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C*-Algebren

August 17th – August 23rd, 2003

The meeting was organised by Dietmar Bisch (Vanderbilt University), Eberhard Kirchberg (Berlin) and Georges Skandalis (Paris).

As in previous years this year's C*-Algebren meeting was a high level meeting which included many top mathematicians from about a dozen different countries (including Canada, Denmark, France, Germany, Great Britain, Ireland, Italy, Japan, Norway, USA). The program consisted of a good mixture of talks by recent Ph.D.'s and talks by more established mathematicians. Many young researchers were given an opportunity to present their latest results at this meeting. At the same time plenty of time was made available for mathematical discussions.

The talks at the conference covered all important research directions within operator algebras. The latest results in the theory of subfactors, free probability theory, non-commutative topology and non-commutative geometry (e.g. related to the Baum-Connes conjecture), the theory of non-commutative dynamical systems, the classification theory of C*-algebras and applications of operator algebraic methods to theoretical physics were presented. This year a fair number of talks were selected in the area of von Neumann algebras whereas the emphasis at the last C*-Algebren meeting in 2001 was on non-commutative topology/geometry and the classification of C*-algebras,

The abstracts below appear in the order in which the talks were presented.

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Abstracts

Künneth formula for topological K-theory of groups

Jerome Chabert
(joint work with S. Echterhoff and H. Oyono-Oyono)

We formalize a two-step scheme which enables us to analyze the topological K-theory of a group, the left hand side of the Baum-Connes conjecture. These two steps consist of : first, by using an adequate realisation of the universal proper space, a Mayer-Vietoris argument and a compression isomorphism, one reduces to the case of groups with compact component group ; the second step is Kasparov's restriction isomorphism, reducing the problem to compact groups. This scheme enables us to prove various permanence properties of the Baum-Connes conjecture, and an analogue of the Künneth formula for the topological K-theory of groups. As a result, we prove that the Baum-Connes conjecture (with trivial action on the algebra) holds for a large class of groups.

Twisted K-theory of groupoids

Jean-Louis Tu
(joint work with P. Xu and C. Laurent)

Let M be a (say compact) space and $\alpha \in H^3(M, \mathbf{Z}) = H^2(M, S^1)$ be a cohomology class. The K-theory group of M twisted by the class α was first studied in the 1970's by Donovan and Karoubi. Recently, string theorists have shown renewed interest since Witten found a connection with D-branes. Moreover, Freed, Hopkins and Teleman announced that the Verlinde algebra is an equivariant K-theory group.

In our paper (math.KT/0306138) we define more generally K-theory groups of a groupoid, twisted by a S^1-valued cohomology class $\alpha \in H^2(\Gamma, S^1)$. This 2-cohomology group turns out to be the Brauer group of Γ as defined by Kumjian, Muhly, Renault and Williams. We discuss conditions under which the twisted K-theory group can be expressed using twisted vector bundles. Finally, we show that there is an associative product $K^i_\alpha \otimes K^j_\beta \to K^{i+j}_{\alpha+\beta}$.

Orbit equivalence for Cantor dynamics

Ian Putnam
(joint work with T. Giordano and C. Skau)

We consider free minimal actions of countable abelian (amenable) groups on a Cantor set. The aim is to classify such systems up to orbit equivalence. The class of dynamics is extended to étale equivalence relations on Cantor sets; this includes AF-relations, which are particularly tractable. The strategy is:

(1) Classify AF-relations (at least minimal ones).
(2) An absorption theorem: if R is a minimal AF-relation on a Cantor set X, with $Y_1, Y_2 \subset X$ "small", and $\alpha : Y_1 \to Y_2$ a homeomorphism, then the relation generated by R and $Graph(\alpha)$ is orbit equivalent to R.
(3) For a free minimal action φ of a group Γ, try to find a large AF-relation R within the orbit relation and write the orbit relation as in part (2).

