MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 8/1994

Harmonische Analyse und Darstellungstheorie topologischer Gruppen

20.02 bis 26.02.1994

Die Tagung fand unter der Leitung von R. Howe (New Haven) und E. Kaniuth (Paderborn) statt. Im Mittelpunkt des Interesses standen die harmonische Analyse auf symmetrischen Räumen und auf halbeinfachen Lie-Gruppen. Des weiteren nahm die Darstellungstheorie lokalkompakter, insbesondere nilpotenter und exponentieller Gruppen einen breiten Raum ein. Außerdem wurden Themen wie die Topologie im Dual und die Stuktur von Gruppen-C^*-Algebren behandelt.

Vortragsauszüge

E.P. VAN DEN BAN:

The most continuous part of the Plancherel decomposition for a semisimple symmetric space

(joint work with H. Schlichtkrull)

Let G be a connected real semisimple Lie group with finite center (or more generally a group of Harish-Chandra's class). Moreover, let σ be an involution of G and H an open subgroup of the group G^σ of fixed points. We discuss a spherical Fourier transform associated with the most continuous part of the Plancherel decomposition of $L^2(G/H)$. Let K be a σ-stable maximal compact subgroup. Then restriction to K-finite functions leads to the setting of a finite dimensional representation (τ, V) of K and a space $C^\infty(G/H, \tau)$ of smooth τ-spherical functions on G/H, i.e. the space of smooth functions $f : G/H \to V$ transforming according to the rule: $f(kx) = \tau(k)f(x)$,

$x \in G$, $k \in K$. We define Eisenstein integrals in $C^\infty(G/H,\tau)$ which generalize Harish-Chandra's normalized Eisenstein integrals for minimal parabolic subgroups in the group case. In the case of a Riemannian symmetric space they are the well known elementary spherical functions, normalized by division by a c-function. In terms of the Eisenstein integrals we define a spherical Fourier transform $\mathcal{F}$ on a space $\mathcal{S}(G/H,\tau)$ of rapidly decreasing functions in $C^\infty(G/H,\tau)$ (this space generalizes Harish-Chandra's Schwartz space).

The first main result is that $\mathcal{F}$ is injective on the space $C_c^\infty(G/H,\tau)$ of compactly supported spherical functions in $C^\infty(G/H,\tau)$. However it is in general not injective on $\mathcal{S}(G/H,\tau)$. In fact the second main result is that there exists a wave packet transform $\mathcal{J}$ which inverts $\mathcal{F}$ modulo the kernel of a non-trivial invariant differential operator $\partial_\tau \in D(G/H)$:

$$\partial_\tau \mathcal{J}\mathcal{F} = \partial_\tau \quad \text{on} \quad \mathcal{S}(G/H,\tau).$$

Since $\ker \partial_\tau$ is small in a suitable spectral sense, these results allow us to isolate the 'most continuous part' of $L^2(G/H)$ and give its direct integral decomposition into irreducibles.

M.B. Bekka:

Simplicity of reduced group C^*-algebras

(joint work with M. Cowling and P. de la Harpe)

The main result is as follows: Let G be a semisimple Lie group without compact factors and with a trivial centre. Let Γ be a Zariski dense (not necessarily closed) subgroup of G. Then the reduced group C^*-algebra $C_r^*(\Gamma)$ of Γ is simple (that is, it has no non-trivial two-sided ideals) and the canonical trace on $C_r^*(\Gamma)$ is unique (as a normalized trace). This applies, in particular, to the case where Γ is a lattice in G. Indeed, by the Borel density theorem, Γ is then Zariski dense in G.

A consequence of the above result is the following theorem which generalizes previous work by R. Howe and J. Rosenberg. Let $\mathbf{G}$ be a semisimple algebraic group over a field k of characteristic 0. Suppose that $\mathbf{G}$ has a trivial centre. Then $\mathbf{G}(k)$, the k-points of $\mathbf{G}$, has a simple reduced C^*-algebra with a unique trace.

An extension of our main result to reduced crossed-product C^*-algebras is also discussed.

T.P. Branson:

The complementary series, sharp inequalities and the functional determinant

Complementary series representations have acquired a reputation for being somewhat useless in harmonic analysis on homogeneous spaces. But they play a central role in recent work on the harmonic analysis of perturbations of homogeneous spaces to 'bumpy manifolds'. On the spheres S^m, intertwinors for complementary series representations of $SO_0(m+1,1)$, and intertwinors at the endpoints of the complementary series, appear naturally in sharp Sobolev and Moser-Trudinger inequalities. These inequalities, in turn, turn out to be perfectly (almost miraculously) adapted to estimating the functional determinant of an elliptic differential operator with nice conformal properties, once we interpret our functions as conformal metrics. In fact for m even, the determinants in question are definite (positive or negative) linear combinations of the quantities asserted positive by sharp inequalities. Equality holds in these inequalities if and only if the conformal metric, represented by the given function, is related to the standard metric on S^m by a conformal diffeomorphism (the standard action of $O(m+1,1)$).

B.N. Currey:

Concrete Plancherel formula for a class of completely solvable homogeneous spaces

Given a finite multiplicity monomial representation τ of a completely solvable Lie group G, which is induced from a closed connected subgroup H, the orbit method allows an irreducible decomposition of τ over the space $\mathfrak{h}^{\perp}/H$. The usual way of making this concrete and constructing an intertwining operator is the Penney-Fujiwara method. However, for non-nilpotent groups, construction of the required distributions is problematic. In the case where τ is induced from a 'Levi' component, we overcome these problems and give an explicit, natural construction of the intertwining operator for an irreducible decomposition of τ over a smooth cross-section for (generic orbits in) $\mathfrak{h}^{\perp}/H$. In a certain sense this decomposition is 'smooth' (smooth vectors are mapped to smooth sections by the intertwining operator) and this formula decomposes the τ-invariant differential operators. In the process we show that in this situation the nilradical of G is two-step.

