Workshop on Long-range Interactions and Synchronization
ICTP-SAIFR, Sao Paulo, Brazil
May 28 – 31, 2018

Talk Titles and Abstracts

1. **Stefano Ruffo**

ICTP COLLOQUIUM
TITLE: Long-range interacting systems

ABSTRACT: Systems with long-range interactions (gravitational systems, charged and dipolar systems) can be made extensive, but are intrinsically non additive. The violation of this basic property of thermodynamics determines ensemble inequivalence, which in turn implies that specific heat can be negative in the microcanonical ensemble, temperature jumps may appear at microcanonical first order phase transitions, ergodicity is typically broken. From the dynamical point of view, these systems show long-lived quasi-stationary states, whose lifetime diverges with system size. Realizing that such features are common to wide class of models has renewed in recent years the interest in long-range interactions.

Workshop Talk 1
TITLE: Systems with long-range interactions: equilibrium properties

ABSTRACT: I will first introduce the basic definitions of long-range interactions, concentrating on the discussion of the non additive properties of the energy. I will present a brief overview of physical systems with long-range interactions: gravitational systems, two-dimensional hydrodynamics, Coulomb systems, etc. I will discuss ensemble inequivalence using as examples the Blume-Capel and the Kardar-Nagel models.

Workshop Talk 2
TITLE: Systems with long-range interactions: dynamical properties

ABSTRACT: I will introduce and discuss the main features of the Hamiltonian Mean Field (HMF) model. I will present the typical relaxation of an out-of-equilibrium initial state, which first “violently” relaxes to a quasi-stationary state on a finite time-scale, and then asymptotically reaches the Boltzmann-Gibbs equilibrium on a time scale which diverges with system size. I will also present the analytical approach based on the Klimontovich and the Vlasov equations. I will show how the Lynden-Bell approach gives a rough interpretation of the dynamical evolution.

2. **Michael Kastner**

TITLE: Quantum long-range systems

ABSTRACT: The first part of this lecture gives a brief overview over the types of long-range interactions (Coulomb, dipolar, van der Waals, phonon- or photon-mediated, etc) that can be investigated in quantum simulators and quantum computers as they are realised by means of trapped cold atoms, molecules, or ions. In the second part I discuss some of the effects that long-range interactions have on equilibrium and nonequilibrium properties of many-body quantum systems. This includes fast and/or slow propagation of excitations, transmission of quantum information, peculiar band structures, and also nonequivalent statistical ensembles. I conclude with an outlook on how some of these features might be used to enhance quantum simulation and other quantum protocols, or increase their versatility.

3. **Antonio Politi**

TITLE: Chaotic collective dynamics in the presence of long-range interactions

ABSTRACT: The emergence of chaotic macroscopic states in ensembles of oscillators is reviewed, starting from mean-field models (of, e.g., logistic maps and Stuart-Landau oscillators) and moving to one-dimensional systems with long-range interactions. The dependence of the complexity of the collective dynamics on the (power-law) decay rate is explored, showing that the mean-field chaos persists over a finite interval of values transforming itself into a sort "hydrodynamic" phenomenon, which affects long spatial scales. At variance with the standard hydrodynamic properties induced by conservation laws, here the corresponding time scales do not scale with the system size. Finally, the existence of a critical value separating collective chaos from standard spatio-temporal chaos is discussed.

4. **Robin Kaiser**

TITLE: Long range dipole dipole coupling in cold atoms: from Anderson Localisation to Dicke subradiance and back

ABSTRACT: The quest for Anderson localization of light is at the center of many experimental and theoretical activities. Cold atoms have emerged as interesting quantum system to study coherent transport properties of light. Initial experiments have established that dilute samples with large optical thickness allow studying weak localization of light, which has been well described by a mesoscopic model.

Recent experiments on light scattering with cold atoms have shown that Dicke super- or subradiance occurs in the same samples, a feature not captured by the traditional mesoscopic models. The use of a long range microscopic coupled dipole model allows to capture both the mesoscopic features of light scattering and Dicke super- and subradiance in the single photon limit.

