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Conference on

Nonlinear Waves and Coherent Structures

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IP1

Opening Remarks and Presentation: Determining Spectral Stability via the Maslov Index and Conjugate Points

Being able to determine the spectral stability of stationary solutions is an important step towards understanding the long-time behavior of PDEs that describe a variety of physical and biological processes. For systems whose evolution respects certain symplectic structures, spectral stability can be understood through the use of a topological invariant know as the Maslov index and the counting of what are called conjugate points. In this talk, these structures and tools will be defined and described, and recent related results will be presented that allow one to efficiently and rigorously determine spectral stability via validated numerics for reaction-diffusion systems with gradient nonlinearity and for the Swift-Hohenberg equation.

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IP2

Instabilities of Water Waves

After 200 years of study, surface water waves continue to be of significant interest. We observe such waves at the beach, but they also matter because of their human life and economic impact, through tsunamis and rogue waves, for instance. Waves of permanent form or traveling waves attract the eye, and are mathematically easier to study. Named for Stokes, the periodic traveling waves are well studied. Less is known about the stability of these waves. Benjamin, Feir and Whitham (1967) started these investigations, establishing the presence of the modulational or Benjamin-Feir instability using formal perturbation methods. More recently, the so-called high frequency instabilities have attracted some attention. The spectral signature of these instabilities has been found numerically in a few instances, but only last year was it confirmed through perturbation methods. In this talk, I will review the history of the topic, recent progress made, and discuss some open problems.

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IP3

Remarks and Presentation: Dynamics of Vortex Filaments in Incompressible Fluids

A vortex filament is a three-dimensional flow with the property that the vorticity of the fluid is concentrated in a small tubular neighborhood of a closed curve, or more generally of a curve with no endpoint inside the fluid domain. Such coherent structures are frequently observed in experiments and numerical simulations of 3D turbulence, and also play an important role in real-world applications. This talk aims at giving an overview of recent mathematical results regarding existence and stability of vortex filaments in inviscid or viscous fluids. Emphasis is put on simple geometries, such as axisymmetric flows without swirl, where a rigorous analysis is easier to conduct. Important open questions, including the derivation of the binormal motion for general curves, are also mentioned.

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IP4

Mixing in Fluids: Irregular Transport, Enhanced Dissipation, and Consequences

Stirring and mixing in fluids, specifically incompressible fluids, have important consequences on many physical and biological processes, from dispersal of pollutants to transport of nutrients. From a mathematical point of view, mixing can be studied in different contexts, from ergodic theory to homogenization. In this talk, I will present a quantitative approach to mixing that arises in the analysis of partial differential equations. In this context, mixing is related to irregular transport by non-Lipschitz vector fields and, when combined with diffusion, it may lead to enhanced dissipation. A variety of techniques have been employed in the literature to study these mechanisms, from geometric analysis to optimal transport to spectral theory and probability. I will first discuss examples of incompressible flows that mix optimally in time. Then, I will show how these examples lead to loss of regularity for solutions of transport equations. Lastly, I will discuss enhanced dissipation and present an application to the two-dimensional Kuramoto-Sivashinsky equation with advection, a model of front propagation in combustion.

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IP5

Remarks and Presentation: Untangling Fronts and Waves in Dementia

It is well appreciated that many dynamical processes such as transport and waves take place in the brain. These are generated by mechanisms relying on various physical principles: action potential along the axon, protein transport in intracellular and extracellular spaces through diffusion, electrophysiological depolarization waves in cortical spreading depression, and cell motion in cancer. Yet, they all share constraints related to tissue heterogeneity, complicated cortical geometry, and the topology of the human brain connectome. In particular, it has been proposed that neurodegenerative diseases are related to the transport and amplification of toxic protein along axonal pathways. We will show that proteins propagate from an initial seeding region like fronts to the rest of the brain. In turn, these toxic proteins damage neuronal tissues and therefore affect the natural oscillatory dynamics of the brain. Therefore, by coupling these two processes and studying nonlinear waves arising from neuronal mass models on evolving networks, we can start to understand the changes in cognitive functions during dementia.

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IP6

On the Energy of Nonlinear Water Waves

The analysis of water waves is an intriguing and challenging subject spanning a number of scientific disciplines, such as mathematics, physics, engineering. Its intrinsic complexity is demonstrated by the range of fundamental theoretical questions which remain open, despite centuries of intensive research. Even in the setting of a perfect fluid (incompressible and inviscid) the governing equations are highly intractable, primarily due to strong nonlinearities, compounded by the presence of an unknown free-boundary. This talk presents recent results concerning excess energy densities for exact nonlinear water waves. Wave energy is a subject of great practical importance which is currently the focus of intense multidisciplinary research, particularly in relation to marine renewable energy. The theory underlying ocean wave energy is a nascent field of scientific research, having been developed in recent decades, and suffers from the fundamental limitation that most of the state-of-the-art is strongly contingent on invoking linear approximations. In this talk we prove that the excess kinetic energy density is always negative, whereas the excess potential energy density is always positive, for nonlinear water waves which are periodic, travelling and irrotational. A characterisation of the total excess energy density as a weighted mean of the kinetic energy along the wave surface profile is also constructed.

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IP7

High Dimensional Integration and Approximation: The Quasi-Monte Carlo (QMC) Way

High dimensional computation, i.e., numerical computation in which there are very many or even infinitely many continuous variables, is a new frontier in scientific computing. Often the high dimensionality comes from uncertainty or randomness in the model or data, e.g., in groundwater flow it can arise from modeling the permeability field that is rapidly varying and uncertain. High dimensional problems present major challenges to computational resources, and require serious theoretical numerical analysis in devising new and effective methods. This talk will begin with a contemporary review of Quasi-Monte Carlo (QMC) methods, which offer tailored point constructions for solving high dimensional integration and approximation problems by sampling. By exploiting the smoothness properties of the underlying mathematical functions, QMC methods are proven to achieve higher order convergence rates, beating standard Monte Carlo sampling. Moreover, QMC error bounds can be independent of the dimension under appropriate theoretical function space settings. In recent years the modern QMC theory has been successfully applied to a number of applications in uncertainty quantification. This talk will showcase some ongoing works where we take QMC methods to new territories including Helmholtz equation in a random medium. This is based on joint work with Ivan Graham and Euan Spence (Bath), Dirk Nuyens (KU Leuven), and Ian Sloan (UNSW Sydney).

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IP8

Closing Remarks and Presentation: Testing Wave Turbulence Theory for Gross-Pitaevskii System

Wave Turbulence theory (WTT) describes statistical evolution of random weakly nonlinear wave fields in a great number of physical applications, from waves in quantum systems, to water waves, to plasma waves in astrophysics and gravitational waves in cosmology. Assumptions used in WTT, weak nonlinearity, phase and amplitude randomness, and infinite size limit, are not self-evident and require rigorous scrutiny. We test the predictions of WTT by performing numerical simulations of the 3D Gross-Pitaevskii equation (GPE) and the associated wave-kinetic equation (WKE). We consider an initial state localized in Fourier space, and we confront the solutions of the WKE obtained numerically with GPE data for both, the waveaction spectrum and the probability density functions (PDFs) of the Fourier mode intensities. We find that the temporal evolution of GP data is accurately predicted by the WKE, with no adjustable parameters, for about two nonlinear kinetic times. Qualitative agreement between the GPE and the WKE persists also for longer times with some quantitative deviations that may be attributed to the breakdown of the theoretical assumptions underlying the WKE. Furthermore, we study how the wave statistics evolves toward Gaussianity in a time scale of the order of the kinetic time. We also study stationary spectra arising when continuous forcing and dissipation are present. The excellent agreement between direct numerical simulations of the GPE and the WKE provides a new and solid ground to the theory of weak wave turbulence.

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SP1

Martin D. Kruskal and T. Brooke Benjamin Prize in Nonlinear Waves Award Presentations and Martin D. Kruskal Prize Lecture - Fluid-boundary Interaction: Confinement Effects, Stratification and Transport

Arguably some of the most interesting phenomena in fluid dynamics, both from a mathematical and a physical perspective, stem from the interplay between a fluid and its boundaries. This talk will present some examples of how boundary effects lead to remarkable outcomes. Singularities can form in finite time as a consequence of the continuum assumption when material surfaces are in smooth contact with horizontal boundaries of a fluid under gravity. For fluids with chemical solutes, the presence of boundaries impermeable to diffusion adds further dynamics which can give rise to self-induced flows and the formation of coherent structures out of scattered assemblies of immersed bodies. These effects can be analytically and numerically predicted by simple mathematical models and observed in simple experimental setups.

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CP1

Stationary, Periodic and Traveling Waves in Neural Field Equations with Adaptation and Inhibition

Neural fields are spatially-extended, nonlinear integrodifferential equations that aim to represent the large-scale dynamics of populations of neurons which are governed by synaptic interactions between neurons as well as other slow neuronal processes, e.g., adaptation. These neural field equations support a wide range of spatiotemporal dynamics, including spatially nonuniform equilibria, spatially-structured time-oscillatory patterns, and traveling waves. We discuss the emergence and interaction of these different patterns of activity that arise in a family of fundamental neuronal networks on 1-dimensional and 2-dimensional spatial domains.

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CP1

Mechanochemical Models for Calcium Waves in Embryonic Epithelia

In embryogenesis, epithelial cells exhibit strong coupling between mechanical responses to chemical signals and most notably to calcium. Recent experiments have shown that the loss of calcium oscillations strongly correlates with embryo malformations, such as anencephaly. We extend the recent model in [Kaouri, Maini, Skourides, Christodoulou, Chapman. J. Math. Biol., 78 (2019) 20592092], to the multi-dimensional case. The governing equations consist of an advection-diffusion-reaction system for calcium coupled with a force balance equation for active-stress linear viscoelasticity. We propose a mixed-primal finite element method for the simulation of this complex problem. The stability and solvability of the continuous weak formulation is shown using fixed-point theory. Guided by the bifurcation analysis of the one-dimensional model, we analyse the behaviour as two bifurcation parameters vary: the level of IP3 concentration and the strength of the stretch-sensitive activation. We identify the parameter regions giving rise to solitary waves and periodic wavetrains of calcium, and reproduce key experimental features, identifying the conditions for suppressing calcium oscillations. Furthermore, we demonstrate the nucleation of random calcium sparks into synchronous calcium waves and show their coupling with tissue deformation waves. This model could also be employed to gain insights into other biological processes such as carcinogenesis and wound healing.

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CP2

Cauchy Problem for the Dispersion Generalized Camassa-Holm Equation

Camassa-Holm equation which is well-known mainly as a model equation for describing the wave propagation of shallow water waves with moderate amplitude at a certain depth can be written as

$$m_t + 2mu_x + u_x = 0,$$

where $m = u - u_{xx}$ is the momentum density. In this work, we change dispersive effects both on the linear and nonlinear terms by introducing $m = (1 - LD_x^2)u$ for which L is a differential operator of order to be determined. We prove local well-posedness results for the corresponding initial value problem. The relation between the order of the operator and the regularity of the solution is discussed. We compare the results obtained for the particular case Camassa-Holm equation and dispersion generalized equation.

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CP2

Time-Periodic Solutions of a Semilinear Wave Equation

We study the semilinear wave equation $V(x)u_{tt} - u_{xx} = f(x,u)$ on $(0,2l) \times \mathbb{R}$ with Dirichlet boundary conditions and look for time-periodic solutions by using variational methods. The main idea is to consider a Fourier expansion ansatz and to analyze the spectrum of the wave operator in dependence of V. With the help of variational methods one can find weak solutions as critical points of appropriate functionals. Furthermore, we discuss regularity properties of our solutions.

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CP2

Some Case Examples of Existence, Stability and Dynamics of Rogue Wave Patterns

In the present work, we revisit a central paradigm of the analysis of rogue waves in nonlinear Schrodinger (NLS) equation systems, namely the Peregrine soliton. We examine how relevant patterns can be numerically extended to non-integrable variants of the NLS model, such as the general power-law nonlinearity, the third-order dispersion model, or a nonlocal variant of the NLS. We discuss how to think of the Peregrine solution as a self-similar waveform in space-time. We also examine generalizations of such waveforms in higher-dimensional models such as ones of the Davey-Stewartson type in 2+1 dimensions. Subsequently, we turn our attention to stability of periodic states such as the Kuznetsov-Ma soliton and consider information that these provide us in the limit (of infinite period) about the Peregrine solution stability. A number of applications of the Peregrine states and their appearance are considered in continuum (e.g., Bose-Einstein multi-component condensates) and discrete (e.g., granular crystals) settings. Finally, an entirely distinct mechanism of potential rogue structure formation in dissipative lattice nonlinear dynamical systems is also proposed.

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CP2

Well-Posedness for a (1+1)-Dimensional Quasilinear Wave Equation

We study the quasilinear wave equation

$$V(x)u_{tt} - u_{xx} + \gamma\delta_0(x)(u_t^3)_t = 0 \qquad \text{on } (x,t) \in \mathrm{R}\times\mathrm{R}$$

from the point of view of time-periodic solutions and global well-posedness. Especially, the potential V being a periodic step potential is of interest in applications. Given initial data $u(x,0) = u_0(x)$, $u_t(x,0) = u_1(x)$, studying a related ODE problem, we show that well-posedness of the associated initial value problem depends on the sign of γ: It is well-posed when $\gamma > 0$, while for $\gamma < 0$ infinitely many solutions are expected to exist.

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CP2

Orbital Stability of Solitary Wave Solutions for a Generalized Fractional BenjaminBonaMahony Equation

In this study the orbital stability of solitary waves to a generalized fractional BenjaminBonaMahony type equation is studied. Besides the well known smooth and positive solitary wave with large wave speed, the existence of smooth negative solitary waves having small wave speed is obtained. Since the analytical solutions are not known, we generate the positive and negative solitary waves numerically by using Petviashvili method. Moreover some numerical experiments for various values of the order of nonlinearity and fractional derivative are presented.

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CP2

Localization and Asymptotic Approximation of a Compressible Navier-Stokes-Fourier System

In this talk we discuss the long time asymptotics and localization properties of the compressible Navier-Stokes-Fourier (NSF) system equipped with ideal gas equations of state. Inspired by the previous work of Hoff and Zumbrun, Gallay and Wayne, and others, we prove existence of solutions to the NSF system in weighted spaces. We then develop a method for approximating the asymptotic behavior of these solutions, and discuss the dependence of the approximations on the assumed initial degree of localization.

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CP3

On the Wave Height Probability of a Wave Spectrum Reflected from a Solid Wall

Coastal regions around the world are densely settled, popular for leisure activities, and home to critical infrastructure. While these locations thrive because of their proximity to the sea, that sea also presents a threat which must be guarded against. Coastal defenses in the form of sea walls and breakwaters are erected to protect against incursions of the sea, and yet the risk of damage looks set to increase as sea levels rise. With the intention of forecasting hazardous ocean conditions, we present a model that allows the study of the probability distribution of wave heights caused by reflection from a solid vertical wall. The model under investigation has as input a wave spectrum for the attacking waves and a constant water depth. The output is the time evolution of a correlation matrix, from which the spectral evolution can be extracted, including a time series of the variance of the free surface elevation and the probability of exceedance for the wave height. We show that depending on the spectrum and the water depth, there is a significant increase in the probability of large amplitude standing waves which can be categorized as freak-waves, i.e. waves whose height is more than twice the significant wave height, created by the reflection from the wall.

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CP3

Probability Distribution of Extreme Events in a Baroclinic Wave Laboratory Experiment

Nonlinear atmospheric waves in the jet streams are driven by temperature differences between low and high latitudes and the rotation of the Earth. Meandering jet streams and propagating Rossby waves are responsible for the variable weather in mid-latitudes. Moreover, extreme weather events like heat waves and cold spells are part of the jet stream dynamics. Since many years an analogue in the form of a simplified laboratory experiment, the differentially heated rotating annulus, has gained insight into the dynamics of the meandering jet stream. In the present study, probability density distributions of extreme events obtained from a long term rotating annulus experiment are studied and compared to the atmospheric probability density distributions. Empirical distributions of extreme value monthly block data are derived for the experimental and the atmospheric case. Generalized extreme value distributions are fit to the empirical distributions and the distribution parameters are compared. Good agreement can be found, however, the distributions of the experimental data show a shift towards larger extreme values and some explanations for this shift are suggested. The results indicate that the laboratory model might be a useful tool for investigating changes in extreme event distributions due to climate change. In the laboratory context, the change can be modeled by an increase in total temperature accompanied by a reduction of the radial heat contrast.

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CP3

Interaction of Internal Solitary Waves of Opposite Polarity in Double Pycnocline Stratifications

Previous studies have suggested that fully nonlinear internal solitary waves (ISWs) in a stratified fluid are very soliton-like as the interaction of two ISWs results in only very small changes in amplitude of the interacting ISWs and in the production of a very small amplitude wave train. These studies have, however, considered ISWs with the polarity predicted by the sign of the quadratic nonlinear coefficient of the KdV equation. The Gardner equation, which is an extension of the KdV equation that includes a cubic nonlinear term, has ISWs of two polarities (i.e., waves of depression and elevation) when the cubic coefficient of the Gardner equation is positive. These waves are soliton solutions of the Gardner equation. In this talk I will discuss the interaction of ISWs of opposite polarity in continuous asymmetric double pycnocline stratifications. Regions in parameter space where ISWs of opposite polarity exist will be discussed and I will demonstrate via fully nonlinear numerical simulations that the interaction of ISWs of opposite polarity waves are far from soliton-like: their interaction can result in very large changes in wave amplitude and may produce a very complicated wave field with multiple large ISWs and an assortment of other waves.

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CP3

Nonlinear Fourier Analysis of Rogue Waves in the Deep Ocean

The Fourier transform is most widely used tools for signal analysis from the time domain to frequency domain. In contrast to the traditional linear Fourier transform, the nonlinear Fourier transform (NFT) enables to decompose a signal into a basis made up by eigenvalues based on their governing nonlinear evolution equations. The unique capability of NFT is to detect hidden solitons and modulational instability, which is vital to the understanding of nonlinear phenomena such as rogue waves. The formation of rogue waves has been extensively discussed in recent studies. Waves in deep water can be described by the nonlinear Schrdinger equation (NLSE). The rogue-wave prototypes from the of analytical solutions of NLSE are breathers and solitons on finite background, which have been found in physical experiments . However, the main mechanisms of formation of rogue waves in real ocean is still under discussion. Here, we demonstrate how the periodic NLSE-NFT can be applied for time series of real-world rogue waves measured from the in-situ buoy station. The characteristics of spectral portraits in complex plane provide a useful representation of the dynamics of nonlinear systems, and can be further used as a predictive tool for the prediction of maximum rogue waves on the space-time domain. Our study presents the first time application of NLSE-NFT on field measurement data of super large rogue waves in extreme sea states in open ocean.

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CP3

Emergence of Shielded Vortex Gas in Instability-Driven 2D Turbulence

Active fluids are composed of units, such as bacteria, that consume energy to drive flow. They feature reduced effective viscosity which can be negative, causing instability and driving multi-scale active turbulence. Likewise, turbulence driven by instabilities, e.g. of convective or baroclinic type, is ubiquitous in geo- and astrophysical flows. Importantly, the energy injection rate of an instability-type forcing grows with the energy of the forced modes, in contrast to externally imposed forcing with constant injection rates that is often assumed. We perform direct numerical simulations of two-dimensional (2D) flows, analysing the transition from random forcing with constant power injection to a negative-viscosity type of forcing modeling an instability. 2D turbulence forced by random forcing that injects constant power generates an inverse energy cascade, resulting in a large-scale condensate. At large instability growth rates, the inverse cascade is disrupted by the formation of coherent structures, forming a gas of weakly interacting, shielded mesoscale vortices embedded in a turbulent background. We show that for certain parameter values the vorticity field of the shielded vortex gas displays spontaneous symmetry breaking: all vortex cores are of the same sign at late times. Because of their weak interaction the resulting vortices resemble passive tracers undergoing Brownian dynamics due to the nearly-Gaussian smaller-scale turbulence in the background.

