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The conformal brane-scan: an update

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Abstract: Generalizing the *The Membrane at the End of the Universe*, a 1987 paper *Supersingletons* by Blencowe and the author conjectured the existence of BPS p-brane configurations ($p = 2, 3, 4, 5$) and corresponding CFTs on the boundary of anti-de Sitter space with symmetries appearing in Nahm's classification of superconformal algebras: $\mathrm{OSp}(N|4)$ $N = 8, 4, 2, 1$; $\mathrm{SU}(2, 2|N)$ $N = 4, 2, 1$; $F^2(4)$; $\mathrm{OSp}(8^*|N)$, $N = 4, 2$. This correctly predicted the $D3$-brane with $\mathrm{SU}(2, 2|4)$ on $AdS_5 \times S^5$ and the $M5$-brane with $\mathrm{OSp}(8^*|4)$ on $AdS_7 \times S^4$, in addition to the known $M2$-brane with $\mathrm{OSp}(8|4)$ on $AdS_4 \times S^7$. However, finding non-singular AdS solutions matching the other symmetries was less straightforward. Here we perform a literature search and confirm that all of the empty slots have now been filled, thanks to a number of extra ingredients including warped products and massive Type IIA. Orbifolds, orientifolds and S-folds also play a part providing examples not predicted: $\mathrm{SU}(2, 2|3)$, $\mathrm{OSp}(3|4)$, $\mathrm{OSp}(5|4)$ and $\mathrm{OSp}(6|4)$ but not $\mathrm{OSp}(7|4)$. We also examine the status of $p = (0, 1)$ configurations.

Keywords: Conformal Field Models in String Theory, M-Theory, P-Branes

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> *Our mistake is not that we take our theories too seriously,*
> *but that we do not take them seriously enough.*
> *Steven Weinberg*

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1 Supersingletons

The *Membrane at the End of the Universe* [1–10] was the name given to a supermembrane [11] (later called the M2-brane) on the $S^1 \times S^2$ boundary of $AdS_4 \times S^7$ described by a SCFT with symmetry

$$\mathrm{OSp}(8|4) \supset \mathrm{SO}(3,2) \times \mathrm{SO}(8) \tag{1.1}$$

namely the $N = 8$ singleton supermultiplet with 8 scalar and 8 spinors and SO(8) R symmetry. We recall that representations of SO(3,2) are denoted $D(E_0, s)$ where E_0 is the lowest energy eigenvalue which occurs and s is the total angular momentum quantum number of the lowest energy state, analogous to the mass and spin of the Poincare group. However, Dirac's singletons $D(1/2, 0)$ and $D(1, 1/2)$ have no four-dimensional Poincare analogue [12] and are best interpreted a residing on the three-dimensional boundary [2, 13, 14].

Accordingly, in 1987 Blencowe and the author [3] conjectured the existence of other BPS p-brane configurations with $p = (2, 3, 4, 5)$ on the $S^1 \times S^p$ boundary of $AdS_{(p+2)}$ and corresponding CFTs with other symmetries appearing in Nahm's classification of superconformal algebras [15], listed in table 1.

In each case the boundary CFT is described by the corresponding singleton (scalar), doubleton (scalar or vector) or tripleton (scalar or tensor) supermultiplet[1] as shown in table 2. The number of dimensions transverse to the brane, $D - d$, equals the number of scalars in the supermultiplets. None of these BPS brane CFTs is self-interacting. (For non-BPS see [18, 19]).

A plot of spacetime dimension D vs worldvolume dimension $d = p + 1$, known as the *brane-scan*, is shown in table 3. This correctly predicted the $D3$-brane [20–25] with $\mathrm{SU}(\mathbf{2},\mathbf{2}|\mathbf{4})$ on $AdS_5 \times S^5$ and the $M5$-brane [22, 23, 26] with $\mathrm{OSp}(\mathbf{8}^*|\mathbf{4})$ on $AdS_7 \times S^4$,

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[1] Our nomenclature, based on the rank of AdS_{p+2}, is singleton $p = 2$, doubleton $p = (2, 3)$, tripleton $p = 5$ and differs from that of Günaydin and Minic [17].

d	G	H		Susy
6	$\mathrm{OSp}(8^*\|N)$	$\mathrm{SO}^*(8)\times \mathrm{USp}(N)$	N *even*	$8N$
5	$F^2(4)$	$\mathrm{SO}(5,2)\times \mathrm{SU}(2)$		16
4	$\mathrm{SU}(2,2\|N)$	$\mathrm{SU}(2,2)\times \mathrm{U}(N)$	$N\neq 4$	$8N$
	$\mathrm{SU}(2,2\|4)$	$\mathrm{SU}(2,2)\times \mathrm{SU}(4)$		32
3	$\mathrm{OSp}(N\|4)$	$\mathrm{SO}(N)\times \mathrm{Sp}(4,\mathbb{R})$		$4N$
2	$G_+\times G_-$			
1	$G_\pm =$			
	$\mathrm{OSp}(N\|2)$	$\mathrm{O}(N)\times \mathrm{SU}(1,1)$		$2N$
	$\mathrm{SU}(N\|1,1)$	$\mathrm{U}(N)\times \mathrm{SU}(1,1)$	$N\neq 2$	$4N$
	$\mathrm{SU}(2\|1,1)$	$\mathrm{SU}(2)\times \mathrm{SU}(1,1)$		8
	$\mathrm{OSp}(4^*\|2N)$	$\mathrm{SU}(2)\times \mathrm{USp}(2N)\times \mathrm{SU}(1,1)$		$8N$
	$G(3)$	$G_2\times \mathrm{SU}(1,1)$		14
	$F(4)$	$\mathrm{Spin}(7)\times \mathrm{SU}(1,1)$		16
	$D^1(2,1,\alpha)$	$\mathrm{SU}(2)\times \mathrm{SU}(2)\times \mathrm{SU}(1,1)$		8

