2022 Shanks Workshop on
Mathematical Aspects of Fluid Dynamics
Contributed Talk Session
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Organizers: Leonardo Abbrescia, Marcelo Disconzi, Gieri Simonett, Jared Speck

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Well-posedness for the dispersive Hunter-Saxton equation

Abstract: This talk represents a first step towards understanding the well-posedness for the dispersive Hunter-Saxton equation. This problem arises in the study of nematic liquid crystals, and its non-dispersive version is known to be completely integrable. Although the equation has formal similarities with the KdV equation, the lack of L^2 control gives it a quasilinear character, with only continuous dependence on initial data. Here, we prove the local and global well-posedness of the Cauchy problem using a normal form approach to construct modified energies, and frequency envelopes in order to prove the continuous dependence with respect to the initial data. This is joint work with Albert Ai.

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Gradient blow-up for dispersive and dissipative perturbations of the Burgers equation

Abstract:
I will discuss a construction of "shock forming" solutions to a class of dispersive and dissipative perturbations of the Burgers equation, which includes the fractional KdV equation with low dispersion, the Whitham equation arising in water waves, and the fractal Burgers equation with low dissipation. Our result seems to be the first construction of gradient blow-up for fractional KdV with dissipation of order between 2/3 and 1. This is joint work with Sung-Jin Oh (UC Berkeley).

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Global expanding solutions of compressible Euler equations

Abstract:
We present some recent works on global existence and stability results to the compressible Euler equations describing the stable expansion mechanism of nonisentropic and isothermal gases. In particular, we show that small suitable perturbations of expanding affine motions stay small for all time.

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USING AMPLITUDE EQUATIONS TO EXPLORE NON-NORMALITY IN FLUID MECHANICS

Abstract: Non-normality is of key importance when considering the equations governing Fluids such as the Navier-Stokes equations and the non-self-adjoint Ginzburg-Landau equation. In this talk, we discuss some of the ramifications of non-normality on whether the eigenvectors of the linear operators of these governing equations form a basis or not. We will also look at the historical context of the use of amplitude equations in Fluid Mechanics. We in particular investigate the use of higher order amplitude equations, which have limited value in non-normal settings.

Patrick Flynn
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THE SCATTERING PROBLEM FOR VLASOV-POISSON

Abstract:
The Vlasov-Poisson system is a kinetic model for a continuous density of particles interacting through either Newtonian or Coulombic gravitation. I will describe the scattering problem for this equation, where one must find the asymptotic dynamic as time goes to infinity, and then connect the asymptotic behavior of the solution at time minus infinity to time plus infinity through the so-called scattering map. I will show that this model exhibits "modified" scattering, where the asymptotic dynamic is given by the linearized equation, plus an explicit nonlinear correction. To solve the scattering problem, we apply the pseudo-conformal transformation, more widely used in the study of the nonlinear Schrodinger equation. This transformation, which inverts time, allows us to reformulate the scattering problem as a Cauchy problem, which we then solve using Picard iteration.

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LONG-TERM DYNAMICS FOR A SEMILINEAR WAVE EQUATION SUBJECT TO BOUNDARY DISSIPATION

Abstract:
In this talk we are going to consider a nonlinear wave equation subject to Neumann boundary conditions, which includes nonlinear source and damping mechanisms. We shall establish the existence of an evolution operator and (mainly) the existence of compact global attractors for the trajectories of the corresponding dynamical system. Such models are of interest and exhaustively studied due to the wide range of applications.

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ON QUANTITATIVE UNIQUENESS FOR PARABOLIC EQUATIONS

Abstract:
We consider the quantitative uniqueness properties for a parabolic type equation $u_t - \Delta u = w(x,t) \cdot \nabla u + v(x,t)u$, when $v \in L_t^{p_2} L_x^{p_1}$ and $w \in L_t^{q_2} L_x^{q_1}$, with a suitable range of exponents p_1, p_2, q_1, and q_2. We prove a strong unique continuation property and provide a pointwise in time observability estimate.

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Enhanced dispersion by tilting the pipe: the role of diffusion-driven flow in micro-fluidic transport

Abstract: In this work, we identify and isolate an unexplored mechanism of the solute dispersion in an inclined capillary pipe. Capillary tubes involving multi-species fluids with different densities are common in many microfluid experiments. Such different density fluids could generate a so-called diffusion-driven flow when the external force field is not parallel to the solid boundary. We have obtained supporting experimental and numerical results which demonstrate the diffusion-driven flow could significantly enhance the dispersion of the solute in an inclined capillary pipe. Additionally, we document the dependence of the dispersion coefficient on the physical parameters such as inclination angle, cross-sectional area, molecular diffusivity, and solute density gradient.

