

Title: Quantum Order and Emergent Space in Holographic Phases of Matter

Date: Oct 18, 2011 02:00 PM

URL: <http://pirsa.org/11100057>

Abstract: In this talk, I will present a first principle construction of a holographic dual for gauged matrix models. The dual theory is a closed string field theory coupled with an emergent two-form gauge field defined in one higher dimensional space. The bulk space with an extra dimension emerges as a well defined classical background only when the two-form gauge field is in the deconfinement phase. Based on this, it is shown that critical phases that admit holographic descriptions form a novel universality class with a non-trivial quantum order.

Quantum Order, Emergent Space in Holographic phases of Matter - (1108.2253)

OUTLINE

- | | |
|--|-----------------------------------|
| I. Motivation | V. Closed String Field Theory |
| II. Quantum Order | VI. Holographic / non-holographic |
| III. Gauged Matrix Model | VII. Comments |
| IV. An Algorithm for general construction of holographic duals | |

I Motivation

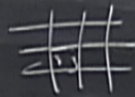
- 1) derive AdS/CFT
- 2) Do all QFT's have holo-duals?
- 3) qualification for QFT's that have holo-dual

II Quantum Order

III

G. Matrix Model

D-dim lattice



[U_{ij} $N \times N$ complex matrix ($\sim N^2$)
 $U_{ij} = V_i^\dagger U_{ij} V_j$, $V_i \in U(N)$]

$$S = N M^2 \underbrace{\text{tr}(U_{ij}^\dagger U_{ij})}_{O(N)} + N^2 V \left[\frac{W_c}{N} \right], \quad W_c = \text{tr} \left[\prod_{ij \in c} U_{ij} \right]$$

$S \sim O(N^2)$, $N \rightarrow \infty$

all mapped
 ↓ ↓ ↓
 diff types of sp

↑ ↑ ↑
 C ~ T ⊕
 V ~ T ⊕

$$V = \sum_{n=1}^{\infty} \sum_{c_1, c_n} \frac{J_{c_1 c_n}}{N^n} W_{c_1} \cdot W_{c_n}$$

general enough to include $U(N)$ gauge th.

$$U_{ij}^\dagger U_{ij} = n I$$

$$W_c = \frac{1}{N} \prod_{i \in c} \tau_i$$

$$V \sim \left[\frac{J_c}{N} \right] W_c$$

$\frac{1}{g^2}$

$$J \sim \frac{1}{Ng^2}$$

all mapped
 ↓ ↓ ↓
 diff types of sp

all mapped
 ↓ ↓ ↓
 $C \sim T \oplus$
 $V \sim T \oplus$

$$V = \sum_{n=1}^{\infty} \sum_{C_n} \frac{J_{C_n}}{N^n} W_{C_n}$$

• general enough to include $U(N)$ gauge th.

$$U_{ij}^\dagger U_{ij} = N I$$

$$W_C = \text{tr} \left[\prod_{ij \in C} U_{ij} \right]$$

$$V \sim \left[\frac{J_C}{N} \right] W_C \quad J \sim \frac{1}{Ng^2}$$

2.4 Construction of holo.-dual

$$Z[J_n(x)] = \int \mathcal{D}\varphi \, e^{-S[\varphi; J_n(x)]}$$

$$\uparrow \downarrow$$

$$-S[\varphi_k + \varphi_2, J_n] \quad \wedge \, e^{-i\int dx}$$

$$= \int \mathcal{D}\varphi_k \mathcal{D}\varphi_2 \, e^{-S[\varphi_k, f_n(J_n, \varphi_2)]}$$

$$= \int \mathcal{D}\varphi_k \mathcal{D}\varphi_2 \, e^{-S[\varphi_k, J_n] + i P_n (J_n - f(J_n, \varphi_2))}$$

