IP1
Travel Time Tomography

We will consider the inverse problem of determining the sound speed or index of refraction of a medium by measuring the travel times of waves going through the medium. This problem arises in global seismology in an attempt to determine the inner structure of the Earth by measuring travel times of earthquakes. It has also several applications in optics, medical imaging and ocean acoustics among others. We will apply the results to the inverse problem of determining the elastic parameters of a medium by measuring the traction produced by a displacement at the boundary of the medium. The problem can be recast as a geometric problem: Can one determine a Riemannian metric of a Riemannian manifold with boundary by measuring the distance function between boundary points? This is the boundary rigidity problem. We will also consider the problem of determining the metric from the scattering relation, the so-called lens rigidity problem. The linearization of these problems involve the integration of a tensor along geodesics, similar to the X-ray transform. We will also describe some recent results, joint with Plamen Stefanov and Andras Vasy, on the partial data case, where you are making measurements on a subset of the boundary. No previous knowledge of Riemannian geometry will be assumed.

Gunther Uhlmann
University of Washington
gunther@math.washington.edu

IP2
PD17 Invited Speaker - Guo

Abstract not available at time of publication.

Yan Guo
Brown University
Yan_Guo@Brown.edu

IP3
Eulerian and Lagrangian Solutions of the Continuity Equation

It is well known that the motion of an incompressible fluid can be described in Eulerian variables (as a solution of a PDE, namely the continuity equation), or alternatively in Lagrangian variables (as a flow of an ODE). The classical DiPerna-Lions-Ambrosio theory ensures well-posedness and provides structural properties for solutions of the continuity equation, under suitable regularity assumptions on the velocity field and integrability assumptions on the solution. In my talk I will focus on the "Lagrangianity" of solutions, that is, on the property of being transported by an ODE flow, hence addressing the question whether an Eulerian solution is automatically a Lagrangian solution. After a brief summary of the DiPerna-Lions-Ambrosio theory, I will present two examples which are outside of the assumptions of such a theory, and in which nevertheless we can prove the Lagrangianity of solutions. The first one concerns vanishing viscosity solutions of the two-dimensional Euler equations, where we can use suitable duality methods (joint work with Stefano Spirito). The second example involves general continuity equations, and requires the proof of a new Lipschitz extension lemma (joint work with Laura Caravenna).

Gianluca Crippa
University of Basel
gianluca.crippa@unibas.ch

IP4
Nonlinear Elliptic Equations with Fractional Diffusion

In this talk I will explain basic ideas concerning fractional Laplacians (in particular, their relation with Lvy flights in Probability) and present the essential tools to treat nonlinear equations involving fractional Laplacians and other elliptic integro-differential operators. We will review their Lagrangian and Hamiltonian structures – two very important tools. The last part of the talk will concern recent developments on fractional perimeters and nonlocal minimal surfaces – a fractional extension of the classical theory of minimal surfaces.

Xavier Cabré
Universitat Politècnica de Catalunya
xavier.cabre@upc.edu

IP5
Regularity Theory in Elliptic Free Boundary Problems

In this talk, we will describe several examples of free boundary problems motivated by problems in the applied sciences. In particular, we will discuss the so-called two-phase free boundary problem, the thin free boundary problem, the obstacle problem and the two-membranes problem. We will focus mainly on the question of regularity of weak solutions and their free boundaries. Some open problems will also be highlighted. The most recent results in the talk are part of joint works with L. Caffarelli and O. Savin.

Daniela De Silva
Barnard College,
Columbia University
desilva@math.columbia.edu

IP6
Partial Differential Equations of Mixed Elliptic-Hyperbolic Type: From Mechanics to Geometry

As is well-known, two of the basic types of linear PDEs are elliptic and hyperbolic types, following the classification for linear PDEs proposed by Jacques Hadamard in the 1920s; and linear theories of PDEs of these two types have been considerably established, respectively. On the other hand, many nonlinear PDEs arising in many areas from mechanics to geometry naturally are of mixed elliptic-hyperbolic type. The solution of some longstanding fundamental problems in these areas greatly requires a deep understanding of such nonlinear PDEs of mixed type. Important examples include transonic shock problems in fluid mechanics (the Euler equations) and isometric embedding problems in differential geometry (the Gauss-Codazzi-Ricci equations). In this talk, we will present natural connections of nonlinear PDEs of mixed elliptic-hyperbolic type with these longstanding problems and will then discuss some of the most recent developments in the analysis of these nonlinear PDEs through the examples with emphasis on developing and identifying mathematical approaches, ideas, and techniques for dealing with the mixed-type problems. Further trends, perspectives, and open problems in this direction will also be addressed.

Gui-Qiang Chen

University of Oxford
chengq@maths.ox.ac.uk

IP7

Small Scale Formation in Ideal Fluids

I will overview some recent progress in understanding creation of small scales and singularity formation in equations of fluid dynamics such as incompressible Euler and surface quasi-geostrophic (SQG) equations. In particular, I will discuss an example of very fast small scale creation in solutions of 2D Euler equation, which achieves an optimal double exponential in time rate. I will also talk about several simplified models that have been designed to better understand the process of possible singularity formation for solutions of 3D Euler equation in a scenario proposed by Tom Hou and Guo Luo.

Alexander Sasha Kiselev
Department of Mathematics
Duke University
kiselev@math.duke.edu

IP8

Stability of Prandtl Boundary Layers

Prandtl boundary layers arise when we consider Navier Stokes equations in the inviscid limit, with Dirichlet boundary conditions. Formally the inviscid limit is the Euler equations for incompressible fluids. However, the boundary conditions differ between Euler and Navier Stokes equations. As a consequence, as the viscosity goes to 0, a boundary layer appears, called Prandtl boundary layer. The mathematical study of this boundary layers appears to be delicate, despite many recent attempts. In this talk we will discuss recent results on the linear and nonlinear instability of this boundary layers. This is a joint work with T. Nguyen (Penn State University)

Emmanuel Grenier
Ecole Normale Supérieure de Lyon
emmanuel.grenier@ens-lyon.fr

SP1

SIAG/Analysis of Partial Differential Equations Prize Lecture: Quantitative Stochastic Homogenization by Variational Methods

Several years ago, with Charles Smart we revisited a variational approach to random homogenization introduced by Dal Maso and Modica in the 1980s for elliptic equations in divergence form. We showed that their old ideas could be combined with some new convex analytic methods to obtain quantitative estimates on the rate of homogenization. Furthermore, we showed that these quantitative estimates imply regularity results for the solutions on large scales. In this talk I will review these results and explain how in recent joint work with Kuusi and Mourrat we have taken them further: the variational perspective leads to a rigorous "renormalization group' argument, eventually yielding an optimal theory of stochastic homogenization for linear elliptic equations.

Scott Armstrong
Courant Institute of Mathematical Sciences
New York University
scotta@cims.nyu.edu

CP1

Computational Analysis of Partial Differential Equation Based on Electro-Magneto-Hydrodynamic Thermo-Fluidic Transport of Biofluids with New Trend of Fractional Derivative Without Singular Kernel

In this work, the electro-magneto-hydrodynamic flow of the non-Newtonian behavior of biofluids, through a cylindrical microchannel was derived based on partial differential equation of fractional order. The governing equations are considered as fractional partial differential equations based on the Caputo-Fabrizio time-fractional derivatives without singular kernel. The most common time-fractional derivative used in Continuum Mechanics is Caputo derivative. However, two disadvantages appear when this derivative is used. First, the definition kernel is a singular function and, secondly, the analytical expressions of the problem solutions are expressed by generalized functions (Mittag-Leffler, Lorenzo-Hartley, Robotnov, etc.) which, generally, are not adequate to numerical calculations. The new time-fractional derivative Caputo-Fabrizio, without singular kernel, is more suitable to solve various theoretical and practical problems which involve fractional differential equations. Using the Caputo-Fabrizio derivative, calculations are simpler and, the obtained solutions are expressed by elementary functions. Analytical solutions of the biofluid velocity and thermal transport are obtained by means of the Laplace and finite Hankel transforms. The influence of the fractional parameter, Eckert number and Joule heating parameter on the biofluid velocity and thermal transport are numerically analyzed and graphic presented.

Mohammed Abdulhameed
Federal Polytechnic Bauchi
amohd@fptb.edu.ng

CP1

A Bottom-Up Approach to Global Upscaling for Reservoir Simulation

Our aim is to develop an efficient yet robust algorithm for solving flow equations in the context of reservoir simulation, which has a vast domain in both space and time. We begin with a global fine-scale model, constructed using established finite volume methods. Using this model, we compute global fine-scale solutions with generic (that is, constant-pressure/no-flow) boundary conditions. We then use the computed pressure and velocity fields, in conjunction with spatially varying, compact multi-point stencils, to determine how to combine grid cells and coarsen the model, while maintaining the accuracy and robustness of the underlying fine-scale model. Numerical experiments will demonstrate the effectiveness of this approach.

Chuan Chen
The University of Southern Mississippi
Chuan.Chen@usm.edu

James V. Lambers
University of Southern Mississippi
Department of Mathematics
James.Lambers@usm.edu

CP1

Analytical and Numerical Investigation of Euler-

Bernoulli Beam Model with Non-Conservative Boundary Conditions

Analytic and numerical results on the Euler-Bernoulli beam model with a two-parameter family of boundary conditions will be discussed. The beam equation is equipped with the boundary conditions given in the form of the co-diagonal matrix depending on two control parameters (k_1 and k_2) that relates a two-dimensional input vector (the shear and the moment at the right end) and the observation vector (the time derivatives of displacement and the slope at the right end). The following results will be presented: (i) high accuracy numerical approximations for the eigenvalues of the discretized differential operator (the dynamics generator of the model); (ii) the formula for the number of the *deadbeat modes* for the case when one control parameter, k_1, is positive and another one, k_2, is zero; (It has been shown that the number of the deadbeat modes tends to infinity, as $k_1 \to 1^+$ and $k_2 = 0$.) (iii) the asymptotic formula for the *double deadbeat modes* for the model. The numerical results corroborating all analytic findings have been produced by using Chebyshev polynomial approximations for the continuous problem.

Laszlo P. Kindrat
University of New Hampshire
laszlokindrat@gmail.com

Marianna Shubov
University of New Hampshire
Department of Mathematics and Statistics
marianna.shubov@gmail.com

CP1

Numerical Solutions of 2-D Unsteady Free Convective Flow With Heat and Mass Transfer In A Rectangular Domain

In this paper, we have implemented a finite volume method to discretize the governing equations of the problem of an unsteady 2-D incompressible flow with heat and mass transfer at different Reynolds and Rayliegh numbers with mixed boundary conditions. We have used the SIMPLE algorithm of QUICK SCHEME to solve the discretized equations along with the boundary conditions and thereby to compute the flow variables, viz. u-velocity, v-velocity, P, T, and C. A SIMPLE algorithm was used to compute the numerical solutions of the flow variables for different Reynolds numbers (Re) and the Rayliegh(Ra) numbers. Local as well as average Nusselt(Nu) and Sherwood numbers(Sh) were computed for fixed Pr=7.2 and Sc=340 for four grid systems at different times.We have used appropriate Prandtl (Pr) and Schmidt (Sc) numbers in consistent with relevancy of the physical problem considered. We have depicted the lines, isotherms,iso-concentric lines.Heat and mass lines are also determined.The entropy generation during free convection is studied due to fluid friction irreversibility and heat transfer irreversibility is studied.Our numerical solutions for u and v velocities along the vertical and horizontal line through the geometric center of the square cavity for different Ra(Rayleigh number) has been compared with benchmark solutions available in the literature and it has been found that they are in good agreement.

Ambethkar Vusala
UNIVERSITY OF DELHI
DELHI-110007
vambethkar@gmail.com

Durgesh Kushawaha
University of Delhi
Delhi-110007
durgeshoct@gmail.com

CP1

Entropy Stable WENO Spectral Collocation Schemes for the 3-D Navier-Stokes Equations

High-order numerical methods that satisfy a discrete analog of the entropy inequality are uncommon. Indeed, no proofs of nonlinear entropy stability currently exist for high-order Weighted Essentially Non-Oscillatory (WENO) finite volume or weak-form finite element methods. In this talk, we present a new family of fourth-order WENO spectral collocation schemes that are provably stable in the entropy sense for the three-dimensional Navier-Stokes equations. Individual spectral elements are coupled using penalty type interface conditions. The resulting entropy-stable WENO spectral collocation schemes achieve design order accuracy, maintain the WENO stencil biasing properties across element interfaces, and satisfy the summation-by-parts (SBP) operator convention, thereby ensuring nonlinear entropy stability in a diagonal norm. Numerical results demonstrating accuracy and non-oscillatory properties of the new schemes are presented for both continuous and discontinuous flows.

Nail Yamaleev
Old Dominion University
nyamalee@odu.edu

Mark H. Carpenter
NASA Langley Research Center
mark.h.carpenter@nasa.gov

CP2

Adaptive Moving Mesh Upwind Scheme for the Two-Species Chemotaxis Model

A common property of all chemotaxis systems is their ability to model a concentration phenomenon—rapid growth of the cell density in small neighborhoods of concentration points/curves (the solution may develop a singular, spiky structures or even blow up within finite time). Therefore, development of accurate and computationally efficient numerical methods for the chemotaxis models is a challenging task. We study the two-species Patlak-Keller-Segel type chemotaxis system, in which the two spieces do not compete, but have different chemotactic sensitivity, which may lead to a significantly different density growth rate. This phenomenon was numerically investigated in [Kurganov and Lukáčová-Medviďová, Discrete Contin. Dyn. Syst. Ser. B, 19 (2014), pp. 131–152] and [Chertock *et al.*, Adv. Comput. Math., to appear], where second- and higher-order methods on uniform Cartesian grids were developed. However, in order to achieve high resolution of the density spikes developed by the species with a lower chemotactic sensitivity, a very fine mesh had to be utilized and thus the efficiency of the numerical method was affected. In this work, we develop an adaptive moving mesh finite-volume semi-discrete upwind method for the two-species chemotaxis system. This approach leads to the concentration of the mesh cells at the blowup region, which allows us to substantially improve the resolution while using relatively small number of finite-volume cells.

Alexander Kurganov
Tulane University

kurganov@math.tulane.edu

CP2

The Class of Conformal Dissipative Relativistic Fluids

Motivated by the fluid/gravity correspondence and the AdS/CFT correspondence conjectured by Maldacena, we study the class of conformal dissipative relativistic fluids of divergence type, from the perspective proposed by Geroch and Lindblom in the early 90's; that is, theories in which dynamics is governed by differential equations that can be written as total divergence equations. More specifically, we give a characterization of the whole family of conformal fluids in terms of a single master scalar function χ, up to second order in dissipative variables. In particular, we identify the equilibrium states, derive the corresponding constitutive relations and analyze the hyperbolicity of these theories, i.e., under what algebraic conditions there exists a well posed initial value problem. This construction allows to generalize a number of previous works in which dissipative relativistic fluids are studied in a frame dependent scheme.

Marcelo Enrique Rubio
FaMAF - Universidad Nacional de Córdoba, Argentina
IFEG - CONICET
merubio@famaf.unc.edu.ar

CP2

A Two Layer Mathematical Model of Blood Flow in Porous Constricted Blood Vessels

In this paper, we discussed a mathematical model for two layered non Newtonian blood flow through porous constricted blood vessels. The core region of blood flow consisting the suspension of erythrocytes as non Newtonian Casson fluid and the peripheral region of plasma flow as Newtonian fluid. The wall of porous constricted blood vessel configured as thin transition Brinkman layer over layered by Darcy region. The boundary of fluid layer is defined as stress jump condition of Ocha-Tapiya and Beavers-Joseph. In this paper, we obtained an analytic expression for velocity, flow rate, wall shear stress. The effect of permeability, plasma layer thickness, yield stress and shape of the constriction on velocity in core & peripheral region, wall shear stress and flow rate discussed graphically. This is found throughout the discussion that permeability and plasma layer thickness have accountable effect on various flow parameters which gives an important observation for diseased blood vessels.

Bhupesh D. Sharma
Motilal Nehru National Institute of Technology
Allahabad,
Allahabad- 211004, India
dutt.bhupesh@hotmail.com

CP2

Interior-Exterior Penality Approach for Solving Quasi-Variational Inequality Arising in Elastohydrodynamic Lubrication

In this article we propose interior-exterior penalty method for solving quasi-variational inequality arising in Elasto-hydrodynamic Lubrication (EHL) problems using discontinuous-Galerkin finite volume method (DG-FVM) or DG-FEM. Stability and convergence analysis are derived here for proposed method. We derived a priori error estimates in the the broken H^1 norm. Furthermore, we derived hp error estimate in L^2 norm. The method presented is robust and easily parallelized in MPI environment. GMRES technique is implemented to solve the matrix obtained after the formulation. Film thickness calculation is done using singular quadrature approach. Numerical results illustrating the theoretical results are provided graphically and discussed. This method is well suited for solving EHL point contact problem and can probably be used as commercial software.

Peeyush Singh
Department of Mathematics & Statistics
IIT Kanpur
peeyushs8@gmail.com

Pravir Dutt
Department of Mathematics,
IIT Kanpur, India
pravir@iitk.ac.in

Prawal Sinha
IIT Kanpur
prawal@iitk.ac.in

CP2

Well-Posedness and Long-Time Dynamics of Geophysical Fluid Flows

The author elucidate in a concrete way dynamical challenges concerning approximate inertial manifolds (AIMS), i.e., globally invariant, exponentially attracting, finite-dimensional smooth manifolds, for nonlinear dynamical systems on Hilbert spaces. The goal of this theory is to prove the basic theorem of approximation dynamics, wherein it is shown that there is a fundamental connection between the order of the approximating manifold and the well-posedness and long-time dynamics of the rotating Boussinesq and quasi-geostrophic equations. Abreast of these results, the author presents a new technique for the construction of AIMS that preserve the structure of attractors for the flow in the thermal convection of Oldroyd-B fluids. Although this article is motivated by challenges in partial differential equations, we consider a two-mode Faedo-Galerkin approximation given by a system of singularly perturbed ordinary differential equations. We note that the foundation for the study of the low-dimensional model of turbulence, which capture the dominant focus energy bearing scales, from the flow for the thermal convection of viscoelastic fluids with a differential constitutive law, is the Lorenz equations extended through singular perturbation. In order to utilize geometric singular perturbation (GSP) theory and Melnikov techniques, we perturb the problem and carry the nonlinear analysis further to the question of the persistence of inclination-flip homoclinic orbits.

Maleafisha Stephen Tladi
University of Limpopo, South Africa
Stephen.Tladi@ul.ac.za

CP2

Coalescing Particle Systems, and Blow-Up in the Components of the Multispecies Keller-Segel Model

We study a stochastic particle system with a logarithmically-singular inter-particle interaction potential which allows for inelastic particle collisions. We

relate the squared Bessel process to the evolution of localized clusters of particles, and develop a numerical method capable of detecting collisions of many point particles without the use of pairwise computations, or very refined adaptive timestepping. We show that when the system is in an appropriate parameter regime, the hydrodynamic limit of the empirical mass density of the system is a solution to a nonlinear Fokker-Planck equation, such as the Patlak-Keller-Segel (PKS) model, or its multispecies variant. We then show that the presented numerical method is well-suited for the simulation of the formation of finite-time singularities in the PKS, as well as PKS pre- and post-blow-up dynamics. Additionally, we present numerical evidence that blow-up with an increasing total second moment in the two species Keller-Segel system occurs with a linearly increasing second moment in one component, and a linearly decreasing second moment in the other component.

Gleb Zhelezov
University of Arizona
gxz144@case.edu

Ibrahim Fatkullin
University of Arizona
Department of Mathematics
ibrahim@math.arizona.edu

CP3

Discontinuous Galerkin Finite Element Methods for the Solution of Diffuse Interface Models

Partial differential equation models based on Cahn-Hilliard type equations coupled with fluid flow will be introduced and numerically solved. Discontinuous Galerkin Finite Element Methods for the numerical solution of the equations will be presented. For the underline schemes: solvability, energy stability, convergence and error estimates will be established. Simulation results will be provided.

Andreas Aristotelous
Dept. of Mathematics
West Chester University
aaristotelous@wcupa.edu

CP3

High-Order, Stable and Conservative Boundary Schemes for Finite Differences

Stable and conservative numerical boundary schemes are constructed such that they do not diminish the overall accuracy of the method for interior schemes of orders 4, 6, and 8 using both explicit (central) and compact finite differences. Previous attempts to develop stable numerical boundary schemes have resulted in schemes which significantly reduced the global accuracy or required numerical dissipation for stability when applied to the non-linear fluid equations. Thus, the schemes presented here are the first to not affect the global accuracy, while also ensuring discrete conservation. We discuss a general procedure for the construction of conservative boundary schemes of any order followed by a simple, yet novel, optimization strategy which focuses directly on the compressible Euler equations. The result of this non-linear optimization process is a set of high-order, stable, and conservative numerical boundary schemes which demonstrate excellent stability and convergence properties on an array of linear and non-linear hyperbolic problems.

Peter Brady
Los Alamos National Lab
ptb@lanl.gov

Daniel Livescu
Los Alamos National Laboratory
livescu@lanl.gov

CP3

Mesh Requirements for Transmission Problems with Sign-Changing Coefficients

Transmission problems with sign-changing coefficients occur in electromagnetic theory in the presence of negative materials (metals at optical frequencies or metamaterials) surrounded by classical materials. For general geometries, establishing well-posedness of these transmission problems is well-understood thanks to the T-coercivity approach. At the discrete level, one simply imposes some meshing rules to guarantee an optimal convergence rate for the finite element approximation. However, in practice the current approach does not hold optimal convergence when the interface presents corners. We propose here a new treatment at the corners of the interface which allows to design meshing rules for an arbitrary polygonal interface and then recover standard error estimates.

Camille Carvalho
UC Merced
ccarvalho3@ucmerced.edu

Anne-Sophie Bonnet-Ben Dhia
POEMS, CNRS-ENSTA-INRIA
anne-sophie.bonnet-bendhia@ensta-paristech.fr

Patrick Ciarlet
Laboratoire POEMS CNRS-ENSTA-INRIA
patrick.ciarlet@ensta-paristech.fr

CP3

Well-Balanced Methods for Hyperbolic Systems of Balance Laws

We present a second-order well-balanced central-upwind scheme for hyperbolic systems of balance laws. Here we advocate a new paradigm based on a purely conservative reformulation of the equations using globally-based fluxes. The proposed scheme is capable of exactly preserving steady-state solutions expressed in terms of a nonlocal equilibrium variable. A crucial step in the construction of the second-order scheme is a well-balanced piecewise linear reconstruction of equilibrium variables which is combined with a well-balanced central-upwind evolution in time. We show the performance of the newly developed central-upwind scheme in a series of one- and two-dimensional examples.

Alina Chertock
North Carolina State University
Department of Mathematics
chertock@math.ncsu.edu

CP3

Solution of PDEs in Frequency Space for Photobleaching Kinetics Using Krylov Subspace Spectral

Methods

We solve the first order reaction-diffusion equations using the photobleaching scanning profile of confocal laser scanning microscopes. The initial conditions that come from prebleach steady states accompanying with a time-domain method known as a Krylov Subspace Spectral method (KSS method) is applied. KSS methods are explicit for solving time-dependent variable-coefficient partial differential equations (PDEs) that were developed by Lambers. We applied KSS methods because of their high-order accuracy and their scalability. In this talk we show how a KSS method can provide an approximate analytical solution which delivers insight into the behavior of the solution in frequency space.

Somayyeh Sheikholeslami, James V. Lambers
The University of Southern Mississippi
s.sheikholeslami@usm.edu, james.lambers@usm.edu

CP4

Pde Systems and Efficient Fire Suppression Allocation

Accumulation of burnable forest fuels is changing natural wildfire regimes. Decisions to quickly suppress fire discount the long-term risk of interrupting nature's course. Recent megafires are an unintended consequence. Our capability to suppress unwanted fires stems from a complex national sharing process in which specialized ground-based and aerial firefighting resources mobilize around the United States to respond to incidents of fire. This work elaborated a coupled system of advection, diffusion, reaction equations and applied them to an archive of risk and allocation data from 2011-2016 in order to forecast upcoming workloads. This presentation will explain how variation in fire risk impacts allocation. By implementing forward and inverse finite difference methods we balanced prediction and assimilation in time-stepping schemes on structured, regionally-connected meshes. We reduced underlying functional spaces to tractable subspaces by using regional risk data surfaces like ongoing fire activity, suppression resource use, fire weather, expenditures, accessibility, and population density. Time series results from pressure-fitting, spatial gradient estimation, and short-term prediction uncovered guidelines that will help managers better justify decisions to let excess fuel burn and restore fire's natural regime.

Alex T. Masarie, Yu Wei, Iuliana Oprea
Colorado State University
alex.masarie@gmail.com, yu.wei@colostate.edu, juliana@colostate.edu

Matt Thompson
Rocky Mountain Research Station
mpthompson02@fs.fed.us

Erin Belval
USDA/FS Rocky Mountain Research Station
mccowene@gmail.com

CP4

On the Numerical Solution to the Far Field Refractor Problem

The far field refractor problem in geometric optics is an inverse problem which deals with constructing a refracting surface that is capable of reshaping a light beam from a one point source with a given illumination intensity into a prescribed intensity distribution. The aim of this talk is to discuss its numerical solution. In particular, we will describe a numerical algorithm which was first used in the work of Caffarelli, Kochengin and Oliker, in relation to synthesis of reflector surfaces and show that a simplified version of this algorithm can be extended to obtain an approximate solution for the refractor problem with arbitrary precision. We further exhibit the convergence in finite steps of the method when the distribution density functions are bounded and mass balance conditions are met.

Henok Mawi, Roberto De Leo
Howard University
henok.mawi@howard.edu, roberto.deleo@howard.edu

Cristian Gutierrez
Department of Mathematics
Temple University
gutierre@temple.edu

CP4

Combined Optimal Stopping and Control of Regime Switching Lévy Processes and Applications

In this paper, we study the combined optimal stopping and optimal control problem of regime switching Lévy processes. We fully characterize the value function is the unique viscosity of the corresponding Hamilton-Jacobi-Bellman variational inequalities. Furthermore, we prove the C^2 regularity of the value function when the running cost is semiconvex. We numerically solve the system of fully nonlinear integrodifferential variational inequalities and derive an approximation of the value function and the optimal control and stopping policies. As an application, we formulate the problem of finding optimal extraction policies for natural resources as a combined optimal stopping optimal control problem and derive optimal extraction rules. A numerical example is presented to illustrate these results.

Moustapha Pemy
Towson University
Department of Mathematics
mpemy@towson.edu

CP4

Nonlinear Magneto-Elasticity: Direct and Inverse Problems

There are studied some direct and inverse problems associated with the vibration of an elastic conductive body governed by the Lamé and Maxwell equations coupled through the nonlinear magneto-elastic effect. We prove the existence and uniqueness for both the direct and inverse problem, which consists in identifying the unknown scalar function $f(t)$ in the elastic force $f(t)\mathbf{g}(\mathbf{x}, t)$ acting on an elastic conductive body when some additional measurement is available.

Viatcheslav I. Priimenko
North Fluminense State University Darcy Ribeiro
National Institute of Science and Technology-GP
slava@lenep.uenf.br, slava211054@gmail.com

Mikhail P. Vishnevskii
Sobolev Institute of Mathematics
North Fluminense State University Darcy Ribeiro

mikhail@uenf.br

CP4

Multigrid Methods for Stochastic Optimal Control Problems

We consider an optimal control problem constrained by an elliptic SPDE, with a stochastic cost functional of tracking type. We use a sparse grid stochastic collocation approach to discretize in the probability space and finite elements to discretize in the physical space. To accelerate the solution process, we propose a deterministic multigrid preconditioner for the stochastic reduced KKT system. Numerical results show that the number of conjugate gradient iterations decreases as the resolution increases, a feature shared by similar multigrid preconditioners for deterministic optimal control problems.

Ana Maria Soane
U.S. Naval Academy
Mathematics Department
soane@usna.edu

CP5

Virtual Element Methods for Time Dependent Convection Diffusion Reaction Equation with Supg Stabilization

In this talk, we would like to discuss virtual element method (VEM)for the approximation of time dependent convection diffusion reaction equation. The implementation procedure of the proposed method does not require explicit construction of basis functions and also suitable for any polyhedral meshes. In order to avoid non-physical oscillations–generally occurred for large mesh Peclet number, we have added a stabilizer which involve additional diffusion in streamline direction. An internal $\%L^2$ %-projection is used to discretize both stationary and non-stationary, and the discretized scheme design such that the bilinear forms involved in the formulation are coercive with respect to SUPG-norm. With the help of suitable projectors, optimal error estimates in SUPG-norm and L2-norm are established for semi-discrete and fully discrete schemes. Further, several numerical test are conducted on voronoi-mesh to validate the proposed method and verify the theoretical results.

Dibyendu Adak
research scholar
dibyendu.jumath@gmail.com

Sarvesh Kumar, E. Natarajan
Indian institute of space science and technology
sarvesh@iist.ac.in, thanndavam@iist.ac.in

CP5

A Numerical Solution for a Class of Differential Initial-Boundary Value Problems Via Convex Optimization

A novel methodology to find approximate continuous solutions of differential boundary value problems (D-BVP) via polynomials (p_d) is formulated. This consist in minimizing the resulting residual functions δ_d from the equality conditions of the D-BVP, via recasting them as polynomial inequalities. The main idea of this approach is based on a notable result from Real Algebraic Geometry: the *Positivstellensatz*. Thus, for domain representations ($\Omega = \{g_j\}$) which are *compact basic semi-algebraic sets*, these inequalities are relaxed via their *Sum-of-Squares* (SOS: $\sum_s$) decomposition, so that the D-BVP can be formulated as:

$$\mathbf{P}_d \left\{ \begin{array}{rl} \gamma^* = & \inf_{\gamma, p_d} \ \gamma \\ \text{subj. to:} & (\rho_M - \delta_d(x) - \sum_{j=1}^m s_{1,j}(x) g_j(x)) \in \sum_s, \\ & (\delta_d(x) - \rho_m - \sum_{j=1}^m s_{2,j}(x) g_j(x)) \in \sum_s, \\ & \gamma \geq 0, \ s_{1,j}, s_{2,j} \in \sum_s, \\ & [\gamma, \rho_M; \rho_M, \gamma] \succeq 0, \ [\gamma, \rho_m; \rho_m, \gamma] \succeq 0, \\ & B_i[p_d(\cdot)](x)|_{x \in \partial\Omega_i} = u_i, \end{array} \right. \tag{1}$$

where ρ_m and ρ_M are the minimum and maximum of δ_d, respectively, to be minimized in Ω and B_i are boundary conditions. This approach leads to a *convex optimization problem*, implementable via semidefinite programming, capable of solving PDE-initial value problems with polynomial non-linearities.

Pedro A. Ascencio
University of Warwick. WMG
P.Ascencio-Ormeno@warwick.ac.uk

W.D. Widanage
University of Warwick
WMG
dhammika.widanalage@warwick.ac.uk

CP5

A Numerical Algorithm for Computational Modeling of Reaction-Diffusion Models Arising in Chemical Processes

In this article, the author developed a numerical algorithm for computational modeling to capture the patterns of some reaction-diffusion models arising in chemical processes with Neumann and Dirichlet boundary conditions. These models arise in the mathematical modeling of chemical systems such as in enzymatic reactions, and in plasma and laser physics in multiple coupling between modes. Accuracy and efficiency of the proposed algorithm successfully tested on some numerical examples such as Gray-Scott, Schnakenberg, Isothermal Chemical models.

Ram Jiwari
Indian Institute of Technology Roorkee
ram1maths@gmail.com

CP5

Invariant Subspace and Functionally Generalized Separable Solutions of n-Dimensional PDEs

This work provides a systematic approach to compute functionally generalized separable solutions of n-dimensional PDEs not only for linear but also for nonlinear ones. Using the notion of invariance of n-dimensional PDE with respect to Lie-Backlund vector field, a result shows that one can construct a sequence of differential equations each with one independent variable less than the previous one. An algorithm is devised that generates the sequence and find invariant subspace generated by the functional involved in each DE. Finally, we demonstrate the efficacy of the method using linear and nonlinear diffusion equations.

