MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Nichtkommutative Geometrie

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The conference was organised by Alain Connes (Paris), Joachim Cuntz (Münster), and Marc Rieffel (Berkeley).

There were 27 lectures altogether. Emphasis was put particularly on the exchange of ideas between mathematicians and physicists. Therefore, many of the lectures were related to problems in quantum physics. Some lecturers investigated the possibilities of quantum field theories over "non-commutative spaces" like deformed Minkowski space or non-commutative tori. The non-commutative tori also have become of interest because they arise as "compactifications" in M-theory. One should also mention here the study of deformations associated to Poisson manifolds. A great breakthrough seems to be the discovery due to Dirk Kreimer and Alain Connes of two closely related Hopf algebras that underly the combinatorics of renormalisation of path integrals in physics and of the index theorem for transversally elliptic operators on foliated manifolds, respectively.

Another topic of great interest was work related to the Baum-Connes conjecture. This conjecture concerns the K-theory of the (reduced) C^*-algebra associated to a locally compact group. The lecture by Vincent Lafforgue describes a proof of this conjecture for a large class of groups, including also some with property (T). Moreover, Guoliang Yu explores the relation to the coarse geometry of metric spaces to prove at least the strong Novikov conjecture for a large class of discrete groups: There are no groups known not to satisfy the necessary condition for his proof to work. Besides the proof of the conjecture, also applications of it have received some attention.

The lectures of Michael Puschnigg and Ralf Meyer contain major advances in our understanding of entire and asymptotic cyclic cohomology theories. It is now known that they also have six term exact sequences like periodic cyclic cohomology. Even for seemingly simple algebras like the algebra of smooth functions on the circle, the entire cyclic cohomology was previously not computable. This is possible now due to excision.

Submitted abstracts in chronological order

Twist Positivity

ARTHUR JAFFE

In this talk I announce a new positivity property that arises in considering quantum triples and that appears related to the existence of a functional integral representation for the triple. The triple $\{H, U(g), \mathcal{H}\}$ consists of a Hilbert space $\mathcal{H}$ and a self adjoint, θ-summable Hamiltonian H acting on $\mathcal{H}$, so that $\mathrm{Tr}_{\mathcal{H}}(e^{-\beta H}) < \infty$ for all $\beta > 0$. Also, $U(g)$ is a unitary representation on $\mathcal{H}$ of a symmetry group G of H, so $U(g)H = HU(g)$. We also assume that $\|e^{-\beta H}\|$ is a simple eigenvalue of $e^{-\beta H}$ with eigenspace spanned by Ω_{vac}, and we normalise $U(g)$ so that $U(g)\Omega_{\text{vac}} = \Omega_{\text{vac}}$.

In numerous examples we find that for all $g \in G$ and all $\beta > 0$,

$$\mathfrak{z}(g,\beta) = \mathrm{Tr}_{\mathcal{H}}\big(e^{-\beta H}U(g)^*\big) > 0,$$

a surprising condition that I call *twist positivity*. Furthermore, we find in these examples that the functional

$$\omega(\bullet)_{g,\beta} = \frac{\mathrm{Tr}_{\mathcal{H}}\big(U(g)^* \bullet e^{-\beta H}\big)}{\mathfrak{z}(g,\beta)}$$

has a representation, when restricted to coordinates,

$$\omega(\bullet)_{g,\beta} = \int_{S'} \bullet \, d\mu_{g,\beta}$$

as an integral on a probability space S' with respect to a countably additive, Borel, probability measure $d\mu_{g,\beta}$.

Mapping Surgery to Analysis

NIGEL HIGSON

(joint work with John Roe)

Let V be a closed, aspherical, smooth manifold, $\pi = \pi_1(V)$. The Baum-Connes assembly map

$$\mu\colon K_*(V) \to K_*(C^*_{\text{red}}\,\pi)$$

fits into a long exact sequence

$$\cdots \to K_{j+1}\big(D^*_\pi(V)\big) \to K_j(V) \to K_j(C^*_{\text{red}}\,\pi) \to K_j\big(D^*_\pi(V)\big) \to \cdots$$

We relate this to the surgery exact sequence, constructing geometrically (and after tensoring by $\mathbb{Z}[1/2]$) a commuting diagram relating the two.

