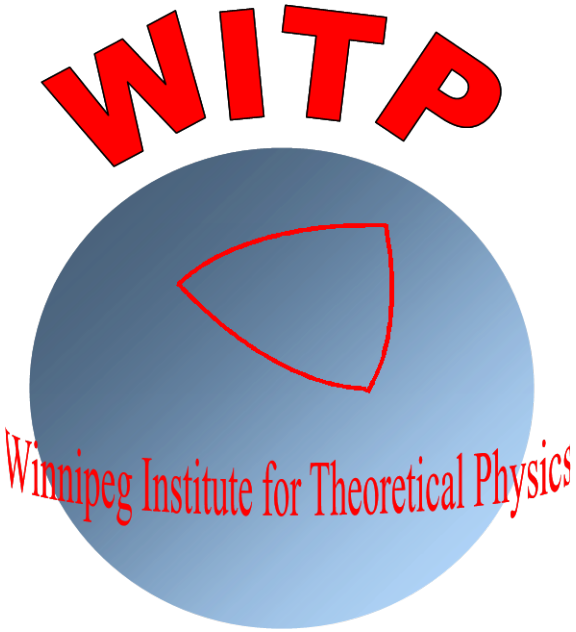
The Winnipeg Institute for Theoretical Physics Annual Report



September 2012 – August 2013

Web site: http://www.physics.umanitoba.ca/WITP/witp.html

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 23rd 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 its recent practice of providing support for Canadian theoretical physics meetings by committing funding for the 15th Canadian Conference on General Relativity and Relativistic Astrophysics, to be held in Winnipeg in 2014. In addition, the WITP underwent its regular review by the University of Manitoba Senate and welcomed two new permanent members.

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 4.5, and the published research work of members is found in section 4.6. Section 5.1 contains a summary of income and expenditures for the period September 1, 2012 to August 31, 2013. The plans for the coming year include a program of invited speakers, visiting research collaborations, and the promotion of postgraduate and postdoctoral research. A major activity that was held for the second time this year was a 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 the University of Manitoba and well-attended by members from all three universities.

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.

In December 2012, the WITP elected a new Executive Committee for a two-year term. The Executive consists of the Director, A. R. Frey (Winnipeg), the Director-Elect, K. Shamseddine (Manitoba), and the Past-Director, G. Kunstatter (Winnipeg). The previous Past-Director (to Dec. 2012) was B. W. Southern (Manitoba).

A. R. Frey
Director, WITP

2 Current List of Members (2012-13)

2.1 Permanent (Faculty) Members

- M.E. Alexander[2], *Ph.D. (Manchester University, UK)*
- 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)*
- J. Hopkinson[3], *Ph.D. (Rutgers)* (left May 2013)
- 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-Universitat Bochum)*
- K.M. Shamseddine[1], *Ph.D. (Michigan State)*
- B.W. Southern[1], *Ph.D. (McMaster)* [Director, 90-91, 07-09]
- D.W. Vincent[2], *Ph.D. (Toronto)* [Director, 94-95]
- J.G. Williams[3], *Ph.D. (Birmingham)* [Director, 96-97]
- M. Whitmore[1], *Ph.D. (McMaster)*

Senior Scholars

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

[1]University of Manitoba
[2]University of Winnipeg
[3]Brandon University

2.2 Associate Members

Research Associates

- Alex Sibirtsev (Blunden)

Postdoctoral Fellows

- Rebecca Danos (Safi-Harb/Shalchi)
- Gilles Ferrand (Safi-Harb)
- Wie-jie Fu (Carrington)
- Harsha Kumar (Safi-Harb)
- Adam Rogers (Safi-Harb)
- Tongchuan Suo (Whitmore)

2.3 Graduate Students

- Siranush Avestiyan (M.Sc.) (Chakraborty)
- Robert Bergen (M.Sc.) (Alexander, co-supervised with C. Bidinosti at Winnipeg)
- Chelsea Braun (M.Sc.) (Safi-Harb)
- Angel Barria Comicheo (Ph.D.) (Shamseddine)
- Bradley Cownden (M.Sc.) (Frey)
- Bryson Dietz (M.Sc.) (Alexander, co-supervised with E. Elhami at Winnipeg)
- Darren Flynn (M.Sc.) (Shamseddine)
- Erica Franzmann (M.Sc.) (Fiege)
- William Grafton (M.Sc.) (Shamseddine)
- Benson Guest (M.Sc.) (Safi-Harb)
- Mohammad Hussein (Ph.D) (Shalchi)
- Damodar Khatri Chhetri (M.Sc.) (Svenne)
- Heather Matheson (Ph.D.) (Safi-Harb)
- Paul Mikula (M.Sc.) (co-supervised Kunstatter and Carrington)
- Travis Redpath (M.Sc.) (Hopkinson)
- Andrew Senchuk (Ph. D) (Shamseddine, co-supervised with G. Gwinner, Manitoba)

