

Title: PSI 2017/2018 - Quantum Gravity - Lecture 15

Date: Apr 06, 2018 10:15 AM

URL: <http://pirsa.org/18040012>

Abstract:

QG?

Loops

Holography

QG = all loop calculation for graviton scattering:

- Loops
- ST
- NC
- 't Hooft: Holography
- Index-cal

Holography

N.C.G

Holography

N.C.G

Shing Heay

QG?

QG = all loop calculation for graviton scattering! ✓

- Loops
- ST
- NC
- 't Hooft: Holography
- Subrelativistic

Geometry:

Loops
Relativistic

Holography

QG?

QG = all loop calculation for graviton scattering! ✓

- Loops
- ST
- NC
- 't Hooft: Holography
- AdS/CFT

Geometry: $(M, [,], g, \nabla)$
 $\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$
 ph metric distance transport

Loops

Relativist

Holography

raphy

N.C.G

Shing Heay
Atomish

Q Q? What is the point?

Q Q = all loop calculation for graviton scattering ✓

- Loops
- ST
- NC
- 't Hooft: Holography
- Subclass

Geometry: $(M, [,], g, \nabla)$

$\underbrace{\begin{matrix} \downarrow \\ \kappa \\ \downarrow \\ p_k \end{matrix}}_{\text{metric}} \quad \underbrace{\begin{matrix} \downarrow \\ \text{matter} \\ \downarrow \end{matrix}}_{\text{metric}} \quad \underbrace{\begin{matrix} \downarrow \\ g \\ \downarrow \\ \text{distance} \end{matrix}}_{\text{metric}} \quad \underbrace{\begin{matrix} \downarrow \\ \nabla \\ \downarrow \\ \text{transport} \end{matrix}}_{\text{metric}}$

Loops

Relativist

Holography

QG? What is the point?

QG = all loop calculation for gravitation scattering! ✓

- Loops
- ST
- NC
- 't Hooft: Holography
- Subclass

Geometry: $(\Pi, [,], g, \nabla)$

$\underbrace{\begin{matrix} \pi \\ \downarrow \\ p_h \end{matrix}}_{\text{ph}} \quad \underbrace{\begin{matrix} \downarrow \\ \text{inter-} \\ \text{connected} \end{matrix}}_{\text{inter-}} \quad \begin{matrix} g \\ \downarrow \\ \text{distance} \end{matrix} \quad \begin{matrix} \nabla \\ \downarrow \\ \text{transport} \end{matrix}$

$\hbar, G$

• (ℓ_P, Π_P)

→ $\begin{cases} \ell_P \Pi_P = \hbar \\ \frac{\Pi_P}{\ell_P} = \frac{1}{G} \end{cases}$

Loops

Relativist

Holography

Holography

N.C.G

Shing Heay
Atomish

- respectability
with a fundamental length scale

Holography

N.C.G

Shing Heay
Atomish

• respect relativity
with a fundamental length scale

Emergence

Holography

N.C.G

Shing Heey
Atomish

• Respect relativity
with a fundamental length scale

Emergence

• Difference invariance →

Holography

N.C.G

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- respect relativity
with a fundamental length scale

Emergence

- Diffeomorphism $\rightarrow \hat{H} = 0, \hat{D}_a \in 0$

Holography

N.C.G

Shing Hee
Atanish

• Respect relativity
with a fundamental length scale

Energy

• Diffeomorphism $\rightarrow \hat{H} = 0, \hat{D}_a = 0$

• $\textcircled{R}_S$ $E = \cancel{E_R} + E_S$
 $P_a = \cancel{P_{aR}} + P_{aS}$

Holography

N.C.G

String Theory
AdS/CFT

• respect relativity
with a fundamental length scale

Energy

$$H = \underbrace{H_G}_{\text{soft}} + \underbrace{H_m}_{\text{hard}} = 0$$

• Diffeomorphism invariance $\rightarrow \hat{H} = 0, \hat{D}_a \neq 0$

• $\left. \begin{array}{l} \textcircled{R}_S \\ E = \cancel{E_R} + E_S \\ P_a = \cancel{P_{Ra}} + P_{Sa} \end{array} \right\}$

