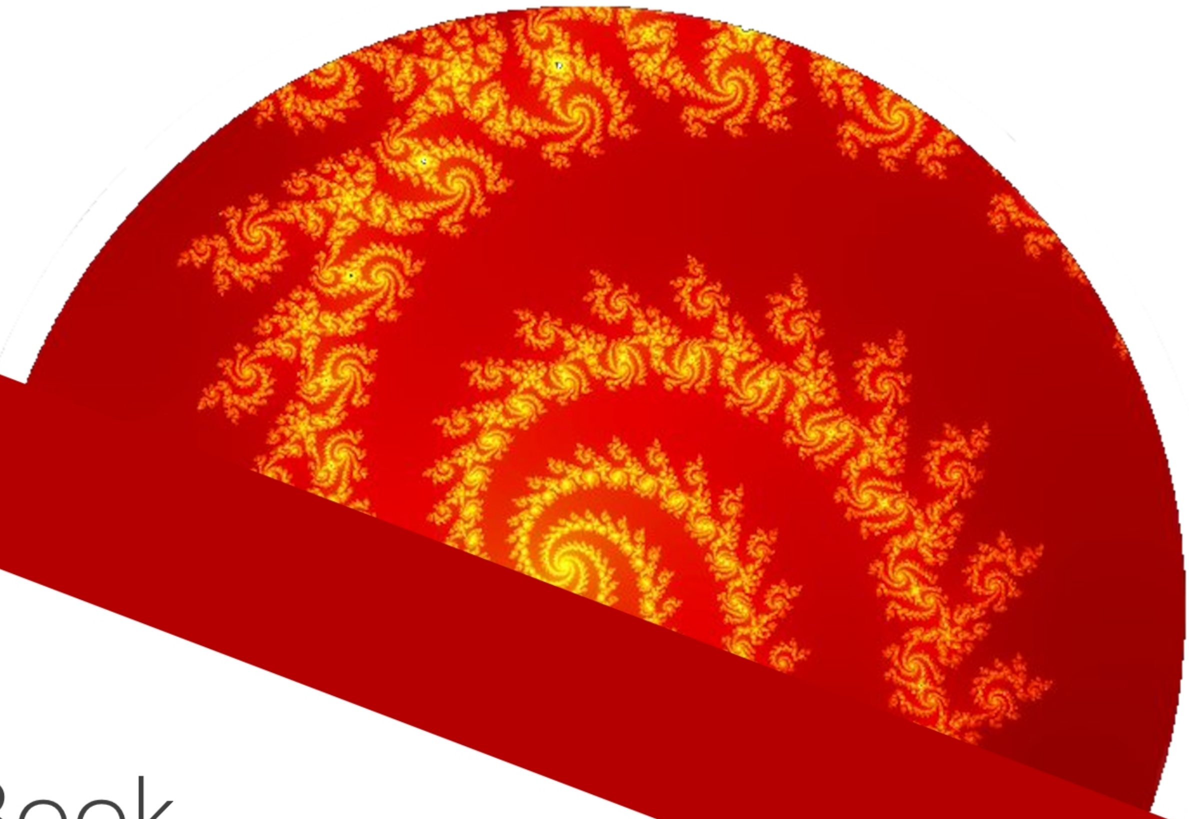
31st Summer School - Conference

"Dynamic Systems and Complexity"

Department of Computer Science and Biomedical Informatics

Lamia, **7-15 July** 2025



Book of Abstracts

ΠΕΡΙΦΕΡΕΙΑ ΣΤΕΡΕΑΣ ΕΛΛΑΔΑΣ Π.Ε. ΦΘΙΩΤΙΔΑΣ

Ο.Π.Α.ΣΤ.Ε. ΟΡΓΑΝΙΣΜΟΣ ΠΟΛΙΤΙΣΤΙΚΗΣ ΑΝΑΠΤΥΞΗΣ ΣΤΕΡΕΑΣ ΕΛΛΑΔΑΣ Π.Ε. ΦΘΙΩΤΙΔΑΣ

ΔΗΜΟΣ ΛΑΜΙΕΩΝ

ΔΗΜΟΚΡΙΤΟΣ DEMOKRITOS

ΤΕΕ ΤΜΗΜΑ ΑΝΑΤΟΛΙΚΗΣ ΣΤΕΡΕΑΣ ΕΛΛΑΔΑΣ

ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ · ΔΠΜΣ ΠΛΗΡΟΦΟΡΙΚΗ ΚΑΙ ΥΠΟΛΟΓΙΣΤΙΚΗ ΒΙΟΙΑΤΡΙΚΗ

ΙΕΡΑ ΜΗΤΡΟΠΟΛΙΣ ΦΘΙΩΤΙΔΟΣ

Εκδόσεις Επιστημονικές ΤΖΙΟΛΑ

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Introduction

We would like to thank all the people who contributed to the 31st Summer School – Conference "Dynamic Systems and Complexity", held at the Department of Computer Science and Biomedical Informatics, co-organised by the Department of Physics, University of Thessaly, from July 7 to July 15, 2025. This year's Summer School - Conference honoured the overall scientific contribution of Kyriakos Hizanidis, Professor Emeritus at NTUA. We extend our sincere thanks to lecturers and speakers who accepted our invitation or volunteered to deliver either introductory or research presentations, enriching the scientific programme with their expertise.

This volume contains the abstracts of all presentations delivered during the conference. For clarity and ease of reference, the abstracts are organized in two sections and listed alphabetically by speaker. We hope this collection will serve as a useful resource for all participants and future readers interested in the topics explored during the event.

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Ευχαριστούμε θερμώς όσους συνέβαλαν στο 31ο Θερινό Σχολείο – Συνέδριο «Δυναμικά Συστήματα και Πολυπλοκότητα», το οποίο πραγματοποιήθηκε στο Τμήμα Πληροφορικής με Εφαρμογές στη Βιοϊατρική και συνδιοργανώθηκε με το Τμήμα Φυσικής του Πανεπιστημίου Θεσσαλίας, από τις 7 έως τις 15 Ιουλίου 2025. Το εφετινό Θερινό Σχολείο - Συνέδριο τίμησε την συνολική επιστημονική συνεισφορά του Κυριάκου Χιτζανίδη, Ομοτίμου Καθηγητού Ε.Μ.Π. Εκφράζουμε ιδιαίτερες ευχαριστίες στους διδάσκοντες και ομιλητές που αποδέχθηκαν την πρόσκλησή μας ή προσφέρθηκαν να παρουσιάσουν εισαγωγικές ή ερευνητικές διαλέξεις, εμπλουτίζοντας το επιστημονικό πρόγραμμα με την εξειδίκευση και τις γνώσεις τους.

Ο παρών τόμος περιλαμβάνει τις περιλήψεις όλων των παρουσιάσεων που πραγματοποιήθηκαν κατά τη διάρκεια του συνεδρίου. Για λόγους σαφήνειας και διευκόλυνσης της αναζήτησης, οι περιλήψεις έχουν οργανωθεί σε δύο ενότητες και παρουσιάζονται αλφαβητικώς ανά ομιλητή. Ελπίζουμε ότι η συλλογή αυτή θα αποτελέσει ένα χρήσιμο εργαλείο για όλους τους συμμετέχοντες, καθώς και για μελλοντικούς αναγνώστες ενδιαφερόμενους για τα θέματα που αναπτύχθηκαν κατά τη διάρκεια του συνεδρίου.

