

Wilson coefficients from a non-renormalization theorem in 2D SYM

Kabir Bajaj

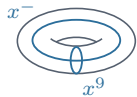
Princeton University

Based on arXiv:2605.27359

LITP Workshop on Quantum Black Holes, University of Michigan, 10 Oct 2026

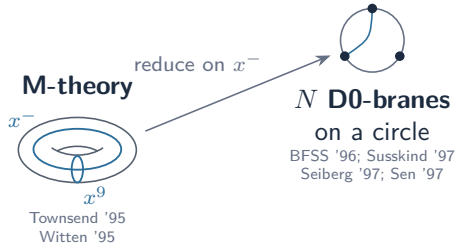
Matrix string theory

M-theory

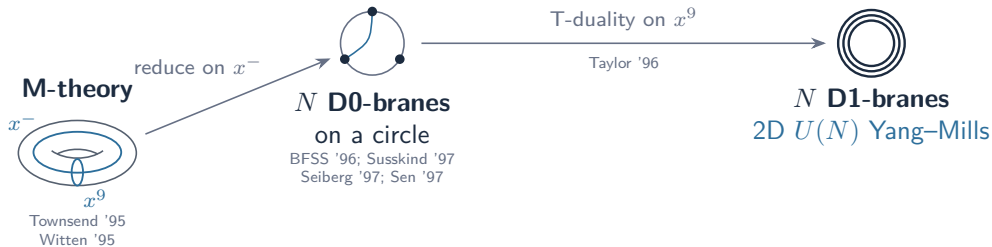


Townsend '95
Witten '95

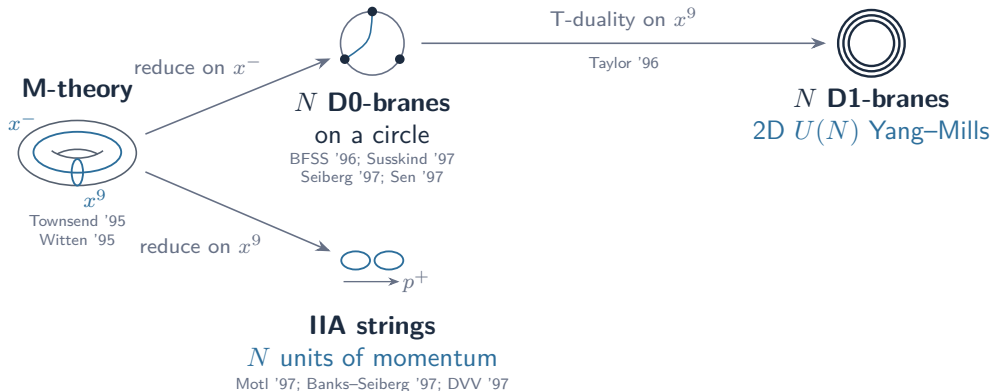
Matrix string theory



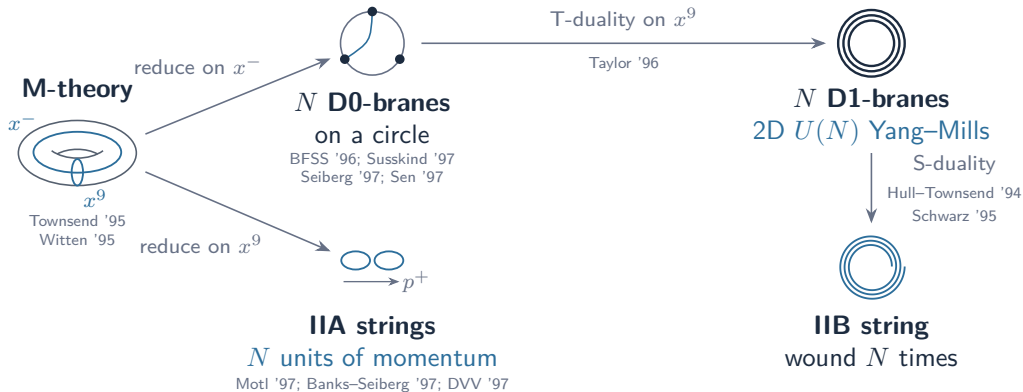
Matrix string theory



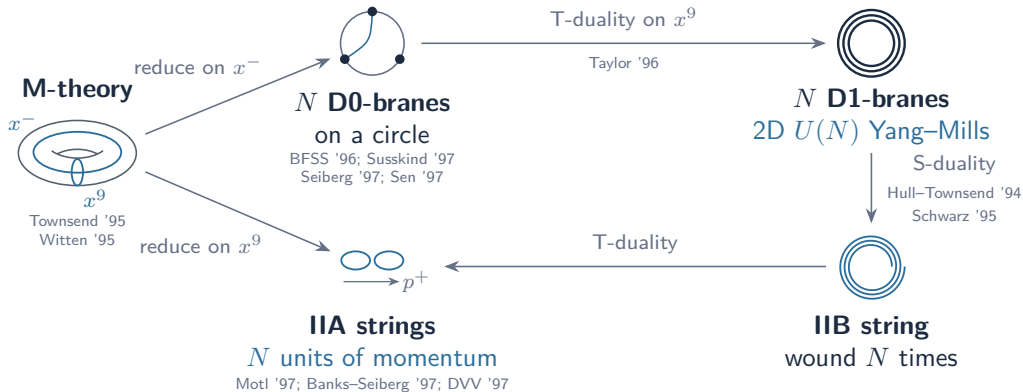
Matrix string theory



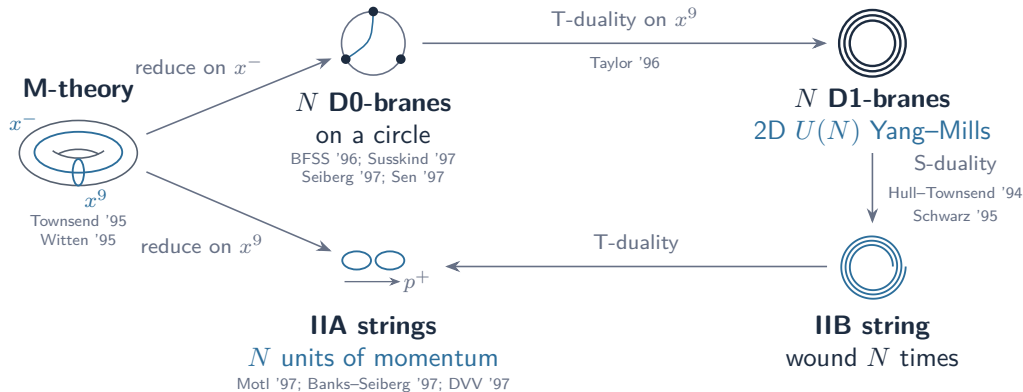
Matrix string theory



Matrix string theory



Matrix string theory

