CP1

Efficient Optimization of Electrostatic Interactions Between Biomolecules

We will present a novel PDE-constrained optimization strategy for analyzing the optimality of electrostatic interactions between biomolecules. These interactions are important factors affecting binding affinity and specificity, and can be analyzed using linear continuum models. The resulting optimization problems are well-posed but computationally expensive. Our method uses an implicit representation of the Hessian, in combination with preconditioned Krylov methods, to dramatically reduce the computational expense. We will discuss several applications in biomolecule analysis and design.

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CP1

Growth of a Spherical Tumor with a Necrotic Core: A Moving Boundary Simulation

After vascularization, a tumor may develop a necrotic core, characterized by an outer rim of proliferating cells and an inner core of dead cells. Research shows that between these is a layer of quiescent cells which can begin dividing if environmental conditions change. What follows is an extension of previous work used to show the concentration of nutrient within the interior of a tumor over time. At each time step, the core boundary and the tumor boundary are free to increase or decrease as appropriate when compared to certain threshold values, thereby simulating a moving boundary problem.

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CP1

A Stochastic Model of the Tumor Growth for Dispersed Cells Regime

A stochastic model is developed to describe the growth of a heterogeneous tumor for dispersed cells regime. The mathematical model is a quasilinear stochastic partial differential equation driven by a space-time white noise. The main feature of the model is that it takes into account random independent interactions between tumor cells, immune system cells and anticancer drugs. The existence of the weak solutions and a comparison theorem are established. Some applications are proposed.

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CP1

Continuous Moran Process and the Diffusion of Genes in Infinite Populations

We consider the so called Moran process with frequency dependent fitness given by a certain pay-off matrix. For finite populations, we show that the final state must be homegeneous, and show how to compute the fixation probabilities. Next, we consider the infinite population limit, and discuss the appropriate scalings for the drift-diffusion limit. In this case, a degenerated parabolic PDE is formally obtained that, in the special case of frequency independent fitness, recovers the celebrated Kimura equation in population genetics. We then show that the corresponding initial value problem is well posed and that the discrete model converges to the PDE model as the size of population goes to infinity. We also study some game-theoretic aspects of the dynamics and characterise the best strategies, in an appropriate sense.

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CP1

Computational Analysis Based on Mathematical Model for Biodegradation of Xenobiotic Polymers

Biodegradation processes of xenobiotic polymers are studied numerically. The weight distribution with respect to the molecular weight before and after biodegradation is introduced into analysis based on a mathematical model and an inverse problem is solved numerically to determine a biodegradation rate. Once the biodegradation rate is found, an initial value problem can be solved numerically to simulate the transition of the weight distribution, and the applicability of the numerical result can be tested.

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CP1

Multiple-Spike Ground State Solutions of the Gierer-Meinhardt Equations

In many biological pattern formations and some biochemical reactions, an activator-inhibitor system of two reaction-diffusion equations serves as a mathematical model. The

typical Gierer-Meinhardt equations

$$A_t = d\Delta A - A + \frac{A^2}{H},$$

$$H_t = D\Delta H - H + A^2,$$

where $d/D << 1$, $A, H > 0$ and $A, H \to 0$ as $\mid x \mid \to \infty$, feature two largely different diffusion coefficients and the essentially nonlocal nonlinearity. By the Lyapunov-Schmidt method, the maximum order estimate of the multiple spike numbers of a ground state solution is found and the construction of such a solution is shown.

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CP2

Particle Motion in the Circular, Restricted Three-Vortex Problem

Can a number of test particles traveling in different periodic orbits in the circular, restricted three-vortex realm be controlled such that they are placed in the same (equal period) orbit? Additionally, can the same or a different controller be used to fix the relative positions of the test particles such that a virtual or dynamically natural formation can be established? It will be shown that the answer to both questions is, yes.

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CP2

On Some Stochastic Fractional Integrodifferential Equations

The purpose of this paper is to study the integro-partial differential equation of fractional order:

$$\frac{\partial^\alpha u(x,t)}{\partial t^\alpha} - \sum_{|q|\le 2m} a_q(x) D^q u(x,t) = f_1(u(x,t)) + \int_0^t f_2(u(x,s)) dW(s),$$

with the nonlocal condition

$$u(x,0) = \varphi(x) + \sum_{k=1}^{p} c_k u(x,t_k),$$

where $0 \le t_1 < t_2 < \ldots < t_p$,
x is an element of the n-dimensional Euclidean space $R^n, D^q = D_1^{q_1} \ldots D_n^{q_n}$,

$$D_j = \frac{\partial}{\partial x_j}, 0 < \alpha \le 1,$$

$q = (q_1, \ldots, q_n)$ is an n dimensional multi-index, $|q| = q_1 + \ldots + q_n$ and $W(t)$ is standard Wiener process over the filtered probability space Ω, F, F_t, P.
It is supposed that $\sum_{|q|=2m} a_q(x) D^q$ is uniformly elliptic on R^n . The existence of solutions of the considered Cauchy problem and some properties are studied under suitable conditions on φ , the constants $c_1, \ldots, c_p$, the functions a_q, f_1 and f_2.

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CP2

On the Stability of Some Stochastic Differential Equations

Stochastic Volterra equations of the form:

$$dx(t) = f(x(t))dt + \int_0^t K(t-s)x(s)ds\ dt + g(x(t))dB(t),$$

are considered, where $\{B(t) : t \ge 0\}$ is standard one - dimensional Brownian motion and the kernel K decreases to zero non-exponentially. We study the convergence rate to zero of the stochastic solutions of the considered equation. It is proved under suitable conditions that :

$$\lim_{t\to\infty} \frac{|x(t)|}{K(t)} = \infty, \quad \text{almost surely.}$$

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CP2

Numerical Realizations of the Stochastic KdV Equation With and Without Damping

We investigate numerical simulations of an exact solution of a stochastic Korteweg deVries equation under Gaussian white noise. We compare the expectation values of the exact solutions to theoretical expectation values and to the numerical simulations of the stochastic Korteweg deVries equation with and without damping. We find that typically on average the diffused soliton vanishes long before the typically reported asymptotic limit.

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CP2

First Passage Time Problem of a Time-Dependent Ornstein-Uhlenbeck Process to a Moving Boundary

In this paper we derive the closed-form formula for the first passage time density (FPTD) of a time-dependent Ornstein-Uhlenbeck process, i.e. the conventional Ornstein-Uhlenbeck process with time-dependent parameters, to a parametric class of moving boundaries by the method of images. We also apply the results to develop a simple, efficient and systematic approximation scheme, namely the multistage approximation, to compute tight upper and lower bounds of the FPTD through a fixed boundary.

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CP2

Convergence Analysis of Operator Upscaling for the Acoustic Wave Equation

Wave propagation in a heterogeneous medium results in models involving multiple scales. Operator-based upscaling solves the problem on a coarse grid, but still retains subgrid information and fine-scale input data. First, the problem is solved for the subgrid component defined locally within each coarse block. Then, the subgrid solutions are used to augment the coarse-grid problem. We present convergence analysis for the method applied to the constant density, variable sound velocity acoustic wave equation.

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CP3

Level Set Method Approaches to Dislocation Models of Grain Boundaries

Grain boundaries in materials can be formally represented as arrays of dislocations lines. This perspective makes it possible to study meso-scale processes, such as mechanisms for grain boundary motion and interactions of dislocations with grain boundaries. Using a level-set formalism for dislocation dynamics pioneered by our group, we investigate several interesting grain boundary problems using dislocation models. The computational efficiency required to study these models is provided by a parallel level set method software library that we have recently developed.

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CP3

Free Boundary Interaction in Stefan Problem with Undercooling

Suppose that the Stefan problem with kinetic undercooling has a classical solution until the moment of contact of free boundaries and the free boundaries have finite velocities until the moment of contact. Under these assumptions, we construct a smooth approximation of the global solution of the Stefan problem with kinetic undercooling, which, in the limit, gives the above classical solution until the moment of contact and becomes the solution of the heat equation after the contact. We study the properties of this approximation. In particular, we show that the velocities of the free boundaries become equal to each other in absolute value at the moment of contact and the temperature has a jump at the point of contact. The obtained analytical and numerical results are compared.

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CP3

The Onset of Superconductivity at a Normal/Superconducting Interface

We Study a modified model of Ginzburg and Landau that considers superconducting electrons diffusing into a normal material in contact with a superconductor. We assume that each region occupy a half-space with a constant applied field parallel to the interface. we show, if the normal conductivity of the superconductor is less than the conductivity of the normal material then normal states are local minimizers for fields down to H_{c2}, which agrees with experimental observations that superconductivity is suppressed in this case. While when the conductivity of the superconductor is larger than that for the normal material the onset occur at fields larger than H_{c2} and less than H_{c3}.

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CP3

Homogenisation of Reaction, Diffusion and Interfacial Exchange in Porous Media with Evolving Microstructure

Chemical degradation mechanisms of porous materials often result in a change of the pore geometry. These effects cannot be captured by the standard periodic homogenisation method due to the local evolution of the microscopic domain. A mathematically rigorous approach is suggested which allows the treatment of such problems. It makes use of a transformation to a stationary (periodic) reference domain on which the homogenisation can be performed. A physical interpretation also allows the direct modelling of the transformed problem.

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CP3

Solutions of the Smoluchowski Equation for Ne-

matic Polymers under Imposed Fields

We solve the Smoluchowski equation for rigid nematic polymers under imposed elongational flow, magnetic or electric fields. We show that: (1)The equation can be cast in a generic form. (2) The steady state solution is of the Boltzmann type, parametrized by material and two order parameters. (3) The external field must be parallel to one of the eigenvalues of the second moment tensor. A bifurcation diagram of the order parameters is presented. The solution method is extended to dilute solutions under imposed electric field. The first moment of the steady state solution is shown parallel to the external field, under certain conditions.

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CP3

Dynamical Instability of Pinned Fundamental Vortices

We show dynamical instability of pinned fundamental ±1 vortex solutions to the Ginzburg-Landau equations with external potentials in R^2. For smooth and sufficiently small external potentials, there exists a perturbed vortex solution centered near each critical point of the potential. Perturbed vortex solutions which are concentrated near minima (resp. maxima) are orbitally unstable (resp. stable). We consider both gradient and Hamiltonian flows.

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CP4

The Taylor-Couette Problem in a Deformable Cylinder

The Taylor-Couette problem is a fundamental example in bifurcation theory, and has been the subject of over 1500 papers. This lecture treats a generalization where the rigid outer cylinder is replaced by a deformable (viscoelastic) cylinder. A steady solution of this liquid-solid interaction problem can be found analytically; its linear stability is governed by a quadratic eigenvalue problem. The purpose of this lecture is to describe the analysis and computation of the spectrum.

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CP4

Floating Drops and Functions of Bounded Variation

Three fluids are in equilibrium under the action of gravitational and surface tension forces. The fluid with intermediate density has a finite volume, and the motivating example is that in which this volume forms a 'drop' floating on thhe most dense fluid wiith the least dense one above. In axisymmetric situations, for example when the other two fluids have infinite volume, this problem can be formulated as a free boundary problem for axisymmetric capillary surfaces. The drop is bounded by a sessile drop and an inverted sessile drop and the exterior interface is an exterior capillary surface. This has been studied both theoretically and numerically, but the general existence theorem has proven difficult to obtain using these methods. We formulate here a variational problem using functions of bounded variation and prove the existence of a solution.

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CP4

Explosive Instabilities In Rimming Flows

The linear stability of a thin film of viscous fluid on the inside of a cylinder with horizontal axis, rotating about this axis is introduced in this paper. Both axial and azimuthal components of the hydrostatic pressure gradient are taken into account, which yield solutions that collapse in both dimensions. Despite the existence of these 'explosive' instabilities, all solutions with harmonic dependence on the axial variable and time (normal modes) are neutrally stable. This type of instability has been described in previous papers. However, no actual solution to describe the movement of the film of liquid through the cylinder has been presented. This paper will rectify this and examine the properties of such a solution.

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CP4

Ideal 2D Flow in a Domain with Holes and the Small Obstacle Limit

We study the limiting behavior of incompressible, ideal flow in a 2D bounded domain with holes, when one of the holes becomes small. The difficulty lies in describing and controlling the behavior of the potential part of the flow in terms of vortex dynamics. This work is a natural extension of [Iftimie *et alli*, CPDE 28 (2003) 349–370], which studied the same limit for flows in the exterior of a single

small obstacle.

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CP4
Analytic Solution of Rayleigh-Taylor Problem

We study the initial value problem for the classical Rayleigh-Taylor problems. If the initial data is analytic and satifies some other conditions, it is proved that unique analytic solution exists locally in time. The analysis is based on a Nirenberg Theorem on abstract Cauchy-Kovalevsky problem in properly chosen Banach spaces.

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CP5
Equilibrium Ice Sheets Solve Variational Inequalities

The standard model for steady (shallow) ice sheet flow on an arbitrary bed with stress-dependent basal sliding and temperature-dependent flow is shown to be a variational inequality whose interior condition is the well-known and highly nonlinear “ice sheet equation,” a nonlinear diffusion which generalizes the p-Laplacian equation. That is, such sheets solve a substantially-generalized p-Laplacian obstacle problem for $p \geq 2$. These abstract problems are variational inequalities for strictly monotone nonlinear operators on the Sobolev space $W_0^{1,p}(\Omega)$. For these problems we establish existence, an *a priori* bound, and continuity of the solution with respect to certain parameter fields. Uniqueness remains unproven in some cases. Finite element methods are considered.

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CP5
A Mathematical Model for Electromagnetic Waves in Magnetized Media

The topic of this talk is the Landau-Lifschitz equation coupled with Maxwell’s equations describing the electromagnetic field in generally nonlinear magnetized medium. The Landau-Lifschitz equation is a first order ordinary differential equation for the magnetization field coupled to Maxwell’s equations for the electromagnetic field. The main subjects are the existence, uniqueness and asymptotic behavior of the solutions as well as certain small parameter limits in this model.

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CP5
Fractal Properties of Hele-Shaw Flow

Hele-Shaw flow in circular geometry leads to well-known instability of the frontline between two immiscible liquids. Mathematically, flows of two liquids are described by Laplace equations, with (curvature-dependent) boundary conditions. Though the numerical simulations allow one to solve the problem, there is no available technique that would describe the time-changing fractal properties of the resulting flows. Such novel approach for time-varying description is proposed in the present work and well compared with experiment.

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CP5
An Approximated Solution to the Two-Dimensional Lid-Driven Cavity Flow, Using Adomian Decomposition Method and the Vorticity-Stream Function Formulation

In this work, we present a reliable algorithm to solve the two-dimensional lid-driven cavity flow, using the Adomian Decomposition Method (ADM). The vorticity-stream function formulation is used for the incompressible flow considered here. The solution is calculated in the form of a series with easily computable coefficients. Also, numerical simulation, using finite difference method (FDM), is performed for comparison purposes. This comparison shows considerably close agreements.

