Harmonic Analysis and PDEs

University of Nebraska-Lincoln

Conference Program

Friday, April 16th

3:15–3:50 PM	**Reception**	Avery Hall 348 (UNL Campus)
4:00–5:00 PM	**Rowlee Lecture by Carlos Kenig**	Avery Hall 115

Saturday, April 17th

All subsequent conference events will take place at the Holiday Inn Downtown.

7:30 – 8:30 AM	**Breakfast**
8:30 – 9:00 AM	Tuncay Aktosun
9:00 – 9:30 AM	Rodolfo Torres
9:30 –10:00 AM	Edriss Titi
10:00–10:30 AM	**Coffee Break**
10:30–11:00 AM	Walter Littman
11:00–11:30 AM	Gustavo Ponce
11:30–12:00 AM	Carlos Kenig
12:00– 1:30 PM	**Lunch**
1:30 – 2:00 PM	Irena Lasiecka
2:00 – 2:30 PM	Oleg Emanouilov
2:30 – 3:00 PM	Amjad Tuffaha
3:00 – 3:25 PM	Jing Zhang
3:25 – 3:50 PM	**Coffee Break**
3:50 – 4:15 PM	Shitao Liu
4:15 – 4:40 PM	Martina Bukac
4:40 – 5:05 PM	Joseph Eichholz
5:05 – 5:30 PM	Sukjung Hwang
Saturday evening: Conference Banquet (details TBA)	

Sunday, April 18th

7:30 – 8:30 AM	**Breakfast**
8:30 – 9:00 AM	Virginia Naibo
9:00 – 9:30 AM	Carlo Morpurgo
9:30 –10:00 AM	Roberto Triggiani
10:00–10:30 AM	Atanas Stefanov
10:30–11:00 AM	Giles Auchmuty
11:00–12:30 AM	**Break / Lunch**
12:30– 1:00 PM	Milena Stanislavova
1:00 – 1:30 PM	Nanhee Kim
1:30 – 1:55 PM	A. Ozkan Ozer
1:55 – 2:20 PM	Aslihan Demirkaya

Abstracts

Rowlee Lecture

Carlos Kenig (University of Chicago)

Title: The Global Behavior of Solutions to Critical Nonlinear Dispersive and Wave Equations

Abstract. We describe a method (which I call the concentration-compactness/rigidity theorem method) which Frank Merle and I have developed to study global well-posedness and scattering for critical non-linear elliptic problems which were studied earlier, for instance in the context of the Yamabe problem and of harmonic maps. We illustrate the method with some concrete examples and also mention other applications of these ideas.

Aktosun, Tuncay (University of Texas at Arlington)

Title: Explicit formulas for exact solutions to integrable evolution equations.

Abstract. A method is presented to construct exact solutions to certain integrable nonlinear evolution equations that are solvable by the inverse scattering transform method involving a Marchenko integral equation. An explicit formula and its equivalents are obtained for each integrable equation to express such exact solutions in a compact form in terms of a triplet of constant matrices and matrix exponentials. Such exact solutions can alternatively be written explicitly as algebraic combinations of exponential, trigonometric, and polynomial functions of the spatial and temporal coordinates. The method is applicable to various equations such as the Korteweg-de Vries equation, the nonlinear Schrödinger equation, and the sine-Gordon equation. This is joint work with F. Demontis and C. van der Mee from University of Cagliari, Italy.

Auchmuty, Giles (University of Houston)

Title: Reproducing kernels for Hilbert spaces of harmonic functions.

Abstract. This talk will describe a family of Hilbert spaces of real harmonic functions on bounded regions in Rn with mild boundary regularity. The family is parametrized by properties of their boundary values. We shall show that, provided the boundary data is L^2, the corresponding spaces of harmonic functions are reproducing kernel Hilbert (RKH) spaces with respect to a natural inner product. The reproducing kernels are described explicitly using the Steklov eigenfunctions of the domain and include the space of H^1-harmonic functions on a region with a standard inner product. This work extends earlier results of Peetre et al. and J.L. Lions.

