BOOK OF ABSTRACTS

18th Central European Quantum Information Processing Workshop

September 5th–September 8th 2023, Smolenice, Slovakia
http://ceqip.eu

CEQIP $|202\rangle|{++}\rangle$

Some things that should not have been forgotten were lost. History became legend. Legend became myth. And for two and a half years, CEQIP passed out of all knowledge ...

But now it is now back as CEQIP $|202\rangle|{++}\rangle$ to cover all years it was forgotten!

CEQIP (Central European Quantum Information Procesing workshop) is traditionally focused on current challenges and paradigms of mathematical and computational aspects of emerging quantum technologies. One of the strengths is the traditionally strong social program creating very friendly and creative atmosphere. Besides traditional wine tasting and a cipher game we plan to visit surrounding natural beauties.

Venue

The workshop will be held in *Smolenice Castle* which history dates back to the 15$^{\text{th}}$ 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.

Invited speakers

- ⋆ Antonio Acín (Barcelona)
- ⋆ Jens Eisert (Berlin)
- ⋆ Sevag Gharibian (Paderborn)
- ⋆ Matthias Kleinmann (Siegen)
- ⋆ Ion Nechita (Toulouse)
- ⋆ Paolo Perinotti (Pavia)
- ⋆ Roope Uola (Geneva)

Selection Comittee

- ⋆ Leevi Leppäjärvi (chair)
- ⋆ Anna Jenčová
- ⋆ Matthias Kleinmann
- ⋆ M. Hamed Mohammady
- ⋆ Natália Móller
- ⋆ Ion Nechita
- ⋆ Martin Plávala
- ⋆ Daniel Reitzner
- ⋆ Michal Sedlák
- ⋆ Roope Uola
- ⋆ Mario Ziman

Organizing Team

- ⋆ Leevi Leppäjärvi
- ⋆ Michal Sedlák
- ⋆ Mario Ziman
- ⋆ Daniel Reitzner
- ⋆ Denisa Lampášová

The workshop is organized by Research Center for Quantum Information, Institute of Physics, Slovak Academy of Sciences (Bratislava) and Quantum Laboratory, Faculty of Informatics, Masaryk University (Brno).

Program

Tuesady, 5.9.2023

16:00	Arrival and registration (with refreshment)
17:00	Evening session
17:00	PAOLO PERINNOTTI (I)
17:40	JENS EISERT (I)
18:20	MATTHIAS KLEINMANN (I)
19:00	End of session
19:00	Welcome dinner

Wednesday, 6.9.2023

08:00	Breakfast
09:00	Morning session
09:00	ANTONIO ACÍN (I)
09:40	TEIKO HEINOSAARI (C)
10:05	NIKOLAI WYDERKA (C)
10:30	MÁTÉ FARKAS (C)
10:55	Coffee & Refreshment
11:30	SEVAG GHARIBIAN (I)
12:10	MIRJAM WEILENMANN (C)
12:35	MATEUS ARAÚJO (C)
13:00	End of session
13:00	Lunch
14:00	Afternoon session
14:00	ROOPE UOLA (I)
14:40	LIN HTOO ZAW (C)
15:05	ALASTAIR ABBOTT (C)
15:30	End of session
15:30	Coffee & Refreshment
16:00	Poster session
18:30	Cipher game registration
18:30	Dinner
19:00	Cipher game

Thursday, 7.9.2023

08:00	Breakfast
09:00	Morning session
09:00	ION NECHITA (I)
09:40	LORENZO MACCONE (C)
10:05	PAOLO ABIUSO (C)
10:30	Group photo
10:35	Coffee & Refreshment
11:00	GIOVANNI SCALA (C)
11:25	PAWEŁ CIEŚLIŃSKI (C)
11:50	LIBOR CAHA (C)
12:15	End of session
12:30	Lunch
13:30	Conference hike
19:30	Conference dinner

Friday, 8.9.2023

09:00	Breakfast
09:20	Morning session
09:20	MOISÉS BERMEJO MORÁN (C)
09:45	MARIA BALANZÓ-JUANDÓ (C)
10:10	MARTIN PLÁVALA (C)
10:35	End of session
10:35	Take Away Refreshment
11:00	Conference bus

(I) Invited talk (35 + 5 min.)
(C) Contributed talk (20 + 5 min.)

Invited talks

1. **Antonio Acín:** Network quantum information processing
2. **Jens Eisert:** Do NISQ devices have applications in machine learning and combinatorial optimization?
3. **Sevag Gharibian:** The optimal depth of variational quantum algorithms is QCMA-hard to approximate
4. **Matthias Kleinmann:** Operational theories in phase-space
5. **Ion Nechita:** Diagonal unitary and orthogonal symmetries in quantum theory
6. **Paolo Perinnotti:** Incompatibility and irreversibility: from Heisenberg to post-quantum theories
7. **Roope Uola:** Genuinely high-dimensional quantum devices

Contributed talks

1. **Alastair Abbott:** Improving social welfare in non-cooperative games with different types of quantum resources
2. **Paolo Abiuso:** Verification of continuous-variable quantum memories
3. **Mateus Araújo:** Quantum key distribution rates from semidefinite programming
4. **Maria Balanzó-Juandó:** All pure multipartite entangled states of qubits can be self-tested up to complex conjugation
5. **Moisés Bermejo Morán:** Bell inequalities with overlapping measurements
6. **Libor Caha:** Single-qubit gate teleportation provides a quantum advantage
7. **Paweł Cieśliński:** Valid and efficient entanglement verification with finite copies of a quantum state
8. **Máté Farkas:** Bell nonlocality is not sufficient for the security of standard device-independent quantum key distribution protocols
9. **Teiko Heinosaari:** Dispensing of quantum information beyond no-broadcasting theorem
10. **Lorenzo Maccone:** Geometric event-based relativistic quantum mechanics
11. **Martin Plávala:** Contextuality as a precondition for entanglement
12. **Giovanni Scala:** What is nonclassical about uncertainty relations?
13. **Mirjam Weilenmann:** Optimisation of time-ordered processes in the finite and asymptotic regime
14. **Nikolai Wyderka:** Refuting spectral compatibility of quantum marginals
15. **Lin Htoo Zaw:** Dynamics-based certification of nonclassicality and entanglement

