Gauged supergravity vacua from intersecting branes

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Abstract

Domain wall and electrovac solutions of gauged N=4 D=4 supergravity, with gauge group $SU(2)$ or $SU(2) \times SU(2)$, are interpreted as supersymmetric Kaluza-Klein vacua of N=1 D=10 supergravity. These vacua are shown to be the near-horizon geometries of certain intersecting brane solutions.

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1 Introduction

Gauged supergravity theories are those for which a subgroup of the R-symmetry group (alias the automorphism group of the supersymmetry algebra) is gauged by vector potentials in the graviton supermultiplet. The gauging is invariably accompanied by a cosmological constant of order $g^2$, where $g$ is the gauge coupling constant, and in the simplest cases (the ‘adS-supergravities’) there is a maximally supersymmetric anti-de Sitter (adS) vacuum, maximal in the sense that the adS vacuum of the gauged supergravity theory preserves the same total number of supersymmetries as the Minkowski vacuum of the ungauged theory. A classic example is gauged N=8 D=4 supergravity, which can be obtained by gauging an $SO(8)$ subgroup of the $SU(8)$ R-symmetry group. This theory has an adS vacuum with the N=8 adS supergroup $OSp(8|4; \mathbb{R})$ as its isometry supergroup. It can also be obtained by $S^7$ compactification of D=11 supergravity, in which case the $SO(8)$ gauge group has a Kaluza-Klein (KK) origin as the isometry group of $S^7$. Another example is the gauged D=5 maximal supergravity for which the gauge group is an $SU(4)$ subgroup of the $Sp(4)$ (alias $USp(8)$) R-symmetry group. This too has an adS vacuum and can be obtained from an $S^5$ compactification of IIB supergravity. Yet another example is the gauged maximal D=7 supergravity, for which the gauge group is the full $Sp(2) \cong Spin(5)$ R-symmetry group. This theory has the curious feature that the $g \to 0$ limit is singular, so it cannot be found by the usual ‘Noether’ procedure, in which the ungauged theory is taken as the starting point; it was actually found from an $S^4$ compactification of D=11 supergravity. We refer to [1, 2] for reviews and references to work of this period.

It was shown in [3] that all the above mentioned KK vacua associated with gauged maximal supergravities arise as near-horizon geometries of 1/2 supersymmetric p-brane solutions of D=10 or D=11 supergravity theories. The $adS_4 \times S^7$ and $adS_7 \times S^4$ vacua of D=11 supergravity are the near-horizon geometries of the extreme membrane and fivebrane solutions, respectively, while the $adS_5 \times S^5$ vacuum of IIB supergravity is the near-horizon geometry of the threebrane solution. In other words, these p-brane solutions interpolate between maximally supersymmetric vacua of the respective supergravity theories. More recently it has been shown that some intersecting brane solutions have a
similar property. For example, the extreme black hole and black string solutions of D=5 minimal supergravity \cite{4} (reducing to $\alpha = 1/\sqrt{3}$ dilaton black holes in D=4) interpolate between either $adS_2 \times S^3$ or $adS_3 \times S^2$, respectively \cite{3, 4, 4}, but these are the reduction of D=11 supergravity solutions that can be interpreted \cite{8} as, respectively, three intersecting M2-branes or three intersecting M5-branes. Other examples have been given in \cite{9, 7}, and it was shown more generally in \cite{7} that intersecting M-branes interpolate between the D=11 Minkowski vacuum and a spacetime of the form $adS_k \times \mathbb{P}^l \times S^m$ (with $k + l + m = 11$).

