Focus Week on Quantum Gravity and Holography

Monday 02 April 2018 - Friday 06 April 2018

Lecture Hall(1F), Kavli IPMU

Programme and abstracts

April 2 (Mon)
09:55 -- 10:00 Welcome address

10:00 -- 11:00 Hirosi Ooguri (Caltech/Kavli IPMU)
“Constraints on Quantum Gravity"

11:00 -- 11:15 Break (Tea time)

11:15 -- 12:15 Monica Guica (IPhT/CEA Saclay/Uppsala)
“JT-bar deformed CFTs and their holographic interpretation”

12:15 -- 13:45 Lunch time

13:45 -- 14:45 Jared Kaplan (Johns Hopkins)
“Exact Bulk Operators and the Fate of Locality”
April 3 (Tue)

10:00 -- 11:00 Xiaoliang Qi (Stanford U)
"Eternal traversable wormhole in two dimensions"

11:00 -- 11:15 Break (Tea time)

11:15 -- 12:15 Emanuel Katz (Boston)
“Non-perturbative QFT methods inspired by holography”

12:15 -- 13:45 Lunch time

13:45 -- 14:45 Suvrat Raju (ICTS)
“A Critique of the Fuzzball Program”
April 4 (Wed)

10:00 -- 11:00 Song He (ITP Chinese Acadeny of Science)
“Scattering Forms from Geometries at Infinity"

11:00 -- 11:15 Break (Tea time)

11:15 -- 12:15 Yasunori Nomura (UC Berkeley)
“Holography for General Spacetimes"

12:45 -- 13:45 Lunch time

13:45 -- 14:45 Bo Sundborg (Stockholm)

“Gravity and interacting O(N) model quantum mechanics"
April 5 (Thu)

10:00 -- 11:00 Petr Horava (UC Berkeley)
“Nonrelativistic Naturalness and Gravity”

11:00 -- 11:15 Break (Tea time)

11:15 -- 12:00 Nico Wintergerst (Leuven)

---------Group Shot----------

12:00 -- 13:15 Lunch time

13:15 -- 13:45 Rene Meyer (ITP Wuerzburg)
“Quantum Information and Topological Complexity in AdS/CFT”

13:45 -- 14:15 Kanato Goto (UTokyo)
“Bulk reconstruction of the black holes in AdS/CFT correspondence”

14:15 -- 14:30 Break (Tea time)

14:30 -- 15:00 Max Riegler (Université libre de Bruxelles)
“Warped Black Holes in Lower Spin Gravity”

15:00 -- 15:30 Takahiro Uetoko (UTokyo)
“Correlators in higher spin AdS_3 holography with loop corrections”

15:30 -- 16:00 Break (Tea time)

16:00 -- 16:30 Masataka Watanabe (Kavli IPMU)
“Big-J in 3D and O(4)”

16:30 -- 17:00 Yun-Long Zhang (APCTP, China)
“The String Worldsheet as one Candidate Dual Description of SYK Model”
April 6 (Fri)

10:00 -- 11:00 Yuta Hamada (Univ. of Wisconsin-Madison)
“Weak Gravity Conjecture, Multiple Point Principle and the Standard Model Landscape”

11:00 -- 11:15 Break (Tea time)

11:15 -- 12:15 Simeon Hellerman (Kavli IPMU)

12:15 -- 13:30 Lunch time

13:30 -- 14:00 Anosh Joseph (ICTS)
“N=2* Super Yang-Mills on a Lattice"

14:00 -- 14:10 Break (Tea time)

14:10 -- 14:40 Goro Ishiki (Univ. of Tukuba)
“Spherical transverse M5-branes from the plane wave matrix model”

14:40 -- 15:10 Yuhma Asano (Dublin Institute for Advanced)
“Phase transitions in the BMN matrix model”

Title (Hirosh Ooguri, Caltech/Kavli IPMU)

