MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 11/1991

Partielle Differentialgleichungen

3.3. bis 9.3.1991

Tagungsleiter: Jochen Brüning, Lars Hörmander, Wolf von Wahl

Das ursprüngliche Konzept der Tagung sah vor, ein Informationsforum für die deutschen Arbeitsgruppen auf dem Gebiet der partiellen Differentialgleichungen zu schaffen und gleichzeitig jüngeren Mathematikern die Gelegenheit zu geben, sich durch Vorträge zu profilieren. Dementsprechend sollten an den Vormittagen überwiegend einstündige Übersichtsvorträge stattfinden, die thematisch in vier oder fünf Gruppen gegliedert sein sollten. Die ursprüngliche Planung sah die folgenden Gebiete vor:

1. Semiklassische Asymptotik, insbesondere Quantenchaos;
2. Methoden der gewöhnlichen Differentialgleichungen, die für die Partiellen Differentialgleichungen von Bedeutung sind (Limesmengen, Methoden der symplektischen Geometrie);
3. Freie Randwertprobleme (Kristallwachstum);
4. Stabilität der Materie (als spektraltheoretisches Problem);
5. Mathematische Ergebnisse in der Theorie der flüssigen Kristalle.

Aufgrund teilweise sehr kurzfristiger Absagen brach diese Programmkonstruktion bis auf den Punkt 2 (Hofer, Vishik) zusammen. Nichtsdestoweniger ermöglichten die zahlreichen Zusagen von renommierten Fachkollegen ein abwechslungsreiches und anregendes Programm auch für die Vormittage. In den Nachmittagsvorträgen kamen, der ursprünglichen Planung entsprechend, in der Mehrzahl jüngere Mathematiker zu Wort; die große Zahl von Zusagen machte es allerdings notwendig, die Zahl der Vorträge hoch anzusetzen. Trotzdem waren die meisten Teilnehmer sich darin einig, daß sie auf dieser Tagung wichtige Informationen und Anregungen erhalten haben. Man sollte trotzdem das ursprüngliche Konzept bei einer späteren Gelegenheit - selbstverständlich der aktuellen Entwicklung angepaßt - zu verwirklichen versuchen.

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Vortragsauszüge

Rotational stationary solutions of inviscid incompressible fluid flow

Hans-Dieter Alber (Darmstadt)

In the talk steady flow of an inviscid, incompressible medium through a bounded domain $\Omega \subset \mathbb{R}^3$ is discussed. This flow is governed by the equations

$$\begin{array}{lll} (1) & \left.\begin{array}{l}(v \cdot \nabla)v + \nabla p = 0 \\ \operatorname{div} v = 0\end{array}\right\} & \text{in } \Omega \\ (2) & & \\ (3) & n \cdot v = f \quad \text{on} \quad \partial\Omega, \int\limits_{\partial\Omega} f(x) dS(x) = 0 . & \end{array}$$

It is well known that an irrotational solution (v_0, p_0) of this problem exists, but it is much less obvious whether solutions with nonvanishing vorticity exist. The following result ist presented: If $v_0(x) \neq 0$ for all $x \in \bar{\Omega}$ and if some other technical assumptions are satisfied, then there exists a neighbourhood of (v_0, p_0) and a flow (v, p) in this neighbourhood with nonvanishing vorticity, which satisfies (1)-(3) and the additional boundary conditions

$$\left.\begin{array}{llll} (4) & n(x) \cdot \operatorname{curl} v(x) & = & h(x) + (n(x) \cdot \operatorname{curl} v_0(x)) \\ (5) & \frac{1}{2}|v(x)|^2 + p(x) & = & g(x) + (\frac{1}{2}|v_0(x)|^2 + p_0(x)) , \end{array}\right\} \quad x \in \partial\Omega_-(f) ,$$

where $\partial\Omega_-(f) = \{x \in \partial\Omega | f(x) < 0\}$ is the part of the boundary through which liquid is entering the domain. g, h must be sufficiently small. Essentially, (4) and (5) prescribe the vorticity of the flow on $\partial\Omega_-(f)$.

Highly degenerate parabolic systems

Herbert Amann (Zürich)

We discuss the well-posedness of a system of differential equations describing diffusion processes in polymers. This system is of a rather unusual type in the sense that it can be considered to be a uniformly degenerate parabolic equation coupled with an ordinary differential equation. It is shown that it can be considered to be a concrete realization of an abstract parabolic evolution equation. However, it does not exhibit any regularizing effect which makes it difficult to apply "classical" techniques of partial differential equations.

A stability result for the Vlasov-Poisson system

Jürgen Batt (München)

It is proven that in a neutral two-component plasma with space homogeneous positively charged background, which is governed by the Vlasov-Poisson system and for which Poisson's equation is considered on a cube in $\mathbb{R}^3$ with periodic boundary conditions, the space homogeneous stationary solutions g with energy gradient $\frac{\partial g}{\partial \epsilon} \leq 0$ and compact support are (nonlinearly) stable in the L^1-Norm with respect to weak solutions of the initial value problem. (joint work with G. Rein, München; to appear in: Annali di Mathematica Pura ed Applicata).

Nonlinear microlocal analysis and 2d fluid mechanics

Jean-Yves Chemin (Palaiseau)

In this talk, we study the regularity for large time of a solution of the following well-known imcompressible Euler system in two space dimension.

$$(E)\quad \begin{aligned} &\partial_t v + v \cdot \nabla v = -\nabla p \\ &\operatorname{div} v = 0 \\ &v_{|t=0} = v_0 \end{aligned}$$

where p is the preasure and $v \cdot \nabla v = \sum_i v^i \partial_i$.

The key quantity in this problem is the vorticity $\omega = \partial_1 v^2 - \partial_2 v^1$. The basic fact in the two space dimension case is that $\partial_t \omega + v \cdot \nabla \omega = 0$.