Local Organising Committee

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Abstracts

Keynote Speakers

Hizanidis, K.

Σχολή Ηλεκτρολόγων Μηχανικών και Μηχανικών Υπολογιστών Ε.Μ.Π.

Κβαντικη Υπολογιστικη Σε Ηλεκτρομαγνητικα Προβληματα Στο Μαγνητισμενο Πλασμα: Απο Τη ”στρεντιγκεροποιηση” Στις Γεωμετρικες Αλγεβρες Κλιφορντ

Θα παρουσιαστούν οι βασικές αρχές των κβαντικών υπολογιστικών τεχνικών για την επίλυση κλασσικών προβλημάτων. Η έμφαση θα είναι το πρόβλημα της διάδοσης ηλεκτρομαγνητικών κυμάτων σε μαγνητισμένο πλάσμα. Θα ακολουθηθούν δύο ξεχωριστές οπτικές για την μετεγγραφή του ηλεκτρομαγνητικού προβλήματος σε σύστημα που θα δύναται να επιλυθεί με κβαντικό τρόπο: (α) αυτό της μετεγγραφής σε πρόβλημα τύπου Schr?dinger και (β) της αναπαράστασης του ηλεκτρομαγνητισμού με τεχνικές της Γεωμετρικής Άλγεβρας του Clifford σε χώρους (1+3 διαστάσεων) Minkowski.

Mendonça, J. T.

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Two Waves - One Particle

This basic three-body interaction is phenomenologically very rich, and covers several diAerent processes, from stochastic acceleration to nonlinear Compton scattering. We discuss both classical and quantum descriptions of this interaction, and illustrate their physical consequences [1]. In the classical description, we use a Superhamiltonian formulation of the particle motion (electron, or ion) in two electromagnetic waves, and show that it is non integrable. DiAusion in phase-space describes stochastic acceleration, and can explain the broad electron energy spectrum observed in intense laser-plasma interactions. In the non-relativistic limit, it can also be explain the stochastic heating of ions by electrostatic waves. In the quantum description, we use Volkov solutions of the relativistic wave equations (Klein-Gordon and Dirac), and shown that they are able to explain the nonlinear Compton scattering of photons and plasmons [2], thus generalizing the traditional view of Compton scattering, which only involves photons. This problem is highly relevant to in the present experiments with PetaWatt laser systems, where the nonlinear quantum plasma regime becomes accessible. Compton scattering is the basic ingredient for a consistent plasma quantum theory, as recently shown in [3]. It is also known that the so-called inverse Compton scattering, which corresponds to scattering of low energy photons by highly relativistic particles, is very important in Astrophysics. The same Volkov solutions can also be used to describe the nonlinear regime of quantum Landau damping, showing that in this regime the electrons can emit and absorb more than one plasmon. Explicit expressions for this multi-plasmon Landau damping can be derived [4]. This explains the possible occurrence of multi-plasmon absorption of electrostatic waves by electrons, and confirms previous simulation results. A similar formalism can be used to describe photon Landau damping of electron plasma waves. Such a similarity with quantum electron Landau damping is not surprising, given the undulatory nature of photons. Relevance of both processes to laser acceleration is exemplified. My lectures will be based on joint work with Antonio Galves, Aline Duarte and Guilherme Ost.

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Plasma Science And Fusion Center

For almost four decades, Kyriakos Hizanidis and I have interacted intellectually and socially – through jocular repartee, as well as by provoking, pestering, and irritating each other. Analogous to fine wine, our friendship has become richer and more enduring over time through common goals and mutual understanding. The underlying stimulant has been our passion for physics. Over the years, our domain of interaction has drawn in younger and vibrant physicists in Greece and in USA. In this talk, I will discuss different topics we have explored in plasma physics along with my vision for the future. Plasmas, whether occurring in the natural environment or in fusion devices, are inherently complex dynamical systems. Our studies on probing this complexity have ranged from linear to nonlinear classical plasma physics and, recently, on developing a framework for plasma physics within quantum information sciences.

General Speakers

Anastassiou, S.

Department of Mathematics, University of Western Macedonia, Kastoria, GR52100, Greece

Hyperbolic Theory Of Dynamical Systems: Short Introduction Through Examples

This lecture introduces the fundamental concepts of the Hyperbolic Theory of Dynamical Systems, providing an accessible entry point for graduate students. We shall explore the core ideas of hyperbolicity, including stable and unstable manifolds, uniform expansion and contraction, and the study of hyperbolic systems. Through intuitive examples, such as Anosov diffeomorphisms, the Smale horseshoe and Plynkin attractors, we shall illustrate how hyperbolicity leads to chaotic yet structured behaviour. Emphasis will be placed on geometric intuition and generic properties of Dynamical Systems. No prior expertise in dynamics is assumed, hoping that this lecture will serve as a friendly introduction to a cornerstone of modern dynamical systems.

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Bezerianos, A.

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EEG And FMRI Techniques And Biomarkers On Brain Complexity And Dynamics

Understanding the intricate complexity and dynamics of the human brain is fundamental to elucidating the mechanisms underlying both normal cognitive function and the complex pathophysiology of neurological and psychiatric disorders. Electroencephalography (EEG) and functional Magnetic Resonance Imaging (fMRI) stand as the primary non-invasive neuroimaging modalities, offering complementary perspectives on brain activity. EEG provides a direct measure of neural electrical activity with high temporal resolution, capturing rapid changes in brain states, while fMRI indirectly assesses neural activity through hemodynamic responses, yielding high spatial resolution and the ability to visualize deep brain structures. This report synthesizes recent breakthroughs in both EEG and fMRI techniques, alongside the biomarkers identified using these methods, for studying brain complexity and dynamics in healthy individuals and those with various neurological and psychiatric conditions. The advancements in high-density EEG systems and sophisticated signal processing, the emergence of mobile EEG for naturalistic data acquisition, and the progress in EEG-based Brain-Computer Interfaces are discussed. Furthermore, the report highlights the impact of advanced analytical methods such as dynamic functional connectivity and the transformative role of Machine Learning (ML) with paradigms from my work on cognitve disorders and human - autonomous car interactions. By examining the established and emerging EEG and fMRI biomarkers across a spectrum of brain states and disorders, this report underscores the crucial role of these neuroimaging techniques in advancing our understanding of brain complexity and dynamics and their potential for clinical translation in diagnosis and treatment monitoring.

Note: Prepared by the author in collaboration with Gemini, a large language model trained by Google.

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Bounties, A.

