MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 46/1991

C^*-ALGEBREN

20.10. bis 26.10.1991

Die Tagung fand unter der Leitung von J.Cuntz (Heidelberg), U.Haagerup (Odense) und L.Zsido (Rom) statt.Insgesamt wurden 28 Vorträge gehalten, die die immer stärkere Verknüpfung der Theorie der Operatoralgebren mit anderen Teildisziplinen der Mathematik und Physik zeigten.Im Mittelpunkt des Interesses standen

1) Die Klassifizierung (amenabler) Unterfaktoren und Beziehungen zur (konformen) Feldtheorie und zu Invarianten von 3-Mannigfaltigkeiten.(Kawahigashi, Nahm, Ocneanu, Popa)

2) Nichtkommutative Dualitätstheorie und Anwendungen in der algebraischen Quantenfeldtheorie (Doplicher, Roberts, Skandalis, Woronowicz)

Daneben wurde auch über aktuelle Fortschritte bei der Lösung klassischer Probleme

1) Jede Quasispur auf einer exakten C^*-Algebra ist eine Spur (Haagerup)

2) Strukturtheorie der irrationalen Rotationsalgebren (Blackadar, Bratteli, Elliott)

und über geometrische Methoden (KK-Theorie und zyklische Kohomologie) auf dem Gebiet der C^*-Algebren berichtet.

Gefördert durch
DFG Deutsche Forschungsgemeinschaft

VORTRAGSAUSZÜGE

DIETMAR BISCH

Entropy of groups and subfactors

We discuss ergodicity properties of inclusions of hyperfinite II_1-factors $N \subset M$ with finite Jones index $[M : N]$.From the downward basic construction

$$M \supset N \supset N_1 \supset N_2 \supset \dots$$

one obtains an inclusion of hyperfinite von Neumann algebras

$$R_0 = \overline{\cup N_i' \cap N}^w \subset R = \overline{\cup N_i' \cap M}^w$$

canonically associated to $N \subset M$.Each algebra N_i is only determined up to conjugation by a unitary operator in N_{i-1}, hence the construction of the tunnel is not canonical.However, the isomorphism class of $R_0 \subset R$ does not depend upon this choice and is therefore an invariant for $N \subset M$.In finite depth ($\sup_i dim Z(N_i' \cap M) < \infty$) the tunnel $\{N_i\}$ can be chosen such that the higher relative commutants $\{N_i' \cap M\}$ exhaust $N \subset M$, i.e.$R_0 = N \subset R = M$. $N \subset M$ is then classified by a finite dimensional commuting square of the form

$$\begin{array}{ccc} N_i' \cap M & \subset & N_{i+1}' \cap M \\ \cup & & \cup \\ N_i' \cap N & \subset & N_{i+1}' \cap N \end{array}$$

(Popa,Ocneanu)

In infinite depth the problem of classifying $N \subset M$ by $\{N_i' \cap N \subset N_i' \cap M\}$ becomes much harder.Consider a finitely generated group $G = \langle g_1, \dots, g_n \rangle$ (discrete) ,$\theta_1, \dots, \theta_n \in Aut(R)(R =$ hyperfinite II_1) such that$\pi(\theta_i) = g_i, \pi : AutR \to AutR/IntR$. Consider

$$N_G = \left\{ \begin{pmatrix} x & & & & & & \\ & \theta_1(x) & & & 0 & & \\ & & \ddots & & & & \\ & & & \theta_n(x) & & & \\ & & & & \theta_1^{-1}(x) & & \\ & & 0 & & & \ddots & \\ & & & & & & \theta_n^{-1}(x) \end{pmatrix} : x \in R \right\}$$

$$N_G \subset R \otimes M_{2n+1\times 2n+1}(\mathbb{C}) = M$$

then $[M : N_G] = (2n+1)^2$.Ergodicity properties of $N_G \subset M$ are reflected in the classical left random walk

$$g \to g_i^{\pm 1} g$$

on G with equal transition probabilities.The ergodicity of the latter is described by the entropy $h(G)$ of G.

Theorem 1:

Let $N_G \subset M$ as above, choose a tunnel $M \supset N_G \supset N_1 \supset N_2 \supset \ldots$, set

$$R_0 := \overline{\cup N_i' \cap N}^w \subset R := \overline{\cup N_i' \cap M}^w$$

then

$$H(R|R_0) + h(G) = ln[M : N_G]$$

($H(R|R_0)$= noncommutative Connes-Stormer entropy)

Theorem 2:

If $G = F_n$, then

$$H(R|R_0) = 2ln(2n+1) - \frac{2n-2}{2n+1} ln(2n-1)$$

Theorem 1 allows to interpret the operator algebra invariant $H(R|R_0)$ as a growth invariant for groups, which becomes maximal for instance for groups with exponential growth and minimal precisely for free groups.Using results of Popa, one gets that $N_G \subset M$ cannot be exhausted by any choice of $\{N_i\}$ iff $h(G) > 0$, which happens for all non-amenable groups (and some amenable ones), because R, R_0 are not ergodic (i.e. factors) in this case.

□

BRUCE BLACKADAR, ALEXANDER KUMJIAN and MIKAIL RORDAM

Approximately divisible C^*-algebras

Definition:

A finite dimensional C^*-algebra is completely noncommutative if it contains no abelian central projections (i.e. no one dimensional direct summands).

Definition:

A (separable, unital) C^*-algebra is approximately divisible if for any $x_1, \ldots, x_n \in A$ and $\epsilon > 0$, there is a completely noncommutative, finite dimensional (unital) C^*-subalgebra B of A with

$$\| [x_i, y] \| < \epsilon \ \forall i = 1, \ldots, n; y \in B; \| y \| \leq 1$$

Examples:

1) A (unital) AF-algebra is approximately divisible if and only if no quotient contains an abelian projection (in particular, if it is simple).

2) A tensor product $A \otimes B$ is approximately divisible if one factor is.

Theorem:

Every irrational noncommutative torus is approximately divisible.
The term "approximately divisible" comes from the following structure theorem:

Theorem:

Let A be approximately divisible.Then A can be written as

$$\overline{[\cup A_n]}$$

where each A_n is a (unital) C^*-subalgebra of A, such that the relative commutant $A_n' \cap A_{n+1}$ contains a completely noncommutative fin.dim. C^*-subalgebra.

