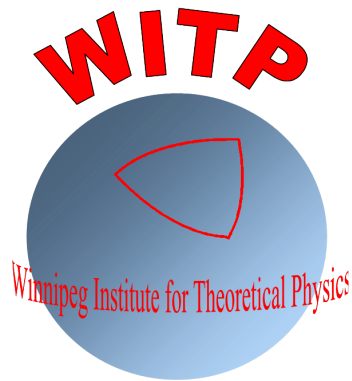


# The Winnipeg Institute for Theoretical Physics <sup>1</sup> Annual Report



September 2010 – August 2011

<sup>1</sup>Web site: <http://www.physics.umanitoba.ca/WITP/witp.html>



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# 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 21<sup>th</sup> 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, such as Theory Canada and the first conference of the newly formed Canadian Prairies Theoretical Physics Network.

For the 2010-2011 academic year, the list of invited speakers is found in section 4.1, visitors in section 4.2, the cumulative list of graduate degrees awarded appears in section 4.3, and the published research work of members is found in section 4.4. Section 5.1 contains a summary of income and expenditures for the period September 1, 2010 to August 31, 2011. The plans for the coming year include a program of invited speakers, visiting research collaborations, and the promotion of postgraduate and postdoctoral research.

All of the funds available to the Institute are spent for workshop and colloquium activities and for 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.

During the past academic year, the Institute's Executive Committee has consisted of B.W. Southern, (past Director - Manitoba) and G. Kunstatter, (Director - Winnipeg).

## 2 Current List of Members (September, 2011)

### 2.1 Faculty Members

- P.G. Blunden<sup>1</sup>, *Ph.D. (Queen's)* [Director, 93–94]
- M.E. Carrington<sup>2</sup>, *Ph.D. (SUNY, Stony Brook)*
- T. Chakraborty<sup>1</sup>, *Ph.D. (Dilbrugarh University, India)*
- J. D. Fiege<sup>1</sup>, *Ph.D. (McMaster)*
- A. Frey<sup>3</sup> *Ph.D. (UCSB)*
- T.D. Fugleberg<sup>2</sup>, *Ph.D. (UBC)*
- J. Hopkinson<sup>2</sup>, *Ph.D. (Rutgers)*
- G. Kunstatter<sup>3</sup>, *Ph.D. (Toronto)* [Director, 91–92, 09–]
- T.A. Osborn<sup>1</sup>, *Ph.D. (Stanford)* [Director, 92–93, 01–04]
- A. Shalchi<sup>1</sup>, *Ph.D. (Ruhr-Universitat Bochum)*
- K.M. Shamseddine<sup>1</sup>, *Ph.D. (Michigan State)*
- B.W. Southern<sup>1</sup>, *Ph.D. (McMaster)* [Director, 90–91, 07– 09]
- D.W. Vincent<sup>3</sup>, *Ph.D. (Toronto)* [Director, 94–95]
- J.G. Williams<sup>2</sup>, *Ph.D. (Birmingham)* [Director, 96–97]
- M. Whitmore<sup>1</sup>, *Ph.D. (McMaster)*

### 2.2 Senior Scholars

- B. Bhakar<sup>1</sup>, *Ph.D. (Delhi)* [Director, Jan. - June 00]
- P.D. Loly<sup>1</sup>, *Ph.D. (London)* [Director, Fall 99, 00–01]
- J.P. Svenne<sup>1</sup>, *Ph.D. (M.I.T.)* [Director, 95–96]
- G.C. Tabisz<sup>1</sup>, *Ph.D. (Toronto)*
- J.M. Vail<sup>1</sup>, *Ph.D. (Brandeis)* [Director, 98–99]

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<sup>1</sup>University of Manitoba

<sup>3</sup>University of Winnipeg

<sup>2</sup>Brandon University

## 2.3 Associate Members

### *Research Associates*

- J. Berashevich (Chakraborty)
- R. E. Cameron (Tabisz)
- S. Kondratyuk (Blunden)

### *Postdoctoral Fellows*

- R. Danos (Shalchi) Sep 2011 –
- D. Abregel (Chakraborty) Nov 2007 –
- A. Manaselyan (Chakraborty)
- W. Chen (Kunstatter/Kobes) April 2007 – Feb 2008
- Ari Peltola (Kunstatter) April 2008 – April 2010
- Mathew Wismayer (Southern) Jan 2009 –
- Yun Guo (Carrington) Oct. 2009 - Oct. 2011
- Wiejie Fu, Sept 2011 -

## 2.4 Graduate Students

- Stasi Baran (M.Sc.) (Co-supervised with Russ Taylor U.Calgary and Tyler Foster U.Brandon)
- Heather Champion (M.Sc.) (Co-supervised by Fiege and Boyd McCurdy)
- Usman Chowdhry (M.Sc.) (Carrington)
- Erica Franzmann (M.Sc.) (Fiege)
- Paul Mikula (M.Sc.) (co-supervised Kunstatter and Carrington)
- A. Mirza (M.Sc) Carrington)
- Neil Moore (Ph.D.) (Whitmore)
- Adam Rogers (Ph. D) (Fiege)
- Andrew Senchuk (Ph. D) (Shamseddine)
- Tim Taves (Ph.D.) (Kunstatter)

## 2.5 Undergraduate Research Students 2010-2011

- K. Buffie (Shalchi)
- T. Chau (NSERC-USRA) (Kunstatler)
- B. Guest (Shalchi)
- W. Grafton (Shamseddine)
- J. Roberts (Shamseddine)
- L. Hayward (Southern)
- J. Hernandez-Melgar (Vail)
- D. McGillis (Carrington/Fugleberg)
- Justin Moes (NSERC-USRA) (Hopkinson)
- M. Pielahn (NSERC-USRA)(Kunstatler)
- Travis Redpath (Hopkinson)
- T. J. Rempel (Shalchi)
- Todd Sierens (Shamseddine)

## 3 Research Interests of Members

### 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  $n$ PI 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 performed 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 Acquisition 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. 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 my attention for the next several years.

## **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.

## **J. Hopkinson**

An important goal of research into strongly correlated electron systems is the discovery of the physical mechanisms responsible for novel emergent phenomena. It is the collective behaviour of electrons and their spins arising from such strong correlations that leads to the realization of exotic new materials. My work is currently focused on a class of strongly correlated materials possessing local moments whose interactions are strongly frustrated by the corner-sharing triangle or tetrahedral lattice sites at which they lie. Such systems are said to be geometrically frustrated because the interactions (antiferromagnetic or ferromagnetic with a locally preferred spin direction) between pairs of spins compete in such a way as to lead to macroscopically degenerate ground states. Important questions to be addressed include: whether or not it is possible to realize a quantum spin liquid, a state with strongly correlated magnetic moments that does not order to zero temperature; whether the interplay of spin and charge frustration in magnetic metals can lead to metallic behaviour of exotic nature; and whether we can design our own artificial mesoscopic spin-ice systems. Such questions are studied by a variety of numerical and analytic theoretical techniques.

## **R. Kobes**

The research involved falls into three related fields of interest.

The first is systems in which quantum effects are important. Quantum theory has proven difficult to interpret, with properties such as "being in two places at once" being quite unintuitive. There has been experimental work recently though on systems, usually at low temperatures, for which quantum effects are pronounced. We will study examples of such systems, such as Bose-Einstein condensation, using finite temperature field theory in order to understand better the origin of their quantum properties. Attention will be paid to systems near a critical point, in which a sharp cross-over from one type of behavior to another occurs.

The second area involves quantum computers and quantum information. During the development of quantum theory it was realized that a computer built on the principles of quantum mechanics could have a significant speed advantage over a classical computer, with recent experimental prototypes suggesting this is indeed the case. We shall examine models of algorithms used in quantum computation with a view towards understanding better which quantum effects are most responsible for the observed speed-up in the computations.

The final topic is systems in which non-linear effects are important. There are two properties of interest here: chaos (long-term unpredictability) and fractalness (self-similarity at different length scales). Such effects arise in many contexts, such as fluid flow, diffusion, chemical reactions, and biological processes. We shall examine a class of models of epidemic growth in a population, with attention paid to incorporating local interactions by analyzing such models on discrete networks. Due to the general nature, many of the tools of quantum theory, especially of systems near a critical point, will be of use.

## **G. Kunstatter**

The quest for a theory that unifies gravity with quantum mechanics is one of the most important in theoretical physics today. Despite substantial progress in string theory and loop quantum gravity, much remains to be understood. It is, however, clear that the thermodynamic properties of black holes seem to provide valuable clues. One of the most striking properties of black hole thermodynamics is its apparent universality: it has the same qualitative features for all black holes, irrespective of which theory of gravity or which underlying microscopic theory one considers. It is this universal nature that motivates my ongoing study of the classical and quantum mechanics of large classes of black hole spacetimes. For example, we are currently investigating the effects on black hole structure and formation of a new, loop quantum gravity motivated quantization scheme called polymer quantization. A related research area is quantum computation and information theory. Quantum computers can in principle solve problems that require an exponentially large amount of resources using traditional computers. In addition, they give rise to fundamental questions about the nature of quantum information that may have application to other fields of physics, most notably quantum gravity and black hole physics. Recent work by my collaborators and me suggested that that isolated quantum systems can suffer decoherence due to quantum anomalies. Quantum anomalies often suggest the presence of hidden degrees of freedom and can render certain systems unsuitable as components for quantum computers. We are exploring the possibility that such a mechanism may help to reveal the nature of the microscopic internal degrees of

freedom that account for the thermodynamic properties of black holes.

### **P.D. Loly**

A new project begun 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 identities (distinct singular value sets) first glimpsed in P.D. Loly, I.C.Cameron, W.Trump and D.S.Schindel, "Magic square spectra", *Linear Algebra Appl.* 430 (10) 2659-2680 (2009).

It also leads to an unexpected indexing scheme for integer squares.

This resulted in a delay in completing several earlier projects, which were the subject of recent conference talks, but which can now take advantage of these new features:

- a) Peter Loly (presenter) with Ian Cameron, "Eigenproperties of an algebraic family of compound magic squares of order  $n = 3^l, l = 1, 2, 3, \dots$ , 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.

## **A. Shalchi**

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

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

## **Khodr M. Shamseddine**

My research interests and activities include various areas of non-Archimedean Analysis: power series and analytic functions, measure theory and integration, optimization, existence and uniqueness of solutions of differential equations, complex analysis and multivariable 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 applica-

tions are not possible with the structures of the field of Non-Standard Analysis. While in the latter discipline, there is a generally valid transfer principle that allows the transformation of known results of conventional analysis, here all relevant calculus theorems are developed separately. Moreover, the Levi-Civita field  $\mathcal{R}$  is not only non-Archimedeanly valued but it also has a total order (which is also non-Archimedean) yielding a richer structure, thus opening up new possibilities of study, like monotonicity, which are not available in other non-Archimedean valued fields like the  $p$ -adic fields for example. This makes  $\mathcal{R}$  an outstanding example, worth to be studied in detail in its own right.

