Title: Quantizing Null Hypersurfaces

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Series: Quantum Gravity

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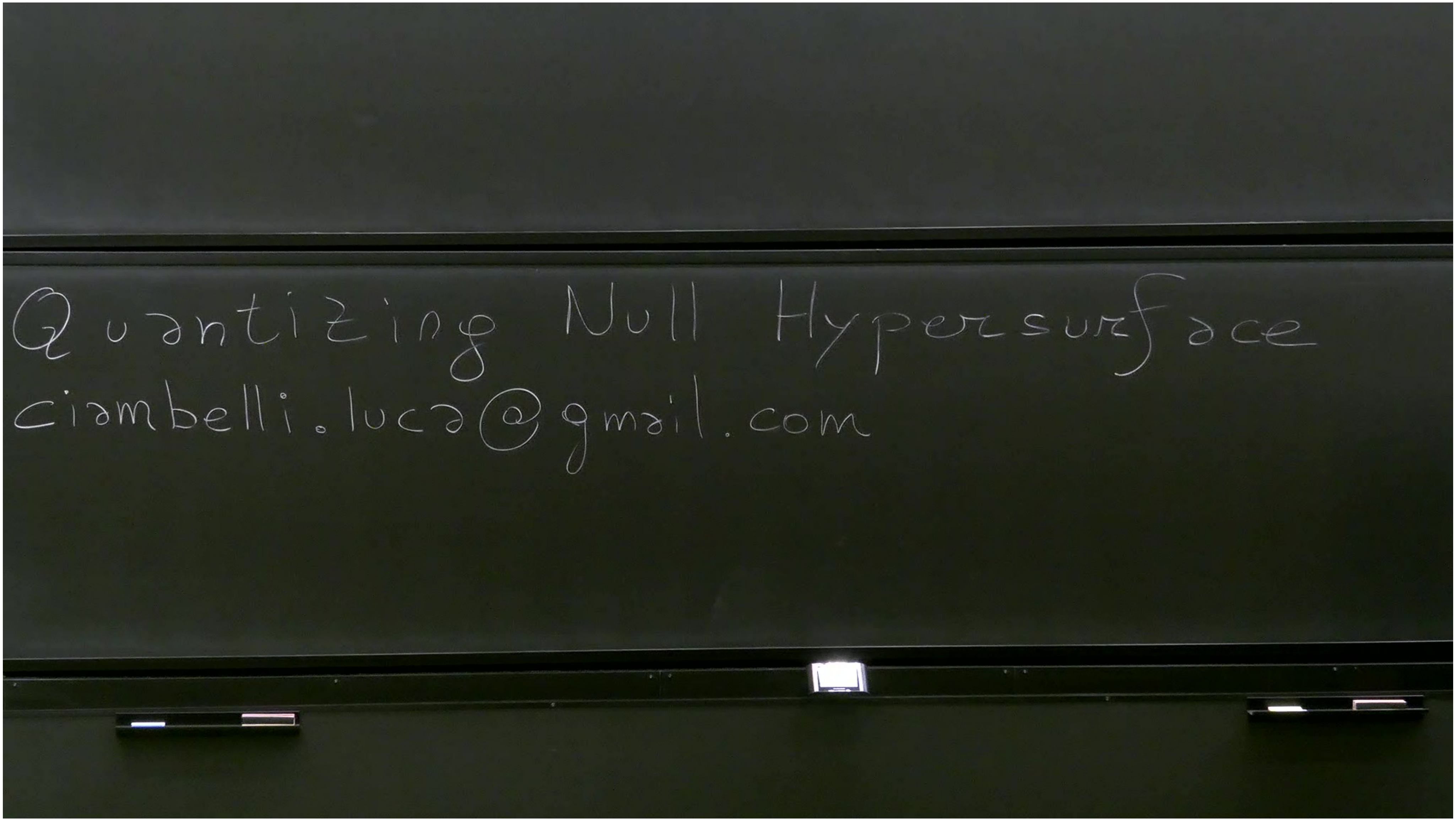
Abstract: In this talk, we first present a detailed analysis of theÂ classical geometry of generic null hypersurfaces. We then reformulateÂ the Einstein equations as conservation laws for the intrinsicÂ geometric data on these hypersurfaces. Following this, we derive theÂ symplectic structure and the corresponding Poisson bracket. UponÂ quantizing this phase space, we propose that the projected EinsteinÂ tensor obeys the operator product expansion of the stress tensor in aÂ conformal field theory along null time. This hypothesis is supportedÂ by