IP1
Tracing Genealogy Within an Invasion Wave

Cell invasion, whereby cells move and undergo cell division, occurs in tumor growth, wound healing and during embryonic development. Continuum models of cell invasion typically employ the well-known Fisher equation. This PDE supports travelling wave solutions, making the population-level behavior highly predictable. However, recent individual cell lineage experiments (within a predictable cell invasion wave) revealed a surprising result: the contribution of individual cells is highly unequal. This paradoxical behavior is examined using various tools, including PDEs to track of the number of divisions that cells undergo within an invasion wave. The method provides a potentially useful technique for deducing cell lineage data when imaging every cell is not feasible.

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IP2
Regularity Properties of the Euler Equations in Lagrangian Variables

The Euler equations for ideal incompressible fluids have two formulations, an Eulerian and a Lagrangian one. These formulations are equivalent in the smooth regime (the velocity field lies in the Holder space $C^{1,\gamma}$ for some $\gamma \in (0,1)$), and the particle paths are just the characteristics associated to the Eulerian velocity fields. In this talk we discuss three instances when the classical solution of the Euler equations has some remarkably good regularity properties, when looked at in Lagrangian variables. In contrast, we then show that these regularity properties are false when looked at in Eulerian variables. Moreover, we prove that some Lagrangian regularity properties are natural for a large class of incompressible inviscid hydrodynamic models, with slightly better than Lipschitz velocity fields. This is part of joint works with Peter Constantin (Princeton), Igor Kukavica (USC), and Jiahong Wu (Oklahoma State).

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IP3
Hypersurfaces with Almost Constant Mean Curvature and Capillarity Theory

Alexandrov's theorem asserts that a (bounded, embedded) constant mean curvature (cmc) hypersurface must be a sphere. It is well-known that if this condition is relaxed and the mean curvature is just assumed to be close to a constant, then the corresponding hypersurfaces does not need to be close to a sphere. Indeed any family of nearby spheres with equal radii connected by short catenoidal necks can be slightly perturbed to obtain examples of almost-cmc hypersurfaces. We show that these examples actually capture the only possible behavior of almost-cmc hypersurfaces, by proving various quantitative bounds on the distance between an almost-cmc hypersurface and a collection of tangent spheres of equal radii in terms of their mean curvature oscillation. This is a joint work with G. Ciraolo (U Palermo). We next discuss these issues for the nonlocal mean curvature introduced by Caffarelli and Souganidis, showing in particular a remarkable rigidity property of the nonlocal problem which prevents bubbling phenomena, in other words, every nonlocal almost-cmc hypersurface must be close to a single sphere. This is a joint work with G. Ciraolo, A. Figalli (UT Austin) and M. Novaga (U Pisa).

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IP4
Long Time Dynamics for Two Dimensional Water Wave Models

The water wave type equations describe the evolution of the free surface of an inviscid, incompressible fluid evolving under the action of gravity, surface tension, etc. Understanding the long time dynamics for such fluid models is a challenging yet very interesting problem. The aim of this talk is to present some recent ideas and results in this direction for two dimensional fluids. This work is joint with Mihaela Ifrim, and also in part with John Hunter and Benjamin Harrop-Griffiths.

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IP5
Optimal Shape and Location of Sensors or Actuators in PDE Models

We consider the problem of optimizing the shape and the location of sensors or actuators for systems whose evolution is driven by a linear PDE model. This problem is frequently encountered in applications where one wants for instance to maximize the quality of the reconstruction of solutions by using only partial observations. For example, we model and solve the following informal question: What is the optimal shape and location of a thermometer? We stress that we want to optimize not only the placement but also the shape of the observation domain, over the class of all possible measurable subsets of the domain having a prescribed measure. We model this optimal design problem as the one of maximizing a functional that we call the randomized observability constant, which reflects what happens for random initial data, and which is of a spectral nature. Solving this problem is then strongly dependent on the PDE model under consideration. For parabolic equations, we prove the existence and uniqueness of a best domain, regular enough, and whose algorithmic construction depends in general on a finite number of modes. In contrast, for wave or Schrodinger equations, relaxation may occur, and our analysis reveals intimate relations with quantum chaos, more precisely with quantum ergodicity properties of the eigenfunctions. These works are in collaboration with Y. Privat (Paris 6) and E. Zuazua (BCAM Bilbao).

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IP6

The Abelian Sandpile and Circle Packings

The Abelian sandpile is a simple and deterministic diffusion process on graphs, devised as a model of self-organized criticality by Bak, Tang, and Weisenfeld. The scaling limit of the sandpile on a periodic graph is a nonlinear elliptic partial differential equation with complicated algebraic structure. I will discuss the sandpile, the algebraic structure of its scaling limit, and explicit descriptions of the fractals it approximates.

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IP7

Scientific Computing in the Movies and Virtual Surgery

New applications of scientific computing for solid and fluid mechanics problems include simulation of virtual materials for movie special effects and virtual surgery. Both disciplines demand physically realistic dynamics for such materials as water, smoke, fire, and brittle and elastic objects. These demands are different than those traditionally encountered and new algorithms are required. Terans talk will address the simulation techniques needed in these fields and some recent results including: simulated surgical repair of biomechanical soft tissues, extreme deformation of elastic objects with contact, high resolution incompressible flow, clothing and hair dynamics. Also included is discussion of a new algorithm used for simulating the dynamics of snow in Disneys animated feature film, "Frozen".

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IP8

Customising Image Analysis Using Nonlinear Partial Differential Equations

When assigned with the task of extracting information from given image data the first challenge one faces is the derivation of a truthful model for both the information and the data. Such a model can be determined by the a-priori knowledge about the image (information), the data and their relation to each other. The source of this knowledge is either our understanding of the type of images we want to reconstruct and of the physics behind the acquisition of the data or we can thrive to learn parametric models from the data itself. The common question arises: how can we customise our model choice to a particular application? Or better how can we make our model adaptive to the given data? Starting from the first modelling strategy this talk will lead us from nonlinear diffusion equations and subdifferential inclusions of total variation type functionals as the most successful image model today to non-smooth second- and third-order variational models, with data models for Gaussian and Poisson distributed data as well as impulse noise. These models exhibit solution-dependent adaptivities in form of nonlinearities or non-smooth terms in the PDE or the variational problem, respectively. Applications for image denoising, inpainting and surface reconstruction are given. After a critical discussion of these different image and data models we will turn towards the second modelling strategy and propose to combine it with the first one using a PDE constrained optimisation method that customises a parametrised form of the model by learning from examples. In particular, we will consider optimal parameter derivation for total variation denoising with multiple noise distributions and optimising total generalised variation regularisation for its application in photography.

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SP1

SIAG/Analysis of Partial Differential Equations Prize Lecture

Abstract not available at time of publication.

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CP1

The Laplace Equation and The Numerical Analysis For Streamline Around a Circle

Abstract- There is a lot of Partial Differential Equation problem in engineering field especially Fluid Mechanic. To solve the equation we can use Numerical Method to get solution that is near the analytical solution. In this research, the author solves several calculation in streamline around the circle with the influence from circulation. Keywords : Fluid Mechanic, Laplace Equation, Streamline, Numerical Analysis, Fluid Dynamics

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CP1

Steklov Eigenproblems and Representations of Solutions of Laplace's Equation

This talk will outline results about the boundary integral kernels that represent solutions of Laplace's equation subject to Dirichlet, Robin or Neumann boundary data. Historically these solutions have been represented using the Poisson kernel - and this has often been expressed in terms of standard eigenfunctions of the Laplacian. The resulting finite approximations are know to have very poor convergence properties. This talk will describe the repesentations of these kernels in terms of harmonic Steklov eigenfunctions and Dirichlet biharmonic Steklov eigenfunctions. These series representations have much better convergence properties and lead to some different results about these boundary value problems.

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CP1

Steklov Representations of Harmonic Functions and Applications

Steklov expansions for a harmonic function on a rectangle are analyzed. The value of a harmonic function at the center of a rectangle is shown to be well approximated by the mean value of the function on the boundary plus a very small number (often 3 or fewer) of additional boundary integrals. Similar approximations are found for the central values of solutions of Robin and Neumann boundary value problems. These results are based on finding explicit expressions for the Steklov eigenvalues and eigenfunctions. This is joint work with Professor Giles Auchmuty.

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CP1

Computing the Thermal Properties of Ground Heat Exchangers

To exploit effectively the ground heat capacity, Ground Heat Exchangers (GHEs) are used together with Ground Heat Pumps. For an efficient operation, the thermal properties of the ground need to be known when sizing the GHE. A thermal model, based on heat equation, that uses a line-heat source is applied and validated experimentally through a transient-flow method. The model is also solved analytically and the possible errors and drawbacks of the whole method are discussed.

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CP1

Asymptotics for the Best Sobolev Constants and Their Extremal Functions

Let Ω be a bounded domain of $\mathbf{R}^N$, $N \geq 2$. Let, for $p > N$,

$$\Lambda_p(\Omega) := \lim_{q\to\infty} \min\left\{\|\nabla u\|_p^p : u \in W_0^{1,p}(\Omega) \quad \text{and} \quad \|u\|_{L^q(\Omega)} = 1\right\}.$$

We prove that

$$\Lambda_p(\Omega) = \min\left\{\|\nabla u\|_p^p : u \in W_0^{1,p}(\Omega) \quad \text{and} \quad \|u\|_{L^\infty(\Omega)} = 1\right\}$$

and that

$$\lim_{p\to\infty} \Lambda_p(\Omega)^{\frac{1}{p}} = \frac{1}{\|\rho\|_\infty},$$

where ρ denotes the distance function to the boundary. Then, we show that, up to subsequences, the extremal functions of $\Lambda_p(\Omega)$ converge (as $p \to \infty$) to the viscosity solutions of a specific Dirichlet problem involving the infinity Laplacian in the punctured Ω. Acknowledgments. The authors thank the support of CNPq and Fapemig, Brazil.

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CP1

Radial Eigenpairs of P-Laplacian Via Inverse Iterations

In this work we develop a constructive method for obtaining the first eigenpair of the eigenvalue problem

$$\begin{cases} -\Delta_p u = \lambda \|u\|_{L^q(\Omega)}^{p-q} |u|^{q-2} u, & \text{in } \Omega \\ u = 0 & \text{on } \partial\Omega, \end{cases} \tag{1}$$

where: $\Delta_p u := \operatorname{div}\left(|\nabla u|^{p-2} \nabla u\right)$ is the p-Laplacian operator, $p > 1$, $\lambda \in \mathbf{R}$, Ω is a bounded, radially symmetric (ball or annulus) domain of $\mathbf{R}^N$, $N > 1$ and $q \geq 1$. In the first part we consider $\Omega = B_1$ a unit ball and

$$1 \leq q < p^\star := \begin{cases} \frac{Np}{N-p}, & \text{if } 1 < p < N \\ \infty, & \text{if } p \geq N. \end{cases}$$

In the second part we consider $\Omega = \Omega_{a,b}$ an annulus.

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CP2

A Rbf-Descent Method for Wind Field Approximation

Motivated by meteorological applications, the problem of concern is the approximation of three dimensional wind fields from horizontal field data. The problem is formulated as a PDE constrained least squares problem. A descent method is developed with computation of the gradient by the adjoint state approach. In each descent iteration, the underlying mass consistent model leads to the solution of

an elliptic problem. The latter is solved using a Radial Basis Functions method.

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CP2

An Analysis of Blended Three-step BDF Time Stepping Scheme For Navier-Stokes Type System Related To Soret Convection

We investigate the stability and convergence of a new class of blended three-step BDF time- stepping scheme for spatially discretized Navier-Stokes type system modeling Soret driven convective flows. A Galerkin mixed finite element spatial discretization is assumed, and the temporal discretization is by the implicit blended three-step BDF scheme. The blended BDF scheme is more accurate than the classical second order accurate two-step BDF (BDF2) scheme yet strongly A-stable. We consider an implicit, linearly extrapolated version to the scheme to improve its efficiency. We present optimal finite element error estimates and prove the scheme is unconditionally stable and convergent. Numerical experiments are presented that compare the scheme to the classical BDF2 scheme.

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CP2

Finite Volume MUSCL Approximation for Transport Equation Originating in a Neuronal Model

We consider a transport equation with mixed boundary conditions (Dirichlet and Neumann) originating in a neuronal model. This equation contains point-wise delay and advanced argument. The objective of this paper is to construct and analyze higher order MUSCL scheme to find a numerical solution. The developed scheme is stable and convergent. The importance of this scheme is that it is valid for large as well as for small values of point-wise delay and advance. Some test examples are included to examine the behavior of the solution and to verify the order of convergence.

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CP2

Steady State and Sign Preserving Semi-Implicit Runge-Kutta Methods for ODEs with Stiff Damping Term

We develop a family of second-order semi-implicit time integration methods for systems of ordinary differential equations (ODEs) with stiff damping term, which is capable of exactly preserving steady states and maintaining the sign of the computed solution under the time step restriction determined by the nonstiff part of the system only. The new semi-implicit methods are based on the modification of explicit strong stability preserving Runge-Kutta (SSP-RK) methods and are proven to have a formal second order of accuracy, A(a)-stability and stiff decay. We implement the proposed SSP-RK based semi-implicit methods on a system of ODEs arising from the semidiscretization of the shallow water equations with friction terms and achieve a remarkable agreement between the numerical results and experimental data.

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CP2

An Asymptotic Preserving Implicit-Explicit Scheme for All-Froude Flows

In this work, we present a framework for an asymptotic preserving scheme using implicit-explicit flux splitting approach, which is applied to one-dimensional shallow water equations. We show that the splitting provides asymptotic consistency, e.g. div-free condition, under a unrestrictive CFL condition. Unlike most other AP schemes which lack stability analysis, we try to show asymptotic stability of the scheme in some appropriate sense.

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CP2

A Theoretical and Computational Framework for Measure-Valued Solutions to Conservation Laws

Recent results cast doubts on the appropriateness of the entropy weak solution for nonlinear systems of conservation laws and it has been conjectured that the more general entropy measure-valued (emv) solutions might be the appropriate notion of solution. We proved that bounded solutions of an arbitrary high order space-time DG scheme combined with a nonlinear shock-capturing converge to an emv solution. The novelty in our work is that no streamline-diffusion terms are used for stabilization.

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CP3

Weak and Strong Probabilistic Solutions for a Class of Strongly Nonlinear Parabolic Problems

We consider higher-order stochastic quasilinear parabolic

equations involving unbounded perturbation of zeroth order. We establish the existence of a probabilistic weak and strong solutions. Our tools are a regularization through a truncation procedure which enables us to adapt the work of Krylov and Rozosvkii, combined with analytic and probabilistic compactness results of Prokhorov and Skorokhod, pseudomonotonicity and Yamada-Watanabe argument due to Ondrejat.

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CP3

Existence of Mild Solution for An Impulsive Neutral Stochastic Fractional Integro-Differential Inclusions with Infinite Delay

This paper studies an impulsive neutral stochastic fractional integro-differential inclusions with infinite delays in an arbitrary separable Hilbert space X. The sufficient condition proving the existence of mild solution to stochastic inclusion problem with impulsive conditions is derived by using resolvent operator and fixed point theorem for multivalued operators due to Dhage.

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CP3

Global Existence of Solutions to System of Isentropic Gas Dynamics in a Divergent Nozzle with Friction

In this talk, we would like to introduce a new method to use the flux functions of nonlinear hyperbolic systems to control the super-linear source terms, and to obtain a uniformly bounded estimate. Some examples such as the river flow equations, the nozzle flow without friction, the nozzle flow with friction are introduced.

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CP3

Elliptic and Parabolic Differential-Difference Operators with Incommesurable Shifts

Consider operator $(Ru)(x) = u(x)+a_1u(x-1)+a_2u(x+\tau)$, where $0 < \tau < 1$. Corresponding Dirichlet problem $-(R_Qu)' = f(x)$ in $Q = (0, d)$ can have nonsmooth solution almost every where in Q (see Sec. 9 in [1]). We consider the conditions of coercitiveness of operator $A = -(R_Qu)'$ and proove the equality $D(A^{1/2}) = D(A^{*1/2})$, using the result of paper [2].
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CP3

Generalized Variable-Coefficient Nonlinear Schroedinger Equation: Explicit Solutions and Finite-Time Blow-Up

Soliton solutions for a generalized variable-coefficient nonlinear Schroedinger equation will be presented. For this end the authors have used a Riccati-Ermakov system with explicit solutions with multiparameters. This system has been used previously to construct spiral laser beam type solutions for paraxial wave equation. As an interesting application of the approach it will show that the parameters provide a control on the dynamics of the solution.

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CP3

Existence Results for Superlinear Elliptic Equations with Nonlinear Boundary Value Conditions

We study the existence of solutions for the following superlinear elliptic equation with nonlinear boundary value condition

$$\begin{cases} -\Delta u + u = |u|^{r-2}u & \text{in } \Omega, \\ \frac{\partial u}{\partial \nu} = |u|^{q-2}u & \text{on } \partial\Omega, \end{cases}$$

where $\Omega \subset \mathbb{R}^N, N \geq 3$ is a bounded domain with smooth boundary. We will prove the existence results for the above equation under four different cases: (i) Both q and r are subcritical; (ii) r is critical and q is subcritical; (iii) r is subcritical and q is critical; (iv) Both q and r are critical.

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CP4

On the Cheeger Constant of An Annulus

The Cheeger constant of a domain D is defined by $h(D) = \min_{E\subset\bar{D}} \frac{|\partial E|}{|E|}$, where $|\partial E|$ and $|E|$ denote the perimeter and volume of a smooth domain $E \subset \bar{D}$. If D is the annulus between spheres $S_a \subset S_b \subset R^N$, we prove that $h(D) = \frac{|\partial D|}{|D|}$ by studing the behavior, as $p \to 1$, of the solution of the problem $-\Delta_p u_p = 1$ in D with homogeneous Dirichlet boundary data.

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CP4
Stationary Disk Assemblies on Inhibitory Vesicles

We assume that a vesicle is modeled by a two-dimensional closed smooth manifold M. In our model, minimization of the free energy reduces to a problem finding the minimizers of a functional $\mathcal{J}$.

$$\mathcal{J}(E) = |D\chi_E|(M) + \frac{\gamma}{2}\int_M |(-\Delta)^{-\frac{1}{2}}|(\chi_E - m)|^2 dx. \quad (2)$$

If a critical point E has a smooth boundary, then the Euler-Lagrange equation is

$$\mathcal{H}(\partial E) + \gamma(-\Delta)^{-1}(\chi_E - m) = \lambda. \quad (3)$$

Our main result is showing the following:

- The existence of stationary disc assemblies under a certain parameter range.
- The centers of E are determined by Green's function.

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CP4
Asymptotics for Dilute Emulsions with Surface Tension

We consider an emulsion formed by two newtonian fluids, one being dispersed in the other under the form of droplets, in the presence of surface tension. We investigate the dilute case where the droplet size a_ϵ is much smaller than the distance ϵ between the droplets' centers. We prove that the limit behavior when $\epsilon \to 0$ is described by the unperturbed Stokes flow and estimate the order of convergence rate of the velocity to be $a_\epsilon^{n/2}$. We improve the convergence result and determine the first corrector in the velocity expansion. Taylor's and Einstein's viscosity formulas are recovered.

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CP4
Slow Motion for the Nonlocal Allen-Cahn in N Dimensions

Slow motion of solutions of the nonlocal Allen–Cahn equation in a bounded domain $\Omega \subset \mathbb{R}^N$, $N > 1$, is studied. The initial data is assumed to be close to a configuration whose interface separating the states minimizes the perimeter; local and global perimeter minimizers are considered. The evolution of interfaces on a time scale ϵ^{-1} is proved, ϵ being the interaction length parameter. Solutions of the Cahn–Hilliard equation in a simpler setting are studied too.

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CP4
Conservative Parabolic Problems

We consider PDE's of drift-diffusion type in the unit interval, supplemented by either two conservation laws or by a conservation law and a further boundary condition. We treat two different cases: (i) uniform parabolic problems; (ii) degenerated problems at the boundaries. The former can be treated in a complete way. For the latter, we restrict ourselves to a class of forward Kolmogorov equations that arise naturally when the corresponding stochastic process has either one or two absorbing boundaries.

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CP4
Method of Evolving Junctions and the Shortest Path Problem.

In this talk, we will use the shortest path problem as an example to illustrate how one can connect optimization, stochastic differential equations and partial differential equations together to solve some challenging real world problems in path planning. On the other end, we will show what new and challenging mathematical problems can be raised from those applications. The talk is based on a joint work by Shui-Nee Chow, Wuchen Li, Jun Lu and Haomin Zhou.

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CP5
Modeling Semi-Arid Deserts Through (in)stabilities of Localized Structure

This talk will discuss the interaction of pulses in coupled reaction-diffusion systems, and the application of such systems in modeling the stability of vegetative patterns in semi-arid climates. For a particular family of fast-slow, weakly-damped reaction-diffusion systems, we rigorously derive laws of motion for multi-pulses. Our main result rigorously demonstrates the stability of the manifold of pulse solutions.

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CP5

Analytical and Numerical Modeling of Ground Heat Exchangers

Ground Source Heat Pumps (GSHP), when coupled with Ground Heat Exchangers (GHE), are used for heating and cooling a space. Here, GHE are modeled and analyzed according to their geometry configuration: horizontal or vertical and U-tube or spiral coil pipe. Based on on the Fouriers law of heat conduction, with emphasis on the infinite-line source and the cylindrical heat source methods, various solutions of the heat equation are presented for reliable predictions on GHE.

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CP5

Modeling Blood Flow and Mass Transport by a Drug Eluting Stent in 3D

In order to study the influence of blood flow in the drug release process we propose a fully coupled model over realistic 3D geometries. When the polymeric coating of the stent is very thin, the numerical solution of the model can be computationally expensive. Thus we replace the Initial boundary value problem associated to the release in the coating, with a Robyn type boundary condition.

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CP5

An Advection and Age-Structured Approach to Modeling Bird Migration and Indirect Transmission of Avian Influenza

We derive a system of reaction-advection equations on a closed loop to model the environmental transmission of low pathogenic avian influenza in juvenile and adult migratory birds. To analyze these partial differential equations, we are able recast them as delay differential equations, from which we obtain sufficient conditions for the local stability of the disease-free equilibrium (for a non-migratory species) and for the disease-free periodic solution (for a migratory species).

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CP5

Turing Pattern Formation in a Host-Parasitoid-Hyper Parasitoid System

We consider a spatially explicit three-species food chain model, describing generalist top predator-specialist middle predatorprey dynamics. We investigate the long-time dynamics of the model and show the existence of a finite dimensional global attractor in the product space. We perform linear stability analysis and show that the model exhibits the phenomenon of Turing instability, as well as diffusion induced chaos. Various Turing patterns such as stripe patterns, mesh patterns, spot patterns, labyrinth patterns and weaving patterns are obtained, via numerical simulations in 1d as well as in 2d. The Turing and non-Turing space, in terms of model parameters, is also explored. Finally, we use methods from nonlinear time series analysis to reconstruct a low dimensional chaotic attractor of the model, and estimate its fractal dimension. This provides a lower bound, for the fractal dimension of the attractor, of the spatially explicit model.

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CP5

A Stationary Core-Shell Assembly in a Ternary Inhibitory System

A ternary inhibitory system motivated by the triblock copolymer theory is studied as a nonlocal geometric variational problem. The free energy of the system is the sum of two terms: the total size of the interfaces separating the three constituents, and a longer ranging interaction energy that inhibits micro-domains from unlimited growth. In a particular parameter range there is an assembly of many core-shells that exists as a stationary set of the free energy functional. The cores form regions occupied by the first constituent of the ternary system, the shells form regions occupied by the second constituent, and the background is taken by the third constituent. The constructive proof

of the existence theorem reveals much information about the core-shell stationary assembly: asymptotically one can determine the sizes and locations of all the core-shells in the assembly. The proof also implies a kind of stability for the stationary assembly.

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CP6

Unified Method to Solve the Heat Equation

General solutions of the heat equation are presented in terms of the Koopman-Darmois family of exponential functions, which include both the separable solution and the fundamental solution. In particular, we derive a new closed-form solution, which may not be obtained via the separation of variables or via an integral transform. It is demonstrated that the new solution describes the time evolution of the distribution of random walkers under an absorbing boundary.

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CP6

Lattice Model of a Fracture in a Composite Infinite Strip

A discrete two-dimensional lattice with a steady propagating crack is considered. The lattice particles of two kinds are connected by massless bonds so as to form a two-layer composite infinite strip. The problem is reduced to a vector Riemann-Hilbert problem, which is solved by using the Wiener-Hopf factorization for the diagonal elements of the matrix-coefficient with subsequent reducing the problem to a system of linear equations. The solution is analysed to determine the crack stability.

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CP6

Self-focusing of Co-propagating Optical Beams

In this talk, I will discuss the invariant properties of time-independent basic two-color optical filament model and the co-existence of infinitely many ground-state solutions under different configurations, such as fundamental-fundamental, vortex-vortex as well as non-stationary dressed states. Part of my presentation will be devoted to the study of the formation of finite distance collapse event due to self-focusing, with analysis of the point of singularity.

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CP6

Linearized Problem for Viscous Free Surface Flow

We consider the linearized problem describing motion of a viscous incompressible fluid flow down an inclined plane under the effect of gravity. In this talk we will formulate the problem for downward periodic disturbances from the laminar steady flow as an evolution equation in the product of Sobolev spaces. Moreover we will state the resolvent estimate for the linear operator in some Sobolev spaces.

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CP6

Investigation and Numerical Solution of the Difference Analogue of One Nonlinear Parabolic Equation

In the present work the difference scheme for initial-boundary value problem to following nonlinear parabolic equation

$$\frac{\partial U}{\partial t} = \frac{\partial}{\partial x}\left(k\left(x,\, t,\, \frac{\partial U}{\partial x}\right)\frac{\partial U}{\partial x}\right) + f\left(x,t,U\right)$$

is considered. For the mentioned difference scheme the convergence of its solution to the solution of the source problem is proved when certain conditions hold. For the same difference scheme the comparison theorems and the existence and uniqueness of its solution is proved for the same conditions. The iteration process for finding difference scheme solution is constructed and its convergence is proved.

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CP6

Dimension Reduction, Stochastic Parametrization and Data Assimilation for Transport in the Ocean

I will present recent results on two problems related to transport in the Ocean. The first problem concerns the slowing down of pollutants as they approach the shore in certain situations, an effect we dub “Nearshore Sticky waters”. I will present an asymptotic reduction of the relevant transport PDEs that helps explain this phenomenon. The second problem concerns data assimilation using Lagrangian coherent structures in a stochas-

tic, reduced dimensional, parametrization for the Quasi-Geostrophic equation.

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CP6

Development of Shear Banding of PEC Model in Poiseuille Flow

The PEC (partially extending strand convection) model of Larson is able to describe thixotropic yield stress behavior in the limit where the relaxation time is large. We discuss the development of shear bands in a Poiseuille flow which is started up from rest with an imposed pressure gradient. We analyze the asymptotic limit of large relaxation time as e measures the ratio of retardation time to relaxation time. We determine the position and width of shear bands as a function of time. We identify an initial phase of fast yielding. Then there is a phase of delayed yielding during which the width of the transition is of order e. Eventually, the width sharpens. We also show how these results are modified by introducing Korteweg stresses which prevent the transition from becoming infinitely sharp.

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CP7

Optimal Design of Energy Conversion Devices

We study the optimal design of materials and devices used for energy conversion. Such materials and devices have to enable transport of multiple species and chemical reactions at selected interfaces. We develop a forward model for the transport and reactions. We then develop the problem of optimal design, and show that this is ill-posed. We present a relaxed formulation as well as a regularized formulation using a phase-field approach and numerical results in two dimensions.

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CP7

On the Existence of Maximizers for Airy-Strichartz Inequalities

Recently, in a joint work with Ademir Pastor, we give a simple proof of the classical Kenig, Ponce and Vega well-posedness result for the generalized KdV equation

$$\partial_t u + \partial_x^3 u + \partial_x(u^{k+1}) = 0.$$

The key ingredient in the proof is the following Airy-Strichartz estimate

$$\|U(t)u_0\|_{L_x^{5k/4}L_t^{5k/2}} \leq C_k \|u_0\|_{\dot{H}_x^{s_k}},$$

where $k > 4$, $s_k = (k-4)/2k$ and $U(t)$ denotes the linear propagator for the KdV equation. Our goal here is to prove the existence of maximizers for the above inequality. The main tool we use is a linear profile decomposition for the Airy equation with initial data in $\dot{H}_x^{s_k}(\mathbb{R})$. This is a joint work with Henrique Versieux (UFRJ). The author was partially supported by CNPq (Brazil) and FAPEMIG (Brazil).

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CP7

Stability and Bifurcation of a Flexible Loop Spanned by a Fluid Film

We will consider the variational problem of finding energetically preferred equilibrium configurations of a system consisting of a closed, locally inextensible loop endowed with elastic resistance to bending that is spanned by a fluid film with constant surface tension. Aside from results of detailed bifurcation and stability analyses, we will discuss various physically relevant generalizations of the problem. Finally, we will establish a connection with the modeling of discoidal high-density lipoprotein particles.

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CP7

Positive Solution for a Class of Coupled (p, q)-Laplacian Nonlinear Systems

In this article, we prove the existence of a nontrivial positive solution for the elliptic system

$$\begin{cases} -\Delta_p u &= \omega(x) f(v) \quad \text{in } \Omega, \\ -\Delta_q v &= \rho(x) g(u) \quad \text{in } \Omega, \\ (u, v) &= (0, 0) \quad \text{on } \partial\Omega, \end{cases}$$

where Δ_p denotes the p-Laplacian operator, $p, q > 1$, Ω is a smooth bounded domain in R^N $(N \geq 2)$, ω and ρ are continuous functions, nonnegative and not identically null in Ω, and the nonlinearities f and g are continuous and satisfy simple hypotheses of local behavior, without involving monotonicity hypotheses or conditions at ∞. We apply Fixed Point Theorem in a Cone to obtain our result. Acknowledgments: We thank UFOP, CNPq and FAPEMIG for partial support.

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CP7

Uniqueness of Viscosity Solutions for a Class of Integro-Differential Equations

We prove comparison theorems and uniqueness of viscosity solutions for a class of nonlocal equations. This class of equations includes Bellman-Isaacs equations containing operators of Lévy type with measures depending on x and control parameters, as well as elliptic nonlocal equations that are not strictly monotone in the u variable. The proofs use the knowledge about regularity of viscosity solutions of such equations.

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CP7

The Fourth-Order Dispersive Nonlinear Schrödinger Equation: Orbital Stability of a Standing Wave

Considered in this talk is the one-dimensional fourth-order dispersive cubic nonlinear Schrödinger equation with mixed dispersion. Orbital stability, in the energy space, of a particular standing-wave solution is proved in the context of Hamiltonian systems. The main result is established by constructing a suitable Lyapunov function.

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CP8

Nonuniqueness of Solutions to the Euler-Smoluchowski System for Compressible Fluids

Well-posedness of weak solutions to the Euler-Smoluchowski system for the interaction of particles and an inviscid, compressible fluid is considered. Using the method of convex integration of De Lellis and Székelyhidi, the existence of infinitely many global-in-time weak solutions for any choice of regular initial data is shown. This result is then investigated in the case of weakly-dissipative admissible solutions obeying an energy inequality and a relative entropy inequality.

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CP8

Central-Upwind Scheme for Shallow Water Equations with Discontinuous Bottom Topography

In this talk, I will present a well-balanced positivity preserving finite-volume method for the Saint-Venant system of shallow water equations with discontinuous bottom topography. A well-balanced property ensures that artificial waves from numerical errors do not exceed the exact solution. While the positivity preserving property serves to avoid non-physical negative values for water depths, an additional level of complexity arises when the bottom topography is discontinuous which will be discussed in detail.

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CP8

Nonlinear Wave-Diffraction in Real Fuids

In this paper, we have examined weakly nonlinear waves with dissipation governed by the (2+1)-dimensional Navier-Stokes equations for a real gas; the evolution equation, which contains both quadratic and cubic nonlinearities, has been derived by using method of multiple scales. By using the theory of nonclassical symmetry reductions, traveling wave solutions for this equation, are obtained. Lastly, the way in which the real gas effects influence the asymptotic wave pattern are elucidated.

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CP8

Exact Two-Point Water Saturation Cdf for Stochastic Two-Phase Immiscible Flows

We show how we can analytically derive the two-point (or even multi-point) cumulative distribution function (CDF) of the water saturation for the stochastic Buckley-Leverett problem. The two-point CDF is determined by deriving and combining PDEs of what is known as the raw CDF for each point. The two-point CDF notably yields the covariance function, which is an essential component of data assimilation in reservoir management. Comparisons with MC simulations are showcased.

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CP8

Homogenization of Linear Hyperbolic Stochastic Partial Differential Equation with Rapidly Oscillating Coefficients: The Two Scale Convergence Method

In this paper we establish new homogenization results for stochastic linear hyperbolic equations with periodically oscillating coefficients. We First use the multiple-scale method to drive the homogenized problem. Next we use the two-scale convergence method and Prokhorov's and Skorokhod's probabilistic compactness results. We prove that the sequence of solutions of the original problem converges in suitable topologies to the solution of a homogenized stochastic hyperbolic problem with constant coefficients. We also prove a corrector result.

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CP8

Approximate Controllability of Fractional Parabolic Integrodifferential Equations

The objective of this paper is to present some sufficient conditions for approximate controllability of semilinear parabolic integrodifferential delay control systems of fractional order $\alpha \in (1, 2]$. The results are obtained by the theory of strongly continuous α-order cosine family and well known Schauder fixed point theorem under the natural assumption that the linear system is approximate controllable.

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CP9

Symmetry Properties and A Priori Decay Estimate for Traveling Wave Solutions to the Whitham Equation

We prove that non-periodic traveling wave solutions to the Whitham Equation are symmetric solutions. In addition, A Priori decay estimate for the traveling wave solutions is given.

