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“Open Problems in Quantum Mechanics Workshop”

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Optical interferometry in the presence of large phase diffusion

Stefano Olivares
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The measurement problem for the optical phase has been traditionally attacked for noiseless schemes or in the presence of amplitude or detection noise. In this presentation we address, both theoretically and experimentally, the estimation of a phase shift in the presence of phase diffusion and, in particular, of large phase diffusion. We present a nearly optimal interferometric scheme based on homodyne detection and coherent signals for the detection of a phase shift in the presence of large phase diffusion. In our scheme the ultimate bound to interferometric sensitivity is achieved already for a small number (hundreds) of measurements without using nonclassical light.

References

M. G. Genoni, et al., Phys. Rev. Lett. 106, 153603 (2011).
M. G. Genoni, et al., Phys. Rev. A 85, 043817 (2012).

Solving the quantum nonlocality riddle by conformal geometrodynamics

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Since the 1935 proposal by Einstein Podolsky and Rosen the riddle of quantum nonlocality, today demonstrated by innumerable experiments, has been a cause of concern and confusion within the debate over the foundations of quantum mechanics. The talk tackles the problem by a non relativistic approach based on the Weyl's conformal differential geometry applied to the Hamilton-Jacobi solution of the dynamical problem of two entangled spin 1/2 particles. It is found that the nonlocality rests on the entanglement of the spin internal variables, playing the role of "hidden variables". At the end, the violation of the Bell inequalities is demonstrated without recourse to the common nonlocality paradigm. A discussion over the role of the "internal space" of any entangled dynamical system involves deep conceptual issues, such the indeterminism of quantum mechanics and explores the in principle limitations to any exact dynamical theory when truly "hidden variables" are present. Because of the underlying geometrical foundations linking necessarily gravitation and quantum mechanics, the theory presented in this work may be considered to belong to the unifying "quantum gravity" scenario.

A stochastic jump description of non-Markovian quantum dynamics and quantification of memory effects

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We present non-Markovian quantum jump description of open system dynamics and discuss how this describes quantum memory effects. Furthermore, we show how to quantify non-Markovianity of open system with a trace distance based measure and information flow concluding with some experimental applications.

Semi-classical approximations based on de Broglie-Bohm theory

Ward Struyve
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Semi-classical approximations to quantum theory describe part of the system classically and part quantum mechanically. In the usual approach, one considers the classical system to move under a mean force, obtained by averaging over the quantum system. We consider an alternative approach based on de Broglie-Bohm theory. This approach has shown to yield better results than the mean force approach for certain non-relativistic systems by e.g. Prezhdo and Brooksby, and Gindensperger et al. We present such semi-classical approximations for quantum electrodynamics and quantum gravity.

Signatures of non-Markovianity in open-system dynamics

Andrea Smirne
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In recent research, a great effort has been put into the study and understanding of non-Markovian features within the dynamics of open quantum systems. At the same time, quantum non-Markovianity has been defined and quantified in terms of quantum dynamical maps, using either a divisibility property or the behaviour of the trace distance between pairs of reduced states evolved from different initial states. We investigate these approaches by means of several examples, especially focusing on their relation with the very definition of non-Markov process used in classical probability theory. Indeed, the notion of non Markovian behaviour in the dynamics of the state of a physical system and the notion of non-Markov process are quite different and it will appear how the former represents sufficient, but not necessary condition with respect to the latter. In particular, we explicitly show that the divisibility property in the classical case is not, in general, equivalent to the Chapman-Kolmogorov equation, proper to Markov stochastic processes.

The collapse of the wavefunction and the origin of cosmic seeds

Gabriel Leon
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The quantum fluctuations of the inflationary field are currently considered as the seeds for cosmic structure and their traces are observed in the cosmic radiation background. However, this paradigm faces a conceptual difficulty in that the proposal does not contain any mechanism capable of breaking the homogeneity and isotropy characterizing the primordial (quantum) state of the Universe. In previous works, it was proposed that a self-induced spontaneous collapse of the wavefunction of the inflation field, would offer a mechanism for the generation of the primordial inhomogeneities. In this talk we will present a novel type of signature in the primordial spectrum, characterizing some unusual statistical aspects that would possibly be associated with the collapse process.