- Tim Taves (Ph.D.) (Kunstatter)
- Jennifer West (Ph.D.) (Safi-Harb)
- Ping Zhou (Ph.D) (Safi-Harb, co-supervised with Yang Chen at Nanjing)

2.4 Undergraduate Research Students 2012-13

- G. Bookatz (Shamseddine)
- G. Chernitsky (Frey)
- N. Deppe (Kunstatter)
- J. Enns (Frey)
- P. Gregoryanz (Frey)
- J. Hernandez-Melgar (Vail)
- A. Kolly (Frey/Kunstatter)
- M. Mercredi (Alexander)
- N. Reid (Frey)
- J. Smith (Carrington/Fugleburg)
- S. Srinivasan (Shalchi)
- C. Tang (Shamseddine)
- L. Yu (Alexander)

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.

My interest is to 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.

I am also involved in developing new methods for medical image processing, based on fast numerical implementations of variational principles and level set methods, that have been applied to image segmentation, image registration, and (in combination with wavelets) to sparse representations of signals (images, spectra, time series, etc.). Recently, segmentation algorithms have been used to classify different regions of an image using a community detection algorithms, derived from statistical mechanics (e.g., the Potts or Ising models). Due to the computationally intensive nature of image processing, we are gradually moving over to high performance parallel computing implemented on Graphics Processing Units. In addition, 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.

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. 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, the accelerated expansion of space at the birth of our universe, in string theory, the only known theory unifying particle physics with gravity. In particular, I ask what role the extra dimensions of string theory play during inflation. Does the growth or bending of the extra dimensions change the shape of our universe? Do the extra dimensions leave behind an imprint, a measurable sign of string theory? Ultimately, can we understand inflation as a consequence of the shape of extra dimensions of space? These questions will occupy much of my attention for the next several years; I also spend some time thinking about holographic theories of physics and the initial conditions of the universe.

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 focussed 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 NASA's Chandra and ESA's 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 to be launched in 2015 and that will study the high-energy universe with unprecedented spectral resolution and a broadband (0.5-600 keV) energy band. Funding has been provided by NSERC through the Canada Research Chairs and Discovery Grants Programs, the Canadian Institute for Theoretical Physics, the Canadian Space Agency, the Canada Foundation for Innovation and Manitoba's 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-Arch imedean 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 upavailable 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. 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.

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 research is concerned with 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.

Our current principal research activity is on the point defect properties in aluminum nitride, and on graphene structured systems.

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, inparticular inhomogeneous copolymer systems, end-tethered polymers, and phospholipid membranes. Both ofthese classes of molecules have relatively high molecular weights, havechemically distinct sections, and are chain-like in structure. The copolymer and phospholipidsystems can self-assemble to form complex nano-scale structures, and undergo subtle phasetransitions. 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 field 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: 2009-2013

Date	Speaker	Title
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"
Feb 25 2009	L. Canton	"Application of the Multi-Channel Algebraic Scattering Formalism to the Spectroscopy of Hypernuclei"
Mar 26 2009	M. Plumer	"Landau Theory of the Magnetic Phase Diagram of Magnetoelectric CuFe02"
May 7, 2009	J.W. Moffat	"Observationally Verifiable Predictions of Modified Gravity"
May 7, 2009	J. W. Moffat	"Einstein's Big Ideas"
May 8, 2009	J.W. Moffat	"Redesigning Electroweak Theory: Does the Higgs Particle Exist?"
May 21, 2009	Hideki Maedi	"Self-similar growth of black holes in the Friedmann universe"
July 20, 2009	Brian Dolan	"Equivariant Dimensional Reduction and Quiver Gauge Theory"

4.2 Visitors: 2009-2013

Date	Visitor	Institution	Host
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
July 19-20 2009	Brian Dolan	National University of Ireland	G. Kunstatter
May 17-23 2009	Hideki Maedi	CECS, Chile	G. Kunstatter
May 7-8 2009	J. W. Moffat	Perimeter Institute	G. Kunstatter
Mar 26-28 2009	M. Plumer	Memorial University	B. Southern

4.3 Summer Student Symposium 2013

In August 2013, the WITP held its second Summer Student Symposium at the University of Manitoba. 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 forty 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. With the success of this event in its first two years, we plan to make it an annual event.

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

4.4 Conferences

- The 12th International Conference on p-Adic Functional Analysis was held at the University of Manitoba from July 2-6, 2012. The WITP provided financial support of $1200 for the conference. WITP member K.M. Shamseddine was the organizer of the conference and the editor of the proceedings, which were published in 2013 by the journal *Contemporary Mathematics* of the American Mathematical Society.

