NCTS Theoretical Physics Symposium 理論物理論壇

(2023/1/17)

Morning session 9:00 – 10:30
Chair: Yueh-Nan Chen (NCKU)
Location: 成功大學物理系館 PH 36373, Dept. of Physics, NCKU

No.	Time	Name	Title of talk
1	9:00 – 9:20	Guang-Yu Guo (NTU)	NCTS-Physics: Past, Present and Future
2	9:20 –9:50	Hsiang-Yi Karen Yang (NTHU)	Unveiling the Origin of the Fermi/eRosita Bubbles
3	9:50-10:10	Sheng-Hong Chen (IMB/AS)	Trigger Waves of Cell Death Oriented by Self-organized Patterns of Spindle-shaped Cells
4	10:10-10:30	Hsiang-Hua Jen (IAMS/AS)	A non-Hermitian Optical Atomic Mirror

Afternoon session 13:30 – 15:00
Chair: Guang-Yu Guo (NTU)
Location: 成功大學物理系館 PH 36373, Dept. of Physics, NCKU

No.	Time	Name	Title of talk
5	13:30 – 14:00	Dimitrios Giataganas (NSYSU)	Holographic RG Flows in Strongly Coupled Systems
6	14:00 –14:20	Cheng-Wei Chiang (NTU)	VBF vs. GGF Higgs with Full-Event Deep Learning — Towards a Decay Agnostic Tagger
7	14:20 –14:40	Pochung Chen (NTHU)	Tensor Network Finite-Size Scaling of Two-Dimensional Classical Models
8	14:40 –15:00	Hsi-Sheng Goan (NTU)	Accurate and Efficient Quantum Computations of Molecular Properties

[1]

NCTS-Physics: Past, Present and Future

Guang-Yu Guo
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Department of Physics, National Taiwan University, Taipei 10617, Taiwan

Welcome to this NCTS Theoretical Physics Symposium in the 2023 TPS Annual Meeting. The National Center for Theoretical Sciences (NCTS) was established in August 1997 by the National Science Council, and consists Mathematics and Physics Divisions. NCTS has entered its 5th phase since Jan. 2021. As the current Director of NCTS Physics Division, in this talk, I will report the present status of the Physics Division especially its organization structure, operation mode and major programs as well as its academic achievements in the past 2 years. I will also outline our plan for the next years. There will be a few minutes for Q&A time, and I will then try to response to the questions, comments, suggestions from the audience. More information can be found on the NCTS-Physics website https://www.phys.ncts.ntu.edu.tw/ .

[2]

Unveiling the Origin of the Fermi/eRosita Bubbles

Hsiang-Yi Karen Yang
Department of Physics, National Tsing Hua University, Hsinchu, Taiwan

Abstract: The newly launched eRosita X-ray satellite revealed two gigantic bubbles above and below the Galactic center. The "eRosita bubbles" bare a remarkable resemblance to the Fermi bubbles detected in gamma rays, suggesting a common origin. The physical origin of these giant Galactic bubbles has been hotly debated. Using 3D magnetohydrodynamic simulations including relevant cosmic-ray physics, we show that the multi-wavelength observational data of the gamma-ray/X-ray bubbles as well as the microwave haze could be simultaneously explained by a single event of jet activity of Sgr A* about 2.6 million years ago. I will highlight some of the important constraints derived from our simulations and discuss the implications of the results on galaxy-scale AGN feedback in general.

[3]

Trigger waves of cell death oriented by self-organized patterns of spindle-shaped cells

Sheng S.-H. Chen
Laboratory for Cell Dynamics, Institute of Molecular Biology, Academia Sinica, Taiwan

Cell death has recently been implicated to spread across cells and cause large-scale tissue damages in various human pathological conditions, yet a clear systems-level understanding of ferroptosis had been lacking. Here, we harness mathematical modeling, time-lapse imaging, and chemical/genetic perturbations to reveal how metabolic stress quantitatively modulate cellular state allowing bistability of reactive oxygen species (ROS), in turn, causing trigger waves of cell death. Intriguingly, these cell death trigger waves (i.e., its initiation, direction and speed) can be oriented by the emergent cellular patterns in a cell population. These cellular patterns dictate cell density and cell-cell alignment that prime cells with heterogeneous sensitivity to metabolic stress. Our findings show how cell death propagation is directed in a cell population via self-organized cellular patterns, featuring how collective cellular behavior in tissues and organs may influence cellular vulnerability to metabolic stress.

[4]

A non-Hermitian optical atomic mirror

Hsiang-Hua Jen (任祥華)
Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, Taiwan

Non-Hermitian nature in light-matter interfaces is well known and ubiquitous in open quantum systems. Here we consider a non-Hermitian system formed from a two-dimensional subwavelength array of neutral atoms, the lightest optical mirror in the world. In this system, we theoretically study its non-Hermitian physics—exceptional point, nontrivial spectral topology, and non-Hermitian skin effect in a stripe geometry and under several open boundaries. We uncover the essential geometry-dependent skin effect with its localization length showing a scale-free behavior, beyond the framework of non-Bloch band theory owing to its long-range interaction mechanism. Our work opens the door to the study of the interplay among non-Hermiticity, topology, and long-range interaction.

