae. This is not surprising since at equilibrium the gravitational length is directly proportional to the diffusion constant through the relation : $l_g = \frac{9\eta}{2R^2\delta\rho g} D_0$, with R is the radius of the particles, $\delta\rho$ is the density difference between the particles and the fluid, η the viscosity of the fluid and g the gravity constant. However, what is much more surprising is that the effective diffusion coefficient computed using our "macroscopic" measurement is one order of magnitude bigger than the one measured in [1] by direct tracking. During this talk, I will then discuss and explain this observed discrepancy, with the help of complementary experiments, consisting mainly of the direct tracking of the beads in a quasi-2D geometry in order to track them efficiently on long-time scales.

[1] K. C. Leptos *et al.*, Phys. Rev. Lett. **103**, 198103 (2009).

Thursday, 11:00 – 11:35 Invited talk

Hydrodynamic Collective Effects of Active Protein Machines

Alexander Mikhailov

Abteilung Physikalische Chemie, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

The cytoplasm and biomembranes in biological cells contain large numbers of proteins that cyclically change their shapes. They are molecular machines that can function as molecular motors or carry out various other tasks in the cell. Many enzymes also undergo conformational changes within their turnover cycles. We analyze the advection effects that non-thermal fluctuating hydrodynamic flows induced by active proteins have on other passive molecules in solution or membranes. We show that the diffusion constants of passive particles are enhanced substantially. Furthermore, when gradients of active proteins are present, a chemotaxis-like drift of passive particles takes place. In lipid bilayers, the effects are strongly nonlocal, so that active inclusions in the entire membrane contribute to local diffusion enhancement and the drift. All active proteins in a biological cell or in a membrane contribute to such effects and all passive particles, and the proteins themselves, will be subject to these effects.

Collective effects of hydrodynamic dipoles: enhancing particle diffusion

Matthew Dennison[1], Raymond Kapral[1, 2], and Holger Stark[1]

[1] *Institut für Theoretische Physik, Technische Universität Berlin, Germany*
[2] *University of Toronto, Toronto, Canada*

The cytoplasm and bio-membranes in cells contain proteins that can change shape cyclically and act as molecular motors. A recent theoretical study [1] has shown how these motors, by acting as force dipoles which generate hydrodynamic flows, can lead to an increase in the diffusion coefficient of a passive colloid. Furthermore, when there is a concentration gradient of motors, the colloid can even undergo a drift similar to diffusiophoretic motion.

We use a hybrid molecular dynamics and multi-particle collision dynamics simulation technique to study how the properties of randomly oscillating molecular motors in a fluid can control the diffusion behaviour of an immersed passive colloid. We model the motors as dumbbells consisting of two hard-sphere-like colloids connected by a Hookean spring. By stochastically switching the rest length of the spring the dumbbell will oscillate, creating a force dipole which gives rise to a flow field in the solvent. We show how both the frequency of the motor oscillations and the magnitude of the force generated, as well as the concentration of motors, can control the effects observed in Ref. [1].

Surprisingly, we find that for small forces the diffusion coefficient can decrease, as the dumbbells act as passive particles to increase the excluded volume of the system while the effects of the flow field are not sufficient to counteract this. For larger forces we find that when there is a homogeneous distribution of motors the diffusion coefficient of the passive particle can be substantially increased, consistent with Ref [1]. By setting a concentration gradient of the motors we also study how the diffusiophoretic drift can be controlled.

[1] A. S. Mikhailov and R. Kapral, to be published in PNAS, arXiv: 1503.02610v1.

Kinetic theory of self-driven particles: Invasion waves and correlation effects

Thomas Ihle

Institute for Physics, Ernst-Moritz-Arndt University Greifswald, Greifswald, Germany
Department of Physics, North Dakota State University, Fargo, ND, USA

Models of self-driven agents similar to the Vicsek model are studied by means of kinetic theory [1,2]. In these models, particles try to align their travel directions with the average direction of their neighbours. At strong alignment a globally ordered state of collective motion forms. An Enskog-like kinetic theory is derived from the exact equation for a Markov chain in phase space using Boltzmann's mean-field approximation of molecular chaos. The kinetic equation is solved numerically by a nonlocal Lattice-Boltzmann-like algorithm. Steep soliton-like waves are observed that lead to an abrupt jump of the global order parameter if the noise level is changed. The shape of the wave is shown to quantitatively agree within 3% with agent-based simulations at large particle speeds [3].This provides a mean-field mechanism to change the second-order character of the flocking transition to first order. At small densities and realistic particle speeds, the mean-field assumption of Molecular Chaos is invalid near the onset of collective motion, and correlation effects become relevant.

I will show how to self-consistently include correlation effects at the level of ring-kinetic theory [4]. Instead of just one kinetic equation, an additional equation for the time evolution of two-particle correlations will be derived. This equation is solved numerically for a homogeneous system and shown to be in excellent agreement with agent-based simulations in certain parameter ranges.

[1] T. Ihle, Phys. Rev. E **83**, 030901 (2011).

[2] Y. L. Chou *et al.*, Phys. Rev. E **86**, 021120 (2012).

[3] T. Ihle, Phys. Rev. E **88**, 040303 (2013).

[4] Y. L. Chou *et al.*, Phys. Rev. E **91**, 022103 (2015).

Cell motility, from the individual to the collective

Herbert Levine

Center for Theoretical Biological Physics, Rice University, Houston, TX, USA

We discuss recent research aimed at constructing computational approaches to the morphodynamics of moving cells. Initial work focused on cells moving on 2d surfaces, both keratocytes which adopt a canonical mesenchymal shape and *Dictyostelium* amoeba with pseudopod-based protrusions. To get closer to the full 3d problem of cells moving in tissues with both obstacles and guidance from the ECM, we will present extensions of this work to mesenchymal cells moving on patterned surfaces. Finally we discuss extending this model to consider collective cell motion, for example the observed rotational dynamics of cells placed in confined geometries.

Actin Waves in Fibroblasts: Noise-induced Circular Dorsal Ruffles

Erik Bernitt, Malte Ohmstede, Alexander Seupt, and Hans-Günther Döbereiner

Institut für Biophysik, Universität Bremen, Bremen, Germany

Circular dorsal ruffles are actin-dense structures on the dorsal side of fibroblast cells. We studied CDRs on heterogeneously shaped cells and on cells that we forced into disk-like morphology using micro-contact printing. We show that CDRs exhibit phenomena such as periodic cycles of formation, spiral patterns, and mutual wave annihilations that are in accord with an active medium description of CDRs. On cells of controlled morphologies, CDRs exhibit extremely regular patterns of repeated wave formation and propagation, whereas on random-shaped cells the dynamics seem to be dominated by the limited availability of a reactive species [1]. The duration of wave propagation is very well described by a simple FitzHugh-Nagumo model with noise. We monitor wave dynamics quantitatively as a function of buffer conditions. A micro-fluidic chamber allows to switch the external solution back and forth repeatedly. Finally, we characterize CDR geometry and ultrastructure employing high-resolution confocal microscopy as well as electron microscopy and find a dynamic granular actin organization resembling a flock.

[1] Erik Bernitt, Cheng Gee Koh, Nir Gov, and Hans-Günther Döbereiner, *Dynamics of Actin Waves on Patterned Substrates: A Quantitative Analysis of Circular Dorsal Ruffles*, PLoS ONE **10**(1): e0115857. doi:10.1371/ journal.pone.0115857 (2015).

Reproducing contact inhibition of locomotion probabilities of colliding cells migrating on micro-patterned substrates

Dirk Kulawiak[1], Brian A. Camley[2], Harald Engel[1], and Wouter-Jan Rappel[2]

[1] *Institut für Theoretische Physik TU Berlin, Berlin, Germany*
[2] *Center for Theoretical Biological Physics, UCSD, USA*

Contact inhibition of locomotion is the process where colliding cells stop migrating in the direction of the collision, repolarize and move away from the location of the collision. In recent experiments, micro-patterned substrates are used to restrict cell migration to linear paths such that collisions between polarized cells occur frequently and consistently. We reproduce the outcomes of collisions and their probabilities as seen in Scarpa *et al.* [1] using a phase field model with contact inhibition as described in [2]. We reveal a subtle balance between internal polarization, contact inhibition of locomotion and cell-cell-adhesion that controls cell migration on micro-patterned substrates.

[1] E. Scarpa, A. Roycroft, E. Theveneau, E. Terriac, M. Piel, and R. Mayor, A novel method to study contact inhibition of locomotion using micropatterned substrates, Biology Open **2**(9), 901 (2013). doi:10.1242/bio.20135504.

[2] B. A. Camley, Y. Zhang, Y. Zhao, B. Li, E. Ben-Jacob, H. Levine, and W.-J. Rappel, Polarity mechanisms such as contact inhibition of locomotion regulate persistent rotational motion of mammalian cells on micropatterns, Proc. Natl. Acad. Sci. USA **111**, 14770 (2014).

