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Superpotentials in IIA compactifications with general fluxes

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Abstract

We derive the effective $N = 1$, $D = 4$ supergravity for the seven main moduli of type IIA orientifolds with D6-branes, compactified on $T^6/(Z_2 \times Z_2)$ in the presence of general fluxes. We illustrate and apply a general method that relates the $N = 1$ effective Kähler potential and superpotential to a consistent truncation of gauged $N = 4$ supergravity. We identify the correspondence between various admissible fluxes, $N = 4$ gaugings and $N = 1$ superpotential terms. We construct explicit examples with different features: in particular, new IIA no-scale models and a model which admits a supersymmetric AdS_4 vacuum with all seven main moduli stabilized.

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1. Introduction

Compactifications of superstrings and M-theory[3] may lead to four-dimensional vacua with exact or spontaneously broken supersymmetries. The pattern of residual and broken supersymmetries strongly depends on the set of moduli fields predicted by the compactification geometry and on the detailed dynamics of these moduli. Even for the phenomenologically attractive compactifications with spontaneously broken $N = 1$ only, information on the dynamics of moduli is provided by the much larger symmetry of the underlying $D = 10$ string theories, with sixteen or thirty-two supercharges. Similarly, in the effective $D = 4$ low-energy supergravity theory, this information on moduli dynamics is encoded in the underlying $N \geqslant 4$ supersymmetry. Thus, the Kähler potential of the $N = 1$ effective supergravity follows from the scalar sigma-model induced by $N = 4$ auxiliary field and gauge-fixing equations. And the $N = 1$ superpotential for the moduli and matter fields is directly related to the $N = 4$ supergravity [2–4] gauging [5], which in turn corresponds to a specific flux structure of the underlying ten-dimensional string theory or eleven-dimensional M-theory.

The generation of a scalar potential for the moduli fields is a crucial ingredient in supersymmetry breaking and in the determination of a stable $D = 4$ background geometry, if any. It is also essential to reduce the number of massless scalars and/or undetermined parameters in the low-energy effective theory. Besides the curvature of the internal space itself, there are several well-known sources for a scalar potential in the compactified ten-dimensional (or eleven-dimensional) theory.

A first source is the Scherk–Schwarz mechanism [6], and its generalization to superstrings via freely acting orbifolds [7]. The relevant fluxes are the geometrical ones, associated with the internal spin connection ω_3. Some of the corresponding effective theories are no-scale supergravity models [8], with broken supersymmetry in a flat $D = 4$ background. However, the gravitino and the other masses generated in this way are proportional (modulo quantized charges) to the inverse length scale of the compactified space, $m \propto R^{-1}$. Therefore, to have supersymmetry breaking and/or preserving TeV scale masses, we need a very large internal dimension, $R \sim 10^{15} l_P$, where l_P is the (four-dimensional) Planck length.

A second source is nonzero "fluxes" of antisymmetric tensor fields, as first identified long ago for the three-form H_3 of the heterotic theory [9]. There is an extensive recent literature [10] on orientifolds of the IIB theory in the presence of three-form fluxes. For instance, simultaneous and suitably aligned NS–NS (NS = Neveu–Schwarz) and R–R (R = Ramond) 3-form fluxes, H_3 and F_3, can lead to no-scale supergravities, but now $m \propto l_P^2 R^{-3}$: as a result, TeV scale supersymmetry breaking and/or preserving masses can be obtained for $R \sim 10^5 l_P$. The richer flux content of the IIA theory has been studied to a lesser extent [11,12].

Both sources, geometric and antisymmetric tensor fluxes, can be combined, as originally examined in the heterotic theory by Kaloper and Myers [13].

[3] For an introduction, see, e.g., [1].