The Jones-Goodwillie map is the (uni)versal map

GUILLERMO CORTIÑAS

The talk focuses on the Jones-Goodwillie map which goes from algebraic K-theory to negative cyclic homology. By a theorem of Goodwillie, this map induces an isomorphism of the relative groups corresponding to a nilpotent ideal. We present a general construction which produces, for each functor going from algebras to spaces—such as the K-theory space—a character which induces an isomorphism of the relative homotopy groups associated to a nilpotent ideal and is (uni)versal with such a property. Then we show that, for the case when the functor is the K-theory space, the versal character agrees with Jones-Goodwillie's.

Excision in Cyclic Homology Theories

MICHAEL PUSCHNIGG

A modified version of the proof of excision in bivariant cyclic cohomology by J. Cuntz and D. Quillen is presented. This modified proof has the advantage of working also in the framework of entire cyclic and asymptotic cyclic cohomology or more generally in the framework of cyclic and local cyclic cohomology of Ind-algebras with supports. As applications we derive an estimate for the behaviour of the dimension of a cyclic cocycle under the boundary map; calculate the entire cyclic cohomology of the algebra of smooth functions on a compact manifold; and construct a bivariant Chern-Connes character on Kasparov's bivariant K-theory.

Harnessed algebras and Excision in Entire Cyclic Cohomology

RALF MEYER

It is not sufficient to define cyclic homology for topological algebras because this does not cover interesting examples like the convolution algebra $C_c^\infty(\Gamma)$ of a smooth group(oid), where the multiplication is not jointly continuous. If instead of a topology we specify a bornology, we get more continuous bilinear map. I call the corresponding class of algebras *harnessed algebras*. Cyclic type homology theories can be defined on this class of algebras. This gives a common framework for the existing theories for algebras without structure, Fréchet algebras, and the cyclic and Hochschild homology of $C_c^\infty(\Gamma)$ as defined by Brylinski and Nistor.

Connes's definition of entire cyclic cohomology carries over immediately to our framework. But now we can rewrite it concisely in the X-complex picture of Cuntz and Quillen as $\mathrm{HE}^*(A) = H^*(X(\mathfrak{T}A))$, where $\mathfrak{T}A$ is a certain completion of the tensor algebra of A; it is a harnessed algebra but not a topological algebra. For a suitable notion of "analytic nilpotence", $\mathfrak{T}A$ is the universal nilpotent extension of A. Using this, (differentiable) homotopy invariance and excision for linearly split extensions can be derived by universal algebra techniques. For a special class of Fréchet algebras, this was previously obtained by Michael Puschnigg.

KK and elliptic operators

PAUL BAUM

(joint work with Alain Connes)

Let G be a locally compact topological group. The Baum-Connes conjecture asserts that μ: $K_*^G(\underline{E}G) \to K_*(\mathrm{C}^*_{\mathrm{red}}G)$ is an isomorphism. Here $\mathrm{C}^*_{\mathrm{red}}G$ is the reduced C^*-algebra of G and $K_*(\mathrm{C}^*_{\mathrm{red}}G)$ its K-theory. $\underline{E}G$ is the universal example for proper G-actions and $K_*^G(\underline{E}G)$ is the equivariant K-homology of $\underline{E}G$ in Kasparov's sense and with G-compact supports. This talk takes up the issue of whether every element of $K_*^G(\underline{E}G)$ can be obtained from G-equivariant elliptic operators. When G is totally disconnected (e.g., G can be a discrete group or a p-adic group), "geometric cycles" are constructed for $K_*^G(\underline{E}G)$ which are somewhat more general than those obtained from elliptic operators on manifolds. This gives some indication of what an elliptic operator on a space with singularities should be. This joint work with Alain Connes will be published as an appendix to our paper "Geometric K-theory for Lie groups and Foliations" (written sixteen years ago and to be published soon).

Bivariant K-theory for Banach algebras

VINCENT LAFFORGUE

This talk is the first announcement of the following result: The Baum-Connes conjecture (without coefficients) is true for p-adic reductive groups and for discrete cocompact subgroups of $\mathrm{Sp}(n,1)$, $\mathrm{Sl}_3(\mathbb{R})$, and $\mathrm{Sl}_3(\mathbb{Q}_p)$.

The proof goes in three steps.

