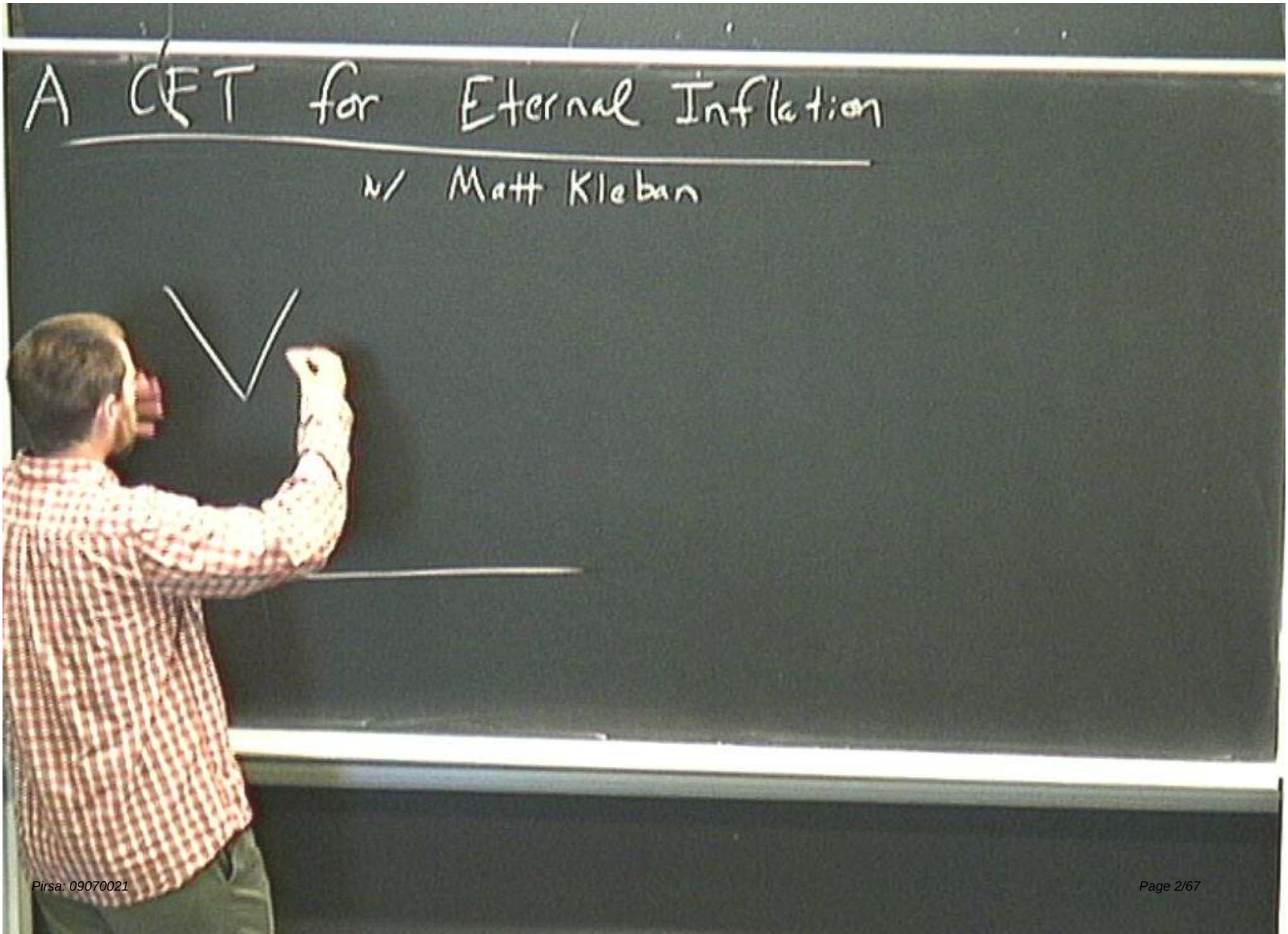
Title: A CFT for Eternal Inflation

Date: Jul 16, 2009 09:00 AM

URL: http://pirsa.org/09070021

Abstract: TBA


A CFT for Eternal Inflation
w/ Matt Kleban

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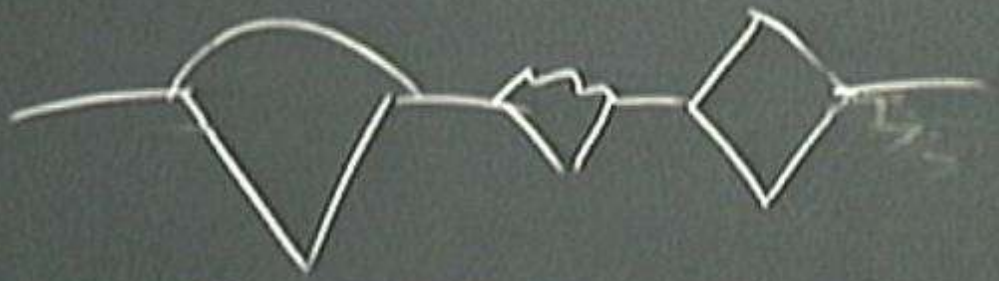

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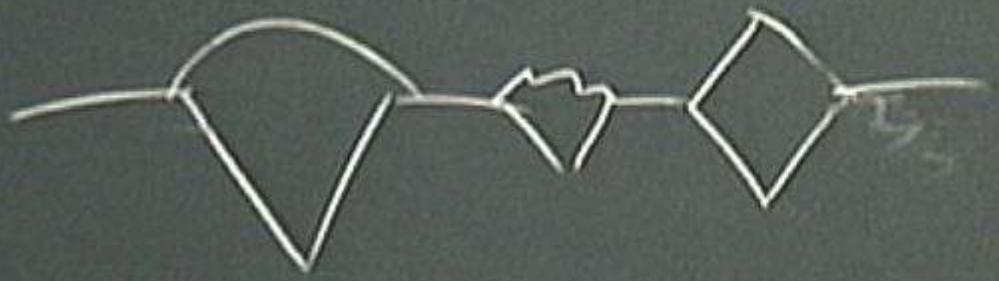

Big universe

CMB

A CFT for Eternal Inflation

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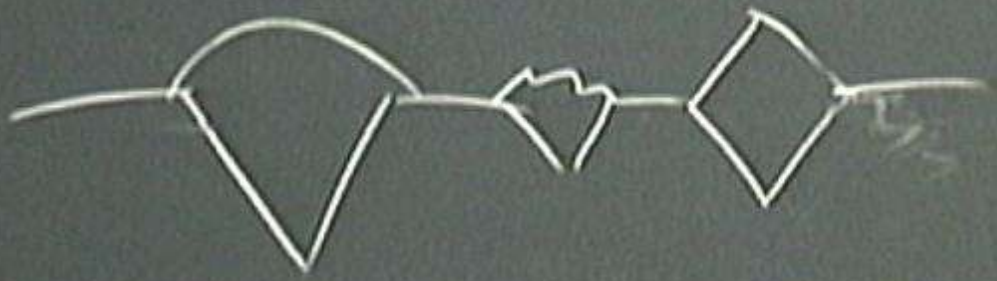

Big universe

^ CMB

2 problems

1. If just start computing → infinities

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2. How to rigorously understand Quantum Gravity (ST)

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String Theory computes

S-Matrix in Minkowski space

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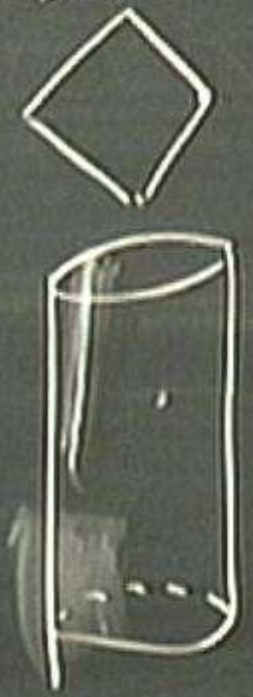

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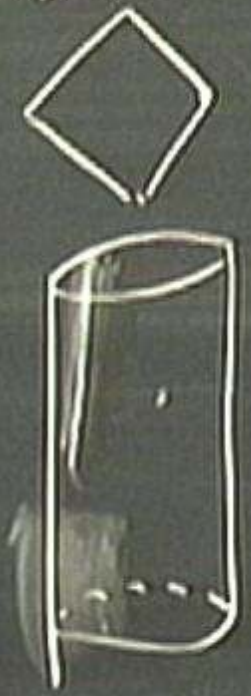

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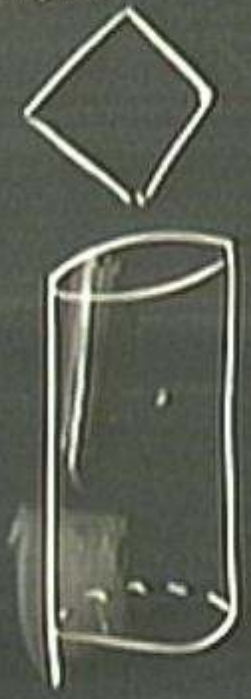
Not helpful for E.I. because E.I. hidden behind horizons.



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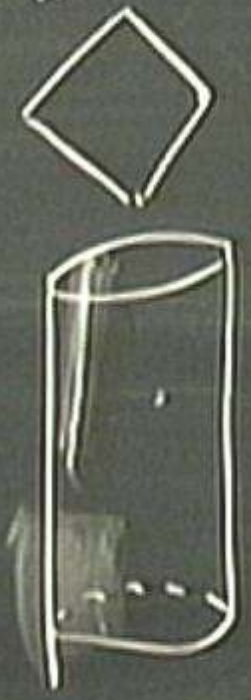

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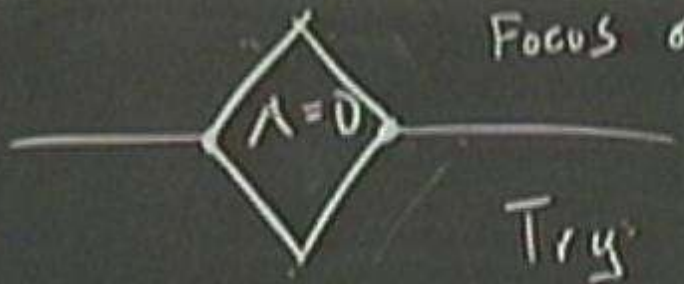
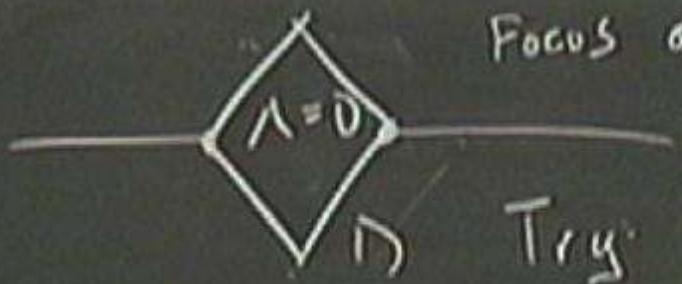
Focus on "knots"

Focus on "hats"



Focus on "hats"

