The Winnipeg Institute for Theoretical Physics Annual Report

September 2013 – August 2014

Web site: http://www.physics.umanitoba.ca/~witp/

Contents

1 Director's Narrative Report

The Winnipeg Institute for Theoretical Physics is a type III research Institute and was created to support theoretical physics research in Manitoba. It has carried out this mandate by encouraging collaboration between members of the Institute and by financially supporting workshops, visiting colloquium speakers, and short and long term visits by research collaborators of international standing. The permanent members of this Institute are drawn from Brandon University, the University of Manitoba, and the University of Winnipeg. Associated with the Permanent Members are research associates, postdoctoral fellows, graduate students and summer undergraduate research assistants.

The past year was the 24th year of the Institute's existence. As usual, the Institute sponsored several research colloquia by out-of-province visitors as well as Institute members. The Institute also continued providing support for Canadian theoretical physics meetings by funding the 15th Canadian Conference on General Relativity and Relativistic Astrophysics, which was held at the University of Winnipeg in May 2014. The WITP was also a sponsor of the Theory Canada 9 conference, the main national conference for theoretical physics. In order to emphasize the strong base of theoretical physics in Manitoba throughout the rest of Canada, the WITP has also agreed to co-sponsor a new PhD thesis prize in conjunction with the Canadian Association of Physicists Division of Theoretical Physics.

For the 2012-2013 academic year, the list of invited speakers is found in section 4.1, visitors in section 4.2, a description of the WITP Summer Student Symposium appears in 4.3, the cumulative list of graduate degrees awarded appears in section 4.6, and the published research work of members is found in section 4.7. Section 5.1 contains a summary of income and expenditures for the period September 1, 2013 to August 31, 2014. The plans for the coming year include a program of invited speakers, visiting research collaborations, and the promotion of postgraduate and postdoctoral research. The WITP also held a summer research symposium, highlighting the summer research done by undergraduate and graduate students under the supervision of WITP members. The symposium was hosted this year at Brandon University and well-attended by members from all three universities; the BU media office documented the event. WITP activities were also profiled in the UM research magazine.

All of the funds available to the Institute are spent for scientific research expenses, including conference support, seminar activities, and travel expenses of visiting scientists. The Institute has no technical support staff or administrative staff. All the administrative work is done on a volunteer basis by the members of the Institute. The Institute's funding is substantially supplemented by contributions from the NSERC grants of individual members in pursuing the Institute's mandate.

The WITP Executive Committee for two-year term of 2013 and 2014 consists of the Director, A. R. Frey (Winnipeg), the Director-Elect, K. Shamseddine (Manitoba), and the Past-Director, G. Kunstatter (Winnipeg). In 2015, Shamseddine will become Director and J. Sirker (Manitoba) will become Director-Elect.

A. R. Frey
Director, WITP

2 Current List of Members (2013-14)

2.1 Permanent (Faculty) Members

- M.E. Alexander[2], *Ph.D. (Manchester University, UK)*
- S. Bacca[14], *Ph.D. (Trento, Italy & Mainz, Germany)*
- P.G. Blunden[1], *Ph.D (Queen's)* [Director, 93-94]
- M.E. Carrington[3], *Ph.D. (SUNY, Stony Brook)*
- T. Chakraborty[1], *Ph.D. (Dilbrugarh University, India)*
- J. D. Fiege[1], *Ph.D. (McMaster)*
- A.R. Frey[2] *Ph.D. (UCSB)* [Director, 12-14]
- T.D. Fugleberg[3], *Ph.D. (UBC)*
- G. Kunstatter[2], *Ph.D. (Toronto)* [Director, 91-92, 09-12]
- T.A. Osborn[1], *Ph.D. (Stanford)* [Director, 92-93, 01-04]
- S. Plosker[3], *Ph.D. (Guelph)*
- S. Safi-Harb[1], *Ph.D. (Wisconsin)*
- A. Shalchi[1], *Ph.D. (Ruhr-Universität Bochum)*
- K.M. Shamseddine[1], *Ph.D. (Michigan State)*
- J. Sirker[1], *Ph.D. (Universität Dortmund)*
- B.W. Southern[1], *Ph.D. (McMaster)* [Director, 90-91, 07-09]
- D.W. Vincent[2], *Ph.D. (Toronto)* [Director, 94-95]
- M. Whitmore[1], *Ph.D. (McMaster)*
- J.G. Williams[3], *Ph.D. (Birmingham)* [Director, 96-97]

Senior Scholars

- B. Bhakar[1], *Ph.D. (Delhi)* [Director, Jan. - June 00]
- P.D. Loly [1], *Ph.D. (London)* [Director, Fall 99, 00-01]

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[1]University of Manitoba
[2]University of Winnipeg
[3]Brandon University
[4]Home Institution: TRIUMF

- J.P. Svenne [1], *Ph.D. (M.I.T.)* [Director, 95-96]
- G.C. Tabisz [1], *Ph.D. (Toronto)*
- J.M. Vail [1], *Ph.D. (Brandeis)* [Director, 98-99]

2.2 Associate Members

Research Associates

- Gilles Ferrand (Safi-Harb)

Research Scholars

- James Babb (Kunstatter)
- Rebecca Danos (Frey/Kunstatter)

Postdoctoral Fellows

- Ared Ghazaryan (Chakraborty)
- Nikos Konstantinidis (Sirker)
- Harsha Kumar (Safi-Harb)
- Wenchen Luo (Chakraborty)
- Moitri Maiti (Sirker)
- Adam Rogers (Safi-Harb)
- Miriam Schmitt (Sirker)
- Tongchuan Suo (Whitmore)
- Yang Zhao (Sirker)

2.3 Graduate Students

- Felix Andraschko (Ph.D.) (Sirker)
- Siranush Avetisyan (M.Sc./Ph.D.) (Chakraborty)
- Chelsea Braun (M.Sc.) (Safi-Harb)
- Angel Barria Comicheo (Ph.D.) (Shamseddine)
- Bradley Cownden (M.Sc.) (Frey)
- Darren Flynn (M.Sc./Ph.D.) (Shamseddine)
- Erica Franzmann (M.Sc.) (Fiege)

- William Grafton (M.Sc.) (Shamseddine)
- Benson Guest (M.Sc.) (Safi-Harb)
- Javier Hernandez-Melgar (Bacca)
- Mohammad Hussein (Ph.D) (Shalchi)
- Damodar Khatri Chhetri (M.Sc.) (Svenne)
- Daniel Maciel (M.Sc.) (Southern)
- Heather Matheson (Ph.D.) (Safi-Harb)
- Paul Mikula (M.Sc.) (Carrington/Kunstatter)
- Andrew Senchuk (Ph. D) (Shamseddine, co-supervised with G. Gwinner, Manitoba)
- Jennifer West (Ph.D.) (Safi-Harb)
- Xiaohong Zhang (Ph.D.) (Plosker, co-supervised with S. Kirkland, Manitoba)
- L.J. Zhou (M.Sc.) (Carrington/Kunstatter)

2.4 Undergraduate Research Students 2013-14

- K. Au (Safi-Harb)
- R. Bergen (Carrington)
- G. Bookatz (Shamseddine)
- G. Chernitsky (Frey)
- N. Deppe (Kunstatter)
- J. Enns (Frey)
- P. Gregoryanz (Frey)
- A. Kolly (Frey/Kunstatter)
- B. Meggison (Carrington)
- J. Perron (Carrington/Plosker)
- N. Reid (Frey)
- L. Yu (Alexander)
- Y. Zhan (Safi-Harb)

3 Research Interests of Members

M.E. Alexander

My principal research interest is the mathematical modeling of emergent behaviour in complex systems. This is a widely found phenomenon, manifest in pattern formation in physical, chemical and biological systems (such as swarming/clustering behaviour of cells and other microorganisms). Interactions between microscopic entities orchestrate the macroscopic behaviour of large numbers of entities, and may give rise to phase changes at the macroscopic scale (e.g., solid-liquid or liquid-gas transitions, or transition from paramagnetic to ferromagnetic behaviour). In biology, the highly complex internal dynamics of cells and their interactions with the environment orchestrate highly complex behaviour at the macroscopic scale: the collective behaviour of large numbers of cells in such an environment can give rise to phase transitions, thereby signalling dramatic changes in immune response, from containment to uncontrolled spread of infection.

I use methods for statistical physics and stochastic processes (e.g., Langevin, Fokker-Planck, Boltzmann, Master Equation, critical phenomena and multi-particle field-theoretic approaches) to model both the microscopic intra-cellular biochemical kinetics and the emergent behaviour of large numbers of cells interacting with their chemical environment, in a self-consistent way. The principal mechanism of interest is chemotaxis, and I am collaborating with Dr Francis Lin (Univ. Of Manitoba, Physics) and his group to complement their single-cell experimental studies in chemotaxis with modelling and simulation. The intent is to provide a useful modelling framework for cell biologists, and contribute to the growing use of mathematical and physical methods in biology to complement traditional experimental approaches. We are also developing a model for the morphology of cells, in an attempt to explain their changes of shape in the presence of a chemotactic field.

Another interest is in close binary star systems, and modelling their tidal and oscillation properties in order to explain observational data on orbital period changes, particularly in subdwarf B-type binary systems. In particular, I am investigating (i) a tidally-induced hydrodynamical mechanism proposed by J,-L. Tassoul, that gives rise to meridional currents and redistribution of angular momentum in a star, and its effect on orbital changes; (ii) the effects of magnetic braking due to stellar winds in these systems, as a possible explanation for period changes. This work is in collaboration with Dr. D. Kilkenny (Univ. Western Cape, South Africa) and Dr. A.E. Lynas-Gray (Univ. of Oxford, UK).

I am developing a fast algorithm for analyzing 2D NMR spectra, which it is hoped will supersede current methods based on the Fast Fourier Transform. This will have direct application to reliable early detection of breast cancer, as it has a higher sensitivity to detecting biomarkers than is possible for 1D NMR spectra. In addition, I am collaborating with Dr Anuraag Shrivastav (Biology, Univ. of Winnipeg) for modelling the survival response of breast cancer to therapeutic agents, using delay differential equations and numerical modelling of breast cancer cells. Finally, with Dr P. Shivakumar, I am developing a feedback control algorithm to automatically deliver insulin to diabetic patients, based on blood glucose readings.

S. Bacca

My research interests lie in nuclear physics, with a focus on the theoretical description of electro-weak observables.

Atomic nuclei are fascinating objects constituted of strongly interacting protons and neutrons. Nuclei drive the synthesis of the chemical elements, they serve as star fuel and as laboratories to test fundamental interactions and the Standard Model. Predictions of nuclear properties that start from the forces among nucleons and their interactions with external probes as described by chiral effective field theory, are arguably the doorway to a solid connection between experimental observations and the underlying fundamental theory of quantum chromo-dynamics. Forging such a strong tie is the objective of my research and is key to answer questions like: *How do protons and neutrons tie together to form stable and unstable nuclei and what are the limits of their existence? How can nuclear physics help discover properties of fundamental interactions and particles?*

Electro-weak observables are well suited to test the predictive power of nuclear theory. The perturbative nature of the electro-weak probes allows for a clear connection between measured cross sections and the calculated nuclear properties. I have a broad portfolio of interests on electro-weak observables, which connects to contemporary experimental efforts and has applications to nuclear physics, astrophysics, atomic physics and particle physics.

Electromagnetic reactions on light nuclei – I contributed to the study of electromagnetic reactions of light nuclei with a series of papers, the last being a commissioned review, which I wrote for J. Phys. G: Nucl. Part. Phys. (2014) together with S. Pastore. My theoretical studies have often motivated experimental activity. For example, the finding that the ^{4}He transition from factor strongly depends on nuclear forces and disagrees with previous experiments [Phys. Rev. Lett. **110**, 042503 (2013)] has led to new proposals to measure this observable via electron scattering [N. Pietralla *et al.*, DFG proposal, S-DALINAC, Darmstadt] and via $\alpha-$scattering [F. Cappuzzello (spokeperson), S. Bacca (co-spokeperson) *et al.*, LNS proposal, Catania].

Halo nuclei – Neutron-rich light nuclei exhibit fascinating phenomena like the formation of a halo structure of loosely-bound neutrons surrounding a tightly bound core, similar to electrons in atoms. The precise mass and charge radii measurements of halo nuclei harvested by the TITAN collaboration at TRIUMF are challenging *ab-initio* theories to provide theoretical interpretations of the data. I have built a strong collaboration with the experimentalists of the TITAN group that led to a joint experimental and theoretical publication [Phys. Rev. Lett. **108**, 052504 (2012), selected as *editor's suggested reading*], which pointed to the importance of three-nucleon forces in ^{6}He, the lightest of the halo nuclei. Refinements of the above mentioned calculations including a study of the convergence in chiral effective field theory and benchmarks with other many-body methods (such as the no-core-shell model and Green's function Monte Carlo method) will be investigated in the future.

Muonic atoms – The "proton radius puzzle" (7σ discrepancy between the proton charge radius extracted in muonic hydrogen and the one obtained from ordinary hydrogen) is posing one of the most compelling questions of the decade. Several beyond-the-standard-model theories, including lepton universality violations, have attempted to solve the puzzle. To date, no commonly accepted explanation of the puzzle exists. Owing to the heavier mass, the muon orbits much closer to the nucleus than does an electron, so that nuclear polarizations modify the atomic energy levels. The theoretical knowledge of such nuclear effects is key to the experimental program at PSI (Switzerland), aimed at shedding light on the proton radius puzzle. By measuring the Lamb-shifts in μ-D, μ-^{3}He$^+$ and μ-^{4}He$^+$, the CREMA collaboration plans to extract the charge radii of light nuclei and to investigate if the discrepancy with ordinary atoms persists or changes as a function of mass number and proton number. To help understanding the proton radius puzzle, I initiated a new research line to deliver the crucial theoretical estimates of nuclear structure corrections in muonic atoms. Using *ab-initio* theoretical tools for electromagnetic reactions, we have performed the first calculation of the nuclear polarizability corrections in μ-^{4}He$^+$ [Phys. Rev. Lett. **111**, 143402 (2013) and Phys. Rev. C **89**, 064317 (2014)] and in μ-D [Phys. Lett. B **736**, 344 (2014)] with chiral effective field theory. In the future, we plan to address μ-^{3}He$^+$ and to investigate nuclear structure corrections relevant to the hyperfine splitting measurements in light muonic atoms, planned at PSI.

Electro-weak reactions in medium-mass nuclei – Predictive *ab-initio* calculations of electro-weak reactions have traditionally been limited to relatively light mass number. Medium-mass and heavy nuclei are typically studied with more phenomenological theories, which, despite being extremely useful, lack a clear connection to quantum chromo-dynamics and solid estimates of the errors introduced by approximations. To extend *ab-initio* studies of electro-weak reactions to medium-mass nuclei, we recently developed a new theoretical approach. We have merged the advantage of the Lorentz integral transform method (*i.e.*, transforming the continuum problem to a bound-state problem) with the mild computational scaling that characterizes coupled-cluster theory with increasing mass number. In a recent paper [Phys. Rev. Lett. **111**, 122502 (2013)] we have first benchmarked this theory on ^{4}He with exact hyperspherical harmonics and then presented the first calculations of the photodisintegration cross section in ^{16}O based on a realistic chiral potential. This study paves the way for many future investigations of continuum responses in medium-mass nuclei for both stable and unstable isotopes.

Applications to astrophysics – Nuclear physics and in particular electro-weak reactions, play a crucial role in nuclear astrophysics. Responding to the quest of improving the nuclear physics input in astrophysical simulations, I have investigated the neutrino response for neutron matter, relevant in supernovas and neutron star cooling [ApJ **758** 34 (2012)], where we found that that chiral effective field theory predicts such observable to be a factor of two smaller with respect to the simple model used in state-of-the-art supernova simulations. More recently, we investigated neutrino-bremsstrahlung from neutron-^{4}He collisions [arXiv:1411.3266], which may play an important role in the supernova environment, where both α-particles and neutrons are available.

Future – I plan to continue in these research directions and, in particular, further develop of the coupled-cluster theory for electro-weak reactions on medium-mass nuclei. My long-term goal is to use the *ab-initio* coupled-cluster technology to tackle neutrino-nucleus interactions. They are crucial to experiments aimed at measuring fundamental properties of neutrinos such as T2K, where presently the data analysis is systematically limited by simple nuclear models for the interaction of neutrinos with the nuclei in the detectors.

B. Bhakar

Present activities are directed towards the understanding of completely integrable and nonintegrable field theories in low [(1+1) and (2+1)] dimensions. Therefore, investigations are being carried out to study the behaviour of spin chain models on a lattice in (1+1) dimensions with nearest neighbour interactions only. These models are closely related to nonlinear sigma models.

P.G. Blunden

My research program focuses on two related themes – electromagnetic and weak interactions, and relativistic approaches to the nuclear many-body problem. A principle aspect of the first research theme is understanding the fundamental properties of nucleons and nuclei through electromagnetic and weak interactions with semileptonic probes. At the nucleon level, calculations of two-photon exchange (TPE) radiative corrections have been instrumental in resolving the discrepancy between measurements of electron-nucleon scattering form factors using Rosenbluth and polarization transfer techniques. A hadronic approach is taken to evaluating the model-dependent TPE amplitudes, including the contribution of nucleon resonances. This has implications for parity-violating electron scattering and other precision measurements (e.g. single spin asymmetries), as well as virtual Compton scattering. One goal is understanding the transition between hadronic approaches at low energies and partonic approaches appropriate at high energies.Weak radiative corrections within the standard Model have also been undertaken. These corrections include those involving one-quark (conventional one-loop), as well as many-quark effects (e.g. those leading to an intrinsic nucleon anapole moment). Expertise developed in the TPE program is used for corresponding processes involving weak interactions. This work is of significance for a new generation of experiments such as the Q-weak measurement of the weak charge of the proton, and parity violating electron scattering.

This ties in strongly with the second research theme, which builds on an established program of relativistic approaches to nuclear many-body problems. Recent approaches emphasize the use of effective field theory and density functional methods. Applications are being developed for nuclear structure studies, electromagnetic properties of nuclei, and parity violating effects in nuclei.

M.E. Carrington

My main area of interest is statistical field theory, with particular emphasis on applications to the quark-gluon plasma. This type of research is also relevant in the context of the study of the early universe.

There are many technical problems associated with statistical field theory. The standard technique for doing field theoretic calculations is perturbation theory. At finite temperature, it has been known for some time that standard perturbation theory leads to inconsistent results. In many cases this problem can be resolved by using the effective expansion developed by Braaten and Pisarski which is based on the resummation of hard thermal loop diagrams into effective green functions.

For systems out of equilibrium, finite temperature field theory cannot be used and completely different techniques are required. There are several strategies that can be used if the system is close to equilibrium. Transport theory uses a linear response approximation to study the transport of conserved quantities over distances that are long compared to the microscopic relaxation scales of the system. There is a non-equilibrium generalization of the htl theory called the hard loop (hl) effective theory, which can be used to study dispersion relations at lowest order. One interesting phenomena that can be studied using this technique is plasma instabilities. These instabilities may significantly delay the equilibration of the system

Far from equilibrium situations require completely new techniques. One approach is the use of nPI effective theories which, in principle, can be used arbitrarily far from equilibrium.

T. Chakraborty

Spin Transport in a Quantum Dot

It has long been recognized that a two-dimensional electron gas (2DEG) in narrow-gap semiconductors, particularly in InAs-based systems with its high values of the g-factor, exhibit zero-field splitting due to the spin-orbit (SO) coupling. This coupling is also the driving mechanism for making futuristic devices based on controlled spin transport, such as a spin transistor, where the electron spins would precess (due to the SO coupling) while being transported through the 2DEG channel. Tuning of this precession in the proposed spin transistor would provide an additional control that is not available in conventional devices, but may be crucial for the rapidly emerging field of semiconductor spintronics. We have developed a theoretical approach where the SO interaction is treated via exact diagonalization of the Hamiltonian for interacting electrons confined in a parabolic QD. Coulomb interaction causes energy levels to cross and at the crossing point magnetization shows a jump. In an magnetic field the strength of the SO coupling is proportional to the field (in addition to the coupling parameter and the angular momentum). Hence, the effect of the coupling is more prominent for slopes of the higher angular momenta energy curves. As a consequence, an increase in the SO coupling strength causes the energy level crossings to move to weaker fields and the jump in magnetization shows a large shift to weaker magnetic fields. This result can be exploited to tune the SO coupling strength that might be useful for spin transport.

Electron Dynamics in a DNA Molecule

The unique properties of DNA, self-assembly and molecular recognition, has rendered the ‘molecule of life’ a promising candidate in the rapidly emerging field of molecular nano-electronics. A recent report of a field-effect transistor based on DNA molecules, that was preceded by a series of seminal experiments on the electron conduction in DNA, has sparked a lot of interest on the electronic properties of the DNA. A thorough understanding of the electronic properties of DNA is crucial in the development of the future DNA-based nanoscale devices. In addition, charge transfer through DNA also plays an important role in radiation damage and repair and therefore important for biological processes. We have preformed theoretical calculations of the electron energy spectrum, based on a two-leg charge ladder model for the poly(dA)-poly(dT) DNA and poly(dG)-poly(dC)

DNA molecules. We take the electron-electron interactions and the electron spin degree of freedom fully into account in our model. The energy spectra for the G-C and the A-T base pairs show a large gap and the interaction was found to enhance the gap. The effect of interaction is less pronounced for the G-C base pairs than that of the A-T pairs. The spin-flip excitations are not the lowest energy excitations. We also analyze the charge distribution for the ground state as well as for the excitations.

J.D. Fiege

My research program involves three areas of astrophysics, plus an interdisciplinary project in medical physics. The common thread of this research is the application of sophisticated optimization methods solve very large multi objective optimization problems or to mode data. The various components of this research program are enumerated below.

