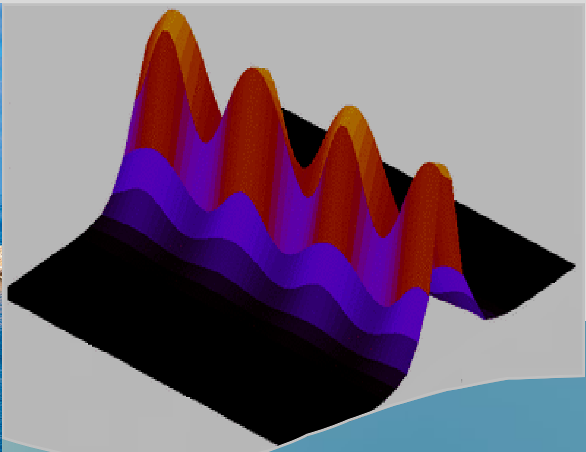
Symposium in honor of the 60th birthday of
Giorgos P. Tsironis

20 – 22 June 2019, Cultural Center of Chania, Crete, Greece



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PROGRAM

Thursday 20 June

9:00 – 10:15	Registration
10:15 -12:00	**Morning session I** **Chairperson: J. Hizanidis**
10:15–10:30	Greetings and Opening Remarks
10:30 -11:00	Moti Segev, Department of Physics and Solid State Institute, Technion Topological Photonics
11:00 -11:30	Nikolaos K. Efremidis, Dept. of Applied Mathematics, University of Crete Perfect Control of Optical Beams
11:30 –12:00	Amnon Yariv*, Applied Physics and EE, Caltech TBA
12:00-12:30	Coffee break
12:30-14:00	**Morning Session II** **Chairperson: A. Bountis**
12:30-13:00	E. N. Economou, Physics Dept., University of Crete, and IESL Chiral Optical Systems Obeying Space Inversion and Time Reversal Symmetry
13:00-13:30	Kostas Makris, Department of Physics, University of Crete Non-Hermitian Wave Control in Complex Photonic Media
13:30-14:00	Yannis Kominis, School of Applied and Physics Sciences, NTUA Symmetry Breaking in Topological Nonhermitian Photonics as an Enabler of High-Performing Devices
14:00 –15:00	Lunch Break – Placement of Posters
15:00 -16:30	**Afternoon session I** **Chairperson: T. Kottos**
15:00 –15:30	Igor Barashenkov, Dept. of Mathematics, University of Cape Town, South Africa New PT-symmetric systems with solitons: Nonlinear Dirac and Landau-Lifshitz equations
15:30-16:00	Claude Baesens, Mathematics Institute, University of Warwick TBA
16:00 –16:30	Evangelos Ch. Mitsokapas, School of Math. Sciences, Queen Mary Univ. of London,UK Peak-end Memory: An extension to Asymmetric Choices
16:30-17:00	Coffee Break
17:00-18:00	**Afternoon Session II** **Chairperson: G. Neofotistos**
17:00-17:30	Robert MacKay, Mathematics Institute, University of Warwick, Stelarator Mathematics: Hidden Symmetries of Guiding Centre Motion
17:30-18:00	Avadh Saxena, Theoretical Division, Los Alamos National Laboratory Power-law Kink Tails in Higher Order Field Theories

Friday 21 June

9:30 – 12:00	**Morning session I [SQUIRREL (ELIDEK) SESSION]** **Chairperson: T. Kottos**
9:30 - 10:00	Steven Anlage, Department of Physics, University of Maryland rf SQUID Metamaterials: A Nonlinear Life
10:00– 10:30	Astero Provata, NCSR Demokritos Chimera States in Brain Dynamics
10:30-11:00	Johanne Hizanidis, Department of Physics, University of Crete Pattern Formation and Chimeras in SQUID Metamaterials
11:00-11:30	Nikos Lazarides, Physics Department, University of Crete Nonlinear Dynamics in SQUID Arrays
11:30-12:00	Alexey Ustinov, Karlsruhe Institute for Technology Nonlinear and Switchable Superconducting Metamaterials
12:00-12:30	Coffee break
12:30-14:00	**Morning Session II** **Chairperson: T. Geisel**
12:30-13:00	David Campbell, Dept. of Physics, Boston University The Subtle Road to Equilibrium in the FPUT Model
13:00-13:30	Ziad Musslimani, Dept. of Mathematics, Florida State University Integrable nonlocal models
13:30-14:00	George Kopidakis, Material Science Dept., University of Crete Nonlinear localization in nanostructures, low-dimensional, and disordered lattices
14:00 –15:00	Lunch break – Placement of Posters
15:00 –16:30	**Afternoon Session I** **Chairperson: N. Lazarides**
15:00 –15:30	Efthimios (Tim) Kaxiras*, Harvard University Localization with a twist: electronic states in moire patterns of graphene bilayers
15:30-16:00	George Kalosakas*, Dept. of Material Sciences, University of Patras Uniaxial compression and buckling of graphene
16:00-16:30	Alex Zolotaryuk, Bogolyubov Institute for Theoretical Physics Contact Interactions in Heterostructures: A squeezed limit
16:30-17:00	Coffee Break
17:00-18:30	**Afternoon Session II** **Chairperson: G. Kalosakas**
17:00-17:30	Siddharth (Montu) Saxena, Trinity College and Cavendish Laboratory, Cambridge Phase Emergence near Quantum Critical Points
17:30 –18:00	Patrick Navez, Dept. of Theoretical Physics, Helmholtz-Zentrum-Dresden Designing quantum many body Hamiltonian from quantum circuits of superconducting qubit line
18:00-18:30	Serge Aubry, Laboratoire Leon Brillouin, CEA Saclay Comment on Quantum Gravity and the Schrödinger Cat