A. Derighetti:

p-pseudomeasures and closed subgroups

(joint work with J. Delaporte)

Let $PM_p(G)$ be the space of all p-pseudomeasures on a locally compact group G. We show the existence of a conditional expectation from $PM_p(G)$ onto $PM_p(H)$ where H is a closed normal subgroup of G. As an application we give a new proof of the fact that H is a set of p-synthesis in G; we also get an inequality involving the operator norm of bounded measures on G. Moreover, in analogy with a theorem of Reiter, we obtain a result concerning the closed ideals of the Figa-Talamanca-Herz algebra of G.

J. FARAUT:

Pseudo-Hermitian symmetric spaces of tube type

If Ω is an open convex cone in $\mathbf{R}^n$, the Hardy space $H^2(T_\Omega)$ of the tube $T_\Omega = \mathbf{R}^n + i\Omega \subseteq \mathbf{C}^n$ is well understood. When Ω is not convex Gindikin has defined a Hardy space by using $\bar\partial$ cohomology. In order to study further these spaces one considers a special class of cones. A (non necessarily convex) connected open cone Ω in $\mathbf{R}^n$ is said to be symmetric if
(S1) There exists a connected group $L \subsetneq GL(n, \mathbf{R})$ which acts transitively on Ω (Ω is homogeneous).
Fix e in Ω and let $A = \{g \in L;\ Le = e\}$.
(S2) (L, A) is a symmetric pair associated to an involutive automorphism σ of L ($\Omega = L/A$ is a symmetric space).
(S3) There exists on $\mathbf{R}^n$ a non-degenerate symmetric bilinear form b such that, for all $g \in L$, $b(gn, y) = b(n, \sigma(g)^{-1}y)$ (semisimplicity condition).
The symmetric cones are in one to one correspondence with the semisimple real Jordan algebras. If Ω is a symmetric cone, the tube T_Ω is equipped with a pseudo-Hermitian metric. Then T_Ω is a pseudo-Hermitian symmetric space if and only if Ω is convex. If not, using a conformal compactification of $\mathbf{C}^n$, it is possible, by adding points at infinity to the tube T_Ω, to obtain a pseudo-Hermitian symmetric space.

A. FIGÀ-TALAMANCA:

Anisotropic diffusion on the boundary of a homogeneous tree

We deal with the problem of defining and computing a diffusion process on a compact ultrametric space. Every compact ultrametric space is naturally the boundary of a tree. The tree is constructed taking the balls $B(x, r) = \{y : d(x, y) \leq r\}$ as vertices and joining together two balls if one is a maximal ball contained in the other. If the tree is homogeneous, that is if the number of edges to which a vertex belongs is always the same one may try to define the diffusion process starting with a simple anisotropic random walk on the tree. A 'time-scaling' procedure allows to define a continuous process on the boundary.
However, an explicit computation of the kernel of the process is possible only when the random walk and the associated process are isotropic. In this case all computations become simple because one can use the group of isometries of the space and the associated spherical functions to diagonalize the process.

M. FLENSTED-JENSEN:

Multipliers for semisimple symmetric spaces

(joint work with E. van den Ban and H. Schlichtkrull)
Let G/H be a semisimple symmetric space, K a maximal compact subgroup of G. $C_c^\infty(K;G/H)$ is the space of K-finite C_c^∞-functions, $\mathfrak{g}$ the Lie algebra of G and $D(G/H)$ the invariant differential operators. A multiplier is a linear operator $M : C_c^\infty(K;G/H)$ ↺, which is $\mathfrak{g}$, K and $D(G/H)$ equivariant and continuous on each subspace $C_c^\infty(G/H)^\mu$, $\mu \in K^\frown$.
Let $\mathfrak{g} = \mathfrak{h} + \mathfrak{q} = \mathfrak{k} + \mathfrak{p}$ as usual. Let $\mathfrak{b} \subset \mathfrak{q}$ be a Cartan subspace such that $\mathfrak{b} = \mathfrak{b} \cap \mathfrak{k} + \mathfrak{b} \cap \mathfrak{p}$. Let $\mathfrak{b}^r = \mathfrak{b} \cap \mathfrak{p} + i(\mathfrak{b} \cap \mathfrak{k})$ be the real form of $\mathfrak{b}_{\mathbf{C}}$ containing the root vectors and W the Weyl group.
$PW(\mathfrak{b}^r)^W$ is the Paley-Wiener space, i.e. W-invariant entire (on $\mathfrak{b}^r_{\mathbf{C}}$) rapidly decreasing functions of exponential type, $PW^*(\mathfrak{b}^r)^W$ is the slowly increasing ....
Let $\pi \in G^\frown$. π is spherical (w.r.t. H) if $\mathcal{V}_\pi = (\mathcal{H}_\pi)^{-\infty,H} \neq \{0\}$. $v \in \mathcal{V}_\pi$ is called spherical of type λ if (appropriately defined)

$$\pi(D)v = \chi_\lambda(D)v, \qquad D \in D(G/H), \qquad \lambda \in (\mathfrak{b}^r_{\mathbf{C}})^*.$$

<u>Theorem.</u> Let $\psi \in PW^*(\mathfrak{b}^r)^W$. There exists a unique multiplier M_ψ, such that for any $\pi \in G^\frown$, $v \in \mathcal{V}_\pi$ spherical of type λ, we have

$$\pi(M_\psi f)v = \psi(\lambda)\pi(f)v, \qquad f \in C_c^\infty(K;G/H).$$

M_ψ extends to $C^{-\infty}(K;G/H)$. If $\psi \in PW(\mathfrak{b}^r)^W$, then M_ψ maps $C_c^{-\infty}(K;G/H)$ into $C_c^\infty(K;G/H)$.
This theorem generalizes results by Arthur and Delorme. The proof is extremely simple using partial holomorphic extension of $C_c^\infty(K;G/H)$ to $C^\infty(H^d;G^d/K^d)$ and convolution by a K^d-spherical distribution with K^d-spherical Fourier transform ψ.
In a paper to appear van den Ban and Schlichtkrull give a conjecture for the Fourier transform of $C_c^\infty(G/H)^\mu$ given an intrinsic characterization of the image $PW_0(G/H,\mu)$ and $PW_0^*(G/H,\mu)$. If their conjecture is true then PW_0 and PW_0^* are invariant under the multipliers M_ψ. We prove also this last fact, in 'favour' of the conjecture.