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CP9

Nonclassical Shocks in Hall-Mhd Flow

We focus on the study of nonclassical shocks in Magnetohydrodynamics (MHD). Perturbation expansions with multiple scales are used to study the behavior of the flow governed by MHD equations with Hall effect and viscosity, supplemented by an equation of state. The transport equation with cubic flux function includes both dissipation and dispersion terms, which gives nonclassical shock as discontinuous solution. The influence of the magnetic field upon formation and propagation of nonclassical shock is investigated.

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CP9

Optimal Dirichlet Type Boundary Condition Control for the 1D Wave Equation: Finite Horizon, Infinite Horizon

We consider a vibrating string with Dirichlet control action at the booth ends. We investigate the optimal control problem of steering this system from given initial data to rest, in time T, by minimizing an objective functional that is the convex sum of the L_2-norm of the control with weight coefficient λ. We provide an explicit solution of this optimal control problem and showing that if the weight of the tracking term is positive, then the optimal control action is concentrated at the beginning and at the end of the time interval, and in-between it decays exponentially. The mathematical formulation of the problem

$$u_{tt}(x,t) - u_{xx}(x,t) = 0,$$

in rectangle $Q_T = [0 \le x \le l] \times [0 \le t \le T]$. Will be found the explicit form of boundary control

$$u(0,t) = \mu(t), \quad u(l,t) = \nu(t)$$

which transfers the system from a given initial state

$$u(x,0) = \phi_1(x), \quad u_t(x,0) = \psi_1(x)$$

to a given final state

$$u(x,T) = \phi_2(x), \quad u_t(x,T) = \psi_2(x)$$

for a predetermined period of time T. Boundary control provide minimum the following energy functional

$$\int_0^T (1-\lambda)\|\mu'(t)\|^2 + \lambda\|\nu'(t)\|^2 dt$$

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CP9

Steady State and Dynamical Radially-Symmetric Solutions of 2D Nonlinear Viscoelasticity

We treat the initial-boundary-value problems for the radial motions of nonlinearly viscoelastic annular plates and spherical shells of strain-rate type, which are described by the geometrically exact 2D theory. The governing equation is a second-order quasilinear parabolic-hyperbolic PDE in one space variable. In the first part of our work, we study the steady-state solutions of our problem by employing several mathematical tools, each of which has different strengths and weaknesses for handling intrinsic diffculties in the mechanics. In the second part, we study the dynamical solutions of our problem. We first introduce a set of constitutive hypotheses which ensure that solutions are unique, exist for all time, and depend continuously on the data. We then exhibit alternative conditions on the constitutive functions and on the boundary terms ensuring that there are globally defined unbounded solutions and there are solutions that blow up in finite time.

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CP9

Traveling Water Waves with Point Vortices

The study of steady water-wave solutions to the incompressible Euler equations has a long history, but only recently has much attention been paid to rotational waves. Such waves can exhibit stagnation points and closed streamlines. We establish the existence of small-amplitude solitary gravity-capillary waves with point vortices on finite depth. As opposed to infinite depth, the properties of these waves depend significantly on the position of the vortex in the fluid domain.

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CP9

Asymmetric Shape Transitions in Epitaxial Quantum Dots from Pyramid to Multifaceted Dome

We construct a two-dimensional continuum model to describe the energetics of shape transitions in fully-faceted epitaxial islands. The energetics of the shape transitions are determined by numerically calculating the facet lengths that minimize the energy of a given island type for prescribed island volume. By comparing the energy of different island types and analyzing the energy, we determine the bifurcation diagram of equilibrium solutions and their stability, as well as the lowest-barrier transition pathway.

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CP10

On Ellipticity of Balance Equations for Atmosphere Dynamics

An adjustment of the initial data for the atmospheric models usually leads to a system of nonlinear diagnostic PDEs representing balance relations. In this study, we derive and analyze the ellipticity conditions for the differential systems of nonlinear adjustment. Based on these results, we show distribution of non-elliptic regions in the gridded data of the actual atmospheric fields for different forms of the balance equations.

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CP10

On the Nonlinear Elliptic Equation Connected with the Solitary Waves

The nonlinear elliptic partial differential equation connected with the cubic nonlinear Schrodinger type equation is considered in the infinite area. The effective solutions of this equation vanishing at infinity exponentially are obtained. Several examples are given. The profiles of symmetric solitary waves connected with this solutions are constructed by using Maple.

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CP10

Almost Automorphic Mild Solutions for Abstract Differential Equations with Iterated Deviating Arguments

In this paper, we are concern with the existence and uniqueness of almost automorphic mild solutions of the functional differential equations with iterated deviating arguments in a Banach space. The existence and uniqueness results for the almost automorphic mild solutions of the functional differential equation are obtained by using Banach fixed point theorem and some basic tools of semigroup theory.

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CP10

Uniform Refraction in Negative Refractive Index Materials

We study the problem of constructing an optical surface separating two homogeneous, isotropic media, one of which has a negative refractive index. In doing so, we develop a vector form of Snells law, which is used to study surfaces possessing a certain uniform refraction property. In the near field problem, unlike the case when both materials have positive refractive index, we show that the resulting surfaces can be neither convex nor concave.

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CP11

Approximation of Solutions to Stochastic Fractional Integro-Differential Equation with Deviated Argument

In this paper we study a stochastic fractional integro-differential equation with deviated argument in a separable Hilbert space. we used the semigroup theory of linear operators to study the existence, uniqueness and convergence of approximate solutions to the given equation with the help of stochastic version of the well-known Banach fixed point theorem. Moreover, the convergence of Faedo-Galerkin approximation of solution is shown. In the last, we give an example to illustrate the applications of the abstract results.

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CP11

The Dynamic Multi-Newsvendor Problem

We articulate a dynamic model of newsvendors where a set of service providers form an oligopoly that is equilibrium tending. The vendors are price setters whose price setting strategies include time lagged impacts on demand. The price setting mechanism involving the providers resembles the replicator dynamics of evolutionary game theory. We show that generalization of the news vendor problem to a Cournot-Nash differential game based on replicator dynamics in a stochastic setting takes the form of a stochastic differential variational inequality. Existence results are provided and an abstract numerical example is solved via sequential linearization of its statement as a complementarity problem, using the GAMS/PATH solver.

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CP11

Approximate Controllability of Semi Linear Control System with Delay Using Tikhonov Regularization

The problem of computing control of an approximate controllable semi linear system with delay for a given target state is ill posed. We use Tikhonov regularization to find regularized control. It is proved that the target state corresponding to the regularized control is close to the actual state to be attained under the assumption that the non linear function f is Lipschitz continuous. Theory is illustrated with an example.

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CP11

Liouville SLE Boundaries on CFT Torus Defined with Scholastic Schrödinger Equation

The Liouville Schramm-Loewner Evolution (SLE) was developed from the Polykov action for 2D gravitational backgrounds. Random surfaces are zipped together on the boundaries of conformal field theories (CFT) 2D string theory and are defined as polygons. The stochastic partial differential equation, crucial to SLE conformal maps, will be defined as a Schrödinger equation for triangular quantum wells. Ritz-Galerkin isogeometrics and transformation optics will be modified to define SLE boundary elements on a toroidal surface.

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CP11

Optimal Multi-Level Monte-Carlo Method for a System of Stochastic PDEs

We consider the drift-diffusion-Poisson equations with random coefficients as the main stochastic model equations for field-effect nanowire sensors and transistors in general. The randomness is due to impurity atoms or molecular motion, binding, and unbinding. We present existence and local uniqueness theorems for the weak solution of the system. We also analyze the rate of convergence and computational complexity of the multi-level Monte-Carlo finite-element method (MLMC-FEM) for this system of stochastic PDEs as well as error bounds and the computational cost. Numerical results show the efficiency of MLMC-FEM in comparison with Monte-Carlo FEM in accuracy and computational cost.

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CP11

Analytical Results for Stress and Particle Velocity on Impact Problems in Elastic Layered Media

An exact discrete model based on the method of characteristics, previously developed to study stress wave propagation in Goupillaud-type layered media subjected to Heaviside or discrete harmonic loading, is adopted to model one dimensional impact problems in elastic layered media. We are able to ?nd formulas for the steady state values of stress and particle velocity and reach interesting conclusions about the properties of the layered target.

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MS1

Geometric Graph Based Algorithms

This talk reviews recent work at UCLA using ideas from phase field models and mean curvature motion in Euclidean space to solve abstract data classification problems on graphs. We consider both semi-supervised and unsupervised learning problems in which the minimum cut problem on a graph serves as a regularizer for a variational problem. Examples include nonlocal means image processing, modularity optimization on social networks, and an extension of the piecewise constant Mumford-Shah functional to the graphical setting.

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MS1

A Chromaticity-Brightness Model for Color Images Denoising

A variational model for imaging denoising aimed at restoring color images is proposed. The model combines Meyer's u+v decomposition with a chromaticity-brightness framework and is expressed in terms of a minimization of energy functionals depending on a small parameter. The asymptotic behavior as this parameter converges to zero is characterized, and convergence of infima, almost minimizers, and energies are established. In particular, an integral representation of the lower semicontinuous envelope of functionals with linear growth and defined for maps taking values on a certain manifold is provided. This study falls outside the realm of existing literature because the underlying manifold has boundary and the underlying integrand and its recession function do not satisfy hypotheses commonly assumed apriori in the literature. The main tools used are Gamma-convergence and relaxation techniques.

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MS1

Reverse Engineering a Pde from An Image Inpainting Algorithm

Many image inpainting algorithms are designed by modelling the image as a continuum, where the restored image is expressed in terms of a PDE, which must be discretized. In this talk I will go in the opposite direction, starting from an inpainting method designed in industry without PDEs in mind, and show how it can be understood in terms of PDEs. I will show how this understanding can be utilized to design an improved algorithm.

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MS1

Variational Approach to Image Segmentation and Inpainting

This talk deals with some second order free discontinuity problems related to image segmentation and inpainting. It is focused on the mathematical analysis of Blake & Zisserman functional under various kind of boundary conditions: existence of strong solution; extremality conditions on optimal segmentation; well-posedness of the problem; energy density estimates; candidate non trivial local minimizers; power series expansion and Almansi decomposition around a crack-tip; variational approximation schemes.

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MS2

Existence and Geometry of Minimisers for the Interaction Energy

We show the existence of compactly supported global minimisers under almost optimal hypotheses for continuum models of particles interacting through a potential. The main assumption on the potential is that it is catastrophic—the complementary assumption to that in classical results on thermodynamic limits in statistical mechanics. If moreover the potential is smooth at the origin, we prove that minimisers have discrete and finite support. Joint works with J.A. Cañizo, J.A. Carrillo and A. Figalli.

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MS2

A New Method for Finding Approximate Global Minimizers to Pairwise Interaction Problems

We present a new analytic based approach for finding approximate global minimizers to pairwise interaction problems. The approach relies on a convex relaxation of the primal pairwise interaction problem that allows for a straightforward solution using standard optimization techniques. Moreover, we show how one can use the solution to the relaxed problem to generate approximate minimizers with recovery guarantees. The advantage of the approach is that it may predict non-standard patterns, and in some cases may be exact. Finally, we demonstrate the connection between the approach at hand and other modern optimization techniques that arise in discrete optimization problems.

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MS2

Nonlocal Functionals and Dimensionality Reduction

The average distance problem asks to find a good way to approximate a high-dimensional object, represented as a measure, by a one-dimensional object. We will discuss two variants of the problem: one where the one-dimensional object is a measure with connected one-dimensional support and one where it is an embedded curve. We will discuss examples that show that even if the data measure is smooth the nonlocality of the functional can cause the minimizer to have corners. Nevertheless the curvature of the minimizer can be considered as a measure. We will discuss a priori estimates on the total curvature and ways to obtain information on topological complexity of the minimizers.

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MS2

Attractive-Repulsive Interaction of Sets and Height Constrained Densities

We consider existence (and non-existence) of minimizers for a class of nonlocal attractive-repulsive interaction energies defined over measurable sets of fixed volume. We address different regimes of the volume parameter and show how this parameter effects the existence via a relaxed problem. We also make comparison with the minimization of a high-order isoperimetric problem with nonlocal interactions of Coulombic type. This is joint work with A. Burchard (Toronto) and R. Choksi (McGill).

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MS3

A Nash-Kuiper Theorem for $C^{1,1/5-\varepsilon}$ Embeddings of Surfaces in 3 Dimensions

Let g be a smooth metric on the unit 2-dimensional disk. For any $\varepsilon > 0$ we show that the h-principle holds for $C^{1,1/5-\varepsilon}$ isometric embeddings in the three-dimensional space. For instance it is possible to embed the disk in an arbitrarily small ball with that regularity. These sort of statements were proved in a pioneering work of Nash, later improved by Kuiper. So far the best regularity known was $1/7 - \varepsilon$. As shown by the recent works of De Lellis, Székelyhidi, Isett and Buckmaster, this type of theorems bear some relations with the Onsager's conjecture.

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MS3

Convex Integration for Active Scalar Equations

I will discuss joint work with V. Vicol on convex integration and h-principles for general active scalar equations. Our results include nonuniqueness of solutions under a certain nondegeneracy condition on the multiplier. It turns out that this nondegeneracy is both necessary and sufficient for the appropriate h-principle to hold.

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MS3

Convex Integration for the Monge-Ampere Equation

A C^2 solution u to the Monge-Ampère equation in two dimensions, with a positive Hessian determinant f is necessarily convex. Similarly if $f = 0$, the graph of u is necessarily developable. In these examples, convexity and developability are the two global characteristics of the given solution displaying its rigidity. The purpose of this talk is to explore rigidity and flexibility of the weak type solutions to the Monge-Ampère equation by replacing the Hessian determinant with its other weaker variants. Following convex integration method a la Nash and Kuiper, we show that fixing the weak Hessian determinant as a regular enough distribution, the C^1 solutions are dense in the space of all continuous functions, and hence they do not admit the same rigidity as the stronger solutions. We will also discuss the connections with isometric immersion problem.

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MS3

Convex Integration and Infinitely Many Weak Solutions to the Perona-Malik Equation in All Dimensions

We prove that the initial-Neumann boundary value problem for the Perona-Malik equation in image processing possesses infinitely many Lipschitz weak solutions on a smooth convex domain in all dimensions for all smooth initial data.

These weak solutions exhibit the certain microstructure in much agreement with the numerical simulations, which had only been ascertained in terms of the Young measure solutions. Our approach for the exact weak solutions is motivated by reformulating the Perona-Malik equation as a nonhomogeneous partial differential inclusion with linear constraint. We then establish a general existence result by a suitable Baire's category argument using a pivotal density hypothesis. Finally we establish this density hypothesis by the convex integration method based on certain approximations from an explicit formula of lamination convex hull of some matrix set involved.

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MS4

The Regularized 3D Boussinesq Equations with Fractional Laplacian and No Diffusion

We study the 3D regularized Boussinesq equations. The velocity equation is regularized through a smoothing kernel of order α in the nonlinear term and with a β fractional Laplacian; we are in the critical case $\alpha + \beta = 5/4$. The temperature equation is a pure transport equation. We prove regularity results when the initial velocity is in the Sobolev space H^r and the initial temperature is in $H^{r-\beta}$ for $r > max 5/2 - 2\alpha, \beta + 1$ with $\beta \geq 1/2$ and $\alpha \geq 0$. This regularity is enough to prove uniqueness of solutions. We also prove a continuous dependence of solutions with respect to the initial conditions.

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MS4

Analyticity Properties of the Navier-Stokes and Euler Equations

We address the persistence of regularity of the Boussinesq system in 2D with zero diffusivity in Sobolev spaces $W^{s,p}$. In the case of the whole space, we prove that the persistence holds with data such that $sp > 2$, while in the case of the torus, there is no restriction on s and p. The results are joint with W. Hu, F. Wang, and M. Ziane

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MS4

A Data Assimilation Algorithm for the Hyperdissipative Sqg Equation

In this article, an algorithm for continuous data assimilation based on feedback control for dissipative dynamical systems is applied to the subcritical surface quasi-geostrophic (SQG) equation. While, in principle, this algorithm should allow the use of any type of measurement data, e.g., modal, nodal, or volume elements, for which an interpolation operator exists, structural obstructions in the SQG equation seem to prevent one from implementing the algorithm with general interpolants. However, by restricting to the case of modal observables, it is shown that the corresponding interpolant, i.e., Galerkin projection, can be suitably modified to deal with this apparent obstruction. It is also shown that this algorithm can be generalized to the more realistic situation of time-averaged measurements. In particular, for sufficiently regular initial data, the solution of the associated feedback control system achieves exact asymptotic synchronization with the reference solution, provided that the window of time-averaging is sufficiently small and the spatial resolution is sufficiently high

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MS4

Backward in Time Behavior of Nonlinear Dissipative Equations The Effect of Energy Spectra

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

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MS5

Long Time Solutions for Two Dimensional Water Waves

This is joint work with Daniel Tataru, and in parts with John Hunter. My talk is concerned with the infinite depth water wave equation in two space dimensions, with either gravity or surface tension. Both cases will be discussed in parallel. We consider this problem expressed in position-velocity potential holomorphic coordinates. Viewing this problem as a quasilinear dispersive equation, we develop new methods which will be used to prove enhanced lifespan of solutions and also global solutions for small and localized data. For the gravity water waves there are several results available; they have been recently obtained by Wu, Alazard-Burq-Zuily and Ionescu-Pusateri using different coordinates and methods. In the capillary water waves case, we were the first to establish a global result (two months later, Ionescu-Pusateri also announced a related result). Our goal is improve the understanding of these problems by providing a single setting for both cases, and presenting simpler proofs. The talk will try to be self contained.

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MS5

Stabilization of a Boussinesq System for Surface Water Waves

A family of Boussinesq systems was proposed by J. L. Bona, M. Chen and J.-C. Saut to describe the two-way propagation of small amplitude gravity waves on the surface of water in a canal. Our work considers a class of these Boussinesq systems which couples two Benjamin-Bona-Mahony type equations posed on a bounded interval. We study the stabilization of the resulting system when a localized damping term acts in one equation only. By means of spectral analysis and eigenvectors expansion of solutions, we prove that the energy associated to the model converges to zero as time goes to infinity. Also, we address the problem of unique continuation property for the corresponding conservative system.

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MS5

An Energy-Conserving One-Dimensional Model of 3D Euler

I will present some properties of an equation derived by M. Wunsch, a variant of the Constantin-Lax-Majda equation and related to a recent model studied by Choi-Hou-Kiselev-Luo-Sverak-Yao. Wunsch's equation is given by

$$m_t + um_x + 2mu_x = 0, m = Hu_x$$

for $x \in S^1$. This is the Euler-Arnold equation for the $\dot{H}^{1/2}$ Riemannian metric on the homogeneous space $(S^1)/S^1$, and conserves the energy. Like the 3D Euler equation, its Lagrangian solution operator is a smooth exponential map on the Sobolev diffeomorphism group for which the differential is not Fredholm (and these are the only known Euler-Arnold PDEs for which this is true). The 1/2 metric is critical for the Fredholmness property and several other geometric properties. We show that all solutions blow up in finite time. The geometry is related to Teichmüller theory as well as string theory and is a well-known example of an infinite-dimensional Kähler manifold. This is joint work with Martin Bauer, Boris Kolev, and Pearce Washabaugh.

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MS5

On Nonlocal Differential Operators and Applications

We prove strong gradient decay estimates for solutions to the multi-dimensional Fisher-KPP equation with fractional diffusion. It is known that this equation exhibits exponentially advancing level sets with strong qualitative upper and lower bounds on the solution. However, little has been shown concerning the gradient of the solution. We prove that, under mild conditions on the initial data, the first and second derivatives of the solution obey a comparative exponential decay in time. We then use this estimate to prove a symmetrization result, which shows that the reaction front flattens and quantifiably circularizes, losing its initial structure.

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MS6

Canonical Transformations on Null Forms

We construct third order Birkhoff normal forms transformations for the class of wave equations on R^n for $n \geq 3$ which are both Hamiltonian PDEs and null forms. We identify the null condition as the vanishing of the three-wave interaction coefficients on the cubic order resonant variety. The main point of the construction is that the normal forms transformation is a continuous mapping of an appropriate Sobolev space which removes the quadratic nonlinear terms of the equation, and this in turn gives a new proof via canonical transformations of the global in time existence theorems of S. Klainerman and J. Shatah for null form wave equations with small data.

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MS6

Wave Maps on Hyperbolic Space

We begin with a survey of some recent results on energy critical wave maps from Minkowski space emphasizing the effect of the geometry of the target manifold on dynamics and the special role played by finite energy harmonic maps. Then we consider equivariant wave maps from the hyperbolic plane into rotationally symmetric targets and discuss new phenomena that arise in this model problem due to the hyperbolic geometry of the domain. This is joint work with Sung-Jin Oh and Sohrab Shahshahani.

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MS6

Recent Progress on the Wave Maps Equation on Hyperbolic Spaces

Abstract not available at time of publication.

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MS6

Effective Dynamics of Charged Interfaces

It has been shown that travelling interfaces that sweep out a Minkowskian minimal surface in space-time arise as solutions to the non-linear wave equation

$$\partial_{tt}u - \Delta u + (u^2 - 1)u = 0 \quad (4)$$

In this talk we show that radially symmetric travelling interfaces with a current confined to the interface arise as solutions to a system of PDEs obtained by coupling (4) to another non-linear wave equation. We will also show that the mean curvature of an interface with a current is proportional to the current strength.

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MS7

Defect Solutions in Vector-Valued Singular Problems

We prove the existence of defect solutions in a wide class of functionals of Ginzburg-Landau type under minimal, physically meaningful assumptions. A blow-up analysis leads to the study of topologically nontrivial minilmizers in entire space with good mapping properties for an associated linear problem. In bounded domains, a variational reduction yields existence of solutions with singularities that approach harmonic maps with defects in the London limit. This is joint work with Xavier Lamy.

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MS7

Some Geometric Ginzburg-Landau Problems

We characterize asymptotic behaviour of a variety of geometric problems of Ginzburg-Landau type, involving (i) the intrinsic covariant energy of tangent vector fields on an abstract 2-dimensional Riemannian manifold; (ii) the extrinsic energy of tangent vector fields on a 2-d manifold isometrically embedded in R^3, and (iii) the energy of (not necessarily tangent) vector fields on a 2-d manifold isolmetrically embedded in R^3, with the normal component penalized. This is joint work with Radu Ignat.

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MS7

Analysis of Minimizers of the Lawrence-Doniach Model for Layered Superconductors in Magnetic Fields

We analyze minimizers of the Lawrence-Doniach energy for layered superconductors occupying a bounded generalized cylinder in the three-dimensional space. For a magnetic field perpendicular to the layers in the intermediate regime, we prove an asymptotic formula for the minimum Lawrence-Doniach energy as the reciprocal of the Ginzburg-Landau parameter and the interlayer distance tend to zero. Our formula also describes the minimum three-dimensional anisotropic Ginzburg-Landau energy as the reciprocal of the Ginzburg-Landau parameter tends to zero.

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MS7

Vortex Scattering and the Gross-Pitaevskii Equation

We look at the Gross-Pitaevskii equation with a spatially varying potential, close to unity. For a unique asymptotic regime it is shown that vortex motion will be affect by both vortex-vortex interaction and the interaction with the perturbation of the background potential. This, in turn, leads to a scattering problem for dipoles.

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MS8

On Well Productivity Index for Compressible Fluid, and Applications

In this paper we discuss the notion of the diffusive capacity for the generalized Forchheimer flow of fluid through porous media. The diffusive capacity is an integral characteristic of the flow motivated by the engineering notion of the productivity index (PI). The PI characterizes the well capacity with respect to drainage area of the well and in general is time dependent. We study its time dynamics for two types of fluids: slightly compressible and strongly compressible fluid (ideal gas).In case of the slightly compressible fluid the PI stabilizes in time to the specific value, determined by the so-called pseudo steady state solution, Here we generalize our results from on long term dynamics of the PI in case of arbitrary order of the non-linearity of the flow. In case of the ideal gas the PI stays almost constant for a long period of time, but then it suddenly blows up as time approaches certain critical value. This value depends on the initial data (initial reserves) of the reservoir. The "greater' are the initial reserves, the larger is this critical value. We present numerical and analytical results for the time asymptotic of the PI and its stability with respect to the initial data.For ideal gas flow in case of Darcy equation we present analytical results on comparison of the general transient solution with the auxiliary one, that corresponds to the time independent PI.

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MS8

Homogenization of a Transmission Problem

We study the homogenization of a transmission problem for bounded scatterers with periodic coefficients modeled by the anisotropic Helmholtz equation. The coefficients are assumed to be periodic functions of the fast variable, specified over the unit cell with characteristic size ϵ. By way of multiple scales expansion, we focus on the $O(\epsilon^k)$, $k = 1, 2$ bulk and boundary corrections of the leading-order ($O(1)$) homogenized transmission problem. The analysis in particular provides the H^1 and L^2 estimates of the error committed by the first-order-corrected solution considering i) bulk correction only, and ii) boundary and bulk correction. We treat explicitly the $O(\epsilon)$ boundary correction for the transmission problem when the scatterer is a unit square. We also establish the $O(\epsilon^2)$-bulk correction describing the mean wave motion inside the scatterer. The analysis also highlights a previously established, yet scarcely recognized fact that the $O(\epsilon)$ bulk correction of the mean motion vanishes identically.

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MS8

Equations for Poroelastic Materials

Permeability and tortuosity play an important role in quantifying transport phenomena and wave dissipation in porous media. In this talk, recent results on the mathematical properties of dynamic permeability/tortuosity will be presented. Not only these results suggest a rigorous way for reconstructing from finite data set the kernel function of the memory term in the time-domain poroelastic wave equations but also provide an efficient way to handle it numerically.

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MS8

On Mathematical Modeling of Charged Laminate Materials

Laminate materials are common in both biological and industrial applications. Of particular interest are charged laminates, a class of materials that is composed of charged solid layers and an interstitial fluid, such as clays and cartilage. Inherent in models of these materials is a characteristic length between the layers that is prescribed a priori. In this work, we solve for this characteristic length by requiring the dominant physical effects of electrostatics, gravity, hydrostatics and capillarity on an array of rigid charged plates separated by an viscous incompressible fluid to be at static equilibrium at an prescribed applied compressive load. The result is a nonlinear integral equation for the spacing distribution between the plates. The resulting spacing function is then used to obtain a stress strain relation for the material. The stress-strain results compare well to experimental results of clays and cartilage. The effects of different stress or strain boundary conditions on the material and dissipation rates for the loading are also discussed.

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MS9

Dynamics of Fermions Near Thermal Equilibrium Interacting with Power Nonlinearities

We prove local and global well-posedness for the effective equations describing a gas of fermions near thermal equilibrium, which interact via delta pair interactions; those equations correspond to the NLS system in 3D. The key difficulty in the analysis of this problem stems from the fact that the comparison solution, describing the Fermi sea at positive temperature, is not of trace class. We are herewith extending important recent work of Lewin and Sabin, which solves the corresponding problem for pair interactions that are much more regular. This is based on joint work with Younghun Hong and Natasa Pavlovic.

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MS9

Global Behavior and Non-squeezing for the NLKG

Abstract not available at time of publication.

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MS9

Many Body Dynamics, Nonlinear Dispersive PDE and Quantum De Finetti Theorems

In this talk we will discuss applications of the quantum de Finetti theorem (which is a quantum analogue of the Hewitt-Savage theorem in probability theory) in the context of nonlinear dispersive PDE. We will focus on certain connections (recently established via quantum de Finetti theorem) between nonlinear Schrodinger equation (NLS) and an infinite hierarchy of linear coupled PDE, called Gross-Pitaevskii hierarchy, that arises in a derivation of NLS from quantum many body systems. In particular, we will discuss a proof of existence of scattering states for a defocusing Gross-Pitaevskii hierarchy.

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MS9

Random Versus Probabilistic Approach in the Study of Wave and Dispersive Equations

Some recent results on almost sure well-posedness.

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MS10

Determining Modes for 3D Navier-Stokes

Abstract not available at time of publication.

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MS10

Global Attractors for Discrete Dynamical Systems Which Approximate the Two-Dimensional Navier Stokes Equations and the Model Error in the Ns-Alpha Model.

We ask the question whether the model error in the LANS-alpha and NS-alpha deconvolution models of turbulence can be represented by a stochastic force. We compute the time evolution of the residual error obtained by plugging a solution on the global attractor of the discrete dynamics of a direct numerical simulation of the 2D Navier-Stokes equations into the corresponding discretized alpha-model. After taking an ensemble everage over independent trajectories on the attractor we conclude for small alpha that the model error behaves as a stochastic force while for larger values of alpha there is systematic bias and the error in the residual grows linearly in time.

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MS10

Ergodicity Results for Stochastic Boussinesq Equations

We will review some recent results on invariant measures for stochastic Boussinesq equations (equations for Rayleigh-Bénard convection perturbed by noise). First we will discuss ergodicity results in the two-dimensional periodic domain with a spatially degenerate forcing. These results generalize recent progress of Hairer and Mattingly on hypoellipticity for semilinear stochastic PDEs. Then, with a less degenerate forcing but more appropriate boundary conditions, we present a simplified proof of ergodicity, and discuss some singular parameter limits.

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MS10

Statistical Solutions and the Asymptotic Behaviour of Evolutionary Systems

Abstract not available at time of publication.

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MS11

A Multi-Level Compressed Sensing Petrov-Galerkin Method for the Approximation of Parametric PDEs

In this talk we review the use of compressed sensing and its weigthed version in the context of high-dimensional parametric and stochastic PDEs. We see that under some rather weak summability and ellipticity assumptions, the Chebysheff polynomial chaos expansion of the solution map shows some weighted compressibility property and derive a compressed sensing framework for its approximation. We further extend our approach with a multi-level scheme solution map shows some compressibility property. We further derive a multi-level scheme to speed up the calculations, leading to a method that has a computational cost in the order of a single PDE solve at the finest level and yet still provide reliable recovery guarantees. This is based on joint work with Benjamin Bykowski, Holger Rauhut, and Christoph Schwab.

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MS11

High-Dimensional Approximation Using Equilibrium Measures

We consider the problem of describing the behavior of partial differential equations whose solutions depend on a large number of parameters. Standard approaches typically involve collecting PDE solutions computed at a judiciously-chosen finite set of parametric samples, and using these to predict the solution manifold behavior for all parameter values. Thus, the choice of parametric samples is paramount. In this talk we consider choosing parameter samples according to the pluripotential equilibrium measure. The properties of this measure enable quasi-optimal statements of mathematical recoverability in both over- or undersampled regression problems. We also show that such an appoach typically yields very stable, high-order computational procedures for parametrized PDE approximation.

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MS11

Multi-Level Monte Carlo with Control Variate for Elliptic Pdes with Log-Normal Coefficients.

Abstract not available at time of publication.

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MS11

Compressed Sensing Approaches for Polynomial Approximation of Hilbert-Valued Functions on Lower Sets

We study a compressed sensing approach for polynomial approximations of the solutions of parametric PDEs. Two issues arising in this setting will be addressed. First, by exploiting the fact that the sets of best s-terms of parametric PDE solutions in many cases are almost downward closed, we establish new recovery property under a reduced number of random samples, which is independent on dimension. Second, a direct application of compressed sensing algorithms to parametric PDEs only returns the solutions at a single point in physical space. We consider uncoupled and coupled methods for Hilbert-valued signal recovery to simultaneously approximating the solution in the entire physical domain. Numerical tests will be provided for supporting the theory.

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MS12

Folding Patterns in Partially Delaminated Thin Films

Elastic films deposited on a substrate are often subject, after thermal expansion, to compressive strains which are released by debonding and buckling, leading to a variety of microstructures. Starting from the work of Gioia and Ortiz in the 90s it has become possible to analyze these structures within the context of the calculus of variations. In the following two decades different geometries have been studied, as for example anisotropic compression. In this talk I shall discuss recent mathematical progress in this area, focusing on the rich phase diagram of partially debonded films with a lateral boundary condition.

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MS12

Unstretchable Two-Dimensional Elastic Bodies: Kinematics and Energetics

We will present a variational theory for two-dimensional bodies that are unstretchable in the sense that they are capable of sustaining only isometric deformations. Aside from the relevant Euler–Lagrange equations, we will derive boundary conditions and the second-variation condition. Elementary applications to ribbons and Möbius bands will also be considered.

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MS12

Isometric Immersions and Self Similar Buckling in Non-Euclidean Elastic Sheets

The edge of torn elastic sheets and growing leaves often form a hierarchical buckling pattern. Within non-Euclidean plate theory this complex morphology can be understood as low bending energy isometric immersions of hyperbolic Riemannian metrics. In this talk we show that for a large class of growth profiles there exist periodic and self-similar deformations of the sheet with vanishing in-plane strain. The construction of these surfaces consists of gluing together local solutions of an isometric immersion problem along "lines of inflection' and "branch points' in such a manner that the resulting surface remains $W^{2,2}$. For hyperbolic non-Euclidean sheets, complex wrinkling patterns are thus possible and our results identify the key role the regularity of the isometric immersion plays in determining the global structure of a non-Euclidean elastic sheet.

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MS12

Understanding Mechanisms of High Sensitivity of Buckling Loads to Imperfections.

Classical formulas for the critical stress of axially compressed circular cylindrical shells predict buckling failure at loads that are three to five times higher than the ones observed in experiments. The culprit is identified to be "high sensitivity to imperfections". In this talk I will describe a mathematically rigorous theory revealing scaling instability as the mechanism of high imperfection sensitivity, and predicting, apriori, which structures will suffer from it.

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MS13

Mathematics of Insurance: Continuous Time Approximations

We introduce a framework for an insurance company which acts at discrete times. Either taking the time-interval to zero or taking the overall rate of claims to infinity allows us to derive a kinetic model. We will examine the behavior of the resulting kinetic model and discuss the how the dynamics can differ from the discrete-time case.

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MS13

Model Predictive Control for Many Agent Systems

Abstract not available at time of publication.

