Matrix Theory Reloaded: A Worldsheet Perspective

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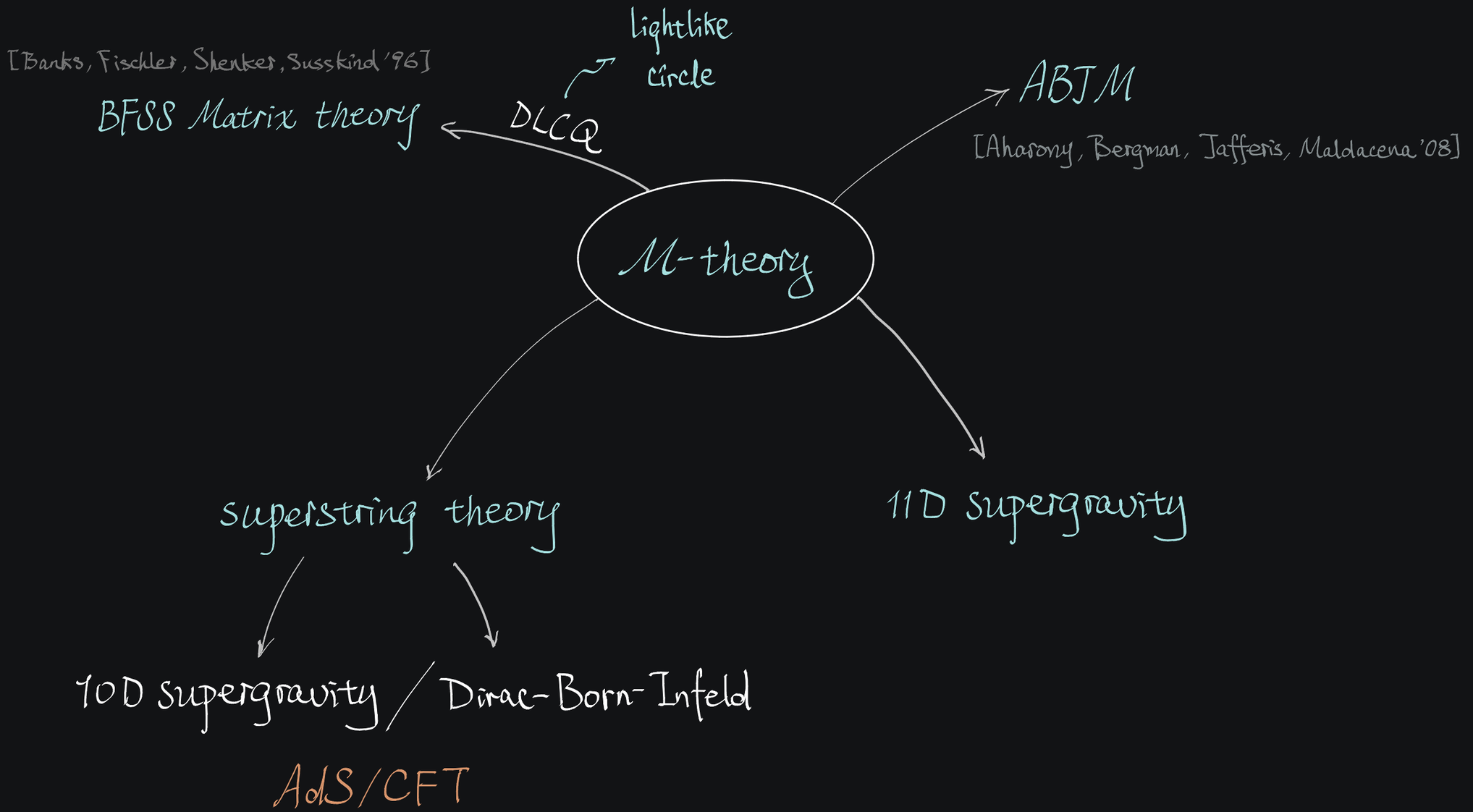
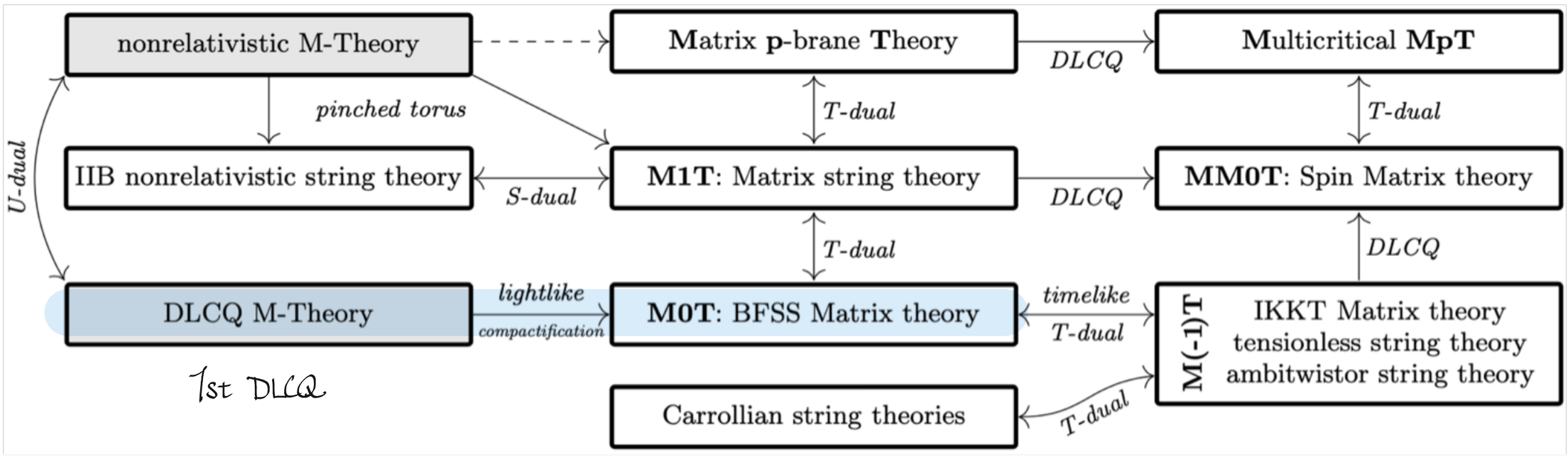
Decoupling Limits