In this talk, we want to study the vortex patches problem, which is the following: let us suppose that the initial data has a vorticity which is the characteristic function of a regular bounded domain. It is well-known that there is a global solution of (E) which is in the space $L^\infty(\mathbb{R}, C^1_*(\mathbb{R}^2))$ where $C^1_*(\mathbb{R}^2)$ is Zygmund's class of bounded functions such that $|u(x+y)+u(x-y)-2u(x)| \leq C|y|$. Then, the vorticity remains, for all time, the characteristic function of a bounded domain. With Green's formula, it is easy to see that this problem is equivalent to solve the following equation

$$(B)\quad \partial_t x(t,s) = \frac{1}{2\pi} \int_{[0,2\pi]} Log|x(t,s) - x(t,\sigma)| \partial_\sigma x(t,\sigma) d\sigma\,.$$

The two questions are:

- does the boundary of the domain remain regular for small time?
- if yes, what happens for big time?

Some years ago, A. Majda announced a proof for a positive answer to the first question and, according to some numerical evidences, conjectured that the answer to the second question was no. Moreover, S. Alinhac proved some instability results for an approximation of equation (B).

In this talk, we are going to explain how Nonlinear Microlocal Analysis allows to prove that equation (B) has a global solution which is $x \in C^\infty(\mathbb{R}, C^{k+\epsilon-0}(S^1, \mathbb{R}^2)) \cap L^\infty_{loc}(\mathbb{R}, C^{k+\epsilon}(S^1, \mathbb{R}^2))$ if the boundary of the domain is $C^{k+\epsilon}$ at time 0. The key point is the use of the non smooth striated structure related to the boundary of the domain for a global control of the Lipschitz norm of the vector field solution of (E). In fact, the actually proved theorem is much more general and can be stated in term of conormal space associated with non smooth hypersurface. From this point of view, the fact that ω is exactly 1 inside the domain and exactly 0 outside has no importance at all.

Existence of vortex sheets for Euler's equation in $\mathbb{R}^2$

Jean-Marc Delort (Orsay)

This talk is devoted to the proof of a global existence theorem for the problem of vortex sheets with distinguished sign on $\mathbb{R}^2$. Let ω_0 be a positive (or negative) measure with compact support on $\mathbb{R}^2$, belonging to the Sobolev space $H^{-1}(\mathbb{R}^2)$ (e.g. $\omega_0 = \delta_\Sigma$ with Σ smooth compact curve). Let v_0 be the vector ${}^t(-\partial_2\Delta^{-1}\omega_0, \partial_1\Delta^{-1}\omega_0)$, with $\partial_j = \frac{\partial}{\partial x_j}, j = 1,2$. Then, there is a couple (v,γ) with v (resp. γ) locally bounded function of time with values in L^2_{loc} functions from $\mathbb{R}^2$ to $\mathbb{R}^2$ (resp. $\mathcal{S}'(\mathbb{R}^2)$) satisfying Euler's equation

$$\frac{\partial v}{\partial t} + \operatorname{div}(v \otimes v) = -\nabla\gamma$$

$$\operatorname{div} v = 0$$

$$v_{|t=0} = v_0$$

where $v \otimes v = (v_i v_j)_{1\leq i,j\leq 2}$ and $\operatorname{div}(v \otimes v)$ means the divergence of every line of the matrix $v \otimes v$.

The Stokes system in exterior domains: A negative result on C^0- regularity

Paul Deuring (Darmstadt)

Let Ω be a bounded domain in $\mathbb{R}^3$, with smooth boundary. Let $\alpha \in (0,1)$. Set

$$(C^\alpha_*)^3 := \{f \in C^\alpha(\mathbb{R}^3 \setminus \Omega)^3 : |f_{|\mathbb{R}^3\setminus B_n}|_\alpha \to 0\,(n \to \infty)\},$$

where B_n denotes a ball in $\mathbb{R}^3$, of radius n and centre 0. Set

$$(C^{2,\alpha}_*)^3 := \{u \in C^2(\mathbb{R}^3 \setminus \Omega)^3 : D^a u \in (C^\alpha_*)^3 \text{for } a \in \mathbb{N}^3_0 \text{with } a_1 + a_2 + a_3 \leq 2\},$$
$$C^\alpha := \{g \in C^1(\mathbb{R}^3 \setminus \Omega) : \nabla g \in (C^\alpha_*)^3\}.$$

Then consider the Stokes-system in the exterior domain $\mathbb{R}^3 \setminus \bar{\Omega}$, under Dirichlet boundary conditions:

(1) $-\Delta u + \lambda u + \nabla\pi = f, \operatorname{div} u = 0 \text{ in } \mathbb{R}^3 \setminus \Omega, u_{|\partial\Omega} = 0.$

Assume $\lambda \in \mathbb{C}\setminus]-\infty,0], f \in (C^\alpha_*)^3$. In this situation, it is natural to look for a solution (u,π) with $u \in (C^{2,\alpha}_*)^3, \pi \in C^\alpha$. If such a solution exists, then u is uniquely determined, and π is unique up to an additive constant. However, C^α-regularity and existence do not hold. In fact, even if Ω is a ball, there is no constant $K > 0$ such that $|u|_0 \leq |-\Delta u + \lambda u + \nabla\pi|_\alpha$ for $\pi \in C^\alpha, u \in (C^{2,\alpha}_*)^3$ with $\operatorname{div} u = 0, u_{|\partial\Omega} = 0$. Furthermore, there exists some $f \in (C^\alpha_*)^3$ such that problem (1) cannot be solved.

Our methods are based on the method of integral equations.

Maximum principles and non-existence results for minimal submanifolds

Ulrich Dierkes (Saarbrücken)

In this talk we discuss generalizations of necessary conditions for the general Plateau problem to arbitrary dimensions and arbitrary genus. This generalizes results of Nitsche, Nitsche-Leavitt, Hildebrandt and Ossermann-Shiffer. We also give an application to the so called neck-pinching in mean curvature flow problems. These results are contained in [D1], [D2].