Collective dynamics of chemically-active sphere dimer motors

Mu-Jie Huang, Peter Colberg, and Raymond Kapral

University of Toronto, Toronto, Canada

Ensembles of chemically-active motors exhibit collective dynamics arising from coupling due to the interplay of direct intermolecular potentials, hydrodynamic interactions and chemical gradients. The talk will describe the continuum and microscopic bases for the propulsion of sphere dimer motors, with a focus on the concentration and flow fields that enter into the description of their active motion. In bulk solution, ensembles of such more show active self assembly and correlated dynamics whose properties will be discussed. If polymeric filaments are present in the solution, the chemically-powered motors tend bind to these filaments and move along them. Features of the collective dynamics of many motors on a filament will also be described.

Kibble-Zurek mechanism in colloidal monolayers: spontaneous symmetry breaking out of equilibrium

Sven Deutschländer, Patrick Dillmann, Georg Maret, and Peter Keim

Department of Physics, University of Konstanz, Konstanz, Germany

How does dimensionality affect phase transitions? Whereas nucleation of super-cooled fluids in 3D is a first order transition, the melting process in 2D system has been a matter of debate for long. Meanwhile the so called Kosterlitz-Thouless-Halperin-Nelson-Young-theory, predicting two continuous transitions is well accepted. It describes the transitions from a crystal to the high symmetry phases by the dissociation of two different kinds of topological defects, thus the translational and orientational order is not destroyed at the same temperature. The intermediate hexatic phase is a fluid but has six-fold orientational order.

Cooling the system at a finite rate offers the possibility to investigate spontaneous symmetry breaking out of equilibrium. Since continuous transitions are accompanied by critical slowing down of order parameter fluctuations, the system has to fall out of equilibrium in the vicinity of the transition. The freeze out time depends on the cooling rate at sets the length scale of symmetry broken domains. The scenario is described by the Kibble-Zurek mechanism which was originally used to describe symmetry breaking of the Higgs field shortly after Big-Bang or vortex formation in quantum fluids.

As colloidal systems are excellent model systems to observe phase transitions with single particle resolution, we were able to investigate the microscopic mechanisms of melting and freezing in and out of equilibrium. This was done by analyzing the time resolved trajectories of micrometer sized particles confined at an interface.

Abstracts: Posters

Two dimensional optical spectroscopy of Coulomb coupled colloidal quantum dots

Anke Zimmermann, Andreas Knorr, and Marten Richter

Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstrasse 36, EW 7-1, 10623 Berlin, Germany

Coulomb coupled colloidal quantum dots (QDs) provide a great flexibility for controlling their optical properties. Due to the Coulomb interaction between closely arranged colloidal QDs, new delocalized states are formed and the individual spectra of separated QDs are modified. The spatial arrangement of different colloidal QDs can be analyzed using two dimensional nonlinear optical spectroscopy, which allows a detailed investigation of the coupling mechanisms.

Since the Coulomb interaction depends on the spatial distance between the QDs and their relative dipole orientation to each other, the strength of the interdot coupling is varied for different spatial arrangements of colloidal QDs: The number of integrals necessary for the calculation of a two-particle Coulomb interaction can be reduced by using a generalized Poisson equation and a Green's function formulation for a fast calculation of Coulomb coupling elements. Without being restricted to specific symmetries, this method enables an inclusion of boundary conditions and arbitrary spatial dependent dielectric properties.

In particular for colloidal QDs in a solvent, the dielectric function differs inside the QD and in the solvent, which results in a spatially varying Coulomb coupling different form a homogenous medium.

To identify the effect of the spatially dependent Coulomb coupling on single excitons and biexcitons, double quantum coherence spectroscopy is used: Determining the third order optical response function of coupled colloidal QDs, the characteristic optical two dimensional spectra of QDs at different positions with varying orientations are calculated and analyzed.

Poster 2

Spatio-temporal propagation of nonclassical light in a coupled quantum dot-waveguide system

Kilian Kuhla, Andreas Knorr, and Marten Richter

Institut für Theoretische Physik, Berlin, Germany

Based on the need for new quantum technologies, propagation of nonclassical light in an optical waveguide doped with semiconductor quantum dots (QDs) constitutes a focus of current experimental and theoretical research. Important properties that influence propagating photons include their propagation delay, waveguide dispersion and optical nonlinearities of the waveguide. Here, we study the time- and space-resolved characteristics of the waveguide-QD-system in the few-photon-limit, e.g. for single photon and (entangled) photons pairs.

To describe an open system dynamics, we propose a density matrix formalism, based on spatial dependent photon operators, specifically suitable for the few photon limit including the possibility to treat all relevant pumping and dissipation mechanisms. Using a Lindblad formalism allows the inclusion of incoherent external pump processes, dephasing and decay processes for the field and the quantum dots. Overall the framework provides a closed set of equation of motion for the excitons in the quantum dot as well as the photon traveling in the waveguide.

The resulting equations are evaluated for different excitation conditions. In particular, the framework reproduces the classical limit, such as classical transmission and reflection of electromagnetic fields in a waveguide. As a typical example for the quantum limit, the interplay of dispersion and nonlinearity for single photon pulse is discussed.

Identification of Crossed Excitons and Observation of Exciton Dynamics in Dot-in-a-Well Structures

Mirco Kolarczik, Nina Owschimikow, Bastian Herzog, Florian Buchholz, Yücel Kaptan, and Ulrike Woggon

Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany

Semiconductors of the III-V family, e.g. gallium arsenide or indium arsenide are unique in the flexibility with which optical transition energies and densities of states can be designed. Not only can the energies be controlled through size, strain, and composition of the material, it is additionally possible to define the dimensionality of carrier confinement by nano-structuring. The variety of possible structures ranges from quantum dots (artificial atoms) to quantum wells, quantum wires or quantum rings. Coulomb interaction among carriers in these systems poses a major challenge for a theoretical description. Such interactions can give rise to crossed excitons (CEs), i.e. bound states of two carriers in different subsystems [1].

We experimentally investigate the non-equilibrium carrier dynamics in an InAs/GaAs system of mixed dimensionality, containing zero-dimensional quantum dots surrounded by a two-dimensional quantum well, and three-dimensional bulk. In all sub-systems, the dimensionality governs scattering and transition rates as well as the density of states. In a first set of experiments we find a direct excitation of quantum dots by far-off-resonant photons. This excitation can be attributed to CEs of quantum dot electrons and bulk holes. The transitions are persistent over a wide range of injection currents which makes them interesting for future applications [2]. In a second set, a thermal non-equilibrium carrier population is created by the selective excitation of a spectral subset of the quantum dot ground states. The time-evolution of the carrier population is traced in ultrafast pump-probe experiments and well described by a rate equation model considering CE states and inter-dot diffusion in the 2D subsystem. For the particular excitation conditions, the complex coupled rate equations describing the dynamics in the coupled 0D-2D potential can be reduced to a linear system and diagonalized. Exploiting this property, we simultaneously fit more than 170 experimental pump-probe curves. We find that electrons and holes do not move independently, but show a correlated behaviour mediated by Coulomb interactions [3].

[1] S. C. Kuhn and M. Richter, Phys. Rev. B **90**, 125308 (2014).

[2] N. Owschimikow, M. Kolarczik, Y. I. Kaptan, N. B. Grosse, and U. Woggon, Appl. Phys. Lett. **105**, 101108 (2014).

[3] M. Kolarczik, N. Owschimikow, B. Herzog, F. Buchholz, Y. Kaptan, and U. Woggon, Phys. Rev. B **91**, 235310 (2015).

Poster 4

Aspects of the Relationship between Non-Markovianity and Time-Dependent Driving

Sebastian Restrepo, Javier Cerrillo, and Tobias Brandes

Technische Universität Berlin, Berlin, Germany

An initial attempt to investigate the relationship between non-Markovian dynamics in open quantum systems and time-depending driving is presented. The posture on seeing Markovianity as divisibility of the dynamical map is adopted while the presence of an information back-flow is considered as a characteristic of non-Markovian systems and as a way to witness it. The models of a qubit driven by circularly polarized light and a qubit with time dependence frequency, both interacting with a bath of infinite bosonic modes at zero temperature, are considered. The results showed that for the circularly polarized driving there is no effect on the non-Markovianity of the system due to the driving only affecting the unitary part of the evolution. For the time dependent frequency qubit, using Floquet theory we concluded that it is possible to shift the dynamics of the system from a non-Markovian evolution presenting back-flow of information, to a Markovian one. The opposite case is also discussed and motivated.

Metal-semiconductor hybrids: Influence of the Förster coupling between the two quantum dots

T. Sverre Theuerholz, Alexander Carmele, Marten Richter, and Andreas Knorr

Institut für Theoretische Physik Technische Universität Berlin, Berlin, Germany

We investigate a hybrid system consisting of two semiconductor quantum dots and a metal nanosphere. The description includes coupling between the metal nanosphere and the two semiconductor quantum dots as well as the Förster coupling between the two quantum dots. All constituents of the hybrid system can be pumped optically.

