Report on activities of the Collaborative Research Group on String Theory

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The goal of the Collaborative Research Group on String Theory is to incubate significant new research on string theory.

Elementary particle physics seeks to discover the most fundamental constituents of nature and the laws which govern their behavior. Current understanding of fundamental physics is in terms of the standard model. This is a beautiful, enormously successful model which describes all known particles and gives a partially unified picture of their interactions. The dynamical framework of the standard model is quantum field theory.

One of the problems of current interest in fundamental physics is to explain the origin of the standard model, particularly the patterns of particles and interactions seen there and to resolve a subtle mathematical inconsistency, the hierarchy problem.

One approach to this is to search for a theory which lies beyond the standard model and encompasses it. It is hoped that such a theory would have a more unified picture of the origin of elementary particles and their interactions. The standard model itself could be regarded as the first successful step in finding such a theory in that it describes the current non-gravitational interactions as gauge field theories and contains a true unification of the electromagnetic interactions and the weak nuclear force. The hope is that identification of the correct unified theory would resolve some of the remaining puzzles of the standard model.

Another long-standing problem is to understand gravitational interactions in regimes where quantum mechanical effects would be important. The present model of gravity is Einstein's general theory of relativity which is a classical field theory. The problem of quantum gravity which asks how to reconcile general relativity with quantum theory has vexed theorists for over half of a century.

String theory is dynamical framework which could simultaneously address both of these problems. It is apparently a consistent theory of quantum gravity. It also has solutions with structures tantalizingly close to the standard model of elementary particle physics. Its promise and excitement have captured the attention of a large fraction of the world's community of theoretical particle physicists for the past twenty years.

Theoretical particle physics is well represented in Canada with many institutions having a long tradition for research in the subject. On the other hand, although it has been a major research area in the international arena for some time, string theory is a relatively new subject for Canada. Following recent faculty hiring initiatives, there are now groups of string theorists at the University of British Columbia, the University of Toronto and the Perimeter Institute, as well as a number of people with interests close to the subject in other institutions nationwide.

Part of the mandate of the Collaborative Research Group on String Theory is to nurture this nascent group of string theorists. It has the aim of seeding collaborative research both at a national and international level and in helping Canadian string theorists to exposit the results of their research to the international community. The Schools, Workshops and Conferences in particular serve these goals while raising the profile of Canadian groups in the international community.

Another essential goal of the program is to expose synergy between string and particle theory and other fields of physics, most notably cosmology and condensed matter physics. String theory, being a theory of quantum gravity has obvious applications to cosmology where it makes predictions about the initial state of the universe. In fact, understanding how string theory dynamics of the initial state might be printed on the present cosmos is now one of the best suggestions for detecting observable manifestations of strings. Theoretical condensed matter physics and string theory have a large number of common mathematical techniques, particularly in conformal field theory and the study of dissipative systems. This overlap has not been exploited to any great extent so far and it is a direction in where the program can make an important contribution.

The benefits of this program are many. As an attractive asset of the local environment, the infrastructure assembled by the Collaborative Research Group has been instrumental in recruiting and the excellent appointments of junior faculty made at the University of British Columbia over the past five years. In string theory, these are assistant professors Moshe Rozali and Joanna Karxzmarek and CRC chair Mark van Raamsdonk (who is also a Sloan Fellow). These researchers form the core of the UBC node of this group. The existence of the CRG also played a role in attracting Andreas Karch to the University of Washington. Andreas continues to be an enthusiastic participant in the programs.

The second great benefit of the Collaborative Research Group infrastructure has been the enhanced educational environment for graduate students and postdoctoral fellows that the activity generates. Both the UBC and University of Alberta group have produced outstanding Ph.D. graduates during the last few years. Also, the suc-

cess rate of postdoctoral fellows who have been involved in the program in finding faculty jobs is high.

Conferences, Workshops and Schools

The Collaborative Research Group on String Theory has organized a significant number of workshops, conferences and schools. The main aim of these events is the efficient dissemination of novel research results and the encouragement of collaborative research. A secondary purpose is to bring together the string theorists in the Canadian community, to encourage synergy between their research programs and to enhance their profile in the international community by sponsoring world class events. This activity has been made possible through the generous funding of PIMS, who supported it as a "Period of Concentration in String Theory" between the years 2003-2005. Since then, PIMS has continued to support this group through their contribution to the funding for the series of Summer Schools.

