XVIII Giambiagi Winter School: Quantum Chaos & Control

Departamento de Física
Facultad de Ciencias Exactas y Naturales
Universidad de Buenos Aires, Argentina

July 25-29, 2016

Sponsors

About the School

The Giambiagi Winter School is organized by the Physics Department of Exact and Natural Sciences School of the University of Buenos Aires, Argentina. The main purpose of the School is to offer graduate students and young researchers an up-to-date perspective given by world-recognized experts.

In 2016 Giambiagi Winter School will be devoted to Quantum Chaos & Control, and will take place from July 25th to July 29th.

Quantum Chaos & Control

Quantum mechanics, initially developed to explain the behavior of matter and its interactions with light on the scale of atoms and subatomic particles, turned out to be the most successful physical theory of the 20th century and the foundation of an ongoing technological revolution.

Due to the Heisenberg uncertainty principle, in quantum mechanics the notion of trajectory is lost. As a consequence, the classical concept of chaos becomes meaningless as well. The quantum manifestations of chaos and its semiclassical limit, a subject known as quantum chaos, have been explored for 40 years.

This research area has received increasing attention because of its relation to control, relaxation and thermalization processes in many-body systems. Chaos plays a fundamental role in the microscopic origin of irreversibility described by the second law of thermodynamics. In fact, entropy is a measure of disorder, and entropy increase is generated by a chaotic time evolution.

The control of microscopic systems in order to obtain a desired final state or a certain value of a physical observable represents a major present goal in the field of quantum technologies. This has led to the development of sophisticated techniques, known generically as quantum control. To assess the efficiency of any quantum-control protocol, especially in a many-body setting, the challenge posed by chaotic dynamics cannot be overlooked.

The main purpose of this School is to bring together these two fundamental aspects of quantum dynamics:

I)The appearance of quantum chaos and an overview of the tools developed for its study

II) The theory of quantum control, and in particular its application to quantum many-body systems.

Invited speakers

- Andreas Buchleitner
  Quantum control: determinism, chaos, disorder
- Adolfo Del Campo
  Shortcut to adiabaticity and quantum speed limits
- Rodolfo Jalabert
  Introduction to semiclassical mechanics
- Horacio Pastawski
  Irreversibility and chaos in quantum mechanics
- Gregor Tanner
  Wave Chaos in Engineering Applications
- Juan Diego Urbina
  Many body semiclassics

Organizing Committee

- Leonardo Ermann
- Ignacio Garca-Mata
- Pablo Tamborenea
- Diego Wisniacki
- Mara Cambn (secretary)

Courses

Determinism, chaos, disorder

Andreas Buchleitner
Institute of Physics Albert-Ludwigs University of Freiburg, Germany

Steering quantum systems into a pre-defined target is a long-standing problem in many research areas, from quantum chemistry to quantum computing. The widespread approach of quantum engineers typically consists in tailoring specific constituents of the system Hamiltonian or of environment coupling agents, such as to generate the desired dynamics. This program is successful when living in rather low-dimensional Hilbert spaces with low spectral densities, but tends to turn fragile as the problem complexity increases. However, quantum control is an interesting challenge only in situations when control is non-trivial, i.e. when fragility actually is an issue. Under such circumstances, the non-trivial and, to some extent, controllable structure of (in general, mixed, regular-chaotic) phase space provides means for robust deterministic control. However, chaos as a deterministic substitute for disorder, together with quantum interference, does induce an unavoidable statistical element which tends to manifest in large fluctuations of, e.g., cross sections or transport coefficients. Quantum control in systems which really merit the attribute complex therefore needs to account for these fluctuations. A possible strategy to do so is to seek control over the statistics of these fluctuations, which, by definition, offers robust solutions.

With some conditioning on the audiences interests and the lecturers average speed, we will touch upon the following topics in some more detail:

1) General aspects of quantum control, motivation, formulation of the problem.

2) Mixed phase space, elliptic islands, semiclassical considerations.

3) Bound space dynamics vs. asymptotics and decay/transport.

4) Statistical quantum control

Shortcut to adiabaticity and quantum speed limits

Adolfo Del Campo
University of Massachusetts, Boston, USA

Lecture 1: Shortcuts To Adiabaticity: noncritical systems

Shortcuts to adiabaticity (STA) speed up the dynamics of a system while controlling excitation formation. In this first talk, I shall introduce the key techniques to engineer STA and control the dynamics of noncritical systems. Prominent examples include STA to expansion and transport processes of trapped matter-waves such as ultracold atoms, ions, BEC, and quantum fluids.

Lecture 2: Shortcuts To Adiabaticity: critical systems

Across a continuous phase transition, the relaxation time diverges and the breakdown of adiabaticty is unavoidable. In such scenario, the Kibble-Zurek mechanism describes the dynamics of symmetry breaking. The density of excitations scales as a power-law of the quench time, and slow driving is needed to approach the adiabatic limit. Fortunately, STA provide ways out of the KZM. We shall focus on two strategies: inhomogeneous driving and counterdiabatic driving across a quantum phase transition.

Lecture 3: Quantum Speed Limits

Quantum Physics dictates fundamental upper bounds to the speed of evolution of any physical systems. In this talk, such quantum speed limits will be derived for arbitrary physical processes. We shall further discuss their use to engineer STA and, more broadly, in Quantum

---

Introduction to semiclassical mechanics

Rodolfo Jalabert
Université de Strasbourg IPCMS, France

1. Classical trajectories and quantum interference in mesoscopic systems.
2. Path integrals and semiclassical approximations.
3. Closed systems: Gutzwiller trace formula and orbital magnetism.
4. Open systems: ballistic transport and conductance fluctuations.
5. Classical trajectories and scanning gate microscopy on nanostructures.
6. Quantum chaos and Coulomb interactions in quantum dots.

