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List of Seminars

Keiju Murata
Department of Physics, Nihon University

Superradiant instability of rotating black strings

Dec. 26th, 16:30-17:10

We investigate the effect of superradiant scattering of gravitational perturbations on the stability of rotating black strings, focusing on the six dimensional equal-spinning Myers-Perry black string (MPBS). We find that rapidly rotating MPBS are unstable to gravitational superradiant modes within a bounded range of string lengths. The instability occurs because momentum along the string direction creates a potential barrier that allows for the confinement of superradiant modes.

For some parameters, this instability competes with the Gregory-Laflamme instability, but otherwise exists independently. The onset of this instability is degenerate and branches to multiple steady-state solutions. We construct a cohomogeneity-1 helical black string in six-dimensional Einstein gravity which branches off from the onset of the gravitational superradiant instability of MPBS. It is a stationary spacetime with an isometry group $\mathbb{R}_t \times U(1)_z \times SU(2)$. The horizon has velocity along the string while the Lorentz boost is absent. The entropy of the helical black string is higher than that of the MPBS when the solutions overlap.

Kazumi Okuyama
Faculty of Science, Shinshu University

Spectral form factor of JT gravity

Dec. 27th, 15:50-16:30

Spectral form factor (SFF) is a useful diagnostics of the random matrix statistics of energy spectrum of quantum chaotic systems. JT gravity is holographically dual to a random matrix model and the SFF of JT gravity is given by a random matrix correlator. The so-called ramp and plateau of SFF is reproduced from the Fourier transform of the sine kernel. We show that the corrections to the sine kernel can be computed systematically using the underlying integrability of JT gravity matrix model. This talk is based on a work (in progress) with Kazuhiro Sakai.

Tomoyuki Morimae
Yukawa Institute for Theoretical Physics, Kyoto University

Quantum cryptography without one-way functions

Dec. 27th, 16:30-17:10

One-way function is a function that is easy to compute but hard to invert. One-way functions are essential for classical cryptography, because almost everything are related to one-way functions. However, interestingly, in quantum cryptography, one-way functions are not necessarily essential [Morimae-Yamakwa and Ananth-Qian-Yuen, CRYPTO2022]. In this talk, I explain pseudorandom states generators, EFI and one-way state generators, which are believed to be essential for quantum cryptography. I also mention some applications of these new fundamental primitives in quantum cryptography to quantum physics. For example, it is shown by Aaronson that Harlow-Hayden decoding was shown to be hard under the assumption that one-way function exist, but Brakerski recently showed that the assumption can be replaced with the existence of EFI.

Masaki Tezuka
Department of Physics, Kyoto University

Spectral form factor and eigenstate entanglement entropy in Sachdev-Ye-Kitaev-type models

Dec. 28th, 9:00-9:40

The Sachdev-Ye-Kitaev (SYK) model, proposed in 2015, is a quantum mechanical model of N Majorana or complex fermions with all-to-all random interactions. In this talk, we discuss the spectral correlation of variants of the SYK model based on the spectral form factor.[1] For the case of an additional random hopping term that induces localization of the many-body eigenstates, we discuss the dependence of the eigenstate entanglement entropy on the hopping strength.[2]

[1] H. Gharibyan, M. Hanada, S. H. Shenker, and MT, JHEP 1807(2018), 124; P. H. C. Lau, C.-T. Ma., J. Murugan, and MT, J. Phys. A 54, 095401 (2021); MT, O. Oktay, E. Rinaldi, M. Hanada, and F. Nori, arXiv:2208.12098.
[2] F. Monteiro, MT, A. Altland, D. A. Huse, and T. Micklitz, Phys. Rev. Lett. 127, 030601 (2021).

Tomonori Ugajin
The Hakubi Center for Advanced Research, Kyoto University

ER= EPR for de Sitter

Dec. 28th, 9:40-10:20

We study microscopic properties of the Hilbert space for de Sitter space, by making it entangled with the QFT Hilbert space on an AdS black hole. As we increase the entanglement, the wormhole connecting these two spacetimes starts to play a significant role in the dynamics. We concretely construct such a wormhole in two dimensional JT gravity with the presence of the backreaction induced by the entanglement. Semi-classical general relativity restricts possible forms of these wormholes, providing a constraint on the microscopic properties of underlying de Sitter Hilbert space. We argue that these properties can be understood by regarding the degrees of freedom of de Sitter space as a superselection sector with respect to the bulk QFT algebra on the AdS black hole. Furthermore, they provide a proper account for some bizarre aspects of the island formula for de Sitter space when it is entangled with a non gravitating reference system.