[5]

Holographic RG Flows in Strongly Coupled Systems

Dimitrios Giataganas
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We study holographically strongly coupled theories in presence of strong fields, with non-trivial renormalization group flows and UV and IR fixed points of different symmetries. We present the challenges on acquiring c-functions for these flows and we suggest possible candidates. Then we study the phase diagram of the theories and the properties of non-local observables and transport coefficients in the confined and deconfined phase. Finally, we discuss the implications of our findings for the strongly coupled systems in nature.

[6]

VBF vs. GGF Higgs with Full-Event Deep Learning — Towards a Decay Agnostic Tagger

Cheng-Wei Chiang
Department of Physics, National Taiwan University, Taipei 10617, Taiwan

Abstract: In the program of Higgs studies at the CERN LHC, one important task is to determine its couplings with the Standard Model particles to high precision. To achieve the goal, one needs to be able to know the production mechanism for each Higgs event. In this talk, I will present our recent work on using deep machine learning methods to help correctly discriminate between the vector boson fusion (VBF) and gluon-gluon fusion (GGF) processes, the two dominant production channels at the LHC. We will show that our classifiers are superior to traditional methods based on shallow machine learning. Moreover, we take initial steps towards the possibility of a VBF vs. GGF tagger that is agnostic to the Higgs decay mode.

[7]

Tensor Network Finite-Size Scaling of Two-Dimensional Classical Models

Pochung Chen
Department of Physics, National Tsing Hua University, Hsinchu, Taiwan

We propose a scheme to perform tensor network based finite size scaling analysis

for the two-dimensional classical models. Starting from the tensor representing the partition function of the model, we use the higher-order tensor renormalization group (HOTRG) method to obtain the renormalized tensor. The renormalized tensor is then used to construct the transfer matrix. By diagonalizing the transfer matrix, the correlation length, the magnetization, and the energy density of an infinite strip can be obtained. We then perform finite size scaling analysis to determine the critical temperature and the critical exponents. As a benchmark we study the two-dimensional classical Ising model. We show that the critical temperature and the critical exponents can be accurately determined. Furthermore, the results can be systematically improved by increasing cut-off bond dimension of the HOTRG method. Finally we study the length scale induced by the finite cut-off bond dimension and elucidate its physical meaning in the context of classical models. **[8]**

[8]
Accurate and efficient quantum computations of molecular properties

Hsi-Sheng Goan
Department of Physics, National Taiwan University, Taipei 10617, Taiwan

Abstract: Quantum chemistry calculation is considered as the most compelling application for quantum computing. However, this is technically limited to only small molecules due to the limitations on the number of qubits and the depth and complexity of computational circuits available in nowadays quantum computers. Consequently, reducing the number of required qubits is necessary to make quantum computation of molecular systems practical. Simulating electronic structure on a quantum computer requires encoding of fermionic systems onto qubits. Common encoding methods transform a fermionic system of N spin-orbitals into an N-qubit system. We propose a generalized qubit-efficient encoding (QEE) scheme that reduce the qubit count to an upper bound of O(m log_2 N), where m is the number of electrons, which is conserved. Using the methods of measurement error mitigation and error-free linear extrapolation, we demonstrate that most of the distributions of the extrapolated energies calculated using our QEE scheme agree with the exact results obtained by Hamiltonian diagonalization in the given basis sets within chemical accuracy. Currently, the minimal contracted Gaussian basis set is commonly used in benchmark studies because it requires the minimum number of spin orbitals and thus the minimal number of qubits; nonetheless, the accuracy is generally low and thus cannot provide useful predictions. We demonstrate that a minimal basis set

constructed from Daubechies wavelet functions for quantum computing can yield accurate results for H2 and LiH in excellent agreement with experimental data. This is an unprecedented demonstration of quantum computation with accuracy comparable with that of the full configuration interaction (FCI) method using a large basis set, whereas the computational cost is merely the same as that of a minimal basis set calculation. We also perform numerical experiments on a quantum simulator with a noise model implemented from a real quantum machine. We demonstrate that most of the error-mitigated data agree well with the exact FCI results within chemical accuracy. Finally, we present a hybrid quantum-classical machine learning computational framework that can be trained unsupervisedly to reliably and efficiently predict molecular potential energy curves and harmonic vibrational frequencies. Thus, our work provides an efficient and accurate scheme for quantum computations of molecular systems, and for the first time demonstrates that predictions in agreement with experimental measurements are possible to be achieved with quantum resources available in near-term quantum computers.