1. Construction of a bivariant K-theory for Banach algebras which is analogous to Kasparov theory, acts on K-theory, and admits a descent homomorphism.

2. Construction of a homotopy between γ and 1 in this Banach algebra K-theory for any bolic group G satisfying an additional technical condition, where γ is the element constructed by Kasparov and Skandalis.
3. Construction of a variant of the Schwartz space for p-adic reductive groups and the fact that cocompact discrete subgroups of $\mathrm{Sp}(n,1)$, $\mathrm{Sl}_3(\mathbb{R})$, and $\mathrm{Sl}_3(\mathbb{Q}_p)$ satisfy property (RD).

Morita equivalence for non-commutative tori

MARC A. RIEFFEL

(joint work with Albert Schwarz)

An n-dimensional non-commutative torus can be specified by an anti-symmetric real $n \times n$ matrix Θ. We define a (partial) action of $\mathrm{SO}(n,n;\mathbb{Z})$ on the space of anti-symmetric matrices and show that, generically, matrices lying in the same orbit for the action give Morita equivalent non-commutative tori. We give some indications of applications to physics ("matrix theory compactifications").

Morita equivalence and duality

ALBERT SCHWARZ

I introduce a notion of complete Morita equivalence and classify multi-dimensional tori up to complete Morita equivalence. I show that compactifications on completely Morita equivalent tori are physically equivalent. This means that there exists a new kind of duality in M(atrix) theory related to the group $\mathrm{SO}(n,n;\mathbb{Z})$.

Duality-symmetric actions on non-commutative tori

GIOVANNI LANDI

(joint work with F. Lizzi and R.J. Szabo)

We construct a bosonic and fermionic action on "two copies" of a non-commutative torus in d dimensions. The basic spectral data is dictated by vertex operator algebra and in particular consists of two chiral Dirac operators. A gauge connection is introduced via two gauge potentials. The covariant Dirac operators combine in a unique manner to produce a bosonic action which is nonlocal due to the deformation of the product. One remarkable fact is that the action is explicitly invariant under an $\mathrm{SO}(d,d)$ duality transformation. A natural fermionic action is also constructed which is also duality invariant.

Diffeomorphism Groups and non-commutative analytic torsion

JOHN LOTT

We state an index theorem concerning the pushforward of flat $\mathfrak{B}$-vector bundles, where $\mathfrak{B}$ is an appropriate algebra. We construct an associated analytic torsion form $\mathfrak{T}$. If Z is a smooth closed aspherical manifold, we show that $\mathfrak{T}$ gives invariants of $\pi_*(\mathrm{Diff}(Z))$.

Non-commutative combinatorial topology

NICOLAE TELEMAN

The talk has to basic components. The first is to present a general procedure for the computation of the Hochschild homology of algebras with local multiplication. The second is to associate with any simplicial embedding $X \to \mathbb{R}^N$ a pair $(A(X), P)$ consisting of an algebra $A(X)$ on X and an idempotent $P \in A(X)$. The purpose of defining such a pair was to produce combinatorial invariants of X via the Chern character of P. The algebra $A(X)$ is related to an algebra previously introduced by Kasparov and Skandalis. This second part needs substantial further research. In the first part of the talk the microlocalization procedure published very recently in a C.R. Note is illustrated for the algebras of smooth functions on smooth manifolds. This procedure has numerous applications as, e.g., the computation of the Hochschild homology of the algebra of piecewise differentiable functions on simplicial complexes, part of a joint work with J.P. Brasselet and A. Legrande.

Anomaly cancellations in the spectral action

ALI CHAMSEDDINE

A non-commutative space defined by a spectral triple $(A, \mathcal{H}, D)$ and endowed with a real structure J and spectrum Σ can have an action associated with it. The dynamics of the metric is governed by the spectral action principle with action given by $\mathrm{Tr}\, F(D^2) + (\Psi, D\Psi)$. The presence of chiral fermions in the standard model of particle physics implies that the trace is projected over the chiral states. This projection is not invariant under chiral rotations unless certain conditions are met. These conditions are related to the gauge anomaly cancellation conditions and mixed gauge gravitational anomalies.