explicit computations in simplified scenarios, such as the absenceÂ of radiation and within the framework of perturbative gravity.
Notably, we discover a non-vanishing central charge, which counts the
local geometric degrees of freedom and diverges in the classicalÂ limit. We suggest that this central charge is a fundamental principleÂ underlying the emergence of time in quantum gravity. If time permits,Â we will conclude by introducing a mesoscopic model of quantum gravityÂ on null hypersurfaces, based on the concept of the "embadon," anÂ operator that creates localized bits of area on cuts.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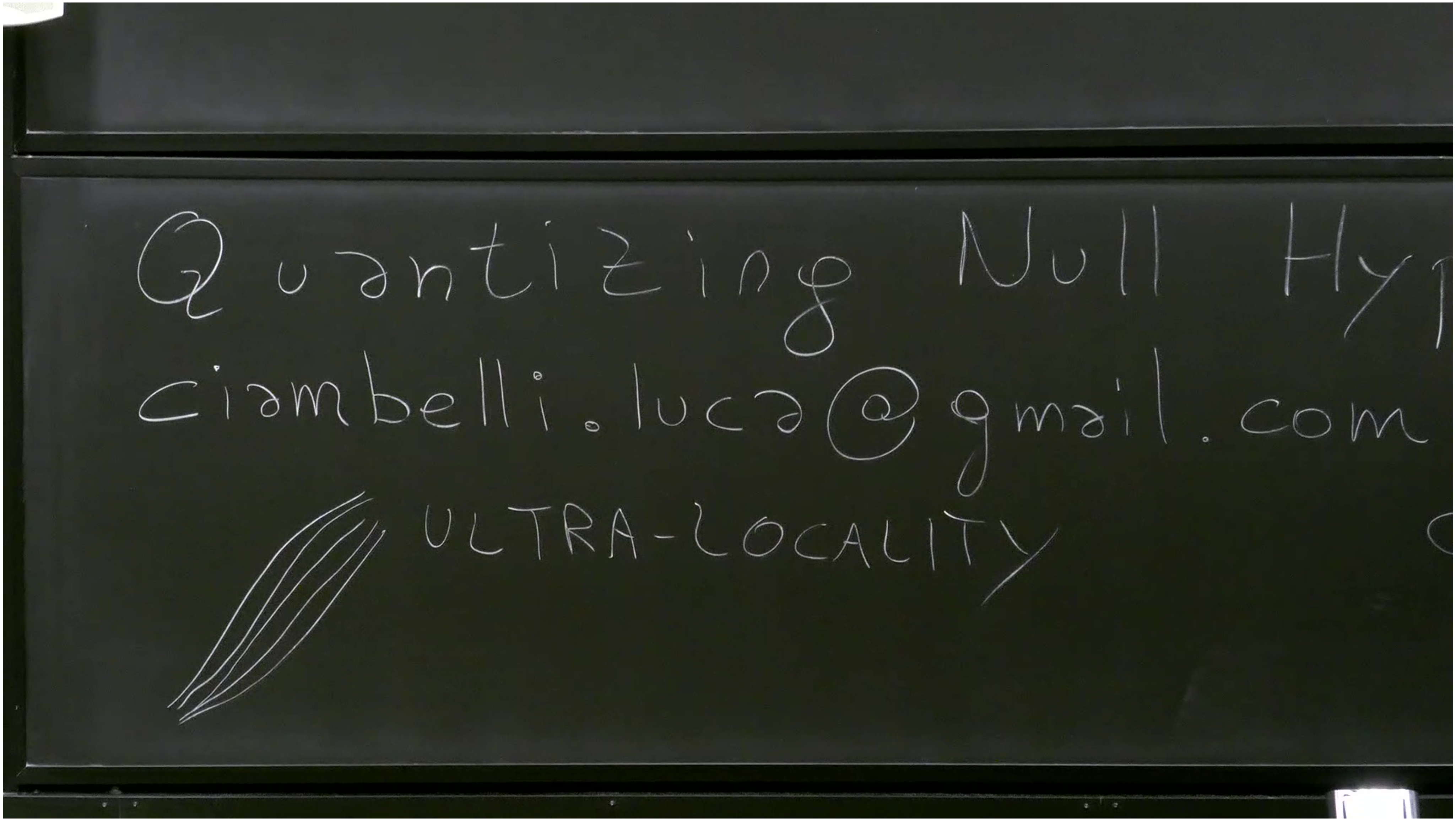
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ULTRA-LOCALITY