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CP5
Wave Propagation Through a Spatio-Temporal Checkerboard Structure

We consider propagation of waves through a spatio-temporal material structure with a checkerboard microgeometry. The squares of the checkerboard are filled with alternating materials having equal impedance but different phase speeds. Within certain parameter ranges, we observe the formation of distinct and stable limiting characteristic paths that attract neighbouring characteristics after a few time periods. The average speed of propagation along the limit cycles remains the same throughout certain ranges of parameters of the microgeometry.

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CP5
Numerical Modeling of Fluid Mixing for Laser Experiments and Supernova

In collaboration with a team centered at U. Michigan and LLNL, we have conducted front tracking simulations for axisymmetrically perturbed spherical explosions relevant

to supernovae as performed on NOVA laser experiments, with excellent agreement with experiments. We have extended the algorithm and its physical basis for preshock interface evolution due to radiation preheat. Our second focus is to study turbulent combustion in a type Ia supernova (SN Ia) which is driven by Rayleigh-Taylor mixing. We have extended our front tracking to allow modeling of a reactive front in SN Ia. Our 2d axisymmetric simulations show a successful level of burning.

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CP6

A PDE-Constrained Optimal Control Problem in Image Processing

We present a control problem motivated by mammographic image processing. The underlying model involves a degenerate parabolic PDE where the control enters in the diffusion coefficients and, implicitely, in the solution space. We discuss spaces of discontinuous functions adapted to this type of control. We further show how a characterization helps in obtaining existence results for the simultaneous solution of the control problem and the PDE.

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CP6

Accelerated Inverse Analysis Using Parameterized Model Order Reduction

One alternative to directly coupling solver and optimizer for PDE constrained optimization problems is to use recently developed parameterized model reduction methods to generate a parameterized low-order model and then use the model in the optimizer. Such model-reduction based optimization methods have advantages in computational efficiency, particularly when the extracted model is used repeatedly. We demonstrate that the method is very effective for an inverse scattering problem associated with optical inspection.

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CP6

Existence of An Optimal Shape for a Pde System in a Free Air/Porous Domain: Application to Hydrogen Fuel Cells

We consider a shape optimization problem related to a nonlinear system of PDE describing the gas dynamics in a free air - porous domain, including gas concentrations, temperature, velocity and pressure. The velocity and pressure are described by Stokes and Darcy laws, while concentrations and temperature are given by mass and heat conservation laws. The system represents a simplified dry model of gas dynamics in channel and graphite diffusive layers in hydrogen fuel cells. The model is coupled with the other part of domain through some mixed boundary conditions, involving nonlinearities, and pressure boundary conditions. Under some assumptions we prove that the system has a solution and that there exists a channel domain in the class of Lipschitz domains minimizing a certain functional measuring the membrane temperature distribution, total current, water vapor transport and channel inlet/outlet pressure drop.

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CP6

Hydrodynamic Limit to Hamilton-Jacobi Equations

we study convolution-generated monotone cellular automata(CA) and ordered transition rules. It turns out that those CA satisfy translation invariance and finite propagation speed. We show that the hydrodynamic limit of the evolving occupied sets in such a CA is the level sets of the viscosity solution to a Hamilton-Jacobi equation, a first order geometric PDE

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CP6

Numerical Study of Optimal Control for Nonlinear Cahn-Hilliard Equations

Cahn-Hilliard (CH) equations are described a continuous model for phase transition in binary systems such as alloy, glasses and polymer-mixtures. This work is to investigate numerical study for optimal control of CH equations by the means of initial, boundary and distributed control. A semi-discrete algorithm is constructed for minimization of quadratic optimal criteria using finite element method. The convergence and error estimate are deduced. Numerical demonstrations illustrated the efficiency of proposed paradigm.

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CP7

Nonoscillatory Central Schemes on Unstructured Triangular Grids for Hyperbolic Systems of Conservation Laws

An extension to unstructured triangulations of Jiang and Tadmor's [SISC 19(6)] scheme will be proposed. Through a direction-insensitive reconstruction, the proposed scheme is of the correct order of accuracy in any direction, not just along coordinate axes. Moreover, the use of an adaptive limiter ensures the sharp resolution of discontinuities and convergence to the unique viscosity solution. Central-upwind extensions, in the spirit of Kurganov et al [SISC 23(3)], will be considered.

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CP7

A Hamiltonian Regularization of the Burgers Equation

We consider the following scalar equation:

$$u_t + uu_x - \alpha^2 u_{txx} - \alpha^2 uu_{xxx} = 0, \quad (1)$$

with $\alpha > 0$. We may rewrite (1) as

$$v_t + uv_x = 0, \quad (2)$$

where

$$v = u - \alpha^2 u_{xx}, \quad (3)$$

One can think of the equation (2) as the inviscid Burgers equation,

$$v_t + vv_x = 0,$$

where the convective velocity in the nonlinear term is replaced by a smoother velocity field u. This idea goes back to Leray (1934) who employed it in the context of the incompressible Navier-Stokes equation. Leray's program consisted in proving existence of solutions for his modified equations and then showing that these solutions converge, as $\alpha \downarrow 0$, to solutions of Navier-Stokes. We apply Leray's ideas in the context of Burgers equation. We show strong analytical and numerical indication that (2)-(3) (or equivalently, (1)) represent a valid regularization of the Burgers equation. That is, we claim that solutions $u^\alpha(x,t)$ of (1) converge strongly, as $\alpha \to 0$, to unique entropy solutions of the inviscid Burgers equation. Interestingly, for all $\alpha > 0$, the regularized equation possesses a Hamiltonian structure. We also study the stability of the traveling waves for equation (1). These traveling waves consist of "fronts", which are monotonic profiles that connect a left state to a right state. The front stability results show that the regularized equation (1) mirrors the physics of rarefaction and shock waves in the Burgers equation.

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CP7

Solutions to Coupled Systems of Conservation Laws

We discuss the construction of solutions to coupled systems of nonlinear conservation laws. These equations arise for example in models for traffic flow on road networks. The coupling is then due to the intersection of roads. We derive necessary conditions including in particular the conservation of all moments of the hyperbolic equation. We construct solutions to the coupled system based on considerations on special Riemann problems posed at the road intersections.

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CP7

Transonic Regular Reflection for the Isentropic Gas Dynamics Equations

We consider a two-dimensional Riemann problem for the isentropic gas dynamics equations and derive regimes for which regular reflection can occur. We restrict our study to transonic regular reflection and write the problem in self-similar coordinates. This change of variables leads to a mixed type system and a free boundary problem for a position of the reflected shock and a subsonic state behind the shock. We present preliminary ideas on analysis of this problem using the theory of second order elliptic equations and the fixed point theory.

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CP7

High Resolution Total Variation Diminishing Scheme for Linear System of Hyperbolic Conservation Laws

A conservative high-resolution TVD scheme for linear hyperbolic systems is constructed using the flux limiter function. In the present work the numerical flux function of high-resolution scheme based on wave speed splitting is constructed in such a way that it respects the physical hyperbolicity property. Bounds are given for limiter functions to satisfy TVD property. Numerical results are given

for both 1-D and 2-D systems, which show high-resolution near points of discontinuity without introducing spurious oscillations.

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CP7

A New Sticky Particle Method for Pressureless Gas Dynamics

I will first present a new sticky particle method for the one- and two-dimensional systems of pressureless gas dynamics. The method is based on the idea of sticky particles, which seems to work perfectly well for the models with point mass concentrations and strong singularity formations. In this method, the solution is sought in the form of a linear combination of delta-functions, whose positions and coefficients represent locations, masses and momenta of the particles, respectively. The locations of the particles are then evolved in time according to a system of ODEs, obtained from a weak formulation of the system of PDEs. The particle velocities are approximated in a special way using a global conservative piecewise polynomial reconstruction technique over an auxiliary Cartesian mesh. This velocities correction procedure leads to a desired interaction between the particles and hence to clustering of particles at the singularities followed by the merger of the clustered particles into a new particle located at their center of mass.

In the two-dimensional case, the convergence of the proposed sticky particle method is still an open problem. I will show that our particle approximation satisfies the original system of pressureless gas dynamics in a weak sense, but only within a certain error, which is rigorously estimated. I will also give an explanation why the relevant errors are expected to diminish as the total number of particles increases.

Finally, I will demonstrate the performance of the new sticky particle method on a variety of one- and two-dimensional numerical examples and compare the obtained results with those computed by a high-resolution finite-volume scheme. The results obtained by the sticky particle method seem to be superior since the evolution of developing discontinuities is accurately tracked and the developing delta-shocks do not get smeared (this is the main advantage of using low-dissipative particle methods).

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CP7

Entropy Solutions for a Triangular System of Conservation Laws Modelling Three Phase Flow in Porous Media.

In this talk, we will consider a 2×2 triangular (hence resonant) system of conservation laws that models ”reduced” three phase flows in a porous medium where saturation of one of the phases is independent of the other phases. A notion of entropy solutions is proposed and the entropy solutions are shown to form a L^1 stable semi-group. Existence of solutions is proved using a vanishing viscosity argument and compensated compactness. Numerical schemes of the Godunov type are proposed and shown to converge to the entropy solution.

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CP8

A Comparison of AB/BDI2 and AB/CN Time Stepping Schemes in a Chebychev-Tau Spectral Navier-Stokes Solver

The semi-implicit time stepping schemes: Adams-Bashforth/Backward-Differencing (AB/BDI2) and Adams-Bashforth/Crank-Nicolson (AB/CN) were implemented in a spectral methods based Navier-Stokes solver. The solver was used for obtaining time dependent velocity and temperature fields for a natural convection in an inclined channel problem. Contrary to the previous literature, for this application, we have seen only a minor stability improvement when AB/BDI2 was used instead of AB/CN. The improvement was not enough to allow for a time step size reduction but it was enough to decrease initial oscillations on the global solution. The comparative results and the comparisons with the previous literature are presented in terms of dimensionless groups.

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CP8

Diagonalizing Similarity Transformations for Variable-Coefficient Differential Operators

Let L be a second-order self-adjoint variable-coefficient differential operator on $C_p(2\pi)$. We show that using symbolic calculus and anti-differentiation operators, we can obtain a sequence of unitary similarity transformations that approximately diagonalizes L, yielding analytical representations of approximate eigenvalues and eigenfunctions. Each transformation has the form $L_{k+1} = U_k^* L_k U_k$, where U_k is the exponential of a skew-symmetric pseudodifferential operator. We will also discuss non-self-adjoint operators, higher-order operators, other boundary conditions, and

higher spatial dimension. Numerical results will be presented.

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CP8

Four Corners: Analytic and Numerical Solution of Poisson's Equation with Discontinuous Coefficients

We present closed-form formulae and an efficient numerical method for Kellogg's solution of Poisson's equation with piecewise constant coefficient on each quadrant of the unit square. The solution has a singular behaviour, $r^k, k < 1$, r = distance from the junction point. We show how this model is a useful framework to analyze numerical methods for diffusion equations on Adaptive Mesh Refined (AMR), cell-centered, finite volume grids, common to CFD and oil reservoire simulations.

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CP8

Intergrid Operators for Optimal Convergence of Multigrid Algorithms

We study the effect of the interpolation and restriction operators on the convergence of multigrid algorithms for solving linear PDEs. Using a modal analysis of a subclass of these systems, we determine how two groups of the modal components of the error are filtered and mixed at each step in the algorithm. We then show how to determine optimal tradeoffs between the convergence rate and computational complexity for a given system.

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CP8

New Techniques for the Numerical Solution of Elliptic and Time Dependent Problems

The unified transform method of A. S. Fokas for solving linear and certain monlinear PDEs, has led to important new developments, regarding the analysis of various types of PDE problems. This work is based on these developments and presents new techniques for the numerical solution of elliptic boundary value problems, as well as time dependent problems. A comparative evaluation with existing well established methods will also be provided.

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CP8

Monotonicity and Stability of Numerical Solutions for Obstacle Problems

Monotonicity and L^∞-stability theorems are established for a discrete obstacle problem which is defined by a piecewise linear finite element discretization of a continuous problem. These theorems extend the discrete maximum principle of Ciarlet from linear equations to obstacle problems. As their applications, we establish a convergence theorem for an iterative algorithm to solve discrete obstacle problems and extend Baiocchi's and Nitsche's L^∞-estimates to a conforming full discrete obstacle problem.

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CP9

Subspace Interpolation and Applications to Regularity for the Biharmonic Problem and the Stokes Systems

We consider the biharmonic Dirichlet problem on a polygonal domain. New regularity estimates in terms of Sobolev-Besov norms of fractional order are proved. The analysis is based on new subspace interpolation results. We apply our results to establish regularity estimates for the Stokes and Navier-Stokes systems on polygonal domains.

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CP9

Some Nonlocal and Global Existence Results for a Nonlinear Heat Equation with Critical Exponent

In this study, we consider the nonlinear heat equation

$$\begin{cases} u_t(x,t) = \Delta u(x,t) + u^p(x,t) & \text{in} \quad \Omega \times (0,T), \\ Bu(x,t) = 0 & \text{on} \quad \partial\Omega \times (0,T), \\ u(x,0) = u_0(x) & \text{in} \quad \Omega, \end{cases}$$

with dirichlet and mixed boundary conditions, where $\Omega \subset \mathbf{R}^n$ is a smooth bounded domain and $p = 1 + 2/n$ is the critical exponent. For some initial condition $u_0 \in L^1$, we prove the nonlocal existence of the solution in L^1 for the mixed boundary condition. We also establish the global existence in $L^{1+\epsilon}$ to the dirichlet problem, for any fixed $\epsilon > 0$ with $\|u_0\|_{1+\epsilon}$ sufficiently small.

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CP9

Positive Solutions to Nonlinear p-Laplace Equa-

tions with Hardy Potential in Exterior Domains

We study the existence and nonexistence of positive (super) solutions to the singular quasilinear p-Laplace equation

$$-\Delta_p u - \frac{\mu}{|x|^p}|u|^{p-2}u = \frac{C}{|x|^\sigma}|u|^{q-1}u$$

in exterior domains of R^N ($N \geq 2$). Here $p \in (1, +\infty)$ and $\mu \leq C_H$, where C_H is the critical Hardy constant. We provide a sharp characterization of the set of $(q, \sigma) \in R^2$ such that the equation has no positive (super) solutions.

The proofs are based on the explicit construction of appropriate barriers and involve the analysis of asymptotic behavior of super-harmonic functions associated to the p–Laplace operator with Hardy-type potentials, comparison principles and an improved version of Hardy's inequality in exterior domains.

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CP9

Lewy-Hörmander Nonexistence and Pseudospectra

In 1957 Lewy showed that linear PDE with smooth coefficients can have no solutions, and soon thereafter Hörmander produced a general theory of such problems which was subsequenty generalized by Nirenberg, Treves, and others. In 2001 Zworski pointed out that the constructions involved in this theory can be intrrepreted in terms of pseudospectra. We will describe the connection between Lewy-Hörmander nonexistence and pseudospectra, and specifically, what are known as wave packet pseudomodes of variable-coefficient differential operators.