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

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

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

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

Most recently, 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.

## **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 has two main themes. The first, and currently most active one, 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 spuriousity, 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  $^{12}\text{C}$ , 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. Some exciting results near the proton drip line, as well as all the mass-7 nuclei from neutron drip line to proton drip line, have already been obtained and published. 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.

The second theme, in collaboration with L. Canton and G. Pisent at Padua University, focuses on pion absorption on very light nuclei. We have been carrying out practical calculations on  $^3\text{H}$  and  $^3\text{He}$ , initially with two-cluster final states; later three-nucleon final states will also be included. This uses various mechanisms and input on  $\pi N$ ,  $NN$  and  $\pi N\Delta$  interactions. The three-nucleon system is treated exactly in a Faddeev-based theory. Final-state interactions are correctly taken into account. In addition to the dominant  $\Delta$  rescattering contribution to pion production, various other mechanisms, important especially near threshold, are also included. We are able to calculate, along with differential and total cross sections, all possible spin observables, measured or, as yet, not. Comparison with data, where available, is now very good. This work is essentially complete, pending completion of a large paper collecting our main results.

## 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, in particular inhomogeneous copolymer systems and phospholipid membranes. Both these classes of molecules have relatively high molecular weights, have chemically distinct sections, and are chain-like in structure. They can self-assemble to form complex nano-scale structures, and undergo subtle phase transitions. A related system is the end-tethered polymer layer, which consists of polymers with one end anchored to a surface, all immersed in solvent. These systems are of wide interest in materials science and biological systems. Our primary goal is to understand them at a fundamental level, primarily using computer-intensive numerical simulations, augmented by relatively simple theories to highlight the underlying physics. In the area of polymers, our primary focus is on the self-assembly of copolymers, the structures that form, the effects of additives, and the structure of end-tethered polymers. For example, we use numerical self-consistent field (NSCF) theory to calculate the phase diagrams of copolymers and copolymer/solvent blends. Recently, we have been working with chemists at the University of Toronto to understand detailed structural properties of copolymer/homopolymer blends that are observed there. The end-tethered polymer system illustrates the advantages of the NSCF approach. At high molecular weight and tethering density, the molecules become highly stretched, and the system reaches a limit known as the "polymer brush". There exist theories that describe this limit, but it has not been known at what point it is reached. In fact, it is now becoming clear that most systems that are created in the laboratory fall outside this limit. The NSCF theory gives results that are in excellent agreement with recent systematic experiments, identify the onset of the brush limit, and provide a new physical picture of the laboratory systems. Because the NSCF theory is a mean field theory, we have also done Monte Carlo simulations of many of these systems. They can also be used to construct visual pictures and movies which can provide considerable physical insight. Very recently, we have begun to extend the NSCF theory to incorporate fluctuation effects, in an attempt to understand a long-standing disagreement between theory and experiment near a mean-field critical point in the phase diagram of block copolymers. My colleague John Whitehead and I have developed an NSCF theory of phospholipid membranes. It provides a detailed picture of these systems, including a range of their structural and thermodynamic properties and their phase behaviour. It is the first theory of its kind to predict effects of pressure which are in good agreement with experiment. In particular, it

predicts that the application of hydrostatic pressure causes the layer thickness to increase, rather than decrease as one might expect. We have recently extended it to mixtures of lipids of different chain lengths, and will now turn our attention to lipids with different headgroups, immersed in a variety of solvents.

### **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: 2008-2011

Date	Speaker	Title
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 CuFeO <sub>2</sub> ”
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”
ct 8 2008	S. Stricker	“Tuning the light-heavy guitar: notes on holographic mesons”
Oct 22 2008	K. Shameseddine	”Non-Archimedean Analysis: Introduction and Motivation”
Nov 5 2008	K. Shamseddine	”Analysis on the Levi-Civita Field and Applications”
Nov 19 2008	D. Abergel	”Optical properties of monolayer and bilayer graphene”

### 4.2 Visitors: 2008-2011

Date	Visitor	Institution	Host
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	Vail
July 19-20 2009	Brian Dolan	National University of Ireland	Kunstatter
May 17-23 2009	Hideki Maedi	CECS, Chile	Kunstatter
May 7-8 2009	J. W. Moffat	Perimeter Institute	Kunstatter
Mar 26-28 2009	M. Plumer	Memorial University	Southern
Oct 6-10 2008	R. Daghigh	Metro State University	Kunstatter
Oct 6-10 2008	S. Stricker	Technical University of Vienna	Kunstatter
Oct-Dec 2008	Mikhail Karasev	Moscow Institute of Electronics and Mathematics	Osborn

### 4.3 Graduate Degrees Supervised

1. Usman Chowdhury (2009), “Cutting Rules for Feynman Diagrams at Finite Temperature,” M.Sc. thesis (Carrington and Kobes).
2. 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)
3. Jonathan Ziprick (2009), “Singularity resolution and dynamical black holes” M.Sc. thesis (Kunstatter)
4. Kenneth Adebayo (2008), ”Magnetic Nanoparticles”, M.Sc. thesis (Southern).

5. Eduard Kavalchuk (2008), “Perturbative Calculations in Many-Particle Systems,” Ph.D. thesis (Carrington and Kobes).
6. Mirsaeed Zelli (2007), ”A Monte Carlo Study of a Family of Heisenberg Non-Collinear Magnets”, M.Sc. thesis, (Southern).
7. J. Bland (2006), Ph.D. thesis (Kunstatter)
8. Senchuk, A ,”Collision-Induced Light Scattering and Absorption in Atoms and Symmetric : a Spherical Tensor Approach”, M.Sc. Thesis, University of Manitoba, September 2006, (Tabisz)
9. Nan Zheng (2006), “Analysis of Binary Phospholipid Bilayers with a Self-Consistent Theory”, M.Sc. thesis, (Whitmore).
10. Aleksandrs Aleksejevs (2005), “Next to leading order and hard-photon bremsstrahlung effects in electroweak electron-nucleon scattering”, Ph.D. thesis (Blunden)

## 4.4 Publications of Permanent Members

### P.G. Blunden

1. P.G. Blunden and S. Kondratyuk, Connection between the high energy-scale evolution of the P- and T-odd  $\pi$ NN coupling constant and the strong  $\pi$ NN interaction, *J. Phys. G: Nucl. Part. Phys.* **35** 115001 (2008).
2. A. Aleksejevs, S. Barkanova, and P.G. Blunden, Computational model for electron-nucleon scattering and the weak charge of the nucleon. [comp-ph/0710.3204] (2007)
3. A. Aleksejevs, S. Barkanova, P.G. Blunden, and N. Deg, Electroweak hard photon bremsstrahlung in electron-nucleon scattering. [nucl-th/0707.0657] (2007)
4. S. Kondratyuk and P.G. Blunden, Contribution of spin 1/2 and 3/2 resonances to two-photon exchange effects in elastic electron-proton scattering, *Phys. Rev. C* **75**, 038201 (2007).
5. S. Kondratyuk and P.G. Blunden, P- and T-violating  $\pi$ NN form factor, *Nucl. Phys. A* **785** 351 (2007).
6. S. Kondratyuk and P.G. Blunden, Calculation of two-photon exchange effects for  $\Delta$  production in electron-proton collisions, *Nucl. Phys. A* **778** 44 (2006).
7. P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Two-photon exchange and elastic electron-proton scattering, *Proceedings of the Workshop on electron-nucleus scattering VIII*, *Eur. J. Phys. A*, 24, Supp. 1 (2005).
8. S. Kondratyuk, P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Delta resonance contribution to two-photon exchange in electron-proton scattering, *Phys. Rev. Lett.* **95**, 172503 (2005).

9. P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Two-photon exchange in elastic electron-nucleon scattering, *Phys. Rev. C.* **72**, 034612 (2005).
10. P.G. Blunden and I. Sick, Proton radii and two-photon exchange, *Phys. Rev. C.* **72**, 057601 (2005).

### Conference Proceedings and Talks

11. S. Kondratyuk, P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Two-photon exchange in elastic and inelastic electron-proton scattering, Proceedings of the Seventeenth International Conference on Particles and Nuclei, AIP Conference Proceedings **842**, ed. P. D. Barnes et al., pg 336 (2006).
12. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Hadron Electromagnetic Form Factors, Trento, Italy, May 12-23, 2008.
13. Recent developments in two-photon exchange, Contributed talk at the 7th European Research Conference on Electromagnetic Interactions in Nucleons and Nuclei (EINN 2007), Milos, Greece, September, 2007.
14. Two-photon exchange: hadronic picture, Invited talk at the 2007 Winter Nuclear and Particle Physics Conference, Banff, February 17, 2007.
15. Two-photon exchange in electron scattering, Invited talk at the 2006 Gordon Conference on photonuclear reactions, New Hampshire, August, 2006 (declined).
16. Two-photon exchange in electron scattering: hadronic picture, Invited talk at the 2005 Joint Jefferson Lab/Institute for Nuclear Theory Workshop on Precision ElectroWeak Interactions, Williamsburg, VA, August 15-17, 2005.
17. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Two-Photon Physics, Trento, Italy, May 23-27, 2005.
18. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Two-Photon Physics, Trento, Italy, May 23-27, 2005.
19. Two-photon exchange in electron scattering: hadronic picture, Invited talk at the 2005 Joint Jefferson Lab/Institute for Nuclear Theory Workshop on Precision ElectroWeak Interactions, Williamsburg, VA, Aug 15-17, 2005.

### M. E. Carrington

#### Journal Articles

1. “*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.

