Schedule

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Talk 2:	Onkar Parrikar (Tata Institute for Fundamental Research)
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Talk 4:	Ayan Mukhopadhyay (Indian Institute of Technology, Madras)
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Gabriel Cardoso: "The gravitational path integral for $\mathcal{N} = 4$ BPS black holes from black hole microstate counting""

Abstract: The degeneracies of 1/4 BPS black holes in four-dimensional D=4 heterotic string theory are given in terms of the Fourier coefficients of the meromorphic Siegel modular form $1/\Phi_{10}$. In the first part of this talk, we show how to obtain an exact expression for these degeneracies by using the symplectic symmetries of $1/\Phi_{10}$ to construct a fine-grained Rademacher type expansion which expresses these BPS degeneracies as a regularized sum over residues of the poles of $1/\Phi_{10}$. The construction uses two distinct $SL(2,\mathbb{Z})$ subgroups of $Sp(4,\mathbb{Z})$ which encode multiplier systems, Kloosterman sums and Eichler integrals appearing therein. We use the exact expression for the microscopic degeneracies of these single-centre black holes to improve on the existing formulation of the corresponding quantum entropy function obtained using supersymmetric localization. The result takes the form of a sum over Euclidean backgrounds including freely acting orbifolds of the Euclidean $\mathrm{AdS}_2 \times S^2$ attractor geometry. We further show how a rewriting of the degeneracy formula is amenable, at a semi-classical level, to a gravitational interpretation involving 2D supersymmetric wormholes. This alternative picture is useful to elucidate different aspects of the gravitational path integral capturing the microstate degeneracies. We also comment on the relation between the corresponding 1D holographic models.

Abhijit Gadde: "A new multi-partite entanglement measure and its holographic dual"

Abstract: I'll define a natural generalization of the von Neumann entropy to multiple parties that is symmetric with respect to all the parties. We call this measure multi-entropy. I'll show that for conformal field theories with holographic duals, the multi-entropy is computed by the area of an appropriate "soap-film" anchored on the boundary.

Arjun Kar: "Non-isometric quantum error correction in gravity"

Abstract: In the holographic approach to quantum gravity, quantum information theory plays a fundamental role in understanding how semiclassical gravity emerges from the microscopic description. The map (sometimes called the dictionary) between these two descriptions has the structure of a quantum error correcting code. In the context of an evaporating black hole, this code can be arbitrarily far from an isometry. Such codes are novel from a quantum information standpoint, and their properties are not yet well understood. I will describe a simple toy model of an evaporating black hole which allows for an explicit construction of the dictionary using the Euclidean gravity path integral. I will also describe the sense in which this dictionary is a non-isometric code, explain its basic properties, and comment on implications for semiclassical physics in the black hole interior.

Finn Larsen: "Thermodynamics of supersymmetric black holes"

Abstract: Supersymmetric black holes have zero temperature but their dependence on chemical potentials defines rather conventional thermodynamics. In anti-de Sitter space, the phase diagram exhibits a confinement/deconfinement transition and other interesting features. The colloquium presents these and other features of black holes in AdS(5) and their CFT dual.

Sam van Leuven: "Modular factorization of superconformal indices"

Abstract: Recent work has revisited the study of supersymmetric black holes in $\mathrm{AdS}_{d>3}$ spaces from the perspective of the dual CFT. Asymptotic limits of the superconformal index have been shown to reproduce the Bekenstein–Hawking entropy exactly. In AdS_5, an unconventional modular property of the elliptic Gamma function plays a crucial role. This property has made an earlier appearance in the context of holomorphic block factorization of superconformal indices of general four-dimensional $\mathcal{N} = 1$ gauge theories. We provide a physical interpretation of the modular property as resulting

from the combined action of an $SL(3,\mathbb{Z})$ and $SL(2,\mathbb{Z})\times\mathbb{Z}_2$ transformation. The former corresponds to a gluing transformation and the latter to an overall large diffeomorphism, both associated with a Heegaard splitting of the underlying geometry. The extension to more general transformations leads us to conjecture the "modular factorization" of superconformal lens indices: a given index can be factorized in terms of a family of holomorphic blocks parametrized by modular (congruence sub)groups. We find precise agreement between this proposal and general modular properties of the elliptic Gamma function. If time permits, I will discuss how this result allows a systematic proof of the proposal that a normalized part of superconformal lens indices defines a non-trivial first cohomology class associated with $SL(3,\mathbb{Z})$.