Irreversibility and chaos in quantum mechanics

Horacio Pastawsky
FAMAF, UNC, Córdoba, Argentina

The following material to be covered along three lectures. Notes will be available.

Classical Dynamics. Chaos and irreversibility in Boltzmann H theorem. Feynman's approach to Quantum Mechanics. Path integral and Schrdinger Equation. Continuous and discrete spaces. Electrons and Phonons. Spins Models. Wave functions and Green's functions. Self-energies and effective Hamiltonians. Periodic systems. Fermi Golden Rule. Disordered Systems: Anderson's localization vs. metallic. Chaos and Diffusion as source for electrical resistance. Anderson localization vs. Diffusion. Thouless criterion for transport. Level statistics in random matrix models Lyapunov instability as source of Localization. Scattering Matrix and Promotion Matrix. Minimum Lyapunov exponent. Scaling methods to assess the Localization phase transition.

Spectral statistics and Parametric correlations as a signature of Quantum Chaos. Early search for dynamical quantum chaos. Many-body chaos. Experiments on spin dynamics. Time reversal of precession of individual spins and many body reversal. Hints for a chaotic regime. The Loschmidt Echo: dynamical definition of quantum Chaos. A simple model: quantum dynamics in a chaotic system. The semi-classical approximation. Diagonal approximation and Fermi Golden Rule. Non-diagonal terms. The regimes of the Loschmidt Echo. Numerical strategies. The Wigner distribution Function. Irreversibility and Decoherence. Loschmidt echo and time reversal mirrors.

More on Many body dynamics experiments. Proliferation of virtual interactions. Many Body decoherence the Central Hypothesis of Irreversibility. External environment and self-environment. The Loschmidt Echo tool in many body localization. Emergent phenomena. Thermalization and equilibration in the thermodynamic limit.

Wave Chaos in Engineering Applications

Gregor Tanner
University of Nottingham, UK

Quantum Chaos as it was introduced in the early 1970ies by Gutzwiller, Berry, Balian and Bloch and others deals with understanding how the properties of a classical dynamics, that is, whether it is regular or chaotic, influences the solution of the corresponding (linear) quantum problem. This ansatz was an inspiration for many and has led to a large body of research since. However, there is nothing inherently quantum in this question. In fact, the same questions can be asked and answered for classical continuum wave problems such as waves in fluids (acoustics) and solids (elasticity and vibrations) as well as electromagnetic wave propagation. In fact, high frequency wave problems calling for an interpretation in terms of ray trajectories exist in abundance in everyday live reaching from noise and vibration issues in mechanical engineering to questions of wireless communication and electromagnetic compatibility. Problems such as Why is it so difficult to model how a car sounds? or Why do we have to switch off mobile phones in an aircraft? are related to short wavelengths asymptotics and can be tackeld with the tools having been developped in Quantum Chaos which we should really call Wave Chaos in this context. In this lecture series, I will give an introduction into the field of Wave Chaos and how this can be helpful to tackle important engineering problems. I will start with giving an overview over the theory necessary mostly developped in the contect of classical and quantum chaos. I will then introduce a method called Dynamical Energy Analysis (DEA), which has been developped in Nottingham to model noise and vibration for complex mechanical structures. In a last lecture, I will consider describing fluctuations due to wave inteference based on DEA results and general ergodicity assumptions.

Lecture 1: From correlation functions to classical phase space propagators

In this lecture, I will give an introduction into the main tools needed to develop efficient algorithms for high frequency wave modelling. I will introdcue wave transfer operators describing boundary integral equations in terms of incoming and outgoing wave solutions. I will then discuss the connection between correlation functions and Wigner functions and between Wigner representations and classical phase space operators, in particular the FrobeniusPerron (FP) operator. The properties of the FP operator being a linear operator for transporting phase space densities will be discussed in more detail.

Lecture 2: Dynamical Energy Analysis and applications

In this lecture, I will discuss the challenges one faces when undertaking noise and vibration modelling in general and will describe some standard engineering solutions for this problem. I will then introduce DEA as a dynamical systems approach for tackeling some of these challenges and discuss its numerical implementation on standart engineering meshes. I will explain how these meshes can be used for a DEA simulation and will show example calculations for engineering structures ranging from cars and airplanes to tractors and ships. I will briefly touch on the challenges associates with describing noise radiated off structrures and undertaking full vibroacoustic simulations including the interaction with the the surrounding fluid (such as air) for exterior but also interior sound modelling.

Lecture 3: Wave fluctuations

DEA gives average sound intensities but can not describe the fluctuations due to the wave nature of the problem. In this lecture, I will introduce concepts based on correlation functions and transfer operators and use ergodicity assumptions to derive explicit relations between diagonal and off- diagonal contributions of the correlation function as well as full propability density functions for wave intensity fluctuations.

Many body semiclassics

Juan Diego Urbina
Universität Regensburg, Germany

Lecture I

a) Systems of identical particles, their description and experimental realization in discrete spaces: Bosons and fermions. Second quantization. The Bose-Hubbard model and its experimental realization.

b) The path integral in Fock space: Coherent and quadrature states, their properties and physical meaning. Superselection rules. Formal construction of the path integral. Similarities and diferences with the single-partticle case.