Testing gravity with atom interferometry

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I will discuss experiments we are conducting using cold atom interferometry for precision tests of gravitational physics. In particular, I will report on the ongoing experiment to measure the gravitational constant *G* with a Rb Raman interferometer [1], and the one based on Bloch oscillations of Sr atoms confined in an optical lattice for precision gravity measurements [2]. I will also update on the development of compact interferometers for applications on Earth [3] and in space [4]. Finally, I will discuss ideas for future ambitious experiments based on atom interferometry such as detecting gravitational waves [5] and testing quantum gravity models [6].

References

[1] G. Lamporesi, A. Bertoldi, L. Cacciapuoti, M. Prevedelli, G.M. Tino, Phys. Rev. Lett. **100**, 050801 (2008)

[2] N. Poli, F.-Y. Wang, M. G. Tarallo, A. Alberti, M. Prevedelli, G. M. Tino, Phys. Rev. Lett. **106**, 038501 (2011)

[3] M. de Angelis, A. Bertoldi, L. Cacciapuoti, A. Giorgini, G. Lamporesi, M. Prevedelli, G. Saccorotti, F. Sorrentino, G. M. Tino, Meas. Sci. and Technol. **20**, 022001 (2009)

[4] F. Sorrentino et al., Microgravity Sci. Technol. **22**, 551 (2010)

[5] G.M. Tino, F. Vetrano, Class. Quantum Grav. **24**, 2167 (2007)

[6] G. Amelino-Camelia, C. Laemmerzahl, F. Mercati, G.M. Tino, Phys. Rev. Lett., **103**, 171302 (2009)

Transition-Edge Sensors in Quantum Land

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During the last years, Transition-Edge Sensors (TESs) have found an ever more growing number of applications as single photon number resolving detectors in fields as quantum optics [1][2], telecommunication [3][4][5], quantum metrology [6][7][8] and quantum technologies [9].
The most important TES characteristics for the quantum land's inhabitant are the negligible numbers of dark-counts, the discrimination of the number of impinging photons on a detector, the high energy resolution and furthermore the possibility to fabricate devices with a very high quantum efficiency.
In particular, is possible to fabricate devices with quantum efficiency (QE) over 90%, very attractive for performing detection loophole free tests of contextuality, steering and eventually, Bell's inequalities.
In this work we present the first results obtained with INRIM TESs in the quantum land during the last two years. We proposed an innovative absolute calibration technique for photon number resolving detectors, using a pulsed heralded photon source based on parametric down conversion. The technique, being absolute, does not require reference standards and is independent upon the performances of the heralding detector [7][9].
The second order correlation function at time delay zero of non-classical light emitted by nitrogen vacancy (NV) centers in nano-diamonds has been studied and measured with our TES and compared with standard methods [8].
We implemented also the first experimental reconstruction of the positive operator-valued measure (POVM) describing the operation of a TES and, in turn, the first demonstration of the binomial assumption [11]. Well characterized photon number resolving detectors are a requirement for many applications ranging from quantum information and quantum metrology to the foundations of quantum mechanics.
Finally, the last results concerning the optimization of important parameters as energy resolution, time response and quantum efficiency of a very fast TES measured at AIST in Japan are present.

References

[1] “Generation of optical coherent-state superpositions by number-resolved photon subtraction from the squeezed vacuum”, Gerrits Thomas, et al., Physical Review A, 82 031802 (2010)

[2] “Non-Gaussian operation based on photon subtraction using a photon-number-resolving detector at a telecommunications wavelength”, Namekata Naoto et al., Nature Photonics, 4 655 (2010).

[3] “Conclusive quantum steering with superconducting transition-edge sensors”, Smith Devin H., et al., Nature Communications, 3 625 (2012).

[4] “On-chip, photon-number-resolving, telecommunication-band detectors for scalable photonic information processing”, Gerrits Thomas et al., Physical Review A, 84 060301 (2011).

