The Winnipeg Institute for Theoretical Physics [1] Annual Report

September 2008 – August 2009

[1]**Web site:** http://www.physics.umanitoba.ca/WITP/witp.html

Contents

1 Director's Narrative Report

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

The past year was the 19^{th} year of the Institute's existence. As usual the Institute sponsored a series of research colloquia by out-of-province visitors as well as Institute members. Associated with the Permanent Members were research associates, postdoctoral fellows, graduate students and summer undergraduate research assistants.

For the 2008–2009 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, 2008 to August 31, 2009. 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 R. Kobes, (past Director - Winnipeg) and B.W. Southern, (Director - Manitoba). The Director for the 2009-2010 year is G. Kunstatter from the University of Winnipeg.

2 Current List of Members (September, 2009)

2.1 Faculty Members

- P.G. Blunden[1], *Ph.D (Queen's)* [Director, 93–94]
- M.E. Carrington[2], *Ph.D. (SUNY, Stony Brook)*
- T. Chakraborty[1], *Ph.D. (Dilbrugarh University, India)*
- J. D. Fiege[1], *Ph.D. (McMaster)*
- T.D. Fugleberg[2], *Ph.D. (UBC)*
- J. Hopkinson[2], *Ph.D. (Rutgers)*
- R. Kobes[3], *Ph.D. (Alberta)* [Director, 97–98, 05–07]
- G. Kunstatter[3], *Ph.D. (Toronto)* [Director, 91–92, 09-]
- T.A. Osborn[1], *Ph.D. (Stanford)* [Director, 92–93, 01-04]
- K.M. Shamseddine[1], *Ph.D. (Michigan State)*
- B.W. Southern[1], *Ph.D. (McMaster)* [Director, 90–91, 07– 09]
- D.W. Vincent[3], *Ph.D. (Toronto)* [Director, 94–95]
- J.G. Williams[2], *Ph.D. (Birmingham)* [Director, 96–97]
- M. Whitmore[1], *Ph.D. (McMaster)*

2.2 Senior Scholars

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

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

2.3 Associate Members

Research Associates

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

Postdoctoral Fellows

- D. Abregel (Chakraborty) Nov 2007 –
- A. Manaselyan (Chakraborty)
- W. Chen (Kunstatter/Kobes) April 2007 – Feb 2008
- Ari Peltola (Kunstatter) April 2008 –
- Mathew Wismayer (Southern) Jan 2009 –
- Yun Guo (Carrington)

2.4 Graduate Students

- Tim Taves (Ph.D.) (Kunstatter)
- Stasi Baran (M.Sc.) (Co-supervised with Russ Taylor U.Calgary and Tyler Foster U.Brandon)
- Usman Chowdhry (M.Sc.) (Carrington/Kobes)
- A. Mirza (M.Sc) (Carrington/Kobes)
- Neil Moore (Ph.D.) (Whitmore)
- Adam Rogers (Ph. D) (Fiege)

2.5 Undergraduate Research Students 2008-2009

- M. Pielahn (NSERC-USRA) (Kunstatter)
- J. Babb (Kunstatter)
- Trevor Rempel (NSERC-USRA) (Shamseddine)
- Todd Sierens (NSERC-USRA) (Shamseddine)
- Lauren Hayward (NSERC-USRA) (Southern)

- Blair Cardigan Smith (NSERC-USRA) (Fiege, co-supervised with Jayanne English)
- Andrew Cull (Fiege, Co-supervised with Boyd McCurdy and Peter Potrebko (CancerCare Manitoba)

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 nPI effective theories which, in principle, can be used arbitrarily far from equilibrium.

T. Chakraborty

Spin Transport in a Quantum Dot

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

Electron Dynamics in a DNA Molecule

The unique properties of DNA, self-assembly and molecular recognition, has rendered the 'molecule of life' a promising candidate in the rapidly emerging field of molecular nano-electronics. A recent report of a field-effect transistor based on DNA molecules, that was preceded by a series of seminal experiments on the electron conduction in DNA, has sparked a lot of interest on the electronic properties of the DNA. A thorough understanding of the electronic properties of DNA is crucial in the development of the future DNA-based nanoscale devices. In addition, charge transfer through DNA also plays an important role in radiation damage and repair and therefore important for biological processes. We have preformed theoretical calculations of the electron energy spectrum, based on a two-leg charge ladder model for the poly(dA)-poly(dT) DNA and poly(dG)-poly(dC) DNA molecules. We take the electron-electron interactions and the electron spin degree of freedom fully into account in our model. The energy spectra for the G-C and the A-T base pairs show a large gap and the interaction was found to enhance the gap. The effect of interaction is less pronounced for the G-C base pairs than that of the A-T pairs. The spin-flip excitations are not the lowest energy excitations. We also analyze the charge distribution for the ground state as well as for the excitations.