Bukac, Martina (University of Houston)

Title: Numerical simulation of arterial blood flow under physiological conditions.

Abstract. We study the flow of an incompressible viscous fluid through a long tube with compliant walls. This problem is motivated by the study of blood flow in large-to-medium arteries. Although blood is a suspension of red blood cells, white blood cells, and platelets in plasma, its non-Newtonian nature is only relevant in small arteries and capillaries where the vessel diameter becomes comparable to the size of the cells. In medium-to-large arteries, such as the coronary arteries (medium) and the abdominal aorta (large), the Navier-Stokes equations for an incompressible viscous fluid are considered to be a good model for blood flow.

The fluid equations are coupled with the equations describing the mechanics of the arterial walls. Even though arterial walls are anisotropic and heterogeneous, and composed of layers with different biomechanical characteristics, a common set of simplifying assumptions includes homogeneity of the material with “small” displacements and “small” deformation gradients leading to the hypothesis of linear elasticity. Following this assumptions, we modeled arterial walls using the linearly viscoelastic cylindrical Koiter shell model.

Demirkaya, Aslihan (University of Kansas)

Title: Conditional stability theorem for the one dimensional Klein-Gordon equation.

Abstract. We explicitly construct the center-stable manifold for the steady state solutions of the one-dimensional Klein-Gordon equation. The main difficulty in the one-dimensional case is that the required decay of the Klein-Gordon

semigroup does not follow from Strichartz estimate alone. In this talk, I will explain how to resolve this issue by proving an additional weighted decay estimate, which will allow us to close the argument.

Eichholz, Joseph (University of Iowa)

Title: Discrete-ordinate discontinuous Galerkin methods for solving the radiative transfer equation.

Abstract. The radiative transfer equation (RTE) occurs in a wide variety of applications. In this talk, we study discrete-ordinate discontinuous Galerkin methods for solving the RTE. The numerical methods are formed in two steps. In the first step, the discrete ordinate technique is applied to discretize the integral operator for the angular variable, resulting in a semidiscrete system. In the second step, the spatial discontinuous Galerkin method is applied to discretize the system. A stability and error analysis is performed on the numerical methods. Some numerical examples are included to demonstrate the convergence behavior of the methods.

This is a joint work with Weimin Han and Jianguo Huang.

Emanouilov, Oleg (Colorado State University)

Title: Partial Cauchy data for general second order elliptic operators in two dimensions.

Abstract. We consider the problem of determining the coefficients of a second order elliptic operator in two dimensions by measuring the corresponding Cauchy data on an arbitrary open subset of the boundary. We show for a simply connected domain that one can determine the coefficients of the operator up to the natural obstruction from this information. Most of the results follow by considering the same problem for a first order perturbation of the Laplacian. From this information we obtain a coupled system of $\partial_{\bar{z}}$ and ∂_z which Another consequence of our result is that the magnetic field and the electric potential are uniquely determined by measuring the partial Cauchy data associated to the magnetic Schrödinger equation measured on an arbitrary open subset of the boundary. of the boundary. We also show that the coefficients of any real vector field perturbation of the Laplacian, the convection terms, are uniquely determined by their partial Cauchy data.

Hwang, Sukjung (Iowa State University)

Title: Bridges between the degenerate and singular cases on quasilinear parabolic equations.

Abstract. After De Giorgi and Moser proved a big theorem on regularity theory for linear elliptic equations, Ladyzhenskaja and Uraltseva adopted De Giorgis idea for quasilinear elliptic equations, whereas Serrin and Trudinger worked with Mosers idea for quasilinear elliptic equations. Later DiBenedetto proved Hölder continuity for solutions of quasilinear parabolic equations using an intrinsic scaling idea. The details of DiBenedettos proof depend on whether the equation is degenerate or singular. People have worked to build a bridge between degenerate and singular equations and huge success on the elliptic equations have been achieved by Lieberman. Our main topic is finding a bridge between degenerate and singular cases in the parabolic equations.

Kenig, Carlos (University of Chicago)

Title: Homogenization for elliptic boundary value problems with periodic coefficients on Lipschitz domains.

