MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 43/1987

C*-Algebren

27.9. bis 1.10.1987

Die nun mittlerweile dritte Oberwolfachtagung über C*-Algebren fand unter der Leitung der Herren J. Cuntz (Marseille) und R. Nagel (Tübingen) statt. In einem sehr reichhaltigen Programm wurde die ganze Vielfalt der Theorie der C*- und W*-Algebren und zahlreiche Aspekte der Anwendungsmöglichkeiten in anderen mathematischen Gebieten repräsentiert. Die thematischen Schwerpunkte reichten von der Strukturtheorie einfacher C*-Algebren über das Klassifikationsproblem für Unterfaktoren, C*-dynamische Systeme und Derivationen, vollständig beschränkte Abbildungen und deren Bedeutung in der Kohomologietheorie bis zur nichtkommutativen Wahrscheinlichkeitstheorie, zur nichtkommutativen Differentialgeometrie und zur K- und KK-Theorie von Operatoralgebren. Ebenso wurden in neuerer Zeit beobachtete und bedeutsam gewordene Zusammenhänge zur Physik, insbesondere zur Quantenfeldtheorie diskutiert. Das Wechselspiel zwischen mathematischen und physikalischen Ideen und die Bedeutung der Geometrie wurden einmal mehr deutlich. In diesem Zusammenhang ist besonders die spektrale Analyse von (diskretisierten) Schrödingeroperatoren zu erwähnen. Vorgestellt wurden auch Anwendungen der C*-Theorie auf Toeplitzoperatoren und auf die harmonische Analyse einfacher Liegruppen.

Zusammenfassend läßt dieser überaus fruchtbare Gedankenaustausch von über 50 Mathematikern und -innen nur einen Wunsch offen: Daß es bald eine vierte C*-Tagung in Oberwolfach geben möge.

Vortragsauszüge

S. Baaj (Orléans) (joint work with **G. Skandalis** (Paris))

Equivariant KK-theory for actions of Hopf algebras

To every pair (A, B) of C*-algebras endowed with an action of a Hopf algebra S, we associate an equivariant KK group denoted $KK_S(A, B)$. For a locally compact group G and the Hopf algebra $S = C_0(G)$, we recover Kasparov's equivariant group $KK_G(A, B)$. If $S = C_r^*(G)$, we find a new group called $KK_{\hat{G}}(A, B)$ equal to the corresponding Kasparov group for abelian G.

THEOREM. Let A, B, D be C*-algebras on which a Hopf algebra S acts. Then (with the usual separability conditions), the Kasparov product:

$$KK_S(A, D) \times KK_S(D, B) \longrightarrow KK_S(A, B)$$

exists and is associative.

Among other results we prove that Kasparov's homomorphism γ_G mapping $KK_G(A, B)$ into $KK_{\hat{G}}(A \times_r G, B \times_r G)$ as well as $\gamma_{\hat{G}} : KK_{\hat{G}}(C, D) \to KK_G(C \times \hat{G}, D \times \hat{G})$ are isomorphisms. In fact, using the generalized Takesaki-Takai duality, these homomorphisms are inverses of each other. We also show that the functors $KK_\Gamma(D, \cdot)$ and $KK_\Gamma(\cdot, D)$ are half exact for amenable discrete groups Γ.

C.J.K. Batty (Oxford)

Derivations and heat semigroups

It is conjectured that if a finite dimensional Lie algebra g acts as a Lie algebra of closed *-derivations on a C*-algebra A, with basis $\delta_1, \dots, \delta_d$, and the Laplacian $\Delta = \sum_i \delta_i^2$ is closable and $\bar{\Delta}$ generates a (holomorphic) contraction semigroup, and $\mathcal{D}(\Delta)$ is a core for each δ_i, then g exponentiates to an action α of the simply-connected covering group G on A. This is proved to be true for $G = \mathbb{R}$, i.e. for a single derivation.

Moreover, in general, δ is a generator if and only if $(\lambda - \delta)^{-1}$ exists and $\sup_n \|[\delta(\lambda - \delta)^{-1}]^n\| < \infty$ for all $\lambda \in \mathbb{R} \setminus \{0\}$.

B. Blackadar (Reno)

Comparability in simple C-algebras*

The following is the most important open question in the structure theory of simple C*-algebras:

Fundamental Comparability Question (F.C.Q.): Let A be a simple unital C*-algebra, p, q non-zero projections in A. If $\tau(p) < \tau(q)$ for all tracial states τ, is $p \prec q$?

This question includes the two well-known open questions of whether every finite simple C*-algebra is stably finite, and whether every quasitrace is a trace. To avoid these questions, the Fundamental Comparability Question can be rephrased:

F.C.Q., Version 2: Let A be a stably finite simple unital C*-algebra, p, q projections in A. If $\tau(p) < \tau(q)$ for all normalized quasitraces τ on A, is $p \prec q$?

The F.C.Q. can be studied via the semigroup $V_0(A)$ of isomorphism classes of non-zero finitely generated projective modules.

THEOREM. A stably finite simple unital C*-algebra A satisfies the F.C.Q. if and only if $V_0(A)$ has strict cancellation and is strictly unperforated, and every homomorphism from $V_0(A)$ into $(\mathbb{R}_+, +)$ is induced by a quasitrace.

The F.C.Q. can be studied by applying the theory of ordered semigroups to the semigroup $W(A)$ formed in analogy with $V_0(A)$, but using arbitrary positive elements in matrix algebras rather than just projections. $W(A)$ has a natural ordering different from the algebraic ordering, and also has a certain type of monotone σ-completeness.