- Pacific Northwest String Seminar,
  - March 2001
  - March 2002, Vancouver
  - November 2003, Vancouver
  - December 2003, Seattle Washington
  - January 2005, Vancouver

  The Pacific Northwest String Seminar is a small meeting which has been held on either the campus of the University of British Columbia or the University of Washington. It is usually over a weekend, during the academic year. It consists of between 5 and 10 one-hour seminars, mostly by invited speakers, about recent developments in string theory. The prime purpose of these meetings is to update and inform the string theory researchers in the collaborative research group, particularly graduate students and postdoctoral Fellows working in the Vancouver and Seattle areas, about the latest results in the field. These events typically cost 5000 dollars and have been supported by PIMS with some help from other sources, such as the PITP.

- APCTP Winter School,
  - Pohang, Korea, December, 2001.
  - Peongchang, Korea, February, 2002
  - Seoul, Korea, February, 2005

  The APCTP Winter Schools have occurred during the past several years, typically for a week in mid-Winter in Korea. They are aimed at educating young researchers, graduate students and postdoctoral fellows and they draw students from Asia, mainly, Korea, China, Taiwan and Japan. With the help of PIMS, we have managed to have a strong presence there a number of times. G. Semenoff, G. Grignani, R. Myers, M. van Raamsdonk and M. Rozali as well as other senior members of the collaborative research group have been speakers at the school on at least one occasion. A number of graduate students and postdoctoral fellows from Canada have been able to attend this school. Financial support from this program comes almost entirely from the Asia Pacific Center for Theoretical Physics and the Korean Institute for Advanced Study, both based in Korea. Members of the collaborative research group, G. Semenoff, Taejin Lee and S. Nam are also organizers of the string program at the APCTP. Travel expenses of some students from Canada to attend the school were paid by PIMS.

- Summer Schools on "Strings, Gravity, Cosmology"
  - July 2003, Vancouver
  - August 2004, Vancouver
  - June 2005, Perimeter Institute, Waterloo, Ontario.
  - August 2006, Vancouver
  - Planned for Summer 2007, Perimeter Institute, Waterloo.

  These summer schools are our major event. They are a two-week long training program consisting of approximately sixty hours of lectures by prominent experts on the latest developments in string theory and are intended for young researchers. They have drawn students from the U.S. as well as Europe, Asia and Canada. The attendance is limited to eighty students and in the past two years they have been heavily oversubscribed. Financial support totalling about 50,000 dollars comes from PIMS (10,000), APCTP (15,000), Perimeter Institute (10,000), PITP (10,000), Institute for Particle Physics (IPP) (2500) the Department of Physics and Astronomy and the Faculty of Science of UBC (5000) and some other sources. These events have been enormously successful. As a pedagogical venue in an advanced field like String Theory, they have no real competitors on the North American Continent. They have therefore been able to draw the very best speakers and students from major institutions worldwide. They are now established as a series of events that students look forward to each year.

- Frontiers of Mathematical Physics Summer Workshops
  - "Particles, Fields and Strings", Simon Fraser University, Burnaby, BC, August 2001.

  - Braneworlds and Supersymmetry, July, 2002, Vancouver

    Before we had Summer Schools, our major Summer event were research workshops. They occurred each year between 1994 and 2002 and involved top physicists from the string theory and theoretical particle physicists from the international community speaking about and collaborating on their ongoing research. Financial support came from PIMS (15,000), the Perimeter Institute (15,000) and the APCTP (15,000).

- Five-day workshops at the Banff International Research Station (BIRS)

  - "Recent Developments in String Theory", March, 2003
  - "New Horizons in String Cosmology", June, 2004.
  - "Developments in String Theory", February, 2006.

  These are high profile events located at the new Banff International Research Station. Our "Recent Developments in String Theory" workshop was the first ever five-day meeting at that institution. All of our workshops there have been extremely successful. They attract the elite of the world's string theorists and cosmologists as participants. They had an intense program of seminars and sessions meant to encourage discussion and collaborative work. These workshops have become well known in the worldwide community as one of the best places for the dissemination of new results and a unique atmosphere which encourages informal discussions. Financial support for local expenses were borne by BIRS. Some support for travel was obtained from the Canadian Institute for Advanced Research (CIAR), the Institute for Particle Physics (IPP) and the National Science Foundation (NSF).

- "String Field Camp", Focused Research Group at the Banff International Research Station, July, 2004

  This was a small gathering of 10 people who spent two weeks in Banff collaborating on research in string theory. It brought together researchers from Eastern and Western Canada, Japan, Korea and the United States. It was intended to encourage research contacts between scientists in Canada and the Pacific rim region and it was quite successful in doing so. A number of research papers have resulted, including some good collaborative work. Financial support for local expenses was supplied by BIRS. Encouraged by our success this time, Amanda Peet (U. of Toronto) and I have proposed to hold another focused research group next Summer. Participants in the 2004 event were:

  - Yoshi Kitazawa, KEK Lab, Japan
  - Yutaka Matsuo, University of Tokyo, Japan
  - Taejin Lee, APCTP, Seoul, Korea
  - David Berenstein, University of California Santa Barbara
  - Anastasia Volovich, KITP, Santa Barbara
  - Marcus Spradlin, KITP, Santa Barbara
  - Gordon Semenoff, UBC
  - Mark van Raamsdonk, UBC
  - Andre Mikhailov, Caltech
  - Amanda Peet, University of Toronto
  - Washington Taylor, MIT
  - Shiraz Minwalla, Harvard University/Tata Institute

PIMS Postdoctoral Fellows

- Konstantin Zarembo (UBC) (Professor at Uppsala University)
- Sumati Surya (Alberta) (faculty, Raman Research Inst., Bangalore)
- Kazuyuki Furuuchi (UBC) (now at Taiwan National University)
- Udi Schreiber (UBC) (financial industry)
- Dominic Brecher (UBC) (financial industry)
- J. Rasmussen (Lethbridge) (now at Melbourne University)
- Vardarajan Suneeta (Alberta) (now at New Brunswick U.)

The activities of this collaborative research group have been greatly enhanced by the presence of a number of PIMS Postdoctoral Fellows.

Other Postdoctoral Fellows

- Domingo Luis-Martinez (UBC) (now faculty at UBC Science 1)
- Andre Dubin (UBC) (senior scientific staff, ITEP, Moscow)
- Roberto Scipioni (UBC) (material science at Oxford University)
- Emil Akhmedov (UBC) (senior scientific staff, ITEP, Moscow)
- Paul Koerber (UBC) (research position at Max Planck Institute, Munich)

- Kazumi Okuyama (UBC) (permanent faculty position in Japan)
- Todd Oliynyk (Alberta) (now at Max Planck Institute, Potsdam)
- Mohammad Akbar (Alberta)

Graduate Students

UBC:
Philip de Boer M.Sc. 2002, Ph.D. 2005. financial industry
Henry Ling, M.Sc. 2003. Ph.D. student at UBC
Mark Laidlaw, Ph.D. 2004. Lecturer at University of Victoria
Donovan Young, M.Sc. 2003, Ph.D. student at UBC
Bojan Ramadanovic, M.Sc. 2003, Ph.D. student at UBC
Shirin Hadizedeh, M.Sc. 2005, Ph.D. student at UBC
Jaffer Gardezi, M.Sc. 2003, Ph.D. student at McMaster University
Matheson Longton, M.Sc. 2006
Matthew Hasselfield, M.Sc. 2006
Simon Yewchuk, M.Sc. 2006
Brian Shieh, M.Sc. 2004, Ph.D. student at UBC

University of Alberta
Murarri Vasevudean, Ph.D. 2006, Postdoc at Stanford.

PIMS Distinguished Chairs

- 2003: **Ashoke Sen, Harish Chandra Research Institute, India**: Professor Sen gave a series of lectures on unstable D-branes in July and August of 2003. All lectures were on the UBC Campus. He also participated as a lecturer in the Frontiers of Mathematical Physics Summer School in 2004.
- 2004: **Washington Taylor, Massachusetts Institute of Technology, USA**: Professor Taylor gave a series of lectures on his work on matrix model formulations of M-theory and on Open String Field Theory. These lectures took place on the UBC Campus during July and August of 2005. He was also a lecture at the Frontiers of Mathematical Physics Summer School and he participated in the Focused Research Group at BIRS in July 2004.

Other Distinguished Visitors

- David Gross, (2003) KITP, Santa Barbara
- Lisa Randall (2004,2005), Harvard University
- Hirosi Ooguri (on three occasions 2004,2005,2006), Caltech
- Nathan Seiberg, (2002) IAS Princeton
- Micheal Duff (2004) Imperial College, London
- John Schwarz (two occasions 2004,2005) Caltech
- Igor Klebanov (2002), Princeton University
- Hermann Verlinde (2005), Princeton University
- Tohru Eguchi (2005), University of Tokyo
- Leonard Susskind (2002,2003,2004,2005), Stanford University
- Steven Shenker (2005), Stanford University
- Alexandre Polyakov (2001), Princeton University

International Collaborations

The greatest success of the Collaborative Research Group is in spawning productive collaborative research. The following are some examples of research collaborations which resulted from activities supported by the CRG.