We describe the complete invariant for AF-relations, completing (1), give a precise statement for (2), and finally describe the current state of (3). There is a complete answer for $\Gamma = \mathbf{Z}$. For $\Gamma = \mathbf{Z}^2$, (3) is done if the action admits sufficiently many 1-cocycles with certain properties. We present two classes of examples where this condition holds.

Strictly outer actions of groups and quantum groups

Stefaan Vaes

An action of a locally compact group or quantum group on a factor is said to be strictly outer when the relative commutant of the factor in the crossed product is trivial. We show that all locally compact quantum groups can act strictly utterly on a free Araki-Woods factor and that all locally compact groups can

act strictly utterly on the hyperfinite II_1-factor. We define a kind of Connes' T invariant for locally compact quantum groups and prove a link with

the possibility of acting strictly utterly on a factor with a given T invariant. Necessary and sufficient conditions for the existence of strictly outer actions of compact Kac algebras on the hyperfinite II_1-factor are given.

Random walks on discrete quantum groups and their boundaries

Sergey Neshveyev

(joint work with L. Tuset)

For a q-tracial state ϕ on a discrete quantum group we consider the convolution operator $P_\phi = (\phi \otimes id)\Delta$. In the study of P_ϕ-harmonic elements we define the Martin boundary A_ϕ. It is a separable C*-algebra carrying natural actions of the quantum group and its dual, and having canonical time evolution. Any harmonic element is given by a positive linear functional on A_ϕ. The unit element can be represented by a KMS state. Any such state ν gives rise to a u.c.p. map from the von Neumann closure of A_ϕ in its GNS representation to the Poisson boundary of P_ϕ, which is an analogue of the Poisson integral. Under additional assumptions this map is an isomorphism which respects the actions of the quantum group and its dual. We identify the Martin boundary of the dual of $SU_q(2)$ with the quantum homogeneous sphere of Podleś. This result extends and unifies previous results of Biane and Izumi. We also formulate a conjecture about the Poisson boundary of the dual of a q-deformation of a compact semisimple Lie group.

Gamma-elements for free quantum groups

Roland Vergnioux

The aim of this talk is to present the construction of an analogue of the gamma element for free quantum groups. We base ourselves on the method of Julg and Valette to prove the K-amenability of groups acting on trees with amenable stabilizers. In this context, the gamma element is induced by the Julg-Valette operator, which maps each edge of the tree to its furthest extremity from a given origin.

In the case of free groups, the geometric object to which the method of Julg and Valette applies is the Cayley tree of a free group. Therefore we are first led to introduce a notion of quantum Cayley graph for discrete quantum groups. In the case of free products of Wang-Banica free quantum groups, the quantum Cayley graph can be considered a tree, and we explain how to define the associated Julg-Valette operator. However, the quantum case present new difficulties, such as the non-involutivity of the direction reversing operator on the space of quantum edges. Finally, in order to define a gamma element for free quantum groups, the "naive" Julg-Valette operator has to be completed by a purely quantum part, the space of "edges at infinity".

K-homology for algebras of unbounded operators

Joachim Cuntz

We outline a framework for an extension of Kasparov's bivariant theory $KK(A,B)$ to the case where A is an arbitrary locally convex *-algebra, and B is a C*-algebra. This covers in particular the following cases:

- A is the algebra generated by $C^\infty(S^1)$ and the differentiation operator D on $C^\infty(S^1)$.
- A is the algebra generated by $S(\mathbf{R})$ and the differentiation operator D on $S(\mathbf{R})$.
- A is the Weyl algebra, i.e. the algebra generated by the position and momentum operators q and p on $S(\mathbf{R})$.

We compute $KK(A,B)$ in these cases. The computation depends on a fundamental new extension of the Weyl algebra which is analogous to the Toeplitz extension of $C(S^1)$.

