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The Winnipeg Institute for Theoretical Physics[1] Annual Report

September 1998 – August 1999

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

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 twelve permanent members of this Institute are drawn from the University of Manitoba, the University of Winnipeg, and Brandon University.

The past year was the ninth year of the Institute's existence. There were research colloquia by out-of-province visitors. Associated with the Permanent Members were research associates, postdoctoral fellows, and graduate students.

For the 1998-1999 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 publications by full members listed in section 4.5 is 37 for 1998-9 and 138 for 1992-8. 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, 1998 to August 31, 1999. The plans for the coming year include a program of invited speakers, visiting research collaborations, and the promotion of postgraduate and postdoctoral research.

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 J. Vail, Director (Manitoba), R. Kobes, Past-Director (Winnipeg), and Director Elect P. Loly (Manitoba). For the year 1999-2000, the Directorship will be split between P. Loly (Manitoba) for October to December 1999, and B. Bhakar (Manitoba) for January to September 2000. This has been necessitated by Dr. Loly's sabbatical leave which begins January 2000. A Director-Elect for October 2000 will be elected at a General Meeting of the Institute in October 1999.

2 Current List of Members (September, 1999)

2.1 Permanent Members

- B. Bhakar[1], *Ph.D. (Delhi)*
- P.G. Blunden[1] , *Ph.D (Queen's)*
- M.E. Carrington[3] , *Ph.D. (SUNY, Stony Brook)*
- R.L. Kobes[2], *Ph.D. (Alberta)*
- G. Kunstatter[2] , *Ph.D. (Toronto)*
- P.D. Loly[1] , *Ph.D. (London)*
- T.A. Osborn[1] , *Ph.D. (Stanford)*
- B.W. Southern[1] , *Ph.D. (McMaster)*
- J.P. Svenne[1] , *Ph.D. (M.I.T.)*
- J.M. Vail[1] , *Ph.D. (Brandeis)*
- D.W. Vincent[2] , *Ph.D. (Toronto)*
- J.G. Williams[3], *Ph.D. (Birmingham)*

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

2.2 Associate Members

- W. Chen *(Postdoctoral Fellow)*
- Hou Defu *(Postdoctoral Fellow)*
- M.F. Kondrat'eva *(Postdoctoral Fellow)*
- C. Sadov *(Postdoctoral Fellow)*
- W. Stephan *(Research Associate)*

2.3 Graduate Students

- Aleksandrs Alexsejevs (M.Sc.) *Blunden*
- Svetlana Barkanova (Ph.D.) *Blunden*
- B. McQuarrie (Ph.D.), *(Osborn and Tabisz)* GRADUATED
- J. Medved (Ph.D.), *(Kunstatter)*
- T. Melde (Ph.D.), *(Svenne)*
- Slaven Peles (Ph.D.), *(Kobes)*
- Zhinong Weng (Ph.D.), *(Vail)*

2.4 Summer Undergraduate Research Students

- C. Shroeder *(Kunstatter)*
- J. Mottershead *(Kunstatter, Carrington)*
- John Sowiak *(Carrington)*
- Marcus Steeds *(Loly)*
- Parmjit Virk *(Kobes)*
- Somchay Yau *(Kunstatter, Kobes)*

3 Research Interests of Permanent Members

B. Bhakar

Present activities are directed towards the understanding of completely integrable and non-integrable 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 electro–weak phase transition in the standard model. 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. Both the imaginary time and real time formalisms are commonly used. The real time formalism is usually considered to be more complicated, but it has the advantage that it produces real time Green functions directly, without involving analytic continuations. Currently I am working on the development of various techniques that can be used to reduce the complexity of finite temperature calculations in the real time formalism.

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

For several years I have been increasingly interested in the dialogue between Carl Gustave Jung and Wolfgang Pauli (Nobel Laureate in Physics in 1945 for discovering the exclusion principle in 1924, and a key contributer to the foundations of quantum physics). Recently Pauli's scientific correspondence in the period 1950-1952 has been published (in German) and I am studying how this dialogue, an intriguing book by their colleague Marie-Louise von Franz ("Number and Time"), and the evident influence on a number of physicists (including Nobel Laureates Maurice Wilkins and Alex Müller) fits with a binary-geometric multi-dimensional classification scheme that I have discovered (talks given in Munich in 1998, and to selected high school mathematics students under the auspices of the Institute for Industrial Mathematics from 1995-99. There is much promise in this dialogue for incorporation into a variety of courses. I can report one surprising outcome this work, namely the discovery of a family of square binary-logic matrices in which all "pandiagonals" have the same sum, but which are not the magic squares which had been expected.

