2024 Theory Canada 16

Report of Abstracts

https://indico.cern.ch/e/1396918

Abstract ID : **2**

Bouncing cosmology; a solution to the singularity problem and more.

Content

Finding a complete explanation for cosmological evolution in its very early stages (about 13 billion years ago) can significantly advance our understanding of physics. Several models have been proposed, with the majority falling into a category called inflationary universes, where the universe experiences rapid exponential expansion. Despite numerous achievements of inflationary models in explaining the origin of the universe, it has been shown that inflationary models generically suffer from being geodesically past incomplete, which is a representation of singularity. Motivated by addressing the singularity problem, we study a recent model of the early universe, called Cuscuton bounce. This model utilizes a theory of modified gravity by the same name, i.e., Cuscuton, which was originally proposed as a dark-energy candidate, to produce a bouncing cosmology. It has been shown that within the Cuscuton model, we can have a regular bounce without violation of the null energy condition in the matter sector, which is a common problem in most bouncing-cosmology models. In addition, the perturbations do not show any instabilities, and with the help of a spectator field, can generate a scale-invariant scalar power spectrum. We will then set out to investigate if this model has a strong coupling problem or any distinguishing and detectable signatures for non-Gaussianities. We expand the action to the third order and obtain all the interaction terms that can generate non-Gaussianities or potentially lead to a strong coupling problem (breakdown of the perturbation theory). While we do not expect the breakdown of the theory, any distinct and detectable sign of non-Gaussianities would provide an exciting opportunity to test the model with upcoming cosmological observations over the next decade.

Research Category

Cosmology and astrophysics

Primary author: Mr DEHGHANIZADEH, Amirhossein (The University of Waterloo)

Co-authors: Prof. GESHNIZJANI, Ghazal (The Perimeter Institute); Dr QUINTIN, Jerome (The University of Waterloo)

Presenter: Mr DEHGHANIZADEH, Amirhossein (The University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **DEHGHANIZADEH, Amirhossein** on **Wednesday, 27 March 2024**

Abstract ID : **3**

Entanglement production through a cosmological bounce

Content

In quantum gravity, it is expected that the Big Bang singularity is resolved and the universe undergoes a bounce. We show that matter-gravity entanglement entropy rises rapidly during the bounce, declines, and then approaches a steady-state value higher than before the bounce. These observations suggest that matter-gravity entanglement is a feature of the macroscopic universe and that there is no Second Law of entanglement entropy.

Research Category

String theory and quantum gravity

Primary authors: HUSAIN, Viqar (University of New Brunswick); JAVED, Irfan (University of New Brunswick); SEAHRA, Sanjeev (University of New Brunswick); X, Nomaan (University of New Brunswick)

Presenter: JAVED, Irfan (University of New Brunswick)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **JAVED, Irfan** on **Wednesday, 3 April 2024**

Abstract ID : **4**

Quantum Fields near Black Holes and Black Holes Evaporation

Content

In the absence of an adequate complete theory of quantum gravity, model theories can guide in the quest to construct a complete theory, and can also provide insight into the sorts of physical effects which may occur in quantum gravity. A highly promising model theory of quantum gravity is quantum field theory in curved spacetime and the associated theory of semiclassical gravity. The study of quantized fields in curved spaces has a long history. In this talk, we review the status of the computations of the renormalized stress-energy tensors near black holes. We then provide a solution of an evaporating nonrotating black hole as a first-order perturbation of the Schwarzschild metric, using the linearized backreaction from a realistic approximation for the stress-energy tensor for the Hawking radiation in the Unruh quantum state.

Research Category

Relativity and gravitation

Primary author: ABDOLRAHIMI, Shohreh

Co-authors: Prof. PAGE, Don N. (University of Alberta); Dr TZOUNIS, Christos (Cal State Pomona)

Presenter: ABDOLRAHIMI, Shohreh

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **ABDOLRAHIMI, Shohreh** on **Monday, 8 April 2024**

Abstract ID : **5**

Distorted static black holes with a bubble

Content

We construct a family of local static, vacuum five-dimensional solutions with two commuting spatial isometries describing a black hole with a S^3 horizon and a 2-cycle 'bubble' in the domain of outer communications. The solutions are obtained by adding distortions to an asymptotically flat seed solution. We show that the conical singularities in the undistorted geometry can be removed by an appropriate choice of the distortion.

Research Category

Relativity and gravitation

Primary authors: ABDOLRAHIMI, Shohreh; BOOTH, Ivan; Prof. KUNDURI, Hari (McMaster University, Mathematics and Physics); TAVAYEF, Matin (Memorial University of Newfoundland)

Presenter: TAVAYEF, Matin (Memorial University of Newfoundland)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **TAVAYEF, Matin** on **Wednesday, 10 April 2024**

Abstract ID : **6**

Quantum gravitational collapse as a Dirac particle on the half-line

Content

It is shown that the quantum dynamics of a thin spherical shell in general relativity is equivalent to the Coulomb-Dirac equation on the half line. The Hamiltonian of the system has discrete bound states for |E| < m, and a continuum of scattering states for |E| > m, where m is the rest mass of the shell and E is the ADM energy. For sufficiently large m, the ground state energy level is negative, indicating that classical positivity of energy does not survive quantization; the scattering states provide a realization of singularity avoidance.

Research Category

String theory and quantum gravity

Primary author: HUSAIN, Viqar

Presenter: HUSAIN, Viqar

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **HUSAIN, Viqar** on **Wednesday, 10 April 2024**

Abstract ID : **7**

Many-particle representations of SU(1,1) and the orthogonal group.

Content

We present a simple algorithm for the explicit construction of n-particle harmonic oscillator states simultaneously belonging to irreducible representations of $Sp(2,\mathbb{R})$ (or $SU(1,1)$) and $O(n)$. For degenerate representations, the construction can be done using generating functions or hyperspherical harmonics. The cases with $n = 2$ and $n = 3$ are investigated at greater length. The analysis is also extended to non-degenerate states, although the states are not so easily obtained as in the degenerate case.

Research Category

Mathematical Physics

Primary authors: Mr KAKEKASPAN, Noah; DE GUISE, Hubert

Presenter: DE GUISE, Hubert

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **DE GUISE, Hubert** on **Thursday, 11 April 2024**

Abstract ID : **8**

How to improve CKM unitarity bounds with nuclear theory

Content

Recent analysis of Fermi decays by C.Y. Seng and M. Gorshteyn and the corresponding V_{ud} determination have revealed a degree of tension with Cabibbo-Kobayashi-Maskawa (CKM) matrix unitarity, confirmation of which would indicate several potential deficiencies within the Standard Model (SM) weak sector. Extraction of V_{ud} requires electroweak radiative corrections (EWRC) from theory to be applied to experimentally obtained ft-values. Novel calculations of corrections sensitive to hadronic structure, i.e., the γW-box, are at the heart of the recent tension. Moreover, to further improve on the extraction of V_{ud}, a modern and consistent treatment of the two nuclear structure dependent corrections is critical. These corrections are (i) δ_C, the isospin symmetry breaking correction (ii) and δ_{NS}, the EWRC representing evaluation of the γW-box on a nucleus. Preliminary estimations of δ_{NS} have been made in the aforementioned analysis, however, the approach cannot include effects from low-lying nuclear states which require a true many-body treatment. Via collaboration with C.Y. Seng and M. Gorshteyn and use of the Lanczos subspace method, these corrections can be computed in ab initio nuclear theory for the first time. We apply the no-core shell model (NCSM), a nonrelativistic quantum many-body theory for describing low-lying bound states of s- and p-shell nuclei starting solely from nuclear interactions. We will present preliminary results for δ_{NS} and δ_C determined in the NCSM for the $^{10}\mathrm{C} \rightarrow {}^{10}\mathrm{B}$ beta transition, with the eventual goal of extending the calculations to $^{14}\mathrm{O} \rightarrow {}^{14}\mathrm{N}$ and $^{18}\mathrm{Ne} \rightarrow {}^{18}\mathrm{F}$.