Try to understand EI just from asymptotic data in hats



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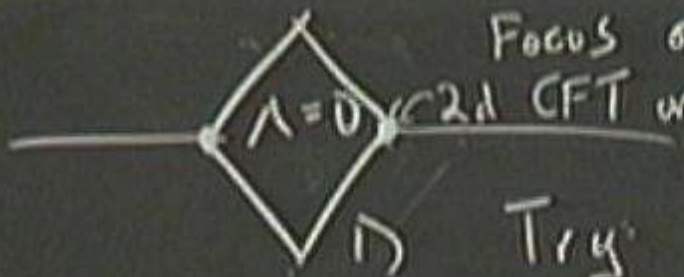
Today:

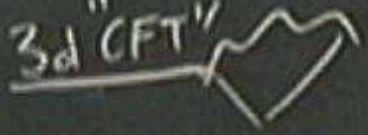


Focus on "hats"

⇒ Try to understand EI just from asymptotic data in hats

Today:

Assume well-defined quantity is a CFT living on future infinity



Focus on Simplest Example

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Compute up to 4 pt function

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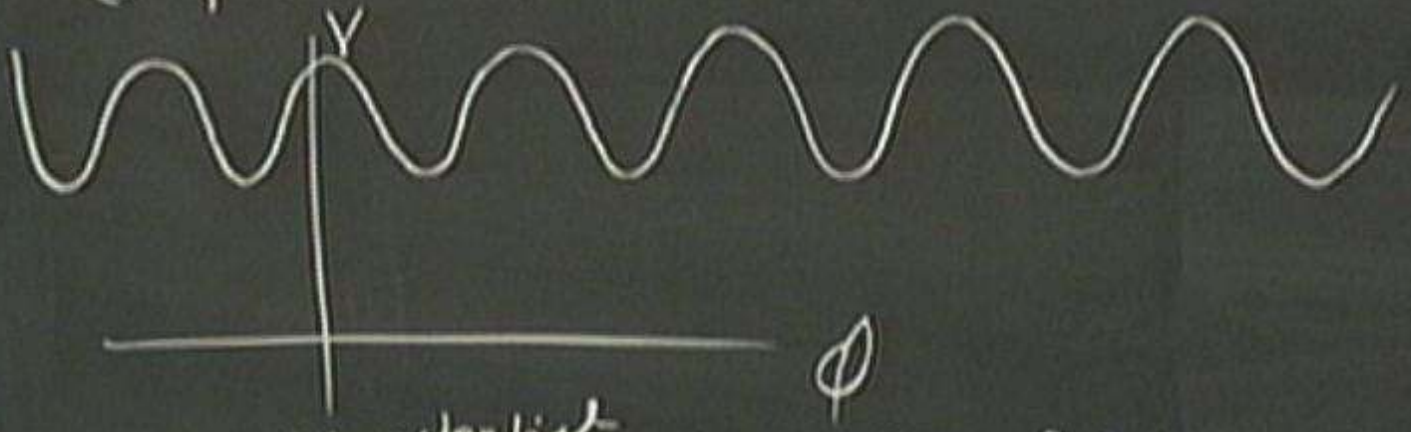
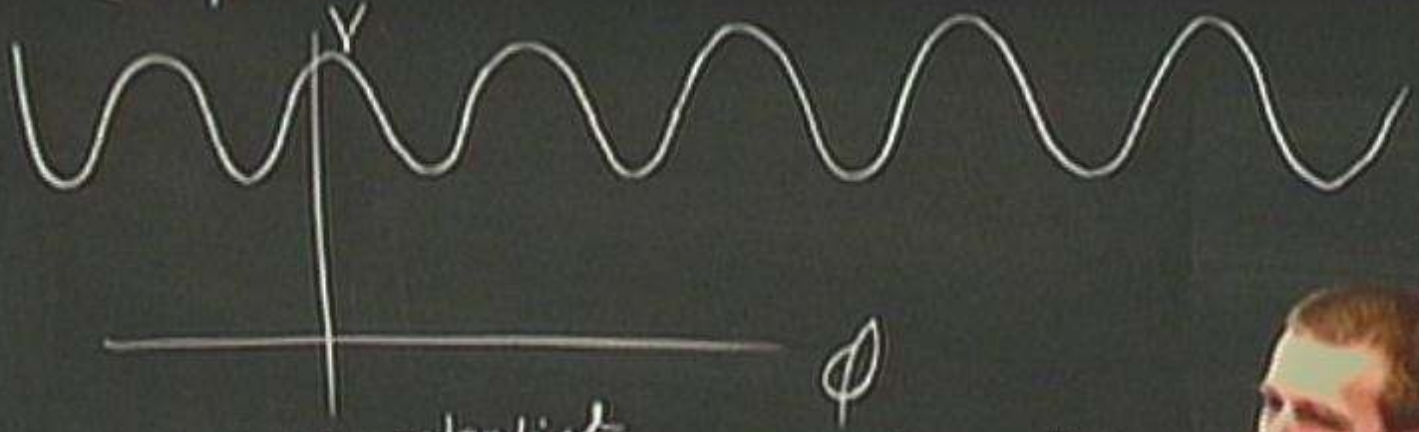


Periodic potential

Discrete shift symm $\varphi \to \varphi + c$

Focus on Simplest Example
Compute up to 4 pt function



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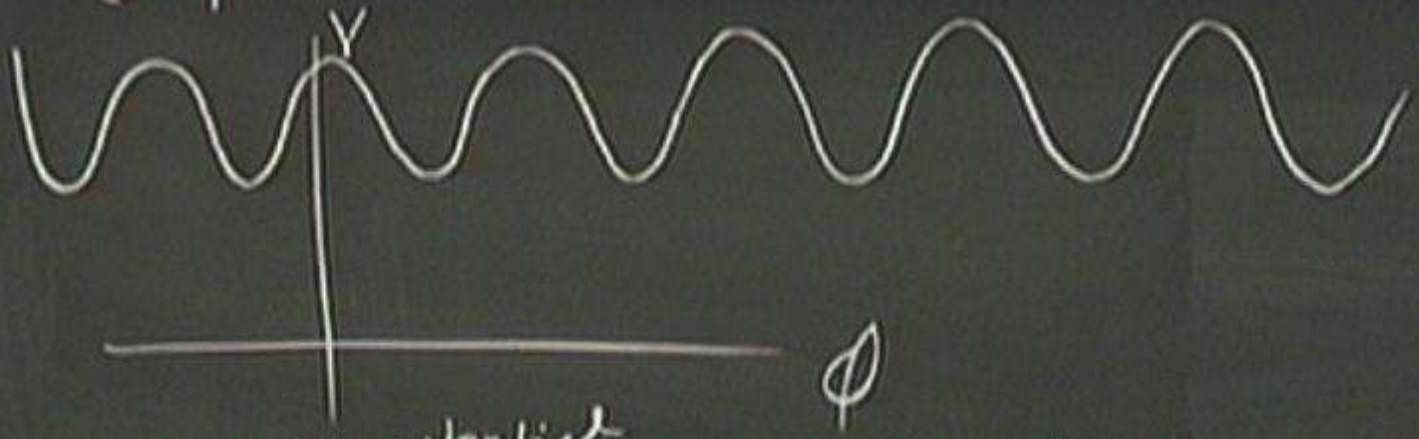

