Probability and Statistical Mechanics Collaborative Research Groups: 2004-2006

I. CRG Members

1. Faculty at PIMS Universities

Martin Barlow (UBC), David Brydges (UBC) (co-chair), Chris Burdzy (UW), Z. Chen (UW), Ander Holroyd (UBC), Rick Kenyon (UBC), Mike Kouritzin (UA), Rachel Kuske (UBC), Vlada Limic (UBC-CNRS), Ed Perkins, (UBC) (co-chair) Byron Schmuland (UA), Gordon Slade (UBC), John Walsh (UBC)

2. Other Faculty (two week min. stay)

May 1 - June 8, 2004, July, 2005: Doug Blount (Arizona State University), UA

May 19 - 31, 2004: Takashi Kumagai (Nagoya University), UBC

May 10 - 23, 2004: Don Dawson (Carleton U.),UBC

May 15 - June 15, 2004: Pierre Tarres (U. Toulouse), UBC

May 19 - June 26, 2004: Greg Lawler (Cornell U. and U. Chicago), UBC

June, July, 2004 and 2005: Mike Kozdron (U. Regina)

June and Aug 15 - Sept 15, 2004: Erwin Bolthausen (U. Zurich), UBC

July 1 - 14, 2004: John Imbrie, (U. Virginia)

July 4 - 31, 2004: Jon Dimock, (SUNY Buffalo)

July 7 - 28, 2004: Pronob Mitter, (U. Montpellier), UBC

August 23 - September 5, 2004: Remco van der Hofstad (Technical University Eindhoven),UBC

September 2004: Ted Cox (Syracuse U.), UBC

November 2004: Takashi Kumagai (Kyoto University), UBC

January 4 - February 4, 2005: Nicolai Krylov (U. Minnesota), UA and UBC

February 13 - March 6, 2005: Alain Sznitman (ETH), UBC

March, 2005: Bruno Remillard (HEC Montreal), UA

June 3 - July 9, 2005: Lorenzo Zambotti, (Pisa), UBC

June - August, 2005: Yongjin Wang (Nankai U.), UBC

June - July, 2005: Peter March (Ohio State), UBC

June - July, 2005: Dan Romik (Weizmann, Institute), UBC

June 6 - July 1, 2005: Yuval Peres (UC Berkeley), UBC

Two months summer, 2005: Takashi Kumagai (Kyoto University), UBC and UW

July 15 - September 15, 2005: Anita Winter (Erlangen), UBC

July - August, 2005: Steve Evans, (Berkeley), UBC

July - August, 2005: Leonid Mytnik, (Technion), UBC

July - August, 2005, N. Ratanov (Bogota, Columbia), UA

August, 2005: Carl Mueller (U. of Rochester), UBC

October - December, 2005: Jean Francois Delmas (Ecole Nationale des Ponts et Chausses)

February 28 - March 9, 2006: Jean-Dominique Deuschel (Technische Universität Berlin), UBC

March, 2006: M. Xu (U. North Carolina at Chapel Hill), UA

March, 2006: S. Smirnov (School of Economics, State U. of Moscow), UA
August 2005 - June 2006: Rami Atar (Technion), UW and UBC
August 15 - September 1, 2005: Anja Sturm (U. Delaware), UBC
May 21 - June 18, 2006: Akira Sakai (EURANDOM), UBC
June 26 - September 9, 2006: Malek Abdesselam (Université Paris 13), UBC
May 21 - June 18, 2006: Akira Sakai (EURANDOM), UBC
July 24 - August 7: Ted Cox (Syracuse U.), UBC

In addition, Zhenqing Chen, UW, spent his sabbatical leave in the fall semester of 2004 at UBC.

PIMS Distinguished Chairs

2004-05 Richard Bass (U. Connecticut) visited UBC for the year and gave an advanced graduate course on "Probabilistic techniques in PDE" – his notes are posted on the web at http://www.math.uconn.edu/ bass/pdeprob.pdf. He also visited U of Alberta and U. Washington and was involved in research projects with Martin Barlow and Ed Perkins (UBC), with Chris Burdzy and Zhenqing Chen (UW) and with Takashi Kumagai (Kyoto) who visited PIMS during his year of residence.