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CP3

Bifurcations in Shallow Water Equations with Simple Energy Backscatter and Bottom Drags

Shallow water equations describe a thin layer of fluid bounded from above by a free surface, and from below by a rigid surface, near which the bottom drag plays a role in the dissipation of wave energy. Motivated by this and numerical schemes for large-scale geophysical flow, we consider the rotating shallow water on the whole space with smooth and non-smoothly quadratic bottom drag terms, and in combination with horizontal kinetic energy backscatter terms built from negative viscosity and stabilising hyperviscosity with constant parameters. We prove the existence of nonlinear Rossby and inertia gravity waves using Lyapunov-Schmidt reduction, and we study the bifurcations of nonlinear explicit flows that simultaneously solve the linear and nonlinear equations. We also discuss the impacts of bottom drags, energy backscatter, and Coriolis force on these flows.

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CP4

Uniform Asymptotic Stability for Convection-Reaction-Diffusion Equations in the Inviscid Limit Towards Riemann Shocks

In this talk, I will present a result obtained in a recent paper about the study of the stability in time of a family $(\underline{U}_\epsilon)_{0<\epsilon<\epsilon_0}$ of traveling waves solutions to

$$\partial_t u + \partial_x(f(u)) = g(u) + \epsilon\partial_x^2 u$$

that approximate a given Riemann shock, and we aim at showing some uniform asymptotic orbital stability result of these waves under some conditions that guarantee the asympotic orbital stability of the corresponding Riemann shock, as proved in a previous work of V. Duchne and L. M. Rodrigues. Even at the linear level, to ensure uniformity in ϵ, the decomposition of the Green function associated with the (fast-variable) linearization about $\underline{U}_\epsilon$ of the above equation into a decreasing part and a phase modulation is carried out in a highly non-standard way. Furthermore, we introduce a multi-scale norm depending in ϵ that is the usual $W^{1,\infty}$ norm when restricted to functions supported away from the shock location. To avoid the use of arguments based on parabolic regularization that would preclude a result uniform in ϵ, we close nonlinear estimates on this norm trough some suitable maximum principle.

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CP4

Solitary Waves and Scaling Relations in Auxin Hormone Dynamics

The hormone auxin plays a critical role in stimulating the growth of plants. We study a model of auxin propagation through an infinite, one-dimensional chain of neighboring cells and impose a traveling wave structure on the concentrations of auxin and related hormones. We solve the resulting nonlocal system in a long wave limit inspired by Friesecke and Pegos analysis of monatomic Fermi-Pasta-Ulam-Tsingou lattice traveling waves. We find that auxin propagates as a solitary wave through the cell chain, while the auxiliary hormones move as fronts. Our results uncover close connections between the biological parameters of the hormone system, the amplitude-wavelength scalings, and the leading order behavior of the traveling wave profiles. We provide ample numerical evidence that motivates and justifies our particular long wave scalings and that indicates the stability of our traveling waves.

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CP4

Modulating Traveling Fronts in a Dispersive Swift-Hohenberg Equation Coupled to An Additional Conservation Law

Consider a one-dimensional Swift-Hohenberg equation coupled to a conservation law, where both equations contain additional dispersive terms breaking the reflection symmetry $x \mapsto -x$. As a parameter increases beyond a critical value, this system undergoes a Turing instability and periodic traveling waves bifurcate from the homogeneous background state. In this talk, I will present an existence result for so-called modulating traveling front solutions for a fixed bifurcation parameter close to the onset of instability. These solutions capture the process of pattern-formation by modeling the transition from the homogeneous ground state to the periodic traveling wave through an invading front. I will outline the existence proof, which is based on center manifold reduction to a finite-dimensional system and the construction of persistent heteroclinic connections in the reduced system. Here, the dimension of the center manifold depends on the relation between the spreading speed of the invading modulating front and the linear group velocities of the system. Furthermore, due to the broken reflection symmetry, the coefficients in the reduced system are genuinely complex. This complicates the analysis of the reduced system.

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CP4

Global Bifurcation of Water Waves with Overhang-

ing Profiles and Arbitrary Vorticity

While the research on water waves modeled by Euler's equations has a long history, mainly in the last two decades traveling periodic rotational waves have been constructed with mathematical rigor by means of bifurcation theorems. In this talk, I will present a new reformulation of this traveling periodic water wave problem in two dimensions in the presence of gravity, a flat bed, and possibly surface tension. Using conformal mappings and a new Babenko-type reformulation of Bernoulli's equation, the problem is equivalently cast into the form "identity plus compact", which is amenable for Rabinowitz' global bifurcation theorem. The main advantages of this new reformulation are that no simplifying restrictions on the geometry of the surface profile and no simplifying assumptions on the vorticity distribution (and thus no assumptions regarding the absence of stagnation points) have to be made. Within the scope of this new formulation, local and global solution curves, bifurcating from laminar flows with a flat surface, are constructed. Moreover, I will further discuss the condition for local bifurcation and the possible alternatives for "endpoints" of the global curve. This is joint work with Erik Wahln.

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CP4

Modulation and Amplitude Equations on Bounded Domains for Nonlinear SPDEs Driven by Cylindrical α-Stable Lévy Processes

In the present work, we establish the approximation via modulation or amplitude equations of nonlinear stochastic partial differential equation (SPDE) driven by cylindrical α-stable Lévy processes. We study SPDEs with a cubic nonlinearity, where the deterministic equation is close to a change of stability of the trivial solution. The natural separation of time scales close to this bifurcation allows us to obtain an amplitude equation describing the essential dynamics of the bifurcating pattern, thus reducing the original infinite dimensional dynamics to a simpler finite-dimensional effective dynamics. In the presence of a multiplicative stable Lévy noise that preserves the constant trivial solution we study the impact of noise on the approximation. In contrast to Gaussian noise, where non-dominant pattern are uniformly small in time due to averaging effects, large jumps in the Lévy noise might lead to large error terms, and thus new estimates are needed to take this into account.

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CP5

Apodizer Design to Efficiently Couple Light into a Fiber Bragg Grating

We provide an optimal control framework for efficiently coupling light in a bare fiber into Bragg gratings with an appreciable Kerr nonlinearity. The light-grating interaction excites gap solitons, a type of localized nonlinear coherent state which propagates with a central frequency in the forbidden band gap, resulting in a dramatically slower group velocity. Viable grating structures found by heuristic methods have previously been reported, [Mok, et al., 2006], [Rosenthal and Horowitz, 2008]. Yet, due to the nature of the band gap, a substantial amount of light is back-reflected by the grating's strong reflective properties. We optimize, via a projected gradient descent method, the transmission efficiency of nonuniform grating structures, in order to couple more slow light into the grating. We further explore the space of possible grating designs using genetic algorithms and parallel computing. Through these methods, we find structures which couple a greater amount of slow light into the grating with the added bonus of working more effectively as a pulse-delayer. In addition, we discuss the use of a second approach based on the nearly-integrable nature of the dynamics found via multiple-scales analysis.

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CP5

Ginzburg-Landau Model for a Nematic Superconducting Medium in the Presence of an Electromagnetic Field

We present a derivation of a system of equations related to the optical response of a superconducting nematic liquid crystal medium, in the presence of an electromagnetic field. We consider the Ginzburg-Landau's superconductor formulation and the related Helmholtz free energy. By a minimizing process on the suitable physical observable variables, we derive a set of four coupled equations. We consider the nematic superconducting in as an infinity strip $(x, y) \in [0, d] \times [0, +\infty)$. Under the assumption of a typical gauge and a dimensionless process, we can reduce this model to a simpler one given by the following ordinary differential system:

$$\begin{cases} A''(x) = 8\pi q^2 \frac{\alpha_s^2}{b\sigma} f(x)^2 A(x) & \text{London eq.} \\ \sigma f''(x) = \left(\sigma q^2 A^2(x) - \frac{v}{u}\beta\left(1 - g^2(x)\right) - 1\right) f(x) + f^3(x) & \text{G-L supec.eq} \\ \mu g''(x) = \left[4\mu \left(\frac{k\pi}{d}\right)^2 - \frac{v}{b\beta}\left(1 - f^2(x)\right) - 1\right] g(x) + g^3(x) & \text{G-L nematic} \end{cases}$$

where $A(x), f(x)$ and $g(x)$ are unknowns, d is the width of the strip and the others ones are parameters. We analyze the response of this system by using simulations. Also, we deal with a hollow cylinder with quantum vortices. In this case the G-L equation becomes into a Bessels type equation.

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CP5

Bifurcation and Asymptotics of Nonlinear Surface Plasmon Polaritons

Nonlinear surface plasmon polaritons (SPPs) are electromagnetic waves localized at the straight interface of a dispersive and a non-dispersive material out of which at least one responds non-linearly to the field. For time harmonic SPPs Maxwell's equation reduce to a (typically non-self-adjoint) eigenvalue problem which is nonlinear in both the frequency and in the eigenfunction. We use the frequency as a bifurcation parameter and prove the bifurcation of nonlinear SPPs from linear eigenfunctions at simple isolated eigenvalues of the linear problem. We use a LyapunovSchmidt reduction and provide an asymptotic expansion of both the nonlinear eigenvalue and the solution. We further prove that if the linear eigenvalue is real and the nonlinear problem PT-symmetric, i.e. the loss and gain of the medium are spatially balanced, then the bifurcating nonlinear eigenvalue remains real. The theory is then applied to two settings in Maxwell's equations: TE-polarized waves leading to a scalar problem and TM-polarized waves leading to a vector problem.

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CP5

Frequency Combs in a Ring Resonator with Two Pumped Modes

Kerr frequency combs are described as solutions of the Lugiato-Lefever equation (LLE)

$$\mathrm{i}a_t = -da_{xx}+(\zeta-\mathrm{i})a-|a|^2a+\mathrm{i}f(x,t), \qquad a\ 2\pi\text{-periodic in } x.$$

The LLE is a nonlinear Schrdinger equation with added terms $-\mathrm{i}a$ corresponding to damping and $\mathrm{i}f(x,t)$ corresponding to forcing. From an experimental point of view it is quite attractive to study the generation of Kerr frequency combs by pumping two modes ($k_0 = 0, k_1 \in \mathbb{Z}\setminus\{0\}$) which corresponds to a forcing term $f(x,t) = f_0 + f_1 \mathrm{e}^{\mathrm{i}(k_1 x-\omega_1 t)}$. We will discuss existence results as well as optimality questions with respect to the design of the pump/microresonator.

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CP5

Time-Periodic Waves for a Quasilinear Wave Equation Based on a Kerr-Nonlinear Maxwell Model

We consider the (1+1)-dimensional quasilinear wave equation $g(x)w_{tt} - w_{xx} + h(x)(w^3)_{tt} = 0$ on $\mathbb{R}\times\mathbb{R}$ which arises in the study of localized electromagnetic waves modeled by Kerr-nonlinear Maxwell equations. We are interested in time-periodic, spatially localized solutions (breathers). Here $h(x) = \gamma\,\delta_0(x)$ is a multiple of a delta-distribution supported at 0 and g is either a bounded potential or a delta-distribution on a constant background. The solutions are bifurcating from simple eigenvalues of the underlying linear model. Moreover they are shown to be exponentially localized in space.

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CP5

Dynamics of Vortex Solitons in the Models Based on Multidimensional Vector NLS Systems

System of coupled Nonlinear Schrodinger Equations with focusing nonlinearity plays an important role in nonlinear optics. In this talk, I will discuss dynamics and stability properties of solutions of (2+1)D models based on coupled NLS equations. The role of the orbital angular momentum and critical power of localized profiles will be discussed.

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CP6

Kink-Breather Interaction in the Phi-4 Equation

In the present study, we used the variational Ansatz for the breather-wobbler configuration of the phi-4 equation. This reduces the partial differential equation to a system of ordinary equations for the amplitudes of the breather and wobbler, and the distance between the two objects. The system of three second-order equations is amenable to analytical consideration. The variational descriptions of the kink-breather interaction include the wobbling degree of freedom and as a result, has captured the kink-breather bound state.

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CP6

Particle Trajectories Beneath Solitary Waves with Non-Constant Vorticity in the KdV Framework

In the last decades, a great attention has been given to the study of waves propagating on linearly sheared currents (constant vorticity). Numerous significant articles have contributed to a wide comprehension of the effect of a constant vorticity on the free surface and in the bulk of the fluid. Nonetheless, a full description of the flow pattern beneath a large-amplitude wave with non-constant vorticity in the presence of internal stagnation points is still an opened problem. In this talk we discuss our numerical results concerning the flow structure beneath solitary waves in the context of non-constant vorticity. Considering the weakly nonlinear and weakly dispersive Korteweg-de Vries equation as a model, we are going to present particle trajectories generated by the current-wave interaction for several underlying current profiles. We present regimes in which the stagnation points have quite different features from the constant vorticity case. This is joint work with Marcelo

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CP7

Damage Identification in Fiber Metal Laminate Using Guided Wave Propagation

One of the most common and vulnerable defects in fiber metal laminate (FML) is impact-related delamination which is often invisible to the human eye. Guided ultrasonic waves (GUW) show high potential for monitoring structural integrity and damage detection in thin-walled structures by using the physical phenomena of wave propagation interacting with the defect. The focus of this research project is on describing an inverse solution for the localization and characterization of the defect in FML. Model-based damage analysis utilizes an accurate finite element model (FEM) of GUW interaction with the damage. A Bayesian inference approach is employed to characterize the damage and quantify its uncertainties. This inference problem in a stochastic framework requires a very large number of forward solves. Therefore, a profound investigation is carried out on different reduced-order modeling (ROM) methods in order to apply a suitable technique that significantly improves computational efficiency. The proposed method is well illustrated on a two-dimensional FEM of a carbon fiber reinforced plastic-steel laminate using GUW propagation for damage identification. The damage, in this case, is modeled as a reduction in the stiffness of the damaged element. The inference problem utilizes a parameterized ROM coupled with a surrogate model instead of the underlying high-fidelity model. This research is funded by the Deutsche Forschungsgemeinschaft Research Unit 3022 under grant LO1436/12-1.

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CP7

Size-Dependent Modelling of Love-Type Waves in Piezoelectric Polymer Wave Guide Bedded over Pre-Stressed Heterogeneous Viscoelastic Substrate

Present research article manifests the propagation of Love-type surface waves in a piezoelectric polymer layer of micro-scale thickness which is rigidly clamped over a heterogeneous viscoelastic substrate. Due to the small thickness of piezoelectric layer, the flexoelectric effect and micro-inertia effect are considered as size-dependent effects. The material properties of the heterogeneous elastic substrate are assumed to be varying exponentially along with the depth of the structure. The lower substrate is considered under initial stress. Analytical methods are employed to obtain the mechanical displacements and electric potential. Complex dispersion relation of Love wave for both electrically open and short cases have been formulated. A numerical example is provided and the influence of elastic, electric and mechanical parameters have been examined on phase velocity and attenuation of Love wave. The results have been shown graphically. This investigation may be utilized in designing and optimization of Love wave sensors.

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CP7

Numerical Simulations of Surface Water Waves over a Shallow Seamount

We investigate long crested wave dynamics over a cross section of a non-monotone bathymetry. The bathymetry is from an area with a shallow isolated seamount at the south coast of Java Indonesia. We simulate an energetic wave with a significant wave height of 4m and wave period of 12s over a cross section through the top of the seamount that is only 2m under sea level and 8km from the coast. The wave simulations by HAWASSI software over a 12km long cross-section to the beach are used to determine numerical and physical aspects such as breaking, the effect of bottom friction, and the second and third-order nonlinearity. The breaking waves and bottom friction may lead to a large energy reduction around the shallower areas continuing until the coast. The wind waves transform into a downward running flow described by very long Infra Gravity waves that persist until the nearshore area with the run-up area of the coast. Short-crested waves with rather small significant wave height (2m) are also shortly presented, in which shoaling and diffraction-refraction are more prominent phenomena.

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CP7

Decomposing the Dynamics of the Lorenz 1963 Model Using Unstable Periodic Orbits: Averages, Transitions, and Quasi-Invariant Sets

The attractor of a chaotic system is densely populated by an infinite number of unstable periodic orbits (UPOs), which are exact periodic solutions of the evolution equa-

tions. UPOs can be used to decompose the complex phenomenology of a chaotic flow into elementary components and have shown great potential for the understanding of macroscopic features in turbulent fluid flows. We considered the case of the Lorenz-63 system and investigated how a chaotic trajectory can be approximated using a complete set of UPOs up to symbolic dynamics period 14. At each point in time we rank in different tiers the UPOs of our database based on their proximity with respect to the orbit and we study the persistence of the ranking. Our goal is twofold. On the one hand, we aim to numerically understand how chaotic trajectories are approximated in terms of UPOs. It emerges that longer period UPOs play a major role in reproducing the invariant measure of the system. On the other hand, we study the statistics of the scattering of the orbit between the various UPOs. Each UPO (and its immediate neighbourhood) is interpreted as a building block of the system, a spatially extended state, and the scattering can be seen as subsequent transitions between different states. We will show that this viewpoint allows for a different interpretation of quasi-invariant sets.

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CP7

Fate of Nonlinear Topological Edge States Delocalization in Mechanical Lattices

We use a mechanical lattice analog of the Su-Shrieffer-Heeger tight-binding lattice model with Klein-Gordon type nonlinearity. We investigate the long-time dynamics of stable and unstable nonlinear topological edge states by computing the entropy and the participation number of the modes and sites energy distributions respectively as well as the maximum Lyapunov exponent of the systems tangent dynamics. By analyzing the dynamical behaviors of these observables, we show that the delocalization of unstable topological edge states results in the thermalization of the entire lattice. Stable nonlinear topological edge states also reach the same fate, but pass a critical strength of perturbation. Interestingly, in all cases, the lattices thermalized state is characterized by a renormalized squared dispersion relation symmetric about the mid band squared frequency. This phenomenon is a reminiscence of the chiral symmetry of the dynamical matrix of the linearized model.

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CP8

Generation of Modulational Instabilities in an Architectural Flexible Elastic Metamaterial

We are interested in wave propagation within architected flexible elastic metamaterials (flexEM) and especially in a structure known as rotating squares structure. The latter is composed of rigid cells linked by highly flexible plastic films. Such artificial composite material is characterized by its high capacity to deform, an intrinsic property that favours the appearance of nonlinear phenomena. The objective of this work is to study the possible occurrence and propagation of various nonlinear envelope waves in flexEM, including extreme wave events, such as rogue waves. Although extreme wave events have already been observed experimentally in continuous media in hydrodynamics or in optics, there is no experimental observation of these events in discrete mechanical structures. The starting point is to understand how rogue waves can be generated in the previously mentioned continuous media in order to apply it to our mechanical system. For that, one key point is the nonlinear Schrdinger equation, which describes weakly nonlinear and weakly dispersive waves. Indeed, one of the first tracks allowing to explain the occurrence of extreme wave events is the focusing nonlinearity, property of the medium causing the appearance of modulational instability (MI). In this talk, we will present the derivation of a system of coupled NLS that describes the dynamics of weakly nonlinear envelope solutions in flexEM, and present in details the existence and control of MI.

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CP8

Propagation of Longitudinal Undular Bores in Homogeneous and Inhomogeneous Waveguides

In this talk I will report experimental observations and modelling of an undular bore generated by fracture in prestrained solid (polymer) bars. Similar waves could be present in the signals generated by earthquakes, fracking, and other events involving fracture. The wave is measured using high speed single point and multi-point photoelasticity. In all cases, oscillations develop at the bottom of the release wave which exhibit the qualitative features of an undular bore, with the oscillatory wave structure gradually expanding and growing in amplitude with distance traveled away from the fracture site. We show that the viscoelastic extended Korteweg - de Vries (veKdV) equation describes the bore well for a suitable choice of fitted parameters, whilst the analytical solution to the linearised near pre-strain Gardner equation gives a reasonable approximation for the first oscillation at the times relevant to the experiment. From the experimental wave speed and strain rate measured close to the fracture site, we use the analytical solution to obtain estimates for the evolution of the bore at a further distance and compare them to experimental measurements, establishing good agreement for the key features of the bore. I will also discuss current experimental and theoretical work regarding strain wave propagation in inhomogeneous waveguides.

