129th STATISTICAL MECHANICS CONFERENCE

Abstracts of Invited Talks

Louis- Pierre Arguin, Baruch
Title: A Statistical Mechanics Approach to Moments of the Riemann zeta function
Abstract: The moments of the Riemann zeta function on the critical line play an important in number theory. In particular, it is related to the Lindelöf hypothesis on the rate of growth of the function on the critical line. In this talk, I will survey recent results on these questions that use large deviation techniques to improve the current estimates. The intuition from statistical mechanics will be emphasized.

Marco Baiesi, University of Padova
Title: Seeing Dissipation Without Forces: A Kinetic Route to Nonequilibrium Inference
How much energy does a system dissipate, and can we tell if it is out of equilibrium, when we only observe its motion? We introduce a framework that infers entropy production directly from kinetic information, without needing to reconstruct forces. The method exploits two measurable kinetic quantities from the time-symmetric part of dynamical fluctuation theory: the traffic (or frenesy) and the inflow rate. By combining steady-state density estimates with the short-time curvature of correlation functions, the approach provides an empirical and robust route to dissipation inference. Applications to simulated systems demonstrate that this estimator is unbiased at equilibrium, numerically stable, and systematically more reliable than conventional velocity-based estimators.

John Barton, University of Pittsburg
Title: Inferring predictive models of viral dynamics from genomic surveillance data
Abstract: : Understanding the predictability of evolution is a classic problem in biology, with particular relevance for rapidly evolving pathogens like influenza. Influenza vaccines must be designed to hit a "moving target," as the virus constantly evolves to escape human immune responses. We developed a novel approach to this problem by combining mathematical methods from statistical physics with epidemiological modeling. In this talk, I'll describe our approach to estimating how different mutations affect the transmissibility of the virus, and how we can use these estimates to forecast future evolution. I'll also discuss how we've applied this approach to model influenza evolution in real data. Despite a shifting immune environment, we can generate successful predictions for both the composition of the viral population in the near future and the success or loss of individual mutations.

Roland Bauershmidt, NYU
Title: Percolation in random forests
Abstract: Given a finite graph, the arboreal gas is the measure on forests (subgraphs without cycles) in which each edge is weighted by a parameter β greater than 0. This is a model for gelation of polymers that can be described as bond percolation conditioned to be a forest, the independent sets of the graphic matroid, or the $q \to 0$ limit of the random cluster representation of the q-state Potts model.

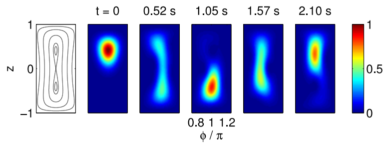
The main question we are interested in is whether the arboreal gas percolates, i.e., whether for a given β the forest has a connected component that includes a positive fraction of the total edges of the graph. We show that in two dimensions the arboreal gas does not percolate for any β greater than 0. On the other hand, in three and higher dimensions, we show that percolation occurs for large β.

Our results rely on the fact that this model is also the graphical representation of the non-linear sigma model with target space the fermionic hyperbolic plane. I will explain what this means and how it is related to more familiar concepts.

David Campbell, Boston University

Title: Sharing an Ultra-Cold Space with Smitha Vishveshwara

Abstract:



Smitha Vishveshwara and I are both condensed matter theorists, but amusingly our closest overlap is in the area of ultra-cold atoms, where we have published on similar topics. One of Smitha's recent papers is entitled "Observation of ultracold atomic bubbles in orbital microgravity" [1] which relates to earlier work that I did with several colleagues on Bose-Einstein Condensates in laser-induced optical lattices [2,3] . In this talk I will review our results on a specific simple system ultra-cold atomic system—a BEC in a double- well optical lattice—and show that, despite its simplicity, the system exhibits remarkable macroscopic quantum behavior that can be understood in many cases by a semi-classical "global phase space" (GPS) approach[2] but which also requires a fully quantum treatment in certain regions of parameter space[3]. I will compare the results of our theoretical studies with existing experimental data and predict new phenomena that should be observed in near-term future experiments. Among these new phenomena are an enhancement of quantum entanglement due to local dissipation and the existence of tunneling[3] between two self-trapped states that are unconnected in the semi-classical approximation.