Corollary:

If $\{A_n\}$ are as above, then for every n and k there are integers $k_1, \ldots, k_r$ with $k_i \geq k$, such that the embedding of A_n into A factors through the diagonal embedding

$$A_n \rightarrow M_{k_1}(A_n) \oplus \cdots \oplus M_{k_r}(A_n)$$

Simple approximately divisible C^*-algebras have nice nonstable K-Theory properties:

Theorem:

Let A be a simple approximately divisible C^*-algebra.Then
1) A is stably finite if it is finite.If A is infinite, it is purely infinite.
2) Every nonzero hereditary C^*-subalgebra of A contains a nonzero projection.
3) If A is finite, then the stable rank of A is one.
4) A has real rank zero if and only if projections on A distinguish quasitraces.
5) A satisfies the fundamental comparability question for positive elements.

Corollary:

Every simple noncommutative torus has stable rank 1 and real rank 0.
The proof of the corollary uses U.Haagerup's result that on an exact C^*-algebra every quasitrace is a trace.

□

OLA BRATTELI

The crossed product of the irrational rotation algebra by the flip (Joint work with D.Evans and A.Kishimoto)

Theorem 1:(BEK)

Let Ω be a totally disconnected, compact, metrisable space, and let α be a minimal homeomorphism of Ω.Let σ be a homeomorphism of order 2 on Ω such that

$$\alpha\sigma = \sigma\alpha^{-1}$$

and assume that σ or $\alpha\sigma$ has a fixed point.It follows that the crossed product

$$C(\Omega) \times_\alpha \mathbb{Z} \times_\sigma \mathbb{Z}_2$$

is an AF-algebra.

This is proved by a modification of Putnam's tower construction

Theorem 2:(BK)

Let A_θ be the universal C^*-algebra generated by two unitaries U, V with

$$VU = UVe^{2\pi i\theta}$$

where θ is irrational, and let σ be the automorphism of A_θ defined by

$$U \to U^{-1},\ V \to V^{-1}$$

It follows that

$$A_\theta \times_\sigma \mathbb{Z}_2$$

is an AF-algebra.

The proof is based on Theorem 1, and a construction of projections in $A_\theta \times_\sigma \mathbb{Z}_2$ due to Kumjian.

□

SERGIO DOPLICHER

Operator algebras and Group duality
(Report on joint work with T.Cecchonini,C.Pinzoni,J.Roberts)

We define a simple C^*-algebra $\tilde{\mathcal{O}}$ which is a variant of the Cuntz algebra O_∞ and is canonically associated to a separable, infinite dimensional Hilbert space H, and carries a canonical action of the unitary group of H.

Any subgroup G of $U(H)$ defines a fixed point subalgebra $\tilde{\mathcal{O}}_G$ with trivial relative commutant in $\tilde{\mathcal{O}}$ .The restriction to $\tilde{\mathcal{O}}_G$ of the canonical endomorphism of $\tilde{\mathcal{O}}$ induced by H gives rise to a subcategory of $End\tilde{\mathcal{O}}_G$ which is an abstract model of the category of tensor powers of the defining representation of G on H, hence if that is the right regular representation, it determines G.In that case, every automorphism of $\tilde{\mathcal{O}}$ leaving $\tilde{\mathcal{O}}_G$ pointwise fixed is in G (identified with its canonical action).In other words, every second countable, locally compact group appears as a Galois closed subgroup of $Aut\tilde{\mathcal{O}}$

If furthermore G is amenable,

$$\tilde{\mathcal{O}}_G \simeq \tilde{\mathcal{O}}$$

Similarly, every finite group acting on the Cuntz algebra O_d, $d = |G|$ via the canonical action of the regular representation, has a fixed point subalgebra isomorphic to O_d itself.

These results are first steps towards a generalisation to non-compact groups of the theory of abstract compact group duals previously developed in collaboration with J.Roberts.

□

GEORGE ELLIOTT

The classification problem for amenable C^*-algebras

The question was raised whether it might not be possible to classify separable amenable C^*-algebras in terms of K-theoretical invariants.(It would be necessary to include the traces, and also the ideal structure, when these are not determined by ordered K_0).

Evidence of two kinds was adduced which suggests an affirmative answer.On one hand, a number of (stably finite) amenable C^*-algebras have recently been shown to be inductive limits of C^*-algebras of type I.On the other hand, the intertwinig methods used to classify AF-algebras have recently been extended to certain more general inductive limits of C^*-algebras of type I.(It may be within reach to classify arbitrary limits of sequences of finite dimensional C^*-algebras tensorised by $C(S^1)$, the algebra of continuous functions on the circle).

□

DAVID EVANS

The structure of the irrational rotation C^*-algebra.
(Joint work with G.Elliott)

This talk describes work on the universal C^*-algebra A_θ generated by unitary elements U, V with $VU = e^{2\pi i\theta}UV$ where θ is an irrational number.It is shown that A_θ is isomorphic to the inductive limit of a sequence of direct sums of two matrix algebras over $C(S^1)$, the algebra of continuous functions on the circle.A given sequence of such algebras has this property if (and only if) the inductive limit is simple and unital, has a unique tracial state, and has order unit K_0-group isomorphic to $(\mathbb{Z} + \mathbb{Z}\theta, 1)$, and K_1-group isomorphic to $\mathbb{Z}^2$.A particular example of such a sequence can be obtained from the continued fraction expansion for θ.Other consequences for A_θ (which are already known by earlier work) of this are:

a) A_θ can be embedded in the AF-algebra with the same order unit K_0 (Pimsner,Voiculescu).

b)A_θ has topological stable rank one (Riedel,Anderson-Paschke,Putnam).

c) A_θ has real rank zero (Choi-Elliott,Blackadar-Kumjian-Rordam/Haagerup).

Possible use of Ocneanu's Fourier transform on path algebras to understand the action $U \to V^{-1}$; $V \to U$ was also mentioned.

□

UFFE HAAGERUP

Quasitraces on exact C^*-algebras are traces

We show that quasitraces (more precisely 2-quasitraces in the sense of Blackadar and Handelman) on exact C^*-algebras are traces.As consequences one gets:

1) Every stably finite unital exact C^*-algebra has a bounded trace $\tau \neq 0$, and

2) If an AW^*-factor of type II_1 is generated (as an AW^*-algebra) by an exact C^*-algebra, then it is a von Neumann II_1-factor.