Muhammad D. Khan
Institute of Business Management

danish.khan@iobm.edu.pk

CP5

Lie Symmetry Analysis and Dust-Acoustic Waves in Dusty Plasma Modeled by Burgers Type Equation

In this work, the Dust-acoustic waves in dusty plasma modeled by nonlinear Burgers type equation are studied through Lie symmetry approach. Using suitable similarity transformations, the given Burgers type equation is reduced to ordinary differential equations (ODEs). During the procedure of reduction, sometime we got some highly nonlinear ODEs which are not easily solvable for traveling wave solutions. Therefore, numerical methods are applied to the reduced ODEs for constructing Dust-acoustic waves.

Vikas Kumar
Department of Mathematics, D.A.V. College Pundri
vikasmath81@gmail.com

CP5

Numerical Study of Reaction Diffusion Fisher's Equation by Fourth Order Cubic B-Spline Collocation Method

Fourth order B-spline collocation method has been applied for study of numerical solutions and physical behaviour of Fisher's equation which represents several important phenomenon such as biological invasions, reaction diffusion in chemical processes and neutron multiplication in nuclear reactions. R.A. Fisher "[Fisher, Ronald Aylmer, Sir,(1890-1962) The Wave of Advance of Advantageous Genes, 7: 355-369 (1937).Issue Date: 1937]" introduced Fisher's equation to investigate the propagation of a virile gene in an infinite long habitat. It is observed that when time becomes sufficiently large, local initial disturbance propagates with constant limiting speed. There are a number of methods to solve Fisher's equation analytically and numerically. In the proposed method we have used fourth order B-spline collocation method to solve Fisher's equation. Earlier work on B-spline collocation method uses second order approximation for double derivative and fourth order approximation for single derivative. In this work, we have improved approximation for double derivative by taking one more term in Taylor series expansion. Results are found to be better than second order B spline method"[R.C. Mittal and Geeta Arora(2010), Efficient numerical solution of Fishers equation by using B-spline method, International Journal of Computer Mathematics,Vol. 87, No. 13, pp. 30393051]".Proposed method is satisfactorily efficient in terms of accuracy and stability.

Rajni Rohila
IIT Roorkee
IIT roorkee
rajnirohila89@gmail.com

R. C. Mittal
IIT Roorkee
rcmmmfma@iitr.ernet.in

CP6

Cell-Centered Finite Volume Element Methods for Elliptic Equations

Two new finite volume element (FVE) schemes are proposed and analyzed for second order elliptic equations. These schemes are based on triangular partitions and provide numerical approximations for both the primary and flux variables. Specifically, the schemes place the primary unknowns on the vertices of the underlying mesh and the flux variable on element edges and discretize the PDE by retaining the flux conserving property on each element, and thus the name of cell-centered FVE methods. Unlike most existing FVE schemes, no Voronoi mesh is needed in our schemes. This Voronoi-free feature makes the method highly flexible and desirable in practical computation.Using the techniques proposed in C. Wang, J. Wang, A primal-dual weak Galerkin finite element method for second order elliptic equations in non-divergence form, the numerical solution is characterized as a minimization of a prescribed non-negative quadratic functional with constraints given by the discrete problem. It is shown that both the finite element solution and the numerical flux converge to the exact solutions with optimal orders. The theoretical results are verified by numerical experiments. A two-phase flow model in porous media has been simulated to illustrate the motivation and the efficiency of this work. The numerical results match the underlying physics and hence show that the conservative fluxes obtained by both CCFVE schemes perform well.

Yujie Liu
Sun Yat-sen University
liuyujie5@mail.sysu.edu.cn

Junping Wang
National Science Foundation
jwang@nsf.gov

Qingsong Zou
Sun Yat-Sen University
mcszqs@mail.sysu.edu.cn

CP6

A Multiscale Approximation of a Cahn-Larch System with Phase Separation on the Microscale

We consider the process of phase separation of a binary system under the influence of mechanical deformation and we derive a mathematical multiscale model, which describes the evolving microstructure taking into account the elastic properties of the involved materials. Motivated by phase-separation processes observed in lipid monolayers in film-balance experiments, the starting point of the model is the Cahn–Hilliard equation coupled with the equations of linear elasticity, the so-called Cahn–Larché system. Owing to the fact that the mechanical deformation takes place on a macrosopic scale whereas the phase separation happens on a microscopic level, a multiscale approach is imperative. We assume the pattern of the evolving microstructure to have an intrinsic length scale associated with it, which, after nondimensionalisation, leads to a scaled model involving a small parameter $\epsilon > 0$, which is suitable for periodic-homogenisation techniques. For the full nonlinear problem the so-called homogenised problem is then obtained by letting ϵ tend to zero using the method of asymptotic expansion. Furthermore, we present a linearised Cahn–Larché system and use the method of two-scale convergence to obtain the associated limit problem, which turns out to have the same structure as in the nonlinear case, in a mathematically rigorous way. Properties of the limit model will be discussed.

Lisa Reischmann
department of mathematics, University of Augsburg

lisa.reischmann@math.uni-augsburg.de

Malte A. Peter
University of Augsburg
malte.peter@math.uni-augsburg.de

CP6

Eigencurves for Linear Elliptic Equations

This talk will describe qualitative properties of eigencurves associated with self-adjoint linear elliptic boundary value problems. Weak forms of the problems are considered, so the analysis is based solely on results for bilinear forms instead of linear operators. First, variational characterizations of the eigencurves are given and various orthogonality results for eigenspaces are detailed. Then continuity, differentiability, and asymptotic results for the eigencurves are analyzed. Lastly, a geometrical description of the eigencurves is discussed. The theory is illustrated by treating the weak form of the Robin-Steklov two-parameter eigenvalue problem.

Mauricio A. Rivas
Wake Forest University
rivasma@wfu.edu

Stephen Robinson
Department of Mathematics
Wake Forest University
sbr@wfu.edu

CP6

Liouville Type Theorem for Some Nonlocal Elliptic Equations

In this talk, we introduce some Liouville theorem for nonlinear elliptic equations involving nonlocal nonlinearity and nonlocal boundary value condition. We extend the Liouville theorems from local problems to nonlocal problem. We use the moving plane method to prove our result.

Xiaohui Yu
Shenzhen University
yuxiao_211@163.com

CP7

A Determination and Comparison of Analytical and Numerical Soliton Solutions of the Coupled Nonlinear Klein-Gordon Equations As Used in Condensed Matter Physics

This research investigates and compares analytical and numerical soliton solutions of the coupled nonlinear Klein-Gordon Equations. Both the cubic and higher power law nonlinearity have been considered. Numerical calculations have been implemented using finite element methods, and results have been compared with analytical outcomes. Variational iteration methods were used to perform the integrations. As the Klein-Gordon equation is the relativistic limiting equation in zero spin quantum systems, its importance and the nonlinear extensions are considered paramount for subsequent density functional calculations.

Matthew E. Edwards, Samuel Uba
Alabama A&M University
matthew.edwards@aamu.edu,
matthew.edwards@aamu.edu

CP7

Fractional Real and Distributed Order Models of Wave Propagation in Viscoelastic Media

Differential and integral operators of noninteger order have become an indispensable tool for modeling certain phenomena in physics, mechanics, engineering, economics, medicine, etc. Over the past years there has been an extensive study of wave propagation in viscoelastic materials within the fractional framework. In this talk we discuss various possibilities for generalizations of the classical wave equation by the use of fractional derivatives of constant real order. As a novel approach, we propose distributed order fractional model to describe wave propagation in viscoelastic infinite media, and study existence and uniqueness of fundamental solutions for the corresponding generalized Cauchy problem. Some particular cases of distributed order fractional constitutive stress-strain relations are examined in details, and numerical experiments are presented to illustrate theoretical results. The talk is based on collaborations with Lj. Oparnica and D. Zorica.

Sanja Konjik
University of Novi Sad
Department of Mathematics and Informatics
sanja.konjik@dmi.uns.ac.rs

CP7

Soliton-Like Behavior in Fast Two-Pulse Collisions in Weakly Perturbed Linear Systems of Coupled-Pdes

In this talk, we present the soliton-like behavior in fast two-pulse collisions in weakly perturbed linear systems of coupled-PDEs. The behavior is demonstrated for linear waveguides with weak cubic loss and for systems described by linear diffusion-advection models with weak quadratic loss. We show that in both systems, the expressions for the collision-induced amplitude shifts due to the nonlinear loss have the same form as the expression for the amplitude shift in a fast collision between two solitons of the nonlinear Schrödinger equation in the presence of weak cubic loss. Our work shows that conclusions drawn from analysis of fast two-soliton collisions in the presence of dissipation can be applied for understanding the dynamics of fast two-pulse collisions in a large class of weakly perturbed linear systems of coupled-PDEs, even though the pulses in the linear systems are not shape preserving.

Quan M. Nguyen
International University, Vietnam National University-HCMC
Vietnam
quannm@hcmiu.edu.vn

Avner Peleg
State University of New York at Buffalo
avpeleg@gmail.com

Toan Huynh
University of Science, Vietnam National University-HCMC
hthtoan@gmail.com

CP7

Haar Wavelets Based Algorithms for Simulation of

Hyperbolic Type Wave Equations

In this article, the authors developed two algorithms based on Haar wavelets operational matrix for simulation of nonlinear hyperbolic type wave equations. These types of equations describe a variety of physical model in the nonlinear optics, relativistic quantum mechanics, solitons and condensed matter physics, interaction of solitons in collisionless plasma and solid state physics etc. The algorithms reduced the equations into a system of algebraic equations and then the system is solved by Gauss-elimination procedure. Some well-known hyperbolic type wave problems are considered as numerical problems to check the accuracy and efficiency of the proposed algorithm. The numerical results are shown in figures and errors form.

Sapna Pandit, Ramesh Chand Mittal
Indian Institute of Technology Roorkee
sappu15maths@gmail.com, mittalrc@gmail.com

CP7

Small Amplitude Wave Propagation in Heterogeneous Media with Cracks: High and Low Frequency Approximations.

In this work, we study small amplitude wave propagation in pre-loaded heterogeneous media with periodic structure of heterogeneities weakened by cracks. We suppose the existence of several length scales: the smallest microscale defining the characteristic size of cracks, the mesoscale defining the characteristic size of periodic distribution of heterogeneities, and the macroscale which can be defined as a global characteristic size. The low-frequency approximation assumes the situation where the wavelength exceeds the mesoscale characteristic size. The high frequency approximation implies the same order of magnitude for these two characteristic lengths. We assume cracks to be isolated, randomly oriented and either open or closed penny shaped. In the case of closed penny shaped cracks, we take into account the Coulomb friction between crack faces. For low-frequency and high-frequency cases we propose multiscale approaches which allow us to replace real heterogeneous materials with effective media. As a result, we derive expressions for displacements and velocities of waves in effective media, and study how these quantities can be influenced by external stress, wave's frequency and the direction of propagation.

Viktoria Savatorova
University of Nevada Las Vegas, USA
National Research Nuclear University "MEPhI", Russia
vsavatorova@gmail.com

Alexey Talonov
National Research Nuclear University
Moscow, Russia
alextalonov@gmail.com

CP7

Periodic Traveling Interfacial Hydroelastic Waves with or Without Mass

We study the motion of an interface between two irrotational, incompressible fluids, with elastic bending forces present; this is the hydroelastic wave problem. We prove a global bifurcation theorem for the existence of families of spatially periodic traveling waves on infinite depth. Our traveling wave formulation uses a parameterized curve, in which the waves are able to have multi-valued height. This formulation and the presence of the elastic bending terms allows for the application of an abstract global bifurcation theorem of "identity plus compact' type. We furthermore perform numerical computations of these families of traveling waves, finding that, depending on the choice of parameters, the curves of traveling waves can either be unbounded, reconnect to trivial solutions, or end with a wave which has a self-intersection. Our analytical and computational methods are able to treat in a unified way the cases of positive or zero mass density along the sheet, the cases of single-valued or multi-valued height, and the cases of single-fluid or interfacial waves.

David W. Sulon
Drexel University Mathematics Department
dws57@drexel.edu

Benjamin Akers
Air Force Institute of Technology
benjamin.akers@afit.edu

David Ambrose
Department of Mathematics
Drexel University
dma68@drexel.edu

CP8

A Class of Linear PDEs Describing Asymptotically Algebraically Unstable Waves

The Fourier-Laplace integral solution for linear constant coefficient PDEs is used to demonstrate the possibility of long-time algebraic growth. Such growth is possible when the dispersion relation extracted from classical stability analysis indicates neutral stability. Interestingly, growth can occur (asymptotically, for long-time) like t^s, where s can be non-integer. Unlike linear constant coefficient ODEs that exhibit such growth only for non-normal systems (i.e. with insufficient eigenvectors) for which s is an integer, the growth mentioned above arises through a different mechanism in normal operators - namely singularity cancellation in Fresnel (and Fresnel-like) integrals that arise from the Fourier-Laplace integral solution of the PDE. The practical relevance of this work is that linear PDEs describing the propagation of disturbances in both space and time may in fact lead to growing responses, even when the linear stability analysis predicts non-growing solutions at the neutral stability threshold.

Nathaniel S. Barlow
Rochester Institute of Technology
nsbsma@rit.edu

Kristina King
University of Virginia
krk1257@rit.edu

Steven Weinstein, Paula Zaretzky, Michael Cromer
Rochester Institute of Technology
krk1257@rit.edu, pmz9319@rit.edu, mec2sma@rit.edu

CP8

Morphological Evolution of Crystal Surfaces below the Roughening Temperature:from Mesoscopic and Macroscopic View

During the heteroepitaxial growth on vicinal surface, step flow is one of various structures created on crystal sur-

faces. Understanding and mastering the thin film growth is a major challenge of materials science. We first introduce the step flow dynamics for mesoscopic models and their continuum limit to 4th order degenerate parabolic equations. Especially, various long range elastic interactions are considered, which leads to the instability of step growth. Then we use the regularized method to deal with one of those degenerate parabolic equations in attachment-detachment-limit regime and obtain a global weak solution, which is sign-preserved almost everywhere.

Yuan Gao
Hong Kong University of Science and Technology
Department of Mathematics
gy2012yg@gmail.com

Jian-guo Liu
Dept. of Mathematics and Physics
Duke University
jian-guo.liu@duke.edu

Jianfeng Lu
Mathematics Department
Duke University
jianfeng@math.duke.edu

CP8

Instability and Dynamics of a Generalized Volatile Thin Film Model

We study the evolution of a mathematical generalized thin film model that characterizes the dynamics of thin films of volatile viscous fluids on a dewetting solid substrate. The governing lubrication model is a fourth-order nonlinear parabolic partial differential equation with a loss term due to evaporation or condensation. Interesting dynamics like pattern formation, finite time singularities, droplet dynamics are investigated. In particular, unlike similar models without evaporation where positivity of solutions is guaranteed, in our model instabilities enhanced by evaporation can cause finite-time rupture. Self-similar dynamics lead to the singularities, produced by balances between evaporation and surface tension or intermolecular forces. The self-similar rupture solutions are analyzed and validated against high resolution PDE simulations.

Hangjie Ji
Duke University, Department of Mathematics
hangjie@math.duke.edu

Thomas P. Witelski
Duke University
Department of Mathematics
witelski@math.duke.edu

CP8

On the Explosive Instability in a Three-Species Food Chain Model with Modified Holling Type IV Functional Response

In earlier literature, a version of a classical three-species food chain model, with modified Holling type IV functional response, is proposed. Results on the global boundedness of solutions to the model system under certain parametric restrictions are derived, and chaotic dynamics is shown. We prove that in fact the model possesses explosive instability, and solutions can explode/blow up in finite time, for certain initial conditions, even under the parametric restrictions of the literature. Furthermore, we derive the Hopf bifurcation criterion, route to chaos, and Turing bifurcation in case of the spatially explicit model. Lastly, we propose, analyze, and simulate a version of the model, incorporating gestation effect, via an appropriate time delay. The delayed model is shown to possess globally bounded solutions, for any initial condition.

Rana Parshad
clarkson university
rparshad@clarkson.edu

Ranjit Upadhyay, Swati Mishra, Satish Ttiwari
indian institute of technology, dhanbad
ranjit.upadhyay@yahoo.com, swatibhu2009@gmail.com, sktiwari.ism@gmail.com

Swarnali Sharma
bengal engineering and science university
swarnali.sharma87@gmail.com

CP8

A Three-Field Formulation for Poroelasticity Equations and Its Solvability Via Fredholm Alternative

In this talk we present a stable and convergent conforming finite element method for the discretisation of the linear poroelasticity equations in a new formulation, where the volumetric contributions to the total stress are merged into an additional unknown. The resulting saddle point formulation can be analysed by means of a Fredholm alternative, after realizing that the problem is a compact perturbation of a Stokes-like invertible system. A generic Galerkin scheme is constructed, whose solvability properties follow closely those from the continuous variational form, and more importantly, given that specific finite dimensional spaces are chosen adequately, it is stable even in the incompressible limit.

Ricardo Ruiz Baier
Ecole Polytechnique Federale de Lausanne
ruizbaier@maths.ox.ac.uk

Ricardo Oyarzua
Universidad del Bio Bio
roarzua@ubiobio.cl

CP9

Controllability of Nonlinear Reaction-Diffusion Equations

We discuss some results concerning the global approximate controllability of semilinear reaction-diffusion equations governed via the coefficient of the reaction term (multiplicative or bilinear control). We study both uniformly parabolic and degenerate equations. We start to consider a one-dimensional uniformly parabolic problem and we extend in [1] some nonnegative controllability results by bilinear controls assuming that both the initial and target states admit no more than finitely many changes of sign. Our method uses a technique, introduced in [1], employing the shifting of the points of sign change by making use of a finite sequence of initial-value pure diffusion problems. The results obtained in [1] have allowed us to approach the multidimensional case with radial symmetry. Indeed, assuming that the initial and final data are radial on a ball about the origin, we reduce the problem to a one-dimensional setting. In this way, we obtain an approximate controllability result for data which admit finitely many hyperspheres of sign change. The method, intro-

duced in [1] for uniformly parabolic equations, can be also extended to degenerate reaction-diffusion equations. [1] P. Cannarsa, G. Floridia, A.Y. Khapalov, Multiplicative controllability for semilinear reaction-diffusion equations with finitely many changes of sign, preprint (2016), to appear on *Journal de Mathématiques Pures et Appliquées.*

Giuseppe Floridia
University of Naples Federico II
giuseppe.floridia@unina.it

CP9

Homogenization and Concentrated Capacity for the Heat Equation with Two Kinds of Microstructures

We investigate how geometric microstructures of a domain can affect the diffusion on the macroscopic level. More precisely, we look at a domain with additional microstructures of two kinds, the first one are periodically arranged 'horizontal barriers' and the second one are 'vertical barriers' which are not periodically arranged, but uniform on certain intervals. Both structures are parametrized in size by a small parameter ε. Starting from such a geometry combined with a diffusion(-reaction) model, we derive the homogenized limit and discuss the differences of the resulting limit problems for various particular arrangements of the microstructures. Moreover, we discuss the motivation of the above mentioned problem by structures observed in strongly folded membranes and conclude by a short outlook.

Laura Keller
ETH Zurich
laura.keller@math.ethz.ch

CP9

The Kirkpatrick-Barton Reaction-Diffusion System in Spatial Evolutionary Ecology

In a paper celebrated by biologists, Kirkpatrick and Barton [American Naturalist 1997] introduced the system $N_t = N_{xx} + N\left(1 - N - \frac{1}{2}Z^2\right)$, $Z_t = Z_{xx} + 2\frac{N_x}{N}(Z_x + B) - AZ$ as a model for the joint evolution of a population density N and the mean Z of a quantitative trait—that is, a continuous random variable such as body size in animals—in a nonhomogeneous selective environment. We present a local existence proof for solutions of this system that may exhibit linear growth of Z as $x \to \pm\infty$, as numerical experiments suggest is true for some traveling wave and stationary (pinned) solutions. We also prove existence of some traveling waves and pinned solutions. These appear to be the first rigorous results of any kind concerning this system.

Judith R. Miller
Georgetown University
Department of Mathematics
Judith.Miller@georgetown.edu

CP9

Global Existence and Uniform Estimates for Volume Surface Reaction Diffusion Systems

We consider coupled reaction-diffusion models where some components react and diffuse on the boundary of a region, while other components diffuse in the interior and react with those on the boundary through mass transport, dynamic or Wentzell boundary conditions. We derive Sobolev estimates for linear dynamic initial boundary value problems and combine these with classical potential theory and classical estimates for linear initial boundary value problems to prove local well-posedness. Conservation of mass and other reasonable assumptions afford a priori estimate, and allow us to employ duality arguments to bootstrap sufficiently to obtain global existence, and uniform sup-norm bounds. Systems of this form arise in a number of physical scenarios.

Vandana Sharma
Arizona State University
vandanas@asu.edu

Jeff Morgan
University of Houston
jjmorgan@central.uh.edu

CP9

Numerical Simulation to Capture the Pattern Formation

This work deals to capture the different types of patterns of nonlinear time dependent coupled reaction-diffusion models. To accomplish this work, a new differential quadrature (DQ) algorithm is developed with the help of modified trigonometric cubic B-spline functions. The stability part of the developed algorithm is studied by matrix stability analysis method. In the experimental part, different types of patterns of Gray-Scott, Schnakenberg, Isothermal Chemical and Brusselator Models are captured which are similar to the existing patterns of the models.

Sukhveer Singh
Thapar University
sukhveer.singh@thapar.edu

CP9

Modelling Pattern Formation on the Surface of a Ferrofluid

Consider an infinite slab Ω separated into two simply connected subdomains: Ω_F is occupied by a ferrofluid and Ω_A is occupied by air, both subjected to an upwards pointing vertical magnetic field of strength $H > 0$. Let $\mathbf{B} : \Omega \to R^3$ denote the magnetic induction and $\mathbf{H} : \Omega \to R^3$ the (irrotational) magnetic field strength. Since the field is irrotational there exist two magnetic potentials ϕ, χ such that $\mathbf{H} = -\nabla\phi$ in Ω_F and $\mathbf{H} = -\nabla\chi$ in Ω_A. Assuming a steady state, Maxwell's equations of magnetostatics imply that χ is harmonic in Ω_A and ϕ is μ-harmonic in Ω_F; here the function μ describes the magnetization law of the ferrofluid. For an arbitrary μ, we extract a free boundary problem involving the magnetic potentials in the ferrofluid and the air together with compatibility and dynamic conditions on the free interface. First, we stay in the planar case and assume that the surface of the ferrofluid can be described by the graph of a function. Using spatial dynamic techniques and an appropriate center manifold reduction we show existence of static solitons on the surface. Next, going back to 3d and dropping the "graph' assumption, we solve the free boundary problem by applying techniques developed for the study of convex-concave functionals.

Athanasios Stylianou
University of Kassel
Institute of Mathematics
stylianou@mathematik.uni-kassel.de

Mark D. Groves
Universitaet des Saarlandes
groves@math.uni-sb.de

David Lloyd
University of Surrey
d.j.lloyd@surrey.ac.uk

Enea Parini
Aix-Marseille Universite
enea.parini@univ-amu.fr

CP10

How Robin Meets Dirichlet

This talk will describe the approximation of the solution of Dirichlet boundary value problems for second order elliptic equations by Robin boundary value problems. The case of Laplace's equation on bounded regions in R^N will be described. It is well known that the Dirichlet boundary value problem with $u = g$ on the boundary has a unique solution in $H^1(\Omega)$ if and only if g is in $H^{1/2}(\partial\Omega)$. The Robin problem with $\epsilon D_\nu u + u = g$ has a unique solution $H^1(\Omega)$ if and only if g is in $H^{-1/2}(\partial\Omega)$. This talk will describe the convergence of the solutions of the Robin problem as $\epsilon \to 0^+$ to those of the Dirichlet problem. When g is in $H^{-1/2}(\partial\Omega)$, there is a unique L^2- solution of the Dirichlet problem and the Robin solutions converge to this Dirichlet solution in the L^2-norm.. Rate of convergence results will be given for $g \in H^s(\partial\Omega)$ and $s > -1/2$.

Giles Auchmuty
Department of Mathematics
University of Houston
auchmuty@uh.edu

CP10

Recent Development in the Boltzmann Equation in Bounded Domains

The Boltzmann equation in smooth convex bounded domain with specular boundary condition was long-standing open problem since the announcement of Shizuta and Asano (1977). After several decades, novel $L^2 - L^\infty$ bootstarp was introduced in [Y.Guo, Decay and Continuity of the Boltzmann equation, ARMA, 2010] for partial result. This problem was completely solved in [Kim and Lee, The Boltzmann equation with specular boundary condition in convex domains, CPAM, 2017] by considering geometric decomposition of particle trajectory and introducing novel triple iteration techniques. We introduce key ideas of the paper. Moreover, we also introduce some recent development for non-convex domains: Asymptotic behavior and Local Holer regularity. We also mention about constructive coercivity which gives higher integrability.

Donghyun Lee
University of Wisconsin Madison
dlee374@wisc.edu

Chanwoo Kim
University of Wisconsin-Madison
ckim.pde@gmail.com

CP10

Asymptotic Investigation of a Nonlinear Initial-Boundary-Value Problem for a Light Multi-Tethered Sphere in Uniform and Modulated Flows

We derive a nonlinear initial-boundary-value problem (IBVP) for a lighter-than-air multi-tethered sphere using the extended Hamilton's principle augmented by Lagrange multipliers that describe the configuration geometric constraints. The tethers are modeled as continuum cables that move in longitudinal, normal, and bi-normal directions. The six-degrees-of-freedom rigid-body motion of the buoyant sphere define the boundary conditions of the IBVP. The entire structure is immersed in modulated aerodynamic flow and incorporates both internal viscoelastic structural damping for the cables and external drag-induced viscous damping of the sphere. Motivated by numerical analysis of the IBVP that exhibits a variety of periodic, quasiperiodic and chaotic solutions in a limiting planar configuration [Mi & Gottlieb 2016], we apply the asymptotic multiple-scales method to investigate the existence of internal resonances that govern energy transfer between the sphere degrees-of-freedom and the cables. Formulation of the IBVP solvability conditions enables construction of the system frequency response which allows comparison of the asymptotic dynamics with their numerical counterparts. A comprehensive bifurcation structure is anticipated to shed light on the orbital stability of multi-tethered sphere in uniform and modulated flows.

La Mi
Technion - Israel Institute of Technology
mila@technion.ac.il

Oded Gottlieb
Technion - Israel Institute of Technology
Department of Mechanical Engineering
oded@technion.ac.il

CP10

A Generalization of the Lions-Aubin-Simon Compactness Lemma to Problems on Moving Domains

We are interested in studying compactness of sequences that approximate functions $\mathbf{u}(t, x)$ in Bochner spaces $L^2(0, T; X(t))$, where $X(t)$ is a Hilbert space, which depends on time. Problems of this type arise, for example, in studying evolution problems modeled by partial differential equations defined on domains that depend on time. Examples include general moving-boundary problems, or more particularly, fluid flows in time-dependent fluid domains that may either be given *a priori*, or in fluid domains that are not known *a priori* but depend on the solution of a fluid-structure interaction problem. In the latter case the elastodynamics of a compliant (elastic, or viscoelastic) structure determines the fluid domain. Thus, the spatial domain depends on time through the unknowns of the problem, giving rise to a strong geometric nonlinearity. This is joint work with S. Canic, University of Houston.

Boris Muha
Department of Mathematics, Faculty of Science
University of Zagreb
borism@math.hr

CP10

L^p Estimates and Higher Regularity for Semilinear Spdes with Monotone Semilinearity

L^p- estimates for semilinear stochastic partial differential equations (on a bounded domain) with monotone semilinear term are obtained. These estimates are then used to

obtain higher interior regularity of solutions to such equations. These L^p-estimates together with known results for linear SPDEs can also be used to obtain the regularity of solution up to boundary in some weighted Sobolev space.

Neelima Neelima, David Siska
University of Edinburgh
N.Neelima@sms.ed.ac.uk, d.siska@ed.ac.uk

CP10

Lower Bounds of the Blow-Up Time under the Local Nonlinear Neumann Boundary Condtions

In this talk, we will focus on the lower bound estimate of the blow-up time T^* for the heat equation $u_t = \Delta u$ in a bounded domain Ω in $\mathbb{R}^n (n \geq 2)$ with positive initial data u_0 and a local nonlinear Neumann boundary condition: The normal derivative $\partial u/\partial n = u^q$ on partial boundary $\Gamma_1 \subseteq \partial\Omega$ for some $q > 1$ and $\partial u/\partial n = 0$ on the rest of the boundary. In particular, we will discuss the asymptotic behavior of T^* as $q \to 1$, $|\Gamma_1| \to 0$ or $M_0 \to 0$, where $|\Gamma_1|$ denotes the surface area of Γ_1 and M_0 denotes the maximum of u_0. This is a joint work with Zhengfang Zhou.

Xin Yang
Michigan State University
xin.yang@uc.edu

Zhengfang Zhou
Department of Mathematics, Michigan State University
East Lansing, MI, USA
zfzhou@math.msu.edu

CP11

On the Wellposedness of Generalized Darcy-Forchheimer Equation

We consider the Generalized Darcy-Forchheimer model,

$$\begin{aligned} \frac{\mu}{\rho}\boldsymbol{K}^{-1}\boldsymbol{u} + \frac{\beta}{\rho}|\boldsymbol{u}|^{m-1}\boldsymbol{u} + \bigtriangledown p = \boldsymbol{f} \qquad &\text{in} \qquad \Omega, m \in (1\ 2] \\ div\boldsymbol{u} = b \qquad &\text{in} \qquad \Omega, \\ \boldsymbol{u}\cdot\boldsymbol{n} = g \qquad &\text{on} \qquad \partial\Omega. \end{aligned}$$

modelling a steady single phase fluid flow in two or three dimensional porous medium, where $\boldsymbol{u}$ and p denote the unknown velocity vector and pressure field respectively. $\boldsymbol{K}$ is the permeability tensor. The parameter ρ,μ,β positive constants represent the density, viscosity and dynamic viscosity of the fluid respectively. f, b and g are given functions satisfying some compatibility conditions.
The problem is nonlinear of monotone type. For $m = 2$, the existence and uniqueness theory is presented in [Girault and Wheeler, Numerical discretization of Darcy-Forchheimer Equation] . For strong inertia flows in simple media,with $m \in (1, 2]$ and under some mild regularity assumptions on the interior and boundary data, we established the existence, uniqueness and stability of the solution $(\boldsymbol{u}, p)$ of (**??**) − (**??**) in $\left(L^m(\Omega)^d \times (W^{1,\frac{m+1}{m}}(\Omega) \bigcap L^2_0(\Omega))\right)$.

Johnson D. Audu
King fahd university of pertroleum and Minerals
King fahd university of pertroleum and Minerals
jdaudy@kfupm.edu.sa

Faisal A. Fairag
KFUPM
ffairag@kfupm.edu.sa

CP11

Multilayered Flows in the Shallow-Water Limit: Dynamics and Loss of Hyperbolicity

In this talk, we will formulate and discuss the problem of density stratified interfacial flows in the shallow-water limit. This type of flow occurs in nature with the atmosphere and ocean as prime examples. Mathematical studies of these are particularly important, since wave motion tends not to be resolved by most numerical climate models due to their fast scales, and thus need to be understood and parameterized. For example waves may break and dissipate energy or mix the underlying fluids and affect the medium in which they are propagating. Consequently this research will both increase the understanding of internal waves, and have an impact on future climate models. We will focus our attention on the two and three-layer flows, without the so-called Boussinesq approximation which requires small density differences. This is a simplified model for geophysical situations, but it is not too simplified: the model has both barotropic (fast waves affecting the whole fluid uniformly) and baroclinic modes (slower waves with more internal structure). The governing equations will be derived and the dynamics of their solutions will be studied from both analytical and numerical points of view, particularly the issue of whether the solutions maintain hyperbolicity (i.e. wave-like behaviour).

