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Quantenstochastik

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The conference was directed by W.v.Waldenfels (Heidelberg) and L.Accardi (Roma). Main fields of interest were quantum groups, quantum white noise, quantum Markov chaines, free noise, quantum flows and connections to classical probability.

Abstracts

A.Barchielli

Semigroups of positive–definite maps on $*$–bialgebras (joint work with G.Lupieri)

Recently P.Glockner and M.Schürmann introduced a new class of quantum stochastic differential equations giving rise to infiniteley divisible representations of $*$–bialgebras. By combining their representations with unitary evolutions (unitary Markovian cocycles) one can introduce and study the new notion of semigroups of positive–definite maps on $*$–bialgebras. This notion extends to a generic $*$–bialgebra our previous work

on the Fourier transform of convolution semigroups of certain operator–valued measures (instruments) on groups.

S.Attal

Representations of bounded operators on Fock space commuting with conditional expectations

We investigate operators T on the boson Fock space over $L^2(\mathbf{R}^+)$ which commute with projections onto $\Gamma(L^2([0,t]))$. We give two classification theorems which classify the operators T by Λ–integrable processes on the one hand and by Maasen–Meyer kernels on the other. An example is given.

A.Verbeure

Phonon limits – phonon dynamics

Non–commutative versions of the central limit theorem lead to representations of the canonical (anti) commutation relations. These are applied to prove the existence of phonons in solid state physics and field theory as bona fide particles. It is also proved that these central limits are stable under our dynamics. This induces a dynamics of the phonons. Multiple properties of the phonon spectra can be derived rigorously.

S.Majid

Braided groups and quantum Fourier transform (some is joint work with Lyubashenko)

Every quantum group (a non–commutative object) can be converted by "transmutation" into a braided group (a commutative Hopf algebra in a braided category). Such objects are like supergroups with ± 1 superstatistics replaced by a braiding Ψ. Converseley every Hopf algebra or bialgebra with braid statistics of a certain type can be "bosonized" to an ordinary bialgebra. Thus quantum non– commutativity and statistical non–commutativity can be interchanged. (For example, bosonization of the braided–line is the Weyl algebra. Essentially, this example was found independently

by M.Schürmann in another context. See his talk at this conference.) Also, when the quantum group $SL_q(2)$ (of function–algebra type) and the quantum group U_qSL_2 (of enveloping algebra type) are transmuted into braided groups BSL_2 and BU_qSL_2 respectively, they are found to be isomorphic. This means that quantum groups of this type , after transmutation are commutative, co–commutative and self–dual (in the braided category), i.e. like abelian groups $\mathbf{R}^n$. In an application (Lyubashenko) we accordingly introduce a "Fourier transform" operator on any such quantum group.

W.Freudenberg

On the construction of locally normal states

We show that to each locally normal state of a boson system one can associate a point process that can be interpreted as the position distribution of the state. Further one can relate to each normal state its family of conditional states describing the behaviour in a bounded region having given a configuration outside. The position distribution and the conditional states together determine the state completely. Conversely, starting with an arbitrary point process satisfying some condition of absolute continuity we sketch in an explicit way a posibility to construct a locally normal state having this point process as its position distribution.

C.Cecchini

Non–commutative Markov chains

After recalling various non–commutative generalizations of Markovianity for states on triples of von Neumann algebras, and discussing their relations, the case of finite von Neumann algebras was considered. In this situation a structure theorem for Markovian states on infinite chaines of mutually commuting von Neumann algebras was given.

S.Rudnicki, R.Alicki

Low density and weak coupling limits in terms of squeezed states

We show that the time evolution of the quantum system coupled to the Bose or

Fermi heat bath tends to the unitary quantum stochastic process governd by a non-commutative stochastic differential equation. The convergence is in the sense of matrix elements given by reference vectors being collective squeezed vectors. In the case of low density limit the quantum Poisson process is obtained while for the weak coupling limit the quantum Brownian motion appears.

P.E.T.Jorgenson

Quantum moment problems

We explain the non-commutative moment problem which is motivated by the theory of representations of the canonical commutation relations; and we also make the connection to the familiar classical moment problems. The algebra $\mathcal{A}$ will be generated by the usual quantum mechanical momentum and position variables p, x (possibly several degrees of freedom) and we consider positive functionals on $\mathcal{A}$.There is an extended algebra $\tilde{\mathcal{A}}$ which includes the inverses $(x+i)^{-1}, i = \sqrt{-1}$. We show that the positive spectrum elements in $\tilde{\mathcal{A}}$ are precisely those which can be written in the form $\sum_k A_k^* A_k$ (finite sum), $A_k \in \tilde{\mathcal{A}}$. We also show that the normal states on $\mathcal{A}$ are precisely those which admit a canonical extension to $\tilde{\mathcal{A}}$. It follows that the familiar non-normal states do not have the extension property. The work is joint with R.T.Powers, and is also based on earlier work by K.Schmüdgen and R.F.Werner.

