KEK Theory Workshop 2022

Report of Contributions

https://conference-indico.kek.jp/e/181

Contribution ID: **1** Type: **not specified**

Solitonic symmetry beyond homotopy: invertibility from bordism and non-invertibility from TQFT

Wednesday, 7 December 2022 14:20 (20 minutes)

Solitonic symmetry is believed to follow the homotopy-group classification of topological solitons. Here, we point out a more sophisticated algebraic structure when solitons of different codimensions coexist in the spectrum. We uncover this phenomenon in a concrete quantum field theory, the 4d $\mathbb{C}P^1$ model. This model has two kinds of solitonic excitations, vortices and hopfions, which would follow two $U(1)$ solitonic symmetries according to homotopy groups. Nevertheless, we demonstrate the nonexistence of the hopfion $U(1)$ symmetry by evaluating the hopfion charge of vortex operators. We clarify that what conserves hopfion numbers is a non-invertible symmetry generated by 3d spin topological quantum field theories (TQFTs). Its invertible subgroup is just $\mathbb{Z}_2$, which we recognize as a spin bordism invariant. Compared with the 3d $\mathbb{C}P^1$ model, our work suggests a unified description of solitonic symmetries and couplings to topological phases.

Primary author: Mr CHEN, Shi (The University of Tokyo)

Presenter: Mr CHEN, Shi (The University of Tokyo)

Session Classification: Parallel session A

Contribution ID: **2** Type: **not specified**

Unstable Nambu-Goldstone modes

Wednesday, 7 December 2022 14:40 (20 minutes)

Nambu-Goldstone (NG) modes for 0-form and higher-form symmetries can become unstable in the presence of background fields. The examples include the instability of a photon with a time-dependent axion background or with a chirality imbalance, known as the chiral plasma instability, and the instability of a dynamical axion with a background electric field. We show that all these phenomena can be universally described by a symmetry algebra for 0-form and higher-form symmetries. We prove a counting rule for the number of unstable NG modes in terms of correlation functions of broken symmetry generators. Based on our unified description, we further give a simple new example where one of the NG modes associated with the spontaneous 0-form symmetry breaking $U(1) \times U(1) \to 1$ becomes unstable.

Primary author: Dr YOKOKURA, Ryo (KEK)

Presenter: Dr YOKOKURA, Ryo (KEK)

Session Classification: Parallel session A

Contribution ID: **3** Type: **not specified**

Formation of chiral soliton lattice

Wednesday, 7 December 2022 15:00 (20 minutes)

The Chiral Soliton Lattice (CSL) is a lattice structure composed of domain walls aligned in parallel at equal intervals, which is energetically stable in the presence of a background magnetic field and a finite (baryon) chemical potential due to the topological term originated from the chiral anomaly. We study its formation from the vacuum state, with describing the CSL as a layer of domain-wall disks surrounded by the vortex or string loop, based on the Nambu-Goto-type effective theory. We show that the domain wall nucleates via quantum tunneling when the magnetic field is strong enough. We evaluate its nucleation rate and determine the critical magnetic field strength with which the nucleation rate is no longer exponentially suppressed. We apply this analysis to the neutral pion in the two-flavor QCD as well as the axion-like particles (ALPs) with a finite (baryon) chemical potential under an external magnetic field. In the former case, even though the CSL state is more energetically stable than the vacuum state and the nucleation rate becomes larger for sufficiently strong magnetic field, it cannot be large enough so that the nucleation of the domain walls is not exponentially suppressed and promoted, without suffering from the tachyonic instability of the charged pion fluctuations. In the latter case, we confirm that the effective interaction of the ALPs generically includes the topological term required for the CSL state to be energetically favored. We show that the ALP CSL formation is promoted if the magnetic field strength and the chemical potential of the system is slightly larger than the scale of the axion decay constant.

Primary author: Dr NISHIMURA, Kentaro (KEK)

Presenter: Dr NISHIMURA, Kentaro (KEK)

Session Classification: Parallel session A

Contribution ID: **4** Type: **not specified**

Boson-fermion duality with subsystem symmetry

Wednesday, 7 December 2022 15:20 (20 minutes)

In this talk, I will introduce an exact duality in (2 + 1)d between the fermionization of a bosonic theory with a Z_2 subsystem symmetry and a fermionic theory with a Z_2 subsystem fermion parity symmetry. A typical example is the duality between the fermionization of the plaquette Ising model and the plaquette fermion model. I will establish the exact duality on the lattice by using the generalized Jordan-Wigner map, with a careful discussion on the mapping of the twist and symmetry sectors. This motivates us to introduce the subsystem Arf invariant, which exhibits a foliation structure.

Primary author: Mr CAO, Weiguang (Kavli IPMU, University of Tokyo)

Presenter: Mr CAO, Weiguang (Kavli IPMU, University of Tokyo)

Session Classification: Parallel session A

Contribution ID: **5** Type: **not specified**

Scalar, fermionic and supersymmetric field theories with subsystem symmetries

Wednesday, 7 December 2022 15:40 (20 minutes)

It is known that the field-theoretic model describing fractons, which have attracted much attention in condensed matter physics, is a theory with non-Lorentz covariant symmetry, called subsystem symmetry. More recently, a fermionic field theory that seems to be related to fractons has been constructed. In this presentation, we discuss detailed properties of these field theories.

Primary author: Mr NAKANISHI, Taiichi (YITP, Kyoto Univ.)

Presenter: Mr NAKANISHI, Taiichi (YITP, Kyoto Univ.)

Session Classification: Parallel session A

Contribution ID: **6** Type: **not specified**

Numerical studies on the IKKT matrix model using Lefschetz thimble method

Wednesday, 7 December 2022 14:20 (20 minutes)

The IKKT matrix model is a candidate for the non-perturbative formalization of superstring theory in 10 dimension. This model suggests that the (9+1)-dimensional Lorentz symmetry is spontaneously broken and (3+1)-dimensional space-time emerges. However, the sign problem is the main obstacle to the numerical analysis of this model. Recently, numerical studies has been conducted by complex Langevin method to overcome the sign problem, but this method has certain application limit. Therefore, we performed, for the first time, the calculation using another method, Lefschetz thimble method, which does not have such application limit.

