Tagungsbericht 14/1996

C^*-Algebren

8-13 April 1996

The meeting was organized by Joachim Cuntz (Heidelberg, Germany), Uffe Haagerup (Odense, Denmark) and Laslo Zsido (Rome, Italy). There where 23 talks with some emphasis on the classification of simple C^*-algebras and the theory of subfactors. There were three inofficial evening sessions by F.Radulescu, G.Elliot and E.Kirchberg (abstracts are included). The plentyful sparetime was used for discussions.

Abstracts of the talks:

"A Polynomially Bounded Operator which is not Similar to a Contraction", Gilles Pisier, Paris

We present the construction of an example as indicated in the title. This solves a problem raised by Halmos around 1970.

The example is an operator T of the following form

$$T = \begin{pmatrix} S^* & \Gamma \\ 0 & S \end{pmatrix}$$

where $\Gamma : H \oplus H \oplus \cdots \to H \oplus H \oplus \cdots$ is a vectorial Hankel operator and where S denotes the shift on $H \oplus H \oplus \cdots$. Here $H = \ell_2$.

The operator Γ has an associated (Hankel) matrix

$$\Gamma = \begin{pmatrix} c_0/2^0 & c_1/2^1 & 0 & c_2/2^2 & 0 & 0 & 0 & c_3/2^3 & \cdots \\ c_1/2^1 & 0 & c_2/2^2 & 0 & 0 & 0 & c_3/2^3 & 0 & \\ 0 & c_2/2^2 & 0 & 0 & 0 & c_3/2^3 & 0 & 0 & \\ c_2/2^2 & 0 & 0 & 0 & c_3/2^3 & 0 & 0 & 0 & \\ 0 & 0 & 0 & c_3/2^3 & 0 & 0 & 0 & 0 & \\ 0 & 0 & c_3/2^3 & 0 & 0 & 0 & 0 & 0 & \\ 0 & c_3/2^3 & 0 & 0 & 0 & 0 & 0 & 0 & \\ c_3/2^3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \\ \vdots & & & & & & & & \end{pmatrix}$$

where $c_n : H \to H$ are operators such that $\forall(\alpha_n) \in \ell_2 : \| \sum \alpha_n c_n \| \leq (\sum |\alpha_n|^2)^{1/2}$.

For any choice of (c_n), the operator T is polynomially bounded (this follows from an idea proposed around 1982 by Peller) but for some choice of (c_n) (for instance if (c_n) is a sequence satisfying the CAR – canonical anticommutation relations –) T is not similar to a contraction.

"Ramanujan Graphs and C^*–Norms on $B(H) \otimes B(H)$", Alain Valette, Neuchâtel

Set $\lambda(n) = \sup \left\{ \frac{\|u\|_{\max}}{\|u\|_{\min}}, u \text{ a tensor of finite rank } n \text{ in } B(H) \otimes B(H) \right\}$. In a remarkable paper (GAFA 1995), M.Junge and G.Pisier proved that there exists a constant $c > 0$ such that

$$cn^{1/8} \leq \lambda(n) \leq \sqrt{n}.$$

In particular, $\|\cdot\|_{\min} \neq \|\cdot\|_{\max}$ on $B(H) \otimes B(H)$, solving a long standing question. Junge and Pisier ask for the asymptotic behavior of $\lambda(\cdot)$. Using Ramanujan graphs, we prove:

<u>Proposition 1:</u> $\lambda(n) \geq \frac{n}{2\sqrt{n-1}} > \frac{\sqrt{n}}{2}$ for $n = 1 + q$, q a prime power.

From this we deduce:

<u>Proposition 2:</u> $\liminf_{n\to\infty} \frac{\lambda(n)}{\sqrt{n}} \geq \frac{1}{2}$

"Almost commuting selfadjoint matrices", Michael Rørdam, Odense

Huaxin Lin proved in 1993/94 the following theorem conjectured by Peter Rosenthal in the late 1960'ies:

There exists a function $f : \mathbb{R}^+ \to \mathbb{R}^+$ with $f(0) = 0$ and continuous at $t = 0$ such that for every $n \in \mathbb{N}$ and every $x \in M_n(\mathbb{C})$ with $\|x\| \leq 1$,

$$\mathrm{dist}(x, N(M_n(\mathbb{C})) \leq f(\|x^*x - xx^*\|),$$

where $N(A)$ is the set of normal elements in A.

We present a new and shorter proof of the theorem, which is a joint work with Peter Friis. The problem can be reduced to showing that for every sequence $\{n_j\} \subset \mathbb{N}$, the C^*-algebra

$$\prod_{j=1}^{\infty} M_{n_j}(\mathbb{C}) / \sum_{j=1}^{\infty} M_{n_j}(\mathbb{C})$$

has property (FN): every normal element can be approximated by finite spectrum normal elements. The key to the short proof uses the observation that for any unital C^*-algebra A, we have $\overline{N(A) \cap Gl(A)} = N(A) \cap \overline{Gl(A)}$. This implies that if A is a C^*-algebra with property (IN) (i.e. $N(A) \subset \overline{Gl(A)}$) the following holds: each normal element in A can be approximated by normal element with 1-dimensional spectrum. Combining this with a theorem of H.Lin yields that A has property (FN) iff A has property (IN), $RR(A) = 0$ and $U(A)$ is connected. The algebra in question is easily seen to have the latter property.

The same methods yield a generalization of Lin's theorem whereby the function $F : \mathbb{R}^+ \to \mathbb{R}^+$ can be chosen to work simultaneously for every stable rank one C^*-algebra and every purely infinite simple C^*-algebra.

