Theory Canada 14

Friday, 31 May 2019 - Saturday, 1 June 2019

UBC

Book of Abstracts

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A connection between linearized Gauss–Bonnet gravity and classical electrodynamics

Author: Mark Baker[1]

[1] *Western University*

Corresponding Author: mbaker66@uwo.ca

The oral presentation will consist primarily of a recently published article in International Journal of Modern Physics D entitled "A connection between linearized Gauss–Bonnet gravity and classical electrodynamics", authored by MR Baker and S Kuzmin. In this article, a connection between a well known gravitational model and classical electrodynamics is derived. Given the excitement among physicists regarding the relationship between the fundamental interactions of nature, this should be an interesting talk for all audiences. A more formal abstract from the article regarding technical contents within is given in the next paragraph, however the talk will be less technical than the contents of the article.

Content abstract: A connection between linearized Gauss–Bonnet gravity and classical electrodynamics is found by developing a procedure which can be used to derive completely gauge-invariant models. The procedure involves building the most general Lagrangian for a particular order of derivatives (N) and a rank of tensor potential (M), then solving such that the model is completely gauge-invariant (the Lagrangian density, equation of motion and energy–momentum tensor are all gauge-invariant). In the case of N=1 order of derivatives and M=1 rank of tensor potential, electrodynamics is uniquely derived from the procedure. In the case of N=2 order of derivatives and M=2 rank of symmetric tensor potential, linearized Gauss–Bonnet gravity is uniquely derived from the procedure. The natural outcome of the models for classical electrodynamics and linearized Gauss–Bonnet gravity from a common set of rules provides an interesting connection between two well-explored physical models.

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On the quantum origin of a small positive cosmological constant

Author: Saurya Das[1]

Co-author: Rajat K. Bhaduri [2]

[1] *University of Lethbridge*

[2] *McMaster University*

Corresponding Author: saurya.das@uleth.ca

We show that Dark Matter consisting of ultralight bosons in a Bose-Einstein condensate induces, via its quantum potential, a small positive cosmological constant which matches the observed value. This explains its origin and why the densities of Dark Matter and Dark Energy are approximately equal.

References: S.Das, R. K. Bhaduri, arXiv:1808.10505, arXiv:1812.07647

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Gravitating magnetic monopole via the spontaneous symmetry breaking of pure R^2 gravity

Authors: Ariel Edery[1]; Yu Nakayama[2]

[1] *Bishop's University*

[2] *Rikkyo University*

Corresponding Author: aedery@ubishops.ca

The pure R^2 gravity is equivalent to Einstein gravity with cosmological constant and a massless scalar field and it further possesses the so-called restricted Weyl symmetry which is a symmetry larger than scale symmetry. To incorporate matter, we consider a restricted Weyl invariant action composed of pure R^2 gravity, SU(2) Yang-Mills fields and a non-minimally coupled massless Higgs field (a triplet of scalars). When the restricted Weyl symmetry is spontaneously broken, it is equivalent to an Einstein-Yang-Mills-Higgs (EYMH) action with a cosmological constant and a massive Higgs non-minimally coupled to gravity i.e. via a term $\xi R|\Phi|^2$. When the restricted Weyl symmetry is not spontaneously broken, linearization about Minkowski space-time does not yield gravitons in the original R^2 gravity and hence it does not gravitate. However, we show that in the broken gauge sector of our theory, where the Higgs field acquires a non-zero vacuum expectation value, Minkowski space-time is a viable gravitating background solution. We then obtain numerically gravitating magnetic monopole solutions for non-zero coupling constant $\xi = 1/6$ in three different backgrounds: Minkowski, anti-de Sitter (AdS) and de Sitter (dS), all of which are realized in our restricted Weyl invariant theory.