Hypersurface

om

CONFORMALITY

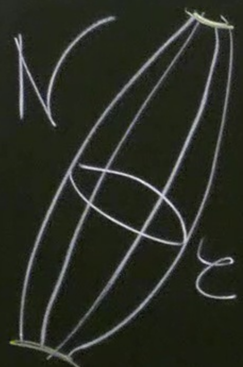
Einstein $\longrightarrow$

θ

1) Raychaudhuri

2) <u>Damour</u>

$G \longrightarrow DT = 0$



Carrollian Structure

$\theta_a{}^b k_b =$

$\ell^a \neq 0, \quad \ell^a q_{ab} = 0 \qquad (\ell, q)$

Ruling $k_a \ell^a = 1 \qquad q_a{}^b = \delta_a{}^b - k_a \ell^b$

$\theta_{ab} = \frac{1}{2} \mathcal{L}_\ell q_{ab} \qquad \theta_a{}^b = \frac{1}{2} \theta q_a{}^b + \sigma_a{}^b \qquad \theta_a{}^b q_{bc} = \theta_{ac}$

$$\theta_{ab} = \frac{1}{2}\alpha_\ell q_{ab} \qquad \theta_a{}^b = \frac{1}{2}\theta q_a{}^b + \sigma_a{}^b \qquad \theta_a{}^b q_{bc} = \theta_{ac}$$

$$D_a \epsilon_N = -\omega_a \epsilon_N$$

$$\epsilon_N = k \wedge \epsilon_\ell$$

$$\omega_a = \kappa k_a + \pi_a$$

$$\pi_a \ell^a = 0$$

$$T_a{}^b \equiv$$

$$\theta_{ab} = \frac{1}{2}\mathcal{L}_\ell q_{ab} \qquad \theta_a{}^b = \frac{1}{2}\theta q_a{}^b + \sigma_a{}^b \qquad \theta_a{}^c q_{bc} = \theta_{ac} \ldots$$

$$D_a \mathcal{E}_N = -\omega_a \mathcal{E}_N \qquad \boxed{\mu = \kappa + \frac{\theta}{2}}$$

$$T_a{}^b \equiv$$

Null Br...

$$\mathcal{E}_N = k \wedge \mathcal{E}_\ell \qquad \omega_a = \kappa k_a + \pi_a$$

$$\pi_a \ell^a = 0$$

$$\boxed{D_b T_a{}^b \ldots}$$

$$\ell^a D_b T_a{}^b = C = (\mathcal{L}_\ell + \theta)\theta - \mu\theta + \sigma_a{}^b \sigma_b{}^a$$

$$q_c{}^a D_b T_a{}^b = P_c = (\mathcal{L}_\ell + \theta)\pi_a + \ldots$$

$\theta_a{}^b q_{bc} = \theta_{ac}$

$+\frac{\theta}{2}$

$+\Pi_a$

a

$$T_a{}^b \equiv D_a l^b - \delta_a^b D_c l^c$$

Null Brown-York

$$\boxed{D_b T_a{}^b \triangleq T^{mat}_{ab}\, l^b}$$

$$T_{ab} = D_{(a} l^c q_{b)c}$$

$$T_{\mu\nu} = 2 D_{(\mu} n_{\nu)}$$

$$\Theta^{can} = \frac{1}{8\pi G}\int_{N}\left(\frac{1}{2}\tau^{ab}\,\delta q_{ab} - \tau_a\,\delta l^a\right)$$

