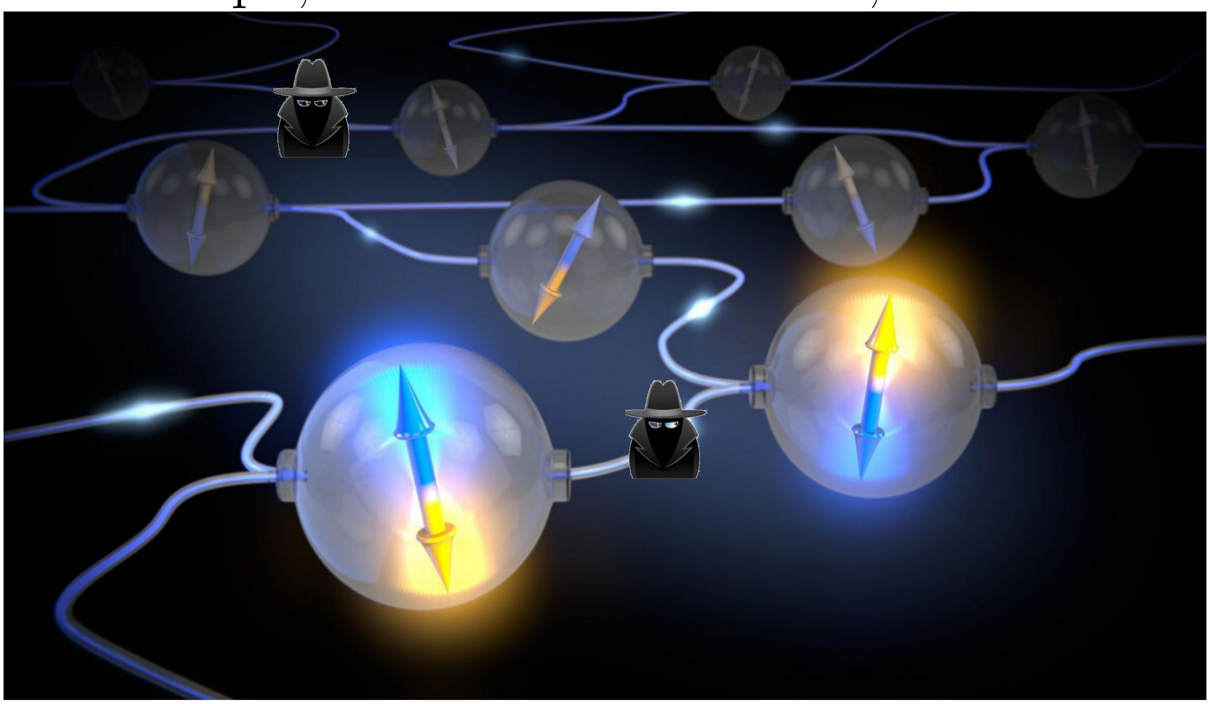
https://qi.lip6.fr/snqs25/

Workshop on Secure Networks of Quantum Sensors

Proceedings

29-31 January 2025

Lip6, Sorbonne Université, Paris



Venue: Room 105, first floor, between towers 25 and 26, 4 place Jussieu, F-7005, Paris

Rafał Demkowicz-Dobrzański (University of Warsaw)

Wednesday 29th January 2025 14:00-15:15

Identifying optimal metrological protocols in presence of noise - can single parameter methods be generalized to multiparameter?

Identifying the optimal quantum metrological protocols in presence of realistic noise is challenging. Brute force methods usually do not allow to study models in the regimes interesting from practical point of view. In this talk I will present the state-of-the-art (and even a bit beyond..) tools that allow for an efficient search of the optimal protocols even in asymptotic regime of infinite available resources (particles, time, etc..) as well as methods to derive fundamental bounds that can certify their optimality. The methods work perfectly for single parameter problems, but some of them can be easily generalized to provide non-trivial insight into multi-parameter metrological problems as well.

Luís Bugalho & Yasser Omar (IST, ULisbon & PQI)

Wednesday 29th January 2025 15:15-16:30

A framework for private distributed quantum sensing

Distributed quantum sensing enables the estimation of multiple parameters encoded in spatially separated probes. While traditional quantum sensing is often focused on estimating a single parameter with maximum precision, distributed quantum sensing seeks to estimate some function of multiple parameters that are only locally accessible for each party involved. In such settings, it is natural to not want to give away more information than is necessary. To address this, we use the concept of privacy with respect to a function, ensuring that only information about the target function is available to all the parties, and no other information. We define a measure of privacy (essentially how close we are to this condition being satisfied) and show it satisfies a set of naturally desirable properties of such a measure. Using this privacy measure, we identify and construct entangled resource states that ensure privacy for a given function under different resource distributions and encoding dynamics, characterized by Hamiltonian evolution. For separable and parallel Hamiltonians, we prove that the GHZ state is the only private state for certain linear functions, with the minimum amount of required resources, up to SLOCC. Recognizing the vulnerability of this state to particle loss, we create families of private states, that remain robust even against loss of qubits, by incorporating additional resources. We then extend our findings to different resource distribution scenarios and Hamiltonians, resulting in a comprehensive set of private and robust states for distributed quantum estimation. These results advance the understanding of privacy and robustness in multi-parameter quantum sensing.

Marco Barbieri (Università Roma Tre)

Thursday 30th January 2025 10:00-11:15

Quantum metrology as a tool for quantum communications

Quantum metrology is about extracting information from a system. Quantum communications are about sending information over a network. These simple statements reveal a common ground, but, simply reading them aloud is already sufficient to realise connections are non trivial.
In this talk we present recent progress that has been recently achieved on how concepts and methods from sensing can be used for a fundamental task of communications: the certification of nonclassical correlations. We will start by reviewing the state of the art, and then move on to presenting some experimental results obtained by our group. Finally, we will discuss some perspectives on secured quantum phase estimation currently under development.