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CP9

Entropy Solutions for the $p(x)$-Laplace Equation

We consider a Dirichlet problem in divergence form with variable growth, modeled on the $p(x)$-Laplace equation. We obtain existence and uniqueness of an entropy solution. The proof is based on *a priori* estimates in Marcinkiewicz spaces with variable exponent. Joint work with Manel Sanchón (CMUC, Portugal).

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CP9

Some Distributions Related to Boundary Value Problems in Domains with Thin Non-Smooth Singularities

The concept of wave factorization for an elliptic symbol was introduced by the author. It is permitted to describe the structure of solutions (or solvability conditions) for a model pseudodifferential equation in canonical non-smooth domains of cone or wedge type. But canonical singularities can be consisting of defferent dimensional components and also non-smooth), and similar arguments lead to analogue results in this case too.

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CP10

Fast Explicit Operator Splitting Method for Convection-Diffusion Equations

Systems of convection-diffusion equations model a variety of physical phenomena which often occur in real life. Computing the solutions of these systems, especially in the convection dominated case, is an important and challenging problem that requires development of fast, reliable and accurate numerical methods. We propose a second-order fast explicit operator splitting (FEOS) method based on the Strang splitting. The main idea of the method is to solve the parabolic problem via a discretization of the formula for the exact solution of the heat equation, which is realized using a conservative and accurate quadrature formula. The hyperbolic problem is solved by a second-order finite-volume Godunov-type scheme. We provide a theoretical estimate for the convergence rate in the case of one-dimensional systems of linear convection-diffusion equations with smooth initial data. Numerical convergence studies are performed for one-dimensional nonlinear problems as well as for linear convection-diffusion equations with both smooth and nonsmooth initial data. We finally apply the FEOS method to the one- and two-dimensional systems of convection-diffusion equations which model the polymer flooding process in enhanced oil recovery. Our results show that the FEOS method is capable to achieve a remarkable resolution and accuracy in a very efficient manner, that is, when only few splitting steps are performed.

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CP10

Global Existence and Uniqueness for a Model of the Flow of a Barotropic Fluid with Capillary Effects

We study the initial-value problem for a system of nonlinear equations that models the flow of an inviscid, barotropic fluid with capillary stress effects. The system includes a hyperbolic equation for the velocity, and an algebraic equation (the equation of state). We prove the global-in-time existence of a unique, classical solution to the system of equations. The key to the proof is a new L^2 estimate for the density ρ.

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CP10

Nondegeneracy, from the Prospect of Wave-Wave Regular Interactions of a Gasdynamic Type

A *parallel* is constructed between Burnat's "algebraic" approach [which uses a *dual* connection between the hodograph and physical characteristic details] and Martin's "differential" approach [centered on a Monge-Ampère type representation] regarding their contribution to describing some nondegenerate gasdynamic [one-dimensional, multidimensional] regular interaction solutions. • Some *specific* aspects of the multidimensional "algebraic" description are beforehand identified and classified with an admissibility criterion − selecting a "genuinely nonlinear" type where other ("hybrid") types are formally possible.

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CP10

Interconnection Between Quasilinear Differential Equations and Infinite Systems of Linear Pdes

We establish an amusing connection between infinite linear systems of PDEs and quasilinear differential equations, including Hopf, Burger's, Korteweg-de-Vriez equations, and other conservation laws. Such a connection enables to prove existence theorems and evaluate properties of solutions for infinite systems. Also, it provides the alternative numerical method for solving quasilinear equations, based on numerical investigation of truncated linear systems. The uniqueness of solutions can be obtained in special functional spaces generated by given infinite system.

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CP10

On the Reduced Description of Reactive Euler Equations of Detonation Theory

We describe a method for reducing reactive Euler equations governing the dynamics of one-dimensional detonations to a nonlinear ordinary differential equation for the lead shock speed. The reduced equation contains a single term that needs to be approximated which depends on spatial derivatives of pressure or particle velocity behind the lead shock. We discuss the properties of the reduced equation in connection with pulsating instability of one-dimensional detonation and also show how the equation can be incorporated into direct numerical simulation of the reactive Euler equations.

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CP11

The Stability of Couette Flow in a Toroidal Magnetic Field*

The stability of the hydromagnetic Couette flow is investigated when a constant current is applied along the axis of the cylinders. It is shown that if the resulting toroidal magnetic field depends only on this current, no linear instability to axisymmetric disturbances is possible. *This material is based upon work supported in part by the U. S. Department of Energy under Grant No. DE-FG02-05ER25666 (to I.H.)

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CP11

Asymptotic Behavior Near Transition Fronts for Equations of Cahn-Hilliard Type

We consider the asymptotic behavior of perturbations of standing wave solutions arising in evolutionary PDE of Cahn–Hilliard type in one space dimension. Under the assumption of spectral stability, described in terms of an appropriate Evans function, we develop detailed asymptotics for perturbations from standing wave solutions, establishing phase-asymptotic orbital stability for initial perturbations decaying with appropriate algebraic rate.

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CP11

Decay of Solutions to Some Nonlinear Wave Equations with Dissipation

We study asymptotic behavior of solutions to the Cauchy problem of some nonlinear wave equations of the form

$$u_t + P(u)_x + K(u) = 0, \qquad (*)$$

where P and u are real-valued functions, K is defined by $\widehat{Kv}(\xi) = k(\xi)\hat{v}(\xi)$ and the circumflexes denote Fourier transforms. The Heat equation, the generalized Burgers equations, the generalized Korteweg-de Vries-Burgers equations, the generalized regularized long wave-Burgers equations, and the generalized Benjamin-Ono-Burgers equations are particular forms of equation (*). The asymptotical representations for large time are studied in detail.

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CP11

Stability and Attractors for Quasi-Steady Model of Cellular Flames

We discuss the recently introduced model of quasi-steady development of cellular flames. The Quasi-Steady equation (QSE) demonstrates the same basic instability mechanism as its better-known counterparts, the Kuramoto-Sivashinsky equation (KSE), and the Burgers-Sivashinsky (BS) equation (the latter being just a linearly forced Burgers equation). Namely, a linear stability analysis reveals the long-wave destabilization, which is suppressed, for the small wavelengths, by the dominant dissipative principal term. In a sense, QSE is intermediate between BSE and KSE, as its dispersion relation coincides with that for BSE for short waves, and is identical to that of KSE (up to the fourth order in k) for long waves. Note that, while BS has trivial dynamics, similarly to KSE, QSE demonstrate very rich dynamical behavior. We demonstrate that QSE possesses a universal absorbing set, and a compact attractor of finite Hausdorff dimension, and give an estimate on it. This is a joint work with Claude-Michel Brauner and Josephus Hulshof.

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CP11

Asymptotic Behavior of FitzHugh-Nagumo Equations

We study the asymptotic behavior of the FitzHugh-Nagumo system on unbounded domains. It is shown that the system has a compact global attractor which contains traveling wave solutions. We also investigate the limiting behavior of the attractors as a parameter $\epsilon \to 0$. It is proved that the limiting system has no global attractor, but all attractors for the perturbed system with positive but small ϵ are contained in a common compact set.

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MS1

Uniqueness of Weak Solutions of the Navier-Stokes Equations of Multidimensional, Compressible Flow

We prove uniqueness and continuous dependence on initial data of weak solutions of the Navier-Stokes equations of compressible flow in two and three space dimensions. The solutions we consider may display codimension-one discontinuities in density, pressure, and velocity gradient, and consequently are the generic singular solutions of this system. The key point of the analysis is that solutions with minimal regularity are best compared in a Lagrangean framework; that is, we compare the instantaneous states of corresponding fluid particles in two different solutions rather than the states of different fluid particles instantaneously occupying the same point of space-time. Estimates for H^{-1} differences in densities and L^2 differences in velocities are obtained by duality from bounds for the corresponding adjoint system.

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MS1

An Equation for the Formation of Step Bunches in the Morphological Evolution of Nano-scale Crystal Surface Structures Below the Roughening Transition

Lagrangian coordinates continuum equations for surface evolution are obtained from a nano-scale description (step interaction equations). The surface consists of interacting steps, moving by adatom diffusion on terraces; and attachment and detachment at steps. Diffusion-limited (DL) and attachment-detachment limited (ADL) kinetics, are considered, for axially symmetric surfaces. The ADL equations capture step bunching. The bunches appear from the interaction between a (destabilizing) negative diffusion (step-line tension effects) and a stabilizing nonlinear diffusion (step-step interactions). The local bunch-dynamics is described by a simple nonlinear equation combining these effects.

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MS1

On Phase Transition Dynamics

A multidimensional model is introduced for the dynamics of a binary mixture of compressible fluids, which undergo possible phase transition due to chemical reaction. The model presented here can accommondate various physical contexts, namely liquid- liquid, gas-liquid, gas-gas phase equilibria, the evolution of gaseous stars, the dynamics of semiconductors and others. The model is formulated by the Navier Stokes equations in Euler coordinates, which is now expressed by the conservation of mass, the balance of momentum and entropy and the species conservation equation. This system takes now a new form due to the choice of rather complex constitutive relations, which are able to accommondate the binary character of the mixture. The existence of globally defined weak solution is obtained by the use of weak convergence methods and compactness arguments in the spirit of Feireisl and P.L. Lions.

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MS1

On Compressible Navier-Stokes Equation

We consider the isentropic compressible Navier-Stokes equation with density dependent viscosity coefficients. We focus our study in the multivariable case when those coef-

ficients vanish on vacuum. In particular we prove the stability of weak solutions of this problem using new kind of entropy inequalities which involve gradients of the density. This leads to new regularity on the density which, surprisingly, holds only for degenerated viscosity coefficients.

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MS2

Controllability of a Coupled System that Models Cochlear Dynamics

The standard 2-dim cochlea model consists of a one-dim elastic structure (modeling the basilar membrane) surrounded by an incompressible 2-dim fluid within a 2-dim cochlear cavity. The dynamics are typically driven by a pressure differential across the basilar membrane transmitted through the round and oval windows (a portion of the boundary of the cochlea). First we describe a highly 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.

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MS2

Uniform Stability of a Nonlinear Plate-Beam Model

The question of uniform stability is considered for a model comprised of a nonlinear *vonKarman* plate coupled with a nonlinear beam equation. Stability properties of linked structures composed of multiple elastic elements give rise to an abundance of mathematical challenges. When a structure is composed of interconnected elastic elements of different dimension, the behavior becomes much harder to both predict and to control. (Joint work with Guenter Leugering.)

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MS2

Tissue Modeling and its Influence on Shear Stiffness Imaging

We discuss tissue properties and their importance in building an elastic model that will yield accurate algorithms and shear stiffness images. Experimental design, elastic, viscoelastic, and anisotropic models will be discussed. Images with laboratory data will be presented.

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MS3

Propagation of Fronts in Porous Media Combustion

Gaseous detonation is a phenomenon with a very complicated dynamics. The mathematical study of the qualitative behavior of solutions of the full problem is out of reach at the moment. Explosions in inert porous media provide a model that is realistic, rich and suitable for a mathematical analysis. We will present some recent mathematical results concerning the long time behavior of solutions of this model. In particular, initiation of detonation, formation of the detonation front, its stability and propagation limits will be discussed.

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MS3

A Variational Approach to Front Propagation in Infinite Cylinders

Gradient reaction-diffusion-advection systems arise in the context of modeling the kinetics of phase transitions, population dynamics and combustion. These systems are known to exhibit a variety of non-trivial spatio-temporal behaviors, most notably the phenomenon of propagation and traveling waves. We introduce a variational formulation for the traveling wave solutions in cylindrical geometries with transverse potential flow, which allows us to construct a certain class of traveling wave solutions and establish their monotonicity, asymptotic decay and uniqueness. These solutions are special in a sense that they are characterized by a non-generic fast exponential decay ahead of the wave and play an important role in propagation phenomena for the initial value problem. We also construct an area-type functional that gives a matching upper and lower bound for the propagation speed in the sharp reaction zone limit for weakly curved fronts.

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MS3
Diffusion and Mixing in Fluid Flow

We study enhancement of diffusive mixing on a compact Riemannian manifold M by a fast incompressible flow. We provide a sharp characterization of the class of flows that make the deviation of the solution of an equation $\phi_t + Au \cdot \nabla\phi = \Delta\phi$ from its average arbitrarily small in an arbitrarily short time, provided that the flow amplitude A is large enough. The necessary and sufficient condition on such flows is that the dynamical system associated with the flow has no eigenfunctions in the Sobolev space $H^1(M)$. In particular, we find that weakly mixing flows always enhance dissipation in this sense.

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MS3
Spreading of Combustion in the Presence of Strong Cellular Flows with Gaps

Recently Fannjiang, Kiselev and Ryzhik showed that cellular flows are capable of quenching large flames, provided the amplitude of the flow is also large. We show that this phenomenon does not occur when flow cells are separated by narrow buffer zones where advection is absent.

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MS4
The Impact of a Van Der Waals Type Interfacial Energy on Dimensional Reduction

The asymptotic behavior of an elastic thin film penalized by a van der Wals type interfacial energy is investigated when both its thickness and the magnitude of the additional energy vanish in the limit. Keeping track of both mid-plane and out of plane deformations (through the introduction of the Cosserat vector), the resulting behavior strongly depends upon the ratio between thickness and interfacial energy. Non-locality is conjectured for a critical value of that ratio.

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MS4
Transport in Molecular Motor Systems

The molecular motor systems which govern much of the transport in eukaryotes may be thought of as governed by a dissipation principle involving conformational changes induced by chemical reactions and potentials. The result in the simplest cases is a weakly coupled system of evolution equations. To the mind's eye, the transport process is analogous to a biased coin toss. We describe how this intuition may be confirmed by a careful analysis of the cooperative effect among the conformational changes and the potentials. This is joint work with Stuart Hastings and Bryce McLeod.

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MS4
Surfactants in Foam Stability: A Phase Field Model

The role of surfactants in stabilizing the formation of bubbles in foams is studied using a phase-field model. The model involves a van der Walls-Cahn-Hilliard-type energy with an added term accounting for the interplay between the presence of a surfactant density and the creation of interfaces. In agreement with experimentation, it is proved that the surfactant segregates to the interfaces. This is work in collaboration with Massimiliano Morini and Valeriy Slastikov.

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MS4
Critical Points of Onsager Model of Nematic Phase Transition

We study Onsagers model of isotropic-nematic phase transitions with orientation parameter on a sphere. We consider symmetric Maier-Saupe potential and prove the axial symmetry and derive explicit formulae for all critical points, thus obtaining their complete classification.

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MS4
Limit of the Non Self-dual Chern-Simons-Higgs Energy

We present some results on the gamma limit of the Chern-Simons-Higgs energy functional, far from self duality. We use a mixture of methods used in the study of related Ginzburg-Landau energies.

