Talks at the 54 Symposium on Mathematical Physics

Luigi Accardi (Rome)

accardi@volterra.uniroma2.it

Hidden Markov processes: classical and quantum

In the past 20 years the number of applications of Hidden Markov processes (HMP) (also called Hidden Markov models (HMM)) has soared, covering a wide range of disciplines such as, artificial intelligence, machine learning, big data analysis, speech or handwriting recognition, image reconstruction, statistical physics (classical and quantum), ion channels, biophysical modelling, finance and economics, etc. However theoreticians have paid to these processes an attention not comparable to their importance in applications.

Some attempts have been made to extend some special aspects of these processes to the quantum domain. However, until recently, no class of quantum processes has been produced with the properties that:

(i) its restriction to some abelian sub-algebra of the algebra of the process gives a classical HMP;

(ii) varying the quantum process and the abelian sub-algebra, one can recover all classical HMP.

Goal of my talk is to describe a solution of this problem which not only recovers all the classical HMP, but also suggests several natural and easily constructable extensions of the classical HMP not covered by the existing classical or quantum literature.

Robert Alicki (Gdańsk)

robert.alicki@ug.edu.pl

Violation of detailed balance for quantum open systems

The Markovian dynamics of a quantum system immersed in a dilute gas at thermodynamic equilibrium is studied by applying the low-density limit technique. It is shown that the Gibbs state at the bath temperature is always stationary while the detailed balance condition at thermal equilibrium can be violated beyond the Born approximation. This violation is generically related to the absence of time-reversal symmetry for the scattering T-matrix. However, additional spatial symmetries can often restore this property. The results are illustrated by a model of an electron hopping between three quantum dots in an external magnetic field.

Joonwoo Bae (Daejeon)

bae.joonwoo@gmail.com

Contextual Advantages and Certification for Maximum-Confidence Discrimination

One of the most fundamental results in quantum information theory is that no measurement can perfectly discriminate between nonorthogonal quantum states. In this work, we investigate quantum advantages for discrimination tasks over noncontextual theories by considering a maximum-confidence measurement that unifies different strategies of quantum state discrimination, including minimum-error and unambiguous discrimination. We first show that maximum-confidence discrimination, as well as unambiguous discrimination, contains contextual advantages. We then consider a semi-device-independent scenario of certifying maximum-confidence measurement. The scenario naturally contains undetected events, making it a natural setting to explore maximum-confidence measurements. We show that the certified maximum confidence in quantum theory also contains contextual advantages. Our results establish how the advantages of quantum theory over a classical model may appear in a realistic scenario of a discrimination task.

Fabio Benatti (Trieste)

benatti@ts.infn.it

Storage capacity of a simple continuous quantum perceptron

Simple classical perceptrons are fundamental units of artificial neural networks. Storage capacities measure their classification capabilities. We show that no quantum advantages are to be expected from their quantization by means of continuous variable quantum systems.

Anindita Bera (Toruń)

aninditatitli@gmail.com

New classes of optimal entanglement witnesses

During my presentation, I will be discussing new classes in entanglement witnesses (EWs) and their optimality. These classes of witnesses generalise the known families of entanglement witnesses, mainly the Choi and the reduction. I will talk about a nontrivial optimization procedure, which is needed if the witnesses are not optimal. While we can use the spanning criterion to achieve optimality, it may not be enough. Some entanglement witnesses are proven to be optimal, without satisfying the spanning criterion.

Andreas Buchleitner (Freiburg)

abu@uni-freiburg.de

Many-particle complementarity and interference

Wave-particle duality is a well established concept on the level of single particle interference phenomena, and describes the trade-off between interference contrast and which-way information. Dynamically evolving systems composed of identical particles exhibit *many-particle* interferences which depend on the level of the paritcles' mutual distinguishability, which, in turn, allows to label many-particle paths. We'll discuss how the availability of many-particle which-way information constrains the interference contrast in the measurement statistics of many-particle observables.

Daniel Burgarth (Erlangen-Nürnberg)

daniel.burgarth@mq.edu.au

Taming the rotating wave approximation

The Rotating Wave Approximation (RWA) is one of the oldest and most successful approximations in quantum mechanics. It is often used for describing weak interactions between matter and electromagnetic radiation. In the semi-classical case, where the radiation is treated classically, it was introduced by Rabi in 1938. For the full quantum description of light-matter interactions it was introduced by Jaynes and Cummings in 1963. Despite its success, its presentation in the literature is often somewhat handwavy, which makes it hard to handle both for teaching purposes and for controlling the actual error that one gets by performing the RWA. Bounding the error is becoming increasingly important. Recent experimental advances in achieving strong light matter couplings and high photon numbers often reach regimes where the RWA is not great. At the same time, quantum technology creates growing demand for high-fidelity quantum devices, where even errors of a single percent might render a technology useless for error-corrected scalable quantum computation. I will give a gentle introduction to the history of the RWA and then report a conceptually simple way of explaining it. Finally, I will show how to tame it by providing non-perturbative error bounds, both for the semi-classical case (as reported last year) and the full quantum case (new!).

