Informal Quantum Symposium 2020

BOOK OF ABSTRACTS

August 24th–August 28th 2020, Smolenice, Slovakia

http://qute.sk/iquas/

IQUAS 2020

Informal quantum symposium (IQUAS) aims to bring together experts working in the area of quantum information science and technologies and to create a motivating environment full of scientific interactions and discussions (while keeping the regulation of safe distance). Conceptually, IQUAS stands somewhere between workshops and unconferences, thus, its goal is not only to present new results, but also to discuss research problems in the areas of interests of participants. Except of either presenting their recent results (as short talks and posters), or give a tutorial on recent scientific topics, participants are expected to actively discuss their current research interests with other participants. The number of participants is limited.

Venue

The workshop will be held in *Smolenice Castle* which history dates back to the 15^{th} century and currently serves as the Congress Center of Slovak Academy of Sciences. It is situated approximately 60 km northeast from Bratislava in the central area of the smallest Slovakian mountains called Malé Karpaty.

Organizing Team

IQUAS 2020 is organized under the initiative qute.sk by the Research Center for Quantum Information, Institute of Physics, Slovak Academy of Sciences. Organizing team consits of Daniel Reitzner, Michal Sedlák and Mária Surovcová.

Invited speakers

- ⋆ Janos Asboth
  (Budapest University of Technology and Economics & Wigner Research Centre for Physics)
- ⋆ Sergey N. Filippov[@]
  (Moscow Institute of Physics and Technology)
- ⋆ Jaromír Fiurášek
  (Palacký University, Olomouc)
- ⋆ Aurél Gábris
  (Czech Technical University in Prague)
- ⋆ Teiko Heinosaari[@]
  (University of Turku)
- ⋆ Jakub Mareček
  (IBM Research & Czech Technical University)
- ⋆ Nikolai Miklin[@]
  (University of Gdansk)
- ⋆ Zbigniew Puchała
  (Institute of Theoretical and Applied Informatics, Polish Academy of Sciences)
- ⋆ Peter Skyba
  (Institute of Experimental Physics, Slovak Academy of Sciences)

[@] Virtual talk

Participants

- ⋆ Jan Bouda
- ⋆ Libor Caha
- ⋆ Bartlomiej Gardas
- ⋆ Andrej Gendiar
- ⋆ Anna Jenčová
- ⋆ Aleksandra Krawiec
- ⋆ Roman Krčmár
- ⋆ Denisa Lampášová
- ⋆ Hamed Mohammady
- ⋆ Daniel Nagaj
- ⋆ Jaroslav Pavličko
- ⋆ Mária Polačková
- ⋆ Peter Rapčan
- ⋆ Daniel Reitzner
- ⋆ Michal Sedlák
- ⋆ Sazim Sheikh
- ⋆ Nidhin Sudarsanan Ragini
- ⋆ Nana Siddhartha Yenamandala
- ⋆ Mária Zelenayová
- ⋆ Mário Ziman
- ⋆ Zoltán Zimborás

Invited talks

1. **Janos Asboth:** TOPOLOGICAL DELOCALIZATION IN TWO-DIMENSIONAL QUANTUM WALKS

   Quantum walks spread faster than classical random walks, which makes them interesting for quantum information applications. However, they are more sensitive to spatial disorder: they can undergo Anderson localization, which stops them from spreading off to infinity. We show that increasing the disorder to the maximum possible value, i.e., using position-dependent rotation operators selected randomly and Haar uniformly, does not lead to Anderson localization, but rather, to a critical dynamical system where the quantum walk spreads diffusively, just like its classical counterpart [1]. The reason behind this has to do with the topological invariants of the quantum walk: maximal disorder tunes the quantum walk to a critical point between phases with different topological invariants [2]. In the talk I will explain what these invariants are, how they are related to edge states [3], how to calculate them in the disordered case, and how we characterized the critical state of the quantum walk.