2004 - 05 Yaozhong Hu (U. Kansas) visited U of Alberta. He gave a series of lectures on Stochastic PDE and Finance, including a public lecture at UA, and travelled to UBC twice to lecture and participate on the 2005 SPDE Workshop. He is working with Mike Kouritzin on tracking Markov processes.

2005 - 06 Frank den Hollander (Leiden U., Netherlands) visited UBC for the year and gave an advanced graduate course on "Large Deviations". He continued his collaborations with Gordon Slade and was involved in a new project on invasion percolation with Omer Angel (PIMS pdf), Jesse Goodman (UBC grad student) and Gordon Slade. He also brought in a sequence of young postdoctoral fellows, Gregory Maillard, Reda Mesikh, Nicolas Petrelis and Rongfeng Sun for a series of one month visits. Each gave a seminar and engaged in CRG activities during their visit. The project with Sun and other co-authors led to related work of Perkins and Bass on degenerate stochastic d.e.'s

2005 - 06 Masatoshi Fukushima (Osaka U.) visited U. Washington July 17-August 27 and gave a series of lectures on Dirichlet forms and symmetric Markov Processes during the International Conference on Stochastic Analysis and its Applications at UW.

3. PDF's

Omer Angel (PIMS pdf 04-06) (now Asst. Prof., U. of Toronto)
Nathanael Berestycki (05-07)
Kevin Buhr (02-05) (now Research Associate, Dept. Statistics, U. Wisconsin)
Codina Cotar (04-06) (now pdf at TU, Berlin)
Alan Hammond (05-06) (now pdf at Courant Institute)
Alex Roitershtein (05-07)
Anja Sturm (03-04) (now Asst. Prof. at U. Delaware)

Anna Talarczyk (03-04) (now Asst. Prof., Inst. Math., U. Warsaw)

4. Graduate students (longterm or PIMS universities)

UBC (current): Jeremy Flowers, Jesse Goodman, Hardeep Gill, Sandra Kliem, Terrry Soo

UBC (graduated during CRG):

Anthony Blackman, [MSc, applied to Graduate school, SFU]

Yang Liu, [MSc, Graduate Financial Mathematics Program at Waterloo]

Mark Holmes [Ph.D., pdf Eurandom 05-07, Asst. Professor, U. of Auckand, 07-]

Feng Yu [Ph.D., pdf, Oxford U.]

UW (current): Ryan Card, Nathaniel Blair-Stahn, Woo Kim

UW (graduated during CRG): Panki Kim [Ph.D., U. of Illinois pdf, now Asst. Prof., Seoul National University, S. Korea 2007-], Daniel Meyer [Ph.D., now pdf at U. of Michigan], David White [Ph.D., now pdf at Cornell], Yan Jiang [Ph.D., working at a financial firm in Vancouver], Jason Swanson [Ph.D., now pdf at U. Wisconsin)

Other: Richard Liang (Berkeley, Summers 2004,05)

II. Activities (May 2004 - August 2006)

The opening event was the Seminar on Stochastic Processes 2004 (May 20-22), an annual N. American probability conference which we are able to host thanks to PIMS financial and staff support, and NSF support through a grant application by Chris Burdzy (UW). Over 80 registrants enjoyed invited lectures by R. Carmona (Princeton), R. Dalang (Lausanne), A. Guionnet (ENS, Lyon), Y. Le Jan (Orsay), and B. Virag (U. Toronto) and a number of informal presentations by the participants. The timing allowed 16 of the student participants of our first Summer School in Probability to also attend.