Research Category

Nuclear Physics

Primary author: Mr GENNARI, Michael

Co-authors: Dr ATKINSON, Mack (Lawrence Livermore National Lab); Dr DRISSI, Mehdi (TRIUMF); GORSHTEYN, Misha (Mainz University); NAVRATIL, Petr; Dr SENG, Chien-Yeah (University of Washington)

Presenter: Mr GENNARI, Michael

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Mr GENNARI, Michael** on **Monday, 15 April 2024**

Abstract ID : **9**

Bottom-up problems treated with inverse methods are still not top-down: Controlling entropy in complex-structured materials and beyond

Content

I will describe how some old statistical mechanics ideas that were developed to describe the physics of supersymmetric black holes underlie a more recent set of foundational results in soft condensed matter physics. I will show how geometry controls local distributions of entropy in soft materials at nano- and micron-scales. I will describe how this understanding guides the bottom-up self assembly of complex and hierarchically-structured materials. And, I will describe how mathematical physics insights at the nanoscale give leverage on, ostensibly non-physical, human-scale problems.

Research Category

Condensed Matter Physics

Primary author: VAN ANDERS, Greg

Presenter: VAN ANDERS, Greg

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Comments:

For health reasons, I have not been to Theory Canada since I returned to Canada. I was planning to give an overview of the work we're doing in my group, but if the subject is too general, I'd be happy to give a more narrowly pitched talk.

Status: SUBMITTED

Submitted by **VAN ANDERS, Greg** on **Thursday, 18 April 2024**

Abstract ID : **10**

TBA

Content

TBA

Research Category

String theory and quantum gravity

Primary author: MUREIKA, Jonas (Loyola Marymount University)

Presenter: MUREIKA, Jonas (Loyola Marymount University)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **MUREIKA, Jonas** on **Sunday, 21 April 2024**

Abstract ID : **11**

Quantization of black holes: LQG, GUP, and beyond

Content

Black holes are one of the most important playgrounds of quantum gravity. Therefore finding ways to quantize them and understanding their quantum properties could be a crucial step towards understanding and developing the ultimate theory of quantum gravity. Furthermore, they might exhibits properties that can be amplified by astrophysical phenomena leading to possible detection of novel quantum gravity signatures from black hole observations. In this talk I will present how quantum black holes are treated in both loop quantum gravity (LQG) and in minimal uncertainty approach, also known as generalized uncertainty principle (GUP) framework. In particular, I will focus on two very recent models that we are developing, one in LQG and one in GUP.

Research Category

String theory and quantum gravity

Primary author: Prof. RASTGOO, Saeed (University of Alberta)

Presenter: Prof. RASTGOO, Saeed (University of Alberta)

Contribution Type: Invited/plenary speaker

Status: SUBMITTED

Submitted by **Prof. RASTGOO, Saeed** on **Monday, 22 April 2024**

Abstract ID : **12**

Choi-defined resource theories

Content

The resource theories of separable entanglement, non-positive partial transpose entanglement, magic, and imaginarity share an interesting property: an operation is free if and only if its renormalized Choi matrix is a free state. In this talk, I refer to resource theories exhibiting this property as Choi-defined resource theories. I demonstrate how and under what conditions one can construct a Choi-defined resource theory, and I prove that when such a construction is possible, the free operations are all and only the completely resource non-generating operations.

Research Category

Quantum information

Primary author: Prof. SCANDOLO, Carlo Maria (University of Calgary)

Presenter: Prof. SCANDOLO, Carlo Maria (University of Calgary)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Prof. SCANDOLO, Carlo Maria** on **Tuesday, 23 April 2024**

Abstract ID : **13**

Randomised benchmarking for universal qudit gates

Content

We introduce a method for characterising a universal qudit gate set, including controlled T gates. Our scheme, along with the associated gate set, is designed to estimate the average gate fidelity of a T gate within a randomised benchmarking framework. For the qubit case, our approach reduces to dihedral benchmarking. The feasibility of our scheme is substantiated by a celebrated mathematical identity; the identity links the k-th Bell number with a sum over integer partitions of an integer n greater than k. Our scheme completes the characterisation of a universal gate set, a result particularly relevant for gates acting on encoded qudits. Additionally, our gate set supports the extension of interleaved benchmarking and shadow estimation, techniques essential for assessing other performance metrics.

Research Category

Quantum information

Primary author: AMARO ALCALA, David (University of Calgary)

Co-authors: SANDERS, Barry; DE GUISE, Hubert

Presenter: AMARO ALCALA, David (University of Calgary)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **AMARO ALCALA, David** on **Wednesday, 24 April 2024**

Abstract ID : **14**

Neutrinoless double-beta decay and how to probe it with muon capture

Content

Neutrinoless double-beta decay is a hypothetical weak-interaction process in which two neutrons inside an atomic nucleus simultaneously transform into protons and only two electrons are emitted. Since the electrons are emitted without accompanying antiparticles, the process violates the lepton-number conservation and requires that neutrinos are Majorana particles, hence providing unique vistas in the physics beyond the Standard Model of particle physics. The potential to discover new physics drives ambitious experimental searches around the world. However, extracting interesting physics from the experiments relies on nuclear-theory predictions, which remain a major obstacle.

I will talk about two approaches to tackle this problem. First, I will discuss the evaluation of recent effective-field-theory corrections to the operators and their effect on the theory predictions based on phenomenological nuclear many-body methods. Then, I will discuss first-principles calculations of muon capture in light nuclei, which have the potential to shed light on the high-momentum-exchange currents driving neutrinoless double-beta decay.

Research Category

Nuclear Physics

Primary author: JOKINIEMI, Lotta

Presenter: JOKINIEMI, Lotta

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **JOKINIEMI, Lotta** on **Wednesday, 24 April 2024**

Abstract ID : **15**

Generalized Husain-Kuchar models in manifolds with boundaries

Content

In this talk, I will present a family of generalizations of some well-known theories, such as the Pontryagin model, the Husain-Kuchar model, and different formulations of 3-dimensional GR with cosmological constant. When boundaries are included, this family presents an interesting holographic principle: we obtain relevant theories in both the bulk and the boundary. I will address the interplay between them within the Hamiltonian framework. I will also explain the appearance of some sectors of the phase space in which the dynamics are different.

Research Category

Relativity and gravitation

Primary author: MARGALEF, Juan

Presenter: MARGALEF, Juan

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **MARGALEF, Juan** on **Thursday, 25 April 2024**

Abstract ID : **16**

Second order perturbation theory in quantum Monte Carlo

Content

In recent years, there has been a dramatic improvement in our ability to probe the nuclear many-body problem, due to the availability of several different powerful many-body techniques and sophisticated nuclear interactions derived from chiral effective field theory (EFT). Our work primarily focuses on the quantum Monte Carlo family of approaches [1] which involve stochastically solving the many-body Schrodinger equation and have been widely applied in nuclear physics, as well as condensed matter and cold-atomic physics. In a recent paper [2], we developed a novel technique to compute second-order perturbation theory contributions in a QMC context, which had previously been prohibitively difficult. We used this new technique to test fundamental assumptions in the chiral EFT interactions that are used almost universally in nuclear many-body calculations. This talk will review this early work, as well as current investigations into how our approach can be extended to more sophisticated QMC approaches, non-local operators, and higher chiral orders.

[1] J. Carlson et al., Quantum Monte Carlo Methods for Nuclear Physics, Rev. Mod. Phys. 87, 1067 (2015).
[2] R. Curry, J.E. Lynn, K.E. Schmidt, and A. Gezerlis., Second-Order Perturbation Theory in Continuum Quantum Monte Carlo Calculations, Phys. Rev. Res. 5, L042021 (2023)

Research Category

Nuclear Physics

Primary author: CURRY, Ryan (University of Guelph)

Co-author: Prof. GEZERLIS, Alexandros

Presenter: CURRY, Ryan (University of Guelph)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **CURRY, Ryan** on **Thursday, 25 April 2024**

Abstract ID : **17**

Scalar cosmological perturbations from quantum-gravitational entanglement

Content

A major challenge at the interface between quantum gravity and cosmology is to understand how cosmological structures can emerge from physics at the Planck scale. In this talk, I will provide a concrete example of such an emergence process by extracting the physics of scalar and isotropic cosmological perturbations from full quantum gravity, as described by a causally complete Barrett-Crane group field theory model. From the perspective of the underlying quantum gravity theory, cosmological perturbations will be associated with (relational) nearest-neighbor two-body entanglement, providing crucial insights into the potentially purely quantum-gravitational nature of cosmological perturbations. I will also show that at low energies the emergent relational dynamics of these perturbations are perfectly consistent with those of general relativity, while at trans-Planckian scales quantum effects become important. Finally, I will comment on the implications of these quantum effects for the physics of the early universe and outline future research directions.

