Beyond I.I.D. in Information Theory
Arriving Sunday, July 5 and departing Friday, July 10, 2015

MEALS

*Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday
*Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday
*Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday
Coffee Breaks: As per daily schedule, in the foyer of the TransCanada Pipeline Pavilion (TCPL)
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in the lecture theater in the TransCanada Pipelines Pavilion (TCPL). An LCD projector, a laptop, a document camera, and blackboards are available for presentations.

SCHEDULE

Sunday

16:00	Check-in begins (Front Desk - Professional Development Centre - open 24 hours)
17:30–19:30	Buffet Dinner, Sally Borden Building
20:00	Informal gathering in 2nd floor lounge, Corbett Hall Beverages and a small assortment of snacks are available on a cash honor system.

Monday

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, TCPL
9:00–10:00	Vincent Y. F. Tan — *Second-order asymptotics in classical information theory*
10:00–10:30	Coffee Break
10:30–11:15	Marco Tomamichel — *Asymptotic and Non-Asymptotic Fundamental Limits for Quantum Communication*
11:15–12:00	Felix Leditzky — *Strong converse theorems using Rényi entropies*
12:00–14:00	Lunch (13:00–14:00: Tour of the Banff Centre)
14:00–14:15	Group photo
14:15–15:15	Elliott H. Lieb & Rupert L. Frank — *Topics in trace inequalities*
15:15–15:45	Coffee Break
15:45–16:30	Min-Hsiu Hsieh — *New Characterizations for Matrix Φ-Entropies, Poincaré and Sobolev Inequalities*
16:30–17:15	Patrick Hayden — *One-shot information theory and emergent space*
17:30–19:30	Dinner

Tuesday

7:00–9:00	Breakfast
9:00–9:45	Anna Jenčová — *Conditions for sufficiency of quantum channels*
9:45–10:30	Omar Fawzi — *Quantum conditional mutual information and approximate Markov chains*
10:30–11:00	Coffee Break
11:00–11:30	Mario Berta — *Relative entropies of recovery and conditional quantum mutual information*
11:30–12:15	Frédéric Dupuis — *Chain rules for Rényi entropies*
12:15–14:00	Lunch

Tuesday (continued)

14:00–14:30	Matthias Christandl — *On private bits*
14:30–15:00	*Introduction to posters*
15:00–15:30	Coffee Break
15:30–16:00	Graeme Smith — *Additive entropic quantities*
16:00–16:30	Masahito Hayashi — *Measurement-based Formulation of Quantum Heat Engine and Optimal Efficiency with Finite-Size Effect*
16:30–18:30	Poster Session
18:30–19:30	Dinner

Wednesday

7:00–9:00	Breakfast
9:00–10:00	Marco Dalai — *Reliability function of classical-quantum channels and related problems*
10:00–10:30	Coffee Break
10:30–11:15	Albert Guillén i Fàbregas — *Mismatched Decoding*
11:15–12:00	Debbie Leung — *Near-linear constructions of exact unitary 2-designs*
12:00–14:00	Lunch
	Free Afternoon
17:30–19:30	Dinner

Thursday

7:00–9:00	Breakfast
9:00–9:30	Philippe Faist — *Gibbs-Preserving Maps and Thermal Operations*
9:30–10:15	Nicole Yunger Halpern — *Beyond heat baths: Generalized resource theories for small-scale thermodynamics*
10:15–10:45	Coffee Break
10:45–11:30	Gilad Gour — *The general structure of quantum resource theories*
11:30–12:00	Dong Yang — *Operational resource theory of coherence*
12:00–14:00	Lunch
14:00–14:45	Aram W. Harrow — *Entanglement spread, communication complexity, and ground states*
14:45–15:15	Coffee Break
15:15–16:00	Volkher Scholz — *Semidefinite hierarchies for information theoretic two-partite problems*
16:00–16:45	Saikat Guha — *Entropy power inequalities, estimation-information relationships, and entropic monotonicity in the central limit theorem: from classical to quantum*
16:45–17:45	Renato Renner and Andreas Winter (moderating) — *Open problems session*
17:45–19:30	Dinner

Friday

7:00–9:00	Breakfast
9:00–9:45	Dave Touchette — *Quantum Information Complexity*
9:45–10:15	David Sutter — *Approximate degradable quantum channels*
10:15–10:45	Coffee Break
10:45–11:15	William Matthews — *Detecting quantum capacity*
11:15–12:00	Milan Mosonyi — *Strong converse exponent for classical-quantum channel coding*
12:00–14:00	Lunch

Checkout by 12 noon. ** 5-day workshop participants are welcome to use BIRS facilities (BIRS Coffee Lounge, TCPL and Reading Room) until 3 pm on Friday (still, checkout from guest rooms by 12pm). **