[5] “Sub-shot-noise-limit discrimination of on-off keyed coherent signals via a quantum receiver with a superconducting transition edge sensor”, Tsujino Kenji et al., Optics Express, 18 8107 (2010).

[6] “Generation of degenerate, factorizable, pulsed squeezed light at telecom wavelengths”, Gerrits Thomas et al., Optics Express, 19 24434 (2011).

[7] “Self consistent, absolute calibration technique for photon number resolving detectors”, Avella A. et al., Optics Express, 19 23249 (2011)

[8] “Photon number statistics of NV centre emission”, Schmunk W. Et al., Metrologia, 49 S156-S160 (2012).

[9] “Ti/Au TES as superconducting detector for quantum technologies”, Lolli L., et al., International Journal of Quantum Information, 9 405 (2011).

[10] “Ti/Au TES to Discriminate Single Photons”, L. Lolli et al., J. Temp. Phys. 10.1007/s10909-
012-0473-2.

[11] “Quantum characterization of superconducting photon counters”, Brida G. et al, NJP (in press)

Stochastic Schroedinger equations and non-Markovian open quantum systems with dissipation

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Stochastic Schroedinger equations (SSEs) are a powerful mathematical formalism which allow for insight into physical systems, like e.g. collapse models. These equations can also be used to study open quantum systems, since they allow for a stochastic unravelling, where the environment is described by a noise. The advantage of this approach is that it allows for analytic treatment of non-Markovian open quantum systems, which are described by a noise with a general time correlation function. We show that this method is also suitable to study the analytical behaviour of non-Markovian systems including dissipative effects.

Time Measurement as Test of Quantum Mechanics

Nicola Vona
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Although time measurements are very often performed in experiments, their theoretical description is largely unclear. Several proposals have been put forward, two of which will be presented in this talk: the one resulting from the application of the orthodox quantum formalism, and that corresponding to the use of Bohmian Mechanics. A situation in which these two approaches lead to different predictions will be analyzed, and its relevance as experimental test of Quantum Mechanics discussed

Numerical Solutions of Quantum Problems via Bohmian Trajectories

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The aim of the talk is to give an overview of the present status of numerical methods to solve quantum problems via Bohmian trajectories. Particularly I will focus on three relevant approaches for the numerical solution of the Time Dependent Schroedinger Equation (TDSE). The first, called Quantum Trajectory Methods (QTM), developed by Wyatt [1], provides a precise description of quantum dynamics in problems of kinetic chemistry. The second, developed by Oriols [2], gives a numerical method for dealing with quantum many-particle problems. The third treats a generic initial wave function by means of a gaussian approximation. The general intent of the talk is to stress how Bohmian trajectories can solve both numerical difficulties arising in standard techniques and conceptual problems such as the measurement issue.

References

[1] C. L. Lopreore and R. E. Wyatt: *Quantum Wavepacket Dynamics with Trajectories*, Phys. Rev. Lett. **82**, 5190-5193 (1999).
[2] X. Oriols: *Quantum-trajectory approach to time-dependent transport in mesoscopic systems with electron-electron interactions*, Phys. Rev. Lett. **98**, 066803 (2007).

Quantum-classical transition in optical twin beams and experimental applications to quantum metrology

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The discrimination between quantum and classical states, besides its very important and deep conceptual relevance, has also recently received much attention due to the development of quantum technologies. On one side, it represents a fundamental point for the studies concerning the transition between quantum and classical world, one of the most intriguing research sectors in the foundations of physics. On the other side it is an important tool when comparing results that can be achieved with quantum and classical protocols.

Considering the experimental interest in the frame of quantum optics, in a recent paper [1], we have considered different ”quantumness” quantifiers applied to the study of quantum-classical transition in seeded parametric down-conversion (PDC): the noise reduction factor (NRF), the Lee parameter, and the logarithmic negativity. It emerges a general understanding of the hierarchy of these three quantifiers in this optical systems. Moreover, we have focused our analysis towards an operational approach linked to measurement schemes, basically showing that these quantifiers can be estimated just measuring the photon numbers in the two beams, and their correlation.