Lecture II

a) The semiclassical aproximation: The mean field as classical limit. The van Vleck-Gutzwiller propagator in Fock space. $1/N$ as effective Planck's constant. The Gross-Pitaevskii equation and its several versions. Coherent sums and interfering paths in Fock space.

b) Relation with other approaches: Mean field theories, variational methods and the Truncated Wigner method as versions of the quantum-classsical correspondence. The Keldysh formalism and other quasi-classical approximations.

Lecture III

a) Coherence and quantum interference in Fock space. The diagonal approximation and its first quantum correction. Anti-unitary symmetries and their consequences. Coherent backscattering and related phenomena. Experimental perspectives.

b) Extensions and generalizations: Semiclassical quantization of classical solitons in continuum theories. Quantum integrable models (the Lieb-Linniger model). Scattering systems. Wavepacket propagation in Fock space.

Talks

Quantum to classical correspondence in dissipative directed transport

Gabriel Carlo

GIyA, CNEA - CONICET, Buenos Aires, Argentina

Feynman [R. P. Feynman, Lectures on Physics (Addison-Wesley, Reading, MA, 1963), Vol. 1.] reignited the interest in directed transport, i.e. unbiased transport phenomena in systems which are driven out of equilibrium. There is a wealth of fields for their application such as in biology, nanotechnology, chemistry, and Bose-Einstein condensates for example. Among the very many alternatives, we focus in ratchets with dissipation which are generally associated with a classical asymmetric chaotic attractor; the quantum versions lead to interesting applications in cold atoms. The classical and quantum aspects of the parameter space of these systems have been the subject of very recent and interesting developments [Phys. Rev. E 93, 042133 (2016), Phys. Rev. E 91, 052908 (2015)]. We will give a glimpse on them, explaining the role of the isoperiodic stable structures (ISSs, Lyapunov stable islands), fundamental for the current properties. The quantum counterparts of these structures (QISSs) have proven to be very well approximated by means of a thermal coarse graining of the classical dynamical equations. The details on this correspondence mechanism open new lines of research and possibly provide with interesting answers to some quantum to classical correspondence questions [arXiv:1604.02743].

Quantum refrigerators: the ultimate limit for cooling and the origin of the third law.

Nahuel Freitas

DF - IFIBA, FCEN, UBA, Buenos Aires, Argentina

I study the asymptotic dynamics of a network of oscillators whose frequencies and couplings are periodically driven while coupled with a number of bosonic reservoirs. I obtain exact results for the heat currents coming into the system from each reservoir (valid beyond the usual weak coupling, weak driving or Markovian approximations). I use these expressions to rigorously prove the validity of the dynamical version of the third law of thermodynamics (Nernst unattainability principle) in this context. The fundamental limit for cooling is imposed by a heating process which is present at zero temperature. It consists of the non resonant creation of pairs of excitations in the reservoirs by the driving field. It is intrinsically quantum, it is linked to the dynamical Casimir effect and it is not captured by usual perturbative treatments. Thus, for any cooling strategy there is a minimum attainable temperature, that we estimate in a number of relevant examples.

Controlled quantum state transfer in spin chains

Omar Osenda

Instituto de Fśica Enrique Gaviola, FAMAF, UNC

The transmission of quantum states in a spin chain can be achieved with high fidelity under appropriate conditions and without the application of external fields, if the coupling between the spins can be tuned to some specific values. In these cases, the time evolution of the quantum state is governed by the time-independent spin chain Hamiltonian. The simplest transmission protocol, in which the states considered are restricted to the one-excitation Hilbert space, is fairly robust, even when some static disorder in the spin couplings is present.

Despite what has been said above, there are cases when a more sophisticated approach is required, and the dynamical evolution of the state to be transmitted is driven, i.e. controlled, using control pulses. There are several possible strategies, depending on the particular situation being scrutinized, for instance, how many spin sites can be accessed for manipulation, how much information is available about the actual spin couplings, the type of physical interaction (isotropic, anisotropic, etc), the range of the interactions and so on.

The general conditions to achieve controllability on spin chains models, the transmission protocol and some results for different spin chain models will be discussed on the talk.

Weak localization in the transport of interacting Bose-Einstein condensates

Cyril Petitjean

Université de Liege - FNRS, Belgium

An important effect in mesoscopic transport physics in the presence of disorder or chaos is the so-called weak localization effect. This effect arises due to constructive interference between reflected paths and their time-reversed counterparts. It has been observed with Bose-Einstein condensates [Aspect experiment] and it corresponds to an enhancement of the backscattered intensity of a wave in the direction of retro-reflection. In this talk I will present a theoretical mean-field study on weak localization of interacting Bose-Einstein condensed atoms that coherently propagate within a guided atom laser across chaotic billiard or disordered ring geometries. We find that the atom-atom interaction within the condensate leads to an inversion of the weak localization peak in two-dimensional chaotic billiard geometries that are exposed to a perpendicularly oriented synthetic gauge field [Ann.Phys.2012]. We recently encountered such an antilocalization effect also in the propagation of Bose-Einstein condensates atoms through disordered Aharonov-Bohm rings, where an inversion of Aronov-Altshuler-Spivak oscillations can be found. Truncated Wigner calculations carried out in this latter context reveal to what extent this antilocalization phenomenon prevails when going beyond the mean-field Gross-Pitaevskii approximation.