Ayan Mukhopadhyay: "Black hole complementarity from microstate models"

Abstract: We will introduce a class of black hole microstate models which mimic classical black holes in terms of energy absorption and relaxation properties, while revealing how black hole complementarity emerges from microscopic dynamics from local (but not global) semiclassical approximation. We will focus on quantum information mirroring, and illustrate how information is copied twice in the interior and exterior without encountering paradoxes. Our models can be potentially simulated in the laboratory.

Onkar Parrikar: "Canonical purification and the quantum extremal shock"

Abstract: We will study the canonical purification (with respect to one of the parties) of pure, bi-partite states obtained by turning on sources in the Euclidean path integral. In holographic conformal field theories, the bulk dual of the canonical purification consists of the corresponding entanglement wedge glued to its CPT image at the quantum extremal surface. However, the mismatch in the classical expansions at the QES due to quantum corrections needs to be supported by a shock in the bulk matter stress tensor for the geometry to satisfy Einsteins equations. Working perturbatively to first order in the sources around the TFD state, we will demonstrate that the state of the bulk matter in the bulk dual to the canonically purified state is precisely such that it gives rise to this quantum extremal shock in the bulk stress tensor. We will discuss how our arguments can be extended beyond perturbation theory.

Suvrat Raju: "The Hilbert space of quantum gravity and holography of information in de Sitter space"

Abstract: We classify solutions of the Wheeler–DeWitt equation in a closed Universe with a positive cosmological constant in the limit where the volume becomes asymptotically large and show that distinct solutions are labelled by Weyl and diffeomorphism invariant functions that satisfy the same Ward identities as the partition function of a CFT. This is true of all states in the theory and not just the Hartle–Hawking state. We show that the perturbative de Sitter Hilbert space described by Higuchi emerges naturally as the space of small excitations about one such wavefunctional. We propose a generalization of the principle of holography of information to de Sitter space: an appropriate set of correlators in an arbitrarily small region suffice to completely specify the state.

Joan Simón: "A proposal for 3d quantum gravity and its bulk factorization"

Abstract: Building on the success of JT gravity, we revisit the existence of an effective 3d quantum theory of gravity. We propose a theory based on the vacuum characters in the dual channel. In the formulation provided by such theory, we use the knowledge on Chern–Simons partition functions to identify the gravitational analogue of the condensed matter anyons responsible for the topological entanglement entropy. This allows us to provide an statistical mechanical interpretation for the black hole entropy. However, we find the gravitational entanglement entropy is finite dimensional, due to the absence of descendants at the entangling surface, and explain this important difference in terms of the different path integral measure in gauge theory and gravity. Time permitting, we will comment on how the (extended)

topological field theory aspects in Chern–Simons may extend to 3d gravity.

Jaco van Zyl: "Nielsen complexity for superconformal primaries"

Abstract: Quantum computation complexity is a measure of how difficult it is to produce a desired quantum from a given reference state. Through the AdS/CFT correspondence this quantity may be given a geometric interpretation and it is conjectured to be linked to black holes. Specifically, the growth of complexity is related to the growth of the black hole interiors. Having in mind applications to holographic duals, it is thus of interest to study complexity for conformal field theories. A popular approach to the computation of quantum complexity utilises a formalism developed by Nielsen. From a (typically simple reference state) the accessible target states may be obtained by acting with unitary operators selected from a symmetry group. The complexity is then given by defining a suitable metric on the manifold of target states and computing the geodesic distance between the points representing the reference and target state. In the context of conformal field theories, the natural choice for the reference state and symmetry group is a conformal primary and the group of conformal transformations respectively. In this talk the Nielsen complexity of super conformal primary operators that transform under an $su(2,2|N)$ symmetry is studied. It is demonstrated that Baker–Campbell–Hausdorff formulas can be employed as powerful tools in computations of this type.