Program of the First Porto Meeting on Theory and Experiment in Nonlinear Physics

7 July	8:00 – 9:00	**Registration; Welcome**	
	9:00 – 9:40	**Fatkhulla Abdullaev**	Dissipative periodic waves, solitons and breathers of the nonlinear Schrodinger equation with complex potentials
	9:40 – 10:10	Alexey Okulov	Cold atoms trapping via helical interference patterns of the phase-conjugated Laguerre-Gaussian beam
	10:10 – 10:40	Usama Al Khawaja	Soliton localization in a vibrating harmonic trap
	10:40 – 11:00	Coffee break	
	11:00 – 11:40	**Boris A. Malomed**	Suppression of the quantum-mechanical collapse by repulsive interactions
	11:40 – 12:10	Goran Gligoric	The effect of dipole-dipole interaction on transition from the immiscible to miscible state in linearly coupled binary dipolar Bose-Einstein condensate
	12:10 – 12:40	Alexander Itin	Many-particle Landau-Zener models and dynamics of quantum phase transitions
	12:40 – 13:10	Vladimir Dubinko	Reaction rate theory with account of discrete breathers
	13:10 – 15:00	Lunch	
	15:00 – 15:40	**Victor M. Pérez Garcia**	Modelling cancer using differential equations: A physical and mathematical trip into medical problems
	15:40 – 16:10	Rui Travasso	Phase-field modeling in tumor growth and angiogenesis
	16:10 – 16:30	Coffee	
	16:30 – 17:10	**Leonor Cruzeiro**	The VES hypothesis and protein function
	17:10 – 17:40	Julia Pulwicki	Dynamical Riemannian Geometry and Plant Growth
	17:40 – 18:10	Marzena Ciszak	Stochastic incoherence in the response of rebound bursters
	18:10 –	Posters session	

8 July			
	9:30 – 10:10	**Majid Taki**	Observation of extreme temporal events in a photonic crystal fiber: Optical Rogue Waves
	10:10 – 10:40	Helder Crespo	To be announced
	10:40 – 11:10	Margarida Facão	Travelling solutions of a higher order quintic complex Ginzburg-Landau equation
	11:10 – 11:30	Coffee break	
	11:30 – 12:00	Jorge Vieira	Non-linear dynamics of intense laser pulses in plasmas
	12:00 – 12:30	David Novoa	Multiple filamentation and dynamical excitation of light condensates in cubic-quintic optical media
	12:30 – 13:00	Mário Ferreira	Nonlinear Effects in Optical Fibers
	13:00 – 15:00	Lunch	
	15:00 – 15:30	Manuel Donaire	Formation of magnetic flux patterns in the intermediate state of Type-I superconductors
	15:30 – 16:00	Luis Miguel Martelo	Exact solution for a boson-fermion model and application to ultra-cold atoms
	16:00 – 16:30	Coffee break	
	16:30 – 17:00	Teresa Maria Vaz Martins	Resonance induced by repulsive interactions in a model of globally coupled bistable systems
	17:00 – 17:30	Myrta Grüning	First principles computational and theoretical tools for the calculation of nonlinear optical properties
	17:30 – 18:00	Francesco Marino	Acoustic black holes in a "photon-fluid"
	Conference Dinner		

Posters

Juan Belmonte Beitia
"Solitons in coupled nonlinear Schrodinger equations with spatially inhomogeneous coefficients"

Antin Mykola Leszczyszyn
"Bidirectional interaction of dispersive shock and rarefaction waves in nonlinear Schrödinger flows"

Sofia Latas and Mário Ferreira
"Soliton explosion control in optical fibers"

Marzena Ciszak
"Synchronization and mixed mode oscillations in a network of coupled light emitting diodes"

J. Barros and V.Brazhnyy
"Resonant transmission of discrete solitons through the defects"

ABSTRACTS

DISSIPATIVE PERIODIC WAVES, SOLITONS AND BREATHERS OF THE NONLINEAR SCHRODINGER EQUATION WITH COMPLEX POTENTIALS

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Exact solutions for the generalized nonlinear Schrodinger (NLS) equation with inhomogeneous complex linear and nonlinear potentials are found. We have found localized and periodic solutions for a wide class of localized and periodic modulations in space of complex potential and nonlinearity coefficient.
Examples of stable and unstable solutions are given. We also demonstrated numerically the existence of stable dissipative breathers in the presence of an additional parabolic trap.