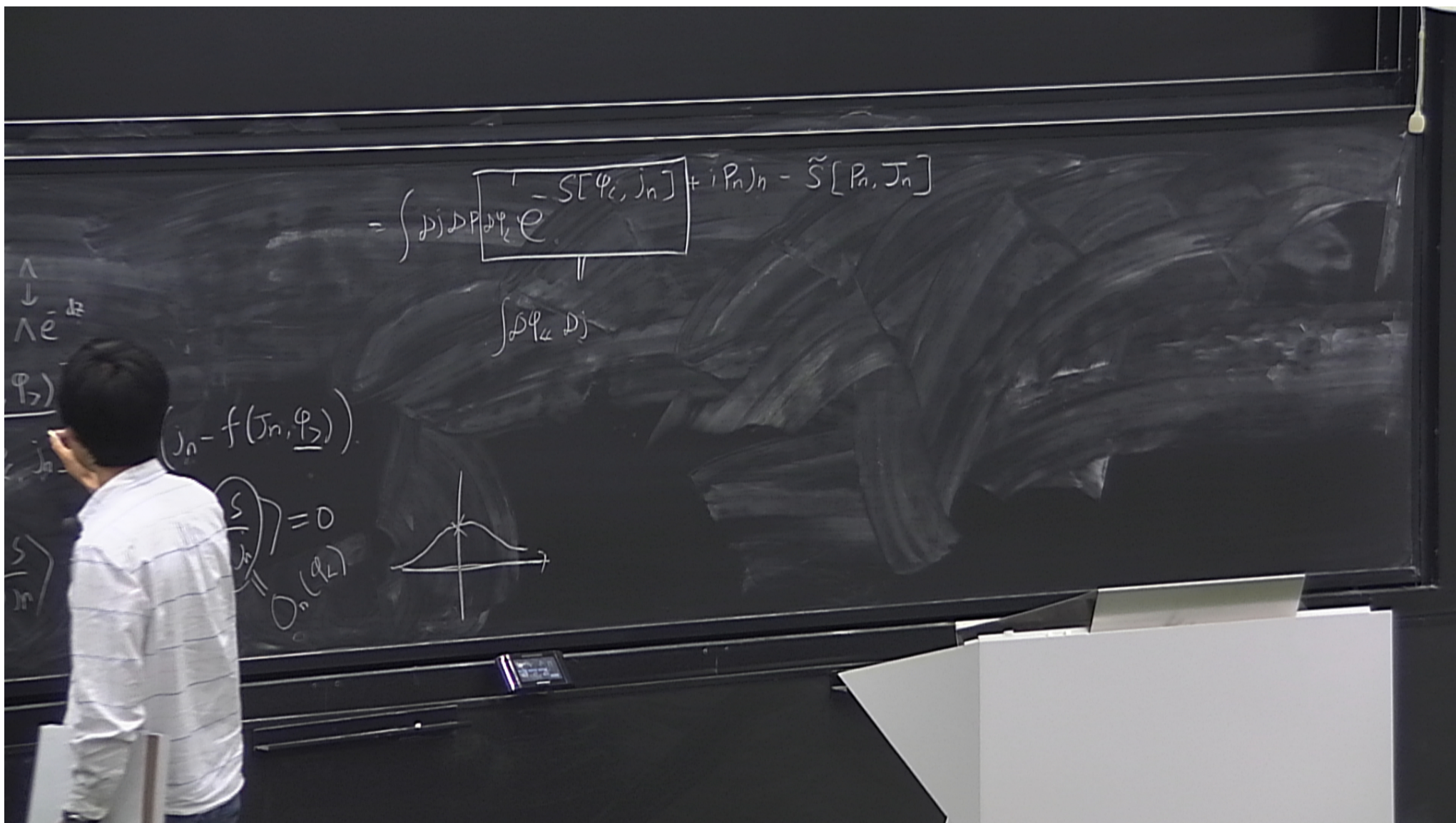
$$= \int \mathcal{D}j \, \mathcal{D}P \, \mathcal{D}\varphi_k \, \boxed{\mathcal{D}\varphi_2} \, e^{-S[\varphi_k, J_n] + i P_n (J_n - f(J_n, \varphi_2))}$$

$$0 = \left\langle \frac{\partial S}{\partial J_n} \right\rangle = \left\langle i P_n - \left(\frac{\partial S}{\partial J_n} \right) \right\rangle = 0$$

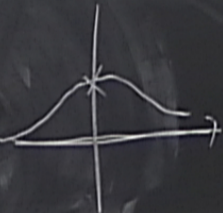
$$= 0_n(\varphi_k)$$

$$= \int \mathcal{D}j \, \mathcal{D}P \, e^{-S[\varphi_k, J_n] + i P_n J_n - \tilde{S}}$$