On the other side, in the last years in our laboratories, we realized several quantum enhanced measurement protocols exploiting twin beams, where the improvement over the corresponding classical protocols is directly related to the NRF, that quantify the sub-shot noise properties of the source. In particular, we will describe the sub-shot-noise quantum imaging (SSNQI) scheme [2], and the quantum illumination (QI) [3]. The first one allows to obtain a almost noise-free image of a weak absorbing object placed in one branch of PDC just subtracting the correlated noise pattern measured un the other branch, while all the classical schemes, based for example on a split thermal beam, are limited by the unavoidable shot noise.

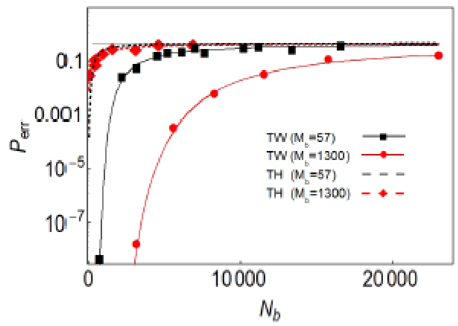

Fig. 1: Error probability of discriminating if the target is present or not in function of the number photons N_b of the background. TW and TH stand for TWin beams and THermal split beams respectively, while Mb is the number of independent modes of the multi-thermal background

The QI protocol is devoted to the detection of a weak reflecting target immersed in a extremely noisy background. In this case we elaborated a measurement scheme allowing performances which are orders of magnitude higher than the classical counterpart (see Fig.1). Furthermore, the most intriguing observation is that the quantum advantage does not disappear even if the signature of ”quantumness” is completely destroyed by the noise introduced at the measurement stage.

References

1. G. Brida, et al., *Found. Phys.* 41(3), 305-316 (2011).

2. G. Brida, M. Genovese and I. Ruo Berchera, *Nat. Phot.* 4, 227 - 230 (2010); G.Brida, et al., *Phys. Rev.*
A 83, 063807 (2011)

3. S. Tan, et al., *Phys. Rev. Lett.* 101, 253601 (2008).

The informational approach to quantum theory: probabilistic theories, quantum principles, and hidden variable models.

Paolo Perinotti
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We will briefly review the operational-probabilistic framework in which quantum theory can be formulated as a theory of information processing. The six principles constituting the axioms that lead to the Hilbert space formalism will be introduced. Relaxing any of these principles opens a wider and largely unexplored scenario, in which alternate theories are allowed. The possibility of interpreting operational probabilistic theories through Hidden Variable models will be discussed, along with the crucial notion of completeness. Finally, we will show a generalization of the EPR paradox that relies on a very restricted set of properties of Quantum Theory, without recurring to itsspecific algebraic structure.

Bohmian solution to the measurement of many-body systems: Sequential current in mesoscopic electron devices

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Electronic industry is pushing devices into the few-nanometer (mesoscopic) limit, where mainly pure quantum effects determine the current owing through them. However, the accurate prediction of their multi-time current correlations is a very challenging problem from, both, the computational and the theoretical point of view [1]. First, computing the time-dependent behaviour of electron devices (at Terahertz frequencies) implies dealing with conduction plus displacement currents. The explicit consideration of the displacement current requires, in turn, the time-dependent solution of the (Coulomb) many-particle Schroedinger equation, i.e. the many-body problem. Second, understanding the multi-time current correlations (such as AC, transients, noise, etc.) in mesoscopic systems requires the ability to reproduce sequential measurements by describing the unitary (between measurements) and non-unitary (during measurements) evolutions of such mesoscopic systems, i.e the wave-function collapse problem.
In this workshop, we will present a solution to these problems through the use of conditional wave-functions, which are natural entities within Bohmian mechanics [2]. In particular, many-body Bohmian trajectories can be computed from a coupled system of single-particle conditional wave-functions. Such conditional wave-functions are solutions of a time-dependent pseudo-Schrödinger equations with a complex potential energy [3]. The previous many-particle Bohmian trajectories can be used to compute the sequential current measurement with a POVM modelling of the ammeter. In addition, under the assumption of a non-overlapping evolution of the different channels of the conditional wave-functions, a very simple procedure for the computation of the sequential current measurement of mesoscopic systems can be obtained through the auxiliary use of Bohmian trajectories. The Bohmian solution mentioned above, apart from its application to quantum electron transport [4,5,6] (see also the BITLLES simulator [7] available for public use), can be straightforwardly adapted to many other fields where one has to face the many-body and
wave-function collapse problems.

