Black Holes, Quantum Chaos, and Solvable Quantum Systems Workshop

January 22-26, 2018

(1) Zhenbin Yang, Princeton University

Title: Full gravitational backreaction of J-T model

Abstract: I will talk about the study of gravitational backreaction of J-T model. The result shows that gravitational backreaction modifies the boundary of witten-diagram to be dynamical, whose dynamics is determined by a particle in imaginary magnetic field.

(2) Antonio M Garcia-Garcia

Title: Ergodicity, black holes and the Sachdev-Ye-Kitaev model

Abstract: Fermions with kbody infinite-range interactions, originally introduced in the context of quantum chaos, and recently re-labelled Sachdev-Ye-Kitaev (SYK) models, are attracting a great deal of attention as toy model of holography. After a pedagogical introduction. I study analytically and numerically the spectral and thermodynamic properties of the model. For sufficiently long times, the SYK model evolves to a fully ergodic state whose dynamics only depends on the global symmetry of the system. This strongly suggests that random matrix correlations are a universal feature of quantum black holes. For shorter times, we found that the SYK model approaches ergodicity by a diffusion process in Fock space. Finally, I discuss the robustness of holographic features by studying a deformation of the SYK model which undergoes a chaotic-integrable transition.

(3) Yiming Chen, Tsinghua University

Title: Bulk Constrained Surfaces and Boundary Modular Flow

Abstract: One intriguing aspect of the holographic AdS/CFT correspondence is the geometrization of quantum entanglement. For static states, the Ryu-Takayanagi (RT) proposal relates the entanglement entropy of boundary theory with the area of minimal surface in the bulk, which is then generalized to time-dependent cases as the Hubeny-Rangamani-Takayanagi (HRT) proposal. The complication of time-dependent geometries makes the HRT proposal more mysterious than the RT proposal. In the talk, I will first quantify this extra complication by considering the constrained minimal surface in the bulk, and then propose the corresponding boundary dual as the entanglement entropy averaged over certain modular flow. I will illustrate this proposal using examples like Vaidya-BTZ spacetime, and also non-holographic lattice models. I will also discuss the lessons that we learn from it about the entanglement in general time-dependent holographic spacetime.

(4) Naoto Tsuji, RIKEN CEMS

Title: Out-of-time-order fluctuation-dissipation theorem and the universal bound on chaos

Abstract: In this talk, I will prove that a generalized fluctuation-dissipation theorem (FDT) holds for a certain class of out-of-time-ordered correlators (OTOCs). The theorem indicates a universal relation between chaotic behavior in quantum many-body systems and a nonlinear response function involving a time-reversed process. The class of OTOCs that satisfy the FDT gives a one-parameter family of OTOCs that have good properties as a regularization of the squared commutator. I then prove that if the OTOC shows an exponential growth regardless of the choice of the regularization, the exponential growth rate must be bounded by $2\pi kT/\hbar$, as conjectured by Maldacena, Shenker, and Stanford.

(5) Chi-Ming Chang, UC Davis

Title: Topological Defect Lines and Renormalization Group Flows in Two Dimensions

Abstract: In conformal field theory, besides local point-like operators, there are extended objects, or "defects", such as boundary conditions and interfaces, that can be characterized purely in terms of the response of local operators in the presence of the defect. A basic example is given by considering a global symmetry element g, which by definition is a linear transformation on the local operators that preserve their OPEs. The action of g on a local operator may be viewed as the contraction of a closed codimension-one topological defect on the local operator. Interestingly, there are topological defect lines (TDLs) that do not correspond to any global symmetry, and are ubiquitous in two-dimensional CFTs. The fusion and crossing relations of general TDLs are captured by a mathematical structure known as fusion category.

I will discuss the constraints from TDLs on renormalization group (RG) flows and on the infrared topological quantum field theories (TQFTs). In particular, I will derive a generalization of the 't Hooft anomaly matching condition: when certain TDLs are preserved along an RG flow, these TDLs will survive in the infrared, maintaining the same fusion and crossing relations that put interesting constraints on the infrared CFT or TQFT. In fact, the TDLs of the TQFT inherited from the ultraviolet CFT allow us to completely determine many interesting TQFTs.