   [1] J.K. Asboth, A. Mallick, *Topological delocalization in the completely disordered two-dimensional quantum walk,* preprint `arXiv:2005.00203`,
   [2] J.M. Edge, J.K. Asboth, *Localization, delocalization, and topological transitions in disordered two-dimensional quantum walks,* Phys. Rev. B **91,** 104202 (2015),
   [3] J.K. Asboth, J.M. Edge, *Edge-state-enhanced transport in a two-dimensional quantum walk,* Phys. Rev. A **91,** 022324 (2015).

2. **Sergey N. Filippov:**[@] TENSOR NETWORKS AND THEIR OPTIMIZATION FOR MULTIPARTITE QUANTUM STATES, QUANTUM CIRCUITS, AND NON-MARKOVIAN QUANTUM DYNAMICS

   Authors: S.N. Filippov, I.A. Luchnikov

   Pure states of a multipartite quantum system naturally adopt the tensor representation $\psi_{i_1 i_2 \ldots i_N}$, where the index i_k refers to the degrees of freedom associated with k-th particle. In general, such a description is rather useless as the tensor has a high rank N and needs exponential resources with respect to N, but the low-energy physics for local Hamiltonians makes the situation much better because the high-rank tensor $\psi_{i_1 i_2 \ldots i_N}$ then adopts a network representation with basic elements being tensors of a fixed rank, say, 3. Besides the efficient description of multipartite states, tensor networks are also useful for a deeper understanding of a circuit implementation of quantum computation. In this case, basic elements of the network are unitary gates. Finally, the open quantum dynamics (when the system in interest interacts with some environment) can also be considered as a tensor network in time domain [1]. This interpretation provides some operational meaning to the distinction between Markovian and non-Markovian evolutions and gives some clue to the idea of Markovian embedding, i.e., treatment of a non-Markovian dynamics as a reduced evolution of an extended Markovian one. This idea, in its turn, allowed us to develop a working algorithm for machine learning non-Markovian quantum dynamics by performing measurements on the system only and having no access or any a priori information about the environment [2]. Being constructed, tensor networks can be optimized to solve a specific quantum control problem, e.g., to create of a highly entangled state. We present new approaches to the optimization of tensor networks, where the basic tensor elements are restricted to a specific class, namely, the Stiefel manifold of unitary or isometric matrices [3]. The presented Riemannian optimization tools together with the automatic differentiation are quite promising for optimization of complex quantum networks with restrictions.

   [1] I.A. Luchnikov, S.V. Vintskevich, H. Ouerdane, S.N. Filippov, *Simulation complexity of open quantum dynamics: Connection with tensor networks,* Phys. Rev. Lett. **122,** 160401 (2019),
   [2] I.A. Luchnikov, S.V. Vintskevich, D.A. Grigoriev, S.N. Filippov, *Machine learning non-Markovian quantum dynamics,* Phys. Rev. Lett. **124,** 140502 (2020),
   [3] I. Luchnikov, M. Krechetov, S. Filippov, *Riemannian optimization and automatic differentiation for*

complex quantum architectures, preprint `arXiv:2007.01287`.

3. **Jaromír Fiurášek:** LINEAR OPTICAL QUANTUM GATES: DESIGN, CHARACTERIZATION, AND APPLICATIONS

   In this talk, I will review the basic principles of linear optical quantum computing and I will discuss the design of various two-qubit and multiqubit entangling linear optical quantum gates such as the CNOT, CZ, partial-SWAP, Toffoli, Fredkin and CCPhase gates. I will present several methods of characterization of the implemented quantum gates: Hofmann bounds on quantum gate fidelity, Monte Carlo sampling of the gate fidelity, and full quantum process tomography. Several applications of the linear optical quantum gates in quantum information processing will be also discussed.

