Discrete gauge symmetries in D-brane models

Angel M. Uranga
IFT-UAM/CSIC, Madrid

In collaboration with
M.Berasaluce-González, L. Ibáñez, P. Soler, arXiv:1106.4169
M. Bersaluce-González, P. G. Cámara, F. Marchesano, in progress

c.f. Pablo's talk

"Iberian strings", Bilbao, Feb 2012

Discrete symmetries in BSM

- Discrete symmetries are a key ingredient in SM
- and a useful tool in BSM model building

- For instance in the MSSM, the most general supo, up to dim 4

$$
\begin{aligned}
W_{\rm MSSM} &= Y_U^{ij}\, Q_i U_j H_u + Y_D^{ij}\, Q_i D_j H_d + Y_L^{ij}\, L_i E_j H_d + \mu\, H_u H_d + \\
&+ \lambda^{ijk}\, U_i D_j D_k + \lambda^{ijk\prime}\, Q_i D_j L_k + \lambda^{ijk\prime\prime}\, L_i L_j E_k + \mu_R^i\, L_i H_u
\end{aligned}
$$

Ops in second line can combine and induce fast proton decay

Introduce discrete symmetries that forbid

- all such ops, e.g. R-parity (Q, D, L, E odd, Hu, Hd even)

- dangerous combinations, e.g. baryon triality B_3

(Q,U, D, L, E, Hu, Hd have charge 0,-1/3,+1/3, -1/3, +1/3,+1/3,-1/3)

Experimental signatures (at the LHC) depend on the symmetry!

Global and gauge symmetries in gravity

..., see recent Banks, Seiberg 2011

- Quantum gravity does not like global symmetries
  - Microscopic arguments in string theory — Banks, Dixon '88
  - General black hole arguments

    Charged black hole evaporates thermally into uncharged vacuum

- Exact symmetries should be gauge

  - Continuous symmetries: Charged black hole's electric field produces biased evaporation

  Key point is that gauge charge is detectable by measurements at infinity

  - Also true for discrete gauge symmetries:
    lasso black hole with charged strings and measure holonomy

Z_n discrete gauge symmetries

- Realize Z_n as U(1) Higgssed by field of charge n

Lagrangian for gauge field and phase of scalar field

$$(da - nA) \wedge *(da - nA) \, + \, \frac{1}{2} F \wedge *F$$

i.e. gauge transformation is

$$A \to A + d\lambda \quad ; \quad a \to a + n$$

- Can be dualized to BF theory

schematically

$$\frac{1}{2} H \wedge *H \, + \, nB \wedge F \, + \, \frac{1}{2} F \wedge *F$$

Zn symmetry read from coefficient of BF coupling

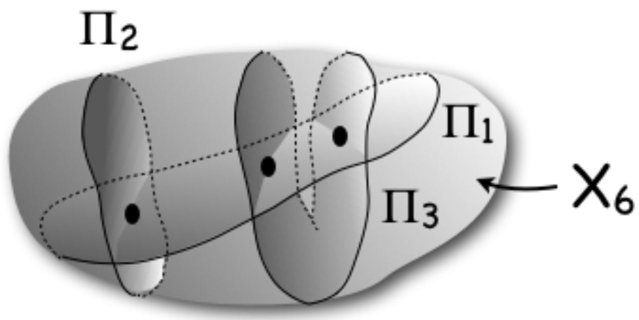
BF couplings and Zn symmetries in D-branes

- BF couplings permeate the physics of D-branes in compactifications to 4d, due to Chern-Simons action

Focus on compactifications with stacks of D6's on 3-cycles

basis of 3-cycles $[\alpha_k]$

and 4d 2-forms $B_2^k = \int_{[\alpha_k]} C_5$



expand 3-cycles $[\Pi_A] = \sum_k r_A^k [\alpha_k]$

KK reduction $\int_{[\Pi_A]\times M_4} C_5 \wedge \mathrm{tr} F_A \to N_A\, r_A^k \int_{4d} B_k \wedge F$

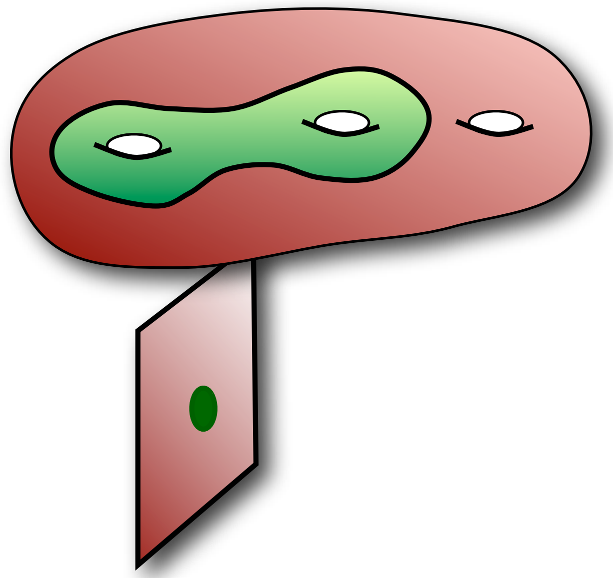
For U(1) comb: $Q = \sum_A c_A Q_A \Rightarrow \left(\sum_A c_A N_A\, r_A^k\right) B_k \wedge F$