COLD ATOMS TRAPPING VIA HELICAL INTERFERENCE PATTERNS OF THE PHASE-CONJUGATED LAGUERRE-GAUSSIAN BEAMS

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The trapping of the dilute Bose gas by a helical interference pattern produced by two counter-propagating Laguerre-Gaussian beams will be discussed.

SOLITON LOCALIZATION IN A VIBRATING HARMONIC TRAP

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We derive exact solitonic solutions of a class of Gross–Pitaevskii equations with a time-dependent harmonic trapping potential and interatomic interaction.
We find families of exact single-solitonic, multi-solitonic and solitary wave solutions. We show that, with the special case of an oscillating trapping potential and interatomic interaction, a soliton can be localized indefinitely at an arbitrary position. The localization is shown to be experimentally possible for sufficiently long time even with only an oscillating trapping potential and a constant interatomic interaction.

SUPPRESSION OF THE QUANTUM-MECHANICAL COLLAPSE BY REPULSIVE INTERACTIONS

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The quantum-mechanical collapse or the fall onto the center is a peculiar phenomenon in quantum mechanics. We demonstrate that the local cubic repulsive nonlinearity in the three-dimensional BEC prevents the singular regime of the fall onto the center of particles attracted by potential -1/r^2.
It corresponds to the attraction of electric dipole moments to a central charge. In lieu of the fall onto the center the nonlinearity creates a ground state. With the addition of the harmonic trapping potential, the model gives rise to a tristability in the case when the respective linear model still does not give rise to the fall onto the center. We develop an analytical approximation for the ground state, which features a reasonable accuracy in comparison with numerical findings.

THE EFFECT OF DIPOLE-DIPOLE INTERACTION ON TRANSITION FROM THE IMMISCIBLE TO MISCIBLE STATE IN LINEARLY COUPLED BINARY DIPOLAR BOSE-EINSTEIN CONDENSATE

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The Bose-Einstein condensate (BEC) has been in the focus of research of many experimental and theoretical groups as an ideal environment for implementation and verification of many ideas from classical and quantum dynamics [1]. Recently developed particle trapping techniques have allowed the creation of multicomponent BECs formed of atoms in different hyperfine (spin) states [2]. The possibility of transitions between immiscible and miscible states has been frequently investigated in such systems. In this context, was shown that the presence of a resonant electromagnetic spin-flipping field may induce the immiscibility; miscibility (IM) transition through the linear coupling of components in the binary BEC [3,4] with contact interactions between atoms. On the other hand, in properties of dipolar binary BECs have been recently widely investigated, which was stimulated by experiments with ultracold polar molecules [5] and chromium [6]. In this work we explore the influence of nonlocal dipole-dipole (DD) interactions on the IM transition in binary dipolar BECs whose components are linearly coupled. The problem is studied analytically by means of a variational approximation, and by direct numerical simulation using the split-step Fourier method. Different combinations of the components' dipolar moments are considered. It is found that, in the binary BEC formed by dipoles polarized in a common direction, the DD interaction can change the value of the linear coupling parameter at the IM transition, but it cannot induce such transition in the absence of the linear coupling. The exception is a binary condensate formed by two identical dipolar components polarized in opposite directions, where the linear coupling is not necessary for the induction of the IM transition. In general, the localized states formed in the presence of the DD interactions evolve into breathers. Only in the case of a very strong attractive DD interaction, where the stationary solitons are very narrow and possess high amplitudes, a small perturbation can destroy the localized state. The binary BECs formed of dipoles with the same orientation but different magnitudes are briefly investigated too.

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[3] R. J. Ballagh, K. Burnett, and T. F. Scott, "Theory of an Output Coupler for Bose-Einstein Condensed Atoms", Phys. Rev. Lett. 78, 1607 (1996).
[4] I. M. Merhasin, B. A. Malomed, and R. Driben, "Transition to miscibility in a binary Bose -Einstein condensate induced by linear coupling", J. Phys. B 38, 877 (2005).
[5] J.D. Weinstein, R. deCarvalho, T. Guillet, B. Friedrich, and J.M. Doyle, "Magnetic Trapping of Calcium Monohydride Molecule", Nature 395, 148 (1998).
[6] J.D. Weinstein, R. deCarvalho, J. Kim, D. Patterson, B. Friedrich, and J.M. Doyle, "Magnetic trapping of atomic chromium", Phys. Rev. A 57, R3173 (1998).