Theorem 1 *Let $M \subset \mathbb{R}^{n+k}$ be an n-dimensional minimal submanifold of class C^2. Then the function $t(x_1, \cdots, x_{n+k}) = x_1^2 + \cdots + x_n^2 - \frac{(n-k)}{k}[x_{n+1}^2 + \cdots + x_{n+k}^2]$ is a subharmonic function on M, i. e. $\Delta_M t \geq 0$ where Δ_M denotes the Laplace-Beltrami operator on M.*

Corollary 1 *If M is a compact minimal submanifold and ∂M is contained in a solid body which is congruent to $H_n^k(\varepsilon) := \{x_1^2 + \cdots + x_n^2 \leq \frac{(n-k)}{k}[x_{n+1}^2 + \cdots + x_{n+k}^2] + \varepsilon\}$ then we have $M \subset H_n^k(\varepsilon)$.*

Corollary 1 yields a considerable improvement over the convex hull property for minimal submanifolds with several boundary components, if e. g. the codimension $k = 1$ and $\varepsilon > 0$, since, in this case the set $H_n^k(\varepsilon)$ represents a solid *connected* hyperboloid.

Furthermore we obtain the following nonexistence result.

Theorem 2 *Let $C \subset \mathbb{R}^{n+1}$ be a solid cone with vertex P_0 which is congruent to the cone $\{x_1^2 + \cdots + x_n^2 \leq (n-1)x_{n+1}^2\} = K^+ \cup \{0\} \cup K^-$ and let C^+, C^- denote the disjoint parts which correspond to K^+, K^- respectively. Then there is no connected, compact n-dimensional minimal submanifold $M \subset \mathbb{R}^{n+1}$ which is of class C^2 with $\partial M \subset C$ such that both $\partial M \cap C^+$ and $\partial M \cap C^-$ are nonempty.*

As a consequence of this result one obtains several *necessary* conditions for the existence of connected minimal submanifolds with two boundary components, see [D1].

Theorem 1 extends to submanifolds with bounded mean curvature H.

Theorem 3 *Let $M \subset \mathbb{R}^{n+1}$ be an n-dimensional C^2-submanifold with mean curvature $H(x)$ and $b \in [0, 1]$. Then $t(x) = x_1^2 + \cdots + x_n^2 - (n-1)bx_{n+1}^2$ is subharmonic on M, if*

$$b + n|H(x)|\left\{\frac{x_1^2 + \cdots + x_n^2}{(n-1)^2} + b^2 x_{n+1}^2\right\}^{\frac{1}{2}} \leq 1$$

holds for all $x \in M$.

We remark that Theorem 2 can be improved considerably by using an enclosure argument which is based on the construction of certain n-dimensional catenoids. These are obtained as revolution surfaces of the extremals of the one dimensional variational integral $\int y^n(1 + y'^2)^{\frac{1}{2}} dx$, for details see [D1].

K. Ecker has pointed out to me that the method used in Theorem 1 also applies to the mean curvature flow problem

(1) $\frac{d}{d\tau}x(\rho,\tau) = n \cdot H(\rho,\tau) \cdot \nu$

of smooth embeddings of some n-dimensional manifold M into $\mathbb{R}^{n+1}$. In particular one may prove a "neck pinch" result if $M_0 = x(M,0)$ has the shape of a barbell handle. We consider here the Dirichlet problem $\partial M_\tau = \partial M_0$ which is connected with the evolution equation (1).

Proposition 1 *Let $\lambda, \Lambda \in \mathbb{R}$ such that $2\lambda - 2 - \Lambda \geq 0$. Then the function $t(x,\tau) := x_1^2 + \cdots + x_n^2 - (n-\lambda)x_{n+1}^2 + \Lambda\tau$ fulfills the inequality $(\Delta - \frac{d}{d\tau})t \geq 0$, where $\Delta = \Delta_{M_\tau}$ denotes the Beltrami operator on $M_\tau = x(M,\tau)$.*

From the maximum principle we conclude

Proposition2 *Let $2\lambda - 2 - \Lambda \geq 0$. Then for all $\tau_1 \geq 0$ such that $M_\tau, \tau \in [0,\tau_1]$ is a differentiable manifold, one has the estimate $\sup_{M_\tau} t \leq \sup_{M_0} t$.*

This implies

Theorem 5 *Let $\lambda < n, \Lambda > 0$ satisfy $2\lambda - 2 - \Lambda \geq 0$ and assume that $\varepsilon > 0$ and M_0 fulfill $M_0 \subset \{x_1^2 + \cdots + x_n^2 - (n-\lambda)x_{n+1}^2 \leq \varepsilon\}$. In addition suppose that M_0 is connected, $\partial M_0 \subset \{x_1^2 + \cdots + x_n^2 \leq (n-\lambda)x_{n+1}^2\}$ such that both intersections $\partial M_0 \cap \{x_{n+1} > 0\}$ and $\partial M_0 \cap \{x_{n+1} < 0\}$ are nonempty. Then the flow (1) develops a singularity before $\tau_0 = \frac{\varepsilon}{\Lambda}$.*

[D1] Dierkes, U.: Maximum principles and nonexistence results for minimal submanifolds. Mon. math. 69, 203-218 (1990).
[D2] Dierkes, U.: Maximum principles and nonexistence results for submanifolds of bounded mean curvature with an application to mean curvature flow. To appear in: Vorlesungsreihe des SFB 256, Analysis Seminar 1990, Universität Bonn.

The stationary Navier-Stokes equations of viscous flow past a body

Reinhard Farwig (Paderborn)

We consider the stationary Navier-Stokes equations for a viscous, incompressible fluid in an exterior domain of $\mathbb{R}^3$. The velocity is assumed to approximate a constant nonvanishing vector at infinity. Linearizing the Navier-Stokes equations we are led to the Oseen equations which we study in weighted Sobolev spaces. The weights are anisotropic and reflect the decay properties of Oseen's fundamental solution. The main tools are the theory of hydrodynamic potentials and estimates of singular and weakly singular integral operators in anisotropic spaces. Furthermore we present a variational approach in weighted Sobolev spaces to a related elliptic equation of second order.

Literature: R. Farwig: Das stationäre Außenraumproblem der Navier-Stokes-Gleichungen bei nichtverschwindender Anströmgeschwindigkeit in anisotrop gewichteten Sobolevräumen. Preprint no. 110, SFB 256, University of Bonn 1990.