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

  - Theory Canada V, UNB, Fredericton 2009 ($517.39).
  - 13th Canadian Conference on General Relativity and Relativistic Astrophysics, Calgary, AB, 2009 ($200.00).
  - Canadian Prairie Theoretical Physics Network meeting, Lethbridge, AB, 2010 ($1,000.00).
  - Theory Canada VII, Lethbridge, AB, 2012 ($400).

- A. Frey, G. Kunstatter, and D. Vincent are organizing the 15th Canadian Conference on General Relativity and Relativistic Astrophysics to be held in Winnipeg during May 2014. Ten leading national and international physicists in the field have committed to coming as plenary lecturers. This biennial national conference was last held in Winnipeg in 1991. The WITP has committed $2000 to this conference.

4.5 Graduate Degrees Supervised

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

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

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

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

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

6. Usman Chowdhury (2009), "Cutting Rules for Feynman Diagrams at Finite Temperature," M.Sc. thesis (Carrington and Kobes).

7. Paul Fraser (2009), "Development and application of a multi-channel algebraic theory for nucleon-nucleus scattering," Ph. D. thesis, Melbourne University (supervisor: Ken Amos, co-supervisors: J.P. Svenne, L. Canton, S. Karataglidis)

8. Jonathan Ziprick (2009), "Singularity resolution and dynamical black holes," M.Sc. thesis (Kunstatter)

4.6 Publications of Permanent Members

M.E. Alexander

1. 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. In Press, Aug. 2013.

2. 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).

3. 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).

4. 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.

5. 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

6. 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).

7. 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).
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8. M.E. Alexander, M. Mercredi. "A model for cell migration in competing chemotactant fields," Submitted: Canadian Applied Math Quarterly (October 2013).

9. 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," Submitted: Phys. Med. Biol. (Oct. 2013).

10. R. Bergen, H. Lin, M. Alexander, and C. Bidinosti. "4-D MR phase and magnitude segmentations with GPU parallel computing,". Submitted Magnetic Resonance Imaging (Nov. 2013).

P.G. Blunden

1. N. L. Hall, P. G. Blunden, W. Melnitchouk, A. W. Thomas and R. D. Young, "Constrained gamma-Z interference corrections to parity-violating electron scattering," Phys. Rev. D **88**, 013011 (2013)

2. P. G. Blunden, W. Melnitchouk and A. W. Thomas, "$\gamma - Z$ box corrections to weak charges of heavy nuclei in atomic parity violation," Phys. Rev. Lett. **109**, 262301 (2012).

3. J. Arrington, P. G. Blunden and W. Melnitchouk, "Review of two-photon exchange in electron scattering," Prog. Part. Nucl. Phys. **66**, 782 (2011).

4. P. G. Blunden, W. Melnitchouk and A. W. Thomas, "New formulation of gamma-Z box corrections to the weak charge of the proton," Phys. Rev. Lett. **107**, 081801 (2011).

5. A. Sibirtsev, P. G. Blunden, W. Melnitchouk and A. W. Thomas, "gamma-Z corrections to forward-angle parity-violating e-p scattering," Phys. Rev. D **82**, 013011 (2010).

6. P. G. Blunden, W. Melnitchouk and J. A. Tjon, "Two-photon exchange corrections to the pion form factor," Phys. Rev. C **81**, 018202 (2010).

7. J. A. Tjon, P. G. Blunden and W. Melnitchouk, "Detailed analysis of two-boson exchange in parity-violating e-p scattering," Phys. Rev. C **79**, 055201 (2009).

8. A. Aleksejevs, S. Barkanova and P. G. Blunden, "Computational model for electron-nucleon scattering and weak charge of the nucleon," J. Phys. G **36**, 045101 (2009).

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9. P. G. Blunden, "gamma Z exchange corrections in parity-violating electron scattering," AIP Conf. Proc. **1374**, 515 (2011).

10. P. G. Blunden, "Two-photon exchange in elastic electron-proton scattering: Theoretical issues," AIP Conf. Proc. **1160**, 8 (2009).

M. E. Carrington

1. "Bethe-Salpeter Equations from the 4PI effective action," M.E. Carrington, WeiJie Fu, T. Fugleberg, D. Pickering and I. Russel, Phys. Rev. D. **88**, 085024 (2013) - arXiv:1310.3295.

2. "Results from the 4PI effective action in 2- and 3-dimensions," M. E. Carrington, Wei-Jie Fu, Eur. Phys. J. C, **73**, 2399 (2013) - arXiv:1202.3165.

3. "Thermal field theory at next-to-leading order in the hard thermal loop expansion," A. Mirza and M.E. Carrington, Phys. Rev. D. **87**, 065008 (2013) - arXiv:1302.3796.

4. "Renormalization group flow equations connected to the nPI effective action," M.E. Carrington, Phys. Rev. D. **87**, 045011 (2013) - arXiv:1211.4127.

