Symposium SKM Dissertation Prize 2024 (SYSD)

jointly organized by
the divisions of the Condensed Matter Section (SKM)

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The divisions belonging to the Condensed Matter Section (SKM) of the DPG annually award the SKM Dissertation Prize. The prize acknowledges outstanding research during the PhD work in the research areas of SKM completed in 2022 or 2023, and its excellent oral presentation. Based on nominations, a jury consisting of the chairpersons of all SKM divisions has selected five finalists for the award to present their work in this symposium. The winner will be selected after the symposium and publicly announced Tuesday, March 19th in the afternoon during the ceremonial session.

Overview of Invited Talks and Sessions

(Lecture hall H 2032)

Invited Talks

SYSD 1.1	Mon	9:30–10:00	H 1012	**Nonequilibrium dynamics in constrained quantum many-body systems** — •Johannes Feldmeier
SYSD 1.2	Mon	10:00–10:30	H 1012	**Controlled Manipulation of Magnetic Skyrmions: Generation, Motion and Dynamics** — •Lisa-Marie Kern
SYSD 1.3	Mon	10:30–11:00	H 1012	**Interactions within and between cytoskeletal filaments** — •Charlotta Lorenz
SYSD 1.4	Mon	11:00–11:30	H 1012	**Field theories in nonequilibrium statistical mechanics: from molecules to galaxies** — •Michael te Vrugt
SYSD 1.5	Mon	11:30–12:00	H 1012	**Lightwave control of electrons in graphene** — •Tobias Weitz

Sessions

SYSD 1.1–1.5	Mon	9:30–12:00	H 1012	**SKM Dissertation Prize**

SYSD 1: SKM Dissertation Prize

Time: Monday 9:30–12:00 Location: H 1012

Invited Talk SYSD 1.1 Mon 9:30 H 1012
Nonequilibrium dynamics in constrained quantum many-body systems — •Johannes Feldmeier — Department of Physics, Harvard University, Cambridge, Massachusetts, USA

Symmetries and constraints constitute central concepts in physics and are vital tools for classifying quantum systems in equilibrium conditions. In this talk, I will discuss the role of constraints in quantum many-body systems out of equilibrium and how they give rise to novel dynamical signatures for characterizing quantum materials and synthetic quantum matter. We first demonstrate that the presence of local gauge constraints - characteristic of exotic quantum phases such as spin liquids - can induce slow dynamical relaxation to equilibrium and in certain cases even prevent such relaxation altogether. Dynamical properties can also serve as important signatures to identify systems with gauge constraints in experiment, and we propose local dynamical probes to detect topological edge states in the Kitaev honeycomb spin liquid. We then go on to consider the dynamics of systems with novel types of mobility constraints - called fracton phases of matter - and show that the time evolution in such systems exhibits a new, subdiffusively slow form of hydrodynamic universality, in agreement with recent results from quantum simulation experiments. Moreover, we demonstrate how such constraints can also significantly slow down the dynamics of quantum information, even inducing a sub-ballistic light cone. I will close with a brief outlook on future directions and the potential for experimental realizations.

Invited Talk SYSD 1.2 Mon 10:00 H 1012
Controlled Manipulation of Magnetic Skyrmions: Generation, Motion and Dynamics — •Lisa-Marie Kern — Max Born Institute, Berlin, Germany

The controlled manipulation of spins is central in spintronics research. Competing interactions can lead to complex nanoscale spin textures, potentially, stabilized by a non-trivial topology. The magnetic skyrmion is the prototypical topological spin texture, possessing unity topological charge. In view of applications in data storage and processing and for their investigation as ideal test ground for topological textures in general, a reliable position control is typically required. We thus developed two control mechanisms based on reflective masks or via focused ion beam irradiation to demonstrate the deterministic formation and manipulation of current- and laser-induced magnetic skyrmions in cobalt-based multilayers. With the level of precision achieved, individual skyrmions can now be controlled on the nanometer-scale and their motion be guided in desired ways. Further, their deterministic generation allowed us to record movies of a spin-orbit torque driven skyrmion interacting with a tailored anisotropy defect, thereby accessing the fundamental character of the topological charge and its magnetization dynamics. Together with my colleagues, I investigated these magnetic skyrmions in real-space soft-x-ray imaging experiments. We established a promising platform to study isolated topological textures under controlled conditions which may improve our general understanding of their emergence and intrinsic magnetization dynamics on ps-timescales and with nm-spatial resolution.