Alex Mogilner and I have resolved the recurring question of zero-energy gaps in 1D bandstructures by using quite general analytical results for the eigenvalues of "oscillatory" matrices.

This exciting development facilitates another paper, extending some explicit calculations of the energy bands of a number of earlier "exactly soluble" potentials. In 2D and 3D we use analogues of the Kronig-Penney potential to study bandstructures of mesoscopic ultrasmall quantum box structures now etched routinely in AlGaAs in semiconductor heterostructures, as an application of our multi-dimension nearly-free-electron code. The programs developed can also be applied to photonic band gap questions.

We take into account realistic band structure effects (e.g. van Hove singularities) that are particularly important in optical processes, especially in my own forte of 2-magnon spectra. Using a Green's function formalism that is rigorous and applicable across ALL dimensions of practical interest we have found a significant interplay between the band singularities and continuum resonances which helps determine resonant frequencies and thus afford a new spectroscopy. The 2D calculations use our linear-analytic triangular scheme for 2D. I also have direct experience of methods restricted to 1D: alternating bond chain using real space rescaling and a continuing study with the Bethe Ansatz.

T.A. Osborn

A principal research interest is the investigation of quantum (and classical) evolution in a variety of gauge theories. Using the methods of mathematical physics, the goal is to describe the dynamics of these strongly interacting systems by the development of non-perturbative, analytically explicit approximate solutions. The usefulness of such an approximate dynamics is that it allows detailed physical insights into the fundamental structure of the system, as well as the computation of all observables of interest (such as the stress-energy tensor). For example, the large mass semi-classical expansion of the propagator for an N-body system coupled via the Lorentz force to an arbitrary external electromagnetic field has been recently shown to admit an asymptotic expansion in the reciprocal mass. This expansion is valid to infinite order in the external fields, is manifestly gauge and Lorentz invariant, possesses simple expansion coefficients, and has an a priori determined error bound. The extension of this type of semi-classical description to characterize relativistic quantum theories evolving on Riemannian and pseudo-Riemannian spacetime manifolds and interacting with Yang-Mills fields is currently underway.

B.W. Southern

The nature of excitations in both regular lattices and disordered systems is being investigated using scaling techniques. Quantum spin chains are being studied in an attempt to understand the differences between integer and half-integer spin systems. A study of the effects of disorder on the nature of phase transitions is also in progress. The disorder can be due to the fact that the degrees of freedom in the problem are not located at the sites of a perfect crystal or due to the fact that the interactions have a distribution of possible values. Both real space renormalization group methods and transfer matrix methods are used to study the relationship between the critical exponents of various models on these structures and the geometrical properties, and to explore questions about universality in these systems.

The study of frustrated systems is also an area of active research. Spin glasses are one example where frustration can either prevent a system from ordering or lead to a new type of glassy phase. Frustration can also lead to novel ground states where the symmetry of the ordered phase is no longer represented as a simple vector. The order parameter is more like a rigid body and hence the excitation spectrum is also different. The symmetry of the order parameter can change the nature of the topological defects present in the system and these defects can exhibit nontrivial unbinding transitions as the temperature increases. These problems are being studied using Monte Carlo methods.

J. P. Svenne

Our current work, in collaboration with a group at Padua University (L. Canton, G. Cattapan, G. Pisent), P.J. Dortmans at Melbourne University, and W. Schadow of Bonn University (now a postdoc at Ohio University), focuses on pion absorption on very light nuclei. The work on pion absorption is proceding along two lines: One is on 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 the same basic mechanisms and input on πN, NN and $\pi N\Delta$ interactions as in pion absorption on the deuteron. The three-nucleon system is treated exactly in a Faddeev-based theory. Final-state interactions are correctly taken into account. In addition, the S-wave mechanism important for absorption at low energies, that is normally credited to Koltun and Reitan, is being re-examined.