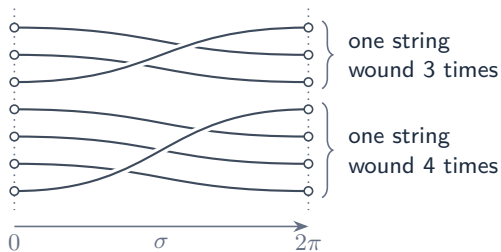


2D $U(N)$ Yang–Mills on a circle = type IIA strings

IR

$$S = \int d\tau d\sigma \operatorname{Tr} \left[\frac{1}{4\pi} (D_\alpha x^i)^2 - \frac{(g_{\text{YM}} R)^2}{16\pi^2} [x^i, x^j]^2 + \frac{1}{4(g_{\text{YM}} R)^2} F_{\alpha\beta}^2 \right], \quad \sigma \sim \sigma + 2\pi$$

Low energy, $g_{\text{YM}} R \rightarrow \infty$: $[x^i, x^j] = 0$



T-duality: winding $K \rightarrow p^+ = K/R_-$

total $p^+ = N/R_-$: DLCQ IIA

Eigenvalues $x_I(\sigma) \in \mathbb{R}^8$, up to S_N :

$$\mathcal{M} = (\mathbb{R}^8)^N / S_N$$

Around the circle:

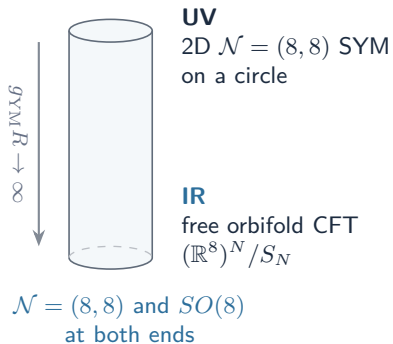
$$x_I(\sigma + 2\pi) = x_{g(I)}(\sigma)$$

Each cycle of $g =$ one long string.