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A stochastic fluid-structure interaction problem describing Stokes flow interacting with a membrane

Abstract: In this talk, we present a well-posedness result for a stochastic fluid-structure interaction model. We study a fully coupled stochastic fluid-structure interaction problem, with linear coupling between Stokes flow and an elastic structure modeled by the wave equation, and stochastic noise in time acting on the structure. Such stochasticity is of interest in applications of fluid-structure interaction, in which there is random noise present which may affect the dynamics and statistics of the full system. We construct a solution by using a new splitting method for stochastic fluid-structure interaction, and probabilistic methods. To the best of our knowledge, this is the first result on well-posedness for fully coupled stochastic fluid-structure interaction. This is joint work with Sunčica Čanić (UC Berkeley).

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On stochastic partial differential equations with a Ladyzenskaya-Smagorinsky type nonlinearity

Abstract: The theory of monotone operators plays a central role in many areas of nonlinear analysis. Monotone operators often appear in fluid dynamics, for example the p-Laplacian appears in a non-Newtonian variant of the Navier–Stokes equations modeled by Ladyzenskaya or in the Smagorinsky model of turbulence. In this talk, we will discuss global existence results of both martingale and pathwise solutions of stochastic equations with a monotone operator, of the Ladyzenskaya-Smagorinsky type, driven by a general Lévy noise. The classical approach based on using directly the Galerkin approximation is not valid. In this talk we will discuss how one can approximate a monotone operator by a family of monotone operators acting in a Hilbert space, so as to recover certain useful properties of the orthogonal projectors and overcome the challenges faced while applying the Galerkin scheme.

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Dynamic Observer Patterns for Continuous Data Assimilation - The Bleeps, the Sweeps, and the Creeps

Abstract: In accurately simulating turbulent flows, two major difficulties arise before the simulation begins; namely the problem of determining the initial state of the flow, and the problem of estimating the parameters. Data assimilation helps to resolve the first problem by eliminating the need for complete knowledge of the initial state. It incorporates incoming observations into the mathematical model to drive the simulation to the correct solution. Recently, a promising new data assimilation algorithm (the AOT algorithm) has been proposed by Azouani, Olson, and Titi, which uses a feedback control term to incorporate observations at the PDE level. In this talk, we examine computationally the effects of observers that move dynamically in time for the 2D incompressible Navier-Stokes equations. We test several movement patterns (which we refer to as "the bleeps, the sweeps, and the creeps") as well as Lagrangian motion and combinations of these patterns, in comparison with static observers. In several cases, order-of-magnitude improvements in terms of the time-to-convergence are observed.

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USING HPPC TO SOLVE DRIVEN CAVITY PROBLEM

Abstract:
This presentation discusses about using high performance parallel computing (HPPC) to solve Driven Cavity Problem by discretizing the system of nonlinear partial differential equations and solving the system with inexact Newton methods. Parallelizing the discetized system uses Schwarz method. Solving the Newton steps uses iterative Krylov methods. The Jacobian matrixes are closely singular or ill-conditioned, so to accelerate the iterations the matrix preconditioners are needed. As the preconditioners the Schwarz method may be used. Therefore, the method is named as Newton Krylov Schwarz (NKS) method. This presentation focuses on the Schwarz method. However, the ending of the presentation mentions other classes of NK methods and discretizations.

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FLUID–STRUCTURE INTERACTION WITH KELVIN-VOIGHT DAMPING: ANALYTICITY, SPECTRAL ANALYSIS, EXPONENTIAL DECAY

Abstract:
We consider a fluid–structure interaction model defined on a doughnut-like domain. It consists of the dynamic Stokes equations evolving on the exterior sub-domain, coupled with an elastic structure occupying the interior sub-domain. A key factor - a novelty over past literature - is that the structure equation includes a strong (viscoelastic) damping term of Kelvin-Voigt type at the interior. This affects the boundary conditions at the interface between the two media and accounts for a highly unbounded "perturbatiom". Results include: (i) analyticity of s.c semigroup of contractions defining the overall coupled system, (ii) its (uniform) exponential decay, along with (iii) sharp spectral properties of its generator. Some results are geometry-dependant.

Ellie Gurvich
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ANALYSIS OF POROELASTIC SYSTEMS DESCRIBING BIOLOGICAL TISSUES

Abstract:
In this talk, we present a biologically-motivated filtration system of a fluid flow adjacent to a saturated poroelastic structure. We discuss several physically-motivated cases, including that of a multilayered solid, describing the coupled dynamics of a 3D poroelastic structure, a poroelastic plate, and an incompressible Stokes flow. Several recent results for this system are described. We conclude with recent work on semigroup generation for the pure filtration problem, where a 3D Stokes flow interacts with a 3D quasi-static Biot equation via the Beavers-Joseph-Saffman conditions at the interface.