2. “*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.
3. “*Techniques for n-Particle Irreducible Effective Theories,*” M.E. Carrington and **Yun Guo**, Phys. Rev. **D83**, 016006 (2011) - arXiv:1010.2978.
4. “*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.
5. “*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.
6. “*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.
7. “*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.
8. “*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.
9. “*The fermion mass at next-to-leading order in the HTL effective theory,*” M.E. Carrington, A. Gynther and D. Pickering, Phys. Rev. D **78**, 045018 (2008) - arXiv:0805.0170.
10. “*Energetic di-leptons from the Quark Gluon Plasma,*” M.E. Carrington, A. Gynther and P. Aurenche, Phys. Rev. D **77**, 045035 (2008) - arXiv:0711.3943.
11. “*Leading Order QED Electrical Conductivity using the 3PI Effective Action,*” M. E. Carrington and E. Kovalchuk, Phys. Rev. D **77**, 025015 (2008) - arXiv:0709.0706.
12. “*QED Electrical Conductivity using the 2PI Effective Action,*” M. E. Carrington and E. Kovalchuk, Phys. Rev. D **76**, 045019 (2007) - arXiv:0705.0162.
13. “*Index Summation in Real Time Statistical Field Theory,*” M. E. Carrington, T. Fugleberg, D. S. Irvine and D. Pickering, Eur. Phys. J. C **50**, 711 (2007) - arXiv:hep-ph/0608298.
14. “*The Soft Fermion Dispersion Relation at Next-to-Leading Order in Hot QED,*” M. E. Carrington; Phys. Rev. D **75**, 045019 (2007) - arXiv:hep-ph/0610372 .
15. “*The Dynamics of Entanglement in the Adiabatic Search and Deutsch Algorithms,*” K. Choy, G. Passante, D. Ahrensmeier, M.E. Carrington, T. Fugleberg, R. Kobes and G. Kunstatter, Can. J. Phys, **85**, 995 (2007) - arXiv:quant-ph/0605040.

16. “*Energy Flow in Acoustic Black Holes,*” K Choy, T Kruk, M.E. Carrington, T. Fugleberg, J. Zahn, R. Kobes, G. Kunstatter and D. Pickering, Phys. Rev. D **73**, 104011 (2006) - arXiv:gr-qc/0505163 .
17. “*Transport Theory Beyond Binary Collisions,*” M.E. Carrington, S. Mrowczynski, Phys. Rev. D **71**, 065007 (2005) - arXiv:hep-ph/0406097 .
18. “*2PI Effective Action and Gauge Invariance Problems,*” M.E. Carrington, G. Kunstatter and H. Zaraket, Eur. Phys. J. C **42**, 253 (2005).

### Papers in Refereed Proceedings

19. “*QED Electrical Conductivity from the 3PI Effective Action,*” M.E. Carrington, Proceedings of the 7th International Conference on Strong and Electroweak Matter 2008 - SEWM 2008, Nucl. Phys. **A820**, 135 (2009).
20. “*Gauge Invariance of the static fermion mass beyond hard thermal loops ,*” M.E. Carrington and E. Mottola, Proceedings of the 7th International Conference on Strong and Electroweak Matter 2006 - SEWM 2006, Nucl. Phys. **A785**, 142 (2007).
21. “*Statistical Field Theory,*” T. Fugleberg and M.E. Carrington, Proceedings of Theory Canada II, Can. J. Phys. **85**, 671 (2007).

### Articles in press

22. “*Parton Energy Loss in an Unstable Quark-Gluon Plasma,*’ M.E. Carrington, K. Deja and S. Mrówczyński, arXiv:1110.4846 (contribution to the proceedings of the HIC for FAIR Workshop and XXVIII Max Born Symposium, to be published in Acta Physica Polonica B).
23. “*Transport Coefficients and nPI Methods,*” M. E. Carrington, arXiv:1110.1238 (contribution to the proceedings of the HIC for FAIR Workshop and XXVIII Max Born Symposium, to be published in Acta Physica Polonica B).
24. “*A New Method to Calculate the n-Particle Irreducible Effective Action,*” M. E. Carrington and Y. Guo, arXiv:1109.5169 (submitted to Phys. Rev D).

### T. Chakraborty

1. Julia Berashevich, Adam D. Bookatz, and T. Chakraborty, J. Phys.: Condens. Matter **20**, 035207 (2008)
2. Julia Berashevich, Vadim Apalkov, and T. Chakraborty, J. Phys.: Condens. Matter **20**, 075104 (2008)
3. Hong-Yi Chen, V. Apalkov and T. Chakraborty, J. Phys.: Condens. Matter **20**, 135221 (2008)



4. K.-B. Broocks, B. Su, P. Schrtter, Ch. Heyn, D. Heitmann, W. Wegscheider, V.M. Apalkov, T. Chakraborty, I.E. Perakis, and C. Schller, *Phys. Stat. Sol. (b)* **245**, 321 (2008)
5. Hong-Yi Chen, J.Z. Garcia, T. Chakraborty, and P. Pietilinen, *Physica E* **40**, 2834 (2008)
6. J.Z. Garcia, P. Pietilinen, Hong-Yi Chen, and T. Chakraborty, *Physica E* **40**, 2839 (2008)
7. Julia Berashevich and T. Chakraborty, *J. Chem. Phys.* **128**, 235101 (2008)
8. Hong-Yi Chen, P. Pietilinen and T. Chakraborty, *Phys. Rev. B* **78**, 073407 (2008)
9. K.-B. Broocks, B. Su, P. Schrtter, Ch. Heyn, D. Heitmann, W. Wegscheider, V.M. Apalkov, T. Chakraborty, I.E. Perakis, and C. Schller, Linear and ultrafast optical spectroscopy in the regime of the quantum Hall effect, *Phys. Stat. Sol. (b)* **245**, 321 (Review) (2008).
10. Julia A. Berashevich, V.M. Apalkov and T. Chakraborty, Polaron tunneling dynamics in the DNA molecule, *J. Phys.: Condens. Matter*, (2008).
11. Julia A. Berashevich, Adam. D. Bookatz and T. Chakraborty, The electric field effect and conduction in the Peyrard-Bishop-Holstein model, *J. Phys.: Condens. Matter* **20**, 035207 (2008).
12. Julia A. Berashevich and T. Chakraborty, Mutational hot spots in DNA: Where biology meets physics, *Physics in Canada* **63**, 103 (2007).
13. Julia A. Berashevich and T. Chakraborty, Influence of solvent on the energetics of hole transfer in DNA, *J. Phys. Chem. B* **111**, 13465 (2007).
14. P. Pietiläinen and T. Chakraborty, Spin configurations and activation gaps of the quantum Hall states in graphene, *Europhys. Lett.* **80**, 37007 (2007).
15. Julia A. Berashevich and T. Chakraborty, Energetics of the hole transfer in DNA duplex oligomers, *Chem. Phys. Lett.* **446**, 159 (2007).
16. V. Apalkov, X.-F. Wang and T. Chakraborty, Physics aspects of charge migration through DNA, (Article in Book) *Charge Migration in DNA*, (Ed.) T. Chakraborty, (Springer), Ch. 5. p. 77–119 (2007).
17. T. Chakraborty (Ed.), (Book) *Charge Migration in DNA: Perspectives from Physics, Chemistry and Biology*, (Springer) (2007).
18. X.-F. Wang and T. Chakraborty, The physics of spin injection into DNA, *Physics in Canada* **63**, 89 (2007).
19. Hong-Yi Chen, V. Apalkov and T. Chakraborty, The Fock-Darwin states of Dirac electrons in graphene-based artificial atoms, *Phys. Rev. Lett.* **98**, 186803 (2007).

20. V. Apalkov, X.-F. Wang and T. Chakraborty, Collective excitations of Dirac electrons in graphene, *Int. J. Mod. Phys. B* 21, 1165 (2007).
21. Hong-Yi Chen, V. Apalkov and T. Chakraborty, Spin-orbit Coupling and Tunneling Current in a Parabolic Quantum Dot, *Phys. Rev. B* 75, 193303 (2007).
22. X.-F. Wang and T. Chakraborty, Coulomb screening and collective excitations in a graphene bilayer, *Phys. Rev. B* 75, 041404 (R) (2007).
23. Julia A. Berashevich and T. Chakraborty, Energy contribution of the solvent to the charge migration in DNA, *J. Chem. Phys.* 126, 035104 (2007).
24. X.-F. Wang and T. Chakraborty, Collective excitations of Dirac electrons in a graphene layer with spin-orbit interaction, *Phys. Rev. B.* 75, 033408 (2007).
25. T. Chakraborty, Graphene: A nanoscale quantum playing field, *Physics in Canada* 62, 351 (2006).
26. X.-F. Wang and T. Chakraborty, Spin injection into a short DNA chain, *Phys. Rev. B* 74, 193103 (2006).
27. V. Apalkov and T. Chakraborty, The fractional quantum Hall states of Dirac electrons in graphene, *Phys. Rev. Lett.* 97, 126801 (2006).
28. X.-F. Wang and T. Chakraborty, Charge transfer via a two-strand superexchange bridge in DNA, *Phys. Rev. Lett.* 97, 106602 (2006).
29. A. Bagga, P. Pietiläinen and T. Chakraborty, Spin hot spots in vertically-coupled few-electron isolated quantum dots, *Phys. Rev. B* 74, 033313 (2006).
30. V.M. Apalkov, A. Bagga and T. Chakraborty, Spin-orbit interaction in a quantum cascade transition, *Phys. Rev. B* 73, 161304 (R) (2006).
31. P. Pietinäinen and T. Chakraborty, Energy levels and magneto-optical transitions in parabolic quantum dots with spin-orbit coupling, *Phys. Rev. B* 73, 155315 (2006).
32. M. Califano, C.-M. Hu, P. Pietiläinen and T. Chakraborty, Breaking of Larmors theorem in quantum Hall states with spin-orbit coupling, *Phys. Rev. B* 73, 113315 (2006).
33. V. Apalkov and T. Chakraborty, Electronic properties of guanine traps in DNA, *Phys. Rev. B* 73, 113103 (2006).
34. V.M. Apalkov, C. Schüller and T. Chakraborty, Spin transitions in an incompressible liquid Coulomb coupled to a quantum dot, *Phys. Rev. B* 73, 073310 (2006).
35. V.M. Apalkov and T. Chakraborty, Transverse tunneling current through guanine traps in DNA, *Phys. Rev. B* 72, 161102 (R) (2005).
36. M. Califano, P. Pietiläinen and T. Chakraborty, Spin precession in a fractional quantum Hall state with spin-orbit coupling, *Appl. Phys. Lett.* 87, 112508 (2005).