Discrete Light Cone Quantization (DLCQ)



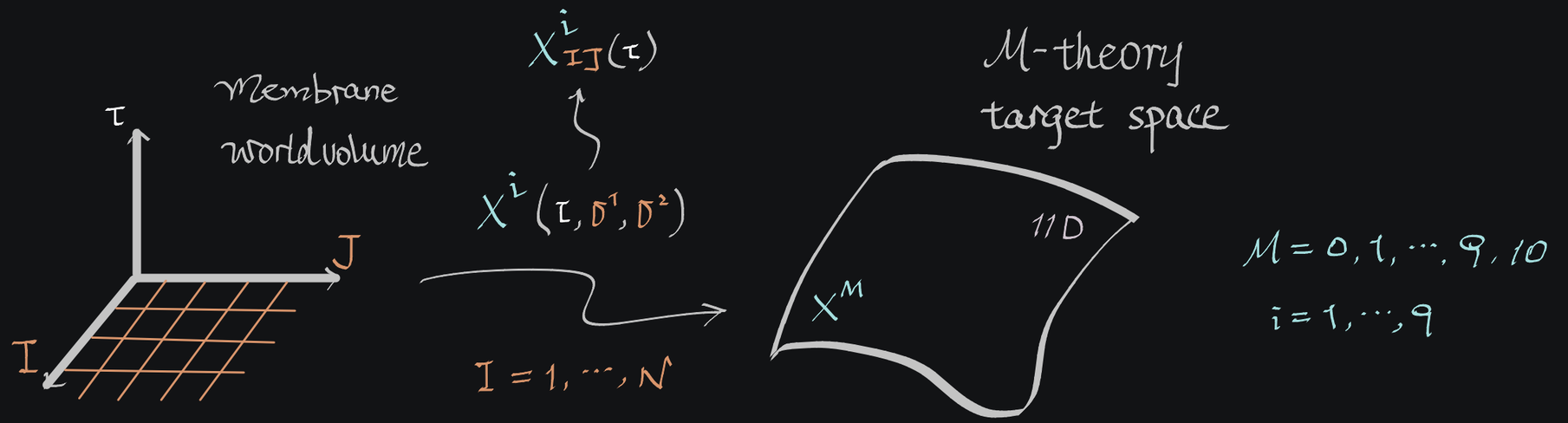
Unification of Decoupling Limits



[de Wit, Hoppe, Nicolai '88]
[Banks, Fischler, Shenker, Susskind '96]
[Seiberg '97]

BFSS Matrix Theory

- membrane sigma model: $S = -T \int d^3\sigma \sqrt{-\det(\partial_a X^M \partial_b X^M)}$



- SU(N) nonrel. quantum mechanics of 9 $N \times N$ matrices

$$S \sim \frac{1}{2g^2} \int d\tau \, tr\left(\dot{X}^i \dot{X}^i + \frac{1}{2} [X^i, X^j]^2 + fermions \right)$$

nonrel. limit of a stack of N D0-particles in IIA ← null compactification — DLCQ M-theory

Matrix 0-Brane Theory: Roadmap

DLCQ M-theory

compactify over a lightlike circle

↓

Matrix 0-brane theory

a decoupling limit of IIA

- D0-branes: BFSS Matrix theory
- D2-branes: noncommutative Yang-Mills
- fundamental string?

