Abstracts of Invited Talks

Vijay Balasubramanian
University of Pennsylvania

Carl M. Bender
Washington University in St. Louis
"PT symmetry in quantum mechanics and quantum field theory"
PT-symmetric quantum theory began with an analysis of the strange-looking non-Hermitian Hamiltonian $H=p^2+x^2(ix)^\epsilon$. This Hamiltonian is PT symmetric and the eigenvalues of this Hamiltonian are discrete, real, and positive when $\epsilon\geq0$. In this talk we discuss the corresponding quantum-field-theoretic Hamiltonian $H=\frac{1}{2}(\nabla\phi)^2+\phi^2(\phi)^\epsilon$ in $D$-dimensional spacetime, where $\phi$ is a pseudoscalar field. We show how to calculate the Green's functions as series in powers of $\epsilon$ directly from the Euclidean partition function. We derive exact finite expressions for the vacuum energy density, the renormalized mass, and the connected n-point Green's functions for all $n$ and for $0\leq D<2$. For $D\geq2$ the one-point Green's function and the renormalized mass become infinite, but perturbative renormalization can be performed. The beautiful spectral properties of PT-symmetric quantum mechanics appear to persist in PT-symmetric quantum field theory.

Bill Bialek
Princeton University

Tommaso Biancalani
Broad Institute of MIT and Harvard
"Disentangling bacterial invasiveness from lethality in an experimental host-pathogen system"
Understanding virulence remains a central problem in human health, pest control, disease ecology and evolutionary biology. Bacterial virulence is typically quantified by phenomenological indicators such as the LT50 (i.e. the time taken to kill 50% of an infected population). However, virulence emerges as a result of complex processes that occur at different stages: the pathogen needs to breach the primary host defenses, find a suitable environment to replicate, and finally express the virulence factors that cause lethality. It is well-known that pathogens exhibit a very broad spectrum of strategies to accomplish these three tasks, yet, phenomenological indicators such as the LT50 cannot distinguish the ability of the pathogen to invade the host from its ability to kill the host. Here, we propose a physical host-pathogen theory that shows how to disentangle colonization, growth, and pathogen lethality from the survival kinetics of a host population. Preliminary experimental data from C. elegans nematodes exposed to various pathogens shows that host mortality becomes severe only once the pathogen population has reached its carrying capacity within the host. In the talk, I will discuss various model predictions and compare them against experimental data.

Paul Bourgade
New York University
"Overlaps between eigenvectors of Ginibre matrices"
Eigenvectors of non-hermitian matrices are non-orthogonal, and their distance to a unitary basis can be quantified through the matrix of overlaps. These variables quantify the stability of the spectrum, and characterize the joint eigenvalues increments under Dyson-type dynamics. They first appeared in the physics literature; well known work by Chalker and Mehlig calculated the expectation of these overlaps for complex Ginibre matrices. For the same model, we extend their results by deriving the distribution of the overlaps and their correlations. As a corollary, at equilibrium, eigenvalues move with diffusive scaling under the Dyson-dynamics. (Joint work with G. Dubach).

Christian Brennecke
Harvard University
"Bogoliubov Theory in the Gross-Pitaevskii Limit"
We consider Bose gases consisting of $N$ particles trapped in a box with volume one and interacting through a repulsive potential with scattering length of the order $N^{-1}$ (Gross-Pitaevskii regime). We determine the ground state energy and the low-energy excitation spectrum, up to errors vanishing as $N \to \infty$. Our results confirm Bogoliubov's predictions. This is joint work with C. Boccato, S. Cenatiempo and B. Schlein.

Edouard Brezin Ecole Normale Supérieure
Tom Butler Amazon
David Campbell Boston University
Eric Carlen Rutgers University

Arup Chackraborty MIT

"Inducing cross-reactive antibody responses by vaccination: a crossroad of statistical mechanics,"

Vaccination has saved more lives than any other medical procedure. But, today some pathogens have evolved that defy successful vaccination using the empirical paradigms pioneered by Pasteur and Jenner over two centuries ago. HIV is a prominent example. A major barrier to the development of a vaccine against HIV is the high mutability of the virus, which enables HIV to mutate to evade vaccine-induced antibodies and T cells that lie ready and waiting for certain strains. Antibodies are produced by a nonequilibrium Darwinian evolutionary process called affinity maturation. A question of great interest is how vaccination protocols can be designed to elicit antibodies that are cross-reactive to diverse HIV strains. I will describe work that shows how vaccination with multiple variant strains to induce cross-reactive antibodies results in conflicting selection forces that “frustrate” affinity maturation. I will then discuss how optimal temporal patterns of frustration can promote the evolution of broadly neutralizing antibodies.