I will close with some comments on Smitha's remarkable accomplishments beyond pure physics and in particular will discuss her long-term interests in the interplay of art and theater with physics, which has led to her receipt in 2025 of the AIP's prestigious Andrew Gemant Prize [4].

[1] R.A. Carollo et al. Nature 606, 281-286 (2022)
[2] Holger Hennig, Dirk Witthaut, and David K. Campbell, *Phys. Rev. A* **86**, 051640 [R] 2012.
[3] Tadeusz Pudlik, Holger Hennig, Dirk Witthaut, and David K, Campbell *Phys. Rev. A* **90,** 053610 (2014)
[4] https://www.aip.org/aip/smitha-vishveshwara-wins-aips-2025-andrew-gemant-award

Paul Chaikin, NYU
Title: Stirred Not Heated: Non-equilibrium melting in 2D

Abstract: Equilibrium 2D melting is among the most studied and best understood phase transitions. Here we present experiments on nonequilibrium melting that mimics the conventional two stage melting controlled by the proliferation of dislocations and disclination. However, the topological defects are created by stirring rather than heating and there is no effective temperature that maps the active system to its equilibrium counterpart. We also study melting in a Biased Random Organization model where overlapping particles are considered active and undergo a repulsive displacement δ, a "kick" $0<\delta<\epsilon$, while non-overlapping particles are not moved. At low density the system evolves until there are no overlaps and motion stops – an absorbing phase. Above a critical density the system never finds a completely absorbing state and continues evolving forever. In 3D the system exhibits Random Close Packing at the absorbing/active boundary. In 2D the system is a close packed crystal with long range order at this boundary. This system melts with a first order transition as ϵ increases.
*with: Ankit D. Vyas, Philipp W.A. Schonhofer, Terrence M. Hopkins
Andrew D. Hollingsworth, Stefano Sacanna, Sharon C. Glotzer, Sam Wilken, Ashley Guo, Dov Levine

Karin Dahmen, University of Illinois Urbana-Champaign
Title: Universal Crackling Noise and Prediction: from Nanoindentation and the Brain to Earthquakes and Stars?

Abstract: Jim Sethna coined the term "Crackling Noise" to describe a system's jerky response to a slowly varying driving force. Consistent with his predictions, such behavior has been observed in a wide range of systems, and on wide ranges of scales with an ever-increasing number of important applications. In this talk we showcase examples of recent progress in different contexts and on different scales: Slowly compressed nanocrystals, bulk metallic glasses, rocks, granular materials, and the earth all deform via intermittent slips or "quakes". Although these systems span 12 decades in length scale, they all show the same scaling behavior for many different statistical, dynamical, and time series properties. For example, the size distributions follow the same power law multiplied with a stress-dependent cutoff, indicating an underlying nonequilibrium phase transition. A simple mean field model for avalanches of slipping weak spots explains the agreement across scales and the effect of the relevant tuning parameters on the statistics. The analysis draws on tools from statistical physics and the renormalization group. The results enable extrapolations from one scale to another, across different materials and structures, from nanoindentation to earthquakes. Applications and connections to neuron avalanches in the brain and recent observations on stars will also be discussed, extending the range of scales to 16 decades in length.

Wade DeGottardi, Texas Tech University
Title: Fluorescence Spectroscopy of Low-Dimensional Quantum Critical Systems
Abstract: Experimental advances in cavity QED have raised the prospect of using strong light-matter coupling to fundamental alter quantum materials. What can be learned by using this technology to probe such materials has received relatively little attention. In this talk, I will present recent work by our group investigating this question in the context of quantum critical systems. For example, their fluorescence spectra can reveal fundamental aspects of the system, such as its central charge and the nature of its interactions. Repeated coherent emission of photons can also lead to superradiance, offering another probe of many-body dynamics.