Posters

1. **Andreas Bluhm:** Polytope compatibility – from quantum measurements to magic squares
2. **Gilberto Borges:** The netQUTE Quantum Key Distribution Network in Slovakia
3. **Pierre Botteron:** Open Question: link between NonLocal Boxes and Communication Complexity?
4. **Susane Calegari:** Contextuality and memory cost of simulation of Majorana fermions
5. **Sébastien Designolle:** Improved local models and new Bell inequalities via Frank-Wolfe algorithms
6. **R Dharmaraj:** Two new genuine measures of entanglement: GBR and GBN
7. **Sophie Egelhaaf:** High-dimensional quantum steering in networks
8. **Kieran Flatt:** Sequential maximum confidence measurements
9. **Aurél Gábris:** Robust quantum search algorithm via non-unitary Zeno-like dynamics
10. **Seyed Arash Ghoreishi:** Revisiting hyperbit limitations unveils quantum communication advantages
11. **Nicolás Gigena:** Biased random access codes
12. **Prabhav Jain:** A tighter version of the Information Causality principle and its implications on quantum correlations
13. **Oskari Kerppo:** Partial-ignorance communication tasks
14. **Shashaank Khanna:** Towards classifying which causal scenarios admit non-classical correlations
15. **Waldemar Klobus:** Salient signatures of entanglement in the surrounding environment
16. **Denisa Lampášová:** Sneaky memory flipping with negligible energy cost
17. **Chiara Leadbeater:** Non-unitary Trotter circuits for imaginary time evolution
18. **Leevi Leppäjärvi:** Simple information processing tasks with unbounded quantum advantage
19. **István Márton:** Certification of quantumness in the prepare-and-measure scenario
20. **Gerard Anglès Munné:** Engineering holography with stabilizer graph codes
21. **Javid Naikoo:** Multiparameter estimation perspective on non-Hermitian singularity-enhanced sensing
22. **Jan Nöller:** Upper bounds on secret key rate in device independent conference key agreement
23. **Ignacio Perito:** Characterization of nonsignaling correlations from mutual information
24. **Martin Johannes Renner:** Simulating qubit correlations with classical communication
25. **Albert Rico:** Entanglement detection with trace polynomials
26. **Ricardo Rivera:** QSAT sub-problem is BQP_1-complete
27. **Sheikh Sazim:** Quantum advantage in random access codes using single d-level system
28. **Michal Sedlák:** Incompatibility of quantum instruments
29. **Ritabrata Sengupta:** Conditions for local transformations between sets of quantum states
30. **Nidhin Sudarshan Ragini:** Single-shot labeling of quantum observables
31. **Jochen Szangolies:** Calibration of syndrome measurements in a single experiment
32. **Lila Cadi Tazi:** Folded Spectrum VQE : A quantum computing method for the calculation of molecular excited states
33. **İskender Yalçınkaya:** Catching a quantum walker by a classical random walker
34. **Mario Ziman:** Quantum dynamics is not strictly bidivisible

Invited talks

1. **Antonio Acín:** NETWORK QUANTUM INFORMATION PROCESSING

   Small quantum networks consisting of several nodes sharing entangled states are within reach with current and near-term technologies. They offer new possibilities for quantum information processing beyond what is achievable in standard point-to-point configurations. In this talk, quantum networks are considered in the device-independent scenario where devices are seen as quantum back boxes processing classical information. We first show how the characterization of correlations in quantum networks is related to the study of causal networks. We then present several results illustrating the possibilities these networks offer in the foundations of quantum physics or for the development of quantum information technologies. In the first case, we show how real quantum theory can be falsified in a small network consisting of three observers in an entanglement swapping configuration. In the second, we discuss a scheme to self-test any pure entangled state.

2. **Jens Eisert:** DO NISQ DEVICES HAVE APPLICATIONS IN MACHINE LEARNING AND COMBINATORIAL OPTIMIZATION?

   There has been substantial excitement recently in identifying tasks for which quantum devices could possibly outperform classical devices. Recent experimental implementations on random circuit sampling have provided strong evidence that near-term quantum devices can outperform classical computers on paradigmatic tasks [Rev. Mod. Phys. 95, 035001 (2023)]. Also, quantum simulators seem to reach regimes out of scope for classical computers. These developments invite further studies to see what further applications of quantum devices could be found. This talk will discuss perspectives of achieving such applications from a rigorous perspective, as is common for CEQIP. Notions of quantum-assisted machine learning are seen as candidates for this. We will have a careful look at such notions of quantum-assisted machine learning, driven by the hope that quantum algorithms could fare better than classical ones in instances of learning tasks. These advantages could refer to computational speedups, but also to better generalization and other figures of merit. We will discuss the comparative power of classical and quantum learners for generative modelling within the probably approximately correct framework, for which we prove a separation between the quantum and classical settings [Quantum 5, 417 (2021), Phys. Rev. A 107, 042416 (2023)]. In the light of new findings on the PAC learnability of the output distributions of near-term local quantum circuits, we will discuss how much structure is actually expected to be required to hope for quantum advantages in quantum-assisted machine learning [arXiv:2110.05517 (2021)]. We prove that the injection of a single T-gate into Clifford circuits renders the task of learning evaluators from samples infeasible in polynomial time. This is in stark contrast to the case of Clifford circuits for which we provide an efficient learning algorithm based on Gaussian elimination [Phys. Rev. Lett. 130, 240602 (2023)]. Finally, we will have a look at the sense in which quantum computers may assist in solving problems of combinatorial optimization. These problems are usually NP-hard in worst case complexity, so it is far from clear what type of quantum advantage one can even hope for, despite commonly made claims of expectations of such advantages in the literature. We discuss a proven super-exponential quantum advantage for combinatorial optimization, providing evidence that quantum computers may indeed be useful for such problems [arXiv:2212.08678 (2022)]. At the end of the talk, we will put these findings into perspective and discuss the potential for near-term quantum computing, including limitations of quantum error mitigation in NISQ devices [arXiv:2210.11505 (2022)], noise being helpful in variational quantum algorithms [arXiv:2210.06723 (2022)], classical surrogates simulating variational quantum algorithms in execution but not in training [Phys. Rev. Lett. 130, in press (2023)] and the exploitation of symmetry in NISQ devices [PRX Quantum 4, 010328 (2023)].

3. **Sevag Gharibian:** THE OPTIMAL DEPTH OF VARIATIONAL QUANTUM ALGORITHMS IS QCMA-HARD TO APPROXIMATE

   Variational Quantum Algorithms (VQAs), such as the Quantum Approximate Optimization Algorithm (QAOA) of [Farhi, Goldstone, Gutmann, 2014], have seen intense study towards near-term applications on quantum hardware. A crucial parameter for VQAs is the depth of the variational "ansatz" used - the smaller the depth, the more amenable the ansatz is to near-term quantum hardware in that it gives the circuit a chance to be fully executed before the system decoheres. In this work, we show that approximating the optimal depth for a given VQA ansatz is intractable. Formally, we show that for any constant $\epsilon > 0$, it is QCMA-hard to approximate the optimal depth of a VQA ansatz within multiplicative factor $N^{(1-\epsilon)}$, for N denoting the encoding size of the VQA instance. (Here, Quantum Classical Merlin-Arthur (QCMA) is a quantum generalization of NP.) We then show that this hardness persists in the even "simpler" QAOA-type settings. To our knowledge, this yields the first natural QCMA-hard-to-approximate problems.