Francesco Buscemi (Nagoya) `buscemif@gmail.com`

Resource-theoretic approach to two problems in the theory of quantum measurements

In this talk, I will show how a resource-theoretic viewpoint on quantum measurements can help clarify some debates that have been going on in the literature for some time. In particular, I will focus on the notions of: (1), incompatibility of quantum instruments, for which there are two competing but logically independent definitions; and (2), measurement sharpness, whose operational interpretation has not been clear. Solutions to both problems are presented based on the theory of statistical comparison and the quantum Blackwell theorem.

Francesco Ciccarello (Palermo) `francesco.ciccarello@unipa.it`

Hermitian and non-Hermitian interactions mediated by a photonic bath

It is well-known that a photonic environment can mediate effective 2nd-order interactions between quantum emitters described by a generally non-Hermitian effective Hamiltonian. Current technology nowadays allows to fabricate relatively sophisticated photonic lattices (e.g. in circuit QED) and to couple them locally to controllable quantum emitters. In particular, as a photonic bath can be tailored so as to possess non-trivial topological and/or non-Hermitian properties, it is natural to wonder whether it can mediate atomic interactions enjoying analogous features. Here, I will discuss some general theorems linking the topology of the emitters to that of the photonic bath in terms of both Hermitian and non-Hermitian topological invariants. Remarkably, the atomic topology can be shown to be the same as or opposite to the photonic one, depending on the (non-)Hermiticity of the bath and the number of spatial dimensions. We in particular predict possible occurrence of atomic boundary modes with group velocity opposite to the photonic one.

References

[1] F. Roccati, S. Lorenzo, G. Calajo, G. M. Palma, A. Carollo, F. Ciccarello, Optica 9, 565-571 (2022)

[2] F. Roccati, M. Bello, Z. Gong, M. Ueda, F. Ciccarello, A. Chenu, A. Carollo, arXiv:2303.00762

Sergey Denysov (Oslo) `sergiyde@oslomet.no`

Spectral properties of noisy intermittent scale quantum circuits

Present quantum computing platforms allows for unitary description on very limited size- and time-scales. Open quantum system theory offers a framework to capture the functioning of these noisy intermediate scale quantum (NISQ) computer prototypes beyond the unitary horizon. We treat variational circuits, implemented on IBM Quantum platform, as quantum channels and extract their spectra by using a Pauli string-based protocol and machine learning technique. The spectra obtained for randomly sampled circuits closely reproduce spectra of the recently introduced ensemble of Kraus maps. We demonstrate how the parameters of the ensemble can be related to the parameters of circuit implementations. Our results highlight the present-day NISQ computers as already established flexible platforms to conduct experimental studies of open quantum systems.

Franco Fagnola (Milano) `franco.fagnola@polimi.it`

The spectral gap of a Gaussian Markov semigroup

Gaussian (quasi-free) quantum Markov semigroups (GQMS) describe the evolution, under the Markovian approximation, of an open quantum system of bosons and generalize bosonic quadratic Hamiltonians. In this talk we first introduce GQMS, describe the GKLS structure of their generators and discuss existence and of uniqueness of invariant states. Then we show that the spectral gap of a GQMS with a unique faithful invariant state, in the space of Hilbert-Schmidt operators determined by the invariant state, is the smallest eigenvalue of a certain matrix expressed in terms of the coefficients of creation and annihiliation operators in the GKLS representation of the generator. We do not assume symmetry (reversibility) with respect to the invariant state nor any quantum detailed balance condition.

Federico Girotti (Nottingham)

federico.girotti@nottingham.ac.uk

Heisenberg scaling in parameter estimation for quantum Markov dynamics

The estimation of an unknown parameter in quantum mechanical systems is a fundamental task for practical applications regarding quantum technologies. In the typical metrological scenario the unknown parameter is encoded in the state of n probes via local unitary operators; if the initial state is suitably engineered, one can estimate the parameter with a mean square error of the order of $1/n^2$ (which improves the standard scaling of $1/n$ corresponding to initial uncorrelated states) and this is what is known as Heisenberg scaling. However, the achievement of the Heisenberg scaling is usually hindered by the presence of noise due to the interaction between the probes and the environment. In our talk we are going to discuss under which conditions the Heisenberg scaling is restored in the case where the parameter to estimate is encoded by a Markovian dissipative dynamic, distinguishing the situation in which we can perform an arbitrary measurement, or we can only measure either the system or the environment. The talk is based on ongoing joint work with Madalin Guta.