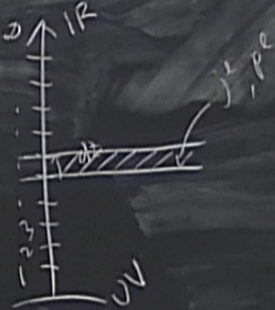


$\Lambda \bar{e} \quad \underline{P}_n$
 $\left[\frac{j_n^{(0)}}{j_n^{(1)}} + i P_n \left(\frac{j_n^{(1)}}{j_n^{(0)}} - f(j_n, \underline{P}_n) \right) \right]$
 $\left\langle \frac{S}{j_n} \right\rangle = \left\langle i P_n - \left(\frac{\partial S}{\partial j_n} \right) \right\rangle = 0$
 $\quad \quad \quad = O_n(q_L)$



$$= \int d j d P d \varphi_k e^{\frac{1}{\hbar} \left[-S[\varphi_k, j_n^{(0)}] + i P_n j_n^{(1)} - \tilde{S}[P_n^{(1)}, j_n] \right]}$$

$$\int d \varphi_k d j_n^{(0)} d P_n^{(1)} e^{-S[\varphi_k, j_n^{(0)}] + i P_n^{(1)} j_n^{(1)} - \tilde{S}[P_n^{(1)}, j_n^{(0)}]} \quad Z = \int d z$$



$Z = \int d j(x, z) d P(y, z) e^{\frac{S[j, P]}{\hbar}}$



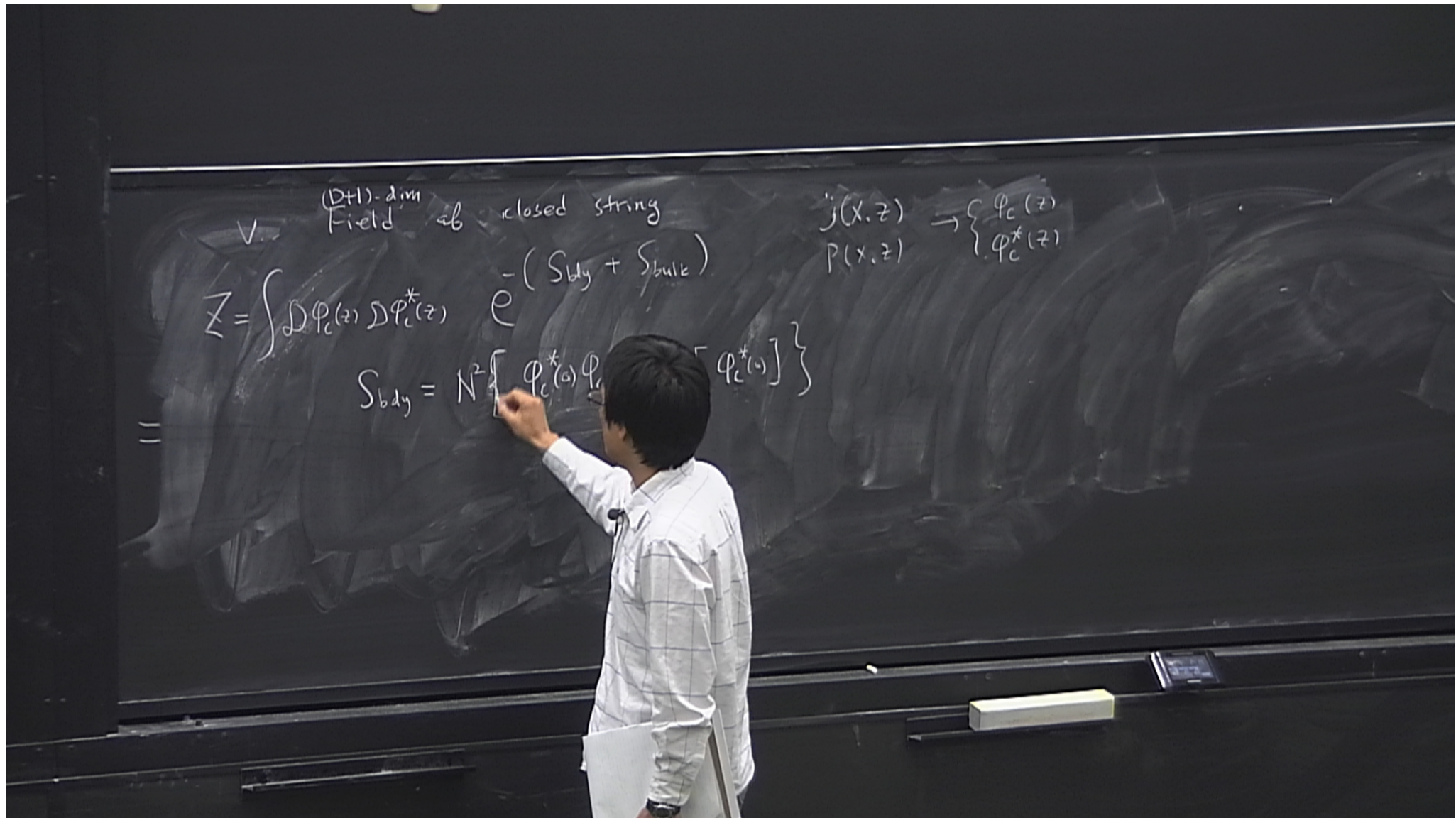
V.