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Γιατι Ονομαζουμε Την Πολυπλοκοτητα Επιστημη;

Στην ομιλία αυτή θα εστιάσουμε στις βασικές έννοιες του κλάδου που ονομάζεται Επιστήμη της Πολυπλοκότητας και θα αναφερθούμε σε θεμελιώδεις της αρχές για την κατανόηση της Φύσης, από άποψη στατικής αλλά και δυναμικής συμπεριφοράς. Πρώτα θα περιγράψουμε εφαρμογές της Πολυπλοκότητας σε γεωμετρικές μορφές φύλλων και δένδρων, και θα ανακαλύψουμε ότι οδηγούν σε σχήματα με μη ακέραιες διαστάσεις που ονομάζονται φράκταλ. Κατόπιν θα μιλήσουμε για ομαδικές κινήσεις πουλιών ή ψαριών και τη λειτουργία του εγκεφάλου. Για να γίνουν καλύτερα αντιληπτές οι ως άνω έννοιες, τις παρουσιάζω εδώ μέσω απλών παραδειγμάτων στα οποία έχω και εγώ εργαστεί. Κατά τη διάρκεια του 31ου Σχολείου, θα έχουμε την ευκαιρία να τις αναλύσουμε περαιτέρω και να αντιληφθούμε την μεγάλη προσφορά της Επιστήμης της Πολυπλοκότητας σε πάμπολλα θέματα φυσικών αλλά και βιολογικών επιστημών.

Διεθνής Βιβλιογραφία:

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Bountis, A.

Πανεπιστήμιο Πατρών, Πάτρα 26500 Ελλάδα

Μη Γραμμικη Δυναμικη Και Χαος

Στην εισαγωγική αυτή ομιλία θα προσπαθήσω να εξηγήσω θεμελιώδεις έννοιες του επιστημονικού κλάδου που ονομάζεται Μη Γραμμική Δυναμική και Χάος. με όσο το δυνατόν απλούστερο τρόπο. Οι έννοιες αυτές έχουν κατά βάση μαθηματικό περιεχόμενο, είναι όμως άρρηκτα συνδεδεμένες με φαινόμενα που συναντούμε σε πολλές επιστήμες. Για να γίνουν καλύτερα αντιληπτές, τις παρουσιάζω μέσω ενός αριθμού ερωτημάτων που απαιτώ από τους ακροατές να προσπαθήσουν να απαντήσουν κατά τη διάρκεια του Σχολείου. Μόνον έτσι θα μπορέσουν να κατανοήσουν και να εκτιμήσουν τη σημασία των εννοιών της δυναμικής και τη σχέση τους με ρεαλιστικά φαινόμενα όλων των Θετικών Επιστημών. Κατά τη διάρκεια του 31ου Σχολείου, θα έχουμε την ευκαιρία να τις αναλύσουμε περαιτέρω και να αντιληφθούμε την μεγάλη προσφορά των Μαθηματικών στην βαθύτερη κατανόηση της φύσης, της ζωής, αλλά και των ανθρώπινων σχέσεων που διέπουν τον κόσμο γύρω μας.

Αναφορές:

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Constantoudis, V.

Ινστιτούτο Νανοεπιστήμης και Νανοτεχνολογίας Ε.Κ.Ε.Φ.Ε. «Δημόκριτος»

Μορφοκλασματικη Γεωμετρια Και Πολυπλοκοτητα Επιφανειων Με Εφαρμογες Στη Μικροηλεκτρονικη» Και Νανοτεχνολογια

Στην ομιλία αυτή θα συζητήσουμε εφαρμογές της μορφοκλασματικής γεωμετρίας στην μικροηλεκτρονική και της πολυπλοκότητας στη νανοτεχνολογία. Και στις δύο περιπτώσεις το σημείο επαφής θα είναι η τραχύτητα των επιφανειών στη νανοκλίμακα. Στην περίπτωση της μικροηλεκτρονικής θα εστιάσουμε στην τραχύτητα των επιφανειών της δομής των τρανζίστορ στο πρώτο στάδιο της λιθογραφικής σχηματοποίησής τους, ενώ στη νανοτεχνολογία θα εισάγουμε την έννοια της πολυπλοκότητας επιφανειών και θα διερευνήσουμε τη σύνδεσή της με τις ιδιότητες των επιφανειών (κυρίως οπτικές και διαβροχής) και τις άλλες μεθόδους περιγραφής της μορφολογίας τους. Θα τονίσουμε την κρίσιμη σημασία της τραχύτητας και της στοχαστικότητας στη σύγχρονη βιομηχανία των ημιαγωγών και τη σύνδεσή τους με τη μετάβαση από την αρχιτεκτονική von Neumman στις νευρομορφικές προσεγγίσεις. Τέλος, θα επιστρέψουμε σε ποιους θεωρητικούς προβληματισμούς και θα συζητήσουμε κατά πόσο μπορούμε να ορίσουμε την πολυπλοκότητα μιας επιφάνειας ως την αντίστασή της στην ομογενοποίησή της.

Drakopoulos, V.

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FRACTAL GEOMETRY: THEORY AND APPLICATIONS

Fractal geometry has become an influential field of study, deeply impacting numerous areas of mathematics and sciences over recent decades. Rooted in the works of Benoit B. Mandelbrot [1], fractal geometry explores mathematical structures that exhibit self-similarity at varying scales. Unlike traditional Euclidean geometry, which deals with regular shapes, fractal geometry applies to irregular and complicated patterns found in nature, such as coastlines, mountains, and biological structures [2]. Fractal objects are characterised by intricate, repeated patterns, whether deterministic or statistical in nature numbers [3]. They have gained attention not only for their theoretical depth but also for their practical applications. These include areas like harmonic analysis, probability theory, dynamic systems, computer graphics, and even fields as diverse as physics, biology, and economics [4]. The appeal of fractals extends beyond mathematics, blending artistry with mathematical theory and providing a novel way to represent complicated natural forms. This presentation provides an overview of fractal geometry, distinguishing between self-affine and self-similar structures and discussing their relevance in both theoretical contexts and real-world applications [5]. Special attention will be paid to the role fractals play in fields such as chaos theory, image compression, and dynamic systems modelling [6].

Keywords: Computer Graphics, Dimension, Dynamic System, Fractal, Interpolation, Chaos.

References:

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A Unified Description Of Optical Thermodynamics

Optical thermodynamics is a recently developed theory that utilizes principles of statistical mechanics in weakly nonlinear multimoded optical settings. Using optical thermodynamics the collective behavior of utterly complex system such as multimode and multicore fibers, waveguide arrays, and coupled microresonators among others, can be unveiled in a physically meaningful context. We analyze fundamental properties that lie in the core of this theory. Specifically, we find that the extensive parameters of the entropy are naturally provided by the propagation constants. Thus, they can be different depending on the system under investigation. We investigate a variety of continuous and discrete settings. In the case of polyatomic lattices, different optomechanical pressures can be defined for each bond. In addition, we develop a theory that can be used to define pressure in systems with non-abrupt boundaries, such as graded index multimode fibers. We analyze the limitations of the Rayleigh-Jeans distribution which might lead to decreasing entropy and pressure singularities.