Table 1. Following [15, 16] we list the AdS supergroups in $d\leq 6$ and their bosonic subgroups in the notation of [17].

in addition to the known $M2$-brane [11, 23] with $\mathrm{OSp}(\mathbf{8}|\mathbf{4})$ on $AdS_4\times S^7$. The purpose of the present paper is to report that all of the other slots have now been filled, thanks to a number of extra ingredients: warped products, massive Type IIA and Chern-Simons theories. Orbifolds, orientifolds and S-folds also play a part providing examples not predicted: $\mathrm{SU}(2,2|3)$, $\mathrm{OSp}(3|4)$, $\mathrm{OSp}(5|4)$ and $\mathrm{OSp}(6|4)$ but not $\mathrm{OSp}(7|4)$. We also examine the status of $p=(0,1)$ configurations.

2 The conformal brane-scan

Comments:

- The list in table 1 is complete if one assumes that the Killing superalgebras of AdS backgrounds are simple. However a more detailed investigation reveals that there may be some additional central generators in the Killing superlgebra for AdS_3 and AdS_5 backgrounds [27, 28]

- The supersingleton lagrangian and transformation rules were also spelled out explicitly in [3]. This *conformal* or (in later terminology) *near-horizon* brane-scan differs from the scan of Green-Schwarz type kappa-symmetric branes [29] which are not in general conformal and which, in any case, include only scalar supermultiplets. Further developments and elaborations on the brane-scan are summarized in Schreiber's n-lab and references therein.

- In early 1988, Nicolai, Sezgin and Tanii [5] independently put forward the same generalization of the *Membrane at the End of the Universe* idea, spelling out the doubleton

	Supergroup	**Supermultiplet**	B^-	V	χ	ϕ	D
AdS_3	$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(8-n\vert 2)$	$(n_+,n_-)=(n,8-n), d=2$ singleton	0	0	8	8	10
	$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(4-n\vert 2)$	$(n_+,n_-)=(n,4-n), d=2$ singleton	0	0	4	4	6
	$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(2-n\vert 2)$	$(n_+,n_-)=(n,2-n), d=2$ singleton	0	0	2	2	4
	$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(1-n\vert 2)$	$(n_+,n_-)=(n,1-n), d=2$ singleton	0	0	1	1	3
AdS_4	$\mathrm{OSp}(8\vert 4)$	$n=8, d=3$ singleton	0	0	8	8	11
	$\mathrm{OSp}(4\vert 4)$	$n=4, d=3$ singleton	0	0	4	4	7
	$\mathrm{OSp}(2\vert 4)$	$n=2, d=3$ singleton	0	0	2	2	5
	$\mathrm{OSp}(1\vert 4)$	$n=1, d=3$ singleton	0	0	1	1	4
AdS_5	$\mathrm{SU}(2,2\vert 2)$	$n=2, d=4$ doubleton	0	0	2	4	8
	$\mathrm{SU}(2,2\vert 1)$	$n=1, d=4$ doubleton	0	0	1	2	6
	$\mathrm{SU}(2,2\vert 4)$	$n=4, d=4$ doubleton	0	1	4	6	10
	$\mathrm{SU}(2,2\vert 2)$	$n=2, d=4$ doubleton	0	1	2	2	6
	$\mathrm{SU}(2,2\vert 1)$	$n=1, d=4$ doubleton	0	1	1	0	4
AdS_6	$F^2(4)$	$n=2, d=5$ doubleton	0	0	2	4	9
AdS_7	$\mathrm{OSp}(8^*\vert 2)$	$(n_+,n_-)=(1,0), d=6$ tripleton	0	0	1	4	10
	$\mathrm{OSp}(8^*\vert 4)$	$(n_+,n_-)=(2,0), d=6$ tripleton	1	0	2	5	11
	$\mathrm{OSp}(8^*\vert 2)$	$(n_+,n_-)=(1,0), d=6$ tripleton	1	0	1	1	7

Table 2. Superconformal groups and their singleton, doubleton and tripleton representations. B^-, V, χ, ϕ denote the number of chiral 2-forms, vector, spinors and scalars in each multiplet. The spacetime dimension D equals the worldvolume dimension d plus the number of scalars.

and tripleton lagrangian and transformation rules, in addition to the singleton. However, by insisting on only scalar supermultiplets as in [29] their list excluded the vector or tensor brane-scans of table 3. In this case, as they point out, the spheres are just the parallelizable ones S^1, S^3 and S^7.

- The two factors appearing in the $p=1$ case, $G_+\times G_-$, are simply a reflection of the ability of strings to have left and right movers on the worldsheet [30]. In this case, there are many candidate supergroups as shown in table 1, so for $p=0,1$ we did not attempt a complete list of which of these would eventually be realized. In [3], we focused on Type IIA, Type IIB and heterotic strings with $\mathrm{OSp}(n|2)_c\times\mathrm{OSp}(8-n|2)_s$, $\mathrm{OSp}(n|2)_c\times\mathrm{OSp}(8-n|2)_c$ and $\mathrm{OSp}(n|2)_c\times\mathrm{Sp}(2,\mathbb{R})$, respectively, since the singleton CFTs (but not the supergravity AdS_3 solutions) had already been identified [30]. For concreteness the Type IIA case appears on the scan of table 3.