"Canonical algebras associated to intermediate subfactors", Dietmar Bisch, Berkeley

The Temperley-Lieb algebras are the fundamental symmetry associated to any inclusion of II_1 factors $N \subset M$ with finite Jones index. If there is an intermediate subfactor P of $N \subset M$ the additional symmetry is captured by a tower of certain algebras IA_n, which are defined in the following way: let $N \subset P \subset M \overset{p_1}{\subset} P_1 \overset{e_1}{\subset} M_1 \overset{p_2}{\subset} P_2 \overset{e_2}{\subset} M_2 \overset{p_3}{\subset} \cdots$ be the Jones basic construction, where $P_i \subset M_i \overset{p_{i+1}}{\subset} P_{i+1}$ and $M_{i-1} \subset M_i \overset{e_{i+1}}{\subset} M_{i+1}$ are the basic constructions. Let $\alpha = [P : N]^{-1}$, $\beta = [M : P]^{-1}$ and define $IA_n(\alpha, \beta) = Alg(1, e_1, p_1, .., e_{n+1}, p_{n+1}) \subset N' \cap M_{n-1}$. These algebras form a Popa system and thus, by a remarkable theorem of Popa, arise as higher relative commutants of a subfactor, which then has necessarily an intermediate subfactor. They are therefore the fundamental symmetry associated to an intermediate subfactor. We describe the structure of the $IA_n(\alpha, \beta)$ and their Bratelli diagram. This is done by studying a hierarchy $((FC_{k,n}(a_0, .., a_k))_{n \in \mathbb{N}})_{k \geq 1}$ of colored generalizations of the Temperley-Lieb algebra, using a diagrammatic approach à la Kaufman, that is independent of the subfactor context. The Fuss-Catalan numbers $\frac{1}{(k+1)n+1}\binom{(k+2)n}{n}$ appear as the dimensions of our algebras. We give a presentation of $FC_{1,n}(a,b)$ and calculate their structure employing a diagrammatic method, which we call the middle pattern analysis. The principal part of the inclusion diagram $FC_{1,1} \subset FC_{1,2} \subset FC_{1,3} \subset \cdots$ turns out to be the Fibonacci tree. Our algebras have a natural trace (which is a two parameter Markov trace) and we compute the trace weights explicitly. If the indices satisfy $\alpha, \beta \leq 1/4$, the algebras $IA_n(\alpha,\beta)$ and $FC_{1,n}(a,b)$ are isomorphic ($\alpha = 1/a^2, \beta = 1/b^2$) and if one of the indices is strictly smaller than $1/4$, they are quotients of $FC_{1,n}$. We give their structure also in this situation. In particular, the $(IA_n, (\alpha,\beta), \mathrm{tr}\ )$ depend only on α and β. Our results generalize to a chain of k intermediate subfactors. This is joint work with Vaughan Jones.

"Quantum Doubles of the Hecke Algebra Subfactors and Orbifolds", Yasu Kawahigashi, Tokyo (joint work with David.E.Evans)

Ocneanu's asymptotic inclusion $M \cup (M' \cap M_\infty)$, especially it's system of $M_\infty - M_\infty$ bimodules has caught much attention recently as a subfactor analogue of the quantum double construction. Ocneanu has observed a mysterious orbifold phenomenon for the $M_\infty - M_\infty$ bimodules of the Jones subfactors of type A_{2n+1}.

We show that this is a general phenomenon and identify some of his orbifolds with the orbifolds in our sense by working on the asymptotic inclusion of the Hecke algebra subfactors of Wenzl. That is, we show that their $M_\infty - M_\infty$ bimodules are described by certain orbifolds. We actually compute several dual principal graphs of the asymptotic inclusions.

Roughly speaking, ghosts appear to recover the non-degeneracy of the braiding, but they are next killed by the orbifold construction.

We can identify Ocneanu's orbifolds with the orbifolds on $N \otimes N \subset M \otimes M$ and this gives a certain "orbifold construction with braiding."

"C^*–Algebras Associated to Unitary Representations of Lattices in Semi-Simple Lie Groups", Mohammed B.Bekka, Metz

We first reported on joint work with M.Cowling and P. de la Harpe:

Theorem 1: Let G be a connected semi-simple Lie group, without compact factors and with trivial center. Let Γ be a Zariski-dense (not necessarily closed) subgroup of G. Then the reduced C^*-algebra $C_r^*(\Gamma)$ (Γ being viewed as discrete) is simple and its canonical trace τ is unique (as normalized trace).

The result applies, for instance, in the following situations:

(i) Γ a lattice in G

(ii) $\Gamma = \mathbb{G}(\mathbb{Q})$ for an algebraic group $\mathbb{G}$ over $\mathbb{Q}$ such that $G = \mathbb{G}(\mathbb{Q})$ satisfies the hypothesis of Theorem 1

(iii) Γ a closed subgroup of G so that the homogeneous space G/Γ is amenable in Eymard's sense (Γ is Zariski dense by a result of Guivarc'h and Stuck).

We then discussed extensions of this result to the C^*-algebra $C^*(\pi(\gamma))$ generated by a unitary representation π of Γ:

Theorem 2: G, Γ, τ being as in Theorem 1, suppose in addition that G is simple. Let π be an irreducible unitary representation of G, $\pi \neq 1$. Then

(i) The regular representation λ of Γ factorizes through $C^*(\pi(\Gamma))$: $C^*(\pi(\Gamma)) \xrightarrow{\lambda_\pi} C_r^*(\Gamma)$ (joint with P. de la Harpe)

(ii) $\mathrm{Ker}\lambda_\pi$ is the unique maximal ideal in $C^*(\pi(\Gamma))$

(iii) $\tau \circ \lambda_\pi$ is the unique trace on $C^*(\pi(\Gamma))$.

