MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Linear Problems in Analysis

20.08.–26.08.1995

24 mathematicians from 10 different countries have participated in this conference, which has been organized by

R. Meise (Düsseldorf)

B.A. Taylor (Ann Arbor)

D. Vogt (Wuppertal).

To the organizers as well as to the participants opinion this conference has been extremely successfull. The 20 talks in which excellent recent research results were exhibited have been throughout of an unusual high scientific level and of a very good quality of presentation. Main topics were:

- Problems of surjectivity and existence of continuous right inverses for partial differential operators, systems of partial differential equations and convolution operators with various regularity conditions.
- Linear and geometrical aspects of the theory of analytic functions.
- Classical structure theory of Fréchet and (LF)-spaces and their operators.

Due to the restricted number of talks there was enough time for critical and fruitful discussions, which was appreciated by the participants and led to further research progress. Moreover, the pleasant atmosphere of the Oberwolfach institute contributed a lot to the success of the conference.

VORTRAGSAUSZÜGE

A. AYTUNA:

Common (Extendible) bases for some pairs of analytic function spaces

Let M be a Stein manifold and $K \subset M$ a compact subset of M. A common basis for $\{\mathcal{O}(M); \mathcal{O}(K)\}$ is a basis $\{e_n\}$ of the Fréchet space $\mathcal{O}(M)$ such that the germs of these vectors $\{e_n\}$ on K also forms a basis for $\mathcal{O}(K)$ with the usual inductive limit topology. In this talk we will discuss the cases

(i) M is a hyperconvex Stein manifold and K is a regular holomorphically convex compact subset of M.

(ii) M is a hyperconvex Stein manifold and K is a polar compactum in M given by a global maximal function (i.e. $K = \{z : \overline{\varphi}(z) = -\infty\}$ where $\overline{\varphi} < 0$ is a proper maximal plurisubharmonic (off K) function on M s.t. $e^{\overline{\varphi}}$ is continuous on M).

(iii) M is parabolic (i.e. there exists a maximal off a compact set plurisubharmonic exhaustion function) and K is a regular compactum.

In all these cases one has common bases and these bases are also bases for the spaces of analytic functions defined on the sublevel sets of a plurisubharmonic function naturally associated to the pair $(M; K)$.

J. BONET:

The range of non-surjective convolution operators on non-quasianalytic classes

The lecture is based on joint work with A. Galbis (Valencia).

Let $\mu \neq 0$ be an ultradistribution of Beurling type with compact support in the space $\mathcal{E}'_\omega(\mathbb{R}^N)$. We investigate the range of the convolution operator T_μ on the space of non-quasianalytic functions of Beurling type $\mathcal{E}_\omega(\mathbb{R}^N)$ associated with a weight ω; in the case the operator is not surjective. It is proved that the range of T_μ always contains the space of real-analytic functions, and that it contains a smaller space of Beurling type $\mathcal{E}_\sigma(\mathbb{R}^N)$ for a weight $\sigma \geq \omega$ if and only if the convolution operator is surjective in the smaller class. A characterization of the pairs of weights $\sigma \geq \omega$ such that every $\mu \in \mathcal{E}'_\omega(\mathbb{R})$, $\mu \neq 0$, with support equal to $\{0\}$ satisfies $\mathcal{E}_\sigma(\mathbb{R}) \subset T_\mu \mathcal{E}_\omega(\mathbb{R})$ is also presented.

A. DEFANT:

Extension and splitting theorems for Fréchet spaces with type and cotype

Maurey's extension theorem states that each (linear and continuous) operator $T : G \to F$ defined on a subspace G of a Banach space E with values in a Banach space F extends to the whole space E whenever E has type 2 and F has cotype 2. We discuss two different types of natural generalizations for operators on Fréchet spaces, and apply them to Grothendieck's problem of topologies and Vogt's theory of splitting short exact sequences. Techniques from local Banach space theory and interpolation theory are combined with some important topological invariants in Fréchet spaces as the density condition and the properties (DN) and (Ω) (joint work with P. Domański, A. Peris, and M. Mastylo).