There is a growing body of empirical evidence in favour of the F.C.Q.

F. Beckhoff (Münster)

Korovkin-theory in algebras, H-algebras and liminal C*-algebras*

The notations are taken from F. Altomare, *Korovkin closures in Banach algebras*, Proc. of the IX. Conf. in Operator Theory, Timişoara-Herculane, 1984. A theorem about H*-algebras implies for dual C*-algebras A that $T \subset A \Longrightarrow Kor^{L^{1,+}}(T \cup T^* \circ T) = J(T)$. This is a partial answer to the question following Theorem 8 in Altomare's article. Let $Kor^u(T)$ be the set of all x in A such that whenever B is a C*-algebra, $\pi : A \to B$ a *-homomorphism, $(P_\alpha)_\alpha$ a net in $L^{1,+}(A, B)$ with the property that $P_\alpha t \longrightarrow \pi t$ for all $t \in T$, then $P_\alpha x \longrightarrow \pi x$, the universal Korovkin-closure. (Different from Altomare's paper.) The last result enables us to achieve an upper estimate for the universal Korovkin-closure by a certain topological closure. This leads for liminal C*-algebras with T_2-spectrum by using some representation theory to the following result: There is a finite subset $T \subset A$ such that $Kor^u(T) = A$ iff there is a finite subset $S \subset A$ such that $J(S) = A$.

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O. Bratteli (Trondheim)
(joint work with **G.A. Elliott** (Copenhagen) and **A. Kishimoto** (Toronto))

Quasi-product actions of compact groups on C^*-algebras .

Let A be a separable C*-algebra, G a compact group with more than one element and α a faithful action of G on A. The following conditions are equivalent:

(1) There is a $\delta > 0$ such that for all $x, y \in A$

$$\sup\{\|xay\| \mid a \in A^\alpha, \|a\| = 1\} \geq \delta \|x\| \, \|y\|$$

where A^α denotes the fixed point algebra.

(2) Condition (1) with $\delta = 1$.

(3) There is a faithful irreducible representation π of A such that $\pi_{|A^\alpha}$ is irreducible. (This is equivalent to the center of the representation on the space $H_\pi \otimes L^2(G)$ given by $\rho = \int_G^\oplus \pi \circ \alpha_g \, dg$ being $1 \otimes L^\infty(G)$.)

(4) There exists a pure α-invariant state ω on A such that $\pi_{\omega|A^\alpha}$ is faithful.

(5) For any sequence (ξ_n) of finite dimensional unitary representations of G, with $d_n = \dim(\xi_n)$, define β_g as the product-type automorphism $\beta_g = \otimes_n Ad(\xi_n(g))$ on the UHF-algebra $C = \otimes_n M_{d_n}$. Then there exists an α^{**}-invariant open projection $q \in A^{**}$ and a globally α-invariant C*-subalgebra B of A such that $q \in B'$, $qAq = Bq$, $q \in J^{**} \subseteq A^{**}$ for any non-zero ideal J in A and $(Bq, G, \alpha^{**}_{|Bq}) \approxeq (C, G, \beta)$.

E. Christensen (Copenhagen) (joint work with **A. Sinclair** (Edinburgh))

Linear mappings on operator algebras

Using techniques due to B.E.Johnson, R.V.Kadison and J.R.Ringrose and a trick which is based on the different nature of the "L^∞-norm on A" and the "L^1-norm on A^*", it was proved that for a C*-algebra A without bounded traces the norm continuous Hochschild cohomology for A with coefficients in the dual space A^* vanishes.

Based on an article by J.Arazy and J.Lindenstrauss it was proved that any injective von Neumann algebra S on a separable Hilbert space H is completely bounded isomorphic to $B(H)$, if S is not finite type I of bounded degree. It is clear that commutative von Neumann algebras are not completely bounded isomorphic to $B(H)$ since they do have the approximation property, which $B(H)$ by a result of A.Szankowski does not.

It is an open problem whether a von Neumann algebra S which is completely bounded isomorphic to $B(H)$ must necessarily be injective.

S. Doplicher (Roma) (joint work with **J. Roberts** (Osnabrück))

Semigroups of endomorphisms of C-algebras, cross products, and duality theory for compact groups*

Our investigations were motivated by the analysis of the superselection structure in Quantum Field Theory in terms of local observables. We characterize those semigroups Δ consisting of unital endomorphisms of C*-algebras A with centre the scalar multiples of the identity such that the associated full subcategory of $\operatorname{End} A$ is an abstract compact group dual. Here $\operatorname{End} A$ is the category with objects the unital endomorphisms of A and with arrows their intertwiners in A. $\operatorname{End} A$ is always a strict monoidal C*-category. We assume that the full strict monoidal C*-subcategory with objects Δ is also symmetric and "spacially directed", i.e. the monoidal operations should behave like associative tensor products and properties similar to the existence of conjugates should hold. We construct a cross product B where each element of Δ becomes inner in the sense that there is a Hilbert space H_ρ in B inducing $\rho \in \Delta$ on A. A compact group emerges, the stabilizer of A in $\operatorname{Aut} B$, unitarily represented on each H_ρ. These representations and their intertwiners form a category isomorphic (as a strict symmetric monoidal C*-category) to the full subcategory of $\operatorname{End} A$ with objects Δ. All compact groups G appear in this way; every representation theory of G (unitary representations with finite dimension greater than one and their intertwiners) can be realized within a cross product of the above mentioned type where the subalgebra A of G-fixed points is simple, and determines on A an abstract G dual in which the given representation category can be embedded as a full subcategory.