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MS13

Agent Based Simulations for Chip Sales to High-End Gamers

The sales of computer chips in the High- End Gamers market are simulated using an agent based simulation environment. We model the succession of 19 products introduced over a 40 month time horizon which includes the recession of 2008 - 2010. Simulated sales are compared to actual sales data and are used to adjust the parameterization of the agents and their environment. A kinetic model is developed that allows a scaling analysis reducing the set of parameters to two dimensionless constants. Simulations of the resulting PDEs show pattern formation and synchronization of the buying behavior from random initial conditions.

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MS14

Sharp Korn Inequalities in Thin Domains: the "first and a Half" Korn Inequality

We will discuss Korn and Korn-like inequalities with Dirichlet boundary conditions in thin domains. The inequalities are asymptotically sharp as the domain thickness goes to zero. We will introduce the "first and a half" Korn inequality that implies both first and second Korn inequalities. Curved domains in 2D with non-constant thickness will be considered. The inequalities become crucial in the

applications to buckling problems via a buckling load formula.

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MS14

Homogenization of Defects: the Emergence of Torsion

The modeling of dislocations in solids has a long ongoing history. One approach, which goes back to Volterra in the early 1900s, views dislocations as geometric singularities in locally-Euclidean manifolds. Another approach, dating from the 1950s, models continuously-distributed edge-dislocations as smooth manifolds endowed with non-symmetric affine connections. That is, distributed dislocations are modeled by a smooth torsion field. In this lecture, the two approaches are reconciled. Both isolated dislocations and distributed dislocations can be described within the scope of Weitzenbock manifold—Riemannian manifolds endowed with a metrically-consistent flat connection. By introducing a new notion of weak convergence, we show how torsion arises as a homogenization limit of locally-flat Riemannian manifolds with distributed singular dislocations, as their density tends to infinity.

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MS14

Energy Scaling for the Regular Cone in the von-Kármán Setting

We consider a single disclination in a thin elastic sheet in the von-Kármán setting. We prove an ansatz-free lower bound for the free elastic energy. This lower bound is optimal in the sense that we find an upper bound that is identical to it in the leading order of the small parameter in the model. We discuss the geometric ideas behind the proof.

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MS14

Sobolev Rigidity of Convex Shells

It is a well known fact in the theory of elasticity that elliptic shells display stronger rigid behaviors than other types of surfaces. A result due, among others, to Hilbert, is that any smooth isometric immersion of a two dimensional sphere into $\mathbb{R}^3$ is a rigid motion. However, elastic deformations do not necessarily need to be as smooth as in the above theorem. Among others, $W^{2,2}$ regular deformations arise in the rigorous thin limit derivation of the thin shell models from the 3-dimensional nonlinear elasticity. We will sketch how to generalize Hilbert's theorem to $W^{2,2}$ regularity by proving the following: Any $W^{2,2}$ isometric immersion into $\mathbb{R}^3$ of an elliptic 2d Riemannian manifold of positive Gaussian curvature is smooth.

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MS15

Energy Driven Pattern Formation in Planar Dipole-Dipole Systems in the Presence of Weak Noise

We study pattern formation driven by line tension and dipole-dipole repulsion observed in ferrofluids which manifests convoluted fingered domains. We asymptotically obtain an energy minimization problem depending only on a generalized line tension, Λ. Numerical studies yield a few highly symmetric stable shapes, but nothing that resembles the experimentally observed diversity. Adding a weak random background stabilizes a smörgåsbord of domain morphologies recovering the diversity observed experimentally. We deduce an algorithm for extracting Λ using only a shape's perimeter and morphology.

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MS15

Analysis of a Particle Method for the Aggregation Equation

The aggregation equation appears in various context as a mathematical model for collective behavior, for example, a school of fish, a flock of birds, etc. In this talk, we will discuss uniform convergences of a linearly transformed particle method for the aggregation equation. In this particle method, particles are pushed onto discrete times according to an approximation of the exact flow. Furthermore, the particles have their own shape which is transformed in the discrete evolution in order to better approach the local flow using a linearization of the exact flow.

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MS15

Interaction Models with Nonlinear Diffusion

We consider a continuum aggregation model with nonlinear local repulsion given by a degenerate power-law diffusion with general exponent. The steady states and their properties in one dimension are studied both analytically and numerically, suggesting that the quadratic diffusion is a critical case. The focus is on finite-size, monotone and compactly supported equilibria. We also investigate numerically the long time asymptotics of the model by simulations of the evolution equation. Issues such as metastability and local/ global stability are studied in connection to the gradient flow formulation of the model.

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MS15

Stationary Solution and Long-time Behavior of 2D Keller-Segel Model with Degenerate Diffusion

In this talk we consider the parabolic-elliptic Keller-Segel equation in 2D with degenerate diffusion. Using Steiner symmetrization, we prove that for any given mass, there exists a unique L^1 non-negative stationary solution up to a translation. In addition, we will show that any solution with compactly supported initial data must converge to a translation of this stationary solution. This is a joint work with J.Carrillo, S. Hittmeir and B. Volzone.

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MS16

Numerical Bifurcation Study for Viscous Shock Waves

We present recent results of a numerical bifurcation study of multidimensional planar viscous shock waves in Magnetohydrodynamics using the Evans function. We describe the numerical methods used and the bifurcation properties observed.

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MS16

Hopf Bifurcation from Fronts in the Cahn-Hilliard Equation

We study Hopf bifurcation from traveling-front solutions in the Cahn-Hilliard equation. Models of this form have been used to study numerous physical phenomena, including pattern formation in chemical deposition and precipitation processes. Technically we contribute a simple and direct functional analytic method to study bifurcation in the presence of essential spectrum. Our approach uses exponential weights to recover Fredholm properties, spectral flow ideas to compute Fredholm indices, and mass conservation to account for negative index.

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MS16

Inhomogeneities in Spatially Extended Pattern Forming Systems

We study the effects of defects on pattern formation from the point of view of perturbation theory, and focus on three examples of spatially extended systems. We will look at striped patterns in Rayleigh Bénard convection, target patterns in chemical oscillations, and wave sources in arrays of non-locally coupled oscillators. We explain why regular perturbation theory fails due to the presence of essential spectrum and show how Kondratiev spaces can help overcome this difficulty.

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MS16

Coherent Structures in Nonlocal Equations

I'll present recent work on pulses and fronts in systems with nonlocal coupling. I'll first discuss pinning and un-

pinning of fronts. Near the Maxwell point, that is, when potential energies of the asymptotic equilibria are close, interfaces are often discontinuous and cannot propagate: they are pinned. I'll describe results that characterize pinning regions in parameter space and and show that speeds obey an unusual but universal $mu^3/2$ asymptotic which is different from conventional $mu^1/2$ asymptotics in discrete systems. I'll also give some motivation and speculation how speed asymptotics may depend in a universal fashion on kernel regularity properties. In the second part of the talk, I'll explore some of the techniques involved in the study of such traveling wave problems. In particular, I'll explain how "spatial dynamics' can be "translated' to traveling-wave problems that cannot be cast as differential equations in a spatial variable. As an application, I'll describe the construction of an excitation pulse in a nonlocal FitzHugh-Nagumo equation.

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MS16

Dynamics and Bifurcation in Multicomponent Bilayer Membranes

Multicomponent bilayer structures are universal in biological structures and synthetic copolymer mixtures with wide applications such as electrolyte membranes, drug delivery and emulsion stabilization. We present an analysis of the dynamics and bifurcation of these membranes within the context of the functionalized Cahn-Hilliard(FCH) free energy. We combine dynamical system tools, especially multi-scale asymptotic expansion and spatial dynamics, with techniques from differential geometry to reduce the FCH free energy to a Canham-Helfrich sharp interface energy. Crucially, the role of intrinsic curvature arises through a Melnikov parameter. We construct asymmetric homoclinic bilayer profiles via a billiard limit potential and determine criteria to initiate the layer-by-layer pearling bifurcation observed experimentally.

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MS17

On Convex Finite-Dimensional Variational Methods in Imaging Sciences, and Hamilton-Jacobi Equations

We consider standard finite-dimensional variational models used in signal/image processing that consist in minimizing an energy involving a data fidelity term and a regularization term. We propose new remarks from a theoretical perspective which give a precise description on how the solutions of the optimization problem depend on the amount of smoothing effects and the data itself. The dependence of the minimal values of the energy is shown to be ruled by Hamilton-Jacobi equations, while the minimizers $u(x,t)$ for the observed images x and smoothing parameters t are given by $u(x,t) = x - t\nabla H(\nabla_x E(x,t))$ where $E(x,t)$ is the minimal value of the energy and H is a Hamiltonian related to the data fidelity term. Various vanishing smoothing parameter results are derived illustrating the role played by the prior in such limits. Finally, we present an efficient numerical numerical method for solving certain Hamilton-Jacobi equations in high dimension. This last part is a joint work with Stanley Osher (UCLA).

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MS17

Approximation of Curvature Dependent Functionals in Imaging

I will discuss the behavior of different diffuse interface (phase field style) approximations of curvature dependent functionals, especially regarding how they handle topological changes. This has implications for image processing, e.g. in the context of inpainting. Joint work with Andreas Ratz and Matthias Roger.

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MS17

Limiting Aspects of Non-Convex TV^q Models in Image Processing

Abstract not available at time of publication.

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MS17

Discrete Varifolds, Point Clouds, and Surface Approximation

There are many models for the discrete approximations of a surface: point clouds, triangulated surfaces, pixel or voxel approximations, etc. We claim that it is possible to study these various approximations in a common setting using the notion of varifolds. Varifolds are tools from geometric measure theory which were introduced by Almgren in the context of Plateau's problem. They carry both spatial and tangential informations, and they have nice properties in a variational context : compactness, continuity of mass, multiplicity information, control of regularity, and a generalized notion of mean curvature. The aforementioned approximations can be associated with "discrete varifolds". The talk will be devoted to approximation properties of such discrete varifolds, to a notion of approximated mean curvature for these objects, and to the convergence properties of this approximated curvature. Numerical evaluations on various 2D and 3D point clouds will illustrate these notions. It is a joint work with Blanche Buet (University of Paris Sud, France) and Gian Paolo Leonardi (University of Modena and Reggio Emilia, Italy).

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MS18

Turbulence in Physical Scales of the Navier-Stokes Equations in the Presence of the Driving Force

I will discuss the connection between the Kolmogorov-type dissipation law (linking the energy dissipation rate with the characteristic velocity and length scale) and the formation of energy cascades in the physical scales of the 3D Navier-Stokes equations and explore the role of the driving force.

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MS18

Data Assimilation Algorithms for the Bénard Convection Model and Other Models of Turbulence

Data assimilation is the process by which observations are incorporated into a computer model of a real system. Applications of data assimilation arise in many fields of geosciences, perhaps most importantly in weather forecasting. In a joint work with M. Jolly and E. S. Titi, we present a new continuous data assimilation algorithm for the two-dimensional Bénard problem based on an idea from control theory. Rather than inserting the observational measurements directly into the equations, a feedback control term is introduced that forces the model towards the reference solution. We show that the approximate solutions constructed using only observations in the velocity field and without any measurements on the temperature converge in time to the reference solution of the two-dimensional Benard problem. Similar results for other models of turbulence will be presented.

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MS18

Minimal Scaling Laws Induced by the Scale of Local Isotropic Diffusion in 3D NSE

A family of scaling laws leading to just enough sparseness of suitable super-level sets of Littlewood-Paley blocks of solutions to the 3D NSE to engage the local isotropic diffusion via the harmonic measure maximum principle will be presented.

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MS18

Statistical Behavior of a Data Assimilation Algorithm for the 2D Navier-Stokes Equations

Recently, a new data assimilation algorithm was proposed based on ideas of finite-dimensional feedback control introduced for dissipative dynamical systems. Our purpose is to analyze the behavior of this new data assimilation algorithm for the two-dimensional incompressible Navier-Stokes equations from a statistical point of view. We consider the general case of measurements with systematic experimental errors and obtain estimates for the difference of time averages of characteristic quantities of the flow associated to the approximating solution and the reference solution. This is a work in progress in collaboration with C. Foias and E. Titi.

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MS19

Analysis of Nonlinear Poro-elastic and Poro-viscoelastic Models

We consider a nonlinear system of PDEs often encountered when modeling fluid flow through deformable porous media. The ability of the fluid to flow within the solid is described by the permeability tensor, which is assumed to vary nonlinearly with the volumetric solid strain. We study the problem of existence of weak solutions in bounded domains with mixed boundary conditions, accounting for non-zero volumetric and boundary forcing terms. We investigate the influence of viscoelasticity on the solution functional spaces and on the regularity requirements for the forcing terms. The theoretical results are complemented with numerical simulations.

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MS19

On the Evolution Equations of Free Liquid Fibers and Films

In this presentation I will discuss recent results on the evolution equations of free liquid fi bers and films. Mathematical models of this kind are used to study important engineering processes to manufacture thin filaments and sheets from a highly viscous fluid and to explain physical phenomena like drop formation, atomization and filament/film breakup (or non-breakup). In their simplest form, the governing equations are given by nonlinear transport equations together with elliptic constraints. They arise from the Navier-Stokes equations with moving boundary in the slender-body approximation. I will give new global existence, regularity and stability results for some isothermal and non-isothermal fiber and film forming flows, including some stationary, linearized and fully nonlinear regimes.

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MS19

Porous Medium Equation with Heterogeneous Constraints and Advection

The advective-diffusive transport and phase change of methane as dissolved gas or hydrate is a free-boundary problem. This is resolved by nonlinear semigroup theory in L1 and coupled to a Darcy system for the flow.

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MS19

Analysis of the Flow of Landau-De Gennes Energy Functional under Weak Anchoring Conditions

In this talk, I will discuss the asymptotic of the heat flow of Landau-De Gennes functional for nematic liquid crystals under weak anchoring boundary, as the parameter tends to zero, in dimensions of two and higher.

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MS20

Nonexistence of Small Doubly Periodic Coherent Structures

We consider the question of existence or nonexistence of time-periodic, spatially periodic waves for dispersive equations, including the KdV equation and nonlinear Schrödinger equations. We introduce an operator whose fixed points are doubly periodic solutions, and we show that this operator has a local contracting property, for almost every possible temporal period. Thus, for almost every possible temporal period, doubly periodic solutions cannot be arbitrarily small. This is joint work with J. Douglas Wright.

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MS20

Dirac Points in the Spectrum of Periodic Planar Networks

We consider planar networks that have two distinct types of vertices modulo a group of rigid translations. The energy spectrum of the associated discrete Laplacian consists of two generally disjoint bands, but sometimes the bands intersect at a conical vertex known as a "Dirac point." These intersections appear at first to be an unusual degenerate case. However, with a modest symmetry assumption, Dirac points are present for an open set in the space of graph parameters.

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MS20

Vortex Scattering Across Material Interfaces

We study dynamics of vortices interacting with a small background such that the forces between vortex-vortex interactions and vortex-background interactions are of the same scale.

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MS20

KdV Dynamics and Traveling Waves in Diatomic Fpu

Famously, the Korteweg-de Vries equation serves as a model for the propagation of long waves in Fermi-Pasta-Ulam (FPU) lattices. If one allows the material coefficients in the FPU lattice to vary periodically, the classical" derivation and justification of the KdV equation go awry. By borrowing ideas from homogenization theory, we can derive and justify an appropriate KdV limit for this problem. While the KdV approximation predicts the existence of solutions which look like solitary waves for long times, it does not guarantee that such solutions remain coherent forever. We discuss recent results on the global in time existence of "generalized solitary waves" in diatomic FPU lattices.

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MS21

Vortices in Liquid Crystals, Superconductivity, Optics, and Hydrodynamics: Siblings Or Not?

I will discuss a kinetic dynamical theory for nematic liquid crystals in the limit when much of the activity in the system may be described via the motion of interacting vortices. Such structures appear in many various contexts in other types of systems. I will discuss the similarities and differences, and what one can learn by establishing correspondences between these diverse systems.

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MS21

Vortices in the Landau De Gennes Model for Chromonic Liquid Crystals

I will describe recent work on modeling of chromonic liquid crystals as well as discuss singularities that form in these materials under various parameter regimes.

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MS21

Stability of Point Defects in Liquid Crystals

We study a class of symmetric critical points in a variational Landau-de Gennes model where the state of nematic liquid crystals is described by symmetric traceless 3×3 matrices. These critical points play the role of topological point defects carrying a non-zero degree.

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MS21

Gamma-Convergence Analysis of Columnar Phases in Bent-Core Liquid Crystals

We analyze a Landau-de Gennes type energy for bent-core molecule liquid crystals (BLC). This model is introduced in the physics literature to study the switching behavior under applied electric field in the so-called columnar phases, where BLC materials form two-dimensional structures made of fragments of smectic layers. As the width of the column tends to infinity, Γ-convergence shows that rotation around the tilt cone is favored, provided the coefficient of the coupling term, between the polar parameter, the nematic parameter, and the layer normal is large.

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MS22

Coupling Models for Darcy, Pre Darcy, and Post Darcy Flows in Porous Media-Analysis and Application

We combine all three regimes of fluid flows in porous media: pre-Darcy, Darcy and Forchheimer. We focus on slightly compressible fluid, and derived a parabolic equation for pressure function. Unlike popular p-Laplacian equations, this is degenerate when the gradient is small and large, but with different order in degeneracy. Structural stability at finite time and at time infinity of solution of corresponding IBVP is studied for wide class of boundary data. All obtained mathematical results have clear physical interpretation

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MS22

Robust Optimization of Multiscale Viscoelastic Composites

The talk discusses a min-max approach to optimal structural design of a domain filled with two viscoelastic materials. The problem is formulated as minimization of the principal compliance which is the maximum of the compliance of the domain under an applied admissible force. Integral representation of the effective viscoelastic tensor is used to explore the properties of the optimally designed structure.

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MS22

Hamilton-Jacobi and Eikonal Pdes from Iterated Homogenization Methods in Finite Elasticity

In this talk, I will present an iterated homogenization result in finite elastostatics for the overall response of a specific but yet fairly general class of composite materials with two-phase particulate microstructures. The result is valid for any choice of elastic behaviors for the underlying matrix and particles, and any choice of the one- and two-point correlation functions describing the microstructure. The required calculations amount to solving a first-order nonlinear (Hamilton-Jacobi-type) partial differential equation for the total energy density of the composite, in which the initial volume fraction of the particles plays the role of 'time' and the applied load plays the role of 'space'. As a first application of the result, an explicit solution will be worked out and presented for the basic case of Neo-Hookean rubber filled with an isotropic distribution of rigid particles. In this case, the required calculations amount to solving an Eikonal partial differential equation in two variables. The properties of this pde will be discussed.

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MS22

From Micro-imaging across Multiple Scales

Micro-imaging such as X-ray micro-tomography and SEM (Scanning Electron Microscope) provide us with vast collections of inspiring images which motivate the mathematical modeling efforts in material science and complex fluids. However, their resolution provides at times too much information for a traditional PDE model to be efficiently upscaled and/or implemented. In the talk we describe our hybrid mathematical and computational models which use micro-imaging data and combine numerical PDEs across various scales with statistical mechanics and/or network models. The hybrid models have a superior data-based modeling capability, but present challenges to the analysis and computation. We present examples from semiconductor modeling, and biofilm modeling at porescale.

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MS23

Local Theory for the Boltzmann-Nordheim Equation in Non Isotropic Setting

In our talk we will present a newly found local Cauchy Theory for the spatially homogeneous bosonic Boltzmann-Nordheim equation in any dimension $d \geq 3$ under mild restrictions on the collision kernel, extending previous studies that only dealt with the isotropic settings of the problem. Interestingly enough, the locality of this result is quite sharp due to the so-called Bose-Einstein condensation. The methods used to achieve this theory are similar to those available for the classical Boltzmann equation, yet are entangled with L^∞ control that dominates the difference between the classical and quantum kinetic equation. Time permitting we will discuss some details about the existence of a global solution to the equation.

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MS23

Some Recent Progress in Boundary Problem of Boltzmann Equation

We discuss some recent progress in some boundary problem of the Boltzmann theory.

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MS23

Anomalous Energy Transport in PFU-beta Chain

FPU chains (an array of weights chained to their neighbors via springs) are used to model 1-dimensional crystals. Depending on the interaction potential considered, anomalous heat transport is expected. Based on the results of Lukkarinen and Spohn, we study the emergence of the fractional heat equation with laplacian of order 4/5 for FPU chains with quartic interaction potentials.

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MS23

Exponential Tails for Solutions to the Homogeneous Boltzmann Equation

We study the tail behavior of solutions to the homogeneous Boltzmann equation for hard potentials with non-integrable angular cross section. We discuss the generation and propagation of L^1 and L^∞ exponentially weighted estimates and the relation between them. The tails that are propagated depend on the singularity rate of the angular cross-section. For some of those rates the corresponding functional weights are super-Gaussians, while for others the weights are Mittag-Leffler functions (fractional power series behaving asymptotically as super-Gaussians).

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MS24

Anisotropic Interactions in First-Order Crowd Models

I will treat an extension of an established model: a first-order system of ODEs for the trajectories of interacting individuals. The original model lacks a crucial ingredient that makes social groups different from systems of non-living particles: mutual interactions are anisotropic since they are vision-based and thus direction-dependent. My main interest is to investigate how this anisotropy influences the model. Uniqueness and continuity of the velocity are the mathematical issues that I will address.

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Lenya Ryzhik
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MS24

Hotspots in a Nonlocal Crime Model

We extend the Short et al. burglary hotspot model to allow for a larger class of criminal movement. Specifically, we allow criminals to travel according to a Lévy flight rather than Brownian motion. This leads to a non-local system of differential equations. The stability of the homogeneous state is studied both numerically and through a Turing-type analysis. The hotspot profiles are then constructed to leading order in a singular regime.

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MS24

Contagion Shocks in One Dimension

We consider an agent-based model of emotional contagion coupled with motion in one dimension that has recently been studied in the computer science community. The model involves movement with speed proportional to a fear' variable that undergoes a temporal consensus averaging with other nearby agents. We study the effect of Riemann initial data for this problem, leading to shock dynamics that are studied both within the agent-based model as well as in a continuum limit. We examine the model under distinguished limits as the characteristic contagion interaction distance and the interaction timescale both approach zero. Here, we observe a threshold for the interaction distance vs. interaction timescale that produces qualitatively different behavior for the system - in one case particle paths do not cross and there is a natural Eulerian limit involving nonlocal interactions and in the other case particle paths can cross and one may consider only a kinetic model in the continuum limit. Time permitting, we will also discuss recent extensions of the model to two dimensions.

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MS24

Efficient Numerical Methods for Multiscale Human Crowd Dynamics with Emotional Contagion

We develop two efficient numerical methods—a hybrid method and a level set method, for a multiscale kinetic equation in the context of crowd dynamics with emotional contagion. Here, the macroscopic limit is an Eulerian system with nonlocal interactions, which ceases to be valid when the underlying microscopic particle characteristics cross. Both methods will provide reasonable solutions to the macroscopic system while capturing the microscopic phenomena.

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MS25

Structured and Unstructured Sampling Methods for the Approximation of Parametric PDEs

The numerical approximation of parametric partial differential equations is a computational challenge, in particular when the number of involved parameter is large due to the so-called "curse of dimensionality. For certain models, the family of solutions to such equations can be approximated by multivariate sparse polynomials in the parameter vector y with a controlled number N of terms. The convergence rate in terms of N does not depend on the number of parameters, which may be arbitrarily large or countably infinite, thereby breaking the curse of dimensionality. However, these approximation results do not describe the concrete construction of these polynomial expansions, and should therefore rather be viewed as benchmark for the convergence analysis of numerical methods. In this presentation, we give an overview of recent results in sampling techniques for polynomial approximation in high dimension. We discuss reduced basis and empirical interpolation, sparse grids, interpolation, least squares and compressed sensing.

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MS25

Polynomial Chaos Expansion Via Gradient-Enhanced ℓ_1-Minimization

Gradient-enhanced Uncertainty Quantification (UQ) has received recent attention, in which the derivatives of a Quantity of Interest (QoI) with respect to the uncertain parameters are utilized to improve the surrogate approximation. Polynomial chaos expansions (PCEs) are often employed in UQ, and when the QoI can be represented by a sparse PCE, ℓ_1-minimization can identify the PCE coefficients with a relatively small number of samples. In this talk, we investigate a gradient-enhanced ℓ_1-minimization, where derivative information is computed to accelerate the identification of the PCE coefficients. For this approach, stability and convergence analysis are lacking, and thus we address these here with a probabilistic result. In particular, with an appropriate normalization, we show the inclusion of derivative information will almost-surely lead to improved conditions, e.g. related to the null-space and coherence of the measurement matrix, for a successful solution recovery.

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MS25

Least Squares Approximation in Multivariate Polynomial Spaces and Application to Elliptic PDEs with Stochastic Data

We review the main results achieved in the analysis of the stability and accuracy of discrete least squares on multivariate polynomial spaces, with noiseless evaluations at random or low-discrepancy point sets, and with noisy evaluations at random points for several noise models. Then we use the least-squares approach to approximate quantities of interest related to the solution of elliptic PDEs with stochastic data, and finally discuss adaptive strategies to enrich the polynomial space.

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MS25

Parameter Identification for PDEs with Random Data

We present a parameter identification problem constrained by PDEs with random input data. Several identification objectives are discussed that either minimize the expectation of a tracking cost functional or minimize the difference of desired statistical quantities in the appropriate L^p norm. The stochastic parameter identification algorithm integrates an adjoint-based deterministic algorithm with the sparse grid stochastic collocation FEM approach. The proof of the error estimates uses a Fink-Rheinboldt theory.

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MS26

Global Minimization with Interacting Particle Systems

The task of minimizing a given function globally is challenging, especially in high-dimensional search space. One well-known idea is to employ agents that explore the search space while communicating amongst each other in some heuristic manner. Examples are particle swarm optimization (PSO) methods, which typically are discrete, second-order and include memory effects, and consensus-based algorithms. In this talk, we develop a global minimization method that mimics central ideas from those algorithms but at the same time bears resemblance to well-known kinetic aggregation equations. The particle system therefore possesses a formal mean-field limit to a partial differential equation, which gives the possibility of analytical treatment. Ideally, one would like the method to show a concentration / consensus formation of particles at the global minimum, so blow-up effects are *desirable* at the right location. In order to illustrate the method and the possible insights from the mean-field equation, we present findings on the numerical performance and discuss first results and ongoing challenges in the analysis. Remarkably, the algorithm shows a competitive performance in standard test cases.

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MS26

Multi-agent Dynamics Models for n-ary Markov Jump Processes on a Dense Graph

Homogeneous Boltzmann-like equations have been used to model the evolution of wealth, opinions or information among a population of agents interacting in groups over time. These equations do not account for underlying network structure constraining agent interactions. We use graphons (large graph limits) to derive kinetic collisional equations for n-ary Markov jump processes on dense graphs and propose a new opinion dynamics model that couples agent interactions with their positions in the network.

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MS26

Coalescing Diffusion, and Composite Stochastic Particle-grid Methods for the Investigation of Blow-ups in the Keller-Segel and Similar PDEs

We introduce a stochastic interacting particle system with collisions, coalescence, and a singular interaction kernel. For suitable parameter choices, this system is related to the Keller-Segel chemotaxis PDE model (K-S). In this regime, each aggregate of particles coalesces into a single massive particlethis corresponds to the formation of Dirac-singularities in the K-S. We develop a composite grid-particle method for the simulation of this particle system, in which particle coalescence is detected using an adaptive mesh clustering method. We then use this numerical method to investigate blow-up dynamics in the K-S PDE, and compare some of the obtained results with classical asymptotic analysis of the PDE. Finally, we investigate coarsening in the system when the domain is the plane, and the number of particles tends to infinity.

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MS27

Particle Laden Flow on an Incline

This talk is about recent work at UCLA on PDE models for particle laden flow on an incline. The work involves comparison with physical experiments and the development of conservation law models for the particle concentration and bulk thickness of the flow mixture. Relevant physics includes hindered settling of the particles and shear-induced migration of the particles within the flow. The resulting equations have interesting solutions including multiple shock structures and singular shocks. Industrial applications include food processing and separation of slurries in the mining industry using devices such as a spiral separator.

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MS27

Mean Oscillations of the Vorticity Direction and A Priori Bounds on the Vorticity in the 3D NSE

It will be shown that uniform-in-time boundedness of the vorticity direction in a class of weighted spaces of bounded mean oscillations suffices to break the usual scaling of a priori estimates on solutions to the 3D Navier-Stokes equations. This is a joint work with Z. Bradshaw and Y. Do.

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MS27

The Free Boundary Euler Equation

We address local existence for the Euler equation with a free boundary. We address minimal conditions for the local existence of solutions and compare the results with the Euler equation in a fixed domain. The results are joint with V. Vicol and A. Tuffaha.

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MS27

Numerical Analysis of the Stochastic Navier-Stokes Equations: Stability and Convergence

We analyze a class of space-time discretizations for the stochastic Navier-Stokes equations (SNSE) subject to a nonlinear state dependent white noise forcing. For these discretizations we develop a notion of the statistical stability and establish conditions in sprit of Courant-Friedrichs-Levy for which this stability is shown to hold. We then analyze the convergence on both finite and infinite time horizons. For the analysis of convergence in the time asymptotic regime we show that the numerical approximations, subject to the our notion of statistical stability possess invariant states. We prove that when the Markovian dynamics corresponding to the limiting equations are contractive in a suitable Lipschitz (i.e. Wasserstein) metric then any such sequence of invariant measures converge to the unique limit measure.

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MS28

Generalized Gevrey Norms with Applications to Dissipative Equations

The regular solutions of the Navier-Stokes equations are well-known to be analytic in both space and time variables, even when one starts with non-analytic initial data. The space analyticity radius has an important physical interpretation. It demarcates the length scale below which the viscous effect dominates the (nonlinear) inertial effect. Foias and Temam introduced an effective approach to estimate space analyticity radius via the use of Gevrey norms which, since then, has become a standard tool for studying analyticity. We extend this approach to a class of dissipative equations, including critical and super-critical quasi-geostrophic equations, where the dissipation operator is a fractional Laplacian and discuss application of these methods to establish optimal decay rate of higher order derivatives. Time permitting we will discuss the extension of some of these methods, including recently introduced one involving higher order energy functional, to bounded domains.

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MS28

Continuity of Attractors for Dynamical Systems

Let Λ be a complete metric space, and let $\{S_\lambda(\cdot) : \lambda \in \Lambda\}$ be a parametrized family of semigroups with global attractors A_λ. We assume that there exists a fixed bounded set D such that $A_\lambda \subset D$ for every $\lambda \in \Lambda$. We show that the attractors A_λ are continuous with respect to the Hausdorff distance at a residual set of parameters λ in the sense of Baire Category. This result is then extended to the pullback and uniform attractors of a family of non-autonomous systems.

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MS28

Turbulence in Vertically Averaged 3D Rayleigh-Benard Convection

We look for features of 2D turbulence in the momentum equations that result by taking the vertical average of the 3D Rayleigh-Benard system. The 2D system has a body force which involves various integrals of the 3D flow. We present rigorous upper bounds for the Grashof number associated with this time-dependent force as well as numerical computations to fill in for the missing lower bounds.

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MS28

Spread of Phage Infection of Bacteria in a Petri Dish

We extend our previous work on the spatial spread of phage infection of immobile bacteria on an agar coated plate by explicitly including loss of viruses by both adsorption to bacteria and by decay of free viruses and by including a distributed virus latent period and distributed burst size rather than fixed values of these key parameters. We extend earlier results on the spread of virus and on the existence of traveling wave solutions when the basic reproductive number for virus exceeds one and we compare the results with those obtained in earlier work. Finally, we formulate and analyze a model of multiple virus strains competing to infect a common bacterial host in a petri dish.

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MS28

Navier-Stokes-alpha Model for Channel Flows

The Navier-Stokes-alpha (NS-alpha) models are a good mathematical model for the dynamics of appropriately averaged turbulent fluid flows. It is considered as an averaged version of the Navier-Stokes equations (NSE). In particular, the NS-alpha analogue of the Poiseuille and Hagen solution in channels and pipes, respectively, display both the classical von Karman and the Barenblatt-Chorin laws. A remarkably successful extension of the classic Blasius theory for turbulent boundary layer to a larger range of Reynolds number was done using the NS-alpha. In this talk, I will present a simple Reynolds type averaging which might be used for explaining the transforming from the NSE into the NS-alpha. This is a joint work with C.Foias, A.Haqverdiyev and J.Tian.

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MS29

Fast Pulses with Oscillatory Tails in the FitzHugh-Nagumo System

It is well known that the FitzHugh-Nagumo system exhibits stable, spatially monotone traveling pulses. Also, there is numerical evidence for the existence of spatially oscillatory pulses, which would allow for the construction of multi-pulses. We discuss analytical results regarding the existence and stability of such pulses using geometric blow-up techniques and singular perturbation theory, and we propose a mechanism that explains the transition from single to double pulses that was observed in earlier numerical studies.

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MS29

How Defects Are Born

Pattern-forming systems typically exhibit defects, whose nature is associated with the symmetries of the pattern in which they appear; examples include dislocations of stripe patterns in systems invariant under translations, disclinations in stripe-forming systems invariant under rotations, and spiral defects of oscillatory patterns in systems invariant under time translations. Numerical simulations suggest that pairs of defects are created when the phase of the pattern ceases to be slaved to its amplitude. Such an event is typically mediated by the build up of large, localized, phase gradients. This talk will describe recent advances on a long-term project whose goal is to follow such a defect-forming mechanism in a system that is amenable to analysis. Specifically, we focus on the appearance of pairs of dislocations at the core of a grain boundary of the Swift-Hohenberg equation. Taking advantage of the variational nature of this system, we show that as the angle between the two stripe patterns on each side of the grain boundary is reduced, the phase of each pattern, as described by the Cross-Newell equation, develops large derivatives in a region of diminishing size.

