Online Workshop on Quantum Gravity, Holography and Quantum Information

Report of Contributions

https://indico.mpp.mpg.de/e/7856

Contribution ID: **1** Type: **not specified**

Towards a Swampland Global Symmetry Conjecture

Wednesday, March 17, 2021 10:30 AM (1 hour)

Given that exact global symmetries are forbidden by quantum gravity, it is natural to expect that bounds on the quality of approximate global symmetries exist. So far, holographic arguments have only been provided for the former claim. I will discuss a classification of approximate global symmetries and describe a simple argument, based the Weak Gravity Conjecture, for a quantitative bound on the sub-class of "gauge-derived" global symmetries. This has intriguing relations to wormhole-based arguments, which I will also present. I will end with a brief discussion of the fundamental problems associated with euclidean wormholes and of some recent developments in this context.

45' talk + 15' discussion

Presenter: HEBECKER, Arthur

Contribution ID: **2** Type: **not specified**

Simple Euclidean wormholes might not contribute in the path integral

Wednesday, March 17, 2021 11:30 AM (1 hour)

I present evidence, both from a GR and a holographic viewpoint, that Coleman's Euclidean axion wormholes do not contribute to the path integral.

45' talk + 15' discussion

Presenter: VAN RIET, Thomas

Contribution ID: **3** Type: **not specified**

The OPE Randomness Hypothesis and Euclidean Wormholes

Wednesday, March 17, 2021 1:30 PM (1 hour)

Recent developments in holography indicate that the semi-classical Euclidean path-integral of Einstein gravity is much more powerful than previously anticipated. It is capable of reproducing a unitary Page curve for black hole evaporation, and can even capture some features of the discrete nature of black hole microstates. Wormhole geometries play a key role in this context. I will propose a mechanism to explain this in the CFT: the OPE Randomness Hypothesis. This ansatz is a generalization of the Eigenstate Thermalization Hypothesis which applies to chaotic CFTs, and treats OPE coefficients of heavy operators as random variables with a given probability distribution. I will present two applications of this framework: First, it resolves a factorization puzzle in AdS_3/CFT_2 due to the genus-2 wormhole, as raised by Maoz and Maldacena. Second, it provides an argument against global symmetries in quantum gravity.

45' talk + 15' discussion

Presenter: BELIN, Alex

Contribution ID: **4** Type: **not specified**

Quantum Complexity, Integrability, and Chaos

Wednesday, March 17, 2021 2:30 PM (1 hour)

The states of quantum systems grow in complexity over time as entanglement spreads between degrees of freedom. Following ideas in computer science, we formulate the complexity of evolution as the length of the shortest geodesic on the unitary group manifold between the identity and the time evolution operator, and use the SYK family of models with N fermions to study this quantity in free, integrable, and chaotic systems. In all cases, the complexity initially grows linearly in time, and the shortest path lies along the physical time evolution. This linear growth is eventually truncated by "shortcuts" on the unitary manifold that are shorter than the physical time evolution. We explicitly locate such shortcuts and hence show that in the free theory, shortcuts occur at a time of O(N^1/2), truncating complexity growth at this scale. We also find an explicit operator which "fast-forwards" time evolution with this complexity. In a class of integrable theories, we show that shortcuts appear in a time upper bounded by O(poly(N)), again truncating complexity growth. Finally, in chaotic theories we argue that shortcuts do not occur until exponential times, after which it becomes possible to find infinitesimally nearby fixed-complexity approximations to the time evolution operator. We relate these results to the Eigenstate Complexity Hypothesis, a new criterion on the spectrum of energy eigenstates that guarantees an exponential increase of complexity over time that is consistent with maximal chaos.

45' talk + 15' discussion

Presenter: BALASUBRAMANIAN, Vijay

Contribution ID: **5** Type: **not specified**

Discussion session

Wednesday, March 17, 2021 3:30 PM (45 minutes)

Presenter: KIRITSIS, Elias

Contribution ID: **6** Type: **not specified**

Islands and Hawking radiation correlations of evaporating black holes

Wednesday, March 17, 2021 4:30 PM (1 hour)

We consider the effect of shockwaves on the entanglement structure of black holes. We examine the correlations in generic subsets of the Hawking radiation emitted by evaporating black holes following the shockwave insertion and find a zoo of competing island saddle points for the associated entanglement entropies. By computing the mutual information between early and late modes we establish long range correlations in the Hawking radiation.