Random density matrices versus random evolution of open systems

Carlos Pineda

Instituto de Fisica, Universidad Nacional Autonoma de Mexico

We present and compare two families of ensembles of random density matrices. The first, static ensemble, is obtained foliating an unbiased ensemble of density matrices. As criterion we use fixed purity as the simplest example of a useful convex function. The second, dynamic ensemble, is inspired in random matrix models for decoherence where one evolves a separable pure state with a random Hamiltonian until a given value of purity in the central system is achieved. Several families of Hamiltonians, adequate for different physical situations, are studied. We focus on a two qubit central system, and obtain exact expressions for the static case. The ensemble displays a peak around Werner-like states, modulated by nodes on the degeneracies of the density matrices. For moderate and strong interactions good agreement between the static and the dynamic ensembles is found. Even in a model where one qubit does not interact with the environment excellent agreement is found, but only if there is maximal entanglement with the interacting one. The discussion is started recalling similar considerations for scattering theory. At the end, we comment on the reach of the results for other convex functions of the density matrix, and exemplify the situation with the von Neumann entropy.

Optimal control of many-body quantum dynamics: chaos and complexity

Pablo Poggi

DF - IFIBA, FCEN, UBA, Buenos Aires, Argentina

Achieving full control of the time-evolution of a many-body quantum system is currently a major goal in physics. Here, I will talk about the different ways in which the controllability of a quantum system may be influenced by its complexity, or even its chaotic properties. Using optimal control theory we are able to derive the control fields necessary to drive various physical processes in a spin chain. We then study the spectral properties of such fields and relate them to different aspects of the system complexity. We find that the spectral bandwidth of the fields is, quite generally, independent of the system state dimension. On the other hand, the spectral complexity of such fields does increase with the number of particles. Nevertheless, we find that the regular o chaotic nature of the system does not affect signficantly its controllability.

Posters

Infinite dimensional kicked ising model

David Amaro-Alcala
Instituto de Física, U.N.A.M

We investigate the infinite dimensional kicked Ising model with abasis that we have developed using Young diagrams exploiting the invariance under permutations. A subespace of this model is equivalent to the quantum kicked top and we are studying properties of both systems using this basis in the corresponding chaotic regime.

Unambiguous State Elimination and Imperfect Oblivious Transfer

Ryan Amiri[1], Petros Wallden[2], and Erika Andersson[1]
[1]SUPA, IPQS, Heriot-Watt University, UK
[2] LFCS, University of Edinburgh, UK

Optimal quantum measurements are important for many applications in quantum information and quantum com- munication. Finding relevant optimal figures of merit often plays an important role in security proofs of quantum cryptographic protocols. Optimal generalised quantum measurements are not only of theoretical interest, but have also been experimentally realised on photons, on NV centres, and could be realised on trapped ions or on atoms with existing experimental means. An interesting class of optimal measurements is unambiguous measurements, which includes the relatively new, yet increasingly useful, unambiguous state elimination (USE). Due to their ability to provide perfect yet partial information, unambiguous measurements seem well suited to cryptographic applications.

One such application is oblivious transfer (OT) - one of the most widely used and fundamental primitives in cryp- tography. Its importance stems from the fact that it can be used as the foundation for secure two-party computations; with OT, all secure two-party computations are possible. Unfortunately, it has been shown that unconditionally se- cure OT is impossible, even with quantum mechanics. Nevertheless, imperfect variants are possible, and in this paper we address the important theoretical question How close to ideal can unconditionally secure OT protocols be? Our paper contains two main contributions:

1. We increase the theoretical lower bound on the minimum cheating probabilities achievable in OT to 2/3 or, if the states sent in the final round are pure, the bound is increased to 0.749.

2. We describe an OT protocol with cheating probabilities essentially tight with the bounds proved here. The protocol improves on all previous unconditionally secure OT protocols, and relies solely on USE. Further, it is fully implementable with current technology.

These contributions close the knowledge gap between what is theoretically possible, and what is known to be achiev- able. By presenting a new application of USE measurements, we hope to encourage its use in future work.

Random Matrix Theory predictions for the statistics of the work in quantum chaotic systems

Eric Arrais

Universidade Federal de Goiás, Brazil

Results from classical Random Matrix Theory (RMT) are well recognized as a way to describe spectral statistical properties of classically chaotic quantum systems, such as the level spacing distribution. We are investigating, both numerically and analytically, if RMT can be used, at least for some regimes, to predict the behavior of the statistics of work performed by quenching some external parameter dictating the dynamics of a quantum chaotic system. In order to check this possibility we are trying to compare results obtained from matrices pertaining to some of the classical RMT ensembles with results obtained from real physical models.

Unified entropic measures of quantum correlations induced by local measurements

G.M. Bosyk and G. Bellomo

IFLP, Universidad Nacional de La Plata, Argentina

We introduce quantum correlation measures based on the minimal change in unified entropies induced by local rank-one projective measurements, divided by a factor that depends on the generalized purity of the system in the case of nonadditive entropies. In this way, we overcome the issue of the artificial increasing of the value of quantum correlation measures based on nonadditive entropies when an uncorrelated ancilla is appended to the system, without changing the computability of our entropic correlation measures with respect to the previous ones. Moreover, we recover as limiting cases the quantum correlation measures based on von Neumann and Rnyi entropies (i.e., additive entropies), for which the adjustment factor becomes trivial. In addition, we distinguish between total and semiquantum correlations and obtain some inequalities between them. Finally, we obtain analytical expressions of the entropic correlation measures for typical quantum bipartite systems.