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Emergence of a Black Hole at the Centre of some Galaxies

Author: Réjean Plamondon[1]

[1] *Polytechnique Montréal*

Corresponding Author: rejean.plamondon@polymtl.ca

Over the last CAP and Theory Canada conferences, we have proposed a conceptual framework to rationalize the use of an erfc potential in a modified Schwarzchild spacetime geometry [1]. Starting from the premise of an interdependence principle interpreted in a Bayesian setting, the linear case of a weak field static symmetric massive object was analyzed to point out how Einstein's equation could be generalized to incorporate a weighting factor that takes into account the probability of presence of a given energy density in its corresponding 4D curved space-time manifold. Using the Central Limit Theorem to model globally the very slow process of star formation and mathematically express the corresponding density, the new framework provides a rationale for the emergence of a weighted Newton's law of gravitation. Although this new metric provides a consistent set of predictions and explanations regarding some open problems in the solar system [2], the residual static offset incorporated in the erfc potential can also be investigated dynamically. This has led to an axisymmetric interpretation of the general metric, the resulting geometry describing any massive body and its curved space-time, subject to a rotation and an expansion. One key feature of this modelling methodology is that it can be applied at different scales and used, for example, to model galaxies formation. In this conference, we show how this can be done and under which condition a black hole will be created at the centre of a galaxy.
[1]Plamondon, R., (2018), General Relativity: an erfc metric, Results in Physics, 9, 456-462.
[2]Plamondon, R., (2017) Solar System Anomalies: Revisiting Hubble's law, Physics Essays, 30(4), 403-411.

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Quantum tasks in holography

Author: Alex May[1]

[1] *University of British Columbia*

Corresponding Author: alexmay28@gmail.com

We consider an operational restatement of the holographic principle, which we call the principle of asymptotic quantum tasks. Asymptotic quantum tasks are quantum information processing tasks with inputs given and outputs required on points at the boundary of a spacetime. The principle of asymptotic quantum tasks states that tasks which are possible using the bulk dynamics should coincide with tasks that are possible using the boundary. We extract consequences of this principle for holography in the context of asymptotically AdS spacetimes. Among other results we find a novel connection between bulk causal structure and the phase transition in the boundary mutual information. Further, we note a connection between holography and quantum cryptography, where the problem of completing asymptotic quantum tasks has been studied earlier. We study the cryptographic and AdS/CFT approaches to completing asymptotic quantum tasks and consider the efficiency with which they replace bulk classical geometry with boundary entanglement.

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New Gravitational Probes of Dark Matter

Author: Evan McDonough[1]

[1] *Brown University*

Corresponding Author: evan_mcdonough@brown.edu

Despite decades of searching, the strongest evidence for dark matter remains gravitational. It is thus worthwhile to consider the extent to which gravitational probes can discriminate between models of cold dark matter. With this in mind, in this talk I will discuss the early universe origins and late universe observables of "superfluid" dark matter. Despite having only gravitational couplings to the standard model, this scenario provides a suite of complimentary observable signatures. A concrete model realization is SU(2) gauge theory with two massless quarks: At finite particle number density and low temperature, the dark quarks condense and form a superfluid, the collective excitations of which behave as cold dark matter. The associated early universe production of gravitational waves can be probed by the CMB, while halo substructure in the form of vortices and disk-like solitons leaves a characteristic imprint on strong gravitational lensing. Talk based on arXiv:1801.07255 and arXiv:1901.03694.

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Nuclear reactions important for astrophysics from ab initio theory

Author: Petr Navratil[1]

[1] *TRIUMF*

Corresponding Author: navratil@triumf.ca

In recent years, significant progress has been made in ab initio nuclear structure and dynamics calculations based on input from QCD employing Hamiltonians constructed within chiral effective field theory. One of the newly developed approaches is the No-Core Shell Model with Continuum (NCSMC) [1,2], capable of describing both bound and unbound states in light nuclei in a unified

way. I will discuss NCSMC calculations of 3H(d,n)4He and 3He(d,p)4He fusion [3]. These transfer reactions are relevant for primordial nucleosynthesis and 3H(d,n)4He in particular is being explored as a possible future energy source. I will also present latest NCSMC calculations of weakly bound states and resonances of exotic halo nuclei 15C and 8B and discuss the 14C(n,γ)15C and 7Be(p,γ)8B capture reactions.The latter reaction in particular plays a role in Solar nucleosynthesis and Solar neutrino physics and has been subject of numerous experimental investigations including ongoing measurements at TRIUMF.

