Theory Canada 8
Bishop's University, Sherbrooke
23-26 May 2013

ABSTRACTS OF ORAL CONTRIBUTIONS

- **Macroscopic quantum spin tunnelling with two interacting spins**
  Solomon Akaraka Owerre (Université de Montréal)

We study the simple Hamiltonian, $H = -K(S_{1z}^2 + S_{2z}^2) \pm \lambda \vec{S}_1 \cdot \vec{S}_2$, of two, large, coupled spins which are taken equal of total spin s. The first term corresponds to an external potential which tends to align them along an easy axis. The second term corresponds to an interaction, the standard exchange coupling, which we will assume to be a small perturbation. The $+$ sign is anti-ferromagnetic coupling while the $-$ sign is ferromagnetic. The exact ground state of this simple Hamiltonian is not known for an antiferromagnetic coupling. In the absence of the exchange interaction, the ground state is four fold degenerate, corresponding to the states where the individual spins are in their highest weight or lowest weight states. The four states are labelled as $|\uparrow,\uparrow\rangle, |\downarrow,\downarrow\rangle, |\uparrow,\downarrow\rangle, |\downarrow,\uparrow\rangle$, in obvious notation. The first two remain exact eigenstates of the full Hamiltonian, which is trivially verified. However, we show the that the two states $|\uparrow,\downarrow\rangle, |\downarrow,\uparrow\rangle$ organize themselves into the combinations $|\pm\rangle = \frac{1}{\sqrt{2}}(|\uparrow,\downarrow\rangle \pm |\downarrow\uparrow\rangle)$, up to perturbative corrections. For a ferromagnetic coupling, the two states $|\uparrow,\uparrow\rangle, |\downarrow,\downarrow\rangle$ are the exact, doubly degenerate, ground states while the states $|+\rangle$ is the first excited state and the state $|-\rangle$ is the second excited state. For an anti-ferromagnetic coupling the states $|\uparrow,\uparrow\rangle, |\downarrow,\downarrow\rangle$ remain exact, degenerate, eigenstates, however they are now the second and third excited states. In this case, the ground state is non-degenerate, and we find the interesting result that for integer spins the ground state is $|+\rangle$, and the first excited state is the anti-symmetric combination $|-\rangle$ while for half odd integer spin, these roles are exactly reversed. The energy splitting however, is proportional to λ^{2s}, as expected by perturbation theory to the $2s^{\text{th}}$ order. We obtain these results through the spin coherent state path integral.

- **Searching for new interactions in the LHCb era**
  Bhubanjyoti Bhattacharya (Université de Montréal)

I will present a brief theoretical discussion of some B meson decay channels accessible to the LHCb experiment where there are prospects of observing interactions beyond the standard model.

- **Alternatives to cosmological inflation**
  Robert Brandenberger (McGill University)

From the point of view of phenomenology, inflationary cosmology has been very successful. However, conceptual problems remain in light of which it is important to search for alternatives. I will discuss two alternative paradigms for cosmological structure formation: string gas cosmology and that matter bounce.

- **Walking the Planck with a string-inflated lifevest**
  Cliff Burgess (McMaster University/Perimeter Institute)

  This talk reviews the motivation for thinking about string inflation instead of simple models, provides a preliminary assessment of the Planck satellite's scorecard for string-inflationary models, and draws conclusions about what should be expected from the upcoming improved sensitivity to primordial gravitational waves.