$$T_a{}^b = \tau_a{}^b + \tau_a l^b$$

$$\tau_a{}^b k_b = 0$$

$$\Theta^{can} = \int T^{\mu\nu}\,\delta g_{\mu\nu}$$

$\ell^a)$

$$\Omega^{con} = \delta \Theta^{con}$$

$$Q_\xi = \int_{N} \xi^b \underbrace{D_a T_b{}^a} + \int_{\mathcal{C}} \varepsilon_b \, \xi^a T_a{}^b$$

$$\Theta^{can} = \frac{1}{8\pi G}\int_N \left(\frac{1}{2}\tau^{ab}\delta q_{ab} - \tau_a \delta l^a\right)$$

$$T_a{}^b = \tau_a{}^b + \tau_a l^b$$

$$\Theta^{can} = \int T^{\mu\nu}\delta g_{\mu\nu}$$

$$\tau_a{}^b k_b = 0$$

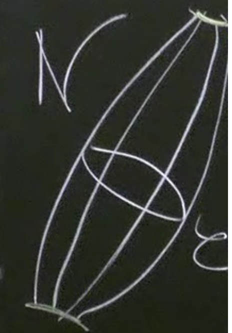
$$\xi^a = f l^a + \cancel{Y^b q_b{}^a}$$

$$\delta_\xi l = [f l, l]$$

$$\Omega^{con} = \delta \Theta^{con}$$

$$\underbrace{\int_{\mathcal{N}} \xi^b \underbrace{D_a T_b{}^a}}_{\mathcal{N}} + \underbrace{\int_{\mathcal{E}} \varepsilon_b \, \xi^a T_a{}^b}_{\mathcal{E}}$$

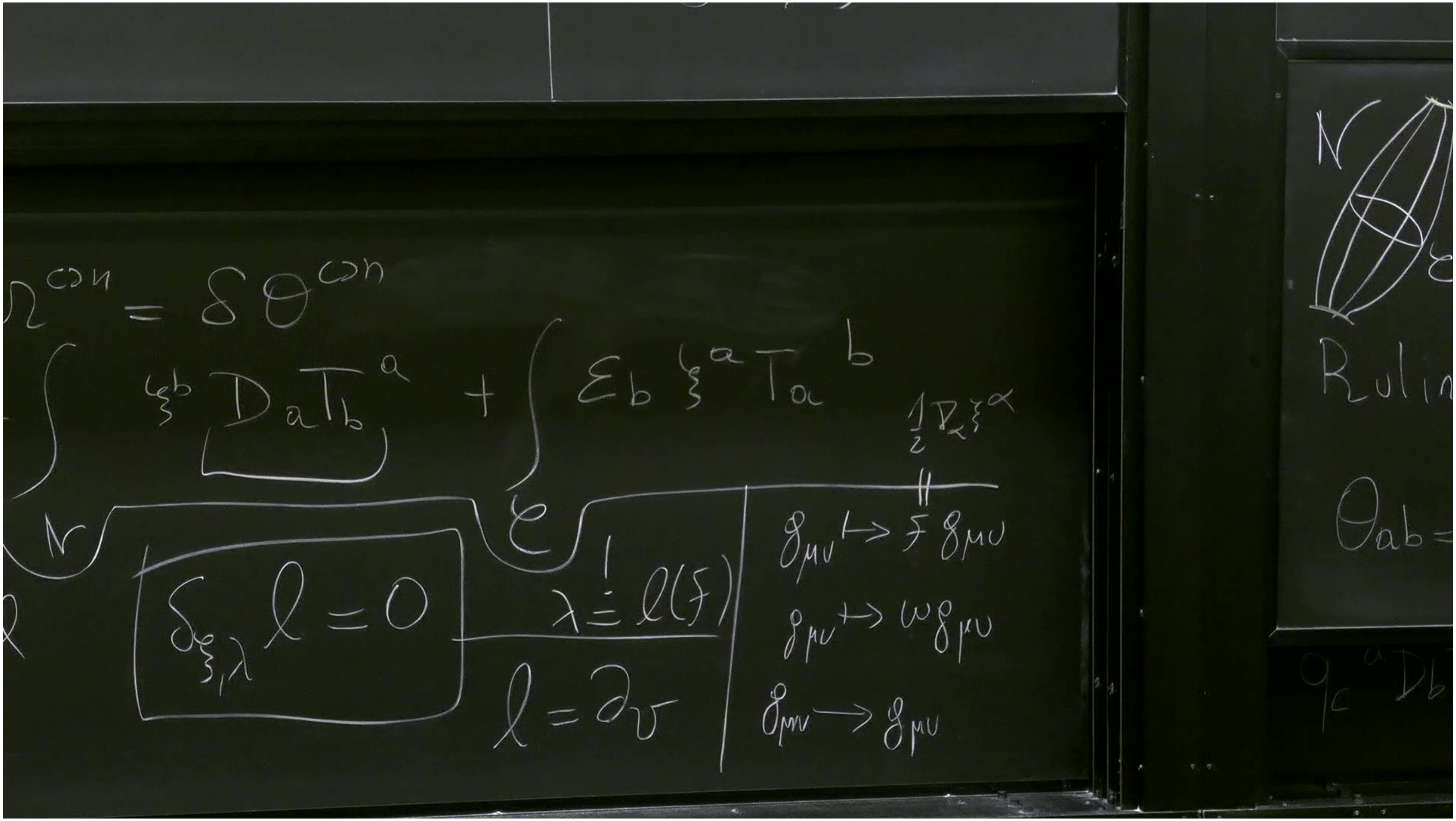
$$\boxed{\delta_{\xi,\lambda} \, l = 0} \qquad \lambda \overset{!}{=} l(f)$$