H. FUJIWARA:

Intertwining operators for unitary representations of exponential groups

(joint work with D. Arnal and J. Ludwig)
Let $G = \exp\mathfrak{g}$ be an exponential group with Lie algebra $\mathfrak{g}$. For a linear form $f \in \mathfrak{g}^*$, we denote by $I(f,\mathfrak{g})$ the set of real polarizations at f satisfying Pukanszky's condition. If one takes two such polarizations $\mathfrak{h}_1, \mathfrak{h}_2 \in I(f,\mathfrak{g})$, then the corresponding induced representations $\pi_j = \mathrm{ind}_{H_j}^G \chi_j$ $(j = 1,2)$, where $H_j = \exp\mathfrak{h}_j$, $\chi_f(\exp X) = e^{if(X)}$ $(X \in$

$\mathfrak{h}_j$) are equivalent irreducible unitary representations of G. Then, our problem is how to construct an explicit intertwining operator from π_1 to π_2, or equivalently a Penney's distribution belonging to $(\mathcal{H}_{\pi_1}^{-\infty})^{H_2,\chi_f\Delta_{H_2,G}^{1/2}}$ with $\Delta_{H_2,G} = \Delta_{H_2}/\Delta_G$.
We have a formal candidate:

$$(T_{\mathfrak{h}_2\mathfrak{h}_1}\phi)(g) = \oint_{H_2/H_1\cap H_2} \phi(gh)\,\chi_f(h)\,\Delta_{H_2,G}^{-1/2}(h)\,d\nu(h) \quad (\text{for all } g \in G).$$

If G is nilpotent, this integral converges for all $\phi \in \mathcal{H}_{\pi_1}^{\infty}$, which is nothing but the Schwartz functions, and $T_{\mathfrak{h}_2\mathfrak{h}_1}$ turns out to be a real intertwining operator (G. Lion). We give a meaning to this formal operator $T_{\mathfrak{h}_2\mathfrak{h}_1}$ in the following two cases; (1) $\mathfrak{h}_1 + \mathfrak{h}_2$ is a subalgebra of $\mathfrak{g}$, (2) $\mathfrak{h}_1$ or $\mathfrak{h}_2$ is a polarization of M. Vergne. In these cases, $T_{\mathfrak{h}_2\mathfrak{h}_1}$ gives us a real intertwining operator.
For the general case, we show that $e^{\frac{i\pi}{4}\tau(\mathfrak{h}_1,\mathfrak{h}_0,\mathfrak{h}_2)}T_{\mathfrak{h}_2\mathfrak{h}_0}\circ T_{\mathfrak{h}_0\mathfrak{h}_1}$ does not depend on the choice of $\mathfrak{h}_0 \in I(f,\mathfrak{g})$, which is assumed to be one of M. Vergne. Here $\tau(\mathfrak{h}_1,\mathfrak{h}_0,\mathfrak{h}_2)$ denotes the Maslov index, and $T_{\mathfrak{h}_2\mathfrak{h}_0}$, $T_{\mathfrak{h}_0\mathfrak{h}_1}$ are intertwining operators, supposed to be suitably normalized, constructed as above. So we change a standpoint and try to write down this real intertwining isometry $T_{\mathfrak{h}_2\mathfrak{h}_1}$. Our result is: there exists a positive H_2-invariant linear form ν such that

$$(T_{\mathfrak{h}_2\mathfrak{h}_1}\phi)(e) = \oint_{H_2/H_1\cap H_2} \phi(h)\,\chi_f(h)\,\Delta_{H_2,G}^{-1/2}(h)\,d\nu(h) \quad (e:\ \text{unit element of } G)$$

for $\phi \in \mathcal{H}_{\pi_1}^{\infty}$ with small support modulo H.

J. HILGERT:

Holomorphic extensions of highest weight representations I

Let G be a Lie group such that its Lie algebra $\mathfrak{g}$ has a compactly embedded Cartan subalgebra $\mathfrak{t}$. Further let $\mathfrak{k}$ be the uniquely determined maximal compactly embedded subalgebra of $\mathfrak{g}$ containing $\mathfrak{t}$. Then the set of roots $\Delta = \Delta(\mathfrak{g}_{\mathbf{C}}, \mathfrak{t}_{\mathbf{C}})$ splits up into compact roots (Δ_k) and non-compact roots (Δ_p). Associated to the pair $(\mathfrak{k}, \mathfrak{t})$ is a Weyl group $W_{\mathfrak{k}}$. A positive system Δ^+ is called $\mathfrak{k}$-adapted if Δ_p^+ is $W_{\mathfrak{k}}$-invariant. Given such a system one can consider unitary highest weight representations, i.e. representations $\pi : G \to \mathcal{U}(\mathcal{H})$ such that $\mathcal{H}^K$ (K-finite vectors) is generated by a primitive vector v_0 ($\mathfrak{g}_{\mathbf{C}}^{\alpha} \cdot v_0 = \{0\}$ for all $\alpha \in \Delta^+$). The main result presented here is the characterization of these representations by the existence of holomorphic extensions to complex semigroups containing G.

A. HULANICKI:

General boundaries for NA groups and the Fatou theorem

Let N be a nilpotent Lie group and A an Abelian group which acts on N diagonally. Let L be a second order subelliptic operator on $S = NA$ which is left-invariant and has no constant term. A boundary for the pair (L, NA) is a quotient space N/N_0, where N_0 is a subgroup of N invariant under the action of A such that the functions $F(s) = \int f(s \cdot x)\, d\nu(x)$ are L-harmonic for a suitable probability measure ν on N/N_0 and $\lim_{t\to\infty} F(\underline{s}_t \cdot x) = f(x(\underline{s}))$, when $\underline{s} = (\underline{s}_t)$ is the diffusion process generated by L on S, for almost all trajectories $\underline{s}$.

Theorem (E. Damek and A. Hulanicki): If s tends to the boundary N/N_0 in an appropriate manner, then for every function $f \in L^p(N/N_0)$, $1 < p \leq \infty$, $F(s) \to f(q(s))$ for almost all points $q(s) \in N/N_0$, where q is the natural map $q : S \to NA/N_0A = N/N_0$.