- Even for $p\geq 2$ not all of the conformal algebras listed in table 1 appear in the scan. For example, since none of our CFTs is self-interacting, we restricted [3] $\mathrm{SU}(2,2|N)$ to $N=1,2,4$ since perturbatively $N=3$ implies $N=4$. But we now know there

D↑								
		SCALAR						
11	.			$\mathrm{OSp}(\mathbf{8}\vert\mathbf{4})$				
10	.		$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(8-n\vert 2)$				$\mathrm{OSp}(8^*\vert 2)$	
9	.					$F^2(4)$		
8	.				$\mathrm{SU}(2,2\vert 2)$			
7	.			$\mathrm{OSp}(4\vert 4)$				
6	.		$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(4-n\vert 2)$		$\mathrm{SU}(2,2\vert 1)$			
5	.			$\mathrm{OSp}(2\vert 4)$				
4	.		$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(2-n\vert 2)$	$\mathrm{OSp}(1\vert 4)$				
3	.		$\mathrm{OSp}(n\vert 2)\times\mathrm{OSp}(1-n\vert 2)$					
2	.							
1	.							
0	.	.	.	.	.	.		
		VECTOR						
11	.							
10	.				$\mathrm{SU}(\mathbf{2},\mathbf{2}\vert\mathbf{4})$			
9	.							
8	.							
7	.							
6	.				$\mathrm{SU}(2,2\vert 2)$			
5	.							
4	.				$\mathrm{SU}(2,2\vert 1)$			
3	.							
2	.							
1	.							
0	.	.	.	.	.	.	.	
		TENSOR						
11							$\mathrm{OSp}(\mathbf{8}^*\vert\mathbf{4})$	
10	.							
9	.							
8	.							
7	.						$\mathrm{OSp}(8^*\vert 2)$	
6	.							
5	.							
4	.							
3	.							
2	.							
1	.							
0	.	.	.	.	.	.	.	
	0	1	2	3	4	5	6	d→

Table 3. The brane-scans of superconformal groups: scalar supermultiplets: singletons ($p = 1, 2$), doubletons ($p = 3, 4$) and tripletons ($p = 5$); vector supermultiplets: doubletons ($p = 3$); tensor supermultiplets: tripletons ($p = 5$). The M2-, D3- and M5-branes are in boldface.

are nonperturbative interacting CFTs with just $N = 3$ [31–35]. We also focussed on $N = 1, 2, 4, 8$ in $\mathrm{OSp}(N|4)$ since they corresponded to the division algebra $\mathbb{R}, \mathbb{C}, \mathbb{H}, \mathbb{O}$ interpretation of the four diagonal lines in the scalar branescan of table 3. The $N = 3, 5, 6, 7$ cases are discussed in section 4.

3 Significance of the brane-scan

The significance of the $M2$, $D3$ and $M5$ and indeed the other configurations on the brane-scan became clearer thanks to four major developments:

- Branes as solitons

  The realization that string theory admits p-branes as solitons [20, 21, 23, 36–41]

- M-theory

  The realization that the Type IIA superstring in $D = 10$ could be interpreted [42] as a wrapped supermembrane in $D = 11$ [11]. The membrane is a 1/2 BPS solution of $D = 11$ supergravity [43], whose spacetime approaches Minkowski space far away from the brane but $AdS_4 \times S^7$ close to the brane, jumping to the full $\mathrm{OSp}(8|4)$ in the limit [44]. Regarded as an extremal black-brane, this limit was also called the near-horizon limit. Moreover multi-brane solutions could be obtained by stacking N branes on top of one another [43], yielding quantized 4-form flux. So $AdS_4 \times S^7$ could equally well be regarded as the large N limit. A similar story applied to its magnetic dual fivebrane [26] as a solution of $D = 11$ supergravity. Moreover, the five string theories were merely different corners of an overarching M-theory [45–47] with $D = 11$ supergravity as its low-energy limit. The membrane and fivebrane were accordingly renamed M2 and M5.

- D-branes

  The realization that p-branes carrying RR charge, with a closed-string interpretation as solitons, admitted an alternative open string interpretation as Dirichlet-branes, surfaces of dimension p on which open strings can end [25]. In particular the self-dual 3-brane, a solution of Type IIB supergravity with $AdS_5 \times S^5$ and $\mathrm{SU}(2, 2|4)$ in the large N limit, was reinterpreted as a D3-brane and renamed accordingly.

- AdS/CFT

  The AdS/CFT conjecture [48–50] proposes that large N limits of certain conformal field theories in d dimensions can be described in terms of supergravity (and string theory) on the product of d+1-dimensional AdS space with a compact manifold. Another vital ingredient, missing in the early days, was the non-abelian nature of the symmetries that appear when we stack N branes on top of one another [51]. Examples include $N = 4$ Yang-Mills in $D = 4$ from $AdS_5 \times S^5$ and ABJM theory [52] from $AdS_4 \times S^7/Z_n$.