- **Mott p-n junctions in layered materials**
  Maxime Charlebois (Université de Sherbrooke)

  Correlated electron heterostructure became a possible alternative when thin film deposition techniques achieved structures with a sharp interface transition [1]. We study here the electronic reconstruction of doped Mott insulator p-n junctions based on a Cluster Dynamical Mean Field Theory (CDMFT) calculation of the Hubbard model in the limit where electrostatic energy dominates over the kinetic energy associated with transport across layers. The grand potential of individual layers is first computed within CDMFT and then the electrostatic potential energy is taken into account in the Hartree approximation. The charge reconstruction in an ensemble of stacked planes of different nature can lead to a distribution of electron charge [2], density of states, and optical properties that are unique to doped-Mott insulators.
  [1] J. Mannhart, D. G. Schlom, Science 327, 1607 (2010)
  [2] T. Oka, N. Nagaosa, PRL 95, 266403 (2005)

- **Mass spectrum of heavy quarkonium hybrids**
  Wei Chen (University of Saskatchewan)

  We have extended the calculation of the correlation functions of heavy quarkonium hybrid operators with various J^{PC} quantum numbers to include QCD condensates up to dimension six. In contrast to previous analyses which were unable to optimize the QCD sum-rules for certain J^{PC}, recent work has shown that inclusion of dimension six condensates stabilizes the hybrid sum rules and permits reliable mass predictions. In this work we have investigated the effects of the dimension six condensates on remaining channels. After performing the QCD sum rule analysis, we update the mass spectrum of charmonium and bottomonium hybrid states with exotic and non-exotic quantum numbers. We identify that the negative-parity states with $J^{PC} = (0, 1, 2)^{-+}, 1^{--}$ form the lightest hybrid supermultiplet while the other four positive-parity states with $J^{PC} = 0^{+-}, 1^{+-}, 1^{++}, 0^{++}$ belong to a heavier hybrid supermultiplet, confirming the supermultiplet structure found in other approaches. The hybrid with $J^{PC} = 0^{--}$ has a much higher mass in our spectrum which may suggest a different excitation of the gluonic field from the other channels. In agreement with previous results, we find that the $J^{PC} = 1^{++}$ charmonium hybrid is substantially heavier than the $X(3872)$, which seems to preclude a pure charmonium hybrid interpretation for this state.

- **Superfluidity in low dimensional quantum fluids**
  Adrian Del Maestro (University of Vermont)

  Superfluidity or dissipation-free flow, is rooted in quantum mechanics with the wave function of the entire fluid being described by an emergent global macroscopic phase. This breaking of gauge symmetry can have dramatic consequences for quantum liquids at temperatures below the superfluid transition, where flow is well established through extremely narrow constrictions, impenetrable to a normal liquid. To understand how the enhancement of both thermal and quantum fluctuations affects superfluidity in the low dimensional constrictions, we have performed quantum Monte Carlo simulations measuring the superfluid response of helium-4 to the linear and rotational motion of the walls of a confining nanopore. Within the pores, the portion of the normal liquid dragged along with the boundaries is dependent on the type of motion and the resulting anisotropic superfluid density exhibits plateaus at low temperature. The origin of this saturation, which is not observed in bulk quantum fluids, is uncovered by computing the spatial distribution of superfluidity, with only the core of the nanopore exhibiting any evidence of phase coherence. We find that the superfluid core displays scaling behavior consistent with Luttinger liquid theory, providing an experimental test for the emergence of a one dimensional quantum liquid.

- **Critical phenomena in higher dimensional Lovelock gravity**
  Nils Deppe (University of Winnipeg)

  Higher dimensional theories such as string theory are motivation to explore the possibility of higher curvature terms in the action. It is expected that if these are necessary, then their contributions are only visible at small length scales. These terms make the equations of motion more complicated, making numerical simulation more difficult, even in spherical symmetry. Results for Einstein-Gauss-Bonnet gravity will be presented for 5 and 6 dimensions, with preliminary results for higher dimensions.

- **Beta-ensembles of random matrices: dualities, perturbations, and phase transitions**
  Patrick Desrosiers (Talca University, Chile and Université Laval)

  Random matrices have been applied to a wide variety of topics in theoretical and mathematical physics: quantum chaos, topological string theory, low energy QCD, topological insulators, etc. In the last two decades, general matrix models unifying different symmetry classes of random matrices have been developed; they are called the beta-ensembles. In this talk, I will briefly introduce these ensembles, relate them to remarkable special functions in many variables (such as Jack polynomials), and review recent advances. The presentation will focus on matrix models that are perturbed by an external field (nonrandom matrix). By using duality properties, I will show that in the limit where the size of the matrices tends to infinity, the variation of the strength of the perturbation can modify drastically the statistical distribution of the eigenvalues.

