	Monday
O. Gühne 9:00 – 9:45	**Quantum Steering and the Geometry of the EPR-Argument** Steering is a type of quantum correlations which lies between entanglement and the violation of Bell inequalities. In this talk, I will first give an introduction into the topic. Then, I will discuss two results on steering: First, I will show how entropic uncertainty relations can be used to derive steering criteria. Second, I will present an algorithmic approach to characterize the quantum states that can be used for steering. With this, one can decide the problem of steerability for two-qubit states. [1] A.C.S. Costa et al., arXiv:1710.04541. [2] C. Nguyen et al., arXiv:1808.09349.
J.-Å. Larsson 9:45 – 10:30	**Quantum computation and the additional degrees of freedom in a physical system** The speed-up of Quantum Computers is the current drive of an entire scientific field with several large research programmes both in industry and academia world-wide. Many of these programmes are intended to build hardware for quantum computers. A related important goal is to understand the reason for quantum computational speed-up; to understand what resources are provided by the quantum system used in quantum computation. Some candidates for such resources include superposition and interference, entanglement, nonlocality, contextuality, and the continuity of state-space. The standard approach to these issues is to restrict quantum mechanics and characterize the resources needed to restore the advantage. Our approach is dual to that, instead extending a classical information processing systems with additional properties in the form of additional degrees of freedom, normally only present in quantum-mechanical systems. In this talk, we will have a look at these additional degrees of freedom and how quantum computers make use of them to achieve the so-called quantum speedup. We will also discuss whether the additional degrees of freedom can be viewed as a "side channel," a term often seen in cryptology, and whether quantum parallelism rather should be viewed as computation performed in some additional degree of freedom.
N. Friis 10:30 – 11 :00	**Non-ideal projective measurements in quantum thermodynamics** This talk will discuss an apparent conflict between the projection postulate of quantum mechanics and the third law of thermodynamics. That is, while ideal projective measurements leave systems in pure states, the unattainability principle prevents one from preparing such pure states. We approach this issue by modelling measurements on a quantum systems as interactions between the system and a pointer. We formalize the notion of ideal measurements in terms of three properties – unbiasedness, faithfulness and non-invasiveness – and discuss their relation and operational meaning [1]. Based on this framework, we resolve the apparent contradiction mentioned above, by showing that it is impossible to perform ideal projective measurements using finite resources – energy, time, and control. As an example that illustrates this problem, we consider a simple quantum system, a qubit, and a pointer consisting of N qubits. For

	this system, we provide explicit calculations that illustrate the trade-off between the energy cost of the measurement and the ability to predict the post-measurement system state. Finally, we discuss some implications for the field of quantum thermodynamics, in particular, for the quantification of work and its fluctuations [2]. [1] Y. Guryanova, N. Friis, and M. Huber, preprint arXiv:1803.06884 [quant-ph] (2018). [2] T. Debarba, G. Manzano, Y. Guryanova, M. Huber, and N. Friis, in preparation
E. Aguilar 11:30 – 12:00	**Connections between Mutually Unbiased Bases and Quantum Random Access Codes** We present a new quantum communication complexity protocol, the promise-quantum random access code, which allows us to introduce a new measure of unbiasedness for bases of Hilbert spaces. The proposed measure possesses a clear operational meaning and can be used to investigate whether a specific number of mutually unbiased bases exist in a given dimension by employing semidefinite programming techniques.
S. Mansfield 12:00 – 12:45	**Non-classicality in sequences and causally ordered scenarios** I will consider two notions of non-classicality that extend familiar treatments of non-locality and contextuality. One is a notion of contextuality for transformations in sequential contexts, distinct from the Bell-Kochen-Specker and Spekkens notions of contextuality. This can be shown to relate to rudimentary quantum advantages analogous to known relationships between BKS contextuality and advantage. Analysis of the phenomenon strongly suggests a more general approach to considering non-classicality in quantum theory and other operational theories. Another notion looks at measurement contextuality in scenarios with causal ordering, which extends existing frameworks to also apply to examples like the Leggett-Garg or double slit experiments.
R. Uola 14:15 – 15:00	**Quantifying quantum resources with conic programming** The aim of quantum resource theories is to formalize the quantification and manipulation of quantum resources, which include but are not limited to entanglement, asymmetry and coherence of quantum states, and incompatibility of quantum measurements. Given a quantum resource, one can ask whether it is useful for some task. More specifically: does there exist a task in which a given resource state performs better than any resourceless state? In this talk, I will answer this question in positive for any resource theory with a convex and compact set of free states (based on quantum state assemblages or sets of quantum measurements). This is reached through the duality theory of conic programming, which I will briefly review. Moreover, some explicit sets of free states, e.g. jointly measurable POVMs, POVMs simulable with projective measurements, and state assemblages preparable with a given Schmidt number are discussed.