J.D. Fiege

My research program applies an advanced genetic algorithm called Ferret to several large and very difficult data-modeling problems in astrophysics. The components of this research address diverse topics that include gravitational lens physics, magnetic fields in star-forming regions, and the interstellar medium of other galaxies. Gravitational lensing is a prediction of general relativity, in which light rays from a distant galaxy or quasar are bent by the gravity of a massive foreground galaxy or galaxy cluster. This natural lens magnifies the background object significantly but often breaks it into multiple images and distorted arcs. We are developing new techniques to determine the optimal mass distribution of the gravitational lens that is best able to re-assemble these shattered images. By applying this technique to a large catalogue of data, we will learn about the spatial distribution of dark matter in lens systems, while also obtaining images of the background sources from these natural telescopes. Rotating disks of neutral hydrogen in nearby galaxies also allow us to probe the structure of dark matter in galaxies, since the velocity of the gas is determined mainly by the gravitational field of the dark matter.

I am leading the development of a new code called "GalAPAGOS" (*Gal*axy *P*arameter *A*quisition by *G*enetic *O*ptimization *S*oftware), which use Ferret to build mathematical models of these systems, thereby determining the distribution of dark matter and properties of the gas component of gaxaxy disks. Stars form in dense cores and filaments within molecular clouds, which are composed primarily of hydrogen gas. These clouds emit partially polarized submillimetre radiation from dust grains that are aligned perpendicular to the magnetic field, on average. I have developed software to model these systems, and plan to use the code to fit theoretical models of magnetized cores and filaments to data from the "Gould's Belt Survey" at the James Clerk Maxwell telescope, which is the largest submillimetre survey of molecular clouds to date. In addition to providing new and well explored models of molecular cloud structure, this work will help to constrain the role of magnetohydrodynamic turbulence in these systems. In addition, I am involved in an interdisciplinary research project with Dr. Boyd McCurdy (CancerCare Manitoba) and CCMB Resident Peter Potrebko to develop software that uses my Ferret code to optimize radiotherapy plans for cancer treatment. Preliminary results show great promise for improving on treatment plans computed by standard techniques.

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

Current research is focussed on completing several projects which were the subject of recent and pending conference talks:

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

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

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

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

T.A. Osborn

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

A series of papers have investigated the quantization of charged particle systems moving in time dependent inhomogeneous magnetic fields on both flat and curved manifolds.

This joint work with Mikhail Karasev has developed a QPS representation that is both gauge and geometrically covariant and has an exact star product determined by a symplectic area phase. The resulting quantum phase space that arises has a curvature which is a function of the electromagnetic field entangled with the Riemannian curvature. The discovery of this quantization induced curvature raises a variety of questions: Is this curvature really a part of nature? Can it be measured? Ongoing projects aim at establishing the ways this curvature can be detected.

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

Khodr M. Shamseddine

Mathematical Physics

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

Research currently in progress aims at understanding the topological structure of the non-Archimedean Levi-Civita fields and developing a complete calculus theory on such fields, extending all the common theorems of real calculus. Multivariable analysis and complex analysis on non-Archimedean fields are then two natural research projects to investigate and try to develop. Moreover, now that an integration theory has been achieved, this will lead naturally to investigating a general theory of differential equations on these fields with possible applications in solving differential equations on the field of real numbers. We have developed all the mathematical tools necessary to work on all the projects above, any one of which (or a part thereof) may also constitute a good research project to work on with a graduate student towards an MS thesis or a PhD dissertation.