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Συντονισμοι Και Διαχυση Arnold

Με αφετηρία την πρωτοποριακή εργασία του Arnold [1], ο όρος “διάχυση Arnold” έχει χρησιμοποιηθεί εκτενώς στη βιβλιογραφία για να περιγράψει την αργή χαοτική διάχυση στο χώρο των ‘δράσεων’ (αδιαβατικών αναλλοίωτων) σε μη-γραμμικά δυναμικά συστήματα τριων ή περισσοτέρων βαθμών ελευθερίας. Η ομιλία θα επικεντρωθεί σε μία αυτόνομη εισαγωγή στις βασικές έννοιες που σχετίζονται με το φαινόμενο της διάχυσης Arnold. Θα συζητήσουμε επίσης πώς το φαινόμενο αυτό μας βοηθά να περιγράψουμε και να ποσοτικοποιήσουμε διάφορα ενδιαφέροντα φυσικά φαινόμενα που απαντώνται σε περιοχές των φυσικών επιστημών σε πολύ διαφορετικές κλίμακες, από την μοριακή φυσική και τη φυσική του πλάσματος, μέχρι την Ουράνιο μηχανική και την εξέλιξη του Ηλιακού συστήματος. Θα δώσουμε και ορισμένα αριθμητικά παραδείγματα με τη βοήθεια του λογισμικού mathematica. Τα παραδείγματα αυτά βοηθούν να γίνει κατανοητός ο κεντρικός μηχανισμός πίσω από το φαινόμενο, ήτοι η στιγμαία απώλεια του αδιαβατικού χαρακτήρα ορισμένων προσεγγιστικά διατηρούμενων ποσοτήτων καθώς οι τροχιές κινούνται πλησίον ‘ομοκλινικών βρόχων’, δηλαδή κοντά στις διαχωριστικές ορισμένων απλών ή πολλαπλών συντονισμών του υπό μελέτη δυναμικού συστήματος.

Αναφορές:

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Halley, J.

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Hyper-Exponential Growth: From Epidemic Models To The Evolution Of Society

Today’s world is full of instances of hyper-exponential growth (HEG). Clear examples of HEG have been identified, including the increase of the human population, the world economy and many aspects of technology. While hyper-exponential growth appears less often in natural sciences than exponential growth, it is especially important to understand of much that is happening today. Models of HEG have been developed to understand biological phenomena such as cancer growth and the dynamics of epidemics such as SARS-CoV-2. In this talk I will develop an epidemic model with evolution of transmission rates to show how HEG emerges naturally in a complex biological system. Solving the equations of growth, I show how many of the phenomena associated with HEG, such as asymptotic increase in finite time, can be understood. Finally, I apply these insights to the wider issues of importance, such as what is the nature of the collapse of hyper-exponential growth if it happens.

Harsoula, M.

Ακαδημία Αθηνών

Σπειροειδεις Γαλαξιες: Αριθμητικα Και Αναλυτικα Σπειροειδη Κυματα Πυκνοτητας

Οι σπειροειδείς βραχίονες στους μεγάλους κανονικούς σπειροειδείς γαλαξίες είναι κύματα πυκνότητας που δεν αποτελούνατι πάντα από τα ίδια αστέρια. Θα εξηγήσουμε την θεωρία του κύματος πυκνότητας για την περίπτωση αναλυτικών δυναμικών που προσομειώνουν μεγάλους κανονικούς σπειρεοειδείς γαλαξίες. (grand design galaxies). Θα εξερευνήσουμε τον χώρο των φάσεων σε ένα γαλαξιακό μοντέλο που προσομειώνει τις σπείρες του δικού μας Γαλαξία με σκοπό τον αριθμητικό εντοπισμό των ευσταθών περιοδικών τροχιών που υποστηρίζουν αυτά τα σπειροειδή κύματα πυκνότητας. Θα δείξουμε ότι οι τροχιές αυτές είναι ελλειπτικές με κύριο άξονα που αλλάζει προσανατολισμό καθώς απομακρυνόμαστε από το κέντρο του γαλαξία και η υπέρθεσή τους σε όλες τις ακτίνες δημιουργεί το σπειροειδές κύμα. Επίσης, θα εξηγήσουμε τη θεωρία εύρεσης προσεγγιστκών αναλυτικών λύσεων των περιοδικών αυτών τροχιών κατασκευάζοντας την Χαμιλτονιανή σε κανονική μορφή (normal form construction) με την βοήθεια των σειρών Lie.

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Superconducting Oscillators: From Complex Dynamics To Neuromorphic Computing

Since their discovery in the early 1960s, Josephson junctions (JJs) remain at the forefront of advancing technology in superconducting electronics, sensing, high-frequency devices, and quantum science. An important JJ-based device is the superconducting quantum interference device (SQUID), a highly sensitive magnetometer that uses JJs to measure extremely small magnetic fields. From a dynamical point of view, the SQUID is a highly nonlinear system exhibiting extreme multistablity and chaos. In the first part of my presentation, I will talk about the complex dynamics of SQUID oligomers and metamaterials, i. e. artificially structured media of periodically arranged, weakly coupled elements, which show extraordinary electromagnetic properties and tunability. Another fascinating application of JJs involves their exploration for the design of superconducting neuromorphic computing systems. When combined in circuits, coupled JJs can emulate sophisticated properties found in biological neurons. From a technological point of view, JJ-based neuromorphic systems are particularly appealing due to their capacity to operate in great speeds and with low energy. In the second part of my talk I will present recent work on such JJ-based systems and discuss the mechanisms underlying the exhibited dynamical properties relevant for neurocomputation.

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A Crash Course On Dispersive Shock Waves

Using the Korteweg-de Vries-Burgers equation we will be presenting a brief but thorough introduction on the concept of dispersive shock waves. Dispersive shock waves are a phenomenon that occurs in nonlinear dispersive media, where traditional shock waves are modified by dispersive effects. Unlike classical shock waves that form sharp discontinuities when nonlinear steepening overcomes dissipation, dispersive shock waves develop into oscillatory structures. In dispersive media - where wave speed depends on wavelength or frequency - the dispersion relation prevents the formation of true discontinuities. Instead of a sharp shock front, these waves evolve into rapidly oscillating wave trains that connect two different uniform states, with oscillations that typically have decreasing amplitude away from the shock front and wavelengths much smaller than the overall system scale.

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The stability and the lifespan of solutions of Nonlinear Schrödinger Equations: The case of nonzero boundary conditions at infinity

The question of whether features and behaviors that are characteristic to completely integrable systems persist in the transition to non-integrable settings is a central one in the study of nonlinear evolution equations. This issue is closely related to the broader problem of the stability of evolution equations [1]. Another fundamental question concerns the lifespan of solutions: whether it is infinite or finite distinguishes between global-in-time existence and instability phenomena, the latter manifested as blow-up in finite time.

We examine these questions in the context of the Nonlinear Schrödinger Equation (NLS) and NLS-type lattices, supplemented with nonzero boundary conditions at infinity [2]–[5]. Numerical investigations, based on high-accuracy schemes [4], [5], highlight the relevance of the accompanying mathematical analysis and yield numerical results in excellent agreement with theoretical predictions.

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Applications Of Non-linear Time Series - Analysis In Physics And Engineering

In the present lecture we briefly review several methods of temporal and non-linear time series analysis, mainly based on phase space reconstruction such as recurrence plots Quadrant Scan, as well as complex network transformed time series based on the visibility algorithm. We discuss the main characteristics of the methods and the insight they can provide of the underlying physical, engineering systems as well as in other systems sch as financial time series, with special focus on system identification and transition detection, event detection, and spatial variation. We present and discuss applications from magnetohydrodynamics and turbulent flows [1,2] as well as river systems [3] and car flow incident detection [4,5] financial data [6,7].