Madalin Guta (Nottingham)

Madalin.Guta@nottingham.ac.uk

Optimal estimation of quantum Markov chains

In this talk I will discuss the problem of estimating dynamical parameters of a quantum Markov chain. The key tool will be the use of a coherent quantum absorber which transforms the problem into a simpler one pertaining to a system with a pure stationary state at a reference parameter value. I will then define certain translationally invariant modes of the output and show that the output state reduces to a coherent state of these modes. This provides a concrete representation of the local asymptotic normality phenomenon for Markov dynamics. I will then discuss how to optimally estimate unknown dynamical parameters by using a recently developed technique of displaced-null measurements.

Beatrix C. Hiesmayr (Vienna)

Beatrix.Hiesmayr@univie.ac.at

Bound entangled states: Status and Prospects

States that are positive under partial transpose (PPT) can also be entangled and no distillation protocol can transform an ensemble of such states to maximally entangled ones. I give in this talk a summary of the recent developments in this field.

Michał Horodecki (Gdańsk) michal.horodecki@ug.edu.pl

Intermediate time dilemma for open quantum systems

A widespread description of open quantum systems that works very well in quantum optics is based on Davies–GKLS (Gorrini-Kossakowski-Lindblad-Sudarshan) master equation which is Markovian. However it works well only for times much greater than inverse of smallest Bohr frequency of the system. If the system has either large Bohr frequencies, or very small ones, then for times that are not too long, another version of Markovian master equation work. However for intermediate times, non-Markovian description seems necessary. One widespread solution to this problem is Bloch-Redfield master equation, which is non-Markovian. Yet it is not completely positive. There is an alternative equation proposed by R. Alicki in 1989, and later developed by A. Rivas. It is known as "refined weak coupling" or "cumulant equation", and it is completely positive. We will show how it interpolates between two Markovian regimes for simple systems. We shall also discuss many problems that appear when one enters non-Markovian regime (including renormalization, "Lamb-shifts", cut-offs) and proposed ways to partially resolve them.

The talk is based on:

arXiv:2106.05776, *Bypassing the Intermediate Times Dilemma for Open Quantum System*, Marek Winczewski, Antonio Mandarino, Michał Horodecki, Robert Alicki

arXiv:2204.00643, *Towards reconciliation of completely positive open system dynamics with the equilibration postulate*, Marcin Łobejko, Marek Winczewski, Gerardo Suárez, Robert Alicki, Michał Horodecki.

Paweł Horodecki (Gdańsk) pawel.horodecki@pg.edu.pl

Quantum correlations and security against postquantum adversary:
from quantum steering to quantum maps assamblages

It has been shown that even in sequential measurements scenarios quantum mechanical statistics can not form an extremal point in the no-signaling set (see [1]). However, in the case of quantum steering sometimes it is no longer true. Counterexamples are known in three-party steering scenarios with the last system is trusted to be quantum with known Hilbert space dimension. Then there are quantum assamblages are extremal even in the larger (postquantum) set guaranteeing a secret bit [1]. The result can be partially extended to the case when the last party has already been subjected to a quantum measurement, so the dimension is not given explicitly, only the final statistics [2].

Quite remarkably, the above type effect are, however, well known to be impossible in bipartite case (see [3] and references therein). All know examples of bipartite secret key against a postquantum attack involve an unbounded increase of the resources: increasing number of settings (cf. [4]). Hence, there has been an open question whether there is any bipartite scenario with finite resources involved where quantum statistics guarantees security against postquantum adversary. We introduce a new steering scenario which involves what we call channel assemblages. In this case Bob has two input-output pair. The first pair represents the classical data, while the second corresponds to quantum ones. In this scenario we answer the above question in the affirmative [5]. Somewhat surprisingly, the final security does not require the corresponding channel assemblage to be extremal in the postquantum set. The result is also discussed in the context of leakage of information from quantumly trusted user.

References

[1] R. Ramanathan, M. Banacki, R. Ravel Rodrigues, PH, npj Quantum Information, 8, 119 (2022).

