# KUMUNU 2017

## University of Nebraska-Lincoln

## Conference Schedule

April 22, 2017 (Saturday)

| Start | End | Event | Location |
|---|---|---|---|
| 8:00 am | 8:45 am | *Registration and Coffee* | Outside Avery 115 |
| 8:45 am | 9:00 am | *Opening Remarks* | Avery 115 |
| 9:00 am | 10:00 am | **Lorena Bociu** | Avery 115 |
| 10:00 am | 10:30 am | **Zhiwu Lin** | Avery 115 |
| 10:30 am | 10:45 am | *Coffee Break* | Outside Avery 115 |
| 10:45 am | 11:15 am | **Pelin Güven Geredeli** | Avery 115 |
| 11:15 am | 11:45 am | **Justin T. Webster** | Avery 115 |
| 11:45 am | 12:15 pm | **Atanas Stefanov** | Avery 115 |
| 12:15 pm | 1:45 pm | *Lunch* | |
| 1:45 pm | 2:45 pm | **Marta Lewicka** | Avery 115 |
| 2:45 pm | 3:15 pm | **Edriss Titi** | Avery 115 |
| 3:15 pm | 3:45 pm | **Mihaela Ignatova** | Avery 115 |
| 3:45 pm | 4:00 pm | *Coffee Break* | Outside Avery 115 |
| 4:00 pm | 5:00 pm | **Anna Mazzucato** | Avery 115 |
| 5:00 pm | 5:30 pm | **Giles Auchmuty** | Avery 115 |
| 5:30 pm | 6:00 pm | **Nicholas J. Kass** | Avery 115 |
| 6:15 pm | 7:30 pm | *Poster Session* | Nebraska Union, Heritage Room |
| 7:30 pm | | *Dinner* | Nebraska Union, Regency Room |

April 23, 2017 (Sunday)

| Start | End | Event | Location |
|---|---|---|---|
| 9:00 am | 10:00 am | **Luz de Teresa** | Avery 115 |
| 10:00 am | 10:30 am | **Ying Wang** | Avery 115 |
| 10:30 am | 11:00 am | **Louis Tebou** | Avery 115 |
| 11:00 am | 11:30 am | **Anna Ghazaryan** | Avery 115 |
| 11:30 am | 12:00 pm | **Scott Hansen** | Avery 115 |

# Contents



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# 1 Talk Abstracts

**Giles Auchmuty** (University of Houston)
*The S.V.D. of the Poisson Kernel*

The solution operator for the Dirichlet problem for the Laplacian on a bounded region in $\mathbb{R}^n$ is often called the Poisson kernel and represented as an integral operator. Fichera (1955) proved, under strong regularity conditions on the boundary, that it is a continuous linear transformation of $L^2(\partial\Omega)$ to $L^2(\Omega)$. He also found that it has norm related to the first eigenvalue of a Steklov eigenproblem for the biharmonic operator on $\Omega$.

The operator may also be regarded as an extension operator from the boundary data to the subspace of $L^2$-harmonic functions on $\Omega$. In this talk I will first outline what boundary regularity results imply that this operator is compact. Then orthogonal bases of the domain and range are found and shown to provide an S.V.D of the operator. These bases are related to the eigenfunctions of the Dirichlet Biharmonic Steklov eigenproblem and the singular values are related to the eigenvalues of this problem.

**Lorena Bociu** (North Carolina State University)
*Fluid Flows Through Deformable Porous Media: Analysis and Applications to Ocular Perfusion*

Modeling of fluid flows through porous deformable media is relevant for many applications in biology, medicine and bioengineering, including blood flow through human tissues and fluid flow inside cartilages and bones. These fluid-structure mixtures are described mathematically by nonlinear poro-visco-elastic systems in bounded domains, with mixed boundary conditions. In this talk, we present well-posedness results for these models, and investigate the influence of structural viscoelasticity on the solution and on the regularity requirements for the forces present in the system. Lastly, we discuss applications of our results in the case of blood flow through ocular tissues, and the connections to the development of glaucoma.