4. **Aurél Gábris:** CLASSICAL AND QUANTUM COHERENCES IN PHOTONIC QUANTUM NETWORKS

   Authors: T. Nitsche, S. Barkhofen, E. Meyer-Scott, S. De, J. Tiedau, J. Sperling, A. Gábris, I. Jex, C. Silberhorn

   In this talk I will be reviewing photonic network implementations of quantum walks, and the state of the art of realising quantum simulation tools based on this platform. Using the language and concepts of quantum optics, I will address the question of what is quantum about quantum walk, leading up to the notion of coherence, a central concept in optics. Finally, I will elaborate on a simple, yet powerful, test of quantum coherences across an extended network, and present an experimental realisation in a time-multiplexed setup.

5. **Teiko Heinosaari:**[@] COMMUNICATION TASKS IN OPERATIONAL THEORIES

   Which communication tasks can be accomplished within a given operational theory? How to formulate this question mathematically? What is the mathematical form and structure of communication tasks? What is the role of shared randomness? Are some communication tasks harder than others?

6. **Jakub Mareček:** MATHEMATICAL OPTIMIZATION IN QUANTUM COMPUTING AND QUANTUM INFORMATION SCIENCE

   Many challenges in quantum computing and quantum information science can also be seen as major challenges in mathematical optimisation. For instance any improvements in the fidelity of two-qubit gates hinge upon improvements to methods for pulse shaping, which are methods for solving a large-scale non-convex non-commutative optimisation problem, in terms of mathematical optimisation. Likewise, improving “fitters” for measurements requires improved solvers for a time-varying non-convex problem, related to parameter estimation in time-varying Gaussian models. Testing quantum non-locality of a state yields a large-scale convex or non-convex optimisation problem. Even from these three examples, it seems clear that non-commutativity, non-convexity and time-varying aspects are crucial in mathematical optimisation for quantum computing and quantum information science.

   At the same time, current methods for these problems disregard non-commutativity, non-convexity (by considering only first-order optimality conditions), and time-varying aspects. We will illustrate why this matters and how to address the non-commutative and non-convex aspects so as to develop globally convergent solvers.

   Note: In part, this is based on [1], which is a joint work with Jiri Vala. In part, this is based on ongoing work with Anna de Rosier.

   [1] J. Marecek, J. Vala, *Quantum Optimal Control via Magnus Expansion and Non-Commutative Polynomial Optimization*, preprint `arXiv:2001.06464 [quant-ph]`.

7. **Nikolai Miklin:@** A UNIVERSAL SCHEME FOR ROBUST SELF-TESTING IN THE PREPARE-AND-MEASURE SCENARIO

   We consider the problem of certification of arbitrary ensembles of pure states and projective measurements solely form the experimental statistics in the prepare-and-measure scenario assuming the upper bound on the dimension of the Hilbert space. To this aim we propose a universal and intuitive scheme based on establishing perfect correlations between target states and suitably-chosen projective measurements. The method works in all finite dimensions and allows for robust certification of the overlaps between arbitrary preparation states and between the corresponding measurement operators. Finally, we prove that for qubits our technique can be used to robustly self-test arbitrary configurations of pure quantum states and projective measurements. These results pave the way towards practical application of the prepare-and-measure paradigm to certification of quantum devices.

8. **Zbigniew Puchała:** DISCRIMINATION AND CERTIFICATION OF QUANTUM MEASUREMENTS

   Authors: P. Lewandowska, A. Krawiec, R. Kukulski, Ł. Pawela, M. Oszmaniec, Z. Puchała

   We present an in-depth study of the problem of symmetric and asymmetric discrimination of von Neumann measurements in finite-dimensional Hilbert spaces. In the case of multiple-shot discrimination, we focus on discrimination of measurements with the assistance of entanglement. Interestingly, we prove that in this setting all pairs of distinct von Neumann measurements can be distinguished perfectly (i.e. with the unit success probability) using only a finite number of queries. We also show that in symmetric and asymmetric scenario queering the von Neumann measurements in parallel gives the optimal strategy and hence any possible adaptive methods do not offer any advantage over the parallel scheme.