P.E.T. JØRGENSEN:

Asymptotics for the heat equation on a stratified nilpotent Lie group

(joint work with C. Batty, O. Bratteli and D. Robinson)
Consider the heat equation $(H + \frac{\partial}{\partial t})u = \varphi$, $u = \varphi$ for $t = 0$, u defined on $\mathbf{R} \times G$, with H a second order generalized elliptic operator on G. Define $S_t\varphi = u$ as a semigroup on $L^2(G)$. Formally $S_t = e^{-tH}$, and the kernel form may be written as a Haar measure integral: $S_t\varphi(x) = \int_G K_t(x,y)\varphi(y)\, dy$.
Let $\mathfrak{g}$ be the Lie algebra, $\mathfrak{g} = \sum^{\oplus} \mathfrak{g}^{(k)}$, $[\mathfrak{g}^{(k)}, \mathfrak{g}^{(l)}] \subset \mathfrak{g}^{(k+l)}$ is assumed, and a scaling group on G is defined by $x^{(k)} \to r^k x^{(k)}$, $x^{(k)} \in \mathfrak{g}^{(k)}$, $r \in \mathbf{R}_+$. When passed to G we get $x \to rx \in \mathrm{Aut}(G)$.
Estimates for $K_t(x,y)$ are known in terms of the metric

$$d_H(x,y) = \sup\{\psi(x) - \psi(y) \mid \psi \in C_c^\infty(G),\ <\psi, H\psi> \leq 1\}$$

but when $t \to \infty$ this estimate becomes inefficient. Instead we show that the formula for $c(\varepsilon^{-1}x)$, applied to an operator H which is assumed Γ-periodic for a fixed lattice Γ in G, yields a system $K_t^\varepsilon(x,y)$ with a $\varepsilon \to 0$ limit $\widehat{K}_t(x,y)$ such that the generator $\widehat{H}$ for $\widehat{S}_t\varphi(x) = \int_G \widehat{K}_t(x,y)\,\varphi(y)\, dy$ is represented by a second order element in $\mathcal{U}_{\mathbf{C}}(\mathfrak{g})$ the enveloping algebra of right-invariant partial differential operators on G. Then we show that the $t \to \infty$ asymptotics is governed by this new metric $d_{\widehat{H}}$ where $\widehat{S}_t = e^{-t\widehat{H}}$.

T. KAWAZOE:

L^1 estimate for Riesz transform and Hardy spaces on real rank 1 semisimple Lie groups

Let G be a real rank one semisimple Lie group and K a maximal compact subgroup of G. Radial maximal operators for suitable dilations, the heat and Poisson maximal operators, and the Riesz transform, which act on K-biinvariant functions on G, satisfy the L^p-norm inequalities for $p > 1$ and a weak type L^1 estimate. Through the Fourier theories on **R** and G we shall duplicate the Hardy space $H^1(\mathbf{R})$ to a subspace $H^1_s(G)$ $(s \geq 0)$ of $L^1(G)$ and show that these operators are bounded from $H^1_s(G)$ to $L^1(G)$.

A. MARKFORT:

On the conjugation representation of a locally compact group

Let G be a locally compact group. Then the conjugation representation of G in $L^2(G)$ is defined by

$$\gamma_G(x)f(y) = \delta_G(x)^{1/2} f(x^{-1}yx)$$

for $f \in L^2(G)$ and $x, y \in G$, where δ_G denotes the modular function of G. Then γ_G is trivial on the center $Z(G)$ of G and defines a faithful representation of $G/Z(G)$. So far the conjugation representation is much less understood than the left regular representation λ_G of G. We are investigating the support of the conjugation representation, that is the set of all irreducible representations of G which are weakly contained in γ_G.
For G a 2-step nilpotent group without non-trivial compact elements it turns out that $\mathrm{supp}\gamma_G$ coincides with $\mathrm{cor}(G)$, the set of all irreducible representations of G which cannot be Hausdorff separated from the trivial representation of G.
Let G be a simply connected nilpotent Lie group of maximal nilpotency class $(\dim(G)-1)$. Using Kirillov's theory it can be shown that $\mathrm{supp}\gamma_G = (G/Z(G))\hat{}$.
If G is a semidirect product of $\mathbf{R}^m$ with $\mathbf{R}^n$ it is possible to give a sufficient condition for $\mathrm{supp}\gamma_G = (G/Z(G))\hat{}$ to hold. This condition is fulfilled if $m = 1$ and in various other cases.
Finally, the support of the conjugation representation for low-dimensional simply connected solvable Lie groups is studied. It turns out that $\mathrm{supp}\gamma_G = (G/Z(G))\hat{}$ holds for all except one such groups of dimension ≤ 5.

V.F. MOLCHANOV:

Harmonic analysis and quantization on para-Hermitian symmetric spaces

Let G/H be a para-Hermitian symmetric space. Our goal is to give a construction for G/H which allows us to construct for G/H a variant of Berezin quantization.
Assume that G is simple and G/H is an orbit $\mathrm{Ad}G \cdot Z_0$ in $\mathfrak{g} = \mathrm{Lie}\, G$. The tangent space $\mathfrak{q}$ of G/H at Z_0 is decomposed into the direct sum $\mathfrak{q} = \mathfrak{q}^+ + \mathfrak{q}^-$ where $\mathfrak{q}^\pm$ are H-invariant abelian subalgebras of $\mathfrak{g}$. The pair $(\mathfrak{q}^+, \mathfrak{q}^-)$ is a Jordan pair. Let p be the genus of this pair. The groups $P^\pm = H \exp \mathfrak{q}^\pm$ are maximal parabolic subgroups of G. The homogeneous spaces $S^\pm = G/P^\mp$ are compact and diffeomorphic to $S = K/K \cap H$ where K is a maximal compact subgroup of G. There are embeddings: $\mathfrak{q}^+ \times \mathfrak{q}^- \hookrightarrow G/H \hookrightarrow S \times S$