As observables of the hybrid system, our focus is on the Rayleigh spectra as well as on the emission statistics, characterized by the second order correlation g^2-function. While the Rayleigh spectra are barely influenced by the Förster interaction between the two semiconductor quantum dots, the emission statistics is very sensitive to the Förster coupling between the two quantum dots. Although the Förster interaction between the two quantum dots is at least one order of magnitude smaller than the interaction between the quantum dots and the metal sphere, it is possible to design the emission statistics dramatically by varying the Förster interaction. Depending on the detuning to the external pump field, it is possible e.g. to strongly increase plasmon bunching. For a slightly different detuning the emission can be changed even qualitatively, from antibunching, to a coherent statistics and, by further increasing the Förster interaction between the two quantum dots, to bunching.

We are able to trace the influence of the Förster interaction on the emission statistics back to the newly formed states in the hybrid system: Due to the interaction between the metal sphere and the semiconductor quantum dots new eigenstates of the coupled system are formed. This model, without the Förster interaction between the quantum dots, already shows antibunching, coherent statistic and moderate bunching. Including additionally the Förster interaction between the quantum dots causes shifts of the new eigenstates and a redistribution of the dipole moments of the hybrid system. Therefore, the Förster interaction can be used to further influence the emission statistic of the hybrid system.

Poster 6

Micro-hydrodynamics of Active Filament

Abhrajit Laskar and Ronojoy Adhikari

Institute of Mathematical Sciences, Chennai, India

Ability to generate and sustain motion through continuous conversion of biochemical energy into mechanical work characterizes living organisms. At the microscopic level, this autonomous motility is achieved through spontaneously generated biomimetic motions by active filaments like flagella and cilia. Recent *in vitro* experiments have reproduced similar behavior, where a remarkable cilia-like beating phenomenon has been observed in a motor-microtubule assembly. Here we study an effective nonequilibrium model of an active filament in a low Reynolds number environment, incorporating hydrodynamic interactions (HI). Numerical simulations show that this model active filament exhibits biomimetic motions observed in the experiments. A stability analysis, disregarding HI, fails to reproduce oscillatory modes, highlighting the crucial role played by HI.

Front Propagation in Sinusoidally Modulated Channels and Tubes

Alexander Ziepke, Steffen Martens, and Harald Engel

Technische Universität, Berlin, Germany

Propagation of traveling fronts in channels and tubes with periodically modulated cross section Q(x) is investigated. In the fashion of our recent paper [1], we apply asymptotic analysis for a small changing rate of the channel's and tube's cross section to reduce the dimensionality of the problem. Within this approach, the Neumann boundary condition translates into a boundary-induced advection term. Treating the latter as a weak perturbation, we derive an equation of motion for the front position [2]. In particular, we study numerically the propagation of fronts through sinusoidally modulated channels and tubes with period length L using the Schlögl model as an example. We map the reaction-diffusion equation for the corrugated geometry onto a regular grid and, finally, solve it numerically. The numerical simulations demonstrate that our analytical results predict properly the nonlinear dependence of the propagation velocity on the ratio of the spatial period of the cross section's modulation to the intrinsic width of the front, including propagation failure.

[1] S. Martens, J. Löber, and H. Engel, Phys. Rev. E **91**, 022902 2015.

[2] J. Löber and H. Engel, Phys. Rev. Lett. **112**, 148305, 2014.

Poster 8

Non-equilibrium size segregation in evaporating films of colloidal mixtures

Andrea Fortini, Ignacio Martin-Fabiani, Joseph L. Keddie, and Richard P. Sear

Department of Physics, University of Surrey, Guildford, United Kingdom

Paints start as a thin layer of a colloidal suspension on a substrate. The water then evaporates, concentrating the suspension until a dry layer of packed particles is deposited. We use Brownian Dynamics simulations in combination with experiments to investigate this process for a binary mixture of colloidal particles.

In simulations, we find that solvent evaporation can induce non-equilibrium size segregation. The big particles are depleted from the region close to the air-water interface, while a layer of small particles accumulate at that interface. This depletion of the large particles occurs over a wide range of size ratios and evaporation velocities. At low concentrations of small particles, this depletion effect disappears and the big particles accumulate at the air-water interface in either a crystalline or disordered structure. In this regime, the small particles fill the interstitial spaces of the large particles. The experimental results agree qualitatively with the simulation findings.

This segregation is a novel example of non-equilibrium phase separation. It may also be useful if stratified coatings are needed. For example, if the smaller particles are harder, they will form a scratch-resistant upper layer to the coating.

Superadiabatic Forces in Brownian Many-Body Dynamics

Andrea Fortini[1], Daniel de las Heras[2], Joseph Brader[3], and Matthias Schmidt[2]

[1] *Department of Physics, University of Surrey, Guildford, United Kingdom*
[2] *Theoretische Physik II, Physikalisches Institut, Universitaet Bayreuth, Bayreuth, Germany*
[3] *Soft Matter Theory, University of Fribourg, Fribourg, Switzerland*

Theoretical approaches to nonequilibrium many-body dynamics generally rest upon an adiabatic assumption, whereby the true dynamics is represented as a sequence of equilibrium states. Going beyond this simple approximation is a notoriously difficult problem. For the case of classical Brownian many-body dynamics, we present a simulation method that allows us to isolate and precisely evaluate superadiabatic correlations and the resulting forces. Application of the method to a system of one-dimensional hard particles reveals the importance for the dynamics, as well as the complexity, of these nontrivial out-of-equilibrium contributions. Our findings help clarify the status of dynamical density functional theory and provide a rational basis for the development of improved theories.

Poster 10

Modulated Filament Structures in a Confined Non-Equilibrium Chemical System: Experiment, Simulation, and Theory

Arash Azhand and Harald Engel

Institut für Theoretische Physik, TU Berlin, Berlin, Germany

A scroll ring (SR) represents one particular example for a three-dimensional nonlinear vortex that occurs in media under non-equilibrium conditions. The vortex center can be considered as a torus and will be denoted as the SR filament.

We studied the evolution of SR filaments in thin layers of the photosensitive Belousov-Zhabotinsky (PBZ) media experimentally [1], and numerically within the three-variable modified complete Oregonator (MCO) model [2]. Both the experimental and the numerical results indicate the emergence of modulated filaments with distinct geometric shapes (ellipsis, triangles, squares, etc.). These modulated filament structures most likely emerge due to perturbations being present intrinsically (interaction between spiral waves within the SR) and extrinsically (interaction with no-flux boundaries).

A theoretical approach by A. Goriely and M. Tabor, that is based upon a nonlinear stability analysis of the dynamical Kirchhoff equations (DKE) for thin elastic ring-shaped ribbons [3], predicts the modulated filaments which we observed in the experiments and in numerical simulations. Moreover, it is worth emphasizing that a conservative theory (DKE) is able to explain evolution of filament structures arising in dissipative (PBZ) media.

[1] A. Azhand, J. F. Totz, and H. Engel, Europhys. Lett. **108**, 10004 (2014).

[2] H.-J. Krug, L. Pohlmann, and L. Kuhnert, J. Phys. Chem. **94**, 4862 (1990).

[3] A. Goriely and M. Tabor, Nonlin. Dyn. **21**, 101 (2000).

Field-controlled phase transitions between two-dimensional assemblies of magnetic Janus particles

Gabi Steinbach[1, 2], Dennis Nissen[3], Manfred Albrecht[3], Sibylle Gemming[1, 2], and Artur Erbe[1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, D-01328 Dresden, Germany*
[2] *Institute of Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany*
[3] *Institute of Physics, University of Augsburg, D-86159 Augsburg, Germany*

Self-assembly of functionalized colloidal particles allows studying collective ordering phenomena in real space via video microscopy. Via sophisticated bottom-up fabrication particles can be specially designed for the specific ordering process, which is under investigation. By the example of ferromagnetic Janus particles we present how directional interparticle interactions can be exploited for controlled and reversible formation of various two-dimensional structures. The spherical particles used in our experiments are hemispherically coated with a ferromagnetic thin film which exhibits perpendicular magnetic anisotropy. The coating leads to a rotationally symmetric magnetization distribution of the particles.

They spontaneously self-assemble into branched clusters with non-collinear magnetic order. Such a structure enables the construction of a rich phase diagram via static self-assembly in two dimensions. Formations of branched clusters, compact clusters, linear chains and separate particles can be formed and reversibly interconverted via constant and low-frequency external magnetic fields. The diversity of these structures is a consequence of two facts: First the higher order magnetic moments of the spatially extended particles allows the tuning of critical transitions between different structures. Second, the hemispherical capping causes an excluded volume by the uncapped hemisphere which leads to the non-collinear magnetic arrangement in the absence of or in low external fields. The possibility of controlled interconversion between these diverse structures allows studying the dynamics of the transitions by taking time-resolved measurements. This provides insight in the interactions between the particles, which depend on the local configuration of the clusters built from the particles. We show that the characteristics of the obtained phase diagram adds fundamentally new possibilities to controlled self-assembly based on the collective ordering of spherical particles.