Recent results on soliton equations

Benno Fuchssteiner (Paderborn)

The basics of the group theoretical analysis of soliton systems are given. Linear operators $\Phi(u)$ on the tangent bundle are said to be hereditary if for all Lie-derivatives L_G we have $\Phi L_G(\Phi) = L_{\Phi G}(\Phi)$. These operators play a central role in so far as they generate infinite-dimensional abelian Lie algebras. An example for such a quantity is $\Phi = \partial_x^2 + 2u + 2\partial_x u \partial_x^{-1}$ which generates the symmetry group of the KdV. If a soliton manifold is parametrized by asymptotic data then Φ must be diagonal with doubly degenerate spectrum such that the eigenvectors correspond to the action-angle-variables. By phase translation in the asymptotic data representation one obtains an ABT (auto Bäcklund transformation) which acts as x-translation on one-solitons. Hence the global ABT can be recovered by functional equations of the one-solitons. These ABT's obviously have a free parameter, which may be used to define an invariant nonlinear spectral problem by violation of the implicit function theorem condition. The associated linear spectral problem then is the one given by the corresponding hereditary operator. By analysis of the approach given above one then discovers an ideal-theoretic characterization of the tangent bundle for multisolitons: In a suitably constructed finitely generated Lie-module a canonical completion of ideals is given via the symplectic form of the system. Multisolitons then correspond to complete prime ideals in that module and a concrete representation is rediscovered by the zero sets of these prime ideals.

Microlocal defect measures and homogenization

Patrick Gerard (Paris)

In order to study the oscillations of the sequence (Ψ^ε) solution of the following oscillating Schrödinger equation

$$(\varepsilon D_t + \frac{1}{2}(\varepsilon D_x)^2 + V(\frac{x}{\varepsilon}))\Psi^\varepsilon = 0$$
$$\Psi^\varepsilon_{|t=0} = e^{iS(x)/\varepsilon} b(x)$$

where $V \in C^\infty(\mathbf{T}^n)$, we introduce the notion of "semi-classical defect measure" on $\mathbb{R}^n_x \times \mathbb{R}^n_\xi$ by the formula

$$\int a(x,\xi)\mu(dxd\xi) = \lim_\varepsilon (a(x,\varepsilon D_x)u^\varepsilon, u^\varepsilon),$$

if $a \in C_0^\infty(\mathbb{R}^n \times R^n), (u_\varepsilon)$ being a given bounded sequence of L^2, $u_\varepsilon \rightharpoonup 0$, and, say, $|\nabla_x u^\varepsilon|_{L^2} \leq \frac{C}{\varepsilon}$. If u_t is the measure corresponding to $u^\varepsilon = \Psi^\varepsilon(t)$, then $\mu_0 = |b(x)|^2 dx\delta(\xi - dS(x))$, and, under some assumptions of generic type on S, we can compute μ_t for each t in terms of the eigenvalues of $\frac{1}{2}(\xi + D_y)^2 + V(y)$ on $\mathbf{T}^n_y$ without any assumption on their multiplicities. (Bloch waves).

The dirichlet problem for some semilinear elliptic differential equations of arbitrary order

Hans-Christoph Grunau (Berlin)

For some special semilinear elliptic equations, e. g. $(-\Delta)^m + g(u) = f$, the existence of a solution of the Dirichlet problem is shown, which is classical in the interior of the domain and takes on the boundary values in a weak sense. The nonlinearity $g : \mathbb{R} \to \mathbb{R}$ has to satisfy the sign condition $tg(t) \geq 0$ and to be bounded from below, e. g. $g(t) = exp(t) - 1$. Furthermore it is possible to treat nonlinearities g with growth conditions, which can be viewed as interpolation between the above extreme case and the standard one $|g(t)| \leq C(1 + |t|^{\frac{n+2m}{n-2m}})$. The crucial lemma is a local maximum principle for solutions of differential inequalities $(-\Delta)^m u \leq f$, which makes use of the positivity of Green's function for $(-\Delta)^m$ in balls.

The essential spectrum of Neumann Laplacians on some bounded singular domains

Rainer Hempel (München)

Neumann Laplacians on singular domains exhibit surprising and fascinating properties. On one hand, there is the recent work of Davies, Simon and others on the spectrum of Neumann Laplacians on (unbounded) *horns*, while, on the other hand, Hempel, Seco and Simon have analyzed the essential spectrum of Neumann Laplacians on some bounded singular domains of the type *rooms* and *passages* and *combs*. Examples of this kind have been known at least since Courant and Hilbert in connection with Rellich's embedding theorem. It turns out that, given any closed subset S of the interval $[0, \infty)$, we can construct a comb-like domain Ω with the property that the Neumann Laplacian on Ω has precisely the set S as its essential spectrum.

The main step in the analysis consists in a *decoupling* along the intervals where rooms and passages meet, by means of certain *natural* boundary conditions, which turn out to be Neumann from the side of the rooms and Dirichlet from the side of the passages (the *Organ-pipe Lemma*).

Concerning *exterior problems* related to rooms and passages, one can obtain existence and completeness of wave operators in situations where one of the operators lacks local compactness properties (joint work with R. Weder).

References

E. B. Davies, B. Simon: Spectral properties of the Neumann Laplacians of horns. Duke Math. J., to appear.

R. Hempel, L. Seco, B. Simon: The essential spectrum of Neumann Laplacians on some bounded singular domains. J. Funct. Anal., to appear.

A new parametrization of the sphere and its applications

T. Herb (Bayreuth)

A new parametrization of the sphere is introduced, which consists of the central projection of a half-equator onto a tangent line and the rotation of the rest of the sphere into this half-equator.

For an application, it is shown that the problem of finding an isometric embedding of a twodimensional Pseudo-Riemannian manifold homeomorphic to the disc in a three-dimensional Pseudo-Riemannian space of constant curvature is equivalent to finding a homeomorphic solution with nonvanishing Jacobian of the associated Darboux system, an elliptic system of Heinz-Lewy type. In order to find such solutions in the Riemannian case, one needs an a-priori estimate of the Dirichlet integral, which is gotten from the Rellich equation for the above introduced parametrization.

A second application are harmonic mappings from the ball into the sphere, where the new parametrization allows to solve the Dirichlet problem with a restriction to a belt around the equator instead of a hemisphere.