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MS29

Stability of Traveling Waves in a Model for a Thin Liquid Film Flow

We consider a model for the flow of a thin liquid film down an inclined plane in the presence of a surfactant, which is known to possess various families of traveling waves. We use a combination of analytical and numerical means to show that the spectra of these waves are within the closed left-half complex plane.

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MS29

Oscillons Near Hopf Bifurcations of Planar Reaction Diffusion Equations

Oscillons are planar, spatially localized, temporally oscillating, radially symmetric structures often arising near forced Hopf bifurcations. Using spatial dynamics, we show that the dynamics on the center manifold of a periodically forced reaction diffusion equation (fRD) near a Hopf bifurcation can be captured by the forced complex GinzburgLandau equation (fCGL). Thus, oscillon solutions to the fRD can be thought of as a foliation over localized solutions to the fCGL.

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MS30

Recent Progress Towards Onsager's Conjecture

Abstract not available at time of publication.

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MS30

Convex Integration and the Stationary Incompressible Euler Equations

In 2007, De Lellis and Székelyhidi constructed bounded, "wild" solutions to the (time-dependent) Euler equations in any dimensions, based on techniques of convex integration developed by Müller and Šverák. Another construction of De Lellis and Székelyhidi, inspired more directly by the work of Nash, led to (Hölder) continuous solutions. The stationary case seems however out of reach of the Hölder construction. On the other hand, the L^∞-construction of stationary solutions (in two space dimensions) does not follow from the time-dependent case. In this talk we will explain the differences, which are of geometric nature.

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MS30

Almost-isometric Deformations and Thin Elastic Sheets

The understanding of the energetic behavior of thin elastic sheets undergoing compressive boundary conditions is still a largely open problem. The appearance of conical singularities and sharp folds calls into play the interaction between various sets of boundary conditions and the metric properties of the considered deformations, with links to classical problems in Differential Geometry like the Nash-Kuiper isometric embedding theorem. In this talk we introduce these problems and review some old and new results.

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MS30

On Weak Solutions to the 2D Savage-Hutter Model of the Motion of a Gravity Driven Avalanche Flow

The theory for gravity driven avalanche flows is qualitatively similar to that of compressible fluid dynamics. I will present one of the models describing flow of granular avalanches - the Savage-Hutter model. I will show how the method of convex integration can be applied to show that the Savage-Hutter system is always solvable but not well posed in the class of weak solutions. The talk is based on common result with Eduard Feireisl and Piotr Gwiazda.

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MS31

Decay Rates for Some Fluid-Structure Models

A rate of rational decay is obtained for solutions of a PDE model which has been used in the literature to describe structural acoustic flows. This structural acoustics PDE consists partly of a wave equation which is invoked to model the interior acoustic flow within a given cavity. Moreover, a structurally damped elastic equation is invoked to describe time-evolving displacements along the flexible portion of the cavity walls. The coupling between these two distinct dynamics will occur across a boundary interface. We obtain the uniform decay rate of this structural acoustic PDE without incorporating any additional boundary dissipative feedback mechanisms. By way of deriving this stability result, necessary a priori inequalities for a certain static structural acoustics PDE model are generated, thereby allowing for an application of a recently derived resolvent criterion for rational decay.

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MS31

Fluid-Elastic Structure Interaction with the Navier Slip Boundary Condition

We study a nonlinear, moving boundary fluid-structure interaction (FSI) problem between an incompressible, viscous Newtonian fluid, modeled by the 2D Navier-Stokes equations, and an elastic structure modeled by the shell or plate equations. The fluid and structure are coupled via the Navier slip boundary condition and balance of contact forces at the fluid-structure interface. The slip boundary condition is more realistic than the classical no-slip boundary condition in situations, e.g., when the structure is rough, and in modeling FSI dynamics near, or at a contact. Cardiovascular tissue and cell-seeded tissue constructs, which consist of grooves in tissue scaffolds that are lined with cells, are examples of rough elastic interfaces interacting with an incompressible, viscous fluid. The problem of heart valve closure is an example of a FSI problem with a contact involving elastic interfaces. We prove the existence of a weak solution to this class of problems by designing a constructive proof based on the time discretization via operator splitting. This is the first existence result for fluid-structure interaction problems involving elastic structures satisfying the Navier slip boundary condition.

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MS31

Uniform Stability to Non-Trivial Equilibrium of a Nonlinear Fluid-Structure Interaction Via Interface and Interior Feedback

We consider uniform stability to a nontrivial equilibrium of a nonlinear fluid structure interaction (FSI) defined on a two or three dimensional bounded domain. This is obtained by implementing a fully supported interior feedback on the fluid domain active together with either an interface or localized interior feedback applied to the solid domain. The proof is based on the multipliers method with the key multiplier constructed from Stokes-Dirichlet solver fed to the fluid via boundary traces on the interface.

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MS32

The Rigorous Derivation of Focusing NLS from Quantum Many-Body Systems

It is widely believed that NLS describes the physical phenomenon Bose-Einstein condensation, a new state of matter which consists of a large number of particles. In this talk, we consider the validity of this belief. We study focusing quantum many-body dynamics which model dilute bose gas in 1D, 2D, and 3D. We prove rigorously that the 1D and 2D focusing cubic NLS arises as the mean-field limits of such many-body dynamics when the particle number tends to infinity.

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MS32

On-Site and Off-Site Solitary Waves of Discrete Nonlinear Schrödinger Type Equations and the Peierls-Nabarro Barrier

We construct families of symmetric solitary standing waves to the discrete nonlinear Schrödinger equation (DNLS) with cubic nonlinearity using bifurcation methods about the continuum limit. Such waves play a role in the propagation of localized states of DNLS. Their energy differences, which we prove to be exponentially small in a natural parameter, are related to the “Peierls-Nabarro Barrier” in discrete systems. We discuss both the nearest-neighbor case and more general long-range (nonlocal) coupling.

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MS32

Existence and Stability Considerations for Schrodinger-Poisson Excited States with a Potential

In this work, we consider the Schrodinger-Poisson equation with a Coulomb-like external potential. We discuss the existence of excited steady state solutions and their stability.

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MS32

On Dispersive Blow-Ups for Nonlinear Schrödinger Equations

In this talk, we provide a simple method for constructing solutions to nonlinear Schrödinger equations that develop point singularities (so called dispersive blow-up solutions). Our construction mainly follows the approach by Bona-Ponce-Saut-Sparber, but we make use of the dispersive estimate to enjoy the smoothing effect of the Schrödinger propagator in the integral term appearing in the Duhamel's formula. In this way, not only do we simplify the argument, but we also reduce the regularity requirement for such construction. We also provide more examples of dispersive blow-ups.

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MS33

Spectral Analysis of a Complex Schrdinger Operator in the Semiclassical Limit

We consider the Dirichlet realization of the operator $-h^2\Delta + iV$ in the semi-classical limit $h \to 0$, where V is a smooth real potential with no critical points. For a one dimensional setting, we obtain the complete asymptotic expansion, in powers of h, of each eigenvalue. In two dimensions we obtain the left margin of the spectrum, under some additional conditions. Joint work with Rapahael Henry

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MS33

Title Not Available at Time of Publication

Abstract not available at time of publication.

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MS33

Distances Between Classes in $W^{1,1}(\Omega, S^1)$

Let Ω be a simply connected domain in $\mathbb{R}^N$. One can decompose the space $W^{1,1}(\Omega, S^1)$ to distinct classes using the equivalence relation: $u \sim v$ iff $\exists \varphi \in W^{1,1}(\Omega, \mathbb{R})$ such that $u = e^{i\varphi}v$. In this talk, based on a joint work with Brezis and Mironescu, we will present estimates for the usual distance and the Hausdorff distance between different classes.

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MS33

A Degenerate Isoperimetric Problem and Traveling Waves to a Hamiltonian System of Allen-Cahn Type

We analyze a non-standard isoperimetric problem in the plane associated with a metric having degenerate conformal factor at two points. Under certain assumptions on the conformal factor, we establish the existence of curves of least length under a constraint associated with enclosed Euclidean area. As a motivation for and application of this isoperimetric problem, we identify these isoperimetric curves, appropriately parametrized, as traveling wave solutions to a bi-stable Hamiltonian system of PDE's. This is joint work with Andres Contreras, Lia Bronsard, Stan Alama and Jiri Dadok.

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MS34

Nonlinear Stability of the Three Dimensional Couette Flow

Abstract not available at time of publication.

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MS34

Long-Time Behavior of Models Arising in Water Waves

We discuss the long-time behaviour of some dispersive equations that arise in the study of water waves.

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MS34
Quasilinear Dispersive Waves

Abstract not available at time of publication.

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MS34
Global Solutions for Some Fluid Models

Abstract not available at time of publication.

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MS35
The Primitive Equations: Viscous and Inviscid Models

Abstract not available at time of publication.

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MS35
Observations on the Vanishing Viscosity Limit

I will speak of several recent observations regarding the vanishing viscosity limit in 2D and 3D in the presence of a boundary.

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MS35
Robust Numerical Methods for Boundary and Interior Layers in Parabolic Problems

To construct layer adapted meshes for singularly perturbed problems, it is necessary to identify both the location and the width of any boundary layers present in the solution. Interior layers can also appear and typically require the introduction of a transformation of the problem, which facilitates the necessary alignment of the mesh to the location of the interior layer. Both the analytical nature of interior layers and their associated discrete approximations will be discussed.

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MS35
On the Long Time Existence of the Prandtl Equations

We consider the Prandtl equations on the half space with initial datum that is real-analytic with respect to the tangential variable. The boundary traces of the horizontal Euler flow and Euler pressure are taken to be constants. We prove that if the initial datum lies within ϵ of a stable boundary lift profile, then the time of existence for the solution of the Prandtl equation is at least $\exp(\epsilon^{-1}/\log(\epsilon^{-1}))$. This is a joint work with M. Ignatova.

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MS36
Nonlocal Electrostatics in Molecular Biology: Water as a Structured Material

Continuum models of solvent-mediated electrostatic interactions between biomolecules offer valuable insights when atomistic molecular-dynamics simulations are too expensive. Classical Poisson approaches use macroscopic dielectric theory for biological water, neglecting water's nanoscale structure. Here we present a nonlocal theory that includes these effects and can be solved efficiently with existing PDE methods, and outline important areas for future modeling.

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MS36
The Richness of Fractional Integro-Differential Operators Defined by Convolution with the Lévy Measure

We start with the view that the operators in a Fokker-Planck equation are defined by the underlying natural process: Brownian motion defines the diffusion equation because the Fourier picture of its Gaussian density function defines a second-order PDE. A natural generalization of Brownian motion is Lévy motion, which is the limit of random walks with infinite variance in at least one direction. Concentrating on the infinite-variance portion only, the density P of a multi-dimensional (multi-scaling) Lévy motion follows a generalized diffusion equation that can be written $P_t = D\nabla_M^{H^{-1}} P$, where D is a scalar diffusion coefficient, H^{-1} is the inverse of the matrix of Hurst coefficients or growth rates of the density, and $M(\theta)$ is a measure of the jump propensity in all directions θ. This general (matrix-order) differential operator is defined by convolution with the Lévy measure. A few examples illustrate the construction: For Brownian motion, the growth rate is isotropic, so $H = diag(1/2), H^{-1} = 2I$, $DM(\theta)$ reverts to the covariance matrix, and the second-order diffusion equation is recovered. In 1-d, there is only one growth rate $H = 1/\alpha$, so $H^{-1} = \alpha$, and $M(\theta) = p(-1) + q(1)$. In

this case, $P_t = Dp(\partial^\alpha P/\partial(x)^\alpha) + Dq(\partial^\alpha P/\partial(-x)^\alpha)$. The relative weights $p + q = 1$ describe skewness in 1-d. The inverse of the multi-order fractional differential operator just described can be used to generalize fractional Brownian motion to have different Hurst coefficients in different directions, along with completely general weights of convolutions in all directions via $M(\theta)$. This talk will show examples of solutions of all of these PDEs and integral equations with emphasis on pollution migration in granular and fractured aquifer material.

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MS36

Heterogeneous Domain Decomposition Methods for Non-local Problems

Heterogeneous domain decomposition methods involve multiple mathematical and/or numerical models operating in different parts of the computational domain. A key challenge is formulation of coupling approaches that allow stable, accurate and physically consistent coupling of the individual models. In this talk we consider an optimization-based approach for heterogeneous domain decomposition for problems involving non-local material models.

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MS36

Computing of Ion-ion Correlations with Nonlocal Density Functional Theory

There are a number of different continuum theories to determine the structure of ions in the electrical double layer (EDL), but many breakdown with high surface charges, high ion concentrations, or high ion valences. In these regimes, ion-ion correlations dominate the EDL structure. Density functional theory of electrolytes is a continuum theory that computes these correlations using nonlocal concentrations. Analysis shows these locally averaged concentrations are required to get the EDL structure correct.

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MS37

Multiscale Mimetic Reduced-Order Models for Spectrally Accurate Wavefield Simulations

Reduced order models approximate transfer functions of large-scale linear dynamical systems by small equivalent ones. We discuss some recent applications of this powerful approach to the numerical solution of multi-scale hyperbolic elasticity problems. By treating our models as composite materials and approximating response of their components via matrix continued fractions, we obtain spectrally accurate discretization scheme with sparsity patter mimicking second order finite-difference schemes.

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MS37

Homogenization of a Toy Model of Non-Linear Composites

We introduce and study a class of models motivated by particle reinforced plastic materials. We obtain a bound on the yield stress of the composites. This bound depends on the shape of the particles. With examples we show that our bound is sharp.

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MS37

Some Recent Mathematics Progress on Negative Index Materials and Their Applications

The Helmholtz equations with sign changing coefficients are used to model negative index materials. These materials are artificial structures whose refractive index are negative over some frequency range. These materials were first investigated theoretically by Veselago in 1964 and their existence was confirmed experimentally by Shelby et al. in 2001. The study of these equations faces two difficulties. First the ellipticity and the compactness are lost in general due to the changing sign coefficients. Second, the localized resonance, i.e., the fields blow up in some regions and remain bounded in some others as the loss (the viscosity) goes to 0, might occur. In this talk, I will discuss various conditions for which the equations are stable or unstable.

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MS37

Optimal Approach for the Numerical Stochastic Homogenization of Elliptic Problems

We consider the numerical stochastic homogenization of elliptic problems for a material with circular inclusions so that the permittivity is piecewise constant. There are three sources of error when calculating the effective coefficient: the discretization error, the statistical error, and error due to a finite domain. We model all three errors for our implementation and by optimizing the number of samples, the fineness of the mesh, and the size of the domain, we arrive at the optimal approach.

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MS38

The Metric-Restricted Inverse Design Problem

We study a class of design problems in solid mechanics, leading to a variation on the classical question of equidimensional embeddability of Riemannian manifolds. In this general new context, we derive a necessary and sufficient existence condition, given through a system of total differential equations, and discuss its integrability. In the classical context, the same approach yields conditions of immersibility of a given metric in terms of the Riemann curvature tensor. We also recast the problem in a variational setting and analyze the infimum value of the appropriate incompatibility energy, resembling the non-Euclidean elasticity.

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MS38

Limits of Elastic Energies of Converging Elastic Bodies

In non-Euclidean (incompatible) elasticity, an elastic body is typically a Riemannian manifold, and the elastic energy measures its failure to be immersed isometrically in the Euclidean space. A natural questions is whether this model is stable under Γ-convergence when the manifolds (elastic bodies) converge. In this talk I will show that the answer is affirmative for an appropriate notion of convergence of manifolds, give an upper Γ-limit bound for a weaker form of convergence, and discuss the results' applications to the mechanics of bodies with continuous distributions of dislocations.

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MS38

Plates with Incompatible Prestrain of Higher Order

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

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MS38

Energy Scaling Laws for an Axially Compressed Thin Elastic Cylinder

A longstanding problem in elasticity is to identify the minimum energy scaling law of a crumpled elastic sheet as thickness tends to zero. Though much is known about scaling laws in tensile settings, the compressive regime is mostly unexplored. I will discuss the case of an axially confined thin elastic cylinder which is prevented from inward displacement by a hard mandrel core. My focus will be the minimum energy scaling in the Foppl-von Karman model.

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MS39

Willmore Surface Equation for Radially Symmetric Solutions

We classify the radially symmetric solutions to the Willmore surface equation defined over a disk or a punctured disk. In particular, we show that the smooth radially symmetric solutions defined on the entire plane must be constant.

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MS39

Curvature Flows on Homogeneous Spaces: Applications of the Bracket Flow

The bracket flow is a way of viewing a geometric flow of Riemannian metrics on homogeneous spaces as a flow of structure constants on the Lie algebra. Much work has been done in this context on Ricci flow, especially as a way of studying generalizations of Einstein manifolds such as Ricci solitons. We will focus primarily on the use of the bracket flow to study deformations of the Ricci flow, especially the two loop renormalization group (RG-2) flow on left invariant metrics of 3D unimodular Lie groups.

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MS39

Asymptotic Rigidity of Shrinking Gradient Ricci Solitons

Shrinking gradient Ricci solitons (SGRS) are generalizations of positive Einstein metrics and are models for the local geometry about a developing singularity under the Ricci flow. At present, all known examples of complete noncompact SGRS are either locally reducible as products or possess conical structures at infinity. I will describe joint work with Lu Wang in which we investigate the rigidity of such asymptotic structures as a problem of parabolic unique continuation.

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MS39

Łojasiewicz-Simon Gradient Inequalities with Applications to Yang-Mills Pairs and Harmonic Maps

Łojasiewicz-Simon gradient inequalities have become increasingly interesting by their wealth of potential applications. In this talk we outline the proof of an abstract version of a Łojasiewicz-Simon gradient inequality established under very weak assumptions and its applications for coupled Yang-Mills energy functionals and the harmonic map energy functional.

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MS40

Compressible Navier-Stokes Equations with Thermodynamically Unstable Pressure and Anisotropic Viscous Stress

We provide global existence of weak solutions for the compressible Navier-Stokes equations for more general stress tensor than those covered by P.-L. Lions and E. Feireisl's theory. More precisely we focus for instance on more general pressure laws which are not thermodynamically stable but include some important physical cases such as virial expansions; We are also able to handle some anisotropy in the viscous stress tensor. To give answers to these two open problems, we revisit the classical compactness theory on the density by obtaining precise quantitative regularity estimates: This requires harmonic analysis tools and more precise analysis of the structure of the equations. Joint work with P.–E. Jabin (University of Maryland).

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MS40

Weak Vs. Strong Solutions to Complete Fluid Systems

We discuss certain problems arising as inviscid limits in fluid dynamics. We show several examples of *ill-posedness* of these problems in the framework of weak solutions even when appended by standard admissibility criteria. Then we identify a class of problems that are *well-posed* in the class of (admissible) weak solutions and can be identified as the corresponding inviscid (vanishing viscosity) limit. Finally, we present some results about the existence of the vanishing dissipation limit for complete fluid systems.

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MS40

Weak/Strong Uniqueness for the Compressible Euler System

For the incompressible Euler equations, DiPerna and Majda showed the global existence of measure-valued solutions for any initial data with finite energy. The main point was to introduce the so-called generalised Young measures, which take into account not only oscillations, but also concentrations. I will discuss the issue of weak-strong uniqueness in the class of admissible measure-valued solutions for the isentropic Euler equations in any space dimension.

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MS40

Existence of Global Strong Solution for the Korteweg System

In this talk we will discuss the existence of local and global strong solutions with discontinuous initial density for the Korteweg system. The main difficulty concerns the proof of new estimates of maximum principle type for the linear system associated to the Korteweg system, this is based on a characterization of the Besov space in terms of the semi group associated to this linear system. We will introduce the notion of quasi-solutions for the Korteweg's system which enables us to obtain the existence of global strong solution with a smallness condition which is subcritical for the scaling of the equations. It allows us when $N = 2$ to exhibit a family of large energy initial data providing global strong solution. As a corollary, we get global strong solution for highly compressible Korteweg system when $N \geq 2$ (which corresponds to a high Mach number regime).

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MS40

Two Velocity Formulation of the Navier-Stokes Equations

This talk will be devoted to existence result for the low Mach number limit system obtained from the full compressible Navier-Stokes model with density-dependent viscosities. We will first present derivation of the incompressible system called Kazhikhov-Smagulov model. Under special compatibility condition between the viscous tensor and the diffusive term we will prove the existence of global in time weak solutions [1]. The proof relies on the use of new relative velocity, which is divergence free and which allows to reduce the coupling between particular subsystems. We will also mention possible generalizations of constraints appearing in the system and present an application to the full compressible system [2], which together with [3] yields the existence of solution. [1] D. Bresch, V. Giovangigli, E. Zatorska. Two-velocity hydrodynamics in fluid mechanics: Part I Well posedness for zero Mach number systems, JMPA, Volume 104, Issue 4, October 2015, Pages 762800. [2] D. Bresch, B. Desjardins, E. Zatorska. Two-velocity hydrodynamics in fluid mechanics: Part II Existence of global

?-entropy solutions to compressible Navier-Stokes systems with degenerate viscosities, JMPA, Volume 104, Issue 4, October 2015, Pages 801836. [3] A. Vasseur, C. Yu. Existence of Global Weak Solutions for 3D Degenerate Compressible Navier-Stokes Equations, arXiv:1501.06803.

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MS41

Non-Markovian Reduced Equations for Stochastic PDEs

In this talk, a novel approach to deal with the parameterization problem of the small" spatial scales by the large" ones for stochastic partial differential equations (SPDEs) will be discussed. This approach relies on stochastic parameterizing manifolds (PMs) which are random manifolds aiming to provide in a mean square sense approximate parameterizations of the small scales by the large ones. Backward-forward systems will be introduced to determine such PMs as pullback limits in practice. These auxiliary systems will be used for the effective derivation of non-Markovian reduced stochastic differential equations from Markovian SPDEs. It will be shown that the corresponding non-Markovian terms allow in certain circumstances to restore in a striking way the missing information due to the coarse-graining, namely to parameterize what is not observed. Noise-induced large excursions or noise-induced transitions in a stochastic Burgers equation will serve as illustrations. This talk will be based on a joint work with Honghu Liu (UCLA) and Shouhong Wang (Indiana University).

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MS41

Shell Models for Turbulent Flows

We discuss the energy cascade in a Desnianskii-Novikov type shell model with stochastic forcing. The model results are consistent with Onsager's conjecture and Kolmogorov's "zeroth law of turbulence".

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MS41

Wasserstein Metrics in Stochastic Partial Differential Equations

We discuss two parameter limit problems in stochastic systems arising in fluids. Here the unifying theme is the use of contraction properties for the Markovian dynamics in a certain Wasserstein metric. In the first problem we consider the limit of infinite Prandtl (Pr) number in high Rayleigh (Ra) number convection. Here stochastic forcing in the bulk represents one of the sources driving the system. We show that statistically invariant states of the finite Pr system converge to those of the infinite Pr system in the limit Pr to ∞. Our second problem concerns the numerical approximation of the stochastic Navier-Stokes equations (SNSE). Here we establish suitable stability conditions for a large class of numerical schemes. Under this condition we then show that statistically invariant states of these discrete numerical approximations converge to those of the SNSE. This represents recent joint works with J. Foldes and G. Richards and with R. Temam and C. Wang.

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MS41

Computation of Entropic Measure-Valued Solutions for Euler Equations

Entropy stability plays an important role in the dynamics of hyperbolic systems of conservation laws. Entropic solutions need not be unique. Instead, they could be interpreted in an average sense as measure-valued solutions, part of an ensemble average in configuration space. We revisit the general framework of numerical entropy stability for difference approximations of such nonlinear equations. Our approach is based on comparing numerical viscosities with entropy conservative schemes. We demonstrate this approach with a host of high order entropic schemes. In particular, this paradigm serves as the building block for a class of non-oscillatory entropic schemes of arbitrarily high-order of accuracy, called TeCNO schemes. Numerical experiments provide a remarkable evidence for the effectiveness of the TeCNO schemes. These include recent TeCNO-based computation of entropy measure valued solutions.

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MS42

Quantum Dots and Dislocations: Dynamics of Materials Defects

The formation and assembly patterns of quantum dots have a signficant impact on the optoelectronic properties of semiconductors. We will address short time existence for a surface diffusion evolution equation with curvature regularization in the context of epitaxially strained three-dimensional films. We will discuss optimal faceted shapes of quantum dots and wetting in the case in which there are a non-vanishing crystallographic miscut and a lattice incompatibility between the film and the substrate. Existence of faceted minimizers. Further, the nucleation of misfit dislocations will be analyzed.

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MS42

Beyond the Burton-Cabrera-Frank (BCF) Model of Surface Defects: A Study in 1+1 Dimensions

In this talk, I will discuss recent work in describing corrections to a near-equilibrium mesoscale model, the Burton-Cabrera-Frank (BCF) theory, for line defects (steps) on crystal surfaces. Ingredients of the BCF model are: a diffusion equation for domains (terraces) between steps, a Robin boundary condition at steps, and a step velocity law by mass conservation. By restriction to 1+1 dimensions, I will describe corrections to this model, particularly nonlinearities appearing in the boundary conditions at steps. This is joint work with Joshua Schneider and Paul N. Patrone.

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MS42

PDEs From Scaling Limits of Atomistic Models in Crystal Surface Evolution

From joint work with J. Weare (Chicago), we discuss a class of 4th order PDEs arising from large crystal limits of an atomistic model for crystal surface evolution. We will discuss both the derivation from previous work and new work relating to the study of the PDEs themselves.

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MS42

Discrete and Continuum Models for the Long-range Elastic Effects of Stepped Epitaxial Surfaces

We present analysis results on the step bunching properties on epitaxial surfaces under elastic interactions, including the energy scaling law, the appearance of the bunch structure, and sharp bounds for bunch size.

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MS43

Numerical Schemes for the Hamilton-Jacobi Equation Continuum Limit of Non-dominated Sorting

Non-dominated sorting arranges a set of points in n-dimensional Euclidean space into layers by repeatedly peeling away the coordinatewise minimal elements. It was recently shown that non-dominated sorting of random points has a Hamilton-Jacobi equation continuum limit. The obvious numerical scheme for this PDE has a slow convergence rate of $O(h^{\frac{1}{n}})$. In this talk, we introduce two new numerical schemes that have formal rates of $O(h)$ and we prove the usual $O(\sqrt{h})$ theoretical rates.

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MS43

Congested Crowd Motion via the Height Constrained Aggregation Equation: Wasserstein Gradient Flow and Free Boundary Characterization

The Keller-Segel equation describes the motion of slime mold evolving according to the competing effects of chemical attraction and (possibly degenerate) diffusion. In the slow diffusion limit, one formally recovers a model of congested crowd motion. Motivated by this model, we extend results on the discrete gradient flow (or JKO) scheme for Wasserstein gradient flow to a more general class of nonconvex energies. We then apply this to give a free boundary characterization of the model.

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MS43

A PDE Approach to Prediction with Expert Advice

Prediction with expert advice is a classical problem in online learning, in which N experts predict in real time the outcomes of a data stream, and a learner tries to bid as close as possible to the best performing expert. The current talk investigates a PDE approach to prediction with expert advice in the case of two history-dependent experts on a binary data stream.

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MS43

Prediction Without Probability

We develop a PDE perspective on a model problem from the machine learning literature. The problem involves prediction via regret minimization. Our PDE approach identifies the optimal strategies and the associated outcomes in the continuum limit. While our PDE is very nonlinear, explicit solutions are available in many cases due to a surprising and convenient link to the linear heat equation. This is a joint work with my advisor Robert Kohn.

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MS44

Weak Anchoring for a Two-Dimensional Liquid Crystal

We study the weak anchoring condition for nematic liquid crystals in the context of the Landau-De Gennes model.

We restrict our attention to two dimensional samples and to nematic director fields lying in the plane, for which the Landau-De Gennes energy reduces to the Ginzburg–Landau functional, and the weak anchoring condition is realized via a penalized boundary term in the energy. We study the singular limit as the length scale parameter $\varepsilon \to 0$, assuming the weak anchoring parameter $\lambda = \lambda(\varepsilon) \to \infty$ at a prescribed rate. We also consider a specific example of a bulk nematic liquid crystal with an included oil droplet and derive a precise description of the defect locations for this situation, for $\lambda(\varepsilon) = K\varepsilon^{-\alpha}$ with $\alpha \in (0, 1]$. We show that defects lie on the weak anchoring boundary for $\alpha \in (0, \frac{1}{2})$, or for $\alpha = \frac{1}{2}$ and K small, but they occur inside the bulk domain Ω for $\alpha > \frac{1}{2}$ or $\alpha = \frac{1}{2}$ with K large.

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MS44

Line Defects in the Asymptotic Analysis of Landau-De Gennes Minimizers

We consider minimizers of the Landau-de Gennes energy functional in a three-dimensional domain. We are interested in the limit as the elastic constant of the medium tends to zero. This problem was already studied by Majumdar and Zarnescu (2010), who proved the convergence of minimizers to a harmonic map (i.e. a minimizer of the Oseen-Franck energy), possibly with point singularities. However, unlike Majumdar and Zarnescu, we suppose that the boundary datum has point disclinations. Then, the energy of minimizers is not uniformly bounded, but rather is comparable to the logarithm of the elastic constant. Moreover, minimizers converge to a locally harmonic map with singularities of dimension one (line defects) and, possibly, zero (point defects).

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MS44

The Micro-Micro Description for Elastic Complex Fluids

Abstract not available at time of publication.

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MS44

On the K13 Problem in the Oseen-Frank Theory of Nematic Liquid Crystals

Some of the most intriguing terms in the energy functionals corresponding to physical theories are the null Lagrangians. For liquid crystals, their effects and experimental determination, remain elusive. One such term is the so-called K13 term. It is well-known that the K13 term in the Oseen-Frank energy functional is compatible with the physical invariances, yet its presence makes the energy unbounded from below. For this reason it is usually ignored by physicists and mathematicians alike. We study critical points in the presence of the K13 term and show that there are no critical points unless the boundary conditions are either hometropic (normal) or tangential at almost all points. Furthermore for tangential boundary conditions the K13 term “overlaps with the ”tame null Lagrangian” the K24 term, but not so for hometropic bundary conditions. One can also obtain some partial regularity results in a suitable setting. This is joint work with Stuart Day (University of Sussex).

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MS45

Controllability of a Cochlea Model and Related Fluid Elastic Systems

The standard 2-dimensional cochlea model consists of a one-dimensional elastic structure which models the basilar membrane (BM) surrounded by an incompressible 2-dimensional fluid within the cochlear cavity. First we describe an idealized model in which the basilar membrane is modeled as an infinite array of oscillators and the fluid is described by Laplace’s equation. In this idealized setting we show that the coupled system is approximately controllable with control acting on an arbitrary open set of the basilar membrane. If the basilar membrane has longitudinal membrane (string) elasticity, then exact controllability can be proved. Related results for similar fluid elastic systems are described.

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MS45

Global Existence for a Fluid-structure Model

We address a fluid-structure system coupling the incompressible Navier-Stokes equations and a linear wave equation with interior damping. The interaction take place on 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.

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MS45

Interface Singularities in Fluid Dynamics

For both fluid-fluid and fluid-solid interfaces, an interesting question is whether or not the interface can self-intersect or collide with a fixed boundary in finite time. It will be shown that under certain natural conditions on the data, this cannot occur.

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MS45

Fluid-structure Interaction with Strongly Damped Structure: Optimal Regularity Under Control Acting at the Interface

We first consider a fluid-structure interaction model where now the structure is subject to strong damping with homogeneous coupling at the interface between the two media. We show that the corresponding free dynamics generates a sc semigroup that is analytic on the natural finite energy space. Moreover, the resolvent set of the generator contains the entire complex plane outside the negative real axis. Finally, such semigroup is exponentially stable with a sharp explicit exponential decay. Next we add a nonhomogeneous term (control) in the Neumann BC of the interface. We then find the optimal regularity of the corresponding "parabolic-like" problem. To this end, we need to characterize the domain of the square root of the generator of the entire system with coupled interface conditions.

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MS46

Recent Advances in the Pseudospectral Method

Implicitly dealiasing of pseudospectral simulations is twice as fast as explicit zero padding, but in 3D uses only 44% of the memory. An adaptive matrix transposition algorithm for hybrid architectures reduces communication costs and allows for a more slab-like decomposition. Nonblocking all-to-all transfers enable user computation and communication to be overlapped. Dynamic moment averaging allows one to extract accurate statistical averages over an arbitrary time window. Conservative integration is useful for verifying underlying dynamical symmetries.

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MS46

Uniformly Attracting Invariant Sets for Critical SQG Equations

We consider the global attractor of the critical SQG semigroup $S(t)$ on the scale-invariant space $H^1(\mathbb{T}^2)$. It is known that this attractor is finite dimensional, and that it attracts uniformly bounded sets in $H^{1+\delta}(\mathbb{T}^2)$ for any $\delta > 0$, leaving open the question of uniform attraction in $H^1(\mathbb{T}^2)$. We answer the question of uniform $H^1(\mathbb{T}^2)$ attraction in the positive, by using ideas from de Giorgi iteration and nonlinear maximum principles.

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MS46

A Diffuse Interface Model for Two-Phase Groundwater Flow

In this talk, we present a diffuse interface model for two-phase groundwater flow. We discuss the existence and uniqueness of global in time weak solution to the model in both 2D and 3D. Finally, some long time numerical simulations will be provided using the proposed model.

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MS46

Data Assimilation Using Approximate Inertial Manifolds

Abstract not available at time of publication.

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MS47

Title Not Available at Time of Publication

Abstract not available at time of publication.

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MS47

Title Not Available at Time of Publication

Abstract not available at time of publication.

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MS47

The Euler-Maxwell and Related Models

I will talk about various models from plasma physics and their relations with each other.

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MS48

Singularities in Jet and Bubble Breakup and Related Applications

In this talk we will review mathematical models for the evolution of thin inviscid, viscous and viscoelastic jets, describe some of their dynamical properties as well as relevant open analytical issues concerning the formation (or not) of singularities.

