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Late Cosmic Acceleration of the Universe in Superstring/M Theory

(Physics / Arts and Sciences)

One of the remarkable discoveries over the past decade is that currently our universe is in its accelerating expansion phase, first observed from Type Ia supernovae measurements [1]. Cross checks from the cosmic microwave background radiation (CMB) and large scale all confirm this [2]. While the late cosmic acceleration of the universe is now well established, the underlying physics remains a complete mystery [3]. Since the precise nature and origin of the acceleration have profound implications, understanding them is one of the biggest challenges of modern cosmology. As the Dark Energy Task Force (DETF) stated [4]: `` *Most experts believe that nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration*."

Within the framework of general relativity (GR), a simple model is to re-introduce a tiny positive cosmological constant (CC), which was first introduced by Einstein in 1917 to construct a static universe. With the discovery of the expansion of the universe in 1929 by E. Hubble, the rationale for the CC evaporated. Fifty years later, Zel'dovich (1968) realized that the CC, mathematically equivalent to the vacuum energy, cannot simply be dismissed. In quantum field theory, the vacuum state is filled with virtual particles and their effects have been measured in many physical processes. However, estimates for the energy density associated with the quantum vacuum are at least 60 orders of magnitude too large, a major embarrassment known as the CC problem [5].

Since the CC problem is intimately related to quantum gravity, its solution is expected to come from quantum gravity, too. At the present, Superstring/M-Theory is our best bet for a consistent quantum theory of gravity, so it is reasonable to ask what string/M-Theory has to say about the CC. Recently, we [6-8] studied the problem and the late transient acceleration of the universe in the framework of the HW heterotic M-Theory. Using large extra dimensions, we showed that the effective CC on a visible brane can be lowered to its current observational value. The domination of this term is only temporary. Due to the interaction of the bulk and the brane, the universe will be in its decelerating expansion phase again, whereby all problems connected with a far future de Sitter universe are resolved. Such studied were further generalized to string theory [9-11], and showed that the same mechanism is also viable in the framework of string theory.

In this project, we shall continuously work along the directions initiated in [6-11]. In particular, we shall focus on the couplings of the radion with the gravitational Kaluza-Klein modes and Standard Model fields both on the branes and in the bulk, observational signals to the Large Hadron Collider and future high energy experiments, the solar system constraints, the growth rate of perturbations, and candidates of dark matter. We shall also study the early universe, including inflation and CMB, in order to obtain further constraints on our models. Such studies will extend and validate our models with observational data sets for further predictions, break parameter degeneracies, reduce statistical errors, and diagnose possible systematics.

In this project, I am joined by my two graduate students, Michael Devin and Qiang (Bob) Wu. I am applying for a URC Grant to cover their local expenses during September 1 – December 15, 2009, as their graduate scholarships from Baylor will be ended in August, 2009. This URC funding will enable both of them to complete their Ph.D. thesis research and defense them by the end of 2009.