4 The missing ingredients $p \geq 2$

Notwithstanding the success with $M2$, $D3$ and $M5$, for quite some time the status of the other slots on the brane-scans remained obscure.[2] Here we perform a literature search and confirm that all of the empty slots have now been filled, largely thanks to warped products, massive Type IIA, and Chern Simons theories as shown below

- d=6 $\mathrm{OSp}(8^*|N)$ $N = 4, 2$; [54–60]
- d=5 $F^2(4)$ [59, 61–68]
- d=4 $\mathrm{SU}(2, 2|N)$ $N = 4, 3, 2, 1$; [20, 31–35, 59, 69–72].
- d=3 $\mathrm{OSp}(N|4)$ $N = 8, 6, 5, 4, 3, 2, 1$ [43, 52, 59, 73–80].

Comments

- We have included $N = 3$ in the $d = 4$ case and $N = 3, 5, 6$ in the $d = 3$ case, which, as previously noted, were not predicted in [3]. $N = 6$ appears in ABJM [52]. and its OSp(6|4) symmetry in [80]. A useful reference on the absence of $N = 7$ is [59].
- There are no AdS_7 solutions in Types IIA and IIB. In M all are locally isometric to $AdS_7 \times S^4$.
- There are no maximally supersymmetric AdS_6 backgrounds in M, IIA or IIB. There are no half BPS (16 supersymmetries) AdS_6 backgrounds in M and IIA with compact internal space.
- There are no such AdS_5 solutions that preserve > 16 supersymmetries in IIA and D=11 In IIB, all supersymmetric solutions are locally isometric to $AdS_5 \times S^5$. This means that all backgrounds preserving 24 supersymmetries in IIB are locally $AdS_5 \times S^5$.
- There are no > 16 AdS_4 supersymmetric solutions in IIA and IIB. In D=11 all > 16 supersymmetric solutions are locally isometric to $AdS_4 \times S^7$. This means that all solutions with 20, 24, 28 are locally $AdS_4 \times S^7$.

5 $p = 0, 1$

- d=2 [55, 78, 81–94]
- d=1 [95–106]

Comment

- Not all of the algebras in Nahm's list correspond to known solutions and indeed there may be some for which no solutions exist. A thorough and up-to-date summary maybe found in [94].

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[2] In [53] we entertained the idea that they might arise from classical branes whose symmetry is enhanced when α' corrections are taken into account, but this did not pan out.

6 Conclusion

Thus not only the M2, D3 and M5 but all of the p-brane configurations on the $S^1 \times S^p$ boundary of $AdS_{(p+1)}$ with $p = (5,4,3,2,1)$ mentioned explicitly in the 1987 paper as shown in table 3 have now been discovered: $\mathrm{OSp}(N|4)$ $N = 8,4,2,1$; $\mathrm{SU}(\mathbf{2},\mathbf{2}|\mathbf{N})$ $N = 4,2,1$; $F^2(4)$; $\mathrm{OSp}(8^*|N)$, $N = 4,2$, as have most of the $(p = 0,1)$ in Nahm's list not mentioned explicitly. Orbifolds, orientifolds and S-folds also play a part providing examples not predicted: $\mathrm{SU}(2,2|3)$, $\mathrm{OSp}(3|4)$, $\mathrm{OSp}(5|4)$ and $\mathrm{OSp}(6|4)$ but not $\mathrm{OSp}(7|4)$. To be fair, if our colleagues did not take our vector and tensor brane-scans seriously in 1987, it may be because, in the Weinberg sense, we did not take them seriously enough ourselves.

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References

[1] M.J. Duff, *Supermembranes: The First Fifteen Weeks*, *Class. Quant. Grav.* **5** (1988) 189 [INSPIRE].

[2] E. Bergshoeff, M.J. Duff, C.N. Pope and E. Sezgin, *Supersymmetric Supermembrane Vacua and Singletons*, *Phys. Lett. B* **199** (1987) 69 [INSPIRE].

[3] M.P. Blencowe and M.J. Duff, *Supersingletons*, *Phys. Lett. B* **203** (1988) 229 [INSPIRE].

[4] M.J. Duff and C. Sutton, *The Membrane at the End of the Universe*, *New Sci.* **118** (1988) 67.

[5] H. Nicolai, E. Sezgin and Y. Tanii, *Conformally Invariant Supersymmetric Field Theories on $S^{**}p \times S^1$ and Super p^- branes*, *Nucl. Phys. B* **305** (1988) 483 [INSPIRE].

[6] E. Bergshoeff, M.J. Duff, C.N. Pope and E. Sezgin, *Compactifications of the Eleven-Dimensional Supermembrane*, *Phys. Lett. B* **224** (1989) 71 [INSPIRE].

[7] M.J. Duff, C.N. Pope and E. Sezgin, *A Stable Supermembrane Vacuum With a Discrete Spectrum*, *Phys. Lett. B* **225** (1989) 319 [INSPIRE].

[8] E. Bergshoeff, E. Sezgin and Y. Tanii, *Stress Tensor Commutators and Schwinger Terms in Singleton Theories*, *Int. J. Mod. Phys. A* **5** (1990) 3599 [INSPIRE].

[9] M.J. Duff, *Classical and Quantum Supermembranes*, *Class. Quant. Grav.* **6** (1989) 1577 [INSPIRE].

[10] P. Claus, R. Kallosh, J. Kumar, P.K. Townsend and A. Van Proeyen, *Conformal theory of M2, D3, M5 and D1-branes + D5-branes*, *JHEP* **06** (1998) 004 [hep-th/9801206] [INSPIRE].

[11] E. Bergshoeff, E. Sezgin and P.K. Townsend, *Supermembranes and Eleven-Dimensional Supergravity*, *Phys. Lett. B* **189** (1987) 75 [INSPIRE].