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CP8

Nonlinear Waves in Nematic Liquid Crystals: Temperature Effects

Temperature Control of Nematicon Trajectories: The effect of thermal energy absorption on the propagation of thermo-reorientational solitary waves, termed nematicons, in nematic liquid crystals is discussed. While nematic liquid crystals have low energy absorption, which is converted to heat from the optical beam forming the optical solitary wave, this thermal energy absorption has measurable effects in the propagation of the solitary wave. Modulation theory, essentially momentum conservation, is used to model trajectories and angular steering of thermo-reorientational solitary waves. These theoretical results are compared with experimental results, with excellent agreement found. Multi-hump Thermo-Reorientational Solitary Waves in Nematic Liquid Crystals: Nematic liquid crystals (NLC) are a nonlinear optical medium which supports optical solitary waves, termed nematicons. In addition to their optical response, they have a thermal response due to absorbing optical energy from the beam, which is converted to thermal energy. Nematicons are governed by an NLS-type equation for the optics and elliptic equations for the medium and temperature effects. The optical response of NLC is focusing, while the thermal response is defocusing, which results in thermo-optical competition, so that two-humped and ring-shaped nematicons exist due to a balance between these effects. These non-standard solitary waves are examined using full numerical solutions and modulation theory.

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CP8

Propagation of Elastic Waves in a Multilayered Structure Laying over a Winkler Foundation

Recent studies examined various configurations for the long-wave low-frequency motion in relation to the plane harmonic waves in an elastic thin layer amidst light Winkler elastic foundations. Thus, in this study, we consider the configuration having posed the more sophisticated Rayleigh-Lamb dispersion relation and further endow it with the presence of magnetic field forces and rotational effects. Approximate analytical solutions of the model comprising the respective displacements and stresses are determined in a rare scenario, in addition to the determination and analysis of the resulting exact Rayleigh-Lamb dispersion relation. Furthermore, we aim to analyze the variational effects of the dimensionless foundation parameter and other material parameters on the lowest dispersion branch of the harmonic waves, as well as on the respective displacements and stresses. We further analyze the graphical behavior of the obtained results due to excitations.

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CP8

Waves in Loosely Bonded Smart Composite Structure with Micro-Scale Flexoelectricity

Present article manifests the influence of mechanical loose bonding on shear horizontal wave propagation in a piezoelectric-flexoelectric / piezomagnetic bi-composite structure. The structure is comprised of a piezoelectric layer of trigonal (3m) symmetry of micro-scale length resting over a functionally graded transversely isotropic piezomagnetic substrate. Due to micro-scale size, flexoelectricity is considered in the piezoelectric layer. Coupled magneto-electro-mechanical field equations are obtained and traveling wave solutions are achieved by rigorous analytical techniques. The interface between piezoelectric and piezomagnetic phases is modeled as a loosely bonded interface. Transcendental phase velocity and damped velocity equations are derived using two different types of magneto-electrical boundary conditions i.e. electrically and magnetically open and short cases. A numerical example and graphical illustrations are provided to represent the influence of flexoelectricity, piezoelectricity, piezomagnetism, functional grading, layer width, and mechanical debonding parameter on phase and damped velocity of considered wave. The investigation may be utilized in the optimization of electromagnetic surface acoustic wave devices and sensors.

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MS1

Instability of Sharp Interfaces in Singularly Perturbed Reaction Diffusion Equations

We consider a class of singularly perturbed 2-component reaction diffusion equations which admit traveling front solutions, manifesting as sharp interfaces between stable homogeneous rest states. In many example systems (such as models of desertification fronts in semiarid ecosystems), such fronts can exhibit an instability by which the interface destabilizes into fingering patterns. Motivated by the appearance of such patterns, we propose a 2D stability criterion for long-wavelength perturbations along the interface in traveling fronts with appropriate singular perturbation structure. The fronts are constructed using geometric singular perturbation techniques by connecting slow orbits on two saddle-type critical manifolds through a fast heteroclinic orbit in the layer problem. The associated stability criterion is expressed in terms of the system nonlinearities and the slow/fast structure of the fronts.

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MS1

Turing Instability via the Generalized Maslov Index

The Maslov index is a topological invariant naturally associated to a Hamiltonian system. This is a useful tool for linear stability analysis, provided the eigenvalue equation can be rewritten in a Hamiltonian form. In this talk I will describe a recent generalization of the Maslov index to non-Hamiltonian systems. This generalization allows one to study reaction-diffusion system of activator-inhibitor type. As an application, I will show how this new index can be used to characterize the Turing instability.

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MS1

Stability of KPP-Type Fronts in Rosenzweig-MacArthur Model

We consider a diffusive Rosenzweig-MacArthur predator-prey model in the situation when the prey diffuses at the rate much smaller than that of the predator. Earlier, the existence of fronts in the system was proved using the Geometric Singular Perturbation Theory. The underlying dynamical system in a singular limit is reduced to a scalar Fisher-KPP equation and the fronts supported by the full system are small perturbations of the Fisher-KPP fronts. The current project is to investigate whether the stability of the fronts is also governed by the scalar Fisher-KPP equation. The techniques of the analysis include a construction of unstable augmented bundles and their treatment as multi-scale topological structures.

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MS1

Spectral Stability via the Maslov Index and Validated Numerics

Results from Sturm-Liouville theory tell us that the number of unstable eigenvalues of a scalar, second order linear operator coincides with the number of zeros of the eigenfunction associated to the zero eigenvalue. Recently, these results have been extended to a more general setting using the Maslov index, which allows for the spectral stability of nonlinear waves to be determined by counting so-called conjugate points. Working with the Swift-Hohenberg equation, we develop a framework using the Maslov index to relate the number of unstable eigenvalues associated to a pulse solution with the number of conjugate points. However, it is not clear if it is easier to count conjugate points than to count the number of unstable eigenvalues. To address this, we'll discuss how a recently developed framework for computing the conjugate points using validated numerics may be extended to determine the spectral stability of pulse solutions to the Swift-Hohenberg equation.

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MS2

Spin Generalizations of the Benjamin-Ono Equation

The Benjamin-Ono equation, a partial integro-differential equation describing internal waves in deep water, admits multi-soliton solutions governed by the Calogero-Moser many-body system. We present and solve new equations whose multi-solitons are governed by spin generalizations of the Calogero-Moser system due to Gibbons and Hermsen. This work is part of a program to systematically construct integrable partial differential equations related to integrable many-body systems.

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MS2

Asymptotic Analysis of the Interaction Between a Soliton and a Regular Gas of Solitons

We analyze the case of a (dense) mKdV soliton gas and its large time behaviour in the presence of a single tracer soliton. The solution, which can be expressed in terms of Fredholm determinants, can be decomposed as the sum of the background gas solution (an elliptic wave), plus a soliton solution: the individual expressions are however quite convoluted due to the interaction dynamics. Additionally, we are able to derive the kinetic velocity equations and the local phase shift of the gas after the passage of the soliton, and we can trace the location of the soliton peak as the dynamics evolves.

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MS2

Solitons and Soliton Interactions for the Complex Coupled Short-Pulse Equation

The complex coupled short pulse equation (ccSPE) describes the propagation in nonlinear media of ultra-short optical pulses, i.e., pulses whose width is of the order of the femtosecond and much smaller than the carrier frequency. The simplest soliton solutions of the ccSPE, fundamental solitons, are found to be the natural vector generalization of scalar one-soliton solutions of the complex short-pulse equation. The ccSPE also admits fundamental breather solutions, corresponding to two fundamental solitons having the same amplitude and velocity but different carrier frequencies, as well as solutions that, while still corresponding to a minimal set of discrete eigenvalues, cannot be reduced to a simple superposition of fundamental solitons, and which we refer to as composite solitons. In this talk we will discuss the interactions between two fundamental solitons, a fundamental soliton and a fundamental breather, and two fundamental breathers, and show that, generically, these interactions result in a non-trivial polarization shift, similarly to the interaction of solitons in the focusing 2-component and defocusing 3-component nonlinear Schrödinger systems.

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MS2

Propagation of Ultrashort Optical Pulse in a Two-Level Laser Amplifier

We consider Maxwell-Bloch equations without spectral broadening and study asymptotics of an input pulse in a long two-level laser amplifier.

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MS3

Rigorous and Data-Driven Koopmanism: Spectral Computations for Nonlinear Systems

Koopman operators globally linearise nonlinear dynamical systems, making their spectral information valuable for understanding dynamics. Their increasing popularity has led to the term "Koopmanism" and $10,000$s of articles over the last decade. However, Koopman operators are infinite-dimensional - they can have continuous spectra and lack finite-dimensional invariant subspaces, making computing their spectral information a considerable challenge. This talk describes new data-driven algorithms with rigorous convergence guarantees that overcome these challenges. We introduce residual dynamic mode decomposition, which provides the first scheme for computing the spectra and pseudospectra of general Koopman operators from snapshot data without spectral pollution (spurious modes). We then combine this approach with the resolvent to compute smoothed approximations of spectral measures associated with measure-preserving dynamical systems. Explicit convergence theorems show high-order convergence even for chaotic systems, when computing continuous spectra and discrete spectra. Finally, we provide kernelized variants of our algorithms for dynamical systems with a high-dimensional state-space. We compute the spectral measure associated with the dynamics of a protein molecule that has a $20,046$-dimensional state-space, and compute nonlinear Koopman modes with error bounds for turbulent flow past aerofoils with Reynolds number $> 10^5$ that has a $295,122$-dimensional state-space.

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MS3

Analytic Continuation of Solutions of Initial-Boundary Value Problems Outside the Domains

The Unified Transform Method (UTM), or the method of Fokas, gives solutions to half-line and finite-interval, linear, constant-coefficient initial and boundary value problems (IBVPs) as contour integrals over a spectral parameter with the space and time variables as parameters in the integral. The contour integrals are defined when the space variable is inside the domain of the problem. We extend the space variable outside the domain and find the appropriate initial conditions that would generate the same solution inside the domain. In general, the extended initial condition is not differentiable or continuous unless the boundary and initial conditions satisfy some compatibility conditions. We analyze both dispersive and dissipative IBVPs.

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MS3

Well-Posedness of KdV and NLS ibvp and the Fokas Method

In this talk we shall discuss a new approach for studying well-posedness of initial value problems (ivp) for dispersive equations in Sobolev spaces, which is analogous to the one used in the case of initial value problems (ivp). It consists of three steps. In the first step, we replace the nonlinearity with a forcing and solve the corresponding linear ibvp via the Fokas Unified Transform Method (UTM), which is a new technique motivated from integrable equations. While the solving of the corresponding problem in the case of an ivp is straightforward, thanks to the spatial Fourier transform on the whole line, which reduces the forced linear ivp to a simple linear differential equation in the time variable, the solving of the linear ibvp is more involved and requires novel ideas from Fokas method. The second step consists of deriving the linear estimates by using the Fokas solution formula with data and forcing in appropriate spaces. The third step consists of showing that the iteration map defined by the UTM formula when the forcing is replaced by the nonlinearity is a contraction map in an appropriate solution space where we are able to establish the needed multilinear estimates. For the Korteweg-de Vries and Nonlinear Schrödinger equations this approach has been implemented for ibvp in one-space dimension and significant progress has been made in higher dimensions. The talk is based on collaborative work with Thanasis Fokas, Dionyssis Mantzavinos and Fangchi Yan.

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MS4

Stationary Direct and Inverse Cascade Spectra in Wave Turbulence in Bose-Einsten Condensate

We report on the results of numerical simulations of the stationary direct and inverse cascade spectra of the Kolmogorov-Zakharov type in wave turbulence in Bose-Einstein condensates. Results obtained from the simulations of the Gross-Pitaevskii model and the respective wave-kinetic equation are presented and compared to each other. For the inverse cascade state, for the first time, we find analytically the prefactor constant of the power-law spectrum, and we validate this spectrum numerically including its scaling and the prefactor constant. For the direct cascade state, we validate numerically the theoretical prediction of the log-corrected spectrum.

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MS5

Intracellular Partitioning Models for Cell Polarity

A class of four-component reaction-diffusion systems are studied in one spatial dimension which seek to capture the interaction between active and inactive forms of two G-protiens, known as ROPs in plants, thought to underly cell polarity formation. We first consider the case where the systems conserves total concentration of each ROP, which enables reduc11 tion to simple canonical forms when one seeks conditions for homogeneous equilibria or heteroclinic connections between them. Transitions between different forms and multiplities of such states are classiffied to using a novel form of catastrophe theory. For the time-dependent problem, the hetro14 clinic connections represent so-called wave-pinned states that seperate regions with different ROP concentrations. It is shown numerically how the form of wave-pinning reached can be predicted, leading to a state diagram of different polairty forms as a function of initial total concentrations and system parameters. Second, we consider the effect of addition of source and loss terms, which leads to a completely different kind of dynamics involving localised patches governed by a homoclinic snaking mechanism. It is shown how interdigitated patterns are preferred to overlaid patterns, which is biologically plausible. Finally, a preliminary singular perturbation analysis of the limit as source and loss terms vanish is presented.

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MS5

Pressure-Driven Wrinkling of Soft Inner-Lined Tubes

A simple equation modelling an inextensible elastic lining of an inner-lined tube subject to an imposed pressure difference is derived from a consideration of the idealised elastic properties of the lining and the pressure and soft-substrate forces. Two cases are considered in detail, one with prominent wrinkling and a second one in which wrinkling is absent and only buckling remains. Bifurcation diagrams are computed via numerical continuation for both cases. Wrinkling, buckling, folding, and mixed-mode solutions are found and organised according to system-response measures including tension, in-plane compression, maximum curvature and energy. Approximate wrinkle solutions are constructed using weakly nonlinear theory, in excellent agreement with numerics. Our approach explains how the wavelength of the wrinkles is selected as a function of the parameters in compressed wrinkling systems and shows how localised folds and mixed-mode states form in secondary bifurcations from wrinkled states. Our model aims to capture the wrinkling response of arterial endothelium to blood pressure changes but applies much more broadly.

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MS5

Pattern Formation on a Finite Disk, Variational and Non Variational Case

The dynamics of the real cubic-quintic Swift-Hohenberg equation over a finite disk with no-flux boundary conditions are studied. The stability properties of the trivial state are determined via linear stability analysis. The unstable modes are followed via numerical continuation, revealing a variety of spatially extended and localized states. We compute families of solutions localized in the interior (multiarm or azimuthal), and at the periphery (localized wall modes). We identify the mechanisms by which localized solutions connect to a domain-filling state. A nonvariational generalization, the complex cubic-quintic Swift-Hohenberg equation, is also considered. In this model, the trivial state becomes unstable via a Hopf bifurcation, generating standing and traveling waves. The associated mode can be spatially extended or take the form of an oscillatory wall mode. Standing oscillations of the latter type may be azimuthally periodic or azimuthally localized and resemble the corresponding states in the one-dimensional case with periodic boundary conditions. The relative stability of extended standing and traveling states is consistent with the predictions of a symmetry-breaking Hopf bifurcation with $O(2)$ symmetry. These findings of this study are expected to be relevant in bistable pattern-forming systems on a disk, such as nonlinear optical systems, and low Prandtl number convection.

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MS5

Turing Patterns in General n-component Reaction-Diffusion Equations Posed on Different Geometries

It has been proven that many different real-world models show Turing instability patterns. These patterns have caught the interest of many people since their existence reveals conditions under which some variables can show interesting non-homogeneous shapes throughout space, where some spots can be seen. Up to now, much work has been done on Turing bifurcations on the line. Some insights have been developed on conditions under which they can occur and their criticality. The latter concept provides an idea of the stability of the patterns that arise from a homogeneous steady state at the corresponding bifurcation point. However, not much has been said in different, complicated geometries. My talk will be about Turing patterns on general reaction-diffusion equations with n components on regular domains and bulk-sphere systems. I will show the conditions required by these systems to go through a Turing bifurcation and provide a way to know its criticality in both cases. Besides, I will show some graphs to explain the main ideas of my talk and show some results obtained after applying the theory to a model formulated within the two different geometries, together with some interesting insights revealed by the theoretical study, including some graphs of the patterns found.

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MS6

Non-Commutative AKNS Hierarchies Discretizations

We consider the generalized matrix AKNS hierarchy. By employing the universal Darboux-dressing scheme we derive solutions for the hierarchy of integrable PDEs via solutions of the matrix Gelfand-Levitan-Marchenko equation, and we also identify recursion relations that yield the Lax pairs for the whole matrix AKNS hierarchy. We also consider suitable space and time discretizations of the scheme and provide simple solutions via dressing methods.

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MS6

Multipolar Boson Stars: Macroscopic Bose-Einstein Condensates Akin to Hydrogen Orbitals

A massive complex scalar field allows for non-topological soliton solutions, Q-balls, if an appropriate self-interaction is provided. When the scalar field is minimally coupled to Einstein gravity boson stars arise. In the presence of gravity a bosonic self-interaction is no longer needed. Often boson stars are considered to be macroscopic Bose-Einstein condensates, where large numbers of bosons are accommodated in the same quantum state. Interestingly, not only spherically symmetric configurations arise, but boson stars can have a multipolar structure with the same morphologies for their energy density as those well-known from the probability density of the hydrogen orbitals. In both cases the solutions are classified by three quantum numbers: N,l,m. When a self-interaction of the bosons is included, supermassive boson stars can arise. These may be considered as black hole mimickers and may be compared to EHT observations of black hole shadows.

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MS7

Unfolding the Transition from Pushed to Pulled Front Propagation

Invasion processes, in which a stable selected state propagates into an unstable background state, play in an important role in describing the onset of structure formation in spatially extended systems. The marginal stability conjectures asserts that the propagation speed and associated properties of the selected state in the wake may be predicted by marginal spectral stability of an associated invasion front solution. The marginally stable spectrum may be essential or point spectrum, leading to so-called pulled or pushed invasion, respectively. We give a generic description of the transition from pushed to pulled front propagation in systems of parabolic equations as parameters are varied. This transition is mediated by an eigenvalue bifurcating from the absolute spectrum, and we track this eigenvalue using a functional analytic analogue of the gap lemma.

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MS7

Stability of Sharp Fronts - Computer Assisted Methods of Proof

Using a combination of analytic and computer assisted methods of proof, we prove stability of traveling front solutions to the KdV-Burgers equation. The methods apply much more generally. In this talk we focus on the rigorous computations involved in the computer assisted methods of proof. We use a Newton-Kantorovich argument and the parametrization method to rigorously enclose the traveling wave profile. We use analytic interpolation of the ODE series solution coefficients in order to establish the result for values of the dispersion parameter ranging over an interval.

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MS7

Convective Stability of a Monostable Front in Non-Linear Advection-Reaction Equations

Arising from biology, reaction-diffusion equations have been widely studied. The dynamic near equilibria and propagating waves is well understood for such equations. Similar questions can be investigated in hyperbolic problems such as scalar, reaction-advection equations. For such models, solutions need not to be smooth in space, and shocks can appear in finite time. I will discuss the time stability of a monostable front, which is a propagating wave that connect a stable equilibria to an unstable one. This study relies on resolvent estimates in suitable weighted spaces. To handle non-linear advection term, we use a non-autonomous formulation of the dynamic.

