Seventh Mandelstam Theoretical Physics School and Workshop 2025

January 9 - 15, 2025
Room P216, Physics Building, University of the Witwatersrand
Johannesburg, South Africa

Schedule of Program

	Jan 9	Jan 10	Jan 13	Jan 14	Jan 15
	Thursday	Friday	Monday	Tuesday	Wednesday
9:00 - 9:15	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea
9:15 - 9:30	Welcome Remarks	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea
9:30 - 9:45	Verbaarschot	Verbaarschot	Forini	Hanada	Hanada
9:45 - 10:00	Verbaarschot	Verbaarschot	Forini	Hanada	Hanada
10:00 - 10:15	Verbaarschot	Verbaarschot	Forini	Hanada	Hanada
10:15 - 10:30	Verbaarschot	Verbaarschot	Forini	Hanada	Hanada
10:30 - 10:45	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea
10:45 - 11:00	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea
11:00 - 11:15	Baggioli	Baggioli	Hanada	De Mello Koch	Soni
11:15 - 11:30	Baggioli	Baggioli	Hanada	De Mello Koch	Soni
11:30 - 11:45	Baggioli	Baggioli	Hanada	De Mello Koch	Soni
11:45 - 12:00	Baggioli	Baggioli	Hanada	De Mello Koch	Soni
12:00 - 12:15	Joseph	Kibe	Van Zyl	Ovchinnikov	Lunch/Discussions
12:15 - 12:30	Joseph	Kibe	Van Zyl	Ovchinnikov	Lunch/Discussions
12:30 - 13:00	Lunch/Discussions	Lunch/Discussions	Lunch/Discussions	Lunch/Discussions	Lunch/Discussions
13:00 - 14:00	Lunch/Discussions	Lunch/Discussions	Lunch/Discussions	Lunch/Discussions	Free Time/ Discussions
14:00 - 14:15	Jevicki	Baggioli	Soni	Forini	
14:15 - 14:30	Jevicki	Baggioli	Soni	Forini	
14:30 - 14:45	Jevicki	Baggioli	Soni	Forini	
14:45 - 15:00	Jevicki	Baggioli	Soni	Forini	
15:00 - 15:15	Coffee/Tea	Coffee/Tea	Coffee/Tea	Coffee/Tea	
15:15 - 15:30	Das	Verbaarschot	Forini	Soni	
15:30 - 15:45	Das	Verbaarschot	Forini	Soni	
15:45 - 16:00	Das	Verbaarschot	Forini	Soni	
16:00 - 16:15	Das	Verbaarschot	Forini	Soni	
16:15 - 16:30	Free Time/ Discussions	Mukhopadhyay	Couzens	Rudra	
16:30 - 16:45		Mukhopadhyay	Couzens	Rudra	
17:00 - 21:00					Dinner

Titles and Abstracts of Talks

Jacobus Verbaarschot (SUNY Stony Brook, USA)	
Pedagogical Talk 1	Title: Random Matrix Theory and the Sachdev-Ye-Kitaev Model
	Abstract: In this lecture, we show that all quantum matter can be classified according to anti-unitary symmetries. This also applies to random matrix theories, and we show that the presence of topology is determined by anti-unitary symmetries. We give a derivation of the Kitaev table for topological insulators and show the connection with instantons in QCD-like theories. Also, the pattern of spontaneous symmetry breaking is determined by anti-unitary symmetries. Spectral observables including the spectral form factor and the number variance will be discussed. We give a brief overview of nonhermitian random matrix theories and discuss a couple of examples. We close with the introduction of the Sachdev-Ye-Kitaev (SYK) Model and classify it according to anti-unitary symmetries. This is illustrated by random matrix universality both in the SYK model and in the sparse SYK model where most of the matrix elements have been put to zero.
Jacobus Verbaarschot (SUNY Stony Brook, USA)	
Pedagogical Talk 2	Title: Quantum Chaos and Dissipation
	Abstract: In this lecture, we introduce Quantum Chaos and lay the groundwork for the study of chaos in dissipative quantum systems. We discuss the relation between chaos and spectral correlations and give semiclassical arguments showing that the spectral form factor of chaotic systems is given by random matrix theory. We introduce the Out of Time Order Correlator and review the derivation of the Maldacena-Shenker Stanford bound. We show that dissipative quantum systems with a Markovian coupling to the environment can be described in terms of system degrees of freedom only through a Lindblad evolution of the density matrix. Some of its properties including its vectorization will be discussed. Details will be worked out for the SYK model with dissipation given by linear jump operators.
Jacobus Verbaarschot (SUNY Stony Brook, USA)	
Research Talk	Title: Chaos, Anomalous Relaxation and Emergent Topology in Many-Body Dissipative Quantum Systems