Saturday 22 June

9:30 –12:00	**Morning session I** **Chairperson: D. Campbell**
9:30 –10.00	Theo Geisel, MPI for Dynamics and Self-Organization, Göttingen, Germany The Beat Generation
10:00-10:30	Sergey V. Dmitriev, Institute for Metals Superplasticity Problems, RAS, Russia Discrete breathers affect macroscopic properties of nonlinear lattices
10:30-11:00	Juan F.R. Archilla, Yusuke Doi, Masayuki Kimura Group of Nonlinear Physics, Universidad de Sevilla, Sevilla, Spain Pterobreathers in their moving frame
11:00-11:30	Elena A. Korznikova, Institute for Metals Superplasticity Problems, RAS, Ufa, Russia Nonlinear spatially localized vibrational modes in metals
11:30-12:00	Vladimir Dubinko, NSC Kharkov Institute of Physics and Technology, Kharkov, Ukraine, Energy Localization in Hydrogenated Metals: Applications to the Rate Theory
12:00-12:30	Coffee Break
12:30-14:30	**Morning Session II** **Chairperson: J. Hizanidis**
12:30-13:00	Demetrios Christodoulides, CREOL, University of Central Florida Optical thermodynamics of heavily multimoded nonlinear optical systems
13:00-13:30	Felix Izrailev, Instituto de Fisica, BUAP (Mexico) and Michigan State University Quench Dynamics and Thermalization in Isolated Systems of Interaction Particles
13:30-14:00	Joniald Shena, National University of Science and Technology MISiS, Moscow, Russia and Nazarbayev University, Astana, Kazakstan Controlling localized patterns in coupled Arrays of Semiconductor Lasers
14:00-14:30	Tsampikos Kottos, Department of Physics, Wesleyan University Coherent wave propagation in multi-mode systems with correlated noise

* To be confirmed

ABSTRACTS

rf SQUID Metamaterials: A Nonlinear Life

Steven M. Anlage
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Through experiments, numerical simulations, and theory we explore the behavior of strongly nonlinear 0D, 1D, and 2D rf SQUID (radiofrequency superconducting quantum interference device) metamaterials, which show extreme tunability and nonlinearity [1-3]. We investigate the SQUID metamaterial as a nonlinear medium through detailed two-tone intermodulation (IM) measurement over a broad range of tone frequencies and tone powers [4]. A sharp onset followed by a surprising strongly suppressed IM region near the resonance is observed. Using a two time-scale analysis technique, we present an analytical theory that successfully explains our experimental observations. The theory predicts that the IM can be manipulated with tone power, center frequency, frequency difference between the two tones, and temperature. The spatial response of the rf SQUID lattice under cryogenic conditions and rf and dc flux bias is investigated with a laser scanning microscope (LSM). LSM photoresponse images at zero dc flux and low rf flux bias show no evidence of large-scale coherent response from the rf SQUID lattice. Instead we find small clusters of coherent SQUIDs adopting a variety of resonant frequencies. Spatial synchronization of the rf SQUIDs occurs under increased rf flux bias,[5] in agreement with our earlier results based on global transmission measurements and simulation [3]. Motivated by the predictions of our colleague G. P. Tsironis, we expect that many other interesting collective behaviors will be discovered in this remarkable nonlinear metamaterial.
Keywords: Nonlinear metamaterial, SQUIDs, Superconductivity, Chaos, Chimera.

Acknowledgements: This work was done in collaboration with A. P. Zhuravel, M. Trepanier, D. Zhang, S. Bae, J. Cai, E. Ott, T. M. Antonsen, and A. V. Ustinov, and UMD research is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering under Award # DESC0018788.