4. **Matthias Kleinmann:** OPERATIONAL THEORIES IN PHASE-SPACE

   Quantum theory has been established to be a special case of the generalized probabilistic theories, which encompass all theories featuring preparation procedures and measurements. Intriguingly, those theories include instances where the correlations reach beyond anything possible according to quantum theory or classical probability theory. However, in this framework, there is no constructive way to suggest an experiment that could achieve such correlations and hence test the validity of quantum theory in that respect. We address this defect by a phase-space description of operational theories allowing us to describe experiments on common systems, such as the harmonic oscillator or the hydrogen atom. Accordingly, we can make predictions on the spectrum, position density, or the time-evolution for theories that are neither classical or quantum mechanical. I will give an introduction to this framework and show how it adds new insights into quantum mechanics and how new experiments can test the structure of any theory of microscopic systems.

5. **Ion Nechita:** DIAGONAL UNITARY AND ORTHOGONAL SYMMETRIES IN QUANTUM THEORY

   We discuss bipartite operators which stay invariant under the local action of the diagonal unitary and orthogonal groups. We investigate structural properties of these operators, arguing that the diagonal symmetry makes them suitable for analytical study, and that they are a rich source of (couter-)examples in the theory of quantum information. We focus on positive semi-definite operators, and relate their separability to completely positive matrices and some generalizations of this notion.

6. **Paolo Perinnotti:** INCOMPATIBILITY AND IRREVERSIBILITY: FROM HEISENBERG TO POST-QUANTUM THEORIES

   In Heisenberg's work on the uncertainty principle, two facets of non classicality were discussed— though at very different depths—that are manifest in quantum theory. One is the irreducible disturbance on a system that comes with every observation, and this was just touched upon in the intuitive argument involving the gamma ray microscope thought experiment. The second one, which is the real stuff the uncertainty principle proves, is incompatibility of different measurements on the same system. We will formulate and analyse the above features in the wide context of operational probabilistic theories, that are theories of information sharing with quantum and classical theory the structures describing parallel and sequential composition of processes, but allowing for a variety of new system types, with possibly odd properties. We will provide various conditions for the presence or absence of measurement disturbance and incompatibility, connecting them with other properties of the theory at hand. We will discuss, in particular, to what extent the two features are distinctive traits of non-classicality. While the presence of incompatible observations always implies irreversibility, the converse is not true. This will be shown through a theory that provides a concrete counterexample: Minimal Classical Theory (MCT).

7. **Roope Uola:** GENUINELY HIGH-DIMENSIONAL QUANTUM DEVICES

   High-dimensional quantum systems form a rapidly developing research field that covers both theoretical and experimental aspects of quantum communication and, more generally, quantum information theory. These systems provide various advantages over their low-dimensional counterparts in terms of, for example, noise resilience and information carrying capacity. In order to reach such benefits, one needs to possess a system that is not effectively low-dimensional. In this theory talk, I will introduce the concept of genuine high-dimensionality for a range of quantum devices, and discuss how this leads to experimentally testable criteria that can rule out central low-dimensional simulation protocols in a semi-device independent manner.

Contributed talks

1. **Alastair Abbott:** Improving social welfare in non-cooperative games with different types of quantum resources

   We investigate what quantum advantages can be obtained in multipartite non-cooperative games by studying how different types of quantum resources can lead to new Nash equilibria and improve social welfare - a measure of the quality of an equilibrium. Two different quantum settings are analysed: a first, in which players are given direct access to an entangled quantum state, and a second in which they are only given classical advice obtained from quantum devices. We show that the latter strategy is strictly more powerful than the former, and use self-testing methods to prove this. Making use of SDP optimisation methods, we obtain upper and lower bounds on the social welfare reachable in each setting and investigate how these quantities depend on the bias of the game.

2. **Paolo Abiuso:** Verification of continuous-variable quantum memories

   A proper quantum memory consists in a quantum channel which cannot be simulated with a measurement followed by classical information storage and a final state preparation. This corresponds to the fact that a quantum memory should be non entanglement breaking (non-EB). Here, we study the semi-device-independent certification of non-EB channels in continuous variable systems. We provide a simple witness based on adversarial metrology, and describe an experimentally friendly protocol that can be used to verify a vast class of Gaussian quantum memories. Our results can be applied to test other devices, such as quantum transducers and transmission lines.

3. **Mateus Araújo:** Quantum key distribution rates from semidefinite programming

   Computing the key rate in quantum key distribution (QKD) protocols is a long standing challenge. Based on a recently discovered semidefinite programming (SDP) hierarchy converging to the conditional von Neumann entropy, used for computing the asymptotic key rates in the device independent case, we introduce an SDP hierarchy that converges to the asymptotic secret key rate in the case of characterised devices. The resulting algorithm is efficient, easy to implement and easy to use. We illustrate its performance by recovering known bounds on the key rate and extending high-dimensional QKD protocols to previously intractable cases. We also use it to reanalyse experimental data to demonstrate how higher key rates can be achieved when the full statistics are taken into account.

4. **Maria Balanzó-Juandó:** All pure multipartite entangled states of qubits can be self-tested up to complex conjugation

   In this work, we give a complete characterization of self-testing in the multipartite qubit case. While the bipartite case has been completely characterized for states of any local dimension, little is known for the multipartite case. One important difference is that, while in the bipartite case all states are equivalent, up to local isometries, to their complex conjugates in any basis, this is not true in the multipartite case. Here, for any pure multipartite entangled state of qubits which is equivalent to its complex conjugate, we exhibit a correlation that self-tests it. On the other hand, for any state which is not equivalent to its complex conjugate, we exhibit a correlation that singles out the state up to complex conjugation.

5. **Moisés Bermejo Morán:** Bell inequalities with overlapping measurements

   The study of Bell non-locality is both of fundamental and practical interest, with breakthrough implications in information processing and cryptography. Most research in the field focuses on the traditional non-signalling scenario, which may be insufficient to exploit the full potential of state of the art quantum technologies. For this purpose, a deeper understanding of the distribution of non-locality in a multipartite system is crucial. Analogous to the quantum marginal problem, we pose a compatibility problem for non-locality: what correlations can be obtained in a multipartite quantum system by players that are allowed to measure overlapping collections of subsystems? Our work adapts standard methods in the study of quantum correlations to these more general scenarios.