This is a partial solution to a well known problem of Kaplansky.The present result was crucial for the proof of $RR(A) = 0$ for every simple irrational rotation algebra A of any dimension given by Blackadar, Kumjian and Rordam.

A key step in our proof is to show that if A is a unital C^*-algebra without nonzero bounded traces, then $A \otimes C_r^*(F_\infty)$ contains a non-unitary isometry.The proof relies heavily on Voiculescu's noncommutative statistics.More precisely it is used, that an infinite semicircular system can be naturally realised inside $C_r^*(F_\infty)$ as well as inside the Cuntz algebra O_∞.

□

PIERRE JULG

$KK_G(\mathbb{C},\mathbb{C})$ for $G = SU(n,1)$
(Joint work with G.Kasparov)

Kasparov introduced in 1981 a commutative ring

$$R(G) = KK_G(\mathbb{C},\mathbb{C})$$

which is the analogue, for locally compact G, of the usual ring $R(G)$ of (formal differences of) representations for compact G.When G is connected, it was known (Kasparov 1981) that if K denotes a maximal compact subgroup of G, the restriction map

$$R(G) \to R(K)$$

is surjective and split.It is interesting to look for the cases where it is bijective.This is the case when G is amenable, but not if G has property (T).An interesting case is that of $G = SO(n,1)$ or $SU(n,1)$, the only simple Lie groups (up to local isomorphism) which do not have property (T).Actually for these two series of groups one has

$$R(G) \xrightarrow{\simeq} R(K)$$

The proof was given in 1983 by Kasparov for $SO(n,1)$, and in our joint work (1990-1991) for $SU(n,1)$.The proof for $SU(n,1)$ uses deeply the geometry of the boudary of the symmetric space associated to $SU(n,1)$ (the "complex hyperbolic space") and analysis of hypoelliptic differential operators associated to it.We need also some results in the representation theory of $SU(n,1)$, namely the existence of some complementary series.

□

YASUYUKI KAWAHIGASHI

Flat Connections,Yang-Baxter equation and orbifold subfactors.

We exploit the similarity between solvable lattice model theory and Ocneanu's paragroup theory in subfactor theory.Especially we apply the Yang-Baxter equation and an idea on the orbifold IRF-model to the classification resp. construction of subfactors.We have the following three applications:

1) D_{2n} is uniquely realised as the principal graph of a subfactor while D_{2n+1} is not realised at all.This was announced by Ocneanu without proof.

2) (with M.Izumi) There are n-2 subfactors with principal graph $D_n^{(1)}$.This gives the last missing number in Popa's classification list and disproves an announcement of Ocneanu.

3)(with D.Evans) We get a series of orbifold subfactors for Wenzl's Hecke algebra subfactors.It turns out that all the connections are flat.

□

EBERHARD KIRCHBERG

On exactness

We gave an outline of the proof of the following Theorem and have discussed some corollaries.

Theorem:

Let A be a unital separable, exact C^*-algebra and

$$\alpha : G \to Aut(A)$$

a strongly continuous action of a compact group G on A.Then there exists a product type action

$$\beta : G \to Aut(M_{2^\infty})$$

of G on the CAR-algebra, an increasing sequence of projections

$$p_1 \leq p_2 \leq \ldots \text{ in the fixed point algebra } (M_{2^\infty})^{\beta(G)} \text{ of } \beta(G)$$

and a G-covariant *-monomorphism

$$h : A \to N(D)/D$$

where

$$D = cl\left(\bigcup_{n=1}^{\infty}(p_n M_{2^\infty} p_n)\right)$$

and

$$N(D) = \{b \in M_{2^\infty} : bD + Db \subset D\}$$

is the normaliser algebra of D in M_{2^∞}.

□

MAGNUS LANDSTAD

Equivariant deformations of homogeneous spaces
(Joint work with Iain Raeburn)

If G is a locally compact group and Γ a closed subgroup we study deformations of the algebra $C_0(G/\Gamma)$, i.e. we want a subspace A of $C_0(G/\Gamma)$ which separates points in G/Γ together with a family of products $*_\lambda$ on A such that

$$f *_\lambda g(x) \to f(x)g(x) \text{ as } \lambda \to 0$$

Define the left action

$$\rho_x f(y\Gamma) := f(x^{-1}y\Gamma)$$

The deformations are called equivariant if

$$\rho_x(f *_\lambda g) = \rho_x(f) *_\lambda \rho_x(g) \; \forall x \in G$$

The construction depends on having an abelian subgroup H such that

$$\gamma H \gamma^{-1} = H; \; \gamma \in \Gamma$$

and a continuous homomorphism

$$\pi : \widehat{H} \to H$$

which is totally skew

$$\langle \pi(s), s \rangle = 1 \; \forall s \in \widehat{H}$$

and such that

$$\gamma \pi(s \circ Ad(\gamma))\gamma^{-1} = \pi(s) \; \forall s \in \widehat{H}, \gamma \in \Gamma$$

Then one can define a "twisted" product on a subspace $C'(G/\Gamma)$ (assume G/Γ compact) and let $C^*(G/\Gamma, \pi)$ be the enveloping C^*-algebra.

Theorem:

$$Center(C^*(G/\Gamma, \pi)) \simeq C(G/\overline{\pi(\widehat{H})\Gamma})$$

in particular

$$C^*(G/\Gamma, \pi) \text{ is simple } \Leftrightarrow \pi(\widehat{H})\Gamma \text{ is dense in } G$$

Example: (Rieffel)

$$G = \left\{ \begin{pmatrix} 1 & y & z \\ 0 & 1 & x \\ 0 & 0 & 1 \end{pmatrix} ; x, y, z \in \mathbb{R} \right\}$$

$$\Gamma = G \cap SL(3, \mathbb{Z})$$

$$H_{\mu,\nu} = \left\{ \begin{pmatrix} 1 & \nu s & t \\ 0 & 1 & \mu s \\ 0 & 0 & 1 \end{pmatrix} ; s, t \in \mathbb{R} \right\}$$

is abelian ($\simeq \mathbb{R}^2$) and normal

$$\pi : \widehat{H} \to H \text{ is given by } \pi(s,t) = (\lambda t, -\lambda s)$$

Then $\pi(\widehat{H})\Gamma$ is dense in G iff $\{\lambda\mu, \lambda\nu, \nu\}$ are independent over $\mathbb{Z}$.
We can also give examples with G a solvable group.