B.W. Southern

Statistical Physics

Cooperative phenomena in systems with competing interactions and disorder is a topic of active study. Disorder can arise in many ways such as the dilution of nonmagnetic materials with magnetic impurities or from the loss of perfect translational order in a solid. In particular, in magnetic systems, this competition can arise from the fact that the exchange interaction between magnetic atoms oscillates with distance. If the atoms are located at the sites of a regular lattice, a state of long ranged magnetic order often occurs. However, if there is some disorder in the positions of the atoms, conflicting messages from neighbouring atoms can destroy or weaken this order. In some cases, even if the atoms are arranged so that they lie at the sites of a regular lattice and the interactions are all of the same sign but negative, the order can be weakened to such an extent that the directions of the magnetic moments at zero temperature become completely random. Such systems are said to be frustrated because of the competing interactions and, in this latter case, we refer to the system as geometrically frustrated. Frustration can lead to novel ground states and can change the nature of the excitations in the system. In particular, it can change the nature of topological defects present in the system. These topological defects can interact and exhibit nontrivial unbinding transitions as the temperature increases.Our understanding of these effects is far from complete. A variety of theoretical techniques are employed to study these systems including renormalization group methods, low temperature series methods and numerical Monte Carlo methods.

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 (Rhodes University, Grahamstown, South Africa) and K. Amos, Paul Fraser and D. van der Knijff (Melbourne University, Australia). The theory uses expansions in Sturmian functions of the channel-coupling interactions, leading to an algebraic solution of the coupled integral equations of the multichannel problem. This enables us to allow for the Pauli principle in the context of a collective model description of the target nucleus, by the use of orthogonalizing pseudo-potentials. The algebraic solution provides us a method of locating all resonances, no matter how narrow, as well as all bound states of the compound system, without the use of an excessively fine energy step sizes. Satisfying the Pauli principle is an essential aspect of the theory, as it removes any spuriosity, in both bound states and resonances and thus provides a theoretical formulation of the scattering problem that has predictive power. The results of the calculations can also be used to give accurate interpretation of the nuclear structure of the target nucleus and the compound system. Our first work was on the well-studied, both theoretically and experimentally, nucleus ^{12}C, with scattering by both neutrons and protons, with inclusion of the Coulomb force. The results compare very well with experiment. We are now working on other light and medium mass nuclear systems including systems well away from the valley of stability. 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 (see publication list, below) and forms a chapter in the Ph.D. Thesis of Paul Fraser, who received his doctorate in 2009, under the supervision of Ken Amos, Melbourne University. I had partial supervision of Paul's thesis work. The work on hypernuclei has been submitted to 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 ^3H and ^3He, initially with two-cluster final states; later three-nucleon final states will also be included. This uses various mechanisms and input on πN, 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 Δ 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 continuing, and a large paper collecting our main results to date is in preparation.

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

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

4.2 Visitors

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

4.3 Graduate Degrees Supervised

1. 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)

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

3. Kenneth Adebayo (2008), "Magnetic Nanoparticles", M.Sc. thesis (Southern).

4. Eduard Kavalchuk (2008), "Perturbative Calculations in Many-Particle Systems," Ph.D. thesis (Carrington and Kobes).

5. Mirsaeed Zelli (2007), "A Monte Carlo Study of a Family of Heisenberg Non-Collinear Magnets", M.Sc. thesis, (Southern).

6. J. Bland (2006), Ph.D. thesis (Kunstatter)

7. 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)

8. Nan Zheng (2006), "Analysis of Binary Phospholipid Bilayers with a Self-Consistent Theory", M.Sc. thesis, (Whitmore).

9. Aleksandrs Aleksejevs (2005), "Next to leading order and hard-photon bremsstrahlung effects in electroweak electron-nucleon scattering", Ph.D. thesis (Blunden)

10. A. Peles (2004), "Frustrated Magnets: A Monte Carlo Study of Stiffness, Vorticity and Topological Excitations". Ph.D. thesis, University of Manitoba, 2004. (University Microfilms), (Southern).

11. A. J. Penner (2004), "Nonlinear Analysis of Complicated Physical Systems", MSc thesis, (Kobes).

12. S. Barkanova (2004), "The Electroweak Radiative Corrections and Parity-Violating Electron-Nucleon Scattering", PhD thesis, (Blunden).

13. I. Abu-Ajamieh (2003) "Lateral Compression of Homopolymers and Copolymers at the Air-Liquid Interfaces for Good Solvents", M.Sc. thesis, (Whitmore)

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 πNN coupling constant and the strong πNN 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 πNN form factor, Nucl. Phys. A **785** 351 (2007).

6. S. Kondratyuk and P.G. Blunden, Calculation of two-photon exchange effects for Δ 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).

11. P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Two-photon exchange and elastic electron-proton scattering, Phys. Rev. Lett. **91**, 142304 (2003).

Conference Proceedings and Talks

12. 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).

13. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Hadron Electromagnetic Form Factors, Trento, Italy, May 12-23, 2008.

14. 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.

15. Two-photon exchange: hadronic picture, Invited talk at the 2007 Winter Nuclear and Particle Physics Conference, Banff, February 17, 2007.

16. Two-photon exchange in electron scattering, Invited talk at the 2006 Gordon Conference on photonuclear reactions, New Hampshire, August, 2006 (declined).

17. 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.

18. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Two-Photon Physics, Trento, Italy, May 23-27, 2005.

19. Recent developments in two-photon exchange physics, Invited plenary talk at the Fall meeting of the Division of Nuclear Physics of the American Physics Society, Chicago, October 2004.

20. Two-photon exchange physics: hadronic picture, Invited talk at the ECT Workshop on Two-Photon Physics, Trento, Italy, May 23-27, 2005.

21. 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.

22. Two-photon exchange and elastic electron-proton scattering, Invited talk at Workshop on Electron-Nucleus Scattering VIII, Elba, Italy, June 2004.

23. Two-photon exchange effects in electron-proton scattering, Colloquium at Argonne National Laboratory, April 2004.

24. Two-photon exchange effects in electron-proton scattering, Colloquium at University of Manitoba, November 2003.

25. Two-photon exchange and elastic electron-proton scattering, Talk presented at Fall Meeting of APS Division of Nuclear Physics, Tuscon, AZ, October 2003.

M. E. Carrington

1. "*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 - arXiv:0906.5220

2. "*Leading Order QCD Shear Viscosity from the 3PI Effective Action,*" M. E. Carrington and E. Kovalchuk - arXiv:0906.1140.

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

4. "*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. Phy. **A820**, 135 (2009).

5. "*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.

6. "*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.

7. "*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.

8. "*QED Electrical Conductivity using the 2PI Effective Action,*" M. E. Carrington and E. Kovalchuk, Phys. Rev. **D76**, 045019 (2007) - arXiv:0705.0162.

9. "*Index Summation in Real Time Statistical Field Theory,*" M. E. Carrington, T. Fugleberg, D. S. Irvine and D. Pickering, Eur. Phys. J. **C50** 711 (2007) - arXiv:hep-ph/0608298.

10. "*The Soft Fermion Dispersion Relation at Next-to-Leading Order in Hot QED,*" M. E. Carrington; Phys. Rev. **D75**, 045019 (2007) - arXiv:hep-ph/0610372 .

11. "*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 - arXiv:quant-ph/0605040 (accepted for publication in the Canadian Journal of Physics).

12. “*Statistical Field Theory,*” T. Fugleberg and M.E. Carrington, Proceedings of Theory Canada II, Can. J. Phys. **85** 671 (2007).

13. “*Gauge Invariance of the static fermion mass beying hard thermal loops ,*” M.E. Carrington and E. Mottola, Proceedings of the 7th International Conference on Strong and Electroweak Matter 2006 - SEWM 2006, Nuc. Phy. **A785**, 142 (2007).

14. “*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. **D73** (2006) 104011.

15. “*Transport Theory Beyond Binary Collisions,*” M.E. Carrington, S. Mrowczynski, Phys. Rev. **D71**, 065007 (2005).

16. “*2PI Effective Action and Gauge Invariance Problems,*” M.E. Carrington, G. Kunstatter and H. Zaraket, Eur. Phys. J. **C42**, 253 (2005).

17. “*The 4PI Effective Action for ϕ^4 Theory,*” M.E. Carrington, Eur. Phys. J. **C35** 383 (2004).

18. “*Dielectric Functions and Dispersion Relations of Ultra-Relativistic Plasmas with Collisions,*” M.E. Carrington, T. Fugleberg, D. Pickering and M.H. Thoma, Can. J. Phys. **82**, 671 (2004).

19. “*Dileptons from Hot, Heavy, Static Photons,*” P. Aurenche, M.E. Carrington and N. Marchal, Phys. Rev. **D68**, 056001 (2003).

20. “*Scattering Amplitudes at Finite Temperature,*” M.E. Carrington, Hou Defu and R. Kobes, Phys. Rev. **D67** 025021 (2003).

Papers in Refereed Proceedings

21. “*Gauge Invariance of the static fermion mass beying hard thermal loops ,*” M.E. Carrington, Proceedings of SEWM 2006, to be published in Nuclear Physics A.