6. **Libor Caha:** Single-qubit gate teleportation provides a quantum advantage

   Gate-teleportation circuits are arguably among the most basic examples of computations believed to provide a quantum advantage: Terhal and DiVincenzo [Quantum Inf. Comput., 4(2):134–145] have shown that these circuits elude simulation by efficient classical algorithms under complexity-theoretic assumptions. Here we consider a weak form of this task – possibilistic simulation [Phys. Rev. A 106, 062430 (2022)], where the goal is to output any string that appears in the support of the output distribution. We show that even for single-qubit Clifford-gates this simulation problem cannot be solved by constant-depth classical circuits with bounded fan-in gates. Our results are unconditional and are obtained by a reduction to the problem of computing parity.

7. **Paweł Cieśliński:** Valid and efficient entanglement verification with finite copies of a quantum state

   The level of confidence in entanglement detection can be used to quantify the validity of the detection scheme via the probability that the measured signal came from a separable state. Yet, for limited sample sizes, to avoid serious misinterpretations of the experimental results, one should also include information about the probability of it coming from an entangled state, i.e. the efficiency of the scheme. We demonstrate this explicitly and propose a general method applicable to arbitrary entanglement witnesses to optimise both the validity and the efficiency in small data sets. As an example, we derive the optimal number of measurement settings and distribution of clicks per setting that guarantee high validity and efficiency of entanglement verification with only 20 copies of a state.

8. **Máté Farkas:** BELL NONLOCALITY IS NOT SUFFICIENT FOR THE SECURITY OF STANDARD DEVICE-INDEPENDENT QUANTUM KEY DISTRIBUTION PROTOCOLS

   We provide a generic tool for upper-bounding key rates in device-independent quantum key distribution protocols. We apply our tools to standard protocols, in which both parties announce their measurement settings. For a large class of nonlocal correlations–obtained by measuring a two-qubit Werner state with arbitrarily many projective measurements—our upper bound is zero. This means that nonlocality of the observed correlations is in general not sufficient for the security of standard protocols. As a special case, we show that the most commonly used CHSH-based protocols become insecure in the large-noise regime, even though the correlations are still nonlocal.

9. **Teiko Heinosaari:** DISPENSING OF QUANTUM INFORMATION BEYOND NO-BROADCASTING THEOREM

   The no-broadcasting theorem is a fundamental result in quantum information theory. Understanding the precise boundaries of this limitation is crucial due to its significance. In this study, we expand upon the standard definition of broadcasting by introducing the concept of a broadcasting test. This test involves restricting the set of states to be broadcast and the sets of measurements used for testing. We analyze and classify various cases, explaining their operational implications through illustrative examples. We introduce a mathematical framework that enables us to analyze all special cases. Interestingly, broadcasting is equivalent to commutativity in certain scenarios, while in others commutativity is not necessary.

10. **Lorenzo Maccone:** GEOMETRIC EVENT-BASED RELATIVISTIC QUANTUM MECHANICS

    We propose a special relativistic framework for quantum mechanics. It is based on introducing a Hilbert space for events. Events are taken as primitive notions (as customary in relativity), whereas quantum systems (e.g. fields and particles) are emergent in the form of joint probability amplitudes for position and time of events. Textbook relativistic quantum mechanics and quantum field theory can be recovered by dividing the event Hilbert spaces into space and time (a foliation) and then conditioning the event states onto the time part. Our theory satisfies the full Poincare' symmetry as a 'geometric' unitary transformation, and possesses relativistic observables for space (location of an event) and time (position in time of an event).

11. **Martin Plávala:** CONTEXTUALITY AS A PRECONDITION FOR ENTANGLEMENT

    Quantum theory features several phenomena which are considered as resources for information processing tasks. Some of these effects, such as entanglement, arise in a non-local scenario. Other phenomena, such as contextuality can be observed, if quantum states are prepared and then subjected to sequences of measurements. Here we provide a connection between these resources by proving that entanglement in a non-local scenario can only arise if there is preparation & measurement contextuality in a sequential scenario derived from the non-local one by remote state preparation. Our result allows us to translate any inequality for testing preparation & measurement contextuality into an entanglement test; in addition, entanglement witnesses can be used to obtain novel noncontextuality inequalities.

12. **Giovanni Scala:** WHAT IS NONCLASSICAL ABOUT UNCERTAINTY RELATIONS?

    Uncertainty relations are generally considered to be a way in which quantum theory entails a departure from the classical worldview. However, this view is undermined by the fact that there exist theories which exhibit uncertainty relations but are generalized noncontextual. In this work we identify an aspect of uncertainty relations that constitutes evidence of genuine nonclassicality. We show that, for a class of theories with a particular symmetry property, the functional form of the predictability tradeoff between a pair of binary outcome measurements is constrained by noncontextuality to be below a linear curve. Qubit quantum theory has the symmetry property and violates the noncontextual bound, thus showing how the functional form of uncertainty relations can witness contextuality.

13. **Mirjam Weilenmann:** OPTIMISATION OF TIME-ORDERED PROCESSES IN THE FINITE AND ASYMPTOTIC REGIME

    Many problems in quantum information theory can be formulated as optimizations over the sequential outcomes of dynamical systems subject to unpredictable external influences. These include many-body entanglement detection through adaptive measurements and limiting the behavior of a (quantum) finite-state automaton. Here, we introduce tractable relaxations of this class of optimization problems. To illustrate their performance, we apply them to problems in finite-state automata, entanglement detection and magic state detection. We further show that the maximum score of a sequential problem in the limit of infinitely many time-steps is in general incomputable. Nonetheless, we provide general heuristics to bound this quantity and show that they provide useful estimates.

14. **Nikolai Wyderka:** REFUTING SPECTRAL COMPATIBILITY OF QUANTUM MARGINALS

    The spectral variant of the quantum marginal problem asks: Given prescribed spectra for a set of quantum marginals, does there exist a compatible joint state? The main idea of this work is a symmetry-reduced semidefinite programming hierarchy for detecting incompatible spectra. The hierarchy is complete, in the sense that it detects every incompatible set of spectra.

The refutations it provides are dimension-free, certifying incompatibility in all local dimensions. The hierarchy equally applies to the sums of Hermitian matrices problem, to optimize trace polynomials on the positive cone, to the compatibility of invariants, and to certify vanishing Kronecker coefficients.

15. **Lin Htoo Zaw:** DYNAMICS-BASED CERTIFICATION OF NONCLASSICALITY AND ENTANGLEMENT

We recently introduced a series of protocols that certify the nonclassicality or entanglement of suitable states of quantum systems, under the assumption that the measured dynamical observable undergoes a known time evolution. These works are based on an unexpected observation by Tsirelson about the quantum harmonic oscillator: despite its time evolution being the same as its classical counterpart—a precession in phase space—its nonclassicality can be detected by probing its position at different times. Our protocols do not rely on sequential or simultaneous measurements, as only one randomly-chosen measurement is performed in each round. They are also more akin to Bell inequalities than to uncertainty relations: in particular, they do not admit false positives from classical theory.