In this paper we shall explore similar issues in the context of N=1 D=10 supergravity. Some observations concerning this case have been made previously in the context of black hole entropy \cite{10, 7, 11}, and the topic has been revitalized by recent conjectures relating near-horizon geometries to large rank limits of supersymmetric gauge theories \cite{12}, but our principal concern is to explore some connections to the N=4 D=4 gauged supergravity theory of Freedman and Schwarz \cite{13}, which we call the ‘FS theory’. The gauge group is $SU(2) \times SU(2)$ with gauge coupling constants $e_A$ and $e_B$, unless $e_B = 0$ in which case the gauge group is $SU(2) \times U(1)^3$ with $e_A \equiv g$ being the $SU(2)$ gauge coupling constant; we shall call the latter theory the ‘half-gauged’ FS model. There is another N=4 D=4 gauged supergravity \cite{14}, usually called the ‘SO(4) theory’, which has the same field content and gauge group but different interactions, except for the ‘half-gauged’ case which coincides with the half-gauged FS model. Only the FS model, gauged or half-gauged, will be of relevance here. Its distinguishing feature is that the single scalar field $\sigma$ (the D=4 dilaton) has a potential

$$V = 2(e_A^2 + e_B^2)e^\sigma$$

(1)

so that there is no Minkowski vacuum. This feature is also shared by gauged D=7 minimal supergravity \cite{15} (with vanishing topological mass term \cite{16}). This is no coincidence as the ‘half-gauged’ FS model is the dimensional reduction on $T^3$ of the D=7 theory \cite{17}.

It is natural to suppose that gauged D=7 supergravity is an $S^3$ compactification of D=10 N=1 supergravity since the $SU(2)$ gauge group would then acquire a KK origin as one factor of the $SU(2) \times SU(2)$ isometry group of $S^3$ (the gauge fields of the other $SU(2)$ factor would have to belong to three vector multiplets which could likely be consistently truncated). If so, the FS model would then have a natural KK interpretation as an
$S^3 \times S^3$ compactification of D=10 N=1 supergravity (followed by a truncation of an $SU(2) \times SU(2)$ Yang-Mills multiplet). The ‘half-gauged’ FS model would then acquire a similar interpretation as an $S^3 \times T^3$ compactification. These suppositions are in fact correct, although it was a long time before this was appreciated [18, 19]. One reason for the delay is that the first $S^3$ compactification of D=10 N=1 supergravity to be found [20] is such that $\Phi \equiv e^\phi$ (where $\phi$ is the D=10 dilaton) is not everywhere positive on $S^3$. The analogous $S^3 \times S^3$ compactification suffers from the same problem, and requiring positivity of $\Phi$ led, in 1983, to a ‘no-go’ theorem that apparently precluded the existence of a physically acceptable $S^3 \times S^3$ compactification to D=4 [21].

There were no further attempts to provide a KK origin for the FS model until 1990, when the FS model was identified as part of the effective D=4 field theory for the heterotic string theory in an $S^3 \times S^3$ vacuum [18]. The ‘no-go’ theorem is circumvented by the fact that the D=4 dilaton is not presumed to be constant. In a subsequent independent development, it was discovered [3] that the (non-singular) fivebrane solution of D=10 supergravity [22, 23] interpolates, in the string metric, between the Minkowski vacuum and an $S^3$ compactification to D=7 Minkowski spacetime, and it was noted that an $S^3 \times S^3$ compactification to D=4 Minkowski spacetime is also possible. Again, neither the D=7 nor the D=4 dilaton is constant in these compactifications but, rather, linear in one of the Minkowski coordinates. We shall show here that the D=7 linear dilaton vacuum is actually the 1/2 supersymmetric domain wall solution of gauged D=7 supergravity found in [24]. This reduces in D=4 to a 1/2 supersymmetric domain wall solution of the half-gauged FS model, which is also a 1/2 supersymmetric solution of the full $SU(2) \times SU(2)$ FS model [17]. There is therefore no obstacle to the identification of gauged D=7 supergravity as a consistent truncation of $S^3$ compactified D=10 N=1 supergravity, and of the $SU(2) \times SU(2)$ FS model as a consistent truncation of $S^3 \times S^3$ compactified D=10 N=1 supergravity (the truncations merely removing inessential matter multiplets). The latter identification was made and verified in [18, 19]. The former identification (conjectured in [7]) then follows from the results in [17].