- M. van Raamsdonk (UBC), O. Aharony (Weizmann Institute, Isreal), S. Minwalla (Harvard University): This collaboration has generated one substantial high-impact work on phase transition in high temperature gauge theory and its mirror in string theory duals of gauge theory, that is collapse to black holes [41]. This collaboration was greatly aided by participation of some of the collaborators in Banff events as well as a visit of both Shiraz Minwalla and Ofer Aharony to UBC. The latter visits were supported by the Period of Concentration which PIMS awarded the CRG in the period 2003-2005.
- M. Rozali (UBC), K. Okuyama (University of Chicago), R. Lee (University of Illinois, Urbana): This collaboration began when Okuyama visited UBC to participate in a Pacific Northwest String Seminar. This visit was supported by the Period of Concentration. It generated a high impact publication [58] Since then, Okuyama has joined UBC as a postdoctoral Fellow.
- M. Rozali (UBC), B. Pioline (University of Paris), M. Berkhooz (Weizmann Institute, Isreal): This collaboration grew out of a the participation of Micha Berkooz of the Weizmann Institute in Isreal as a speaker in the Frontiers of Mathematical Physics Summer School in 2003. It generated a very good publication exploring the nature of some

exotic cosmologies which are solutions of string theory [33]. As testament to its importance, it was presented by Berkhooz in a plenary lecture at the Strings 2004 conference in Paris in 2004.

- M. van Raamsdonk (UBC), A. Volovich, M. Spradlin (KITP, Santa Barbara): This collaboration resulted from interactions at the BIRS Focused Research Group which occurred in July, 2004. It has generated a research paper [63] which is considered an important input to its subject.

- G.W.Semenoff (UBC), Ch. Kristjansen (Niels Bohr Institute, Copenhagen), J. Plefka, N. Beisert, M. Staudacher (Albert Einstein Institute, Potsdam): This collaboration began with Period of Concentration sponsored one-month visits by J. Plefka and M. Staudacher of the Albert Einstein Institute in Pottsdam to PIMS in the Spring of 2002 and continued with a subsequent visit of G. Semenoff to the Albert Einstein Institute for one month. It produced a new approach to computing string interactions in string theory on a certain background. As a measure of its importance, it produced two 100+ citation papers [53, 57]. In fact, the first one [57] achieved 100 citations within a year of its first appearance on the hep-th archive, and was among only six papers in the entire field of elementary particle physics to have done so at the time.

- G. W. Semenoff (UBC), Yu. M. Makeenko, A. Morozov, A. Marshakov, A. Mironov (ITEP, Moscow), J. Ambjorn, (Niels Bohr Institute, Copenhagen): This is a long-time collaboration which has existed for fifteen years. It has examined various aspects of random matrix theories and their applications to gauge field theories and string theory. It has been supported by visitor fellowships at the Niels Bohr Institute and a NATO Collaborative Research Grant. The collaboration occurred in the Summer of 2003 during a visit by Y. Makeenko to UBC as a speaker in the Summer School.[26]

- G. W. Semenoff (UBC), G. Grignani, V.Forini, M. Orselli, G. de Risi (University of Perugia, Italy): This has been an ongoing collaboration for the past ten years. It focuses on issues in quantum field theory and string theory and has generated a number of published works [22, 49, 55]. It is presently working on a project in string theory. Financial support from the Italian INFN and a crucial element of the collaboration has been a number of visits to PIMS by G. Grignani and M. Orselli.

- G. W. Semenoff (UBC), K. Zarembo (Uppsala, Sweden): This collaboration has been ongoing for almost ten years. It began in 1995 with a visit by G. Semenoff to Moscow where K. Zarembo and continued when Zarembo joined UBC as a NATO Postdoctoral Fellow and then a PIMS Postdoctoral Fellow. It produced a number of results in string theory [59]. The collaboration has continued at a slower pace since Zarembo moved to Uppsala University in Sweden in 2002. It presently has some results which will eventually be published.

- G. W. Semenoff, Philip Stamp (UBC), Taejin Lee (APCTP and Kangwon University, Korea): Fermionization of the rolling Tachyon boundary conformal field theory. We found exact boundary states for a decaying unstable D-brane and used them to confirm a number of speculations about the behavior of the system. The work was supported by a year-long visit of Taejin Lee to PIMS in 2004. With the participation of Philip Stamp, it was then extended to cover some condensed matter systems where the exact solution of the boundary conformal field theory that we found has interesting applications to the motion of particles in a dissipative environment.[31][28].

Participants from PIMS Sites

The following is a list of faculty members of the PIMS member universities who actively participate in this program.