Non-commutative integrability

CTIRAL KLIMCIK

The concept of quantisation of the de Rham complex of some Kähler manifolds is introduced. The coboundary operator d is generated (at the classical level) by certain odd elements of the superalgebra into which the de Rham complex is naturally injected. d then acts by taking the (super) Poisson bracket of these odd generators with de Rham forms. After quantisation, the Poisson bracket is replaced by the commutator in the quantised superalgebra, thus allowing to enlarge the action of the Hamiltonian vector fields on non-commutative manifold also to the non-commutative de Rham complex. It turns out that the superalgebra into which the standard classical de Rham complex is injected coincides with the algebra of superfields of the supersymmetric field theories. The elements that are not in the image of the injection turn out to be the so-called auxiliary fields of the supersymmetric field theories.

Equivariant homology

PETER SCHNEIDER

(joint work with Paul Baum)

For a locally compact and totally disconnected group G acting continuously on two locally compact spaces Y and X we define the (compactly delocalized) bivariant equivariant cohomology by

$$H^*_{G,c}(Y,X) = \mathrm{Ext}^*_{\mathfrak{Sh}_G(G_0)}(R\phi_{Y!}\mathbb{C}, R\phi_{X!}\mathbb{C}).$$

For this we introduce $G_0 = \{g \in G \mid g \text{ compact}\}$, as well as $\hat{X} = \{(g,x) \in G_0 \times X \mid gx = x\}$ together with the projection $\phi_X \colon \hat{X} \to X$. On the right hand side in the above definition we form the higher direct images with proper support on G_0 of the constant sheaf on Y, resp. X, then we form the higher Ext-groups in the category of G-equivariant sheaves on G_0.

It is explained how this definition generalises all previous constructions in special cases. Some examples are computed. Finally, it is explained how this new theory is the recipient of a Chern character isomorphism from equivariant K-homology.

The coarse Baum-Connes conjecture for spaces which admit a uniform embedding into a Hilbert space

GUOLIANG YU

I present the proof of the coarse Baum-Connes conjecture for spaces which have bounded geometry and admit a uniform embedding into Hilbert space. This result implies the strong Novikov conjecture for finitely generated groups which admit a uniform embedding into Hilbert space as a metric space with word length metric. The class of finitely generated groups which admit a uniform embedding into Hilbert space contains a subclass of groups closed under semidirect product and containing word hyperbolic groups and amenable groups. It is an open question due to Gromov whether every separable metric space (or finitely generated group) admits a uniform embedding into Hilbert space, although it is easy to prove that every separable metric space admits a uniform embedding into a separable Banach space.

The K-homology classes of the Euler characteristic and signature operators

JONATHAN ROSENBERG

As is well-known, an elliptic operator D on a manifold M defines a K-homology class $[D]$. A fundamental problem is to determine what geometric information is encoded in $[D]$ when D is one of the standard geometric operators. We study this problem for both the Euler characteristic and the signature operators. Both of these operators are given by $d + d^*$ acting on differential forms, but with different grading data. Rationally, the K-homology class of the Euler characteristic operator is the Poincaré dual of the Euler class, and the K-homology class of the signature operator is the Poincaré dual of the Atiyah-Singer $\mathfrak{L}$-class. In this talk we consider the additional information contained in the torsion part of $[D]$.

Hermitian non-commutative spaces

OLIVIER GRANDJEAN

We show how the notions of Riemannian and Kähler non-commutative spaces emerge from superconformal field theory. It turns out that these spaces are characterised by spectral data consisting of a Hilbert space $\mathcal{H}$, a unital $*$-algebra A acting faithfully on $\mathcal{H}$ by bounded operators, a set of supercharges (Dirac operators) acting on $\mathcal{H}$, and a Lie algebra of symmetries commuting with the elements of the algebra A. Concretely, conformal field theories with $N = (1,1)$, $N = (2,2)$, and $N = (4,4)$ describe Riemannian, Kähler, and Hyper-Kähler spaces, respectively. We explain a possible procedure to produce $N = (1,1)$ data starting from a spectral triple (also called $N = 1$ data), in the sens of A. Connes. As an example, we show how to get successively $N = (1,1)$ and $N = (2,2)$ spectral data for the non-commutative 2-torus T^2_θ for irrational θ, starting from the usual $N = 1$ data. The complex structure on T^2_θ obtained this way coincides with that originally found by Connes. The nice feature of the notion of Kähler space emerging from superconformal field theory is that it does not rely on the equivalence of conformal and complex structures in two dimensions.