On exactness and uniform embeddability

Marius Dadarlat

(joint work with E. Guentner)

We proved recently that the class of countable groups that are uniformly embeddable in a Hilbert space is closed under free products with amalgamation. Our first proof of this result was an adaptation of an argument of J.-L. Tu, who proved by geometric methods a similar result for exact groups. In the present talk we sketch a simpler proof based on a reformulation of property A of Yu in terms of partitions of unity. This was inspired by a paper of G. Bell.

Connective E-theory and bivariant homology

Andreas Thom

We analyze bivariant homology theories on the category of C^*-algebras. A definition of connective E-theory is given. This is a connective version of Connes-Higson E-theory. The algebraic properties of this theory are analyzed. Furthermore a generalization of bivariant homology to C^*-algebras is given and some applications are discussed.

On the classification of topologically finite-dimensional simple C^*-algebras

Wilhelm Winter

Let A be a simple separable unital C^*-algebra with finite decomposition rank (a notion of covering dimension for nuclear C^*-algebras introduced by Eberhard Kirchberg and the speaker) and real rank zero. Then $K_0(A)$ is weakly unperforated and has the Riesz interpolation property. If, additionally, the extreme boundary of the tracial state space is compact and zero-dimensional, then A has stable rank one and tracial rank zero. As a consequence, if B is another such algebra, and if A and B have isomorphic Elliott invariants and satisfy the universal coefficient theorem, then they are isomorphic. Furthermore, we provide equivalent characterisations of when C^*-algebras with finite decomposition rank have real rank zero and compact and zero-dimensional extremal state spaces.

We consider various examples, including crossed products arising from minimal diffeomorphisms and Villadsen's algebras with stable rank strictly larger than one.

The topological version of free entropy

Dan Voiculescu

Notions of topological free entropy and free capacity are introduced in the C^*-algebra context. Basic properties, basic problems and connections to potential theory and random matrix theory are discussed.

Invariant Means on C*-algebras

Nathaniel Brown

We discuss invariant means on C*-algebras. In addition to some general theory, we discuss connections with (geometric) group theory, K-homology, Connes' embedding problem and Elliott's classification program.

Subquotients of Hecke C^*-algebras

Nadia Larsen

(joint work with N. Brownlowe, I. Putnam and I. Raeburn)

We consider the Hecke C^*-algebra of Bost and Connes as a limit of Hecke C^*-algebras which involve actions of finite sets of prime numbers. Each approximating C^*-algebra is a semigroup crossed product, and we describe a composition series of ideals for it. There are a large type I ideal and a commutative quotient, and the intermediate subquotients are direct sums of simple C^*-algebras. We can describe the simple summands as ordinary crossed products by actions of $\mathbf{Z}^S$, for S a finite set of primes. When $|S| = 1$, these actions are odometers, and the crossed products are Bunce-Deddens algebras. When $|S| > 1$, the actions are an apparently new class of higher rank odometer actions, and the crossed products are classifiable AF algebras.

L^2-Betti numbers for von Neumann algebras

Dimitri Shlyakhtenko

(joint work with A. Connes)

We introduce the notion of L^2-Betti numbers for a von Neumann algebra with a trace. These numbers are attained by using the correspondence between group representations and bimodules over a W^*-algebra to "rewrite" the group definition in a way that would generalize to W^*-algebras. The definition seems to have many nice properties, including a surprising connection with the free entropy dimension of Voiculescu.

Is conformal field theory pointless?

Antony Wassermann

This talk explained two aspects of point evaluations of loop groups LG, continuous and piecewise differentiable maps $S^1 \to G$ (with G compact and simply connected). LG inherits a topology from the projective unitary group of any positive energy representation. In 1989 Vaughan Jones and I showed that in this topology "points are irrelevant", i.e. loops trivial at a finite set of points are dense in LG or one of its normal subgroups $L_I G$ of loops supported in an interval I of S^1. This argument fails for Diff(S^1). We explain an argument obtained in early 2000 for proving irrelevance of points based on a simple analytic interpretation of the operator product expansion for generating primary fields. This gives another proof for loop groups, such as $LSU(N)$ and Diff(S^1). On the other hand, point evaluations at two points that divide S^1 into intervals I and I^c give an exact sequence