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On Non-Abelian Elastic Collisions

We introduce the notion of integrability of partial difference equations in two independent variables and how it is related to a consistency relation of maps of a specific type. As a prototypical example, we present the equations that describe non-relativistic elastic collision of two particles in one dimension. Extending these equations to an arbitrary associative algebra, relativistic elastic collision equations turn out to be a particular case. Furthermore, we show that these equations can be reinterpreted as difference systems defined on the $\mathbb{Z}^2$ graph. Finally, if time permits, we will show how this reinterpretation relates the linear and the non-linear approach of discrete analytic functions.

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Hamiltonian Dynamics For Plasma Physics And Fusion

In this introductory presentation we will discuss the strong relation between Hamiltonian Dynamics and Fusion Plasma Physics. Starting from some historical remarks and basic concepts of fusion plasmas, we will present the advantages of the Hamiltonian formalism in describing magnetic field lines and charged particle orbits.

We will consider integrable Hamiltonian systems describing particle motion under specific magnetic field symmetries and utilize a transformation to Action-Angle variables. The latter will be shown to allow for a systematic dynamical reduction as well as the calculation of all the orbital frequencies (Orbital Spectrum) which is the first step for the study of complex particle dynamics under the presence of perturbative symmetry-breaking modes rendering the system non-integrable. The resonant character of the mode-particle interactions suggests that the effect of the perturbations is strongly localized in the phase space. The specific resonance locations can be predicted in terms of the calculated unperturbed Orbital Spectrum. Moreover, the existence of Transport Barriers, related to non-twist conditions of the particle orbits is shown to be predicted, and confirmed by numerical orbit calculations. Hamiltonian bifurcations and chaos of particle orbits will also be discussed.

The presented methods and results demonstrate the theoretical and practical advantages of the Hami-ltonian formalism in terms of studying particle energy and momentum transport in fusion plasmas under the presence of multi-scale perturbations and its implications on the efficient operation of future fusion devices.

Koukouloyannis, V.

Τμήμα Μαθηματικών, Πανεπιστήμιο Αιγαίου, Ηγεμονικό Μέγαρο, Καρλόβασι, 83200, Σάμος

Περιοδικες Τροχιες Και Δυναμικα Συστηματα

Στο μάθημα αυτό θα εξετάσουμε την ύπαρξη, τη σημασία και τις ιδιότητες των περιοδικών τροχιών στα Δυναμικά Συστήματα συνεχούς και διακριτού χρόνου με ιδιαίτερη έμφαση και στα Χαμιλτονιανά Συστήματα. Αρχικά θα εξετάσουμε το ρόλο που παίζουν οι περιοδικές τροχιές στη μελέτη των Δυναμικών συστημάτων. Έπειτα, θα μελετήσουμε τη δυνατότητα ύπαρξης ή μη περιοδικών τροχιών ανάλογα με τη διάσταση του Συστήματος. Στη συνέχεια θα επικεντρωθούμε στα Χαμιλτονινά συστήματα και θα συζητήσουμε τρόπους εύρεσης καθώς και την ευστάθεια των περιοδικών τροχιών στα συστήματα αυτά. Τέλος θα εξετάσουμε συστήματα διακριτού χρόνου και θα μελετήσουμε τη διακλάδωση διπλασιασμού περιόδου ως μια οδό προς τη χαοτική συμπεριφορά.

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Everything You Always Wanted To Know About Solitons In Plasmas But Were Afraid To Ask

Large ensembles of charged particles (electrons and ions), aka *plasmas*, are ubiquitous in Nature. It is often claimed that 99% of matter in the Universe is in plasma state [1, 2]. By their very nature, a plasmas is a highly complex many-body system, whose dynamics in subject to a plethora of physical mechanisms, including long-range inter-particle interactions ("collisions") and interactions with electric or/and magnetic fields, among others. The intricate interplay among these mechanisms allows for a rich dynamics that makes plasmas an excellent test-bed for nonlinear theories [3]. Among a wide variety of phenomena, collective excitations occur in a plasma: these are propagating vibrations (i.e. waves), characterized by the inherent dispersion and nonlinearity of the plasma medium, in addition to various other mechanisms (e.g. dissipation, forcing and "noise", among others).

This is a pedagogical level presentation, aiming to provide the basic analytical framework needed to model nonlinear electrostatic waves in a plasma. A plasma fluid a will be adopted as starting point, considering – in the simplest version of the model – the dynamics of an ion fluid in nonlinear interaction with an electron "cloud", assumed to be at thermal equilibrium. This description is known to give rise to various types of nonlinear waves, including solitary waves (often modeled as *solitons*), super-solitons, double layers and envelope solitons, to name but a few.

The presentation will consist of two core parts, as follows.

In Part I, a pseudopotential analysis method will be adopted to link the fluid model to a pseudo-mechanical problem of particle motion in a nonlinear potential [4, 5]. The resulting nonlinear "motion" of the system represents a solitary wave, that is, a pulse-like excitation (for the plasma state variables, i.e. the fluid density and speed, the electrostatic potential and the electric field) with stable, stationary profile, that propagates through the plasma. An alternative method of analysis will also be presented, based on a reductive perturbation method, reducing this fluid model to a PDE in the form of a Korteweg - de Vries (KdV) equation [6, 7]. The KdV equation possesses exact solutions in the form of *solitons*, whose form is qualitatively analogous to the result obtained from the exact (i.e. non-perturbative) pseudopotential method. As expected, the results by these two methods coincide in a certain range of parameter values (but may differ, in general).

The above analysis has been adopted in the modeling of electrostatic solitary waves in planetary magnetospheres, including a recent study of Mars's induced magnetosphere [8, 9]. A remarkable outcome of this study is the prediction of coexistence of positive and negative polarity solitary waves (pulses), an aspect absent in e.g. KdV-based approaches. The main results of this line of research will be briefly presented.

In Part II, a multiple-scale method, tantamount to Newell's perturbation technique in nonlinear optics, will be adopted [10]. The fluid model is thus reduced to a PDE in the form of a nonlinear Schrodinger (NLS) equation modeling the dynamics of the envelope (amplitude) of a wavepacket. The NLS equation is known to possess analytical solutions in the form of *envelope solitons* (bright solitons, or dark solitons, in different parameter ranges). Certain analytical forms (known as *breathers*), in particular, have been used as prototypes for freak waves (or rogue waves) [11, 12]. The relevance of these models to electrostatic and electromagnetic waves in plasmas will be discussed.

Some recent research results, including a study relating the methodology of Part II to real plasma experiments on negative-ion plasmas, will be briefly presented [13].

This presentation may be delivered either as one or as a series of (e.g. two) successive lectures, depending on organization and time constraints.

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Causality Amd Modeling Of Multivariate Time Series

In the analysis of multivariate time series, the first objective is the estimation of the connectivity structure of the observed variables (or subsystems), where connectivity is also referred to as interdependence, coupling, information flow or Granger causality. Depending on the type of analysis one wants to pursues, also indicated by the size of the data, one selects a connectivity measure to estimate the driving-response connections among the observed variables. For example, if the multi-variate time series is very short, one would rather use a linear measure of bivariate (Granger) causality, or even the linear cross-correlation. On the other extreme of a very long multivariate time series, one would prefer to use a nonlinear and even multivariate measure of causality, where multivariate measure is considered a measure that for the estimation of a driving-response relationship of two of the observed variables, the other observed variables are also considered. When the measure is computed for all directed pairs of observed variables, a complex network is formed, called also connectivity or causality network, where the nodes are the observed variables, and the connections are the estimated interdependences. For a network with binary connections the interdependences are discretized to zero (not significant) and one (significant) by applying a criterion for the significance, e.g., arbitrary threshold or statistical testing.