Hopf algebras, Cyclic cohomology, and the transverse fundamental class

ALAIN CONNES

(joint work with Henri Moscovici)

In this talk the solution of the transverse index formula is presented. The solution involves several ingredients. First, the local index formula valid for any spectral triple with discrete dimension spectrum. Secondly, the computation of the entries in this formula for the hypoelliptic operator associated to the transverse structure of a foliation gives rise to a Hopf algebra $\mathcal{H}(n)$ only depending on the dimension n of the foliation. The general structure of $\mathcal{H}(n)$ is given by a construction of G. Kac from the decomposition of any diffeomorphism g of $\mathbb{R}^n$ as a product $g = g_1 g_2$ with g_1 affine and $g_2(0) = 0$, $g_2'(0) = \mathrm{id}$.

Thirdly, one gets the general notion of cyclic cohomology of Hopf algebras. It is dictated by the above computation and gives the proper substitute of Lie algebra cohomology in this generality. It comes from a quite subtle cyclic structure on the cosimplicial space associated to the Hochschild complex of the coalgebra.

Finally, one shows that that the computation of the cyclic cocycle occurring in the local index formula takes place in the cyclic cohomology of the Hopf algebra. The latter is computed to be Gelfand-Fuchs cohomology, which allows to solve the above problem. There is an exciting relation of the Hopf algebra $\mathcal{H}(n)$ to the Hopf algebra found by Dirk Kreimer.

Hopf algebras and quantum field theory

DIRK KREIMER

(joint work with Alain Connes)

This talk explains how perturbative quantum field theory upon the process of renormalisation gives rise to a Hopf algebra of rooted trees. The antipode in this Hopf algebra captures the combinatorics of Zimmermann's forest formula responsible for the renormalisation of path integrals.

This Hopf algebra is shown to be related to the Hopf algebra found by Connes and Moscovici, in the sense that the commutative subalgebra $\mathcal{H}_0$ of the Connes-Moscovici Hopf algebra is a Hopf subalgebra of the Hopf algebra occurring in quantum field theory. Both Hopf algebra can be generalised to the same Hopf algebra $\overline{\mathcal{H}_n}$ maintaining the algebraic results of Connes and Moscovici.

Quantum Fields on non-commutative spaces

JOSEPH C. VARILLY

(joint work with José M. Gracia Bendia)

It is proposed to construct quantum fields directly on non-commutative spaces, understood as spectral triples satisfying Connes' geometric axioms. Quantisation of Weyl fermions is carried out on a smooth non-commutative 3-torus, using the Segal-Shale-Stinespring formulation. It is explained why the ultraviolet behaviour of this quantisation is governed by the classical dimension of the spectral triple.

Formality conjecture for chains

BORIS TSYGAN

By the formality theorem of Kontsevich, there is an L_∞ quasi-isomorphism between the differential graded Lie algebras of multivector fields on a manifold M and that of Hochschild cochains of $C^\infty(M)$. As a consequence, the set of equivalence classes of deformations of $C^\infty(M)$ is bijective to the set of equivalence classes of formal Poisson structures on M.

Consider a Poisson structure π on M and denote by $A(\pi)$ the deformed algebra given by Kontsevich's theorem. We make a conjecture that Hochschild, cyclic, etc., theories of this algebra are isomorphic to the corresponding versions of Poisson homology of (M, π). As a consequence, we obtain a characteristic class $\hat{A}(M, \pi)$. If π is regular, this is equal to $\hat{A}(T\mathfrak{F})$, where $T\mathfrak{F}$ is the (symplectic) tangent bundle to the foliation of symplectic leaves of π. We make another more general conjecture. It is well known that the algebra $\mathfrak{g}^{\cdot}_S(M)$ acts on $\Omega^{\cdot}(M)$ and that $\mathfrak{g}^{\cdot}_G(A)$ acts on the Hochschild, cyclic, etc., complex of A. Thus, by the formality theorem, both $\Omega^{\cdot}(M)$ and $C_{\cdot}(A)$ are L_∞-modules over $\mathfrak{g}^{\cdot}_S(M)$ if $A = C^\infty(M)$. We conjecture that there is a L_∞-quasi-isomorphism of these L_∞-modules. The same should be true if we replace $\mathfrak{g}^{\cdot}_S$ by $(\mathfrak{g}^{\cdot}_S[\epsilon], \partial/\partial\epsilon)$, $\epsilon^2 = 0$, $|\epsilon| = 1$. In other words, we conjecture that the well-known quasi-isomorphism of Connes is $\mathfrak{g}^{\cdot}_S[\epsilon]$-equivariant. This question is related, in particular, to various versions of the equivariant index theorem.