MANY-PARTICLE LANDAU-ZENER MODELS AND DYNAMICS OF QUANTUM PHASE TRANSITIONS

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We consider dynamics of quantum phase transitions in Dicke and Lipkin-Meshkov-Glick models, and the related many-particle Landau-Zener models using truncated Wigner approximation. Initial state of the quantum system is represented by an ensemble of classical trajectories according to its Wigner function. Sweeping a parameter through a critical value, the quantum system undergoes a quantum phase transition. Corresponding ensemble of classical trajectories undergoes passage through a bifurcation. Deviation from adiabaticity is calculated from mapping of the classical dynamics to Painleve equation. We discuss possible experimental probes of the obtained power laws and universal distributions.

[1] Altland et al, Phys.Rev. A 79, 042703 (2009).
[2] A.P. Itin, P. Torma, Phys. Rev. A 79, 055602 (2009).
[3] A.P. Itin, P.Torma, arXiv::0901.4778.

REACTION RATE THEORY WITH ACCOUNT OF DISCRETE BREATHERS

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The problem of escape from metastable states is of importance to many fields of physics, chemistry, engineering and biology. It is well-known that in thermal equilibrium the fluctuation-activated reaction rate is expressed by Arrhenius' law. It has been shown that in crystals with sufficient anharmonicity a special kind of time-periodic and spatially localized vibrations can appear named intrinsic localized modes (ILMs) or discrete breathers (DBs) [1-5]. MacKay and Aubry [2] suggested that this could result in apparent violation of Arrhenius law, that is, the phenomenon of chemical reactions taking place at much lower temperatures than expected. Further development of this hypothesis by Archilla et al [3] has taken into account the DB statistics [4] for the evaluation of the reaction rate due to the DBs having energies above the activation energy. In this report we show that reaction rates depend on DBs of all energies due to effect of the time-periodic modulation of the activation energy. Large amplitude oscillations of atoms about their equilibrium positions in the lattice cause local potentials of alternating sign, which may be described in terms of time-periodic modulations of the potential barriers for chemical reactions taking place in the vicinity of DBs. The modulation effect rapidly increases with increasing reaction barrier up to the maximum DB energy, above which it becomes the only mechanism of the reaction rate amplification.

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MODELLING CANCER USING DIFFERENTIAL EQUATIONS: A PHYSICAL AND MATHEMATICAL TRIP INTO MEDICAL PROBLEMS

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PHASE-FIELD MODELING IN TUMOR GROWTH AND ANGIOGENESIS

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Tumor growth is becoming a central problem in biophysics both from its social and medical interest and, more fundamentally, because it is a remarkable example of an emergent complex system. Often tumors recruit vessels, through a process deemed angiogenesis, with the function of delivering the nutrients the tumor cells need to proliferate. During angiogenesis, capillary endothelial cells respond to local concentrations of various proteins to form a new network of capillaries. Focusing on the description of the spatial and dynamical features of tumor growth and angiogenesis, I will introduce recent modeling approaches using a technique borrowed from Materials Science: the phase-field model. This technique permits an elegant and multifaceted numerical description of complex nonlinear problems with moving boundaries. The phase-field is a tailorable method that can be easily adapted to describe quantitatively an extremely vast range of mechanical and dynamical properties of interfaces as a function of bulk properties. Using this method we are able, with a large degree of generality, to identify the paramount mechanisms controlling angiogenesis and the growth of tumor cells, as well as to propose new guidelines for experimentation both in simulation and in the laboratory. These results highlight the ability of mathematical models to suggest relevant hypotheses with respect to the role of different parameters in these processes, hence underlining the necessary collaboration between mathematical modeling, in vivo imaging and molecular biology techniques to improve current diagnostic and therapeutic tools.

THE VES HYPOTHESIS AND PROTEIN FUNCTION

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DYNAMICAL RIEMANNIAN GEOMETRY AND PLANT GROWTH

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The intricate forms of plant leaves are a biological mystery, yet the shapes and symmetries encountered here hint at having a mathematical origin. Treating the leaf as a 2-dimensional Riemannian surface, the effects of curvature evolution and material transport on a curved surface can be studied numerically. The ultimate goal of this work is to create a set of nonlinear PDEs based on reaction-diffusion type equations on a curved background manifold whose parameters can be adjusted to yield a variety of leaf shapes resembling those found in nature.