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MS48

Existence and Application of Cusps and Cuspidal Edges at Fluid Interfaces

An intriguing question in fluid dynamics is on the interrelation between dynamic singularities – unboundedness of the velocity field in an appropriate norm – and the geometric ones – divergence of curvature at fluid interfaces. In this talk I will focus on two generic interfacial singularities – genuine cusps and cuspidal edges – found in both two and three dimensions thus establishing a relation between real fluid interfaces and geometric singularity theory.

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MS48

Higher-Order PDE Describing Two-Phase Flow in Porous Media

A phase field model for two-fluid flow, developed by Cueto-Felgueroso and Juanes, results in a singular PDE with higher-order terms. We find traveling wave solutions of the PDE for different constitutive laws, describing flow in a capillary tube and in a Hele-Shaw cell. The behavior near the singularity is analyzed. Finite difference simulations of the injection of gas into water show a traveling wave advancing ahead of a diffusive wave.

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MS48

Healing Capillary Films

We study the dynamics of a converging thin film driven by surface tension. A nonlinear partial differential equation is obtained to describe the time evolution of the film thickness. A self-similar solution is obtained with the scaling exponent determined by solving a nonlinear eigenvalue problem. Laboratory experiments have also been conducted using various silicone oils, and the experimental observations are found in good agreement with the theoretical predictions.

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MS49

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MS49

Initial-Boundary Layer Associated with the Darcy-Brinkman-Oberbeck-Boussinesq Model for Convection in Porous Medium

In this talk, we will present the asymptotic analysis of the Darcy-Brinkman-Oberbeck-Boussinesq model for convection in porous medium at small Darcy number. The analysis involves singular structures both in space and time (boundary layer, initial layer, corner layer). We establish convergence results in Sobolev norms via energy method.

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MS49

Stability of Time Periodic Solutions of the Navier-Stokes-Maxwell System?

We study global wellposedness of a time periodic forced system of Magneto-Hydro-Dynamic equations. The system is a coupling of the incompressible Navier-Stokes equations with the Maxwell equations through the Lorentz force and Ohms law for the current. We first show the existence of global small time-periodic mild solutions. Then, we prove their asymptotic stability.

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MS49

Sharp Interface Limit of the Coupled Cahn-Hilliard-Stokes-Darcy System

We investigate the sharp interface limit of the coupled Cahn-Hilliard-Stokes-Darcy system which models two-phase flows in karstic geometry. We show that the sharp interface limit of the Cahn-Hilliard-Stokes-Darcy system is the sharp interface model for two-phase problem in karstic geometry in the sense of varifold.

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MS50

On the Optimal Control of Parabolic Free Boundary Problems

This lecture will present recent advances made in solving inverse free boundary problems. A new variational formulation based on optimal control framework is employed, where unknown boundary data/coefficients of the PDE and free boundary are components of the control vector, and optimality criteria allows us to tackle situations when the phase transition temperature is not known explicitly, and is available through measurement with possible error. It also allows for the development of iterative numerical methods of least computational cost due to the fact that for every given control vector, the parabolic PDE is solved in a fixed region instead of full free boundary problem. We prove well-posedness in Sobolev spaces framework, perform full discretization and prove convergence of discrete optimal control problems to the original problem both with respect to cost functional and control, and Frechet differentiability and application of iterative projected gradient methods in Hilbert space framework.

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MS50

A Necessary and Sufficient Condition for the Continuity of Local Minima of Parabolic Variational Integrals with Linear Growth

For a proper weak solution u of the parabolic 1-laplacian, we establish a necessary and sufficient condition for u to be continuous at a point, in terms of a sufficient fast decay of the local integral of the gradient Du. These equations arise as minima of parabolic variational integrals with linear growth with respect to $|Du|$. Hence, the continuity condition is in force for such minima.

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MS50

Reconstruction in Phaseless Inverse Scattering Problems

The Phaseless Inverse Scattering Problems (PISPs) arise in applications to imaging of microstructures of sizes of the micron range of less. Only the intensity rather than the phase can be measured in these applications. Reconstruction procedures for 3-d PISPs will be presented. Quite surprising they are based on the solutions of Inverse Kinematic Problem, the Problem of Integral Geometry and the Radon transform.

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MS50

On the Optimal Control of the Inverse Multiphase Stefan Problem

We consider the inverse multiphase Stefan problem, where the fixed boundary heat flux is unknown as well as the temperature and free boundaries. Optimal control framework is pursued, with boundary heat flux as the control. Full discretization through finite differences is implemented and discrete optimal control problem is introduced. We prove well-posedness in Sobolev spaces framework and convergence of discrete optimal control problems to the original problem both with respect to cost functional and control.

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MS50

SDEs and Optimal Control, a Method of Evolving Junction

In this talk, we will use the shortest path problem as an example to illustrate how one can connect optimal control, stochastic differential equations and partial differential equations together to solve some challenging real world problems, such as path planning. On the other end, we will show what new and challenging mathematical problems can be raised from those applications. The talk is based on a joint work by Shui-Nee Chow, Wuchen Li, Jun Lu and Haomin Zhou.

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MS51

Bilayers and Multilayers in Copolymer-solvent Blends

Amphiphilic molecules like those in block copolymers have a tendency to form localized, layered structures of alternating composition. A continuum model is considered which formulates this problem in terms of coupled equations describing macroscopic and microscopic phase segregation. Certain distinguished limits of parameters give rise to a free boundary problem describing layers domains. A Legendre transform of the bulk potential to a Hamiltonian system which can be completely solved. Stability of the resulting solutions is determined by analyzing the limiting energy.

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MS51

Continuum Model of Cyanobacteria Motion

In a recent work, Levy and Galante modelled the motion of the cyanobacteria Synechocystis using a large system of ODE's on a lattice. We consider their model in the limit large number of lattice bins. We obtain a novel reaction-diffusion PDE system as a limiting case. We then characterize explicitly the steady states of the system which look like spikes. These spiky states correspond to bacterial aggregations, and they bifurcate off the homogeneous state. We explicitly compute this bifurcation as a function of certain parameters. The spikes appear to be stable numerically, but it remains an open problem to characterize their stability analytically. Joint work with Paul Chavy-Waddy (Dalhousie).

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MS51

Vibrational Patterns of Thin Plates with Clamped Patches

In this talk I will discuss the problem for the modes of vibration of a thin elastic plate with a collection of N small clamped patches. This talk will center on several fourth order eigenvalue problems and analysis of these in the limit of small patch size. These N patches represent defects in the plate and the main goal is to understand the effect of the number and location of these holes on the vibrational modes of the plate. The deviation of the eigenvalues from the patch free case are quantified and certain configurations which maximize this deviation for certain N are identified.

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MS51

Refined Stability Thresholds for Steady-State Multi-Spot Solutions to Reaction-Diffusion Systems in Finite 2-D Domains

The linear stability of steady-state patterns of localized spots in a bounded domain $\Omega \in \mathbf{R}^2$ for the two-component Gierer-Meinhardt (GM) and Schnakenburg reaction-diffusion models is analyzed in the semi-strong interaction limit corresponding to an asymptotically small diffusion coefficient ϵ^2 of the activator concentration. In the limit of large inhibitor diffusivity D, where $D = \mathcal{O}(-\log \epsilon)$, it is well-known through the derivation and analysis of a nonlocal eigenvalue problem that, to leading-order in $-1/\log \epsilon$, the stability threshold value for D depends only on the number of spots and the area of Ω. By using a combination of asymptotic analysis and spectral theory, we derive a two-term expansion for this threshold, where the second term depends on the spatial configuration of the spots through a Green's interaction matrix. Furthermore, we show, rather surprisingly, that there is only a rather narrow parameter regime where Hopf bifurcations of the spot amplitudes can occur. Finally, we compare our results for the finite domain with corresponding results obtained recently for the stability threshold of periodic patterns of localized spots in $\mathbf{R}^2$.

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MS52

D-Bar Problems: Computation, Asymptotics, and Applications

The goal is to understand the asymptotic behavior of integrable nonlinear PDE's in 2 spatial dimensions, and the sticking point is semi-classical analysis of Complex Geometrical Optics solutions of $\overline{\partial}$-problems.

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MS52

Global Solutions for the Zero-Energy Novikov-Veselov Equation by Inverse Scattering

Using the inverse scattering method, we construct global solutions to the Novikov-Veselov equation at zero energy for decaying initial data q_0 with the property that associated Schrödinger operator $-\bar{\partial}\partial + q_0$ is nonnegative. These results considerably extend previous results of Lassas-Mueller-Siltanen-Stahel and Perry. Our analysis draws on previous work of the first author and on ideas of S. V. Manakov and P. Grinevich.

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MS52

Direct Scattering and Small Dispersion for the Benjamin-Ono Equation with Rational Initial Data

We propose a construction procedure for the scattering data of the BO equation with a rational initial condition, under mild restrictions. We will show that for a certain class of initial conditions, the recovery of the scattering data can be done explicitly using the analyticity properties of the Jost functions. We will finish by showing that our formulas validate well-known formal asymptotic results obtained in the zero-dispersion limit.

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MS52

A Spectral Problem Related to the Scattering Transform of the Benjamin-Ono Equation

The Benjamin-Ono equation models internal waves in deep stratified fluids. It was discovered to be completely integrable by Fokas, Ablowitz and Anderson. A rigorous justification of the direct scattering transform requires a spectral analysis of a singular integral perturbation of the derivative operator. In this talk, we will discuss a few key properties of the spectrum that are useful for the scattering method.

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MS53

The Quilted Atiyah-Floer Conjecture and the Yang-Mills Heat Flow

We will begin by discussing a variant of the Atiyah-Floer conjecture that is well-posed for 3-manifolds with positive first Betti number. Then we will mention some recent progress towards a proof that involves the Yang-Mills heat flow in a crucial way.

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MS53

Global Existence and Convergence of Smooth Solutions to Yang-Mills Gradient Flow over Compact Four-Manifolds

We describe our results on global existence and convergence of smooth solutions to the gradient flow equation for the Yang-Mills energy functional on a principal bundle, with compact Lie structure group, over a closed, four-dimensional, Riemannian, smooth manifold. If the initial connection is close enough to a minimum of the Yang-Mills energy functional, in a norm or energy sense, then we prove that the Yang-Mills gradient flow exists for all time and converges to a Yang-Mills connection.

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MS53

Higher Order Yang-Mills Flow

We define a family of functionals generalizing the Yang-Mills functional. We study the corresponding gradient flows and prove long-time existence and convergence results for subcritical dimensions as well as a bubbling criterion for the critical dimensions. Consequently, we have an alternate proof of the convergence of Yang-Mills flow in dimensions 2 and 3 given by Rade and the bubbling criterion in dimension 4 of Struwe.

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MS53

Generalized Kahler Ricci Flow

I will discuss a geometric evolution equation extending the Kahler-Ricci flow to the setting of generalized Kahler geometry. I will discuss long time existence and convergence results for this flow which lead to topological classification results. These works stem from the "pluriclosed flow" introduced in my joint works with G. Tian.

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MS54

The Nonlinear Stage of the Modulational Instability

First I will review how the modulational instability manifests itself in the context of the inverse scattering transform (IST) for the focusing nonlinear Schrodinger (NLS) equation with non-zero boundary conditions. Then I will characterize the nonlinear stage of modulational instability by computing the long-time asymptotic behavior of solutions of the focusing NLS equation with initial conditions that are a small perturbation of a constant background. In the long-time asymptotics, the xt-plane divides into three regions: a left far field and a right far field, in which the solution equals the boundary condition to leading order, and a central region in which the asymptotic behavior is described by a slowly modulated elliptic solution.

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MS54

Forward Scattering for the Semiclassical Three Wave Equation

The three-wave resonant interaction equations model the evolution of three electrical pulses in a dispersive medium with quadratic linearity. Typical phenomena include the interaction of two soliton waves in two separate channels leading to the creation and eventual annihilation of a pulse in the third channel. Since interactions in these materials can be induced more rapidly than in those with cubic nonlinearities, the model has sparked interest in alternate possibilities for designing feasible all-optical switching devices. We analyze the small-dispersion (or semiclassical) behavior using the inverse scattering formalism. We present analytic results on the WKB approximation of the scattering data, as well as a numerical study of exact solutions that suggests semiclassical behavior (i.e. approximation of solutions by modulated elliptic functions) similar to that seen in other nonlinear wave equations such as the KdV, NLS, and sine-Gordon equations. This work is joint with Robert Jenkins and Peter Miller.

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MS54

Inverse Scattering and Long-Time Asymptotics for the Derivative Nonlinear Schrodinger Equation

The Derivative Nonlinear Schrodinger Equation (DNLS) is a nonlinear dispersive wave equation modeling Alfven waves in plasma physics. In this talk I will present a rigorous analysis of the direct and inverse scattering map in some weighted Sobolev spaces for DNLS. We will also compute the long time asymptotics of the solution. This is a joint work with P. Perry and C. Sulem.

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Catherine Sulem
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MS54

Initial-Boundary Value Problems of Integrable Systems

It is well known that the difficulty of deriving the solution of initial-boundary value problems of integrable systems arises mainly from the fact that the scattering data required to construct the waveform involve boundary data that are not known a priori. We will describe a spectral dynamics approach to this problem.

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MS55

Primitive Equations and Convergence to the 3D-Quasi-Geostrophic Model

In this talk we are interested in the asymptotics for the solutions of the primitive equations in the whole space, when the influence of the rotation and the vertical stratification of the density are strong (modelized by a small parameter). The limit system (called the 3D-quasi-geostrophic system) involves a non-local non-radial diffusion operator. The precise study of this operator and the use of dispersive estimates will be required to obtain a large lower bound (in terms of the small parameter) for the lifespan of the solutions of the primitive equations and the convergence.

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MS55

Navier-Stokes Equations of Slightly Compressible Flows

We aim at presenting recent results for the Compressible Navier-Stokes system concerning the case when the divergence of the velocity is close to zero. This assumption is controlled by the suitable magnitude of the bulk (volume) viscosity. The limit as that viscosity is going to infinity is also discussed. The considerations are done for regular solutions. The talk will be based on joint result with Raphael Danchin (Paris).

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MS55

On Multiphase Flows: Modeling and Analysis

Abstract not available at time of publication.

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MS55

Global Existence of Solutions to the 3D Navier-Stokes Equations with Degenerate Viscosities

We prove the existence of global weak solutions for 3D compressible Navier-Stokes equations with degenerate viscosities. The method is based on the Bresch and Desjardins entropy. The main contribution is to derive the Mellet-Vasseur type inequality for the weak solutions, even if it is not verified by the first level of approximation. This provides existence of global solutions in time, for the compressible Navier-Stokes equations, for any $\gamma > 1$ in three dimensional space, with large initial data, possibly vanishing on the vacuum.

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MS56

Hölder Gradient Estimates for Parabolic Homogeneous p-Laplacian Equations

We prove interior Hölder estimates for the spatial gradient of viscosity solutions to the parabolic homogeneous p-Laplacian equation

$$u_t = |\nabla u|^{2-p} \operatorname{div}(|\nabla u|^{p-2}\nabla u),$$

where $p \in (1, \infty)$. This equation arises from tug-of-war-like stochastic games with noise. It can also be considered as the parabolic p-Laplacian equation in non divergence form.

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MS56

Variational Models for Crystal Image Analysis

Abstract not available at time of publication.

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MS56

A Non-local Variational Problem Arising from Studies of Nonlinear Charge Screening in Graphene Monolayers

This talk is concerned with energy minimizers in an orbital-free density functional theory that models the response of massless fermions in a graphene monolayer to an out-of-plane external charge. The considered energy functional generalizes the Thomas-Fermi energy for the charge carriers in graphene layers by incorporating a von-Weizsaecker-like term that penalizes gradients of the charge density. Contrary to the conventional theory, however, the presence of the Dirac cone in the energy spectrum implies that this term should involve a fractional Sobolev norm of the square root of the charge density. We formulate a variational setting in which the proposed energy functional admits minimizers in the presence of an out-of-plane point charge. 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. In addition, a bifurcation from zero to non-zero response at a finite threshold value of the external charge is proved.

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MS56

Motion by Mean Curvature for a Second Order Gradient Theory

We prove in a radially symmetric geomety, the convergence in the sharp interfacial limit, to motion by mean curvature of a second order gradient model for phase transition. This is in spirit similar to the classical Allen-Cahn theory of phase boundary motion. However the corresponding dynamical equation is fourth order thus creating some challenging difficulties for its analysis. A characterization and stability analysis of the optimal profile are performed which are in turn used in the proof of convergence of an asymptotic expansion.

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MS57

Numerical Methods for Anisotropic Curvature Flow of Networks of Surfaces

I will describe recent progress in extending Merriman, Bence, and Osher's threshold dynamics (MBO) algorithm for mean curvature motion (which in its original form works only for networks with isotropic and equal suface tensions) to grain boundary networks where the surface energy of each interface can potentially have a different anisotropic (normal dependent) energy density. Joint work with Matt Elsey and Felix Otto.

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MS57

Novel Techniques for Integrating over Implicitly Defined Curves and Surfaces

We describe new formulations for integrating over smooth curves and surfaces that are described through a level set function or directly by their closest point mapping. Contrary to the common practice with level set methods, the volume integrals derived from our formulations coincide exactly with the surface or line integrals that one wish to compute. With these formulations, one can solve elliptic boundary value problems on implicitly defined domains using boundary integral methods. We present numerical results in two and three dimensions. Joint work with Richard Tsai (UT Austin and KTH Royal Institute of Technology).

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MS57

Fast Numerical Methods for Optimal Transportation for General Costs

Optimal transportation comes with natural linear programming interpretation. However linear programming approach suffers two long-standing problems: high computational cost which has prevented its wide applications and sensitivity to discretization that makes it difficult to recover optimal transport map. With these issues in mind, we develop a multi-scale linear programming solver, which is faster than ordinary solver and able to tackle large scale problems. To recover optimal transport map, we introduce a barycentric projection approach, rigorous proof of convergence is provided. Inherent in our approach is its ability to deal with general costs.

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MS57

Numerical Methods for the 2-Hessian Elliptic Partial Differential Equation

In this talk we focus on the elliptic 2-Hessian equation, a fully nonlinear partial differential equation. We explain why the naive finite difference method fails and provide explicit, semi-implicit and Newton solvers that perform better by enforcing a convexity type constraint needed for the ellipticity of the equation itself. We build a monotone wide stencil finite difference discretization, which is less accurate but provably convergent as a result of the Barles-Souganidis theory. Computational results are presented.

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MS58

Recent Progress on the Exterior Domain Problem on a Hyperbolic Plane

The exterior domain problem has a satisfactory answer in three dimensions in the Euclidean setting, but it is open in two dimensions. We describe a recent progress on the exterior domain problem in two dimensions on a hyperbolic plane.

Magdalena Czubak
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MS58

Small Moving Rigid Body into a Viscous Fluid

We consider rigid bodies moving under the influence of a viscous fluid and we study the asymptotic as the size of the solids tends to zero. In a bounded domain, if the solids shrink to "massive' pointwise particles, we obtain a convergence to the solution of the Navier-Stokes equations independently to any possible collision of the bodies with the exterior boundary. In the case of "massless' pointwise particles, the energy equality is not sufficient anymore to derive a uniform estimate for the velocity of the solid. Our basic remark is that the small obstacle limit is related to the long-time behavior though the scaling property of the Navier-Stokes equations $u^\varepsilon(t,x) = \varepsilon^{-1}u^1(\varepsilon^{-2}t, \varepsilon^{-1}x)$. Hence, we derive L^p-L^q decay estimates for the linearized equations in the exterior of a unit disk. We then apply these estimates to treat the massless pointwise particle. These works are in collaboration with S. Ervedoza, M. Hillairet and T. Takahashi.

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MS58

An Anisotropic Partial Regularity Criterion for the 3D Incompressible Navier-Stokes Equations

We address the partial regularity of suitable weak solutions of the incompressible Navier-Stokes equations. We prove an interior regularity criterion involving only one component of the velocity. Namely, if (u,p) is a suitable weak solution and a certain scale-invariant quantity involving only u_3 is small on a space-time cylinder $Q_r(x_0,t_0)$, then u is regular at (x_0,t_0).

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MS58

Recent Developments on the Magnetohydrodynamics and Related Systems

Magnetohydrodynamics system is obtained through a coupling of the Navier-Stokes and the Maxwell's equations and describes the motion of electrically conducting fluids. We discuss recent developments on the mathematical analysis of this system from both deterministic and stochastic perspectives, along with other systems of relevance, such as the Boussinesq system, micropolar and magneto-micropolar fluid systems.

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MS59

Large System Limits in Control of Multi-Vehicular Formations

One of the main issues of large-scale formation and vehicular control problems is the role that interaction or network topology plays in determining the best achievable performance. This problem involves the quantification of performance bounds for a large class of interaction rules, rather than exploring the collective behavior induced by a specific set of rules. We use results for regular topologies like lattices and fractal networks to conjecture how more general topologies may be studied. For regular topologies, analysis of the bounds for large networks can be related to properties of the Laplacian operator in that geometry as a continuum limit. The analysis is however somewhat different than standard diffusive dynamics, where more complex node dynamics gives rise to a continuum limit of more general PDEs.

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MS59

Phase Transitions in a Kinetic Cucker-Smale Model with Preferred Speed and Diffusion

Swarming models simulate the collective dynamics of large groups of organisms such as insects, fish, birds, and mammals. Mathematically, these models are of great interest

because they produce complex dynamics from simple interaction rules and often exhibit phase transitions. They have been studied at the particle, kinetic, and hydrodynamic levels. Here, we consider a kinetic Cucker-Smale-like model with self-propulsion and diffusion. We prove that a phase transition from more than one stationary solution to only one stationary solution occurs as we vary the diffusion coefficient. We further examine the system numerically, validating the phase transition and exploring the effects of the parameters on the resulting bifurcation diagram.

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MS59

Control of PDE Models of Robotic Swarms with Stochastic Behaviors

This talk presents a control and estimation framework for robotic swarms that lack global position information, dependable communication, and prior data about the environment. The framework relies on advection-diffusion-reaction PDE models of swarm population dynamics that describe the robots' roles, task transitions, and motion. It can be applied to mapping regions of interest using temporal robot data and to achieving target spatial distributions of robot activity using only local sensing and common broadcast information.

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MS59

A Blob Method for the Aggregation Equation

The aggregation equation models the motion of particles moving to minimize a nonlocal interaction energy. Often, the interaction between particles is chosen to scale according to a power law potential, leading to aggregation or repulsion, depending on the sign of the potential. In general, the corresponding interaction energies are neither convex nor differentiable, placing them outside the scope of most existing results on energy minimization and gradient flow In this talk, I will present joint work with Andrea Bertozzi on a new numerical method for the aggregation equation, inspired by vortex blob methods for the Euler equations. I will present quantitative results on the convergence of this regularized particle method, along with numerical examples exploring its qualitative behavior. I will then present recent work with Ihsan Topaloglu, in which we examine the effect of regularization on measure solutions of the aggregation equation and prove Gamma-convergence results showing that minimizers converge to minimizers and gradient flows converge to gradient flows.

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MS60

On the Attractor for the Semi-dissipative Boussinesq Equations

We study the long time behavior of solutions of a variant of the Boussinesq system in which the equation for the velocity is parabolic while the equation for the temperature is hyperbolic. We prove that the system has a global attractor which retains some of the properties of the global attractors for the 2D and 3D Navier-Stokes equations. Moreover, this attractor contains infinitely many invariant manifolds in which, potentially, several universal properties of the Batchelor, Kraichnan, Leith theory of turbulence holds. This is a joint work with Larios and Foias.

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MS60

Forward Discretely Self-Similar Solutions of the Navier-Stokes Equations

For discretely self-similar initial data that is point-wise bounded by $c_0|x|^{-1}$ where c_0 is allowed to be large, we construct forward discretely self-similar local Leray solutions in the sense of Lemarié-Rieusset to the 3D Navier-Stokes equations in the whole space. No further assumptions are imposed on the initial data; in particular, the data is not required to be continuous away from the origin.

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MS60

Finite Dimensionality of the Global Attractor for the Solutions to the 3D Primitive Equations with Viscosity

The system of 3D Primitive Equations is a fundamental mathematical model for the large scale fluid flows occurring in the ocean and atmosphere. Recently, there have been important progresses in the development of rigorous mathematical theory for this model, despite its complicated and difficulty features. Existence of H^1 solutions global in time was first proved by C. Cao and E. Titi. Then, similar global regularity result was also proved by Kobelkov. Later on, I. Kukavica and M. Ziane obtained H^1 regularity for another set of boundary conditions. Existence of the global

attractor of the strong solutions was proved by N. Ju, the speaker. Recently, H^2 regularity and finiteness of the dimensions of the global attractor was proved by N. Ju and R. Temam for a first set of non-periodic boundary conditions. More recently, some further new ideas were developed and new results were obtained by the speaker to include more general cases for more general boundary conditions and with less regularity requirement. In this presentation, the speaker will give an overview of the new development and discuss some details.

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MS60

On the Serrin-type Regularity Criteria of the Navier-Stokes Equations and MHD Equations

In this talk, we address some improved Prodi-Serrin type regularity criteria for the weak solutions of the MHD equations in terms of one component of the velocity and one component of the magnetic field each.

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MS61

Rigorous Asymptotics of Traveling-Wave Solutions to the Thin-Film Equation and Tanner's Law

We study the asymptotics of traveling-wave solutions with zero static contact angle to the thin-film equation with inhomogeneous mobility $h^3 + \lambda^{3-n} h^n$. Here h, λ, and $n \in (3/2, 3)$ denote film height, slip length, and mobility exponent, respectively. As $h \to \infty$, we recover Tanner's solution for the apparent macroscopic contact angle to leading order, solving the corresponding unperturbed problem with $\lambda = 0$. Corrections turn out to affect this law only by a trivial scaling transformation and a higher-order correction, both depending smoothly on n.

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MS61

Asymptotical Decay and Rupture of Solutions to Thin Film Equations

We demonstrate rigorously existence of finite time rupture for the weak solutions to coupled PDEs describing dewetting of thin liquid films in presence of van der Waals attractive forces and large slippage at the polymer-substrate and including the free film model introduced by T. Erneux and S. H. Davis. In contrast, in presence of Born repulsion forces or large initial film thickness asymptotic convergence of the solutions and the corresponding decay rates to flat profile are shown.

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MS61

The Thin Film Equation Close to Self-similarity

We consider the thin film equation in $\mathbf{R}^N$ with linear mobility in the complete wetting regime. It is expected (and in some particular cases proved) that the large time behavior of any solution is governed by the self-similar solution. In this talk, I will review some results on the spectrum of the linearized equation, and explain how these results can be used to compute higher order asymptotic expansions. This is partially joint work with R. McCann.

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MS61

Dispersive and Diffusive-Dispersive Shock Waves

The modified KdV-Burgers equation

$$u_t + (u^3)_x = \mu u_{xx} + \beta u_{xxx},$$

in which $\mu \geq 0$ and β are constant, is both dissipative and dispersive. Moreover, the flux u^3 is non-convex. Much can be learned from the structure of solutions of initial value problems with Riemann initial data, in which $u(x, 0)$ is piecewise constant with a single jump. When $\mu > 0$ the solutions are easily related to shock waves and rarefaction waves for the conservation law $u_t + (u^3)_x = 0$. However, with $\mu = 0$, the solutions involve dispersive shock waves (DSWs). I show how the two cases are related, discuss the limit $\mu \to 0+$, and demonstrate time scales over which different wave structures appear. The construction of the DSWs turns out to contain subtleties related to the presence of undercompressive traveling waves for the $\mu > 0$ case, and to the construction of shock-rarefaction wave solutions of the conservation law, due to the non-convex flux.

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MS62

Three-Dimensional Solitary Water Waves with

Weak Surface Tension

I will present a variational existence theory for three-dimensional fully localised solitary water waves with weak surface tension. The water is modelled as a perfect fluid of finite depth undergoing irrotational flow; a fully localised solitary wave is a travelling wave which decays to the undisturbed state of the water in every horizontal direction. These waves are constructed as critical points of the functional $\mathcal{E} - c\mathcal{I}$, where $\mathcal{E}$ and $\mathcal{I}$ are the energy and momentum of the wave and c is its speed. A key ingredient is a variational reduction method which reduces the problem to a perturbation of the Davey-Stewartson equation. This is joint work with B. Buffoni (Lausanne) and E. Wahlén (Lund).

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MS62
The Dynamics of Floating Structures

Motivated by the study of Wave Energy Convertors (WEC) used to transform ocean wave energy into electricity, we are interested here with the dynamics of a floating solid device at the surface of an ocean. In absence of any device, this problem reduces to the classical water waves problem. Adding a floating device to this problem adds some classical fluid/structure interactions issues. In particular, the motion of the device depends on the forces exerted by the waves, which require the knowledge of the immerged part of the device and of the pressure on this wetted surface. Conversely, the presence of the WEC modifies the behavior of the waves. We will present this problem in full generality and derive also simpler models that allow for efficient numerical computations.

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MS62
On the Highest Wave for the Whitham Equation

I will discuss recent progress on the existence of a highest, cusped, travelling wave solution of the Whitham equation $u_t + 2uu_x + Lu_x = 0$, where L is the Fourier multiplier operator with symbol $m(\xi) = (\tanh(\xi)/\xi)^{1/2}$. Using global bifurcation theory and precise information about the corresponding integral kernel, the highest wave is obtained as a limit of smooth periodic solutions bifurcating from the trivial solution. I will describe what we know about its qualitative properties so far.

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MS62
Existence and Qualitative Theory for Solitary Stratified Water Waves

In this talk, we will report some recent results concerning two-dimensional gravity solitary water waves with hereogeneous density. The fluid domain is assumed be bounded below by an impenetrable flat ocean bed, while the interface between the water and vacuum above is a free boundary. Our main existence result states that, for any smooth choice of upstream velocity and streamline density function, there exists a path connected set of such solutions that includes large-amplitude surface waves. Indeed, this solution set can be continued up to (but does not include) an "extreme wave' that possess a stagnation point. We will also discuss a number of results characterizing the qualitative features of solitary stratified waves. In part, these include bounds on the Froude number from above and below that are new even for constant density flow; an a priori bound on the velocity field and lower bound on the pressure; a proof of the nonexistence of monotone bores for stratified surface waves; and a theorem ensuring that all supercritical solitary waves of elevation have an axis of even symmetry.

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MS63
Parabolic Problems with a Fractional Time Derivative

In this talk we will explore the different notions of a fractional-time derivative and their applications in physics. We will then focus on some specific parabolic problems involving fractional time derivatives and discuss existence, uniqueness, and regularity. This is joint work with L. Caffarelli and A. Vasseur.

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MS63
Singular Points in Two-Phase Free Boundary Problems for Harmonic Measure

We investigate properties of the singular set in two-phase free boundary problems for harmonic measure on NTA domains, where blow-ups of the boundary are known to be zero sets of homogeneous harmonic polynomials. This talk will describe several new results on the size, structure, and regularity of the singular set under $C^{0,\alpha}$, continuous, and sub-continuous (VMO) free boundary conditions.

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MS63

The Obstacle Problem for the Fractional Laplacian with Drift

We prove existence, uniqueness and optimal regularity of solutions for the stationary obstacle problem for the fractional Laplacian with drift, in the subcritical regime. Moreover, we establish the $C^{1+\gamma}$-Hölder regularity of the regular free boundary. Our method of the proof consists in proving a new Weiss-type monotonicity formula and an epiperimetric inequality, which are a generalization of the ideas of G. Weiss from the classical obstacle problem for the Laplace operator, to the framework of fractional powers of the Laplace operator with drift. This is joint work with Nicola Garofalo, Arshak Petrosyan, and Mariana Smit Vega Garcia.

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MS63

Regularity for Boundary Nonlocal Equations

We establish regularity estimates for solutions to the following nonlocal boundary Neumann problem in a domain D:

$$\Delta u = 0, \text{ in } D, \quad \partial_\nu^\sigma u = f, \text{ on } \partial D,$$

where $0 < \sigma < 1$. Here $\partial_\nu^\sigma u$ is the fractional power of the normal derivative. This operator is defined via the Steklov eigenfunctions as follows. If $g = \sum_k g_k s_k \in L^2(\partial D)$ the normal derivative of its harmonic extension u to the interior of D is characterized by

$$\partial_\nu u = \sum_k \lambda_k g_k s_k, \quad \text{on } \partial D.$$

Then we define

$$\partial_\nu^\sigma u := \sum_k \lambda_k^\sigma g_k s_k.$$

This gives a nonlocal operator of order σ on the boundary ∂D. Using the semigroup language approach we prove that if f is C^α then u is $C^{\sigma+\alpha}$ up to the boundary. Joint work with Luis A. Caffarelli.

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MS64

Breast Cancer Detection Through Electrical Impedance Tomography: Variational Method Through Optimal Control Theory

Electrical Impedance Tomography (EIT) is a novel noninvasive medical imaging technique which is widely used as an alternative option to mammography and magnetic resonance imaging for breast cancer detection. A mathematical description to reconstruct conductivity of the humans body from its surface electrode measurements (Calderon's inverse problem) will be presented to introduce a new variational formulation for locating malignant breast tissues. The robustness of our gradient-based computational algorithm will be examined using experimental data.

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MS64

Computational Studies on Dynamical Boundaries in Two-Phase Gels

The fluid media surrounding many microorganisms are often mixtures of multiple materials with very different physical properties. The composition and rheology of the mixture may strongly affect the related locomotive behaviors. We study the classical Taylors swimming sheet problem within a two-fluid model, which describes a mixture of a viscous fluid solvent and a viscoelastic polymer network. Our results indicate that depending on the interactions between the swimming surface and the network, elasticity may have drastically different effects on the swimming speed.

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MS64

On the Optimal Control of the Stefan Problem

A method of solution for the inverse Stefan problem introduced in *U.G. Abdulla, Inverse Problems and Imaging, 7,2(2013), 307-340* employing an optimal control framework is implemented; boundary heat flux and free boundary comprise the control vector, and the optimality criterion consists of the minimization of the sum of L_2-norm declinations from measurements of the final and phase transition temperatures. Frechet differentiability of the functional is proven, and the numerical method is implemented and solved using iterative projective gradient methods. Numerical examples with nonsmooth data are demonstrated.