The first Summer School in Probability at UBC (May 25-June 25, 2004) featured two graduate courses by Martin Barlow (UBC) on Random Walks and the Geometry of Graphs and Greg Lawler (Cornell U.) on Schramm-Loewner Evolution (SLE) and Other Conformally Invariant Processes in the Plane. The 35-hour courses were attended by over 45 students roughly in equal numbers from Canada (including students at UA, UBC and UW), the U.S. and Europe and were officially offered as Graduate level courses by the Dept. of Mathematics at UBC. PIMS provided local accommodation for 24 of the participants in Gage apartments and critical staff support while the Dept. of Mathematics at UBC provided teaching credit for Martin Barlow's course. These students were carefully selected based on letters of reference. Barlow's course studied the relation between geometric properties of graphs (as given for example by isoperimetric inequalities), analytic inequalities on the graph, and properties of the transition densities of the random walk. Greg Lawler's course provided a comprehensive introduction to SLE which has provided a range of conformally invariant processes in the plane which have arisen as scaling limits of loop-erased random walk, percolation on the triangular lattice and the frontier of planar Brownian motion. Thus many of the predictions made by conformal

field theory in the physics literature have been rigorously proved. The joint works on SLE by Lawler, Schramm and Werner, much of which was described in the course, led to Werner's Fields medal, Schramm's plenary lecture at the 2006 ICM in Madrid and the Henri Poincaré Prize awarded to Schramm at the 2003 International Congress of Mathematical Physics. Tutorial sessions for Lawler's course were given by Jose Ramirez (U. de Costa Rica).

Many of the students at the course enjoyed a short break to participate in a two day conference: Analysis, Probability, and Logic: A Conference in Honor of Edward Nelson June 17-18, which was held with the generous support of NSF and PIMS. It featured review lectures on areas influenced by Nelson's seminal papers: Quantum Field Theory, Stochastic Quantum Mechanics, Logic, Nonstandard Analysis and Functional Analysis. Lectures were given by David Brydges, Sam Buss, Eric Carlen, Len Gross, Greg Lawler, Barry Simon, Cedric Villani, and Jay Hook. This unusual conference for a unique man was concluded by an introduction to the role of group theory in music and a piano concert by Ed's former student Jay Hook, Professor of Music at Indiana University. Forty one people, including many of Nelson's former students, registered for the conference and were inveigled into wide ranging discussions by the good weather and relaxed schedule. Princeton University Press is about to publish a book "Diffusion, Quantum Theory, and Radically Elementary Mathematics" http://www.pupress.princeton.edu/titles/8345.html arising from the conference.

Many of the summer school students also attended the first two of an outstanding sequence of five lectures given by Erwin Bolthausen (U. Zurich) on Sherrington-Kirkpatrick Spin Glasses (June 21-July 2/04). These lectures concerned a deep development in the physics of high dimensions where an outstanding open problem for nearly thirty years has been to prove that the ansatz for the Sherrington-Kirkpatrick (SK) model found by the Italian physicist, Giorgio Parisi, is actually the exact solution. He explained that the SK model is an instance of the classical problem of finding the maximum of a family of Gaussian random variables. Although Fernique, Talagrand and others have developed methods for handling such quantities, "these theories never give exact constants, the Parisi-theory does, revealing an absolutely marvelous mathematical structure behind the problem, which is still very poorly understood, to this day".

The Second Summer School in Probability was held at UBC June 6 - 30, 2005 and featured 30-hour graduate courses on "The Lace Expansion and its Applications" by Gordon Slade (UBC) and "Mixing for Markov Chains and Spin Systems" by Yuval Peres (Berkeley-Microsoft). Over 50 students from four continents attended the lectures which were supplemented by presentations by 25 of the participants themselves. PIMS, MITACS and the UW VIGRE program provided local accommodation for 36 of the participants, while the UBC Dept. of Mathematics provided teaching credit for Gordon Slade's course – both were taken for credit by UBC students. Slade's course [Slade,Springer Lecture Notes in Mathematics #18] was a self-contained introduction to the lace expansion and its application to the determination of critical exponents

and the construction of scaling limits in statistical mechanics above the critical dimension. Mark Holmes (Ph. D. student, UBC) provided tutorial sessions for Slade's course and organized the participants' presentations. Peres' course focused on rates of convergence for irreducible finite state Markov chains to their stationary distributions. The course took off from ground prepared by Barlow's course in the previous year, harmonic functions on graphs, coupling, mixing rates, spectral gap estimates and Kantorovich metric, but quickly focused on specific examples. These included card shuffling on the symmetric group and Glauber dynamics for spin systems. The focus, not unrelated to Barlow's was on how properties of graphs are reflected in mixing rates and how to achieve very fast rates.

