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

September 1995 – August 1996

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

# Contents

# 1 Director's Narrative Report

The Winnipeg Institute of 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, by financially supporting expert seminars in the research areas of concern, and by financially supporting the long term visits of internationally respected scientists to the Institute so as to facilitate collaboration of these scientists with Institute members. The 12 permanent members of this Institute are drawn from the University of Manitoba, the University of Winnipeg, and Brandon University.

The past year (1995-1996) was the sixth year of the Institute's existence. It saw a continuation of the activities of previous years with research seminars being given by 11 short term out-of-province visitors. Other researchers connected with and taking part in the Institute activities were the following: one research associate, three postdoctoral fellows, and six graduate students.

For the 1995-1996 academic year the list of invited speakers is found in section 4.1 of the report. Visiting scientists, whose stay lasted longer than one week, are listed in section 4.2. The list of graduate degrees awarded appears in section 4.3, and the published research work of members, associate members and graduate students is found in sections 4.4 and 4.5. The total number of publications by full members listed in section 4.5 is 38 in 1995-6 and a total of 154 in 1990-96. 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, 1995 to September 30, 1996.

Plans for the forthcoming year continue our established programs. As in previous years, the seminar program of invited guest speakers aims to bring to Winnipeg about a dozen new visiting physicists. During the coming year, members of the Institute will begin planning for a proposed Workshop on Innovative Approaches to Curricula in Theoretical Physics, likely to be held in 1999.

Essentially all the funds available to the Institute are expended for the workshop and symposium activities and for the travel funds needed to support visiting scientists. The Institute has no technical support staff or administrative staff. All the required administrative work is done on a volunteer basis by the members of the Institute. The Institute benefits substantially from the financial supplements of members using their individual NSERC Research Grants to defray part of the costs of visitors.

The Institute director for the past academic year has been J.P. Svenne (University of Manitoba), who prepared this report. Other members of the Institute executive were the past director, D.W. Vincent (University of Winnipeg), and the incoming director, J.G. Williams (Brandon University). J.G. Williams begins his term in October 1996. The executive for the 1996-1997 year consists of J.G. Williams, J.P. Svenne and R.L. Kobes (University of Winnipeg), who has agreed to be the director in 1997-1998.

# 2 Current List of Members (September, 1996)

## 2.1 Permanent Members

- B. Bhakar[1], *Ph.D. (Delhi)*
- P.G. Blunden[1] , *Ph.D (Queen's)*
- M.E. Carrington[2], *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

- J.I. Johansson *(Research Associate)*
- E. Petitgirard *(Postdoctoral Fellow)*
- C. Soo *(Postdoctoral Fellow)*
- Huang-Jian Xu *(Postdoctoral Fellow)*

## 2.3 Graduate Students

- J. Chen (M.Sc.), *(Kobes)*
- Yu.V. Gusev (Ph.D., 1996), *(Osborn)*
- J. Martinez-Cuellar (M.Sc.), *(Southern)*
- T. Melde (Ph.D.), *(Svenne)*
- Slaven Peles, *(Kobes)*
- Iain Stewart (M.Sc., 1996), *(Blunden)*

## 2.4 Summer Undergraduate Research Students

- M. Bromirski, May–August, 1996
- E. Emberly, May–August, 1996
- A. Jofre, May–August 1996
- R. Petryk, July–August, 1996
- R. Petryk (Career Focus), May–August, 1995
- M. Potter, May–August 1996
- S. Shelemy, July–August, 1996

# 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 of the topics under current investigation include: Dirac-Hartree-Fock calculations for the properties of finite nuclei; hadronic and electromagnetic reactions; a relativistic treatment of mesonic currents; and exact and approximate treatments of the negative energy Dirac sea in finite nuclei.

## 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 interested in a study of properties of high temperature gauge theories such as the quark-gluon plasma, as well as a general investigation of calculational methods in finite temperature field theory.

## 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

Periodic Systems: I now operate two major themes, one with a nearly-free-electron flavour, and the other concerned with excitations in magnets which has more of a tight-binding flavour.