In this lecture, I will review experimental and theoretical state of the art on the possibility of Anderson localization of light by cold atoms.

5. **Arkady Pikovsky**

TITLE: Hierarchy of synchronization models

ABSTRACT: In this lecture I discuss how synchronization phenomena can be described with models of different complexity. First I outline the phase reduction method and elementary properties of phase locking and frequency entrainment of two coupled oscillators with noise. In the second part I describe analytical methods suitable for description of synchronization in mean-field models.

6. **Julien Barre**

TITLE: Large Deviations, long-range interactions and synchronization (?)

ABSTRACT: Large deviation theory is quickly becoming a fundamental tool for statistical physicists. It is in particular especially well suited to study long range interacting systems, both their stationary and dynamical properties. In these two lectures, I will first introduce at a simple level the key concepts and tools of large deviation theory. This will be enough to explain in detail why and how it can be used to tackle various questions on long range interacting system: I will give a few concrete cases. In comparison, large deviations seem to play a less central in the literature on synchronization of complex systems. Could there be some new territory to explore? I will present and discuss some examples.

7. **Ram Ramaswamy**

TITLE: Patterns of synchrony in modular networks of coupled oscillators

ABSTRACT: We consider phase oscillators on modular networks, with general nonlinear coupling and distributed time delays. On a bipartite network, phase-locked solutions arise with oscillators in each partition being perfectly synchronized among themselves but with a phase difference between partitions. As a function of the mean time delay, the system exhibits hysteresis, phase flips, final state sensitivity, and an extreme form of multistability where the numbers of stable in-phase and antiphase synchronous solutions with distinct frequencies grow without bound. Similar behaviour is obtained in networks of Landau-Stuart oscillators as well. In the absence of time delay such states are not observed in phase oscillators.

For nonlocally coupled phase oscillators in a modular network, there can be a number of different dynamical states. In addition to global synchrony there can also be modular synchrony when each module can synchronize separately to a different frequency. There can also be multicluster frequency chimeras, namely coherent domains consisting of modules that are separately synchronized to different frequencies, coexisting with modules within which the dynamics is desynchronized. The Ott-Antonsen ansatz can be applied in order to reduce the effective dimensionality and thereby carry out a detailed analysis.

8. **Anna Zakharova**

TITLE: Chimera patterns: interplay of dynamics, structure, noise, and delay

ABSTRACT: Time delay and stochasticity arise naturally in real-world systems. The interplay of time delay with network topology, nonlinearity, and noise leads to a plethora of complex phenomena with applications to various fields. We investigate peculiar partial synchronization patterns, chimera states. These hybrid states are made up of spatially separated domains of synchronized and desynchronized behavior. They arise surprisingly in networks of identical units and symmetric coupling topologies. We analyze different chimera types occurring in paradigmatic models of nonlinear dynamics, the Stuart-Landau oscillator and the FitzHugh-Nagumo model. In particular, we investigate amplitude chimeras, chimera death and coherence-resonance chimeras. We focus on the role of time delay and stochasticity for these synchronization-question of robustness and control of chimera states. Moreover, we demonstrate how noise and time delay can induce new dynamical behavior.

9. **Ricardo Luiz Viana**

TITLE: Synchronization in populations of oscillators with coupling mediated by the diffusion of a chemical substance

ABSTRACT: We investigate the transition to phase and frequency synchronization in a one-dimensional chain of phase oscillator cells where the coupling is mediated by the local concentration of a chemical which can diffuse in the inter-oscillator medium and it is both secreted and absorbed by the oscillator cells, influencing their dynamical behavior. This coupling has the advantage of having a tunable parameter which makes it possible to pass continuously from a global (all-to-all) to a local (nearest-neighbor) coupling form. We have verified that synchronous behavior depends on the coupling strength and coupling length.