"On von Neumann Algebras Associated with Discrete Groups",
Florin Radulescu, Otawa

Let Γ be a lattice in $PSL(2, \mathbb{R})$. Recall that for a type II_1 factor M and for any positive number t the von Neumann algebra M_t is the isomorphism class of the algebra eMe where e is any projection in M of trace t.

By using the Berezin quantization deformation method and the computation of the von Neumann dimension of the Hilbert space of an irreducible unitary representation of a semisimple Lie group as a left module over the algebra of a discrete subgroup (due to Atyiah and Schmidt, Connes, Goodman and de la Harpe and Jones) we find the following generators and relation description for the von Neumann algebra $\mathcal{L}(\Gamma)_r$, $r > 1$. Let $[x, y, z, t]$ be the cross ratio of the points x, y, z, t in the upper half plane $\mathbb{H}$. For any z, ζ in $\mathbb{H}$ there exists elements $e^r_{z,\zeta}$ in $\mathcal{L}(\Gamma)_r$ so that

$$tr(e^r_{z,\zeta} e^r_{z_1,\zeta_1}) = \sum_{\gamma \in G} [\overline{(\gamma(z))}, \gamma(\zeta), \overline{z_1}, \zeta_1]^r,$$

for all z, ζ, z_1, ζ_1 in $\mathbb{H}$.

Moreover

$$e^r_{z,\zeta} e^r_{z_1,\zeta_1} = \sum_{\gamma\in\Gamma} [\overline{(\gamma(z))}, \gamma(\zeta), \overline{z_1}, \zeta_1]^r e^r_{z_1,\gamma(\zeta)}.$$

This is done by introducing a stronger norm on a strongly dense $*-$ subalgebra of $\mathcal{L}(\Gamma)_r$. The cyclic cohomology cocycle associated with the Berezin deformation is bounded with respect to this norm too.

"The free $O(n)$ & $U(n)$ compact quantum groups", Theodor Banica, Paris

The "non commutative" analogues of $O(n)$ and $U(n)$ in Woronowicz' theory are the Hopf C^*-algebras $A_O(F)$ and $A_U(F)$:

Definition : Let $n \in \mathbb{N}$ and $F \in Gl(n)$.

(i) $A_U(F) := C^*(\{(u)_{i,j=1,..,n} \mid u \text{ unitary}, F\bar{u}F^{-1}\text{unitary}\})$,

(ii) $A_O(F) := C^*(\{(u)_{i,j=1,...,n} \mid u = F\bar{u}F^{-1} \text{ unitary}\})$
(here $F\bar{F} \in \mathbb{R} \cdot I_n$, otherwise u is not irreducible).

It turns out that the irreducible representations of $A_O(F)$ are labeled by $\mathbb{N}$ and satisfy the same product formulae as those of $SU(2)$. The representation theory of $A_U(F)$ is given by:

The irreducible representations of $A_U(F)$ may be labeled by $\mathbb{N} \oplus \mathbb{N}$. They verify $\Gamma_0 = 1$, $\Gamma_\alpha = u$, $\Gamma_\beta = \bar{u}$, the adjoints are given by $\bar{\Gamma}_x = \Gamma_{\bar{x}}$ and the product formulae are:

$$\Gamma_x\Gamma_y = \sum_{\substack{x=ag \\ y=\bar{g}y}} \Gamma_{ab}.$$

(here $\mathbb{N} \oplus \mathbb{N}$ is generated by α, β and $\bar{}$ is the involution on $\mathbb{N} \oplus \mathbb{N}$ defined by $\bar{\alpha} = \beta$).

Other results: $A_O(F)$ and $A_U(F)$ $(n \geq 3)$ are not amenable. $A_U(F)$ is not exact. $A_O(I_n)_{red}$ and $A_U(I_n)_{red}$ are not nuclear. $A_U(F)_{red}$ is simple with a unique KMS-state - the Haar measure. There is an embedding $A_U(F)_{red} \hookrightarrow C(\mathbb{T}) *_{red} A_O(F)$, if $F\bar{F} \in \mathbb{C}I_n$. The factor $A_U(I_2)''_{red}$ is equal to $W^*(\mathbb{F}_2)$. There is an embedding of Hopf-C^*-algebras $C(SO(3)) \hookrightarrow A_U(I_2)$. The character $\chi(u)$ of the fundamental representation u of $A_O(F)$ has a semicircular distribution with respect to the Haar measure. In the case of $A_U(F)$, the character $\chi(u)$ has a circular *-distribution. The commutants Mor(u^k, u^k) of the $k-$th tensor power of the fundamental representation u of $A_O(F)$ are Temperley-Lieb algebras.

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"An Axiomatization of the Higher Relative Commutants of a Subfactor", Sorin Popa, Paris

We consider a set of axioms for a system of finite dimensional algebras $\{A_{ij}\}_{0\leq i\leq j\leq n}$ that are shown to be necessary and sufficient for $\{A_{i,j}\}$ to occur as higher relative commutants of some subfactor $N \subset M$, i.e., such that $A_{i,j} = M_i' \cap M_j$, where $N \subset M \subset M_1 \subset \ldots$ is the Jones' tower of factors for $N \subset M$. The axioms required are:

(i) The commuting square axiom

(ii) A braid relation for some representation of the Jones relation for some representation of the Jones projections in $\bigcup A_{0j}$

(iii) A Markov condition

(iv) A commutation relation, $[A_{0,j}, A_{jk}] = 0$.

