Featured Speakers

Andrew Archer (University of Loughborough)

Patterns formed in soft matter after a quench

Results will be presented for two-dimensional systems of soft particles interacting via soft potentials that may be considered to be simple models for the effective interaction between dendrimers and other such polymeric macromolecules in solution. Density functional theory and Dynamical Density Functional Theory (DDFT) are used to study the structures that are formed from quenching the uniform liquid to a state where it is unstable with respect to freezing. The systems that we study all have a common feature: there are two lengths and two energy scales in the interaction potential(s). The systems we study include both binary mixtures and one-component systems. The interplay of the different length and energy scales during the solidification process can lead to a variety of different equilibrium and metastable structures (i.e. global and local minima of the free energy), including crystals, disordered solids, quasicrystals (QC) and a so-called crystal-liquid. The latter is an exotic periodic state with a sizeable fraction of highly mobile particles. The QC structures may be created by a competition between linear instability at one scale and nonlinear selection of the other. This dynamic mechanism for forming QCs is qualitatively different from mechanisms observed previously. The system first forms a small length scale crystal. Only when this phase is almost fully formed (i.e., the dynamics is far into the nonlinear regime) does the longer length scale start to appear, leading to the formation of QCs.

Dwight Barkley (University of Warwick)

Patterns and Dynamics in Shear Turbulence

More than a century ago Osborne Reynolds launched the quantitative study of turbulent transition as he sought to understand the conditions under which fluid flowing through a pipe would be laminar or turbulent. Since laminar and turbulent flow have vastly different drag laws, this question is as important now as it was in Reynolds' day. I will recall some of the history of hydrodynamic stability theory with a view to explaining why even the simplest case of pipe flow is both a fascinating and difficult problem. Then I will exploit a surprising analogy between the subcritical transition to turbulence and the dynamics action potentials in neurons to understand the onset of turbulence in pipe flow. The focus here is on fronts connecting laminar flow (quiescent state) to turbulent flow (excited state). Combining with experiments and simulations, the various stages in the transition to turbulence are explained.

Alain Bergeon (IMFT)

Localised states in double diffusive convection and related problems

Doubly diffusive convection, that is, convection driven by a combination of concentration and temperature gradients, is known to display a wealth of dynamical behavior whose properties depend both on the direction and the magnitude of the initial or imposed gradients. Our presentation mainly concerns the case in which convection is driven by imposed temperature and concentration differences between two opposite vertical walls. This system is known to exhibit homoclinic snaking producing stationary symmetric localized states. In a first part, we will review some of our recent results obtained in 2D and 3D.

In a second part, we will relate some of these behaviours to others systems including convection with rotation, marangoni convection and Soret convection in a porous medium.

Alan Champneys (University of Bristol)

Turing Bifurcation, Wave Pinning and Localised Pattern, three sides of the same coin?

In this talk which is joint work with Nicolas Verscheuren, I will describe recent work on a system of reaction diffusion equations of Schnakenberg-type that has been used to described cellular polarity formation. This is one of a family of models describing the dynamics of small G-proteins known as ROPs. The active form diffuse more slowly as they are constrained the cell membrane whereas the inactive form are free to diffuse in the cytosol. A subcritical Turing bifurcation gives the onset of localised patterns, which transform into spike-like solutions in another part of the domain. In this talk I shall give three recent updates. First, an asymptotic study shows how in the singular limit of protein conservation, the spikes become fronts in a non-trivial way, recovering the so-called wave-pinning dynamics. Second, the mechanism for localised pattern to spike transition is studied using a Shilnikov-type analysis. The transition is argued to be Universal and examples are found in a models of vegetation patterning, nonlinear optics and crime-wave hotspots. Finally, preliminary results are presented on how the protein dynamics feeds back into cell shape morphogenesis.

Keith Julien (University of Colorado, Boulder)

Asymptotic Strategies for Modeling Geophysical and Astrophysical Flows

Geophysical and astrophysical fluid flows occur on scales that are often strongly influenced by forces such as buoyancy, rotation, magnetic and shear. In many cases it is typical that one or more of these forces dominate and constrain the observed dynamics. Such situations are characterized by the extreme values of non-dimensional parameters measuring the relative magnitude of applied forces. Current models and simulations are conducted at parameters orders of magnitudes away from observed values and often in regimes where extrapolations are questionable. Improvements in computing power through Moore's laws will produce minimal advances with present-day models. It is therefore clear that advances must occur through new model development and associated simulations utilizing extreme parameter values in an asymptotic manner. This will require a body of knowledge gained from large-scale direct numerical simulations, laboratory experiments and observations that explore the tendency towards extreme parameter values in controlled settings.

In this talk, an overview is given of recent advances utilizing asymptotic method to develop reduced partial differential equations that capture the relevant dynamics. Rotationally constrained flows will be used as case study illustrating how advancements are occurring through a confluence of asymptotic models, laboratory investigations and direct numerical simulations of the Navier-Stokes equations.

Edgar Knobloch (University of California, Berkeley)

Past, Present and Future

Few of us would be successful without the work of our students. In this presentation I will briefly discuss some of the work of my students over the years and describe how it has influenced my own work and the larger field. I will also attempt to identify significant but tractable problems for the near future.

Bjorn Sandstede (Brown University)

Geometry and Analysis of Localized Structures

I will give an overview of results on localized pattern formation in one and two space dimensions. Specifically, I will discuss analytical and geometric approaches to snaking of localized rolling plateaus and outline the differences between snaking in one and two space dimensions.

Mary Silber (University of Chicago)

Transport and Feedback in Models of Self-Organizing Vegetation Patterns

Bands of vegetation, alternating nearly periodically with bare soil, have been observed in many dryland environments since their discovery in the Horn of Africa in the 1950s. Mathematical modeling efforts over the past two decades have sought to account for these bands via interaction between vegetation and the limited water resources. The focus of this talk will be on the role of topography in shaping the bands and their position on the landscape. For instance, in many cases these vegetation bands are arced, with field observations suggesting a link between the orientation of arcing relative to the grade and the curvature of underlying terrain. We consider an idealized topography, consisting of alternating valley and ridge lines, and modify the Klausmeier model of water-biomass dynamics to account for water transport in a simple manner. We compare the model results with satellite images from three continents. We hope that this globe trotting, albeit virtual, will add to this celebration of Edgars contributions to our training. Much of the work I will present is done in collaboration with Punit Gandhi, another former student of Edgars.

Uwe Thiele (Universität Münster)

Straightening and moving the snake – localised clusters in passive and active Phase Field Crystal models

First, we consider the bifurcation structure of localised solutions for the standard (passive or thermodynamic) phase field crystal (PFC) model [aka conserved Swift-Hohenberg (cSH) equation with cubic nonlinearity] that may be obtained as a local approximation of a dynamical density functional theory (DDFT). It is thought to provide the simplest microscopic continuum description of the thermodynamic transition from a fluid state to a crystalline state and is frequently used to model colloidal crystallisation [1].