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MS7

Nonlinear Stability and Asymptotic Behavior of Periodic Wave Trains in Reaction-Diffusion Sys-

tems Against C^2_{ub}-perturbations

In this talk I present a nonlinear stability theory for periodic wave trains in reaction-diffusion systems, which relies on pure L^∞-estimates only. Our analysis shows that localization or periodicity requirements on perturbations, as present in the current literature, can be completely lifted. Instead, we only require that the initial perturbation and sufficiently many of its derivatives are bounded. Hampered by the lack of localization, we must fully rely on diffusive smoothing to render decay in the nonlinear argument. We apply the Cole-Hopf transform to eliminate the most critical nonlinear terms, which cannot be controlled by diffusive smoothing. Ultimately, we establish nonlinear modulational stability of diffusively spectrally stable wave trains against C^2_{ub}-perturbations and approximate the spatio-temporal phase modulation by a solution of the viscous Hamilton-Jacobi equation.

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MS8

Manakov System with Parity Symmetry on Nonzero Background and Associated Boundary Value Problems

We characterize initial value problems for the defocusing Manakov system (coupled two-component nonlinear Schrödinger equation) with nonzero background and well-defined spatial parity symmetry (i.e., when each of the components of the solution is either even or odd), corresponding to boundary value problems on the half line with Dirichlet or Neumann boundary conditions at the origin. We identify the symmetries of the eigenfunctions arising from the spatial parity of the solution, and we determine the corresponding symmetries of the scattering data. All parity induced symmetries are found to be more complicated than in the scalar case. In particular, we show that the discrete eigenvalues giving rise to dark solitons arise in symmetric quartets, and those giving rise to dark-bright solitons in symmetric octets. We also characterize the differences between the purely even or purely odd case (in which both components are either even or odd functions of x) and the "mixed parity' cases (in which one component is even while the other is odd). Finally, we show how, in each case, the spatial symmetry yields a constraint on the possible existence of self-symmetric eigenvalues, corresponding to stationary solitons, and we study the resulting behavior of solutions.

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MS8

Breather and Rogue Wave Solutions to the Massive Thirring Model

In this talk, we will present multi-breather and higher order rogue wave solutions to the massive Thirring (MT) model via the KP hierarchy reduction method. First, starting from the discrete KP equation, we construct a set of bilinear equations which derive the MT model and its multi-breather solutions. Then, by taking a limiting process, we obtain higher order rogue wave solutions expressed by Schur polynomials. The wave pattern will be studied by linking it to the root of some orthogonal polynomials.

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MS8

Self-Similar Boundary Layers in the Maxwell-Bloch Systems

There is a unique causal solution of the Maxwell-Bloch system corresponding to a suitable input optical pulse. Through a Riemann-Hilbert representation of this solution in the sharp-line limit, we describe a transitional phenomenon by which smooth and rapidly-decaying (or even compactly-supported) input pulses generate, over an infinitesimal propagation distance, a fat dispersive tail that actually removes the pulse from the space in which the classical inverse-scattering transform is well-defined. The generation of the tail is described by a Painlev transcendent that also describes rogue waves of infinite order. This is joint work with Sitai Li (Xiamen).

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MS8

Wave Patterns in Higher-Order KP-I Lumps

Pattern formation in higher-order lumps of the Kadomtsev-Petviashvili I equation at large time is analytically studied. For a broad class of these higher-order lumps, we show that two types of solution patterns appear at large time. The first type of patterns comprise fundamental lumps arranged in triangular shapes, which are described analytically by root structures of the Yablonskii-Vorob'ev polynomials. As time evolves from large negative to large positive, this triangular pattern reverses itself along the x-direction. The second type of patterns comprise fundamental lumps arranged in non-triangular shapes in the outer region, which are described analytically by nonzero-root structures of the Wronskian-Hermit polynomials, together with possible fundamental lumps arranged in triangular shapes in the inner region, which are described analytically by root structures of the Yablonskii-Vorob'ev polynomials. When time evolves from large negative to large positive, the non-triangular pattern in the outer region switches its x and y directions, while the triangular pattern in the inner region, if it arises, reverses its direction along the x-axis. Our predicted patterns at large time are compared to true solutions, and excellent agreement is observed.

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MS9

Revisiting Problems for Linear PDEs

In almost every textbook for Partial Differential Equations(PDEs), solutions of linear PDEs for specific initial and boundary value problems (IBVPs) are presented. Many of these problems are considered classical, since they provide a paradigm of how the several methods for solving linear PDEs are applied. In this talk we revisit some of these classical problems using the Unified Transform (UT) method, also known as the Fokas method. Our goal is twofold: (a) show some major limitations of the classical transform methods (b) give the outline of a new unified methodology which overcomes these limitations and provides effective pathways for the relevant analytical and numerical solutions.

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MS9

Fokass Unified Transform for the Well-Posedness of Initial-Boundary Value Problems

It is often the case in physical and other applications that nonlinear dispersive PDEs arise in domains with a boundary. Such situations lead to the formulation of initial-boundary value problems, which are generally supplemented with various types of nonzero boundary conditions. In this talk, we will discuss a general method for establishing the well-posedness (i.e. existence and uniqueness of solution, and its continuous dependence on the data) of such initial-boundary value problems. Our main vehicle for doing so will be the nonlinear Schrödinger equation. Importantly, we will focus on recent progress on the analysis of this equation in two spatial dimensions. This talk is based on joint works with Thanasis Fokas and Alex Himonas.

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MS11

Unified Framework for Localised Patterns in Reaction-Diffusion Models

We extend our previous work for Schnakenberg-like models involving the onset of localised patterns through homoclinic snaking that emerges from a degenerate Turing bifurcation and the connection of these patterns to the spike-like modes that can be studied using semi-strong interaction theory. This talk shall present three recent extensions. First through the use of PDE2path we are able to explain many more of the intraciate details of the instabilities of localised patterns through breathing Hopf bifurcations. Second we are able to explain the presence of disconnected branches leading to what was previously described as foliated snaking, and show the relation of these states to travelling-wave ladder branches within the homoclinic snake. Finally, we are able to extend the analysis to a much wider class of system, including systems with more than two components and models that were previously thought to not satisfy the necessary conditions for Turing instability.

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MS11

The Virtual Element Method for Bulk-Surface PDEs: Analysis and Application to Battery Modeling

We present the Bulk-Surface Virtual Element Method (BSVEM) for the spatial approximation of stationary and time-dependent coupled bulk-surface PDEs in three space dimensions, thereby extending previous work on the two dimensional case. The method combines the polyhedral VEM for the bulk equations and the surface Virtual Element Method (SVEM) for the surface equations. We provide a geometric error analysis of polyhedral meshes independent of the method. Then, we provide a full error analysis in the lowest order case that holds even in the presence of curved boundaries. The method brings all the advantages of general polyhedral meshes into the context of bulk-surface PDEs. We show the application of the method to a novel bulk-surface reaction-diffusion PDE system for battery modeling in three space dimension, thereby illustrating that the polyhedral approach allows for accurate approximation of geometry and fast matrix assembly at once.

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MS11

Sensing the Environment from Within: How Cellular Scales Integrate Long-Range Signals

By using simple reaction-diffusion models to describe polarity determinants within the cell, we can predict when cells can be triggered or spontaneously undergo break-of-symmetry. Depending on the resultant mode of intracellular patterning, cells interact in different ways with noisy environments and external signals. Even the cell shape itself, usually considered a downstream output of the intracellular polarity mechanism, can in fact have a functional impact on the organisation and coordination of the polarity itself. During this talk I will review several biological instances in which these feedbacks are biologically relevant to confer a robust and precise cellular decision in response to the environment. Given these mathematical and modelling insights, we realise that spatio-temporal bioimaging is an important element to properly unravel such shape-based biological feedbacks. This brings me to the last part of the talk, in which I will show how we are integrating imaging methods and analysis to better understand how processes related to intracellular partitioning and shape determination translate up to the multicellular level.

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MS11

Coupling Passive Diffusion in Bounded Domains to Dynamically Active Boundaries

Motivated by the spatial segregation of intracellular proteins between the cytoplasm and the cellular membrane, we investigate the spatio-temporal dynamics of bulk-surface coupled models. For such models, a passive diffusion process occurring inside a bounded domain is coupled to a nonlinear reaction-diffusion process restricted to the boundary. A variety of simple, idealized, bulk geometries are considered. We focus on analyzing bifurcations using a combination of analytical and numerical methods. Lastly we analyze a simple mass-conserved protein oscillations model on a circular domain.

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MS12

Optimal Control of Nonlinear Optical Waves

We present two problems in which methods of optimal control are used to construct the spatially-varying index of refraction in an optical device in order to transform the electromagnetic field into a desired state. In the first, we design an optical coupler that transforms the transverse profile of a solution from the eigenfunction of an input waveguide to that of an output waveguide, working in the paraxial regime described by a linear Schrdinger equation. In the second, we design an anodization profile to minimize reflection at the input to a Bragg grating profile and shape the input into a gap soliton. This system is described by a variable coefficient version of the nonlinear coupled mode equations.

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MS12

ODE Approximations to PDE Systems and Their Steady States

In many biological systems, especially in the context of infectious diseases, coefficients may depend on the time since the onset of a particular process (e.g., infection). As a result, these systems are modeled by PDEs with two temporal (independent) variables: time t and the age of progression a. The PDE system then involves transport-like PDEs that are coupled with nonlinear ODEs. In this talk, we will show an averaging of coefficients that converts the PDE system into an ODE one, whose steady-states have the same stability properties as those of the original PDE system, but are more straightforward to obtain.

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MS12

Evolution of Quantum Information

Quantum information is encoded in density operators and its evolution is governed by von Neumann-Lindblad equation which extends the von Neumann equation of quantum statistics to open systems. In this talk I will explain how the von Neumann-Lindblad equation arises and present some recent results. I will start with basic definitions and I will not assume any knowledge of quantum mechanics, quantum statistics or quantum information theory by the audience.

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MS12

Free Boundary Problem for a Gas Bubble in a Liquid, and Asymptotic Stability of the Manifold of Spherically Symmetric Equilibria

We consider an asymptotic model for the dynamics of an expanding and contracting gas bubble, immersed in an incompressible fluid. This model has a family of spherically symmetric equilibria, parameterized by the bubble mass. We prove that this manifold of spherically symmetric equilibria is nonlinearly and asymptotically stable relative to small spherically symmetric perturbations.

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MS13

Spiral Waves in Nonlocal Oscillatory Media

Numerical experiments show that nonlocal interactions can generate interesting patterns in oscillatory media. For example, in the early 2000's Kuramoto and co-authors confirmed that long range connections can produce new structures called spiral chimeras. As a first step in understanding these patterns we explore the existence of regular spiral waves in oscillatory media with nonlocal coupling. Starting from a nonlocal amplitude equation that captures the leading order behavior of rotating patterns, we use a multiple scale analysis combined with a Lyapunov-Schmidt reduction to obtain our result. In the process, we also find that the phase dynamics of these structures is governed by the same viscous eikonal equation that models target patterns in these systems. However, in contrast to the case of target patterns, our equation is more challenging to solve since it encodes information about the spiral's amplitude in the form of a large perturbation.

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MS13

Pattern Selection of Hexagon Fronts and Patches Inside and Out of the Snaking Region

In this talk, I will present numerical results on the computation of the pattern selection of hexagon fronts both stationary (inside the snaking region) and invading (outside the homoclinic snaking region) in the planar Swift-Hohenberg equation. The numerical method employs a far-field core decomposition idea that is generalizable to general reaction-diffusion systems. These numerical computations then allow us to trace out a "compatibility" diagram that we conjecture provides the wavenumber selection of the hexagon cells in a localized patch of cellular hexagons.

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MS13

Snaking Without Subcriticality: Pinned Pentagon-Hepta Defects

Non-topological defects such as grain boundaries abound in pattern forming systems, arising from local variations of pattern properties such as amplitude, wavelength, orientation, etc. We introduce the idea of treating such non-topological defects as spatially localised structures that are embedded in a background pattern, instead of treating them in an amplitude-phase decomposition. Using the two-dimensional quadratic-cubic SwiftHohenberg equation as an example we obtain fully nonlinear equilibria that contain grain boundaries which are closed curves containing multiple penta-hepta defects separating regions of hexagons with different orientations. These states arise from local orientation mismatch between two stable hexagon patterns, one of which forms the localised grain and the other its background, and do not require a subcritical bifurcation connecting them. Multiple robust isolas that span a wide range of parameters are obtained even in the absence of a unique Maxwell point, underlining the importance of retaining pinning when analysing patterns with defects, an effect omitted from the amplitude-phase description.

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MS13

Dynamics and Equilibria of Vegetation Spot Patterns

Localized spots represents the last stage of vegetation survival in a dryland. In this talk, we discuss their dynamics and steady-state behaviours in two models. In the first part of the talk, we focus on the Klausmeier reaction-diffusion system, for which we establish an asymptotic theory to analyze the dynamics and stability of quasi equilibria and equilibria of localized spots. In the second part, we present an ongoing work, which aims to bridge the study of localized spots to periodic patterns. The ultimate question is: how does a periodic array of spots transit to a sparse and localized spot configuration? Our study is primarily based on numerical continuation in a nonlocal vegetation model.

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MS14

Numerical Direct and Inverse Scattering Transform Analysis of Stochastic Nonlinear Wavefields

The numerical direct and inverse scattering transform applications represent a broad topic of nonlinear wave field studies. Here we investigate various stochastic nonlinear wavefields with the dominant role of a large number of solitons within the one-dimensional nonlinear Schrodinger equation model. First, applying the recently developed direct scattering transform numerical scheme allowing accurate identification of the complete wavefield scattering data, we find distributions of all soliton amplitudes, velocities, positions, and phases. Identification of soliton positions, and phases represent a challenging numerical issue and demand implementation of high-precision arithmetic operations. Using the previously developed numerical tools of solving the inverse scattering problem for a large number of solitons, we reconstruct the solitonic content of the initial wave field, which allows us to estimate the role of solitons in the initial wave field composition. Then we discuss the obtained scattering data distributions, paying particular attention to the correlations in parameters of different solitons. The accurate characterization of soliton parameters in stochastic nonlinear wavefields can be used in further studies of spontaneous modulation instability development and integrable turbulence.

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MS14

Nonlocal Nonlinear Schrodinger Equation: Riemann-Hilbert Approach and Large Time Asymptotics

We develop the Riemann-Hilbert approach for the focusing nonlinear Schrodinger equation $iq_t(x,t) + q_{xx}(x,t) + 2q^2(x,t)\bar{q}(-x,t) = 0$ on the line with various non-zero boundary conditions having a step-like structure (different behavior at different spatial infinities). Using this approach, we study the large time behavior of solutions of the corresponding initial value problems. An emphasis is made on the differences between the cases of local and non-local equations.

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MS14

Integrability and Wave Instabilities: An Algebraic-Geometric Approach

Recently, a direct construction of the eigenmodes of the linearization of 1+1, multicomponent, nonlinear, partial differential equations of integrable type has been introduced. This construction employs only the associated Lax pair, with no reference to spectral data and boundary conditions. In particular, this technique allows to study the instabilities of continuous wave solutions in the parameter space of their amplitudes and wave numbers, leading to the construction of the so-called stability spectra, which, for multi-component systems with more than two components, in general differs from the continuous spectra of the spatial Lax operator. In the context of modulation instability, it provides also a necessary condition in the parameters for the onset of rational solitons. The derivation of the stability spectra is completely algorithmic, and, in the case of plane waves, their study makes use of some basic ideas from algebraic-geometry. Indeed, it turns out that, for a Lax Pair that is polynomial in the spectral parameter, the problem of classifying the stability spectra is transformed into a problem of classification of certain varieties. The method is general enough to be applicable to a large class of integrable systems and in principle to all typologies of their solutions. Joint work with M. Caso-Huerta (Northumbria University), A. Degasperis (Roma "La Sapienza"), P. Leal da Silva (Loughborough University) and S. Lombardo (Loughborough University).

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MS14

The Inverse Problem of Perturbed Kadomtsev-Petviashvili Multi-Line Soltions

The stability problem of the Kadomtsev-Petviashvili multi line solitons is an interesting open problem which can be investigated by the inverse scattering theory. In this talk, we will report our recent progress in the inverse problem, including, proving a unique solvability of the Cauchy integral equation and deriving representation formula for the Kadomtsev-Petviashvili solitons.

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MS15

A Novel Two-Parameter Class of Finite-Band Potentials of the Non-Self-Adjoint Dirac Operator

The dynamics of self-focusing media governed by the focusing nonlinear Schrodinger (NLS) equation with periodic boundary conditions has received renewed attention both from a theoretical and experimental point of view. In this talk I will review some recent results in this area. In particular, I will present: (i) Numerical evidence of the formation of a coherent soliton condensate in the semiclassical limit and a corresponding asymptotic analysis; (ii) New bounds on the spectrum of the non-self-adjoint Zakharov-Shabat operator with periodic potentials; and (iii) A novel two-parameter family of elliptic finite-band potentials of the non-self-adjoint Zakharov-Shabat operator.

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MS15

The Closeness of the Ablowitz-Ladik Lattice to Non-Integrable DNLS Lattices

While the Ablowitz-Ladik lattice is integrable, the DNLS equation, which is more significant for physical applications, is not. We prove closeness of the solutions of both systems in the sense of a "continuous dependence" on their initial data in the l^2 and l^∞ metrics. The most striking relevance of the analytical results is that small amplitude solutions of the Ablowitz-Ladik system persist in the DNLS one. It is shown that the closeness results are also valid in higher dimensional lattices as well as for generalised nonlinearities. We also discuss extensions of this approach to NLS partial differential equations and its potential applications.

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MS15

Inverse Scattering Transform and Soliton Solutions of the Complex Coupled Short-Pulse Equation

We present the inverse scattering transform (IST) for the complex coupled short pulse equation (ccSPE) on the line. Our work extends to the complex, coupled case the Riemann-Hilbert approach to the IST for the real, scalar short-pulse equation proposed by A. Boutet de Monvel and collaborators in 2016. One-soliton solutions are also investigated within the framework of the IST. The simplest soliton solutions, fundamental solitons, are found to be the natural vector generalization of scalar one-soliton solutions of the complex short-pulse equation. But in the coupled case one can also have more complicated, composite soliton solutions, corresponding to two fundamental solitons having the same amplitude and velocity but different carrier frequencies, as well as solutions that, while still corresponding to a minimal set of discrete eigenvalues, cannot be reduced to simple superposition of fundamental solitons. Moreover, it is found that the same constraint on the discrete eigenvalues which leads to regular, smooth one-soliton solutions in the complex SPE, also holds in the coupled case, for both a single fundamental soliton and a single fundamental breather, but not, in general, in the case of a composite breather.

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MS17

The Hydrodynamics of Integrable Systems

Hydrodynamics is a powerful framework for large-wavelength phenomena in many-body systems. At its basis is the assumption that one can reduce the dynamics to that of long-lived, effective degrees of freedom obtained from the available conservation laws. This fundamental idea, applied until now to systems with few conservation laws, can be extended to integrable systems, which admit an extensive number. The ensuing "generalised hydrodynamics (GHD) is a universal theory for the large-scale dynamics in integrable classical and quantum chains, gases and fields. Using hydrodynamic ideas, it gives rise to a wealth of results hitherto unaccessible, including non-equilibrium steady states, diffusion, dynamical correlation functions and fluctuations in non-equilibrium transport. In this talk, I will review the basic aspects of GHD and some of these results.

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MS17

Theory and Experiments on Breathers in a Non-Integrable System

Integrable systems such as the Korteweg-de Vries equation exhibit two classes of degenerate 2-phase breather solutions that can be viewed as nonlinear superpositions between a soliton and a periodic (e.g., cnoidal) traveling wave. Using a simple fluid experimentthe viscous fluid conduitand direct numerical computations, the persistence of this interpretation to a physical, non-integrable setting is demonstrated. Cnoidal-like, locally periodic traveling waves are experimentally generated and shown to interact with a soliton on a constant background by forming a breather state consisting of a localized, moving topological defect within the cnoidal-like wave. Both dark and bright breathers as well as their interactions are measured. The existence of dark and bright breather solutions to the corresponding nonlinear, long-wave model, the conduit equation, is demonstrated by numerical solution of a space-time boundary value problem.

