MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Probability and Analysis in the Context of Mathematical Physics and Biology

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This meeting was organized by Andreas Greven (Erlangen) and Frank den Hollander (Nijmegen).

Mathematical physics and mathematical biology are rapidly developing areas. Probability theory and analysis provide the main part of the mathematical ideas, techniques and results. In particular, the combination of probabilistic and analytic tools prove to be useful. The 30 lectures of this meeting (among which were 10 talks of 90 minutes duration) gave an overview on the recent development and the state of the art in such fields as branching processes, hydrodynamic scaling, genetic evolution models, genetic algorithms, large deviations, statistical mechanics, and geophysics.

Even though the conference was in the last week before Christmas it attracted the top specialists from all over the world. Certainly it was a highlight of modern probability theory in Germany this year.

This report was written by Achim Klenke

Abstracts

PAVEL BLEHER

Scaling Limits and Universality in the Matrix Model

(joint work with Alexander Its)

About thirty years ago Freeman Dyson found an exact solution for the scaling limit of correlations between eigenvalues in the Gaussian unitary ensemble of random matrices. He conjectured that this scaling limit should appear in a much broader class of non-Gaussian unitary ensembles of random matrices. This constitutes the famous conjecture of universality in the theory of random matrices. Dyson found also a remarkable formula which expresses the eigenvalue correlations in terms of orthogonal polynomials on the line with exponential weight. This enables to reduce the universality conjecture to semiclassical asymptotics of orthogonal polynomials. In the talk we will discuss a new approach to the semiclassical asymptotics of orthogonal polynomials on the line with respect to exponential weights. This approach is based on the methods of the theory of integrable systems and on an appropriate matrix Riemann-Hilbert problem. As an application of the semiclassical asymptotics, we prove the conjecture of universality for unitary ensembles of random matrices for models with quartic interaction.

GÉRARD BEN AROUS

Aging regime and dynamical phase transition for a spherical model of spin glasses

We presented a survey about dynamics of Sherrington-Kirkpatrick spin-glasses, in Langevin form as recently worked out in a series of papers with A. Guionnet. We analyzed the longtime behaviour of the limiting self-consistent dynamics, which prove to be non-Markovian in a simplified model, i.e. the spherical one.

In this context, in a joint work with A. Dembo and A. Guionnet we find a dynamical phase transition, and one aging regime, i.e. for low temperature, the time-correlation of these limiting dynamics is such that

$$\lim_{\substack{s \to \infty \\ t \to \infty \\ t_s = o(s)}} C(s,t)$$

is a constant but

$$C(s,t) \sim \kappa \left(\frac{t-s}{s}\right)^{-3/4} \qquad \text{if } t_s \gg s.$$

MICHIEL VAN DEN BERG

Heat Equation on the Arithmetic von Koch Snowflake

Let $0 < s \leq 1/3$, and consider a unit square in $\mathbb{R}^2$. Replacing repeatedly the middle proportion s of each side by the three other sides of a square results in the s-adic von Koch snowflake K_s. Let T_{K_s} be the first exit time of K_s of a Brownian motion. We show that if

(i) K_s is non-arithmetic (i.e., $\log(\frac{1-s}{2})/\log(s) \notin \mathbb{Q}$) then

$$\int_{K_s} P_x[T_{K_s} \leq t]\, dx = C_s t^{1-d_s/2} + o(t^{1-d_s/2}), \quad t \downarrow 0$$

for some positive constant C_s;

(ii) K_s is arithmetic with $\log(\frac{1-s}{2})/\log(s) = \frac{p}{q}$, $p \in \mathbb{Z}^+$, $q \in \mathbb{Z}^+$, $(p,q) = 1$ then there exists a strictly positive, $\frac{2}{q}\log\frac{1}{s}$-periodic function Φ_s such that

$$\int_{K_s} P_x[T_{K_s} \leq t]\, dx = \Phi_s(-\log t) t^{1-d_s/2} + o(t^{1-d_s/2}), \quad t \downarrow 0,$$

d_s is the interior Minkowski dimension of the boundary of K_s, and is given by the unique positive root of $3s^d + 2\left(\frac{1-s}{2}\right)^d = 1$.

KRZYSZTOF BURDZY

A new Ray-Knight-type theorem

(joint work with Richard Bass)

Let B_t be a Brownian motion, $\beta_1, \beta_2 \in \mathbb{R}$, and let X_t^y be the solution to

$$\frac{dX_t^y}{dt} = \begin{cases} \beta_1 & \text{if } X_t^y < B_t \\ \beta_2 & \text{if } X_t^y > B_t; \end{cases} \qquad X_0^y = y.$$

Let L_t^y be the local time of $X_t^y - B_t$ at 0. Fix some $t > 0$. Then dX_t^y/dy is a smooth function of L_t^y. If $\beta_1, \beta_2 > 0$ and $\beta_1 - \beta_2 > 0$ then $\{L_\infty^y, y \geq 0\}$ and $\{L_\infty^{-y}, y \geq 0\}$ are diffusions. The function $y \to X_t^y$ is $C^{1,\gamma}$ for $\gamma < 1/2$ but it is not $C^{1,1/2}$.

TERENCE CHAN

Dynamic scaling exponents for interacting KPZ equations

Consider the following non-linear stochastic partial differential equation (known as the Kardar-Parisi-Zhang equation)

$$\frac{\partial u}{\partial t} = \nu \Delta u + \frac{\lambda}{2}|\nabla u|^2 + \sigma W(t,x), \quad u(0,x) = f(x),$$

and more generally, the system of equations

$$\frac{\partial u_0}{\partial t} = \nu \Delta u_0 + \frac{\lambda}{2}|\nabla u_0|^2 + \frac{\theta}{2}(|\nabla u_1|^2 + |\nabla u_2|^2) + \sigma_0 W_0(t,x),$$
$$\frac{\partial u_i}{\partial t} = \nu \Delta u_i + \lambda \nabla u_0 \cdot \nabla u_i + \sigma_i W_i(t,x), \quad i = 1,2.$$

(Here, $x \in R^d$, ν, λ, θ and σ_i are constants and W_i are independent space-time white noises. The initial conditions $f_i(x)$ are given.) It has long been accepted in the physics literature that the solution u (and more generally u_i) satisfy scaling properties of the form $b^{-1}E[u(b^{3/2}t, bx)^2] = E[u(t,x)^2]$, or $b^{-1/2}u(b^{3/2}t, bx)$ converges in some sense to a non-degenerate limit. However, except for the case of 1 spatial dimension ($d = 1$), the solution of such SPDEs are typically some kind of stochastic distribution (for example in the Hida sense) and cannot be interpreted as ordinary random variables. There is therefore a non-trivial problem in giving a meaning to the non-linear terms in the above equations and also to things like $E[u(t,x)^2]$ (except in the 1-dimensional case). The appropriate interpretation of the non-linear terms turns out to be Wick products (which is actually already implicit in much of the physics literature). This talk presents a family of weighted L^2-like spaces of distributions to which solutions to the KPZ equations belong; moreover, the solutions admit a Wiener chaos expansion. This allows one to give a natural meaning to ideas like expectation and convergence in distribution – ideas which are crucial to any discussion of scaling properties. However, a mathematically rigorous proof of the aforementioned scaling properties is still an open problem.