After introducing the cSH equation as an example of a conserved dynamics, its steady states and their bifurcations are analysed. In particular, We focus on the variety of spatially localized structures, that are found in addition to periodic structures. The location of these structures in the temperature versus mean concentration plane is determined using a combination of numerical continuation in one and two dimensions and direct numerical simulation in two and three dimensions. Localized states are found in the region of thermodynamic coexistence between the homogeneous and structured phases, and may lie outside of the binodal for these states. The results are related to the phenomenon of slanted snaking but take the form of standard aligned homoclinic snaking when the solutions are plotted employing the chemical potential as main control parameter [2]. We also show how the localised states are related to the Maxwell construction of the crystallisation isotherm.

Second, We consider the active phase field crystal (aPFC) model [3] that results as a combination of the passive PFC model and the Toner-Tu theory for self-propelled particles. It is considered a simple model that describes the transition between resting and traveling ('living') crystals. In the linear regime, analytical expressions for the transitions from the liquid state to both types of space-filling crystals are obtained and the resulting phase-diagram is discussed [4]. In the nonlinear regime, we describe a variety of localized resting and travelling clusters that may exist besides spatially extended crystals. We provide a semi-analytical criterion for the onset of motion in the nonlinear regime, that corresponds to drift pitchfork and drift transcritical bifurcations [5]. Numerical continuation is applied to follow resting and traveling localized states while varying the activity and the mean concentration as well as to determine their regions of existence. Based on this information we finally discuss teh scattering behaviour of the found travelling localised states.

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Jose Manuel Vega (Universidad Politécnica de Madrid)

Analyzing nonlinear dynamics via higher order dynamic mode decomposition

Standard dynamic mode decomposition (DMD) was introduced by Schmid (2010) and is related to seminal ideas by Koopman (1931). This method is a very useful to post-process spatio-temporal data resulting from nonlinear dynamics. The decomposition is an expansion of spatial modes times exponentials in the time variable, which exhibit generally nonzero growth rates. As such, DMD is an advantageous alternative to more classical methods to obtain such expansions (with zero growth rates), such as fast Fourier transform or power spectral density. However, standard DMD does not always give the correct results, even in cases in which the provided data admit an exact expansion in spatial modes times exponentials in time. This difficulty has been solved by the authors (2017) by developing a new method, called higher order DMD (HODMD), which applies standard DMD to a set of enlarged snapshots that also contains time-delayed snapshots. Thus, HODMD synergically combines standard DMD and direct consequences of the well-known Takens delay embedding theorem (1981). The HODMD method will be illustrated using some toy-model dynamics and its performance will be tested using both, numerically generated databases from various nonlinear dynamical systems (complex Ginzburg-Landau equation, thermal convection in rotating spherical shells, cylinder wake) and experimental measurements on various fluid configurations (zero-net-mass-flux jet, confined non-isothermal flows around vortex promoters, incoming flow upstream a wind turbine, and aeroelastic flight tests). Some preliminary results on nuclear magnetic resonance data will also be presented.

Talks

Arantxa Alonso (Universitat Politècnica de Catalunya)

Numerical study of novel time-dependent patterns arising in inclined cylindrical binary convection

Convection in a fluid layer is affected by its orientation with respect to the gravitational field. In the present work, we investigate numerically pattern selection in a vertical cylindrical cell heated from below for positive Soret coefficient mixtures, where square patterns, roll structures and cross-roll regimes are expected to arise, and analyze the effect of small inclinations of gravity in pattern formation. The competition between shear effects and horizontal and vertical buoyancy alters significantly the dynamics observed in non-inclined convection. The large-scale shear flow (LSSF) induced by the small tilt of gravity overcomes the square-like arrangements observed in non-inclined cylinders in the Soret regime, stratifies the fluid along the direction of inclination, and produces an enhanced separation of the two components of the mixture. Additional unexpected time-dependent patterns coexist with the basic LSSF. We focus on the unusual superhighway convection state (SHC) reported in the recent experiment of Croccolo et al. (2013), a periodic state in which ascending and descending regions of fluid move in opposite directions.

Daniele Avitabile (University of Nottingham)

Analysing coherent structures via interfacial dynamics: from spatio-temporal canards to coarse-grained computations

We will discuss level-set based approaches to study the existence and bifurcation structure of spatio-temporal patterns in biological neural networks. Using this framework, which extends previous ideas in the study of neural field models, we study the first example of canards in an infinite- dimensional dynamical system, and perform a computational reduction of dimensionality in certain neural network models.

We will initially consider a spatially-extended network with heterogeneous synaptic kernel. Interfacial methods allow for the explicit construction of a bifurcation equation for localised steady states, so that analytical, closed-form expressions for a classical "snakes and ladders bifurcation scenario can be derived. When the model is subject to slow variations in the control parameters, a new type of coherent structure emerges: the structure displays a spatially-localised pattern, undergoing a slow-fast modulation at the core. Using interfacial dynamics and geometric singular perturbation theory, we show that these patterns follow an invariant repelling slow manifold, hence we name them "spatio-temporal canards". We classify spatio-temporal canards and give conditions for the existence of folded-saddle and folded-node canards. We also find that these structures are robust to changes in the synaptic connectivity and firing rate. The theory correctly predicts the existence of spatio-temporal canards with octahedral symmetries in a neural field model posed on a spherical domain.

We will then discuss how the insight gained with interfacial dynamics may be used to perform coarse-grained bifurcation analysis on neural networks, even in models where the network does not evolve according to an integro-differential equation. As an example I will consider a well-known event-driven network of spiking neurons, proposed by Laing and Chow. In this setting, we construct numerically travelling waves whose profiles possess an arbitrary number of spikes. An open question is the origin of the travelling waves, which have been conjectured to form via a destabilisation of a bump solution. We provide numerical evidence that this mechanism is not in place, by showing that disconnected branches of travelling waves with countably many spikes exist, and terminate at grazing points; the grazing points correspond to travelling waves with an increasing number of spikes, a well-defined width, and decreasing propagation speed.

This is joint work with Mathieu Desroches, Edgar Knobloch, Joshua Davis and Kyle Wedgwood.

Eberhard Bodenschatz (Max Planck Institut)

Non Boussinesq Effects in Turbulent Thermal Convection

We critically analyze the different ways to evaluate Nu [4] over Ra dependence in measurements of the heat transport in turbulent RBC under general NOB conditions and show the sensitivity of this dependence to the reference temperature at which the fluid properties are evaluated. For the case when the fluid properties depend exclusively on the temperature and are almost independent of the pressure we propose a method to estimate the bulk temperature. We demonstrate perfect agreement between the theoretical predictions and the Gttingen measurements of the bulk temperature [2, 3]. We further show that the normalized heat transport Nu=Ra1=3 is independent of whether it is evaluated in the lower or upper part of the convection cell, if the correct reference temperatures are used.