Holography

N.C.G

String Theory
AdS/CFT

• respect relativity
with a fundamental length scale

Energy

• Diffeomorphism invariance $\rightarrow \hat{H} = 0, \hat{D}_a = 0$

• $\left. \begin{array}{l} \textcircled{R}_S \\ E = \cancel{E_R} + E_S \\ P_a = \cancel{P_{Ra}} + P_{Sa} \end{array} \right\}$

$$H = \underbrace{H_G}_{\text{soft}} + \underbrace{H_m}_{\text{hard}} = 0$$

phy

N.C.G

Shing Heay
Atomish

relativity

fundamental length scale

Emergence

$$H = \underbrace{H_G}_{\text{soft}} + \underbrace{H_m}_{\text{hard}} = \mathcal{D}(\)$$

invariance

$$\rightarrow \hat{H} = 0, \hat{D} \in \mathbb{C}$$

$$\left. \begin{aligned} E &= \cancel{P_b} + E_S \\ P &= \cancel{P_b} + P_S \\ 0 &= 0 \end{aligned} \right\}$$

phys

N.C.G

Strong Heavy
Atomish

relativity
fundamental length scale

Emergence

$$H = \underbrace{H_G}_{\text{soft}} + \underbrace{H_m}_{\text{hard}} = \mathcal{D}_d()$$

$\circ T \nearrow \underline{E > 0} : \underline{\text{non screening}}$

invariance $\rightarrow \hat{H} = 0, \hat{\mathcal{D}}_d < 0$

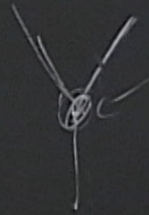
$$\left. \begin{aligned} E &= \cancel{E_R} + E_S \\ P &= \cancel{P_R} + P_S \end{aligned} \right\}$$