J. Kiukas 15:00 – 15:45	**The formulation of quantum steering in terms of incompatibility breaking channels - some applications** Using a general state-channel duality, we formulate the connection between quantum measurement incompatibility and steering in terms of incompatibility breaking quantum channels. More precisely, any bipartite state is non-steerable by a collection of measurements if and only if the associated channel maps the measurements into a jointly measurable set. We illustrate the use of this equivalence with examples related to the transfer of quantum correlations through spin systems.
Z. Wang 16:15 – 17:00	**A Marginally Interesting Story of Dominoes and Tiles** This talk is about the classical marginal problem for translation-invariant probability distributions in 1 and 2 dimensions. Various characterizations, approximations and limitations arising from this problem can be proven using geometric/combinatoric tools.

	Tuesday
C. Spee 9:00 – 9:45	**Temporal correlations can certify the quantum dimension** Temporal correlations of a single system have been employed to formulate inequalities, so-called Leggett-Garg inequalities, that allow to distinguish between the classical theory of macroscopic realism and quantum mechanics. We show that the temporal correlations that can be realized within quantum mechanics can also be used to formulate inequalities that act as dimension witnesses, i.e. a violation establishes a dimension bound on the measured quantum system. Quantum mechanics is well known to fulfill the Arrow of Time (AoT) constraints, i.e. signaling in time is only allowed with respect to the future. As the no-signaling constraints the AoT constraints define a polytope, the temporal correlation polytope. We characterize the extreme points of the temporal correlation polytope and show that in quantum mechanics without any dimension restriction all possible correlations in this polytope can be realized even if at each time step the set of possible measurements is the same. However, if the dimension is bounded some correlations cannot be obtained. This allows one to use temporal correlations to certify a lower bound on the quantum dimension.
A. Cabello 9:45 – 10:30	**The physical origin of quantum nonlocality and contextuality** What is the physical principle that singles out the quantum correlations for Bell and contextuality scenarios? Here we show that, if we restrict our attention to correlations that, as is the case for all correlations in classical and quantum physics, can be produced by measurements that: (i) yield the same outcome when repeated, (ii) only disturb measurements that are not jointly measurable, and (iii) all their coarse-grainings have realizations that satisfy (i) and (ii), then the question has a surprising answer. The set of quantum correlations is singled out by the following principle: There is no law governing the outcomes of the measurements; for any scenario made of these measurements, every not inconsistent behavior does take place. "Inconsistent" behaviors are those that violate a condition that holds for measurements satisfying (i)-(iii), namely, that the sum of the probabilities of any set of pairwise exclusive events is bounded by one. Two events are exclusive if they correspond to different outcomes of the same measurement. To prove the result, we begin by characterizing the sets of not inconsistent probability assignments for each "graph of exclusivity," without referring to any particular scenario, but treating all Bell and contextuality scenarios at once. The restrictions of each scenario are introduced at the end of the proof and then we obtain the set of behaviors that satisfies the above principle for each scenario. Each of these sets is equal to the corresponding set in quantum theory.
A. Garner 10:30 – 11:00	**Phase, interference and computation beyond quantum theory** A quantum bit is qualitatively different from a classical bit - it allows for the coherent super-position of possibilities, demonstrating different behaviours depending on the phase between them. These behaviours constitute interference phenomena, and underlie the existence of algorithms in quantum computing which are faster all known classical alternatives. What if quantum theory did not hold in all scenarios, or was

