

Bridging between background independent quantum gravity coupled to matter fields and the Standard Model: description for the general public

Over the past century, General Relativity and quantum field theory imposed themselves as revolutionizing theories and the cornerstones of modern theoretical physics. They flourished in several aspects ranging from the description of the Universe on the scale of galaxies and stars, to the understanding of the fundamental nature of matter culminating in the Standard model of elementary particles. Ironically, these achievements also exposed many conceptual and technical issues in these theories. One then comes to the conclusion that the foundations of one, or both frameworks must be modified. This is where the idea of developing a quantum theory of gravity coupled to matter emerges as a possible solution. One could reasonably expect that a quantum theory joining gravity and matter might hold the key to consistently solve the issues present in both general relativity and standard quantum field theory.

The idea of quantizing the gravitational field is actually almost as old as the general theory of relativity: in one of his papers in 1916 Albert Einstein wrote: Nevertheless, ..., it appears that quantum theory would have to modify not only Maxwellian electrodynamics, but also the new theory of gravitation. Indeed, the first attempts to quantize the gravitational field date back to shortly after the formulation of general relativity. A century later, the research field known today as quantum gravity has largely developed but the challenge to define a consistent and complete quantum theory of gravity is still standing as strenuous and puzzling as ever.

The loop quantization is a non-perturbative approach to quantize gravity and matter fields. It relies on the idea of background independence which arises in General Relativity, where it is understood that gravity is geometry encoded in a metric. Carrying this notion to the quantum realm requires giving up the standard Fock quantization. The loop quantization was first developed for gravity and gauge theories, and it provides a framework where gravity and the fields of the Standard Model are quantized in a background independent fashion. The question is then how one could recover, if at all, General Relativity or the Standard Model from the more fundamental theory obtained by the loop quantization? Our project goes exactly in the direction of answering this question.

The goal of our project that is to understand how the Fock representation of matter fields on Minkowski and curved spacetime arises from the background independent loop quantization of these matter fields coupled to gravity. We will investigate the loop quantization of the Standard Model matter fields and its dynamics on a fixed gravitational background structure, and establish connections with lattice quantum field theories using the concepts of continuum limit and coarse graining. We will also analyse the process of spontaneous symmetry breaking in the context of the loop quantum theory, then eventually we will realize the passage to the general model of a loop quantum matter fields on a quantum gravity background by invoking coherent states and semi-classical methods. Finally, we want to extract the possible quantum corrections to the phenomenological aspects of the propagation of matter fields on a semi-classical background of the polymer quantum theory.