Some Recent Results on Hierarchical Chaotic Systems: a tribune to J.S. Nicolis' heritage

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ABSTRACT

Hierarchical dynamical systems are complex systems consisting of multiple levels of sub-systems interlinked through non-linear, parametric, couplings. The role of chaos in such systems has been a prominent research activity spearheaded by the early work of J.S. Nicolis. In this presentation we shall revisit the subject by reviewing two recent results. The first one is a discovery of a class of such systems which exhibit block-entropy growth rates apart of the typical rates of growth, i.e. exponential or polynomial, which are associated with standard dynamical systems. This class of systems consists of discrete non-autonomous systems coming from a combination of two or more graphs. Analytic and numerical results will be presented for both purely deterministic and purely probabilistic cases. We will discuss also the conditions giving rise to stretched exponential type of block entropy growth, typical of natural language systems. Next we shall present another class of hierarchical systems exhibiting emerging, coherent, collective motion due to chaotic dynamics. This is a system of interacting motile particles endowed with an inner, adaptive, steering mechanism. By means of their non-linear parametric coupling, the system elements are able to explore the bifurcation route to chaos. Their collective synchronized motion is quantified by means of a graph representation. The higher degrees of coherence and group cohesion are attained when the motile sub-systems display a combination of ordered and chaotic behaviours, which emerges from a collective, deterministic, self-organization process.

Keywords: Entropy, Graphs, Symbolic Dynamics, Non-autonomous systems, Self-organization.

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Chimera states in networks of excitable elements and coupled damped pendulums

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ABSTRACT

The chimera state is a peculiar synchronization phenomenon discovered ten years ago in systems of nonlocally coupled elements which split into two domains: one coherent and phase locked and another incoherent and desynchronized. Chimera states have been found in numerous models from phase oscillators to coupled chaotic maps and recently there were reports on experimental evidence as well. In the present work we study the existence and stability of chimera states in two different systems: the first one is a network of Hindmarsh-Rose oscillators which provide a realistic model for neuron dynamical behaviour. This system is motivated by neuroscience where chimera states could explain the phenomenon of unihemispheric sleep observed in many birds and dolphins sleep with one eye open. The second system we consider is an extension of the famous Kuramoto phase oscillator where a second order derivative term has been added. The mechanical analog of such a system corresponds to coupled damped pendulums where chimera states are reported for the first time.

Dynamical localization in chaotic systems: spectral statistics and localization measure in kicked rotator as a paradigm for time-dependent and time-independent systems

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ABSTRACT

We study quantum kicked rotator in the classically fully chaotic regime, in the domain of the semiclassical behaviour. We use Izrailev's N-dimensional model for various N<=4000, which in the limit N-> infinity tends to the quantized kicked rotator, not only for K=5 as studied previously, but for many different values of the classical kick parameter 5<=K<=35, and also of the quantum parameter k. We describe the dynamical localization of chaotic eigenstates as a paradigm for other both time-periodic and time-independent fully chaotic or/and mixed type Hamilton systems. We generalize the localization length L and the scaling variable (L/N) to the case of anomalous classical diffusion. We study the generalized classical diffusion also in the regime where the simple minded theory of the normal diffusion fails. We greatly improve the accuracy of the numerical calculations with the following conclusions: The level spacings distribution of the eigenphases is very well described by the Brody distribution, systematically better than by other proposals, for various Brody exponents. When N->infinity and L is fixed we have always Poisson, even in fully chaotic regime. We study the eigenfunctions of the Floquet operator and characterize their localization properties using the information entropy measure describing the degree of dynamical localization of the eigenfunction. The resulting localization parameter is found to be almost equal to the Brody parameter. We show the existence of a scaling law between the localization parameter and the scaling variable L/N, now including the regimes of anomalous diffusion. The above findings are important also in time-independent Hamilton systems, like in mixed type billiards, where the Brody distribution is confirmed to a very high degree of precision for dynamically localized chaotic eigenstates.

