Vienna Quantum Foundations Conference, Vienna Sept. 7th-10th 2021
Poster Abstracts

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I. FLOOR 1

1. Alastair A. Abbott, Inria Grenoble
   Device-Independent Quantification of Quantum Resources
   Poster Abstract: The ability to certify entanglement in a completely device independent manner (by violating Bell inequalities) is a remarkable feature of quantum mechanics with numerous applications. It allows us to certify a quantum resource without assuming quantum theory, and instead relying on much weaker principles such as no-signalling. Remarkably, although some entangled states cannot violate any Bell inequality, all entangled states can be certified in a device independent way by combining the techniques of semi-quantum games (and measurement device independence) and self-testing.

   While such techniques have been extensively studied for entanglement, their applicability to more general quantum resources remains a big question mark. Here we take a major step in this direction, studying the ability to certify resources based on quantum channels in a completely device-independent manner. Such resources encompass both state-based resources (such as entanglement) and measurement resources (such as incompatibility), as well as dynamical resources (such as non-entanglement breaking channels).

   Building on recent work that shows that all channel based resources can provide advantages in input-output games, we develop a method, again using techniques from self-testing, to certify and even quantify channel-based resources in a device independent way. Several complications not present in the case of entanglement arise in this more general scenario, yet we manage to show that many important resources can be certified in this way, and derive conditions that must be satisfied for a resource for such certification to be possible.

   Our work shows that a wide range of quantum resources can be certified without assuming quantum mechanics, and even opens the door to fully device-independent certification of further resources, such as the causal nonseparability of the quantum switch.

   This submission is based on a work in preparation: A. Abbott, N. Brunner, I. Supic, R. Uola, "Device-Independent Quantification of Quantum Resources".

2. Luca Apadula, IQOQI Vienna
   Quantum Relativistic Reference Frame
   Poster Abstract: We extend the notion of Quantum Reference Frames to the relativistic scenario. A foundamental request for such generalization is represented by time being treated on the same footing as spatial coordinates. Then, we have found that a timeless approach, such as the Page-Wooters formalism and the Covariant Quantum Mechanics is a natural field where this connection can be understood. In particular we see that the new quantum relativistic frame, which can be thought as multipartite system composed of a clock and rod, is a carrier of both space and time information. This allows for a better understanding of the notion of superposition of

boost, for istance whenever the choosen reference is found to be in a superposition of speeds, from which a novel phenomena as the superposition of simultaneity surfaces emerges naturally.

3. Pablo Arnault, CEA Paris-Saclay / IRFU / Laboratoire de Recherche sur les Sciences de la Matière (LARSIM)
Clifford algebra out of quantum automata and unitary Wilson fermions
Poster Abstract: We present a quantum-automata spacetime discretization of the Dirac equation that achieves two important goals at once. First, we have a Clifford algebra emerge out of the unitary operators defining our quantum automata, and the latter is invariant under changes of representation of this Clifford algebra, which parallels exactly the continuum situation; To this aim, we proceeded as Dirac did with his equation, that is, we required that the square of the discrete scheme be a valid spacetime discretization of the Klein-Gordon equation, where the definition of "validity" is a completely natural one, namely, our discrete Klein-Gordon scheme should hold for scalar automata. The second goal that we achieve is the finding of naturally unitary Wilson fermions in discrete time, while in standard lattice gauge theory this unitarity is not a given in discrete time, and has to be proven.

4. Veronika Baumann, IQOQI Vienna
Non-casual Page-Wootters circuits
Poster Abstract: We combine the process matrix framework with a generalization of the Page-Wootters formalism in which one considers several observers, each with their own discrete quantum clock. It enables us to describe processes with indefinite casual order via a history state with multiple clocks. This imposes constraints on the implementability of process matrices into this framework and on the perspectives of the observers. We implement processes were the different definite causal orders are coherently controlled and explain why certain non-causal processes might not be implementable within this setting.
Arxiv: 2105.02304

5. Fatemeh Bibak, IQOQI and University of Vienna
Dissipative phase transition of optomechanical systems
Poster Abstract: In this work, we studied dissipative phase transitions (DPT) in optomechanical systems. We applied the stability analysis at a well-defined thermodynamic limit to arrive at the corresponding phase diagram, which exhibits two types of instability lines: soft and hard mode instabilities directly related to DPTs. The optomechanical phase diagram exhibits a rich structure composed of first and second-order DPT (with and without symmetry breaking). The analysis is supplemented with the computation of critical exponents and corresponding universality class. Finally, we studied the quantum properties of the steady-state quantified via squeezing and entanglement. We demonstrate that one can boost these quantities by applying auxiliary passive linear optic operations to the steady-state.

6. Pawel Blasiak, Institute of Nuclear Physics Polish Academy of Sciences, Krakow
Violations of locality and free choice are equivalent resources in Bell experiments
Poster Abstract: Faced with a violation of Bell inequalities, a committed realist might pursue an explanation of the observed correlations on the basis of violations of the locality or free choice (sometimes called measurement independence) assumptions. The question of whether it is better to abandon (partially or completely) locality or free choice has been strongly debated since the inception of Bell inequalities, with ardent supporters on either side. We offer a comprehensive treatment that allows a comparison of both assumptions on an equal footing, demonstrating their deep interchangeability. This both advances the foundational debate and provides quantitative answers regarding the weight of each assumption for causal (or realist) explanations of observed correlations.
Reference:
P. Blasiak, E. M. Pothos, J. M. Yearsley, C. Gallus, and E. Borsuk "Violations of locality and free choice are equivalent resources in Bell experiments" PNAS 118 (17) e2020569118 (2021)
Arxiv: 2105.09037

7. Xavier Coiteux-Roy, Università della Svizzera italiana
Any Physical Theory of Nature Must Be Boundlessly Multipartite Nonlocal
Poster Abstract: We introduce the class of Genuinely Local Operation and Shared Randomness (LOSR) Multipartite Nonlocal correlations, that is, correlations between N parties that cannot be obtained from unlimited shared randomness supplemented by any composition of (N-1)-shared causal Generalized-Probabilistic-Theory (GPT) resources. We then show that noisy N-partite GHZ quantum states as well as the 3-partite W quantum state can produce such correlations. This proves, if the operational predictions of quantum theory are correct, that Nature's nonlocality must be boundlessly multipartite in any causal GPT. We develop a computational method which certifies that a noisy N=3 GHZ quantum state with fidelity 85 percent satisfies this property,

making an experimental demonstration of our results within reach. We motivate our definition and contrast it with preexisting notions of genuine multipartite nonlocality.
Arxiv: 2105.09380

8. Luis C. Barbado, Universität Wien
Unruh effect for detectors in superposition of accelerations
Poster Abstract: The Unruh effect is the phenomenon that accelerated observers detect particles even when inertial observers experience the vacuum state. In particular, uniformly accelerated observers are predicted to measure thermal radiation that is proportional to the acceleration. Here we consider the Unruh effect for a detector that follows a quantum superposition of different accelerated trajectories in Minkowski spacetime. More precisely, we analyze the excitations of a pointlike multilevel particle detector coupled to a massless real scalar field and moving in the superposition of accelerated trajectories. We find that the state of the detector excitations is, in general, not a mere (convex) mixture of the thermal spectrum characteristics of the Unruh effect for each trajectory with well-defined acceleration separately. Rather, for certain trajectories and excitation levels, and upon the measurement of the trajectory state, the state of the detector excitations features in addition off-diagonal terms. The off-diagonal terms of these "superpositions of thermal states" are related to the distinguishability of the different possible states in which the field is left after its interaction with detector's internal degrees of the freedom.
Arxiv: 2003.12603

