# Lap Project, Master 1:
# Decoherence of a localized Fermion coupled to a Spinfoam

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Loop Quantum gravity is one of the most important proposal of quantum gravity theory. It is sometimes presented as the main competitor against string theory.

Compared to string theory, loop quantum gravity focuses on the canonical quantization of Einstein's general relativity. By analogy with the quantization of the electromagnetic field, the goal consists of exhibiting a set of relevant classical observable that can be used to construct a well-defined quantum theory. In gravity, we cannot use plane waves as a basis building blocks of the field. To avoid, this problem, the gravitational field is expressed in terms of loop. Loops can be interpreted as gravitational faraday line, and they carry information about the space-time curvature [1].

Dynamics of the quantum space-time can be expressed with the Hamiltonian formalism or the path integral formalism. During the last years, researches have focused on the path-integral approach. Due to the space-time quantization, the path integral can be regarded as a sum of networks labeled by SU(2) representations (spins), which carry information about space-time itself. When these networks are drowned, they remind foam (like bubbles of soap). For that reason, they are called, spinfoams (see Figure 1) [2].

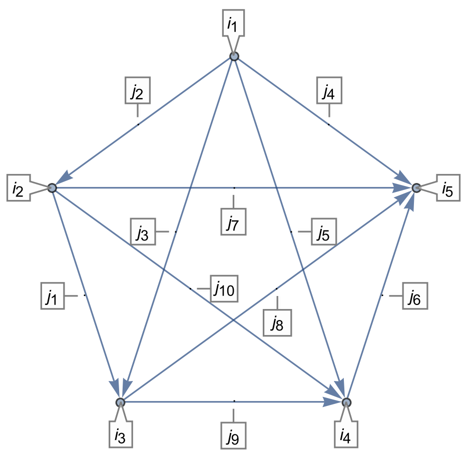


Figure 1 – Graph representing the boundary state of a spinfoam with 1-vertex.

Despite the presence of a long list of problems solved successfully, the number of physical predictions of loop quantum gravity remains small (compared to standard quantum fields theories). This can be partially explained by two facts : explicit numerical computations are arduous, and the coupling with a matter field has not been deeply investigated [3].

When a fermion is coupled to a gravitational field, it is expected to observe a relaxation effect (gravitationnal decoherence) [4]. This idea is encountered in many theories, such as string theory, or semi-classical theories. Solving explicitly the path integral of a fermion coupled to a spinfoam is currently out of reach, but a simplified model could give us a better understanding of the full theory.

As a preliminary work, the selected candidate will study bibliography references about general relativity, loop quantum gravity, spinfoams,and fermion fields. Then, the goal is to develop a numerical code in C that allows us to compute the correlation function of a fermion localized on a small portion of a spinfoam, and to study the decoherence effect. This will require advanced multidimensional integration techniques and parallelization methods. Additionally, the code will have to be compatible with the SL2Cfoam library. Depending on the candidate, several extension of the work can be imagined : to implement machine learning methods in order to speed up further numerical simulations, or to extend the calculations to study diffusion process in the spinfoam network.

In order to complete successfully this project, the candidate should have strong skills in *quantum mechanics, mathematics, and scientific programming.*

**[1]** C. Rovelli, *Quantum Gravity*, Cambridge University Press, (2004)
**[2]** C. Rovelli and F. Vidotto, *Covariant Loop Quantum Gravity : An Elementary Introduction to Quantum Gravity and Spinfoam Theory*, Cambridge University Press, (2014)
**[3]** E. Bianchi and al., *Spinfoam Fermions*, Classical and Quantum Gravity, 30 235023 (2013)
**[4]** A. Bassi and al., *Gravitational Decoherence*, https ://arxiv.org/abs/1706.05677 (2017)