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MS64

A Flexible, High Order Numerical Method for Viscoelastic Fluid Simulation Using FFT-Based Spectral Methods in Complex Domains

We present a robust, high-order numerical scheme for solving PDE on domains with smooth boundaries using FFT based spectral methods. The solution to the PDE is coupled with an equation for a smooth extension of the unknown solution; high-order accuracy is a consequence of this regularity. Elliptic equations can be directly solved, allowing for the implict timestepping of parabolic equations; Dirichlet, Neumann, and Robin boundary conditions are all naturally handled. Results are provided for Stokes, Navier-Stokes, and Oldroyd-B equations.

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MS65

Stationary Points of Binary and Ternary Inhibitory Systems

Pattern formation problems arise in many physical and biological systems as orderly outcomes of self-organization principles. I will discuss a central theme in the construction of various patterns as solutions to some well known PDE and geometric problems: how a single piece of structure built on the entire space can be used as an ansatz to produce a near periodic pattern on a bounded domain. The main examples are the Gierer-Meinhardt system, the FitzHugh-Nagumo system, and some block copolymer problems.

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MS65

The Impact of the Domain Boundary on An Inhibitory System: Boundary Half Discs in Stationary Assemblies

Ohta-Kawasaki diblock copolymer theory yields an inhibitory system with self-organizing properties. Inherently the system has the property of preventing a disc from drifting towards the domain boundary. I present the existence and location of a stationary set of such a system composed of a perturbed half disc in the interior of the domain. Stationary assemblies are then introduced consisting of a collection of interior discs and boundary half discs.

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MS65

Minimizers of an Energy Modelling Nanoparticle-Polymer Blends

In many applications filler nanoparticles are added in a blend of macromolecules to alter the morphology of microdomains. In this talk I will consider the case of diblock copolymers. In particular, using regularity and first and second variation arguments, I will discuss the local and global minimality of certain configurations via the sharp interface limit of an extended Ohta-Kawasaki energy. These minimizers will clearly demonstrate how the addition of nanoparticles affects the geometry of the phase boundaries. This is a joint work with S. Alama and L. Bronsard.

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MS65

Emergent Parabolic Scaling of Nano-Faceting Crystal Growth

Nano-faceting of material interfaces is a paradigmatic, non-equilibrium self-assembly process which arises in a wide variety of physical settings; for example, high-efficiency photo-electrochemical cells yielding solar-energy storage through hydrogen production, and enantiomer-specific heterogeneous catalysts with application to biology. The dynamics of slightly undercooled crystal-melt interfaces possessing strongly anisotropic and curvature-dependent surface energy and evolving under attachment-detachment limited kinetics finds expression through a certain singularly perturbed, hyperbolic-parabolic, geometric partial differential equation. Among its solutions, we discover a remarkable family of 1D convex- and concave- translating fronts whose fixed asymptotic angles deviate from the thermodynamically expected *Wulff* angles in direct proportion to the degree of undercooling: a non-equilibrium (*thermokinetic*) effect. We also present a novel geometric matched-asymptotic analysis that demonstrates that the slow evolution of the large-scale features of 1D solutions $\mathcal{I}$

are captured by a Wulff-faceted interface $\mathcal{A}$ evolving under an intrinsic facet dynamics. This emergent dynamics possesses a Peclet length L_p below which a spatio-temporal symmetry of parabolic type appears. We thereby theoretically predict, and numerically verify, that within the sub-Peclet regime the universal scaling law $\mathcal{L} \sim t^{1/2}$ governs the time t evolution of the characteristic length $\mathcal{L}$ of the interface $\mathcal{I}$.

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MS66

Capillary Induced Deflections of a Thin Elastic Plate

Motivated by elasto-capillary experiments done in the context of capillary origami, I will discuss the equilibrium elastic deformations of a thin plate due to the surface tension of a liquid drop. The two main foci will be deriving governing PDEs in the idealized vanishing plate-thickness limit by minimizing the total energy of the system and constructing solutions to the resulting system, which couples a developable Willmore surface with a constant mean curvature surface.

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MS66

Phyllotaxis: A Dynamical Systems Approach

Starting with a PDE model that we have developed for the formation of patterns on plants, referred to as phyllotaxis, I will derive amplitude equations for the active Fourier modes. Next, I will demonstrate the presence of pushed nonlinear fronts and provide evidence for universal fibonacci-like transitions between active modes.

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MS66

Low Energy Deformations of Thin Elastic Shells

The deformations of thin elastic shells are governed by the interplay between geometry and elasticity. When shells are sufficiently thin, they deform without stretching. Rather than being limiting, it turns out there are numerous ways to deform a shell while keeping the stretching energy small, through the introduction of singularities, folds and wrinkles. I will discuss how these features can be exploited to manipulate the dynamics of shells and how flat sheets can wrap spheres.

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MS66

Surfaces Produced at Vapor-to-Particle Nucleation and Growth Interfaces

We report on a set of topochemically organized, nanoparticulate experimental systems in which vapor diffuses and convects to form surfaces formed from agglomerated particles. In the reaction zones, a complex sequence of catalyzed proton-transfer, nucleation, growth, aggregation, hydration, charging processes, and turbulence produce rings, tubes, spirals, pulsing crystals, oscillating fronts and patterns such as Liesegang rings. We synthesize a proposed mechanism for the chemical reactions and propose mathematical models of the patterns.

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MS67

Theoretical and Numerical Studies of Staggered-grid Schemes on Unstructured Meshes

In this talk, we present a new theoretical framework for analyzing FD/FV schemes for a wide range of fluid problems. There are two essential ingredients to this framework. The first is the external approximation of function spaces, which seems particular adept in dealing with discontinuous functions. The second is the tracking of divergence and vorticity, instead of individual derivatives. This approach gets rid of the requirement for a Cartesian coordinate system, and makes this framework applicable to unstructured meshes. Once the framework has been presented, we will apply it to the classical incompressible Stokes problem, and prove that the discrete solutions converges to the solution of the continuous system, without assuming that one actually exists.

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MS67

Invariant Measures for Passive Scalars in the Small Noise Inviscid Limit

We consider a class of invariant measures for a passive scalar f driven by an incompressible velocity $\mathbf{u}$ field on a periodic domain. The measures are obtained as limits of stochastic viscous perturbations. We prove that the span of the H^1 eigenfunctions of the operator $\mathbf{u} \cdot \nabla$ contains the support of these measures, and apply the result to a number of examples in which explicit computations are possible (relaxation enhancing, shear, cellular flows).

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MS67

New Time Differencing Methods for Stiff Problems and Applications

A semi-analytical method is developed based on conventional integrating factor (IF) and exponential time differencing (ETD) schemes for stiff problems. The latter means that there exists a thin layer with a large variation in their solutions. The occurrence of this stiff layer is due to the multiplication of a very small parameter ϵ with the transient term of the equation. Via singular perturbation analysis, an analytic approximation of the stiff layer, which is called a corrector, is sought for and embedded into the IF and ETD methods. These new schemes are then used to approximate the non-stiff part of the solution. Since the stiff part is resolved analytically by the corrector, the new method outperforms the conventional ones in terms of accuracy. In this paper, we apply our new method for both problems of ordinary differential equations and some partial differential equations.

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MS67

Well-posedness of Initial and Boundary-value Problems for the Inviscid Linear and Non-linear Shallow Water Equations. Connection with the Primitive Equations

In this lecture we will discuss the issue of the well-posedness of initial and boundary value problems for the inviscid shallow water equations, in the linearized case and for some fully nonlinear cases. The relation with the inviscid Primitive Equations will be discussed. We will also make the connection with the study of the viscous Primitive Equations when the viscosity is small.

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MS67

Approximating Long-time Statistical Behavior of Dissipative Systems

It is well-known that physical laws of large chaotic systems are revealed statistically. We present a few recent results on numerical schemes that are able to asymptotically capture the long-time statistical behavior of dissipative systems. Semi-discrete in time or space, and fully discretized schemes will be discussed. The main theme is to be faithful to the underlying dissipative system. In particular, the preservation of the dissipativity and the convergence (on the unit time interval modulo an initial layer) seem to be crucial to the convergence of long-time statistical properties. Applications to the infinite Prandtl number model for convection and the 2D Navier-Stokes system will be presented.

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MS68

Evans Function Computation for Planar Viscous Shocks in Reactive Navier-Stokes

Detonations are commonly modeled with the reactive Euler/ZND equations, thus ignoring diffusive effects as negligible. We review recent developments regarding the spectral stability of their viscous counterparts - strong detonation wave solutions of the reactive Navier Stokes equations. Evans function computation reveals a new phenomenon called viscous hyperstabilization. We extend this study to detonations in the multi-dimensional setting.

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MS68

Nonlinear Partial Differential Equations: Grassmann Flows, Computing Spectra and Maslov Index

Absract: We address the problem of computing the Maslov index for large linear symplectic systems on the real line. The Maslov index measures the signed intersections (with a given reference plane) of a path of Lagrangian planes. The natural chart parameterization for the Grassmannian of Lagrangian planes is the space of real symmetric matrices. Linear system evolution induces a Riccati evolution in the chart. For large order systems this is a practical approach as the computational complexity is quadratic in the order. The Riccati solutions, however, also exhibit singularites (which are traversed by changing charts). Our new results involve characterizing these Riccati singularities and two trace formulae for the Maslov index as follows. First, we show that the number of singular eigenvalues of the symmetric chart representation equals the dimension of intersection with the reference plane. Second, the Cayley map is a diffeomorphism from the space of real symmetric matrices to the manifold of unitary symmetric matrices. We show the logarithm of the Cayley map equals the arctan map (modulo 2i) and its trace measures the angle of the Langrangian plane to the reference plane. Third, the Riccati flow under the Cayley map induces a flow in the manifold of unitary symmetric matrices. Using the natural unitary action on this manifold, we pullback the flow to the unitary Lie algebra and monitor its trace. This avoids singularities, and is a natural robust procedure. We demonstrate the effectiveness of these approaches by applying them to a large eigenvalue problem. We also discuss the extension of the Maslov index to the infinite dimensional case. This is joint work with Margaret Beck (BU).

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MS68

Validated Numerics and Connecting Orbits for Parabolic Partial Differential Equations

Abstract not available at time of publication.

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MS68

Rigorous Computation of Unstable Manifolds for Nonlinear Parabolic Pdes Via the Parametrization Method

We present a validated numerical method based on the so-called parametrization method to compute a parametrization of the finite dimensional local unstable manifold for a hyperbolic equilibrium solution to a scalar parabolic nonlinear PDE. An important ingredient for the method is rigorous control of the spectrum of the linearization at the equilibrium which is achieved by computer assistance. The method is important for computer assisted proofs of connecting orbits between equilibria. We show illustrating examples.

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MS69

Determining Wavenumber for Fluid Equations

In this talk we review classical results on determining modes for fluid equations and present a slightly different approach where we start with a time-dependent determining wavenumber defined for each individual trajectory and then study its dependence on the force. While in some cases this wavenumber has a uniform upper bound, it may blow up when the equation is supercritical. Nevertheless, the average determining wavenumber is uniformly bounded even for the 3D Navier-Stokes and some supercritical SQG equations.

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MS69

On the Inviscid Limit

Abstract not available at time of publication.

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MS69

On the Kolmogorov Entropy of the Weak Global Attractor of the 3D Navier-Stokes Equations

Motivated by the long-standing question concerning the finite-dimensionality of three-dimensional turbulent flows, we study the long time behavior of solutions to the 3D Navier-Stokes equations with respect to the functional dimensional of the weak global attractor. By using the squeezing property of the trajectories, we are able to obtain an estimate of the Kolmogorov entropy of the weak global attractor in terms of physical parameters of the flow. Such estimate then provides an upper bound of the functional dimension given by 5/2.

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MS69

Asymptotic Stability of Solitary Waves in 1-D Nonlinear Dirac Equation

We explore the nonlinear Dirac equation in (1+1)D with scalar self-interaction (Gross-Neveu model), and with quintic or higher order nonlinearities. We prove that solitary wave solutions are asymptotically stable in the even subspace of perturbations. The approach is based on the spectral information about the linearization at solitary waves which we obtain numerically. For the proof, we develop the spectral theory for the linearized operators and obtain appropriate estimates in mixed Lebesgue spaces with and without weights.

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MS69

Global Solutions to the Derivative NLS Equation with the Inverse Scattering Transform Method

We address existence of global solutions of the derivative nonlinear Schrödinger equation without the small-norm assumption. By using the inverse scattering transform method without eigenvalues and resonances, we construct a unique global solution in $H^2(\mathbb{R}) \cap H^{1,1}(\mathbb{R})$ which is also Lipschitz continuous with respect to the initial data. Compared to the existing literature on the spectral problem for the derivative NLS equation, we transform the Riemann-Hilbert problem in the complex plane to the jump on the real line.

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MS70

Incompressible Euler Equations and the Effect of

Changes at a Distance

For solutions to the Euler equations to be physically meaningful, one would expect that the effects on a solution of a localized change to the initial velocity would decrease as distance from the localized change increases. One can easily show that this is the case for solutions having spatial decay, giving these solutions a type of stability. In this talk, we consider the more difficult case of solutions lacking spatial decay, and we show that such stability still holds.

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MS70

Title Not Available at Time of Publication

Abstract not available at time of publication.

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MS70

On Global Existence for Euler-Maxwell System

We prove that small and smooth perturbations of a neutral homogeneous background of electron lead to solutions to the Euler-Maxwell system that remain smooth for all time and in particular do not produce shocks.

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MS70

Rigorous Bounds on the Transport of Heat in Rayleigh-Bnard Convection at Infinite Prandtl Number

We review the model of infinite Prandtl number Rayleigh Bnard convection and its application to convection in the Earth's mantle. Using variational techniques we demonstrate a method to bound the vertical heat transport in this model. These rigorous bounds provide insight into the role that various boundary conditions and other aspects of the problem (rigid body rotation, non-Newtonian viscosity etc.) play in the nonlinear evolution and subsequent heat transport.

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MS71

Inhomogeneous Boltzmann-Type Equations Modeling Opinion Leadership and Political Segregation

We propose and investigate 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.

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MS71

Adaptive Control of Multiscale Dynamical Systems

This paper presents new approximate dynamic programming (ADP) recurrence relationships for multiscale dynamical systems comprised of many interacting agents. The ADP relationships presented in this paper are obtained using a distributed optimal control (DOC) approach by which the performance of the multiscale dynamical system is represented in terms of a macroscopic state, and is optimized subject to a macroscopic description provided by the continuity equation. The proof of convergence presented in this paper shows that by the new ADP recurrence relationships, the state and control of the multiscale dynamical system can be optimized over time, eventually converging to the optimal control law and value function.

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MS71

Macroscopic PDEs for Flocking Dynamics

In a human crowd or in a shoal of fish, thousands of individuals interact and form large scale structures. Although the interaction among individuals might be simple, the resulting dynamics is quite complex. To understand the link between microscopic and macroscopic dynamics, we have developed new tools based on kinetic theory and asymptotic analysis. The challenge is now to investigate how to extend this micro-macro derivation once we add a control in the microscopic dynamics.

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MS71

Kinetic Models for Differential Games

We present a kinetic framework for the time evolution of multi agent systems where individual agents make decisions

based on concepts of behavioral and evolutionary game theory. Applications to insurance policies and wealth distribution in economies are discussed.

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MS72

Well-Posedness for Nonlinear Wave Equations

In this talk, we will discuss a sequence of recent progresses on the global well-posedness of energy conservative Holder continuous weak solutions for the Camassa-Holm and nonlinear variational wave equations, modeling water waves, Liquid crystals, etc. A common feature of solutions in these systems is the formation of cusp singularity and peaked soliton waves (peakons), even when initial data are smooth. The lack of Lipschitz continuity of solutions gives the major difficulty in studying the well-posedness and behaviors of solutions. Several collaboration works with Alberto Bressan and Qingtian Zhang will be discussed, including the uniqueness by characteristic method, Lipschitz continuous dependence on a Finsler type optimal transport metric and a generic regularity result using Thom's transversality theorem. All results are large data global-in-time results.

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MS72

Coupling Einstein and Navier-Stokes Equations

We consider Einstein's equations coupled to a relativistic version of the Navier-Stokes equations proposed by Lichnerowicz. Assuming that the fluid is irrotational and incompressible (in a relativistic sense), we show that the system is well-posed and causal.

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MS72

On Minimizers of the Landau-De Gennes Energy Functional under Weak Anchoring Boundary Conditions

Abstract not available at time of publication.

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MS72

Doubling Estimates, Vanishing Order and Nodal Sets of Steklov Eigenfunctions

Recently the study of Steklov eigenfunctions has been attracting much attention. We investigate the qualitative and quantitative properties of Steklov eigenfunctions. We obtain the sharp doubling estimates for Steklov eigenfunctions on the boundary and interior of the manifold using Carleman inequality. As an application, optimal vanishing order is derived, which describes quantitative behavior of strong unique continuation property. We can ask Yau's type conjecture for the Hausdorff measure of nodal sets of Steklov eigenfunctions. We derive the lower bounds for interior and boundary nodal sets. In two dimensions, we are able to obtain the upper bounds for singular sets and nodal sets. Part of work is joint with Chris Sogge and X. Wang.

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MS73

Complex Fluids and Electroconvection

Abstract not available at time of publication.

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MS73

Spectral Gaps and Bloch Decomposition for the Linearized Water-Waves Equations

In this talk, I will consider the spectral problem for the Dirichlet – Neumann operator of the unperturbed free surface associated to the linearized water-waves equations about equilibrium. In the case in which the bottom boundary is a small periodic perturbation of constant depth, this spectral problem admits a Bloch decomposition in terms of Bloch eigenvalues and eigenfunctions that can be constructed analytically. I will describe this construction and show that the spectrum consists of a series of bands separated by spectral gaps. This is a joint work with W. Craig, C. Lacave and C. Sulem.

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MS73

Almost Global Existence of the Prandtl Equations

We address the Prandtl equations on the half space with real-analytic initial datum with respect to the tangential variable. The boundary traces of the horizontal Euler flow and pressure are taken to be constants. We establish that if the initial datum lies within ϵ of a stable profile, then the time of existence for the solution is at least $\exp(\epsilon^{-1}/\log(\epsilon^{-1}))$. This is a joint work with V. Vicol.

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MS73

Very Weak Solutions to the Stokes Problem in a

Convex Polygon

Motivated by the study of the corner singularities for the so-called driven cavity flow, we study the existence and uniqueness of very weak solutions to the Stokes problem in a convex polygon. We establish a trace theorem for L^2 solutions to the Stokes problem and derive the existence and uniqueness of such solutions in a suitable function space.

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MS74

Blow Up of Solutions to Some Quasilinear Equations Arising from Water Waves

We investigate the blow-up mechanism of solutions to a class of quasilinear equations arising from shallow water waves. The dynamics of the blow-up quantity along the characteristics involves the interaction between the solution u and its gradient u_x. We use a refined analysis on the evolution of certain combinations of u and u_x to derive some exact blow-up criteria.

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MS74

Multi-Dimensional Bifurcation in Steady Water Waves with Vorticity

We survey a couple of recent results on multi-dimensional bifurcation for steady water waves. More precisely, we show how to construct two- and three-dimensional families of gravity-driven rotational waves with multiple crests in each minimal period. The bifurcation argument is done via a blow-up technique, which gives rise to a fairly rich variety of wave patterns. A particular emphasis is placed on the analysis of the obtained solution set.

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MS74

Instabilities in some shallow water models

I will speak on the wave breaking and the modulational instability in the Whitham equation, which combines the dispersion relation of water waves and the nonlinearity of the shallow water equations. I will then discuss their extensions to bi-directional Whitham, or Boussinesq-Whitham equations. I will discuss the exact water wave problem, if time permits.

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MS74

On the Slope of Steady Water Waves

Consider the angle of inclination of the profile of a steady 2D inviscid symmetric periodic or solitary water wave subject to gravity. Although the angle may surpass 30 degrees for some irrotational waves close to the extreme wave, Amick proved in 1987 that the angle must be less than 31.15 degrees if the wave is irrotational. For waves that are not irrotational, the question of whether there is a bound on the angle has been completely open. Of course, the extreme Gerstner wave, which has adverse vorticity, has vertical cusps. Moreover, numerical calculations show also that waves of finite depth with adverse vorticity can overturn. We prove, on the other hand, an upper bound of 45 degrees for a large class of waves with favorable vorticity and finite depth. This is joint work with Miles Wheeler.

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MS75

Second-Order Gamma-Limit for the Cahn-Hilliard Functional with Applications to Slow Motion of Phase Boundaries

The Cahn-Hilliard functional models phase transitions in a variety of physical settings. This talk will discuss the resolution of a long standing open problem, namely, the asymptotic development of order 2 by Γ-convergence of the mass-constrained Cahn-Hilliard functional. This is achieved by developing a rearrangement technique, which works without Dirichlet boundary conditions. We also discuss applications of this Γ-convergence result to slow motion estimates for the nonlocal Allen-Cahn Equation.

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MS75

Homogenization of the Peierls-Nabarro Model for Dislocation Dynamics

Dislocations are moving defects in crystals that can be described at several scales by different models. We consider an evolution equation arising in the Peierls-Nabarro model, which is a phase field model describing dislocation dynamics at a microscopic scale. We present an homogenization problem related to the long-time behavior of the system at a macroscopic scale. We identify an evolution model for

the dynamics of a density of dislocations, which is a macroscopic model for crystal elasto-visco-plasticity. The results that will be presented have been obtained in collaboration with E. Valdinoci.

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MS75

Poincare Inequalities and Diffusion Along Ergodic Flows

We improve the classical Poincare inequality on the torus T^d. In two dimensions, for example, we show that there exist vectors $\alpha \in T^2$ such that for all $u \in L^2(T^2)$ with mean 0

$$\|\nabla u\|_{L^2(T^2)} \| \langle \nabla u, \alpha \rangle \|_{L^2(T^2)} \geq c \|u\|^2_{L^2(T^2)}.$$

This holds for $\alpha = (1, \sqrt{2})$ but fails for $\alpha = (1, e)$, where e is Euler's number. The inequality suggests that, at least for some manifolds, differentiation along a sufficiently fast-mixing vector field can compensate for the fact that a directional derivative is blind in $d-1$ directions. The result is closely tied to the study of diffusion with a drift.

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MS75

Some Inverse Problems in Periodic Homogenization of Hamilton-Jacobi Equations

We look at the effective Hamiltonian $\bar{H}$ associated with the Hamiltonian $H(p,x) = H(p) + V(x)$ in the periodic homogenization theory. Our central goal is to understand the relation between V and $\bar{H}$. We formulate some inverse problems concerning this relation. Such type of inverse problems are in general very challenging. I will discuss some interesting cases in both convex and nonconvex settings. Joint work with Songting Luo and Yifeng Yu.

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MS76

A Stochastic Galerkin Method for Nonlinear Systems of Hyperbolic Conservation Laws with Uncertainty

In this talk, I will present a class of stochastic Galerkin methods for nonlinear systems of hyperbolic conservation laws with random inputs. The methods are based on a generalized polynomial chaos approximation (referred to as the gPC-SG method). It is well-known that such approximations do not necessarily yield globally hyperbolic systems. I will discuss a way of obtaining a globally hyperbolic gPC-SG approximations for some nonlinear systems with uncertainty. The performance of the new gPC-SG method will be illustarted on a number of numerical examples.

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MS76

Stochastic Galerkin Formulations of Conservation Laws: Challenges in the Generalization of Deterministic Solvers to New Systems of PDEs

Stochastic Galerkin projection of PDEs with uncertainty leads to extended systems of equations whose properties typically resemble those of the corresponding deterministic problems. However, for nonlinear conservation laws, the increased complexity gives rise to phenomena not present in the deterministic formulations, e.g. multiple discontinuities and degeneracy. This leads to challenges in the design of robust numerical methods. This talk will highlight some of these challenges with examples from fluid mechanics and subsurface flow.

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MS76

Numerical Methods for Quantification of Model-form Uncertainty

We present a strategy for correcting model deficiency using observational data. We first present the model correction in a general form, involving both external correction and internal correction. The model correction is then parameterized and casted into an optimization problem. More importantly, we discuss the incorporation of physical constraints from the underlying physical problem. Various examples demonstrate the effectiveness of this approach.

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MS76

Uncertainty Quantification with Limited Data

We propose a new method for uncertainty quantification of physical systems with high dimensional random space using compressive sensing based generalized polynomial chaos. We employ an iterative procedure to identify a new set of random variables, which enables a sparser representation of the quantity of interest. Hence, we may be able to exploit information from limited data. We use PDEs with random coefficients to demonstrate the effectiveness and the efficiency of this method.

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MS77

Feedback Control and Optimization of Release and Dispatch Policies in Production Models

We develop a control scheme for a PDE model of the production flow extending the concept of a clearing function to allow control over both, the release rates and priority allocations in re- entrant production. We analyze the resulting schemes as a feedback control as well as an optimization problem and show significant improvement in many performance indicators like average wip, cycle times and mismatch between demand and production output.

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MS77

On the Control of the Improved Boussinesq Equation

We are interested in the control properties of the Improved Boussinessq equation, used to approach the flow of shallow water waves with small amplitude. First, we consider a boundary control and prove that the system is approximately controllable but not exactly controllable. Second, we introduce an internal control supported on a moving region and prove that the system is exactly controllable. The main tools we use are spectral analysis and the Moment Theory.

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MS77

A Controllability Result for the the Non-Isentropic 1-D Euler Equation

We examine the question of the boundary controllability of the 1D nonisentropic Euler equation for compressible polytropic gas, in the context of weak entropy solutions. We consider the system in Eulerian and in Lagrangian coordinates. For both systems a result of controllability toward constant states is obtained (with a limitation on the adiabatic constant for the Lagrangian system). Moreover the solutions that are constructed remain of small total variation in space for all time.

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MS77

Turnpike Property for the Optimal Control of Partial Differential Equations

We consider the turnpike property for the optimal control problem of evolutional systems arising in the context of finite or infinite dimensional cases. We develop two approaches to analyze the turnpike theorems: one is from the perspective of the dissipativity of the system, and another is from the aspect of Pontryagin maximum principle as well as the saddle point theory of Hamiltonian system.

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MS78

Dimension Reduction for the Landau-De Gennes Model in Planar Thin Films

We use the method of Γ-convergence to study the behavior of the Landau-de Gennes model for a nematic liquid crystalline film in the limit of vanishing thickness. In this asymptotic regime, surface energy plays a greater role and we take particular care in understanding its influence on the structure of the minimizers of the derived two-dimensional energy. We assume general weak anchoring conditions on the top and the bottom surfaces of the film and the strong Dirichlet boundary conditions on the lateral boundary of the film. The constants in the weak anchoring conditions are chosen so as to enforce that a surface-energy-minimizing nematic Q-tensor has the normal to the film as one of its eigenvectors. We establish a general convergence result and then discuss the limiting problem in several parameter regimes. This is joint work with Dmitry Golovaty and Alberto Montero.

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MS78

Active Liquid Crystal Models and Their Applications in Life Science

Input your abstract, including TeX commands, here. We will present a set of hydrodynamical models for active liquid crystal solutions and gels. We will systematically study their linear stability properties and nonlinear evolution in the regime where spontaneous flows can emerge. We will classify the spatial-temporal structures due to the spontaneous flow with respect to the active parameters. In particular, we will look for spatial-temporal travel waves and explore their applications in modeling cell oscillation and motility.

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MS78

Vorticity Driven Dynamics in Nematic Liquid Crystals

In 1990, Janossy made an astonishing observation; he showed that if a small amount of photoisomerizable dye is dissolved in the liquid crystal, the threshold intensity for the optical Freedericksz transition is reduced by two orders

of magnitude. The anomalous reduction of the threshold intensity is the Janossy effect. The dye molecules under photoexcitation in a liquid crystal host act as rotors of molecular motors, and generate vorticity and subsequent flow. In this talk, we present a numerical study of the dynamics of nematic liquid crystal driven by local vortices using a hydrodynamic Q tensor theory. We shall investigate the effects the distributions of the local vortices on the alignment of liquid crystals in different geometries.

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MS79

Near-field Imaging with Far-field Data

A rigorous mathematical model and an efficient computational method are proposed to solving the inverse surface scattering problem which arises from the near-field imaging of periodic structures known as diffraction gratings. We demonstrate how a super resolved resolution can be achieved by using more easily measurable far-field data. The grating surface is assumed to be a small and smooth perturbation of a perfect electrically conducting plane. By placing a slab of a homogeneous medium above the surface, more propagating wave modes can be utilized from the far-field data which contributes to a higher reconstruction resolution. The method begins with the transformed field expansion to derive an analytic solution for the direct problem. An explicit inversion formula is deduced from the close form solution. Moreover, a nonlinear correction scheme is developed to improve the accuracy of the reconstruction. The approach requires a single illumination at a fixed frequency and is realized by the fast Fourier transform. Results show that the proposed method is capable of reconstructing grating surfaces with subwavelength resolution even by using the far-field data.

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MS79

Perturbations of Transmission Eigenvalues Due to Small Inhomogeneities in the Medium

This work concerns the transmission eigenvalue problem for an inhomogeneous media of compact support containing small penetrable homogeneous inclusions or small voids. Assuming that the inhomogeneous background media is known and smooth, we investigate how these small volume inclusions affect the real transmission eigenvalues. In particular, in addition to proving the convergence rate for the eigenvalues corresponding to the perturbed media as inclusions volume goes to zero, we also provide the explicit first correction term in the asymptotic expansion for simple eigenvalue.

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MS79

Surface Plasmon Resonance Biosensors: Analysis and Numerical Simulation

Abstract not available at time of publication.

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MS79

Applications of Maxwell's Equations

Abstract not available at time of publication.

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MS79

Integral Equations for Maxwell's Equations

Abstract not available at time of publication.

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MS80

A Derivation of the Kinetic Wave Equation

Abstract not available at time of publication.

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MS80

Scalar Conservation Laws with Markov Initial Data

Abstract not available at time of publication.

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MS80

Coagulation Dynamics in Branching Processes

Scaling limits of Smoluchowski's coagulation equation are related to probability theory in numerous remarkable ways. Such an equation governs the merging of ancestral trees in critical branching processes, as observed by Bertoin and Le Gall. A simple explanation of this relies on how Bernstein functions relate to a weak topology for Levy triples. From the same theory, we find the existence of 'universal' branching mechanisms which generate complicated dynamics that contain arbitrary renormalized limits. This talk is based on joint work with Gautam Iyer and Nick Leger.

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MS80

On Deriving Stochastic Burgers Equations from a Class of Particle Systems

We consider a class of stochastic interacting particle systems on Z where the single particle jump rates are weakly-asymmetric. For such systems, the scaled space-time (hydrodynamic) limit of the mass density empirical measure is known. In this talk, we discuss the associated fluctuations, in certain reference frames, when the initial condition is an invariant measure. The limit can be seen to satisfy a type of stochastic Burgers equation, which connects to 'KPZ' phenomena. This work is partly joint with P. Goncalves and M. Jara.

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MS81

Rigorous Verification of Stability of Traveling Waves Via Computer Assisted Proof

We discuss recent results in rigorous verification of stability of traveling waves via computer assisted proof. In particular, we describe the difficulties that arise when using interval arithmetic, a key component of rigorous verification, and the solutions we use to overcome these challenges. Through a combination of analytic results and rigorous computations, we establish spectral stability, hence nonlinear stability, of some traveling waves in conservation laws.

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MS81

Computational Evans-Function Techniques for the Spectral Stability of Viscous Detonation Waves

We give an overview of the use of computational Evans-function techniques for studying the spectral stability of viscous detonation waves. The examples considered include both the use of these techniques as a key component in a program for establishing the nonlinear stability of these waves and also their use as a tool for detecting unstable point spectrum. This talk draws on joint work with Blake Barker, Jeffrey Hendricks, Jeffrey Humpehrys, and Kevin Zumbrun.

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MS81

Spectra, Stability and Numerical Continuation

Determining spectral stability of nonlinear waves quickly becomes intractable by rigorous analysis. One approach to numerically compute and track boundaries of spectra uses continuation and is based on analytic formulations via Evans-functions or dispersion relations. In this talk we discuss recent developments in the theory for multi-scale problems as well as applications of this method to semi- and quasilinear reaction diffusion type problems. This is based on joint work with various collaborators.

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MS81

Error Estimates for Numerical Evans Approximation

Abstract not available at time of publication.

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MS82

Minimizers of Anisotropic Surface Tensions under Gravity from a Symmetrization Viewpoint

We study minimizers for a variational model describing the shape of liquid drops and crystals under the influence of gravity and supported by a horizontal surface. Making use of anisotropic symmetrization techniques we establish existence, convexity and symmetry of minimizers. A major obstacle in this setting is a lack of analyticity, which leads to a delicate analysis in the framework of sets of finite perimeter. In the case of smooth surface tensions, we obtain uniqueness of minimizers via an ODE characterization.

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MS82

Comparison Theorems for a Class of Degenerate Elliptic Operators

In this talk we show a host of comparison theorems for a class of degenerate elliptic problems via a form of weighted symmetrization.

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MS82

Shapes of One-Phase Free Boundaries in the Plane

We describe the space of solutions to the one-phase free boundary problem in the disk having simply-connected positive phase. If two components of the free boundary are close, we show that the solution resembles the solution discovered by Hauswirth, Helein and Pacard in a fairly strong sense. Our result is the analogue of theorems by Colding and Minicozzi on minimal surfaces, the two subjects being remarkably related, as discovered by Traizet.