9. Anne-Catherine de la Hamette, University of Vienna
Quantum reference frames for general symmetry groups
Poster Abstract: Treating reference frames as physical systems, subject to the laws of quantum mechanics, they become quantum reference frames. Located at the interplay of quantum and gravitational physics, their treatment marks an essential step towards the construction of a relational quantum theory. In this work, we introduce a relational formalism which identifies coordinate systems with elements of a symmetry group G. We define a general operator for reversibly changing between quantum reference frames associated to a group G. This generalises the known operator for translations and boosts to arbitrary finite and locally compact groups, including non-Abelian groups.
Arxiv: 2004.14292

10. Ismael Lucas Paiva, Bar-Ilan University
Energy measurements with quantum clocks: time-energy uncertainty relations and non-unitarity
Poster Abstract: Uncertainty relations play a crucial role in quantum mechanics. A well-defined method exists for deriving such uncertainties for pairs of observables. It does not include, however, an important family of fundamental relations: the time-energy uncertainty relations. As a result, different approaches have been used for obtaining them in diversified scenarios. The one of interest here revolves around the idea of the existence or inexistence of a minimum duration for an energy measurement with a certain precision. In our study, we use the Page and Wooters timeless framework to investigate how energy measurements modify the relative "flow of time" between internal and external clocks. This provides a unified framework for discussing the topic, recovering previous results and leading to new ones. We also show that the evolution of the external clock with respect to the internal one is non-unitary.
Arxiv: 2106.00523

II. FLOOR 2

11. Jose de Ramon Rivera, University of Waterloo
Relativistic causality in particle detector models: Faster-than-light signaling and impossible measurements
Poster Abstract: We analyze potential violations of causality in Unruh DeWitt-type detector models in relativistic quantum information. We proceed by first studying the relation between faster-than-light signaling and the causal factorization of the dynamics for multiple detector-field interactions. We show in what way spatially extended nonrelativistic detector models predict superluminal propagation of the field's initial conditions. We draw parallels between this characteristic of detector models, stemming from their nonrelativistic dynamics, and Sorkin's "impossible measurements on quantum fields" [R. D. Sorkin, in Directions in General Relativity: Proceedings of the 1993 International Symposium, Maryland (Cambridge University Press, 1993), Vol. 2, pp.

293-305.]. Based on these features, we discuss the validity of measurements in quantum field theory when performed with nonrelativistic particle detectors.
Arxiv: 2102.03408

12. Flavio Del Santo, IQOQI Vienna
Advancements on the Wigner's Friend Gedankenexperiment
Poster Abstract: The Wigner's friend gedankenexperiment exemplifies the quantum measurement problem: the tension between the unitary evolution of the wave function and the state-update rule (or "collapse"). There, different observers (one of whom is observed by the other) describe one and the same interaction differently, the Friend via state-update and Wigner unitarily. In my poster I will report on recent results we have recently achieved on the conceptual understanding of this problem. On the one hand, we have applied the Page-Wootters mechanism to give an a priori timeless description of Wigner's friend-like scenarios, showing that it allows Wigner and his Friend to unambiguously assign two-time conditional probabilities for the gedankenexperiment [Baumann, V., Del Santo, F., Smith, A.R., Giacomini, F., Castro-Ruiz, E. and Brukner, C., 2019. Generalized probability rules from a timeless formulation of Wigner's friend scenarios. arXiv preprint arXiv:1911.09696.]. We proposed three rules to assign two-time conditional probabilities, all of which reduce to standard quantum theory for non-Wigner's friend scenarios. However, when applied to the Wigner's friend setup each rule assigns different conditional probabilities, potentially resolving the probability-assignment paradox in a different manner. On the other hand, I will report on a recent no-go theorem for the persistent reality of Wigner's friend's perception, which allowed us to conclude that the perceptions that the friend has of her own measurement outcomes at different times cannot 'share the same reality', if seemingly natural quantum mechanical assumptions are met [Guérin, P.A., Baumann, V., Del Santo, F. and Brukner, C., 2021. A no-go theorem for the persistent reality of Wigner's friend's perception. Communications Physics, 4(1), pp.1-7.]. More formally, this means that, in a Wigner's friend scenario, there is no joint probability distribution for the friend's perceived measurement outcomes at two different times, that depends linearly on the initial state of the measured system and whose marginals reproduce the predictions of unitary quantum theory. This theorem entails that one must either (1) propose a nonlinear modification of the Born rule for two-time predictions, (2) sometimes prohibit the use of present information to predict the future thereby reducing the predictive power of quantum theory or (3) deny that unitary quantum mechanics makes valid single-time predictions for all observers. Arxiv: 1911.09696,

13. Roberto Baldijão, State University of Campinas
Quantum Darwinism and the spreading of classical information in non-classical theories
Poster Abstract: Quantum Darwinism posits that the emergence of a classical reality relies on the spreading of classical information from a quantum system to many parts of its environment. But what are the essential physical principles of quantum theory that make this mechanism possible? We address this question by formulating the simplest instance of Darwinism – CNOT-like fan-out interactions – in a class of probabilistic theories that contain classical and quantum theory as special cases. We determine necessary and sufficient conditions for any theory to admit such interactions. We find that every non-classical theory that admits this spreading of classical information must have both entangled states and entangled measurements. Furthermore, we show that Spekkens' toy theory admits this form of Darwinism, and so do all probabilistic theories that satisfy principles like strong symmetry, or contain a certain type of decoherence processes. Our result suggests the counterintuitive general principle that in the presence of local non-classicality, a classical world can only emerge if this non-classicality can be "amplified" to a form of entanglement Arxiv: 2012.06559

14. Hippolyte Dourdent, Institut Néel, Université Grenoble-Alpes, CNRS
Semi-device-independent certification of causal nonseparability with trusted quantum inputs
Poster Abstract: While the standard formulation of quantum theory assumes a fixed background causal structure, one can relax this assumption within the so-called "process matrix framework" [1]. There, the relation between parties performing local quantum operations in closed laboratories is described by a higher-order operation, the "process matrix", a generalization of density matrix. Remarkably, some processes are incompatible with a definite causal order, also called causally nonseparable.

    Some causally nonseparable process matrices can generate so-called noncausal correlations, allowing their causal nonseparability to be certified in a deviceindependent (DI) way by violating "causal inequalities" [1, 2]. However, not all causally nonseparable process matrices are noncausal in this strong sense [3–5]. Indeed, it remains unclear if any physically realisable process can violate a causal inequality, and causal models have recently been formulated for a large class of quantum-realisable processes [6, 7]. On the other hand, causally nonseparable process matrices can always be certified by causal witnesses [3, 8]. This approach, however, has the drawback of being device-dependent (DD), as it requires one to perfectly trust the operations performed by the involved parties.