ABSTRACTS
(in alphabetic order by speaker surname)

Speaker: **Mario Berta** (Caltech)
Title: *Relative entropies of recovery and conditional quantum mutual information*
Abstract: Fawzi and Renner (arXiv:1410.0664) recently established a lower bound on the conditional quantum mutual information (CQMI) of tripartite quantum states ρ^{ABC} in terms of the fidelity of recovery (FoR), i.e. the maximal fidelity of the state ρ^{ABC} with a state reconstructed from its marginal ρ^{BC} by acting only on the C system. The FoR measures quantum correlations by the local recoverability of global states and has many properties similar to the CQMI. We sightly generalize the FoR and show that the resulting measure is multiplicative by utilizing semi-definite programming duality. This allows us to simplify an operational proof by Brandão et al. (arXiv:1411.4921) of the above-mentioned lower bound that is based on quantum state redistribution. In particular, in contrast to the previous approaches, our proof does not rely on de Finetti reductions. Finally, we also discuss how to use convex programming duality to study additivity properties of general relative entropy of recovery measures leading to (potentially stronger) lower bounds on the CQMI.
Based on work with Marco Tomamichel (arXiv:1502.07973) and Omar Fawzi (unpublished).

Speaker: **Matthias Christandl** (Copenhagen University)
Title: *On private bits*
Abstract: to be added.

Speaker: **Marco Dalai** (University of Brescia)
Title: *Reliability function of classical-quantum channels and related problems*
Abstract: We discuss the problem of determining the so called reliability function of a classical-quantum channel, which is the error exponent of optimal codes at rates smaller than the classical capacity. Achievability results, which partially extend classical results by Fano, Shannon, Gallager and Berlekamp, were first derived by Holevo and then by Hayashi and Nagaoka. In this talk, we will first discuss the extension of the main classical converse, the so called sphere packing bound. We show that such a converse can be written in terms of Renyi divergences D_α and that, at high rates, it coincides with the expression which is respectively proved and conjectured by Holevo to be achievable for pure states and mixed state channels, respectively. An interesting aspect of this converse is observed at low rates; we show in fact that the sphere packing bound for cq-channels is as powerful as to include Lovász' (and Marton's) bound on the zero-error capacity of the channel.
We then discuss the connection of reliability function with the problem of determining bounds on the minimum distance of codes, with particular focus on the case where some symbols cannot be confused, which is reasonably modeled by an infinite-valued distance. We present some results which mix Lovász' construction with other combinatorial considerations to deduce bounds on minimal code distance in this setting.
Finally, we conclude by turning back our attention to missing steps in the extension of classical results to classical-quantum channels, discussing some interesting problems which arise in this context.

Speaker: **Frédéric Dupuis** (Masaryk University Brno)
Title: *Chain rules for quantum Rényi entropies*
Abstract: I will give a proof of the chain rules for the "sandwiched" Rényi entropies presented in arXiv:1410.5455. These are inequalities of the form $H_\alpha(AB|C) \lesseqgtr H_\beta(A|BC) + H_\gamma(B|C)$, where the direction of the inequality depends on the Rényi parameters. Along the way, I will present the main mathematical tool used, namely the Hadamard three-line theorem, a powerful tool that deserves to be promoted.

Speaker: **Philippe Faist** (ETH Zurich)
Title: *Gibbs-Preserving Maps and Thermal Operations*
Abstract: We compare two frameworks for characterizing possible operations in quantum thermodynamics. One framework considers thermal operations—unitaries which conserve energy. The other framework considers all maps which preserve the Gibbs state at a given temperature. Thermal operations, being motivated operationally, are useful for achievability results while Gibbs-preserving maps are a framework of choice for proving fundamental limits. Classically, the two frameworks are equivalent. In the quantum regime, all thermal operations preserve the Gibbs state, yet Gibbs-preserving maps allow more general state transitions. Indeed, a Gibbs-preserving map may create coherent superpositions of energy levels whereas thermal operations are by construction time covariant. This leaves open the question of which of the two frameworks captures the true physical situation. We point at evidence that the gap is due to some subtle implicit assumptions: by "perverting" the notion of the Gibbs state and of energy levels, one may perform the transition forbidden by thermal operations using simple physical operations. We discuss current investigations of the relevance of this difference.