Posters

1. **Andreas Bluhm:** Polytope compatibility – from quantum measurements to magic squares

   Several central problems in quantum information theory such as measurement compatibility can be rephrased as membership in the minimal matrix convex set corresponding to special polytopes such as the hypercube. To generalize this idea, we introduce the notion of polytope compatibility. We find that semiclassical magic squares correspond to Birkhoff polytope compatibility. We prove that polytope compatibility is in one-to-one correspondence with measurement compatibility, when the measurements have some elements in common and the post-processing of the joint measurement is restricted. Finally, we consider how much appropriate tuples of operators must be scaled in order to become polytope compatible and give both analytical sufficient conditions and numerical ones based on linear programming.

2. **Gilberto Borges:** The netQUTE Quantum Key Distribution Network in Slovakia

   Quantum Key Distribution(QKD) promises an unconditional security based on the laws of quantum physics that eavesdroppers cannot retrieve key information without inducing disturbances. Therefore, QKD enables two remote parties to share sequences of private key to realize secure communication without relying on an assumption of attacker's limited computing power. Among current implementations, one recent work has demonstrated that entanglement-based QKD serves as one of the most suitable candidate for creating fully connected topologies, which greatly reduces the overhead cost of adding a new user. In this work, we report the plan of building the backbone infrastructure of a national Slovak and the current developed entangled photon pair source. A broadband of entangled pair emitter is realized by utilizing the parametric down conversion process in a Sagnac interferometer with a visibility of near 99 %.

3. **Pierre Botteron:** Open Question: link between NonLocal Boxes and Communication Complexity?

   Non-signalling boxes (NS) are theoretical resources that generalize quantum correlations (Q). Some of them are known to collapse communication complexity (CC), although this collapse is strongly believed to be impossible in Nature. It is still an open question to determine what post-quantum boxes indeed collapse CC. In this poster, we present a partial answer, presenting new collapsing non-signalling boxes.

4. **Susane Calegari:** Contextuality and memory cost of simulation of Majorana fermions

   We prove state-independent contextuality for Majorana fermions via graph theory and demonstrate that contextuality gives lower bounds on the memory cost of simulating restricted classes of quantum computation. Specifically, we apply these results to two models of quantum computation based on the braiding of Majorana fermions: Topological Quantum Computation (TQC) with Ising anyons and Fermionic Linear Optics (FLO), finding saturable lower bounds on the memory cost that scales, respectively, log-linearly and quadratically with the number of fermionic modes. Showing those pre-existing simulation algorithms based on the stabilizer and matchgate formalism asymptotically saturate the above bounds on the memory cost.

5. **Sébastien Designolle:** Improved local models and new Bell inequalities via Frank-Wolfe algorithms

   In Bell scenarios with two outcomes per party, we algorithmically consider the membership problem for the local polytope: constructing local models and deriving separating hyperplanes (Bell inequalities). We take advantage of recent developments in Frank-Wolfe algorithms to increase the convergence rate of existing methods. As an application we study the threshold value for the nonlocality of two-qubit Werner states under projective measurements. Here, we improve on both the upper and lower bounds known so far. Our bounds are analytical and yield bounds on the Grothendieck constant of order 3. We also address multipartite scenarios and give the first local models with visibilities noticeably higher than the entanglement threshold.

6. **R Dharmaraj:** Two new genuine measures of entanglement: GBR and GBN

   Even though various Genuine Measures of Entanglement (GME's) for multipartite pure states exist, there are certain limitations to them. We have defined and demonstrated features of a new GME (called GBR) based on the geodesic distance in state space, which overcomes the limitations. Later, we define a GME for mixed states (called GBN) through an alternate approach in geometry. A major drawback with existing mixed state measures is that they can't detect various bound entangled states. Bound entanglement has been proven to be useful in information processing protocols. The newly defined GBN is highly discriminant and can detect various bound entangled states. We have shown through examples that GBN could reveal new properties of entanglement dynamics that haven't been observed previously.

7. **Sophie Egelhaaf:** High-dimensional quantum steering in networks

   Bipartite low dimensional entanglement has been studied extensively. However, many findings cannot be extrapolated to multiple parties and moreover, increasing the dimensions of the systems adds complexity to the entanglement structure. We are interested in characterizing the degree of high-dimensional entanglement, specifically focusing on various multipartite quantum steering scenarios. One such example is a triangle network with only one trusted party, or more generally a line network with some trusted parties. We investigate what can be deduced about the strength of entanglement between the different nodes of the network in such scenarios. We are especially interested in entanglement dimensionality, i.e. the question of how many degrees of freedom can be certified to be entangled, for which we provide analytical bounds.

8. **Kieran Flatt:** SEQUENTIAL MAXIMUM CONFIDENCE MEASUREMENTS

   Sequential state discrimination is a form of state discrimination in which multiple parties aim to determine, through repeated measurement of the same quantum system, which state was prepared from some ensemble. Previous schemes have been based on unambiguous state discrimination, which is limited in its application. Here, we present a new sequential scheme based on maximum confidence measurements, which generalise unambiguous approaches. We characterise both the scenarios in which it can perform optimally, propose an alternative scheme which is applicable to all ensembles and analyse the latter's performance in some concrete examples.

9. **Aurél Gábris:** ROBUST QUANTUM SEARCH ALGORITHM VIA NON-UNITARY ZENO-LIKE DYNAMICS

   We propose and analyze a non-unitary variant of the continuous time Grover search algorithm based on frequent Zeno-type measurements. We show that the algorithm scales similarly to the pure quantum version by deriving tight analytical lower bounds on its efficiency for arbitrary database sizes and measurement parameters. We study the behavior of the algorithm subject to noise, and find that under certain oracle and operational errors our measurement-based algorithm outperforms the standard algorithm, showing robustness against these noises.

10. **Seyed Arash Ghoreishi:** REVISITING HYPERBIT LIMITATIONS UNVEILS QUANTUM COMMUNICATION ADVANTAGES

    Pawlowski and Winter's Hyperbit Theory, proposed in 2012, presented itself as a captivating alternative to quantum theory, suggesting novel ways of redefining entanglement and classical communication paradigms. This research undertakes a meticulous reevaluation of Hyperbit Theory, uncovering significant operational constraints that question its equivalence with quantum mechanics. Crucially, the supposition that Hyperbit Theory and Quantum Theory are equivalent relies on the receiver having unattainable additional knowledge about the sender's laboratory, indicating that the work by Pawlowski and Winter is incorrect. This study accentuates the constraints of hyperbits in information processing and sheds light on the superiority of quantum communication, thereby advancing the investigation at the intersection of classical and quantum communication.