References

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Greg Chini (University of New Hampshire)

Baroclinic Acoustic Streaming

Recently, Chini *et al.* [*J. Fluid Mech.*, Vol. 744 (2014)] demonstrated the potential for large-amplitude acoustic streaming in compressible channel flows subjected to strong background cross-channel density variations. In contrast with classic Rayleigh streaming, standing acoustic waves of $O(\epsilon)$ amplitude acquire vorticity owing to baroclinic torques acting throughout the domain rather than via viscous torques acting in Stokes boundary layers. More significantly, these baroclinically-driven streaming flows have a magnitude that also is $O(\epsilon)$, i.e. comparable to that of the sound waves. In the present study, the consequent potential for fully two-way coupling between the waves and streaming flows is investigated using a novel WKBJ analysis. The analysis confirms that the wave-driven streaming flows are sufficiently strong to modify the background density gradient, thereby modifying the leading-order acoustic wave structure. Simulations of the wave/mean-flow system enabled by the WKBJ analysis are performed to illustrate the nature of the two-way coupling, which contrasts sharply with classic Rayleigh streaming, for which the waves can first be determined and the streaming flows subsequently computed.

Pascal Chossat (Université Nice Côte d'Azur-CNRS)

Stability of simple and pseudo simple heteroclinic cycles in R^4

Recently the classification of robust heteroclinic cycles in R^4, for systems with symmetry group $G \subset O(4)$, has shown that their stability properties strongly differ according to their type. The classical simple cycles can be asymptotically stable, while pseudo-simple cycles are completely unstable if G is included in $SO(4)$, or can be fragmentarily stable if G contains reflections in $O(4)$. I will review these different cases and show how the group action induces these differences. This is joint work with Olga Podvigina and Alexander Lohse.

Emmanuel Dormy (ENS-CNRS)

Weak and Strong Field Dynamos

The dynamo bifurcation in a rotating sphere is studied numerically. In addition to the weak-dipolar branch and to the fluctuating-multipolar branche, widely discussed in the literature, a third regime has been identified. This third branch appears to correspond to the expected dominant force balance between the Coriolis force and the Lorentz force.

Bérengère Dubrulle (CEA-CNRS)

Dissipation, intermittency and singularities in turbulent flows

Many phenomena in nature involve motion of viscous flows, which are widely believed to be described by Navier-Stokes equations (NSE). These equations are used for instance in numerical simulations of flows in astrophysics, climate or aeronautics. These equations are the cornerstones of many physical and engineering sciences, and are routinely used in numerical simulations. From a mathematical point of view, however, it is still unclear whether the Navier-Stokes equations are a well-posed problem in three dimensions, i.e. whether their solutions remain regular over sufficient large time or develop singularities.

Historically, the search for singularities in NSE was initiated by Leray who introduced the notion of weak solutions (i.e. in the sense of distribution). This notion was used to prove that the mathematical singular set has a one-dimensional Haussdorff measure equals to zero in space-time. Therefore, if these singularities exist, they must be extremely localized events in space and time. This makes their direct detection an outstanding problem. For some times, the best suggestive evidence of their existence was provided by the observation that the energy dissipation rate in turbulent flows tends to a constant at large Reynolds numbers This observation is at the core of the 1941 Kolmogorov theory of turbulence, and was interpreted by Onsager as the signature of singularities with local scaling exponent $h = 1/3$. Later, it was conjectured that the singularities are organized into a multifractal set. Analysis of measurements of 3D numerical or 1D experimental velocity fields showed that the data are compatible with the multifractal picture, with a most probable h close to 1/3. However, this analysis could not reveal any information on the space-time statistics of (possible) singularities. A major breakthrough was achieved when Duchon and Robert performed a detailed energy balance for weak solutions of INSE, and compute the contribution stemming from an eventual lack of smoothness. They show that it can be lumped into a single term, that quantifies the "inertial" energy dissipation, i.e. the energy dissipated by non-viscous means.

The purpose of this talk is to discuss how this mathematical result can be used for high spatial resolution measurements of the velocity field in an experimental turbulent swirling flow to infer properties of the energy dissipation in a turbulent flow. First, we show that our results are consistent with the existence of quasi-singularities even at the dissipative scales of turbulence. We show that they are very intermittent in space and time and provide the first experimental attempt at characterization of extreme events of inertial-dissipation.

Reference : E.-W. Saw, D. Kuzzay, D. Faranda, A. Guittonneau, F. Daviaud, C. Wiertel-Gasquet, V. Padilla, B. Dubrulle, Experimental characterization of extreme events of inertial dissipation in a turbulent swirling flow, Nature Communication 7 (2016)

Miguel Duran-Olivencia (Imperial College London)

General framework for nonequilibrium dynamics and statistical mechanics of soft matter

We introduce a bottom-up derivation of a formal theoretical framework to describe (passive) soft-matter systems out of equilibrium subject to fluctuations. We provide a formal connection between the constituent-particle dynamics of real systems and the time evolution equation of their observables (coarse-grained quantities), such as local density and velocity. Through appropriate model-reduction techniques we obtain the fluctuating-hydrodynamic equations governing the time-evolution of the mesoscopic density and momentum fields. The equations have the structure of a dynamical density-functional theory (DDFT) with an additional fluctuating force coming from the random interactions with the bath [1]. We show that our fluctuating DDFT formalism corresponds to a particular version of the fluctuating Navier-Stokes equations, originally derived by Landau et. al. [2]. Our formalism is exemplified through one of the most frequent phase transitions, that of nucleation. Specifically we offer a rigorous and systematic derivation of a mesoscopic nucleation theory (MeNT), reconciling the inherent randomness of the nucleation process with the deterministic nature of DDFT. For systems subject to strong dissipation due to the bath, as is the common case in colloidal fluids, we demonstrate that the most likely path (MLP) for nucleation to occur is determined precisely by the DDFT equations. We also present computations of MLPs for homogeneous and heterogeneous nucleation in colloidal suspensions. For homogeneous nucleation, the MLP obtained is in excellent agreement with the reduced order-parameter description of MeNT, which predicts a multistage nucleation pathway. For heterogeneous nucleation, the presence of impurities in the fluid affects the MLP, but remarkably, the overall qualitative picture of homogeneous nucleation persists. Finally, we highlight the use of fluctuating DDFT as a simulation toolbox, which is especially appealing as there are no known applications of MeNT to heterogeneous nucleation.

Selected references:

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Michael Field (Imperial College London)

Dynamics of adaptive feedforward networks with some feedback

Motivated in part by ideas from neural nets and neuroscience, we consider the dynamics of adaptive feedforward networks and the effects of adding feedback. We use several different dynamic protocols that are suggested by ideas from unsupervised learning and "asynchronous functional" networks. This work is joint with Manuela Aguiar and Ana Dias (University of Porto).

Lendert Gelens (KU Leuven)

Spatial waves organize cell division in the early frog embryo

The early frog embryo rapidly divides twelve times to reduce its size from a single large cell of about 1 mm to somatic cell size of about 10 microns. Recent experiments and modeling have shown that cell division could be coordinated in space via traveling waves sweeping through the embryo. Such traveling waves likely arise from the interaction of bistability and spatial diffusive coupling within the large frog egg.

Here, using in vitro frog egg extracts, we experimentally characterize the dynamics of such spatial waves in heterogeneous media in multiple spatial dimensions. We complement this experimental study with a theoretical analysis of the regulatory protein network at the heart of the observed cell cycle oscillations, as well as simple generic models.

