Emergence of collective oscillations in massive human crowds

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Abstract

Though a combination of field observations, measurements and theory I will show how spontaneous chiral oscillations emegerge in ultra dense crowds. I will then explain this unanticipated dynamics showing that packed human crowds realize a form of odd active matter.

*Speaker

Dynamic Scaling of Two-Dimensional Polar Flocks

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Abstract

We propose a hydrodynamic description of the homogeneous ordered phase of polar flocks. Starting from symmetry principles, we construct the appropriate equation for the dynamics of the Goldstone mode associated with the broken rotational symmetry. We then focus on the two-dimensional case considering both "Malthusian flocks" for which the density field is a fast variable that does not enter the hydrodynamic description and "Vicsek flocks" for which it does. In both cases, we argue in favor of scaling relations that allow one to compute exactly the scaling exponents, which are found in excellent agreement with previous simulations of the Vicsek model and with the numerical integration of our hydrodynamic equations.

*Speaker

Discontinuous transition to active nematic turbulence

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Abstract

Active fluids exhibit chaotic flows at low Reynolds number known as active turbulence. I will discuss the nature of the transition from laminar to turbulent flows. Through simulations of a minimal model of unbounded active nematics, we find that the transition to active turbulence is discontinuous. The transition features a jump in the mean-squared velocity, as well as bistability and hysteresis between laminar and chaotic flows. From distributions of finite-time Lyapunov exponents, we identify the transition at a value $A^* \approx 4900$ of the dimensionless activity number. Below the transition to chaos, we find subcritical bifurcations that feature bistability of different laminar flow patterns. These bifurcations give rise to oscillations and to chaotic transients, which become extremely long close to the transition to turbulence. Altogether, our finding of a discontinuous transition contrasts with the continuous transition previously found in channel confinement. We propose that, without confinement, the transition to turbulence is discontinuous because the long-range hydrodynamic interactions of Stokes flow suppress the spatial coexistence of turbulent puffs and laminar flow.

*Speaker

Emergence of mesoscale flows under non-equilibrium drive in crowded environments

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Abstract

When non-equilibrium driving at the particle level competes with crowding at high densities in overdamped particle systems, spontaneous velocity correlations can give rise to mesoscale flows resembling turbulence. We demonstrate that such flows can originate not only from the persistent self-propulsion forces of active particles, such as active Ornstein-Uhlenbeck particles, but also from non-reciprocal inter-particle forces.
The emergence of turbulent-like flows in various experimental active systems has inspired numerous theoretical studies. However, none of these theories capture the unique flow characteristics observed in our systems. Strikingly, we find significant similarities between the flows generated by activity and those arising from non-reciprocal interactions, suggesting common underlying principles. Moreover, tuning the respective control parameters–persistence time for active particles or the degree of non-reciprocity–allows the time and length scales of these flows to grow arbitrarily large.
In the non-reciprocal system, this scaling behaviour is linked to a non-equilibrium phase transition to absorbing states, where particle positions self-organise such that every particle experiences identical forces, abruptly halting the turbulent-like flows. The critical exponents we measure are consistent with the conserved directed percolation universality class.

*Speaker

Collective dynamics of confined droplet microswimmers

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Abstract

Autophoretic droplets are a versatile microswimmer prototype that can be easily synthesized in large numbers with high uniformity. They exhibit rich emergent dynamics like mutual signalling and aggregation effects, which can be compared to elementary active matter models. Based on experiments in confined microfluidic geometries, I will discuss in which cases essential dynamics can be understood using pure chemical ('dry') or hydrodynamic interactions, and where a full chemohydrodynamic modelling is necessary.

*Speaker

State-dependent temperature and fluctuation(-dissipation) relation out of equilibrium

Rémi Goerlich*[1], Benjamin Sorkin[2], Dima Bosiskovsky[1], Cyriaque Genet[3], Benjamin Lindner[4], and Yael Roichman[1]

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Abstract

Building a consistent thermodynamic framework for non-equilibrium systems is a major challenge. For such systems, even the generalization of state variables like temperature is problematic. Here, we take the bet of applying a transformation on a non-equilibrium state, rather than focusing on steady-state. Doing so, we reveal a surprisingly consistent ensemble of state variables and thermodynamic relations. More precisely, an optically trapped microparticle is driven into a non-equilibrium state using an engineered correlated stochastic force. We investigate the thermodynamic response of the microparticle to a stiffness change of the potential. First, we derive a fluctuation-dissipation relation, which allows us to differentiate between equilibrium and non-equilibrium states, and to further resolve the origin of effective temperatures, whether arising from white or colored noise. Second, we investigate the stochastic thermodynamics of the microparticle during a state-to-state transformation. We define a state-dependent effective temperature with which the Second Law of thermodynamics is recovered. This temperature further allows us to derive a new fluctuation theorem that we confirm experimentally. This consistent thermodynamic framework far from equilibrium offers new tools to describe and control active and driven systems.

*Speaker

Active nematics : Investigations of texture in 3D systems

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Abstract

In this talk, I will briefly review Active nematic hydrodynamics and some experimental and numerical results on structure of disclination loops in 3D fluids. I will present an analysis framework for nematic structure from 3D data and use it to illustrate the influence of nematogen stiffness and boundary patterning on the topological properties of nematic textures in the active fluid.

*Speaker

Single active particle engine utilizing a nonreciprocal coupling between particle position and self-propulsion

Grzegorz Szamel*[1]

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Abstract

A self-propelled particle is formally equivalent to a system consisting of two sub-systems interacting with their own heat reservoirs and coupled by a nonreciprocal (violating Newton's third law) interaction. We previously showed that this approach allows us to generalize stochastic thermodynamics to systems of active particles. Here we argue that the nonreciprocal coupling can be used to extract useful work from a single self-propelled particle maintained at constant temperature. We demonstrate one way to achieve this extraction, through manipulating correlations between the particle's position and self-propulsion using an externally controlled aligning interaction. We analyze quantitatively the work extracted, the power and the efficiency of the resulting single active particle engine. Finally, we investigate an information engine based on the same principles.

*Speaker

Turing Foams and Active Foams

Erwin Frey*[1]

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Abstract

Non-equilibrium protein pattern formation and the self-organization of motor-filament mixtures, driven by NTPase cycles, are crucial mechanisms for cellular processes like division and polarization. Despite their distinct physical origins, both systems can form remarkably similar structures. Protein diffusion-reaction dynamics lead to foam-like patterns, which we termed "Turing foams," that follow non-equilibrium interface laws similar to equilibrium foams(1). Motor-filament mixtures similarly self-organize into supramolecular structures, including micelles, bilayers, and foams, driven by instabilities (2). This talk will discuss the shared non-equilibrium principles governing these systems, focusing on interface laws linked to thermodynamic-like relations.

(1) Deciphering the Interface Laws of Turing Mixtures and Foams, Henrik Weyer, Tobias A. Roth, and Erwin Frey, (arXiv:2409.20070).

(2) Supramolecular assemblies in active motor-filament systems: micelles, bilayers, and foams, Filippo De Luca, Ivan Maryshev, and Erwin Frey, Physical Review X 14, 031031 (2024).

*Speaker