International Conference

Nonlinear Analysis

in Honor of

Herbert Amann´s 80th Birthday

June 11-14, 2019
Palazzone, Scuola Normale Superiore di Pisa
Cortona, Italy

Confirmed Participants

H. Abels, Regensburg
H. Beirao da Veiga, Pisa
J. Bemelmans, Aachen
P. Biler, Wroclaw
G. Bizhanova, Almaty
D. Bothe, Darmstadt
R. Chill, Dresden
D. Daners, Sydney
G. Da Prato, Pisa
I. Denisova, St. Petersburg
R. Denk, Konstanz
I. Diaz, Madrid
K. Disser, Darmstadt
R. Farwig, Darmstadt
E. Frolowa, St. Petersburg
G.P. Galdi, Pittsburgh
D. Guidetti, Bologna
R. Haller-Dintelmann, Darmstadt
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T. Hishida, Nagoya
G. Karch, Wroclaw
M. Köhne, Düsseldorf
H. Kozono, Tokyo
P. Kunstmann, Karlsruhe
Ph. Laurencot, Toulouse
J. Lopez-Gomez, Madrid
L. Lorenzi, Parma
G. Metafune, Lecce
P. Mucha, Warsaw
S. Necasova, Prague
J. Neustupa, Prague
V. Nistor, Metz
M. Pierre, Rennes
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J. Rehberg, Berlin
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V.A. Solonnikov, St. Petersburg
M. Specovius-Neugebauer, Kassel
Ch. Stinner, Darmstadt
G. Ströhmer, Ames
G. Sweers, Köln
W. Varnhorn, Kassel
P. Weidemaier, Freiburg
L. Weis, Karlsruhe
M. Wilke, Halle
S.W. Zajaczkowski, Warsaw

Organizers: M. Chipot - F. Flandoli - P. Guidotti - M. Hieber - P. Koch-Medina - A. Lunardi - G. Simonett - Ch. Walker

Further Information: https://www2.mathematik.tu-darmstadt.de/~igk/cortona/ or contact cortona2019@mathematik.tu-darmstadt.de

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16:15-17:00	Elmar Schrohe	*Bounded* H_∞*-calculus for Boundary Value Problems on Manifolds with Conical Singularities*
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2 Abstracts

On some Korn Inequalities

Michel Chipot

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Let Ω be a smooth open set of $\mathbb{R}^n$, $n \geq 1$. We denote by $\mathbb{H}_0^1(\Omega)$ the space $(H_0^1(\Omega))^n$, i.e.,

$$\mathbb{H}_0^1(\Omega) = \{v = (v_1, \dots, v_n) \mid v_i \in H_0^1(\Omega)\ \forall i = 1, \dots, n\}.$$

$\nabla v = (\frac{\partial v_i}{\partial x_j})$ will denote the jacobian matrix of v.

If l_i, $i = 1, \dots, k$ denote linear forms on the space of $n \times n$ matrices, $\big| \ \big|_2$ the usual $L^2(\Omega)$-norm, we are looking for inequalities of the type

$$C\left|\nabla v\right|_2^2 \leq \sum_{i=1}^{k} \left|l_i(\nabla v)\right|_2^2 \quad \forall v \in \mathbb{H}_0^1(\Omega).$$

In particular we would like to investigate the smallest k for which such an inequality exists.

Eventually Positive Semi-Groups and Perturbation

Daniel Daners

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There is a well established theory of positive semi-groups of linear operators covering many applications. However, there are some applications that do not involve positive semi-groups, but exhibit a weaker positivity property in the sense that the orbits associated with positive initial conditions only become and stay positive for large time. We call such semi-groups eventually positive. Examples include certain non-local problems such as delay differential equations or problems with non-local boundary conditions. It also includes some evolution problems involving the Dirichlet-to-Neumann operator or certain fourth order evolution problems.

We will look at some characterisations of eventually positive semi-groups in terms of properties of the resolvents and the spectrum of the generator. We furthermore discuss how stable eventual positivity is under perturbations of the generator.

The material presented is based on joint work with Jochen Glück (formerly Ulm) and James Kennedy (Lisbon).

