# Quantum Information Theory and Mathematical Physics 2023

Budapest, 28-30 August 2023

# Program

| | Monday 28.08 | Tuesday 29.08 | Wednesday 30.08 |
|---|---|---|---|
| 9:30 – 10:45 | Ludovico Lami | Fumio Hiai | Carlos Palazuelos |
| 10:45 – 11:15 | Coffee break | | |
| 11:15 – 12:30 | Anna Jencova | Cambyse Rouzé | Francesco Buscemi |
| 12:30 – 14:30 | Lunch | | Free |
| 14:30 – 15:45 | Nilanjana Datta | Christoph Hirche | |
| 15:45 – 16:15 | Coffee break | | |
| 16:15 – 18:00 | Free discussion | Free discussion | |
| 19:30 – 21:00 | | Conference dinner | |

### Sunday Beer:

Time: Sunday, 27 August, 18:00-
Location: **KEG Sörművház**, Orlay utca 1, Budapest 1114, Hungary
google maps

### Conference dinner:

Time: Tuesday, 29 August, 19:30-22:00
Location: **Ape Regina**, 1065 Budapest, Podmaniczky u. 18.
**google map**

# Talks

**Speaker: Francesco Buscemi**

**Title: Petz recovery, Jeffrey retrodiction, and von Neumann's "other" entropy**

**Abstract:** Besides the quantity that is nowadays eponymously known as the von Neumann entropy, in his 1932 book von Neumann discusses also another entropic quantity, which he calls "macroscopic", arguing that it is the latter, and not the former, the relevant quantity to use when analyzing thermodynamic systems. However, for a long time, von Neumann's "other" entropy was largely forgotten and has appeared only sporadically in the literature, overshadowed by its more famous sibling. In this talk I will discuss a recent generalization of von Neumann's macroscopic entropy, called "observational entropy", focusing on its mathematical properties (leading to a strong version of Petz recovery) and statistical interpretation. Concerning the latter, I will discuss two interpretations of observational entropy, one as statistical deficiency, the other one as irretrodictability. These interpretations suggest ways to obtain fully quantum generalizations of observational entropy. I will discuss some possibilities in this direction.

**Speaker: Nilanjana Datta**

**Title: Ergodicity and Mixing Properties of Quantum Channels**

**Abstract:** Ergodicity and mixing are notions concerning the long-term behaviour of the dynamics of physical systems. We discuss various characterizations of ergodicity and mixing of quantum channels, which provide the most general description of the dynamics of quantum-mechanical systems. We focus in particular on a family of quantum channels which satisfy a certain covariance property. For this family of channels, ergodicity and mixing are governed essentially by a classical stochastic matrix and hence can be verified by studying connectivity properties of an associated directed graph. We apply our analysis to a family of quantum circuits which model the dynamics of a spin chain with nearest neighbour interactions. This talk is based on work done jointly with Ion Nechita and Satvik Singh.

**Speaker: Fumio Hiai**

**Title: Equality cases in monotonicity of quasi-entropies**

**Abstract:** We revisit and improve joint concavity/convexity and monotonicity properties of quasi-entropies due to Petz in a new fashion in the finite-dimensional setting. Then we characterize equality cases in the monotonicity inequalities (the data-processing inequalities) of quasi-entropies in several ways as follows: Let $\Phi : \mathcal{B}(\mathcal{H}) \to \mathcal{B}(\mathcal{K})$ be a trace-preserving map such that $\Phi^*$ is a Schwarz map. When $f$ is an operator monotone or operator convex function on $[0, \infty)$, we present several equivalent conditions for the equality $S_f^K(\Phi(\varrho)\|\Phi(\sigma)) = S_f^{\Phi^*(K)}(\varrho\|\sigma)$ to hold for given positive operators $\varrho, \sigma$ on $\mathcal{H}$ and $K \in \mathcal{B}(\mathcal{K})$. The conditions include equality cases in the monotonicity versions of Lieb's concavity and Ando's convexity theorems. Specializing the map $\Phi$ we have equivalent conditions for equality cases in Lieb's concavity and Ando's convexity. Similar equality conditions are discussed also for monotone metrics and $\chi^2$-divergences. We further consider some types of linear preserver problems for those quantum information quantities.

**Speaker: Christoph Hirche**

**Title: Quantum Rényi and $f$-divergences from integral representations**

**Abstract:** Smooth Csiszár $f$-divergences can be expressed as integrals over so-called hockey stick divergences. This motivates a natural quantum generalization in terms of quantum Hockey stick divergences, which we explore here. Using this recipe, the Kullback-Leibler divergence generalises to the Umegaki relative entropy, in the integral form recently found by Frenkel. We find that the Rényi divergences defined via our new quantum f-divergences are not additive in general, but that their regularisations surprisingly yield the Petz Rényi divergence for $\alpha < 1$ and the sandwiched Rényi divergence for $\alpha > 1$, unifying these two important families of quantum Rényi divergences. Moreover, we find that the contraction coefficients for the new quantum $f$-divergences collapse for all $f$ that are operator convex, mimicking the classical behaviour and resolving some long-standing conjectures by Lesniewski and Ruskai. We derive various inequalities, including new reverse Pinsker inequalites with applications in differential privacy and also explore various other applications of the new divergences. (Joint work with Marco Tomamichel.)