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[1] M. Trepanier, D. Zhang, S. M. Anlage, O. Mukhanov, “Realization and Modeling of Metamaterials Made of rf Superconducting Quantum-Interference Devices,” Phys. Rev. X 3, 041029 (2013).
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Pterobreathers in their moving frame

Juan F.R. Archilla[1], Yusuke Doi[2], Masayuki Kimura[3]
[1]*Group of Nonlinear Physics, Universidad de Sevilla, Sevilla, Spain*
[2]*Department of Adaptive Machine Systems, Graduate School of Engineering, Osaka University, Osaka, Japan*
[3]*Department of Electrical Engineering, Kyoto University Katsura, Kyoto, Japan*

Discrete moving breathers are moving localized vibrations in a nonlinear lattice that are transient solution of the Hamiltonian, although often with long flight paths. Pterobreathers are similar entities but coupled to a nonlinear plane wave, called wing. Pterobreathers can be constructed as exact solutions with a given symmetry and often they have small wings. We propose a description of pterobreathers in their moving frame based in the concept of fundamental time and frequency. The complexity of the breather spectrum is thus reduced to just two frequencies, the internal breather frequency and the wing frequency. Exact solutions allow for the use of continuation methods in terms of the frequency and thus allow for the obtention or pterobreathers with no wings, or exact moving breathers, for a specific frequency in each symmetry. We apply the theory to a realistic model for a layered silicate.
Keywords: moving breathers, pterobreathers, moving frame, nonlinear lattices, exact moving breathers, nonlocality.

Analysis of a scenario for chaotic breathing

Claude Baesens and **Robert MacKay**

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Preparations from rat brain stems doped with opium have been observed to continue to produce regular expiration signals but fail to produce some inspiration signals [1]. The numbers of expirations between two successive inspirations form an apparently random sequence. In this talk we propose an explanation based on the qualitative theory of dynamical systems. The idea is that a relatively simple scenario for the dynamics of interaction between the generators of expiration and inspiration signals produces pseudo-random behaviour of the type observed.

References:

[1] Feldman JL, Del Negro CA: *Looking for inspiration: new perspectives on respiration rhythm*, Nature Reviews Neurosci. **7**:232-242 (2006).

[2] Baesens C, MacKay RS: *Analysis of a scenario for chaotic quantal slowing down of inspiration*, The Journal of Mathematical Neuroscience https://doi.org/10.1186/2190-8567-3-18 (2013).

New PT-symmetric systems with solitons: nonlinear Dirac and Landau-Lifshitz equations

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Although the spinor field in (1+1) dimensions has the right structure to model a dispersive bimodal system with gain and loss, the plain addition of gain to one component of the field and loss to the other one results in an unstable dispersion relation. In this talk, we advocate a different recipe for the PT-symmetric extension of spinor models -- the recipe that does not produce instability of the Dirac equation. We consider the PT-symmetric extensions of nonlinear spinor models and demonstrate a remarkable sturdiness of spinor solitons in two dimensions. Another new class of PT-symmetric systems comprises the nanoferromagnetic films with spin torque transfer. In the vicinity of the exceptional point, the corresponding Landau-Lifshitz equation reduces to a nonlinear Schroedinger equation with a quadratic nonlinearity. In the simplest, isotropic, case the equation has the form iψt + ψxx – ψ + ψ2=0. We show that this PT-symmetric Schroedinger equation has stable soliton solutions.

Keywords: Parity-time symmetry, gain and loss, nonlinear Dirac equations, Landau-Lifshitz equation, spin torque transfer, dissipative solitons

The Effect of Long Range Interactions on the Dynamics and Statistics of 1D Hamiltonian Lattices

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I will first review recent results with H. Christodoulidi and C. Tsallis on how the dynamics and statistics of β – FPU 1D Hamiltonian lattices are affected by long range interactions (LRI) in their potential ($1/r^{\alpha}$, $0 \le \alpha < \infty$) leading to the onset of a weak form of chaos dynamically as well as statistically in the thermodynamic limit [1,2]. Similar effects also occur in 1D Hamiltonians with LRI in the presence of on site potentials of the Klein Gordon (KG) type [3]. I will then report on more recent findings with J. Macias Diaz and H. Christodoulidi, which show that LRI influences significantly the important effect of nonlinear supratransmission in Hamiltonian 1D lattices: Specifically, we find for the FPU case that threshold amplitudes increase the longer the interaction ($\alpha \to 0$) [4] while for Hamiltonians with KG on – site potentials, there is a sharp decrease of the threshold amplitudes, $0 \le \alpha < 1.5$ [5], which still remains a mystery!