1. Gravitational lens modeling: Gravitational lens systems probe the structure of dark matter haloes, while also using these systems as natural telescopes to study distant extra galactic sources. My Ph.D. student Adam Rogers and I have developed new and very efficient methods to explore and reconstruct the lens density profile and background source in gravitational lens systems, leading to the largest lens reconstructions in the literature.

2. Polarization modeling: Submillimetre polarization mapping is the best observational technique to study magnetic fields in molecular cloud cores. My M.Sc. student Erica Franzmann and I have developed a modeling technique to simultaneously constrain the density structure and magnetic field geometry in cores and filaments. We are providing theoretical support to two international surveys (JCMT Gould's Belt survey and a CARMA polarization survey).

3. I develop a code called "GalAPAGOS" (Galaxy Parameter Aquisition by Genetic Optimization Software), which uses a genetic algorithm to constrain the kinematics of rotating neutral hydrogen (HI) disks in galaxies by modeling their HI data cubes.

4. I collaborate with Boyd McCurdy on the development of a code called PARETO, as part of unique interdisciplinary project in medical physics, which applies optimization methods to treatment planning in cancer radiotherapy. PARETO is the first software package to use a multi objective GA (Ferret) to simultaneously optimize radiation beam orientations and fluence patterns by solving a large scale, monolithic, multi objective optimization problem.

A. R. Frey

My research program addresses major questions in cosmology using the tools of fundamental physics, namely particle physics and string theory.

The majority of my research aims to discover the composition of the modern universe, specifically uncovering the nature of dark matter, yet-to-be-discovered particles known only by their influence on gravity. We are in an era of rapid discovery, with multiple experiments to detect dark matter now active and highly sensitive astrophysical observatories. I relate models of dark matter favored by terrestrial detection experiments can affect astrophysics, finding new tools in astrophysics to unravel the mystery of dark matter. I have a particular expertise in models with dark matter charged under a new non-Abelian gauge group, which are especially interesting in relation to anomalous measurements in astrophysics. As more data becomes available, I am also interested in interpreting results from the Large Hadron Collider at CERN.

The other theme of my research program is answering fundamental questions regarding inflation and the cosmological constant, both related to the accelerated expansion of space, in string theory, the only known theory unifying particle physics with gravity. Specifically, I study the potential energy that stabilizes the size and shape of extra dimensions. While most existing literature works in an effective four-dimensional theory to study various contributions to dark energy (specifically including curvature, brane tensions, and gaugino condensation), some recent studies have questioned whether all these ingredients are in fact compatible in a fully ten-dimensional framework. My work explores these issues. More broadly, understanding cosmology in string theory requires an understanding of dynamics, so I am also studying gravitational collapse in the AdS/CFT correspondence, which provides a nonperturbative framework for quantum gravity within string theory. At the classical level, it has been conjected that any extra energy added to the vacuum ultimately leads to black hole formation; my work has provided evidence that quantum effects can alter this conclusion.

T.D. Fugleberg

My current research interests are in three main areas.

The first is the study of a novel form of superconductivity called colour superconductivity. This is the study of a new state of matter - the colour superconducting state - which may be present in neutron and/or quark stars with consequences detectable in astronomical observations. The colour superconducting state arises in the theory of the strong nuclear force, Quantum Chromodynamics, (QCD). I have looked at refining models used in this analysis to include the physical masses of the quarks and other degrees of freedom in as complete a way as possible in order to make definitive quantitative predictions for observation. This research involves free colour charge and is thus related to the main unsolved problem of QCD - colour confinement.

The second area is non-equilibrium and thermal field theory. Both of these topics have important applications in the physics of the early universe and in heavy ion collisions. I am developing techniques for simplifying calculations in the real time formalism of thermal field theory. Non-equilibrium field theory is still in its infancy but has important implications in the search for the quark gluon plasma and the evolution of the universe immediately following the big bang.

The third area of research is in the area of quantum computation. A computer designed to utilize quantum mechanical indeterminacy in the computation process will theoretically be capable of solving difficult problems much more rapidly than a classical computer. This has important implications since international monetary security depends on cryptographic systems based on the fact that certain problems are "too hard" to solve in a reasonable amount of time. Since very simple quantum computers have already been constructed, quantum computation is a very important field of research. In particular I have been studying a particular model of quantum computation - adiabatic quantum computation - with the goal of gaining insight into the fundamental physical quantity or quantities responsible for the power of a quantum computer.

G. Kunstatter

Einstein's theory explains the motions of planets, galaxies and the universe as a whole, while quantum mechanics describes the sub-atomic world. Both theories have been well tested in their own realms, but they appear to be incompatible with each other so that at least one must break down at the Planck scale. My research focuses on perhaps the most important question in theoretical physics today: what is the theory that unifies Einstein's theory of gravity with quantum mechanics? Given the difficulty of obtaining experimental data at such ridiculously small scales, it is important to look for clues by pushing the existing theories to their limits. Black holes provide excellent theoretical laboratories in this regard because they pose fundamental questions, such as the resolution of the inevitable central singularity, the endpoint of black hole evaporation and the source of the so-called information loss paradox. The long term goal of my research is to place constraints on the form of the ultimate quantum theory of gravity by studying as generally as possible the classical and quantum dynamics of black holes.

Einstein's theory of gravity must undergo corrections at microscopic distance scales. Quantum theory suggests the need to add higher-curvature terms whereas string theory requires the existence of extra spatial dimensions. Lovelock gravity is arguably the most natural generalization of this type. One of the projects I am currently undertaking is the numerical study of microscopic black hole formation in Lovelock gravity. Another is the quantum mechanics of black holes in Lovelock theory, in order to see whether the inherent "fuzziness" or uncertainty in quantum mechanics can cure the singularities in this class of theories.

It has been conjectured that off-shell processes in string theory can be described qualitatively by solutions to RG flows of world-sheet sigma models. In the case of closed string theory the simplest of these RG flows is the so-called Ricci flow. The AdS/CFT correspondence relates asymptotically AdS black holes to thermal states in a conformal field theory (CFT) on the boundary of space-time. In the case of 5D AdS, the CFT is a 4D supersymmetric Yang-Mills theory. Since the underlying string theory provides Ricci flow in the bulk AdS spacetime with a physical interpretation a question arises as to the nature of the corresponding deformation in the boundary CFT. This is also currently under investigation.

P.D. Loly

In August 2012 I participated in the University of Iceland - University of Manitoba 2012 Partnership Conference on "Origins" in Reykjavik.

Also our claim to the use of modern data mining techniques, Shannon entropy and a novel index, has now been cemented by our July 2012 video presentation sent to the joint sessions of IWMS21 and LINSTAT2012 conferences in Bedlewo, Poland. [see http://www.physics.umanitoba.ca/ icamern/Poland2012/]

This project began early in 2010 with Ian Cameron and Adam Rogers has matured to provide robust measures for comparing doubly stochastic matrices, principally the integer Latin and natural magic squares, by elucidating clan signatures (distinct singular value sets) first glimpsed in P.D. Loly, I.D.Cameron, W.Trump and D.S.Schindel, "Magic square spectra", Linear Algebra Appl. 430 (10) 2659-2680 (2009).

This project resulted in a delay in completing several other projects, which were the subject of 2008, 2009 conference talks, but which can now take advantage of these new features. These will now be completed, taking advantage of the new measures.

a) Peter Loly (presenter) with Ian Cameron, "Eigenproperties of an algebraic family of compound magic squares of order $n = 3^l, l = 1, 2, 3...$, and construction and enumeration of their fundamental numerical forms", CMS Winter Meeting 2009, Windsor, Dec. 2009.

b) A.M. Rogers (presenter), with P.D. Loly and G.P.H. Styan: "Sums of Kronecker Products for Compound Magic Squares - Eigenproperties", WCLAM2008 (Western Canada Linear Algebra Meeting, Winnipeg, May/June 2008), and

c) P.D. Loly (presenter), "Two Small Theorems for Square Matrices Rotated a Quarter Turn", WCLAM2008.

Website: http://home.cc.umanitoba.ca/˜ loly/

T.A. Osborn

My research program aims to achieve a unification of classical and quantum mechanics in a common mathematical framework. The theory that emerges (quantum phase space, QPS) is an altered version of classical phase space in which the usual commutative product of functions is deformed (as Planck's constant varies away from zero) into a noncommutative (star) product. With this one structural modification it is possible to state the full content of quantum mechanics as a noncommutative phase-space theory. In this setting, the Schrödinger wave function never arises, Hilbert space operators are represented by phase-space (Wigner) distributions, and quantum expectation values are given by integrals over phase space. This unification via QPS provides an alternate, autonomous statement of quantum mechanics that clarifies its content and interpretation and at the same time provides a new computational platform that has many parallels to that of classical mechanics.

A series of papers have investigated the quantization of charged particle systems moving in time dependent inhomogeneous magnetic fields on both flat and curved manifolds. This joint work with Mikhail Karasev has developed a QPS representation that is both gauge and geometrically covariant and has an exact star product determined by a symplectic area phase. The resulting quantum phase space that arises has a curvature which is a function of the electromagnetic field entangled with the Riemannian curvature. The discovery of this quantization induced curvature raises a variety of questions: Is this curvature really a part of nature? Can it be measured? Ongoing projects aim at establishing the ways this curvature can be detected.

A second theme in my current research applies the general concepts and methods of noncommutative phase space to problems in quantum optics. This new research direction is undertaken with Karl-Peter Marzlin (St. Francis Xavier). At present, a paper that obtains an exact solution to quantum dynamics for Kerr type nonlinear optical media is complete. For squeezed states, this work predicts a detectable, half-period resonance-like phenomena. Currently we aim to extend this program by 1) including multimode phenomena in nonlinear quantum optics, 2) obtaining QPS representations of photon entanglement, and 3) developing a quantum phase-space theory for open quantum optical systems coupled to a heat bath.

S. Plosker

Quantum cryptography, quantum error correction, quantum probability measures, entanglement theory.

S. Safi-Harb

My research is focused on the study of supernova remnants (SNRs) and associated phenomena. These include neutron stars, pulsar wind nebulae, and the interaction of these objects with the interstellar medium. The science goals of my program are targeted to understand the aftermath of a supernova explosion, the growing diversity of neutron stars (including magnetars), their relativistic outflows, their evolution and interaction with their hosting supernova remnant shells, and the acceleration of cosmic rays at supernova shocks up to very high energies. My program makes use of multi-wavelength observations from radio to very high-energies, with current focus on X-ray data acquired with NASAs Chandra and ESAs XMM-Newton telescopes. As well, my team includes numericists/theorists developing models and performing state-of-the-art numerical simulations to apply to data. I am also a member of the upcoming international, JAXA-led, ASTRO-H X-ray mission that will study the high-energy universe with unprecedented spectral resolution and a broadband (0.5-600 keV) energy band. At gamma-ray energies, I have become (by nomination) an associate member of the currently operating H.E.S.S. mission. Funding for my research program has been provided by NSERC through the Canada Research Chairs and Discovery Grants Programs, the Canadian Institute for Theoretical Physics, and the Canadian Space Agency. A local computing cluster used for the numerical work has been funded by the Canada Foundation for Innovation and Manitobas Research and Innovation Fund.

A. Shalchi

A fundamental problem in astrophysics is the interaction between space plasmas and energetic particles. Space plasmas can be found in any astrophysical scenario. This could be the plasma of the solar wind or the interstellar medium. Examples for energetic particles are the so-called Solar Energetic Particles (SEPs) and Cosmic Rays. These particles experience strong scattering while they propagate through the interplanetary or interstellar space. Describing these scattering effects theoretically is important to understand the motion of Cosmic Rays through the Universe and the mechanism of diffusive shock acceleration. The latter mechanism is important for understanding the origin of cosmic radiation.

In recent years we have achieved a more complete understanding of the fundamental scattering mechanisms due to the development of computer simulations and nonlinear diffusion theories. Currently, our research team explores these scattering mechanisms to achieve further progress in the theory of charged particle transport by using numerical and analytical tools. The results are applied to different physical scenarios such as Cosmic Ray propagation and acceleration of particles at interplanetary shocks and supernova remnants.

Khodr M. Shamseddine

My research interests and activities include various areas of non-Archimedean Analysis: power series and analytic functions, measure theory and integration, optimization, existence and uniqueness of solutions of differential equations, complex analysis, multivariable analysis, and functional analysis. The focus of my research has been on the Levi-Civita fields which were first introduced by the Italian mathematician Tullio Levi-Civita at the end of the nineteenth century. Of those Levi-Civita fields, one (which we denote by $\mathcal{R}$) is of particular interest; it is shown to be the smallest non-Archimedean field extension of the real numbers that is complete in the order topology and real closed. In fact, $\mathcal{R}$ is small enough so that the numbers of the field can be implemented on a computer; and this allows for many useful applications, one of which is the fast and accurate computation of the derivatives of real-valued functions up to high orders. Such computational applications are not possible with the structures of the field of Non-Standard Analysis. While in the latter discipline, there is a generally valid transfer principle that allows the transformation of known results of conventional analysis, here all relevant calculus theorems are developed separately. Moreover, the Levi-Civita field $\mathcal{R}$ is not only non-Archimedeanly valued but it also has a total order (which is also non-Archimedean) yielding a richer structure, thus opening up new possibilities of study, like monotonicity, which are not available in other non-Archimedean valued fields like the p-adic fields for example. This makes $\mathcal{R}$ an outstanding example, worth to be studied in detail in its own right.

We have studied convergence of sequences and series in two different topologies, which led to an exhaustive study of power series. A handful of people had investigated power series on the Levi-Civita fields before, but all the previous studies had been restricted to the special case of power series with real coefficients. We have dropped that restriction and showed that power series on Levi-Civita fields have all the nice smoothness properties that real power series have. In particular, they satisfy the intermediate value theorem, the extreme value theorem, and the mean value theorem; they are infinitely often differentiable; and they are re-expandable around any point within their domain of convergence.

While it is a known fact that conventional continuity or differentiability are not sufficient to guarantee that a function on a closed interval of a non-Archimedean field be bounded or satisfy any of the common theorems of real calculus, we have shown that under mild conditions, differentiability is sufficient for the function to assume all intermediate values and have a differentiable inverse function. We also showed that conventional differentiability is not the right one to study optimization questions on non-Archimedean fields in general; and based on a stronger concept of differentiability, we studied finite-dimensional optimization both with and without constraints. In both cases, we derived necessary and sufficient conditions of first and second order for a function to have a local minimum (or maximum) at a point of its domain.

We developed a measure theory and integration on the Levi-Civita field $\mathcal{R}$. We introduced a measure that proved to be a natural generalization of the Lebesgue measure on the field of the real numbers and to have similar properties. Then we introduced a family of simple functions from which we obtained a larger family of measurable functions. We showed how to integrate measurable functions over measurable sets, and we showed that the resulting integral satisfies similar properties to those of the Lebesgue integral of Real Analysis.

We studied existence and uniqueness of solutions of ordinary differential equations (ODE's) over $\mathcal{R}$. In particular, we showed that an ODE of the form $[y'(t) = f(y,t); y(a) = y_0]$, with $f(y,t)$ infinitely often derivate differentiable, admits a solution that is itself infinitely often derivate differentiable and that the solution so obtained is unique among all the infinitely often derivate differentibale functions.

We studied two topologies on $\mathcal{R}$: the valuation topology induced by the order on the field, and another weaker topology induced by a family of seminorms, which we call weak topology. We showed that each of the two topologies results from a metric on $\mathcal{R}$, that the valuation topology is not a vector topology while the weak topology is, and that $\mathcal{R}$ is complete in the valuation topology while it is not in the weak topology. Then we studied the properties of both topologies in detail; in particular, we gave simple characterizations of open, closed, and compact sets in both topologies. Finally, we showed that the metric which induces the weak topology is translation invariant.

Most recently, together with two collaborators from Chile, we developed an operator Theory on a Banach space over $\mathcal{C} := \mathcal{R} \oplus i\mathcal{R}$. Let c_0 denote the space of all null sequences $x = (a_n)$, $a_n \in \mathcal{C}$. The natural inner product on c_0 induces the sup-norm of c_0. We showed that c_0 is not orthomodular then we characterized those closed subspaces of c_0 with an orthonormal complement with respect to the inner product; that is, those closed subspaces M of c_0 such that $c_0 = M \oplus M^\perp$. Such a subspace, together with its orthonormal complement, defines a special kind of projection, the so-called normal projection. We presented a characterization of such normal projections as well as a characterization of other kinds of operators, the self-adjoint and compact operators on c_0. Then we worked on some B*-algebras of operators, including those mentioned above; we studied normal and Hilbert-Schmidt operators; and finally, we studied the properties of positive operators on c_0, which we then used to introduce a partial order on the B^*-algebra of compact and self-adjoint operators on c_0 and studied the properties of that partial order.

While the Levi-Civita field $\mathcal{R}$ is interesting to study in detail for the reasons stated above, I have recently started expanding my research focus to include any non-Archimedean field F extension of the real numbers R that is real closed and complete in the topology induced by the order and whose Hahn group is Archimedean. For example, with two NSERC USRA students, I recently proved the inverse function theorem and implicit function theorem for locally uniformly differentiable functions from F^n to F^n and from F^n to F^m $(m < n)$, respectively. Then, in a followup paper, we studied the properties of locally uniformly differentiable functions on F or F^n, and most recently, we proved a local version of the mean value theorem and Taylor's theorem for locally uniformly differentiable functions on F. Enlarging the scope of my research will make it more interesting to a wider audience of mathematicians and will thus open the door to new collaborations in non-Archimedean Analysis.

J. Sirker

Quantum mechanics predicts that electrons in a solid or atoms in a gas can loose there single particle properties completely and instead start behaving collectively. This often leads to the emergence of new states of matter which are a fascinating topic for fundamental research and offer the potential for technological advances. Important examples include high-temperature superconductivity in certain cuprates and iron pnictides, quantum wires such as carbon nanotubes, as well as the Bose-Einstein condensation in trapped atomic gases at ultracold temperatures.

More specifically, my research interests lie in the theoretical explanation of the physics of such strongly correlated quantum systems. Recent publications include work on:

- Quenches, thermalization, and many-body localization in quantum systems,
- transport in spin chains and quantum wires,
- multiferroic behavior in spin chains,
- domain walls in ferromagnetic Luttinger liquids,
- compounds with orbital degrees of freedom,
- quantum critical points in magnetic systems with frustration,
- field- or pressure-driven phase transitions in magnetic systems (Bose-Einstein condensation of magnons).

My research on these topics often combines field-theoretical methods (bosonization, conformal field theory, nonlinear sigma-models, renormalization group) with numerical methods, in particular, the density-matrix renormalization group (DMRG). Recently, we have developed in my group several new DMRG-type algorithms to study quantum dynamics both in equilibrium at finite temperatures and in non-equilibrium following a quantum quench.

B.W. Southern

Nanomagnetism

The study of magnetism in confined geometries has produced much new science and many technical applications in the past thirty years and will continue to be a rewarding area of research yielding applications in the foreseeable future. Confined systems that exhibit novel properties often consist of dissimilar materials that include at least one or more magnetic component (ferromagnetic, antiferromagnetic, etc.). A fundamental understanding of nanomagnetism will lead to the development of integrated systems with complex structures and architectures that possess new functionalities. Controlled release of drugs from nanostructured functional materials, especially nanoparticles, is attracting increasing attention because of the opportunities in cancer therapy and the treatment of other ailments. The potential of magnetic nanoparticles stems from the intrinsic properties of their magnetic cores combined with their drug loading capability and the biochemical properties that can be bestowed on them by means of a suitable coating. Magnetic properties at interfaces and surfaces, which make up a large fraction of nanostructured and confined materials, can be qualitatively different from those of bulk systems. Fundamental to understanding these differences is understanding the evolution of the magnetism as the structural scale descends from the bulk to the nanoscale. Due to reduced symmetry, the magnetic anisotropy at a surface or interface can be orders of magnitude larger than in the bulk. This result can lead to magnetic frustration and reorientation of the magnetization at the surface and interface. For example, when in contact with an antiferromagnet, the properties of a ferromagnet change dramatically; the coercive field is enhanced and, the magnetization curve can become asymmetric showing the exchange bias effect. My research is investigating the complex atomic spin structure of magnetic nanostructures using both analytic and computational approaches in order to gain a fundamental understanding of nanomagnetism.

J. P. Svenne

Our current work involves work with a multi-channel algebraic system (MCAS) to study scattering of nucleons from light nuclei, and reactions initiated by such. This is a four-continent collaboration with Drs. L. Canton, G. Pisent (Padova University, Italy), S. Karataglidis (University of Johannesburg, S.A.) and K. Amos, Paul R. Fraser (now at Padova, It.) and D. van der Knijff (Melbourne University, Australia). The theory uses expansions in Sturmian functions of the channel-coupling interactions, leading to an algebraic solution of the coupled integral equations of the multichannel problem. This enables us to allow for the Pauli principle in the context of a collective model description of the target nucleus, by the use of orthogonalizing pseudo-potentials. The algebraic solution provides us a method of locating all resonances, no matter how narrow, as well as all bound states of the compound system, without the use of an excessively fine energy step sizes. Satisfying the Pauli principle is an essential aspect of the theory, as it removes any spuriosity, in both bound states and resonances and thus provides a theoretical formulation of the scattering problem that has predictive power. The results of the calculations can also be used to give accurate interpretation of the nuclear structure of the target nucleus and the compound system. Our first work was on the well-studied, both theoretically and experimentally, nucleus ^{12}C, with scattering by both neutrons and protons, with inclusion of the Coulomb force. The results compare very well with experiment. We are now working on other light and medium mass nuclear systems including systems well away from the valley of stability. We use the method of mirror nuclei to reach proton-rich nuclei at or near the proton drip line. A “proof of concept” paper for the MCAS method [K. Amos, et al, Nuclear Physics **A728**, 65 (2003)] was our publication in 2006 [L. Canton *et al*,Phys. Rev. Letters, **96**, 072502 (2006)], where we predicted narrow states in the proton-unstable nucleus ^{15}F, whose existence were confirmed in 2009 [Mukha, *et al*, Phys. Rev. C **79**, 061301 (2009)]. Two new developments are our ability, now, to consider systems in which the target nuclei may have particle-unstable excited states, and the ability to apply MCAS to study hypernuclei. The first has been published in a Physical Review Letter and in the Mexican J. of Physics (see publication list, below). The work on hypernuclei has been published in the International Journal of Modern Physics.