Some of the participants stayed on to attend the Workshop on Uniqueness Questions for Infinite-Dimensional Diffusions which was held at UBC July 4 - 8, 2005. This specialized workshop with over twenty participants featured one hour lectures in the mornings by Don Dawson (Carleton U.), Steve Evans (Berkeley), Yaozhong Hu (Kansas and PIMS Distinguished Chair), Jean-Francois Le Gall (ENS), Leonid Mytnik (Technion), John Walsh (UBC), Yongjin Wang (Nankai), and Lorenzo Zambotti (Milan). Afternoons were dedicated to informal presentations or working in smaller groups. Several of the participants stayed for longer periods and continued to work on problems arising from the meeting. For example Mytnik and Perkins were able to establish a new pathwise uniqueness result for parabolic spde's driven by white noise in the following weeks [MP].

A minicourse on the Lace Expansion for the Ising Model was given by Akira Sakai (Eurandom) at UBC, May 25 - June 15. The Ising model of ferrromagnetism is a central example in statistical mechanics, and provides a paradigm for phase transitions and critical phenomena. In a recent breakthrough, Akira Sakai (postdoc at UBC January 2001 to December 2002, now Lecturer in Probability at University of Bath) has shown how to derive and apply the lace expansion to study detailed properties of the phase transition of the Ising model above four dimensions. Sakai gave a fascinating 7-hour minicourse on his results and methods.

The International Conference on Stochastic Analysis and its Applications was held at the University of Washington from August 7 - 11, 2006. The conference was devoted to several areas of stochastic analysis, including Markov processes, jump type processes, measure-valued processes, Dirichlet forms, and multiparameter processes. There were 26 invited 40-minute lectures, mini-courses by Prof.'s Fukushima, Khoshnevisan and Röckner, and informal sessions. Over 60 participants attended the meeting. In addition to PIMS support, the meeting received financial support from the NSA and U. Washington.

Other Activities (not described above)

BIRS Research in Teams, Competing Species and Predator-Prey Stochastic Models, Aug. 2-16, 2004. Rick Durrett, Leonid Mytnik, and Ed Perkins, spent two weeks working on a stochastic spatial model for competing species and predator-prey systems. It led to the publication [BMP]. A BIRS meeting on Stochastic Processes in Evolutionary and Disease Genetics occurred

during this time and allowed for some additional interactions. A discussion of Durrett and Perkins with Ted Cox who was participating in the genetics meeting, led to a project resolving a number of open questions on another Lotka-Volterra model [CDP].

BIRS Research in Teams, Stability and Computations for Stochastic Delay-Differential Equations, July 24- Aug. 7, 2004 The goal was to bring together a group of researchers (Rachel Kuske (UBC), Evelyn Buckwar (Humboldt U.), Mohammed Salah (Southern Illinois) and Tony Shardlow (Manchester)) working on dynamics of stochastic delay differential equations (SDDE's) from different perspectives: theoretical aspects, nonlinear effects in stochastic dynamics, numerical methods, and mathematical modeling in applications. The goals of the group for the two weeks were to identify new directions in this research area and to begin preliminary work to determine productive directions to pursue. Publications [BKES,BKMS] resulted from this meeting.

Canadian Mathematical Society Winter Probability Session, Dec. 10-12, 2005, U. Victoria. This session was cosponsored by the Canadian Mathematical Society and featured an associated plenary lecture by Oded Schramm (Microsoft). The session was a showcase of Canadian probability as 12 of the 13 speakers were from Canadian universities: Omer Angel, David Brydges, Richard Kenyon and Vlada Limic (UBC); Mike Kozdron (U. Regina): Juan Alvarez and Christine Soteros (U. Saskatchewan); Jeremy Quastel and Balint Virag (U. Toronto); Tom Salisbury (York U.); Antal Jarai (Carleton); Bruce Reed (McGill). The 13th was Jean-Francois Delmas who visited UBC on his sabbatical from Ecole Nationale des Ponts et Chausses) for the fall semester.