	only a limiting case of some broader theory? In this case, can we still meaningfully talk about phase and interference? In my talk, I will present key results from a project to generalize phase and interference into post-quantum theories. I will discuss the special role the uncertainty principle plays in enabling non-trivial dynamics, and draw conclusions about the possibility of non-classical algorithms for computation beyond quantum theory.
I. Kull 11:30 – 12:00	**A Spacetime Area Law Bound on Quantum Correlations** Area laws are a far-reaching consequence of the locality of physical interactions, and they are relevant in a range of systems, from black holes to quantum many-body systems. Typically, these laws concern the entanglement entropy or the quantum mutual information of a subsystem at a single time. However, when considering information propagating in spacetime, while carried by a physical system with local interactions, it is intuitive to expect area laws to hold for spacetime regions. In this work, we prove such a law for quantum lattice systems. We consider two agents interacting in disjoint spacetime regions with a spin-lattice system that evolves in time according to a local Hamiltonian. In their respective spacetime regions, the two agents apply quantum instruments to the spins. By considering a purification of the quantum instruments, and analyzing the quantum mutual information between the ancillas used to implement them, we obtain a spacetime area law bound on the amount of correlation between the agents' measurement outcomes. Furthermore, this bound applies both to signaling correlations between the choice of operations on the side of one agent, and the measurement outcomes on the side of the other; as well as to the entanglement they can harvest from the spins by coupling detectors to them.
G. Tóth 12:00 – 12:45	**How long does it take to obtain a physical density matrix?** The statistical nature of measurements alone easily causes unphysical estimates in quantum state tomography, i.e., we obtain a density matrix that is not positive-semidefinite. There are several methods to restore the physical state from the data obtained from the measurements. These methods remove the negative eigenvalues of the density matrix, but also make the large, important eigenvalues smaller. This way, they distort the most informative part of the density matrix. This is a large problem, since fitting a physical density matrix on the measured data is carried out in most state tomographies. Hence, there is a decade long intensive discussion on finding alternatives. We show that usual tomographic methods lead to eigenvalue distributions converging to the Wigner semicircle distribution for already a modest number of qubits. This enables to specify the number of measurements necessary to avoid unphysical solutions. We introduce a simple method to obtain a physical density matrix from the measured values, without disturbing the large eigenvalues. Our method solves the long lasting problem mentioned above. [1] L. Knips, C. Schwemmer, N. Klein, J. Reuter, G. Toth, and H. Weinfurter, arxiv:1512.06866

M. Kleinmann 14:15 – 15:00	**Optimal states and methods for verifying bound entanglement** Bound entangled states are a rather small and particular class of entangled states. Besides their theoretical importance, bound entangled states are notoriously difficult to prepare experimentally, because they are both, entangled and mixed. Even for a successful experimental preparation, yet another challenge is the actual verification that such a preparation was successful. In this talk I will present methods to find states which are most suitable for preparation and verification and I detail the methods for verifying that an experimental state was indeed bound entangled.
M. Müller 15:00 – 15:45	**Exact operational interpretation of entropy and free energy without the thermodynamic limit** Thermodynamics at the nanoscale is known to differ significantly from its familiar macroscopic counterpart: the possibility of state transitions is not determined by free energy alone, but by an infinite family of free-energy-like quantities; strong fluctuations (possibly of quantum origin) allow to extract less work reliably than what is expected from computing the free energy difference. However, these known results rely crucially on the assumption that the thermal machine is not only exactly preserved in every cycle, but also kept uncorrelated from the quantum systems on which it acts. Here we lift this restriction: we allow the machine to become correlated with the microscopic systems on which it acts, while still exactly preserving its own state. Surprisingly, we show that this restores the second law in its original form: free energy alone determines the possible state transitions, and the corresponding amount of work can be invested or extracted from single systems exactly and without any fluctuations. At the same time, the work reservoir remains uncorrelated from all other systems and parts of the machine. Thus, microscopic machines can increase their efficiency via clever “correlation engineering” in a perfectly cyclic manner, which is achieved by a catalytic system that can sometimes be as small as a single qubit. Our results also solve some open mathematical problems on majorization which may lead to further applications in entanglement theory. [1] M. P. Müller arXiv:1707.03451 (accepted by PRX).
M. Woods 16:15 – 17:00	**Quantum Clocks: from fundamental bounds on their accuracy to applications in quantum information** This will be an overview of some of my recent theory work on clocks. I will start by discussing the differences between quantum clocks and quantum stopwatches, and their classical counterparts. We will then set out to discuss why there is a quantum advantage to measuring time. Finally, we will discuss one of the well know quantum clocks in the literature, the so-called Seleker-Wigner-Peres quantum clock, and show that it is only as good as the best classical clock. We will then move on to applications, and show that how well time can be measured via a quantum clock, has a one-to-one relationship to how well quantum error correcting codes can be made covariant.

