DY 3: Active Matter A (joint session DY/CPP)

Time: Monday 9:30–12:45 Location: H20

Invited Talk DY 3.1 Mon 9:30 H20

Collective behavior and self-organisation of active granular particles — •Thorsten Pöschel, Michael Engel, Christian Scholz, and Harol Torres — Friedrich-Alexander-Universität Erlangen-Nürnberg

Biological organisms and artificial active particles self-organize into swarms and patterns. Open questions concern the design of emergent phenomena by choosing appropriate forms of activity and particle interactions. A particularly simple and versatile system are 3D-printed robots on a vibrating table that can perform self-propelled and self-spinning motion. Here we study a mixture of minimalistic clockwise and counter-clockwise rotating robots, called rotors. Our experiments show that rotors move collectively and exhibit super-diffusive interfacial motion and phase separate via spinodal decomposition. On long time scales, confinement favors symmetric demixing patterns. By mapping rotor motion on a Langevin equation with a constant driving torque and by comparison with computer simulations, we demonstrate that our macroscopic system is a form of active soft matter.

C. Scholz, T. Pöschel, Phys. Rev. Lett. 118, 198003 (2017)
C. Scholz, M. Engel, T. Pöschel, Nature Comm. 9, 931 (2018)
C. Scholz, S. D'Silva, T. Pöschel, New J. Phys. 18, 123001 (2016)
C. Scholz, T. Pöschel, Revista Cubana de Física 34, 69 (2017)

DY 3.2 Mon 10:00 H20

Approximating microswimmer dynamics by active Brownian motion: Energetics and efficiency — •Jannik Ehrich and Marcel Kahlen — Institut für Physik, Carl von Ossietzky Universität, 26111 Oldenburg, Germany

We consider the dynamics of a microswimmer and show that they can be approximated by active Brownian motion. The swimmer is modeled by coupled overdamped Langevin equations with periodic driving. We compare the energy dissipation of the real swimmer to that of the active Brownian motion model finding that the latter can massively underestimate the complete dissipation. This discrepancy is related to the inability to infer the full dissipation from partial observation of the complete system. We introduce an efficiency that measures how much of the dissipated energy is spent on forward propulsion.

[1] J. Ehrich and M. Kahlen, arXiv:1809.07235 (2018)

DY 3.3 Mon 10:15 H20

Magnetocapillary Microswimmers — •Maxime Hubert[1,2], Galien Grosjean[2], and Nicolas Vandewalle[2] — [1]PULS group, Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]GRASP Lab, CESAM UR, University of Liège, Liège, Belgium

The study of artificial microswimmers is of major interest in many area of physics, from the understanding of microorganisms swimming strategies to applications in microfluidic and micromanipulation. While there exists numerous theoretical studies on microswimmers, experimental realizations are technologically challenging. We focus in this presentation on a simple system made of three soft ferromagnetic particles trapped at air-water interfaces and self-assembling in triangles. Complex behaviors can arise under a time-dependent magnetic field. In particular, those assemblies can undergo deformations in non-time-reversible sequences, a necessary condition for low Reynolds number locomotion. Because of their controllability, such structures can be used for capture, transport and release of a microcargo, or the mixing of fluids at low Reynolds number. During this talk, the key mechanism for the collective motion of the beads is described from a numerical point of view and a model for their dynamics is discussed, opening the way for optimal control and efficiency of experimental magnetocapillary microswimmers.

DY 3.4 Mon 10:30 H20

Self-assembly of dipolar active Brownian particles in two dimensions — •Guo-Jun Liao and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

We computationally study the self-assembly behavior of self-propelled Brownian particles with additional dipole-dipole interactions, stemming from a point dipole in the particle center. The propulsion direction of each particle is parallel to its dipole moment. At low densities and small dipolar coupling, the system undergoes a transition from a homogeneous state to a state with finite-sized (and orientationally disordered) clusters, when the particle motility is increased. Such cluster formation could be regarded as the asymptotic behavior of conventional active Brownian particles [1]. For strongly coupled dipolar colloids and zero motility, the model exhibits gel-like structures. On increasing particle motility, we observe a transition into a state with orientationally-ordered, finite-sized clusters. We analyze this state via the cluster size distribution and the net orientation. We also propose a mechanism to describe the emergence of such clusters.