45' talk + 15' discussion

Presenter: KUMAR, Prem

Contribution ID: **7** Type: **not specified**

Comments on Euclidean wormholes and holography

Wednesday, March 17, 2021 5:30 PM (1 hour)

Euclidean wormholes comprise exotic types of gravitational solutions, that still challenge our physical intuition and understanding. In the first part of the talk, I will analyse asymptotically AdS wormhole solutions in the context of holography. From a bottom up perspective a study of correlation functions of local and non-local operators indicates the universal properties that any putative holographic dual should exhibit. The system is very weakly cross-coupled in the UV, and becomes strongly cross-coupled in the IR. In the second part, I will describe some concrete field theoretic setups which exhibit such a behaviour and comment on various issues arising in the alpha-parameter interpretation of the wormhole gas.

45' talk + 15' discussion

Presenter: BETZIOS, Panos

Contribution ID: **8** Type: **not specified**

Free discussion

Wednesday, March 17, 2021 6:30 PM (30 minutes)

Contribution ID: **9** Type: **not specified**

Phases of Holographic Interfaces

Thursday, March 18, 2021 10:30 AM (1 hour)

Domain walls between Anti-de Sitter vacua are important for the study of the string-theory landscape, and enter in recent toy models of black hole evaporation. In this talk I will describe the phase diagram of a simple 2+1 dimensional model of thin domain walls anchored at the AdS boundary, and I will comment on its dual holographic interpretation.

45’ talk + 15’ discussion

Presenter: BACHAS, Costas

Contribution ID: **10** Type: **not specified**

Towards a microscopic model of AdS fragmentation

Thursday, March 18, 2021 11:30 AM (1 hour)

A salient feature of black holes near extremality is the appearance of an AdS_2 throat in their near-horizon geometry. Depending on the underlying theory, these AdS_2 throats may be unstable to fragmentation, wherein a single throat is instead replaced by a tree-like structure of branched AdS_2 throats. For Einstein-Maxwell theory, the underlying reason behind this instability is the existence of multi-centered configuration in the moduli space of black hole solutions at fixed total charge. Given the success of the Schwarzian/SYK paradigm for understanding a single AdS_2 it is time to revisit the fragmentation story. To build up intuition, I will present a model, studied in the statistical mechanics literature, that shares many features with SYK, including exact solvability at large-N and an emergent conformal symmetry that gets weakly broken in the UV. The novel feature of this model is the appearance of a spin glass phase at O(1) temperatures, which I will try to relate to the fragmentation story.

45' talk + 15' discussion

Presenter: ANOUS, Tarek

Contribution ID: **11** Type: **not specified**

Pole skipping away from maximal chaos

Thursday, March 18, 2021 1:30 PM (1 hour)

The pole skipping phenomenon is a subtle effect in the thermal energy density retarded two point function at a special point in the complex frequency and momentum planes. For maximally chaotic theories, this special point is related to data characterising the butterfly effect, and is explained by a common dynamical origin of energy transport and scrambling. I will argue that pole skipping also happens in non-maximally chaotic theories and its location corresponds to the stress tensor contribution to many body chaos. I will test this proposal in the large q limit of an SYK chain, where I determine both the Lyapunov growth of the OTO correlator and the energy density two point function exactly as a function of the coupling, interpolating between weekly coupled and maximally chaotic behaviour.

45' talk + 15' discussion

Presenter: SÁROSI, Gábor

Contribution ID: **12** Type: **not specified**

A Wheeler DeWitt approach for Liouville quantum gravity

Thursday, March 18, 2021 2:30 PM (1 hour)

I will present the connection between the Wheeler-DeWitt approach for two-dimensional quantum gravity and holography, focusing in the case of Liouville theory coupled to c = 1 matter. The analysis is in a spirit similar to the recent studies of Jackiw-Teitelboim gravity. Matrix quantum mechanics and the associated double scaled fermionic field theory, are providing the complete dynamics of such two-dimensional universes with c=1 matter, including the effects of topology change.