Rulin

$\Theta_{ab} =$

$g_c{}^a D_b$


Ω^con = δΘ^con
ξ^b D_a T_b^a + ∫ ε_b ξ^a T_a^b
N
C
1/2 ∇_α ξ^α
g_μν ↦ f g_μν
δ_{ξ,λ} ℓ = 0
λ ≐ ℓ(f)
g_μν ↦ ω g_μν
ℓ = ∂v
g_μν → g_μν
Rulin
Θ_ab =
q_c^a D_b

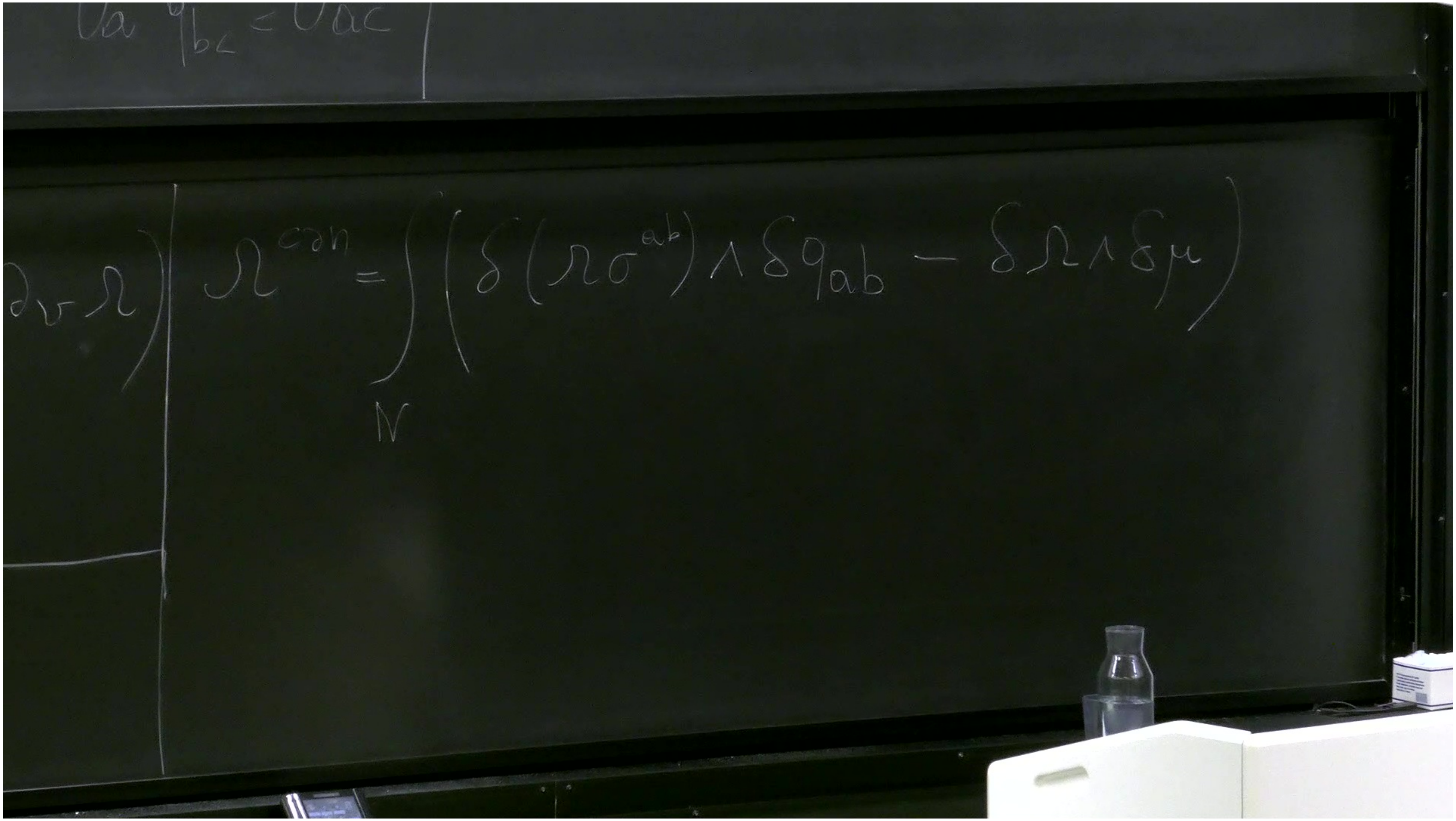
$$\sigma_{ab} = \frac{1}{2} \ldots \ell\, q_{ab} \qquad \sigma_a = \frac{1}{2}\theta q_a{}^b + \sigma_a{}^b \qquad \ldots q_{bc} = \ldots$$

$$Q_f = \frac{1}{8\pi G}\int_{N} f\, C + \int_{\mathcal{E}} \left(\Omega\, \partial_v f - f\, \partial_v \Omega\right)$$

$$\int_{\mathcal{E}} \Omega = A$$

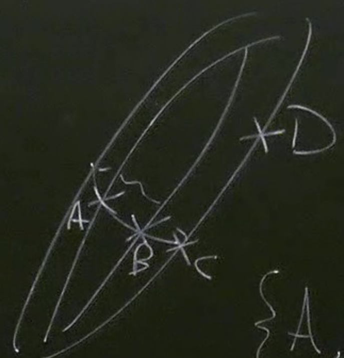
$$q_{ab} = \Omega\, \bar{q}_{ab}$$

$$q_{ab},\ \sigma_{ab},\ \mu \longrightarrow (\Omega, \mu),\ (\sigma^{ab}, \bar{q}_{ab})$$