TBA

JT-bar deformed CFTs and their holographic interpretation (Monica Guica, IPhT/CEA Saclay /Uppsala)

It has been recently shown that the deformation of an arbitrary two-dimensional conformal field theory by the composite irrelevant operator
TT-bar, built from the components of the stress tensor, is solvable; in particular, the finite-size spectrum of the deformed theory can be obtained from that of the original CFT through a universal formula. We study a similarly universal, Lorentz-breaking deformation of two-dimensional CFTs that possess a conserved U(1) current, J. The deformation takes the schematic form JT-bar and it is interesting because it preserves an SL(2,R) x U(1) subgroup of the original global conformal symmetries. For the case of a purely (anti)chiral current, we find the finite-size spectrum of the deformed theory and study its thermodynamic properties. Next, we show that the holographic dual of JT-bar deformed CFTs for J chiral is AdS_3 with certain modified boundary conditions. We then use holography to argue that the global symmetries of the model are enhanced to a Virasoro x Virasoro x U(1) Kac-Moody algebra, just as before the deformation; the only effect of the latter is to modify the
spacetime dependence of the right-moving Virasoro generators, whose action becomes state-dependent and effectively non-local.

Exact Bulk Operators and the Fate of Locality (Jared Kaplan, Johns Hopkins)

We recently used Virasoro symmetry considerations to propose an exact formula for a bulk proto-field φ in AdS3. In this talk we will explain the construction and study the propagator <φφ>. Many techniques from the study of conformal blocks can be generalized to compute it, and when the results are expanded at large central charge, they match gravitational perturbation theory for a free scalar field coupled to gravity in Fefferman-Graham gauge. Although the propagator appears to be local to all orders in perturbation theory, we explicitly compute non-perturbative effects in G ~ 1/c that spell the breakdown of bulk locality: the commutator (or retarded propagator) is non-vanishing at small spacelike separations.

Eternal traversable wormhole in two dimensions (Xiaoliang Qi, Stanford U)

We study two Sachdev-Ye-Kitaev models with a relevant coupling, and show that a subsector of this theory is dual to a gravity in nearly AdS2 geometry, with two causally connected boundaries. The coupling corresponds to matter with negative null energy in gravity theory. We study the ground state and finite temperature properties of this model. There is an interesting phase transition at finite temperature, similar to the Hawking-Page transition in higher dimensions, between a thermal AdS phase and a black hole phase.

Non-perturbative QFT methods inspired by holography (Emanuel Katz, Boston)

I will describe a new numerical approach for calculating dynamical quantities in QFT in the non-perturbative regime.

In this approach any QFT (including a gauge theory) can be formulated as a relevant perturbation of a UV CFT.

The states of the CFT are used as a basis to describe the resulting RG-flow. Holography motivates a certain truncation of the CFT basis which allows for numerical calculation. I will provide numerical evidence in certain 2D and 3D theories that this truncation provides for an effective approximation for evaluating certain non-perturbative quantities (like the Zamolodchikov c-function along an RG-flow). Implementing the method in the context of light-cone quantization has various advantages including greatly simplifying flows in the large-N limit. Whether such a simplification occurs depends on properties of the UV large-N CFT and can be checked via a certain diagnostic. Here, again, holographic models are useful in clarifying the issues faced by the light-cone approach.

A Critique of the Fuzzball Program (Suvrat Raju, ICTS)

We explore the viability of fuzzballs as candidate microstate geometries for the black hole, and their possible role in resolutions of the information paradox. We argue that if fuzzballs provide a description of black-hole microstates, then the typical fuzzball microstate can only differ significantly from the conventional black-hole geometry at a Planck-scale-distance from the horizon. However,

precisely in this region quantum fluctuations in the fuzzball geometry become large and the fuzzball geometry becomes unreliable. We verify these expectations through a detailed calculation of quantum expectation values and quantum fluctuations in the two-charge fuzzball geometries. We then examine a subset of the solutions discovered in arXiv:1607.03908. We show, based on a calculation of a probe two-point function in this background, that these solutions, and others in their class, violate robust expectations about the gap in energies between successive energy eigenstates and also violate the eigenstate thermalization hypothesis. We conclude that while fuzzballs are interesting star-like solutions in string theory, they do not appear to be relevant for resolving the information paradox, and cannot be used to make valid inferences about black-hole interiors.