Neumann Problem in Infinite Dimension

Giuseppe Da Prato

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We are given a separable Hilbert space X and a Kolmogorov operator

$$\mathscr{L}\varphi = \frac{1}{2}\operatorname{Tr}[D^2\varphi] + \langle x, AD\varphi\rangle, \quad \varphi \in \mathscr{F}C_b^\infty(X),$$

where $A = -\frac{1}{2}Q^{-1}$ with Q symmetric, strictly positive and of trace class. It is well known that $\mathscr{L}$ has a unique maximal extension in $L^2(X,\mu)$ (that is $\mathscr{F}C_b^\infty(X)$ is a core for $\mathscr{L}$) and that the Gaussian measure $\mu = N_Q$ is invariant for $\mathscr{L}$.

We are also given a continuous convex function $g : X \to \mathbb{R}$. We set $K = \{x \in X : \ g(x) \le 0\}$ and $\Sigma = \{x \in X : \ g(x) = 0\}$. We prove some well–posedness and regularity for the Neumann problem

$$\begin{cases} \lambda\varphi - \mathscr{L}\varphi = f \quad \text{in } K, \\ \partial_n\varphi = 0 \quad \text{on } \Sigma, \end{cases}$$

using penalisation. Here $\lambda > 0$, $f \in L^2(K,\mu)$ and ∂_n represents the exterior normal of Σ.

Beyond the Unique Continuation: "Flat Solutions" for Reactive Slow Diffusions, the Infinite and Hardy Potential for Schrödinger Equation and 2-d Electron Beams

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Solutions with compact support for some nonlinear elliptic and parabolic equations, and many other free boundary problems, are formulations for which the unique continuation property fails. In such problems, which have attracted the attention of many specialists, and among them this lecturer, the solution u and its normal derivative vanish on a region of the boundary (which leads to the definition of a "flat solution" of the corresponding equation).

In this talk I will present, in a very sketched way, some recent results in this direction, trying to show how many open problems of this nature still remain as a source of current research.

More specifically, I will report on some results concerning the following problems:

I) Stable flat solutions of $u_t - \Delta u^m + u^a = \lambda u^b$ for $0 < a < b < m$ under the stability condition $2(m+a)(m+b) - N(m-a)(m-b) < 0$ (joint work with J. Hernández and Y. Sh. Ilyasov),

II) Flat solutions to $\mathbf{i}\frac{\partial \psi}{\partial t} = -\Delta \psi + V(x)\psi$ in $\mathbb{R}^N$, for $V(x) \geq C d(x, \partial\Omega)^{-2}$ for some bounded domain Ω (my research continued in collaboration with J. M. Rakotoson, D. Gómez-Castro, R. Temam and J. L. Vázquez),

III) Partially flat solutions ($u(x,0) = \frac{\partial u}{\partial y}(x,0) = 0$ for $x \in (-a,0)$) to $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = \frac{j(x)}{\sqrt{u(x,y)}}$, $x \in (-a,a)$, $y \in (0,1)$, for suitable $j(x)$, independent of y (formulation raised to me by H. Brezis and J. Lebowitz).

Viscous Flow past a Body Translating by Time-Periodic Motion with Zero Average

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We study existence, uniqueness, regularity and asymptotic spatial behavior of a Navier-Stokes flow past a body, $\mathscr{B}$, moving by a time-periodic translational motion of period T, and with zero average. For example, $\mathscr{B}$ moves in an oscillating fashion. The flow is also time-periodic with same period T. However, sufficiently “far" from the body, the oscillatory component decays faster than the averaged component, so that the flow shows there a distinctive steady-state character. This provides a rigorous proof of the “steady streaming" phenomenon.

A Novel Optimization Approach to Fictitious Domain Methods

Patrick Guidotti

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Many numerical methods for (initial) boundary value problems require a discrete representation of the domain in which the equations are set. When used in order to solve moving boundary problems or (domain) optimization problems (for instance), they require remeshing which can significantly add to the complexity and the computational cost of the resulting algorithms. Embedding methods, such as fictitious domain or immersed boundary methods try to avoid these issues by formulating the problem in a simpler (read regular) larger numerical domain (grid). Due to the singularities introduced by the extension to the larger domain, such methods have often very limited order of accuracy. Meshfree methods also provide an approach which circumvents the need for remeshing and allow for higher order implementations.

