CIM PostDoc Proposal: Mathematics of Realistic String Vacua

Goal:
This project aims at determining the mathematical structure underlying realistic, four-dimensional ground states of heterotic string theory.

Background:
String theory is a mathematically consistent and tightly constrained theory that provides a candidate ultraviolet completion of general relativity. This achievement comes at a price: string theory requires, for consistency, spacetimes with extra dimensions. Conflict with observations may nevertheless be avoided, if the extra dimensions form a small and compact manifold. The ultimate goal of such string compactifications is to construct a model that describes the observed world.

While the compact manifold in a string compactification is small, it is not forgotten: its geometry and topology determine the 4D laws of physics. This interplay between the mathematical and phenomenological aspects of string compactifications has led to great advances in the past. Firstly, there are several good models that describe *either* aspects of particle physics *or* aspects of cosmology. Secondly, the study of string compactifications has revealed that different string theories are all connected (by dualities) to an underlying M-theory. Finally, mathematics has benefited from this field of research. As an example, string theorists interest in compactifications on Calabi Yau manifolds led to the discovery of mirror symmetry, and a major development of the field of algebraic geometry.

Project Plan:
In this project, the aim is to explore *realistic* compactifications of the heterotic string. In the heterotic setting, the cosmology and particle physics of the compactification is determined by the geometry of a manifold M and a vector bundle V. When M is Calabi Yau, algebraic geometry can be used to determine the particle physics of the resulting model in great detail. However, such models do not satisfy cosmological constraints. Therefore, in this project we will study compactifications on non Calabi Yau manifolds, with vector bundles. Recent results in string theory, supergravity and generalised geometry has shed new light on the mathematics of such constructions, thus making the proposed study possible.

We will endeavour both to construct new examples of geometries and bundles and to determine generic features of these spaces. In particular, we will focus on the so-called moduli space of the compactifications, and study its relevance for string theory model building.

Interdisciplinary aspect:
The success of this project relies on combining methods from theoretical physics (e.g. string theory and supergravity) with mathematics (e.g. algebraic, complex, differential, generalised, symplectic and toric geometry). Part of the project is likely to require machine calculations using, for example, Mathematica and algebro-geometric programs such as Singular. Applicants with experience in these fields are encouraged to apply for the proposed position. The successful applicant will work in a new collaboration between the Theoretical Physics group and the Algebra and Geometry group, which provides excellent prospects for further training in these fields. The cross-disciplinary environment of CIM provides the postdoctoral researcher with a network where technical aspects of the research can be discussed, which will be of great value for the project.

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