Matthew P.A. Fisher, U C Santa Barbara
Title: Symmetry Breaking in Quantum and Classical Open System Dynamics
Abstract: In generic open quantum systems, universal dynamical processes tend to exhibit classicality - dissipation washes out quantum effects. Here I consider open quantum dynamics in the presence of a global U(1) symmetry. In mixed states, this symmetry can be either strong or weak, and distinct dynamical phases can be characterized by the spontaneous breaking of either symmetry. The strong-to-weak spontaneous symmetry breaking (SW-SSB) transition is characterized by various information theoretic quantities which are non-linear in the system's mixed state density matrix. Within a Lindblad framework for U(1) dynamics, we show that finite-time SW-SSB transition occurs in two and three dimension, whereas in one dimension the correlation length grows linearly with time and diverges only in the infinite-time steady state. Moreover, with carefully chosen Lindblad dynamics, the SW-SSB transition signals finite time breakdown of quantum dynamics, giving rise to classical dynamics described by a stochastic Langevin equation (Model F of Halperin-Hohenberg). When the weak symmetry is spontaneously broken, the system enters a superfluid state with classical hydrodynamics.

Bryce Gadway, Penn State University
Title: Quantum magnetism and dynamics in arrays of many-level Rydberg atoms
Arrays of interacting Rydberg atoms represent a versatile emerging platform for quantum computation and analog quantum simulation. While the standard approaches to quantum simulation with Rydberg atoms utilizes only a single Rydberg level to mediate interactions or logical gates between atoms, further possibilities for quantum control and simulation arise if one harnesses the many, many stable internal states of Rydberg atoms. I'll describe some lines of research we're pursuing based on the control of multi-level Rydberg atoms with optical and microwave fields. First, I'll describe how the microwave-engineered coupling of internal states can be used to explore few- and many-body dynamics along a so-called "synthetic" dimension of internal states, touching on several studies relevant to topology, disorder-induced localization, dissipation, and many-body dynamics. I'll then describe how we are planning to use the designer control of "microwave-dressed" Rydberg states to explore exotic forms of quantum magnetism.

Todd Gingrich, Northwestern
Title: Simulating reactions and diffusion: Lessons from toy models
Abstract: Chemical systems can deviate from equilibrium for a variety of reasons: because they are kinetically trapped, because they are subject to a time-varying drive, or because they are simultaneously in contact with multiple incommensurate reservoirs. This last scenario, which generates a nonequilibrium steady state (NESS), yields a stationary distribution over microstates that is not Boltzmann and that sustains currents. I will describe my group's efforts to build coarse-grained molecular motor models and to explicitly sample the NESS dynamics driven by a catalyzed "fuel" decomposition. The open-system molecular dynamics simulations can offer a new perspective on motor design, current reversals, and power strokes.

Paul Goldbart, Stony Brook University
Title: Random proximity measurements on quantum fluids and the hidden organization they induce
Abstract: Proximity measurements probe whether pairs of particles are close to one another, regardless of their absolute location in space. We consider the consequences of making a random sequence of proximity measurements on a fluid of many distinguishable quantum particles, focusing on the case of full post-selection. Via a self-consistent mean-field theory, we find that such measurements lead to an unusual kind of particle organization: with a prevalence that increases over time, particles mutually localize one another in space, thus constituting an ever-thickening macroscopic correlated assembly. Owing to its structural randomness, however, when viewed macroscopically this assembly retains the homogeneity of the original fluid. Ultimately, all particles become localized, and the distribution of their localization lengths stabilizes with a characteristic length-scale determined by the measurement rate. The stable distribution of these lengths is governed by a universal scaling form that has arisen in several distinct settings.
Work done with Pushkar Mohile (arXiv:2507.23085)

Chris Jarzynski, University of Maryland
Title: Fluctuation theorems for autonomous work
Abstract: In stochastic thermodynamics, fluctuation theorems for the work performed on a system of interest have been derived within a non-autonomous paradigm, in which a parameter (such as a piston's position) is varied according to an externally imposed schedule. I will describe analogous fluctuation theorems within an autonomous paradigm, in which the externally manipulated parameter is replaced by a physical body, or "work source", with which the system of interest exchanges energy. The work source evolves dynamically, and experiences back-action as it interacts with the system of interest. This back-action introduces a new term into the autonomous fluctuation theorem, and into the corresponding second-law inequality. In the limit of a work source with infinite inertia, the back-action vanishes and the usual (non-autonomous) fluctuation theorem and second law are recovered.