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MS82

Nonlinear Spatio-Temporal Instability Regime for Electrically Forced Viscous Jets

This paper considers the problem of nonlinear instability in electrically driven viscous axisymmetric jets with respect to spatial and temporal growing disturbances in the presence of a uniform or nonuniform applied electric field. The mathematical modeling for the jets, which uses the original electrohydrodynamics equations (Melcher and Taylor, 1969) [8], is based on the nonlinear mechanics that govern the liquid jet due to tangential electric field effects. At the linear stage, we found that a particular jet of fluid could exhibit the Rayleigh and Conducting flow Instabilities for the spatial and temporal evolution of the disturbance. For the nonlinear regime of the problem, we studied the resonant instability and nonlinear wave interactions of certain modes that satisfy the dyad resonant condition. The resulting nonlinear solutions for the jet thickness, jet's electric field, jet's surface charge and jet velocity are presented and discussed.

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MS83

Ill-posedness Results for Transport Equations

We will discuss some recent work on well/ill-posedness for transport equations.

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MS83

Some Recent Progresses in Boundary Layer Analysis

In this talk, we review some recent progresses in boundary layer analysis of singular perturbation problems related to the fluids equations.

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MS83

Well-Posedness and Regularity for a Class of Thin-Film Free Boundary Problems

We investigate a free boundary problem for a thin-film equation with quadratic mobility and perfect wetting. This problem can be derived by a lubrication approximation from the Navier-Stokes system with a Navier-slip condition at the substrate. The method for proving well-posedness requires to subtract the leading-order singular expansion at the free boundary in the maximal regularity estimates for the linearized evolution. We also discuss the regularizing effect of the degenerate-parabolic operator to arbitrary orders of the singular expansion and possible extensions to general mobilities. (partially joint with Lorenzo Giacomelli, Hans Knüpfer, and Felix Otto)

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MS83

Singular Perturbation Analysis of the Scattering Problem

We study the asymptotic behavior of the two dimensional Helmholtz scattering problem with high wave numbers in an exterior domain, the exterior of a circle. We impose the Dirichlet boundary condition on the obstacle, which corresponds to an incidental wave. For the outer boundary, we consider the Sommerfeld conditions. Using a polar coordinates expansion, the problem is reduced to a sequence of Bessel equations. Investigating the Bessel equations mode by mode, we find that the solution of the scattering problem converges to its limit solution at a specific rate depending on k.

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MS84

Estimating Fragmentation in Polymerization Equations

In this talk, we will address the question of estimating the fragmentation rate, fragmentation kernel and depolymerization rate in aggregation-fragmentation equations. This question is of key importance for molecular biology, since fragmentation determines the acceleration of the chain reactions involved in protein polymerization, which is responsible for a wide range of diseases (Alzheimer's, Huntington's, Parkinson's, prion diseases etc.). Our approach combines asymptotic analysis, which allows us to reduce the complexity, and deterministic and stochastic approaches to the inverse problem.

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MS84

On Concentrated Polymers Model

We will concentrate on a class of mathematical models for polymeric fluids, which involve the coupling of the Navier-Stokes equations with a parabolic-hyperbolic integro-differential equation describing the evolution of the polymer distribution function in the solvent, and a parabolic integro-differential equation for the evolution of the monomer density function in the solvent. The viscosity coefficient includes dependence on the shear-rate as well as on the weight-averaged polymer chain length. We discuss the existence of global-in-time, large-data weak solutions under fairly general hypotheses.

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MS84

Weak Solutions to Cucker-Smale System

I would like to present recent results for the Cucker-Smale system modeling collective motion. The main aim is to present results concerning existence of weak solutions to the PDEs version of the system being a limit of solutions to the ODEs version of the Cucker-Smale system. We consider the case with the communication weight being singular such that it allows to observe gluing of trajectories/characteristics. As an initial state we can take arbitrary measure in the phase space with compact support. So uniqueness properties (weak/atomic one) will be discussed, too. The talk is based on joint results with Jan Peszek (Warszawa)

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MS84

Kinetic Models for the Description of Sedimenting Suspensions

Kinetic models appear in modeling sedimentation of suspensions of rigid rods. We consider a model describing suspensions of rod–like molecules in a solvent fluid, coupling a microscopic Fokker-Planck equation to a macroscopic Stokes flow. One objective is to compare such models with traditional models used in macoscopic viscoelasticity as the well known Oldroyd model. We provide a quantitative analysis of cluster formation. We discuss the instability of the quiescent flow and the derivation of the collective response in the diffusive regime. We derive a reduced model for the description of the collective flow that ammounts to a flux-limited Keller-Segel model, and show that it describes well the aggregate response of the sedimenting suspension. (joint with Ch. Helzel)

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MS85

Existence and Stability of Weak Solutions for a Degenerate Parabolic System of Thin Film Type

The evolution of two fluid phases in a porous medium is considered. The fluids as well as the wetting phase from the air are separated by interfaces which evolve in time. It is shown that the problem can be reduced to an abstract evolution equation. A generalized Rayleigh–Taylor condition characterizes the parabolicity regime of the problem and allows to establish a general well-posedness result and to study stability properties of flat steady states. If surface tension effects on the interface between the fluids are included and if the more dense fluid lies above, bifurcating finger-shaped equilibria exist, which are however all unstable.

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MS85

Stability of Cylinders in Surface Diffusion Flow under General Perturbations

The surface diffusion flow is a geometric evolution equation which prescribes the normal velocity of points on immersed, oriented manifolds to equal the Laplace–Betrami operator acting on the mean curvature at the point. Given a parametrization for the manifold, the morphological evolution is expressed by a fourth–order, quasilinear, parabolic pde. In this talk, I will discuss recent results regarding the stability of unbounded cylinders (as stationary solutions to surface diffusion flow) under general perturbations which exhibit periodicity along the cylindrical axis.

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MS85

On Qualitative Properties of Solutions to Microelectromechanical Systems with General Permittivity

Qualitative properties of solutions to the evolution problem modelling microelectromechanical systems with general permittivity are investigated. The system couples a parabolic evolution problem for the displacement of a membrane with an elliptic moving boundary problem for the electric potential in the region between the membrane and a rigid ground plate. Conditions are specified which ensure the non-positivity of the membrane's displacement. Moreover, given a non-positive displacement, the solution is shown to develop a finite-time singularity.

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MS85

A Free Boundary Problem for MEMS

Idealized microelectromechanical systems (MEMS) consist of a fixed ground plate above which a thin elastic plate is suspended that deforms due to a voltage difference that is applied between the two plates. The mathematical model involves the harmonic electrostatic potential in the free domain between the plates along with a singular evolution equation for the displacement of the elastic plate that depends on the trace of the potential gradient. In this talk we address questions related to the possible pull-in phenomenon when the elastic plate touches down on the ground plate.

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MS86

Recent Results on the Analysis of Liquid Crystals

We will present recent results on the qualitative behavior of minimizers for the Landau-de Gennes energy describing liquid crystals.

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MS86

Weak Solutions for the Cahn-Hilliard Equation with Phase-Dependent Diffusion Mobility

We discuss the well-posedness of Cahn-Hilliard equations with degenerate phase-dependent diffusion mobility. We consider a popular form of the equations which have been used in phase field simulations of phase separation and microstructure evolution in binary systems. We define a notion of weak solutions for the nonlinear equation. The existence of such solutions is obtained by considering the limits of Cahn-Hilliard equations with non-degenerate mobilities. We will also present numerical simulation results to show the behavior of the solution.

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MS86

Sawtooth Profile in Smectic A Liquid Crystals

We study de Gennes and Chen-Lubensky free energies for smectic A liquid crystals over $\mathbb{S}^2$ valued vector fields to understand the chevron (zigzag) pattern formed in the presence of an applied magnetic field. As the applied field increases well above the critical field, the sinusoidal shape of the smectic layer at the onset of undulation will change into the chevron patterns with a longer period. We consider a square domain to represent the cross section of a three dimensional smectic A liquid crystal sample. Well above the instability threshold, we show via Γ-convergence that a chevron structure where the director connects two minimum states of the sphere is favored. Numerical simulations illustrating the chevron structures for both models will be presented. This is a joint work with T. Giorgi and C. J. García-Cervera.

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MS86

Dynamic Analysis of Chevron Structures in Liquid Crystal Cells

A SmC* phase develops in liquid crystals as molecules self-organize into layers. In a thin cell, these layers deform into V-shaped layers forming a chevron structure. We study the molecular reorientation dynamics of this structure between two stable states caused by an applied electric field. Our model is based on the Chen-Lubensky energy and we use a gradient flow method to establish the existence and uniqueness of a solution to this time-dependent problem.

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MS87

On Neumann Type Problems for Non-Local Equations

We study Neumann type boundary value problems for nonlocal equations related to Lévy processes. Since these equations are nonlocal, Neumann problems can be obtained in many ways, depending on the "reflection' we impose on the outside jumps. We develop a viscosity theory which includes comparison and existence. For problems involving fractional Laplacian operators we prove that solutions of all our nonlocal Neumann problems converge as $\alpha \to 2^-$ to the solution of a classical Neumann problem.

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MS87

A Non-local Porous Medium Equation

A degenerate nonlinear nonlocal evolution equation is considered; it can be understood as a porous medium equation whose pressure law is nonlinear and non-local. We show the existence of sign-changing weak solutions to the corresponding Cauchy problem. Moreover, we construct explicit compactly supported self-similar solutions which generalize Barenblatt profiles – the well-known solutions of the classical porous medium equation.

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MS87

Global Regularity for 2D Muskat Problem with Finite Slope

We consider the 2D Muskat equation for the interface between two constant density fluids in an incompressible porous medium, with velocity given by Darcy's law. We establish that as long as the slope of the interface between the two fluids remains bounded and uniformly continuous, the solution remains regular. The proofs exploit the nonlocal nonlinear parabolic nature of the equations through a series of nonlinear lower bounds for nonlocal operators. We furthermore provide a global regularity result for small initial data: if the initial slope of the interface is sufficiently small, there exists a unique solution for all time.

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MS87

Global Well-Posedness of a Non-local Burgers Equation

We are concerned with the study of a non-local Burgers equation for positive bounded periodic initial data. The equation reads

$$u_t - u|D|u + |D|(u^2) = 0.$$

At a heuristic level, this model displays some striking similarities with classical models of hydrodynamics (Euler, Navier-Stokes, Burgers,...). Using the specific structure of this model, we will construct global classical solutions starting from smooth positive data, and global weak solutions starting form data in L^∞. Any weak solution is instantaneously regularized into C^∞. The long time behavior of all solutions is also understood. Our methods follow several recent advances in the regularity theory of parabolic integro-differential equations.

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MS88

Vorticity Dynamics in Rotating Flow: Geophysical Applications

Vorticity dynamics in rotating flows are investigated using a Lagrangian Particle Method (LPM). The method is based on the point vortex discretization of an incompressible fluid with smooth vorticity distribution. Velocity is computed from the Biot-Savart integral and a quadrature scheme. A new remeshing technique is applied at regular time intervals to maintain spatial accuracy and minimize error due to particle distortion. Particles are inserted and removed adaptively to maintain resolution of the flow as small scale features develop. Applications related to atmospheric and oceanic fluid flows are presented in planar and spherical geometries and include interacting dipoles, Rossby-Haurwitz waves, Gaussian vortices, and a polar vortex model. Strategies for extending LPM into compressible flow regimes are discussed.

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MS88

Blow-Up Criteria for the 3D Incompressible Euler Equations Based on the Voigt Regularization

We will discuss a computational study of two new blow-up criteria for the 3D incompressible Euler equations, based on the 3D Euler-Voigt equations. Traditional computational searches for blow-up have analyzed the vorticity coming from the 3D Euler equations themselves, which are not known to be globally well-posed, and moreover, are extrem ely difficult to simulate accurately. In contrast, the new blow-up criteria described here rely only on analyzing the vorticity of the 3D Euler-Voigt equations, which are known to be globally well-posed and are less computationally intensive to simulate.

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MS88

Deflection of Vortex Dipoles by a Flat Plate, With and Without Viscosity

Abstract not available at time of publication.

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MS88

A Mean Field Limit of Bec Vortices

The mean field behavior of an inhomogeneous Gross-Pitaevskii equation with asymptotically large numbers of vortices is examined. Under an asymptotic limit with small background perturbation, the vortex cloud moves according to a mean field equation that resembles an incompressible Euler equation with forcing. We discuss the behavior of the limiting equation.

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MS89

Advances in the Modeling of UQ for Kinetic and Scalar Equations

This work investigates the mathematical structure of projection or moment methods for the modeling of UQ, with the idea that it should be performed rather at the level of kinetic equations, and that the hyperbolic equations with UQ are obtained at the limit. Therefore, this family of methods has two natural parameters which are: N the number of polynomial moments used for the modeling of

UQ; and $\varepsilon > 0$ the usual small parameter which trigger the limit between kinetic and hyperbolic equations. I will show that this approach is endowed with rigorous BV and contraction estimates and that it generates new algorithms. Simple numerical simulations for the Burgers equation illustrate the theoretical results. I will finish with a review of open problems.

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MS89

A Stochastic Galerkin Method for the Boltzmann Equation with Uncertainty Efficient in the Fluid Regime

We develop a stochastic Galerkin method for the nonlinear Boltzmann equation with uncertainty. The method is based on the generalized polynomial chaos (gPC) and can handle random inputs from collision kernel, initial data or boundary data. We show that a simple singular value decomposition of gPC related coefficients combined with the Fourier-spectral method (in velocity space) allows one to compute the collision operator efficiently. When the Knudsen number is small, we propose a new technique to overcome the stiffness. The resulting scheme is uniformly stable in both kinetic and fluid regimes, which offers a possibility of solving the compressible Euler equation with random inputs.

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MS89

Analysis and Approximation of Parametric Hyperbolic Pde

Parametric PDE are useful for representing systems where the input data are uncertain. For a wide class of elliptic and parabolic PDE, It has been shown that best M-term polynomial approximations converge algebraically independent of dimension. Results for hyperbolic problems are perhaps less satisfactory. In this talk, we extend existing results on best M-term approximation to a larger class of parametric hyperbolic PDEs, also exploring the case where the parameters may vary in an unbounded domain.

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MS89

A Path-based Method for Simulating Large Deviations and Rare Events in Stochastic Nonlinear Schroedinger Equations

Lightwave propagation in fibers is modeled by the nonlinear Schroedinger equation. Errors in such systems are often associated with rare, noise-induced large deviations of the pulse. We present a method to determine the most probable manner in which such rare events occur by solving a sequence of constrained optimization problems. These results then guide importance-sampled Monte-Carlo simulations to determine the events probabilities. The method applies to a general class of intensity-based optical detectors, to arbitrarily shaped and multiple pulses.

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MS90

Regularity of Solutions of Hamilton Jacobi Equation on a Domain

In this lecture, we will explain a new method to show that regularity on the boundary of a domain implies regularity in the inside for PDE's of the Hamilton-Jacobi type. There are several variants of this result in different settings. One of these settings concerns continuous viscosity solutions $U : \mathbf{T}^N \times [0,+\infty[\to \mathbf{R}$ of the evolutionary equation

$$\partial_t U(x,t) + H(x, \partial_x U(x,t)) = 0,$$

where $\mathbf{T}^N = \mathbf{R}^N/\mathbf{Z}^N$, and $H : \mathbf{T}^N \times \mathbf{R}^N$ is a Tonelli Hamiltonian, i.e. $H(x,p)$ is C^2, strictly convex superlinear in p. Let now D be a compact smooth domain with boundary ∂D contained in $\mathbf{T}^N \times]0,+\infty[$. If U is differentiable at each point of ∂D, then this is also the case on the interior of D.

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MS90

Weak Kam Theory on the Infinite Symmetric Product of the Torus

Abstract not available at time of publication.

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MS90

Regularity of Weak Kam Solutions

We review recent results on the regularity of weak KAM solutions and discuss other related problems.

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MS90

Homogenization of Equivariant Hamilton-Jacobi

Equations

In this talk I would like to discuss the homogenization problem for Hamilton-Jacobi equations, in the case of Tonelli Hamiltonians which are invariant under the action of a discrete group. This different point of view, besides providing a general setting that embraces previous results in the literature (from the classical work by Lions, Papanicolaou and Varadhan to the more recent one by Contreras, Iturriaga and Siconolfi), will allow us to get a clearer understanding of the geometry of the limit space and of the structure of the homogenized problem.

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MS91

Nearly Parallel Vortex Filaments in the Ginzburg-Landau Equations

We present some recent results on the study of nearly parallel vortex filaments in the 3d Ginzburg-Landau equations. We derive an effective interaction energy of vortex filaments in the London limit and present some consequences such as the existence of nontrivial critical points of the Ginzburg-Landau energy whose defects converge to stationary solutions of the nearly parallel vortex filaments system of Klein-Majda-Damodaran. This is joint work with Robert Jerrard.

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MS91

Vortex Filaments in the Euler Equation

Classical fluid dynamics arguments suggest that in certain limits, the evolution of thin vortex filaments in an ideal incompressible fluid should roughly be governed by an equation called the binormal curvature flow. However, these classical arguments rely on assumptions that are so unrealistic that it would be hard even to extract from them a precise conjecture that admits any realistic possibility of a proof. We present a different approach to this question that yields a reasonable formulation of a conjecture and strong supporting evidence, and that clarifies the very substantial obstacles to a full proof. Parts of the talk are based on joint work with Didier Smets and with Christian Seis.

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MS91

On the Leapfrogging Phenomena in Fluid Mechanics

The mathematical analysis of the time evolution of arbitrary vortex tubes in fluid mechanics remains widely open. The particular case of vortex rings, somewhat simpler due to the reduction to cylindrical symmetry, was tackled by Helmholtz and Kelvin in the second half of the nineteenth century, and the subject has largely developed since then. Helmholtz did already described, without being able to observe it, an interaction phenomenon between rings which is now referred to as "leapfrogging", and which has been observed in real fluids since then. In the talk, I'll describe the problem in its historical perspective and I'll next report on recent works with R.L. Jerrard (for quantum fluids) and E. Miot and P. Gravejat (for classical fluids) which aim at a rigorous mathematical justification of the leapfrogging phenomenon.

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MS91

The Evolution of the Vortex Filament Equation for a Regular Polygon

We consider the geometric flow $\mathbf{X}_t = \kappa\mathbf{b}$, where κ is the curvature and $\mathbf{b}$ is the binormal component of the Frenet-Serret formulae. It can be expressed as

$$\mathbf{X}_t = \mathbf{X}_s \wedge \mathbf{X}_{ss}, \tag{5}$$

where $\wedge$ is the usual cross-product, and s denotes the arc-length parameterization. This equation is known as the Vortex Filament Equation. Since the tangent vector $\mathbf{T} = \mathbf{X}_s$ remains with constant length, we can assume that it takes values on the unit sphere. Differentiating (1), we get the so-called Schrödinger map equation onto the sphere:

$$\mathbf{T}_t = \mathbf{T} \wedge \mathbf{T}_{ss}. \tag{6}$$

We study the evolution of (1) and (2), taking a planar regular polygon of M sides as $\mathbf{X}(s,0)$. Assuming uniqueness and bearing in mind the invariances and symmetries of (1) and (2), we are able to fully characterize, by algebraic means, $\mathbf{X}(s,t)$ and $\mathbf{T}(s,t)$, at rational multiples of $t = 2\pi/M^2$. We show that the values of $\mathbf{X}$ and $\mathbf{T}$ at those points are intimately related to the generalized quadratic Gauß sums:

$$G(a,b,c) = \sum_{l=0}^{c-1} e^{2\pi i(al^2+bl)/c}. \tag{7}$$

We also compare the results with those obtained when $\mathbf{X}(s,0)$ consists of just one single corner. Finally, we mention some fractality phenomena appearing during the evolution of $\mathbf{X}$ and $\mathbf{T}$. All the results are completely supported by numerical simulations.

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MS92

Numerical Simulation of Maxwell's Equations

Abstract not available at time of publication.

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MS92

Field Enhancement in Nanogaps

Abstract not available at time of publication.

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MS92

Nonlinear Maxwell's Equations

Abstract not available at time of publication.

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MS93

Compactness Estimates for Hamilton-Jacobi Equations

We will discuss quantitative estimates of compactness in $\mathbf{W}^{1,1}_{loc}$ for the map S_t, $t > 0$, that associates to every initial data $u_0 \in \mathrm{Lip}\ (\mathbb{R}^N)$ the corresponding solution $S_t u_0$ of

$$u_t + H\Big(x, \nabla_x u\Big) = 0\,, \qquad t \geq 0, \quad x \in \mathbb{R}^N,$$

with a convex coercive Hamiltonian. Joint work with F. Ancona and Khai. T. Nguyen.

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MS93

Stochastic Homogenization of Non Convex Hamilton-Jacobi Equations

Abstract not available at time of publication.

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MS93

On the Global Behavior of Generalized Characteristics of Hamilton-Jacobi Equations

This is based on the joint works with Piermarco Cannarsa and Cui Chen. In this talk, we give an intrinsic proof the existence of generalized characteristics using sup-convolutions with the kernel driven by the original characteristic system. By this approach, we get the results on the global propagation of singularities along generalized characteristics for certain Tonelli systems, as well as the improvement of the local results of generalized characteristic for general cases.

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MS93

An Abstract K.A.M. Theorem with Applications to Pdes

Abstract not available at time of publication.

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MS94

Direct Scattering by a Penetrable Media

We are interested in calculating the scattered field generated by an incident wave to a penetrable medium. To do so, we represent the scattered field by a volume potential and consider the integral formulation of the scattering problem, which gives us the Lippmann-Schwinger equation. The algorithm presented here is highly accurate, works on an adaptive data structure and solves the resulting linear system with a fast direct solver. Some numerical results will be displayed.

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MS94

Numerical Methods for Time Domain Two-dimensional Wave-structure Interaction

The interaction between an acoustic wave and a linearly elastic solid is studied as an exterior problem for the Laplace resolvent equation and an interior problem for the Navier-Lamé resolvent equation communicating through coupling conditions. For problems with constant elastic coefficients, space discretization leads to a system of boundary integral equations, while for variable elastic coefficients a Boundary Element-Finite Element symmetric coupling scheme is applied. Time marching combines Convolution Quadrature and standard time stepping.

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MS94

Droplet Footprint Control

Controlling droplet shape via surface tension has numerous technological applications, such as droplet lenses and lab-on-a-chip. This motivates a PDE-constrained shape optimization approach for controlling the shape of droplets on flat substrates by controlling the surface tension of the substrate. We use shape differential calculus to derive an L2-gradient flow approach to compute equilibrium shapes for

sessile droplets on substrates. We then develop a gradient-based optimization method to find the substrate surface tension coefficient yielding an equilibrium droplet shape with a desired footprint (i.e., the liquid-solid interface has a desired shape). Moreover, we prove a sensitivity result with respect to the substrate surface tensions for the free boundary problem associated with the footprint. Numerical results are also presented to showcase the method.

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MS94

Sub-Linear Solver for the 2D High-Frequency Helmholtz Equation

We present a new fast and scalable algorithm to solve the 2D high-frequency Helmholtz equation in heterogeneous medium. The algorithm relies on domain decomposition, integral operators, and fast methods. The resulting algorithm has, for the first time, an online runtime $\mathcal{O}(N/P)$, where N is the number of unknowns, and P is the number of nodes in a distributed memory environment; provided that $P = \mathcal{O}(N^{1/5})$.

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MS95

Striated Regularity of Velocity for the Euler Equations

The well-posedness of the Euler equations in Hölder spaces for short time in 3D goes back to the work of Gunther and Lichtenstein in the 1920s; the global-in-time 2D result is due to Wolibner in 1933. The work in 2D of Chemin and in higher dimensions of Gamblin and Saint Raymond, and of Danchin, in the 1990s established analogous results for vorticity possessing negative Hölder space regularity only in directions given by a sufficient family of vector fields, which are themselves transported by the flow ("striated' regularity). We prove that the propagation of striated velocity in a positive Hölder space also holds, by establishing the equivalence of striated regularity of vorticity and of velocity. We re-express this result in a particularly simple form using the Lagrangian velocity.

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MS95

How to Control Flutter Arising in Flow Structure Interactions

An appearance of flutter in oscillating structures is an endemic phenomenon. Most common causes are vibrations induced by the moving flow of a gas (air, liquid) which is interacting with a nonlinear structure. Typical examples include: turbulent jets, vibrating bridges, oscillating facial palate in the onset of apnea. The intensity of the flutter depends heavily on the speed of the flow (subsonic, transonic or supersonic regimes). Thus, reduction or attenuation of flutter is one of the key problems in aeroelasticity with application to a variety of fields including aerospace engineering, structural engineering, medicine and life sciences. Mathematical models describing this phenomenon involve coupled systems of partial differential equations (Euler Equation and nonlinear plate equation) with interaction at the interface - which is the boundary surface of the structure. The aim of this talk is to present a mathematical theory describing: (1) asymptotic stability and associated long time behavior and (2) feedback control strategies aiming at the elimination or attenuation of the flutter . We shall show that at the subsonic speeds feedback control applied to the structure eliminates asymptotically the flutter. This is joint work with Justin Webster from NC State University

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MS95

Optimal Mixing Rates

I will discuss recent results on optimal mixing of a passive scalar by incompressible flows. The mixing rate is measured by a negative Sobolev norm. I will present examples of flows that achieve the theoretical optimal rate under various physical constraints on the flow.

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MS95

Weak Vorticity Formulation, Circulation, Net force and Torque

We present a weak vorticity formulation of the 2D incompressible Euler equations, in a smooth, bounded domain, which can be used in the study of flows with vortex sheet regularity, i.e., whose vorticity is a bounded Radon measure with finite kinetic energy. We use this formulation to examine the possible exchange between flow vorticity and circulation around boundary components, especially for those solutions obtained by mollifying initial data and passing to the limit, with the portion of vorticity singular with respect to the Lebesgue measure assumed to be non-negative. We note that, if the weak solution conserves circulation around boundary components, then it is a boundary coupled weak solution, a stronger version of the weak vorticity formulation. We show that the net mechanical force which the flow exerts on each boundary component is well-defined, for vortex sheet flows, if and only if the flow is a boundary coupled weak solution. The same holds for the net torque.

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MS96

Accuracy of Suboptimal Bayesian Filters in the Presence of Model Error

Data assimilation for PDEs is hampered by the high dimensionality of the problem and errors in the reduced computational model. Various approximate Gaussian filters are known to be provably accurate for estimating the mean state of mildly non-Gaussian dynamics in the perfect model scenario provided that the full state is observed. Here we examine a class of suboptimal filters for 2D Navier-Stokes dynamics, with non-Gaussian update and a Gaussian analysis step, which do not rely on the knowledge of the truth dynamics and were shown to be effective in dealing with various sources of model error in turbulent systems.

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MS96

Bayesian Filtering as Transportation

We present a new approach to nonlinear filtering using transport maps. Our scheme avoids both Gaussian approximations and the use of weighted particles, instead constructing a sequence of deterministic maps that push forward a reference probability measure to the posterior. The approach considers the joint distribution of the states between one assimilation step and the next, effectively performing smoothing over limited time intervals. We will present notions of dimension reduction and localization—and their expressions in the transport map framework—that are essential to making the computation of transport maps tractable for PDE models.

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MS96

Continuous Data Assimilation for Modified 3D Navier-Stokes Equations

In this talk, I will present few mathematical results about the 3D Brinkman-Forchheimer-extended Darcy (BFeD) Model for porous media. This model is believed to be accurate when the flow velocity is too large for Darcy's law to be valid, and additionally the porosity is not too small. Additionally, I will introduce an algorithm for continuous data assimilation for BFeD. The algorithm is inspired by ideas developed for designing finite-parameters feedback control for dissipative systems. Specifically, the algorithm involves a feedback control that nudges the large scales of the approximate solution toward those of the reference solution associated with the spatial measurements. Eventually, the convergence the algorithm is shown for two different type of observations interpolants.

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MS96

Stratification of Markov Processes for Rare Event Simulation

I will discuss an ensemble sampling scheme based on a decomposition of the target average of interest into subproblems that are each individually easier to solve and can be solved in parallel. The most basic version of the scheme computes averages with respect to a given density and is a generalization of the Umbrella Sampling method for the calculation of free energies. We have developed a careful understanding of the accuracy of the scheme that is sufficiently detailed to explain the success of umbrella sampling in practice and to suggest improvements including adaptivity. For equilibrium versions of the scheme we have developed error bounds that reveal that the existing understanding of umbrella sampling is incomplete and leads to a number of erroneous conclusions about the scheme. Our bounds are motivated by new perturbation bounds for Markov Chains that we recently established and that are substantially more detailed than existing perturbation bounds for Markov chains. They demonstrate, for example, that equilibrium umbrella sampling is robust in the sense that in limits in which the straightforward approach to sampling from a density becomes exponentially expensive, the cost to achieve a fixed accuracy with umbrella sampling can increase only polynomially. I will also discuss extensions of the stratification philosophy to the calculation of dynamic averages with respect a given Markov process. The scheme is capable of computing very general dynamic averages and offers a natural way to parallelize in both time and space.

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MS97

Surprising Solutions to the Isentropic System of

Gas Dynamics

This talk is concerned with the well-posedness problem for the isentropic compressible Euler equations of gas dynamics in several space dimensions. In particular, we are interested in investigating the efficiency of different selection criteria proposed in the literature in order to weed out non-physical solutions to more-dimensional systems of conservation laws. Building upon the method of convex integration developed by De Lellis-Székelyhidi for the incompressible Euler equations, we can construct infinitely many bounded solutions to the compressible Euler equations satisfying the entropy inequality, even for some Lipschitz initial data. We also show that the maximal dissipation criterion proposed by Dafermos does not favour in general the self-similar solution. Finally we discuss the stability of the initial data allowing for such non–uniqueness results.

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MS97

Uniqueness of Rarefaction Waves in Multidimensional Compressible Euler Systems

We consider two systems of partial differential equations; the compressible isentropic Euler system and the complete Euler system describing the time evolution of an inviscid nonisothermal gas. In both cases we show that the rarefaction wave solutions of the 1D Riemann problem are unique in the class of all bounded weak solutions to the associated multi-D problem. This may be seen as a counterpart of the non-uniqueness results of physically admissible solutions emanating from 1D shock waves constructed recently by the method of convex integration.

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MS97

Recent Advances Concerning the Three-dimensional Primitive Equations of Atmospheric and Oceanic Dynamics

In this talk I will discuss some of the recent advances concerning the global regularity of the three-dimensional primitive equations and atmospheric and oceanic dynamics in the presence of various kinds of anisotropic viscosity and diffusion. Moreover, we will show that in the non-viscous case there is a class of solutions that develop a singularity in finite time.

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MS97

A Variational Time Discretization for the Compressible Euler Equations

We introduce a variational time discretization for the multi-dimensional gas dynamics equations, in the spirit of minimizing movements for curves of maximal slope. Each timestep requires the minimization of a functional measuring the acceleration of fluid elements, over the cone of monotone transport maps. We prove convergence to measure-valued solutions for the pressureless gas dynamics and the compressible Euler equations. For one space dimension, we obtain sticky particle solutions for the pressureless case.

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MS98

Global Existence Results for the Stable Muskat Equation

In this talk, we shall focus on the stable Muskat equation. This problem modelises the interface between two immiscible and incompressible fluids of different caracteristics (e.g. oil and water). We present an other formulation for the problem which allows us to prove some new global existence results.

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MS98

Global Well Posedness For A Two-Fluid Model

We study a two fluid system which models the motion of a charged fluid. Local in time solutions of this system were proven by Giga-Yoshida. In this paper, we improve this result in terms of requiring less regularity on the electromagnetic field. We also prove that small solutions are global in time.

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MS98

Long Time Stability of the Implicit Euler Scheme

for An Incompressible Two-Phase Flow Model

In this talk we present results on the stability for all positive time of the fully implicit Euler scheme for an incompressible two-phase flow model. More precisely, we consider the time discretisation scheme and with the aid of the discrete Gronwall lemma and of the discrete uniform Gronwall lemma we prove that the numerical scheme is stable.

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MS99

Finite-Time Blow Up and Long-Wave Unstable Thin-Film Equations

Abstract not available at time of publication.

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MS99

Traveling Wave Solutions for Some Reaction Diffusion Equations with Fractional Laplacians

Abstract not available at time of publication.

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MS99

Some Degenerate Parabolic Equations Inspired by Image Processing

A class of linear and nonlinear degenerate diffusions inspired from and with application to Image Processing will be presented and analyzed.

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MS99

High-Order Time Stepping for Nonlinear PDE Through Componentwise Approximation of Matrix Functions

Krylov subspace spectral (KSS) methods are high-order accurate, explicit time-stepping methods with stability characteristic of implicit methods. This "best-of-both-worlds' compromise is achieved by computing each Fourier coefficient of the solution using an individualized approximation, based on techniques from "matrices, moments and quadrature' for computing bilinear forms involving matrix functions. In this talk, it will be shown how this approach can be applied to nonlinear PDE.

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MS100

Minimizers of the Landau-De Gennes Energy Around a Spherical Colloid Particle

We consider energy minimizing configurations of a nematic liquid crystal around a spherical colloid particle, in the context of the Landau-de Gennes model. The nematic is assumed to occupy the exterior of a ball B_{r_0}, and satisfy homeotropic weak anchoring at the surface of the colloid and approach a uniform uniaxial state as $|x| \to \infty$. We study the minimizers in two different limiting regimes: for balls which are small $r_0 \ll L^{\frac{1}{2}}$ compared to the characteristic length scale $L^{\frac{1}{2}}$, and for large balls, $r_0 \gg L^{\frac{1}{2}}$. The relationship between the radius and the anchoring strength W is also relevant. For small balls we obtain a limiting quadrupolar configuration, with a "Saturn ring' defect for relatively strong anchoring, corresponding to an exchange of eigenvalues of the Q-tensor. In the limit of very large balls we obtain an axisymmetric minimizer of the Oseen–Frank energy, and a dipole configuration with exactly one point defect is obtained.