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MS5

Wiener's Criterion for Uniqueness of Solutions to the Elliptic and Parabolic Problems in Domains with Noncompact Boundaries

In this talk I will introduce a notion of regularity of infinity for the elliptic and parabolic equations and will formulate a necessary and sufficient condition for the existence of a unique bounded solution to the classical and parabolic Dirichlet problems in arbitrary open sets with noncompact boundaries. The criterion is the exact analogue of Wieners test for boundary regularity of harmonic and thermic functions and demonstrates the thinness of the exterior of a domain at infinity.

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MS5

Harnack Estimates for Non-negative Solutions of Quasi-linear Degenerate Parabolic Equations with Measurable Coefficients

The classical Harnack estimates for non-negative solutions of the heat equations do not hold for solutions of degenerate equations (counterexample will be given). The estimate holds however in an "intrinsic form". The novelty of the investigation is that it continues to hold for quasi-linear degenerate equations with merely measurable coefficients. This will be connected with the issue of local Hölder continuity of solutions of such degenerate equations. The approach is entirely different from the classical approach of Moser, in that it dispenses with BMO, coverings and cross-over, and it is only based on measure-theoretical ideas.

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MS5

Continuity of Solutions of Nonlinear Filtration Equations

We consider local bounded solutions of

$$\beta(u)_t = \sum_{i,j=1}^{n} D_i(a_{ij}(x,t)D_j(u))$$

where the coefficients a_{ij} are uniformly elliptic, bounded and measurable functions and β is a C^1-piecewise function with at least a linear growth. If s_0 is an irregular point for β, we assume β to be locally concave in a proper right neighborhood of s_0 and locally convex in a proper left neighborhood of the same point. By using suitable DeGiorgi's techniques, we have the following alternative:

(1) either u is continuous and its modulus of continuity can be given in a quantitative way,

(2) or in cylinders Q of length $\frac{\beta(s)}{s}$ we have that

$$\frac{\beta'(s)s}{\beta(s)} \leq C_1 \frac{|\{(x,t) \in Q \text{ such that } u(x,t) \leq s\}|}{|Q|} \leq C_2(\log s)^{-1}$$

This latter inequality implies the regularity of the solution for a large class of functions β and therefore we are able to extend DeGiorgi's theory to suitable non power-like singularities.

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MS5

On a Boundary Harnack Inequality for p-Harmonic Functions

Let $D \subset \mathbf{R^n}$ be a bounded Lipschitz domain, $x \in \partial D$, and $B(x,r) = \{y \in \mathbf{R^n} : |y-x| < r\}$. Given $p, 1 < p < \infty$, let u, v be positive weak solutions to the p Laplacian in $D \cap B(x,r)$ with $u = v = 0$, continuously on $\partial D \cap B(x,r)$. We show there exists c depending only on p, n and the Lipschitz constant for D such that $u/v \leq c$ in $B(x,r/2) \cap D$. We also discuss Hölder continuity of u/v.

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MS5

The Neumann Problem for the Infinity-Laplacian

We consider the ∞-Laplacian with Neuman boundary conditions. We study the limit as $p \to \infty$ of solutions of $-\Delta_p u_p = 0$ in a domain Ω with $|Du_p|^{p-2}\partial u_p/\partial\nu = g$ on $\partial\Omega$. We obtain a natural minimization problem that is verified by a limit point of $\{u_p\}$ and a limit problem that is satisfied in the viscosity sense. Hoewever, contrary to the Dirichlet case, there is no uniqueness for viscosity solutions of the limit problem. It turns out that the limit variational problem is related to the Monge-Kantorovich mass transfer problem when the measures are supported on $\partial\Omega$.

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MS6

A Kinetic Transport and Reaction Model for Process Models in Microelectronics Manufacturing

The manufacturing of microelectronics devices involve gas flow at various total pressures, characterized by the Knudsen number as relevant dimensionless group. We introduce a kinetic transport and reaction model and simulator based on a system of time-dependent linear Boltzmann equations that is valid over a wide range of Knudsen numbers. We present results that demonstrate the ability of the model to analyze the behavior of the system and to provide unique insights into non-equilibrium effects.

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MS6

Discontinuous Galerkin Approximation of the Boltzmann-Poisson System

We analyze the problem of numerically solving linear variants of the space inhomogeneous multidimensional linear Boltzmann equation for charged transport. Deterministic methods can be very accurate for problems in which the solution may or may not be far from thermodynamical equilibrium and high accuracy is required. Additionally, they yield specific details of transient solutions and consequently can be more efficient than the traditional probabilistic Monte Carlo techniques for the computation of transients. We employ a discontinuous Galerkin finite element method to preserve local conservation properties and exploit the advantages of these methods for the computations of Boltzmann-Poisson problems with large doping profiles, such as in the modeling of semiconductor devices or collisional plasma. Theoretical and numerical results are discussed.

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MS6

A WENO Algorithm for the Radiative Transfer and Ionized Sphere at Reionization

In this presentation, we will show that the algorithm based on the weighted essentially nonoscillatory (WENO) scheme with anti-diffusive flux corrections can be used as a solver of the radiative transfer equations. This algorithm is highly stable and robust for solving problems with both discontinuities and smooth solution structures. We tested this code with the ionized sphere around point sources. It shows that the WENO scheme can reveal the discontinuity of the radiative or ionizing fronts as well as the evolution of photon frequency spectrum with high accuracy on coarse meshes and for a very wide parameter space. This method would be useful to study the details of the ionized patch given by individual source in the epoch of reionization. We demonstrate this method by calculating the evolution of theionized sphere around point sources in physical and frequency spaces. It shows that the profile of the fraction of neutral hydrogen and the ionized radius are sensitively dependent on the intensity of the source.

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MS6

Deterministic Solver for Non-linear Boltzmann Dissipative Equations

We present a kinetic solver for Boltzmann energy dissipative equations based on spectral methods. We compute example of states associated to homogeneous cooling for granular flows and dynamically scaled solutions to elastic gases models in the presence of a thermostat. These models have stationary or self-similar states that correspond to non-equilibrium statistical states (NESS). In particular we show that our calculations resolve long time dynamics to probability distribution functions with finite or infinity energy, unbounded at the origin and power tails, which are self-similar solutions to energy dissipative Maxwell Molecules models.

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MS7

Extracting *s*-wave Scattering Lengths from BEC Dynamics

See MS1 in under annual meeting (AN06 abstracts.)

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MS7

Multi-Component Vortex Solutions in Coupled NLS Equations

See MS1 in under annual meeting (AN06 abstracts.)

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MS7

Bose-Einstein Condensates in Optical Lattices and

Superlattices

See MS1 in under annual meeting (AN06 abstracts.)

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MS7

Derivation of the Gross-Pitaevskii Equation for Rotating Bose Gases

See MS1 in under annual meeting (AN06 abstracts.)

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MS8

Variational Systems of Wave Equations

We consider systems of wave equations that are governed by variational principles whose Lagrangians are quadratic functions of the derivatives of the wave-field with coefficients depending on the wave-field itself. We introduce notions of genuine nonlinearity and linear degeneracy for such equations that are analogous to, but different from, the corresponding notions for hyperbolic systems of conservation laws, and we derive a new weakly nonlinear asymptotic equation for waves that lose genuine nonlinearity in a system. We use this equation it to study the propagation of 'twist' waves in a massive director field.

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MS8

The L^1 Well-Posedness for Steady Supersonic Euler Flow Past a Curved Wedge by Wave Front Tracking Method

We study the L^1 well-posedness for two-dimensional steady supersonic Euler flows past a Lipschitz wedge. The wedge perturbs the flow and the waves reflect after interacting with the strong shock front or the boundary. After studying the Lyapunov functional between two solutions and dealing with the boundary difficulty, we prove that the functional decreases in the flow direction. Therefore, the L^1 stability is established, so is the uniqueness of the solutions obtained by the wave front tracking method.

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MS8

A Mixed Type Problem for Two-dimensional Wave Interactions

The wave interactions in two-dimensional Riemann problems of gas dynamics will be discussed. A degenerate Goursat problem will be studied. The solution in the hyperbolic region up to the sonic curve is obtained.

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MS8

Periodic Solutions of Euler's Equations

We consider the interactions of shocks in the p-system. We obtain bounds for incident shocks of arbitrary strength, arbitrarily close to the vacuum. We obtain bounds for the states themselves, and for the wave strengths. We will discuss these in the context of global solutions with BV initial data.

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MS9

Homogenization of Strongly Local Dirichlet Forms in Perforated Media

We investigate the homogenization for strongly local Dirichlet forms in perforated media giving an extension of the results known for Laplace operator. The main difficulties arrive from the absence of a good notion of periodicity and of extension properties for "regular" domains.

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MS9

Undulations and Fluctuations

The issue of computing the flux of a fluctuating vector field across an undulating surface is commonly approached by exploring the limits within which the formula established under blanket smoothness hypotheses is still valid, the general wisdom being that the wigglier the surface, the smoother the field has to be (and vice versa). I argue here that the dim no man's land lying just beyond these limits is well worth being penetrated, even though cautiously.

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MS9

A Constructive Approach to Some Fractal Trans-

mission Problems

We describe a constructive approach to certain fractal transmission problems for second order elliptic or parabolic operators. The transmission condition on the layer is of second order. The fractal layer is obtained in the limit of polyhedral (pre-fractal) surfaces, by self-similar iteration at small scales. From an analytic point of view, the main problem to be studied is the convergence of the solutions obtained with the pre-fractal layers when the geometry becomes fractal. The main difficulty in this study is the jump of the geometric dimension of the layer, which is two for all pre-fractal approximations and intermediate between two and three for the limit layer. In other words, while the approximating layers have finite two-dimensional area, the limit layer is non rectifiable with infinite area. We first consider the elliptic case. We will describe the variational approach consisting in proving the convergence of suitable energy forms in the sense of homogeneization and we will also describe some extensions to the heat equation, by relying on the convergence of the related semigroups. In order to obtain these convergence properties, we have to introduce suitable renormalization factors.

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MS9
On Some Second Order Transmission Problems

We describe some transmission problems across fractal layers imbedded in Euclidean domains. There is a wide literature dealing with transmission problems of this kind, which arise naturally in various fields: e.g., in electrostatics, magnetostatics, hydraulic fracturing and in the study of absorption or irrigation properties. In many of these applications, one is interested in considering layers that possess much greater conductivity or permeability than the surrounding space. By referring, for example, to heat conduction, the heat flow is then absorbed by the layer and starts diffusing within it much more efficiently. This leads to a jump of the normal derivatives across the two sides of the layer and this jump acts as a source term for the diffusion within the layer. In our talk we shall describe some model examples of second order elliptic transmission problems with highly conductive layers. The transmission condition is also of second order, what is unusual in the case of second order operators. Moreover, the condition has an implicit character, since the source term of the layer equation - the jump of the normal derivatives - is not among the data of the problem, but depends on the solution itself in the surrounding space. The layers we consider - say, in a domain of $\mathbf{R}^3$ - have an additional unusual characteristic: they are of fractal type, with a (Hausdorff) dimension intermediate between 2 and 3. Layers of this type can be expected to enhance the layer effects described above, by absorbing more energy from the surrounding space. We present some regularity and numerical results, in the aim of better understanding the analytical problems which arise when fractal and Euclidean structures mutually interact.

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MS10
The Stability of Fronts in Cahn–Hilliard Type Equations

The stability of stationary fronts in Cahn–Hilliard type equations is important to the understanding of the evolution of fronts in the sharp interface limit. In this talk we discuss a method for establishing the asymptotic stability that is based on a detailed analysis of dissipation at the fronts. This leads to a system of non-linear inequalities which may be used to prove convergence. The method is fairly robust, and may be used to derive conditions for stability in a range of setting. The work presented here is joint work with M. Carvalho and E. Orlandi

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MS10
Thin-film Equations: Blow-up, the Cauchy Problem, Solutions and Countable Spectra of Asymptotic Patterns

We consider the fourth-order thin film equation in $\mathbf{R} \times (0,T)$ with an unstable second-order term

$$u_t = -(|u|^n u_x)_{xxx} - (|u|^{p-1}u)_{xx}, \;\; n \in [0, \frac{3}{2}), \;\; p > 1.$$

We show that at the critical exponent $p = p_0 = n+3$, there exists a countable spectrum of blow-up patterns, where the first one is expected to be stable. We study both nonnegative solutions of the free-boundary zero contact angle problem and oscillatory sign changing solutions of the Cauchy problem. Some other aspects concerning the correct functional setting of the Cauchy problem are discussed where the limit $n \to 0$ plays a key role. We also investigate the uniqueness question for the free-boundary problem.

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MS10
Blow-up for Quasilinear Parabolic Equations with Thin-Film-Diffusion Like Operators

We consider higher-order thin film equations with lower-order terms of reaction type. Using an extension of the nonlinear capacity method, we calculate the critical Fujita exponents establishing precise parameter intervals where no global nontrivial solutions are available.

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MS10

The Degenerate Cahn-Hilliard Equation and Wetting

We consider

$$u_t + (u^n(u_{xxx} + u^\beta u_x))_x = 0, \quad x \in (0, L), t > 0,$$
$$u_x = u^n u_{xxx} = 0, \quad x = 0, L, t > 0,$$

which generalizes the (one-sided) deep quench Cahn-Hilliard equation and constitutes also a thin film equation in the unstable regime, when $\beta < 2$ and n is suitably restricted. Using energy estimates corresponding to the equation under consideration as well as thin film entropy arguments, we prove global existence of non-negative entropy solutions. Using a generalised Stampacchia lemma, estimates on the rate of propagation of the degeneracy set have also been obtained

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MS11

Telephone-cord Instabilities in Thin Smectic Capillaries

Telephone-cord patterns have been recently observed in smectic liquid crystal capillaries. In this talk we analyse the effects that may induce them. As long as the capillary keeps its linear shape, we show that a nonzero chiral cholesteric pitch favors the SmA*-SmC* transition. However, neither the cholesteric pitch nor the presence of an intrinsic bending stress are able to give rise to a curved capillary shape. The key ingredient for the telephone-cord instability is spontaneous polarization. The free energy minimizer of a spontaneously polarized SmA* is attained on a planar capillary, characterized by a nonzero curvature. More interestingly, in the SmC* phase the combined effect of the molecular tilt and the spontaneous polarization pushes towards a helicoidal capillary shape, with nonzero curvature and torsion.

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MS11

Phase Transition from Chiral Nematic Toward Smectic Liquid Crystals

The Chen-Lubensky energy is used to investigate phase transitions from chiral nematic to smectic C* and smectic A* liquid crystal phases. We consider a liquid crystalline material confined between two parallel plates, where the dimensions of the material are assumed to be large relative both to the width of a smectic layer and the material's chiral pitch. We take boundary conditions so that the smectic phase melts at the plates' surfaces and prove the existence of energy minimizers. Then under the physically observed assumption that the Frank elasticity constants become large near a phase transition, we establish estimates for the transition region separating phases. In particular we derive analytic estimates proving that chirality lowers the transition temperature regime above which minimizers are nematic and below which minimizers are in a smectic phase.