Mehran Kardar, MIT
Title: Spatiotemporal noise stabilizes diversity in strongly-interacting metacommunities
Abstract: Classical ecological models predict that large, diverse communities should be unstable, presenting a central challenge to explaining the stable biodiversity seen in nature. We revisit this long-standing problem by extending the generalized Lotka-Volterra model to include both spatial dispersal and environmental fluctuations across space and time. We find that neither dispersal nor environmental noise alone can resolve the tension between diversity and stability, but that their combined effects permit arbitrarily many species to stably coexist despite strong competitive interactions. We analytically characterize the noise-induced transition to coexistence, tracing its origin to an effective nonlinear self-inhibition generated by the noise, and support our results with extensive numerical simulations. Spatiotemporal noise thus provides a novel resolution to the diversity-stability paradox and a generic mechanism by which complex communities can persist.

Jaron Kent-Dobias, ICTP South American Institute for Fundamental Research
Title: Very persistent random walkers reveal transitions in landscape topology
Abstract: In large random systems, certain behaviors are reliably predicted, like the energy density of the ground state. The long-time behavior of many physical and algorithmic dynamics is likewise predictable, through DMFT and related approaches. But can these behaviors be connected to static structures of the problem at hand, like its energy landscape? Recently, development of the Overlap Gap Property, which depends on the existence of a system-spanning component of the energy level set, suggests that static topological properties can predict the performance of the best algorithms. Here, I will describe progress towards predicting the performance of the mediocre but simple algorithms we usually use. We use the ergodicity of a random walker to probe whether typical configurations belong to a system-spanning component of the energy level set. Passive random walkers lose ergodicity at a depth associated with the glass transition, but active random walkers remain ergodic to greater depth. We argue that in the limit of infinite persistence time, the ergodicity-breaking transition coincides with the point at which system-spanning components become atypical, and discuss connections with gradient descent dynamics.

Jason Kim, Cornell University
Title: Discovering model manifolds of emergent function from high-dimensional data
Abstract: Natural systems of many interacting constituents often organize to produce low dimensional emergent behaviors. For example, hundreds of thousands of neurons in the brain coordinate to represent the three-dimensional world around us. Similar emergent behaviors arise in the tens of thousands of genes that coordinate to produce the cellular processes that maintain life. What is the bottleneck for understanding how such emergent behaviors arise from these complex systems? This challenging problem is no longer limited by data: recent technological advances now allow us to measure the expression of every gene at the resolution of single cells, and the simultaneous activity of a million neurons, giving us the opportunity to model emergence

at an unprecedented scale. What is missing are methods for taking such high dimensional data and mapping them to a small number of relevant emergent variables in a principled and quantitative way.

In this talk, I will discuss novel methods I am pioneering that combine differential geometry with deep neural networks to quantitatively model emergent behaviors using high-dimensional, high-throughput data from genomics and neuroscience. I will discuss fundamental problems of model identifiability (degeneracy in model parameters that fit the data), interpretability (mapping emergent variables back to gene and neuron circuits), and predictive power, and how geometry-aware deep learning models ameliorate these problems to enable new discoveries. Finally, I will describe some of the discoveries that we have made using this method including new pathways for cancers to develop (thereby providing new potential targets for drug therapies) and how mice update the representations of the mazes that they run through.

Kasper Larsen, Rutgers University
Title: Equilibrium models in mathematical finance
Abstract: In this overview talk, we will outline a few typical systems of equations that characterize equilibrium models coming from financial economics. We then discuss how to analyze these systems in order to prove existence and uniqueness of solutions.