The second line of inquiry is further to develop the complete coupled three-body to four-body theory of the $\pi NNN - NNN$ system, on which extensive work has has already been done by members of the collaboration. This work elaborates the complicated set of coupled integral equations for this problem, which are not amenable to exact solution in the foreseeable future. Approximations and calculational techniques for the solution of these equations will be developed for a simplified, perhaps schematic, model. This could be useful in deriving methods for treating more realistic problems.

Finally, in a separate collaborationn with Drs. G. Pisent and P.J. Dortmans, we are studying the presence and behaviour of compound and quasi-compound resonances in complex nuclear systems.

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, and classical and quantum diffusion.

Three projects are currently in progress: (1) overlap and localization effects from the embedding region in the simulation of point defects by small clusters; (2) defect properties of barium fluoride and lead fluoride: optical excitation of the F center and of oxygen; (3) a formulation of the many-body problem in terms of two-body density functionals.

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
Nov. 25,1998	Dr. Walter Stephan	Dept. of Physics and Astronomy University of Manitoba	An Introduction to Spin-Charge Separation
Dec. 3, 1998	Dr. Kurt Busch	Dept. of Physics University of Toronto	Tunable Photonic Crystal
Jan. 7, 1999	Mr. Iain Stewart	Division of Physics, Mathematics and Astronomy, California Institute of Technology	Renormalization Schemes and Two-Nucleon Effective Field Theory
Jan. 21,1999	Dr. Manu Paranjape	Département de physique Université de Montreal	Is Conformal Gravity an Alternative to Dark Matter?
Mar.11,1999	Dr. Wolfgang Schadow	Dept. of Physics and Astronomy Ohio University	Three-Nucleon Systems: An Approach Without Using Partial Waves
April 1, 1999	Dr. T. McMullen	Dept. of Physics Virginia Commonwealth University	Electrons of Many Flavors: The Spectral Function of the Two-Dimensional Large-N t- J Model
May 28,1999	Dr. David Feder	Electron and Optical Physics Division, National Institute of Standards and Technology, Gaithersburg, MD	The Search for Vortices in Trapped Bose Condensed Gases
Aug. 26,1999	Dr. Steve Fulling	Dept. of Mathematics Texas A & M University	A First Look at Quantum Computation

4.2 Visiting Scientists

Dates	Visitor	Institution
September, 1998 - July, 1999	Junxian Liu	Maribor University, Slovenia
March 1 - 14, 1999	Luciano Canton	Padua University, Italy
March 9-15, 1999	Wolfgang Schadow	Ohio University

4.3 Graduate Degrees Supervised

1. B. R. McQuarrie, Ph.D. December 1997 (*T.A. Osborn and G.C. Tabisz*), "Molecular Collisions: Effect on the HD Infrared Spectrum and the Development of a Moyal Quantum Mechanical Description"
2. J.L. Martinez-Cuellar, M.Sc., July 1997 *(B.W. Southern)*. "Three Magnon Excitations in Alternating Quantum Spin/Bond Chains."
3. Yu.V. Gusev, Ph.D., October 1996 *(T.A. Osborn)*. "Covariant Computation of Heat Kernels in Perturbation Theory."
4. Iain Stewart, M.Sc., March 1996 *(P.G. Blunden)*. "Derivative Expansion Approximation of Vacuum Polarization Effects."
5. Ning Li, University of Manitoba M.Sc., February 1995 *(C.H. Woo)*.
6. J. Chen, University of Manitoba, M.Sc., October 1994 *(R. Kobes)*. "Proximity Effect and the Thermodynamic Properties of Superlattice Systems."
7. Sandra Cyr, M.Sc., October 1994 *(B.W. Southern)*. "Multi-Magnon Excitations in One-Dimensional Quantum Spin Chains with NNN Interactions."
8. R. Epp, University of Manitoba Ph.D., September 1993 *(G. Kunstatter)*. "Curved Space Quantization, and Dirac *vs.* Reduced Quantization of Poincare Invariant Gauge Theories."
9. Domingo Louis-Martinez, University of Manitoba Ph.D October 1994 *(G. Kunstatter)*. "Dirac's Constrained Systems: Two Dimensional Gravity and Spinning Relativistic Particle."
10. K. Mak, University of Manitoba Ph.D., September 1993 *(R. Kobes, G. Kunstatter)*. "Damping rates and hot gauge theories."
11. J. Wang, University of Manitoba M.Sc., September 1992 *(R. Kobes)*. "Finite layers effect in metallic superlattices."
12. K. Mak, University of Manitoba M.Sc., September 1991 *(R. Kobes, G. Kunstatter)*. "Hamiltonian analysis of Yang–Mills fields in a general class of linear gauges."