In this work, we report progress towards the certification of causally nonseparable process matrices in an intermediate semi-device-independent approach. Inspired by recent developments in the area of quantum nonlocality [9, 10], we consider a causal game scenario where the parties receive inputs in the form of trusted quantum systems (instead of classical ones), but are otherwise untrusted. Defining the new notion of causally nonseparable distributed measurements, we show that certain causally nonseparable processes which cannot violate any causal inequality, such as the quantum switch [11], can generate non-causal correlations in our semi-DI with quantum inputs scenario. Moreover, under a weak additional constraint on the uncharacterised operations, we show that all bipartite causally nonseparable process matrices can be certified in this way.

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15. Fay Dowker, Imperial College London

Recovering General Relativity from a Planck scale discrete theory of quantum gravity

Poster Abstract: Extended abstract: We present an argument that if a theory of quantum gravity is physically discrete at the Planck scale and the theory recovers General Relativity as an approximation, then, at the current stage of our knowledge, causal sets must arise within the theory, even if they are not its basis. We show in particular that an apparent alternative to causal sets, viz. a certain sort of discrete Lorentzian simplicial complex, cannot recover General Relativistic spacetimes in the appropriately unique way. For it cannot discriminate between Minkowski spacetime and a spacetime with a certain sort of gravitational wave burst.

The argument is based on two assumptions. Assumption 1 is that one's theory of quantum gravity—call it 'X'—recovers a large class of 4-dimensional general relativistic spacetimes that vary slowly on Planckian scales; including for example, spacetimes with gravitational waves, or large portions of Minkowski spacetime. Assumption 2 is that X is discrete in the sense that for each spacetime (M,g) to be recovered, X has a state that contains or gives rise to a set of discrete physical data (DPD) from which (M,g) can be recovered essentially uniquely. So such a theory X must postulate a discrete-continuum correspondence (DCC) specifying (up to some tolerance) when a general relativistic spacetime is recovered from a DPD. Thus the argument does not target theories that use: either (i) piecewise flat Lorentzian manifolds as continuum approximations to continuum geometries; or (ii) a discreteness length used as a regulator that is taken to zero in a continuum limit.

We then make two claims. Claim 1 is that a causal set is a set of DPD that, taken as discrete on the Planck scale, can recover a general relativistic spacetime. We make Claim 1 precise by formulating a Discrete-Continuum Correspondence (DCC) for causal sets; and then we review the evidence for this Correspondence (both in analytic results and in numerical work). Claim 2 is that there is, in the current literature, no other proposal for a set of Planck scale DPD that can recover a general relativistic spacetime as a continuum approximation. We support Claim 2 by focussing on a natural proposal: a combinatorial 4-dimensional Lorentzian Regge complex (CLRC). Such a complex includes information about connectivity (incidence), and Lorentzian edge-lengths that are no more than a few Planck units. But it excludes continuum information about the interior of its simplices. We then argue for Claim 2, by formulating a Discrete-Continuum Correspondence (DCC) for CLRCs—and showing that it fails, by exhibiting a specific example.

The idea is that the DCC fails because it breaks the requirement that for each DPD, the spacetime recovered is essentially unique, i.e. up to some tolerance. We show this by presenting a specific CLRC that (according to this DCC) "recovers" equally well both Minkowski spacetime and also a spacetime that is a perturbation of

Minkowski spacetime with a plane-fronted gravitational wave burst. The requirement of essential uniqueness means that this "double win" is a failure.

Arxiv: 2106.01297

16. Miguel Gallego, University of Vienna
Macroscopically nonlocal quantum correlations
Poster Abstract: It is usually believed that coarse-graining of quantum correlations leads to classical correlations in the macroscopic limit. Such a principle, known as macroscopic locality, has been proved for correlations arising from independent and identically distributed (IID) entangled pairs. In this work we consider the generic (non-IID) scenario. We find that the Hilbert space structure of quantum theory can be preserved in the macroscopic limit. This leads directly to a Bell violation for coarse-grained collective measurements, thus breaking the principle of macroscopic locality.
Arxiv: arxiv.org/abs/2104.03988

17. Jonte Hance, QETLabs, University of Bristol
Wavefunctions can Simultaneously Represent Knowledge and Reality
Poster Abstract: Harrigan and Spekkens give formal definitions for the wavefunction in quantum mechanics to be *psi*-ontic or *psi*-epistemic, such that the wavefunction can only be one or the other. We argue that nothing about the informal ideas of epistemic and ontic interpretations rules out wavefunctions representing both reality and knowledge. The implications of the Pusey-Barrett-Rudolph theorem and many other issues need to be rethought in the light of our analysis.
Arxiv: 2101.06436

18. Michael Heaney, Huladyne Research & Consulting
A time-symmetric resolution of the Einstein's Boxes paradox
Poster Abstract: The Einstein's Boxes paradox was developed by Einstein, de Broglie, and others to demonstrate the incompleteness of the Copenhagen Formulation of quantum mechanics. I explain the paradox using the Copenhagen Formulation. I then show how a Time-Symmetric Formulation of quantum mechanics resolves the paradox in the way predicted by Einstein and de Broglie. Finally, I describe an experiment that can distinguish between these two formulations.

19. Sebastian Horvat, University of Vienna
Interference as an information-theoretic game
Poster Abstract: The double slit experiment provides a demarcation between classical and quantum theory, while multi-slit experiments demarcate quantum and higher-order interference theories. In this work we show that these experiments pertain to a broader class of processes, which can be formulated as information-processing tasks that involve two parties and communication between them. We show the connection between the order of interference and the probabilities of successfully achieving the given tasks. Furthermore, we prove the order of interference to be additive under composition of systems both in classical and quantum theory. Finally, we extend our game formulation within the generalized probabilistic framework and prove that tomographic locality implies the additivity of the order of interference under composition.
Arxiv: 2003.12114v4

20. Viktoria Kabel, IQOQI Vienna
Falling Through a Massive Superposition
Poster Abstract: The current theories of quantum physics and general relativity on their own do not allow us to study situations in which the gravitational source is quantum. In particular, it is still unclear what the gravitational field sourced by a mass configuration in a spatial superposition looks like and how other objects move in its vicinity. Here we propose a strategy which allows us to answer the latter question utilising quantum reference frame (QRF) transformations. In particular, we show that as long as the different positions of the mass configuration are related via isometries, it is possible to find a QRF in which the mass configuration becomes definite. The transformation to this frame is achieved via an extension of the current framework of QRFs to "quantum isometries" - superpositions of classical coordinate transformations, which leave the metric invariant. Assuming that the laws of physics are invariant under these transformations, we can change into a reference frame in which the mass configuration is definite and use standard quantum mechanics on a fixed spacetime background to determine the evolution of test particles in the presence of this fixed gravitational source. By applying the inverse QRF transformation to the time-evolved state, we find the trajectory of the test particles in the original frame, in which the mass configuration is in a superposition.

