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A Note on Orientifolds and Dualities of Type 0B String Theory

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Abstract

We generalize the construction of four dimensional non-tachyonic orientifolds of type 0B string theory to non-supersymmetric backgrounds. We construct a four dimensional model containing self-dual D3 and D9-branes and leading to a chiral anomaly-free massless spectrum. Moreover, we discuss a further tachyon-free six dimensional model with only D5 branes. Eventually, we speculate about strong coupling dual models of the ten-dimensional orientifolds of type 0B.

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1. Introduction

Non-supersymmetric string theories have received a lot of attention during the last year [1–18]. Most of the effort went into a better understanding of phenomena in the effective non-supersymmetric gauge theories including a new approach to solve the hierarchy problem by a non-supersymmetric conformal gauge theory in some intermediate energy regime [19]. Parallel to that there were some attempts to construct consistent non-supersymmetric four dimensional string vacua. Besides the seven heterotic non-supersymmetric ten-dimensional string theories there also exist the two non-supersymmetric type 0A/B string theories [20]. The latter models both contain a tachyonic mode which renders the theory unstable. One way to circumvent this problem is by placing enough RR flux in the background which shifts the square of the tachyon mass to positive values. This approach was used in [1] to reliably study the effective theory on the D3 branes. Another way of getting rid of the tachyon is by doing a special orientifold [21,22,23].

There exist three independent orientifold projections of type 0B string theory $\{\Omega, \Omega(-1)^{F_R}, \Omega(-1)^{f_R}\}$, where $(-1)^{F_R}$ is the right moving space-time fermion number and $(-1)^{f_R}$ is the right moving world-sheet fermion number. The first two models still contain a bulk tachyon, whereas in the third, the type $0'$, model the tachyon is projected out. The massless spectrum of the resulting ten-dimensional non-supersymmetric string theory contains the graviton, the dilaton, a RR 0-form, a 2-form and a self-dual 4-form in the closed string sector and a gauge field in the adjoint of U(32) equipped by a left-handed Majorana-Weyl fermion in the $\mathbf{496} \oplus \overline{\mathbf{496}}$ representation in the open string sector. The latter fermions necessarily appear for this class of orientifolds, because the world-sheet fermion number operator $(-1)^{f_R}$ exchanges a D9 brane charged under the first of the two RR 10-forms in type 0B with a D9' brane charged under the second of the two RR 10-forms. Open strings stretched between these different kinds of 9-branes lead to space-time fermions.

As was pointed out in [24,11] requiring the absence of tachyons also for compactified type $0'$ orientifolds is highly restrictive and so far only one $\mathbb{Z}_2$ orientifold in six-dimensions and one $\mathbb{Z}_3$ orientifold in four dimensions have been constructed. In all other cases there appear extra tachyons in twisted sectors which can not all be projected out as long as Ω exchanges a g-twisted sector with a g^{-1} twisted sector. One can allow Ω to act without exchanging twisted sectors but as was argued in [25] such models contain extra non-perturbative states.

All compact models studied so far were supersymmetric backgrounds in the sense that when used in a type IIB compactification they preserve some supersymmetry. However, since type 0B is non-supersymmetric anyway, one might try to consider backgrounds not preserving any supersymmetry at all. In this case the absence of tachyons is highly restrictive, as well, but in the first part of this letter in some detail we will present one specific $\mathbb{Z}_2$ model in which everything works out nicely. It turns out that in order to cancel all RR tadpoles one has to introduce D9/D9' and D3/D3' branes. Of course, as in all type $0'$ orientifolds there remains an uncancelled dilaton tadpole which can be cured by the Fischler/Susskind mechanism [26]. In the second part of this paper we will discuss one more compact model in six dimensions followed by some speculations about possible dual models of the ten-dimensional type 0B orientifolds.