Abstract. In joint work with Zhongwei Shen we have established uniform estimates for boundary value problems for dilates of symmetric second order elliptic systems with periodic coefficients, on Lipschitz domains. These problems arise in homogenization and are extensions of works of Avellaneda and Lin for the Dirichlet problem in smooth domains.

Kim, Nanhee (Wichita State University)

Title: Carleman estimates with two large parameters and their applications.

Abstract. This talk will be on Carleman estimates with two large parameters for general second order partial differential operators and their applications to elasticity with residual stress. We recently obtained these results by using differential quadratic forms and Fourier analysis. We discuss Hölder and Lipschitz stabilities for the Cauchy problem. We also discuss applications to inverse problem of the identification of elasticity systems with residual stress. We think that these results can be extended onto Schrödinger type equations and therefore onto systems for plates and shells.
This is a joint work with Victor Isakov.

Lasiecka, Irena (University of Virginia)

Title: Well-posedness of weak and strong solutions in nonlinear flow of gas and structure interactions.

Abstract. Dynamics for a class of nonlinear hyperbolic systems modeling gas-flow interactions will be considered. These are Euler equations (flow of gas) coupled at the interface with nonlinear plate (structure) equations. The coupling leads to non-conservative and non-dissipative models with supercritical sources. Both subsonic and supersonic flows will be considered. One of the main difficulties encountered in the analysis is due to the loss of ellipticity for the static operator describing the supersonic flow. This leads to the loss of coercivity in the corresponding potential energy. In order to deal with these PDE difficulties, harmonic analysis and microlocal tools will be developed and appropriately employed. It will be shown that finite energy solutions do exist globally, are unique and satisfy Hadamard wellposedness criterium.

Littman, Walter (University of Minnesota)

Title: Boundary control of two PDE's separated by interface conditions.

Abstract. We discussion the null boundary controllability of two PDE's, modelling a composite solid with different physical properties in each layer. Interface conditions are imposed.
This is a joint work with Orazio Arena.

Liu, Shitao (University of Virginia)

Title: Inverse problem for a wave equation.

Abstract. I would like to present an inverse problem about the wave equation with time-independent potential and Neumann boundary data. More precisely, let $\Omega \subset \mathbb{R}^n$, $n \geq 2$, be a bounded domain and its boundary $\Gamma = \partial\Omega$ be of class C^2, consisting of the closure of two disjoint parts: $\Gamma = \overline{\Gamma_0 \cup \Gamma_1}$, $\Gamma_0 \cap \Gamma_1 = \emptyset$. We consider the following wave equation:

$$\begin{cases} w_{tt}(x,t) = \Delta w(x,t) + q(x)w(x,t) & \text{in } Q = \Omega \times [0,T] \\ w(\cdot, T/2) = w_0(x) & \text{in } \Omega \\ w_t(\cdot, T/2) = w_1(x) & \text{in } \Omega \\ \frac{\partial w}{\partial \nu}(x,t) = g(x,t) & \text{in } \Sigma = \Gamma \times [0,T] \end{cases} \tag{1}$$

and the following *nonlinear inverse problem*: Let $w = w(q)$ be a weak solution to the equation under some geometrical conditions on Γ_0; is it possible to retrieve the potential $q(x)$, $x \in \Omega$, from the measurements of $w(q)$ on $\Sigma_1 = \Gamma_1 \times [0,T]$?

This is a joint work with Roberto Triggiani.

Morpurgo, Carlo (University of Missouri, Columbia)

Title: Adams inequalities on measure spaces.

Abstract. In 1988 David Adams obtained sharp Moser-Trudinger inequalities on bounded domains of $\mathbb{R}^n$. The main step was a sharp exponential integral inequality for convolutions with the Riesz potential. In a joint paper with Luigi Fontana we extend and improve Adams' results to functions defined on arbitrary measure spaces with finite measure. The Riesz fractional integral is replaced by general integral operators, whose kernels satisfy suitable and explicit growth conditions, given in terms of their distribution functions; natural conditions for sharpness are also given. Most of the known results about Moser-Trudinger inequalities can be easily adapted to our unified scheme. New applications of our theorems include: sharp higher order Moser-Trudinger trace inequalities, sharp Adams/Moser-Trudinger inequalities for general elliptic differential operators (scalar and vector-valued), for sums of weighted potentials, and for operators in the CR setting.