45’ talk + 15’ discussion

Presenter: PAPDOULAKI, Olga

Contribution ID: **13** Type: **not specified**

Discussion session

Thursday, March 18, 2021 3:30 PM (45 minutes)

Presenter: DE BOER, Jan

Contribution ID: **14** Type: **not specified**

Mini-break

Contribution ID: **15** Type: **not specified**

On the geometry of quantum complexity

Thursday, March 18, 2021 4:30 PM (1 hour)

Computational complexity is a quantum information concept that recently has found applications in holography. I will consider quantum computational complexity for n qubits using Nielsen's geometrical approach. In the definition of complexity there is a big amount of arbitrariness due to the choice of the penalty factors, which parameterize the cost of the elementary computational gates. In order to reproduce desired features in holography, negative sectional curvatures are required. With the simplest choice of penalties, this is achieved at the price of singular curvatures in the large n limit. I will consider a choice of penalties in which negative curvatures can be obtained in a smooth way. I will also talk about the relation between operator and state complexities, framing the discussion in the language of Riemannian submersions. Finally, I'll discuss conjugate points for a large number of qubits in the unitary space and I'll provide a strong indication that maximal complexity scales exponentially with the number of qubits in a certain regime of the penalties space.

45' talk + 15' discussion

Presenter: AUZZI, Roberto

Contribution ID: **16** Type: **not specified**

Complexity for CFTs in General Dimensions

Thursday, March 18, 2021 5:30 PM (1 hour)

In this talk I will discuss circuit complexity in the setting of higher dimensional conformal field theories. I will consider unitary gates built from a representation of the conformal group, two different circuit cost functions defined using either the Fubini-Study metric or the one-norm, and paths that start from an initial spinless primary state. We will see that the resulting Fubini-Study metric is the metric on a particular coadjoint orbit of the conformal group, while the one-norm computes the geometric action associated to this orbit. This generalizes recent results in 2d connecting the one-norm to a Virasoro geometric action, and also shows that coadjoint orbits provide a unified geometric framework that applies to different choices of cost functions. I will end with some comments about symmetry groups other than the conformal group, using group theoretic generalizations of coherent states. This is based on a work with Nicolas Chagnet, Jan de Boer and Claire Zukowski.

45' talk + 15' discussion

Presenter: CHAPMAN, Shira

Contribution ID: **17** Type: **not specified**

Free discussion

Thursday, March 18, 2021 6:30 PM (30 minutes)

Contribution ID: **18** Type: **not specified**

Page Curve from Holographic Moving Mirror and End of the World brane

Friday, March 19, 2021 10:30 AM (1 hour)

In this talk we calculate the entanglement entropy in the presence of a moving mirror in a CFT. We employ the AdS/BCFT construction to describe a gravity dual of moving mirrors. We will show that the time evolution of entanglement entropy for a class of moving mirror, which models an evaporating black hole, follows an ideal page curve. In this gravity dual of this model and also in earlier works on holographic page curves, the end of the world-brane in AdS plays a crucial role. I will also present our recent result on their chaotic spectrum in holographic CFTs.

45' talk + 15' discussion

Presenter: TAKAYANAGI, Tadashi

Contribution ID: **19** Type: **not specified**

The principle of holography of information and its low-energy tests

Friday, March 19, 2021 11:30 AM (1 hour)

The principle of holography of information states that, in any theory of quantum gravity, a copy of all the information available on a Cauchy slice is also available near the boundary of the slice. This principle can be made precise and proved, under weak assumptions, for theories of gravity in AdS and in flat space and it has interesting implications for black holes. In this talk, we will describe how this principle can be tested within the realm of low-energy effective field theory. We will describe how observers placed in a low-energy state near the boundary of AdS can use a simple physical protocol to completely identify the state of the bulk without directly visiting the bulk. We will also describe low-energy thought experiments that can be used to similarly obtain information about the bulk state from near the boundary of flat space.