S. DIEROLF:

Quasiregular LF-spaces

(joint work with J.C. Diaz).

An inductive sequence $(E_n)_{n\in\mathbb{N}}$ of lcs is called quasiregular if the natural map $E'_\beta \to \operatorname{proj} E'_{n,\beta}$ is topological, or – equivalently – if for every bounded set B in $E := \operatorname{ind} E_n$ there is $n \in \mathbb{N}$ and a bounded set A in E_n such that $B \subset \overline{A}^E$. Generalizing a result of Vogt, we prove:

Given a weakly acyclic LF-space $E := \operatorname{ind} E_n$, then

i) for every bounded and separable subset $B \subset E$ there is n and $A \subset E_n$ bounded such that $B \subset \overline{A}^E$;

ii) if for all $n \in \mathbb{N}$, E_n is either distinguished or weakly sequentially complete, then $\operatorname{ind} E_n$ is quasiregular.

Furthermore we present an example of a weakly acyclic LF-space which is not quasiregular.

P. DOMAŃSKI:

There is an exact complex over $C^\infty(\Omega)$ which does not split at dimension 1

An exact complex (Ω open subset of $\mathbb{R}^m$, T_n linear continuous operators)

$$(*) \qquad 0 \to \ker T_0 \to C^\infty(\Omega) \xrightarrow{T_0} C^\infty(\Omega) \xrightarrow{T_1} C^\infty(\Omega) \xrightarrow{T_2} C^\infty(\Omega) \to \cdots$$

is called graded exact if, roughly speaking, it is a "projective limit" of analogous exact complexes for Ω_n instead of Ω, where (Ω_n) is an increasing relatively compact exhaustion of Ω. The complex (*) splits at dimension k if $T_k : C^\infty(\Omega) \to \operatorname{im} T_k$ has a right linear and continuous inverse.

To each linear differential operator $T_0 = P_0(D)$ with constant coefficients one associates a complex (*) which is exact for suitable Ω (in fact, the complex is differential, i.e., T_k are all differential operators). It has been proved by D. Vogt and the author that differential (convolution) exact complexes (*) are automatically graded exact, moreover, graded exact complexes (*) splits at dimension $k = 2, 3, \ldots$ while in the differential or convolution case also at dimension $k = 1$.

The aim of this talk, based on a joint work with D. Vogt, is to show that the above result is optimal, i.e., there exists a graded exact complex (*) non-splitting at dimension $k = 1$.

U. FRANKEN:

Extension of zero-solutions of linear partial differential operators defined on convex sets

(Joint work with R. Meise).

Let $K \subset \mathbb{R}^n$ be a compact, convex set with $\mathring{K} \neq \emptyset$ and let $P \in \mathbb{C}[z_1, \ldots, z_n]$ be non-constant. By $\mathcal{E}_P(K)$ resp. $\mathcal{D}'_P(K)$ denote the subspace of all zero-solutions of $P(D)$ in the space of all C^∞-functions resp. distributions on K. Consider the restriction maps $\rho_K : \mathcal{E}_P(\mathbb{R}^n) \to \mathcal{E}_P(K)$, $f \mapsto f|_K$ and $\rho'_K : \mathcal{D}'_P(\mathbb{R}^n) \to \mathcal{D}'_P(K)$, $\mu \mapsto \mu|_K$. It is shown that the surjectivity of ρ_K and ρ'_K can be characterized by Phragmén-Lindelöf principles holding on the variety $V(P)$ of P. From this we obtain equivalence of the surjectivity of ρ_K, ρ'_K and local restriction maps $\rho_{K,x}$, where x is a boundary point of K.