- **Bootstraps and extraordinary invariants in BRST cohomology**
  John Dixon (University of Toronto)

  BRST Cohomology of free massless theories gives rise to 'Extraordinary Invariants'. So free theories 'know about' their possible interacting versions, in a way that is a kind of 'soft bootstrap'. Free gauge theory bootstraps to Yang-Mills. For SUSY the free theory bootstraps to the SSM, and also to related Infinite Towers of higher spin Leptons, Quarks and Gauge/Higgs particles. This implies a natural mechanism for spontaneous gauge symmetry breaking accompanied by a very special non-spontaneous and explicit SUSY breaking. However, the SUSY breaking is certainly afflicted with terrible troubles such as Tachyons and Ghosts. Whether these are solvable remains to be seen, but now the full action (for Leptons and Quarks) is available for inspection.

- **Entanglement entropy of gauge fields**
  William Donnelly (University of Waterloo)

  It has been suggested that the entropy of black holes and other causal horizons is at least partly (and perhaps entirely) due to entanglement of the vacuum. For scalar and spinor fields, the black hole entropy at one loop can be interpreted as a sum of entanglement entropy and a term related to the Wald entropy. For gauge fields, a similar interpretation is possible only at the expense of adopting a gauge-variant expression for the Wald entropy, whose value is divergent and negative. We show that in two dimensions, when the topological sector is treated properly, the negative contribution disappears and is replaced by the positive entropy of the edge states. We comment on the generalization of these results to higher dimensions.

- **Kitaev's Z_d-codes threshold estimates**
  Guillaume Duclos-Cianci (Université de Sherbrooke)

  We introduce and study the quantum error correction threshold of Kitaev's toric code over the group Z_d subject to a generalized bit-flip noise. This problem requires novel decoding techniques, and for this purpose we generalize the renormalization group method we previously introduced for Z_2 topological codes. Our numerical results show that the threshold value increases as a function of d. Moreover, its behaviour is in very good agreement with a scaling predicted by the hashing bound.

- **Scattering theory calculations of Casimir energies**
  Noah Graham (Middlebury College)

  At short distance scales, quantum-mechanical fluctuations of charges and fields give rise to Casimir forces, which play an important role both in fundamental physics and in applications to micro-electromechanical devices. Recent advances in experimental technology have motivated a wide range of efforts to extend Casimir's original calculation of the force between uncharged parallel conducting plates to a variety of other situations. I will describe a set of techniques for calculating these forces based on scattering theory, which is applicable to a wide range of geometries and materials. In this approach, the Casimir interaction energy for a collection of objects can be expressed in terms of the scattering T-matrices for each object individually, combined with universal translation matrices describing the objects' relative positions and orientations. These translation matrices are derived from an expansion of the free Green's function in an appropriate coordinate system, independent of the details of the objects themselves. This method proves particularly valuable for geometries involving high curvature, such as edges and tips. I will describe this approach in general terms, give results from problems to which it has been applied successfully, and summarize new developments in scattering theory that have been motivated by these calculations.

- **Where and when can a qubit be?**
  Patrick Hayden (McGill University)

  One of the most important properties of quantum information is that it cannot be copied. That statement, however, is not completely accurate. While the no-cloning theorem of quantum mechanics prevents quantum information from being copied in space, the reversibility of microscopic physics actually requires that the information be copied in time. In spacetime as a whole, therefore, quantum information is widely replicated but in a restricted fashion. In this talk, I will fully characterize which regions of spacetime can all hold the same quantum information. Because quantum information can be delocalized through quantum error correction and teleportation, it need not follow well-defined trajectories. Instead, replication of the information in any configuration of spacetime regions not leading to obvious violations of causality or the no-cloning principle is allowed. This provides a simple and complete description of where and when a qubit can be located in spacetime, revealing a remarkable variety of possibilities.