Naokazu Shibata
Department of Physics, Tohoku University

Entanglement entropy of quantum Hall systems in torus and spherical geometry

Dec. 28th, 10:40-11:20

We investigate the entanglement entropy of two-dimensional electron systems in magnetic fields by the density matrix renormalization group (DMRG) method. Many body interacting systems on torus and spherical geometries are mapped onto 1D models by using guiding center and angular momentum, respectively. The DMRG method is then applied to these 1D models and the entanglement entropy S of topologically ordered states is calculated at fractional fillings 1/m of the Landau level. The entanglement entropy S and the coefficient c in area law $S = cL - \gamma + O(1/L) + \dots$ are analyzed for various sizes of the system in torus and spherical geometries.

Hiroshi Ueda
Center for Quantum Information and Quantum Biology, Osaka University

Search for tree tensor networks matching the entanglement structure of quantum many-body states

Dec. 28th, 11:20-12:00

The tree tensor network (TTN) is defined as a tree-type network consisting of isometry tensors, which can be viewed as a sequence of renormalization transformations for composite spin degrees of freedom. So far, several TTN algorithms have been developed, where the resulting TTN states can represent the wavefunction of a quantum many-body system accurately (sometimes rigorously). In such a well-established TTN algorithm as DMRG, however, the network structure is fixed to be a certain form designed rather intuitively, although it is an intrinsic factor for determining the accuracy of the algorithm. How can we extract the "optimal TTN structure"? This question is the central motivation for our work.

An essential feature of the TTN is that cutting any single bond in the network divides the TTN into two parts, which means that every bond carries an entanglement entropy for the corresponding bipartition. In the "optimal TTN" where the entanglement entropies on the bonds are kept small, the effect of the reduction of degrees of freedom by the isometry tensor on the wave function approximation is expected to be minor. In this talk, we will discuss two approaches to search for the "optimal TTN": one is a top-down approach to minimize the maximum loss of the entanglement entropy [1], and the other is an automatic optimization algorithm to optimize the network structure by local reconnection of isometries [2]. We demonstrate that both approaches successfully generate the optimal network structure, which can be regarded as a fingerprint of the entanglement structure contained in the quantum state. For example, we obtained the matrix product state (MPS) with dimer units for the Heisenberg chain under the open boundary condition. Other applications of the methods to spatially inhomogeneous systems and two-dimensional clusters will also be discussed.

[1] K. Okunishi, HU, T. Nishino, arXiv:2210.11741.
[2] T. Hikihara, HU, K. Okunishi, K. Harada, T. Nishino, arXiv:2209.03196.

Takuya Okuda
Graduate School of Arts and Sciences, The University of Tokyo

Real-device quantum simulation of spin chains with integrable Trotterization

Dec. 28th, 13:20-14:00

When simulating the time evolution of quantum many-body systems on a digital quantum computer, one faces the challenges of quantum noise and of the Trotter error due to time discretization. If the discrete time evolution preserves integrability, one can absorb the Trotter error into a redefinition of conserved charges so that the new charges are exactly conserved. In this this talk I report on the results of digital quantum simulations on real quantum computers and on classical simulators, where we implement the integrable Trotterization of the spin-1/2 Heisenberg XXX spin chain. We study how quantum noise affects the time evolution of several conserved charges, and observe the decay of the expectation values. We in addition study the early time behaviors of the time evolution, which can potentially be used to benchmark quantum devices and algorithms in the future. We also provide an efficient method to generate the conserved charges at higher orders. Based on arXiv:2208.00576.

Tsutomu Kobayashi
Department of Physics, Rikkyo University

Cosmology and Gravity beyond General Relativity

Dec. 28th, 14:00-14:40

For those who are not familiar with cosmology, I start my talk with a brief review of current issues in this field. I then describe how one can tackle the issues by introducing gravity beyond general relativity. I also explain how one can test theories of gravity with cosmological and gravitational-wave observations. Topics concerning quantum gravity and braneworlds are also discussed.

Andrew S. Darmawan
Yukawa Institute for Theoretical Physics, Kyoto University

Low-depth random Clifford circuits for quantum coding against Pauli noise using a tensor-network decoder

Dec. 28th, 15:10-15:30

Recent work [M. J. Gullans et al., Physical Review X, 11(3):031066 (2021)] has shown that quantum error correcting codes defined by random Clifford encoding circuits can achieve a non-zero encoding rate in correcting errors even if the random circuits on n qubits, embedded in one spatial dimension (1D), have a logarithmic depth $d = O(\log n)$. However, this was demonstrated only for a simple erasure noise model. In this work, we discover that this desired property indeed holds for the conventional Pauli noise model. Specifically, we numerically demonstrate that the hashing bound, i.e., a rate known to be achieved with $d = O(n)$-depth random encoding circuits, can be attained even when the circuit depth is restricted to $d = O(\log n)$ in 1D for depolarizing noise of various strengths. This analysis is made possible with our development of a tensor-network maximum-likelihood decoding algorithm that works efficiently for log-depth encoding circuits in 1D.