2. Type 0' orientifold on a non-supersymmetric background

We take type 0B string theory, compactify it on a six torus $T^6 = (S^1)^6$ and divide out by the orientifold group $\{(1+R)+\Omega'(1+R)\}$ with $\Omega' = \Omega(-1)^{f_R}$ and $R : z_i \to -z_i$ for all $i \in \{1,2,3\}$. Note, that in a type IIB compactification R would not satisfy level-matching in the NS-R and R-NS sector. However, precisely these two sectors are absent in type 0B string theory so that dividing out by R leads to a modular invariant torus amplitude. Already at this stage we would like to point out that there exists a subtlety in the Ramond sector which will become important in the open string sector. Since the action of R on the left-moving Ramond sector ground states is given by

$$R|s_1\, s_2\, s_3\, s_4\rangle = e^{\pi i(s_2+s_3+s_4)}|s_1\, s_2\, s_3\, s_4\rangle = \pm i|s_1\, s_2\, s_3\, s_4\rangle \qquad \text{with } s_i = \pm\frac{1}{2}, \tag{2.1}$$

it acts rather like a $\mathbb{Z}_4$ than a $\mathbb{Z}_2$ operation. Of course in the closed string sector the left-moving Ramond sector is always paired with the right-moving Ramond sector, so that here R really acts like a $\mathbb{Z}_2$. As usual in orientifolds one has to compute all one-loop diagrams and require tadpole cancellation.

2.1. The Klein bottle amplitude

The computation of the Klein bottle amplitude is straightforward

$$\begin{aligned} K &= 4\,c \int_0^\infty \frac{dt}{t^3}\, \mathrm{Tr}\left[\frac{\Omega'}{2}\, \frac{1+R}{2}\, \frac{1+(-1)^{f_L+f_R}}{2}\, e^{-2\pi t(L_0+\overline{L}_0)}\right] \\ &= -2\,c \int_0^\infty \frac{dt}{t^3}\, \frac{f_4^8(e^{-2\pi t})}{f_1^8(e^{-2\pi t})} \left(\left[\sum_m e^{-\pi t \frac{m^2}{\rho}}\right]^6 + \left[\sum_n e^{-\pi t n^2 \rho}\right]^6\right), \end{aligned} \tag{2.2}$$

with $c = V_4/(8\pi^2\alpha')^2$ and $\rho = r^2/\alpha'$. The transformation to tree channel reveals that there are RR 10-form and RR 4-form tadpoles but no NS tadpole.

2.2. The annulus amplitude

In order to cancel these RR tadpoles we introduce N_9 pairs of D9/D9' branes and N_3 pairs of D3/D3' branes. Note, that in a type I compactification this would be impossible, as in contrast to type $0'$ string theory type I string theory simply does not contain any D3-branes. Since open strings stretched between a Dp and Dp' brane have fermionic zero modes, we are facing the subtlety mentioned in (2.1). The action of R on the modes leads to extra factors of i which must be compensated by further factors of i from the action of R on the Chan-Paton factors of the open strings. Thus, in the open string sector we better consider R as a $\mathbb{Z}_4$ action, so that the annulus amplitude is

$$A = c \int_0^\infty \frac{dt}{t^3} \mathrm{Tr} \left[\frac{1}{2} \; \frac{1+R+R^2+R^3}{4} \; \frac{1+(-1)^{F_s}}{2} \; \frac{1+(-1)^f}{2} \; e^{-2\pi t L_0} \right] \tag{2.3}$$

where the trace has to be taken over all open strings stretched between the four different kinds of D-branes $\{D9, D9', D3, D3'\}$. The presentation of the whole amplitude would be much too lengthy to present here. However, completely analogous to the model discussed in [27], cancellation of the twisted RR tadpoles requires

$$\mathrm{Tr}(\gamma_{R,p}) = 0 \qquad \text{with } p \in \{9, 9', 3, 3'\}. \tag{2.4}$$