- **How to see the dark: signatures of strings and other things in the 21 cm radiation from high-redshift hydrogen**
  Oscar Hernandez (Marianopolis/McGill University)

  Because the physics of the Dark Ages is relatively simple and well understood, any observed deviation from the expected evolution would be a clean signature of new physics. I will discuss this physics and show how the 21 cm line can be used to
  1. see cosmic strings, if they exist, and
  2. test the assumptions of statistical isotropy of the universe through the matter power spectrum.

- **Local topological order inhibits thermal stability in 2D**
  Olivier Landon-Cardinal (Université de Sherbrooke)

  We put severe constraints on the existence of a self-correcting quantum memory made of a two-dimensional (2D) array of particles. Such a memory would passively protect the encoded information thanks to its dynamics at low temperature. To be robust to perturbation, candidates for such devices encode information in topological degrees of freedom, which are impervious to local errors on a short timescale. However, we show that, for any topologically ordered 2D local commuting projector code, thermal excitations can accumulate and corrupt the encoded information. We thus prove a no-go theorem, extending the known results to non-stabilizer codes.

- **Phase transition in Renyi Entropy**
  Shunji Matsuura (McGill University)

  Entanglement entropies characterize the degree of entanglement present in a given quantum state, and in doing so probe interesting features of strongly coupled quantum systems. In this talk, we consider entanglement Renyi entropies of conformal field theories (CFT). If the CFT possesses a sufficiently low dimension scalar operator, the Renyi entropies will exhibit a phase transition at a critical value of the Renyi parameter. The location of the phase transition, along with the lowest eigenvalue of the reduced density matrix, can be computed as a function of the dimension of the lowest dimension non-trivial scalar operator in the theory.

- **The singularity problem, bouncing universes, and the CMB**
  Evan McDonough (McGill University)

  Bouncing Cosmology provides a way to match the current state of observational cosmology, while avoiding the Singularity Problem of Standard Big Bang cosmology. By extending time backwards to include a slow contracting phase, we replace the big bang by a bounce; which can be mediated using new physics, to avoid the singularity altogether. In this talk, I review attempts at constructing bouncing universes, and how these are affected by the latest observational limits from PLANCK. I will come to focus on new models using galileon-like matter, and demonstrate that a non-singular bouncing universe is in agreement with the current state of observation. We finish with an outline for how future observation may distinguish between inflationary and bouncing scenarios.

- **Low-lying string state mixing in the D1-D5 orbifold CFT**
  Amanda Peet (University of Toronto)

  Originating from string theory, the fuzzball programme pioneered by S.D. Mathur has sparked important advances in understanding black hole entropy and the information paradox. One of the best-studied systems is the D1-D5 system obtained by wrapping N_1 D1-branes on S^1 and N_5 D5-branes on $S^1 \times T^4$. Its entropy can be computed either from the Bekenstein-Hawking formula or from the partition function of open strings and D-branes. This system has a moduli [parameter] space, with different physical descriptions at different points. The black hole description differs from the microscopic description, which is a (super)conformal field theory living on the symmetric orbifold $(T^4)^N/S_N$, where $N = N_1 * N_5$. Our work is a contribution to studying the microscopic side as we deform away from the orbifold point towards the black hole.

  In the first of two companion papers 1211.6689 and 1211.6699, we generalize Lunin-Mathur technology for computing correlation functions in the D1-D5 orbifold CFT to cover non-twist sector states and certain classes of excitations of twist sector states. In the second, we develop a method for tracking operator mixing and anomalous dimensions of string states as the CFT is marginally deformed away from the orbifold point. Specifically, for the low-lying string state $\partial X \partial X \bar{\partial} X \bar{\partial} X$, we show that it acquires an anomalous dimension at first order in conformal perturbation theory and compute the mixing coefficient. Our main tool is investigating factorization limits of four-point functions containing two of the low-lying string state operators and two deformation operators. This helps us identify which operators participate in mixing and cuts down on the work involved in diagonalizing to find the anomalous dimensions.