**Speaker: Anna Jencova**

**Title: Is it possible to broadcast anything genuinely quantum?**

**Abstract:** No-broadcasting theorem is one of the most fundamental results in quantum information theory; it guarantees that the simplest attacks on any quantum protocol, based on eavesdropping and copying of quantum information, are impossible. Due to the fundamental importance of the no-broadcasting theorem, it is essential to understand the exact boundaries of this limitation. We generalize the standard definition of broadcasting by restricting the set of states which we want to broadcast and restricting the sets of measurements which we use to test the broadcasting. We show that in some of the investigated cases broadcasting is equivalent to commutativity, while in other cases commutativity is not necessary. This part of the talk is based on joint work with Teiko Heinosaari and Martin Plávala (arxiv:2208.10341). We also discuss broadcasting in terms of distinguishability of states, using the results in arxiv:2303.11707.

**Speaker: Ludovico Lami**

**Title: Slightly better quantum data hiding**

**Abstract:** Quantum data hiding is the existence of pairs of bipartite quantum states that are (almost) perfectly distinguishable with global measurements, yet close to indistinguishable when only measurements implementable with local operations and classical communication are allowed. Remarkably, data hiding states can also be chosen to be separable, meaning that secrets can be hidden using no entanglement that are almost irretrievable without entanglement — this is sometimes called "nonlocality without entanglement". Essentially two families of data hiding states were known prior to this work: Werner states and random states. Hiding Werner states can be made either separable or globally perfectly orthogonal, but not both — separability comes at the price of orthogonality being only approximate. Random states can hide many more bits, but they are typically entangled and again only approximately orthogonal. In this paper, we present an explicit construction of novel group-symmetric data hiding states that are simultaneously separable, perfectly orthogonal, and even invariant under partial transpose, thus exhibiting the phenomenon of nonlocality without entanglement to the utmost extent. A scheme to hide arbitrarily many bits with zero global error and controllable LOCC-retrievable mutual information is deduced.

**Speaker: Carlos Palazuelos**

**Title: Quantum entanglement in XOR games**

**Abstract:** In this talk I will explain some results about the use of quantum entanglement in both classical and quantum XOR games, showing that these games are very suitable to compare different resources in quantum information theory. Then, I will present some new results about the natural question of whether quantum entanglement can be more powerful than classical communication to play XOR games.

**Speaker: Cambyse Rouzé**

**Title: Additive and multiplicative strengthenings of the monotonicity of the quantum relative entropy.**

**Abstract:** The monotonicity of the quantum relative entropy with respect to quantum channels is at the core of many important results in quantum information theory and quantum physics. The last decade has seen the development of different strengthenings of this entropic inequality. Roughly speaking, these bounds can be divided into two categories, namely (i) additive strengthenings, sometimes referred to as recovery bounds; and (ii) multiplicative strenghtenings, also known as strong data processing inequalities. Recently, new connexions between these two types of refinements of the monotonicity of the relative entropy were discovered for a subset of channels satisfying a strong kind of detailed balance, the proof of which use non-trivial infinite dimensional operator algebraic reduction techniques. In this talk, I will provide simpler, matrix algebraic proofs of these entropic inequalities. If time permits, I will then discuss applications to the problem of thermalization in quantum lattice spin systems.

# Posters

**Presenter: Dávid Bugár**

**Title: Interpolating between Rényi entanglement entropies for arbitrary bipartitions**

**Abstract:** The asymptotic restriction problem for tensors can be reduced to finding all parameters that are normalized, monotone under restrictions, additive under direct sums and multiplicative under tensor products, the simplest of which are the flattening ranks. Over the complex numbers, a refinement of this problem, originating in the theory of quantum entanglement, is to find the optimal rate of entanglement transformations as a function of the error exponent. This trade-off can also be characterized in terms of the set of normalized, additive, multiplicative functionals that are monotone in a suitable sense, which includes the restriction-monotones as well. For example, the flattening ranks generalize to the (exponentiated) Rényi entanglement entropies of order $\alpha \in [0, 1]$. More complicated parameters of this type are known, which interpolate between the flattening ranks or Rényi entropies for special bipartitions, with one of the parts being a single tensor factor.

We introduce a new construction of subadditive and submultiplicative monotones in terms of a regularized Rényi divergence between many copies of the pure state represented by the tensor and a suitable sequence of positive operators. We give explicit families of operators that correspond to the flattening-based functionals, and show that they can be combined in a nontrivial way using weighted operator geometric means. This leads to a new characterization of the previously known additive and multiplicative monotones, and gives new submultiplicative and subadditive monotones that interpolate between the Rényi entropies for all bipartitions. We show that for each such monotone there exist pointwise smaller multiplicative and additive ones as well. In addition, we find lower bounds on the new functionals that are superadditive and supermultiplicative.

**Presenter: Kohtaro Kato**

**Title: Exact and Local Compression of Quantum Bipartite States**

**Abstract:** Quantum data compression is one of the most fundamental quantum information processing. We study an exact local compression of a quantum bipartite state; that is, exact, one-shot noiseless quantum data compression of general mixed state sources without side information or entanglement assistance. We provide a formula for computing the minimal achievable compression dimensions, provided as a minimization of the Schmidt rank of a particular pure state constructed from that state.