Theoretical Cosmology

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Cosmology is the study of the universe as a whole, aiming to understand its origin, evolution and, possibly, end. This discipline has experienced a number of paradigm shifts during the XX century. First of all, starting from the pioneering paper by Einstein [1] in which the general theory of Relativity is applied to a static universe, to the astonishing discovery that faraway galaxies are receding from each other at a speed proportional to the distance, the so-called Hubble's law (or Hubble-Lemaître law) [2]. Then, the serendipitous discovery of the cosmic microwave background (CMB) radiation in 1965 [3], which made cosmology a precision science, and finally the discovery that the expansion of the universe is accelerating [4], rather than decelerating, as the attractive nature of gravity would require.

Since gravity is, to the best of our knowledge, the only interaction acting on the distance scales that interest cosmology (hundreds of millions of parsecs), it is a conundrum and an active area of research to understand what causes the accelerated expansion of the universe, which needs a sort of anti-gravity effect to be explained. This effect is widely known nowadays as Dark Energy and the search for its origin is done, theoretically, in two ways: either there exists an exotic form of matter-energy doing the job, or gravity is different from what we think on the largest observable scales.

A contact point between the two views is the cosmological constant Λ. It fits all the symmetry requirements of General Relativity (see Lovelock's theorem [5]), and provides, if positive, an anti-gravitational effect without the need of modifying Einstein's gravity theory. Indeed, the cosmological model based on Λ, the standard model of cosmology, the ΛCDM model, is the simplest and most successful one.

The problem with Λ is mostly theoretical. In fact, it is expected, on the basis of our current knowledge of particle physics and quantum field theory, that Λ should acquire quantum corrections from the matter fields which make its value huge and incompatible with observation. So, one should think of extending the standard model of particles and fields in a way to preserve the smallness of Λ from those large corrections. This is a formidable task and no one has succeeded yet in accomplishing it.

My research at Insubria University is mainly devoted to Dark Energy and its explanation as a modification of gravity on the largest scales, with particular emphasis on the cosmological constant problem.

Prospective students who desire to know more about my research on the above topics can find a complete list of my research papers on `https://inspirehep.net/`.

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