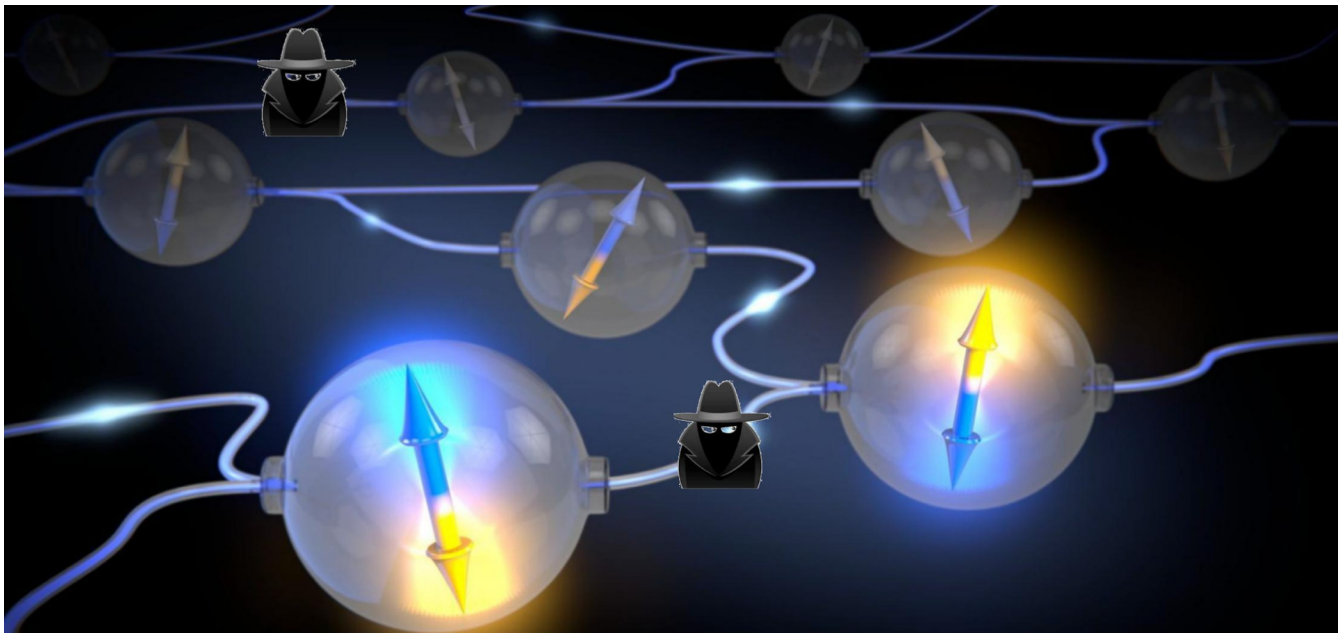
# Workshop on Secure Networks of Quantum Sensors
# Proceedings

**19-21 October 2022-LIP6, Sorbonne Université, Paris**
https://qi.lip6.fr/snqs/



Venue: Room 105, first floor, tower 25-26, 4 place Jussieu, F-75005, Paris

## Marco Barbieri (Università degli Studi Roma Tre, Italy)

***Title***: primer (and a bit more) on quantum metrology

***Abstract***: As quantum systems are sensitive to evolution it is natural to ponder on how to use them to probe their environment. This simple consideration is the basis of quantum metrology. In this seminar we will discuss what are the key concepts and methods used when inspecting the metrological capabilities of quantum objects. We will adopt quantum optics as the guiding example, in part due to the relevance of optical phases in real sensing devices. In our discussion, we will start by formalising key concept such as 'what it takes to carry out a measurement' and 'how much this measurement informs us' and then build on them to understand how the optimal measuring conditions can be designed - or, more often, how far the actual condition departs from the ideal.
We will try and understand how we can apply the methods of quantum metrology for scenarios that are relevant for communications, such as distributed sensing with a fixed number of rounds.

## Thierry Debuisschert (Thales, France)

***Title***: Current applications of quantum sensors and perspectives offered by quantum networks.

***Abstract***: Quantum sensors exploit the quantum properties of matter to measure external quantities with increased sensitivity and precision or to provide new functionalities. The sensor is coupled to the external physical quantity to be measured and the modification of its quantum properties makes it possible to precisely follow this physical quantity. Quantum sensors can measure a wide variety of physical quantities such as magnetic field, electromagnetic field, gravity, etc. They address many applications in the automotive industry, medicine, communication, mining industry, etc. At Thales, we are exploring several platforms such as NV centers in diamond, superconducting material or doped rare earth material for the detection of electromagnetic fields as well as cold atoms or atomic vapors for navigation applications. Currently, most quantum sensors operate as a single device and produce a classical signal. However, combining them in quantum networks that distribute the entanglement between them offers the prospect of increased performance or improved security.