G. Tabisz

My research interests involve the theoretical and experimental study of the interaction of light with molecules with the aim of obtaining information on intra- and inter- molecular dynamical processes. Current areas of special interest are nonlinear optical rotation effects in chiral molecules and the theory of collision-broadened spectral line shapes.

J.M. Vail

My principal research area has been in developing and applying methods to simulate the properties of solid materials. Reliable simulation is an important complement to experiment in studying material properties where subtle variations of chemical composition, crystal structure, electronic configuration, and disorder are crucial, or where time scales, and temperature and pressure regimes are experimentally inaccessible. In 1984, with collaborators, we made a major advance in the atomistic simulation of point defects in ionic materials by combining accurate electronic structure methods for the defect with total energy analysis of the crystal. The method includes physically consistent boundary conditions, the quantum-mechanical ion-size effect, and lattice distortion and polarization, and is embodied in an automated user-friendly program. The method has been applied to charge state and structural stability of defect complexes, optical and spin resonance properties of color centers and impurities, local modification of valence and conduction band edges by impurities, derivation of effective interatomic forces, hole trapping and electron loss by impurities in oxides, local phonon mode frequencies, and classical and quantum diffusion.

My current research is on Charge density waves having the electronic properties of graphene: stability conditions. It examines the physical limitations for stability of such CDWs, and the dependence of the total energy upon the parameter which defines the effective electron-electron interaction, including the phonon-mediated component. A report is being written for publication.

D.W. Vincent

My general research interests lie in gravitation theory and early universe cosmology. I am currently involved with calculations on multidimensional cosmology solutions of Einstein’s equations, which have relevance to the cosmological constant problem, the Anthropic Principle, and the Many-Worlds approach to quantum cosmology .

M. Whitmore

My research group does theoretical studies of soft condensed matter systems, in particular inhomogeneous copolymer systems, end-tethered polymers, and phospholipid membranes. Both of these classes of molecules have relatively high molecular weights, have chemically distinct sections, and are chain-like in structure. The copolymer and phospholipid systems can self-assemble to form complex nano-scale structures, and undergo subtle phase transitions. The end-tethered polymers can be used to stabilize colloids, control the properties of functional surfaces, and control transport properties inside microtubles. Our approach is theoretical and computational, using a variety of techniques including self-consistent feld theory and, with our collaborators, Monte Carlo and molecular dynamics simulations. In the areas of copolymers, current work is on the analysis of cylinder-forming polymers, and the use of fluorescence decay measurements to extract detailed interfacial properties in these systems. Our work on end-tethered polymers is on universal control parameters of polymers inside microtubles, and flow through these and other related systems.

J.G. Williams

One of the developing trends in general relativity has been the interest in global, as opposed to local, properties of spacetime. My current research includes spacetimes admitting gravity kinks, i.e. light cone configurations for which the cones tip over an integral number of times. Progress to date includes a kink classification for noncompact product spacetimes in both 3+1 and 2+1 dimensions and the construction of a covariant kink counting number formula in 1+1 dimensions that is related to the Gauss-Bonnet theorem and Morse's Law of Vector Fields. More recently, I have been studying aspects of a new approach to general relativity due to Ted Newman and his group: the null surface formulation. In this approach, it is the intersection of the light cone with null infinity, the so-called light cone cut, that plays the major role. The metric is no longer a fundamental quantity, but is derivable (to within a conformal factor) from the light cone cut function. Progress to-date includes the explicit construction of a light cone cut function for a (2+1)-dimensional Friedman-Robertson-Walker spacetime and the calculation of the standard NSF functions for this model. Future effort will be directed towards the construction of such cut functions for asymptotically flat spacetimes and the analysis of any resulting singularities.

4 Research Activities

4.1 Seminars: 2010-2014

In 2014, WITP began using the Google Hangout service to broadcast seminars privately to members who were unable to attend. While some technological issues remain, we hope to continue to provide this service to our members into the future.

Date	**Speaker**	**Title**
Dec. 3, 2014	H. Fertig	“Topological Edges and Defects of Quantized Hall States in Graphene”
Oct. 22, 2014	Z. Papic	“Entanglement and dynamics in topological phases and interacting disordered systems”
Oct. 10, 2014	S. Kirkland	“Sensitivity Analysis for Perfect State Transfer in Quantum Spin Networks”
Oct. 3, 2014	V. Dwarkadas	“CSI Supernova: Hydrodynamic and X-ray Modeling of the Circumstellar Medium as Clues to Supernova Progenitors”
Sep. 18, 2014	W. Töws	“Many-body theory of laser-induced ultrafast demagnetization and angular momentum transfer in ferromagnetic transition metals”
Sep. 15, 2014	V. Freilikher	“Charge transport in graphen and light propagation in dielectric structures with metamaterials: A comparative study”
July 2, 2014	T. Taves	“Modelling the Evaporation of Non-singular Black Holes”
May 26, 2014	B. Underwood	“Non-Canonical Scalar Fields in Inflation and Reheating”
March 20, 2014	S. Plosker	“On Majorization and Trumping”
Sep. 27, 2013	T. Jones	“The Interplay of Shocks, Turbulence and Magnetic Fields in the Formation of Galaxy Clusters”
Aug. 9, 2013	D. Garfinkle	“Collapse of a Massive Scalar field in AdS”
Apr. 10, 2013	K. Shamseddine	“Characterization of compact and self-adjoint operators, and study of positive operators on a Banach space over a non-Archimedean field”
Feb. 1, 2013	S. Bacca	“From Nuclear Forces to Nuclei”
Nov. 8, 2012	K. Dasgupta	“A UV complete model of large N thermal QCD”
Aug. 16, 2012	E. Hatefi	“Critical Collapse in the Axion-Dilaton system in Diverse Dimensions”
Aug. 15, 2012	J. Babb	“Conformal AdS Dumb Holes and Their Quasinormal Mode Spectrum ”
May 25, 2012	H. Maeda	“Gauss-Bonnet Braneworld Redux: Novel Scenario for the Bouncing Universe”
Apr. 4, 2012,	J. Louko	“Probing a Quantum Field by a Nonstationary Detector ”
Feb. 16, 2012	Robert Brandenberger	”Searching for Cosmic Strings in New Observational Windows”
Nov. 11 2011	A. Ghosh	“The Fluid-Gravity Correspondence and Dumb Holes”
Jan. 17 2011	J. Whitehead	“Microdomain Formation in Ultra-Thin Magnetic Films”’
Nov. 24, 2010	J. Medved	“A Ghost in the Machinery”
Nov. 5, 2010	A. Nielsen	“Black Holes and the Laws of Physics”

4.2 Visitors: 2010-2014

Date	Visitor	Institution	Host
Dec. 2-5, 2014	Herb Fertig	Indiana University	T. Chakraborty
Oct 22-23, 2014	Zlatko Papic	Perimeter Institute	J. Sirker
Oct. 3, 2014	Vikram Dwarkadas	University of Chicago	S. Safi-Harb
Aug. 11 - Sep. 16, 2014	Valentin Freilikher	Bar-Ilan University	J. Page (Manitoba)
May 22-27, 2014	Bret Underwood	Pacific Lutheran University	A. Frey
Jan. 3- July 7, 2014	Tim Taves	C.E.C.s., Chile	G. Kunstatter
Sept. 26-27, 2013	Tom Jones	University of Minnesota	S. Safi-Harb
Aug. 7-10, 2013	David Garfinkle	Oakland University	G. Kunstatter
Jan. 31- Feb. 2, 2013	Sonia Bacca	TRIUMF	J. Svenne
Nov. 7-10, 2012	Keshav Dasgupta	McGill University	A. Frey
Aug. 15-20, 2012	Ehsan Hatefi	I.C.T.P., Trieste	G. Kunstatter/A. Frey
May 21-June 5, 2012	Hideki Maeda	C.E.C.s., Chile	G. Kunstatter
April 1-9, 2012	Jorma Louko	University of Nottingham, U.K.	G. Kunstatter
Feb. 16-18, 2012	R. Brandenberger	McGill Univeresity	G. Kunstatter/A. Frey
Jan.-Apr., 2012	R. Daghigh	Metropolitan State University	G. Kunstatter
Nov. 8-12, 2011	Archisman Ghosh	University of Kentucky	G. Kunstatter
July 1-July 15, 2011	Luciano Canton	INFN, Sezione di Padova, Italy	J. Svenne
Jan 14-18, 2011	John Whitehead	Memorial University	B. Southern
Nov 21-Nov27, 2010	Joey Medved	KIAS, South Korea	G. Kunstatter
Oct 31-Nov 6, 2010	Alex Nielsen	Max Planck Institute	G. Kunstatter
June 20-July 4, 2010	Luciano Canton	INFN, Sezione di Padova, Italy	J. Svenne
May - June 2010	Zhoufei Wang	South China Agricultural University, Guangzhou, China	J. Vail

4.3 Summer Student Symposium 2014

In August 2014, the WITP held its third Summer Student Symposium at Brandon University. Graduate students and undergraduate students working with WITP members between May and August were invited to give a short oral presentation of their work in a somewhat formal but friendly setting. It was a one day event with coffee and lunch provided for all speakers and attendees. The symposium was a great success with about twenty people attending altogether. It provided the students, and the WITP, an opportunity to showcase the world class research in theoretical physics that is being done in Manitoba. This has become a very successful annual event for the WITP.

The schedule of talks is given in the Appendix to this report.

4.4 Public Lecture

On 21 May 2014, the WITP co-sponsored a public lecture with the 15th Canadian Conference on General Relativity and Relativistic Astrophysics, which was held in Eckhardt-Gramatte Hall at the University of Winnipeg. The lecture, titled "Higgs Bang," was presented by Neil Turok, the Director and Niels Bohr Chair of the Perimeter Institute and the 2013 CBC Massey Lecturer. This was a rare event for Winnipegers to see one of the leading minds of cosmology, and close to 200 people attended. The lecture poster is included in the Appendix.

4.5 Conferences and National Events

- The 15th Canadian Conference on General Relativity and Relativistic Astrophysics was held at the University of Winnipeg from 20-23 May 2014. Approximately 70 scientists attended, with 10 invited plenary talks by leading national and international physicists and 45 contributed talks. The WITP provided $2000 of funding for this biennial conference (previously held in Winnipeg in 1991) and also co-sponsored a public lecture with the conference. WITP members A. Frey, R. Danos, G. Kunstatter, and D. Vincent organized the conference. The conference poster and program are given in the Appendix.

- The WITP also provide modest support in recent years for several national theoretical physics conferences:

  - Canadian Prairie Theoretical Physics Network meeting, Lethbridge, AB, 2010 ($1,000.00).
  - Theory Canada VII, Lethbridge, AB, 2012 ($400).
  - Theory Canada 9, Wilfrid Laurier University, Waterloo, ON, 2014 ($500)

- The WITP also entered into an agreement with the Canadian Association of Physicists Division of Theoretical Physics to co-sponsor a prize for the best Ph.D. thesis in theoretical physics each year. The WITP will provide $250/year for the first three years, at which point the agreement may be renewed. The prize will be known as the DTP/WITP Thesis Prize, and the WITP Past Director will sit on the award committee. 2015 will be the first year that the prize is awarded.

4.6 Graduate Degrees Supervised

1. Paul Mikula (2014), "Yang-Mills Flow in 1+1 Dimensions Coupled with a Scalar Field," M.Sc. thesis (Carrington/Kunstatter)

2. Bradley Cownden (2014), "Linear Perturbations of Type IIB SUGRA in Flux Compactifications," M.Sc. thesis (Frey)

3. Erica Franzmann (2014), "Modeling Submillimetre Polarization of Molecular Cloud Cores Using Successive Parametrized Coordinate Transformation," M.Sc. thesis (Fiege)

4. Heather Matheson (2014), "Investigating the Properties of Pulsar Wind Nebulae Without Prominent Supernova Remnant Shells: X-Ray Observations of the Young Pulsar Wind Nebula G21.5-0.9, and the Evolved Pulsar Wind Nebulae CTB 87 (G74.9+1.2) and G63.7+1.1.," Ph.D. thesis (Safi-Harb)

5. Siranush Avetisyan (2014), "Fock-Darwin States of Anisotropic Quantum Dots with Rashba Spin–Orbit Coupling," M.Sc. thesis (Chakraborty).

6. Harsha S. Kumar (2013), "X-ray studies of highly magnetized neutron stars and their environs," Ph.D. thesis (Safi-Harb).

7. Tim Taves (2013), "Black Hole Formation in Lovelock Gravity," Ph.D. thesis (Kunstatter).

8. Adam Rogers (2012), "Gravitational Lens Modeling with Iterative Source Deconvolution and Global Optimization of Lens Density Parameters," Ph.D. thesis (Fiege)

9. Heather Champion (2012), M.Sc. thesis (co-supervisors: J. Fiege with B. McCurdy, Manitoba).

10. Alex Mirza (2012), "Thermal Field Theory and the Hard Thermal Loop Resummation," M.Sc. thesis (Carrington).

4.7 Publications of Permanent Members

M.E. Alexander

1. B. Dietz, E. Elhami, M. Alexander, "Registration of positron emission tomography and magnetic resonance imaging for use in stem cell quantification studies of the infarcted myocardium," Accepted: Phys. Med. Biol. (Oct. 2014).

2. R. Bergen, H. Lin, M. Alexander, and C. Bidinosti. "4-D MR phase and magnitude segmentations with GPU parallel computing,". Accepted Magnetic Resonance Imaging (Oct. 2014).

3. M.E. Alexander, M. Mercredi. "A model for cell migration in competing chemotactic fields." Canadian Applied Mathematics Quarterly, accepted April 2014.

4. Q. Zhang, M.E. Alexander, L. Ryner. "Multimodality Neurological Data Visualization with Multi-VOI Based DTI Fiber Dynamic Integration." IEEE Journal of Biomedical and Health Informatics, **PP** Issue 99, 2014.

5. Q. Zhang, M. Alexander, L. Ryner. Synchronized 2D/3D optical mapping for interactive exploration and real-time visualization of multi-function neurological images. Computerized Medical Imaging and Graphics, **37** (7-8): 552 (2013).

6. M.E. Alexander, R. Kobes. "Effects of vaccination and population structure on influenza epidemic spread in the presence of two circulating strains." BMC Public Health, **11** (Suppl 1), S8 (2011).

7. B. Schattka, M. Alexander, S. Low Ying, A. Man, R.A. Shaw. "Metabolic fingerprinting of biofluids by infrared spectroscopy: Modeling and optimization of flow rates for laminar fluid diffusion interface sample preconditioning." Analytical Chemistry **83** (2): 555 (2011).

8. Murray E. Alexander, Randy Kobes, "Generating and solving the mean field and pair approximation equations in epidemiological models" (submitted to Computer Physics Communications) ; arXiv:1007.2883.

9. Murray E. Alexander, Randy Kobes, "Expansion of the conditional probability function in a network with nearest-neighbour degree correlations" (submitted to Phys. Rev. E); arXiv:1007.0717

10. M.E. Alexander, S.M. Dietrich, Y. Hua, and S.M. Moghadas. "A comparative evaluation of modelling strategies for the effect of treatment and host interactions on the spread of drug resistance," J. Theor. Biol. **259**, 253 (2009).

11. T.J. Vincent, J.D. Thiessen, L.M. Kurjewicz, S.L. Germscheid, A.J.. Turner, P Zhilkin, M.E. Alexander, M. Martin. "Longitudinal Brain Size Measurements in APP/PS1 Transgenic Mice," Magnetic Resonance Insights **4**, 1 (2010).

S. Bacca

1. NEUTRINO-PAIR BREMSSTRAHLUNG FROM NUCLEON-α VERSUS NUCLEON-NUCLEON SCATTERING
R. Sharma, S. Bacca and A. Schwenk, submitted to Phys. Rev. C, arXiv:1411.3266.

2. GIANT AND PIGMY DIPOLE RESONANCES IN ^{4}HE, ^{16,22}O AND ^{40}CA FROM CHIRAL NUCLEON-NUCLEON INTERACTIONS
S. Bacca, N. Barnea, G. Hagen, M. Miorelli, G. Orlandini and T. Papenbrock, accepted on Phys. Rev. C, arXiv:1410.2258.

3. Electromagnetic Reactions on Light Nuclei
S. Bacca and S. Pastore, commissioned topical review, J. Phys. G: Nucl. Part. Phys. **41** 123002 (2014).

4. Improved estimates of the nuclear structure corrections in μD
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11. C. Danielle Leonard, J. Ziprick, G. Kunstatter and R. Mann, "Gravitational collapse of K-essence matter in Painleve-Gullstrand coordinates", JHEP **2011** 28 (2011); arXiv:1106.2054.

12. J. Babb, R. Daghigh and G. Kunstatter, "Highly Damped quaisnormal modes and the small scale structure of quantum corrected black holes", Phys. Rev. **D84** 084031 (2011); arXiv:1106.4357.

13. D. Buhr, M.E. Carrington, T. Fugleberg, R. Kobes, G. Kunstatter, D. McGillis, C. Pugh, D. Ryckman, "Geometrical entanglement of highly symmetric multipartite states and the Schmidt decomposition" Journal of Phys. A: Math.Theor. **44** 365305 (2011); arXiv:1104.3159

14. Tim Taves and Gabor Kunstatter, "Higher Dimensional Choptuik Scaling in Painleve Gullstrand Coordinates", Phys. Rev. **D84** 044034 (2011); arXiv:1105.0878

15. G. Kunstatter, J. Louko, and A. Peltola, "Quantum dynamics of the Einstein-Rosen wormhole throat", Phys. Rev. D 83, 044022 (2011); arXiv:1010.3767

16. M. Carrington, R. Kobes, G. Kunstatter, D. Ostapchuk and G. Passante, , "Geometric measures of entanglement and the Schmidt decomposition ", J. Phys. A. **43** 315302 (2010); arXiv:1003.4755 .

17. J. Ziprick and G. Kunstatter, "Quantum Corrected Spherical Collapse: A Phenomenological Framework" Phys.Rev.D82:044031 (2010); arXiv:1004.0525 .

18. G. Kunstatter, J. Louko and A. Peltola, "Polymer quantization of the einstein-rosen wormhole throat", Phys.Rev.D81:024034 (2010) ; arXiv:0910.3625.

Chapters in Books

19. J. Gegenberg and G. Kunstatter, "Midi-superspace models for quantum black holes", **(invited)** *Recent Research in Quantum Gravity*, (Nova Scientific, 2012) ed. A. Dasgupta.

20. J. Gegenberg and G. Kunstatter, "2-D Midisuperspace Models for Quantum Black Holes", **(invited)** published in 'Fundamental Interactions: A Memorial Volume for Wolfgang Kummer,' Editors: Daniel Grumiller, Anton Rebhan and Dimitri Vassilevich, World Scientific, 2010, pp.231-247; arXiv:0902.0292

Invited papers presented at meetings

21. G. Kunstatter, "Spherically Symmetric Black Hole Formation in Lovelock Gravity"**Invited**, Black Holes IX, Saskatoon, May, 2013.

22. "Boundary Conditions for Quantum Mechanics on the Discretized Half Line" **Invited**, CAP Congress, Montreal, May, 2013.

23. G. Kunstatter, "Lovelock gravity: geometrodynamics and quantum mechanics", **Invited**, CAP Congress, U. Calgary, June, 2012.

24. G. Kunstatter, "Quantum Mechanics on the Discretized Half Line" **Invited**, CMS Meeting, Regina, June 2012.

25. G. Kunstatter, “Singularity Resolution Inside Radiating 2-D Black Holes” **(Invited)**, Black Holes: New Horizons, BIRS Workshop, Banff, November, 2011.

26. G. Kunstatter, “Quantum Corrected Spherical Collapse: A Phenomenological Framework”, **(Invited)**, CMS Annual Meeting, Fredericton, June, 2010.

27. G. Kunstatter, , **(Invited)** CAP Congress, Toronto, June, 2010.

Invited Lectures

28. “Black hole information loss: is there light at the end of the tunnel?”, UWinnipeg, October, 2014.

29. “Black hole information loss: is there light at the end of the tunnel?”, SFU, October, 2014.

30. “Stability of AdS Spacetime in Einstein-Gauss-Bonnet Gravity”, SFU, October, 2014.

31. “Black hole information loss: let’s lose the singularity instead of the information”, UNB, July, 2014.

32. “Quantum Mechanics of the Interior of Radiating 2D Black Holes”, Rykkyo University, Tokyo, June, 2013.

33. “Lovelock Gravity: Geometrodynamics and Quantum Mechanics”, Univerite de Montreal, March 2012.

34. “Singularity resolution inside radiating black holes”, McGill University, March, 2012.

35. “Singularity resolution inside radiating black holes”, Universit de Montreal, December, 2011.

36. “Singularity resolution inside radiating black holes”, C.E.C.S. Valdivia, Chile, October, 2011.