[1] S. Baroni, P. Navrátil, and S. Quaglioni, Phys. Rev. Lett. 110, 022505 (2013); Phys. Rev. C 87, 034326 (2013).
[2] P. Navrátil, S. Quaglioni, G. Hupin, C. Romero-Redondo, A. Calci, Physica Scripta 91, 053002 (2016).
[3] G. Hupin, S. Quaglioni, and P. Navrátil, Nature Communications (2019) 10:351; https://doi.org/10.1038/s41467-018-08052-6

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On Negative Mass

Author: Manu Paranjape[1]

Co-authors: Antoine Savard [1]; Matthew Johnson [2]; Natalia Tapia-Arellano [3]

[1] *Université de Montréal*

[2] *Perimeter Institute/York University*

[3] *Universidad de Santiago*

Corresponding Author: paranj@lps.umontreal.ca

We review the notion of negative mass in general relativity. We show the existence of stable, thin wall bubbles in a de Sitter background. The outside metric is the exact negative mass Schwarzschild-de Sitter metric, while inside, it is a smooth non-singular metric, with a corresponding energy-momentum tensor that satisfies the dominant energy condition.

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Fine-tuning of the cosmological constant is not needed

Author: Qingdi Wang[1]

Co-author: William Unruh [1]

[1] *University of British Columbia*

Corresponding Author: qingdi@phas.ubc.ca

We show that the usual formulation of the cosmological constant problem breaks down when the effect of the huge fluctuations in quantum vacuum stress-energy tensor is considered. Even if one has successfully fine-tuned the bare cosmological constant in the Einstein equations to the required accuracy of 10^{-122}, the fluctuations would still cause the universe to explode. The fluctuations would also produce a large positive contribution to the averaged macroscopic spatial curvature of the Universe. In order to cancel this contribution, the bare cosmological constant has to take large negative values, and if it is large enough, the spacetime structure would be similar to the cyclic model of the universe in the sense that at small scales every point in space is a "micro-cyclic universe" which is following an eternal series of oscillations between expansions and contractions. Moreover, due to the weak parametric resonance effect caused by the fluctuations of the quantum vacuum stress-energy, the size of each "micro-universe" increases a tiny bit at a slowly accelerating rate during each micro-cycle of oscillation. Accumulation of this effect over the cosmological scale gives an

accelerating universe. More importantly, the extreme fine-tuning of the cosmological constant is not needed. This resolves the cosmological constant problem and suggests that it is the quantum vacuum fluctuations serve as the dark energy which is accelerating the expansion of our Universe.

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Investigation of the A=7 systems within the No-Core Shell Model with Continuum

Author: Matteo Vorabbi[1]

Co-authors: Guillaume Hupin [2]; Petr Navratil [1]; Sofia Quaglioni [3]

[1] *TRIUMF*

[2] *CEA*

[3] *LLNL*

One of the recently developed approaches capable of describing both bound and scattering states in light nuclei simultaneously is the No-Core Shell Model with Continuum (NCSMC).
This technique represents a state-of-the-art *ab initio* approach and combines the No-Core Shell Model (NCSM) description of short-range correlations with the clustering
and scattering properties of the Resonating Group Method. Recent NCSMC calculations of ^{7}Be and ^{7}Li will be presented. The properties of these nuclei were investigated
by analyzing the continuum of all the binary mass partitions involved in the creation of these systems, using chiral interactions as the only input.
Our calculations reproduce all the experimentally known states in the correct order and predict new possible resonances with negative and positive parity. A positive-parity S wave resonance is found analyzing the continuum of p + ^{6}He at a very low energy above the threshold, which produces a very pronounced peak in the astrophysical S factor of
the ^{6}He(p,γ) ^{7}Li radiative capture. Possible implications for astrophysics have still to be investigated.

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Custodial symmetry and the Higgs sector

Author: Heather Logan[1]

[1] *Carleton University*

Corresponding Author: logan@physics.carleton.ca

Custodial symmetry is an accidental symmetry of the Standard Model Higgs sector that underlies the well-tested relationship between the W and Z boson masses and their gauge couplings. In extended Higgs sectors this symmetry can be violated, with potentially fatal experimental consequences. I'll describe the effects of this violation in the Georgi-Machacek model, which serves as a prototype for models of electroweak symmetry breaking from "exotic" Higgs fields larger than electroweak doublets.