G.A. Elliott (Copenhagen and Toronto) (joint work with **M.-D. Choi** (Toronto))

All spectral gaps are open for an almost Mathieu operator with Liouville frequency

It is an open question whether the self-adjoint operator $h(\theta,\lambda)$ on $\ell^2(\mathbb{Z})$ defined by

$$(h(\theta,\lambda)\xi)_n = \xi_{n-1} + \xi_{n+1} + \lambda(2\cos 2\pi n\theta)\xi_n,$$

where $0 \le \theta \le 1$ and $\lambda > 0$, has spectrum a Cantor set if θ is irrational. This was shown by Bellisard and Simon in 1982 for a dense set of pairs (θ,λ). We show this for θ a Liouville number (i.e. for θ such that for every $c > 0$ there exists $\frac{p}{q} \in \mathbb{Q}$ with $|\theta - \frac{p}{q}| < c^{-q}$), and for λ arbitrary. Using a result of Bellisard and Simon, we also show that, when θ is a Liouville number, for every integer m there exists a gap in the spectrum of $h(\theta,\lambda)$ at which the integrated density of states (i.e. the trace of the spectral projection $e_{]-\infty,\mathrm{gap}]}(h(\theta,\lambda))$ in the C*-algebra generated by the bilateral shift and the multiplication operator $n \mapsto e^{2\pi i n\theta}$ — the irrational rotation C*-algebra — is $m\theta \pmod{\mathbb{Z}}$). In other words (by results of Pimsner and Voiculescu, 1980), all possible gaps in the spectrum exist.

The proof uses the rational and the irrational rotation C*-algebras, and, specifically, the following noncommutative binomial theorem for the generators of these algebras:

Let a and b be elements of an algebra such that $ba = \gamma ab$ with $\gamma \in \mathbb{C}$. Then

$$(a+b)^n = \sum_{k=0}^{n} \binom{n}{k}_\gamma a^{n-k}b^k$$

with $\binom{n}{k}_\gamma = \frac{(1-\gamma^n)(1-\gamma^{n-1})\cdots(1-\gamma^{n-k+1})}{(1-\gamma)(1-\gamma^2)\cdots(1-\gamma^k)}$. If γ is a primitive (n+1)-st root of unity, then $|\binom{n}{k}_\gamma| = 1$.

D.E. Evans (Swansea)

Critical phenomena and operator algebras

Two dimensional lattice models in classical statistical mechanics, such as the Potts or Andrews-Baxter-Forrester models can be reformulated in a one-dimensional quantum or non-commutative setting. This is via the transfer matrix method, where projections satisfying the Jones′ relations appear naturally. In the continuum limit, where the lattice spacing goes to zero, one gets a conformal field theory, with representations of the Virasoro algebra. The classification of unitary irreducible highest weight representations of the Virasoro algebra is in terms of a central charge c, which is either greater than 1 or $1-\frac{6}{m(m+1)}$, $m = 3,4,\ldots$, has been associated to the Potts and ABF models. It is thus natural to ask for a direct link between the Jones classification of index of subfactors and that of Fredan, Qin, and Slenker on the above classification of representations of the Virasoro algebra. A. Connes and the speaker have shown how to construct currents from the Jones′ algebra, and so representations of the Virasoro algebra with central charge the same as in the case of index 2 (Ising model).

T. Giordano (Genève) (joint work with **D.E. Handelman** (Ottawa))

Real AF C-algebras with K_0 of small rank*

A real AF C*-algebra is the norm closure of a direct limit of finite dimensional real C*-algebras (with real *-algebra maps). Let R be a simple complex AF C*-algebra such that $K_0(R)$ is free of rank 2 or 3. The problem is to find (up to Morita equivalence) all real AF C*-algebras A such that $A \otimes \mathbb{C} \cong R$.

If the rank is 2, then generally there are 8 such classes. The exceptional cases arise when the ratio of the two generators in $K_0(R)$ is a q-adic (algebraic) number and here, there are 4, 5 or 8 Morita equivalence classes, the number depending largely on the behaviour of the prime 2 in the relevant algebraic number field.

Let S be a subset of $\{r,c,h\}$. A real AF C*-algebra A is said to be of type S if it can be written as a limit of a direct sum of matrix algebras over the fields indicated in S. When $K_0(R)$ has rank 3, the corresponding A must be of one of the types r, h, rc, ch or rh (but it cannot be of type c). The classification of type rh is then analogous to that of the rank 2 situation.

In the case of rc (and ch is similar, since we can go from one to the other by tensoring with the quaternions), there is a unique trace on R. There are generally just 3 Morita equivalence classes of such A, and in the exceptional cases (corresponding to a quadratic image in the reals), there are 2 or 1.