Poster 12

Double layer formation of driven magnetic Janus like particles

Arzu B. Yener and Sabine H. L. Klapp

Institut für Theoretische Physik, TU Berlin

Motivated by the synthesis of novel magnetic colloidal particles [1-3], we investigate a model of spherical particles with a permanent dipole moment laterally shifted out of their geometric centres. The total pair interaction is modeled by a short ranged soft core potential and the point dipole potential. Using Molecular Dynamics simulations, we investigate the equilibrium self-assembly process due to the shift.

Further, we apply a rotating magnetic field to the same system successively increasing the shift. For zero shift, which is the conventional model for dipolar systems, it is known that the particles interact via an averaged dipolar potential which causes the particles to organize in layered structures if they are synchronized with the external field [4]. Investigating if layer formation is possible also in the shifted system, and especially asking to which extend the condition of synchronization is required, we derive the averaged dipolar potential for shifted dipoles. Moreover, by using Langevin Dynamics simulations, we show that the effect of the shift is two-fold. First, the layers occurring in the non-shifted system break down upon increase of the shift. Second, the averaged dipolar potential imposes additional conditions which lead to qualitatively different patterns. Specifically, we observe the formation of bilayers which feature a high degree of orientational as well as of translational order. We thus observe the nonequilibrium formation of crystalline structures.

[1] J. Yan, M. Bloom, S. C. Bae, E. Luijten, and S. Granick, Nature **491**, 578 (2012).

[2] D. Zerrouki, J. Baudry, D. Pine, P. Chaikin, and J. Bibette, Nature **455**, 380 (2008).

[3] S. Sacanna, L. Rossi, and D. Pine, J. Am. Chem. Soc. **134**, 6112 (2012).

[4] S. Jäger, and S. H. L. Klapp, Soft Matter **7**, 6606 (2011).

Simple shear flows of frictionless, hard and soft spheres

Dalila Vescovi and Stefan Luding

University of Twente, Enschede, The Netherlands

This work focuses on the simple shear flow, under steady conditions, of an ideal granular material, composed of identical, frictionless spheres, ranging form very hard to very soft. The simple shear configuration is the simplest geometry which allows to analyze the rheology of complex fluids like granular materials, i.e., to study the constitutive relations which relate stresses and deformations and their rates.

The parameters particle stiffness is related to the existence of persistent deformations of the particles and finite contact durations. When the particle stiffness is small, two effects influence the particles motion even at small densities: multiple collisions occur and collisions are not instantaneous but take a finite time during which a part of the energy, the elastic potential energy, is stored due to the persistent deformations of the particles [1].

A series of Discrete Element Method simulations are performed on a simple shear flow configuration, in order to investigate the role of particle stiffness (and contact duration) at different densities.

Numerical simulations performed by using perfectly rigid spheres have shown that pressure, shear stress and granular temperature diverge when the volume fraction approaches a critical value, as predicted by the standard kinetic theory [2]. In contrast, our results with soft particles show that steady, constant volume flows are possible also at volume fractions larger than the critical value. The measured stresses display a dependence on the particle stiffness at volume fractions larger than the critical value, that is when the density of the flow is large enough to allow the development of enduring contacts and particle deformations. These results are in qualitative agreement with those obtained using frictional particles [4,5] and provide an insight into the behavior of frictionless grains at large densities and their related phase transition collective dynamics.

[1] S. Luding, Towards dense, realistic granular media in 2D. Nonlinearity **22**, R101 (2009).

[2] D. Vescovi, D. Berzi, P. Richard, and N. Brodu, Physics of Fluids **26**, 053305 (2014).

[3] N. Mitarai and H. Nakanishi, Phys. Rev. E **75**, 031305 (2007).

[4] A. Singh, V. Magnanimo, K. Saitoh, and S. Luding, New J. Phys. **17**, 043028 (2015).

[5] S. Chialvo, J. Sun, and S. Sundaresan. Phys. Rev. E **85**, 021305 (2012).

Poster 14

Nonequilibrium Dynamical States in Driven Colloids

Ellen Fischermeier, Matthieu Marechal, and Klaus Mecke

Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Erlangen, Germany

The influence of external potentials on liquid crystals is of great importance in many technological and biological applications. We study the arguably most simple model system for a colloidal liquid crystal, a system of hard spherocylinders of aspect ratio $L/D = 5$, with Langevin Dynamics simulations.

In our study, we apply an external potential that induces a preferred direction of alignment of the spherocylinders that rotates in the x-y-plane. In experiments such a potential could be realized, e.g., by electric fields. We discover a variety on nonequilibrium dynamical states that depend strongly on the driving frequency of the external potential and the packing fraction of the system.

At low frequencies and high packing fractions, the particles collectively follow the external potential and give rise to a single peak in the angular distribution of particle orientations. With increasing driving frequency more and more particles are no longer able to follow the external field. This leads first to a periodic modulation of the intensity of the peak in the angular distribution, then to the appearance of a second peak and finally, for the highest driving frequencies, results again in a single peak, that no longer follows the external field but oscillates in the x-y-plane.

For low packing fractions and low frequencies, the behavior is identical to the one at higher packing fractions. For high frequencies, however, a single peak is observed that follows the external field, though the individual particles do not.

With the Langevin Dynamics simulation we can explain these collective dynamical states by the trajectories of the individual particles.

[1] E. Fischermeier *et al.*, J. Chem. Phys. **141**(19), 1-7 (2014).

Fluctuating Lattice Boltzmann simulations of microswimmers

Felix Winterhalter, Matthieu Marechal, and Klaus Mecke

Theoretische Physik 1 FAU, Erlangen, Germany

During the last years the interest in microswimmers has steadily increased. To gauge the effect of hydrodynamical interactions between the microswimmers and to obtain information about the flow of the solvent around the swimmer, a simulation technique with a good model for the solvent is required. Our method of choice is fluctuating Lattice Boltzmann simulations that include thermal fluctuations, which are often important for synthetic swimmers. The currently existing particle simulation using the software WaLBerla will be expanded to encompass self-propelled microswimmers to study their behavior in a variety of confining geometries and external fields.

Poster 16

Fission and fusion scenarios for magnetic microswimmer clusters

Francisca Guzman-Lastra, Andreas Kaiser, and Hartmut Löwen

Institut für Theoretische Physik II – Soft Matter, Heinrich-Heine-Universität Düsseldorf, Germany

Fission and fusion processes of particle clusters occur in many areas of physics and chemistry from subnuclear to astronomical length scales. Here we study fission and fusion of magnetic microswimmer clusters as governed by their hydrodynamic and dipolar interactions. Rich scenarios are found including scattering processes which are ubiquitous in nature. Those different scenarios depends crucially on whether the swimmer is a neutral swimmer, a pusher or a puller. Our predictions are obtained by computer simulations and they are verifiable in experiments on active colloidal Janus particles and magnetotactic bacteria.

Inhomogeneous flow induced dynamics of nematic colloidal binary mixtures

Henning Reinken, Rodrigo Lugo-Frias, and Sabine H. L. Klapp

Institute of Theoretical Physics, Technical University of Berlin, Berlin, Germany

Due to their presence in a wide variety of biological contexts and technological applications, the study of homogeneous [1] and inhomogeneous mixtures of anisotropic particles has increased considerably in recent years. One important question in that context is how their rheological properties change when they are driven out of equilibrium [2,3].

In the scope of linear irreversible thermodynamics [4,5] we derive the equations governing the non-equilibrium dynamics of an anisotropic binary mixture of hard rods. These relations couple the average orientation of both species in the system with the flow field. Particularly, for a one component system, we investigate the space-time dependence of the velocity field in an already aligned state.

[1] R. Lugo-Frias and S. H. L. Klapp, in preparation (2015).

[2] M. Forest *et al.*, J. Non-Newtonian Fluid Mech. **155**, 130 (2008).

[3] M. Golmohammadi and A. D. Rey, J. Non-Newtonian Fluid Mech. **165**, 698 (2010).

[4] S. R. de Groot and P. Mazur, Non-Equilibrium Thermodynamics, Ed. Dover (1984).

[5] S. Hess and I. Pardowitz, Z. Naturforsch. A **36a**, 554 (1981).

Poster 18

Polymer looping in crowded solutions of active particles

Jaeoh Shin

Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

We study the dynamics of polymer chains in a bath of self-propelled, active particles (SPP) by using molecular dynamics simulations in two dimensions. We analyze the polymer looping properties versus the particle activity and investigate how it changes the chain conformational statistics. Namely, the SPPs make flexible chains more expanded but compact stiffer polymers, in agreement with the previously published results. Larger activities of SPPs yield a higher "effective temperature" of the bath and thus facilitate the looping kinetics of a passive polymer chain. We explicitly compute the looping probability and looping time in a wide range of model parameters. We analyzed the motion of a tracer and the polymer center of mass in the presence of active particles based on time averaged mean square displacements. Our results are applicable to studying polymer dimensions and looping at constantly fluctuating and often actively driven conditions inside biological cells.