10. **Oleh Omelchenko**

TITLE: Chimera states in spatially extended systems with nonlocal coupling

ABSTRACT: This talk will give an overview of the chimera states which appear as coherence-incoherence patterns in systems of nonlocally coupled phase oscillators. I will describe the continuum limit approach to these states, their typical bifurcations and their stability properties as a function of the system dimension and of the system parameters. It will be shown how these results can be used to control chimera states and to reveal the relationship between system design and the type of chimera states which are observed.

11. **Tarcisio Filho**

TITLE: Simulating long-range systems on a GPU

ABSTRACT: We will discuss in this tutorial how to perform efficient numeric simulations of systems with long-range interactions using Graphic Processing Units (GPUs), with a focus on molecular dynamics and the numerical solution of the Vlasov equation. For molecular dynamics we consider implementations of both Symplectic and Runge-Kutta integrators, with applications ranging from the Hamiltonian Mean Field model to 3D self-gravitating systems. For the Vlasov equation we consider a semi-lagrangian method for 1D systems. We will discuss key concepts in parallel algorithms and a few important issues including efficient memory management.

12. **Mustansir Barma**

TITLE: **Stochastic Evolution of Interacting Particle Systems**

ABSTRACT: Stochastically evolving systems of interacting particles display interesting dynamical properties. The interactions in question encompass processes such as exclusion, annihilation, coalescence and fragmentation. These two lectures aim to introduce the formalism, the condition to be in equilibrium and out of it, and to discuss briefly results for the steady states for a few interesting examples. More specifically, we will discuss the Master equation, and how probabilities evolve and settle into a steady state. Conditions for this to be an equilibrium state will be derived. We will discuss some techniques to determine nonequilibrium steady states as also a fruitful correspondence between the evolution operator and a many-body quantum Hamiltonian. We will illustrate all these points with reference to some paradigmatic models: the simple exclusion process, both symmetric (SEP) and asymmetric (ASEP); the single-step model of an interface with symmetric (Edwards-Wilkinson) and asymmetric (Kardar-Parisi-Zhang) evolution; the zero-range process; and coupled interface-particle models.

13. **Giovanna Morigi**

TITLE: Collective dynamics of atomic ensembles due to long-range optomechanical forces

ABSTRACT: In this talk we will present recent theoretical work on cooling and spontaneous spatio-temporal pattern formation of atomic and molecular ensembles in optical resonators, where the key ingredient of the dynamics are the coherent and dissipative long-range optomechanical forces mediated by multiple scattering of the cavity photons. These dynamics reveal the existence of prethermalized states which are expected to be stable over the experimental time scales even in the bad cavity limit.

14. **Alessandro Campa**

TITLE: The derivation of kinetic equations: main physical aspects

ABSTRACT: In these lectures we will first derive the evolution equations of the reduced distribution functions, and then we will use them as a starting point to obtain kinetic equations. We will try to underline the main physical motivations for the choice of the necessary approximations that are employed when a kinetic equation, suitable for a certain class of systems, is constructed. In particular, we will consider the Landau and the Lenard-Balescu equations; in both cases, the collision integral, absent in the collisionless Vlasov equation, drives the one-particle distribution function to equilibrium, similarly to what occurs in the celebrated Boltzmann equation.

15. **Celia Anteneodo**

TITLE: Synchronization: interplay between range of the interactions and time delay

ABSTRACT: Simple models that capture the essential features of the synchronization phenomenon are coupled map lattices (CMLs). Traditionally, when studying emergent patterns in CMLs, the updating of the constituent units is made synchronously (parallel updating), however, the elements in real arrays are not perfectly synchronous, that is, they do not change all at once. Then, the inclusion of time delays or other kinds of asynchronicity seems more realistic and leads to quite different emerging patterns. On the other hand, within the spatial domain, another realistic ingredient in modeling extended systems is the coupling range. We investigate the formation of completely synchronized states (CSSs) in CMLs as a function of interaction strength, range of the interaction (that can vary from first neighbors to global coupling), and a parameter that allows one to scan continuously from non-delayed to one-time delayed dynamics. We identify in parameter space, periodic orbits, limit cycles, and chaotic trajectories, and describe how these structures change with delay. These features can be explained by studying the bifurcation diagrams of a two-dimensional non-delayed map, allowing us to understand the effects of one-time delays on CSSs, e.g., regularization of chaotic orbits and synchronization of short-range coupled maps, observed when the dynamics is moderately delayed.
Refs.: Phys. Rev. E 93, 052230 (2016), Phys. Rev. E 95, 062213 (2017)

