String Theory and Dark Energy

Just as quantum electrodynamics reduces in everyday life processes to a classical field theory defined by the laws of Maxwell, so does everyday life string theory reduce to a classical field theory which we call *supergravity*. Since string theory describes gravity at the quantum regime, its classical partner is pretty similar to Einstein's theory of relativity. Nevertheless, they radically differ in the number of spacetime dimensions in which both theories are formulated: string theory predicts namely the existence of at least ten dimensions. After realizing this, a valid standpoint would be to reject the theory altogether; after all, we have never seen any of these extra dimensions. However, there is no need for being so pessimistic. We could instead ask ourselves: can supergravity describe spacetimes with four large dimensions and six small and compact ones, such that they could have remained unobserved until the present day? On the technical level, this amounts to finding solutions of the classical equations of motion for the *metric* (the field that accounts for the structure of spacetime) with the desired properties. This is already not an easy task, but it becomes even worse when we take into account the experimental fact that our universe is expanding at an accelerated rate, due to the presence of a positive cosmological constant, also referred to as dark energy. In fact, before the experimental evidence for the accelerated expansion arrived, it was a common believe that string theory would not allow for such a phenomenon.

Is this bad news for string theory? Not at all. One of the main criticisms that the theory receives is its sometimes claimed lack of predictability when it comes to real experiments. String theory seems to be just a general framework capable of accommodating any possible experimental result, with no way of making clear-cut predictions. Dark energy provides a golden opportunity to refute this argument: using its existence as experimental input could severely constrain the structure of the theory and lead to falsifiable statements, ranging from the domain of cosmology to that of particle physics.

Up to the present day, there is one dominant proposal for the description of dark energy in string theory: the KKLT mechanism,[1] named after its authors. In essence, one considers a solution to the equations of motion for the metric without dark energy, which we know how to construct, and then one places extended objects which act as a source for dark energy, without perturbing the background too much. In recent years this model has been the subject of quite some criticism among string theorists. The way in which these extended objects, called D-branes, back-react on a given background geometry is not fully understood, and arguments have been put forward to show that such a construction does not lead to stable, long-lived universes as the one in which we live. In order to settle down the debate, the full solution including the back-reaction of the D-branes should be found. This seems to be however an intractable problem, both in analytical and even numerical terms. As a step towards the final answer, in recent work together with collaborators in Leuven and Amsterdam we have developed a powerful technique, which allows us to infer certain properties of the fully back-reacted solution. In my talk I will present some of these latest insights in the area of string cosmology.

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[1] S. Kachru, R. Kallosh, A. D. Linde, and S. P. Trivedi, Phys. Rev. D68 (2003) 046005.