11. **Nicolás Gigena:** BIASED RANDOM ACCESS CODES

    A Random Access Code (RAC) is a communication task in which the sender encodes a random message into a shorter one to be decoded by the receiver, so that a randomly chosen character of the original message is recovered with some probability. In this paper we extend this protocol by allowing more general distributions for the inputs, which alters the encoding and decoding strategies optimizing the protocol performance, either with classical or quantum resources. We first approach the problem numerically and introduce a Python package that optimizes the RAC value over both classical and quantum strategies. We then use this numerical tool to investigate single-parameter families of biased RACs in the $n^2 \mapsto 1$ and $2^d \mapsto 1$ scenarios, for which we derive analytical results.

12. **Prabhav Jain:** A TIGHTER VERSION OF THE INFORMATION CAUSALITY PRINCIPLE AND ITS IMPLICATIONS ON QUANTUM CORRELATIONS

    Information causality is a physical principle which has been used successfully in the past to bound the set of observed quantum correlations. In this work, we devise a general and computationally simple tool to derive quantum Bell inequalities in a general bipartite nonlocality scenario, and apply it to a family of scenarios with arbitrary number of settings and outcomes. Moreover, we derive a tighter version of information causality, which allows us to obtain tighter bounds on correlations is previously considered scenario using our new tool. Specifically, we derive inequalities which are tighter than Uffink inequality in the CHSH scenario.

13. **Oskari Kerppo:** PARTIAL-IGNORANCE COMMUNICATION TASKS

    We introduce a specific type of communication task between Alice and Bob, where the goal is for Bob to exclude certain outcomes based on a state sent by Alice and by an additional input sent by a third party. These communication tasks are called partial-ignorance communication tasks. Various methods are used to obtain optimal strategies and bounds on success probabilities, including semidefinite programming, ultraweak monotones for communication matrices, and frame theory for quantum states. The simplest instances of this communication task family are studied exhaustively for bits and qudits. Semidefinite programming methods can be used to derive numerical bounds, while frame theory can be used in conjunction with the Helstrom bound to derive analytical bounds.

14. **Shashaank Khanna:** TOWARDS CLASSIFYING WHICH CAUSAL SCENARIOS ADMIT NON-CLASSICAL CORRELATIONS

    We extend the work of Henson Lal and Pusey (HLP). to classify "interesting" causal structures which can possess non-classical correlations. We show strong evidence that HLP's condition to test if a causal scenario is boring in the sense that it cannot exhibit non-classical correlations is both necessary and sufficient. We also provide a theorem based on a graphical condition called "e-separation" to attest if a causal scenario can definitely possess non-classical correlations. Applying this along with the framework of mDAGs we are able to solve the problem of finding "interesting" causal scenarios of total 7 nodes significantly.

15. **Waldemar Klobus:** SALIENT SIGNATURES OF ENTANGLEMENT IN THE SURROUNDING ENVIRONMENT

    We develop a model in which presence of entanglement in a quantum system can be confirmed through coarse observations of the environment surrounding the system. This counter-intuitive effect becomes possible when interaction between the system and its environment is proportional to an observable being an entanglement witness. While presenting intuitive examples we show that: 1) a cloud of an ideal gas, when subject to a linear potential coupled with the entanglement witness, accelerates in the direction dictated by the sign of the witness; 2) when the environment is a radiation field, the direction of dielectric polarization depends on the presence of entanglement; 3) quadratures of electromagnetic field in a cavity coupled with two qubits (or a 4-level atom) are displaced in the same manner.

16. **Denisa Lampášová:** SNEAKY MEMORY FLIPPING WITH NEGLIGIBLE ENERGY COST

    Consider a quantum memory or an error-correcting code where degenerate ground states of a Hamiltonian represent codewords; and where a constant energy barrier to excited states and no direct local transformation from one ground state to another protect codewords from errors. Could an error-correcting codeword evolve into a different codeword, undetected, even though we would often check whether the word is still in the codespace and correct possible errors? We analyze unexpected ways to sneakily (keeping the intermediate energy low) flip naive Ising-like memories. We argue that the ability to locally distinguish ground states can result in shorter ground-state traversal paths.

17. **Chiara Leadbeater:** NON-UNITARY TROTTER CIRCUITS FOR IMAGINARY TIME EVOLUTION

    We propose an imaginary time equivalent of the well-established Pauli gadget primitive for Trotter-decomposed real time evolution. Imaginary time evolution is widely used for obtaining the ground state of a system on classical hardware. Near-term implementations on quantum hardware rely on heuristics, compromising their accuracy. Since it is not possible to implement a non-unitary gate deterministically, we resort to the implementation of probabilistic imaginary time evolution algorithms, which rely on a unitary quantum circuit to simulate a block encoding of the ITE operator - that is, they rely on successful ancillary measurements to evolve the system non-unitarily.

18. **Leevi Leppäjärvi:** SIMPLE INFORMATION PROCESSING TASKS WITH UNBOUNDED QUANTUM ADVANTAGE

    Communication scenarios between two parties can be implemented by first encoding messages into some states of a physical system which acts as the physical medium of the communication and then decoding the messages by measuring the state of the system. We show that already in the simplest possible scenarios it is possible to detect a definite, unbounded advantage of quantum systems over classical systems. We do this by constructing a family of operationally meaningful communication tasks each of which on one hand can be implemented by using just a single qubit but which on the other hand require an unboundedly larger classical system for classical implementation. Furthermore, we show that even though with the additional resource of shared randomness the proposed communication tasks can be implemented by both quantum and classical systems of the same size, the number of coordinated actions needed for the classical implementation also grows unboundedly. In particular, no finite storage can be used to store all the coordinated actions needed to implement all the possible quantum communication tasks with classical systems. As a consequence, shared randomness cannot be viewed as a free resource.

19. **István Márton:** CERTIFICATION OF QUANTUMNESS IN THE PREPARE-AND-MEASURE SCENARIO

    We have tested the quantumness of two-dimensional systems in the prepare-and-measure scenario with n preparations and m binary-outcome measurement settings, where n and m fall well into the range of 70. In this setup, a real $n \times m$ matrix M defines the coefficients of a linear witness. $L_2(M)$ is the exact value of the one-bit bound associated with matrix M. We found an efficient see-saw type algorithm for computing $L_2(M)$. We introduced a new constant K_D which is related to the finite detection efficiency threshold of Bob's measurements. As an application of the above algorithm we established a lower bound on K_D.

20. **Gerard Anglès Munné:** ENGINEERING HOLOGRAPHY WITH STABILIZER GRAPH CODES

    The discovery of holographic codes established a surprising connection between quantum error correction and the AdS/CFT correspondence. Recent technological progress in artificial quantum systems renders the experimental realisation of such holographic codes now within reach. Formulating the hyperbolic pentagon code in terms of a stabilizer graph code, we propose an experimental implementation that is tailored to systems with long-range interactions. We show how to obtain encoding and decoding circuits for the hyperbolic pentagon code [JHEP 2015:149 (2015)], before focusing on a small instance of the holographic code on twelve qubits. Our approach allows to verify holographic properties by partial decoding operations, recovering bulk degrees of freedom from their nearby boundary.