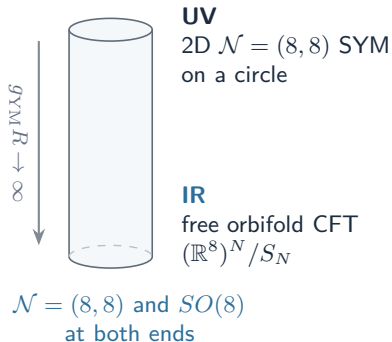
IR: free strings on $\mathcal{M}$.

Interactions?

RG flow



RG flow



Near the IR fixed point, add irrelevant operators:

$$\mathcal{L} = \mathcal{L}_{\text{orb}} + \sum_a \lambda_a \mathcal{O}_a$$

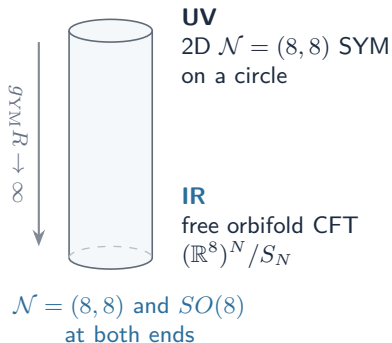
$\mathcal{N} = (8, 8)$ and $SO(8)$ fix the leading one:

$$\frac{\lambda}{g_{\text{YM}}} \int d^2 z \, \Sigma, \quad \Sigma = \sum_{I < J} G_{-\frac{1}{2}} \tilde{G}_{-\frac{1}{2}} (\sigma S \tilde{\sigma} \tilde{S})_{(IJ)}$$

$$G^{\dot{a}} = \theta^a \gamma_{a\dot{a}}^i \partial x^i \text{ acts on } S^{\dot{a}} \text{ (one } \dot{a}), \quad \sigma: x_I \leftrightarrow x_J$$

DVV '97

RG flow



Near the IR fixed point, add irrelevant operators:

$$\mathcal{L} = \mathcal{L}_{\text{orb}} + \sum_a \lambda_a \mathcal{O}_a$$

$\mathcal{N} = (8, 8)$ and $SO(8)$ fix the leading one:

$$\frac{\lambda}{g_{\text{YM}}} \int d^2 z \, \Sigma, \quad \Sigma = \sum_{I < J} G_{-\frac{1}{2}} \tilde{G}_{-\frac{1}{2}} (\sigma S \tilde{\sigma} \tilde{S})_{(IJ)}$$

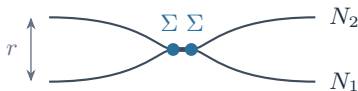
$$G^{\dot{a}} = \theta^a \gamma_{a\dot{a}}^i \partial x^i \text{ acts on } S^{\dot{a}} \text{ (one } \dot{a}), \quad \sigma: x_I \leftrightarrow x_J$$

They fix Σ , but not its Wilson coefficient λ .

What is λ ?

DVV '97

IR amplitude

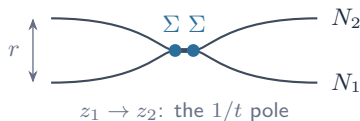


Second-order conformal perturbation theory in Σ :

$$\mathcal{A} = -\frac{\pi^3 \lambda^2}{4g_{\text{YM}}^2 R^2} K_{\text{NS}} \frac{\Gamma(-\frac{s}{4}) \Gamma(-\frac{t}{4}) \Gamma(-\frac{u}{4})}{\Gamma(1 + \frac{s}{4}) \Gamma(1 + \frac{t}{4}) \Gamma(1 + \frac{u}{4})}$$

10D Lorentz invariance from a 2D orbifold, up to λ^2 .