References

[1] Ya. M. Blanter, and M. Buttiker, Physics Reports, 336, 1 (2000)
[2] D. Dürr, S. Goldstein, N. Zanghí, J.Stat. Phys., 116, 959 (2004)
[3] X. Oriols, Phys. Rev. Let. 98(6), 066803, (2007).
[4] G. Albareda, H. Lopez, X. Cartoixà, J. Sũnė, X. Oriols, Phys. Rev. B, 82, 085301, (2010).
[5] G. Albareda, J. Sũnė, and X. Oriols, Phys. Rev. B. 79, 075315, (2009).
[6] F.L.Traversa et al., IEEE Transaction on Electron Devices, 58, 2104 (2011).
[7] http://europe.uab.es/bitlles

Particle oscillations in collapse models

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Collapse models are phenomenological models developed to solve the measurement problem in Quantum Mechanics. In these models one assumes that the evolution of the wave function is driven by an equation obtained introducing new non-linear and stochastic terms in the Schrödinger equation.
Accordingly, collapse models make different predictions than Quantum Mechanics, so they can be tested.
A phenomenon that could be used, in principle, to test the collapse models is particle oscillations. This oscillation is observed when the flavour eigenstates of a particle, that are the ones usually founded when a measurement is performed, have not definite mass. In such a case it is supposed that the flavour eigenstates are superposition of the mass eigenstates. Since each of the mass eigenstates has a different time evolution, there is a non zero probability that an initial flavour eigenstate ends up in a different flavour eigenstate after some time t. This phenomenon has been studied in Quantum Mechanics, and it has been shown that these probability oscillate. We analyzed the effects of collapse models in particle oscillations, focusing our attention in particular on neutrinos and kaons. We have shown that the effect of the collapse is to damp this
oscillation behaviour with an exponential factor.

Testing quantum mechanics and discrete symmetries with entangled neutral K mesons

Antonio di Domenico
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The neutral kaon doublet is one of the most intriguing systems in nature. Entangled pairs of neutral K mesons produced in T decays offers a unique possibility to perform very precise tests of fundamental discrete symmetries in nature, as well as of basic principles of quantum mechanics. The most recent results will be reviewed and perspectives in the field will be discussed.

Non-commutative fields in semiclassical gravity: anomalous diffusion and deformed Fock space

Michele Arzano
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Relativistic particles with momentum space described by a group manifold provide a very interesting link between gravity, quantum group symmetries and non-commutative field theories. I will discuss how group valued momenta emerge in the context of three dimensional Einstein gravity and describe the related non-commutative field theory. As an application I will introduce a non-commutative heat-kernel, calculate the associated spectral dimension and comment on its non-trivial behaviour. In four space-time dimensions the only known example of momenta living on a group manifold is encountered in the context of the k-Poincaré algebra which bears many structural analogies with the algebra of deformed symmetries encountered in the three dimensional case. I will discuss the construction of a one-particle Hilbert space from the classical k-deformed phase space and show how the group manifold structure of momentum space leads to an ambiguity in the quantization procedure. At the multiparticle level I will show how the quantum group symmetry of the Hilbert space induces additional structure which reflects in a non-trivial, momentum-dependent statistics. The richer structure of the deformed Fock space allows for the possibility of entanglement between the field modes and "planckian" degrees of freedom.