- **Gravitational self-force approach to extreme mass-ratio inspirals**
  Eric Poisson (University of Guelph)

  I will present a brief overview of the gravitational self-force, a description of the motion of a small body around a much larger mass, in a treatment that goes beyond the test-mass approximation in which the small body moves on a geodesic in the background spacetime of the large mass. In this approach, the gravitational perturbation created by the small body has an influence on its motion, which is accelerated in the background spacetime. One of the motivations behind this work is the need to model gravitational waves emitted by a solar-mass black hole captured by a supermassive black hole found in a galactic core; such inspirals are a promising source of gravitational waves for spacebased detectors such as the forthcoming eLISA.

- **Two dimensional quantum memories**
  David Poulin (Université de Sherbrooke)

  I will present an overview of recent advances in our understanding of two-dimensional quantum memories. In such memories, information is stored in the degenerate ground state of a many-body quantum system. Under a certain set of conditions collectively known as "local topological order", the low energy spectrum of a many-body system is robust to local perturbations. This has the consequence that quantum information encoded in the degenerate ground state of such a system is stable at zero temperature. On the other hand, the existence of a macroscopic energy barrier between ground states imply that information encoded in the low energy manifold is robust against thermal fluctuations. Here, we demonstrate that in two spacial dimensions, local topological order prohibits the existence of an energy barrier, which shows a tradeoff between robustness to quantum and thermal fluctuations.

- **Testing AdS/QCD using diffraction and radiative B decays**
  Ruben Sandapen (Université de Moncton & Mount Allison University)

  We show that anti-de Sitter/quantum chromodynamics (AdS/QCD) generates predictions for the rate of diffractive ρ-meson electroproduction that are in agreement with data collected at the Hadron Electron Ring Accelerator electron-proton collider. We also show that AdS/QCD Distribution Amplitudes yield successful predictions for observables in radiative B decays.

- **A tale of two metals: How strong interactions can destroy an ordinary metal**
  André-Marie Tremblay (Université de Sherbrooke)

  Band theory is one of the great successes of standard solid state physics. The failure of band theory became apparent in the 1940's when it was realized that because of strong interactions, half-filled-band materials that should have been metallic were instead insulators, so-called Mott insulators. In this talk, I will discuss the simplest model that embodies the physics of strong interactions, the one-band Hubbard model, and introduce Cluster Dynamical Mean-Field Theory with Continuous-Time Quantum Monte Carlo as a method to study this problem. The resulting phase diagram shows that the effect of strong-interactions, or of Mott physics if you want, extends far from half-filling. In particular, the phase diagram contains a first-order transition in the normal state. That transition separates a pseudogap phase from a correlated metallic state. The pseudogap does not break symmetry and does not come from precursor Cooper pairs. The pseudogap temperature follows the so-called Widom-line of the first order transition, a concept that I will explain. I will show that the phenomenology of the pseudogap and of superconductivity found for strong interactions is very close to that of hole-doped high-temperature superconductors.

- **Reflections on/in superintegrable models**
  Luc Vinet (Centre des Recherches Matématiques, Université de Montréal)

  The paradigm example of a quantum system whose Hamiltonian involves reflection operators is that of the parabosonic oscillator in one dimension. Upon combining such models, one constructs Dunkl oscillators. This talk will discuss simple systems of that type in two dimensions that exhibit superintegrability. The symmetries will be seen to realize novel algebraic structures with involutions. Their representations will also be shown to offer a simple context in which many of the recently found -1 orthogonal polynomials occur.
  (Based on joint work with V.X. Genest, M.H.E. Ismail and A. Zhedanov.)