5. "A New Method to Calculate the n-Particle Irreducible Effective Action," M.E. Carrington and Yun Guo, Phys. Rev. D **85**, 076008 (2012) - arXiv:1109.5169.

6. "A New Method to Calculate the n-Particle Irreducible Effective Action," M.E. Carrington and Yun Guo, Phys. Rev. D **85**, 076008 (2012) - arXiv:1109.5169.

7. "Perturbative and Nonperturbative Kolmogorov Turbulence in a Gluon Plasma," M.E. Carrington and A Rebhan, Eur. Phys J. C **71**, 1787 (2011) - arXiv:1011.0393.

8. "Geometrical Entanglement of Highly Symmetric Multipartite States and the Schmidt Decomposition," D Buhr, M E Carrington, T Fugleberg, R Kobes, G Kunstatter, D McGillis, C Pugh and D Ryckman, J. Phys. A: Math. Theor. **44**, 365305 (2011) - arXiv:1104.3159.

9. "Techniques for n-Particle Irreducible Effective Theories," M.E. Carrington and Yun Guo, Phys. Rev. **D83**, 016006 (2011) - arXiv:1010.2978.

10. "Geometric measures of entanglement and the Schmidt decomposition," M.E. Carrington, R. Kobes, G. Kunstatter, D. Ostapchuk and G. Passante, J. Phys. A: Math. Theor. **43**, 5302 (2010) - arXiv:1003.4755.

11. "Next-to-Leading Order Transport Coefficients from the Four-Particle Irreducible Effective Action," M.E. Carrington and E. Kovalchuk, Phys. Rev. D **81**, 065017 (2010) - arXiv:0912.3149.

12. "On the imaginary part of the next-to-leading-order static gluon self-energy in an anisotropic non-Abelian plasma ," M.E. Carrington and A. Rebhan, Phys. Rev. D **80**, 065035 (2009) - arXiv:0906.5220.

13. "Leading Order QCD Shear Viscosity from the 3PI Effective Action," M. E. Carrington and E. Kovalchuk, Phys. Rev. D **80**, 085013 (2009) - arXiv:0906.1140.

14. "Next-to-leading Order Static Gluon Self-energy for Anisotropic Plasmas," M.E. Carrington and A. Rebhan, Phys. Rev. D **79**, 025018 (2009) - arXiv:0810.4799.

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15. " 4-point vertices from the 2PI and 4PI Effective Actions," M.E. Carrington, Wei-Jie Fu, P. Mikula and D. Pickering, arXiv:1310.4352.

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16. "Parton Energy Loss in the Extremely Prolate Quark-Gluon Plasma, Margaret E. Carrington, Katarzyna Deja, Stanislaw Mrowczynski (contribution to the proceedings of Xth Quark Confinement and the Hadron Spectrum, Munich, Germany, October 8-12, 2012), PoS (Confinement X) 175 (2013) - arXiv:1301.4563.

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4. A. Manaselyan, A. Ghazaryan & T. Chakraborty, Europhys. Lett. 99, 17009 (2012)
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17. D.S.L. Abergel & Tapash Chakraborty, Nanotechnology 22, 015203 (2011)
18. T. Chakraborty, Physics in Canada 66, 289 (2010)
19. X.F. Wang, T. Chakraborty & J. Berashevich, Nanotechnology 21, 485101 (2010)
20. D.S.L. Abergel & T. Chakraborty, Phys. Rev. B 82, 161409(R) (Rapid Commun.) (2010)
21. Julia Berashevich & T. Chakraborty, Phys. Rev. B 82, 134415 (2010)
22. Aram Manaselyan & T. Chakraborty, Nanotechnology 21, 355401 (2010)
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J. Fiege

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17. "Not-So-Dark Matter," York University & University of North Dakota, 2013.

18. "What is String Theory?" public lecture at the Millennium Library, Winnipeg, 2012.

19. "Gamma Rays at 130 GeV and How They Might Come from Dark Matter," McGill, 2012, & Perimeter Institute, 2013.

20. "Warped Dimensional Reduction," McGill University, Canadian Conference on General Relativity and Relativistic Astrophysics hosted by Memorial University, 2012

21. "Metastable Dark Matter and 511 keV Gammas from the Galactic Center," Dark Matter from Every Direction workshop hosted by McGill University, 2011.

22. "Light from Dark Matter," San Francisco State University, University of Heidelberg, University of Winnipeg, University of Manitoba, 2011.

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24. "Warped Kaluza-Klein Dark Matter," Rencontres Théoriciennes (Paris Joint String Theory Meeting), hosted by CEA Saclay Institut de Physique Théorique, 2010.

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27. "Could Dark Matter Come from Extra Dimensions?" with Rebecca Danos, Annual Alumni Colloquium at Wake Forest University, 2009.