Speaker: **Omar Fawzi** (ENS Lyon)
Title: *Quantum conditional mutual information and approximate Markov chains*
Abstract: The Shannon and von Neumann entropies quantify the uncertainty in a system. They are operationally motivated by natural information processing tasks such as compression, channel coding or randomness extraction. In addition to characterizing the fundamental rates at which such tasks can be performed, their additivity properties make them a very valuable tool in applications ranging from complexity theory to many-body systems.
A difficulty that arises when dealing with quantum systems is the operational meaning of quantum observers, or the way to interpret conditional entropies. A particularly interesting quantity is the mutual information between two systems conditioned on a third quantum system. What notion of conditional independence does this quantity measure? After an overview of some of the applications of the conditional mutual information, I will show how the quantum conditional mutual information can be related to the task of local recovery and discuss some properties of such a recovery map.
Based on joint work with Renato Renner (arXiv:1410.0664) and David Sutter and Renato Renner (arXiv: 1504.07251).

Speaker: **Gilad Gour** (University of Calgary)
Title: *The general structure of quantum resource theories*
Abstract: In recent years it was recognized that properties of physical systems such as entanglement, athermality, and asymmetry, can be viewed as resources for important tasks in quantum information, thermodynamics, and other areas of physics. This recognition followed by the development of specific quantum resource theories (QRTs), such as entanglement theory, determining how quantum states that cannot be prepared under certain restrictions may be manipulated and used to circumvent the restrictions. In this talk I will show that all such QRTs have a general structure and, in particular, show that under a few physically motivated assumptions, a QRT is asymptotically reversible if its set of allowed operations is maximal. In this case, the asymptotic conversion rate is given in terms of the regularized relative entropy of a resource which is the unique measure/quantifier of the resource in the asymptotic limit of many copies of the state. As an example, I will introduce a resource theory in which the quantum conditional entropy (or more precisely $\log|A| - S(A|B)$) provides the unique asymptotic conversion rate.

Speaker: **Saikat Guha** (Raytheon BBN Technologies)
Title: *Entropy power inequalities, estimation-information relationships, and entropic monotonicity in the central limit theorem: from classical to quantum*
Abstract: In this talk, I will first relate a storyline connecting a sequence of intertwined developments in three very closely related topics in classical information theory: various forms of the entropy power inequality (EPI), monotonicity of the differential entropy in the central limit theorem (CLT), and a relationship

between the minimum mean squared error (MMSE) and mutual information (MI). Shannons original formulation of the EPI found many applications in classical information theory, a profound example being in its application to the capacity converse proof of the Gaussian-noise broadcast channel by Bergmans in 1974. In 1978, Lieb conjectured the monotonic increase of entropy in the CLT as i.i.d. random variables are incrementally added together (divided by the square root of the number of variables added) towards the entropy of the Gaussian random variable with the same variance. The first rigorous proof of this was provided in 2004, and was found to be closely related to the EPI. Some stronger versions both of the EPI and the monotonicity theorem, and their equivalences were subsequently developed in 2007 by Madiman and Barron. In 2005, Guo, Shamai and Verdú proved a relationship between MMSE and MI, which was applied thereafter to develop particularly elegant proofs of both the EPI as well as the monotonicity conjecture. Guo recently further generalized the MMSE-MI relationship to non-Gaussian channels.
In the latter portion of my talk, I will relate a closely parallel development in quantum information theory, which began when we stumbled upon a quantum version of the EPI – which we named the entropy photon number inequality (EPnI) while attempting the converse proof of the capacity (and the capacity region) of the lossy-noisy bosonic channel (respectively, the bosonic broadcast channel). We showed that two minimum-output-entropy conjectures, each of which is implied by the EPnI but are not known to be equivalent to one another, suffice to prove these two capacity theorems. One of these conjectures was proven in 2014 by Giovannetti, Holevo, Cerf and Garcia-Patron, which completes the capacity proof of the lossy-noisy bosonic channel. The other minimum output entropy conjecture, as well as the EPnI itself, remain yet unproven. In 2012, Smith and Koenig proposed a different quantum version of the EPI, which they called the q-EPI, which while not sufficient to prove the aforesaid capacity converses, provide upper bounds to the bosonic channel capacities. The q-EPI was recently proven in a fairly general form by De Palma and coauthors. I had proposed a quantum version of the conjecture on the monotonicity in the CLT for bosonic states in 2008, a partial proof of which – for the number of variables increasing in powers of 2 – is now trivially true given the proof of the q-EPI. However, the general proof of the monotonicity remains open. Finally, in 2014, Tsang proved some initial results towards a quantum version of the MMSE-MI relationship. However, any concrete connections of his result to either the q-EPI, EPnI or monotonicity, are yet unknown. I will describe in detail some of these recent developments in our understanding of the quantum versions of the EPI, MMSE-MI relationship, and the entropic monotonicity in the CLT. I will end my talk with an array of open problems and their potential inter-relationships, as well as their potential applications to the quantum information theory for bosonic systems.