The effect of hydrodynamics and electrostatics on particle diffusion in polymer networks

Johann Hansing[1], Xiaolu Zhang[2], Jason E. DeRouchey[2], and Roland R. Netz[1]

[1] *Fachbereich für Physik, Freie Universität Berlin, Berlin, Germany*
[2] *Department of Chemistry, University of Kentucky, Lexington, USA*

Transport processes within biological polymer networks, such as mucus and the extracellular matrix, play an important role in the human body, where they serve as a filter for the exchange of molecules and nanoparticles. Such polymer networks are complex and heterogeneous hydrogel environments that regulate diffusive processes through finely tuned particle- network interactions. We present a theoretical study to examine the role of electrostatics and hydrodynamic interactions on the basic mechanisms governing the diffusion of charged probe molecules inside model polymer networks. The diffusing particle is modeled as a Brownian hard sphere and a Stokesian Dynamics approach is employed to include hydrodynamic interactions. A number of experimentally observed phenomena attributed to nonsteric interactions between hydrogel polymers and diffusing particle are naturally reproduced by our model. Our simulations reveal how hydrodynamics are critical to reproduce certain effects, but electrostatics and steric interactions are often sufficient to produce simulation behavior that is in qualitative agreement with experiments.

Poster 20

Dynamical density functional theory for mixtures of active and passive colloids

Josua Grawitter and Holger Stark

Technische Universität Berlin, Berlin, Germany

Mixtures of self-propelling microorganisms and equally sized colloids exhibit useful behaviour such as "herding" [1] and targeted accumulation [2] of the passive colloids. We study these phenomena using an extension of classical dynamical density functional theory. The method combines a free energy functional for hard-core particles derived from fundamental measure theory with a flux expression accounting for active motion.

[1] J. Stenhammar, R. Wittkowski, D. Marenduzzo, and M. E. Cates, Phys. Rev. Lett. **114**, 018301 (2015).

[2] N. Koumakis, A. Lepore, C. Maggi, and R. Di Leonardo, Nat. Commun. **4**, 2588 (2013).

Transport coefficients of suspensions of spherical particles

Karol Makuch

University of Warsaw, Warsaw, Poland

Investigation of the transport properties of colloidal suspensions is an important statistical physics subject. The history started over a century ago, when Einstein calculated the effective viscosity of a dilute hard-sphere suspension. Nowadays there is no satisfactory method of calculations of the transport coefficients even for the intermediate volume fractions of the suspension, about 25%. The obstacle here is to deal with the hydrodynamic interactions which are of long-range and many-body character, and particles in close configuration in suspension strongly influence their motion.

We introduce a novel method of calculations of the transport coefficients of suspensions such as the effective viscosity or the sedimentation coefficient. The starting point of our statistical physics considerations is the expression for the transport properties introduced by Felderhof, Ford and Cohen. According to their formula, the transport coefficients are represented by the cluster expansion. They also identified terms in the cluster expansion which lead to the Saito formula for the effective viscosity of suspensions, which is an analog of the famous Clausius-Mossotti formula for the dielectric constant describing a dielectric system.

We perform the analysis of their cluster expansion and perform its renormalization. It leads to a rigorous formula for the transport coefficients which we call the ring expansion. In analogy to the Clausius-Mossotti approximation based on the cluster expansion, we generalize the Clausius-Mossotti approximation. The generalization of the Clausius-Mossotti approximation is motivated by the structure of our ring expansion. The transport coefficients of suspension such as the effective viscosity and the sedimentation coefficient obtained within our generalized Clausius-Mossotti approximation are compared to the results of the numerical simulations and other methods for the volume fractions of suspensions up to 45%. To calculate the transport properties within the generalized Clausius-Mossotti approximation, the volume fraction and the two-particle correlation function are needed as an input.

Poster 22

Active particles in complex environments

Maria Zeitz and Holger Stark

Technische Universität Berlin, Germany

From the perspective of physics biological microswimmers such as bacteria can often be viewed as self-propelled active particles. Since bacteria often live in colonies and inhabit porous or crowded environments, we examine the collective dynamics of such self-propelled particles in a complex environment.

Active Brownian Particles suspended in a fluid provide a simple model for swimming microorganisms. ABPs have an intrinsic speed and perform rotational as well as translational diffusion. They can undergo phase separation, where they separate into a dense, crystalline and a gas-like phase. The phase transition depends on the total area fraction of active particles in the fluid and on the Peclet number which compares the advective transport to the diffusive transport.

We aim to understand, how a complex environment of randomly placed fixed obstacles promotes this phase transition by providing nucleation sites. Moreover, in a second step we will study the dynamical properties of the dense phase.

Non-Gaussian polymers described by alpha-stable chain statistics: Model, effective interactions in binary mixtures and application to on-surface separation

Maciej Majka

Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland

The Gaussian chain model is a classical description of polymers, providing the insight into many aspects of polymer physics, ranging from the size of a single particle to the phase behavior of multicomponent mixtures. However, it is known that the adsorption to a surface or the non-Gaussian persistence length distribution can result in the power-law shape of the underlying chain statistics and the breakdown of Gaussian model. In our research [1] we study the properties of such non-Gaussian polymers. First, we add another context for our research by showing that the presence of the power-law type spatial correlations in the thermal noise (e.g. in the near phase transition regime) can also induce the heavy tailed chain statistics via the spontaneous unfolding effect [2]. Further, we introduce the alpha-stable chain model based on the alpha-stable Levy distributions. Similarly to the Gaussian case, the alpha-stable chain model provides multiple analytical results with respect to the segments distribution, chain-chain interaction potential and effective interactions in binary mixtures. This last problem is studied via our recently developed analytical approach [3], which leads to the generalization of spinodal decomposition condition for Gaussian particles. This result is finally applied to compare the "in the bulk" and "on the surface" separation of polymer blends, which allows us to predict the parameters for homogeneous versus inhomogeneous adsorption from polymer blends.

[1] M. Majka and P. F. Góra, Phys. Rev. E **91**(5), 052602 (2015).

[2] M. Majka and P. F. Góra, Phys. Rev. E **86**(5), 051122 (2012).

[3] M. Majka and P. F. Góra, Phys. Rev. E **90**(3), 032303 (2014).

Poster 24

Nonequilibrium dynamics of Polydisperse Lattice-Gas

Pablo de Castro and Peter Sollich

Department of Mathematics, King's College London, Strand, London, WC2R 2LS, United Kingdom

When the constituent particles of a many body system exhibit variation in terms of some attribute such as their size, shape or charge, then that system is termed "polydisperse". Occurring, as it does, in soft matter systems as diverse as colloids, liquid crystals and polymers, the phenomenon of polydispersity is both widespread and basic. However, owing to the complexity that polydispersity imparts to a system, gaining an understanding of its physical consequences represents a considerable challenge. Starting from the Polydisperse Lattice-Gas Model [1], where the polydisperse attribute controls the strengths of interaction between particles (and the hydrodynamics of the background solvent is manifested only via its possible effects on mediating particle-particle interactions), in this work we develop and analyse a set of mean-field kinetic equations in order to improve our understanding of the phase separation dynamics in polydisperse fluids. We are particularly interested in testing Warren's proposal of a two-timescale scenario [2] for polydisperse phase separation dynamics, e.g. in the regime of spinodal decomposition. We consider two different choices for the rates of the (vacancy-mediated) particle jumps between two neighbouring sites: the first is an Arrhenius Law, with activation to a barrier state where the jumping particle is removed from the system, whereas the second choice consists in using the well-known Glauber rates. In the second case, we argue by analogy with work on binary systems [3] that a further mild approximation to the mean-field kinetics is useful to enforce consistency with the mean-field equilibrium conditions for the Polydisperse Lattice Gas Hamiltonian. For both choices of rates we show that a factorisation for the mean-field particle currents (previously studied for binary mixtures with Arrhenius rates [4, 5]) extends to multi-component mixtures and hence in particular to polydisperse systems. We then provide a systematic numerical test of the proposed two-timescale scenario for polydisperse phase separation dynamics.

[1] N. B. Wilding, P. Sollich, and M. Buzzacchi, Phys. Rev. E **77**, 011501 (2008).

[2] P. B. Warren, Phys. Chem. Chem. Phys. **1**, 2197 (1999).

[3] S. Puri, Chap. 1 in Kinetics of Phase Transitions (CRC Press, 2009) pp. 1-61.

[4] M. Plapp and J.-F. Gouyet, Phys. Rev. Lett. **78**, 4970 (1997).

[5] M. Plapp and J.-F. Gouyet, EPJ B **9**, 267 (1999).

Controlling the dynamics of complex fluids by time-delayed feedback

Peter Kalle and Holger Stark

Institut für Theoretische Physik, TU Berlin, Berlin, Germany

Soft materials or complex fluids strongly respond to external fields and thereby show prominent non-equilibrium structure formation. We explore different control strategies to manipulate complex liquids and induce novel motional flow patterns. Applying specific control strategies such as feedback control to shape and engineer the flow of Newtonian and complex fluids on the micron scale virtually is an unexplored field.