9. **Peter Skyba:** SUPERFLUID HELIUM-3 AS MODEL SYSTEM FOR COSMOLOGY

   An aim of this lecture is to introduce and present superfluid helium-3 as model system for cosmology. In particular, I show the experimental results of the experiment made in a limit of absolute zero temperature (600 μK) studying the spin wave analogue of black/white hole horizon using a spin (magnonic) superfluidity in superfluid 3He-B. As an experimental tool simulating the properties of the black/white horizon we used the spin-precession waves propagating on the background of the spin super-currents between two Bose-Einstein condensates of magnons in form of the homogeneously precessing domains. We provide experimental evidence of the white hole formation for spin precession waves in this system, together with observation of an amplification effect. Finally, I will show and discuss the latest observation of an anomalous damping of the motion of an mechanical resonator in zero velocity limit that seems to be an evidence for an analogue of the Unruh effect in superfluid helium-3.

Contributed talks

1. **Libor Caha:** VERY ENTANGLED SPIN CHAINS, REWRITING RULES, AND COMBINATORIAL TECHNIQUES IN CONDENSED MATTER PHYSICS

   Authors: L. Caha, D. Nagaj

   How entangled can a ground state of a simple quantum matter be? It turns out that a power law violation of entanglement entropy for translationally invariant spin chains with a reasonable energy gap is possible, as one could see for Motzkin spin-2 [1] and Fredkin spin-3/2 chains (with next-nearest-neighbor interaction) [2].

   In [3], we demonstrate that one can find such surprising properties even in spin-1 chains (qutrits on a line). There we presented the pair-flip (PF) model, a translationally invariant spin chain with an inverse polynomial energy gap, $\sqrt{N}$ half-chain entanglement entropy scaling for a particular ground state on N sites and conjectured that the ground state can be made unique by adding a small perturbation while retaining the entropy (a partial analytical result).

All of the above mentioned models belong to a class of "rewriting" Hamiltonians, whose ground space and their properties can be understood in terms of rewriting rules and have an intriguing connection to formal languages. For completeness, we enumerate all such 1D Hamiltonians with qubits and show that most of them have ground states in the form of product states only.

Note: partially based on [3] and additional results

[1] R. Movassagh, P.W. Shor, *Supercritical entanglement in local systems,* PNAS 201605716 (2016),
[2] L. Dell'Anna, O. Salberger, L. Barbiero, A. Trombettoni, V.E. Korepin, *Violation of cluster decomposition and absence of light cones in local integer and half-integer spin chains,* Phys. Rev. B **94,** 155140 (2016),
[3] L. Caha, D. Nagaj, *The pair-flip model: a very entangled translationally invariant spin chain,* preprint `arXiv:1805.07168`.

2. **Bartlomiej Gardas:** PARALLEL IN TIME DYNAMICS WITH QUANTUM ANNEALERS

   Authors: K. Jałowiecki, A. Więckowski, P. Gawron, B. Gardas

   Recent years have witnessed an unprecedented increase in experiments and hybrid simulations involving quantum computers. In particular, quantum annealers. Although quantum supremacy has not been established thus far, there exist a plethora of algorithms promising to outperform classical computers in the near-term future. Here, we propose a parallel in time approach to simulate dynamical systems designed to be executed already on present-day quantum annealers. In essence, purely classical methods for solving dynamics systems are serial. Therefore, their parallelization is substantially limited. In the presented approach, however, the time evolution is rephrased as a ground–state search of a classical Ising model. Such a problem is solved intrinsically in parallel by quantum computers. The main idea is exemplified by simulating the Rabi oscillations generated by a two-level quantum system (i.e. qubit) experimentally.

3. **Andrej Gendiar:** CAN STRONG INTERACTIONS AFFECT MAJORANA'S?