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MS11

Steady Poiseuille Flows of Nematic Liquid Crystals at Large

We consider a system of nonlinear second order ordinary differential equations modeling Poiseuille flow of liquid crystals with variable degree of orientation, at the limit of large Ericksen number. The system is singularly perturbed and degenerate, and as a result the solutions are highly oscillatory. We obtain the relations satisfied by the Young measures generated by sequences of weak solutions, and show that the persistent oscillations are encoded in the Young measure generated by the molecular alignment variable ϕ. The effective equations consist of the isotropic Newtonian flow equation, supplemented by algebraic momentum relations for the Young measure generated by ϕ. The latter relations impose restrictions on admissible microstructures in the effective flow. We conclude that the configuration of the flow is effectively isotropic with an ordering remnant.

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MS11

Molecular Dynamics Models of Liquid Crystal Elastomers

Liquid crystal elastomers are a fascinating class of materials that combine the elasticity of rubber with the nematic or smectic order of liquid crystals. These materials have been called "artificial muscles" because they rapidly change shape under heating/cooling, applied fields, or optical illumination, with induced strains as high as 400%. We have developed a finite element elastodynamics technique to model shape change in these materials, with explicit coupling between liquid crystalline order and elastic strain. We model several geometries, including a nematic elastomer artificial "earthworm" that moves via expansion/contraction combined with anisotropic friction. Once validated, such models will serve as a bridge between fundamental soft condensed matter theory and practical engineering design.

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MS12

Homogenization of Free Boundary Velocity

We study the homogenization limit of some (Hele-Shaw/Stefan type) free boundary problems with oscillating free boundary velocity. We first prove the existence of the limiting free boundary velocity, which yields the uniform convergence of the free boundaries in the homogenization

limit.

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MS12

On the Contact-angle Condition for Stranski-Krastanow Islands

In this talk we present a rigorous derivation of the zero contact-angle condition for Stranski-Krastanow islands in strained solid films.

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MS12

Flame Propagation in Periodic Media

I will describe some results on the homogenization of a free boundary problem arising in the modeling of flame propagation in premixed gas. The asymptotic regime corresponds to a situation in which the flame width is smaller than the characteristic length of the inhomogeneities of the medium.

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MS12

Self-propagating High temperature Synthesis (SHS) in the High Activation Energy Regime

We derive the precise limit of SHS in the high activation energy scaling suggested by B.J. Matkowksy-G.I. Sivashinsky in 1978 and by A. Bayliss-B.J. Matkowksy-A.P. Aldushin in 2002. In the time-increasing case the limit turns out to be the Stefan problem for supercooled water with spatially inhomogeneous coefficients. Our precise form of the limit problem suggest a strikingly simple explanation for the numerically observed pulsating waves.

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MS13

On Vortices in a Spinor Ginzburg–Landau Model

Recent papers in the physics literature have introduced spin-coupled (or spinor) Ginzburg–Landau models for complex vector-valued order parameters in order to account for ferromagnetic or antiferromagnetic effects in high-temperature superconductors and in optically confined Bose–Einstein condensates. These models give rise to new types of vortices, with fractional degree and non-trivial core structure. By studying the associated system of equations in R^2 which describes the local structure of these vortices, we show some new and unconventional properties of these vortices. We illustrate the various possibilites with some specific examples of Dirichlet problems in the unit disk. These results are obtained in collaboration with L. Bronsard, P. Mironescu, and E. Sandier.

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MS13

The Boundary Distribution of Surface Superconductivity

It is well-known that when the applied magnetic field is in the range $H_{C_2} < h_{ex} < H_{C_3}$, superconductivity is concentrated in a thin boundary layer. The distribution of ψ - the superconductivity order parameter- in this boundary layer is still unknown in some part of the above range of applied magnetic fields values. We prove, in the large κ limit that when $H_{C_3} - \epsilon\kappa < h_{ex}$ the distribution of ψ along the boundary is uniform. This work is the result of a collaboration with Bernard Helffer from Orsay.

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MS13

Ginzburg-Landau Minimizers with Prescribed Degrees - Emergence of Vortices and Existence/nonexistence of the Minimizers

Let Ω be a 2D domain with a hole ω. In the domain $A = \Omega\backslash\omega$ consider a class $\mathcal{J}$ of complex valued maps having degrees 1 and 1 on $\partial\Omega$, $\partial\omega$ respectively. In a joint work with P. Mironescu we show that if cap$(A) \geq \pi$ (subcritical domain), minimizers of the Ginzburg-Landau energy E_κ exist for each κ. They are vortexless and converge in $H^1(A)$ to a minimizing S^1-valued harmonic map as the coherency length κ^{-1} tends to 0. When cap$(A) < \pi$ (supercritical domain), for large κ, we establish that the minimizing sequences/minimizers develop exactly two vortices—a vortex of degree 1 near $\partial\Omega$ and a vortex of degree -1 near $\partial\Omega$ which rapidly converge to ∂A. In this work it was conjectured that the global minimizers do not exist when $\kappa > \kappa_0$. In a subsequent joint work with D. Golovaty and V. Rybalko this conjecture was proved. The proof is based on an introduction of a related auxiliary linear problem which allows for an explicit energy estimate.

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MS13

Vortices for a Rotating Toroidal Bose-Einstein Condensate

We construct local minimizers of the Gross-Pitaevskii energy, introduced to model Bose–Einstein condensates (BEC) which are subject to a uniform rotation. We consider the case where the condensate occupies a solid torus of revolution in R^3 with starshaped cross-section. For large enough angular speeds we produce local minimizers of the energy which exhibit vortices, for small enough values of the length-scale parameter ϵ. These vortices concentrate at one or several planar arcs which minimize a line energy, obtained as a Γ-limit of the Gross-Pitaevskii functional. The location of these limiting vortex lines can be described under certain geometrical hypotheses on the cross-sections of the torus. These results are obtained in collaboration with S. Alama and J.A. Montero.

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MS14

Fluid-Structure Interaction in Blood Flow

Fluid-structure interaction in blood flow will be discussed.

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MS14

Stability of Compressible Vortex Sheets

Compressible vortex sheets are important in multidimensional compressible Euler flows. In this talk we will discuss some recent developments in the theoretical analysis of compressible vortex sheets and related free boundary problems in multidimensional fluid dynamics and MHD. Some further trends and open problems on compressible vortex sheets will also be addressed.

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MS14

Non-conservative Boltzmann Equations

We consider energy dissipative space homogeneous Boltzmann Transport Equations (BTE) for interactions of Maxwell type, which have a good representation in Fourier space. Examples are inelastic BTE modeling granular gases or Elastic BTE for gas mixtures. We study self-similar solutions, usually referred as homogeneous cooling states, their asymptotic behavior by analyzing their spectral properties in Fourier space. We show self-similar solutions with initial finite moments of all orders will have power like tails, and so they can not have finite moments for all orders. This fact posses new challenges and issues on hydrodynamic fluid limit models. In addition, we show the long time asymptotics is qualitatively similar to classical non-linear wave equations. This work has been carried out in collaboration with S. Bobylev and C. Cercignani.

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MS14

Traveling Waves in Thin Liquid Films Driven by Surfactant

In the lubrication approximation, the motion of a thin liquid film is described by a single fourth-order partial differential equation that models the evolution of the height of the film. When the fluid is driven by a Marangoni force generated by a distribution of insoluble surfactant, the thin film equation is coupled to an equation for the concentration of surfactant. In this talk, I show the basic structure of this system, and begin an analysis of wave-like solutions in the specific context of a thin film flowing down an inclined plane. Numerical simulations reveal an array of traveling waves, which persists when capillarity and surface diffusion are neglected. The analysis of the limiting system has some surprises, and in this talk, I show how far we have come in understanding the numerical results analytically, and the analytical results numerically.

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MS15

Control Problems in Fluid-Structure Interactions

Fluid structure interaction coupled system comprising of a three dimensional Navier Stokes equation coupled to a dynamic system of elasticity will be considered. The coupling takes place on the boundary – fixed interface between the solid and the fluid. The following new results will be presented: 1) wellposedness of weak and strong solutions; 2) boundary feedback stabilization in the neighborhoods of unstable equilibriums.

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MS15

Control of Elastic Systems with Nonlinear Constitutive Law

We consider an elastic body in a region $R_0 \subset R^m$, $m = 2$ or 3. Our purpose in this talk is to explore the control implications of the use of nonlinear constitutive laws obtained from adding quartic terms to the quadratic potential energy expressions of the theory of linear elasticity. We indicate the effect of incorporating those terms and explore consequences for both static and dynamic control applications.

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MS15

Mathematical Analysis of Aircraft Wing–Airflow Interaction

A model describing interaction of a long slender aircraft wing with subsonic inviscid isentropic potential air flow will be presented. It is governed by a system of hyperbolic PDEs with time convolution integral forcing terms. Asymptotic formulas for aeroelastic modes (wing vibration frequencies) will be given. Expansion of a solution of the model equations with respect to the aeroelastic mode shapes will be presented. Application to flutter instability and its suppression will be discussed.

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MS15

On the Developments of Galin's Stick-Slip Contact Problem

In this talk, an analytical solution procedure developed for the the problem of indentation with friction of a rigid indenter into an elastic half-space is considered. The corresponding mixed boundary-value problem is formulated in planar bipolar coordinates, and reduced to a singular integral equation with respect to the unknown normal stress in the slip zones. An exact analytical solution of this equation is constructed using the Wiener-Hopf technique, which allowed for a detailed analysis of the contact stresses, strain, displacement, and relative slip zone sizes. Also, a simple analytical solution is furnished in the limiting case of full stick between the cylinder and half-space.

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MS16

Invariant Manifolds and the Stability of Traveling Waves in Burgers Equation

Invariant manifolds are constructed in the phase space of perturbations to the traveling wave solution of Burgers equation and used to determine the asymptotic rate of convergence to the wave. This provides a geometric explanation of existing results demonstrating that the decay rate of perturbations can be increased by requiring that initial data lie in appropriate algebraically weighted spaces.

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MS16

Evans Function Computation for Large Systems

We describe our new approach to Evans function computation for large systems, which avoids the spatial and temporal blow up of exterior-product methods. We introduce a polar-coordinate shooting method, for which the angular equation is a variation of continuous orthogonalization and the radial equation is easily computable and restores analyticity. We then use this new method to explore the shock wave stability problem for large one-dimensional viscous and viscous-dispersive conservation laws.

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MS16

Multi-pulses in PDEs with Reflection and Phase Invariance

We consider parameter-dependent dynamical systems with reflection and SO(2) symmetry which possess a homoclinic orbit to a saddle focus. The reflection symmetry is broken by the wave speed. To address the existence of N-pulse solutions and their PDE stability we use Lin's method and Lyapunov-Schmidt reduction. We discuss standing and traveling 2 and 3-pulse solutions. Motivation comes from the complex cubic-quintic Ginzburg-Landau equation.

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MS16

The Saddle-node of a Homogeneous Oscillation in Spatially Extended Reaction-diffusion Systems

We study the saddle-node bifurcation of a spatially homogeneous oscillation in a reaction-diffusion system posed on the real line. Beyond stability of the primary homogeneous oscillations created in the bifurcation, we investigate existence, bifurcation and stability of wave trains with large wavelength that accompany the homogeneous oscillation.

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MS17

On the Existence of Stokes Waves of Extreme Form

In this talk we present an alternative proof of the existence of (weak) Stokes waves of extreme form in the finite depth

case. We also show the existence of a family of regular waves. The approach is based on free boundary techniques of Alt, Caffarelli, and Friedman.

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MS17

Some Problems in the Modeling and Analysis of Quasi-static Evolution in Brittle Fracture

Some problems in the modeling and analysis of quasi-static evolution in brittle fracture Based on Griffith's criterion for crack growth, a method was recently proposed for determining crack paths by taking continuous-time limits of discrete-time variational problems. This has been successfully carried out, but an important difference remains between these solutions and Griffith's model. I will explain the method and the main issues in its implementation, and then describe the remaining gap and some efforts to remove it.

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MS17

Relaxed Energies for $H^{1/2}$–Maps with Values into the Circle

We consider, for maps in $H^{1/2}(\mathbf{R}^2; S^1)$, a family of energies related to seminorms equivalent to the standard one. These seminorms are associated to measurable matrix fields in the half space. For maps having finitely many prescribed topological singularities, we show that the infimum of the energy is equal to the lenght of a minimal connection relative to a natural geodesic distance on the plane, connecting the singularities. As a consequence, we compute the relaxed energy functionals on smooth maps. This is a joint work with A. Pisante.

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MS17

Convergence of Equilibria of Thin Elastic Beams

In a series of recent papers a hierarchy of lower dimensional theories for nonlinearly elastic thin beams has been rigorously derived,starting from three-dimensional elasticity, by means of Gamma-convergence. This approach guarantees convergence of minimizers of the 3d elastic energy to minimizers of the Gamma-limit problem.In this talk the convergence of (possibly non-minimizing) stationary points of the 3d elastic energy is discussed. These are joint works with S. Müller and M. Schultz.

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MS18

A New Phase Space Based Formulation for Transmission Tomography

A new formulation is developed for travel time tomography. Our new method uses multiple arrival times and phase information between the source and the measurement on the boundary of the domain. The formulation can also deal with anisotropic medium property. Numerical results show that the unknown wave speed can be recovered with a good accuracy with fast convergence. This is a joint work with Jianliang Qian, Gunther Uhlmann, and Hongkai Zhao.

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MS18

A Lax-Friedrichs Sweeping Method for Static Hamilton-Jacobi Equations

In this talk, we will present a Lax-Friedrichs fast sweeping method to approximate the viscosity solution of static Hamilton-Jacobi equations. By solving for the value of a specific grid point in terms of its neighbors and incorporating a group-wise causality principle into the Gauss-Seidel iteration, we have an easy-to-implement and fast convergent numerical method. For computational boundary condition, we give a simple recipe which enforces a version of discrete min-max principle. Some convergence analysis is done for the one-dimensional eikonal equation. Extensive 2-D and 3-D numerical examples illustrate the efficiency and accuracy of the approach.

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MS18

On the Complexity of Fast Sweeping Algorithms

We explore—both theoretically and empirically—the computational complexity of fast sweeping algorithms. While there are no surprises in two dimensions, the situation for three dimensions is less encouraging than it might first appear. On the empirical side, we also present a flexible new code base for approximating the solution of stationary Hamilton-Jacobi equations, and discuss some of the tradeoffs in the choice of Python as an implementation language.

