Physics 8.872, Fall 2025
The geometry and physics of supergravity and string vacua in various dimensions

Instructor: W. Taylor

Supergravity and string theory provide a rich framework in which physical theories of gravity, gauge symmetries, and matter are encoded in the geometry of extra compact dimensions of space-time.

This course will introduce many of the geometric structures and related physical ideas underlying these theories, giving students a perspective and tools to understand the rich variety of vacuum solutions of supergravity and string theory, and how these connect to physical structures like those observed in our universe. The course will emphasize geometric and physical methods, introducing some basics of string theory but not getting into extensive string theory-based analysis.

The course will begin with an overview and introduction to some of the basic tools needed, such as group theory and supersymmetry. The agenda will then be to start with the unique 11D supergravity and 10D supergravity/string theories, and then systematically compactify to lower dimensions, where different geometric choices produce vacua with diverse gauge groups and matter content, culminating in an overview of four-dimensional compactifications of supergravity and string theory that exhibit features like those seen in nature.

Prerequisites: some exposure to quantum field theory, and some familiarity with either differential geometry or general relativity. No previous background in string theory is needed.

Class time and location: Tuesdays/Thursdays 9:30-11, room 32-155; first lecture 9/4/25

8.872 Fall 2025: Course Outline

This is a basic outline of the material we will try to cover in the course. Timing is very approximate, we may cover more or less depending on the level of detail and discussion.

0. Introduction: Overview of course, big picture of the set of supergravity compactifications ($\sim$ 1 lecture)

1. Basic tools: Group theory and representations, SUSY and representations, QFT + gravity ($\sim$ 3 lectures)

2. Quantum gravity in high D: 11D supergravity and M-theory ($\sim$ 1 lecture)

3. 10D supergravity: Type IIA and IIB supergravity, Compactification 11D $\rightarrow$ IIA; brief intro to string theory and D-branes. $\mathcal{N} = 1$ 10D supergravity + Yang Mills theory: anomaly constraints, SO(32) and heterotic theories, string universality ($\sim$ 3 lectures)

4. Toroidal compactification and 9D supergravity: Theories with 32 supercharges (II/T^d), theories with 16 supercharges (heterotic/T^d); string quantization on the torus; Narain moduli space ($\sim$ 2 lectures)

5. 7D and 8D supergravity: K3 geometry and M-theory/K3 = heterotic/T^3 duality; introduction to F-theory: elliptic curves, elliptic K3 and 8D F-theory ($\sim$ 4 lectures)

6. 6D supergravity: 6D F-theory and elliptic Calabi-Yau threefolds; toric geometry; F-theory/heterotic duality in 6D; intersecting brane models; asymmetric orbifolds ($\sim$ 6 lectures)

7. 4D supergravity: 4D $\mathcal{N} = 2$ supergravity from type II on a Calabi-Yau threefold; 4D $\mathcal{N} = 1$ supergravity: fluxes, superpotential; IIB and IIA flux compactifications, heterotic 4D models, 4D F-theory; realizations of the Standard Model in 4D string vacua; comments on moduli stabilization and cosmology ($\sim$ 6 lectures)