Quantum Well Spectra: Very recently, postdoctoral fellow 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 will use analogues of the Kronig-Penney potential to study bandstructures of mesoscopic ultrasmall quantum box structures now etched routinely in AlGaAs in semiconductor heterostructures which caught our interest as an application of our multi-dimension nearly-free-electron code.

### 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) focuses on pion absorption on very light nuclei. The pion plays an important role in the understanding of the nucleon-nucleon interaction and in nuclear reactions and structure. As the lightest meson, it is responsible, in the boson–exchange model of the NN interaction, for the longest–range part of the interaction. In addition, it is considered to be the particle, resonating with a nucleon, which gives rise to the lowest-energy and strongest isobar resonance of the nucleon, the $\Delta$ resonance. Thus, any treatment of $\pi d$ reactions and related inelasticities require (at least) the simultaneous description of the $\pi$NN–$\Delta$N–NN dynamics. These same processes dominate pion reactions and absorption on other light nuclei, such as $^3$He.

Work is in progress on pion absorption on $^3$H and $^3$H, with two–cluster final states. Three–nucleon final states will be included in the future. 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 and Reitan is being re-examined. It turns out that, despite the vintage (1966) of this mechanism, there are questions relating to it that are not well understood.

Work is also continuing on the complete coupled three–body to four–body theory of the $\pi NNN - NNN$ system, which has been developed 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 developing methods for treating more realistic problems.

## 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 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 optical and spin resonance properties of color centers and impurities, derivation of effective interatomic forces, hole trapping by impurities in oxides, and quantum diffusion.

Four projects are currently in progress: (1) simulation of complicated laser–active impurity F-type centers, such as $(F_2^+)^*$ in NaF:Mg; (2) overlap effects from the embedding region in the simulation of defects by small clusters (collaboration at Virginia Commonwealth University);

(3) simulation of optical properties of high density luminescent materials: (a) the optical excitation of oxygen in $BaF_2$ ; (b) electronic structure and optical properties of $PbWO_4$ (collaboration at Michigan Technological University).

### 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 uses techniques of differential geometry and algebraic topology to study general relativistic metrics that represent homotopically nontrivial light cone configurations on spacetime manifolds that can be either simply or multiply connected. Progress to date includes the discovery of a number of perfect fluid solutions to the classical Einstein equations representing such twists in the light cone field. Work in (2+1) dimensions has demonstrated the existence of similar interesting solutions for the Einstein-Maxwell equations for a fluid with rotation and electric charge. For (2+1)-dimensional relativity, the manifold that forms the range of mapping for the light cone field has no natural group structure and is merely a set. Because of this, the homotopy analysis of the metric tensor bundle is considerably more complicated than in the usual (3+1)-dimensional case, and new kinds of topological invariants have been shown to arise. Future effort will be directed towards studying the quantization of scalar fields in these kinds of non-globally hyperbolic spacetimes.

# 4 Research Activities

## 4.1 Seminars

| Date | Speaker | Institution | Title |
|---|---|---|---|
| Sept. 27, 1996 | Dr. John Madore | L.P.T.H.E.<br>University of Paris South | Quantum Space-Time<br>and Classical Gravity |
| Sept. 13, 1996 | Dr. Mark Burgess | Oslo College and<br>Inst. of Phys.,<br>Univ. of Oslo | Squeezed States and<br>Non-Equilibrium Field Theory |
| Sept. 5, 1996 | Dr. Mikhail Karasev | MIEM, Moscow | Formulae for Quantum<br>Evolution via Geometric<br>Membrane Amplitudes |
| Aug. 1. 1996 | Dr. Ian Lawrie | University of Leeds | The Case of the<br>Cheshire Clock |
| June 11, 1996 | Dr. Terry Goldman | Los Alamos NL | Neutrino Clouds |
| May 21, 1996 | Dr. E. Petitgirard | University of Winnipeg | Resummation Scheme<br>in Hot Gauge Theories<br>and the Soft Photon<br>Production Rate |
| Jan. 26, 1996 | Dr. Andrei Barvinsky | Lebedev Physical Inst. | Quantum Cosmology of<br>the Early Inflationary<br>Universe |
| Dec. 14, 1995 | Dr. Walter Stephan | Università di Roma<br>MPI für Physik complex<br>Syst. Stuttgart | A New Perspective on the<br>Lattice Polaron Problem |
| Dec. 12, 1995 | Dr. Richard Epp | UC Davis | The Phase Space of General<br>Relativity in the<br>(2+2) Formalism |
| Nov. 22, 1995 | Dr. David Salopek | University of Alberta | The Nature of Cosmic Time |
| Oct. 18. 1995 | Dr. T. Strobl | Inst. Theor. Phys.<br>Aachen | Informal seminar at UW |
| Sept. 14, 1995 | Dr. Mikhail Karasev | MIEM, Moscow | Membrane Quantization<br>and the Semiclassical<br>Approximation |
| Sept. 12, 1995 | Dr. Tim Evans | Imperial College | Galactic Magnetic Fields<br>from Quantum Field<br>Fluctuations |