H.Hasegawa

Dynamics and stochastic processes of random matrices

The purpose of this talk is to communicate the present development of the studies of level statistics in the physical community by the name of "quantum chaos": the old results formed by Wigner, Porter, Mehta and Dyson around 1960 have been reformulated in the language of a hamiltonian dynamics and the associative stochastic processes. It is hoped to stimulate mathematicians interests so that a mere advanced understanding of the subject can be achieved.

M.Skeide

On the structure of 1–cocycles and conditionally positive functionals on Woronowicz $SU_q(2)$

Given an arbitrary $*$–representation p of $SU_q(2)$ acting on a Hilbert space H we develop a family (depending on the algebra elements) of bounded operators in H such that every 1–cocycle w.r. to π can be obtained by applying this family to a fixed corresponding vector in H. This correspondence is one to one. As a corollary we find that to every 1–cocycle belongs a conditionally positive functional (expressible as matrix element of another operator family) which is just the "inversion" of a theorem due to M.Schürmann.

K.Dykema

Applications of freeness to II,–factors

A brief introduction to II,–factors is given, followed by a description of some applications of Voiculescu's theory of freeness to the II,–factors of free groups.This will include a description of the use of random matrices as the essential tool to obtain these results.

D.Applebaum

Quantum stochastic flows on manifolds

A simple example of a quantum stochastic flow on a manifold is constructed out of two commuting vector fields and a single (classical) Brownian motion.

J.–L.Sauvageot

Riemannian foliations and quantum processes

The transverse heat semigroup on the C^*–algebra of Riemannian foliation is dilated into ϕ_2 quantum flow.

P.D.F.Ion

q in quantum stochastics?

The naive algebraic approach to a non–commutative probability formalism can, in its simplest form, be tried on the free non– commutative algebra. There is a natural co–product leading to a convolution on the algebra of functionals, the non–commutative power series, which is the classical shuffle product. The wish to work with fermions, and than to interpolate between them and the ordinary case, leads to the introduction of a changed shuffle product parametrized with a q. This can be described in a mere high–brow way in terms of a co–action. The one–dimensional special case shows a formalism naturally full of 'basic' numbers, binomials etc. This suggests a natural relationship with the 'scaling' q–difference operator, with classical q–analysis and even with quantum groups.

V.P.Belavkin

Quantum Ito algebras and Hida distributions

A quantum Ito algebra indexed by a #–algebra A is introduced. It admits a Fock space representation in $\Gamma(E)$ as a sum of a number, a creation and an anihilaton process evaluated at a #–representation i and a cocycle k w.r. to to this representation. Introducing an Ito algebra of pairs (a, β) with $a \in A$ and $\beta \in C$,this algebra can be represented as b–algebra of triangular 3×3–block–matrices in the complex Minkowski space $\mathbf{C} \oplus E \oplus \mathbf{C}$, given in terms of the maps i and k.

M.Fannes

Ground states for quantum spin chains

It is in general a very difficult problem to obtain information on equilibrium on ground states of quantum spin systems. This is even the case for models on a chain. Using the 'valence band solid' construction however a nearest–neighbour rotation and translation invariant antiferromagnetic spin 1 interaction has been constructed with unique ground state. All correlation functions of this state can be computed, they decay exponentially in space and the Hamiltonian has a 'ground state gap'. In a joint work with

G.Nachtergale and R.F.Werner we considered generalized valence band states. This class of states turns out to be a w^*-dense convex subset of the translation invariant states on the chain. We explicitely obtain the decomposition into extremal periodic states and the necessary and sufficient conditions for purity. There is an abundance of pure states in the class and each of these pure states is shown to be the unique ground state of a suitable finite gauge interaction with a spectral gap. The natural starting point for obtaining these results is an expression for the correlation functions of such states in terms of a transfer-matrix like formular similar to that expressing the joint probabilities of a Markov process.

M.Epple

A class of non–commutative stationary processes over the 2x2– matrices

In the talk a class of non–commutative stationary processes over the non–commutative probability space (M_2, tr) was specified. It is well–known that the Markovian processes in this class are couplings to white noise. It was shown that the essentially commutative processes in this class (not necessarily Markovian) are couplings to the sum of a random variable and a coloured commutative noise. This result was derived from a representation theorem on unitary cocycles of measure–theoretical dynamical systems.