Naibo, Virginia (Kansas State University)

Title: Bilinear pseudo-differential operators: recent developments on symbolic calculus.

Abstract. Since the pioneering work of Coifman and Meyer in the 70's, the theory of bilinear pseudodifferential operators has greatly developed due to their applications in analysis and PDE's.

In this talk new results on bilinear pseudodifferential operators with symbols in the bilinear analog of all the Hörmander classes are discussed. In particular, precise results about which classes are closed under transposition and can be characterized in terms of asymptotic expansions are presented. Applications include new estimates in the form of Leibniz' rule and alternative ways to recover the boundedness on products of Lebesgue spaces for the classes that yield operators with bilinear Calderón-Zygmund kernels. This is joint work with Árpád Bényi, Diego Maldonado, and Rodolfo Torres.

Ozer, Ahmet Ozkan (Iowa State University)

Title: Boundary feedback stabilization of an undamped multi-layer Rao-Nakra beam.

Abstract. We consider the boundary feedback stabilization of an undamped Multi-Layer Rao-Nakra sandwich beam. We prove the Riesz basis property for the uncoupled system and show that the uncoupled system is exponentially stable. Furthermore, we show that the semigroup of the coupled system is the compact perturbation of the one of the uncoupled system. Then the exponential stability of the coupled system follows directly from the strong stability of the coupled system.

Ponce, Gustavo (University of California-Santa Barbara)

Title: On the IVP for the Benjamin-Ono equation in weighted Sobolev spaces.

Abstract. We consider the initial value problem for the Benjamin-0no equation (and its generalized form) in weighted Sobolev spaces $Z_{s,b} = H^s(\mathbb{R}) \cap L^2(|x|^{2b}dx)$ with $s \geq 1$, and $s \geq b$, with $s, b \in [0, \infty)$. We deduce necessary and sufficient conditions for the persistence property of the solution flow to hold in this spaces $Z_{s,b}$. These results extend previous ones due to R. I. Iorio.

Stanislavova, Milena (University of Kansas)

Title: Stability analysis for stationary solutions of the Kuramoto-Sivashinsky equation.

Abstract. We consider the problem for conditional stability of the stationary solutions of the Kuramoto-Sivashinsky equation in the periodic setting. We establish rigorously the general structure of of the spectrum of the linearized operator, in particular the linear or spectral instability of steady states. In addition, we show conditional asymptotically stability with asymptotic phase, under a natural spectral hypothesis for the linearized operator.

Stefanov, Atanas (University of Kansas)

Title: Global regularity for quadratic wave equations in high dimensions.

Abstract. We show global persistence of solutions with small data for the model equation $\Box u = u \cdot \nabla u + u^3$, on $\mathbb{R}^{1+d}, d \geq 5$, subject to the Coulomb gauge condition $\text{div}(u) = 0$. In particular, this covers the important case of the Yang-Mills problem, $d \geq 5$.

Titi, Edriss (Weizmann Institute of Science and University of California, Irvine)

Title: Mathematical study of certain geophysical models.

Abstract. The basic problem faced in geophysical fluid dynamics is that a mathematical description based only on fundamental physical principles, the so-called the "Primitive Equations", is often prohibitively expensive computationally, and hard to study analytically. In this talk I will survey the main obstacles in proving the global regularity for the three-dimensional Navier-Stokes equations and their geophysical counterparts. However, taking advantage of certain geophysical balances and situations, such as geostrophic balance and the shallowness of the ocean and atmosphere, geophysicists derive more simplified and manageable models which are easier to study analytically. In particular, I will present the global well-posedness for the three dimensional Benard convection problem in porous media, and the global regularity for a three-dimensional viscous planetary geostrophic models. Furthermore, these systems will be shown to have finite dimensional global attractors.