A complex fluid with an inherent nonlinearity occurs when a small amount of long-chain polymers is added to a Newtonian fluid. This results in elastic instabilities and even elastic turbulence. A prominent way of modeling such a complex fluid is the so-called Oldroyd B model. We study a time-delayed feedback scheme applied to this model in a two-dimensional circular geometry. The idea is that the inherent nonlinearities will generate novel spatio-temporal patterns in combination with the applied delayed feedback scheme. We present results from linear stability analysis and supplement them by numerical calculations. A further step is to study whether we can stabilize unstable periodic solutions, as first envisaged by Pyragas.

Poster 26

Local transport via density excitations in confined colloidal mixtures under shear flow

Sascha Gerloff, Tarlan A. Vezirov, and Sabine H. L. Klapp

Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Driving crystalline surfaces against each other displays a vast variety of complex non-linear dynamics [1]. For small driving forces, the dynamics of the surfaces are dominated by a local transport mechanism provided by topological defects. In order to understand the frictional response of the surfaces, the dynamics and properties of these topological defects are of great interest.

Here, we investigate the sliding dynamics of colloidal crystal layers of two different species, which are induced by a strong slit-pore confinement and stabilized by a constant de-mixing force. The colloids interact via a combined soft-sphere and screened *Coulomb* interaction with parameters suitable to model ludox-silica particles. As in previous studies of the one-component system, the colloids are driven by a planar shear flow [2,3].

Overdamped *Brownian* dynamics are employed, allowing a detailed examination of the local dynamics of the topological defects. These are identified as clusters of high and low local density, forming density excitations. One key result is the connection between the velocity of the layer and the velocity as well as amount of density excitations, displaying a strong dependence of the velocity of the layer on the amount of density excitations. Furthermore, novel dynamics for low local density excitations are observed, which can be explained by elastic deformations of the adjacent colloidal crystal layers. Moreover, we are interested in the general influence of the deformable substrate, altering the dynamics and nucleation of topological defects.

Potentially by obtaining a deep understanding of this mechanism, we aim to develop feedback control strategies, allowing to alter the frictional response of the considered system and therefore following previous studies on applying feedback control schemes to soft matter systems [3].

[1] T. Bohlein, J. Mikhael, and C. Bechinger, Nat. Mater. **11**, 126-130 (2012).

[2] T. A. Vezirov and S. H. L. Klapp, Phys. Rev. **88**, 052307 (2013).

[3] T. A. Vezirov, S. Gerloff, and S. H. L. Klapp, Soft Matter **11**, 406-413 (2015).

Active particles in confined geometries

Sebastian Ehrig[1], Jonathan Ferracci[1, 2], Richard Weinkamer[1], John Dunlop[1], and Peter Fratzl[1]

[1] *Max-Plank Institute of Colloids and Interface, Potsdam, Germany*
[2] *Humboldt University of Berlin, Berlin, Germany*

Systems containing out of equilibrium particles exhibit an interesting range of motion patterns that can be found in a variety of systems spanning multiple length scales. Prominent examples can be found in living and non-living systems ranging from the microscopic (e.g. bacteria suspensions, nematic fluids) to the macroscopic scale (e.g. schools of fish). However, not much is known about how the geometry of the confinement effects the motion patterns in these active systems. We therefore develop active particle simulations in confined geometries to explore the impact of spatial boundaries on the collective behaviour of active matter that gives rise to the formation of large scale patterns. Our work shows the importance of physical cues such as geometry on the emergence of patterns in active systems that could have significant implications in understanding phenomena in biology and physics.

Poster 28

Dynamics of active Brownian particles in heterogeneous media

Zahra Mokhtari and Annette Zippelius

Institut für Theoretische Physik, University of Göttingen, Germany

We study numerically a model of self-propelled polar disks in suspension. The active particles are driven along their axes, which are subject to rotational noise. We study the dynamics of such particles in a heterogeneous medium composed of frozen particles as obstacles, that are modeled as hard disks and are randomly distributed in the system. We furthermore study different regimes of motion due to the interplay of activity and interaction with the spatial heterogeneities and show that a superdiffusive regime emerges in the high damping limit, whose characteristics can be controlled by the rotational noise amplitude.

Concentration profiles of actin-binding molecules in motile cells

Martin Falcke

Max Delbrück Center for Molecular Medicine, Robert-Rössle-Str. 10, 13156 Berlin

Motile cells form lamellipodia in the direction of motion, which are flat membrane protrusions containing an actin filament network. The network flows rearward relative to the leading edge of the lamellipodium due to actin polymerization at the front. Thus, actin binding molecules are subject to transport towards the rear of the cell in the bound state and diffuse freely in the unbound state. We analyse this reaction-diffusion-advection process with respect to the concentration profiles of these species and provide an analytic approximation for them. Network flow may cause a depletion zone of actin binding molecules close to the leading edge. The existence of such zone depends on the free molecule concentration in the cell body, on the ratio of the diffusion length to the distance bound molecules travel rearward with the flow before dissociating, and the ratio of the diffusion length to the width of the region with network flow and actin binding. Our calculations suggest the existence of depletion zones for the F-actin cross-linkers filamin and α-actinin in fish keratocytes (and other cell types), which is in line with the small elastic moduli of the F-actin network close to the leading edge found in measurements of the force motile cells are able to exert.

Poster 30

Inference of chemotactic strategies of *E. coli* and *Pseudomonas putida* using Kramers-Moyal coefficients

Oliver Pohl[1], Marius Hintsche[2], Carsten Beta[2], and Holger Stark[1]

[1] *Technische Universität Berlin, Berlin, Germany*
[2] *Universität Potsdam, Potsdam, Germany*

Bacteria like *Escherichia coli* and *Pseudomonas putida* move with alternating runs and tumbles that occur with a mean tumble rate. In the presence of gradients of a chemoattractant, they both perform chemotaxis. We set up a general time-continuous random-walk model that describes runs and tumbles as a stochastic process of the bacterium's swimming direction and speed. The dynamics includes rotational Brownian motion and shot noise which initiates tumbling events based on chemical gradients.

By analyzing experimental data of swimming trajectories, we infer the parameters of our model. For this purpose generalized Kramers-Moyal coefficients are calculated for our shot-noise model and matched to the ones determined from the experimental trajectories. In contrast to common tumbling recognition algorithms no free parameters need to be preset. By analyzing trajectories in chemical concentration fields we first show that our method is capable of identifying "temporal chemotaxis", typical for prokaryotic cells which use information of the near past to detect and move along chemical gradients. Second, we find evidence that *E. coli*, in contrast to *P. putida*, uses an additional turning bias during tumble events when moving in chemical gradients.

Vortex arrays and mesoscale turbulence of self-propelled particles

Robert Großmann[1], Pawel Romanczuk[2, 3], Markus Bär[1], and Lutz Schimansky-Geier[3]

[1] *Physikalisch-Technische Bundesanstalt, Berlin, Germany*
[2] *Princeton University, Princeton, USA*
[3] *Humboldt-Universität zu Berlin, Berlin, Germany*

Inspired by the Turing mechanism for pattern formation, we propose a simple self-propelled particle model with short-range alignment and antialignment at larger distances. It is able to produce orientationally ordered states, periodic vortex patterns, and mesoscale turbulence, which resembles observations in dense suspensions of swimming bacteria. The model allows a systematic derivation and analysis of a kinetic theory as well as hydrodynamic equations for density and momentum fields. A phase diagram with regions of pattern formation as well as orientational order is obtained from a linear stability analysis of these continuum equations. Microscopic Langevin simulations of self-propelled particles are in agreement with these findings.

Poster 32

A kinetic model for description of collective dynamics of magnetotactic bacteria

Fabian Koessel and Sara Jabbari-Farouji

Institute of Physics, Johannes Gutenberg-Universität Mainz

Magnetotactic bacteria contain built-in intracellular magnetic nano-crystals that result in a permanent magnetic dipole [1]. Hence, they can be driven externally by a magnetic field. This magneto-sensing feature, known as magnetotaxis, can be exploited in bio-technological applications such as targeted drug-delivery.

Additionally, magnetotactic bacteria also respond to oxygen gradient in the environment. The interplay between self-propulsion, chemical sensing and magnetic drive, leads to emergence of novel patterns of collective dynamics and travelling magneto-aerotactic bands [2, 3] which are not well-understood. Previous models of magneto-aerotaxis [4] are a 1D approximation to the motion of the bacteria and do not take into account the thermal fluctuations and hydrodynamic interactions of magnetotactic bacteria with the suspending fluid. To account for these effects, we present a 3D kinetic theory for transport of bacteria that is based on Smoluchowski equation for magnetic self-propelled particles coupled to macroscopic Stokes equation describing the flow field created as a result of self-propulsion of the bacteria. The effects of external magnetic field and oxygen gradient on spatio-temporal dynamics and transport properties of magnetotactic bacteria are investigated using a linear stability analysis and numerical simulations.

[1] R. B. Frankel, D. A. Bazylinski, and B. L. Taylor, *Magneto-aerotaxis in marine coccoid bacteria*, Biophys. J. **73**, 994 (1997).