P.D. Loly

1. Ian Cameron, Adam Rogers & Peter Loly, ”Signatura of magic and Latin integer squares: isentropic clans and indexing”, Discussiones Mathematicae Probability and Statistics, xx (xxxx) 129, online c. December 2013, in paper 2014.

2. Loly, P.D, Styan, G.P.H. ”Philatelic Latin squares”, in Proceedings of the Canadian Society for History and Philosophy of Mathematics (35th Annual Meeting, Concordia University), A. Cupillari, ed. 23 (Montreal, QC 2010), pp. 273-297. (C1)

3. Peter D. Loly and George P. H. Styan, ”Some comments on 5x5 philatelic Latin squares”, CHANCE (2010) 23(2): 57-62, April 01, 2010, (C1)

4. Peter D. Loly and George P. H. Styan, ”Some comments on 4x4 philatelic Latin squares”, CHANCE (2010) 23(1): 57-62, March 01, 2010, (C1)

Talks

5. Peter Loly (speaker), with Ian Cameron and Adam Rogers, ”Shannon entropy of small matrices for physicists”, Colloquium, 7 Nov. 2014, Department of Physics and Astronomy, University of Manitoba.

6. Peter Loly (speaker), with Adam Rogers and Ian Cameron, ”Knut Vik Designs are Multimagic””, CMS Summer 2014, 7 June, Winnipeg.

7. Peter Loly (presenter) ”Board Games on a square grid - Sudoku, chess, and magic squares - from refereed papers to personal web pages or vice versa”, at the August 2012 University of Iceland - University of Manitoba 2012 Partnership Conference, on ”Origins”, Reykjavik.

8. Ian Cameron, Adam Rogers & Peter Loly (all presenters) Bewedlo, ”Signatura of magic and Latin integer squares: isentropic clans and indexing”, IWMS21 and LINSTAT2012 conferences at Bedlewo, Poland.

Book Review

9. Reviewed by Peter D. Loly: “Before Sudoku – The World of Magic Squares”, by Seymour S. Block and Santiago A. Tavares, 2009, Oxford, 239 pages. ISBN-10: 0195367901, ISBN-13: 978-0195367904, in IMAGE, The Bulletin of the International Linear Algebra Society (ILAS) 47, Fall 2011, page 24.

T.A. Osborn

1. Karl-Peter Marzlin and T. A.Osborn, ”Quantum Collapse Bell Inequalities”, Phys. Rev. A 89, 032123, (2014)

Conference Proceedings and Invited Talks

2. T. A.Osborn, Aharonov-Bohm Effect without Potentials, Theory Canada 7, Lethbridge, AB, June 9, 2012 (Invited talk).

S. Plosker

Peer-Reviewed Journal Articles

1. R. Pereira and S. Plosker. *Extending a characterization of majorization to infinite dimensions.* Linear Algebra and its Applications, in press, DOI: 10.1016/j.laa.2014.01.026.

2. T. Jochym-O’Connor, D. W. Kribs, R. Laflamme, and S. Plosker. *Quantum subsystems: Exploring the complementarity of quantum privacy and error correction.* Physical Review A, **90**, 032305, 2014.

3. D. W. Kribs and S. Plosker. *Private quantum codes: introduction and connection with higher rank numerical ranges.* Linear and Multilinear Algebra, **62**, pp. 639-647, 2014.

4. T. Jochym-O'Connor, D. W. Kribs, R. Laflamme, and S. Plosker. *Private quantum subsystems.* Physical Review Letters, **111**, 030502, 2013.

5. R. Pereira and S. Plosker. *Dirichlet polynomials, majorization, and trumping.* Journal of Physics A: Mathematical and Theoretical, **46**, 225302, 2013.

6. D. Farenick, R. Floricel, and S. Plosker. *Approximately clean quantum probability measures.* Journal of Mathematical Physics, **54**, Issue 5, 052201, 2013.

7. D. W. Kribs, R. Pereira, and S. Plosker. *Trumping and power majorization.* Linear and Multilinear Algebra, **61**, pp. 1455-1463, 2013.

8. D. Farenick, S. Plosker, and J. Smith. *Classical and nonclassical randomness in quantum measurements.* Journal of Mathematical Physics, **52**, Issue 12, 122204, 2011.

9. A. Church, D. W. Kribs, R. Pereira, and S. Plosker. *Private quantum channels, conditional expectations, and trace vectors.* Quantum Information & Computation (QIC), **11**, no. 9 & 10, pp. 774 - 783, 2011.

S. Safi-Harb

1. Jackson, M., Safi-Harb, S., & Kothes, R. 2014, MNRAS, 444, 2228

2. Ferrand, G., Danos, R., Shalchi, A., Safi-Harb, S., Edmon, P. & Mendygral, P. 2014, ApJ, 792, 133

3. Ferrand, G., Decourchelle, A., Safi-Harb, S. 2014, ApJ, 789, 49

4. Zhou, P., Safi-Harb, S., Chen, Y. Zhang,X., Jiang,B., Ferrand,G. 2014, ApJ, 791, 87

5. Zhou, P., Chen, Y., Li, X.-D., Safi-Harb, S., Mendez, M., Terada, Y., Sun, W. 2013, Ap.J. (Letters), 781, L16

6. Kumar, H. S., Safi-Harb, S., Slane, P., & Gothelf, E. V. 2013, Ap.J., 781, 41

7. Matheson, H., Safi-Harb, S., & Kothes, R. 2013, Ap.J., 774, 33

8. Ferrand, G., Decourchelle, A., & Safi-Harb, S. 2012, Ap.J., 760, 34

9. Kumar, H. S., Safi-Harb, S., & Gonzalez, M. E. 2012, Ap.J., 754, 96

10. Ferrand, G., & Safi-Harb, S. 2012, Advances in Space Research, 49, 1313

11. Arzoumanian, Z., Gotthelf, E. V., Ransom, S. M., Safi-Harb, S., Kothes, R., & Landecker, T. 2011, Ap.J., 739, 39

12. Bietenholz, M. F., Matheson, H., Safi-Harb, S., Brogan, C., & Bartel, N. 2011, MNRAS, 412, 1221

13. Kumar, H. S., & Safi-Harb, S. 2010, Ap.J.Lett., 725, L191

14. Matheson, H., & Safi-Harb, S. 2010, Ap.J., 724, 572

15. Kumar, H. S., Ibrahim, A. I., & Safi-Harb, S. 2010, Ap.J., 716, 97

16. Jiang, B., Chen, Y., Wang, J., Yang, Zhou, X., Safi-Harb, S., & DeLaney, T. 2010, Ap.J., 712, 1147

Proceedings Papers

17. Safi-Harb, S., for the ASTRO-H team, American Astronomical Society Meeting, Seattle, 4-8 Jan. (2015)

18. Takahashi, T. et al. 2014, Proceedings of the SPIE Astronomical Instrumentation, arXiv:1412.1356 (2014)

19. Ferrand, G. & Safi-Harb, S., Cosmic Rays and the Interstellar Medium (CRISM 2014), Proceedings of Science, paper I on the simulations, in press

20. Ferrand, G. & Safi-Harb, S., Cosmic Rays and the Interstellar Medium (CRISM 2014), Proceedings of Science, paper II on the SNR catalogue, in press

21. Hughes, J. P., Safi-Harb, S. et al., 40th COSPAR Scientific Assembly; Moscow, Russia, Aug. (2014)

22. Zhou, P., Chen, Y., Safi-Harb, S. & Ming, S., 40th COSPAR Scientific Assembly; Moscow, Russia, Abstract E1.16-41-14, Aug. (2014)

23. Zhou, P. et al., 40th COSPAR Scientific Assembly; Moscow, Russia, Abstract E1.12-20-14., Aug. (2014)

24. Zhou, P., Safi-Harb, S. et al., Proceedings of the IAU Symposium, Cambridge U. Press, Volume 296, 360 (2014)

25. Kumar, H. S., Safi-Harb, S., Slane, P., & Gotthelf, E. V., Proceeding of the IAU Symposium, Cambridge U. Press, Volume 296, 235 (2014)

26. Safi-Harb, S., Ferrand, G., & Matheson, H. 2013, Proceedings of the IAU Symposium, 291, 483, Cambridge U. Press (arXiv:1210.5264)

27. Safi-Harb, S., & Kumar, H. S. 2013, Proceedings of the IAU Symposium, 291, 480, Cambridge U. Press (arXiv:1210.5261)

28. Safi-Harb, S. 2013, Proceedings of the IAU Symposium, 291, 251, Cambridge U. Press (arXiv:1211.0852; invited review)

29. Takahashi, T., Mitsuda, K., Kelley, R.,... Safi-Harb et al. 2012, Proc. SPIE, 8443, 22pp. (arXiv:1210.4378)

30. Safi-Harb, S. 2012, American Institute of Physics Conference Series, 1505, 13 (arXiv:1210.5406; invited review)

31. West, J. L., Safi-Harb, S., & Foster, T., Astronomical Society of the Pacific Conference Series, 438, 354 (2010)

Conference Organization

32. Main Scientific Organizer for the Committee for Space Research (COSPAR) session on Supernova Remnants and Pulsar Wind Nebulae held in Bremen, Germany during July (2010). The report summarizing *New Insights into the Physics of SNRs and PWNe*, edited by S. Safi-Harb, was published in the COSPAR's Information Bulletin 'Space Research Today', Volume 180, P. 20-22 (2011). On-line proceedings published at: http://www.physics.umanitoba.ca/~samar/COSPAR2010E19.

White Papers and Reports to agencies

33. Young Supernova Remnants, Hughes, Safi-Harb et al., ASTRO-H White Paper, arXiv:1412.1169

34. Older Supernova Remnants and Pulsar Wind Nebulae, Long et al., ASTRO-H White Paper, arXiv:1412.1166

35. Accreting Pulsars, Magnetars, and Related Sources, Kitamoto, Enoto, Safi-Harb et al., ASTRO-H White Paper, arXiv:1412.1165

36. *plus* 13 other white papers for the ASTRO-H team (all posted on the arXiv on 03 Dec 2014): arXiv:14121190, 1412.1179, 1412:1177, 1412:1176, 1412:1175, 1412:1174, 1412:1173, 1412:1172, 1412:1171, 1412:1170, 1412:1164, 1412:1163, 1412:1162.

37. Astro-H White Paper on Young Supernova Remnants by Hughes, J. P., Safi-Harb, S. et al., submitted to the ASTRO-H science office at ISAS/JAXA (2013).

38. Astro-H White Paper on Old Supernova Remnants and Pulsar Wind Nebulae by Long, K. et al. including Safi-Harb, submitted to the ASTRO-H science office at ISAS/JAXA (2013).

39. Astro-H White Paper on High-Mass X-ray Binaries and Magnetars by Kitamoto, Enoto, T., Safi-Harb, S. et al., submitted to the ASTRO-H science office at ISAS/JAXA (2013).

40. The Origin of the Elements and The Nuclear Physics of Extreme Matter and Astrophysical Explosions, Canadian Nuclear Astrophysics White Paper. Contributors: Bacca, S., Buchmann, L., Chen, A., Cumming, A., Davids, B., Fryer, C., Heinke, C., Herwig, F., Kruecken, K., Navratil, P., Ouyed, R., Ruiz, C., Safi-Harb, S., Venn, K., Nov. (2011).

41. The Future of X-ray Astronomy in Canada by Gallo, L. Babul, A., Cumming, A., Gallagher, S., Hall, P., Hanna, D., Heinke, C., Heyl, J., Holder, G., Hutchings, J., Ivanova, N., Kaspi, V., Leahy, D., McNamara, B., Moffat, A., Moon, D.-S.,

Nelson, L., Ouyed, R., Ragan, K., Rutledge, R., Safi-Harb, S., Stairs, S., Taylor, J., Thompson, C., & van Kerkwijk, M., submitted to Canada's Long Range Plan (LRP), Feb. (2010).

42. Neutron Stars by Stairs, I. Thompson, C. Heyl, J., Ivanova, N., Kaspi, V., Ouyed, R., Pfeiffer, H, Safi-Harb, S., & van Kerkwijk, M., submitted to Canada's Long Range Plan (LRP), Feb. (2010).

Invited Talks and Colloquia

43. Supernova Remnants: An Astrophysical Factory for High-Energy and Exotic Phenomena, Colloquium at the U. of Alberta, 13 Nov. (2014)

44. Two lectures on Supernova Remnants, Pulsar Wind Nebulae and Neutron Stars, ASTRO-H 5th Summer School, Paris (France), July (2014)

45. Neutron Stars, CCGRA15, U. of Winnipeg, 21-23 May (2014)

46. Pulsar Wind Nebulae and Magnetars, ASTRO-H HXI/SGD Workshop at Hiroshima U. (Japan), 24-25 Feb. (2014)

47. Pulsar Wind Nebula – Supernova Remnant Interaction, International Astronomical Union Symposium entitled 'Supernova Environmental Impacts', Calcutta, India, 6–11 Jan. (2013).

48. Neutron Stars and Supernova Remnants, International Astronomical Union Symposium 291 entitled 'Neutron Stars and Pulsars: Challenges and Opportunities after 80 years', Beijing, China, 20–31 Aug. (2012).

49. Supernova Remnants as Cosmic Laboratories for Studying the Physics of the Extreme and our Origins, Women in Physics Conference, University of British Columbia, Vancouver, Canada, 2–4 Aug. (2012).

50. Plerionic Supernova Remnants, 5th International Symposium on High-Energy Gamma-Ray Astronomy dedicated to a centenary of cosmic ray research, Heidelberg, Germany, 9–13 July (2012).

51. Invited to give a talk on Neutron Stars at the 13th Marcel Grossmann Meeting, Stockholm, 1–7 July (2012).

52. Supernova Remnants and Neutron Stars in X-rays, Colloquium at St. Mary's University, Halifax, Canada, 30 March. (2012).

53. The High-Energy Universe, Physics and Astronomy Day, University of Manitoba, Canada, 26 Nov. (2011).

54. The Diversity of Neutron Stars Associated with Supernova Remnants: Highlights from Recent X-ray Discoveries, American University of Beirut, Lebanon, 27 July (2011).

55. Viewing the Universe and Supernova Remnants Through X-ray Eyes, keynote lecture for the 100th anniversary of the Royal Astronomical Society (Winnipeg Chapter), General Assembly meeting, Winnipeg, Canada, 3 July (2011).

56. Supernova Remnants and Neutron Stars: The Hunt for the Heavy Elements and the Extreme in a Violent Universe, Max-Planck-Institut fur extraterrestrische Physik in Garching, Germany, July 20 (2010).

57. Supernova Remnants as Nearby Laboratories for the Study of Extreme Physics and the Lifecycles of Matter and Energy, Physics and Astronomy Colloquium (Prairie Series), University of Calgary, 26 March (2010).

58. Supernova Remnants as Nearby Laboratories for the Study of Extreme Physics and the Lifecycles of Matter and Energy, U. of Lethbridge (Prairie Series), 25 March (2010).

Conference Presentations

59. Supernova remnants as astrophysical laboratories for the formation of the elements, Braun, C. & Safi-Harb, S., WITP, Winnipeg, Aug. (2013)

60. A new galactic pulsar candidate revealed by the Chandra X-ray Observatory, Guest, B. & Safi-Harb, S., WITP, Winnipeg, Aug. (2013)

61. Young Supernova Remnants with Astro-H, Safi-Harb for the ASTRO-H Science Working Group on Young SNRs, Yale U. (2013)

62. Magnetars and High-Mass X-ray Binaries with Astro-H, Kitamoto et al., ASTRO-H Science Working Group on compact objects, Yale U., Jul (2013)

63. Old Supernova Remnants and Pulsar Wind Nebulae with Astro-H, Long et al., ASTRO-H Science Working Group on Old SNRs and PWNe, Yale U., Jul (2013)

64. Bilateral Symmerty in Supernova Remnants and the Connection to the Galactic Magnetic Field, West, J., Safi-Harb, S. Jaffe, T., Kothes, R., Landecker, T., & Foster, T., Seventh NAIC/NRAO Single-Dish Summer School, Puerto Rico, July (2013).

65. The Astro-H X-ray Mission, Safi-Harb, S., Gallo, L., McNamara, B. et al., CASCA, U. of British Columbia, May (2013).

66. Applications of Global Optimization Methods in High-Energy Astrophysics, Rogers, A., Safi-Harb, S., & Fiege, J., CASCA, U. of British Columbia, May (2013).

67. Modelling polarized radio emission from supernova remnants, West, J., Safi-Harb, S. Jaffe, T., Kothes, R., Landecker, T., & Foster, T., CASCA, U. of British Columbia, May (2013).

68. Modelling polarized radio emission from supernova remnants, West, J., Safi-Harb, S. Jaffe, T., Kothes, R., Landecker, T., Foster, T., S, & Landecker, T. 2010, International EMU/POSSUM/GALFACTS Meeting, British Columbia, May (2013).

69. Prospects for Astro-H studies of Young SNRs, Old SNRs and PWNe, and High-Mass X-ray Binaries+Magnetars; a total of 9 posters total for the ASTRO-H Science Working Group Meeting, Tsukuba, Japan, Feb. (2013).

70. An XMM-Newton study of the mixed?-morphology supernova remnant W28, Zhou, P., Safi-Harb, S. et al., Supernova Environmental Impacts, IAU Symposium No. 296, Calcutta, India, Jan. (2013).

71. X-ray imaging and spectroscopic study of the SNR Kes 73 hosting the magnetar 1E 1841–045, Kumar, H. S., Safi-Harb, S., Slane, P., & Gotthelf, E. V., Supernova Environmental Impacts, IAU Symposium No. 296, Calcutta, India, Jan. (2013).

72. Pulsar Wind Nebulae, Kumar delivered on behalf of Safi-Harb, Supernova Environmental Impacts, IAU Symposium No. 296, Calcutta, India, Jan. (2013).

73. Pulsar Wind Nebulae: On their growing diversity and association with highly magnetized neutron stars, Safi-Harb, S., IAU Symposium 291: Neutron Stars and Pulsars: Challenges and Opportunities after 80 years, Beijing, China, 20–31 Aug. (2012).

74. A high-energy catalogue of galactic SNRs and PWNe, Safi-Harb, S., Ferrand, G., & Matheson, H. 2013, IAU Symposium 291: Neutron Stars and Pulsars: Challenges and Opportunities after 80 years, Beijing, China, 20–31 Aug. (2012).

75. On the environments and progenitors of supernova remnants associated with highly magnetized neutron stars, Safi-Harb, S. & Kumar, H. S., IAU Symposium 291: Neutron Stars and Pulsars: Challenges and Opportunities after 80 years, Beijing, China, 20–31 Aug. (2012).

76. 3D simulations of the emission from young supernova remnants including particle acceleration, Ferrand, G., Safi-Harb, S., The Cosmic Kaleidoscope, Pulsars and their Nebulae, Supernova Remnants and More, Kruger Park, S. Africa, 13–17 Aug. (2012).

77. An X-ray study of the pulsar wind nebula G63.7+1.1 with Chandra and XMM-Newton, Matheson, S., Safi-Harb, S., & Kothes, R., The Cosmic Kaleidoscope, Pulsars and their Nebulae, Supernova Remnants and More, Kruger Park, S. Africa, 13–17 Aug. (2012).

78. A Census of High-Energy Observations of Galactic Supernova Remnants and Pulsar Wind Nebulae, Ferrand, G., Safi-Harb, S., & Matheson, H., The Cosmic Kaleidoscope, Pulsars and their Nebulae, Supernova Remnants and More, Kruger Park, S. Africa, 13–17 Aug. (2012).

79. An XMM-Newton Study of the Mixed-?Morphology Supernova Remnant W28, Zhou, P., Safi-Harb, S. et al.. The Cosmic Kaleidoscope, Pulsars and their Nebulae, Supernova Remnants and More, Kruger Park, S. Africa, 13–17 Aug. (2012).

80. Plerionic Supernova Remnants, Safi-Harb, S., the 5th Symposium on Gamma-Ray Astronomy, Heidelberg, Germany, 9–13 Jul. (2012).

81. SNR Plasmas White Paper Task Force, Hughes, J., Safi-Harb, S. et al., Astro-H Science Working Group (SWG) meeting, Cambridge, U.K., 9–11 Jul. (2012).

82. Magnetars/High-Mass-X-ray Binaries White Paper Task Force, Enoto, Kitamoto, Safi-Harb, S. et al., Astro-H SWG meeting, Cambridge, U.K., 9–11 Jul. (2012).

83. SNR Dynamics White Paper Task Force, Long, K. et al. including Safi-Harb, S., Astro-H SWG meeting, Cambridge, U.K., 9–11 Jul. (2012).

84. The Astro-H X-ray Observatory: The mission, science, and Canadian participation, Gallo, L., Safi-Harb, S. (presenter), McNamara, B., on behalf of the Astro-H team, Canadian Astronomical Society Meeting (CASCA), U. of Calgary, 4–7 June (2012).

85. 3D simulations of the emission from young supernova remnants including particle acceleration, Ferrand, G., Safi-Harb, S., Decourchelle, A., Pomarede, D., Canadian Astronomical Society Meeting (CASCA), U. of Calgary, 4–7 June (2012).

86. On the Plerionic Supernova Remnant CTB 87 (G74.9+1.2) and Its Powering Engine: Insights from the Chandra X-ray Observatory on Evolved Plerions by Safi-Harb, S., Matheson, H., Kothes, R., American Astronomical Society (AAS) Meeting #218, #228.08; Bulletin of the American Astronomical Society, Vol. 43, 2011, Boston, MA (2011).

87. 3D simulations of the morphological and spectral evolution of supernova remnants undergoing particle acceleration, Ferrand, G. & Safi-Harb, S., Canadian Astronomical Society (CASCA) Meeting, University of Western Ontario, London, ON, 30 May–2 June (2011).