An important application of our axiomatization is that if $\{A_{ij}\}$ is a lattice of higher relative commutants and $A_{ij}^{\circ} \subset A_{ij}$ contains the Jones' projections of A_{ij} and satisfies i) then $\{A_{ij}^{\circ}\}$ is itself a lattice of higher relative commutants. This corollary enables us to obtain some obstruction criteria for bipartite graphs to be graphs of subfactors.

"Conformal field theory and subfactors", Antony Wassermann, Cambridge

We explained how three important ideas in the multiparticle theory of von Neumann algebras – Doplicher-Haag-Roberts theory of superselection sectors, Connes fusion for bimodules, Jones theory of subfactors – could be applied to models in the conformal field theory. Positive energy representations of $LSU(N) = C^\infty(S^1, SU(N))$ are classified by a level $l \geq 1$ and a lowest energy representation V_f, an irreducible representation of $SU(N)$ which must have signature $f_1 \geq \cdots \geq f_N$ with $f_1 - f_N \geq N$. The fusion problem in CFT is to define a natural tensor product structure on the representations of level l. We gave a solution using Connes fusion of the bimodule arising by considering a p.e.representation as a representation of $L_I G \times L_{I^c} G$ where I and I^c are complementary intervals in S^1 and $L_J G$ denotes loops trivial off J. Fusion is computed using the braiding relations for vector primary fields and their conjugates. This provides a rich source of subfactors of type II, and type III, and in particular gives a conceptually simple construction of the Jones-Wenzl and Erlijman-Wenzl subfactors. These constructions make it easy to compute the towers of higher relative commutants which classify the subfactors. In addition we show how the natural monodromy representation of the braid group on products of primary fields makes the level l p.e.representation into a modular braided tensor category. Modularity can be seen using Weil's metaplecic representation of $SL(2,\mathbb{Z})$ associated with a finite Abelian group (the weight lattice modulo (N+L) times the root lattice). We briefly showed how the level one theory extended to Segal's modular functor for Riemann surfaces, regarded as bordisms between disjoint unions of boundary circles. This should extend to level L representations. Finally we remarked that these loop groups examples provided the only non-trivial example of chiral theories in $1+1$ dimensions satisfying the DHR axioms with non-integer dimension.

"Unitary Topological Quantum Field Theories and Subfactors", Hans Wenzl, San Diego

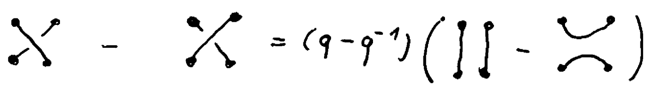
We explained how one can construct modular braided tensor categories from tangle categories (joint work with Turaso). Checking the modularity condition leads to graph automorphisms of the principal graph of the associated subfactors. From this one can get new examples of subfactors.

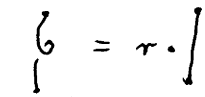
A modular braided tensor category is a monoidal semisimple category with only finitely many equivalence classes of simple objects, say $\{V_\lambda, \lambda \in I\}$. Let $a_{\lambda,\mu} : V_\lambda \otimes V_\mu \to V_\mu \otimes V_\lambda$ be the canonical braiding isomorphism, and define

$$s_{\lambda\mu} = \mathrm{Tr}_{V_\lambda \otimes V_\lambda}(c_{\mu\lambda} \circ c_{\lambda\mu}).$$

Then the matrix $S = (S_{\lambda\mu})$ is required to be invertible. Such tensor categories have been constructed using the representation theory of quantum groups, or loop groups. Our method here goes as follows. Let T be the tangle category. Its objects are the nonnegative integers $\mathbb{N}$. $\mathrm{Hom}(n,m)$ is the $\mathbb{C}-$vector space spanned by isotopy classes of (n,m) tangles. e.g. a (2,4) tangle is:

Concatenation is as with braids. This category is too big for our purposes. Modding out by the skein relations of the Kaufman polynomial



and 

we obtain finite dimensional quotients $\overline{Hom}(n,m)$. From this we derive a new category C, where the objects are projections in $\overline{End}(n)$, $n \in \mathbb{N}$ and where morphisms are spanned by

$$Hom(p_1,p_2) = \mathrm{span}\{\overline{p_2tp_1}, t \text{ a } (h_1,h_2) \text{ tangle if } p_1 \in \overline{End}(h_1), p_2 \in \overline{End}(h_2)\}.$$

One can show the following:

C has finitely many simple objects
$\iff$ $r = \pm q^n$, $n \in \mathbb{Z}$ and q a root of unity

The objects can be described as a set of Young diagrams, $\Gamma(r,q)$. One has 3 cases:

(i) simplectic case: $\Gamma(r,q) = \{\lambda |\ \lambda_1 \leq M, \lambda_1' \leq N\}$, where $\lambda_1 = \#$ boxes in first row, $\lambda_1' = \#$ boxes in first column

(ii) BC case: $\Gamma(R,Q) = \{\lambda | \lambda_1 \leq M, \lambda_1' + \lambda_2' \leq N, N \text{ odd}\}$

(iii) orthogonal case: $\Gamma(r,q) = \{\lambda | \lambda_1 + \lambda_2 \leq M, \lambda_1' + \lambda_2' \leq N\}$

Here M and N can be computed from the degree of the root of unity q and from $r = \pm q^n$. These categories satisfy all conditions except possibly the modularity condition. It is checked that the latter only holds in the simplectic case. One can define graph automorphisms derived from the restriction rules for $O(N)$ to $SO(N)$. This way, we obtain new subfactors corresponding to $SO(2N)$ via a so-called 'orbifold construction', and conjecturally further subfactors via an orbifold w.r.t. $\mathbb{Z}/2 \times \mathbb{Z}/2$.