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MS17

Recent Developments in the Spectral Theory of Soliton and Breather Gases

Recent developments in spectral theory of soliton and breather gases for integrable systems, such as one dimensional focusing Nonlinear Schrödinger Equation (fNLS) and Korteweg-de Vries equation, will be discussed in this talk. That include derivations of average densities and fluxes for such gases, thermodynamic limits of quasimomentum and quasienergy differentials, etc. We then introduce and discuss the notion of periodic fNLS and KdV gases. Certain accuracy estimates of the obtained results are also included.

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MS18

Novel Coherent Structures to Single- and Multi-Component NLS Systems: Theory and Computation

The primary focus of this talk is on the exploration of the configuration space of solutions to the Nonlinear Schrödinger (NLS) equation, either single (and continuous or discrete, e.g., Ablowitz-Ladik and DNLS) or multi-component versions thereof. This will be accomplished by the introduction of algorithmic procedures, called continuation methods that are capable of tracing branches of solutions. These methods will be applied to NLS systems for identifying the pertinent steady states whose stability is determined via spectral stability analysis techniques. Through the use of the above techniques and methodologies, we will present novel coherent structures that had not been reported before, and discuss bifurcations involving such states. If time permits, a discussion about ongoing work and timely challenges in these systems will be offered too.

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MS18

Finding all Coherent Structures Supported by a Given Nonlinear Wave Equation

I will present a new technique capable of uncovering all coherent structures supported by a given equation. It relies on global bifurcation theory which shows that, in the Fredholm domain, the coherent structures organize themselves in manifolds which are either closed or must reach the boundary of the Fredholm domain. I will show how to determine all the limit points of the manifolds at this boundary and how to trace the actual coherent structures from these limit points on a particular class of nonlinear Schrödinger equations. The surprise is that there are infinitely many limit points, hence infinitely many branches of "ground-states" for this equation i.e., solutions that are positive modulo rotations in the complex plane, which connect to each other via bifurcation points in a complicated but tractable manner.

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MS18

Twist Waves in Nematic Liquid Crystals

Nematic liquid crystals are a paradigmatic example of optically inhomogeneous and anisotropicmaterial. The characteristic feature of the material is provided by the local alignment of the rod-like molecules. Its dynamics are modelled by a coupling of Navier-Stokes equations (describing the velocity of the centers of mass of the molecules) and an equation describing the evolution of the directors. The directors evolution is in general of hyperbolic nature, involving a second order material derivative, an inertia, which is usually neglected. This inertia allows for a very special phenomenon, the twist waves, which are dynamics of directors that do not affect the flow, despite the coupling. We will present some basic facts about the contexts in which models allow for theoretically having such a phenomena.

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MS19

Predictions of Spiral Wave Spectra in a Reaction-Diffusion System with a Rank-Deficient Diffusion Matrix

Spiral waves emerge in numerous pattern forming systems and are commonly modeled with reaction-diffusion systems. Some systems used to model biological processes, such as ion-channel models, fall under the reaction-diffusion category and often have one or more non-diffusing species which results in a rank-deficient diffusion matrix. Previous theoretical research focused on spiral spectra for strictly positive diffusion matrices. In this research, we use a general two-variable reaction-diffusion system to compare the essential and absolute spectra of spiral waves for strictly positive and rank-deficient diffusion matrices. We show that the essential spectrum is not continuous in the limit of vanishing diffusion in one component. Moreover, we predict locations for the absolute spectrum in the case of a non-diffusing slow variable. Predictions are confirmed numerically for the Barkley and Karma models.

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MS19

Stability of Multidimensional Periodic Waves of Reaction-Diffusion Systems

As a first step towards a complete stability theory for genuinely multidimensional periodic traveling waves of parabolic systems, we investigate the dynamics near such waves in two-dimensional reaction-diffusion systems. On one hand we prove that spectral stability implies nonlinear asymptotic stability in a suitable sense and on the other hand we provide large-time asymptotics in terms of solutions to averaged, modulation systems. Thus, for such systems, we extend the comprehensive theory now available for plane periodic waves to the multidimensional context. A significant part of the analysis is devoted to obtaining new results on near-constant anisotropic dynamics, to be applied to the averaged systems and including delicate dispersive-diffusive estimates and derivations of artificial viscosity systems.

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MS19

Pattern Formation on 2D Singular Manifolds

Phase transition and minimal hypersurfaces on singular manifolds The Cahn-Hilliard problem consists in finding stationary points, in particular minima, of an energy composed of a double well and an interface energy, with parameter ϵ, and under some mass constraint. Over smooth manifolds it is well known that for $\epsilon \to 0$ the energy Gamma-converges, and that limits of minimizers yield minimal hypersurfaces. Here we show an analogous result over manifolds with conical singularities, and illustrate the result numerically in 2D, which indicates that the resulting minimal hypersurfaces may cross conical singularities.

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MS19

Pattern Formation for a Consumer Chain Model

In this talk results on a three-component reaction-diffusion system modelling a consumer chain will be presented. The model is based on Schnakenberg type kinetics in one or two space dimensions. In the model there is one consumer feeding on the producer and a second consumer feeding on the first consumer. Due to cooperation between consumers the self-interaction terms are quadratic. We consider two different regimes for the diffusivities: (i) small diffusivity in 2nd equation and very small diffusivity in 3rd equation (ii) small diffusivity in 2nd equation only; the remaining diffusivities are large. Through a rigorous mathematical analysis, we show that there exist two solutions with differing amplitudes, if the feed rates are small. In case (i) we get spike clusters, in case (ii) we have spikes. Further, we also establish stability results: The large amplitude solution can be stable under certain conditions, and the small-amplitude solution is always unstable. The analytical results have been confirmed by numerical computations.

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MS21

A Riemann-Hilbert Approach to the Elastodynamic Equation. Half Plane

Following the general ideas of Fokas's Unified Transform Method, we are presenting an approach, based on the Riemann-Hilbert apparatus, to the elastodynamic equations on the half plane. A special attention will be given to the appearance of the Rayleigh waves within the scheme.

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MS21

A Riemann-Hilbert Approach to the Elastodynamic Equation. Quarter Plane

This is a sequel to Elizabeth Its's talk. Following the general ideas of Fokas's Unified Transform Method, we are presenting an approach, based on the Riemann-Hilbert apparatus, to the elastodynamic equations on the quarter plane. The original boundary problem is reduced to a matrix Riemann-Hilbert problem with a shift posed on a tours. We shall also present the recent developments concerning the exact calculation of the connection formulae between the Rayleigh waves propagating along vertical and horizontal boundaries.

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MS21

Dirichlet-to-Neumann Map for Evolution PDEs on the Half-Line with Time-Periodic Boundary Conditions

For a well-posed boundary value problem, a certain number of boundary values must be prescribed as boundary conditions, while the rest of the boundary values are unknown. The task of determining the unknown boundary values in terms of the prescribed ones is called the computation of the "generalised Dirichlet-to-Neumann map". Here we elaborate on a new approach for finding the Dirichlet-to-Neumann map in the large time limit for evolution PDEs on the half-line, for the physically significant case of time-periodic boundary conditions [Fokas and Van der Weele, *Stud. Appl. Math.*, 147(4):1339-1368, 2021]. The method is illustrated both for linear PDEs (including the heat equation, the convection-diffusion equation and the linearised KdV equation) and for integrable nonlinear PDEs, in particular for the focusing NLS equation. It is shown that the time-dependent part of the Lax pair is instrumental in yielding, via an elegant algebraic calculation, the large t asymptotics of the periodic unknown boundary values in terms of the prescribed periodic boundary data. This method is based on earlier work by Lenells and Fokas [*Proc. R. Soc. A*, 471:20140926, 2015], in which the NLS equation was treated via a more complicated approach.

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MS22

Dispersive Shock Waves in Lattices: A Dimension Reduction Approach

Dispersive shock waves (DSWs), which connect states of different amplitude via a modulated wave train, form generically in nonlinear dispersive media subjected to abrupt changes in state. The primary tool for the analytical study of DSWs is Whitham's modulation theory. While this framework has been successfully employed in many space-continuous settings to describe DSWs, the Whitham modulation equations are virtually intractable in most spatially discrete systems. In this talk, we explore other avenues to elucidate properties of lattice DSWs that are based on reducing the dynamics to a low dimensional

ODE. Connection of these results to Whitham modulation theory and lattices with beyond nearest-neighbor coupling will also be discussed.

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MS22

On Single and Coupled Ostrovsky Equations

I will first discuss the effects of the parallel shear flow on weakly-nonlinear internal waves in a rotating ocean extending the results. We found examples when the shear flow changes the sign of the rotation coefficient in the Ostrovsky equation leading to unusual dynamics. Secondly, I will discuss the dynamics of two distinct linear long wave modes with nearly coincident phase speeds described by the system of coupled Ostrovsky equations. The dominant features of the complex dynamical behaviour observed in numerical simulations can be interpreted in terms of the main features of the linear dispersion curves. Finally, I will discuss how one can by-pass the so-called zero-mass contradiction in the class of periodic functions on a finite interval.

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MS22

Nonlinear Waves of a Nonlocal NLS Equation

In this talk, I will present a new nonlocal nonlinear Schrodinger (NLS) equation that extend the nonlocal Ablowitz-Musslimani equation. In the first part of the talk, I will discuss the inverse scattering transform of the equation and derive the soliton solutions. The second part of the talk will be on some numerical simulations for general initial conditions, where we show that, unlike the soliton solution of the Ablowitz-Musslimani equation, the new equation's localised solution does not have a periodic blow up.

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MS23

Generalised Hydrodynamics of KdV Soliton Gas

Generalised hydrodynamics (GHD) is a rather recent theory for the thermodynamics and hydrodynamics of many-body integrable systems. We construct the GHD description of the soliton gas for the Korteweg-de Vries (KdV) equation and re-contextualise the tools of GHD in the terms of soliton gas theory. In particular we predict the exact form of the entropy and free energy for the soliton gas, as well as the static correlation matrices of conserved charges and currents. For this purpose, we identify the solitons' statistics with that of classical particles, and confirm the resulting GHD static correlation matrices by numerical simulations.

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MS23

Dispersive Hydrodynamics of Soliton Condensates for the KdV Equation

We consider large-scale dynamics of non-equilibrium dense soliton gas for the Korteweg-de Vries (KdV) equation in the special "condensate' limit. We prove that in this limit the integro-differential kinetic equation for the spectral density of states reduces to the N-phase KdV-Whitham modulation equations derived by Flaschka, Forest and McLaughlin (1980) and Lax and Levermore (1983). We consider Riemann problems for soliton condensates and construct explicit solutions of the kinetic equation describing generalised rarefaction and dispersive shock waves. We then present numerical results for "diluted' soliton condensates exhibiting rich incoherent behaviours associated with integrable turbulence. The developed theory admits broad generalisations to other integrable systems.

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MS23

Connecting Different Models of Soliton and Breather Gases

Soliton and breather gasses are solutions of integrable systems which can be thought of as many particle limits of multi-soliton (or multi-breather) solutions. Different models for analytically modeling these solutions have been proposed. One popular technique models a soliton gas using the 'primitive potential' approach introduced by Dyachenko, Zakharov, and Zakharov (2016). Another effective technique is to treat the gas as the thermodynamic limit of finite gap quasi-periodic solutions of the underlying integrable system (KdV, NLS, etc.) as described in El and Tovbis (2020). In this talk we will show that the two methods are equivalent, at least in certain cases. In particular, we will show that given initial data in one model, we can choose initial data in the other model which produce in their "many particle" limits generate the same soliton gas. Time permitting we will discuss some simple examples.

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MS24

Using Rigorous Numerics and Formal Proof to Compute Limit Cycles in Hilbert 16th Problem

Abelian integrals play a key role in the infinitesimal version of Hilbert's 16th problem. Being able to evaluate such integrals – with guaranteed error bounds – is a fundamental step in computer-aided proofs aimed at this problem. Using interpolation by trigonometric polynomials and quasi-Newton- Kantorovitch validation, we develop a validated numerics method for computing Abelian integrals in a quasi-linear number of arithmetic operations. Our approach is both effective, as exemplified on two practical perturbed integrable systems, and amenable to an implementation in a formal proof assistant, which is key to provide fully reliable computer-aided proofs.

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MS24

A Computer-Assisted Existence Proof for the Navier-Stokes Problem on an Unbounded Strip Domain with an Obstacle

The incompressible stationary 2D Navier-Stokes equations are considered on an unbounded strip domain with a compact obstacle, and with the Poiseuille flow as a background flow near infinity. A computer-assisted existence and enclosure result for the velocity (in a suitable divergence-free Sobolev space) is presented. Starting from an approximate solution (computed with divergence-free finite elements), we determine a bound for its defect, and a norm bound for the inverse of the linearization at the approximate solution via eigenvalue bounds. For the latter purpose, the Rayleigh-Ritz method, the Temple-Lehmann-Goerisch method, and a homotopy method for obtaining the needed spectral pre-information are applied. The desired result can now be obtained by Banachs fixed point theorem. Finally, if the computer-assisted proof provides the existence of a velocity field, the existence of a corresponding pressure can be obtained by purely analytical techniques. In addition, for a given approximate solution to the pressure our methods provide an error bound (in a dual norm) as well.

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MS24

Computer Assisted Proofs for Spiral Waves in the Complex Ginzburg-Landau Problem

The cubic complex Ginzburg-Landau equation is among the prototypical systems in the study of pattern formation. One of its dynamic features is the occurence of rotating spirals. Due to special symmetries of this partial differential equation, a spiral wave Ansatz reduces the problem to a nonautonomous ordinary differential equation. Finding spiral waves thus corresponds to establishing certain connecting orbits in a finite dimensional dynamical system. In this talk we discuss how to approach this problem via computer assisted proof techniques. We use a domain decomposition which allows a combination of Taylor series, Chebyshev series and the parametrization of a center-stable manifold.

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MS25

Instabilities of Surface Water Waves

Different asymptotic regimes of surface water waves lead to different mathematical models, many of which are integrable. I will discuss how the stability results of the traveling wave solutions of the integrable models relate to the stability results for the traveling wave solutions of the Euler water wave problem.

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MS25

Stability of Periodic Lugiato-Lefever Waves

In this talk I will describe recent advances in the stability analysis of T-periodic stationary solutions of the Lugiato-Lefever equation, a damped nonlinear Schrdinger type equation with forcing that arises in nonlinear optics. Several recent works have studied the stability of such waves to so-called subharmonic perturbations, i.e. NT-periodic perturbations for some natural number N. However, these results are degenerate for large N since both the rate of decay of perturbations, along with the domain of attraction, both tend to zero as N tends to infinity. In this talk, I will discuss a new methodology for obtaining subharmonic stability results for the LLE which are uniform in N. This approach is quite general, and applies to a wide class of dissipative models.

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MS25

Bright and Dark Multi-Solitons in a Fourth-Order Nonlinear Schrdinger Equation

We consider the existence and spectral stability of multi-pulse solitary wave solutions to a nonlinear Schrdinger equation which incorporates both fourth and second-order dispersion terms. We do this for both the bright and the dark soliton regimes. We first show that a discrete family of multi-pulse solutions exists, which is characterized by the distances between consecutive copies of the the primary solitary wave. In the bright soliton regime, we then reduce the spectral stability problem to computing the determinant of a matrix which is, to leading order, block diagonal. Under additional assumptions, which can be verified numerically and are sufficient to prove orbital stability of the primary solitary wave, we show that all bright multi-solitons are spectrally unstable. By contrast, using a similar approach in the dark soliton regime, we find that dark multi-solitons can be spectrally neutrally stable. Finally, we show results of numerical spectral computations, which are in good agreement with our analytical results. This is supplemented with numerical timestepping experiments, which are interpreted using our spectral computations.

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MS25

Stability and Dynamics of Capillary-Gravity Solitary Waves

Nonlinear capillary-gravity waves are of interest due to their complexity and applications to wind-ocean coupling. In this talk, we reexamine the stability and dynamics of two-dimensional capillary-gravity solitary waves in deep water based on a new numerical scheme. We integrate hodograph transformation and time-dependent conformal map so that the stability characteristics of solitary waves, including both symmetric and asymmetric, can be thoroughly investigated. Surprisingly, it was found that the large-amplitude overhanging depression waves turn out to be stable. Still, some multi-packet solitary waves are unstable and exhibit collision-like behaviors in the long-time dynamics, similar to the weak interaction of solitary waves in fiber optics. Finally, numerical results show that stable solitary waves can be excited by moving one or two Gaussian pressure with speed close to the phase speed minimum to mimic the jet of air impinging on the surface of a steady stream.

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MS27

Diffusion on Networks: Singular Perturbations and Consensus Dynamics

Diffusion equations are usually described by partial differential equations (PDEs). When the underlying space is discrete, the PDEs transform in a set of ordinary differential equations (ODEs), with a network structure. The network could reflect, for example, a discretisation of the continuous space where the PDE is defined. The aim of this talk is to describe the consensus dynamics when a singular perturbation acts as a drift in the (nonlinear) diffusion process. In order to disclose the behaviour near consensus we employ techniques from geometric singular perturbation theory (GSPT), equivariant dynamical systems theory, and algebraic graph theory.

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MS27

A Galerkin Approach to Slow Manifolds in Infinite Dimensions and Their Extension Around Non-Hyperbolic Singularities

We introduce and compare two approaches to slow manifolds for infinite-dimensional evolution equations: an abstract evolution equation framework and a finite-dimensional spectral Galerkin approximation. We prove that the slow manifolds constructed within each approach are asymptotically close under suitable conditions, allowing us to change between different characterizations of slow invariant manifolds. This gives a suitable framework to study extensions of slow manifolds around non-hyperblic singularities in reaction-diffusion PDEs, using the geometric blow-up method in the respective Galerkin ODE systems.

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MS27

A PDE Model for Unidirectional Flows: Stationary Profiles and Asymptotic Behaviour

In this talk, we investigate the stationary profiles of a convection-diffusion model for unidirectional pedestrian flows in domains with a single entrance and exit. The inflow and outflow conditions at both the entrance and exit as well as the shape of the domain have a strong influence on the structure of stationary profiles, in particular on the formation of boundary layers. We are able to relate the location and shape of these layers to the inflow and outflow conditions as well as the shape of the domain using geometric singular perturbation theory. Furthermore, we confirm and exemplify our analytical results by means of computational experiments.

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MS27

Slow Eigenvalue Problems for Regularised Shock Waves

Reaction-nonlinear diffusion PDEs can exhibit shock-fronted travelling wave solutions. Prior work by other authors has shown the utility of geometric singular perturbation theory (GSPT) in constructing such solutions when a high-order regularising term is present. In this talk we discuss the spectral stability of such waves, in particular how to count the eigenvalues in the point spectrum. We find that the associated eigenvalue problem of the original system is strongly controlled by a slow eigenvalue problem defined near the slow manifolds of the PDE in the travelling wave frame; concretely, the eigenvalues of the 'full problem are generated by twisting of projectivised singular solutions in the reduced problem. A key technical issue in our work is how to monitor solutions of the eigenvalue problem when the so-called 'elephant trunk lemma' is not available.

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MS28

Travelling Waves in PT Nonlinear Metamaterials

In this talk we will investigate a one-dimensional parity-time (PT)-symmetric magnetic metamaterial that consists of split-ring dimers having gain or loss. By employing a Melnikov analysis I will talk about the existence of localized travelling waves, i.e. homoclinic or heteroclinic solutions. I will show conditions under which the homoclinic or heteroclinic orbits persist. Moreover, I will talk about the agreement between the analytical results and the direct numerical computations.