   The existence of Majorana bound states has been confirmed for various low-dimensional fermion models. Recently, a weak fermion interaction has been introduced by applying Bosonization techniques which linearize the dispersion law. In the current study, we investigate the impact of the moderate and strong Coulomb interactions on the stability of Majorana fermions. Having considered a sufficiently strong interaction, the violation of the exponentially decaying Majorana quantum states remains questionable. For this purpose, we impose both the on-site and the nearest-neighbor repulsive interactions on the system and analyze it by generalized Density Matrix Renormalization Group (no symmetries conserve in such systems, apart from the electron parity). The spin-fermion model is described by a one-dimensional InSb wire in proximity of a superconductor with spatially modulated spin-orbit couplings, Zeeman magnetic effects, and the Coulomb interactions. The impact of the strong Coulomb interaction on the Majorana wave functions is discussed.

4. **Anna Jenčová:** INCOMPATIBILITY IN GPT AND TENSOR NORMS

   Authors: A. Bluhm, A. Jenčová, I. Nechita

   We study incompatibility of measurements in general probabilistic theories (GPT), from a geometric point of view. We concentrate on collections of two-outcome measurements, or effects, and discuss several characterizations of (in)compatible collections of effects. For this, we use a representation of a collection of effects as a positive map on a section of a simplicial cone and show that the collection is compatible iff this map is extendible, resp. entanglement breaking. Another characterization uses a generalization of free spectrahedra from the matrix case. Further, a notion of incompatibility degree is studied and it is shown that it is related to properties of certain cross norms on the tensor product of the space of the GPT with l_1^k. In the case of centrally symmetric GPTs, we show that the maximal attainable incompatibility degree for a collection of k effects is given by the ratio of the minimal and the maximal cross norm.

5. **Aleksandra Krawiec:** ASYMPTOTIC ENTROPY OF THE GIBBS STATE

   Authors: A. Glos, A. Krawiec, Ł. Pawela

   We study the entropy of the Gibbs state corresponding to a graph. The Gibbs state is obtained from the Laplacian, normalized Laplacian or adjacency matrices associated with a graph. We calculated the entropy of the Gibbs state for a few classes of graphs and studied their behavior with changing graph order and temperature. We illustrate our analytical results with numerical simulations for Erdős-Rényi, Watts-Strogatz, Barabási-Albert and Chung-Lu graph models and a few real-world graphs.

6. **Roman Krčmár:** TENSOR NETWORKS IN PHYSICS

   In the talk the definition of the tensor network (TN) will be provided and its graphical representation will be presented. Various geometries one dimensional, two dimensional and fractal will be discussed. Use of the TNs in the classical and quantum physics will be explained with the emphasis on the Corner Transfer Matrix Renrmalization Group (CTMRG) and the Higher Order Tensor Renormalization Group (HOTRG) methods.

7. **Daniel Reitzner:** NAVIGATING A MAZE USING QUANTUM-WALK SEARCHES

   Authors: D. Reitzner, M. Hillery

   We show that it is possible to use a quantum walk to find a path from one marked vertex to another. In the specific case of M stars connected in a chain, one can find the path from the first star to the last one in $O(M\sqrt{N})$ steps, where N is the number of spokes of each star. First we provide an analytical result showing that by starting in a phase-modulated highly superposed initial state we can find the path in $O(M\sqrt{N} log M)$ steps. Next, we improve this efficiency by showing that the recovery of the path can also be performed by a series of successive searches when we start at the last known position and search for the next connection in $O(\sqrt{N})$ steps leading to the overall efficiency of $O(M\sqrt{N})$. For this result we use the analytical solution that can be obtained for a ring of stars of double the length of the chain.

8. **Sazim Sheikh:** REVERSE ENTROPY POWER INEQUALITY FOR QUDITS

   We prove a reverse entropy power inequality for qudits conjectured in [1]. The underlying addition rule for which these inequality hold is given by a quantum channel that depends on the parameter $a \in [0, 1]$ and acts like a finite-dimensional analogue of a beam splitter with transmissivity a, converting a two-qudit product state into a single qudit state. We refer to this channel as a partial swap channel because of the particular way its output interpolates between the states of the two qudits in the input as a is changed from zero to one.

   We also show that the quantum addition operation commutes with an incoherent channel, which may have possible implications for resource theories of coherence.