"An Analogue of the Kac-Wakimoto formula and Black Hole Entropy", Roberto Longo, Roma "Tor Vergata"

In 1985 Kac and Wakimoto showed in particular that if ρ is a lowest weight representation a certain Kac-Moody algebra, H_ρ is the conformal Hamiltonian and H_0 is the conformal Hamiltonian in the vacuum representation then

$$\lim_{\beta \to 0+} \frac{\mathrm{Tr}(e^{-\beta H_\rho})}{\mathrm{Tr}(e^{-\beta H_0})} = d(\rho) \qquad (1)$$

where $d(\rho)$ has the formal property of a dimension. It is believed that (1) holds in more generality.

We found a local version of (1):

$$(e^{2\pi K_\rho}\Omega, \Omega) = d(\rho)$$

where $K_\rho = i\frac{d}{dt}U(\Lambda(t))|_{t=0}$ is the generator of the special conformal group associated with I, $(\cdot\,\Omega, \Omega)$ is the vacuum state on the von Neumann algebra $A(I)$, ρ is localized in I and $d(\rho)$ is the Doplicher-Haag-Roberts dimension.

An analogue of this formula holds for quantum field theory on Minkowski space if the von Neumann algebra is associated to a wedge region.

Based on Sewell model we find an independent derivation of Hawking's formula for the temperature of a black hole

$$F(\omega|\varphi_\rho) = \frac{1}{2}\beta^{-1}H(\rho)$$

where F is the relative free energy between the vacuum and the KMS state in the sector ρ:

$$F(\omega|\varphi_\rho) = \omega(K_\rho) - \beta^{-1}S(\omega|\varphi_\rho)$$

with S Araki's relative entropy, β the Hawking inverse temperature and

$$H(\rho) = H(A(w)|\rho(w))$$

is the Connes-Størmer conditional entropy of ρ.

"A Class of C^*–algebras considered by Pimsner generalizing Cuntz-Krieger algebras", Claudia Pinzari, Rome "Tor Vergata"/Copenhagen joint work with S.Doplicher and S.Doplicher, J.E.Roberts

We started by discussing an model action of quantum matrix subgroups of $S_\mu U(d)$ (defined via Tannaka-Krein duality) on Cuntz algebras. Results of Doplicher-Roberts for the case $\mu = 1$, can be generalized to get a universal crossed product $\tilde{\mathcal{B}}$ of a C^*–algebras $\mathcal{A}$ by an endomorphism with determinant 1, that carries a coaction of $S_\mu U(d)$. The problem of the abstract characterization of coactions of subgroups cannot have a positive solution if the relative commutant $\mathcal{A}' \cap \tilde{\mathcal{B}}$ does not have a character. We noticed that if $\mathcal{A}$ is generated by the intertwiners, $\tilde{\mathcal{B}}$ is a Pimsner C^*–algebra associated with a finite projective module gifted with a conjugate in a power of it.
Motivated by this example, we introduced a criterion on the bimodul of powers of the module that guarantees a control on the ideal structure of the Pimsner algebras in terms of ideals of the coefficient algebra. This criterion applies as

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well to Cuntz-Krieger bimodules, or to real and pseudoreal bimodules. Then we discussed the notion of conjugation in the 2-C^*-category of Hilbert bimodules in terms of Pimsner-Popa inequality, as equivalent to the existence of an adjoint functor that tensorizes on the left by the bimodule. Extending results of Brown-Green-Rieffel, we discussed the general form of a Hilbert bimodule, countably generated, equipped with a conjugate (a notion that generalizes strong Morita equivalence) over $\sigma-$unital, stable C^*-algebras.

"Continuous fields of nuclear C^*-algebras", Etienne Blanchard, Luminy

Given a unital separable continuous field of nuclear C^*-algebras A over a compact metrizable space X, we show that the $C(X)-$algebra A is isomorphic to a unital $C(X)-$subalgebra of the trivial continuous field $\mathcal{O}_2 \otimes C(X)$ (where $\mathcal{O}_2$ is the Cuntz C^*-algebra), image of $\mathcal{O}_2 \otimes C(X)$ by a norm one projection.

"K-groups of simple C^*-algebras", George A.Elliott, Copenhagen, Toronto

A construction was described that yields a separable amenable simple C^*-algebra with pre-ordered K_0-group an arbitrary countable simple pre-ordered abelian group which is weakly unperforated (i.e., in which $ng > 0$ for some $n = 2, 3, ..$ implies $g \geq 0$), with cone of positive traces an arbitrary lattice topological convex cone with compact metrizable base, with duality between K_0-group and tracial cone an arbitrary pairing which is weakly unperforated ($\tau(g) > 0$ for every non-zero τ in the cone implies $g \geq 0$), and with K_1-group an arbitrary countable abelian group.

"On the classification of simple C^*-algebras", Eberhard Kirchberg, Humboldt Universität Berlin

First the following classification-theorem for continuous fields of C^*-algebras was presented.

Theorem: a) If A is a nuclear separable continuous field of C^*-algebras over a space X then there exists a continuous $C(X)$-algebra $P(A)$ with purely infinite separable unital nuclear fibres such that

(i) $P(A) \otimes \mathcal{O}_\infty = P(A) \otimes_{C(X)} C(X, \mathcal{O}_\infty) \simeq P(A)$

(ii) $P(A) \sim_{\mathcal{R}KK^{(1)}(X,\cdot,\cdot)} A$

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b) Let A, B be separable continuous fields of C^*-algebras with simple nuclear fibers such that $A \otimes \mathcal{O}_\infty \simeq A$ and $B \otimes \mathcal{O}_\infty \simeq B$. Then, every invertible element in $\mathcal{R}KK^{\{1\}}(X, A, B)$ is induced by a $C(X)$-isomorphism of A onto B.