where the images are open and dense.
For $\lambda \in \mathbf{C}$, let ω_λ be the character of $P^\pm$ defined by $\omega_\lambda(h \exp X) = |\det(\mathrm{Ad}h)_{\mathfrak{q}^+}|^{-\lambda/p}$. Let $T_\lambda^\pm = \mathrm{ind}_{P^\pm}^G \omega_{\pm\lambda}$. There are operators E_λ intertwining $T_\lambda^\pm$ with $T_{-\lambda-p}^\mp$. Let $\phi(s,t) = \phi_t(s)$, $s,t \in S$, be the kernel of $E_{-\lambda-p}$. This function plays the role of a supercomplete system in the sense of Berezin. For an operator $\widehat{A}$ acting on functions on S we define a symbol $A(s,t)$ as follows: $A(s,t) = \widehat{A}\,\phi_t(s)/\phi(s,t)$. The multiplication of operators gives rise to a multiplication of symbols. The corresponding integral contains a kernel called a Berezin kernel. The transform on $S \times S$ (or on G/H) with this kernel is called the Berezin transform. The symbols form an associative algebra depending on a parameter $h = -1/\lambda$ ('the Planck constant'). Since it commutes with translations on G/H, the Berezin transform is expressed in terms of Laplace operators $\Delta_1, \ldots, \Delta_r$ on G/H ($r = \mathrm{rank}\ G/H$). If we know this expression we can write its asymptotics when $h \to 0$. From that we can get information on when the correspondence principle is true. All this is closely connected with the problem of the decomposition of the tensor product $T_\lambda^{+'} \otimes T_\lambda^-$ into irreducible representations.
We succeeded in the realization of this program for G/H of rank one: $G = SL(n,\mathbf{R})$, $H = GL(n-1,\mathbf{R})$.

K.-H. NEEB:

Holomorphic extensions of highest weight representations II

We consider the following three problems concerning general highest weight representations: their classification, the characterization and a degree formula for square integrable representations, and a geometric character formula.
The classification is obtained by decomposing the representation as a tensor product of an extended metaplectic representation and a representation of a reductive group. The characterization of the square integrable representations generalizes Harish-Chandra's condition for the holomorphic discrete series, and his degree formula can also be extended to general groups. The geometric character formula expresses the holomorphic character of the representation by Fourier-transforms of appropriate coadjoint orbits. The main tool is a generalization of the Duistermaat-Heckman formula which is due to E. Prato and S. Wu.

N.V. PEDERSEN:

Quantization and matrix coefficients of nilpotent Lie groups

Let G be a connected and simply connected nilpotent Lie group with Lie algebra $\mathfrak{g}$, and let π be a strongly continuous, unitary, irreducible representation of G on $\mathcal{H}$. Realizing π naturally on $\mathcal{H} = L^2(\mathbf{R}^{d/2})$ we denote by $B(\mathcal{H})_\infty$ the bounded operators on $\mathcal{H}$ given by Schwartz kernels $K \in \mathcal{S}(\mathbf{R}^d)$. For $A \in B(\mathcal{H})_\infty$ we define the function f_π^A

by $f_\pi^A(s) = \mathrm{Tr}(\pi(s)A)$, $s \in G$, and set $R(G,\pi)_\infty$ to be the set of all such functions f_π^A, $A \in B(\mathcal{H})_\infty$. We call $R(G,\pi)_\infty$ the smooth matrix coefficients of π. One main point of the talk is that an analogue of the Schur orthogonality relations valid for compact groups can be proved also for nilpotent groups: After fixing a Jordan-Hölder sequence $0 = \mathfrak{g}_0 \subset \mathfrak{g}_1 \subset \ldots \subset \mathfrak{g}_{m-1} \subset \mathfrak{g}_m = \mathfrak{g}$ in $\mathfrak{g}$ and elements $X_j \in \mathfrak{g}_j \setminus \mathfrak{g}_{j-1}$ we can define the set e of jump indices for π by $e = \{1 \le j \le m \mid d\pi(x_j) \notin d\pi(U((\mathfrak{g}_{j-1})_{\mathbf{C}}))\}$. Writing $e = \{j_1 < \ldots < j_d\}$ and setting $\mathfrak{g}_e = \mathbf{R}X_{j_1} \oplus \ldots \oplus \mathbf{R}X_{j_d}$ we then have

$$\int_{\mathfrak{g}_e} f_\pi^A(\exp X)\,\overline{f_\pi^B(\exp X)}\,dX = \frac{(2\pi)^{1/2}}{|P_e(g)|}\,\mathrm{Tr}(AB)$$

for all $A, B \in B(\mathcal{H})_\infty$. Here $g \to P_e(g)$ is a computable polynomial on $\mathfrak{g}^*$, and P_e is invariant on the orbit $O = G \cdot g$ associated with π.

Applications to the determination of $R(G,\pi)_\infty$ by a system of differential equations are mentioned.

R.C. PENNEY:

The Hua-Johnson-Koranyi operators on a bounded homogeneous domain in $\mathbf{C}^n$

We discuss the problem of finding a system of operators on a bounded homogeneous domain in $\mathbf{C}^n$ which define the concept of harmonicity. We propose the following system of operators: Let X be a Kählerian manifold. Let $\bar\partial\partial$ be the operator defined in local coordinates by

$$\bar\partial\partial f = \sum \frac{\partial^2}{\partial\bar Z_i \partial Z_j} f \, d\bar Z_i \otimes dZ_j.$$

Let γ be the Riemannian connection for the Bergmann metric. We define the Hua-Johnson-Koranyi operator by

$$HJK(f) = \sum R(\bar Z_i, Z_j)\,\bar\partial\partial f(Z_i, \bar Z_j)$$

where Z_i is a local orthonormal frame for $T^{(1,0)}(X)$. We say that f is Hua harmonic if $HJK(f) = 0$. Our main result is that Hua harmonic functions have boundary values on the Shilov boundary and that they are uniquely determined by their boundary values. These results generalize results of Hua and Johnson-Koranyi for semi-simple tube domains.