45' talk + 15' discussion

Presenter: RAJU, Suvrat

Contribution ID: **20** Type: **not specified**

The Unreasonable Effectiveness of Higher-Derivative Supergravity in AdS_4 Holography

Friday, March 19, 2021 2:30 PM (1 hour)

I will describe the four-derivative corrections to four-dimensional N=2 minimal gauged supergravity and show that they are controlled by two constants. Interestingly, the solutions of the equations of motion in the two-derivative theory are not modified by the higher-derivative corrections. I will use this to arrive at a general formula for the regularized on-shell action for any asymptotically locally AdS_4 solution of the theory and show how the higher-derivative corrections affect black hole thermodynamic quantities in a universal way. I will employ these results in the context of holography to derive new explicit results for the subleading corrections in the large N expansion of supersymmetric partition functions on various compact manifolds for a large class of three-dimensional SCFTs arising from M2- and M5-branes. I will also briefly discuss possible extensions and generalizations of these results.

45’ talk + 15’ discussion

Presenter: BOBEV, Nikolay

Contribution ID: **21** Type: **not specified**

Discussion session: Holographic Complexity

Friday, March 19, 2021 1:30 PM (45 minutes)

Computational complexity is a notion from information theory, initially defined for finite-dimensional systems, measuring the number of gates that have to be applied to a given reference state to reach a target state. Susskind's proposals for defining computational complexity also for characterising quantum properties black holes have triggered significant interest in defining computational complexity also for quantum field theories, i.e. for infinite-dimensional Hilbert spaces. The idea is to establish a precise holographic dictionary for complexity. There are successful proposals for complexity definitions in free quantum field theory. Recently, there have been several proposals also for interacting theories, mostly in the context of conformal field theories, building gate sets from symmetry generators. Questions to be discussed include, in addition to further questions about the talks on the subject presented at the workshop: - What is the status of defining complexity for interacting field theories? - How do different proposals for gate sets, reference states and cost functions compare to each other? - What is the status of establishing a holographic dictionary? - What are promising avenues to be pursued for further progress?

Presenter: ERDMENGER, Johanna

Contribution ID: **22** Type: **not specified**

Saturons

Friday, March 19, 2021 4:00 PM (1 hour)

We introduce the concept of saturons, systems that saturate a certain bound on entropy, which is imposed
by S-matrix and unitarity. Such objects share certain niversal properties (e.g., the area-law of entropy, near-thermal emission, inner entanglement, …) that goes well beyond gravity. We give an example from QCD. We show that black holes and de Sitter are saturons and this determines their physical properties such as their entanglement curves. Both exhibit anomalous quantum break-time which for de Sitter is deadly. Through this mechanism, the S-matrix formulation
of quantum gravity/string theory excludes de Sitter vacua.

45’ talk + 15’ discussion

Presenter: DVALI, Gia

Contribution ID: **23** Type: **not specified**

Quantum BTZ black hole

Friday, March 19, 2021 5:00 PM (1 hour)

The study of quantum effects on black holes including their gravitational backreaction is an important but notoriously hard problem. I will begin by reviewing how the framework of braneworld holography allows to solve it for strongly-coupled quantum conformal fields. Then I will describe a holographic construction of quantum rotating BTZ black holes (quBTZ) using an exact dual four-dimensional bulk solution. Besides yielding the quantum-corrected geometry and the renormalized stress tensor of quBTZ, we use it to show that the quantum black hole entropy, which includes the entanglement of the fields outside the horizon, rather non-trivially satisfies the first law of thermodynamics, while the Bekenstein-Hawking-Wald entropy does not.

45' talk + 15' discussion

Presenter: EMPARAN, Roberto

Contribution ID: **24** Type: **not specified**

Outlook and discussion

Friday, March 19, 2021 6:00 PM (30 minutes)

Presenter: EMPARAN, Roberto

Contribution ID: **25** Type: **not specified**

Opening address

Wednesday, March 17, 2021 10:20 AM (10 minutes)

Presenter: LÜST, Dieter