37. P. Pietiläinen and T. Chakraborty, Optical signatures of spin-orbit interaction effects in a Parabolic Quantum Dot, *Phys. Rev. Lett.* 95, 136603 (2005).
38. M. Califano, P. Pietiläinen and T. Chakraborty, Tuning of the gap in a Laughlin Bychkov Rashba incompressible liquid, *Phys. Rev. Lett.* 94, 246801 (2005).
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## J. Fiege

1. Rogers, A. and Fiege, J. D., 2011, *Ap.J.*, accepted 743, 68, Strong Gravitational Lens Modeling with Spatially Variant Point Spread Functions
2. Fiege, J., McCurdy, B., Potrebko, P., Cull, A., and Champion, H., 2011, *Med. Phys.* 38, 5217, A Novel Evolutionary Optimization Approach to Multi Objective IMRT Planning
3. Rogers, A. and Fiege, J. D., 2011, *Ap.J.*, 727, 80, Gravitational Lens Modeling with Genetic Algorithms and Particle Swarm Optimizers
4. Rogers, A. and Fiege, J. D., 2007, *Ap.J.*, *submitted*, “Einstein’s Evolution: Modeling Gravitational Lenses with a Genetic Algorithm”
5. Ward-Thompson et al. and 61 co-authors (including myself), 2007, *PASP*, 119, 555-870, “The JCMT Legacy Survey of Nearby Star-forming Regions in the Gould Belt”
6. Vallée, J. P. and Fiege, J. D., 2007, *AJ*, 133, 1012-1026, “OMC-1: A Cool Arching Filament in a Hot Gaseous Cavity: Geometry, Kinematics, Magnetic Vectors, and Pressure Balance”
7. Vallée, J. P. and Fiege, J. D., 2007, *AJ*, 134, 628-636, “The Cool Dark Globule CB68 and Its Associated Protostar: Geometry, Kinematics, Magnetic Vectors, and Pressure Balance”
8. Vallée, J. P. and Fiege, J. D., 2006, *Ap.J.*, 636, 332-347, “A Cool Filament Crossing the Warm Protostar DR 21(OH): Geometry, Kinematics, Magnetic Vectors, and Pressure Balance”
9. Vallée, J. P. and Fiege, J. D., 2005, *Ap.J.* 627, 263-276, “A Cool Magnetized Shell Wrapped around the Hot H II Region S106: Geometry, Kinematics, Magnetic Vectors, and Pressure Balance”

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10. Rogers, A. and Fiege, J. D., 2011, Ap. J., submitted, Global Optimization methods for Gravitational Lens Systems with Regularized Sources
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12. Fiege, J., Champion, H., Potrebko, P., Cull, A., and McCurdy, B., Evolving and Optimizing IMRT Treatment Plans with PARETO, AAPM/COMP meeting, 02 Aug. 2011, Vancouver, BC (oral + refereed abstract: Med. Phys. 38, 3740)
13. Champion, H., Fiege, J., Potrebko, P., Cull, A., and McCurdy, B., Investigation of Fluence Parameterization Methods for PARETO, AAPM/COMP meeting, 31 Jul 2011, Vancouver, BC (poster + refereed abstract: Med. Phys. 38, 3688)
14. Fiege, J. D., Applications of a Multi Objective Genetic Algorithm to Data Modeling Problems in Astrophysics, colloquium, University of Calgary, Feb. 17, 2011
15. Friesen, J., Rogers, A. and Fiege, J. D., 2011, JRASC, 105, 61, Challenging Einstein: gravitational lensing as a test of general relativity (NSERC)
16. Baran, A., Fiege, J. D., Taylor, A. R., Foster, T., and Landecker, T., 2010, Noise Characterization of the DRAO Synthesis Telescope: Measuring the Diffuse Polarized Foreground of the ELAIS N1 Deep Field, in ASP Conference Series, The Dynamic ISM: A Celebration of the CGPS, San Francisco: ASP
17. Fiege, J. D., 2010, Qubist Users Guide: Optimization, Data Modeling, and Visualization with the Qubist Optimization Toolbox for MATLAB, (Winnipeg Canada: nQube Technical Computing Corp.), 257 page book, ISBN: 978 0 9865559 0 9
18. English, J., Fiege, J., Wiegert, T., Koribalski, B., Kerzendorf, W., and Freeman, K.C., 2010, The DiVAs Mask: Iconifying Galaxies and Revealing HI Anomalies, in Galaxies and their Masks eds. Block, D.L., Freeman, K.C., and Puerari, I., 2010, Springer (New York) Fiege, J., PIN: 160346 Page 3
19. Fiege, J., McCurdy, B., Cull, A., Champion, H., and Potrebko, P., 2010, PARETO: A Novel Evolutionary Optimization Approach to Multi Objective Radiotherapy Planning, COMP 2010 \*Oral Competition Finalist, Ottawa, ON (oral + refereed abstract: Med. Phys. 37, 3907)
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22. Potrebko, P., McCurdy, B., Fiege, J., and Cull, A., Improving IMRT Treatment Planning Using Multi Objective Beam Orientation Optimization (poster + refereed abstract: Med. Phys. 36, 4319)
23. Fiege, J. D., Astrophysical Data Modeling and Optimization with the Qubist Global Optimization Toolbox for MATLAB, CASCA Meeting, Halifax, NS, May 24 27, 2010 (poster)
24. Fiege, J. D., Wiegert, T., English, J., GalAPAGOS: An Evolutionary Computing Approach to Modeling Warped HI Galaxy Disks, May 28, 2010, CASCA Meeting, Halifax, NS (oral)
25. Rogers, A. and Fiege, J. D., Modeling Gravitational Lens Systems with Genetic Algorithms and Particle Swarm Methods, May 28, 2010, CASCA Meeting, Halifax, NS (oral)
26. Baran, A., Fiege, J. D., Taylor, A. R., Foster, T., and Landecker, T., Diffuse Polarized Foreground of the ELAIS N1 Deep Field, CASCA Meeting, Halifax, NS, May 24 27, 2010 (oral)
27. Fiege, J. D., 2005, in ASP Conf. Ser. 343, Astronomical Polarimetry: Current Status and Future Directions, ed. A. J. Adamson et al. (San Francisco: ASP), 171-175, "Computational Intelligence Techniques for Submillimetre Polarization Modeling"

### **Patents**

28. Provisional patent: Fiege, J., McCurdy, B., Cull, A., Champion, H., and Potrebko, P., 07 June 2010, application number 61/352091, PARETO: Optimization and visualization software for radiotherapy treatment planning (PCT Application, 07 June 2011)

### **Talks & Colloquia**

29. "Applications of an Advanced Genetic Algorithm to Data-Modeling Problems in Astrophysics", Nov. 26, 2007, University of Winnipeg, Winnipeg, MB (colloquium)
30. "Lessons from Natural Systems: Paradigms for Global Optimization", May 18, 2007, CancerCare Manitoba, Winnipeg, MB (colloquium)
31. "The Ferret Genetic Algorithm: Theory and Applications", Nov. 22, 2005, NRC Institute for Biodiagnostics, Winnipeg, MB (colloquium)

32. May 24 - June 4, 2005, Astrobiology and the Origins of Life, Conference & Workshop, McMaster University, Hamilton, ON, “The Ocean and Ice of Europa: Results from a Genetic Algorithm-Powered Planetary Structure Code” (May 27, 2005, conference)

### Posters

33. Fiege, J.D. and Ferchoff, L., 2006, “An Automated Genetic Algorithm-Powered Polarization Modeling Code”, CASCA Meeting, Calgary, AB, June 1-4, 2006
34. Rogers A. and Fiege, J. D., 2006, “The Ferret Genetic Algorithm as a Gravitational Lens Modeling Machine”, CASCA Meeting, Calgary, AB, June 1-4, 2006
35. Wiegert, T., English, J., and Fiege, J.D., 2006, “A Kinematic Study Of Nearby Spiral Galaxies”, CASCA Meeting, Calgary, AB, June 1-4, 2006

### A. R. Frey

1. J. M. Cline and A. R. Frey, “Light dark matter versus astrophysical constraints,” *Physics Letters B* (2011), in press [arXiv:1109.4639 [hep-ph]].
2. R. J. Danos, A. R. Frey and Y. Wang, “Canny Algorithm: A New Estimator for Primordial Non-Gaussianities,” arXiv:1108.2265 [astro-ph.CO] (submitted to *Phys. Rev. D*).
3. J. M. Cline and A. R. Frey, “Minimal hidden sector models for CoGeNT/DAMA events,” *Phys. Rev. D* **84**, 075003 (2011) [arXiv:1108.1391 [hep-ph]].
4. J. M. Cline, A. R. Frey and F. Chen, “Metastable dark matter mechanisms for INTEGRAL 511 keV  $\gamma$  rays and DAMA/CoGeNT events,” *Phys. Rev. D* **83**, 083511 (2011) [arXiv:1008.1784 [hep-ph]].
5. F. Chen, J. M. Cline, A. Fradette, A. R. Frey, and C. Rabideau, “Exciting dark matter in the galactic center,” *Phys. Rev. D* **81**, 043523 (2010) [arXiv:0911.2222 [hep-ph]].
6. A. R. Frey, R. J. Danos, and J. M. Cline, “Warped Kaluza-Klein Dark Matter,” *JHEP* **0911**, 102 (2009) [arXiv:0908.1387 [hep-th]].
7. F. Chen, J. M. Cline, and A. R. Frey, “Nonabelian dark matter: models and constraints,” *Phys. Rev. D* **80**, 083516 (2009) [arXiv:0907.4746 [hep-ph]].
8. R. H. Brandenberger, A. R. Frey, and L. C. Lorenz, “Entropy fluctuations in brane inflation models,” *Int. J. Mod. Phys. A* **24**, 4327-4354 (2009) [arXiv:0712.2178 [hep-th]].

9. F. Chen, J. M. Cline, and A. R. Frey, “A new twist on excited dark matter: implications for INTEGRAL, PAMELA/ATIC/PPB-BETS, DAMA,” *Phys. Rev. D* **79**, 063530 (2009) [arXiv:0901.4327 [hep-ph]].
10. A. R. Frey, G. Torroba, B. Underwood, and M. R. Douglas, “The universal Kaehler modulus in warped compactifications,” *JHEP* **0901**, 036 (2009) [arXiv:0810.5768 [hep-th]].
11. A. R. Frey, “Backreaction in closed string tachyon condensation,” *JHEP* **0808**, 053 (2008) [arXiv:0805.0570 [hep-th]].
12. R. J. Danos, A. R. Frey and R. H. Brandenberger, “Stabilizing moduli with thermal matter and nonperturbative effects,” *Phys. Rev. D* **77**, 126009 (2008) [arXiv:0802.1557 [hep-th]].
13. J. M. Cline, A. R. Frey, and G. Holder, “Predictions of the causal entropic principle for environmental conditions of the universe,” *Phys. Rev. D* **77**, 063520 (2008) [arXiv:0709.4443 [hep-th]].
14. R. H. Brandenberger, A. R. Frey, and S. Kanno, “Emergence of fluctuations from a tachyonic Big Bang,” *Phys. Rev. D* **76**, 083524 (2007) [arXiv:0706.1104 [hep-th]].
15. R. H. Brandenberger, A. R. Frey, and S. Kanno, “Towards a nonsingular tachyonic Big Crunch,” *Phys. Rev. D* **76**, 063502 (2007) [arXiv:0705.3265 [hep-th]].
16. R. Allahverdi, A. R. Frey, and A. Mazumdar, “Graceful exit from a stringy landscape via MSSM inflation,” *Phys. Rev. D* **76**, 026001 (2007) [arXiv:hep-th/0701233].
17. A. R. Frey and A. Maharana, “Warped spectroscopy: Localization of frozen bulk modes,” *JHEP* **0608**, 021 (2006) [arXiv:hep-th/0603233].
18. A. R. Frey, A. Mazumdar, and R. Myers, “Stringy effects during inflation and reheating,” *Phys. Rev. D* **73**, 026003 (2006) [arXiv:hep-th/0508139].
19. A. R. Frey and M. Lippert, “AdS strings with torsion: Non-complex heterotic compactifications,” *Phys. Rev. D* **72**, 126001 (2005) [arXiv:hep-th/0507202].