22. *“Chapman-Enskog Expansion of the Boltzmann equation and its Diagrammatic Interpretation”*, M.E. Carrington, Hou Defu, R. Kobes, refereed paper published electronically in the proceedings of the XXXI International Symposium of Multiparticle Dynamics, Sept 1-7, 2001, Datong, China.

23. *“Contributions to Transport Theory from Multi-particle Interactions and Production Processes”*, M.E. Carrington, refereed paper published in the proceedings of ‘Strong and Electroweak Matter 2004’ June 16-19, Helsinki, Finland.

T. Chakraborty

1. V. Apalkov and T. Chakraborty, Phys. Rev. B (in press) (2008)
2. Julia Berashevich and T. Chakraborty, J. Phys. Chem. B (in press) (2008)
3. Julia Berashevich, Adam D. Bookatz, and T. Chakraborty, J. Phys.: Condens. Matter **20**, 035207 (2008)
4. Julia Berashevich, Vadim Apalkov, and T. Chakraborty, J. Phys.: Condens. Matter **20**, 075104 (2008)
5. Hong-Yi Chen, V. Apalkov and T. Chakraborty, J. Phys.: Condens. Matter **20**, 135221 (2008)
6. K.-B. Broocks, B. Su, P. Schrter, Ch. Heyn, D. Heitmann, W. Wegscheider, V.M. Apalkov, T. Chakraborty, I.E. Perakis, and C. Schller, Phys. Stat. Sol. (b) **245**, 321 (2008)
7. Hong-Yi Chen, J.Z. Garcia, T. Chakraborty, and P. Pietilinen, Physica E **40**, 2834 (2008)
8. J.Z. Garcia, P. Pietilinen, Hong-Yi Chen, and T. Chakraborty, Physica E **40**, 2839 (2008)
9. Julia Berashevich and T. Chakraborty, J. Chem. Phys. **128**, 235101 (2008)
10. Hong-Yi Chen, P. Pietilinen and T. Chakraborty, Phys. Rev. B **78**, 073407 (2008)
11. K.-B. Broocks, B. Su, P. Schrter, 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).
12. Julia A. Berashevich, V.M. Apalkov and T. Chakraborty, Polaron tunneling dynamics in the DNA molecule, J. Phys.: Condens. Matter, (2008).
13. 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).
14. Julia A. Berashevich and T. Chakraborty, Mutational hot spots in DNA: Where biology meets physics, Physics in Canada 63, 103 (2007).
15. Julia A. Berashevich and T. Chakraborty, Influence of solvent on the energetics of hole transfer in DNA, J. Phys. Chem. B 111, 13465 (2007).
16. P. Pietiläinen and T. Chakraborty, Spin configurations and activation gaps of the quantum Hall states in graphene, Europhys. Lett. 80, 37007 (2007).

17. Julia A. Berashevich and T. Chakraborty, Energetics of the hole transfer in DNA duplex oligomers, Chem. Phys. Lett. 446, 159 (2007).

18. 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).

19. T. Chakraborty (Ed.), (Book) Charge Migration in DNA: Perspectives from Physics, Chemistry and Biology, (Springer) (2007).

20. X.-F. Wang and T. Chakraborty, The physics of spin injection into DNA, Physics in Canada 63, 89 (2007).

21. 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).

22. V. Apalkov, X.-F. Wang and T. Chakraborty, Collective excitations of Dirac electrons in graphene, Int. J. Mod. Phys. B 21, 1165 (2007).

23. 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).

24. X.-F. Wang and T. Chakraborty, Coulomb screening and collective excitations in a graphene bilayer, Phys. Rev. B 75, 041404 (R) (2007).

25. Julia A. Berashevich and T. Chakraborty, Energy contribution of the solvent to the charge migration in DNA, J. Chem. Phys. 126, 035104 (2007).

26. 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).

27. T. Chakraborty, Graphene: A nanoscale quantum playing field, Physics in Canada 62, 351 (2006).

28. X.-F. Wang and T. Chakraborty, Spin injection into a short DNA chain, Phys. Rev. B 74, 193103 (2006).

29. V. Apalkov and T. Chakraborty, The fractional quantum Hall states of Dirac electrons in graphene, Phys. Rev. Lett. 97, 126801 (2006).

30. X.-F. Wang and T. Chakraborty, Charge transfer via a two-strand superexchange bridge in DNA, Phys. Rev. Lett. 97, 106602 (2006).