Periodic potential

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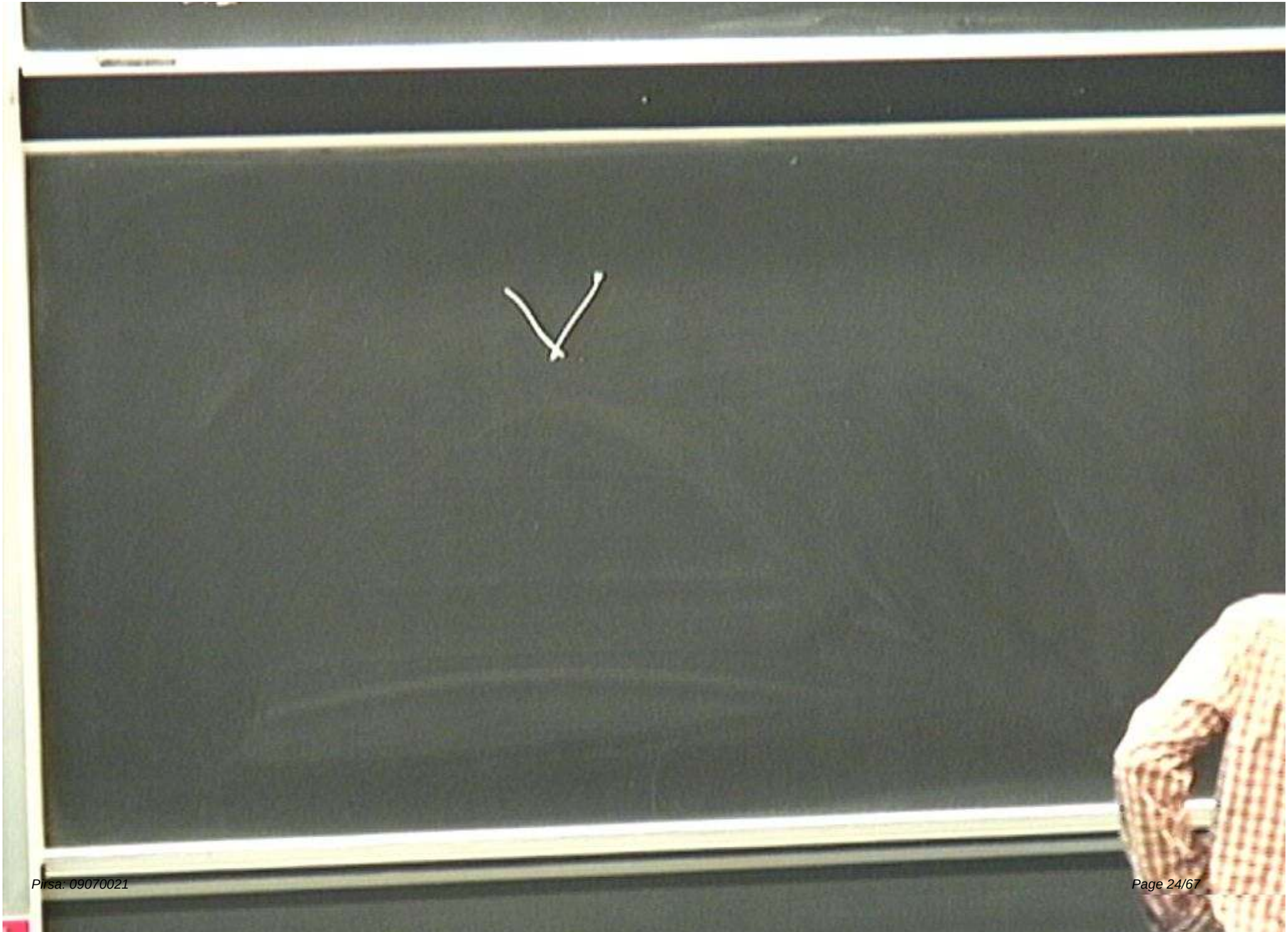
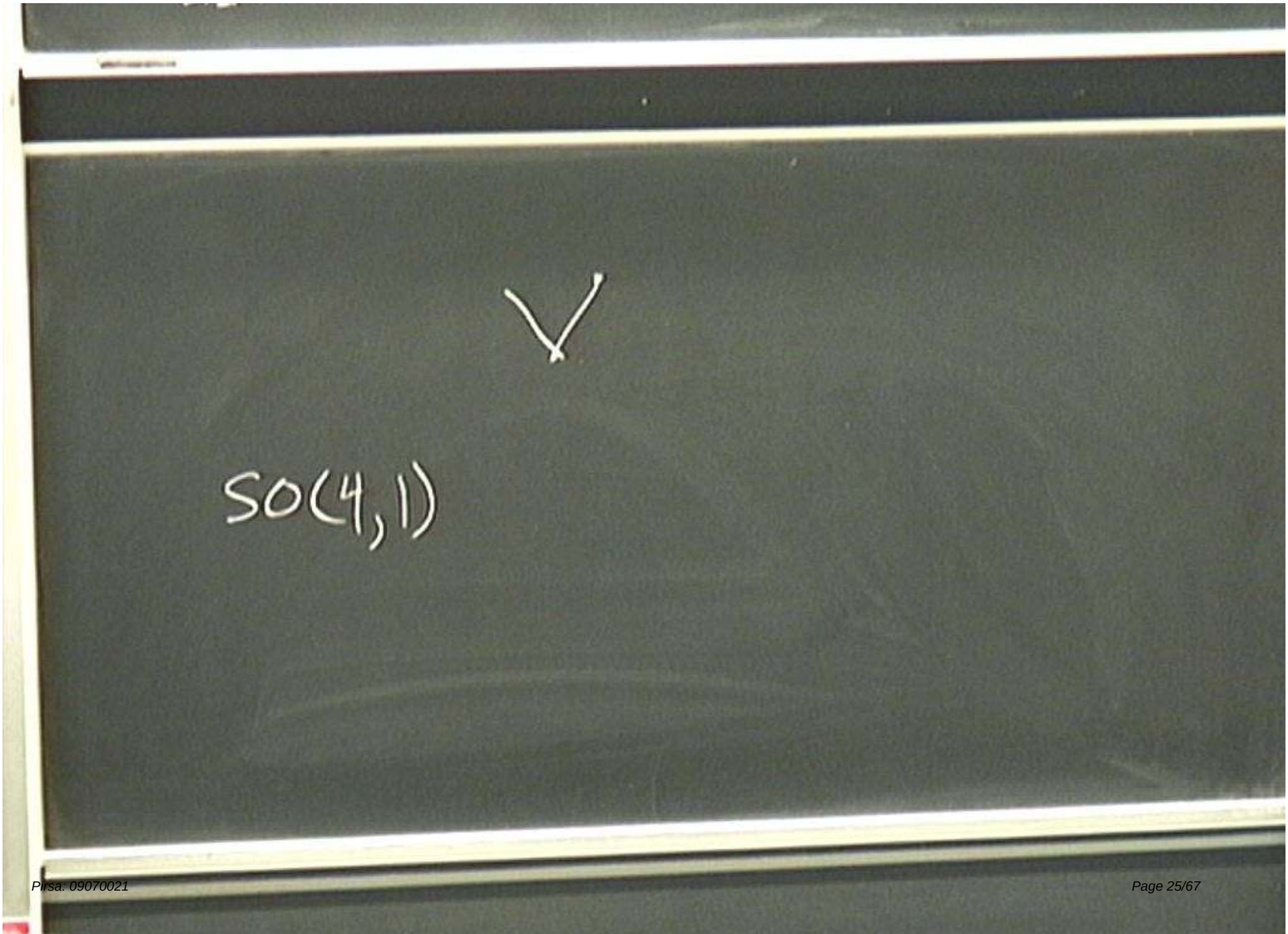
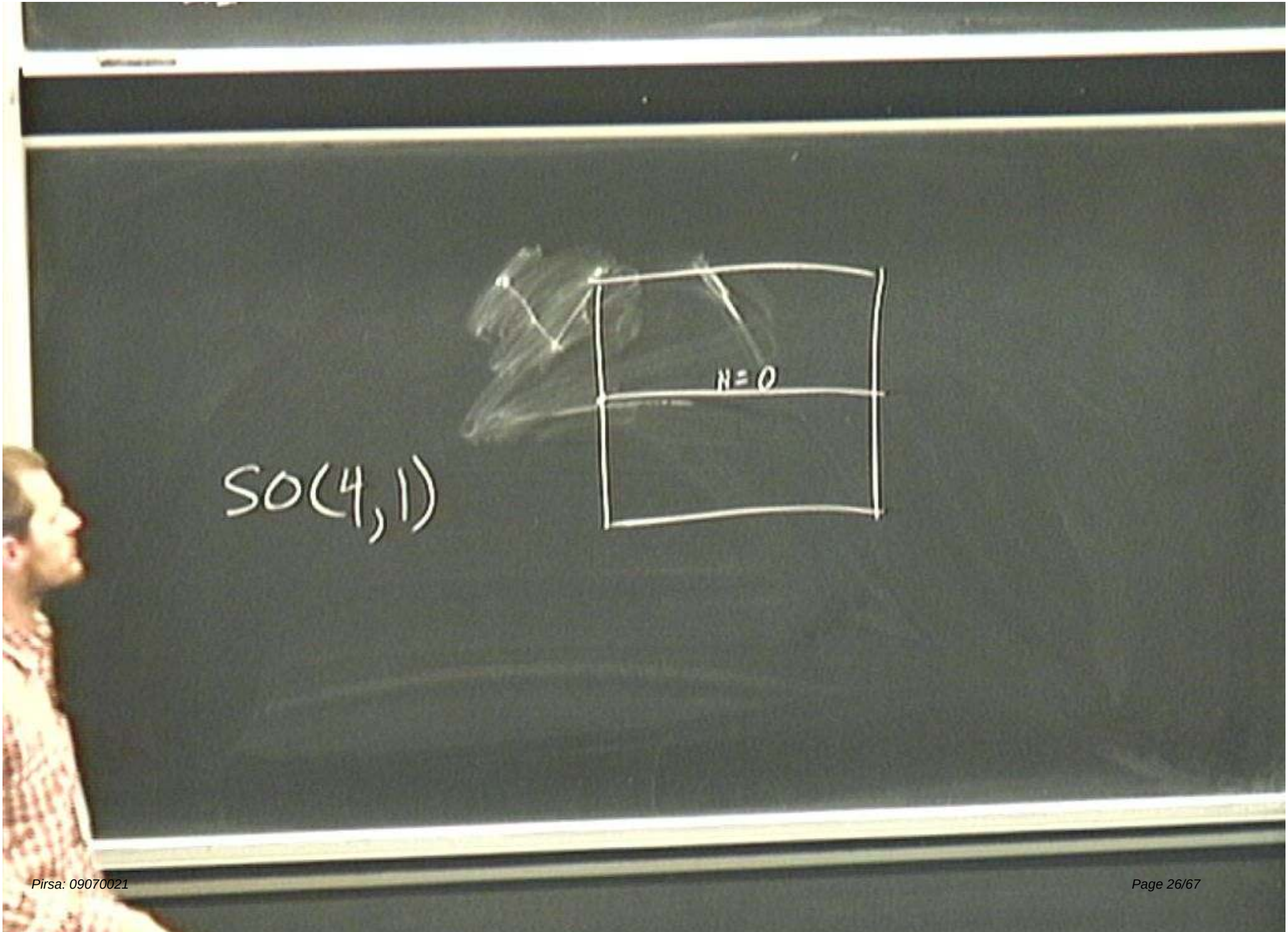



V
SO(4,1)


N=0
SO(4,1)