In this talk we will describe a new fictitious domain method based on the simple idea of recasting well-posed boundary value problems as under-determined system in a larger domain which are then solved as minimization problems of appropriate objective functionals enforcing regularity. This simple approach delivers flexible

methods of high tunable accuracy which perform well for (initial) boundary value problems in general domains, with non-constant coefficients and general boundary conditions. They can be interpreted as new meshfree methods and thus provide a unifying approach to a wide class of numerical methods for BVPs.

The talk is based on results obtained in collaboration with my students Daniel Agress and Dong Yan.

Analysis of the Ericksen-Leslie Equations for Nematic Liquid Crystal Flows

Matthias Hieber

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In this talk we discuss various aspects of the analysis of the Ericksen-Leslie equations describing the flow of nematic liquid crystals both in the isothermal and non-isothermal situation.

We consider here the case of general Leslie and general Ericksen stress. Starting with the development of thermodynamically consistent models, we investigate these models analytically by regarding them as quasilinear parabolic evolution equations and obtain a rather complete understanding of the dynamics of these systems. This is joint work with Jan Prüss.

Asymptotic Properties of Steady Solutions to the 2D Navier-Stokes Equations with the Finite Generalized Dirichlet Integral

Hideo Kozono

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We consider the stationary Navier-Stokes equations in the whole plane $\mathbb{R}^2$ and in the exterior domain outside of the large circle. The solution v is handled in the class with $\nabla v \in L^q$ for $q \geq 2$. Since we deal with the case $q \geq 2$, our class may be larger than that of the finite Dirichlet integrals, i.e., for $q = 2$ where a number of results such as asymptotic behavior of solutions have been observed. For the stationary problem we shall show that $\omega(x) = o(|x|^{-(\frac{1}{q}+\frac{1}{q^2})})$ as $|x| \to \infty$, where $\omega \equiv \mathrm{rot}\, v$. As an application, we prove the Liouville type theorems under the assumption that $\omega \in L^q(\mathbb{R}^2)$ for $q > 2$.

This talk is based on the joint work with Yutaka Terasawa (Nagoya Univ.) and Yuta Wakasugi (Ehime Univ.).

A Constrained Model for MEMS with Varying Dielectric Properties

Philippe Laurençot

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A semilinear parabolic equation with constraint modeling the dynamics of a microelectromechanical system (MEMS) with heterogeneous dielectric properties is derived and studied. In contrast to the commonly used MEMS model, the well-known pull-in phenomenon occurring above a critical potential threshold is not accompanied by a break-down of the model, but is recovered by the saturation of the constraint for pulled-in states. It is shown that a maximal stationary solution exists and that saturation only occurs for large potential values. In addition, the existence, uniqueness, and large time behavior of solutions to the evolution equation are studied. Joint works with Christoph Walker (Hannover).

The Characterization of the Strong Maximum Principle

J. López-Gómez

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Let $\mathfrak{L}$ be a second order linear elliptic operator on a bounded domain of $\mathbb{R}^N$, Ω, and $\mathfrak{B}$ a mixed boundary operator of non-classical type on $\partial\Omega$. The main goal of this talk is to discuss the next fundamental characterization theorem:

Theorem. *The following conditions are equivalent:*

(1) $\sigma \equiv \sigma[\mathfrak{L}, \mathfrak{B}, \Omega] > 0$, *where* σ *stands for the principal eigenvalue of* $(\mathfrak{L}, \mathfrak{B}, \Omega)$.

(2) *The tern* $(\mathfrak{L}, \mathfrak{B}, \Omega)$ *admits a positive strict supersolution.*

(3) *The tern* $(\mathfrak{L}, \mathfrak{B}, \Omega)$ *satisfies the strong maximum principle.*

This theorem goes back to J. López-Gómez & M. Molina-Meyer [5] for cooperative systems under Dirichlet boundary conditions and to H. Amann & J. López-Gómez [2] in the present setting. Simultaneously to [5], the equivalency between (1) and (3) was also established for a single equation by H. Beresticky, L. Nirenberg & S. R. S. Varadhan [3]. However, from the point of view of the applications, the most useful condition is (2). Further extensions to cooperative systems were given by H. Amann in [1]. The proof sketched in this talk relies on the classical minimum principles of E. Hopf, O. Oleinik and M. H. Protter & H. F. Weinberger, and it follows the general patterns of [4].