University of British Columbia

Moshe Rozali
Gordon Semenoff
Mark van Raamsdonk
Joanna Karczmarek
Don Witt
Kristen Schleich
Jim Bryan

University of Alberta

Eric Woolgar
Don Page
Valeri Frolov
Bruce Cambell (Now at Carleton)
Terry Gannon

University of Lethbridge

Mark Walton

University of Washington

Andreas Karch
Matt Strassler
Charles Doran

Partial List of Seminars

- October 30, 2006: Jaume Gomis, Perimeter Institute, "Holographic Wilson Loops"
- October 26, 2006, Matt Strassler, University of Washington, "Mysterious Metamorphoses: Duality in Quantum Theory"
- September 10, 2006, Gordon Semenoff UBC, "Fermion droplets, giant gravitons and giant Wilson loops"
- March 28, 2006, Vardarajan Suneeta , University of New Brunswick, "Geometric Flows and String Theory" (at University of Alberta)
- March 30, 2006, Lee Smolin, Perimeter Institute, "Emergence of the standard model from quantum gravity"
- March 9, 2006, Joe Polchinski, KITP and University of California at Santa Barbara, "Cosmic Strings and Superstrings"
- December 9, 2005, Todd A. Oliynyk, Albert Einstein Institute, Potsdam, "Newtonian Limit for Perfect Fluids" (at University of Alberta)
- December 5, 2005, Nadav Drukker, Niels Bohr Institute Copenhagen, "Circular loop operators in conformal field theories"
- December 1, 2005, Paul J. Steinhardt, Princeton University, "Einstein, Time and the Future of the Universe"
- November 14, 2005, Hermann Verlinde, Princeton University, "A Bottom-Up Approach to String Phenomenology"
- October 17, 2005, Mark Trodden, Syracuse University, "Connecting Cosmology and Fundamental Physics"
- October 10, 2005, Hitoshi Murayama, University of California at Berkeley, "The next twenty years in particle physics"
- October 3, 2005, A. Barvinsky Lebedev Physics Institute, Moscow, "Cosmological branes and macroscopic extra dimensions"
- April 11, 2005, Rafael Bousso, University of California at Berkeley, "From Quantum Gravity to the Physics of Flat Space"
- March 21, 2005, Sergei Gukov, Caltech, "The geography of extra dimensions"
- March 7, 2005, Mark van Raamsdonk UBC, "An analytic study of confinement/deconfinement in four dimensional gauge theory"
- January 31, 2005, Petr Horava, University of California, Berkeley, "From Godel Universes to Astrophysics of Compact Objects in String Theory"
- January 24, 2005, S. Mathur, Ohio State University, "The quantum structure of black holes"
- January 17, 2005, David Kutasov, University of Chicago, "Fun With Tachyons"
- January 26, 2004, M. Strassler, University of Washington, "An Example of Surprising Nonsupersymmetric Physics in Field Theory and String Theory"
- January 5, 2004, Y. Frishman, Weizmann Institute, Isreal, "QCD2 as a Model for Quantum Chromodynamics"
- November 17, 2003, Steven Shenker, Stanford University, "Exploring the Black Hole Singularity in String Theory"
- October 6, 2003, Steven Giddings, University of California at Santa Barbara, "Moduli, branes, fluxes, and the fate of four dimensions"
- September 22, 2003, Micheal Peskin, Stanford Linear Accleerator Center, "Laboratory Astrophysics" of Supersymmetry and Dark Matter"
- September 8, 2003, Sean Carroll, University of Chicago, "Dark Energy and the Preposterous Universe"

Publications

[1] S. Alexander, K. Schleich and D. M. Witt, "Fermionic sectors for the Kodama state," arXiv:gr-qc/0503062. [2]

[2] V. Balasubramanian, D. Marolf and M. Rozali, "Information recovery from black holes," arXiv:hep-th/0604045.

[3] C. Quigley and M. Rozali, "Recursion relations, helicity amplitudes and dimensional regularization," JHEP **0603**, 004 (2006) [arXiv:hep-ph/0510148].

[4] O. Aharony, J. Marsano and M. Van Raamsdonk, "Two loop partition function for large N pure Yang-Mills theory on a small S**3," arXiv:hep-th/0608156.

[5] H. Ling, A. R. Mohazab, H. H. Shieh, G. van Anders and M. Van Raamsdonk, "Little string theory from a double-