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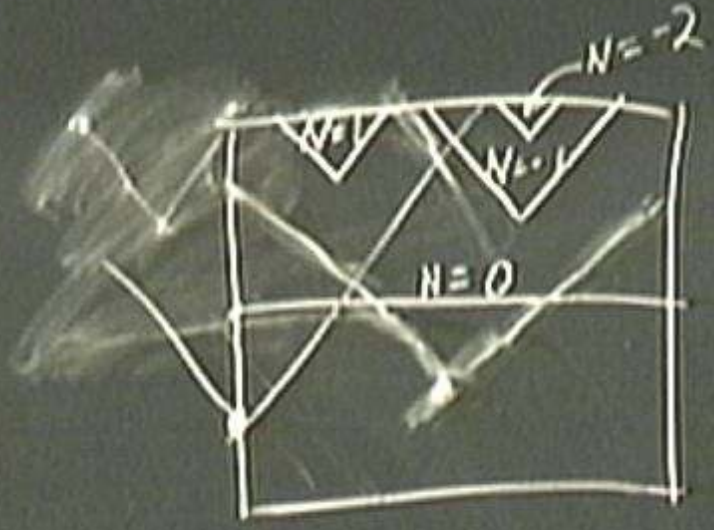
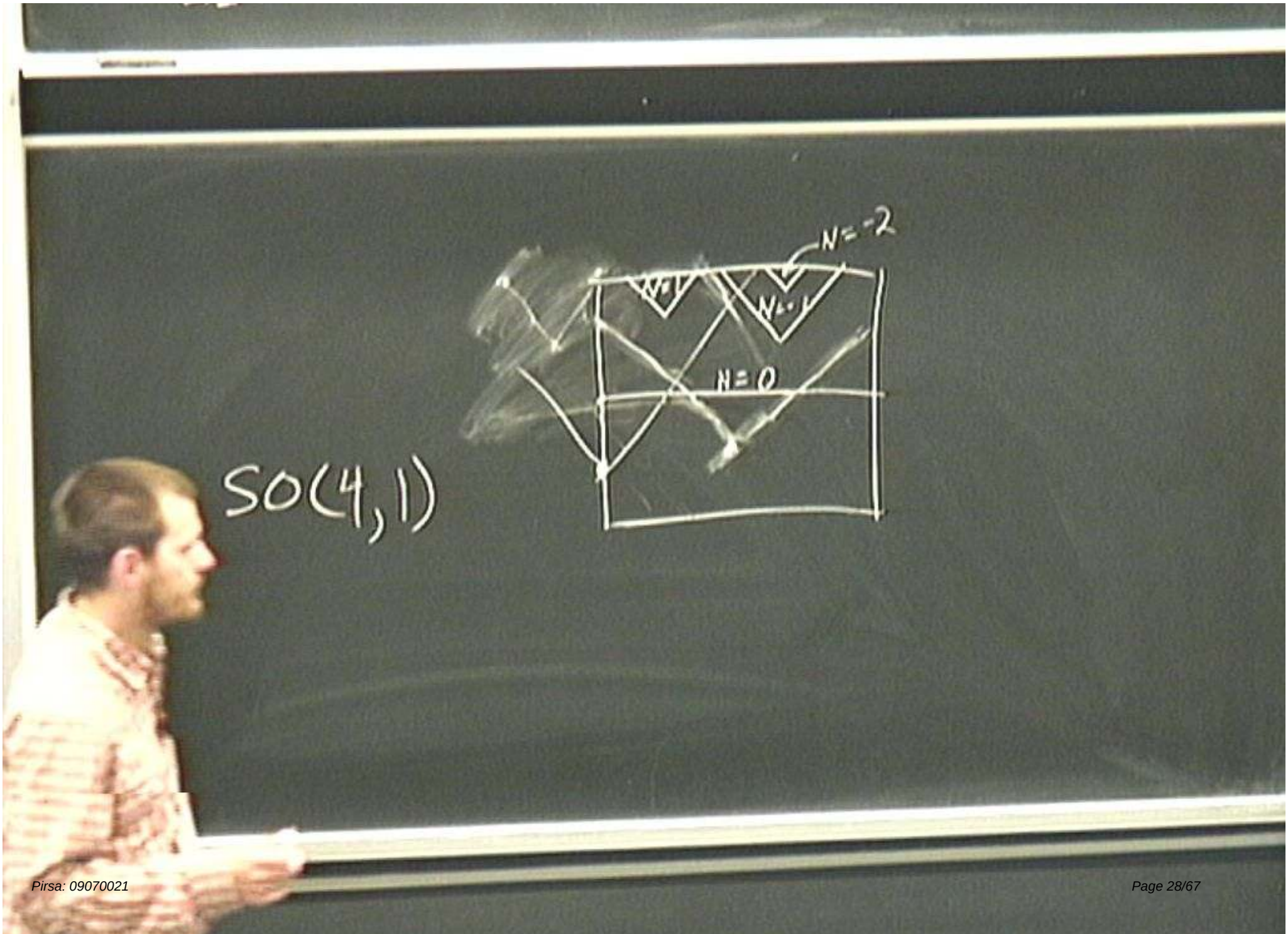
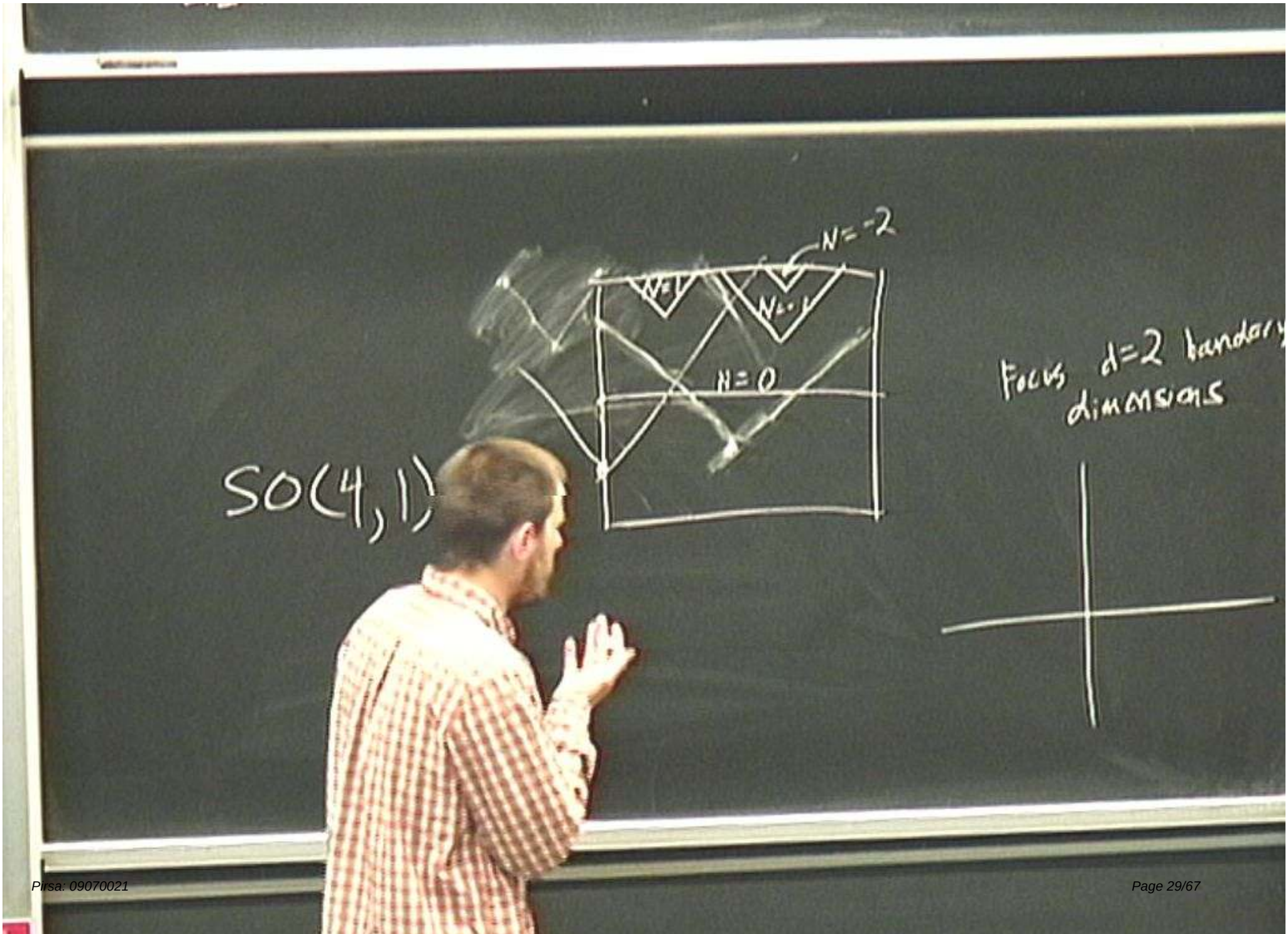
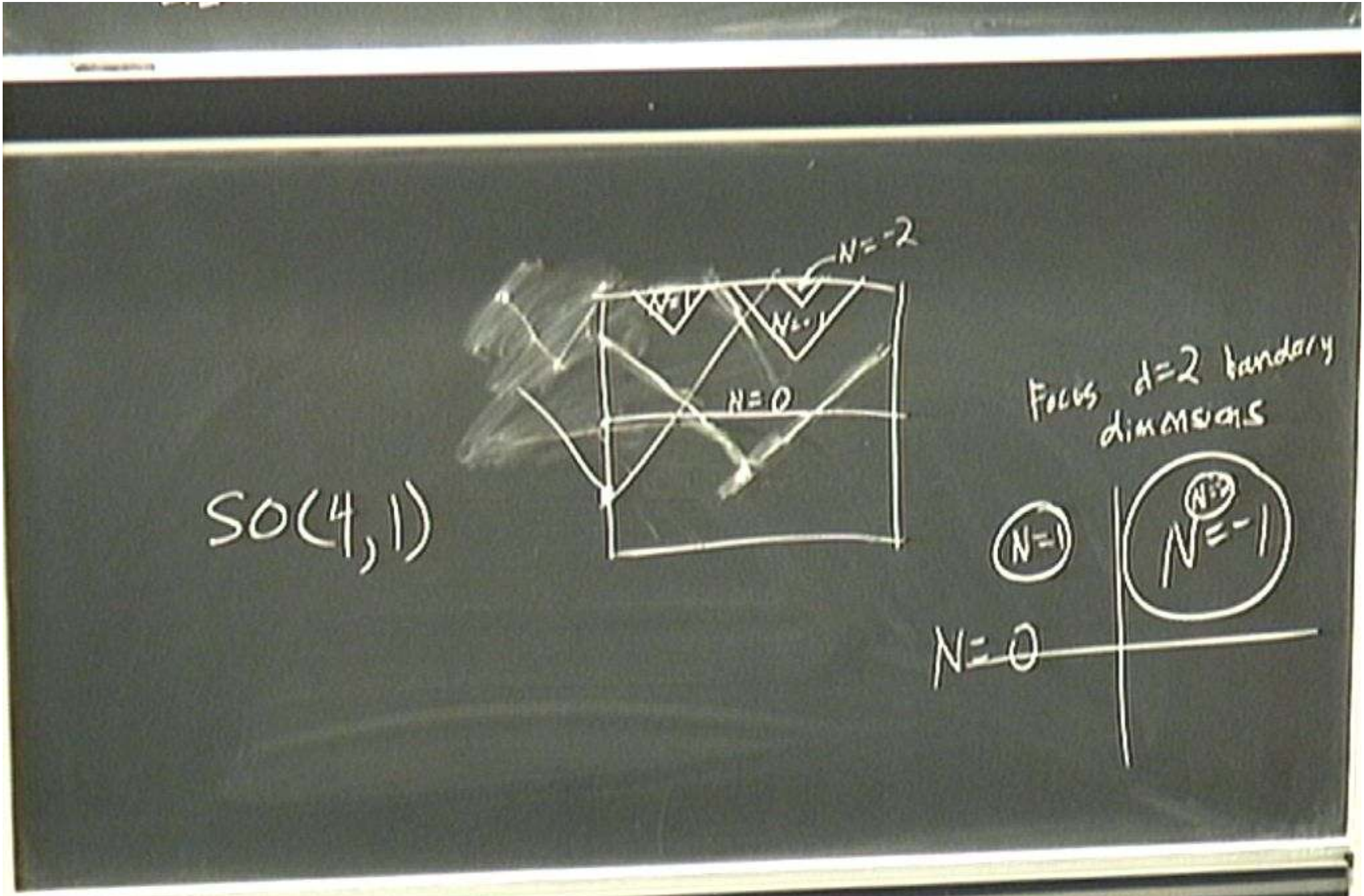



N=-2
N=-1
N=0
SO(4,1)


N=-2
N=-1
N=-1
N=0
SO(4,1)
Focus d=2 boundary
dimensions


N=-2
N=-1
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SO(4,1)
Focus d=2 boundary dimensions
N=1
N=-1
N=0

Dual to a Simple Statistical System

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Scale invariant distribution of disks

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Scale invariant distribution of disks

$$Z = \sum_n$$

Dual to a Simple Statistical System

Scale invariant distribution of disks

$$Z = \left(\sum_n \frac{\gamma_+^n}{n!} \prod_{k=1}^{n} \int \frac{dr_k}{r_k^3} \int d^2x_k \right) \left(\sum \frac{\gamma_-^n}{n!} \prod_{k} \int \frac{dr}{r_k^3} \int d^2x_k \right)$$