□

Gefördert durch DFG Deutsche Forschungsgemeinschaft

ROBERTO LONGO

Inclusions of factors and Quantum Field Theory

There is an interplay between index theory of subfactors and Quantum Field Theory (algebraic) that is producing results in both fields.If M is an infinite factor $Sect(M)$, the quotient of the endomorphism semigroup by inner automorphisms, has a structure of an involutive semiring.The dimension (square root of the minimal index) is an involutive homomorphism of $Sect_0(M)$ (sections with finite index) to $\mathbb{R}_+$.As a corollary the index of a standard braided endomorphism (an endomorphism with a certain braid group symmetry) has further restrictions beside the Jones series.In QFT the Doplicher Haag Roberts statistical dimension equals the dimension of the endomorphism representing the sectors; this excludes the occurence of several subfactors from QFT.The conjugate of a sector in QFT gives a coherent family of conjugate endomorphisms of local algebras.This implies that Poincare covariance is equivalent to the existence of a global conjugate, at least in finite statistics; it is also equivalent to the fact that a superselection sector gives a sheaf map modulo inners for a natural sheaf structure.

□

WERNER NAHM

Penrose tilings, Jones imbeddings and Conformal Quantum Field Theory

Consider a conformal quantum field theory of chiral fields, e.g. the theory of positive energy projective representations of $Diff(S^1)$ or $Map(S^1, G)$, G compact, with fixed central extension.Restricting to maps which have support in an interval I one gets imbeddings of von Neumann III_1-factors

$$\mathcal{A}(I) \subset \mathcal{A}(I_C)$$

where I_C is the complementary interval.The index of the imbedding depends on the representation, it is 1 for the basic representation, which is given by the $SU(1,1)$ invariant vacuum state ($SU(1,1) \subset Diff(S^1)$) (Haag duality, proofs by Wassermann,Buchholz). The indices can be calculated from the behaviour of

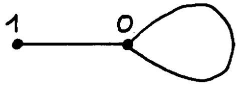
$$tr\ q^{L_0}$$

L_0 generator of $U(1) \subset SU(1,1)$, trace over the irreducible representation spaces of $\mathcal{A}(S^1)$, under the modular transformations

$$\tau \to \frac{a\tau + b}{c\tau + d}, \begin{pmatrix} a & b \\ c & d \end{pmatrix} \in SL(2, \mathbb{Z}), \quad q = e^{2\pi i\tau}$$

in particular for $\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$

A very similar picture should exist for nonunitary representations, where present operator algebra theory cannot be applied.In particular, the smallest nontrivial representation of $Diff(S^1)$ is the one with central extension $c = -\frac{22}{5}$. Here a basis for the two possible representations can be labeled by the paths on the graph



obtained from folding the A_4 graph

with the action of L_0 on

$$Z = (z_0, z_1, \dots), z_j \in \{0,1\}, z_j = 0 \text{ for } j >> 0$$

given by

$$L_0(Z) = \left(\sum_1^{\infty} : z :\right) Z$$

Then

$$\sum_{\text{paths with } z_0=1} \langle Z | q^{L_0} | Z \rangle$$

yields the basic character, and the sum with $z_0 = 0$ the other one. The paths are in one-to-one correspondence with the tiles of a Penrose tiling of the half plane.The correspondence to a C^*-algebra was given by Connes.It can be generalised as follows.For a tiling $\mathcal{T}$ of a homogeneous space with symmetry group $\sum$ and U a finite subset of $\mathcal{T}$ let

$$\mathcal{M}(U) \subset \mathcal{B}(l^2(\mathcal{T}))$$

be given by

$$- \forall i,j \in U, \sigma \in \sum \text{ such that } \sigma(U) \subset \mathcal{T}, \text{ let } A_{\sigma(i)\sigma(j)} = A_{ij}$$
$$- \forall i,j \in \mathcal{T}, \text{ if } \nexists \sigma \text{ with } \sigma(i) \in U, \sigma(j) \in U \text{ let } A_{ij} = 0$$

Then the union of the $\mathcal{M}(U)$ is an algebra. Properties of the Penrose tiling are reflected in detail in the representation theory of $Diff(S^1)$ at $c = -\frac{22}{5}, c = -\frac{3}{5}$ and $c = \frac{7}{10}$ (Nakanishi,W.N., for $c = \frac{7}{10}$ earlier work by Connes and Evans).

□

RYSZARD NEST

Geometric cyclic cocycles
(Joint work in progress with B.Tsygan)

We give a general construction of cyclic cocycles which come from geometric structures on the de Rham complex of an algebra $\mathcal{A}_0$ and a $\mathcal{D}$-invariant trace τ on $\mathcal{A}_0$:

$$\tau_{\#} : (C_*^{Lie}(\mathcal{D}; \mathbb{C}), \partial_{Lie}) \to HC^*(\mathcal{A}_0)$$

In the particular case when $\mathcal{D}$ is given by some algebra of multiplier derivations, i.e.

$$\mathcal{D} = ad(g)$$

this leads to a natural map

$$\tau_{\#} : \overline{HC}_*(g) \to HC^*(\mathcal{A}_0)$$

which (after stabilisation) factors through the boundary map

$$\partial : \overline{HC}_*(g) \to HC_{*-1}(\mathbb{C})$$

of the long exact sequence of reduced cyclic homology.

