7-brane Wilson lines and multi-branched potentials

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String Phenomenology 2016, Ioannina

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Based on: Carta, Marchesano, Staessens, GZ '16

See also: Marchesano talk

For applications: Landete & Wieck talk

Type IIB orientifolds

Grimm, Louis '04

- Type IIB compactifications on CY 3-folds with O7/O3-planes
- Closed string moduli: Kähler moduli & complex structure moduli

$$T_\alpha = \frac{1}{2}\mathcal{K}_{\alpha\beta\gamma}v^\beta v^\gamma - iC_\alpha \qquad\qquad \Omega = X^I\alpha_I - F_I\,\beta^I$$

- Kähler potential is

$$K_{\mathbf{Q}} = -\log\left[i(X^I\overline{F}_I - \overline{X}^I F_I)\right]$$

$$K_{\mathbf{K}} = -2\log\left[\frac{1}{6}\mathcal{K}_{\alpha\beta\gamma}v^\alpha v^\beta v^\gamma\right]$$

- Moduli space factorises

$$\mathcal{M}_{\mathcal{N}=1} = \mathcal{M}_{\rm CS}\times\mathcal{M}_{\rm K}$$

D7-brane Wilson line moduli

- D7-branes are necessary to cancel tadpoles

$$\sum_a [\mathcal{S}_a] + [\mathcal{R}\mathcal{S}_a] = 8\,[\pi_{O7}]$$

- There is a sector of open string moduli

$$\xi_i \qquad\qquad i = 1, \ldots, h^{(0,1)}(\mathcal{S}_a)$$

$$\Phi^m \qquad\qquad m = 1, \ldots, h^{(2,0)}(\mathcal{S}_a)$$

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- Dimensional reduction ansatz

$$A = \frac{\pi}{l_s} \mathrm{Im}\left[\xi_i\, \overline{\gamma}^i\right] \qquad\qquad \overline{\gamma}^i \in H^{(0,1)}(\mathcal{S}_a)$$

where the forms $\bar{\gamma}^i$ are defined as

$$\gamma^{\bar{\imath}} = (\mathrm{Im} f)^{ij} \left[\tilde{\alpha}_i + f_{jk}(z)\tilde{\beta}^k\right] \qquad (\tilde{\alpha}_i, \tilde{\beta}^j) \in H^1(\mathcal{S}_a, \mathbb{Z})$$

D7-brane Wilson line moduli

- Real components of WL moduli are written as

$$\xi_i = \eta_i + f_{ij}(z)\,\theta^j \longrightarrow \begin{aligned} \eta_i &\sim \eta_i + 1 \\ \theta^i &\sim \theta^i + 1 \end{aligned}$$

- WL moduli redefine Kähler moduli

$$\hat{T}_\alpha = T_\alpha - \frac{i}{4}\sum_a (\mathcal{C}_\alpha^a)^i_k\,(\mathrm{Im}\,f)^{kj}\,\xi_i\,\mathrm{Im}\,\xi_j$$

- New variable shifts holomorphically under shifts of WL

Camara et al, '09

- Kähler potential has to be expressed in terms of new variables
- Addition of WL moduli breaks factorisation of moduli space

Wilson Lines moduli & superpotential

- WL moduli enter in the D7-brane superpotential

Jockers, Louis '04
Martucci '06

$$W_{D7} = \int_{\Sigma_5} \Omega \wedge \mathcal{F} \qquad\qquad \partial\Sigma_5 = \sum_a [\mathcal{S}_a] + [\mathcal{R}\mathcal{S}_a] - 8[\pi_{\rm O7}]$$

$$W_{D7} = \sum_a \eta_i \left[(c_a)^i_I \, X^I - (h_a)^{iI} F_I \right] + \theta^i \left[(d_a)^I_i F_I - (p_a)_{iI} X^I \right]$$

- Coupling with CS moduli appears if 4-cycle has non-trivial 3-cycle

Marchesano, Regalado, GZ '14

- Holomorphicity of superpotential fixes

$$\left[X^I (c_a)^i_I - F_I (h_a)^{iI} \right] f_{ij}(z) = \left[F_I (d_a)^I_i - X^I (p_a)_{jI} \right]$$

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$$W_{D7} = \sum_a \left[X^I (c_a)^i_I - (h_a)^{iI} F_I \right] \xi_i$$

- Bilinear coupling with CS moduli (inflation with stabiliser)

Escobar, Landete & Wieck talk

- Adding the flux superpotential (only RR)

$$W_{\rm IIB} = X^I \tilde{e}_I + F_I \, \tilde{m}^I \quad \longrightarrow \quad \text{discrete shift symmetries}$$

F-term scalar potential

- Kähler metric obeys no scale conditions

$$K^{A\bar{B}} K_{\bar{B}} = -2i \,\mathrm{Im}\, \Psi^A \qquad\qquad K^{A\bar{B}} K_A K_{\bar{B}} = 7$$

if $f_{ij}(z)$ is linear

- Scalar potential is sum of two terms

$$V = V_{\mathrm{RR+CS}}(\tilde{e}_I, \tilde{m}^I) + V_{DBI}$$

- Consistent with dimensional reduction (3-form formulation)

Kaloper & Sorbo, '08

Kaloper, Lawrence, Sorbo, '08

Bielleman, Ibáñez & Valenzuela, '15

Wilson Line moduli in F-theory

- In F-theory Wilson lines come from (2,1) forms

Grimm '10

$$\psi \sim \omega_a \wedge \overline{\gamma}$$

- Get unified with RR axions
- Consistent with redefinition of Kähler moduli

$$\hat{T}_\alpha = T_\alpha + d_{\alpha a b}(z, \bar{z})\, N^a \,\mathrm{Im}\, N^b$$

- Mirror symmetry gives linear $f_{ij}(z)$

Greiner, Grimm '15

Conclusions

- Revisited definition of open string adjoint moduli
- WL moduli provide a redefinition of Kähler moduli
- Redefinition ensures holomorphic shifts of Kähler moduli
- Moduli space no longer factorises
- Superpotential & scalar potential have discrete shift symmetries (gives a Kaloper-Sorbo formulation)
- Results are compatible with F-theory uplift

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Thank you