   [1] L. Zhang, J. Wang, Z. Chen, *Spectral density of mixtures of random density matrices for qubits*, Phys. Lett. A **382,** 1516 (2018).

Posters

1. PRIVATE QUANTUM CHANNELS FOR MULTI-PHOTON PULSES AND UNITARY k-DESIGNS

   Authors: Jan Bouda, Michal Sedlák, Mário Ziman

   We address the question of existence of private quantum channel for qubits encoded in polarization degrees of freedom of a photon, that remains secure even if multi-photon (instead of single-photon) pulse is emitted. We show that random unitary channel distributed according to $SU(2)$ Haar measure has this property. Further we analyze the qubit unitary k-designs. We show they ensure security only if the photons' parity of the source is guaranteed. Otherwise, unlike in case of private quantum channels single-photon sources the qubit unitary k-designs do not guarantee perfect security.

2. AREA-LAW SCALING OF QUANTUM ISING MODEL OM HYPERBOLIC LATTICE GEOMETRIES (ADS)

   Authors: Andrej Gendiar

   Magnetic properties of the transverse-field Ising model on curved (hyperbolic) lattices are studied by a tensor product variational formulation that we have generalized for this purpose. First we identify the quantum phase transition for each hyperbolic lattice by calculating the magnetization. We study the entanglement entropy at the phase transition in order to analyze the correlations of various subsystems located at the center with the rest of the lattice. We confirm that the entanglement entropy satisfies the area law at the phase transition for fixed coordination number, i.e., it scales linearly with increasing size of the subsystems. On the other hand, the entanglement entropy decreases as power-law with respect to the increasing coordination number.

3. QUANTUM POTTS MODELS ON THE SIERPIŃSKI PYRAMID

   Authors: Roman Krčmár, Mária Zelenayová, Libor Caha, Peter Rapčan, Tomotoshi Nishino, Andrej Gendiar

   Phase transition of the two- and three-state quantum Potts models on the Sierpiński pyramid are studied by means of a tensor network framework, the higher-order tensor renormalization group method (HOTRG). Critical values of the transverse magnetic field and the magnetic exponent β are evaluated. Despite the fact that the Hausdorff dimension of the Sierpiński pyramid is exactly two ($= \log_2 4$), the obtained critical properties show that the effective dimension is lower than two.

4. STATE PREPARATION BY ALTERNATING HAMILTONIANS

   Authors: Denisa Lampášová, Daniel Nagaj

   The aspiration was to investigate the potential and limitations of a promising quantum algorithm for approximate optimization – the Quantum approximate optimization algorithm (QAOA). We have decided to do this by exploring the range of states one can reach using QAOA's lowest-complexity versions, with emphasis on the reachability of computational basis states. That is because the results of the computational basis measurement performed on the prepared states represent candidate solutions/near-optimal solutions to the combinatorial optimization problems we wish to solve. Such analysis led us to three interesting results.

   The first one applies to the search for optimal QAOA's parameters – a part that is essential for the success of QAOA but also challenging. We present (and prove) the existence of several symmetries that reduce the number of parameter values needed to examine to $\frac{1}{2 \cdot 8^p}$ of the initially required amount. Furthermore, we have shown that the lowest-complexity ($p = 1$) QAOA can be used for the efficient preparation of GHZ states with an odd number of qubits. Based on numerical evidence, we also assume that $p = 2$ QAOA will extend this possibility to an even number of qubits. The last result concerns the limitations of this algorithm. Even for simple MaxCut instances that can be solved by classical computers in linear time (or one round in gate model of computation), a low-round QAOA cannot reach computational basis states with sufficient probability (including the MaxCut solutions). More precisely, using numerical tools, we have shown that the probability of reaching the optimal MaxCut solutions for rings (2-regular, connected graphs) decreases exponentially with the number of qubits/vertices. This result leads us to assume that QAOA cannot be very successful when limited only to a few rounds.

