JUNIOR TRIESTE QUANTUM DAYS

A gathering of PhD candidates and post-docs of the Department of Physics of the University of Trieste and of the Mathematics Area of SISSA Trieste working on quantum mechanical topics, with the purpose of presenting their own ongoing research in a pedagogical manner, favoring interactions and discussions, and sharing motivations, tools, and perspectives.

Organisers: Angelo Bassi (DF-UniTS), Fabio Benatti (DF-UniTS), Alessandro Michelangeli (SISSA)

WHEN
12 AND 19 MAY 2017

WHERE
ICTP, Department of Physics - Room 204 and **SISSA - VII floor panoramic room**

INFO
http://www.sissa.it/~alemiche/junior-tsqd-2017.html

Friday 12 May 2017 – *ICTP / Department of Physics, room 204*

9:30 Stefano Bacchi • *The correspondence between trace dynamics and quantum theories*
10:30 ***coffee break***
10:50 Alessandro Olgiati • *Mixture and pseudo-spinorial BEC: rigorous derivation of the effective dynamics*
11:50 Sandro Donadi • *An introduction to the spontaneous wave function collapse models*

lunch

15:00 Mattia Carlesso • *Experimental bounds on collapse models from gravitational wave detectors*
16:00 Matteo Gallone • *Self-adjoint realisations of the Dirac-Coulomb Hamiltonian*
17:00 ***coffee break***
17:20 Stefano Marcantoni • *Thermodynamics of non-Markovian open quantum systems*
18:20 Raffaele Scandone • *Dispersive and scattering properties of the Hamiltonian of point interaction*

Friday 19 May 2017 – *SISSA, 7th floor panoramic room*

8:40 Luca Cucuraci • *QRLA: Quantum-like representation algorithm*
9:40 Francesca Fassioli • *Quantum coherence in photosynthesis*
10:40 ***coffee break***
11:10 Alessandro Carotenuto • *Curvature of Jordan modules and particle physics*
12:10 Marco Bilardello • *Heating effects and localization mechanism in cold Bose gases*

lunch

15:00 Daniele Dimonte • *Thomas-Fermi limit and N-body vortex state dynamics in a Bose-Einstein condensate*
16:00 Giulio Gasbarri • *Collisional models for a quantum particle in a gas*
17:00 ***coffee break***
17:20 Marko Erceg • *Hilbert space approach to PDEs of Friedrichs type*
18:20 Luca Ferialdi • *Non-Markovian Gaussian open system dynamics*

Junior Trieste Quantum Days 2017

The Correspondence between trace dynamics and quantum theories

Stefano Bacchi
Department of Physics, University of Trieste

Trace Dynamics (TD) is a pre-quantum theory, which declares to recover standard Quantum Mechanics (QM) by a thermodynamic-like procedure as explained in [1]. TD is an underlying theory for spontaneous collapse models [2], which at present are phenomenological models for solving the quantum measurement problem and the absence of macroscopic superposition. TD is a very young theory, with several crucial open problems both from the theoretical physics as well as mathematical physics point of view, we explain the main issues. In order to formulate TD, which lies on a space over a Grassmann algebra, one needs an average procedure on this algebra; we specify the mathematical details of this procedure. Moreover we evolve the space of TD into a super Hilbert space and we prove the existence of a well-defined relation between the super Hilbert space of TD and a standard Hilbert space. We make explicit what are the constraints in order to derive a rigorous correspondence linking TD and Quantum Field Theory.

References

[1] S.L. Adler. Quantum Theory as an Emergent Phenomenon: The Statistical Mechanics of Matrix Models as the Precursor of Quantum Field Theory. Cambridge University Press, 2004.

[2] Angelo Bassi, Kinjalk Lochan, Seema Satin, Tejinder P. Singh, and Hendrik Ulbricht. Models of wave-function collapse, underlying theories, and experimental tests. Rev. Mod. Phys., 85:471527, Apr 2013.