Z_n gauge symmetry iff

$$\sum_A c_A N_A r_A^k = 0 \bmod n, \text{ for all } k$$

Zn gauge symmetries and instantons

- Instantons from euclidean D2-branes wrapped on 3-cycles [Π], violate U(1)'s



but consistently with unbroken Zn's

basis of 3-cycles $[\beta_k]$

and 4d scalars $a_k = \int_{[\beta_k]} C_3$

expand $[\Pi] = \sum_k s_k [\beta_k]$

Instanton amplitude $e^{S_{\rm cl.}} \sim e^{{\rm Vol}(\Pi) + i \sum_k s_k a_k}$

Under $A \to A + d\lambda \quad ; \quad a_k \to a_k + \sum_A c_A N_A r_A^k \, \lambda$

Then phase of $e^{S_{\rm cl.}}$ rotates by multiple of $2\pi i \, n \lambda$

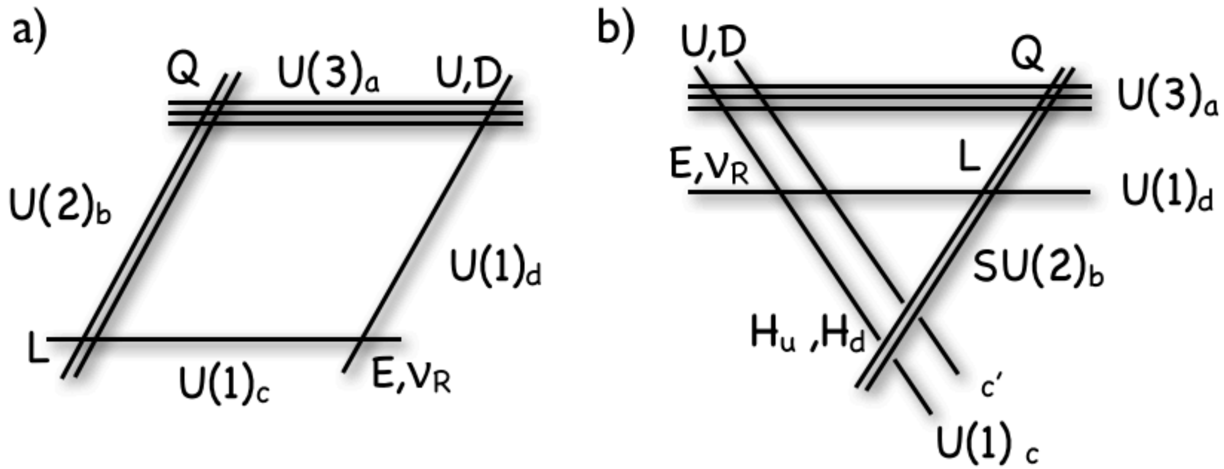
unbroken Zn's

- In particular, Zn's are non-anomalous

D6-brane MSSM model building

- Compactifications with D6-branes on intersecting 3-cycles produce 4d sectors of gauge interactions and charged bi-fundamental fermions

- Several classes of models leading to (MS)SM



(ignore O6-planes for simplicity)

R-parity and B3 in D-brane models

- For instance, in toroidal models Ibáñez, Marchesano, Rabadán'01

N_i	(n_A^1, m_A^1)	(n_A^2, m_A^2)	(n_A^3, m_A^3)
$N_a = 3$	$(1/\beta^1, 0)$	$(n_a^2, \epsilon\beta^2)$	$(1/\rho, 1/2)$
$N_b = 2$	$(n_b^1, -\epsilon\beta^1)$	$(1/\beta^2, 0)$	$(1, 3\rho/2)$
$N_c = 1$	$(n_c^1, 3\rho\epsilon\beta^1)$	$(1/\beta^2, 0)$	$(0, 1)$
$N_d = 1$	$(1/\beta^1, 0)$	$(n_d^2, -\beta^2\epsilon/\rho)$	$(1, 3\rho/2)$

$$F^a \wedge 3\left(\frac{1}{\rho} B_2^2 + n_a^2 \frac{B_2^3}{2}\right)$$
$$F^b \wedge 2\left(- B_2^1 + 3\rho n_b^1 \frac{B_2^3}{2}\right)$$
$$F^c \wedge 2n_c^1 \frac{B_2^3}{2}$$
$$F^d \wedge \left(-\frac{1}{\rho} B_2^2 + 3\rho n_d^2 \frac{B_2^3}{2}\right)$$

- R-parity (Qc) is automatic
- Baryon triality (Qa) if $\rho = 1/3 \text{ and } n_a^2 = 0 \text{ mod } 3$
- Etc...

- Nicely dovetails the classification of discrete gauge symmetries in the MSSM (plus right-handed neutrinos) Ibáñez, Ross '91, '92

Final remarks

- Extends similarly to type IIB models
- Can be analyzed similarly in F-theory models

  SU(5) x $U(1)_{B-L}$ can produce R-parity via BF couplings

- Connected with torsion homology classes

  c.f. Pablo's talk

- Further directions

  R-symmetries

  Non-abelian discrete gauge symmetries and flavour physics: in progress

  - Torsion classes with relations Gukov, Rangamani, Witten
  - Gaugings: fluxes, twisted tori
  - Constraints on toroidal Yukawas