Primary author: Mr YAMAMORI, Naoyuki (SOKENDAI)

Presenter: Mr YAMAMORI, Naoyuki (SOKENDAI)

Session Classification: Parallel session B

Contribution ID: **7** Type: **not specified**

Analytical analysis of the bosonic Lorentzian IKKT matrix model with a mass term

Wednesday, 7 December 2022 14:40 (20 minutes)

The IKKT matrix model was conjectured to provide a non-perturbative definition of the type IIB string theory. One of the most attractive features of this model is that spacetime emerges dynamically by interpreting the matrix degrees of freedom as ten-dimensional spacetime coordinates. There have been many numerical simulations suggesting the appearance of (3+1)-dimensional expanding universe. In the recent work [1], it was shown that the spacetime arising from the bosonic version of the model is Euclidean and complex. To realize a real Lorentzian spacetime, an additional mass term was then introduced. In this work, we investigate the bosonic Lorentzian IKKT matrix model with a mass term analytically. [1] K. Hatakeyama, K. Anagnostopoulos, T. Azuma, M. Hirasawa, Y. Ito, J. Nishimura, S. K. Papadoudis, and A. Tsuchiya, Complex Langevin studies of the emergent space-time in the type IIB matrix model, in East Asia Joint Symposium on Fields and Strings 2021, 1, 2022. arXiv:2201.13200.

Primary author: Mr PIENSUK, Worapat (SOKENDAI)

Presenter: Mr PIENSUK, Worapat (SOKENDAI)

Session Classification: Parallel session B

Contribution ID: **8** Type: **not specified**

Fractional topological charge in lattice Abelian gauge theory

Wednesday, 7 December 2022 15:00 (20 minutes)

Since Gaiotto et.~al discussed the low-energy dynamics of gauge theories on the basis of the mixed 't Hooft anomaly between discrete and higher-form symmetries, this type of application of the anomaly has been studied vigorously. In this study, in order to understand this type of application of the anomaly in a completely regularized framework, we formulate the fractional topological charge associated with the $U(1)/\mathbb{Z}_q$ principal bundle in the compact $U(1)$ lattice gauge theory by generalizing L\"uscher's construction. This fractional topological charge in lattice gauge theory is $\mathbb{Z}_q$ one-form gauge invariant and odd under the lattice time reversal transformation. By employing these properties of the fractional topological charge, we can show that the $U(1)$ gauge theory containing matter fields with charge $q \in 2\mathbb{Z}$ has the mixed 't Hooft anomaly between the $\mathbb{Z}_q$ one-form symmetry and the time reversal symmetry when $\theta = \pi$. This is analogous to the mixed 't Hooft anomaly between the $\mathbb{Z}_N$ one-form symmetry and the time reversal symmetry in $SU(N)/\mathbb{Z}_N$ theory when $\theta = \pi$.

Primary author: Mr ABE, Motokazu (Kyushu University)

Presenter: Mr ABE, Motokazu (Kyushu University)

Session Classification: Parallel session B

Contribution ID: **9** Type: **not specified**

Phase structure of linear quiver gauge theories from anomaly matching

Wednesday, 7 December 2022 15:20 (20 minutes)

We consider the phase structure of the linear quiver gauge theory, using the ‘t Hooft anomaly matching condition. This theory is characterized by the length K of the quiver diagram. When K is even, the symmetry and its anomaly are the same as those of massless QCD. Therefore, one can expect that the spontaneous symmetry breaking similar to the chiral symmetry breaking occurs. On the other hand, when K is odd, the anomaly matching condition is satisfied by the massless composite fermions. We also consider the thermal partition function under the twisted boundary conditions. When K is even, from the anomaly at finite temperature, we estimate the relation between the critical temperatures associated with the confinement/deconfinement and the breaking of the global symmetry. Finally we discuss the anomaly matching at finite temperature when K is odd.

Primary author: Mr WADA, Hiroki (Osaka University)

Presenter: Mr WADA, Hiroki (Osaka University)

Session Classification: Parallel session B

Contribution ID: **10** Type: **not specified**

Spontaneous CP breaking in 4D SU(N) gauge theory at $\theta = \pi$ and its restoration at finite temperature

Wednesday, 7 December 2022 15:40 (20 minutes)

Recent studies on the 't Hooft anomaly matching condition for 4D SU(N) gauge theory have suggested that the phase structure at $\theta = \pi$ should be nontrivial. Namely, some symmetry will be spontaneously broken, or gapless modes will appear. In the large-N limit, it is known that CP symmetry at $\theta = \pi$ is broken in the confined phase, while it restores in the deconfined phase, which is indeed one of the consequence of the anomaly matching. However, at small N, one may find a qualitatively different phase structure, which will be another possible scenario consistent with the anomaly matching. Here we investigate this issue for $N = 2$ by direct lattice calculations. The crucial point of our method is that the restoration of CP symmetry can be probed by the sudden change of the topological charge distribution at $\theta = 0$, which can be seen by simulating the theory at imaginary θ without the sign problem. Our results suggest that the CP symmetry at $\theta = \pi$ is restored at higher temperature than the deconfining temperature unlike the situation in the large-N limit.