16. **Erik Martens**

TITLE: Chimera states in modular networks

ABSTRACT: Phase oscillator networks model a variety of dynamical phenomena in nature and technological applications. Many real-world networks have modular structure, that is, they consist of distinct communities. Such networks support chimera states, localized synchrony patterns where one part of the oscillators are synchronized while others drift incoherently. I discuss how chimera states and other synchronization patterns emerge in modular networks and how their mean-field dynamics can be studied via dimensional reduction methods. These insights are a fist step towards understanding how chimera states may be involved in functional and computational properties of the network. For instance, localized synchronization may encode information and thus provide function in neuro-biology.

17. **Hugues Chate**

TITLE: Synchronization and long-range interactions in dense bacterial suspensions

ABSTRACT: This talk will show that bacterial suspensions, beyond their intrinsic, dominating importance in biology, are also excellent systems to explore and test theoretical results on active matter. I will present recent experimental results on dense bacterial suspensions obtained in the groups of Masaki Sano (University of Tokyo) and Yilin Wu (Chinese University of Hong Kong). I will put them in context, situating them within our current knowledge of active matter, which I will present from a viewpoint adapted to the topic of this workshop.

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List of Abstracts

SHORT TALKS

Synchronization induced by external forces in modular networks

Carolina Arruda Moreira (Instituto de Física Gleb Wataghin)

The processing of information in the cerebral cortex seems to be associated with the synchronized firing of a specific group of neurons. However, overall synchronization is related to abnormalities such as epilepsy and Alzheimer's disease. In this seminar we will study the synchronization model in complex networks subject to external stimuli. We are interested in analyzing the balance between spontaneous synchronization and that triggered by external stimulus. In particular, we will show under which conditions (network topology, connection strength and external force) the stimulation of a fraction of the network nodes leads to global synchronization.

Bifurcations in Vlasov and Kuramoto equations

David Métivier (Los Alamos National Laboratory)

The mean field description of plasmas and self-gravitating systems leads to the Vlasov (or Collisionless Boltzmann) equation. Similarly, a large system of Kuramoto oscillators can be described through a kinetic equation sometime refered as the Kuramoto equation. A lot of efforts have been made to study the stability of their steady states resulting, for example, in the discovery of the Landau damping - which is a common feature of both systems. In my presentation, I will address the question of the bifurcations in these systems by studying weakly unstable steady states. What is the nature and shape of the bifurcation? Physically, this question is relevant to study, for example galactic dynamics (e.g. radial orbit instability) or the synchronization of coupled oscillators. Again both models share similarities, but also differences that I will review in different examples. This is joint work with J. Barré, Y. Y. Yamaguchi and S. Gupta.

Activity induced synchronization

Demian Levis (Ecole Polytechnique Federale de Lausanne)

The emergence of synchronized states in populations of mobile entities is widely observed in very different contexts: from animal groups - like fireflies flashing at unison, flocks of birds moving coherently or crowds of people walking cooperatively on the London's Millenium bridge - to robot swarms or synthetic colloidal systems. However, previous studies on synchronization have focused on, either immobile oscillators, or mobile oscillators which phase does not directly influence the way they move in space.Here, we focus on the synchronization of motile entities - active particles which rotate with an intrinsic frequency - and show that self-propulsion, or activity, induces a qualitatively new and generic synchronization route. This new synchronization scenario generates two novel phases: (i) a first phase where oscillators cooperate to suppress their intrinsic rotations and move collectively along a given direction; a phase showing long-range order in 2D (akin to the celebrated Toner-Tu flocking phase). (ii) a second phase where particles of opposite chirality segregate into two macroscopic structures. Both phases feature motility-induced macroscopic synchronization in 2D, which is not achievable for the typically considered case of immobile oscillators in low dimensional systems.