4.4 Publications of Associate Members/Graduate Students

T. Melde

1. T. Melde (1995), "A photon number density operator in the covariant formulation of quantum electrodynamics", Can. J. Physics, **77**, 167-175 (1999)
2. M. Hawton and T. Melde (1995), "Photon number density operator $i\hat{E}\cdot\hat{A}$", Phys. Rev. A51, 4186-4190. (C1)

W. Stephan

1. R. Neudert, M. Knupfer, M. S. Golden, J. Fink, W. Stephan, K. Penc, N. Motoyama, H. Eisaki, and S. Uchida, "Manifestation of Spin–Charge Separation in the Dynamic Dielectric Response of One–Dimensional Sr_2CuO_3", Phys. Rev. Lett. **81**, 657 (1998). (C1)

2. C. M. Canali, W. Stephan, L. Y. Gorelik. R. I. Shekhter, and M. Jonson, "Coulomb correlations and coherent charge tunneling in mesoscopic coupled rings", Europhys. Lett. **40**, 67 (1997). (C1)

3. M. Capone, W. Stephan, and M. Grilli, "Small polaron formation and optical absorption in Su-Schrieffer-Heeger and Holstein models", Phys. Rev. B **56**, 4484 (1997). (C1)

4. W. Stephan, M. Capone, M. Grilli and C. Castellani, "Influence of electron–phonon interaction on superexchange", Phys. Lett. A 227, 120 (1997). (C1)

5. C. M. Canali, W. Stephan, L. Y. Gorelik, R. I. Shekhter, and M. Jonson, "Ordering effect of Coulomb interaction in ballistic double–ring systems", Solid State Comm. **104**, 75 (1997). (C1)

6. Walter Stephan and Karlo Penc, "Dynamical density-density correlations in one-dimensional Mott insulators", Phys. Rev. B **54**, R17269 (1996). (C1)

7. Walter Stephan, "Single-polaron band structure of the Holstein model", Phys. Rev. B **54**, 8981 (1996). (C1)

8. C. M. Canali, C. Basu. W. Stephan, and V. E. Kravtsov, "Distribution of level curvatures for the Anderson model at the localization-delocalization transition", Phys. Rev. B **54**, 1431 (1996). (C1)

9. Peter Horsch and Walter Stephan, "Drude weight and f-sum rule of the Hubbard model at strong coupling", in *The Hubbard Model*, Eds. D. Baeriswyl et al., Plenum Press, New York, 1995, pp. 193-200. (C3)

10. Henk Eskes, Andzrej Oles, Marcel Meinders and Walter Stephan, "Spectral properties of the Hubbard bands", Phys. Rev. B **50**, 17980 (1994). (C1)

11. J. H. Jefferson and W. Stephan, "A real-space finite cluster approach to the correlated electron problem", Physica C **235-240**, 2251 (1994). (C1)

12. Peter Horsch and Walter Stephan, "Frequency–dependent conductivity of the one–dimensional Hubbard Model at strong coupling", Phys. Rev. **B 48**, 10595 (1993). (C1)

13. Walter Stephan and Peter Horsch, "Single–particle and optical excitations in doped Mott–Hubbard insulators", Int. J. Mod. Phys. **B 6**, 589 (1992). (C1)

14. W. Stephan and J.P. Carbotte, "Conductance of a spin-glass with proximity induced superconductivity", Phys. Rev. **B46**, 317 (1992). (C1)

15. Peter Horsch and Walter Stephan, "One- and Two-Particle Excitations in Doped Mott-Hubbard Insulators", in *Electronic Properties of High Temperature Superconductors*, Eds. H. Kuzmany, M. Mehring and J. Fink (Springer, Berlin, 1993). (C3)

16. Peter Horsch and Walter Stephan, "Moderately doped Antiferromagnets: Spectral Functions and Fermi Surface", in *Electronic Properties and Mechanisms of Superconductivity*, eds. T. Oguchi, K. Kadowaki and T. Sasaki (North–Holland, Amsterdam, 1992). (C3)