U. Haagerup (Odense) (joint work with **E. Størmer** (Oslo))

Equivalence of states on von Neumann algebras and the flow of weights

Two positive normal functionals φ, ψ on a von Neumann algebra M are called *equivalent* $(\varphi \sim \psi)$ if $\exists\, u_n \in U(M)$ such that $\lim\limits_{n\to\infty} \|\psi - u_n \varphi u_n^*\| = 0$. The equivalence classes $M_*^+/\sim$ form a metric space with metric

$$d([\varphi],[\psi]) = \inf_{u\in U(M)} \|\psi - u\varphi u^*\|.$$

We construct a map $\varphi \mapsto \hat{\varphi}$ of M_*^+ into the positive normal functionals on the smooth flow of weights for M realized as the center $Z(N)$ of the crossed product $N = M \times_{\sigma^\omega} \mathbb{R}$ for some fixed normal faithful semifinite weight ω on M as follows: Let $(\theta_s)_{s\in\mathbb{R}}$ be the dual action of σ^ω and τ the canonical trace on N for which $\tau \circ \theta_s = e^{-s}\tau$. For every $\varphi \in M_*^+$, there is a unique projection $e = e_\varphi \in L^1(N,\varphi)$ with the properties that

$$\theta_s(e) \le e,\ s > 0 \quad \text{and} \quad \tau(xe) = \varphi(x),\ x \in M.$$

Put $\hat{\varphi}(z) = \tau(e_\varphi z)$, $z \in Z(N)$. We prove that $\varphi \mapsto \hat{\varphi}$ defines an isometry of M_*^+ into the set $P(N) = \{\chi \in Z(N)_*^+ \mid \chi \circ \theta_s \ge e^{-s}\chi,\ s > 0\}$. Moreover, if M has no type I or II_1 summands, then the range of the map is all of $P(N)$.

As an application, we get a new proof of the diameter formula

$$\operatorname{diam}(s_n(M)/\sim) = 2\,\frac{1-\lambda^{\frac{1}{2}}}{1+\lambda^{\frac{1}{2}}}$$

for the normal state space of a factor of type III_λ, $\lambda \in [0,1]$.

U. Haagerup (Odense)

Informal seminar on *Harmonic analysis on* $Sp(1,n)$ *and type* II_1*-factors.*

P. de la Harpe (Genève)

On the set of indices for subalgebras of finite dimensional algebras

Let ε be the set of those real numbers $s > 0$ such that $s^2 = [M : N]$ for some pair $N \subset M$ of finite dimensional von Neumann algebras, where $[\,:\,]$ indicates index à la Jones. Works of Lagrange (1759), Kronecker (1857) and Coxeter (around 1950) imply that $\varepsilon \cap [1,2[= \{2\cos(\frac{\pi}{q})\}_{q=3,4,\ldots}$. A.J.Hoffman (Springer Lecture Notes **303** (1972), 165-172) showed that limit points of ε less than $\lambda_\infty = \sqrt{\sqrt{5}+2}$ constitute an increasing sequence $\lambda_2 = 2 < \lambda_3 < \ldots \to \lambda_\infty$. On the other hand, it is easy to check that $st \in \varepsilon$ and $s+t \in \varepsilon$ if $s,t \in \varepsilon$. Here are two recent progresses.

THEOREM (J.Shearer). The closure of ε contains $[\lambda_\infty, \infty[$.

PROPOSITION (P. de la Harpe and H.Wenzl). Define polynomials $(R_j)_{j\geq 0}$ in $\mathbb{Z}[T]$ by $R_0 = 1$, $R_1 = T$, $R_j = TR_{j-1} - R_{j-2}$. If $\lambda \in \varepsilon$ satisfies $\lambda \geq 2\cos(\frac{\pi}{k+1})$, then $R_k(\lambda) \in \varepsilon$.

R. Herman (University Park)

Pairs of factors: The infinite index case

We show that, for $N \subseteq M$, pairs of II_1-factors, a basis for M over N always exists. This extends the results of Pimsner and Popa for finite index. If M_1 denotes the first extension (in the sense of Jones) there is an operator valued weight from M_1 to M relating the traces. (This is a result of Haagerup.) We show that M_1 is isomorphic to $\mathrm{Mat}(N)$ and M_2 is isomorphic to $\mathrm{Mat}(M)$ with the inclusion being the obvious one. There thus exists a projection from M_2 onto M_1. These general results are then used to characterize twisted crossed products by discrete groups. The theorem is that M is a twisted crossed product of N by a discrete group if and only if $N' \cap M = \mathbb{C}1$, $N' \cap M_1$ is abelian and $N' \cap M_2$ is a factor.

P. Julg (Paris) (joint work with **A. Valette** (Bruxelles))

Fredholm modules and Bruhat-Tits buildings

The proof of non-existence of non-trivial projections in $C^*_r(F_n)$ (Pimsner-Voiculescu, Cuntz, Connes, Julg-Valette) has led to a Fredholm module associated with a group action on a tree. In order to generalize this to more general groups one has to generalize the construction of that Fredholm module to contractible simplicial complexes. We show that this is possible in the case of affine type buildings which were introduced by F.Bruhat and J.Tits as analogues of the Riemannian symmetric spaces of non-compact type, when Lie groups are replaced by p-adic groups. If $\Delta^q = \{q\text{-simplices of the building}\}$ and $x_0 \in \Delta^0$, we define an unbounded operator $d : \ell^2(\Delta^q) \to \ell^2(\Delta^{q+1})$ which is roughly speaking the exterior multiplication by the "vector field" $x \mapsto (xx_0)$. One has $d^2 = 0$ and

$(d+d^*)^2 = dd^* + d^*d = \rho^2$ where ρ is the distance to x_0. The operator $D = d + d^*$ on $\ell^2(\Delta)$ satisfies the axioms of θ-summable Fredholm modules introduced by A.Connes:

(1) $[D, g]$ is bounded for any $g \in G$

(2) e^{-tD^2} is trace class for any $t > 0$.

D. Kastler (Marseille)
(joint work with **R. Stora**, **A. Jadczyk** and **R. Coquereaux**)

Remarks on non-commutative differential and integral calculus

In our talk we discussed the following topics:

The Fredholm modules yielded by elliptic operators as the starting point of A.Connes' discovery of cyclic cohomology.