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MS18

Fast Sweeping Methods for Eikonal Equations on Triangular Meshes

The original fast sweeping method relies on natural ordering provided by a rectangular mesh. We propose novel ordering strategies so that the fast sweeping method can be extended efficiently and easily to any unstructured mesh. To that end we introduce multiple reference points and order all the nodes according to their distances to those reference points. We show extensive numerical examples to demonstrate the accuracy and efficiency of the new algorithm on triangular meshes.

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MS19

Nonlinear Fourth-order Parabolic Equation and Related Entropy Functionals

A nonlinear fourth-order parabolic equation is presented; the equation appears in quantum semiconductor modeling and also in the study of interface fluctuation in spin system. Several Lyapunov functionals are used in order to show existence results and long-time asymptotics for bounded and unbounded domains in one and more dimensional space. Exponential decay in time of solutions to the steady state is proved by the entropy-entropy production method using logarithmic Sobolev inequalities.

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MS19

A Semiclassical Model for Thin Quantum Barriers

We present a time-dependent semiclassical transport model for mixed state scattering with thin quantum barriers. The idea is to use a multiscale approach as a means of connecting regions for which a classical description of the system dynamics is valid across regions for which the classical description fails, such as when the gradient of the potential is undefined. We do this by first solving a stationary Schrödinger equation in the quantum region to obtain the scattering coefficients. These coefficients allows us to build the interface condition to the particle flux that bridges the quantum region, connecting the two classical domains. Away from the barrier, the problem may be solved by traditional numerical methods. Therefore, the overall numerical cost is roughly the same as solving a classical barrier. In the one-dimensional case, we use a finite-volume method that extends the Hamiltonian-preserving scheme introduced by Jin and Wen for a classical barrier. In the two-dimensional case, we consider a mesh-free particle method that can be computed efficiently and that may be extended to higher-dimensions.

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MS19

Simulating the Wigner Equation with the Discontinuous Galerkin Method and a Non-polynomial Approximation Space

The Wigner equation, with a suitable collision operator, models the interaction between a quantum system and its environment. It is a useful model for semiconductor devices, and current simulations are typically based on operator splitting methods. We demonstrate simulation via the Discontinuous Galerkin method, using an oscillatory basis. The use of a non-polynomial approximation space for DG calculations has recently been proposed by Yuan and Shu, and promises greater accuracy on a coarser mesh.

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MS20

Optical Manipulation of Matter Waves

See MS16 in under annual meeting (AN06 abstracts.)

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MS20

Soliton Dynamics and Scattering for the Gross-Pitaevskii Equation

See MS16 in under annual meeting (AN06 abstracts.)

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MS20

Topological Effects with Matter Waves: A New Twist on BEC

See MS16 in under annual meeting (AN06 abstracts.)

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MS20

High Temperature Superfluidity and the Superfluid - Mott Insulator Transition in Ultracold

Atomic Gases

See MS16 in under annual meeting (AN06 abstracts.)

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MS21

Exact Solutions to Supersonic Flow onto a Solid Wedge

We present a problem arising in supersonic flow onto a solid wedge and show how to construct exact solutions for the compressible potential flow model.

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MS21

Traffic Congestion-An Instability in a Hyperbolic System

In this talk I'll discuss second order traffic models and show they support stable oscillatory traveling waves typical of those seen on a congested roadway. These solutions arise when the trivial solution of uniformly spaced cars traveling at constant velocity is unstable. Wave profiles and speeds will be exhibited.

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MS21

Hyperbolic Conservation Laws on Manifolds

The theoretical work on discontinuous solutions of nonlinear hyperbolic conservation laws in several space variables has been restricted so far to problems set in the Euclidian space. Motivated by numerous applications, to geophysical fluid flows and general relativity in particular, I will attempt to set the foundations for a study of entropy solutions to hyperbolic conservation laws on a manifold. Understanding the interplay between the geometry of the manifold and the behavior of discontinuous solutions of partial differential equations is particularly challenging. In this lecture, I will discuss the derivation of the L1 contraction property and the total variation diminishing property, which are known to play a central role in the theory and the numerical analysis of hyperbolic problems. Next, I will present the generalization to manifolds of, both, Kruzkov's and DiPerna's well-posedness theories. Finally, I will establish the convergence of the finite volume schemes on manifolds, with a special attention for the case of the 2-sphere. This a joint work with M. Ben-Artzi (Jerusalem).

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MS21

Computing Multi-valued Solutions for Euler-Poisson Equations

In this talk we first review the critical threshold phenomena for Euler-Poisson equations, which arise in the semiclassical approximation of Schrödinger-Poisson equations and plasma dynamics. We then present a novel level set method for the computation of multi-valued velocity and electric fields of one-dimensional Euler-Poisson equations. This method uses an implicit Eulerian formulation in an extended space—called field space, which incorporates both velocity and electric fields into the configuration space. Multi-valued velocity and electric fields are captured through common zeros of two level set functions, which solve a linear homogeneous transport equation in the field space. The evaluation of density is also discussed.

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MS22

Homogenization of Integral Energies via the Periodic Unfolding Method

We consider the periodic homogenization of nonlinear integral energies of the type

$$u \in W^{1,p}(\Omega;\mathbf{R}^m) \mapsto \int_\Omega f\left(\frac{x}{\varepsilon_h}, \nabla u\right) dx, \tag{1}$$

where Ω is a bounded open subset of $\mathbf{R}^n$ with a Lipschitz boundary, and f is a Carathéodory energy density satisfying

$$\left\{ \begin{array}{l} f \,:\, (x,z) \in \mathbf{R}^n \times \mathbf{R}^{nm} \mapsto f(x,z) \in [0,+\infty[, \\ f(\,\cdot\,,z) \text{ Lebesgue measurable, } Y\text{-periodic for every} \\ z \in \mathbf{R}^{nm}, f(x,\,\cdot\,) \text{ continuous a.e. } x \in \mathbf{R}^n. \end{array} \right. \tag{4}$$

with Y the reference cell $]0,1[^n$. Assume that $f(x,\cdot)$ *is quasiconvex for a.e.* $x \in \mathbf{R}^n$, and furthermore that, for $p \in [1,+\infty[$, $M > 0$, and an Y-periodic $a \in L^1(Y)$, it satisfies the following growth conditions:

$$\left\{ \begin{array}{ll} f(x,z) \leq a(x) + M|z|^p & \text{for a.e. } x \in \mathbf{R}^n, \text{ and every } z \in \mathbf{R}^{nm}, \\ vertz|^p \leq f(x,z) & \text{for a.e. } x \in \mathbf{R}^n, \text{ and every } z \in \mathbf{R}^{nm}. \end{array} \right. \tag{5}$$

It is then known that as $\varepsilon_h \to 0$, one has

$$\begin{aligned} &\inf\Big\{\liminf_{h\to+\infty} \textstyle\int_\Omega f\left(\frac{x}{\varepsilon_h}, \nabla u_h\right) dx : \\ &\{u_h\} \subset W^{1,p}(\Omega;\mathbf{R}^m), u_h \to u \text{ in } L^p(\Omega;\mathbf{R}^m)\Big\} \\ &= \inf\Big\{\limsup_{h\to+\infty} \textstyle\int_\Omega f\left(\frac{x}{\varepsilon_h}, \nabla u_h\right) dx : \\ &\{u_h\} \subset W^{1,p}(\Omega;\mathbf{R}^m), u_h \to u \text{ in } L^p(\Omega;\mathbf{R}^m)\Big\} \\ &= \textstyle\int_\Omega f_{hom}(\nabla u) dx, \end{aligned}$$

where the homogenized energy density f_{hom} is defined by

$$f_{hom} \,:\, z \in \mathbf{R}^{nm} \mapsto \lim_{t\to+\infty} \frac{1}{t^n} \inf\Big\{ \int_{tY} f(y, z + \nabla v) dy :$$

$$v \in W_0^{1,p}(tY; \mathbf{R}^m) \Big\}.$$

This convergence result was established in [1] and [2] by sophisticated Γ-convergence arguments. Since then, many attempts at simplifying the proof (for example by using two-scale convergence), seem not to have borne fruit. In [5], a joint paper with Alain Damlamian and Riccardo De Arcangelis, we apply the tool of periodic unfolding from [3]. This gives a direct proof of the convergence result (under slightly weaker assumptions than in [1] and [2]), making use of simple weak convergence arguments in L^p-type spaces. This paper is part of a series of ongoing works concerning the applications of the periodic unfolding method to homogenization. The first one [4], treated the same problem but in the case of convex densities.

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MS22

The Unfolding Approach for Periodic Homogenization of Non Linear Elliptic PDE's and for the Mosco-convergence of Convex Integrals

In this presentation, we show how the use of the periodic unfolding method greatly simplifies and clarifies the homogenization of non-linear elliptic operators (in the multivalued framework generalizing the Leray-Lions type, as a map from the space $W_0^{1,p}(\Omega)$ to its dual space). In the case of subdifferentials of convex functions, the result can be expressed in terms of the Mosco-convergence of the corresponding sequence of integral functionals on the space $W_0^{1,p}(\Omega)$.

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MS22

Asymptotics of a Spectral Problem Associated with the Neumann Sieve

We analyze the asymptotic behavior of a Steklov spectral problem associated to the Neumann Sieve model, i.e a three dimensional set Ω, cut by a hyperplan Σ where each of the two-dimensional holes, $\epsilon-$ periodically distributed on Σ, have diameter r_ϵ. Depending on the asymptotic behavior of the ratios $\frac{r_\epsilon}{\epsilon^2}$ we find the limit problem of the ϵ spectral problem and prove that the sequences λ_n^ϵ, formed by the n-th eigenvalue of the ϵ problem, converge to λ_n, the n-th eigenvalue of the limit problem, for any $n \in \mathbf{N}$. We also prove the weak convergence, on a subsequence, of the associated sequence of eigenvectors u_n^ϵ, to an eigenvector associated to λ_n. When λ_n is a simple eigenvalue, we show that the entire sequence of the eigenvectors converges. As a consequence, similar results hold for the spectrum of the DtN map associated to this model.

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MS23

Weak and Strong Global Attractors for the 3D Navier-Stokes Equations

Often the evolution of an autonomous dissipative dynamical system can be described by a semigroup of solution operators. If this semigroup is asymptotically compact, then the classical theory of attractors yields the existence of a compact global attractor. However, for some dynamical systems the semigroup is not asymptotically compact. Some dynamical systems do not even possess the semigroup due to the lack of uniqueness (or proof of uniqueness). We will define and study such objects as an omega-limit, invariant set, and global attractor for a dynamical system that is not well-posed. Then we will apply the obtained results to the 3D incompressible Navier-Stokes equations.

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MS23

The Weak Attractor of the 3-D Navier-Stokes Equations

We study the pojection of the weak attractor of the 3D periodic Navier-Stokes in the normalized, dimensionless energy-enstrophy plane, obtaining restrictive bounds on the attractor's location. These bounds imply that the conditions necessary for the direct energy cascade can occur either near the origin of the phase space or near a singularity.

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MS23

The Attractor of the 2-D Navier-Stokes Equations in the Energy-enstrophy Plane

We examine how the global attractor of the 2-D Navier-Stokes equations projects in the normalized, dimensionless energy-enstrophy plane. A particular motivation is to see whether a condition for a direct energy cascade can be achieved. For any force, the attractor must lie between a line (the Poincare inequality) and a parabola. An optimization of the bounding parabola results in a sharper bound, yet preliminary computations suggest that an even sharper, linear estimate holds.

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MS23

Forced Two Layer Beta-plane Quasi-geostrophic Flow

We consider a model of quasigeostrophic turbulence that has proven useful in theoretical studies of large scale heat transport and coherent structure formation in planetary atmospheres and oceans. The model consists of a coupled pair of hyperbolic PDE's with a forcing which represents domain-scale thermal energy source. Although the use to which the model is typically put involves gathering information from very long numerical integrations, little of a rigorous nature is known about long-time properties of solutions to the equations. First we define a notion of weak solution, and show using Galerkin methods the long-time existence and uniqueness of such solutions. Then we show that the unique weak solution produces, via the inverse Fourier transform, a classical solution for the system. Moreover, we prove that this solution is analytic in space and positive time.

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MS24

Optimal Structures of Multiphase Composites and their Fields

The translation bounds for multiphase mixtures are sharp only in a range of volume fractions of components. We analyse the fields in translation-optimal structures for two- and three-dimensional conductive composites and describe the largest possible classes of multimaterial structures that achieve the bounds as well as the limits of attainability of these bounds. The two schemes of synthesis of optimal structures are suggested. One is an "inverse lamination scheme" in which the rank-one connected fields in laminates are fixed but the geometry is varied, the second is an adjusted differential scheme. Our results bring together and expand classes of optimal microgeometries found earlier by Milton, Milton and Kohn, Lurie and Cherkaev, Gibiansky and Cherkaev, Gibiansky and Sigmund. We also discuss new supplementary bounds for multicomponent mixtures and structures that realize these bounds. Some results were obtained in collaboration with Vincenzo Nezi.

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MS24

Solute Transport in Porous Media with Network Microgeometry

We study solute transport in porous media with periodic microstructures consisting of collections of interconnected by thin channels. We identify a physical mechanisms that promotes mixing of the solute with the host liquid and obtain the macroscopic transport equation that the concentration of solute satisfies. We discuss examples motivated by the transport of nutrients in bones.

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MS24

Optimal Lower Bounds on the L^∞ Norm of the Stress in Random Elastic Composites

Consider a cube containing two isotropic linear elastic materials. The only information given on the configuration of the two materials is the measure of the set occupied by each material. Subject to this limited geometric information one is interested in the L^∞ norm of a specified stress invariant when the domain is subject to a uniform force on the boundary. We provide a methodology for deriving optimal lower bounds on the L^∞ norm for various stress invariants when only the volume fraction of each material is known.

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MS24

Fluctuating Fractal Surfaces

We construct a family of fractal surfaces with fluctuating geometry at all scales and describe some metric and analytic properties of these sets from the point of view of composite media.

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MS25

Shocks in Driven Liquid Films

Driven contact line problems in thin liquid films are an active area of research. The mathematical theory of shock waves has recently been shown to play an important role in our understanding of basic properties of the contact line motion. I will present the theory for two recently studied experimental systems: (1) Thermally driven films counterbalanced by gravity are described by a scalar conservation with a non-convex flux. Such systems are known to produce 'undercompressive shocks' in which characteristics emerge from the shock on one side. (2) A related problem is that of particle laden flow driven by gravity. The differential settling rate of the particles with respect to the fluid results in the formation of double shock fronts which are solutions of a system of two conservation laws for the motion of the species. Comparison between theory and experiment will be discussed, along with open mathematical problems directly related to the experiments.

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MS25

The Hele-Shaw Problem as a "Mesa" Limit of Stefan Problems: Existence, Uniqueness, and Regularity of the Free Boundary

We study a Hele-Shaw problem as a "Mesa" type limit of one phase Stefan problems in exterior domains. We study the convergence, determine some of qualitative properties of the unique limiting solution, and prove regularity of the free boundary of this limit under very general conditions on the initial data. Indeed our results handle changes in topology and multiple injection slots. This project is joint work with Marianne Korten and Charles Moore.