- **Accidental supersymmetry and the renormalization of co-dimension 2 branes**
  Matthew Williams (McMaster University)

  In this talk, I'll give a brief summary of how one-loop bulk effects renormalize both bulk and brane effective interactions for geometries sourced by codimension-two branes. I'll then discuss what these results imply for a six-dimensional supergravity model which aims to capture the features that make extra-dimensional physics attractive for understanding naturalness issues in particle physics. I'll also emphasize the role that brane back-reaction plays in yielding unexpected results, and present a one-loop contribution to the 4D vacuum energy whose size is set by the KK scale.

- **Perturbations in Loop Quantum Cosmology**
  Edward Wilson-Ewing (Louisiana State University)

  In loop quantum cosmology, the quantization procedure of loop quantum gravity is used in order to study the role of quantum gravity effects in cosmological models when the space-time curvature nears the Planck scale. After a brief review of the loop quantum cosmology of the simplest homogeneous space-times, I will explain how linear perturbations can be studied by working on a lattice. In this setting, it is possible to determine the loop quantum cosmology corrections to the Mukhanov-Sasaki equation that governs the dynamics of perturbations in cosmology. I will end by showing how these equations can be used in the matter bounce scenario to evolve the perturbations through the bounce, and explain how the power spectra of the resulting scalar and tensor perturbations are (i) modified by quantum gravity effects, and (ii) compatible with the latest data from the Planck satellite.

- **Phase transitions and single-particle dynamics of Hubbard models on honeycomb lattice**
  Wei Wu (Université de Sherbrooke)

  The Hubbard model and extended Hubbard model can be seen as the prototype models of the single layer graphene sheet placed in high kappa environment with screened Coulomb interaction. By using dynamical cluster approximation method, we numerically found that the Fermi liquid is stable in the presence of short-ranged Coulomb interaction and the Fermi velocity stays invariant as the tight-binding model value of the honeycomb lattice. As the on-site and nearest neighbor

Coulomb repulsion increases, phase transitions between semi-metal, spin density wave and charge density wave states would take place. Phase diagrams for these phase transitions are also presented in our study.

- **Dissipative dynamics of trapped atomic Bose-Einstein condensates**
  Zhigang Wu (Queen's University)

  We investigate the effect of a weak correlated disorder potential on the collective dipole motion of a harmonically-confined elongated condensate. By using an extension of the Harmonic Potential Theorem, we demonstrate that the dynamics of the system can be described equivalently in terms of a disorder potential oscillating relative to a stationary condensate. This latter point of view allows the application of linear response theory to determine the drag force experienced by the condensate and to evaluate the damping rate of the centre of mass oscillation. The density response function for the elongated condensate is determined with a new local density approximation that takes into account the tight radial confinement of the atomic cloud. Our linear response theory reveals the detailed dependence of the damping rate on various system parameters. A comparison with available experimental data is only partially successful and points to the need for additional experimental and theoretical work.

- **Twisted flat-cell geometries in the loop gravity phase space**
  Jonathan Ziprick (Perimeter Institute)

  The phase space of loop gravity is written in terms of a discrete set of variables. These loop variables describe spatial geometries which are composed of a discrete set of cells. Given a particular set of loop variables there is freedom in choosing the shape and metric for each cell. If we reduce this ambiguity by requiring the intrinsic and extrinsic curvature to vanish within each cell, we obtain a flat-cell geometry which closely resembles a Regge geometry, the difference being that the boundary of each cell in a Regge geometry is a union of straight edges and flat faces forming a polyhedron, whereas cells of the flat-cell geometry may have generally curved boundaries. In this talk we present a method to choose particular cell shapes for the flat-cell geometry by minimizing the lengths of the edges in cell boundaries. We find that minimization twists each edge into a helix. We explore the extent to which the loop gravity phase space can be interpreted in terms of these twisted flat-cell geometries.