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MS29

Statistics of Extreme Events in Integrable Turbulence

Integrable turbulence has proven to be a successful framework to describe random nonlinear waves in integrable dynamics such as the focusing nonlinear Schrdinger (fNLS) equation: $i\psi_t + \psi_{xx} + 2|\psi|^2\psi = 0$. The soliton gas, which can be seen as a stochastic ensemble of interacting solitons, constitutes one of the fundamental cases of integrable turbulence. We investigate in this work the likelihood of extreme events for a soliton gas of the fNLS equation, by computing analytically the kurtosis of the corresponding random nonlinear wave-field $\psi(x,t)$. The theory is illustrated by physically relevant examples of dense soliton gas. We first consider the asymptotic development of the noise induced modulational instability of the fNLS equation, which can be modeled by a bound state soliton gas. We then extend the result to the more general problem of the evolution of partially coherent waves, corresponding to stochastic initial conditions with slowly varying amplitude. For each example, the analytical formula of the kurtosis successfully compares to the value obtained with the numerical implementation of the problem.

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MS29

Soliton Gases, Breather Gases, and Finite-Gap Solutions of Integrable Nonlinear Wave Equations

In the study of completely integrable nonlinear wave equations on the torus, a special role is played by the so-called finite-gap solutions. In this talk I will: (i.) discuss the spectral theory of soliton and breather gases; (ii.) introduce two families of elliptic finite-gap potentials of the Korteweg-deVries (KdV) and nonlinear Shrödinger (NLS) equations, and show how in certain asymptotic limits, they give rise to soliton and breather gases, respectively; and finally, (iii.) present numerical solutions of the corresponding nonlinear dispersion relations which have some interesting physical consequences.

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MS29

Numerical Spectral Synthesis of Soliton and Breather Gas

Soliton gas was introduced by Zakharov [Sov. Phys. JETP 33, 538 (1971)] as an infinite ensemble of interacting KdV solitons randomly distributed in velocity and positions. This concept has been extended by El and Tovbis [PRE, 101, 052207 (2020)], in their development of the spectral theory of soliton and breather gases, in the framework of the focusing Nonlinear Schrodinger (fNLS) equation. Moreover, it has been shown in a recent work by Gelash et al. [PRL, 123, 234102 (2019)] how the spectral soliton gas formalism could lead to a new understanding of the evolution of random processes in integrable systems, the so-called integrable turbulence. In this context, the ability to numerically build the soliton and breather gas solutions from the nonlinear spectral plane is a key element for testing the mathematical model and investigating its physical applications. In this work, we present the algorithms for the synthesis of soliton and breather gases in the KdV and fNLS framework and we discuss the theoretical and numerical challenges that arise in the implementation.

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MS29

Soliton Gas Experiments in Optical Fibers and in Water Tank

The concept of soliton gas (SG) as a large ensemble of solitons randomly distributed on an infinite line and elastically has been first introduced by Zakharov [Sov. Phys. JETP 33, 538 (1971)]. Zakharovs kinetic equation describes diluted SG and has been generalized to the case of a dense SG [Phys. Rev. Lett. 95,204101 (2005), PRE, 101, 052207 (2020)]. The SG is characterized by a density of state (DOS) which corresponds to the spatial distribution of the spectral parameters (in the framework of inverse scattering transform). We report the generation and the measurement of SG in water waves and in optical fiber experiments [Phys Rev. Lett. 125, 264101 (2020)]. We show that the asymptotic stage of the noise-induced modulation instability corresponds to a SG having a specific DOS. This SG can be described by a N-soliton solution of the focusing one-dimensional nonlinear Schrdinger equation (1DNLSE). Our investigation reveals a remarkable agreement between spectral (Fourier) and statistical properties of the long-term evolution of the MI (observed in experiments and in numerical simulations of the 1DNLSE) and those of a constructed multisoliton, random-phase bound states [Phys. Rev. Lett. 123 (23), 234102 (2019)].

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MS30

Global Dynamics and Finite Time Blowup in Non-

conservative Nonlinear Schrdinger Equations

In this talk we discuss the nonlinear Schrödinger equation $iu_t = u_{xx} + u^2$ with $x \in \mathbb{T} \equiv \mathbb{R}/\mathbb{Z}$. This NLS does not have gauge invariance, $(e^{i\theta}u)^2 \neq e^{i\theta}u^2$ for generic $\theta \in \mathbb{R}$, and it does not admit a natural Hamiltonian structure. In a recent series of papers, together with JP Lessard and A Takayasu, we have used computer assisted proofs to show that this equation exhibits rich dynamical behavior: such as non-trivial equilibria, homoclinic orbits, and heteroclinic orbits. Furthermore it turns out that the class of functions supported only on non-negative Fourier modes form an integrable subsystem, somewhat similar to the cubic Szegő equation. Within this class of initial data, we are able to explicitly construct solutions that are periodic, and solutions which blowup in finite time. This integrable subsystem is somewhat surprising, as it is also the case that the original PDE is nonconservative. I will conclude the talk with a discussion of some open problems.

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MS30

Delays, Degenerate Hopf and Codimension-2 Bifurcations

Validation of delay differential equations has already produced a variety of interesting results such as [Groothedde, Chris M., and JD Mireles James, Parameterization method for unstable manifolds of delay differential equations] and [van den Berg, Jan Bouwe, and Jonathan Jaquette, A proof of Wright's conjecture]. Developing such validation techniques in extended generality, allows us to consider a variety of DDEs and combine them with a blow up approach to detect and validate Hopf bifurcations. We then combine such results with 2-dimensional manifold validation, allowing us to consider equations with two parameters. This opens the door to cxdimension 2 bifurcations. To showcase the combination of these techniques, we validate endemic bubbles, "bubble" of periodic orbits enclosed between two Hopf bifurcations. The tools presented are developed in great generality, allowing us to look at the SI model

$$\dot{y}(t) = -y(t) + R_0 e^{-py(t-\tau)} y(t)(1 - y(t))$$

varying both R_0 and p.

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MS30

Rigorous Integrator for Higher Spatial Dimensional PDEs

In this talk we provide a method of rigorous forward integration for time-dependent PDEs. Rigorous integrator proves the existence and local uniqueness of the solution in a neighborhood of a numerically computed approximate solution, which is given by the spectral method (Chebyshev series in time and Fourier series in space). The main advantage of this method is that rigorous numerics can be performed for higher spatial dimensional PDEs with the same approach. Our implementation of the spectral method is based on MATLAB's ODE solver and Chebyshev interpolation. As applications of our method, we introduce results of computer-assisted proofs for complex-valued nonlinear heat equation, nonlinear Schrdinger equation, and Swift-Hohenberg equation.

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MS31

Existence Theory for Models of Fluid Flow in Viscoelastic Vessels

We study models of fluid flow in viscoelastic vessels arising in the study of blood flow, which were derived by Mitsotakis, Dutykh, Li, and Peach. For their simplest bidirectional model, in which the undisturbed radius of the vessel is constant with respect to the axial coordinate, we prove well-posedness in Sobolev spaces. When allowing the undisturbed radius to be spatially variable, we argue that this bidirectional model is ill-posed, but still prove existence of solutions in analytic function spaces by applying an abstract Cauchy-Kowalevski theorem. Finally, we show existence of some traveling waves for the model with constant undisturbed radius.

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MS31

A Perturbation Method for All Spectral Instabilities of Stokes Waves

Spectral instabilities of small-amplitude, periodic water waves are investigated using a newly developed perturbation method. Thes instabilities include the famous Benjamin-Feir instability as well as the recently discovered high-frequency instabilities. Explicit estimates of growth rates and coherent structures for both types of instabilities are obtained and compared directly with numerical results, to excellent agreement.

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MS31

A Dissipative Nonlinear Schrodinger Model for Wave Propagation in Sea Ice

Sea ice attenuates waves propagating from the open ocean. We present a model for the evolution of unidirectional random waves in sea ice with a nonlinear Schrodinger equation, with a frequency dependent dissipative term consistent with current model paradigms and recent field observations. The preferential dissipation of high frequency components results in a concurrent downshift of the spectral peak that leads to a less than exponential energy decay, but at a lower rate compared to a corresponding linear model. Attenuation and downshift contrast nonlinearity, and nonlinear wave statistics at the edge tend to Gaussianity farther into sea ice.

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MS32

Long-Time Asymptotics for the 1d Cubic Nonlinear Schrdinger Equation with a Potential

I will illustrate the long-time asymptotics of the 1d cubic NLS with a potential in various settings.

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MS32

Complex Geometric Optics Solutions to Dirac Problems

Complex geometric optics (CGO) solutions to d-bar problems appear in many applications, for instance in Electrical Impedance Tomography and in the scattering theory of integrable PDEs in two dimensions. We discuss various numerical approaches to construct CGO solutions to d-bar systems. Of particular interest is the limit of large values of the spectral parameter where the solutions have an essential singularity. This is work in collaboration with K. McLaughlin, J. Sjstrand and N. Stoilov.

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MS32

Recent Developments in Spectral Theory of Focusing NLS Soliton Gases: Average Densities, Fluxes and Periodic Gases

In this talk, we will discuss soliton and breather gases for one dimensional integrable focusing Nonlinear Schrdinger Equation (fNLS). The derivation of average densities and fluxes for such gases will be presented. Thermodynamic limits of quasimomentum, quasienergy, and their connections with the corresponding g-functions will also be discussed. We then introduce the notion of periodic fNLS gases and calculate for them the average densities, fluxes and thermodynamic limits of meromorphic differentials, including error estimation. Our results constitute another step towards the mathematical foundation for the spectral theory of fNLS soliton and breather gases that appeared in work of G. El and A. Tovbis, Phys. Rev. E, 2020.

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MS33

Stochastic Mass-Conserved Systems Model Travelling Waves Inside Crawling Amoeboid Cells

The coupling of the internal mechanisms of cell polarization to cell shape deformations and subsequent cell crawling poses many interdisciplinary scientific challenges. Here, we consider the interplay between nonlinear waves originated from nonlinear biochemical reactions and the stochastic fluctuations commonly originated int the interior of the living cells. We employ a phase field that encodes the morphology of the cell, together with the integration of stochastic partial differential equations that account for the polarization mechanism inside the cell domain. This approach is employed to model the motion of single cells of the social amoeba Dictyostelium discoideum, a widely used model organism to study actin-driven motility and chemotaxis of eukaryotic cells. We have performed numerical simulations of this model, first characterizing the motion of single cells in terms of their polarity and velocity vectors and the transitions among the different cellular shapes observed during locomotion. Next, we have studied the collisions between two cells that provided the basic interaction scenarios also observed in larger ensembles of interacting amoebae. And finally, some cells may form oversized multinucleate individuals where we have also reported a new form of cell division that is driven by self-organized actin waves and does not require the formation of an actomyosin contractile ring. Daughter cells that emerge from this process of wave-mediated cytofission

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MS33

Projection Methods for Spatially-Extended Neurobiological Models

We will discuss recent progress on the numerical analysis of neural fields and, more generally, on nonlocal, continuum, spatially-extended neurobiological networks. Such systems are often simulated heuristically and, in spite of their popularity in mathematical neuroscience, their numerical analysis is not yet fully established. We introduce generic projection methods for neural fields, and derive a-priori error bounds for these schemes. We find that the convergence rate of a projection scheme for a neural field is determined to a great extent by the convergence rate of the projection operator. This abstract analysis, which unifies the treatment of collocation and Galerkin schemes, is carried out in operator form, without resorting to quadrature rules for the integral term, which are introduced only at a later stage, and whose choice is enslaved by the choice of the projector. Using an elementary timestepper as an example, we demonstrate that the error in a time stepper has two separate contributions: one from the projector, and one from the time discretisation. We give examples of concrete projection methods: two collocation schemes (piecewise-linear and spectral collocation) and two Galerkin schemes (finite elements and spectral Galerkin); for each of them we derive error bounds from the general theory, introduce several discrete variants, provide implementation details, and present reproducible convergence tests.

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MS33

How Actin Waves Drive Cellular Function

Many cellular functions, such was motility, phagocytosis, and cell division, are driven by coherent patterns of activity in the actin cytoskeleton. Among them, actin waves are a recurrent motive that is commonly observed across different cell types. Here, we present experimental results demonstrating the rich variety of wave patterns in the actin cortex of motile amoeboid cells. We show that ring-shaped actin waves, commonly acting as precursors of macropinocytic cups, can mediate switches between different modes of motility, a pseudopod-based amoeboid mode, and a more persistent, wave-driven migratory mode, reminiscent of keratocyte motility. In multinucleate, oversized amoeboid cells, the same waves may also trigger spontaneous, cell cycle-independent cytofission events, resulting in mononucleated daughter cells of a well-defined size. We also demonstrate that a second wave pattern can coexist with the ring-shaped macropinocytic waves. It emerges in a cell-size dependent manner and consists of rapidly moving planar pulses that show typical signatures of an excitable system. Our experimental findings demonstrate the functional versatility of cortical waves patterns. They can be rationalized based on a minimal reaction-diffusion model that mimic the evolution of cortical wave patterns and is coupled to a dynamic phase field to take the cell shape evolution into account. In addition, bifurcation analysis provides a more detailed understanding of how regimes of pattern coexistence may emerge.

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MS33

Waves on the Cell Surface

Experimental work in large cells of embryos and oocytes in frogs and echinoderms has revealed spectacular wave patterns that rival in their complexity and quality the patterns observed in the best known in vitro systems, such as the Belousov-Zhabotinsky reaction and bacterial MinD system. We proposed a model of the activator-inhibitor-substrate type that appears to adequately capture the main classes of experimental behavior. In my talk I will first introduce this novel experimental system and then present salient results of our model analysis.

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MS34

Propagation Phenomena in Monostable Equation with General Nonlocal Operators

Propagation phenomena arise naturally in biology, especially in population dynamics where its characterization is of great interests to understand the underlying mechanisms that trigger some peculiar propagation behaviour such as accelerated propagation. After a quick introduction, I will review the results that have been obtained in the recent years on the description of propagation phenomena that arise in several homogeneous semi-linear reaction diffusion equations. Then, I will present some new results obtained in collaboration with E. Bouin (Ceremade) and G. Legendre (Ceremade) on the precise characterisation of the speed of acceleration.

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MS34

2D Spatio-Temporal Patterns in Coupled Phase Oscillators: Spiral Waves and Chimeras

It is now clear that much of what was once regarded as synchronous oscillatory dynamics in the brain actually takes the form of various types of spatio-temporal activity in the form of traveling waves and rotating waves. A natural platform for the modeling on the spatio-temporal dynamics of filtered LFP is phase equations, that is equations that govern the dynamics of the phases of networks of oscillators:

$$u_t = \omega(x) + \int_D W(x-y)H[u(y,t) - u(x,t)]$$

where $u(x,t)$ is the phase of the oscillator at a point $x \in D$, the two-dimensional domain. $W(x)$ is a coupling kernel and $H(u)$ is the phase-interaction function. In this talk, I will discuss the existence and stability of rotating waves on annulus. I will show that as the inner radius shrinks, rigid rotating waves lose existence through a saddle-node bifurcation and this results in the birth of so-called chimeras.

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MS34

Sharp Discontinuous Traveling Waves in a Hyperbolic Cell-Cell Repulsion Model

This talk concerns a hyperbolic model of cell-cell repulsion with a dynamics in the population of cells. More precisely, we consider a population of cells producing a field (the 'pressure') which induces a motion of the cells following the opposite of the gradient. The field indicates the local density of population and we assume that cells try to avoid crowded areas and prefer locally empty spaces which are far away from the carrying capacity. We analyze the well-posedness property of the associated Cauchy problem on the real line. We start from bounded initial conditions and we consider some invariant properties of the initial conditions such as the continuity, smoothness and monotony. We also describe in detail the behavior of the level sets near the propagating boundary of the solution and we find that an asymptotic jump is formed on the solution for a natural class of initial conditions. Finally, we prove the existence of sharp traveling waves for this model, which are particular solutions traveling at a constant speed, and argue that sharp traveling waves are necessarily discontinuous. This analysis is confirmed by numerical simulations of the PDE problem. This is a joint work with Xiaoming Fu and Pierre Magal.

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MS34

A Look at the Effect of Local and Non-Local Directed Movement on the Survival of a Species Subject to an Allee Effect

The use of PDEs to model social and ecological complex systems has been popularized in the past decades. In this talk, I present a unifying model for the dynamics of ecological populations and street vendors, an important part of many informal economies. I discuss the effects of local directed movement of populations subject to the Allee Effect. Particularly, we will discuss whether directed movement can help a population overcome the Allee effect in the case of bounded and unbounded domains. I also discuss what happens under competition. Finally, I will present some related results for local and non-local aggregation equations with an Allee-effect.

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MS35

Stochastic Speed Corrections for Non-Lipschitz Noise

We describe a framework to uncover the speed corrections caused by noise-terms that are non-Lipschitz. By using perturbative techniques, we avoid the need to use the comparison principle. In this setting it is no longer sufficient to use the standard linear operators associated to the deterministic travelling waves.

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MS35

The One-Dimensional KPP Equation Driven by Space-Time White Noise

The one-dimensional KPP equation driven by space-time white noise,

$$\partial_t u = \partial_{xx} u + \theta u - u^2 + u^{\frac{1}{2}} dW, \qquad t > 0, x \in \mathbb{R}, \theta > 0, \qquad u(0,x) = u_0(x) \geq 0$$

is a stochastic partial differential equation (SPDE) that exhibits a phase transition for initial non-negative finite-mass conditions. If θ is below a critical value θ_c, solutions die out to 0 in finite time, almost surely. Above this critical value, the probability of (global) survival is strictly positive. Let $\theta > \theta_c$, then there exist stochastic wavelike solutions which travel with positive linear speed. For initial conditions that are "uniformly distributed in space', the corresponding solutions are all in the domain of attraction of a unique non-zero stationary distribution. For θ big enough, the latter also applies to arbitrary initial conditions if we condition on survival, a property called complete convergence. In my talk, I will first introduce the model in question. Then I will discuss the interplay of questions on complete convergence and positive travelling wave speeds. In particular, I will motivate constructions that allow for comparisons with N-dependent oriented site percolation with density $1 - \rho$ (cf. [Chapter 4, R. Durrett, Ten lectures on particle systems, Lectures on Probability Theory (Saint-Flour, 1993)]). Such comparisons are then used to establish the existence of positive travelling wave speeds.

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MS35

Stochastic Patterns: From Translation to Rotation

In this talk, we start with a short summary of several important mathematical results for stochastic travelling waves generated by monostable and bistable reaction-diffusion stochastic partial differential equations (SPDEs). The aim is to bridge different backgrounds and to identify the most important common principles and techniques currently applied to the analysis of stochastic travelling wave problems. Then we are going to explain a recent result on stochastic pattern formation going beyond travelling waves: stochastic rotating waves generated by SPDEs. We establish two different approaches for stochastic rotating waves, the variational phase and the approximated variational phase, which both help us to compute a stochastic ordinary differential equation (SODE), which describes the effect of noise on neutral spectral modes associated to the special Euclidean symmetry group of rotating waves. Furthermore, we prove transverse stability results for rotating waves showing that over certain time scales and for small noise, the stochastic rotating wave stays close to its deterministic counterpart.

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MS35

Ergodicity of Stochastic Patterns

In this talk I present a general framework in which one can rigorously study the effect of spatio-temporal noise on traveling waves, stationary patterns and oscillations that are invariant under the action of a finite-dimensional set of continuous isometries (such as translation or rotation). This formalism can accommodate patterns, waves and oscillations in reaction- diffusion systems and neural field equations. To do this, we define the phase by precisely projecting the infinite-dimensional system onto the manifold of isometries. Two differing types of stochastic phase dynamics are defined: (i) a variational phase, obtained by insisting that the difference between the projection and the original solution is orthogonal to the non- decaying eigenmodes, and (ii) an isochronal phase, defined as the limiting point on manifold obtained by taking t to infinity in the absence of noise. We outline precise stochastic differential equations for both types of phase. In the case that the manifold is periodic, the isochronal phase SDE is used to determine asymptotic limits for the average occupation times of the phase as it wanders in the basin of attraction of the manifold over very long times. In particular, we find that frequently the correlation structure of the noise biases the wandering in a particular direction, such that the noise induces a slow oscillation that would not be present in the absence of noise.