A.S.Holevo

On the Levy–Khinchine formula in quantum probability

Classical probability is based on the theory of measures with values in $\mathbf{R}$. In quantum probability an important role is played by measures with values in a non–commutative algebra of transformations. Such measures, called instruments, describe transformations of quantum systems, depending on the results of measurements. A convolution semi group of instruments is an object which is related to continuous measurement process in a way formally similar to the relation between usual convolution semi group of probability measures and processes with independent increments. An important and difficult problem is to describe generator of convolution semi group of instruments in terms of a non–commutative Levy–Khinchine formula. A survey of recent results in this direction is presented, including construction of semi groups with unbounded generators

of non–Lindblad type.

D.Voiculescu

Entropy and perturbations of operators

We have studied the perturbation of operators via the existence problem of quasi central approximate units relative to a normal ideal. If τ is an n–tuple of operators and J a normed ideal there is an invariant $k_j(\tau)$ measuring the obstruction to the existence of quasi central approximate units for τ relative to J. If $J = C_\infty^{-1}$ the Macaev ideal given by the norm $\mid T \mid_\infty^- = \sum \lambda_j j^{-1}$, where $\lambda_1 \geq \lambda_2 \geq \ldots$ are the s–numbers of T, we show that the invariant k_j can be used to define an invariant of dynamical system related to entropy (probably proportional).

M.Bozejko

Geometry of Weyl group and q–deformed probability

We considered the classical finite Weyl (Coxeter) group as the method of perturbation of the full Fock space. We have shown that for every Coxeter group (W,S) the function $\phi_{\underline{q}}(x) = q_1^{l_1(x)} \ldots q_k^{l_k(x)}$ is positive definite on W. We defined a new class of creation and annihilation operators and then q–deformed classes of probability q–independence. We get a central limit theorem such that the corresponding orthogonal polynomials are q–Hermite polynomials. We find application of q–probability to Nelson's hypercontractivity inequality when q tends to 1 starting from free probability (q=0).

T.Hida

White noise analysis

Let μ be the standard Gaussian measure on the space of generalized functions over R^1. The white noise analysis is carried on the Hilbert space $L^2(\mu)$. Since the measure μ is invariant under the infinite dimensional rotation group, we can discuss an infinite dimensional harmonic analysis, where the Volterra as well as the Levy Laplacian play

important roles. Also, it is shown that these Laplacians can be characterized in terms of the infinitesimal generators of the rotations.

K.R.Parthasarathy

Classical Markov processes and quantum stochastic differential equations

A certain type of stochastic differential equations, in which the differentials and the their coefficients are handled as matrix entries, is introduced. The quantum Ito's formula is given. The necessary and sufficient condtions for the coefficients that the solution of the differential equation is contractive isometric and coisometric respectively are given. From the unitary processes being solutions of such equations and a fixed operator in the initial algebra there is constructed another class of processes and the differential equation for which they are solutions and theire connections are given. The introduction of matrix notation allowed to write down all this properties very elegant. Examples in which certain (especially classical) Markov processes can be recovered are given.

R.L.Hudson

The Feynman–Kac formula and quantum stochastic calculus

Let U satisfy the quantum stochastic differential equation $dU = U(LdA^+ - LdA - 1/2L^+Ldt), U_0 = 1$ when L is an operator in the initial space. For the Feynman–Kac formula $exp(-t(1/2L^+L + V)) = E[M_tU_t]$, we consider wether the cocycle M_t is the soulution of the ordinary differential equation $dM = MUVU^{-1}dt, M_0 = 1$, can be expressed as exponential. In other words, when is the process UVU^{-1} commutative? Necessary conditions for this are found to be that $[V,[V,L]] = 0, 1/2[L^+L, V^2] = [L^+VL, V]$. These are satisfied if $V = v(xp + yq), x, y$ fixed and L is linear in p and q, corresponding to Feynman–Kac formula for Brownian motion, the Ornstein–Uhlenbeck and the anti–Ornstein–Uhlenbeck process respectively.

M.Schürmann

Quantum white noise on $*$–bialgebras

We consider triplets (L, B, α) consisting of a $*$–group L, an L– graded $*$–algebra B and a $*$–representation α of L as automorphisms on B. Let A be another $*$–algebra together with a state. An n– tuple of $*$–algebra homomorphisms from B to A is called independent if they fullfill certain commutation rules and if the state factorizes. A twisted $*$–bialgebra is such a triplet together with a compatible coalgebra structure. Now we introduce a notion of white noise. It can be shown that each such white noise can be realized as solution of a quantum stochastic differential equation.