BIRS Workshop on Critical Scaling for Polymers and Percolation, May 28-June 2, 2005. Participants from mathematics, theoretical physics, and chemistry shared viewpoints and knowledge of recent advances in determination of phase structure and critical properties of polymers and related models in statistical mechanics. A group of lectures by leading experts focused on the challenges of connecting the Conformal Field Theory picture with the Schramm-Loewner picture of two dimensional models. In a different direction, also championed by a younger scientist, former PIMS postdoc Akira Sakai talked about his recent discovery of how to carry out the Lace expansion for the Ising model. See http://www.pims.math.ca/birs/

Pacific Northwest Probability Seminars, UW, Oct. 23, 2004, and Oct. 22, 2005. These Annual daylong seminars allow for a regular meeting of the probability groups at UW, UBC, Microsoft Theory Group, and Oregon State U. in a relaxed atmosphere. These seminars received support from MSRI as a Network Conference and these funds allowed led to an upgrading of the Seminar to 4 speakers, 3 from local participants and a Birnbaum Lecturer. The speakers in 2004 were Rick Kenyon (UBC), Mina Ossiander (Oregon State), Oded Schramm (Microsoft) and the Birnbaum Lecturer was Ofer Zeitouni (Minnesota). In 2005 the speakers were Rami Atar (Technion, visiting UW), Nathanael Berestycki (UBC), Yevgeniy Kovchegov (Oregon State U.)

and the Birnbaum Lecturer was Charles Newman (Courant Institute). PIMS support provided travel and local support for graduate students, postdoctoral fellows and speakers from other PIMS universities.

BIRS Focussed Research Group on Random Sorting Processes, April 22-May 6, 2006 Participants: O. Angel, N. Berestycki, A. Hammond, A. Holroyd (UBC); A. Gamburg (Inst. Advanced Study); M. Kassabov (Cornell); D. Romik (Berkeley); B. Virag (U. of T.); D. Wilson (Microsoft Research). See III.3 below for a discussion of this work.

Probability Seminar at UA

In 2005, a series of special probability seminars at UA were organized by M. Kouritzin and A. Melnikov. The speakers were R. Bass (U. Connecticutt), N. Ratanov (Rosario U., Bogota), D. Blount (Arizona State), M. Xu (U. N. Carolina), and S. Smirnov (State University of Moscow).

III. Sample Research Projects Fostered by the CRG

1) Degenerate SDE's and Large Scale Behaviour of Particle Systems

Frank den Hollander and his visiting pdf, Rongfeng Song are involved in an ambitious project with Dawson, Greven and Swart to show that the large scale behaviour of certain classes of interacting diffusions fall into a finite number of universality classes. The rescaling led to a class of degenerate stochastic differential equations whose coefficients arise from an intricate renormalization map. They needed to know the equations had a unique solution but none of the standard methods applied. Don Dawson and Ed Perkins had obtained uniqueness under a Hölder continuity assumption on the degenerate coefficients but during his visit to PIMS in 05-06 Frank den Hollander confirmed that they could not verify this condition for their renormalization map. During Rich Bass' visit as Distinguished Chair the previous year he and Ed Perkins had started to look at weakening the Hölder condition and developed a possible strategy. During Frank's and Rongfeng's visit it became clear that the uniqueness result was the main obstruction to their program and that the result Bass and Perkins were pursuing would in fact allow them to at least obtain some important partial results on the domain of attraction they were trying to find. After a series of meetings between den Hollander, Perkins and Song and a visit of Perkins to Bass, the required uniqueness result was proved and is current being written up in [BP] while den Hollander, Song et al prepared a preprint on their work [DGHSS].