Robert Ecke (Los Alamos National Laboratory)

Rotating Rayleigh–Bénard Convection: From patterns to turbulence

I will review experimental results on rotating Rayleigh-Benard convection (RRBC) including traveling-wave wall modes, pattern formation and Kuppers-Lortz instability, phase diagram of RRBC, and turbulent RRBC. Using experimental probes of heat transport, optical shadowgraph, and local temperature and velocity measurements, I will illustrate the main features of RRBC and the relationship of bifurcation theory, nonlinear pattern formation, and asymptotic analysis to the experimental results.

Azam Gholami (Max Planck Institute)

Convective Instability and Boundary Driven Oscillations in a Reaction-Diffusion-Advection Model

In a reaction-diffusion-advection system, with a convectively unstable regime, a perturbation creates a wave train that is advected downstream and eventually leaves the system. We show that the convective instability coexists with a local absolute instability when a fixed boundary condition upstream is imposed. This boundary induced instability acts as a continuous wave source, creating a local periodic excitation near the boundary, which initiates waves travelling both up and downstream. To confirm this, we performed analytical analysis and numerical simulations of a modified Martiel-Goldbeter reaction-diffusion model with the addition of an advection term. We provide a quantitative description of the wave packet appearing in the convectively unstable regime, which we found to be in excellent agreement with the numerical simulations. We characterize this new instability and show that in the limit of high advection speed, it is suppressed. This type of instability can be expected for reaction-diffusion systems that present both a convective instability and an excitable regime. In particular, it can be relevant to understand the signaling mechanism of the social amoeba Dictyostelium discoideum that may experience fluid flows in its natural habitat.

Damia Gomila (Universitat de les Illes Balears)

Fairy circles under the sea

Posidonia Oceanica is a marine clonal plant of capital importance in the Mediterranean sea. It forms extensive meadows which provide important ecosystem services. Close to the cost such meadows are not uniform but display a variety of spatial patterns. We propose a simply model for clonal growth able to reproduce the the diversity of seascapes observed in these ecosystems as emerging from plant interactions within the meadow. These seascapes include two extreme cases, a continuous meadow and a bare landscape, along with intermediate states that range from the occurrence of persistent but isolated fairy circles, or dissipative solitons, to seascapes with multiple fairy circles, banded vegetation, and leopard skin patterns consisting of bare seascapes dotted with plant patches.

Leonardo Gordillo (Universidad de Santiago de Chile)

Fluid-supported elastic sheet under compresion: Multifold solutions

The properties of a floating elastic sheet under compression are considered. Numerical continuation is used to compute spatially localized buckled states with one and several folds. Both symmetric and antisymmetric states are computed and the corresponding bifurcation diagrams determined. Weakly nonlinear analysis shows to puzzle out several properties of the single and multifold solutions and their dependence on the length of the floating sheet. The stability properties of different competing states are also determined providing a deep insight of the dynamics of system and folds interactions.

Oleg Kirillov (Northumbria University)

Singular diffusionless limits of double-diffusive instabilities in magnetohydrodynamics

We study local instabilities of a differentially rotating viscous flow of electrically conducting incompressible fluid subject to an external azimuthal magnetic field. In the presence of the magnetic field, the hydrodynamically stable flow can demonstrate non-axisymmetric azimuthal magnetorotational instability (AMRI) both in the diffusionless case and in the double-diffusive case with viscous and ohmic dissipation. Performing stability analysis of amplitude transport equations of short-wavelength approximation, we find that the threshold of the diffusionless AMRI via the HamiltonHopf bifurcation is a singular limit of the thresholds of the viscous and resistive AMRI corresponding to the dissipative Hopf bifurcation and manifests itself as the

Whitney umbrella singular point. A smooth transition between the two types of instabilities is possible only if the magnetic Prandtl number is equal to unity. Otherwise, the threshold of the double-diffusive AMRI is displaced by finite distance in the parameter space with respect to the diffusionless case even in the zero dissipation limit. The complete neutral stability surface contains three Whitney umbrella singular points and two mutually orthogonal intervals of self-intersection. At these singularities, the double-diffusive system reduces to a marginally stable system which is either Hamiltonian or paritytime-symmetric.

Florian Kogelbauer (ETH Zürich)

The Relation between Conservative and Nonconservative Nonlinear Normal Modes

In the computation of backbone curves, it is usually (tacitly) assumed that the response of a damped-forced system is somewhat close to the response of the conservative limit. We justify this heuristics by rigorously establishing the convergence of two-dimensional spectral submanifolds (SSMs) to their conservative limit for a general, autonomous nonlinear mechanical system with damping. This gives a mathematical underpinning for a well-acknowledged intuition in computational and experimental structural vibrations. We point out, however, that there are cases for which this intuition fails. Namely, we prove that the conservative limit does not exist, if certain non-resonance conditions are violated. The abstract results are illustrated on specic examples.

Stefan Llewellyn Smith (University of California, San Diego)

Generalizing point vortices

Kirchhoffs equations of motion for point vortices are a paradigm of reduction of an infinite-dimensional dynamical system, namely the incompressible Euler equations, to a finite-dimensional system. Yet the original incompressible Euler equations neglect physical phenomena that may be important, for example compressibility, density differences and other wave fields such as those caused by background vorticity gradients. In addition, one can also examine other generalizations of the point vortex singularity, such as higher singularities or the effect of different desingularizations of the point vortex system. The history of point vortices and a number of these extensions, in particular hollow vortices and Sadovskii vortices, are discussed. Some related mathematical problems are mentioned.

David Lloyd (University of Surrey)

Invasion of fronts near the homoclinic snake

In 2016 at the Lorentz Centre workshop “Analysis and Applications of Localized Structures in Nonlinear Media, Edgar posed an open problem about what happens to depinning fronts near the homoclinic snaking region. These fronts typically select a far-field wave number and travel at a non-constant propagation speed making them difficult to set up the boundary value problem. In this talk, I will present a new numerical continuation algorithm to investigate invading depinning fronts near the homoclinic snaking region in the planar Swift-Hohenberg equation. We find that these fronts have a rich bifurcation structure. In particular, we find that fast depinning fronts may regain transverse stability in the Swift-Hohenberg equation with a cubic-quintic nonlinearity and that different orientated hexagon fronts may travel at different speeds. This work also sheds some light on growing patches of pattern in the plane.

Francisco Marques (Universitat Politècnica de Catalunya)

Extensional channel flow: a dynamical systems perspective

The behaviour of a viscous fluid confined within a two-dimensional infinitely long channel whose parallel walls are stretching or shrinking independently is analyzed. This problem has been frequently used as a paradigm for self-similar flows, i.e., exact solutions of the Navier-Stokes equations that satisfy spatial scale invariance properties in unbounded domains. Historically the main focus on the study of self-similar flows was the description of steady solutions. More recently, dynamical studies of these flows have shown interesting dynamics for particular parameter values. This complex dynamics restricts the validity of the self-similar solutions to moderate Reynolds numbers. We present a comprehensive exploration of the dynamics of the extensional channel flow for all stretching/shrinking configurations, analyzing the first bifurcations of these flows, and localizing several codimension-two bifurcations that act as organizing centers of the dynamics.