H.Maasen

Scattering in quantum optics

A criterion is given for the well–definedness and completeness of the scattering operator for a quantum Markov process. For the sake of concreteness, the criterion is applied to the process of light scattering on a single atom. If a dynamical system (A, ϕ, T_t) has the Markov dilation $(A \otimes N, \phi \otimes \psi, \kappa \mapsto U_t^*(1 \otimes \sigma_t)(\kappa)u_t)$, obtained by coupling to the noise (N, ψ, σ_t) via the cocycle u_t, which in our example satisfies a quantum stochastic differential equation, then two "Møller morphisms" exist, provided an additional condition on the coefficient of the differential equation is satisfied.

R.Werner

Tagged particles in a mean–field enviroment

The thermodynamical limit of dynamical semi groups, whose generators at finite system size are obtained from a lattice interaction by averaging over permutations, leads to evolutions of the following form: the evolution of the bulk of particles is described by a flow on the one–particle state space, whereas the motion of a tagged particle (or dually, of a locally perturbed state) is described by a cocycle of completely positive maps with respect to the flow. If the finite–size generators are Hamiltonian, both the cocycle and the flow are Hamiltonians, and any Hamiltonian on the one–particle state space arises in this way. If the finite–size generators are expressible in Lindblad form in terms of

intensive variables, the cocycle is still Hamiltonian, but the flow may be contracting or chaotic. In the general case the evolution is given by an essentially arbitrary function associating a Lindblad on the one–particle algebra with each state on this algebra.

A.Paszkievicz

Kolmogorovian description of measurements on quantum system

A family of stochastic processes indexed by t, which attaches stochastic prozesses to functions with values in M, can be described as a single stochastic process indexed by such functions, if a consistency condition holds.

Y.G.Lu, L.Accardi

The quantum stochastic calculus on Hilbert module

Starting from a quantum Hamiltonian system, by considering the Markovian limits of this system, we find that a new type of quantum stochastic calculus is suggested naturally. This new type of quantum stochastic calculus is not based on a Hilbert space but Hilbert module and moreover the initial module (denoted by H_0) is not longer independent of the noise module (denoted by $\Gamma(H_1)$ and H_1 a Hilbert module). Based on the tensor Hilbert module $\Gamma(H_1)\otimes H_0$, the quantum stochastic calculus theory is established in some special but interesting case, e.g. H_1 is a C–Hilbert module and C is a commutative C^*–algebra. As an application of this new type quantum stochastic calculus, the Markovian limit of the wave operator (or evolution) of the quantum Hamiltonian system which we are considering is described by the unitary solution of a certain quantum stochastic differential equation in the new sense.

L.Accardi, P.Gibilisco

Induced representations of path groups and parallel transports

We show that induced representations raise naturally for a certain class of locally groups introduced by the physicist M.B.Mensky. We generalize and prove some statements made at a formal level by Mensky.

A.Chebotarev

Conservation recipes for quantum dynamics and for quantum stochastic flows.

In the talk we introduce the minimal solutions for quantum dynamical problems and for quantum stochastic equations. Then we demonstrate technics for reconstructing the minimal solutions in order to obtain the conservative ones.

D.Koroliuk

Quantum Markov chains

One can introduce stopping and hitting times for quantum Markov chains. Using the stopping procedure, we have obtained a new criteria of recurrency applicable for Heisenberg spin model's Markov potential.

Dènes Petz

Discrimination between states by measurements

Let A be the observable algebra of a quantum system. Information on the system is obtained by measurements which are thought of as positive unital mappings $\alpha : \mathbf{C}^n \mapsto A$. If ϕ and ω are possible states of the system, we would like to decide which of them is the "true" state. We consider only the following type of decision procedure. First maximal amount of informaton is obtained by measurements on (ϕ,ω) and the decision is made using classical statistics of the previously received data. Measurement is called sufficient if it provides all the information on the relation of the two states ϕ and ω. Thm: If ϕ and ω do not commute then sufficient measurement does not exist. When the given quantum system may be observed in arbitrary many copies, we are in a position to consider the asymptotics of the information supplied by the measurements. Thm: Asymptotically sufficient measurement does exist for any ϕ and ω. The formal theory of sufficient measurements leads to new kind of entropy inequalities which are interesting independently as well. The lecture is based on a joint work with F.Hiai.

