Symposium Fluids with Broken Time-Reversal Symmetry: Odd/Hall Viscosity between Active Matter and Electron Flows (SYBS)

jointly organised by
the Dynamics and Statistical Physics Division (DY),
the Chemical and Polymer Physics Division (CPP),
the Magnetism Division (MA), and
the Low Temperature Physics Division (TT)

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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 Symposium will connect the wider condensed matter and active matter physics communities with recent theoretical advances in odd viscosity.

Overview of Invited Talks and Sessions

(Lecture hall HSZ/AUDI)

Invited Talks

SYBS 1.1	Tue	9:30–10:00	HSZ/AUDI	**Odd viscosity in three-dimensional fluids: flows, wakes, and eddies** — •Tali Khain
SYBS 1.2	Tue	10:00–10:30	HSZ/AUDI	**Odd viscosity in two-dimensional hydrodynamic electron transport** — •Igor Gornyi, Dmitry Polyakov
SYBS 1.3	Tue	10:30–11:00	HSZ/AUDI	**Odd slip on chiral active surfaces** — •Andrej Vilfan, Yuto Hosaka
SYBS 1.4	Tue	11:15–11:30	HSZ/AUDI	**Parity-odd transport in electron fluids** — •Johanna Erdmenger
SYBS 1.5	Tue	11:30–11:45	HSZ/AUDI	**Curved Odd Elasticity** — Lazaros Tsaloukidis, Yuan Zhou, Jack Binysh, Nikta Fakhri, Corentin Coulais, •Piotr Surówka

Sessions

SYBS 1.1–1.5	Tue	9:30–11:45	HSZ/AUDI	**Fluids with broken time-reversal symmetry: Odd/Hall viscosity between active matter and electron flows**

SYBS 1: Fluids with broken time-reversal symmetry: Odd/Hall viscosity between active matter and electron flows

Time: Tuesday 9:30–11:45 Location: HSZ/AUDI

Invited Talk SYBS 1.1 Tue 9:30 HSZ/AUDI
Odd viscosity in three-dimensional fluids: flows, wakes, and eddies — •Tali Khain — Harvard University, Cambridge, MA, USA

Systems composed of spinning particles or driven by a magnetic field break mirror symmetry at the microscopic level. These chiral fluids can be described by adding so-called “odd” viscosities, which do not dissipate energy, in the Navier-Stokes equations. In this talk, I will discuss a theoretical fluid mechanics framework to describe the consequences of these broken symmetries on fluid flow [1]. Using a combination of analytical and numerical methods, we show how these odd viscosity coefficients modify flow across a range of Reynolds numbers. In the low Reynolds number limit, sedimenting objects in a chiral fluid generate a rotating flow that is absent in usual fluids; in turn, this flow affects how immersed objects respond to forces and torques [2]. At intermediate Reynolds numbers, odd viscosity reshapes the vortex structure of the wake of a sphere, which affects the onset and nature of the periodic vortex shedding state. At high Reynolds numbers, the non-dissipative nature of odd viscosity disrupts the energy cascade that occurs in fully developed turbulent flows, leading to pattern formation with a tunable scale [3].

[1] Khain, Scheibner, Fruchart, Vitelli, JFM (2022)
[2] Khain, Fruchart, Scheibner, Witten, Vitelli, JFM (2024)
[3] de Wit, Fruchart, Khain, Toschi, Vitelli, Nature (2024)

Invited Talk SYBS 1.2 Tue 10:00 HSZ/AUDI
Odd viscosity in two-dimensional hydrodynamic electron transport — •Igor Gornyi and Dmitry Polyakov — Karlsruhe Institute of Technology, Karlsruhe, Germany

We discuss the role of odd (Hall) viscosity in two-dimensional hydrodynamic electron transport in two spatial dimensions. We formulate a general framework to study the flow of the electron fluid past a random array of impenetrable obstacles in the presence of a magnetic field and derive a linear-response resistivity tensor. For the no-slip boundary condition on the obstacles, the resistivity tensor does not depend on the Hall viscosity. By contrast, for the specular boundary condition, the total electric field is rotated by Hall viscosity, which means the emergence of a Hall-viscosity-induced effective magnetic field that leads to a deviation of the Hall constant from its universal value, as well as to a modification of the longitudinal resistivity. We combine the hydrodynamic and electrostatic perspectives by addressing the distribution of charges that create the flow-induced electric fields around obstacles and provide a connection between the resistivity tensor and the disorder-averaged electric dipole induced by viscosity at the obstacle. This establishes a conceptual link between the resistivity in hydrodynamics and the notion of the Landauer dipole.