The $\mathbb{Z}/2$-graded cyclic cohomology of a complex algebra A (definition based on the multiplication algorithm in the differential envelope $\Omega(A)$).

The unital differential envelope ΩA as a subalgebra of the ideal $A\Omega(A)$ of $\Omega(A)$. Description of $\Omega(A)$ for A $\mathbb{Z}/2$-graded in terms of $\Omega(\underline{A})$, with $\underline{A}$ the corresponding trivially graded algebra.

The notion of Lie Cartan pairs (resp. graded Lie Cartan pairs) as the extraction of the algebraic aspects of usual (resp. fermionic) differential geometry.

The Berezin integral (fermionic integration) in terms of the $\mathbb{Z}/2$-graded cyclic cohomology of the Grassmann algebra.

A. Kishimoto (Toronto)

Type I orbits in the pure states of C-dynamical systems*

B. Kümmerer (Tübingen)

On non-commutative stationary Markov processes

We consider a pair (A, φ) (A a W*-algebra, φ a normal state on A) as a non-commutative probability space. Given such a probability space $(\hat{A}, \hat{\varphi})$ with $\hat{\varphi}$ faithful we define a non-commutative random variable to be an injective *-homomorphism $i : A \to (\hat{A}, \hat{\varphi})$, A another W*-algebra, such that there exists a conditional expectation from $\hat{A}$ onto $i(A)$ which leaves $\hat{\varphi}$ invariant. From this we derive the notions of non-commutative stationary processes, transition operators, Chapman-Kolmogorov-equations and Markov processes. In the non-commutative setting for a given semigroup of transition operators, a corresponding Markov process need not to exist, and if it exists it is no longer determined by its transition operators (in contrast to the situation in classical probability theory). Beside the problem of extending the commutative theory to the non-commutative setting we are therefore faced with an existence problem and a classification problem for Markov processes. We give a number of results on these problems.

R. Longo (Roma)

Recent developments concerning split inclusions in mathematics and in physics

The first part of this talk deals with the problem of restricting a compact action $\alpha : G \to \mathrm{Aut}(M)$ on an infinite factor M to an injective subfactor. If M_* is separable and α is dominant (M^α is infinite and the monoidal spectrum is full) we construct an α-invariant injective subfactor $R \subseteq M$ which is simple ($R \vee JRJ = B(H)$, where J is the modular conjugation of M); since simple subfactors determine the isomorphisms the restriction of α to R determines α; moreover there exists a dense copy in R of the Cuntz algebra $\mathcal{O}_\infty$ that is α-invariant and $\alpha_{|\mathcal{O}_\infty}$ is of canonical type (i.e. determined by a unitary representation on a Hilbert space of isometries generating $\mathcal{O}_\infty$).

Since all actions can be perturbed to a dominant action, every action is cocycle conjugate to an action that normalizes a simple injective subfactor.

The second part of the talk describes a joint work with D.Buchholz and C.D'Antoni. Motivated by the Buchholz-Wichmann nuclearity condition in Quantum Field Theory, we characterize the split property of an inclusion of von Neumann algebras $A \subseteq B$ by the nuclearity of the map $A \ni a \mapsto \Delta_B^{\frac{1}{4}} a\Omega$ for some cyclic separating vector Ω for B.

T. Loring (Swansea)

Homology and homotopy groups for C^*-algebras

Let F_*K_* be a filtration of K-theory

$$F_0K_0 = K_0 \supseteq F_2K_0 \supseteq F_4K_0 \supseteq \dots$$
$$F_1K_1 = K_1 \supseteq F_3K_1 \supseteq F_5K_1 \supseteq \dots$$

which extends the homology of finite CW-complexes in the sense that for $n \geq 0$

$$(\ddagger) \qquad F_nK_n(C(X)) \otimes \mathbb{Q} \cong ch^{-1}\Big(\bigoplus_{k\geq 0} H^{n+2k}(X;\mathbb{Q})\Big).$$

On the negative side, it was shown that no such filtration can satisfy the following three axioms simultaneously:

additivity:	$F_nK_n(A \oplus B) \cong F_nK_n(A) \oplus F_nK_n(B)$
matrix stability:	$F_nK_n(A \otimes M_k) \cong F_nK_n(A)$
continuity:	$F_nK_n(\varinjlim A_k) \cong \varinjlim F_nK_n(A_k)$.

There is, however, a filtration, called the spherical filtration, which satisfies (‡) and the first two of the above axioms. It arose in joint work with R.Exel. The definition is, for A a unital C*-algebra, $n \geq 2$, $F_n K_n(A) = \{x \in K_n(A) \mid \exists$ unital $\varphi : C(S^n) \to A \otimes M_k,\ \varphi_*(\text{Bott-element}) = x\}$.

M. Mathieu (Tübingen)

Report on elementary operators

Elementary operators originate in the study of matrix equations at the end of the last century. Since the early 1970's, there has been an extensive investigation of the properties of elementary operators acting on $B(H)$, H a Hilbert space. We report on some recent results on complete positivity and (weak) compactness as well as the spectrum of elementary operators on more general C*-algebras.