88. A Multi-wavelength Study of the Pulsar Wind Nebula G63.7+1.1 by Matheson, H., Safi-Harb, S., Kothes, R. & Fedotov, K., CASCA, University of Western Ontario, London, ON, 30 May-2 June (2011).

89. X-ray and Radio Studies of the Plerionic SNR CTB 87 (G74.9+1.2): an Evolved PWN? by Safi-Harb, S., Matheson, H. & Kothes, R., CASCA, University of Western Ontario, London, ON, 30 May-2 June (2011).

90. Modeling supernova remnants using radio and X-ray data by West, J., Safi-Harb, S. & Foster, T., GALFACTS/POSSUM workshop, Calgary, Aug. (2010).

91. Arzoumanian, Z., Safi-Harb, S., Ransom, S., Kothes, R., & Landecker, T. 2010, 38th COSPAR Scientific Assembly, 38, 2807

92. Kothes, R., Safi-Harb, S., Matheson, H., & Fedotov, K. 38th COSPAR Scientific Assembly, 38, 2805, Bremen, Germany, Jul. (2010)

93. West, J., Safi-Harb, S., & Foster, T. 2010, 38th COSPAR Scientific Assembly, 38, 2796, Bremen, Germany, Jul. (2010)

94. Matheson, H., Safi-Harb, S., & Bietenholz, M. 2010, 38th COSPAR Scientific Assembly, 38, 2784, Bremen, Germany, Jul. (2010)

95. Matheson, H., & Safi-Harb, S. 2010, 38th COSPAR Scientific Assembly, 38, 2783, Bremen, Germany, Jul. (2010)

96. Safi-Harb, S., & Franzmann, E. 2010, 38th COSPAR Scientific Assembly, 38, 2782, Bremen, Germany, Jul. (2010)

97. Safi-Harb, S. 2010, 38th COSPAR Scientific Assembly, 38, 2767, Bremen, Germany, Jul. (2010)

98. Kumar, H. S., Safi-Harb, S., Slane, P., & Gotthelf, E. 2010, 38th COSPAR Scientific Assembly, 38, 2766, Bremen, Germany, Jul. (2010)

99. Jiang, B., Chen, Y., Wang, J., Zhou, X., Safi-Harb, S., DeLaney, T. 2010, 38th COSPAR Scientific Assembly, 38, 2755, Bremen, Germany, Jul. (2010)

Media and Press Releases

100. 'Travels Through Space': Interview and article featuring Safi-Harb's group's research in the International Innovation magazine published by ResearchMedia, July (2013).

101. '3D Simulations of Supernova Remnants', U. of Manitoba and CEA/Saclay Press Release, Nov. (2012)

102. UofM's Research Life interview and feature article, Jan. (2012)

103. 'Canadian stellar sleuth seeks to unravel mysteries of exploding stars', Radio Canada International (RCI) interview, The Link. Broadcast replayed as one of their 'Best of 2011' shows during the holiday period (Dec. 2011).

104. Canadian Space Agency News announcing the three Canadian Science Working Group Members: 'Canada Partners on Upcoming Japanese X-ray Space Observatory', Aug. (2011).

105. U. of Manitoba Press Release, 'Winnipeg-sized magnet bursting in a supernova remnant: Burst from an X-ray source challenges magnetar prediction', Dec. (2010).

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Conference Proceedings and Talks

71. Dosch, A. and Shalchi, A., Particle Scattering in Magnetized Plasmas and Diffusive Shock Acceleration at Perpendicular Interplanetary Shock Waves, Partially Ionized Plasmas throughout the Cosmos. 2010 Huntsville Workshop. 2011, American Institute of Physics Conference Proceedings, 1366, 13

Khodr M. Shamseddine

Refereed Journal Publications

1. On the solutions of linear ordinary differential equations and Bessel-type special functions on the Levi-Civita field, *Alpár Mészáros and Khodr Shamseddine*, **Journal of Contemporary Mathematical Analysis**, in press.

2. Inner product on B*-algebras of operators on a Free Banach space over the Levi-Civita field, *José Aguayo, Miguel Nova and Khodr Shamseddine*, **Indagationes Mathematicae**, in press (to appear in Volume 26 # 1, January 2015, Pages 191–205.)

3. Characterization of compact and self-adjoint operators on Free Banach spaces of countable type over the complex Levi-Civita field, *José Aguayo, Miguel Nova and Khodr Shamseddine*, **Journal of Mathematical Physics**, Volume 54 # 2, 2013.

4. New results on integration on the Levi-Civita field, *K. Shamseddine*, **Indagationes Mathematicae**, Volume 24 # 1, 2013, pp. 199-211.

5. One-variable and multi-variable calculus on a non-Archimedean field extension of the real numbers, *Khodr Shamseddine*, ***p*-Adic Numbers, Ultrametric Analysis, and Applications**, Volume 5 # 2, 2013, pp. 160-175.

6. On locally uniformly differentiable functions on a complete non-Archimedean ordered field extension of the real numbers, *Khodr Shamseddine and Todd Sierens*, **ISRN Mathematical Analysis**, Volume 2012, Article ID 387053, 20 pages.

7. Preliminary notes on Fourier Series for functions on the Levi-Civita field, *Khodr Shamseddine and William Grafton*, **International Journal of Mathematical Analysis**, Volume 6, 2012, # 19, pp. 941-950.

8. On the topological structure of the Levi-Civita field, *Khodr Shamseddine*, **Journal of Mathematical Analysis and Applications**, Volume 368, 2010, pp. 281-292.

Edited Proceedings

9. Advances in Ultrametric Analysis, Proceedings of the Twelfth International Conference on p-Adic Functional Analysis, *Khodr Shamseddine, editor*, **Contemporary Mathematics, American Mathematical Society**, Volume 596, 2013, ISBN-13: 978-0-8218-9142-1.

10. Advances in p-Adic and Non-Archimedean Analysis, Proceedings of the Tenth International Conference on p-Adic and Non-Archimedean Analysis, *Martin Berz and Khodr Shamseddine, editors*, **Contemporary Mathematics, American Mathematical Society**, Volume 508, 2010, ISBN 978-0-8218-4740-4.

Refereed Conference Proceedings

11. Analysis on the Levi-Civita field and computational applications, *Khodr Shamseddine*, **Applied Mathematics and Computation**, in press.

12. A brief survey of the study of power series and analytic functions on the Levi-Civita fields, *Khodr Shamseddine*, **Contemporary Mathematics, American Mathematical Society**, Volume 596 (Advances in Ultrametric Analysis), 2013, pp. 269-280.

13. Absolute and relative extrema, the mean value theorem and the inverse function theorem for analytic functions on a Levi-Civita field, *Khodr Shamseddine*, **Contemporary Mathematics, American Mathematical Society**, Volume 551 (Advances in Non-Archimedean Analysis), 2011, pp. 257-268.

14. Nontrivial order preserving automorphisms of non-Archimedean fields, *Khodr Shamseddine*, **Contemporary Mathematics, American Mathematical Society**, Volume 547 (Function Spaces in Modern Analysis), 2011, pp. 217-225.

15. Analysis on the Levi-Civita field, a brief overview, *Khodr Shamseddine and Martin Berz*, **Contemporary Mathematics, American Mathematical Society**, Volume 508 (Advances in p-Adic and Non-Archimedean Analysis), 2010, ISBN 978-0-8218-4740-4, pp. 215-237.

Invited Talks at Conferences

16. New results on the Lebesgue-like measure and integration theory on the Levi-Civita field and applications, 13th International Conference on p-Adic Functional Analysis, Paderborn, Germany, August 12-16, 2014.

17. On positive operators on a Banach space over the complex Levi-Civita field, The Seventh Conference on Function Spaces, Southern Illinois University- Edwardsville, Illinois, USA, May 20-24, 2014.

18. Preliminaries in non-Archimedean Functional Analysis, The Seventh Conference on Function Spaces, Southern Illinois University- Edwardsville, Illinois, USA, May 20-24, 2014.

19. Analysis on non-Archimedean ordered field extensions of the real numbers and applications, NUMTA2013 (Numerical Computations: Theory and Applications) International Conference and Summer School, Falerna, Italy, June 16-23, 2013

20. B*-algebras of operators and study of positive operators on a free Banach space of countable type over the complex Levi-Civita field, 12th International Conference on

p-Adic Functional Analysis, University of Manitoba, Winnipeg, Canada, July 2-6, 2012.

21. (Co-author, talk given by Jose Aguayo) Characterization of Compact and self-adjoint operators on free Banach spaces of countable type over the complex Levi-Civita field, 12th International Conference on p-Adic Functional Analysis, University of Manitoba, Winnipeg, Canada, July 2-6, 2012.

22. (Co-author, talk given by Todd Sierens) On locally uniformly differentiable functions: the Inverse Function Theorem and the Implicit Function Theorem in a non-Archimedean setting, 12th International Conference on p-Adic Functional Analysis, University of Manitoba, Winnipeg, Canada, July 2-6, 2012.

23. Absolute and relative extrema, the mean value theorem and the inverse function theorem for analytic functions on a Levi-Civita field, 11th International Conference on p-Adic Functional Analysis, Université Blaise Pascal, Clermont-Ferrand, France, July 5-9, 2010.

24. Nontrivial order preserving automorphisms of non-Archimedean fields, The Sixth Conference on Function Spaces, Southern Illinois University- Edwardsville, Illinois, USA, May 18-22, 2010.

Seminars and Colloquia at Universities

25. Department of Mathematics, University of Manitoba, March 21, 2014.

26. Department of Physics, University of Regina, March 7, 2014.

27. Department of Physics and Engineering Physics, University of Saskatchewan, March 6, 2014.

28. Department of Mathematics & Statistics (Algebra seminar), University of Saskatchewan, March 6, 2014.

29. Department of Physics and Astronomy and Winnipeg Institute for Theoretical Physics (joint colloquium), University of Manitoba, April 10, 2013.

30. Science Department, Texas A & M University in Qatar, October 23, 2012.

31. Department of Mathematics, Western Illinois University, August 31, 2012.

32. Departments of Mathematics (Joint Mathematics Colloquium), Universidad del Bio-Bio and Universidad de Concepcion, Concepcion, Chile, December 5, 2011.

33. Department of Mathematics, American University of Beirut, Beirut, Lebanon, July 21, 2011.

J. Sirker

1. F. Andraschko, T. Enss, J. Sirker, "Purification and many-body localization in cold atomic gases", Phys. Rev. Lett. **113**, 217201 (2014).

2. J. Sirker, M. Maiti, N.P. Konstantinidis, N. Sedlmayr, "Boundary Fidelity and Entanglement in the symmetry protected topological phase of the SSH model", J. Stat. Mech. P10032 (2014).

3. R. G. Pereira, V. Pasquier, J. Sirker, I. Affleck, "Exactly conserved quasilocal operators for the XXZ spin chain", J. Stat. Mech. P09037 (2014).

4. J. Sirker, N.P. Konstantinidis, F. Andraschko, N. Sedlmayr, "Locality and Thermalization in Closed Quantum Systems", Phys. Rev. A **89**, 042104 (2014).

5. F. Andraschko, J. Sirker, "Dynamical quantum phase transitions and the Loschmidt echo: A transfer matrix approach", Phys. Rev. B **89**, 125120 (2014).

6. N. Sedlmayr, D. Morath, J. Sirker, S. Eggert, I. Affleck, "Conducting fixed points for inhomogeneous quantum wires: a conformally invariant boundary theory", Phys. Rev. B **89**, 045133 (2014).

7. N. Sedlmayr, P. Korell, J. Sirker "Two-Band Luttinger Liquid with Spin-Orbit Coupling: Applications to Monatomic Chains on Surfaces", Phys. Rev. B **88**, 195113 (2013).

8. N. Sedlmayr, J. Ren, F. Gebhard, J. Sirker, "Closed and Open System Dynamics in a Fermionic Chain with a Microscopically Specified Bath: Relaxation and Thermalization", Phys. Rev. Lett. **110**, 100406 (2013).

9. N. Sedlmayr, P. Adam, J. Sirker, "Theory of the conductance of interacting quantum wires with good contacts and applications to carbon nanotubes", Phys. Rev. B **87**, 035439 (2013).

10. J. Sirker, "Entanglement measures and the quantum to classical mapping", J. Stat. Mech. P12012 (2012).

11. N. Sedlmayr, J. Ohst, I. Affleck, J. Sirker, S. Eggert, "Transport and scattering in inhomogeneous quantum wires", Phys. Rev. B **86**, 121302(R) (2012).

12. J. Ren and J. Sirker, "Spinons and helimagnons in the frustrated Heisenberg chain", Phys. Rev. B **85**, 140410(R) (2012).

13. F. Gebhard, K. zu Muenster, J. Ren, N. Sedlmayr, J. Sirker, B. Ziebarth, "Particle injection into a chain: decoherence versus relaxation for Hermitian and non-Hermitian dynamics", Ann. Phys. **524**, 286 (2012).

14. J. Sirker, "The Luttinger liquid and integrable models", Int. J. Mod. Phys. B. **26**, 1244009 (2012).

15. T. Enss and J. Sirker, “Lightcone renormalization and quantum quenches in one-dimensional Hubbard models”, New J. Phys. **14**, 023008 (2012).

16. A. Herzog, A.M. Oles, P. Horsch and J. Sirker, “The dimerized ferromagnetic Heisenberg chain”, Phys. Rev. B **84**, 134428 (2011).

17. J. Sirker, V. Y. Krivnov, D. V. Dmitriev, A. Herzog, O. Janson, S. Nishimoto, S.-L. Drechsler, J. Richter, “The J1-J2 Heisenberg model at and close to its z=4 quantum critical point”, Phys. Rev. B **84**, 144403 (2011).

18. N. Zafar Ali, J. Sirker, J. Nuss, P. Horsch and M. Jansen, “Spin exchange dominated by charge fluctuations of the Wigner lattice in the newly synthesized chain cuprate Na5Cu3O6”, Phys. Rev. B **84**, 035113 (2011).

19. N. Sedlmayr, S. Eggert and J. Sirker, “Electron scattering from domain walls in ferromagnetic Luttinger liquids”, Phys. Rev. B **84**, 024424 (2011).

20. A. Herzog, A.M. Oles, P. Horsch and J. Sirker, “Magnetic excitations in one-dimensional spin-orbital models”, Phys. Rev. B **83**, 245130 (2011).

21. J. Sirker, R. G. Pereira and I. Affleck, “Conservation laws, integrability and transport in one-dimensional quantum systems”, Phys. Rev. B **83**, 035115 (2011).

22. J. Sirker, “Finite temperature fidelity susceptibility for one-dimensional quantum systems”, Phys. Rev. Lett. **105**, 117203 (2010).

23. J.Sirker, “Thermodynamics of multiferroic spin chains”, Phys. Rev. B **81**, 014419 (2010).

Submitted Articles

24. C. Karrasch, R. G. Pereira, J. Sirker, “Low temperature dynamics of nonlinear Luttinger liquids”, arXiv: 1410.2226 (2014).

Refereed Proceedings

25. N. Sedlmayr, S. Eggert and J. Sirker, “Non-Collinear Ferromagnetic Luttinger Liquids”, J. Phys.: Conf. Ser. **303**, 012107 (2011).

26. A. Herzog, P. Horsch, A.M. Oles and J. Sirker, “Spin-wave theory for dimerized ferromagnetic chains”, J. Phys.: Conf. Ser. **200**, 022017 (2010).

Talks

27. “Dynamical quantum phase transitions and the Loschmidt echo. Quantum Integrability”, Conference: Conformal Field Theory and Topological Quantum Computation, Natal, Brazil, 2014.

28. “Thermalization in quantum systems: Conservation laws and effective baths”, Colloquium, Bonn, Germany (2014).

29. "Transport in one-dimensional quantum systems and conservation laws", Conference: Correlation days 2013, Dresden, Germany (2013).

30. "When is a bath a bath? Hermitian and Non-Hermitian relaxation dynamics in a toy model", Conference: Quantum Many-body systems out of equilibrium, Dresden, Germany (2013).

31. "Thermalization in quantum systems: Conservation laws and effective baths. Amsterdam", Summer Workshop on Low-D Quantum Condensed Matter, Amsterdam, Netherlands (2013).

32. "Thermalization in quantum systems: Conservation laws and effective baths", Colloquium, Physics Department, Heidelberg, Heidelberg, Germany (2013).

33. "Some thoughts and numerical experiments on thermalization in quantum systems", Frontiers of quantum condensed matter physics: light, matter and unusual devices out of equilibrium, New York, United States (2013).

34. "Entanglement measures and the quantum-to-classical mapping", APS March Meeting 2013, Baltimore, United States (2013).

35. "Non-equilibrium dynamics in one-dimensional quantum models", Condensed Matter Seminar, University of British Columbia, Vancouver, Canada (2012).

36. "Non-equilibrium dynamics in one-dimensional quantum models" Condensed Matter Seminar, Simon Fraser University, Vancouver, Canada (2012).

37. "Dephasing, relaxation and thermalization in one-dimensional quantum systems", Colloquium, Physics Department, U Sao Paulo in Sao Carlos, Sao Carlos, Brazil (2012).

38. "Dephasing, relaxation and thermalization in one-dimensional quantum systems", Conference: The beauty of Integrability, Natal, Brazil (2012).

39. "Conservation laws: Consequences for thermalization and transport", Theory Colloquium, U Dortmund, Dortmund, Germany (2012).

40. "Transport in quantum wires and conservation laws", GGI Workshop: New quantum states of matter in and out of equilibrium, Florence, Italy (2012).

41. "New aspects of transport in spin chains", 504. WEH-Seminar: Quantum Magnetism in Low Spatial Dimensions, Bad Honnef, Germany (2012).

42. "Decoherence, relaxation and thermalization in one-dimensional quantum models", Theory colloquium U Hannover, Hannover, Germany (2012).

43. "Lightcone renormalization and quantum quenches in one-dimensional Hubbard models", APS March Meeting 2012, Boston, United States (2012).

44. “Decoherence, relaxation and thermalization in one-dimensional quantum models”, Theory seminar Max-Planck Institute for Solid State Research, Stuttgart, Germany (2012).

45. “Non-equilibrium dynamics: Numerical simulations and models for cold atomic gases”, SFB colloquium U Mainz, Mainz, Germany (2011).

46. “Decoherence, relaxation and thermalization in one-dimensional quantum systems”, Theory seminar U Greifswald, Greifswald, Germany (2011).

47. “Transport in low-dimensional quantum structures”, Colloquium U Greifswald, Greifswald, Germany (2011).

48. “Decoherence, relaxation and thermalization in one-dimensional quantum systems”, Theory seminar, Max-Planck Institute for the Physics of Complex Systems, Dresden, Germany (2011).

49. “Light cone renormalization and quantum quenches in one-dimensional Hubbard models”, Theory seminar U Marburg, Marburg, Germany (2011).

50. “Fidelity susceptibility for one-dimensional quantum systems”, APS March Meeting 2011, Dallas, United States (2011).

51. “Dynamical correlations in 1D quantum systems: Violations of the Luttinger liquid paradigm”, Theory seminar, TU Muenchen, Munich, Germany (2011).

52. “Transport in low-dimensional quantum systems”, Colloquium U Wuppertal, Wuppertal, Germany (2011).

53. “Finite temperature fidelity for 1D quantum systems”, 465. WEH conference: Analytical and numerical methods for strongly correlated electron systems, Bad Honnef, Germany (2011).

54. “Transport and conservation laws”, NOVMAG workshop, Kolymbari, Greece (2010).

55. “Finite temperature transfer-matrix DMRG: Dynamical correlations and fidelity”, Conference: Density matrix renormalization group 2010, Beijing, China (2010).

56. “Fidelity for one-dimensional quantum systems”, Theory seminar, UBC Vancouver, Vancouver, Canada (2010).

57. “Transport in spin chains”, Conference: New Trends in Magnetism, Paris, France (2010).

58. “Diffusion and ballistic transport in one-dimensional quantum systems”, APS March Meeting, Portland, United States (2010).

B.W. Southern

Refereed Publications

1. M.D. LeBlanc, B.W. Southern, M.L. Plumer and J.P. Whitehead, "Spin Waves in the Anisotropic FCC Kagome Antiferromagnet" Phys. Rev. B **90**, 144403 (2014)

2. P. Hyde, Lihui Bai, D.M.J. Kumar, B.W. Southern, C.-M. Hu, S.Y. Huang, B.F. Miao and C.L. Chien, "Electrical Detection of Direct and Alternating Spin Current Injected from a Ferromagnetic Insulator into a Ferromagnetic Metal" Phys. Rev. B **89**, 180404(R) (2014)

3. E. Skoropata, R.D. Desautels, B.W. Southern and J. van Lierop, Comment on "Colossal reduction in Curie temperature due to finite-size effects in CoFe2O4 nanoparticles" , Chemistry of Materials **25**, 1898 (2013)

4. M. D. LeBlanc, M. L. Plumer, J. P. Whitehead, and B. W. Southern, "Monte Carlo simulations of the fcc kagome lattice: Competition between triangular frustration and cubic anisotropy" , Phys. Rev. B**88** , 094406 (2013).