$$1 \to L_I G \times L_{I^c} G \to LG \to G \times G \to 1$$

Conjugation leads to a homomorphism $\alpha : G \to Out(M)$, where $M = \pi(L_I G)''$, a type III_1-factor. α is called a G-kernel, and has a Connes-Jones invariant $\Omega \in H^3_{Borel}(G, \mathbf{T})$, Moore's Borel group cohomology. All invariants are realised. Conjugation by constant loops G gives a minimal action $\beta : G \to Aut(M)$, and by Brown and Pearcy's trace-class version of BDF theory, it can be checked that α is stable, i.e. $\alpha \otimes \beta \cong \alpha \otimes id$. The subfactor classification of minimal actions, obtained with Popa, shows that stable G-kernels are classified up to isomorphism by their Connes-Jones invariants. The original motivation for studying G-kernels came from Teichner and Stolz's programme to understand elliptic cohomology using von Neumann algebras and Connes fusion. The G-kernels can be used to describe spin structures on loop space as well as the G-equivariant gerbe (continuous trace algebra) on G referred to by Jean-Louis Tu.

Super super supertransitive subfactors

Vaughan Jones

A subfactor $N \subset M$ is said to be k-supertransitive if $dim(N' \cap M_{k-1})$ is as small as possible, i.e. the Catalan number $\frac{1}{k+1}\begin{pmatrix} 2k \\ k \end{pmatrix}$. The definition is made by analogy with the group-subgroup subfactor $M^G \subset M^H$, where the corresponding relative commutant has dimension as small as possible, if the action of G on G/H is k-transitive. Further conditions of supertransitivity are defined in terms of the dimensions of the $N' \cap M_{k-1}$. In the most supertransitive situations possible, two constraints are obtained on the principal graph, giving information in particular about the Haagerup subfactor of index $\frac{5+\sqrt{13}}{2}$.

The Baum-Connes conjecture via derived functors

Ralf Meyer

(joint work with R. Nest)

We develop an alternative formulation of the Baum-Connes conjecture using the framework of triangulated categories. Thus $K^{top}(G, A)$ appears as a left derived functor of $K(A \times_r G)$. The main technique is the existence of an analogue of the Dirac element for arbitrary locally compact groups. The new approach avoids using proper actions and thus is more suitable to extend the conjecture to quantum groups. For coactions of compact, connected Lie groups, the conjecture is already known: it asserts that $K(A) = 0$ if $K(A \times G) = 0$.

The barebones of quantum field theory

Dirk Kreimer

After a review of the Hopf algebra approach to renormalisation, developed in recent years in collaboration with Alain Connes and others, we study the question of how much primitive graphs determine the Dyson-Schwinger equation. We show that the latter generalize the Khniznik-Zamolodchikov equations of conformal field theory, and discuss the relation of primitive graphs to number theory. The requirement that Green functions give rise to proper sub-Hopf algebras leads to identities between graphs which equal, for nonabelian gauge theories, the Slavnov-Taylor identities for the couplings of that theory.

Amenability and rigidity in the study of type II_1-factors

Sorin Popa

We explain a general strategy for studying type II_1-factors, which consists in "playing amenability against rigidity" whenever some (weak) versions of these properties are met. The coexistence of these opposing properties creates enough "tension" within the algebra to unfold much of its structure. We illustrate this with several examples and results.