[2] M. Banacki, P. Mironowicz, R. Ramanathan, P. H., New J. Phys. 24, 083003 (2022)

[3] A. B. Sainz, N. Brunner, D. Cavalcanti, P. Skrzypczyk, T. Vertesi, Phys. Rev. Lett. 115, 190403 (2015)

[4] J. Barrett, L. Hardy, A. Kent, Phys. Rev. Lett. 95, 010503 (2005)

[5] M. Banacki, R. Ramanathan, P. Horodecki, Multipartite channel assemblages, arXiv:2205.05033 (2022).

Victor Kasatkin (Los Angeles) kasatkin@usc.edu

Which differential equations correspond to the Lindblad equation?

The Lindblad master equation can always be transformed into a first-order linear ordinary differential equation (1ODE) for the coherence vector. We pose the inverse problem: given a finite-dimensional, non-homogeneous 1ODE, does a corresponding Lindblad equation exist? If so, what are the corresponding Hamiltonian and Lindblad operators? We provide a general solution to this problem, including a complete positivity test in terms of the parameters of the 1ODE. We also describe a few properties relating the two representations (master equation and 1ODE), which are of independent interest and comment on the probability of 1ODE corresponding to a Lindblad master equation.

Jerzy Kijowski (Warszawa) kijowski@cft.edu.pl

Arrival time in quantum mechanics (demonstrated in geometrical order)

A geometric construction of the arrival time in conventional quantum mechanics is presented. It is based on a careful mathematical analysis of different quantization procedures for classical observables as functions of positions and momenta. A class of observables is selected which possess a unique (if any) quantized version. A simple criterion for existence of such a quantized version is formulated. These mathematical results are then applied to the classical "arrival time" observable. Physically, the resulting "Quantum arrival time" is identical with the one published in 1974 by ROMP, but the proof is much simpler and elegant. Moreover, the uniqueness of this procedure is proved.

Gen Kimura (Tokyo) gen@shibaura-it.ac.jp

Relaxed Bell's inequalities between the measurement dependence and the hiddenness

A relaxed Bell's inequality provides a tradeoff relation between measures of each underlying assumption, such as reality and locality, behind Bell's theorem. In this talk, considering one of the essential assumptions to be the introduction of the hidden parameter, we provide suitable measures for this assumption, which we refer to as "hiddenness". We derive several relaxed Bell's inequalities as a tradeoff relation between the hiddenness and the measurement dependence in any local models.

References

[1] Gen Kimura, Yugo Susuki, Kei Morisue, Relaxed Bell inequalities as a trade-off relation between measurement dependence and hiddenness, arXiv:2206.06196

[2] Ryo Takakura, Kei Morisue, Issei Watanabe, Gen Kimura, Trade-off relations between measurement dependence and hiddenness for separable hidden variable models, arXiv:2208.13634.

1. Ryszard P. Kostecki (Gdańsk)

Ryszard.Kostecki@fuw.edu.pl

Postquantum Brègman entropic projections and quasi-nonexpansive operators: general structure and some resource-theoretic applications

The Brègman family of relative entropies satisfies very nice geometric properties: 1) the generalised cosine and pythagorean theorems (i.e. an additive decomposition of relative entropy into parts corresponding to "signal" and "noise", with respect to an entropic projection, defined as a nonlinear map into a state which is a unique maximiser of relative entropy among a given closed convex subset); 2) their third order Taylor expansion determines a family of hessian (a.k.a. dually flat) geometries. Furthermore, in the reflexive Banach space setting, these relative entropies determine monoids of nonlinear quasi-nonexpansive operators, which satisfy a topological version of a generalised pythagorean theorem, and provide a generalisation of entropic projections. However, so far, an extension of a theory of Brègman relative entropies to arbitrary (nonreflexive, arbitrary dimensional) state spaces (in probabilistic, quantum, Jordan-algebraic, and base normed settings) was missing. We construct a solution to this problem, using a fusion of infinite-dimensional nonlinear convex analysis and nonlinear homeomorphy of Banach spaces, which allows us to provide a wide range of operator-algebraic examples (including, e.g., families of Brègman entropies and corresponding operators determined by the norm geometric characteristics of: noncommutative Orlicz spaces, nonassociative L_p spaces, generalised spin factors). The resulting theory is parallel to (and independent of) the theory of Csiszár–Morimoto/Kosaki–Petz f-divergences (with the Kullback–Leibler/Umegaki–Araki relative entropies belonging to an intersection of these two geometric worlds). As an application, we introduce categories and monoids of nonlinear (post)quantum quasi-nonexpansive operators with convergence controlled in terms of Brègman relative entropy, which give rise to a class of nonlinear (post)quantum resource theories. On the conceptual side, one can view these families of operators as a brègmanian analogue of CPTP maps, and as a generalisation of the method of inductive inference provided by the constrained relative entropy maximisation, with generalised pythagorean theorem playing the role of the fundamental geometric characteristic of an inference process.