[12] P.A.M. Dirac, *A remarkable representation of the 3 + 2 de Sitter group*, *J. Math. Phys.* **4** (1963) 901 [INSPIRE].

[13] C. Fronsdal, *The Dirac Supermultiplet*, *Phys. Rev. D* **26** (1982) 1988 [INSPIRE].

[14] H. Nicolai and E. Sezgin, *Singleton Representations of Osp(N,4)*, *Phys. Lett. B* **143** (1984) 389 [INSPIRE].

[15] W. Nahm, *Supersymmetries and their Representations*, *Nucl. Phys. B* **135** (1978) 149 [INSPIRE].

[16] A. Van Proeyen, *Tools for supersymmetry*, *Ann. U. Craiova Phys.* **9** (1999) 1 [hep-th/9910030] [INSPIRE].

[17] M. Günaydin and D. Minic, *Singletons, doubletons and M-theory*, *Nucl. Phys. B* **523** (1998) 145 [hep-th/9802047] [INSPIRE].

[18] N. Seiberg and E. Witten, *The D1/D5 system and singular CFT*, *JHEP* **04** (1999) 017 [hep-th/9903224] [INSPIRE].

[19] A. Batrachenko, M.J. Duff and J.X. Lu, *The membrane at the end of the (de Sitter) universe*, *Nucl. Phys. B* **762** (2007) 95 [hep-th/0212186] [INSPIRE].

[20] G.T. Horowitz and A. Strominger, *Black strings and P-branes*, *Nucl. Phys. B* **360** (1991) 197 [INSPIRE].

[21] M.J. Duff and J.X. Lu, *The selfdual type IIB superthreebrane*, *Phys. Lett. B* **273** (1991) 409 [INSPIRE].

[22] M.J. Duff and J.X. Lu, *Type II p-branes: The brane scan revisited*, *Nucl. Phys. B* **390** (1993) 276 [hep-th/9207060] [INSPIRE].

[23] M.J. Duff, R.R. Khuri and J.X. Lu, *String solitons*, *Phys. Rept.* **259** (1995) 213 [hep-th/9412184] [INSPIRE].

[24] J. Polchinski, *Dirichlet Branes and Ramond-Ramond charges*, *Phys. Rev. Lett.* **75** (1995) 4724 [hep-th/9510017] [INSPIRE].

[25] J. Polchinski, *TASI lectures on D-branes*, in *Theoretical Advanced Study Institute in Elementary Particle Physics (TASI 96): Fields, Strings, and Duality*, (1996), pp. 293–356 [hep-th/9611050] [INSPIRE].

[26] R. Güven, *Black p-brane solutions of $D = 11$ supergravity theory*, *Phys. Lett. B* **276** (1992) 49 [INSPIRE].

[27] S. Beck, U. Gran, J. Gutowski and G. Papadopoulos, *All Killing Superalgebras for Warped AdS Backgrounds*, *JHEP* **12** (2018) 047 [arXiv:1710.03713] [INSPIRE].

[28] A.S. Haupt, S. Lautz and G. Papadopoulos, *A non-existence theorem for $N > 16$ supersymmetric AdS$_3$ backgrounds*, *JHEP* **07** (2018) 178 [arXiv:1803.08428] [INSPIRE].

[29] A. Achucarro, J.M. Evans, P.K. Townsend and D.L. Wiltshire, *Super p-Branes*, *Phys. Lett. B* **198** (1987) 441 [INSPIRE].

