DY 34: Focus Session: Fluids with Broken Time-Reversal Symmetry – Odd/Hall Viscosity Between Active Matter and Electron Flows

Viscosity is a fundamental property of fluids and an important physical quantity characterizing resistance to flow and energy dissipation. While time-reversal symmetry holds in conventional fluids, its violation can lead to striking phenomena, one of which is the emergence of a dissipationless transport coefficient called odd viscosity. Odd viscosity, also known as Hall viscosity, was originally proposed by Avron et al., as a quantized observable in electron fluids with a magnetic field. Since this seminal work, odd viscosity has been studied in various systems, such as 2D electron fluids, fractional Hall fluids, and ionic crystals. Although odd viscosity was also known in plasma physics, it was largely overlooked in fluid dynamics, mainly due to the technical challenges involved in its experimental realization. In recent years, however experiments in driven colloidal systems led to a surge of interest in odd viscosity in the active matter community. In parallel, our understanding of odd phenomena was advanced by continuum theories with many novel exact solutions. Major open questions in the field include the microscopic mechanisms that lead to odd viscosity, its experimental manifestations, the transition from two- to three-dimensional systems, and the effect of odd viscosity on hydrodynamic phenomena at different length scales, ranging from microrheology to turbulent flows. This Focus Session will connect the wider condensed matter and active matter physics communities with recent theoretical advances in odd viscosity. It is organized along with a Symposium on the same topic.

Organized by Yuto Hosaka (Göttingen) and Ewelina M. Hankiewicz (Würzburg)

Time: Wednesday 9:30–12:30 Location: ZEU/0160

Invited Talk DY 34.1 Wed 9:30 ZEU/0160

Active turbulence and odd viscosity in a colloidal chiral active system in bulk and in patterned environments — Joscha Mecke[1,2], Yongxiang Gao[1], and •Marisol Ripoll[2] — [1]Institute for Advanced Study, Shenzhen University, Shenzhen, China — [2]Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

Experiments for a chiral active fluid composed of a carpet of standing and spinning colloidal rods are compared with simulations for synchronously rotating hard discs in a hydrodynamic explicit solvent [1]. The emergence of multi-scale eddies, with features of self-similar dynamics, indicates the existence of active turbulence, while the particles accumulation in the centre of the vortices allows the quantification of the system odd viscosity. The existence of a non-negligible substrate friction can be shown to be responsible of the truncation of the energy spectra and the related reduction of the vortex size [2], and the interaction with fixed obstacles shows to originate a flow opposite to the rotation direction which induces a pinning vortex effect [3].

[1] J. Mecke, Y. Gao, C. Ramirez-Medina, D. Aarts, G. Gompper and M. Ripoll, Comm. Phys. 6 (2023), 324 [2] J. Mecke, Y. Gao, G. Gompper and M. Ripoll, Comm. Phys. 7 (2024), 332 [3] J. Mecke, Y. Gao and M. Ripoll, Phys. Fluids 37 (2025), 112016

DY 34.2 Wed 10:00 ZEU/0160

From Gels to Rotors: Tunable Chiral Phases in Odd Colloidal Fluids — •Dennis Schorn[1], Stijn van der Ham[2], Suvendu Mandal[1], Benno Liebchen[1], and Hanumantha Rao Vutukuri[2] — [1]Institute for Condensed Matter Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]MESA+ Institute, University of Twente, 7500 AE Enschede, The Netherlands

Starfish embryos aggregate into chiral crystals exhibiting odd elasticity (Tan *et al.* Nature **607**, 287 (2022)). Similar structures have been recently observed in externally driven magnetic colloids. In this talk, I present experiments and simulations of binary mixtures of magnetic spinners and passive colloids. We develop a model to predict the phase diagram of the system, which comprises four distinct phases that can be systematically reproduced in experiments. In particular, our simulations and experiments reveal a phase in which the passive particles form a gel-like network, with significant holes filled with self-organized, rotating chiral clusters composed of spinners. This phase can be reversed by changing the system's composition and magnetic field strength, resulting in a spanning spinner phase with embedded counter-rotating chiral clusters made of passive colloids. Both phases exhibit odd viscosity and diffusivity, whose magnitudes depend sensitively on spinner fraction and magnetic field strength. Our system may open the route towards a new type of viscoelastic active chiral matter involving nonreciprocal interactions between both species.