Carlos Martel (Universidad Politécnica de Madrid)

Aeromechanic Problems in Turbomachinery

I will describe several aeromechanic problems that appear in the design and analysis of Turbomachinery components (fan, compressor, turbine) that are of interest from the industrial point of view and whose description require the application of tools from nonlinear science. In particular I will focus on two of them: (i) the aeroelastic vibration of bladed discs, which is saturated by nonlinear friction forces and shows an very high sensitivity to small imperfections (known as "mistuning"); in this case the growth of vibration amplitude, the effect of the friction and the imperfections are all small effects that can be captured using a long time, envelope equation formulation. And (ii) "rotating stall", which typically appears in compressors and consists of a spatially localized pulse of flow blockage that covers a few blade passages and rotates at a fraction of the rotating speed; rotating stall can be regarded as a solitary wave that propagates from blade to blade around of the compressor rotor, and constitutes a very interesting example of a localized propagating state that appears in a realistic industrial situation

Joanne Mason (University of Exeter)

Flux Expulsion with Dynamics

In the classical process of flux expulsion a magnetic field is expelled from a region of closed streamlines on a $TRm^{1/3}$ time scale, for magnetic Reynolds number $Rm \ll 1$ (T being the turnover time of the flow). This result applies in the kinematic regime where the flow is specified independently of the magnetic field. Our work extends this result to the dynamical regime, where there is competition between the process of flux expulsion and the Lorentz force, which suppresses the differential rotation. We use a quasi-linear model in which the flow is constrained to be axisymmetric. The magnetic Prandtl number is taken to be small and a range of initial magnetic field strengths are considered. Two scaling laws are proposed and confirmed numerically. For initial magnetic fields below the threshold bcore $= O(URm^{-1/3})$, flux expulsion operates despite the Lorentz force. For larger initial fields the Lorentz force is dominant and the flow creates Alfvn waves that propagate away. The second threshold is bdynam $= O(URm^{-3/4})$, below which the field follows the kinematic evolution and decays rapidly. Between these two thresholds the magnetic field is strong enough to suppress differential rotation, leaving a magnetically controlled core spinning in solid body motion, which then decays slowly on a time scale of order TRm.

Isabel Mercader (Universitat Politècnica de Catalunya)

Binary convection in a slightly inclined rectangular cavity

Thermal convection in a binary fluid layer heated from below is a system that exhibits a great variety of pattern-forming phenomena when driven away from equilibrium. In binary mixtures, the concentration flux depends both on concentration and temperature gradients (Soret effect). This effect is quantified by the Soret coefficient, and its sign determines a different behavior of the mixture. With negative Soret coefficient, the heavier component migrates towards the hotter boundary, resulting in a stabilizing concentration gradient competing with the destabilizing thermal gradient that produces it. In such type of mixtures, a especially interesting stationary localized structure has been identified in rectangular cells, the so-called convectons (Batiste et al. 2005). The systematic study of these states has motivated many recent works among the international community. Our team has participated actively in this study, helping to understand their origin and properties, mainly with the discovery of the snaking branches of solutions where convectons are located (Batiste et al 2006, Mercader et al. 2006, 2010, 2013. Such states can be disturbed by a small inclination of the cell. The effect of inclination is particularly interesting as it induces a large scale flow along the bottom wall with a return flow along the top wall that substitutes the quiescent state. We investigate both, the behavior of the large scale flow and that of the persistent convectons for small inclination. Noteworthy, we obtain that in order for the inclined system to resemble the system without inclination, this must be remarkably small.

Jeff Moehlis (University of California, Santa Barbara)

Neural Oscillators: Symmetry, Clusters, and Control

In this talk, I will describe a research trajectory that began with Professor Edgar Knobloch and the use of symmetry methods to understand pattern forming fluid systems. This allowed entry into the world of neural oscillators via the use of related symmetry methods to understand phase-locked solutions for systems of identical globally coupled oscillators. Under generic conditions, such systems have solutions in which the oscillators split into symmetric clusters. We have recently hypothesized that analogous clusters might result from deep brain stimulation of neural populations, and that such clustering overcomes pathological synchronization associated with Parkinson's disease. In fact, forming such clusters of neurons may prove to be more effective than achieving complete desynchronization, in particular by promoting plasticity effects that might persist after stimulation is turned off. With this in mind, we have developed a single-input low-power control strategy to achieve such clustering in neural populations. More broadly, this work illustrates that choosing a good initial condition can lead to an unpredictable yet exciting research trajectory.

Yasumasa Nishiura (Tohoku University)

A snaky structure of traveling pulses with oscillatory tails and their dynamics in heterogeneous media

It is known that the traveling pulses display a variety of dynamics such as crossing, rebound, and pinning when they collide with defects (jump discontinuity or bump) in the media. When the pulse has an oscillatory tail, then each trap of oscillatory tail starts to interact with defects and may present a kind of hierarchical responce depending on its strength (height of jump) of defect, which makes a sharp contrast with monotone tail case.

We first study the global structure of the set of stationary and traveling pulses with oscillatory tails in homogeneous media and show that it presents a double-snaky structure with respect to an appropriate parameter in the system. When heterogeneity is introduced in the media, then a variety of heterogeneity-induced ordered patterns (HIOPs) emerge. Our conclusion is that all the outputs of traveling pulses after colliding with defects are contained in the component of HIOP set, which is connected to the trivial background state at height = 0. Moreover each dynamic transition point (say from crossing to rebound) is characterized by the associated homoclinic bifurcation to some scattor separating two different dynamics.

Oleh Omel'chenko (Weierstrass Institute, Berlin)

Discrete oscillatory media and chimera states

Discrete oscillatory media are spatially embedded networks of coupled oscillators with distance-dependent interaction between them. Typically, under homogeneous conditions in such systems all oscillators either move synchronously (coherently), or show completely independent (incoherent) behavior. In some cases, however, these homogeneous systems exhibit self-organized spatially intermittent patterns of regions with coherent and incoherent motions. Because of their counterintuitive nature such coherent-incoherent patterns were called chimera states. If the oscillators are distributed densly and uniformly in space, then the coarse-grained dynamics of chimera states is described by a hyperbolic integro-differential equation for the corresponding probability density function. In this talk, we will discuss recent results concerned with the anlysis of this equation, including bifurcations of chimera states, control of chimera states and some applications.

Michel Rieutord (Institut de Recherche en Astrophysique et Planétologie)

Modelling rotating stars: a stiff non-linear problem

Modelling stars is a challenging problem due to its intrinsic non-linearities and the associated instabilities. This is indeed the challenge of computing a solution of the Navier-Stokes and heat equations including compressibility and self-gravity. In this talk I will present the recent progresses in the modelling of fast rotating stars in two dimensions with the ESTER code. In particular I will address the question of the numerical method, discussing briefly the merits of Picard and Newton's method. I will illustrate the results with the comparison between models and data on gravity darkening, a feature that has been measured in the recent years with new infrared interferometers (e.g. VLTI/PIONIER, CHARA/MIRC). I will finally discuss the open problems of stellar physics and the challenges they represent for nonlinear sciences.