Primary author: Dr MATSUMOTO, Akira (RIKEN iTHEMS)

Presenter: Dr MATSUMOTO, Akira (RIKEN iTHEMS)

Session Classification: Parallel session B

Contribution ID: **11** Type: **not specified**

Optimized flow for generalized Lefschetz thimble method

Wednesday, 7 December 2022 16:00 (20 minutes)

Generalized thimble method is one of powerful methods to overcome the sign problem in numerical simulations. We point out that the method has a subtle property when applied to a nearly continuum system. The point is that solutions of the flow equation generically show exponential behavior, and the growing rates largely differ depending on the modes. It implies the ranges of the flow time where we resolve the sign problem and the Ergodicity problem are largely different mode by mode. It can leads to a great inefficiency in the simulation, in particular where we move the sampling point on the original contour. In order to deal with the subtlety, we propose the modified flow equation which preserves the properties of the original one and nevertheless normalizes the growing rates. As a demonstration, we reproduce the real-time evolution of an anharmonic oscillator with the modified flow, where it is difficult to perform the simulation with the original one.

Primary author: Dr SAKAI, Katsuta (Tokyo Medical and Dental University)

Presenter: Dr SAKAI, Katsuta (Tokyo Medical and Dental University)

Session Classification: Parallel session B

Contribution ID: **12** Type: **not specified**

The emergence of (3+1)-dimensional space-time in the type IIB matrix model

Thursday, 8 December 2022 14:00 (20 minutes)

We perform numerical studies of the type IIB matrix model, which was proposed as a nonperturbative formulation of superstring theory in 1996. We overcome the sign problem by using the complex Langevin method and show that it is necessary to add a term corresponding to infrared regularization to the action of the original model. By these procedures, we find the (3+1)D expanding space-time in this model.

Primary author: Dr HATAKEYAMA, Kohta (KEK)

Presenter: Dr HATAKEYAMA, Kohta (KEK)

Session Classification: Parallel session A

Contribution ID: **13** Type: **not specified**

Bond-weighting method for the Grassmann tensor renormalization group

Thursday, 8 December 2022 14:20 (20 minutes)

Recently, the tensor network description with bond weights on its edges has been proposed as a novel improvement for the tensor renormalization group (TRG). The bond weight is controlled by a single hyperparameter, whose optimal value is estimated in the original work via the numerical computation of the two-dimensional critical Ising model. We develop this bond-weighted TRG algorithm to make it applicable to the fermionic system, benchmarking with the two-dimensional massless Wilson fermion. We show that the accuracy with the fixed bond dimension is improved also in the fermionic system and provide numerical evidence that the optimal choice of the hyperparameter is not affected by whether the system is bosonic or fermionic. In addition, by monitoring the singular value spectrum, we find that the scale-invariant structure of the renormalized Grassmann tensor is successfully kept by the bond-weighting technique.

Primary author: Prof. AKIYAMA, Shinichiro (The University of Tokyo)

Presenter: Prof. AKIYAMA, Shinichiro (The University of Tokyo)

Session Classification: Parallel session A

Contribution ID: **14** Type: **not specified**

Path Integral and Phase Space Dynamics of U(1) Quantum Pendulum

Thursday, 8 December 2022 14:40 (20 minutes)

We study the time dependent behavior of a quantum pendulum by path-integral and Wigner-Weyl phase space quantum mechanics. In both cases, we encounter a negative sign problem, and propose certain approximation similar to the truncated Wigner approximation, which sheds some light on the sign problem.

Primary author: Prof. MATSUI, Tetsuo (Kindai University)

Presenter: Prof. MATSUI, Tetsuo (Kindai University)

Session Classification: Parallel session A

Contribution ID: **15** Type: **not specified**

Bounds on expectation values in Quantum mechanics

Thursday, 8 December 2022 15:00 (20 minutes)

The range of motion of a particle with certain energy E confined in a potential is determined from the energy conservation law in classical mechanics. The counterpart of this question in quantum mechanics can be thought of as what the possible range of the expectation values of the position operator x of a particle, which satisfies $E = H$. This range would change depending on the state of the particle, but the universal upper and lower bounds, which is independent of the state, must exist. In this talk, I show that these bounds can be derived by using the uncertainty relations and their generalization.

Primary author: Prof. MORITA, Takeshi (Shizuoka University)

Presenter: Prof. MORITA, Takeshi (Shizuoka University)

Session Classification: Parallel session A

Contribution ID: **16** Type: **not specified**

Real-time evolution of quantum tunneling via the thimble approach

Thursday, 8 December 2022 15:40 (20 minutes)

Quantum tunneling has been playing an important role in various fields of theoretical physics. So far, the only way for us to gain insights into the mechanism is to use the instanton method, which is based on imaginary-time formalism. However, to study its dynamics, it is essential to use real-time formalism, whose path integral is highly oscillatory. Fortunately, Picard-Lefschetz theory can be used to make the integral converge, enabling us to perform the Monte Carlo simulation. In this work, we apply the Monte Carlo simulation based on thimbles to study the real-time evolution of the tunneling process. In particular, we show that quantum tunneling can be characterized by the dominance of complex classical solutions in the $\hbar \to 0$ limit.

Primary author: Dr YOSPRAKOB, Atis (Niigata University)

Presenter: Dr YOSPRAKOB, Atis (Niigata University)

Session Classification: Parallel session A

Contribution ID: **17** Type: **not specified**

Exact solution of the finite Grosse-Wulkenhaar model

Thursday, 8 December 2022 16:00 (20 minutes)

We find the exact solutions of the Φ_2^3 finite matrix model (Grosse-Wulkenhaar model). In the Φ_2^3 finite matrix model, multipoint correlation functions are expressed as $G_{|a_1^1 \ldots a_{N_1}^1|\ldots|a_1^B \ldots a_{N_B}^B|}$. The $\sum_{i=1}^B N_i$-point function denoted by $G_{|a_1^1 \ldots a_{N_1}^1|\ldots|a_1^B \ldots a_{N_B}^B|}$ is given by the sum over all Feynman diagrams (ribbon graphs) on Riemann surfaces with B-boundaries, and each $|a_1^i \cdots a_{N_i}^i|$ corresponds to the Feynman diagrams having N_i-external lines from the i-th boundary. It is known that any $G_{|a_1^1 \ldots a_{N_1}^1|\ldots|a_1^B \ldots a_{N_B}^B|}$ can be expressed using $G_{|a^1|\ldots|a^n|}$ type n-point functions. Thus we focus on rigorous calculations of $G_{|a^1|\ldots|a^n|}$. The formula for $G_{|a^1|\ldots|a^n|}$ is obtained, and it is achieved by using the partition function $\mathcal{Z}[J]$ calculated by the Harish-Chandra-Itzykson-Zuber integral.