## 4.2 Visiting Scientists

| Dates | Visitor | Institution |
|---|---|---|
| Oct., 1995 | T. Strobl | Inst. Theor. Phys. Aachen |
| Nov. 1995 | E. Woolgar | U. of Saskatchewan |
| Dec. 1995 | R. Epp | U. of California |
| Jan. 1- March 28, 1996 | A. Barvinsky | Lebedev Inst. |
| July 22- Aug. 7, 1996 | I. Lawrie | U. of Leeds |
| July, Aug., 1996 | R. Epp | U. of California |
| July 9 – Sept. 9, 1996 | M. Karasev | MIEM, Moscow |
| Sept. 6 - Sept. 23, 1996 | M. Burgess | Oslo College |

## 4.3 Graduate Degrees Supervised

1. J. Chen, University of Manitoba M. Sc., October, 1994 *(R. Kobes).* "Proximity effect and the thermodynamic properties of superlattice systems."
2. Sandra Cyr, M.Sc., Oct. 1994 *(B.W. Southern).* "Multi-Magnon Excitations in One-Dimensional Quantum Spin Chains with NNN Interactions."
3. R. Epp, University of Manitoba Ph.D., Sept. 1993 *(G. Kunstatter).* "Curved Space Quantization, and Dirac *vs.* Reduced Quantization of Poincare Invariant Gauge Theories."
4. Y. Gusev, Ph.D., Oct. 1996 *(T.A. Osborn).* "Covariant Computations of Heat Kernels in Perturbation Theory."
5. Ning Li, University of Manitoba M.Sc., Feb. 1995 *(C.H. Woo).*
6. Domingo Louis-Martinez, University of Manitoba Ph.D Oct. 1994 *(G. Kunstatter).* "Dirac's Constrained Systems: Two Dimensional Gravity and Spinning Relativistic Particle."
7. 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."
8. K. Mak, University of Manitoba Ph. D., September, 1993, *(R. Kobes, G. Kunstatter).* "Damping rates and hot gauge theories."
9. Iain Stewart, M.Sc., March, 1996 *(P.G. Blunden).* "Derivative Expansion Approximation of Vacuum Polarization Effects."
10. J. Wang, University of Manitoba M. Sc., September, 1992 *(R. Kobes).* "Finite layers effect in metallic superlattices."

## 4.4 Publications of Associate Members/Graduate Students

### Yu.V. Gusev

1. A.O. Barvinsky, T.A. Osborn, and Yu.V. Gusev (1995), "A phase-space technique for the perturbation expansion of Schrödinger propagators", J. Math. Phys., **36** 300-61 (1995). (C1)
2. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V.V. Zhytnikov (1995), "Asymptotic behaviors of 1-loop vertices in the gravitational effective action", Class. Quantum Grav. **12**, 2157-2172 (1995). (C1)
3. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V. V. Zhytnikov (1995), "The one-loop effective action and trace anomaly in four dimensions", Nucl. Phys. B. **439**, 561-582 (1995). (C1)