The cocycles (as opposed to cohomology classes) obtained this way reflect the geometry of the situation and behave nicely under perturbations of the geometric structure.In particular, the construction applied to

$$\mathcal{A}_0 = \mathcal{K}^\infty(L^2(\mathbb{R}^n)); \ \tau = Tr;$$

$$\omega = x_1 \wedge \cdots \wedge x_n \wedge \frac{d}{dx_1} \wedge \cdots \wedge \frac{d}{dx_n} \in \overline{HC}_{2n-1}(Diff(\mathbb{R}^n))$$

leads to a simple proof of the Atiyah-Singer Index Theorem for $\mathbb{R}^n$. The case of a general compact manifold with non-trivial Todd class requires localisation of the construction for $\mathbb{R}^n$, which, via the double complex

$$C^*_{Cech}(M, \overline{CC}_*(\widetilde{Diff}(M))$$

with $\widetilde{Diff}(M)$ being the sheaf of differential operators on M, gives a natural class in the total cohomology of this double complex which on one hand computes the trace of a projection in $\mathcal{K}^\infty(L^2(M))$ and on the other hand becomes identified, via the Gelfand-Fuks map

$$H^*_{Lie}(W_n, gl_n(\mathbb{C}); \mathbb{C}) \to H^*(M)$$

with the Todd class of TM.

As another application one gets cyclic cocycles on group algebras naturally associated with the orbit structure and orbit geometry of the coadjoint representation.

□

ADRIEN OCNEANU

Operator algebras and invariants for manifold

A finite bimodule system $(\mathcal{A}, \mathcal{M})$ is a finite family $\mathcal{A}$ of hyperfinite II_1- factors, and a finite family $\mathcal{M}$ of irreducible mutually inequivalent bimodules of finite index ${}_A x_B$, where $A, B \in \mathcal{A}$, such that $\mathcal{M}$ is closed under tensor products and conjugation, and for any $A, B \in \mathcal{A}$ there exists ${}_A x_B \in \mathcal{M}$.Such a system is produced, e.g. by a subfactor $A \subset B$ with finite index and finite depth, by a generating procedure from the bimodule ${}_A L^2(B)_B$. We show that a complete invariant for $(\mathcal{A}; \mathcal{M})$ is the quantum 3-cocycle Z and quantum classifying space $\mathcal{BM}$ constructed as follows.The vertices of $\mathcal{BM}$ are labeled by elements $A \in \mathcal{A}$, edges between A, B are labeled by bimodules ${}_A x_B \in \mathcal{M}$, triangles with faces ${}_A x_B, {}_B y_C, {}_A z_C$ by a basis of $Hom[{}_A x \otimes_B y_C, {}_A z_C]$, and finally one adds all higher dimensional simplices with 2-faces in the above set. Given a tetrahedron with vertices, edges and faces labeled, one obtains a number $Z(T)$ by composing all the face homomorphisms. It is shown that Z satisfies a 3-cocycle property, which is, in fact, necessary and sufficient for the construction of a topological quantum field theory in the sense of Atiyah-Witten, generalising the Turaev-Viro invariant, having the following ingredients. For any closed surface S one obtains a Hilbert space H_S, with

$$H_{S_1 \uplus S_2} = H_{S_1} \otimes H_{S_2}$$

and

$$H_\emptyset = H_{S_2} = \mathbb{C}$$

For any 3-manifold M with boundary, one obtains a linear functional

$$Z(M) : H_{\partial M} \to \mathbb{C}$$

or equivalently, a vector

$$\zeta_M \in H_{\partial M}$$

In particular when $\partial M = \emptyset$, then $\zeta(M) \in \mathbb{C}$ is a numerical topological invariant for M.For $M = M_1 \cup M_2$ we have the glueing property

$$\zeta_M = Tr_{H_S}(\zeta_{M_1} \otimes \zeta_{M_2}) = \zeta_{M_1} \otimes_{H_S} \zeta_{M_2}$$

Conversely, from such a quantum classifying space and 3-cocycle one constructs a finite bimodule system $(\mathcal{A}, \mathcal{M})$.

The constructed invariant has applications in subfactor structure theory, representation theory for finite groups (generalising the Frobenius-Schur theorem), number theory, solutions to the quantum Yang-Baxter equations and others.

□

GERT K. PEDERSEN

Facial structure in C^*-algebras

With A a C^*-algebra, A^* its dual space, and B, B^* the unit balls of A, A^*, respectively, the sets $\mathcal{F}$ and $\mathcal{F}^*$ of closed faces of B and B^* were described.The case where $F \in \mathcal{F}_+$ (the set of faces in B_+) was determined by order structure:

$$F = \{x \in B_+ | p \leq x \leq q\}$$

Here p, q are uniquely determined projections in the enveloping von Neumann algebra A^{**} of A, p is compact and q is open.The fact that each such interval $[p, q]$ gives a face in B_+ uses Akemann's noncommutative Urysohn Lemma.The formula $B_{sa} = 2B_+ - 1$ allows us to describe elements F in $\mathcal{F}_{sa}$-faces in B_{sa}. We get

$$F = \{x \in B_{sa} | 2p - 1 \leq x \leq 1 - 2q\} = \{x \in B_{sa} | (p - q)x = p + q\}$$

for a unique pair p, q of orthogonal, compact projections in A^{**}. The case of general faces in $\mathcal{F}$ is solved by Halmos'trick of imbedding A in $M_2(A)_{sa}$.If $F \in \mathcal{F}$ define

$$\hat{F} = \left\{ \begin{pmatrix} a & x^* \\ x & b \end{pmatrix} | x \in F, a, b \in A_{sa}, \| \begin{pmatrix} a & x^* \\ x & b \end{pmatrix} \| \leq 1 \right\} \in \mathcal{F}_{sa}(M_2(A))$$

The previous models then give

$$F = \{x \in B | v^* x = v^* v\} = \{v + (1 - vv^*)B(1 - v^* v)\} \cap A$$

Here v is a uniquely determined partial isometry in A^{**} that belongs locally to A in the sense that $v = xv^*v$ for some x in A.We note that if $F = \{v\}$ we recover Kadisons characterisation of extreme points in B. Finally we mentioned the duality between $\mathcal{F}$ and $\mathcal{F}'$: If $F \in \mathcal{F}$ define

$$F^f := \{\varphi \in B^* | \varphi(x) = 1, \forall x \in F\}$$

Similarly, if $G \in \mathcal{F}'$ define

$$G_f := \{x \in B | \varphi(x) = 1, \forall \varphi \in G\}$$

Then the assignements

$$F \to F^f, \ G \to G_f$$

are the inverse of each other and give an order-reversing isomorphism between $\mathcal{F}$ and $\mathcal{F}'$.