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[3] H. Beresticky, L. Nirenberg and S. R. S. Varadhan, The principal eigenvalue and maximum principle for second order elliptic operators on general domains, *Comm. Pure Appl. Maths.* **XLVII** (1994), 47–92.

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Schauder Theorems for Elliptic and Parabolic Equations in Finite and Infinite Dimension

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I will present maximal Hölder and Zygmund regularity results for the solutions to equations such as

$$\lambda u - Lu = f,$$

with $\lambda > 0$, where L is the generator of a "generalized Mehler semigroup", expressed as

$$P_t f(x) = \int_X f(T_t x + y)\mu_t(dy), \quad f \in C_b(X, \mathbb{R}),\ t > 0.$$

Here X is a separable Banach space, T_t is a strongly continuous semigroup in X, and $\{\mu_t : t \geq 0\}$ is a family of suitable Borel measures. The generator of P_t in the space $C_b(X, \mathbb{R})$ is the operator L whose resolvent operator is given by

$$(R(\lambda, L)f)(x) = \int_0^\infty e^{-\lambda t} P_t f(x)\, dt, \quad \lambda > 0.$$

The function f in the right hand side of the equation is either continuous and bounded, or Hölder continuous (possibly, along suitable directions) and bounded.

The general theory is applicable to a number of examples. In finite dimension ($X = \mathbb{R}^n$) the class of admissible operators L includes the Laplacian and the powers of $-\Delta$, all Ornstein-Uhlenbeck operators, and Ornstein-Uhlenbeck operators with fractional diffusion part. In infinite dimension it includes again Ornstein-Uhlenbeck operators, the Gross Laplacian Δ_G and $(-\Delta_G)^\alpha$ for $\alpha \in (0, 1)$.

The talk rests on recent works in collaboration with S. Cerrai and M. Röckner.

Singular Manifolds Versus Amann Triples

Victor Nistor

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Singular spaces and domains arise in many applications. One way to study them is to conformally change the metric. This works well if the resulting space has bounded geometry, such as in the case of polyhedral domains in arbitrary dimensions, and has lead Amann to introduce the notion of a "singular manifold." This approach is the one that arises in applications. From a theoretical point of view, however, it may be more convenient to start with a manifold with bounded geometry (possibly also with boundary) and to proceed in the opposite direction by an inverse conformal change of metric. We called the resulting objects "Amann triples." In my talk, I will present some results (mostly due to Amann or to Amann-Grosse-Nistor) that will illustrate these two complementary points of view.

Well-posedness for the Keller-Segel Model – based on a Pioneering Result of Herbert Amann

Joachim Rehberg

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In this lecture we prove the well-posedness of the full Keller-Segel system on non-smooth domains, a quasilinear strongly coupled reaction-crossdiffusion system, in the spirit that it always admits a unique local-in-time solution in an adequate function space, provided that the initial values are suitably regular.

The proof is carried out for general source terms and is based on recent nontrivial elliptic and parabolic regularity results which hold true even on fairly general spatial domains, combined with an abstract solution theorem for nonlocal quasilinear equations by Amann.

Bounded H_∞-calculus for Boundary Value Problems on Manifolds with Conical Singularities

Elmar Schrohe

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We consider differential boundary value problems on manifolds with conical singularities. In order to simplify the analysis, we blow up the singular points and study conically degenerate operators on the resulting object.

We present a novel way of determining the closed extensions of elliptic boundary problems in weighted Mellin-Sobolev spaces. Moreover, we show that a stronger condition, namely parameter-ellipticity guarantees the existence of a bounded H_∞-calculus.

As an application we establish the existence of short time solutions for the porous medium equation with Neumann boundary conditions on manifolds with (possibly warped) cones for positive initial data.

(Joint work with Nikolaos Roidos (Hannover) and Jörg Seiler (Turin)).

Towards Personalized Accurate Cardiovascular Simulations Using Clinical Data

Adélia Sequeira

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Mathematical modeling and simulations of the human circulatory system is a challenging and complex wide-range multidisciplinary research field that has seen a tremendous growth in the last few years. This field, with a strong socio-economic impact, is rapidly progressing motivated by the fact that cardiovascular diseases are a major cause of death in developed countries.