**Pelin Geredeli** (Hacettepe University, Annkara, Turkey)
*A Wellposedness and Stability Analysis for a Compressible Flow-Structure PDE Model*

In this talk, we present recently derived results of wellposedness and stability for a coupled partial differential equation (PDE) system which models a compressible fluid-structure interaction of current interest within the mathematical literature. The coupled PDE model under discussion will involve a linearized compressible viscous fluid flow evolving within a 3-D cavity, and a linear elastic plate–in the absence of the rotational inertiawhich evolves on a portion of the fluid cavity wall. Since the fluid equation component is the result of a careful linearization of the compressible Navier-Stokes equations about an arbitrary state, this interactive PDE component will include a nontrivial ambient flow profile, which tends to complicates the analysis. Moreover, there is an additional coupling PDE which determines the associated pressure variable of the fluid-structure system. We give a result of wellposedness for (sufficiently smooth) arbitrary ambient flow field. Furthermore, under an additional assumption on the ambient state, we are in a position to provide results of decay in large time.

**Anna Ghazaryan** (Miami University)
*Traveling Waves in a Population Model for Mussel-Algae Interaction*

I will discuss traveling waves in a model that describes formation of mussel beds on soft sediments. The model consists of nonlinearly coupled PDEs that capture evolution of mussel biomass on the sediment and algae in the water layer overlying the mussel bed. The system accounts for the diffusive spread of mussel, while the diffusion of algae is neglected and at the same time the tidal flow of the water is considered to be the main source of transport for algae, but does not affect mussels, therefore both the diffusion and the advection matrices in the system are singular. We use Geometric Singular Perturbation theory to analytically study wave formation mechanisms in this system. This is a joint work with V. Manukian.

**Scott Hansen** (Iowa State University)
*Exact Controllability Spaces of a Class of PDEs Involving an Internal Point Mass*

It is known that a 1-d wave equation with an internal point mass subject to boundary control at one end is exactly controllable on an asymmetric Sobolev space which differs by one Sobolev order across the point mass. In the case of a Schrödinger equation the description of the EC spaces is more complex as the spaces can be symmetric, asymmetric or a combination, depending upon coefficients and boundary conditions. We present a characterization of the spaces for the case of Dirichlet control at one end. We also discuss the nature of the EC spaces for the case of an EB beam with an internal point mass.

**Mihaela Ignatova** (Princeton University)
*Critical SQG in bounded domains*

We establish nonlinear lower bounds (nonlinear maximum principle) and commutator estimates for the Dirichlet fractional Laplacian in bounded domains. As an application global existence of weak solutions of critical SQG were obtained. We prove global a priori interior Hölder bounds for large data. This is a joint work with Peter Constantin.

**Nicholas Kass** (University of Nebraska-Lincoln)
*Weak solutions for damped wave equations of the p-Laplacian type with boundary sources*

Results on the existence of suitably defined weak solutions of a damped wave equation propagated by the $p$-Laplacian with boundary sources are given using a Galerkin scheme, with particular attention given to the convergence of the nonlinearities arising from the $p$-Laplacian. It is shown that these solutions must satisfy an appropriate energy inequality, and from this sufficient conditions for global existence are obtained.

**Marta Lewicka** (University of Pittsburgh)
*A Model of Controlled Growth*

We consider a free boundary problem for a system of PDEs, modeling the growth of a biological tissue. A morphogen, controlling volume growth, is produced by specific cells and then diffused and absorbed throughout the domain. The geometric shape of the growing tissue is determined by the instantaneous minimization of an elastic deformation energy, subject to a constraint on the volumetric growth. For an initial domain with $C^{2,\alpha}$ boundary, our main result establishes the local existence and uniqueness of a classical solution, up to a rigid motion. This is a joint work with Alberto Bressan.