Speaker: **Albert Guillén i Fàbregas** (Universitat Pompeu Fabra Barcelona)
Title: *Mismatched Decoding*
Abstract: This talk will review the mismatched decoding problem. In particular, the talk will review the fundamental limits of mismatched channel-decoder pairs in a point-to-point setup, with particular focus on random coding ensembles, achievable information rates and the corresponding error exponents.

Speaker: **Aram W. Harrow** (MIT)
Title: *Entanglement spread, communication complexity, and ground states*
Abstract: Imagine a world where EPR pairs are free but classical communication is expensive. In the bizarre economy there, the [communication] cost of a pure bipartite entangled state is given by its "entanglement spread," which measures the difference between different Renyi entropies of its reduced state. More informally, entanglement spread measures the deviation from maximal entanglement; it scales as $\sqrt{n}$ for n copies of a fixed states and can be $O(n)$ for states such as embezzling states or superpositions of product states with n EPR pairs. In some cases it can change communication rates, e.g. when simulating noisy channels on non-i.i.d. inputs. In this talk, I'll describe two settings where we don't have to worry about entanglement spread. First, in communication complexity, I'll show that maximally entangled states can be used more or less without loss of generality. Second, I will show that the entanglement spread of ground states of local Hamiltonians is bounded by an area law: that is, the number of cut interactions divided by the gap. This holds even for Hamiltonians on arbitrary graphs where the entropy of entanglement does

not always satisfy an area law.
This is based on arXiv:0909.1557 and unpublished work.

Speaker: **Masahito Hayashi** (Nagoya University)
Title: *Measurement-based Formulation of Quantum Heat Engine and Optimal Efficiency with Finite-Size Effect*
Abstract: There exist two formulations for quantum heat engine. One is semi-classical scenario, and the other is full quantum scenario. The former is formulated as a unitary evolution for the internal system, and is adopted by the community of statistical mechanics. In the latter, the whole process is formulated as unitary. It was adopted by the community of quantum information. However, their formulation does not consider measurement process. In particular, the former formulation does not work when the amount of extracted work is observed. In this paper, we formulate the quantum heat engine as the measurement process because the amount of extracted work should be observed in a practical situation. Then, we clarify the contradiction of the former formulation by using a novel trade-off relation. Next, based on our formulation, we derive the optimal efficiency of quantum heat engines with the finite-size heat baths, without assuming the existence of quasi-static processes. That is, we as ymptotically expand the optimal efficiency up to the third order when we extract work from the pair of hot and cold baths. The first term is shown to be Carnot efficiency. We also investigate the effect by finiteness of the resources by classifying it into two types.
Based on arXiv:1504.06150.

Speaker: **Patrick Hayden** (Stanford)
Title: *One-shot information theory and emergent space*
Abstract: to be added.

Speaker: **Min-Hsiu Hsieh** (UTS Sydney)
Title: *New Characterizations for Matrix Φ-Entropies, Poincaré and Sobolev Inequalities*
Abstract: We derive new characterizations for the matrix Φ-entropies introduced by Tropp [Electron. J. Probab. 19(20):1-30, 2014]. The fact that these new characterizations are a direct generalization of their corresponding equivalent statements for classical Φ-entropies provides additional justification to the original definition of matrix Φ-entropies. Moreover, these extra characterizations allow us to better understand the properties of matrix Φ-entropies, which are a powerful tool for unifying the study matrix concentration inequalities. We then move on to prove a Poincaré inequality for these matrix Φ-entropies. Along the way, we also provide a new proof for the matrix Efron-Stein inequality. Finally, we derive a restricted logarithmic Sobolev inequality for matrix-valued functions defined on Boolean hypercubes. Our proof relies on the powerful matrix Bonami-Beckner inequality.

Speaker: **Anna Jenčová** (Slovak Academy of Sciences)
Title: *Title: Conditions for sufficiency of quantum channels*
Abstract: In classical statistics, a sufficient statistic for a parametrized family of probability distributions is a transformation of the sample space such that the best estimators can be obtained as functions of the transformed data. Alternatively, sufficiency can be characterized by existence of a common conditional expectation preserving all distributions in the family. This notion was extended to quantum channels by Petz [1986 & 1988] as follows: a channel is sufficient with respect to a given family of quantum states if these states can be recovered from the output states by application of another channel. Petz proved that sufficiency is characterized by the fact that the relative entropy is preserved under application of the channel. Moreover, the recovery channel can be obtained as a kind of dual of the channel in question, with respect to a given faithful state.
I will give an overview of some equivalent characterizations of sufficient channels. These are given by preservation of distinguishability measures like relative entropy and generalized entropies [Hiai, Mosonyi, Petz and Bény, 2011], L_1-distance and quantum Chernoff distance [Jenčová, 2012]. Further conditions are

obtained in terms of a certain factorization of the states and the channel [Mosonyi and Petz, 2004, Jenčová and Petz, 2006], a special case of this is the characterization of short Markov chains by equality in strong subadditivity of entropy [Hayden, Josza, Petz and Winter, 2004]. All the results are presented for families of states on a finite dimensional Hilbert space, but most of them can be extended to infinite dimensions.

