Gauged Linear Sigma Model for Exotic Five-brane

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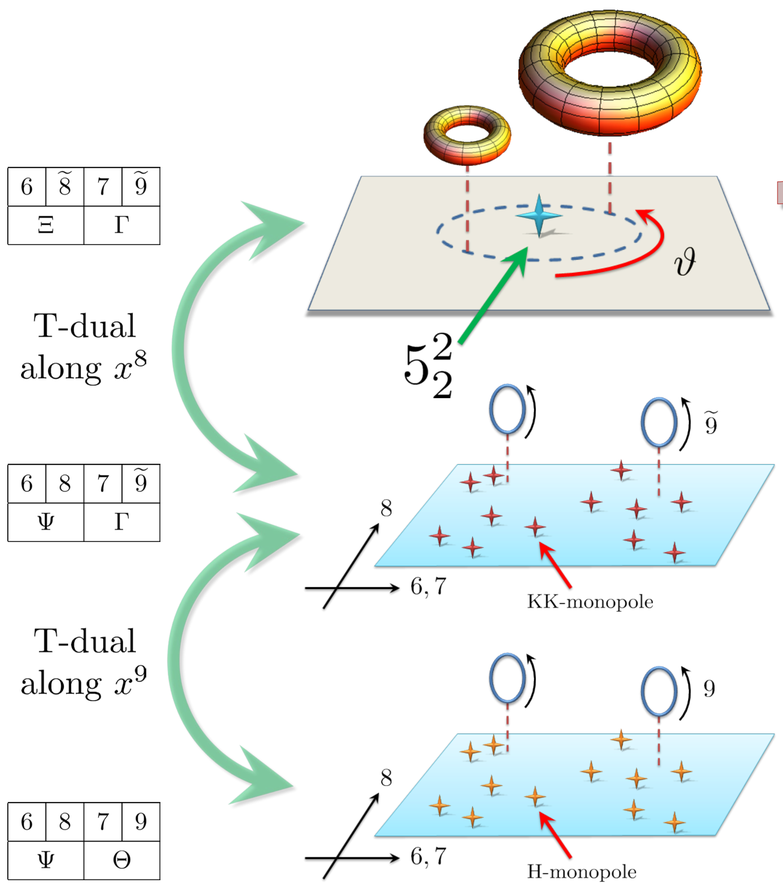
THE Model We Found

10D spacetime description

$$\mathrm{d}s^2 = \mathrm{d}x^2_{012345} + H\left[(\mathrm{d}\varrho)^2 + \varrho^2(\mathrm{d}\vartheta)^2\right] + HK^{-1}\left[(\mathrm{d}\widetilde{x}^8)^2 + (\mathrm{d}\widetilde{x}^9)^2\right]$$

$$H = h + \sigma\log\left(\frac{\mu}{\varrho}\right) \qquad K = H^2 + (\sigma\vartheta)^2$$

$$B_{89} = -(\sigma\vartheta)K^{-1} \qquad \mathrm{e}^{2\Phi} = HK^{-1}$$



T-duality

(free) string	sign-flip (parity) in right-mover momentum ↔ winding
spacetime	Buscher rule $(G_{mn}, B_{mn}) \to (G'_{mn}, B'_{mn})$
SUSY sigma model	Roček-Verlinde formula chiral ↔ twisted chiral

2D N=(4,4) Gauge Theory

NEW!

$$\mathscr{L}_{\mathrm{GLSM}} = \sum_{a=1}^{k}\int \mathrm{d}^4\theta\,\frac{1}{e_a^2}\Big(-\overline{\Sigma}_a\Sigma_a + \overline{\Phi}_a\Phi_a\Big) + \sum_{a=1}^{k}\int \mathrm{d}^4\theta\Big\{\overline{Q}_a\mathrm{e}^{2V_a}Q_a + \overline{\widetilde{Q}}_a\mathrm{e}^{-2V_a}\widetilde{Q}_a\Big\}$$

$$+\int \mathrm{d}^4\theta\Big\{-\frac{g^2}{2}\Big(\Xi + \overline{\Xi} - \sqrt{2}\sum_{a=1}^{k}(C_a + \overline{C}_a)\Big)^2\Big\} + \int \mathrm{d}^4\theta\,\frac{g^2}{2}\Big(\Gamma + \overline{\Gamma} + 2\sum_{a=1}^{k}V_a\Big)^2$$

$$-\sqrt{2}\sum_{a=1}^{k}\int \mathrm{d}^4\theta\,(\mathring{\Psi} - \overline{\mathring{\Psi}})(C_a - \overline{C}_a)$$

$$+\sqrt{2}\sum_{a=1}^{k}\Big\{\int \mathrm{d}^2\theta\Big(\widetilde{Q}_a\Phi_aQ_a + s_a\Phi_a\Big) + \int \mathrm{d}^2\widetilde{\theta}\,\big(t_a\Sigma_a\big) + (\mathrm{h.c.})\Big\} - \sqrt{2}\,\varepsilon^{mn}\sum_{a=1}^{k}\partial_m(\theta^9A_{n,a})$$

5^2_2-brane is from H-monopoles (smeared NS5-branes) or from KK-monopoles under string T-duality (see the left pictures). This never appears in gravitational theories *without B-field*. This object is exotic because :

- logarithmic harmonic function (co-dim. 2)
  → no well-defined asymptotic behaviors
- non-trivial monodromy charges
  → globally non-geometric structure
- etc...