In the era of big data and complex systems, the case of high-dimensional time series is of particular interest, where each time series (observed variable) corresponds to a subsystem, and the underlying system is composed of many subsystems. In this case, even in the presence of long time series, the multivariate measure of causality or inter-dependence may fail unless dimension reduction is designed in the estimation scheme. Dimension reduction in the estimation of direct causality of a driving-response variable pair indicates to restrict the number of the other observed variables, which is high to only a small number of them being the most relevant, i.e., most related to the response.

When the connectivity structure of the underlying system is estimated appropriately, it can be further be exploited to model the multivariate time series and make predictions. Nowadays, machine learning and particularly deep learning models have dominated the domain of modeling of multivariate time series, especially when their dimension is high. However, these are black-box models giving no or little insight onto the underlying system. On the other hand, sparse regression models, which attempt to find the most relevant explanatory variables to the response variable. In the multivariate time series setting, the response variable is one of the observed variables at a time head (typically one step ahead) and the explanatory variables are lag variables of all the observed variables, where for each observed variable the lag variables are defined for each lag (zero lag at the present time, one lag for one time step back, etc). The lag variable selection is a crucial step in the sparse regression modeling and different schemes have been developed implementing for example sophisticated optimization algorithms or genetic algorithms.

I will present first the framework of connectivity analysis of multivariate time series and focus on direct connections and many observed variables. In our research group, we have developed appropriate methodology for this scope and I will also attempt to introduce causality measures that apply dimension reduction. I will illustrate on simulated data the ability of causality measures using dimension reduction to identify the underlying complex network (connectivity structure of the underlying complex system) solely on the basis of the observed multivariate times series. Case studies on real-world applications will be presented, and in particular multivariate time series records of epileptic electroencephalograms and world financial markets.

In the last part, I will move to modeling the multivariate time series and discuss the sparse regression modeling. I will present some recent work we have done on sparse regression models of multivariate time series based on the dimension reduction schemes we used for the causality estimation.

Maaita, T.-O.

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Υλοποιηση Μη Γραμμικων Δυναμικων Συστηματων Με Τη Βοηθεια Με Γραμμικων Ηλεκτρονικων Κυκλωματων

Δυναμικά ονομάζονται τα συστήματα που εξελίσσονται στο χρόνο και περιγράφονται με διαφορικές εξισώσεις ή απεικονίσεις. Η μελέτη αυτών των συστημάτων παρουσιάζει μεγάλο ενδιαφέρον αφού μας επιτρέπει να γνωρίσουμε τη δυναμική συμπεριφορά του συστήματος και μας δίνει την δυνατότητα πρόβλεψης. Ιδιαίτερα τα μη γραμμικά δυναμικά συστήματα αποτέλεσαν σημαντικό τομέα μελέτης αφού παρουσιάζουν ενδιαφέροντα χαρακτηριστικά και φαινόμενα όπως διακλαδώσεις, χαοτική συμπεριφορά κ.α. Τα δυναμικά συστήματα μπορούν να υλοποιηθούν με τη βοήθεια των ηλεκτρικών και ηλεκτρικών κυκλωμάτων. Το γεγονός αυτό μας δίνει τη δυνατότητα πειραματικής επιβεβαίωσης των μαθηματικών μας αποτελεσμάτων αλλά και την αξιοποίηση τους σε εφαρμογές. Ο πρώτος που υλοποίησε μη γραμμικά δυναμικά συστήματα μέσω μη γραμμικών ηλεκτρικών κυκλωμάτων ήταν ο L. Chua ο οποίος έδειξε πειραματικά διάφορα φαινόμενα, όπως η χαοτική συμπεριφορά, και έβαλε τέλος στη συζήτηση που υπήρχε τότε, για το αν φαινόμενα όπως το χάος είναι μόνο μαθηματικές εφευρέσεις και κατασκευές! Στην παρούσα διάλεξη θα γίνει μια σύντομη παρουσίαση εννοιών των δυναμικών συστημάτων, των μη γραμμικών ηλεκτρικών και ηλεκτρονικών στοιχείων και θα παρουσιάσουμε τον τρόπο με τον οποίο μπορεί να υλοποιηθούν τα μη γραμμικά δυναμικά συστήματα τη βοήθεια μη γραμμικών ηλεκτρονικών στοιχείων και κυκλωμάτων.

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Chaos And The Melnikov Theory

We present the theory of chaos. We give the definition of chaos and some examles and counterexamples. We concentrate on the chaotic set of the smale horseshoe and we prove that it is chaotic through its topological conjugacy with sympolic dynamics i.e. the Bernoulli shift on the doubly infinite series of symbols. Finally we present the Melnikov theorem that proves chaos through the tranverse intersection of the stable and unstable manifolds of a saddle point in a Poincare map of a one and a half degrees of freedom periodic system of differential equations.

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‘Lifting The Blanket’: Why Wholesale Electricity In Southeast European (See) Interconnected Countries Is Systematically Higher Than In The Rest Of Europe? Using Machine Learning Methods Of Causality Discovery (Causal Structure Learning, Csl) And Rolling Correlations To Reveal The ‘real’ Causes Of Price Surges.

We investigate the key factors that shape the dynamic evolution of Day-Ahead spot prices of seven European interconnected electricity markets (Austria, Hungary, Slovenia, Romania, Bulgaria, Greece and Italy), with emphasis on their price surges and discrepancies during the period 2022-2024, that challenge the reliability and efficiency of the European target model. The high differences in the prices of the two groups, has generated political reactions from the countries that ‘suffer’ from these price discrepancies, expressed with different ways (e.g. a noticed reaction is the letter of the Greek Prime Minister sent to European Commission President). To ‘reveal’ the whole path of surging prices (from north to south), we employ combination of Machine Learning (ML) approaches in learning the causal structure of this phenomenon. Local, causal structures learning (LCSL) and Markov Blanket (MB) learning are combined to ‘lift the blanket’ that covers the ‘true structure’ of the path of causalities, responsible for the price disparity. Markov Blanket Learning is useful for identifying key fundamental variables but should be combined with causal structure learning to uncover true causes of price surges. Finally, we compute the correlation curves of rolling volatility of spot prices as well as of cross-border transfer availabilities (CBTA) identified as crucial factors by MB and LCSL, of all markets, to study their volatility spillover (a tool to detect the entire path of volatility propagation from the upstream to downstream SEE countries). The main findings of this hybrid approach are: the hierarchy of clustering process of the correlations of volatilities mentioned, between the Central European markets of Austria (AT), Germany (DE), Czechoslovakia (CZ), Slovenia (SL) and Romania (RO), with those of the South East European markets of Bulgaria (BG) and Greece (GR), reveals their strong interaction, with the volatility of Austrian market’s spot price and its CBTAs with DE, CZ, and SI, ‘uncovered’ to be a pivotal market, behaving as a ‘transmitter’ of spot price and cross-border activity volatility, over its entire connection path with SEE markets, which finally ‘receive’ the volatility disturbances, causing their price surge. These findings seem to be important and can inform policy and market decisions for a better incorporation of the electricity markets of this region in the main body of the European target model.