(6) Finn Larsen, University of Michigan

Title: Quantum corrections to AdS(2)

Abstract: TBA

(7) Yingfei Gu, Harvard Univeristy

Title: Spread of entanglement in a Sachdev-Ye-Kitaev chain

Abstract: We study the spread of Rényi entropy between two halves of a Sachdev-Ye-Kitaev (SYK) chain of Majorana fermions, prepared in a thermofield double (TFD) state. The SYK chain model is a model of chaotic many-body systems, which describes a one-dimensional lattice of Majorana fermions, with spatially local random quartic interaction. We find that for integer Rényi index n¿1, the Rényi entanglement entropy saturates at a parametrically smaller value than expected. This implies that the TFD state of the SYK chain does not rapidly thermalize, despite being maximally chaotic: instead, it rapidly approaches a prethermal state. [Ref: `arXiv 1708.00871` with A Lucas and XL Qi]

(8) Ippei Danshita, YITP Kyoto University

Title: A proposal for experimental realization of a Sachdev-Ye-Kitaev model with ultracold gases

Abstract: We propose a possible route for realizing a Sachdev-Ye-Kitaev model experimentally with use of ultracold gases in optical lattices [1]. Specifically, we introduce a variant of the SYK model, in which the random two-body hopping is real. This model is equivalent to the origincal SYK model in the large-N limit. We show that this model can be created in principle by confining ultracold fermionic atoms into optical lattices and coupling two atoms with molecular states via photo- association lasers. We also show how to measure out-of-time-order correlators of the SYK model, which may allow for capturing one of the most crucial characteristics of a black hole, namely maximally chaotic property.

[1] I. Danshita, M. Hanada, and M. Tezuka, Prog. Theor. Exp. Phys. 2017, 083I01.

(9) Huajia Wang, UIUC

Title: Probing beyond ETH at large c

Abstract: Eigenstate thermalization hypothesis (ETH) is a phenomena often observed in systems characterized by quantum chaos. In this talk, we study ETH in 2d CFTs with large central charges. In particular, we focus on observables consisting of bilocal "probe" operators $\mathcal{O}_L(x)\mathcal{O}_L(0)$. A sharp feature of ETH in this context is the so-called "forbidden" singularities, arising in the thermodynamic limit $c \to \infty$. We explore their resolutions by finite c effects, and analyze the associated non-perturbative phenomena. We also discuss some interesting similarities between the related real-time dynamics and the spectral form factors in both the SYK model and BTZ black holes.

(10) Shao-Kai Jian, Tsinghua University

Title: Phase transitions in higher-dimensional SYK models and in AdS2 spacetime

Abstract: In the first part of my talk, I will focus on many-body localization transition in a higher-dimensional generalization of the Sachdev-Ye-Kitaev model. The model on a bipartite lattice has N Majorana fermions with SYK interactions on each site of the A sublattice and M free Majorana fermions on each site of the B sublattice, where N and M are large and finite. For $r = M = N < r_c = 1$, it describes a diffusive metal exhibiting maximal chaos. Remarkably, its diffusive constant D vanishes as $r \to r_c$, implying a dynamical transition to a MBL phase. It is further supported by numerical calculations of level statistics which changes from Wigner-Dyson ($r < r_c$) to Poisson ($r > r_c$) distributions. Our higher-dimensional SYK model may provide a promising arena to explore exotic MBL transitions [1]. In the second part, I will focus on another type of transition in SYK model that has holographic description. We show that the quantum critical point (QCP) between a diffusive metal and ferromagnetic (or antiferromagnetic) phases in the SYK chain has a gravitational description corresponding to the double-trace deformation in an AdS2 chain. Specifically, by studying a double-trace deformation of a Z2 scalar in an AdS2 chain where the Z2 scalar is dual to the order parameter in the SYK chain, we find that the susceptibility and RG equation describing the QCP in the SYK chain can be exactly reproduced in the holographic model. Our results suggest that the infrared geometry in the gravity theory dual to the diffusive metal of the SYK chain is also an AdS2 chain [2]. [1] Shao-Kai Jian and Hong Yao, Phys. Rev. Lett. 119, 206602 (2017) [2] Shao-Kai Jian, Zhuo-Yu Xian, and Hong Yao, arXiv:1709.02810

(11) Ling-Yan Hung, Fudan University

Title: Tensor network and p-adic AdS/CFT revisited

Abstract: We will discuss the construction of a tensor network that recovers correlation function of a p-adic CFT and how features of the AdS/CFT dictionary is recovered. We demonstrate how this can be generalized to higher genus surfaces and discuss the connection of these tensor networks with a p-adic version of CS theory and the corresponding expectation values for networks of Wilson lines.