### Conference Proceedings

20. A. R. Frey, “Effects of strings in inflation and reheating,” APS Division of Particles and Fields 2004 Meeting Proceedings, *Int. J. Mod. Phys. A* **20**, 3438 (2005).

### Talks

21. “Light from Dark Matter,” San Francisco State University, University of Heidelberg, UWinnipeg, University of Manitoba, 2011.

22. “Direct and Indirect Detection of Metastable Dark Matter,” CalTech, UCSB, University of Toronto, 2010.
23. “Warped Kaluza-Klein Dark Matter,” Rencontres Théoriciennes (Paris Joint String Theory Meeting), hosted by CEA Saclay Institut de Physique Théorique, 2010.
24. “Constraints on Extra-Dimensional Dark Matter,” University of Cincinnati, 2010.
25. “Dark Matter is Exciting!” University of Cincinnati, 2010.
26. “Could Dark Matter Come from Extra Dimensions?” with Rebecca Danos, Annual Alumni Colloquium at Wake Forest University, 2009.
27. “String Theory in the Universe,” Annual Alumni Colloquium at Wake Forest University, 2009.
28. “Warped Kaluza-Klein Dark Matter: Surveying the Landscape,” University of Michigan, 2009.
29. “Holography and Kaluza-Klein Dark Matter,” Holographic Cosmology conference hosted by the Perimeter Institute, 2009
30. “A Tour of Flux Compactification Dynamics,” University of Wisconsin, 2009.
31. “An Inverted Mass Hierarchy for Exciting Dark Matter,” Perimeter Institute, University of Wisconsin, 2009.
32. “Top-Down Model Building for Cosmology,” Carleton University, 2008.
33. “Cosmic Compactification: Cosmology and the Importance of Dimensional Reduction,” University of Massachusetts – Amherst, Massachusetts Institute of Technology (Joint Tufts/Harvard Center for Astrophysics/MIT Cosmology seminar), 2008.
34. “Backreaction in Closed String Tachyon Condensation,” PASCOS '08 (Particles, Strings, & Cosmology) conference hosted by the Perimeter Institute, 2008.
35. “Entropy Modes at the End of Brane Inflation,” McGill, University of Michigan, 2008.
36. “Warped Spectroscopy,” McGill, 2006.
37. “AdS Strings with Torsion,” CalTech, 2005.
38. “Stringy Effects During Inflation and Reheating,” APS Division of Particles and Fields meeting hosted by UC Riverside, UC Berkeley, UCSB, CalTech, UC Los Angeles, Aspen Center for Physics, and Stanford University, 2004-2005.



## T. D. Fugleberg

1. K. Choy, G. Passante, D. Ahrensmeier, M.E. Carrington, T. Fugleberg, R. Kobes, G. Kunstatter, *The Dynamics of Entanglement in the Adiabatic Search and Deutsch Algorithms*, arXiv:quant-ph/0605040, Can. J. Phys. **85**, 995 (2007)
2. M.E. Carrington, T. Fugleberg, D.S. Irvine, D. Pickering, *Index summation in real time statistical field theory*, Eur. Phys. J. **C50** (2007) 711-727.
3. K. Choy, T. Kruk, M.E. Carrington, T. Fugleberg, J. Zahn, R. Kobes, G. Kunstatter, D. Pickering, *Energy Flow in Acoustic Black Holes*, [gr-qc/0505163], Phys. Rev. **D73** (2006) 104011-1 to 104011-5.

## Refereed Conference Proceedings

4. T. Fugleberg, M.E. Carrington, *Simplifying Calculations in Real Time Finite Temperature Field theory*, talk presented at **Theory Canada 2**, Perimeter Institute, Waterloo, ON, (June 7-10, 2006) published in Can. J. Phys. **85** (2007) 671-677

## J. Hopkinson

1. Spin ice on the trillium lattice studied by Monte Carlo calculations, Travis E. Redpath and John M. Hopkinson, Phys. Rev. B **82**, 014410, (2010).
2. Origin and consequence of an unpinned helical magnet: application to partial order in MnSi under pressure, John M. Hopkinson and Hae-Young Kee, Phys. Rev. B **79**, 014421 (2009)
3. Fate of partial order on trillium and distorted windmill lattices, Sergei V. Isakov, John M. Hopkinson and Hae-Young Kee, Phys. Rev. B **78**, 014404 (2008). (9 pages)
4. Classical antiferromagnet on a hyper-kagome lattice, John M. Hopkinson, Sergei V. Isakov, Hae-Young Kee and Yong Baek Kim, Phys. Rev. Lett. **99**, 03721 (2007). (4 pages)
5. Microscopic model for spiral ordering along (110) on the MnSi lattice, John M. Hopkinson and Hae-Young Kee, Phys. Rev. B **75**, 064430 (2007). (5 pages).
6. Geometrical frustration inherent to the trillium lattice, a sublattice of the B20 structure, John M. Hopkinson and Hae-Young Kee, Phys. Rev. B **74**, 224441 (2006) . (14 pages)
7. Quantum dot in the pseudogap Kondo state, J. Hopkinson, K. Le Hur and E. Dupont. Euro. Phys. J. B (Rapid Note) **48** 429 (2005). (4 pages)

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8. Do quantum dots allow one access to pseudogap Kondo physics?, J. Hopkinson, K. Le Hur and E. Dupont, *Physica B* **359-361** 1454-1456 (2005) (3 pages)

## Unpublished

9. Origin and consequence of an unpinned helical magnet: application to partial order in MnSi under pressure, John M. Hopkinson and Hae-Young Kee, arXiv:0808.0712. (5 pages)

## G. Kunstatter

1. J. Gegenberg, G. Kunstatter and T. Taves, “Singularity Resolution Inside Radiating 2-D Black Holes”, *Phys. Rev. D* (to appear).
2. T. Taves, D. Leonard, G. Kunstatter and R. Mann, ”Hamiltonian Formulation of Scalar Field Collapse in Einstein Gauss Bonnet Gravity”, *Class. Qu. Grav.* **29** 015012 (2011).
3. M. Pielahn, G. Kunstatter and Alex B. Nielsen, “Critical Analysis of Dynamical Surface Gravity in Spherically Symmetric Black Hole Formation”, *Phys. Rev. D* **84** 104008 (2011); arXiv:11030750.
4. C. Danielle Leonard, J. Ziprick, G. Kunstatter and R. Mann, “Gravitational collapse of K-essence matter in Painleve-Gullstrand coordinates”, *JHEP* **2011** 28 (2011); arXiv:1106.2054.
5. J. Babb, R. Daghigh and G. Kunstatter, “Highly Damped quasinormal modes and the small scale structure of quantum corrected black holes”, *Phys. Rev. D* **84** 084031 (2011); arXiv:1106.4357.
6. D. Buhr, M.E. Carrington, T. Fugleberg, R. Kobes, G. Kunstatter, D. McGillis, C. Pugh, D. Ryckman, “Geometrical entanglement of highly symmetric multipartite states and the Schmidt decomposition” *Journal of Phys. A: Math.Theor.* **44** 365305 (2011); arXiv:1104.3159
7. Tim Taves and Gabor Kunstatter, “Higher Dimensional Choptuik Scaling in Painleve Gullstrand Coordinates”, *Phys. Rev. D* **84** 044034 (2011); arXiv:1105.0878
8. G. Kunstatter, J. Louko, and A. Peltola, “Quantum dynamics of the Einstein-Rosen wormhole throat”, *Phys. Rev. D* **83**, 044022 (2011); arXiv:1010.3767
9. M. Carrington, R. Kobes, G. Kunstatter, D. Ostapchuk and G. Passante, , “Geometric measures of entanglement and the Schmidt decomposition ”, *J. Phys. A.* **43** 315302 (2010); arXiv:1003.4755 .

10. J. Ziprick and G. Kunstatter, "Quantum Corrected Spherical Collapse: A Phenomenological Framework" *Phys.Rev.D*82:044031 (2010); arXiv:1004.0525 .
11. G. Kunstatter, J. Louko and A. Peltola, "Polymer quantization of the einstein-rosen wormhole throat", *Phys.Rev.D*81:024034 (2010) ; arXiv:0910.3625.
12. A. Peltola and G. Kunstatter, "Semiclassical Polymerization of D-Dimension Black Hole Interiors", *Phys. Rev. D***80**, 044031 (2009); arXiv:0902.1746.
13. J. Ziprick and G. Kunstatter, "Dynamical Singularity Resolution in Spherically Symmetric Black Hole Formation", *Phys. Rev. D***80** 024032 (2009); arXiv:0902.3224.
14. J. Ziprick and G. Kunstatter "Spherically Symmetric Black Hole Formation in Painleve-Gullstrand Coordinates", *Phys. Rev. D***79** 101503(R) (2009); arXiv:08012.0993.
15. A. Peltola and G. Kunstatter, "A complete, single-horizon quantum corrected black hole spacetime", *Phys. Rev. D* **79**, 061501R (2009); arXiv:0811.3240.
16. G. Kunstatter, J. Louko and J. Ziprick, "Polymer quantization, singularity resolution and the  $1/r^2$  potential", *Phys. Rev. D***79**, 032104 (2009); arXiv:0809.5098;
17. Kai Choy, Gina Passante, D. Ahrensmeier, M.E. Carrington, T Fugleberg, R. Kobes and G. Kunstatter, "The Dynamics of Entanglement in the Adiabatic Search and Deutsch Algorithms" *Can. J. Phys.* **85**, 995 (2007); quant-ph/0605040.
18. J. Bland and G. Kunstatter, "The 5-D Choptuik critical exponent and holography", *Phys.Rev. D***75**: 101501R (2007); hep-th/0702226.
19. R. Daghigh, G. Kunstatter and J. Ziprick, "The mystery of the asymptotic quasinormal modes of Gauss-Bonnet black holes", *Class.Quant.Grav.* **24**:1981-1992 (2007); gr-qc/0611139.
20. R. Daghigh, J. Gegenberg, and G. Kunstatter, "Partially Gauge Fixed Hamiltonian for Spherically Symmetric Scalar Field Collapse", *Class.Quant.Grav.* **24**:2099-2107 (2007); gr-qc/0607122
21. G. Kunstatter and J. Louko, "Transgressing the horizons: time operator in two dimensional dilaton gravity" *Phys. Rev. D***75** 024036 (2007); gr-qc/0608080.
22. J. Gegenberg and G. Kunstatter, "The Quantum Structure of Space Near a Black Hole Horizon", *Class. Qu. Grav.* **23**, 6087-6100 (2006); gr-qc/0606002.
23. R. Daghigh, G. Kunstatter, Dave Ostapchuk and Vince Bagnulo " The Highly Damped Quasinormal Modes of  $d$ -dimensional Reissner-Nordström Black Holes in the Small Charge Limit", *Class.Quant.Grav.* **23** (2006) 5101-5116 gr-qc/0604073.
24. R. Daghigh and D. Kunstatter, "Universality of highly damped quasinormal modes for single horizon black holes" *Can. J. Phys., Theory 1 Canada Special Proceedings* (2006).