[2] C. T. Lefevre, M. Bennet, L. Landau, P. Vach, D. Pignol, D. A. Bazylinski, R. B. Frankel, S. Klumpp, and D. Faivre, *Diversity of magneto-aerotactic behaviors and oxygen sensing mechanisms in cultured magnetotactic bacteria*, Biophys. J. **107**, 527 (2014).

[3] M. Bennet, A. McCarthy, D. Fix, M. R. Edwards, F. Repp, P. Vach, J. W. C. Dunlop, M. Sitti, G. S. Buller, S. Klumpp, and D. Faivre, *Influence of Magnetic Fields on Magneto-Aerotaxis*, PLOS ONE 9, e101150 (2014).

[4] M. J. Smith, P. E. Sheehan, and L. J. Whitman, *Quantifying the Magnetic Advantage in Magnetotaxis*, Biophys. J. **91**, 1098 (2006).

Actin based cell motility; Phase field modeling of gel-like cytoskeleton and highly dynamic leading edge membrane.

Setareh Dolati and Martin Falcke

Max Delbrück Center for Molecular Medicine, Berlin, Germany

Phase field method has been widely used for modeling of cell migration. Actin polymerization and myosin contraction control the movement in different models. Current models for single cell migration include stokes flow inside the cell body and diffusion reaction equations for actin filaments and myosin. We introduce more detail on the dynamics of a region juxtaposed to the leading edge membrane: A highly dynamic semi-flexible region (SR) of the actin network close to the leading edge plus binding to and dissociation from the membrane of filaments. We keep the gel-like behavior for the cell body. Temporal solution of this model agrees well with experimental data. To investigate the morphodynamics, we use the phase field method to describe the gel body of the cell. The dynamics of the SR couples to the gel by via force and velocity boundary conditions. Our goal is to understand the morphodynamics of the single cell including oscillations and waves on the membrane.

Poster 34

The Role of Rotation Induced Polymorphic Transitions during Tumbling of an *E. coli*

Tapan Chandra Adhyapak and Holger Stark

Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

The nature of cell movement of a peritrichous bacterium such as *E. coli* crucially depends on the level of self-organization of several rotating flagella emanating from the cell body. When all the flagella rotate in the same sense, counter body movement, hydrodynamic and steric interactions together with an intricate balance of elasticity of the flagella cause them to synchronize and form a single bundle leading to propulsion in a straight line [1]. Such straight runs of the bacterium frequently terminate at relatively short lived tumbling events, during which one or more of the flagella reverse rotate and leave the bundle disrupting uniform motion and causing the bacterium to change its course. During the same time, the reverse rotated flagella are observed to undergo a series of rotation-induced polymorphic transitions between different flagellar states [2]. These transitions, in addition to hydrodynamic interactions and elasticity, are believed to be important in re-orientating the bacterium. However, the detailed process is complex and very little understood. We investigate the tumbling strategy of an *E. coli* modeling its propulsion using an extended continuum theory of elasticity in the presence of hydrodynamic interactions. We examine, in particular, the role of the rotation-induced polymorphic transitions of flagella during such processes and study how important are these in comparison to the contribution from hydrodynamic and steric interactions.

[1] T. C. Adhyapak and H. Stark, arXiv:1504.02310 (2015).

[2] R. Vogel and H. Stark, Phys. Rev. Lett. **110**, 158104 (2013).

Nonequilibrium assembly of filaments: analytical results

Thomas Niedermayer[1, 2] and Reinhard Lipowsky[2]

[1] *Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany*
[2] *Max Planck Institute of Colloids and Interfaces, Potsdam, Germany*

The coupling of stochastic growth and shrinkage of one-dimensional structures to random aging of the constituting subunits defines the simple association-dissociation-aging process (SADAP) which captures the essential features of the nonequilibrium assembly of cytoskeletal filaments. While previously employed mean field methods fail, we found an ansatz for the full master equation enabling the analytical study of SADAPs. A recursion relation allows for the calculation of the collective dynamics with increasing accuracy and in excellent agreement with stochastic simulations.

Poster 36

Trail-Following in Simple Models of Bacteria

Till Kranz, Anatolij Gelimson, and Ramin Golestanian

Rudolf-Peierls-Centre for Theoretical Physics, Oxford, United Kingdom

A number of bacterial species are known to leave trails on surfaces. It is generally believed that bacteria will follow each others trails. Based on a simple model for bacterial motility and the bacterium-trail interaction, we discuss how the trail profile affects bacterium-trail encounters and the stability of trail-following behaviour.

Participants

Adhyapak, Tapan Chandra	TU Berlin, Germany tapan.c.adhyapak@tu-berlin.de	94
Alirezaeizanjani, Zahra	Universität Potsdam, Germany alirezae@uni-potsdam.de	
Azhand, Arash	TU Berlin, Germany azhand@itp.tu-berlin.de	70
Bär, Markus	PTB Berlin, Germany Markus.Baer@ptb.de	
Bernitt, Erik	PTB Berlin, Germany eb@biophysik.uni-bremen.de	54
Beta, Carsten	Universität Potsdam, Germany beta@uni-potsdam.de	
Blaschke, Johannes	TU Berlin, Germany johannes.blaschke@tu-berlin.de	16
Bodenschatz, Eberhard	MPIDS Göttingen, Germany Eberhard.Bodenschatz@ds.mpg.de	14
Brandes, Tobias	TU Berlin, Germany tobias.brandes@tu-berlin.de	
Brenner, Michael P.	Harvard University, USA brenner@seas.harvard.edu	38
Buser, Maximilian	TU Berlin, Germany maximilianbuser@itp.tu-berlin.de	
Castro, Pablo de	King's College London, UK pabloodecastro@gmail.com	84
Chaté, Hugues	CEA Saclay, France hugues.chate@cea.fr	17
Dennison, Matthew	TU Berlin, Germany matthew.dennison@yahoo.co.uk	51
Dolati, Setareh	Max Delbrück Center Berlin, Germany setareh.dolati@mdc-berlin.de	93
Drescher, Knut	MPI Marburg, Germany k.drescher@mpi-marburg.mpg.de	41
Eckert, Julia	TU Berlin, Germany julia.eckert@tu-berlin.de	
Ehrig, Sebastian	MPI Potsdam, Germany ehrig@mpikg.mpg.de	87
Engel, Harald	TU Berlin, Germany Harald.Engel@TU-Berlin.de	

Erbe, Artur	Helmholtz-Zentrum Dresden-Rossendorf, Germany a.erbe@hzdr.de	71
Falcke, Martin	Max Delbrück Center Berlin, Germany martin.falcke@mdc-berlin.de	89
Ferracci, Jonathan	MPI Potsdam, Germany Jonathan.Ferracci@mpikg.mpg.de	
Fielding, Suzanne	Durham University, UK suzanne.fielding@durham.ac.uk	48
Fischermeier, Ellen	Universität Erlangen-Nürnberg, Germany ellen.fischermeier@fau.de	74
Fortini, Andrea	University of Surrey, UK a.fortini@surrey.ac.uk	68, 69
Fraden, Seth	Brandeis University, USA fraden@brandeis.edu	35
Gemming, Sibylle	Helmholtz-Zentrum Dresden-Rossendorf, Germany s.gemming@hzdr.de	
Gerloff, Sascha	TU Berlin, Germany s.gerloff@tu-berlin.de	86
Golestanian, Ramin	University of Oxford, UK ramin.golestanian@physics.ox.ac.uk	24
Grawitter, Josua	TU Berlin, Germany josua.grawitter@physik.tu-berlin.de	80
Grill, Stephan	TU Dresden & MPI Dresden, Germany stephan.grill@biotec.tu-dresden.de	44
Großmann, Robert	PTB Berlin, Germany grossmann@physik.hu-berlin.de	46, 91
Guzman-Lastra, Francisca	Heinrich-Heine-Universität Düsseldorf, Germany francisca.guzman@thphy.uni-duesseldorf.de	76
Hansing, Johann	Freie Universität Berlin, Germany johannh@zedat.fu-berlin.de	79
Haas, Pierre	University of Cambridge, UK P.A.Haas@damtp.cam.ac.uk	43
Hauser, Marcus J. B.	Otto-von-Guericke-Universität Magdeburg, Germany marcus.hauser@ovgu.de	13
Heidenreich, Sebastian	PTB Berlin, Germany sebastian.heidenreich@ptb.de	21
Hermes, Michiel	University of Edinburgh michielhermes@colloids.nl	36
Hintsche, Marius	Universität Potsdam, Germany marius.hintsche@uni-potsdam.de	15