P.S. Muhly (Iowa City) (joint work with **R. Curto** and **J. Xia**)

Random operators and real indices

Let $(X, \mathbb{R})$ be a compact flow and let $\varphi \in C(X)$. For each $x \in X$, let $\varphi_x(t) = \varphi(x+t)$, $t \in \mathbb{R}$, and consider the Toeplitz operator T_{φ_x} on $H^2(\mathbb{R})$. We are concerned with the spectral properties of all the T_{φ_x} as x ranges over X. Choose an invariant ergodic probability measure m on X. Then the direct integral $\int^{\oplus} T_{\varphi_x}\, dm(x)$ is unitarily equivalent to an operator T_φ living in a II_∞-factor $\mathcal{M}$.

THEOREM 1. (a) T_φ is Breuer-Fredholm in $\mathcal{M}$ $\iff$ $\varphi \in C(X)^{-1}$.
(b) Index $T_\varphi = -\mu_x(\varphi)$ a.e. m where $\mu_x(\varphi) := \lim\limits_{T\to\infty} \frac{1}{4\pi T}\{\arg(\varphi(x+T)) - \arg(\varphi(x-T))\}$.
(c) If the flow is strictly ergodic (so that the $\mu_x(\varphi)$ exist for all x and have the same value $:= \mu(\varphi)$, assuming $\varphi \in C(X)^{-1}$), and if μ is injective when viewed, as it may be viewed, as a homomorphism of $H^1(X, \mathbb{R})$ into $\mathbb{R}$, then T_φ and all the T_{φ_x} are invertible if and only if $\varphi \in C(X)^{-1}$ and $\mu(\varphi) = 0$.

THEOREM 2. Suppose $(X, \mathbb{R})$ is strictly ergodic and let $\varphi \in C(X)$ be such that $\varphi_x \in H^\infty(\mathbb{R})$ for all $x \in X$. If $\varphi \in C(X)^{-1}$ and if $\int \varphi\, dm \neq 0$, then there are y_1, y_2 with $0 < y_1 < y_2$ such that the zeros of the analytic extensions of all the φ_x's to the upper half-plane $0 < \operatorname{Im} z$ all lie in the strip $y_1 < \operatorname{Im} z < y_2$ and Index $T_\varphi = -$ the density of the zeros of any φ_x in the strip.

The proofs use the Pincus principal function and generalizations of Jessen's and Tornehave's work on the value distribution theory of analytic almost periodic functions.

A. Ocneanu (University Park)

Classification of subfactors of finite depth

We classify subfactors with index less than 4 of the elementary von Neumann algebra R : there are one for each Dynkin diagram A_n and D_{2n}, and two anticonjugate but nonconjugate for each of the E_6 and E_8 diagrams. In general, we introduce a Galois type invariant for inclusions of algebras, called a paragroup, which is a group-like object, with the underlying set of the group replaced by a graph, the Haar measure substituted by a harmonic weight on the vertices, elements of the group replaced by strings on the graph and harmonic analysis in the paragroup similar to partition function computations in string theory. We show more generally that for subfactors of finite index, finite depth and scalar centralizer of R, the paragroup is a complete conjugacy invariant.

A. Ocneanu (University Park)

Informal seminar on *Examples of subfactors.*

V. Paulsen (Houston)

Schur products, matrix completions, and semi-discreteness

We exploit a duality between extensions of Schur product maps and completions of partially defined matrices to obtain some Hahn-Banach type theorems for Schur product maps and some matrix completion results. We apply these results to prove that contractive representations of certain subalgebras of matrices are completely contractive.

We have obtained certain analogues of the concepts of semi-discreteness and hyper-finiteness which hold for a wide class of commutative subspace lattice algebras (CSL). Combining these results allows us to conclude that σ-weakly contractive representations of some CSL-algebras are completely contractive.

D. Petz (Budapest)

Canonical extension of states on a subalgebra

Let M be a von Neumann algebra with a subalgebra M_0. If E is a conditional expectation from M into M_0, then any faithful normal state φ_0 on M_0 admits a natural extension $\varphi = \varphi_0 \circ E$ to M. If E_ω is only an ω-conditional expectation then $\varphi_0 \circ E_\omega$ is not an extension of φ_0 in general. However, we can define a canonical extension φ of φ_0 with respect to E_ω which has remarkable properties.

R. Plymen (Manchester)

Reduced C-algebras of reductive matrix groups (real and p-adic)*

Let G be a reductive matrix group over F, where F is $\mathbb{R}, \mathbb{C}$ or a local field. The C*-Plancherel Theorem is stated for such groups. The reduced C*-algebra $C^*_{red}(G)$ is determined, up to Morita equivalence, for $GL(n,F)$, $SL(2,F)$ and $SL(3,F)$ where F is a local field. Of special interest is $SL(3,\mathbb{Q}_p)$ when $p=3$ or $p \equiv 1 \bmod 3$. Then $C^*_{red}(G)$ contains finitely many components Morita equivalent to $\mathbb{Z}/3 \times C(\mathbf{T}^2)$ which is an "orbifold" homeomorphic to the 2-sphere with 3 triple points. It is shown how $C^*_{red}(SL(2,F))$ reflects the arithmetic of the local field F.

J. Renault (Paris)

The ideal structure of groupoid crossed product C-algebras*

The results of Sauvageot, Gootman and Rosenberg on the generalized Effros-Hahn conjecture are extended to groupoid crossed product C*-algebras. As a corollary, the simplicity of the reduced crossed product $C^*_{red}(G,A)$ is established under the hypothesis that G is Hausdorff, the action of G on $Prim\,A$ is minimal and there is a point in $Prim\,A$ with discretely trivial isotropy. Moreover, the ideal structure of $C^*(G,A)$ is determined when G is Hausdorff and the action of G on $Prim\,A$ is amenable and essentially free.