PHLIPPE CLÉMENT

On the Attracting Orbit of a Nonlinear Transformation Arising from Renormalization of Hierarchically Interacting Diffusions

(joint work with Jean-Bernard Baillon, Andreas Greven and Frank den Hollander)

In this lecture the asymptotic behavior of the iterates of a non-linear transformation F acting on a class of functions $g : [0,\infty) \to [0,\infty)$ is considered. This problem arises in a probabilistic context, namely the study of systems of hierarchically interacting diffusions discussed in the previous lecture by Professor Dawson. This study is a part of a larger area, where the goal is to understand universal behavior on large space-time scales of stochastic systems with interacting components.

The transformation F under consideration plays the role of a *renormalization transformation* for an infinite system of diffusions, taking values in $[0,\infty)$ and interacting with each other in a hierarchical fashion. The iterates $F^n g$ ($n \geq 0$) describe the behavior of this system along an *infinite hierarchy of space-time scales* indexed by n. The n-th iterate $F^n g$ is the local diffusion rate of a typical block average on space-time scale n. If for some class of functions g, we have

$$\lim_{n\to\infty} F^n g = g^* \quad \text{(in an appropriate sense)}$$

where g^* is a fixed point of F and is independent of g in the class, then the space-time scaling limit of the corresponding infinite system of interacting diffusions on $[0,\infty)$ has universal behavior independent of model parameters.

The Transformation

Let $\mathcal{H}$ denote the class of functions $g : [0, \infty) \to [0, \infty)$ locally Lipschitz continuous satisfying $g(0) = 0$, $g(x) > 0$ for $x > 0$ and $\lim_{x\to\infty} x^{-2}g(x) = 0$. For $g \in \mathcal{H}$, let $(\nu_\theta^g)_{\theta\in[0,\infty)}$ be the family of probability measures on $[0, \infty)$ given by $\nu_0^g = \delta_0$ (point measure at 0) and

$$\nu_\theta^g(dx) = \frac{1}{Z_\theta^g}\left\{\frac{1}{g(x)}\exp\left[-\int_\theta^x \frac{y-\theta}{g(y)}dy\right]\right\}dx, \quad \theta > 0,$$

where Z_θ^g is the normalizing (finite) constant. The transformation F is defined as

$$(Fg)(\theta) = \int_0^\infty g(x)\nu_\theta^g(dx), \quad \theta \in [0, \infty).$$

Since ν_θ^g is the equilibrium (probability) measure of a single diffusion with drift towards θ and with local diffusion rate given by g, $(Fg)(\theta)$ is the average diffusion rate in equilibrium as a function of the drift parameter θ. It appears that for $g \in \mathcal{H}$, $(Fg)(\theta)$ is well-defined for $\theta \in [0, \infty)$ and that $Fg \in \mathcal{H}$.

Fixed points of F

From the moment relations:

$$\int_0^\infty \nu_\theta^g(dx) = 1, \quad \int_0^\infty x\nu_\theta^g(dx) = \theta,$$
$$\int_0^\infty x^2\nu_\theta^g(dx) = \theta^2 + (Fg)(\theta),$$

for all $g \in \mathcal{H}$ and $\theta \in [0, \infty)$, it follows in particular that the linear functions $g_a(x) = ax$, $a > 0$, $x \geq 0$, are fixed points of F in the class $\mathcal{H}$. We have:

Theorem A *There are no fixed points in $\mathcal{H}$ other than $(g_a)_{a\in(0,\infty)}$.*

Universal behavior

Theorem B *If for $g \in \mathcal{H}$, $\lim_{x\to\infty} x^{-1}g(x) = a \in (0, \infty)$, then $\lim_{n\to\infty} F^n g = g_a$ uniformly on bounded intervals.*

Idea of the proof of Theorem B

After observing that the map $F : \mathcal{H} \to \mathcal{H}$ is order-preserving, i.e. $g_1, g_2 \in \mathcal{H}$ and $g_1 \leq g_2$ implies $Fg_1 \leq Fg_2$, we use a "monotone iterations" argument. Let g^+ (resp. g^-) denote the concave upper (resp. convex lower) enveloppe of g, then $g^+ \geq Fg^+$, $Fg^- \geq g^-$ follow from the first two moment relations and Jensen's inequality and from $g^+ \geq g \geq g^-$ follows $F^n g^+ \geq F^n g \geq F^n g^-$, $n \geq 1$.

Next it is shown that the monotone decreasing (resp. increasing) sequence $F^n g^+$ (resp. $F^n g^-$) converges to a fixed point, which by Theorem A is a linear function g_{a^+} (resp. g_{a^-}). From $\lim_{x\to\infty} x^{-1}g^+(x) = \lim_{x\to\infty} x^{-1}g^-(x) = a$, we infer $a^+ = a^- = a$.

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Idea of the proof of Theorem A

We use the "quasilinear" structure of the transformation F. Let $\mathcal{B}$ be the class of measurable functions h on $(0,\infty)$ be such that there exist $a, b \geq 0$ with $|h(x)| \leq a + bx^2$, $x \geq 0$. Then for each $g \in \mathcal{H}$,

$$(K_g h)(\theta) := \int_0^\infty h(x)\nu_\theta^g(dx), \quad \theta \geq 0$$

is well-defined and $K_g h \in \mathcal{B}$. Note that $\mathcal{H} \subset \mathcal{B}$ and $K_g g = Fg$. The linear operator $K_g : \mathcal{B} \to \mathcal{B}$ can be shown to map convex functions into convex functions. Setting $K_g^{(n)} := K_{F^{n-1}g} \circ \cdots \circ K_{F^0 g}$, with $F^0 = \mathrm{Id}$, $n =\geq 1$, we have by iterating the moment relations:

$$K_g^{(n)} e_0 = e_0, \quad K_g^{(n)} e_1 = e_1 \quad \text{and}$$
$$K_g^{(n)} e_2 = e_2 + n(F^n g), \quad n \geq 1,$$

where $e_j(x) = x^j$, $j = 0, 1, 2$.

If $g^* \in \mathcal{H}$ is a fixed point of F, we have

$$g^* = \lim_{n\to\infty} F^n g^* = \lim_{n\to\infty} \frac{1}{n} K_g^{(n)} e_2,$$

which is convex since e_2 is convex.

By using a comparison argument with a translate of a linear function (supporting the convex function g^*) and a kind of "strong" order preserving property of F one concludes that g^* has to be linear.

Reference J. Funct. Anal. 146, No. 1, 236–298 (1997) where other properties of the transformation F are discussed.