$$\gamma_+ = \gamma_-$$

$$Z = e^{\gamma \int \frac{dr}{r^3} \int d^2x}$$

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$\gamma_+ = \gamma_-$

$$Z = e^{\gamma \int \frac{dr}{r^3} \int d^2 x}$$

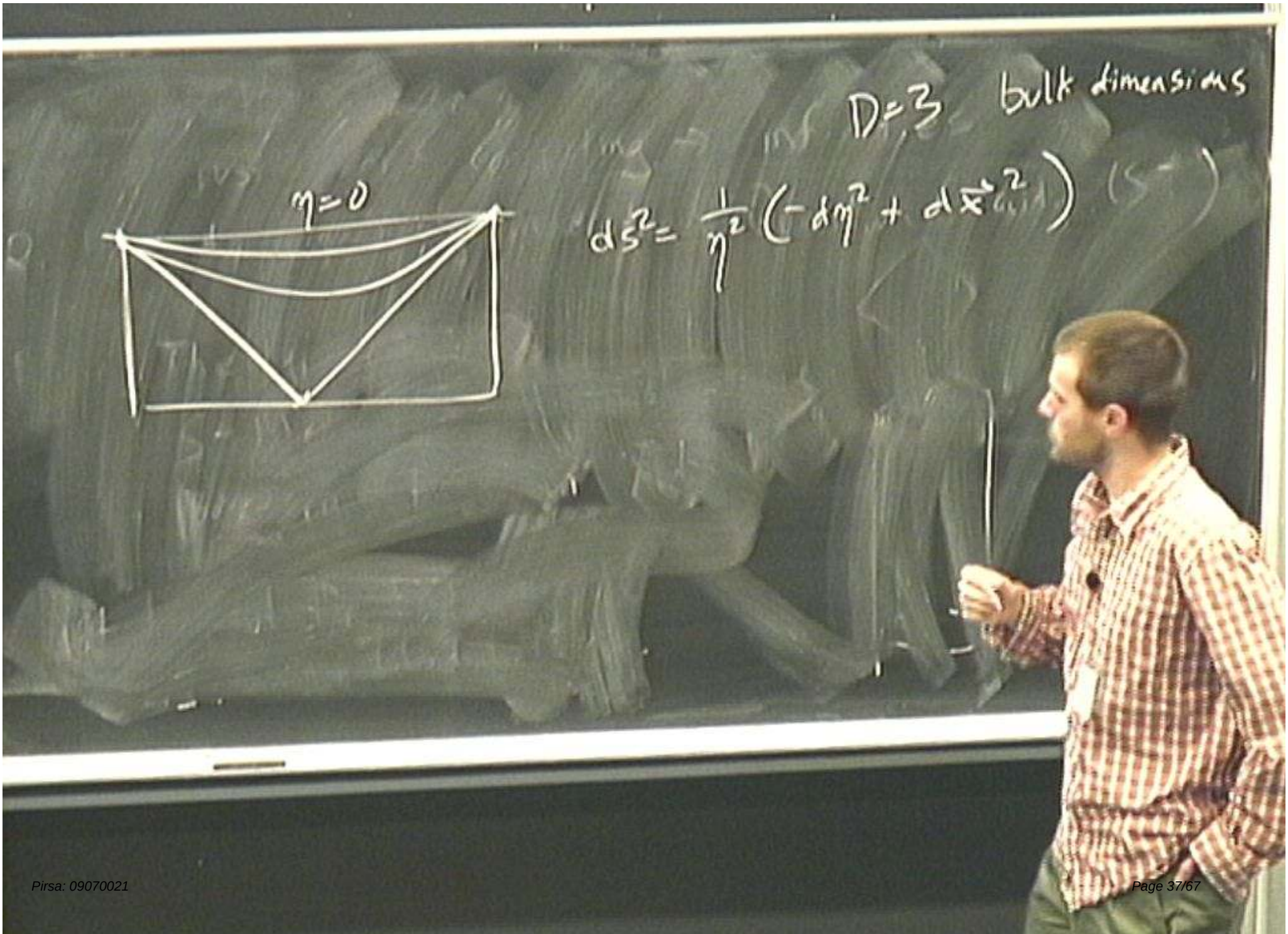
Outline:

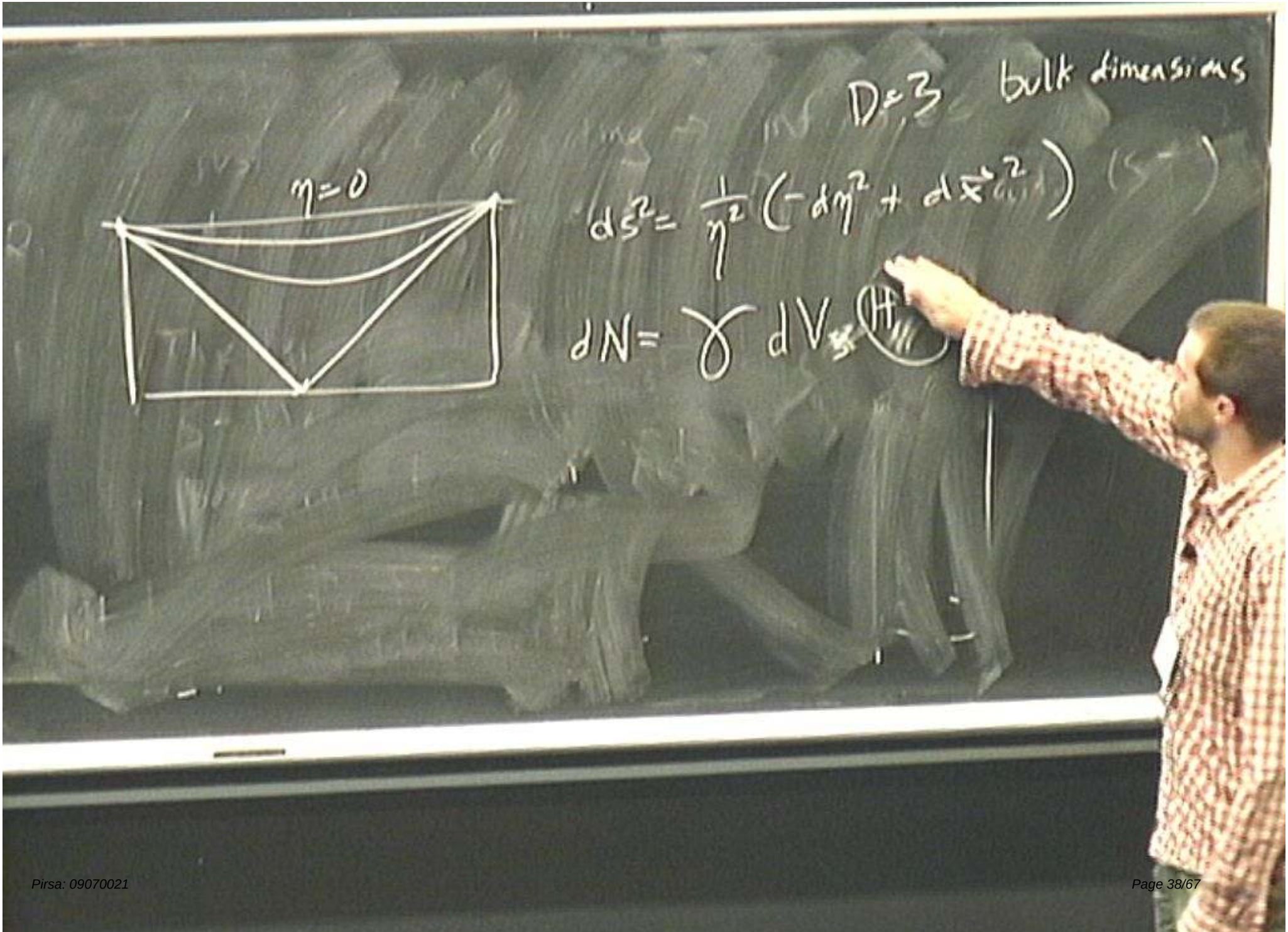
I. Derive Z from bulk

II. Compute 2-point fn

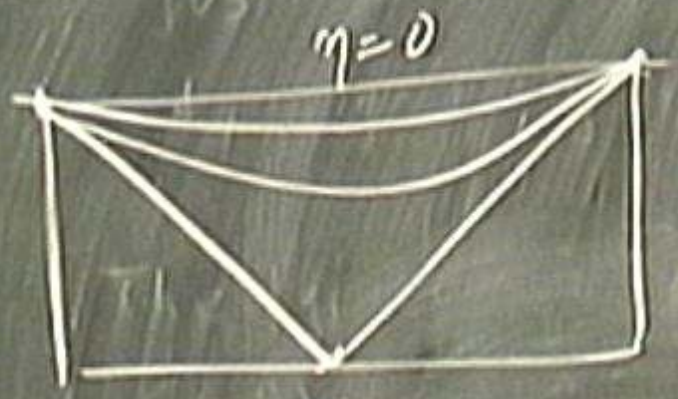
III. 3, 4 pt fns

IV Future


D=3 bulk dimensions
η=0
$ds^2 = \frac{1}{\eta^2}(-d\eta^2 + d\vec{x}^2)$


D=3 bulk dimensions
η=0
$ds^2 = \frac{1}{\eta^2}(-d\eta^2 + d\vec{x}^2)$
$dN = \gamma\, dV$

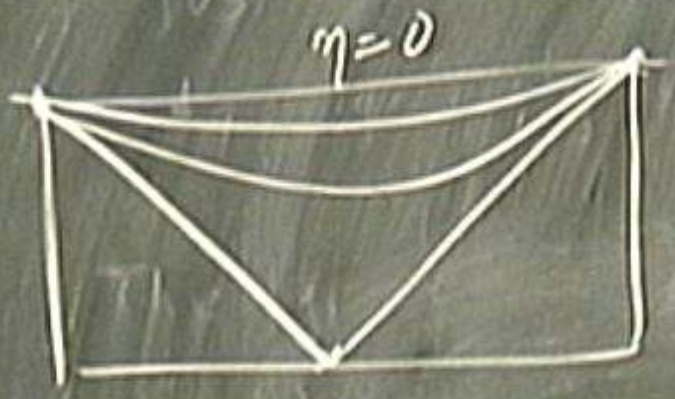
D=3 bulk dimensions



$$ds^2 = \frac{1}{\eta^2}\left(-d\eta^2 + d\vec{x}^2\right) \quad (5-)$$

$$dN = \gamma\, dV \to 1$$

D=3 bulk dimensions



$$ds^2 = \frac{1}{\eta^2}\left(-d\eta^2 + d\vec{x}^2_{(1,1)}\right)$$

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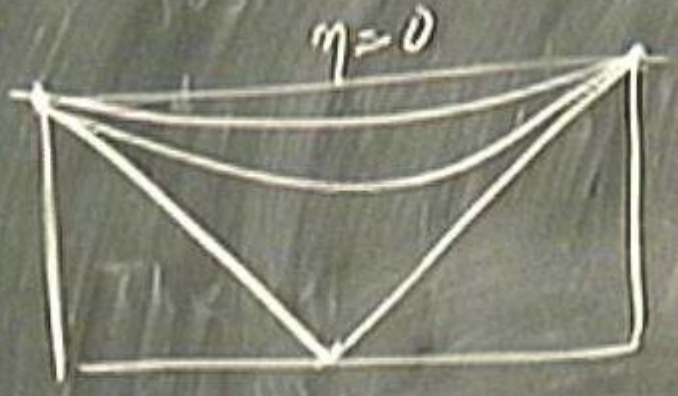
$$dN = \frac{1}{\eta^2}\, d\eta\, dx$$

D=3 bulk dimensions



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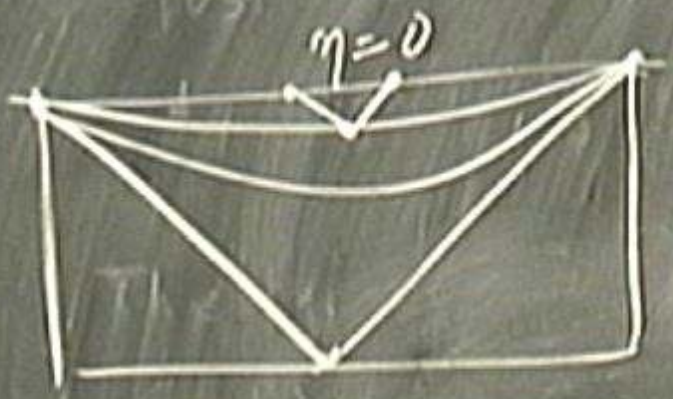
$D=3$ bulk dimensions