Speaker: **Felix Leditzky** (University of Cambridge)
Title: *Strong converse theorems using Rényi entropies*
Abstract: We use a Rényi entropy approach to prove strong converse theorems for certain information-processing tasks which involve local operations and quantum (or classical) communication between two parties. These include state redistribution, coherent state merging, quantum state splitting, randomness extraction against quantum side information, and data compression with quantum side information. We prove that for each of these protocols, for any sequence of codes with rates outside the achievable rate region, the error incurred necessarily tends to one (and is not simply bounded away from zero). Moreover, this convergence to unity occurs exponentially fast in the number of uses of the underlying resource. The optimal rates for these protocols hence provide a sharp threshold for the information-processing task in question, and they are said to satisfy the strong converse property. The method which we employ in proving these results extends ideas developed by Sharma [arXiv:1404.5940] to prove the strong converse theorem for state merging.
For state redistribution there are two quantities of interest, namely the quantum communication cost (Q) and the entanglement cost (E). Recently, Berta et al. [arXiv:1409.4338] proved a strong converse theorem for Q using the smooth entropy framework. We extend this result to establish that the boundary of the entire achievable rate region in the Q-E plane satisfies the strong converse property. For the other protocols as well, our results constitute alternative proofs for strong converse theorems, which were previously established using smooth entropies. The main tools in our proofs are two inequalities involving Rényi entropies, proved by van Dam and Hayden [arXiv:quant-ph/0204093]: a lower bound on the difference of the Rényi entropies of two quantum states in terms of their fidelity, as well as a subadditivity property. For the former, we provide a simplified proof using Hölder's inequality for Schatten p-norms. These two inequalities allow us to establish certain Rényi generalizations of the optimal rates of the above protocols as strong converse exponents. The strong converse theorems are then established by employing the additivitiy of the Rényi entropy with respect to tensor powers, and the fact that the Rényi entropy converges to the von Neumann entropy on taking the Rényi parameter to one.
This is joint work with Nilanjana Datta (arXiv:1506:02635).

Speaker: **Debbie Leung** (IQC & University of Waterloo)
Title: *Near-linear constructions of exact unitary 2-designs*
Abstract: Haar-random unitary matrices facilitate many analysis?in quantum information. However, they are highly inefficient to implement or to sample. Unitary 2-designs are distributions on finite sets of unitary matrices that have some specific properties in common with?the Haar measure. We present exact unitary 2-designs on n qubits that can be implemented with circuits of Clifford gates, with size $O(n \log^2 n \log\log n)$, depth $O(\log^2 n)$, and can be sampled with $5n$ random bits.
Joint work with Richard Cleve, Li Liu, and Chunhao Wang (arXiv:1501.04592).

Speaker: **Elliott H. Lieb** (Princeton University) and **Rupert L. Frank** (Caltech)
Title: *Topics in trace inequalities*
Abstract: We begin with a brief review of important results from the last millenium (SSA, convexity, etc). We show several routes to the proof of the convexity of relative entropy and the monotonicity of Rényi's entropy. One route uses the triple matrix inequality, which will play a role in the sequel, namely the quantum version of the uncertainty principle, which extends the classical Maassen-Uffink inequality. The next act in the play concerns the sandwiched Rényi entropies and their monotonicity under CPTP maps. We then go on to the α-z entropies, their monotonicity and their open problems. Finally, there are some new concavity/convexity theorems extending work of Hiai.

Speaker: **William Matthews** (University of Cambridge)
Title: *Detecting quantum capacity*
Abstract: The capacity to transmit quantum information is essential to quantum cryptography and computing, but the Lloyd-Shor-Devetak formula for quantum capacity involves maximising the coherent information over arbitrarily many channel uses. This is because entanglement across channel uses can increase the coherent information, even from zero to non-zero! However, it could be that evaluating the coherent information for some fixed number of channel uses, greater than one, always suffices to detect whether the capacity is non-zero. I will describe our recent proof that this is not the case: for any n, there are channels for which the coherent information is zero for n uses, but which nonetheless have positive quantum capacity.
Joint work with T. S. Cubitt *et al.*, arXiv:1408.5115.