Invited Talk SYBS 1.3 Tue 10:30 HSZ/AUDI
Odd slip on chiral active surfaces — •Andrej Vilfan[1] and Yuto Hosaka[2] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Chiral active surfaces are characterized by persistent energy input with a defined sense of chirality, for example by a carpet of symmetrically rotating biological or artificial cilia. We demonstrate that when subjected to a shear flow, such a surface can lead to an effective odd slip velocity, in addition to classical Navier slip. Odd Navier slip represents a novel category of odd responses beyond the established concepts of odd viscosity and elasticity, which occur in bulk fluids or solids, and odd diffusivity of point particles. We show that a suspension of particles with odd slip can exhibit odd viscosity, providing a new mechanism for its emergence.

15 min. break

Invited Talk SYBS 1.4 Tue 11:15 HSZ/AUDI
Parity-odd transport in electron fluids — •Johanna Erdmenger — Institut für Theoretische Physik und Astrophysik, Julius-Maximilians-Universität Würzburg, 97074 Würzburg

Parity-odd transport in two-dimensional electron systems reveals an interplay between geometry, topology, and hydrodynamics. In channel geometries, the Hall viscous force competes with the Lorentz force, leading to nonlinear Hall voltage profiles and, at a critical magnetic field, a complete cancellation of the total Hall response [1,2]. Channel voltage measurements provide a direct experimental probe. Similar effects arise for the hydrodynamic inverse Nernst signal [2].

For hydrodynamic spin transport, non-dissipative parity-breaking transport phenomena are generated by torsion. The torsional Hall viscosity has interesting connections to recent developments in general relativity. We analyse the impact of magnetic fields and quadratic band-structure corrections on the torsional transport coefficient, showing that torsional response can reverse direction relative to conventional Hall viscous forces, while still distinguishing topologically trivial and nontrivial regimes [3].

[1] I. Matthaiakakis, D. Rodríguez, C. Tutschku, J. Erdmenger, E. M. Hankiewicz and R. Meyer, Phys.Rev.B 101 (2020) 4, 045423.
[2] Z.Y. Xian, S. Danz, I. Matthaiakakis, R. L. Klees, J. Erdmenger, R. Meyer, E. M. Hankiewicz et al, Phys.Rev.B 107 (2023) 20, L201403.
[3] I. Matthaiakakis, W.Z. Jia, R. L. Klees, D. Rodríguez Fernández, Z.Y. Xian, R. Meyer, J. Erdmenger and E. M. Hankiewicz, arXiv:2504.13250 [cond-mat.mes-hall].

Invited Talk SYBS 1.5 Tue 11:30 HSZ/AUDI
Curved Odd Elasticity — Lazaros Tsaloukidis[2], Yuan Zhou[3], Jack Binysh[3], Nikta Fakhri[4], Corentin Coulais[3], and •Piotr Surówka[1] — [1]Institute of Theoretical Physics, Wrocław University of Science and Technology, 50-370 Wrocław, Poland — [2]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, 01187, Dresden, Germany — [3]Institute of Physics, University of Amsterdam, Science Park 904, 1098 XH, Amsterdam, The Netherlands — [4]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA

Living materials such as membranes, cytoskeletal assemblies, cell collective and tissues can often be de- scribed as active solids materials with a elastic response about a well defined reference configuration and energized from within. These materials often live in complex and curved manifolds, yet most descriptions of active solids are flat. Here, we explore the interplay between curvature and non-reciprocal elasticity by a co- variant effective theory on curved manifolds in combination with numerical simulations. We find that curvature spatially patterns activity, gaps the spectrum, modifies exceptional points and introduces non-Hermitian de- fect modes. Together these results establish a foundation for hydrodynamic and rheological models on curved manifolds, with direct implications for living matter and active metamaterials.