David Limmer, University of California, Berkeley
Title: Large deviations of ionic currents in electrolytes
Abstract: In my talk I will review some of our recent work understanding the rare fluctuations of driven electrolyte systems. I will discuss both analytic results using macroscopic fluctuation theory and results from molecular simulation using enhanced sampling methods. Particular emphasis will be on Wien effects in both strong and weak electrolytes which can be understood using path reweighting and nonequilibrium response theory.

Nathan Lundblad, Bates College
Title: Exploring quantum gases on curved manifolds
Abstract: Exploring the effects of geometry, topology, dimensionality, and interactions on ultracold atomic ensembles has been a continually fruitful line of inquiry in the decades since the first observation of Bose-Einstein condensation (BEC). One previously unexplored configuration for ultracold ensembles is that of a bubble or shell, where trapped atoms are confined in the vicinity of a spherical or ellipsoidal surface. Such a quantum system could offer new collective modes, topologically-sensitive behavior of quantized vortices, self-interference and shell collapse, as well as the exploration of trapped ultracold systems with mm-scale spatial extent. Recently, observations of trapped bubbles of ultracold atoms have been made on earth and in space aboard ISS; I will review insights gained and future prospects.

Ben Machta, Yale University
Title: Bacterial chemotaxis is limited by sensory information, but sensory information isn't limited by ligand diffusion
Abstract: E. coli navigate chemical gradients using 'run and tumble' navigation. Too small to measure a gradient, they instead intersperse straight swimming 'runs' with reorienting 'tumbles' when conditions appear to be worsening. In the absence of sensory information, a bacterium using this strategy could execute a sort of random walk, but would be unable to bias this walk up a chemical gradient. Here we develop an information theory framework, based on rate distortion theory, to probe the relationship between the rate of sensory information and a bacterium's ability to climb a gradient. In the first part of the talk I will use this approach to show that E coli climb shallow gradients with average speeds near a bound set by the limited information rate of their sensor. I will also present results showing how different strategies are optimal under different amounts and types of information, with abrupt transitions between optimal strategies as information rates improve. In the second part of the talk I will show that, contrary to past theoretical expectations, the fidelity of E. coli's sensor is not limited by the arrival of individual particles. I will discuss several possibilities for why this could

be, with a particular focus on the mechanism for sensory amplification, which could be adding substantial noise to the system.
Joint work with Henry Mattingly, Keita Kamino, Thierry Emonet

Bruno Nachtergaele, UC Davis
Title: Charge Gap and Neutral Gap Comparison for Fractional Quantum Hall Systems.
Abstract: We introduce an elementary inequality relating the charge and neutral gaps of a family of quantum many-body systems and discuss an application to the so-called pseudo-potentials modeling fractional quantum Hall systems. These are quantum many-body Hamiltonians that are frustration free and have two symmetries, one related to the conservation of charge (particle number) and another to the conservation of dipole moment (angular momentum), in addition to translation invariance. We show that for such systems the general inequality can be refined, opening the possibility of new applications to the study of the spectral gap of such systems.
(Joint work with Marius Lemm, Simone Warzel, and Amanda Young, arxiv:2507.18814).

Naoko Nakagawa, Ibaraki University
Title: Global Thermodynamics for Heat Conduction Systems
Abstract: While powerful, standard continuum descriptions of non-equilibrium systems do not always capture global balances. We therefore introduce "Global Thermodynamics," a minimal-variable framework based on a single global temperature. When applied to two-phase coexistence under a weak heat flux, our framework predicts the stabilization of metastable states near the interface, a phenomenon beyond the reach of conventional heat conduction theory. This prediction is verified by numerical simulations. The framework also formulates an effective gravity induced by the heat flux. This talk is based on a series of works in collaboration with S.-i. Sasa [arXiv:2505.10380 (2025) and references therein].