Finally, an "axiomatization" of the proof of classification theorems which includes the classification theorem for *pisun* C^*-algebras and the above classification theorem for continuous fields has been discussed. A main part of the proof consists in showing that the map from the analogue of Rørdam's group $R(X, A, B)$ into $\mathcal{R}KK^{\{1\}}_{nuc}(X, A, B)$ given by the mapping cone construction is an isomorphism.

Note that for the proof of the classification theorem for *pisun* C^*-algebras one has to apply the following theorem, taking $A \otimes \mathcal{K}$, $Q^s(SB)$, $C_b(\mathbb{R}_+, \mathcal{K} \otimes B)/C_0(\mathbb{R}_+, \mathcal{K} \otimes B)$ as A, B, J.

<u>Proposition:</u> Let A be a separable C^*-algebras, B a unital C^*-algebra and $J \subset B$ a closed ideal. Assume given two monomorphisms $h_0, H_0 : A \to B$, and an involution $\sigma : B \to B$ with $h_0(A) \subset J, \sigma H_0 = H_0$ and $\sigma(J) \cap J = \{0\}$. Define $C := H_0(A)' \cap B$ and consider the following hypothesis:

(i) $h_0(A)' \cap H_0(A)' \cap B \subset C$ contains a unital copy of $\mathcal{O}_2$ with $\sigma_{|\mathcal{O}_2} = \mathrm{id}_{\mathcal{O}_2}$

(ii) if $k : A \to B$ is dominated by H_0 (i.e. there exists an isometry $s \in B$ such that for all $a \in A$, $k(A) = s^* H_0(a) s$) then there exists $u \in B$ unitary such that for all $a \in A$ one has $u^*(k \oplus H_0)(a) u - H_0(a) \in J$

(iii) $\exists D \subset C$ C^*−algebra such that $\sigma(D) = D$ and $DH_0(A) \subset J + \sigma(J)$ verifying $\forall f \in J + \sigma(J), q \in D$, q projection, $\exists p \in D$ with $pf = fp = f$ and $q \leq p, q \neq p$

(iv) $\exists\sigma$-invariant projection $p_0 \in D$ and σ-invariant isometry $s_0 \in B$ such that $s_0 s_0^* = p_0$ and $\forall a \in A$, $s_0^* H_0(a) s_0 = h_0(a) + \sigma(h_0(a))$
$1 - p_0$ is the range projection of a σ-invariant isometry $t_0 \in C$

(v) every non-zero projection in D is unitarily equivalent to p_0 by a unitary in $1 + D$

(vi) $h_0 + \sigma h_0$ dominates h_0
if $d : A \to B$ maps A into J and $d + \sigma(h_0)$ is dominated by H_0 then d is dominated by h_0.

(vii) if s, t are the generators of the copy $\mathcal{O}_2 \subset B$, there exists a unitary $u_1 \in J' \cap B$ such that $u_1 \sigma_0 h_0(\cdot) s s^* = t t^* \sigma_0 h_0(\cdot) u_1$

If (i)-(vii) are satisfied, then

(i) $h_0 \oplus H_0$ is unitarily equivalent to H_0

(ii) the map $[k \oplus h_0] \mapsto [k \oplus H_0]$ defines a group isomorphism
$D(A, B, h_0) + [h_0] \to D(A, B, H_0) + [H_0]$
where $D(A, B, h_0) = \{[h] : h \text{ dominated by } h_0\}$

Remark: In the case of *pisun* C^*-algebras and bundles with *pisun* fibres, (vi) is equivalent to the existence of an asymptotic Weyl-von Neumann theorem.

"Application of amalgamated products to approximation in C^*-algebras", Terry Loring, Albuquerque

Amalgamated products of C^*-algebras do not always have intractable internal structure. For example, there is an isomorphism of $M_n(A)$ with $M_n(C_0(0,1]) \star_{C_0(0,1]} A$ when A is σ-unital, i.e., there is a push-out diagram

$$\begin{array}{ccc} C_0(0,1] \otimes e_{11} & \longrightarrow & M_n(C_0(0,1]) \\ \downarrow & & \downarrow \\ A \otimes e_{11} & \longrightarrow & M_n(A) \end{array}$$

Given a commutative diagram

$$\begin{array}{ccccccccc} 0 & \longrightarrow & I_2 & \longrightarrow & A_2 & \longrightarrow & B & \longrightarrow & 0 \\ & & \alpha\uparrow & (*) & \uparrow & & \| & & \\ 0 & \longrightarrow & I_1 & \longrightarrow & A_1 & \longrightarrow & B & \longrightarrow & 0 \end{array}$$

with exact rows, if α is proper $(\overline{\alpha(I_1)I_2\alpha(I_1)} = I_2)$ then $(*)$ is a push-out. (This is joint work with S.Eilers and G.Petersen.) By interpeting C^*-algebra concepts, such as real-rank zero, as extensions of morphism problems, such as

$$\begin{array}{ccc} C[0,1/2] \oplus C[1/2,1] & \searrow & \\ \uparrow \cup & & \\ C[0,1] & \xrightarrow[\varphi]{} & \prod_1^\infty A / \bigoplus_1^\infty A \end{array}$$

we can derive corollary extension results using amalgamated products. In this way, hard lifting problems are reduced to easy ones. Now approximation results can be derived. For example, we know that matrix-valued approximate representations of the equations

$$A^*A = AA^*, B^*B = BB^*, B^*A = AB^*, B^2 = (1-A)A$$

can be perturbed to exact representations. The equations are a presentation of $C(\mathbb{RP}^2)$ so we know that approximately multiplicative finite dimensional representations of $C(\mathbb{RP}^2)$ are close to $*$-homomorphisms.