Joan Sánchez Umbría (Universitat Politècnica de Catalunya)

Bifurcation tracking techniques for bifurcations of periodic orbits of dissipative PDEs

Continuation methods are commonly used to track curves of solutions depending on parameters. These methods have been used in Fluid Mechanics mainly to compute bifurcation diagrams of steady solutions. More recently they have also been used for periodic orbits.

Following our previous work we have developed a new efficient methodology for the continuation of the codimension-one bifurcations of periodic orbits, including pitchfork bifurcations present in reflection-symmetric systems. It is based on the combination of Newton-Krylov techniques applied to extended systems, and the integration of systems of variational equations up to second order. The extended systems are adapted from those usually found in the literature for fixed points of maps. It will be shown that to evaluate the action of the Jacobian it is only necessary to integrate systems of ODEs of dimension at most four times that of the original system. This minimizes the computational cost.

The thermal convection of a mixture of two fluids in a two-dimensional rectangular box is used as test problem. It is known that the onset of convection is oscillatory below a certain negative value of one of the parameters (the separation ratio), giving rise to a rich dynamics. A non-trivial diagram of periodic orbits is first deployed, by varying only the Rayleigh number, and some of the bifurcations found on the main branch of periodic orbits are followed by adding as second parameter the Prandtl number. Several codimension-two points have been found. Boundaries of Arnold's tongues have also been computed in this way.

Tobias Schneider (EPFL)

Localized unstable states control when a soda can buckles

Thin-walled cylindrical shells such as rocket walls (or soda cans) offer exceptional strength-to-weight ratios yet predicting at which load the structure becomes unstable and fails remains an unsolved problem. Shells buckle and collapse at loading conditions much below those predicted by linear stability theory. We thus propose a fully nonlinear approach and show that fully nonlinear equilibrium states located on the boundary of the unbuckled state's basin of attraction define critical perturbation amplitudes and guide the nonlinear initiation of catastrophic buckling. For a clamped thin cylindrical shell under axial compression a fully localized single dimple deformation is identified as the edge statethe attractor for the dynamics restricted to the stability boundary. Under variation of the axial load, the single dimple undergoes homoclinic snaking in the azimuthal direction, creating states with multiple dimples arranged around the central circumference. Once the circumference is completely filled with a ring of dimples, snaking in the axial direction leads to further growth of the dimple pattern. The bifurcation structure of the equilibria closely resembles that observed in the Swift-Hohenberg equation with quadratic-cubic nonlinearity.

Shigeru Shinomoto (Kyoto University)

From oscillation to spiking

In more than 30 years ago, we analyzed the processes through which macroscopic rhythm emerges in a system of mutually interacting excitable elements [1]. At that time, we were assuming that the model excitable elements may represent neurons. Since then, I have been analyzing signals recorded from real nervous systems of behaving animals. In this talk, I present what I have seen in reality [2-4].

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Andrew Soward (Newcastle University)

Spin-down in a rapidly rotating cylinder container with mixed rigid and stress free boundary conditions

Greenspan and Howard (J. Fluid Mech., 1963) studied the linear spin-down of a rapidly rotating viscous fluid at small Ekman number E inside a container with rigid boundaries, following an instantaneous small change in container angular velocity. Outside the Ekman layers, thickness $O(E^{1/2})$, the mainstream is in almost rigid rotation (geostrophic) but spins down rapidly due to Ekman suction. Additionally, there are thickening quasi-geostrophic and very weak ageostrophic $E^{1/3}$ shear layers adjacent to the cylindrical side-wall. Motivated by applications to isolated atmospheric structures (e.g., tropical cyclones, tornadoes) without side and top boundaries, we study numerically and asymptotically a variant with stress-free side-wall and top boundaries, which leads to unexpected consequences. The mainstream no longer rotates rigidly, while the ageostrophic $E^{1/3}$ shear layer, far from being passive, determines a spin-down rate dependent on ln E. It is linked to an $E^{1/2} \times E^{1/2}$ corner region, where the rigid base and the stress-free side-wall meet; a singularity that limits asymptotic progress.

Jim Swift (Northern Arizona University)

Synchrony and Anti-Synchrony for Difference-Coupled Vector Fields on Graph Network Systems

A graph network is a coupled cell network where there are only one type of cell and one type of symmetric coupling between the cells. For a difference-coupled vector field on a graph network system, all the cells have the same internal dynamics, and the coupling between cells is identical, symmetric, and depends only on the difference of the states of the interacting cells. We define four nested sets of difference-couples vector fields by adding further restrictions on the internal dynamics and the coupling functions. These restrictions require that these functions preserve zero or are odd or linear. We characterize the synchrony and anti-synchrony subspaces with respect to these four subsets of admissible vector fields. Synchrony and anti-synchrony subspaces are determined by partitions and matched partitions of the cells that satisfy certain balance conditions. The synchrony and anti-synchrony subspaces have a lattice structure. We apply our theory to systems of coupled van der Pol oscillators.

Geoffrey Vallis (University of Exeter)

Rainy–Bénard Convection

Rayleigh-Benard convection convection of a Boussinesq fluid between two plates held at fixed temperature is probably the simplest model of convection that has relevance to the natural world. Convection in the atmosphere differs in a million ways: the medium is a compressible ideal gas, there is no upper boundary, radiation is present, clouds are present and, moist importantly, the release of latent heat by condensation largely drives the convection. As a result, studies of atmospheric convection use very complicated models. In this study we try to bridge this gap by adding a condensate to Rayleigh-Benard convection but keeping all other aspects simple. In this talk we will describe the linear and nonlinear properties of this system, including a semi-analatic 'drizzle solution' and its linear stability properties and some fully nonlinear numerical integrations.

Patrick Weidman (University of Colorado, Boulder)

On the terminal motion of sliding spinning disks with uniform Coulomb friction

We study the terminal motion of disks sliding and spinning with uniform dry friction across a horizontal plane. Previous analysis show that a uniform circular disk of radius R always stops sliding and spinning at the same instant. Moreover, under arbitrary nonzero initial values of translational speed v and angular rotation rate ω, the terminal value of the speed ratio $\epsilon_0 = \nu/R\omega$ is always 0.653. In the current study we show that an annular disk of radius ratio $\eta = R_1/R_2$ stops sliding and spinning at the same time, but with a terminal speed ratio dependent on η. For a two-tier disk with lower tier of thickness H_1 and radius R_1 and upper tier of thickness H_2 and radius R_2, the motion depends on both η and the thickness ratio $\lambda = H_1/H_2$. While translation and rotation stop simultaneously, their terminal ratio ϵ_0 either vanishes when $k > 2/3$, is a nonzero constant when $1/2 < k < 2/3$, or diverges when $k < 1/2$, where k is the normalized radius of gyration. New experiments with PVC disks sliding on a nylon fabric stretched over a plexiglass plate corroborate the three different types of terminal motions. The talk ends with preliminary results obtained for disks sliding and spinning up or down inclined planes.