Matrix 0-Brane Theory: String Sigma Model

- membrane in DLCQ $S = -T\int d^3\sigma \sqrt{-\det(\partial_a X^M \partial_b X^M)}$

$\sigma^a = (\tau, \sigma^1, \sigma^2)$

$X^+ \sim X^+ + 2\pi R$

double dimensional reduction: $X^+ = \sigma^2$, $X^- = X^0$

$$S_{NG} = T\int d^2\sigma \sqrt{\det\begin{pmatrix} 0 & \partial_\beta X^0 \\ \partial_\alpha X^0 & \partial_\alpha X^i \partial_\beta X^i \end{pmatrix}} \qquad \sigma^\alpha = (\tau, \sigma)$$

- Polyakov formulation flat gauge

$$S_P = \frac{T}{2}\int d^2\sigma \left(\partial_\sigma X^0 \partial_\sigma X^0 + \partial_\tau X^i \partial_\tau X^i + \lambda\, \partial_\tau X^0\right)$$

non-Riemannian worldsheet

tropological sigma models?

nonequilibrium string?

[Albrychiewicz, Ellers, Valiente, Hořava '23]

Symmetries in Matrix 0-Brane Theory

- string action

$$S = \frac{T}{2}\int d^2\sigma \left(\partial_\sigma X^0\,\partial_\sigma X^0 + \partial_\tau X^i\,\partial_\tau X^i + \lambda\,\partial_\tau X^0\right)$$

$$\lambda \;\rightsquigarrow\; 2v^i\partial_\tau X^i$$

- target space Galilei boost

$$\delta X^0 = 0 \qquad \delta X^i = v^i X^0 \qquad \delta\lambda = -2v^i\partial_\tau X^i$$

Symmetries in Matrix 0-Brane Theory

- string action

$$-2\,\partial_\sigma X^0\,\partial_\tau X^0$$

$$S = \frac{T}{2}\int d^2\sigma \left(\partial_\sigma X^0\,\partial_\sigma X^0 + \partial_\tau X^i\,\partial_\tau X^i + \lambda\,\partial_\tau X^0\right)$$

- target space Galilei boost

$$\delta X^0 = 0 \qquad \delta X^i = v^i X^0 \qquad \delta\lambda = -2 v^i \partial_\tau X^i$$

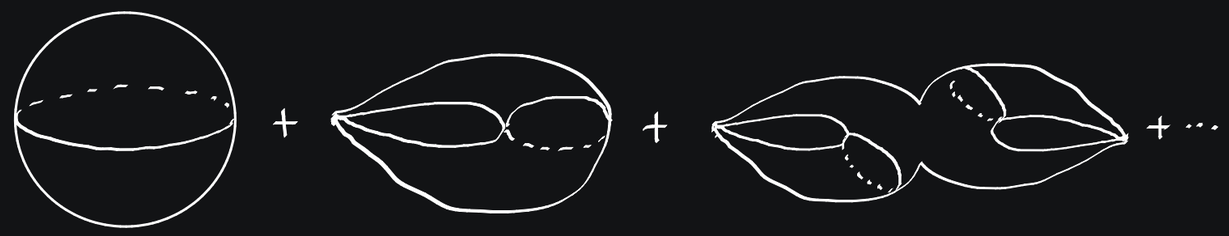
- Worldsheet Carroll boost

$$\delta\tau = v^i \sigma \qquad \delta\sigma = 0 \qquad \delta\lambda = 2 v^i \partial_\sigma X^0$$

Worldsheet Topologies: Nodal Spheres

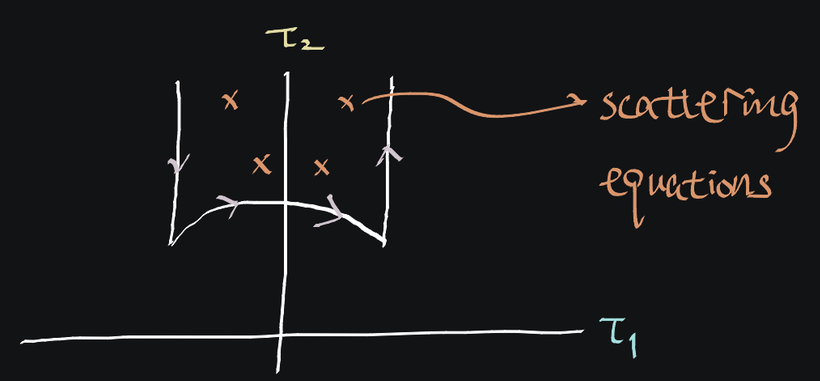
pinching modulus $\tau \to i\infty$

pinched torus



ambitwistor string amplitudes

$\tau \to i\infty$



[Geyer, Mason, Monteiro, Tourkine '15]