Here we consider further these $S^3$ and $S^3 \times S^3$ compactifications of D=10 supergravity
We take the $D=10$ action to be

$$S = \int d^{10}x \sqrt{-g} e^{-2\phi}[R + 4(\partial \phi)^2 - \frac{1}{12}F^2] \quad (2)$$

where $\phi$ is the dilaton and $F$ is the 3-form field strength. The metric is thus the string-frame metric. We shall show that the $S^3 \times S^3$ compactification of this theory is the near horizon geometry of a solution representing the intersection of two fivebranes on a line. The latter solution [23], which preserves 1/4 supersymmetry, therefore interpolates between the fully supersymmetric Minkowski vacuum and the 1/2 supersymmetric $S^3 \times S^3$ compactification to the domain wall of the FS model.

The domain wall is not the only 1/2 supersymmetric solution of the FS theory. There is a 1/2 supersymmetric electrovac solution of the half-gauged model [26]. This was shown in [17] to descend from an analogous ‘electrovac’ solution of gauged $D=7$ supergravity, for which the metric is actually just $(adS)_3 \times \mathbb{E}^4$, corresponding to an $adS_3 \times \mathbb{E}^4 \times S^3$ solution of $D=10$ supergravity. Unlike the domain wall, the ‘electrovac’ solution has a constant dilaton. Here we shall show that it is the near-horizon geometry of a 1/4 supersymmetric intersecting brane solution of $D=10$ supergravity in which a string lies inside a fivebrane.

Alternatively, by replacing $\mathbb{E}^4$ by $T^4$ in the $D=10$ ‘electrovac’ solution, we can consider it as an $adS_3 \times S^3$ solution of the dimensionally reduced $D=6$ supergravity. This solution is the near horizon geometry of the self-dual $D=6$ string of [28], which is the reduction to $D=6$ of the $D=10$ intersecting brane solution. Considered in the context of minimal $D=6$ supergravity, the self-dual $D=6$ string is similar to the M2-brane, M5-brane and D3-brane in that it is a 1/2 supersymmetric solution that interpolates between the fully supersymmetric $Mink_6$ and $adS_3 \times S^3$ vacua of this theory. Thus, surprisingly, the Gibbons/Freedman electrovac of gauged $D=4$ supergravity is directly related to the $D=6$ self-dual string.

The $D=10$ string-in-fivebrane solution can be generalized to a string in the intersection of two fivebranes (which we choose to be orthogonal); this 1/4 supersymmetric solution can be found by an application of a ‘generalized harmonic function rule’ of [27, 30, 31].

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1This fact was also noted in [27], but without the connection to the FS model. A related observation was made in [10].

2See [29] for recent related observations.
By an appropriate choice of the harmonic functions one can arrange for the dilaton to be constant and for the metric to interpolate between the Minkowski vacuum and an $S^3 \times S^3$ compactification to $adS_3 \times \mathbb{E}$. This establishes the existence of a supersymmetric $adS_3 \times \mathbb{E}$ vacuum of the $SU(2) \times SU(2)$ FS model with at least 1/4 supersymmetry. It is presumably the 1/4 supersymmetric ‘axionic’ solution recently found in [32].

2 Domain walls from intersecting fivebranes

The 1/4 supersymmetric solution of D=10 supergravity (in string frame) representing two orthogonal fivebranes intersecting on a line is

$$ds^2 = ds^2(\mathbb{E}^{(1,1)}) + Hdx \cdot dx + H'dx' \cdot dx'$$

$$e^{2\phi} = HH'$$

$$F = \star dH + \star' dH'$$

(3)

where $\mathbb{E}^{(1,1)}$ indicates a (1+1)-dimensional Minkowski space, $H$ and $H'$ are harmonic functions on their respective 4-dimensional Euclidean spaces with metrics $dx \cdot dx$ and $dx' \cdot dx'$, and $\star$ and $\star'$ are the Hodge duals on these two spaces. We choose the harmonic functions to be

$$H = 1 + \frac{1}{r^2} \quad H' = 1 + \frac{1}{r'^2}$$

(4)

where $r = |x|$ and $r' = |x'|$ are the distances from the origins of the two 4-dimensional Euclidean spaces.