Primary author: Mr KANOMATA, Naoyuki (Tokyo University of Science)

Presenter: Mr KANOMATA, Naoyuki (Tokyo University of Science)

Session Classification: Parallel session A

Contribution ID: **18** Type: **not specified**

Nucleon D-term in holographic QCD

Thursday, 8 December 2022 16:20 (20 minutes)

The D-term is one of the conserved charges of hadrons defined as the forward limit of the gravitational form factor D(t). We calculate the nucleon's D-term in a holographic QCD model in which the nucleon is described as a soliton in five dimensions. We show that the form factor D(t) is saturated by the exchanges of infinitely many 0++ and 2++ glueballs dual to transverse-traceless metric fluctuations on the Wick rotated AdS7 black hole geometry. We refer to this phenomenon as 'glueball dominance', in perfect analogy to the vector meson dominance of the electromagnetic form factors. However, the value at vanishing momentum transfer D(t = 0) can be interpreted as due to the exchange of pairs of pions and infinitely many vector and axial-vector mesons without any reference to glueballs. We find that the D-term is slightly negative as a result of a cancellation between the isovector and isoscalar meson contributions.

Primary author: Dr FUJITA, Mitsutoshi (Sun Yat-Sen University)

Presenter: Dr FUJITA, Mitsutoshi (Sun Yat-Sen University)

Session Classification: Parallel session A

Contribution ID: **19** Type: **not specified**

Curved domain-wall fermion and its anomaly inflow

Thursday, 8 December 2022 14:00 (20 minutes)

We propose a lattice fermion formulation with a curved domain-wall mass term as a nonperturbative regularization of quantum field theory in a gravitational background. In KEK-TH 2021 last year, we reported that the edge-localized modes appear on the curved domain-wall in free fermion theory on a square lattice, and they feel gravity through the induced spin and spin-c connections. We continue the study adding nontrivial $U(1)$ gauge field background to the S^1 or S^2 domain-wall fermion systems. We find a good consistency with continuum theory in the anomaly inflow described by the Atiyah-Patodi-Singer index. This talk is based on our paper https://arxiv.org/abs/2203.03782 and some preliminary results.

Primary author: Mr AOKI, Shoto (Osaka University)

Presenter: Mr AOKI, Shoto (Osaka University)

Session Classification: Parallel session B

Contribution ID: **20** Type: **not specified**

A microscopic description of the Witten effect with negatively massive fermions

Thursday, 8 December 2022 14:20 (20 minutes)

Inside topological insulators or in the theta=pi vacuum, magnetic monopoles gain fractional electric charges, which is known as the Witten effect. In this work, we try to give a microscopic description for this phenomenon, solving a "negatively" massive Dirac equation. The "Wilson term" plays a key role in 1) identifying the sign of the fermion mass, 2) confirming evidence for dynamical domain-wall creations, and 3) understanding why the electric charge is fractional.

Primary author: Prof. FUKAYA, Hidenori (Osaka University)

Presenter: Prof. FUKAYA, Hidenori (Osaka University)

Session Classification: Parallel session B

Contribution ID: **21** Type: **not specified**

Reality from maximizing overlap in the periodic complex action theory

Thursday, 8 December 2022 14:40 (20 minutes)

We study the periodic complex action theory (CAT) by imposing a periodic condition in the future-included CAT where the time integration is performed from the past to the future, and extend a normalized matrix element of an operator O, which is called the weak value in the real action theory, to another expression. We present two theorems stating that the expression becomes real for O being Hermitian with regard to a modified inner product that makes a given non-normal Hamiltonian H normal. The first theorem holds for a given period t_p in a case where the number of eigenstates having the maximal imaginary part B of the eigenvalues of H is just one, while the second one stands for t_p selected such that the absolute value of the transition amplitude is maximized in a case where $B \leq 0$ and $|B|$ is much smaller than the distances between any two real parts of the eigenvalues of H. The latter proven via a number-theoretical argument suggests that, if our universe is periodic, then even the period could be an adjustment parameter to be determined in the Feynman path integral. This is a variant type of the maximization principle that we previously proposed. This talk is based on the collaboration with Holger Bech Nielsen [Prog. Theor. Exp. Phys. 2022 (9) 091B01] (arXiv:2203.07795 [quant-ph]).

Primary author: Prof. NAGAO, Keiichi (Ibaraki University)

Presenter: Prof. NAGAO, Keiichi (Ibaraki University)

Session Classification: Parallel session B

Contribution ID: **22** Type: **not specified**

Supersymmetric affine Toda field equations and ODE/IM correspondence

Thursday, 8 December 2022 15:00 (20 minutes)

The linear differential system of the $\mathcal{N} = 1$ super affine Toda field equations (ATFEs) (Classical) with Lie superalgebras is studied. The modified linear equations reduce to a couple of ordinary differential equations (ODEs). The $osp(2|2)^{(2)}$ giving the Schrodinger equation with squared potential verifies the ODE/IM correspondence.

Primary author: Mr ZHU, Mingshuo (Tokyo Institute of Technology)

Presenter: Mr ZHU, Mingshuo (Tokyo Institute of Technology)

Session Classification: Parallel session B

Contribution ID: **23** Type: **not specified**

Renormalization group approach to cMERA

Thursday, 8 December 2022 15:40 (20 minutes)

The MERA has attracted attention as a model that describes the geometry that emerges from boundary theory. Its continuous version, the cMERA, is expected to be a method to derive geometry directly from a continuous theory. In free field theories, the cMERA was successfully constructed based on the variational method. However, from the holographic point of view, it is crucial to construct the cMERA for interacting theories. Since constructing the cMERA is equivalent to determining the scale dependence of the wavefunctional, we consider an approach based on the renormalization group. We first construct the cMERA perturbatively in interacting scalar theories, and furthermore, we derive non-perturbative renormalization group equation for the wavefunctional.