	Abstract: In this lecture, we study the effect of chaos on Markovian dissipative many-body systems, by analyzing both the integrable Sachdev-Ye-Kitaev (SYK) model with a two-body (q=2) interaction and the interacting SYK model with at least a four-body (q=4) interaction. The Markovian dissipation is modeled by a Lindblad equation for the evolution of the density matrix. For the q=2 problem, we obtain a full analytical explanation of the Out of Time Order Correlator (OTOC) and find that the spectral form factor dominates the late time evolution. In contrast, the short time relaxation obeys a power law. For the q=4 problem, we find an anomalous relaxation which is absent for q=2. For a better understanding of the relaxation, we have analyzed the spectrum of the vectorized Lindblad operator. Surprisingly, we found that the real eigenvalues of this non-hermitian operator have topological properties closely related to the topological properties of the Wilson lattice QCD Dirac operator.
Matteo Baggioli (Jiao Tong University, China)	
Pedagogical Talk 1	Title: Breaking translations: from effective theories to holography and back
	Abstract: In these two lectures, I will consider physical systems with broken translations from a macroscopic point of view. I will discuss recent developments about their description at the interplay between effective field theories, hydrodynamics and applied holography. I will put particular emphasis on simple holographic models that allow us to study strongly coupled systems with no quasiparticles, where translations can be broken explicitly, spontaneously or in a combination of these two. For simplicity, I will mostly focus on the holographic axion model, but I will also provide a general overview and a (biased) status report on the topic. Applications to hard condensed matter and soft matter will be discussed.
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Matteo Baggioli (Jiao Tong University, China)	
Research Talk	Title: Go with the flow, hydrodynamic theory of electrically driven non-equilibrium steady states

	Abstract: Hydrodynamics, as an effective theory capturing long-wavelength and late-time dynamics around thermal equilibrium states, finds applications in diverse physical systems, ranging from electron flow in metals, to ocean wave propagation, traffic flow, bacterial motion and the quark-gluon plasma. On the other hand, non-equilibrium steady states (NESS), characterized by a stationary flow of energy or matter in the presence of a driving force, are pervasive in nature but they present significant challenges to the foundational principles of statistical physics, as it is generally unclear if and how they satisfy the axiomatic assumptions of thermodynamics. The capability of hydrodynamics to accurately describe slow and long-wavelength fluctuations around a NESS remains an open question. In this study, we provide positive evidence by specifically addressing electrically driven non-equilibrium charged steady states. Our approach involves introducing gapped modes and extending the effective description into a relaxed hydrodynamic theory (RHT). Leveraging the gauge-gravity duality as a tool for controlled computations within non-equilibrium systems, we establish an ultraviolet complete model for these NESS that confirms the validity of our RHT. In summary, our findings present a concrete realization of a RHT applicable to a NESS. This expands the regime of validity of hydrodynamics beyond thermal equilibrium, offering valuable insights into the dynamics of non-equilibrium systems.
Valentina Forini (Humboldt University, Germany)	
Pedagogical Talk 1	Title: Holography and conformal defects I
	Abstract: After a general introduction to conformal defects, we consider the example of the 1/2 BPS Wilson line in N=4 super Yang Mills theory in four dimensions. We review perturbative and nonperturbative approaches to study the conformal field theory defined by it.
Valentina Forini (Humboldt University, Germany)	
Pedagogical Talk 2	Title: Holography and conformal defects II
	Abstract: We look at tools from the analytic bootstrap (inversion relation, Witten diagrams bootstrap) in the context of conformal defects, and highlight recent research lines on the subject.
Valentina Forini (Humboldt University, Germany)	
Research Talk	Title: Conformal field theories from line defects, holography and the analytic bootstrap
	Abstract: Wilson lines are a prototypical example of defect in quantum field theory. After reviewing the superconformal case - in which the one-dimensional defect CFT that they define is particularly interesting - I will discuss some analytic tools that may prove useful in this context, but are developed for generic 1d CFTs. Among them, a representation of the four-point correlator as a Mellin amplitude and via a dispersion relation.
Masanori Hanada (Queen Mary University London, UK)	
Pedagogical Talk 1	Title: Universal framework for quantum simulation of Yang-Mills theory on digital quantum computer I

