Quantum Shannon theory and Quantum Darwinism

Executive Summary

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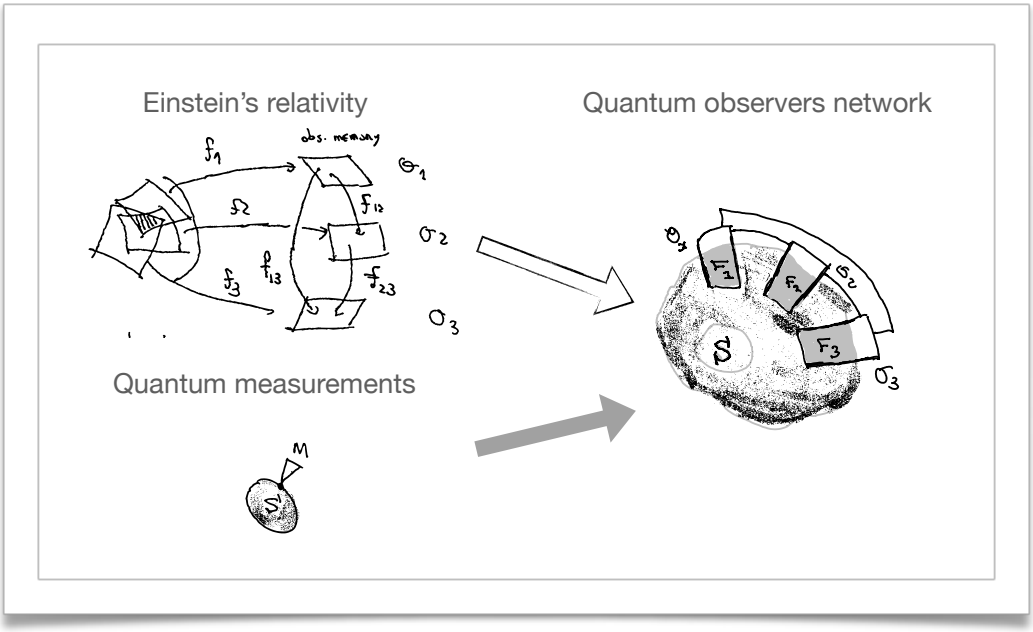
Picture:



Motivation:

The emergence of the classical world from quantum theory, and especially of a consensus among different observers, is a long-standing problem for the foundations of quantum theory. Using recent advances in multipartite quantum information theory, we shed light on these problems. Besides their interest for fundamental physics, they are related to quantum sensing and metrology using a quantum-network of stations, a situation of interest for the potential use of quantum based measurement probes for space and universe exploration.

Methodology:

Quantum theory is the fundamental framework which describes all of modern physics except gravity. Despite its tremendous successes, fundamental questions regarding its foundations and interpretation are still actively investigated. A key question is to understand the quantum-to-classical transition without relying on ad-hoc postulates. Quantum decoherence, a significant step towards answering this question, has recently been renewed by considering the information flow from a system into its environment. This led to a paradigm shift called "quantum Darwinism" in which the environment is now seen as a quantum communication channels between the system and observers. In this study, we propose to push this idea forward by considering the full (quantum) network of observers in the quantum Shannon theory framework.

Results:

- Definition of quantum-enabled observers. **Dictionary between the observer approach to quantum Darwinism and quantum Shannon theory**. A hierarchy of quantum-enabled observers based on their communication capabilities: depending wether we allow them to use full quantum communication links or not, and if not to the degree of collaboration allowed between them.

- The quantum Darwinism framework has been extended to account for different situations, based on the above mentioned hierarchy of quantum-enabled observers: **information theoretical criteria for the emergence of objectivity in each of the observer classes that we have obtained have been obtained and the corresponding shared quantum state structure established (up to one class for which it is still a conjecture)**.

- **Identification of various "phases" of objectivity** corresponding to "shared maximally entangled states", "information locking", "secret sharing" and finally "quantum Darwinian objectivity." **Role of scaling in this hierarchy of phases** (each one appearing at a specific scale) opening a way to understand the emergent character of Everettian branches in a quantum multiverse.

Publications:

- *Quantum-enabled observers and quantum Shannon theory*, A. Feller, B. Roussel, I. Frérot, O. Fawzi and P. Degiovanni. In preparation for Phys. Rev. X Quantum (most probable).

- Comment on "*Strong Quantum Darwinism and Strong Independence are Equivalent to Spectrum Broadcast Structure*", A. Feller, B. Roussel, I. Frérot, O. Fawzi and P. Degiovanni. In preparation for Phys. Rev. Lett.

Highlights:

Our main result is the clarification of the information theoretical criteria for independent and shared objectivity as well as the identification of the corresponding shared quantum states between the system and the quantum-enabled observers. This leads to a (non-trivial) separation between the classical information broadcasted to the observers by the system and the (correlated) quantum noise they experience, clarifying the structure of the global correlations in the "*observed system/many observer*s" quantum system.