Quantum non-locality without reference frame

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Quantum communication employs the counter-intuitive features of quantum physics to perform tasks that are impossible in the classical world. It is crucial for testing the foundations of quantum theory and promises to revolutionize our information and communication technologies. However, for two or more parties to execute even the simplest quantum transmission, they must establish, and maintain, a shared reference frame. This introduces a considerable overhead in communication resources, particularly if the parties are in motion or rotating relative to each other. We experimentally demonstrate how to circumvent this problem with the efficient transmission of quantum information encoded in rotationally invariant states of single photons. By developing a complete toolbox for the efficient encoding and decoding of quantum information in such photonic qubits, we demonstrate the feasibility of alignment-free quantum key-distribution, and perform a proof-of-principle alignment-free entanglement distribution and violation of a Bell inequality.
Our scheme should find applications in fundamental tests of quantum mechanics and satellite-based quantum communication.

Quantum superposition of complex organic molecules

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Quantum interference experiments allow us to unambiguously demonstrate the wave nature of matter. In the past, matter wave interference experiments have been performed with a variety of objects, ranging from neutrons, atoms, and even complex organic molecules.
I will present recent successful quantum interference of large organic molecules [1], as well as new results with molecules beyond $m=10^4$ amu, the current mass record in any type of quantum superposition experiment.
Additionally I will discuss the influence of the internal molecular properties, such as permanent and vibrationally induced electric moments [2] [3] [4] on quantum coherence and the use of de Broglie interferometry as a tool to precisely measure these quantities.

References

[1] S. Gerlich, S. Eibenberger, M. Tomandl, S. Nimmrichter, K. Hornberger, P. J. Fagan, J. Tüxen, M. Mayor und M. Arndt, „Quantum interference of large organic molecules“ *Nature Communications* 2, p. 263, 2011.

[2] S. Eibenberger, S. Gerlich, M. Arndt, J. Tüxen und M. Mayor, „Electric moments in molecule interferometry“ *New Journal of Physics* 13, Nr. 4, p. 043033, 2011.

[3] M. Gring, S. Gerlich, S. Eibenberger, S. Nimmrichter, T. Berrada, M. Arndt, H. Ulbricht, K. Hornberger, M. Müri, M. Mayor, M. Böckmann und N. Doltsinis, „Influence of conformational molecular dynamics on matter wave interferometry“ *Phys. Rev. A* 81, p. 031604, 2010.

[4] J. Tüxen, S. Gerlich, S. Eibenberger, M. Arndt und M. Mayor, „Quantum interference distinguishes between constitutional isomers“ *Chem. Commun.* 46, pp. 4145-4147, 2010.

A new Experimental upper limit on the λ parameter

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The Spontaneous Emission of radiation by free electrons phenomenon arises from the direct interaction of a free electron and a fluctuating scalar field, postulated in the framework of Spontaneous Collapse theories as a trigger to obtain the system wave function collapse and solve the *dualism problem*.
The important role played by this new phenomenon in checking such class of theories is easily understandable considering that its cross-section is a function of λ, a fundamental parameter in the Collapse Master Equations. Nowadays the strongest upper bound on λ is set by the experimental search of spontaneous X-ray emitted by the electrons in a low-energy Ge-based experiment, presented in the pioneering work of Q. Fu. In this work we analyze this result and present a new upper limit on λ parameter as a result of the new analysis done on data published by the IGEX collaboration.

A quantum cellular automaton extension of quantum field theory

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Quantum cellular automata extend Quantum Field Theory (QFT) to include localized states and observables. They can provide a simple unified framework to describe the Planck scale, the ultra-relativistic regime, along with the usual QFT. The latter is recovered in the "field-limit" of the automaton, for infinitely many time-steps and space-periods, the period of the automaton representing the Planck distance. Lorentz covariance along with all symmetries and dispersion relations are violated, and are recovered only in the relativistic field-limit. The quantum-automaton framework is also relevant for QFT foundations, since it can be derived from principles of pure information-theoretical nature, achieving Wheeler's assertion that "Physics is Information".