Francisco De Melo Virissimo
University of Bath
fdmv20@bath.ac.uk

Paul A. Milewski
Dept. of Mathematical Sciences
University of Bath
p.a.milewski@bath.ac.uk

CP11

Continuous Data Assimilation for the Magnetohydrodynamic Equations in 2D

We propose several continuous data assimilation algorithms based on feedback control for the 2D magnetohydrodynamic (MHD) equations. We show that for sufficiently large choices of the control parameter and resolution and assuming that the observed data is error-free, the solution of the controlled system converges exponentially (in L^2 and H^1 norms) to the reference solution independently of the initial data chosen for the controlled system. We also obtain results when controls are placed only on the horizontal (or vertical) variables, or on a *single* Elsässer variable, under more restrictive conditions on the control parameter and resolution. Finally, using the data assimilation system, we show the existence of *abridged* determining modes, nodes and volume elements.

Joshua Hudson
University of Maryland, Baltimore County
Department of Mathematics and Statistics
joshuahudson@umbc.edu

Animikh Biswas
University of Maryland, Baltimore County
abiswas@umbc.edu

Adam Larios

Department of Mathematics
University of Nebraska-Lincoln
alarios@unl.edu

Yuan Pei
University of Nebraska-Lincoln
ypei4@unl.edu

CP11

Flows of Immiscible Fluids Through the Channels with Porous Media in the Presence of Magnetic Field

This paper concerns with the flow of viscous, steady, incompressible and immiscible fluids with different viscosities in the channels of two infinite parallel plates. The flow is driven by the constant pressure gradient in the presence of transverse magnetic field of uniform strength. Both the channels are filled with the highly porous media and having different permeability. The flows through the channels are governed by the Brinkman equation with the inclusion of inertia term. No-slip conditions at the end of plates, continuity of velocity and continuity of shearing stress at the interface have been used as the boundary conditions to get the solution of the considered problem. The effect of various fluid parameters like permeability of porous region, magnetic number etc on the flow velocity profile, flow rate and shearing stress has been discussed graphically.

Sneha Jaiswal
MNNIT ALLAHABAD
snehajswl10@gmail.com

Pramod Kumar Yadav
MNNIT, Allahabad
pramod547@gmail.com

CP11

Mathematical and Numerical Analysis of Some Viscoelastic Flows

We present our recent theoretical and numerical results for the Peterlin viscoelastic fluids. This constitutive model is motivated by the Peterlin dumbbell theory with a nonlinear spring law for an infinitely extensible spring. A diffusion term is included in the constitutive model. We prove global existence of weak solutions for large data. For more regular data and a special choice of nonlinear constitutive functions the regularity and uniqueness of the solution can be shown. The Peterlin viscoelastic model has been investigated also from the numerical point of view and approximated by the LagrangeGalerkin scheme. We prove error estimates with the optimal convergence order without any relation between the time increment and the mesh size. The result is valid for both the diffusive and nondiffusive models. If time permits we report on our recent existence results for the multiscale model combining the macroscopic flow equations with the kinetic equation for viscoelastic effects. Here the elastic stress tensor is defined by the Kramers expression through the probability density function that satisfies the corresponding Fokker-Planck equation. The present research has been realized in the cooperation with H. Mizerova (Mainz), S. Necasova (Prag), M. Renardy (Virginia Tech), M. Tabata (Tokyo), H. Notsu (Kanazawa), A. Swierczewska-Gwiazda (Warsaw) and P. Gwiazda (Warsaw). It has been supported by the German Science Foundation DFG under the grant TRR 146.

Maria Lukacova
University of Mainz
Institute of Mathematics
lukacova@mathematik.uni-mainz.de

CP11

Fracture Modeling and Optimization for Nonlinear Flows in Coupled Fracture Porous Media

In this study, we analyze the flow filtration process of slightly compressible fluids in porous media containing fractures with complex geometries. We model the coupled fracture-porous media system where the linear Darcy flow is considered in porous media and the nonlinear Forchheimer equation is used inside the fracture. We develop a model to examine the flow inside fractures with complex geometries and variable thickness on a Riemannian manifold. The fracture is represented as the normal variation of a surface immersed in $\mathbb{R}^{⊮}$ and using Laplace Beltrami operator, an equation that describes the flow is formulated. Using the model, pressure profile of a nonlinear flow is analyzed and compared with the actual pressure profile obtained numerically in order to validate the model. Also, we couple the fracture model with the reservoir system. The diffusive capacity, a functional that measures the performance of the reservoir, is analyzed and compared with the actual diffusive capacity.

Pushpi J. Paranamana
Texas Tech University
pushpi.paranamana@ttu.edu

Eugenio Aulisa, Magdalena Toda, Akif Ibraguimov
Department of Mathematics and Statistics.
Texas Tech University
eugenio.aulisa@ttu.edu, magda.toda@ttu.edu, akif.ibraguimov@ttu.edu

MS1

Weak Solutions of Conservation Laws and Energy/Entropy Conservation

A common feature of systems of conservation laws of continuum physics is that they are endowed with natural companion laws which are in such case most often related with the second law of thermodynamics. This observation easily generalizes to any symmetrizable system of conservation laws. They are endowed with nontrivial companion conservation laws, which are immediately satisfied by classical solutions. Not surprisingly, weak solutions may fail to satisfy companion laws, which are then often relaxed from equality to inequality and overtake a role of a physical admissibility condition for weak solutions. We want to answer the question what is a critical regularity of weak solutions to a general system of conservation laws to satisfy an associated companion law as an equality. An archetypal example of such result was derived for the incompressible Euler system by Constantin et al. in a context of the seminal Onsager's conjecture. This general result can serve as an easy criterion to numerous systems of mathematical physics to prescribe the regularity of solutions needed for an appropriate companion law to be satisfied.

Piotr Gwiazda
Insitute of Applied Mathematics and Mechanics
University of Warsaw

pgwiazda@duch.mimuw.edu.pl

MS1

On the Energy Flux of Homogeneous Solutions to the Euler Equation

In this talk we will discuss mechanisms for energy balance restoration in 2D and 3D Onsager-critical homogeneous solutions to the incompressible Euler system. We also discuss classification of such solutions.

Roman Shvydkoy
University of Illinois at Chicago
shvydkoy@uic.edu

MS1

Nonuniqueness of Weak Solutions to the SQG Equation

We prove that weak solutions of the inviscid and the dissipative SQG equations are not unique. In view of the well-known global existence of weak solutions for the dissipative SQG equation with datum at the level of the Hamiltonian, our work is the first to show that weak solutions constructed via convex integration can exist in a regularity class in which the nonlinearity is weakly continuous. This is joint work with T. Buckmaster and S. Shkoller.

Vlad C. Vicol
Princeton University
Department of Mathematics
vvicol@math.princeton.edu

MS1

Statistical Solutions and Onsager's Conjecture

Recently, Fjordholm et al. introduced a statistical notion of solution for conservation laws. We adapt their framework to the incompressible Euler equations and prove a suitable version of the "conservative" part of Onsager's Conjecture. As a byproduct, we obtain an alternative proof of the classical statement for weak solutions.

Emil Wiedemann
University of Bonn
wiedemann@ifam.uni-hannover.de

Ulrik S. Fjordholm
University of Oslo
ulrik.fjordholm@sam.math.ethz.ch

MS2

Multi-Species Kinetic and Fluid Models and Applications

A kinetic description for evolving gases is given the so called BGK model, or ES-BGK models, or BGK models for a polyatomic gas. To overcome the restriction of this type of model to a single specific gas in applications, where gas mixtures are important, one is lead to multi-species kinetic models. All these models are devised so that they relax towards fluid models, such that correct features of the macroscopic partial differential equations (like viscosity coefficients) are recovered. These two fluid models allow one to present a hierarchy of fluid models. We shall illustrate this by beginning with ions and electrons, arriving at two fluid plasma equations. We shall illustrate the improved physical understanding of multi-species fluid models, and give examples of their numerical simulation. This is joint work with Marlies Pirner, Gabriella Puppo und Anas Crestetto.

Christian F. Klingenberg
Wurzburg University, Dept. of Mathematics
Germany
klingen@mathematik.uni-wuerzburg.de

MS2

A Bgk Model for Polyatomic Gas Flows at High Temperature

For atmospheric reentry problems, it is necessary to make numerical simulation of complex hypersonic flows, in which the temperature can be very large. For flows in continuous (dense) regime, simulation codes use models that take into account high temperature effects, like the excitation of the rotational and vibrational energy of the molecules. This is done by using a special equation of state (EOS), which is even not not known analytically, and is rather given by a numerical table. For such flows in high altitude, the air is rarefied, and a kinetic model must be used, like the Boltzmann equation. At the computational level, taking into rotational and vibrational non equilibrium in the Boltzmann equation induces a model with a very large dimension (more than 7 degrees of freedom). Its numerical solving is almost impossible, at least for transitional flows, in which DSMC solvers are known to be inefficient. In this talk, I will show that it is possible to design a simpler BGK model that is consistent with any arbitrary EOS. This model can take into account rotational and vibrational non equilibrium with the same level of accuracy as a CFD solver in a dense regime, with a complexity which is close to that of a simple monoatomic gas. This work is in collaboration with C. Baranger, G. Marois, J. Mathe, and J. Mathiaud, (French atomic energy agency).

Luc Mieussens
Institut de Mathematiques de Bordeaux
luc.mieussens@math.u-bordeaux1.fr

MS2

Well-Balanced and Asymptotic Preserving Schemes for Kinetic Models

We propose a general framework for designing numerical schemes that have both well-balanced (WB) and asymptotic preserving (AP) properties, for various kinds of kinetic models. We are interested in two different parameter regimes, 1) When the ratio between the mean free path and the characteristic macroscopic length ε tends to zero, the density can be described by (advection) diffusion type (linear or nonlinear) macroscopic models; 2) When $\varepsilon = O(1)$, the models behave like hyperbolic equations with source terms and we are interested in their steady states. We apply the framework to three different kinetic models: neutron transport equation and its diffusion limit, the transport equation for chemotaxis and its Keller-Segel limit. Numerical examples are given to demonstrate the properties of the schemes.

Min Tang
Shanghai Jiao Tong University, Department of Math
China

tangmin@sjtu.edu.cn

MS2

Self-organized Pattern Formation in a Kinetic Transport Equation for Chemotactic Bacteria

Collective motion of chemotactic bacteria as E. Coli relies, at the individual level, on a continuous reorientation by runs and tumbles. It has been established that the length of run is decided by a stiff response to temporal sensing of chemical cues along the pathway. We analyze consequences on self-organized pattern formation resulting from modulation of tumbling frequency with stiff response. Thanks to both analytical arguments and numerical simulations, we show that the stationary homogeneous state of population density is destabilized in realistic ranges of parameters. A remarkable property is that the unstable frequencies remain bounded, as it is the case in Turing instability.

Shugo Yasuda
University of Hyogo
yasuda@sim.u-hyogo.ac.jp

MS3

Application of Herglotz Functions to the Study of Viscodynamics of Porous Media

One important quantity in the study of porous media is the dynamic tortuosity, which characterizes the effective ebergy dissipation and the inertia coupling between the viscous fluid phase and the solid phase in a porous media. It plays the role of the the memory kernel in the generalized Biot equations, which are the governing equations of wave propagation in poroelastic media when the wave length is much longer than the length scale of the microstructure. In this talk, we will illustrate how the Herglotz function arises in the study of dynamic permeability, following the 1991 paper by Avellaneda and Torquato , and show how this result can be applied to the study of dynamic tortuosity and its Prony type approximation. Both the isotropic and anisotropic cases will be considered. We will show how the close tie between the Herglotz function and the Multipoint Pade (or rational) approximation is explored in this line of research.

Miao-Jung Y. Ou
University of Delaware, USA
Department of Mathematical Sciences
mou@udel.edu

Chuan Bi
University of Delaware
bichuan@udel.edu

MS3

Constraint Energy Minimizing Generalized Multiscale Finite Element Method

In this talk, we present Constraint Energy Minimizing Generalized Multiscale Finite Element Method (CEM-GMsFEM). The key part of the method is the design of multiscale basis functions within GMsFEM framework such that the convergence of method is independent of the contrast and linearly decreases with respect to mesh size if oversampling size is appropriately chosen. Our construction starts with an auxiliary multiscale space by solving local spectral problems. In auxiliary multiscale space, we select the basis functions that correspond to small (contrast-dependent) eigenvalues. These basis functions represent the channels (high-contrast features that connect the boundaries of the coarse block). Using the auxiliary space, we propose a constraint energy minimization to construct multiscale spaces. The minimization is performed in the oversampling domain, which is larger than the target coarse block. The constraints allow handling non-decaying components of the local minimizers. If the auxiliary space is correctly chosen, we show that the convergence rate is independent of the contrast and is proportional to the coarse-mesh size. We will also present some numerical results to verify the theoretical estimates. (The research is supported by Hong Kong RGC General Research Fund (Project 14317516).)

Eric Chung
The Chinese University of Hong Kong
Department of Mathematics
tschung@math.cuhk.edu.hk

MS3

Navier Slip Condition for Viscous Fluids on a Rough Boundary

In this talk, using homogenization methods and boundary layer techniques, I will derive asymptotically the effective Navier slip boundary condition, as a first-order corrector, to the no-slip condition on the interface between a fluid and a rough surface. The method used provides a formula to calculate the slip length for various geometries. I will also show some computations done, using FreeFem++, which agree with experimental data.

Silvia Jimenez Bolanos
Department of Mathematics
Colgate University
sjimenez@colgate.edu

Bogdan M. Vernescu
Worcester Polytechnic Inst
Dept of Mathematical Sciences
vernescu@wpi.edu

MS3

Criteria for Opening Band Gaps in Periodic Media

Explicit conditions on geometry and material contrast are identified for creating band gaps in 2-d photonic and 3-d acoustic crystals. The approach applied here makes use of the electrostatic and quasi-periodic source free resonances of the crystal, which deliver a spectral representation for solution operators associated with the propagation of waves inside the periodic high contrast medium. This, together with the Dirichlet spectrum and an auxiliary spectrum associated with the inclusions, delivers conditions for opening band gaps at finite contrast for a given inclusion geometry. This is joint work with Robert Viator Jr.

Robert P. Lipton
Department of Mathematics
Louisiana State University
lipton@math.lsu.edu

MS4

Low Reynolds Number Fluid-Structure Interactions: Modeling the Response of Soft Microfluidic

Devices

In this talk, we will summarize some recent results on the mathematical and computational modeling of microfluidic devices. Rectangular channels with deformable walls are used as one of the simplest models for the main component of lab-on-a-chip devices. Experimentally, these devices are found to deform into a non-rectangular cross-section due to fluid–structure interactions, leading to a non-linear relationship between the volumetric flow rate and the pressure drop. We predict this relation via perturbative calculations involving a coupled system of Stokes ($Re = 0$) flow in a 3D rectangular channel with a top wall that is a linearly elastic Kirchhoff–Love plate. We have benchmarked and verified the theoretical predictions by 3D numerical simulations, calibrated with experimental pressure drop–flow rate data, using the commercial software suite ANSYS. We will also discuss recent extensions of this work to solid geometries that are not well approximated as plates, and also cylindrical domains. The transient problem of inflation/deflation of a microchannel will also be touched upon.

Ivan C. Christov, Tanmay Shidhore
Purdue University
christov@purdue.edu, tshidhor@purdue.edu

MS4
The Einstein-Navier-Stokes System

We consider Einstein's equations coupled to equations modeling relativistic fluids with viscosity. We establish existence, geometric uniqueness, and causality of the corresponding initial-value problem. If time allows, we shall discuss applications to quark-gluon plasmas that form in collisions of heavy ions.

Marcelo Disconzi
Vanderbilt University
marcelo.disconzi@vanderbilt.edu

MS4
Plasticity by a Phase Field Model

In plastic metal theory, the mechanical behavior is related with the underlying micro-scale structure, such as dislocations and disclinations, which are considered as defects in the crystal structure of metals. It is well known that the plastic behavior is due to the increasing disorder of the crystal lattice caused by the strains. So, the dislocation migration is described by a differential system, from which by numerical simulation, we obtain the classical hysteresis loop for cyclic hardening under strain control.

Mauro Fabrizio
Universita di Bologna
mauro.fabrizio@unibo.it

MS4
Fluid Flow Through Deformable Porous Media: Analysis, Simulations and Applications

Fluid flow through porous deformable media is relevant for many applications in biology, medicine and bioengineering. In this talk, we discuss the problem of existence of weak solutions in bounded domains, accounting for non-zero volumetric and boundary forcing terms, with particular focus on the role of structural viscoelasticity. The theoretical analysis shows that different time regularity is required for the volumetric source of linear momentum and the boundary source of traction depending on whether or not viscoelasticity is present. The theoretical results are further investigated via numerical simulations based on a novel dual mixed hybridized finite element discretization. Simulations show that, in the purely elastic case, the solutions might become unbounded if the data do not enjoy the time regularity required by the theory. Furthermore, solution blow-up is proved by exhibiting an explicit solution in the one-dimensional case. Applications will be presented in the case of blood flow through ocular tissues. In this context, the theoretical findings led us to formulate a novel hypothesis concerning the causes of hemorrhages in the optic disc, namely that abrupt time variations in stress conditions, due to changes in intraocular or cerebrospinal fluid pressure, combined with lack of structural viscoelasticity, due to aging or disease, could lead to microstructural damage and rupture of blood vessels due to local fluid-dynamical alterations.

Giovanna Guidoboni
Indiana University-Purdue University at Indianapolis
Department of Mathematical Sciences
gguidobo@math.iupui.edu

Lorena Bociu
NC State University
Raleigh, NC
lvbociu@ncsu.edu

Riccardo Sacco
Politecnico di Milano
riccardo.sacco@polimi.it

Maurizio Verri
Dipartimento di Matematica
Politecnico di MIlano
maurizio.verri@polimi.it

Justin Webster
Department of Mathematics
College of Charleston
websterj@cofc.edu

MS5
Longtime Existence of Models of Water Waves on the Torus

We shall discuss a new method for the longtime existence of models of water waves.

Steve Shkoller
Univiversity of California, Davis
Department of Mathematics
shkoller@math.ucdavis.edu

MS5
Two Dimensional Water Waves

We consider the question of describing the long time dynamics for several one dimensional water wave models. Our primary focus will be the Benjamin-Ono equation, but if time permits the discussion will also involve the cubic NLS equation and the KdV equation.

Daniel Tataru
University of California, Berkeley

tataru@math.berkeley.edu

MS5

On Local-in-Time Existence of Solutions to the Free Moving Boundary Incompressible Euler Equations Without Surface Tension

We establish a priori estimates for local-in-time existence of solutions to the water wave model consisting of the 3D incompressible Euler equations on a domain with a free surface, without surface tension, under minimal regularity assumptions on the initial data and the Rayleigh-Taylor sign condition. The initial data is allowed to be rotational and it is assumed to belong to Sobolev space $H^{2.5+\delta}$, where $\delta > 0$ is arbitrary. This is joint work with Igor Kukavica from the University of Southern California.

Igor Kukavica
University of Southern California
kukavica@usc.edu

Amjad Tuffaha
American University Sharjah
atufaha@aus.edu

MS5

Challenges in the Modeling and Analysis of Axial Flow Flutter

Flutter is a (bounded response, self-excitation) 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 significant portion of the structures boundary is free and the flow is along the principal length 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 rigorous analysis. Beyond the obvious applications in aeroscience, the flutter phenomenon also arises in the biomedical realm and in sustainable energies. We will discuss 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), and emphasize the effect of rotational inertia in the structure. The challenges in the analysis can be viewed as reflections of the difficulty in modeling the physics of the problem. Recent results will be discussed that address well-posedness and global attractors of various cantilevered dynamics, along with recent numerical simulations.

Justin T. Webster
Department of Mathematics
College of Charleston
websterj@umbc.edu

Daniel Toundykov
Department of Mathematics
University of Nebraska-Lincoln
dtoundykov@unl.edu

Jason Howell
College of Charleston
howelljs@cofc.edu

MS6

Anomaly Detection and Classification for Streaming Data Using Partial Differential Equations

Non-dominated sorting, also called Pareto Depth Analysis (PDA), is widely used in multi-objective optimization and has recently found important applications in multi-criteria anomaly detection. Recently, a PDE continuum limit was discovered for non-dominated sorting, which provides a fast and convenient method for approximate PDA. A second PDE continuum limit was discovered which sorts points within their Pareto fronts, based on the extent to which they violate a criterion. In this talk we present an algorithm based on the discretization of these PDEs which provides a real-time streaming version of the PDA algorithm that exploits the computational advantages of the PDE and has the added benefit of being able to classify anomalies. Numerical experiments conducted on both synthetic and real data validate the efficacy of the algorithm are presented.

Bilal Abbasi
McGill University
bilal.abbasi.ba@gmail.com

MS6

Deep Relaxations: Partial Differential Equations for Optimizing Deep Neural Networks

This paper establishes a connection between non-convex optimization and nonlinear partial differential equations (PDEs). We interpret empirically successful relaxation techniques motivated from statistical physics for training deep neural networks as solutions of a viscous Hamilton-Jacobi (HJ) PDE. The underlying stochastic control interpretation allows us to prove that these techniques perform better than stochastic gradient descent (SGD). Moreover, we derive this PDE from a stochastic homogenization problem which proves connections to algorithms for distributed training of deep networks like Elastic-SGD. Our analysis provides insight into the geometry of the energy landscape and suggests new algorithms based on the non-viscous Hamilton-Jacobi PDE that can effectively tackle the high dimensionality of modern neural networks.

Pratik A. Chaudhari
UCLA
pratikac@ucla.edu

Adam M. Oberman
Department of Mathematics and Statistics
adam.oberman@mcgill.ca

Stanley J. Osher
University of California
Department of Mathematics
sjo@math.ucla.edu

Stefano Soatto
UCLA
soatto@cs.ucla.edu

Guillaume Carlier
CEREMADE
Universite Paris IX Dauphine

carlier@ceremade.dauphine.fr

MS6

A PDE Approach to Prediction with Mixed Strategies

This work investigates a classical problem from online machine learning using methods from optimal control theory. The problem is a discrete time iterative process involving decision making at every step; the goal for mathematical analysis is to understand the optimal strategy and its consequences over a long period of time. The solution is analyzed through its continuous limit - an appropriately defined value function, which solves a PDE in the viscosity sense. The PDE is then used to determine the optimal strategies.

Nadejda Drenska
Courant Institute of Mathematical Sciences
drenska@cims.nyu.edu

Robert V Kohn
Courant Institute of Mathematical Sciences
New York University
kohn@cims.nyu.edu

MS6

Elliptic PDE Tackled by Primal-Dual Optimization

Elliptic PDE are the Euler-Lagrange equations of a *convex* optimization problem. Here we propose to make use of the recent efficient primal-dual hybrid gradients method to solve the PDE through a convex optimization lens. The proposed scheme avoids inversion of the operator and uses adjoints instead. Elimination of the dual variable eventually yields an explicit scheme with faster convergence than traditional stiffness-condition limited explicit scheme. The speed-up is due to an apparent boosting term, reminiscent of the momentum method. We present preliminary numerical results on standard problems (Poisson problem, obstacle problem), applied problems (H1-regularized least squares, MBO motion by mean curvature), random walks, and diffuse interfaces on graphs. Off-label use extends the proposed method to non-convex problems such as Schroedinger eigenfunctions and pagerank.

Dominique P. Zosso
Montana State University
Department of Mathematical Sciences
dominique.zosso@montana.edu

Braxton Osting
University of Utah
osting@math.utah.edu

MS7

Slow Motion for the 1D Swift–Hohenberg Equation

We study the behavior of certain solutions to the Swift–Hohenberg equation on a one-dimensional torus. Combining results from Γ-convergence and ODE theory, we show that solutions corresponding to initial data that is L^1-close to a jump function v, remain close to v for large time. This can be achieved by regarding the equation as the L^2-gradient flow of a second order energy functional, and obtaining asymptotic lower bounds on this energy in terms of the number of jumps of v.

Gurgen Hayrapetyan
Ohio University
Department of Mathematics
hayrapet@ohio.edu

Matteo Rinaldi
Carnegie Mellon University
matteor@andrew.cmu.edu

MS7

A Generalized Swift-Hohenberg Model for Active Liquid Crystal Suspensions

Recent laboratory experiments have demonstrated that biological rod-protein assemblies exhibit a 2D active liquid crystal phase characterized by a rich topological defect dynamics. This remarkable discovery has sparked considerable theoretical and experimental interest. I will present and validate a tensor Swift-Hohenberg PDE model for this system by merging universality ideas with the classical Landau-de Gennes theory. The resulting model agrees quantitatively with recently published data and, in particular, predicts a previously unexplained regime characterized by antipolar order of topological defects. Our results suggest that complex nonequilibrium pattern-formation phenomena might be predictable from a few fundamental symmetry-breaking and scale-selection principles.

Anand Oza
Courant Institute, NYU
oza@cims.nyu.edu

Jorn Dunkel
Mathematics, MIT
dunkel@math.mit.edu

MS7

Moduli Spaces of Growth Patterns

Interfaces or boundaries affect the formation of crystalline phases in sometimes quite dramatic ways. Examples range from the alignment of convection roles in Benard convection perpendicular to the boundary, to the robust patterning through presomites in limb formation. Mathematically, the object of interest is a moduli space of solutions to elliptic equations in unbounded domains. This moduli space contains the relation between rate of growth and crystallographic parameters such as the width and orientation of convection rolls or presomites. I will explain the role of this moduli space and give results and conjectures on its shape in examples, starting with simple convection-diffusion and phase separation problems, and concluding with Turing patterns.

Ryan Goh
Boston University
rgoh@bu.edu

Rafael Monteiro da Silva, Antoine Pauthier
School of Mathematics
University of Minnesota
rmonteir@umn.edu, apauthie@umn.edu

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

Jasper Weinburd
University of Minnesota - Twin Cities
weinburd@umn.edu

MS7

The Effect of Impurities on Stripes

We study the effect of algebraically localized impurities on striped phases in one and higher space-dimension. We therefore develop a functional-analytic framework which allows us to cast the perturbation problem as a regular Fredholm problem despite the presence of essential spectrum, caused by the soft translational mode. Our results establish the selection of jumps in wavenumber and phase, depending on the location of the impurity and the average wavenumber in the system. We also show that, for select locations, the jump in the wavenumber vanishes.

Qiliang Wu
Michigan State University
wuq@ohio.edu

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

Gabriela Jaramillo
The University of Arizona
gjaramillo@math.arizona.edu

MS8

The Lagrangian and Eulerian Analyticity for the Euler Equations

We revisit preservation of analyticity and Gevrey regularity for the Euler equation. We provide a result on preservation of Gevrey norm and analyticity in Lagrangian formulation and discuss the validity of the result in the Eulerian variables.

Guher Camliyurt
University of Southern California
camliyur@usc.edu

MS8

Inertial Manifolds for the Hyperviscous Navier-Stokes Equations

We prove the existence of an inertial manifold, i.e., a globally invariant, exponentially attracting, finite-dimensional smooth manifold, for the incompressible hyperviscous Navier-Stokes equations on the two or three-dimensional torus:

$$u_t + \nu(-\Delta)^\beta u + (u \cdot \nabla)u + \nabla p = f, \quad (t, x) \in \mathbb{R}_+ \times \mathbb{T}^d,$$

with $\nabla \cdot u = 0$, where $d = 2$ or 3 and $\beta \geq 3/2$. Since the spectral gap condition is not available for the aforementioned problem in three dimensions, we employ the spatial averaging method introduced by Mallet-Paret and Sell.

Ciprian Gal, Yanqiu Guo
Florida International University
cgal@fiu.edu, yanguo@fiu.edu

MS8

On a Subclass of Solutions of the 2D Navier-Stokes Equations with Constant Energy and Enstrophy

It is not yet known if the global attractor of the space periodic 2D Navier-Stokes equations contains nonstationary solutions u(x; t) such that their energy and enstrophy per unit mass are constant for every t. Due to the hypothetical existence of such solutions, they were called ghost solutions. In this work, we introduce and study geometric structures shared by all ghost solutions.This study led us to consider a subclass of ghost solutions for which those geometric structures have a supplementary stability property. In particular, we show that the wave vectors of the active modes of this subclass of ghost solutions must satisfy certain supplementary constraints. We also find a computational way to check for the existence of these ghost solutions.

Jing Tian, Bingsheng Zhang
Texas A&M University
jtian@towson.edu, bszhang@math.tamu.edu

MS8

Efficient Numerical Algorithms for Approximating Long Time Statistical Behavior of Certain Fluid Models

The long-time dynamics of many infinite-dimensional dynamical systems, especially those generated by various fluid models, are very complex with abundant chaotic/turbulent behaviors which calls for statistical descriptions. The long-time statistics, characterized by the invariant measures, which describes the “climate” of the system is of particular significance in many applications. The design of algorithms that are able to capture the ”climate” is intrinsically a challenge since small errors might accumulate over an extended time interval. We present a set of Lax type conditions that consists of an appropriate consistent condition and a suitable stability condition. The Lax type conditions guarantee the convergence of the long-time statistical properties of the discrete schemes to those of the underlying PDEs both in the semi-discrete in time case and the fully discretized case. Applications to the two-dimensional Navier-Stokes equations and the barotropic quasi-geostrophic equation, the infinite Prandtl number model for convection, a double diffusive convection model, and the complex Ginzburg-Landau equation will be discussed.

Xiaoming Wang
Florida State University
wxm.math@outlook.com

MS9

Optimal Shape of Isolated Ferromagnetic Domains

We investigate the optimal shape and the scaling of the minimal energy of isolated magnetic domains in hard magnetic materials. The underlying energy is given by the interfacial energy of the domain and a competing nonlocal term due to magnetostatic energy. This energy appears in the nucleation theory for magnetization reversal in uniaxial materials. We show existence of minimizers for all volumes and derive a scaling law for the minimal energy. Moreover, we show further properties on regularity and topology for local minimizers and the potential.

Hans Knuepfer
University of Heidelberg
knuepfer@uni-heidelberg.de

Cyrill B. Muratov
New Jersey Institute of Technology
Department of Mathematical Sciences
muratov@njit.edu

Florian Nolte
University of Heidelberg
Institute for Applied Mathematics
f.nolte@uni-heidelberg.de

MS9

A Variational Model for Charged Drops

Equilibrium shapes of charged, conducting liquid drops are governed by a geometric variational problem that involves a perimeter term modeling surface tension and a capacitary term modeling Coulombic repulsion. I will discuss the well-posedness of such model in two and three dimensions, and show the global stability of the ball when the total charge is sufficiently small.

Matteo Novaga
Università di Pisa
novaga@dm.unipi.it

Michael Goldman
CNRS
goldman@math.univ-paris-diderot.fr

Cyrill B. Muratov
New Jersey Institute of Technology
Department of Mathematical Sciences
muratov@njit.edu

Berardo Riffini
Université de Montpellier
berardo.ruffini@umontpellier.fr

MS9

Analysis and Numerics for Induced-charge Electrokinetic Flow with Interfaces

Abstract Not Available At Time Of Publication.

Michael Siegel
New Jersey Institute of Technology
michael.s.siegel@njit.edu

MS9

Energy-based Phase Field Model for Two Phase Ferrodroplet Deformation and Breakup under Magnetic Field

Abstract Not Available At Time Of Publication.

Xiaofeng Yang
University of South Carolina
xfyang@math.sc.edu

MS10

Inviscid Limit of Viscous Flows in Domains with Rough Boundaries

We will present a joint work with Lacave, NGuyen and Rousset about the inviscid limit of the Navier-Stokes equation endowed with a slip condition at a rough boundary. In the case of smooth boundaries, the inviscid limit can be shown easily either by direct energy estimates or by compactness properties of the vorticity. These methods fail in the rough case due to an "inviscid" boundary layer generated by the roughness. We will show how to handle this issue under suitable conditions on the viscosity and roughness parameters.