IR amplitude



Second-order conformal perturbation theory in Σ :

$$\mathcal{A} = -\frac{\pi^3 \lambda^2}{4g_{\text{YM}}^2 R^2} K_{\text{NS}} \frac{\Gamma(-\frac{s}{4}) \Gamma(-\frac{t}{4}) \Gamma(-\frac{u}{4})}{\Gamma(1 + \frac{s}{4}) \Gamma(1 + \frac{t}{4}) \Gamma(1 + \frac{u}{4})}$$

10D Lorentz invariance from a 2D orbifold, up to λ^2 .

$$t \rightarrow 0 \quad (\text{large } r): \quad \mathcal{A} \rightarrow -\frac{\pi^3 \lambda^2}{g_{\text{YM}}^2 R^2} \frac{s^2}{t} \quad \Rightarrow \quad L \supset \frac{\lambda^2}{16\pi^2} \frac{R N_1 N_2}{g_{\text{YM}}^2} \frac{v^4}{r^6}$$

Arutyunov–Frolov '97; Arutyunov–Frolov–Polishchuk '98

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

UV: Coulomb branch

$$X^i = \begin{pmatrix} x_1^i \mathbf{1}_{N_1} & W^i \\ W^{i\dagger} & x_2^i \mathbf{1}_{N_2} \end{pmatrix}$$

$$f = \frac{2\pi R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

UV: Coulomb branch

$$X^i = \begin{pmatrix} x_1^i \mathbf{1}_{N_1} & W^i \\ W^{i\dagger} & x_2^i \mathbf{1}_{N_2} \end{pmatrix}$$

$$f = \frac{2\pi R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

← ? →

IR



$$f = \frac{\lambda^2}{16\pi^2} \frac{R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

UV: Coulomb branch

$$X^i = \begin{pmatrix} x_1^i \mathbf{1}_{N_1} & W^i \\ W^{i\dagger} & x_2^i \mathbf{1}_{N_2} \end{pmatrix}$$

$$f = \frac{2\pi R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

← ? →
generically not

IR



$$f = \frac{\lambda^2}{16\pi^2} \frac{R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

UV: Coulomb branch

$$X^i = \begin{pmatrix} x_1^i \mathbf{1}_{N_1} & W^i \\ W^{i\dagger} & x_2^i \mathbf{1}_{N_2} \end{pmatrix}$$

$$f = \frac{2\pi R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

← = →
hint: D1 probe in the D1 background

IR



$$f = \frac{\lambda^2}{16\pi^2} \frac{R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

We prove non-renormalization in the UV: f is one-loop exact.

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Fixing λ

two clusters at large r , zero relative flux: $L_{\text{eff}} = L_{\text{free}} + f(r) v^4 + \dots$

UV: Coulomb branch

$$X^i = \begin{pmatrix} x_1^i \mathbf{1}_{N_1} & W^i \\ W^{i\dagger} & x_2^i \mathbf{1}_{N_2} \end{pmatrix}$$

$$f = \frac{2\pi R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

← = →
hint: D1 probe in the D1 background

IR



$$f = \frac{\lambda^2}{16\pi^2} \frac{R N_1 N_2}{g_{\text{YM}}^2 r^6}$$

We prove non-renormalization in the UV: f is one-loop exact.

$$\lambda^2 = 32\pi^3$$

Douglas–Kabat–Pouliot–Shenker '96; BFSS '96; Maldacena '97; Paban–Sethi–Stern '98 (matrix QM)

Summary

2D $\mathcal{N} = (8, 8)$ SYM $\rightarrow$ free orbifold; leading irrelevant operator $\frac{\lambda}{g_{\text{YM}}} \int d^2 z \Sigma$

Non-renormalization in the UV fixes its Wilson coefficient: $\lambda^2 = 32\pi^3$

Consistent with matrix string theory: a first-principles check of $g_A = 1/(\sqrt{2\pi} g_{\text{YM}} R)$

Questions

Higher irrelevant operators: all zero but DVV? (Dijkgraaf–Motl '03)

Fixed by protected v^6 or multi-body terms?

Electric-flux sectors: states with D0-brane charge? (Koloğlu '16; Cho–Gabai–Scheinpflug–Yin '26)

M-momentum transfer: processes beyond perturbative strings? (Keski-Vakkuri–Kraus '98)