$\square$

SORIN POPA

Classification of amenable subfactors

□

STEPHEN POWER

Non-selfadjoint limit algebras

We discuss how two developments in the theory of non-selfadjoint limit algebras lead to some problems of an essentially C^*-algebraic nature.

1) Let $A = limT_{n_k}$ be a limit algebra in the UHF-C^*-algebra $B = limM_{n_k}$ where the embeddings $\varphi_k : T_{n_k} \to T_{n_{k+1}}$ are unital star extendable embeddings of the upper triangular subalgebras.In this case

$$\varphi_k((a_{ij})) = (a_{ij}U_k^{j-i})$$

for some unitary matrices U_k, the algebra A is a (homogeneous) nest subalgebra of B.The automorphism conjugacy class (in B) of the *masa* $C = A \wedge A^*$ is an isomorphism invariant for A.By considering rapidly increasing embedding multiplicities and nonpermutation unitaries U_k we can obtain a variety of singular *masas* C.It is natural then to classify the conjugacy classes of such *masas*, at least for certain prescribed families.

2) A digraph limit algebra $A = limA(G_k)$ can be associated with a direct system of digraph (poset) matrix algebras $A(G_k)$, where the embeddings map matrix units to sums of matrix units but are not necessarily isometric.Although A is an operator algebra the (groupoid) C^*-algebra need not be AF, and in fact such C^*-algebras can be wildly diverse.Constraints on the first simplicial homology of the simplicial complexes of the digraphs can reduce this diversity.In particular there is a close connection between the stipulation $H_1(\Delta(G_k)) = 0 \ \forall k$, and the C^*-algebra $C^*(A)$ being a limit of circle algebras with real rank zero.

□

MICHAEL PUSCHNIGG

Asymptotic cyclic cohomology

Asymptotic cyclic cohomology is introduced as universal extension of the functors

$$HC^0/kerS$$

$$HC^1$$

from the category of unital Banach algebras to the homotopy category of linear asymptotic homomorphisms between Banach algebras.

The two main results are

1)(Obtained independently by R.Nest)

Let (α_t) be a one-parameter group of isometric automorphisms of the unital Banach algebra A.Suppose that the algebra

$$\mathcal{A}^k := \overline{dom(\delta^k)}$$

is dense in A.(δ the generating unbounded derivation of (α_t)).Then the natural map

$$\mathcal{A} \to A$$

induces an isomorphism on asymptotic cyclic cohomology.

2) Asymptotic cyclic cohomology defines on the category of separable C^*-algebras a stable, split-exact and Bott-periodic homotopy functor.Therefore it behaves functorial under the Kasparov-category "KK" with separable C^*-algebras as objects and morphisms

$$mor(A, B) := KK(A, B)$$

□

JEAN RENAULT

Exactness of group C^*-algebras
(Joint work with M.Hilsum and G.Skandalis)

There are two standing conjectures on the exactness of group C^*-algebras.The first one concerns the full C^*-algebra $C^*(\Gamma)$ of a discrete group Γ:

Is $C^*(\Gamma)$ exact (in the sense of E.Kirchberg) only if Γ is amenable?

We show that this is the case if Γ is a subgroup of the unitary group of the hyperfinite II_1 factor.

The second concerns the reduced C^*-algebra $C^*_r(\Gamma)$:Is it always exact?

We show that this is the case when Γ is a discrete subgroup of a connected Lie group and when Γ is a hyperbolic group.In fact, we construct for these groups a Γ space which is compact and amenable, which shows that $C^*_r(\Gamma)$ is in fact subnuclear.When Γ is a discrete subgroup of a connected Lie group G, the Fürstenberg boundary G/P of G is such a Γ space.In fact, if Γ admits any compact and amenable Γ space at all, then the Fürstenberg boundary of Γ is also amenable.When Γ is a hyperbolic group, its boundary in the sense of Gromov is an amenable Γ space.This is shown by an explicit construction of an approximate invariant mean.

□

JOHN ROBERTS

Spontaneously broken symmetry and Goldstone's Theorem (Joint work with D.Buchholz,S.Doplicher,R.Longo)

If $\mathcal{A}$ is the C^*-algebra of observables satisfying essential duality in the vacuum sector and $\mathcal{F}$ is the canonical C^*-algebra of fields with normal Bose-Fermi commutation relations let

$$\Gamma := \{\gamma \in Aut(\mathcal{F}) : \gamma(A) = A, A \in \mathcal{A}\}$$

Lemma:

If $\gamma \in \Gamma$ then

$$\gamma(\mathcal{F}(\mathcal{O})) = \mathcal{F}(\mathcal{O})$$

for each double cone $\mathcal{O}$.If ω_0 is the vacuum state of $\mathcal{F}$ then

$$G := \{g \in \Gamma : \omega_0 \circ g = \omega_0\}$$

is the compact subgroup of Γ describing the superselection structure of $\mathcal{A}$.

The elements of Γ commute with spacelike translations if the "energy-momentum tensor" is, in a certain technical sense; an observable.The elements of $\Gamma\backslash G$ are the spontaneously broken symmetries.The group Γ can be implemented locally.In particular, if $\lambda \to \gamma_\lambda$ is a continuous one parameter subgroup of Γ there is a skewadjoint $J_\mathcal{O}$ with

$$(\Phi, \delta(F)\Psi) = (\Phi, [J_\mathcal{O}, F]\Psi), \Phi, \Psi \in D(J_\mathcal{O}), F \in D(\delta) \cap \mathcal{F}(\mathcal{O})$$

where δ is the generator of $\lambda \to \gamma_\lambda$.

$$\omega_0 \circ \gamma_\lambda = \omega_0, \lambda \in I\!\!R \Leftrightarrow \omega_0 \circ \delta = 0$$

If the vacuum vector $\Omega \in D(J_\mathcal{O})$ then

$$|\omega_0 \circ \delta(F)| \leq c_\mathcal{O}(\| F\Omega \| + \| F^*\Omega \|), F \in D(\delta) \cap \mathcal{F}(\mathcal{O}), \text{ with } c_\mathcal{O} \leq \| J_\mathcal{O}\Omega \|$$

In general, given $\epsilon > 0, \exists c_{\mathcal{O}\epsilon}$ with

$$|\omega_0 \circ \delta(F)| \leq c_{\mathcal{O}\epsilon}(\| F\Omega \| + \| F^*\Omega \|) + \epsilon \| \delta(F) \|, F \in D(\delta) \cap \mathcal{F}(\mathcal{O})$$

The behaviour of $c_{\mathcal{O}\epsilon}$ as $\mathcal{O}$ grows is crucial for deciding whether one can conclude that $\omega_0 \circ \delta = 0$.