Vadim Oganesyan, College of Staten Island
Title: Spatio-temporal order in nonunitary magnets and pumped matter
Abstract: *I will discuss general considerations (esp. theoretical) and certain specific examples for realizing novel modulated (quasiperiodic) many-body phases of matter. These include an exactly solvable variant of the Ising model where lattice-based classical-to-quantum correspondence affords a detailed look at the "heralded" dynamics near the time-periodic steady state obtained from recently discovered modulated phases in the 2D Ising model (based on* PhysRevResearch.4.013018). Time-permitting, I will also mention materials-oriented examples of pattern formation in non-equilibrium superconductivity (2501.08216) and high-harmonics generation in a spin systems (PhysRevB.110.064420).

Tami Pereg-Barnea, McGill University
Title: The bosonic Kitaev chain and topological amplification
Abstract: The Kitaev chain is a toy model for a one dimensional topological superconductor. It demonstrates how the superconductor can host Majorana modes at its edges. These special modes are their own antiparticles, exhibit non-abelian statistics and can serve as building blocks of qubits. In its original form the model is written for fermions (electron quasiparticles) and the Majoranas can be thought of as a half of an electron. after a short review of the fermionic model, I will introduce a bosonic analogue for the Kitaev model, intended for photonic or cold atom systems. This model does not result in Majorana edge modes as those can not be made of bosons. Nevertheless, the topology of the model leads to some interesting effects where a hermitian Hamiltonian leads to non-hermitian dynamics.

Sid Redner, Santa Fe Institute
Title: Optimization and Wealth Sharing in First-Passage Resetting

Abstract: We introduce first-passage resetting, in which a diffusing particle is reset to its starting point whenever it reaches a specified threshold. We present two applications of this mechanism: (1) Optimization in a finite domain, in which a cost is incurred whenever the diffuser is reset to the origin and a reward is given when the particle stays near the reset (maximal performance) point. We derive the condition to optimize the net reward minus the net cost. (2) We also explore consequences of first-passage resetting in a toy model of wealth sharing to try to determine whether altruism or selfishness is the optimal strategy.

Shin-ichi Sasa, Kyoto University
Title: Statistical Mechanics of Phase Coexistence in the Discrete Model B under External Driving
Abstract: To advance the theoretical understanding of a novel phenomenon—the flux-induced stabilization of metastable states in non-equilibrium phase coexistence—we study the discrete Model B under external driving. By analyzing the Zubarev-Maclennan distribution for this model, we derive the variational function that determines the steady-state configuration of the liquid-gas interface. We show that this function is equivalent to the one derived from the phenomenological framework of global thermodynamics. As a result, we obtain a phase coexistence condition in which the chemical potential at the interface deviates from its equilibrium value. This talk is based on our recent paper [S.-i. Sasa and N. Nakagawa, J. Stat. Phys.192, 26 (2025)].

Salvatore Torquato, Princeton University
Title: Hyperuniform Classical and Quantum-Mechanical Systems, and Their Novel Physical Properties
Abstract: The study of hyperuniform states of matter is an emerging multidisciplinary field, influencing and linking developments across the fields of physics, chemistry materials science, mathematics and biology. Hyperuniform many-particle systems in d-dimensional Euclidean space are characterized by an anomalous suppression of density fluctuations at large length scales relative to those in ordinary disordered systems. The hyperuniformity concept provides a unified theoretical framework to categorize crystals, quasicrystals and exotic disordered systems. Disordered hyperuniform many-particle systems behave more like crystals or quasicrystals in the manner in which they suppress large-scale density fluctuations, and yet are also like typical liquids and glasses in that they are statistically isotropic structures with no Bragg peaks. I will provide a brief overview of the hyperuniformity concept and its generalizations, and present classical and quantum-mechanical examples. I will describe how the hybrid crystal-liquid attribute of disordered hyperuniform states endow them with novel physical properties.

Misha Tsodyks, Weizmann Institute
Title: Random Tree Model of Meaningful Memory
Abstract: We introduce a statistical ensemble of random trees to represent narratives as hierarchies of key points, where each node is a compressed representation of its descendant leaves, which are the original narrative segments. Recall from this hierarchical representation is constrained by working memory capacity. Our analytical solution aligns with observations from large-scale narrative recall experiments. Specifically, our model explains that (1) average recall length increases sublinearly with narrative length, and (2) individuals summarize increasingly longer narrative segments in each recall sentence. Additionally, the theory predicts that for sufficiently long narratives, a universal, scale-invariant limit emerges, where the fraction of a narrative summarized by a single recall sentence follows a distribution independent of narrative length.