Neglecting all the terms becoming zero by the choice in (2.4), for instance in the 99, 9'9', 99' and 9'9 sectors the total annulus amplitude reads

$$\begin{aligned} A_{99} = c \int \frac{dt}{t^3} \left[\sum_m e^{-2\pi t \frac{m^2}{\rho}} \right]^6 & \left[\frac{N_9^2}{8} \left(\frac{f_3^8 - f_4^8 - f_2^8}{f_1^8} \right) (e^{-\pi t}) + \right. \\ & \frac{1}{16} \left[\mathrm{Tr}(\gamma_{R^2,9}) \mathrm{Tr}(\gamma^{-1}_{R^2,9}) + \mathrm{Tr}(\gamma_{R^2,9'}) \mathrm{Tr}(\gamma^{-1}_{R^2,9'}) \right] \left(\frac{f_3^8 - f_4^8}{f_1^8} \right) (e^{-\pi t}) + \\ & \left. \frac{1}{8} \; \mathrm{Tr}(\gamma_{R^2,9}) \mathrm{Tr}(\gamma^{-1}_{R^2,9'}) \; \frac{f_2^8}{f_1^8} (e^{-\pi t}) \right]. \end{aligned} \tag{2.5}$$

For open strings stretched between D3/D3' branes the result is completely analogous. If we would simply choose $\mathrm{Tr}(\gamma_{R^2,9}) = \mathrm{Tr}(\gamma_{R^2,9'}) = 0$ then only the first term in (2.5) would be non-zero. However, since we have introduced in (2.3) an extra factor of two in the denominator compared to a usual $\mathbb{Z}_2$ annulus amplitude, we would get a problem with tadpole cancellation. We can cure this missing factor of two by requiring that the second and third term in (2.5) add up exactly to the first term leading to

$$\begin{aligned} &\mathrm{Tr}(\gamma_{R^2,9}) \mathrm{Tr}(\gamma^{-1}_{R^2,9}) = \mathrm{Tr}(\gamma_{R^2,9'}) \mathrm{Tr}(\gamma^{-1}_{R^2,9'}) = N_9^2 \\ &\mathrm{Tr}(\gamma_{R^2,9}) \mathrm{Tr}(\gamma^{-1}_{R^2,9'}) = -N_9^2. \end{aligned} \tag{2.6}$$

A solution to the conditions (2.4) and (2.6) is

$$\Gamma_{R,9} = \begin{pmatrix} \gamma_{R,9} & 0 \\ 0 & \gamma_{R,9'} \end{pmatrix}_{2N_9,2N_9} = \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & -I & 0 & 0 \\ 0 & 0 & i\,I & 0 \\ 0 & 0 & 0 & -i\,I \end{pmatrix}_{2N_9,2N_9} \tag{2.7}$$

where I denotes the matrix $I = \mathrm{diag}[1,\ldots,1]$. With this choice of Chan-Paton actions the non-zero contribution of the open strings stretched between the various 9 and 3 branes to the annulus amplitude is

$$A_{93} = c \int \frac{dt}{t^3}\frac{1}{2} N_9 N_3 \left(\frac{f_3^2 f_2^6 - f_2^2 f_3^6}{f_1^2 f_4^6} \right) (e^{-\pi t}). \tag{2.8}$$

As we will see below in tree channel this leads to further NSNS tadpoles.

2.3. The Möbius amplitude

In order to compute the Möbius amplitude

$$M = c \int_0^\infty \frac{dt}{t^3}\, \mathrm{Tr}_{99',33'} \left[\frac{\Omega'}{2}\, \frac{1+R+R^2+R^3}{4}\, \frac{1+(-1)^{F_s}}{2}\, \frac{1+(-1)^f}{2}\, e^{-2\pi t L_0} \right] \tag{2.9}$$

we have to take into account that Ω' acts on the ground states in the 99' and 33' sector in the following way

$$\begin{aligned} \Omega' |s_1\, s_2\, s_3\, s_4\rangle_{99'} &= -|s_1\, s_2\, s_3\, s_4\rangle_{99'} \\ \Omega' |s_1\, s_2\, s_3\, s_4\rangle_{33'} &= -e^{\pi i (s_2+s_3+s_4)} |s_1\, s_2\, s_3\, s_4\rangle_{33'}. \end{aligned} \tag{2.10}$$