Speaker: **Milan Mosonyi** (Universitat Autònoma de Barcelona)
Title: *Strong converse exponent for classical-quantum channel coding*
Abstract: We determine the exact strong converse exponent of classical-quantum channel coding, for every rate above the Holevo capacity. Our form of the exponent is an exact analogue of Arimoto's exponent, given as a transform of the Rényi capacities of the channel with parameters $\alpha > 1$.
It is important to note that, unlike in the classical case, there are (infinitely) many inequivalent ways to define the Rényi divergence of two quantum states, and hence the Rényi capacities of channels. Our exponent is in terms of the Rényi capacities corresponding to a version of the Rényi divergences (denoted by D_α^* here) that has been introduced recently by [Müller-Lennert, Dupuis, Fehr, Szehr, Tomamichel, 2013] and [Wilde, Winter, Yang, 2013]. These Rényi divergences have been shown to be the natural quantifiers of the strong converse trade-off relations in various binary hypothesis testing problems [Mosonyi, Ogawa, 2013, 2014; Cooney, Mosonyi, Wilde, 2014; Hayashi, Tomamichel, 2014]. Our result shows that this distinguished role of the D_α^*-divergences is not restricted to hypothesis testing problems, and supports the expectation that it might hold in any information theoretic problem with two competing operational quantities and a well-defined strong converse region.
It is known that, at least in the problem of binary state discrimination, a different notion of Rényi divergence (denoted by D_α) is needed to quantify the trade-off relations in the direct domain [Hayashi 2006; Nagaoka 2006; Audenaert, Nussbaum, Szkoła, Verstraete 2007], and it is expected that these two versions, D_α and D_α^*, are sufficient to describe the full trade-off curve in a large variety of coding problems. In this work, however, we show that there is at least one more quantum Rényi divergence (denoted by $D_\alpha^\flat$) that is worth considering when extending classical information theoretic results to the quantum domain. Its importance stems from the fact that classical divergence sphere-optimization forms of optimal exponents translate naturally to expressions in terms of the $D_\alpha^\flat$-divergence instead of the correct divergence D_α or D_α^*. Although the resulting exponents are suboptimal in the quantum setting, they may be asymptotically convertible to the right exponents, as we demonstrate on the present example of classical-quantum channel coding.
Talk based on [Mosonyi, Ogawa, arXiv:1409.3562].

Speaker: **Volkher Scholz** (ETH Zurich)
Title: *Semidefinite hierarchies for information theoretic two-partite problems*
Abstract: We consider classical quadratic programs and develop a procedure to "quantize" them by allowing for non-commutative variables. Our procedure immediately leads to the construction of a hierarchy of semidefinite programs (SDP) approximating the value of the quantum program better and better. Compared to other hierarchies for non-commutative programs, our SDPs possess more constraints, implying better bounds on low levels. We illustrate the usefulness of our approach (and in particular the new constraints) by considering two examples from information theory:

(1) one-shot classical channel coding with entanglement assistance;

(2) quantum-proof randomness extractors.

This is joint work with Mario Berta and Omar Fawzi.

Speaker: **Graeme Smith** (IBM Research T J Watson, Yorktown NY)
Title: *Additive entropic quantities*
Abstract: to be added.

Speaker: **David Sutter** (ETH Zurich)
Title: *Approximate degradable quantum channels*
Abstract: A quantum channel is called degradable if its complementary channel can be obtained from the channel by applying a degrading map. These channels are interesting as they satisfy several desirable properties, e.g., they offer a single-letter formula for the quantum and the private classical capacity. At the same time, the notion of a degradable channel seems to be fragile since when adding a tiny perturbation, it might not be degradable anymore. Is it possible to define a robust generalization of the concept of a degradable channel? Can we prove that these approximate degradable channels approximately inherit all the favorable properties that degradable channels offer? I would like to answer these two questions and discuss some applications where approximate degradable channels can be helpful.
Based on joint work with Volkher Scholz and Renato Renner (arXiv:1412.0980).

Speaker: **Vincent Y. F. Tan** (NUS Singapore)
Title: *Second-order asymptotics in classical information theory*
Abstract: In this talk, I will present existing results and recent advances in classical information theory where we depart from the requirement that the error probability decays asymptotically in the blocklength. Instead, the error probabilities for various problems are bounded above by non-vanishing constants and the spotlight is shone on achievable coding rates as functions of the growing blocklengths. This represents the study of asymptotic estimates with non-vanishing error probabilities. In particular, we focus on the so-called second-order coding rates which approximately quantify the backoff from the first-order fundamental limit at finite blocklengths.
We first discuss Strassens seminal result for binary hypothesis testing where the type-I error probability is non-vanishing and the rate of decay of the type-II error probability with growing number of independent observations is characterized. We subsequently show that this basic hypothesis testing result can be leveraged to develop second-order asymptotic expansions for source and channel coding. Finally, we consider some network information theory problems for which the second-order asymptotics are known. These includes special classes of Gaussian multiple-access and interference channels.
This talk is based, in part, on the speaker's recent monograph, see http://www.nowpublishers.com/articles/foundations-and-trends-in-communications-and-information-theory/CIT-086

