The Winnipeg Institute for Theoretical Physics[1] Annual Report

September 2002 - August 2003

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

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1 Director's Narrative Report

The Winnipeg Institute for Theoretical Physics 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 fourteen permanent members of this Institute are drawn from Brandon University, the University of Manitoba, and the University of Winnipeg.

The past year was the 12^{th} year of the Institute's existence. The Institute is pleased to report that the University of Brandon has significantly increased its support of theoretical physics through the appointment of a new assistant professor, Todd Fugleberg, and the award of Tier II chair to Meg Carrington.

An upcoming development of some importance is the award of a Tier I chair by the University of Manitoba in the area of theoretical nanophysics. It is expected that the recipient. Dr. Tapash Chakraborty, will join the University of Manitoba faculty in the fall of 2003. This appointment will bring a new area of work into the range of research supported by the Institute.

As usual the Institute sponsored a series research colloquia by out-of-province visitors as well as Institute members. Associated with the Permanent Members were research associates, postdoctoral fellows, and graduate students.

For the 2002–2003 academic year, the list of invited speakers is found in section 4.1. Visiting scientists whose stay lasted longer than one week are listed in section 4.2. The cumulative list of graduate degrees awarded appears in section 4.3, and the published research work of associate members/graduate students and of members are found, respectively, in sections 4.4 and 4.5. The total number of refereed publications by full members listed in section 4.5 is 50 for years 2002 and 2003. These numbers do not count twice those that are collaborative publications among members of the Institute. Section 5.1 contains a summary of income and expenditures for the period September 1, 2002 to August 31, 2003. The plans for the coming year include a program of invited speakers, visiting research collaborations, and the promotion of postgraduate and postdoctoral research.

The new academic year at the Institute will be an active one. At present the following professors are scheduled to visit:

- Professor Yuri Vorobiev (November)
- Dr. Andrei Barvinsky (January)
- Professor Mikhail Karasev (September – November)
- Dr. C.R. Praharaj (January – June)
- Dr. Thomas Melde (December – March)

Essentially 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 T. A. Osborn, Director (Manitoba), P. Loly, Past-Director (Manitoba), and R. Kobes (Winnipeg).

2 Current List of Members (September, 2003)

2.1 Permanent Members

- B. Bhakar[1], *Ph.D. (Delhi)* [Director, Jan. - June 00]
- P.G. Blunden[1], *Ph.D (Queen's)* [Director, 93–94]
- M.E. Carrington[3], *Ph.D. (SUNY, Stony Brook)*
- T.D. Fugleberg[3], *Ph.D. (UBC)*
- R.L. Kobes[2], *Ph.D. (Alberta)* [Director, 97–98]
- G. Kunstatter[2], *Ph.D. (Toronto)* [Director, 91–92]
- P.D. Loly[1], *Ph.D. (London)* [Director, Fall 99, Acting Director July 00 - Oct. 01]
- T.A. Osborn[1], *Ph.D. (Stanford)* [Director, 92–93, 02-04]
- B.W. Southern[1], *Ph.D. (McMaster)* [Director, 90–91]
- 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]
- D.W. Vincent[2], *Ph.D. (Toronto)* [Director, 94–95]
- J.G. Williams[3], *Ph.D. (Birmingham)* [Director, 96–97]

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

2.2 Associate Members

Research Associates

- Ruth E. Cameron B.Sc. (Manitoba), M.Sc. (Rochester), Ph.D (Rochester)
- S. Bekhechi (Southern) June '01– present

Postdoctoral Fellows

- Weixing Qu (Tabisz) 2001– present
- H. Zaratek, (Carrington, Kobes, Kunstatter) July '01– present
- W. Chen, (Carrington, Kobes, Kunstatter) Sept. '02– Nov. '02
- Daria Ahrensmeier (Carrington, Kobes, Kunstatter) Feb. '02– May '03
- Todd Fugelberg (Carrington, Kobes, Kunstatter) July '02– Aug. '03