Rosario Lo Franco (Palermo)

rosario.lofranco@unipa.it

Asymptotically-deterministic robust preparation of maximally entangled states

Realistic preparations of entangled states are jeopardized by the unavoidable interaction with the surrounding environment, whose noisy action is detrimental for the quantum correlations within the system. For this reason, many different techniques to circumvent the problem have been proposed over time.

We present a general scheme to prepare a pure Bell singlet state of two bosonic qubits, in a way that is robust under the effect of any type of local noise. Considering a photonic platform, the procedure utilizes passive optical devices and a polarization-insensitive, non-absorbing, parity check detector in an iterative process with probability which converges exponentially to one with the number of repetitions, thus being asymptotically deterministic. Distributing the photons over two distinct spatial modes, we further show that the elements of the basis composed of maximally entangled states can be divided in two sets according to an equivalence based on passive optical transformations. We demonstrate that the parity check detector can be used to connect these two sets of states.

The reported results hold for any type of bosonic system, thus not being limited to photons. Therefore, the proposed procedure can be ultimately exploited to prepare any pure state of two bosons which are maximally entangled in either the internal degree of freedom (Bell states) or the spatial mode (NOON states).

Davide Lonigro (Bari)

davide.lonigro@ba.infn.it

Markovianity and classicality of pure dephasing phenomena

We investigate the validity of quantum regression for a family of quantum Hamiltonians leading to phase-damping reduced dynamics, constructing a hierarchy of equations equivalent to the validity of quantum regression under arbitrary interventions; in particular, we find necessary conditions for a nontrivial dephasing to be compatible with quantum regression. In this framework, we investigate the existence of qubit-environment coupling functions that ensure the exact validity of quantum regression for a class of dephasing-type generalized spin-boson (GSB) models. Furthermore, we search for measurement protocols whose statistics satisfy the Kolmogorov consistency conditions possibly up to a finite order, unveiling a phenomenology of dephasing processes which can be interpreted in classical terms.

Joint work with D. Chruściński (UMK).

Kimmo Luoma (Turku)

ktluom@gmail.com

Non-Markovian Quantum Dynamics in Strongly Coupled Multimode Cavity Conditioned on Continuous Measurement

An important challenge in non-Markovian open quantum systems is to understand what information we gain from continuous measurement of an output field. For example, atoms in a cavity QED systems provide an exciting platform to study many-body phenomena in regimes where the atoms are strongly coupled amongst themselves and with the cavity modes, but the strong coupling makes it complicated to infer the conditioned state of the atoms from the output light. In this work we address this problem, describing the reduced atomic state via a conditioned hierarchy of equations of motion, which provides an exact conditioned reduced description under monitoring (and continuous feedback). We utilize this formalism to study how different monitoring schemes affect our information gain for an atomic state.

Carlo Marconi (Barcelna)

Carlo.Marconi@uab.cat

PPT-entanglement in multipartite symmetric states of N qudits

The celebrated Peres-Horodecki criterion states that positivity under partial transposition (PPT) is necessary to ensure the separability of a quantum state. However, while this condition is also sufficient for low dimensional systems, the same is no longer true already in the case of two qutrits, giving rise to the phenomenon of PPT-entanglement. In this talk we discuss the characterization and detection of PPT-entangled states for a class of multipartite systems, dubbed symmetric, whose states are invariant under any permutation of the parties. Using linear mappings techniques and graph-theoretic approach we show how to construct PPT-entangled states of N qudits, presenting also the entanglement witness that detect them.

Marco Merkli (St. John's)

merkli@mun.ca

Stability of PPT in equilibrium states

We use simple spectral perturbation theory to show that the positive partial transpose property is stable under bounded perturbations of the Hamiltonian, for equilibrium states in infinite dimensions. The result holds provided the temperature is high enough, or equivalently, provided the perturbation is small enough. This is joint work with Mitch Zagrodnik.

Massimo Palma (Palermo)

massimo.palma@unipa.it

An operational definition of quantum information scrambling

Quantum system can store information non-locally into the correlations between different components. When information is not locally retrievable, it is said to be scrambled. Quantum information scrambling (QIS) is a feature common to various phenomena as thermalization or quantum chaos. If one think of QIS as inability to recover some input information through local measurement, it is essential to quantify it in terms of quantities not containing discordant contributions. In this work, we fill the gap by proposing a new quantifier of QIS that does not suffer of accessibility issues and has a clear operation meaning in terms of quantum state discrimination. Our proposal is expressed in terms of min-entropy, a single-shot generalization of Von Neumann entropy. We apply this new definition to various examples and observe that it is able to faithfully witness QIS.

