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Aspects of Information Theory in Quantum Gravity

During the last decade, the vocabulary of the quantum gravity community got enriched by the typical jargon of computer science. Concepts like entanglement entropy, complexity, circuits, tensor networks, quantum error correction, which belonged to the quantum information realm, gradually acquired more importance in theoretical high-energy physics. This new synergy is mainly related to two very important issues: the black hole information loss paradox and holography.

On the one hand, the (apparent) violation of unitarity in the quantum mechanical evolution of a black hole, a problem that keeps on puzzling physicists since 70's, may be solved by "carefully analyzing" the quantum information properties of the gravitational system itself.

On the other hand, after more than twenty years since its birth, holography remains a mysterious relation between a strongly-coupled quantum mechanical system with many degrees of freedom and gravity. The very first crystallization of this idea, which is still a conjecture in its entirety, was the so called "AdS/CFT correspondence": indeed, there is a limit where string theory living on anti-de Sitter spacetime (AdS) is dual, which means physically equivalent, to a conformal field theory (CFT) that lives on the boundary of the anti-de Sitter spacetime. This groundbreaking discovery deeply revolutionized theoretical high-energy physics and led to crucial insights about the quantum nature of gravity. Moreover, its applicability range is huge, as it can also be applied to condensed matter physics. Since then, the "AdS/CFT correspondence" has been generalized in several different ways, a fact suggesting that holography is much more general than originally perceived. Nevertheless, there is still no clue about why holography should work, namely the basic mechanism underlying it is not known yet: rather unexpectedly, quantum information theory might provide an answer.

Inspired by the widely supported belief that gravity is an emergent phenomenon due to a great number of highly-correlated degrees of freedom, the aim of this PhD project is to carry out a detailed analysis on the numerous analogies between gravity and quantum information discovered in the last decade. Namely, conjectured proposals will be tested in different settings and ultimately compared with each other in order to shed light on nowadays open problems in this young and rapidly growing research field.