Invited Talk SYSD 1.3 Mon 10:30 H 1012
Interactions within and between cytoskeletal filaments — •Charlotta Lorenz — Georg-August University Göttingen, DE — ETH Zürich, CH — Cornell University, US

While we live our lives, the biological cells of our body are exposed to many different mechanical challenges: Skin cells need to resist various forces, cells can squeeze through tissues and cells in blood vessels need to constantly adjust to changing pressure. To master all these complex situations, the biological cell relies on an intricate network of biopolymers, the cytoskeleton, which determines cellular mechanics. In my PhD thesis, I identified interactions within and between these biopolymers as a key player for both their mechanical and dynamic response.

We measured the mechanical properties of the biopolymers by stretching single biopolymers or crossing two biopolymers with optical tweezers. With coarse-grained models we could infer information about the interactions within and between filaments from their mechanical response. Our combination of experiments and theoretical approaches also showed that electrostatic and hydrophobic effects contribute to the interaction within and between the biopolymers. Thus, by tuning the interactions within as well as between filaments via a change in the concentration of electrostatic or hydrophobic components the cell might have a toolbox to adapt its mechanical response. Generally, these results are also interesting for the design of new recyclable and sustainable biologically-inspired materials.

Invited Talk SYSD 1.4 Mon 11:00 H 1012
Field theories in nonequilibrium statistical mechanics: from molecules to galaxies — •Michael te Vrugt — DAMTP, Centre for Mathematical Sciences, University of Cambridge, Cambridge CB3 0WA, United Kingdom

The collective dynamics of systems far from thermodynamic equilibrium is significantly richer, but also significantly less well understood than that of their equilibrium counterparts. An improved understanding can be gained from coarse-grained theories, which describe the system on a macroscopic level and which can be systematically derived from the microscopic dynamics. In this talk, I will discuss this using two examples. First, I present a model for infectious disease spreading [1] based on dynamical density functional theory [2] in which effects of social distancing are explicitly incorporated as repulsive interactions. Second, I discuss an extension of the Mori-Zwanzig projection operator formalism towards general relativity [3] and thereby show how statistical mechanics allows for a better understanding of the expansion of the universe.

[1] MtV, J. Bickmann, R. Wittkowski, Nature Communications 11, 5576 (2020)

[2] MtV, H. Löwen, R. Wittkowski, Advances in Physics 69, 121*247 (2020)

[3] MtV, S. Hossenfelder, R. Wittkowski, Physical Review Letters 127, 231101 (2021)

Invited Talk SYSD 1.5 Mon 11:30 H 1012
Lightwave control of electrons in graphene — •Tobias Weitz — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Ultrashort and intense laser pulses enable the control of electrons inside solids. In the realm of lightwave electronics, the induced electronic motion is harnessed to both encode and process information with a bandwidth up to petahertz frequencies, fundamentally set by the oscillation period of light. While control of these attosecond electron dynamics has advanced over the last decade, their implementation and use for information technology is a remaining problem. To bridge this gap, I utilize a 2D conductor, monolayer graphene, to provide ultrafast information processing using lightwaves.

In this talk, I report on the optical strong-field control of electrons in a gold-graphene-gold heterostructure to induce electric currents. Here I can distinguish and take advantage of two types of charge carriers by matching the temporal symmetry of an incident few-cycle laser waveform to spatial symmetries of electron motion in the graphene structure: Real carriers emerge from laser-driven electron interferometry in the unique cone-shaped band structure of graphene and carry a current after their excitation. Virtual carriers exist during illumination only and may be rectified at inherent functional gold-graphene interfaces within the duration of a single optical cycle. With the understanding of the underlying dynamics, I demonstrate a proof-of-concept of an ultrafast logic gate as a step to link photonics with electronics.