4. A.O. Barvinsky and Yu.V. Gusev (1995), "Heat kernel and one-loop radiation currents by the generating function method", *in* Proceedings of the Heat Kernel Techniques and Quantum Gravity conference, Winnipeg, Canada, August 1994, ***Discourses in Mathematics and its Applications, No. 4*** (Texas A&M University Press: College Station, Texas, 1995), S. Fulling, ed. pp. 189-202. (C3)

5. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V. V. Zhytnikov (1995), "Covariant curvature expansion and trace anomaly in four dimensions", *ibid* pp. 163-188. (C3)

6. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V.V. Zhytnikov (1994), "The basis of nonlocal curvature invariants in quantum gravity theory. (Third order)", J. Math. Phys. **35**, 3525-3542 (1994). (C1)

7. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V.V. Zhytnikov (1994), "Asymptotic behaviors of the heat kernel in covariant perturbation theory", J. Math. Phys. **35**, 3543-3559 (1994). (C1)

8. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V.V. Zhytnikov (1994), "Covariant nonlocal effective action", *in* Proceedings of the fifth Canadian conference on general relativity and relativistic astrophysics, Waterloo, Canada, May 1993 (World Scientific: Singapore, 1994), eds. R. B. Mann and R. G. McLenaghan, p. 147-152. (C3)

9. A.O. Barvinsky, Yu.V. Gusev, G.A. Vilkovisky, and V.V. Zhytnikov (1993), "Covariant perturbation theory (IV). Third order in the curvature", report of the University of Manitoba, 192 pp. (University of Manitoba, Winnipeg, 1993). (C)

**J. I. Johansson,**

1. M. Hedayati-Poor, J.I. Johansson and H.S. Sherif (1995), "Relativistic Calculations for Photonuclear Reactions (II): Nonrelativistic Reductions and Nuclear Medium Effects", Nuc. Phys. **A593**, 377-398 (1995). (C1)
   e-print archive: nucl-th/9507021.

2. J.I. Johansson, H.S. Sherif and G.M. Lotz (1996), "Relativistic Calculations for Photonuclear Reactions (III): A Consistent Relativistic Analysis of $(e, e'p)$ and $(\gamma, p)$ Reactions", Nuc. Phys. **A605**, 517-530 (1996). (C1)
   e-print archive: nucl-th/9603026.

3. J.I. Johansson, H.S. Sherif and G.M. Lotz (1996), "Relativistic Analysis of $(e, e'p)$ and $(\gamma, p)$ Reactions in a Consistent Model", Fourteenth Particle and Nuclei International Conference (PANIC96) Williamsburg, Virgina, USA, May 22-28, 1996. Poster presented by G.M. Lotz. (C3)

4. J.I. Johansson and H.S. Sherif (1996), "Spin Observables in Consistent Relativistic Models of $(e, e'p)$ and $(\gamma, p)$ Reactions", $12^{th}$ International Symposium on High-Energy Spin Physics (SPIN96), Amsterdam, The Netherlands, September 10-14, 1996, to be published by World Scientific. Presented by J.I. Johansson. (C3)

T. Melde

1. M. Hawton and T. Melde (1995), "Photon number density operator $i\hat{E}\cdot\hat{A}$", Phys. Rev. A51, 4186-4190 (1995)

E. Petitgirard

1. P. Aurenche, F. Gelis, R. Kobes and E. Petitgirard (1996), "Breakdown of the hard thermal loop expansion near the light-cone", submitted to Z. Phys. C. (C1)
2. P. Aurenche, F. Gelis, R. Kobes and E. Petitgirard (1996), "Enhanced photon production rate on the light-cone", Phys. Rev. D (in press). (C1)
3. E. Petitgirard (1995), "Soft photon production in quark-gluon plasma", in *The Proceedings of the Workshop on Quantum Infrared Physics*, eds. H.M. Fried and B. Muller (World Scientific, Singapore), 519-524. (C3)
4. T. Altherr, E. Petitgirard and T. del Rio Gaztelurrutia (1994), "Axion emission from red giants and white dwarfs", Astropart. Phys. 2, 175. (C1)
5. T. Altherr, E. Petitgirard and T. del Rio Gaztelurrutia (1993), "Photon propagation in dense media", Astropart. Phys. 1, 289. (C1)
6. P. Aurenche, T. Becherrawy and E. Petitgirard (1993), "Retarded/ advanced correlation functions and soft photon production in the hard loop approximation", preprint ENSLAPP-A-452-93 (hep-ph/9403320).
7. P. Aurenche, E. Petitgirard and T. del Rio Gaztelurrutia (1992), "On the three-point function in finite temperature field theory", Phys. Lett. **B297**, 337. (C1)
8. T. Altherr, E. Petitgirard and T. del Rio Gaztelurrutia (1993), "Damping rate of a moving fermion", Phys. Rev. **D47**, 703. (C1)
9. E. Petitgirard (1992), "Massive fermion dispersion relation at finite temperature", Z. Phys. **C54**, 673. (C1)