TED COX

A spatial model for the abundance of species

(joint work with Maury Bramson and Rick Durrett)

In recent years theoretical biologists have begun to use interacting particle systems to model biological and ecological systems. These models are typically quite complicated, making mathematical analysis difficult. This talk summarizes recent work of Bramson, Cox and Durrett on a simple interacting particle system viewed as a model of speciation, for which rigorous results can be obtained. This work was motivated in part by recent data of Hubbell on species abundances of woody plants in a 50 hectare plot on Barro Colorado Island, Panama. In this study, counts of different plant species were made, and the data arranged in "octaves." That is, if $N(i)$ is the number of different species which had exactly i representatives observed, and $N(I) = \sum_{i\in I} N(i)$, the data was recorded in the form $N(I_j)$, with $I_j = [2^j, 2^{j+1})$, $j = 0, 1, \ldots$

The mathematical model used is the two-dimensional multitype voter model with mutation, ξ_t. This model is easily defined. Let $\mathbb{Z}^2$ be the two-dimensional integer lattice, and let $\xi_t(x)$ denote the type at site x at time t, $\xi_t(x) \in (0,1)$. At each site x, at rate 1, independently of all other sites, a site y is chosen at random from the nearest neighbors of x, and the type at site x is replaced by the type at site y. In addition, at rate α (the mutation rate), the type at x is replaced by a new type not previously observed in the system. For strictly positive α, there is a unique equilibrium ξ_∞ such that for any initial state ξ_0, $\xi_t \to \xi_\infty$ in law as $t \to \infty$. We are interested in the species abundance distribution of ξ_∞ for small α.

Inside $B(L)$, the square of side L centered at the origin, we count the number of different types in ξ_∞ which are represented by exactly i sites, and denote this by $N^L(i)$. Let $N^L(I) = \sum_{i \in I} N^L(i)$, and assume that $L = L(\alpha)$ satisfies $\alpha L^2 \geq \theta(\log(1/\alpha))^4$ for a positive constant θ. Thus, as $\alpha \to 0$, $L \to \infty$. We show that as $\alpha \to 0$, for intervals I_j which are large but not too large, $N(I_j) \approx c(\alpha L^2)j$ for an appropriate constant c, and this approximation is valid uniformly over the range considered. We also obtain another estimate for the very large I_j, and observe exponential fall off in this range.

The limiting formulas obtained do not closely fit Hubbell's data; this is to be expected, since one has gone "too far" in the limit $\alpha \to 0$. However, abundance data obtained from simulations of the two-dimensional model on large grids for small but positive α seem to fit very well. It also appears that the the two-dimensional model provides a much better fit to Hubbell's data than does the corresponding mean field model.

DONALD DAWSON

Multiple Space-Time Scale Analysis of Hierarchically Interacting Measure-valued Processes

This work is motivated by the study of stochastic models of macroevolution. These models involve a collection of subpopulations $\{X_\xi(t) \in M_1[E] : \xi \in S, t \geq 0\}$ where S is the set of population sites and E is the set of types of individuals. The dynamics includes local demographic fluctations given either by measure-valued branching or Fleming-Viot sampling. We assume that $S = \Omega_N$, the hierarchical group indexed by the positive integer N and that the migration is given by a random walk in which individual jumps to a randomly chosen point in the ball of radius k with rate c_k/N^k. The recurrence-transience dichotomy for these random walks is related to the divergence or convergence of the series $\sum(c_k)^{-1}$. We then consider the infinite interacting system including local demographic fluctuations and migration via the random walk. When the random walk is transient and the initial configuration is stationary and ergodic the system converges to a mean-preserving equilibrium. Otherwise, the only invariant measures are concentrated on configurations consisting of a single type. The final ingredient in our analysis is the asymptotic study of the system when the parameter N goes to ∞. This leads to a $M_1[E]$-valued reverse time Markov chain which describes the multiscale behavior of this system. It turns out that the measure-valued branching and Fleming-Viot systems arise as attractors for two "universality" classes. For example, in the special case in which $E = \{0,1\}$ and the resulting Fisher-Wright dynamics is replaced by a more general class of diffusions, the Fisher-Wright nevertheless emerges at large space-time scales in the recurrent case. This convergence has been studied by Baillon, Clément, Greven and den Hollander. Finally, we give a short discussion of the effects of selection and mutation-selection on these systems.

JEAN-DOMINIQUE DEUSCHEL

Anharmonic Droplet Construction and Large Deviations

(joint work with Giambattista Giacomin and Dmitry Ioffe)

We consider a continuous S-O-S model with Hamiltonian

$$H_{D_N}(\phi) = \sum_{<x,y>} V(\phi(x) - \phi(y))$$

here the sum is over nearest neighbors and we set $\phi_x \equiv 0$ at the boundary of the set $D_N = ND \cap \mathbb{Z}^d$. In case $V(\phi) = \phi^2$ this corresponds to a Gaussian, or harmonic model. We are looking at anharmonic models, assuming strict convexity of the function V.

Let

$$X_N(\phi)(x) = \frac{1}{N}\phi([Nx]), \qquad x \in D$$

be the rescaled profile. Our aim is to described the asymptotic of the law of X_N under a hard wall condition $\{X_N(\phi)(x) \geq 0\}$ and a volume condition $\{\int_D X_N(\phi)\,dx \geq v\}$ for some $v > 0$. We prove that as $N \to \infty$, the profile converges to a deterministic shape ψ_v, solution of the variational problem

$$\inf\{I_D(\phi) = \int_D \sigma(\nabla\phi(x))\,dx : \phi \in H_0^1(D) \int_D \phi(x)\,dx \geq v\}.$$

Here σ is the strictly convex surface tension. Our main step in the proof is the derivation of a large deviation principle for $X_N(\phi)$ with rate function I_D.

JÜRGEN GÄRTNER

Exact asymptotic formulas for moments and Lifshitz tails of the Anderson Hamiltonian

(joint work with S. A. Molchanov)

We consider the tails $\bar{N}(\lambda)$, $\lambda \to \infty$, of the spectral distribution function for the Hamiltonian $\mathcal{H} = \kappa\Delta + \xi$ in $l^2(\mathbb{Z}^d)$. Here $\xi(x)$, $x \in \mathbb{Z}^d$, is a field of i.i.d. random variables with tails $\bar{F}(\lambda) = P(\xi(0) > \lambda)$ which decay slower than double exponential tails. This means that the overwhelming part of the high exceedances of the potential consists of single site 'peaks'. Under these assumptions we show that the tail behavior of $\bar{N}(\lambda)$ is determined by the tails of the principle eigenvalue of $\mathcal{H}$ in a ball of fixed large radius (with Dirichlet and reflection boundary conditions, respectively). In particular, this allows to derive exact asymptotic formulas for $\bar{N}(\lambda)$ as $\lambda \to \infty$ in the case of fractional exponential tails $\bar{F}(\lambda) = \exp\{-\lambda^\gamma\}$, $0 < \gamma < \infty$. A similar approach allows to find corresponding formulas for the moments of the solution to the Cauchy problem $\partial u/\partial t = \mathcal{H}u$, $u(0,x) \equiv 1$.