- [30] M. Günaydin, B.E.W. Nilsson, G. Sierra and P.K. Townsend, *Singletons and Superstrings*, *Phys. Lett. B* **176** (1986) 45 [INSPIRE].
- [31] S. Ferrara, M. Porrati and A. Zaffaroni, *$N = 6$ supergravity on AdS_5 and the $SU(2, 2/3)$ superconformal correspondence*, *Lett. Math. Phys.* **47** (1999) 255 [`hep-th/9810063`] [INSPIRE].
- [32] O. Aharony and M. Evtikhiev, *On four dimensional $N = 3$ superconformal theories*, *JHEP* **04** (2016) 040 [`arXiv:1512.03524`] [INSPIRE].
- [33] I. García-Etxebarria and D. Regalado, *$\mathcal{N} = 3$ four dimensional field theories*, *JHEP* **03** (2016) 083 [`arXiv:1512.06434`] [INSPIRE].
- [34] O. Aharony and Y. Tachikawa, *S-folds and 4d $N = 3$ superconformal field theories*, *JHEP* **06** (2016) 044 [`arXiv:1602.08638`] [INSPIRE].
- [35] L. Borsten, M.J. Duff and A. Marrani, *Twin conformal field theories*, *JHEP* **03** (2019) 112 [`arXiv:1812.11130`] [INSPIRE].
- [36] P.K. Townsend, *Supersymmetric extended solitons*, *Phys. Lett. B* **202** (1988) 53 [INSPIRE].
- [37] A. Strominger, *Heterotic solitons*, *Nucl. Phys. B* **343** (1990) 167 [*Erratum ibid.* **353** (1991) 565] [INSPIRE].
- [38] M.J. Duff and J.X. Lu, *A duality between strings and five-branes*, *Class. Quant. Grav.* **9** (1992) 1 [INSPIRE].
- [39] M.J. Duff, R.R. Khuri and J.X. Lu, *String and five-brane solitons: Singular or nonsingular?*, *Nucl. Phys. B* **377** (1992) 281 [`hep-th/9112023`] [INSPIRE].
- [40] C.G. Callan Jr., J.A. Harvey and A. Strominger, *Supersymmetric string solitons*, `hep-th/9112030` [INSPIRE].
- [41] G.W. Gibbons, D. Kastor, L.A.J. London, P.K. Townsend and J.H. Traschen, *Supersymmetric selfgravitating solitons*, *Nucl. Phys. B* **416** (1994) 850 [`hep-th/9310118`] [INSPIRE].
- [42] M.J. Duff, P.S. Howe, T. Inami and K.S. Stelle, *Superstrings in $D = 10$ from Supermembranes in $D = 11$*, *Phys. Lett. B* **191** (1987) 70 [INSPIRE].
- [43] M.J. Duff and K.S. Stelle, *Multimembrane solutions of $D = 11$ supergravity*, *Phys. Lett. B* **253** (1991) 113 [INSPIRE].
- [44] M.J. Duff, G.W. Gibbons and P.K. Townsend, *Macroscopic superstrings as interpolating solitons*, *Phys. Lett. B* **332** (1994) 321 [`hep-th/9405124`] [INSPIRE].
- [45] C.M. Hull and P.K. Townsend, *Unity of superstring dualities*, *Nucl. Phys. B* **438** (1995) 109 [`hep-th/9410167`] [INSPIRE].
- [46] E. Witten, *String theory dynamics in various dimensions*, *Nucl. Phys. B* **443** (1995) 85 [`hep-th/9503124`] [INSPIRE].
- [47] M.J. Duff, *M theory (The Theory formerly known as strings)*, *Int. J. Mod. Phys. A* **11** (1996) 5623 [`hep-th/9608117`] [INSPIRE].
- [48] J.M. Maldacena, *The large N limit of superconformal field theories and supergravity*, *Adv. Theor. Math. Phys.* **2** (1998) 231 [`hep-th/9711200`] [INSPIRE].
- [49] S.S. Gubser, I.R. Klebanov and A.M. Polyakov, *Gauge theory correlators from noncritical string theory*, *Phys. Lett. B* **428** (1998) 105 [`hep-th/9802109`] [INSPIRE].

[50] E. Witten, *Anti-de Sitter space and holography*, *Adv. Theor. Math. Phys.* **2** (1998) 253 [`hep-th/9802150`] [INSPIRE].

[51] E. Witten, *Bound states of strings and p-branes*, *Nucl. Phys. B* **460** (1996) 335 [`hep-th/9510135`] [INSPIRE].

[52] O. Aharony, O. Bergman, D.L. Jafferis and J. Maldacena, $N = 6$ *superconformal Chern-Simons-matter theories, M2-branes and their gravity duals*, *JHEP* **10** (2008) 091 [`arXiv:0806.1218`] [INSPIRE].

[53] M.J. Duff, *Near-horizon brane-scan revived*, *Nucl. Phys. B* **810** (2009) 193 [`arXiv:0804.3675`] [INSPIRE].

[54] R. Güven, J.T. Liu, C.N. Pope and E. Sezgin, *Fine tuning and six-dimensional gauged N=(1,0) supergravity vacua*, *Class. Quant. Grav.* **21** (2004) 1001 [`hep-th/0306201`] [INSPIRE].

[55] J.D. Edelstein, A. Garbarz, O. Mišković and J. Zanelli, *Stable p-branes in Chern-Simons AdS supergravities*, *Phys. Rev. D* **82** (2010) 044053 [`arXiv:1006.3753`] [INSPIRE].

[56] F. Apruzzi, M. Fazzi, D. Rosa and A. Tomasiello, *All* AdS_7 *solutions of type-II supergravity*, *JHEP* **04** (2014) 064 [`arXiv:1309.2949`] [INSPIRE].

[57] D. Gaiotto and A. Tomasiello, *Holography for* $(1,0)$ *theories in six dimensions*, *JHEP* **12** (2014) 003 [`arXiv:1404.0711`] [INSPIRE].

[58] S. Cremonesi and A. Tomasiello, *6d holographic anomaly match as a continuum limit*, *JHEP* **05** (2016) 031 [`arXiv:1512.02225`] [INSPIRE].

[59] C. Cordova, T.T. Dumitrescu and K. Intriligator, *Multiplets of Superconformal Symmetry in Diverse Dimensions*, *JHEP* **03** (2019) 163 [`arXiv:1612.00809`] [INSPIRE].

[60] C. Núñez, J.M. Penín, D. Roychowdhury and J. Van Gorsel, *The non-Integrability of Strings in Massive Type IIA and their Holographic duals*, *JHEP* **06** (2018) 078 [`arXiv:1802.04269`] [INSPIRE].

[61] A. Brandhuber and Y. Oz, *The D-4 – D-8 brane system and five-dimensional fixed points*, *Phys. Lett. B* **460** (1999) 307 [`hep-th/9905148`] [INSPIRE].

[62] O. Bergman and D. Rodriguez-Gomez, *5d quivers and their* AdS_6 *duals*, *JHEP* **07** (2012) 171 [`arXiv:1206.3503`] [INSPIRE].

[63] Y. Lozano, E. Ó Colgáin, D. Rodríguez-Gómez and K. Sfetsos, *Supersymmetric* AdS_6 *via T Duality*, *Phys. Rev. Lett.* **110** (2013) 231601 [`arXiv:1212.1043`] [INSPIRE].

