# OMU-NTHU Joint Meeting on Modern Advances in Physics, Osaka Metropolitan University - National Tsing-Hua University.

Friday, 7 February 2025 - Saturday, 8 February 2025

NTHU

# Book of Abstracts

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## A proposal for the theory of quantum gravity and quantum mechanics of black hole

**Author:** Chong-Sun Chu[1]

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We propose a quantum mechanical theory of quantum spaces described by large N noncommutative geometry as a model for quantum gravity. The theory admits fuzzy sphere and fuzzy ellipsoid as solution. We show that these solutions reproduces precisely the horizon radius of a Schwarzschild black hole and a Kerr black hole. Moreover our quantum mechanical description gives rise to a set of microstates over these geometries, which reproduces precisely the Bekenstein-Hawking entropy of black hole. These results provide support that our proposed theory of quantum spaces is a plausible candidate for the theory of quantum gravity. Further progress and directions will be discussed.

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## Investigating the driver of the diversity in early exoplanetary systems

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The diversity of exoplanetary systems arises in part from the physical structure of the parent protoplanetary disks. Star-forming regions serve as natural laboratories to study the origins of planetary systems and rocky planets like Earth. By observing the birth environment of these planets, we can understand how planets are being assembled. With the largest millimeter interferometer telescope, Atacama Large Millimeter/sub-millimeter Array, planet-forming disks are being spatially resolved down to 10 au to uncover the substructures in both dust and gas to reveal the presence of young planets as they interact with the protoplanetary disk. We are now building a better picture of planet formation using state-of-the-art telescopes.

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## The Gamma-ray Transients Monitor (GTM) onboard Formosat-8B

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The Gamma-ray Transients Monitor (GTM) is a secondary science payload of Formosat-8B (FS-8B) for monitoring Gamma Ray Bursts (GRBs) and other transients in the energy band from 50 keV to 2 MeV. GTM consists of two identical modules located on two opposite sides of FS-8B, a Taiwanese

remote sensing satellite. Each module has four sensor units facing different directions to cover half of the sky. The two modules will then cover the whole sky, including the direction occulted by the Earth. Each sensor unit is composed of a GAGG scintillator array (50 mm × 50 mm × 8 mm) to be readout by SiPM with 16 pixel-channels. Based on different flux levels detected by different sensor units, the direction of the GRB event can be determined. GTM will enhance the sky coverage of contemporary missions and provide independent event localization measurement. Spectral analysis and polarization-state determination for bright GRBs can be conducted with GTM data. GTM is expected to detect about 50 GRBs per year. Its flight model has gone through all required environmental tests successfully and was delivered to Taiwan Space Agency (TASA) in September 2023. On-ground calibration is being conducted. The launch is expected in 2026.

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# Extraction of Conformal Data using Tensor Network Renormalization

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We propose a scheme to extract the conformal data of critical two-dimensional classical models. The basic idea is to perform finite-size scaling to extract central charge, scaling dimension, conformal spin, and operator product expansion (OPE) coefficients. The key point is to identify the length scale below which the system is in the finite-size scaling regime. While above such a length scale the system crossovers into finite-entanglement scaling regime due to bond-dimension induced relevant perturbation. The scheme can work with any tensor network renormalization method. In this work, we benchmark against three tensor network renormalization method: HOTRT, PTMRG, CTRG and apply the scheme to 2D Ising model and 3-state clock model at criticality. Our results show that all conformal data can be extracted with high accuracy. Moreover, we show how to define entanglement scaling for classical systems.

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# High magnetic field research on correlated electron systems at NTHU

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The ability to generate high magnetic field exceeding 30 T in a controlled manner, in combination with the create of ultra-low temperature environment, in large-scale international research facilities have play a pivotal role in uncovering new phenomena in condensed matter research. Transition metal oxides, in particular, offer a fertile playground to realize novel quantum phase of matter, thanks to its diverse structural motifs and electronic configurations. In this talk, I will introduce the research topics that are being actively pursued using large magnetic fields, including the manipulation of electronic ground state in correlated iridate semimetal, investigation of transport phenomenology in new nickelate superconductors, and probing of phase-incoherent superconductivity in overdoped high-Tc cuprates. Challenges, prospects, and collaborative opportunities in these research activities will be discussed.