For the 99' sector there are non-zero contributions from the Ω' and $\Omega' R^2$ insertions in the trace. With the choice of the Γ_R matrix above one gets

$$M_{99'} = c \int_0^\infty \frac{dt}{t^3}\, \frac{1}{8} \mathrm{Tr}(\Gamma^T_{\Omega',9}\, \Gamma^{-1}_{\Omega',9})\, \frac{f_2^8(i\, e^{-\pi t})}{f_1^8(i e^{-\pi t})} \left[\sum_m e^{-2\pi t \frac{m^2}{\rho}} \right]^6 . \tag{2.11}$$

For the 33' sector there are non-zero contributions from the $\Omega' R$ and $\Omega' R^3$ insertions in the trace. With the choice of the Γ_R matrix above one gets

$$M_{33'} = c \int_0^\infty \frac{dt}{t^3}\, \frac{1}{8} \mathrm{Tr}(\Gamma^T_{\Omega' R,3}\, \Gamma^{-1}_{\Omega' R,3})\, \frac{f_2^8(i\, e^{-\pi t})}{f_1^8(i e^{-\pi t})} \left[\sum_n e^{-2\pi t n^2 \rho} \right]^6 . \tag{2.12}$$

Thus, the Möbius amplitude only leads to RR tadpoles in the tree channel.

2.4. Tadpole Cancellation

Transforming all the amplitude in tree channel and extracting the divergent pieces one derives the following two RR tadpole cancellation conditions

$$
\begin{aligned}
V_4\rho^3 \left(N_9^2 - 32\,\mathrm{Tr}(\Gamma^T_{\Omega',9}\,\Gamma^{-1}_{\Omega',9}) + 2^{10}\right) &= 0 \\
V_4/\rho^3 \left(N_3^2 - 32\,\mathrm{Tr}(\Gamma^T_{\Omega' R,3}\,\Gamma^{-1}_{\Omega' R,3}) + 2^{10}\right) &= 0.
\end{aligned}
\tag{2.13}
$$

The first equation tells us that $\Gamma_{\Omega',9}$ is symmetric, where we can always make the choice

$$
\Gamma_{\Omega',9} = \begin{pmatrix} 0 & 0 & I & 0 \\ 0 & 0 & 0 & I \\ I & 0 & 0 & 0 \\ 0 & I & 0 & 0 \end{pmatrix}_{2N_9,2N_9}
\tag{2.14}
$$

so that $N_9 = 32$. T-duality as well as the algebra of γ matrices leads to the following choice of $\Gamma_{\Omega',3}$ and $\Gamma_{R,3}$

$$
\Gamma_{\Omega',3} = \begin{pmatrix} 0 & 0 & -i\,I & 0 \\ 0 & 0 & 0 & i\,I \\ I & 0 & 0 & 0 \\ 0 & -I & 0 & 0 \end{pmatrix}_{2N_3,2N_3}, \qquad \Gamma_{R,3} = \begin{pmatrix} i\,I & 0 & 0 & 0 \\ 0 & -i\,I & 0 & 0 \\ 0 & 0 & I & 0 \\ 0 & 0 & 0 & -I \end{pmatrix}_{2N_3,2N_3},
\tag{2.15}
$$

which indeed satisfies

$$
\Gamma_{R,3}\Gamma_{\Omega',3} \sim \Gamma_{\Omega',3}(\Gamma^{-1}_{R,3})^T \sim \Gamma_{\Omega',9}
\tag{2.16}
$$

up to phases implying that $N_3 = 32$. As always in type $0'$ orientifolds there remains an uncancelled NSNS tadpole

$$
8c \int_0^\infty dl\ V_4\ \left(N_9^2\rho^3 + N_3^2/\rho^3 - N_9 N_3/8\right).
\tag{2.17}
$$

which needs to be cancelled by the Fischler/Susskind mechanism [26].