[64] E. D'Hoker, M. Gutperle, A. Karch and C.F. Uhlemann, *Warped* $AdS_6 \times S^2$ *in Type IIB supergravity I: Local solutions*, *JHEP* **08** (2016) 046 [`arXiv:1606.01254`] [INSPIRE].

[65] E. D'Hoker, M. Gutperle and C.F. Uhlemann, *Holographic duals for five-dimensional superconformal quantum field theories*, *Phys. Rev. Lett.* **118** (2017) 101601 [`arXiv:1611.09411`] [INSPIRE].

[66] E. D'Hoker, M. Gutperle and C.F. Uhlemann, *Warped* $AdS_6 \times S^2$ *in Type IIB supergravity III: Global solutions with seven-branes*, *JHEP* **11** (2017) 200 [`arXiv:1706.00433`] [INSPIRE].

[67] D. Corbino, E. D'Hoker and C.F. Uhlemann, $AdS_2 \times S^6$ *versus* $AdS_6 \times S^2$ *in Type IIB supergravity*, *JHEP* **03** (2018) 120 [`arXiv:1712.04463`] [INSPIRE].

[68] Y. Lozano, N.T. Macpherson and J. Montero, AdS_6 *T-duals and type IIB* $AdS_6 \times S^2$ *geometries with 7-branes*, *JHEP* **01** (2019) 116 [`arXiv:1810.08093`] [INSPIRE].

[69] D. Gaiotto and J. Maldacena, *The gravity duals of $N = 2$ superconformal field theories*, JHEP **10** (2012) 189 [arXiv:0904.4466] [INSPIRE].

[70] R.A. Reid-Edwards and B. Stefanski Jr., *On Type IIA geometries dual to $N = 2$ SCFTs*, Nucl. Phys. B **849** (2011) 549 [arXiv:1011.0216] [INSPIRE].

[71] O. Aharony, L. Berdichevsky and M. Berkooz, *4d $N = 2$ superconformal linear quivers with type IIA duals*, JHEP **08** (2012) 131 [arXiv:1206.5916] [INSPIRE].

[72] C. Núñez, D. Roychowdhury, S. Speziali and S. Zacarías, *Holographic aspects of four dimensional $\mathcal{N} = 2$ SCFTs and their marginal deformations*, Nucl. Phys. B **943** (2019) 114617 [arXiv:1901.02888] [INSPIRE].

[73] J.H. Schwarz, *Superconformal Chern-Simons theories*, JHEP **11** (2004) 078 [hep-th/0411077] [INSPIRE].

[74] E. D'Hoker, J. Estes and M. Gutperle, *Exact half-BPS Type IIB interface solutions. I. Local solution and supersymmetric Janus*, JHEP **06** (2007) 021 [arXiv:0705.0022] [INSPIRE].

[75] E. D'Hoker, J. Estes, M. Gutperle and D. Krym, *Exact Half-BPS Flux Solutions in M-theory. I: Local Solutions*, JHEP **08** (2008) 028 [arXiv:0806.0605] [INSPIRE].

[76] M. Chiodaroli, E. D'Hoker, Y. Guo and M. Gutperle, *Exact half-BPS string-junction solutions in six-dimensional supergravity*, JHEP **12** (2011) 086 [arXiv:1107.1722] [INSPIRE].

[77] B. Assel, C. Bachas, J. Estes and J. Gomis, *Holographic Duals of $D = 3$ $N = 4$ Superconformal Field Theories*, JHEP **08** (2011) 087 [arXiv:1106.4253] [INSPIRE].

[78] A.S. Haupt, S. Lautz and G. Papadopoulos, *AdS_4 backgrounds with $N > 16$ supersymmetries in 10 and 11 dimensions*, JHEP **01** (2018) 087 [arXiv:1711.08280] [INSPIRE].

[79] F. Marchesano, E. Palti, J. Quirant and A. Tomasiello, *On supersymmetric AdS_4 orientifold vacua*, JHEP **08** (2020) 087 [arXiv:2003.13578] [INSPIRE].

[80] M.A. Bandres, A.E. Lipstein and J.H. Schwarz, *Studies of the ABJM Theory in a Formulation with Manifest $SU(4)$ R-Symmetry*, JHEP **09** (2008) 027 [arXiv:0807.0880] [INSPIRE].

[81] Y. Lozano and C. Núñez, *Field theory aspects of non-Abelian T-duality and $\mathcal{N} = 2$ linear quivers*, JHEP **05** (2016) 107 [arXiv:1603.04440] [INSPIRE].

[82] Y. Lozano, N.T. Macpherson, J. Montero and C. Núñez, *Three-dimensional $\mathcal{N} = 4$ linear quivers and non-Abelian T-duals*, JHEP **11** (2016) 133 [arXiv:1609.09061] [INSPIRE].

[83] C. Couzens, C. Lawrie, D. Martelli, S. Schäfer-Nameki and J.-M. Wong, *F-theory and AdS_3/CFT_2*, JHEP **08** (2017) 043 [arXiv:1705.04679] [INSPIRE].

[84] Y. Lozano, C. Núñez and S. Zacarias, *BMN Vacua, Superstars and Non-Abelian T-duality*, JHEP **09** (2017) 008 [arXiv:1703.00417] [INSPIRE].

[85] G. Itsios, Y. Lozano, J. Montero and C. Núñez, *The AdS_5 non-Abelian T-dual of Klebanov-Witten as a $\mathcal{N} = 1$ linear quiver from M5-branes*, JHEP **09** (2017) 038 [arXiv:1705.09661] [INSPIRE].