Research Category

String theory and quantum gravity

Primary author: Dr MARCHETTI, Luca (University of New Brunswick)

Presenter: Dr MARCHETTI, Luca (University of New Brunswick)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Dr MARCHETTI, Luca** on **Friday, 26 April 2024**

Abstract ID : **18**

On Some Classical Features of Quantum Mechanics

Content

Multiple approaches to the classical limit have been shown to be inadequate as a general description of classical emergence. Here we study features of quantum mechanics that appear classical, regardless of an $\hbar \longrightarrow 0$ limit. In one approach, we split the quantum Wigner function into classical and nonclassical parts where the former is one that can afford a classical interpretation. Another direction we explore is how certain Hamiltonians for two quantum degrees of freedom can model classical behaviour of their combination.

Research Category

Mathematical Physics

Primary author: Mr AMIN, Mustafa (University of Lethbridge)

Co-author: WALTON, Mark

Presenter: Mr AMIN, Mustafa (University of Lethbridge)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Mr AMIN, Mustafa** on **Friday, 26 April 2024**

Abstract ID : **19**

Evaporating non-singular black holes in 2D gravity

Content

Arguments from general relativity and quantum field theory suggest that black holes evaporate through Hawking radiation, but without a full quantum treatment of gravity the endpoint of the process is not yet understood. Two dimensional, semi-classical theories of gravity can be useful as toy models for studying black hole dynamics and testing predictions of quantum gravity. Of particular interest are non-singular black holes, since quantum gravity is expected to resolve the singularities that are pervasive in general relativity. This talk will present a general model of evaporating black holes in 2D dilaton gravity, with a focus on a Bardeen-like regularized black hole model. I will discuss results from numerical simulations including the dynamics of the apparent horizons and additional trapped anti-trapped regions formed by backreaction.

Research Category

String theory and quantum gravity

Primary author: BARENBOIM, Jonathan

Presenter: BARENBOIM, Jonathan

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **BARENBOIM, Jonathan** on **Saturday, 27 April 2024**

Abstract ID : **20**

More on the first-order thermodynamics of scalar-tensor gravity

Content

The first-order thermodynamics of scalar-tensor gravity is an analogy between the effective stress-energy tensor of the gravitational scalar field of scalar-tensor gravity, including viable Horndeski, and that of a dissipative fluid. The analogy allows one to describe the approach of modified gravity to General Relativity (the zero-temperature state) as dissipation, to introduce an effective temperature of gravity" and an equation describing the approach to GR (cooling of gravity") or the departure from it ("heating"of gravity). Recent progress on this formalism will be presented.

Research Category

Relativity and gravitation

Primary author: FARAONI, Valerio

Presenter: FARAONI, Valerio

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **FARAONI, Valerio** on **Sunday, 28 April 2024**

Abstract ID : **21**

GinOE-GinUE crossover in correlated disordered non-hermitian spin chains

Content

We illustrate a spectral crossover between two non-Hermitian random matrix ensembles, the Ginibre Orthogonal (GinOE) and Ginibre Unitary (GinUE) classes, within a non-Hermitian disordered one-dimensional spin-1/2 Hamiltonian. Here, the standard isotropic XY Heisenberg term is modified by incorporating nonreciprocal hopping parameters [1], while the Ising interaction is left unaltered. Additionally, this system incorporates a stochastic, Zeeman-like magnetic field combined with an alternating imaginary gain-loss parameter [2,3] breaking both conventional and non-conventional time reversal symmetries, facilitating a GinOE-GinUE crossover. In another variant, we introduce a three-site scalar spin-chiral term [4] coupled with the stochastic Zeeman-like magnetic field. This combination breaks, all time reversal symmetries [5], once again resulting in a crossover between the GinOE and GinUE classes. To examine this crossover for these spin chain models, we use several well-established quantifiers of non-Hermitian quantum chaos such as distribution of complex eigenvalues, corresponding complex spacing ratios (CSR) [6], the dissipative spectral form factor (DSFF) [7,8] and singular value statistics [9]. Notably, in non-Hermitian Ginibre ensembles cubic level repulsion is observed across all symmetry classes (orthogonal, unitary, or symplectic) unlike in the Hermitian Gaussian ensembles [9, 10]. As a result, distinguishing between GinOE and GinUE ensembles based solely on eigenvalue distributions and spectral fluctuation measures like CSR or DSFF proves to be difficult [11]. Therefore, we use singular-value statistics to more effectively investigate these symmetry classes. We utilize analytical results from random matrix theory to model the numerical data from these spin chain systems. Moreover, in the crossover region and for the GinOE classes lacking analytical results, we correlate our numerical findings with simulations from the GinOE-GinUE crossover matrix model, which is based on the Pandey-Mehta Hamiltonian [12].

1) N. Hatano and D. R. Nelson, Localization Transitions in Non-Hermitian Quantum Mechanics, Phys. Rev. Lett. **77**, 570 (1996).
2) R. Hamazaki, K. Kawabata, and M. Ueda, Non-Hermitian Many-Body Localization, Phys. Rev. Lett. **123**, 090603 (2019).
3) Spectral properties of disordered interacting non-Hermitian systems, S. Ghosh, S. Gupta, and M. Kulkarni, Phys. Rev. B **106**, 134202 (2022).
4) X. G. Wen, F. Wilczek, and A. Zee, Chiral spin states and superconductivity, Phys. Rev. B **39**, 11413 (1989).
5) D. Kundu, S. Kumar, and S. Sen Gupta, Spectral crossovers and universality in quantum spin chains coupled to random fields, Phys. Rev. B **105**, 014205 (2022).
6) L. S\'{a}, P. Ribeiro, and T. Prosen, Complex spacing ratios: A signature of dissipative quantum chaos, Phys. Rev. X **10**, 021019 (2020).
7) J. Li, T. Prosen, and A. Chan, Spectral statistics of non-hermitian matrices and dissipative quantum chaos, Phys. Rev. Lett. **127**, 170602 (2021).
8) A. M. Garc\'{i}a-Garc\'{i}a, L. S\'{a}, and J. J. M. Verbaarschot, Universality and its limits in non-hermitian many-body quantum chaos using the sachdev-ye-kitaev model, Phys. Rev. D **107**, 066007 (2023).
9) K. Kawabata, Z. Xiao, T. Ohtsuki, and R. Shindou, Singular-value statistics of non-hermitian random matrices and open quantum systems, PRX Quantum **4**, 040312 (2023).
10) R. Grobe and F. Haake, Universality of cubic-level repulsion for dissipative quantum chaos, Phys. Rev. Lett. **62**, 2893 (1989).
11) A. Sarkar, S. Sen, and S. Kumar, Spectral crossovers in non-Hermitian spin chains: Comparison

with random matrix theory, Phys. Rev. E **108**, 054210 (2023).
12) A. Sarkar, D. Kundu and M. Kulkarni, Manuscript in preparation.

Research Category

Condensed Matter Physics

Primary author: SARKAR, Ayana

Co-authors: Prof. KULKARNI, Manas (International Centre for Theoretical Sciences, Tata Institute of Fundamental Research); Dr KUNDU, Debojyoti (International Centre for Theoretical Sciences, Tata Institute of Fundamental Research)

Presenter: SARKAR, Ayana

Track Classification: Poster - Contributed Posters

Contribution Type: Contributed oral

Comments:

Keywords: Non-Hermitian spin chains and non-Hermitian random matrix theory. Either Oral or Poster presentation works for me.

Status: SUBMITTED

Submitted by **SARKAR, Ayana** on **Monday, 29 April 2024**

Abstract ID : **22**

The Theory of Electrodynamic Space-time Relativity（Revision 5）—An attempt to inherit and develop the special theory of relativity

Content

The theory of electrodynamic space-time relativity (TESTR) studies the space-time transformation relationship between two reference systems that have both inertial velocity differences and electric potential differences. It is a fundamental physical theory that has gradually developed and been established based on Einstein's special theory of relativity and electric potential limit constant assumption. It is an attempt to inherit and develop the special theory of relativity.