21. **Javid Naikoo:** MULTIPARAMETER ESTIMATION PERSPECTIVE ON NON-HERMITIAN SINGULARITY-ENHANCED SENSING

    In our work [arXiv:2303.05532v2], we focus on the possibility of achieving unbounded sensitivity when using the system to sense linear perturbations away from a singular point. By combining multiparameter estimation theory of Gaussian quantum systems with the one of singular-matrix perturbations, we introduce the necessary tools to study the ultimate limits on the precision attained by such singularity-tuned sensors. We identify under what conditions and at what rate can the resulting sensitivity indeed diverges, in order to show that nuisance parameters should be generally included in the analysis, as their presence may alter the scaling of the error with the estimated parameter.

22. **Jan Nöller:** UPPER BOUNDS ON SECRET KEY RATE IN DEVICE INDEPENDENT CONFERENCE KEY AGREEMENT

Device-independent quantum conference key agreement (DICKA) is a quantum cryptographic paradigm that allows multiple honest users to establish a secret key while putting minimal trust in their devices, by violating some Bell inequality. Contrary to the bipartite case there is a large zoo of inequalities, testing different levels of non-locality. For two parties, upper bounds on secure key rates have been derived using the convex combination attack, to show that nonlocality is insufficient for DIQKD. Similarly, we derive a visibility threshold for various noise scenarios, below which no secure key can be extracted. These thresholds are far above the noise value where the shared states become bi-separable, indicating that genuine multipartite entanglement is not sufficient for DICKA.

23. **Ignacio Perito:** CHARACTERIZATION OF NONSIGNALING CORRELATIONS FROM MUTUAL INFORMATION

We present a characterization of the set of nonsignaling correlations in terms of a two-dimensional representation that involves the maximal value of a Bell functional and the mutual information between the parties. We apply this representatoin to the simplest Bell scenario where, through numerical optimization methods and some analytical results, we investigate the frontier between the different subsets of the nonsignaling correlations, focusing on the quantum and postquantum ones. Our analysis exhibits that there is a trade-off between the amount of classical correlations existing between the parties and the magnitude of the violation of a given Bell inequality. Notably, the Tsirelson bound appears as a singular point of this trade-off without resorting to quantum mechanics.

24. **Martin Johannes Renner:** SIMULATING QUBIT CORRELATIONS WITH CLASSICAL COMMUNICATION

We consider general prepare-and-measure scenarios in which Alice can transmit qubit states to Bob, who can perform general measurements in the form of positive operator-valued measures (POVMs). We show that the statistics obtained in any such quantum protocol can be simulated by the purely classical means of shared randomness and two bits of communication. Furthermore, we prove that two bits of communication is the minimal cost of a perfect classical simulation. In addition, we apply our methods to Bell scenarios. We show that two bits of communication are enough to simulate all quantum correlations associated to arbitrary local POVMs applied to any entangled two-qubit state. We also provide improved protocols for the simulation of arbitrary local projective measurements on qubit pairs..

25. **Albert Rico:** ENTANGLEMENT DETECTION WITH TRACE POLYNOMIALS

We provide a systematic method for nonlinear entanglement detection based on trace polynomial inequalities. In particular, this allows to employ multi-partite witnesses for the detection of bipartite states, and vice versa. We identify witnesses for which linear detection of an entangled state fails, but for which nonlinear detection succeeds. With the trace polynomial formulation a great variety of witnesses arise from immanant inequalities, which can be implemented in the laboratory through randomized measurements.

26. **Ricardo Rivera:** QSAT SUB-PROBLEM IS BQP_1-COMPLETE

Ref. [arXiv:2101.08381] attempted to show that there is a Quantum SAT problem that represents the full power of one-side error quantum computation, leading to the first natural problem that is complete for the class BQP_1. Here, we point out a couple of his oversights, the complications that arise from them and how we deal with them successfully. Besides, we also strengthen the result by reducing the qudit dimensionality. The circuit-to-Hamiltonian construction demonstrates how to encode a quantum circuit into local Hamiltonians. While this is most often used to demonstrate negative results, like "estimating the ground state energy of local Hamiltonians is unlikely with quantum computers", here we do the contrary. We show that when the clauses of a satisfiability problem are given by a variation of these Hamiltonians, there is a quantum algorithm that computes the answer with certainty. Finally, we think that our construction can be modified to yield similar QSAT problems that are complete for other quantum and classical complexity classes.

27. **Sheikh Sazim:** QUANTUM ADVANTAGE IN RANDOM ACCESS CODES USING SINGLE d-LEVEL SYSTEM

Quantum random access codes (Q-RACs) often give an advantage over classical RACs. However, to compare, it is necessary to find optimal strategies for the classical RACs. Therefore, for the considered task, first, we characterize all the optimal classical RACs and prove that the previously conjectured "majority-encoding-identity-decoding" is indeed an optimal classical strategy. Then, we show an advantage over optimal classical RACs by constructing possible quantum protocols for 'encoding-decoding' by assigning different values to the variables n and d. Finally, we discuss the open questions concerned with finding optimal quantum RACs for given values of n and d.

28. **Michal Sedlák:** INCOMPATIBILITY OF QUANTUM INSTRUMENTS

Quantum instruments describe outcome probability as well as state change induced by measurement of a quantum system. Incompatibility of two instruments, i. e. the impossibility to realize them simultaneously on a given quantum system, generalizes incompatibility of channels and incompatibility of positive operator-valued measures (POVMs). We derive implications of instrument compatibility for the induced POVMs and channels. We also study the relation of instrument compatibility to the concept of non-disturbance. Finally, we prove equivalence between instrument compatibility and post-processing of certain instruments, which we term complementary instruments. We illustrate our findings with examples of various classes of instruments.

29. **Ritabrata Sengupta:** CONDITIONS FOR LOCAL TRANSFORMATIONS BETWEEN SETS OF QUANTUM STATES

    We study the problem of transforming a set of pure bipartite states into another using deterministic LOCC (local operations and classical communication). Necessary conditions for the existence of such a transformation are obtained using LOCC constraints on state transformation, entanglement, and distinguishability. These conditions are shown to be independent but not sufficient. We discuss their satisfiability and classify all possible input-output pairs of sets accordingly. We also prove that strict inclusions hold between LOCC, separable, and positive partial transpose operations for set transformation problems.