Scattering Forms from Geometries at Infinity(Song He, Beijing ITP)

Scattering amplitudes play a prominent role not only in high energy particle physics, but also for quantum gravity in asymptotically flat spacetime.The search for a "theory at infinity" of the S-Matrix has revealed surprising geometric structures underlying amplitudes ranging from the string worldsheet to the amplituhedron, but these are all geometries in auxiliary spaces as opposed to the space at infinity where amplitudes actually live. By thinking of amplitudes as differential forms, we propose a novel geometric picture directly in kinematic space for a wide range of massless theories in
general dimensions.

As a primary example, we show that tree amplitudes of bi-adjoint scalars are given by the “volume” of an associahedron living naturally in kinematic space, and scattering equations act as a diffeomorphism from the open-string moduli space (also an associahedron) to it. We find general “scattering forms” dual to color-dressed amplitudes e.g. for gluons and pions, which is possible due to a remarkable fact -- “Color is Kinematics”. All these forms are well-defined in projectivized space, a property which provide a geometric origin for color-kinematics duality.

Holography for General Spacetimes (Yasunori Nomura, Berkeley)

TBA

Gravity and interacting O(N) model quantum mechanics (Bo Sundborg, Stockholm)

I wish to apply quantum field theory (and quantum mechanics) to define a quantum gravity theory in a simple case. AdS/CFT and gauge/gravity correspondences suggest calculating bulk quantities by boundary methods, by-passing bulk action principles. Interacting O(N) model quantum mechanics is a simple relative to higher dimensional boundary theories dual to gravity with broken higher spin symmetry. I present some calculations relevant to a connection to d=2 bulk physics, and to choosing between gauging or not gauging theories of N-component vectors in the large N limit.

Nonrelativistic Naturalness and Gravity (Petr Horava, Berkeley)

Some of the leading and most persistent puzzles of theoretical physics (the Higgs mass hierarchy puzzle, the cosmological constant puzzle, etc) can be viewed as problems of technical naturalness. We show that, when embedded into the framework of nonrelativistic quantum field theory, the concept of technical naturalness acquires new features, leading to new phenomenological scenarios in which the traditional hierarchy problems can be reduced or eliminated.

Black holes from singlet models (Nico Wintergerst, Stockholm)

Thermal boundary correlation functions provide a direct and accessible way to probe features of an emergent bulk geometry. In free large N gauge theories dual to higher spin gravity and tensionless string theory, two point correlators of singlet operators encode propagation through an approximate AdS spacetime at low temperatures. Contrarily, in high temperature phases, we discover characteristic signatures of bulk black holes. This includes the existence of evanescent modes and the exponential decay of time dependent correlations, as well as significant departure of spatial correlators from their bulk thermal AdS form. Surprisingly, correlators reveal in addition the emergence of a new scale beyond which they recover their thermal AdS structure up to an overall temperature dependent normalization. This finite volume effect is most prominently seen in the O(N)/U(N) vector model in 2+1 dimensions, dual to 3+1-dimensional Vasiliev higher spin gauge theory.

