The Scalar Potential in String Theory

E. Silverstein

This is a rough outline of topics to be covered in my lectures at the 2002 Prospects in Theoretical Physics school, with a list at the end of a few of the simplest references on these topics that might be helpful (and these themselves contain many useful references). The lectures will center on one very basic quantity, the scalar potential energy $\Lambda(\phi_i)$ (a function of scalar fields ϕ_i present in generic backgrounds of string theory). This quantity is important for low-energy phenomenology and cosmology, and at the same time is related in fascinating ways to more "fundamental" aspects of the theory such as counts of degrees of freedom and classical and quantum stability. Its physics illustrates some basic similarities and differences between string theory and quantum field theory. In the lectures, some of the basic aspects of Λ and some recent advances in understanding its behavior particularly with respect to instabilities will be explained. Despite its importance, this is one of the least understood aspects of string theory, and provides a rich set of open problems, so the lectures will also aim to explain clearly the limits of our knowledge in this area.

I. Introduction

a) Low-energy effective field theory from string theory, with Λ the leading term at low energies but also sensitive to the UV via quantum effects.

b) Compactification moduli and dilaton, basic observational problems, runaway problem, vacuum selection problem.

c) Three basic issues: tadpoles, tachyons, vacuum energy.

II. Structure of $\Lambda(\phi_i)$

a) Case I: low-energy SUSY theories, N=1 SUGRA scalar potential. Nonrenormalization of superpotential, but loop corrections to Λ after SUSY breaking. (Review of material probably covered in other lectures.)

b) Case II: string-scale SUSY breaking. Tachyons; perturbative corrections to Λ. Tree-level contribution proportional to $D - D_{critical}$.

c) Some basic contributions to Λ:

i) RR and NS field strengths and flux contributions.

ii) Branes, orientifolds.

iii) Perturbative quantum contributions: calculation of the 1-loop cosmological term in a string-theoretic Scherk-Schwarz compactification; UV sensitivity; UV-IR relation to asymptotic density of states.

iv) Instanton effects.

III. Recent developments

a) Tadpoles: flux stabilization. Basic idea in toy example; complete example (time permitting). "Solution" of runaway problem by introduction of large number of flux quanta. Enhanced symmetry points, modding by T-duality.

b) Tachyons: open strings: brane-antibrane annihilation; closed strings: decay of noncompact orbifolds to flat space. Relation to number of degrees of freedom via RG flow. Compare and contrast to analogous issues in quantum field theory.

c) Vacuum energy: fine-tuning problem; fine tuning in string theory via choice of flux quanta and/or coupling to large-N field theories. de Sitter space, horizons, and the conjectured relation of horizon area to entropy. References on request to ideas that have been explored: study these further or find new ones!

**d) Time (and background) permitting: duality and Λ. AdS/CFT relation between moduli potential $\Lambda(\phi_i)$ and violations of conformal invariance, between classical tachyons and Coleman-Weinberg instabilities, and between classical flux superpotentials and nonperturbative effects in field theory. String duality relations between instanton effects and classical contributions.

A few references to browse through in advance; more will be added during the talks

SUSY readings, in particular the parts on the structure of the scalar potential, [1] (especially vol I pages 220-222 "physics of vacuum amplitude" and section 3.7 on strings in background fields)[2] (especially strings in background fields and the chapters on low energy physics from string compactification) [3][4][5][6][7][8][9].

References

[1] J. Polchinski, *String Theory*

[2] Green, Schwarz, and Witten, *Superstring Theory*

[3] M. Dine and N. Seiberg, "Is The Superstring Weakly Coupled?," Phys. Lett. B **162**, 299 (1985).

[4] S. Dimopoulos and G. F. Giudice, "Macroscopic Forces from Supersymmetry," Phys. Lett. B **379**, 105 (1996) [arXiv:hep-ph/9602350].

[5] S. Kachru, M. Schulz and S. Trivedi, "Moduli stabilization from fluxes in a simple IIB orientifold," arXiv:hep-th/0201028.

[6] A. Sen, "Tachyon condensation on the brane antibrane system," JHEP **9808**, 012 (1998) [arXiv:hep-th/9805170].

[7] A. Adams, J. Polchinski and E. Silverstein, "Don't panic! Closed string tachyons in ALE space-times," JHEP **0110**, 029 (2001) [arXiv:hep-th/0108075].

[8] S. M. Carroll, "The cosmological constant," Living Rev. Rel. **4**, 1 (2001) [arXiv:astro-ph/0004075].

[9] R. Bousso, "Adventures in de Sitter space," arXiv:hep-th/0205177.