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Focus Issue on Statistical Physics of Self-Propelled Colloids Editorial

Hartmut Löwen, Sabine Klapp and Holger Stark

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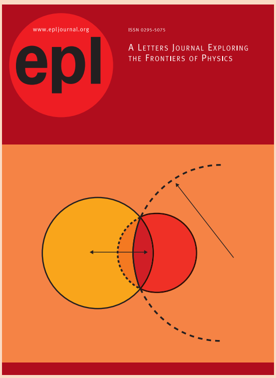

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EPL Focus Issue on Statistical Physics of Self-Propelled Colloids

Editorial

Micron-sized particles equipped with their own motorization have been a topic of intense recent research in physics. These mesoscopic active entities can harness and harvest energy from the environment and are therefore important as carriers of drugs and cargos. Their motion is governed by the laws of nonequilibrium physics. Well-characterized self-propelled colloids are ideal model systems to study the underlying novel concepts of nonequilibrium statistical physics in a quantitative and systematic way. While different self-propulsion mechanisms for a single colloidal particle in a surrounding bulk fluid are by now well understood, new research has considered such particles in a heterogenous and complex environment and also focussed on many-body systems. A wealth of new nonequilibrium structures and patterns has been discovered which are much richer than those of their equilibrium counterparts. Moreover, an important step is to equip the particles with more "intelligence" such that they can sense stimuli, learn to react to those and perform simple tasks in an optimized way. Complementary work involving laboratory experiments of well-controlled model systems, computer simulations, and a broad spectrum of theoretical methods from statistical physics have provided important new insights in this interdisciplinary research area.

This Focus Issue of *EPL* includes one perspective article [1] and 17 research letters [2–18] all centered around statistical physics of self-propelled colloids.

Most of the papers are based on computer simulations of model systems [2–18], some of them include statistical theories, *e.g.*, [2,5,7,9,14], one is experimental [2]. This somehow reflects the proportion in current research on active matter where most of the papers are dealing with simulations of model systems and there are fewer papers on fundamental microscopic nonequilibrium theories (as here in ref. [5]) and even fewer on particle-resolved experiments. But it is important to mention that many experiments on active matter go hand-in-hand with current theories and simulations as documented here in [1,2,17].

In terms of topics, most of the papers have to do with active colloids in *complex environments*. Such an environment can be represented by an *external field with a Hamiltonian potential*. The simplest case treated here is an external harmonic potential [2,4] but it can be systematically made more complicated including periodic obstacle matrices [3] or corrugated channels [7]. External potentials can be applied with programmed feedback, which produces memory effects, a model for that is studied in depth here [6]. Next a *motility landscape* can provide a complex environment as well, two cases of which are considered in this special issue, namely a motility ratchet [12] and traveling activity wave [14]. Third, the active colloids can move in a *non-Newtonian complex solvent* such as a viscoelastic fluid as considered here in [11]. Finally the *fluctuations* of the environment can be anomalous and nonthermal, interesting examples are provided here by active particles in vesicles of fluctuating shapes [16] and by inverting the role of passive and active particles in studying a passive particle in a sea of active ones [9].

Further papers consider more *complex particle shapes and interactions* beyond that of spheres and reciprocal pairwise interactions. Important examples are dumbells composed of spinners [18] where complicated hydrodynamic interactions are at play, circle swimmers [10], multi-component systems [8,9] or particles with delayed [17] or social interactions [15] which can lead to new emerging nonequilibrium patterns.

Next the aspect of *steering active particles* is currently intensely debated and the special issue includes papers with self-steering colloidal particles [4] and active colloids subject to taxis [14]. Moreover, the perspective article [1] contains a short review on optimizing particle steering by external and internal means.

Finally machine learning methods have been considered to equip active particles with additional *intelligence*. Such learning active systems have been studied in [13] and reviewed by [1] here. We think that this aspect of combining concepts of artifical intelligence with active colloids has a great potential for the future both in terms of a fundamental understanding and for actual applications.

Hartmut Löwen, Sabine Klapp and Holger Stark
Focus Issue Editors

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