In this talk we consider some mathematical models and simulations of the cardiovascular system and comment on their significance to yield realistic and accurate numerical results, using reliable and efficient computational methods. In particular, to improve blood flow simulations, we propose the integration of known data into the numerical simulations, using Data Assimilation techniques based on a Discretize then Optimize (DO) approach and the solution of a non-linear optimal control problem. Results on the simulation of some image-based patient specific clinical cases will be presented.

The Radial Lemma of Strauss - Extensions to Function Spaces of Fractional Order of Smoothness and Consequences

Winfried Sickel

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At the end of the seventies Strauss was the first who observed that there is an interplay between the regularity and decay properties of radial functions. We recall his

Radial Lemma: Let $d \geq 2$. Every radial function $f \in H^1(\mathbb{R}^d)$ is almost everywhere equal to a function $\widetilde{f}$, continuous for $x \neq 0$, such that

$$|\widetilde{f}(x)| \leq c\,|x|^{\frac{1-d}{2}}\,\|\,f\,|H^1(\mathbb{R}^d)\|\,, \qquad x \neq 0\,, \tag{2.1}$$

where c depends only on d.

Strauss stated (2.1) with the extra condition $|x| \geq 1$, but this restriction is not needed. The *Radial Lemma* contains three different assertions:

(a) the existence of a representative of f, which is continuous outside the origin;

(b) the decay of f near infinity;

(c) the limited unboundedness near the origin.

These three properties do not extend to all functions in $H^1(\mathbb{R}^d)$, of course. In particular, $H^1(\mathbb{R}^d) \not\subset L_\infty(\mathbb{R}^d)$, $d \geq 2$, and consequently, functions in $H^1(\mathbb{R}^d)$ can be unbounded in the neigborhood of any fixed point $x \in \mathbb{R}^d$. The decay properties of radial functions can be used to prove compactness of embeddings of radial subspaces into Lebesgue spaces. Let $RH^1(\mathbb{R}^d)$ denote the subspace of $H^1(\mathbb{R}^d)$ consisting of all radial functions in $H^1(\mathbb{R}^d)$. Then

$$RH^1(\mathbb{R}^d) \hookrightarrow\hookrightarrow L_p(\mathbb{R}^d)$$

holds, if $2 < q < q^*$, where $q^* := \infty$ if $d = 2$ and $q^* = \frac{2d}{d-2}$ if $d \geq 3$.
We will give a survey how these classical results extend to functions spaces with fractional order of smoothness like Besov and Lizorkin-Triebel spaces. Also extensions to smoothness spaces built on Morrey spaces (Besov-type spaces) will be discussed.

The Surface Diffusion Flow for Uniformly Regular Hypersurfaces

Gieri Simonett

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We consider the surface diffusion flow acting on a general class of (possibly non–compact) hypersurfaces parameterized over a uniformly regular reference manifold possessing a tubular neighborhood with uniform radius. The surface diffusion flow gives rise to a fourth–order quasilinear parabolic equation with nonlinear terms satisfying a specific singular structure. We establish well–posedness for initial surfaces that are $C^{1+\alpha}$–regular and are parameterized over a uniformly regular hypersurface. As an application, we consider surfaces parameterized over an infinitely long cylinder. Moreover, we establish global existence and convergence results in some cases. (Joint work with J. LeCrone and Y. Shao).

On Evolution Free Boundary Problem for Viscous Fluids of Different Types: Compressible and Incompressible

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The communication is devoted to the problem of evolution of two viscous fluids: compressible and incompressible, separated by a free interface and contained in a bounded vessel. It is assumed that the fluids are subject to the mass and capillary forces. For this problem a unique local solvability is established in the Sobolev-Slobodetskii spaces $W_2^{l,l/2}$; moreover, stability of the rest state (velocity vector field vanishes, pressure and density are constant, free interface is a sphere) is proved.

Fourth Order Elliptic Equations and Positivity

Guido Sweers

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• In general there is no positivity preserving property for the biharmonic Dirichlet problem

$$\Delta^2 u = f \text{ in } \Omega \text{ with } u = \tfrac{\partial}{\partial \nu} u = 0 \text{ on } \partial\Omega. \tag{2.2}$$

Here $\Omega \subset \mathbb{R}^n$ with $n \geq 2$ is a generic bounded and smooth domain. Balls are exceptional cases, where

$$f \geq 0 \implies u \geq 0 \tag{2.3}$$

holds true. When considering a continuous deformation $t \mapsto \Omega_t$ of the ball, one finds, see [2], that the positivity preserving property (2.3) is lost before the positivity of the first eigenfunction is lost.