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MS25

Free Boundary Measures and Partial Regularity of Solutions in a Mixed Type Evolution Equation

Solutions of the mixed type equation

$$u_t = \Delta_x \alpha(u) + \mathrm{div}_x F(u),$$

where $x \in I\!R^n$, $\alpha(u)$ is a continuous piecewise linear function such that $\alpha(u) = 0$ for $|u| \leq 1$ and having slope 1 otherwise, and $F(u)$ is a Lipschitz from $I\!R$ to $I\!R^n$, combine the features of conservation laws, and of free boundary problems. We will discuss the regularity of weak solutions to this equation, in particular, we will show that for solutions locally in L^2, $\alpha(u)$ satisfies local energy estimates, and that u is continuous in the set $\{|u| > 1\}$. With this in hand we will identify the free boundary measures supported on the boundary of $\{|u| > 1\}$. This allows us to study separately the jumps in u at the free boundary and the discontinuities occuring within the region $\{|u| < 1\}$ governed by the consevation law.

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MS25

A Deterministic Control Based Approach to Curvature Flows

In a joint work with Bob Kohn, we give a new control-type interpretation on the level-set approach to motion by curvature and related interface motion laws. More precisely, we give a family of discrete-time, two-person games whose value functions converge in the continuous-time limit to the solution of the motion-by-curvature PDE. The value function of a deterministic control problem is normally a first-order Hamilton-Jacobi equation, while the level-set formulation of motion by curvature is a second-order parabolic equation.

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MS26

Lawrence-Doniach System for High-temperature Superconductors

We consider the Lawrence-Doniach model for layered superconductors, which describes a large class of high-temperature superconductors as a finite number of parallel superconductors, with Josephson coupling between them, including nonlinear Maxwell's equations that describe the induced magnetic field. Assuming an applied magnetic field which is nontangential to the layers, we prove that a change of phase from superconducting to normal occurs, and we estimate the upper critical field in terms of the material parameters, the Josephson constant, and the angle of the nontangential applied field. Our estimates extend to the nonlinear regime predictions by physicists based on the linearized system.

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MS26

Bifurcation Structure of a Ginzburg-Landau Model in a Ring

We deal with the one-dimensional Ginzburg-Landau energy functional which is a simplified model of the superconductivity in a thin tubular ring. The Euler-Lagrange equation of this functional, called the Ginzburg-Landau equation, has two physical parameters. We show a global bifurcation

structure in the parameter space if the tubular domain has uniform thickness. Moreover we exhibit a local bifurcation diagram around a singularity for the case of nonuniform thickness.

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MS26

Transitions of Liquid Crystals and Critical Values of Elastic Coefficiants

We use the Landau-de Gennes model to examine the effects of twist and bend to liquid crystals. In the case of equal elastic coefficients ($K_i = K_2 = K_3 = K$) we show that there exists a critical value K_c such that the liquid crystal is in the smectic state if $K < K_c$ and is in the nematic state if $K > K_c$. Under some non-degeneracy and regularity assumptions on the nematic states we find the precise value of K_c and obtain the asymptotic behavior of minimizers of $\mathcal{E}_K$ as K approach K_c.

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MS26

Something About Ginzburg-Landau Vortices in the High-Kappa Limit

I will talk either about vortex collisions in the Ginzburg-Landau heat flow or about some refined Gamma-convergence results for Ginzburg-Landau with applied magnetic field

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MS27

Dependence of Large Entropy Solutions to the Euler Equations on Physical Parameters

We compare the entropy solution U^μ to a hyperbolic system of conservation laws for which the flux function depends on a parameter vector $\mu = (\mu_1, \ldots, \mu_k)$ with the Standard Riemann Semigroup $\mathcal{S}$ generated when $\mu \equiv 0$ and establish L^1 error estimates pointwise in time with respect to the flux parameter μ. We apply our results to the isentropic and relativistic Euler equations with large oscillations for which the parameters are the adiabatic exponent $\gamma > 1$ and the speed of light $c < \infty$ in comparison with the isothermal Euler equations.

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MS27

A Particular Large Data Solution of the 1-D Euler System

It is known from explicit examples of finite time blowup in BV and L^∞ that the class of strictly hyperbolic systems is too large to allow a general global existence result for large data. On the other hand it is hoped that physical systems, and especially the Euler system, have enough structure to admit global weak solutions, even for large amplitude/variation data. We present an example of a solution to the Euler system which exhibits the same type of interaction pattern for which blowup has been shown in other systems. The data giving rise to these particular solutions may be arbitrarily large in BV or L^∞. By carefully estimating the interactions we show that no blowup occurs for these particular solutions.

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MS27

Self-similar Solutions for Transonic 2D Riemann Problems

We discuss recent developments of transonic self-similar 2D Riemann problems.

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MS27

Transonic Shock Solutions for a System of Euler-Poisson Equations , 1-d Case

A boundary value problem for a 1-d system of Euler-Poisson equations is considered. The boundary conditions are supersonic on the left end and subsonic on the right end. The solutions with transonic shocks are constructed, and the shock locations are shown to be uniquely and explicitly determined by the boundary data.

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MS28

Artificial Compressibility Method for the Incompressible Navier Stokes Equations

We study an hyperbolic approximation of the Leray solution to the $3D$ Navier Stokes equation. In particular we describe an hyperbolic version of the so called compressibilty method investigated by J.L.Lions, Temam. This approximation is motivated by numerical analysis applications where, in order to overcome the difficulty related the divergence free condition, an artificial compressibilty is introduced. We will study the problem on unbounded domains by replacing Sobolev compact embedding with the use of dispersive estimates of Strichartz type combined with bilinear estimates.

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MS28

The Existence of Weak, Small Energy Solutions for the Equations of Motion of 3D Compressible, Viscous Fluid Flows with the No-slip Boundary Conditions

We consider the equations of motion of a compressible, viscous, isentropic fluid in a bounded domain in $R2$ or $R3$ with the no-slip boundary conditions. Given a constant, equilibrium state we construct a global in time, regular weak solution, provided that initial data are close to the quilibrium when measured by weak norms and discontinuities in the initial density decay near the boundary.

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MS28

Boundary Layer Analysis for Isentropic Gas Dynamics with Real Viscosity and Related Systems

We study the problem of boundary layer formation for viscosity approximations of the isentropic gas dynamics, including source terms as friction and topography, for physical viscosity models. The case of Saint-Venant equations for shallow water is also discussed.

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MS28

Homogenization in Parabolic Equations

We are interested in homogenization of parabolic equations including diffusion equation, Incompressible Navier-Stokes equation in reticulated domain or perforated domain, which are arose from cell biology, rheology. In the limit, we identify the effective parabolic equations.

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MS29

On Singular Limits for the Full Navier-Stokes-Fourier System

We discuss some singular limits of global-in-time solutions to the full Navier-Stokes-Fourier system describing the dynamics of a compressible, viscous, and heat conducting fluid. In particular, we concentrate on the case when the Mach number tends to zero. We shall show that in the limit we arrive at the Oberbeck-Boussinesq approximation. Several generalizations of this result are also discussed, in particular the case of a chemically reacting fluid.

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MS29

Lagrangean Structure and Propagation of Singularities in Multidimensional Compressible Flow

Not available at time of publication.

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MS29

Navier's Slip and Incompressible Fluids with Temperature, Pressure and Shear Rate Dependent Viscosity

There is compelling experimental evidence for the viscosity of a fluid depending on the temperature, the shear rate as well as the mean normal stress (pressure). Moreover, while the viscosity can vary by several orders of magnitude the density suffers very minor variation, when the range of the pressure is sufficiently large, thereby providing justification for considering the fluid as being incompressible while at the same time possessing a viscosity that is dependent on the pressure. We investigate the mathematical properties of internal unsteady three-dimensional flows of such fluids subject to Navier's slip at the boundary. We establish the long-time existence of a weak solution for large data provided that the viscosity depends on the temperature, the shear rate and the pressure in a suitably specified manner. This specific relationship however includes the classical Navier-Stokes-Fourier fluids and power-law fluids as special cases. This talk is based on joint work with M. Bulicek and K.R. Rajagopal.

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MS30

The Control-theoretic Approach to Construction of Fast Iterative Solvers

We outline the dynamical systems/optimal control perspective on the design of numerical approximations. In particular, we describe a natural class of process level discretizations of a continuous time/continuous state deterministic optimal control problem, when the goal is that the related iterative solver for the dynamic programming equation should converge with a number of iterations that is independent of the discretization. An extension to deterministic differential games is also described.

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MS30

An Application of Fast Sweeping Methods to Transmission Traveltime Tomography

Traditional transmission travel-time tomography hinges on ray tracing methods. We propose a new PDE-based approach which avoids using the cumbersome ray-tracing technique. We start from the eikonal equation, define a mismatching functional and then derive the gradient of the functional using an adjoint state method. These computations can be efficiently done using the fast sweeping method. We demonstrate the robustness of the method with examples including the Marmousi synthetic velocity model.

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MS30

A Fast Sweeping Method Based on Discontinuous Galerkin Methods for Static Hamilton-Jacobi Equations

We will report on our preliminary results on combining the discontinuous Galerkin methods, a properly chosen numerical Hamiltonian, and Gauss-Seidel iterations with alternating-direction sweepings to design a high order fast sweeping method for static Hamilton-Jacobi equations. The main new feature of the method is to explore the advantages of the local compactness of the discontinuous Galerkin methods which fits well in the fast sweeping framework. A description of the algorithm and preliminary numerical results for Eikonal equations will be presented.

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MS30

Wide Stencil Schemes for First and Second Order Degenerate Elliptic Equations

We will present a useful class of wide stencil schemes for degenerate elliptic equations. These types of schemes have been used to build convergent schemes for several types of second order equation, including: Level Set Motion by Mean Curvature, the Monge-Ampere equation, the Infinity Laplacian, the equation for the convex envelope. These schemes are easy to build, and are provably convergent. We will discuss adapting these schemes to build schemes for Hamilton-Jacobi equations on unstructured grids.

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MS31

Existence and Stability of Traveling Waves of the Regularized Short Pulse and Ostrovsky Equations

We consider the question of existence and stability of traveling waves for the regularized short pulse and Ostrovsky equations. The regularization term in the short pulse equation arises naturally as a higher order expansion term in the derivation of the original short pulse equation. The existence of single bump traveling waves for both equations is proved via the Fenichel theory for singularly perturbed ODEs and a Melnikov type transversality calculation. We then consider the spectral stability of the waves via topological arguments based on the augmented Evans bundle, which is constructed from the fast-slow decomposition of the underlying traveling wave.

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MS31

On Subsonic Detonation Waves in Inert Porous Medium

We consider Sivashinsky's model of subsonic detonation that describes propagation of combustion fronts in highly resistable media. It is known that there exists a traveling wave asymptotically connecting the unburnt and burnt states, which is unique if thermal diffusivity is neglected. Using geometric singular perturbation theory we study the uniqueness and stability of the wave in the case of positive thermal diffusivity.

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MS31

Rigorous Asymptotic Expansions for Critical Wave Speeds in a Family of Scalar Reaction-diffusion Equations

We investigate traveling waves in the family of reaction-diffusion equations given by

$$u_t = u_{xx} - 2u^m(1-u).$$

For $m \geq 1$ real, there is a critical wave speed $c_{\mathrm{crit}}(m)$ which separates waves of exponential structure from those that decay only algebraically. We derive rigorous asymptotic expansions for c_{crit} by perturbing off two solvable cases, the classical Fisher-Kolmogorov-Petrowskii-Piscounov equation ($m = 1$) and a degenerate cubic equation ($m = 2$). In addition, we study the asymptotic critical speed in the limit as $m \to \infty$. Our approach uses geometric singular perturbation theory, as well as the blow-up technique, and confirms results previously obtained through asymptotic analysis.

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MS31

Exchange Lemma for Nontrivial Slow Flows

The Exchange Lemma of Jones and Kopell deals with the passage of solutions near a slow manifold of a geometric singular perturbation problem $\dot{x} = \epsilon f(x, y)$, $\dot{y} = g(x, y)$, $(x, y) \in R^m \times R^n$. For $\epsilon = 0$ the slow manifold is given by $g(x, y) = 0$ and consists of normally hyperbolic equilibria. For small $\epsilon > 0$ the slow manifold is nearby, and on it, after a change of variables, the differential equation becomes $\dot{x}_1 = \epsilon, \dot{x}_2 = \cdots = \dot{x}_m = 0$. However, if normal hyperbolicity fails somewhere, then some fast directions must be added to the slow manifold, and usually the blowing-up technique of Roussarie, Dumortier, Szmolyan, et. al. must be used to analyze the flow on the enlarged slow manifold. I shall discuss generalizations of the Exchange Lemma needed to study the flow past the enlarged slow manifold. The motivation for this work is rarefaction-like solutions of the Dafermos regularization of a system of conservation laws.

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MS32

On the Long Time Regularity of the Shallow Water Equations

We study the long time existence of classical solutions to the Shallow Water (SW) equations with pressure gradient and rotational forcing that are both singular within certain scaling regime of the Froude and Rossby numbers. The SW dynamics is then shown to be asymptotically close to the one governed by the 2-D "pressureless" rotational Euler equations with subcritical initial data, which in turn yields the increasingly long time existence at this singular regime. The novelty of our approach is the use of an approximate system that is linear while still capturing both the singularity and the advection dynamics of the underlying nonlinear system. The near periodic dynamics shown here is closely related to the circular fluid motions observed in geophysical sciences.

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MS32

Weakly Nonlinear Approximation of Multi-D Hyperbolic-Parabolic System with Entropy

We consider weakly nonlinear approximation around a constant state of general multi-D hyperbolic-parabolic system with entropy. Using method of multiple time scales, we derive the averaged system. We give a sufficient condition under which global weak solution to the averaged system exists. We apply the results to the multi-D Navier-Stokes-Fourier system of compressible gas dynamics, which satisfies the structure condition and derive a new averaged system on the fast mode. We apply the global solutions to the averaged system to construct local Maxwellian to approximate solutions to the Boltzmann equation

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MS32

On the Conditional Global Regularity of the 1D Euler-Poisson Equations with Pressure

We prove that the one-dimensional Euler-Poisson system driven by the Poisson forcing together with the usual γ-law pressure admits global solutions for a large class of initial data. Thus, the Poisson forcing regularizes the generic finite-time breakdown in the 2×2 p-system. Global regularity is shown to depend on whether the initial configuration of the Riemann invariants and density crosses an intrinsic critical threshold.