KENNETH HOCHBERG

The Longtime Behaviour of Multilevel Branching Systems

(joint work with Andreas Greven)

We consider $(Y_t)_{t\geq 0}$, a critical two-level superprocess on $\mathbb{R}^d$, that is the high-density, short-lifetime, small-mass diffusion limit of the following particle system. Initially, particles are situated in $\mathbb{R}^d$ and are grouped into superparticles. Since the superparticles can be viewed as being elements of $\mathcal{M}(\mathbb{R}^d)$, the state of the two-level system is an element of $\mathcal{M}(\mathcal{M}(\mathbb{R}^d))$, with $\mathcal{M}$ denoting the set of positive Radon measures. Individual particles move according to a Brownian motion, and they split or die according to a critical branching mechanism with finite variance in which the offspring always belong to the same parent superparticle. In addition, every superparticle is replaced by two copies of itself or becomes extinct, with equal probability.

Our focus is on the behaviour of the process $(Y_t)_{t\geq 0}$ as $t \to \infty$ and, in particular, on the features that are different from those of a single-level system—i.e., super-Brownian motion. Specifically, we discuss classes of initial distributions for which the behaviour of the law of Y_t as $t \to \infty$ can be determined.

The longtime behaviour depends on the relative strength of the two competing forces, migration and branching—one flattening the mass distribution and the other causing local accumulation of mass. In low dimensions, the branching dominates, while in higher dimensions, the migration tends to dominate. In dimensions $d \leq 4$, the limit of $\mathcal{L}(Y(t))$ will be $\delta_{\delta_{\underline{0}}}$ or $\delta_{\delta_{\underline{\infty}}}$ where $\underline{0}$ denotes the zero measure and $\underline{\infty}$ denotes the measure that satisfies $\underline{\infty}(A) = \infty$ for every Borel set with positive Lebesgue measure. Because of the influence of the level-1 branching, each of the dimensions 1,2,3,4 has a distinct way of approaching $\delta_{\delta_{\underline{0}}}$ or $\delta_{\delta_{\underline{\infty}}}$, respectively.

In dimensions $d > 4$, the limit is either a nondegenerate equilibrium state with finite intensity or has the degenerate form $\delta_{\delta_{\underline{0}}}$ or $\delta_{\delta_{\underline{\infty}}}$; the determination as to which limit occurs depends on two parameters—-the initial intensity of the particles and the spatial distribution of the superparticles. In particular, in $d > 4$, for a given particle intensity there are different equilibrium states, depending on the subdivision into superparticles. Nonetheless, it is also possible that in $d > 4$ the system becomes extinct, in the event that the particles are initially grouped into superparticles that are too "large" in a certain well-defined sense. In contrast, for super-Brownian motion, the intensity is the only relevant parameter determining the longtime behaviour of an initial law in high dimensions.

ACHIM KLENKE

Branching Random Walk in a Catalytic Medium

(joint work with Andreas Greven and Anton Wakolbinger)

Consider (critical binary) branching random walk $(\xi_t)_{t\geq 0}$ on $\mathbb{Z}^d$ in a space-time varying catalytic medium $(\eta_t)_{t\geq 0}$. The medium determines the local branching rate of $(\xi_t)_{t\geq 0}$. We consider the special case where $(\eta_t)_{t\geq 0}$ is itself ordinary branching random walk. Our aim is to investigate the longtime behavior of $(\xi_t)_{t\geq 0}$ if both $(\eta_t)_{t\geq 0}$ and $(\xi_t)_{t\geq 0}$ are started in Poison field field with intensity 1.

(1) If $(\eta_t)_{t\geq 0}$ is persistent (i.e. if its symmetrized motion is recurrent), $(\xi_t)_{t\geq 0}$ shows the classical dichotomy of extinction and persistence.

(2) If both $(\eta_t)_{t\geq 0}$ and $(\xi_t)_{t\geq 0}$ perform symmetric simple random walk in $\mathbb{Z}$, $(\eta_t)_{t\geq 0}$ dies out fast enough such that $(\xi_t)_{t\geq 0}$ converges to a Poisson mean 1 field. However, if $(\xi_t)_{t\geq 0}$ has a drift it hits all the catalyst clusters and dies out (in distribution).

(3) If $(\eta_t)_{t\geq 0}$ and $(\xi_t)_{t\geq 0}$ perform both according to symmetric simple random walk on $\mathbb{Z}^2$, a new phenomenon occurs. Since $(\eta_t)_{t\geq 0}$ dies out locally only in distribution and not almost surely, $(\xi_t)_{t\geq 0}$ converges to a limit that reflects the history of the catalytic medium: a mixed Poisson field. The law of the mixture can be understood in terms of the density of catalytic super-Brownian motion, investigated in a recent paper with Klaus Fleischmann.

WOLFGANG KÖNIG

Moment Asymptotics for the Continuous Anderson Model

(joint work with Jürgen Gärtner)

We consider the parabolic problem

$$\begin{aligned} \partial u(t,x) &= \kappa\Delta u(t,x) + u(t,x)\xi(x), \quad t>0,\ x\in\mathbb{R}^d, \\ u(0,\cdot) &= 0, \end{aligned}$$

where $\xi = \{\xi(x); x\in\mathbb{R}^d\}$ is a random stationary Hölder continuous potential. We write $\langle\cdot\rangle$ for expectation w.r.t. ξ and assume the finiteness of $H(t) = \log\langle e^{t\xi(0)}\rangle$ for all $t>0$. Furthermore, we assume that the potential has high peaks on small islands with certain probabilities; more precisely, for some scale function $\alpha(t)\to 0$ and all test measures $\mu\in\mathcal{P}_c(\mathbb{R}^d)$, the limit

$$J(\mu) = -\lim_{t\to\infty}\frac{\alpha^2(t)}{t}\log\left(\langle e^{t\int\xi(\alpha x)\,\mu(dx)}\rangle e^{-H(t)}\right)$$

is assumed to exist. Then our main result says that, for all $p\in[1,\infty)$, the asymptotic expansion

$$\langle u(t,0)^p\rangle = \exp\left\{H(t) - \frac{t}{\alpha^2(t)}(\chi + o(1))\right\}$$

holds where the convergence parameter is given by $\chi = \inf\{J(\mu)+\mathcal{S}(\mu)\colon \mu\in\mathcal{P}_c(\mathbb{R}^d)\}$, and $\mathcal{S}$ is the Donsker-Varadhan rate function for the Brownian occupation-times measures. We explain the result in terms of the largest eigenvalue of the random operator $\kappa\Delta+\xi$.

Gregory F. Lawler

Intersection Exponent and Multifractal Spectrum for Brownian Paths

The intersection exponent for Brownian motion is a measure of how likely Brownian motion paths in two and three dimensions do not intersect. We consider the intersection exponent $\xi(\lambda) = \xi_d(k, \lambda)$ as a function of λ and show that ξ has a continuous, negative second derivative. One major application of this result is to the multifractal spectrum of harmonic measure on a Brownian path; we show that the multifractal spectrum is nontrivial and give a formula for the spectrum in terms of the intersection exponent.