III. FLOOR 3

21. Shashaank Khanna, University of York, UK
Characterising which causal structures might not support a classical explanation based on any underlying physical theory
Poster Abstract: A causal relationship can be described using the formalism of Generalised Bayesian Networks. This framework allows the depiction of cause and effect relations (causal scenarios) effectively using generalised directed acyclic graphs (GDAGs). A GDAG is "not interesting" if the causal relations existing can be explained classically regardless of the underlying physical theory. Henson, Lal and Pusey (HLP) have proposed a sufficient condition to check whether a causal scenario is "not interesting". With their methods and some more developments the problem of identifying "interesting" causal structures has been solved for GDAGs of 6 nodes. But the problem of identifying "interesting" causal scenarios for GDAGs of 7 nodes is still open. We propose a new graphical theorem (and call it the E-separation theorem) to check several of the GADGs of 7 nodes which couldn't be checked by HLP's condition. Finally we also use "fine-grained" entropic inequalities to check whether the remaining GDAGs (of 7 nodes) are interesting or not.

22. Nikolaos Kollas, Physics Department, University of Patras, Greece
Inconsistency measures of quantum histories
Poster Abstract: Based on the resource theory of quantum coherence, we construct a set of measures which can quantify the degree of inconsistency of a set of quantum histories. As an example we compute the inconsistency of histories consisting of two projective measurements on a qubit at two different times. We demonstrate in a geometric way that this amount depends on the choice of each projection axis on the Bloch sphere as well as on the time that each choice was made. For an initial system with three energy levels we show how different coarse grained measurements, each defined as a sum of one dimensional projections, affect the degree of inconsistency. These simple toy models serve to illustrate the usefulness of a measure based approach in the study of quantum foundations

23. Ryszard Kostecki, International Center for Theory of Quantum Technologies, University of Gdansk
Nonlinear postquantum brègmanian inference + Adjointness in epistemic foundations
oster Abstract: I will present two new postquantum foundational approaches, both aiming at consistent description of multi-user inference and resources beyond tensor products. First approach: 1) establishes a framework for nonlinear postquantum statistical inference (including, e.g., local information geometric structures, norm-to-norm continuous solutions of nonlinear convex best approximation problems, etc.) which is well-defined for base norm spaces of arbitrary dimensionality; 2) provides a functional analytic implementation of Mielnik's idea of nonlinear transmitters, with pullbacks of Brègman nonexpansive operations replacing CPTP maps, giving rise to a family of nonlinear postquantum resource theories of states; 3) has concrete examples constructed using nonlinear duality maps together with the Mazur (resp., Kaczmarz) maps on Lp (resp., Orlicz) spaces over JBW- (resp., W*-) algebras. Second approach: 1) provides a category-theoretic framework for multi-(co)agency and intersubjectivity of epistemic knowledge, combining Lawvere's adjointness paradigm with Jaynes-inspired semantic twist, via actions (resp., facts) available to a given user encoded in terms of monad (resp., comonad); 2) determines corresponding resource theories of states; 3) has concrete examples provided by the first approach.
Arxiv: 2103.07810

24. Hlér Kristjánsson, University of Oxford
Witnessing latent time correlations with a single quantum particle
Poster Abstract: When a noisy communication channel is used multiple times, the errors occurring at different times generally exhibit correlations. Classically, these correlations do not affect the evolution of individual particles: a single classical particle can only traverse the channel at a definite moment of time, and its evolution is insensitive to the correlations between subsequent uses of the channel. In stark contrast, here we show that a single quantum particle can sense the correlations between multiple uses of a channel at different moments of time. Taking advantage of this phenomenon, it is possible to enhance the amount of information that the particle can reliably carry through the channel. In an extreme example, we show that a transmission line that outputs white noise at every time step can exhibit correlations that enable a perfect transmission of classical bits. When multiple transmission lines are available, time correlations can be used to simulate the application of quantum channels in a coherent superposition of alternative causal orders, and even to provide communication advantages that are not accessible through the superposition of causal orders.
Arxiv: 2004.06090

25. Marian Kupczynski, Université du Quebec en Outaouais (UQO)

Demystifying quantum nonlocality
Poster Abstract: CHSH inequality is a noncontextual inequality for a 4 -cyclic Bell scenario, Therefore its violation should be correctly interpreted as the violation of noncontextuality , which is neither local causality nor exprimenters' freedom of choice. Noncontextuality means only that there exists a counterfactual joint –probability distribution of 4 random variables describing clicks registered in 4 incompatible spin polarisation correlation experiments (SPCE). According to noncontextuality or counterfactual definiteness (CFD) the measurement outcomes are predetermined by ontic properties describing photonic signals arriving to PBS-detector modules. If contextual, setting dependent, variables describing these modules are correctly incorporated in the probabilistic model, then the correlations observed in SPCE may be reproduced in a causally local way. We also explain that, contrary to a general belief, setting dependence of hidden variables is only the manifestation of contextuality and it does not restrict experimenters‘ freedom of choice. The misunderstanding is based on the incorrect interpretation of Bayes Theorem. Therefore all speculations about mysterious quantum nonlocality and quantum magic are unfounded. In our opinion, if one starts evoking magic, it is the end of science.

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26. Tae-Hun Lee, Center for Theoretical Physics PAS, Warsaw
Implications of Haag's Theorem in Quantum Field Theories
Poster Abstract: The Standard Model of particle physics is a relativistic quantum field theoretic model. Despite its great success in prediction it is not completely satisfactory in several theoretical aspects. One of them is that the channel of the prediction is limited mainly through scattering cross sections, due to the fact that the theory relies solely on perturbation.On the other hand there is a mathematical theorem which states equivalence of two relativistic quantum field theories for neutral scalar fields related in a unitary mapping, the so-called Haag's theorem. Due to Haag's theorem, our empirical formula, the S-matrix, which uses a unitary mapping between free fields and interaction fields, namely the interaction picture, would give us trivial results of a free field theory. At a first glance it can be regarded as a paradox. It has not been completely solved yet. One of the reasons is that the practical success of the Standard Model is dominant over our curiosity. Another is that there is no general Haag's theorem to be applicable to more general theories like the Standard Model. In this poster, I will try to explain how the interaction picture can be used in practice despite Haag's theorem.

27. Matteo Lostaglio, UvA, QuSoft
Certifying quantum signatures in thermodynamics and metrology via contextuality of quantum linear response
Poster Abstract: We identify a fundamental difference between classical and quantum dynamics in the linear response regime by showing that the latter is in general contextual. This allows us to provide an example of a quantum engine whose favorable power output scaling emphunavoidably requires nonclassical effects in the form of contextuality. Furthermore, we describe contextual advantages for local metrology. Given the ubiquity of linear response theory, we anticipate that these tools will allow one to certify the nonclassicality of a wide array of quantum phenomena.
Arxiv: 2004.01213

28. Stefan Ludescher, IQOQI Vienna
Quantum Reference Frames for S_3
Coordinate descriptions of physical systems are given in terms of reference frames. Those reference frames can be thought of as an idealization and abstraction of a physical system (e.g. a gyroscope). However, even in standard relativistic quantum mechanics those reference systems are associated to some classical system. If we take the idea seriously that our world behaves quantum, we have to think of the reference systems as quantum as well, that is, they also have to obey the laws of quantum theory. This leads to the notion of quantum reference frames (QRFs), where the reference system itself behaves quantum mechanically. Right now, the treatment of QRFs is widely discussed in different communities (quantum gravity, quantum information theory, quantum foundations...).