D. POGUNTKE:

Kirillov picture for diamond groups

We present a contribution to the (still unsettled) problem of describing the topology on the primitive ideal space Priv $C^*(G)$ of an arbitrary simply connected solvable Lie group G. It took almost 30 years since the birth of the famous Kirillov orbit method, until J. Ludwig could show that for exponential groups the Kirillov map from the coadjoint orbit space $\mathfrak{g}^*/G$ into Priv $C^*(G)$ $(= \widehat{G}$ in this case) is a homeomorphism. Pukanszky has given a parametrization of Priv $C^*(G)$ for general simply connected solvable Lie groups G. This parametrization yields a bijective map, the Pukanszky-Kirillov-map, from the quasiorbit space $\mathfrak{g}^*/G$ into some quotient of Priv $C^*(G)$. Recently, J. Ludwig has proved that this map is open for so-called diamond groups. These groups are splitting extensions $\mathbf{R}^n \ltimes N$ of the Heisenberg group N, where $\mathbf{R}^n$ acts on the Lie algebra $\mathfrak{n}$ of N by center-fixing semisimple automorphisms with spectrum in the unit circle. Examples show that the Pukanszky-Kirillov-map is discontinuous in general. Nevertheless a modification of the Pukanszky parametrization is available for general diamond groups, such that one gets a description of the full topological space Priv $C^*(G)$ as the space of quasiorbits for a certain transformation group.

T. PRZEBINDA:

The oscillator character formula

(joint work with A. Paszkiewicz and N. Copernicus)
Let G, G' be an irreducible dual pair of type I in the stable range with G the smaller member. Let V, $(\,,)$; V', $(\,,)'$ be the defining modules for G, G', respectively. Let Θ denote the character of the oscillator representation ω of the metaplectic group $\widetilde{Sp} \supseteq \tilde{G}, \widetilde{G'}$. Let $\chi(t) = \exp(2\pi i t)$, $t \in \mathbf{R}$; and let $\chi_z(w) = \chi(< z(w), w >)$, $z \in \mathfrak{sp}$, $w \in W = \mathrm{Hom}(V', V)$. Denote by $C(x) = (x+1)(x-1)^{-1}$ the Cayley transform. Let π be a genuine irreducible unitary representation of $\tilde{G}$, and let π' be the irreducible unitary representation of $\widetilde{G'}$ obtained from π via Howe's correspondence. Suppose the form $(\,,)'$ is split, $\dim V' \geq (\dim V + 2)^2$, and the restriction of π to the (preimage of) the Zariski identity component of identity is reducible.
Then there is a non-empty Zariski open subset $G'' \subseteq G'$ such that the value of the character $\Theta_{\pi'}$ on any test function $\Phi \in C_c^\infty(\widetilde{G''})$ is given by

$$(*)\quad \Theta_{\pi'}(\Phi) = \int_{\tilde{G}} \int_{G\backslash W^{max}} \int_{\widetilde{G''}} \Phi(\tilde{g}')\,\Theta(\tilde{g}')\chi_{C(g')+C(g)}(w)\,\Theta(\tilde{g})\,\bar{\Theta}_\pi(\tilde{g})\,d\tilde{g}'\,d\dot{w}\,d\tilde{g},$$

where $W^{max} \subseteq W$ is the canonical dense open subset, $d\dot{w}$ is the measure obtained by fibration of the Lebesgue measure on W, and each single integral is absolutely convergent.
Recall the moment maps

$$\tau : W \to \mathfrak{g}^*, \qquad \tau(w)(z) = < z(w), w >,\ w \in W,\ z \in \mathfrak{g}$$
$$\tau' : W \to (\mathfrak{g}')^*, \qquad \ldots .$$

The above character formula together with Rossmann's Picard-Lefschetz theory imply that $WF(\pi') = \tau'\tau^{-1}(WF(\pi))$.
By rewriting (*) in the coordinates of the Cayley transform one obtains an algorithm for constructing irreducible unitary representations of classical groups, whose characters have Fourier transform supported on single nilpotent coadjoint orbits.

G. RATCLIFF:

The moment map for a multiplicity free action

(joint work with C. Benson, J. Jenkins and R. Lipsman)
A semidirect product $G = K \ltimes N$ of a compact automorphism group K of a nilpotent group N gives a Gelfand pair (G, K) if $L^1(G//K)$ is an abelian convolution algebra. When $N = V \rtimes \mathbf{R}$ is the Heisenberg group, then K is a subgroup of the unitary group $\mathcal{U}(V)$. In this case, (G, K) is a Gelfand pair if and only if the action of K on the polynomials $\mathbf{C}[V]$ is multiplicity free.
Materiated by the orbit method for describing the representations of G, we conjecture that the action of K on $\mathbf{C}[V]$ is multiplicity free if and only if, for each $\xi \in \mathfrak{g}^*$ (the dual of the Lie algebra of G), the intersection of the coadjoint orbit $\mathcal{O}_\xi$ through ξ with $\mathfrak{k}^\perp$, the annihilator of the Lie algebra of K, is a single K-orbit.
Define the moment map $\tau : V \to \mathfrak{k}^*$ by $\tau(v)A = \omega(v, Av)$ where ω is the symplectic form on V. Then $\tau^* : I[\mathfrak{k}^*] \to \mathbf{C}[V_\mathbf{R}]^K$ maps the Ad^*K-invariant polynomials on $\mathfrak{k}^*$ to the (real) K-invariant polynomials on V.
Theorem 1. K on $\mathbf{C}[V]$ is multiplicity free if and only if $\mathbf{C}[V_\mathbf{R}]^K$ is a finitely-generated Image(τ^*)-module.
2. The above condition holds if and only if τ is finite-to-one on K-orbits.
This theorem then says that K on $\mathbf{C}[V]$ is multiplicity free if and only if $(K \ltimes H_V)$ is a Gelfand pair if and only if $\tilde{\tau}$ is finite-to-one on K-orbits if and only if $\mathcal{O}_\xi \cap \mathfrak{k}^\perp$ is a finite union of K-orbits for every $\xi \in \mathfrak{g}^*$.

