Mini-Workshop on Applied Dynamical Systems
3rd and 4th of August, 2022
Institute of Physics, University of São Paulo (IF-USP)

List of Abstracts:

Lecture 1
Author: Yves Elskens (Univ. Aix-Marseille, France)
Title: Wave-particle interaction in a traveling wave tube
Abstract: Wave-particle interactions are central in plasma physics. To avoid the ubiquitous noise and nonlinearities of plasma, it is advantageous to replace the fundamental beam-plasma system with a traveling wave tube (TWT), where the waveguide is a ``quiet'' and intrinsically linear substitute for the plasma. In particular, our 4-meter long, 20 – 100 MHz device [1] enabled the detailed analysis of the self-consistent interaction between longitudinal waves and a (cold or warm) electron beam. Besides this basic physics interest, TWTs are widely used as amplifiers in satellite telecommunications, where the need for higher power, wider passband and higher data flow push these devices into nonlinear regimes near the wave saturation. Gyrotrons, klystrons, free electron lasers and various other devices operate along similar principles. To simulate the wave-particle dynamics, kinetic models in time domain, like partice-in-cell algorithms, are slow due to their large number of degrees of freedom. Fast specialized models in frequency domain are industrial standards, but are not suited to investigate nonlinear behaviours. We developed [2-5] a new many-particle time-domain model, which was validated both for industrial TWTs (5 – 20 cm, 1 – 100 GHz scales) and for an academic (3 m, 200 MHz) device from UCSD [4, 6]. This hamiltonian model rests on an adapted reduction of the wave degrees of freedom. It is much faster than PIC codes and can describe devices whose propagation characteristics change along their length. The contribution will review both experimental and modeling aspects. [1] M.C. de Sousa *et al.*, Phys. Plasmas **27** (2020) 093108. [2] D.F.G. Minenna *et al.*, Europhys. Lett. **122** (2018) 44002. [3] D.F.G. Minenna *et al.*, IEEE Trans. El. Dev. **66** (2019) 4042. [4] D.F.G. Minenna *et al.*, Phys. Plasmas **28** (2021) 092110. [5] Kh. Aliane *et al.*, IEEE Trans. El. Dev. **68** (2021) 6476. [6] Kh. Aliane *et al.*, 22nd IEEE Intl Vac. El. Conf. (2021).

Lecture 2
Author: Gustavo Paganini Canal (IF-USP)
Title: The development of an advanced set of ELM control coils for TCABR
Abstract: Edge localized modes (ELMs) are instabilities that usually occur in the edge of tokamak plasmas operated in the so-called high confinement mode (H-mode). These instabilities can cause unacceptably high transient heat fluxes onto plasma facing components thus reducing their lifetime significantly. This drives the need for the development of ELM control techniques to mitigated, or completely suppressed, ELMs in future fusion power plants based on the tokamak concept. Experiments carried out on several tokamaks around the world have demonstrated that externally applied, relatively small, non-axisymmetric magnetic perturbations that are resonant at rational surfaces located in the edge of H-mode plasmas can be used to stabilize ELMs. Due to the observed effectiveness of this technique, ELM control coils have been added to the design of the International Thermonuclear Experimental Reactor (ITER). However, even though ELM control coils have been successfully used to suppress ELMs in several tokamaks, the present understanding of their impact on ELM mitigation/suppression is still at a stage that does not allow a reliable physics-based extrapolation towards larger machines such as ITER. To provide a better insight into the physics basis behind the effect of magnetic field perturbations on ELM behavior, an advanced set of ELM control coils is being designed for the Tokamak à Chauffage Alfvén Brésilien (TCABR). New high performance power supplies will also be installed to allow for the creation of ohmic H-mode

plasmas with a large variety of boundary shapes. After its upgrade, TCABR will be capable of creating a well controlled environment where the physics basis behind the effect of magnetic perturbations on ELMs can be addressed over a wide range of (i) plasma scenarios, (ii) RMP coil geometries and (iii) perturbed magnetic field spectra. TCABR will be equipped with 54 in-vessel coils on the low field side and other 54 in-vessel coils on the high field side (a total of 108 in-vessel coils), all being independently powered to allow for different toroidal modes ($n_{tor} \leq 9$) to rotate simultaneously with different velocities. In this work, the current status of the development of the TCABR ELM control coils will be described along with preliminary simulations of the perturbed magnetic field spectra created by these coils.