scaled matrix model," arXiv:hep-th/0606014.
[6] D. Brecher, P. Koerber, H. Ling and M. Van Raamsdonk, "Poincare invariance in multiple D-brane actions," JHEP **0601**, 151 (2006) [arXiv:hep-th/0509026].
[7] O. Aharony, J. Marsano, S. Minwalla, K. Papadodimas, M. Van Raamsdonk and T. Wiseman, "The phase structure of low dimensional large N gauge theories on tori," JHEP **0601**, 140 (2006) [arXiv:hep-th/0508077].
[8] ** O. Aharony, J. Marsano, S. Minwalla, K. Papadodimas and M. Van Raamsdonk, "A first order deconfinement transition in large N Yang-Mills theory on a small S**3," Phys. Rev. D **71**, 125018 (2005) [arXiv:hep-th/0502149].
[9] P. Koerber, "Stable D-branes, calibrations and generalized Calabi-Yau geometry," JHEP **0508**, 099 (2005) [arXiv:hep-th/0506154].
[10] K. Okuyama, "'t Hooft expansion of 1/2 BPS Wilson loop," arXiv:hep-th/0607131.
[11] K. Okuyama, "D-brane amplitudes in topological string on conifold," arXiv:hep-th/0606048.
[12] K. Okuyama and M. Rozali, "Hairpin branes and D-branes behind the horizon," JHEP **0603**, 071 (2006) [arXiv:hep-th/0602060].
[13] K. Okuyama, "1/2 BPS correlator and free fermion," JHEP **0601**, 021 (2006) [arXiv:hep-th/0511064].
[14] K. Okuyama, "D1-D5 on ALE space," JHEP **0512**, 042 (2005) [arXiv:hep-th/0510195].
[15] K. Okuyama, "Linear sigma models of H and KK monopoles," JHEP **0508**, 089 (2005) [arXiv:hep-th/0508097].
[16] K. Okuyama, "Annulus amplitudes in the minimal superstring," JHEP **0504**, 002 (2005) [arXiv:hep-th/0503082].
[17] T. A. Oliynyk and E. Woolgar, "Asymptotically Flat Ricci Flows," arXiv:math.dg/0607438.
[18] T. Oliynyk, V. Suneeta and E. Woolgar, "A gradient flow for worldsheet nonlinear sigma models," Nucl. Phys. B **739**, 441 (2006) [arXiv:hep-th/0510239].
[19] J. Bryan, T. Graber and R. Pandharipande, "The orbifold quantum cohomology of C^2/Z_3 and Hurwitz-Hodge integrals," arXiv:math.ag/0510335.
[20] G. W. Semenoff and D. Young, "Exact 1/4 BPS loop: Chiral primary correlator," arXiv:hep-th/0609158.
[21] F. Zhou and G. W. Semenoff, "Quantum insulating states of F=2 cold atoms in optical lattices," arXiv:cond-mat/0607463.
[22] D. Astolfi, V. Forini, G. Grignani and G. W. Semenoff, "Finite size corrections and integrability of N = 2 SYM and DLCQ strings on a pp-wave," arXiv:hep-th/0606193.
[23] G. W. Semenoff and P. Sodano, "Stretching the electron as far as it will go," arXiv:cond-mat/0605147.
[24] G. Grignani, M. Orselli, B. Ramadanovic, G. W. Semenoff and D. Young, "AdS/CFT vs. string loops," JHEP **0606**, 040 (2006) [arXiv:hep-th/0605080].
[25] K. Okuyama and G. W. Semenoff, "Wilson loops in N = 4 SYM and fermion droplets," JHEP **0606**, 057 (2006) [arXiv:hep-th/0604209].
[26] Y. Makeenko, P. Olesen and G. W. Semenoff, "Cusped SYM Wilson loop at two loops and beyond," Nucl. Phys. B **748**, 170 (2006) [arXiv:hep-th/0602100].
[27] G. W. Semenoff and P. Sodano, "Teleportation by a Majorana Medium," arXiv:cond-mat/0601261.
[28] M. Hasselfield, T. Lee, G. W. Semenoff and P. C. E. Stamp, "Critical boundary sine-Gordon revisited," arXiv:hep-th/0512219.
[29] G. Grignani, M. Orselli, B. Ramadanovic, G. W. Semenoff and D. Young, "Divergence cancellation and loop corrections in string field theory on a plane wave background," JHEP **0512**, 017 (2005) [arXiv:hep-th/0508126].
[30] G. W. Semenoff, "Black holes and thermodynamic states of matrix models,"
[31] T. Lee and G. W. Semenoff, "Fermion representation of the rolling tachyon boundary conformal field theory," JHEP **0505**, 072 (2005) [arXiv:hep-th/0502236].
[32] G. W. Semenoff and D. Young, "Wavy Wilson line and AdS/CFT," arXiv:hep-th/0405288.
[33] M. Berkooz, B. Pioline and M. Rozali, "Closed strings in Misner space: Cosmological production of winding strings," JCAP **0408**, 004 (2004) [arXiv:hep-th/0405126].
[34] G. W. Semenoff, "Matrix model thermodynamics," arXiv:hep-th/0405107.
[35] D. Brecher, K. Furuuchi, H. Ling and M. Van Raamsdonk, "Generally covariant actions for multiple D-branes," JHEP **0406**, 020 (2004) [arXiv:hep-th/0403289].
[36] E. Schreiber, "Excited mesons and quantization of string endpoints," arXiv:hep-th/0403226.
[37] S. Slobodov, K. Schleich and D. M. Witt, "Effects of a cosmological constant on the X-ray fluorescence spectra of black hole accretion disks," arXiv:gr-qc/0402066.
[38] J. Bryan and D. Karp, "The closed topological vertex via the Cremona transform," arXiv:math.ag/0311208.
[39] G. W. Semenoff, "On the Yang-Mills dual of pp-wave strings," `SPIRESentry` *Prepared for 2002 International Workshop on Strong Coupling Gauge Theories and Effective Field Theories (SCGT 02), Nagoya, Japan, 10-13 Dec 2002*
[40] K. Furuuchi, E. Schreiber and G. W. Semenoff, "Five-brane thermodynamics from the matrix model," arXiv:hep-th/0310286.
[41] O. Aharony, J. Marsano, S. Minwalla, K. Papadodimas and M. Van Raamsdonk, "The Hagedorn / deconfinement phase transition in weakly coupled large N gauge theories," arXiv:hep-th/0310285.
[42] D. Brecher, U. H. Danielsson, J. P. Gregory and M. E. Olsson, "Rotating black holes in a Goedel universe," JHEP **0311**, 033 (2003) [arXiv:hep-th/0309058].
[43] J. Bryan and R. Pandharipande, "Curves in Calabi-Yau 3-folds and topological quantum field theory," arXiv:math.ag/0306316.
[44] N. Pippenger and K. Schleich, "Topological characteristics of random surfaces generated by cubic arXiv:gr-qc/0306049.
[45] D. Brecher, P. A. DeBoer, D. C. Page and M. Rozali, "Closed timelike curves and holography in compact plane waves," JHEP **0310**, 031 (2003) [arXiv:hep-th/0306190].
[46] M. Van Raamsdonk, "Blending local symmetries with matrix nonlocality in D-brane effective JHEP **0309**, 026 (2003) [arXiv:hep-th/0305145].
[47] D. Brecher and P. M. Saffin, "Decay modes of intersecting fluxbranes," Phys. Rev. D **67**, 125013 (2003) [arXiv:hep-th/0302206].
[48] S. Alexander, R. Brandenberger and M. Rozali, "Non-topological inflation from embedded defects," arXiv:hep-th/0302160.
[49] G. Grignani, M. Orselli, G. W. Semenoff and D. Trancanelli, "The superstring Hagedorn temperature in a pp-