2.5. The massless spectrum

Having defined all the actions of the R and Ω' on the various modes and on the Chan-Paton factors it is now a straightforward exercise to compute the massless spectrum as displayed for the closed string sector in Table 1.

sector	field
untwisted NS-NS	$G_{\mu\nu}$, dilaton Φ, 21 scalars
untwisted R-R	32 scalars
twisted NS-NS	massive
twisted R-R	64 scalars

Table 1: *Closed string spectrum of* $T^6/\mathbb{Z}_2$

Thus, there is the graviton, the dilaton and 117 further scalars. For the case that all 32 D3/D3' branes are placed on the same fixed point of R on T^6, we derive the massless open string spectrum listed in Table 2.

sector	field	gauge U(16)× U(16)$\|_9$× U(16) × U(16)$\|_3$
99, 33	vector	**Adj**
$9'9'$, $3'3'$	scalar	$6\times\{(\mathbf{16},\overline{\mathbf{16}};\mathbf{1},\mathbf{1})+(\overline{\mathbf{16}},\mathbf{16};\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{1};\mathbf{16},\overline{\mathbf{16}})+(\mathbf{1},\mathbf{1};\overline{\mathbf{16}},\mathbf{16})\}$
93, $9'3'$	–	massive
$99'$, $33'$	Weyl	$4\times\{(\mathbf{120},\mathbf{1};\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{120};\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{1};\mathbf{120},\mathbf{1})+(\mathbf{1},\mathbf{1};\mathbf{1},\mathbf{120})\}$
	Weyl	$4\times\{(\overline{\mathbf{16}},\overline{\mathbf{16}};\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{1};\overline{\mathbf{16}},\overline{\mathbf{16}})\}$
$93'$, $39'$	Weyl	$\{(\mathbf{16},\mathbf{1};\mathbf{16},1)+(\mathbf{1},\mathbf{16};\mathbf{1},\mathbf{16})\}$

Table 2: *Open string spectrum of* $T^6/\mathbb{Z}_2$

Note, that the chiral massless spectrum in Table 2 passes the non-trivial check of absence of non-abelian gauge anomalies. Similar to the supersymmetric case we expect the anomalous U(1)s to be cancelled by some generalized Green-Schwarz mechanism [28].

3. Type 0' orientifold in 6D with D5-branes

We now discuss the possibility of constructing type 0' orientifolds using certain symmetry properties of the compactified manifolds. In particular, orientifolds of type IIB on K3 have been constructed previously [29,30] and give rise to anomaly free models in six dimensions with different number of tensor, vector and hyper-multiplets. It is also known that K3 possesses certain discrete isometries which can be combined with orientifold projections. Since these isometries maintain supersymmetry, one is able to obtain consistent models without breaking supersymmetry further. Such projections have also been utilized earlier for constructing type II examples of string models which are dual to the reduced rank heterotic string compactifications with maximal supersymmetry [31].

We now show that such projections can also be applied to construct consistent type 0' orientifolds. As an explicit example we concentrate on a particular $\mathbb{Z}_2$ isometry of K3 which leaves all three self-dual 2-forms of K3 invariant. However among the 19 anti-self-dual 2-forms 8 are odd under its operation. We work with a particular realization of this projection in the orbifold limit $T^4/\mathbb{Z}_2$ of K3 [29]. The orbifold is constructed by complex coordinates (z_1, z_2) on the torus T^4 defined by periodic identifications: $z_1 \sim z_1 + 1$, $z_1 \sim z_1 + i$ (similarly for z_2) and by dividing the torus by $\mathbb{Z}_2 \equiv \{1, R\}$, where the projection R acts on complex coordinates as, $R : (z_1, z_2) \to (-z_1, -z_2)$. On the other hand the isometry of K3 mentioned above is represented by an operation $S : (z_1, z_2) \to (-z_1 + \frac{1}{2}, -z_2 + \frac{1}{2})$.