5. EQUIVALENCE OF QUANTUM PROCESSORS

   Authors: Jaroslav Pavličko, Mário Ziman

   Quantum processor is device in functionality analogous to the classical processor — its purpose is to transform data in (quantum) computer. Quantum processor has data and program register. State in program register decides which completely positive map is applied on data register. There exist two basic types of processors — deterministic and probabilistic. In deterministic processor, program state deterministically decides which transformation is applied. Deterministic processors are not universal — one processor cannot apply arbitrary transformation. Stochasticity is introduced in probabilistic processors through measurement on the program register. Probabilistic processors are universal. Equivalence of quantum processor means that two distinct processor can apply the same transformations on the data (in case of probabilistic processor there is additional requirement that both processors must apply transformations with at least some probability).

   Sufficient and necessary conditions were proved for deterministic and probabilistic processors with the same dimensions of program space. Sufficient conditions for deterministic and probabilistic processors with different dimensions of program spaces were found. Also, relation for being deterministically and probabilistically equivalent at the same time was uncovered.

6. ON SOME PROPERTIES OF CRITICAL QUANTUM SPIN CHAINS AT ZERO TEMPERATURE. *Authors:* Andre M. C. Souza, Peter Rapčan, Constantino Tsallis

   We study the ground state of the one-dimensional spin-1/2 Ising ferromagnet at its transverse-field critical point, which is an entangled state following the area law with a logarithmic correction. When this problem is expressed in terms of independent fermions, we show that the usual thermostatistical sums emerging within Fermi-Dirac statistics can, for an L-sized subsystem, be indistinctively taken up to L terms or up to $\propto \ln L$ terms, providing a neat understanding of the origin of the logarithmic scaling of the entanglement entropy in the system. This is interpreted as a compact occupancy of the phase-space of the L-subsystem, hence standard Boltzmann-Gibbs thermodynamics quantities with an effective system size $V \propto \ln L$ are appropriate and are explicitly calculated. The calculations can then be done in a Hilbert space whose effective dimension is 2^V instead of 2^L. In this we can assume ergodicity. We show explicitly how the constant of proportionality in $V \propto \ln L$ depends on the desired numerical precision and we hypothesize the relation between the proportionality constant, at any fixed finite precision, and the universality class of the critical chain in question. Most of the results are are based on the paper [1]

   [1] A.M.C. Souza, P. Rapčan, C. Tsallis, *Area-law-like systems with entangled states can preserve ergodicity,* Eur. Phys. J. Spec. Top. **229,** 759 (2020).

7. GROVER SEARCH UNDER LOCALIZED DEPHASING

   Authors: Daniel Reitzner, Mark Hillery

   Decoherence in quantum searches and in Grover search in particular has already been extensively studied, leading very quickly to the loss of the quadratic speedup over the classical case, when searching for some target (marked) element within a set of size N. The noise models used were, however, global. In this paper we study Grover search under the influence of localized partially dephasing noise of rate p. We find, that in the case when the size k of the affected subspace is much smaller than N, and the target is unaffected by the noise, namely when $kp \ll \sqrt{N}$, the quadratic speedup is retained. Once these restrictions are not met, the quadratic speedup is lost. In particular, if the target is affected by the noise, the noise rate needs to scale as $1/\sqrt{N}$ in order to keep the speedup. We observe also an intermediate region, where if $k \sim N^{\mu}$ and the target is unaffected, the speedup seems to obey N^{μ}, which for $\mu > 0.5$ is worse than the quantum, but better than the classical case.

8. PROBABILISTIC STORAGE AND RETRIEVAL OF QUBIT PHASE GATES

   Authors: Michal Sedlák and Mário Ziman

   Probabilistic storage and retrieval (PSR) of unitary quantum dynamics is possible with exponentially small failure probability with respect to the number of systems used as a quantum memory [1]. Here we study improvements due to a priori knowledge about the unitary transformation to be stored. In particular, we study $N \to 1$ PSR of qubit phase gates, i.e. qubit rotations around Z axis with an unknown angle, and show that if we access the gate only N-times, the optimal probability of perfect retrieving of its single use is $N/(N+1)$. We propose a quantum circuit realization for the optimal protocol and show that programmable phase gate [2] can be turned into $(2^k - 1) \to 1$ optimal PSR of phase gates and requires only k CNOT gates, while having exponentially small failure probability in k.