5^2_2-brane has been investigated in supergravity from the "conventional spacetime viewpoint". Now we are ready to analyze it from the **string worldsheet** viewpoint, because the sigma model for NS5-branes/KK-monopoles is well established. String worldsheet theory will tell us much richer property of the 5^2_2-brane, because the theory naturally contains B-field on the target space. Here, we report that we found the worldsheet model ***as a 2D N=(4,4) SUSY gauge theory (GLSM)*** for the 5^2_2-brane (see the above), though it **seemed hard to construct** the worldsheet model caused by the above exotic features themselves.

Two Techniques

NEW!

1: F-terms → D-terms chiral superfield → general superfield

$$\Phi_a = \overline{D}_+\overline{D}_-C_a$$

$$\mathscr{L}_\Psi = \int \mathrm{d}^4\theta\,\frac{1}{g^2}\overline{\Psi}\Psi + \sqrt{2}\sum_{a=1}^{k}\Big\{\int \mathrm{d}^2\theta\,(-\Psi\Phi_a) + (\mathrm{h.c.})\Big\}$$

$$= \int \mathrm{d}^4\theta\Big\{\frac{c}{g^2}(\Psi+\overline{\Psi})^2 - \sqrt{2}(\Psi+\overline{\Psi})\sum_{a=1}^{k}(C_a+\overline{C}_a) + \frac{2c-1}{2g^2}(\Psi-\overline{\Psi})^2 - \sqrt{2}(\Psi-\overline{\Psi})\sum_{a=1}^{k}(C_a-\overline{C}_a)\Big\}$$

$$\mathscr{L}_{RSX\Xi} \equiv \int \mathrm{d}^4\theta\Big\{\frac{c}{g^2}R^2 - \sqrt{2}R\sum_{a=1}^{k}(C_a+\overline{C}_a) + R(\Xi_1+\overline{\Xi}_1) + R(X+\overline{X})\Big\}$$

$$+\int \mathrm{d}^4\theta\Big\{\frac{2c-1}{2g^2}(\mathrm{i}S)^2 - \sqrt{2}(\mathrm{i}S)\sum_{a=1}^{k}(C_a-\overline{C}_a) + \mathrm{i}S(\Xi_2-\overline{\Xi}_2) + \mathrm{i}S(X-\overline{X})\Big\}$$

integrate out Ξ_1, Ξ_2 and X → GLSM for KK-monopoles

integrate out R and Ξ_2 → new GLSM (see the right above)

2: shift symmetry vs **dual coordinate analysis**

The term $\int \mathrm{d}^2\theta\,(\mathring{\Psi} - \overline{\mathring{\Psi}})(C_a - \overline{C}_a)$ looks pathological because this breaks the shift symmetry, i.e., the isometry on the geometry. BUT, this term plays an **essential** role! *If absent, …*

- *IR theory is reduced to a chiral model: conflict w/ N=(4,4) SUSY,*
- *Target space metric is single-valued: trivial monodromy,*
- *Target space B-field does not appear: conflict w/ Buscher rule.*

This term yields the T-dual (non-geometric) coordinate, which is inevitable to derive the exotic brane geometry!

Worldsheet Model in IR

Easy!

IR limit of the gauge theory is the NLSM on the 5^2_2-brane with B-field. The procedure is parallel to the one in the case of KK-monopoles :

1. find a SUSY vacuum $\mathscr{L}^{\mathrm{pot}}_{\mathrm{GLSM}} = 0$
2. solve the constraints on charged fields in $(Q_a, \widetilde{Q}_a)$
3. take IR limit $e_a \to \infty$ and integrate out the gauge fields
4. integrate out the T-dual Coordinate Fields

$\int \mathrm{d}^2\theta\,(\mathring{\Psi} - \overline{\mathring{\Psi}})(C_a - \overline{C}_a)$ plays a crucial role in process 4.

We successfully produced the exotic five-brane metric with B-field ! (see **the left above "10D spacetime description"**)

NEXT Quests

Ambitious!

- ✓ Analyze worldsheet instantons via gauge theory instantons
  (see our work arXiv:1305.4439, skipped here)
- ✓ Explore quantum moduli space as in N=(2,2) GLSM
- ✓ Construct bound states of NS5-branes and exotic 5^2_2-brane
  (see de Boer and Shigemori arXiv:1209.6056)
- ✓ Apply this object to stringy cosmic string(?), and defective matters(?)
- ✓ Etc., etc…