ABSTRACTS OF POSTER CONTRIBUTIONS

- **Optical nonlinear absorption coefficient of PbS nanoparticles studied by the Z-scan technique**
  Mohammad Bagher (Islamic Azad University, Iran)

  WITHDRAWN

  Nonlinear optics deals with the study of phenomena in which the optical properties of materials in the presence of light will change. Environments, nonlinear optics, nonlinear polarization materials strongly depends on the applied electric field, Z-scan technique is one of the best ways that we can, by this method, the nonlinear optical properties of materials in the presence of nonlinear absorption coefficient beat high intensity lights (Laser light) to be determined. Compared to the z-scan method using this method, the nonlinear optical properties of materials can be simultaneously measured with high precision. In the present study, the absorption coefficient by a Fortran programming environment PbS nanoparticles suspended in alcohol has achieved.

- **Dynamical apparent horizons in inhomogeneous Brans-Dicke universes**
  Valerio Faraoni (Bishop's University)

  We study the presence and evolution of apparent horizons in a two-parameter family of spherically symmetric and time-dependent solutions of Brans-Dicke gravity. These solutions were originally intended to represent central objects embedded in a spatially flat universe and to model space- and time-varying gravitational couplings. We find that the solutions possess multiple evolving apparent horizons, both black hole horizons covering a central singularity and cosmological ones. Sometimes two of these apparent horizons merge and annihilate, leaving behind a naked singularity covered only by a cosmological horizon. The limit in which the theory reduces to general relativity and the limit to static solutions are discussed.
  [Based on V. Faraoni, V. Vitagliano, T.P. Sotiriou, and S. Liberati, Phys. Rev. D 86, 064040 (2012).]

- **The Clebsch-Gordan/Racah coefficients of $sl_{-1}(2)$ and orthogonal polynomials of the Bannai-Ito scheme**
  Vincent Genest (Université de Montreal)

  The $sl_{-1}(2)$ algebra is an associative algebra with four generators, including an involution ($R^2 = id$), satisfying both commutation and anticommutation relations. It occurs as the dynamical algebra of the parabosonic (or Dunkl) oscillator in 1 dimension. In this talk, I will show that the Clebsch-Gordan and Racah problems for this algebra can be solved by identifying the corresponding "hidden" algebra in each case. I will also show how these structures allow one to obtain the exact formulas for the CG and Racah coefficients in terms of orthogonal of the Bannai-Ito scheme.

- **Constraining theories of gravity using gravitational radiation reaction**
  Lorne Nelson (Bishop's University)

  A new test to constrain alternative theories of gravity based on the predictions that they make with respect to the magnitude of gravitational radiation losses is proposed. Specifically, the effects of angular momentum losses predicted by alternative theories on the evolution of a particular class of close interacting binaries known as Cataclysmic Variables (CVs) are examined. CVs are stellar binaries consisting of an ordinary star that is so close to its white dwarf companion that it overflows its Roche Lobe thereby losing matter to the companion. Over the billions of years that it takes for these binary systems to evolve, the orbital period decreases from $\sim$ 10 hours to 80 minutes and then back to higher periods. The value of the orbital period minimum is governed almost solely by the magnitude of the angular momentum losses. Larger orbital angular momentum losses due to gravitational radiation will cause the minimum orbital period to be shifted to larger values. Unlike some tests that are rendered insensitive because the two binary components are similar in mass and composition (e.g., the famous binary pulsar PSR1913+16), the proposed test does not suffer from this limitation. The strengths and weaknesses of this new test are fully explored.

- **Long-range interactions between adjacent and distant bases in a DNA and their impact on the RNAP-DNA dynamics**
  Mirabeau Saha (University of Yaoundé I)

  WITHDRAWN

  It is well known that a DNA macromolecule is a most important complex biological system for the simple reason that it is the repertory of the genetic codes of a descent. Thus, the behavioral study of its functioning is the center of interest of several researchers. For instance, understanding the mechanisms of transcription and replication in the DNA double-helix are some of essential problems of DNA physics and molecular biology. Complete solution of the problem has not been attained because of insufficient knowledge of the DNA helix transformation mechanisms and the complex structure of the macromolecule. It had been found that due to the presence of phosphate groups along the DNA's strands, the long-range interaction (LRI) exists in that macromolecule and allows to take into account the screening of the interactions or an indirect coupling between base pairs via water filaments. Furthermore, the DNA and RNA-polymerase (RNAP) are constituted by specific sites such as promoter, coding, or terminator, which has a specific sequence of bases and peptides, and this makes the strands site dependent or inhomogeneous. Many qualitative discrepancies have been discovered and shared by theoretical findings so that the real long-range

