Discrete symmetries in D-brane models

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Plan

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Introduction

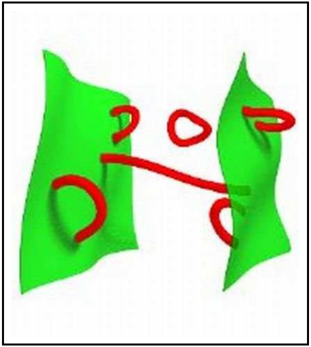
* Discrete symmetries: invoked to forbid unwanted terms in the Lagrangian. Ex: *R-parity* guarantees the absence of dimension four baryon- and lepton- number violating operators
* In the case of *R-parity*, the discrete gauge symmetry may be obtained as a $\mathbb{Z}_2$ subgroup of a $U(1)_{B-L}$ gauge factor

Stringy Approach

* Would be interesting to track the origin of discrete symmetries and know if they could emerge from string theory
* The study of some compactification setups would allow the emerging of such symmetries: type II orientifold constructions
* **These models contain U(1)'s symmetries which are generically broken to $\mathbb{Z}_n$ discrete gauge symmetries by the presence of $B \wedge F$ couplings**

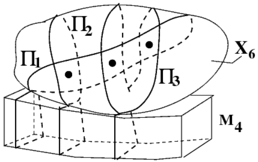
D-Branes: some properties

* Type II string theories contain extended objects in which open strings end: D-branes
* They were originally found as solutions of the low-energy supergravity equations of motion and
* Later (Polchinski, 1995), these objects were described as $(p+1)$-dimensional subspaces within string theory



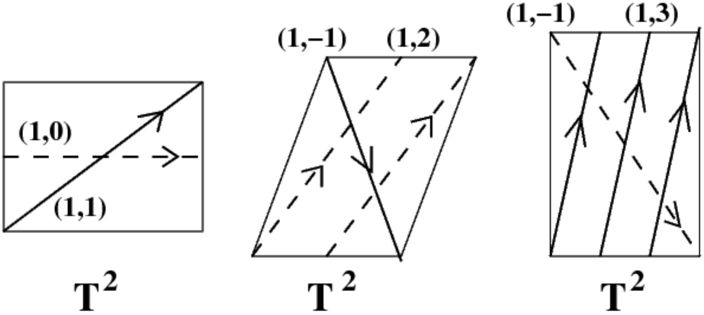
D-Branes: some properties

* Dynamical
* Charged under a RR $(p+1)$-form potential C_{p+1}
* Carry tension
* They may wrap curved non-trivial homology cycles



Toroidal models:compactification scheme

N D6-branes wrapping $3-cycles$ in a 6d torus factorized as $T^6 = T^2$ x T^2 x T^2 (Soler, Uranga, Ibañez, Berasaluce-González; 2011)



Model 1

N_i	(n^1, m^1)	(n^2, m^2)	(n^3, m^3)
$N_a = 3$	$(1, 0)$	$(n_a^2, 1)$	(N_g, m_a^3)
$N_b = 1$	$(0, 1)$	$(1, 0)$	$(0, -1)$
$N_c = 1$	$(n_c^1, 1)$	$(1, 0)$	$(0, 1)$
$N_d = 1$	$(1, 0)$	$(n_d^2, -N_g)$	$(1, m_d^3)$

* Intersection numbers:

$$I_{ab} = I_{ab*} = 3; \quad I_{ac} = I_{ac*} = -3$$
$$I_{db} = I_{db*} = -3; \quad I_{cd} = -3; \quad I_{cd*} = 3$$

$$I_{ab} = ({n_a}^1 {m_b}^1 - {m_a}^1 {n_b}^1) \times ({n_a}^2 {m_b}^2 - {m_a}^2 {n_b}^2) \times ({n_a}^3 {m_b}^3 - {m_a}^3 {n_b}^3)$$

$B \wedge F$ couplings

$$S_{BF} = \int_{\Pi_A} C_5 \wedge F_A = \sum_k N_A {s_A}^k B_k \wedge F_A$$

$$B_k = \int_{\beta_k} C_5$$

$$a_k = \int_{\alpha_k} C_3$$

$$dB_k = *_{4d} da_k$$

* In general, the factor of N_A implies the appareance of a Z_{N_A} discrete gauge symmetry.
* The structure of the couplings shows that an additional Z_n symmetry appears when the coefficients ${s_A}^k$ are multiplets of n, for all k, more precisely, when $n = gcd({s_A}^k)$

* Focus on discrete subgroups of U(1) linear combination of the form

$$Q = \sum_A c_A Q_A$$

$$S_{BF} = \left(\sum_A c_A N_A {s_A}^k \right) B_k \wedge F$$

where the field F is the one associated to the Q generator and

$${s_A}^k = [\Pi_A] \cdot [\alpha^k] = \otimes_{i=1}^{3} ({n_A}^i [\alpha_i] + {m_A}^i [\beta_i]) \cdot [\alpha^k]$$

So there is a $\mathbb{Z}_n$ gauge symmetry if the quantities $\sum_A c_A N_A {s_A}^k$ are multiplets of n, for all k.