Keywords: Electricity wholesale electricity prices surge in SEE, Local causality structure; Markov blanket; Bayesian tool; wholesale Electricity prices; spot price volatility spillover.

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Hamiltonian Dynamics And Structure Formation In Disk Galaxies

Disk galaxies are complex systems where stars, gas, and dust evolve within dark matter halos through gravitational interactions. Among their most prominent features are bars and spiral arms, whose formation and structure are shaped by nonlinear dynamical processes.

Observational data, theoretical orbital studies using analytic potentials, and fully self-consistent N-body simulations collectively indicate that the spiral arms are mainly two-dimensional structures. On the other hand, bars comprise two structural elements: an elongated outer "slim" region and a more compact, vertically extended central "thick" component.

To gain insight into how these structures form and persist, we examine the nature of stellar orbits within galactic disks. The orbital behavior in both two- and three-dimensional Hamiltonian systems that model rotating barred potentials provides the foundation for interpreting the observed morphologies of barred-spiral galaxies. Due to the strong departure from axisymmetry introduced by bars and spirals, nonlinear dynamical processes are essential in understanding their evolution.

Stellar orbits provide the key to understanding these features. Two-dimensional (2D) orbital models help explain the dynamics of spiral arms and outer bars, where both regular and chaotic orbits may play structural roles. However, to explore the vertically extended, central "thick" parts of bars—often observed as boxy or peanut-shaped (b/p) bulges in edge-on galaxies—three-dimensional (3D) models are essential.

These bulges are supported by specific 3D families of periodic orbits that bifurcate from the central planar x1 family at vertical resonances. Although many of these families exhibit complex instability, orbits in their vicinity can still contribute to building the vertical structure, especially through sticky behavior in phase space.

This talk will present the key orbital mechanisms supporting bars and spirals, with a focus on how certain orbit families shape b/p bulges and the characteristic X-shaped structures embedded within them.

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Localized Structures In Saturable Discrete Nls Equation With Next-nearest-neighbor Interactions

We address the existence of solitons and periodic traveling wave solutions in saturable Discrete NLS (dNLS) Equation with non-nearest-neighbor (NNN) interactions. Calculus of variations and Nehari manifolds are employed to establish the existence of discrete solitons. We prove the existence of periodic travelling waves studying the mixed-type functional differential equations using Palais-Smale conditions and variational methods.

Keywords: Discrete Nonlinear Schrödinger, Solitons, Travelling Waves, Calculus of Variations [MSC Classification] 37K40, 35Q55, 46N20, 34K

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Periodic, Quasi-periodic, Fractal And Random DNA Sequences: Charge Transfer And Transport

After an introduction to the structure of nucleic acids DNA and RNA, we will focus on periodic and aperiodic (quasi periodic, fractal and random) nucleotide sequences. We will give some attention to genetically determined sequences. We discern charge transfer from charge transport. We give prominence to the role of trimers or codons. We discern coherent processes (quantum transmission) from incoherent or thermal processes (hopping). We will describe our methods, i.e., tight binding (TB) variants (coarse grained or at the atomic level) and based on density functional theory (DFT). Next, we will present results [1, 2, 3, 4] concerning charge transfer and transport in periodic and aperiodic nucleotide sequences. Finally, we will give an overview.

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Numerical Methods Of Chaos Detection

Determining the chaotic or regular nature of orbits of dynamical systems is a fundamental problem of nonlinear dynamics, having applications to various scientific fields. The most employed method for distinguishing between regular and chaotic behavior is the evaluation of the maximum Lyapunov exponent (MLE), because if the MLE > 0 the orbit is chaotic. The main problem of using this chaos indicator is that its numerical evaluation may take a long -and not known a priori- amount of time to provide a reliable estimation of the MLE's actual value. In this talk we will focus our attention on two very efficient methods of chaos detection: the Smaller (SALI) and the Generalized (GALI) Alignment Index techniques. We will first recall the definitions of the SALI and the GALI and will briefly discuss the behavior of these indices for conservative Hamiltonian systems and area-preserving symplectic maps. Then, we will explain how one can use these methods to investigate the dynamics of time-dependent dynamical systems, and we will discuss the applicability of these indicators to dissipative systems. Furthermore, we will present some recently introduced methods to estimate the chaoticity of orbits in conservative dynamical systems from computations of Lagrangian descriptors on short time scales.

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Bohmiam Chaos And The Origin Of Born's Rule

A deep understanding of the mechanisms behind chaos generation in Bohmian trajectories is essential for addressing a fundamental problem in Bohmian Quantum Mechanics (BQM): the dynamical origin of Born's Rule (BR). BQM is a well-known interpretation of Quantum Mechanics in which quantum particles follow deterministic trajectories governed by the so-called Bohmian equations of motion:

$$m_i \frac{dr_i}{dt} = \hbar \Im \left(\frac{\nabla_i \Psi}{\Psi} \right). \tag{1}$$

BQM provides deep insights into quantum phenomena from both theoretical and experimental perspectives. It is a highly nonlocal quantum theory, where quantum entanglement (QE) plays a central role in the evolution of Bohmian trajectories. While BR is postulated as an axiom in standard quantum theory, in BQM one can, in principle, begin with an initial particle distribution that does not satisfy BR. This raises a critical question: is BR dynamically accessible from arbitrary initial conditions, and if so, what mechanisms govern this process?

In the last years, we have investigated this question through a series of works, focusing on the Bohmian dynamics of an entangled two-qubit system built from appropriately engineered coherent states of the quantum harmonic oscillator. This system is central in Quantum Information theory and exhibits rich Bohmian dynamics.

We analyzed the basic features of the trajectories in our model across various values of physical parameters, revealing both ordered (periodic or not) and chaotic trajectories, and examined their connection to QE. Particular emphasis was placed on the role of the NPXPC (Nodal Point-X-point complex) mechanism and its direct link to quantum entanglement.

Nodal points, along with their corresponding X-points, form a characteristic structure of the Bohmian flow known as the 'nodal point-X-point complex' (NPXPC). An X-point is an unstable point of the Bohmian flow located near a nodal point of the wavefunction. It acts as a local hyperbolic fixed point where nearby trajectories are exponentially repelled along unstable directions and attracted along stable ones. These points typically occur at local maxima of the quantum potential in the region surrounding nodal points. The cumulative action of many such scattering events by these NPXPC structures leads to the saturation of the Lyapunov characteristic number at a positive value, which is a hallmark of chaos in the system.

Our model, which features infinitely many nodal points arranged on straight lattices when entanglement is non-zero, exhibits increasing chaotic behaviour as entanglement grows. In contrast, when entanglement is absent, all trajectories remain ordered.

In strongly entangled regimes, we observed that arbitrary initial distributions tend to converge with high accuracy to Born's Rule, as they are dominated by chaotic, ergodic trajectories. Specifically, we found that the long-time distribution of points along chaotic trajectories is independent of the initial condition. We then explored the implications of ergodicity for the dynamical realization of BR across different levels of entanglement. But despite the ergodic nature of the chaotic trajectories at all entanglement values, ergodicity alone is not sufficient for convergence to BR due to the presence of coexisting ordered trajectories.