Lecture 3

Author: Gisele Akemi Oda (IB-USP)

Title: Synchronization of Multi-Oscillator Biological Clocks

Abstract: The biological oscillator that regulates our 24h rhythms is composed by populations of neurons in our brains and is synchronized by the Earth´s light/dark cycle. Several rhythmic biological phenomena can be understood in terms of this forced, multi-oscillator system and, in particular, how organisms synchronize seasonal rhythms by the annual variation of the daily ratio between day and night-length (photoperiod). This is achieved by the annual change in the phase relationship between two oscillator subpopulations that comprise the biological clock. Modeling, simulations and experimental results of minimal light exposure patterns and synchronization of subterranean animals will be presented to illustrate this study (FAPESP, CONICET, FoncyT, CNPq, CAPES).

Oral Communication 1

Author: Matheus Jean Lazarotto (IF-USP)

Title: Chaotic dynamics in periodic potentials

Abstract: Spatial diffusion of particles in periodic potential models has provided a good framework for studying the role of chaos in global properties of classical systems. Here a bidimensional “soft” billiard, which is a classical dynamics derived from an optical lattice hamiltonian system, is used to study diffusion transitions under variation of the control parameters. Sudden transitions between normal and ballistic regimes are found and characterized by inspection of topological changes in phase-space. Transitions correlated with increases in global stability area are shown to occur for energy levels where local maxima points become accessible, deviating trajectories approaching them. These instabilities promote a slowing down of the dynamics and an island myriad bifurcation phenomenon, along with the suppression of long flights within the lattice. Other diffusion regime variations occurring within small intervals of control parameters are shown to be related to the emergence of a set of orbits with long flights, thus altering the total average displacement for long integration times but without global changes in phase-space.

Oral Communication 2

Author: Rodrigo Simile Baroni (UNESP)

Title: A route for the destruction and resurgence of the quasiperiodic shearless attractor

Abstract: We consider a dissipative version of the standard nontwist map. It is known that nontwist systems may present a robust transport barrier, called shearless curve, that gives rise to an attractor that retains some of its properties when dissipation is introduced. This attractor is known as shearless attractor, and it may be quasiperiodic or chaotic depending on the control parameters. We describe a route for the destruction and resurgence of the quasiperiodic shearless attractor by analyzing the manifolds of the unstable periodic orbits (UPOs) which are fixed points of the map.

We show that the shearless attractor is destroyed by a collision with the UPOs and it resurges after the reconnection of the unstable manifolds of different UPOs.

Oral Communication 3

Author: Gabriel Cardoso Grime (IF-USP)

Title: Shearless bifurcations in particle transport for reversed shear tokamaks

Abstract: For some discharge configurations in tokamaks, transport barriers reduce particle transport, improving plasma confinement. In this context, a model has been applied to describe the turbulent transport by drift waves, attributing this transport to ExB chaotic drift orbits. In the present work we use this model to investigate the influence of magnetic safety factor on creation, maintaining and destruction of particle transport barriers. The model results in a set of differential equations that describe the motion of a test particle on the plasma, that we integrate numerically and analyze the behavior of trajectories using Poincaré sections. Introducing a nonmonotonic safety factor profile, the phase space structure is deeply modified and a shearless invariant curve appears. Such curves are robust under electrostatic fluctuations, so they act like Shearless Transport Barriers (STB). By changing the parameters of the nonmonotonic safety factor profile, the appearance and disappearance of these shearless curves are observed. The successive shearless curves break-up and recovering is explained using concepts from bifurcation theory. We also present bifurcation sequences associated to the creation of multiple shearless curves. Physical consequences of scenarios with multiple shearless curves are discussed.