Jacob Dunningham (University of Sussex)

Wednesday 29th January 2025 11:15-12:30

Secure quantum-enhanced measurements on networks of sensors

I will present a scheme for achieving secure quantum remote sensing between two parties without the need for entangled states. This has practical advantages in terms of the simplicity of the scheme and the resources needed and has recently been experimentally realised using optical states over 50 km of optical fibre. I will then discuss how this idea can be scaled up to networks of sensors where one party can directly measure functions of parameters at the different nodes using entangled states. The problem with such a scheme is that the security decreases exponentially with the number of nodes, making it very vulnerable to attack. However, I will show how this problem can be overcome in a hybrid protocol that utilises both entangled and separable states to achieve quantum-enhanced measurement precision and security on networks of any size.

Matteo Paris (Università degli Studi de Milano Statale)

Thursday 30th January 2025 14:00-15:15

About Some Small Advances in the Field of Multiparameter Quantum Metrology

In multiparameter quantum estimation, an achievable ultimate scalar bound on the overall precision of the strategy is provided by the so-called Holevo bound, CH. Unfortunately, this bound cannot be evaluated analytically in the general case. The Holevo bound is itself bounded by the relation $CS \leq CH \leq CS(1+R)$, where CS is the bound obtained from the SLD-based quantum Fisher information, and R is referred to as the asymptotic incompatibility (or simply "quantumness") of the quantum statistical model. Since $0 \leq R \leq 1$, this relation is considered to mitigate the difficulties in evaluating CH. In this talk, we present some results on the evaluation of the Holevo bound for specific, yet relevant, quantum statistical models. We also discuss whether and when the quantity R is suitable for quantifying the difference between CS and CH. Finally, we explore how to assess the precision of stepwise multiparameter quantum estimation and compare it to joint estimation schemes.

Eleni Diamanti (Lip6, Sorbonne Université)

Thursday 30th January 2025 15:15-16:00

Experimental quantum certification of channels and states

Developing robust and practically relevant certification tools for quantum resources is a fundamental task in quantum information as it determines how much trust can be placed in those resources. One would also like to make as minimal assumptions as possible on the functioning of the certification setup itself, in a so-called device-independent (DI) setting. Often, this is only possible when considering large, identically and independently distributed (IID) samples, which weakens the DI claim and makes experimental implementations challenging. We show two cases where we have crafted theoretical protocols enabling in practice the certification of a quantum channel and of a multipartite entangled state, in the non-IID regime and considering losses and errors, based on high-fidelity polarization-entangled Bell pair and GHZ states, respectively. The implementation based on GHZ states also forms the basis of preliminary work on the experimental exploration of privacy in networks of sensors.

Ilya Karuseichyk (Laboratoire Kastler Brossel)

Thursday 30th January 2025 16:30-17:15

Efficient Moment-based Multi-parameter Characterization of a Gaussian State

Quantum metrology traditionally focuses on maximizing the information encoded in a probe about parameters of interest. However, assessing whether a given measurement scheme effectively extracts all the available information, as predicted by the quantum Cramer-Rao bound, often remains challenging in practical scenarios. Additionally, constructing computationally feasible data-processing algorithms that fully exploit the measured data poses another challenge, particularly in multiparameter estimation scenarios.

To address these challenges we explore the moments-based approach to multiparameter estimation — a data-processing technique leveraging the first statistical moments of measurement results. This method provides straightforward estimators with associated sensitivity bounds, facilitating easy computation and relaxing demands on the detection system. This method is versatile and can be applied to various scenarios; here, we demonstrate its effectiveness in characterizing Gaussian states based on homodyne detection. By employing the method of moments, we derive optimal unbiased estimators expressed as simple algebraic transformations, providing a more accessible and computationally efficient alternative to traditional optimization-based methods.

Naomi Solomons (Lip6, Sorbonne Université)

Thursday 30th January 2025 17:15-18:00

Practicalities of private function estimation: use cases and anonymity.

Networks of sensors can be used for the secure estimation of linear functions, such as the mean of a set of parameters where the individual parameters must remain unknown. I will discuss the implications of this for realistic use cases, in particular when this is implemented by some subset of the network that wishes to remain anonymous, and how this can be realised by combining with other protocols from classical information. We will consider several different scenarios with different required levels of privacy and anonymity, and the resource requirements of these.

Ben Lanyon (University of Innsbruck)

Friday 31st January 2025 10:00-11:15

Experimental distributed quantum sensing in a noisy environment

TBD

Laurent Lebonté (Université Côte d'Azur)

Friday 31st January 2025 11:15-12:30

Quantum interferometric metrology with entangled photons

Quantum supremacy represents a major benchmark in the development of quantum technologies, characterized by an unconditional violation of the shot noise limit. However, its realization is predominantly confined to the controlled conditions of a laboratory. In contrast, we introduce another benchmark: quantum advantage, defined as the ratio between the Fisher Information of an entangled photon pair and that of a single photon. While quantum advantage is less ambitious than quantum supremacy from a computational perspective, it offers significant potential for practical applications. More tolerant to losses and more feasible for real-world deployment, quantum advantage bridges the gap between theoretical advancements and practical implementations. By leveraging the enhanced sensitivity provided by non-classical light, quantum advantage paves the way for quantum technologies to address real-world challenges across diverse fields such as sensing, imaging, and navigation.