According to the difficulty of self-energy divergence of point charges that cannot be overcome by theory in electromagnetism, the author puts forward the hypothesis that there is a fundamental physical constant, namely the electric potential limit constant. Further developed the basic physics concepts and unified the two physical quantities of potential and velocity in the mathematical form of biquaternions. In mathematics, special relativity develops from real numbers to complex numbers, special

biquaternions, and complete biquaternions. In physics, the special theory of relativity has been developed from four-dimensional space-time to five-dimensional space-time and nine-dimensional space-time.

This paper discusses in detail the process of establishing the theory of complex electrodynamic space-time relativity, the theory of biquaternion electrodynamic space-time relativity, and their various conversions and transformations. Using the new concept of "system time" leads to the expression of the fundamental equations of TESTR being as concise as the form of Galilean transformation. In addition, its content is also more symmetrical and universal. It can correctly derive a general form of the four-dimensional space-time special relativity equation. At the same time, it proved that the special theory of relativity is a special case of TESTR, and another important new special case was found: the theory of electric potential relativity.

The paper theoretically predicts some new physical effects of space-time. They provide a theoretical basis for future experimental verification of the theory. The symmetrical, concise, and abstract mathematical and physical properties displayed by electrodynamic space-time relativity are worthy of further in-depth discussion. Finally, appendix A of the paper proves mathematically that the fundamental equations of the theory are consistent with the postulates.

Research Category

Relativity and gravitation

Primary author: Mr YANG, YINGTAO (Retired, Formerly of CCTEG Xi'an Research Institute)

Presenter: Mr YANG, YINGTAO (Retired, Formerly of CCTEG Xi'an Research Institute)

Track Classification: Talk - Contributed Talks

Abstract ID : **23**

Accelerated detector in a superposed spacetime

Content

In pursuit of a full-fledged theory of quantum gravity, operational approaches offer insights into quantum-gravitational effects produced by quantum superposition of different spacetimes not diffeomorphic to one another. Recent work applies this approach to superpose cylindrically identified Minkowski spacetimes (i.e. periodic boundary conditions) with different characteristic circumferences, where a two-level detector coupled to a quantum field residing in the spacetime exhibits resonance peaks in response at certain values of the superposed lengths. Here, we extend this analysis to a superposition of cylindrically identified Rindler spacetimes, considering a two-level detector constantly accelerated in the direction orthogonal to the identified length. Similarly to previous work, we find resonance peaks in the detector response at rational ratios of characteristic circumferences, which we observe to be accentuated by the acceleration of the detector. Furthermore, for the first time, we confirm the detailed balance condition, expected from the acceleration due to the Unruh effect, in superposition of spacetimes. The resonant structure of detector response in the presence of event horizons, for the first time observed in 3+1 dimensions, may offer clues to the nature of black hole entropy in the full theory of quantum gravity.

Research Category

Quantum information

Primary author: GOEL, Lakshay (University of Waterloo)

Co-authors: AFSHORDI, Niayesh; AFSHORDI, Niayesh (University of Waterloo); AFSHORDI, Niayesh; Prof. MANN, Robert (University of Waterloo, Physics); PATTERSON, Everett (University of Waterloo); PRECIADO-RIVAS, Maria Rosa (University of Waterloo); TORABIAN, Mahdi

Presenter: GOEL, Lakshay (University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Comments:

Can I be selected to present on May 24th?

Status: SUBMITTED

Submitted by **GOEL, Lakshay** on **Monday, 29 April 2024**

Abstract ID : **24**

Charged Quark Stars in Regularized 4D Einstein-Gauss-Bonnet Gravity

Content

Since the derivation of a well-defined D ⟶ 4 limit for 4D Einstein Gauss-Bonnet (4DEGB) gravity coupled to a scalar field, there has been interest in testing it as an alternative to Einstein's general theory of relativity. Using the Tolman-Oppenheimer-Volkoff (TOV) equations modified for charge and 4DEGB gravity, we model the stellar structure of charged, non-interacting quark stars. We find that increasing the Gauss-Bonnet coupling constant α or the charge Q both tend to increase the mass-radius profiles of quark stars described by this theory, allowing a given central pressure to support larger quark stars in general. As in the uncharged case, we find that quark stars can exist below the general relativistic Buchdahl bound (BB) and Schwarzschild radius R = 2M , due to the lack of a mass gap between black holes and compact stars in the 4DEGB theory. Even for small α well within current observational constraints, we find that quark star solutions in this theory can describe Extreme Compact Objects (ECOs), objects whose radii are smaller than what is allowed by general relativity.

Research Category

Cosmology and astrophysics

Primary authors: GAMMON, Michael (University of Waterloo); Prof. MANN, Robert (University of Waterloo, Physics)

Presenter: GAMMON, Michael (University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **GAMMON, Michael** on **Monday, 29 April 2024**

Abstract ID : **25**

Freely Falling UDW Detector in Rotating BTZ Spacetime

Content

Recent studies have shown that an Unruh-DeWitt (UDW) detector coupled to a massless scalar field in (3+1) Schwarzschild and (2+1) non-rotating BTZ spacetimes exhibits a local extremum in transition rate at the horizon. This non-monotonicity is of interest, as it suggests that the event horizon is distinguishable to a local probe when QFT is taken into consideration. In this study, we calculate the transition rate of a freely falling UDW detector in (2+1)-dimensional rotating BTZ spacetime. We explore different values of black hole mass, black hole angular momentum, and boundary conditions of the field at infinity. The results that we obtain are consistent with previous studies in the limit as black hole angular momentum vanishes; however, the presence of rotation introduces new phenomena, and our results provide a more general profile for the infalling detector problem in BTZ spacetime. There is now a growing body of evidence for detector excitement across black hole event horizons, and we anticipate that further searches will be conducted in other spacetimes to better understand its physical meaning.

Research Category

Quantum information

Primary authors: WANG, Sijia (University of Waterloo); PRECIADO-RIVAS, Maria Rosa (University of Waterloo); MANN, Robert

Presenter: WANG, Sijia (University of Waterloo)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **WANG, Sijia** on **Monday, 29 April 2024**

Abstract ID : **26**

Quantum Charged Black Holes

Content

In the framework of braneworld holography, we construct a quantum charged black hole that is localized on a three-dimensional anti-de Sitter brane and incorporates quantum backreaction effects from the boundary field theory. The field on the brane consists of higher curvature gravitation coupled with a nonlinear electromagnetic field, and it does not exhibit conformal symmetry. We also investigate the thermodynamics of these quantum charged black holes from three distinct perspectives: a pure bulk description, where the bulk gravitation interacts with a brane; a brane description, where local dynamical gravitation is subject to quantum backreaction from the dual quantum conformal field; a boundary description, where the degrees of freedom for defect quantum conformal matters are considered. In so doing we obtain doubly holographic formulations of both the first law of thermodynamics and the Smarr (energy) relations.

Research Category

String theory and quantum gravity

Primary authors: MANN, Robert; ZHANG, Ming

Co-authors: Ms FENG, Yiji (Jiangxi Normal University); Ms MA, Hao (The Chinese University of Hong Kong); Mr XUE, Yesheng (Jiangxi Normal University)

Presenter: ZHANG, Ming

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **ZHANG, Ming** on **Monday, 29 April 2024**

Abstract ID : **27**

Quantum Signature of Black Holes in Quantum Superposition

Content

A new approach for operationally studying the effects of spacetime in quantum superpositions of semiclassical states has recently been proposed by some of the authors. This approach was applied to the case of a (2+1)-dimensional Bañados-Teitelboim-Zanelli (BTZ) black hole in a superposition of masses, where it was shown that a two-level system interacting with a quantum field residing in the spacetime exhibits resonant peaks in its response at certain values of the superposed masses. Here, we extend this analysis to a mass-superposed rotating BTZ black hole, considering the case where the two-level system co-rotates with the black hole in a superposition of trajectories. We find similar resonances in the detector response function at rational ratios of the superposed outer horizon radii, specifically in the case where the ratio of the inner and outer horizons is fixed. This suggests a connection with Bekenstein's seminal conjecture concerning the discrete horizon spectra of black holes in quantum gravity, generalized to the case of rotating black holes. Our results suggest that deeper insights into quantum-gravitational phenomena may be accessible via tools in relativistic quantum information and curved spacetime quantum field theory.