**Zhiwu Lin** (Georgia Institute of Technology)
*Invariant Manifolds for Supercritical KDV Equation*

Consider generalized KDV equations with a power non-linearity $(u^p)_x$. These KDV equations have solitary traveling waves, which are linearly unstable when $p \geq 5$ (supercritical case). Jointly with Jiayin Jin and

Chongchun Zeng, we constructed invariant manifolds (stable, unstable and center) near the orbit of the unstable traveling waves in the energy space. In particular, the local uniqueness and orbital stability of the center manifold is obtained. These invariant manifolds give a detailed description of the dynamics near unstable traveling waves.

**Anna Mazzucato** (Pennsylvania State University)
*Mixing and Transport by Incompressible Flows*

I will discuss recent results on optimal mixing and stirring of passive scalars, such as pollutants, advected by incompressible flows. In particular, I will show a construction of optimal mixers under physical constraints, such as an energy or enstrophy budget. This construction also gives a loss of regularity result for transport equation by irregular (non-Lipschitz) flows.

**Atanas Stefanov** (University of Kansas)
*On the Global Regularity of the Boussinesq System*

We consider the Boussinesq system, which features a Navier-Stokes type equation for the velocity of a fluid, coupled to its temperature, which is also advected by the flow. Both equations are subjected to fractional dissipation operators. The main result is that the system admits global regular solutions for all (reasonably) smooth and decaying data for a substantial portion of the dissipative parameters domain. The main new idea is the introduction of a new, second generation Hmidi-Keraani-Rousset type, change of variables, which further improves the linear derivative in temperature term in the vorticity equation, which allows us to considerably improve the domain of the parameters. This is complemented by new set of commutator estimates for fractional Laplacians, which may be of independent interest. Based on joint work with F. Hadadifard.

**Louis Tebou** (Florida International University)
*Carleman Inequalities for the Wave Equation with Dynamic Wentzell Boundary Conditions*

We consider the wave equation with mixed boundary conditions in a bounded domain; on one portion of the boundary, we have dynamic Wentzell boundary conditions, and on the other portion, we have homogeneous Dirichlet boundary conditions. First, using an appropriate geometric partition of the boundary, we prove some Carleman estimates for this system. Then, we apply those estimates to prove a boundary controllability result for a nonconservative model of the system under consideration. Our results improve earlier Carleman estimates and boundary controllability results established in the Dirichlet boundary conditions setting.

**Luz de Teresa** (Instituto de Mathemátics, National Autonomous University of Mexico)

*New Phenomena on the Null Controllability of Parabolic Systems*

One of the primary goals of control theory is to drive the state of a system to a given configuration using a control that acts through a source term located inside the domain or through a boundary condition. Reference works for linear parabolic problems are due to H. O. Fattorini & D. L. Russell in the 70's for the one-dimensional case; to A. V. Fursikov & O.Yu. Imanuvilov and G. Lebeau & L. Robbiano, both in the 90's, for the multi-dimensional case. They established null-controllability of heat equations with distributed or boundary controls in arbitrary time and for any control domain. The goal of this talk is to give an overview of the recent developments on the controllability of parabolic coupled equations. Through simple examples, I will show that new phenomena appear as a minimal time of control and the dependence on the location of the control. The presentation is based on work in collaboration with Farid Ammar-Khodja, Assia Benabdallah and Manuel González-Burgos.

**Edriss Titi** (The Weizmann Institute of Science and Texas A&M University)
*Some Remarks on a Generalization of the Bardos-Tartar Conjecture for Nonlinear Dissipative PDEs*

In this talk I will show that every solution of a KdV-Burgers-Sivashinsky type equation blows up in the energy space, backward in time, provided the solution does not belong to the global attractor. This is a phenomenon contrast to the backward behavior of the periodic 2D Navier-Stokes equations studied by Constantin, Foias, Kukavica and Majda, but analogous to the backward behavior of the Kuramoto-Sivashinsky equation discovered by Kukavica and Malcok. I will also discuss the backward behavior of solutions to the damped driven nonlinear Schrödinger equation, the complex Ginzburg-Landau equation, and the hyperviscous Navier-Stokes equations. In addition, I will provide some physical interpretation of various backward behaviors of several perturbations of the KdV equation by studying explicit cnoidal wave solutions. Furthermore, I will discuss the connection between the backward behavior and the energy spectra of the solutions. The study of backward behavior of dissipative evolution equations is motivated by a conjecture of Bardos and Tartar which states that the solution operator of the two-dimensional Navier-Stokes equations maps the phase space into a dense subset in this space.