A network of networks model to study phase synchronization using structural connection matrix of human brain

Fabiano Alan Serafim Ferrari (Universidade Federal dos Vales do Jequitinhonha e Mucuri)

The cerebral cortex plays a key role in complex cortical functions. It can be divided into areas according to their function (motor, sensory and association areas). In this paper, the cerebral cortex is described as a network of networks (cortex network), we consider that each cortical area is composed of a network with small-world property (cortical network). The neurons are assumed to have bursting properties with the dynamics described by the Rulkov model. We study the phase synchronization of the cortex network and the cortical networks. In our simulations, we verify that synchronization in cortex network is not homogeneous. Besides, we focus on the suppression of neural phase synchronization. Syn- chronization can be related to undesired and pathological abnormal rhythms in the brain. For this reason, we consider the delayed feedback control to suppress the synchronization. We show that delayed feedback control is efficient to suppress synchronous behavior in our network model when an appropriate signal intensity and time delay are defined.

Mobility-induced persistent chimera states

Gabriela Petrungaro (Instituto de Investigacion en Biomedicina de Buenos Aires)

Chimera states are complex spatio-temporal patterns in which order and disorder coexist within the same state in systems of identical oscillators. Since their discovery in 2002, they have demonstrated to be broadly encountered in multiple systems in one and two dimensions with distinct coupling schemes, both in theoretical and experimental systems. Despite the great progress made in understanding chimera states, the mechanisms and conditions for their existence are still not clear. In addition, although they are thought to play a role in natural systems, most of the experimental evidence is find in carefully designed laboratory setups. In this work we study chimera states that spontaneously emerge in a system of mobile, locally coupled identical oscillators in the presence of coupling delays. The system has its main motivation in the vertebrate segmentation clock, a tissue generating cyclic patterns that is thought to be a population of coupled oscillators where significant coupling delays occur together with cell movements. In addition to well-known chimera states where in-phase order coexists with disorder, we find other kinds: antichimera states where antiphase order coexists with disorder and dual-chimera states where both in-phase and anti-phase order coexist with disorder. These chimera states are dynamic and can persist for long times for intermediate mobility values. We analyse their occurrence and persistence and discuss the mechanisms leading to the formation of these chimera states in different mobility regimes (Petrungaro et al. 2017).

Reconstruction of oscillatory systems: the impact of local network characteristics on the probabilities of false positive and false negative conclusions about links

Gloria Cecchini (University of Aberdeen)

Networks are one of the most frequently used modelling paradigms for dynamical systems. Investigations towards synchronisation phenomena in networks of coupled oscillators have attracted considerable attention, and so has the analysis of chaotic behaviour and corresponding phenomena in networks of dynamical systems to name just a few. A typical network inference procedure estimates the connectivity between a-priori specified nodes in a network. If the connectivity measure passes a certain threshold, a link between the corresponding nodes is assumed to be present.

Selecting the threshold, not only controls how many links are inferred correctly but also establishes the number of incorrectly determined links. There are two types of errors, (i) a link may be erroneously considered present, this false positive conclusion is referred to as a type I error; (ii) a present link may remain undetected, this false negative conclusion is referred to as a type II error. We consider two different oscillatory systems and reconstruction methods, namely pulse-coupled neuronlike oscillators, and coupled phase oscillators.

We present numerical simulations showing that local network characteristics influence the probability of type I and type II errors. In particular, we show that the probability of type I error is influenced by the shortest path length and the probability of type II error by the detour coefficient. The same behaviour is present for different network dimensions, coupling strength, and number of data points used for the reconstruction of the network. From our findings, we can conclude that for each value of the threshold, it is more likely to have a false positive conclusion about a link, when this non-existing link connects 2 nodes with shorter distance, and that it is more likely to have a false negative conclusion about a link when it has a higher detour coefficient.