wave background," JHEP **0306**, 006 (2003) [arXiv:hep-th/0301186].

[50] P. A. DeBoer and M. Rozali, "Thermal correlators in little string theory," Phys. Rev. D **67**, 086009 (2003) [arXiv:hep-th/0301059].

[51] J. Giedt, E. Poppitz and M. Rozali, "Deconstruction, lattice supersymmetry, anomalies and branes," JHEP **0303**, 035 (2003) [arXiv:hep-th/0301048].

[52] J. Maldacena, M. M. Sheikh-Jabbari and M. Van Raamsdonk, "Transverse fivebranes in matrix theory," JHEP **0301**, 038 (2003) [arXiv:hep-th/0211139].

[53] ** N. Beisert, C. Kristjansen, J. Plefka, G. W. Semenoff and M. Staudacher, "BMN correlators and operator mixing in N = 4 super Yang-Mills theory," Nucl. Phys. B **650**, 125 (2003) [arXiv:hep-th/0208178].

[54] K. Dasgupta, M. M. Sheikh-Jabbari and M. Van Raamsdonk, "Protected multiplets of M-theory on a plane wave," JHEP **0209**, 021 (2002) [arXiv:hep-th/0207050].

[55] G. Grignani, M. Laidlaw, M. Orselli and G. W. Semenoff, "O(D) invariant tachyon condensates in the 1/D expansion," Phys. Lett. B **543**, 127 (2002) [arXiv:hep-th/0206025].

[56] * K. Dasgupta, M. M. Sheikh-Jabbari and M. Van Raamsdonk, "Matrix perturbation theory for M-theory on a PP-wave," JHEP **0205**, 056 (2002) [arXiv:hep-th/0205185].

[57] ** C. Kristjansen, J. Plefka, G. W. Semenoff and M. Staudacher, "A new double-scaling limit of N = 4 super Yang-Mills theory and PP-wave Nucl. Phys. B **643**, 3 (2002) [arXiv:hep-th/0205033].

[58] * R. G. Leigh, K. Okuyama and M. Rozali, "PP-waves and holography," Phys. Rev. D **66**, 046004 (2002) [arXiv:hep-th/0204026].

[59] G. W. Semenoff and K. Zarembo, "Wilson loops in SYM theory: From weak to strong coupling," Nucl. Phys. Proc. Suppl. **108**, 106 (2002) [arXiv:hep-th/0202156].

[60] D. Brecher, J. P. Gregory and P. M. Saffin, "String theory and the classical stability of plane waves," Phys. Rev. D **67**, 045014 (2003) [arXiv:hep-th/0210308].