C. Soo

1. C. Soo and L.N. Chang (1996), "Invariant Regularization of Anomaly–Free Chiral Theories", VPI-IPPAP-96-3, hep-th/9606174, submitted to Phys. Rev. D. (C1)
2. C. Soo and L.N. Chang (1996), "Invariant Regularization of Local Lorentz Invariance and Neutrino Masses", VPI-IPPAP-96-5. *Proceedings of the 28th. International Conference on High Energy Physics*, Warsaw, Poland, 1996. (in press) (C3)
3. C. Soo and L.N. Chang (1996), "Chiral Fermions, Gravity, and GUTs", CGPG-94/9-3, *Proceedings of the 4th Drexel Symposium 1994*, (in press). (C3)

4. C. Soo and L.N. Chang (1996), "The Standard Model with Gravity Couplings", Phys. Rev. **D53**, 5682 (1996). (C1)
5. C. Soo (1995), "Self–Dual Variables, Positive Semidefinite Action, and Discrete Transformations in Four–Dimensional Quantum Gravity", Phys. Rev. **D52**, 3484 (1995). (C1)
6. C. Soo and Lee Smolin (1955), "The Chern–Simons Invariant as the Natural Time Variable for Classical and Quantum Cosmology", Nucl. Phys. **B449**, 289 (1995), (C1).
7. C. Soo and L.N. Chang (1994), "Superspace Dynamics and Perturbations around 'Emptiness' " Int. J. Mod. Phys. **D3**, 529 (1994), (C1).
8. C. Soo and L.N. Chang (1994), "Einstein Manifolds and SO(3) Instantons: Invariants and Phases", VPI-IHEP-93-4, in *Proceedings of the 5th. Asia Pacific Physics Conference*. Kuala Lumpur. Malaysia (1992), eds. S. P. Chia et al (World Scientific, 1994), (C3).
9. C. Soo and L.N. Chang (1992), "BRST Cohomology and Invariants of Four–Dimensional Gravity in Ashtekar Variables", Phys. Rev. **D46**, 4257-4262 (1992), (C1)
10. C. Soo and L.N. Chang (1992), "BRST Invariants of 4D-Gravity in Ashtekar Variables", VPI-IHEP-92/8, in *Proceedings of the XXIst. International Conference on Differential Geometric Methods in Theoretical Physics*, Nankai, China (1992), (C3).
11. C. Soo and L.N. Chang (1991), "Ashtekar's Variables and the Topological Phase of Quantum Gravity", VPI-IHEP-91-2, in *Proceedings of the XXth. Differential Geometric Methods Conference*, New York, N.Y. (1991) eds. S. Catto and A. Rocha (World Scientific, 1991), (C3).

## H-J. Xu

1. H-J. Xu and B.W. Southern (1996) "Phase Transitions in the 2D XY Antiferromagnet on the Triangular Lattice", J. Phys. A:Math. Gen. **29** L133-L139. (C1)
2. B.W. Southern and H-J. Xu (1995) "Monte Carlo Study of the Heisenberg Antiferromagnet on the Triangular Lattice", Phys. Rev. **B52**, R3836-R3839. (C1)
3. B. Bergersen , Z. Racz and H-J. Xu (1995) "Correlations in Ising Chains with Non-integrable Interactions" , Phys. Rev. **E52**, 6031-6036. (C1)
4. H-J. Xu and L. Knopoff (1994) "Periodicity and Chaos in a One-dimensional Model of Earthquakes", Phys. Rev. **E50**, 3577-3581. (C1)
5. R. Bhagavatula ,K. Chen , C. Jayaprakash and H-J. Xu (1994) "Green's Function Method for Random Fuse Network Problems" , Phys. Rev. **E49**, 5001-5006. (C1)