In our work we follow the quantum foundational approach to QRFs invented by Giacomini et al. We consider the symmetry group S_3 and its representation on an equilateral triangle, where every element of the group acts as a permutation of the edges of the triangle. In contrast to the case where S_3 acts on $L^2(S_3)$, this representation gives rise to imperfect QRFs associated with systems of coherent states. This choice of coherent states is however not unique, and different choices lead to different properties of the QRF. Furthermore, we show that this choice also influences the possible conditional states that the rest of the system can occupy. Finally, we address the question if there are better and worse choices, if we want to learn as much as possible about the relative system.

29. Esteban Martínez-Vargas, Universitat Autònoma de Barcelona
Quantum Sequential Hypothesis Testing
Poster Abstract: We introduce sequential analysis in quantum information processing, by focusing on the fundamental task of quantum hypothesis testing. In particular our goal is to discriminate between two arbitrary quantum states with a prescribed error threshold, ε, when copies of the states can be required on demand. We obtain ultimate lower bounds on the average number of copies needed to accomplish the task. We give a block-sampling strategy that allows to achieve the lower bound for some classes of states. The bound is optimal in both the symmetric as well as the asymmetric setting in the sense that it requires the least mean number of copies out of all other procedures, including the ones that fix the number of copies ahead of time. For qubit states we derive explicit expressions for the minimum average number of copies and show that a sequential strategy based on fixed local measurements outperforms the best collective measurement on a predetermined number of copies. Whereas for general states the number of copies increases as $\log 1/\varepsilon$, for pure states sequential strategies require a finite average number of samples even in the case of perfect discrimination, i.e., $\varepsilon = 0$.
Arxiv: 2011.10773

30. Sidiney Bruno Montanhano, University of Campinas
Contextuality in the Fibration Approach and the Role of Holonomy
Poster Abstract: Contextuality can be understood as the impossibility to construct a globally consistent description of a model even if there is local agreement. In particular, quantum models present this property. We can describe contextuality with the fibration approach, where the scenario is represented as a simplicial complex, the fibers being the sets of outcomes, and contextuality as the non-existence of a global section in the measure fibration, allowing direct representation and formalization of the already used bundle diagrams. Using the generalization to continuous outcome fibers, we built the concept of measure fibration, showing the Fine-Abramsky-Brandenburger theorem for the fibration formalism in the case of non-finite fibers. By the Voroby'ev theorem, we argue that the dependence of contextual behavior of a model to the topology of the scenario is an open problem. We introduce a hierarchy of contextual behavior to explore it, following the construction of the simplicial complex. GHZ models show that quantum theory has all levels of the hierarchy, and we exemplify the dependence on higher homotopical groups by the tetraedron scenario, where non-trivial topology implies an increase of contextual behavior for this case. For the first level of the hierarchy, we construct the concept of connection through Markov operators for the measure bundle using the measure on fibers of contexts with two measurements and taking the case of equal fibers we can identify the outcome space as the basis of a vector space, that transform according to a group extracted from the connection. With this, it is possible to show that contextuality at the level of contexts with two measurements has a relationship with the non-triviality of the holonomy group in the frame bundle. We give examples and treat disturbing models through transition functions, generalizing the holonomy.
Arxiv: 2105.14132

IV. FLOOR 4

31. David Oaknin, RAFAEL Advanced Defense Systems
The Bell's theorem revisited: geometric phases in gauge theories
Poster Abstract: The Bell theorem stands as an insuperable roadblock in the path to a very desired intuitive solution of the Einstein-Podolsky-Rosen paradox and, hence, it lies at the core of the current lack of a clear interpretation of the quantum formalism. The theorem states through an experimentally testable inequality that the predictions of quantum mechanics for the Bell polarization states of two entangled qubits cannot be reproduced by any statistical model of hidden variables that shares certain intuitive features. The proof of the inequality, however, implicitly assumes a preferred frame of reference in which the orientations of the detectors that test the polarization of the pair of qubits can be independently described: the proof does not hold when the experiments are described taking the orientation of one of the detectors as a reference direction. This observation

suggests that the Bell theorem can be overcome if the global rotational symmetry is spontaneously broken by the hidden configurations of the pair of entangled qubits. Following this observation, we build an explicit local model of hidden variables that reproduces the predictions of quantum mechanics for the Bell states.

32. Mahasweta Pandit, University of Gdansk, Poland
Cooperation and dependencies in multipartite systems
Poster Abstract: We propose an information-theoretic quantifier for the advantage gained from cooperation that captures the degree of dependency between subsystems of a global system. We prove an inequality characterizing the lack of monotonicity of conditional mutual information under local operations and provide intuitive understanding for it. This underlines the distinction between the multipartite dependence measure introduced here and multipartite correlations.
Arxiv: arXiv:2003.12489

33. Gabriel Pereira Alves, Faculty of Physics, University of Warsaw
For rank-one projective measurements incompatibility implies non-locality
Poster Abstract: Bell non-locality is an important feature of quantum mechanics as the correlations established among distributed quantum systems are stronger than those allowed by classical physics. In this context, entanglement combined with incompatibility of measurements [1] are two necessary prerequisites to generate non-locality. Here, we show that for rank-one and projective measurements acting on the same finite-dimensional space there is a tight connection between non-locality and incompatibility.

In ref. [2] a Bell functional was constructed in a way that it is tailored to mutually unbiased bases (MUBs), i.e., its maximum quantum violation - or the quantum value of the functional - is achieved if the two possible measurements performed by one of the parts correspond to rank-one MUBs projectors. In this work, we generalize this construction to an arbitrary pair of incompatible rank-one projective measurements.

The following development consists of building a family of Bell functionals whose quantum realisation can be obtained from a previously defined Bob's pair of incompatible measurements and a suitable choice of measurements of Alice, as well as a proper entangled state. Once the family of functionals is set, a couple of results can be extracted, as follows.

Result 1. If a pair of rank-one projective measurements are incompatible, then they can be used to generate nonlocal correlations. Moreover, there exists a non-trivial Bell inequality for which these measurements are optimal.

In this context, the non-triviality of a Bell inequality means that the quantum value is strictly larger than the local one, forming a gap. Our proof to result in 1 is fully constructive; for every pair of measurements of Bob, we can explicitly construct a functional and show that it is non-trivial. Now, it is natural to ask for what functionals corresponding to particular measurements we have the biggest gap, that is, what is the pair of measurements that turn the quantum value the biggest possible when compared to the local one?

Result 2. For rank-one projective measurements acting on a d-dimensional complex space, where d is even, the largest gap between the quantum and local values is achieved if and only if the rank-one projective measurements correspond to a direct sum of MUBs in dimension 2.

The initial guess was that the pair of measurements that would reveal the biggest gap would be the one produced by rank-one MUBs projectors in dimension d. Instead, we found out that the matrix of overlaps between the two incompatible measurements can be decomposed into 2×2 blocks and all the entries inside these blocks are equal to $1/\sqrt{2}$. Our results significantly improve our understanding of the relation between incompatibility of measurements and Bell non-locality. Moreover, they show that the notion of "the most incompatible measurements" in a given scenario greatly depends on the exact definition of incompatibility.