Close to the first fivebrane, but far from the second one, we have $H \sim 1/r^2$ and $H' \sim 1$. In this case, the asymptotic metric is

$$ds^2 \sim ds^2(\mathbb{E}^{(1,1)}) + dx' \cdot dx' + \frac{dr^2}{r^2} + ds^2(S^3)$$

$$= ds^2(\mathbb{E}^{(1,6)}) + ds^2(S^3)$$

(5)

while the dilaton is $\phi \sim \rho$, where $\rho = -\log r$. From the discussion in the introduction we now deduce that this $S^3$ compactification of D=10 supergravity implies the existence of a solution of D=7 gauged supergravity with dilaton $\phi = \rho$, Minkowski 7-metric and vanishing D=7 gauge fields. Using the relation $ds^2_E = e^{-4\phi/5}ds^2$ between the string-frame
7-metric and the Einstein-frame 7-metric we find that this solution has Einstein-frame 7-metric

\[ ds_E^2 = e^{-\frac{4}{5} \rho}[ds^2(E^{(1,5)}) + d\rho^2] \] (6)

Defining \( y = (1/2)e^{2\rho} \) we find the solution

\[ ds_E^2 = H^{-\frac{4}{5}} ds^2(E^{(1,5)}) + H^{-1} dy^2 \]
\[ e^{2\phi} = H \] (7)

with \( H = 2y \).

To compare with the solutions of gauged D=7 supergravity we need to write the D=10 dilaton \( \phi \) in terms of the D=7 dilaton \( \phi^{(7)} \). Later we shall need to do the same for the D=4 dilaton \( \phi^{(4)} \equiv \sigma \). We therefore pause here to deduce the relation between \( \phi \) and the D-dimensional dilaton \( \phi^{(D)} \). Since the 10-metrics we consider are direct products of D-dimensional metrics with spheres, or products of spheres, of constant radius, the D=10 dilaton \( \phi \) remains the only scalar field in the lower dimension, so that the effective D-dimensional lagrangian is still of the form

\[ L = \sqrt{-g}e^{-2\phi}[R + 4(\nabla \phi)^2 + \ldots] . \] (8)

This is equivalent to

\[ L_E = \sqrt{-g_E}[R - \frac{1}{2}(\nabla \phi^{(D)})^2 + \ldots]_E , \] (9)

where

\[ \phi^{(D)} = \frac{2\sqrt{2}}{\sqrt{D-2}} \phi , \] (10)

and the subscript ‘E’ indicates a D-dimensional Einstein-frame metric. Thus, for D=7 we have

\[ \phi^{(7)} = \frac{2\sqrt{2}}{\sqrt{5}} \phi . \] (11)

Using this relation one sees that the solution (7) is the 1/2 supersymmetric domain wall solution of [24] (for which, in general, \( H \) is piecewise linear in \( y \)).

We now turn to the asymptotic metric in the region near both fivebranes. In this case \( H \sim 1/r^2 \) and \( H' \sim 1/r'^2 \). Setting

\[ \rho = -\frac{1}{\sqrt{2}} \log(rr') \quad \lambda = \frac{1}{\sqrt{2}} \log(r/r') , \] (12)
we then find

\[ ds^2 \sim ds^2(\mathbb{E}(1,1)) + d\rho^2 + d\lambda^2 + ds^2(S^3 \times S^3) \]

\[ \phi \sim \sqrt{2}\rho \]  