Oral Communication 4

Author: Leonardo Costa de Souza (UFPR)

Title: Fractal structures in the drift motion of particle in tokamaks

Abstract: In this work we study the particle dynamics in the edges of a tokamak, caused by electrostatic perturbations. To describe these perturbations we use a drift wave model proposed by Horton, that allows us to obtain a two-dimensional map, which simplifies the analysis and allows the study of the system for large iteration times. In this map model is necessary to establish profiles of physical quantities like electric field, the plasma velocity en the safety factor, we use values based on experimental results of the Tokamak Chauffage Alfvén Brésilien TCABr located at USP, along with real parameters also from TCABr. We initially establish two exits through which particles can escape, these define escape basins, set of initial conditions that reach the exits within iteration time, we show that the boundary between these basins is fractal. Using the uncertainty dimension we quantify the dimension of the boundary and using the informational entropy as proposed by Daza et al. we quantify how mixed are the basins. We define a third exist which allows us to evaluate whether the map has the Wada property, where a point on the boundary of one basin is simultaneously a boundary point of the others two basins.

Oral Communication 5

Author: Martim Zurita (IF-USP)

Title: Analyzing the dynamical nature of plasma turbulence through the lens of stochastic modeling, complexity, and entropy

Abstract: In the literature, considerable evidence shows that edge plasma turbulence in tokamaks has characteristics of both stochastic and chaotic systems. On the one hand, a stochastic pulse train model, developed over the last ten years, has been successfully applied to turbulent density fluctuations on a variety of tokamaks [OE Garcia, Phys. Rev. Lett. 108, 265001 (2012)]. On the other hand, a recent work revealed that these types of plasma signals are located in the chaotic region of the so-called complexity-entropy diagram (CHD) [Z. Zhu *et al.*, Phys. Plasmas 24, 042301 (2017)]. Therefore, Zhu et al. (2017) have put into question whether the stochastic pulse train model could reproduce the nature of experimental data in this diagram. In this seminar, I will compare, using the CHD, the results of TCABR Langmuir-probed data and the stochastic pulse train model. It is found that the stochastic model with Gaussian background is unable to reproduce the behavior of the experimental data in the diagram, while a stochastic model with a pulse background can be very close to the experimental complexity-entropy points, indicating that the last two can have similar dynamical nature. The results also pointed out that the stochastic pulse train model is not so stochastic as initially thought, as it has a strong deterministic component, enough to lift data to the chaotic region of the CHD."

Oral Communication 6

Author: Felipe M. Salvador (IF-USP)

Title: Conceptual design and optimization of RMP coils for the TCABR Tokamak

Abstract: An upgrade of the TCABR tokamak ($R0 = 0.62$ m, $a \leq 0.18$ m, $Ip \leq 120$ kA and $B0 \leq 1.1$ T) is being designed to make it capable of creating a well controlled environment where the impact of resonant magnetic perturbation (RMP) fields on edge localised modes could be addressed over a wide range of (i) plasma scenarios, (ii) RMP coil geometries and (iii) perturbed magnetic field spectra. To this end, an unique and innovative set of in-vessel RMP coils is being designed and, in this work, the conceptual design and optimisation of these coils are presented. This set of in-vessel RMP coils is composed of three toroidal arrays of coils on the low field side and three toroidal arrays of coils on the high field side. Each of these six toroidal arrays is composed of 18 coils thus allowing for the creation of RMP fields with toroidal mode numbers as high as $n = 9$. To study dynamical effects of RMP fields of different toroidal mode numbers rotating with different velocities (applied simultaneously or not), each of the 108 RMP coils will be powered independently by power supplies that can provide currents of up to 2 kA with frequencies of up to 10 kHz. A set of physical criteria were used to determine the optimal coil geometry and number of turns. The conceptual design and optimisation of the coils were carried out using both the so-called vacuum approach and the plasma response model implemented in the non-linear two-fluid resistive MHD code M3D-C1

Oral Communication 7

Author: Arnold Alonso Alvarez (IF-USP)

Title: Wavelet spectral analysis for extreme events in Texas Helimak

Abstract: Magnetically confined plasma have gradually gained relevance during the last seventy years due to its viability in fusion energy production which is cleaner and more efficient. It presents challenges, such as the effective control of particles loss due to anomalous transport on plasma edge, driven by electrostatic turbulence that commonly presents high density and short duration events known as bursts. In Texas Helimak, by applying a constant electrostatic potential (bias) it is possible to control the rate of appearance of these bursts. In this work, a data analysis was made for a Langmuir probe data by means of the wavelet transform method with the aim of identify and characterize these extreme events for a fixed radial position and height. The characteristics of the wavelet transform method, as a complementary method to the Fourier transform, allows to study phenomena in both frequency and time space, for this reason it was found to be optimal for this work.