2.3 Graduate Students

- Aleksandrs Alexsejevs (Ph.D.) (Blunden)
- Svetlana Barkanova (Ph.D.) (Blunden)
- Jason Bland (Ph.D.) (Kunstatter)
- Edward Kavalchuk (M. Sc.) (Kobes)
- Amra Peles (Ph.D.) (Southern)
- A. J. Penner (M.Sc.) (Kobes)
- Andrew Senchuk (M. Sc) (Tabisz)
- J. Medved (Ph.D.) (Kunstatter) GRADUATED 2000
- T. Melde (Ph.D.) (Svenne) GRADUATED 2001
- Slaven Peles (Ph.D.) (Kobes) GRADUATED 2001

2.4 Summer Undergraduate Research Students 2002-2003

- T. Kruk, *(Carrington)*
- A. Rodgers, *(Loly)*
- M. Rempel, *(Loly)*
- J. Haywood, *(Osborn)*
- D. Schindel, *(Vail)*

3 Research Interests of Permanent 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

Electromagnetic interactions in complex and few-nucleon systems are being studied. I am particularly interested in the description of electron scattering at large energy and momentum transfers, the so-called quasi-elastic region, in which one or more constituents are knocked out of the nucleus. In this kinematical regime one can explore different aspects of the nuclear response to learn about two-nucleon correlations, two-body electromagnetic currents, the role of nucleon substructure, and the momentum distribution of the initial struck nucleon.

Another area of interest is in a quantum field theory of mesons and hadrons (QHD). Some recent work includes: Dirac-Hartree-Fock calculations for the properties of finite nuclei; hadronic and electromagnetic reactions; a relativistic treatment of mesonic currents; the exact numerical evaluation of one-loop quantum corrections to solitons in 3+1 dimensions; a quark-meson coupling model that treats the nucleon as a collection of confined relativistic quarks embedded in the nuclear medium; and a relativistic mean-field treatment of finite nuclei using light front coordinates.

M.E. Carrington

Finite temperature field theory has applications in many areas. It can be used to study phase transitions like the QCD phase transition in the quark-gluon plasma and the electroweak phase transition in the early universe. It can also be used to study collective behaviour in many body systems, like the production of thermal masses and the propagation of damped plasma oscillations.

It is also of interest to develop calculational techniques to study systems that are not at equilibrium. For example, the lifetime of the quark-gluon plasma is extremely short and it is not clear that there is time to reach equilibrium before the plasma state dissolves. It is likely that an accurate mathematical description of the quark-gluon plasma will involve the use of non-equilibrium methods. Conventional field theoretic techniques assume equilibration, and thus do not apply to unequilibrated systems. Systems close to equilibrium can be studied using transport theory. I am currently working on developing techniques to extend the range of validity of transport theory calculations. In addition, I am working on the development of more general methods based on effective theories.

T.D. Fugleberg

My current research interests have to do with matter and quantum fields under extreme conditions.

I am studying 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). My research involves 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.

I am also doing research in the areas of 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. I am performing numerical studies of ϕ^4 theory in the 2PPI model in order to understand how quantum fields evolve for arbitrary non-equilibrium initial conditions.

R.L. Kobes

The general area of research is quantum field theory at finite temperature and density, with applications particularly in particle physics. We are presently studying aspects of hot gauge theories such as the quark–gluon plasma, as well as general calculational methods in finite temperature field theory. We are also interested in classical theories which exhibit chaotic behaviour, and have begun a numerical study of some properties of a particular system similar to a forced pendulum.

G. Kunstatter

Gauge theories provide the theoretical basis for virtually all phenomenological descriptions of the fundamental interactions. They are also playing an increasingly important role in our understanding of certain condensed matter systems. The quantization of gauge theories is, however, complicated by the presence of unphysical modes in the classical description, which must be factored out in order to expose the true physical content of the theory. My research uses geometrical techniques to investigate questions concerning gauge dependence in quantized gauge theories such as Quantum Chromodynamics, Chern-Simons theory and Quantum Gravity, both at zero and finite temperature. Most recently, I have been examining the quantum mechanical behaviour of black holes via simplified field theoretic models in two spacetime dimensions. These models are ideal theoretical laboratories for the study of fundamental issues surrounding black hole evaporation, such as the statistical mechanical source of entropy and the endpoint of gravitational collapse.