Speaker: **Marco Tomamichel** (University of Sydney)
Title: *Asymptotic and Non-Asymptotic Fundamental Limits for Quantum Communication*
Abstract: The quantum capacity of a channel is often used as a single measure to characterize the ability of a memoryless channel to transmit quantum information coherently. The capacity determines the maximal rate at which we can code reliably over asymptotically many uses of the channel. I will argue that this asymptotic treatment is insufficient in the quantum setting when decoherence limits our ability to manipulate large quantum systems in the encoder and decoder. For all practical purposes we should instead focus on the trade-off between three parameters: the rate of the code, the number of coherent uses of the channel, and the fidelity of the transmission. The aim is then to specify the region determined by allowed combinations of these parameters.
As a first step towards this goal, I will discuss the strong converse property for a class of quantum channels, including generalized dephasing and erasure channels with classical post-processing. We will establish that for these channels any asymptotically achievable rate cannot exceed the capacity, even if we allow for a fidelity below one. Moreover, we find an approximate characterization of the region of allowed triplets for the qubit dephasing channel and for the erasure channel, the so-called second order approximation. In each case the region is parametrized by the capacity and a second channel parameter, the quantum channel

dispersion. In the process we also develop several general inner and outer bounds on the achievable region that are valid for all quantum channels.

Speaker: **Dave Touchette** (Université de Montreal)
Title: *Quantum Information Complexity*
Abstract: For interactive quantum communication, the quantum information complexity of a bipartite task quantifies the least amount of information that must be exchanged between Alice and Bob in any protocol implementing that task. It has an operational interpretation as the amortized quantum communication complexity, that is, the optimal asymptotic communication cost per copy for implementing many copies of the task in parallel. The definition of quantum information complexity is strongly tied to the task of quantum state redistribution.
The direct sum question in quantum communication complexity, asking how much more efficiently it is possible to implement multiple copies of a given task in parallel vs. implementing them separately, is directly related to the ability to compress a single copy of a protocol down to its information cost. We will discuss progresses and challenges related to performing such one-shot interactive protocol compression, along with other questions of interest relating quantum information and communication complexities, in particular for concrete communication lower bounds.

Speaker: **Dong Yang** (Universitat Autònoma de Barcelona)
Title: *Operational resource theory of coherence*
Abstract: We establish an operational theory of coherence (or of superposition) in quantum systems. Namely, we introduce the two basic concepts — "coherence distillation" and "coherence cost" in the processing quantum states under so-called *incoherent operations* [Baumgratz *et al.*, Phys. Rev. Lett. 113:140401 (2014)]. We then show that in the asymptotic limit of many copies of a state, both are given by simple single-letter formulas: the distillable coherence is given by the relative entropy of coherence (in other words, we give the relative entropy of coherence its operational interpretation), and the coherence cost by the coherence of formation, which is an optimization over convex decompositions of the state. An immediate corollary is that there exists no bound coherent state in the sense that one would need to consume coherence to create the state but no coherence could be distilled from it. Further we demonstrate that the coherence theory is generically an irreversible theory by a simple criterion that completely characterizes all reversible states.

Speaker: **Nicole Yunger Halpern** (Caltech)
Title: *Beyond heat baths: Generalized resource theories for small-scale thermodynamics*
Abstract: Thermodynamics describes diverse systems, from heat exchanges and ideal gases to electrochemical batteries and magnets. Heat exchanges have been modeled recently with *resource theories*. These models reconcile thermodynamics, typified by large systems, with small scales, relevant to single-molecule experiments. In light of these successes, why not spread the joy of resource theories throughout thermodynamics? I will generalize thermodynamic resource theories to many types of baths (such as heat-and-particle baths), to many quantities exchanged by subsystems (such as particles and angular momentum), and to many free energies (beyond the Helmholtz free energy). While shedding new light on oft-used resource theories, this generalization expands resource theories potential for describing experiments and quantum phenomena.
References: arXiv:1409.3998, arXiv:1409.7845v2. This work was conducted with Joseph Renes.

POSTERS
(in alphabetic order by presenter surname)

Presenter: **Nilanjana Datta** (University of Cambridge)
Title: *TBD*
Abstract: to be added.

Presenter: **Philippe Faist** (ETH Zürich)
Title: *The Entropy Zoo*
Abstract: to be added.