Oral Communication 8

Author: Luis Fernando Bernardi de Souza (UNESP)

Title: Transport barriers for two modes drift wave map

Abstract: The Texas Helimak is a plasma magnetic confinement machine that through the application of an external electric potential (bias) change the radial profile of the plasma electric field and, therefore, modifies the particle transport. To investigate the transport, a Hamiltonian approximation is made that leads to a nonlinear map with three coupled equations and infinite drift wave resonant modes. We study the effect of the second mode on the system that is already reported with only one mode. The map has three interdependent coordinates and control parameters related to the considered modes. By fixing the parameters related to the first mode and varying the second mode amplitude, we observed that the existence of the barriers depends on the second mode amplitude. The profile of the winding number, the recurrence times and the parameter space are used to study the particle transport and the existence of the shearless curve. We also observe that even after the shearless destruction, the stickiness in its neighborhood continues to have a transport blocking effect to some extent. So, to evaluate the effectiveness of the barriers, we compute the ratio of initial conditions that crossed the barriers and by using the space parameter we highlighted the sensitivity of transport barriers to perturbations.

Oral Communication 9
Author: Marcos Vinícius de Morais (IF-USP)
<u>Title: Transport barrier in non-twist maps</u>
Abstract: Since the middle of the last century, the tokamak magnetic configuration has shown the most positive results for the control of controlled thermonuclear fusion. However, there are numerous factors that affect the performance of such devices. The anomalous transport of particles at the edge of the plasma, far superior to the diffusion of confined particles initially predicted for the gradients of the equilibrium profiles in this region, is one of them. Several experiments have indicated the existence of particle transport barriers at the edge of the plasma, which improves its confinement. These barriers depend on the plasma profiles, such as the density of electric current and the amplitude of the magnetic perturbations. The application of magnetic perturbations, created by electrical currents in external loops, can control these variations in equilibrium profiles. In order to study these transport barriers, we use a sympletic map proposed by Ullmann, which describes tokamaks with ergodic limiters considering a non-monotonic current density. In this model, the introduced map provides the Poincaré maps in a poloidal section (at a fixed toroidal angle). Thus, we identify the mechanism for the emergence of chaos, in the system's phase space, from the breaking of the separatrix of the islands created by the superposition of resonances.

Oral Communication 10
Author: Matheus Palmero (IF-USP)
<u>Title: Recurrence plots and change-point analysis of chaotic transient orbits</u>
Abstract: In this work, we show that recurrence plots of chaotic orbits can be used as an illustrative tool to compare the transient behaviours of different trajectories with very close initial conditions. We do so considering the Chirikov-Taylor Standard Map, a textbook example of an area-preserving two-dimensional nonlinear map and, analysing the differences between the recurrence plots of trajectories evolved from initial conditions in different domains in the phase space. After this initial comparison, we consider two trajectories evolved from a chaotic region of the phase space with a relative difference of 10^{-14} in their initial conditions. The inherently chaotic behaviour of the dynamics is clearly seen by their respective recurrence plots, making them particularly suitable to illustrate the well-known sensitivity to initial conditions of chaotic orbits. Furthermore, we investigate peculiar intermittent dynamics while evolving one of these particular trajectories, showing how recurrence plots easily distinguish different dynamical behaviours in a given time frame, allowing a practical change-point analysis while varying initial conditions.