**Ying Wang** (University of Oklahoma)
*Mathematical Analysis and Numerical Methods for an Underground Oil Recovery Model*

In this talk, I will discuss a multi-scale underground oil recovery model which include a third-order mixed derivatives term resulting from the dynamic effects in the pressure difference between the two phases. Analytic study on the computational domain reduction will be provided. A variety of numerical examples in both one and two space dimensions will be given. They show that the solutions may have many different saturation profiles depending on the initial conditions, diffusion parameter, and the third-order mixed derivatives parameter. The results are consistent with the study of traveling wave solutions and their bifurcation diagrams.

**Justin Webster** (College of Charleston)
*Modeling Challenges for the Flutter of a Cantilevered Structure in a Flow*

Flutter is a (bounded response) instability brought about by the interaction of an elastic structure in a surrounding fluid flow. Here, we describe the difficult problem of modeling the flutter phenomenon for plates (or beams), when a portion of the structures boundary is free and the flow is along the principle axis. Much can be said at the qualitative level about flag, flap, and wing flutter; these phenomena are of great interest in engineering. Mathematically, there is a lack of well-posedness and long-time analysis. Beyond the obvious applications in aeroscience, the flutter phenomenon arises in: the biomedical realm and sustainable energies. We begin by discussing some recent results for mathematical models of panel flutter, a simpler situation involving a fully clamped structure. We then discuss the ways in which this analysis breaks down when a portion of the structures boundary is free. We review two classes of pertinent beam models (including the recent inextensible models proposed by Dowell et al). The analytical challenges in the analysis can be viewed as reflections of the difficulty in modeling the physics of the problem. Recent results will be discussed which address well-posedness and in/stability of various cantilevered dynamics, along with recent numerical simulations.

## 2 Poster Session Abstracts

**Lucas Castle** (North Carolina State University)
*Optimal Control in a Free Boundary Fluid Elasticity Interaction*

We consider an optimal control for the problem of minimizing flow turbulence in the case of a nonlinear fluid-structure interaction model. If the initial configuration is regular, then a class of sufficiently smooth control inputs contains an element that minimizes, within the control class, the vorticity of the fluid flow around a moving and deforming elastic solid. We establish this existence and derive the first order optimality conditions on the optimal control.

**Sutthirut Charoenphon** (University of Memphis)
*Vanishing Relaxation Time Dynamics of the Moore-Gibson-Thompson (MGT) Equation Arising in High Frequency Ultrasound*

The MGT equation is a model describing acoustic wave propagation and arises as a model of high-frequency ultrasound (HFU) waves. The dynamic response of MGT depends on the relaxation parameter $\tau$, which accounts for the finite speed of propagation-thus eliminates the so called infinite speed of propagation paradox. Since $\tau$ is relatively small, it is important to trace the dynamics with vanishing parameter $\tau \to 0$. It is shown that the decay rates for the finite energy are preserved uniformly. The corresponding result provides not only a robust stabilizing mechanism for HFU waves but also leads to a new "higher energy" stability estimates.

**Kyle Claassen** (University of Kansas)
*Numerical Bifurcation and Spectral Stability of Wavetrains in Bidirectional Whitham Models*

We provide a numerical investigation of periodic traveling wave solutions in a handful of bidirectional Whitham water wave models, which are nonlocal and possess the same dispersion relation as the full Euler equations. Most notably, while unidirectional and bidirectional Whitham models both demonstrate modulational instabilities, we find that the bidirectional Whitham models also exhibit high-frequency instabilities for waves of sufficiently large amplitude.