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MS100

The Landau-De Gennes Model for Nematic Liquid Crystalline Films

We use the method of Γ-convergence to study the behavior of the Landau-de Gennes model for a nematic liquid crystalline film in the limit of vanishing thickness. In this asymptotic regime, surface energy plays a greater role and we take particular care in understanding its influence on the structure of the minimizers of the derived two- dimensional energy. We assume general weak anchoring conditions on the top and the bottom surfaces of the film. The constants in the weak anchoring conditions are chosen so as to enforce that a surface-energy-minimizing nematic Q-tensor has the normal to the film as one of its eigenvectors. We establish a general convergence result and then discuss the limiting problem in several parameter regimes

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MS100

Properties of Minimizers for the Maier-Saupe Energy

We will describe our work on regularity and qualitative features of minimizers for the constrained (Maier-Saupe) energy. This is joint work with Patricia Bauman.

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MS100

Wetting-Driven Phase Transition in a Nanoparticle-Block Copolymer Blend

We identify the Γ-limit of an energy related to nanoparticle/block copolymer models as the number of particles goes to infinity and as the size of the particles and the phase transition thickness of the polymer phases approach zero. The limiting energy consists of two terms: the perimeter of the interface separating the phases and a penalization term related to the density distribution of the infinitely many small nanoparticles; and, can be considered as a toy model where a penalization term affects the phase transition morphology. We prove that local minimizers of the limiting energy admit regular phase boundaries and derive necessary conditions of local minimality via the first and second variations of the limiting energy functional. Finally we discuss possible critical and minimizing patterns in two dimensions and how these patterns vary from global minimizers of the purely local isoperimetric problem.

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MS101

Propagation in Some Nonlocal Population Dynamics Models

Non local effects are very relevant in population dynamics models and, from the mathematical point of view, can lead to complex behaviors, that require new tools. For example, nonlocal diffusion with heavy tails can accelerate the level sets of the invading solutions. On the other hand nonlocal competition typically prevents the use of comparison arguments and some natural problems remain open. We discuss recents developments on such issues.

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MS101

On a Fractional Thin Film Equation for Hydraulic Fractures

Abstract not available at time of publication.

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MS101

Crystal Dislocations with Different Orientation and Collisions

Dislocations are moving defects in crystals that can be described at several scales by different models. We consider a 1D evolution equation arising in the Peierls-Nabarro model, which is a phase field model describing dislocation dynamics at a microscopic scale. Differently from the previous literature, we treat the case in which dislocations do not occur all with the same orientations (i.e. opposite orientations are allowed as well). We show that, at a long time scale, and at a mesoscopic space scale, the dislocations have the tendency to concentrate as pure jumps at points which evolve in time, driven by the external stress and by a singular potential. Due to differences in the dislocations orientation, these points may collide in finite time. We provide an estimates on the relaxation times of the system after collision. The results that will be presented have been obtained in some papers in collaboration with E. Valdinoci.

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MS101

A Family of Higher Order Parabolic Non-Local Equations

We study a nonlocal degenerate parabolic equation of order $\alpha + 2$ for $\alpha \in (0, 2)$. The equation is a generalization of the one arising in the modeling of hydraulic fractures studied by Imbert and Mellet. Using the same approach, we prove the existence of solutions for $0 < \alpha < 2$ and for nonnegative initial data satisfying appropriate assumptions. The main difference is the compactness results due to different Sobolev embeddings. For $\alpha > 1$, we construct a nonnegative solution for nonnegative initial data under weaker assumptions.

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MS102

Data-driven Vortex Modeling of Separated Flows

Abstract not available at time of publication.

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MS102

Hovering in Oscillatory Flows

Abstract not available at time of publication.

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MS102

Vortex Shedding from Smooth Two-Dimensional Objects Using Boundary Layers

We propose coupling a visocus boundary layer to an inviscid outer flow with continuous velocity and vorticity flux as a model for vortex shedding from smooth two-dimensional objects with Reynolds number of 1000-10000. We demonstrate the accuracy of this model for impulsively started flow past a rotating circular cylinders, and show comparison with flow patterns, force, and circulation obtained from numerical solution of Navier Stokes equations. The method is extensible to three dimensions.

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MS102

Numerical Study of Hierarchical Vorticity Separations of Viscous Flow Past Wedges

Viscous flow past a wedge with varying angles is numerically studied. The physical domain with a wedge is transformed into an upper half plane using conformal mapping for computational convenience. A split method is applied to compute the 2D Navier-Stokes equations in which the inviscid and viscous parts of the vorticity are solved separately. As the flow impulsively starts, a positive primary vortex forms behind the wedge, which is known as the starting vortex. The starting vortex induces a negative vorticity region within it, which attaches to the wedge near the tip. With a non-zero wedge angle, another positive vorticity region would appear, induced by the negative vorticity. The talk will focus on the formation of this hierarchical vorticity separations.

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MS103

Approximation of Fractional Powers of Accretive Operators.

We study the numerical approximation of fractional powers of accretive operators in this paper. Namely, if A is the accretive operator associated with an regular sesquilinear form $A(\cdot,\cdot)$ defined on a Hilbert space V contained in $L^2(\Omega)$, we approximate $A^{-\beta}$ for $\beta \in (0,1)$. The fractional powers are defined in terms of the so-called Balakrishnan integral formula. We construct a numerical approximation in a finite element $V_h \subset V$ and provide error estimates in Sobolev norms.

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MS103

A PDE Approach to Fractional Diffusion

We study solution techniques for problems involving fractional powers of symmetric, coercive and elliptic operators. These can be realized as the Dirichlet to Neumann map for a nonuniformly elliptic problem posed on a semi-infinite cylinder, which we analyze in the framework of Muckenhoupt weighted Sobolev spaces. Motivated by the rapid decay of the solution to this problem, we propose a truncation that is suitable for numerical approximation. We discretize this truncation using first degree tensor product finite elements. We derive suboptimal a priori error estimates for quasi-uniform discretizations and quasi-optimal error estimates for anisotropic discretizations. We explore extensions and applications of the a priori theory previously described: a posteriori error analysis and adaptivity; parabolic equations with fractional diffusion and Caputo fractional time derivative; elliptic and parabolic fractional obstacle problems; and optimal control problems.

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MS103

A Petrov-Galerkin Finite Element Method for Fractional Convection-Diffusion Equations

In this work, we discuss novel variational formulations of Petrov-Galerkin type for one-dimensional fractional boundary value problems involving either a Riemann-Liouville or a Caputo fractional derivative of order $\alpha \in (3/2, 2)$ and both convection and potential terms. These boundary value problems arise in the mathematical modeling of asymmetric super-diffusion processes in heterogeneous media. The well-posedness of the variational formulations and sharp regularity pickup of the variational solutions are established. Further, a novel finite element method is developed, which employs continuous piecewise linear finite elements and "shifted' fractional powers of the form $(x_{i+1}-x)_+^{\alpha-1}$ for the trial and test space, respectively. The new approach has a number of distinct features when compared with existing ones Extensive numerical results are presented to verify the convergence analysis and robustness of the numerical scheme.

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MS104

Waves Traveling Through Obstacles in Lattice Differential Equations

We consider scalar lattice differential equations posed on square lattices in two space dimensions. Under certain natural conditions we show that wave-like solutions exist when obstacles (characterized by "holes') are present in the lattice. Our work generalizes to the discrete spatial setting the results obtained by Berestycki, Hamel and Matano for the propagation of waves around obstacles in continuous spatial domains. The analysis hinges upon the development of sub and super-solutions for a class of discrete bistable reaction-diffusion problems and on a generalization of a classical result due to Aronson and Weinberger that concerns the spreading of localized disturbances.

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MS104

Appropriate Discretization Schemes for Travelling Waves in Bistable Reaction-Diffusion Problems

We study various temporal and spatial discretization methods for bistable reaction-diffusion problems. The main focus is on the functional differential operators that arise after linearizing around travelling waves in the spatially discrete problem and studying how the subsequent discretization of time affects the spectral properties of these operators. This represents a highly singular perturbation that we attempt to understand via a weak-limit method based on the pioneering work of Bates, Chen and Chmaj (2003). Once this perturbation is understood, one can study the existence and (non)-uniqueness of waves in the fully discretized reaction-diffusion system.

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MS104

Nonlinear Schrodinger Equation on Quantum Graphs

We consider standing waves in the focusing nonlinear Schrödinger (NLS) equation on a barbell graph (two rings attached to a central line segment subject to the Kirchhoff boundary conditions at the junctions). In the limit of small norm solutions, the ground state (orbitally stable standing wave of the smallest energy at a fixed L^2 norm) is represented by a constant solution. However, when the L^2 norm is increased, this constant state undertakes at least two symmetry breaking bifurcations. The first bifurcation occurs under anti-symmetric perturbations and lead to the standing wave being localized in one of the two rings. The second bifurcation occurs under symmetric perturbations and lead to the standing wave being localized in the central line segment. Both standing waves are orbitally stable in the limit of large norm solutions, but only one standing wave is a ground state. This is a joint work with Jeremy Marzuola (University of North Carolina at Chapel Hill).

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MS104

Agent-Based and Continuum Models for Stripe Formation in Zebrafish

Zebrafish (Danio rerio) is a small fish with distinctive black and yellow stripes that form due to the interaction of different pigment cells. We study the development of wild-type and mutated zebrafish patterns using discrete (agent-based) and continuum (non-local conservation law) models on a growing domain. We find that fish growth shortens the necessary scale for long-range interactions and that local repulsion between cells maintains stripe boundary integrity.

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MS105

Asymptotic Preserving Methods for Kinetic Chemotaxis Systems

We consider numerical approximations of the kinetic equations describing a collective behavior of bacteria and their interaction with chemoattractant. We introduce a nondimensional small parameter (the ratio of the mean free paths corresponding to isotropic and chemotactic reorientation) and by choosing a diffusion scaling we obtain a transport equation in nondimensional form depending on this parameter. We then derive asymptotic preserving schemes for the resulting kinetic chemotaxis equations.

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MS105

Entropy Satisfying Methods for Competition Dynamics

Abstract not available at time of publication.

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MS105

Positivity-preservation in a Class of Locally-implicit Discontinuous Galerkin Schemes

We consider a class of discontinuous Galerkin finite element methods that make use of a locally-implicit time-stepping procedure. One advantage of this approach is that it allows us the flexibility to update our variables of choice (i.e., conserved, primitive, or entropy variables). Using this framework, we construct limiters that allow us to enforce positivity of relevant variables (e.g., density and pressure in the compressible Euler equations). We consider several standard test cases for the Euler equations to validate the proposed method.

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MS105

Entropy Satisfying Methods for Fokker-Planck Equations

We design and analyze up to third order accurate discontinuous Galerkin (DG) methods satisfying a strict maximum principle for FokkerPlanck equations. A procedure is established to identify an effective test set in each computational cell to ensure the desired bounds of numerical averages during time evolution. This is achievable by taking advantage of the two parameters in the numerical flux and a novel decomposition of weighted cell averages. Based on this result, a scaling limiter for the DG method with first order Euler forward time discretization is proposed to solve the one-dimensional FokkerPlanck equations. Strong stability preserving high order time discretizations will keep the maximum principle. It is straightforward to extend the method to two and higher dimensions on rectangular meshes. We also show that a modified limiter can preserve the strict maximum principle for DG schemes solving FokkerPlanck equations. As a consequence, the present schemes preserve steady states. Numerical tests for the DG method are reported. The new applications of the method will be discussed.

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MS106

Burgers Equation in the Complex Plane and Random Matrix Theory

We present an elementary introduction to the surprising appearance of Burgers equation in the complex plane in random matrix theory. In particular, we connect the Calogero-Moser system with the asymptotics of Harish-Chandra's integral. This problem arises in the analysis of the asymptotics of the fundamental solution to the heat equation in the space of Hermitian matrices, Her(n), as $n \to \infty$.

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MS106

Weak Solutions for Integrable Free-Boundary Dynamics in Two Dimensions

Planar free-boundary problems with an infinite number of conservation laws are known to exhibit finite-time singularities for boundaries with initial real-analytic data, geometrically characterized by formation of cusps. Considered as classical Cauchy problems, this feature is equivalent to the non-existence of strong solutions after a finite time. Several classes of weak solutions have been proposed in the literature, equivalent to various ways of boundary smoothing, and incompatible with the set of conservation laws. This lecture introduces a new form of weak solutions, compatible with the set of conservation laws, which allow to continue the dynamics through the finite-time singularity, by applying a complexified version of the Lax entropy criterion to select the proper solution for a complex hyperbolic equation.

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MS106

Multi-Scale Conformal Maps for Singular Interfaces in Free Boundary Problems

Conformal maps are a powerful analytical tool for studying two dimensional problems in Fluid flows, electrostatics and elasticity. The problem of interest is converted to a "simpler" problem using a conformal mapping to a standard reference domain, usually the unit circle. There however are significant difficulties in using numerical (i.e discretized) conformal maps for domains with sharp or nearly singular interfaces. This is due the phenomenon of *crowding*, i.e a tendency of nodes in the discretization concentrating near the sharp parts of the boundary, leaving the rest unresolved. There is no easy way to fix this, because numerical conformal mapping methods are intrinsically non-adaptive. In our work, we have developed an approach, that allows us to solve for *two conformal maps*, an inner map for the sharp region and an outer map for the rest of the boundary and then formulating appropriate matching conditions, so in effect we have a 2 scale (and hence adaptive) discretization. We use this method to solve a free boundary electro-mechanical problem.

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MS106

Conformal Mapping Technique for a Supercavitating Flow Around a Wedge Or a Hydrofoil

The flow induced by the motion of a body and the formation of a trailing cavity is of considerable interest in marine applications such as the design and analysis of hydrofoils and marine propellers. The problem considered in this talk involves a wedge or a hydrofoil moving beneath a free surface or in a jet with a uniform speed. A trailing cavity forms behind a wedge or a hydrofoil. The cavity closure mechanism is described according to the Tulin's single-spiral-vortex model. A closed form solution to the

governing nonlinear boundary value problem is found by the use of conformal mappings. The double-connected flow domain is treated as the image by this map of the exterior of two slits in a parametric plane. The mapping function is constructed through the solution to two boundary-value problems of the theory of analytic functions, the Hilbert problem for two slits in a plane and the Riemann-Hilbert problem on an elliptic surface. Numerical results for the shape of the cavity and the free surface, the drag and lift coefficients, and the circulation are reported. Comparison of the numerical results with the Tulin's double-spiral-vortex model is presented.

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MS107

A Fractional Space-time Optimal Control Problem: Analysis and Discretization

We study a linear-quadratic optimal control problem involving a parabolic equation with fractional diffusion and Caputo fractional time derivative of orders $s \in (0,1)$ and $\gamma \in (0,1]$, respectively. The spatial fractional diffusion is realized as the Dirichlet-to-Neumann map for a nonuniformly elliptic operator. Thus, we consider an equivalent formulation with a quasi-stationary elliptic problem with a dynamic boundary condition as state equation. The rapid decay of the solution to this problem suggests a truncation that is suitable for numerical approximation. We consider a fully-discrete scheme: piecewise constant functions for the control and, for the state, first-degree tensor product finite elements in space and a finite difference discretization in time. We show convergence of this scheme and, for $s \in (0,1)$ and $\gamma = 1$, we derive a priori error estimates.

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MS107

The State of the Art in Polytopal Finite Element Methods

Numerical approximation of the solution of PDEs over meshes of generic polygons in 2D or polyhedra in 3D is receiving significant current attention from both mathematicians and engineers. In this talk, I will briefly describe three major approaches in this area - virtual element methods, weak Galerkin methods, and generalized barycentric coordinate methods - and summarize the key findings of the recent conference "Polytopal Element Methods in Mathematics and Engineering," held at Georgia Tech in October 2015. I will conclude with a discussion of where the field seems likely to head in the coming years.

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MS107

C^0 DG Methods for Elliptic Problems in Non-divergence Form

In this talk, we describe a class of finite element methods for $W^{2,p}$ strong solutions of second-order linear elliptic PDEs in non-divergence form. The main novelty of the method is the inclusion of an interior penalty term, which penalizes the jump of the flux across the interior element edges/faces, to augment a nonsymmetric piecewise defined and PDE-induced bilinear form. Existence, uniqueness and error estimate in a discrete $W^{2,p}$ energy norm are proved for the proposed finite element method. This is achieved by establishing a discrete Calderon-Zygmund-type estimate and mimicking strong solution PDE techniques at the discrete level.

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MS107

Finite Element Approximation of the Isaacs Equation

We propose and analyze a two-scale finite element method for the Isaacs equation. The fine scale is given by the mesh size h whereas the coarse scale ε is dictated by an integro-differential approximation of the partial differential equation. We show that the method satisfies the discrete maximum principle provided that the mesh is weakly acute. This, in conjunction with weak operator consistency of the finite element method, allows us to establish convergence of the numerical solution to the viscosity solution as $\varepsilon, h \to 0$, provided $\varepsilon \geq Ch|\log h|$. In addition, using a discrete Alexandrov Bakelman Pucci estimate we deduce rates of convergence, under suitable smoothness assumptions on the exact solution.

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MS108

A New Analytic Approach to Wave Turbulence

In this talk we discuss improvements to a new approach to wave turbulence instigated by Zaher Hani, Pierre Germain and Erwan Faou. This approach will combine techniques from analytic number theory and dispersive PDE theory to study an example of discrete turbulence, for which dynamics is dominated by the exact resonances of the equation. Specifically we will study the large box limit of the Nonlinear Schrödinger Equation in the weakly nonlinear regime. This is joint work with Zaher Hani, Pierre Germain and Jalal Shatah.

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MS108

Well/Ill-Posedness for Transport Equations

We will discuss some recent work on well/ill-posedness for transport equations.

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MS108

Normal Form Transformations for Capillary-Gravity Water Waves

This work concerns the equations of capillary-gravity waves in a two-dimensional channel of finite or infinite depth. These equations are considered in the framework of Hamiltonian systems, for which the Hamiltonian energy has a convergent Taylor expansion in canonical variables near the equilibrium solution. We give an analysis of the Birkhoff normal form transformation that eliminates third-order non-resonant terms of the Hamiltonian. We also provide an analysis of the dynamics of remaining resonant triads in certain cases, related to Wilton ripples. This is a joint work with Walter Craig.

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MS108

Persistence of Regularity for Solutions of the Boussinesq Equations in Sobolev Spaces

We address the persistence of regularity of the Boussinesq system in 2D with zero diffusivity in Sobolev spaces $W^{s,p}$. In the case of the whole space, we prove that the persistence holds with data such that $sp > 2$, while in the case of the torus, there is no restriction on s and p.

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MS109

Continuous Data Assimilation with Stochastically Noisy Data

We analyze the performance of a data-assimilation algorithm based on a linear feedback control when used with observational data that contains measurement errors. Our model problem consists of dynamics governed by the two-dimensional incompressible Navier-Stokes equations. The observational measurements are given by finite volume elements or nodal points of the velocity field and the measurement errors are represented by a stochastic noise. Under these assumptions, the data-assimilation algorithm consists of a system of stochastically forced Navier-Stokes equations. The main result provides explicit conditions on the observation density (resolution) which guarantee explicit asymptotic bounds, as the time tends to infinity, on the error between the approximate solution and the actual solutions which is corresponding to these measurements, in terms of the variance of the noise in the measurements.

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MS109

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MS109

Kalman Filtering and Inverse Problems with Infinitely Dimensional Data

Since PDE-based numerical models lead to high-dimensional states and remote sensing can result in high-dimensional data, methods with performance that does not deteriorate for high-dimensional and infinite-dimensional states and data as the asymptotic limit are of interest. The posterior state distribution in the Bayesian approach is well defined when the data is finite dimensional even if the prior state distribution is a Gaussian measure on a separable Hilbert space. However, when the data space is infinitely dimensional Hilbert space, data error distributions for which the Bayes formula is well posed are limited to those tied to the state distribution by the Feldman-Hajek theorem. This excludes even a simple case when the whole state is observed and the prior state distribution and the data distribution are Gaussian measures. However, this limitation disappears when the data distribution is white noise, which has a stabilizing effect. White noise on a Hilbert space is not measurable because its distribution is only a finitely additive cylindrical measure rather than a probability measure, but the posterior is again a probability measure. This observation is applied to the large sample convergence of the Ensemble Kalman filter with infinitely dimensional data.

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MS109

Sequential Data Assimilation for Urban Crime Model

We explore some of the various issues that may occur in attempting to sequentially estimate state and parameters of a dynamical model of agent-based model for residential crime to data on just the attack times and locations. We derive an ensemble Poisson-Kalman filter (PKF) and show how to carry out the PKF for the continuum-limit PDE of

the agent-based crime model.

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MS110

The Cauchy Problem for the Pressureless Euler/ Isentropic Navier-Stokes Equations

In this talk, we present coupled hydrodynamic equations which can be formally derived from Vlasov-Boltzmann/Navier-Stokes equations. More precisely, our proposed equations consist of the compressible pressureless Euler equations and the isentropic compressible Navier-Stokes equations. For the equations, we establish the global existence of classical solutions, and its large-time behavior which shows the exponential alignment between two fluid velocities.

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MS110

Entropy Stable Methods for Numerical Solutions of the Multidimensional Euler and Ideal Magnetohydrodynamics Equations

Using a symmetrization technique for hydrodynamics and magnetohydrodynamics an energy stability analysis is performed for the discontinuous Galerkin finite element approximation of these equations. In this analysis the mathematical entropy serves as a suitable energy for these systems of equations. The entropy stability analysis yields sufficient conditions that must be met by the discontinuous Galerkin formulation so that nonlinear entropy stability of numerical solutions is obtained. Furthermore, we prove under suitable conditions that the approximate solutions converge to the entropy measure valued solutions for nonlinear systems of conservation laws. This is joint work among others with Sibusiso Mabuza.

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MS110

Conservative Weak Solutions of the 2D Euler Equations

We seek optimal conditions under which a weak solution of the two dimensional incompressible Euler equations conserves kinetic energy.

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MS110

Weak-Strong Uniqueness for Inviscid Flows

Various concepts of weak solution have been suggested for the fundamental equations of inviscid fluid flow over the last few decades. A common problem is a vast degree of non-uniqueness that all these types of solution exhibit. Nevertheless, a conditional notion of uniqueness, the so-called weak-strong uniqueness, can be established in various situations. We present some recent results, both positive and negative, on weak-strong uniqueness in the realm of incompressible and compressible Euler flows.

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MS111

Aggregation Models for Liquid Crystals with Polydispersity

I will discuss a class of aggregation models describing polymeric systems where monomers may form polymers of variable lengths. Combining these models with Onsager-type models for distribution of orientation densities of liquid crystalline systems, I will derive free energies which characterize distributions of both lengths and orientations of polymeric systems.

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MS111

Modeling the Motion and Locomotion of Liquid Crystal Elastomers

Liquid crystals are exceptionally responsive to external stimuli due to their symmetry. Liquid crystal elastomers (LCEs) are soft solids, where, due to coupling of orientational order and mechanical strain, this responsivity leads to large changes in shape, enabling motion and locomotion. In talk, I will review experimental observations, and present a new mode of locomotion of LCE samples in restricted geometries. I will describe the corresponding equations of motion, present numerical results, and discuss the relevant parameters characterizing the response.

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MS111

Features of Minimizers to Liquid Crystals Energies

We examine the qualitative structure of stable states for liquid crystal energies.

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MS111

On the Classical and Statistical Dynamics of Hard, Non-Spherical Particle Systems

It is a challenge to try to understand how observable phenomena arise in liquid crystals by starting from models for the dynamics of hard, non-spherical particles, as opposed to starting with continuum models for vector- or tensor-valued order parameter fields. In this talk, we discuss some recent results on the dynamics of such non-spherical particle systems. Part of this work is joint with Laure Saint-Raymond.

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MS112

Liouville Theorems for the Navier Stokes Equation on a Hyperbolic Space

The problem for the stationary Navier-Stokes equation in 3D under finite Dirichlet norm is open. In this talk we answer the analogous question on the 3D hyperbolic space. This is joint work with Chi Hin Chan.

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MS112

Existence and Maximal L^p-Regularity of Solutions for the Porous Medium Equation on Manifolds with Conical Singularities

We consider the porous medium equation

$$\begin{aligned} u'(t) + \Delta(u^m(t)) &= f(u,t), \quad t \in (0, T_0], \\ u(0) &= u_0. \end{aligned}$$

on a manifold with conical singularities. We assume that $m > 0$ and $f = f(\lambda, t)$ is a holomorphic function of λ on a neighborhood of $\mathrm{Ran}(u_0)$ with values in Lipschitz functions in t on $[0, T_0]$. We model the manifold with conical singularities by an n-dimensional compact manifold B with boundary, $n \geq 2$, endowed with a degenerate Riemannian metric g, which, in a collar neighborhood $[0,1) \times \partial B$ of the boundary ∂B, is of the form $g(x,y) = dx^2 + x^2 h(y)$. Here, h is a (non-degenerate) Riemannian metric on ∂B, and $(x,y) \in [0,1) \times \partial B$. By Δ we denote the Laplacian associated with this metric. It naturally acts on scales of Mellin-Sobolev spaces $\mathcal{H}_p^{s,\gamma}(B)$ We show existence, uniqueness and maximal L^p-regularity of a short time solution. In particular, we obtain information on the short time asymptotics of the solution near the conical point. Our method is based on bounded imaginary powers results and R-sectoriality perturbation techniques. More specifically: Given $s > -1$ and p, q sufficiently large, we consider the extension of Δ in $\mathcal{H}_p^{s,\gamma}(B)$ with domain $\mathcal{D} = \mathcal{H}_p^{s+2,\gamma+2}(B) \oplus \mathbf{C}$ for a suitable choice of the weight γ. For any strictly positive initial value

$$u_0 \in (\mathcal{D}, \mathcal{H}_p^{s,\gamma}(B))_{\frac{1}{q},q}$$

there exists a $T > 0$ such that the porous medium equation, considered in the space $L^q(0,T;\mathcal{H}_p^{s,\gamma}(B))$, has a unique solution

$$u \in L^q(0,T;\mathcal{D}) \cap W^{1,q}(0,T;\mathcal{H}_p^{s,\gamma}(B)).$$

(joint work with Nikolaos Roidos)

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MS112

Maximal Regularity Theory on Manifolds with Singularity

In this talk, we will introduce the concept of manifolds with singularities and study a class of elliptic differential operators that exhibit degenerate or singular behavior near the singularities. Based on this theory, we investigate how to start geometric flows with bad initial metrics.

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MS112

On Fluid Flows and Phase Transitions

A thermodynamically consistent model for incompressible two-phase fluid flows with phase transitions is introduced and analyzed. Concentrating on the case of equal densities, we establish well-posedness and study the qualitative behavior of solutions. In particular, we characterize all equilibria and study their stability properties.

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MS113

Evolution and Interaction of Localized Structures with Oscillatory Tails

The analysis of localized structures is an important method of gaining insight into the rich dynamics of nonlinear partial differential equations. While localized structures approaching a constant state at the infinities (e.g. front solutions or pulses) are well-understood, the theory for such structures with oscillatory tails (e.g. defects or generalized modulating pulses) is still developing. This talk gives a an overview of the subject and presents some new results for the interaction of such solutions.

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MS113

Traveling Fronts in Holling-Tanner Model with

Slow Diffusion

For wide range of parameters, we study traveling waves in a diffusive version of the Holling-Tanner predator-prey model from population dynamics. Fronts are constructed using geometric singular perturbation theory and the theory of rotated vector fields. We focus on the appearance of the fronts in various singular limits.

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MS113

Structure and Stability in Localized Patterns

Motivated by numerical stability results on spatially localized patterns in spatially extended systems, we show how the stability of patterns that are formed of nonlocalized fronts can be understood from the spectra of the underlying fronts. We use extended Evans functions to understand the spectral properties of these patterns on the original unbounded domain and on large but bounded domains, and we compare our results to previous findings on resonance poles and edge bifurcations.

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MS113

Nonlinear Damping Estimates and Stability of Large-amplitude Periodic Wave Trains

In the stability theory for shock waves of partially dissipative equations such as compressible Navier-Stokes, MHD, etc., two delicate points are the establishment of high-frequency resolvent bounds, and the handling of regularity issues in the absence of (strictly) parabolic smoothing. Both of these can be handled together in a straightforward way by the use of linear and nonlinear damping estimates obtained by "Kawashima-type' energy estimates, which for small-amplitude (slowly-varying) shocks are straightforward by the original ideas of Kawashima, but for large-amplitude shocks require the additional ingredient of a "Goodman-type' exponential weight penalizing transverse convection. We first review these ideas in the shock wave context, then give a recent analog established with L.M. Rodrigues in the context of periodic wave trains of the Saint Venant equations for inclined thin film flow. As in the shock case, this gives for the first time a nonlinear stability result for large-amplitude spectrally stable waves, or, what turns out to be equivalent, waves with large Froude number. This includes waves of Froude number in the range physically relevant for applications in hydraulic engineering, which were inaccessible by previously existing theory.

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MS114

An Asymptotic Preserving Maxwell Solver Resulting in the Darwin Limit ...

In plasma simulations where the speed of light times a characteristic length is at a much higher frequency than the relevant parameters in the system, such as the plasma frequency, implicit methods begin to play an important role in generating efficient solutions in these multi-scale problems. Under conditions of scale separation, one can rescal Maxwells equations in such a way as to give a magneto static limit known as the Darwin model of electromagnetics. This model converts Maxwells equations into 8 eleptic equations. In this work we present a new approach to solving Maxwells equations based on a method of lines transpose formulations, combined with fast sumation that, an under the right scaling, results in an asymptotic preserving method that recovers the Darwin limit of electromagnetics.

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MS114

Multi-Level Monte Carlo Methods for Computing Uncertain Systems of Conservation Laws.

We briefly review the theory of entropy measure valued solutions, and show how we can compute statistics of multi-dimensional systems of conservation laws using entropy preserving schemes and stochastic sampling. The numerical framework can be improved by Multi-level Monte-Carlo (MLMC) approximations, obtaining a speedup compared to ordinary Monte-Carlo sampling procedure, even in the setting where we do not have convergence of single samples. We show some numerical experiments computing the statistics of the Kelvin-Helmholtz instability.

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MS114

Velocity Scaling Methods for Kinetic Equations with Nonlocal Interactions

We consider a family of kinetic equations with nonlocal interactions, which have been successfully used to model biological complex behaviors. The main difficulty in designing numerical methods on such systems is the loss of smoothness of the solution in velocity variable as time becomes large. We propose a velocity scaling method which characterizes the exact blowup structure of the equations, and the scaled equation remains smooth global in time. We also proposed a correction on upwind scheme to preserve the first moment of the scaled equation. This is a joint work with Thomas Rey.

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MS114

L2 Stable Discontinuous Galerkin Methods for One-dimensional Two-way Wave Equations

Simulating wave propagation is one of the fundamental problems in scientific computing. In this talk, we consider one-dimensional two-way wave equations, and investigate a family of L2 stable high order discontinuous Galerkin methods, which is defined through a general form of numerical fluxes. For these L2 stable methods, we systematically establish stability, energy conservation, error estimates, superconvergence and dispersion analysis. Numerical examples are presented to illustrate the accuracy and the long-term behavior of the methods under consideration.

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PP1

Four-Step Hybrid Type Method with Vanished Phase-Lag and Its First Derivatives for Each Level for the Approximate Integration of the Schrodinger Equation

In this paper, we present a new methodology for the development of four-step hybrid type methods of sixth algebraic order with vanished phase-lag and its derivatives. The methodology is based on the vanishing of the phase-lag and its derivatives on its level of the hybrid method. We present a comparative error and stability analysis for the produced new method. The efficiency of the new obtained methods is examined by application to the resonance problem of the Schrodinger equation

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PP1

Phase Slip Solutions in Magnetically Modulated Taylor-Couette Flow

We numerically investigate Taylor-Couette flow in a wide-gap configuration, with ri=ro = 1=2, the inner cylinder rotating, and the outer cylinder stationary. The fluid is taken to be electrically conducting, and a magnetic field of the form $Bz(1 + \cos(2z = z0)) = 2$ is externally imposed, where the wavelength $z0 = 50(ro - ri)$. Taylor vortices form where the field is weak, but not where it is strong. As the Reynolds number measuring the rotation rate is increased, the initial onset of vortices involves phase slip events, whereby pairs of Taylor vortices are periodically formed and then drift outward, away from the midplane where $Bz = 0$. Subsequent bifurcations lead to a variety of other solutions, including ones both symmetric and asymmetric about the midplane. For even larger Reynolds numbers a different type of phase slip arises, in which vortices form at the outer edges of the pattern and drift inward, disappearing abruptly at a certain point.

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PP1

Charged Boundary-Layer Domain Walls in Thin Ferromagnetic Films

We study a two-dimensional limit of the micromagnetic energy in whichthe logarithmic divergence of the nonlocal magnetostatic energy due to aline charge is compensated by the choice scaling of the film thickness.This allows for optimal-energy configurations containing charged domain-walls. We consider a large sample of soft (isotropic) material in astrong single-well potential (for example due to an applied magneticfield, or an exchange-coupled bilayer), and develop Gamma-convergenceresults for the 2D energy, with either tangent boundary conditions or apenalization energy on the boundary.

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PP1

Frechet Differentiability in the Optimal Control of Parabolic Free Boundary Problems

We consider an optimal control of the Stefan type free boundary problem the general second order linear parabolic PDE. The density of heat sources, the unknown free boundary, and the boundary heat flux are components of the control vector, and the cost functional consists of the L_2-declination of the trace of the temperature at the final moment, the temperature at the free boundary, and the final position of the free boundary from available measurements. We follow a new variational formulation developed in U. G. Abdulla, Inverse Problems and Imaging, 7,2(2013),307-340. In this project we prove Frechet differentiability of the cost functional in Hilbert space framework. Extension of differentiable calculus to the infinite-dimensional setting is the major mathematical challenge in this context. We apply the idea of decomposition of the domain, and analyze carefully the effect of the boundary integrals on the derivation of the first variation of the cost functional. With the delicate use of sharp embedding theorems in fractional Sobolev-Besov spaces we prove Frechet differentiability, and derive the formula for the Frechet gradient.

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