Michael Vogelius, Rutgers University
Title: Scattering vs. non-scattering
Abstract: I shall review some recent work through which we have determined quite general conditions on regularity, geometry and non-degeneracy that guarantee scattering from transmitting inhomogeneities in the context of the Helmholtz equation.

Tzu-Chieh Wei, Stony Brook (Monday or early Tuesday)
Title: Local symmetries and extensive ground-state degeneracy of a one-dimensional supersymmetric fermionic chain
We study a one-dimensional supersymmetric hard-core fermion model first proposed by Fendley, Schoutens, and de Boer [Phys. Rev. Lett. 90, 120402 (2003)]. We focus on the full Hilbert space instead of a restricted subspace. Exact diagonalization shows the degeneracy of zero-energy states scales exponentially with size of the system, with a recurrence relation between different system sizes. We solve the degeneracy problem by showing the ground states can be systematically constructed by inserting immobile walls of fermions into the chain. Mapping the counting problem to a combinatorial one and obtaining the exact generating function, we prove the recurrence relation on both open and periodic chains. We also provide an explicit mapping between ground states, giving a combinatorial explanation of the recurrence relation.

This is based on joint work with Shuyu Zhang, Hiroki Sukeno, and Kazuki Ikeda, Physical Review B 111, 235151 (2025).

Helvi Witek, University of Illinois Urbana-Champaign
Title: Searching for bosonic "condensates" around black holes with gravitational waves
Abstract: Black holes are among the most intriguing predictions of general relativity,
composed of the fabric of spacetime itself. Observations of black holes, and of the gravitational waves that their collision produces, offer unique access to extreme gravity and enable us to address pressing puzzles in in fundamental physics
ranging from dark matter to the very nature of gravity itself.
The latter is possible through the ``condensation'' of light scalar or vector fields,
some of which are compelling candidates for dark matter, around black holes.

We have come a long way since black holes and gravitational waves were conceived of more than a century ago: this year we are celebrating 10 years of gravitational wave observations with LIGO, and I will give an overview on their status in the first part of my presentation.
In the second part of my talk, I will discuss ``condensates'' of light bosons that can form around black holes through superradiance or accretion, and their imprint in gravitational-wave observations.

Stefano Zapperi, University of Milan
Title: Epidemiology of the Great Fear of 1789 in France
The Great Fear of 1789, a wave of panic and unrest in rural France fuelled by the spreading of rumours, was an important moment at the onset of the French Revolution, marking the collapse of feudalism and the rise of the new regime. The Great Fear provides a vivid example of the role the spreading of rumours has in driving political changes that might be relevant today. We collected existing historical records related to the Great Fear and use epidemiology tools and models4 to reconstruct the network of its transmission from town to town. In this way, we quantify the spatiotemporal spread of the rumours and compute key epidemiological parameters, such as the basic reproduction number. Exploiting information on the structure of the road network in eighteenth century France, we estimate the most probable diffusion paths of the Great Fear and quantify the distribution of spreading velocities. By endowing the nodes in our reconstructed network with indicators related to the institutional, demographic and socio-economic conditions of the time, including literacy, population size, political participation, wheat prices, income and ownership laws, and the unequal distribution of land ownership, we compute factors associated with spread of the Great Fear. Our analysis sheds light on unresolved historiographic issues on the significance of the Great Fear for the French Revolution, providing a quantitative answer to the unresolved debate between the role of emotions and rationality in explaining its diffusion.

Zapperi, S., Varlet-Bertrand, C., Bastidon, C. La Porta, C. A. M., Parent A. Epidemiology models explain rumour spreading during France’s Great Fear of 1789. Nature (2025). https://doi.org/10.1038/s41586-025-09392-2