**Thomas Clark** (Dordt College)
*Modeling Lotic Organism Populations with Partial Differential Equations*

We present a mathematical model for a population of caddisfly larvae in the Upper Mississippi River, which can either live in the current of the water or fix themselves to large wood debris submerged throughout the river. The model consists of a system of partial differential equations which captures these coupled dynamics. After introducing the model, we give a qualitative analysis of the dynamics, which includes a steady state solution followed by a numerical solution to the system using a finite difference scheme implemented in R. Finally, we extend the model to a competitive system with the goal of capturing the dynamics of the interaction between native caddisfly larvae and invasive zebra mussels. Our results demonstrate that although analyzing the exact behavior of lotic organism populations remains a difficult task, utilizing mathematical models such as the one presented in this paper can lead to further knowledge regarding which characteristics of lotic organisms have greatest influence over population growth.

**Luca Codenotti** (University of Pittsburgh)
*Visualization of anomalous $\mathcal{C}^{1,\alpha}$ solutions to the Monge Ampére equation*

We numerically implement the first steps in the constructions of the anomalous $\mathcal{C}^{1,\alpha}$ solutions of the Monge Ampére equation. A Nash-Kuiper iterative scheme is used to create an algorithm which returns the approximate solutions. Our method follows a result by Lewicka and Pakzad which proved the density of $C^{1,\alpha}$

with $\alpha < \frac{1}{7}$ solutions in the space of continuous functions. Calculations and images are provided for several examples of the right hand side function.

**Aslihan Demirkaya** (University of Hartford)
*Kink Dynamics in a Parametric $\phi^6$ System: A Model With Controllably Many Internal Modes*

In the present work, we intend to explore a variant of the $\phi^6$ model originally proposed in Phys. Rev. D 12, 1606 (1975) as a prototypical, so-called, "bag" model where domain walls play the role of quarks within hadrons. We examine the prototypical steady state of the model, namely an apparent bound state of two kink structures. We explore its linearization and find that as a function of a prototypical parameter controlling the curvature of the potential an effectively arbitrary number of internal modes may arise in the point spectrum of the linearized analysis. We intend to use Evans function analysis to predict the bifurcation points of the relevant internal modes and confirm these theoretical predictions numerically. Finally, given the remarkable flexibility of the model in possessing different numbers of internal modes we once again intend to explore the dynamics of multi-bound-state collisions to identify the role of the additional internal modes in enhancing the complexity of the observed scattering scenarios.

**Wen Feng** (University of Kansas)
*Stability of Vortex Solitons for the $n$-dimensional Focusing NLS*

We consider the nolinear Schrödinger equation in n space dimension

$$iu_t + \triangle u + |u|^{p-1}u = 0,\ x \in \mathbb{R}^n,\ t > 0$$

and study the existence and stability of standing wave solutions of the form

$$\begin{cases} e^{iwt}e^{i\sum_{j=1}^{k} m_j\theta_j}\phi_w(r_1, r_2, \cdots, r_k), & n = 2k \\ e^{iwt}e^{i\sum_{j=1}^{k} m_j\theta_j}\phi_w(r_1, r_2, \cdots, r_k, z), & n = 2k+1 \end{cases}$$

For $n = 2k$, $(r_j, \theta_j)$ are polar coordinates in $\mathbb{R}^2$, $j = 1, 2 \cdots, k$; for $n = 2k+1$, $(r_j, \theta_j)$ are polar coordinates in $\mathbb{R}^2$, $(r_k, \theta_k, z)$ are cylindrical coordinates in $\mathbb{R}^3$, $j = 1, 2 \cdots, k-1$. We show the existence of such solutions as minimizers of a constrained functional and conclude from there that such standing waves are stable if $1 < p < 1 + 4/n$.

**Stephen Guffey** (University of Memphis)
*Control and Analysis for a Partial Differential Equation Model Arising in Wound Healing*

Chronic wounds, ones that do not heal within a period of 30 days, affect 1.3 to 3 million Americans. The United States spends an estimated \$5-\$10 billion each year in the treatment of these wounds. In this work we investigate a partial differential equation chemotaxis model arising in wound healing. We start our investigation with finding local solutions to the system utilizing maximal regularity arguments. We also include a specific PDE model in the case of a radially-symmetric wound.

