Inflation from String Theory

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1 Overview of the Field

String cosmology is a rapidly changing field, which is still in its early days. One of the most promising applications is to inflation, the theory of superluminal expansion of the early universe, which is receiving spectacular confirmation from experiments, like WMAP, which measure the cosmic microwave background (CMB) fluctuations. Many string theorists hope that this wealth of new data can help to give some empirical tests of string theory, which are so far lacking in particle physics experiments.

Although it may be unlikely that the CMB by itself can decide whether inflation is due to string theory or conventional field theory, string theory is also tightly constrained by its own rich mathematical structure, which has made it challenging to build successful models of inflation within realistic and fully consistent vacuum states of string theory. Through a combination of the experimental constraints and those imposed from the need for internal mathematical consistency, it may be possible to eventually pinpoint the most likely models of stringy inflation, and to better focus the strategies of experimental verification.

2 Recent Developments and Open Problems

One of the most distinctive proposals for inflation from string theory is that inflation is due to the relative motion of D-branes, higher dimensional objects intrinsic to string theory, within the compact internal dimensions which are equally essential. The main realizations involve D3- and anti-D3 branes (where 3 denotes the spatial dimension) and D3 and D7 branes. The major challenge is to find ways of making the potential between the branes sufficiently flat to support a long period of inflation, during which the size of the universe grew by a factor of at least e^{60}. This question cannot be fully addressed until stability of the size of the extra dimensions has been assured by some mechanism, since the dynamics of this compact space has a strong effect on the force between the branes. Warped compactifications in type IIB string theory have provided a mathematically rigorous framework for stabilizing the extra dimensions, and have thus made the problem of constructing a flat potential mathematically well-posed.

To this point, flat inflaton potentials do not seem to arise in generic compactifications. Instead, it appeared necessary to tune parameters of the compactification (like fluxes of gauge fields, or rank of the gauge groups) in a very special way to achieve flatness. However, even these attempts have suffered from a lack of mathematical rigor. It was known that there exist corrections to the superpotential describing the force on a D3 brane in a warped throat which could potentially be tuned to give a flat potential [1], but these corrections had never been explicitly calculated, only parametrized. Thus the details of how flatness could be achieved in a specific string background remain to be elucidated.

3 Scientific Progress Made

We were fortunate in that an important breakthrough was made by authors at Princeton University in computing the aforementioned superpotential corrections [2], just when our meeting at BIRS began. We quickly absorbed the content of this work so that we could begin to apply it to the D3-$\overline{\mathrm{D3}}$ and D3-D7 systems. The goal is to see whether it is indeed possible to tune these corrections in the way that was originally envisioned, to flatten the inflaton potential to an acceptable level.

In the process of this investigation, we made two serendipitous discoveries which enhance the mathematical consistency of the basic framework for the two systems which we are studying. These discoveries pertain to the description of forces acting on the D3 branes within a supergravity framework. In the D3-D7 system we were able to compute in the language of supergravity what form the potential for the D3 brane takes, as a result of forces associated with stabilization of the extra dimensions, and from supersymmetry-breaking fluxes on the D7 brane.

In the the context of the D3-$\overline{\mathrm{D3}}$ system, we discovered a new way of *uplifting* the brane potential from negative to positive values, as needed to obtain inflation rather than anti-de Sitter space solutions. This uplifting was achieved in the seminal reference [3] using the supersymmetry-breaking effect of the $\overline{\mathrm{D3}}$-brane, but we have discovered, as a result of the newly computed superpotential corrections, that uplifting can be achieved even without the $\overline{\mathrm{D3}}$-brane, without the explicit breaking of supersymmetry. This is an improvement over the original construction of [3] in terms of keeping approximations under control.

4 Outcome of the Meeting

Based on the above progress, we have prepared drafts of two papers which are nearing completion [4], and which set the stage for further, more detailed study, of the actual inflationary process in these systems. Our meeting at BIRS thus laid the groundwork for continued collaboration on inflation within string theory, sharpening our understanding of the framework within which to construct specific realizations. The meeting was an ideal venue for defining the problem; that step required intensive interaction. We are now able continue working together from a distance and we hope to make further significant progress during the coming year.

References

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