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Geometry, Topology, and Physics Seminar

K3 surfaces, modular forms, and non-geometric heterotic compactifications

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Room 6635 South Hall

Abstract: Type IIB string theory has an $\mathrm{SL}(2,\mathbb{Z})$ symmetry and a complex scalar field τ valued in the upper half plane, on which $\mathrm{SL}(2,\mathbb{Z})$ acts by fractional linear transformations; this naturally suggests building models in which τ is allowed to vary. Although the $\mathrm{SL}(2,\mathbb{Z})$-invariant function $j(\tau)$ can reveal some of the structures of these models, for their full construction and study we need $\mathrm{SL}(2,\mathbb{Z})$ modular forms, particularly the Eisenstein series $E_4(\tau)$ and $E_6(\tau)$ and the corresponding Weierstrass equations. The Weierstrass equations can also be analyzed in algebraic geometry via the theory of elliptic curves. This approach leads to the "F-theory" compactifications of type IIB theory.

Similarly, the heterotic string compactified on T^2 has a large discrete symmetry group $\mathrm{SO}(2,18;\mathbb{Z})$, which acts on the scalars in the theory in a natural way; there have been a number of attempts to construct models in which these scalars are allowed to vary by using $\mathrm{SO}(2,18;\mathbb{Z})$-invariant functions. In our new work, we give (in principle) a more complete construction of these models, using $\mathrm{SO}(2,18;\mathbb{Z})$-modular forms analogous to the Eisenstein series. In practice, we restrict to special cases in which either there are no Wilson lines – and $\mathrm{SO}(2,2;\mathbb{Z})$ symmetry – or there is a single Wilson line – and $\mathrm{SO}(2,3;\mathbb{Z})$ symmetry. In those cases, the modular forms can be analyzed in detail and there turns out to be a precise theory of K3 surface with prescribed singularities which corresponds to the structure of the modular forms. Using these two approaches – modular forms on the one hand, and the algebraic geometry of the K3 surfaces on the other hand – we can construct non-geometric compactifications of the heterotic theory.