(D+1)-dim
Field ab closed string

$$j(x,z) \rightarrow j_c(z)$$

$$Z = \int$$

==

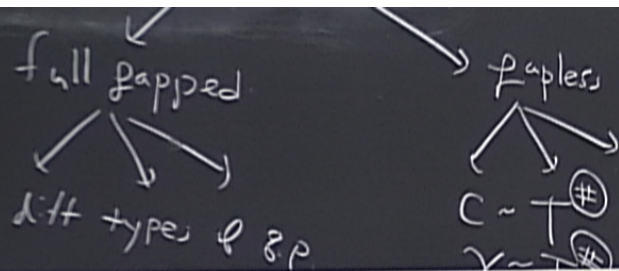


V (D+1)-dim
 Field ab closed string

$$Z = \int D\phi_c(z) D\phi_c^*(z) e^{-(S_{\text{bdy}} + S_{\text{bulk}})}$$

$$S_{\text{bdy}} = N^2 \left\{ \phi_c^*(0) \phi_c(0) + V[\phi_c^*(\cdot)] \right\}$$

$$\begin{aligned}
 j(x, z) &\rightarrow \phi_c(z) \\
 p(x, z) &\rightarrow \phi_c^*(z)
 \end{aligned}$$



$$I = \sum_{n=1}^{\infty} \sum_{c_1, c_n} \frac{J_{c_1 c_n}}{N^n} W_{c_1} \cdots W_{c_n}$$

general enough to include
 $U_{ij}^{\dagger} U_{ij} = n I$

$$V \sim \frac{J_c}{N} W_c \quad J \sim \frac{1}{Ng^2}$$

$$= \int d\varphi_c d\varphi_c^* e^{-J_{c_1 c_n} W_{c_1} \cdots W_{c_n} + i \varphi_c (\varphi_c^* - W_c)}$$

$$Z = \int D\varphi_c(z)$$

$$S_{\text{bulk}} =$$

(D+1)-dim
Field ab closed string

$$\begin{aligned} j(x,z) &\rightarrow \phi_c(z) \\ p(x,z) &\rightarrow \phi_c^*(z) \end{aligned}$$

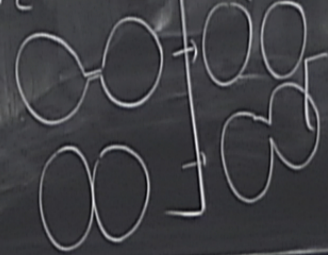
$$Z = \int D\phi_c(z) D\phi_c^*(z) e^{-(S_{\text{bdy}} + S_{\text{bulk}})}$$