6. H-J. Xu , B. Bergersen and K. Chen (1993) "A Plaquet Representation of Ruptures and Models for Earthquakes", J. de Physique 3, 2029-2040. (C1)

7. H-J. Xu , B. Bergersen and Z. Racz (1993) "Long-Range Interactions Generated by Random Levy Flights - Spin-Flip and Spin-Exchange Kinetic Ising Model in 2 Dimensions" Phys. Rev. **E47**, 1520-1524. (C1)

8. H-J. Xu , B. Bergersen and K. Chen (1992) "Self-Organized Ruptures in an Elastic Medium - A Possible Model for Earthquakes" J. Phys. A: Math. Gen. **25**, L1251-L1256. (C1)

9. H-J. Xu , B. Bergersen and Z. Racz (1992) "Monte-Carlo Simulations on Ising Dipoles - Finite Size Scaling and Logarithmic Corrections" J. Phys. Condensed Matter **4**, 2035-2042. (C1)

10. H-J. Xu , B. Bergersen and Z. Racz (1991) "Ordering of Ising Dipoles" J. Phys. Condensed Matter 3, 4999-5012. (C1)

## 4.5 Publications of Permanent Members

### P.G. Blunden

1. Peter G. Blunden and Gerald A. Miller (1996), "Quark-meson coupling model for finite nuclei", Phys. Rev. C54, 359 (1996). (C1)

2. Peter G. Blunden and Gerald 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)

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# 5 Financial

## 5.1 Statement of Income and Expenditures

### Income

| Income Source | Amount |
|---|---|
| **University of Manitoba** | |
| Carry over from Aug. 31, 1995 | $11,258.59 |
| Faculty of Science | $3,000 |
| **Brandon University** | |
| Vice President | $300.00 |
| Faculty of Science | $200.00 |
| **University of Winnipeg** | |
| Vice President (Academic) | $2,000 |
| **Total Funds That Were Available** | $16,758.59 |

### Expenditures

| Activity | Particulars | Amount Spent |
|---|---|---|
| Seminars | | |
| | (1) Mikhail Karasev, Sept. 14, 1995 | $1,207.52 |
| | (2) David Salopek, Nov. 22, 1995 | $644.12 |
| | (3) Richard Epp, Dec. 12, 1995 | $190.33 |
| | (4) Andrei Barvinsky, Jan. 26, 1996 | $1,000.00 |
| | (5) Terry Goldman, June 11, 1996 | $80.00 |
| | (6) Ian Lawrie, Aug. 1, 1996 | $923.40 |
| | (7) Mikhail Karasev, Sept. 5, 1996 | $999.20 |
| | (8) John Madore, Sept. 27, 1996 | $198.36 |
| | Total Seminar Costs | $5,242.93 |
| Miscellaneous | FAX, mail, printing, supplies | $6.86 |
| | **Total Expenditures (1995-1996)** | $5,249.79 |

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 $204,900 of individual NSERC Research Grants. In addition, members of the Institute receive research support from other sources, notably NATO, and other external and internal sources, for an additional total of

$27,600. These funds have a significant fortifying effect on the level of activities in which we are able to engage.

The Institute had no endowment and/or 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, Growth, etc.

The Institute has no substantial fixed costs and for this reason it is an intrinsically stable entity. 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 Faculty of Science at the University of Manitoba are fortified by the individual NSERC research grants of members. This shows 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 only upon the associate members (i.e. graduate students, postdoctoral fellows, research associates, etc.) that it can attract. The number and quality of these associate members is entirely dependent on the positive research atmosphere that we can create. This in turn depends highly upon the level of funding that the Institute receives.

The report guidelines suggest that we indicate the percentage of time the 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.