L. FRERICK:

A splitting theorem for nuclear Fréchet spaces

For nuclear Fréchet spaces E and F we characterize $\mathrm{Ext}^1(E,F) = 0$ by a "computable" condition. More precisely: Let both spaces be written as reduced projective limits $E = \mathrm{proj}_{\leftarrow N}(E_N, \|\ \|_N)$, $F = \mathrm{proj}_{\leftarrow n}(F_n, \|\ \|_n)$ of sequences of Banach spaces. Then every short exact sequence

$$0 \longrightarrow F \longrightarrow G \longrightarrow E \longrightarrow 0$$

splits if and only if the pair (E,F) satisfies Vogt's condition (S_2^*), i.e.

$$\forall n \quad \exists m > n, N \quad \forall k > m, M > N \quad \exists S > 0, K > M \quad \forall x \in E_K, y \in F'_m$$

$$\|x\|_M \|y\|_m^* \leq S(\|x\|_K \|y\|_k^* + \|x\|_N \|y\|_n^*).$$

C. KISELMAN:

Lineal convexity, a kind of convexity in complex analysis between pseudoconvexity and usual convexity

In contrast to pseudoconvexity and usual convexity, lineal convexity is not a local property: it may happen that a set possesses the property in a neighborhood of every point but not globally. The sets exhibiting this behaviour do not have a smooth boundary. In the smooth case it is not known whether the property can be characterized by differential conditions. We shall prove that the answer is in the affirmative in the special case of Hartogs domains with boundary of class C^2 in two variables.

H. KOMATSU:

Solution of Differential Equations by Means of Laplace Hyperfunctions

Employing the theory of Laplace hyperfunctions, we show how to compute the solutions to the initial value problems of linear ordinary differential equation with constant coefficients and Bessel's equation, and the fundamental solutions to Laplace's equation, Helmholtz's equation, the wave equation and the heat equation.

M. LANGENBRUCH:

Surjective partial differential operators on ultradifferentiable functions of Roumieu type

For an open set $\Omega \subset \mathbb{R}^n$ let $\mathcal{E}_{\{\omega\}}(\Omega)$ be the space of $\{\omega\}$-ultra-differentiable functions of Roumieu type. Let $P(D)$ be a partial differential operator with constant coefficients. It is proved that $P(D)$ is surjective in $\mathcal{E}_{\{\omega\}}(\Omega)$ if and only if (roughly) $P(D)$ has (shifted) elementary solutions on Ω with large holes in the $\mathcal{E}_{\{\omega\}}$-singular support. Using an appropriate result on extension of $\mathcal{E}_{\{\omega\}}$-regularity this implies a strong relation of the surjectivity of $P(D)$ in $\mathcal{E}_{\{\omega\}}(\Omega)$ and $\{\omega\}$-hybrid type operators. As an easy consequence, for semielliptic operators $P(D)$ we can give an explicit characterization of the weights ω and the open sets Ω such that $P(D)$ is surjective on $\mathcal{E}_{\{\omega\}}(\Omega)$.

S. MOMM:

Partial differential equations for analytic functions on locally closed convex subsets of $\mathbb{C}^N$

Let $Q = \mathring{Q} \cup \omega \subset \mathbb{C}^N$ be convex, bounded with $\mathring{Q} \neq \emptyset$, where $\omega \subset \partial Q$ is open. If Q is strictly convex at $\partial_r\omega$, all nonzero partial differential operators $P(D) : A(Q) \to A(Q)$, $P(D)f := \sum_{\alpha\in\mathbb{N}_0^N} a_\alpha f^{(\alpha)}$ on the analytic functions $A(Q)$ are surjective. If Q is in addition sufficiently smooth near $\partial_r\omega$, we characterize those Q for which each $P(D) : A(Q) \to A(Q)$ admits a continuous linear right inverse $R : A(Q) \to A(Q)$ by means of the boundary behaviour of two extremal plurisubharmonic functions associated to $\mathring{Q}$ and $\overline{Q}$, respectively. (This is joint work with S.N. Melikhow.)