5. N. H. G. Grenda, P. A. Hyde, Y. S. Gui, M. P. Wismayer, J. D. A. Jung, C. M. Hu, B. W. Southern, and K. W. Lin, "Angular dependence of ferromagnetic resonance measurements in exchange coupled $NiFe_{20}$/NiO bilayers" , J. Phys. D: Applied Physics **46**, 205002 (2013)

6. V. Hemmati, M. L. Plumer, J. P. Whitehead, and B.W. Southern, "Monte Carlo simulations of magnetic ordering in the fcc kagome lattice" , Phys. Rev. B. **86**, 104419(1:8) (2012)

7. B.W. Southern, "Triangular Antiferromagnets and Universality", Invited review in "Frustrated Magnetism", Physics in Canada **68**, no 2, 83 87 (2012)

8. M.P. Wismayer, B.W. Southern, X. L. Fan, Y.S. Gui, C. M. Hu and R. E. Camley , "Nonlinear Behavior for the Uniform Mode and Horizontal Standing Spin Wave Modes in Metallic Ferromagnetic Microstrips: Experiment and Theory", Phys. Rev. B **85**, 064411(1:7) (2012)

9. Lihui Bai, Y.S. Gui, Z.H. Chen, S.C. Shen, Junsaku Nitta, C. M. Hu, L.E. Hayward, M.P. Wismayer and B.W. Southern, "The spin wave gap observed via direct mapping of spin wave evolution in ferromagnetic microstructures", J. Appl. Phys. **109**, 093902(1:6) (2011).

10. M.L. Plumer, J. van Lierop, B.W. Southern, and J.P. Whitehead ,"Micromagnetic simulations of interacting dipoles on a fcc lattice", J. Phys. Condens. Matter **22**, 296007 (2010).

11. O. Kasyutich, R. D. Desautels, B. W. Southern and J. van Lierop, "New aspects of magnetic interactions in a macroscopic 3D nanoparticle based crystal", Phys. Rev. Lett. **104**, 127205 (2010).

Conference Contributions

12. Can-Ming Hu, Lihui Bai, P. Hyde, B.W. Southern, C.L. Chien, “Electrical detection of dynamically generated DC and AC currents”, Canadian Association of Physicists Congress Sudbury (2014)

13. B. Alkadour, J. P. Whitehead, and B. W. Southern. ”Simulation of the Magnetic Properties of Close Packed Arrays of Maghemite Nanospheres”, Canadian Association of Physicists Congress Montreal (2013)

14. B. Alkadour, J.P. Whitehead, J.I. Mercer, B.W. Southern, ”Simulation of Maghemite Nanospheres on a triangular lattice”, Canadian Association of Physicists (CAP) Congress Calgary (2012)

15. B. Alkadour, J.P. Whitehead, J.I. Mercer, B.W. Southern, ”Simulation of Maghemite Nanospheres on a triangular lattice”, Magnetic North III, Banff (2012)

16. B.W. Southern, ”Angular dependence of FMR measurements in exchange coupled NiFe/NiO bilayers: Experiment and Theory”, invited talk, Magnetic North III, Banff (2012)

17. M.P. Wismayer, B.W. Southern, X. L. Fan, Y.S. Gui, C. M. Hu and R. E. Camley, ”Nonlinear Behavior for the Uniform Mode and Horizontal Standing Spin Wave Modes in Metallic Ferromagnetic Microstrips: Experiment and Theory”, APS March Meeting (2012)

18. V. Hemmati, M. L. Plumer, J. P. Whitehead, and B.W. Southern, ”Monte Carlo simulations of the fcc Kagome lattice”, APS March Meeting (2012)

19. M.P. Wismayer and B.W. Southern, ”Non Linear Micromagnetic Simulations of Permalloy Strips”, Magnetic North II, Memorial University (2011)

20. M.L. Plumer, J. van Lierop, B.W. Southern and J.P. Whitehead, ”Micromagnetic simulations of interacting dipoles on a fcc lattice: application to nanoparticle assemblies”, Magnetic North I, University of Western Ontario (2010)

21. M.P. Wismayer, L.E. Hayward and B.W. Southern, ”Magnetic Excitations in Microstrips”, Magnetic North I, University of Western Ontario (2010)

22. M.P. Wismayer, L.E. Hayward and B.W. Southern, ”Magnetic Excitations in Microstrips”, CAP Congress Toronto (2010)

Seminars and Colloquia

23. B. W. Southern, ”Monte Carlo Studies of the FCC Kagome Lattice”, Department of Physics and Astronomy, University of Manitoba, March 8, (2013).

J.P. Svenne

1. A multichannel model for clusters of an α and select N = Z nuclei, K. Amos, L. Canton, P. R. Fraser, S. Karataglidis, J. P. Svenne, and D. van der Knijff. Submitted to Physical Review C, October 27, 2014; **Reviewed; in revision.**

2. Conditional charge symmetry for nuclear mirror systems n+^{14}C and p+^{14}O, P. R. Fraser, K. Amos, L. Canton, S. Karataglidis, D. van der Knijff, J. P. Svenne. Submitted to Physics Letters B, September, 2014; **Reviewed; in revision.**

3. Comparing coupled-channel spectra with no-core multi-$\hbar\omega$ shell-model results for carbon isotopes and mirror nuclei, S. Karataglidis, K. Amos, L. Canton, P.R. Fraser, J.P. Svenne and D. van der Knijff, Revised version submitted to European Physical Journal A, November, 2013, 22 pp. **In revision**

4. Reactivity Impact of ^{2}H and ^{16}O Elastic Scattering Nuclear Data for Critical System with Heavy Water, D. Roubtsov, K.S. Kozier, J.C.Chow, A.J.M. Plompen, S. Kopecky, J.P. Svenne, and L. Canton, Nuclear Data Sheets **118**, 414-417 (2014).

5. The angular distribution of neutrons scattered from deuterium below 2 MeV, N. Nankov, A.J.M. Plompen, S. Kopecky, K.S. Kozier, D. Roubtsov, R. Rao, R. Beyer, E. Grosse R. Hannaske, A.R. Junghans, R. Massarczyk, R. Schwenger, D. Yakorev, A. Wagner, M. Stanoiu, L. Canton, R. Nolte, S. Rötger, J. Beyer, and J.P. Svenne, Nuclear Data Sheets **119**, 98-103 (2014).

6. Coupling to two target-state bands in the study of the n+^{22}Ne system at low energy, P. R. Fraser, L. Canton, K. Amos, S. Karataglidis, J. P. Svenne, and D. van der Knijff, Phys. Rev. **90**, 024616[1-13 pp.] (2014)

7. Modelling scattering and resonances of weakly-bound radioactive nuclei, P. R. Fraser, L. Canton, R. Fossion, K. Amos, S. Karataglidis, J. P. Svenne, and D. van der Knijff, Heavy Ion Accelerator Symposium on Fundamental and Applied Science, Canberra, Australia, 8-12 April 2013. EPJ Web of conferences, published online: 19 December 2013. DOI: http://dx.doi.org/10.1051/epjconf/20136302010

8. Analysis of a coupled-channel continuum approach for spectra of mass-17 compound systems, K. Amos, L. Canton, P.R. Fraser, S. Karataglidis, J. P. Svenne, and D. van der Knijff. Nuclear Physics, **A912**, 7-17 (2013).

9. Linking the exotic structure of ^{17}C to its unbound mirror ^{17}Na, K. Amos, L. Canton, P.R. Fraser, S. Karataglidis, J. P. Svenne, and D. van der Knijff, Nuclear Physics **A879**, 132-145 (2012).

10. Linking nuclear masses with nucleon-removal thresholds and the mass of the proton-emitter ^{17}Na, K. Amos, D. van der Knijff, L. Canton, P.R. Fraser, S. Karataglidis, and J. P. Svenne. European Physics Letters, **99**, 12001 (2012).

11. The case for a return to nuclear power, J.P. Svenne, The Environmentalist, **32**, 346-352 (2012). DOI 10.1007/s10669-011-9358-1

12. Scattering and resonances on p-shell nuclei, L. Canton, P. R. Fraser, J. P. Svenne, K. Amos, S. Karataglidis, and D. van der Knijff, Journal of Physics: Conference Series **336**, 012002 (2011).

13. Energy-dependent target widths in a coupled-channel scattering study, L. Canton, P. R. Fraser, J. P. Svenne, K. Amos, S. Karataglidis, and D. van der Knijff, Physical Review C **83**, 047603-4 (2011).

14. Scattering of nucleons from nuclei with couplings to particle-unstable excited states, P.R. Fraser, K. Amos, L. Canton, S. Karataglidis, J.P. Svenne, and D. van der Knijff, Revista Mexicana di Física, **57**, 20-29 (2011).

15. Coupled-channel calculation of bound and resonant spectra of ${}^{9}_{\Lambda}$Be and ${}^{13}_{\Lambda}$C hypernuclei, L. Canton, K. Amos, S. Karataglidis, and J.P. Svenne, Int. J. of Mod. Phys. E **19**, 1435-1450 (2010).

Refereed Conference Proceedings

16. Comparison of multi-$\hbar\omega$ shell-model results with MCAS, J.P. Svenne, S. Karataglidis, K. Amos, L. Canton, P.R. Fraser, Dirk van der Knijff, INPC 2013, International Nuclear Physics Conference, Florence, Italy, June 2-7, 2013. Accepted for publication on-line by EPJ Web of Conferences.

17. Investigating the astrophysical ^{22}Ne$(p,\gamma)^{23}$Na and ^{22}Mg$(p,\gamma)^{23}$Al reactions with a multi-channel scattering formalism. International Nuclear Physics Conference, Florence, Italy, June 2-7, 2013. Submitted for publication on-line by EPJ Web of Conferences, in review.

18. Exploring exotic nuclei with MCAS, S. Karataglidis [*et al*], invited talk presented at the first International African Symposium on Exotic Nuclei, Somerset West, South Africa, December 2013.

19. Aspects of the structure of heavy carbon isotopes, S. Karataglidis, K. Amos, J. P. Svenne, L. Canton, P. R. Fraser, and D. van der Knijff, talk presented at the 58th Annual Conference of the South African Institute of Physics, SAIP2013, Richards Bay, South Africa, July 2013, Proceedings to be published.

20. Recent developments in Multi-Channel Algebraic Scattering calculations, L. Canton, K. Amos, S. Karataglidis, P.R. Fraser, J.P. Svenne, and D. van der Knijff, invited parallel talk at the 10th Latin American Symposium on Nuclear Physics and Applications held on December 1-6, 2013 in Montevideo, Uruguay. Proceedings of Science 047.

21. Medium-light nuclei beyond the drip line: the proton-emitter ^{17}Na, P.R. Fraser, L. Canton, K. Amos, S. Karataglidis, J.P. Svenne and D. van der Knijff; Villa Monastero, Varenna, Italy June 11-17, 2012. CERN Proceedings 2012, 243-249 (2012)

22. Neutron scattering from deuterium and oxygen: New theoretical results, J.P. Svenne and L. Canton, WINS 2012, Workshop on (In) elastic Neutron Scattering, Boston, Ma, U.S.A., September 17-19, 2012. Invited paper, published on-line.

23. Structure of medium-light nuclei near the proton drip line, J.P. Svenne, K. Amos, D. van der Knijff, L. Canton, P.R. Fraser, S. Karataglidis; contributed paper (poster) at NS2012, Nuclear Structure 2012 Conference August 13-17, 2012, Argonne National Laboratory, Illinois, U.S.A. Papers published on-line.

24. Systematics of nuclear masses and nucleon-removal thresholds, J.P. Svenne, K. Amos, D. van der Knijff, L. Canton, G. Pisent, P.R. Fraser, S. Karataglidis; contributed paper at the Canadian Association of Physicists Annual Congress, June 11-15, 2012, Calgary, AB, Canada. Abstract on-line.

25. Status of Deuterium Nuclear Data for the Simulation of Heavy Water Reactors, K.S. Kozier, D. Roubtsov, R. Rao, J.P. Svenne, L. Canton, A.J.M. Plompen, M. Stanoiu, N. Nankov and C. Rouki, Int. Conf. Future of HWRs, Ottawa, Ontario, Canada, Oct. 02-05, 2011. Proceedings online: http://www.cns-snc.ca/home

26. Using mirror symmetry to extract information on nuclei near or beyond the proton drip line, J.P. Svenne, K. Amos, D. van der Knijff, L. Canton, G. Pisent, P.R. Fraser, S. Karataglidis; contributed paper at the Canadian Association of Physicists Annual Congress, June 13-17, 2011, St. John's, NL, Canada. Abstract on-line.

27. Recent advances in Multi-Channel Algebraic Scattering, S. Karataglidis, P.R. Fraser, K. Amos, L. Canton, G. Pisent, J.P. Svenne and D. van der Knijff; contributed paper at the FINUSTAR-3 conference: Frontiers In Nuclear Structure, Astrophysics and Reactions, Rhodos, Greece, August 23-27, 2010; AIP Conference Proceedings, **1377**, 286-290 (2011).

28. Revisiting Elastic Scattering of D(n, n)D reaction, M. Stanoiu, L. Canton, K. S. Kozier, N. Nankov, A. Plompen, R. Rao, D. Roubtsov, C. Rouki, and J. P. Svenne, International Symposium on Exotic Nuclei, 28 September-2 October 2009, Sochi, Russia, AIP Conf. Proc. **1224**, pp. 234-240, 2010.

29. Weakly-bound rare isotopes with a coupled-channel approach that includes resonant levels, L. Canton, P. R. Fraser, J. P. Svenne, K. Amos, S. Karataglidis and D. van der Knijff, contributed poster (Canton, Svenne) to the INPC2010 International Nuclear Physics Conference, Vancouver, BC, July 4-9, 2010; Proceedings published electronically.

30. Neutron-deuteron elastic scattering measurements, ND-1366, M. Stanoiu, N. Nankov, A. Plompen, C. Rouki, K. Kozier, R. Rao, D. Roubtsov, J.P. Svenne, and L. Canton; ND2010, International Conference on Nuclear Data for Science and Technology, April 26-30, 2010, Jeju Island, Korea. Proceedings, ISSN 0374-4884; DOI: 10.3938/jkps.59.1825

31. Scattering cross sections involving particle-unstable resonances in the MCAS formalism, J. P. Svenne, P. R. Fraser, K. Amos, L. Canton, S. Karataglidis, G. Pisent and D. van der Knijff, contributed poster (Svenne) to the CAP2010 Congress, Toronto, ON, June 7-11, 2010; abstract in *Physics in Canada*, **66**, no. 2 (supplementary), May/June 2010

32. Spectroscopy of Hypernuclei with a Multi-Channel Algebraic Scattering Formalism, J. P. Svenne, K. Amos, L. Canton and S. Karataglidis, contributed paper (Svenne) to the CAP2010 Congress, Toronto , ON, June 7-11, 2010; abstract in *Physics in Canada*, **66**, no. 2 (supplementary), May/June 2010

33. Extending MCAS to hypernuclei and radiative capture reactions, L. Canton, K. Amos, S. Karataglidis, and J.P. Svenne, 2nd International Workshop on Compound Nuclear Reactions and Related Topics, Bordeaux, France, October 5-8, 2009; Proceedings: EPJ Web of Conferences, **2**, 09003 (2010)

G.C. Tabisz

1. A. Senchuk and G. C. Tabisz, "General expression for the depolarization ratio for first order collision induced light scattering", Journal of Raman Spectroscopy, 42, 1046 1048 (2011).

2. A. Senchuk and G. C. Tabisz, "Second order collision induced light scattering: a spherical tensor approach", Journal of Raman Spectroscopy, 42, 1049 1054 (2011).

3. G. C. Tabisz, "Intra collision effects in the collision broadening of spectral line profiles", International Review of Atomic and Molecular Physics, 1, 53 61 (2010).

4. G. C. Tabisz, "Intra-collision effects in the collision-broadening of spectral line profiles", International Review of Atomic and Molecular Physics, 1, 53-61 (2010).

5. A. Senchuk and G. C. Tabisz, "Second-order collision-induced light scattering: a spherical tensor approach", accepted for publication in the Journal of Raman Spectroscopy, 2010 (6 journal pages).

6. A. Senchuk and G. C. Tabisz, "General expression for the depolarization ratio for first-order collision-induced light scattering", accepted for publication in the Journal of Raman Spectroscopy, 2010 (3 journal pages).

Colloquia

7. G. C. Tabisz, "Collisional Interference effects in the infrared spectrum of HD", Department of Physics, National University of Singapore, Sept 15, 2011. This colloquium was given at the invitation of Professor C.Kim Ong, who received his Ph.D from the University of Manitoba in 1973 under the supervision of Professor J. M.Vail.

J.M. Vail

1. Vail, J. M., Haroon, T., Hernandez-Melgar, J., Chevrier., D. K, and Pandey, R., "Nitrogen Vacancy and Oxygen Impurity in AlN: Spintronic Quantum Dots", Radiation Effects and Defects in Solids, 164, 585-591 (2009).

M. Whitmore

Refereed Publications

1. Tongchuan Suo and Mark D. Whitmore, *Self-consistent Field Theory of Tethered Polymers: One Dimensional, Three Dimensional, and High Stretching Theories*, J. Chem. Phys. (submitted)

2. Tongchuan Suo and Mark D. Whitmore, *Controlling Microtube Permeability via Grafted Polymers and Solvent Quality*, J. Chem. Phys. **140**, 114902-1 to 7 (2014)

3. Tongchuan Suo and Mark D. Whitmore, *Doubly Self-Consistent Field Theory of Grafted Polymers Under Simple Shear in Steady State*, J. Chem. Phys. **140**, 114901-1 to 14 (2014)

4. Mark D. Whitmore, Jeffrey D. Vavasour, John G. Spiro and Mitchell A. Winnik, *On Cylindrical PS-b-PMMA in Moderate and Weak Segregation,* Macromolecules **46**, 9045–9054 (2013)

5. Tongchuan Suo and Mark D. Whitmore, *Grafted Polymers inside Cylindrical Tubes: Chain Stretching vs Layer Thickness,* J. Chem. Phys. **138**, 164907: 1–11 (2013)

6. Tongchuan Suo, Tyler N. Shendruk, Owen A. Hickey, Gary W. Slater and Mark D. Whitmore, *Controlling Grafted Polymers Inside Cylindrical Tubes,* Macromolecules **46**, 1221–1230 (2013)

7. John G. Spiro, Nicolas Illy, Mitchell A. Winnik, Jeffrey D. Vavasour and Mark D. Whitmore, *Theory of Lamellar Superstructure from a Mixture of Two Cylindrical PS-PMMA Block Copolymers,* Macromolecules **45**, 4289 – 4294 (2012)

J.G. Williams

1. T.A. Harriott and J.G. Williams, "Solutions in the 2+1 null-surface formulation," in Relativity and Gravitation, Springer Proceedings in Physics 157, edited by J. Bicak and T. Ledvinka, (Springer, New york), pp. 283–286 (2014).

2. T.A. Harriott and J.G. Williams, "Solution for the null-surface formulation of general relativity in 2+1 dimensions," in General Relativity and Gravitation, **46**, 1666 (2014).

3. T.A. Harriott and J.G. Williams, "Exact positive curvature solution for the null surface formulation in 2+1 dimensions," in Essays on Mathematics and Statistics: Volume 4, edited by V. Akis (Atiner, Athens), pp. 3–10 (2013).

4. T.A. Harriott and J.G. Williams, "Light cone cut solution in the 2+1 null surface formulation," in Proceedings of the 12th Marcel Grossmann Meeting on General Relativity, edited by T. Damour, R.T. Jantzen and R. Ruffini (World Scientific, Singapore), pp. 1896–1898 (2012).

5 Financial

5.1 Statement of Income and Expenditures

Income

Income Source	Amount
Carry Over	$4532.61
UWinnipeg Dean of Science & VP Research	$1600.00
UManitoba Dean of Science	$1600.00
Brandon Univ VP Research	$1000.00
Total Funds Available	$8732.61

Expenditures

Activity	Amount Spent
Contribution to CCGRRA XV	$2000.00
Contribution to Theory Canada 9	$500.00
Seminar by Sarah Plosker	$269.51
Public lecture by Neil Turok	$220.53
Visit by Bret Underwood	$317.15
Seminar by Tim Taves	$51.82
Summer Student Symposium	$\sim$ $200
Visit by Valentin Freilikher	$300.00
Visit by Vikram Dwarkadas	$300.00
Webcam for seminar broadcast	$68.16
Total Expenditures	$4227.17

The income listed above represents commitments to WITP funding from the three major universities in Manitoba from which the WITP draws its members. For the five-year period 2013-17, the University of Winnipeg and University of Manitoba have each committed $1600 per annum, and Brandon University has committed $1000 per annum.

In addition to the supporting funds indicated above, it should be pointed out that the members of the Institute use their individual NSERC discovery grants to subsidize Institute activities. As of January 2013, the members from the three universities drew upon more than $600,000 of individual NSERC Research Grants. These funds have a significant fortifying effect on the level of activities in which we are able to engage. The financial contribution of the members associated with the expenses of visiting guest theorists and supports the activities and goals of the Institute, but it does not appear in the budget data shown above.

The Institute has neither endowment nor trust fund support. The Institute has no significant space requirements. The occasional long term visitor requires a desk, but these needs have been accommodated by the space available to the physics departments at the member Universities. The host departments also supply occasional secretarial support such as that required for the preparation of seminar notices and research papers.

An estimated annual budget for the current five-year period follows:

- Conference support: $1700
  Advertises theoretical physics in Manitoba throughout Canada, promotes research collaborations and dissemination of results, provides opportunity to recruit graduate students
  - Theory Canada conferences: $500
    Main annual conference for Canadian theoretical physics
  - Canadian Prairie Theoretical Physics Network conferences: $500
    Annual regional conference for theoretical physics

  - National & international conferences held in Manitoba and surrounding region: $700
    Average annual amount

- Summer Symposium for undergraduate student researchers: $500
- Visitor Support: $1800
  - Prominent visiting scientist for public lecture: $2000 twice in five years
    Outreach to the public, as well as scientific discussion
  - Support for other WITP visitors: $1000
    The WITP visitor program is primarily funded by Members; this funding is to allow visits that individual Members may not otherwise be able to afford or to increase the length of time that visitors can stay in Manitoba.
- Miscellaneous: $500
  Printing, advertising of study opportunities at Canadian Undergraduate Physics Conference only

Total: $4500 per annum

5.2 Financial Stability and Growth

The Institute has no substantial fixed costs and for this reason it is intrinsically stable. It can operate in a productive fashion at a variety of funding levels. All of the funds that the Institute receives are transformed directly into its research enhancing activities. The funds allocated to the Institute by supportive administrative bodies such as the Faculties of Science and Graduate Studies at the University of Manitoba are fortified by the individual NSERC research grants of members. This is a strong commitment to the Institute by the Institute members. In view of its overall research productivity, in terms of published papers and supervised graduate students, its capacity for running very successful conferences and workshops, and the demonstrated ability to attract excellent short-term and long-term visiting scientists, the Institute is achieving its goals.