Research Category

String theory and quantum gravity

Primary author: SURYAATMADJA, Cendikiawan (University of Waterloo)

Co-authors: FOO, Joshua; MANN, Robert; ZYCH, Magdalena

Presenter: SURYAATMADJA, Cendikiawan (University of Waterloo)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **SURYAATMADJA, Cendikiawan** on **Monday, 29 April 2024**

Abstract ID : **28**

Weighted Monte-Carlo sampling of Feynman graphs in ϕ^4-theory

Content

Recent algorithmic progress has made it possible to numerically compute individual Feynman integrals at more than 10 loops. On the other hand, the number of non-isomorphic Feynman graphs grows factorially with loop order; for example there are around 1 billion distinct subdivergence-free graphs contributing to the beta function of ϕ^4-theory at 16 loops. Individual graphs contribute very differently, which makes it challenging to estimate their sum from a non-complete uniform random sample of graphs.

We demonstrate, for the example of subdivergence-free graphs in ϕ^4-theory, that the relative importance of individual graphs can be estimated efficiently from properties of the graph, without actually solving the Feynman integral. These estimations allow for a non-uniform sampling of graphs, weighted by their estimated Feynman integral, which greatly reduces the sampling uncertainty. We implemented one possible weighting algorithm and numerically computed the primitive beta function of ϕ^4-theory at 16 loops. The results require approximately 1000-times less computational effort compared to uniform random sampling.

Based on joint work with Kimia Shaban, arxiv 2403.16217

Research Category

Particles and fields

Primary author: BALDUF, Paul (University of Waterloo, Waterloo ON)

Presenter: BALDUF, Paul (University of Waterloo, Waterloo ON)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **BALDUF, Paul** on **Tuesday, 30 April 2024**

Abstract ID : **29**

Dynamic behaviours of black hole phase transitions near quadruple points

Content

Treating the horizon radius as an order parameter in a thermal fluctuation,the free energy landscape model sheds light on the dynamic behaviour of black hole phase transitions. Here we carry out the first investigation of the dynamics of the recently discovered multicriticality in black holes. We specifically consider black hole quadruple points in D = 4 Einstein gravity coupled to non-linear electrodynamics. We observe thermodynamic phase transitions between the four stable phases at a quadruple point as well as weak and strong oscillatory phenomena by numerically solving the Smoluchowski equation describing the evolution of the probability distribution function. We analyze the dynamic evolution of the different phases at various ensemble temperatures and find that the probability distribution of a final stationary state is closely tied to the structure of its off-shell Gibbs free energy.

Research Category

Relativity and gravitation

Primary authors: MANN, Robert; YANG, Jiayue

Presenter: YANG, Jiayue

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **YANG, Jiayue** on **Tuesday, 30 April 2024**

Abstract ID : **30**

Neutron star science with gravitational waves

Content

As endpoints of massive stellar evolution, showcases for the densest matter in the universe, and sites for heavy element nucleosynthesis, neutron star mergers are superb laboratories for astrophysics, strong gravity and nuclear physics. Gravitational-wave observations of these mergers are beginning to reveal neutron stars' internal structure, provide insight into the astrophysical processes that form them, and expose their role in the chemical evolution of the Galaxy. I will describe how our theoretical understanding in these areas is being shaped by recent gravitational-wave discoveries.

Research Category

Relativity and gravitation

Primary author: LANDRY, Philippe (Canadian Institute for Theoretical Astrophysics)

Presenter: LANDRY, Philippe (Canadian Institute for Theoretical Astrophysics)

Contribution Type: Invited/plenary speaker

Status: SUBMITTED

Submitted by **LANDRY, Philippe** on **Wednesday, 1 May 2024**

Abstract ID : **31**

Exotic nuclear superfludity in heavy nuclei

Content

Nuclear pairing, i.e., the tendency of nucleons to form pairs, has important consequences to the physics of heavy nuclei and compact stars. While the pairing found in nuclei typically happens between identical nucleons and in spin-singlet states, the exotic spin-triplet and mixed-spin pairing phases have also been hypothesized. In this talk, I will present new investigations confirming the existence of these novel superfluids, even at the face of the antagonizing nuclear deformation, at regions that is experimentally accessible. These results also provide general conclusions on superfludity in deformed nuclei. Finally, I will discuss the possible effect of these exotic superfluid phases in nuclear collisions and their signature in spectroscopic quantities and two-particle transfer direct reaction cross sections.

Research Category

Nuclear Physics

Primary authors: GEZERLIS, Alex (University of Guelph); PALKANOGLOU, Georgios; Mr STUCK, Michael (University of Ottawa)

Presenter: PALKANOGLOU, Georgios

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **PALKANOGLOU, Georgios** on **Wednesday, 1 May 2024**

Abstract ID : **32**

Dissolving a black hole

Content

When two black holes collide, the event horizons merge continuously (though not smoothly) as described by the well-known pair-of-pants diagram. The evolution of the apparent horizons is more intricate. After a new, common apparent horizon forms
around those original horizons, numerical simulations have shown that the original pair persists inside. They approach each other, intersect and then, ultimately, disappear in a flurry of creation and annihilation events involving unstable (horizon-like) marginally outer trapped surfaces (MOTS). In this talk I will discuss another, this time analytic, situation in which an apparent horizon "dissolves"under the influence of external gravitational fields. The Weyl-distorted Schwarzschild solutions describe a non-rotating black hole distorted by arbitrarily strong external gravity with that distortion characterized by one or more continuous parameters. Focusing on quadrupole distortions, I will show how increasing the distortion parameter causes the Schwarzschild horizon to become unstable and hence no longer a boundary between trapped and untrapped regions.

Research Category

Relativity and gravitation

Primary authors: BOOTH, Ivan (Memorial University); OKPALA, Chiamaka Mary (Memorial University)

Presenter: BOOTH, Ivan (Memorial University)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **BOOTH, Ivan** on **Thursday, 2 May 2024**

Abstract ID : **33**

Holographic scattering and non-minimal RT surfaces

Content

In the AdS/CFT correspondence, the causal structure of the bulk AdS spacetime is tied to entanglement in the dual CFT. This relationship is captured by the connected wedge theorem, which states that a bulk scattering process implies the existence of strong entanglement between associated boundary subregions. We study the connected wedge theorem in two asymptotically AdS_{2+1} spacetimes: the conical defect and BTZ black hole geometries. In these settings, we find that bulk scattering processes require not just large entanglement, but also additional restrictions related to candidate RT surfaces which are non-minimal. We argue these extra relationships imply a certain CFT entanglement structure involving internal degrees of freedom. Because bulk scattering relies on sub-AdS scale physics, this supports the idea that sub-AdS scale locality emerges from internal degrees of freedom.

Research Category

String theory and quantum gravity

Primary authors: CAMINITI, Jacqueline (Perimeter Institute for Theoretical Physics); FRIEDMAN-SHAW, Batia (Perimeter Institute for Theoretical Physics); MAY, Alex (University of British Columbia); MYERS, Robert; PAPADOULAKI, Olga

Presenter: CAMINITI, Jacqueline (Perimeter Institute for Theoretical Physics)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **CAMINITI, Jacqueline** on **Thursday, 2 May 2024**

Abstract ID : **34**

Theoretical status of quantum gravity with anisotropic scaling

Content

I'll review the approach to quantum gravity postulating invariance with respect to anisotropic (Lifshitz) scaling in the deep ultraviolet domain. At low energies it leads to scalar-tensor gravity, with a timelike gradient of the scalar field breaking local Lorentz invariance. There are two types of models differing by the dynamics in the scalar sector. The first, projectable, model has been shown to be perturbatively renormalizable and the full renormalization group (RG) flow of its marginal operators has been computed. The flow possesses a number of asymptotically free fixed points with one of them being connected by RG trajectories to the region of the parameter space where the kinetic term of the theory acquires the general relativistic form. The gravitational coupling exhibits non-monotonic behavior along the flow, vanishing both in the ultraviolet and the infrared. I'll mention the challenges facing the model in the infrared domain. The second, non-projectable, model is known to reproduce the phenomenology of general relativity in a certain region of parameters. Full proof of its renormalizability is still missing due to its complicated structure. I'll review recent progress towards constructing such proof.

