Quantum-to-classical transition seen through quantum signals: reconstruction of a classical image from a network of observers.

Internship-Thesis
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Research project: The measurement problem and the quantum-to-classical transition are major conceptual problems since the advent of quantum theory and have become central practical problems since the developments in quantum technologies in recent years.

The physics of decoherence, coming from the entanglement between the system and its environment, made it possible to lay the theoretical foundations to understand these problems in depth. However, despite many successes, the quantum-to-classical problem is still not completely clarified. A central missing element in the traditional approach of decoherence is the study of the physics of observers themselves, and not just that of the system, in order to understand how a network of observers, equipped with specific resources, can reconstruct a common classic image, if it exists at all. This question was highlighted by the work of Zurek on quantum Darwinism where the tools of quantum information theory are predominant. However, theses ideas are still in their infancy and tools are needed to assess the existence of a classical image and the reconstruction abilities of a network of observers.

This project aims to build **a general resource-based quantum information framework** allowing us to precisely analyze the problem of the emergence and reconstruction of a classical description. A specific aim of this work is to put these general ideas to the test *via* the study **measurement signals**.

The present project will tackle the following questions:

1. *Bosonic signals*: How to define and test the role of resources available to observers in the emergence of a classical consensus remains a largely open question. A simple case study to properly define and test it experimentally is through the study of bosonic signals (multimode light), in the spirit of quantum Darwinism, from circuit electrodynamics and quantum optics experiments. It will help lay the foundations of the **"one-shot" quantum information approach** to the problem, a necessary step to get closer to experimental reality.

2. *Fermionic signals*: Analysis of this problem for fermionic degrees of freedom, especially their entanglement, remains largely to be done. It's a major issue for fermionic quantum technologies. An important part of the proposed work is to clarify what we mean by **fermionic entanglement** and to understand how to characterize it through experimental quantum signals, like those of optics quantum optics.

3. *N-body signals and correlations*: Finally, the final objective of the proposed work will be to bridge the gap between the "practical point of view" (measurement signals) and the **N-body correlations** structure of the quantum state. The central question to address is to determine what kind of correlations are needed between N-bodies for a classical description to exit and being recovered at a certain scale.

Planned collaborations: This project will be carried out in collaboration with **Pascal Degiovanni** (Laboratoire de Physique, ENS de Lyon) as well as **Benjamin Roussel** (Aalto University) who are both experts in electronic quantum optics but also on quantum information theory and quantum signal processing.