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34. Nicola Pinzani, University of Oxford
The sheaf theoretic structure of definite and indefinite causality
Poster Abstract: We fill a gap in the study of contextuality by extending the sheaf-theoretic framework for non-locality by Abramsky and Brandenburger to deal with operational scenarios in the presence of arbitrary definite and indefinite causal orders. This allows us to understand the intimate relationship between contextuality and the causal order of processes in a theory independent way. Recent works on causality, stemming from the seminal intuition on the "quantum switch" and frameworks of process theories, have resulted in attempts to provide an experimental realisation and verification of indefinite causal structures. Facing the need to certify the realisability of indefinite causal structures, we are confronted with a common limitation of all descriptive

approaches to date: they are all a generalisation of quantum theory, from which causality is hard to extricate as an independent and observable phenomenon. What do we really mean when we talk about indefinite causality? Are the realisable operational contexts implicit in the aforementioned experimental realisations compatible with a definite causal structure, or are we in the presence of genuine indefinite causality? What do we really mean when we talk about indefinite causality? Are the realisable operational contexts implicit in the aforementioned experimental realisations compatible with a definite causal structure, or are we in the presence of genuine indefinite causality? The sheaf-theoretic language already provided a stand-alone description of non-locality and contextuality, independent of physical theory or experimental realisation. Today, we extend this language to answer questions about causality, moving one step closer to an understanding of Bohr's claim that contextuality and complementarity present themselves as a rational generalisation of the very idea of causality.
Arxiv: 2103.13771

35. Martin Plávala, Universität Siegen
Operational Theories in Phase Space: Toy Model for the Harmonic Oscillator
Poster Abstract: We show how to construct an energy observable dependent on position and momentum in general probabilistic theories. The construction is in accordance with classical and quantum theory and allows for physical predictions, such as observing tunneling behavior. We demonstrate the construction by formulating a toy model for the harmonic oscillator that is neither classical nor quantum. The model features a discrete energy spectrum, a ground state with sharp position and momentum, an eigenstate with non-positive Wigner function as well as a state that has tunneling properties. The toy model demonstrates that operational theories can be a viable alternative approach to formulating physical theories.
Arxiv: 2101.08323

36. Polina Pogrebinskaya, University of Vienna,
Duality between classical waves and particles
Poster Abstract: Interference of single particles lies at the core of quantum mechanics. The most prominent demonstration of this effect is the double-slit experiment: a single experimental run indicates an experiment with single particles, however the statistics of repeated runs reassembles interference fringes. This is the source of the celebrated wave-particle duality. In this work we show that classical wave mechanics combined with the statistical detection model can completely reproduce quantum interference experiments with single particles. The recreation of quantum double-slit experiment using classical waves shows that the dual behaviour between waves and particles (at least its part described in this work) is not necessarily proof of a genuine quantum effect.

37. Martin Renner, University of Vienna
Reassessing the computational advantage of quantum-controlled ordering of gates
Poster Abstract: Research on indefinite causal structures is a rapidly evolving field that has a potential not only to make a radical revision of the classical understanding of space-time but also to achieve enhanced functionalities of quantum information processing. For example, it is known that indefinite causal structures provide exponential advantage in communication complexity when compared to causal protocols. In quantum computation, such structures can decide whether two unitary gates commute or anticommute with a single call to each gate, which is impossible with conventional (causal) quantum algorithms. A generalization of this effect to n unitary gates, originally introduced in M. Araújo et al., Phys. Rev. Lett. 113, 250402 (2014) and often called Fourier promise problem (FPP), can be solved with the quantum-n-switch and a single call to each gate, while the best known causal algorithm so far calls $O(n^2)$ gates. In this work, we show that this advantage is smaller than expected. In fact, we present a causal algorithm that solves the only known specific FPP with $O(n\log(n))$ queries and a causal algorithm that solves every FPP with $O(n\sqrt{n})$ queries. Besides the interest in such algorithms on their own, our results limit the expected advantage of indefinite causal structures for these problems.
Arxiv: arXiv:2102.11293

38. Pedro Resende, Instituto Superior Tecnico, Lisbon
An abstract theory of physical measurements
Poster Abstract: I study the question of what should be meant by a measurement from a mathematical perspective whose physical interpretation is that a measurement is a fundamental process via which a finite amount of classical information (an observable property) is generated. This translates to a geometric definition of space of measurements which provides a realist picture, yet also operational, such that measurements and classical information arise interdependently as primitive concepts [1]. The hope is that such a theory may help convey a sense in which measurements have an existence of their own, independently of previously defined notions of system, apparatus, observer, etc. I will focus on the topological and algebraic structure of measurement spaces,

on top of which additional measure-theoretic and geometric structure will need to be added if a reconstruction of quantum mechanics is to be achieved.

Concretely, measurement spaces are sober topological spaces whose points are abstract measurements and whose open sets are the observable properties. They are also equipped with algebraic structure which includes a continuous operation of logical disjunction of measurements and another of sequential composition that expresses causal dependence such as when measuring the spin of a silver atom along z using a Stern–Gerlach apparatus and then measuring the spin of the same atom along x with another Stern–Gerlach apparatus.

Despite their simplicity, these operations give measurement spaces a structure of stably Gelfand quantale (whose structure is rich enough to classify unital C*-algebras [2]), due to which each measurement space has many naturally associated étale groupoids [3]. The latter can be related to Schwinger's selective measurements [4,5] and also to a derived notion of classical observer from which a mathematical formulation of Bohr's classical/quantum divide emerges. Moreover, the model is background independent, but it can be argued that a primitive notion of time is implicit in the algebraic structure, and that the associated groupoids carry derived spatial structure.

The main examples of measurement spaces are obtained from locally compact groupoids and C*-algebras: (1) the quantale Max A of a C*-algebra A [6], equipped with the lower Vietoris topology; (2) the quantale O(G) of a locally compact groupoid G [7], equipped with the Scott topology — this is of "classical type" and may describe a classical experimental apparatus; (3) the quantale of the reduced C*-algebra of a locally compact groupoid G — in this case the measurement space is of "quantum type" but it is equipped with a canonical classical observer associated to G.