Reference:
[1] G.-J. Liao and S. H. L. Klapp, Soft Matter 14, 7873 (2018)

DY 3.5 Mon 10:45 H20

Experimental optimization of escape strategies in active systems. — •Hugo Wendehenne, François Lavergne, and Clemens Bechinger — Department of Physics, University of Konstanz, 78464 Konstanz, Germany

Groups formed by living organisms frequently react to external perturbations which can be repulsive (incoming predator) or attractive (presence of food). These responses are a combination of individuals reacting directly to the perturbation and collective mechanisms within the group. However, it is unclear whether collective interactions are a real benefit for an individual to escape from a repulsive perturbation. Here, we show that a change of the individuals' motilities and polarities in response to their visual perception of a perturbation leads to an effective escaping motion. Experimentally, this is demonstrated using active particles whose propulsion velocities and orientations are individually light-controlled by an external feedback-loop. We show that for a single active particle reacting to the perturbation within a restricted field of view, there is an increase of its rotational diffusion. The escape dynamics is characterized by ballistic transport, which is maximized for an optimal width of the particle's field of view. Interestingly, for a multi-particle system where individuals interact with their peers using a cohesion-based mechanism, we show that the escaping motion becomes more efficient. We expect this escaping mechanism to be relevant for cases where the perturbation is mobile, such as prey-predator interactions.

DY 3.6 Mon 11:00 H20

Dynamics and configurations of active polymers — •Paolo Malgaretti — Max Planck Institute for Intelligent Systems, Stuttgart, Germany

We study the dynamics and conformation of polymers composed by active monomers. By means of Brownian dynamics simulations we show that, when the direction of the self-propulsion of each monomer is aligned with the backbone, the polymer undergoes a coil-to-globulelike transition, highlighted by a marked change of the scaling exponent of the gyration radius. Concurrently, the diffusion coefficient of the center of mass of the polymer becomes essentially independent of the polymer size for sufficiently long polymers or large magnitudes of the self-propulsion. These effects are reduced when the self-propulsion of the monomers is not bound to be tangent to the backbone of the polymer. Our results, rationalized by a minimal stochastic model, open new routes for activity-controlled polymers and, possibly, for a new generation of polymer-based drug carriers[1].

[1] V. Bianco, E.Locatelli, P. Malgaretti PRL 121, 217802 (2018)

15 min. break

DY 3.7 Mon 11:30 H20

Collapse Dynamics of Polymers with Vicsek-like Activity — •Subhajit Paul[1], Suman Majumder[1], Subir K Das[2], and Wolfhard Janke[1] — [1]Institute for Theoretical Physics, University of Leipzig, Leipzig, Germany. — [2]Theoretical Sciences Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur P.O., Bangalore, India

Many biologically active systems can effectively be understood within the framework of active matter models in statistical physics. In this regard, even modeling a single component Lennard-Jones-type fluid with Vicsek-like activity shows both rich phase and dynamical behavior. Motivated by this we construct a flexible bead-spring polymer model with Vicsek-like activity of the monomer beads. We pay particular emphasis on exploring the pathways of its collapse, following a quench from a high-temperature random coil state into a low-temperature phase where the equilibrium phase is a compact globule in the passive limit of the model. In the active case, however, our results from molecular dynamics simulations reveal that depending upon the strength of activity there is a rich phase behavior of the model that ranges from compact globule to dumbbells. On the nonequilibrium dynamics front, we compare our results with the passive polymer case, from the perspective of various scaling laws related to the collapse time, cluster coarsening, etc.

DY 3.8 Mon 11:45 H20

Collective guiding of self-acoustophoretic particles in complex environments* — Tobias Nitschke and •Raphael Wittkowski — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany

Using self-propelled microparticles for medical applications like targeted drug delivery has been a dream for many decades. With the recent discovery of self-acoustophoretic particles, which move when they are exposed to ultrasound, a new type of particles with a biocompatible propulsion mechanism has become available. It turned out that these particles can be made from biocompatible materials and be equipped with mechanisms for the encapsulation and release of drugs. However, the hitherto insufficient capabilities for controlling the collective motion of the particles remained as a big obstacle preventing far-reaching medical applications.