(13)

while the 3-form field strength is now the sum of the volume forms of the two \( S^3 \) factors. This result implies the existence of a supersymmetric solution to the D=4 \( SU(2) \times SU(2) \) FS model with vanishing gauge fields. Passing to the (D=4) Einstein frame, for which \( \phi_{(4)} \equiv \sigma = 2\phi \), and defining \( y = (1/2\sqrt{2})e^{2\sqrt{2}\rho} \), we find that

\[ ds^2_{\mathcal{E}} = H^{-1}ds^2(\mathbb{E}(1,2)) + H^{-3}dy^2 \]

\[ e^{-\sigma} = H \]  

(14)

with \( H = \sqrt{2}y \). This is just the 1/2 supersymmetric domain wall solution of [17], shown there to be the dimensional reduction of the D=7 domain wall solution.

Thus, the intersecting fivebrane solution interpolates between the D=10 Minkowski vacuum and a 1/2 supersymmetric domain wall solution of either D=7 gauged supergravity or \( SU(2) \times SU(2) \) D=4 gauged supergravity, according to whether we are close to just one of the fivebranes or both of them.

3 Electrolytes from string-in-fivebrane

The 1/4 supersymmetric string-in-fivebrane solution of D=10 supergravity is

\[ ds^2 = H_1^{-1}ds^2(\mathbb{E}(1,1)) + H_5dx \cdot dx + ds^2(\mathbb{E}^4) \]

\[ e^{2\phi} = H_1^{-1}H_5 \]

\[ F = vol(\mathbb{E}^{(1,1)}) \wedge dH_1^{-1} + *dH_5 \]  

(15)

where \( H_1 \) and \( H_5 \) are both harmonic functions on the 4-space with Euclidean 4-metric \( dx \cdot dx \), and \( * \) is the Hodge dual on this space. We shall choose

\[ H_1 = H_5 = H(x) \].  

(16)
This choice has the property that the dilaton is constant, in fact zero. The metric and 3-form field strength are now

\[ ds^2 = H^{-1}ds^2(E^{(1,1)}) + Hdx \cdot dx + ds^2(E^4) \]

\[ F = vol(E^{(1,1)}) \wedge dH^{-1} + \star dH \]  

(17)

Ignoring the \( E^4 \) factor (which may be replaced by \( T^4 \)), this field configuration is automatically a 1/4 supersymmetric solution of the (1,1) D=6 supergravity theory obtained by \( T^4 \) compactification of D=10 supergravity. Because the dilaton vanishes it is also a 1/2 supersymmetric solution of the minimal (1,0) D=6 supergravity. In fact, it is just the self-dual string solution of [28] (for which the singularities of \( H \) were shown in [4] to be horizons of the geodesically complete maximal analytic extension). It then follows from the analysis below that the self-dual string solution interpolates between the maximally supersymmetric Minkowski and \( adS_3 \times S^3 \) vacua of (1,0) D=6 supergravity. In this respect the D=6 self-dual string is similar to the M2-brane, M5-brane and D3-brane.

We now return to (17) and choose

\[ H(x) = 1 + \frac{1}{r^2} \]  

(18)

where \( r = |x| \). Near the origin the asymptotic metric is

\[ ds^2 \sim r^2 ds^2(E^{(1,1)}) + \frac{dr^2}{r^2} + ds^2(S^3) + ds^2(E^4) \]  

(19)

which is \( adS_3 \times S^3 \times E^4 \). The 3-form field strength \( F \) is asymptotic to the sum of the volume forms on the \( S^3 \) and \( adS_3 \) factors. By ignoring the \( E^4 \) factor, we deduce the result just claimed above for the D=6 self-dual string. Instead, we may ‘ignore’ the \( S^3 \) factor, i.e. we may interpret the asymptotic solution just found as a new \( S^3 \) compactification of D=10 supergravity preserving at least 1/4 supersymmetry. This implies the existence of an \( adS_3 \times E^4 \) vacuum of gauged D=7 supergravity, again preserving at least 1/4 supersymmetry. It actually preserves 1/2 supersymmetry, so supersymmetry is partially restored near the horizon. This follows from the fact that the ‘new’ \( adS_3 \times E^4 \) vacuum of gauged D=7 supergravity is actually the D=7 ‘electrovac’ found in [17]. The D=7 ‘electrovac’ metric is essentially of the form

\[ ds^2 = -e^{2\rho}dt^2 + d\rho^2 + (dy + e^\rho dt)^2 + ds^2(E^4) \]  