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$$dN = \gamma\, dV \to 1$$

$$dN = \frac{\gamma}{\eta^2}\, d\eta\, d^3x$$

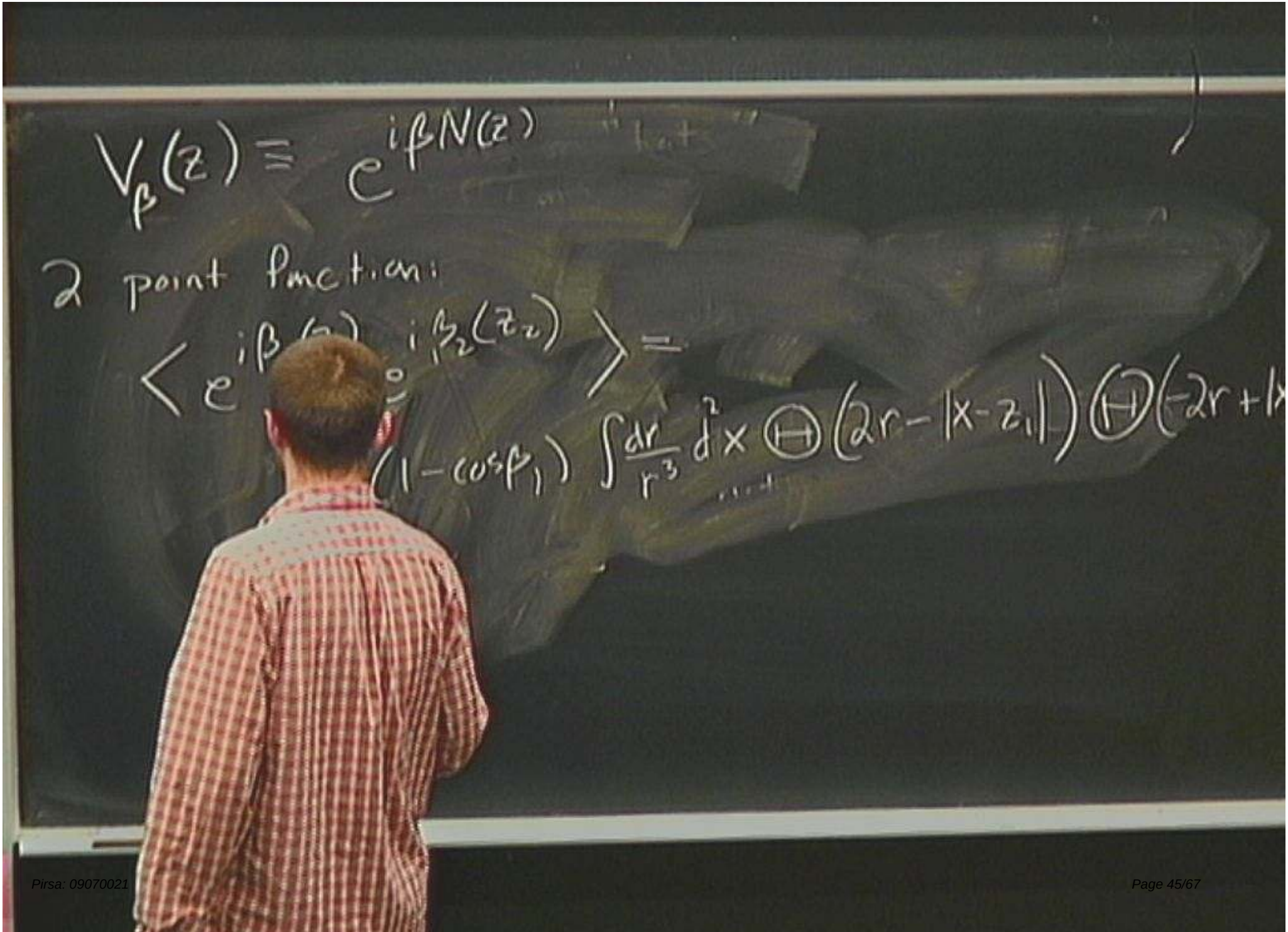
Size $r = |\eta|$

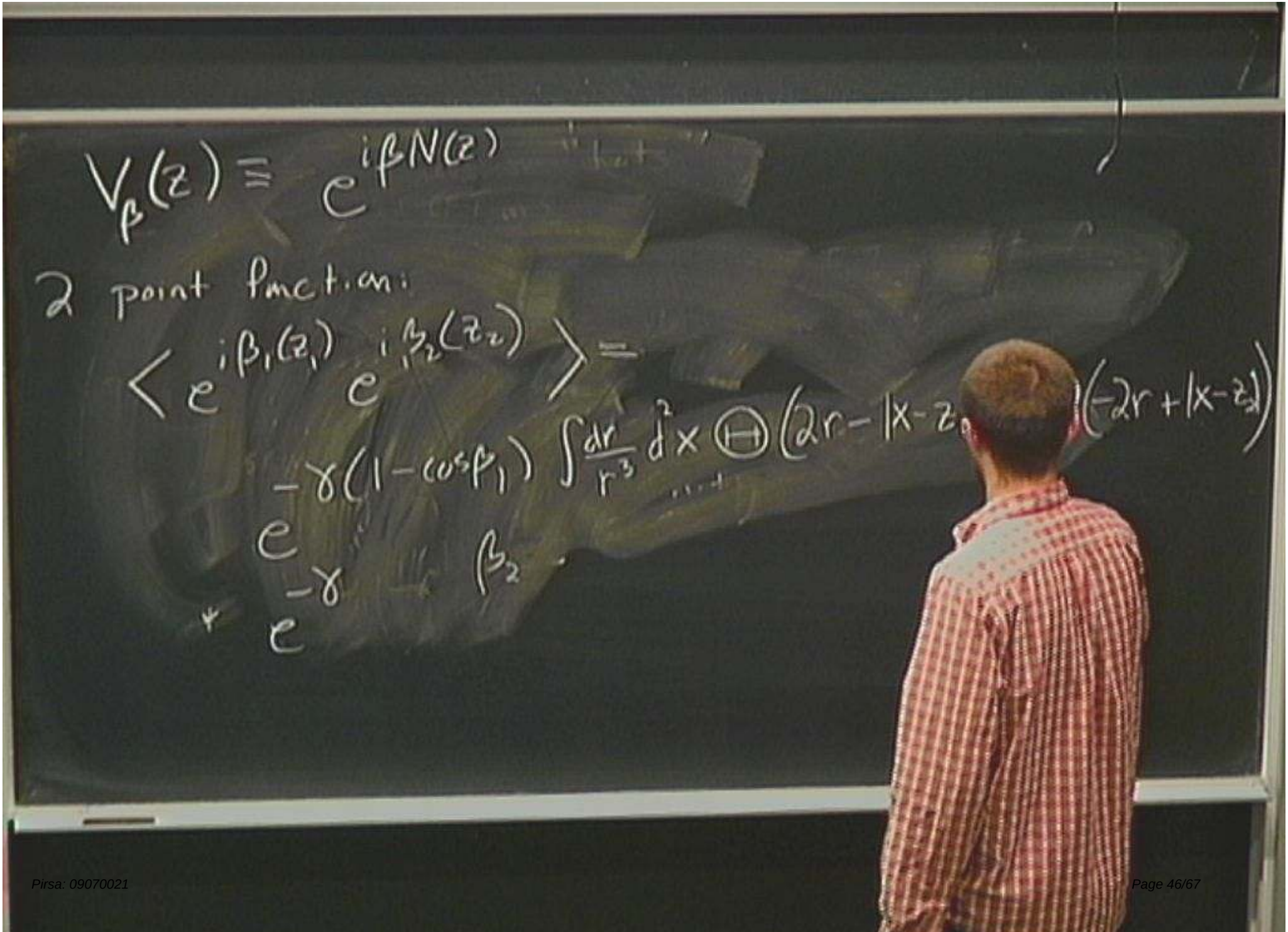
$$V_\beta(z) \equiv e^{i\beta N(z)}$$

$V_\beta(z) \equiv e^{i\beta N(z)}$ "vertex"

2 point function:

$\langle e^{i\beta_1(z_1)} \; e^{i\beta_2(z_2)} \rangle =$


$V_\beta(z) \equiv e^{i\beta N(z)}$
2 point function:
$\langle e^{i\beta_1(z_1)} e^{i\beta_2(z_2)} \rangle =$
$(1-\cos\beta_1)\int \frac{dr}{r^3} d^2x\, \Theta(2r-|x-z_1|)\,\Theta(-2r+|x$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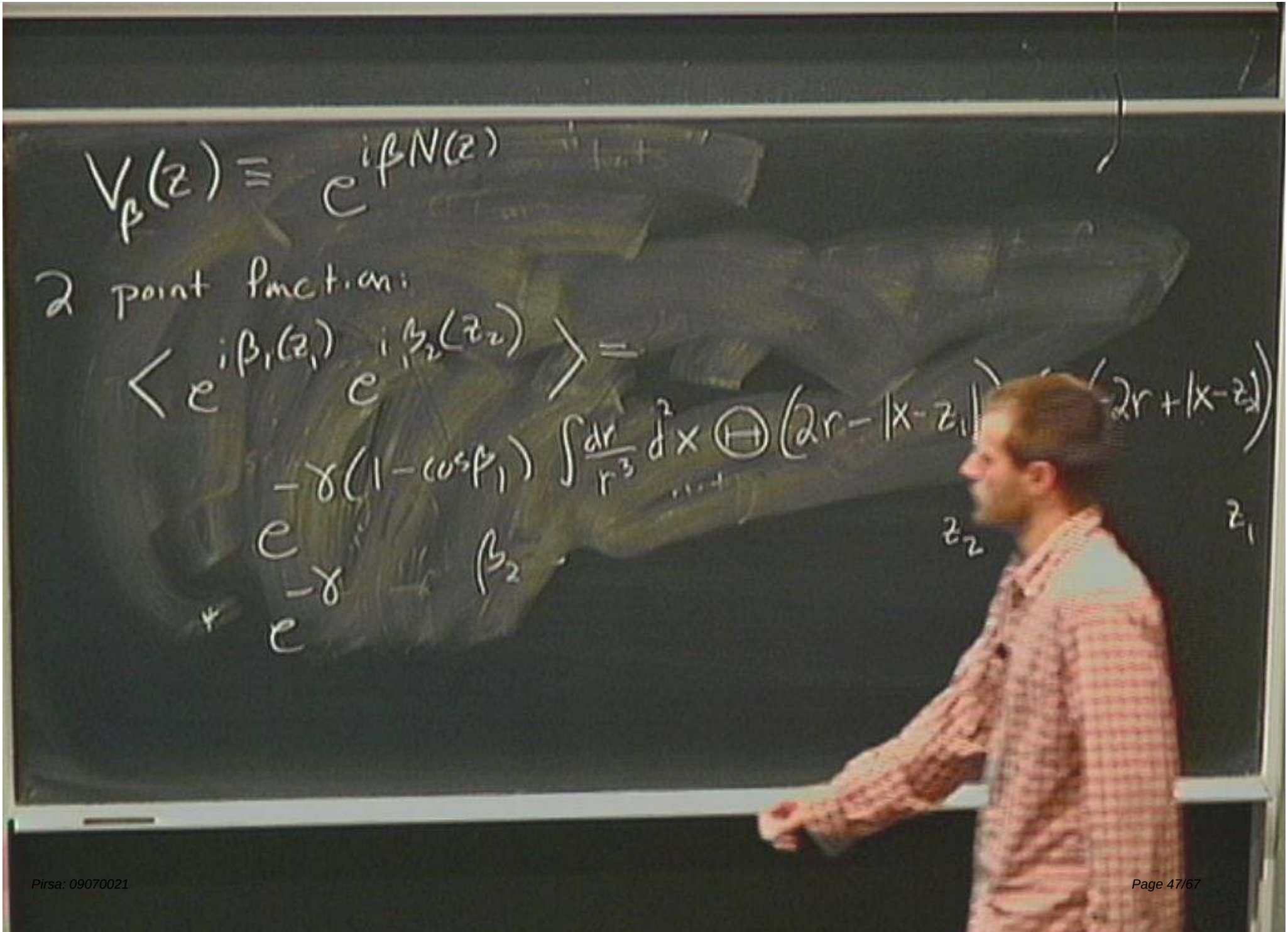
2 point function:
$\langle e^{i\beta_1(z_1)} e^{i\beta_2(z_2)} \rangle =$
$e^{-\gamma(1-\cos\beta_1)\int \frac{dr}{r^3} d^2x \Theta(2r-|x-z_1|)\Theta(-2r+|x-z_2|)}$
$e^{-\gamma \beta_2}$
$+ e^{-\gamma \beta_2}$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$e^{-\gamma(1-\cos\beta_1)} \int \frac{dr}{r^3} d^2x \ominus(2r - |x-z_1|)$
z_2
z_1
$e^{-\gamma}$
β_2