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2. H. Christodoulidi, T. Bountis, C. Tsallis and L. Drossos, “Chaotic Behavior of the Fermi-Pasta-Ulam Model with Different Ranges of Particle interactions”, J. Stat. Mech. 12 (12) (2016) 123206.
DOI: 10.1088/1742-5468/aa4f0e
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4. J. C. Macias Diaz, A. Bountis, “On the Transmission of Energy in β-Fermi–Pasta–Ulam Chains with Different Ranges of Particle Interactions”, CNSNS, vol. 63 (2018) 307–321 (2018).
5. J. E. Macias-Diaz, A. Bountis, H. Christodoulidi, “Energy Transmission in Hamiltonian Systems with Globally Interacting Particles and On-Site Potentials”, to appear in AIMS Journal of Mathematics in Engineering (2019).

The Subtle Road to Equilibrium in the FPUT Model

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Boston, Massachusetts USA

The interpretation and consequences of the celebrated Fermi, Pasta, Ulam, Tsingou (FPUT) numerical experiment have challenged scientists for more than six decades.
The history of how the original FPUT discovery led to the theory of “solitons,” was key in the understanding of Hamiltonian chaos, and led to the birth of “nonlinear science” is well documented, but there are many fascinating details which are only now being explored and understood. In this presentation, I will discuss two recent examples: namely, the existence and breakdown of recurrences and super-recurrences in both the alpha- and beta- versions of the FPUT system, and the remarkable intermittent dynamics, involving long-time, large deviations, that occur once the systems has nominally reached equilibrium.
In the first study [1], we find higher-order recurrences (HoR)s—which amount to “super-super-recurrences” in both the alpha and beta models. The periods of these HoR scale non-trivially with energy due to apparent singularities caused by nonlinear resonances, which differ in the two models. Further, the mechanisms by which the HoR breakdown differ strikingly in the two models.
In the second study [2], we find that the dynamics at equilibrium is characterized by a power-law distribution of excursion times far off equilibrium, with diverging variance. Long excursions arise from sticky dynamics close to localized excitations in normal mode space (q-breathers). Measuring the exponent allows to predict the transition into nonergodic dynamics.
*Work in collaboration with Carlo Danielli, Sergej Flach, and Salvatore Pace.

References:

[1] Salvatore D. Pace and David K. Campbell, “Behavior and Breakdown of Higher-Order-Fermi- Pasta-Ulam-Tsignou Recurrences,” arXiv:181100663 (Chaos, to appear).
[2] C. Danieli, D. K. Campbell, and S. Flach, “Intermittent many-body dynamics at equilibrium,” Phys. Rev. E 95 060202(R) (2017).

Discrete breathers affect macroscopic properties of nonlinear lattices

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Defect-free crystal lattices can support spatially localized, large amplitude vibrational modes called either discrete breathers (DBs) or intrinsic localized modes (ILMs). This has been confirmed by a number of molecular dynamics and in a few cases first-principle simulations. There exist many experimental measurements of crystal vibrational spectra aiming to prove the existence of DBs in thermal equilibrium at elevated temperatures. However these experimental results can be interpreted in different ways and they are still debated. Direct high-resolution imaging of DBs in crystals is hardly possible due to their nanometer size and picosecond lifetime. An alternative way to prove the existence of DBs in crystalline solids is to evaluate their impact on the measurable macroscopic properties of crystals. In fact, such measurements of heat capacity have been done for alpha-uranium by Manley with co-workers. In the present study, with the use of a simple 1D and 2D nonlinear lattices, we analyse the effect of DBs on heat capacity, thermal expansion, elastic constants, and thermal conductivity. In the most transparent way this can be done by monitoring the lattice parameters in a non-equilibrium process, during the development of modulational instability of the zone-boundary mode ($q=\pi$) or the gamma-mode ($q=0$), with total energy of the chain being conserved. It is well-known that the instability results in the appearance of long-lived DBs that gradually radiate energy and eventually the system approaches thermal equilibrium with spatially uniform and temporally constant temperature. The variation of heat capacity and other macroscopic properties at constant volume is evaluated during this system transformation. It is concluded that DBs affect all the above mentioned macroscopic characteristics of the studied nonlinear lattices.

Keywords: discrete breather, intrinsic localized mode, nonlinear lattices, heat capacity, thermal expansion, elastic constants, thermal conductivity.

Energy Localization in Hydrogenated Metals: Applications to the Rate Theory

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Energy localization in crystals manifest itself as intrinsic localized modes or discrete breathers (DBs). We present atomistic simulations of DBs in nickel, palladium and their hydrides. Large amplitude atomic motion in DBs may result in time-periodic driving of adjacent potential wells occupied by hydrogen ions (protons or deuterons). This driving has been shown to result in the increase of amplitude and energy of zero-point vibrations and in broadening of the wave packet. In this context, we present numerical solution of Schrodinger equation for a particle in a non-stationary double well potential, which is driven time-periodically imitating the action of a DB. We show that the rate of tunneling of the particle through the potential barrier separating the wells is drastically enhanced by the driving with a resonant frequency ranging from w0 to 2w0, where w0 is the eigenfrequency of the potential well. The effect increases strongly with increasing amplitude of the driving. These results support the concept of DB mediated catalysis and extend it to low temperatures where quantum tunneling prevails over thermal activation controlling the reaction rates in solids.
Keywords: Discrete breathers, Quantum Tunneling, Rate Theory, Catalysis.

