# The Winnipeg Institute for Theoretical Physics[1] Annual Report

September 2000 – August 2001

[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 eleventh 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 2000-2001 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 36 for 2000-2001. 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, 2000 to August 31, 2001. 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 P.D.Loly has acted as director of the institute. A new Director will be elected at a General Meeting of the Institute in October 2001.

One highlight of the past year saw former University of Manitoba undergraduate and WITP summer student Eldon Emberly, who published several papers with WITP's Loly and Vail, recently winning one of four national NSERC Distinguished Dissertation Awards for his Ph. D. Thesis at Simon Fraser University.

# 2 Current List of Members (September, 2001)

## 2.1 Permanent Members

- B. Bhakar[1], *Ph.D. (Delhi)* [Director, Jan - June 2000]
- P.G. Blunden[1], *Ph.D (Queen's)* [Director, 93-94]
- M.E. Carrington[3], *Ph.D. (SUNY, Stony Brook)*
- 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 2000 - October 2001]
- T.A. Osborn[1], *Ph.D. (Stanford)* [Director, 92-93]
- 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*

- Wang Zhoufei, Northeast Normal University, Changchun, PR China

*Postdoctoral Fellow*

- S. Bekhechi *(Southern)*
- W. Chen *(Carrington, Kobes)*
- Saurya Das *(Kunstatter)*
- Hou Defu *(Carrington, Kobes)*
- Weixing Qu, (Shanghai) *(Tabisz)*

## 2.3 Graduate Students

- Aleksandrs Alexsejevs (M.Sc.) *(Blunden)*
- Svetlana Barkanova (Ph.D.) *(Blunden)*
- Jason Bland (Ph.D.) *(Kunstatter)*
- J. Medved (Ph.D.) *(Kunstatter)* GRADUATED Dec. 2000
- T. Melde (Ph.D.) *(Svenne)* GRADUATED 2001
- Slaven Peles (Ph.D.) *(Kobes)* GRADUATED 2001
- Amra Peles (Ph.D.) *(Southern)*

## 2.4 Summer Undergraduate Research Students 2000-2001

- D. Irvine *(Carrington)*
- C. Palmer *(Carrington)*
- A.J. Penner *(Southern)*
- A. Yang *(Vail)*

# 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 interested in how the dialogue between Carl Gustave Jung and Wolfgang Pauli, 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 developed. One aspect which continued to crop up in writings by Jung and von Franz concerns the 3-by-3 magic square of sequential integers (all rows, columns and the main diagonals having the same sum) and resonated with aspects of theoretical physics. I can now report several outcomes of a study of magic squares which have interdisciplinary character: (i) An old idea for compounding magic squares is updated with modern computational methods in order to facilitate the generation of very large-order numerical matrices, which include magic squares. When the base and frame squares are different, a second compound square results from their interchange, while identical squares may be said to generate "fractal" squares, i.e. self-similar on different scales. In this way we have been able to break existing world records for the size of magic squares. (ii) We have also clarified that all magic squares have a special eigenvector whose elements are all ones. This lead us to analyse the 880 distinct $4 \times 4$'s in the 12 Dudeney groups, finding that members of the first 6 (singular) groups have three distinct eigenvalue patterns, with a subset of the first 3 groups having 3 zero eigenvalues, while the last 6 (non-singular) groups have two further eigenvalue patterns. (iii) Several classes of purely pandiagonal, i.e. non-magic, number squares having dimensions of the powers of 2 have also been discovered. These are related to the Gray code and square Karnaugh maps. If these are treated as matrices they possess two non-zero eigenvalues. (iv) A new invariance for magic squares is reported for the "moment of inertia" of these squares which depends only on the dimension of the square. This extends to results for the moment of inertia of large squares with distributions of random numbers or random mass density.

### 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

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 geometically 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 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 TRIUMF), 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 $\pi N$, $NN$ 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, is included.

The second line of inquiry is further to develop the complete coupled three-body to four-body theory of the $\pi NNN - NNN$ system, for which a definitive publication has now been published by Luciano Canton, a member of the collaboration: 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. Approximations and calculational techniques for the solution of these equations have been developed for a simplified, perhaps schematic, model. This could be useful in deriving methods for treating more realistic problems. Current work has indicated an interesting link between this theory and three-nucleon forces, which leads to new results in describing three-nucleon observables.