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Relativistic Generalized Uncertainty Principle and minimum length

Author: Vasil Todorinov[1]

Co-authors: Pasquale Bosso [2]; Saurya Das [3]

[1] *University of Lenthbridge*

[2] *Universidad de Guanajuato*

[3] *University of Lethbridge*

Corresponding Author: v.todorinov@uleth.ca

Theories of Quantum Gravity predict a minimum measurable length and acorresponding modification of the Heisenberg Uncertainty Principle to theso-called Generalized Uncertainty Principle (GUP). However, this modification isnon-relativistic, making it unclear whether the minimum length is Lorentzinvariant. We formulate aRelativisticGeneralized Uncertainty Principle, resultingin aLorentz invariantminimum measurable length. We show that this implies thatspacetime coordinates are non-commutative and that spacetime itself is fuzzy atthe Planck scale. We examine potential experimental signatures of our result andnote that this is the first step in formulating quantum field theories with aminimum length.

Reference :Relativistic Generalized Uncertainty Principle,V. Todorinov, P. Bosso, S. Das, Ann. Phys.405, 92-100 (2019)[arXiv :1810.11761].

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Sending quantum information through a quantum field

Author: Petar Simidzija[1]

[1] *University of Waterloo*

Corresponding Author: psimidzi@uwaterloo.ca

The theory of classical information transmission through quantum fields has been extensively studied in previous literature. On the other hand, while there have been successful experiments transmitting quantum information over hundreds of kilometres, our understanding of the fundamental mechanism by which quantum information is broadcast through a quantum field has been limited. In this talk we will analyze the most elementary setup which allows an emitter Alice to transmit a qubit of information to a receiver Bob via a quantum field, thus providing insight into the information theoretic aspects of fundamental light-matter interactions.

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From alpha clustering to homogeneous nucleonic matter

Author: Alex Gezerlis[1]

[1] *University of Guelph*

Corresponding Author: gezerlis@uoguelph.ca

Over the last few decades the study of nuclei and neutron-rich matter from first principles has entered a new era. This has partly been driven by the development of novel interactions between two or three nucleons. In an attempt to produce a systematic expansion, several groups have produced Effective Field Theory (EFT) interactions, whether of finite range (chiral EFT) or zero range (pionless EFT). Pionless EFT has been quite successful in studies of cold-atomic Fermi gases. In this talk, I will present recent Quantum Monte Carlo calculations of 8-particle systems and discuss their impact on

8Be and the physics of alpha clustering. I will also discuss recent work on trying to connect ab initio theory with simpler qualitative pictures. Specifically, I will address the first ever systematic non-perturbative calculations of the single-particle excitation spectrum in strongly interacting neutron matter. In addition to impacting light and neutron-rich nuclei, this work and this talk also touch upon the physics of ultracold gases and of neutron stars.

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Quantum Chaos and Effective Field Theory

Author: Felix Haehl[1]

[1] *UBC Vancouver*

Corresponding Author: felix@phas.ubc.ca

I discuss the physics of quantum chaos in conformal field theories with a large number of degrees of freedom. We focus on two-dimensional theories, but also comment on the one-dimensional case (related to the SYK model) and higher-dimensional generalizations. A novel formulation using effective field theory methods at large central charge provides a useful perspective and computational framework. For instance, we can compute out-of-time-order correlators diagnosing quantum chaos, as well as certain more fine-grained higher-point generalizations.

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Thermodynamic Parameters of a Boulware-Deser Black Hole from Fluid-Gravity Correspondence

Authors: Dylan Sutherland[1]; Saurya Das[1]; Subramaniam Shankaranarayanan[2]

[1] *University of Lethbridge*

[2] *Indian Institute of Technology Bombay*

Corresponding Author: dylan.sutherland@uleth.ca

As a solution to the equations of Lanczos-Lovelock Gravity (a natural extension of General Relativity for higher dimensions), the Boulware-Deser black hole presents as an interesting system. Indeed, given the universal success had to this point by prospective theories of quantum gravity in modelling the Schwartzchild black hole, the next challenge for such theories may be found in correctly modelling the Boulware-Deser black hole. To this end, the thermodynamic parameters of the Boulware-Deser black hole have been found and are shown here to be nearly identical to the corresponding parameters of a Schwartzchild black hole, each with an additive correction term. The culminating purpose of this work is to continue within a fluid-gravity model in order to calculate the bulk viscosity of the horizon fluid of the Boulware-Deser black hole.