Primary author: Mr KUWAHARA, Takaaki (Shizuoka University)

Presenter: Mr KUWAHARA, Takaaki (Shizuoka University)

Session Classification: Parallel session B

Contribution ID: **24** Type: **not specified**

Fluid model of black hole/string transition

Thursday, 8 December 2022 16:00 (20 minutes)

We propose a fluid model of self-gravitating strings. It is expected that black holes turn into strings around the end of black hole evaporation. The transition will occur near the Hagedorn temperature. After the transition, strings would form a bound state by the self-gravitation. Horowitz and Polchinski formulated a model of self-gravitating strings by using winding strings wrapping on the Euclidean time circle. We first show that winding strings in the Horowitz-Polchinski model approximately behave as a perfect fluid. Then, we solve the Einstein equation for the fluid of winding strings. Our solution reproduces behaviors of the self-gravitating string solution in the Horowitz-Polchinski model near the Hagedorn temperature, while it approaches the Schwarzschild black hole in low temperature. Thus, our fluid model of self-gravitating strings gives a description of the transition between black holes and strings.

Primary author: Dr MATSUO, Yoshinori (Kindai University)

Presenter: Dr MATSUO, Yoshinori (Kindai University)

Session Classification: Parallel session B

Contribution ID: **25** Type: **not specified**

Krylov complexity of free and interacting scalar QFTs in the continuum limit

Thursday, 8 December 2022 16:20 (20 minutes)

Krylov complexity is a measure of operator growth that is considered to capture quantum chaos in lattice systems. We study the Krylov complexity and Lanczos coefficients of free scalar theories and their perturbative theories in the continuum limit. In particular, we discuss the effects of mass, hard UV cutoff, thermal mass, and perturbative interactions.

Primary author: Dr NISHIDA, Mitsuhiro (Pohang University of Science and Technology)

Presenter: Dr NISHIDA, Mitsuhiro (Pohang University of Science and Technology)

Session Classification: Parallel session B

Contribution ID: **26** Type: **not specified**

Entropy and its conservation in expanding Universe

Friday, 9 December 2022 14:00 (20 minutes)

We investigate properties of the conserved charge in general relativity, recently proposed by one of the present authors with his collaborators, in the inflation era, the matter dominated era and the radiation dominated era of the expanding Universe. We show that the conserved charge becomes the Bekenstein-Hawking entropy in the inflation era, and it becomes the matter entropy and the radiation entropy in the matter and radiation dominated eras, respectively, while the charge itself is always conserved. These properties are qualitatively confirmed by a numerical analysis of a model with a scalar field and radiations. Results in this paper provide more evidences on the interpretation that the conserved charge in general relativity corresponds to entropy.

Primary author: Prof. AOKI, Shinya (Yukawa Institute for Theoretical Physics, Kyoto University)

Presenter: Prof. AOKI, Shinya (Yukawa Institute for Theoretical Physics, Kyoto University)

Session Classification: Parallel session A

Contribution ID: **27** Type: **not specified**

Entropy constraints on effective field theory

Friday, 9 December 2022 14:20 (20 minutes)

In effective field theory, the positivity bounds of higher derivative operators are derived from analyticity, causality, and unitarity. We show that the positivity bounds on a class of effective field theories, e.g., dimension-eight term of a single massless scalar field, the Standard Model Effective Field Theory dimension-eight $SU(N)$ gauge bosonic operators, and Einstein-Maxwell theory with higher-derivative operators, generated by interactions between heavy and light degrees of freedom can be derived by the non-negativity of relative entropy. For such a class of effective field theories, we prove that the interactions increase thermodynamic entropy at fixed energy and charge, which is intimately connected with the extremality relations of black holes exhibiting Weak-Gravity-Conjecture. These arguments are applicable when corrections from the interactions involving higher-derivative operators of light fields are not dominant in the effective field theories. The entropy constraint is a consequence of the Hermiticity of Hamiltonian, and any theory violating the non-negativity of entropy would not respect the second law of thermodynamics.

Primary author: Dr UEDA, Daiki (Peking University)

Presenter: Dr UEDA, Daiki (Peking University)

Session Classification: Parallel session A

Contribution ID: **28** Type: **not specified**

No Smooth Beginning for The Universe and Trans-Planckian Physics

Friday, 9 December 2022 14:40 (20 minutes)

In minisuperspace quantum cosmology, the Lorentzian path integral formulations of the no-boundary and tunneling proposals have recently been analyzed, but it has been pointed out that the wave function of linearized perturbations around a homogeneous and isotropic background is of an inverse Gaussian form and thus that their correlation functions are divergent. In this talk, I will discuss the problem and revisit this issue of the Lorentzian quantum cosmology by modifying the dispersion relation based on trans-Planckian physics. I consider two modified dispersion relations, the generalized Corley/Jacobson dispersion relation with higher momentum terms and the Unruh dispersion relation with a trans-Planckian mode cut-off, as examples, and show that the inverse Gaussian problem of perturbations in the Lorentzian quantum cosmology is hard to overcome with minimal modifications of the gravity theory, such as modifying the dispersion relation at short distances.