	Wednesday
N. Milkin 9:00 – 9:45	**Semi-device-independent certification of nonprojective measurements** A general form of quantum measurement, formalized by the notion of positive-operator valued measure (POVM), is not only a nice theoretical abstraction, but is also necessary to give a correct description of some physical experiments [1]. Nonprojective measurements were also shown to be optimal for certain quantum information processing tasks, including state discrimination [2], tomography [3], and optimal randomness certification [4]. However, experimental demonstration of nonprojective measurements in a way, which would not rely on the functionality of the devices, turned out to be a complicated task. Only in 2016 a nonprojective qubit measurement was certified for the first time in the device-independent manner [5]. In our work we demonstrate certification of entire families of nonprojective measurements in a set-up, that is a generalization of Quantum Random Access Codes (QRACs) [6]. We consider a figure of merit with some tunable parameters allowing for certification of various nonprojective measurements. We estimate the robustness of this certification and show, that even for some measurements that are very close to be projective, there exist a non-zero threshold allowing for the certification. The proposed scheme is also allowing for discrimination between realization of nonprojective measurements and their simulation with the projective ones. Finally, based on the above results, we provide new monogamy relations for QRACs. [1] e.g the Stern–Gerlach experiment. [2] S. M. Barnett, and S. Croke., Advances in Optics and Photonics 1.2 (2009) [3] A.J. Scott, Journal of Physics A, 39.43 (2006) [4] A. Acin, et al., Physical Review A 93.4 (2016) [5] E.S. Gomez, et al., Physical review letters 117.26 (2016) [6] A. Ambainis, et al., arXiv preprint arXiv:0810.2937 (2008)
M. Navascues 9:45 – 10:30	**Chunking quantum networks** As quantum technologies develop, we acquire control of an ever-growing number of quantum systems. Unfortunately, current tools to certify non-classical properties of quantum states, such as entanglement and Bell nonlocality, are just practical for systems of a very modest size, of around 4 sites. Our approach to solve this ``many-body quantum information problem" uses a class of linear transformations, called connectors, which join or chunk different sites of the considered network in a way that preserves the property under investigation. Applying these operations recursively, very quickly we end up with a network of manageable size, whose properties can be explored via usual techniques. Moreover, in case of a successful detection, the method outputs a linear witness which admits an exact tensor network state representation. Using a normal desktop, we test our method by certifying entanglement, Bell nonlocality and supra-quantum Bell nonlocality in networks with hundreds of sites.

F. Giacomini 10:30 – 11:00	**Quantum mechanics and the covariance of physical laws in quantum reference frames** In physics, every observation is made with respect to a frame of reference. Although reference frames are usually not considered as degrees of freedom, in all practical situations it is a physical system which constitutes a reference frame. Can a quantum system be considered as a reference frame and, if so, which description would it give of the world? The relational approach to physics suggests that all the features of a system —such as entanglement and superposition— are observer-dependent: what appears classical from our usual laboratory description might appear to be in a superposition, or entangled, from the point of view of such a quantum reference frame. In this work, we develop an operational framework for quantum theory to be applied within quantum reference frames. We find that, when reference frames are treated as quantum degrees of freedom, a more general transformation between reference frames has to be introduced. With this transformation we describe states, measurement, and dynamical evolution in different quantum reference frames, without appealing to an external, absolute reference frame. The transformation also leads to a generalisation of the notion of covariance of dynamical physical laws, which we explore in the case of ‘superposition of Galilean translations’ and ‘superposition of Galilean boosts’. In addition, we consider the situation when the reference frame moves in a ‘superposition of accelerations’, which leads us to extend the validity of the weak equivalence principle to quantum reference frames. Finally, this approach to quantum reference frames also has natural applications in defining the notion of the rest frame of a quantum system when it is in a superposition of momenta with respect to the laboratory frame of reference.
P. Höhn 11:30 – 12:00	**From quantum reference systems to quantum general covariance** Reference frames (or, more generally, systems) provide the vantage points from which to describe the remaining physics. Treating them fundamentally as quantum systems is inevitable in quantum gravity, where coordinates are a priori unavailable, but also in quantum foundations once accepting that all frames are physical systems. Both fields thus face the question of how to describe physics from the perspective of quantum reference systems and how the descriptions relative to different such choices are related. I will summarize a recent systematic method for such switches, which works in analogy to coordinate changes on a manifold, except that these `quantum coordinate changes' proceed between different Hilbert spaces. This method employs a symmetry principle, sets the stage for a quantum version of general covariance and applies to both temporal and spatial reference systems.
M. Weilenmann 12:00 – 12:30	**Analysing causal structures in generalised probabilistic theories** Causal structures are crucial to understanding the inferences that can be extracted from experimental data. Although well-studied in the classical setting, the growing number of quantum mechanical experiments has necessitated a generalisation to the quantum realm. So far, in the context of causal structures, little is known about the comparison between agents acting according to quantum theory and those restricted by other generalised probabilistic theories. Here, we initiate a systematic comparison by

	proposing a method for analysing these differences based on the so-called measurement entropy. We apply our technique to study several causal structures, focusing our analysis mainly on the theory of box-world. In addition, we make several technical contributions that crucially affect the analysis of quantum causal structures. Most notably, we prove that the set of achievable entropies in any generalised probabilistic theory and any causal structure is convex.