Duality Web from T-Dualities

MOT string $i=1,\cdots,9$

$$S_{MOT}=\frac{T}{2}\int d^2\sigma\left(\partial_\sigma X^0\partial_\sigma X^0+\partial_\tau X^i\partial_\tau X^i+\lambda\,\partial_\tau X^0\right)$$

T-dualize X^1

T-dualize X^0

M1T string $a=0,1$ $i=2,\cdots,9$

$$S_{M1T}=\frac{T}{2}\int d^2\sigma\left(-\partial_\sigma X^a\partial_\sigma X_a+\partial_\tau X^i\partial_\tau X^i+\lambda_a\,\partial_\tau X^a\right)$$

D1-string: Matrix string theory

[Verlinde, Verlinde, Dijkgraaf '97]

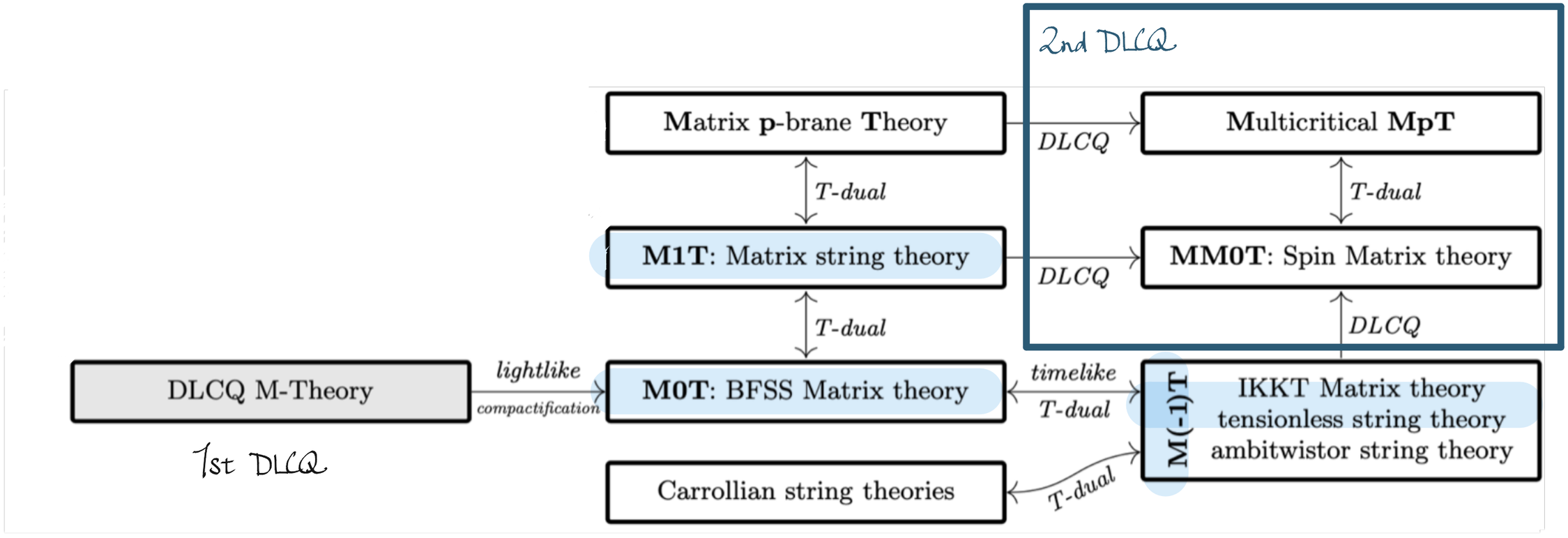
tensionless string [Lindström, Sundborg, Theodoridis '91]

$$S_{M(-1)T}=\frac{T}{2}\int d^2\sigma\,\partial_\tau X^\mu\partial_\tau X_\mu \qquad \mu=0,\cdots,9$$

D(-1)-instanton: IKKT Matrix theory

[Ishibashi, Kawai, Kitazawa, Tsuchiya '96]

Unification of Decoupling Limits



Many new arenas to be explored!

Thank You!