[3] Oliver Rudolph. Super Hilbert spaces. Comm. Math. Phys., 214(2):449467, 2000.

Heating effects and localization mechanism in cold Bose gases

Marco Bilardello
Department of Physics, University of Trieste

Collapse models solve the measurement problem by adding non-linear and stochastic terms to the usual Schroedinger dynamics. The resulting dynamics localizes in position macroscopic systems, while preserves quantum mechanical predictions for microscopic systems. Interesting systems to experimentally test collapse models are cold atomic gases because, besides their very low temperatures, cold atomic gases show quantum properties at the mesoscopic level. In this talk, we will see focus on one of the most studied among collapse models, i.e. CSL model. In this case, we will show how two main effects of collapse models - heating effects and localization mechanism - can be tested using cold Bose gases, by studying the CSL dynamics of free expanding gases and of Bose Josephson junctions.

Experimental bounds on collapse models from gravitational wave detectors

Matteo Carlesso
Department of Physics, University of Trieste

Wave function collapse models postulate a fundamental breakdown of the quantum superposition principle at the macro-scale. We compute the upper bounds on the col- lapse parameters, which can be inferred by the gravitational wave detectors LIGO, LISA Pathfinder and AURIGA. We consider the most widely used collapse model, the Continuous Spontaneous Localization (CSL) model. We show that these experiments exclude a huge portion of the CSL parameter space, the strongest bound being set by the recently launched space mission LISA Pathfinder.

Curvature of Jordan modules and particle physics

Alessandro Carotenuto
SISSA Trieste

In his paper "*Exceptional quantum geometry and particle physics*", Michel Dubois-Violette shows how some problems related to the noncommutative formulation of standard model of particle physics (such as quark-lepton symmetry and the existence of three generations of particles) might be solved by reformulating it in terms of Jordan modules. It is then important to study (nonassociative) geometry of such modules. In particular the study of flat connections on modules of the exceptional Jordan algebra may reveal essential for further developing of this model. This a joint work with M. Dubois-Violette and L. Dabrowski.

QRLA: Quantum-like representation algorithm

Luca Cucuraci
Department of Physics, University of Trieste

Abstract: Consider two random variables with two probability distributions. QRLA is procedure which associate to the two probability distributions a wave-functionand two basis (one for each random variable) of an Hilbert spaceHin which the wave function is defined.Then the statistical description of the two random variable can be obtained from the wave function taking the square modulus of the projection of the wave function on the associated basis, i.e. using the Born rules of quantum mechanics.

Suppose to collect data (of any origin, not only from physics) about the frequencies of the outcomes of two different random phenomena. From these data one can derive statistical informations like probabilities and averages. From the data, it can be checked if the Bayes theorem for conditional probabilities holds or not. When Bayes theorem does not hold QRLA applies and one can describe the two random phenomena using a Hilbert space and the rules of quantum mechanics.

In the talk, the QRLA for two dichotomic random variables is reviewed. Possible extension to more general cases briefly discussed.

References

[1] Khrennikov, A. - Ubiquitous quantum structure; Springer (2014)

[2] Khrennikov, A. - Contextual approach to quantum formalism; Springer science & business media, 2009

Thomas-Fermi limit and N-body vortex state dynamics in a Bose-Einstein condensate

Daniele Dimonte
SISSA Trieste

We consider the dynamics of an interacting Bose gas in the Thomas-Fermi regime. The initial state of the system is assumed to be a many-body vortex state, that is a condensate state containing one or more vortices. We show that the many-body dynamics of such a state can be well approximated by an effective time evolution, composing the usual Gross-Pitaevskii dynamics of the density profile with a classical notion of the vortex positions. Based on a work in progress with M. Correggi and P. Pickl.