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

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

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

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

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

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

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

31. G. Kunstatter, "Dynamical Singularity Resolution in Quantum Corrected Black Hole Formation", **Invited**, CAP Congress, Moncton, June 2009.

32. G. Kunstatter, "A Non-singular, single horizon Quantum Corrected Black Hole Spacetime", **Invited**, Theory Canada V, University of New Brunswick, June 2009.

33. G. Kunstatter, "Midi-Superspace Models for Semi-classical Black Holes" **Invited**, Canadian Conference on General Relativity and Relativistic Astrophysics, University of Calgary, May, 2009.

34. G. Kunstatter, "Spherically Symmetric Scalar Field Collapse in Flat Slice Coordinates", Black Holes VII, Banff, May, 2009.

35. G. Kunstatter, "Singularity Resolution in Quantum Corrected Black Holes", **Invited** Atlantic Regional Conference on General Relativity, Fredericton, April, 2009.

36. G. Kunstatter, "Singularity Resolution in the Scolymerized (BTZ) Black Hole", **Invited**, ESI Workshop on 3-D Gravity, Vienna, April, 2009.

Invited Lectures

37. "Quantum Mechanics of the Interior of Radiating 2D Black Holes", Rykkyo University, Tokyo, June, 2013.

38. "Lovelock Gravity: Geometrodynamics and Quantum Mechanics", Univerite de Montreal, March 2012.

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

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

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

42. “Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation”, University of California (Davis), May 26, 2009.

43. “Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation”, University of Western Ontario, March 19, 2009.

44. “Quantum Black Holes: Portals to Strange New Universes”, Prairies Regional Lecture Series, University of Saskatoon and University of Regina, January, 2009.

45. “Black Holes”, guest lecturer, Introduction to Physics, University of Winnipeg, January, 2009.

P.D. Loly

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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)

5. P.D. Loly, I.D.Cameron, W.Trump and D.S.Schindel, ”Magic square spectra”, Linear Algebra Appl. 430 (10) 2659-2680 (2009). (C1)

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7. 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.

8. 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.

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1. Karl-Peter Marzlin and T. A.Osborn, "Quantum Collapse Bell Inequalities", submitted to Phys. Rev. A, ; arXiv Quant.Phys 1306.2574, [2013]

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

S. Plosker

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

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2. Jackson, M., Safi-Harb, S., & Kothes, R. 2013, MNRAS (under revision)
3. Zhou, P., Chen, Y., Li, X.-D., Safi-Harb, S., Mendez, M., Terada, Y., Sun, W. 2013, to appear in Ap.J. (Letters); arXiv:1310.7705
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30. 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).

31. 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).

32. 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).

33. 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).

34. 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).

35. 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).

36. Report of the Canadian Space Agency Discipline Working Group in High-Energy Astrophysics by Kaspi, V., Babul, L., Cumming, A., Gallagher, S., Gallo, L., Hall, P., Hanna, D., Heinke, C., Heyl, J., Holder, G., Hutchings, J., Kaspi, V., Leahy, D., McNamara, B., Moffat, A., Moon, D.-S., Nelson, L., Ragan, K., Rutledge, R., Safi-Harb, S. (Chair of the Supernova Remnants Subcommittee), Stairs, S., Taylor, J., Thompson, C., & van Kerkwijk, M., a 35-page report submitted to the Canadian Space Agency, March (2009).

Invited Talks and Colloquia

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

38. 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).

39. 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).

40. 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).

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

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

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

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

45. 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).

46. 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).

47. 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).

48. 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).

49. Mystery Magnetic Stars, Women in Space Science (Two parts), Public Lecture at University of British Columbia, 30 Sep. (2009).

Conference Presentations

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

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

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

53. 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)

54. 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)

55. 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).

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

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

58. 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).

59. 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).

60. 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).

61. 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).

62. 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).

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

64. 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).

65. 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).

66. 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).

67. 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).

68. 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).

69. 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).

70. 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).

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

72. 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).

73. 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).

74. 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).

75. 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).

76. 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).

77. 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).

78. 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).

79. 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).

80. 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).

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

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

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

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

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

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

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

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

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

90. 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

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

92. '3D Simulations of Supernova Remnants', U. of Manitoba and CEA/Saclay Press Release, Nov. (2012)

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

94. '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).

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

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

97. RCI 'Sans Limite' Program, Interview with Radio Canada International, Nov. (2010).

A. Shalchi

1. Qin, G. and Shalchi, A., The Role of the Kubo Number in Two-Component Turbulence, Physics of Plasmas **20**, 092302 (2013).

2. Shalchi, A., Simple Analytical Forms of the Perpendicular Diffusion Coefficient for Two-Component Turbulence, I. Magnetotstatic Turbulence, The Astrophysical Journal **774**, 7 (2013).