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## New twists in the research of strongly correlated electronic systems

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## The Telescope Array Experiment: Exploring the Extremely High-Energy Universe

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Cosmic rays are high-energy protons and nuclei originating from outer space, and they are thought to be associated with the most energetic phenomena in the universe. Their energy ranges from GeV to 100 EeV (10^20 eV, ten-to-the-twentieth electron volts). Among these, those with energies exceeding 1 EeV (10^18 eV) are referred to as ultra-high-energy cosmic rays (UHECRs).

To study UHECRs, we constructed a large-scale cosmic ray detector, the Telescope Array (TA), in the desert of Utah, USA. Since 2008, the TA experiment has been continuously observing UHECRs. Key measurements include the energy spectrum, mass composition, and anisotropy in the arrival directions of UHECRs.

In this presentation, I will share recent highlights from the TA experiment and discuss the future prospects of UHECR studies. This includes collaboration with observations of other messengers, such as high-energy neutrinos, to further our understanding of these cosmic phenomena.

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## Gravitational wave emissions from core-collapse supernovae

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Core-collapse supernovae (CCSNe) are among the most explosive events in the universe and are the birthplaces of neutron stars and stellar-mass black holes under extreme conditions. CCSNe are also ideal multi-messenger sources, as they are expected to be detected not only through electromagnetic waves but also via neutrinos and gravitational waves.

In this talk, I will present the latest findings from our multi-dimensional supernova simulations with self-consistent neutrino transport and general relativistic corrections. In particular, I will focus on how the supernova progenitor, rotation, or magnetic fields affect the explosion engine and gravitational wave emission. I will also present our Machine-learning methods for searching CCSN events and estimating the possible physical parameters, such as rotational rates or nuclear equation of states.

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# Research on Ge quantum dot spin qubit devices

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Gate-defined quantum dot spin qubit arrays based on undoped Ge/SiGe quantum wells have attracted tremendous research interest due to their long coherence time and strong spin-orbital coupling. However, the fabrication of conventional overlapping-gate quantum dot devices poses a challenge for many research groups, because it requires at least four metal layers, three oxide layers, and 10-nm alignment accuracy. Therefore, developing a simpler and more reliable architecture for Ge quantum dot arrays can speed up the material and device optimization process. Here we present a new design of Ge quantum dot devices with a global accumulation gate and depletion-style fine gates. The device fabrication consists of only three metal layers, two oxide layers, and needs only micrometer alignment accuracy. We measured these devices and successfully observed Coulomb blockade and Coulomb diamond both in DC transport and RF reflectometry. In addition, we used the Coulomb peaks to characterize the charge noise and obtained a noise power spectrum density of 1.1μeV/√Hz at 1Hz, confirming the quality of the material and device. Finally, we present our progress in spin qubit control.

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# Geometrical View of Quantum Phase Transition: From Kähler to Pseudo-Kähler Structure Transition

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We study the quantum geometry of the quantum phase transition system consisting of a single-mode bosonic quadratic coupling Hamiltonian with the SU(1,1) symmetry, where the system parameters corresponding to the three generators forms a three-dimensional parameter space.
The phase boundary appears in the form of a light cone in the parameter space which is regarded as the exceptional surface.
We have obtained the complex eigenmodes which diagonalize the Hamiltonian all over the parameter space, enabling us to study analytical continuation across the phase boundary.
We have defined the quantum geometric tensor of the complex eigenmodes based on the principal bundle theory.
The symmetric part of the tensor, known as the quantum metric, is a positive-definite Riemannian metric in the stable region.
However, in the unstable region, we found that part of it becomes negative, turning into a pseudo-Riemannian metric.
The antisymmetric part represents the Berry curvature, which shows the transition from the real phase to the complex phase on the QPT.
It is found that the present system possesses the K{\"a}hler structure in the stable domain which shows a topological change to a pseudo-K{\"a}ler structure in the unstable domain.
Our method reveals the analytic continuation on the QPT from the stable region to the unstable region.

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# Measurement of the Variation of Electron-to-Proton Mass Ratio Using Ultracold Molecules Produced from Laser-Cooled Atoms

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## Nuclear structure studies at Osaka Metropolitan University

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## Gravitational wave observation approaching the origin and physics of Black holes

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## Tea break

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## Opening Remarks from NTHU: Dean of the College of Science (Chung-Yu Mou) + Chair of the Department of Physics (Yi-Wei Liu)

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## Opening Remarks from OMU: Director of NIETP (Nobuyuki Kanda)

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## Out of equilibrium dynamics with 1D Bose-Einstein Condensate

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## Phenomenology of primordial black hole from a first order phase transition

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## Quantum information processing with narrowband single and entangled photons

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