David Gerard-Varet
Institut Mathématiques de Jussieu.
Université Paris Diderot (Paris 7)
gerard-varet@math.jussieu.fr

MS10

A Proof of Onsager's Conjecture

In an effort to explain how anomalous dissipation of energy occurs in hydrodynamic turbulence, Onsager conjectured in 1949 that weak solutions to the incompressible Euler equations may fail to exhibit conservation of energy if their spatial regularity is below 1/3-Hölder. I will discuss a proof of this conjecture that shows that there are nonzero, $(1/3-\epsilon)$-Hölder Euler flows in 3D that have compact support in time. The construction is based on a method known as "convex integration," which has its origins in the work of Nash on isometric embeddings with low codimension and low regularity. A version of this method was first developed for the incompressible Euler equations by De Lellis and Székelyhidi to build Hölder-continuous Euler flows that fail to conserve energy, and was later improved by Isett and by Buckmaster-De Lellis-Székelyhidi to obtain further partial results towards Onsager's conjecture. The proof of the full conjecture combines convex integration using the Mikado flows introduced by Daneri-Székelyhidi with a new gluing approximation technique. The latter technique exploits a special structure in the linearization of the incompressible Euler equations.

Philip Isett
Massachussets Institute of Technology
isett@math.mit.edu

MS10

On the Riemann Problem for the MultiD Isentropic Euler System

We consider the Riemann problem for the two-dimensional compressible isentropic Euler system, i.e. we solve the equations on the whole 2D space and the initial data consists of two pairs of constants, each on one of the half-planes. This classical problem possesses a one-dimensional self-similar admissible solution which is unique in the class of self-similar 1D solutions. We study uniqueness of this solution in the broader class of essentially bounded 2D functions. We summarize the up-to-date results concerning uniqueness and nonuniqueness of admissible weak solutions in certain cases of initial data. The nonuniqueness results are based on the theory of De Lellis and Székelyhidi for incompressible Euler equations and in particular the results show that the entropy inequality is not good enough to single out a unique solution. The uniqueness results are based on the relative entropy method.

Ondrej Kreml
Institute of Mathematics ASCR, Zitna 25, 115 67 Praha 1

kreml@math.cas.cz

MS10

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Alexis F. Vasseur
University of Texas at Austin
vasseur@math.utexas.edu

MS11

Bgk Models for Mixtures of Polyatomic Gases with Discrete Or Continuous Internal Energy

In kinetic theory, non–translational degrees of freedom of polyatomic molecules are modelled allowing the distribution function to depend also on a discrete or continuous internal energy variable. Besides classical elastic collisions, particles are subject to inelastic encounters changing their internal energy state (transforming part of kinetic energy into internal energy or vice versa) and/or to chemical reactions implying also transfer of mass. We propose consistent BGK approximations of the cumbersome Boltzmann equations for polyatomic gas mixtures, where parameters of the Maxwellian attractors are uniquely determined as functions of the main macroscopic fields (densities, velocities, and temperatures) by imposing preservation of exact equilibria and collision invariants of the original kinetic approach. This BGK approximation is well suited both for gases with a set of discrete internal energy levels (where a single gas is described as a mixture of monatomic components, each one with a fixed internal energy), and for gases with continuous internal energy. Even simple reactive flows are investigated, managing additional difficulties due to the mass action law, a transcendental equation relating equilibrium temperature with number densities of the constituents. An asymptotic Chapman–Enskog analysis is then performed in the continuum limit in order to achieve consistent fluid–dynamic Navier–Stokes equations for the macroscopic fields.

Marzia Bisi
Parma University
Italy
marzia.bisi@unipr.it

MS11

Construction of BGK Models from Entropy Minimization Principles

In this talk we will present a derivation principle of BGK models using the resolution of an entropy minimization problem. The construction is based as on the introduction of relaxation coefficients and a principle of entropy minimization under constraints for moments. These free parameters are next adjusted to transport coefficients when performing a Chapman-Engskog expansion up to Navier-Stokes. Firstly, the methodology will be explained and illustrated for a monoatomic and polyatomic single gas. -Next the case of gas mixtures is considered. In this part, after clarifying the Chapman-Engskog, a BGK model is derived. This BGK model is proved to satisfy Fick and Newton laws. In a last part, we will explain how to extend our model to reacting gas mixtures.

Stephane Brull
Institut de Mathématiques de Bordeaux UMR 5251
Institut Polytechnique de Bordeaux
stephane.brull@math.u-bordeaux1.fr

MS11

A Consistent Kinetic Model for a Two-component Mixture of Polyatomic Molecules

We consider a multi-component gas mixture with translational and internal energy degrees of freedom assuming that the number of particles of each species remains constant. We derive a two species kinetic model which can easily be generalized to more species. The two species are allowed to have different degrees of freedom in internal energy. We prove consistency of our kinetic model: conservation properties, positivity of the temperature, H-theorem, convergence to a global equilibrium in the form of a global Maxwell distribution, existence, uniqueness and positivity of solutions. Then, we derive the corresponding macroscopic conservation laws. For numerical efficiency we apply the Chu reduction to our kinetic model for polyatomic gases and give an application for a gas consisting of a mono atomic and a diatomic species. This is joint work with Christian Klingenberg (Würzburg University) and Gabriella Puppo (Università Insubria).

Marlies Pirner
Dept. of Mathematics
Wuerzburg University
marlies.pirner@mathematik.uni-wuerzburg.de

MS11

A Dichotomy in the Dissipation Estimates for the Polatomic BGK Model

In this talk, we consider a dichotomy observed in the dissipation estimates for the polyatomic BGK model. By dissipation estimate, we mean either the entropy-entropy production estimate of the nonlinear polyatomic BGK model, or the coercive estimate of the linearized polyatomic relaxation operator. In the former case, we observe a jump in the coefficient and the target equilibrium state as a relaxation parameter tends to zero. In the latter case, we show that the coefficient and the degeneracy of the coercive estimate see a sudden jump as the same relaxation parameter reaches zero. We also discuss how these two results are related.

Seok-Bae Yun
Sungkyunkwan University
South Korea
sbyun01@skku.edu

MS12

Homogenization of the Poincaré-Neumann Operator

We study the spectrum of the Neumann-Poincaré operator K_ε^* of a periodic collection of smooth inhomogeneities, as the period $\varepsilon \to 0$. Under the assumption that the pattern of inhomogeneity is strictly included in the periodicity cell,we show that the limit set $\lim_{\varepsilon\to 0} \sigma(K_\varepsilon^*)$ is the union of a Bloch spectrum and of a boundary spectrum, associated with eigenfunctions which are not too small (as functions in H^1) near the boundary.

Eric Bonnetier
Université Grenoble-Alpes
Laboratoire Jean Kuntzmann
eric.bonnetier@univ-grenoble-alpes.fr

Charles Dapogny, Faouzi Triki
Laboratoire Jean Kuntzmann
Université Grenoble Alpes
charles.dapogny@univ-grenoble-alpes.fr,
faouzi.triki@univ-grenoble-alpes.fr

MS12

Low-Frequency, Low-Wavenumber Approximation of the Willis Effective Model for Periodic Media

Willis (1981,2009) proposed the effective constitutive relations (coupling stress, momentum density, strain, and particle velocity) describing the mean wave motion in elastic composites with either random or periodic microstructure. The focus of this work is to establish a uniform representation of the Willis effective constitutive relations for periodic media and to explore their connection to the previously established framework of multiple-scales homogenization. We first show via an eigenfunction approach that the Willis effective constitutive relations are well defined in the non-degenerate case, and that they may have singularities in the exceptional case. The Willis framework of homogenization can be deemed *exact* in the sense that the germane dispersion relationship, when computed in terms of the averaged quantities, recovers that written in terms of the original (non-averaged) fields. We next compare the low frequency low wavenumber (LF-LW) expansion of the Willis effective impedance with that computed by the two-scale homogenization approach. We show for the first time that in the Fourier domain, the two approximations *differ by a factor* which is a polynomial in wave vector and frequency. This modulation factor is found to arise from homogenization of the *source term* in the governing field equation, that is often ignored by multiple-scales homogenization analyses.

Bojan B. Guzina
University of Minnesota
guzin001@umn.edu

Shixu Meng
IMA
University of Minnesota
shixu.meng@gmail.com

MS12

Data-to-Born Transform for Inversion and Imaging with Waves

We consider an inverse problem for the acoustic wave equation, where an array of sensors probes an unknown medium with pulses and measures the scattered waves. The goal is to determine from these measurements the structure of the scattering medium, modeled by a spatially varying acoustic impedance function. Many conventional inversion algorithms assume that the dependency of the scattered waves on the unknown impedance is approximately linear. The linearization, known as the Born approximation, is not accurate in strongly scattering media, where the waves undergo multiple reflections before reaching the sensors. This results in artifacts in the impedance reconstructions. We show that it is possible to remove the multiple scattering effects from the data, using a reduced order model (ROM). The ROM is an orthogonal projection of the wave equation propagator on the subspace spanned by the time domain snapshots of the wavefields. While the snapshots are only known at sensor locations, this information is enough to construct the ROM. Once the ROM in constructed, we use its perturbations to generate a new data set that the same impedance would generate if the waves in the medium propagated according to Born approximation. We refer to such procedure as the Data-to-Born transform. Once the multiple scattering effects are removed from the data by the transform, it can be fed to conventional linearized inversion workflows.

Alexander V. Mamonov
University of Houston
mamonov@math.uh.edu

Liliana Borcea
University of Michigan
borcea@umich.edu

Vladimir L. Druskin, Mikhail Zaslavsky
Schlumberger-Doll Research
druskin1@slb.com, mzaslavsky@slb.com

MS12

Effect of Asymmetries on Bulk Resonance in Multi-Scale Periodic Structures

I will discuss the relationships between several aspects of periodic structures: symmetries, embedded eigenvalues, factorability of the dispersion relation, and resonance. By controlling the amount of asymmetry at the meso-scale of a periodically micro-structured material, one can control the sharpness of the resonances that define the bulk wave-propagation properties. Bilayer graphene with periodically dispersed defects provides an illustrative example.

Stephen Shipman
Louisiana State University
shipman@math.lsu.edu

MS13

Stabilization of Maxwell's Equations

We will discuss the stabilizability of the dynamic Maxwell equations by means of a conductivity term. Various results will be given, depending on the set in which the conductivity is known to be strictly positive. The initial configuration of the magnetic field will be assumed to be divergence free which is in agreement with most physical models.

Matthias Eller
Georgetwon University
Department of Mathematics
mme4@georgetown.edu

MS13

Global Existence for Fluid-Structure Models

We address a fluid-structure system coupling the incompressible Navier-Stokes equations and a linear wave equation with interior damping. The interaction take place at a common interface and it is described by the transmission boundary conditions matching the velocities and the stress forces at the interface. We prove the global existence and exponential decay of solutions for small initial data in a suitable Sobolev space. This is a joint work with Igor Kukavica, Irena Lasiecka, and Amjad Tuffaha.

Mihaela Ignatova
Princeton University
mihaelai@math.princeton.edu

Igor Kukavica

University of Southern California
kukavica@usc.edu

Amjad Tuffaha
American University Sharjah
atufaha@aus.edu

Irena M. Lasiecka
University of Memphis
lasiecka@memphis.edu

MS13

On the Muskat Flow

Of concern is the motion of two uids separated by a free interface in a porous medium, where the velocities are given by Darcy's law. We consider the case with and without phase transition. It is shown that the resulting models can be understood as purely geometric evolution laws, where the motion of the separating interface depends in a nonlocal way on the mean curvature. It turns out that the models are volume preserving and surface area reducing, the latter property giving rise to a Lyapunov function. We show well-posedness of the models, characterize all equilibria, and study the dynamic stability of the equilibria. Lastly, we show that solutions which do not develop singularities exist globally and converge exponentially fast to an equilibrium.

Gieri Simonett
Vanderbilt University
gieri.simonett@vanderbilt.edu

MS14

Fluid-Structure and Structure-Structure Interaction with Slip

In fluid mechanics the widely accepted boundary condition for viscous flows is the no-slip condition. When applied to fluid-structure interaction problems this condition states that the fluid velocity at the moving structure boundary is equal to the velocity of the structure boundary itself. Recent advances in mathematical analysis and experimental measurements have shown, however, that the no-slip condition is not adequate to capture certain important physical phenomena. Examples include flows over hydrophobic surfaces (e.g. spray fabricated liquid repellant surfaces), flows over rough boundaries such as elastic tissue scaffolds, and contact between elastic bodies in a viscous, incompressible fluid. Despite a relatively rich literature on FSI problems with no-slip boundary condition, there are no analytical results or partitioned numerical schemes that deal with the Navier slip condition. In this talk we present an existence result and a partitioned numerical scheme for this class of problems. The existence proof is constructive, based on the time-discretization via operator splitting. In addition to the theoretical results, we will show numerical simulations with laminated structures, where different layers are connected with a slip boundary condition. Our results show that laminated structures with slip damp high frequency oscillations in FSI problems, which has practical importance in the design of, e.g., oceanic platforms, and vascular constructs.

Suncica Canic
University of Houston
suncicacanic@gmail.com

B. Muha
University of Zagreb
Department of Mathematics
borism@math.hr

Martina Bukac
University of Pittsburgh
Department of Mathematics
martinab@pitt.edu

MS14

Energy Estimates for A Relativistic Liquid

We prove new energy estimates for the free boundary problem for a compact relativistic liquid. These energies control the fluid velocity as well as the regularity of the free boundary. This is joint work with Hans Lindblad.

Daniel Ginsberg
Johns Hopkins University
dginsbe5@math.jhu.edu

MS14

A Flow Map Approach to the Water Wave Equations

This work is concerned with the infinite depth water wave equations in two space dimensions. We revisit the local well posedness and cubic existence of solutions for small data. Neither of these results are new; they have been recently obtained by Alazard-Burq-Zuily, Wu, Hunter-Ifrim-Tataru using different coordinates, and methods. Instead our goal will be to improve the understanding of this problem by providing a "flow map' approach that will uncover the special structure of the water waves system. This presentation will be self contained.

Mihaela Ifrim
University of California, Berkeley
Berkeley
ifrim@berkeley.edu

MS14

Long-time Behavior and Stability of Rigid Bodies with a Fluid-filled Gap

We consider the fluid-solid interactions occurring when a viscous incompressible fluid is confined to move in a bounded domain between two rotating rigid bodies. We study the long-time dynamics and stability of steady-states of the whole system S of rigid bodies with the fluid-filled gap. We show that the fluid has a stabilizing effect on the motions of both the rigid bodies. More precisely, the fluid velocities relative to the solids tend, respectively, to zero as time approaches to infinity. Moreover, the long-time dynamics of the whole system is completely characterized by permanent rotations with S moving as a whole rigid body. The stability of such permanent rotations will be also discussed.

Giusy Mazzone
Vanderbilt
giusy.mazzone@vanderbilt.edu

MS15

The Weighted p-Laplacian and Semi-Supervised Learning

Semi-supervised learning refers to machine learning algorithms that make use of both labeled data and unlabeled data for learning tasks. Examples include large scale non-parametric regression and classification problems, such as predicting voting preferences of social media users, or classifying medical images. In this talk, we will present some new results on continuum limits for graph-based semi-supervised learning in the limit of infinite unlabeled data and finite labeled data. We show that the continuum limits correspond to solving a weighted p-Laplace equation in the viscosity sense and are non-degenerate only when $p > d$.

Jeff Calder
University of Minnesota
jcalder@umn.edu

MS15

Gromov-Hausdorff Limit of Wasserstein Spaces on Point Clouds

Inferring geometric properties of a ground-truth measure based on the observation of finitely many samples is an important task with applications to machine learning and statistics. Given that many analytical and geometrical notions at the continuum level can be analyzed by interpreting them in Wasserstein space, it is then natural to do the same at the sample level by considering the right notion of discrete Wasserstein space and ask: when and how are these notions stable as the sample size grows to infinity? The main result that I will present in the talk can be used to establish a variety of consistency results for evolutions of gradient flow type that are relevant to tasks like manifold learning and clustering.

Nicolas Garcia Trillos
Brown University
nicolas_garcia_trillos@brown.edu

MS15

Auction Dynamics: A Volume Constrained Mbo Scheme

We show how auction algorithms, originally developed for the assignment problem, can be utilized in Merriman, Bence, and Osher's threshold dynamics scheme to simulate multi-phase motion by mean curvature in the presence of equality and inequality volume constraints on the individual phases. The resulting algorithms are highly efficient and robust, and can be used in simulations ranging from minimal partition problems in Euclidean space to semi-supervised machine learning via clustering on graphs. Numerous numerical experiments, particularly exhaustive in the case of the latter application, are presented that demonstrate on various benchmark datasets results exceeding the state-of-the-art in accuracy while requiring a fraction of the computational time.

Ekaterina Merkurjev
Department of Mathematics
Michigan State University
kmerkurjev@gmail.com

MS15

A Generalized MBO Diffusion Generated Motion for Orthogonal Matrix Valued Fields

MBO diffusion generated motion is a method introduced by Merriman, Bence, and Osher for evolving the boundary of a set by mean curvature flow. The method consists of two simple steps, which are iterated until convergence. The first is the time evolution of an indicator function of the set by the diffusion equation for a short time. The second is the point-wise thresholding of this function to obtain a new indicator function. Over the last 25 years, this method has been further analyzed, developed, and employed in a variety of interesting applications. In this talk, I'll discuss a generalization of this method to orthogonal matrix valued fields. In particular, following the Ginzburg-Landau approach, we consider a relaxation of the Dirichlet energy for orthogonal matrix valued fields that includes a term that penalizes the matrix not being orthogonal. We introduce a generalization of the MBO diffusion generated motion that effectively finds local minimizers of this relaxed energy. We extend the Lyapunov function of Esedoglu and Otto to show that the method is non-increasing on iterates and hence, unconditionally stable. We also give a proof of convergence for the algorithm. The algorithm is efficiently implemented using the closest point method and non-uniform FFT. I'll conclude by presenting several numerical experiments to demonstrate the range of behavior for local minimizers of this generalized energy.

Braxton Osting, Dong Wang
University of Utah
osting@math.utah.edu, dwang@math.utah.edu

MS16

Vortices in Rapidly Rotating Boussinesq Convection

We study long time asymptotics in the Boussinesq approximation for rapidly rotating stably-stratified fluids in a three dimensional infinite layer with either stress-free or periodic boundary conditions. For initial data satisfying certain smallness criteria, we use self-similar variables to show that the baroclinic vorticity converges to an Oseen Vortex with algebraic rate while the baroclinic component decays to zero faster than any algebraic rate. In the case of periodic boundary conditions, we also find that the barotropic vertical velocity and thermal fluctuations converge to decaying Gaussians whose amplitudes oscillate with opposite phase of each other. We also use dispersive estimates and Lyapunov functional techniques to determine asymptotics in the rapid rotation limit for a broader class of initial data where we only require smallness in the quasi-geostrophic part of the baroclinic dynamics.

Ryan Goh
Boston University
rgoh@bu.edu

C. Eugene Wayne
Boston University
Dept. of Mathematics and Statistics
cew@math.bu.edu

MS16

Travelling Waves for the Stochastic Nagumo Equation

In this talk we study stochastic traveling waves in the Nagumo equation using methods from deterministic nonlinear stability analysis. Combining classical methods with stochastic calculus enables us to compute the changes in the expected speed and shape of the stochastic wave compared with the deterministic wave. Furthermore, we can prove stability of the stochastic travelling wave when we extend the estimates from the well known deterministic case.

Christian Hamster
Leiden University
c.h.s.hamster@math.leidenuniv.nl

Hermen Jan Hupkes
University of Leiden
Mathematical Institute
hhupkes@math.leidenuniv.nl

MS16

Bifurcation to Locked Fronts in Two Component Reaction Diffusion Equations

We study invasion fronts and spreading speeds in two component reaction-diffusion systems. Using Lin's method, we construct traveling front solutions and show the existence of a bifurcation to locked fronts where both components invade at the same speed. Expansions of the wave speed as a function of the diffusion constant of one species are obtained. The bifurcation can be sub or super-critical depending on whether the locked fronts exist for parameter values above or below the bifurcation value. Interestingly, in the sub-critical case the spreading speed of the system does not depend continuously on the coefficient of diffusion.

Gregory Faye
Universite de Toulouse
gregory.faye@math.univ-toulouse.fr

Matt Holzer
Department of Mathematics
George Mason University
mholzer@gmu.edu

MS16

Competing Interactions, Patterns, and Traveling Waves in Discrete Systems

We consider bistable lattice differential equations with competing first and second nearest neighbor interactions. We construct heteroclinic orbits connecting the stable zero equilibrium state with stable spatially periodic orbits of period p=2,3,4 using transform techniques and a bilinear bistable nonlinearity. We investigate the existence, global structure, and multiplicity of such traveling wave solutions. For smooth nonlinearities an abstract result on the persistence of traveling wave solutions is presented and applied to lattice differential equations with repelling first and/or second neighbor interactions and to some problems with infinite range interactions.

Erik Van Vleck
Department of Mathematics
University of Kansas
erikvv@ku.edu

Anna Vainchtein
Department of Mathematics
University of Pittsburgh
aav4@pitt.edu

Aijun Zhang
University of Kansas
azhang@math.ku.edu

MS17

Gaining Two Derivatives on a Singular Force in the 2D Navier-Stokes Equations

It has long been known, for the autonomous 2D Navier-Stokes equations with singular forcing in H^{-1}, that there exist unique solutions which are globally in L^2, a gain of one derivative. These classical techniques also show us that the solution is almost everywhere in H^1. On the other hand, if the forcing term is in L^2, it is known that the solution remains in H^2 globally, a gain of two derivatives. In this paper, we explore classical techniques to show that if the force is in H^α for $\alpha \in (-1, 0)$, then the solution gains two derivatives globally. These methods break down for forces in H^{-1}. In this scenario, we use a Littlewood-Paley decomposition in Fourier space to show that a solution which exists in H^1 at some time t must then remain in H^1 for a small interval of time. This is a joint work with Landon Kavlie.

Alexey Cheskidov
University of Illinois Chicago
acheskid@math.uic.edu

MS17

Geometry of 3D Turbulent Flows and the Navier Stokes Regularity Problem

We show that the scaling gap in the 3D Navier-Stokes equation regularity problem can be reduced by an algebraic factor. All preexisting improvements have been logarithmic in nature, regardless of the functional set up utilized. This result is inspired by the geometry of the regions of intense vorticity observed in computational simulations of 3D turbulent flows.

Zachary Bradshaw
University of British Columbia
Department of Mathematics
zb002@uark.edu

Aseel Farhat
Department of Mathematics
University of Virginia
af7py@virginia.edu

Zoran Grujić
University of Virginia
zg7c@virginia.edu

MS17

Asymptotic Enslavement in Hydrodynamic Equations and Applications to Dynamics and Data Assimilation

In their 1967 seminal paper, Foias and Prodi captured precisely a notion of finitely many degrees of freedom in the context of the two-dimensional (2D) incompressible Navier-Stokes equations (NSE). In particular, they proved that if a sufficiently large low-pass filter of the difference of two solutions converge to 0 asymptotically in time, then the corresponding high-pass filter of their difference must also converge to 0 in the long-time limit. In other words, the high modes are eventually enslaved by the low modes. One could thus define the number of degrees of freedom to be the smallest number of modes needed to guarantee this convergence for a given flow, insofar as it is represents as a solution to the NSE. This property has since led to several developments in the longtime behavior of solutions to the NSE, such as, for instance, uniqueness of invariant measures for stochastically forced NSE, and to data assimilation as well. In this talk, we will discuss applications of this asymptotic enslavement property in the context of hydrodynamic and related equations, which are stochastically forced.

Vincent R. Martinez
Tulane University
vmartin6@tulane.edu

MS17

Numerical Approximations of a Feedback-Control Data Assimilation Algorithm: Uniform in Time Error Estimates

We consider a feedback-control (nudging) approach for data assimilation that works for a general class of dissipative dynamical systems and observables. The algorithm is defined by modifying the original forecast system through the addition of an extra term which relaxes only the coarse scales of the solution towards the spatially coarse observations. Our goal is to obtain an analytical estimate of the error committed when numerically solving this modified system by using a post-processing technique for the spectral Galerkin method, inspired by the theory of approximate inertial manifolds. This numerical approximation yields a dimensionally reduced version of the modified system. Most importantly, our error estimate is uniform in time, which reflects its global stability. This is a joint work with E. S. Titi.

Cecilia F. Mondaini
Texas A&M University
cmondaini@math.tamu.edu

Edriss S. Titi
Texas A&M University
Weizmann Institute of Science
titi@math.tamu.edu, edriss.titi@weizmann.ac.il

MS18

Stability of the Gaussian Isoperimetric Problem

Abstract Not Available At Time Of Publication.

Vesa Julin
Department of Mathematics and Statistics
University of Jyvaskyla, Finland
vesa.julin@jyu.fi

MS18

Nonlinear Stability Results for the Nonlocal Mullins-Sekerka Flow

Abstract Not Available At Time Of Publication.

Massimiliano Morini
Universita degli Studi di Parma
Parma, Italy
massimiliano.morini@unipr.it

MS18

A Universal Thin Film Model for Ginzburg-Landau Energy with Dipolar Interaction

We present an analytical treatment of a three-dimensional variational model of a system that exhibits a second-order phase transition in the presence of dipolar interac- tions. Within the framework of Ginzburg-Landau theory, we concentrate on the case in which the domain occupied by the sample has the shape of a flat thin film and obtain a reduced two-dimensional, non-local variational model that describes the ener- getics of the system in terms of the order parameter averages across the film thickness. Namely, we show that the reduced two-dimensional model is in a certain sense asymp- totically equivalent to the original three-dimensional model for small film thicknesses. Using this asymptotic equivalence, we analyze two different thin film limits for the full three-dimensional model via the methods of G-convergence applied to the reduced two- dimensional model. In the first regime, in which the film thickness vanishes while all other parameters remain fixed, we recover the local two-dimensional Ginzburg-Landau model. On the other hand, when the film thickness vanishes while the sample's lateral dimensions diverge at the right rate, we show that the system exhibits a transition from homogeneous to spatially modulated global energy minimizers. We identify a sharp threshold for this transition.

Cyrill B. Muratov
New Jersey Institute of Technology
Department of Mathematical Sciences
muratov@njit.edu

MS18

Droplet Breakup in the Liquid Drop Model

The liquid drop model, proposed by George Gamow and described by a nonlocal geometric variational problem, is a successful model which predicts the shape of atomic nuclei of small masses and nuclear fission at large masses. In this talk I will present on a recent project in which we consider a variant of this model with a long-range attractive background potential with weight Z. In the regime of small Z we characterize the structure of minimizers by means of a sharp asymptotic expansion of the energy. This asymptotic limit leads to a discrete attractive-repulsive nonlocal functional. In the process of studying this limit we also characterize all minimizing sequences for the Gamows model in terms of generalized minimizers

Ihsan Topaloglu
Department of Mathematics and Applied Mathematics
Virginia Commonwealth University
iatopaloglu@vcu.edu

Stan Alama, Lia Bronsard
McMaster University
Department of Mathematics and Statistics
alama@mcmaster.ca, bronsard@mcmaster.ca

Rustum Choksi
Department of Mathematics
McGill University
rchoksi@math.mcgill.ca

MS19

On Stochastic Anisotropic 3D Navier-Stokes Equations

Three dimensional Navier-Stokes equations in the whole space subject to an anisotropic viscosity and a random perturbation of multiplicative type is described. By adding a term of Brinkman-Forchheimer type to the model, existence and uniqueness of global weak solutions in the PDE sense are proved. These are strong solutions in the probability sense. The convective term given in terms of the Brinkman-Forchheirmer provides some extra regularity in space. As a consequence, the nonlinear term has better properties which allows to prove uniqueness. The proof of existence is performed through a control method. A Large Deviations Principle is shown.

Hakima Bessaih
University of Wyoming
Bessaih@uwyo.edu

MS19

Explosion in the Multiplicative Stochastic Process Associated with the 3D Navier-Stokes Equations

We will consider a stochastic branching process that can be naturally associated with the Navier-Stokes equations, showing that it develops infinite number of branches in finite time – a phenomenon called explosion. Possible connections of this explosion to the problem of uniqueness of the solutions will also be discussed.

Radu Dascaliuc
Oregon State University
dascalir@math.oregonstate.edu

MS19

On Measure-Valued Solutions and Their Applications in Numerical Analysis

We introduce a concept of dissipative measure valued solution to problems arising in fluid dynamics, notably the Euler and Navier-Stokes systems of equations. These are, roughly speaking, the most general objects that comply with the so-called weak-strong uniqueness principle. Applications to convergence of numerical schemes will be discussed.

Eduard Feireisl
Mathematical Institute ASCR, Zitna 25, 115 67 Praha 1
Czech Republic
feireisl@math.cas.cz

MS19

Adaptive RBF-WENO Methods for Hyperbolic Conservation Laws

We present adaptive ENO/WENO methods by adopting infinitely smooth radial basis functions (RBFs) for solving nonlinear hyperbolic conservation laws. The RBF-ENO/WENO finite difference and finite volume method slightly perturb the reconstruction coefficients with RBFs as the reconstruction basis and enhance accuracy in the smooth region by locally optimizing the shape parameters. The optimization is obtained by considering the local flow conditions. Consequently the RBF-ENO/WENO methods provide more accurate reconstruction than the regular ENO/WENO reconstruction and provide sharper solution profiles near the jump discontinuity. We present several numerical examples including weak shock reflections.

Jae-Hun Jung, Jingyang Guo
SUNY at Buffalo
jaehun@buffalo.edu, jguo4@buffalo.edu

MS20

On the Convergence of Statistical Solutions of Evolution Equations

In this talk we will present an abstract framework for the theory of statistical solutions for general evolution equations. This theory extends the notion of statistical solutions initially developed for the 3D incompressible Navier-Stokes equations to other evolution equations that have global solutions which are not known to be unique. We will prove the convergence of statistical solutions of regularized evolution equations to statistical solutions of the original one. The applicability of the theory will be illustrated with the 2D inviscid limit, that is, the convergence of statistical solutions of the 2D Navier-Stokes to the statistical solutions of the 2D Euler equations. This is a joint work with Cecilia Mondaini (Texas A&M) and Ricardo Rosa (UFRJ).

Anne Bronzi
Universidade Estadual de Campinas
annebronzi@ime.unicamp.br

MS20

Non-Decaying Solutions to the 2D Euler Equations

We establish the existence of weak solutions to the 2D Euler equations in the whole plane for which the vorticity is bounded and the velocity is allowed to grow at a prescribed rate at infinity, showing how the rate of growth affects the existence time. We also establish higher regularity of solutions for more regular initial data.

James P. Kelliher
University of California at Riverside
kelliher@math.ucr.edu

Elaine Cozzi
Dept. Math - Oregon State University
cozzie@math.oregonstate.edu

MS20

The Lighthill Principle and Vorticity Estimates for Flows with Symmetry

Abstract Not Available At Time Of Publication.

Milton Lopes Filho
Universidade Federal do Rio de Janeiro
mlopes@im.ufrj.br

MS20

Finite Time Singularity of a Vortex Patch Model in the Half Plane

The question of global regularity v.s. finite time blow-up remains open for many fluid equations. In this talk, I will discuss a family of equations which interpolate between the 2D Euler equation and the surface quasi-geostrophic (SQG) equation. We focus on the patch dynamics for this family of equation in the half-plane, and obtain the following results: For the 2D Euler patch model, the patches remain globally regular even if they initially touch the boundary of the half-plane; whereas for the family of equations that are slightly more singular than the 2D Euler equation, the patches can develop a finite-time singularity. This talk is based on a joint work with A. Kiselev, L. Ryzhik and A. Zlatos.

Alexander Sasha Kiselev
Department of Mathematics
Duke University
kiselev@math.duke.edu

Lenya Ryzhik
Stanford University
ryzhik@math.stanford.edu

Yao Yao
Georgia Tech University
yaoyao@math.gatech.edu

Andrej Zlatos
UCSD
zlatos@ucsd.edu

MS21

Two-Grid Discretization for Interior Penalty and Mixed Finite Elements Methods for the Monge-Ampere Equation

Abstract Not Available At Time Of Publication.