$\Omega^{can} = \int_N \left(\delta(\Omega \sigma^{ab}) \wedge \delta q_{ab} - \delta\Omega \wedge \delta\mu \right)$

$$\delta \pi_a \wedge \delta e^a$$

$$(B_i, A_i) = (\Omega, \mu, \sigma, \bar{q}, \pi, e)$$



$$\{A^1_i, B^2_\delta\} = F(v_1, v_2)\, C_{i\delta}\, \boxed{\delta(z_1 - z_2)\, \delta(\bar{z}_1 - \bar{z}_2)}$$

$$\{A, B\} = 0 \qquad x_1 = (v_1, z_1, \bar{z}_1)$$

$$\{C, D\} \neq 0$$

$$\{C_f, C_g\} = -8\pi G\, C_{[f,g]}, \quad C_f = \int_N f\, C \Rightarrow \{C_f, \cdot\} = \delta_f$$

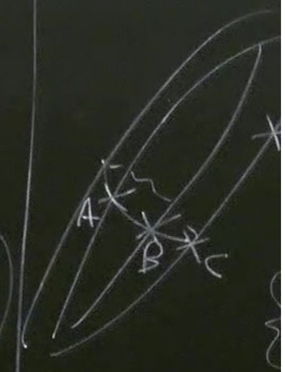
$\delta \pi_L a \wedge \delta e$

$(B_i, A_i) = (\Omega, \mu, \sigma, \bar{q},$