**Jessie Jamieson** (University of Nebraska-Lincoln)
*Beam me up, Scotty!*

In this poster, we take a tour of the seminal result by John Lagnese on the wellposedness of a nonlinear elasticity model that represents a beam analogue of the von Karman plate. Interest in nonlinear beams has been recently reinvigorated by the study of aeroelastic flutter, as lower dimensional simulations of beams in 2D flow provide many insights into the phenomenon. To facilitate further analytic and numerical study of the von Karman beam, we revisit Lagnese's proof and provide a more streamlined version thereof using the framework of locally Lipschitz perturbations of $m$-accretive operators.

**Adam Larios** (University of Nebraska-Lincoln)
*Nonlinear Continuous Data Assimilation*

We will present new nonlinear continuous data assimilation algorithms. These models will be compared with the linear continuous data assimilation algorithm introduced by Azouani, Olson, and Titi (AOT). As a proof-of-concept for these models, we computationally investigate these algorithms in the context of the 1D Kuramoto-Sivashinsky equation. We observe that the nonlinear models experience super-exponential convergence in time.

**Hung Le** (University of Missouri)
*Elliptic Equations with Transmission and Wentzell Boundary Conditions and an Application to Steady Water Waves in the Presence of Wind*

We present results about the existence and uniqueness of solutions of elliptic equations with transmission and Wentzell boundary conditions. We provide Schauder estimate in Hölder and Sobolev spaces. As an application, we develop existence theory for small-amplitude two dimensional traveling waves in an air–water system with surface tension. The water region is assumed to be irrotational and of finite depth, and we permit a general distribution of vorticity in the atmosphere.

**Shasha Liao** (Georgia Institute of Technology)
*Nonlinear Modulational Instability of Dispersive PDE Models*

Joint with Jiayin Jin and Zhiwu Lin, we prove the nonlinear modulational instability for a lot of dispersive models including nonlinear Schrödinger equation, BBM and KdV type equations (Benjamin-Ono, KDV, Whitham etc.). Under both periodic and localized perturbations, we provide two methods to study the nonlinear instability of periodic traveling waves under two different types of assumptions on the equations. The main ingredients in the proof are: for the linear step, the semigroup estimates are obtained by using the Hamiltonian structures of the linearized PDEs; for the nonlinear step, the loss of derivative for smooth nonlinear terms is overcome by the construction of higher order approximation solutions, and for $C^1$ nonlinear terms by using bootstrap strategy.

**Juan Lopez** (University of Houston)
*Finite Energy Solutions of Axisymmetric Div-Curl Problems on Bounded Domains*

Some results on the finite energy solutions of axisymmetric div-curl problems are presented. The poloidal and toroidal decomposition permit a decoupling of the divergence and curl equations. The poloidal part of the problem is treated through the use of orthogonal projections onto special gradient, curl, and harmonic subspaces, while the toroidal part is treated separately. The gradient and curl potentials are used to analyze the behavior arising from the prescribed divergence and curl, and the harmonic component may be used to analyze the behavior due to the prescribed normal or tangential trace.

**Rasika Mahawattege** (University of Memphis)
*Optimal Control Theory for a Fluid-Structure Interaction Model Arising in Biology*

We consider a fluid-structure interaction model arising in the biological sciences. Consider a doughnut-like domain: a fluid occupies the exterior subdomain, while an elastic structure occupies the interior subdomain. They are described by the corresponding evolution equations which present strong coupling at the interface between the two domains. A key factor—a novelty over past literature—is that the structure equation includes a term defining strong damping at the interior. We establish several mathematical results describing the character of the overall evolution either free or else under the action of a control at the interface or at the exterior boundary.

**Satbir Malhi** (University of Kansas)
*Optimal Damping for Exponential Energy Decay in 1D Wave Equation*

We consider the following damped wave equation on $\mathbb{R} \times \mathbb{R}$ :

$$u_{tt} - \Delta u + u + \gamma(x) u_t = 0, \tag{1}$$

where $\gamma(x) \geq 0$ for all $x$. We study the optimal conditions on the damping coefficient $\gamma(x)$ under which the solution of (1) decay exponentially. This is achieved via new functional analytic approach, which translates the conditions in terms of a damping operator. We prove that the semigroup associated with (1) decays exponentially as long as the damping operator is a bounded linear operator mapping $L^2(\mathbb{R})$ to $L^2(\mathbb{R})$. We also provide several examples that fit this framework.