Jeffrey Weiss (University of Colorado, Boulder)

Quantifying Spatio-Temporal Patterns in the Climate System and Beyond

Complex nonlinear systems exhibit a broad variety of self-organized coherent spatio-temporal patterns. Examples of such patterns in the climate system include the El-Nino Southern Oscillation, the Madden-Julien Oscillation, and the North Atlantic Oscillation. These spatio-temporal patterns each have their preferred spatial and temporal scales and are governed by different detailed dynamical processes. The trajectories of these patterns all exhibit a preferred rotation in the phase space of their dominant state variables. This rotation is a generic feature of fluctuations within nonequilibrium steady-states. The phase space rotation can be quantified using a new diagnostic, the probability angular momentum, providing a metric for quantifying and comparing spatio-temporal patterns in complex nonlinear systems.

Jin-Han Xie (New York University)

Jet formation in modified Rayleigh–Bénard convection

Large-scale coherent structures such as jets have received increasing attention in Rayleigh-Bénard Convection (RBC) and related systems. This work numerically and theoretically studies jet formation in two-dimensional salt fingering convection using the asymptotically derived modified Rayleigh-Bénard convection (MRBC) model where the effect of the stabilizing component (temperature) is equivalent to an additional anisotropic large-scale damping for the single-component RBC. The MRBC system has two external parameters, the Schmidt number Sc and the Rayleigh ratio Ra, a ratio between the Rayleigh numbers of the destabilizing and stabilizing components. Two parameter regimes of Ra with fixed $Sc = 1$ are explored: (i) For intermediately large Rayleigh ratio, the MRBC model captures the relaxation-oscillation quasiperiodic state, a key feature observed in the direct numerical simulations of the primitive equations; (ii) When the Rayleigh ratio is of $O(1)$, a regime that the direct numerical simulation of the primitive equations is difficult to reach because of the fast gravity waves, the MRBC model shows the existence of statistically steady jets whose properties are studied in detail. Three hierarchical models – the MRBC, the quasilinear and the single-mode models – which are found to retain basic phenomenon and the capture the main mechanism of jet formation are used to confirm that the mechanism of jet formation is the direct perturbation-perturbation interaction and that the perturbation-mean interaction dominates the nonlinear perturbation dynamics. Even though the small-scale structures exhibited by the three models are different, a uniform power-law spectrum for the large-scale horizontally averaged mean fields – the jets – are discovered: the mean streamfunction scales as m^{-3} and the mean salinity field scales as m^{-1}, and based on the dominant balances theses exponents are calculated. In the physical space, these mean spectra indicate that the jet velocity has a linear dependence on the vertical coordinate at the jet flank, which is justified by numerical simulations. A three-component phenomenological model consisting of a linearly growing component, a linearly damping component and a mean component is proposed to explain the transition from steady to quasiperiodic jets with increasing Rayleigh ratio as a Hopf bifurcation.

Arik Yochelis (Ben-Gurion University of the Negev)

Localized Turing states embedded in spiral-type Hopf oscillations: A solution to an “old” puzzle

Motivated by experiments on chlorite-iodide-malonic-acid chemical reaction, a mechanism for the emergence of spatially localized states embedded in an oscillatory background is demonstrated. The localization is of Turing type and appears in two space dimensions as a comb-like state in either π phase shifted Hopf oscillations or inside a spiral core. Specifically, the localized states appear in absence of the well known flip-flop dynamics (associated with collapsed homoclinic snaking) that is known to arise in the vicinity of Hopf-Turing bifurcation in one space dimension. Derivation and analysis of three Hopf-Turing amplitude equations in two space dimensions reveal a local dynamics pinning mechanism for Hopf fronts, which in turn allows the emergence of perpendicular (to the Hopf front) Turing states. Finally, the results are shown to agree well with the comb-like core size that forms inside spiral waves.

Posters

Yuval Edri (Ben-Gurion University of the Negev)

Molding the asymmetry of localized frequency-locking waves: Implications for sound discrimination in the inner ear

Frequency locking to an external forcing frequency is a known phenomenon. In the auditory system it results in a localized traveling wave, the shape of which is essential for efficient discrimination between incoming frequencies. An amplitude equation approach is used to show that the shape of the localized traveling wave crucially depends on the relative strength of additive vs. parametric forcing components; the stronger the parametric forcing the more asymmetric the response profile and the sharper the traveling-wave front. The analysis captures empirically observed regions of linear and nonlinear responses and highlights the significance of studying parametric-forcing mechanisms for understanding sound discrimination.

Punit Gandhi (Ohio State University)

Localized states in the Gray–Scott/generalized Klausmeier model

Spatially localized states frequently appear in reaction-diffusion systems that exhibit pattern formation through Turing instabilities of spatially uniform states. We study the formation of such localized states in a generalized Klausmeier model of dryland vegetation that is equivalent to the well-studied Gray–Scott model for activator-inhibitor type chemical dynamics. We focus on a regime in which the diffusivities of the two species are comparable. Localized states arise in the vicinity of a subcritical Turing instability present in this regime, and from folds in the branch of spatially periodic Turing states. They also arise from the fold of spatially uniform states. We use a combination of numerical continuation techniques and weakly nonlinear theory to explore the global behavior of the resulting solution branches.

María Higuera (Universidad Politécnica de Madrid)

The role of fluid dynamics on Langmuir monolayers

Monolayer experiments frequently measure surface rheological properties by periodically modulating surfactant concentration with two slightly immersed solid barriers that control the free surface area of a shallow liquid layer. Because the modulation is slow, most theoretical studies ignore fluid dynamics in the bulk. We present a long wave theory that also takes fluid dynamics and symmetries into account.In addition, apparent irreversibility is also discussed that may result from artifacts associated with the menisci dynamics when surface tension is measured using a Wilhelmy plate. Results from this theory are discussed for varying values ofthe parameters,which permit establishing specific predictions on experiments. On the other hand, these results compare fairly well with the available experimental observations, at least qualitatively. The overall conclusion is that the fluid dynamics should not be ignored in the analysis of these experimental devices.

Reiner Lauterbach (Universität Hamburg)

Equivariant bifurcation and higher dimensional fixed point spaces

We present results on bifurcations for equivariant systems with higher dimensional fixed point spaces. The methods rely on quaternionic computations and representation theory.

Marta Net (Universitat Politècnica de Catalunya)

Low Prandtl number steady and periodic double-diffusive convection with lateral heating

The steady and oscillatory flows of low Prandtl number pure and binary fluids, filling a slot heated by the side, are studied by using continuation methods and stability analysis of the solutions. The general case of double-diffusive convection with the thermal and solutal buoyancies unbalanced, together with the Soret term, are taken into account in the equations. The bifurcation points on the branches of solutions are determined with precision by calculating their spectra for a large range of Rayleigh and Prandtl numbers. The role played by the shear stresses of the steady field, and the two buoyancies, at the onset of the oscillations is analized by means of the energy equation of the perturbations. It is found that the shear is always the main responsible for the instabilities, and that the thermal and solutal buoyancies can even help to stabilize the fluid.