The crossed product by the noncommutative Fourier transform

N. Christopher Phillips

(joint work with W. Lück and S. Walters)

Let A_θ be the irrational rotation algebra, generated by unitaries u and v satisfying the relation $vu = e^{2\pi i\theta}uv$, for some fixed irrational θ. There are "standard" automorphisms of orders 2,3,4 and 6 coming from an action of $SL_2(\mathbf{Z})$ on A_θ. The automorphism σ of order 2 is determined by $\sigma(u) = u^*$ and $\sigma(v) = v^*$, and the corresponding crossed product $C^*(\mathbf{Z}_2, A_\theta, \sigma)$ was proved to be AF at the beginning of the 1990's. There is special structure here: for a suitable action of the infinite dihedral group $D = \mathbf{Z} \times \mathbf{Z}_2$ on the circle S^1, one has $C^*(\mathbf{Z}_2, A_\theta, \sigma) \cong C^*(D, S^1)$, and moreover D is a free product $\mathbf{Z}_2 * \mathbf{Z}_2$.

The automorphism φ of order 4, called the "noncommutative Fourier transform" is determined by $\varphi(u) = v$ and $\varphi(v) = u^*$. There is apparently no analogue of the special structure available for σ, which makes the situation much more difficult. We have now produced a proof that $C^*(\mathbf{Z}_4, A_\theta, \varphi)$ is AF for every $\theta \notin \mathbf{Q}$. The proof uses:

- The Elliot classification program, specifically H. Lin's classification theorem for the case of tracial rank zero.
- The Baum-Connes conjecture, known to hold for discrete amenable groups.
- Cyclic cohomology and the Chern-Connes character.

Finite group actions and classifiable C^*-algebras

Masaki Izumi

Finite group actions with the Rohlin property are completely classified by their actions on the K-groups. The K-groups of C^*-algebras admitting such actions are always completely cohomologically trivial (CCT) G-modules. For a given pair of CCT G-modules a model action is constructed.

Commuting squares and automorphisms of subfactors

Anne Louise Svendsen

We study two infinite series of irreducible, hyperfinite subfactors, which are obtained from an initial commuting square by iterating Jones' basic construction. They were constructed by Haagerup and Schou and have A_∞ as principal graph, which means that their standard invariant is "trivial". We use certain symmetries of the initial commuting squares to construct explicitly non-trivial outer automorphisms of these subfactors. These automorphisms capture information about the subfactor which is not contained in the standard invariant.

The quasinilpotent DT-operator T: Invariant subspaces and free (non-microstate) entropy dimension.

Uffe Haagerup

(joint work with K. Dykema, P. Sniady and L. Aagaard)

In this talk I give a record of recent results on the quasinilpotent DT-operator T (which can be described by a random matrix model $(T_n)_{n=1}^{\infty}$ of strictly upper triangular random matrices with i.i.d. complex Gausian entries above the diagonal), namely

(1) The von Neumann algebra vN(T) generated by T is a II_1-factor isomorphic to the free group factor $L(\mathbf{F}_2)$.
(2) T has a one-parameter family of invariant subspaces affiliated with vN(T).
(3) The non-microstate free entropy dimension $\delta_0^*(T)$ of T is equal to 2 [Aagaard].
(4) The Brown measure of $T + \sqrt{\epsilon}\, C$, where C is a circular operator *-free from T, is equal to the uniform distribution on the disk $B(0, \frac{1}{\sqrt{\ln(1+1/\epsilon)}})$.

In the proofs of (1) and (2) the following moment formula due to Sniady plays a key role:

$$tr(((T^*)^k T^k)^n) = \frac{n^{nk}}{(nk+1)!} \quad n, k = 1, 2, ..$$

A new application of random matrices: $Ext(C_r^*(\mathbf{F}_2))$ is not a group.