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Arxiv: arXiv:2102.01712

39. Vinicius Rossi, ICTQT, University of Gdansk
Wigner's friend and the quasi-ideal clock
Poster Abstract: In 1962, Eugene P. Wigner introduced a thought experiment that highlighted the incompatibility in quantum theory between unitary evolution and wave function reduction in a measurement. This work resulted in a class of thought experiments often called Wigner's friend scenarios, which have been providing insights over many frameworks and interpretations of quantum theory. Recently, a no-go theorem obtained by D. Frauchiger and R. Renner [Nat. Commun. 9, 3711 (2018)] brought attention back to the Wigner's friend and its potential of putting theories to the test. Many answers to this result pointed out how timing in the thought experiment could be yielding a paradox. In this work, we ask what would happen if the isolated friend in a Wigner's friend scenario did not share a time reference frame with the outer observer, and time were tracked by a quantum clock. For this purpose, we recollect concepts provided by the theory of quantum reference frames and the quantum resource theory of asymmetry, to learn how to internalize time in this scenario, and introduce a model for a feasible quantum clock [Ann. Henri Poincaré 20, 125 (2019)] called the quasi-ideal clock. Our results have shown that this approach produces no decoherent behavior, and the disagreement between the superobserver and its friend persists even for an imprecise clock on Wigner's side. However, the Gaussian spread of this clock model can control which observables do not raise a paradox, indicating the relevance of deepening this analysis.
Arxiv: 2009.10218

40. Maximilian H. Ruep, University of York, UK
Causality in quantum field theory on fixed backgrounds
Poster Abstract: In 1993 Sorkin argued, that ideal measurements of most local observables of QFT enable superluminal signaling. In fact, the underlying protocol does not rely on ideal measurements, nor is it tied to Minkowski spacetime. It rather shows quite generally that many reasonable, conceivable quantum channels of any QFT on a fixed background might signal superluminally even when the fields commute at spacelike separation. On this poster I present the following results: (i) local quantum operations arising from local

dynamics are causal; and (ii) this renders the measurement theory of [2] (which is based on local interaction between the system and a probe) causal as well [3].

This poster reports on joint work with H. Bostelmann and C. J. Fewster.

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Arxiv: 2003.04660

V. FLOOR 5

41. Fattah Sakuldee, International Centre for Theory of Quantum Technologies, Gdansk, Poland
On Tensor Decomposition of Operation for Generic Open Quantum System
Poster Abstract: We analyse the decomposition of a unitary operation on the bipartite system into the operation of the product form. We introduce the Leibniz type identity for the generators of the unitary group. From that, we translate the conditions of the reduced evolution maps on one system into properties of the other system and summarise the conditions for Markovianity. We demonstrate the observation in a characterisation of the environment correlation and initial correlation recovery. The structure of the decomposition sets the building blocks for consideration of correlations in multiparty undergoing processes with interventions in general and we expect to extend the formulation to describe such correlation in the complex schema.

42. Shubhayan Sarkar, Center for Theoretical Physics, Polish Academy of Sciences
Certification of maximal unbounded randomness from all bipartite entangled states using non-projective measurements
Poster Abstract: In recent times, certification of quantum systems has been studied extensively which has led to several important applications in quantum information, one of them being certification of genuine randomness. It remains unanswered whether every bipartite entangled state of local dimension d can generate the maximal amount of randomness possible using quantum systems, that is, $2\log_2 d$ bits of randomness. Further, it also remains a highly non-trivial problem to propose a scheme which can self-test all bipartite entangled states using a single family of inequalities. In this work, we first propose a family of steering inequalities which can be maximally violated by every bipartite entangled state and with minimal number of measurements per party, that is, two. Then, we show that the proposed steering inequalities can be used to self-test every bipartite entangled states. Then, we find robustness bounds of our self-testing result in presence of experimental errors. Using our self-testing scheme, we then certify every extremal measurements including extremal d^2-outcome non-projective measurements which in turn is used to certify $2\log_2 d$ bits of randomness from any bipartite entangled state.

43. José Diogo Simão, Theoretical Physics Institute Jena
Semiclassical behaviour of Lorentian Spin-Foams
Poster Abstract: Spin-foam models are non-perturbative and background-independent putative theories of quantum gravity. Such models propose a discrete and fuzzy structure for quantum space-time, where geometry is replaced by algebraic and group-theoretic data: hence the term "Spin-foam". This poster discusses in which sense Lorentzian spin-foam theories can recover in some appropriate semiclassical regime a discrete theory of general relativity. We find in this regime that the model is dominated by more configurations than those corresponding to discrete gravity, hinting the theory may need further refinement.

44. Athanasios Tzemos, Research Center for Astronomy and Applied Mathematics of the Academy of Athens
Studying Born's rule with entangled Bohmian qubits
Poster Abstract: Bohmian Quantum Mechanics (BQM) is a famous interpretation of Quantum Mechanics (QM), where the quantum particles follow certain deterministic trajectories, guided by the so 'called Bohmian equations of motion'.

The non linear character of the Bohmian equations, allows the existence of both ordered and chaotic trajectories for the quantum particles. In the past we presented the so called 'nodal-point-X-point mechanism', according to which, whenever a quantum particle comes close to a nodal point of the wavefunction (where the wavefunction vanishes), it gets scattered by a characteristic stagnant point of the Bohmian flows in the frame of reference of the moving node, the so called 'X-point'. The cumulative action of many such scattering events implies the saturation of Lyapunov characteristic number at a positive value, something that indicates the existence of chaos. Nodal points along with their corresponding X-points form a characteristic structure of the Bohmian flow, called 'nodal point-X-point complex' (NPXPC). Trajectories that do not approach NPXPCs are ordered.

A deep understanding of chaos generation in Bohmian trajectories is necessary in order to study the origin of Born's rule (BR). BR is a cornerstone of Quantum Mechanics (QM) and has never been doubted by the experiment. However, while in standard QM BR is an axiom, in BQM one can, in principle, start with an initial distribution of particles that does not satisfy BR. Consequently it is of fundamental importance to understand whether BR is dynamically accessible to an arbitrary initial distribution, or not, and what is the underlying mechanism behind this process. In the last 3 years we have presented in a series of works the Bohmian dynamics of an entangled two-qubit system made of properly engineered coherent states of the quantum harmonic oscillator. This system plays a key role in Quantum Information theory and has very rich Bohmian dynamics.

Our system, which has infinitely many nodal points on straight lattices whenever the entanglement is non zero, has more chaotic trajectories when the entanglement increases. In the absence of entanglement all trajectories are ordered.

In the case of strong entanglement, we find that all initial distributions reach with a good accuracy the Born rule, because they are dominated by chaotic trajectories, which are ergodic. Namely we find that the long limit distribution of the points of the chaotic trajectories is the same for every initial condition. However ergodicity is not sufficient to guarantee the dynamical approach of BR due to the existence of ordered trajectories.

We find that the critical parameter for the establishment of BR is the ratio between ordered and chaotic trajectories inside a distribution of particles. Namely, an arbitrary distribution will approach BR in the long run only when the ratio between its ordered and chaotic trajectories is the same with that of the BR distribution.

45. Lina Vandré, Universität Siegen
On Quantum Sets of Non-Contextuality Inequalities
Poster Abstract: Bell inequalities and other non-contextuality (NC) inequalities are fundamental for quantum information processing. The underlying scenarios can be represented by exclusivity graphs [1]. In the graph-theoretic approach, events of the inequality are represented by vertices, while exclusivity relations between events are encoded by edges. While a Bell or NC scenario has a unique graph but the same graph can correspond to different scenarios. Originally there is no distinction between parties. In Ref. [2], the approach got modified by using coloured graphs to represent scenarios of multiple parties. Edges of different colours represent exclusivities of different parties what describes the underlying Bell or NC scenarios more precisely. The mathematical properties of the graph are then used for finding the classical and the quantum bound of the inequality. Also the complete set of behaviours allowed by classical probability theory as well as the quantum set can be characterised using these methods.