"$C \longrightarrow \dfrac{\hat{C}}{4G\hbar}$"

$$\langle \phi_1 \phi_2 \rangle = \delta_{12}$$

$$\hat{C}_1 \hat{C}_2 \sim \left(\frac{cN}{2(v_{12}-i\epsilon)^4} + \frac{2\hat{C}_2}{(v_{12}-i\epsilon)^2} + \frac{\partial_{v_2}\hat{C}_2}{v_{12}-i\epsilon} \right) \delta(z_{12})$$



$$f C \Rightarrow \{ C_f , \cdot \} = \delta_f$$

$$\Theta_{ab} = \frac{1}{2} \mathcal{L}_\ell q_{ab}$$

$$\delta \pi_a \wedge \delta \ell^a$$

$$(B_i, A_i) = (\Omega, \mu, \sigma, \bar{q}, \pi, \ell)$$

$$Q_f = \frac{1}{8\pi G} \int f C$$

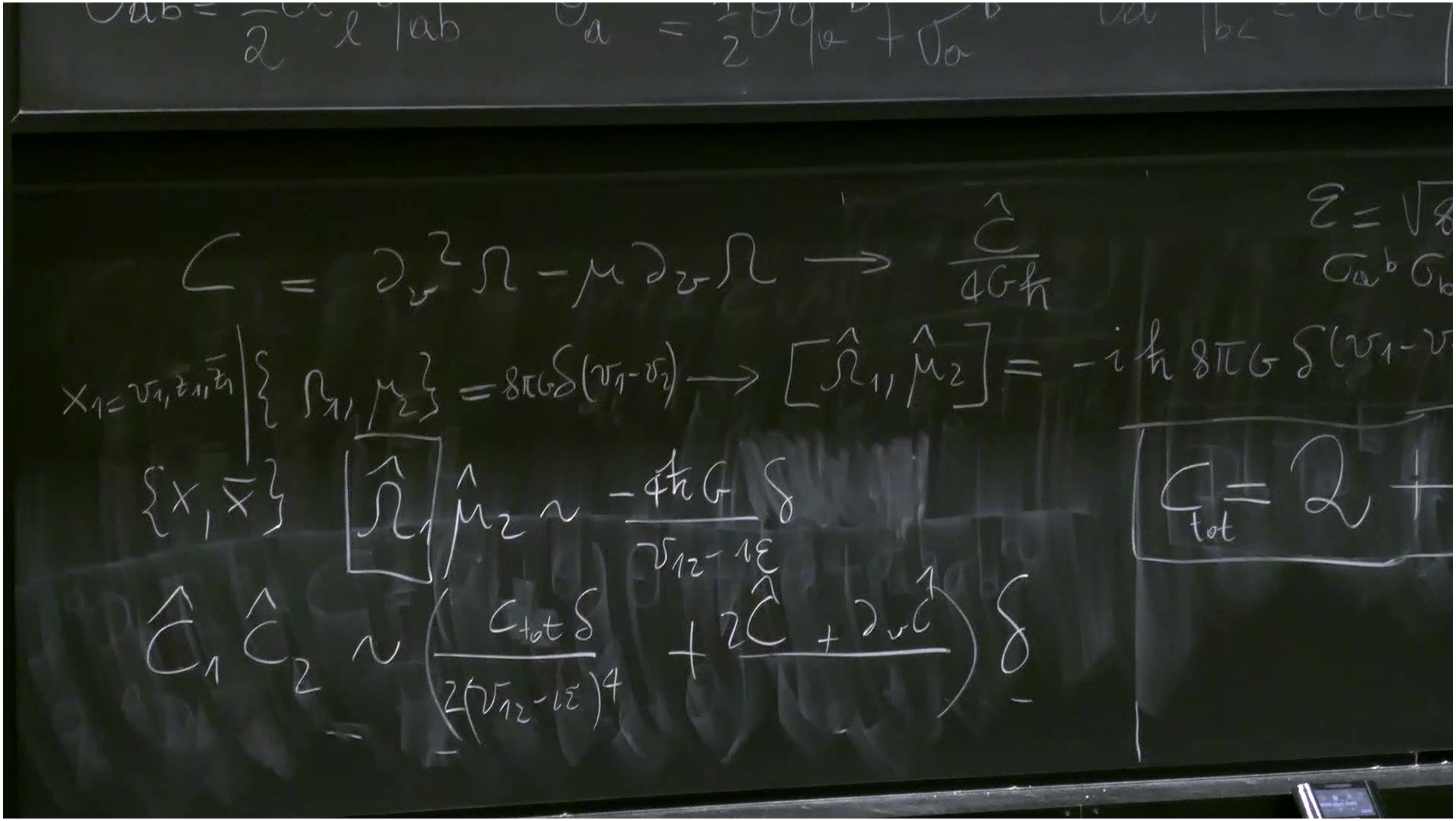
$$\{ A^1_i , B^2_j \} = F(v_1, v_2)\, C_{ij} \boxed{\delta(z_1 - z_2)\, \delta(\bar{z}_1 - \bar{z}_2)}$$