M. NACINOVICH:

Generalized Cauchy problems for overdetermined systems

Let

$$(*) \qquad 0 \longrightarrow C^\infty(X, E^0) \xrightarrow{A_0} C^\infty(X, E^1) \xrightarrow{A_1} \dots \xrightarrow{A_n} C^\infty(X, E^n) \longrightarrow \dots$$

be a complex of l.p.d.o.'s acting on smooth vector bundles over a paracompact real differentiable manifold X. Given an "allowable" assignment $\mathcal{F}$ of closed subsets of X, parametrized by $\xi \in S^d$, we set $F = \bigcap_\xi F_\xi$, $\check{F} = \bigcup_\xi F_\xi$. Then we obtain a generalized Mayer-Vietoris exact sequence for the Whitney cohomology:

$$\dots H_A^m(\check{F}) \longrightarrow H_\Delta^m(\mathcal{T}(\mathcal{F})) \longrightarrow H_A^{m-d}(F) \longrightarrow H_A^{m+1}(\check{F}) \longrightarrow \dots$$

The term $H_\Delta^m(\mathcal{T}(\mathcal{F}))$ can be interpreted either as the total cohomology of the double complex obtained from $(*)$ and the coboundary operator associated to a proper convex cell decomposition of S^d, or from $(*)$ and d_ξ on S^d, on the closed subset $\widetilde{X} = \{(x,\xi) \in X \times S^d \mid x \in F_\xi\}$.

This general framework is useful to investigate the Whitney cohomology of $(d+1)$-codimensional closed submanifolds of X. In this way we reprove or give complete proofs of results about the validity and non-validity of the Poincaré-Lemma, wedge decomposition, wedge extendability, and edge of the wedge type theorems for CR cohomology classes, functions and forms in the case of locally embeddable CR manifolds.

V. PALAMODOV:

Quaternionic Cauchy-Riemann system, removable singularities of solutions

An quaternionic analogue of the Cauchy-Riemann system of differential equations for functions of several quaternionic variables is considered. Solutions of the homogeneous QSD-system could be called "holomorphic" functions of quaternionic variables but really have quite different properties. Some facts and problems concerning a structure and Hartog's type property for the solutions of the QSD-system will be talked.

M. POPPENBERG:

The inverse function theorem in some classes of Fréchet spaces

Classical inverse function theorems of so called Nash-Moser type are proved for Fréchet spaces that admit a family of smoothing operators. In this lecture two inverse function theorems of Nash-Moser type are stated for more general classes of Fréchet spaces; this generalizes a result of S. Lojasiewicz and E. Zehnder.
As a first result an inverse function theorem is proved for Fréchet spaces that admit certain generalized smoothing operators; for instance, this applies to any Köthe sequence space which satisfies property (Ω) in standard form in the sense of D. Vogt and M.J. Wagner and the topological condition (DN) of D. Vogt.
As a second result a smoothing property called $(S_\Omega)_t$ is introduced and an inverse function theorem is proved for Fréchet spaces that have to satisfy properties $(S_\Omega)_t$ and (DN); for Fréchet-Hilbert spaces property (Ω) in standard form is sufficient for $(S_\Omega)_t$. This inverse function theorem can be applied to the spaces $C^\infty(\overline{\Omega})$ provided the bounded open set $\Omega \subset \mathbb{R}^n$ satisfies a generalized cone condition in the sense of M. Tidten or if Ω is subanalytic in the sense of E. Bierstone; different from the classical case singularities of the boundary of Ω like cusps are allowed. In the latter case partial differential operators on $C^\infty(\overline{\Omega})$ do in general not satisfy the required formal estimates of the classical inverse function theorem. Therefore, the above result is proved under the assumption of more general 'non-interpolated' estimates which are fulfilled by partial differential operators on $C^\infty(\overline{\Omega})$ and their derivatives also if the boundary of Ω has singularities.