Gerard Awanou
Northern Illinois University
awanou@uic.edu

MS21

A Trefftz Discontinuous Galerkin Method for Time Harmonic Waves with Generalized Impedance Boundary Conditions

We show how a Trefftz Discontinuous Galerkin (TDG) method for the displacement form of the Helmholtz equation can be used to approximate problems having a generalized impedance boundary condition (GIBC) involving surface derivatives of the solution. Such boundary conditions arise naturally when modeling scattering from a scatterer with a thin coating. The thin coating can then be approximated by the GIBC. A second place GIBCs arise is as higher order absorbing boundary conditions. Since the TDG scheme has discontinuous elements, we propose to couple it to a surface discretization of the GIBC using continuous finite elements. We prove convergence of the resulting scheme and demonstrate it with two numerical examples.

Shelvean Kapita
Department of Mathematics
University of Georgia
Shelvean.Kapita@uga.edu

MS21

Multivariate Splines for Numerical Solution of Maxwell Equations in Potential Function Formulation

Abstract Not Available At Time Of Publication.

Clayton Mersmann
Department of Mathematics
University of Georgia
cmersmann@gmail.com

MS21

Discrete Theories for Elliptic Problems in Nondivergence Form

In this talk, two discrete theories for elliptic problems in non-divergence form are presented. The first, which is applicable to problems with continuous coefficients and is motivated by the strong solution concept, is based on discrete Calderon-Zygmund-type estimates. The second theory relies on discrete Miranda-Talenti estimates for elliptic problems with discontinuous coefficients satisfying the Cordes condition. Both theories lead to simple, efficient, and convergent finite element methods. We provide numerical experiments which confirm the theoretical results, and we discuss possible extensions to fully nonlinear second order PDEs.

Michael J. Neilan
University of Pittsburgh
Department of Mathematics
neilan@pitt.edu

MS22

Recent Advances on Optimal Control of Parabolic Free Boundary Problems

This talk presents recent advances on optimal control of Stefan type free boundary problems for the second order parabolic PDEs arising in control of phase transition processes, laser ablation of biomedical tissues and other applications. We analyze well-posedness of the optimal control problems, energy estimates and convergence of the sequence of discrete optimal control problems to the original problem both with respect to cost functional and control, Frechet differentiability in Besov spaces, necessary conditions for optimality, Pontryagin's maximum principle under the minimal regularity assumptions on the data.

Ugur G. Abdulla
Department of Mathematical Sciences
Florida Institute of Technology
abdulla@fit.edu

MS22

A Two-Fluid Mixture Model of Platelet Aggregation

We present a two-phase model of platelet aggregation in coronary-artery-sized blood vessels. The model tracks the number densities of three platelet populations as well as the concentration of a platelet activating chemical. Through the formation of elastic bonds, activated platelets can cohere with one another to form a platelet thrombus. Bound platelets in a thrombus move in a velocity field different from that of the bulk fluid. Stresses produced by the elastic bonds act on the bound platelet material. The relative motion between bound platelets and the background fluid permits intraclot transport of individual platelets and activating chemical, allows the bound platelet density to reach levels much higher than the platelet density in the bulk blood, and allows thrombus formation to occur on a physiological timescale, all of which were precluded by our earlier single phase model. Computational results from the two-phase model indicate that through complicated fluid-structure interactions, the platelet thrombus can develop significant spatial inhomogeneities and that the amount of

intraclot flow may greatly affect the growth, density, and stability of a thrombus.

Jian Du
Department of Mathematics
Florida Institute of Technology
jdu@fit.edu

Aaron L. Fogelson
University of Utah
fogelson@math.utah.edu

MS22

Stabilization and Control of a 3 D Fluid Structure Interaction

We consider interface problem consisting of a 3 D- fluid equation interacting with a 3 -D dynamic elasticity. The interface is moving according to the speed of the fluid. Boundary control problem corresponding to a minimization of hydrodynamic resistance on the interface. The problem is motivated by applications arising in biomechanics, aeroelasticity and industrial processes. The fluid is governed by Navier-Stokes equation while the structure is represented by the system of dynamic elasticity. The interface between the two environments undergoes oscillations which leads to moving frame configuration giving rise to quasilinear system. The boundary control is exerted on a part of the surface of the fluid and the functional cost represents hydrodynamic pressure on the wall of the body. This leads to nonconvex and non-smooth optimization problem. It is shown that under small disturbance hypothesis, control-to-state map is well posed, within a suitable topological framework, and the optimal control problem admits a solution. Both finite and infinite horizon optimal control problem will be considered which correspond, respectively, to local and global solvability of the underlying quasilinear system. The latter depends on recent results established in *Small data global existence for a fluid-structure model model* by M. Ignatova, I. Kukavica. I. Lasiecka and A. Tuffaha- *Nonlinearity*, 2017

Irena M. Lasiecka
University of Memphis
lasiecka@memphis.edu

MS22

Phaseless Scattering and Global Convergence for Coefficient Inverse Problems

The Phaseless Coefficient Inverse Scattering Problem amounts to the determination of an unknown coefficient of the Helmholtz equation from measurements of the absolute value of the complex valued wave field outside of the scatterers. Phase is not measured. Since 2014 a significant progress has been made in works of M.V. Klibanov and V.G. Romanov in addressing this problem. More precisely, uniqueness theorems were proved, reconstruction procedures were established and numerical results were obtained. These works constitute the first solution of a long standing problem posed by. K. Chadan and P.C. Sabatier in 1977. The second topic of my talk is globally convergent numerical method for Coefficient Inverse Problems (CIPs). CIPs are both highly nonlinear and ill-posed. These two factors cause very substantial challenges in the development of numerical methods for them. This is especially true for the most difficult case of CIPs with single measurement data. A natural idea to solve CIPs is the least squares minimization. However, this approach inevitably suffers from the phenomenon of multiple local minima and ravines. The latter makes computational results unreliable. Our research group has proposed two globally convergent numerical methods for CIPs with single measurement data. The main advantage of these numerical techniques over all other available ones is that a small neighborhood of the solution is reached without any a priori knowledge of that neighborhood.

Loc Nguyen
UNC Charlotte
lnguye50@uncc.edu

Michael V. Klibanov
University of North Carolina at Charlotte
Department of Mathematics
mklibanv@email.uncc.edu

MS23

Global Existence and Finite Time Singularity for Solutions to Solid Film Model and Tear Film Model

The governing equations for tear film dynamics on human eyes and solid film dynamics on vicinal surface are 4th order degenerate parabolic equations. When the mobility exponents vary in several different ranges, the behaviors of the solution are dramatically different. We analytically prove the global existence of solutions to tear film model with specific ranges of exponents and present some numerical simulation. Characterizing the finite time singularity is more challenging so we formulate the problem as the gradient flow of a suitably-defined convex functional in a non-reflexive Banach space. Then we introduce two methods to study the global solution with hidden singularity: gradient flow in metric space; maximal monotone operators in non-reflexive space.

Yuan Gao
Hong Kong University of Science and Technology
Department of Mathematics
gy2012yg@gmail.com

Jian-Guo Liu
Duke University
jliu@math.duke.edu

Hangjie Ji
Duke University, Department of Mathematics
hangjie@math.duke.edu

Thomas P. Witelski
Duke University
Department of Mathematics
witelski@math.duke.edu

MS23

Backward Behavior of Some Dissipative Evolution Equations

In this talk, I will discuss the backward-in-time behaviors of several dissipative evolution equations. This line of study was motivated by investigating the Bardos-Tartar conjecture on the 2D Navier-Stokes equations.

Yanqiu Guo
Florida International University
yanguo@fiu.edu

Edriss S. Titi
Texas A&M University
Weizmann Institute of Science
titi@math.tamu.edu, edriss.titi@weizmann.ac.il

MS23

Title Not Available At Time Of Publication

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Jian-guo Liu
Dept. of Mathematics and Physics
Duke University
jian-guo.liu@duke.edu

MS24

Aggregation in Mean Field Games

In this talk we consider time-dependent viscous Mean-Field Games systems in the case of local, decreasing and unbounded coupling. These systems arise in mean field game theory, and describe Nash equilibria of games with a large number of agents aiming at aggregation, i.e. at converging to a common state. From the PDE viewpoint, several issues are intrinsic in this framework, mainly caused by the lack of regularizing effects induced by increasing monotonicity of the coupling. Non-existence, non-uniqueness of solutions, non-smoothness, and concentration are likely to arise. Even more than in the competitive case, the assumptions on the Hamiltonian, the growth of the coupling and the dimension of the state space affect the qualitative behavior of the system. We prove the existence of weak solutions that are minimisers of an associated non-convex functional, by rephrasing the problem in a convex framework. Under additional assumptions involving the growth at infinity of the coupling, the Hamiltonian, and the space dimension, we show that such minimisers are indeed classical solutions by a blow-up argument and additional Sobolev regularity for the Fokker-Planck equation.

Marco Cirant
Università di Padova
cirant@math.unipd.it

Daniela Tonon
CEREMADE Université Paris Dauphine
tonon@ceremade.dauphine.fr

MS24

Stationary Mean-Field Games with Congestion

Mean-field games (MFGs) are models for large populations of competing rational agents that seek to optimize a suitable functional. In the case of congestion, this functional takes into account the difficulty of moving in high-density areas. Here, we study stationary MFGs with congestion with quadratic or power-like Hamiltonians. First, using explicit examples, we illustrate two main difficulties: the lack of classical solutions and the existence of areas with vanishing density. Our main contribution is a new variational formulation for MFGs with congestion. This result was not previously known, and, thanks to it, we prove the existence and uniqueness of solutions. Finally, we consider some applications to numerical methods.

Diogo Gomes
King Abdullah Universityy of Science and Technology
dlcvag@gmail.com

MS24

On the Variational Formulation of Some Stationary Second Order Mean Field Game Systems

We consider the variational approach to prove the existence of solutions of second order stationary mean field games on a bounded domain $\Omega \subset \mathbb{R}^d$, with Neumann boundary conditions, and with and without density constraints. We consider Hamiltonians which growth as $|\cdot|^{q'}$, where $q' = q/(q-1)$ and $q > d$. Despite this restriction, our approach allows us to prove the existence of solutions in the case of rather general coupling terms. When density constraints are taken into account, our results improve those in [A.R. Mészáros and F.J. Silva, A variational approach to second order mean field games with density constraints: the stationary case, *J. Math. Pures Appl.*, Vol. 104 (2015), 6, 1135-1159]. Furthermore, our approach can be used to obtain solutions of systems with multiple populations. The talk is based on a joint work with F. J. Silva (University of Limoges, France).

Alpar Meszaros
UCLA
alpar@math.ucla.edu

Francisco J. Silva
Univesite de Limoges
francisco.silva@unilim.fr

MS24

Singular Mean Field Games

We prove the existence of smooth solutions for mean-field games with a singular mean-field coupling; that is, a coupling in the Hamilton-Jacobi equation of the form $g(m) = -1/m^a$. We consider stationary and time-dependent settings. The function g is monotone, but it is not bounded from below. With the exception of the logarithmic coupling, this is the first time that MFGs whose coupling is not bounded from below is examined in the literature. This coupling arises in models where agents have a strong preference for low-density regions. To prove the existence of solutions, we consider an approximate problem for which the existence of smooth solutions is known. Then, we prove new a priori bounds for the solutions that show that $1/m$ is bounded. Finally, using a limiting argument, we obtain the existence of solutions. The proof in the stationary case relies on a blow-up argument and in the time-dependent case on new bounds for $1/m$.

Hector Sanchez Morgado
UNAM
hector@matem.unam.mx

MS25

Bubbly Media: From Super-resolution to Metamaterials

The aim of this talk is to review recent results on the propagation of acoustic waves in bubbly media. Our main focus is on developing a mathematical and computational framework for the analysis of Minnaert bubbles. By characterizing and exploiting the Minnaert resonance frequencies of bubbles in a variety of situations, we construct a unified theory of super-focusing of acoustic waves, acoustic metamaterials, and controlling acoustic wave propagation at the subwavelength scale. Super-resolution and metamaterials are usually studied within the context of different approaches. Remarkably, as shown in this talk, they owe their origin to the same underlying physical mechanism, namely, wave interaction with a subwavelength resonator.

Brian Fitzpatrick
ETH Zurich, Switzerland
brian.fitzpatrick@sam.math.ethz.ch

Habib Ammari
CNRS & Ecole Polytechnique, France
ammari@cmapx.polytechnique.fr

Hyundae Lee
Inha University
Department of Mathematics
hdlee18@gmail.com

Sanghyeon Yu
ETH
sanghyeon.yu@sam.math.ethz.edu

Hai Zhang
Hong Kong University of Science and Technology
haizhang@ust.hk

MS25

Title Not Available At Time Of Publication

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Laure Giovangigli
University of California at Irvine
lgiovang@uci.edu

MS25

Fractional White-Noise Limit and Paraxial Approximation for Waves in Random Media

Abstract Not Available At Time Of Publication.

Christophe Gomez
Aix-Marseille University
christophe.gomez@latp.univ-mrs.fr

MS25

Beam-Wave Scattering and Imaging

Abstract Not Available At Time Of Publication.

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

MS26

Lojasiewicz Inequalities for Yang-Mills and Harmonic Map Energy Functions

The Lojasiewicz-Simon gradient inequality is a generalization, due to Leon Simon (1983), to analytic or Morse-Bott functionals on Banach manifolds of the finite-dimensional gradient inequality, due to Stanislaw Lojasiewicz (1963), for analytic functions on Euclidean space. We shall discuss several recent generalizations of the Lojasiewicz-Simon gradient inequality and a selection of their applications, such as global existence and convergence of Yang-Mills gradient flow over four-dimensional manifolds and discreteness of the energy spectrum for harmonic maps from Riemann surfaces into analytic Riemannian manifolds.

Paul Feehan
Rutgers
paul.feehan@rutgers.edu

MS26

Lavrentiev Gap Phenomena for Harmonic Maps

Minimizing harmonic maps (i.e. minimizers of the Dirichlet integral) with prescribed boundary conditions from the ball to the sphere may have singularities. For some boundary data it is known that all minimizers of the energy have singularities and the energy is strictly smaller than the infimum of the energy among the continuous extensions (the so called Lavrentiev gap phenomenon occurs). We prove that the Lavrentiev gap phenomenon for harmonic maps into spheres holds on a dense set of zero degree boundary data. This is joint work with P. Strzelecki.

Katarzyna Mazowiecka
University of Warsaw
k.mazowiecka@mimuw.edu.pl

MS26

On Free Boundary Problems for Conformally Invariant Variational Functionals

I will present a regularity result at the free boundary for critical points of a large class of conformally invariant variational functionals. The main argument is that the Euler-Lagrange equation can be interpreted as a coupled system, one of local nature and one of nonlocal nature, and that both systems (and their coupling) exhibit an antisymmetric structure which leads to regularity estimates.

Armin Schikorra
University of Pittsburgh
armin@pitt.edu

MS26

A Minimizing Problem Involving Nematic Liquid Crystal Droplets

In this talk, we will describe an energy minimizing problem arising from seeking the optimal configurations of a class of nematic liquid crystal droplets. More precisely, the general problem seeks a pair (Ω, u) that minimizes the energy functional:

$$E(u,\Omega) = \int_\Omega \frac{1}{2}|\nabla u|^2 + \mu \int_{\partial\Omega} f(x, u(x))d\sigma,$$

among all open set Ω within the unit ball of $\mathbb{R}^3$, with a fixed volume, and $u \in H^1(\Omega, \mathbb{S}^2)$. Here $f : \mathbb{R}^3 \times \mathbb{R} \to \mathbb{R}$ is a suitable nonnegative function, which is given. While the existence of minimizers remains open in the full generality, there has been some partial progress when Ω is assumed to be convex. In this talk, I will discuss some results for Ω that are not necessarily convex. This is a joint work with Qinfeng Li.

Chang You Wang
Purdue University

wang2482@purdue.edu

MS27

No Equations, No Variables, No Parameters, No Space, No Time: Data and the Computational Modeling of Complex/multiscale Systems

Obtaining predictive dynamical equations from data lies at the heart of science and engineering modeling, and is the linchpin of our technology. In mathematical modeling one typically progresses from observations of the world (and some serious thinking!) first to equations for a model, and then to the analysis of the model to make predictions. Good mathematical models give good predictions (and inaccurate ones do not) - but the computational tools for analyzing them are the same: algorithms that are typically based on closed form equations. While the skeleton of the process remains the same, today we witness the development of mathematical techniques that operate directly on observations -data-, and appear to circumvent the serious thinking that goes into selecting variables and parameters and deriving accurate equations. The process then may appear to the user a little like making predictions by "looking in a crystal ball". Yet the "serious thinking" is still there and uses the same -and some new- mathematics: it goes into building algorithms that "jump directly" from data to the analysis of the model (which is now not available in closed form) so as to make predictions. Our work here presents a couple of efforts that illustrate this "new path from data to predictions. It really is the same old path, but it is travelled by new means.

Ioannis Kevrekidis
Dept. of Chemical Engineering
Princeton University
yannis@princeton.edu

MS27

Common Variable Learning Using Alternating Diffusion and Deep Siamese Networks

One of the challenges in signal processing is to distinguish between different sources of variability. In this work, we consider the manifold learning perspective and deep networks perspective on using diversity for separating sources of variability. From the manifold learning standpoint, we introduce a method based on alternating products of diffusion operators, which extracts the common source of variability from multimodal recordings. From the deep networks perspective, we discuss an approach based on Siamese Networks.

Roy Lederman
Princeton University
rrl@math.princeton.edu

MS27

How Can We Order and Organize Laplacian Eigenfunctions Naturally?

For the development and theory of discrete wavelets on regular lattices in $\mathbf{R}^d$, the Fourier series and transforms have played a significant role. Hence, when attempting to develop wavelet theory for graphs and networks, some researchers have used graph Laplacian eigenvalues and eigenvectors in place of the frequencies and complex exponentials, respectively. While tempting to do so, there are several fundamental problems in this viewpoint. One of them is the intricate relationship between the frequencies and the Laplacian eigenvalues. For undirected and unweighted paths (or cycles), the Laplacian eigenvectors are the discrete cosine (or Fourier) basis vectors and the corresponding eigenvalues are square of their frequencies. Consequently on those simple graphs, one can precisely develop the classical wavelets using the Littlewood-Paley theory. However, as soon as a graph becomes even slightly more complicated (e.g., a discretized thin rectangle in 2D), the situation completely changes: we cannot view the eigenvalues as a simple monotonic function of frequency anymore. Hence, a fundamental question is how to order Laplacian eigenfunctions without using the eigenvalues and to create a *dual* domain graph. In this talk, we discuss this important problem further and explain our effort using Earth Mover's Distance to measure natural distances between eigenfunctions followed by embedding the resulting distance matrix into an appropriate Euclidean domain.

Naoki Saito
Department of Mathematics
University of California, Davis
saito@math.ucdavis.edu

MS27

Interactions Between Graph Laplacians and Elliptic Pdes

I plan to discuss several recent results that apply equally to classical elliptic partial differential equations and such equations on graph – the unifying ingredient is that tools from the discrete world can be used profitably in the continuous world and either simplify existing proofs or motivate totally new statements. I will also discuss a new phenomenon that arose in this context and has yet to be explained. Partially joint with Manas Rachh, Xiuyuan Cheng, Gal Mishne and Janna Lierl.

Stefan Steinerberger
Yale University
stefan.steinerberger@yale.edu

MS28

On the Local Well-posedness and a Prodi-Serrin Type Regularity Criterion of the Three-dimensional MHD-Boussinesq System without Thermal Diffusion

Abstract Not Available At Time Of Publication.

Adam Larios
Department of Mathematics
University of Nebraska-Lincoln
alarios@unl.edu

MS28

A Hamiltonian Preserving Discontinuous Galerkin Method for the Generalized Korteweg-De Vries Equation

Abstract Not Available At Time Of Publication.

Hailiang Liu
Iowa State University
USA

hliu@iastate.edu

MS28

New Unilateral Problems Related to the Humid Atmosphere

In this lecture we will present new unilateral problems related to the humid atmosphere. The formulation involves variational or quasi-variational inequalities. We will discuss issues related to the modeling, the theory and the approximation of these problems.

Roger M. Temam
Inst. for Scientific Comput. and Appl. Math.
Indiana University
temam@indiana.edu

MS28

Global Solutions for Active Hydrodynamics

The hydrodynamics of active liquid crystals in the Beris-Edwards framework with the Landau-de Gennes Q-tensor order parameter arises in wide applications including many biophysical systems. Global existence of weak solutions, regularity, and uniqueness will be discussed.

Dehua Wang
University of Pittsburgh
Department of Mathematics
dwang@math.pitt.edu

Rongfang Zhang
University of Pittsburgh
roz14@pitt.edu

MS29

Non-decaying Solutions to the Euler Equations Part II: Uniqueness and Stability

As in Part I, we consider weak solutions to the 2D Euler equations in the whole plane for which the vorticity is bounded and the velocity is allowed to grow at a prescribed rate at infinity. For this class of solutions, we establish uniqueness and continuous dependence on the initial data. We also bound the effect that distant changes to the initial data have on a solution over time.

Elaine Cozzi
Dept. Math - Oregon State University
cozzie@math.oregonstate.edu

James P. Kelliher
University of California at Riverside
kelliher@math.ucr.edu

MS29

On the Hall-Magneto-Hydrodynamics System

We will discuss some properties of solutions to the 3D incompressible Hall-magneto-hydrodynamics (Hall-MHD) system. The Kolmogorov 41 phenomenological theory of turbulence predicts that there exists a critical wavenumber above which the high frequency part is dominated by the dissipation term in the fluid equation. Inspired by this idea, we apply an approach of splitting the wavenumber to obtain a new regularity criterion which is weaker than conditions in the existing criteria (Prodi-Serrin type criteria) for the 3D Hall-MHD system. We also study the asymptotic behavior of strong solutions to the generalized Hall-magneto-hydrodynamics system with one single diffusion. In light of the Fourier splitting technique, we establish that one single diffusion, can be weak as $(-\Delta)^\alpha b$ or $(-\Delta)^\beta u$ with small enough α, β, is sufficient to prevent asymptotic energy oscillations for certain strong solutions to the system.

Mimi Dai
University of Illinois-Chicago
mdai@uic.edu

MS29

2D Incompressible Euler with Singular Vorticity

Abstract Not Available At Time Of Publication.

Tarek M. Elgindi
Princeton University
tme2@princeton.edu

MS29

The Surface Quasi-geostrophic Equation in Domains with Boundaries

The surface quasi-geostrophic equation (SQG) of geophysical significance is an active scalar in which the incompressible velocity is determined through Riesz transforms of the scalar. This equation has been extensively studied in the whole plane and on the 2D torus. In bounded domains with boundaries, well-posedness issues are more delicate due to the lack of translation invariance of fractional Dirichlet Laplacian which induces among other difficulties the lack of good commutator estimates. We will report recent results in joint work with P. Constantin on local well-posedness of strong solutions and global existence of weak solutions.

Huy Nguyen
Princeton University
qn@math.princeton.edu

MS30

Bernstein Bezier Basis for High Order Finite Elements on Tetrahedra and Hexahedra

Abstract Not Available At Time Of Publication.

Guosheng Fu
Division of Applied Mathematics
Brown University
guosheng_fu@brown.edu

MS30

A New Regularity of the Solution to Dirichlet Problem of Poisson Equations and Its Applications

We study the regularity of the solution of Dirichlet problem of Poisson equations over a bounded domain. A new condition, uniformly positive reach is introduced. Under the assumption that the closure of the underlying domain of interest has a uniformly positive reach, the H^2 regularity of the solution of the Poisson equation is established. In particular, this includes all star-shaped domains whose closures is of positive reach, regardless if they are Lipschitz domains or non-Lipschitz domains. An application to the

second order elliptic PDE in non-divergence form is presented to demonstrate the usefulness of the new regularity condition.

Ming-Jun Lai
University of Georgia
Department of Mathematics
mjlai@math.uga.edu

Fuchang Gao
University of Idaho
fuchang@uidaho.edu

MS30

Construction of Smooth Gbc over Quadrilateral Partitions

Abstract Not Available At Time Of Publication.

James Lanterman
Department of Mathematics
University of Georgia
jay.lanterman@gmail.com

MS30

A Primal-Dual Weak Galerkin Finite Element Method for Fokker-Planck Type Equations

The speaker will present a primal-dual weak Galerkin (PD-WG) finite element method for a class of second order elliptic equations of Fokker-Planck type. The method is based on a variational form where all the derivatives are applied to the test functions so that no regularity is necessary for the exact solution of the model equation. The numerical scheme is designed by using locally constructed weak second order partial derivatives and the weak gradient commonly used in the weak Galerkin context. Optimal order of convergence is derived for the resulting numerical solutions. The speaker will demonstrate the numerical results to show the performance of the numerical scheme.

Chunmei Wang
Texas State University
c_w280@txstate.edu

MS31

The Bayesian Formulation of EIT

We provide a rigorous Bayesian formulation of the Electrical Impedance Tomography (EIT) problem in an infinite dimensional setting, leading to well-posedness in the Hellinger metric with respect to the data. We focus particularly on the reconstruction of binary fields where the interface between different media is the primary unknown. We consider three different prior models - log-Gaussian, star-shaped and level set. Numerical simulations based on the implementation of MCMC are performed, illustrating the advantages and disadvantages of each type of prior in the reconstruction, in the case where the true conductivity is a binary field, and exhibiting the properties of the resulting posterior distribution. We then consider a hierarchical Bayesian approach wherein interface properties, such as regularity, are not assumed to be known a priori, and are instead learned from the data. We illustrate numerically the improvement in reconstruction quality that this can lead to.

Matthew M. Dunlop
Computing + Mathematical Sciences
California Institute of Technology
mdunlop@caltech.edu

MS31

Frechet Differentiability in Besov Spaces in the Optimal Control of Parabolic Free Boundary Problems

We consider the inverse Stefan type free boundary problem, where information on the boundary heat flux and density of the sources are missing and must be found along with the temperature and the free boundary. We pursue optimal control framework analyzed in *Inverse Problems and Imaging, 7, 2(2013), 307-340; 10, 4(2016), 869–898*, where boundary heat flux, density of sources, and free boundary are components of the control vector. We prove the Frechet differentiability in Besov spaces, and derive the formula for the Frechet differential under minimal regularity assumptions on the data. The result implies a necessary condition for optimal control and opens the way to the application of projective gradient methods in Besov spaces for the numerical solution of the inverse Stefan problem.

Jonathan Goldfarb
Florida Institute of Technology
jgoldfar@my.fit.edu

Ugur G. Abdulla
Department of Mathematical Sciences
Florida Institute of Technology
abdulla@fit.edu

MS31

Evolution of Interfaces for the Nonlinear Double Degenerate Parabolic Equation of Turbulent Filtration with Absorption

We prove the short-time asymptotic formula for the interfaces and local solutions near the interfaces for the nonlinear double degenerate reaction-diffusion equation of turbulent filtration with strong absorption

$$u_t = \left(|(u^m)_x|^{p-1}(u^m)_x\right)_x - bu^\beta,\ mp > 1,\ \beta > 0.$$

Full classification is pursued in terms of the nonlinearity parameters m, p, β and asymptotics of the initial function near its support. Numerical analysis using a weighted essentially nonoscillatory (WENO) scheme with interface capturing is implemented, and comparison of numerical and analytical results is presented.

Adam Prinkey
Mathematical Sciences Department
Florida Institute of Technology
aprinkey2009@my.fit.edu

Ugur G. Abdulla
Department of Mathematical Sciences
Florida Institute of Technology
abdulla@fit.edu

Jian Du
Department of Mathematics
Florida Institute of Technology
jdu@fit.edu

MS31

Breast Cancer Detection through Electrical

Impedance Tomography and Optimal Control Theory: Theoretical and Computational Analysis

We analyze the inverse problem of breast cancer detection through Electrical Impedance Tomography. EIT is a non-invasive medical imaging method to recover electrical conductivity of the body from electrical measurements on its surface and potentials which are applied to the electrodes such that $\sum U_i = 0$. Mathematical formulation of the problem is referred to as Calderon's inverse problem on the identification of the conductivity coefficient of the second order elliptic PDE from additional boundary measurements. We pursue variational formulation and consider the optimal control problem on the minimization of the L_2-norm declination of the flux on certain subset of the boundary for the uniformly elliptic PDE

$$(a_{ij}(x)u_{x_j})_{x_i} = 0$$

with unknown matrix a_{ij} and Potentials $U_1, U_2, ..., U_m$ such that $\sum U_i = 0$, and subject to the mixed Neumann-Robin type boundary conditions. We prove Frechet differentiability in the Banach space of bounded measurable matrix functions, and derive first order optimality condition. We pursue numerical analysis in a simplified two-dimensional case by implementing projective gradient method in Banach spaces, re-parametrization and space reduction based on principal component analysis, Tikhonov regularization and sensitivity analysis with respect to relative size and locations of cancerous tumors.

Ugur G. Abdulla
Department of Mathematical Sciences
Florida Institute of Technology
abdulla@fit.edu

Vladislav Bukshtynov
Florida Institute of Technology
Department of Mathematical Sciences
vbukshtynov@fit.edu

Saleheh Seif
Mathematical Sciences Department
Florida Institute of Technology
sseif2014@my.fit.edu

MS32

Title Not Available At Time Of Publication

Abstract Not Available At Time Of Publication.

Ming Chen
University of Pittsburgh
mingchen@pitt.edu

MS32

Barotropic Instability of Shear Flows

We consider linear instability of shear flows for incompressible fluids with Coriolis effects. For a class of shear flows including the one with sinus profile, we proved sharp stability conditions for the whole parameter space, which corrected previous results in the fluid literature. Our results are confirmed by more precise numerical computations. The addition of the Coriolis force is found to bring fundamental changes to the stability of shear flows. Moreover, we study the bifurcation of nontrivial steady solutions and the linear inviscid damping near the shear flows. The first ingredient of our proof is a careful analysis of the neutral limiting modes. Second, we use the Hamiltonian structure of the linearized fluid equation and an instability index theory recently developed by Lin and Zeng for Hamiltonian PDEs. This is a joint work with Jinchang Yang and Hao Zhu.

Zhiwu Lin
Georgia Institute of Technology
School of Mathematics
zlin@math.gatech.edu

MS32

On the Muskat Problem with Viscosity Jump: Global in Time Results

This talk is about the Muskat problem, modeling the filtration of two incompressible immiscible fluids in porous media. We consider the case in which the fluids have different constant densities together with different constant viscosities. In this situation the equations are non-local, not only in the evolution system, but also in the implicit relation between the amplitude of the vorticity and the free interface. Among other extra difficulties, no maximum principles are available for the amplitude and the slopes of the interface in L^∞. We prove global in time existence results for medium size initial stable data in critical spaces. We also improved previous methods showing smoothing (instant analyticity) together with sharp decay rates of analytic norms for a more general class of initial data. The found technique is twofold, giving ill-posedness in unstable situations for lower regularity solutions. This is a joint work with Francisco Gancedo, Eduardo Garcia Juarez, and Neel Patel.

Robert M. Strain
University of Pennsylvania
strain@math.upenn.edu

MS32

Critical Thresholds, Spectral Gap and Singular Kernels in Flocking Hydrodynamics

We discuss the question of global regularity for a general class of Eulerian dynamics driven by a forcing with a commutator structure. The study of such systems is motivated by the hydrodynamic description of agent-based models for flocking driven by alignment. When the commutators involve bounded kernels, global regularity follows for subcritical initial data such that the initial divergence is not too negative and, in the 2D case, the initial spectral gap of the velocity gradient is not too large. In contrast, at least in the 1D case, singular kernels lead to global smooth solutions approaching a flocking wave behavior. The global existence is not restricted by the initial configuration.