4.5 Publications of Permanent Members

P.G. Blunden

1. P.G. Blunden, M. Burkardt and G.A. Miller, 1999, Light-front nuclear physics: Toy models, static sources and tilted light-front coordinates, submitted to Phys. Rev. C, nucl-th/9908067. (C1)

2. 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)

3. P.G. Blunden, M. Burkardt and G.A. Miller, 1999, Rotational invariance in nuclear light-front mean field theory, Phys. Rev. C **59**, R2998 (1999). (C1)

4. I.W. Stewart and P.G. Blunden (1997), "Quantum solitons at strong coupling", Phys. Rev. D **55**, 3742. (C1)

5. P.G. Blunden and G.A. Miller (1996), "Quark-meson coupling model for finite nuclei", Phys. Rev. C**54**, 359. (C1)

6. P.G. Blunden and G.A. Miller (1996), "Quark-meson coupling model in finite nuclei", Oral presentation at PANIC96, Williamsburg, VA, May, 1996. To be published by World Scientific. (C3)

7. A.S. Raskin and P.G. Blunden (1994), Comment on "Collective Modes in Dense Neutrino Systems", Phys. Rev. D**50**, 7742. (C1)

8. J.P. Adams, P.G. Blunden, B. Castel and Y. Okuhara (1993), "Role of Nuclear Structure in the Spin-Isospin Nuclear Response Problem", Phys. Rev. **48**C, 1438. (C1)

9. P.G. Blunden (1993), "The Nuclear Current Operator: Where Do We Stand?", Workshop on Electron-Nucleus Scattering, Elba, Italy, eds. O. Benhar (World Scientific), in press. (C3)

10. K. Tsushima, D.O. Riska and P.G. Blunden (1992), "The Electromagnetic Exchange Current, the Nucleon-Nucleon Interaction, and Nuclear Magnetic Moments", Nucl. Phys. **A559**, 543. (C1)

11. P.G. Blunden and D.O. Riska (1992), "The Isoscalar Electromagnetic Current Operator and the Nucleon-Nucleon Interaction", Nucl. Phys. **A536**, 697. (C1)

M.E. Carrington

1. "Approach to Equilibrium in the Micromaser", D. Leary, S. Yau, M.E. Carrington, R. Kobes and G. Kunstatter (submitted to Phys. Rev. A). (C1)

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

3. Two-Loop Quantum Corrections of Scalar QED with Non-Minimal Chern-Simons Coupling", M. E. Carrington, W.F. Chen and G. Kunstatter (submitted to Phys. Rev. D). (C1)

4. *"Non-Equilibrium HTL Resummation"*, M.E. Carrington, Hou Defu, M.H. Thoma, refereed paper published electronically in the proceedings at the 5th International Workshop on 'Thermal Fields and their Applications,' August 10-14, 1998, Regensburg, Germany (C3)

5. *"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** (1999) 347-354. (C1)

6. *"Ward Identities in Non-Equilibrium QED,"* M.E. Carrington, Hou Defu and Markus Thoma, Phys. Rev. **D58** (1998) 6372 (C1)

7. *"The Effective Action For a Relativistic Jaynes-Cummings Model,"* M. Burgess, M.E. Carrington and G. Kunstatter, in print, Canadian Journal of Physics (1998). (C1)

8. M. Carrington and R. Kobes, 1998, "The general cancellation of ladder graphs at finite temperature", Phys. Rev. **D57**, 6372–6385. (C1)

9. M. Carrington, R. Kobes and E. Petitgirard, 1998, "Cancellation of ladder graphs in an effective expansion", Phys. Rev. **D57**, 2631–2634. (C1)

10. M.E. Carrington and U. Heinz (1996), "Three Point Functions at Finite Temperature", preprint hep-th/9606055, Z. Physik C, 1997, in press. (C1)

11. M.E. Carrington (1996), "The Bosonization of Theories with Pseudo-vector Interactions", Z. Physik C, **72**, 1531. (C1)

12. M. Burgess and M.E. Carrington (1995), "Boundaries and Junctions in=20 Two Parity Violating Models in 2+1 Dimensions", Phys. Rev. **B52**, 5052. (C1)