The orientifold model that we are considering involves the projections R and $\Omega' S$. The closed string spectrum in the untwisted NS-NS sector then consists of the graviton, dilaton and 10 scalars denoted by the representations $[(3,3) + 11(1,1)]$ of $SU(2) \times SU(2)$, which is the little group of the Lorentz group in six dimensions. The untwisted R-R sector consists of 4 self-dual and 4 anti-self-dual 2-forms, in addition to 8 scalars, represented as: $[4(3,1) + 4(1,3) + 8(1,1)]$. The twisted NS-NS sectors contribute 64 scalars and the twisted R-R sectors contribute states: $[8(3,1) + 8(1,3) + 16(1,1)]$.

As a result the total closed string spectrum consists of graviton, dilaton, 98 scalars and 12 self-dual as well as 12 anti-self-dual 2-forms. The model is free of gravitational anomaly, as the self-dual and anti-self-dual 2-forms come in equal numbers.

To obtain the open string spectrum, one analyses the tadpole cancellation conditions. Twisted RR tadpoles are once again cancelled by choosing γ_R traceless for both 9 and 5-branes. Since the action of S includes shifts along coordinates x_6 and x_8, the model is also free of the massless RR 10-form tadpoles in the untwisted sector. As a result, apart from uncancelled NS-NS tadpoles, one only has RR 6-form tadpoles which are cancelled by adding only 32 D5 and 32 D5'-branes in two possible ways:

(i) 16 5-branes and 16 5'-branes at a fixed point y of R and the same numbers of them at the image of y under S. The Chan-Paton indices are determined by a 32×32 block-diagonal matrix $\gamma_R = \mathrm{diag}[M, M]$ with M a 16×16 matrix: $M = \mathrm{diag}[I_8, -I_8]$. The resulting open string spectrum is listed in Table 3.

sector	spin	gauge U(8)× U(8)× U(8)' × U(8)'
55, 5'5'	vector $(1,1)$	**Adj** $4\times\{(\mathbf{8},\overline{\mathbf{8}};\mathbf{1},\mathbf{1})+(\overline{\mathbf{8}},\mathbf{8};\mathbf{1},\mathbf{1})+(\mathbf{1},\mathbf{1};\mathbf{8},\overline{\mathbf{8}})+(\mathbf{1},\mathbf{1};\overline{\mathbf{8}},\mathbf{8})\}$
$55'$	$(1,2)$ $(2,1)$	$2\times\{(\mathbf{8},\mathbf{1};\mathbf{8},\mathbf{1})+(\overline{\mathbf{8}},\mathbf{1};\overline{\mathbf{8}},\mathbf{1})+(\mathbf{1},\mathbf{8};\mathbf{1},\mathbf{8})+(\mathbf{1},\overline{\mathbf{8}};\mathbf{1},\overline{\mathbf{8}})\}$ $2\times\{(\mathbf{8},\mathbf{1};\mathbf{1},\mathbf{8})+(\overline{\mathbf{8}},\mathbf{1};\mathbf{1},\overline{\mathbf{8}})+(\mathbf{1},\mathbf{8};\mathbf{8},\mathbf{1})+(\mathbf{1},\overline{\mathbf{8}};\overline{\mathbf{8}},\mathbf{1})\}$

Table 3: *Open string spectrum of* $T^4/\mathbb{Z}_2$

Since there are equal number of left and right-handed fermions, the model is anomaly free.