Eitan Tadmor
University of Maryland
USA
tadmor@cscamm.umd.edu

MS33

Existence Theory for Mean Field Games with Non-Separable Hamiltonians

Many existence results for the mean-field games system assume that the Hamiltonian is additively separable; in the separable case, there are two further subcases, in which the coupling may either be local or nonlocal. However, in practice, non-separable Hamiltonians are frequently of interest. We discuss existence proofs for strong solutions in the case of non-separable Hamiltonians. The functional

settings considered include spaces based on the Wiener algebra, and also standard Sobolev spaces. Our various results all require a smallness constraint, and this can be on the size of the data, on the size of the time interval, or on the Hamiltonian itself.

David Ambrose
Drexel University
ambrose@math.drexel.edu

MS33

Singular Mean Field Games

In this talk, we discuss the well-posedness for mean field games with a singular mean field coupling of the form $g(m) = -m^{-\alpha}$. We consider stationary and time-dependent settings. The function g is monotone, but it is not bounded from below. This coupling arises in models where agents have a strong preference for low-density regions. Paradoxically, this causes the agents to spread and prevents the creation of solutions with a very-low density. The existence of solutions follows from new a priori bounds for the solutions, combined with an approximate problem and a limiting argument. The proof in the stationary case relies on a blow-up argument whereas in the time-dependent setting, we use new bounds for m^{-1}.

Edgard Pimentel
PUC-Rio
pimentel@puc-rio.br

MS33

Energy Production and Mean Field Game Models

The dramatic decline in oil prices, from around $110 per barrel in June 2014 to around $30 in January 2016 highlights the importance of competition between different energy producers. Indeed, the price drop has been primarily attributed to OPEC's strategic decision (until very recently) not to curb its oil production in the face of increased supply of shale gas and oil in the US, which was spurred by the development of fracking technology. Most dynamic Cournot models focus on supply-side factors, such as increased shale oil, and random discoveries. However declining and uncertain demand from China is a major factor driving oil price volatility. We study mean field Cournot games in a stochastic demand environment, and present asymptotic and numerical results, as well as a modified Hotelling's rule for games with stochastic demand.

Ronnie Sircar
Princeton University
sircar@princeton.edu

MS33

Balanced Growth Path Solutions of a Boltzmann Mean Field Game for Knowledge Growth

In this paper we study balanced growth path solutions of a Boltzmann mean field game model, which models knowledge growth in an economy. Agents can either increase their knowledge level by exchanging ideas in learning events or by producing goods with the knowledge they already have. The existence of balanced growth path solutions implies exponential growth of the overall production in time. We proof existence of balanced growth path solutions if the initial distribution of individuals with respect to their knowledge level satisfies a Pareto-tail condition. Furthermore we give first insights into the existence of such solutions if in addition to production and knowledge exchange the knowledge level evolves by geometric Brownian motion.

Marie-Therese Wolfram
Mathematics Department, University of Warwick
m.wolfram@warwick.ac.uk

MS34

Intensity Correlation Imaging in Random Media

Wave propagation in random media can be studied by multi-scale and stochastic analysis. We first show that, in a physically relevant regime of separation of scales, wave propagation is governed by a Schrodinger-type equation driven by a Brownian field. We analyze the associated moment equations. In particular we solve the fourth-moment equation and we study recent imaging modalities based on speckle intensity correlations that allow for imaging through scattering media.

Josselin Garnier
Ecole Polytechnique
josselin.garnier@polytechnique.edu

Knut Solna
University of California at Irvine
ksolna@math.uci.edu

MS34

Inverse Boundary Problems for Magnetic Schrodinger Operators in Transversally Anisotropic Geometries

Abstract Not Available At Time Of Publication.

Katya Krupchyk
University of California at Irvine
katya.krupchyk@uci.edu

MS34

A One-step Reconstruction Method for Photoacoustics with Multispectral Data

We present a one-step approach for numerical reconstructions in photoacoustics where we intend to reconstruct partial information on both the ultrasound speed and the optical absorption/scattering. We assume that data from multiple optical wavelength are available in this setup. We will also discuss briefly some related theoretical issues. This talk involves joint work with Sarah Vallelian (NCSU) and Yimin Zhong (UT Austin).

Kui Ren
University of Texas at Austin
ren@math.utexas.edu

MS34

Inverse Boundary Value Problem for the Anisotropic Elastic Wave Equation

Abstract Not Available At Time Of Publication.

Maarten de Hoop
Rice University

mdehoop@rice.edu

MS35

Almgren-Pitts Min-Max and the Space of Minimal Hypersurfaces

We use Lusternik-Schnirelmann Theory to study the topology of the space of closed embedded minimal hypersurfaces on a manifold of dimension between 3 and 7 and positive Ricci curvature. Combined with the recent work of Marques-Neves we can also obtain more information on the geometry of the minimal hypersurfaces they found. When the metric is bumpy we can further show that there exist minimal hypersurfaces with arbitrarily large index+area.

Nicolau Aiex
University of British Columbia
nsarquis@math.utoronto.ca

MS35

Harmonic Maps into Metric Spaces with Upper Curvature Bounds

We consider harmonic maps from Riemannian manifolds to metric spaces with upper curvature bounds in the sense of Alexandrov. We will present a Sacks-Uhlenbeck type result for such maps, which we prove by demonstrating that the tools harmonic replacement can be extended to this setting. This work is joint with Fraser, Huang, Mese, Sargent, Zhang.

Christine Breiner
Fordham University
cbreiner@fordham.edu

MS35

Rigidity in Npc Metric Spaces

The goal of this talk is to describe different approaches of using harmonic maps into general metric spaces of non-positive curvature in the sense of Alexandrov (NPC spaces) and describe how one can obtain enough regularity to extend the classical Bochner formulas in this setting.

Giorgios Daskalopoulos
Brown University
daskal@math.brown.edu

MS35

A Fully Nonlinear Sobolev Trace Inequality

The k-Hessian operator σ_k is the k-th elementary symmetric function of the eigenvalues of the Hessian. It is known that the k-Hessian equation $\sigma_k(D^2u) = f$ with Dirichlet boundary condition $u = 0$ is variational; indeed, this problem can be studied by means of the k-Hessian energy $\int -u\sigma_k(D^2u)$. We construct a natural boundary functional which, when added to the k-Hessian energy, yields as its critical points solutions of k-Hessian equations with general non-vanishing boundary data. As a consequence, we prove a sharp Sobolev trace inequality for k-admissible functions u which estimates the k-Hessian energy in terms of the boundary values of u. This is joint work with Jeffrey Case.

Wang Yi
Johns Hopkins University
ywang@math.jhu.edu

MS36

Laplacian Regularization for Localized Function Models

Regression problems typically assume the training data are independent samples, but in many modern applications samples come from individuals connected by a network or some other form of baseline information. In the case that the population is divided into discrete and disjoint classes with no notion of inter-class connection, hierarchical linear modelling can address such issues. We propose a series of optimization schemes that create generalized linear models, which incorporate both the local neighborhoods and global structure of the population network Laplacian to define localized regressions that smoothly vary with respect to the network. Depending on the context of the data and function, this method can be used to learn local function gradients on a manifold, model and denoise time varying processes with drift terms determined by some initial condition on a network, and perform co-clustering of a matrix or tensor. We also discuss incorporating the local regression coefficient estimates to redefine the network geometry and build a function adapted diffusion process.

Alexander Cloninger
Department of Mathematics
University of California, San Diego
alexander.cloninger@yale.edu

MS36

An Overview of Numerical Acceleration Techniques for Nonlinear Dimension Reduction

Since we live in an increasingly data-dependent world, it is necessary for researchers to offer methods that allow processing of complex, large, high-dimensional data sets. Techniques from machine learning, such as e.g., non-linear dimension reduction, seek to organize this wealth of data by extracting fewer descriptive features. These techniques, though powerful in their ability to find compact representations, are hampered by their high computational costs. This prevents us from processing large modern data collections in a reasonable time or with modest computational means. In this talk we shall present some of the important numerical techniques which significantly improve the computational efficiency of the aforementioned methods, while preserving much of their representational power. Specifically, we address Random Projections, Approximate k-Nearest Neighborhoods, Approximate Kernel methods, and Approximate Matrix Decomposition methods.

Wojciech Czaja
University of Maryland, College Park
wojtek@math.umd.edu

MS36

Jigsaw Puzzle and Graph Connection Laplacian

In this work we introduce a new non greedy algorithm to solve large jigsaw puzzles, which is known to be an NP-hard problem. We consider square puzzle pieces with unknown orientations and shuffled locations. We introduce a new method to construct the affinity graph, corresponding to the puzzle, where the vertices are the puzzle pieces and the edges connect between them. Then, we use this graph's Graph Connection Laplacian to complete the puzzle. Our proposed algorithm has state-of-the-art performance for the puzzles, where the orientation of the pieces are unknown.

Vahan Huroyan
University of Minnesota
School of Mathematics
huroy002@umn.edu

MS36

Hierarchical Geometric Organization of Tensors

We develop a nonlinear, data-driven and model-free approach for the analysis of a spatio-temporal dynamical system, represented as a rank-3 tensor. Our approach gives rise to the joint data-driven organization of the spatial regions and dynamic patterns in hierarchical data structures. These provide a local to global representation of the data: from a local partitioning via flexible trees, we derive new multiscale transforms and metrics, which are then integrated in a global manifold embedding. The application of our technique to in-vivo video recordings of neuronal activity in an awake animal demonstrates the capability of extracting neuronal activity patterns and identifying temporal trends. By jointly organizing neurons along time segments and across repetitive experiments, our methodology reveals co-dependencies and patterns of activation related to external short-term triggers (e.g., a tone), long-term manipulations introduced in the experiments and behavioral events (e.g., the sequence of motor actions). A by-product of the dynamic organization is an automateddetailed in-depth morphology of the imaged brain.

Gal Mishne
Applied Mathematics Program
Yale University
gal.mishne@yale.edu

MS37

Eventual Regularity of Infinite Energy Solutions to the Navier-Stokes Equations

The finite energy solutions constructed by J. Leray in 1934 eventually regularize in the sense that there exists a finite time after which a solution is smooth. This is, in general, unknown for the local Leray solutions introduced by Lemarie-Rieusset, which are local analogues of Leray's solutions in that they evolve from uniformly locally square integrable, preserve energy locally, and satisfy the local energy inequality. In this talk we discuss sufficient conditions for eventual regularity of local Leray solutions and mention some applications.

Zachary Bradshaw
University of British Columbia
Department of Mathematics
zb002@uark.edu

Tai-Peng Tsai
Department of Mathematics
University of British Columbia
ttsai@math.ubc.ca

MS37

An Onsager Singularity Theorem for the Compressible Euler Equations

Abstract Not Available At Time Of Publication.

Theodore D. Drivas
Princeton University
tdrivas@princeton.edu

Gregory L. Eyink
Dept. Mathematics
Johns Hopkins University
eyink@jhu.edu

MS37

Geometric Function Theory and Navier-Stokes Equations

The goal of this lecture is to review some recent results in which a suitably defined scale of sparseness of the super-level sets of the positive and negative parts of the vorticity components in the 3D NSE plays a major role in the study of turbulent dissipation and possible singularity formation in the model. In particular, this approach led to an algebraic reduction of the ever-resisting 'scaling gap' in the 3D NS regulartiy problem (a joint work with Z. Bradshaw and A. Farhat). A key mathematical component is utilization of the diffusion–manifested by the local-in-time spatial analyticity quantified in the L^∞-type spaces–via the harmonic measure maximum priciple. Certain rigidity is necessary; however, the analytic structure may prove to be 'too rigid', and some comments will be made about a possble role the theory of quasi-conformal mappings might play in this enterprise.

Zoran Grujic
University of Virginia
zg7c@virginia.edu

Zachary Bradshaw
University of British Columbia
Department of Mathematics
zb002@uark.edu

Aseel Farhat
Department of Mathematics
University of Virginia
af7py@virginia.edu

MS37

The Energy Measure for the Euler and Navier-Stokes Equations

The potential failure of energy equality for a solution u of the Euler or Navier-Stokes equations can be quantified using a so-called 'energy measure': the weak-$*$ limit of the measures $|u(t)|^2 \,\mathrm{d}x$ as t approaches the first possible blowup time. We show that membership of u in certain (weak or strong) $L^q L^p$ classes implies uniform boundedness of a certain upper s-density of $\mathcal{E}$, giving a uniform lower bound on the lower local dimension of $\mathcal{E}$. We also define and give lower bounds on the 'concentration dimension' associated to $\mathcal{E}$, which is the Hausdorff dimension of the smallest set on which energy can concentrate. Both the lower local dimension and the concentration dimension of $\mathcal{E}$ measure the departure from energy equality. As an application of our results, we prove that any solution to the 3-dimensional Navier-Stokes Equations which is Type-I in time must satisfy the energy equality at the first blowup time. Furthermore, we give new criteria for energy conservation (equality) in terms of the dimension of the singularity set and classical $L^q L^p$ conditions.

Trevor Leslie
University of Illinois-Chicago
tlesli2@uic.edu

Roman Shvydkoy
University of Illinois at Chicago
shvydkoy@uic.edu

MS38

Optimal Bounds and Extremal Trajectories for Time Averages in Dynamical Systems

For any quantity of interest in a system governed by ordinary differential equations, it is natural to seek the largest (or smallest) long-time average among solution trajectories. Upper bounds can be proved a priori using auxiliary functions, the optimal choice of which is a convex optimization. We show that the problems of finding maximal trajectories and minimal auxiliary functions are strongly dual. Thus, auxiliary functions provide arbitrarily sharp upper bounds on maximal time averages. They also provide volumes in phase space where maximal trajectories must lie. For polynomial equations, auxiliary functions can be constructed by semidefinite programming, which we illustrate using the Lorenz system. This is joint work with David Goluskin and Ian Tobasco.

Charles R. Doering
University of Michigan
Mathematics, Physics and Complex Systems
doering@umich.edu

MS38

The Vanishing Viscosity Limit for a Forced Active Scalar Equation

Abstract Not Available At Time Of Publication.

Susan Friedlander
University of Southern California
susanfri@usc.edu

MS38

Data Assimilation in Ocean and Atmosphere Dynamics

In the presentation, we discuss some recent results of the data assimilation algorithm proposed by Titi, etc, applied to the ocean and atmosphere dynamics. Namely, we prove the data assimilation scheme for the three dimensional primitive equations.

Yuan Pei
University of Nebraska-Lincoln
ypei4@unl.edu

MS38

Improved Algebraic Splitting Methods for NSE and MHD

We develop efficient and accurate solvers for saddle point linear systems that arise at each time step of an incompressible flow simulation. The solvers are based on high order algebraic splitting (discretize then split) and incremental variables formulation, and create SPD Schur complements that are the same at each time step. We analyze the solver by recasting the split system back into discrete PDEs, and prove it is fourth order accurate with respect to the time step size. Numerical tests show the solver approximation error is significantly lower than the discretization error, and several numerical tests are given that show its effectiveness. Extension to MHD is also discussed, and we show here that the method reduces the MHD block Schur complements into to 2 decoupled SPD Stokes Schur complements.

Leo Rebholz
Clemson University
Department of Mathematical Sciences
rebholz@clemson.edu

MS39

Some Error Estimates on Virtual Element Methods

Abstract Not Available At Time Of Publication.

Long Chen
University of California, Irvine
?chenlong@math.uci.edu

MS39

Saddle Point Least Squares Methods for Mixed Variational Formulations

We introduce a Saddle Point Least Squares method for discretizing first and second order boundary value problems written as primal mixed variational formulations. For the mixed formulation we assume a stability LBB condition and a data compatibility condition at the continuous level. For the proposed discretization method a discrete $\inf - \sup$ condition is automatically satisfied by the natural choices of test spaces (first) and the corresponding trial spaces (second). The discretization and the iterative approach does not require nodal bases for the trial space and a SPD preconditioner acting on the discrete test space can be adopted to speed up the approximation process. A stopping criterion based on matching the order of the the iteration error with the the order of the expected discretization error can be considered. Applications of the method include discretizations of second order PDEs with oscillatory or rough coefficients and first order systems of PDEs, such as $div - curl$ systems and time-hamonic Maxwell equations. This is joint work with Jacob Jacavage.

Bacuta Constantin, Jacob Jacavage
University of Delaware
bacuta@udel.edu, .

MS39

Macro Element Analysis for Axisymmetric Stokes Equations

Abstract Not Available At Time Of Publication.

YoungJu Lee
Texas State University

yjlee@txstate.edu

MS39

Weak Galerkin Finite Element Methods

Abstract Not Available At Time Of Publication.

Junping Wang
National Science Foundation
jwang@nsf.gov

MS40

On the Relative Entropy Method for Thermoviscoelasticity

The idea of relative entropy, introduced by Dafermos and DiPerna, is quite powerful in comparing solutions of conservation laws or balance laws and it has been applied to problems that are classified under the domain of hyperbolic-parabolic systems. In this talk, we extend the class of computations that go under the general term "relative entropy" to the broader class of hyperbolic and hyperbolic-parabolic systems by systematizing the derivation of relative entropy identities. The resulting identity is useful to provide measure valued weak versus strong uniqueness theorems for the hyperbolic problem. Also, it yields a convergence result in the zero-viscosity limit to smooth solutions in an L^p framework. The relative entropy identity is also developed for the system of thermoviscoelasticity with viscosity and heat-conduction and for the system of thermoviscoelasticity with polyconvex Helmholtz free energy, for which we construct a symmetrizable extension. The corresponding identities are used to prove convergence of strong solutions in the adiabatic limit and a weak-strong uniqueness theorem for dissipative measure-valued solutions. Existing differences between the examples and the general hyperbolic-parabolic theory are underlined. The work presented is joint work with Athanasios E. Tzavaras and M. Galanopoulou.

Cleopatra Christoforou
University of Cyprus
christoforou.cleopatra@ucy.ac.cy

MS40

Transonic Solutions to Multidimensional Riemann Problems

We present the recent result on the existence of the transonic self-similar solution to the nonlinear wave system. The nonlinear wave system is a reduced model from the compressible Euler system of multi-dimensional conservation laws. We discuss transonic solutions to the Riemann problems.

Eun Heui Kim
California State University, Long Beach
EunHeui.Kim@csulb.edu

MS40

Radial Solutions to the Cauchy Problem for the Wave Equation as Limits of Exterior Solutions

We consider the strategy of realizing the solution of a Cauchy problem (CP) with radial data as a limit of radial solutions to initial-boundary value problems posed on the exterior of vanishing balls centered at the origin. The goal is to gauge the effectiveness of this approach in a simple, concrete setting: the three-dimensional (3d), linear wave equation with radial Cauchy data. We are primarily interested in this as a model situation for other, possibly nonlinear, equations where neither formulae nor abstract existence results are available for the radial symmetric CP. In treating the 3d wave equation we therefore insist on robust arguments based on energy methods and strong convergence. Our findings show that while one can obtain existence of radial Cauchy solutions via exterior solutions, one should not expect such results to be optimal. We also show that external Neumann solutions yield better regularity than external Dirichlet solutions. This is joint work with Helge Kristian Jenssen (PSU).

Charis Tsikkou
West Virginia University
tsikkou@math.wvu.edu

MS40

Challenges to the Theory of Conservation Laws Posed by the Problem of Fracture

Many problems of material response lead to fracture. The objective of this talk is to review some works that indicate some challenges posed to analysis by the modeling and analysis of fracture. We will outline works in two directions: (i) The problem of dynamic cavitation in nonlinear isotropic elastic material, which offers a playground to study very singular solutions (with delta-shocks) for systems of conservation laws. (ii) The problem of localization into shear bands in high strain-rate plasticity, which offers a test case for studying the compound effect of Hadamard instability and viscosity.

Athanasios Tzavaras
King Abdullah University of Science and Technology (KAUST)
athanasios.tzavaras@kaust.edu.sa

MS41

Incompressible MHD Without Resistivity on Periodic Boxes

We study the global existence of classical solutions to the 3D incompressible viscous MHD system without magnetic diffusion on periodic boxes. In Eulerian coordinate, we employ a specially designed time-weighted energy estimates to show that if the initial data is close enough to a nontrivial magnetic equilibrium along with some symmetries over the periodic boxes, then the initial value problem admits a unique global classical solution. This is a joint work with Yi Zhou and Yi Zhu.

Ronghua Pan
Georgia Tech.
panrh@math.gatech.edu

MS41

Global Strong Solution to Compressible Navier-Stokes Equations with Heat Conduction in Three Dimensions

In this talk, we will introduce our recent work on the global existence and uniqueness of compressible Navier-Stokes equations with heat conduction in three dimensions with vacuum. The initial mass is small in some sense. The initial density vanishes when the spatial variables go to infinity. Therefore the case that the initial density has a compact support is covered. This work is joint with Professor Changjiang Zhu.

Huanyao Wen
South China University of Technology, China
mahywen@scut.edu.cn

MS41

Second Proof of the Global Regularity of the Two-Dimensional Mhd System with Full Diffusion and Arbitrary Weak Dissipation

In regards to the mathematical issue of whether a system of equations admits a unique solution for all time or not, given an arbitrary initial data sufficiently smooth, the case of the magnetohydrodynamics (MHD) system may be arguably more difficult than that of the Navier-Stokes equations (NSE). In this talk, some recent developments will be reviewed, in particular the global regularity issue of the 2D MHD system with full magnetic diffusion but not necessarily full dissipation, as well as other topics such as logarithmically supercritical MHD system, Hall-MHD system, micropolar and magneto-micropolar fluid systems, in both deterministic and stochastic perspectives.

Kazuo Yamazaki
Department of Mathematics
Washington State University
kyamazak@ur.rochester.edu

MS41

Energy Conservation for the Compressible Navier-Stokes Equations

In this talk, we will talk on the energy conservation for the weak solutions of the compressible Navier-Stokes equations globally in time, under some certain conditions. Our argument can handle the vacuum issue.

Cheng Yu
The University of Texas
yucheng@math.utexas.edu

MS42

Inhomogeneous Boltzmann-Type Equations Modelling Opinion Leadership and Political Segregation

We discuss different kinetic models for opinion formation, when the opinion formation process depends on an additional independent variable, e.g. a leadership or a spatial variable. More specifically, we consider: (i) opinion dynamics under the effect of opinion leadership, where each individual is characterised not only by its opinion, but also by another independent variable which quantifies leadership qualities; (ii) opinion dynamics modelling political segregation in 'The Big Sort', a phenomenon that US citizens increasingly prefer to live in neighbourhoods with politically like-minded individuals. Based on microscopic opinion consensus dynamics such models lead to inhomogeneous Boltzmann-type equations for the opinion distribution. We derive macroscopic Fokker-Planck-type equations in a quasi-invariant opinion limit and present results of numerical experiments.

Bertram Düring
University of Sussex
b.during@sussex.ac.uk

MS42

On a Boltzmann Mean Field Model for Knowledge Growth

We analyze a Boltzmann type mean field game model for knowledge growth, which was proposed by Lucas and Moll. It describes a population of agents structured by their knowledge level. Each agent optimizes their future earnings by choosing between producing with their current knowledge level or learning to increase their knowledge. We discuss the underlying mathematical model, which consists of a coupled system of a Boltzmann type equation for the agent density and a Hamilton-Jacobi-Bellman equation for the optimal strategy. We study the analytic features of the fully coupled system. Furthermore we focus on the existence of special solutions, which are related to exponential growth in time - so called balanced growth path solutions.

Alexander Lorz
Laboratoire Jacques-Louis Lions
Universite Pierre et Marie Curie - Paris 6
alexander.lorz.1@kaust.edu.sa

MS42

Traveling Waves in Myxobacteria - An Age-Structured Model

Myxobacteria are social bacteria, that can glide in 2D and form counter-propagating, interacting waves. In this talk I will present a novel age-structured, continuous macroscopic model for the movement of myxobacteria. The derivation is based on microscopic interaction rules that can be formulated as a particle-based model and set within the SOH (Self-Organized Hydrodynamics) framework. The strength of this combined approach is that microscopic knowledge or data can be incorporated easily into the particle model, whilst the continuous model allows for easy numerical analysis of the different effects. This allows to analyze the influence of a refractory (insensitivity) period following a reversal of movement. Our analysis reveals that the refractory period is not necessary for wave formation, but essential to wave synchronization, indicating separate molecular mechanisms. I will present analytical as well as numerical results.

Angelika Manhart
Courant Institute of Mathematical Sciences
New York University
angelika.manhart@cims.nyu.edu

Pierre Degond
Imperial College of London, Department of Mathematics
pdegond@imperial.ac.uk

Hui Yu
RWTH Aachen University
hyu@igpm.rwth-aachen.de

MS42

Opinion Dynamics over Kinetic Networks

In recent years the importance of large scale social networks has grown enormously due to the rapid proliferation of novel communication platforms. The need to handle with millions, and often billions, of vertices implies a considerable shift of interest to large-scale statistical properties of networks which may be described through the methods of the kinetic theory. In this talk we propose a kinetic description of the agents' distribution over the evolving network which combines an opinion update based on binary interactions between agents with a dynamic creation and removal process of new connections *G.Albi, L. Pareschi, M. Zanella, KRM (2017).* The number of connections of each agent influences the spreading of opinions in the network, further the way connections are created is influenced by the agents' opinion. We will study the evolution of the network of connections by showing that its asymptotic behavior is consistent both with Poisson distributions and truncated power-laws. In order to study the large time behavior of the opinion dynamics we derive a mean-field description which allows to compute exact stationary solutions in some simplified situations. Structure preserving numerical methods are hence employed to describe correctly the large time behavior of the system, see *L. Pareschi, M. Zanella, 2017.*

Mattia Zanella
Politecnico di Torino
mattia.zanella@polito.it

MS43

Coupling Between Internal and Surface Waves

Based on a Hamiltonian formulation of a two-layer ocean, we consider the situation in which internal waves are treated in the long-wave regime while surface waves are described in the modulation regime. We derive an asymptotic model for surface-internal wave interactions, in which the nonlinear internal waves evolve according to a KdV equation while the smaller-amplitude surface waves propagate at a resonant group velocity and their envelope is described by a linear Schrodinger equation. In the case of an internal soliton of depression, for small depth and density ratios of the two layers, the Schrodinger equation is shown to be in the semi-classical regime in analogy with quantum mechanics, and thus admits localized bound states. This leads to the phenomenon of trapped surface modes, which propagate as the signature of the internal wave, and thus it is proposed as a possible explanation for bands of surface roughness above internal waves in the ocean. Some numerical simulations taking oceanic parameters into account are also performed to illustrate this phenomenon. This is joint work with Walter Craig and Catherine Sulem.

Philippe Guyenne
University of Delaware
guyenne@udel.edu

MS43

Wave Turbulence: A Story Far from Over

We discuss the premises under which closure can be achieved for weakly nonlinear resonantly interacting waves, the successes that the theory has had and some of the open challenges.

Alan Newell
University of Arizona
Department of Mathematics
anewell@math.arizona.edu

MS43

Coupled Nonlinear Schrödinger Equations, Lotka-Volterra Models, and Nonlinear Dynamics of Optical Soliton Amplitudes

We study the propagation of N sequences of colliding solitons in nonlinear optical waveguides in the presence of dissipative perturbations. The propagation is described by a system of N perturbed coupled nonlinear Schrödinger (NLS) equations. We show that the collision-induced dynamics of soliton amplitudes in N-sequence systems is described by generalized N-dimensional Lotka-Volterra (LV) models. To derive the LV models, we first analyze the effects of a single two-soliton collision, using a perturbative expansion in the eigenmodes of the linear operator describing small perturbations about the fundamental NLS soliton. We then use stability and bifurcation analysis for the equilibrium points of the LV models to develop ways for achieving robust transmission stabilization and switching of the soliton sequences. Further enhancement of transmission stability is enabled by suppression of resonant emission of radiation in nonlinear waveguide couplers with frequency dependent linear gain-loss. Furthermore, we show that supercritical Hopf bifurcations of the equilibrium points of the LV models can be used to induce large stable oscillations of soliton amplitudes along ultra-long distances. The latter finding is an important step towards realizing spatio-temporal chaos with multiple sequences of colliding NLS solitons.

Avner Peleg
State University of New York at Buffalo
avpeleg@gmail.com

Quan M. Nguyen
International University, Vietnam National University-HCMC
Vietnam
quannm@hcmiu.edu.vn

Debananda Chakraborty
New Jersey City University
dchakraborty@njcu.edu

Toan Huynh
University of Science, Vietnam National University-HCMC
hthtoan@gmail.com

MS43

Orbital Stability of Domain Walls in Coupled Gross-Pitaevskii Systems

Domain walls are minimizers of energy for coupled one-dimensional GrossPitaevskii systems with nontrivial boundary conditions at infinity. In my talk, I will show that these solutions are orbitally stable in the space of complex H^1 functions with the same limits at infinity. Also, adopting a new weighted H^1 space, I will show how to control perturbations of the domain walls and improve the orbital stability result. A major difficulty arises from the degeneracy of linearized operators at the domain walls and the lack of coercivity.

Dmitry Pelinovsky
McMaster University
Department of Mathematics
dmpeli@math.mcmaster.ca

MS44

Vortex Filament Clustering in 3D Ginzburg-

Landau

Abstract Not Available At Time Of Publication.

Andres A. Contreras
New Mexico State University
acontre@nmsu.edu

MS44

External Field Response of Smectic A Liquid Crystals in Three Dimensions

Abstract Not Available At Time Of Publication.

Sookyung Joo
Old Dominion University
sjoo@odu.edu

MS44

High Dimensional Ginzburg-Landau Equations under Weak Anchoring Boundary Conditions

Abstract Not Available At Time Of Publication.

Changyou Wang
Purdue University
wang2482@purdue.edu

MS44

(-1)-Homogeneous Solutions of Stationary Incompressible Navier-Stokes Equations with Singular Rays

In 1944, L.D. Landau first discovered explicit (-1)-homogeneous solutions of 3-d stationary incompressible Navier-Stokes equations (NSE) with precisely one singularity at the origin, which are axisymmetric with no swirl. These solutions are now called Landau solutions. In 1998 G. Tian and Z. Xin proved that all solutions which are (-1) homogeneous, axisymmetric with one singularity are Landau solutions. In 2006 V. Sverak proved that with just the (-1)-homogeneous assumption Landau solutions are the only solutions with one singularity. He also proved that there are no such solutions in dimension greater than 3. Our work focuses on the (-1)-homogeneous solutions of 3-d incompressible stationary NSE with finitely many singularities on the unit sphere.

Xukai Yan
Georgia Institute of Technology
xukai.yan@math.gatech.edu

Li Li
Harbin Institute of Technology
lilihit@126.com

YanYan Li
Mathematics Department
Rutgers University
yyli@math.rutgers.edu

MS45

The Data Assimilation Map and Its Applications to the Foias-Prodi Statistical Solutions of the Navier-Stokes Equations

Motivated by feed-back control, Azouni, Olson and Titi introduced a data assimilation algorithm for dissipative systems by incorporating a nudging term on the coarse scales. Based on this algorithm, we construct a data assimilation map for the Navier-Stokes equations and investigate its properties. This map is then used to develop a data assimilation scheme for statistical solutions of the two-dimensional Navier-Stokes equations, where the coarse scale statistics of the system is obtained from measurements. As a corollary, we deduce that the statistical solutions of the Navier-Stokes equations are determined by their coarse scale distributions. This establishes the existence of determining parameters for statistical solutions.

Animikh Biswas
University of Maryland, Baltimore County
abiswas@umbc.edu

MS45

Porous Media Flow: Analysis and Applications in Biomechanics

Modeling of fluid flows through porous deformable media is relevant for many applications in biology, medicine and bioengineering, like tissue perfusion and fluid flow inside cartilages and bones. These fluid-structure mixtures are described mathematically by nonlinear poro-elastic or poro-visco-elastic systems on bounded domains, with nonhomogeneous, mixed boundary conditions for both the elastic displacement and the fluid pressure. In most of the applications, the boundary conditions are the primary drivers of the dynamics of these systems. Their influence over and ability to control the solution is an important open question, with beneficial implications in the development of novel strategies to improve experimental and clinical approaches in bio-engineering and medicine. In this talk we present some recent results on (i) well-posedness results for these models, (ii) the influence of structural viscoelasticity on the solution and on the regularity requirements for the forces present in the system, and (iii) sensitivity analysis of solutions with respect to the boundary data. Lastly, we discuss applications of our results in the case of blood flow through the optic nerve head, and the connections to the development of glaucoma.