Horbach, Jürgen	Heinrich-Heine-Universität Düsseldorf, Germany horbach@thphy.uni-duesseldorf.de	26
Ihle, Thomas	Ernst-Moritz-Arndt-Universität Greifswald, Germany thomas.ihle@ndsu.edu	52
Irani, Ehsan	Georg-August-Universität Göttingen, Germany ehsan.irani@theorie.physik.uni-goettingen.de	39
Jabbari-Farouji, Sara	Johannes Gutenberg-Universität Mainz, Germany sjabbari@uni-mainz.de	92
Jaurigue, Lina	TU Berlin, Germany linajaurigue@mailbox.tu-berlin.de	33
Jeanneret, Raphael	University of Warwick, UK r.p.jeanneret@warwick.ac.uk	49
Kalle, Peter	TU Berlin, Germany p.kalle@mail.tu-berlin.de	85
Kanehl, Philipp	TU Berlin, Germany philipp.kanehl@campus.tu-berlin.de	37
Kapral, Raymond	University of Toronto, Canada rkapral@chem.utoronto.ca	56
Katuri, Jaideep	MPI Stuttgart, Germany katuri@is.mpg.de	22
Keeling, Jonathan	University of St Andrews, UK jmjk@st-andrews.ac.uk	30
Keim, Peter	Universität Konstanz, Germany peter.keim@uni-konstanz.de	57
Klapp, Sabine	TU Berlin, Germany klapp@physik.tu-berlin.de	
Knorr, Andreas	TU Berlin, Germany andreas.knorr@physik.tu-berlin.de	
Kolarczik, Mirco	TU Berlin, Germany Mirco.Kolarczik@tu-berlin.de	63
Kranz, Till	University of Oxford, UK kranz@physics.ox.ac.uk	96
Kruse, Karsten	Universität des Saarlandes, Germany k.kruse@physik.uni-saarland.de	12
Kuhla, Kilian	TU Berlin, Germany kilianku@physik.tu-berlin.de	62
Kuhr, Jan-Timm	TU Berlin, Germany jan-timm.kuhr@tu-berlin.de	
Kulawiak, Dirk	TU Berlin, Germany h.engel@physik.tu-berlin.de	55

Laskar, Abhrajit	Institute of Mathematical Sciences Chennai, India abhra@imsc.res.in	66
Levine, Herbert	Rice University, USA herbert.levine@rice.edu	53
Löber, Jakob	TU Berlin, Germany jakob@physik.tu-berlin.de	19
Lozano, Celia	MPI Stuttgart, Germany c.lozano@physik.uni-stuttgart.de	25
Lugo-Frías, Rodrigo	TU Berlin, Germany lugo-frias@mailbox.tu-berlin.de	40
Majka, Maciej	Jagiellonian University, Poland maciej.majka@uj.edu.pl	83
Makuch, Karol	University of Warsaw, Poland kmakuch@fuw.edu.pl	81
Menon, Karthik	TU Berlin, Germany karthikmenon.13@gmail.com	
Mikhailov, Alexander	FHI Berlin, Germany mikhailov@fhi-berlin.mpg.de	50
Mokhtari, Zahra	Georg-August-Universität Göttingen, Germany zahra.mokhtari@theorie.physik.uni-goettingen.de	88
Niedermayer, Thomas	PTB Berlin & MPI Potsdam, Germany thomas.niedermayer@mpikg.mpg.de	95
Orland, Henri	CEA Saclay, France henri.orland@cea.fr	29
Palacci, Jérémie	University of California San Diego, USA palacci@physics.ucsd.edu	23
Peyla, Philippe	University Grenoble Alpes, France philippe.peyla@ujf-grenoble.fr	47
Pohl, Oliver	TU Berlin, Germany oliver.pohl@tu-berlin.de	90
Prabhakara, Kaumudi	MPIDS Göttingen, Germany khp35@cornell.edu	
Reinken, Henning	TU Berlin, Germany henning.reinken@campus.tu-berlin.de	77
Restrepo, Sebastian	TU Berlin, Germany s.restrepo55@me.com	64
Richter, Marten	TU Berlin, Germany mrichter@itp.tu-berlin.de	
Rivas, Nicolas	Helmholtz Institute Erlangen-Nürnberg, Germany nicorivas@gmail.com	28

Sano, Masaki	The University of Tokyo, Japan sano@phys.s.u-tokyo.ac.jp	20
Schaaf, Christian	TU Berlin, Germany cschaaf@itp.tu-berlin.de	
Schöll, Eckehard	TU Berlin, Germany schoell@physik.tu-berlin.de	
Schwille, Petra	MPI Martinsried, Germany schwille@biochem.mpg.de	11
Seiden, Gabriel	MPI Dresden, Germany seiden@pks.mpg.de	45
Seyrich, Maximilian	TU Berlin, Germany seyrich@tu-berlin.de	
Shin, Jaeoh	MPI Dresden, Germany jshin@pks.mpg.de	78
Silberzan, Pascal	Institut Curie, Paris, France pascal.silberzan@curie.fr	42
Skarmeta, Melissa	TU Berlin, Germany meliskamo@gmail.com	
Speck, Thomas	Johannes Gutenberg-Universität Mainz, Germany thomas.speck@uni-mainz.de	18
Stark, Holger	TU Berlin, Germany holger.stark@tu-berlin.de	
Steinbach, Gabi	TU Chemnitz, Germany stga@hrz.tu-chemnitz.de	
Strasberg, Philipp	TU Berlin, Germany phist@physik.tu-berlin.de	34
Straube, Arthur	Humboldt-Universität zu Berlin, Germany straube@physik.hu-berlin.de	31
Theuerholz, T. Sverre	TU Berlin, Germany theuerholz@itp.tu-berlin.de	65
Tierno, Pietro	Universitat de Barcelona, Spain ptierno@ub.edu	27
Totz, Carl Hendrik	TU Berlin, Germany cht@physik.tu-berlin.de	
Vescovi, Dalila	University of Twente, The Netherlands d.vescovi@utwente.nl	73
Vidal, Estefania	MPIDS Göttingen, Germany tefavidal@gmail.com	
Winterhalter, Felix	Universität Erlangen-Nürnberg, Germany felix.winterhalter@fau.de	75

Wubs, Martijn	Technical University of Denmark, Denmark mwubs@fotonik.dtu.dk	32
Yener, Arzu B.	TU Berlin, Germany arzu.yener@itp.tu-berlin.de	72
Zeitz, Maria	TU Berlin, Germany maria.zeitz@tu-berlin.de	82
Ziepke, Alexander	TU Berlin, Germany ziepke@itp.tu-berlin.de	67
Zimmermann, Anke	TU Berlin, Germany anke@itp.tu-berlin.de	61
Zorkot, Mira	University of Oxford, UK mira.zorkot@physics.ox.ac.uk	

Impressum

NECD15 is organized by the research training group GRK1558, which studies nonequilibrium collective dynamics in hard and soft condensed matter as well as in biological systems. Our research concentrates on

- nonlinear transport and quantum optics in semi-conductors
- collective dynamics in dispersions of colloidal particles and molecular machines
- self-organization and nonlinear waves in active media.

Research Training Group GRK 1558

Technische Universität Berlin
Institut für Theoretische Physik
Hardenbergstraße 36
10623 Berlin
Germany

www.itp.tu-berlin.de/grk1558

Conference homepage:

www.itp.tu-berlin.de/necd15

The conference is kindly supported by:

- Deutsche Forschungsgemeinschaft (DFG)
- Technische Universität Berlin
- GRK 1558

Conference booklet

Jan-Timm Kuhr & Rodrigo Lugo-Frías

Number of participants:	105
Total number of contributions:	83
Number of invited talks:	23
Number of contributed talks:	24
Number of posters:	36

	Monday, October 5	Tuesday, October 6	Wednesday, October 7	Thursday, October 8
Breakfast	7:00 – 8:50	7:00 – 9:00	7:00 – 9:00	7:00 – 9:00
8:50 – 9:00	Opening			
9:00 – 9:35	Schwille	Palacci	Fraden	Peyla
9:35 – 10:10	Kruse	Golestanian	9:35 – 9:55 Hermes	Fielding
10:10 – 10:30	Hauser	Lozano	9:55 – 10:15 Kanehl	Jeanneret
Coffee break 10:30 – 11:00			10:15 – 11:00	Check-Out hotel
11:00 – 11:35	Bodenschatz	Horbach	Brenner	Mikhailov
11:35 – 11:55	Hintsche	Tierno	Irani	Dennison
11:55 – 12:15	Blaschke	Rivas	Lugo-Frías	Ihle
Lunch 12:15 – 2:00				
2:00 – 2:35	Chaté	Orland	Drescher	Levine
2:35 – 3:10	Speck	Keeling	Silberzan	2:35 – 2:55 Bernitt
3:10 – 3:30	Löber	Straube	Haas	2:55 – 3:15 Kulawiak
Coffee break 3:30 – 4:00				3:15 – 3:45
4:00 – 4:35	Sano	Wubs	Grill	3:45 – 4:20 Kapral
4:35 – 4:55	Heidenreich	Jaurigue	Seiden	4:20 – 4:55 Keim
4:55 – 5:15	Katuri	Strasberg	Großmann	4:55 Closing remarks
Poster session and buffet	6 – late	6 – late	6:30 – 9:30	
Dinner (optional)			Dinner on board	

Timetable NECD15

GRK1558
research training group