[86] Y. Lozano, N.T. Macpherson, C. Núñez and A. Ramirez, *AdS_3 solutions in Massive IIA with small $\mathcal{N} = (4, 0)$ supersymmetry*, JHEP **01** (2020) 129 [arXiv:1908.09851] [INSPIRE].

[87] Y. Lozano, N.T. Macpherson, C. Núñez and A. Ramirez, 1/4 *BPS solutions and the* AdS_3/CFT_2 *correspondence*, *Phys. Rev. D* **101** (2020) 026014 [`arXiv:1909.09636`] [INSPIRE].

[88] Y. Lozano, N.T. Macpherson, C. Núñez and A. Ramirez, *Two dimensional* $\mathcal{N} = (0, 4)$ *quivers dual to* AdS_3 *solutions in massive IIA*, *JHEP* **01** (2020) 140 [`arXiv:1909.10510`] [INSPIRE].

[89] Y. Lozano, N.T. Macpherson, C. Núñez and A. Ramirez, AdS_3 *solutions in massive IIA, defect CFTs and T-duality*, *JHEP* **12** (2019) 013 [`arXiv:1909.11669`] [INSPIRE].

[90] Y. Lozano, C. Núñez, A. Ramirez and S. Speziali, M*-strings and* AdS_3 *solutions to M-theory with small* $\mathcal{N} = (0, 4)$ *supersymmetry*, *JHEP* **08** (2020) 118 [`arXiv:2005.06561`] [INSPIRE].

[91] F. Faedo, Y. Lozano and N. Petri, *Searching for surface defect CFTs within* AdS_3, *JHEP* **11** (2020) 052 [`arXiv:2007.16167`] [INSPIRE].

[92] F. Faedo, Y. Lozano and N. Petri, *New* $\mathcal{N} = (0, 4)$ AdS_3 *near-horizons in Type IIB*, *JHEP* **04** (2021) 028 [`arXiv:2012.07148`] [INSPIRE].

[93] G. Dibitetto and N. Petri, AdS_3 *from M-branes at conical singularities*, *JHEP* **01** (2021) 129 [`arXiv:2010.12323`] [INSPIRE].

[94] N.T. Macpherson and A. Tomasiello, $\mathcal{N} = (1, 1)$ *supersymmetric* AdS_3 *in 10 dimensions*, *JHEP* **03** (2022) 112 [`arXiv:2110.01627`] [INSPIRE].

[95] G. Dibitetto and N. Petri, AdS_2 *solutions and their massive IIA origin*, *JHEP* **05** (2019) 107 [`arXiv:1811.11572`] [INSPIRE].

[96] J.P. Gauntlett, N. Kim and D. Waldram, *Supersymmetric* AdS_3*,* AdS_2 *and Bubble Solutions*, *JHEP* **04** (2007) 005 [`hep-th/0612253`] [INSPIRE].

[97] N. Kim, *Comments on* AdS_2 *solutions from M2-branes on complex curves and the backreacted Kähler geometry*, *Eur. Phys. J. C* **74** (2014) 2778 [`arXiv:1311.7372`] [INSPIRE].

[98] M. Chiodaroli, M. Gutperle and D. Krym, *Half-BPS Solutions locally asymptotic to* $AdS_3 \times S^3$ *and interface conformal field theories*, *JHEP* **02** (2010) 066 [`arXiv:0910.0466`] [INSPIRE].

[99] M. Chiodaroli, E. D'Hoker and M. Gutperle, *Open Worldsheets for Holographic Interfaces*, *JHEP* **03** (2010) 060 [`arXiv:0912.4679`] [INSPIRE].

[100] D. Corbino, E. D'Hoker, J. Kaidi and C.F. Uhlemann, *Global half-BPS* $AdS_2 \times S^6$ *solutions in Type IIB*, *JHEP* **03** (2019) 039 [`arXiv:1812.10206`] [INSPIRE].

[101] D. Corbino, *Warped* AdS_2 *and* $SU(1, 1|4)$ *symmetry in Type IIB*, *JHEP* **03** (2021) 060 [`arXiv:2004.12613`] [INSPIRE].

[102] G. Dibitetto, Y. Lozano, N. Petri and A. Ramirez, *Holographic description of M-branes via* AdS_2, *JHEP* **04** (2020) 037 [`arXiv:1912.09932`] [INSPIRE].

[103] Y. Lozano, C. Núñez, A. Ramirez and S. Speziali, *New* AdS_2 *backgrounds and* $\mathcal{N} = 4$ *conformal quantum mechanics*, *JHEP* **03** (2021) 277 [`arXiv:2011.00005`] [INSPIRE].

[104] Y. Lozano, C. Núñez, A. Ramirez and S. Speziali, AdS_2 *duals to ADHM quivers with Wilson lines*, *JHEP* **03** (2021) 145 [`arXiv:2011.13932`] [INSPIRE].

[105] E. D'Hoker, J. Estes and M. Gutperle, *Gravity duals of half-BPS Wilson loops*, *JHEP* **06** (2007) 063 [`arXiv:0705.1004`] [INSPIRE].

[106] C. Bachas, E. D'Hoker, J. Estes and D. Krym, *M-theory Solutions Invariant under* $D(2, 1; \gamma) \oplus D(2, 1; \gamma)$, *Fortsch. Phys.* **62** (2014) 207 [`arXiv:1312.5477`] [INSPIRE].