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26. J. Gegenberg and G. Kunstatter, “Ricci Flow of 3D Manifolds with One Killing Vector”, J.Math.Phys. 47 (2006) 032304 hep-th/0509091.
27. J. Bland, G. Kunstatter, M. Becker and B. Preston and V. Husain, “Dimension-Dependence of the Critical Exponent in Spherically Symmetric Gravitational Collapse”, Class. Quantum Grav. 22 (2005) 5355-5364.
28. R. Daghighi and G. Kunstatter, “Highly Damped Quasinormal-Modes of Generic Schwarzschild-like Black holes”, Class. Quantum Grav. 22 (2005) 4113-4128.
29. M. Carrington, G. Kunstatter and H. Zaraket, “2PI effective action and gauge dependence identities”, Eur.Phys.J. C42 253-259, (2005).

### Chapters in Books

30. J. Gegenberg and G. Kunstatter, “Midi-superspace models for quantum black holes”, *Recent Research in Quantum Gravity*, (Nova Scientific, 2009) ed. A. Dasgupta .
31. J. Gegenberg and G. Kunstatter, “2-D Midisuperspace Models for Quantum Black Holes”, (**invited**) *Wolfgang Kummer Memorial Volume*, (World Scientific, 2009) eds. D. Grumiller, A. Rebhan and D. Vassilevich.

### Invited papers presented at meetings

32. G. Kunstatter, “Singularity Resolution Inside Radiating 2-D Black Holes” (**Invited**), Black Holes: New Horizons, BIRS Workshop, Banff, November, 2011.
33. G. Kunstatter, “Quantum Corrected Spherical Collapse: A Phenomenological Framework”, (**Invited**), CMS Annual Meeting, Fredericton, June, 2010.
34. G. Kunstatter, , (**Invited**) CAP Congress, Toronto, June, 2010.
35. G. Kunstatter, “Dynamical Singularity Resolution in Quantum Corrected Black Hole Formation”, **Invited**, CAP Congress, Moncton, June 2009.
36. G. Kunstatter, “A Non-singular, single horizon Quantum Corrected Black Hole Spacetime”, **Invited**, Theory Canada V, University of New Brunswick, June 2009.
37. G. Kunstatter, “Midi-Superspace Models for Semi-classical Black Holes” **Invited**, Canadian Conference on General Relativity and Relativistic Astrophysics, University of Calgary, May, 2009.
38. G. Kunstatter, “Spherically Symmetric Scalar Field Collapse in Flat Slice Coordinates”, Black Holes VII, Banff, May, 2009.

39. G. Kunstatter, "Singularity Resolution in Quantum Corrected Black Holes", **Invited** Atlantic Regional Conference on General Relativity, Fredericton, April, 2009.
40. G. Kunstatter, "Singularity Resolution in the Scolymerized (BTZ) Black Hole", **Invited**, ESI Workshop on 3-D Gravity, Vienna, April, 2009.
41. G. Kunstatter, "Anomalies, Decoherence, Quantum Computing and Black Holes", 3rd Asia Pacific Conference on Quantum Computing and Information Science", Singapore, August, 2007.
42. G. Kunstatter, "Can Holographic Arguments Yield the 5-D Choptuik Scaling Exponent From 4-D Yang-Mills Theory?" , CAP Congress, Saskatoon, June 2007.
43. G. Kunstatter, "Highly Damped Quasinormal Modes of Generic Single Horizon Black Holes" , Black Holes V, Banff, May 2005.
44. G. Kunstatter, "Highly Damped Quasinormal Modes of Generic Single Horizon Black Holes" , Workshop on Quantum Gravity, University of New Brunswick, April, 2005.

### **Invited Lectures**

45. "Singularity resolution inside radiating black holes", C.E.C.S. Valdivia, Chile, October, 2011.
46. "Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation", University of California (Davis), May 26, 2009.
47. "Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation", University of Western Ontario, March 19, 2009.
48. "Quantum Black Holes: Portals to Strange New Universes", Prairies Regional Lecture Series, University of Saskatoon and University of Regina, January, 2009.
49. "Black Holes", guest lecturer, Introduction to Physics, University of Winnipeg, January, 2009.
50. "Quantum Corrected Black Hole Spacetimes", CECS Theoretical Physics Institute, Valdivia, Chile, November, 2008.
51. "Black Holes: Portals to the Holy Grail of Theoretical Physics", Trent University, March, 2008.

## **P.D. Loly**

1. 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)
2. Peter D. Loly and George P. H. Styan, Some comments on 44 philatelic Latin squares, CHANCE (2010) 23(1): 57-62, March 01, 2010, (C1)
3. P.D. Loly, I.C.Cameron, W.Trump and D.S.Schindel, "Magic square spectra", Linear Algebra Appl. 430 (10) 2659-2680 (2009). (C1)
4. Peter Loly, "Franklin Squares: A Chapter in the Scientific Studies of Magical Squares", Complex Systems, vol. 17 (2007) 143-161. (C1)
5. P. D. Loly and D. G. Schindel, A Simplified Demonstration of Counting the 880 Fourth Order Magic Squares Using Mathematica, NKS 2006 Wolfram Science Conference, (2006); [www.wolframscience.com/conference/2006/presentations/materials/loly.nb](http://www.wolframscience.com/conference/2006/presentations/materials/loly.nb)
6. Daniel Schindel, Matthew Rempel and Peter Loly, "Enumerating the bent diagonal squares of Dr Benjamin Franklin FRS", Proceedings of the Royal Society A: Physical, Mathematical and Engineering, 462 (2072) 2271-2279 (2006). (C1)
7. Adam Rogers and Peter Loly, "The electric multipole expansion for a magic cube", European Journal of Physics 26 (2005) 809-813. (C1)
8. P. D. Loly and Steeds, "A new class of pandiagonal squares", International Journal of Mathematical Education in Science and Technology, vol. 36, No. 4, 2005, 375-3881. (C1)
9. Adam Rogers and Peter Loly, "Rotational sorcery - The inertial properties of magic squares and cubes", Canadian Undergraduate Physics Journal, III(2), 25, 2005. (C1)

## **Papers Presented**

10. Peter Loly (presenter) with Ian Cameron, Eigenproperties of algebraic family of compound magic squares of order  $n = 3^l, l = 1, 2, 3, ..$  and construction and enumeration of their fundamental numerical forms, Canadian Mathematical Society, Winter Meeting, December 2009, Windsor, Ontario.
11. 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
12. P.D. Loly (presenter), "Two Small Theorems for Square Matrices Rotated a Quarter Turn", WCLAM2008.

## **T.A. Osborn**

1. Karl-Peter Marzlin and T. A. Osborn, “Moyal phase-space analysis of nonlinear optical Kerr media”, J. Phys. A, 27 pgs, in press. [2009]
2. M. V. Karasev and T. A. Osborn, “Magnetic quantization over Riemannian manifolds”, Canadian Journal of Physics, **84** 551-556 (2006).
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143. Shalchi, A. and Kourakis, I., Nonlinear Field-Line-Random-Walk and Generalized Compound Diffusion of Charged Particles, Proceedings of the 30th International Cosmic Ray Conference. Eds.: R. Caballero, J. C. D'Olivo, G. Medina-Tanco, L. Nellen, F. A. Sanchez, J. F. Valdes-Galicia. 2008, Universidad Nacional Autonoma de Mexico, 1, 405
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## Khodr M. Shamseddine

### Refereed Publications

1. One-variable and multi-variable calculus on a non-Archimedean field extension of the real numbers, *Khodr Shamseddine*, **Annales Mathématiques Blaise Pascal**, submitted.
2. On locally uniformly differentiable functions on a complete non-Archimedean ordered field extension of the real numbers, *Khodr Shamseddine and Todd Sierens*, **Pacific Journal of Mathematics**, submitted.
3. 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.
4. On the topological structure of the Levi-Civita field, *Khodr Shamseddine*, **Journal of Mathematical Analysis and Applications**, Volume 368, 2010, pp. 281-292.
5. 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. This is number 5 in the attached pdf file.
6. Generalized Power Series on a Non-Archimedean Field, *Khodr Shamseddine and Martin Berz*, **Indagationes Mathematicae**, Volume 17 # 3, 2006, pp. 457-477.

7. Analytical Properties of Power Series on Levi-Civita Fields, *K. Shamseddine and M. Berz*, **Annales Mathématiques Blaise Pascal**, Volume 12 # 2, 2005, pp. 309-329.

### Edited Proceedings

8. 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.

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9. 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.
10. 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.
11. 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.
12. Intermediate Value Theorem for Analytic Functions on a Levi-Civita Field, *K. Shamseddine and M. Berz*, **Bulletin of the Belgian Mathematical Society**, Volume 14, 2007, pp. 1001-1015.

### Invited Talks at Conferences

13. 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.
14. Nontrivial order preserving automorphisms of non-Archimedean fields, The Sixth Conference on Function Spaces, Southern Illinois University- Edwardsville, Illinois, USA, May 18-22, 2010.
15. Analysis on the Levi-Civita Field, a Brief Overview, Tenth International Conference on  $p$ -Adic and Non-Archimedean Analysis, Michigan State University, East Lansing, Michigan, USA, June 30- July 3, 2008.

16. Intermediate Value Theorem for Analytic Functions on a Levi-Civita Field, Ninth International Conference on P-adic Functional Analysis, University of Concepcion, Concepcion, Chile, July 10-14, 2006.