An introduction to the spontaneous wave function collapse models

Sandro Donadi
Department of Physics, University of Trieste

Collapse models are phenomenological models, proposed to solve the measurement problem. In these models the Schroedinger equation is modified and the state vectors evolve according to a non-linear and stochastic dynamics. The effect of these non-linear terms is to induce the wave function collapse in space. The dynamics is built in such a way that the deviations from the linear Schroedinger dynamics are very small for microscopic systems (e.g. particles and atoms) while they become more and more relevant when the systems size increases, explaining the quantum to classical transition. The models make predictions different from quantum mechanics hence, they can be tested in experiments. In this talk, I will give a general introduction to the most relevant collapse models and their properties. Then, I will present a summary of the current bounds set by different kind of experiments (macromolecule interference, radiation emission, cantilevers, etc..) on the parameters of these models.

Hilbert space approach to PDEs of Friedrichs type

Marko Erceg
SISSA Trieste and PMF Zagreb

The Friedrichs (1958) theory of positive symmetric systems of first order partial differential equations encompasses many standard equations of mathematical physics, irrespective of their type. This theory was recast in an abstract Hilbert space setting by Ern, Guermond, and Caplain (2007), and by Antonić and Burazin (2010), while more recently a purely operator-theoretic description of abstract Friedrichs systems is developed. In this talk we shall present this abstract theory of Friedrichs systems and apply it on several boundary value problems of interest. At the end we study the question whether for any differential operator of the Friedrichs type there exist boundary conditions such that the problem is well-posed. This talk is based on joint works with Nenad Antonić, Krešimir Burazin, Ivana Crnjac, and Alessandro Michelangeli.

Quantum coherence in photosynthesis

Francesca Fassioli
Department of Physics, University of Trieste

The last decade has seen a renewed interest in exciton and charge transfer dynamics in light-harvesting systems fuelled by experimental evidence of long-lasting quantum coherence in several photosynthetic complexes isolated from bacteria, algae and plants. In this talk I will give an overview of the field, discussing the experiments, the theoretical approaches to study quantum coherent effects in light harvesting and how the molecular environment seems to be crucial in the observed quantum coherence. Finally, I will show two recent results of my current research regarding the role of the environment in sustaining quantum coherence.

Non-Markovian Gaussian open system dynamics

Luca Ferialdi
Department of Physics, University of Trieste

Non-Markovian dynamics describe general open quantum systems when no approximation is made. We provide the exact map for the class of Gaussian, completely positive, trace preserving, non-Markovian dynamics. We further characterize the class of stochastic Schroedinger equations that unravel this map. Moreover, by exploiting Wick's theorem, we derive the exact non-Markovian master equation for bosonic systems. We show that the master equation for non-Markovian quantum Brownian motion is a particular case of our general result.

Self-adjoint realisations of the Dirac-Coulomb Hamiltonian

Matteo Gallone
SISSA Trieste

Central in relativistic quantum mechanics is the Dirac equation, a partial differential equation that describes the dynamics of a spin-$\frac{1}{2}$ fermion. When one studies such dynamics in the electrostatic field generated by a nuclear point charge in the origin, one has to face the problem of qualifying the self-adjoint realisation(s) of the minimal Dirac-Coulomb operator. For sufficiently large atomic number, it is well known that there is indeed an infinite multiplicity of physically distinct realisations. We will survey the state-of-art of the problem and the main open questions, together with an explicit characterisation of the Dirac-Coulomb self-adjoint extensions in the so-called sub-critical regime, recently obtained in a joint work with Alessandro Michelangeli.

Collisional Models for a quantum particle in a gas

Giulio Gasbarri
Department of Physics, University of Trieste

Collisional theory of motion of a test particle in a gas as been extensively used to study the atomic kinematics - e.g. in Brownian motion. Under the assumption that the gas is sufficiently rarefied and the temperature issufficiently high, the interaction between a test particle and the gas can be approximated torepeated and independent collisionsbetween the test particle and each particle ofthe gas. The knowledge of the differential scattering cross section is then enough to capture the dynamics of the test particle.