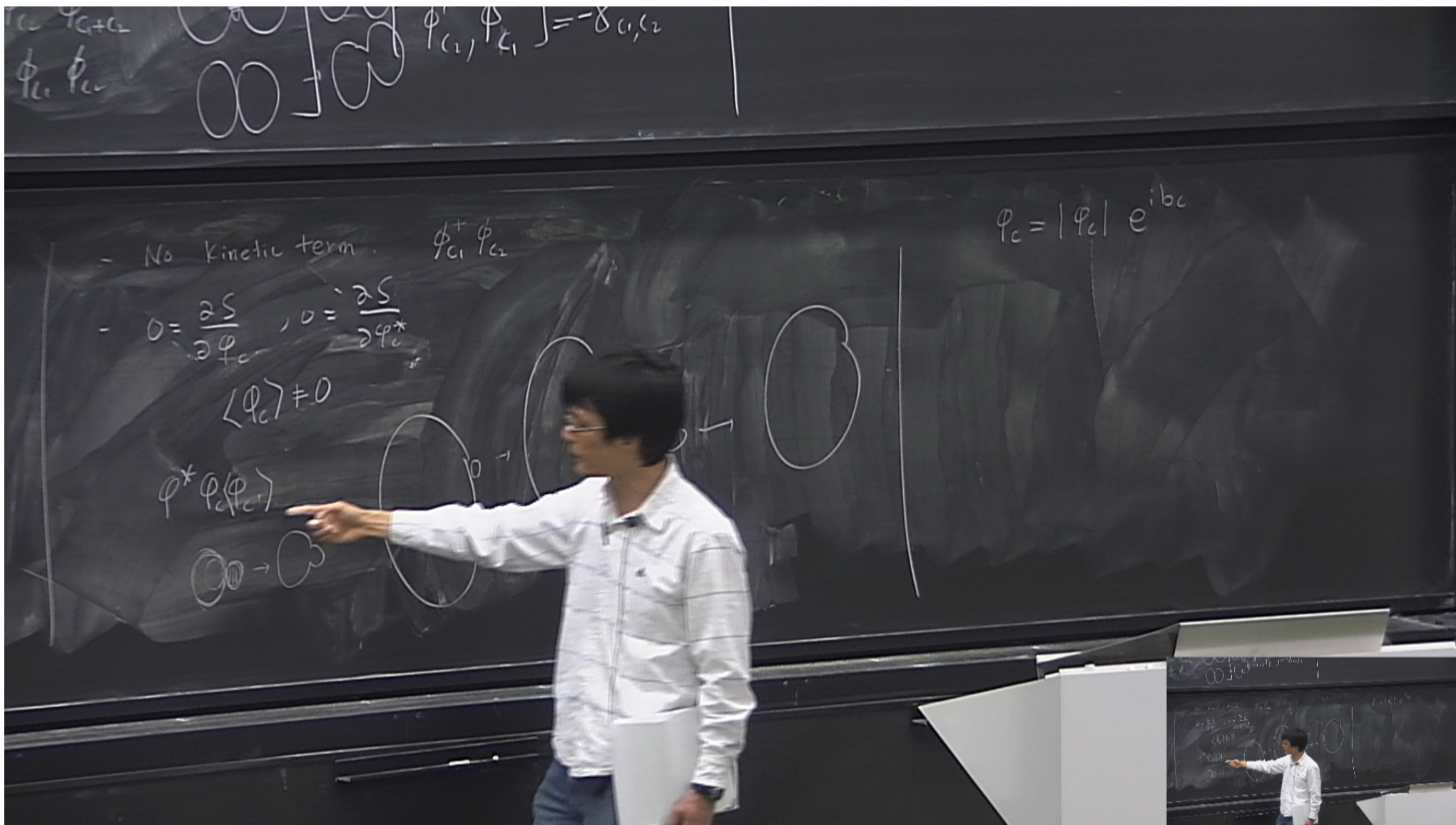
$$S_{\text{bdy}} = N^2 \left\{ \phi_c^*(0) \phi_c(0) + V[\phi_c^*(0)] \right\}$$