### Seminars and Colloquia at Universities

17. Departments of Mathematics (Joint Mathematics Colloquium), Universidad del Bio-Bio and Universidad de Concepcion, Concepcion, Chile, December 5, 2011.
18. Department of Mathematics, American University of Beirut, Beirut, Lebanon, July 21, 2011.
19. Department of Mathematics, University of Wisconsin- Eau Claire, December 17, 2008.
20. Winnipeg Institute of Theoretical Physics, November 5, 2008.
21. Winnipeg Institute of Theoretical Physics, October 22, 2008.
22. Department of Mathematics, University of Wisconsin- Eau Claire, July 7, 2007.
23. Department of Mathematics, University of Wisconsin- Eau Claire, June 21, 2007.
24. Department of Physics & Astronomy, University of Manitoba, November 24, 2006.

### B.W. Southern

1. "Nonlinear Behavior for the Uniform Mode and Horizontal Standing Spin Wave Modes in Metallic Ferromagnetic Microstrips: Experiment and Theory" M.P. Wismayer, B.W. Southern, X. L. Fan, Y.S. Gui, C.-M. Hu and R. E. Camley , PRB, submitted [2011].
2. 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].
3. 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].
4. 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].
5. Mirsaeed Zelli, K. Boese and B.W. Southern, "Short-time dynamics study of Heisenberg noncollinear magnets", Phys. Rev. **B76**, 224407 [2007].

6. J. van Lierop, B.W. Southern, K.-W. Lin, Z.-Y. Guo, C.L. Harland, R.A. Rosenberg, and J.W. Freeland, "Exchange bias in a columnar nanocrystalline  $Ni_{80}Fe_{20}/CoO$  thin-film", Phys. Rev. **B76**, 224432 [2007].
7. T.N. Shendruk, R.D. Desautels, B.W. Southern and J. van Lierop, "The effect of surface spin disorder on the magnetism of  $\gamma - Fe_2O_3$  nanoparticle dispersions, Nanotechnology **18**, 455704 [2007].
8. J. van Lierop, K.-W. Lin, Z.-Y. Guo, H. Ouyang and B.W. Southern, "Proximity effects in an exchange biased  $Ni_{80}Fe_{20}/Co_3O_4$  thin-film, Phys. Rev. **B75**, 134409 [2007].
9. J. van Lierop, B.W. Southern, K.-W. Lin and Z.-Y. Guo, "Enhancement of the exchange-bias onset temperature in a columnar nanocrystalline  $Ni_{80}Fe_{20}/Co_3O_4$  thin-film", J. App. Phys. **99** 08C101 [2006].
10. B.W. Southern and A. Peles, "Topological Phase transitions in Frustrated Magnets", Theory Canada I Conference Proceedings, Can. J. Phys. **84**, 517[2006].
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### Conference Contributions

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2. 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)
3. M.P. Wismayer, L.E. Hayward and B.W. Southern, Magnetic Excitations in Microstrips, Magnetic North I, University of Western Ontario (2010)
4. M.P. Wismayer, L.E. Hayward and B.W. Southern, Magnetic Excitations in Microstrips, CAP Congress Toronto (2010)
5. K. Adebayo and B.W. Southern, Monte Carlo Study of Maghemite Nanoparticles, CAP Congress Quebec City (2008)
6. M. Zelli, K. Boese and B.W. Southern, Frustrated Heisenberg magnets: first or second order phase transition? , CAP Congress Saskatoon (2007)
7. J. van Lierop and B.W. Southern, Frustrated Heisenberg magnets: first or second order phase transition?, CAP Congress Vancouver (2006)

## J.P. Svenne

1. The case for a return to nuclear power, J.P. Svenne, *The Environmentalist*, published on-line November 8, 2011; Paper copy to be published. DOI 10.1007/s10669-011-9358-1
2. 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).
3. 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 Fsica*, **57**, 20-29 (2011).
4. Coupled-channel calculation of bound and resonant spectra of  ${}^9_{\Lambda}\text{Be}$  and  ${}^{13}_{\Lambda}\text{C}$  hypernuclei, L. Canton, K. Amos, S. Karataglidis, and J.P. Svenne, *Int. J. of Mod. Phys. E* **19**, 1435-1450 (2010).
5. 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*, bf 101, 242501 (2008).
6. Neutron-deuteron scattering calculation for evaluated neutron data libraries, J.P. Svenne, L. Canton, and K. Kozier, contributed paper (Svenne) to the 20th European Conference on Few-Body Problems in Physics (EFB20), Pisa, Italy, September 10-14, 2007; *Proceedings: Few Body Systems* **44**, 31-34 (2008).
7. Constraints on the spectra of  ${}^{17,19}\text{C}$ , S. Karataglidis, K. Amos, P. Fraser, L. Canton, J.P. Svenne, *Nuclear Physics* **A813**, 235-251 (2008).
8. Nuclear Theory – Nuclear Power, J.P. Svenne, L. Canton, and K.S. Kozier, *Latvian Journal of Physics and Technical Sciences*, **45** no.4, 57-68 (2008).
9. Two causes of non-localities in nucleon-nucleus potentials and their effects in nucleon-nucleus scattering, P. Fraser, K. Amos, S. Karataglidis, L. Canton, G. Pisent, and J.P. Svenne, *European Physical Journal A*, **35**, 69-80 (2008).
10. **Canton et al Reply**, to a Comment by Fortune & Scherr, *Physical Review Letters*, **99**, 089202 (2007)
11. Particle-unstable and weakly-bound nuclei with a Sturmian approach that preserves the Pauli principle, L. Canton, K. Amos, S. Karataglidis, G. Pisent, J. P. Svenne, and D. van der Knijff, *Nuclear Physics* **A790**, 251c-256c (2007); contributed paper (Canton) to the 18th International IUPAP Conference on Few-Body Problems in Physics, Santos, SP, Brazil, August 21-26, 2006; *Proceedings*, L. Tomio, S. Adhikari and G. Krein, Eds.
12. Collective-coupling analysis of spectra of mass-7 isobars:  ${}^7\text{He}$ ,  ${}^7\text{Li}$ ,  ${}^7\text{Be}$ ,  ${}^7\text{B}$ , L. Canton, G. Pisent, K. Amos, S. Karataglidis, J.P. Svenne, and D. van der Knijff, *Phys. Rev. C*, **74**, 064605 (2006); arXiv: nucl-th/0604072

13. Predicting narrow states in the spectrum of a nucleus beyond the proton drip line, L. Canton, G. Pisent, J.P. Svenne, K. Amos and S. Karataglidis, Phys. Rev. Letters, **96**, 072502 (2006); arXiv: nucl-th/0510067
14. Low-energy neutron- $^{12}\text{C}$  analyzing powers: results from a multichannel algebraic scattering theory, J.P. Svenne, K. Amos, S. Karataglidis, D. van der Knijff, L. Canton and G. Pisent, Phys. Rev. C, **73**, 027601 (2006); arXiv: nucl-th/0510088
15. Comparison between two methods of solution of coupled equations for low-energy scattering, K. Amos, S. Karataglidis, D. van der Knijff, L. Canton, G. Pisent, and J.P. Svenne, Phys. Rev **C72**, 065604 (2005); arXiv: nucl-th/0510067.
16. Compound and quasi-compound states in low-energy scattering of nucleons from  $^{12}\text{C}$ , G. Pisent, J.P. Svenne, L. Canton, K. Amos, S. Karataglidis, and D. van der Knijff. Phys. Rev. C **72**, 014601 (2005); arXiv: nucl-th/0502016
17. Role of the Pauli principle in collective-model coupled-channel calculations, L. Canton, G. Pisent, J.P. Svenne, D. van der Knijff K. Amos, and S. Karataglidis.; Phys. Rev. Lett. **94**, 122503 (2005); arXiv: nucl-th/0409050

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18. 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 to be published in Journal of Physics: Conference Series (JPCS).
19. 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
20. 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
21. Constraints on the spectra of  $^{17,19}\text{C}$ , S. Karataglidis, K. Amos, P. Fraser, L. Canton, J.P. Svenne; contributed paper (Karataglidis) to the South African Institute of Physics Conference, University of Limpopo, Polokwane, South Africa, July 2008; abstract only published, in the “Book of Abstracts”.
22. Coulomb energy differences and Coulomb displacement energies from a coupled-channel scattering theory, J. P. Svenne, K. Amos, P. Fraser, D. van der Knijff, L. Canton, G. Pisent, and S. Karataglidis, contributed paper (Svenne) to the CAP2008

- Congress, Québec City, PQ, June 8-11, 2008; abstract in *Physics in Canada*, **64**, no. 2 (supplement), Congress 2008, p.99
23. Multichannel algebraic scattering theory and the structure of exotic compound nuclei, K. Amos, P. Fraser, S. Karataglidis, L. Canton, G. Pisent, and J. P. Svenne, contributed paper (Amos) to the Ispun 2007, International Symposium on Physics of Unstable Nuclei, July 3-7, 2007, Hoi An, Viet Nam; *Proceedings*, Eds. D, Y, Kkhoa, P. Egelhof, S. Gales, N. van Gai, and T. Motobayashi, World Scientific, Singapore, May 2008, p. 131-138. ISBN-13 978-981-277-614-3
  24. Coupled-channel study of scattering from and structure of light unstable nuclei, J. P. Svenne, L. Canton, G. Pisent, K. Amos, P. Fraser, S. Karataglidis, and D. van der Knijff, invited paper (Svenne) to the CAP2007 Congress, Saskatoon, SK, June 17-20, 2007; abstract in *Physics in Canada*, **63**, no. 2 (supplementary), May/June 2007, p.124
  25. New analysis for low-energy neutron-deuteron elastic scattering using three-nucleon theory, J. P. Svenne, L. Canton, K. Kozier, and L. Townsend, contributed poster (Svenne) to the CAP2007 Congress, Saskatoon, SK, June 17-20, 2007; abstract in *Physics in Canada*, **63**, no. 2 (supplementary), May/June 2007, p.138
  26. Re-evaluating low-energy neutron-deuteron elastic scattering using three-nucleon theory, J. P. Svenne, L. Canton, K. Kozier, and L. Townsend, contributed poster (Svenne, Canton) to the International Conference on Nuclear Data for Science and Technology, Nice, France, April 22-27, 2007; *Proceedings*, editors O.Bersillon, F.Gunsing, E.Bauge, R.Jacqmin, and S.Leray, EDP Sciences, 2008, pp 243-246
  27. The spectra of exotic light mass nuclei determined with MCAS theory, K. Amos, L. Canton, G. Pisent, J. P. Svenne, and S. Karataglidis, contributed paper (Amos) to the International Conference on Nuclear Data for Science and Technology, Nice, France, April 22-27, 2007; *Proceedings*, editors O.Bersillon, F.Gunsing, E.Bauge, R.Jacqmin, and S.Leray, EDP Sciences, 2008, pp 139-142
  28. Structure model inputs for nuclear multi-channel algebraic scattering calculations, P. Fraser, K. Amos, J. P. Svenne, S. Karataglidis, L. Canton, G. Pisent, and D. van der Knijff, contributed paper (Fraser) to the Winter Nuclear and Particle Physics Conference (WNPPC'07), Banff, AB, February 16-18, 2007.
  29. Coupled-channel study of scattering from and structure of nuclei on and off the line of stability, J. P. Svenne, L. Canton, G. Pisent, K. Amos, S. Karataglidis, and D. van der Knijff, invited paper (Svenne) to the Winter Nuclear and Particle Physics Conference (WNPPC'07), Banff, AB, February 16-18, 2007.
  30. Analyzing powers from a multichannel algebraic scattering theory, J. P. Svenne, K. Amos, L. Canton, S. Karataglidis, G. Pisent, and D. van der Knijff, contributed paper (Svenne) to the CAP2006 Congress, Brock University, St. Catharines, June 11-14, 2006; abstract in *Physics in Canada*, **62**, no. 3, May/June 2006, p.50