Symplectic homology

H. Hofer (Bochum)

Let (M, ω) be a symplectic manifold. A basic question is the following: Do there exist monotonic invariants other than volume? To be more precise let us assume M and N have the same dimension. Can we attach a nummer $c(M)$ to M and the same to N, which has the following properties.

(A1) $c(M, \omega) > 0$
(A2) $c(B^2(1) \times \mathbf{C}^{n-1}) < 0$
(A3) $c(M, \alpha\omega) = |\alpha| c(M, \omega)$
(A4) $M \hookrightarrow N$ symplectically then $c(M, \omega) \leq c(N, \tau)$

It is interesting to note that (A1),(A3) and (A4) would be satisfied by $M \to (\int_M \omega^n)^{\frac{1}{n}}$ with $\dim M = 2n$. However, (A2) excludes all volume-related quantities. Here $B^2(1) \times \mathbf{C}^{n-1}$ carries the standard symplectic structure induced from $\mathbf{C}^n$. A "c" satisfying (A1-A4) is called a *symplectic capacity*. Quantities satisfying the above axioms exist and are surprisingly related to existence theory of periodic solutions of Hamiltonian systems. One can show that periodic trajectories are a necessary ingredient in a symplectic rigidity theory. Periodic solutions with prescribed period or energy satisfy a variational principle and therefore can be expected to be related by algebraic properties in view of Morse theory. However Morse theory is not applicable, at least not in its standard form, due to the fact that the dimensions of stable and unstable manifolds of the variational problem are infinite. Floer's variational interpretation of Gromov's pseudoholomorphic curve theory leads to the desired variational theory. This variational theory is based on the study of first order elliptic systems associated to the space of connecting orbits between critical points. Merging the construction of symplectic capacities with Floer's so called Instanton-homology (also called Floer homology) one is able to construct a huge family of functions depending on two real and one integer parameter. These functions are interrelated by exact sequences and have many useful properties. One calls them symplectic homology functors. Having this theory one can explain many known results from a unique point of view and obtains some new results like Gromov's symplectic polydisc conjecture, new cases of the Weinstein conjecture, and some highly interesting results on the topological properties of spaces of symplectic embeddings.

Regularity of parabolic systems (n=2)

Oldrich John (Praha)

As it is known, the parabolic system

(1) $\frac{\partial u^i}{\partial t} - \sum_{j=1}^{m} \sum_{\alpha,\beta=1}^{n} D_\alpha(A_{ij}^{\alpha\beta}(t,x)D_\beta u^j) = 0, i = 1, \cdots, m$,
(2) $\sum_{i,j=1}^{m} \sum_{\alpha,\beta=1}^{n} A_{ij}^{\alpha\beta}(t,x)\xi_\alpha^i \xi_\beta^j \geq \lambda|\xi|^2, \lambda > 0, A$ symmetric

of m equations in n spatial variables $x = [x_1, \cdots, x_n]$ with bounded measurable coefficients in $Q = (0,T) \times \Omega, \Omega \subset \mathbb{R}^n$ bdd., can be constructed (for $n \geq 3, m \geq 2$) in a way that it has singular (discontinuous) weak solution. There is an example that the weak solution starts from smooth boundary data and becomes singular in some point of Q (J. Stará, O. John, J. Malý, Comment Math. Univ. Carol, 27, 1986). The construction is based on the fact that there is the elliptic system with bounded measurable coefficients having singular solutions. It is true if and only if $n \geq 3$.

So there was still an open problem, what can happen with the parabolic system if $n = 2$. Is it regular? A partial answer gives the following

Theorem *(V. Kondratjev, J. Stará, O. John). Let $n = 2$. Let the coefficients of (1),(2) be of $L_\infty(Q)$. Assume, further, that the coefficients are Lipschitz continuous in t, uniformly with respect to x in Q. Then each weak solution of (1),(2) is regular (locally Hölder continuous) in Q.*

Symmetry, smoothness, and nodal properties in global bifurcation analysis of quasi-linear elliptic equations

Hansjörg Kielhöfer (Augsburg)

We investigate global bifurcation for a quasilinear elliptic boundary value problem. If the domain is symmetric some eigenfunctions of the linearization about the trivial solution have certain symmetric nodal configurations. We prove that these nodal configurations persist also for the nonlinear problem along global branches provided the equation is equivariant with respect to their symmetry group. For a subclass of problems we can show that these global branches are in fact smooth curves in the appropriate fixedpoint subspaces defined by their symmetry.

A priori estimates and their application for the classical solvability of boundary value problems for fully nonlinear elliptic equations

Nicolai Kutev (Karlsruhe)

The best possible conditions for boundary gradient estimates for fully nonlinear elliptic and parabolic equations

$$F[u] = F(x, u, Du, D^2u) = 0 \text{ in } \Omega,$$
$$-u_t + F(t, x, u, Du, D^2u) = 0 \text{ in } Q = \Omega \times (0,T)$$

in a bounded smooth domain $\Omega \subset \mathbb{R}^n$ or a cylinder $Q = \Omega \times (0,T)$ are proposed. The important role of the geometry of the domain and the nonlinearity of the equations for the general solvability of the Dirichlet problem is shown. Applications for the classical solvability of Monge-Ampere type equations, curvature type equations and others is given, too. In case of one-dimensional nonlinear parabolic equations

$$u_t - u_{xx} = f(t,x,u,u_x) \text{ in } (a,b)\times(0,\infty)$$
$$u(a,t) = A\,, u(b,t) = B\,, A,B = \text{const}\,; u(x,0) = \psi(x)$$

as a consequence of the existence and nonexistence results global solvability or finite blow up of the solutions is proved when the difference of the data $B - A$ is sufficiently large.