Saverio Pascazio (Bari)

saverio.pascazio@ba.infn.it

Entanglement by dissipation and multimerization in waveguide QED

We consider a system of two-level quantum emitters coupled to a closed waveguide, in different geometries, and look at states in which one or two excitations are shared between the field and the emitters.

We focus on the relaxation towards bound states, entanglement generation, correlated emissions, and multimerized bound states.

Jyrki Piilo (Turku)

jyrki.piilo@utu.fi

Efficient quantum teleportation under noise with hybrid entanglement and reverse decoherence

Decoherence constitutes one of the biggest hindrances to efficient quantum technologies. Quantum teleportation, for example - the cornerstone of quantum information processing — typically becomes futile in a noisy setting, with decoherence degrading quantum to classical. Hence, new ways to control noise and decoherence are being actively developed. Here, we consider quantum teleportation under pure decoherence, i.e. dephasing, which we show how to reverse with hybrid entanglement. We implement the noisy quantum teleportation and reverse decoherence in all-optical experiments. Remarkably, we achieve high teleportation fidelities without the initial resource qubits ever violating the Bell-CHSH inequalities. Our results therefore shed new light on nonlocal resources, e.g., hidden nonlocality, while simultaneously providing an efficient way to resist decoherence.

Anna Sanpera Trigueros (Barcelona)

Anna.Sanpera@uab.cat

Unveiling the structure of the symmetric subspace and its implications

Authors: Carlo Marconi, Jennifer Abhiale, Jordi Romero-Palleja, Sandro Romanicino, Anna Sanpera-Trigueros

I will describe the structure of the symmetric subspace for an arbitrary number of parties and arbitrary (finite) dimensions. Its relation with the cone of copositive matrices, graph theory and some of the consequences that steem for it.

Thomas Schulte-Herbrueggen (Munich)

tosh@tum.de

Markovianity in quantum thermodynamics

We connect quantum control theory with quantum thermodynamics within the framework of Lie-semigroup theory. In particular, we sketch how to construct the Markovian counterparts of several types of quantum Thermal Operations via their respective Lie wedge.

In an explicit qubit example, we parameterise the Markovian subset of maps within the set of all the Thermal Operations.

As an application, we give inclusions in terms of d-majorisation for reachable sets of bilinear control systems, where coherent controls are complemented by switchable couplings to a thermal bath as additional resource.

Joint work with Frederik vom Ende, Emanuel Malvetti, and Gunther Dirr based on arxiv:2303.01891 and Open Syst. Inf. Dyn. 30 (2023), 2350005.

Fereshte Shahbeigi (Kraków, Poland)

fereshteshahbeigi@gmail.com

When to/not to quantumly simulate a classical transition?

The concept of Markovianity, asking whether a given channel can be realised through a memoryless interaction with the environment, has been a long-standing question in both classical and quantum physics. Over the years, various applications of Markovian maps have been introduced separately for classical and quantum systems. Recently, the novel concept of quantum embeddability has been discovered, which constructs a bridge between the quantum Markovian world and the classical realm. A stochastic matrix is said to be quantum embeddable if it is the classical action of a Markovian quantum channel. This allows the benefits of memoryless quantum evolution to be applied to classical systems that typically require memory to be simulated. Here, we elaborate on which classical transition matrices are memory-wise beneficial to be simulated quantumly and when we still need memory anyway.

2. Kyrylo Simonov (Wien, Austria)

kyrylo.simonov@univie.ac.at

Supermaps without definite causal order: Informational and thermodynamic aspects

The nature of causality remains one of the key puzzles in science. In quantum theory, the causal structure is not subject to quantum uncertainty and plays rather a background role. One can ask whether the background causal structure can be dropped, for example, by respecting causality only locally. Such scenarios of local validity of quantum theory while relaxing the global definite causal order of operations can be described via the machinery of higher-order operations, i.e. supermaps. An important example of scenarios of this kind is quantum SWITCH, a process realizing a quantum superposition of causal orders of operations. Looking for the possible applications of quantum SWITCH has been the subject of growing interest in the scientific community as it could provide communication and computational resources not realizable via standard quantum theory. Moreover, in the last few years, the benefits potentially offered by quantum SWITCH for thermodynamic tasks have appeared in the spotlight. My talk aims at highlighting the benefits and applications of higher-order maps to information processing and thermodynamics.