Chiral Optical Systems Obeying Space Inversion and Time Reversal Symmetry

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Although chirality seems to be in general incompatible with space and time symmetry, we show that special optical systems exist combining chiral loss and chiral gain components and obeying space inversion and time reversal symmetry, in the sense that the permittivity, the permeability, and the chirality transform under the action of PT as follows: These systems possess an Exceptional Point below which the eigenvalues of the transfer matrix are real in spite of the non-hermitian nature of the Hamiltonian and even when the chirality violates the requirement of PT symmetry. This freedom regarding the chirality can be explored by considering realistic chiral metamaterials, finding by retrieval their permittivity, permeability, and chirality, and simulating their behavior towards desired optical properties such as optical rotation, ellipticity, anisotropic transmission, etc. Possibilities for exciting applications open up.

References
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Perfect Control of Optical Beams

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There are three fundamental features that characterize an optical beam: its beam-width, its amplitude, and the trajectory the it follows. We examine the possibility to generate optical beams where we can simultaneously control these properties. We focus in the case of two different classes of optical waves: Bessel beams and Airy/accelerating beams. Although the underlying mechanism for the generation of such classes of optical waves is fundamentally different, it is still possible in both cases to engineer their properties in generating a beam with pre-defined characteristics.

References:

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[2] Michael Goutsoulas and Nikolaos K. Efremidis, Precise amplitude, trajectory, and beam-width control of accelerating and abruptly autofocusing beams, Physical Review A, vol. 97, art. no. 063831 (2018).
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Pattern formation and chimeras in SQUID Metamaterials

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The radio frequency (rf) Superconducting QUantum Interference Device (SQUID) is a highly nonlinear oscillator exhibiting rich dynamical behavior [1,2]. When driven by a time-periodic (ac) flux either with or without a constant (dc) bias, the SQUID exhibits extreme multistability at frequencies around the (geometric) resonance which is manifested by a "snake-like" form of the resonance curve [3]. Repeating motifs of SQUIDs form metamaterials, i. e. artificially structured media of weakly coupled discrete elements that exhibit extraordinary properties e. g. negative diamagnetic permeability. We report on the emergent collective dynamics of two-dimensional lattices of coupled SQUID oscillators, which involves a rich menagerie of spatio-temporal pattern formation and chimera states [4,5]. Both types of dynamics emerge near the synchronization-desynchronization transition occurring in the driving frequency-dc bias parameter space. A continuation analysis reveals that the lines of this transition coincide with bifurcations of the single SQUID. The latter provides useful insight into the observed collective dynamics: chimeras emerge due to the snake-like form of the resonance curve, while patterns occur at lower driving frequencies.

References:

[1] S. M. Anlage: *The physics and applications of superconducting metamaterials*, J. Opt. 13, 024001 (2011).
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Quench Dynamics and Thermalization in Isolated Systems of Interaction Particles

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The onset of quantum chaos and thermalization is studied in isolated systems of interacting bosons and fermions. The goal is to establish the conditions under which the properties of energy spectra and eigenstates can be described with the use of Two-Body Random Interaction models. It was shown that under these conditions the spread of wave packets in the Hilbert space follows an exponential time dependence, thus leading to a linear increase of Shannon entropy. After the saturation, this entropy can be treated as the thermodynamical one and its value is defined by the spread of local density of many-body eigenstates in the energy shell created by the projection of the total Hamiltonian onto the unperturbed one. We demonstrate that the results can be also applied to integrable systems with no random parameters, such as to the celebrated Lieb-Liniger model describing the point-like interaction between bosons in 1D optical traps.

References:
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Uniaxial compression and buckling of graphenes

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The mechanical response of single- and multi-layer graphenes [1], as well as of graphene nanoribbons of various lengths and widths [2], under uniaxial compression is presented. Molecular dynamics simulations are used to calculate compressive stress-strain curves and critical buckling values. The dependence of the critical buckling on the size of graphenes is discussed. In graphene nanoribbons, a single master curve describes the variation of the critical buckling with the aspect ratio of the nanostructure. The obtained results are compared with the predictions of the continuum elasticity theory [3-5].