31. A. Bagga, P. Pietiläinen and T. Chakraborty, Spin hot spots in vertically-coupled few-electron isolated quantum dots, Phys. Rev. B 74, 033313 (2006).

32. V.M. Apalkov, A. Bagga and T. Chakraborty, Spin-orbit interaction in a quantum cascade transition, Phys. Rev. B 73, 161304 (R) (2006).

33. 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).

34. 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).

35. V. Apalkov and T. Chakraborty, Electronic properties of guanine traps in DNA, Phys. Rev. B 73, 113103 (2006).

36. 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).

37. V.M. Apalkov and T. Chakraborty, Transverse tunneling current through guanine traps in DNA, Phys. Rev. B 72, 161102 (R) (2005).

38. 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).

39. P. Pietiläinen and T. Chakraborty, Optical signatures of spin-orbit interaction effects in a Parabolic Quantum Dot, Phys. Rev. Lett. 95, 136603 (2005).

40. M. Califano, P. Pietiläinen and T. Chakraborty, Tuning of the gap in a Laughlin Bychkov Rashba incompressible liquid, Phys. Rev. Lett. 94, 246801 (2005).

41. P. Pietiläinen and T. Chakraborty, Correlations in a Quantum Dot with Bychkov-Rashba Coupling, Phys. Rev. B 71, 113305 (2005).

42. V. M. Apalkov and T. Chakraborty, Electron Dynamics in a DNA Molecule, Phys. Rev. B 71, 033102 (2005).

43. T. Chakraborty and P. Pietiläinen,“Correlation effects on Rashba precession in a two-dimensional electron gas” (to be published)

44. C. Schüller, K.-B. Broocks, P. Schrter, Ch. Heyn, D.Heitmann, M. Bichler, W. Wegschedier, T. Chakraborty, and V.M. Apalkov,“How to probe a fractionally-charged quasihole?”, Physica E 22, 131-134 (2004).

45. Schüller, C., Broocks, K.-B., Schröter, P., Heyn, Ch., Heitmann, D., Bichler, M., Wegscheider, W., Chakraborty, T., and Apalkov, V. M.,“Optical Probing of a Fractionally Charged Quasihole in an Incompressible Liquid,” Phys. Rev. Lett. 91, 116403 (2003).

46. T. Chakraborty and V. M. Apalkov, “Quantum cascade transitions in nanostructures”, Advances in Physics 52, 455-521 (2003).

47. T. Chakraborty and V.M. Apalkov,“Magnetic field effects on intersubband transitions in a quantum nanostructure”, Physica E 16, 253-258 (2003).

Other Refereed Publications

48. Tapash Chakraborty, F. M. Peeters, and U. Sivan (Eds.), “Nano-Physics & Bio-Electronics: A New Odyssey”, 1st ed. (Elsevier, 2002).

J. Fiege

1. Rogers, A. and Fiege, J. D., 2007, Ap.J., *submitted*, "Einstein's Evolution: Modeling Gravitational Lenses with a Genetic Algorithm"
2. 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"
3. 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"
4. 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"
5. 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"
6. 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"
7. Vallée J. P., Greaves J. S. and Fiege J. D., 2003, Ap.J., 588, 910-917, "Magnetic Structure of a Dark Bok Globule"
8. Fiege, J. D., Johnstone, D., Redman, R. O., and Feldman, P. A. 2004, Ap.J., 616, 925-942, "A Genetic Algorithm-based Exploration of Three Filament Models: A Case for the Magnetic Support of the G11.11-0.12 Infrared-dark Cloud"
9. Fiege, J. D. 2003, in Turbulence and Magnetic Fields in Astrophysics, ed. E. Falgarone and T. Passot (Berlin: Springer), 299-328, invited review (book chapter): "The Structure and Dynamics of Filamentary Molecular Clouds"
10. Johnstone, D., Fiege, J. D., Redman, R. O., Feldman, P. A., Carey, S. J., 2003, Ap.J.Lett., 588, 37, "The G11.11-0.12 IRDC: Anomalous Dust and a Nonmagnetic Isothermal Model"

Non–refereed publications

11. 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"

Talks & Colloquia

12. "Applications of an Advanced Genetic Algorithm to Data-Modeling Problems in Astrophysics", Nov. 26, 2007, University of Winnipeg, Winnipeg, MB (colloquium)