Finally, in a separate collaborationn with Drs. L. Canton, G. Pisent (Padova), K. Amos and P.J. Dortmans (Melbourne), 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 current: (1) computing optical properties of point defects in high-density luminescent crystals; (2) development of a localizing potential for point defect calculations in crystals; (3) a two- particle density functional formulation of many-body quantum 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 .

### 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 |
|---|---|---|---|
| July 14, 2000 | Richard Froese | UBC | Realizing Holonomic Constraints in Classical and Quantum Mechanics |
| August 31, 2000 | Mikhail Karasev | Moscow | Deformation of Algebras and the Quantization Idea |
| Nov. 8, 2000 | Luciano Canton | INFN, Padua | Three-Nucleon Reactions: Where is the Pion? |
| May 30, 2001 | P. Majumdar | IMS, India | Cosmological Optical Activity |
| October 24, 2001 | Raymond Laflamme | Waterloo | Quantum Information Processing and Linear Optics |

## 4.2 Visiting Scientists

| Dates | Visitor | Institution |
|---|---|---|
| Oct. 31 - Nov. 15, 2000 | Luciano Canton | INFN, Padua |

## 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

### 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, M. Burkardt and G.A. Miller, (2000), "Light-front nuclear physics: Toy models, static sources and tilted light-front coordinates", Phys. Rev. C **61**, 025206, nucl-th/9908067. (C1)
2. P.G. Blunden, M. Burkardt and G.A. Miller, (2000), Light-front nuclear physics: Mean field theory for finite nuclei, Phys. Rev. C **60**, 055211, 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)

**Invited Talk**

7. P.G. Blunden, "Nuclear Theory on the light front", Workshop on Relativistic Dynamics and Few-Hadron Systems, Trento, Italy (November, 2000). (E2)

### M.E. Carrington

1. Mark Burgess, M.E. Carrington and G. Kunstatter, "*Covariant approach to equilibration in effective field theories,*", hep-ph/0103188 to be published in Canadian Journal of Physics. (C1)
2. M.E. Carrington, Hou Defu, R. Kobes, "*Nonlinear Response from Transport Theory and Quantum Field Theory at Finite Temperature,*", Phys. Rev. **D64** 025001 (2001). (C1)
3. D.S. Irvine, M.E. Carrington, G. Kunstatter and D. Pickering, "*Spontaneous Symmetry Breaking for Scalar QED with Nonminimal Chern-Simons Coupling,*", Phys. Rev. **64** 045015 (2001). (C1)
4. M.E. Carrington, WF Chen and R. Kobes, "*Spontaneous Scale Symmetry Breaking in 2+1 Dimensional QED at Both Zero and Finite Temperature,*", Eur. Phys. J **C18**, 757 (2001). (C1)

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

6. M.E. Carrington, Hou Defu and R. Kobes, "*Shear Viscosity in $\phi^4$ Theory from an Extended Ladder Resummation,*", Phys. Rev. **D62**, 085013, (2 000). (C1)

7. Hou Defu, M.E. Carrington, R. Kobes and U. Heinz, "*Four-Point Spectral Functions and Ward Identities in Hot QED,*", Phys. Rev. **D61**, 085013 (20 00). (C1)

8. M.E. Carrington, R. Kobes and G. Kunstatter, "*A New Formulation of a 1+1 Dimensional Field Theory Constrained to a Box,* Phys. Rev. **D61**, 12500 8 (2000). (C1)

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

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

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

12. D. Leary, S. Yau, M.E. Carrington, R. Kobes and G. Kunstatter, 2001, "*Approach to Equilibrium in the Micromaser*", Canadian Journal of Physics, **79**, 783-799. (C1)

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

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

15. M.E. Carrington, Hou Defu, M.H. Thoma, *"Non-Equilibrium HTL Resummation"*, 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)

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

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

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

19. M.E. Carrington, "*The Bosonization of Theories with Pseudo-vector Interactions,*", Z. Phys. C. **72**, 531 (1996). (C1)

1. R. Kobes, J. Liu, and S. Peles, 2001, "Analysis of a parametrically driven pendulum", Phys. Rev. **E63**, 031111. (C1)

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

3. M. E. Carrington, Hou Defu, and R. Kobes, 2000, "Shear viscosity in $\phi^4$ theory from an extended ladder resummation", Phys. Rev. **D62**, 025010. (C1)

4. Hou Defu, M. E. Carrington, R. Kobes, and U. Heinz, 2000, "Four-point spectral functions and Ward identities in hot QED", Phys. Rev. **D61**, 085013. (C1)