(20)

\(^3\)Here we set \( g = \sqrt{2} \), set \( \phi = 0 \), and choose horospherical coordinates.
The 3-form field strength of D=7 gauged supergravity is dual to a 4-form field strength which, in this solution, is proportional to the volume form on $\mathbb{E}^4$. The $SU(2)$ gauge fields are zero. If we dimensionally reduce on $y$ and two of the cartesian coordinates of $\mathbb{E}^4$ then we recover the 1/2 supersymmetric Gibbons-Freedman electrovac of the half-gauged FS model (with $adS_2 \times \mathbb{E}^2$ 4-metric), hence the name given to the D=7 solution in \cite{17}. However, the 3-metric obtained by ignoring the $\mathbb{E}^4$ factor is just $adS_3$, as we have verified by a computation of the Ricci tensor. In fact, the D=7 ‘electrovac’ is equivalent to the compactification to $adS_3$ found in \cite{33}.

4 ‘Axiovac’ from string-in-two-fivebranes

We now turn our attention to the solution representing a string in the common linear-intersection of two fivebranes. The solution is

$$ds^2 = H_1^{-1} ds^2(\mathbb{E}^{(1,1)}) + H_5 dx \cdot dx + H'_5 dx' \cdot dx'$$

$$e^{2\phi} = H_1^{-1} H_5 H'_5$$

$$F = vol(\mathbb{E}^{(1,1)}) \wedge dH_1^{-1} + \ast dH_5 + \ast' dH'_5$$

(21)

where $H_5$ is a harmonic function on the Euclidean 4-space with the $x$ coordinates, $H'_5$ is a harmonic function on the Euclidean 4-space with the $x'$ coordinates, and the function $H_1$ satisfies \cite{30,31}

$$[(H_5)^{-1}\nabla^2 + (H'_5)^{-1}\nabla'^2]H_1 = 0.$$  

(22)

It was noted in \cite{31} that this can be solved by additive separation of variables. Of more relevance here is the fact that it can also be solved by multiplicative separation of variables. Specifically, it is solved by $H_1 = ff'$ where $f$ is harmonic in $x$ and $f'$ is harmonic in $x'$. In particular, we may choose

$$H_1 = H_5 H'_5.$$  

(23)

This choice has the property that the dilaton is again zero. The other fields are

$$ds^2 = (H_5 H'_5)^{-1} ds^2(\mathbb{E}^{(1,1)}) + H_5 dx \cdot dx + H'_5 dx' \cdot dx'$$

$$F = vol(\mathbb{E}^{(1,1)}) \wedge d(H_5 H'_5)^{-1} + \ast dH_5 + \ast' dH'_5$$

(24)
We now choose
\[ H_5 = 1 + \frac{1}{r^2}, \quad H'_5 = 1 + \frac{1}{r'^2}. \] (25)

Far away from one fivebrane, but close to the other one, we recover the previous \( adS_3 \times S^3 \times E^4 \) solution. Near both fivebranes we use the coordinates (8) to write the asymptotic metric as
\[ ds^2 = e^{-2\sqrt{2}\rho} ds^2(\mathbb{R}^{(1,1)}) + d\rho^2 + d\lambda^2 + ds^2(S^3 \times S^3) \] (26)
We recognize this as \( adS_3 \times S^3 \times S^3 \times E^1 \). The square of the radius of curvature of the \( adS_3 \) factor is now half as large as before, as required by the presence of two \( S^3 \) factors (given constant dilaton). The original intersecting brane solution of D=10 supergravity preserves 1/4 supersymmetry, so the asymptotic solution near the fivebranes must also preserve at least this fraction. It therefore corresponds to a solution of the D=4 FS model that preserves at least 1/4 supersymmetry and has metric \( adS_3 \times E^1 \). This is presumably the 1/4 supersymmetric ‘axionic’ vacuum solution, or ‘axiovac’, of [32].