F.Hiai

Some remarks on trace of operator logarithm and relative entropy

The Golden–Thompson inequality $Tre^{(A+B)} \leq Tre^A e^B$ is one of the most famous and important trace inequalities. We first mention that it can be strengthened due to Araki's recent generalization of Lieb and Thirring's inequality. We prove a class of trace inequalities which complements Golden–Thompson inequality. This inequalities give rise to upper and lower bounds of the relative entropy. In particular we have $S(X,Y) \leq S_{BS}(X,Y)$ where $S(X,Y)$ is Umegaki's relative entropy and $S_{BS}(X,Y)$ is Belavkin and Staszewski's one. This inequality can be extended to the setup of hyperfinite semifinite von Neumann algebras. We finally present an additivity formula for the trace of operator logarithm in semifinite von Neumann algebras, which enables us to extend Fuglede and Kadison's determinant theory to the semifinite case.

M.Ohya

Information dynamics; thermodynamical systems and their applications

Various physical and nonphysical systems can be described by states, such that the dynamics of a system is described by the state change. One of essential characters of a state is expressed by its complexity. Complexity such as entropy is a key concept in information theory. We call the study of the state change together with such complexities "information dynamics", which is a kind of synthesis of dynamics of state change and information theory. Here we explain what information dynamics is and indicate how it can be used in several physical and nonphysical fields.

M.Ohya, N.Watanabe

A new formulation of communication theory with Gaussian channels

Gaussian communication processes have been treated by Baker et al. Their discussion has two defects: namely (1) Shannon's type entropy is always infinite for any Gaussian measure; (2) if we take the differential entropy as information of any input state, then this entropy becomes less than the mutual entropy. These points are not well–matched to Shannon's communication theory. In order to avoid these defects and discuss Gaussian

communication processes on Hilbert space, we introduce the entropy functional of an input system and the mutually entropy functional based on the quantum von Neumann entropy and the mutual entropy (information) introduced by Ohya 1983.

F.Fagnola

Characterization of isometric weakly differentiable cocycles in Fock space

The notion of weakly differentiable cocycles in Fock space is introduced. A correspondence between these cocycles and a certain class of operators in a slightly enlarged Hilbert space is given, in the way that they fullfill quantum stochastic differential equations in which the corresponding operator enters. A necessary and sufficient condition for such cocycles to be isometric is given.

K.B.Sinha

The solution of an abstract H–P equation and application to classical diffusion

A unique solution is constructed for the abstract H–P equation: $dV = V(iLdB(t) + (-1/2L^2 + iH)dt)$ where L and H are self adjoint operators satisfying some further conditions. In the case where L and H are associated with smooth and bounded vector fields in R', this leads to the construction of a class of classical Ito diffusion in one dimension.

R.Speicher

Random sums of operators

An "interpretation" of free convolution is given by shapening a theorem of Voiculescu: If $A = (A_n)_{n\in\mathbf{N}}, B = (B_n)_{n\in\mathbf{N}}$ are sequences of selfadjoint $n\times n$–matrices with $\mu_{A_n} \to \mu_A$ and $\mu_{B_n} \to \mu_B$ and if μ_A and μ_B have compact support, then $\mu_{A_n+U_nB_nU_n^*}$ converges to the free convolution of μ_A and μ_B for almost all random sequences of unitary operators $U = (U_n)_{n\in\mathbf{N}} \in \otimes_{n\in\mathbf{N}} U(n)$.

J.M.Lindsay

Feynman–Kac representation of some non–commutative Markov semigroups

Markov semigroups have recently been constructed on semifinite algebras with trace. As an example $*$–derivations δ which fullfill certain conditions are investigated. Applied to a standard Brownian motion this leads to a Feynman–Kac realization of the semigroup $e^{-t\delta^*\delta}$. It is not clear at the moment how to extend this to Markov generators given by two or more derivations.

T.Hudetz

Quantum topological entropy for C^*–dynamical systems

We introduce a notion of topological entropy for automorphisms of arbitrary (non–commutative but unital) nuclear C^*–algebras A, generalizing the "classical" topological entropy for a homeomorphism $T : X \to X$ of an arbitrary (possibly connected) compact Hausdorff space X, where the generalization is of course understood in the sence that the latter topological dynamical system (with Z–action) is equivalently viewed as the C^*–dynamical system given by the T–induced automorphism of the Abelian C^*– algebra $A = C(X)$. As a simple but basic example, we calculate our quantum topological entropy for shift automorphisms on AF algebras associated with topological Markov chains; and also a real physical interpretation of our simple "quantum probabilistic" entropy functions can be discussed.

B.Kümmerer

Stationary quantum Markov processes

The problem if a stationary non–commutative Markov process over Mn, the algebra of $n \times n$–matrices, is a coupling to a generalized Bernoulli shift, is reduced to the problem if there are two embedings of Mn into a certain W^*–algebra, fullfilling some conditions. The answer is yes, if this algebra is not of type III. Otherwise a counterexample is given.

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