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Near-extremal Black Holes and Jackiw-Teitelboim Gravity

Authors: Ashish Shukla[1]; Pranjal Nayak[2]; Ronak Soni[3]; Sandip Trivedi[3]; V. Vishal[3]

[1] *University of Victoria*

[2] *University of Kentucky*

[3] *Tata Institute of Fundamental Research*

Corresponding Author: ashish@uvic.ca

I will talk about the dynamics of near-extremal Reissner-Nordstrom black holes in four-dimensional asymptotically AdS space. Working in the spherically symmetric approximation, I will present results about the thermodynamics and the response of the system to a probe scalar field. I will present evidence that the dynamics in the low energy limit is very well captured by the two-dimensional Jackiw-Teitelboim (JT) theory of gravity. The reason behind the efficacy of JT gravity for near-extremal black holes can be understood based on symmetry principles. The talk is based on the paper arXiv:1802.09547.

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High-frequency gravitational-wave astronomy

Authors: Denis Martynov[1]; Huan Yang[2]

Co-author: Haixing Miao [1]

[1] *University of Birmingham*

[2] *Uniersity of Guelph*

Corresponding Author: huan.yang07@gmail.com

In this talk I will discuss some recent development towards detecting gravitational waves in the kilo Hertz band. On the detector side, we propose a new interferometer design that significantly improves detector sensitivity above 1 kHz. On the science front, we identify several key questions that can be answered by combining high-frequency gravitational-wave detection and electromagnetic observation, including binary neutron star post-merger process, tests of modified gravity theories and understanding star disruption in black hole/neutron star mergers.

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The Status of the Nuclear Shell Model

Author: Ragnar Stroberg[1]

[1] *University of Washington*

Corresponding Author: stroberg@uw.edu

For 70 years, the nuclear shell model has provided the conceptual and computational framework for most of low-energy nuclear structure. In particular, since the 1980s large-scale shell model calculations have achieved remarkable success in reproducing and (sometimes) predicting experimental data. However, these calculations are inevitably phenomenological in nature, with parameters fit to the data they hope to describe. Efforts to derive shell model parameters based on the underlying interaction between nucleons date back to the 1960s, but have been beset by persistent difficulties. Such a derivation is desirable both for a more reliable extrapolation beyond the range of existing data, and for applications to searches for physics beyond the standard model, where parameters cannot be fixed by experiment.

In the past decade, the formulation of the nuclear force in an effective field theory framework and many-body techniques based on renormalization group ideas have combined with increased computational power to enable substantial progress on this decades-old problem. I will summarize recent advances which allow for a parameter-free connection of the shell model to the underlying interaction, paving the way for robust predictions with quantified theoretical uncertainties.

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Interference Effects in Higgs Decays

Author: Daniel Stolarski[1]

[1] *Carleton University*

Corresponding Author: stolar@physics.carleton.ca

I will describe how measurements of interference effects in Higgs decays at the LHC can lead to novel measurements of parameters that are difficult to constrain in other ways such as the sign of the ratio of the Higgs coupling to the W relative to the Z boson.

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The SJ Vacuum in de Sitter Spacetime

Authors: Nomaan X[1]; Sumati Surya[1]; Yasaman Yazdi[2]

[1] *Raman Research Institute*

[2] *University of Alberta*

Corresponding Author: kouchekz@ualberta.ca

I present results from a study of the Sorkin-Johnston (SJ) vacuum in de Sitter spacetime for a free scalar field theory. We find evidence for a new vacuum state in de Sitter spacetime which is de Sitter invariant in 4d. Using a causal set discretisation of a slab of 2d and 4d de Sitter spacetime, we find the causal set SJ vacuum for a range of masses $m \geq 0$ of the free scalar field. While our simulations are limited to a finite volume slab of global de Sitter spacetime, they show good convergence as the volume is increased. We find that the 4d causal set SJ vacuum, while de Sitter invariant, shows a significant departure from the continuum Mottola-Allen α-vacua. Moreover, the causal set SJ vacuum is well-defined for all masses, including the minimally coupled massless $m = 0$ case which is ill-defined in other de Sitter invariant vacuum state definitions. I will also briefly discuss how our results differ from earlier work on the continuum de Sitter SJ vacuum.