5 Discussion

We have shown that various supersymmetric vacua of the N=4 D=4 gauged supergravity model of Freedman and Schwarz can be reinterpreted as compactifications of D=10 N=1 supergravity, and that these compactifications are the near-horizon geometries of various intersecting brane solutions. The FS vacua that we can interpret in this way include the domain wall, the \( SU(2) \times U(1)^3 \) electrovac, and the \( adS_3 \times E^1 \) ‘axiovac’.

There are other supersymmetric solutions for which we have not yet found a similar interpretation. An example which we believe should have such an interpretation is the 1/4 supersymmetric electrovac of the \( SU(2) \times SU(2) \) FS model [26]. Although we have not seen how to interpret this solution in terms of intersecting branes its existence follows from the 1/4 supersymmetric \( adS_3 \times E^1 \) ‘axiovac’. To see this, one writes the \( adS_3 \times E^1 \) metric in the form (20) and reduces to D=3 in the \( y \) direction. This yields a D=3 electrovac which can be lifted to the D=4 electrovac with \( adS_2 \times E^2 \) metric. Thus these two 1/4 supersymmetric solutions of the \( SU(2) \times SU(2) \) FS model are dual to each other.

There are also other gauged supergravities. Many have now been provided with a
KK interpretation and, given such an interpretation, it is often possible to interpret the KK compactification as the near-horizon geometry of a p-brane or, as shown here, of intersecting branes. An exception is the gauged D=7 supergravity with topological mass term [16]. This theory has an adS vacuum but no known KK interpretation, although it is tempting to suppose that it is obtainable by some modification of the $S^3$ compactification. Another outstanding exception is the D=6 $SU(2)$ gauged supergravity of Romans [34]. This theory has an adS vacuum with the exceptional supergroup $F(4)$ as its isometry supergroup, but it has no known KK interpretation. It is natural to suspect that it arises as the effective theory in some compactification of D=10 supergravity. If so one might suppose that it is again the near-horizon geometry of some intersecting brane solution, but no obvious candidate presents itself. We should also point out that there are non-compact gaugings of D=4 N=8 supergravity that arise from ‘non-compact’ compactifications of D=11 supergravity [35], but the latter are not known to occur as near-horizon geometries of any brane, or intersecting brane, solutions.

Consideration of the near-horizon geometries of branes and their intersections has led to a number of compactifications of D=10 and D=11 supergravity theories that were unknown in the heyday of Kaluza-Klein theory. The $S^3$ and $S^3 \times S^3$ compactifications of D=10 supergravity to domain walls and electrovacs are examples. Another example is the $S^7$ compactification of IIA supergravity to an adS$_3$ ‘linear dilaton’ vacuum [36]. The $S^3 \times S^3$ compactification to the D=4 ‘axiovac’ discussed here similarly establishes a new 1/4 supersymmetric $S^3 \times S^3 \times S^1$ compactification of D=10 N=1 supergravity to D=3; the effective D=3 field theory is presumably a matter-coupled adS supergravity. One may wonder whether there are any new gauged supergravity theories that might be found in this way. For example, the fact that the near horizon geometry of the linear intersection of an M2-brane with an M5-brane is $adS_3 \times \mathbb{E}^5 \times S^3$ [3, 4] means that there is an $S^3$ compactification of D=11 supergravity to D=8 preserving at least 1/4 supersymmetry.

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