References:
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Abrupt Transitions from the Interplay of Nonlinearity and Diffusion: Applications to Population Extinction in Bacteria and Epidemics

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The interplay of nonlinearity and diffusion is shown to lead to fascinating consequences such as abrupt extinction of populations in bio/ecological systems. The applications demonstrated are for the quite different systems of bacteria in a Petri dish and the spread of the Hantavirus epidemic arising from random walks of rodents on the New Mexico terrain. The former analysis is exact while the latter develops controlled approximation procedures. The basic dynamic equations are modified Fisher equations. Early references below exemplify the subject.

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Symmetry Breaking in Topological Nonhermitian Photonics as an Enabler of High-Performing Devices

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The interplay between non-Hermiticity and topology, due to inhomogeneous gain and loss distributions, along with the nonlinearity of a photonic system, is shown to result to fascinating dynamical features. The latter are very promising for advanced functionality of next-generation integrated photonic devices and structures, especially in the case of non-trivial asymmetric gain and loss inhomogeneities. Such configurations allow for controlled formation and propagation of solitary beams in planar inhomogeneous photonic structures [1], tailored modulation response crossing the 100GHz barrier [2], controlled location of exceptional points for enhanced sensitivity [3] and localized synchronization [4] in coupled lasers, as well as targeted transfer of energy in active couplers [5].

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Nonlinear spatially localized vibrational modes in metals

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Crystal lattice dynamics is one of the most important branches of condensed matter physics. When studying nonlinear oscillations in crystal lattices, their spatial dimension is of great importance. There exist one-dimensional crystals (polymer chains, carbin, DNA, etc.) as well as two-dimensional crystals (graphene, silicene, boron nitride, etc.), but the vast majority of crystals used in practice are three-dimensional. In one-dimensional crystals, discrete breathers (DBs) or intrinsic localized modes (ILMs) are exponentially localized in space, zero-dimensional objects. In two-dimensional crystals, both zero-dimensional and one-dimensional DBs are possible, in the latter case they are spatially localized along one coordinate direction and delocalized along the other. This means that a one-dimensional DB is localized on a chain of atoms and the vibration amplitudes decrease exponentially with distance from the chain. By analogy, in three-dimensional crystals one can speak of zero-dimensional, one-dimensional, and two-dimensional discrete breathers. In the latter case, it is assumed that atoms are excited along a certain atomic plane, and, with distance from this plane, the amplitude of atomic oscillations decrease exponentially. It should be noted that the possibility of the existence and properties of one-dimensional and two-dimensional DBs in three-dimensional crystals has hitherto been unknown and work has not been done in this direction. In this study properties of zero-dimensional, one-dimensional and three-dimensional DBs in fcc Al, Cu and Ni, as well as in hcp Ti are analysed with the help of molecular dynamics simulations based on many-body potentials. Delocalized nonlinear vibrational modes (or bushed of normal nonlinear modes) derived by Chechin with co-workers are widely used for excitation of two-dimensional Dbs. Overall, DBs of new type are analysed in pure metals. It is demonstrated that the same metal can support various spatially localized nonlinear vibrational modes.

Keywords: discrete breather, intrinsic localized mode, metal, fcc lattice, hcp lattice

Nonlinear dynamics in SQUID arrays

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Metamaterials, i.e., artificial media designed to achieve properties not available in natural materials, have been the focus of intense research for more than two decades. Many properties have been discovered and multiple designs have been devised that lead to numerous conceptual and practical applications. SQUID (superconducting quantum interference device) arrays in various geometries operate as magnetic metamatrials, producing further specificity and functionality. Such SQUID metamaterials [1-3] are both theoretically and experimentally investigated and exciting new phenomena have been found. The SQUID is a unique nonlinear oscillator that encompass the Josephson effect and can be manipulated through multiple external fields. This domain flexibility is inherited to SQUID metamaterials, which present a nonlinear dynamics lab where numerous complex spatiotemporal phenomena may be explored. An overview of nonlinear dynamics in SQUID arrays, with the emphasis on basic propert! ies related to their individual and collective responses to external magnetic fluxes, is given. Specifically, properties such as multistability and chaos in single SQUIDs, as well as resonance tunability and the emergence of various spatially inhomogeneous states (such as intrinsically localized [4], chimera [5], and patterned states) in SQUID metamaterials, are discussed. Moreover, SQUID metamaterials with specific lattice geometries (e.g., on a Lieb lattice), reveal the possibility of flat-band localization [6] as well as the emergence of peculiar spatially-synchronized temporally-chaotic states [7].

Keywords: Superconducting metamaterials, SQUIDs, chimera states, intrinsic loclization, flat-band localization.