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Reduced Quantum Dynamics from Observables

Authors: Ashmeet Singh[1]; Jason Pollack[2]; Oleg Kabernik[2]

[1] *California Institute of Technology*

[2] *University of British Columbia*

Corresponding Author: jpollack@phas.ubc.ca

When they can be defined, reduced density matrices provide a powerful tool for determining the entanglement structure, approximate dynamics, and potential classical behavior of a portion of a quantum system. It is straightforward to generate a reduced density matrix by tracing out a portion of the full density matrix of a (pure or mixed) quantum state of the full system, but many natural reductions cannot be arrived at by this method. We investigate reductions which are specified by a discrete set of observables which do not span the full algebra of observables on the Hilbert space. Such a set need not be mutually commuting or even a subalgebra. For example, the set might represent a discrete set of measurements which could be classically implemented by an experimenter. We provide an algorithm for passing from a full state and a set of observables to a reduced density

matrix which preserves the expectation values of observables in the set. Formally, we embed the space spanned by the observables in the set into the space of linear operators on a different, auxiliary Hilbert space in such a way that the projection of the original state onto the space is itself a bona fide reduced density matrix. This embedding is nontrivial and the methods we use to accomplish it are novel. One special case of the reduction procedure yields an explicit construction of the block decomposition of a Hilbert space with respect to a von Neumann algebra. Another special case classifies collective observables into irreducible representations of the permutation group. We adapt the methods of the decoherence program to investigate under what circumstances coarse-grained states can be described as classical. Our results have relevance for quantum error correction, bulk reconstruction in holography, and quantum gravity.

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Two-major shell-model effective Hamiltonian from in-medium similarity renormalization group approach

Author: Takayuki Miyagi[1]

Co-authors: Jason Holt [1]; Noritaka Shimizu [2]; Ragnar Stroberg [3]

[1] *TRIUMF*

[2] *CNS, U Tokyo*

[3] *University of Washington*

Corresponding Author: tmiyagi@triumf.ca

In the past decade, many efforts have been made in the ab initio calculations. The capability of ab initio many-body calculations has reached to mass number 100 region. The calculation methods which are available for the medium-mass region such as coupled-cluster method, self-consistent Green's function method, and in-medium similarity renormalization group (IM-SRG) are typically limited the applications to closed-shell nuclei. The combination of the IM-SRG and conventional shell-model calculation is one of the powerful tools to access the open-shell systems. In this framework, the effective Hamiltonian for the shell-model calculations is obtained through the IM-SRG so that the valence-space Hamiltonian is decoupled with the core and outside of the valence space. So far this framework was mainly applied for the single major-shell valence space problem. However, we obviously need the two (or multi) major-shell effective Hamiltonian to investigate the unnatural parity states, excitation spectra for doubly magic nuclei (16O, 40Ca, …), and exotic region such as the island of inversion. In this talk, we will present how to calculate the two-major shell-model effective Hamiltonian in the IM-SRG framework and show the numerical results with them.

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Quantum Material Simulation with D-Wave Processors

Author: Mohammad Amin[1]

[1] *D-Wave Systems Inc.*

Corresponding Author: amin@dwavesys.com

One of the most natural and also probably most important applications of quantum computation is simulation of other quantum systems. Qubits are particularly suitable for simulating spin-1/2 particles in magnetic materials. In this presentation, after a brief introduction to D-Wave quantum processors, I provide examples in which D-Wave qubits were used for simulation of quantum magnetic systems with different lattice structures. I show experimental evidence of spin glass phase transition in 3D lattices [Science 361, 162 (2018)] and Kosterlitz-Thouless (KT) phase transition in 2D lattices [Nature 560, 7719 (2018)]. The latter is specially interesting because the rotational symmetry,

essential for KT physics, appears due to an interplay between frustration and quantum mechanics in a transverse field Ising Hamiltonian.