Thomas M. Liggett

Stochastic Growth Models on Trees

The contact process on a graph G is a continuous time Markov process with state space the collection of all subsets of G. Points are removed from the set at rate one, and points are added to the set at a rate that is a constant multiple of the number of neighbors in the set. When $G = \mathbb{Z}^d$, there is a critical value that separates the regimes of survival and extinction. It was proved by Bezuidenhout and Grimmett that in the subcritical regime, extinction occurs at a time with exponential tails, while in the supercritical regime, survival occurs in a strong sense, expressed for example by the complete convergence theorem. In particular, there are always either exactly one or exactly two extremal invariant measures.

In 1992, Pemantle proved that the picture is richer on (most) homogeneous trees. There are now two critical values, and three types of behavior: extinction, weak survival, and strong survival. This talk is a survey of the dozen+ papers that have appeared since 1992 on this process. Greatest interest centers on the intermediate phase of weak survival. Here there are infinitely many extremal invariant measures. Two families of invariant measures are constructed.

Jean-François Le Gall

Branching processes, supoerprocesses and Lévy processes

We discuss some recent developments concerning the genealogy of continuous-state branching processes, and their applications to superprocesses and interacting particle systems. The genealogy of a discrete-time Galton-Watson branching process is described by a discrete tree, the genealogical tree of the population. One of the goals of this talk is to study the analogous description for the genealogy of continuous-state branching processes, which are the possible scaling limits of discrete-time Galton-Watson branching processes. To this end, we determine the so-called contour process associated with the genealogical structure of a continuous-state branching process. Informally, the contour process of a tree gives the motion of a particle that explores the tree by moving up and down along its branches. In the special case of Feller's diffusion, the simplest continuous-state branching process, it has been known for a long time that the associated contour process is reflecting Brownian motion on the positive real line. A consequence of this fact is the Brownian snake construction of superprocesses with a quadratic branching mechanism. This construction can be applied to various properties of solutions of the partial differential equation $\Delta u = u^2$ in a domain, including the existence of solutions with boundary blow-up and the classification of general nonnegative solutions.

As another application of the description of the genealogy of Feller's diffusion, we investigate certain limit theorems for systems of coalescing random walks and for the voter model. In particular, for the voter model in $\mathbf{Z}^d$ starting initially with all types different, we show that the random measure describing the positions at time t of all individuals with the same type as the origin converges (after a suitable rescaling) asymptotically to a simple functional of super-Brownian motion (joint work with M. Bramson and T. Cox).

For a general continuous-state branching process, the contour process can be determined as a simple functional of a spectrally positive Lévy process (joint work with Yves Le Jan). This leads to a new connection between branching processes and Lévy processes, which can be used to derive new results in both theories. In particular, we get an extension for general spectrally positive Lévy processes of the classical Ray-Knight theorem on Brownian local times. We also derive a path-valued process construction of superprocesses with a general branching mechanism, which extends the Brownian snake approach of the quadratic case.

JOHN T. LEWIS

Large Deviation Theory and Statistical Mechanics

The insights which Large Deviation Theory has provided in Statistical Mechanics have far-reaching consequences; I describe some of these including the use of equipartition measures in information theory and ergodic theory.

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- J.T. Lewis, Ch.-E. Pfister, W.G. Sullivan: Large Deviations and Generic Points (DIAS preprint, 1998)

TERRY LYONS

Biological Models for Solving Stochastic PDEs

The Zakai/Kushner Stratonovich SPDE of nonlinear filtering is typical of a class of parabolic pdes where there is a practical interest in obtaining numerical solutions in moderately high dimensions - and where the solution is a probability measure. In this case effective algorithms can be built from Branching particle systems. The greatest efficiency is achieved if the variance of these random algorithms can be minimised) - this has been been achieved in some directions - but the question of how to recombine particles efficiently has not been settled completely satisfactorily at the present time.

The methods developed to date are effective, and of value. They are due to a number of people Relevant references are Grisan, Lyons PTRF 1997, Grisan, Gaines, Lyons SIAM 1998, and papers of del Moral, Guionnet, Grisan, Smith, Gordon, Clifford,...

STEFANO OLLA

Equilibrium Fluctuations for the Ginzburg-Landau $\nabla\varphi$ Interference Model

(joint work with G. Giacomin and H. Spohn)

Consider an effective interface in $d+1$ dimensions $\{\varphi(x) \in \mathbb{R},\ x \in \mathbb{Z}^d\}$ with interference energy

$$H(\varphi) = \sum_{\alpha=1}^{d} \sum_{x} V_\alpha(\varphi(x+e_x) - \varphi(x))$$

(massless field model). We consider the corresponding Langevin dynamics

$$d\varphi_t(x) = -\frac{\partial H}{\partial \varphi(x)} dt + dW_t(x).$$

The Gibbs measure e^{-H}/Z is reversible with respect to this dynamics.

We prove that the fluctuation field

$$\xi^\varepsilon(f,t) = \varepsilon^{1+d/2} \sum_x f(\varepsilon x)\varphi_{\varepsilon^{-2}t}(x)$$

converges in law, as $\varepsilon \downarrow 0$, to the infinite dimensional Ornstein-Uhlenbeck process

$$d\xi(f,t) = -\xi(Af,t)dt + dW(x,t)$$

with drift operator $A = -\sum_{i,j} \partial_i q_{ij} \delta_j$; and we give a variational characterization and upper and lower bounds for the diffusion matrix q_{ij}.

GEORGE PAPANICOLAOU

A survey of some recent work on waves in random media with applications to seismology

I presented three problems: The O'Doherty-Anstey theory for the behavior of the front of pulses travelling in randomly layerd media, the universality theory for wave localization in the time domain (also for randomly layered media), and the universality theory for the P to S wave energy ratio in the deep coda of elastic waves in general random media.

Charles-Edouard Pfister

Large deviations and surface phase transition

(joint work with Y. Velenik)

We study the 2D Ising model in a square box Λ_L of linear size L, when the temperature is below the critical one. There is a real boundary magnetic field h acting on one side of the box. We determine the exact asymptotic behaviour of the large deviations of the magnetization $\sum_{t\in\Lambda_L}\sigma(t)$ when L tends to infinity. Scaling the lengths by $1/L$, the model is defined in a fixed box B of the Euclidean plane. The main result is the following one.

Let $\beta > \beta_c$; h a real number; $-m^* < m < m^*$ (spontaneous magnetization) and $0 < c < 1/4$. Then there exist a, $0 < a < 1$ and L_0 such that for all $L \geq L_0$,

$$\mathrm{Prob}_{L,\beta,h}\Big[\Big|\sum_{t\in\Lambda_L}\sigma(t) - m|\Lambda_L|\Big| \leq \frac{|\Lambda_L|}{L^c}\Big] = \exp\Big(-L \inf_{\substack{K\subset B\\ Vol\,K=\frac{m^*-m}{2m^*}}} \mathcal{F}(\partial K) + O(L^a)\Big),$$

where $\mathcal{F}(\partial K)$ is a functional on curves in B, given by

$$\mathcal{F}(\partial K) = \int_{\partial K}\tau(n_s)\,ds + \Delta(\beta,h)|\partial K\cap W|\,.$$

Here $\tau(n_s)$ is the surface tension of an interface perpendicular to n_s; $\Delta(\beta,h)$ is a boundary free energy coming from the action of the magnetic field h on the side W of the box B; $|\partial K\cap W|$ is the Lebesgue measure of $\partial K\cap W$.