2) Enumeration of Self-Avoiding Walks [CLS]

Richard Liang graduated from UBC in 2004 and attended the 2004 Summer School in Probability as he was planning to pursue graduate work in probability at Berkeley. As a summer undergraduate research student in 2004 working with Gordon Slade, Richard wrote a computer program to exactly enumerate certain random walk configurations that arise in the lace expansion. Using these, it is easy to enumerate N-step self-avoiding walks for certain values of N. By the end of the summer it was apparent that the method would be sufficient to carry

out the enumerations for larger values of N than had been previously obtained in dimensions 3 and higher, but that to do so would require use of a cluster computer. Nathan Clisby, a Research Fellow from the University of Melbourne and an expert in computational enumeration, attended the PIMS Summer School in 2005, and a 3-way collaboration was begun at that time. (Liang was by then a graduate student at UC Berkeley and was again a participant at the summer school.) The cluster computer is currently at work and is expected to extend the known expansion to 30 terms for d=3 (from 26 terms), to 24 terms in all dimensions up to and including d=12. It is known by subadditivity arguments that if c_N is the number of N-step self-avoiding walks then $\lim_N c_N^{1/N}$ exists and is called the connective constant μ. Finite asymptotic expansions for μ in powers of $1/d$ have been studied. The above enumerative methods have also provided 13 terms in this expansion (previously 7 terms were known). The scaling limit of two-dimensional self-avoiding walk is conjectured to be SLE (8/3) while for dimensions greater than 4, the lace expansion has shown that the scaling limit is a Brownian motion. For the physically important dimension 3, where very little is known theoretically about the number of N-step self-avoiding walks. These results may give good estimates on the critical exponents for the number of walks and mean-square displacement.

3) Sorting Networks [AHR,AHKV,AHKRV]

This is joint work between Omer Angel (PIMS pdf), Ander Holroyd (UBC), Martin Kassabov (Cornell), Dan Romik (PIMS Summer School participant) and Balint Virag (U. Toronto). The project started during the Spring 2005 programme at MSRI. It benfitted greatly from Dan Romik's visits to PIMS (including the 2005 Summer School), and obviously from Omer Angel's presence at UBC. The project was also advanced during a Focussed Research Group at BIRS April 22-May 6, 2006 which was also attended by UBC pdfs Alan Hammond and Nathanael Berestycki (now also a PIMS pdf).

Sorting a list of items is perhaps the most celebrated problem in mathematical computer science. If one must do this only by swapping neighbouring pairs, then the worst initial condition is when the n items are in reverse order, and this requires $n(n-1)/2$ swaps to sort. A sorting network is any sequence of $n(n-1)/2$ swaps which achieves this. For example when n=3 there are exactly two sorting networks.

Here the goal is to study the behaviour of a uniformly random n-element sorting network, as $n \to \infty$. It is shown that the space-time process of swaps converges to the product of the semi-circle law and Lebesgue measure. Simulations and heuristic arguments have led to striking conjectures: for example the trajectories of individual particles appear to converge to sine curves of random phases and amplitudes, while the support of the half-time permutation matrix appears to converge to the circularly symmetric measure obtained by projecting surface measure of the 2-sphere. See http://www.math.ubc.ca/ holroyd/sort for pictures. Weaker statements are proved: asymptotically, the trajectories are Holder-1/2, while the support of the permutation matrix lies within a certain octagon. A key tool is a bijection with Young tableaux discovered by Edelman

and Greene.

4) Invasion Percolation [AGHS]

This project is joint work of Omer Angel (PIMS pdf), Jesse Goodman (Ph.D. student, UBC), Frank den Hollander (PIMS Distinguished Chair) and Gordon Slade (UBC). Invasion percolation is a dynamic percolation model in which fluid invades the adjacent channel which offers least resistance, where channel resistances are independently and randomly chosen between 0 and 1. For ordinary percolation channels are opened independently of each other with probability p and there is a critical value p_c above which the fluid percolates, that is flows to infinity. In contrast, invasion percolation always produces an infinite cluster of wet sites. It is known (recent work of former PIMS pdf Antal Jarai) that there is a close relationship between invasion percolation and ordinary critical ($p = p_c$) percolation conditioned to percolate, the so-called incipient infinite cluster. The problem studied here is to find the scaling limit of invasion percolation on a tree.