Csiszr Quantum Distanc

Diego G. Bussandri, Tristán M. Osán, Pedro W. Lamberti
Instituto de Fśica Enrique Gaviola, FAMAF, UNC

Csiszár's divergences were introduced as measures of distinguishability between classical probability distributions. The general expression of a Csiszár divergence, for discrete probability distributions p and q is $D(p;q) = \sum_i p_i f(\frac{q_i}{p_i})$ with $f(x)$ a convex function such that $f(1) = 0$. The widely used Kullback-Leibler divergence is an example of them, with $f(x) = -\log(x)$. Another examples are the Jensen-Shannon divergence, the Hellinger distance, the triangular discrimination and the variational distance. In this work we proposed a way for extending the Csiszár divergence to the realm of quantum information theory. We studied the properties of the resulting distances and, from our scheme, we built a monopartametric family of metric between pure quantum states. We proposed a manner of extending these metrics for mixed quantum states and we related them with some previously introduced by D. Petz.

Superadiabatic Quantum Computation

Alan Costa dos Santos
IF - Universidade Federal Fluminense (UFF), Brazil

Recently, we proposed that superadiabatic evolutions can be used to mimic adiabatic quantum computation when we want implement quantum gates. In this poster we will present our model of superadiabatic quantum computing where we use the concept of superadiabatic controlled evolutions to implement n-controlled quantum gates. Remarkably, this task can be done using an additional time-independent counter-diabatic Hamiltonian. In addition, we analyze the total evolution time of superadiabatic dynamics by using quantum speed limit (QSL). To end, we will discuss about our recent developments on superadiabatic quantum computing to open quantum systems.

Scaling of the local quantum uncertainty at quantum phase transitions

Ivan Coulamy
Universidade Federal Fluminense (UFF), Brazil

We investigate the local quantum uncertainty (LQU) between a block of L qubits and one single qubit in a composite system of n qubits driven through a quantum phase transition (QPT). A first-order QPT is analytically considered through a Hamiltonian implementation of the quantum search. In the case of second-order QPTs, we consider the transverse-field Ising chain via a numerical analysis through density matrix renormalization group. For both cases, we compute the LQU for finite-sizes as a function of L and of the coupling parameter, analyzing its pronounced behavior at the QPT.

Irreversible adiabatic decoherence of dipole-interacting nuclear-spin pairs coupled with a phonon bath

Federico Daniel Dominguez
Instituto de Fśica Enrique Gaviola, FAMAF, UNC

We study the quantum adiabatic decoherence of a multispin array, coupled with an environment of harmonic phonons, in the framework of the theory of open quantum systems. We follow the basic formal guidelines of the well-known spin-boson model, since in this framework it is possible to derive the time dependence of the reduced density matrix in the adiabatic time scale, without resorting to coarse-graining procedures. However, instead of considering a set of uncoupled spins interacting individually with the boson field, the observed system in our model is a network of weakly interacting spin pairs; the bath corresponds to lattice phonons, and the system-environment interaction is generated by the variation of the dipole-dipole energy due to correlated shifts of the spin positions, produced by the phonons. By identifying the coupling of the dipole-dipole spin interaction with the low-frequency acoustic modes as the source of decoherence, we calculate the decoherence function of the reduced spin density matrix in closed way, and estimate the decoherence rate of a typical element of the reduced density matrix in one- and three-dimensional models of the spin array. Using realistic values for the various parameters of the model we conclude that the dipole-phonon mechanism can be particularly efficient to degrade multispin coherences, when the number of active spins involved in a given coherence is high. The model provides insight into the microscopic irreversible spin dynamics involved in the buildup of quasiequilibrium states and in the coherence leakage during refocusing experiments in nuclear magnetic resonance of crystalline solids.

Dissipation and decoherence effects on a moving particle in front of a dielectric plate

María Belén Farias
DF - IFIBA, FCEN, UBA, Buenos Aires, Argentina

In this work, we consider a particle moving in front of a dielectric plate and study two of the most relevant effects of the vacuum field fluctuations: the dissipation and the decoherence of the particles internal degrees of freedom. We consider the particle to follow a classical, macroscopically fixed trajectory. To study the dissipative effects, we calculate the in-out effective action by functionally integrating over the vacuum field and the microscopic degrees of freedom of both the plate and the particle. This in-out effective action develops an imaginary part and, hence, a nonvanishing probability for the decay (because of friction) of the initial vacuum state. We analyze how the dissipation is affected by the relative velocity between the particle and the plate and the properties of the microscopic degrees of freedom. In order to study the effects of decoherence over the internal degrees of freedom of the particle, we calculate the closed time path or Schwinger-Keldysh influence action, by functionally integrating over the vacuum field and the microscopic degrees of freedom of the plate.

We estimate the decoherence time as the time needed by two different quantum configurations (of the internal degree of freedom of the particle) to be possible to differentiate from one another. We analyze the way in which the presence of the mirror affects the decoherence and the possible ways to maximize or reduce its effects.

Decoherent time-dependent transport beyond the Landauer-Büttiker formulation: A quantum-drift alternative to quantum jumps

Lucas J. Fernández-Alcázar and Horacio M. Pastawski

Instituto de Física Enrique Gaviola and Facultad de Matemtica, Astronomía, Física y Computación, Universidad Nacional de Córdoba

We develop and implement a model for including decoherent processes underlying time-dependent transport. Inspired in a dynamical formulation of the Landauer-Büttiker equations, it boils down into a form of wave function that undergoes a smooth stochastic drift. Thus, decoherence arises from a random perturbation of the environment on the phase in a local basis, the quantum-drift (QD) model. This drift is nothing else but a local energy fluctuation. Unlike quantum-jumps (QJ) models, no jumps are present in the density as the evolution is unitary. Using numerical calculations, we show the equivalence among the QD and steady state transport through a resonant state $|0\rangle$ that undergoes decoherence. In order to test the dynamics, we consider a two level system (TLS) that oscillates among $|0\rangle$ and $|1\rangle$. We show that QD model recovers not only the exponential damping of the oscillations in the low perturbation regime, but also the non-trivial bifurcation of the damping rates at a critical point, i.e. the quantum dynamical phase transition. By evaluating the Loschmidt Echo (LE), we find that the pure states $|0\rangle$ and $|1\rangle$ are quite robust against the local decoherence. In contrast, the LE, and hence coherence, decays faster when the system is in a superposition state$(|0\rangle + |1\rangle)/\sqrt{2}$ which is consistent with the general trend recently observed in spin systems through NMR. Because its simple implementation, the method is well suited to asses decoherence both in transport problems and in many body dynamics.