Primary author: Dr MATSUI, Hiroki (Yukawa Institute for Theoretical Physics, Kyoto University)

Presenter: Dr MATSUI, Hiroki (Yukawa Institute for Theoretical Physics, Kyoto University)

Session Classification: Parallel session A

Contribution ID: **29** Type: **not specified**

Numerical study of quantum cosmology by the generalized Lefschetz thimble method

Friday, 9 December 2022 15:00 (20 minutes)

Quantum cosmology is established as a way to understand the beginning of universe. Picard-Lefschetz theory has raised recent interest on the "tunneling from nothing"proposal by Vilenkin and the "no boundary"proposal by Hartle-Hawking. The two proposals can be closely related through analysis on saddle points and boundary conditions. In this work, we demonstrate a first principle calculation on the mini-superspace model. We overcome the sign problem arising from the Lorentzian path integral formulation with generalized Lefschetz thimble method. At the initial time, we also perform calculations using the Robin boundary condition, which interpolates the Dirichlet and Neumann boundary conditions. The Stoke's theorem from Vilenkin to Hartle-Hawking can be shown at the critical value of interpolating factor in Robin boundary condition.

Primary author: Mr CHOU, Chien Yu (SOKENDAI)

Presenter: Mr CHOU, Chien Yu (SOKENDAI)

Session Classification: Parallel session A

Contribution ID: **30** Type: **not specified**

Path integrals of perturbative strings on all the curved backgrounds from string geometry theory and a potential energy of the backgrounds

Friday, 9 December 2022 15:20 (20 minutes)

One perturbative string theory is defined on one fixed background. On the other hand, it is necessary that a non-perturbative formulation of string theory includes all the perturbatively stable vacua and perturbative string theories on various curved backgrounds are derived from the single theory. In this talk, we derive perturbative string theories on all the curved backgrounds from the fluctuations around fixed backgrounds in a single string geometry theory, which is one of the candidates of the non-perturbative formulation of string theory. Furthermore, we can define a potential energy of the backgrounds because they do not depend on the string geometry time. A background can be determined by minimizing the energy. Because this mechanism does not depend on supersymmetry, we can study general compactifications. We discuss this application to string phenomenology.

Primary author: Prof. SATO, Matsuo (Hirosaki University)

Presenter: Prof. SATO, Matsuo (Hirosaki University)

Session Classification: Parallel session A

Contribution ID: **31** Type: **not specified**

M2-branes and q-Painleve equations

Friday, 9 December 2022 14:00 (20 minutes)

It is known that the partition function of ABJM theory, the 3d Chern-Simons matter theory on N M2-branes probing C^4/Z_k orbifold, solves a non-linear difference relation called q-deformed Painleve III system. This connection is motivated with the idea of Painleve/gauge correspondence and the topological string/spectral theory correspondence for the quantization of algebraic curves, which also suggests that the similar connection exists for a more general class of M2-brane theories. As a concrete example, we present the connection between the four node circular quiver Chern-Simons theory and the q-deformed Painleve VI system. We also demonstrate how the partition function of this theory reduces to the partition function of the ABJM theory under the coalescence limit of the q-Painleve systems.

Primary author: Dr NOSAKA, Tomoki (Kavli Institute for Theoretical Sciences, University of Chinese Academy of Sciences)

Presenter: Dr NOSAKA, Tomoki (Kavli Institute for Theoretical Sciences, University of Chinese Academy of Sciences)

Session Classification: Parallel session B

Contribution ID: **32** Type: **not specified**

6d Seiberg-Witten curves for E-string and Little string theories from 5-brane webs

Friday, 9 December 2022 14:20 (20 minutes)

We propose a systematic way of obtaining 6d Seiberg-Witten curves from Type IIB 5-brane webs with or without orientifold planes, by generalizing the construction of 5d Seiberg-Witten curves from 5-brane webs. We apply our construction to two kinds of theories: 6d E-string theory and little string theory. In particular, the expression of Seiberg-Witten curve for the E-string theory drastically reduces compared with Eguchi-Sakia's curves. The Seiberg-Witten curve for little string theory that we consider is consistent with the known result. Furthermore, we discuss some other possibilities which may define different little string theories.

Primary author: Dr SUGIMOTO, Yuji (POSTECH)

Presenter: Dr SUGIMOTO, Yuji (POSTECH)

Session Classification: Parallel session B

Contribution ID: **33** Type: **not specified**

Axiomatic rational RG flow

Friday, 9 December 2022 14:40 (20 minutes)

We axiomatize rational massless renormalization group flow as Kan extension.

Primary author: Dr KIKUCHI, Ken (YMSC)

Presenter: Dr KIKUCHI, Ken (YMSC)

Session Classification: Parallel session B

Contribution ID: **34** Type: **not specified**

Application of Nambu Dynamics to Non-equilibrium thermodynamics

Friday, 9 December 2022 15:00 (20 minutes)

In 1973, Yoichiro Nambu published a GHD paper(titled Generalized Hamitonian Dynamics). This paper was the beginning of what is now known as Nambu dynamics. Nambu dynamics is the generalization of Hamiltonian dynamics involving multiple Hamiltonians, and has applications to string theory and fluid dynamics. In this talk, We will present our successful formulation of Nambu dynamics applied to Non-equilibrium thermodynamics, including the concrete example. The content of this talk is available at arXiv:2209.08469.

Primary author: Mr MATSUOKA, Yoshiki (The Open University of Japan)

Presenter: Mr MATSUOKA, Yoshiki (The Open University of Japan)

Session Classification: Parallel session B

Contribution ID: **35** Type: **not specified**

Hierarchical structure of physical Yukawa couplings from matter field Kaehler metric

Friday, 9 December 2022 15:20 (20 minutes)

We study the impacts of matter field Kaehler metric on physical Yukawa couplings in string compactifications. Since the Kaehler metric is non-trivial in general, the kinetic mixing of matter fields opens a new avenue for realizing a hierarchical structure of physical Yukawa couplings, even when holomorphic Yukawa couplings have the trivial structure. The hierarchical Yukawa couplings are demonstrated by couplings of pure untwisted modes on toroidal orbifolds and their resolutions in the context of heterotic string theory with standard embedding. Also, we study the hierarchical couplings among untwisted and twisted modes on resolved orbifolds.