	Abstract: Orbifold lattice Hamiltonian, originally invented by Kaplan, Katz, and Unsal to regularize super Yang-Mills keeping exact SUSY, turned out to be ideal for quantum simulations of Yang-Mills theory and QCD. I will explain how Yang-Mills theory can be simulated on digital quantum computer, starting with much simpler systems (spins; bosons; and fermions) and showing how the same universal prescription applies to orbifold lattice Hamiltonian.
Masanori Hanada (Queen Mary University London, UK)	
Pedagogical Talk 2	Title: Universal framework for quantum simulation of Yang-Mills theory on digital quantum computer II
	Abstract: Orbifold lattice Hamiltonian, originally invented by Kaplan, Katz, and Unsal to regularize super Yang-Mills keeping exact SUSY, turned out to be ideal for quantum simulations of Yang-Mills theory and QCD. I will explain how Yang-Mills theory can be simulated on digital quantum computer, starting with much simpler systems (spins; bosons; and fermions) and showing how the same universal prescription applies to orbifold lattice Hamiltonian.
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Ronak Soni (Chennai mathematical Institute, India)	
Pedagogical Talk 1	Title: Minimal Area from Entangled Matrices I
	Abstract: I will go over the Ryu-Takayanagi formula and its derivation, emphasizing aspects interesting for our work. I will then explain the concept of relational operators and quantum reference frames in gauge theories (with a specific emphasis on MQM) and introduce a class of notions of subsystems. Finally, I will explain how to calculate entanglement entropies, being clear about the arbitrary choices involved. I will show how some sort of minimization formula can emerge. Based on section 2 of the paper: arXiv:2408.05274.
Ronak Soni (Chennai mathematical Institute, India)	
Pedagogical Talk 2	Title: Minimal Area from Entangled Matrices II
	Abstract: I will introduce a particular MQM called the mini-BMN model. I will go over how geometry emerges in the IR in this model and show how to calculate entanglement in this theory. Based on sections 3 and 4 of the paper: arXiv:2408.05274.
Ronak Soni (Chennai mathematical Institute, India)	
Research Talk	Title: Minimal Area from Entangled Matrices

	Abstract: I will show that an RT-like minimal area formula is the entanglement entropy of a specific choice of subsystem in the mini-BMN model. Based on section 5 of the paper: arXiv:2408.05274.
Sumit Das (University of Kentucky, USA)	
Research Talk	Title: Dynamical Phases in Floquet Conformal Field Theories
	Abstract: We explore dynamical phases and phase transitions in periodically driven conformal field theories in 3+1 and 2+1 dimensions. Our results provide evidence that these phases are classified by the conjugacy classes of the quaternionic Mobius group SL(2,H).
Antal Jevicki (Brown University, USA)	
Research Talk	Title: Large N Thermofield
	Abstract: Through the collective representation on the Schwinger-Keldysh contour, we develop analytical and numerical methods at Large N. This gives thermodynamic properties of general matrix and vector type quantum systems.
Robert de Mello Koch (HuZhou University, China)	
Research Talk	Title: Hairy black hole microstates
	Abstract: We construct new 1/16-BPS cohomologies of the maximal super-Yang-Mills theory and interpret them as black holes wrapped by dual giant graviton hairs.
Ayan Muchopadhyay (IFIS, Pontificia Universidad Catolica de Valparaiso, Chile)	
Research Talk	Title: Fundamental strings, gravity and quantum processors
	Abstract: I will show that the Nambu-Goto equations for.a string follow from the junction conditions of three dimensional gravity. The solutions of the junction conditions between two copies of an Einstein spacetime M are in one-to-one correspondence with the solutions of the non-linear Nambu-Goto equations obeyed by the average embedding of the junction in M up to rigid parameters related to spacetime and worldsheet isometries. In AdS, the solution of the Nambu-Goto equation corresponding to the bulk junction can be decoded from the relative time reparametrization at the dual CFT interface. In the more general constructions, each solution of the Nambu-Goto equation should be understood as a quantum processor i.e. a map between the Hilbert spaces of the CFT on the two sides of the dual interface. These results, remarkably, can be generalized to multi-way junctions between three dimensional spacetimes.
Sergei Ovchinnikov (Institute for Theoretical and Mathematical Physics, Russia)	
Research Talk	Title: Uniqueness of supersymmetric black holes in gauged supergravities