P.D. Loly

The dialogue between C. G. Jung and Wolfgang Pauli (*Atom and Archetype*, ed. C. A. Meier), an intriguing book by their colleague Marie-Louise von Franz *(Number and Time)*, and interest in these matters by a number of physicists (including Nobel Laureates Maurice Wilkins and Alex Müller) caught my attention over the last decade. One aspect which continued to crop up in writings by Jung and von Franz concerns the 3-by-3 Chinese magic square of the first nine sequential integers (all rows, columns and the main diagonals having the same sum) and this resonated for me with aspects of theoretical physics. One question concerned whether the 4-by-4 type matrix of the well known (Jungian) Myers-Briggs personality classification, or Type Indicator (MBTI), was a magic square. The negative result (J. Rec. Math.) lead me to the discovery of a new class of number squares that share a basis with a binary-geometric multi-dimensional classification scheme that I have developed. More recently I applied these ideas to a study of Chinese patterns (J. Yijing Stud.). Such pandiagonal non-magic squares are related to the Gray code and Karnaugh maps, and if treated as matrices possess two non-zero eigenvalues (in preparation with Marcus Steeds). I have also discovered a new invariance for the moment of inertia of magic squares which depends only on their order (The Mathematical Gazette) and have extended this to the moment of inertia of magic cubes and large squares with distributions of random numbers or random mass density. A larger study of magic squares nearing completion (with Hruska, Williams and Steeds) clarifies their n-agonal eigenvector and gives an analysis of the 880 distinct 4×4's in the twelve Dudeney groups, finding that members of the first six (singular) groups have three distinct eigenvalue patterns, with a subset of the first three groups having three zero eigenvalues, while the last six (non-singular) groups have just two further eigenvalue patterns. An offshoot of these magic square studies is a modern update to an old idea for compounding magic squares (IMA's Mathematics Today) in order to facilitate the generation of very large-order numerical matrices.

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, autonomus statement of quantum mechanics that clarifies its content and interpretation and at the same provides a new computational platform that has many parallels to that of classical mechanics.

Two active projects are: 1) In recent work on charged particle systems in electromagnetic fields we have developed a QPS representation (called a perfect quantization) that is both gauge and geometrically covariant and has an exact star product determined by a symplectic area phase. Perfect quantization provides an ideal platform for studying the semiclassical charged particle dynamics. We aim to extend this perfect quantization to general non-Abelian gauge theories, i.e., to include Riemannian manifolds and arbitrary spin structure. 2) Develop effective methods to treat long time dynamics in QPS. Rigorously define quantum chaos and the quantum Lyapunov exponent. Investigate the role of the Heisenberg uncertainty principle in the suppression of quantum chaos effects.

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, 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}H and ^{3}He, 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.

In addition, we have developed the complete coupled three-body to four-body theory of the $\pi NNN - NNN$ system (Phys. Rev. C58, 3121 (1998)). This work elaborates the complicated set of coupled integral equations for this problem, which are not amenable to exact solution in the foreseeable future. A practical approximation scheme has been developed and calculations have been carried out for a simplified, one-dimensional, model. Preliminary results have been obtained also for more realistic problems. This work shows an interesting link between this theory and three-nucleon forces, which leads to new results in describing three-nucleon observables. In particular, we believe that this is able to resolve the long-standing A_y problem in the scattering of nucleons from deuteron.

Finally, in a separate collaboration with Drs. L. Canton, G. Pisent (Padova), K. Amos and D. van der Knijff (Melbourne, Australia), we are studying the presence and behaviour of compound and quasi-compound resonances in complex nuclear systems. Recent work on the scattering of neutrons from ^{12}C suggests that the approach to the theory we use, an algebraic solution of the coupled integral equations of the multichannel problem, obtained by expansions in Sturmian functions of the channel-coupling interactions, provides a theoretical formulation of the scattering problem that has predictive power. Other light and medium mass nuclear systems will be investigated.

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.

Two research projects are current: (1) optical transitions between the electronic state localized at the angstrom level and a state localized at the nanometer level; (2) point-defect properties of group III nitrides.

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 .

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 is concerned with 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. The problem of geodesic incompleteness in spherically symmetric kink spacetimes has been studied in relation to the weak and strong energy conditions, and null geodesics in a number of such spacetimes have been completed using the Kruskal technique. In 2+1 dimensions, a kink solution has been found for the Einstein equations with a perfect fluid source. The mass density, pressure and curvature are all well behaved and the vorticity is nonzero. Future effort will be directed towards introducing time-dependence and to studying the properties of scalar fields in such non-globally hyperbolic spacetimes.