Model 1

* BF couplings:

$$F^a \wedge 3\left(N_g B_2{}^2 + n_a^2 m_a^3 B_2{}^3\right)$$
$$F^c \wedge n_c^1 B_2{}^3$$
$$F^d \wedge \left(-N_g B_2{}^2 + n_d^2 m_d^3 B_2{}^3\right)$$

One can identify the generators as $Q_a = 3B$, $R = -Q_c$ and $L = Q_d$.

* Symmetries:
  - Z_9, if $N_g = 3$ and $n_a^2 m_a^3$ is multiple of 3; B_3; and Z_{N_g}, if $n_a^2 m_a^3$ is multiple of N_g
  - R_N, if $N = n_c^1$
  - L_{N_g}, if $n_d^2 m_d^3$ is multiple of N_g
  - $R_3 L_3^2$, if $n_c^1 + n_d^2 m_d^3 = 3$; and $R_2 B_3$, if $n_c^1 = 2$ and $n_a^2 m_a^3$ is multiple of 3

Model 2

N_i	(n^1, m^1)	(n^2, m^2)	(n^3, m^3)
$N_a = 6$	$(1, 0)$	$(N_g, 1)$	$(N_g, -1)$
$N_b = 2$	$(0, 1)$	$(1, 0)$	$(0, -1)$
$N_c = 2$	$(0, 1)$	$(0, -1)$	$(1, 0)$
$N_d = 2$	$(1, 0)$	$(N_g, 1)$	$(N_g, -1)$

* Intersection numbers:

$$I_{ab} = I_{ab*} = 3; \quad I_{ac} = I_{ac*} = -3$$
$$I_{d*b} = I_{d*b*} = -3; \quad I_{cd*} = -3, \quad I_{cd} = 3$$

Model 2

* BF couplings:

$$F^a \wedge 3N_g \left({B_2}^2 - {B_2}^3\right)$$
$$F^d \wedge N_g \left({B_2}^2 - {B_2}^3\right)$$

* Symmetries:
  - B_3 for $N_g = 3$
  - $R_3 L_3^2$ if $N_g = 3$

Model 3

N_i	(n^1, m^1)	(n^2, m^2)	(n^3, m^3)
$N_a = 3$	$(1, 0)$	$(n_a^2, 1)$	$(1/\rho, 1/2)$
$N_b = 2$	$(n_b^1, -1)$	$(1, 0)$	$(1, 3\rho/2)$
$N_c = 1$	$(n_c^1, 3\rho)$	$(1, 0)$	$(0, 1)$
$N_d = 1$	$(1, 0)$	$(n_d^2, -1/\rho)$	$(1, 3\rho/2)$

Third torus is tilted.

$\rho = 1, 1/3$

* Intersection numbers:

$$I_{ab} = 1, \quad I_{ab*} = 2; \quad I_{ac} = -3, \quad I_{ac*} = -3$$
$$I_{bd} = 0, \quad I_{bd*} = -3; \quad I_{cd} = -3, \quad I_{cd*} = 3$$

Model 3

* BF couplings:

$$F^a \wedge 3\left(\frac{1}{\rho}{B_2}^2 + n_a^2\frac{{B_2}^3}{2}\right)$$

$$F^b \wedge 2\left(-{B_2}^1 + 3\rho n_b^1\frac{{B_2}^3}{2}\right)$$

$$F^c \wedge 2n_c^1\frac{{B_2}^3}{2}$$

$$F^d \wedge \left(-\frac{1}{\rho}{B_2}^2 + 3\rho n_d^2\frac{{B_2}^3}{2}\right)$$

* Symmetries:
  - B_3, for $\rho = 1/3$ and n_a^2 multiple of 3
  - R_N, for $N = 2n_c^1$
  - R_2
  - L_3, for $\rho = 1/3$ and n_d^2 multiple of 3
  - R_2B_3, for $n_c^1 = 1$, $\rho = 1/3$ and n_a^2 multiple of 3

Conclusions and future work

* Symmetries as R_N, B_3 and L_3 appear generically
* To find *non-abelian* discrete gauge symmetries from the models above

Massive U(1)'s

* Type II orientifold models contain $U(1)$ symmetries on the worldvolume of D-branes which are generically broken to $\mathbb{Z}_N$ discrete gauge symmetries by the presence of $B \wedge F$ couplings
* Appearance of discrete gauge symmetries in D-brane models from the analysis of their BF couplings