force to be adopted for DNA dynamics remains unclear. To contribute to these behavioral analysis of the DNA's molecule while studying the influence of LRI on its dynamics, we have considered spin model of that molecule in which we introduce the intra-strand LRI when an inhomogeneous RNAP molecule comes to bind on an inhomogeneous DNA molecule at the biological temperature. It comes out from our results that the breather-like solitons, solitary waves which govern the transport of bubbles during the transcription, are deeply influenced by the LRI. Indeed we find that the bubble's energy decreases with the decreasing of the LRI's parameter and if a base pair interacts with many other pairs which form the bubble (the width of bubble increases while its height decreases). The results also show that inhomogeneities introduce some fluctuations in the localized region of the breather. This dynamical behavior may act as energetic activators of the enzyme transport during the process of transcription in DNA, and reinforces the efficiency and sturdiness of energy localization within transcription phenomenon.
(This work was published by Chaos. View online: http://dx.doi.org/10.1063/1.3683430.)

- **Evolving apparent horizons in the McVittie spacetime**
  Andres Zambrano (Bishop's University)

  The McVittie spacetime of General Relativity, which contains evolving cosmological and black hole apparent horizons, is studied on the model of one of its special cases: the Schwarzschild-de Sitter/Kottler spacetime. By plotting the areal radii of the apparent horizons versus comoving time and assuming a dust-dominated universe, we find that a pair of apparent horizons are created after a critical time. A cosmological horizon grows with time while a black hole horizon asymptotes to an areal radius corresponding to a singularity at a value of $2m$. The relationship between the areas of the horizons and entropy is discussed, as well as the solution for a phantom-dominated "background" universe.

- **Dirac fields in BTZ**
  Adamantia Zampeli (University of Lethbridge)

  We present some results from the study of the Wightman function for Dirac fields in a $2+1$ dimensional BTZ black hole. As a first result, we find that this function obtains the form of a product of thermal distributions, and we use it to calculate the response function of an Unruh-DeWitt detector confined in this spacetime.

PUBLIC LECTURE/AFTER-BANQUET SPEECH

Flying: High and Fast in Space; Low and Slow in a 100 Year Old Aircraft
Bjarni Tryggvason (University of Western Ontario)

In 1997 the speaker flew on the US space shuttle Discovery on a 12 day mission that focused on science in the free fall environment and on science that used the vantage point of space to view the Earth and the solar system. As well as training and flying as an astronaut, the speaker played a leading role with science teams developing fluid science experiments and led the team of engineers that developed the hardware required to support these experiments. The first version of the Microgravity Vibration Isolation Mount (MIM-1) flew on the Russian space station Mir; MIM-2 flew on shuttle mission STS-85; and the MVIS is currently on board the ISS. The Mir and shuttle experiments with MIM were designed to examine the effect of spacecraft vibrations on fluids in the free fall environment. This work was done to determine the effects that can be expected on fluid physics and material science experiments planned for the International Space Station (ISS).

The ISS is the largest spacecraft ever assembled and the largest international cooperative space program undertaken thus far, through a partnership between the USA, Russia, Canada, Japan and the European Union. The ISS' primary role is to support science in the free fall environment. The ISS has been crewed on a continual basis since 2000 and full assembly was completed in 2010. The normal crew complement is six people, drawn from the international partners. Canadian Bob Thirsk spent six months on the ISS in 2010-11 and Chris Hatfield just returned from a five month mission included serving as the commander of the ISS during the last three months.

In 2009 the speaker flew the 100th anniversary flight of the Silver Dart, the first powered aircraft to fly in Canada. The presentation will review aspects of the author's 12-day adventure in space and contrast that with the challenge of flying one of earliest aircraft ever flown.

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