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An index for interacting topological phases

Author: Sven Bachmann[1]

Co-authors: Alex Bols [2]; Martin Fraas [3]; Wojciech De Roeck [2]

[1] *University of British Columbia*

[2] *KU Leuven*

[3] *Virginia Tech*

Corresponding Author: sbach@math.ubc.ca

I will discuss an index associated to a local unitary and a projection in the setting of many-body interacting particles on a lattice. Its values are in general rational, being integer multiples of the inverse of the rank of the projection. In the appropriate setting, the index is the Hall conductance.

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An Introduction to Knot Theory from String Theory

Author: Keshav Dasgupta[1]

Co-authors: Radu Tatar [2]; Ramadevi Pichai [3]; Veronica Errasti-Diez [4]

[1] *McGill University*

[2] *University of Liverpool*

[3] *Indian Institute of Technology, Mumbai*

[4] *DESY*

Corresponding Author: dasgupta.keshav8@gmail.com

In this talk I'll summarize some of the recent developments in both computing and understanding knot polynomials using certain brane constructions from string theory. The talk will be pedagogical and accessible to physicists with minimal knowledge of string theory.

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Higher-Curvature Gravity, Black Holes, and Holography

Author: Robie Hennigar[1]

[1] *Memorial University of Newfoundland*

Quantum gravitational effects are expected to produce higher-curvature modifications to general relativity, but the complete structure of these modifications is unknown. Nonetheless, the study of generic higher-curvature gravities has proven useful, providing valuable insights into the nature of black hole thermodynamics and helping to uncover universal properties for field theories

via AdS/CFT. In this talk I will introduce a class of higher-curvature theories –generalized quasi-topological gravities –and discuss their applications as useful higher-curvature toy models. I will discuss the properties of these theories, their black hole solutions, and some applications in context of squashed-sphere holography.

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The Majorana-Hubbard Model

Author: Ian Affleck[1]

Co-authors: Armin Rahmani [2]; Dmitry Pikulin [3]; Kyle Wamer [1]; Marcel Franz [1]; Tarun Tummuru [1]; Xiaoyu Zhu [4]

[1] *University of British Columbia*

[2] *Western Washington University*

[3] *Microsoft Station Q*

[4] *Xi'an Jiaotong University*

Corresponding Author: iaffleck@phas.ubc.ca

A superconductor in a magnetic field in proximity with a topological insulator is predicted to have a Majorana mode (corresponding to a Hermitian fermion operator) at the centre of each vortex core. The low energy Hamiltonian for these fermion operators has both hopping terms and interaction terms. By tuning the chemical potential in the topological insulator it is possible to set the hopping terms to zero so that the dimensionless interaction strength becomes infinite. This motivate solving for the complete phase diagram of the model as a function of interaction strength. I will discuss results on this model in both 1 and 2 dimensions based on a combination of mean field theory, quantum field theory and Density Matrix Renormalization Group techniques.

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Forging the Universe's gold

Author: Daniel Siegel[1]

[1] *Perimeter Institute for Theoretical Physics & University of Guelph*

Corresponding Author: dsiegel@perimeterinstitute.ca

Gravitational-wave observatories are currently revolutionizing astrophysics and astronomy. Detections of neutron star mergers trigger follow-up campaigns of unprecedented scope by astronomers and particle (astro)physicists worldwide. In this talk, I will attempt to provide an overview of some exciting recent results at the interface of high-energy astrophysics, strong gravity, and nuclear physics. In particular, I will focus on what one can learn from neutron star mergers and other astrophysical phenomena related to compact objects in terms of cosmic nucleosynthesis. To celebrate the 150th anniversary of the periodic table, I will show how recent theoretical results in combination with observations of compact binary mergers overthrow our understanding of how the Universe creates the heavy elements. I will highlight implications for high-energy astrophysics, nuclear physics, and cosmology.

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DTP/WITP P R Wallace Thesis Prize Award Winners

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Abstract Test

Author: David Morrissey[1]

[1] *TRIUMF*

Corresponding Author: dmorri@triumf.ca

Abstracts are great!