Quantum Information and Topological Complexity in AdS/CFT(Rene Meyer, ITP Wuerzburg)

Recently, using the AdS/CFT correspondence exciting new relations are being established between aspects of quantum information theory and of the geometry of black holes in Anti de Sitter space-times. After a concise review of the roles of entanglement measures such as e.g. the entanglement entropy as well as of the computational complexity within the AdS/CFT correspondence, I discuss the notion of subregion complexity of a 2D critical state from three di erent viewpoints: the AdS3/CFT2 correspondence, random tensor networks, and kinematic space.
From the AdS3/CFT2 point of view I explain how in the discontinuity of subregion complexity as given by the volume within the Ryu-Takayanagi surface is related to the Euler characteristic of the re- spective bulk regions via the Gauss-Bonnet theorem. I then discuss how the volume of these sub regions can be calculated in kinematic space, which is the space of geodesics on the time-slice of AdS3, and present a new CFT expression of subregion complexity. Finally, I present results that qualitatively reproduce the discontinuity in complexity in a tensor network approach. Based on arXiv:1710.01327 [hep-th].

Bulk reconstruction of the black holes in AdS/CFT correspondence (Kanato Goto, UTokyo)

In the context of AdS/CFT, one of the most important problem is to understand how CFTs describe the bulk interior of the AdS spacetime. Especially, it is not clear whether CFTs can describe the black hole interior. In order to understand it, we construct the bulk local states which are dual to the the states locally excited by a scalar fields in the AdS black holes. For double-sided BHs dual to the

thermofield double states and single-sided BHs dual to the CFT boundary states, our construction correctly reproduces the classical spacetime not only outside the horizon but also its inside. We also analyzed the spacetime structure dual to the high energy eigenstates in CFT with our construction. We found that classical black hole spacetime can be reproduced from CFT side unless we probe the deep interior in the bulk. We found the possibility that as we probe the deep interior, the classical notion of spacetime might break down and quantum corrections cannot be neglected. It might be related to the firewall problem which has been actively argued recently.

Warped Black Holes in Lower Spin Gravity (Max Riegler, Université libre de Bruxelles)

In this talk I present a novel and very efficient description of spacelike warped Anti-de Sitter black holes in terms of a lower spin Chern-Simons theory that allows for various interesting extensions. A special focus will be on how to determine the thermal entropy as well as entanglement entropy holographically in this formulation. The validity of the results obtained in the Chern-Simons formalism will be verified by providing an additional metric interpretation.

Correlators in higher spin AdS_3 holography with loop corrections (Takahiro Uetoko, Ritsumeikan)

We study the correlators of 2d W_N minimal models and quantum effects in the dual gravity theory. From boundary viewpoint, we develop a new method to compute three point functions with two scalar operators and a higher spin current and obtain new results at the next non-trivial order in 1/N expansion [arXiv:1708.02017]. From bulk viewpoint, we propose new regularization prescription with the symmetry of dual CFT by utilization open Wilson lines and obtain two point functions of scalar operator up to two loop order [arXiv:1708.08657]. I will explain these methods and results.

The String Worldsheet as one Candidate Dual Description of SYK Model (Yun-Long Zhang , APCTP)

Recent studies of the fluctuations of an open string in AdS space show some pieces of evidence that the string with a worldsheet horizon could be a dual description of SYK model, as they saturate universal chaos bound and share the same symmetry. An open string hangs from the AdS boundary to the horizon of black brane could be dual to a 0+1 dimensional boundary state. To be specific, we find that the fluctuation of the string in charged BTZ black hole has an asymptotic scaling symmetry, and its Euclidean IR fixed point is governed by the quadratic order of Schwarzian action, which is just the low energy effective theory of the SYK model. Considering the open string worldsheet also has natural reparametrization symmetry, we conjecture that the action of the string worldsheet is an effective dual description of SYK model.

