SYQC 1: Topology in Quantum and Classical Physics – From Topological Insulators to Active Matter

Time: Wednesday 15:00–17:45 Location: HSZ 01

Invited Talk SYQC 1.1 Wed 15:00 HSZ 01

Topological magnetic whirls for computing — •Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, 47057 Duisburg, Germany

Novel computational paradigms in combination with suitable hardware solutions are required to overcome the limitations of our state-of-the-art computer technology. In this talk, I focus on the potential of magnetic whirls – so-called skyrmions – for computing.

Skyrmions are topologically stable whirls that occur in various areas of physics and were discovered by Tony Skyrme in the 1960s in particle physics. Skyrmions occurring in magnetic systems were first observed experimentally in 2009. Within a decade, the field of magnetic skyrmions has become a very active area of research, with the aim of exploiting the topological properties of the magnetic whirl-like particles for spintronics applications. For example, the peculiar twist of the magnetization in skyrmions leads to a very efficient coupling to electric currents and allows for "banana kicks" analogous to those in soccer. More recently, magnetic skyrmions have become the focus of unconventional computing schemes such as reservoir computing.

Invited Talk SYQC 1.2 Wed 15:30 HSZ 01

Topological waves from solids to geo/astrophysical flows — •Pierre Delplace[1], Antoine Venaille[1], Nicolas Perez[1,2], Guillaume Laibe[2], Armand Leclerc[2], Manolis Perrot[1], and Brad Marston[3] — [1]CNRS, Laboratory of Physics, ENS de Lyon, France — [2]CRAL, ENS de Lyon France — [3]Brown University

Robust uni-directionnal edge modes are the hallmark of Chern insulators, a peculiar kind of topological insulators. Such topological states have been engineered in various platforms, from quantum solids to various classical analogs in photonics, acoustics and mechanics. Remarkably, such chiral modes also exist in continuous media encountered in nature. This is the case of oceanic and atmospheric equatorial waves that only propagate their energy eastward. This remarkable property, that triggers the El nino southern oscillations and impacts the climate over the globe, has a topological interpretation somehow similar to Chern insulators. Maybe more importantly, such topological tools actually also allow the prediction of previously unoticed waves in strongly stratified fluids that might be observable e.g. in stars.

Invited Talk SYQC 1.3 Wed 16:00 HSZ 01

Topological Phase Transitions in Population Dynamics — •Erwin Frey — LMU Muenchen, Theresienstrasse 37, 80333 Muenchen, Germany

In this talk, I discuss how topological phases determine the behavior of nonlinear dynamical systems that arise, for example, in population dynamics. We have shown that topological phases can be realized with the antisymmetric Lotka-Volterra equation (ALVE). It governs, for example, the evolutionary dynamics of zero-sum games, such as the rock-paper-scissors game [1]. It also describes the condensation of non-interacting bosons in driven-dissipative setups [2]. We have shown that robust polarization emerges at the chain's edge for the ALVE, defined on a one-dimensional chain of rock-paper-scissors cycles [3]. The system undergoes a transition from left to right polarization as the control parameter passes through a critical value. We found that the polarization states are topological phases and that this transition is indeed a topological phase transition. Remarkably, this phase transition falls into symmetry class D within the "ten-fold way" classification scheme of gapped free-fermion systems. Beyond the observation of topological phases in the ALVE, it might be possible to generalize the approach of our work to other dynamical systems in biological physics whose attractors are nonlinear oscillators or limit cycles.

[1] J. Knebel, T. Krüger, M. F. Weber, and E. Frey, Phys. Rev. Lett. 110, 168106 (2013). [2] J. Knebel, M. F. Weber, T. Krüger, and E. Frey, Nature Communications 6, 6977 (2015). [3] J. Knebel, P. M. Geiger, and E. Frey, Phys. Rev. Lett. 125, 258301 (2020).

15 min. break

Invited Talk SYQC 1.4 Wed 16:45 HSZ 01

Topological invariants protect robust chiral currents in active matter — •Evelyn Tang — Rice University, Houston, USA

Living and active systems exhibit various emergent dynamics necessary for system regulation, growth, and motility. However, how robust dynamics arises from stochastic components remains unclear. Towards understanding this, I develop topological theories that support robust edge currents, effectively reducing the system dynamics to a lower-dimensional subspace. In particular, I will introduce stochastic networks in molecular configuration space that can model different systems from a circadian clock to the stochastic dynamics of cytoskeletal filaments. The edge localization results in new properties, e.g., the clock demonstrates increased precision with simultaneously decreased cost. These out-of-equilibrium systems further possess uniquely non-Hermitian features such as exceptional points and vorticity. More broadly, my work provides a blueprint for the design and control of novel and robust function in correlated and active systems.

Invited Talk SYQC 1.5 Wed 17:15 HSZ 01

Topological defects in biological active matter — •Amin Doostmohammadi — Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

The spontaneous emergence of collective flows is a generic property of active fluids and often leads to chaotic flow patterns characterized by topological defects [1]. I will first discuss two examples of these collective features helping us understand biological processes: (i) to explain the tortoise & hare story in bacterial competition: how motility of Pseudomonas aeruginosa bacteria leads to a slower invasion of bacteria colonies, which are individually faster [2], and (ii) how self-propelled defects lead to finding an unanticipated mechanism for cell death [3,4]. I will then discuss various strategies to tame, otherwise chaotic, active flows, showing how hydrodynamic screening of active flows can act as a robust way of controlling and guiding active particles into dynamically ordered coherent structures. I will also explain how combining hydrodynamics with topological constraints can lead to further control of exotic morphologies of active shells [6].

[1] A. Amiri, R. Mueller, and A. Doostmohammadi, J. Phys. A. (2021).
[2] O. J. Meacock et al., Nat. Phys. (2021).
[3] T. N. Saw et al., Nature. (2017).
[4] R. Mueller, J. M. Yeomans, and A. Doostmohammadi, Phys. Rev. Lett. (2019).
[6] L. Metselaar, J. M. Yeomans, and A. Doostmohammadi, Phys. Rev. Lett. (2019).