QCT study of the F+HCl reaction in symmetric hyperspherical coordinates

Victor Manuel Freixas Lemus

Universidad Nacional de Quilmes (UNQ), Argentina

Reactive dynamics of the triatomic system F+HCl is investigated for total angular momentum equal zero and for different low-lying rovibrational states of the diatomic molecule. To this purpose, the Quasi-Classical Trajectories (QCT) method was implemented in a symmetric hyperspherical configuration space. Interatomic interactions are described by a London-Eyring-Polanyi-Sato potential energy surface, specially developed for the title reaction. Probabilities of reaction are reported for each possible product as a function of the collision energy and the initial orientation of the diatomic molecule. This information allows to control the reaction by manipulating the initial conditions for maximizing the production of a desired outcome.

Quantum logic operations with continuos variable in a single trapped ion

Bruna Gabrielly de Moraes Araujo

DF- UFPE (Federal University of Pernambuco)

We propose the realization of quantum computation over continuous variables using the ion trap as physical platform. The central idea of our work is to provide a toolbox of Gaussian logic gates from the coherent manipulation of the vibrational modes of a trapped ion. By irradiating monochromatic and bichromatic classical laser beams in a confined ion, we propose gaussian logic gates similar to the operations of linear and nonlinear optics. We connect these gates with operations already employed in the discrete case, such as Fourier, CNOT and CPHASE gates. The execution of each of these logical operations is selected by the frequency of the interacting laser and the Lamb-Dicke parameters. Bringing together all the proposed operations, Gaussian and non-Gaussian, we show the simulation of Hamiltonians with polynomial expansion in the phase space coordinates.

Quantum Chaos and Quantum Randomness: a unifying perspective

Lina Maria Gallo Espinosa

Universidad Nacional de Colombia

Quantum mechanics imposes fundamental limits on the amount of information extractable from microscopic scales leading to the end of chaotic behaviour after a finite time. However, this suppression of chaos can be partially lifted by allowing the environment to provide an "entropy donation". Analogy suggests that in a quantum measurement, the randomness of specific outcomes ("second collapse") comes from fluctuations in the degrees of freedom of the meter. To test this interpretation, we model quantum measurement in a closed system, where the meter comprises only a finite number of modes and the time evolution is unitary. Starting from an unpolarized Schrdinger-cat state, the polarization initially tends towards one of the two possible orientations and then oscillates between the extremes -1 and +1. We show that as the degrees of freedom of the meter N increases, spin reversals become less frequent, more abrupt and more irregular; this leads us to expect that with $N \to \infty$ the first polarized episode will be the definite outcome. Since the "random" outcome of the measurement is determined by the initial state of the meter, this can be the starting step into a path to change, and make unnecessary, the "fundamental randomness" idea, and possibly changing foundational interpretation of quantum randomness. Possible relevance of these results on the Quantum Randomness interpretation is discussed.

Survival Probability and Entropy of Resonant States

Natalia Agustina Giovenale, Omar Osenda

FaMAF - UNC

The aim of this work is to understand the relationship between the en- tropy associated to resonant states, quantity that does not depend on time, and the time dependent entropy obtained by evolving in time a given local- ized initial condition. To accomplish this, we will analyze a relatively simple model of two particles (fermions) in a confinement potential, and interact- ing through a repulsive potential. We obtain approximate solutions for the spectrum and eigenfunctions of the Hamiltonian, together with its entropy, together with the numerical integration of the time-dependent Schr odinger equation. All the quantities mentioned are obtained near the ionization threshold, that is, in the region where the confinement potential is not at- tractive enough to sustain a two-particle bound state.

Quantum Hysteresis in Coupled Light-Matter Systems

Fernando Javier Gómez Ruiz
Universidad de Los Andes, Bogot.

During the last decades, there have been significant advances in the experimental realization and control of many-body quantum systems. Many of these realizations can be regarded as particular cases of an interaction between matter and radiation (or some sort of bosonic excitation field). Also, from a theoretical point of view, in several cases these systems can be readily modeled as matter consisting of a single or several two-level systems (qubits) and radiation as a set of independent harmonic oscillators. In particular, the Dicke Model (DM), a set of N qubits coupled to a single field mode, describes a radiation-matter system which, despite its simplicity, exhibits a wide range of complex collective phenomena, many of them specifically associated with the existence of a quantum phase transition (QPT). We have explored some aspects of finite-sized DM under linear ramping processes across the QPT boundary [1,2]. By ramping the radiation-matter coupling strength in round trips, between weak and strong values, we quantify the hysteresis or irreversible quantum dynamics [3]. Analyzing the systems quantum fidelity, we find that the near-adiabatic regime exhibits the richest phenomena, with a strong asymmetry in the internal collective dynamics depending on which phase is chosen as the starting point. From our results, novel prescriptions can be advanced to areas like quantum simulations, quantum control, and the general characterization of phase transitions.