Andrea Smirne (Milano)

andrea.smirne@unimi.it

Nonperturbative approach to open-system multi-time expectation values in Gaussian Bosonic environments

One of the main obstacles towards a fully satisfactory description of the evolution of open quantum systems is certainly represented by the non-Markovian regime, in which the impact of strong-coupling and memory effects makes the characterization of the evolution of relevant open-system quantities considerably more demanding. While recently several results have been derived to analyze the dynamics of the reduced open-system state, i.e., of the single-time expectation values, very few methods are available to describe the evolution of multi-time quantities in general situations, beyond the regime of validity of the quantum regression theorem. In this talk, I will present a nonperturbative treatment of the multi-time expectation values of operators and maps of open quantum systems interacting with a continuous set of bosonic modes by means of a limited number of damped modes [1]. The method can be applied to deal with fully general coupling strengths and non-Markovian regimes, and it generalizes a previously derived [2] equivalence theorem for the reduced dynamics, relying on the division of the influence of the environment on the open system into a non-Markovian core, which encloses all the memory effects during the evolution, and a further Markovian component, representing the unidirectional leakage of information out of the non-Markovian core. Our approach sets the ground for the investigation of open-system multi-time quantities in fully general regimes, as shown by its recent use in the evaluation of 2D electronic spectra of a dimeric complex in realistic parameter regimes [3].

References

[1] A.Smirne, D. Tamascelli, J. Lim, M.B. Plenio, and S.F. Huelga, Op. Sys. Inf. Dyn. 29, 2250019 (2022)

[2] D. Tamascelli, A. Smirne, S.F. Huelga, and M.B. Plenio, Phys. Rev. Lett. 120, 030402 (2018)

[3] A. Nüßeler, D. Tamascelli, A. Smirne, J. Lim, S. F. Huelga, and M. B. Plenio, Phys. Rev. Lett. 129, 140604 (2022)

Walter Strunz (Dresden)

walter.strunz@tu-dresden.de

Open quantum system dynamics and thermodynamics from a global state point of view

Irreversible quantum (thermodynamic) processes are ubiquitous in nature and offer challenges both from an applied and fundamental point of view. Important practical (computational) and conceptual issues are still open. Fundamentally, quantum irreversibility arises as subdynamics of a unitary global evolution. In this contribution we employ such a global state point of view for the study of the dynamics of a quantum heat engine, allowing us to investigate in detail the various energetic contributions and changes during each cycle.

Bassano Vacchini (Milano)

bassano.vacchini@mi.infn.it

Quantum divergences for the characterization of information backflow

A well-known approach for the description of memory effects in the reduced quantum dynamics of an open system is based on the notion of information exchange between the open system and its environment. This exchange has typically been quantified studying the variation in time of the trace distance between distinct initial system states. We point to the fact that such an information exchange can actually be described by a large class of quantum divergences, including not only distances, but also entropic quantifiers. We derive general upper bounds on the revivals of quantum divergences conditioned and determined by the formation of correlations and changes in the environment. We will discuss in particular the different relationship between distinguishability and divisibility for the trace distance and the Jensen-Shannon divergence.

Paola Verruchi (Firenze)

verrucchi@fi.infn.it

Schwarzschild black holes from a quantum viewpoint

In this work we propose a strategy for establishing a dialogue between quantum mechanics and general relativity, and describe how certain facts about gravity can emerge from the standard quantum mechanical description of open quantum systems. In fact, starting from the classical discourse on gravity, we find that an underlying quantum picture exists, where Schwarzschild Black Holes find their place as macroscopic quantum objects, despite being predictions of a genuinely classical theory such as the Einstein's general relativity. Fundamental tools of our approach are i) the Page and Wootters mechanism, to make sense of the parameter time in a quantum mechanical setting, and ii) generalized coherent states to treat the quantum-to-classical crossover in a formal way.

Joint work with Alessandro Coppo.

Noboru Watanabe (Noda)

watanabe@is.noda.tus.ac.jp

Note on complexities for the quantum compound systems

In order to discuss the efficiency of information transmission of the quantum communication processes consistently, we consider the entropy type functional and the mutual entropy type functional with respect to the initial state and the quantum communication channel. In this study, the mutual entropy type measures are constructed by the compound state between the initial and final systems. In this paper, we modify the compound state and examine the entropy functional and the mutual entropy functional defined by the modified compound states by means of the initial state and the completely positive channel to study the efficiency of information transmission of the quantum communication processes.