String Theory

PP : paint like palette

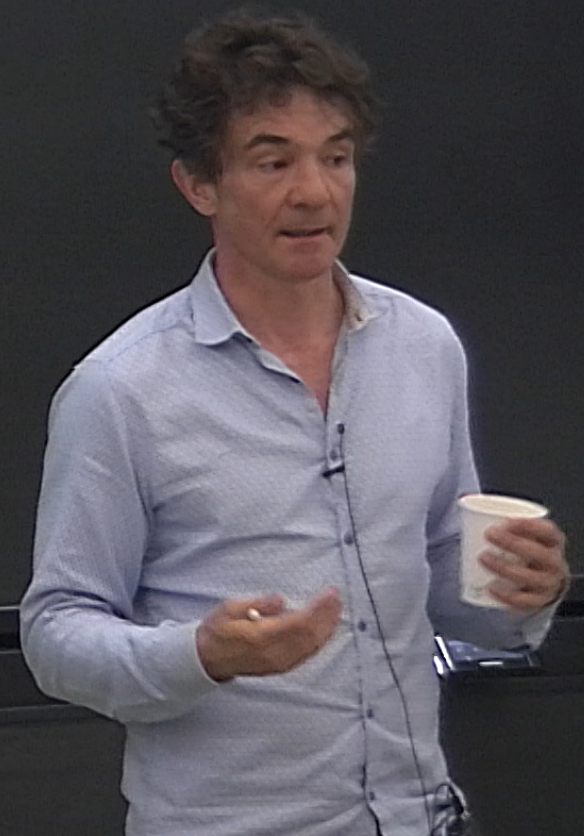
String Theory

PP : point like particle



String Theory: Friedman

PP: point like particle



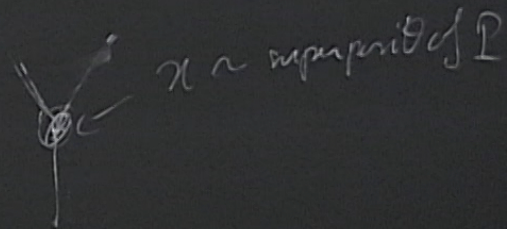
• String Theory: Friedman

• PP : point like particle : extrinsic P



• String Theory: Friedman

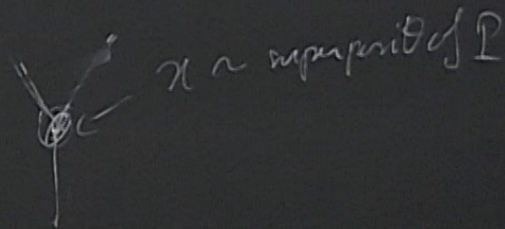
• PP : point like particle : extension P



• String Theory: Friedan

• PP: point like particle: extrinsic P

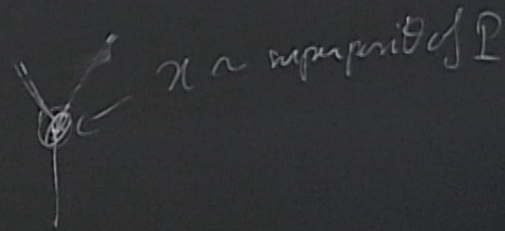
• relativity:



• String Theory: Friedman

• PP: point like particle: extrinsic

• relativity: γ dal Lorentz = $\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \beta^2}}$

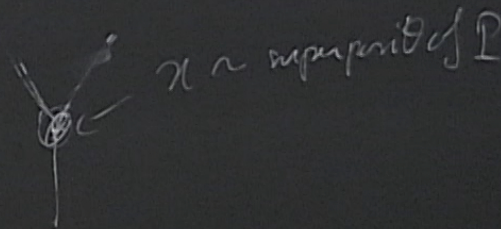


• String Theory: Friedman

• PP: point like particle: even P

• relativity: $\gamma \text{ dal Lorentz} = \frac{1}{\sqrt{1 - \beta^2}} = \frac{1}{\sqrt{1 - \alpha^2}}$

• $e^{i \frac{1}{2\pi\alpha'} \int \partial x \cdot \bar{\partial} x} \leftarrow e^{i \frac{1}{2\pi} \int \sqrt{\dot{x}}^2}$



ay: Friedan

like particle : exhibit P

$$\text{del tension} = \frac{N}{L} = \frac{1}{q} = \alpha'$$

$$x(\partial x) \leftarrow e^{-\frac{i}{2\pi} \int \sqrt{x}^2}$$



ST₂ 2d.CFT

ST₂ isomorphism: $P_2 = 0$

ex: Friedan

like particle : exhibit P

$$\text{del tension} = \frac{N}{L} = \frac{1}{q} = \alpha'$$
$$x \cdot \partial x) \leftarrow e^{-\frac{i}{\hbar} \int \sqrt{x}^2}$$

