WINNIPEG INSTITUTE

FOR

THEORETICAL PHYSICS

ANNUAL REPORT

September 1996 – August 1997

The Winnipeg Institute for Theoretical Physics[1] Annual Report

September 1996 – August 1997

[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, 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 (1996–1997) was the seventh year of the Institute's existence. It saw a continuation of the activities of previous years with research seminars being given by seven out-of-province visitors. Other researchers connected with and taking part in the Institute activities were the following: one research associate, five postdoctoral fellows, and eight graduate students.

For the 1996–1997 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 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 33 for 1996-7 and totals 170 for 1990-97. 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, 1996 to September 30, 1997. For the forthcoming year, the Institute intends to continue with its established programs. As in previous years, the seminar program of invited guest speakers aims to bring to Winnipeg a number of visiting physicists.

Essentially all of the funds available to the Institute are expended for the workshop and symposium activities and for the travel expenses 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.G. Williams (Brandon University), who prepared this report. Other members of the Executive were the past director, J.P. Svenne (University of Manitoba), and the incoming director, R.L. Kobes (University of Winnipeg). R.L. Kobes begins his term on October 1, 1997. The Executive for the upcoming 1997–1998 year will consist of R.L. Kobes, J.G. Williams and a member yet to be chosen, who will become director in October 1998.

2 Current List of Members (September, 1997)

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

- S. Burnett *(Postdoctoral Fellow)*
- J.I. Johansson *(Research Associate)*
- M.F. Kondrat'eva *(Postdoctoral Fellow)*
- 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., 1997), *(Southern)*
- B. McQuarrie (Ph.D.), *(Osborn and Tabisz)*
- T. Melde (Ph.D.), *(Svenne)*
- Slaven Peles (M.Sc.), *(Kobes)*
- Iain Stewart (M.Sc., 1996), *(Blunden)*
- Zhinong Weng (M.Sc.), *(Vail)*

2.4 Summer Undergraduate Research Students

- M. Bromirski, *(Vail)*, May–August, 1997
- H. Dobrovolny, *(Kobes)*, May–August, 1997
- E. Emberly, *(Vail)*, May–August, 1997
- T. Gawlick, *(Kunstatter)*, May–August, 1997
- D. Leary, *(Carrington)*, May–August, 1997
- T. Ross, *(Southern)*, May–July, 1997
- S. Yau, *(Kunstatter)*, May–August, 1997

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

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), and P.J. Dortmans at Melbourne University, 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 Δ resonance. Thus, any treatment of πd reactions and related inelasticities require (at least) the simultaneous description of the πNN–ΔN–NN dynamics. These same processes dominate pion reactions and absorption on other light nuclei, such as ^{3}He.

The work on pion absorption is proceeding along two lines: One is 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 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 developing methods for treating more realistic problems.

Finally, in a separate collaboration 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 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 in this area are currently in progress: (1) simulation of complicated laser–active impurity F-type centers, such as $(F_2^+)^*$ in NaF:Mg; (2) overlap and localization 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).

A collaborative project has just begun in a new area, to simulate braze-bonding and related processes for Ti and TiAl by molecular dynamics based on many-body potentials. The collaboration includes Bristol Aerospace Ltd., Mechanical and Industrial Engineering at Manitoba, and Physics at the University of Montreal.

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
Sept. 13, 1996	Dr. Mark Burgess	Oslo College and Institute of Physics, University of Oslo	Squeezed states and non-equilibrium field theory
Nov. 29, 1996	Dr. Jolanta Lagowski	Physics Dept. Memorial University	Investigation of geometrical and electronic structures of polymers – a computational approach
Dec. 13, 1996	Dr. B.P. Zapol	Dept. of Theoretical Physics, University of Latvia	Electron correlation and pseudopotentials
April 10 , 1997	Dr. A.V. Smilga	TPI, Univ. of Minnesota and ITEP, Moscow	Quark condensate in magnetic field
April 11, 1997	Dr. A.V. Smilga	TPI, Univ. of Minnesota and ITEP, Moscow	Physics of thermal QCD
April 14, 1997	Dr. J. Gegenberg	Univ. of New Brunswick	Solitons and black holes
June 17, 1997	Dr. David Lavis	King's College, University of London	Subjective probabilities and statistical mechanics
June 19, 1997	Dr. E. Shidlovskaya	Inst. of Chemical Physics University of Latvia	Simulation of point defects in insulators: embedded clusters based on non-orthogonal functions

4.2 Visiting Scientists

Dates	Visitor	Institution
Aug–Sept, 1997	M.V. Karasev	MIEM, Moscow
Sept. 6 – Sept. 23, 1996	M. Burgess	Oslo College
Dec., 1996	B.P. Zapol	U. of Latvia
April, 1997	A.V. Smilga	U. of Minnesota & ITEP, Moscow
April, 1997	J. Gegenberg	U. of New Brunswick
April–June, 1997	D.A. Lavis	King's College, London
June, 1997	E. Shidlovskaya	U. of Latvia

4.3 Graduate Degrees Supervised

1. J.L. Martinez-Cuellar, M.Sc., July 1997 *(B.W. Southern)*. "Three Magnon Excitations in Alternating Quantum Spin/Bond Chains."