Research Category

String theory and quantum gravity

Primary author: Dr SIBIRYAKOV, Sergey (McMaster U. & Perimeter Inst.)

Presenter: Dr SIBIRYAKOV, Sergey (McMaster U. & Perimeter Inst.)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Dr SIBIRYAKOV, Sergey** on **Thursday, 2 May 2024**

Abstract ID : **35**

Experimental Entanglement Harvesting: Bridging the gap between theory and experiments

Content

Recent advances in superconducting circuits have provided a method to tune the coupling between superconducting qubits and a waveguide, going from strong coupling to no coupling in nanoseconds [https://arxiv.org/abs/2208.05571]. These advances open the possibility to build an experimental platform to test predictions from relativistic quantum information (RQI). In particular, entanglement harvesting is an established prediction of RQI which has not been verified experimentally, but that could be tested in the aforementioned superconducting platform. To make this possible, we upgrade the UDW particle detector model to include features of the more complex experimental superconducting qubits coupled to waveguides. We will present how these new features affect the amount of entanglement harvested from the waveguide, which will be essential for the entanglement harvesting experiments that are planned for the near future.

Research Category

Particles and fields

Primary authors: Dr DAI, Xi (Institute for Quantum Computing (University of Waterloo)); Prof. LUPASCU, Adrian (Institute for Quantum Computing (University of Waterloo)); MARTIN-MARTINEZ, Eduardo (Institute for Quantum Computing (University of Waterloo) and Perimeter Institute for Theoretical Physics); TEIXIDÓ BONFILL, Adam (Applied Mathematics, University of Waterloo)

Presenter: TEIXIDÓ BONFILL, Adam (Applied Mathematics, University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **TEIXIDÓ BONFILL, Adam** on **Friday, 3 May 2024**

Abstract ID : **36**

Generalized Renyi entropy accumulation theorem and generalized quantum probability estimation

Content

The entropy accumulation theorem, and its subsequent generalized version, is a powerful tool in the security analysis of many device-dependent and device-independent cryptography protocols. However, it has the drawback that the finite-size bounds it yields are not necessarily optimal,and furthermore, it relies on the construction of an affine min-tradeoff function, which in practice can often be challenging to construct optimally. In this work, we address both of these challenges simultaneously by deriving a new entropy-accumulation bound. Informally speaking, we derive a bound of the form
\begin{align}
H^\uparrow_\alpha(S_1^n | E_n)*{\rho*{|\Omega}} \geq n h_{\widehat{\alpha}} - \frac{\alpha}{\alpha-1} \log\frac{1}{\text{Pr}[\Omega]} \end{align}
where $H_\alpha^\uparrow$ is a Renyi entropy with $\alpha > 1$, and $h_{\widehat{\alpha}}$ is a Renyi single round quantity, which qualitatively, it can be described as follows: suppose for simplicity that the protocol simply consists of a sequence of channels producing some secret registers S_j and classical "testing registers" C_j, with the side-information system being held constant throughout. Suppose the S_j (resp.$\tilde{C}_j$) registers are all isomorphic to a single register S (resp.$\tilde{C}$), and suppose that Ω is the event that the frequency distribution on the classical "testing registers" C_1^n lies within some convex set S_Ω. Then we basically show that for $\widehat{\alpha} = 1/(2-\alpha)$, we have:
\begin{align}
h_{\widehat{\alpha}} \geq
\inf_{\mathbf{q} \in S_\Omega} \inf_{\nu\in \Sigma} \left(\frac{1}{\widehat{\alpha}-1}D\left(\mathbf{q}
\middle\Vert \mathbf{{\nu}*{C}}\right)+\sum*{c\in\mathcal{C}}q(c)H_{\widehat{\alpha}}(S|\widetilde{E})*{\nu*{|c}}
\right)
\end{align}
where Σ is the set of all states that could be generated in any single protocol round (and ν_{C} denotes the distribution induced by ν on C), with $\widetilde{E}$ being a purifying register for the input state in that round.\\
Our bound yields significantly better finite-size performance, and can be computed as a convex optimization without any specification of affine min-tradeoff functions. Furthermore, it can be applied directly at the level of Renyi entropies if desired, yielding fully-Renyi security proofs. Our proof techniques are based on elaborating on a connection between entropy accumulation and the framework of quantum probability estimation, and in the process we obtain some new results with respect to the latter framework as well.

Research Category

Quantum information

Primary authors: Mr ARQAND, Amir (Institute for Quantum Computing, University of Waterloo); Mr HAHN, Thomas (Weizmann Institute of Science); Dr TAN, Ernest Y.-Z. (Institute for Quantum

Computing, University of Waterloo)

Presenter: Mr ARQAND, Amir (Institute for Quantum Computing, University of Waterloo)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **ARQAND, Amir** on **Friday, 3 May 2024**

Abstract ID : **37**

Improved de Finetti reductions with applications to optical quantum key distribution

Content

Composite systems consisting of a large number of similar subsystems play an important role in many areas of physics as well as in information theory. Their analysis, however, often relies on the assumption that the subsystems are mutually independent (or only weakly correlated). de Finetti reductions can be used to reduce the general analysis to the more tractable analysis for independent subsystems with a dimensional-dependent penalty.
Our work improves the existing de Finetti reductions by improving the dimensional scaling of the penalty in the presence of symmetries. This is particularly important for optical implementations of quantum information protocols, where the optical setups are described by block-diagonal matrices. Additionally, we develop new techniques to rigorously impose a finite-dimensional photon-number cutoff on infinite-dimensional optical setups, even in adversarial situations. This facilitates the application of de Finetti reductions to optical implementations of adversarial quantum information processing tasks such as quantum key distribution.

Research Category

Quantum information

Primary author: NAHAR, Shlok Ashok (University of Waterloo, IQC)

Co-authors: Prof. LÜTKENHAUS, Norbert (University of Waterloo, IQC); Dr TAN, Ernest (University of Waterloo, IQC); Mr TUPKARY, Devashish (University of Waterloo, IQC); Mr ZHAO, Yuming (University of Waterloo, IQC)

Presenter: NAHAR, Shlok Ashok (University of Waterloo, IQC)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **NAHAR, Shlok Ashok** on **Friday, 3 May 2024**

Abstract ID : **38**

Exact results for surface operators in $\mathcal{N} = 4$ super Yang-Mills

Content

Local operators contain a lot of information. However, there are more general classes of operators one can define. Non-local operators, supported on submanifolds of spacetime, can capture very interesting physical information, often being order parameters for phase transitions. We compute exactly for any value of g^2_{YM} different observables related to $1/2$ BPS surface operators in $4d$ $\mathcal{N} = 4$ super Yang-Mills using supersymmetric localization. We prove that their expectation value, and correlation functions with Chiral Primary Operators and Wilson loops, can be computed by localizing the $\mathcal{N} = 4$ super Yang-Mills on S^4 to a deformed version of $2d$ Yang-Mills on S^2. These correlation functions have a finite number of quantum corrections that can be computed in the $2d$ super Yang-Mills theory, using perturbative techniques in $4d$, and using the supergravity description of the surface operators due to the AdS/CFT correspondence. We show the exact agreement between these three perspectives. Surprisingly, supergravity captures all the quantum corrections of these observables.

Research Category

String theory and quantum gravity

Primary authors: CHOI, Changha (Perimeter Institute); GOMIS, Jaume (Perimeter Institute); IZQUIERDO GARCÍA, Raquel (Perimeter Institute for Theoretical Physics)

Presenter: IZQUIERDO GARCÍA, Raquel (Perimeter Institute for Theoretical Physics)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **IZQUIERDO GARCÍA, Raquel** on **Friday, 3 May 2024**

Abstract ID : **39**

Measuring gravity with spin-spin coupling

Content

Recent developments in electron pair resonance (EPR) have led to ultra precise distance measurements using dipole-dipole coupling in spin-labeled molecules. These precise rulers can be used to probe the geometry of spacetime. Using quantum field theory in curved spacetime, we investigate the effects of gravity on spin-spin coupling. We describe an atom's electron as an excitation of a Dirac field, localized through a Coulomb potential. Expanding to leading order in curvature around the trajectories of two atoms, we calculate an effective Hamiltonian of their interaction with an external electromagnetic field with curvature corrections that can ultimately be measured. This is the first step towards devising an EPR measurement that may be used to probe gravity at the nanometer scale, and eventually see quantum gravitational effects at low energies.