Primary author: Prof. OTSUKA, Hajime (Kyushu University)

Presenter: Prof. OTSUKA, Hajime (Kyushu University)

Session Classification: Parallel session B

Contribution ID: **36** Type: **not specified**

Symmetries in QFT and applications

Wednesday, 7 December 2022 09:00 (1 hour)

Quantum field theory is a framework that can describe universal behavior in the low-energy region for quantum many-body systems, but solving it is often very difficult as it often becomes strongly coupled systems. One of possible approaches to such problems is to constrain the dynamics from general viewpoints instead of solving the dynamics directly. Symmetry in field theories has played a very important role from this perspective. In recent years, the notion of symmetry itself has been generalized in a remarkable manner, and such a generalization produces rigorous constraints on strongly-coupled field theories. In this talk, the generalized notion of symmetry will be explained from the basics and some of its applications will be introduced.

Primary author: Prof. TANIZAKI, Yuya (YITP, Kyoto University)

Presenter: Prof. TANIZAKI, Yuya (YITP, Kyoto University)

Session Classification: Invited talk

Contribution ID: **37** Type: **not specified**

Non-invertible symmetries on the lattice

Wednesday, 7 December 2022 10:20 (1 hour)

Recently, the concept of symmetry has been generalized, and what was not traditionally called symmetry is now being used similarly as symmetry. In this talk, we discuss a class of such generalized symmetries, called non-invertible symmetries, from the viewpoint of the lattice field theories. In particular, we construct topological defects in four-dimensional Z_2 lattice gauge theory, including the Kramers-Wannier-Wegner (KWW) duality defect; the KWW defect is an example of non-invertible symmetries. Also, we consider the system with a boundary and discuss the relations between the disk partition functions derived from the non-invertible symmetry.

Primary author: Prof. YAMAGUCHI, Satoshi (Osaka University)

Presenter: Prof. YAMAGUCHI, Satoshi (Osaka University)

Session Classification: Invited talk

Contribution ID: **38** Type: **not specified**

Neutrino Masses from Generalized Symmetry Breaking

Wednesday, 7 December 2022 13:00 (1 hour)

It is now understood that the concept of symmetry in quantum field theory should be vastly generalized from the ones come from a group action on fields. The generalization includes the higher-form symmetry, which acts on extended operators, and non-invertible symmetry, which does not have an inverse operation. In particular, a classical symmetry with an ABJ-anomaly with an abelian gauge group should be regarded as a non-invertible symmetry. A non-invertible symmetry of this type can naturally be broken by a dynamical monopole loop, and such an effect is non-perturbative. In this talk, I discuss the models where this mechanism gives masses to neutrinos. There are two models, one of which gives Majorana masses and the other gives Dirac masses. These models contain a Z' vector boson gauging the lepton number difference $U(1)_{L_\mu - L_\tau}$, which is completed into a non-abelian group in the further UV. These UV models are relatively simple; e.g. the Dirac masses model only contains the standard model fermions and three right handed neutrinos as its fermion content. Since this work mainly focus on the absolute magnitude of neutrino masses, more phenological investigations are desired, e.g. about texture.

Primary author: Prof. OHMORI, Kantaro (University of Tokyo)

Presenter: Prof. OHMORI, Kantaro (University of Tokyo)

Session Classification: Invited talk

Contribution ID: **39** Type: **not specified**

Sign problem and the Worldvolume Hybrid Monte Carlo method

Thursday, 8 December 2022 09:00 (1 hour)

The numerical sign problem is one of the major obstacles to first-principles calculations in a variety of important systems. Typical examples include finite-density QCD, some condensed matter systems such as strongly correlated electron systems and frustrated spin systems, and real-time dynamics of quantum fields. Until very recently, individual methods were developed for each target system, but over the past decade there has been a movement to find a versatile solution to the sign problem. In this talk, starting with the basics of Markov chain Monte Carlo methods, I first explain the essence of the sign problem and outline some of the approaches proposed in line with the movement. I then focus on methods based on the Lefschitz thimble, and argue that the "Worldvolume Hybrid Monte Carlo method" [Fukuma and Matsumoto, arXiv:2012.08468] is a promising method due to its reliability and versatility. If I have time, I also briefly discuss recent topics related to thimbles, such as resurgence and quantum cosmology.

Primary author: Prof. FUKUMA, Masafumi (Kyoto University)

Presenter: Prof. FUKUMA, Masafumi (Kyoto University)

Session Classification: Invited talk

Contribution ID: **40** Type: **not specified**

Tensor renormalization group in field theory

Thursday, 8 December 2022 10:20 (40 minutes)

Recently, a novel approach using tensor renormalization group (TRG) has made great progress in the numerical computation of lattice field theory. In the TRG, partition functions and correlation functions are represented as tensor networks. Their values can be evaluated by coarse-graining the network without using probabilities like Monte Carlo methods. Therefore, the TRG can easily be applied to systems with sign problems. In this talk, I review the TRG method and talk about how it is used in computations of lattice field theory.

Primary author: Prof. KADOH, Daisuke (Doshisha University)

Presenter: Prof. KADOH, Daisuke (Doshisha University)

Session Classification: Invited talk

Contribution ID: **41** Type: **not specified**

Solving the sign problem in the IKKT model and the real-time quantum evolution by the generalized Lefschetz thimble method

Thursday, 8 December 2022 11:20 (40 minutes)

I report on recent developments in the generalized thimble method based on the Hybrid Monte Carlo algorithm using backpropagation. In particular, I discuss interesting results for the IKKT matrix model and the real-time evolution in quantum mechanics.