Synchronisation in coupled oscillators with time-varying parameters

Maxime Lucas (University of Florence)

Complex oscilatory dynamics abounds in nature. Moreover, such oscillations often interact and can yield a plethora of synchronisation phenomena. Synchronisation is of key importance in many real systems: it can be beneficial, as in circadian rhythms, or detrimental, as in epilepsy. Another key element in many real life systems is the ongoing influence of their ever changing environment. This influence makes them open systems, and the equations to describe them non-autonomous, e.g. via time-varying parameters or an external driving. Here, we present some results about the influence of time-varying parameters on synchronisation, in different coupled oscillators scenarios. In particular, we will illustrate how a time-varying driving frequency can increase the Arnold tongue of the system, and hence increase its stability. Moreover, this scenario yields a new regime of intermittent synchronisation, that does not exist in the classic case of fixed-frequency forcing. We will also illustrate how, on the other hand, in a network, fast time-variability of the coupling can induce instability in the synchronous solution of a network, yielding oscillation death. In summary, the effect of time-varying parameters -- a key element in real systems, and not much studied to date -- on different coupled oscillators systems will be presented, and various effects on their stability and synchronisation will be discussed.

Dynamical invariance on complex networks

Pau Clusella Cobero (University of Aberdeen)

Given a reaction-diffusion system on a complex undirected network, we propose two different techniques to modify the network topology while preserving the dynamical behaviour. In the region of parameters associated to the Benjamin-Feir instability, the homogeneous solution is spontaneously destabilized when introducing the network of connections.Both schemes exploit spectral properties of the Laplacian operator associated to the graph in order to generate a new network that preserves the unstable manifold. Therefore, a small perturbation of the unstable fixed point give raise to the same irregular spatio-temporal patterns than in the original setup. The first method acts directly on the eigenmodes, thus resulting on a general redistribution of link weights which in some cases can completely change the structure of the original network. The second method uses localization properties of the eigenvectors to identify and randomize a subnetwork that is mostly embedded only into the stable manifold. We test both techniques on different network topologies using the Ginzburg-Landau system as a reference model, as well as a comparison with the Brusselator model. Whereas using the first method the correlation between the original dynamics and the new one is larger, the second method allows for a greater control at the level of singles nodes. This opens a new perspective on the multiple possibilities for the choice of a discrete spatial support so as to obtain a chosen behavior as a result of a generic reaction-diffusion system.

Nonequilibrium statistical mechanics of two dimensional vortex systems

Renato Pakter (Instituto de Física - Universidade Federal do Rio Grande do Sul)

Formation of large scale vortices is very common in two dimensional systems. The classical example of this is the great red spot of Jupiter. To explain this phenomenon, seventy years ago Onsager introduced the concept of negative temperature. The underlying assumption of Onsager's theory is the ergodicity of point vortex motion which he suggested to be valid in the thermodynamic limit (infinite number of point vortices). In this paper we will show that this assumption is not correct and that in the thermodynamic limit vortex motion is not ergodic. This notwithstanding, it is possible to show that a thermodynamic vortex system will relax to a stationary state with a core-halo structure which we can calculate explicitly.

Bacterial active nematics driven by long-range hydrodynamic interactions

Xianqin Shi (CEA-Saclay / Soochow U.)

In direct continuation of Hugues Chaté's talk, I will present yet another dense bacterial suspension experiment, performed in the group of Hepeng Zhang (Shanghai Jiaotong University). I will show that this time, global order/synchronization is destroyed by the long-range interactions mediated by the fluid in which bacteria try to swim.