**Giusy Mazzone** (Vanderbilt University)
*Long-time Dynamics of Rigid Bodies With a Liquid-filled Gap*

We consider the fluid-solid interactions occurring when a viscous incompressible fluid (simply called liquid) is confined to move in a bounded domain between two rotating rigid bodies. More precisely, let $\mathcal{B}_1$ and $\mathcal{B}_2$ be two rigid bodies with $\mathcal{B}_1$ containing a hollow cavity $\mathcal{C}$. We assume that $\mathcal{B}_2$ is strictly contained in $\mathcal{C}$, and the gap between the solids is completely filled by a viscous liquid. We are interested in the long-time dynamics of the whole system $\mathcal{S}$ of rigid bodies with the liquid-filled gap when $\mathcal{B}_1$ and $\mathcal{B}_2$ are constrained to rotate about a fixed point. The equations governing the motion of $\mathcal{S}$ are given by the Navier-Stokes equations coupled with the balances of the angular momentum of $\mathcal{B}_1$ and $\mathcal{B}_2$, respectively. We show that the class of weak solutions corresponding to initial data with arbitrary (finite) kinetic energy is nonempty. Concerning the long-time behavior of $\mathcal{S}$, we show that the liquid has a stabilizing effect on the motions of both the rigid bodies. More precisely, the liquid velocities relative to $\mathcal{B}_1$ and $\mathcal{B}_2$ tend, respectively, to zero as time approaches to infinity. Moreover, the long-time dynamics of $\mathcal{S}$ is completely characterized by permanent rotations with $\mathcal{S}$ moving as a whole rigid body.

**Cecilia Mondaini** (ICERM/Brown University)
*Postprocessing Galerkin method applied to a data assimilation algorithm: a uniform in time error estimate*

We consider a data assimilation algorithm for recovering the exact value of a reference solution of the two-dimensional Navier-Stokes equations, by using continuous in time and coarse spatial observations. The algorithm is given by an approximate model which incorporates the observations through a feedback control (nudging) term. Our goal is to obtain an analytical estimate of the error committed when numerically solving this approximate model by using a post-processing technique for the spectral Galerkin method, inspired by the theory of approximate inertial manifolds. Most importantly, this error estimate is uniform in time. This is in contrast with the error estimate for the usual Galerkin approximation of the 2D Navier-Stokes equations, which grow exponentially in time. This is a joint work with E. S. Titi.

**Buddhika Priyasad** (University of Memphis)
*Turbulence in Sobolev/Besov Spaces*

Navier-Stokes equations defined on $\Omega \subset \mathbb{R}^d$, $d = 2, 3$ with no-slip boundary conditions and subject to an external forcing will be considered. It is known, that such forcing may cause turbulence. The goal of this research is to show that an appropriately constructed feedback operator, acting on an arbitrary small subset $\omega \subset \Omega$ of positive measures, stabilizes the dynamics in the neighborhood of unstable equilibrium. The proof relies on: (i) recently developed maximal regularity theory for Stokes Operators acting on $L^p$ based Sobolev and Besov spaces and (ii) unique continuation theorem developed for Oseen's operators via Carleman's estimates. This result provides an extension of theories previously known in Hilbert settings only. The advantage of $L^p$ setting is not only that this brings new and interesting mathematics but also it allows to control "turbulence" with finite rank operators (physically attractive).

**Diego Ricciotti** (University of Pittsburgh)
[POSTER I] *Regularity of $p$-Harmonic Functions in the Heisenberg Group*

We give a proof of the Hölder continuity of horizontal derivatives of $p$-harmonic functions in the Heisenberg group for $p > 4$.