Primary author: Prof. NISHIMURA, Jun (KEK)

Presenter: Prof. NISHIMURA, Jun (KEK)

Session Classification: Invited talk

Contribution ID: **42** Type: **not specified**

Quantum Superpositions of Massive Bodies and Gravitationally Mediated Entanglement

Friday, 9 December 2022 09:00 (1 hour)

In order to avoid contradictions with complementarity and causality in a gedankenexperiment involving a quantum superposition of a massive body, it was previously shown (in arXiv:1807.07015) that it is necessary for there to be both quantized gravitational radiation and local vacuum fluctuations
of the spacetime metric. We review this gedankenexperiment and the previously given "back of the envelope"arguments that resolve it. We then improve upon this analysis by providing a precise and rigorous description of the entanglement and decoherence effects (given in arXiv:2112.10798). As a by-product of our analysis, we show that under the protocols of the gedankenexperiment, there is no clear distinction between entanglement mediated by the Newtonian gravitational field of a body and entanglement mediated by on-shell gravitons emitted by the body. This suggests that Newtonian entanglement implies the existence of graviton entanglement and supports the view that the experimental discovery of Newtonian entanglement—as envisioned in proposed experiments—may be viewed as evidence for the existence of the graviton

Primary author: Prof. WALD, Robert (University of Chicago)

Presenter: Prof. WALD, Robert (University of Chicago)

Session Classification: Invited talk

Contribution ID: **43** Type: **not specified**

Expanding Edges of Quantum Hall Systems in a Cosmology Language - Hawking Radiation from de Sitter Horizon in Edge Modes

Friday, 9 December 2022 10:20 (1 hour)

Expanding edge experiments are promising to open new physics windows of quantum Hall systems. In a static edge, the edge excitation, which is described by free fields decoupled with the bulk dynamics, is gapless, and the dynamics preserve conformal symmetry. When the edge expands, such properties need not be preserved. We formulate a quantum field theory in 1+1 dimensional curved spacetimes to analyze the edge dynamics. We propose methods to address the following questions using edge waveforms from the expanding region: Does the conformal symmetry survive? Is the nonlinear interaction of the edge excitations induced by edge expansion? Do the edge excitations interact with the bulk excitations? We additionally show that the expanding edges can be regarded as expanding universe simulators of two-dimensional dilaton-gravity models, including the Jackiw-Teitelboim gravity model. As an application, we point out that our theoretical setup might simulate emission of analog Hawking radiation with the Gibbons-Hawking temperature from the future de Sitter horizon formed in the expanding edge region.

Primary author: Prof. HOTTA, Masahiro (Tohoku University)

Presenter: Prof. HOTTA, Masahiro (Tohoku University)

Session Classification: Invited talk

Contribution ID: **44** Type: **not specified**

Holography of information and the black-hole information paradox

Friday, 9 December 2022 16:00 (1h 30m)

We review recent progress in our understanding of how information is localized in a theory of quantum gravity. In such theories, we argue that, subject to weak assumptions, information in any bounded region is also available in its complement. This is very different from the manner in which quantum information is localized in nongravitational quantum field theories. This implies that the so-called split property fails in theories of quantum gravity. We show how this observation leads to the identification of an error in Hawking's argument for information loss and a resolution of some paradoxes about black holes.
References:
1) Lessons from the Information Paradox, Phys.Rept. 943 (2022), [arXiv:2012.05770]
2) Failure of the split property in gravity and the information paradox, Class.Quant.Grav. 39 (2022), [arXiv:2110.05470]

Primary author: Prof. RAJU, Suvrat (ICTS)

Presenter: Prof. RAJU, Suvrat (ICTS)

Session Classification: Invited talk

Contribution ID: **45** Type: **not specified**

Toward realistic de Sitter heterotic-string models with stable moduli

Wednesday, 7 December 2022 16:30 (1 hour)

The Standard Model of particle physics accounts for all experimental observations to date, and may provide viable parameterisation up to the Planck scale. In this eventuality, further insight into the fundamental origin of the Standard Model parameters can only be gleaned by synthesising it with gravity. String theory provides a framework for the construction of phenomenological models that are consistent with perturbative quantum gravity. Since the late eighties quasi-realistic supersymmetric string models were constructed that reproduce the structure of the Minimal Supersymmetric Standard Models and provide the arena for calculating the parameters of the Standard Model from a theory of quantum gravity. In recent years these studies were extended to non-supersymmetric string vacua including tachyon free vacua that descends from tachyonic ten dimensional vacua. I will give an overview of this work, including work in progress toward the construction of quasi-realistic de Sitter vacua with stable moduli.

Primary author: Prof. FARAGGI, Alon (University of Liverpool)

Presenter: Prof. FARAGGI, Alon (University of Liverpool)

Session Classification: Invited talk

Contribution ID: **46** Type: **not specified**

Stability of open-string models with broken supersymmetry

Thursday, 8 December 2022 17:00 (40 minutes)

We consider type IIB orientifold models in four-dimensional Minkowski spacetime, with N=2 supersymmetry spontaneously broken to 0. For an arbitrary choice of D9- and D5-brane configuration, we analyze the generation of masses at one-loop for all open- and closed-string sector moduli fields. In order to find non-tachyonic models at one-loop, a key ingredient is to consider brane configurations with rigid positions.

Primary author: Prof. PARTOUCHE, Hervé (Ecole Polytechnique)

Presenter: Prof. PARTOUCHE, Hervé (Ecole Polytechnique)

Session Classification: Invited talk

Contribution ID: **47** Type: **not specified**

Constructions of Non-SUSY String Vacua with Vanishing Cosmological Constant

Friday, 9 December 2022 13:00 (40 minutes)

In this talk, I discuss how one can systematically construct non-supersymmetric string vacua with vanishing cosmological constant at one loop, founded mainly on a series of my works. After making a review of related studies, I present the constructions of the string vacua possessing such a property based on the asymmetric orbifolds in various CFT set-ups. We further discuss the physical aspects of these vacua.

Primary author: Prof. SUGAWARA, Yuji (Ritsumeikan University)

Presenter: Prof. SUGAWARA, Yuji (Ritsumeikan University)

Session Classification: Invited talk