"Continuous Embeddings of Continuous Fields of Nuclear C^*-Algebras in $\mathcal{O}_2$ (with a side remark on non-classification of purely infinite simple C^*-algebras)", Christopher Phillips, Eugene

The first (shorter) part of the talk was about the following "non-classification" theorem:

Theorem: Let G_0 and G_1 be countable abelian groups, and let $g \in G_0$. Then there exist uncountably many mutually non-isomorphic separable unital purely infinite simple C^*-algebras A with $K_0(G) \cong G_0$, $K_1(A) \cong G_1$, and $[1] = g_0$ in $K_0(A)$.

Thus, the classification theorem for purely infinite simple C^*-algebras fails dramatically (as aspected) for non-nuclear algebras. This result is easy to obtain from the resent results of Junge and Pisier on non-separability in the cb-Banach-Mazur distance of spaces of finite dimensional operator spaces. The talk considered the slightly easier case $K_*(A) = 0$.

The second part is on joint work with Eberhard Kirchberg. Let A be a continuous field of C^*-algebras (in the sense of Dixmiers book) over a sufficently nice compact space X (such as a finite complex), with section algebras $\Gamma(A)$ separable and with the fiber $A(x)$ $(x \in X)$ nuclear. Then there is a family of embeddings of the fibers, $\varphi_x : A(x) \to \mathcal{O}_2$ for $x \in X$, which is continuous in the sense that if $a \in \Gamma(A)$ is a continuous section, then $x \mapsto \varphi_x(a(x))$ is a continuous functions from X to $\mathcal{O}_2$. Moreover, one can control the embeddings so as to control the modulus of continuity of the function $x \mapsto \varphi(a(x))$ for specific sections $a \in \Gamma(A)$, in terms of the structure of A and how the sections a sit inside $\Gamma(A)$. For example, let A_θ be the rotation algebra, and let $u(\theta)$ and $v(\theta)$ be the standard generating unitaries satisfying $u(\theta)v(\theta) = v(\theta)u(\theta) \cdot e^{2\pi i\theta}$. Then there are unital embeddings $\varphi_\theta : A_\theta \to \mathcal{O}_2$ such that $\|\varphi(u(\theta_1)) - \varphi(u(\theta_2))\|, \|\varphi(v(\theta_1)) - \varphi(v(\theta_2))\|$ are both $\leq C|\theta_1 - \theta_2|^{1/4}$, for some constant C (which can be chosen less than 140000000). (Haagerup an d Rørdam gave similar embeddings in $L(H)$, with exponent $1/2$ instead of $1/4$).

"Combinatorial Aspects of the Theory of Free Random Variables",
Alexandru Nica, Ann Arbor
joint work with Roland Speicher

The theory of free random variables was developed by D.Voiculescu, with motivation from problems on free products of operator algebras; it is a collection of results paralleling aspects of classical probability, in a context where the fundamental roles of tensor products and independence are now taken by free products and freeness for (non-commutative) random variables.

The main object in the talk is the multivariable R–transform, which is, in some sense the free analogue for the logarithm of the Fourier transform for an n–dimensional probability distribution. We show how the R–transform can be used in an efficient (and elegant) way in the study of free random variables. Concrete examples presented are related to compressions by free projections and to the realization of the free Poisson process. Also, we show how the R–transform can be used for obtaining a combinatorial description for the operation of taking the commutator of two free random variables.

"Free product of finite dimensional von Neumann algebras", Ken Dykema, Odense

The von Neumann algebra free product

$$(M, \phi) = (A, \phi_A) \star (B, \phi_B),$$

of finite dimensional algebras A and B for arbitrary faithful states ϕ_A and ϕ_B is of the form

$$M = M_0 \quad \text{or} \quad M = M_0 \oplus D$$

where D is finite dimensional and M_0 is a factor. The algebras M_0 and D and the state, ϕ on them, are described in detail.

"Shape equivalence, nonstable K–theory and AH algebras", Cornel Pasnicu, San Juan

We give several necessary and sufficient conditions for an AH algebra (i.e. an inductive limit of homogeneous C^*–algebras) to have its ideals generated by their projections. Denote by $\mathcal{C}$ the class of AH algebras as above and in addition with slow dimension growth. We completely classify the algebras in $\mathcal{C}$ up to a shape equivalence by a K–theoretical invariant. For this, we show first, in particular, that any C^*–algebra in $\mathcal{C}$ is shape equivalent to an AH-algebra with slow dimension growth and real rank zero (generalizing so a result of Elliott-Gong). We prove that any C^*-algebra in $\mathcal{C}$ has stable rank one, generalizing result of Blackadar-Dadarlat-Rørdam and of Elliott-Gong. Other result concerning weakly unperforation in $K_0(A)$, $A \in \mathcal{C}$ are obtained (they extend theorem of Dadarlat-Nemethi, Martin-Pasnicu and Blackadar).

"The Baum-Connes conjecture for discrete amenable groups",
Gennadii Kasparov, Marseille

This is a joint work with Nigel Higson and (partly) also with his student Jody Trout.

The Main Theorem: The Baum-Connes conjecture is true for any discrete group Γ acting affine-isometrically and properly (in the metric sense) on a Hilbert space.

Applying the result of Bekka, Cherix, Valette on the existence of proper affine-isometric actions of amenable groups on a Hilbert space we get the Baum-Connes conjecture for amenable discrete groups.