In this contribution I will discuss the coloured graph approach to the CHSH inequality and provide a method to characterise the corresponding quantum set. Moreover, I introduce a family of subgraphs of the CHSH graph which have the same underlying non-coloured graph (shadow) as the CHSH graph but represent different Bell or NC scenarios. I will compare the quantum sets of different graphs from this family and show how changes in the graph influence the underlying scenario and the quantum set. This contribution is based on Ref. [3].

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Arxiv: arXiv:2105.08561

46. Augustin Vanrietvelde, Imperial College London / University of Oxford
Routed quantum circuits
Poster Abstract: We argue that the quantum-theoretical structures studied in several recent lines of research cannot be adequately described within the standard framework of quantum circuits. This is in particular the case whenever the combination of subsystems is described by a nontrivial blend of direct sums and tensor products of Hilbert spaces. We therefore propose an extension to the framework of quantum circuits, given by textitrouted

linear maps and textitrouted quantum circuits. We prove that this new framework allows for a consistent and intuitive diagrammatic representation in terms of circuit diagrams, applicable to both pure and mixed quantum theory, and exemplify its use in several situations, including the superposition of quantum channels and the causal decompositions of unitaries. We show that our framework encompasses the 'extended circuit diagrams' of Lorenz and Barrett [arXiv:2001.07774 (2020)], which we derive as a special case, endowing them with a sound semantics.
Arxiv: 2011.08120

47. Lucas Vieira, IQOQI Vienna / University of Vienna
Temporal correlations in the simplest measurement sequences
Poster Abstract: We investigate temporal correlations in the simplest measurement scenario, i.e., that of a physical system on which the same measurement is performed at different times, producing a sequence of dichotomic outcomes. The resource for generating such sequences is the internal dimension, or memory, of the system. We characterize the minimum memory requirements for sequences to be obtained deterministically, and numerically investigate the probabilistic behavior below this memory threshold, in both classical and quantum scenarios. A particular class of sequences is found to offer an upper-bound for all other sequences, which suggests a nontrivial universal upper-bound of $1/e$ for the classical probability of realization of any sequence below this memory threshold. We further present evidence that no such nontrivial bound exists in the quantum case.
Arxiv: 2104.02467

48. Rafael Wagner, International Iberian Nanotechnology Laboratory/ Universidade do Minho
Emergence of noncontextuality in quantum Darwinism
Poster Abstract: A deep understanding of the concept of classicality is essential. Historically, the initial debates over quantum theory regarding its completeness, consistency, and relation to classical reasonings ripened into at least two fruitful paradigms for classicality. One is the description of classicality in terms of objectivity, meaning the agreement between different observers about macroscopic reality. The second is known as the notion of noncontextuality; the fact that operationally indistinguishable processes should be modeled in the same way. In this work, we show a clear connection between these two seemingly unrelated paradigms of classical reality.

Since the early days of quantum mechanics, objectivity was considered a minimum requirement for the quantum-to-classical transition to be consistent with the observed classical world. In other words, 'strange' effects such as entanglement should disappear, and objective aspects of physical reality should emerge as we go from analyzing microscopic to macroscopic systems. A partial description of how the emergence of classical objectivity appears in observations is well-posed by the theory of decoherence, but although this constitutes, arguably, an incredible development into understanding quantum-to-classical transitions, decoherence theory does not answer many questions such as how the classical (decohered) information reaches the observers, or how these observers are actually capable of agreeing about what they measure.

Quantum Darwinism is a hypothesis that proposes a mechanism for the proliferation of classical information by promoting the environment into an active carrier of information about systems of interest, answering the above-mentioned questions left by decoherence theory. But the following criticism remains: why is objectivity itself a good notion of classicality? Why should we engage in a notion of classical reality based on the emergence of agreement between observers, and not the emergence of something that is, by all means, classical? Is this kind of objectivity necessarily classical? We show that, if one takes Spekkens' notion of noncontextuality as the notion of classicality and the approach of Brandão, Piani, and Horodecki to quantum Darwinism, the answer to the above question is that agreement in a quantum Darwinism paradigm implies the existence of a non-contextual model for the system for each observer. Moreover, not only our work proposes specific requirements for quantum Darwinism to describe the emergence of classical reality, but also that noncontextuality itself can be seen as an emergent phenomenon even if quantum Darwinism does not occur.
Arxiv: 2104.05734

49. Tian Zhang
Quantum correlations in time
Poster Abstract: In these work, we aim to under time in quantum theory from the perspective of quantum correlations. We assume that in quantum theory, temporal correlations are treated on an equal footing as spatial correlations. We investigate quantum correlations in time in different space-time approach, including pseudo-density matrices, process matrices in indefinite causal structures, consistent histories, generalised quantum games, out-of-time-order correlations, and path integrals. We claim that quantum correlations in time are operationally equivalent in these approaches, except the path integral representation. We further applied temporal correlations to understanding quantum time crystals and time translation symmetries. As a result,

we also find that quantum correlations in space and quantum correlations in time are quite different, which suggests that time is very different from space in terms of quantum correlations.
Arxiv: 2002.10448, 2101.08693

50. Beata Zjawin, International Centre for Theory of Quantum Technologies (ICTQT)
Resource theory of steering under local operations and shared randomness
Poster Abstract: Non-classical resources can be studied and quantified in a resource-theoretic framework. Recently, local operations and shared randomness (LOSR) were motivated to be the natural set of free operations in resource theories of Bell scenarios and entanglement. Here, we explore a resource theory of steering under LOSR. We study different physical scenarios: (i) traditional bipartite scenarios, (ii) traditional multipartite scenarios, and (iii) bipartite Bob-with-Input scenarios. This is the first resource theory developed for multipartite steering and Bob-with-Input steering. In each of the scenarios, we describe how the set of free operations looks like and motivate what an unsteerable assemblage is. By doing so, we clarify the definition of classicality for steering. We show that resource conversion under LOSR operations can be evaluated with a single instance of a semidefinite program for all scenarios, making the problem tractable relative to other paradigms. We implement this program and study the pre-order of resources. In the Bob-with-Input scenario, we study the pre-order even for the post-quantum assemblages. Moreover, we derive new steering resource monotones and confirm the structure of the pre-order analytically.

VI. FLOOR 6

51. Paulo Cavalcanti, ICTQT
Witworld: A Generalized Probabilistic Theory to Realize Post-Quantum Steering
Poster Abstract: We introduce the first generalized probabilistic theory (GPT) which is capable of realizing post-quantum steering and use it to show explicitly the first instance of an information processing task, namely Remote State Preparation, for which post-quantum steering is a resource more powerful than any quantum resource.
Arxiv: arXiv:2102.06581

52. Marco Túlio Quintino, IQOQI-Vienna
Strict hierarchy between parallel, sequential, and indefinite- causal-order strategies for channel discrimination
Poster Abstract: We present an instance of a task of minimum-error discrimination of two qubit-qubit quantum channels for which a sequential strategy outperforms any parallel strategy. We then establish two new classes of strategies for channel discrimination that involve indefinite causal order and show that there exists a strict hierarchy among the performance of all four strategies. Our proof technique employs a general method of computer-assisted proofs. We also provide a systematic method for finding pairs of channels that showcase this phenomenon, demonstrating that the hierarchy between the strategies is not exclusive to our main example.
Arxiv: 2011.08300, 2105.13369