3. Dosch, A., Shalchi, A., and Zank, G. P., Perpendicular Transport of Charged Particles: Results for the Unified Nonlinear Transport theory derived from the Newton-Lorentz equation, Advances in Space Research **52**, 936 (2013).

4. Danos, R. J., Fiege, J. D., and Shalchi, A., Numerical Analysis of the Fokker-Planck Equation with Adiabatic Focusing: Isotropic Pitch-Angle Scattering, The Astrophysical Journal **772**, 35 (2013).

5. Tautz, R. C. and Shalchi, A., Simulated Energetic Particle Transport in the Interplanetary Space: The Palmer Consensus Revisited, Journal of Geophysical Research **118**, 642 (2013).

6. Shalchi, A. and Kolly, A., Analytical description of field line random walk in Goldreich-Sridhar Turbulence, Monthly Notices of the Royal Astronomical Society **431**, 1923 (2013).

7. Shalchi, A., Perpendicular Diffusion in Magnetostatic Slab Turbulence: The Theorem on Reduced Dimensionality and Microscopic Diffusion, Journal of Atmospheric and Solar-Terrestrial Physics **97**, 37 (2013).

8. Shalchi, A. and Danos, R. J., On the different results for the parallel diffusion coefficient of cosmic particles with adiabatic focusing, The Astrophysical Journal **765**, 153 (2013).

9. Shalchi, A., Benchmarking the unified nonlinear transport theory for Goldreich-Sridhar turbulence, Astrophysics and Space Science **344**, 187 (2013).

10. Buffie, K., Heesen, V., and Shalchi, A., Theoretical Explanation of the Cosmic Ray Perpendicular Diffusion Coefficient in the Nearby Starbust Galaxy NGC 253, The Astrophysical Journal **764**, 37 (2013).

11. Shalchi, A., Analytical description of nonlinear particle transport in slab turbulence: High particle energies and stochastic acceleration, Physics of Plasmas **19**, 102901 (2012).

12. Shalchi, A., Fitting Analytical Forms of Spatial and Temporal Correlation Functions to Spacecraft Data, Astrophys. Space Sci. Trans. **8**, 35 (2012).

13. Shalchi, A., Gyrophase Diffusion of Charged Particles in Random Magnetic Fields, Monthly Notices of the Royal Astronomical Society **426**, 880 (2012).

14. Buffie, K. and Shalchi, A., Compound Diffusion of Energetic Particles: A Kappa Model for the Parallel Distribution Function, Astrophysics and Space Science **340**, 351 (2012).

15. Shalchi, A., Webb, G. M., and le Roux, J. A., Parallel transport of cosmic rays for non-diffusive pitch-angle scattering. I. Using the standard Fokker-Planck equation, Physica Scripta **85**, 065901 (2012).

16. Qin, G. and Shalchi, A., Numerical investigation of the influence of large turbulence scales on the parallel and perpendicular transport of Cosmic Rays, Advances in Space Research **49**, 1643 (2012).

17. Guest, B. and Shalchi, A., Random Walk of Magnetic Field Lines in Dynamical Turbulence: A Field Line Tracing Method, II. Two Dimensional Turbulence, Physics of Plasmas **19**, 032902 (2012).

18. Li, G., Shalchi, A., Ao, X., Zank, G. P., and Verkhoglyadova, O. P., Particle acceleration and transport at an oblique CME-driven shock, Advances in Space Research **49**, 1067 (2012).

19. Shalchi, A., Dosch, A., le Roux, J. A., Webb, G. M., and Zank, G. P., Magnetic Field Line Random Walk in Turbulence: A Two-point Correlation Function Description, Physical Review E **85**, 026411 (2012).

20. Tautz, R. C. and Shalchi, A., Drift coefficients of charged particles in turbulent magnetic fields, The Astrophysical Journal **744**, 125 (2012).

21. Shalchi, A., Comment on "Cosmic ray diffusion: Detailed investigation of a recent model" [Phys. Plasmas 18, 082305 (2011)], Physics of Plasmas **18**, 114701 (2011).

22. Shalchi, A., Magnetic Field Line Random Walk in Two-dimensional turbulence: Markovian Diffusion versus Superdiffusion, Contributions to Plasma Physics **51**, 10 (2011).

23. Shalchi, A., Rempel, T. J., and Rempel, T. J., Test-particle Transport: Higher-order Correlations and Time-dependent Diffusion, Plasma Physics and Controlled Fusion **53**, 105016 (2011).

24. Shalchi, A., A heuristic derivation of an improved analytical theory for perpendicular diffusion of charged particles, Advances in Space Research **48**, 1499 (2011).

25. Abramowski, A., ..., Shalchi, A., et al., Simultaneous multi-wavelength campaign on PKS 2005-489 in a high state, Astronomy & Astrophysics **533**, A110 (2011).