(ii) Alternatively, one can take 16 5-branes (as well as 16 5'-branes) to lie at a fixed point x of S and the remaining ones at the image of x under R. In this case the gauge group is U(16). To compare, for a similar IIB model the gauge group was $SO(16)$ [29] and the difference comes due to the form of $\gamma_{\Omega' S}$. In our case $\gamma_{\Omega' S}$ is a 32×32 matrix with identities (I_{16}) along the off-diagonal blocks, so as to mix the 5 and 5'-branes under Ω'. In this case, one obtains the massless spectrum shown in Table 4.

sector	spin	gauge U(16)
55, 5'5'	vector $(1,1)$	**Adj** $4\times$ **Adj**
$55'$	$(1,2)$ $(2,1)$	$2\times\{\mathbf{120}+\overline{\mathbf{120}}\}$ $2\times\{\mathbf{120}+\overline{\mathbf{120}}\}$

Table 4: *Open string spectrum of* $T^4/\mathbb{Z}_2$

The model is once again anomaly free.

In this section we have presented one tachyon free six dimensional type 0' orientifold using a discrete isometry of K3. As mentioned earlier, K3 has several other discrete isometries, knows as finite abelian automorphism groups. One can use these isometries as projection elements to construct other models as well. One can also use certain supersymmetry non-preserving involution of K3, known as Enrique involution, to construct a type 0' model. However it turns out that the Klein-Bottle amplitude is free of tadpoles and hence there is no need to add any D-branes. The model is found to be purely bosonic in the closed string sector.

4. A duality conjecture

In [12] a very intriguing conjecture about the strong coupling limit of type 0A was presented, namely that type 0A string theory at strong coupling is M-theory compactified on $S^1/(-1)^{F_s}S$, where S denotes the half-shift along the compact circle. So far no dual candidate has been conjectured for the type $0'$ orientifold. In [23] arguments were given that the type 0 orientifold might be dual to the bosonic string compactified on an SO(32) torus. Here we would like to speculate about a different scenario. Analogous to the discussion in [32], consider M-theory compactified to nine dimensions on $S^1/\mathbb{Z}_2 \times S^1/(-1)^{F_s}S$, where the first $\mathbb{Z}_2$ is the reflection $I_1 : x_{10} \to -x_{10}$ combined with the change of the sign of the three-form. Compactifying first x_{10} and then x_9 one arrives at the $E_8 \times E_8$ heterotic string compactified on $S^1/(-1)^{F_s}S$. As argued in [33], after applying T-duality for $r_9 \to 0$ this should be the ten-dimensional non-tachyonic SO(16)$\times$ SO(16) heterotic string. Exchanging the role of x_{10} and x_9 one arrives at type $0A/\Omega\, I_1$, which is supposed to be T-dual to type $0B/\Omega$. Taking this chain of dualities seriously, one is led to the following strong-weak duality conjecture:

$$\textbf{Type 0 orientifold} \overset{\text{“dual”}}{\Longleftrightarrow} \textbf{non-susy SO(16)}\times\textbf{ SO(16) heterotic string.}$$

At first glance this seems to make no sense, as the gauge group of the type 0 orientifold has rank equal to 32. However, as was noticed in [12,34], at strong coupling the pair of a Dp and a Dp' brane might form a bound state in which half of the zero modes at weak coupling are frozen. By T-duality this implies that also the rank of the gauge group get reduced by a factor of two at strong coupling. Therefore, we think the conjecture not necessarily is nonsence and it deserves a more detailed investigation about the actual sense in which the duality relation should be understood. In view of the duality above, it is very tempting to make the following conjecture for the type $0'$ orientifold:

$$\textbf{Type 0' orientifold} \overset{\text{“dual”}}{\Longleftrightarrow} \textbf{non-susy U(16) heterotic string.}$$

The U(16) heterotic model has a tachyon which makes the whole picture somehow symmetric. In the former dual pair the heterotic model encounters a tachyonic instability at strong coupling whereas in the latter dual pair it is the orientifold model which has a tachyonic instability at strong coupling. The analysis of interpolating models carried out in [33] suggests that all these models are dynamically driven to their supersymmetric counterparts.

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