CPP 39: Active Colloids

Time: Thursday 9:30–11:00 Location: ZEU 260

Invited Talk CPP 39.1 Thu 9:30 ZEU 260

Clustering and phase separation of repulsive self-propelled discs — •Thomas Speck — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz

A striking non-equilibrium phenomenon is the clustering of phoretically propelled colloidal particles due to the interplay of volume exclusion and persistence of motion. I will review recent experimental results and present first steps towards a microscopic theory for active Brownian particles without alignment. Starting from the many-body Smoluchowski equation in two dimensions, an effective evolution equation of the tagged particle density is derived. Even for purely repulsive disks, this equation reveals a dynamical instability corresponding to a mobility-induced phase transition. This instability leads to the phase separation of the suspension into a dilute gas phase of single active particles, and a single large cluster. The analytical results are corroborated by extensive numerical simulations for different repulsive pair potentials.

CPP 39.2 Thu 10:00 ZEU 260

Gravitaxis of asymmetric microswimmers — •Felix Kümmel[1], Borge ten Hagen[2], Raphael Wittkowski[3], Hartmut Löwen[2] und Clemens Bechinger[1,4] — [1]2. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, Germany — [3]SUPA, School of Physics and Astronomy, University of Edinburgh, United Kingdom — [4]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany

Micron-sized self-propelled colloidal particles can serve as models for real biological swimmers [1]. For giving better insight into the swimming properties of biological microorganisms with an asymmetric shape, we recently studied the motional features of L-shaped microswimmers under bulk conditions [2]. However, most motile objects additionally respond to an external gravitational field, a phenomenon called gravitaxis. For many flagellates and ciliates, such as Chlamydomonas or Paramecium, negative gravitaxis has been observed, i.e. a swimming motion opposed to the gravitational field. Such a behavior often originates from an inhomogeneous mass distribution, which aligns the cell similar to a buoy. In contrary, we study the motion of asymmetric L-shaped microswimmers with homogeneous mass distribution, in the presence of a gravitational force. In experiments and by theoretical modeling we demonstrate that a shape anisotropy alone is sufficient to induce gravitactic motion. [1] G. Volpe, et al., Soft Matter 7, 8810 (2011). [2] F. Kümmel, et al., Phys. Rev. Lett. 110, 198302 (2013).

CPP 39.3 Thu 10:15 ZEU 260

Alignment of active particles with hydrodynamic interactions and formation of a self-assembled pump — Marc Hennes, •Katrin Wolff, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin

Hydrodynamically interacting active particles in an external harmonic potential are known to form a self-assembled pump at large enough Peclet numbers [1]. Here, we give a quantitative criterion for the formation of the pump for active Brownian particles depending on the rotational diffusion of particles, their swim speed and the strength of the harmonic trap. The emerging flow field caused by the swimmers corresponds to a regularized stokeslet and stabilises the pump. We find that the particle distribution settles into a non-equilibrium steady state with non-vanisihing flux. The particle orientations can be mapped onto an equilibrium system as they align along a common "pump axis" in analogy to dipoles in an electric field. We perform Brownian dynamics simulations with hydrodynamic interactions and compare the many-particle simulations with an analytically tractable mean field system.

[1] R. W. Nash et al., Phys. Rev. Lett. 104, 258101 (2010)

CPP 39.4 Thu 10:30 ZEU 260

Size dependent efficiency of optically heated Janus Particles. — •Andreas Bregulla and Frank Cichos — Universität Leipzig, Deutschland

For nanoscale manipulations in liquids Brownian motion is a limiting factor. In nature various transport mechanisms have evolved which overcome the Brownian fluctuations. Recently, a number of model swimmer have been fabricated and shown to provide similar function. However, hardly no detailed experimental study of their swimming efficiency exists. Here we investigate experimentally the efficiency of self-propelled photophoretic swimmers based on metal-coated polymer particles of different size. The metal hemisphere absorbs the incident laser power and converts its energy into heat, which dissipates into the environment. A phoretic surface flow arises from the temperature gradient along the particle surface and drives the particle parallel to its symmetry axis. Scaling the particle size from micro to nanometers the efficiency of converting optical power into motion is expected to rise with the reciprocal size for ideal swimmers.However, due to the finite size of the metal cap, the efficiency of a real swimmer reveals a maximum depending sensitively on the details of the metal cap shape. We compare the experimental results to numerical simulations.

CPP 39.5 Thu 10:45 ZEU 260

Non-Gaussianity in suspensions of self-propelled Janus particles — •Borge ten Hagen[1], Xu Zheng[2], Andreas Kaiser[1], Zhanhua Silber-Li[2], and Hartmut Löwen[1] — [1]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, CAS, Beijing 100190, People's Republic of China

Spherical Janus particles are one of the most prominent examples for active Brownian objects. Here, we study the diffusiophoretic motion of such microswimmers in experiment and in theory. Three stages are identified: simple Brownian motion at short times, super-diffusion at intermediate times, and finally diffusive behavior again at long times. These three regimes observed in the experiments are compared with a theoretical model for the Langevin dynamics of self-propelled particles with coupled translational and rotational motion. Besides the mean square displacement also higher displacement moments are addressed. In particular, theoretical predictions regarding the non-Gaussian behavior of self-propelled particles are verified in the experiments. The non-Gaussianity is also clearly manifested in the displacement probability distribution of the Janus particles. In agreement with Brownian dynamics simulations, either an extremely broadened peak or a pronounced double-peak structure is found depending on the experimental conditions.