Howard Wiseman (Queensland)

prof.howard.wiseman@gmail.com

Open quantum systems are harder to track than open classical systems

This topic is related to open quantum systems, continuous-in-time measurement, quantum feedback control (for adaptive measurement) and exact numerical solutions to systems of polynomial equations.

Dayou Yang (Ulm)

dayou.yang@uni-ulm.de

New opportunities for sensing via continuous measurement

The continuous monitoring of driven-dissipative quantum optical systems provides key strategies for the implementation of quantum metrology, with prominent examples ranging from the gravitational wave detectors to the emergent driven-dissipative many-body sensors. Fundamental theoretical questions about the ultimate performance of such a class of sensors remain openâ€"for example, can they achieve quantum-enhanced precision scaling without squeezed input; how to perform the optimal measurement to approach their ultimate precision? In this talk, I will present our recent efforts to answer these questions. In the first part I will introduce dissipative criticality as a resource for nonclassical precision scaling for continuously monitored sensors, by establishing universal scaling laws of the quantum Fisher information in terms of the critical exponents of generic dissipative critical points. In the second part I will present a general continuous measurement strategy to retrieve the full quantum Fisher information of the nonclassical, temporally correlated fields emitted by generic open quantum sensors, thereby to achieve their fundamental precision limit.

Mario Ziman (Bratislava) mario.ziman@savba.sk

Strict bidivisibility of quantum processes

After short introduction of the concept of channel divisibility we will question of the existence of quantum channels that are divisible in two quantum channels but not in three or, more generally, channels divisible in n but not in $(n+1)$ parts. We show that for the qubit those channels do not exist, whereas for general finite-dimensional quantum channels the same holds at least for full Kraus rank channels. To prove these results, we introduce a decomposition of quantum channels which separates them into a boundary and Markovian part, and it holds for any finite dimension. Additionally, the introduced decomposition amounts to the well-known connection between divisibility classes and implementation types of quantum dynamical maps and can be used to implement quantum channels using smaller quantum registers.

Joint work with David Davalos.

Karol Życzkowski (Kraków) karol.zyczkowski@uj.edu.pl

*Quantum transport problem and energy distance between pure quantum states**

While processing quantum information one often needs to distinguish between two given quantum states or to describe how close they are apart. Depending on the envisaged application, various distances are employed. While the standard solutions (including trace distance D_{Tr}, Hilbert-Schmidt distance or the fidelity-based, Bures distance) are unitarily invariant, for some purposes it is convenient to work with more general notions.

Basing on the transport problem of Monge-Kantorovich-Wasserstein and their quantum analogues [1,2] we introduce an *energy distance* W_H determined by any Hamiltonian H. For eigenstates $|\psi_i\rangle$ of the Hamiltonian, $\langle\psi_i|H|\psi_i\rangle = E_i$, their distance is given by the absolute value of the energy difference,

$$W_H(|\psi_i\rangle, |\psi_j\rangle) = |E_i - E_j|.$$

Thus for the hydrogen atom, the distance from the ground state $|0\rangle$ to a Rydberg state is much larger than to the first excited state, $W_H(|0\rangle, |100\rangle) \gg W_H(|0\rangle, |1\rangle)$, although the trace distance and distinguishability between all three orthogonal states are equal,

$$D_{\mathrm{Tr}}(|0\rangle, |100\rangle) = D_{\mathrm{Tr}}(|0\rangle, |1\rangle) = D_{\mathrm{Tr}}(|1\rangle, |100\rangle).$$

The energy distance is analyzed for several physical models. A quantum speed limit relation is established: the time T required to transform a state $|\psi\rangle$ into $|\phi\rangle$ by any interaction Hamiltonian V is bounded from below by the ratio, $T \geq \frac{W_H(|\psi\rangle, |\phi\rangle)}{\langle v\rangle}$, where $\langle v\rangle$ denotes the average speed computed with respect to the energy distance. It is thus fair to expect that this non-unitary-invariant distance will find several applications in quantum theory, including the studies on quantum chaos and quantum Lapunov exponent.

References

[1] K. Życzkowski and W. Słomczyński, Monge distance between quantum states, *J. Phys.* **A 31**, 9095 (1998).

[2] S. Friedland, M. Eckstein, S. Cole, K. Życzkowski, Quantum Monge-Kantorovich problem and transport distance between density matrices, *Phys. Rev. Lett.* **129**, 110402 (2022).

* Joint work with Rafał Bistroń, Michał Eckstein, Shmuel Friedland and Tomasz Miller.