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Stellarator Mathematics: Hidden Symmetries of Guiding Centre Motion

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The study of confinement of a charged particle in a strong magnetic field has been greatly aided by an excellent approximate symmetry, namely rotation of the particle's "gyroradius vector" around its "guiding centre". This reduces the problem (to high accuracy) to that of confining the guiding centre. If the guiding-centre motion has a continuous symmetry then the guiding centre is confined to a specific region associated to its initial condition, generically the projection of an invariant 2-torus to position-space. More formally, the guiding-centre motion is "integrable".
An obvious example of such symmetry occurs if the magnetic field has rotation symmetry about some axis. This is the principle of tokamaks. They have the defects, however, that they need a strong toroidal current to make the confinement tight, driving such a current for long times is not easy, and it generates instabilities.
Stellarators are a class of magnetic confinement devices in which no toroidal current is required. To achieve integrability without axisymmetry, however, requires a hidden symmetry, called quasi-symmetry. Although this can be achieved to a good approximation, it is widely believed that exact quasi-symmetry is impossible. Yet it is worth keeping in mind the amazing result of Kovalevskaya that in addition to the axisymmetric integrable tops of Lagrange there is a family of non-axisymmetric integrable tops. I will report on strong constraints that we have derived on quasi-symmetries.

Coherent wave propagation in multi-mode systems with correlated noise

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Imperfections in multimode systems lead to mode-mixing and interferences between propagating modes. Such disorder is typically characterized by a finite correlation time (in quantum evolution) or correlation length (in paraxial evolution). We show that the long-scale dynamics of an initial excitation that spread in mode space can be tailored by the coherent dynamics on short-scale. In particular, we unveil a universal crossover from exponential to power-law ballistic-like decay of the initial mode. Our results have applications to various wave physics frameworks, ranging from multimode fiber optics to quantum dots and quantum biology.

Non-Hermitian Wave control in Complex Photonic Media

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In this talk we are going to present recent results concerning wavefront control in disordered, nonlinear, and non-hermitian complex photonic media.

Peak-end Memory: An extension to Asymmetric Choices

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The peak-end rule [1] of behavioural economics is a psychological heuristic which describes the way us humans tend to particularly remember extreme and recent experiences. Recent work modelling this effect in a simple discrete-choice model (a random walker with extreme-value memory) revealed how this memory distortion could qualitatively affect the long-time behaviour [2]. We report preliminary investigations, extending the framework to the asymmetric case where the two possible choices have different distributions of experience. This opens up the possibility that, due to the peak-end memory, the agent becomes trapped in the rationally-less-good choice. The probability of this trapping depends on the level of noise in the decision-making process. Significantly, we present numerical evidence that there is an optimal value of noise maximizing the agent's expected experience and we discuss analytical approaches to predict this.

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Designing quantum many body Hamiltonian from quantum circuits of superconducting qu-bit line

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Quantum superconducting circuits have become recently a new alternative description of quantum phenomena such as entanglement or quantum computation in low temperature microship devices.
We report on the ability of a transmon (qu-bit) 1D array device embedded in a wave guide to act as an emitter of entangled pair of microwave radiation. The self and mutual capacitance of a series of such aligned transmon is used to allow the propagation a plasmon-like collective excitation with a tailored dispersion relation. These excitations are produced by a sudden sweep of the carrier number inside these devices. By a suitable design of a quadratic coupling from the Josephson junctions, they can decay collectively into a pair of entangled photons beam whose the maximum intensity is only bounded by the number of emitters. As a result, the quadratures obtained from a homodyne detection of these outputs beams form a pair of correlated continuous variables similarly to the EPR experiment. We calculate the decay rate of the transmon excitation both into a continuum of photon state and into a one-mode cavity. In the latest, we determine the Rabi-like frequency oscillation with the transmon mode resulting from a detuning.

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Chimera States in Brain Dynamics

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Chimera states are mixed states composed of coexisting coherent and incoherent domains in networks of coupled nonlinear oscillators. Chimeras are particularly relevant in brain dynamics where neuronal oscillators organized in complex networks exchange electrical and chemical signals. Using as working example the Leaky Integrate-and-Fire (LIF) model to represent the single neuron dynamics, we study the collective hehaviour of coupled LIF elements. We discuss the parameter values which give rise to chimera states and the influence of the network connectivity in the frequency profile of the coherent and incoherent domains. Some insights regarding the mechanisms giving rise to chimera states are presented.

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On multi-dimensional compact solitary patterns

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As though to compensate for the rarity of multidimensional integrable systems in higher dimensions, spatial extensions of many of the well-known nonlinear dispersive equations on the line, exhibit a remarkably rich variety of solitary patterns unavailable in 1-D. Our work systematizes this observation with a special attention paid to compactons - solitary waves with compact support - where this effect is found to be far more pronounced and begets a zoo of multi-dimensional compact solitary patterns.
One manifestation of this phenomenon is found in the sublinear NLS and Complex Klein-Gordon where the compactons inducing mechanism coupled with azimuthal spinning may expel the compact vortices from the origin to form a finite or countable number of genuine ring-vortices. Such rings are an exclusive feature of compacton supporting systems.