Since the simplicity and the elegance of Classical collisional Theory many physicist have tried to extend the classical model in the quantum realm, where the scattering matrixis expected tocapture the dynamics of the quantum particle.

In this talk we review the most famous quantum collisional models derived so far and we show how these modelscan beeffectivelyderived from the microscopic nature of the system. We then show the limits of a collisionalapproachbased on scatteringtheory for thedescription of a test particle in a gas.

Thermodynamics of non-Markovian open quantum systems

Stefano Marcantoni
Department of Physics, University of Trieste

The theory of quantum dynamical semi-groups has been used since the late seventies to describe the non-equilibrium thermodynamics of a small quantum system weakly interacting with a large thermal bath. In this framework, the variation of energy in the system is easily split into heat and work, and the positivity of the entropy production is rigorously proved, thus providing a sound statement of the second law of thermodynamics [1]. Instead, a consistent thermodynamic description of a quantum system strongly coupled with its environment and undergoing a non-Markovian time evolution is still missing. For instance, one can show that the entropy production defined as in the Markovian case fails to be positive for a class of non-Markovian dynamics, suggesting that a more careful formulation of the second law of thermodynamics should be given in this context [2]. A possible approach to the problem is to consider a generic bipartite quantum system, initially prepared in a product state, and to study the exchange of energy and entropy between the interacting subsystems [3]. By properly defining heat, work and entropy production in this setting, one can write a generalized version of the first and second law of thermodynamics that highlights the role of correlations and interaction.

References

[1] H. Spohn and J. L. Lebowitz, Adv. Chem. Phys. 38, 109 (1979)

[2] S. Marcantoni, S. Alipour, F. Benatti, R. Floreanini and A. T. Rezakhani, submitted

[3] S. Alipour, F. Benatti, M. Afsary, F. Bakhshinezhad, S. Marcantoni and A. T. Rezakhani, Sci. Rep. 6, 35568 (2016)

Mixture and pseudo-spinorial BEC: rigorous derivation of the effective dynamics

Alessandro Olgiati
SISSA Trieste

Bose-Einstein condensation of particles with multiple degrees of freedom is a current frontier in cold atoms experiments; its mathematical treatment is a recently developing and active field, involving scaling limits together with techniques from operator theory and functional analysis. After an overview of the rigorous description of BEC and its effective dynamics, I will introduce two models of multiple condensation, namely mixtures and pseudo-spinors. Their effective dynamics is ruled by suitable systems of coupled non-linear Schroedinger equations, the rigorous derivation of which from the many-body linear Schroedinger dynamics was proven first in recent joint works with Alessandro Michelangeli

Dispersive and scattering properties of the Hamiltonian of point interaction

Raffaele Scandone
SISSA Trieste

The study of dispersive properties of Schrödinger operators with point interactions is a fundamental tool for understanding the behaviour of many body quantum systems interacting with very short range potential, whose dynamics can be approximated by non-linear Schrödinger equations with singular interactions. In this talk I will mainly discuss the case of a single point interaction in $\mathbb{R}^3$. After introducing a one parameter family $\{H_\alpha\}$, $\alpha \in (-\infty, +\infty]$ of self-adjoint operators on $L^2(\mathbb{R}^3)$, formally realising the Hamiltonian with point interaction, I will present a new result (in collaboration with G. Dell'Antonio, A. Michelangeli and K. Yajima) on the L^p-boundedness of wave operators relative to the pair $(H_\alpha, -\Delta)$. As a consequence, one can deduce dispersive and Strichartz estimates for the unitary evolution generated by H_α. I will also discuss a new result (in collaboration with A. Michelangeli and V. Georgiev) on the fractional powers of H_α, providing in particular a class of Banach spaces preserved by the linear flow e^{itH_α}. As a final application, I will provide some preliminary local existence result for the non-linear Schrödinger equations with a point interaction.