Oral Communication 11
Author: Joelson Davyson Veloso Hermes (IFE-MG)

Title: Break-up of invariant curves in the Fermi-Ulam model

Abstract: In this work we investigate, for the Fermi-Ulam model, the location of invariant curves that separate chaotic areas in the phase space. Applying the Slater's theorem we verify that the mapping presents a family of invariant spanning curves with a rotation number whose expansion into continued fractions has an infinite tail of the unity, acting as local transport barriers. We study the destruction of such curves and find the critical parameters for that. The determination of the rotation number in the vicinity of one of the considered spanning curves allowed us to understand the dynamics in the vicinity of the considered curve, both before and after criticality.

Oral Communication 12

Author: Bruno Borges Leal (IF-USP)

Title: Ullmann map and bifurcations

Abstract: The magnetic field lines, generated by the magnetic field that is able to trap a plasma inside a tokamak, have a Hamiltonian description. Therefore, if we wish to describe the spatial evolution of these magnetic field lines, along the toroid, in a discretized way, we need to use a symplectic map. In the bidimensional condition, symplectic maps are synonymous of space phase area preservation. We will use the modified Ullmann map to describe the magnetic field lines under the action of a set of ergodic magnetic limiters. Magnetic limiters produce perturbation in plasma column giving risen to chaotic magnetic field lines on the internal tokamak wall. The modified Ullmann map is a bidimensional symplectic map that describes the perturbation of two magnetic limiters on the magnetic field. With this map, we will show the risen of different types of bifurcations due to the variation of the electric current of the limiters. In summary, the presentation will have two main goals: to show the modified Ullmann map and some examples of bifurcations.

Oral Communication 13

Author: Pedro Haerter Neto (UFPR)

Title: Synchronization of oscillators coupled by a diffusive substance to different geometries

Abstract: Understanding how a group of elements work together is interesting to multiple fields of physics, mainly when associated with other fields of knowledge, such as Chemistry, Meteorology and Biology. For the latter, you can consider the biological system as being pointlike oscillators that will emit and absorb a diffusive substance through the medium and cause the coupling between the oscillators, like cells interacting via hormones. Using the Kuramoto model of coupling, we described mathematically how the interaction between a set of phase oscillator, that will be coupled via a function that depends on the concentration of the substance in each point and the phase of the oscillators, resulting in an integro-differential equation. The solution of the integro-differential equation was obtained through a numerical integration method that we revised and adapted. Using the methods developed by Kuramoto to study synchronization between oscillators, like the order parameter and the perturbed frequency analysis, it was possible to find a relationship between the substance parameters (diffusion coefficient and degradation) and the degree of synchronization of the oscillators to three different spatial geometries.

Oral Communication 14

Author: Sílvio Luiz Thomaz de Souza (UFOP)

Title: Nonlinear dynamics of a memristor-based circuit

Abstract: In this talk, we report a considerable collection of nonlinear phenomena identified from numerical experiments for a simple circuit composed of a inductor, a capacitor, and a memristor [1]. In 1971 [2], Leon Chua identified theoretically as one of fundamental electrical components which comprises also the resistor, capacitor and inductor. From a mathematical point of view, memristors present a typical nonlinear description. Here we provide an appreciable overview of the rich

dynamical behavior for such system, such as chaotic oscillations, coexistence of attractors, fractal basin boundaries, compound periodic windows, and resonance tongues. In addition, considering a harmonic perturbation [3] we observe in two-parameter space diagrams a remarkable transition of periodic windows to quasi-periodic structures. [1] Bharathwaj Muthuswawy, Leon O. Chua. Simplest Chaotic Circuit. International Journal of Bifurcation and Chaos 20: 1567–1580 (2010); [2] Leon Chua. Memristor-The missing circuit element. IEEE Transactions on Circuit Theory 18 (5): 507–519 (1979); [3] Sadataka Furui, Tomoyuki Takano. On the Amplitude of External Perturbation and Chaos via Devil's Staircase - Stability of Attractors. International Journal of Bifurcation and Chaos 25: 1550145 (2015).

Oral Communication 15
Author: Diogo Ricardo da Costa (UFPR)
Title: Estruturas auto-similares em sistemas caóticos.
Abstract: Neste trabalho, abordaremos alguns sistemas dinâmicos não-lineares que apresentam estruturas auto-similares. Mostraremos que existe uma relação entre tais estruturas e as condições que levam às reflexões ou colisões múltiplas. Estudaremos um bilhar cogumelo modificado, o modelo Fermi-Ulam e também um mapeamento bidimensional que descreve o comportamento de partículas clássicas em uma barreira de potencial.