Research Category

Quantum information

Primary authors: Mr PERCHE, T. Rick (Perimeter Institute for Theoretical Physics); SHAH, Ruhi (Perimeter Institute for Theoretical Physics)

Presenter: SHAH, Ruhi (Perimeter Institute for Theoretical Physics)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **SHAH, Ruhi** on **Friday, 3 May 2024**

Abstract ID : **40**

A Beginner's Struggle: How to incorporate EDI into teaching theoretical physics?

Content

For the last decade, the Canadian academic world has become more aware of Equity, Diversity, and Inclusion (EDI) concepts, recognizing systemic barriers and acknowledging underrepresented groups in science. Yet, incorporating EDI into undergraduate-level teaching is still a developing field. In this talk, I will present my struggle as a first-time instructor to combine theoretical physics teaching with EDI and show my students' perspectives.

Research Category

Relativity and gravitation

Primary author: DURGUT, Turkuler

Presenter: DURGUT, Turkuler

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **DURGUT, Turkuler** on **Friday, 3 May 2024**

Abstract ID : **41**

Exploring Rare B-Decay: Analyzing Effective Vertices without Unitarity Condition using Mathematica

Content

The study of rare B-decays provides a unique opportunity to probe the Standard Model and search for signs of new physics. These decays are calculated from effective vertices that appear at a one-loop level. One New Physics scenario is augmenting the Standard Model with additional vector-like quarks, which leads to a non-unitary extended quark mixing matrix. In this work, we analyze effective vertices without unitarity conditions using Mathematica as a computational tool.

Research Category

Particles and fields

Primary author: BIBI, Maryam (Memorial University of Newfoundland)

Presenter: BIBI, Maryam (Memorial University of Newfoundland)

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **BIBI, Maryam** on **Friday, 3 May 2024**

Abstract ID : **42**

Unruh phenomena and thermalization for qudit detectors

Content

We study Unruh phenomena for a qudit detector coupled to a quantized scalar field, comparing its response to that of a standard qubit-based Unruh-DeWitt detector. We show that there are limitations to the utility of the detailed balance condition as an indicator for Unruh thermality of higher-dimensional qudit detector models. This can be traced to the fact that a qudit has multiple possible transition channels between its energy levels, in contrast to the 2-level qubit model. We illustrate these limitations using two types of qutrit detector models based on the spin-1 representations of SU(2) and the non-Hermitian generalization of the Pauli observables (the Heisenberg-Weyl operators).

Research Category

Particles and fields

Primary authors: LIMA, Caroline (Perimeter Institute/ University of Waterloo); MANN, Robert; PATTERSON, Everett (University of Waterloo); TJOA, Erickson (University of Waterloo)

Presenter: LIMA, Caroline (Perimeter Institute/ University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **LIMA, Caroline** on **Saturday, 4 May 2024**

Abstract ID : **43**

Lagrangian Partition Functions Subject to a Fixed Spatial Volume Constraint in the Lovelock Theory

Content

We evaluate here the quantum gravity partition function that counts the dimension of the Hilbert space of a simply connected spatial region of a fixed proper volume in the context of Lovelock gravity, generalizing the results for Einstein gravity. It is found that there are sphere saddle metrics for a partition function at a fixed spatial volume in Lovelock theory. Those stationary points take exactly the same forms as in Einstein gravity. The logarithm of Z corresponding to a zero effective cosmological constant indicates that the Bekenstein–Hawking entropy of the boundary area and that corresponding to a positive effective cosmological constant points to the Wald entropy of the boundary area. We also show the existence of zeroth-order phase transitions between different vacua, a phenomenon distinct from Einstein gravity.

Research Category

Relativity and gravitation

Primary authors: LU, Mengqi; MANN, Robert

Presenter: LU, Mengqi

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **LU, Mengqi** on **Saturday, 4 May 2024**

Abstract ID : **44**

A quantum detector freely falls into a three-dimensional black hole

Content

Alice has embarked on a journey across (2+1)-dimensional spacetime. Suddenly, she starts to freely fall toward a black hole. Fortunately, Alice brought a quantum detector that couples to a quantum field in the (2+1)-dimensional black hole. Can Alice, using this detector, know when she will cross the event horizon? To address this question, we study the response of an Unruh-DeWitt detector that interacts with the Hartle-Hawking vacuum state of a massless scalar field in a Bañados-Teitelboim-Zanelli (BTZ) black hole as the detector freely falls toward and across the event horizon. Contrary to expectations based on the equivalence principle, we find that the response is not a monotonic function of the infalling radius, and Alice could potentially use the quantum detector as an 'early warning system,'enabling her to continue her journey without crossing the event horizon.

Research Category

Quantum information

Primary authors: PRECIADO-RIVAS, Maria Rosa (University of Waterloo); NAEEM, Manar (University of Waterloo); MANN, Robert (University of Waterloo); LOUKO, Jorma (University of Nottingham)

Presenter: PRECIADO-RIVAS, Maria Rosa (University of Waterloo)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **PRECIADO-RIVAS, Maria Rosa** on **Sunday, 5 May 2024**

Abstract ID : **45**

A New Look at Quark Stars

Content

Quark stars —a gravitationally bound quark-gluon plasma —have been hypothesized to be the last gravitationally stable state of matter preceding collapse into a black hole. Originally such stars were thought to necessarily contain a significant component of strange quarks, but recent work has shown that up-down quark matter can be more stable than ordinary nuclei at sufficiently large baryon number beyond the periodic table. I shall describe how such up-down quark stars open up new possibilities for astrophysical searches for such objects as well as new tests of general relativity.

Research Category

Relativity and gravitation

Primary author: MANN, Robert

Presenter: MANN, Robert

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **MANN, Robert** on **Sunday, 5 May 2024**

Abstract ID : **46**

Cauchy-characteristic matching

Content

Two major approaches are used when numerically solving the Einstein field equations. The first one is to use spatial Cauchy slices and treat the system as a standard Cauchy initial value problem. Characteristic evolution serves as the second approach, which evolves spacetime based on null hypersurfaces. The Cauchy formulation is well-suited for strong gravitational fields, yet extending it to the wave zone increases computational expense. Conversely, the Characteristic approach demonstrates efficiency in the wave zone but encounters limitations near binary systems due to the caustics of null surfaces. By combining those two techniques —simulating the inner region with Cauchy evolution and the outer region with characteristic evolution, Cauchy-Characteristic matching (CCM) enables us to take advantage of both methods. In this talk, I present our recent implementation of CCM based on a numerical relativity code SpECTRE. I also discuss how CCM improves the accuracy of Cauchy boundary conditions —a benefit that allows us to evolve less of the wave zone in the Cauchy code without losing precision.

Research Category

Relativity and gravitation

Primary author: MA, Sizheng (Perimeter Institute)

Presenter: MA, Sizheng (Perimeter Institute)

Track Classification: Talk - Contributed Talks

Status: SUBMITTED

Submitted by **MA, Sizheng** on **Monday, 6 May 2024**

Abstract ID : **47**

Non-linearity and chaos in the quantum kicked top

Content

Classical chaos arises from the inherent non-linearity of dynamical systems. However, quantum maps are linear; therefore, the definition of chaos is not straightforward. To address this, we study a quantum system that exhibit chaotic behavior in their classical limits. One such system of interest is the kicked top model, where classical dynamics are governed by Hamilton's equations on phase space, while quantum dynamics are described by the Schr¨odinger equation in Hilbert space. Here, we aim to determine the critical degree of non-linearity (p) necessary for a system to exhibit chaotic behavior. To achieve this, we modify the original Hamiltonian such that a non-integer value of
p is allowed. Our findings reveal two distinct behaviors of the modified kicked top depending on the value of p. Chaos intensifies as p varies within the range of $1 \leq p \leq 2$, whereas it diminishes for $p > 2$, eventually leading to a transition to a purely regular oscillating system as p tends to infinity. This investigation sheds light on the complex relationship between non-linearity and chaos in classical systems, offering valuable insights into their dynamic behavior.