## Rafał Demkowicz-Dobrzański (University of Warsaw, Poland)

***Title***: Multiparameter quantum metrology; dramatis personae: Heisenberg, Fisher, Bayes and Noise

***Abstract***: Fisher and Bayes are invited to a party organized by Heisenberg, where they find themselves in an intense dispute over the real meaning of the Heisenberg limit. At some point, an unexpected guest Noise arrives.... [SPOILER WARNING] Heisenberg is forced to hide behind a magic quantum error correction curtain. Bayes and Fisher become friends in the ends

## Jacob Dunningham (University of Sussex, UK)

***Title***: New regimes for quantum sensors

***Abstract***: Recent advances and applications for quantum sensors have motivated a need to understand their performance in new regimes. I will discuss how a new mathematical framework has been developed to find sensitivity bounds and analyse their performance in cases where sensors are networked, have limited data, and are used to estimate functions of parameters directly. These results will be linked to recent experiments that have tested the theory and opened the door to interesting new applications.

## Alexey Gorshkov (University of Maryland, USA)

***Title***: Quantum Sensor Networks

***Abstract***: Entangling quantum sensors, such as magnetometers or interferometers, can dramatically increase their sensitivity. In this talk, we will discuss how entanglement in a network of quantum sensors can be used to accurately measure one or more properties of spatially varying fields and how to do such measurements with a minimal use of entanglement.

## Arne Hamann (Unversity of Innsbruck, Austria)

***Title***: Noise cancelling in quantum sensor networks

***Abstract***: We consider sensing of scalar-valued fields with specific spatial dependence using a network of sensors. We show how to harness spatial correlations to sense only a specific signal and be insensitive to others. This insensitive can be used to protect from noise sources or certain types of attacks on the estimation. This is achieved by constructing a decoherence-free subspace for sources at fixed, known positions and on certain surfaces. For general situations (i.e. sources on other surfaces or within a certain volume), the notion of an approximate decoherence-free subspace is introduced. It significantly suppresses noise for all sources in a volume, at the cost of reducing the signal strength in a controlled way. This approach can be used to maintain Heisenberg-scaling over long times and for a large number of sensors, despite the presence of multiple noise sources or attackers in large volumes

## Jan(Janek) Kołodyński (CeNT, University of Warsaw, Poland)

***Title***: Quantum metrology with imperfect measurements

***Abstract***: The impact of measurement imperfections on quantum metrology protocols has not been approached in a systematic manner so far. In this work, we tackle this issue by generalising firstly the notion of quantum Fisher information to account for noisy detection, and propose tractable methods allowing for its approximate evaluation. We then show that in canonical scenarios involving N probes with local measurements undergoing readout noise, the optimal sensitivity depends crucially on

the control operations allowed to counterbalance the measurement imperfections -- with global control operations, the ideal sensitivity (e.g. the Heisenberg scaling) can always be recovered in the asymptotic N limit, while with local control operations the quantum-enhancement of sensitivity is constrained to a constant factor. We illustrate our findings with an example of NV-centre magnetometry, as well as schemes involving spin-1/2 probes with bit-flip errors affecting their two-outcome measurements, for which we find the input states and control unitary operations sufficient to attain the ultimate asymptotic precision.

arxiv link:
https://arxiv.org/abs/2109.01160

## Jean Lautier-Gaud (iXBlue, France)

***Title***: Networks of quantum sensors seen by quantum sensors

***Abstract***: to be announced

## Nathan Shettell (National University of Singapore, Singapore)

***Title***: Formulating a Cryptographic Framework for Quantum Sensing

***Abstract***: As quantum sensing networks rise in popularity for distributed sensing tasks, it is imperative to acknowledge one of the biggest obstacles to quantum networks: security threats. For example, a malicious adversaries intercepting one or more unsecured quantum channels can effectively nullify the estimation of a latent parameter by applying a bias. As a consequence, it is critical to adopt cryptographic protocols which can detect such an adversary without effecting the underlying quantum sensing task.
In this talk, I will introduce a cryptographically motivated framework for quantum metrology in the presence of a malicious adversary. This includes how to construct an estimate with a (possibly) altered resource state, and quantifying the amount of bias and loss in precision as function of the soundness of a cryptographic protocol. After, I will give examples of cryptographic protocols which can be adopted to quantum sensing networks.

## Nicolas Treps (LKB, Sorbonne Universite, France)

***Title***: Experimental approaches to optical quantum sensing in the multimode scenario

***Abstract***: We will describe recent experimental implementations of multimode quantum sensing with light, along with the necessary conceptual background. We will show in particular how the concept of mode is central to quantum sensing, and is a natural framework for the extension to network of quantum sensors.