Rodica Costin Ohio State University
Ayse Erzan Istanbul Technical University
Paul Goldbart University of Texas at Austin
Jeffrey Harvey University of Chicago
Björn Hof IST Austria
Ian Jauslin Princeton University

Mehran Kardar MIT

"Bacterial range expansions on a growing front: Roughness, Fixation, and Directed Percolation”"
Igor Klebanov
Princeton University

Christian Maes
KU Leuven
“Cosmic acceleration from quantum Friedmann equations”
We consider a simplified model of quantum gravity using a mini-superspace description of an isotropic and homogeneous universe with dust. We derive the corresponding Friedmann equations for the scale factor, which now contain a dependence on the wave function. We identify wave functions for which the quantum effects lead to a period of accelerated expansion that is in agreement with the apparent evolution of our universe, without introducing a cosmological constant. Authors: Thibaut Demaerel, Christian Maes and Ward Struyve (Instituut voor Theoretische Fysische, KU Leuven)

Juan Maldacena
Institute for Advanced Study
“Entanglement and the geometry of spacetime”
We will discuss how the quantum mechanical property of entanglement is related to the geometry of spacetime.

Vieri Mastropietro
University of Milan

Thierry Mora
Ecole Normale Supérieure
“Diversity and specificity of immune repertoires”
The diversity of repertoires of B-cell and T-cell receptors is generated by a stochastic process of gene rearrangement called VDJ recombination, and is later sculpted by selection, clonal proliferation, and somatic hypermutations. I will show how these processes can be learned quantitatively from high-throughput repertoire sequencing data. The resulting models can then be used to estimate the diversity of repertoires and their overlap between individuals, to identify condition-specific immune receptors from patient cohort data, and to detect signatures of immune responses in single patients.

Narayanan Bhargav Peruvemba
Rutgers University
“Diffusion on graphs”
Diffusion on a graph is a cellular automaton describing how integer labels on the vertices evolve. The label of a vertex is just the number of particles at that vertex, and at each step, each vertex simultaneously sends one particle to each of its neighbours with fewer particles, mimicking flow towards lower concentrations. What can we say about the trajectories of various initial configurations in this process? Here’s an amuse bouche: this firing rule may generate negative labels when started from a completely positive initial configuration, so it is not clear, a priori, if one must even have a stable final state, or even periodic behaviour necessarily!

Phil Nelson
University of Pennsylvania
Stefano Olla
Université Paris Dauphine-PSL

Jeremy Quastel
University of Toronto
“The strong coupling fixed point of the KPZ universality class”
We describe the scaling invariant, completely integrable Markov process which governs long time large scale fluctuations of 1d random interface growth. It was discovered through a complete solution of TASEP, the
most popular discretization of the Kardar-Parisi-Zhang equation. Joint work with Konstantin Matetski and Daniel Remenik

Pablo Sartori Institute for Advanced Study
Tatyana Shcherbina Princeton University
Hong-Yan Shin University of Illinois
Nicolas Sourlas École Normale Supérieure
Katepalli Sreenivasan New York University
Ramon Van Handel Princeton University
Kalín Vetsigian University of Wisconsin (Madison)
Vincenzo Vitelli University of Chicago

“Odd Elasticity”
Hooke's law states that the deformations or strains experienced by an elastic object are proportional to the applied forces or stresses. The number of coefficients of proportionality between stress and strain, i.e. the elastic moduli, is constrained by energy conservation. In this Letter, we generalize continuum elasticity to media in which energy is not conserved, such as solids with microscopic activity. This generalization, which we dub odd elasticity, reveals that two additional elastic moduli exist in an isotropic solid with non-conservative interactions. Such an odd-elastic solid can be regarded as a distributed engine: work is locally extracted, or injected, during quasi-static cycles of deformation. By coarse graining illustrative microscopic models, we show how odd elasticity emerges in active metamaterials composed of non-reciprocal springs that actuate internal torques in response to strain. Our predictions, corroborated by simulations, uncover phenomena ranging from activity-induced auxetic behavior and buckling to wave propagation powered by self-sustained active elastic cycles.

Alexandra Walczak CNRS and Ecole Normale Supérieure
“Prediction in immune repertoires”
Predicting the future state of a complex environment requires weighing the trust in new observations against prior experiences. In this light, I will present a view of the adaptive immune system as a dynamic Bayesian machinery that updates its memory repertoire by balancing evidence from new pathogen encounters against past experience of infection to predict and prepare for future threats. The results suggest that pathogenic environments are sparse and that memory repertoires significantly decrease infection costs even with moderate sampling.

Shenshen Wang University of California, Los Angeles
“Evolving generalists in changing landscapes”
Evolving systems, be it an antibody repertoire in the face of mutating pathogens or a microbial population exposed to varied antibiotics, respond to ever changing environments through a constant search for adaptive solutions in high-dimensional fitness landscapes. Generalists are robust performers that remain fit under varied environmental conditions. For better (induction of broad antibody response) or worse (emergence of multi-drug resistance), it is important for evolution to discover these adaptive solutions efficiently. Yet, whether and when environmental changes can offer them evolutionary advantage over specialists remains an open question. We use a generative model within a generic landscape framework to study evolutionary discovery of generalists in slowly changing environments. We show that switching rugged fitness landscapes can enhance the propensity to evolve high performers, if the landscapes’ topography is related in a way that balances the
trade-offs between diversity, quality and accessibility of such solutions, thus demonstrating a general route toward favoring or avoiding generalists via a proper choice of cycling environments.

Jean Zinn-Justin