Presenter: **Fabian Furrer** (Tokyo University)
Title: *Continuous-Variable Protocols in the Noisy-Quantum-Storage Model*
Abstract: We present a protocol for oblivious-transfer that can be implemented with an optical continuous-variable system, and prove its security in the noisy-storage model. This model assumes that the malicious party has only limited capabilities to store quantum information at one point during the protocol. The security is quantified by a trade-off relation between generated quantum uncertainty and the classical capacity of the memory channel. As a main technical tool, we study and derive uncertainty relations for continuous-variable systems for Rényi and smooth min-entropies that are essential to analyse security in the noisy quantum-storage model.
Joint work with Christian Schaffner and Stephanie Wehner.

Presenter: **Ciara Morgan** (University of Hannover)
Title: *The strong converse theorem for the product-state capacity of quantum channels with ergodic Markovian memory*
Abstract: Joint work with Tony Dorlas.

Presenter: **Milan Mosonyi** (Universitat Autònoma de Barcelona)
Title: *Strong converse exponents for a quantum channel discrimination problem and quantum-feedback-assisted communication*
Abstract: The trade-off relations between the two error probabilities in binary quantum state discrimination are by now fully understood, and quantified in terms of two different families of Rényi divergences. The state discrimination problem can be considered as a special instance of the much more complex problem of channel discrimination, where both channels are replacer channels that replace any input with a fixed output state. Here we consider a natural interpolation between the fully understood case of state discrimination, and the still largely open problem of general quantum channel discrimination, where we allow one channel to be arbitrary, and keep the second channel (alternative hypothesis) a replacer channel. We compute explicitly the strong converse exponent for this problem, in terms of sandwiched channel Rényi divergences, and show that adaptive discrimination strategies don't offer any advantage over product strategies. As a consequence, we obtain Stein's lemma for this problem. By combining our results with recent results of Hayashi and Tomamichel, we find a novel operational interpretation of the mutual information of a quantum channel $\mathcal{N}$ as the optimal type II error exponent when discriminating between a large number of independent instances of $\mathcal{N}$ and an arbitrary "worst-case" replacer channel chosen from the set of all replacer channels. Finally, by applying the same techniques, we can establish a strong converse theorem for the quantum-feedback-assisted capacity of a channel, sharpening a result due to Bowen.
Joint work with Tom Cooney and Mark M. Wilde, based on arXiv:1408.3373.

Presenter: Tomohiro Ogawa (Tokyo University) Title: *TBD*
Abstract: to be added.

Presenter: **David Reeb** (University of Hannover)
Title: *A Mrs. Gerber's Lemma with quantum side information*

Abstract: We investigate the entropy increase under convolution of binary random variables which are conditioned on quantum systems. Interestingly, the resulting bound has to be weaker than in the classical case [Wyner, Ziv, IEEE-IT 19(6):769 (1973)], and we conjecture a tight bound based on special cases and numerics. We are able to prove a weak version of this conjecture in the high-entropy regime, using the recent Fawzi-Renner recoverability result. The full weak version would suffice to prove that quantum polar codes are efficient in the sense that the gap between the classical channel capacity and the code rate decreases inverse-polynomially in the blocklength [cf. arXiv:1304.4321]. Our conjectured inequality resembles a binary analogue of a conjectured conditional entropy power inequality which has been proven for Gaussian quantum states [arXiv:1304.7031].
Joint work with Christoph Hirche.

Presenter: David Sutter (ETH ZÚrich) Title: *TBD*
Abstract: to be added.

Presenter: **Vincent Y. F. Tan** (NUS Singapore)
Title: *Strong converse for Gaussian MACs*
Abstract: to be added.

Presenter: **Mark M. Wilde** (LSU Baton Rouge)
Title: *Recoverability in quantum information theory*
Abstract: The fact that the quantum relative entropy is non-increasing with respect to quantum physical evolutions lies at the core of many optimality theorems in quantum information theory and has applications in other areas of physics. In this work, we establish improvements of this entropy inequality in the form of physically meaningful remainder terms. One of the main results can be summarized informally as follows: if the decrease in quantum relative entropy between two quantum states after a quantum physical evolution is relatively small, then it is possible to perform a recovery operation, such that one can perfectly recover one state while approximately recovering the other. This can be interpreted as quantifying how well one can reverse a quantum physical evolution. Our proof is elementary, relying on the method of complex interpolation, basic linear algebra, and the recently introduced Rényi generalization of a relative entropy difference. The theorem has a number of applications in quantum information theory, which have to do with providing physically meaningful improvements to many known entropy inequalities.
Based on arXiv:1505.04661 and joint work with Mario Berta and Kaushik P. Seshadreesan in arXiv:1502.07977, arXiv:1410.1443, and arXiv:1403.6102.