(12) Pengfei Zhang, Tsinghua University

Title: OTOC-RE theorem, sonic black hole and generalized SYK models

Abstract: This talk contains three parts. In the first part, after introducing the concept of Out-of-time-ordered correlation function (OTOC) which is proposed to study quantum chaos, I will present an exact theorem that relates the OTOC to the Renyi entropy which has already been used in experiments. This makes us able to predict the general behavior of OTOC in Anderson localized, Many-body localized or thermalized system. We also present numerical results for realistic models including random field XXZ model and Bose Hubbard model to support our general prediction.

In the second part, we propose experimental set-up to observe the shock wave effect, which is the holographic dual of the OTOC on gravity side, using

the sonic black hole analogy in a Bose-Einstein condensate. After an introduction to the sonic black hole, we study the back reaction of a sound wave packet to the background flow. We find an exponential growth of the phase of the condensate wave function, which make us able to identify a "Lyapunov exponent".

In the third part, I will give a brief introduction to the famous concrete model on quantum chaos called Sachdev-Ye-Kitaev model (SYK). Then we use SYK interaction to construct various exact solvable models to address profound open questions in condensed matter physics. In the first generalization, we consider two SYK dots coupled by quadratic hopping, to address the non-Fermi liquid phases and the transition between them. In the second generalization, we consider a SYK lattice with constant hopping, to address a crossover from a diffusive metal to a Luttinger Liquid. In the third generalization, we consider a SYK lattice with topological band structure, to address interaction effect in topological band and the interaction induced topological transition.

Ref: [1]. "Out-of-Time-Order Correlation for Many-Body Localization", Ruihua Fan, Pengfei Zhang, Huitao Shen, Hui Zhai, Science Bulletin, 62 (10), 707-711 (2017). [2]. "Out-of-Time-Order Correlation at a Quantum Phase Transition", Huitao Shen, Pengfei Zhang, Ruihua Fan, Hui Zhai, Phys. Rev. B 96, 054503 (2017). [3]. "Measuring out-of-time-order correlators on a nuclear magnetic resonance quantum simulator", Jun Li, Ruihua Fan, Hengyan Wang, Bingtian Ye, Bei Zeng, Hui Zhai, Xinhua Peng, Jiangfeng Du, Phys. Rev. X 7, 031011 (2017). [4]. "Competition between Chaotic and Non-Chaotic Phases in a Quadratically Coupled Sachdev-Ye-Kitaev Model", Xin Chen, Ruihua Fan, Yiming Chen, Hui Zhai, Pengfei Zhang, Phys. Rev. Lett. 119, 207603 (2017). [5]. "Dispersive SYK model: band structure and quantum chaos", Pengfei Zhang, Phys. Rev. B 96, 205138 (2017).

(13) Bin Chen, Peking University

Title: On the Mutual Information in Conformal Field Theory

Abstract: In this work, we study the universal behaviors in the mutual information of two disjoint spheres in a conformal field theory(CFT). By using the operator product expansion of the spherical twist operator in terms of the conformal family, we show that the large distance expansion of the mutual information can be cast in terms of the conformal blocks. We develop the 1/n prescription to compute the coefficients before the conformal blocks. For a single conformal family, the leading nonvanishing contribution to the mutual information comes from the bilinear operators. We show that the coefficients of these operators take universal forms and such universal behavior persists in the bilinear operators with derivatives as well. Consequently the first few leading order contributions to the mutual information in CFT take universal forms. Our formalism could be applied to any CFT potentially. Furthermore we study such universal behaviors from holographic point of view.