[61] D. Brecher, C. V. Johnson, K. J. Lovis and R. C. Myers, "Penrose limits, deformed pp-waves and the string duals of N = 1 large N JHEP **0210**, 008 (2002) [arXiv:hep-th/0206045].

[62] D. Brecher, B. Janssen and Y. Lozano, "Chern-Simons couplings for dielectric F-strings in matrix string theory," Fortsch. Phys. **50**, 864 (2002) [arXiv:hep-th/0201107].

[63] M. Spradlin, M. Van Raamsdonk and A. Volovich, "Two-loop partition function in the planar plane-wave matrix model," arXiv:hep-th/0409178.

[64] T. Oliynyk, V. Suneeta and E. Woolgar, "Irreversibility of world-sheet renormalization group flow," arXiv:hep-th/0410001.

[65] E. Woolgar, "AdS/CFT and the topology of black holes," `SPIRESentry` *Prepared for 9th Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Gravitation and Relativistic Field Theories (MG 9), Rome, Italy, 2-9 Jul 2000*

[66] G. J. Galloway, S. Surya and E. Woolgar, "Non-existence of black holes in certain Lambda ¡ 0 spacetimes," Class. Quant. Grav. **20**, 1635 (2003) [arXiv:gr-qc/0212079].

[67] E. Woolgar, "Positive energy proof for asymptotically anti-de Sitter space-times," *Prepared for 7th Marcel Grossmann Meeting on General Relativity (MG 7), Stanford, California, 24-30 Jul 1994*

[68] D. N. Page, S. Surya and E. Woolgar, "Positive mass from holographic causality," Phys. Rev. Lett. **89**, 121301 (2002) [arXiv:hep-th/0204198].

[69] G. J. Galloway, S. Surya and E. Woolgar, "On the geometry and mass of static, asymptotically AdS spacetimes, and the uniqueness of the AdS soliton," Commun. Math. Phys. **241**, 1 (2003) [arXiv:hep-th/0204081].

[70] G. J. Galloway, S. Surya and E. Woolgar, "A uniqueness theorem for the adS soliton," Phys. Rev. Lett. **88**, 101102 (2002) [arXiv:hep-th/0108170].

[71] C. Cadeau and E. Woolgar, "New five dimensional black holes classified by horizon geometry, and a Bianchi VI braneworld," Class. Quant. Grav. **18**, 527 (2001) [arXiv:gr-qc/0011029].

[72] G. J. Galloway, K. Schleich, D. Witt and E. Woolgar, "The AdS/CFT correspondence conjecture and topological censorship," Phys. Lett. B **505**, 255 (2001) [arXiv:hep-th/9912119].

[73] M. A. Walton and J. G. Zhou, "PP-wave Green-Schwarz superstring, polygon divergent structure and conformal field theory," Phys. Rev. D **68**, 066004 (2003) [arXiv:hep-th/0305228].

[74] L. Begin, C. Cummins, P. Mathieu and M. A. Walton, "Fusion rules and the Patera-Sharp generating-function method," arXiv:hep-th/0210182.

[75] G. Flynn, J. Rasmussen, M. Tahic and M. A. Walton, "Higher-genus su(N) fusion multiplicities as polytope volumes," J. Phys. A **35**, 10129 (2002) [arXiv:hep-th/0209020].

[76] M. A. Walton and J. G. Zhou, "D-branes in asymmetrically gauged WZW models and axial-vector duality," Nucl. Phys. B **648**, 523 (2003) [arXiv:hep-th/0205161].

[77] T. Kubota, J. Rasmussen, M. A. Walton and J. G. Zhou, "Maximally symmetric D-branes in gauged WZW models," Phys. Lett. B **544**, 192 (2002) [arXiv:hep-th/0112078].

[78] J. Rasmussen and M. A. Walton, "Purely affine elementary SU(N) fusions," Mod. Phys. Lett. A **17**, 1249 (2002) [arXiv:hep-th/0110223].

[79] J. Rasmussen and M. A. Walton, "Affine su(3) and su(4) fusion multiplicities as polytope volumes," J. Phys. A **35**, 6939 (2002) [arXiv:hep-th/0106287].

[80] J. Rasmussen and M. A. Walton, "On the level-dependence of Wess-Zumino-Witten three-point functions," Nucl. Phys. B **616**, 517 (2001) [arXiv:hep-th/0105294].

[81] J. Rasmussen and M. A. Walton, "Fusion multiplicities as polytope volumes: N-point and higher-genus SU(2) fusion," Nucl. Phys. B **620**, 537 (2002) [arXiv:hep-th/0104240].

[82] D. N. Page and S. Surya, "Positive mass without positive energy," APCTP Bull. **5**, 13 (2002).

* Fifty plus citations.

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