On the Wigner-Poisson-system

Horst Lange (Köln)

We consider the Cauchy problem for the Wigner-Poisson-equation

$$\text{(WP)} \qquad \begin{cases} \partial_t \rho + V\cdot\nabla_x\rho + \Theta(V)\rho = 0 \\ \rho_{|t=0} = \rho_I \end{cases}$$

called sometimes the quantum transport equation; here $\Theta(V)$ stands for the Fourier integral operator with symbol

$$\frac{i}{\hbar}[V(x+\frac{\hbar}{2}\eta,t) - V(x-\frac{\hbar}{2}\eta,t)]$$

with $\Delta V = -\varepsilon n, n(x,t) = \int_{\mathbb{R}^3}\rho(x,v,t)dv, \varepsilon = \pm 1$. By using the equivalence of (WP) with a system of coupled Hartree type nonlinear Schrödinger equations

$$i\partial_t\psi_n = -\frac{1}{2}\Delta\psi_n + V(\psi)\psi_n$$
$$\psi_n(x,0) = \varphi_n(x)$$

(where $\Delta V = -\varepsilon_n, n(x,t) = \sum_1^\infty \lambda_n|\psi_n(x,t)|^2$) we show global existence of (WP) in an H^2-setting for $\varepsilon = \pm 1$ and asymptotical decay of $\rho, n, V, \nabla V$ in various norms as $|t| \to \infty$ for the repulsive case $\varepsilon = 1$.(jointly with R. Illner, P. Zweifel).

Nonlinear initial value problems for elastic media with cubic symmetry

Rolf Leis (Bonn)

We start formulating some linear initial boundary value problems, indicate solution methods and hint at problems from qualitative solution theory (asymptotic behaviour for large t, scattering theory). We then briefly remind of some results on the existence of global smooth solutions of nonlinear equations with small data.

The third and main part of the lecture is concerned with the system of linear equations of elasticity in $\mathbb{R}^2$. We assume the medium to be anisotropic with cubic symmetry. The Fresnel surfaces are classified and the different asymptotic behaviour as $t \to \infty$ of the solutions is described using stationary phase methods. These results are applied to obtain global smooth solutions for nonlinear equations with initially anisotropic cubic medium.

Hilbert complexes

Matthias Lesch (Augsburg)

In this talk I give a report on a joint work with J. Brüning. Its purpose is to give a framework for the investigation of elliptic complexes on non-compact manifolds. For such a complex of differential operators

$$0 \to C_0^\infty(E_0) \xrightarrow{d_0} C_0^\infty(E_1) \xrightarrow{d_1} \cdots \xrightarrow{d_{N-1}} C_0^\infty(E_N) \to 0$$

between vector bundles E_i on a Riemannian manifold M the concept of an *ideal boundary condition* plays an important role. An ideal boundary condition is just a choice of closed extensions D_i of d_i such that we obtain again a complex

$$0 \longrightarrow \mathcal{D}_0 \xrightarrow{D_0} \mathcal{D}_1 \xrightarrow{D_1} \cdots \xrightarrow{D_{N-1}} \mathcal{D}_N \longrightarrow 0 .$$

An abstract complex of this type is called a *Hilbert complex.* Although this is a very simple object, it reflects much of the structure known from elliptic complexes on compact manifolds.

I discuss some aspects of these complexes, such as Fredholmness, Poincaré duality, homotopy operators etc. For manifolds with cone-like singularities I state a uniqueness result for ideal boundary conditions.

Fundamental solutions for PDO's depending analytically on parameters

Frank Mantlik (Dortmund)

We consider a family $P_\lambda(D) = \sum_{|\alpha|\le m} a_\alpha(\lambda)D^\alpha$ of constant coefficients PDO's, where each a_α depends analytically on a parameter λ in a complex manifold Λ. Assuming $P_\lambda(D)$ is equally strong for each λ we prove the existence of fundamental solutions $f_\lambda, P_\lambda(D)f_\lambda = \delta_0$ in $\mathbb{R}^n$ (with optimal regularity properties), which also depend analytically on $\lambda \in \Lambda$. This result answers a question of L. Hörmander. It has been shown by F. Treves that the assumption of constant strength is necessary (and also sufficient locally in Λ). Our method of proof also yields analytic solutions for the more general equation $P_\lambda(D)f_\lambda = g_\lambda$, where g_λ is a given analytic function with values in some distribution space. As a principal tool we use a theorem of J. Leiterer on sheaves of Banach-valued analytic functions.

Some remarks on large data problems for semilinear wave equations

Hartmut Pecher (Wuppertal)

We consider the following Cauchy problem

$$u_{tt} - \Delta u = g(u)$$
$$u(x,0) = \varphi(x), u_t(x,0) = \psi(x)$$

for $(x,t) \in \mathbb{R}^3 \times \mathbb{R}$. Assume that $g \in C^{2,\alpha}(\mathbb{R})$, $g(s) \le$ const $\forall s \in \mathbb{R}, |g(s)| \le$const as $s \to -\infty$.

Under these assumptions this problem has a unique global classical solution for any smooth data φ and ψ. If

$$g(s) = \begin{cases} 0 & s \leq 0 \\ -|s|^p & s > 0 \end{cases}$$

where $p > 2$, the scattering operator in the sense of energy norms can be shown to exist for any smooth data which decay sufficiently rapidly at infinity.

Small solutions to nonlinear hyperbolic and parabolic equations in domains with boundaries

Reinhard Racke (Karlsruhe)

(1) Simple examples are presented for solutions of wave equations in bounded domains in $\mathbb{R}^n$ which always develop singularities in finite time — in contrast to the corresponding situation in exterior domains.
(2) Global existence theorems for small, smooth solutions to equations of the following type are given.

$$u_t + \Delta^2 u = f(u, \nabla u, \nabla^2 u, \nabla^3 u, \nabla^4 u)$$

and

$$u_{tt} - \partial_i a_{ik}(x)\partial_k u + u_t = h(u, u_t, \nabla u, \nabla u_t, \nabla^2 u),$$

in unbounded domains with star-shaped complement.
(3) Results in one-dimensional nonlinear thermoelasticity are shortly mentioned.