Stability and self-organization of planetary systems

Yan Levin (Instituto de Física, UFRGS)

We show that stability of planetary systems is intimately connected with their internal order. An arbitrary initial distribution of planets is susceptible to catastrophic events in which planets either collide or are ejected from the planetary system. These instabilities are a fundamental consequence of chaotic dynamics and of Arnold diffusion characteristic of many body gravitational interactions. To ensure stability over astronomical time scale of a {\it realistic} planetary system -- in which planets have masses comparable to those of planets in the solar system -- the motion must be quasi-periodic. A dynamical mechanism is proposed which naturally evolves a planetary system to a quasi-periodic state from an arbitrary initial condition. A planetary self-organization predicted by the theory is similar to the one found in our solar system.

Velocity distribution for the non identical particle Hamiltonian means field model

ZOLACIR TRINDADE DE OLIVEIRA JR (EXACT AND TECNOLOGICAL SCIENCES DEPARTMENT)

Since the early times of statistical physics development Gibbs noticed that systems which interact via long range forces are not well fitted for the statistical physics description. So new tools must be developed. In this work we study a non-identical particle Hamiltonian mean field model and we look to the velocity distribution function (VDF) of this system. We show that the VDF exhibit long tails and can be described by Lévy probability distribution function (PDF). We calculate the exponent of the Lévy PDF as 1.614 and show the rescaling of the various distributions obtained by random variables summation using the velocity as a random variable. This is an expected feature of the generalized Central Limit Theorem. We also show that each velocity for each particle behaves as a Lévy flight.

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POSTERS

Recovering synchronization in the Kuramoto Model

JONAS FERREIRA DE OLIVEIRA (Universidade Federal de Goiás)

We investigate the Kuramoto model of globally coupled oscillators with natural frequencies distributed according to a Log-Normal function. The Log-Normal is an unimodal asymmetric function tunned by two parameters that are related to its mean and variance. We analyzed the order parameter in a parameter space and we observed that the variation of the parameter related to the variance can destroy the synchronization of the system but under certain condition also recover such synchronization. We point out that the emergence of synchronization recovery is due to particular proprieties of the Log-Normal distribution.

Many-body homogeneous one-dimensional self-gravitating systems do not relax to thermodynamic equilibrium

Lydiane Ferreira de Souza (UnB)

The dynamics of systems with long-range interactions, which antiparticle potential decaying at long distances as $r^{-\alpha}$ with $\alpha \leq d$ where d is the spatial dimension, comprises essentially three phases: (i) An initial violent relaxation described by the Vlasov equation; (ii) A slow relaxation towards thermodynamic equilibrium described by the relevant kinetic equation, e.~g.\ Landau or Balescu-Lenard equations and (iii) The final thermodynamic equilibrium. In the present context kinetic equations can be obtained from the Born-Bogolyubov-Green-Kirkwood-Yvon (BBGKY) hierarchy~\cite{liboff,balescu} by taking into account contributions from the two-body correlation functions. In the case of homogeneous one-dimensional systems these contributions vanish as two-particle collisions only exchange the velocities of the two-particles and the velocity distribution function cannot change by this mechanism. As a consequence three-particle correlations must be considered leading to a much more slowly relaxation than for non-homogeneous states~\cite{marciano}. In the present work we study the relaxation to equilibrium of one-dimensional homogeneous self-gravitating systems (self-gravitating sheets)~\cite{joyce,miller}. Starting from the BBGKY hierarchy and the Mayer cluster expansion we show that collisional effects vanish for homogeneous states, and thus the system never relaxes to equilibrium. This is similar to what occurs for a homogeneous gas of one-dimensional hard-spheres. This similarity is due to the event-driven nature of the dynamics in both systems. \begin{thebibliography}{} \bibitem{liboff} R.~L.~Liboff, {\it Kinetic Theory - Classical, Quantum, and Relativistic Descriptions}, 3rd ed, Springer-Verlag (New York, 2003). \bibitem{balescu} R.~Balescu, {\it Statistical Dynamics - Matter out of Equilibrium}, Imperial College Press (London, 1997). \bibitem{marciano} T.~M.~Rocha Filho, A.~E.~Santana, M.~A.~Amato and A.~Figueiredo, Phys.\ Rev.\ E {\bf 90} (2014) 032133. \bibitem{joyce} M.~Joyce, T.~Worrakitpoonpon, Phys.\ Rev.\ E {\bf 84} (2011) 011139. \bibitem{miller} K.~R.~Yawn and B.~N.~Miller, Phys.\ Rev.\ E {\bf 68} (2003) 056120. \end{thebibliography}