Gaussian ensembles from an information geometric approach

Sebastian Ignacio Gómez
IFLP, UNLP, La Plata, Argentina

We present the Gaussian Orthogonal Ensembles (GOE) of Random Matrix Theory as a particular case of the information geometrodynamical approach to chaos (IGAC) applied to statistical models on curved manifolds. Moreover, using IGAC we also propose a geometrodynamical version of the Ergodic Hierarchy which allows to study the GOEwithin the more chaotic level, i.e. the Bernoulli level. This proposal justifies the validity of application of the GOE in strongly chaotic quantum systems from an information geometric viewpoint.

Dynamic control of currents in locally driven potentials

Nicolás Medina Sanchez
Universidad Nacional de Colombia

We present an analysis of scattering through 2 types of non linear potentials (asymptotic symmetrical/asymmetrical) that are driven locally. Classically these potentials carry currents in phase space that could be regulated in different ways by the parameters of the driving while the same parameters change the phase space structure that in general is mixed, with chaos, cuasi-periodicity and periodicity. In the quantum approach, we shows how this topological transformations in the classic scenario change the way definite states propagate through the potentials. This could be understood as a solid-state surface that is interacting with a laser in a specific region.

Two distinguishable particles Interacting with a quantum bath is not only decoherence producing

Marco Alfredo Nizama Mendoza[1,2] and Manuel O. Cáceres[1]
[1] CAB, CNEA, Instituto Balseiro and CONICET
[2] Departamento de Física, Universidad Nacional del Comahue, Neuquén, Argentina

We have analyzed two distiguisble particles in an infinite dimension Hilbert space interacting with a quantum bath. The distinguishable particles are studied analytically using the quantum master equation. We show that for temperature T ¿ 0 the time-evolution of the reduced density matrix cannot be written as the direct product of two independent particles. We found a time-scale that characterizes the time when the bath-induced correlation is maximum before being wipe out by dissipation (purity, spatial, measuresof coherence, and quantum correlations). We introduce a Phase space distribution function (Wigner function) associated to the Wannier lattice where the dissipative quantum walks move. Thus we discuss the peculiarities of the scenario of enlarging the lattice to the semi-integers in order to fulfill all the fundamental properties of the Wigner function. We have supported the quantum character of the correlations by analyzing the negativity of the Wigner function.

Spontaneous parametric down conversion and quantum walk topology

Graciana Puentes

DF - IFIBA, FCEN, UBA, Buenos Aires, Argentina

We propose a novel scheme for the all-optical quantum simulation of topological phases by means of implementation of a discrete-time quantum walk architecture. The main novel ingredient is the inclusion of the nonlinear process of spontaneous parametric downconversion (SPDC) along the quantum network. By means of a simple theoretical model, the interplay between quantum walk lattice topology and spatial correlations of biphotons produced by SPDC is numerically explored. We describe different opticaldetection methods suitable for the implementation of our proposed experimental scheme [1]. [1] Graciana Puentes, J. Opt. Soc. Am. B 33, 461-467 (2016).

Quantum speed limit and non-Markovianity

Nicolás Mirkin

Departamento de Física, FCEyN, Universidad de Buenos Aires

Quantum physics dictates a fundamental bound for the minimum evolution time between two states of a given system. Known as the quantum speed limit (QSL), it is a useful tool in the context of quantum control, quantum metrology, quantum chemical dynamics and quantum computation. Nevertheless, while QSL expressions for unitary dynamics have been well studied, the non-unitary regime has remained fairly unexplored despite being usually the relevant problem in the context of decoherence. In this work, we present several bounds for the QSL that have been derived for non-unitary dynamics recently in the literature and we apply them to the paradigmatic damped Jaynes-Cummings model. We demonstrate that all bounds are extremely sensible to the initial-state and to parameters related to the characteristics of the environment. We also study the connection of the QSL with the memory effects that controls the flow of information from the environment back to the system, also known as non-Markovianity. We show that non-Markovianity is not correlated with QSL as was previously stated in the literature.

Fluctuation relations and equilibration in the Dicke Model

Sara Ramirez Montoya
Universidad Nacional de Colombia

The Dicke model is one of the most paradigmatic systems to study light matter interaction, rising interest because it presents a quantum phase transition as well as classical and quantum chaos. Only recently, however, effective equilibration for its unitary dynamics under conditions of classical chaos was demonstrated via a Fokker-Planck equation obeyed by the Husimi function of the system. Here we derive a set of equivalent Langevin equations for the system dynamics with noise that is quantum in origin, providing an alternative approach to the study of equilibration in this system under the light of fluctuation relations.

Properties and control of an hybrid qubit based on a double quantum dot.