There are two regimes. There exists $h_w(\beta)$ such that if $h > h_w(\beta)$, then $\Delta(\beta,h) = 0$. If $h < h_w(\beta)$, then $\Delta(\beta,h) < 0$, so that the solution of the isoperimetric problem depends explicitly on h. The solution is a convex body whose boundary has a non-empty intersection with the side W of B.

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Michael Röckner

Analysis and Geometry on Configuration Spaces: the Gibbsian Case

(joint work with Sergio Albeverio and Yuri Kondratiev)

Using a natural "Riemannian–geometry–like" structure on the configuration space Γ over $\mathbb{R}^d$, we prove that for a large class of potentials ϕ the corresponding canonical Gibbs measures on Γ can be completely characterized by an integration by parts formula. That is, if ∇^Γ is the gradient of the Riemannian structure on Γ one can define a corresponding divergence div_ϕ such that the canonical Gibbs measures are exactly those measures μ for which ∇^Γ and div_ϕ are dual operators on $L^2(\Gamma,\mu)$.

One consequence is that for such μ the corresponding Dirichlet forms $\mathcal{E}_\mu^\Gamma$ are defined. In addition, each of them is shown to be associated with a conservative diffusion process on Γ with invariant measure μ. The corresponding generators are extensions of the operator $\Delta_\phi^\Gamma := \mathrm{div}_\phi \nabla^\Gamma$. The diffusions can be characterized in terms of a martingale problem and they can be considered as a Brownian motion on Γ perturbed by a singular drift. Another main result of this paper is the following: if μ is a canonical Gibbs measure, then it is extreme (or a "pure phase") if and only if the corresponding weak Sobolev space $W^{1,2} = (\Gamma,\mu)$ on Γ is irreducible. As a consequence we prove that for extreme canonical Gibbs measures the above mentioned diffusions are time–ergodic. In particular, this holds for tempered grand canonical Gibbs measures ("Ruelle measures") provided the activity constant is small enough. We also include a complete discussion of the free case (i.e., $\phi \equiv 0$) where the underlying space $\mathbb{R}^d$ is even replaced by a Riemannian manifold X.

HERMANN ROST

Stationary Non-equilibrium States in a Random Environment

One perturbs the selfadjoint (=reversible) Markov chain with random jump rates $a(x,y) = a(y,x)$ on $\mathbb{Z}^d$ by passing to $\tilde{a}(x,y) = \exp(u\cdot(y-x))$, where $u \in \mathbb{R}^d$ is a fixed vector, interpreted as external field if the chain describes the position of a charged particle. The problem is to find an invariant measure $\overline{u}(x)$, $x \in \mathbb{Z}^d$, which is spatially stationary, jointly with the environment $a(\cdot,\cdot)$. In generality, the pattern is not yet solved. Partial solutions for $d = 1$ or a periodic environment are known to exist. Here we show that on a strip $\mathbb{Z} \times$ finite set a solution exists and that the current induced by the field is bounded from below, independently of the width of the strip. The method of showing that relies on a model study for finite Markov chains, in which reversibility is perturbed by adding an "external term" which is not of the gradient type.

ALEXANDER SCHIED

A Rademacher Type Theorem on Configuration Space and some Applications

(joint work with Michael Röckner)

We consider an L^2-Wasserstein type distance ρ on the configuration space Γ_X over a Riemannian manifold X. Typically the distance between two configurations will be infinite - a situation reminiscent of the Cameron-Martin norm on Wiener space. We prove that ρ-Lipschitz functions are contained in a certain Dirichlet space associated with a measure on Γ_X satisfying certain assumptions. They are in particular fulfilled by a large class of tempered grandcanonical Gibbs measures with respect to a superstable lower regular pair potential. Both examples rely on the recent integration by parts formula of Albeverio, Kondratiev and Röckner (1997). As an application we show that, if A is a set with full measure, then the set of all configurations having non-zero ρ-distance to A is exceptional. This immediately implies, for instance, a quasi-sure version of the spatial ergodic theorem. We also show that our Dirichlet form is quasi-regular, which implies the existence of an associated process. Finally we prove in the case $\dim X \geq 2$ that the distance ρ is optimal in the sense that it is the so-called intrinsic metric of our Dirichlet form.

KARL-THEODOR STURM
Dirichlet forms and harmonic maps

In this talk, two problems and partial solutions related to generalized harmonic maps between singular spaces were presented.

The first problem is how to construct a reversible diffusion process X_t on a given metric space (M, d). The solution consists in constructing a regular local Dirichlet form as a Γ-limit of certain non-local Dirichlet forms defined in terms of the metric d and the reversible measure m, see [1].

The second problem is how to define and approximate the energy of a map f with values in a metric space N. This leads to the question whether

$$\frac{1}{2t}\mathbb{E}_m\left[d^2(f(X_0), f(X_t))\right]$$

as a function of t is always decreasing in t (or whether at least it converges for $t \to 0$). Affirmative answers can be given either if X_t is BM on $M = \mathbb{R}^m$ (with arbitrary f, N, d) or if the space (N, d) has nonnegative curvature (with arbitrary M, X_t, f), see [2].

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DOMOKOS SZÁSZ
Ball-Avoiding Theorems

According to the Boltzmann-Sinai Ergodic hypothesis, the system of N hard balls on the ν-dimensional torus is ergodic on submanifolds of the phase space specified by the trivial conserved quantities of mechanics.

A cornerstone of establishing the hypothesis for concrete systems is the handling of ball-avoiding sets; in particular, the proof of smallness of the subset of those phase points where the set of the balls can be partitioned into two non-trivial classes such that the two subgroups of balls do not interact in the future.

Weak ball-avoiding theorems claim that the measure of these ball-avoiding trajectories is zero, and strong ones claim that the subset of these orbits has topological codimension at least two. Strong ball-avoiding theorems are necessary in proofs of ergodicity of hard ball systems (and, in general, of semi-dispersing billiards), whereas weak ones are sufficient when one proves that the system in question is hyperbolic, a property implying that the ergodic components are open.

Examples of ball-avoiding theorems are presented, for instance, a weak theorem of Nándor Simányi and myself, which is needed in our recent proof of the following theorem: the system of N hard balls of masses $m_1, \ldots, m_N$ and of radii r given on the ν-torus is hyperbolic — apart from a countable union of analytic submanifolds of the geometric parameters $m_1, \ldots, m_N, r$.

BÁLINT TÓTH AND WENDELIN WERNER

Self-Repelling Motions I. & II.