ST₂. 2d.CFT

ST eq of motion: $p_a = 0 \Rightarrow \frac{\partial S}{\partial g^a} = 0$

F.T $g_a \hat{O}_a$

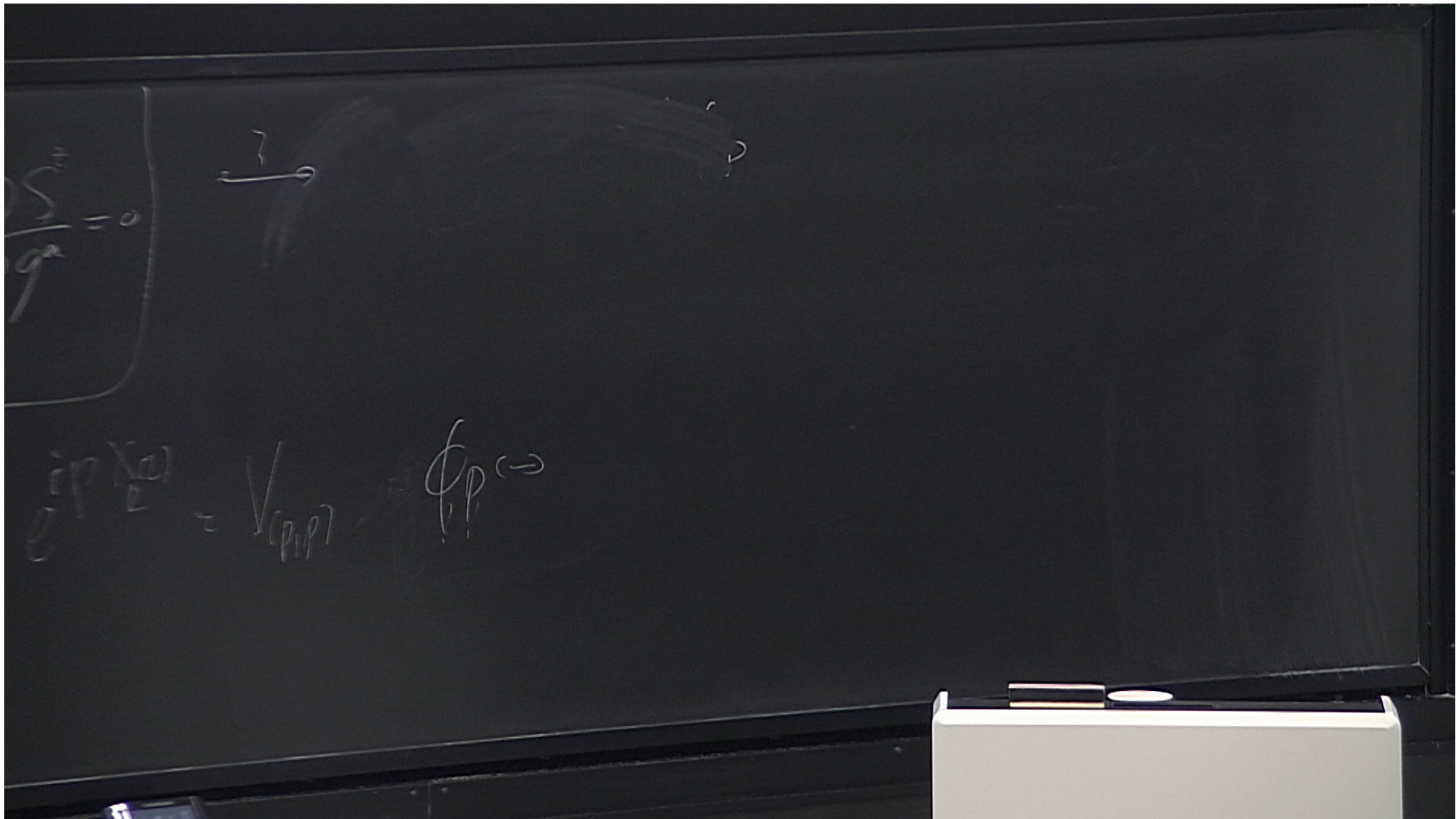
ST. 2d. CFT

ST eq of motion: $p_a = 0 \Rightarrow \frac{\partial S^z}{\partial g^a} = 0$

F.T $g_a \hat{O}_a$

$$\phi(x) = \int dx e^{ipx} \phi_p$$

$$V_p = e^{ip \hat{X}(z, \bar{z})} = e^{ip \hat{X}_L(z)} e^{ip \hat{X}_R(\bar{z})} = V_{(p,p)} \quad \phi_p \mapsto$$