W.T. ROSSMANN:

Picard-Lefschetz theory and characters of semisimple Lie groups

Let $G_\mathbf{R}$ be a semisimple real Lie group, connected and with finite center. Let π be an irreducible, admissible representation of $G_\mathbf{R}$, Θ its pull-back to the Lie algebra $\mathfrak{g}_\mathbf{R}$ by exp, and $\hat{\Theta}$ its Fourier transform. In their paper 'The local structure of characters', Barbasch and Vogan (1980) proved that there is an asymptotic expansion of the form

$$\hat{\Theta} = \sum_{\mathcal{O}} \sum_{k \geq -k_\mathcal{O}} D_{\mathcal{O},k}$$

where $\mathcal{O}$ runs over the nilpotent $G_\mathbf{R}$-orbits in $i\mathfrak{g}_\mathbf{R}^*$ and $D_{\mathcal{O},k}$ is homogeneous of degree k supported on $\overline{\mathcal{O}}$. They define $AS(\Theta)$ to be the union of the supports of these $D_{\mathcal{O},k}$'s and conjecture that $AS(\Theta) = WF_0(\Theta)$, the wave-front set of Θ at 0. I have a proof of this conjecture based on Picard-Lefschetz theory for the coadjoint quotient $\mathfrak{g}^* \xrightarrow{q} W \setminus \mathfrak{h}^*$ of the complexification $\mathfrak{g}$ of $\mathfrak{g}_{\mathbb{R}}$. The proof is based on the fact that $\hat{\Theta}$ can be expressed as an integral, $\hat{\Theta} = I(\Gamma, \lambda_0)$ over a cycle Γ on the fibre $q^{-1}(\lambda_0)$ over the infinitesimal character $W \cdot \lambda_0 \in W \setminus \mathfrak{h}^*$ of π. These integrals $I(\Gamma, \lambda)$ are holomorphic in λ on all of $\mathfrak{h}^*$ and admit a Taylor expansion at $\lambda = 0$ of the form

$$I(\Gamma, \lambda) = \sum_{\mathcal{O}} \sum_{k \geq l_{\mathcal{O}}} P_{\mathcal{O},k}(\Gamma, \lambda)\mu_{\mathcal{O}},$$

where $\mu_{\mathcal{O}}$ is the invariant measure on $\mathcal{O}$, and $P_{\mathcal{O},k}(\Gamma, \lambda)$ a differential operator along $\mathcal{O}$, a homogeneous polynomial of degree k in λ, which transforms under W by Springer's representation attached to $\mathcal{O}$. This leads to a proof of the conjecture.

S. SAHI:

Small unitary representations

The talk describes a procedure, based on Jordan algebras, to give an explicit construction of certain 'small' unitary representations of a reductive group G.
The explicit description enables one to compute tensor products of two such representations. One finds that there is a symmetric space G'/K' whose representation theory controls the decomposition of the tensor product.
This gives rise to a 'functional' correspondence between the representations of G' and G, which extends Howe's theory of dual reductive pairs.

G. SCHLICHTING:

Minimal primal and Glimm ideal spaces of group C^*-algebras

(joint work with E. Kaniuth and K.F. Taylor)
An ideal I of a C^*-algebra A is a called primal if whenever finitely many ideals $J_1, \ldots, J_n$ of A are given with trivial intersection then $I \supset J_i$ for some $1 \leq i \leq n$. The space $\mathfrak{M}$ of minimal primal ideals of A is intimately related to the space of primitive ideals Prim$A$ of A but more suitable with respect to topology. The space $\mathfrak{G}$ of Glimm ideals of A is related to the complete regularisation of Prim$A$ and relevant for representing A as a ring of continuous sections. We explicitly determine $\mathfrak{M}$ and $\mathfrak{G}$ for some classes of group C^*-algebras $C^*(G)$ including all discrete amenable groups and certain semi-direct products like generalised motion groups and groups of the form $\mathbf{R}^n \rtimes \mathbf{R}$ with hyperbolic action.

R.J. STANTON:

Cohomology of flag manifolds computed by principal series representations

(joint work with L. Casian)

Let G be a linear, connected, real semisimple Lie group and $P = LU$ a parabolic subgroup. We define a finite complex, parametrized by an ordered graph G with vertices corresponding to $W_G^P = \{w \in W_G | w\Delta_G^+ \supseteq \Delta_L^+\}$, and order prescribed by a refinement of the Bruhat order. The differential is obtained from a modification of the one introduced by Bernstein-Gelfand-Gelfand and incorporates, in a way, the real form G. Then we prove

Theorem $H^\bullet(\mathsf{G}, d; \mathbf{C}) \simeq H^\bullet(G/P; \mathbf{C})$.

The proof begins with a complex of principal series obtained from Zuckerman's functor applied to the BGG/Lepowsky resolution. Using the Beilinson-Bernstein correspondence one obtains a complex of sheaves attached to $K_{\mathbf{C}}$ orbits in $G_{\mathbf{C}}/B$, B a Borel subgroup. A careful analysis of the differential is possible because of Bernstein's sheaf-theoretic formulation of Zuckerman's functor.

If P is a minimal parabolic, $P_{\min}$, these techniques allow us to compute $H^\bullet(G/P_{\min}; \mathbf{Z})$ by means of $H^\bullet(\mathsf{G}, d; \mathbf{Z})$. In this sense, the representation theory of G detects torsion in the cohomology of G/P.

M. TADIĆ:

On characters of irreducible unitary representations of $GL(n)$

We present an explicit formula which reduces characters of irreducible unitary representations of $GL(n)$ over a non-archimedian local field $\mathbf{F}$ in terms of characters of irreducible square integrable representations. Our approach uses the character identities coming from the ends of complementary series. In this way we are able to avoid completely related multiplicities of generalized principal series. Using the similarity of ends of complementary series of $GL(n, \mathbf{C})$, we can use Zuckerman's formula for the character of the trivial representation in terms of standard characters to get the formula for characters in the p-adic case for a set of irreducible unitary representations. Using Gelfand-Kazhdan derivatives, we get the formula in the general case.

K.F. TAYLOR:

Square integrable representations

Let H be a closed subgroup of $GL(n, \mathbf{R})$ and form the semi-direct product $G = \mathbf{R}^n \rtimes H$. Assume that the natural action of H on $\widehat{\mathbf{R}^n}$ is such that there exists an open, free H-orbit U. Let $\mathcal{H}_U^2 = \{g \in L^2(\mathbf{R}^n) : \mathrm{supp}(\hat{g}) \subseteq U\}$ and define a representation ρ_U of G

on $\mathcal{H}^2_U$ by, for $g \in \mathcal{H}^2_U$ and $(\underline{x}, h) \in G$,

$$\rho_U(\underline{x}, h)g(\underline{y}) = \delta(h)^{-1/2}g(h^{-1}(\underline{y} - \underline{x})), \qquad \text{for all } \underline{y} \in \mathbf{R}^n,$$

where $\delta(h) = |\det h|$, for $h \in H$. Then ρ_U is an irreducible square-integrable representation of G, and we present an elementary proof of the Duflo-Moore orthogonality relations which makes the form of the formal dimension operator very explicit for ρ_U. A discrete version of the reproducing formula is developed to give a frame for $\mathcal{H}^2_U$ whose elements are all translations, of a single admissible g in $\mathcal{H}^2_U$, under the action of ρ_U.