Iryna Omelchenko (Technische Universität Berlin)

Tweezer control for chimera states

Systems of nonlocally coupled oscillators can exhibit complex spatiotemporal patterns, called chimera states, which consist of coexisting domains of spatially coherent (synchronized) and incoherent dynamics. Chimera states are usually difficult to observe in small networks because of their short lifetime and erratic motion of their spatial position. A tweezer feedback control scheme can stabilize such chimera states and fix their position. We analyse the action of the tweezer control in small nonlocally coupled networks of limit cycle oscillators. We demonstrate that the tweezer control allows for stabilization of chimera states with different shapes, and can be used as an instrument for controlling the coherent domains size, as well as the maximum average frequency difference of the oscillators.

Pedro Parra-Rivas (KU Leuven)

Bifurcation structure of localized states in the Lugiato-Lefever equation with anomalous dispersion

The origin, stability and bifurcation structure of different types of bright localized structures described by the Lugiato-Lefever equation is studied. This mean field model describes the nonlinear dynamics of light circulating in fiber cavities and microresonators. In the case of anomalous group velocity dispersion and low values of the intracavity phase detuning these bright states are organized in a homoclinic snaking bifurcation structure. We describe how this bifurcation structure is destroyed when the detuning is increased across a critical value, and determine how a new bifurcation structure known as foliated snaking emerges.

Anton Pershin (University of Leeds)

Dynamics of spatially localized states in transitional plane Couette flow

Spatiotemporal dynamics of localized perturbations in shear flows has been actively investigated in the recent years due to its relevance to the transition to turbulence. In numerical studies, turbulent spots have been usually imitated by some form of random perturbations or taken from a turbulent state at higher Reynolds numbers. In contrast, this talk concerns the dynamics of exact localized states of plane Couette flow found on two branches of equilibria and travelling waves intertwined in a bifurcation pattern known as homoclinic snaking. Homoclinic snaking in plane Couette flow and its usage as a source of initial conditions are first discussed. The map of the parameter space composed of the Reynolds number up to transitional ones and the width of the localized states is then presented where different dynamical regimes of the flow are identified and characterized. Finally, a series of possible connections between the localized states and other exact solutions in plane Couette flow is proposed.

Benjamin Ponedel (University of California, Berkeley)

Gap solitons and forced snaking

We introduce the phenomenon known as forced snaking to the study of gap solitons. We report a new family of multistable solutions to the cubic-quintic Gross-Pitaevskii equation with a spatially periodic potential. The new solutions exist only in the semi-infinite gap. We provide the bifurcation structure of the solutions and determine their stability. Specifically we show that multi-pulse solutions of all parities are stabilized when the spatial scale of the periodic forcing is sufficiently large, effectively quenching the self interactions between the pulses. Finally we show that the solitons unbind from the potential with sufficiently large perturbations and provide a strongly nonlinear theory to capture the dynamics during this transition.

Jeff Porter (Universidad Politécnica de Madrid)

A coupled parametrically forced oscillator model of subharmonic surface waves with application to vibroequilibria

An open container of fluid vibrated at high frequency and sufficient amplitude will exhibit subharmonic surface waves. If the vibration is horizontal, these waves are called cross-waves and are strongest near the solid walls acting as wavemakers. In some situations, the waves are sufficiently localized to be modelled by a pair of weakly-coupled parametrically forced oscillators. We analyze such a model in the neighborhood of the primary subharmonic instability and note how both primary and subsequent instabilities depend crucially on the symmetry that remains in the presence of coupling, which, in turn, depends on the relative phases of the parametric forcing terms. A bifurcation study reveals a complex series of transitions organized in part by Bogdanov-Takens points. The case of out-of-phase forcing, which is relevant to horizontally vibrated fluids, is compared with direct numerical simulations and with recent experiments on modulated cross-waves. Both the initial Hopf bifurcation and subsequent saddle-node heteroclinic bifurcation are confirmed. Simulations of vibroequilibria (quasi-steady non-flat surface configurations supported by vibrations) are also discussed. In particular, it is found that subharmonic surface waves may destabilize the underlying vibroequilibria state by driving an odd sloshing motion. The modulated states analyzed in the coupled parametrically forced oscillator model appear to be the key to effective coupling between the high-frequency surface waves and the low-frequency sloshing modes, an interaction with the potential to destabilize/destroy vibroequilibria states.

J. Porter, P. Salgado Snchez, J. Fernndez, I. Tinao, A. Lavern-Simavilla
Universidad Politecnica de Madrid
Escuela Tcnica Superior de Ingeniera Aeronutica y del Espacio

Reinhard Richter (Universität Bayreuth)

Localized States and Homoclinic Snaking at the Surface instability of Ferrofluid

We report on localised patches of cellular hexagons observed on the surface of a magnetic fluid in a vertical magnetic field. These patches are spontaneously generated by jumping into the neighbourhood of the unstable branch of the domain-covering hexagons of the Rosensweig instability upon which the patches equilibrate and stabilise. They are found to coexist in intervals of the applied magnetic field strength control parameter around this branch. We formulate a general energy functional for the system and a corresponding Hamiltonian that provide a pattern selection principle allowing us to compute Maxwell points (where the energy of a single hexagon cell lies in the same Hamiltonian level set as the flat state) for general magnetic permeabilities. Using numerical continuation techniques, we investigate the existence of localised hexagons in the YoungLaplace equation coupled to the Maxwell equations. We find that cellular hexagons possess a Maxwell point, providing an energetic explanation for the multitude of measured hexagon patches. Furthermore, it is found that planar hexagon fronts and hexagon patches undergo homoclinic snaking, corroborating the experimentally detected intervals. Besides making a contribution to the specific area of ferrofluids, our work paves the ground for a deeper understanding of homoclinic snaking of two-dimensional localised patches of cellular patterns in many physical systems.

Authors are: David J. B. Lloyd, Christian Gollwitzer, Ingo Rehberg and Reinhard Richter

Priya Subramanian (University of Leeds)

Mode Interactions and Superlattice patterns

Pattern formation in systems in many real world systems such as neural-field models, reaction-diffusion systems and fluid systems such as the Faraday wave system have separation of scales leading to nonlinear modal interactions. A general analysis of possible terms that can arise via modal interactions is subject to both the choice of a lattice grid and the ratio between the two length scales q. Motivated by the observance of different grid states and superlattice states in experiments of the Faraday wave system, here we consider a hexagonal lattice grid and identify families of amplitude equations for different values of the ratio in the range $0 < q < 1/2$. We find that the ratio of $q = 1/\sqrt{7}$ gives rise to the maximum number of terms in the amplitude equations (up to third order terms) and that other families of amplitude equations can be recovered by setting the coefficients of certain modal interactions in this 'general' to vanish. For the case with $q = 1/\sqrt{7}$, we use equivariant bifurcation analysis to investigate the existence and stability of different patterns over a range of marginally stable growth rates for both the length scales. We also contrast our results with a codimension-1 analysis which assumes that only one of the length scales is marginally stable.

Also my co-authors for this work are: Pakwan Riyapan (Prince of Songkla University, Thailand) & Alastair Rucklidge (University of Leeds).