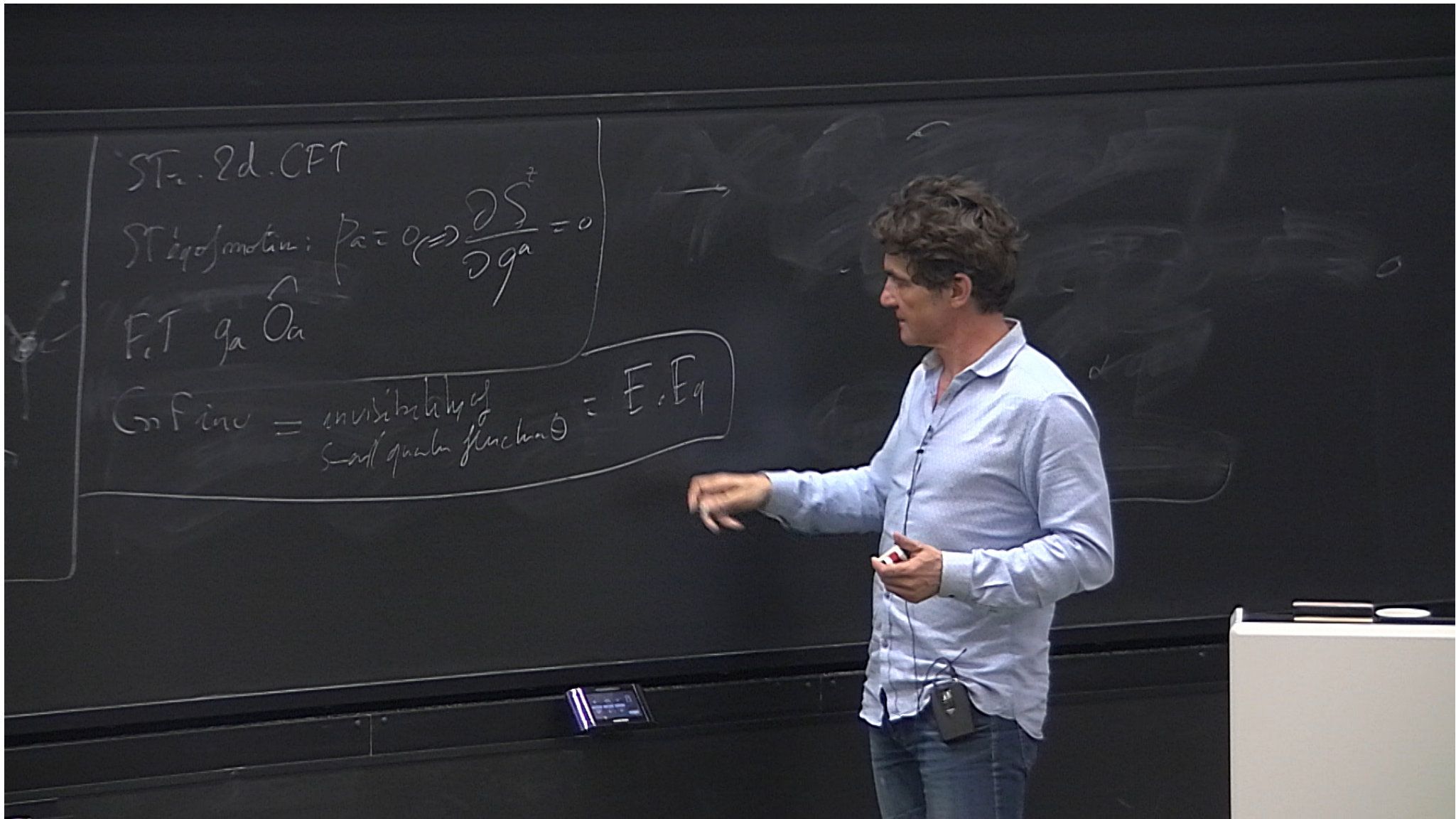


$$\frac{\delta}{\delta g^a} = 0$$

$$\rightarrow \delta \Gamma_a = \langle R_{ab} u^b \rangle \delta x^a$$

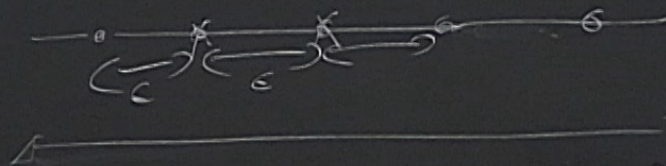
$$\Rightarrow R_{abcd} \underbrace{\left(\hat{p}^a \hat{p}^b \right)}_{\propto g^{ab}} \delta x^c = 0$$

$$\delta \left(\frac{1}{2} \dot{x}^a \dot{x}_a \right) = V(p, p) \Rightarrow \phi(p) \Rightarrow \underbrace{R_{ab} = 0}$$