Existence of the global attractor for some strongly coupled reaction-diffusion systems

Reinhard Redlinger (Karlsruhe)

The model system (a_i, b_i, c_i, e_i and α are positive constants)

$$(*)\begin{cases} u_t &= [(c_1 + \alpha v)u]_{xx} &+ \quad u(e_1 - a_1 v - b_1 u) \\ v_t &= c_2 v_{xx} &+ \quad v(e_2 - a_2 u - b_2 v) \end{cases} \qquad \text{for } 0 < x < \ell, t > 0$$

(two competing species with triangular diffusion matrix, space dimension $n = 1$) under homogeneous Neumann boundary conditions and with nonnegative initial data is considered. Existence of the global attractor for $(*)$ in the space $X = \{(u, v) \in W^{1,p}(0, l) : n, v \geq 0\}$ for arbitrary $1 < p < \infty$ is proved. The result can be extended to higher (e. g. Dirichlet boundary conditions), if the term $b_1 u$ is replaced by a function $h(u)$ with the following properties: $h \geq 0$, and there is an $\varepsilon > 0$ such that $\frac{h(u)}{u^{1+\varepsilon}} \to \infty$ as $u \to \infty$.

Semilinear elliptic eigenvalue problems in $\mathbb{R}^N$

Wolfgang Rother (Bayreuth)

We present some existence results for the semilinear equation

$$-\Delta u - q(x)|u|^{\sigma_1} u + r(x)|u|^{\sigma_2} u = \lambda u \text{ in } \mathbb{R}^N \qquad (*)$$

and state some conditions for the functions q, r and the positive constants σ_1, σ_2 such that $\lambda = 0$ is a bifurcation point for equation $(*)$.

Sucessive bifurcations in the Conette-Taylor problem

Jürgen Scheurle (Hamburg)

The Conette-Taylor problem deals with the flow of an incompressible viscous fluid between two coaxial rotating cylinders. Depending on the angular velocities of the cylinders, one observes different flow patterns. Mathematically, transitions between different flow patterns are described by instabilities and bifurcations of corresponding solutions of the Navier-Stokes equations for this problem. We are going to discuss a systematic method to analyze the occurence of whole sequences of such phenomena when an external parameter is varied, and present an example.

The weak Dirichlet problem in L^q for Δ in exterior domains

C. G. Simader (Bayreuth)

We give report on joint work with H. Sohr (Paderborn). Let $G \subset \mathbb{R}^n$ be an open set with $\bar{G} \subset \mathbb{R}^n, \bar{G} \neq \mathbb{R}^n, \partial G \in C^1$ and $1 \leq q < \infty$. Then the usual Sobolev space $H_0^{1,q}(G)$ is defined as the closure of $C_0^\infty(G)$ with respect to the norm $\|\phi\|_{1,q} := (\|\phi\|_q^q + \|\nabla\phi\|_q^q)^{\frac{1}{q}}$. If G is bounded an equivalent norm is defined by $\|\nabla\phi\|_q$. This holds no longer true for unbounded domains. So we define more generally $\hat{H}_0^1(G) := \{p : G \to \mathbb{R}$ measurable, $p \in L^q(G_R)$ for all $R > 0$, $\nabla p \in (L^q(G))^n$ and there exists a sequence $(p_i) \subset C_0^\infty(G)$ such that $\|p - p_i\|_{q,G_R} \to 0$ for each $R > 0$ and $\|\nabla p - \nabla p_i\|_{p,G} \to 0\}$. Here $G_R := G \cap B_R$ where $B_R := \{x \in \mathbb{R}^n : |x| < R\}$. Then $\hat{H}_0^{1,q}(G)$ is a Banach ($q = 2$: Hilbert) space with respect to the norm $\|\nabla \cdot\|_q$ and reflexive for $1 < q < \infty$. Beside this space we consider $\hat{H}^{1,q}(G) := \{p : G \to \mathbb{R}$ measurable, $p \in L^q(G_R)$ for each $R > 0, \nabla p \in (L^q(G))^n$ and for each $\eta \in C_0^\infty(\mathbb{R}^n)$ holds $(\eta p) \in H_0^{1,q}(G)\}$. Again $\hat{H}^{1,q}(G)$ with norm $\|\nabla \cdot\|_q$ is a Banach space. For G bounded $H_0^{1,q}(G) = \hat{H}_0^{1,q}(G) = \hat{H}^{1,q}(G)$. If $0 \in K \subset\subset \mathbb{R}^n$ and if $G := \mathbb{R}^n \setminus \bar{K}$ is a domain, we call G an exterior domain. In this case holds $\hat{H}_0^{1,q}(G) = \hat{H}^{1,q}(G)$ for $q \geq n$. But if $1 \leq q < n$ we choose $R > 0$ such that $K \subset\subset B_R$ and $\varphi_R \in C^\infty(\mathbb{R}^n)$ with $0 \leq \varphi_R \leq 1$ and $\varphi_R(x) = 0$ for $|x| \leq 1, \varphi_R(x) = 1$ for $|x| \geq 2$. Then $\varphi_R \in \hat{H}^{1,q}(G)$ but $\varphi_R \notin \hat{H}_0^{1,q}(G)$. Furthermore $\hat{H}^{1,q}(G) = \hat{H}_0^{1,q}(G) \oplus \{\alpha\varphi_R : \alpha \in \mathbb{R}\}$. The main result states that for G bounded or an exterior domain, $\partial G \in C^1$, there exists for $1 < q < \infty$ a constant $C_q > 0$ such that $\|\nabla p\|_q \leq \sup\{<\nabla p, \nabla\phi>: \phi \in \hat{H}^{1,q'}(G), \|\nabla\phi\|_{q'} \leq 1\}$ holds for all $p \in \hat{H}^{1,q}(G)$ where $q' = \frac{q}{q-1}$. Equivalent to this property is the representation theorem: For each $F^* \in (\hat{H}^{1,q}(G))^*$ there exists a unique $p \in \hat{H}^{1,q}(G)$ such that $F^*(\phi) = <\nabla p, \nabla\phi>$ for all $\phi \in \hat{H}^{1,q'}(G)$ and $C_q^{-1}\|\nabla p\|_q \leq \|F^*\|_{q'}^* \leq \|\nabla p\|_q$. If G is an exterior domain ($G \subset \mathbb{R}^n, n \geq 2$) then there exists $0 \neq h \in \bigcap_{\frac{n}{n-1}<r<\infty} \hat{H}^{1,r}(G)$ with $\Delta h = 0$. For $\frac{n}{n-1} < q < n (\Rightarrow n \geq 3)$ holds $\hat{H}^{1,q}(G) = H_0^{1,q}(G) \oplus \{\alpha h : \alpha \in \mathbb{R}\}$. But for $q \geq n$ if $n \geq 3$ resp. $q > n = 2$ holds $h \in \hat{H}_0^{1,q}(G)$.