Research Category

Mathematical Physics

Primary authors: ANAND, Amit; GHOSE, Shohini (Wilfrid Laurier University); MANN, Robert

Presenter: ANAND, Amit

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **ANAND, Amit** on **Monday, 6 May 2024**

Abstract ID : **48**

Fractional Skyrmions

Content

We consider Skyrmions which are topologically stable due to the third homotopy group being Z_N. Then N such objects combine (homotopically) to the vacuum configuration. We exploit the relation between Skyrmions and magnetic monopoles to give explicit configurations. We speculate about using these solitons to directly represent quarks.

Research Category

Particles and fields

Primary authors: Prof. PARANJAPE, Manu; SEMENOFF, Gordon; Dr WILLIAMS, Ben (UBC)

Presenter: Prof. PARANJAPE, Manu

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **Prof. PARANJAPE, Manu** on **Wednesday, 8 May 2024**

Abstract ID : **49**

Studying Dark Photon-Photon oscillations in astrophysical environments

Content

Dark matter (DM) comprises of nearly 80% of the mass of the universe, yet its exact nature eludes us. Specifically, the Dark Photon (DP) is a well-motivated candidate for DM, and offers a relatively simple extension to Standard Model (SM) physics. Dark photons act as a portal between SM and DM particles via kinetic mixing, thus oscillating into photons (and vice-versa) while propagating. For our consideration, DP form a part of the dark sector. These DP may be produced in the Sun, and due to the existence of a non-monotonic plasma potential in the Solar chromosphere, can oscillate back resonantly into photons. We study this oscillation phenomenon to calculate how many of such photons we can detect at Earth. Since the energies of these photons (produced via dark sector interactions) may be higher than that of photons produced via SM processes in the chromosphere, a comparison of the fluxes of these two types of photons can also lead to bounds on the dark photon-photon mixing parameter.

Research Category

Cosmology and astrophysics

Primary author: CHUGH, Aditya (University of Toronto)

Co-author: Prof. SCHUTZ, Katelin (McGill University)

Presenter: CHUGH, Aditya (University of Toronto)

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **CHUGH, Aditya** on **Wednesday, 8 May 2024**

Abstract ID : **50**

Classification of Nilpotent and Solvable Lie Algebras of sl(n,C)

Content

Lie algebras are a central object in mathematical physics, with applications ranging from general relativity to supersymmetry. Understanding them can help us better our understanding of the physical world. The classification of solvable lie algebras has been a long-standing unsolved problem. In this talk, I will discuss part of my research in classifying the conjugacy classes for solvable and nilpotent subalgebras of sl(n,C) and give an introduction to lie algebras from an algebraic viewpoint. Particularly, we shall be discussing codimension 1 sub-algebras, and given time look at further results.

Research Category

Mathematical Physics

Primary author: DHAR, Shreya

Co-author: Dr REPKA, Joe (University of Toronto)

Presenter: DHAR, Shreya

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **DHAR, Shreya** on **Wednesday, 8 May 2024**

Abstract ID : **51**

Correlation harvesting between particle detectors in uniform motion

Content

We investigate the correlation harvesting protocol using two Unruh-DeWitt particle detectors moving along four classes of uniformly accelerated trajectories categorized by Letaw: linear, catenary, cusped, and circular motions. For each trajectory, two types of configurations are carried out: one possesses a stationary (time-translation invariant) Wightman function and the other is nonstationary. We find that detectors undergoing linear, catenary, and cusped motions gain fewer correlations in the nonstationary configurations compared to those in stationary configurations. Detectors in circular motion have similar behavior in both configurations. We discuss the relative suppression of correlation harvesting due to high acceleration for each case. Remarkably we find that under certain circumstances detectors in both linear and circular states of motion can harvest genuine (non-communication assisted) entanglement even though they are in causal contact.

Research Category

Particles and fields

Primary authors: BOZANIC, Lana; GALLOCK-YOSHIMURA, Kensuke (University of Waterloo); MANN, Robert; NAEEM, Manar

Presenter: BOZANIC, Lana

Status: SUBMITTED

Submitted by **BOZANIC, Lana** on **Thursday, 9 May 2024**

Abstract ID : **52**

Lorentzian spacetimes in the IKKT model

Content

Under a suitable i-epsilon regularization of the Lorentzian matrix integral, the IKKT model has time dependent semiclassical solutions. I I will describe how the metric and a sensible Feynman propagator can be obtained.

Research Category

String theory and quantum gravity

Primary author: KARCZMAREK, Joanna

Presenter: KARCZMAREK, Joanna

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **KARCZMAREK, Joanna** on **Friday, 10 May 2024**

Abstract ID : **53**

Edge states and their cousins in an open SSH model

Content

The Su-Schrieffer-Heeger model is perhaps the simplest model with edge stages, states that are an essential aspect of materials known as topological insulators. In this talk, I will briefly describe the SSH model and will discuss edge states in a finite SSH chain in isolation and a chain with leads attached to the ends. The effect of the leads on the details of the states and in particular on the energy spectrum will be discussed.

Research Category

Condensed Matter Physics

Primary author: MACKENZIE, Richard

Presenter: MACKENZIE, Richard

Contribution Type: Contributed oral

Comments:

Could be CMP (my preference), math phys or quantum info; please put it in whichever session you prefer!

Status: SUBMITTED

Submitted by **MACKENZIE, Richard** on **Friday, 10 May 2024**

Abstract ID : **54**

Distinguishing Underlying Causal Explanations from Statistical Data

Content

Many times in science our interest does not lie in the correlations between events under study, but instead in their causal connections: it is not enough to merely know that there is a correlation between taking a drug and recovering, because this correlation could be due to a hidden common cause (for example, health awareness). The area of Causal Inference was born as a sub-area of statistics to fill this gap, answering questions about the underlying causal explanations for the observed statistical correlations.

This area was brought to the attention of physicists working in foundations of Quantum Theory after the realization that the famous Bell's Theorem can be seen as a statement about causality. In fact, Bell's theorem poses a challenge to the classical notions of causality, and begs for a modification in the way causality works. This has lead to the development of the area of Quantum Causal Models.

There are, however, questions in classical Causal Inference that remain unanswered, and that could be of interest for understanding causality in the quantum world. Two of those questions are the focus of investigation of this work: the indistinguishability of causal structures under data obtained from passive observations and from interventions.

In general, one can obtain more information about the underlying causal structure of a phenomenon by intervening on the experiment, forcing a variable to take a specific value. For example, if we force a group of people to take a drug and another group to take the placebo, any remaining correlation between taking the drug and recovering must be due to the direct causation effect betweeen these variables. However, sometimes it is impossible or unethical to perform an interventional experiment: we cannot force a group of people to smoke to see if they will develop lung cancer. Therefore, it is important to know how much we can learn about the causal structure when we only have access to passive observations. The first question of this project studies the limitations of this knowledge: we are trying to find out when two causal structures can explain exactly the same set of probability distributions obtained from passive observations, and thus are indistinguishable when we only have access to this type of experiment. In pursuit of this goal, I have compiled all theorems found in literature, as well as proved some new ones, that show that if two causal structures satisfy certain graphical conditions, then they are indistinguishable under passive observations. However, all of the existing theorems are still not enough to provide a necessary and sufficient graphical condition for such indistinguishability.

One could also ask about indistinguishability of causal structures when there is access to interventions: sometimes, even with these more powerful experiments it is impossible to distinguish between two causal structures. This is the second question of interest of this project. As it turns out, we have shown that for this case there is a necessary and sufficient graphical criterion.

Knowing about such indistinguishabilities between causal structures is important to adjudicate between different causal explanations for a set of data. Such a classification can also help us filter which causal structures might present quantum-classical gaps, that is, nonclassical features like the one witnessed by the causal structure related to Bell's theorem.

Research Category

Quantum information

Primary authors: MACIEL ANSANELLI, Marina; SPEKKENS, Robert (Perimeter Institute for Theoretical Physics); Dr WOLFE, Elie (Perimeter Institute)

Presenter: MACIEL ANSANELLI, Marina

Track Classification: Talk - Contributed Talks

Contribution Type: Contributed oral

Status: SUBMITTED

Submitted by **MACIEL ANSANELLI, Marina** on **Friday, 10 May 2024**