4 Research Activities

4.1 Seminars

Date	Speaker	Institution	Title
Dec. 6, 2002	Dr. Daria Ahrensmeier	University of Winnipeg	Far-from-Equilibrium Quantum Field Dynamics for Heavy Ion Collisions
Nov. 22, 2002	Dr. J.G. Williams	Brandon University	The Kink in Godel's Spacetime
Feb. 26, 2003	Dr. J.M. Vail	Univ. of Manitoba	Density Functionals in the Many-Body Problem
March 5, 2003	Dr. M.V. Karasev	MIEM (Moscow)	Quantum Sphere and Quantum Hyperboloid
May 8, 2003	Dr. Victor Elias	Univ. of Western Ontario	New Hope for Radiative Electroweak Symmetry Breaking

4.2 Visiting Scientists

Dates	Visitor	Institution
Jan. - Mar. 2003	Prof. M. V. Karasev	Moscow Institute for Electronics and Mathematics

4.3 Graduate Degrees Supervised

1. J. Medved (2000), "Thermodynamics of Charged Black Holes in Two-Dimensional Gravity". Ph.D. thesis, University of Manitoba, 2001. (University Microfilms)
2. S. Peles (2001), "Nonlinear Phenomena and Chaos in Periodically Driven Classical Systems". Ph.D. thesis, University of Manitoba, 2001. (University Microfilms)
3. T. Melde (2001), "The Three Nucleon System including one Dynamical Pion: A one dimensional test case". Ph.D. thesis, University of Manitoba, May 2001. (University Microfilms)

4.4 Publications of Associate Members/Graduate Students

S. Bekhechi

1. N. Moussa and S. Bekhechi, 'Surface Critical Behavior of Thin Ising Films at the "Special Point" ', *Physica A* **320**, *435* (2003). (C1)
2. S. Bekhechi and B.W. Southern, 'Damage Spreading in Two-Dimensional geometrically frustrated lattices: the triangular and kagome anisotropic Heisenberg model', *J. Phys. A: Math. Gen.***36** , *8549* (2003). (C1)
3. S. Bekhechi and B. W. Southern, 'Off-equilibrium study of the fluctuation-dissipation relation in the easy-axis Heisenberg antiferromagnet on the kagome lattice', *Phys. Rev.* **B67**, *212406* (2003). (C1)
4. S. Bekhechi and B.W. Southern, 'Low Temperature Static and Dynamic Behaviour of the Easy-Axis Heisenberg Antiferromagnet on the Kagome Lattice', *Phys. Rev.* **B67** , *144403* (2003). (C1)

T. Melde

1. Pion Dynamics in the Three-Nucleon System, Juris P. Svenne, Thomas Melde and Luciano Canton, contributed paper to the 2nd World Congress of Latvian Scientists, Riga, Latvia, August 14-15, 2001 (paper delivered orally in Latvian). (C3)
2. Meson Dynamics and the resulting "3-Nucleon Force" diagrams: Results from a simplified test case. L. Canton, T. Melde and J.P. Svenne, contributed paper to "Mesons and Light Nuclei" conference, Prague, Czech Republic, July 2-6, 2001. Proceedings to be published. (C1)
3. Three-Nucleon Portrait with Pion, L. Canton, G. Pisent, W. Schadow, T. Melde, and J.P. Svenne, contributed paper to the "VIII Convengo su problemi di fisica teorica", Cortona, Italy, October 18-20, 2000. Proceedings: *Theoretical Nuclear Physics in Italy*, G. Pisent, S. Boffi, L. Canton, A. Covello, A. Fabriocini, and S. Rosati, eds. (World Scientific, Singapore, 2001) pp.249-256. (C1)

4. Practical Approximation Scheme for the Pion Dynamics in the Three-Nucleon System, L. Canton, T. Melde, and J.P. Svenne, Physical Review C, **63**, 034004-1-10 (2001)

5. L. Canton, T. Melde and J.P. Svenne, Practical scheme for approximate treatment of the pion dynamics in three-nucleon systems (poster), Few Body XVI conference at Taipei, Taiwan, March 6-10, 2000. (C1)