In this talk, we present a method that allows to guide a large number of self-acoustophoretic particles collectively to a prescribed target region. The method is based on combining a moving focused ultrasound beam with a synchronized time-dependent magnetic field. Our method is harmless to patients and works even in complex environments like a patient's vasculature, when the particles are distributed throughout the body, and without information about the positions or orientations of the particles. Furthermore, we present a particle design that is particularly advantageous for applications.

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DY 3.9 Mon 12:00 H20

Emergent biomechanics in growing bacterial colonies — •Anupam Sengupta — Physics of Living Matter Group, Physics and Materials Science Research Unit, University of Luxembourg

Bacterial colonies, known to mediate key ecological and industrial processes, constitute a class of active matter within which geometry, order, and topology emerge spontaneously over the lifespan of a colony. Although numerous studies have been carried out on growing colonies, so far we have lacked a comprehensive biomechanical framework that could capture the cell-to-colony dynamics and the consequences thereof. In this talk I will present recent results [1] obtained by combining micro-scale experiments, molecular dynamics simulations, and continuous modeling, that capture the continuous evolution of the geometry, order and topology in a growing colony of non-motile strain of E.coli bacteria. We reveal how steric forces between neighboring cells (favoring cell alignment), compete with the extensile stresses due to the cell growth (reducing the local order), leading to emergent biomechanics within the growing colony: spontaneous hydrodynamic flows, anisotropy of internal stresses, and emergent motility due to non-motile cells. The results indicate at activity-driven cell-cell communications preceding biofilm formation, and can be extended beyond bacterial communities, for instance, to study mammalian cells, many of which exist as non-motile elongated phenotypes.

[1] Geometry and Mechanics of Microdomains in Growing Bacterial Colonies: Z. You, D. Pearce, A. Sengupta*, and L. Giomi*, Phys. Rev. X 8, 031065, 2018.

DY 3.10 Mon 12:15 H20

Phase transitions in huddling emperor penguins — •Alexander Winterl[1], Sebastian Richter[1,2], Richard Gerum[1], Ben Fabry[1], and Daniel Paranhos Zitterbart[1,2] — [1]Biophysics Group, Friedrich-Alexander University, Erlangen, Germany — [2]Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, United States of America

Emperor penguins (*Aptenodytes forsteri*) breed under the harsh conditions of the Antarctic winter. To save energy and survive for 120 days of fasting, they from tight huddles. Using time-lapse images of an emperor penguin colony in Terre Adelie, we study huddle formation in response to environmental conditions (temperature, humidity, solar radiation, and wind speed). Huddle formation can be described as a phase transition from a freely moving state to a solid-like state where individual movements stall. We find a larger huddling probability with decreasing temperature and solar radiation and with increasing wind speed and humidity. These environmental factors can be lumped to an apparent temperature that would result in the same huddling probability in the absence of wind, humidity, and solar radiation, with weights of 1°C/°C for temperature, 2.9°C/(m/s) for wind, 0.5°C/% for rel. humidity, and 0.3°C/(W/m^2) for solar radiation. For the month of May, we find a critical temperature of −48.2°C for a 50% huddling probability. We expect this critical temperature to rise during fasting as the animals consume their insulating fat layer, and propose that the critical temperature can serve as an indicator for energy reserves and thus colony health.

DY 3.11 Mon 12:30 H20

Delayed feedback control of active particles: a controlled journey towards the destination — Seyed Mohsen Jebreiil Khadem and •Sabine H. L. Klapp — Institut für Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin.

We explore theoretically the navigation of an active particle based on delayed feedback control. The delayed feedback enters in our expression for the particle orientation which, for an active particle, determines (up to noise) the direction of motion in the next time step. Here we estimate the orientation by comparing the delayed position of the particle with the actual one. This method does not require any real-time monitoring of the particle orientation and may thus be relevant also for controlling sub-micron sized particles, where the imaging process is not easily feasible. We apply the delayed feedback strategy to two experimentally relevant situations, namely, optical trapping and photon nudging. To investigate the performance of our strategy, we calculate the mean arrival time analytically (exploiting a small-delay approximation) and by simulations.

References:
[1] S. M. J. Khadem and Sabine H. L. Klapp arXiv:1811.06849v2 (2018).