The existence of steady vortex rings in an ideal fluid

Michael Struwe (Zürich)

Theorem (Ambrosetti-Struwe) *Let g be non-decreasing, $g \geq 0 = g(0) < \lim_{t\to\infty} g(t) < \infty$, and continuous on $]0,\infty[$. Also let $k \geq 0, W > 0$ be given. Then there is a solution $0 \not\equiv u = u(r,z) = u(r,-z)$ of the problem*

$$(P)\begin{cases} -\Delta u = r^2 g(r^2(u - \frac{W}{2}) - k) \text{ in } \mathbb{R}^5 \\ u(r,z) \to 0 \text{ as } |(r,z)| \to \infty, \text{ where } r = \sqrt{x_1^2 + \cdots + x_4^2}, z = x_5. \end{cases}$$

u is non-increasing in $|z|$ and $A = supp(\Delta u)$ is non-empty and bounded.

Physically, A corresponds to the cross section (in a meridional plane) of a vortex ring with flux k and vorticity function g, travelling at speed W.

Plateau's problem

Friedrich Tomi (Heidelberg)

In this survey talk some recent developments in the theory of Plateau's problem are discussed. The following topics are considered:

(I) A modern approach to the classical theory

(II) Incompressible minimal surfaces and barrier constructions

(III) Unstable minimal surfaces.

In (I) I describe the existence proof for area minimizing surfaces of prescribed genus $p > 1$ spanning a given Jordan curve in a Riemannian manifold using the description of the moduli space of a surface as the quotient of Riemannian metrics of curvature -1 by the diffeomorphism group of the surface. This is based on work of Fisher-Tromba. In (II) I show how the concept of incompressible surfaces (i. e. surfaces which induce a monomorphism of fundamental groups) can be exploited for existence proofs to Plateau's problem. I illustrate this with several examples in $\mathbb{R}^3$ using suitable, topologically non-trivial mean-convex barriers. In (III) finally I discuss various ways of applying Morse and Ljusternik-Schnirelman theories to Plateau's problem and I briefly describe some recent results by Struwe, Jost-Struwe, and Min-Yin.

A maximum principle for elliptic systems

Wolfgang Walter (Karlsruhe)

Let

$$Lu = \sum_{i,j=1}^{m} a_{ij}(x) u_{x_i x_j} + \sum_{i=1}^{m} b_i(x) u_{x_i}$$

be an elliptic operator and $0 < \alpha I \leq (a_{ij}), |a|, |b| \leq K$ and $-K \leq c = c(x)$.

Theorem A (Walter 1989) *Assume that $D \subset \mathbb{R}^m$ satisfies a uniform interior ball condition and*

$$Lu + cu \leq 0 \text{ in } D, u \geq 0 \text{ on } \Gamma = \partial D,$$

and that a function h with

$$Lh + ch \leq 0 \text{ in } D, h > 0 \text{ in } D$$

exists. Then (i) $u > 0$ in D or (ii) $u \equiv 0$ in D or (iii) $u = -\alpha h, \alpha > 0$. In case (iii) u is an eigenfunction for the operator $L + c$.

Now consider an elliptic system where $L = diag(L_1, \cdots, L_n), u = (u_1, \cdots, u_n)^T$, $c(x) = (c_{ij})$ essentially positive, i. e. $c_{ij} \geq 0$ for $i \neq j$.

Theorem A_n *If $c(x)$ is essentially positive and irreducible then Theorem A holds as it stands (inequalities interpreted componentwise)*

Special case *$L_1 = \cdots = L_n = L^*, \lambda_1$ =first eigenvalue of $L^*\varphi + \lambda\varphi = 0$ in $D, \varphi = 0$ on Γ. Then*

$$\sum_{j=1}^{n} c_{ij}(x) \leq \lambda_1 \text{ with } \not\equiv \text{ for one index } i$$

implies $u > 0$ or $u \equiv 0$.

Large time asymptotics for wave equations with periodic coefficients

Peter Werner (Stuttgart)

We study the inital value problem

$$\partial_t^2 u - c^2[\rho\partial_x(\frac{1}{\rho}\partial_x u) - qu] = fe^{-i\omega t} \text{ for } (x,t) \in \mathbb{R} \times \mathbb{R}^+ ,$$
$$u(x,0) = \partial_t u(x,0) = 0$$

for $\omega > 0, f \in C_0^\infty(\mathbb{R})$ and smooth p-periodic coefficients $c > 0, \rho > 0, q \geq 0$. This problem is of interest, since spatial periodicity can produce resonances, as this example shows. In fact, u has a resonance of order $t^{\frac{1}{2}}$if ω^2 belongs to the boundary of the band spectrum of the self-adjoint extension A of the spatial operator $A_0 = c^2[\rho d(\frac{1}{\rho}d) - q]$ and if f is orthogonal to the p-periodic or p-semiperiodic solutions of $(A_0 - \omega^2)V = 0$ ("standing waves") with respect to the weight $(\rho c^2)^{-1}$, while $u(x,t)$ is bounded as $t \to \infty$ for all other choices of ω and f. Similar results hold if the coefficients are perturbed by additional terms with compact support.

Global solutions to a class of strongly coupled parabolic systems

Michael Wiegner (Bayreuth)

We consider strongly coupled parabolic systems of the type

$$\frac{\partial u^k}{\partial t} + \text{div}(j^k) = f^k \text{ on } \Omega_T = \Omega \times (0,T), 1 \leq k \leq N ,$$

together with initial boundary conditions. The flux-vectors j^k are assumed to be of the structure

$$j^k = -a(x,t,u)\nabla u^k + r^k(x,t,u) + c^k(x,t,u)\nabla H(x,t,u)$$

with matrices a, c^k and some function H behaving like $|u|^2$. In biological systems H can serve as a model for environmental influences produced by the species themselves, which may in turn react differently according to the c_k. We prove a-priori estimates in $C_{\alpha,\frac{\alpha}{2}}(\Omega_T)^N$, thereby getting the existence of global classical solutions, using results of H. Amann.

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