13. M.E. Carrington (1995), "The Meissner Effect in Scalar QED with Magnetic Moment Interactions", Phys. Rev. **D51**, 4451. (C1)

14. M.E. Carrington and G. Kunstatter (1995), "Maxwell-Chern-Simons Scalar QED with Magnetic Moment Interactions," Phys. Rev. **D51**, 1903. (C1)

15. M.E. Carrington and G. Kunstatter (1994), "Massless Scalar QED with Non-Minimal Chern-Simons Coupling", Phys. Rev. **D50**, 2830. (C1)

16. M.E. Carrington and G. Kunstatter (1994), "Phase Transitions in Massless Scalar QED with non-minimally coupled Chern-Simons Term", Phys. Lett. **B321**, 223. (C1)

17. M.E. Carrington (1993), "Self-Consistent Resummation Scheme in Scalar QED", Phys. Rev. **D48**, 3836. (C1)

18. M.E. Carrington and J.I. Kapusta (1993), "Dynamics of the Electroweak Phase Transition", Phys. Rev. D47, 5304. (C1)

19. M.E. Carrington (1993), "Ring Diagram Summations in the Finite Temperature Effective Potential", Can. J. Phys. 71, 227. (C1)

20. M.E. Carrington (1992), "The Effective Potential at Finite Temperature in the Standard Model", Phys. Rev. D45, 2933. (C1)

R.L. Kobes

1. P. Aurenche, F. Gelis, R. Kobes, and H. Zaraket, 1999, "Two loop Compton and annihilation processes in thermal QCD", Phys. Rev. D (to appear). (C1)

2. M. Carrington and R. Kobes, 1998, "The general cancellation of ladder graphs at finite temperature", Phys. Rev. **D57**, 6372–6385. (C1)

3. M. Carrington, R. Kobes and E. Petitgirard, 1998, "Cancellation of ladder graphs in an effective expansion", Phys. Rev. **D57**, 2631–2634. (C1)

4. P. Aurenche, F. Gelis, R. Kobes, and H. Zaraket, 1998, "Bremsstrahlung and photon production in thermal QCD", (to appear in Z. Phys. **C**). (C1)

5. P. Aurenche, F. Gelis, R. Kobes and E. Petitgirard (1997), "Breakdown of the hard thermal loop expansion near the light–cone", Z. Phys. **C75**, 315–332. (C1)

6. P. Aurenche, F. Gelis, R. Kobes and E. Petitgirard (1996), "Enhanced photon production rate on the light cone", Phys. Rev. D **54**, 5274–5279. (C1)

7. R. Kobes (1996), "Hard thermal loop resummation methods in hot gauge theories", in *Thermal Field Theories and Their Applications*, edited by Y.X. Gui, F.C. Khanna and Z.B. Su (World Scientific, Singapore). (C3)

8. R. Kobes (guest editor), (1996), *Memorial issue for Professor Umezawa*, Physics Essays **9**, no. 4. (B)

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5 Financial

5.1 Statement of Income and Expenditures

Income

Income Source	Amount
Carry over from Aug. 31, 1998	$5,989.97
Total Funds That Were Available	$5,989.97

Expenditures

Activity	Particulars	Amount Spent
Seminars		
	(1) W. Schadow, March, April 1999	$339.39
	(2) S. Fulling, July 1999	$1025.35
	Total Seminar Costs	$1,364.74
Miscellaneous	FAX, mail, printing, supplies	$294.63
	Total Expenditures (1998–1999)	$1,659.37
	Carryover, Sept. 1, 1999	4,330.60

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 $211,341 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 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 recent years, there has been a marked decrease in the funds made available to the Institute by the three Manitoba universities. The Institute has approached the appropriate university Departments of Private Funding with a view to financing part of its activities from the private sector. To date, nothing definitive has resulted.

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.

This past year, members of the Institute met with Dr. F. de Toro, newly appointed Dean of the Faculty of Graduate Studies, University of Manitoba. Dr. de Toro expressed strong support for the Institute, and offered to assist with financing, and related advice. He has in fact already contributed toward the expenses of one visitor, to be reported in next year's Report. However, the fact that we are unable to give a detailed budget of expenditures for a year in advance makes it impossible for him to make other than ad hoc commitments. This is a problem that might be addressed in the coming year by the Institute.