Résumé du projet de recherche (Langue 1)

Following the development of quantum physics, information theory and complexity theory, the study of quantum information as a discipline was born in the 80s and many so-called "classical" results have seen their quantum analogue be demonstrated recently, as for example some results on the compression of the information or the transmission of it. Quantum information, however, has unusual properties (superposition of states, entanglement, decoherence) and it can be expected that quantum algorithms also have singular properties. In 1994, Peter Shor developed a quantum algorithm that allows probabilistic factorization of an integer in polynomial time, which no conventional algorithm is able to do today. Since the most used encryption systems were then based on the supposed impossibility of effectively factorizing an integer, we understand the craze, elicited in particular by this algorithm, for the theory of quantum information. Examples include the European initiative Quantera, a 34 million euro fund deployed in 2017 by the Horizon 2020 research program of the European Union to support research projects in quantum technologies.

Shor's algorithm is effective in theory, but the experimental reality makes its realization complex, especially because of the phenomenon of decoherence. One of the main challenges of quantum information research is therefore to identify the resource that would allow a quantum computer to outperform its classical counterpart, in order to protect it during an experimental realization.

This will be carried out under the supervision of Damian Markham and Elham Kashefi, researchers at the Jussieu Computer Science Laboratory (LIP6) and cofounders of the Paris Center for Quantum Computing (PCQC). This center brings together several theoretical and experimental groups in Paris (LTCI, LIP6, LMPQ, LKB among others) to be a player in the transition to quantum technology.

Thesis director will be Damian Markham and Elham Kashefi will be co-director. These two researchers are also coordinators of various projects supported by the Quantera initiative, which shows their involvement in the field.

The objectives of the thesis are the following:

• In a first step, a discrete variable reflection around "matchgate formalism", originally developed in graph theory, will allow to associate the notion of quantum superiority with that of remote action in a quantum circuit (arXiv: 0804.4050v2). I will then make the formalistic link of quasi-probability distributions, in which the notion of quantum superiority is associated with the negativity of a quasi-probability function, called Glauber-Sudarshan (arXiv: 1511.06519v2).

• In a second step, it will be a question of extending this notion of quantum superiority to the formalism of the continuous variable, with the example of "measurement based quantum computation models" (arXiv: 0910.1116v2).

• In a third step, I will carry out a more fundamental study to determine which axioms of quantum physics lead to this superiority. Beyond this guideline, other tracks can be explored as the link with the notion of contextuality or the analogy between quantum computation and phase transition (arXiv: quant-ph / 0702020v2).

Finally, the theoretical team of Damian Markham and Elham Kashefi is in permanent dialogue, punctuated by regular meetings, with the experimental team of Nicolas Treps (LKB). Thus, the theoretical work carried out during this thesis will be based on intuition resulting from experience, in the tradition of scientific research.