Steen Thorbjørnsen

(joint work with U. Haagerup)

In the 1980's, Voiculescu generalized Wigner's famous Semi-circle Law in showing that if $X_1^{(n)}, \ldots, X_r^{(n)}$, are independent random matrices from the Gaussian Unitary Ensemble (suitably normalized), then

$$lim_{n\to\infty}\, \mathbf{E} \circ tr_n[p(X_1^{(n)}, \ldots, X_r^{(n)})] = \tau[p(\chi_1, \ldots, \chi_r)]$$

for any polynomial p in r non-commuting variables, where $(\chi_1, \ldots, \chi_r)$ is a semi-circular system. In recent work we proved that Voiculescu's theorem still holds (even in the "almost sure" sense) if the normalized trace tr_n is replaced by the operator norm. More precisely

$$lim_{n\to\infty}\, ||p(X_1^{(n)}, \ldots, X_r^{(n)})|| = ||p(\chi_1, \ldots, \chi_r)||$$

almost surely, for any polynomial p in r non-commuting variables. Combined with another theorem of Voiculescu, this implies that the Ext semi-group of the reduced C^*-algebra $C_r^*(\mathbf{F}_2)$ is not a genuine group.

On O_∞-absorbing C^*-algebras

Mikael Rørdam

(joint work with E. Kirchberg)

Any C*-algebra (simple or not) that tensorially absorbs the Cuntz algebra O_∞ is purely infinite, and there exist good classification results, due to Kirchberg, for such algebras, provided that they also are separable and nuclear. Perhaps surprisingly, it turns out that purely infinite C*-algebras can arise as inductive limits of algebras of the form $C_0(X, M_k)$; i.e. that a so-called AH_0-algebra can be purely infinite. We recently showed that any O_∞-absorbing, separable, nuclear C^*-algebra which is homotopic to 0 in an ideal-system preserving way is an AH_0-algebra (and the spaces X can be chosen to be 1-dimensional graphs). We discuss this result, its proof, and various applications.

Induced co-representation theory for locally compact quantum groups

Johan Kustermans

The notion of a locally compact quantum group has been well established by now, but it is a different matter whether this definition gives rise to a rich and interesting theory of locally compact quantum groups. A good test of this fact consists of an investigation of the behaviour of locally compact quantum groups with respect to induction procedures. In this talk we look at the quantum version of Mackey's induction procedure of group representations. We explain the definition of induced co-representations and discuss the behaviour of this definition with respect to categorical properties, commutants, induction in stages and the quantum version of Mackey's imprimitivity theorem.

Non-simple C^*-algebras are sometimes better tools for dealing with minimal dynamics than simple ones

Søren Eilers

(joint work with T. Carlsen)

In the standard vocabulary of non-commutative topology, the terms "minimal dynamical system", "simple C^*-algebra" and "simple ordered group" are usually expected to correspond to each other; mainly through the processes of taking crossed products and applying the K-functor.

We were therefore surprised when the computation of the ordered K-groups of the C^*-algebras associated via the work of Kengo Matsumoto to a class of substitutional symbolic dynamics revealed that it is sometimes very worthwhile to associate non-simple C^*-algebras and K-groups with a non-simple and degenerate order structure to such minimal shift spaces.

Indeed, examples can be given where this construction leads to a strictly finer invariant for conjugacy than what was achieved by the ground-breaking work of Giordano, Putnam and Skau, which does conform to the standard correspondence outlined above. Our methods draw heavily on this work, as adapted to this setting by Durand, Host and Skau.

I outlined a recently constructed example of a pair of substitutions which may be distinguished by the ordered K-groups described above, but by no known smaller invariant of the same type. In particular, the example shows that the ordered group is a strictly finer invariant than the group itself. The example was constructed using a Java program which may be sampled at http://www.math.ku.dk/∼eilers/papers/cei.html.

A topology on KK-groups

Mihai Pimsner

We show how to construct a topology on the equivariant $KK^G(A,B)$ groups. Its main property is that a sequence $\{x_n\}_{n\in\mathbf{N}}$ converges to x_∞ in this topology if and only if there exists an element $y \in KK^G(A, B \otimes C(\overline{\mathbf{N}}))$ such that $x_n = y(n)$ for every $n \in \overline{\mathbf{N}}$ (where $y(n)$ is the restriction of y to the point n). Several applications are discussed.

Edited by Tom Hadfield

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