Oral Communication 16
Author: Michele Mugnaine (UFPR)
Title: Dynamics of nontwist maps
Abstract: The standard nontwist map (SNM) is a two dimensional area-preserving map, where the twist condition is violated locally, and it is used to describe the dynamical behavior of nontwist systems in general. The SNM exhibits a meandering invariant tori, known as the shearless curve, twin island chain scenario and separatrix reconnection in the phase space, particular features for non-monotonic systems. The SNM is a conservative perturbed map, hence the coexistence between chaos and regularity is present in the phase space. The dynamics of the SNM has been widely studied and the bibliography on the subject is vast. These dynamical properties can be modified significantly by the inclusion of new terms in the SNM. In order to analyze the dynamics of modified standard nontwist maps, we present our results about the Extended Standard Nontwist Map (ESNM), defined by the inclusion of a perturbation in the SNM, and the Dissipative Standard Nontwist Map (DSNM), a dissipative version of the SNM. From our simulations, we observe that the inherent symmetry of the system can be preserved or broken with the addition of the new perturbation in the ESNM, which leads to a modified twin island chain scenario. We also identify the modification in coexistence of chaos and regularity scenario by the inclusion of dissipation in the system, resulting in chaotic transients and attractors in the phase space.

Oral Communication 17
Author: André Farinha Bósio (IF-USP)
Title: Drift Wave Induced Particle Transport in TCABR
Abstract: Tokamaks are one of the best options for magnetic confinement of plasmas, however one of many current challanges of these devices is related to anomalous transport present at the plasma edge, which results in a great loss of particles, making thermonuclear fusion harder. The mechanism behind this transport is still being studied, however, $E \times B$ drift waves, arising from electrical oscillations due to density gradients in the plasma play an important role in this phenomenon. When only one wave is present, the Hamiltonian is integrable and particles are trapped in trajectories of constant energy, forming a lattice of islands. When there is at least two waves with diferent phase velocities, integrability is broken and chaotic transport is present. One way to reduce this process is

the introduction of an electrical radial profile, deforming the separatrix and reducing the transport. Following a model already present in the literature, we performed numerical experiments to characterize the transport at the plasma edge. In the present work we use a similar model to study the chaotic transport at the edge of a toroidal plasma using an aproximation from a experiental data extracted from TCA-BR discharges, to investigate those transport mechanisms.

Oral Communication 18
Author: José Danilo Szezech Jr. (UEPG)
Title: Total attenuation of control measures for epidemic communities modeled by cellular automata
Abstract: Mathematical models can provide important information for analyzing and controlling the impact of epidemics. One example is estimating the impact of control measures to extinguish a possible second wave of infections. In this work we analyze a SEIR epidemic model based on stochastic cellular automata. We analyzed measures to restrict the mobility of individuals in space to reduce the total number of infected. However, the total attenuation of control measures in the system can lead to a second wave scenario and/or the total number of infected approaches the uncontrolled case. We studied the impacts of these mitigations and whether they could eventually extinguish possible epidemics.

Oral Communication 19
Author: Kelly Iarosz (UTB, Telêmaco Borba, PR)
Title: Data science... are we data scientists now?
Abstract: A simplistic view of scientific work is to apply the scientific method. We look for partnerships (graduate programs, grants, projects...), we collect data, design computational routines, make everything converge to well-defined theories or diverge and create new ones. Finally, we publish all this study in scientific journals. In this presentation you will see an example of how scientific works that simulate brain behavior are built, you will have a vision of why data is now being called Big Data and why we can consider ourselves data scientists.