For the proof of the main theorem we construct a C^*-algebra $\mathcal{A}(H)$ of a Hilbert space H. Let S the algebra $C_0(\mathbb{R})$ which we consider as $\mathbb{Z}_2$-graded (by even and odd functions). We prove first the Bott periodicity result (same assumptions on Γ-action):

Theorem: $\mathcal{A}(H)$ is Γ-equivariantly E-equivalent to S (where E is the bivariant K-theory of Connes-Higson). Moreover, $C^*(\Gamma, \mathcal{A}(H)) \simeq C^*_r(\Gamma, \mathcal{A}(H))$ is E-equivalent to both $C^*(\Gamma) \otimes S$ and $C^*_r(\Gamma) \otimes S$.

Corollary: A discrete group Γ acting properly, affine-isometrically on H is E-amenable.

For the proof of the Bott periodicity, the Dirac and dual Dirac elements in E-theory are constructed. Then we use an exhaustive system of Hilbert Γ-submanifolds with boundary $\bar{X}_1 \subset \ldots \subset \bar{X}_m \subset \ldots \subset H$, each $\bar{X}_k$ having bounded fundamental domain, to present both $C^*(\Gamma, \mathcal{A}(H))$ and $C^*_r(\Gamma, \mathcal{A}(H))$ as an inductive limit: $\lim_{\substack{\longrightarrow \\ k}} C^*(\Gamma, \mathcal{A}(X_k))$, where $\mathcal{A}(X_k)$ is a subalgebra of $\mathcal{A}(H)$ associated with $X_k = Int(\bar{X}_k)$. Finally, we prove a version of Poincare duality in E-theory:

$$E_*(C^*(\Gamma, C_0(\bar{X}_k)), S) \simeq K_*(C^*(\Gamma, \mathcal{A}(X_k))),$$

which gives the proof of the main theorem.

"Topological Orbit Equivalence, full groups and extensions",
Thierry Giordano, Ottawa
joint work with Ian Putnam and Christain Skau

To a minimal Cantor system (X, φ) (i.e. X Cantorset, φ minimal selfhomeomorphism of X), we associate the full group $[\varphi] = \{\gamma \in Homeo(X) | \gamma(x) = \varphi^{n(x)}(x), x \in X, n(x) \in \mathbb{Z}\}$ and the topological full group $\tau[\varphi] = \{\gamma \in [\varphi]; n :$

$X \to \mathbb{Z}$ continuous}. Extending a result of H.Dye, we show:

Theorem : Let (X_i, φ_i) be minimal Cantor systems ($i = 1, 2$). If α is an isomorphism between $[\varphi_1]$ and $[\varphi_2]$ (resp. $\tau[\varphi_i]$ and $\tau[\varphi_2]$), than it is spatial (i.e. $\exists a : X_1 \to X_2$ homeomorphisms s.t. $\alpha(\sigma) = a\sigma\bar{a}^{-1}, \forall\sigma \in [\varphi_1]$ (resp. $\tau[\varphi_1]$)).
Corollary : Let (X_i, φ_i) minimal Cantor systems. The following are equivalent

(i) (X_1, φ_1) and (X_2, φ_2) are flip conjugate (reps. orbit equivalent)

(ii) $\tau[\varphi_1]$ and $\tau[\varphi_2]$ (reps. $[\varphi_1]$ and $[\varphi_2]$) are isomorphic.

Extending results of Connes-Brieger and Hamachi, we define a homeomorphism *mod* from the normalizer $N[\varphi]$ of φ to $\mathrm{Aut}\Big(K^0(x,\varphi)/\mathrm{Inf}(K^0(X,\varphi)\Big)$. Recall that $K^0(X,\varphi)/\mathrm{Inf}(K^0(X,\varphi))$ is a complete invariant of orbit equivalence of φ. We show that:

Proposition : *mod* is surjective and Ker(mod) $= [\bar{\varphi}]$ (for the pointwise convergence in norm in $C(X)$).
We finish our talk be presenting results using the $K-$Theory to study extensions of minimal Cantor systems.

"Toeplitz C^*-algebras on Multivaribale Hardy Spaces", Harald Upmeier, Marburg

C^*-algebras generated by Toeplitz operators on multi-variable Hardy spaces arise in several complex variables and Berezin quantization. A general situation covering many examples (Reinhardt domains, symmetric domains, etc.) is as follows: Let K be a compactly embedded (i.e., compact) Lie group, and let $K_\sigma = K/K^\sigma$ be the symmetric space under an involution σ. Then the complexification $K_\sigma^{\mathbb{C}}$ has a cannoniacal Hardy space $H^2(K_\sigma)$ associated with an arbitrary polyhedral cone Λ in a Cartan subspace of $k_\sigma = k/k^\sigma$.

Theorem : The Toeplitz C^*-algebra $\mathcal{T}(K_\sigma)$ has an C^*-filtration

$$\mathcal{K} = I_1 \lhd I_2 \lhd \cdots \lhd I_r \lhd \mathcal{T}$$

of length $R = \dim\Lambda$, such that I_{k+1}/I_k in the direct sum of foliation C^*-algebras $C^*(K/\tilde{K})$ (Kronecker type), where $\tilde{K}$ is a (not necessarily closed) subgroup of K associated with any k-dimensional face $\tilde{\Lambda}$ of Λ.

Partial results have been obtained in new situations, for example for the Hardy space

$$H^2(SL(2,\mathbb{R})) = \sum\nolimits^{\oplus} \text{discrete series representations}$$

occurring in the Gelfand-Gindikin program, and in the infinite dimensional setting of symmetric domains of Hilbert-Schmidt operators.

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