M.S. RAMANUJAN:

Semi-Fredholm, Mercerian and Tauberian operators in Fréchet spaces

(Joint work with J. Bonet).
We initiate, in the framework of Fréchet spaces, a study of class of operators (called Mercerian operators) and in the Banach space set up these are equivalent to the semi-Fredholm operators. For Fréchet spaces E, F a map $T \in L(E, F)$ is said to be Mercerian if for a bounded set B in E, $T(B)$ relatively compact in F implies B is already relatively

compact in E. Retaining the definition of semi-Fredholm operator T as one with $R(T)$ closed and $\dim N(T) < \infty$ we see that the implication T semi-Fredholm $\Rightarrow T$ Mercerian is non-reversible. We obtain several characterizations and properties of Mercerian operators (including perturbation results). A linear partial differential operator with constant coefficients which is surjective between the local spaces of Hörmander is Mercerian if and only if it is hypoelliptic. We also study characterizations and some properties of Tauberian operators $T \in L(E,F)$ which are those such that for bounded set B, $T(B)$ is relatively (weakly) compact in F implies B is relatively weakly compact in E. Clearly T is Mercerian $\Rightarrow T$ is Tauberian (and the above example related to partial differential operators gives the falcity of the reverse implication); however every Tauberian operator defined on a Köthe echelon space of order 1 it is also Mercerian. We provide also two 'Tauberian' theorems of the type: If $0 \neq T$ is Tauberian, (x_n) is a bounded basic sequence in E and $(T(x_n))$ is a shrinking (resp. boundedly complete) basic sequence in F then (x_n) is also shrinking (resp. boundedly complete).

J. SCHMETS:

The Borel theorem in real Banach spaces

Given a sequence $(r_m)_{m \in \mathbb{N}_0}$ of real numbers, the usual Borel theorem states that the existence of a function $f \in C_\infty(\mathbb{R})$ such that $f^{(m)}(0) = r_m$ for every $m \in \mathbb{N}_0$. There is a sharper form stating that f is also real-analytic on $\mathbb{R} \setminus \{0\}$.
The extension of the usual statement to real Banach spaces is well known. An extension of the sharper form will be presented.
Note: the material of the talk comes from a joint research with M. Valdivia (U. of Valencia/Spain).

K. SEIP:

A Hilbert space of Dirichlet series and systems of dilated functions in $L^2(0,1)$

(Joint work with Håkan Hedenmalm and Peter Lindquist).
We consider the space $\mathcal{H} := \{f(s) = \sum_{n=1}^\infty a_n n^{-s} : \sum |a_n|^2 < \infty\}$ endowed with the natural inner product $< f,g > := \sum_{n=1}^\infty a_n \overline{b_n}$ if $f(s) = \sum_{n=1}^\infty a_n n^{-s}$, $g(s) = \sum_{n=1}^\infty b_n n^{-s}$. $\mathcal{H}$ is a Hilbert space of analytic functions in $\mathrm{Re}(s) > \frac{1}{2}$, and we seek to reveal its basic analytic properties. Our study of $\mathcal{H}$ is partly motivated by the following problem of Beurling: For which $\varphi \in L^2(0,1)$ (φ considered as an odd periodic function of period 2) is the system $\{\varphi(nx)\}_{n=1}^\infty$ complete/a Riesz basis in $L^2(0,1)$? The Riesz basis problem has a simple solution: $\varphi(x) = \sum_{n=1}^\infty a_n \sin \pi n x$ generates a Riesz basis if and only if $\sum_{n=1}^\infty a_n n^{-s}$ and its reciprocal are multipliers on $\mathcal{H}$. A main result is: The multipliers on $\mathcal{H}$ consist of those bounded analytic functions in $\mathrm{Re}(s) > 0$ which can be represented by Dirichlet series. Several function theoretic results are proved. An illuminating and useful point is that $\mathcal{H}$ can be regarded as $H^2(D^\infty)$, D^∞ the infinite dimensional polydisk.