2. Yu.V. Gusev, Ph.D., October 1996 *(T.A. Osborn)*. "Covariant Computation of Heat Kernels in Perturbation Theory."

3. Iain Stewart, M.Sc., March 1996 *(P.G. Blunden)*. "Derivative Expansion Approximation of Vacuum Polarization Effects."

4. Ning Li, University of Manitoba M.Sc., February 1995 *(C.H. Woo)*.

5. J. Chen, University of Manitoba, M.Sc., October 1994 *(R. Kobes)*. "Proximity Effect and the Thermodynamic Properties of Superlattice Systems."

6. Sandra Cyr, M.Sc., October 1994 *(B.W. Southern)*. "Multi-Magnon Excitations in One-Dimensional Quantum Spin Chains with NNN Interactions."

7. R. Epp, University of Manitoba Ph.D., September 1993 *(G. Kunstatter)*. "Curved Space Quantization, and Dirac *vs.* Reduced Quantization of Poincare Invariant Gauge Theories."

8. Domingo Louis-Martinez, University of Manitoba Ph.D October 1994 *(G. Kunstatter)*. "Dirac's Constrained Systems: Two Dimensional Gravity and Spinning Relativistic Particle."

9. K. Mak, University of Manitoba Ph.D., September 1993 *(R. Kobes, G. Kunstatter)*. "Damping rates and hot gauge theories."

10. 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."

11. 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

S.S.C. Burnett

1. S.S.C. Burnett (1997),"Additive renormalization of the specific heat of $O(n)$ symmetric systems in three loop order", submitted. (C1)

2. S.S.C. Burnett, M. Strösser and V. Dohm (1997), "Minimal renormalization without ϵ-expansion: Amplitude functions for $O(n)$ symmetric systems in three dimensions below T_C", Nucl. Phys., in press. (C1)

3. S.S.C. Burnett, M. Strösser and V. Dohm (1996), "Superfluid density of ^{4}He near T_λ in two-loop order", Czech. J. Phys. **46** (S1), 169. (C1)

4. S.S.C. Burnett and S. Gartenhaus (1994), "Phenomenology, specific heat and corrections to scaling in copper ammonium bromide", Phys. Rev. B **49**, 1137. (C1)

5. S.S.C. Burnett and S. Gartenhaus (1993), "Zero-field susceptibility of the antiferromagnetic square Ising lattice", Phys. Rev. B **47**, 7944. (C1)

6. S.S.C. Burnett and S. Gartenhaus (1991), "Phenomenology and corrections to scaling in Heisenberg ferromagnets", Phys. Rev. B **43**, 591. (C1)

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. (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. (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. (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. (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. (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. (G)

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. (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 (γ,p) Reactions", Nuc. Phys. **A605**, 517-530. (C1)
e-print archive: nucl-th/9603026.

3. J.I. Johansson, H.S. Sherif and G.M. Lotz (1996),=20 "Relativistic Analysis of $(e,e'p)$ and (γ,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 (γ,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. (C1)

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 (1997), "The Weyl theory of fundamental interactions: Is CPT violated?", hep-th/9702171, Nucl. Phys. B, submitted. (C1)

2. F.L. Lin and C. Soo (1997), "Quantum field theory with and without conical singularities: black holes with cosmological constant and the multihorizon scenario", gr-qc/9708049, Phys. Rev. D, submitted. (C1)

3. C. Soo and L.N. Chang (1996), "Invariant Regularization of Anomaly–Free Chiral Theories", Phys. Rev. D **55**, 2410. (C1)

4. 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)

5. 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)

6. C. Soo and L.N. Chang (1996), "The Standard Model with Gravity Couplings", Phys. Rev. **D53**, 5682. (C1)

7. C. Soo (1995), "Self–Dual Variables, Positive Semidefinite Action, and Discrete Transformations in Four–Dimensional Quantum Gravity", Phys. Rev. D**52**, 3484. (C1)

8. C. Soo and Lee Smolin (1995), "The Chern–Simons Invariant as the Natural Time Variable for Classical and Quantum Cosmology", Nucl. Phys. **B449**, 289. (C1).

9. C. Soo and L.N. Chang (1994), "Superspace Dynamics and Perturbations around 'Emptiness' " Int. J. Mod. Phys. **D3**, 529. (C1).

10. 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). (C3).

11. C. Soo and L.N. Chang (1992), "BRST Cohomology and Invariants of Four–Dimensional Gravity in Ashtekar Variables", Phys. Rev. D**46**, 4257-4262. (C1)

12. 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. (C3)

13. 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, Singapore). (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)

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