Even though the Primitive Equations look as if they are more difficult to study analytically than the three-dimensional Navier-Stokes equations I will show in this talk that they have a unique global (in time) regular solution for all initial data.
This is a joint work with Chongsheng Cao.

Triggiani, Roberto (University of Virginia)

Title: Uniform energy decay rates of some non-linear boundary dissipative problems: from Schrödinger equations to the system of dynamic elasticity.

Abstract. We shall consider several dynamics, including: (i) Schrödinger equations with non-linear boundary (and interior) dissipation in the Neumann BC and in the state space L2; (ii) wave equations and (iii) the system of dynamic elasticity with a non-linear, non-local boundary (and interior) dissipation in the Dirichlet BC and in the state space $L^2 \times H^{-1}$. In each case, we shall provide uniform energy results with optimal decay rates. For the last 2 cases we shall present a (deliberately) non-direct approach based on an intriguing and hard-to-prove boundary $\to$ boundary (B^*L) regularity result, which requires micro-local analysis. This property happens to hold true for these dynamics (but fails for some

other dynamics: e.g. wave with Neumann BC in the state space $H^1 \times L^2$). For the first case, we shall present, instead, a direct approach. In all cases, we shall fall, via energy estimates, into the Lasiecka-Tataru strategy, originally introduced (1992) in the case of waves with non-linear boundary dissipation in the Neumann BC and in the state space $H^1 \times L^2$. The talk is based on several recent joint papers with I. Lasiecka.

Torres, Rodolfo (University of Kansas)

Title: Sobolev space estimates for a class of bilinear pseudodifferential operators unbounded on Lebesgue spaces.

Abstract. We will describe the reappearance of a sometimes called exotic behavior of certain classes of pseudodifferential operators. We will show that an anomalous phenomenon is also present in a recently introduced class of bilinear pesudo-differential operators, which can be seen as variable coefficient counterparts of the bilinear Hilbert transform and other singular bilinear multipliers operators. These operators are in general unbounded on products of Lebesgue spaces but bounded on spaces of smooth functions. This is joint work with Frederic Bernicot.

Tuffaha, Amjad (University of Southern California)

Title: Strong solutions to a Navier-Stokes-Lame fluid-structure interaction system.

Abstract. In this talk I consider the existence of local-in-time strong solutions to a well established coupled system of partial differential equations arising in Fluid-Structure interactions. The system consists of an incompressible Navier-Stokes equation and an elasticity equation with velocity and stress matching boundary conditions at the interface in between the two domains where each of the two equations is defined. I discuss new existence results for a range of regularity in the initial data as well as the differences in the existence results when domains with non-flat boundaries are considered.

Zang, Jing (University of Virginia)

Title: Uniform stabilization for the system of elasticity with Dirichlet boundary control with geometric condition on the boundary.

Abstract. Let Ω be an open bounded domain in $\mathbb{R}^3$ with boundary Γ satisfying certain geometric condition. We consider the following elastic dynamical system

$$\begin{cases} \mathbf{w}_{tt} = L\mathbf{w} & \text{in} \quad Q^T; \\ \mathbf{w}(0,x) = \mathbf{w}_0(x) & \text{in} \quad L_2(\Omega); \\ \mathbf{w}_t(0,x) = \mathbf{w}_1(x) & \text{in} \quad H^{-1}(\Omega); \\ \mathbf{w}|_\Gamma = \mathbf{u}(t,x) & \text{in} \quad \Sigma^T \end{cases}$$

where Q^T denotes $\Omega \times (0,T)$ and Σ^T denotes $\Gamma \times (0,T)$ for $T \in (0,\infty)$. The operator L represents the operator for system of elasticity, which acts on $\mathbb{R}^3$-valued functions.

We seek to express the nonhomogenous Dirichlet boundary term $\mathbf{u}(t,x)$ as a suitable linear feedback operator of the velocity $\mathbf{w}_t$, so that the whole system becomes a closed loop dissipative system and generates a strongly continuous contraction semigroup. We also show that the energy for this system decay exponentially with time t by lifting the level of energy space and applying energy methods.