Energy transport in coupled chains with long-range interparticle interactions

María Florencia Carusela (Instituto de Ciencias, Universidad Nacional de General Sarmiento)

In this work we study the energy transport along two one-dimensional chains of atoms with long-range interactions. The chains are connected together by a short-ranged modulated coupling and short-coupled to thermal reservoirs at different temperatures. We analyze the role of the interplay between the modulation of the contact and the range \alpha of the interactions. We study the existence of different energy transport regimes depending on frequencies, size of the system and \alpha. The heat current and the temperature profiles in the nonequilibrium steady state are obtained by dynamical molecular simulations.

Anderson Localization of Light and Multifractality

Noel Araujo Moreira (Instituto de Física de São Carlos - Universidade de São Paulo)

Scattering in a medium may block wave transport, creating a wave localized over a region. This phenomenon is known as Anderson Localization and was first discovered for electrons in disordered solids, but it also applies to sound or light waves. In 3D models, such effect shows a phase transition between localization-delocalization, and multifractal structure may be found studying wavefunctions or energy spectrum of the system. However, no study of multifractality over light Anderson localization was reported. In this work, we simulate a cold atom cloud with long-range interactions via light scattering. The nature of the phase transition is investigate using multifractals statistics over wavefunctions. The results shows regions which localization-delocalization have distinct signatures, even though the expected values from multifractal theory could not be achieved due to computational limitation.

What does virialization mean?

Suzana Ester R. J. de Oliveira (Universidade Estadual de Santa Cruz)

The virial theorem allows one to know the fractions of the total energy of a system and, as a consequence, the estimate of several important characteristics of its evolution. Systems that interact by long range forces are known to have proper features, as a stage called violent relaxation; unequivalence of ensembles; negative heat capacity; non additivity of extensive thermodynamic variables; invalidity of the energy equipartition theorem; weak ergodicity breaking; and long lasting non-equilibrium quasi-stationary states. So it is possible to say that these systems do not follow a Gaussian statistics unless they have reached the thermodynamic equilibrium. One example of a long-range interacting system is the toy model Hamiltonian Mean Field (HMF). HMF with different masses presents mass segregation (MS). The MS reveals that the system is non ergodic and, therefore, it is not in the thermodynamical equilibrium. The system constituents do not visit the phase space with equal probabilities. The system evolves as Lévy flights. So how long it takes for a system with these features to reach thermodynamic equilibrium and also how long it takes to virialize? The statment that system is virialized may depend on a greater foundation. Thermodynamical characteristics of long-ranged systems are essentially different from those short-ranged, as in the case of ideal gases. Furthermore if a system is said to be virialized, we have to ask how much time it did take to virialize. The required time to attain the virialization seems to depend on a limit process and may be function of both on the initial conditions and the number N of the system's constituent particles. The aim of this work is to stablish these relations on virializtion time, N (the number of particles) and the corresponding system initial conditions. In this sense to set how virialization occurs may elucidate a fundamental process.

Quantum effects in the cooperative scattering of light by ultracold dilute atomic clouds

Tiago Santiago do Espirito Santo (Instituto de Física de São Carlos)

We analyze the fluorescence power spectrum of the light radiated by a ultracold, dilute and large cloud of strongly driven two-level atoms. The photon-mediated long-range interaction between the atoms leads to cooperative effects. Our simulation method is based on a truncation, which includes up to two-atoms quantum correlations, in the BBGKY hierarchy. In addition to the usual Mollow triplet, we observed additional sidebands at twice the frequency of the Mollow sidebands and an asymmetry of the Mollow triplet for a detuned laser with the resonant optical thickness, which plays the role of cooperativity parameter.