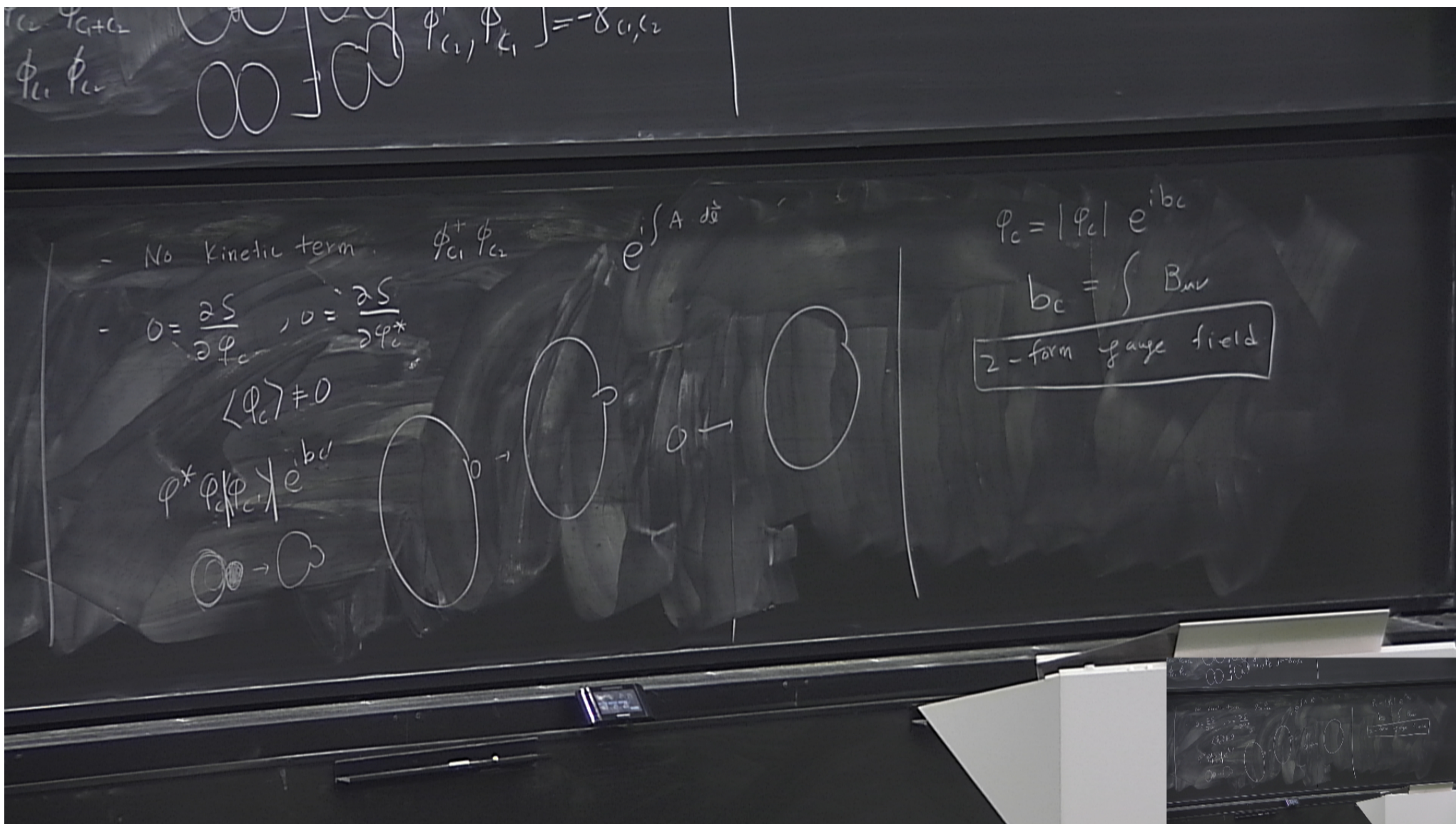
$$0 = \frac{\partial S}{\partial \phi_c^*(0)} = \phi_c(0) + \frac{\partial V[\phi^*]}{\partial \phi_c^*}$$

$$S_{\text{bulk}} = \int_0^\infty dz \left[\phi_c^* \partial_z \phi_c + L_c \phi_c^* \phi_c \right. \\ \left. - \# \phi_{c_1}^* \phi_{c_2}^* \phi_{c_1+c_2} \right. \\ \left. - \phi_{c_1+c_2}^* \phi_{c_1} \phi_{c_2} \right]$$

$$V = -T_c \phi_c^* - T_{c_1 c_2} \phi_{c_1}^* \phi_{c_2}^* \\ [\phi_{c_1}^*, \phi_{c_1}] = -\delta_{c_1, c_2}$$