J. WENGENROTH:

Acyclic inductive spectra of Fréchet spaces

We recall Palamodov's definition of acyclic and weakly acyclic inductive spectra of Fréchet spaces and show the connection to the subspace problem in (LF)-spaces (i.e. which subspaces of an (LF)-space are again (LF)-spaces) which appears in a canonical way if one is concerned with the problem whether some (differential or convolution) operator on a space of distributions is surjective.
It is shown that sequentially retractive (LF)-spaces (i.e. (LF)-spaces where each null sequence already converges to 0 in some step) are acyclic (and vice versa).
Moreover, for the important special case where the steps are Fréchet-Montel, we prove that all regularity conditions for (LF)-spaces considered in the literature coincide; in particular Grothendieck's question whether regular (LF)-spaces are complete has a positive solution for this case of Montel steps.
Finally, we point out how Vogt's condition (wQ) which is easiest one for calculations in concrete applications, enters the picture via Bierstedt's notion of boundedly stable spectra.

A. ZERIAHI:

Pluricomplex Green functions with weighted multiple poles and applications to approximation

Let D be a hyperconvex manifold of dimension n, i.e. D is a complex analytic manifold which admits a bounded plurisubharmonic exhaustion $\rho : D \to [-\infty, +\infty)$. Suppose there is given a potential function $\varphi : D \to [-\infty, +\infty)$ plurisubharmonic on D such the set of poles of φ is a compact set K and the set $A_\varphi := \{a \in D; \nu(\varphi; a) > 0\}$ is a dense subset of K. Here the number $\nu(\varphi; a)$ can be defined by the formula : $\nu(\varphi; a) = \lim_{r\to 0} \frac{\sup_{|z|=r}\varphi(z)}{\log r}$ where z is some local holomorphic coordinate at the point a. Then we can define a weighted Green function associated to the potential function φ by the formula: $G_D(z;\varphi) := \sup\{u(z); u \in P_0(D,\varphi)\}$ where $P_0(D,\varphi)$ denotes the class of plurisubharmonic functions u on D such that $u \leq 0$ on D and $\nu(u;.) \geq \nu(\varphi;.)$ on D. This is a generalization of the Green function with logarithmic isolated singularities considered earlier by Demailly (1987), Klimek (1985), Lempert (1983), Lelong (1989) and Zahariuta (1985). Our Green function may have infinite number of singularities and poles. It is in some cases a multidimensional counterpart of the classical Evans potential. We first prove that the weighted Green function solves uniquely a "Weighted Dirichlet problem" for the complex Monge-Ampère equation on the hyperconvex manifold.
We then construct using this Green function an orthonormal basis in a suitable weighted Bergman space and prove that this gives a common Schauder basis in all spaces $\mathcal{O}(D_\rho)$, where $D_\rho := \{z \in D; G_D(z;\varphi) < \log\rho\}$, $0 < \rho \leq 1$.
In some special cases we have $K = \bigcap_{0<\rho<1} D_\rho$ and then we obtain a partial answer to an open problem in the theory of spaces of analytic functions posed earlier by Zahariuta and solved in one complex variable by Kadampata and Zahariuta (1980). Our theorem contains the theorem of Kadampata and Zahariuta.

V. ZAHARIUTA:

Linear topological invariants

(joint with P. Chalov and P. Djakov).
The complete isomorphic classification and quasiequivalence property (uniqueness of unconditional basis) are obtained for finite families of c_0- or l_1-weighted spaces by using of some new geometrical invariants.
The complete isomorphic classification on the class of all cartesian products $E_0(a) \times E_\infty(b)$ is proved by a pure invariant way. The previous our results (with Djakov, and Djakov and Jurdakul) were performed only partially in an invariant way, because in the case when both of Cartesian factors are not shift stable we used an old result (Studia Math. 1973), based on Riesz theory. Two-rectangle invariants (look in the issue: Linear Topological Spaces and Complex Analysis 1 (1994), METU-TÜBITAK, Ankara, pages 155-156) proved to be sufficient to distinguish all non-isomorphic spaces of the above class considered as a subclass of the class $\mathcal{E}$ of all power Köthe spaces of the first kind.
It is shown also that any m-rectangle invariant is essentially weaker than $(m+1)$-rectangle invariant on the class $\mathcal{E}$.

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