[POSTER II] *Plates with Incompatible Prestrain of Higher Order*

We study the effective elastic behaviour of incompatibly prestrained thin plates, characterized by a Riemannian metric $G$ on the reference configuration. We assume the incompatible elastic energy $E^h$ has scaling of order less than $h^2$ in terms of the plate's thickness $h$. We show that the $\Gamma$-limit of the scaled functionals $h^{-4}E^h$ consists of a von Karman-like energy and prove that in the scaling regime $E^h \sim h^\beta, \beta > 2$ , there is no other non trivial limiting theory.

**Connor Smith** (University of Kansas)
*Dynamics of Unstable Solitary Waves: A Case Study*

When studying nanoscale pattern formation, one finds a solitary wave with unstable essential spectrum and stable point spectrum. Despite this nominal instability, there appears to be asymptotic orbital instability in exponentially weighted spaces. In this poster we discuss recent efforts to establish this partial notion of stability. Joint work with Mathew Johnson and Greg Lyng.

**Selim Sukhtaiev** (University of Missouri)
*The Maslov Index and the Spectra of Second Order Elliptic Operators*

I will present a formula relating the spectral flow of the one-parameter families of second order elliptic operators to the Maslov index, the topological invariant counting the signed number of conjugate points of paths of Lagrangian planes.

**Feifei Wang** (Iowa State University)
*Coefficient of Restitution for a Damped Elastic Rod*

A damped one-dimensional wave equation is used to model an elastic rod that bounces off the ground with a given initial velocity, under the influence of gravity. In the case of viscous damping, an explicit solution is derived, based on the method of descent and D'Alembert's formula. The time of contact with the ground is determined, and corresponding expressions for the motion of the center of mass and internal vibrational energy at the bounce time are obtained. A corresponding definition of "coefficient of restitution" is proposed and analyzed. Related numerical studies for structural damped model are presented.

**Kelsey Wells** (University of Nebraska-Lincoln)
*A state-based Laplacian: connections with other nonlocal and local counterparts*

In this work we define a new nonlocal counterpart to the Laplacian operator inspired by the state-based models introduced by Stewart Silling in 2007. This state Laplacian incorporates dependence on two kernels and we study the connections between this operator, the bond-based nonlocal Laplacian, and the classical Laplace operator.

**Laura White** (University of Nebraska-Lincoln)
*Doubly Nonlocal Cahn-Hilliard Equation*

The Cahn-Hilliard (C-H) system is one of the most widely studied models in applied mathematics. Its applications vary from phase separation in alloys to image processing. The classical formulation of the system requires the unknown to have a large degree of differentiability which is unphysical. In fact, the concentration unknown function could be discontinuous when changing location from one material to the other. We propose a doubly nonlocal C-H model that incorporates two integrable kernels, thus removing the differentiability requirements. For the linearized model we obtain bounds that show the decay of solutions with the end goal of generalizing the estimates to the nonlinear setting.

**Cory Wright** (University of Nebraska-Lincoln)
*Calculus of Variations in Nonlocal Theory*

Nonlocal theory has grown in interest to many recently in the math and engineering field. This theory allows us to model a system which may exhibit discontinuous behavior such as fractures or corrosion. Often it is important to model the energy of these systems and to study these resulting functionals. In this presentation we investigate results of these functionals in the nonlocal setting. In particular we will show the necessity of the Euler-Lagrange equations, sufficient conditions for minimizers of the energy functionals, and a regularity result for these nonlocal minimizers.

**Yajie Zhang** (Pennsylvania State University)
*Parabolic Transmission Problem*

We study theoretical and practical issues for second order linear parabolic equation with jump discontinuities in its coefficients on a polygonal domain that may have cracks or vertices that touch the boundary. We consider in particular a linear parabolic equation with appropriate initial condition and mixed boundary/interface conditions, where the matrix A has variable, piecewise smooth coefficients. We establish some regularity results and, under some additional conditions, we also establish well-posedness in weighted Sobolev spaces in the cases when there are no Neumann boundary conditions imposed on adjacent sides of the polygonal domain. When Neumann boundary conditions are imposed on adjacent sides, we fail to have a quasi-contraction semigroup according to the Lumer-Phillips Theorem.