$$1 = (v_1, z_1, \bar{z}_1)$$

$$q_{ab} = \Omega\, \bar{q}_{ab}$$

$$\langle \phi_1 \phi_2 \rangle \sim \frac{1}{X_{12}^{2\Delta_1 \Delta_2}}$$

$$q_{ab}, \sigma_{ab}, \mu \longrightarrow (\Omega, \mu)$$


$C = \partial_v^2 \Omega - \mu \partial_v \Omega \longrightarrow \frac{\hat{C}}{4G\hbar}$
$x_1 = v_1, z_1, \bar{z}_1$
$\{\Omega_1, \mu_2\} = 8\pi G \delta(v_1 - v_2) \longrightarrow [\hat{\Omega}_1, \hat{\mu}_2] = -i\hbar\, 8\pi G\, \delta(v_1 - v$
$\{x, \bar{x}\}$
$\boxed{\hat{\Omega}_1} \hat{\mu}_2 \sim -\frac{4\hbar G}{v_{12} - i\varepsilon} \delta$
$\hat{C}_1 \hat{C}_2 \sim \left(\frac{C_{tot}\, \delta}{2(v_{12} - i\varepsilon)^4} + \frac{2\hat{C} + \partial_v C}{} \right) \delta$
$\boxed{C_{tot} = Q +}$
$\varepsilon = \sqrt{8}$
$\sigma_a{}^b \sigma_b$

"$C \longrightarrow \frac{\hat{C}}{4G\hbar}$"

$\langle \phi_1 \phi_2 \rangle = \frac{\delta_{12}}{v_{12}}$

$\#/ \times$ Number of

$$\hat{C}_1 \hat{C}_2 \sim \left(\frac{\boxed{cN}}{2(v_{12}-i\varepsilon)^4} + \frac{2\hat{C}_2}{(v_{12}-i\varepsilon)^2} + \frac{\partial_{v_2}\hat{C}_2}{v_{12}-i\varepsilon} \right) \delta(z_{12})$$