In this talk I will review the phenomenology occurring in the case of the quantum automaton corresponding to the Dirac field in 1 dimension, in all regimes. The Dirac equation is just the equation describing the pure flow of quantum information. The field-limit is achieved through an analytical approximation, describing very closely the automaton for smooth delocalized states, and leading to a diffusion equation with a drift. Computer simulations will be shown in real-time during the talk, for single-particle states. A fundamental kind of violation of dispersion relations occurring for all such automaton theories is a mass-dependent refraction index of vacuum, predicting that the Planck mass is the maximum particle mass. The new informational principles open totally unexpected routes and re-definitions of mechanical notions (as inertial mass, Planck constant, Hamiltonian, Dirac equation as free flow of information). The automaton can be also considered an "ab-initio quantum" theory, whereas the classical mechanics is recovered from the automaton in terms of the amplitude crest, whereas the Lagrangian is reversely obtained from the unitary of the automaton. The field is eliminated and substituted by localized qubits. For dimension larger than 1 the anti-commutativity of the field is achieved by localized qubits, thus solving the Feynman problem of simulating anti-?commuting fields by a quantum automaton. Here an unexpected role is played by associated Majorana fields (also achieved by qubits): the latter, being prepared in a special vacuum, are simply witnessing the evolution, accounting just for the anti-commutation of Dirac fields.

Environmental distinction of pointer states

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University of Duisburg-Essen

Can one understand the emergence of classical physics in a quantum mechanical framework? An important step to answer this question is to explain the origin of super-selection rules observed at macroscopic scales. Two specific cases will be discussed, based on microscopically realistic master equations. In the first part, I will show how the distinction and stability of chiral molecular configuration states can be explained by decoherence. In the second part, the emergence and dynamics of motional pointer states will be explored, by associating them with the solitonic solutions of a nonlinear equation related to a particular stochastic unraveling of the appropriate master equation.

References

[1] J. Trost and K. Hornberger, Hund's paradox and the collisional stabilization of chiral molecules, Phys. Rev. Lett 103, 023202 (2009);
[2]M. Busse and K. Hornberger, Emergence of pointer states in a non-perturbative environment, J. Phys. A: Math. Theor. 42, 362001 (2009);
[3]M. Busse and K. Hornberger, Pointer basis induced by collisional decoherence, J. Phys. A: Math. Theor. 43, 015303 (2010).

The Quantum illusionist: a game with correlations between gaussian states

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Optical correlations at the quantum level represent a resource for the development of technologies overcoming the limits of the classical physics, with very promising opportunities for future widespread applications [1, 2]. These results, besides paving the way to new technologies, also permit deeper insights in quantum world.
Here we will show, both theoretically and experimentally an innovative scheme that exploit correlations between Gaussian beams of light: the optical illusionist game. In the game, an "illusionist" ask to the public to measure correlations between two uncorrelated light beams, excited in the same Gaussian state [3], mixed in a beam splitter (BS). Both in the presence and in the absence of the BS, no correlations arise between them. However, the illusionist can identify the presence of the BS, by means of a correlation measurement, when the public is asked to insert the BS behind the illusionist's back. Here we unveil the trick and the physics that explain these counterintuitive correlations of quantized light.

References

[1] Bouwmeester, D., et al. The Physics of Quantum Information: Quantum Cryptography,Quantum Teleportation,Quantum Computation (2000).
[2] Genovese,M. Research on hidden variable theories: A review of recent progresses. Phys.Rep.413,319-396 (2005).
[3] Ferraro, A.et al. Gaussian States in Quantum Information (2005)

Horizon 2020 and last opportunities of FP7

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The increasing difficulty of the agencies (Universities and Research Institutes) in financing fundamental research makes more and more compelling to look around for external sources, in primis those made available by the European Union.
These opportunities are often unknown, in many cases considered too "aliens", for a supposed difficulty of approach, in other (few) cases object of participation, also successful. Next year the long and successful series of EU Framework Programs (FP) will arrive to the end with FP7.
A completely new scheme has been created, which will bring together all existing EU funding schemes for research and innovation: Horizon 2020.
The scope of this talk is to inform in due time the scientific community about Horizon 2020,which will enter into force in 2014 until 2020.
The information may hopefully stimulate the interest towards some of the many offered opportunities and, therefore, help overcoming the lack of knowledge, the reluctance to participate, the sense of frustration for the unavoidable failures, so frequent features of the attitude towards European programs.
Last but not least, the last opportunities of FP7 will be recalled.