Goldstone's Theorem asserts that $\lambda \to \gamma_\lambda$ is spontaneously broken only if there are massless bosons present.This result requires $\lambda \to \gamma_\lambda$ to be generated by a conserved covariant current j_μ.Thus if $\mathcal{O}_R$ denotes the double cone with face $\{\vec{x} : |\vec{x}| < R\}$ and

$$J_R := i \int j_0(x) f(x^0) g\left(\frac{\vec{x}}{R}\right) dx$$

where $f, g \in \mathcal{D}, \int f(x^0)dx^0 = 1, g(\vec{x}) = 1$ for $|\vec{x}| < 1$ then

$$(\Phi, \delta(F)\Psi) = (\Phi, [J_R, F]\Psi), \Phi, \Psi \in D(J_R), F \in D(\delta) \cap \mathcal{F}(\mathcal{O}_R)$$

In this case $\Omega \in D(J_R)$ and as is well known,

$$\| J_R\Omega \| \leq const. R^{\frac{s-1}{2}}$$

where s is the number of space dimensions.Examples show that such currents do not necessarily exist.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

Proposition:

If there is a mass gap $m > 0$ then there is a model independent constant $c > 0$ such that if

$$|\omega_0 \circ \delta(F)| \leq c_\epsilon e^{\mu R}(\| F\Omega \| + \| F^*\Omega \|) + \epsilon \| \delta(F) \|, F \in D(\delta) \cap \mathcal{F}(\mathcal{O}_R)$$

for some

$$0 \leq \mu < c.m$$

then

$$\omega_0 \circ \delta = 0$$

One can take $c = \frac{e}{4\pi}$.We can, however, have spontaneous symmetry breaking if $\mu = (1+\delta)m, \delta > 0$.

Proposition:

Suppose

$$|\omega_0 \circ \delta(F)| \leq c_{R,\epsilon}(\| F\Omega \| + \| F^*\Omega \|) + \epsilon \| \delta(F) \|, F \in D(\delta) \cap \mathcal{F}(\mathcal{O}_R)$$

i) If

$$\liminf_{R\to\infty} c_{R,\epsilon} R^{-\frac{s-1}{2}} = 0$$

then

$$\omega_0 \circ \delta = 0$$

ii) If

$$\liminf_{R\to\infty} c_{R,\epsilon} R^{-\frac{s-1}{2}} < +\infty$$

then

$$\omega_0 \circ \delta \neq 0$$

only if there are massless Bosons present.

iii) If $c_{R,\epsilon}$ is polynomially bounded in R, then

$$\omega_0 \circ \delta \neq 0$$

only if the spectrum of translations is the forward light cone (but there need not be any massless particles present).

□

GEORGES SKANDALIS

Duality for Locally compact "Quantum groups"
(Joint work with S.Baaj)

Locally compact "quantum groups" can be defined as given by a unitary operator acting on a tensor square of a Hilbert space ($V \in \mathcal{L}(H \otimes H)$) and satisfying the pentagon equation

$$V_{12}V_{13}V_{23} = V_{23}V_{12}$$

Out of such a unitary, one can construct two algebras acting on H, whose norm closures are "usually" Hopf-C^*-algebras called $C_r^*(V)$ and $\widehat{C}_r^*(V)$.Corepresentations of one of these C^*-algebras are exactly representations of the other one (in an amenable setting; in general, one constructs full C^*-algebras $C^*(V)$ and $\widehat{C}^*(V)$ whose representations are the corepresentations of $\widehat{C}_r^*(V)$ and $C_r^*(V)$ respectively).

Takesaki duality for von Neumann crossed products can be proved modulo some mild natural assumptions.Some stronger assumptions lead to a Takesaki-Takai duality for reduced C^*-crossed products.

It is natural to look at bimeasurable transformations of a measure space X

$$v : X \times X \to X \times X$$

satisfying the pentagon equation

$$v_{12}v_{23} = v_{23}v_{13}v_{12}$$

With an extra assumption of "regularity", these always come from a locally compact group G and two closed subgroups G_1, G_2 such that the map

$$(x_1, x_2) \to x_1 x_2$$

is a homeomorphism from $G_1 \times G_2$ onto a dense open subset of G.

Conversely, associated to such a decomposition is a multiplicative unitary, which satisfies Takai duality if and only if

$$G = G_1 G_2$$

$\square$

CHRISTIAN SKAU

C^*-algebras associated to minimal dynamical systems and topological orbit equivalence
(Joint work with T.Giordano and I.Putnam)

Let $C(X) \times_\varphi \mathbb{Z}$ denote the C^*-crossed product associated to the minimal dynamical system (X, φ), where X is the Cantor set.Then $K_0(C(X) \times_\varphi \mathbb{Z})$ is a simple dimension group and is order isomorphic to

$$C(X, \mathbb{Z})/Im(Id - \varphi_*) =: K^0(X, \varphi)$$

(endowed with induced ordering from $C(X, \mathbb{Z})^+$.)We show that all simple dimension groups arise in this fashion.Moreover $K^0(X, \varphi)$ turns out to be a complete isomorphism invariant for $C(X) \times_\varphi \mathbb{Z}$.

Theorem:

Let (X, φ_1) and (X, φ_2) be two minimal dynamical systems on the Cantor set X.Then

$$C(X) \times_{\varphi_1} \mathbb{Z} \simeq C(X) \times_{\varphi_2} \mathbb{Z}$$

(equivalently $K^0(X, \varphi_1) \simeq K^0(X, \varphi_2)$) iff (X, φ_1) and (X, φ_2) are strongly topologically orbit equivalent, i.e. φ_1, φ_2 may be transferred by conjugating maps so that

$$orbit_{\varphi_1}(x) = orbit_{\varphi_2}(x) \ \ \forall x \in X$$

and

$$x \to n(x), \ x \to m(x)$$

have at most one point of discontinuity, where $n(x), m(x)$ are the integer valued functions uniquely defined by

$$\varphi_1(x) = \varphi_2^{n(x)}(x), \ \ \varphi_2(x) = \varphi_1^{m(x)}(x)$$

(if $n(x)$ or $m(x)$ is continuous for all x, then it may be shown that φ_1 is conjugate to φ_2 (M.Boyle).