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MS36

Existence of Approximate Localised Dihedral Patterns near a Turing Bifurcation

Fully localised patterns involving cellular hexagons or squares have been found experimentally and numerically in various continuum models. However, there is currently no mathematical theory for the emergence of these localised cellular patterns from a quiescent state near a Turing instability. In this talk, I will present recent progress regarding the existence of approximate small-amplitude localised dihedral patterns (not necessarily hexagon or square) bifurcating from the trivial state near a Turing bifurcation for a general class of two-component reaction-diffusion systems. The planar problem is approximated through a semi-analytical Galerkin scheme; we carry out a finite-mode Fourier decomposition in polar coordinates to yield a large, but finite, system of coupled radial ordinary differential equations. We then apply radial invariant manifold techniques to derive an algebraic matching condition for localised patterns to exist in the finite-mode reduction. We analytically and numerically study this matching condition for various finite-mode reductions, uncovering a plethora of localised dihedral patterns. We conclude by using numerical continuation to find localised dihedral patterns at larger amplitudes, as well as present a proof for the existence of localised patches with 6m-fold symmetry for arbitrarily large finite-mode Fourier decompositions.

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MS36

Invasion into Remnant Instability: A Case Study of Front Dynamics

We study the invasion of an unstable state by a propagating front in a peculiar but generic situation where the invasion process exhibits a remnant instability. Here, remnant instability refers to the fact that the spatially constant invaded state is linearly unstable in any exponentially weighted space in a frame moving with the linear invasion speed. Our main result is the nonlinear asymptotic stability of the selected invasion front for a prototypical model coupling spatio-temporal oscillations and monotone dynamics. We establish stability through a decomposition of the perturbation into two pieces: one that is bounded in the weighted space and a second that is unbounded in the weighted space but which converges uniformly to zero in the unweighted space at an exponential rate. Interestingly, long-time numerical simulations reveal an apparent instability in some cases. We exhibit how this instability is caused by round-off errors that introduce linear resonant coupling of otherwise non-resonant linear modes, and we determine the accelerated invasion speed.

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MS36

Stable Stripes in a Reaction-Diffusion Model

Stable stripe patterns in a generalized Gierer-Meinhardt model Plant growth in desert-like conditions exhibits spatial patterns such as waves, dots and stripes. The time evolution of this vegetation can be modeled by the Gierer-Meinhardt equations; a set of reaction-diffusion equations describing a system of an activator (water) and an inhibitor *vegetation*. In this model the localized stripe pattern is described as a one-dimentional pulse solution that is translation invariant in the second spatial direction. These types of stripe patterns are, unfortunately, unstable with respect to instabilities along the stripe. We study a class of singularly perturbed reaction-diffusion systems that generalize the one-dimensional Gierer-Meinhardt equations. Using geometrically singular perturbation theory we show that, under the right conditions, these systems can exhibit a $slow - fast$ double front solution. When extended to two spatial dimensions this pattern can be thought of as localized stripe solutions, but we show it to be non-linearly stable using spectral theory. Furthermore, the geometric existence proof allows us to keep track of the stability and study the onset of instability as we vary the parameters in the model, as well as interpret the behaviour around bifurcation points.

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MS36

Towards Controllable Chaotic Dynamics of Lo-

calised Structures

The aim of this work is to design and analyse a system of singularly perturbed reaction diffusion equations that support localised structures that exhibit chaos. The main candidate system we investigate is a generalised four-component singularly perturbed FitzHughNagumo model that couples a fast perturbed Allen-Cahn component to three slow linear components. In previous works (M. Chirilus-Bruckner et al. , J. Nonl. Science, 2015, 2019) we used geometric singular perturbation theory, the nonlocal eigenvalue problem approach for Evans function analysis and centre manifold reduction to analyse localised structures in its three-component counterpart. We envision that by appropriately choosing the nonlinear coupling of the fast component with the slow components, we can imprint any desired singularity structure into the extended model and this could lead to a normal form of a chaotic system. So, this would lead to one of the rare cases where chaos can be rigorously proved in the context of a nonlinear PDE.

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MS37

Ripples

Wilton Ripples are a class of resonant traveling waves which are a nonlinear combination of two Stokes waves at a special value of the Bond number. These waves exist and are parametrically analytic (in amplitude) in a number of wave models. An analogy between these waves and the eigenvalue collisions in the spectral stability problem is made. Extensions of recent Wilton ripple results to the spectrum of Stokes waves will be discussed. Joint with David Nicholls and Olga Trichtchenko.

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MS37

Extreme Superposition: High-Order Rogue Waves and Solitons, and Solutions Interpolating Between Them

We present a family of solutions of the focusing nonlinear Schrdinger equation that contains fundamental rogue waves and multiple-pole solitons of all orders. This family is indexed by a continuous parameter, allowing us to continuously tune between between rogue waves and solitons of different integer orders. In this framework the parameter represents the order, and solitons and rogue waves of increasing integer orders alternate as the continuous order parameter increases. We show that solutions in this family exhibit certain universal features in the limit of large continuous order. This is joint work with Peter Miller (U. Michigan).

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MS37

Stability of Waves on Fluid of Infinite Depth with Constant Vorticity

We investigate the stability of periodic travelling waves on infinite depth fluid when there is a constant background shear field and ignoring the effects of gravity and surface tension. The base waves are described by a exact solution that was discovered recently by Hur Wheeler (2020) and which, remarkably, has identical surface wave profiles to the Crapper solution for capillary waves. We calculate linear growth rates using both an asymptotic approach valid for small amplitude waves and a numerical approach based on a collocation method. Both superharmonic and subharmonic perturbations are considered. We find that instability occurs for any non-zero amplitude wave.

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MS37

Stability Analysis of Solutions to the b-family of Peakon Equations

The Camassa-Holm equation with linear dispersion was originally derived as an asymptotic equation in shallow water wave theory. Among its many interesting mathematical properties, perhaps the most striking is the fact that it admits weak multi-soliton solutions - 'peakons' - with a peaked shape corresponding to a discontinuous first derivative. There exists a one-parameter family of generalized Camassa-Holm equations, most of which are not integrable, but which all admit peakon solutions. In this talk, we establish information about the point spectrum of the peakon solutions and notably find that for suitably smooth perturbations there exists point spectrum in the right half plane rendering the peakons unstable for $b < 1$. The linearized operator is extended on the space of functions $L^2(\mathbb{R})$. For $b \neq \frac{5}{2}$, the spectrum of that extended linearized operator is proved to cover a closed vertical strip of the complex plane around the imaginary axis. For $b = \frac{5}{2}$, the strip shrinks to the imaginary axis, but an additional pair of real eigenvalues exists due to projections to the peakon and its spatial translation. We explore numerically these ideas for the different parameter regimes. We also discuss recent results concerning the nonlinear stability of smooth solitary wave solutions on a nonzero background. These results were obtained in collaboration with E.G. Charalampidis, P.G. Kevrekidis, R. Parker, and D.E. Pelinovsky.

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MS38

Zero-Dispersion Limit for the Benjamin-Ono on the Torus

We discuss the zero-dispersion limit for the Benjamin-Ono equation on the torus given a single well initial data. We prove that there exist approximate initial data converging to the initial data, such that the corresponding solutions admit a weak limit as the dispersion parameter tends to zero. The weak limit is expressed in terms of the multivalued solution of the inviscid Burgers equation obtained by the method of characteristics. We construct our approximation by using the Birkhoff coordinates of the initial data, introduced by Grard, Kappeler and Topalov. We compare this description with previous works from Miller, Xu and Miller, Wetzel for the same equation on the real line.

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MS38

Shielding of Soliton for the Focusing Nonlinear Schroedinger Equation

We consider a gas of N solitons for the Focusing Nonlinear Schr odinger (FNLS) equation in the limit N ? 8 with a point spectrum chosen to interpolate a given spectral soliton density over a domain of the complex spectral plane. We call this class of initial data, deterministic soliton gas. We show that when the domain is a disc and the soliton density is an analytic function, then the corresponding deterministic soliton gas surprisingly yields the one-soliton solution with point spectrum the center of the disc. We call this effect soliton shielding. When the domain is an ellipse, the soliton shielding reduces the spectral data to the soliton density concentrating between the foci of the ellipse. The physical solution is asymptotically step-like oscillatory, namely, the initial profile is a periodic elliptic function in the negative xdirection while it vanishes exponentially fast in the opposite direction.

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MS38

Inverse Scattering and Asymptotics for the Sine-Gordon Equation and Massive Thirring Model

In this talk we present our current result on the analysis of the sine-Gordon equation and massive Thirring model. Although the inverse scattering transform for both integrable PDEs are well-established, we are yet to give a rigorous justification of the Inverse scattering transform and long-time analysis. We are mainly interested in prescribing the suitable function space for the initial condition and studying role of the phase factor $z \pm z^{-1}$ played in the analysis. This is joint work with Gong Chen, Cheng He and Bingying Lu.

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MS38

Higher Order Airy and Painlev Asymptotics for the mKdV Hierarchy

In this talk, we consider Cauchy problem for the modified Korteweg-de Vries hierarchy on the real line with decaying initial data. Using the Riemann–Hilbert formulation and nonlinear steepest descent method, we derive a uniform asymptotic expansion to all orders in powers of $t^{-1/(2n+1)}$ with smooth coefficients of the variable $(-1)^{n+1}x((2n+1)t)^{-1/(2n+1)}$ in the self-similarity region for the solution of n-th member of the hierarchy. It turns out that the leading asymptotics is described by a family of special solutions of the Painlev II hierarchy, which generalize the classical Ablowitz-Segur solution for the Painelv II equation and appear in a variety of random matrix and statistical physics models. We establish the connection formulas for this family of solutions. In the special case that the reflection coefficient vanishes at the origin, the solutions of Painlev II hierarchy in the leading coefficient vanishes as well, the leading and subleading terms in the asymptotic expansion are instead given explicitly in terms of derivatives of the generalized Airy function. Joint work with Lin Huang.

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MS39

Spatio-Temporal Heterogeneities in a Mechano-Chemical Model of Collective Cell Migration

Models for the chemical polarization of motile cells described by reaction-diffusion systems have been studied mathematically to determine conditions for spontaneous polarization that leads to directed cell motility. A more complex problem is how a cells interact and repolarize (reverse their direction) when they meet. Mathematically, this requires destabilization of a nonuniform steady state chemical distribution and stabilization of the symmetrically opposite state. Advanced PDE bifurcation analysis is applied to a popular model for cell polarization ('wave-pinning') to characterize the distinct outcomes of cell-cell collisions. The results are applied to finding conditions for 1D cell "trains" where many cells synchronize to repolarize and move in the same direction.

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MS39

Mechanochemical Waves in Collective Cell Migration

Collective cell migration offers a rich field of study for non-equilibrium physics and cellular biology, revealing phenomena such as glassy dynamics, pattern formation and active turbulence. However, how mechanical and chemical signalling are integrated at the cellular level to give rise to such collective behaviours remains unclear. We address this by focusing on the highly conserved phenomenon of spatiotemporal waves of density and extracellular signal-regulated kinase (ERK) activation, which appear both in vitro and in vivo during collective cell migration and wound healing. First, we propose a biophysical theory, backed by mechanical and optogenetic perturbation experiments, showing that patterns can be quantitatively explained by a mechanochemical coupling between active cellular tensions and the mechanosensitive ERK pathway. Next, we demonstrate how this biophysical mechanism can robustly induce long-ranged order and migration in a desired orientation, and we determine the theoretically optimal wavelength and period for inducing maximal migration towards free edges, which fits well with experimentally observed dynamics. We thereby provide a bridge between the biophysical origin of spatiotemporal instabilities and the design principles of robust and efficient long-ranged migration.

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MS39

Moving Spiral Wave Chimeras

In this talk, we describe a new type of spiral wave observed in discrete oscillatory media with nonlocal interaction. We consider a two-dimensional array of heterogeneous nonlocally coupled phase oscillators with periodic boundary conditions and study the bound states of two counter-rotating spiral chimeras. Each spiral chimera is a spiral pattern with synchronized (coherent) spiral arms and a spatially randomized (incoherent) core. Unlike other known spiral chimeras with motionless incoherent cores, the two-core spiral chimeras typically exhibit drift motion. Due to this drift, their incoherent cores become spatially modulated and develop specific fingerprint patterns of varying synchrony levels. In the continuum limit of infinitely many oscillators, the two-core spiral chimeras can be studied using the Ott-Antonsen equation. Numerical analysis of this equation allows us to identify three main classes of these chimeras: symmetric, asymmetric, and meandering spiral chimeras.

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MS39

Nonlinear Initiation of Side-Branching by Biochemical Morphogenesis

An understanding of the underlying mechanism of side-branching is paramount in controlling and/or therapeutically treating mammalian organs, such as lungs, kidneys, and glands. Motivated by an activator-inhibitor-substrate approach that is conjectured to dominate the initiation of side-branching in a pulmonary vascular pattern, I demonstrate a distinct transverse front instability in which new fingers grow out of an oscillatory breakup dynamics at the front line without any typical length scale. These two features are attributed to unstable peak solutions in 1D that subcritically emanate from Turing bifurcation and that exhibit repulsive interactions. As such, the generation of finite-amplitude transversely localized oscillations at the front line represents a template from which localized physical structures develop in the transverse direction in 2D. The results are based on bifurcation analysis and numerical simulations and provide a potential strategy for developing a framework of side-branching for other biological systems, such as plant root hairs, cancer, cellular protrusions, and even somitogenesis.

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MS40

Pattern Formation in Random Networks Using Graphons

Turing bifurcations are the primary pattern forming mechanism in spatially extended systems. In this talk we will demonstrate how to understand Turing bifurcations on one-dimensional random ring networks, characterized by the fact that the probability of a connection between two nodes depends on the distance between the two nodes. We will discuss an approach that uses the theory of graphons to approximate the graph Laplacian in the limit as the number of nodes tends to infinity by a nonlocal operator - the graphon Laplacian. For large networks we derive estimates that relate the eigenvalues and eigenvectors of the finite graph Laplacian to those of the graphon Laplacian. We apply these results to the Swift-Hohenberg equation, which is a phenomenological model for systems undergoing a Turing bifurcation. We prove that with high probability the bifurcations that occur in the finite graph are well approximated by those in the graphon limit, allowing one to understand pattern formation in random landscapes simply through the limiting nonlocal graphon Swift-Hohenberg equation.

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MS40

Pinning and Propagation Reversal on Infinite K-ary Trees

Wave-pinning is a famous property of traveling wave solutions to bistable reaction-diffusion LDEs posed on the integer lattice $\mathbb{Z}$. In short, for small diffusion parameters, the wave speed is zero, and the wave does not propagate for a range of bistable parameters. This result inspired us to study traveling wave solutions to LDEs posed on infinite k-ary trees. Our primary question is how propagation direction of the wave changes as we vary the diffusion parameter d and the bistable parameter a. We show that small diffusion leads to pinning. With increasing diffusion, the wave travels in both directions, depending on the parameter a. However, as we further increase the diffusion, the wave propagates in a single direction, for all bistable parameters a. This phenomenon does not happen for the traditional LDEs posed on the integer lattice. In particular, our results imply that the change of diffusion parameter can lead to the reversal of the propagation direction.

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MS40

Graphon Dynamical Systems: a Law of Large Numbers, Large Deviations, and Metastability

For a class of interacting particle systems on random graphs we review the derivation of the continuum limit and discuss a law of large numbers and a large deviation principle. We further extend the continuum limit formalism to interacting diffusions on graphs. As an application, we examine metastable transitions in the Kuramoto model of coupled phase oscillators.

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MS40

Numerical Continuation for Fractional PDEs Within PDE2path

Partial differential equations (PDEs) involving fractional Laplace operators have been used increasingly to model non-local diffusion processes and are actively investigated using both analytical and numerical approaches. In order to study the effects of the spectral fractional Laplacian on the bifurcation structure of reaction-diffusion systems on bounded domains, we need advanced numerical continuation techniques to compute the solution branches. Since currently available continuation packages only support systems involving the standard Laplacian, we extend the pde2path software to treat fractional PDEs (in the spectral definition). The numerical approximation is based on a sinc quadrature approximation of the Balakrishnan representation formula. The new capabilities are then applied to the study of the Allen-Cahn equation, the Swift-Hohenberg equation and the Schnakenberg system (in which the standard Laplacian is replaced by the spectral fractional Laplacian). In particular, we investigate the changes in snaking bifurcation diagrams and in the spatial structure of non-trivial steady states upon variation of the fractional order.

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MS41

Stochastic Slow Manifolds and Interface Motion

We consider stochastic partial differential equations, for example the Cahn-Hilliard or Allen-Cahn equation perturbed by additive noise, and study the dynamics of interfaces or droplets. For small noise the dynamics of the stochastic infinite dimensional system is well approximated by the motion along a deterministic finite dimensional slow manifold M parametrized by the interface or droplet positions. An SDE on the manifold describes the motion well for very long time-scales until an interface breaks down or the droplets merge. In the abstract approach the main results are the stochastic stability and the attractivity of the manifold M and the derivation of an effective equation on the manifold. This is joint work with Alexander Schindler, Dimitra Antonoupoulu and Georgia Karali.

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MS41

Understanding Stochastic Waves in Cell Movement Models, from Gillespie Algorithms to (S)PDEs

Single-cell organisms are remarkably good at sensing food, especially if you consider that they lack our sensing organs and have to measure a gradient in the food supply over the length of a single cell. The precise mechanisms behind this gradient sensing are not fully understood yet, but scientists have determined many relevant molecules that are relevant in the motion of the cell and we can see how these molecules are activated in wavelike patterns. These processes can be used to build Gillespie-type stochastic models for cell movement. These models are complex, both numerically and analytically, so we often summarise everything into 'simpler' PDEs. In this talk, I would like to advocate an in-between option, so-called Chemical Langevin Equations, effectively an SPDE approximation of the Gillespie algorithms. This approach allows us to use all the insights from the underlying deterministic PDE, without throwing away the stochastic nature of the models.

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MS41

Center Manifolds for Rough PDEs

We prove a center manifold theorem for rough partial differential equations (rough PDEs). The class of rough PDEs we consider contains as a key subclass reaction-diffusion equations driven by nonlinear multiplicative noise, where the stochastic forcing is given by a γ-Hlder rough path, for $\gamma \in (1/3, 1/2]$. Our proof technique relies upon the theory of rough paths and analytic semigroups in combination with a discretized Lyapunov-Perron-type method in a suitable scale of interpolation spaces. The resulting center manifold is arandom manifold in the sense of the theory of random dynamical systems. We also illustrate our main theorem for reaction-diffusion equations as well as for the Swift-Hohenberg equation.

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MS41

Stabilization by Boundary Noise: Chafee-Infante

Equation with Dynamical Boundary Conditions

The stabilization of parabolic PDEs by multiplicative noise is a well know phenomenon that has been studied extensively over the past decades. However, the stabilizing effect of a noise that acts only on the boundary of a domain had not been investigated so far. As a first model case we consider the Chafee-Infante equation with dynamical boundary conditions and analyze whether a multiplicative It noise on the boundary can stabilize the equation. We prove that there exists a finite range of noise intensities that imply the exponential stability of the zero steady state. Our results differ from previous works on stabilization, where the noise acts inside the domain and stabilization typically occurs for an infinite range of noise intensities.