(14) Masaki Tezuka, Kyoto University

Title: The Sachdev-Ye-Kitaev model, random matrices and Lyapunov exponents

Abstract: We study the Sachdev-Ye-Kitaev model and its variants having one-body random terms and/or reduced range of the two-body terms. Numerically we find that the level statistics match the random matrix prediction for the SYK model, and see how they are changed as the model is modified. In the case of an additional one-body infinite-range random interaction, which is a relevant perturbation in the infrared, a chaotic-integrable transition, characterized by the vanishing of the Lyapunov exponent and spectral correlations given by Poisson statistics, eventually occurs in the low temperature limit. On the other hand, reducing the range of the two-body interaction leads to a transition to an insulating state. I will also comment on the spectral statistics of the Lyapunov spectrum of the models.

(15) Ya-wen Sun, UCAS

Title: Topological semimetals from holography

Abstract: Topological states of matter have been a research focus in condensed matter physics for the past decade. In this talk I will introduce a framework in holography to generate gapless topological semimetal states. As explicit examples, we introduce the holographic model of Weyl semimetals and topological nodal-line semimetals. We show that in each of these systems, there exists a quantum phase transition between the topologically trivial semimetal states and the topologically nontrivial Weyl/nodal-line semimetal states. Evidence including anomalous transport properties and "ARPES" calculations as well as predictions for possible new transport properties, including the presence of Hall viscosity associated with the mixed gravitational anomaly, will be discussed. This suggests that at strong coupling we could still have a physical system with the essential properties of the weakly coupled topology semimetals. Our model might lead to a general paradigm in holography to generate topological states of matter.

(16) Jun Nian, IHES

Title: Black Hole Entropy from Supersymmetric Localization

Abstract: Supersymmetric localization is a powerful tool that can provide us with some exact results of quantum field theories. By applying it to gravity, one can test the AdS/CFT correspondence more precisely and in some cases compute the black hole entropy with subleading corrections. In this talk, I will discuss some concrete examples. For the 4d case, we consider the 4d N=2 off-shell supergravity on topological black hole, which provides the gravity dual of the ABJM theory on the boundary S1*H2. We can compute the black hole entropy with the logarithmic correction beyond the classical Bekenstein-Hawking result, and test the identification of the bulk black hole entropy with

the entanglement entropy of the boundary CFT. For the 3d gravity, the strategy is similar but slightly different. We can map the 3d pure gravity to the supersymmetric Chern-Simons theory and then perform the localization. In this way, we discuss the entropy of BTZ black holes. Some possible applications to the Sachdev-Ye-Kitaev model and the corresponding gravity dual will also be discussed. The talk is based on my recent joint work arXiv:1705.01896 and some work in progress.

(17) Mirjam Cvetic, University of Pennsylvania

Title: Lifshitz Geometries and Holography: Application to Subtracted Geometry of Non-extremal Black Holes

Abstract: TBA

(18) Andrew Lucas, Stanford University

Title: Constraints on hydrodynamics from many-body quantum chaos

Abstract: Quantum chaos describes the dynamics of a many-body system at the onset of thermalization, while hydrodynamics describes the late time dynamics after thermalization has occurred locally. Consistency between these two descriptions provides constraints linking hydrodynamic data such as diffusion constants and sound speeds to quantum chaos. This provides an intuitive explanation for recently observed connections between the butterfly velocity and diffusion constants in many strongly interacting systems. I will conclude by describing some of the subtleties that modify these constraints in various large N theories, along with non-trivial consistency checks of these constraints in Sachdev-Ye-Kitaev chains and in holographic models.

(19) Ioannis Papadimitriou, KIAS

Title: TBA

Abstract: TBA

(20) Boyang Yu, Tsinghua University

Title:
AdS_2 Quadrality: From AdS_3/WCFT to AdS_2/CSYK TBA

Abstract:
We discuss connections among complex Sachdev-Ye-Kitaev models (CSYK), Einstein-Maxwell-Dilaton gravities, near extremal black holes, and warped conformal field theories (WCFT). Einstein gravity on asymptotically AdS_3 spacetime with Dirichlet-Neumann boundary conditions are holographically dual to WCFT, featuring a Virasoro-Kac-Moody algebra. We discuss a mapping from WCFT to the conformal limit of CSYK. By a near horizon expansion of near extremal BTZ black holes and a dimensional reduction, we get Einstein-Maxwell-Dilaton gravities, and reproduce the effective action of CSYK model in the IR limit.