26. Aharonian, F., ..., Shalchi, A., et al., Primary particle acceleration above 100 TeV in the shell-type Supernova Remnant RX J1713.7-3946 with deep H.E.S.S. observations (Corrigendum), Astronomy & Astrophysics **531**, C1 (2011).

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28. Abramowski, A., ..., Shalchi, A., et al., Search for a Dark Matter Annihilation Signal from the Galactic Center Halo with H.E.S.S., Physical Review Letters **106**, 161301 (2011).

29. Abramowski, A., ..., Shalchi, A., et al., Search for Lorentz Invariance breaking with a likelihood fit of the PKS 2155-304 flare data taken on MJD 53944, Astroparticle Physics **34**, 738 (2011).

30. Abramowski, A., ..., Shalchi, A., et al., Detection of very-high-energy γ-ray emission from the vicinity of PSR B1706-44 and G 343.1-2.3 with H.E.S.S., Astronomy & Astrophysics **528**, A143 (2011).

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32. Abramowski, A., ..., Shalchi, A., et al., Revisiting the Westerlund 2 Field with the HESS Telescope Array, Astronomy & Astrophysics **525**, A46 (2011).

33. Acero, F., ..., Shalchi, A., et al., Discovery and follow-up studies of the extended, off-plane, VHE gamma-ray source HESS J1507-622, Astronomy & Astrophysics **525**, A45 (2011).

34. Tautz, R. C. and Shalchi, A., Numerical test of improved nonlinear guiding center theories, The Astrophysical Journal **735**, 92 (2011).

35. Dosch, A., Shalchi, A., and Tautz, R. C., Numerical investigation of the cosmic ray scattering anisotropy and Bohm diffusion in space plasmas, Monthly Notices of the Royal Astronomical Society **413**, 2950 (2011).

36. Shalchi, A., Charged Particle Transport in Space Plasmas: An Improved Theory for Cross Field Scattering, Plasma Physics and Controlled Fusion **3**, 074010 (2011).

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38. Shalchi, A., Velocity Correlation Functions of Charged Particles Derived from the Fokker-Planck Equation, Advances in Space Research **47**, 1147 (2011).

39. Tautz, R., Shalchi, A., and Dosch , A., Simulating heliospheric and solar particle diffusion using the Parker spiral geometry, Journal of Geophysical Research **116**, A02102 (2011).

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42. Abramowski, A., ..., Shalchi, A., et al., VHE γ-ray emission of PKS 2155-304: spectral and temporal variability, Astronomy & Astrophysics **520**, A83 (2010).

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44. Abramowski, A., ..., Shalchi, A., et al., Multi-wavelength Observations of H 2356-309, Astronomy & Astrophysics **516**, A56 (2010).

45. Aharonian, F., ..., Shalchi, A., et al., Erratum to "Observations of the Sagittarius dwarf galaxy by the HESS experiment and search for a dark matter signal" [Astropart. Phys. 29(1) (2008) 55-62], Astroparticle Physics **33**, 274 (2010).

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88. Dosch, A. and Shalchi, A., Quasi-linear Perpendicular Diffusion Coefficients of Charged Cosmic Rays Calculated Directly from the Newton-Lorentz Equation, Monthly Notices of the Royal Astronomical Society **394**, 2089 (2009).

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Conference Proceedings and Talks

92. 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

93. Li, G., Webb, G., Shalchi, A., and Zank, G. P., Non-linear Guiding Center Theory and Acceleration of Cosmic Rays at Supernova Remnant Shocks, Shock waves in space and astrophysical environments. 8th Annual International Astrophysics Conference. 2009, American Institute of Physics Conference Proceedings, 1183, 57

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95. Shalchi, A., Schlickeiser, R., Tautz, R. C., and Skoda, T., Nonlinear Cosmic Ray Propagation and Confinement in the Galaxy, Proceedings of the 31th International Cosmic Ray Conference, 2009, Abstract ID: 168, University of Lodz, Poland

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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*, **Indagationes Mathematicae**, submitted.

2. B*-algebras of operators and study of normal and Hilbert-Schmidt operators on a Banach space over the complex Levi-Civita field, *José Aguayo, Miguel Nova and Khodr Shamseddine*, **Journal of Mathematical Physics**, revision requested.

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.

9. The implicit function theorem in a non-Archimedean setting, *Khodr Shamseddine, Trevor Rempel and Todd Sierens*, **Indagationes Mathematicae**, Volume 20 # 4, 2009, pp. 603-617.

Edited Proceedings

10. 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.

11. 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

12. Analysis on the Levi-Civita field and computational applications, *Khodr Shamseddine*, **Applied Mathematics and Computation**, submitted.

13. 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.

14. 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.

15. 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.

16. 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

17. 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

18. 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.

19. (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.

20. (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.

21. 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.

22. 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

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

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

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

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

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

B.W. Southern

Refereed Publications

1. 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).

2. 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)

3. 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]

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

5. 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]

6. 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].