30. **Nidhin Sudarshan Ragini:** SINGLE-SHOT LABELING OF QUANTUM OBSERVABLES

    We identify and study a particular class of distinguishability problems for quantum observables (POVMs), in which observables with permuted effects are involved. We refer to these problems as the labeling problem, as the task reveals the labeling of the observables. Consequently, we identify the binary observables those can be "labeled" perfectly. In this work, we study these problems in the single-shot regime.

31. **Jochen Szangolies:** CALIBRATION OF SYNDROME MEASUREMENTS IN A SINGLE EXPERIMENT

    Methods of quantum error correction are starting to be beneficial on current quantum computing hardware. Typically this requires to perform measurements which yield information about the occurred errors on the system. However, these syndrome measurements themselves introduce noise to the system. A full characterization of the measurements is very costly. Here we present a calibration method which allows to take the additional noise into account. Under reasonable assumptions we require only a single additional experiment. We give examples of how to apply this method to noise estimation and error correction. Finally we discuss the results of experiments carried out on an IBM quantum computer.

32. **Lila Cadi Tazi:** FOLDED SPECTRUM VQE : A QUANTUM COMPUTING METHOD FOR THE CALCULATION OF MOLECULAR EXCITED STATES

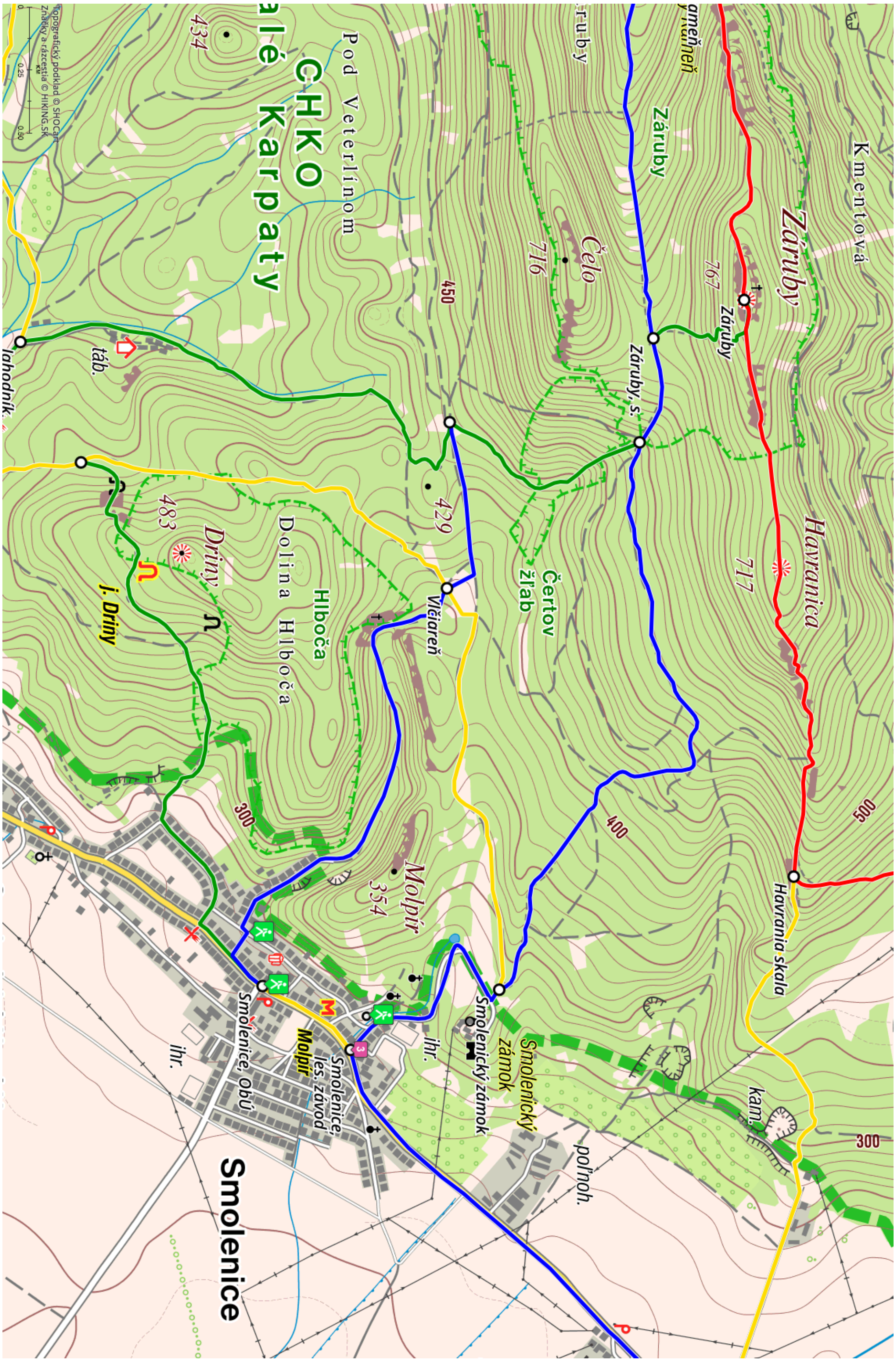
    The Variational Quantum Eigensolver (VQE) algorithm was successfully introduced for quantum chemistry as an effective method to compute the ground state energy of small molecules. The current study investigates the Folded Spectrum (FS) method as an extension to the VQE algorithm for the computation of molecular excited states. We alleviate the potentially poor scaling of this method by employing a Pauli grouping procedure, identifying sets of commuting Pauli strings that can be evaluated simultaneously. This allows for a significant reduction of the computational cost. We apply the FS-VQE method to small molecules, obtaining all electronic excited states with chemical accuracy on ideal quantum simulators.

33. **İskender Yalçınkaya:** CATCHING A QUANTUM WALKER BY A CLASSICAL RANDOM WALKER

    We calculate the escape probability (EP) of a quantum walker (QW) on a line with a moving absorption center (sink). The sink, behaving like a classical random walker, follows the QW and projects out probability amplitudes at overlapping locations at every step. As the sink moves, the EP is lower compared to when the sink is stationary. Surprisingly, when considering a lazy sink that can either move or stay in place with some probabilities, we observe counterintuitive results. Intuitively, as the sink transitions from being immobile to a regular random walker, the EP would decrease monotonically due to the sink's step probability defining its diffusion coefficient. Our study reveals that, in a wide range of step probabilities, the QW has a higher EP than when the sink is stationary.

34. **Mario Ziman:** QUANTUM DYNAMICS IS NOT STRICTLY BIDIVISIBLE

    We address the 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 novel 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.



Scenic route: Smolenický zámok – [yellow] – Vlčiareň – [blue] – [green] – [blue] – [green] – Záruby – [red] – Havrania skala (viewpoint) – (unmarked path) – [blue] – Smolenický zámok