N. Riedel (New Orleans)

Some problems related to a certain class of Schrödinger operators and C-algebras*

The irrational rotation C*-algebras A_α are considered, which are generated by two unitaries u, v satisfying the relation $uv = \lambda vu$, where $\lambda = e^{2\pi i\alpha}$, α an irrational number. For any real constant β the almost Mathieu operator $h(\alpha,\beta) = u + u^* + \beta(v + v^*)$ is defined. An eigenstate φ on A_α for χ in $\mathrm{Sp}(h(\alpha,\beta))$ is a state having the property $\varphi(h(\alpha,\beta)a) = \chi\varphi(a)$ for all $a \in A_\alpha$. The following conjecture is discussed: The set of all pure eigenstates of $h(\alpha,\beta)$ is compact with respect to the weak*-topology on A^*_α and the connected components of this compact space are homeomorphic to the circle.

J.E. Roberts (Osnabrück) (joint work with **S. Doplicher** (Roma))

A new duality theory for compact groups

The following characterization of the category of finite-dimensional continuous unitary representations is given.

THEOREM. Every strict symmetric monoidal C*-category with conjugates and closed under (finite) direct sums and subobjects for which the C*-algebra of endomorphisms of the monoidal unit reduces to the complex numbers is isomorphic to

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a category of finite-dimensional continuous unitary representations of a compact group determined uniquely up to isomophism.

N. Salinas (Lawrence)

Hermitian holomorphic vector bundles

The definition of hermitian holomorphic vector bundles over a complex manifold with fibres in the (real analytic) manifold of all self-adjoint idempotents in a given unital C*-algebra is introduced. Various equivalent conditions of this definition are given. It is also proved the following result:

Let T be an n-tuple in a given C*-algebra such that the "range" of $|T-\omega| = \left(\sum |T_j - \omega_j|^2\right)^{\frac{1}{2}}$ is closed for every ω in a bounded domain $\Omega \subseteq \mathbb{C}^n$, and such that the projection $P(\omega)$ onto $\ker(T-\omega)$ $(= \ker|T-\omega|)$ is nontrivial for every ω in Ω. Then P is a topological vector bundle if and only if it is a holomorphic vector bundle.

C. Skau (Trondheim)

On the ergodic-theoretic proof of Szemerédi's theorem

Fürstenberg proved in 1977 the following multiple recurrence theorem:

Let $(X, \mathcal{B}, \mu, T)$ be a Lebesgue measure-preserving ergodic system with $\mu(X) = 1$. Let $A \in \mathcal{B}, \mu(A) > 0$. For any natural number k there exists a natural number n such that $\mu(A \cap T^{-n} \cap \ldots \cap T^{-kn}) > 0$.

This theorem is actually equivalent to Szémerédi's theorem on arithmetic progressions in subsets of the natural numbers with positive upper density.

We consider the possibility of giving a proof of Fürstenberg's theorem by using Jewett-Krieger's representation theorem of $(X, \mathcal{B}, \mu, T)$ as a uniquely ergodic action on a Cantor set and then apply van der Waerden's theorem. In that way we may avoid the dichotomy in Fürstenberg's proof between weak mixing and compact systems, which makes his proof so complicated. To make the new approach work it is necessary to modify Jewett's "perturbation to uniformity"-technique so that a given set $A \in \mathcal{B}$ will correspond to a set with non-empty interior. This is as yet not achieved.

E. Størmer (Oslo) (joint work with **U. Haagerup** (Odense))

Centralizers of normal states

Let M be a von Neumann algebra without a direct summand of type I. If $\varphi, \psi \in M_*^+$ then $\varphi \sim \psi$ if there exists a sequence (u_n) of unitaries in M such that $\|u_n \psi u_n^* - \varphi\| \to 0$. If $M = P \otimes M_n(\mathbb{C})$ and τ_0 is the tracial state on $M_n(\mathbb{C})$ then the map $\rho \mapsto \rho \otimes \tau_0$ induces an isometry between the quotient spaces $P_*^+/\sim$ and $M_*^+/\sim$. Using this it follows that given $\varphi \in M_*^+$ then there exists $\psi \sim \varphi$ such that the centralizer M_ψ contains a I_2-factor. A recursive argument proves that if φ is faithful then there exists a faithful $\psi \sim \varphi$ such that M_ψ is of type II_1.

H. Upmeier (Lawrence)

Toeplitz C-algebras and several complex variables*

To any bounded symmetric domain D in $\mathbb{C}^n$ one can associate the C*-algebra $\mathcal{T}_D$ generated by all Toeplitz operators (with continuous symbols) on the Hardy space $H^2(S)$ over the Shilov boundary S of D.

THEOREM 1. $\mathcal{T}_D$ is a solvable C*-algebra of length $r = \text{rank}$ of D, with a canonical composition series given in terms of the boundary geometry of D.

THEOREM 2. The composition series $\mathcal{I}_1 \subset \ldots \subset \mathcal{I}_r$ of $\mathcal{T}_D$ induces analytical j-indices $(1 \le j \le r)$ which can be topologically expressed as the K-theoretic index character of the j-th stratum of ∂D.

Similar results hold for Wiener-Hopf integral operators on symmetric cones in $\mathbb{R}^n$.

A. Valette (Bruxelles)

Informal seminar on *p-summable Fredholm modules*, following A. Connes.

We discuss the following recent results of Connes that rule out the existence of p-summable unbounded Fredholm modules on a number of interesting C*-algebras.