5. D. Leary, S. Yau, M.E. Carrington, R. Kobes and G. Kunstatter, 2001, "*Approach to Equilibrium in the Micromaser*", Canadian Journal of Physics, **79**, 783-799. (C1)

6. M. Carrington, R. Kobes and G. Kunstatter, 2000, "A new formulation of a 1+1 dimensional field theory constrained to a box", Phys. Rev. **D61**, 125008. (C1)

7. P. Aurenche, F. Gelis, R. Kobes, and H. Zaraket, 1999, "Two loop Compton and annihilation processes in thermal QCD", Phys. Rev. **D60**, 76002. (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. P. Aurenche, F. Gelis, R. Kobes, and H. Zaraket, 1999, "Bremsstrahlung and photon production in thermal QCD", Z. Phys. **C60**,. (C1)

11. P. Aurenche, F. Gelis, R. Kobes and E. Petitgirard (1998), "Breakdown of the hard thermal loop expansion near the light–cone", Phys. Rev. **B58**, 85003. (C1)

12. 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)

13. 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)

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

### Refereed conference proceedings

1. R. Kobes, 2000, "Calculating the viscosity (the hard way)", in *BNL Summer Study on QCD at Nonzero Temperature and Density*, edited by H. de Vega, D. Boyanovsky, and R. Pisarski, (BNL publication, 2000). (C3)

2. R. Kobes, 1998, "Beyond the hard thermal loop approxiamtion in thermal QCD", workshop on thermal fields in and out of equilibrium (Brookhaven, 1998). (C3)

3. 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, 1996). (C3)

### Conference proceedings edited

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

### G. Kunstatter

1. M. Burgess, M.E. Carrington and G. Kunstatter, "Covariant approach to equilibration in effective field theories", to appear in Can. J. Phys. (C1)

2. E. Vaz, M.E. Carrington, R. Kobes and G. Kunstatter, "Equilibration in an Interacting Field Theory", submitted to Phys. Rev. D. (C1)

3. A. Barvinksy, S. Das and G. Kunstatter, "Quantum Mechanics of Charged Black Holes", Physics Lett. B (to appear). (C1)

4. A. Barvinsky, S. Das and G. Kunstatter, "The Spectrum of Charged Black Holes–The Big Fix Mechanism Revisited", To appear in Class. and Qu. Grav.; gr-qc/0012066. (C1)

5. D.S. Irvine, M.E. Carrington, G. Kunstatter and D. Pickering, "Spontaneous Symmetry Breaking for Scalar QED with Non-minimal Chern-Simons Coupling", Phys. Rev. **D64** 045015, 2001. (C1)

6. A.J.M. Medved and G. Kunstatter, "One-Loop Corrected Thermodynamics of the Extremal and Non-Extremal BTZ Black Hole", Phys. Rev. **D63**, 104005 (2001); hep-th/0009050. (C1)

7. W. Chen and G. Kunstatter, "Constraint from the Lamb shift and anomalous magn etic moment on radiatively induced Lorentz and CPT violation effects in quantum elecrodynamics", Phys. Rev. **D62** (2000) 105029; hep-ph/0002294. (C1)

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# 5 Financial

## 5.1 Statement of Income and Expenditures

### Income

| Income Source | Amount |
|---|---|
| Carry over from Aug. 31, 2000 | $2024.04 |
| Faculty of Graduate Studies | $500.00 |
| Total Funds That Were Available | $2524.04 |

### Expenditures

| Activity | Particulars | Amount Spent |
|---|---|---|
| Seminars | | |
| | (1) Karasev visit | $1500.00 |
| | Total Expenditures (2000-2001) | $1500.00 |
| | Carryover, Sept. 1, 2001 | $1024.00 |

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 $264,739 (1999-2000: $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. There are no significant space requirements. The occasional long term visitor requires a desk and computer access, 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.

Finally, Howard Burton, Executive Director of the Perimeter Institute for Theoretical Physics, a Waterloo-based endowed, autonomous research institution dedicated to exploring foundational issues in contemporary theoretical physics, has approached Joanne Keselman, Vice President Research, at the University of Manitoba, to elicit interest in signing a Memorandum of Understanding for cooperation in theoretical physics. We have indicated that WITP is interested in proceeding in that direction, and it will fall to the incoming director of WITP to follow up on this initiative.