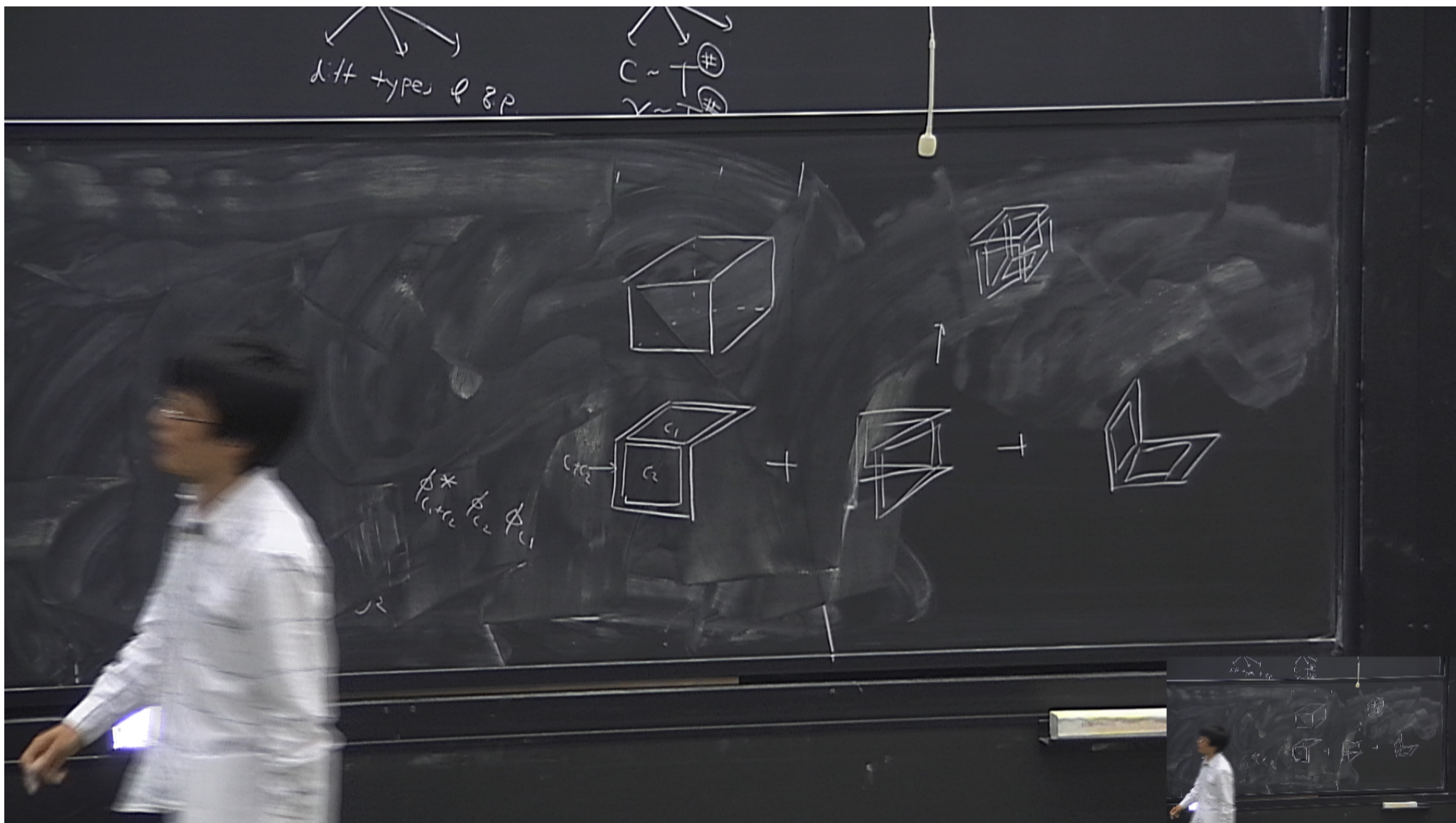


$$\frac{1}{g^2} \int H^2$$

$$\int_{2-f}^2 = \infty$$

$$g_{2-f}^2 \sim \frac{1}{N^2}$$

$$H = dB$$



$$\frac{1}{g_{2-f}^2} \int H^2$$

$$\boxed{g_{2-f}^2 = \infty}$$

$$g_{2-f}^2 \sim \frac{1}{N^2}$$

$$H = dB$$

Compact 2-form

$$e^{ibc} = e^{i(b_c + 2\pi)}$$

$$\begin{array}{ccc} {}^3H & \xleftrightarrow{(D+1)} & {}^{D-2}\tilde{H} \\ \uparrow & & \uparrow \\ {}^2B & & {}^{D-3}\tilde{B} \end{array}$$

D-3

$\boxed{NS_{(D-4)}\text{-brane}}$