Our current research focuses on the impact of the ratio between ordered and chaotic trajectories within an initial distribution. We have identified this ratio as a critical parameter determining whether or not BR will emerge dynamically. Consequently, there exist infinitely many initial distributions that will asymptotically approach BR, but only if their ratio of ordered to chaotic trajectories matches that of the BR-consistent distribution.

Recently, we also discovered that fixed unstable points in the inertial frame of reference, referred to as ‘Y-points’, play a role in the generation of chaos, although their influence is not as significant as that of the X-points. Together, the X-points and Y-points provide a detailed understanding of the Lyapunov exponent profiles of chaotic trajectories.

This talk will be a review of our findings. We will begin by introducing the fundamental mechanisms of chaos in Bohmian trajectories before delving into the details of how the interplay between chaos, order, and entanglement governs the dynamical emergence of Born’s Rule. We will also emphasize the importance of the X- and Y-points in characterizing chaotic behavior and the Lyapunov spectrum.

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Non-Extensive Statistical Physics and Beck-Cohen Superstatistics Applied to Gutenberg-Richter, Omori, and Cumulative Benioff Strain Patterns

The earthquake generation process is a complex phenomenon, manifested in the nonlinear dynamics and in the wide range of spatial and temporal scales that are incorporated in the process. Despite the complexity of the earthquake generation process and our limited knowledge on the physical processes that lead to the initiation and propagation of a seismic rupture giving rise to earthquakes, the collective properties of many earthquakes present patterns that seem universally valid. The most prominent is scale-invariance, which is manifested in the size of faults, the frequency of earthquake sizes and the spatial and temporal scales of seismicity. The frequency magnitude distribution exhibits a decay that is commonly expressed with the well-known Gutenberg-Richter (G-R) law. The aftershock production rate following a main event generally decays as a power-law with time according to the modified Omori formula. Scale-invariance and (multi)fractality are also manifested in the temporal evolution of seismicity and the distribution of earthquake epicentres. The organization patterns that earthquakes and faults exhibit have motivated the statistical physics approach to earthquake occurrence. Based on statistical physics and the entropy principle, a unified framework that produces the collective properties of earthquakes and faults from the specification of their microscopic elements and their interactions, has recently been introduced. This framework, called non extensive statistical mechanics (NESM) was introduced as a generalization of classic statistical mechanics due to Boltzmann and Gibbs (BG), to describe the macroscopic behaviour of complex systems that present strong correlations among their elements, violating some of the essential properties of BG statistical mechanics. Such complex systems typically present power-law distributions, enhanced by (multi)fractal geometries, long-range interactions and/or large fluctuations between the various possible states, properties that correspond well to the collective behaviour of earthquakes and faults. Here, we provide an overview on the fundamental properties and applications of NESP. Initially, we provide an overview of the collective properties of earthquake populations and the main empirical statistical models that have been introduced to describe them. We provide an analytic description of the fundamental theory and the models that have been derived within the NESP framework to describe the collective properties of earthquakes. The fundamental laws of Statistical seismology as that of Gutenberg-Richter (GR) and Omori law a analysed using the ideas of Tsallis entropy and its dynamical superstatistical interpretation offered by Beck and Cohen.

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Το Περιορισμενο Προβλημα Των Τριων Σωματων Και Το Δυναμικο Περιβαλλον Του Διπλου Αστεροειδη 65803 Διδυμος

Σε αυτή την εισαγωγική ομιλία περιγράφουμε το φημισμένο περιορισμένο πρόβλημα των τριών σωμάτων και κάνουμε μια εισαγωγή στα βασικά του δυναμικά χαρακτηριστικά. Συγκεκριμένα θα παράξουμε τις εξισώσεις κίνησης και το ολοκλήρωμα Jacobi, θα βρούμε τα σημεία ισορροπίας του και θα μελετήσουμε τα όρια της κίνησης. Μέσω της τομής Poincare θα περιγράψουμε τη τοπολογία του χώρου φάσεων και τα είδη τροχιών του συστήματος με έμφαση στον υπολογισμό των περιοδικών τροχιών και της ευστάθειάς τους. Για να εφαρμόσουμε το προηγούμενο μοντέλο και μεθοδολογία στον διπλό αστεροειδή Δίδυμος-Δίμορφος και στην κίνηση μικρών σωμάτων και διαστημοσυσκευών στο περιβάλλον του, θα πρέπει να το επεκτείνουμε θεωρώντας α) Σώματα πεπερασμένης διάστασης και μη σφαιρικά β) Τη βαρυτική δύναμη που ασκεί ο Ήλιος ως τέταρτο σώμα και γ) την πίεση της ηλιακής ακτινοβολίας. Θα μελετήσουμε την τροχιακή δυναμική μέσα από τις περιοδικές τροχιές του απλού μοντέλου και στη συνέχεια θα εφαρμόσουμε τις επιπλέον δυνάμεις ως διαταραχές. Η μελέτη της τροχιακής δυναμικής στο παραπάνω φυσικό σύστημα είναι ιδιαίτερα χρήσιμη για την διαστημική αποστολή Hera η οποία έχει ξεκινήσει και θα φτάσει στον διπλό αστεροειδή στα τέλη του 2026.

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Traveling Fronts In Homogeneous And Heterogeneous Environments

Granular matter can behave – depending on the circumstances – like a solid, a fluid or a gas, yet often with an unexpected twist owing to the special nature of this complex, multi-particle medium. Here we present two case studies:

1. *Vibrated sand: a counter-intuitive gas* [1] – [3]

If granular matter is shaken vigorously, the particles fly about, forming a kind of gas. Unexpectedly, however, they do not spread out uniformly over the available space as a standard gas would do, but they tend to cluster together. This spontaneous breakdown of equipartition shows up in a particularly clear-cut fashion when the space is divided in two compartments, as in the so-called “Maxwell's Demon” experiment. We describe this experiment in terms of Dynamical Systems theory and show how the clustering transition manifests itself as a pitchfork bifurcation.

2. *Flowing sand: roll waves as stick-slip oscillations* [4] – [7]

Our second case study focuses on granular matter flowing down a chute, and more specifically, on the roll wave patterns frequently encountered in this type of flow. These nonlinear waves consist of long rising flanks followed by abrupt falls and can adequately be described by the generalized Saint-Venant equations for shallow granular flows. More surprisingly, as we will demonstrate, they can also be seen as the Fluid Dynamical analogue of the famous stick-slip phenomenon found in many mechanical systems.

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Turbulent Flow And The Phenomenon Of Intermittency

In nature, the vast majority of fluid flows are turbulent. Therefore, understanding and predicting turbulence and its temporal evolution is of great importance. In the context of dynamical systems, intermittency refers to the irregular alternation between phases of periodic behavior and chaotic dynamics, or between different forms of chaotic behavior.

Pomeau and Manneville identified three types of intermittency, where a nearly periodic system exhibits irregularly spaced bursts of chaos [1]. These types - Type I, II, and III - are associated with the approach to a saddle–node bifurcation, a subcritical Hopf bifurcation, and an inverse period–doubling bifurcation, respectively.

In this presentation, we begin with a brief introduction to turbulence, followed by a discussion of intermittency in turbulent flows. We then introduce simple mathematical models that capture aspects of intermittent behavior in turbulence. Finally, we explore more advanced approaches for characterizing intermittency in turbulent flows.

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