- ST- $S(\hat{\phi}) = (\hat{X}^a)$

• KS



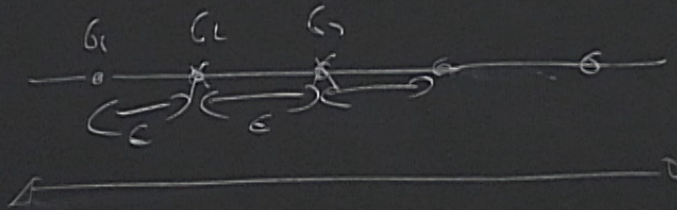
$NE = P_+$

$\rightarrow D$

$\rightarrow D$

$$\bullet \text{ ST- } S(\hat{\Phi}) = (\hat{X}^a)$$

KS



$$N \in \mathbb{P}_+$$

$$E \rightarrow D$$

$$N \rightarrow 2$$

$$\Delta \hat{X}_i = \hat{X}(\sigma_{i+1}) - \hat{X}(\sigma_i)$$

$$\sigma_{i+1} = \sigma_i + \epsilon$$

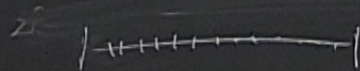
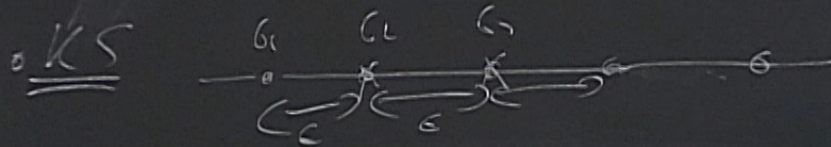
$$(\Delta \hat{X}_i) \xrightarrow{\epsilon \rightarrow 0}$$

$$N\epsilon = P_+$$

$$\epsilon \rightarrow 0$$

$$N \rightarrow \infty$$

$$\bullet \text{ ST- } S(\hat{\Phi}) = (\hat{X}^a)$$



$$= \frac{1}{2}$$

$$Ne = P_+$$

$$E \rightarrow D$$

$$N \rightarrow D$$

$$\Delta \hat{X}_i = \hat{X}(i+1) - \hat{X}(i)$$

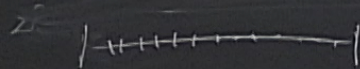
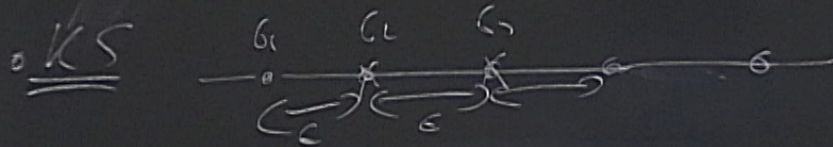
$$G(i+1) = G(i) + \epsilon$$

$$(\Delta \hat{X}^L)$$

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$$\bullet \text{ ST- } S(\hat{\phi}) = (\hat{X}^a)$$



$$= \frac{1}{2}$$

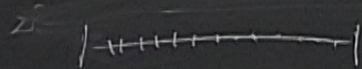
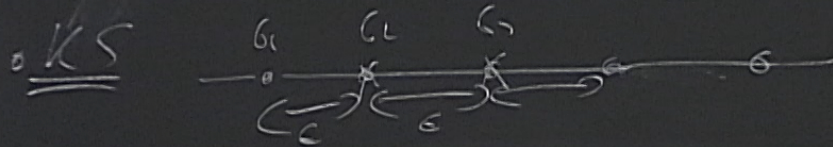
$$\bullet V(p, \tilde{p}) = e^{i p \hat{X}}$$