13. "Lessons from Natural Systems: Paradigms for Global Optimization",, May 18, 2007, CancerCare Manitoba, Winnipeg, MB (colloquium)

14. "The Ferret Genetic Algorithm: Theory and Applications", Nov. 22, 2005 , NRC Institute for Biodiagnostics, Winnipeg, MB (colloquium)

15. "Evolution meets Astrophysics: Advanced Genetic Algorithms for Astrophysical Data Modeling", Aug. 25, 2004, National Research Council, DRAO, Penticton, BC (colloquium)

16. "Computational Intelligence Techniques for Submillimetre Polarization Modeling", March 15-19, 2004, Astronomical Polarimetry: Current Status and Future Directions, Waikoloa, Hawaii (conference)

17. 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)

18. "Evolution Meets Astrophysics: Using Advanced GAs to Search and Visualize Large Parameter Spaces", June 13-16, 2004, CASCA/CAP conference, Winnipeg, Manitoba (conference)

19. "Computational Intelligence Techniques for Astronomy & Astrophysics",Feb. 10, 2004, University of Manitoba, Winnipeg, Manitoba (colloquium)

20. "Evolution meets Astrophysics: Genetic Algorithms in Submillimetre Astronomy & Planetary Science", Feb. 9, 2004, University of Manitoba, Winnipeg, Manitoba (colloquium)

21. "Magnetic Fields in Molecular Clouds: A Genetic Algorithm-Based Modeling Technique", April 29, 2003, Dublin Institute for Advanced Study, Dublin, Ireland (colloquium)

Posters

22. Fiege, J.D. and Ferchoff, L., 2006, "An Automated Genetic Algorithm-Powered Polarization Modeling Code", CASCA Meeting, Calgary, AB, June 1-4, 2006

23. 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

24. Wiegert, T., English, J., and Fiege, J.D., 2006, "A Kinematic Study Of Nearby Spiral Galaxies", CASCA Meeting, Calgary, AB, June 1-4, 2006

25. Fiege, J.D., Redman, R., Feldman, P., 2003, "The Magnetic Structure of the Filamentary Infra-Red Dark Cloud G11.11-0.12.", conference: Magnetic fields and star formation: theory versus observations, Madrid, Spain, April 21 - 25, 2003

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.

4. M.E. Carrington, T. Fugleberg, D. Pickering, M.H. Thoma, *Dielectric Functions and Dispersion Relations of Ultra-Relativistic Plasmas with Collisions,* Can.J.Phys. **82** (2004) 671-678.

5. T. Fugleberg, *General Quasiparticle Propagator and Mass Dependence in Degenerate Color Superconductivity*, Phys.Rev. **D67** (2003) 034013 [hep-ph/0206033] (35 pages).

Refereed Conference Proceedings

6. 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. 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)

2. 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)

3. 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)

4. 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).
5. 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)
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28. G. Kunstatter, "A Non-singular, single horizon Quantum Corrected Black Hole Spacetime", **Invited**, Theory Canada V, University of New Brunswick, June 2009.

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

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

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

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

33. G. Kunstatter, "Anomalies, Decoherence, Quantum Computing and Black Holes" , 3rd Asia Pacific Conference on Quantum Computing and Information Science", Singapore, August, 2007.

34. G. Kunstatter, "Can Holographic Arguments Yield the 5-D Choptuik Scaling Exponent From 4-D Yang-Mills Theory?" , CAP Congress, Saskatoon, June 2007.

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37. G. Kunstatter, "Critical Behaviour in Black Holes Formation: from 2-d to infinity", Workshop on 2-D Gravity, Erwin Schrodinger Institute, Vienna, Oct. 2003.

38. G. Kunstatter, "From Quasi-normal Modes to Black Hole Microstates",, Black Holes IV, May, 2003

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1. “Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation”, University of California (Davis), May 26, 2009.
2. “Dynamical Singularity Resolution in Spherically Symmetric Black Hole formation”, University of Western Ontario, March 19, 2009.
3. “Quantum Black Holes: Portals to Strange New Universes”, Prairies Regional Lecture Series, University of Saskatoon and University of Regina, January, 2009.
4. “Black Holes”, guest lecturer, Introduction to Physics, University of Winnipeg, January, 2009.
5. “Quantum Corrected Black Hole Spacetimes”, CECS Theoretical Physics Institute, Valdivia, Chile, November, 2008.
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Khodr M. Shamseddine

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33. Properties of the $pd \rightarrow (\mathrm{A} = 3\ ) + \pi^0$ reaction from threshold up to the Δ resonance, L. Canton, L.G. Levchuk, G. Pisent, W. Schadow, A.V. Shebeko, and J.P. Svenne, contributed paper (L.C., poster) FB17 International Conference on Few-Body Problems in Physics, June 5-10, 2003, Durham, NC, U.S.A. Published in "Book of Abstracts" only.