We construct and study a continuous real-valued random process, which is of a new type: It is self-interacting (self-repelling) but only in a local sense: it only feels the self-repellance due to its occupation-time measure density at 'immediate neighbourhood' of the point it is just visiting. We focus on the most natural process with these properties that we call 'true self-repelling motion'. This is the continuous counterpart to the integer-valued 'true' self-avoiding walk, which had been studied among others by the first author. One of the striking properties of true self-repelling motion is that, although the couple (X_t, occupation-time measure of X at time t) is a continuous Markov process, X is not driven by a stochastic differential equation and is not a semi-martingale. It turns out, for instance, that it has a finite variation of order 3/2, which contrasts with the finite quadratic variation of semi-martingales. One of the key-tools in the construction of X is a continuous system of coalescing Brownian motions similar to those that have been constructed by Arratia. We derive various properties of X (existence and properties of the occupation time densities $L_t(x)$, local variation, etc.) and an identity that shows that the dynamics of X can be very loosely speaking described as follows: $-dX_t$ is equal to the gradient (in space) of $L_t(x)$, in a generalized sense, even if $x \mapsto L_t(x)$ is not differentiable.

S.R.S. VARADHAN

Hydrodynamic scaling, recent developments and open problems

Hydrodynamic scaling is the problem of tracking, over time, the spatial distribution of conserved quantities in a large system. Space and time are to be suitable rescaled before the limiting behavior is established.

The simple exclusion models provide a convenient class of examples that illustrate the various phenomena that arise. The number of particles is the only conserved quantity and the quantity to be tracked is the local density over macroscopic scales of space and time.

In the asymmetric case the limiting equation is a hyperbolic nonlinear conservation equation that develops shocks. the interesting question is how well the microscopic particle system tracks the shock, especially how the entropy loss associated with the shock is mirrored in the particle system.

There are issues of large deviation that arise in both the symmetric as well as the asymmetric case. If we look at the case of Kawasaki dynamics relative to a Gibbs measure, the system turns out to be "non gradient" and consequently much more complex.

WENDELIN WERNER

Self-Repelling Motions I. & II.

(see Bálint Tóth and Wendelin Werner)

MARC YOR

Ranked Functionals of Brownian Excursions

(joint work with Jim Pitman)

The lecture aimed at presenting descriptions of some important random measure in terms of the laws of ranked lengths of excursions of Brownian motion or, more generally, Bessel processes.

Define $F(dx) = \sum_{i=1}^{\infty} V_i^0 \delta_{X_i}(dx)$, where the X_i's are iid, with common distribution σ on $[0,1]$, and $V^0 = (V_1^0, V_2^0, \dots)$ is a random sequence of masses which add up to 1. As far as the law of F is concerned, one may replace the (V_i^0) sequence by its decreasing reordering $V_1 \geq V_2 \geq \dots$ Important random measures may be constructed by the stick-breaking-procedure starting from beta variables. This gives the two-parameter GEM distributions, whose reordering are the Poisson-Dirichlet laws PD(α, θ), for $0 \leq \alpha < 1$, $\theta > -\alpha$.

In terms of stochastic processes, PD$(0, \theta)$ is the law of $\left\{ \frac{V_n(\sigma_\theta^0)}{\sigma_\theta^0},\ n \geq 1 \right\}$ where $(\sigma_\theta^0,\ \theta \geq 0)$ denotes the gamma subordinator, whereas PD$(\alpha, 0)$ is the law of $\left\{ \frac{V_n(\sigma_1^{(\alpha)})}{\sigma_1^{(\alpha)}},\ n \geq 1 \right\}$ where $(\sigma_s^{(\alpha)},\ s \geq 0)$ denotes the stable (α) subordinator. In both cases, the above notation $\left\{ \frac{V_n(t)}{t},\ n \geq 1 \right\}$ indicates the normalized sequence of ranked lengths of component intervals of $[0,1] \setminus Z$, where Z is the closure of the range of the corresponding subordinator $(\sigma_s,\ s \geq 0)$.

References about this work, done with J. Pitman, are found in

J. Pitman, M. Yor: Ranked Functionals of Brownian excursions. To appear in Comptes Rendus Acad. Sci. Paris; end of December 1997 or January 1998.

E-mail list of participants

Name	First name	E-mail address
Baillon	Jean-Bernard	baillon@jonas.univ-lyon1.fr
Ben Arous	Gérard	benarous@masg57.epfl.ch
van den Berg	Michiel	M.vandenBerg@bristol.ac.uk
Biskup	Marek	biskup@cucc.ruk.cuni.cz
Bleher	Pavel	bleher@math.iupui.edu
Bolthausen	Erwin	eb@amath.unizh.ch
Burdzy	Chris	burdzy@math.washington.edu
Chan	Terence	terence@ma.hw.ac.uk
Clément	Philippe	clement@twi.tudelft.nl
Cox	Ted	jtcox@math.ubc.ca
Dawson	Don	ddawson@fields.utoronto.ca
Deuschel	Jean-Dominique	deuschel@math.tu-berlin.de
Fleischmann	Klaus	fleischm@wias-berlin.de
Gärtner	Jürgen	jg@math.tu-berlin.de
Geiger	Jochen	geiger@mi.informatik.uni-frankfurt.de
Georgii	Hans-Otto	georgii@rz.mathematik.uni-muenchen.de
Greven	Andreas	greven@mi.uni-erlangen.de
Gundlach	Matthias	gundlach@math.uni-bremen.de
Hochberg	Kenneth	hochberg@macs.biu.ac.il
den Hollander	Frank	denholla@sci.kun.nl
Kersting	Götz	kersting@math.uni-frankfurt.de
Kirsch	Werner	werner.kirsch@mathphys.ruhr-uni-bochum.de
Klenke	Achim	klenke@mi.uni-erlangen.de
König	Wolfgang	koenig@math.tu-berlin.de
Lawler	Greg	jose@math.duke.edu
LeGall	Jean-François	legall@dmi.ens.fr
Lewis	John	lewis@stp.dias.ie
Liggett	Tom	tml@math.ucla.edu
Lyons	Terry	T.Lyons@ic.ac.uk
Manthey	Ralf	manthey@minet.uni-jena.de
Olla	Stefano	olla@paris.polytechnique.fr
Papanicolaou	George	papanico@math.stanford.edu
Pfister	Charles-Ed.	charles.pfister@dma.epfl.ch
Röckner	Michael	roeckner@mathematik.uni-bielefeld.de
Rost	Hermann	rost@math.uni-heidelberg.de
Schied	Alexander	schied@mathematik.hu-berlin.de
Sturm	Karl-Theodor	sturm@uni-bonn.de
Swart	Jan	janswart@sci.kun.nl
Szász	Domokos	szasz@math-inst.hu
Tóth	Bálint	balint@math-inst.hu
Varadhan	S.R.S.	varadhan@cims.nyu.edu
Werner	Wendelin	werner@stats.math.u-psud.fr
Winter	Anita	winter@mi.uni-erlangen.de
Yor	Marc	secret@proba.jussieu.fr

Tagungsteilnehmer

Prof.Dr. Jean-Bernard Baillon
Departement de Mathematiques
Universite Claude Bernard de Lyon I
LAN Bat. 101
43, Bd. du 11 Novembre 1918

F-69622 Villeurbanne Cedex

Prof.Dr. Krzysztof Burdzy
Dept. of Mathematics
Box 354350
University of Washington
C138 Padelford Hall

Seattle , WA 98195-4350
USA

Prof.Dr. Gerard Ben Arous
Departement de Mathematiques et
d'Informatiques
Ecole Normale Superieure
45, rue d'Ulm

F-75230 Paris Cedex 05

Prof.Dr. Terence Chan
Dept. of Mathematics
Heriot-Watt University
Riccarton-Currie

GB-Edinburgh , EH14 4AS

Dr. Marek Biskup
Mathematisch Instituut
Katholieke Universiteit Nijmegen
Toernooiveld 1

NL-6525 ED Nijmegen

Prof.Dr. Philippe Clement
Department of Mathematics
TU Delft
P.O. Box 5031

NL-2600 GA Delft

Prof.Dr. Pavel Bleher
Department of Mathematical Sciences
Indiana University
Purdue University of Indianapolis
402 N. Blackford St.