6. Pion Dynamics and Three-Nucleon Forces, T. Melde, J.P. Svenne, and L. Canton, contributed paper to the DNP-2000 Conference of the APS, October 4-7, 2000, Williamsburg, VA, U.S.A. (oral presentation by Svenne) (C1)

7. L. Canton, T. Melde and J.P. Svenne, "Interpreting the 3-nucleon force diagrams" (oral presentation by Melde), CAP-2000, York University. (C1)

8. T, Melde and J.P. Svenne, The piNNN scattering problem revisited (oral presentation by Melde), CAP-1999, University of New Brunswick, Fredricton. (C1)

4.5 Publications of Permanent Members

P.G. Blunden

1. P.G. Blunden, W. Melnitchouk, and J.A. Tjon, 2003, Two-photon exchange and elastic electron-proton scattering, nucl-th/0306076. Accepted in Physical Review Letters.

2. S. Barkanova, A. Aleksejevs, and P.G. Blunden, 2002, Radiative corrections and parity-violating electron-nucleon scattering, nucl-th/0212105. Submitted to Physical Review C.

3. P.G. Blunden, M. Burkardt, and G.A. Miller 2000, Light-front nuclear physics: Toy models, static sources, and tilted light-front coordinates, Phys. Rev. **C61**, 025206. nucl-th/9908067 (C1)

4. P.G. Blunden, M. Burkardt and G.A. Miller, 1999, Light-front nuclear physics: Mean field theory for finite nuclei, To appear in Phys. Rev. C, nucl-th/9906012. (C1)

5. P.G. Blunden, M. Burkardt and G.A. Miller, 1999, Rotational invariance in nuclear light-front mean field theory, Phys. Rev. **C59**, R2998 (1999). (C1)

Conference Proceedings and Talks

1. Radiative corrections and parity-violating electron scattering, Workshop on Fundamental Symmetries and Weak Interactions, Institute for Nuclear Theory, Seattle, WA November 26, 2002 (presented by A. Aleksejevs, Ph.D. student).

2. Parity violating effects in the deuteron, Workshop on Fundamental Symmetries and Weak Interactions, Institute for Nuclear Theory, Seattle, WA December 3, 2002.

3. Light-front nuclear physics: Mean field theory for finite nuclei, International Workshop on Relativistic Dynamics and Few-Hadron Systems, ECT Trento, November 6-17, 2000.

M.E. Carrington

1. "*2PI Effective Action and Gauge Invariance Problems,*" M.E. Carrington, G. Kunstatter and H. Zaraket, hep-0309084 (submitted to Phys. Rev. D). (C1)

2. "*Dileptons from Hot, Heavy, Static Photons,*" P. Aurenche, M.E. Carrington and N. Marchal, hep-ph/0305226 (accepted for publication in Phys. Rev. D). (C1)

3. "*Scattering Amplitudes at Finite Temperature,*" M.E. Carrington, Hou Defu and R. Kobes, Phys. Rev. **D67** 025021 (2003). (C1)

4. "*Infrared behaviour of the pressure in $g\phi^3$ theory in 6 dimensions,*" M.E. Carrington, T.J. Hammond and R. Kobes, Phys. Rev. **D65** 067703 (2002). (C1)

5. "*Equilibration in an Interacting Field Theory,*" M.E. Carrington, R. Kobes, G. Kunstatter, D. Pickering and E. Vaz, Can. J. Phys. **80** 987 (2002). (C1)

6. "*A General expression for Symmetry Factors of Feynman Diagrams,*" C.D Palmer and M.E. Carrington, Can. J. Phys. **80** 847 (2002). (C1)

7. "*Covariant approach to equilibration in effective field theories,*" Mark Burgess, M.E. Carrington and G. Kunstatter, Can. J. Phys. **80** 97 (2002). (C1)

8. "*A Diagrammatic Interpretation of the Boltzmann Equation,*" M.E. Carrington, Hou Defu, R. Kobes, Phys. Lett. **B523** 221 (2001). (C1)

9. "*Nonlinear Response from Transport Theory and Quantum Field Theory at Finite Temperature,*" M.E. Carrington, Hou Defu, R. Kobes, Phys. Rev. **D64** 025001 (2001). (C1)