$$\Delta \hat{X}_i = \hat{X}_{(i+1)} - \hat{X}_{(i)}$$

$$i+1 = i + \epsilon$$

$$(\Delta \hat{X}^L) \xrightarrow{\epsilon \rightarrow 0} \mathbb{R}^2$$

$$\bullet \text{ ST- } S(\hat{\Phi}) = (\hat{X}^a)$$



$$= \frac{1}{a}$$

$$\bullet N\epsilon = P_+$$

$$\epsilon \rightarrow 0$$

$$\Delta \hat{X}_K = \hat{X}_{(i+1)} - \hat{X}_{(i)}$$

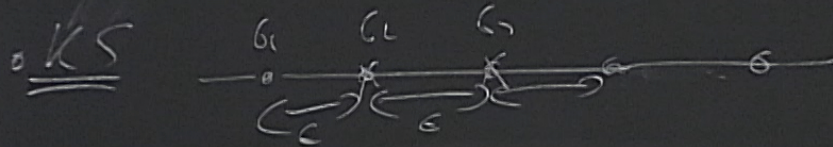
$$U_{i+1} = U_i + \epsilon$$

$$(\Delta \hat{X}^L) \xrightarrow{\epsilon \rightarrow 0} \mathbb{R}^2$$

$$\bullet V(p, \tilde{p}) = e^{i p (\hat{X}_{\tilde{p}}) / \hbar} e^{i \tilde{p} (\hat{X}_p) / \hbar}$$

$$\left| \begin{array}{l} p + \tilde{p} = (N + \tilde{N} - 2) \\ p - \tilde{p} = N - \tilde{N} \end{array} \right|$$

$$\bullet \text{ ST- } S(\hat{\Phi}) = (\hat{X}^a)$$



$$Z = \int \dots$$

$$= \frac{1}{\dots}$$

$$\bullet N\epsilon = P_+$$

$$\epsilon \rightarrow 0$$

$$\Delta \hat{X}_{\vec{n}} = \hat{X}_{(\vec{n}+1)} - \hat{X}_{(\vec{n})}$$

$$U(i+1) = U(i) + \epsilon$$

$$\bullet (\Delta \hat{X}^L) \xrightarrow{\epsilon \rightarrow 0} \mathbb{1}^2$$

$$\bullet V(p, \tilde{p}) = e^{i p (\hat{X}_{\vec{n}}) / \hbar} e^{i \tilde{p} (\hat{X}_{\vec{n}} - \hat{X}_{\vec{n}})}$$

$$\left(\begin{array}{l} p + \tilde{p} = (N + \tilde{N} - 2) \\ p, \tilde{p} = N, \tilde{N} \end{array} \right)$$

$$\rightarrow (N - \tilde{N}) \rightarrow \tilde{p} \rightarrow$$

$$\hat{X}_\epsilon = \hat{X}(\sigma\epsilon+1) - \hat{X}(\sigma)$$

$$|\sigma+1| = |\sigma| + \epsilon$$

$$(\Delta \hat{X}^\epsilon) \xrightarrow{\epsilon \rightarrow 0} \mathbb{L}^2$$

→ Generalised Geometry?
 → Geometry of T-duality

$$\hat{X}_\epsilon = \hat{X}(\sigma_{i+1}) - \hat{X}(\sigma_i)$$

$$\sigma_{i+1} = \sigma_i + \epsilon$$

$$(\Delta \hat{X}^\epsilon) \xrightarrow{\epsilon \rightarrow 0} \mathbb{L}^2$$

→ Generalised Geometry?

→ Geometry of T-duality

$$\left(R \sim \frac{1}{R} \right)$$