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AdS wormholes

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Abstract

We obtain a large class of smooth Lorentzian p-brane wormholes in supergravities in various dimensions. They connect two asymptotically flat spacetimes. In cases where there is no dilaton involved in the solution, the wormhole can connect an $AdS_n \times S^m$ in one asymptotic region to a flat spacetime in the other. We obtain explicit examples for $(n, m) = (4, 7), (7, 4), (5, 5), (3, 3), (3, 2)$. These geometries correspond to field theories with UV conformal fixed points, and they undergo decompactification in the IR region. In the case of AdS_3, we compute the central charge of the corresponding conformal field theory.

1. Introduction

Asymptotically AdS solutions in supergravities play an important rôle in the AdS/CFT correspondence [1–3], since they provide supergravity duals to quantum field theories with conformal fixed points in the UV region. In the bulk of such a solution, there are limited possibilities. There can be a black hole horizon with non-zero (or zero) temperature, or there can be an AdS horizon of different AdS radius, corresponding to a conformal field fixed point in the IR region [4]. A third possibility is that the solution is solitonic, such as an R-charged AdS bubble solution in an AdS gauged supergravity [5–7]. Most likely, the solution will have a naked singularity. Ex-

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amples include the large class of AdS domain wall solutions with naked singularities constructed in [8,9], which are dual to the Coulomb branch of the dual gauge theories.

A more intriguing situation is when there exists a wormhole in the bulk that connects smoothly to different AdS boundaries. In Lorentzian signature such a geometry appears unlikely, and disconnected boundaries can only be separated by horizons [10]. Thus the recent studies of wormholes in string theory and in the context of the AdS/CFT correspondence have so far concentrated on Euclidean-signature spaces [11–15].

In [16], Ricci-flat and charged Lorentzian wormholes in higher dimensions were obtained. These include the previously-known $D = 5$ Ricci-flat case [17]. The wormholes are smooth everywhere, and connect two asymptotically flat Minkowski spacetimes. Although these wormholes are not traversable geodesically (see [18,19] and [16]), it was demonstrated in [16] that there exist traversable accelerated timelike trajectories across the wormholes.

A class of magnetically-charged wormholes in $D = 5$ supergravity was also obtained in [16]. It was shown that for appropriate choices of the parameters, the wormhole can connect an $AdS_3 \times S^2$ in one asymptotic region to a Minkowski spacetime in the other. This geometry then provides a supergravity dual of a two-dimensional field theory at the boundary of the AdS_3.

In this paper, we begin in Section 2 with a review of the Ricci-flat wormhole solutions that were obtained in [16]. We then construct p-brane wormhole solutions in Section 3, supported by a dilaton and n-form field strength. In non-dilatonic cases, these p-brane wormholes connect an $AdS_n \times S^m$ in one asymptotic region to a flat spacetime in the other. We obtain explicit examples for $(n, m) = (4, 7), (7, 4), (5, 5), (3, 3), (3, 2)$. These geometries correspond to field theories with UV conformal fixed points, which undergo decompactification in the IR region.

In Section 4, we study the AdS_3 wormhole obtained in [16] in detail and compute the central charge of the corresponding dual conformal field theory.

In Sections 5 and 6, we examine AdS_5, AdS_4, AdS_7 and another AdS_3 wormhole in detail. Included in these discussions is a calculation of the mass and momentum of the configurations, as measured from the asymptotically AdS region. To do this, we make use of a construction of conserved charges in asymptotically AdS spacetimes, which we summarise in an Appendix A.

We conclude the paper in Section 7.

2. Ricci-flat wormholes in $D \geqslant 5$ dimensions

In this section, we review the Ricci-flat wormhole solutions in general dimensions obtained in [16]; they are given by

$$ds_D^2 = \left(r^2 + a^2\right) d\Omega_{D-3}^2 + \frac{r^2\, dr^2}{(r^2 + a^2)\sin^2 u} + \cos v\left(-dt^2 + dz^2\right) + 2\sin v\, dt\, dz, \tag{2.1}$$

where v and u are functions of r, given by

$$v = \sqrt{\frac{D-3}{2D-8}}(\pi - 2u), \tag{2.2}$$

and

$$u = \arctan\sqrt{\left(1 + \frac{r^2}{a^2}\right)^{D-4} - 1}. \tag{2.3}$$