$$V_\beta(z) \equiv e^{i\beta N(z)}$$

2 point functions:

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$$e^{-\gamma(1-\cos\beta_1)\int \frac{dr}{r^3} d^2x\, \Theta(2r-|x-z_1|)\Theta(-2r+|x-z_1|} \cdot$$

$$e^{-\gamma \quad \beta_2 \quad z_2} \cdot$$

$$* \; e^{-\gamma(1-\cos(\beta_1+\beta_2))\int \frac{dr}{r^3} d^2x\, \Theta(2r-|x-z_1|)\Theta(2r-|x-}$$

$$* \; e^{}$$

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$$* e^{-\gamma \beta_2 \int_{z_2}^{z_1}}$$

$$* e^{-\gamma(1-\cos(\beta_1+\beta_2))\int \frac{dr}{r^3} d^2x\, \Theta(2r-|x-z_1|)\Theta(2r-|x-z_2|)}$$

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$$* \; e^{-\gamma \; \beta_2 \; z_2 \; z_1}$$

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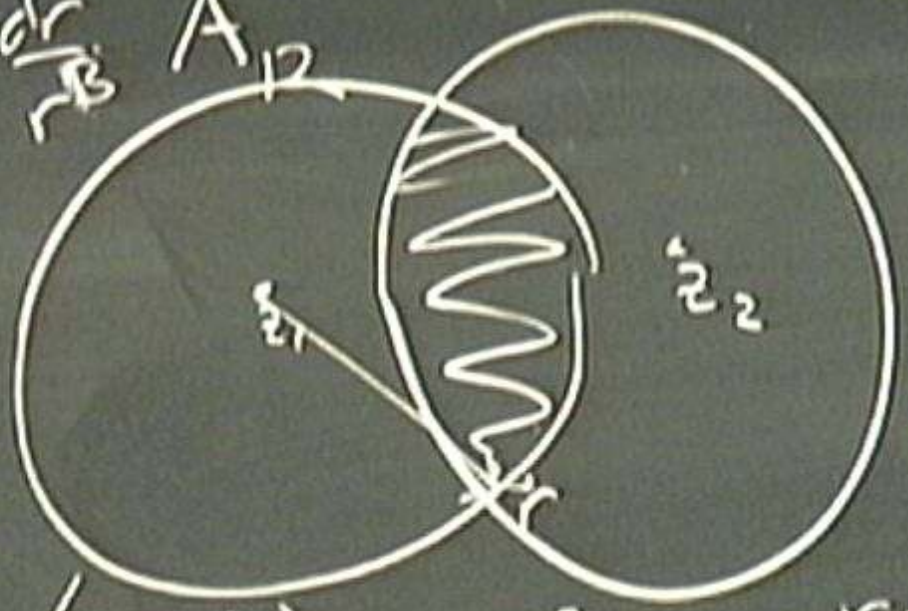
$\int \frac{d^3r}{r^3} A_{12}$



$A_{12}(r, z_1, z_2) \to \pi r^2$ as $r \to \infty$

$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(z_2)} \rangle = 0$ unless $\cos(\beta_1 + \beta_2) = 1 \Rightarrow \beta_1 + \beta_2 = 2\pi n$

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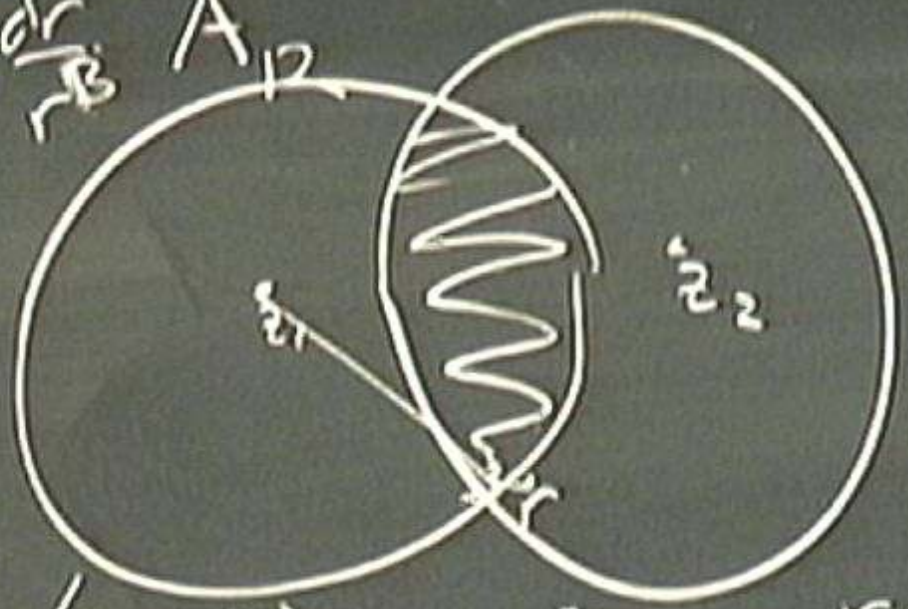

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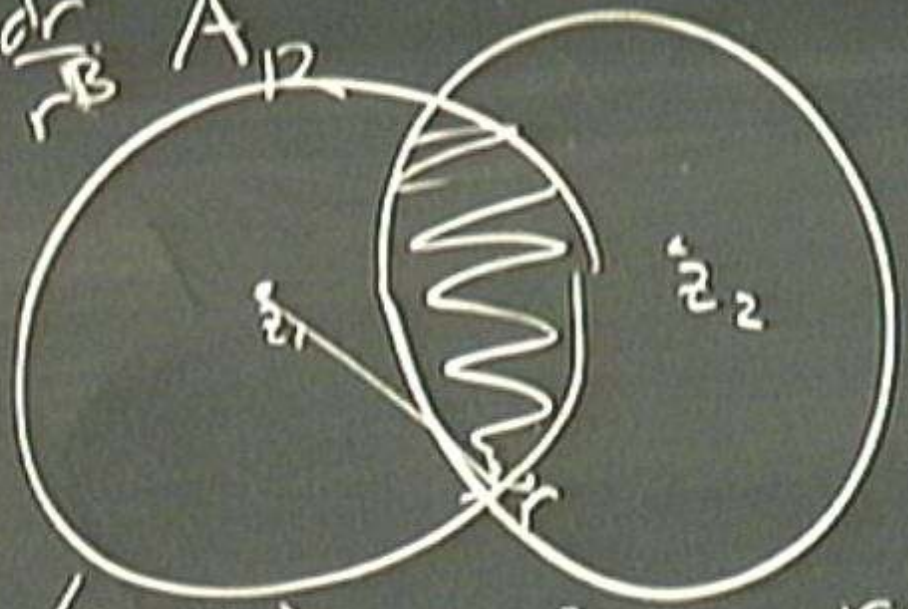
mdor $N \to N+1$ $\quad \langle \; \rangle \to e^{i(\beta_1+\beta_2)} \langle \; \rangle$