Following preliminary discussions in Fall 2005 between Angel and Slade, work began in earnest in January 2006 when Frank den Hollander arrived in Vancouver as PIMS Distinguished Chair. Given the above it was expected that the scaling limit would be the same as that for the infinite incipient cluster, but in fact the work took a surprising turn when it was realized that this was false. The work resulted in an extensive understanding of invasion percolation on a tree and gave a detailed description of the scaling limit and the mechanism that makes it different. This is interesting on its own, but it also provides valuable insights into what we should expect for invasion percolation on Z^d.

IV. Conclusions The probability and statistical physics group at UBC had been operating as a successful collective unit for some time, but the CRG was an enabling catalyst led to a number of new and larger initiatives. The main ones here were the two large international summer schools which would have never happened without the staff and financial support offered by the CRG. These large initiatives then had a number of spin-offs which in turn were even more successful due to the large number of resident graduate students and postdoctoral fellows. The effects are nonlinear. For example Greg Lawler wanted to organize the meeting for Ed Nelson in the summer of 2004 when he was committed to teach at our first summer school. The solution was clear: host it at PIMS. It brought NSF support with it and enabled a number of the 45 graduate students and pdf's already present to participate in a meeting which was ideal for them. A similar thing happened with the 2005 Workshop in SPDE and Erwin Bolthausen's mini-course on Spin Glass models in 2004. Although we had already been involved in an annual PNW Probability seminar with our colleagues at UW, the CRG did bring these groups closer with Zhenqing Chen's sabbatical at UBC, the participation of a number of UW graduate students in the summer schools, and the organization of the the summer 2006 activities at UW.

Of course, the probability summer schools also provided a dozen PIMS graduate students (UA, UBC, and UW) with the opportunity to enroll in 4 well

attended advanced topics courses given by local and international experts and to integrate themselves in the coming generation by meeting their peers from all round the world. They also gave the PIMS probability group international exposure. The UBC group observed a dramatic increase in quantity and quality in their 2005 and 2006 pdf applicant pool. Many of the best applicants participated in the Summer Schools as graduate students including one of our new pdf's at UBC, Mathieu Merle (ENS). In addition there was a marked increase in the number of Summer school applications in the second year in spite of the existence of a new competing summer school (in July) at Cornell U. as well as other summer schools at Les Houches and Saint Flour. Of these, ours was the only one that offered full length graduate courses. In short there appears to be strong interest in a probability summer school in Vancouver and there are ongoing discussion as to whether or not something permanent could be set up on a rotating basis with other schools. Both schools also provided Lawler and Peres (the latter with Levin and Wilmer) with the opportunity to develop material for text books on fundamental topics in modern probability [L, LLW], while Barlow's notes will appear together with Bolthausen's lectures in a forthcoming volume.

The size of the pdf group in probability at UBC increased from 2 to 3 thanks to the PIMS pdf program and from 3 to 5 during the CRG. This was also assisted by an NSERC Leadership grant. This and the presence of two very active Distinguished Chairs created a much higher level of activity during the academic year including two parallel seminars at UBC in 2005-06, one focussed on open problems, organized by PIMS pdf, Omer Angel. The critical mass allowed considerable interaction between the pdf's themselves. Most of the larger activities were focussed in the summer period where the activity level at UBC in 04-05 and UW in 06 bordered on the exhausting. The plan was that after a period of retrenchment and recovery we would consider doing something like this again in the near future. In fact David Brydges and Gordon Slade are already leading a joint CRM-PIMS period of concentration in Probability. It will be called the CRM-PIMS 2008-09 thematic year in Mathematical Physics and Probability Theory and the probability section will be concentrated in Jan - July, 2009. It will involve many of the protagonists mentioned in this report.

V. Papers arising directly from CRG collaborations

[AGHS] O. Angel, J. Goodman, F. den Hollander, G. Slade. Invasion percolation on regular trees., submitted.