Conjecture:

(X, φ_1) is topologically orbit equivalent to (X, φ_2) iff G_1/H_1 is order-isomorphic to G_2/H_2, where H_i denotes the infinitesimal subgroup of $G_i = K^0(X, \varphi_i)$.

several examples were presented to support the conjecture.One direction is known to be true:Orbit equivalence implies

$$G_1/H_1 \simeq G_2/H_2$$

$\square$

ROLAND SPEICHER

Interpolation between CAR-, Cuntz- and CCR-algebra

We show that there exist on some twisted Fock space "creation" and "annihilation" operators fulfilling the relations

$$c(f)c^*(g) - \mu c^*(g)c(f) = \langle f, g\rangle 1$$
$$f, g \in L^2(\mathbb{R}); -1 \leq \mu \leq 1$$

The essential ingredient is the fact that the function

$$\pi \longrightarrow \mu^{i(\pi)}$$

is positive definite on the symmetric group, where $i(\pi)$ is the number of inversions of the permutation π.Furthermore a "Wick-ordering" Theorem is shown for these relations.

□

KLAUS THOMSEN

Inductive limits of interval algebras

The talk was the presentation of an existence result for inductive limits of sequences of C^*-algebras of the form

$$C[0,1] \otimes \text{ (finite dimensional)}$$

The main part of the talk consisted in the description of the classifying invariant, which basically is an adaption of the construction of the semigroup underlying the K_0 -group with projections substituted by general positive elements of norm less than 1.The emphasis was on the new features, primarily the metric structure of the invariant.

□

ALAIN VALETTE

On duals of Lie groups made discrete
(Joint work with Mohammed Bekka)

Let G be a locally compact group; we denote by G_d the same group with the discrete topology.Dualising

$$G_d \rightarrow G$$

we get an inclusion

$$\widehat{G} \hookrightarrow \widehat{G_d}$$

which is continuous with respect to Fell topologies.Density of $\widehat{G}$ in $\widehat{G_d}$ is equivalent to the fact that any positive definite function on G_d can be approximated pointwise by continuous, positive definite functions on G.It is known (Dunkel-Ramirez 1972, Bekka-Lou-Schlichting 1990) that, if G_d is amenable, then $\widehat{G}$ is dense in $\widehat{G_d}$.Dunkel and Ramirez asked also whether this is true for any G.The following results show that this is not the case in general.

Theorem 1:

Let G be a noncompact semisimple Lie group with finite center and property (T).Let Γ be a lattice in G, and let ϱ be a nontrivial, irreducible representation of Γ that factors through a finite group.Then the copy of $M_{deg\varrho}(\mathbb{C})$ in $C^*(\Gamma)$ that corresponds to ϱ is in the kernel of the canonical homomorphism $C^*(\Gamma) \to M(C^*(G))$. As a consequence, $\widehat{G}$ is not dense in $\widehat{G_d}$.

Theorem 1 answers negatively a question of Rieffel (1974):if H is a closed subgroup in G, the canonical homomorphism $C^*(H) \to M(C^*(G))$ is not always injective.

Theorem 2:

Let G be a connected linear Lie group.Equivalent are
i) $\widehat{G}$ is dense in $\widehat{G_d}$;
ii) G is solvable.

The proof of i)$\Rightarrow$ii) reduces quickly to two cases: a) G a simple compact Lie group.We use the solution of the Ruziewicz problem for G (Sullivan,Margulis,Drinfeld). b) $G = PSL_2(\mathbb{R})$.We use Selberg's inequality $\lambda_1 \geq \frac{3}{16}$ for arithmetic surfaces, plus results of Casselman-Milicic and Pukanszky on complementary series.

$\square$

STANISLAS WORONOWICZ

Quantum E(2) group and its Pontrjagin dual*

By definition

$$E(2) := \left\{ \begin{pmatrix} v & n \\ 0 & v^{-1} \end{pmatrix} : v \in S^1, n \in \mathbb{C} \right\}$$

The algebra $C_\infty(E(2))$ is endowed with the comultiplication Φ introduced by the formula

$$(\Phi e)(g_1, g_2) = e(g_1 g_2)$$

Let $\mu \in]0,1[$ be a deformation parameter.To construct a quantum deformation of $E(2)$ we replace $C_\infty(E(2))$ by

$$A := C_\infty(\Lambda) \times_\mu \mathbb{Z}$$

where Λ is a closed subset of $\mathbb{C}$ invariant under multiplication by $\mu^k; k \in \mathbb{Z}$.

Let v be a unitary and n be a normal operator acting on a Hilbert space H such that

$$Sp(n) = \Lambda \quad \text{and} \quad vnv^* = \mu n$$

Then A may be identified with the norm closure of

$$\left\{ \sum_{finite} v^k f_k(n); f_k \in C_\infty(\Lambda) \right\}$$

The comultiplication is defined by the formula

$$\Phi(\sum v^k f_k(n)) = \sum(v^k \otimes v^k) f_k(v \otimes n + n \otimes v^*)$$

It is selfconsistent if and only if

$$\Lambda = \{\lambda \in \mathbb{C} : \lambda = 0 \text{ or } |\lambda| \in \mu^{\mathbb{Z}}\}$$

This fact follows from the detailed analysis** of the pair of normal operators

$$(R, S)$$

such that

$$SR = \mu^2 RS \text{ and } SR^* = R^* S$$

The general formula expressing unitary representations of the quantum $E(2)$ in terms of pairs (N, b) of closed operators satisfying simple commutation relations is presented.It leads in a natural way to the construction of the Pontrjagin dual of quantum $E(2)$.It turns out that it is a quantum deformation of the "$ax + b$" (where $a \in \mathbb{R}_+, b \in \mathbb{C}$) group.

* Quantum $E(2)$ group and ..., Letters on Math.Phys., to appear
** Operator equalities ..., Commun. in Math. Phys., to appear

□

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