Oral Communication 20
Author: Adriane da Silva Reis (IF-USP)
Title: Controlling synchronization in clustered scale-free neuronal networks
Abstract: In this lecture, we will investigate the synchronization properties of a neuronal network model inspired by the connection architecture of the human cerebral cortex keeping the focus on neuronal synchronization in a network with coupled scale-free and network properties. The neuronal dynamic is given by a two-dimensional iterated map that can generate quiescence, tonic spiking, and bursting behavior. The model considers a coupling term that depends on a human connection map, a neuronal activation function. The synaptic connections can be chemical and electrical. There is also considered a neuronal potential, that could be excitatory or inhibitory. To evaluate the neuronal burst phase synchronization, we analyze the Kuramoto order parameter. It is known that synchronized neuronal activities can be associated with motor pathologies, such as Parkinson's disease, essential tremors, and epilepsy. In this way, the goal is to find a good method that can suppress or reduce singnificantly neuronal burst synchronization by using different construction of scale-free networks and distinct techniques to suppress neuronal synchronization.

Oral Communication 21
Author: Eduardo Luiz Brugnago (IF-USP)
Title: Covariant Lyapunov vectors and prediction in chaotic systems

Abstract: We show that features of the tangent space, related to the evolution of chaotic trajectories, such as those obtained using the Lorenz system and the Rikitake geomagnetic model, can be related to future behavior of these same trajectories. In particular, the angles formed between pairs of Covariant Lyapunov Vectors (CLVs) and the rate of expansion of these are related to transitions between regions defined in the state space and regime durations defined according to the spatial symmetry of the chaotic attractor. We propose predictive techniques based on the alignment between the pairs of CLVs and the maximum expansion of these in each regime. Additionally, we used machine learning techniques on the data from the CLVs and obtained predictions with accuracy greater than 99% in predictions up to 18 Lyapunov times.

Oral Communication 22

Author: Enrique Chipicoski Gabrick (UEPG)

Title: Effect of two vaccine doses in the SEIR epidemic model using a stochastic cellular automaton.

Abstract: In this work, we propose the inclusion of two vaccination doses in the SEIR model considering a stochastic cellular automaton. For this, we analyse three different scenarios of vaccination: (i) unlimited doses, (ii) limited doses into susceptible individuals, and (iii) limited doses randomly distributed overall individuals. Our results suggest that the number of vaccinations and time to start the vaccination are more relevant than the vaccine efficacy, delay between the first and second doses, and delay between vaccinated groups. Furthermore, scenarios (ii) and (iii) are more realistic and the (ii) is more efficient, once the vaccination is applied to people who have not yet been infected.

Oral Communication 23

Author: Matheus Hansen Francisco (ICT-UNIFESP)

Title: Investigation of pollen release by poricidal anthers using billiard models

Abstract: Buzz pollination is described using a mathematical model considering a billiard approach. Applications to a simplified morphology of a typical poricidal anther of a tomato flower (Solanum lycopersicum) experiencing vibrations applied by a bumblebee (Bombus terrestris) are made. The anther is described by a rectangular billiard with a pore on its tip while the borders are perturbed by specific oscillations according to the vibrational properties of the bumblebee. Pollen grains are considered as non-interacting particles that can escape through the pore. Our results not only recover some observed data in the literature but also provide a possible answer to an open problem involving pollen release in buzz pollination.

Oral Communication 24

Author: Vitor Martins de Oliveira (IME-USP)

Title: Spin-orbit resonances and chaotic rotation in the Solar System

Abstract: Spin-orbit resonances (SOR) occur when the rotational and orbital periods of anorbiting body, such as a planet or a satellite, become commensurable. The gradient formed by the gravitational field exerted by the primary leads to a phenomenon called tidal forces,which depends on the rheology of the orbiting body and can lead to trapping into a SOR. In this talk, we will present some cases of SOR observed in the Solar System and discuss a few preliminary results regarding the rotational dynamics of Hyperion, a moon of Saturn that iscurrently rotating chaotically.

Oral Communication 25

Author: Paulo Protachevicz (IF-USP)

Title: Effect of chemical synapses on neuronal synchronization.

Abstract: Neuronal synchronization develops a key role in healthy and unhealthy brain activities. Thus, an important focus of research is to understand how neuronal networks achieve and avoid high synchronous patterns. In this talk, it will be shown how specific connections of chemical excitatory and inhibitory synapses can contribute to synchronous and asynchronous patterns in neuronal networks.