STOCHASTIC INCOHERENCE IN THE RESPONSE OF REBOUND BURSTERS

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At an optimal value of the noise intensity, the maximum variability in rebound burst durations is observed and referred to as a response stochastic incoherence. A general mechanism underlying this phenomenon is given, being different from those reported so far in excitable systems. It is shown to be determined by (i) the monotonic reduction of the hysteresis responsible for bursting caused by noise and consequent transformation of responses from rebound bursts to single spikes, and (ii) a symmetry breaking in distributions of burst durations caused by the existence of the minimum response length. The phenomenon is studied numerically in a Morris-Lecar model for neurons and its mechanism is explained with the use of canonical models describing hard excitation states.

OBSERVATION OF EXTREME TEMPORAL EVENTS IN A PHOTONIC CRYSTAL FIBER: OPTICAL ROGUE WAVES

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TO BE ANNOUNCED

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TRAVELLING SOLUTIONS OF A HIGHER ORDER QUINTIC COMPLEX GINZBURG-LANDAU EQUATION

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Recently, numerical simulations have shown the complete elimination of pulse explosions occurring under the quintic complex Ginzburg-Landau equation if higher order effects, such as intrapulse Raman scattering, self-steepening and third order dispersion, are added to the equation [1]. Since in those conditions, the pulse profile evolves steadily on a straight trajectory, here we use a travelling similarity variable transformation in order to find the steady profiles and then study their spectral stability.

[1] S. C. Latas and M. F. Ferreira. Soliton explosions control by higher-order effects. Optics Letters, 35:To be published, 2010.

NON-LINEAR DYNAMICS OF INTENSE LASER PULSES IN PLASMAS

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The non-linear interaction between intense lasers and plasmas has important implications in wakefield acceleration, an advanced accelerator concept with the potential to revolutionize standard acceleration techniques, and in the generation of single-cycle laser pulses with intensities beyond current technology, which can be used in imaging devices. In this work we present a photon kinetics model for the laser pulse dynamics in plasmas, which generalizes previous models where self-similar solutions for the evolution of the laser intensity profile were assumed. In photon kinetics the laser pulse is described by a Wigner-like quasi-particle distribution of photons whose transport is determined by the Wigner-Moyal equation. Our photon kinetics model is used to investigate stable laser propagation regimes, critical for wakefield accelerators, and to identify the onset of self-steepening and optical shock formation in plasmas, key mechanisms for the generation of single cycle ultra-intense laser pulses.

MULTIPLE FILAMENTATION AND DYNAMICAL EXCITATION OF LIGHT CONDENSATES IN CUBIC-QUINTIC OPTICAL MEDIA

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In this work we analyze both theoretically and by means of numerical simulations the phenomena of multiple filamentation and dynamical formation of light condensates in optical media featuring competing cubic and quintic nonlinearities. We provide a description of recent experiments in terms of a linear stability analysis supported with simulations, showing the possibility of the observation of modulational instability suppression of intense light pulses travelling across such nonlinear media. We also show a novel mechanism of indirect excitation of flat-topped solitary waves involving coalescence processes of nonlinear coherent structures produced by managed filamentation of high power laser beams.

DISSIPATIVE SOLITONS IN OPTICAL FIBER SYSTEMS

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Dissipative solitons have many unique properties which differ from those of their conservative counterparts and which make them similar to living things. We focus our discussion on dissipative solitons in optical fiber systems, which can be described by the cubic-quintic complex Ginzburg-Landau equation (CGLE). The conditions to have stable solutions of the CGLE are discussed using the perturbation theory. Several exact analytical solutions, namely in the form of fixed-amplitude and arbitrary-amplitude solitons, are presented. The numerical solutions of the quintic CGLE include different types of pulses, namely plain, flat-top, composite, pulsating, erupting, and creeping pulses. The interaction between plain and composite pulses is analyzed using a two-dimensional phase space. Stable bound states of both plain and composite pulses are found. The impact of some higher-order effects on these pulses is also discussed.