Power-law Kink Tails in Higher Order Field Theories

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Since the initial observation of a power-law tail in a phi-8 field theory [1], we have recently found several examples of a large class of one- dimensional higher order field theories with kink solutions which asymptotically have a power-law tail either at one end or at both ends [2,3]. We provide analytic solutions for the kinks in a few cases but mostly provide implicit solutions. We also provide examples of a family of potentials with two kinks, both of which have power law tails either at both ends or at one end. In addition, we show that for kinks with a power law tail at one end or both the ends, there is no gap between the zero mode and the continuum of the corresponding stability equation [4]. This is in contrast to the kinks with exponential tail at both the ends in which case there is always a gap between the zero mode and the continuum. Moreover, we obtain analytically and verify numerically the kink-kink and kink-antikink interaction for representative higher-order field theories [5]. Finally, we provide some examples of logarithmic potentials with power-law kink tails.

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Topological Photonics

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The fundamental concepts underlying the new area of Topological Photonics will be presented, along with exciting applications such as topological insulator lasers, new ideas related to photonic topological insulators in synthetic dimensions, topological protection of entangled states, exciton-polariton topological insulator, current challenges and open questions.

Controlling localized patterns in coupled array of semiconductor lasers

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Phased arrays of optically coupled semiconductor lasers are systems possessing radically complex dynamics that are useful for numerous applications in beam forming and beam shaping.
Previously, stable asymmetric phase-locked states in an active photonic dimer have been theoretically investigated showing new dynamical behavior [1-2]. The asymmetry comes from carrier densities corresponding to values that are above and below threshold resulting in gain and loss coefficients of opposite signs in each laser, so that the respective electric fields experience gain and loss [3]. We investigate for the first time a coupled array of active photonic dimers consisting of two qw lasers in driven externally with differential pumping rates.
We find that localized oscillations close to the fix point coexists with large amplitude oscillations where their field amplitudes and phases can be dynamically controlled by appropriate gain values in each dimer. Different spatial patterns such as chimera [4] and breather like states [5] are fully controllable even for random detuning, showing the path top on demand generation of optical diverse waveforms.

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Nonlinear and Switchable Superconducting Metamaterials

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Superconducting circuits with Josephson junctions allow for utilizing compact low-loss resonators with well-controlled nonlinearity and frequency tunability in the microwave and mm-wave frequency ranges. Moreover, it turns out that superconducting quantum interference devices (SQUIDs) can be used as intrinsically switchable meta-atoms. Lazarides and Tsironis have theoretically shown [1] that the intrinsic nonlinearity of a SQUID leads to multi-stable dynamical states in a metamaterial, each of them associated with a specific value and sign of the magnetic susceptibility. We have experimentally detected these states [2] and demonstrated that it is possible to switch between them by applying nanosecond-long microwave pulses, in addition to the microwave probe signal. The potential application of this effect is a wireless (all-"optical") switchable metamaterial based on SQUID type meta-atoms. More recently, we hav! e explored the nonlinearity of SQUID metamaterials by performing a two-tone resonant spectroscopy [3]. The small-amplitude response of the metamaterial under strong driving by a microwave pump signal leads to pronounced oscillations of the metamaterial transparency band. The response to the probe signal also displays instabilities and sidebands. The theoretical analysis of these observations is in good agreement with our experimental results.

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Contact Interactions in Heterostructures: A Squeezed Limit

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The heterostructures composed of two and three parallel plane layers are studied in the squeezed limit as both the thickness of the layers and the distance between them simultaneously tend to zero. The presence of a squeezed prewell in the potential profile in the system is shown to be crucial for the appearance of non-zero tunneling transmission through zero-thickness heterostructures. The typical example of such a system is the bilayer for which the squeezed potential profile is the first derivative of Dirac's delta function. It is demonstrated that the squeezed potentials are not required to have a limit in the sense of distributions and there exists a whole family of well-defined single-point interactions of one-dimensional Schroedinger equations for which the resonant tunneling transmission occurs at some hypersurfaces in the space formed by the layer strength constants (curves for a bilayer on the 2D plane and surfaces for a trilayer in the 3D space). These hypersurfaces form a countable (discrete) resonance set on which the transmissivity is non-zero, whereas beyond this set the system is fully opaque satisfying the Dirichlet boundary conditions at both the sides of the potential. The conditions for the resonant tunneling and the reflection-transmission coefficients for these interactions are computed explicitly. It is shown that for a given multilayer system, the resonance set crucially depends on the way of one-point shrinking. One these ways results in the appearance of a bound state in the derivative delta potential. The notion of point (contact) interactions with bias potentials is introduced. The transmission matrix and reflection-transmission coefficients for biased point systems are interpreted and computed asymptotically. References below exemplify the subject.

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