The WITP membership includes all of the theoretical physicists in the province. Hence its growth relies upon the Associate and Student Members that it can attract (i.e. graduate students, post- doctoral fellows, and research associates), along with occasional new faculty hires. Another area of potential growth is identifying new Permanent Members at UM, UW, and Brandon University among current faculty members in related fields. For example, experimental physicists who work closely with theorists may be candidate members, as may mathematicians whose research is closely related to mathematical physics. The WITP has recently added members that fit these criteria.

The report guidelines suggest that some indication be given of the percentage of time that members spend on Institute research. Since the Institute's programs enhance the ongoing research interests of its members, there is no distinction between individual research and Institute research. The director has spent less than 5% of his time with the administrative aspects of the Institute.

1 Appendix: Supplementary Material

2014 Summer Symposium Schedule

29 Aug 2014, Brodie Building Room 54, Brandon University

Time	Speaker	Title
9:00		Refreshments
10:00	Gabriel Chernitsky	Quintuplet Dark Matter
10:30	Gidon Bookatz	On locally uniformly differentiable functions over non-Archimedean ordered field extensions of the real numbers
11:00	L.J. Zhou	Spin Hall effect by surface roughness
11:30	Jarrad Perron	Geometric measure of entanglement for generalized classes of symmetric pure states
12:00		Lunch
13:00	Ryan Bergen	Matrix Representations of Feynman Diagrams
13:30	Brett Meggison	Scalar Field Theory
14:00	Brad Cownden	Linear Perturbations of Type IIB SUGRA in Flux Compactifications
14:30	Paul Mikula	TBA

Public Lecture Poster

The poster for the joint public lecture with the 15th Canadian Conference on General Relativity and Relativistic Astrophysics follows this page.

CCGRRA XV Material

The poster for the 15th Canadian Conference on General Relativity and Relativistic Astrophysics is in two pages, and the conference program follows.

Public Lecture

Higgs Bang

Recent measurements using the Large Hadron Collider (LHC) and the Planck Satellite have revealed the universe to us, from scales a billion times smaller than an atom to ten trillion times larger than the solar system. Amazingly, the universe turned out to be simpler than we expected, in both cases. This is profoundly encouraging to those of us seeking deep explanations for the origin and the future evolution of the universe. In the talk, I will review a very recent idea: that the Higgs field discovered by the LHC played a key role in initiating the big bang, and that it will initiate another big bang in the future.

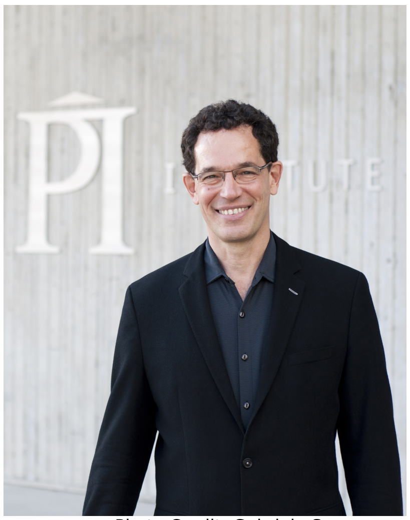

Photo Credit: Gabriela Secara

Neil Turok

Director and Niels Bohr Chair, Perimeter Institute

World-renowned South African physicist **Neil Turok** is Director and Niels Bohr Chair of Canada's Perimeter Institute for Theoretical Physics. One of the world's leading minds in physics and cosmology, the former Princeton professor and Cambridge Chair in Mathematical physics is known for his innovative approach. Turok has received numerous awards, and in 2012 he was selected to deliver the prestigious CBC Massey Lectures. His resulting series "The Universe Within: From Quantum to Cosmos" sold-out in other cities across Canada. This is Winnipeg's chance to see Dr. Turok speak live!

7:30PM 21 May 2014
Eckhardt-Gramatté Hall, University of Winnipeg

Free Admission
Reserve tickets by calling 204-786-9852 or emailing CCGRRA@uwinnipeg.ca
Or first-come, first-served at the door starting 6:30PM
Refreshments will be served after the lecture

Proudly co-sponsored by the **15th Canadian Conference on General Relativity & Relativistic Astrophysics** and the **Winnipeg Institute for Theoretical Physics**

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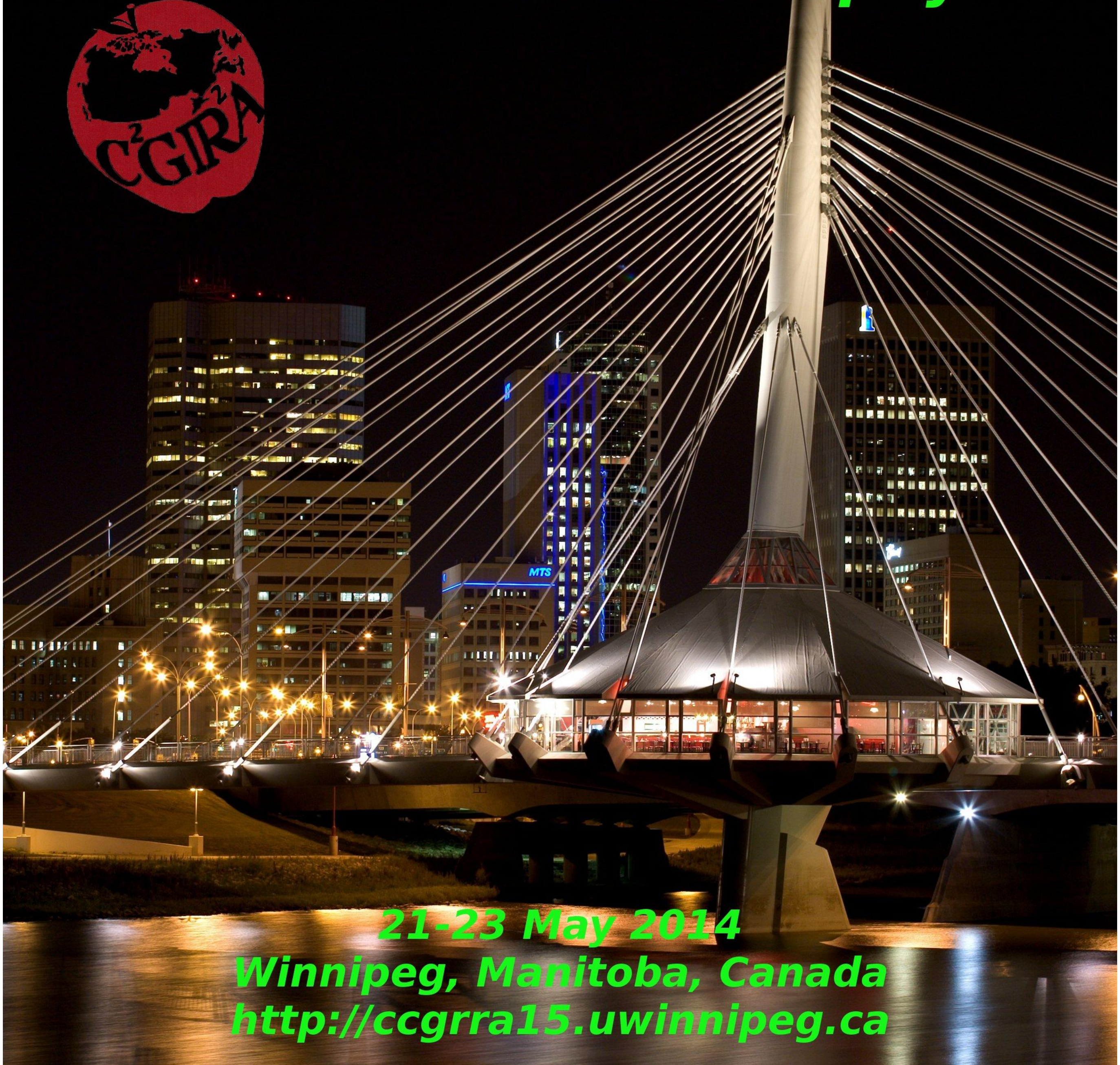

21-23 May 2014
Winnipeg, Manitoba, Canada
http://ccgrra15.uwinnipeg.ca

Confirmed Plenary Speakers

- A. Ashtekar (Penn State)
- L. Boyle (Perimeter)
- M. Johnson (York & Perimeter)
- A. Maloney (McGill)
- J. Moffat (Perimeter)
- L. Pogosian (Simon Fraser)
- J. Polchinski (KITP, UCSB)
- F. Pretorius (Princeton)
- S. Safi-Harb (Manitoba)
- N. Turok (Perimeter)
- J. Zanelli (CECs, Chile)

Organizing Committee

A. Frey
G. Kunstatter
D. Vincent
(Univ of Winnipeg)

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CCGRRA XV
Conference Program

May 21-23, 2014

Sponsors

- Winnipeg Institute for Theoretical Physics
- The University of Winnipeg
- Perimeter Institute for Theoretical Physics
- Fields Institute
- Canadian Institute for Theoretical Astrophysics

Plenary Sessions

Session Chairs: *A. Frey, J. Gegenberg, G. Kunstatter, J. Williams, R. Danos, D. Vincent*

Joseph Polchinski
KITP, U of California at Santa Barbara
The Black Hole Information Paradox, Alive and Kicking
Thought experiments have played an important role in figuring out the laws of physics. For the unification of quantum mechanics and gravity, where the phenomena take place in extreme regimes, they are even more crucial. Hawking's 1976 paper "Breakdown of Predictability in Gravitational Collapse" presented one of the great thought experiments in the history of physics, arguing that black holes destroy information in a way that requires a modification of the laws of quantum mechanics. Skeptics for years failed to poke holes in Hawking's argument, but concluded that if quantum mechanics is to be saved then our understanding of spacetime must break down in a radical way. For a time it seemed that Maldacena's discovery of gauge/gravity duality had resolved the issue, but the recent firewall argument has opened many new questions.

Levon Pogosian
Simon Fraser University
Cosmological Tests of Gravity
The accelerated expansion of the universe and the unexplained nature of dark matter motivated many to consider extensions of General Relativity. Independently, the rapidly improving quality of cosmological data will eventually allow for testing the validity of Einstein's equations on cosmological scales. I will discuss the recent progress and open issues in developing theoretical frameworks for probing gravitational physics with upcoming large scale surveys.

Abhay Ashtekar
Institute for Gravitation & the Cosmos, Penn State
Gravitational Physics with a Positive : Fundamental Open Issues
In the positive cosmological constant sector, several basic questions in classical and quantum gravity whose answers we take for granted in the zero cosmological constant sector have remained open. For example, a common requirement that scri of asymptotically de Sitter space-times be conformally flat –so that the asymptotic symmetry group is the de Sitter group– turns out to be an unphysical and severe restriction that by fiat removes half of space-times we should consider. Furthermore, irrespective of this restriction, we still do not have a satisfactory notion of gravitational radiation in exact GR, nor a positive energy theorem. Similarly, the standard constructions of 'in' and 'out' Hilbert spaces on scri that we routinely use (e.g. in the analysis of black hole evaporation) do not extend to space-times that are asymptotically de Sitter in a physical sense. In this talk I will present some illustrative examples of these quandaries and introduce an approach to resolve the open issues.

Matthew Johnson
York University/Perimeter Institute
From cosmic bubble collisions to cosmological observables with numerical relativity
The theory of eternal inflation in an inflaton potential with multiple vacua predicts that our universe is one of many bubble universes nucleating and growing inside an ever-expanding false vacuum. The collision of our bubble with another could provide an important observational signature to test this scenario. I will present a complete set of predictions for the signature of bubble collisions from first principles and comment on the prospects for constraining models of eternal inflation using Cosmic Microwave Background data.

Neil Turok
Perimeter Institute for Theoretical Physics

Jorge Zanelli
Centro de Estudios Cientficos (CECs), Dept of Physics, Chile
2+1 black hole with SU(2) hair

Frans Pretorius
Princeton University
Highlights from Numerical Relativity
Numerical relativity has become a valuable tool in the approach to understanding general relativity through the study of explicit solutions to the Einstein Field Equations. It is particularly useful for exploring highly dynamical phenomena where the non-linearities of the equations are most strongly manifest, and where there are no underlying symmetries in the problem. In this talk I will review some highlights from recent results, ranging from applications to gravitational wave astrophysics, to those inspired by the holographic dualities of string theory.

John Moffat
Perimeter Institute
Variable Speed of Light, Inflation and BICEP2
Inflation models and their consequences for early universe cosmology are considered in relation to the potential B-mode polarization observation of primordial gravitational waves by the BICEP2 collaboration. Positive as well as negative features of the inflationary paradigm are reviewed. An alternative variable speed of light (VSL) cosmology model is developed with a spontaneous breaking of Lorentz invariance in the early universe. A non-minimal electromagnetic coupling to curvature and the resulting QED vacuum polarization dispersive medium can produce $c \gg c_0$ in the early universe, where c_0 is the measured speed of light today. The primordial scalar fluctuation and gravitational wave power spectra and spectral indices are derived. The VSL results for the scalar and tensor spectral indices are $n_s = 0.96$ and $n_t = -0.04$, respectively, with the observed BICEP2 scalar/tensor ratio $r = 0.2$ (zero or small foreground dust) giving $r/n_t = -5$, which is close to the single-field inflation consistency condition $r/n_t = -8$. A VSL model can avoid the fine-tuning and potential multiverse scenario encountered in inflationary models.

Alexander Maloney
McGill University
Holographic Entanglement Entropy
The ground state of a quantum field theory contains a high degree of quantum entanglement. In certain conformal field theories this entanglement can be studied using the holographic (AdS/CFT) correspondence, which relates entanglement entropy to black hole entropy. We show that the relevant black holes exhibit a novel "superconducting" phase transition, whereby a previously hairless black holes can acquire scalar hair. This leads to a novel, non-analytic feature in the entanglement structure of strongly coupled conformal field theory.

Samar Safi-Harb
University of Manitoba
Neutron stars
As remnants of supernova explosions of massive stars, neutron stars represent some of the densest, hottest, and most magnetic objects in the Universe. They provide a laboratory where all four fundamental forces of nature are important and act as excellent probes for physics in extreme conditions. I will provide an overview of these fascinating objects, focusing on observations revealing a growing diversity (including magnetars), while highlighting their relevance to relativistic astrophysics.

Latham Boyle
Perimeter Institute
Non-Commutative Geometry, Non-Associative Geometry and the Standard Model of Particle Physics
Connes has developed a notion of non-commutative geometry (NCG) that generalizes Riemannian geometry, and provides a framework in which the standard model of particle physics, coupled to Einstein gravity, may be concisely and elegantly reformulated. I explain that his formalism may be recast in a way that generalizes immediately from non-commutative to non-associative geometry. In the process, several of the standard axioms and formulae are conceptually reinterpreted. This reformulation also suggests a new constraint on the finite NCG corresponding to the standard model of particle physics. Remarkably, this new condition resolves a long-standing puzzle about the NCG embedding of the standard model, by precisely eliminating from the action the collection of 7 unwanted terms that previously had to be removed by an extra (empirically-motivated) assumption.

Parallel Sessions

Session 1

Room A Chair: *F. Pretorius*

Don Witt
University of British Columbia
Negative Mass in Kaluza-Klein Spacetimes

Tina Harriott
Mount Saint Vincent University
Non-singular solution for the null-surface formulation of general relativity in 2+1 dimensions
The null-surface formulation of general relativity (NSF) is an alternative way of describing the gravitational field in terms of families of null surfaces. By solving the third-order nonlinear field equations of the (2+1)-dimensional NSF directly an exact solution is presented. The solution is also shown to be consistent with the topological massive gravity field equation.

Hari Kunduri
Dept of Mathematics, Memorial University of Newfoundland
First Law of Black Hole and Soliton Mechanics
Gravitational solitons are stationary, globally regular, finite energy asymptotically flat spacetimes. I will discuss a mass formula and a mass variation law for such spacetimes, in a general five dimensional theory of gravity coupled Abelian gauge and scalar fields. If the spacetime is everywhere regular, these mass formulas reduce to a sum of flux terms defined on its non-trivial 2-cycles. If there is a black hole, one obtains a mass variation law more general than previously obtained, which also has contributions from the 2-cycles exterior to the black hole. This can be interpreted as the first law of black hole mechanics in a background soliton containing bubbles.

Room B Chair: *J. Zanelli*

Tim Taves
Centro de Estudios Cientficos (CECs), Dept of Physics, Chile
Collapsing Black Holes with Radiating Terms

Xun Wang
Physics Dept., University of Victoria
Kerr-AdS Black Holes and Force-Free Magnetospheres
We obtain analogs of the Blandford-Znajek split monopole solution for force-free magnetospheres around a slowly rotating Kerr-AdS black hole. For small black holes, we find an analytic solution to first order in the ratio of horizon radius to AdS scale, r_H/l, which exhibits a radial Poynting flux and for $r_H/l \to 0$ smoothly approaches the Blandford-Znajek configuration in an asymptotically flat Kerr background. However, for large Kerr-AdS black holes with $r_H/l > 1$, namely those for which the bulk black hole holographically describes the thermodynamics of a strongly-interacting boundary field theory, the existence of a globally well-defined timelike Killing vector external to the horizon suggests the absence of energy extraction through the Blandford-Znajek process. In this regime, we find that at least for slow rotation the force-free solution still exists but exhibits a range of angular velocities for the field lines, corresponding to the freedom in the dual field theory to rotate a magnetic field through a neutral plasma. As a byproduct of this work, we also obtain an analytic solution for a rotating monopole magnetosphere in pure AdS, analogous to the Michel solution in flat space.

David W. Tian
Memorial University of Newfoundland
Lessons from $f(R, R_c^2, R_m^2, \mathscr{L}_m)$ gravity: smooth Gauss-Bonnet limit, energy-momentum conservation and nonminimal coupling
This paper studies a generic fourth-order theory of gravity with Lagrangian density $f(R, R_c^2, R_m^2, \mathscr{L}_m)$. By considering explicit R^2 dependence and imposing the "coherence condition" $f_{R^2} = f_{R_m^2} = -f_{R_c^2}/4$, the field equations of $f(R, R^2, R_c^2, R_m^2, \mathscr{L}_m)$ gravity can be smoothly reduced to that of $f(R, \mathcal{G}, \mathscr{L}_m)$ generalized Gauss-Bonnet gravity. We use Noether's conservation law to study the $f(\mathcal{R}_1, \mathcal{R}_2 \ldots, \mathcal{R}_n, \mathscr{L}_m)$ model with nonminimal coupling between $\mathscr{L}_m$ and Riemannian invariants $\mathcal{R}_i$, and conjecture that the gradient of nonminimal gravitational coupling strength $\nabla^\mu f_{\mathscr{L}_m}$ is the only source for energy-momentum non-conservation. This conjecture is applied to the $f(R, R_c^2, R_m^2, \mathscr{L}_m)$ model, and the equations of continuity and non-geodesic motion of different matter contents are investigated. Finally, the field equation for Lagrangians including the traceless-Ricci square and traceless-Riemann (Weyl) square invariants is derived, the $f(R, R_c^2, R_m^2, \mathscr{L}_m)$ model is compared with the $f(R, R_c^2, R_m^2, T) + 2\kappa\mathscr{L}_m$ model, and consequences of nonminimal coupling for black hole and wormhole physics are considered. The arXiv article number is: 1404.7823 [gr-qc].

Room C Chair: *A. Buchel*

Tomohiro Harada
Department of Physics, Rikkyo University, Japan
Analytic formula for the threshold of primordial black hole formation
We present a new analytic formula for the amplitude of density perturbation at the threshold of primordial black hole formation in the universe dominated by a perfect fluid with the equation of state $p = w\rho c^2$ for $w \geq 0$.

Sanjeev Seahra
University of New Brunswick
Primordial fluctuations from deformed Heisenberg algebras
We study the generation of primordial fluctuations during inflation when the fundamental quantum commutator between the inflation's amplitude and momentum receives short distance corrections. We compare our results to current Planck observations of the CMB and discuss the feasibility of observing effects in future probes of baryon acoustic oscillations.

Callum Quigley
Dept. of Math and Stats, University of Alberta
In Search of de Sitter Solutions in String Theory
De Sitter spacetimes necessarily violate the strong energy condition (SEC), but this is extremely difficult to achieve in the context of string theory. Supergravity alone does not suffice, because of well known no-go theorems, so additional ingredients are required. In an earlier study we demonstrated that SEC violations cannot be achieved by the inclusion of higher derivative corrections coming from string theory. Here we extend this analysis by including non-perturbative corrections in the string coupling. The lack of SEC violation suggests de Sitter solutions do not exist in any perturbative regime of string theory.

Session 2

Room A Chair: *J. Moffat*

Daniel Guariento
Perimeter Institute for Theoretical Physics/Universidade de São Paulo, Brazil
Causal structure and field sources of the generalized McVittie metric
Some exact solutions of General Relativity which contemplate cosmological expansion and local compact objects look deceptively simple, yet display interesting peculiarities such as a rich causal structure and a puzzling behavior of the source matter. One of the simplest of such solutions, the so-called generalized McVittie metric, describes a dynamic black hole with a time-dependent mass in an expanding universe. We review some of its properties and the fields which may serve as its source.