FORMATION OF MAGNETIC FLUX PATTERNS IN THE INTERMEDIATE STATE OF TYPE-I SUPERCONDUCTORS

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EXACT SOLUTION FOR A BOSON-FERMION MODEL AND APPLICATION TO ULTRA-COLD ATOMS

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The progress on ultra-cold atoms experiments allowing to tune fermionic systems through a Freshbach resonancewhere itinerant fermionic atoms may form tightly bound pairs ("bosonic" molecules) [M.W. Zwierlein et al., "Observation of Bose-Einstein Condensation of Molecules", Phys. Rev. Lett. 91, 250401 (2003); C. A. Regal et al., "Observation of Resonance Condensation of Fermionic Atom Pairs", Phys. Rev. Lett. 92, 040403 (2004)] has lead to a renewed theoretical interest in boson-fermion models. We study a 1D boson fermion resonance model describing itinerant spin-1/2 fermions and itinerant scalar bosons coupled through a local interaction which describes the binding of a pair of opposite spin fermions to form a scalar boson, and the reverse process. The model also includes a detuning term characterized by a detuning parameter. It is found that the model has an exact solution by Bethe Ansatz. We find that the model supports fermion bound pairs. For sufficiently large values of the detuning parameter the ground state consists of purely unbound fermions forming a Fermionic liquid. As one decreases the detuning parameter the system goes through a Feshbach resonance and the ground state becomes unstable with respect to the formation of bound fermion pairs. In this case unbound fermions and bound fermions pairs coexist. The BCS-BEC scenario will also be discussed.

RESONANCE INDUCED BY REPULSIVE INTERACTIONS IN A MODEL OF GLOBALLY COUPLED BISTABLE SYSTEMS

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Our work concerns the effect of disorder in the response of nonlinear systems to weak external signals. In particular, we study a generic globally coupled bistable system, and show that the response of the macroscopic variable to a sub-threshold forcing is optimal for an intermediate proportion of repulsive links. We relate this resonance to the appearance of a multistable region, and we predict the location of the resonance peaks, by a spectral analysis of the Laplacian matrix.

FIRST PRINCIPLES COMPUTATIONAL AND THEORETICAL TOOLS FOR THE CALCULATION OF NONLINEAR OPTICAL PROPERTIES

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The author is co-developing [1] computational and theoretical tools for the calculation of optical properties and the simulation of optical processes within the framework of Many-Body Perturbation Theory and time-dependent density-functional theory. In contrast with the standard linear response approach in frequency domain, the fundamental quantities (either the one-particle Green function or the electronic density) are propagated in time. Real time propagation offers several advantages from a numerical/computational point of view, and it naturally allows for the treatment of nonlinear properties and the study of non-equilibrium phenomena.The tools are developed within the Yambo code [2], a code for electronic structure calculations in solid state and molecular physics. The poster presents the main ideas of the theoretical framework and behind the implementaion. As well it shows the first results obtained for the second harmonic generation of bulk GaAs.

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[2] "Yambo: an ab initio tool for excited state calculations", A. Marini, C. Hogan, M. Grüning, D. Varsano, Comp. Phys. Comm. 180, 1392 (2009)

ACOUSTIC BLACK HOLES IN A "PHOTON-FLUID"

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Exploiting the relation between nonlinear optics and fluid dynamics we show that acoustic black holes can be created in a self-defocusing optical cavity. Light-matter interaction in self-defocusing media can be indeed described in terms of a two-dimensional ``photon-fluid", where the optical intensity corresponds to fluid density and the gradient of the phase to the fluid velocity. On this fluid, linear excitations of the background (sound-waves) experience an effective Lorentzian curved spacetime determined by the physical properties of the flow. Since in an optical cavity configuration the background flow is "pinned" by the driving field, the injection of a suitable optical vortex beam allows the generation of acoustic ergoregions and event horizons. An experiment simulating the main features of the rotating black hole geometry is proposed.

POSTERS

"Solitons in coupled nonlinear Schrodinger equations with spatially inhomogeneous coefficients"
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"Bidirectional interaction of dispersive shock and rarefaction waves in nonlinear Schrödinger flows"
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"Soliton explosion control in optical fibers"
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"Synchronization and mixed mode oscillations in a network of coupled light emitting diodes"
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"Resonant transmission of discrete solitons through the defects"
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