	Abstract: The classification of anti de Sitter black holes is an open problem of central importance in holography. In this talk, I will present new advances in classification of supersymmetric solutions to the five-dimensional gauged supergravity coupled to an arbitrary number of Abelian vector multiplets. In particular, we prove a black hole uniqueness theorem within a subclass of solutions with biaxial symmetry and a certain twistor structure. This subclass includes all known solutions of this theory, both analytic and numerical. The proof is based on the near-horizon data only and is agnostic of the asymptotic region. We therefore deduce that a classification of CFT states in the UV of the holographic correspondence can be derived from the deep IR.
Tanay Kibe (University of the Witwatersrand, South Africa)	
Research Talk	Title: QNEC and generalized Clausius inequalities in holographic quenches
	Abstract: Quantum thermodynamics generalizes the classical Clausius inequality stating that the irreversible entropy produced in any process is not only positive, but has both a lower and an upper bound. In this talk I will describe how the quantum null energy condition (QNEC) implements similar bounds on entropy production after a global quench in 1+1 dimensional holographic conformal field theories.
Christopher Couzens (University of Oxford, UK)	
Research Talk	Title: Localising Romans Supergravity
	Abstract: In this talk I will discuss how Equivariant Localization can be used to compute observables in supergravity without the need to solve the equations of motion. We will use 6d Romans supergravity as our test case and show that the on-shell action is almost completely determined in terms of topological data. This allows us to recover known results in the literature and to make predictions for hitherto unknown solutions.
Jaco van Zyl (University of Cape Town, South Africa)	
Research Talk	Title: Operator growth and the Jordan-Wigner transformation
	Abstract: In this talk I will discuss the operator growth / complexity of operators on either side of the Kitaev chain / Ising spin chain duality as realised by a Jordan-Wigner transformation. When considering open boundary conditions there is a neat organisation of the operator dynamics on either side of the duality, both consistent with growth expected in a quadratic fermion model like the Kitaev chain. When examining periodic chains, however, the mapping of boundary terms provides access to multiple branches of highly complex operators. These give rise to much larger saturation values of complexity for parity-mixing operators and are in contrast to what one would expect for a quadratic Hamiltonian.
Anik Rudra (University of the Witwatersrand, South Africa)	
Research Talk	Title: Black hole in S-fold

	Abstract: Type IIB String theory can accommodate non-geometric background which involves a transition function in the internal geometry as an element of the non-perturbative S-duality group. Among such backgrounds, I will first introduce a particular class, dubbed S-folds: $AdS_4 \times_{\phi} S_1 \times_{\phi} S_5$ featuring a novel AdS_4 vacua with gauge group $[SO(6) \times_{\phi} SO(1, 1)] \times_{\phi} T_{12}$ which is the second most supersymmetric AdS vacuum in any maximal supergravity theory. Finally, we will see how a universal AdS_4 black hole can be accommodated in this background, conjectured to be dual to the conformal manifold of N = 2 S-fold CFTs. Instead of being technical, I will try to discuss a glossary of terminologies: Janush Interface, Non-geometry, Vacua in a Gauged Supergravity, Consistent Truncation, Conformal manifold, Attractor Mechanism in gauged supergravity, and Exceptional field theory, Scherk-Schwarz reduction relevant to this work in a non-technical way.
Anosh Joseph (University of the Witwatersrand, South Africa)	
Research Talk	Title: Finite-temperature phase diagram of the BMN matrix model on the lattice
	Abstract: We investigate the thermal phase structure of the BMN matrix model using non-perturbative lattice Monte Carlo calculations. Our main analyses span three orders of magnitude in the coupling, involving systems with sizes up to 24 lattice sites and SU(N) gauge groups with N ranging from 8 to 16. We find results for the deconfinement temperature that interpolate between the perturbative prediction at weak coupling and the large-N dual supergravity calculation at strong coupling. While we confirm that the phase transition is first order for strong coupling, it appears to be continuous for weaker couplings.