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MS42

Gravity-Driven Thin Liquid Flow on Vertical Fibers: Experiments and Applications

Viscous thin liquid films flowing down vertical strings can exhibit interesting dynamics via the formation of droplets. Motivated by novel experimental results, we present a thin film model for the gravity-driven flow. The experimental data agreement with the numerical solutions provides information which can be used as a predictive tool for designing heat/mass exchanger equipments.

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MS42

Onsagers Principle, Variational Inequality for Two-Way Coupling Obstacle Problems

In this talk, I will discuss the dynamics of droplets placed on impermeable substrate coupled with moving contact line. With insoluble surfactant laid on the capillary surface, the adhesion of droplets to some textured substrates becomes more complicated: (i) insoluble surfactant disperses along the evolving capillary surface (ii) the surfactant-dependent surface tension will in turn drive the full dynamics of droplets, particularly the moving contact lines. and focus on the Onsagers principle and variational inequality for obstacle problems and the associated computations. To enforce impermeable obstacle constraint, the full dynamics of the droplet can be formulated as a gradient flow on a manifold with boundary, and two equivalent variational inequalities are derived using Onsager's principle for obstacle problems. A projection method for the variational inequality with phase transition information at emerged contact lines is developed to compute the contact angle hysteresis, unavoidable splitting/merging of droplets.

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MS42

Thermally-Driven Coalescence in Thin Liquid Films Flowing Down a Fiber

In this talk, a study on the dynamics of a thin liquid film flowing down a vertical cylindrical fiber under a stream-wise thermal gradient will be discussed. Previous works on isothermal flows have shown that the inlet flow and fiber geometry are the main factors that determine a transition from the absolute to the convective instability flow regimes. Our experiments demonstrate that an irregular wavy pattern and bead coalescence, which are commonly seen in the convective regime, can also be triggered by applying a thermal gradient along the fiber. We develop a lubrication model that accounts for gravity, temperature-dependent viscosity, and surface tension to describe the thermal effects on downstream bead dynamics. Numerical simulations of the model show good agreement between the predicted droplet coalescence dynamics and the experimental data.

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MS42

Modeling Plug Formation in Falling Films Inside Tubes: Impact of Surfactant and Viscosity Stratification

Viscous liquid films coating the interior of a tube occur in a variety of applications. If the film is thick enough, it may pinch off and form a plug, occluding the tube. In this talk I will discuss recent work examining the impact of surfactant and viscosity stratification both of which are relevant for understanding occlusion in human airways on plug formation.

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MS43

Special Solutions of Painlev II via Orthogonal Poly-

nomials

This work centers around a family of orthogonal polynomials corresponding to the measure

$$\mathrm{d}\mu(z) = e^{-NV(z;t)}\mathrm{d}z, \quad z \in \Gamma$$

where Γ is a particular contour in the complex plane and

$$V(z;t) := -\frac{1}{3}z^3 + tz, \quad t \in \mathbb{C}.$$

These polynomials arise naturally while studying the complex cubic ensemble of random matrices and have an intimate relationship with special function solutions of Painlev II. Since the weight of orthogonality is complex-valued, the corresponding polynomials are more difficult to analyze in the large-degree limit; a particular difficulty being that the nth polynomial might have degree less than n. In this talk, I will highlight the relationship between the family of orthogonal polynomials and special solutions of Painlev II and discuss some of the important features of the large-degree asymptotic analysis of the orthogonal polynomials in the regime where $|n - N|$ remains bounded.

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MS43

Quantization of Benjamin-Ono Periodic Traveling Waves

The Benjamin-Ono equation is a model for a variety of classical fluid interfaces. In addition, the quantization of this model is conjectured to describe such interfaces at scales in which quantum effects must be taken into account. In this talk, we present recent results on (I) the quantization of the multi-phase ensembles of interacting Benjamin-Ono periodic traveling waves and (II) the relation between these coherent structures and models in integrable probability.

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MS43

Integrable Systems Governing KPZ Fixed Points

Consider the totally asymmetric simple exclusion process (TASEP) on the line and the ring with the step initial condition. We are interested in the infinite time scaling limit of these models. Its one point distribution as the function of three variables is the tau function of the Kadomtsev-Petviashvili (KP-II) equation. The multitime distribution have the representation as the multiple contour integral of the integrable Fredholm determinant. We study the differential equations associated to it.

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MS44

The Entropy of Collective Motion Patterns

One of the main challenges in the research of collective motion phenomena lies in quantitative characterization of the dynamics. Statistical physics provides some widely used tools, such as correlation functions, density fluctuations and approximations to known processes. These can be used, with some partial success, to classify collective states and compare swarming regimes. However, one of the major tools of statistical physics the entropy has seldom been used. Entropy is one of the principle thermodynamic variables and its definition can be extended to nonequilibrium systems based on its relation to information (Shannon entropy). However, applying this definition in practice is practically impossible. In this talk, I present a new method that relates the entropy to other integrated, macroscopic properties, which are accessible experimentally. The advantage of using entropy to characterize collective motion is demonstrated in examples, including swarming bacteria.

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MS44

Modelling and Controlling Vortex Dynamics in Active Fluids and Cardiac Tissue

Many relevant experimental systems and applications exhibit irregular dynamics such as spatiotemporal chaos or turbulence. In this talk, two examples of such behavior will be presented where the goal is to control such states and transform their dynamics into a homogeneous steady-state or a regular periodic pattern. The specific applications are (i) defibrillation of cardiac tissue by periodic pacing and (ii) turbulence in active suspensions. For the cardiac system, we used simulations as well as data analysis not only to identify suitable conditions e. g. pacing strength and periods, but also to determine the mechanism of defibrillation in this specific modus. For active turbulence, a simple phenomenological deterministic continuum model was used for quantitative modeling of experimental control in bacterial suspensions. Detailed investigations showed how the turbulent collective dynamics could be transformed into more regular, periodic spatiotemporal patterns using a periodic array of obstacles. This is in line with recent experimental findings using confinement by an array of pillars. A follow-up study addresses the competition between the controlling effect of confinement and a nonlinear advection term behind the emergence of turbulence in active fluids demonstrating that the breakdown of control is associated with an Ising-like phase transition.

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MS44

Self-Organized Marine Vegetation Patterns and Traveling Pulses

Factors such as competition for water and nutrients, or interactions through herbivores or toxic agents drive spatial instabilities in landscapes of terrestrial plants, resulting in pattern formation phenomena that have been a subject of intense research. Observations from air and side-scan sonar data have recently revealed analogous pattern forming phenomena in submerged vegetation in the Mediterranean Sea, mainly in meadows of seagrasses such as Posidonia oceanica and Cymodocea nodosa. Beyond the formation of stationary periodic patterns, traveling pulses of vegetation forming rings and spirals are also observed from the aerial images. In this talk I'll present models derived from the growth rules of these clonal plants able to provide an explanation and reproduce the observed submarine patterns of isolated fairy circles, landscapes of spots and stripes, and the formation of expanding rings. I'll discuss also the interaction mechanisms at play leading to these dynamical regimes. Beyond a qualitative description of the observed patterns, and their prevalence under different meadow conditions, the model fits well measurements of the population density of Posidonia.

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MS44

A Particle-Field Approach Bridges Phase Separation and Collective Motion in Active Matter

Active matter research focuses on the emergent behavior of interacting self-propelled particles. Linking seemingly disconnected realms of active matter – active phase-separation of repulsive discs and collective motion of self-propelled rods – is a major contemporary challenge. In this talk, we present a framework based on the representation of active particles by smoothed continuum fields which brings the simplicity of alignment-based models, enabling analytical analysis, together with more realistic models for self-propelled objects including their steric, repulsive interactions. Based on the collision kinetics, we demonstrate how non-equilibrium stresses acting among self-driven, anisotropic objects hinder the formation of phase-separated states as observed for self-propelled discs and facilitate the emergence of orientational order. Besides particle shape, the rigidity of self-propelled objects controlling the symmetry of emergent ordered states is as a crucial parameter: impenetrable, anisotropic rods are found to form polar, moving clusters, whereas large-scale nematic structures emerge for soft rods, notably separated by a bistable coexistence regime. These results indicate that the symmetry of ordered states is not dictated by the symmetry of the microscopic interactions but is rather a dynamical, emergent property of active systems. The presented framework may represent various systems including bacterial colonies, cytoskeletal extracts, or shaken granular media.

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MS45

Coupled Cell Systems: Patterns of Synchrony, Quotients and Lifts

Coupled cell systems are dynamical systems that can be interpreted as individual systems that interact. The structure of a coupled cell system can be abstracted by a coupled cell network - each cell represents an individual dynamical system and the connections the mutual interactions between those individual dynamics. One of the main aims in the study of coupled cell systems is to understand the collective dynamics forced by the associated network structure, independently of the specific dynamics at the nodes. A relevant example are the synchrony subspaces - subspaces defined by equalities of cell coordinates and that are flow-invariant by all the coupled cell systems that are compatible with the network structure. The existence of synchrony subspaces can have a strong impact on the dynamics, for example in terms of bifurcations. The synchrony subspaces of a network are in a one-to-one correspondence with its balanced equivalence relations (colorings) and form a complete lattice. The restriction of a coupled cell system to a synchrony subspace is again a coupled cell system associated with a quotient network - where cells in the same class are identified. The original network is said to be a lift of the smaller network. Considering codimension-one steady-state synchrony-breaking bifurcations of coupled cell systems, the lifting bifurcation problem addresses the issue of understanding when the bifurcation branches of a network can be lifted from its quotient networks.

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MS45

Fibration Symmetry in Networks

A fibration of graphs is a local isomorphism of in-neighbourhoods, much in the same way a covering projection is a local isomorphism of neighbourhoods. Fibrations express a form of symmetry that is sensitive to inputs of nodes, but not to their outputs, and as such it has natural applications to biological, physical and distributed systems described by directed networks where synchrony is determined by incoming signals only. In this talk we will provide some basic definitions, examples and connections to other important concepts (like centrality, computability and self-stabilizing systems).

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MS45

Symmetry in Dynamical Systems

Going back to Henri Poincar, the main concern of dynamical systems theory is the qualitative characterization of solutions. Symmetries, described by group transformations, help immensely in this quest - providing that they exist, which is often the case only in very special dynamical systems. In this work, we significantly enlarge the class of dynamical systems which can be studied by symmetry methods, moving our focus from groups to groupoids as the underlying algebraic structure. Building on the groupoid framework, we crucially generalize the notion of symmetry and equivariance. As a result, we obtain a generalized equivariant bifurcation theory. In particular we prove equivaroid versions of the Equivariant Branching Lemma and the Equivariant Hopf Bifurcation Theorem.

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MS45

Generalising Symmetry via Quiver Representations: Equivariant Dynamics and Applications

Symmetry is an important driving mechanism that induces all sorts of intriguing dynamics. While classical symmetries of an ODE system are usually given by representations of groups, we observe that the central property allowing them to impact dynamics is the fact that they are given by (linear) maps sending solutions to solutions. This allows to greatly generalise the concept of symmetry to relate different dynamical systems with arbitrary linear maps. Once again, these symmetries can be summarized in an algebraic structure, namely that of a quiver. We explore how quiver symmetries impact and organise dynamics and illustrate their value for network dynamical systems.

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PP1

Compressible Navier-Stokes Equations with Heat Transfer by Finite Element Method

In the real world, most fluid flow situations are described by Navier-Stokes equations, which are models of nonlinear partial differential equations. The nonlinearity is caused by convective acceleration, which is an acceleration associated with the change in velocity in time. It is very difficult to describe and analyze most problems because of nonlinearities that make them impossible to solve. However, if the Navier-Stokes equations are solved, they can also be used to describe and analyze more complex materials and fluid flow problems. The numerical solution of Navier-Stokes equations can be carried out using a number of different approaches at present, including finite difference, finite volume, and finite element methods. In this work, we intend to study the Taylor vortex flow of compressible viscous fluid with heat transfer in a unit square cavity. For simplicity, assumed that pressure satisfies the isentropic state equation. The governing partial differential equations system is solved by finite difference-element method with periodic boundary conditions. Euler backward method is applied for time discretization and the finite element method is for space discretization. Time evolution of the density, velocity components, and temperature are examined in the form of contour.

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PP1

Non-Stationary Radially Symmetric Patterns in a Three-Component FitzHugh-Nagumo System

In this work, we study the dynamics of patterns in a planar three-component FitzHugh-Nagumo reaction-diffusion model. We focus on dynamically evolving radially symmetric solutions with N interfaces. By using geometric singular perturbation theory, we show the formal derivation of systems of ODEs that describe the evolution of the position of the interfaces along the radial axis. In addition, we describe the stability of radially sym- metric stationary and non-stationary solutions such as spot, ring, and spot-ring patterns. Numerical simulations of solutions of the three-component FitzHugh-Nagumo system are performed to illustrate and confirm the results of the dynamics of the patterns with three and four interfaces. Non-stationary radially symmetric solutions include a stationary spot solution surrounded by a non-stationary ring solution with non-constant width as well as solutions in which interfaces may collide, resulting in a reduction of the number of interfaces.

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PP1

Analysis of Kerr Frequency Combs in Silicon Microresonators

Stationary 2π-perodic solutions of the Lugiato-Lefever equation (LLE)

$$\mathrm{i}\frac{\partial a}{\partial t} = -d\frac{\partial^2 a}{\partial x^2} + (\zeta - \mathrm{i} - |a|^2)a + \mathrm{i}f$$

can be used as a model for frequency combs. From a practical point of view, silicon-based microresonators are of particular interest. To analyze the formation of frequency combs in such materials, a modification of the LLE is needed which takes into account two-photon absorption and free carrier absorption. We show that modulation instability occurs for a certain parameter range, which could lead to subsequent comb formation.

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PP1

Center Manifolds in Nonlocal Systems

We construct center manifolds for nonlocal spatial dynamics in spatially extended systems, under optimal regularity assumptions for the nonlinearity. The reduced vector fields and phase space are identified a posteriori through the shift on bounded solutions. A key ingredient is Fredholm properties of linear operators on C^0, with pointwise invertibility of the principal part together with invertibility at spatial infinity identified as necessary and sufficient conditions for Fredholm. As an application of nonlocal center manifolds, we establish uniqueness of small periodic wave trains in a Lyapunov center theorem using only C^1-regularity of the nonlinearity.

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PP1

Delayed Feedback Stabilization with and Without Symmetry

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PP1

Oblique Stripes and Checkerboards in the Quenched Cahn-Hilliard Equation

The Cahn-Hilliard equation is used to model phase separative pattern formation in many contexts, such as binary alloy mixtures, chemical precipitation, and evaporative deposition experiments, and can form many different types of patterns. In two spatial dimensions, we study which types of transversely modulated patterns can be selected in the wake of a simple plateau quenching heterogeneity. Such a heterogeneity spatially progressively travels across the domain with fixed speed, exciting patterns in its wake. Using a functional analytic approach based on exponential weights and Lyapunov-Schmidt reduction, we show that two families of patterns, induced by $O(2)$-symmetry in the system, generically arise via a Hopf bifurcation from the background front as the quenching speed is varied.

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PP1

Stability and Approximation of Dispersive Electromagnetic Surface Waves

We study Maxwell equations at an interface between optical media with memory and saturable nonlinearity. As an evolutionary equation, this system is well-posed in an exponentially weighted Bochner-type Hilbert space. Moreover, under spectral conditions on the material functions, solutions to small data decay exponentially with time. The linearization admits a family of evanescent surface modes. Constructing an ansatz based on these modes for the nonlinear system, an amplitude equation can formally be derived. Exponential stability of the error equation provides a strategy to justify the amplitude equation over long time scales.

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PP1

Orbital Stability and Quantisation in a Pilot-Wave System

We present the results of asymptotic analyses into the dynamics of a vibrating particle propelled by its quasi-monochromatic self-induced wave field, under the influence of a Coriolis force. This pilot wave encodes the history of the particle motion. When subject to a Coriolis force, the particle trajectories take the form of circular orbits, whose orbital radii appear to be quantised. Using a novel asymptotic expansion for the pilot-wave stability function, we propose a physical mechanism for orbital quantisation and demonstrate the relationship between the instability of the free walking state and the end of orbital quantisation. We also show the relationship between the curvature of the mean wave field and the type of instability undergone by the corresponding circular orbit. In addition, we highlight the influence of various types of resonance in orbital stability, and thus present a detailed characterisation of orbital stability under the influence of a Coriolis force.

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PP1

Stepsize Variations for Lyapunov Exponents to Counter Persistent Errors

Lyapunov exponents are important quantities in the analysis of complex dynamical systems. Most commonly, they are computed with Benettin's algorithm, which propagates linear perturbations along a background trajectory. While many application trust in convergence of the algorithm, they often do not consider the effects of numerical errors. In fact, the convergence of Benettin's algorithm strongly depends on the relation between numerical errors and stepsizes. With the usual constant stepsizes, integration errors accumulate and lead to limits different from the Lyapunov exponents. We investigate how integration errors can affect the convergence of Benettin's algorithm and suggest stepsize variations and weighted averages to counter persistent errors. Our examples demonstrate that both of the suggested approaches can improve the accuracy and the speed of convergence of Benettin's algorithm. More rigorous results are obtained in a theoretical analysis, in which we derive conditions for stepsizes and weights under which Benettin's algorithm convergences in the presence of linear integration errors.

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PP1

A Parametric Basis for the Internal Wave Model Idemix

The IDEMIX (Internal Wave Dissipation, Energy and Mixing) model links internal gravity wave (IGW) energy sources and dissipation and thereby provides an energetically consistent representation of wave-induced mixing and drag in the ocean and atmospheric general circulation models. The energy spectrum of internal gravity wave (IGW) has a power-law kind of correlation structure with bandwidth where bandwidth is a width parameter for the wavenumber spectrum. A coupled system of predictive equations for energy and bandwidth (for up-and downward propagating waves) results in a bandwidth that relates to energy by a power-law with an exponent given by the dynamical parameters. The power-law agrees with the Argo float observation dataset for energy, bandwidth, and slope. Power-law implementation of the coupled energy-bandwidth model for 1D IDEMIX on the Arakawa C-grid is presented.

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PP1

Rigorous Asymptotic Analysis and Numerics for 2D Maxwell's Equations with Interface

We consider Maxwell's Equations in 2D for two Kerr isotropic media with a planar interface. For space-dependent material functions we formally construct an approximative solution with the method of amplitude equations where the envelope is given by a nonlinear Schrdinger equation. By extending an existing well-posedness result with the help of a bootstrapping argument we show the exact approximation properties on a large time-scale analytically. We also present numerical methods to compute the asymptotic solution and suitable initial values close to the ansatz such that solutions of Maxwell's equations exist.

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PP1

Data-Driven AKNS Lax-Pair Identification Using Conserved Quantities

The nonlinear Fourier transform (NFT) (a.k.a. Direct Scattering Transform) is a powerful tool which can analytically solve a Lax-integrable nonlinear partial differential equation (PDE) $u_t = F(u, u_x, \dots)$, as well as predict the presence of solitonic components [Ablowitz, Kaup, Newell, Segur, 1974]. Given space series $u(x, t_n)$, it would be beneficial to identify an integrable PDE that governs the system as closely as possible. We investigate the possibility of identifying the structure of an AKNS-type integrable system from data. AKNS-type PDEs share a clear structure for their Lax pairs, in which the first Lax-operator is defined as

$$L = \begin{bmatrix} i\partial_x & -iq \\ ir & -i\partial_x \end{bmatrix},$$

where $q(u)$ and $r(u)$ are functions of the measured quantity u. For example, the focussing nonlinear Schroedinger equation arises from $(q, r) = (u, -u^*)$. Associated with the L-operator is an infinite number of conserved quantities that only depend on q and r. Our proposal is to expand the functions q and r as linear combinations of predefined terms of u. Then, the coefficients of the expansions are determined such that the first N quantities are conserved as best as possible for the dataset $u(x, t)$. The advantages and disadvantages of this proposal are discussed, and numerical examples are presented.

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