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MS32

Non-selfsimilar Global Solutions and Their New Structures of Multi-dimensional Conservation Laws

In this talk, we will discuss the multi-dimensional conservation laws whose Riemann data just contain two different constant states which are separated by a smooth curve or a surface. Non-selfsimilar structures and properties are discovered. Furthermore, global solutions of a class of 2-D systems of conservation laws will be also presented and are formulated by implicit function, their structure combining 2-D non-selfsimilar elementary waves and non-constant intermediate states will be shown.

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MS33

Coherence in SPDE

There has been much recent work in the phenomenon of stochastic systems which become coherent in certain scaling regimes. In this talk, we will present examples of PDE or their corresponding discretizations which act coherently but non-trivially under the application of small stochastic forcing.

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MS33

Noise-induced Target Pattern Formation in Excitable Media

Spatially distributed excitable systems, or "excitable media", are an important class of excitable systems whose main biological function is long-range signal transmission through self-sustained waves of activity. The standard modeling approach to excitable media is via systems of nonlinear deterministic partial differential equations. These ignore the effect of small random fluctuations inherent in such media. Here, we show that under rather generic conditions the inclusion of the noise may lead to qualitatively new dynamical behaviors, which, nevertheless, remain essentially deterministic. Specifically, we analyze patterns of recurrent activity in a prototypical model of an excitable medium in the presence of noise. Without noise, this model robustly predicts the existence of spiral waves as the only recurrent patterns in two dimensions. Remarkably, we found that, in addition, small noise is capable of generating coherent target patterns, another type of recurrent activity which is widely observed experimentally. Our findings demonstrate the need to re-examine current modeling approaches to active biological media.

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MS33

Modulation Equations: Stochastic Bifurcation in Large Domains

We consider the stochastic Swift-Hohenberg equation on a large domain near its change of stability. We show that, under the appropriate scaling, its solutions can be approximated by a periodic wave, which is modulated by the solutions to a stochastic Ginzburg-Landau equation. We then proceed to show that this approximation also extends to the invariant measures of these equations.

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MS33

Rare Events in Large Systems

Large deviation theory analyzes the probability of a rare event in a system of bounded size, in the limit of vanishing noise. Other limits are also mathematically interesting and physically relevant. In particular, rare events in systems that are large (exponentially large in the inverse noise strength) raise new questions.

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MS34

Thin Films of Martensitic Materials: Can We Predict Their Microstructure?

Because of their technological applications as microactuators, martensitic thin films utilizing the shape memory effect have been intensively studied in recent years. The key analytical issue for these applications is to provide a rigorous derivation of effective thin film models from Nonlinear Elasticity via dimension reduction. I will describe a new mathematical theory of martensitic thin films and discuss its connections with several recent results in this direction.

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MS34

Atomistic Potential Energy Surfaces and Solid Mechanics

How does collective "solid mechanics" behaviour emerge from (accurate quantum-mechanical or approximate) many-atom potential energy surfaces? I will discuss basic open problems, scope and limitation of known methods (e.g. homogenization theory), and recent mathematical results. One such result (joint with F.Theil, Warwick) is identification of the 3D fcc (face-centered cubic) lattice as a local minimizer of the celebrated Lennard-Jones pair interaction model. For a long time any progress in this direction was beyond reach; a key ingredient is a recent rigidity theorem from nonlinear PDE theory (due to Friesecke, James, and Müller).

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MS34

Mathematical and Computational Methods for Coarse-graining

In this talk we discuss recent progress in obtaining coarse-grained stochastic approximations of microscopic lattice dynamics. We prove rigorous error estimates both at equilibrium and non-equilibrium in terms of weak convergence and relative entropy calculations and obtain a posteriori estimates that can guide adaptive coarse-grained simulations. We also demonstrate, with direct comparisons between microscopic Monte Carlo and coarse-grained simulations, that the derived mesoscopic models provide a substantial CPU reduction in the computational effort.

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MS34

Inclusions for Which Constant Magnetization Implies Constant Field, and Their Applications

In this paper, we find a class of special regions that have the same property with respect to second order linear partial differential equations that ellipsoids have in infinite space. That is, in physical terms, constant magnetization of the inclusion implies constant magnetic field on the inclusion. The inclusions apparently enjoy many interesting properties with respect to homogenization and energy minimization. In particular, we use them to give new results on a) homogeneous and inhomogeneous inclusion problems subject to periodic boundary conditions; b) optimal bounds of the effective moduli of two-phase composites; c) energy-minimizing microstructures; and d) the characterization of the G_θ-closure of two well-ordered composites.

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MS35

Wave Atoms and Time Upscaling of Wave Equations

We present a geometric algorithm for solving the 2D wave equation in smooth inhomogeneous periodic media. We introduce a tight frame of 'wave atoms', a family of wave packets interpolating between wavelets and Gabor, whose key property is a precise balance between oscillations and support called parabolic scaling. In that frame, the time-dependent Green's function of the wave equation decomposes in a sparse and separable way. As a result, it becomes realistic to build the full matrix exponential up to some time which is much bigger than the usual CFL timestep. Once available, this new representation can be used to perform giant 'upscaled' time steps to solve the wave equation faster than with a spectral method. We will show numerical examples as well as complexity results based on a priori estimates of sparsity and separation ranks.

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MS35

Nonlinear Wave Equations on a Curved Background

We will discuss a local well-posedness result for a semilinear wave equation with variable coefficients in 4+1 dimensions. As part of the proof we will present a new definition for the $X^{s,b}$ spaces in the variable coefficient case.

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MS35

Combining Finite Elements and Geometric Wave Propagation in 1-D

We show that the initial value problem for a strictly hyperbolic partial differential equation on the circle can be solved at cost $O(N)$. To obtain this the equation is approximately decoupled, into first order equations that can be solved using the method of characteristics. An ODE for the error is of the form $dv/dt = R(t)v$, with $R(t)$ bounded, which, with an appropriately designed scheme, leads to the stated complexity.

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MS35

Evolution Equations, Curvelet Transform, and Curvelet-curvelet Interaction

We discuss how to solve certain evolution equations with the curvelet transform. The analysis presented here yields an approach that requires solving, scale-wise, for the geometry reminiscent of the propagation of singularities on the one hand, and solving a matrix Volterra integral equation (of the second kind) on the other hand. The Volterra equation can be solved by recursion, in a step-by-step manner with refinement – as in the computation of certain multiple scattering series; this process reveals the curvelet-curvelet interaction. It is shown that the representation (matrix) of the kernel in the Volterra equation is optimally sparse.

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MS36

Numerical Simulation of Vortex Dynamics in Ginzburg-Landau-Schrödinger Equation

In this talk, we will study numerically vortex dynamics in the Ginzburg-Landau-Schrödinger equation (GLSE) in two dimensions (2D)

$$(\alpha - i\beta)\partial_t \psi(\mathbf{x},t) = \Delta\psi + \frac{1}{\varepsilon^2}\left(V_0(\mathbf{x}) - |\psi|^2\right)\psi,$$
$$\mathbf{x} \in R^2,\ t > 0,$$
$$\psi(\mathbf{x},0) = \psi_0(\mathbf{x}), \qquad \mathbf{x} \in R^2,$$

with nonzero far field conditions

$$|\psi(\mathbf{x},t)| \to 1 \text{ (e.g. } \psi \to e^{im\theta}), \quad t \geq 0,$$
$$\text{when } r = |\mathbf{x}| = \sqrt{x^2+y^2} \to \infty;$$

where $\psi(\mathbf{x},t)$ is the complex-valued wave function, $V_0(\mathbf{x})$ is a given real-valued external potential satisfying $V_0(\mathbf{x}) \to 1$ when $|\mathbf{x}| \to \infty$, ε is a positive constant, α and β are two nonnegative constants satisfying $\alpha+\beta > 0$. We will present an efficient and accurate numerical method for numerical simulation of and apply it to study quantized vortex dynamics in GLSE. By formulating the equation in 2D polar coordinate system, the nonzero far field conditions which are highly oscillating in the transverse direction will be efficiently resolved in phase space in a natural way. This allows us to develop a time-splitting method which is unconditionally stable, efficient and accurate for the problem. Moreover, the method is time reversible when it is applied to the nonlinear Schrödinger equation (NLSE) with nonzero far field conditions. We also apply the numerical method to study issues such as the stability of quantized vortex, interaction of a few vortices, dynamics of the quantized vortex lattice and motion of vortex with an inhomogeneous external potential in GLSE. Based on our numerical results, we find that the quantized vortex with winding number $|m| = 1$ is dynamically stable, and resp., $|m| > 1$ dynamically unstable, in GLSE. Furthermore, different interaction patterns between a few vortices with winding number $m = \pm 1$ as well as dynamics of quantized vortex lattices in GLSE are reported. This talk is based on joint works with Qiang Du and Yanzhi Zhang.

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MS36

Composite Superconducting Systems

The talk will deal with analytical results regarding surface nucleation in superconducting samples in contact with a semiconductor or normal material, in the context of the Ginzburg-Landau theory. In particular, we will show that for a superconductor coated with a properly chosen semiconductor one should expect enhanced surface superconductivity. In contrast, for an appropriate metal coating, the surface sheet can be completely suppressed.

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MS36

Capacity of a Multiply-connected Domain and Nonexistence of Ginzburg-Landau Minimizers with Prescribed Degrees on the Boundary

Suppose that $\omega \subset \Omega \subset R^2$. In the annular domain $A = \Omega \setminus \bar{\omega}$ we consider the class J of complex valued maps having the same degree d on $\partial\Omega$ and on $\partial\omega$. The existence of minimizers of E_κ for all κ when $cap(A) \geq \pi$ (domain A is "thin") and for small κ when $cap(A) < \pi$ (domain A is "thick") was established by Berlyand and Mironescu ('04). Here we provide the answer for the remaining case of large κ when $cap(A) < \pi$. We prove that, when $cap(A) < \pi$, there exists a finite threshold value κ_1 of the Ginzburg-Landau parameter κ such that the minimum of the Ginzburg-Landau energy E_κ is not attained in J when $\kappa > \kappa_1$ while it is attained when $\kappa < \kappa_1$.

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MS36

On a Minimization Problem with a Mass Constraint Involving a Potential Vanishing on Two Curves

We study a singular perturbation type minimization problem with a mass constraint over a domain or a manifold, involving a potential vanishing on two curves in the plane. In the case of the problem on the sphere we give a precise description of the limiting behavior of both the minimizers and their energies when the small parameter epsilon goes to zero.

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PP0

Spectral-Element Simulations of Electrokinetic Fluid Flows in Nanochannels

Micro- and nano-fluidic systems hold tremendous promise for separation and mixing of biochemical samples. Many simple devices can be modeled using a two dimensional approximation to the governing PDEs for electrokinetic fluid flows. Modeling more sophisticated devices, however, will require the simulation of three-dimensional problems, which are computationally challenging to solve using traditional finite-element methods. Spectral elements offer an attactive alternative, especially because many commonly encountered problem geometries are highly regular. We present spectral-element simulations of several electrokinetic devices.

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PP0

An Ant Algorithm for the Multi-Row Layout Problem in Automated/flexiable Manufacturing Systems

Multi-row layout problem is one of commonly used layout patterns in which each machine or facility is located in a coordinate system as (x,y). This layout pattern can used in flexible/automated manufacturing systems. In this paper, this problem is formulated as a q.a.p. programming model. An ant algorithm has been developed to solve this problem. An improvement heuristic called local search technique is developed to obtain a betters solution. The performance of the proposed heuristic is tested over a number of problems selected from the literature. Solving these problems with proposed algorithm yields better solution compared to existing algorithm in this area.

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PP0

Mathematical Analysis to An Adaptive Network of the Plasmodium System

Physarum polycephalum contains a tube network by means of which nutrients and signals circulate through the body. When the organism is put in a maze and food sources are presented at two exits, the tube network changes its shape to connect two exits through the shortest path. Recently, a mathematical model for this adaptation process of path-finding was proposed by Tero et al. We analyze this model for some special cases mathematically rigorously.

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PP0

Viscoelastic Dynamics for a Scalar Two Dimensional Continuum Model for Microstructure creation at an Austenite-Martensite Interface

A pseudo-spectral Fourier-Chebyshev collocation method for simulating a scalar two-dimensional viscoelastic dynamic model of microstructure creation with capillarity, $u_{tt} - \beta\Delta u_t = (3u_x^2 - 1)u_{xx} + u_{yy} - \epsilon\Delta^2 u$, is developed and implemented in Matlab. By using an integration matrix formulation for the Chebyshev modes, the numerical instability associated with large dimension Chebyshev differentiation matrices is overcome. The integration matrices are sparse and so allow a large number of modes to be computed, and hence for small values of the spatially regularizing capillarity parameter to be used. The computational results are compared to previous simulations without capillarity.

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PP0

Symbolic Integration and Summation

The homotopy algorithm is a powerful method for indefinite integration of total derivatives, and for the indefinite summation of differences. By combining these ideas with straightforward Gaussian elimination, we construct an algorithm for the optimal symbolic integration or summation of expressions that contain terms that are not total derivatives or differences. The optimization consists of minimizing the number of terms that remain unintegrated or are not summed. Further, the algorithm imposes an ordering of terms so that the differential or difference order of these remaining terms is minimal.

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PP0

The Billiard Problem in Nonlinear and Nonequilibrium System

We consider about the billiard problem in nonlinear and nonequilibrium system, whose behavior is similar to the usual billiard problem at a glance. However it has some remarkable properties quite different from the usual one in view of dynamical system. We reveal some of them by use of a reduction equation. We finally show that the strange behavior comes from intermittent type Chaos possessed by the system by use of computer simulation.

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PP0

Oil Production Linked to Stochastic Differential Equation

Oil barrel price is a random variable that can be modeled by a stochastic differential equation. Here we illustrate a simple model for the net cash of the oil production based on the oil well production, oil barrel price, production costs, initial costs, and the decline production in order to calculate the production to maximize the net cash. The optimization problem is solved by two approaches: a discrete method and one based on Markov controls.

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PP0

Double Reduction from the Association of Symmetries with Conservation Laws: Applications to the Heat, Bbm, and One Dimensional Gas Dynamics Equations

A method to find a double reduction of partial differential equations (PDEs) with two independent variables is derived. The method is based on the definition of the association of Lie point symmetries of PDEs with conservation laws [Kara A.H. and Mahomed F.M.,*The relationship between symmetries and conservation laws*, Int. J. Theoretical Phys. 39(1)(2000) pp24-30].

Applications to the linear heat equation,the BBM equation and a system of differential equations from one dimensional gas dynamics illustrate the new theory.

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PP0

A Quasistationary Analysis of a Stochastic Chemical Reaction: Keizer's Paradox Revisited

The deterministic and stochastic models of an autocatalytic biochemical reaction are compared. The two models show distinctly different steady state behavior. To resolve this "paradox" proposed by J. Keizer, we compute the expected time to extinction and a quasistationary probability distribution in the stochastic model. Mathematically, we identify that exchanging the limits of infinite system size and infinite time is problematic. An appropriate system size for numerical computations is discussed.

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