Superconducting Metamaterials

N. Lazarides and G. Tsironis

ABSTRACT

The metamaterials are artificially structured composites characterized by nonconventional material parameters, such as negative permeability and/or refractive index. Superconducting metamaterials constitute a particular class of artificial media that provide reduced losses and intrinsic nonlinearities, due to the extreme sensitivity of the superconducting state to external field. Moreover, the use of superconducting elements that encompass the Josephson effect, known as rf Superconducting Quantum Interference Devices or rf SQUIDs, allows for real time tunability without degradation or even destruction of the superconducting state. We present SQUID-based metamaterial models in one and two dimensions and investigate nonlinear wave propagation, tunability and bistability properties, and the possibility for generating nonlinear localized excitations of the discrete breather type.

Discrete nonlinear lattices embedded in non-zero temperature heat bath

Thomas Oikonomou

ABSTRACT

We explore the statistical properties of discrete breathers (localized oscillations) in nonlinear lattices. Particularly, we drive an 1--dimensional lattice of first neighbors coupled oscillators into a thermal equilibrium of temperature T_0. We then bring the edges of the lattice in contact with heat baths, both of them with the same temperature $T \neq T_0$, and let the total system evolve in time. The coupling potential of each oscillator is given by the relation

$$W(x_i) = \frac{k}{4}\left(x_{i+1} - x_i\right)^2 + \frac{k}{4}\left(x_{i-1} - x_i\right)^2, \quad \text{MERGEFORMAT}$$

and their on-site potential is of the form

$$V(x_i) = \frac{x_i^2}{2} + \frac{x_i^4}{4}. \qquad \text{MERGEFORMAT}$$

The first term in Eq. (1.2) is called linear while the second one is denoted as nonlinear characterizing the lattice. The existence of the nonlinear potential may create breathers [1,2] in one or more lattice points, which live for long time scales out of Boltzmann equilibrium state. Such states are known in literature as *metaequilibrium states* and present the origin of Tsallis *q*--statistics and the associated *q*--distributions [3].

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A dynamical study of a system of interacting vortices in a confined Bose-Einstein condensate

V. Koukouloyannis

ABSTRACT

In this work we study the dynamical behavior of interacting vortices in a confined Bose-Einstein condensate. First, we consider a system of three vortices with alternating charges. Since the system possesses two integrals of motion, the "Energy" H and the "Angular Momentum" L, we can study it as a two-degrees of freedom system by treating L as a parameter. In this case, we can use Poincare sections in order to distinguish the regions of regular and chaotic motion. After that, we consider a system of four interacting vortices. This is a system of four degrees of freedom and the Poicare section cannot provide a clear image of the underlying dynamics. In this case, our main studying instrument become the stability maps acquired by using the GALI chaoticity index.

Wave Localization and Propagation in Disordered Nonlinear Systems

G. Kopidakis

ABSTRACT

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Modeling charge transfer in DNA

G. Kalosakas

ABSTRACT

Due to applications in nanotechnology as well as in biology, charge transfer in DNA has attracted intense research interest (see [1] and references therein). Using a novel LCAO parametrization for π molecular orbitals of planar organic molecules [2], we have calculated the complete set of electronic parameter describing electron or hole transfer in DNA [3]. These parameters have been used to simulate [4] experimental results on hole transfer rates between guanine radical cations and GGG traps within appropriately synthesized DNA segments [5,6].

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Linear Optical Rogue Waves in Disordered Photonic networks

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ABSTRACT

We investigate numerically as well as experimentally the generation of optical rogue waves in disordered photonic networks, which are consisted of inverted Luneburg lenses. We show that optical rogue waves may exist in absence of nonlinearities and that the nonlinearities does not affect the position that a rogue wave appears.

Furthermore we propose that there are two important physical parameters for linear rogue waves to appear. The distortion of the system (related to the spontaneous nature of the phenomenon) and the refractive index variation, which seems to be the most dominant.

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