[1] M. Sedlák, A. Bisio, M. Ziman, *Optimal Probabilistic Storage and Retrieval of Unitary Channels,* Phys. Rev. Lett. **122,** 170502 (2019),
[2] G. Vidal, L. Masanes, J.I. Cirac, *Storing Quantum Dynamics in Quantum States: A Stochastic Programmable Gate,* Phys. Rev. Lett. **88,** 047905 (2002).

9. CLASSICAL COMMUNICATION WITH INDEFINITE CAUSAL ORDERS FOR N COMPLETELY DEPOLARIZING CHANNELS

   Authors: Sheikh Sazim, Kratveer Singh, and Arun Kumar Pati

   In the presence of indefinite causal order, two identical copies of a completely depolarizing channel can transmit non-zero information. This effect emerges due to the quantum superposition of two alternative orders of these channels. Here, we study how well we can transmit classical information with superposition of N depolarizing channels with multiple number of causal orders and find that there is always an additional classical communication advantage. We also find that there is almost threefold gain in communication if we go from two channels to three channels instead of twofold. We also show that the gain in classical communication rate decreases exponentially with the dimension of the channel and increases rapidly with the increase in the number of causal orders. However, for qubit systems it saturates at 0.31 bits and can never reach the noiseless transmission scenario. Finally, we derive an analytical expression for the Holevo quantity for N completely depolarizing channels with superposition of $M \in [2, N!]$ orders.

10. DISCRIMINATION AND IDENTIFICATION OF POVMS WITH IDENTICAL RANGE

    Authors: Nidhin Sudarsanan Ragini

    The problem of discrimination of observables (POVM's with same underlying outcome-label set) has been addressed in the literature. But this is achieved at the expense of considering every POVM's with identical range to be equivalent. In principle, such POVM's which are within any such equivalence class, are generally different observables in the sense that each map same outcome labels to different effects. In this spirit, each observable within such a class can be seen as having permuted outcome label-effect assignments which define or underly the POVM. This study focuses on discrimination and identification between such observables, POVM's with identical range.

11. PERFORMANCE OF QUANTUM ENGINES FUELLED BY COUPLED QUANTUM SYSTEMS

Authors: Nana Siddhartha Yenamandala

Perfect adiabatic processes are essential to achieving the optimal efficiency of a thermodynamic cycle viz. Otto, Carnot. Necessary and sufficient conditions to achieve shortcuts to adiabaticity using non-markovian dynamics are derived. The effect of imperfect adiabatic processes and their corresponding deviations from optimal performance is systematically described. We also outline a way to suppress inefficiencies in bipartite systems undergoing a quantum Stirling cycle. The formalism is shown to be extensible with minor modifications to higher dimensions, paving the way to study the reliability and performance of thermal devices. A feasible experimental proposal with ultracold atoms is proposed.

12. PHYSICAL PROPERTIES OF QUANTUM SPIN SYSTEMS ON FRACTAL STRUCTURES

Authors: Mária Zelenayová and Andrej Gendiar

Physical properties of phase transition of the quantum spin model on the fractals known as Sierpinski triangle (gadget) and Sierpinski pyramid were studied. We chose the Ising model in the transversal and longitudinal magnetic fields which we investigated using two numerical methods, namely (1) improved mean-field approximation and (2) real-space renormalization group. We identify the critical magnetic field of the phase transition for both Sierpinski fractal structures as well as determine critical the critical exponents beta and delta. An open question arises: how to determine the correct fractal dimension as our results imply that the standard fractal Hausdorff dimension is not suitable for the scaling relations in the terms of universality classes in the theory of condensed matter.

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