Gheorge Adrian Lupu
Mathematics, Technical High School Decebal, Dr. Tr. Severin, Romania
The classification of the nonsymmetrical, relativistic models, with applications in astrophysics and cosmology
In this paper we will continue our researches regarding the relativistic type models with some ones which have a larger interpretation , including the area of the relativistic astrophysics and cosmology. An important role in these researches play the nonsymmetrical Einstein models.It is already given a classification of these models: a) The nonsymmetrical equivalent models b) The class of the nonsymmetrical models which are equivalents with the symmetrical Einstein model c) The nonsymmetrical models which are equivalent but also almost equivalents ones with the symmetrical Einstein model d) For a possible larger interpretation we will extend the study to the case of a vector bundle with an one-dimensional type fiber. We will also mention few models whose study is in progress.

Viqar Husain
University of New Brunswick
Time, Vacuum Energy and the Cosmological Constant
I will describe a link between the "cosmological constant problem" and the problem of time in quantum gravity. This arises by examining the relationship between the cosmological constant and vacuum energy in light of non-perturbative formulations of quantum gravity.

Room B Chair: *K. Schleich*

David Kubiznak
Perimeter Institute
Black hole analogue of Van der Waals fluid and reentrant phase transition
Treating the cosmological constant as a thermodynamic pressure and its conjugate quantity as a thermodynamic volume, we reconsider the critical behavior of charged anti de Sitter black holes. We complete the analogy of this system with the liquid/gas system and study its critical point, which occurs at the point of divergence of specific heat at constant pressure. We calculate the critical exponents and show that they

coincide with those of the Van der Waals fluid. For rotating black holes in higher dimensions we find a phenomenon of reentrant phase transitions, in which a monotonic variation of the temperature yields two phase transitions from large to small and back to large black holes. This situation is similar to that seen in multicomponent liquids.

Aaron Zimmerman
Canadian Institute for Theoretical Astrophysics
Quasinormal Modes of Deformed Black Holes
I will discuss recent work on computing the quasinormal mode spectrum of a black hole spacetime, when the spacetime geometry differs slightly from Kerr. In one application, this method reveals a possible mechanism for the onset of turbulence around rapidly rotating black holes. Another is to the computation of the quasinormal mode frequencies of a weakly charged Kerr black hole. Collaborators: Huan Yang (Perimeter Institute), Zachary Mark (Oberlin), Yanbei Chen (Caltech).

Ivan Booth
Dept of Math and Stats, Memorial University of Newfoundland
Slowly evolving horizons and the membrane paradigm
Proxy horizons are a class of geometric objects that include the event, Killing, trapping, isolated, dynamical, apparent and stretched horizons associated with near-equilibrium black holes (and branes). Technically they are a slight generalization of slowly evolving trapping horizons and we show that starting from any such proxy horizon one may (perturbatively) construct nearby event horizon candidates and stretched horizons. We consider the mechanics of these objects as well as apply them to study the non-uniqueness of geometric horizons.

Room C Chair: *J. Polchinski*

Cristián Martínez
Centro de Estudios Cientficos (CECs), Chile
Rotating hairy black hole and its microscopic entropy in three spacetime dimensions
We present a spinning hairy black hole dressed with a minimally coupled to a self-interacting real scalar field in three spacetime dimensions. The black hole has a single horizon that encloses a curvature singularity and the scalar field is regular everywhere. The presence of a scalar field with a slower falloff at infinity leads an anti-de Sitter asymptotic behavior that differs from the one found by Brown and Henneaux, and as a consequence, the scalar field contributes to the generators of the asymptotic symmetries, which are found using the Regge-Teitelboim approach. Remarkably, these relaxed asymptotic conditions have the same symmetry group as in pure gravity. In this way, the mass and angular momentum of this solution are computed. The thermodynamics properties are studied and it is verified that the first law of black hole thermodynamics holds. A scalar soliton, which is a finite mass regular solution devoid of integration constants, plays the role of the ground state. The existence of this soliton is the key to deriving the semiclassical entropy of the rotating hairy black hole using the counting of microscopic states provided by the Cardy formula.

Matteo Smerlak
Perimeter Institute
Last gasp of a black hole: why unitary evaporation must be non-monotonic
I will describe the relationship between radiated energy and entanglement entropy of massless fields at future null infinity (the "Page curve") in two-dimensional models of black hole evaporation. I will use this connection to derive a general feature of any unitary-preserving evaporation scenario: the Bondi mass of the hole must be non-monotonic. Time permitting, I will comment on time scales in such scenarios.

Todd Sierens
Perimeter Institute
Holographic Rényi Entropy
We apply a framework for calculating the Rényi entropy of a conformal field theory (CFT) with a spherical entangling surface by extending the definition of Rnyi entropy to include a chemical potential. A CFT with spherical entangling surface is mapped to a hyperbolic cylinder in a thermal bath via a conformal transformation, the temperature of which has a simple relationship with the radius of the original theorys entangling surface. Using the AdS/CFT correspondence, the thermal bath in the hyperbolic CFT can be related to a black hole in an asymptotically AdS spacetime. This talk discusses an application of this framework for AdS-RN and AdS-Kerr spacetimes with hyperbolic boundaries. A holographic calculation of the weight of a twist operator and of a magnetic response operator is included alongside the calculation of the Rnyi entropy for these theories.

Session 3

Room A Chair: *M. Johnson*

Eduardo Guendelman
Ben Gurion U
Dynamical Volume Element in Scale-Invariant and Supergravity Theories
The use in the action integral of a volume element of the form $\Phi d^D x$, where Φ is a metric-independent measure density, can yield new interesting results in all types of known generally coordinate-invariant theories: (1) 4-D theories of gravity plus matter fields; (2) reparametrization invariant theories of extended objects (strings and branes); (3) supergravity theories. In case (1) we obtain interesting insights concerning the cosmological constant problem, inflation and quintessence without the fifth force problem. In case (2) the above formalism leads to dynamically induced tension and to string models of non-abelian confinement. In case (3), we show that the modified-measure supergravity generates an arbitrary dynamically induced cosmological constant, i.e., a new mechanism of dynamical supersymmetry breaking.

Jack Gegenberg
Dept. of Mathematics & Statistics, University of New Brunswick
The Dust-Modified Bosonic String
We study a modified bosonic string theory that has a pressureless "dust" field on the string worldsheet. The dust is a real scalar field with unit gradient which breaks conformal invariance. Hamiltonian analysis reveals a time reparametrization constraint linear in the dust field momentum and a spatial diffeomorphism constraint. This feature provides a natural "dust time" gauge in analogy with the parametrized particle. In this gauge we give a Fock quantization of the theory, which is complete and self-consistent in $d < 26$. The Hamiltonian of the theory is not a constraint; as a consequence the Hilbert space and mass spectrum are characterized by an additional parameter, and includes the usual string spectrum as a special case. The other sectors provide new particle spectra, some of which do not have tachyons.

Aghil Alaee
Memorial University of Newfoundland
Existence of small deformations of extreme black hole initial data
Cauchy initial data for solutions of Einstein's equations consist of a Riemannian manifold M with metric h and extrinsic curvature K. Valid data (h,K) must satisfy constraint equations which form an elliptic system on M. In this talk I consider the following problem: given initial data corresponding to a vacuum extremal 5d black hole solution of Einstein's equations, can one find small deformations of this data with the same asymptotic behaviour and symmetries? We prove the existence of a one parameter maximal family of weak solutions (with respect to an appropriate norm) and it has the same angular momentum and area of the event horizon of an extreme Myers-Perry black hole. Moreover, the geometry of this family is close (in a

suitable sense) to the extreme Myers-Perry initial data set. We discuss this result in the context of the recently found instabilities of extreme black holes.

Room B Chair: *A. Ashtekar*

Saurya Das
University of Lethbridge
Quantum Raychaudhuri equation
I compute quantum corrections to the Raychaudhuri equation, by replacing classical geodesics with quantal (Bohmian) trajectories, and show that focusing of trajectories and the formation of conjugate points are avoided. I discuss implications for the Hawking-Penrose singularity theorems, for curvature singularities, and applications to cosmology.

Yifu Cai
McGill University
Constraining bouncing cosmologies with latest observations
The recently released BICEP2 data has put the study of very early universe models into a status that has never been reached. The detected primordial B-mode polarization signals, if are all due to primordial gravitational waves, will present a stringent constraint on all these models. I will talk about observational implications on non-singular bouncing cosmologies from the Planck and BICEP2 experiments. In particular I will focus on two representative bounce models in the frame of matter bounce cosmology. Today's observations favor a bounce model which occurs pretty slowly at an energy scale near the GUT scale.

Jonathan Ziprick
University of New Brunswick
Point Particles in 3d Loop Gravity
We derive a Hamiltonian theory for point particles in three dimensional gravity. Using a triangulation, we develop covariant position and momentum variables and show how these are naturally represented within the loop gravity phase space. Dynamics leads to interesting behaviour in the triangulation, and gives some insight into how we might describe dynamics in the full 4d theory of loop gravity.

Room C Chair: *V. Faraoni*

Christos Tzounis
University of Alberta
Spectral line broadening in magnetized black holes
We consider weakly magnetized non-rotating black holes. In the presence of a regular magnetic field the motion of charged particles in the vicinity of a black hole is modified. As a result the position of the innermost stable circular orbit (ISCO) becomes closer to the horizon. When the Lorentz force is repulsive (directed from the black hole) the ISCO radius can reach the gravitational radius. In the process of accretion charged particles (ions) of the accreting matter can be accumulated near their ISCO, while neutral particles fall down to the black hole after they reach 6M radius. The sharp spectral line Feα, emitted by iron ions at such orbits, is broadened when the emission is registered by a distant observer. In this paper we study this broadening effect and discuss how one can extract information concerning the strength of the magnetic field from the observed spectrum.

David Garfinkle
Dept. of Physics, Oakland University, USA
Gravitational wave memory
Gravitational wave memory, the change induced in a detector by the passage of a gravitational wave, is

calculated in perturbation theory and illustrated by a simple example. An analog of gravitational wave memory for electromagnetism is also presented.

Ofek Birnholtz
Hebrew University of Jerusalem, Israel
An Action for Reaction - from a bead on a string to Gravitational Waves
Several methods inspired by Effective Field Theory are adapted for formulating Action principles for treatment of radiative systems. Using field-doubling, gauge-invariant fields and zone-separation these methods are shown to be generally applicable. Thus the GR 2-body problem involving Gravitational Waves and the Abraham-Lorentz-Dirac problem of EM radiation-reaction can both be dimensionally-reduced to the classical 1+1d problem of a bead on a string - and solved, perturbatively. Results for GR and for high dimensional scalar and EM fields are presented in: "Theory of post-Newtonian radiation and reaction", Phys. Rev. D 88, 104037 (2013) "An action for reaction in general dimension", Phys. Rev. D 89, 045003 (2014) "Radiation reaction at the level of the action", arXiv:1402.2610 [hep-th]

Session 4

Room A Chair: *A. Maloney*

Shohreh Abdolrahimi
University of Oldenburg
Large Randall-Sundrum II Black Holes
Using a novel numerical spectral method, we have constructed an AdS_5-CFT_4 solution to the Einstein equation with a negative cosmological constant Lambda that is asymptotically conformal to the Schwarzschild metric. This method is independent of the Ricci-DeTurck-flow method used by Figueras, Lucietti, and Wiseman. We have perturbed the solution to get large static black hole solutions to the Randall-Sundrum II (RSII) braneworld model. Our solution agrees closely with that of Figueras et al. and also allows us to deduce the new results that to first order in $1/(-\Lambda M^2)$, the Hawking temperature and entropy of an RSII static black hole have the same values as the Schwarzschild metric with the same mass, but the horizon area is increased by about $4.7/(-\Lambda)$.

Alex Buchel
UWO/PI
Universality of Abrupt Holographic Quenches
We make an analytic investigation of rapid quenches of relevant operators in d-dimensional holographic CFT's, which admit a dual gravity description. We uncover a universal scaling behaviour in the response of the system, which depends only on the conformal dimension of the quenched operator in the vicinity of the ultraviolet fixed point of the theory. Unless the amplitude of the quench is scaled appropriately, the work done on a system during the quench diverges in the limit of abrupt quenches for operators with dimension $d/2 \leq \Delta < d$.

Stephen Green
Dept of Physics, University of Guelph
Holographic Thermalization, Stability of AdS, and the FPU Paradox
For a real massless scalar field in general relativity with a negative cosmological constant, we uncover a large class of spherically symmetric initial conditions that are close to AdS, but whose numerical evolution does not result in black hole formation. According to the AdS/CFT dictionary, these bulk solutions are dual to states of a strongly interacting boundary CFT that fail to thermalize at late times. Furthermore, as these states are not stationary, they define dynamical CFT configurations that do not equilibrate. We develop a two-timescale perturbative formalism that captures both direct and inverse cascades of energy and agrees with our fully nonlinear evolutions in the appropriate regime. We also show that this formalism admits a

large class of quasi-periodic solutions. Finally, we demonstrate a striking parallel between the dynamics of AdS and the classic Fermi-Pasta-Ulam-Tsingou problem.

Room B Chair: *T. Harriott*

Bret Underwood
Pacific Lutheran University
Non-Linear Resonance in Relativistic Preheating
The parametric resonance effect of preheating is sensitive to the linearity of the reheating sector. Additional self-interactions in the reheating sector, such as non-canonical kinetic terms like the DBI Lagrangian, can frustrate the parametric resonance effect of preheating. In the case of a DBI reheating sector, preheating is described by parametric resonance of a damped relativistic harmonic oscillator. We will discuss how the non-linear terms in the relativistic oscillator shut down the parametric resonance effect, limiting the effectiveness of preheating when there are non-linear self-interactions.

Shohreh Rahmati
University of New Brunswick
Effects of non-standard kinetic terms on parametric resonance
I discuss the phenomenon of preheating in the early universe when the matter field action involves non-standard kinetic terms motivated by polymer quantization, Dirac-Born-Infeld inflation, and other models.

Valerio Faraoni
Physics Department, Bishop's University
Are quantization rules for horizon areas universal?
Holographic/string-inspired quantization rules for the horizon areas of stationary black holes (or the products of the radii of real and virtual horizons) have been somehow claimed to be universal. Doubts have been expressed on this universality already in 4-dimensional general relativity. Noting that realistic black holes are not stationary but time-dependent, we produce counterexamples. These are 4-dimensional general-relativistic spacetimes containing dynamical black holes for at least part of the time, which do not satisfy the quantization rules even counting virtual horizons. (Based on V. Faraoni & A.F. Zambrano Moreno 2013, Phys. Rev. D 88, 044011.)

Room C Chair: *V. Husain*

Ariel Edery
Bishop's University
Formation of a condensate during collapse of a massless charged scalar field to a black hole
During the gravitational collapse of a massless charged (complex) scalar field to a black hole, we observe in numerical simulations that a condensate forms in the interior of the black hole. Unlike the neutral case, the magnitude of the scalar field in the interior tends to a non-zero constant; spontaneous symmetry breaking occurs and the black hole horizon becomes superconducting. Interestingly, this occurs without the usual symmetry breaking quartic potential being present. Our numerical results lend strong support to previous analytical work which had reported that black holes in an AdS_4 background can superconduct in the Abelian Higgs model without the usual quartic potential. The spacetime in our numerical simulation is asymptotically flat suggesting the phenomena is not limited to a particular background.

Kristin Schleich
University of British Columbia
Near horizon limits in asymptotical de Sitter spacetimes

Paul Mikula
University of Manitoba
Yang-Mills Flow in 1+1 Dimensions

Session 5

Room A Chair: *I. Booth*

James Babb
University of Winnipeg
An acoustic analogue of the Anti de Sitter-Schwarzschild black hole
Acoustic black holes (also known as "dumb holes") are fluid flows which mimic some of the behaviour of black hole spacetimes. In particular, there exists a threshold at which the fluid's flow velocity exceeds the speed of sound in the fluid, and so sound waves may never classically return from beyond this surface. In analogy with gravitational black holes this threshold is known as an "acoustic horizon," and it is expected to emit Hawking radiation and possess a spectrum of scalar quasi-normal modes. In my talk, I will show the derivation of an acoustic black hole that is conformal to a Scwarzschild black hole embedded in a 3+1 dimensional Anti-de Sitter spacetime. I will then obtain the scalar quasi-normal mode spectrum of this effective spacetime.

David Hobill
University of Calgary
The Road to Chaos: Discrete Self Similarity and Golden Rectangles in Bianchi IX spacetimes
Bianchi-IX cosmologies can exhibit an infinite number of periodic solutions, each of which is associated with a discrete self-similar oscillatory structure. The solution with the lowest period generates oscillations between Bianchi-I and Bianchi-II solutions that take the form of self-similar "Golden Rectangles". Other interesting relationships with the golden ratio are also generated by this solution. Since the solution is a period-3 solution its perturbations generate chaotic motions by the LI-Yorke (1975) theorem.

Gabor Kunstatter
University of Winnipeg
Throat quantization of the Schwarzschild-Tangherlini(-AdS) black hole
Adopting the throat quantization pioneered by Louko and Makela, we derive the mass and area spectra for the Schwarzschild-Tangherlini black hole and its anti-de Sitter (AdS) generalization in arbitrary dimensions. We find that the system can be quantized exactly in three special cases: the three-dimensional BTZ black hole, toroidal black holes in any dimension, and five-dimensional Schwarzshild-Tangherlini(-AdS) black holes. For the remaining cases the spectra are obtained for large mass using the WKB approximation. For asymptotically at black holes, the area/entropy has an equally spaced spectrum. In the asymptotically AdS case on the other hand, it is the mass spectrum that is equally spaced. Our exact results for the BTZ black hole mass with Dirichlet boundary conditions are consistent with the spectra of the corresponding operators in the dual CFT.

Room B Chair: *L. Pogosian*

Brian Corbett
University of Guelph
Non-standard methods for geodetic precession
There is a correspondence between continuous systems of differential equations and the discrete systems used to approximate solutions. It is desirable for a discrete system to preserve dynamical properties such as bifurcations, stability, and equilibria; with this in mind, we construct a non-standard scheme specifically for a geodetic orbit in the Schwarzschild exterior metric, and we examine its perihelion precession. This

formalism may be applied to systems of partial differential equations in order to improve the stability or accuracy of their numerical solutions. We discuss an example of this from critical phenomena.

Brad Cownden
University of Manitoba
Linear Perturbations of Type IIB SUGRA in Flux Compactifications
We consider linear perturbations of the background Type IIB SUGRA solutions and the effects these have on the equations of motion for the moduli. In particular, we allow for spacetime fluctuations of the D3-branes' position in the compact dimensions. The movement of the D3-branes is shown to affect the warp factor at linear order. We then use the equations of motion for the D3-branes, the universal volume modulus, and the universal axion to construct a second-order effective action. Using dimensional reduction, a 4-dimensional action that encodes the interactions between the moduli can then be determined.

Andrew Frey
University of Winnipeg
Stringy Corrections from (Almost) Classical Supergravity
We discuss how and in which circumstances flux and warping correct the Kähler metric on moduli space, using the dimensional reduction of form fields in flux compactifications as a case study. In the large volume limit, these corrections scale like α'^2, lower order than expected in bulk supergravity.

Session 6

Room A Chair: *S. Das*

Nils Dieppe
University of Winnipeg
Critical Phenomena in Higher Dimensional Gravity Using Adaptive Mesh Refinement
Investigating gravitational collapse in higher dimensional spherically symmetric general relativity using adaptive mesh refinement. In contrast to much previous work, we do not use double-null coordinates, but instead a generalized form of Painlevé-Gullstrand coordinates. In order to achieve sufficient resolution we use adaptive mesh refinement. Although the code produces excellent results near four spacetime dimensions, higher dimensions are still problematic.

Allison Kolly
University of Winnipeg
Stability of AdS spacetime in Einstein-Gauss-Bonnet Theory
An interesting property of anti-de Sitter space is that massless fields can travel to infinity in a finite time, bounce back more focussed and collapse to form a black hole. This has recently been shown to lead to the instability of AdS against the formation of black holes. Our goal is to shed light on this by numerically examining the effect of adding higher curvature terms to the Einstein-Hilbert action. In the case of of 5-dimensional Einstein-Gauss-Bonnet gravity, for example, there exists a mass gap. That is, there appears to exist a minimum mass below which no black holes can form. It is of interest to see if this mass gap restores stability to AdS space in Einstein-Gauss-Bonnet gravity.

Room B Chair: *H. Kunduri*

Mohammed Akbar
Dept of Mathematics, University of Texas at Dallas
Warped Faces of Flat Space

Adam Rogers
University of Manitoba
Modeling Highly Magnetized Pulsars
The origin of the large magnetic fields inferred from X-ray observations of soft gamma repeaters and anomalous x-ray pulsars remains mysterious. A variety of mechanisms have been suggested to generate these strong fields, including dynamo effects in the rapidly spinning proto-neutron star, accretion of fall-back material left over from the pre-collapse stage, and exotic compact objects such as quark stars.

In this talk, I will discuss our on-going efforts to develop a global optimization based approach to simultaneously model the x-ray spectral and timing properties of these objects. We make use of multi-objective genetic algorithms and particle swarm optimization methods to study entire classes of solutions that can constrain the equation of state of these enigmatic objects and provide clues to their true nature.

I will also discuss the effects of a distribution of plasma in the environment around a slowly rotating compact object. Ray tracing through the Schwarzschild metric in the presence of a plasma with an index of refraction introduces frequency dependent and observable changes to the pulse profiles and spectra, which can help to distinguish between dynamo and accretion driven models.