

Statement of Research Interests

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String theory continues to have a number of challenges to address if it is to be made experimentally verifiable. Cosmology offers an exciting opportunity to explore such challenges, since the early universe provides conditions where string dynamics would play a vital role. To investigate the predictions of string cosmology it is important to have concrete constructions of string models in backgrounds that are compatible with our understanding of the early universe. In particular, this presents us with the challenge of finding solutions of string theory in time-dependent backgrounds and at nonzero temperature.

The usual method for constructing models of string cosmology is to compactify any extra dimensions and then focus on the low energy, massless degrees of freedom. However, this presents a problem since the low energy equations of motion lack potentials to fix the massless modes or moduli. For cosmology, this implies the existence of many light scalars, which if not fixed at late times would seem to contradict current observations. Nevertheless, a few light scalars could prove valuable to cosmology, since they could address the issue of dark energy, dark matter, or provide a theoretical motivation for inflation or its alternatives.

My research has focused on addressing a number of these issues. I have considered the role of both quantum corrections and finite temperature on stabilizing moduli. This leads one to consider all the modes of the string in addition to the usual massless modes. In time-dependent backgrounds, where the radii of the dimensions are free to evolve, one finds that there are preferred radii where the string's symmetry is enhanced and massive modes become massless. One finds that accounting for these additional states can lead to rich dynamics exhibiting attractor, repeller, and even accelerating solutions. In particular, I showed that for heterotic strings in toroidal compactifications one can stabilize the internal dimensions (volume moduli), while three spatial dimensions will grow large and isotropic. I also investigated the role of inhomogeneities in this background and found that the model is stable to linear perturbations.

From this research I have learned the importance of gaining a better understanding of the moduli space of compactifications. I have found that by considering string corrections one can unveil degrees of freedom that would usually be absent in the tree level effective action. My work has primarily focused on toroidal compactifications, where the calculation of string corrections is tractable. I would like to continue my investigations for more realistic compactifications and in the presence of flux. This is plausible since the source of the

interesting dynamics was the presence of points of enhanced symmetry (ESPs), which appear generically in string constructions. I would also like to explore the recent proposal that scattering by the additional states appearing at ESPs offers a dual description of near-horizon dynamics of black holes. Lastly, another challenging aspect will be to account for the physics of ESPs on the boundary of moduli space where violent transitions can occur and an accurate description of the dynamics is lacking.

The stability of moduli is an important challenge for string cosmology; however, a few evolving scalars are useful not only for explaining the origin of inflation, but also for addressing the problems of dark energy and dark matter. In my research I have considered string motivated constructions that lead to both dark energy and dark matter candidates. However, in these models many of the moduli were assumed to be stabilized. Thus, the natural next step would be to consider the presence of all the moduli and see if dark energy/dark matter candidates could still be realized. Models of string cosmology containing branes offer additional scalar degrees of freedom that could have cosmological consequences. My investigations have included a detailed look at the robustness of brane inflation models taking into account their dynamics. I would like to continue to better understand the possibility of brane phenomenology, including the behavior of branes in the presence of flux and at short distances. Both of these conditions can lead to additional degrees of freedom and thus interesting dynamics.

A very challenging aspect of string cosmology is the issue of resolving singularities. In attempting to resolve singularities it is very important to understand all the relevant degrees of freedom and corrections coming from string theory. I have begun to consider a number of stringy effects that show promise for resolving singularities. These include considering corrections in both the string tension and the string coupling constant. Modifications to the usual Einstein equations near the singularity can arise from including additional degrees of freedom that become light as in the case of ESPs. There is also the promise of better understanding the role of flux backgrounds, since flux can act to polarize branes leading to non-commutative backgrounds. This dielectric effect shows promise in resolving the problems of singularities and brane collapse. Understanding the collapse near singularities is certainly a challenging endeavor. However, one would hope that with a more complete understanding of the behavior of strings in time-dependent backgrounds a complete picture of string cosmology may emerge.