Lorena Bociu
NC State University
Raleigh, NC
lvbociu@ncsu.edu

MS45

Exponential Stability Analysis for a Compressible Flow-Structure Pde Model

In this talk, we present recently derived results of uniform 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 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 complicate the analysis. Moreover, there is an additional coupling PDE which determines the associated pressure variable of the fluid-structure system. Under a suitable assumption on the ambient vector field, and by

obtaining an appropriate estimate for the associated fluid-structure generator on the imaginary axis, we provide a result of exponential stability for finite energy solutions of the fluid-structure PDE system.

Pelin Guven Geredeli
University of Nebraska-Lincoln
Hacettepe University
pguven@hacettepe.edu.tr

George Avalos
University of Nebraska-Lincoln
Department of Mathematics and Statistics
gavalos@math.unl.edu

MS45

H^2 Solutions and z-Weak Solutions for 3D Viscous Primitive Equations

Recent results on global in time uniform boundedness for H^2 solutions and wellposedness for z-weak solutions for viscous 3D Primitive Equations for large scale ocean will be presented. Related results may also be discussed.

Ning Ju
Oklahoma State University
ning.ju@okstate.edu

MS46

Numerical Analysis of the Stochastic Navier-Stokes Equation

We consider the statistical inverse problem of estimating a background fluid flow from the partial and noisy observation of a passive scalar (e.g., the concentration of a pollutant). Here our unknown is a divergence free vector field that is fully specified by an infinite number of degrees of freedom. Our work expands on frameworks developed in recent years for infinite-dimensional Bayesian inference. We approach the problem both analytically and computationally developing Metropolis-Hastings type algorithms to generate unbiased samples from the posterior distribution. This is joint work with Jeff Borggaard and Justin Krometis

Nathan Glatt-Holtz
Tulane University
negh@tulane.edu

MS46

Dispersion of Vorticity in Solutions of the Euler-Alpha Equations

Abstract Not Available At Time Of Publication.

Helena Nussenzveig Lopes
Universidade Federal do Rio de Janeiro
hlopes@im.ufrj.br

MS46

Global Regularity for Burgers Equation with Density Dependent Fractional Dissipation

Fractional Burgers equations are a family of equations which connect inviscid and viscous Burgers equations. It is well-known that if the dissipation is strong, the solution is globally regular. On the other hand, it the dissipation is weak (called supercritical case), the solution can lose regularity at a finite time. In this talk, I will introduce a model where the dissipation depends on density. The model is motivated by self-organized dynamics in math biology. Despite that the equation shares a lot of similarities to fractional Burgers equation, the solution is globally regular, even in the supercritical case. I will explain the regularization mechanism that is due to the nonlocal nonlinear modulation of dissipation. This is a joint work with T. Do, A. Kiselev, and L. Ryzhik.

Changhui Tan
Rice University
ctan@rice.edu

MS46

Global Stability of Solutions to a Beta-Plane Equation

We study the motion of an incompressible, inviscid two-dimensional fluid in a rotating frame of reference. There the fluid experiences a Coriolis force, which we assume to be linearly dependent on one of the coordinates. This is a common approximation in geophysical fluid dynamics and is referred to as beta-plane. In vorticity formulation the model we consider is then given by the Euler equation with the addition of a linear anisotropic, non-degenerate, dispersive term. This allows us to treat the problem as a quasilinear dispersive equation whose linear solutions exhibit decay in time at a critical rate. Our main result is the global stability and decay to equilibrium of sufficiently small and localized solutions. Key aspects of the proof are the exploitation of a double null form that annihilates interactions between waves with parallel frequencies and a Lemma for Fourier integral operators, which allows us to control a strong weighted norm and is based on a non-degeneracy property of the nonlinear phase function associated with the problem. Joint work with Fabio Pusateri; prior work with Tarek Elgindi.

Klaus Widmayer
Brown University
klaus@math.brown.edu

Fabio Pusateri
Princeton University
fabiop@math.princeton.edu

MS47

Data Assimilition for Geophysical Flows Employing Only Surface Measurements

We prove that data assimilation by feedback control can be achieved for the three-dimensional quasi-geostrophic equation using only large spatial scale observables on the dynamical boundary. On this boundary a scalar unknown (buoyancy or temperature of a fluid) satisfies the surface quasi-geostrophic equation. The feedback nudging is done on this 2D model, yet ultimately synchronizes the streamfunction of the three-dimensional flow. The main analytical difficulties involved in ensuring the synchronization property arise from the presence of a nonlocal dissipative operator in the surface quasi-geostrophic equation. This necessitates the derivation of various boundedness and approximation properties for the observation operators used in the feedback nudging.

Michael S. Jolly
Indiana University
Department of Mathematics

msjolly@indiana.edu

Vincent R. Martinez
Tulane University
vmartin6@tulane.edu

Edriss S. Titi
Texas A&M University
Weizmann Institute of Science
titi@math.tamu.edu, edriss.titi@weizmann.ac.il

MS47

The Stampacchia Maximum Principle for Stochastic Partial Differential Equations and Applications

Stochastic partial differential equations are considered, linear and nonlinear, for which we establish comparison theorems for the solutions, or positivity results a.e., and a.s., for suitable data. Comparison theorems for SPDEs are available in the literature and comparisons are made with our results. The originality of our approach is that it is based on the use of truncations, following the Stampacchia approach to maximum principle. We believe that our method, which does not rely too much on probability considerations, is simpler than the existing approaches and more general. As an application we also show how one can prove the existence of positive solutions for SPDEs with a quadratic nonlinearity (and possibly other nonlinearities).

Mickael Chekroun
University of California, Los Angeles
Department of Atmospheric and Oceanic Sciences
mchekroun@atmos.ucla.edu

Eunhee Park
Indiana University
parkeh@indiana.edu

Roger M. Temam
Inst. for Scientific Comput. and Appl. Math.
Indiana University
temam@indiana.edu

MS47

A Model for Hyporheic Zone

We propose a model for fluid flows in hyporheic zone. The hyporheic zone is a region beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behavior in this zone is of great importance to the health of rivers and streams and the associated ecological systems. In the first part of the talk, we discuss the small Darcy number regime and demonstrate the equivalence of two seemingly disparate interface boundary conditions: the balance of the normal component of normal stress, and the balance of the normal component of the normal stress that takes into account the dynamic pressure as suggested by J.L. Lions. Connections to popular simplified models in groundwater community will be discussed as well. In the second part, we present a novel numerical method that has a discrete energy law and decouples the computation of the free flow from the Darcy flow.

Xiaoming Wang
Florida State University
wxm.math@outlook.com

MS47

Far Field Regularity for the Supercritical Quasi-Geostrophic Equations

We address the far field regularity for solutions of the surface quasi-geostrophic equation

$$\theta_t + u \cdot \nabla\theta + \Lambda^{2\alpha}\theta = 0 \qquad u = \mathbb{R}^{\perp}\theta = (-\mathbb{R}_2\theta, \mathbb{R}_1\theta),$$

in the supercritical range $0 < \alpha < 1/2$ with α sufficiently close to $1/2$. We prove that if the datum is sufficiently regular, then the set of space-time singularities is compact in $\mathbb{R}^2 \times \mathbb{R}$. The proof depends on a new spatial decay result on solutions in the supercritical range.

Fei Wang
University of Southern California, USA
wang828@usc.edu

MS48

Fully Discrete Models in Viscoelastic Wave Propagation

Using Zeners classical model, we analyze the propagation of waves through viscoelastic materials. In addition to the continuous problem, we study the semidiscretization in space in the framework of using Finite Elements. For the time discretization, we use Convolution Quadrature in the Laplace domain. It is in the Laplace domain that we study the stability and convergence of the discrete problem. A direct in time analysis using semigroup theory is also achieved for the semidiscrete (in space) model, where we assume our solution is continuous in time. To complete this analysis, we must reformulate the model into a first order form involving displacement, strain, and diffusive stress. We also apply this analysis to the fractional Zener model which uses fractional order derivatives to relate the stress and strain.

Thomas S. Brown, Francisco J. Sayas
Department of Mathematical Sciences
University of Delaware
tsbrown@udel.edu, fjsayas@math.udel.edu

MS48

New Anisotropic Fems on Polyhedral Domains

Abstract Not Available At Time Of Publication.

Hengguang Li
Wanye State University
li@wayne.edu

MS48

Weak Galerkin for H(div) Approximation on Quadrilaterals

Abstract Not Available At Time Of Publication.

James Liu
Department of Mathematics
Colorado State University
liu@math.colostate.edu

MS48

High Order Scheme with Exponential Fitting for

Convection Diffusion Equations

Abstract Not Available At Time Of Publication.

Ludmil Zikatanov
Pennsylvania State University
ludmil@psu.edu

MS49

Recent Progress for Large Solutions of the p-system

The existence of large BV solution for the p-system is a long-standing open problem. We will discuss some recent progress on this topic.

Geng Chen
University of Kansas
gengchen@ku.edu

MS49

Invariant Measures for the Stochastic One-dimensional Compressible Navier-Stokes Equations

We discuss the existence of invariant measures for the one-dimensional compressible Navier-Stokes system, in the case of perfect gas pressure law. We prove existence of an invariant measure for the Markov process generated by strong solutions. We overcome the difficulties of working with non-Feller Markov semigroups on non-complete metric spaces by generalizing the classical Krylov-Bogoliubov method, and by providing suitable polynomial and exponential moment bounds on the solution.

Michele Coti Zelati
University of Maryland
micotize@umd.edu

MS49

Eulerian and Lagrangian Solutions to the Continuity and Euler Equations with L^1 Vorticity

In my talk I will describe some recent results obtained in collaboration with C. Nobili (Basel), C. Seis (Bonn), and S. Spirito (L'Aquila). First of all we establish a uniqueness result for continuity equations with velocity field whose derivative can be represented by a singular integral operator of an L^1 function, extending the Lagrangian theory in [Bouchut-Crippa, JHDE 2013]. The proof is based on a combination of a stability estimate via optimal transport techniques developed in [Seis, Ann IHP 2017] and some tools from harmonic analysis introduced in [Bouchut-Crippa, JHDE 2013]. In addition, we address a question that arose in [Mazzucato-Lopes-Lopes, ARMA 2006], namely whether 2D Euler solutions obtained via vanishing viscosity are renormalized (in the sense of DiPerna and Lions) when the initial data has low integrability. We show that this is the case even when the initial vorticity is only in L^1, extending the proof for the L^p case in [Crippa-Spirito, CMP 2015].

Gianluca Crippa, Camilla Nobili
University of Basel
gianluca.crippa@unibas.ch, camilla.nobili@unibas.ch

Christian Seis
Institut fuer Angewandte Mathematik
Universitaet Bonn
seis@iam.uni-bonn.de

Stefano Spirito
University of L'Aquila
stefano.spirito@univaq.it

MS49

Convergence Rates of Finite Difference Schemes for the Linear Advection and Wave Equation with Rough Coefficient

We prove convergence rates of explicit finite difference schemes for the linear transport and wave equation in one space dimension with Hölder continuous coefficient. The obtained convergence rates explicitly depend on the Hölder regularity of the coefficient and the modulus of continuity of the initial data. We compare the theoretically established rates with the experimental rates of a couple of numerical examples.

Franziska Weber
University of Maryland
fraenschii@gmail.com

MS51

Continuum Descriptions of the Vicsek Model

Flocking models abound in the recent mathematical literature. Applications areas include bacteria, insects, birds, and even humans, while mathematical investigations can be found at the particle, kinetic, and hydrodynamic levels. The Vicsek model is the basis for many of these investigations and applications, although the interpretation of the model varies quite a bit. Here, we will explore several variations of the Vicsek model, deriving continuum limits and analyzing the differing behaviors that these models exhibit.

Alethea Barbaro
Dept. of Mathematics, Applied Mathematics & Statistics
Case Western Reserve University
alethea.barbaro@case.edu

MS51

Kinetic Games and Insurance Plans

There are many methods for deriving continuous models for populations of rational agents interacting in a game theoretical framework. Examples range from replicator equations to hydrodynamic closures to mean-field games. In this talk, we introduce a new framework for deriving kinetic equations governing asymmetric games where two populations play a game against each other. We specifically separate the dynamics of the state and strategy of each population. This allows each population to "learn" based on the results of previous games. We will investigate the resulting dynamics and present an application involving shopping for insurance plans.

Daniel Brinkman
Department of Mathematics and Statistics
San Jose State University
daniel.brinkman@sjsu.edu

Christian Ringhofer
Arizona State University

ringhofer@asu.edu

MS51

Variational Mean Field Games for Market Competition with Renewable Resources

In this paper, we explore a variant of Chan and Sircar's Mean Field Games model for market competition. We consider a situation with reflecting boundary conditions, which expresses the fact that producers can renew their stock as soon as it depletes. We prove existence, uniqueness and regularity of solutions to the corresponding system of equations, and show that this system can be written as an optimality condition of a convex minimization problem. Finally, we prove existence of weak solutions to the corresponding first order system at the deterministic limit.

Jameson Graber
Baylor University
jameson_graber@baylor.edu

Charafeddine Mouzouni
Ecole Centrale de Lyon
charafeddine.mouzouni@ec-lyon.fr

MS51

Agent-based Model of the Effect of Globalization on Inequality and Class Mobility

We consider a variant of the Bouchaud-Mezard model for wealth distribution in a society which incorporates the interaction radius between the agents, to model the extent of globalization in a society. The wealth distribution depends critically on the extent of this interaction. When interaction is relatively local, a small cluster of individuals emerges which accumulate most of the societys wealth. In this regime, the society is highly stratified with little or no class mobility. As the interaction is increased, the number of wealthy agents decreases, but the overall inequality rises as the freed-up wealth is transferred to the remaining wealthy agents. However when the interaction exceeds a certain critical threshold, the society becomes highly mobile resulting in a much lower economic inequality (low Gini index). This is consistent with the Kuznets upside-down U shaped inequality curve hypothesis.

Theodore Kolokolnikov, Joep Evers, John Rumsey
Dalhousie University
tkolokol@mathstat.dal.ca, j.evers@dal.ca,
john.rumsey@dal.ca

David Iron
Dalhousie University, Canada
iron@mathstat.dal.ca

MS52

Stabilizing the Propagation of Colliding Soliton Sequences of Nonlinear Schrödinger Models with Frequency Dependent Linear Gain-Loss

We study transmission of multiple sequences of optical solitons in Kerr nonlinear optical waveguide loops. The transmission is described by a system of coupled nonlinear Schrödinger (NLS) equations. Our numerical simulations with the coupled-NLS system shows that transmission destabilization in a single lossless waveguide is caused by resonant formation of radiative sidebands, i.e., peaks in the graph of the Fourier transform of the optical field as a function of the frequency ω. Additionally, we investigate the possibility to increase transmission stability by optimization with respect to the Kerr nonlinearity coefficient γ. Moreover, we develop a general method for transmission stabilization, based on frequency dependent linear gain-loss in Kerr nonlinear waveguide couplers, and implement the method in two-sequence and three-sequence transmission. We show that the introduction of frequency dependent loss leads to significant enhancement of transmission stability even for non-optimal γ values via decay of radiative sidebands, which takes place as a dynamic phase transition. For waveguide couplers with frequency dependent linear gain-loss, we observe stable oscillations of soliton amplitudes due to decay and regeneration of the radiative sidebands. Transmission stabilization is achieved without dispersion-management or filtering.

Debananda Chakraborty
New Jersey City University
dchakraborty@njcu.edu

Avner Peleg
State University of New York at Buffalo
avpeleg@gmail.com

Quan M. Nguyen.
International University
Vietnam National University
quannm@hcmiu.edu.vn

MS52

Multi-Component Nonlinear Waves in Optics and Atomic Condensates: Theory, Computations and Experiments

Motivated by work in nonlinear optics, as well as more recently in Bose-Einstein condensate mixtures, we will explore a series of nonlinear states that arise in such systems. We will start from a single structure, the so-called dark-bright solitary wave, and then expand our considerations to multiple such waves, their spectral properties, nonlinear interactions and experimental observations. A twist will be to consider the dark solitons of the one component as effective potentials that will trap the bright waves of the second component, an approach that will also prove useful in characterizing the bifurcations and instabilities of the system. Beating so-called dark-dark soliton variants of such states will also be touched upon. Generalizations of all these notions in higher dimensions and, so-called, vortex-bright solitons will also be offered and challenges for future work will be discussed.

Panayotis Kevrekidis
University of Massachusetts
kevrekid@math.umass.edu

MS52

Nonlinear Optics Models in Some Nonperturbative Regimes

I will discuss the derivation of some multiscale nonperturbative models for the propagation of short and intense optical pulses in a gas. Some mathematical and computational aspects will be presented, as well as some applications in laser physics.

Emmanuel Lorin
Carleton University

elorin@math.carleton.ca

MS52

Rogue Waves and Large Deviations in Nonlinear Schroedinger Models

The appearance of rogue waves in deep sea is investigated using the modified nonlinear Schroedinger (MNLS) equation with random initial conditions that are assumed to be Gaussian distributed, with a spectrum approximating the JONSWAP spectrum obtained from observations of the North Sea. It is shown that by supplementing the incomplete information contained in the JONSWAP spectrum with the MNLS dynamics one can reliably estimate the probability distribution of the sea surface elevation far in the tail at later times. Our results indicate that rogue waves occur when the system hit small pockets of wave configurations hidden in the core of their distribution that trigger large disturbances of the surface height via modulational instability. The rogue wave precursors in these pockets are wave patterns of regular height but with a very specific shape that is identified explicitly, thereby allowing for early detection. The method proposed here builds on tools from large deviation theory that reduce the calculation of the most likely rogue wave precursors to an optimization problem that can be solved efficiently.

Eric Vanden-Eijnden
Courant Institute
New York University
eve2@cims.nyu.edu

MS53

Liquid Crystal Electrokinetics

Abstract Not Available At Time Of Publication.

Carme Calderer
University of Minnesota
calde014@umn.edu

MS53

Analysis of a One-Dimensional Landau-De Gennes Model for Bent-Core Liquid Crystals

Abstract Not Available At Time Of Publication.

Tiziana Giorgi
Department of Mathematical Sciences
New Mexico State University
tgiorgi@math.nmsu.edu

MS53

Least Action Principles for Incompressible Flows and Optimal Transport Between Shapes

Abstract Not Available At Time Of Publication.

Jian-guo Liu
Dept. of Mathematics and Physics
Duke University
jian-guo.liu@duke.edu

MS53

Global Well-Posedness for Dynamical Models of Nematic Liquid Crystals

Abstract Not Available At Time Of Publication.

Francesco de Anna
The Pennsylvania State University
fzd16@psu.edu

MS54

Distributed Controllability of Elastic Systems Enclosing a Linear Potential Fluid

A variable coefficient string or beam equation is used to model the flexible portion of the boundary of the domain of a two dimensional linear potential fluid. Exact controllability is proved when control is applied over an open interval of positive length. The method of proof is based on application of Ingham's inequality together with mini-max estimates of eigenvalues.

Scott Hansen
Department of Mathematics
Iowa State University
shansen@math.iastate.edu

MS54

Uniform Stability to Non-Trivial Equilibrium of a Fluid-Structure Interaction Via Interior Feedback Control

Uniform stability to a non-trivial equilibrium of a nonlinear fluid structure interaction model is studied. We propose control action depending on the equilibrium and applied to the interior of the fluid and solid domain to achieve this goal. The stabilization result obtained is global and no assumptions on the smallness of the initial data or the size of equilibrium point are needed. The damping placed on the solid domain is the Kelvin-Voigt type of viscoelastic damping. Due to viscoelasticity, the boundary transmission conditions are highly unbounded, which requires perturbation independent argument. To overcome this difficulty, we seek to construct special multipliers based on the Stokes solver and a special projection operator on L_2 space.

Yongjin Lu
Virginia State University
ylu@vsu.edu

MS54

Spectral Analysis and Control Problems for Mathematical Model of Energy Harvester

A set of our recent results on a model of a piezoelectric energy harvester is presented. The model is well known from engineering literature. It is governed by a system of two equations. The first of them is the Euler/Bernoulli model for the transverse vibrations of a damped beam subject to action of an external force. The second equation represents the Kirchhoffs law for the electric circuit. Both equations are coupled by means of the direct and converse piezoelectric effects. The boundary conditions for the beam equations are of clamped free type with an additional term that is proportional to the voltage on the resistive load and is produced by the converse piezoelectric effect. The circuit equation contains an extra term that depends on the transverse displacement of the beam and is produced by the direct piezoelectric effect. The system is written as a single operator evolution equation in a Hilbert space, whose dynamics generator is a nonselfadjoint operator with compact resolvent. The following results will be presented. 1) Asymptotic formulas for the eigenvalues of the dynamics generator. 2) Completeness, minimality, and Riesz basis property of the generalized eigenvectors. 3) Solutions by the spectral decomposition method of three control problems: zero controllability problem and two versions of output tracking problem. The Interpolation theory in the Hardy space of analytic functions is used to solve the tracking problems.

Marianna Shubov
University of New Hampshire
Department of Mathematics and Statistics
marianna.shubov@gmail.com

MS54

Analyticity, Spectral Analysis, and Uniform Stability of a Heat-viscoelastic Plate Interaction Model

We consider a heat equation defined on an interior bounded domain coupled with visco-elastic plate defined on surrounding external domain. Coupling occurs at the interface between the two domains, through high order coupling conditions between the two dynamics. We establish that the coupled system generates a strongly continuous contraction semi-group on the natural space of finite energy, which moreover is analytic and uniformly stable. A sharp spectral analysis is also provided. In particular, the generator fails to have compact resolvent operator.

Roberto Triggiani
University of Memphis
rtrggani@memphis.edu

MS55

Force Convergence in Phase Field Models

The Cahn-Hilliard functional is a phase field version of free energy for many systems involving free interfaces. It is well known that the Cahn-Hilliard functional Gamma converges to the interface area. In this talk we will discuss the convergence of generalized forces, under minimal assumptions. As an application we will mention some results about a phase field model for molecule solvation.

Shibin Dai
Department of Mathematics
New Mexico State University
sdai@nmsu.edu

Bo Li
Department of Mathematics, UC San Diego
bli@math.ucsd.edu

Jianfeng Lu
Mathematics Department
Duke University
jianfeng@math.duke.edu

MS55

Evolution Equations from Epitaxial Growth

Abstract Not Available At Time Of Publication.

Xin Yang Lu
Department of Mathematics and Statistics
McGill University
xinyang.lu@mcgill.ca

MS55

Gradient Flow for a Relaxed Model for Bent-Core Liquid Crystals

Liquid crystals composed of bent-core molecules enjoy a characteristic shape within their molecules that allows for spontaneous polarization. We consider a columnar phase of these liquid crystals where the polarization can be reoriented by applying an electric field. To understand the switching mechanism, we consider a relaxed Landau-De Gennes-type free energy. We construct a discretized-in-time gradient flow through energy minimization and prove existence and uniqueness of the continuous gradient flow.

Tiziana Giorgi
Department of Mathematical Sciences
New Mexico State University
tgiorgi@math.nmsu.edu

Sookyung Joo
Old Dominion University
sjoo@odu.edu

Lidia Mrad
Department of Mathematics
University of Arizona
lmrad@math.arizona.edu

MS55

An Elementary Proof to the Eigenvalue Preservation Property in the Beris-Edwards System

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Xiang Xu
Old Dominion University
x2xu@odu.edu

MS56

Agent-Based and Continuous Models of Locust Hopper Bands: The Role of Intermittent Motion, Alignment and Attraction

Locust swarms pose a major threat to agriculture, notably in North Africa and the Middle East. In the early stages of aggregation, locusts form hopper bands. These are coordinated groups that march in columnar structures that are often kilometers long and may contain millions of individuals. We propose a model for the formation of locust hopper bands that incorporates intermittent motion, alignment with neighbors, and social attraction, all behaviors that have been validated in experiments. Using a particle-in-cell computational method, we simulate swarms of up to a million individuals, which is several orders of magnitude larger than what has previously appeared in the locust modeling literature. We observe hopper bands in this model forming as a fingering instability. Our model also allows homogenization to yield a system of partial integro-differential evolution equations. We identify a bifurcation from a uniform marching state to columnar structures, suggestive of the formation of hopper bands.

Andrew J. Bernoff
Harvey Mudd College
Department of Mathematics
ajb@hmc.edu

Chad Topaz
Department of Mathematics and Statistics
Williams College
cmt6@williams.edu

MS56

Small Noise - Huge Pattern Changes: Predicting Large Fluctuations in High Dimensional Systems

Many dynamical processes in physics and biology are modeled discretely because either their continuum limits do not always exist at small spatial scales, or it is difficult to analyze the effects of long range interactions; e.g., crystal growth, swarming dynamics, collective cellular dynamics, social dynamics, to name a few. When taking continuum limits, it is typical to derive models in a deterministic setting. However, one important aspect missing in continuum limits is the lack of internal noise generation due to random interactions in finite dimensional systems. It is known that small noise in dynamical systems can induce large fluctuations in which noise causes pattern switching between different meta-stable states. Here I will present new results on high dimensional discrete networks that predict how such large fluctuations cause pattern switching. In addition, I will discuss how we might be able to control the rate of pattern switching using theory. Applications will be to physical spin systems (also used to model opinion formation), the creation of new swarming patterns, as well as large scale population dynamics.

Ira B. Schwartz
Naval Research Laboratory
ira.schwartz@nrl.navy.mil

Jason Hindes
US Naval Research Laboratory
US Naval Research Laboratory
jason.hindes.ctr@nrl.navy.mil

Klementyna Szwaykowska
Plasma Physics Divsion
Naval Research Laboratory
klementyna.szwaykowska.ctr@nrl.navy.mil

MS56

Macroscopic Models for Mixed Human-Autonomous Vehicle Traffic Flow

In vehicular traffic flow, the collective human driving behavior can produce macroscopic emergent stop-and-go traffic waves. This “phantom traffic jam” phenomenon can be explained as an instability in PDE-based traffic models. However, the reality of traffic flow is about to change in the near future, due to the insertion of autonomous vehicles (AVs) into the traffic stream. These will themselves drive differently (hopefully: more safely and efficiently) than humans. This, in turn, will affect the traffic flow at whole in ways that, ideally, should be understood, before AVs get deployed. We present mathematical models for mixed human-AV flow, focusing on the near-future situation of having only few AVs on the road. Via numerical simulations, as well as actual experiments, we demonstrate that even at low penetration rates, AVs can have substantial impact on the safety and efficiency of the overall traffic flow.

Benjamin Seibold
Temple University
seibold@temple.edu

MS56

Agent-Based and Continuum Models for Stripe Formation on the Fins of Zebrafish

Black and yellow pigment cells self-organize on the body and fins of the zebrafish to produce its namesake stripes. These patterns develop on the growing fish skin through a combination of short- and long-range interactions, including cell movement, differentiation, and competition, but mutations suggest different interactions are present on the body and tailfin. To help reconcile differences between these two regions, we study the development of zebrafish patterns using discrete (agent-based) and continuum (nonlocal conservation law) models on growing domains. Our models suggest that the presence of boney rays and altered types of skin growth can reconcile why different self-organization mechanisms are at work on the body and tailfin of zebrafish.

Alexandria Volkening
Division of Applied Mathematics
Brown University
alexandria_volkening@brown.edu

Bjorn Sandstede
Brown University
SIAM Journal on Applied Dynamical Systems (SIAM)
bjorn_sandstede@brown.edu

MS57

Heterogeneous Fast Multipole Method for 2-D Wave Scattering in Layered Media

Numerical simulation for wave scattering in layered media plays a crucial role in designing and optimizing modern electronic devices. In this talk, a heterogeneous fast multipole method (H-FMM) for 2-D Helmholtz equation in layered will be presented. First, the layered media Greens function is represented with Sommerfeld integrals. Then, for many source points, source contribution is compressed with multipole expansion of the free-space Greens function and the far field contribution is also compressed with the same free-space multipole expansion. Then, the compressed information is translated over the tree-data structure using Grafs addition theorem. In particular, the spatially variant information of domain Greens function is collected in a newly developed multipole-to-local operator. Numerical experiments show linear complexity in low frequency regime. Moreover, due to equivalence between the method of image and Sommerfeld representation of the Greens function, H-FMM can be easily generalized to multi-layered media.

Min Hyung Cho
Department of Mathematical Sciences
University of Massachusetts Lowell
minhyung_cho@uml.edu

Jinfang Huang
UNC Chapel Hill
Applied Mathematics
huang@email.unc.edu

Dangxing Chen
Department of Mathematics,
University of North Carolina, Chapel Hill
dangxing@live.unc.edu

Wei Cai
University of North Carolina, Charlotte
wcai@uncc.edu

MS57

Modeling and Computation of Nano-Optics

We present a multiscale modeling and computational scheme for optical- mechanical responses of nanostructures. The multi-physical nature of the problem is a result of the interaction between the electromagnetic (EM) field, the molecular motion, and the electronic excitation. To balance accuracy and complexity, we adopt the semi-classical approach that the EM field is described classically by the Maxwell equations, and the charged particles follow the Schr oidnger equations quantum mechanically. To overcome the numerical challenge of solving the high dimensional multi-component many- body Schr odinger equations, we further simplify the model with the Ehrenfest molecular dynamics to determine the motion of the nuclei, and use the Time- Dependent Current Density Functional Theory (TD-CDFT) to calculate the excitation of the electrons. This leads to a system of coupled equations that computes the electromagnetic field, the nuclear positions, and the electronic current and charge densities simultaneously. In the regime of linear responses, the resonant frequencies initiating the out-of-equilibrium optical-mechanical responses can be formulated as an eigenvalue problem. A self-consistent multiscale method is designed to deal with the well separated space scales. The isomerization of Azobenzene is presented as a numerical example.

Di Liu
Michigan State University
Department of Mathematics
richardl@math.msu.edu

MS57

Stable, High-Order Computation of Impedance-Impedance Operators

The faithful modeling of the propagation of linear waves in a layered, periodic structure is of paramount importance in many branches of the applied sciences. In this talk we discuss a novel numerical algorithm for the simulation of such problems which is free of the artificial singularities present in related approaches. We advocate for a surface integral formulation which is phrased in terms of Impedance-Impedance Operators that are immune to the Dirichlet eigenvalues which plague the Dirchlet-Neumann Operators that appear in classical formulations. We demonstrate a High-Order Spectral algorithm to simulate these latter operators based upon a High-Order Perturbation of Surfaces methodology which is rapid, robust, and highly accurate. We demonstrate the validity and utility of our approach with a sequence of numerical simulations.

David P. Nicholls
University of Illinois at Chicago
davidn@uic.edu

MS57

Well-Conditioned Boundary Integral Equation Formulations and Nystrom Discretizations for the Solution of Helmholtz Problems with Impedance Boundary Conditions in Two-Dimensional Lipschitz Domains

Title Not Available At Time Of Publication

Catalin Turc
Department of Mathematical Sciences
New Jersey Institute of Technology
catalin.c.turc@njit.edu

MS58

Gelfand Type Problems for Reactive Turbulent Jets

Gelfand problem is one of the canonical problems in the theory of non-linear parabolic and elliptic partial differential equations (PDEs). This problem naturally arises in the Frank-Kamenetskii theory of thermal explosion (autoignition) and describes an initial stage of evolution of a temperature field in reactive materials and mixtures. In this talk I will present a generalization of Gelfand problem for analysis of autoignition of reactive turbulent jets. I will present both derivation of this new model and its analysis. The latter is performed using a combination of rigorous, formal asymptotic and numerical techniques. It will be shown that similar to the classical Gelfand problem an autoignition in jets occur exclusively owing to the absence of self-similar temperature distribution which, in mathematical terms, leads to loss of regularity (blow-up) of underlying PDE. The detailed analysis of self-similar temperature profiles will be presented and a sharp characterization of an autoignition event in terms of principal geometric and physical parameters of the problem will be given. This a joint work with U.G. Hegde and M.C. Hicks of NASA Glenn Research Center.