DY 34.3 Wed 10:15 ZEU/0160

Odd Droplets: Fluids with Odd Viscosity and Highly Deformable Interfaces — •Hugo França and Maziyar Jalaal — Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Science Park 904, Amsterdam, 1098XH, The Netherlands

Flows with deformable interfaces are commonly controlled by applying an external field or modifying the boundaries that interact with the fluid, but realizing such solutions can be demanding or impractical in various scenarios. Here, we demonstrate that fluids with broken symmetries can self-control their mechanics. We present a continuum model of a viscous fluid with highly deformable interfaces subject to capillary stresses. Our model features odd viscosity, a parity-violating property that emerges in chiral fluids. Using direct numerical simulations, we focus on the impact of an odd droplet on a superhydrophobic surface. By numerically solving the full conservation equations, we are able to study this highly non-linear problem hardly accesible through analytical methods. We demonstrate that odd viscosity dramatically disrupts conventional symmetric spreading by inducing asymmetric deformations and chiral flow patterns. Our analysis reveals a variety of dynamic regimes, including leftward and rightward bouncing, as well as rolling, depending on the relative strength of the odd viscosity. Our work illustrates that regulating odd viscosity provides a promising framework for controlling multiphase flows and designing functional metamaterials with tailored fluidic properties.

DY 34.4 Wed 10:30 ZEU/0160

The notion of dissipation in three-dimensional fluids with odd viscosity — •Jeffrey Everts[1,2], Laura Meissner-Oszer[1], and Bogdan Cichocki[1] — [1]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [2]Institute of Physical Chemistry, Polish Academy of Sciences, 01-224 Warsaw, Poland

Odd viscosity is a transport coefficient that occurs in fluids where the constituent particles carry a non-trivial spin angular momentum. Exemplary realisations in this context are chiral active fluids and electronic systems in an external magnetic field. Due to the symmetry properties of the resulting viscosity tensor it is often stated in the literature that odd viscosity does not contribute to viscous dissipation. In this talk, I will explicitly demonstrate that this statement is incorrect for incompressible odd viscous fluids in three spatial dimensions. In this case, the fluid flow velocity can be affected by odd viscosity, which gives a non-trivial contribution to the dissipated power. As an example, we will show by explicit calculation how odd viscosity contributes to viscous dissipation for a spherical (colloidal) particle immersed in an odd viscous fluid. Furthermore, we will make general statements for viscous dissipation by generalising the Helmholtz minimum dissipation theorem -which is well known for ordinary Stokesian fluids - to fluids with odd viscosity.

DY 34.5 Wed 10:45 ZEU/0160

Exact flow patterns in systems with odd viscosity — •Laura Meissner-Oszer[1], Bogdan Cichocki[1], and Jeffrey Everts[1,2] — [1]nstitute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [2]Institute of Physical Chemistry, Polish Academy of Sciences, 01-224 Warsaw, Poland

Chiral active fluids are composed of self-spinning particles with a non-trivial spin-angular momentum that is maintained through a continuous injection of energy at the microscopic scale. Due to this property, there are antisymmetric contributions in the viscosity tensor, which are called odd viscosity. In the low Reynolds-number regime we show that there is a uniqueness theorem for such flows akin to ordinary Stokesian fluids. In order to analyse the effect of odd viscosity on flow patterns of a three-dimensional incompressible fluid in the creeping flow regime, we focus on a simple model of a chiral active fluid described by one shear viscosity and one odd viscosity. By considering the Green's function of the linear momentum-balance equation in the presence of a point force, we derive exact closed-form analytical expressions for the velocity and pressure field of the fluid around a translating and rotating spherical particle. Furthermore, we highlight specific features of such flows due to the presence of odd viscosity and we demonstrate how the direction of spin momentum affects the qualitative features of the streamlines.

15 min. break

DY 34.6 Wed 11:15 ZEU/0160

Resonances in Odd Viscoelastic Materials — •Julius Kiln and Alexander Mietke — Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford, United Kingdom

Active matter describes materials that are powered by microscopic sources of energy. This injection of energy can lead to a wide variety of phenomena and unconventional material properties, including odd elasticity and odd viscosity. Despite recent analytical examination of these systems, a widely applicable method for solving force balance equations for odd materials on finite domains was so far not available.

The Papkovich-Neuber (PN) ansatz, introduced almost a hundred years ago, has proved an invaluable method for solving the force balance equation of a Stokes fluid and of a passive linearly elastic solid. We generalise this idea and find an ansatz for odd solids and fluids that reduces to the known PN solutions in the limit of vanishing odd material parameters. Altogether, this provides a new and versatile method for finding analytical solutions to this class of problems. Using this result, we construct the displacement field for an odd elastic material in circular domain under both displacement and stress boundary conditions. Further extending this method to write displacement and flow solutions of an odd viscoelastic material explicitly, we study the response to oscillatory forcing at the boundary, finding resonances at certain forcing frequencies even in an overdamped system. Finally, based on these new PN solutions, we propose rheological protocols for measuring odd material properties.