Weak Gravity Conjecture, Multiple Point Principle and the Standard Model Landscape (Yuta Hamada Wisconsin, Madison)

The requirement for an ultraviolet completable theory to be well-behaved upon compactification has been suggested as a guiding principle for distinguishing the landscape from the swampland. Motivated by the weak gravity conjecture and the multiple point principle, we investigate the vacuum structure of the standard model compactified on S1 and T2. The measured value of the Higgs mass implies, in addition to the electroweak vacuum, the existence of a new vacuum where the Higgs field value is around the Planck scale. We explore two- and three-dimensional critical points of the moduli potential arising from compactifications of the electroweak vacuum as well as this high scale vacuum, in the presence of Majorana/Dirac neutrinos and/or axions. We point out potential sources of instability for these lower dimensional critical points in the standard model landscape. We also point out that a high scale AdS4 vacuum of the Standard Model, if exists, would be at odd with the conjecture that all non-supersymmetric AdS vacua are unstable. We argue that, if we require a degeneracy between three- and four-dimensional vacua as suggested by the multiple point principle, the neutrinos are predicted to be Dirac, with the mass of the lightest neutrino O(1-10) meV, which may be tested by future CMB, large scale structure and 21cm line observations.

Title (Simeon Hellerman (Kavli IPMU)

TBA

N=2* Super Yang-Mills on a Lattice (Anosh Joseph, ICTS)

Four-dimensional N=2* super Yang-Mills theory is obtained by introducing a one parameter mass deformation to the hypermultiplet of four-dimensional N=4 Yang-Mills. Four-dimensional N=2* Yang-Mills is a non-conformal gauge theory and its gravitational dual has been constructed by Pilch and Warner. The theory exhibits many interesting properties at finite temperature. We formulate N=2* super Yang-Mills on a Euclidean spacetime lattice using the method of topological twisting. The lattice formulation is local, gauge invariant, doubler free and preserves one supersymmetry charge at finite lattice spacing. Such a construction can be used for finite temperature nonperturbative explorations of the theory and test the gauge-gravity duality conjecture in a non-conformal theory.

Complex Langevin dynamics and large-N gauge theories (Pallab Basu, ICTS)

Using complex Langevin dynamics and stochastic quantization we examine the phase structure of a large N unitary matrix model at low temperature with finite quark chemical potential. This model is obtained as the low temperature effective theory of QCD with N number of colors and N_f number of quark flavors. We simulate several observables of the model, including Polyakov lines and quark number density, for large N and N f . The action is manifestly complex and thus the dominant contributions to the path integral come from the space of complexified gauge field configurations. For this reason, the Polyakov line eigenvalues lie off the unit circle and out in the complex plane. A distinct feature of this model, the occurrence of a series of Gross-Witten-Wadia transitions, as a function of the quark chemical potential, is reproduced using complex Langevin simulations.

Big-J in 3D and O(4) (Masataka Watanabe, Kavli IPMU)

I will discuss conformal O(4) model at large global charges. Unlike the case in the O(2) model, the ground state configuration is inhomogeneous and its 2-point function exhibits an interesting behaviour.

Spherical transverse M5-branes from the plane wave matrix model (Goro Ishiki, Tsukuba)

We consider the matrix theoretical description of transverse M5-branes in M-theory on the 11-dimensional maximally supersymmetric pp-wave background. We apply the localization to the plane wave matrix model (PWMM) and show that transverse spherical fivebranes emerge as the distribution of low energy moduli of the scalar fields in PWMM.

Phase transitions in the BMN matrix model (Yuhma Asano, Dublin IAS/KEK)

An idea to formulate string theory or M-theory by a gauge theory attracts theorists and has been extensively studied. The gauge theory should be lower dimensional so that a geometry in string or M-theory, which has higher dimensions, must emerge from it. This suggests that there should be a phase transition in the gauge theory and that the geometry would appear as its temperature decreases. In this talk, we focus on the BMN matrix model, which is considered as a non-perturbative formulation of M-theory on the pp-wave geometry and also conjectured to have a gauge/gravity duality, which relates each vacuum on the gauge theory side to a bubbling geometry in the type IIA supergravity. Our preliminary results of Monte Carlo simulations show two phase transitions and one of them looks related with emergent geometry.