# Lorenzo Sorbo's research - in very broad terms

For millennia, questions regarding the origin, the size and the content of our Universe have been central to human thought. During the last century, the development of General Relativity has given an elegant and compelling framework for the description of gravitational phenomena, while the theory of Quantum Fields – and its specific realization in the Standard Model of particle physics – has led us to understand the nature and behavior of the elementary components of matter. These discoveries have provided a setting where the fundamental questions about the nature of the Universe can be addressed in a scientific language. Only in the last few years, however, a rapidly increasing quantity and quality of data have turned cosmology into a observational science, that is now living its most exciting days.

Cosmology, born as the study of our Universe as a whole, is today also a unique source of information about the fundamental laws that govern the microscopic world. Such information, complementary to that which can be obtained by accelerator experiments, concerns the behavior of Nature from the shortest to the largest distances one can meaningfully talk about. The interplay of the physics of the Standard Model, General Relativity and Quantum Field Theory is realized in this context at its highest degree.

It is by looking at the sky we see most of the evidence that there must be new physics beyond the Standard Model of fundamental interactions. Such new physics is needed to account for the fact that our Universe contains more matter than antimatter, for the presence of dark matter, for the current accelerated expansion of the Universe as well as the primordial phase of inflation. The coming years will bring important progress towards the understanding of these phenomena, both with terrestrial particle physics experiments and with cosmological observations. It is important that a well motivated, extensive and consistent theoretical stage be set by the time the new data will become available.

Gravity, which plays a key role in cosmology, is the most mysterious of the known fundamental forces. The relation between gravity and quantum mechanics is not yet fully understood. The most interesting phenomenon in this context is black hole evaporation: while classically nothing can escape from a black hole, quantum mechanically black holes emit radiation. Many aspects of this process are still unclear. Does black hole radiation carry information about the original lump of matter that has led to the formation of the black hole itself? What are the final stages of this process? Black hole evaporation is not the only interesting question about gravity and quanta. There is a close connection between cosmology and quantum fields in gravitational backgrounds, since the structures (galaxies, clusters of galaxies...) that host us originate from small quantum mechanical fluctuations that have been amplified during primordial inflation, when the Universe was $10^{-38}$ seconds (or so) old. Hence, the existence of galaxies such as the one we inhabit is the most apparent effect of quantum mechanics on gravitational backgrounds.

An additional open question about Einstein's gravity concerns the possibility of modifying it. Is it possible to do so while maintaining a viable theory? For instance, is it possible to give a small mass to the particle that carries the gravitational force, the graviton? If we want to understand cosmology, it is crucial to know to what extent we trust Einstein's theory and to understand in which ways it can be modified.

My research contains a mix of analysis of data, of study of known models, and of model building. My work can be organized along two lines. The first, more related to observations, concerns the two phases of accelerated expansion of the Universe, with a special focus on pseudo-Nambu-Goldstone bosons (pNGbs). These hypothesized particles are among the main candidates for the explanation of the current acceleration and/or the primordial inflationary epoch. The second, more genuinely theoretical, deals with the deepest properties of gravity, of quantum matter in interaction with gravity, and with possible modifications to Einstein's theory.