31. On the resonance spectra of particle-unstable light nuclei with a Sturmian approach that preserves the Pauli principle, L. Canton, K. Amos, S. Karataglidis, G. Pisent, J.P. Svenne, invited paper, (Canton) to the 11th International Conference on Nuclear Reaction Mechanisms, Villa Monastero, Varenna, Italy, June 12-17, 2006. *Proceedings*, Universita degli Studi di Milano, Ricerca Scientifica ed Educazione Permanente, vol. **126**, p. 75, 2006.
32. Solution of multi-channel problems using MCAS for spectra and scattering cross sections, K. Amos, S. Karataglidis, P. Fraser, D. van der Knijff, J. P. Svenne, L. Canton, G. Pisent, invited paper (Amos) to the Workshop on Perspectives for Nuclear Data for the Next Decade, Bruyeres-le-Chatel, France, Sept. 2005; NEA **6121**, 57-66 (2006).
33. Low energy nuclear scattering and sub-threshold spectra from a multi-channel algebraic scattering theory, K. Amos, P. Fraser, S. Karataglidis, D. van der Knijff, J. P. Svenne, L. Canton, G. Pisent, invited paper (Amos), to the FINUSTAR conference, Kos, Greece, Sept. 2005; AIP Conference Proceedings, vol. 831, 258-262 (2006);
34. Structure of light nuclei from a multichannel algebraic scattering theory, J. P. Svenne, G. Pisent, L. Canton, K. Amos, S. Karataglidis, and D. van der Knijff, contributed paper (Svenne) to the CAP2005 Congress, UBC, Vancouver, June 5-8, 2005; abstract in *Physics in Canada*, **61**, no. 3, May/June 2005, p.59
35. Compound and quasi-compound states in the low energy scattering of neutrons and protons by the  $^{12}\text{C}$  nucleus, G. Pisent, L. Canton, J.P. Svenne, K. Amos, S. Karataglidis, and D. van der Knijff, invited paper (Pisent), to the 10th Conference on Problems in Theoretical Nuclear Physics, Cortona, Italy, October 6-9, 2004. *Proceedings: Theoretical Nuclear Physics in Italy*, S. Boffi, A. Covello, M. Di Toro, A. Fabriocini, G. Pisent, and S. Rosati, eds. (World Scientific, Singapore,2005) pp.301-308.

## G.C. Tabisz

### Refereed Publications

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).
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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).
7. G. C. Tabisz, R. Cameron and W. Qu, "Theory calculation and observation of nonlinear optical activity in chiral molecules", Annu. Rep. Prog. Chem, Sect. C, **104**, 13-34 (2008).
8. R. Cameron and G.C. Tabisz, "Characterization of intensity-dependent optical rotation phenomena in chiral molecules in solution", J. Chem. Phys., **126**, 224507-224507-10 (2007).
9. Qu, W. and G.C. Tabisz, "Ab initio Calculations of Nonlinear Optical Rotation by Several Small Chiral Molecules and by Uridine Stereoisomers", J. Chem. Phys. **124**, 184305-1-9 (2006).
10. McQuarrie, B.M., G. C. Tabisz and T. A. Osborn, "Collision-Broadened Line Shapes: A Different Perspective via Moyal Quantum Mechanics", 18th International Conference on Spectral Line Shapes, Auburn University, Auburn, Alabama, June 2006, invited talk presented by G. C. Tabisz.

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11. B. M. McQuarrie, G. C. Tabisz and T.A..Osborn, "Collision-broadened line shapes: a different perspective via Moyal quantum mechanics", Spectral Line Shapes: 18th International conference on spectral line shapes, edited by E. Oks and M. Pindzola, (AIP, Melville, 2006) pp.151-1661.

### **Colloquia**

12. 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).

2. Vail, J. M., Chevrier, D.K., Pandey, R.A., and Blanco, M.A. ., The Nitrogen Vacancy in Aluminum Nitride, *Journal of Physics: Condensed Matter* 18, 2125-2135 (2006).
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5. Vail, J. M., Computational Modelling of Point Defect Properties in Insulators, International Symposium, Advances in the Chemistry and Physics of Complex Materials, University College London, UK, 25-27 June, 2007, Session 1a.
6. Vail, J.M., Haroon, T., Hernandez-Melgar, J., Chevrier, D.K., Pandey, R. Oxygen Substitutional Impurity in Aluminum Nitride, 16th International Conference on Defects in Insulating Materials, Aracaju-SE-Brazil, 24-29 August, 2008, Abstract A004.
7. J. M. Vail, R. Pandey, and D. K. Chevrier, Point Defects in Group III Nitrides, The 10th Europhysical Conference on Defects in Insulating Materials, Milan, Italy, July 10-14, 2006, Abstract 0FrD2, p. 128.
8. J. M. Vail, M. A. Blanco, W. A. Coish, A. Costales, H. He, H. Jiang, R. Pandey, O. Penner, Q.C. Qiu, D. Schindel, Y. Xu, and A. Yang, Diffuse Localized Electronic States in Insulating Crystals, The 15th International Conference on Defects in Insulating Materials. ICDIM-2004, Riga, Latvia, July 11-16, 2004, Abstract WE-B-02, p. 21.

### Invited Workshop Contributions

9. International Workshop on Computational Materials Science, The American University in Cairo, November 17-20, 2008

## M. Whitmore

### Refereed Journal Publications

1. N. Zhang, J. Geehan and M. D. Whitmore, *Self-Consistent Field Theory of Two-Component Phospholipid Membranes*, *Phys. Rev. E* **75**,051922-1–051922-17 (2007) [ Selected for highlighting by the Virtual Journal of Biological Research, **39** (June 1, 2007) ]

2. J. G. Spiro, J. Yang, J.-X. Zhang, M. A. Winnik, Y. Rharbi, J. D. Vavasour, M. D. Whitmore and R. Jérôme (NSERC), *Experimental and Theoretical Investigation of the Lamellar Structure of a Styrene-Butyl Methacrylate Diblock Copolymer by Fluorescence Resonance Energy Transfer, Small-Angle X-Ray Scattering, and Self-Consistent Field Simulations*, *Macromolecules* **39**,7055–7063 (2006)
3. M. D. Whitmore and R. Baranowski, *End-Anchored Polymers: Compression by Different Mechanisms, and Interpenetration of Apposing Layers*, *Macromolecular Theory and Simulations* **14**,75–95 (2005)

### Non-refereed Publications

4. A. B. MacIsaac and M. D. Whitmore, *High Performance Computing in Canada: The Early Chapters*, in *Physics in Canada*, vol. 64, 85-88 (2005)
5. M. D. Whitmore and G. Drake, Honorary Guest Editors of *Physics in Canada Theme Issue on Fast Computing*, vol. 64 No. 2 (2008)

### Book Chapters

6. M. D. Whitmore, *Theory of Block Copolymers*, in *Supramolecular Polymers, 2nd edition*, A. Ciferri, editor, CRC Press, Taylor and Francis Group, Bacon Rouge, 301–350 (2005)

### Invited Presentations

1. M. D. Whitmore, *Copolymers and Computing: A Decade of Progress*, keynote talk at the High Performance Computing Systems and Applications (HPCS '06), St. John's, NL (2006)
2. M. D. Whitmore, *High Performance Computing: The New and Growing Environment in Canada*, Canadian Association of Physicists Congress, Winnipeg, Manitoba (June, 2004).
3. M. D. Whitmore, *ACEnet: Transforming Research in Atlantic Canada*, High Performance Computing Systems and Applications (HPCS '04), Winnipeg, Manitoba, (May, 2004).

### Contributed Presentations

4. M. D. Whitmore and Nan Zheng, *Self-Consistent Field Theory of Two-Component Phospholipid Membranes*, C.A.P. Congress, St. Catharines (2006).
5. J. G. Spiro, J. Yang, M. A. Winnik, J. P. S. Farinha, J. D. Vavasour and M. D. Whitmore, *Characterization of Nanoscopic Template Materials*, Canadian Materials Science Conference, Vancouver (2005)

6. M. D. Whitmore and R. Baranowski, *Compression of End-Anchored Polymers*, C.A.P. Congress, Vancouver (2005).
7. A. Borodich and M. D. Whitmore, *Compositional Fluctuations in Diblock Copolymer Lamellae Studied with the Method of Averaging in the Weak Segregation Limit*, C.A.P. Congress, Vancouver(2005).

### **J.G. Williams**

1. 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 (to appear 2011).
2. 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 (2008).
3. T.A. Harriott and J.G. Williams, “Kinks, cobordisms and topology change,” in Proceedings of the Albert Einstein Century International Conference, Paris, France 18-22 July 2005, edited by J.-M. Alimi and A. Fuzfa, AIP Conference Proceedings 861 (American Institute of Physics, Melville, NY), pp. 374-378 (2006).
4. J.G. Williams, “Vorticity and kinks,” (with T.A. Harriott), in Proceedings of the 10th Marcel Grossmann Meeting on General Relativity, edited by M. Novello, S.P. Bergliaffa and R. Ruffini, (World Scientific, Singapore), pp. 1898–1900 (2005).
5. T.A. Harriott and J.G. Williams, “Degree of mapping for general relativistic kinks,” *Nuovo Cimento B* 120, 915-930 (2005) (C1).

## 5 Financial

### 5.1 Statement of Income and Expenditures

#### Income

Income Source	Amount
Carry over from 2010	\$4296.00
Total Funds Available	\$4296.00

#### Expenditures

Activity	Amount Spent
Conference Support	\$1,200.00
Visitor Support	\$ 1570.00
Total Expenditures (2009-2010)	\$2776.00
Current funds available	\$1520.00

*Noten that the carryover of \$4296.00 corrects an error in the 2010 Annual Report. An erratum has been filed*

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. Currently the members from the three universities draw upon more than \$350,000 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, supports the activities and goals of the Institute, but 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.

### 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 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.