DY 34.7 Wed 11:30 ZEU/0160

Edge currents shape condensates in chiral active matter — •Boyi Wang[1,2], Patrick Pietzonka[4], and Frank Jülicher[1,2,3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Center for Systems Biology Dresden, Dresden, Germany — [3]Cluster of Excellence Physics of Life, TU Dresden, Germany — [4]SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom

Chiral active matter, which breaks both parity symmetry and detailed balance, is widespread in living systems. Here, we introduce a minimal two-dimensional chiral active Ising model by incorporating stochastic, biased local rotations. At low temperatures, the system coarsens into condensates with chiral orientations and faceted, crystal-like shapes rather than circular ones observed under Kawasaki dynamics. The interfaces align at characteristic angles to the lattice axes and support persistent, unidirectional, angle-dependent edge currents.

To generalise these results, we develop a continuum theory by adding an active edge-current term to Model B. An edge current with n-fold symmetry produces condensates with corresponding n-fold polygonal shapes. In the sharp-interface limit, we construct an effective active surface potential that predicts the steady-state condensate geometry, consistent across both the lattice model and the continuum description.

Our results reveal how local chiral activity generates global edge currents and demonstrate their fundamental role in governing phase separation and interfacial dynamics in chiral active systems.

DY 34.8 Wed 11:45 ZEU/0160

A mobility based approach to self diffusion in odd-mobile systems — •Filippo Faedi and Abhinav Sharma — University of Augsburg

Odd-diffusive systems, defined by antisymmetric diffusion tensors, display unusual dynamics including enhanced self-diffusion due to interactions, oscillatory force autocorrelation functions in over-damped systems, and reversal of particle mobility. This work introduces a mobility-based approach by externally driving particles with constant forces, uncovering profound transport anomalies. We demonstrate an inverted density wake around a driven tracer, where increasing oddness reverses collision effects, reducing effective friction and enhancing mobility. Using fluctuation-dissipation, mobility-derived self-diffusion confirms prior findings, providing a unified view of interaction-induced anomalous dynamics in chiral media.

DY 34.9 Wed 12:00 ZEU/0160

Exceptional points, chirality and entropy production in non-reciprocal polar active matter — Kim L. Kreienkamp and •Sabine H. L. Klapp — Institut für Physik, Technische Universität Berlin, Germany

Non-reciprocal couplings significantly impact the collective dynamics of mixtures. A particularly striking consequence of such couplings is the spontaneous emergence of time-dependent phases that break parity-time symmetry. Here, we study a paradigmatic model of a non-reciprocal polar active mixture by combining field-theoretical analyses and particle-based simulations. When different species have opposing alignment tendencies, flocking states with spontaneously broken rotational symmetry transform into chiral states characterized by a rotating polarization direction. At the field-theoretical level, the transition to these parity-time-symmetry-breaking chiral states is indicated by so-called exceptional points. We demonstrate that these theoretical concepts have clear counterparts in particle-based systems [1]: we observe chimera-like states with coexisting locally synchronized and disordered regions, and find that both the spontaneous chirality and the entropy production rate [2] peak at coupling strengths corresponding to the exceptional points. Our results highlight the diverse effects of non-reciprocity across different scales.

[1] K. L. Kreienkamp and S. H. L. Klapp, Communications Physics **8**, 307 (2025)

[2] K. L. Kreienkamp and S. H. L. Klapp, arXiv:2508.05209 (2025)

DY 34.10 Wed 12:15 ZEU/0160

The chiral random walk: A model for odd transport on the lattice — Jan Wójcik[1] and •Erik Kalz[2] — [1]Institute of Theoretical Physics and Astrophysics, University of Gdánsk, 80-308 Gdánsk, Poland — [2]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany

We present a model for an isotropic chiral random walk on a lattice. Inspired by the quantum random walk framework, we equip the walker with an internal degree of freedom representing chirality and show, both numerically and analytically, that this model resembles odd transport properties on the continuum level. Chirality further acts as a control parameter, and the model resembles unitary transport in the strong-chirality regime. Building on established results from Quantum Random Walk theory, we analyse features such as topologically protected transport in this limit. We find that this qualitative persists also into the dissipative regime, allowing us to theoretically ground edge-transport phenomena, characteristics of dissipative odd systems. We illustrate our approach in spatially confined geometries and in systems with random chirality.