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The 6D superswirl

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Abstract

We present a novel supersymmetric solution to a nonlinear sigma model coupled to supergravity. The solution represents a static, supersymmetric, codimension-two object, which is different to the familiar cosmic strings. In particular, we consider 6D chiral gauged supergravity, whose spectrum contains a number of hypermultiplets. The scalar components of the hypermultiplet are charged under a gauge field, and supersymmetry implies that they experience a simple paraboloid-like (or 2D infinite well) potential, which is minimised when they vanish. Unlike conventional vortices, the energy density of our configuration is not localized to a string-like core. The solutions have two timelike singularities in the internal manifold, which provide the necessary boundary conditions to ensure that the scalars do not lie at the minimum of their potential. The 4D spacetime is flat, and the solution is a continuous deformation of the so-called "rugby ball" solution, which has been studied in the context of the cosmological constant problem. It represents an unexpected class of supersymmetric solutions to the 6D theory, which have gravity, gauge fluxes and hyperscalars all active in the background.

Keywords: Extra dimensions; Gauged supergravity; Supersymmetry; Topological defects

1. Introduction

Sigma models in quantum field theory constitute one of the most interesting theories with a wide range of applications in high energy physics. One of the most remarkable examples of this is

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represented in the linear sigma model theories, by the (non)-Abelian Higgs model, where a complex scalar field has a Mexican hat potential. This theory has interesting static solitonic solutions, which are the well-known vortices (for a review, see, e.g., [1]). When coupled to gravity, these solitons give rise to codimension-two objects, or cosmic strings, which have the effect of producing a conical singularity in spacetime, and which could have been formed in early stages of the universe's evolution, with important implications for cosmology [2]. Recently, cosmic strings with a superstring origin have also been considered due to its relevance for possible connections between string theories and experiment [3]. In this context, cosmic string solutions, or vortex solutions to (non)-Abelian Higgs models coupled to supergravity, have been considered recently, with interesting results [4]. Other global and local supersymmetric codimension-two solutions to Abelian Higgs models have been considered in a different context in three dimensions [5,6]. Moreover, string-like solutions in nonlinear sigma models (i.e., those with non-canonical kinetic terms) have long been known to exist [7].

In this article, we would like to consider a particular nonlinear sigma model, which is coupled to gauged 6D supergravity [8], and study new examples of static, codimension-two, supersymmetric configurations, different from cosmic strings. Nonlinear sigma models appear quite generically in this context, because once scalar fields (which can arise in matter or supergravity multiplets) are coupled to supergravity, they always seem to form such structures [9]. This allows an elegant geometrical treatment of what would otherwise seem a highly intractable nonlinear system. Moreover, gauged supergravities are coming to the fore in recent years, since they describe the low energy effective theory of string theory compactifications with fluxes. There, the sigma model describes the moduli of the compactification, and the fluxes gauge certain isometries of the sigma model manifold, inducing a scalar potential in the theory. Indeed, in contrast to bosonic sigma models, where there is no unique way to construct a gauge-invariant potential, for supersymmetric theories, supersymmetry (SUSY) is often powerful enough to determine the form of the potential uniquely. In general, it will be different to the familiar Mexican hat shape.

In this paper, we concentrate our attention on six-dimensional chiral gauged supergravity [10–13], in which a complex scalar field, ϕ, has a paraboloid-like potential with a minimum at $\phi = 0$ [14]. We are interested in static configurations which represent codimension-two objects in spacetime and, moreover, preserve some fraction of the supersymmetry of the original system.

1.1. *The model under consideration*

The 6D supergravity theory that we study here has received much attention in the past, mainly due to its interesting phenomenological applications. For example, it shares many of the features of 10D supergravity—and so also of string vacua—such as the existence of chiral fermions [10] with nontrivial Green–Schwarz anomaly cancellation [15], as well as the possibility of having chiral compactifications down to flat four dimensions [10].

In its minimal form, the bosonic spectrum contains the graviton, dilaton, and antisymmetric two- and three-form field strengths. The gauging of a global R-symmetry, together with supersymmetry, requires the presence of a positive-definite potential for the dilaton, with a Liouville form.

The presence of anomalies can be avoided by adding to the spectrum a number of hypermultiplets, suitably charged under the gauge group [10], rendering the theory consistent also at the quantum level. The scalars of the hypermultiplets appear in the potential, which has a minimum only when they vanish.