Non-commutative Minkowski space

JULIUS WESS

A deformation of the Heisenberg algebra based on a q-deformed Lorentz group is introduced and the construction of the corresponding algebra explained. Hilbert space representations are constructed and the problem of finding selfadjoint representations discussed. Among the irreducible representations of the deformed algebra, there are no representations in the form of selfadjoint operators. Selfadjoint representations can be obtained by composing irreducible representations suitably. The question arises what the general structure of such representations is. The spectrum of the position and momentum operators forms a q-lattice with accumulation points on the light cone.

Continuous deformations of symplectic structures

RYSZARD NEST

Given a compact symplectic manifold (M,ω) and a formal deformation $A^{\hbar}(\omega)$ of $C^{\infty}(M)[[\hbar]]$ with an associative product $*_{\hbar}$ we construct (under the condition that $\pi_2(M)=0$) a continuous field of C*-algebras $[0,1]\ni t\mapsto A_t$ such that $A_0=C(M)$ and the asymptotics of the product at $t=0$ in the algebra of sections of the field (A_t) is identical with the formal $*_{\hbar}$-product. The first non-trivial case is when M is a closed Riemannian surface of genus $g>1$ with the standard symplectic structure. The construction amounts to the construction of the continuous field of C*-algebras $t\mapsto \mathfrak{K}_t$, where $\mathfrak{K}_t$ is the algebra of compact operators on the Bergman space $H_{1/t}$, $H_0=C_0(\mathbb{D})$, $\mathbb{D}$ the open unit disk; and a continuous projection valued section e_t in $\mathfrak{K}_t\rtimes\Gamma$, where $\Gamma=\pi_1(M)$ acts via the natural projective representation on $\mathbb{D}$. The resulting field $e_t(\mathfrak{K}_t\rtimes\Gamma)e_t$ provides an example of the construction.

Quantisation on non-commutative Hardy spaces

HARALD UPMEIER

We consider Hardy spaces $H^2(S)$ of holomorphic functions in several complex variables, associated with a compact symmetric space S and a suitable domain $S_+^{\mathbb{C}}$ in its complexification. Depending on S and any polyhedral cone Λ in its Cartan subspace, there is a Peter-Weyl decomposition

$$H^2(S)=\sum_{\alpha\in\hat{K}\cap\Lambda^{\#}}\langle K\rangle_{\alpha}$$

under the isometry group K, where $\Lambda^{\#}$ is the dual cone of Λ. The corresponding Toeplitz C*-algebras $\mathfrak{T}(S)$ is analysed in detail. The main result is a composition series with subquotients given by foliation C*-algebras $C^*(K/\overline{K})$, where $\overline{K}$ is a non-closed subgroup of K associated with a face $\overline{\Lambda}$ of Λ. Special cases include symmetric domains/Reinhardt domains and the non-symmetric Hardy spaces occurring in the well-known Gelfand-Gindikin program.

Towards a quantum index theorem for superselection sectors

ROBERTO LONGO

A way is proposed to incorporate some geometry into algebraic quantum field theory.

We view superselection factors as analogous to (equivalence classes of) elliptic operators. In conformal quantum field theory on S^1, we have the formula

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

where K_ρ is the generator corresponding to special conformal transformations and ρ is an endomorphism localised in an interval.

By restricting a black hole spacetime QFT on the horizon we have

$$d(\rho) = \exp(-k/2\pi F(\phi_\rho, \phi))$$

with ϕ, ϕ_ρ thermal states and k the surface gravity.

We propose the formula

$$\tau^\rho(a_0, \ldots, a_n) = \tau\big(\bar{\rho}(a_0), \ldots, \bar{\rho}(a_n)\big)$$

with τ the JLO cyclic cocycle in the thermal state as a cohomology class associated to ρ.

This report was written by Ralf Meyer, Münster.

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