10. "*Spontaneous Symmetry Breaking for Scalar QED with Nonminimal Chern-Simons Coupling,*" D.S. Irvine, M.E. Carrington, G. Kunstatter and D. Pickering, Phys. Rev. **64** 045015 (2001). (C1)

11. "*Spontaneous Scale Symmetry Breaking in 2+1 Dimensional QED at Both Zero and Finite Temperature,*" M.E. Carrington, WF Chen and R. Kobes, Eur. Phys. J **C18** 757 (2001). (C1)

12. "*Approach to Equilibrium in the Micromaser,*" D. Leary, S. Yau, M.E. Carrington, R. Kobes and G. Kunstatter, Can. J. Phys. **79** 783 (2001). (C1)

13. "*KMS conditions for 4-point green functions at finite temperature,*" M.E. Carrington, Hou Defu and J.C. Sowiak, Phys. Rev. **D62** 065003 (2000). (C1)

14. "*Shear Viscosity in ϕ^4 Theory from an Extended Ladder Resummation,*" M.E. Carrington, Hou Defu and R. Kobes, Phys. Rev. **D62** 085013 (2000). (C1)

15. "*Four-Point Spectral Functions and Ward Identities in Hot QED,*" Hou Defu, M.E. Carrington, R. Kobes and U. Heinz, Phys. Rev. **D61** 085013 (2000). (C1)

16. "*A New Formulation of a 1+1 Dimensional Field Theory Constrained to a Box,* M.E. Carrington, R. Kobes and G. Kunstatter, Phys. Rev. **D61** 125008 (2000). (C1)

17. "*Evaluating Real Time Finite Temperature Feynman Amplitudes,*" M.E. Carrington, Hou Defu, A. Hachkowski, D. Pickering and J.C. Sowiak, Phys. Rev. **D61** 25011 (2000). (C1)

18. "*Two-Loop Quantum Corrections of Scalar QED with non-Minimal Chern-Simons Coupling,*" M.E. Carrington, W.F. Chen, G. Kunstatter and J. Mottershead, Phys. Rev. **D60** 125018 (1999). (C1)

19. *"Equilibrium and Non-Equilibrium Hard Thermal Loop Resummation in the Real Time Formalism,"* M.E. Carrington, Hou Defu and Markus Thoma, Eur. Phys. J. **C7** 347 (1999). (C1)

20. *"Ward Identities in Non-Equilibrium QED,"* M.E. Carrington, Hou Defu and Markus Thoma, Phys. Rev. **D58** 085025 (1998). (C1)

21. *"The General Cancellation of Ladder Graphs at Finite Temperature,"* M.E. Carrington and R. Kobes, Phys. Rev. **D57** 6372 (1998). (C1)

22. *"Cancellation of Ladder Graphs in an Effective Expansion."* M.E. Carrington, R. Kobes and E. Petitgirard, Phys. Rev. **D57** 2631 (1998). (C1)

23. *"The Effective Action For a Relativistic Jaynes-Cummings Model,"* M. Burgess, M.E. Carrington and G. Kunstatter, Can. J. Phys. **76** 1 (1998). (C1)

24. *"Three Point Functions at Finite Temperature,"* M.E. Carrington and U. Heinz, Eur. Phys. J. **C1** 619 (1998). (C1)

- *Papers in Refereed Proceedings*

25. *"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. (C3)

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5 Financial

5.1 Statement of Income and Expenditures

Income

Income Source	Amount
Carry over from Aug. 31, 2002	$932
Dean of Science Support (2002)	$5000
Total Funds Available	$5932

Expenditures

Activity	Particulars	Amount Spent
Seminars		
	M. Karasev, March 2003	$1,000
	Total Seminar Costs	$1.000
Miscellaneous	FAX. mail, printing, supplies	$22
	Total Expenditures (2003-2003)	$1022

In relation to the supporting funds indicated above, it should be pointed out that the members of the Institute use their individual NSERC grants to subsidize Institute activities. Currently the members from the three universities draw upon more than $200,000 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 activity 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. In comparison with its first half dozen years years, in the past six years there has been a marked decrease in the funds made available to the Institute by the three Manitoba universities. This has meant we have not been able to sponsor any costly conferences during this period of time.

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.