Alba Ramos
Instituto de Fśica Enrique Gaviola, FAMAF, UNC

Electronic spins confined in semiconductor quantum dots is considered one of the most promising alternatives as qubits. It has been thoroughly investigated what the typical problems associated with its implementation are. This problems include quantum operation times which ar e very short or very large, decoherence, difficulty in preparing a specific initial state, among others. A remarkable difficulty relies in the low coupling between electronic spin and external magnetic fields applied to the quantum dot. In consequence, the operation times to generate, for instance, a logical gate become excessively large allowing the decoherence mechanisms to deteriorate the quantum state. In order to solve this kind of problem, it has been proposed to use hybrid quantum dots, which have short operation times. In hybrid qubits, information is stored in the el ectronic spin whereas the operations on the qubit are performed through external electric fields. In this work we study the quantum dynamics of a hybrid qubit based on a double quantum dot in presence of constant external magnetic fields and periodic time dependent electric fields. We model the qubit as a quartic potential well and we use the effective mass approximation. In this work, we not only consider the usual spinorial depend ence with the magnetic field but also we include the orbital dependence. Through a oscillatory electric field we control the Rabi oscillations of the qubit. We analyze the robustness of the system when the initial state is different from an eigenstate of the system and when the forcing frequency is slightly different to the resonance frequency of the system. Since the original proposal of DiVincenzo and Loss (Phys. Rev. A57, 120 (1998)) to use the spin of an electron trapped in a quantum dot as qubit, a lot of work has been done to circumvent the huge difficulties associated to the implementation. One of the major problems associated to spin qubits is the long timerequired to implement quantum logical gates or other control operations. This is so because the low strength of the coupling between the spin andthe external magnetic fields applied to the quantum dot. This low strength causes that the operation times are too long allowing that different coherence mechanisms change the state of interest. To solve such problem, i.e. to have shorter time operations, hybrid qubits have been proposed, so the information is effectively stored in the spin degrees of freedom, but the operations are implemented through the application of e lectric fields. In this poster, we analyze the performance of the hybrid qubit proposed by Tokura et al. (Phys. Rev. Lett. 96, 047202 (2006)), which is based in a double quantum dot with external magnetic fields ap plied to it and driven by a time dependent electric field. To model the q uantum dot we use the Effective Mass Approximation, with a quartic we ll poten- tial. We considered the complete magnetic field dependence, in both the orbital and spinorial parts.

Finite-time response function of two accelerated detectors: entanglement at finite temperature and stability

Cristian David Rodriguez Camargo
CBPF, Brazil

The Unruh effect consists in one uniformly accelerated detector which will perceive the vacuum state as a thermal bath with a temperature proportional to its proper acceleration. That thermalization process is taken as an analogous to the Hawking effect in a black hole. Such works constitute some of the most relevant results in the area of quantum field theory in curved spacetime and in the study of a possible thermal nature of vacuum. In this work we investigate the entanglement stability of two accelerated detectors weakly coupled with a massless scalar field in Minkowski vacuum. We study this stability via finite-time response function. In our framework, the Unruh effect is the source of the excitation mechanism of the system. Although that thermalization process will induce a greater decoherence degree, we are able to identify the mutual influences of detectors via fields as a coherence agent in each response function terms. Since the response function of an accelerated detector switched on for a long time is the same that the response function of an inertial detector in equilibrium with a thermal bath, the thermal spectrum measured by the accelerated detector is found for long times, and we present a discussion about the possibility of maintaining entanglement at finite temperature. We study a finite on-time switching in order to obtain a more realistic situation and contribute to a deeper understanding for non-equilibrium conditions in front of the equilibrium thermodynamics description. We obtain the mean life times of those entangled states for different accelerations and on-times switching. Possible relevance of these results for non-equilibrium phenomena, stochastic properties of entanglement and entanglement at finite temperature is discussed.

Stern-Gerlach splitters based on quasi-spin

Antonio Sebastian Rosado Gonzalez
Instituto de Fsica, Universidad Nacional Autnoma de Mxico

We design a Stern-Gerlach apparatus that separates quasi-spin components on the lattice, without the use of external fields. The effect is engineered using intrinsic parameters, such as hopping amplitudes and on-site potentials. A theoretical description of the apparatus relying on a generalized Foldy-Wouthuysen transformation beyond Dirac points is given. Our results are verified numerically by means of wavepacket evolution, including an analysis of Zitterbewegung on the lattice.

Optimal control theory in ultracold atom systems

Diego Tielas[1] and U.J. Lode [2]
[1] Department of Physics, University of La Plata, Argentina
[2] Department of Physics, University of Basel, Switzerland

The ability to lead a quantum system from a given state to one with desired properties as can be: Entanglement, defined angular momentum, etc .; and how to do it, for example minimizing time to avoid decoherence, is of vital importance in the development of technologies for quantum information processing. In this work we show the implementation of the chopped random basis optimal control technic (CRAB) [1] in the context of multi configuracional time dependent Hartree for bosons-fermions theory (MCTDH-X) [2]. We will describe applications examples, and show work current in progress in ultracold atoms systems.
References: [1] Phys. Rev. Lett. 106, 190501 (2011); [2] Phys. Rev. A 93, (2016) http://ultracold.org; [3] Nature Physics 7, 608611 (2013), Phys. Rev. A 92, 062110 (2015)

Proliferation of effective interactions: Decoherence-induced

Pablo R. Zangara, Denise Bendersky and Horacio M. Pastawski
Instituto de Fsica Enrique Gaviola (IFEG), FaMAF, UNC

We address the question of how weak perturbations, which are quite ineffective in small many-body systems, can lead to decoherence and hence to irreversibility when they proliferate as the system size increases. This question is at the heart of solid-state NMR. There, an initially local polarization spreads all over due to spin-spin interactions that conserve the total spin projection, leading to an equilibration of the polarization. In principle, this quantum dynamics can be reversed by changing the sign of the Hamiltonian. However, the reversal is usually perturbed by nonreversible interactions that act as a decoherence source. The fraction of the local excitation recovered defines the Loschmidt echo (LE), here evaluated in a series of closed N spin systems with all-to-all interactions. The most remarkable regime of the LE decay occurs when the perturbation induces proliferated effective interactions. We show

that if this perturbation exceeds some lower bound, the decay is ruled by an effective Fermi golden rule (FGR). Such a lower bound shrinks as N increases, becoming the leading mechanism for LE decay in the thermodynamic limit. Once the polarization stayed equilibrated longer than the FGR time, it remains equilibrated in spite of the reversal procedure.

Author Index