Peter Gordon
Kent State University, USA
pgordon8@kent.edu

MS58

Free Discontinuity Problems Associated to Singular Integral Operators

We shall introduce a set of free discontinuity problems that arise naturally when studying the geometry of measures for which an associated singular integral operator has various prescribed analytic properties. Joint work with Fedor Nazarov.

Benjamin Jaye
Department of Mathematical Sciences
Kent State University
bjaye@kent.edu

MS58

Suppression of Chemotactic Explosion by Mixing

Chemotaxis plays a crucial role in a variety of processes in biology and ecology. In many instances, processes involving chemical attraction take place in fluids. One of the most studied PDE models of chemotaxis is given by the Keller-Segel equation, which describes a population density of bacteria or mold which attract chemically to substance they secrete. Solutions of the Keller-Segel equation can exhibit dramatic collapsing behavior, where density concentrates positive mass in a measure zero region. A natural question is whether presence of fluid flow can affect singularity formation by mixing the bacteria thus making concentration harder to achieve. I will discuss a result that shows that in two or three dimensions, there exist incompressible flows with that can suppress the finite time blow up. This ability of the flow is closely linked with its mixing properties. The talk is based on a joint work with Xiaoqian Xu.

Alexander Sasha Kiselev
Department of Mathematics
Duke University
kiselev@math.duke.edu

MS58

Density Functional Theory of Charge Screening in Graphene

We discuss a density functional theory of Thomas-Fermi-Dirac-von Weizsacker type to describe the response of a single layer of graphene resting on a dielectric substrate to a point charge or a collection of charges some distance away from the layer. We formulate a variational setting in which the proposed energy functional admits minimizers. We further provide conditions under which those minimizers are unique. The associated Euler-Lagrange equation for the charge density is also obtained, and uniqueness, regularity and decay of the minimizers are proved under general conditions.

Vitaly Moroz
Department of Mathematics
Swansea University
V.Moroz@swansea.ac.uk

MS59

Mean Field Limit of Interacting Filaments and Vector Valued Non Linear PDEs

Families of N interacting curves are considered, with long range, mean field type, interaction. A family of curves defines a 1-current, concentrated on the curves, analog of the empirical measure of interacting point particles. This current is proved to converge, as N goes to infinity, to a mean field current, solution of a nonlinear, vector valued, partial differential equation. In the limit, each curve interacts with the mean field current and two different curves have an independence property if they are independent at time zero. This set-up is inspired from vortex filaments in turbulent fluids.

Michele Coghi
University of Bielefeld
michele.coghi@gmail.com

MS59

Title Not Available At Time Of Publication

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Peter Constantin
Princeton University
const@math.princeton.edu

MS59

Mathematical Aspects of Distributed Control for Compressible Fluids

The compressible Navier-Stokes equations comprise a system of PDE describing the evolution of a linearly viscous compressible fluid. We consider the general problem of driving the fluid to a given state over a fixed time T, under the influence of a distributed control in the form of a body force. An optimal control is sought such that a certain integral cost functional is minimized. We first obtain the existence of optimal controls for the nonlinear system. Our result relies on the weak-strong uniqueness property of the compressible Navier-Stokes equations to ensure the existence of unique states. Next we obtain the first order necessary conditions for a linearized version of the compressible system in the form of a Pontryagin maximum principle. We will remark on challenges with the full nonlinear system and how this result may be extended.

Stefan Doboszczak
Air Force Institute of Technology
stefan.doboszczak@afit.edu

MS59

Large Deviations for Landau-Lifschitz-Gilbert Equations with Pure Jump Noise

In this talk we consider a stochastic Landau-Lifshitz equation on a bounded interval and with pure jump noise in the Marcus canonical form. We first show that there exists a pathwise unique solution to this equation and that this solution has the maximal regularity property. Next, we prove the large deviations principle for small noise asymptotic of solutions using the weak convergence method. This is a joint work with Zdzislaw Brzezniak and Jianliang Zhai.

Utpal Manna
Indian Institute of Science Education and Research
Thiruvana
manna.utpal@iisertvm.ac.in

MS60

Quantum and Kinetic Models in Spin-magnetization Coupling

The Schrdinger-Poisson-Landau-Lifshitz-Gilbert (SPLLG) system is an effective microscopic model that describes the coupling between conduction electron spins and the magnetization in ferromagnetic materials. This system has been used in connection to the study of spin transfer and magnetization reversal in ferromagnetic materials. In this work, we rigorously prove the existence of weak solutions to SPLLG and derive the Vlasov-Poisson-Landau-Lifshitz-Glibert system as the semiclassical limit.

Lihui Chai
UCSB
chai@ucsb.edu

Carlos Garcia-Cevera
Department of Mathematics
Univ. of California, Santa Barbara
cgarcia@math.ucsb.edu

Xu Yang
Department of Mathematics
University of California, Santa Barbara
xuyang@math.ucsb.edu

MS60

The Derivation of Heat Conduction Models with Fluctuations

During the past two decades, there has been rapidly grow-

ing interest in modeling heat transport at the microscopic scale. As the size of electrical and mechanical devices is decreased to the micron and sub-micron scales, they often exhibit heat conduction properties that are quite different from the observations familiar at macroscopic level, e.g., Fourier Law. At such scale, the observable quantities also carry substantial fluctuations. In this talk, heat conduction models are derived directly from the many-particle system as a coarse-grained description. By selecting the local energy as the coarse-grained variables, we apply a projection formalism to derive the reduced model. In sharp contrast to conventional energy transport models, this derivation yields a stochastic dynamics model for the spatially averaged energy. The model also exhibits non-locality in space and time. We discuss the approximation of the non-local term, along with the approximation of the random force using both additive and multiplicative noises, to ensure the correct statistics of the solution, especially the variance of the solution.

Weiqi Chu
PSU
wzc122@psu.edu

MS60

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Abstract Not Available At Time Of Publication

Florian Mehats
IRMAR - Université de Rennes 1
florian.mehats@univ-rennes1.fr

MS61

Spectral Stability of Solutions to the Vortex Filament Hierarchy

The Vortex Filament Equation (VFE) is part of an integrable hierarchy of filament equations. Several equations in this hierarchy have been derived to describe vortex filaments in various situations. Inspired by these results, we develop a general framework for studying the existence and the linear stability of closed solutions of the VFE hierarchy. The framework is based on the correspondence between the VFE and the nonlinear Schrödinger (NLS) hierarchies. Our results establish a connection between the AKNS Floquet spectrum and the stability properties of the solutions of the filament equations. We apply our machinery to solutions of the filament equation associated to the Hirota equation. We also discuss how our framework applies to soliton solutions.

Stephane Lafortune
College of Charleston
Department of Mathematics
lafortunes@cofc.edu

Thomas Ivey
College of Charleston
iveyt@cofc.edu

MS61

Center Manifolds for a Class of Degenerate Evolution Equations and Existence of Small Amplitude Kinetic Shocks

We construct center manifolds for a class of degenerate evolution equations including the steady Boltzmann equation and related kinetic models, establishing in the process existence and behavior of small-amplitude kinetic shock and boundary layers. Notably, for Boltzmann's equation, we show that elements of the center manifold decay in velocity at near-Maxwellian rate, in accord with the formal Chapman-Enskog picture of near-equilibrium ow as evolution along the manifold of Maxwellian states, or Grad moment approximation via Hermite polynomials in velocity. Our analysis is from a classical dynamical systems point of view, with a number of interesting modifications to accommodate ill-posedness of the underlying evolution equation.

Alin Pogan
Miami University
Department of Mathematics
pogana@miamioh.edu

Kevin Zumbrun
Indiana University
USA
kzumbrun@indiana.edu

MS61

Nonlinear Stability of Bilayers under Geometric Flow

We present a fully nonlinear analysis of the stability of nearly circular bilayers in the Functionalized Cahn HIlliard equation under the H-1 gradient flow. We recover a linearized version of the Willmore flow associated to the geometric evolution. A key step is the control of interfaces proximal to the circular shape in terms of normal mode perturbations.

Keith Promislow
Michigan State University
kpromisl@math.msu.edu

Gurgen Hayrapetyan
Ohio University
Department of Mathematics
hayrapet@ohio.edu

MS61

Optimal Damping for Exponential Energy Decay in 1D Wave Equation

Abstract Not Available At Time Of Publication.

Milena Stanislavova
University of Kansas
stanis@ku.edu

MS62

Banach Spaces

Abstract Not Available At Time Of Publication.

Luis M. Abia
Universidad de Valladolid
Dpto Matematica Aplic y Comp
abia@mac.cie.uva.es

MS62

Iterative Solutions for Variational Inclusions Prob-

lems in Banach Spaces

Abstract Not Available At Time Of Publication.

Oriehi E. D. Anyaiwe
Oakland University
oanyaiwe@oakland.edu

Chika Moore
Nnamdi Azikiwe University
Awka, Nigeria
dogoodmoore@yahoo.com

MS62

Iterative Solutions

Abstract Not Available At Time Of Publication.

Breno Giacchini
UFMG - UNIVERSIDADE FEDERAL DE MINAS GERAIS
brenolg@ufmg.br

MS62

Accretive Operators

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Andrew W. Moore
Google Pittsburgh
Carnegie Mellon University
awm@cs.cmu.edu

MS63

Mathematical Models of Bi-layer Nanostructures

Abstract Not Available At Time Of Publication.

Dmitry Golovaty
The University of Akron
Department of Mathematics
dmitry@uakron.edu

MS63

Gamma-convergence of an Anisotropic Superconductivity Model with Magnetic Fields Near H_{c_1}

We analyze the Lawrence-Doniach model for layered superconductors occupying a bounded generalized cylinder, $\Omega \times (0, L)$, in R^3, where Ω is a bounded simply connected smooth domain in R^2. For an applied magnetic field $\vec{H}_{ex} = h_{ex}\vec{e}_3$ that is perpendicular to the layers with $h_{ex} \sim |\ln \epsilon|$ as $\epsilon \to 0$, where ϵ is the reciprocal of the Ginzburg-Landau parameter, we prove Gamma-convergence of the Lawrence-Doniach energy as ϵ and the interlayer distance s tend to zero, under the additional assumption that the layers are weakly coupled.

Guanying Peng
University of Cincinnati
penggg@ucmail.uc.edu

MS63

Analysis and Stability of a Landau-de Gennes Model for the Switching Mechanism in the $B_{\mathbf{1RevTilted}}$ Phase of Bent-Core Liquid Crystals

The $B_{\mathrm{1RevTilted}}$ is a smectic tilted columnar phase of bent-core molecule liquid crystals, in which it is possible to reorient the spontaneous polarization by applying an electric field. The reorientation can be achieved by either a rotation around the smectic cone or the molecular axis, or more in general by a combination of both. In our work, we consider a Landau-de Gennes-type energy functional used in the physics literature to model experimental results of the switching mechanism seen in this columnar phase. As the width of the column tends to infinity, Γ-convergence shows that rotation around the smectic tilt cone is favored, provided the coefficient of the coupling term, between the polar parameter, the nematic parameter, and the layer normal is large. We will also discuss the existence and stability of positive solutions to simplified Euler-Lagrange equations.

Feras Yousef
Department of Mathematics
The University of Jordan
fyousef@ju.edu.jo

MS64

Improved Non-Overlapping Domain Decomposition Algorithms for the Eddy Current Problem

Abstract Not Available At Time Of Publication.

Yassine Boubendir
Department of Mathematical Sciences
boubendi@njit.edu

MS64

A High-Order Perturbation of Surfaces Method for Scattering of Linear Waves by Periodic Multiply Layered Gratings in Two and Three Dimensions

Abstract Not Available At Time Of Publication.

Youngjoon Hong
University of Illinois, Chicago
hongy@uic.edu

MS64

Scattering by a Periodic Array of Narrow Slits: Field Enhancement and Anomalous Diffraction

In this talk, I will present mathematical studies of field enhancement by the scattering of a periodic array of perfect conducting narrow slits. The scattering problem in three different configurations will be investigated, where the geometry in different configurations varies depending on the scaling between the size of slits, the size of period, and the wavelength of the incident wave. Based upon the layer potential technique, asymptotic analysis and the homogenization theory, the enhancement mechanisms in these three regimes are studied quantitatively.

Junshan Lin
Auburn University
jzl0097@auburn.edu

MS64

The Imaging of Small Perturbations in An

Anisotropic Media

Abstract Not Available At Time Of Publication.

Shari Moskow
Drexel University
Department of Mathematics
moskow@math.drexel.edu

MS65

Precise Asymptotics of the Aris Equations Via Poisson Summation

Understanding the behavior of a passive tracer distribution in laminar, pressure-driven pipe flow requires understanding of the moments – mean, variance, skewness – of the distribution along flow lines throughout the cross section. In particular, the skewness has nontrivial dependence on the cross section of the pipe, which has motivated us to explore of the importance of cross section on the distribution's moments in general. In the case of flow between infinite parallel plates, the Aris moment equations have been shown to have explicit, single-series solutions for the first three moments. Here, we show how the form of these solutions allows them to be rewritten, using Poisson summation, as an equivalent series which is well-ordered at short time. This allows for an excellent two-term method of images approximation for the moments before diffusive timescales, and from these approximations we derive higher-order correction terms to the short time asymptotics of the skewness. After this, we explore the potential of using images of the same functional form for deriving correction terms in the asymptotics of the moments for a general cross section, without the need for the explicit solutions for the tracer moments, and comparisons to numerical simulation will be shown for a few families of cross sections.

Manuchehr Aminian
UNC
manuchehr.aminian@colostate.edu

Roberto Camassa
University of North Carolina
camassa@amath.unc.edu

Richard McLaughlin
University of North Carolina at Chapel Hill
rmm@email.unc.edu

MS65

How Boundaries Shape Chemical Deliveries in Microfluidics

We present the results of a combined theoretical, computational and experimental study of the dispersion of a passive scalar in laminar shear flow through various pipe geometries. First, we derive the single-series longitudinal moments of the scalar concentration through exact analysis valid at all times. Then we show through Monte Carlo simulation, asymptotic analysis, and experiments that the cross-sectional aspect ratio sets the sign of the average skewness at long times (relative to the Taylor diffusion timescale). The skewness describes the longitudinal asymmetry of the tracer distribution and universally, thin channels (aspect ratio $\ll 1$) result in negative average skewness, whereas thick channels (aspect ratio ~ 1) result in positive average skewness. Our analysis also allows us to define a "golden aspect ratio which separates thin from thick channels. More exotic geometries will be discussed as well as possible microfluidics applications.

Francesca Bernardi
University of North Carolina at Chapel Hill
bernardi@live.unc.edu

Manuchehr Aminian
UNC
manuchehr.aminian@colostate.edu

Roberto Camassa
University of North Carolina
camassa@amath.unc.edu

Daniel Harris, Richard McLaughlin
University of North Carolina at Chapel Hill
dmh@email.unc.edu, rmm@email.unc.edu

MS65

Porous Spheres Settling in Stratified Fluids

Marine snow, aggregates composed of organic and inorganic matter, are fundamental to the carbon flux from the surface ocean to the deep ocean. Most of these macroscopic particles are extremely porous, allowing diffusion of a stratifying agent from the ambient fluid to affect the density and therefore the settling dynamics. We study the case of a single spherical particle settling in water stratified by salt, focusing on effects of porosity and diffusion. A parametric study of the settling behaviors and comparisons between modeling and experiments will be presented.

Shilpa Khatri
School of Natural Sciences
University of California, Merced
skhatri3@ucmerced.edu

MS65

Modeling Viscous Film Flows Driven by Oscillatory Airflow in a Tube

The flow of an annular liquid film lining the inside of a vertical tube arises in both biological and engineering problems. In the absence of airflow in the tube, the film will flow downwards due to gravity; when the air inside the core region of the tube is forced to flow due to an imposed pressure gradient, the annular film may be driven downwards or upwards. In this talk, we focus on films driven by periodic airflow with a net volume flux of zero over each period. Physical experiments have shown that if such periodic airflow is biased, e.g. having relatively fast upwards flow for less than half the period and relatively slow downwards flow for the remainder of the period, it is possible for the airflow to transport the film upwards against gravity. A recently-derived model for the flow of a viscous film driven by either steady or oscillatory airflow inside a tube will be discussed; the model is a single nonlinear partial differential equation that describes the evolution of the free surface of the film. Linear stability analysis of the model demonstrates improved agreement with experiments when compared with earlier versions of the model in the case of steady airflow. Model solutions found numerically will be shown to qualitatively match results of earlier film transport experiments. Finally, the implications of asymptotic assumptions made in deriving the model will be discussed briefly.

H. Reed Ogrosky
Virginia Commonwealth University

hrogrosky@vcu.edu

Roberto Camassa, Jeffrey Olander
University of North Carolina
camassa@amath.unc.edu, olander@physics.unc.edu

MS66

Fast Flow Asymptotics for Stochastic Incompressible Viscous Fluids in the Plane and Spdes on Graphs

Fast advection asymptotics for a stochastic reaction-diffusion-advection equation is studied in this paper. To describe the asymptotics, one should consider a suitable class of SPDEs defined on a graph, corresponding to the stream function of the underlying incompressible flow.

Sandra Cerrai
University of Maryland
cerrai@math.umd.edu

MS66

Stochastic Damped Navier-Stokes in R^d

We deal with the damped Navier-Stokes equations in R^d with a multiplicative noise forcing term, with low space regularity. We prove the existence of martingale solutions for $d = 2$ or $d = 3$ and, for $d = 2$, the pathwise uniqueness of solutions. Moreover, we prove existence of invariant measures for $d = 2$ and existence of stationary solutions for $d = 3$. This is based on a joint work with Z. Brzezniak.

Benedetta Ferrario
University of Pavia
benedetta.ferrario@unipv.it

MS66

Existence of a Density on Finite Projections of the 2D Stochastic Navier Stokes Equation Driven by Lévy Processes or Fractional Brownian Motion

Let us consider the 2D Navier Stokes Equation a torus $\mathbb{T}^2$ driven by a Levy noise or a fractional Brownian motion and let us denote the solution process by u. In the talk we will present regularity properties of the probability measure induced by the solution process. To be more precise, if $F \subset L^2(\mathbb{T})$ is a finite dimensional subspace and $t > 0$, then we present under which conditions on the characteristic measure of the Lévy process or the Hurst parameter of the fractal Brownian motion, the, on F by $u(t)$ induced measure, is absolutely continuous with respect to the Lebesgue measure on F. First we will present the deterministic 2D Navier Stokes and some control theoretical results. Then I will present in which they these control properties of the deterministic equation corresponds to regularity properties of the probability measure induced by the solution process. This is a joint work with P. Razafimandimby.

Erika Hausenblas
Montanuniversität leoben
hau.leoben@gmail.com

MS66

Data Assimilation Algorithm Based on Feedback Control Theory

We investigate the effectiveness of a simple finite-dimensional feedback control scheme for globally stabilizing solutions of infinite-dimensional dissipative evolution equations introduced by Azouani and Titi. This feedback control algorithm overcomes some of the major difficulties in control of multi-scale processes: It does not require the presence of separation of scales nor does it assume the existence of a finite-dimensional globally invariant inertial manifold. We present a theoretical framework for a control algorithm which allows us to give a systematic stability analysis, and present the parameter regime where stabilization or control objective is attained. In addition, the number of observables and controllers that were derived analytically and implemented in our numerical studies is consistent with the finite number of determining modes that are relevant to the underlying physical system. We verify the results computationally in the context of the Chafee-Infante reaction-diffusion equation, the Kuramoto-Sivashinsky equation, and other applied control problems, and observe that the control strategy is robust and independent of the model equation describing the dissipative system. This is joint work with Edriss S. Titi.

Evelyn Lunasin
United States Naval Accademy
lunasin@usna.edu

MS67

Spectrwm: Spectral Random Walk Method for Stochastic Partial Differential Equations

The numerical solution of stochastic partial differential equations (SPDE) presents challenges not encountered in the simulation of PDEs or SDEs. Indeed, the roughness of the noise in conjunction with nonlinearities in the drift typically make these equations particularly challenging to simulate. In practice, this means that it is tricky to construct, operate, and validate numerical methods for SPDEs. This is especially true if one is interested in path-dependent expected values, long-time simulations, or in the simulation of SPDEs whose solutions have constraints on their domains. To address some of these issues, this talk introduces a Markov jump process approximation for SPDEs, which we refer to as the spectral random walk method (SPECTRWM).

Nawaf Bou-Rabee
Department of Mathematical Sciences
Rutgers UniversityCamden
nawafbourabee@me.com

MS67

Regularity and Decay Results for Point Defects in Complex Crystals

Crystal defects play an important role in determining the mechanical and electrical properties of crystalline materials. In this talk, we formulate a model for a point defect in a multilattice crystal with an empirical interatomic potential interaction and quantify the decay of the long-range elastic fields with increasing distance from the defect. These decay estimates are essential in quantifying approximation errors in coarse-grained models and in developing multiscale atomistic-to-continuum methods. We present an example of how the decay rates are used in the construction of an optimal numerical method for approximating a Stone-Wales defect in graphene using the blended force-based quasicontinuum method.

Derek Olson
Mathematical Sciences

Rensselaer Polytechnic Institute
olsond2@rpi.edu

Christoph Ortner
University of Warwick
c.ortner@warwick.ac.uk

MS67

First-principle Modeling of Large-scale Atomistic Systems with Applications

We discuss new computational methods based on the FEAST eigensolver that can positively impact the existing methodologies used in first-principle DFT ground state and TDDFT excited states calculations of complex molecular systems and nanostructures. Simulation results with applications will be presented ranging from computational electronic spectroscopy of molecules, to plasmonic excitations in carbon-based nanostructures.

Eric Polizzi
University of Massachusetts, Amherst, USA
polizzi@ecs.umass.edu

MS67

Homogenization Theory for Biased Random Walks on Graphs Embedded in the Euclidean Space

We study the homogenization limit of a biased random walk on a periodic graph embedded in the multidimensional Euclidean space. Under certain conditions and under appropriate scaling we show that the random walk converges to a Brownian motion. Our model problem is inspired by the problem of solute diffusion in an aqueous polymer environment where both obstruction of solute by the polymer as well as interactions between the solute and polymer in the form of attraction, repulsion or bond formation play a role in determining effective solute diffusivity. The presence of interactions necessitates biased random walk models. Prediction of effective solute diffusivity in aqueous polymer environments enables the design of polymer-based drug and protein delivery devices as well as cell scaffolds for tissue engineering, among other applications. Our rationale for considering a random walk on a graph as the finescale model instead of a Brownian motion with drift and reflections, is to account for the fact that the mean path length of a diffusing solute may not be negligible in comparison with the finescale length of the structures of interest. When the finescale length of interest is only a few nanometers, as in the case of polymer gel networks, the case for our starting point is quite strong. We present both formal asymptotics as well as rigorous convergence results.

Muruhan Rathinam, Preston Donovan
University of Maryland, Baltimore County
muruhan@umbc.edu, pdonovan@umbc.edu

MS67

Accelerated Transition Path Sampling for Molecular Dynamics

A common question in the study of atomistic systems is how transitions occur between different conformations of the system, usually corresponding to distinct minima of a potential energy landscape. Here, we model our system by the overdamped Langevin equation and consider the problem of sampling from the conditioned diffusion, where particular arrangements are assumed at fixed initial and terminal times. Using relative entropy, we are able to compute Gaussian approximations of the path space distribution which can then be used to accelerate exact sampling of the conditioned diffusion. Numerical examples and pitfalls of this approach will be presented.

Gideon Simpson
Department of Mathematics
Drexel University
simpson@math.drexel.edu

MS68

Stability of Fast Traveling Waves for a Doubly-Diffusive FitzHugh-Nagumo System

The Maslov index is a topological invariant assigned to curves of Lagrangian planes. It has been used in recent years to understand the spectra of linear operators, often arising in the stability analysis of nonlinear waves. In the context of waves, the Maslov index can be thought of as a generalization of Sturm-Liouville theory to systems of equations. One issue plaguing the application of the Maslov index to stability problems is that it is difficult to calculate in practice. This typically entails tracking the tangent space to an invariant manifold as it moves around phase space. We address this issue by analyzing traveling pulses in a FitzHugh-Nagumo system. The timescale separation in the traveling wave equation allows us to reduce the dimension of the problem and make the calculation of the index tractable. We use this calculation in conjunction with a recent result relating the Maslov index to stability in skew-gradient systems to prove that the fast traveling pulses are stable.

Paul Cornwell
University of North Carolina at Chapel Hill
pcorn@live.unc.edu

Chris Jones
University of North Carolina-Chapel Hill
ckrtj@email.unc.edu

MS68

Defects in Oscillating Spatially Extended Systems

We look at defects in oscillating spatially extended systems, such as chemical reactions or arrays of oscillators. Here, defects are represented as inhomogeneities which can be modeled as perturbations of the relevant equations. It is well known that when these inhomogeneities are stationary they can lead to interesting behavior like target and spiral waves. Here we look instead at effects of moving defects and show that, depending on their speed, the level sets of the solutions' phase can have different profiles. Since the linearization about the steady state has a zero eigenvalue embedded in the essential spectrum, finding solutions via perturbation theory is not straight forward. One can resolve this issue with the help of weighted Sobolev spaces which make the operator Fredholm.

Gabriela Jaramillo
The University of Arizona
gjaramillo@math.arizona.edu

MS68

Traveling Waves in Gray-Scott Model in Bistable

Regime

Using singularly perturbed nature of the Gray-Scott model, we apply multi-scale analysis in a systematic way to show the existence and stability of a traveling front and a traveling pulse. While the traveling front is stable, the pulse is unstable.

Vahagn Manukian
Miami University Hamilton
manukive@miamioh.edu

Anna R. Ghazaryan
Miami University
ghazarar@miamioh.edu

MS68

The Maslov Index and the Spectra of Second Order Elliptic Operators

In this talk I will discuss 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 certain paths of Lagrangian planes. In addition, I will present formulas expressing the Morse index, the number of negative eigenvalues, in terms of the Maslov index for several classes of second order operators: the $\theta-$periodic Schrödinger operators on a period cell $Q \subset \mathbb{R}^n$, the elliptic operators with Robin-type boundary conditions, and the abstract self-adjoint extensions of the Schrödinger operators on star-shaped domains. This is joint work with Y. Latushkin.

Selim Sukhtaiev
Department of mathematics
University of Missouri
sswfd@mail.missouri.edu

PP1

Traveling Waves in Mass and Spring Dimer Fermi-Pasta-Ulam-Tsingou Lattices

The Fermi-Pasta-Ulam-Tsingou (FPUT) lattice is an infinite chain of particles connected by springs and constrained to move on a horizontal line. We investigate wave behavior in two classes of heterogeneous FPUT lattices: the mass dimer, in which the particles alternate in mass but the springs are identical, and the spring dimer, in which all the particles are the same but the spring forces alternate. In each case, we prove the existence of traveling waves that are nanopterons. These traveling waves are not classical solitary waves but instead are asymptotic at spatial infinity to periodic waves with extremely small amplitude.

Timothy E. Faver
Drexel University
tef36@drexel.edu

Doug Wright
Drexel University
Mathematics
jdoug@math.drexel.edu

PP1

Adi Extrapolated Crank-Nicolson Orthogonal Spline Collocation for Burgers' Equation in Two Space Variables

Burgers' equation in two space variables is a coupled system of non-linear parabolic problems. We discretize these equations in space using orthogonal spline collocation with splines of degree $r \geq 3$ and we use ADI extrapolated Crank-Nicolson scheme for time discretization. The scheme is initialized with a predictor/corrector method. We show theoretically that the H^1 norm of the error at the final time level is of optimal order r in space and of order 2 in time. Our numerical results demonstrate also that the maximum norm of the error at the final time level is of optimal order $r+1$ in space and of order 2 in time.

Nick Fisher
Department of Applied Mathematics and Statistics
Colorado School of Mines
nfisher@mines.edu

Bernard Bialecki
Colorado School of Mines
bbialeck@mines.edu

PP1

Suppression of Blow-Up in Patlak-Keller-Segel Via Shear Flows

In this paper we consider the parabolic-elliptic Patlak-Keller-Segel models in $\mathbb{T}^d$ with $d = 2, 3$ with the additional effect of advection by a large shear flow. Without the shear flow, the model is L^1 critical in two dimensions with critical mass 8π; solutions with mass less than 8π are global and solutions with mass larger than 8π with finite second moment, all blow up in finite time. In three dimensions, the model is $L^{3/2}$ critical and L^1 supercritical; there exists solutions with arbitrarily small mass which blow up in finite time arbitrarily fast. We show that the additional shear flow, if it is chosen sufficiently large, suppresses one dimension of the dynamics and hence can suppress blow-up. In two dimensions, the problem becomes effectively L^1 subcritical and so all solutions are global in time (if the shear flow is chosen large). In three dimensions, the problem is effectively L^1 critical, and solutions with mass less than 8π are global in time (and for all mass larger than 8π, there exists solutions which blow up in finite time).

Siming He
University of Maryland, College Park
simhe@math.umd.edu

Jacob Bedrossian
University of Maryland
jacob@cscamm.umd.edu

PP1

Development Towards a Methodology for Predicting Long-Time Algebraic Growth in Linear Wave Equations.

One of the lesser understood topics of fluid instability is long time algebraic growth that can occur when a fluid is deemed classically (exponentially) neutrally stable. The aim of this work is to develop a methodology that would allow one to predict possible long time algebraic growth of disturbances in fluids (for example, coating processes), given the partial differential equations that describe the evolution of the disturbance. Specifically, progress has been made towards an algorithm that one may use to predict the algebraic growth rate.

Meaghan Hoitt, Colin Huber, Nicole Hill, Nathaniel S. Barlow, Steve Weinstein
Rochester Institute of Technology
mlh1964@rit.edu, cmh7271@rit.edu, nsh3709@rit.edu, nsbsma@rit.edu, sjweme@rit.edu

PP1

Almost Planar Waves on Square Lattices

We consider traveling wave solutions to the spatially discrete reaction-diffusion equation posed on the square lattice and look for traveling corners solutions that bifurcate from planar waves. Due to the discrete setting of the problem, we made use of a global center manifold reduction on a difference equations system posed on Banach spaces. We prove the existence of interior or exterior corners depending on the geometry of the angular wave speed function.

Leonardo Morelli
University of Leiden
l.morelli@math.leidenuniv.nl

Hermen Jan Hupkes
University of Leiden
Mathematical Institute
hhupkes@math.leidenuniv.nl

PP1

Pulse Solutions for the Discrete FitzHugh-Nagumo Equation with Infinite-Range Interactions

We establish the existence and nonlinear stability of travelling pulse solutions for the discrete FitzHugh-Nagumo equation with infinite-range interactions close to the continuum limit. For the verification of the spectral properties, we need to study a functional differential equation of mixed type (MFDE) with unbounded shifts. We avoid the use of exponential dichotomies and phase spaces, by building on a technique developed by Bates, Chen and Chmaj for the discrete Nagumo equation. This allows us to transfer several crucial Fredholm properties from the PDE setting to our discrete setting.

Willem M. Schouten
Leiden University
w.m.schouten@math.leidenuniv.nl

Hermen Jan Hupkes
University of Leiden
Mathematical Institute
hhupkes@math.leidenuniv.nl

PP1

Modeling the Development of Mutated Patterns on Zebrafish

Zebrafish (Danio rerio) is a small fish with distinctive black and yellow patterns that form due to the self-organizing interactions of different pigment cells. While wild-type zebrafish feature stripes, altered cell interactions produce a wide range of mutations on the body of the growing fish, including spots and labyrinth curves. Working closely with the biological data, we present an agent-based model for the development of wild-type stripes on growing domains and discuss associated continuum limits. Our model identifies altered cell interactions that lead to patterns consistent with zebrafish mutations as well as close relatives within the Danio genus.

Alexandria Volkening, Bjorn Sandstede
Division of Applied Mathematics
Brown University
alexandria_volkening@brown.edu,
bjorn_sandstede@brown.edu