(1) Let Γ be a countable group having Kazhdan's property (T). Then

(i) There exists no p-summable unbounded Fredholm module over the reduced C*-algebra $C_r^*(\Gamma)$.
(ii) Any p-summable bounded Fredholm module over the group algebra $\mathbb{C}[\Gamma]$, with $1 \le p \le 2$, is homotopic to a trivial module.

(2) If a unital C*-algebra admits a p-summable unbounded Fredholm module, then it admits a positive normalized trace.

(3) If a unital C*-algebra A admits a unique tracial state τ, and if moreover τ is faithful, then for any p-summable unbounded Fredholm module (H, D) with H quasi-equivalent to $L^2(A, \tau)$, the weak closure of A on H is a hyperfinite von Neumann algebra.

(4) Let Γ be a countable group containing a copy of the free group on two generators. Then there exists no p-summable unbounded Fredholm module (H, D) over $C_r^*(\Gamma)$, with H quasi-equivalent to $\ell^2(\Gamma)$.

A. Wassermann (Berkeley)

Informal seminar on

Ergodic actions of compact groups on factors and the Yang-Baxter equation.

Ergodic actions with factor crossed product are classified by bicharacters $\beta \in \mathcal{R} \otimes \mathcal{R}$ and perturbations δ of the comultiplication on the group algebra $\mathcal{R}$. β satisfies the Yang-Baxter equation $\beta_{12}\beta_{13}\beta_{23} = \beta_{23}\beta_{13}\beta_{12}$. By taking the component of β corresponding to a faithful irreducible representation and composing with the flip, one obtains a matrix $R \in \mathrm{End}(V \otimes V)$ such that $\pi_R((i, i+1)) = R_{i,i+1}$ defines a factor representation π_R of the infinite symmetric group $S(\infty)$ in $\bigotimes \mathrm{End} V$. Let $N = \pi_R(S(\infty))'' \subseteq M = (\bigotimes \mathrm{End} V)''$. Then β and δ can be recovered from the higher relative commutants of the inclusion $N \subset M$. For $SU(2)$, $SO(3)$ and $SU(3)$ one can completely determine the bicharacters and hence show that these groups do not admit ergodic actions of full multiplicity on the hyperfinite II_1 factor.

J. Weidner (Heidelberg)

Kasparov theory for generalized operator algebras

Kasparov's KK-theory which was originally defined only for C*-algebras can be extended to inverse limits of C*-algebras. This is done in such a way that $KK(\mathbb{C}, C(X))$ is isomorphic to the representable K-theory $K^o(X) = [X, \mathcal{F}(H)]$ ($\mathcal{F}(H)$ the Fredholm operators on a separable infinite dimensional Hilbert space) for a large class of spaces containing for example all CW-complexes.

R. Zekri (Marseille)

Extensions of C-algebras and $\varepsilon(A)$*

For any C*-algebra A, let $QA = A \star A$ be the free product of A with itself. Denote by qA the kernel of the multiplication map, sending QA onto A. (Just identify the two copies of A.) Cuntz has shown that, if A and B are separable, trivially graded C*-algebras, then $KK^o(A, B) \simeq [qA, \mathcal{K} \otimes B]$, the group of homotopy classes of homomorphisms from qA to $\mathcal{K} \otimes B$. We define the C*-algebra $\varepsilon(A)$ as the cross product of qA by the automorphism exchanging the two copies of A, and show that $KK^1(A, B) \simeq [\varepsilon(A), \mathcal{K} \otimes B]$. We also discuss the Kasparov product in the setting of the qA and $\varepsilon(A)$ C*-algebras.

G. Zeller-Meier (Marseille)

Some so far apparently unnoticed remarks on Hilbert C-modules*

Let B be a C*-algebra. Every B-inner product $< \xi, \eta >$ on a complex vector space E defines a semi-norm and $\| < \xi, \eta > \| \leq 2\|\xi\|\|\eta\|$ is true (with equality obtainable for $B = M_2(\mathbb{C})$, $E = \mathbb{C}^2$). Thus, we can copy the complex Hilbert space theory even if we do not have a B-module action. Let E be a B-Hilbert space. One gets (Rieffel made the first step) that a non-degenerate (faithful) representation of a C*-algebra A into the C*-algebra $L_B(E)$ (of all maps with adjoints) can be extended into a (faithful) representation of $LM(A)$ (the Banach algebra of all the left centralizers of A) into $L_{\mathbb{C}}(E)$. Now if E is a Hilbert B-module, one gets an identification of $LM(K_B(E))$ with the Banach algebra $B_B(E)$ of all bounded B-module endomorphisms. Let E be a B-pre-Hilbert space. Then we get (constructing a Hilbert B-module from a positive B-kernel) that there are a Hilbert B-module F and a linear map, preserving the B-inner product, from E into F iff E has the Gramm property (i.e. for every finite set $\{\xi_1, \ldots, \xi_n\}$ in E, the matrix $(<\xi_i, \xi_j>_{ij})$ belongs to $M_n(A)_+$). If B is abelian, every B-pre-Hilbert space has the Gramm property.

L. Zsidó (Stuttgart)

On the sequential approach for operator algebras

The opposite notion to the σ-additive linear functionals on a Rickart algebra, the σ-singular linear functionals can be defined. It is reasonable to believe that the σ-singular linear functionals on a Rickart subalgebra of a von Neumann algebra can be similarly characterized as this was done by M. Takesaki for singular linear functionals on von Neumann algebras. The proposed characterization could be used to prove continuity properties of Jauch-Piron states on von Neumann algebras.

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