G.C. Tabisz

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3. 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).

4. 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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6. Tabisz, G. C.,"Interference Effects in the Infrared Spectrum of HD; Atmospheric Implications," in Weakly Interacting Molecular Pairs: Unconventional Absorbers of Radiation in the Atmosphere, C. Camy-Peyret and A. A. Vigasin, eds. (Kluwer Academic, Dordrecht, 2003), pp. 83-92.

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J.M. Vail

1. 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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3. J. M. Vail, D. Schindel, A. Yang, O. Penner, R. Pandey, H. Jiang, M. A. Blanco, A. Costales, Q. C. Qiu, and Y. Xu, "Effect of Dielectric Polarization on the Properties of Charged Point Defects in Insulating Crystals: the Nitrogen Vacancy in AlN", J. Phys.: Condens. Matter 16, 3371-3378 (2004).

4. J.M. Vail, *Topics in the Theory of Solid Materials* (Institute of Physics Publishing, Bristol, 2003), 368+xvi pages.

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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 Subsitutional 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.

9. J.M. Vail, M.A. Blanco, A. Costales, H. Jaing, R. Pandey, O. Penner, Q. C. Qiu, Y. Xu and A. Yang, "Embedded Molecular Clusters: Group III Nitrides", 2003 Canadian Association of Physicists, Charlottetown, PEI, June 8-11, 2003, abstract MO-PoS52, *Physics in Canada* May/June, **59**, 106 (2003)

Invited Workshop Contributions

10. 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 Structureof 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-AnchoredPolymers: Compression by Different Mechanisms, and Interpenetrationof Apposing Layers*, Macromolecular Theory and Simulations **14**,75–95 (2005)

4. M. D. Whitmore, *End-Anchored Polymers and the Polymer Brush*, Physics in Canada **59**, 103-110 (2003)

5. Y. Rharbi, J.-X. Zhang, J. G. Spiro, L. Chen, M. A. Winnik,J. D. Vavasour, M. D. Whitmore and R. Jérôme, *An Energy Transfer Study of Homopolymer Localization in Block Copolymers*, Macromolecules **36**,1241-1252 (2003)

Non-refereed Publications

6. A. B. MacIsaac and M. D. Whitmore, *High Performance Computing in Canada: The Early Chapters*, in Physics in Canada, vol. 64, 85-88 (2005)

7. 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

8. M. D. Whitmore, *Theory of Block Copolymers,* in *Supramolecular Polymers,2nd edition*, A. Ciferri, editor, CRC Press, Taylor and FrancisGroup, 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).

8. I. Mahmoud Abu-Amajieh and M. D. Whitmore, *An Examination of the Surface-Pressure Isotherms in End–TetheredPolymer Layers*, C.A.P. Congress, Charlottetown, PEI (2003).

J.G. Williams

1. 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).

2. 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).

3. 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).

4. T.A. Harriott and J.G. Williams, "Degree of mapping for general relativistic kinks," Nuovo Cimento B 120, 915-930 (2005) (C1).

5. T.A. Harriott and J.G. Williams ,"Rotating kink spacetime," Gen. Rel. Grav. 35, 341-357 (2003)

5 Financial

5.1 Statement of Income and Expenditures

Income

Income Source	Amount
Carry over from 2008	$9,599.00
Total Funds Available	$9,599.00

Expenditures

Activity	Amount Spent
M. Plumer	$1,800.12
L. Canton	$626.26
J. Moffat	$485.00
Theory Canada V support	$517.39
General Relativity and Relativistic Astrophysics support	$200.00
Printing etc.	$334.36
Total Expenditures (2007-2008)	$3,963.13
Current funds available	$5,635.87

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

Institute membership includes all of the theoretical physicists in the province. Hence its growth relies solely upon the associate members that it can attract (i.e. graduate students, postdoctoral fellows and research associates). The number and quality of these associate members is dependent on the Institute being able to create a positive research atmosphere. This in turn depends strongly upon the level of funding that the Institute receives.

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.