7. 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].

8. 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].

Submitted for Publication

9. 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 DC and AC Spin Current Injected from a Ferromagnetic Insulator into a Ferromagnetic Metal" , aiXiv:1310.4840[cond-mat-mtrl-sci](2013).

Conference Contributions

10. 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)

11. 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)

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

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

14. 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)

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

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

17. 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)

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

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

Seminars and Colloquia

20. 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. 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.

2. 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).

3. 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).

4. 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).

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

6. 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).

7. 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).

8. 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).

9. 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).

10. Coupled-channel evaluations of cross sections for scattering involving particle-unstable resonances, P. Fraser, K. Amos, L. Canton, G. Pisent, S. Karataglidis, J.P. Svenne, and D. van der Knijff, Physical Review Letters, **101**, 242501 (December, 2008).

Refereed Conference Proceedings

11. 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.

12. 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.

13. 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)

14. 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.

15. 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.

16. 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.

17. 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

18. 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.

19. 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).

20. 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.

21. 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.

22. Impact of deuterium nuclear data on critical systems involving heavy water, Ken Kozier, J.P. Svenne, Luciano Canton and Dan Roubtsov; ND2010, International Conference on Nuclear Data for Science and Technology, April 26-30, 2010, Jeju Island, Korea. Abstract only.

23. 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

24. 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

25. 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

26. 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)

27. Recent MCAS applications on hypernuclei and radiative capture, L. Canton, K. Amos, S. Karataglidis, and J.P. Svenne, 12th International Conference on Nuclear Reaction Mechanisms, Varenna, Italy, June 15-19, 2009; Proceedings: vol. **2**, pp 129-136, CERN Proceedings series.

28. Analysis of neutron-deuteron scattering for science and atomic applications, L. Canton, K.S. Kozier and J.P. Svenne, 2nd International Conference on Current Problems in Nuclear Physics and Atomic Energy, Kyiv, Ukraine, June 9-15, 2008, Proceedings (pp. 533-536), Kyiv, Ukraine, 2009.

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. 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)

2. 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)

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

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)

J.G. Williams

1. 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).

2. 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).

3. T.A. Harriott and J.G. Williams, "Euler numbers on cobordant hypersurfaces," in Proceedings of the 11th Marcel Grossmann Meeting on General Relativity, edited by H. Kleinert, R.T. Jantzen and R. Ruffini (World Scientific, Singapore), pp. 2211–2212 (2008).

5 Financial

5.1 Statement of Income and Expenditures

Income

Income Source	Amount
Carry Over	$1566.36
UWinnipeg Dean of Science & VP Research	$1600.00
UManitoba Dean of Science	$1600.00
Brandon Univ VP Research	$1000.00
Total Funds Available	$5766.36

Expenditures

Activity	Amount Spent
Visit by Sonia Bacca	$218.00
Visit by David Garfinkle	$300.00
Summer Student Symposium	$415.75
Visit by Tom Jones	$300.00
Commitment to CCGRRA XV	$2000.00
Total Expenditures	$3233.75

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.

Appendix: Summer Student Symposium Program

The program for the 2013 WITP Summer Student Symposium follows this page.

WITP Summer Symposium 2013

29 Aug 2013, Allen Building Room 519, University of Manitoba

Research talks will be 20 minutes, including time for questions.

9:15 Welcome by Mark Whitmore, Dean of Science, University of Manitoba

9:30 *Brad Cownden* "Modern models of extra dimensions in string theory"

9:50 *Nick Reid* "A dark theory for a light problem"

10:10 Break

10:30 *Joe Smith* "The 4-vertex in scalar-Ψ^4 theory using the 2PI effective action"

10:50 *Gabriel Chernitsky* "Searching for gamma radiation in dwarf galaxies"

11:10 Break

11:20 *Morgan Mercredi* "Cell migration in competing chemotactic environments"

11:40 *Jared Enns* "Dark light: Exploring dark radiation Models"

12:00 Lunch & Discussion

13:30 *Nils Deppe* "Adaptive mesh refinement for constrained 1D hyperbolic systems"

13:50 *Allison Kolly* "Gravitational collapse in anti-de Sitter space"

14:10 Break

14:30 *Ben Guest* "A new galactic pulsar candidate revealed by the Chandra X-ray Observatory"

14:50 *Chelsea Braun* "Supernova remnants as astrophysical laboratories for the formation of the elements"

15:10 Break

15:20 *Angel Barria* "On the algebraic and topological structures of the Levi-Civita field"

15:40 *Darren Flynn* "On delta functions on the Levi-Civita field"

16:00 Break

16:10 *Gidon Bookatz* "On locally uniformly differentiable functions on the Levi-Civita field: the inverse function theorem and the intermediate function theorem"

16:30 *William Grafton* "Fourier analysis on the Levi-Civita field"