• In a joint work with Grunau and Robert [1] one finds that the Green function $G_0(x, y)$ for the biharmonic Dirichlet problem on a bounded, smooth domain $\Omega \subset \mathbb{R}^n$ can be written as the difference of a positive function, which bears the singularity at $x = y$, and a rank-one positive function, both of which satisfy the boundary conditions. More precisely: $G_0(x, y) = H(x, y) - c\, d(x)^2 d(y)^2$ holds, where d the distance to the boundary $\partial\Omega$ and H is positive.

In a recent manuscript with Inka Schnieders [3] we consider the case that there is a positive eigenfunction but no positivity preserving property for (2.2). We extend the corresponding estimates from [1] to $G_\lambda(x, y)$, which is the Green function for

$$\left(\Delta^2 - \lambda\right) u = f \text{ in } \Omega \text{ with } u = \tfrac{\partial}{\partial \nu} u = 0 \text{ on } \partial\Omega, \tag{2.4}$$

with an optimal dependance on λ. We show as a consequence that the existence of a strictly positive eigenfunction with a simple eigenvalue λ_i implies a positivity preserving property for (2.4) in a left neighbourhood of λ_i: there is $\varepsilon > 0$ such that for u_λ the solution of (2.4) and $\lambda \in (\lambda_i - \varepsilon, \lambda_i)$ one finds that (2.3) holds for $u = u_\lambda$. Note that ε does not depend on f. This result could be called a converse of Krein-Rutman.

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[3] I. Schnieders, G. Sweers, A biharmonic converse to Krein-Rutman: a maximum principle near a positive eigenfunction, submitted.

Dynamics of a Free Boundary Problem Modeling MEMS

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Idealized electrostatically actuated microelectromechanical systems (MEMS) consist of a fixed ground plate above which an elastic membrane is suspended. Applying a voltage difference between the two components induces a Coulomb force that deforms the membrane. Of particular interest is the dynamics in dependence of the applied voltage as large voltage values may lead to pull-in instabilities. The corresponding mathematical model couples the harmonic electrostatic potential in the angular free domain between membrane and ground plate to a quasilinear singular evolution equation for the membrane displacement. Results will be presented on local and (non-)global well-posedness of the model as well as on existence and non-existence of stationary solutions. This is joint work with J. Escher and Ph. Laurençot.

Regularity Results for Random Field Solutions of Stochastic Evolution Equations

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We present a new approach to the regularity theory of non time dependent stochastic evolution equations of parabolic type, including maximal regularity results. One advantage of this method is that one can view the solution processes as random fields and obtain sharp regularity results for the paths, in particular Hölder continuity. We illustrate this with classes of parabolic stochastic PDE with rough coefficients. An interesting feature of our method is that the optimal trace spaces for initial values are not Besov spaces as in the traditional approach, but rather Triebel Lizorkin spaces.

3 Participants

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4 Notes

International Conference Nonlinear Analysis in Honor of
Herbert Amann´s 80th Birthday
Cortona, June 11-14, 2019

Time	Tuesday	Wednesday	Thursday	Friday
09:00h	Opening			
09:15h-10:00h	**Galdi**	**Da Prato**	**Nistor**	**Lopez-Gomez**
10:15h-11:00h	**Lunardi**	**Kozono**	**Hieber**	**Chipot**
11:00h-11:30h	Coffee Break	Coffee Break	Coffee Break	Coffee Break
11:30h-12:15h	**Sickel**	**Díaz**	**Weis**	**Solonnikov**
12:20h				Closing
12:30h	Lunch Special Event 14.30h-15:00h	Lunch	Lunch	Lunch
15:15h-16:00h	**Rehberg**	**Sweers**	**Guidotti**	
16:15h-17:00h	**Daners**	**Laurençot**	**Schrohe**	
17:00h-17:30h	Coffee Break	Coffee Break	Coffee Break	
17:30h-18:15h	**Walker**	**Sequeira**	**Simonett**	
19:00h-22:00h		Conference Dinner		