Indianapolis , IN 46202-3216
USA

Prof.Dr. John Theodore Cox
Dept. of Mathematics
University of British Columbia
1984 Math. Road

Vancouver , BC V6T 1Z2
CANADA

Prof.Dr. Erwin Bolthausen
Institut für Angewandte Mathematik
Universität Zürich
Winterthurerstr. 190

CH-8057 Zürich

Prof.Dr. Donald A. Dawson
The Fields Institute
22 College St.

Toronto , Ont. M5T 3J1
CANADA

Prof.Dr. Jean Dominique Deuschel
Fachbereich Mathematik
Technische Universität Berlin
Straße des 17. Juni 136

10623 Berlin

Prof.Dr. Ilya Y. Goldshejd
Institute of Mathematics
Russian Academy of Science
Chernyshevsky str. 112

450000 Ufa
RUSSIA

Dr. Klaus Fleischmann
Weierstraß-Institut für
Angewandte Analysis und Stochastik
im Forschungsverbund Berlin e.V.
Mohrenstr. 39

10117 Berlin

Prof.Dr. Andreas Greven
Mathematisches Institut
Universität Erlangen
Bismarckstr. 1 1/2

91054 Erlangen

Prof.Dr. Jürgen Gärtner
Fachbereich Mathematik / FB 3
Sekr. MA 7-5
Technische Universität Berlin
Straße des 17. Juni 136

10623 Berlin

Matthias Gundlach
Institut für Dynamische Systeme
Universität Bremen
Postfach 330440

28334 Bremen

Dr. Jochen Geiger
Fachbereich Mathematik
Universität Frankfurt
Postfach 111932

60054 Frankfurt

Prof.Dr. Kenneth J. Hochberg
Dept.of Mathematics & Comp. Scie
Bar-Ilan University

52900 Ramat-Gan
ISRAEL

Prof.Dr. Hans-Otto Georgii
Mathematisches Institut
Universität München
Theresienstr. 39

80333 München

Prof.Dr. Frank den Hollander
Mathematisch Instituut
Katholieke Universiteit Nijmegen
Toernooiveld 1

NL-6525 ED Nijmegen

Prof.Dr. Götz Kersting
Fachbereich Mathematik
Universität Frankfurt
Postfach 111932

60054 Frankfurt

Prof.Dr. Werner Kirsch
Institut f. Mathematik
Ruhr-Universität Bochum
Gebäude NA

44780 Bochum

Dr. Achim Klenke
Mathematisches Institut
Universität Erlangen
Bismarckstr. 1 1/2

91054 Erlangen

Dr. Wolfgang König
Fachbereich Mathematik / FB 3
Sekr. MA 7-5
Technische Universität Berlin
Straße des 17. Juni 136

10623 Berlin

Prof.Dr. Greg Lawler
Dept. of Mathematics
Duke University
P.O.Box 90320

Durham , NC 27708
USA

Prof.Dr. Jean-Francois Le Gall
Laboratoire de Probabilites-Tour 56
Universite P. et M. Curie
4, Place Jussieu

F-75252 Paris Cedex 05

Prof.Dr. John T. Lewis
Institute for Advanced Studies
School for Theoretical Physics
10, Burlington Road

Dublin 4
IRELAND

Prof.Dr. Thomas M. Liggett
Dept. of Mathematics
University of California
405 Hilgard Avenue

Los Angeles , CA 90095-1555
USA

Prof.Dr. Terence J. Lyons
Dept. of Mathematics
Imperial College of Science
and Technology
180 Queen's Gate, Huxley Bldg

GB-London , SW7 2BZ

Prof.Dr. Ralf Manthey
Fakultät für Mathematik und
Informatik
Friedrich-Schiller-Universität
Ernst-Abbe-Platz 1-4

07743 Jena

Prof.Dr. Stefano Olla
Centre de Mathematiques Appliquees
Ecole Polytechnique
Plateau de Palaiseau

F-91128 Palaiseau Cedex

Dr. Alexander Schied
Math. Science Research Institute
1000 Centennial Drive

Berkeley , CA 94720-5070
USA

Prof.Dr. George C. Papanicolaou
Department of Mathematics
Stanford University

Stanford , CA 94305-2125
USA

Dr. Wilhelm Stannat
Fakultät für Mathematik
Universität Bielefeld
Universitätsstr. 25

33615 Bielefeld

Prof.Dr. Charles-Edouard Pfister
Departement de Mathematiques
Ecole Polytechnique Federale
de Lausanne
MA-Ecublens

CH-1015 Lausanne

Prof.Dr. Karl-Theodor Sturm
Institut für Angewandte Mathematik
Universität Bonn
Wegelerstr. 6

53115 Bonn

Prof.Dr. Michael Röckner
Fakultät für Mathematik
Universität Bielefeld
Postfach 100131

33501 Bielefeld

Jan Swart
Mathematisch Instituut
Katholieke Universiteit Nijmegen
Toernooiveld 1

NL-6525 ED Nijmegen

Prof.Dr. Hermann Rost
Institut für Angewandte Mathematik
Universität Heidelberg
Im Neuenheimer Feld 294

69120 Heidelberg

Prof.Dr. Domokos Szasz
Mathematical Institute of the
Hungarian Academy of Sciences
P.O. Box 127
Realtanoda u. 13-15

H-1364 Budapest

Prof.Dr. Balint Toth
Mathematical Institute of the
Hungarian Academy of Sciences
P.O. Box 127
Realtanoda u. 13-15

H-1364 Budapest

Prof.Dr. Marc Yor
Laboratoire de Probabilites-Tour
Universite P. et M. Curie
4, Place Jussieu

F-75252 Paris Cedex 05

Prof.Dr. Michiel van den Berg
School of Mathematics
University of Bristol
University Walk

GB-Bristol BS8 1TW

Prof.Dr. Srinivasa R.S. Varadhan
Courant Institute of
Mathematical Sciences
New York University
251, Mercer Street

New York , NY 10012-1110
USA

Prof.Dr. Wendelin Werner
Mathematiques
Universite de Paris Sud (Paris XI)
Centre d'Orsay, Batiment 425

F-91405 Orsay Cedex

Anita Winter
Mathematisches Institut
Universität Erlangen
Bismarckstr. 1 1/2

91054 Erlangen