A. VALETTE:

Group cohomology, ends and harmonic functions

(joint work with M.E.B. Bekka)
For an infinite finitely generated group Γ, we study the meaning of the vanishing of the first cohomology group $H^1(\Gamma, \lambda_\Gamma)$ of Γ taking value in its left regular representation λ_Γ.
We first show that $H^1(\Gamma, \mathbf{C}\Gamma)$ injects into $H^1(\Gamma, \lambda_\Gamma)$; the dimension of $H^1(\Gamma, \mathbf{C}\Gamma)$ is -1 plus the number of ends of Γ; as a consequence, if $H^1(\Gamma, \lambda_\Gamma) = 0$, then Γ is not amenable with just one end (the converse is false, as surface groups indicate).
Let X be any Cayley graph of Γ. If Γ is not amenable, we show that $H^1(\Gamma, \lambda_\Gamma)$ is isomorphic to $HD(X)/\mathbf{C}$, where $HD(X)$ is the space of harmonic functions with finite Dirichlet sum on X; the latter space is itself isomorphic to the space of passive electric currents on the set E of edges of X, i.e. the space $H^1EL^2(\Gamma)$ of harmonic 1-cochains which are exact (this is exactly the first L^2-cohomology of Γ, according to Cheeger-Gromov). Here is a sample of corollaries of these isomorphisms (proofs appeal to results of Paschke, Soardi, Thomassen):
(1) (Gromov, Soardi-Woess) If Γ has infinitely many ends, then $HD(X) = \mathbf{C}$.
(2) If Γ has property (T), then $HD(X) = \mathbf{C}$.
(3) The property $H^1(\Gamma, \lambda_\Gamma) = 0$ is invariant under quasi-isometry.
(4) Let $\Gamma = \Gamma_1 \times \Gamma_2$, with Γ_1 non-amenable, Γ_2 infinite, then $H^1(\Gamma, \lambda_\Gamma) = 0$.
(5) Either $H^1(\Gamma, \lambda_\Gamma) = 0$ or $H^1(\Gamma, \lambda_\Gamma)$ is infinite-dimensional.

V.S. VARADARAJAN:

On the transverse symbol of a distribution and applications to harmonic analysis

(joint work with J.A.C. Kolk)
Let X be a smooth manifold and $O \subset X$ a closed submanifold. Let $M^{(r)}$ be the r-th graded part of the transverse jet bundle on O. If E is a Fréchet space, then, to any E-distribution on X supported by O and of transversal order $\leq r$ everywhere on O,

we can associate an $M^{(r)'}(\cdot)$ E-distribution living on O, denoted by $\sigma^{(r)}(T)$. This is the transverse symbol of T. It is uniquely determined by T and its local specification. The map $T \mapsto \sigma^{(r)}(T)$ is injective modulo E-distributions supported by O of transversal order $\leq r-1$. If T is invariant under a Lie group H of diffeomorphisms of X leaving O invariant, $\sigma^{(r)}(T)$ is also H-invariant.
The correspondence $T \mapsto \sigma(T)$ $(= \sigma^{(r)}(T))$ can be used to give a briefer treatment of the irreducibility of parabolically induced representations of connected semisimple Lie groups with finite center, than the treatment of Bruhat (minimal parabolic) and Harish-Chandra (any parabolic). It can also be used to give a transparent proof of the fundamental vanishing theorem of Harish-Chandra in his theory of Whittaker functions on semisimple Lie groups and their spectral analysis.

H. YAMASHITA:

Differential operators of gradient-type and representations of semisimple Lie groups

Let G be a connected semisimple Lie group with finite center, and K be a maximal compact subgroup of G. The complexified Lie algebras of G and K are denoted by $\mathfrak{g}$ and $\mathfrak{k}$, respectively. We assume the Harish-Chandra rank condition $\mathrm{rank}(G) = \mathrm{rank}(K)$.

I describe the associated varieties and Gelfand-Kirillov dimensions of discrete series $(\mathfrak{g}, K)$-modules, by an elementary and direct method using the gradient-type differential operator $D_\lambda : \Gamma^\infty(G \times_K V_\lambda) \to \Gamma^\infty(G \times_K V_\lambda^-)$. Here, V_λ is the lowest K-type of the discrete series in question. The descriptions are as follows:
Theorem 1: If H_Λ is the $(\mathfrak{g}, K)$-module of the discrete series with Harish-Chandra parameter $\Lambda = \lambda + \rho_c - \rho_n$, its associated variety $\mathcal{V}(H_\Lambda) \subseteq \mathfrak{g}$ coincides with the nilpotent cone $\mathrm{Ad}(K)\mathfrak{p}_-$. Here, $\mathfrak{p}_- = \sum_{\beta \in \Delta_n^-} \mathfrak{g}_\beta$ is the sum of root spaces $\mathfrak{g}_\beta$ of $\mathfrak{g}$ corresponding to the non-compact roots β such that $(\Lambda, \beta) < 0$.
Theorem 2: (i) There exists a unique nilpotent K_C-orbit $O_{\mathfrak{p}_-}$ in $\mathfrak{p}$ such that $\mathcal{V}(H_\Lambda) = \overline{O_{\mathfrak{p}_-}}$. Here $K_C \subseteq \mathrm{Int}(\mathfrak{g})$ is the analytic subgroup of $\mathrm{Int}(\mathfrak{g})$ with Lie algebra $\mathfrak{k}$.
(ii) The orbit $O_{\mathfrak{p}}$ can be specified explicitly for $G = SU(p,q)$ and $Sp(n, \mathbf{R})$. This allows us to give explicit formulae for the Gelfand-Kirillov dimensions of discrete series.
Some related results are also presented.

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