[ABGP] S.R. Athreya, R.F. Bass, M. Gordina, and E.A. Perkins, Infinite dimensional stochastic differential equations of Ornstein-Uhlenbeck type, Stoch. Proc. and their Applic. 116 (2006) 381-406.

[BJKS] M.T. Barlow, A.A. Jarai, T. Kumagai, G. Slade. Random walk on the incipient infinite cluster for oriented percolation in high dimensions, submitted.

[BCK] M.T. Barlow, T. Coulhon and T. Kumagai. Characterization of sub-Gaussian heat kernel estimates on strongly recurrent graphs. *Comm. Pure. Appl. Math.* **LVIII** (2005), 1642-1677.

[BBK] M.T. Barlow, R.F. Bass, T.Kumagai. Stability of parabolic Harnack inequalities on metric measure spaces. *J. Math. Soc. Japan* (2) **58** (2006), 485–519.

[BK] M.T. Barlow, T.Kumagai. Random walk on the incipient infinite cluster on trees. To appear *Illinois J. Math. (Doob volume)*.

[BBC]R.F. Bass, K. Burdzy, and Z.-Q. Chen, On the Robin problem in fractal domains, submitted.

[BBC] R. Bass, C. Burdzy and Z. Chen, Pathwise uniqueness for a degenerate stochastic differential equation, submitted.

[BK] R.F. Bass and T. Kumagai, Symmetric Markov chains on Zd with unbounded range, Trans. Amer. Math. Soc., to appear.

[B] David Brydges, Symanzik, Nelson and Self-Avoiding Walk, chapter in Diffusion, Quantum Theory, and Radically Elementary Mathematics, edited by William G. Faris, editor, volume 47 of Mathematical Notes, Princeton University Press, 2006.

[BT] David Brydges and Anna Talarczyk. Finite range decompositions of positive-definite functions. J. Funct. Anal., 236:682–711, 2006.

[BHK] D. Brydges, Remco van der Hofstad, and Wolfgang König. Joint density for the local times of continuous-time Markov chains. To appear in Annals of Probability, 2006.

[BKES] E. Buckwar, R. Kuske, B. L'Esperance, and T. Soo, Noise sensitivity in machine tool vibrations, International Journal of Bifurcation and Chaos, to appear.

[BKMS] E. Buckwar, R. Kuske, S.E.Mohammed, and T. Shardlow, The Weak Euler Scheme for Stochastic Differential Delay Equations, in review.

[BEPR] S. Bhamidi, S. Evans, R. Peled and P. Ralph, Brownian motion on disconnected sets, basic hypergeometric functions, and some continued fractions of Ramanujan, To appear in a Festschrift for David Freedman.

[DGHSS] D.A. Dawson, A. Greven, F. den Hollander, R. Sun, and J.M. Swart, The renormalization transformation for two-type branching models: I. Construction and basic properties, preprint.

[DMP] Richard Durrett, Leonid Mytnik and Edwin Perkins, Competing Super-
Brownian motions as limits of interacting particle models, *Elect. J. Probability* **10**, 1147-1220 (2005).

[ES] S. Evans and David Steinsaltz, Damage segregation at fissioning may increase growth rates: A superprocess model, submitted.

[KBHK] M.A. Kouritzin, D. Ballantyne, Y. Hu and H. Kim. On sonobuoy placement for submarine tracking, Proc. SPIE Int. Soc. Opt. Eng. 5809, 244-252 (2005).

[L] Greg Lawler, Conformally Invariant Processes in the Plane, AMS, (2005)

[VS] V. Limic and A. Sturm, The spatial Lambda-coalescent" Elect. J. Probability **11**, 363–393, 2006.

[LT] V. Limic and P. Tarres, Attracting edge and strongly reinforced walks, to appear in Ann. Prob.

LW] V. Limic and A. Winter, Representation theorems for interacting Moran models, interacting Fisher–Wright diffusions and applications, Elect. J. Probability **10**, 1286–1358, 2005.

In Preparation:

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