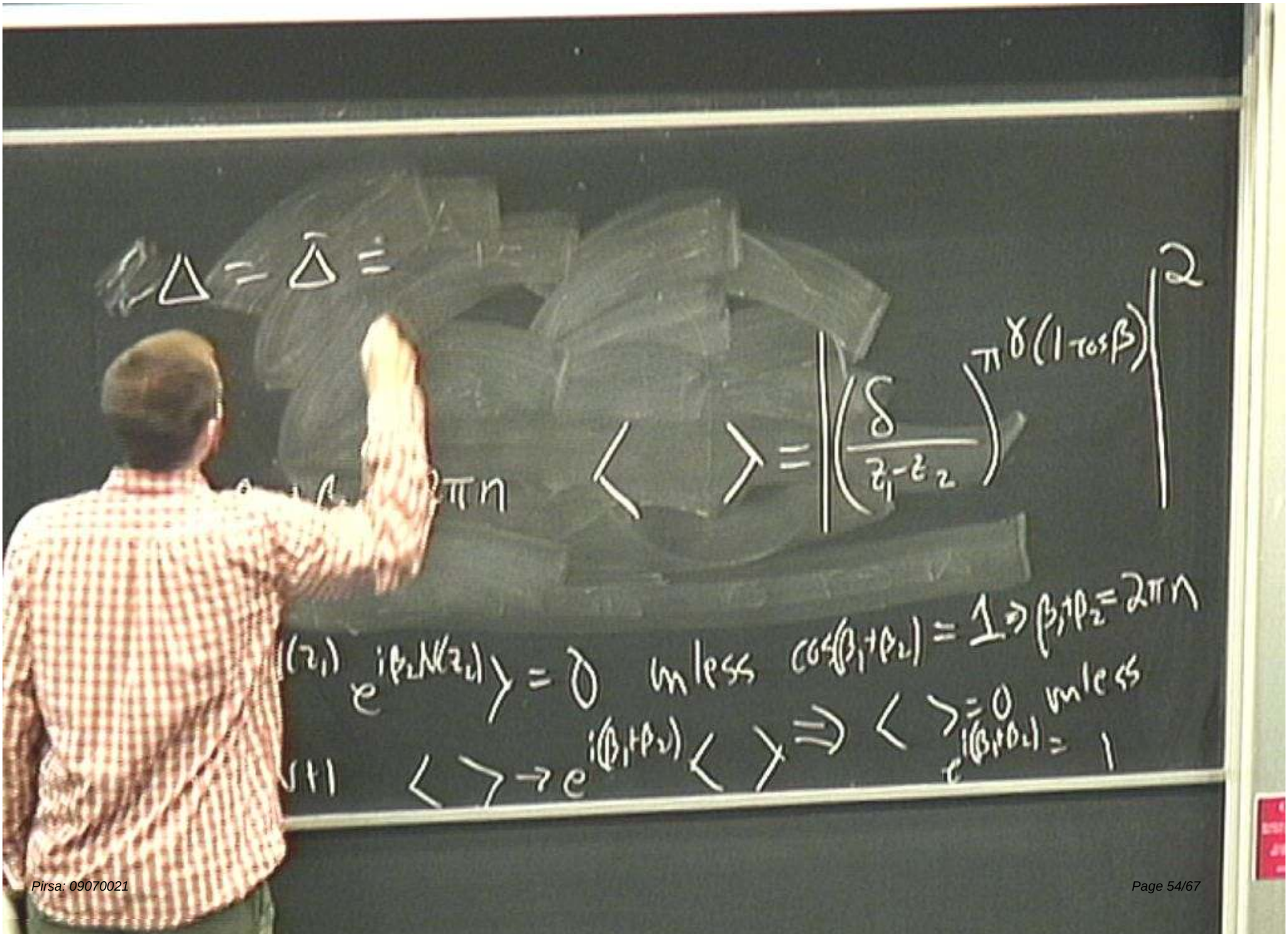
$\int \frac{d^3r}{r^3} A_{12}$



$A_{12}(r, z_1, z_2) \to \pi r^2$ as $r \to \infty$

$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(z_2)} \rangle = 0$ unless $\cos(\beta_1+\beta_2) = 1 \Rightarrow \beta_1+\beta_2 = 2\pi\Lambda$

under $N \to N+1$ $\quad \langle\ \rangle \to e^{i(\beta_1+\beta_2)} \langle\ \rangle \Rightarrow \langle\ \rangle = 0$ unless $e^{i(\beta_1+\beta_2)} = 1$


$\Delta = \bar{\Delta} =$
πn
$\langle\ \rangle = \left| \left(\frac{\delta}{z_1 - z_2} \right)^{\pi \gamma (1 - \cos\beta)} \right|^2$
$\cos(\beta_1 + \beta_2) = 1 \Rightarrow \beta_1 + \beta_2 = 2\pi n$
unless
$\langle\ \rangle \to e^{i(\beta_1 + \beta_2)} \langle\ \rangle \Rightarrow \langle\ \rangle = 0$ unless
$e^{i(\beta_1 + \beta_2)} = 1$

$$\Delta = \bar{\Delta} = \frac{\pi\gamma}{2}(1-\cos\beta)$$

$$\text{if } \beta_1+\beta_2 = 2\pi n \qquad \langle\ \rangle = \left|\left(\frac{\delta}{z_1-z_2}\right)^{\pi\gamma(1-\cos\beta)}\right|^2$$

$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(z_2)}\rangle = 0 \quad \text{unless} \quad \cos(\beta_1+\beta_2) = 1 \Rightarrow \beta_1+\beta_2 = 2\pi n$$

under $N \to N+1$ $\quad \langle\ \rangle \to e^{i(\beta_1+\beta_2)}\langle\ \rangle \Rightarrow \langle\ \rangle = 0$ unless $e^{i(\beta_1+\beta_2)} = 1$

$$\Delta - \bar{\Delta} = \frac{\pi\gamma}{2}(1-\cos\beta)$$

UV cutoff

$$\text{if } \beta_1+\beta_2 = 2\pi n \qquad \langle\ \rangle = \left|\left(\frac{\delta}{z_1-z_2}\right)^{\pi\gamma(1-\cos\beta)}\right|^2$$

$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(z_2)}\rangle = 0 \quad \text{unless} \quad \cos(\beta_1+\beta_2) = 1 \Rightarrow \beta_1+\beta_2 = 2\pi n$$

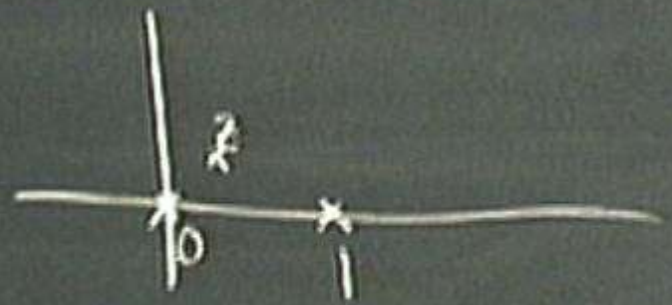
under $N \to N+1$ $\quad \langle\ \rangle \to e^{i(\beta_1+\beta_2)}\langle\ \rangle \Rightarrow \langle\ \rangle = 0$ unless $e^{i(\beta_1+\beta_2)} = 1$

3 pt function: Standard

4 pt function:

3 pt function: Standard

4 pt function:

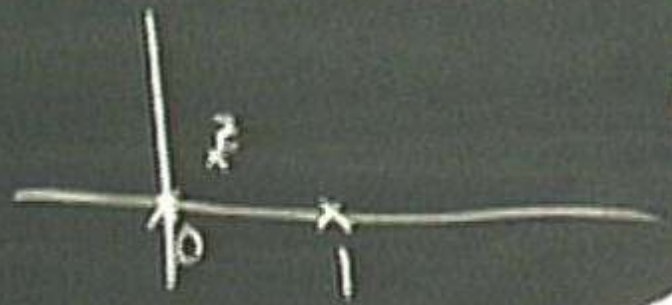


$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

$$= \frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(1-z)^{\Delta_1+\Delta_2-\Delta_1}}$$

3 pt function: Standard

4 pt function:



$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{\quad} \quad \infty \rangle$$

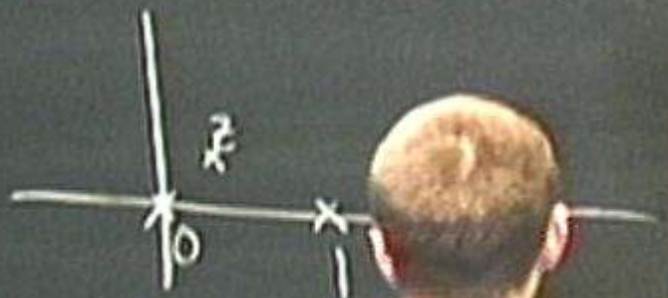
$$= \left(\frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(} \right) \quad d(\Delta_i)\, \mathrm{sgn}(\mathrm{Im}\, z) \left[\mathrm{Im} \log z \log(1-z) + D_2(z) \right]$$

3 pt function: Standard

4 pt function:

$D_2(z)$: Bloch Wigner function

Real analytic away from $z=0, z=1$



$$\langle e^{i\beta_1 N(z_1)} \cdots e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

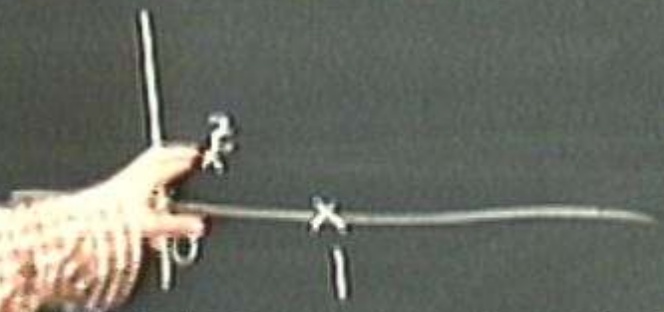
$$= \left(\frac{\delta(\sum_i \beta_i \Delta_i)}{|z^{\Delta_1 + \cdots}|^2 \cdots \Delta_{12}|^2} \right) e^{\int d(\Delta_i) \operatorname{sgn}(\operatorname{Im} z) \left[\operatorname{Im} \log z \log(1-z) + D_2(z) \right]}$$

3 pt function: Standard

4 pt function:

$D_2(z)$: Bloch Wigner function

Real analytic away from $z=0, z=1$



$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

$$= \frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(1-z)^{\Delta_1+\Delta_3-\Delta_{13}}|^2} \, e^{\int d(\Delta_i)\, \text{sgn}(\text{Im } z)\left[\text{Im}\log z \log(1-z) + D_2(z)\right]}$$

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$D_2(z)$: Bloch Wigner function

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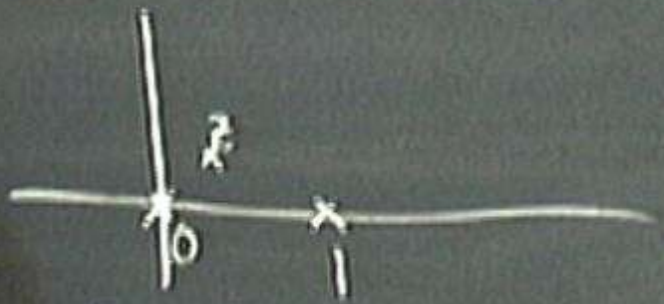


$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

$$= \frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(1-z)^{\Delta_1+\Delta_2-\Delta_{12}}|^2} e^{\left[d(\Delta_i) \operatorname{sgn}(\operatorname{Im} z) \left[\operatorname{Im} \log z \log(1-z) + D_2(z) \right] \right]}$$

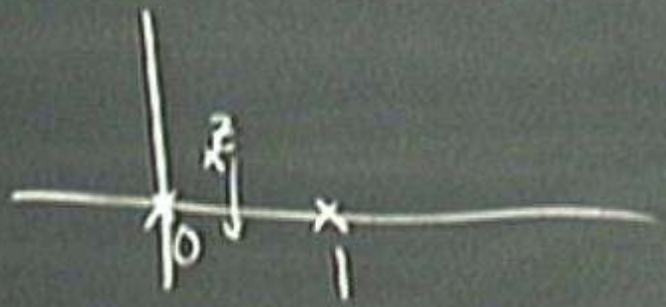
3 pt function: Standard

4 pt function:

$D_2(z)$: Bloch Wigner function

Real analytic away from $z=0, z=1$

$z = \frac{1}{1-z}$



$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

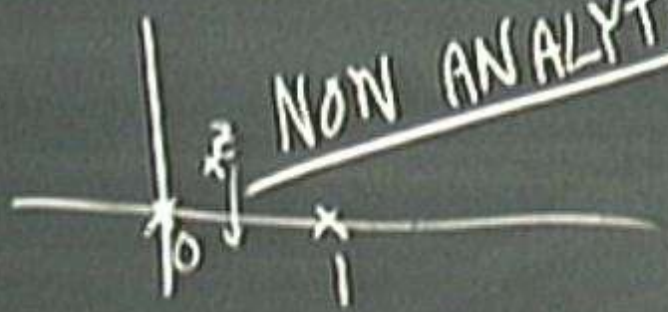
$$= \frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(1-z)^{\Delta_1+\Delta_3-\Delta_{13}}|^2} e^{\left[\prod d(\Delta_i)\,\mathrm{sgn}(\mathrm{Im}\,z)\left[\mathrm{Im}\log z \log(1-z) + D_2(z)\right]\right]}$$

3 pt function: Standard

4 pt function:

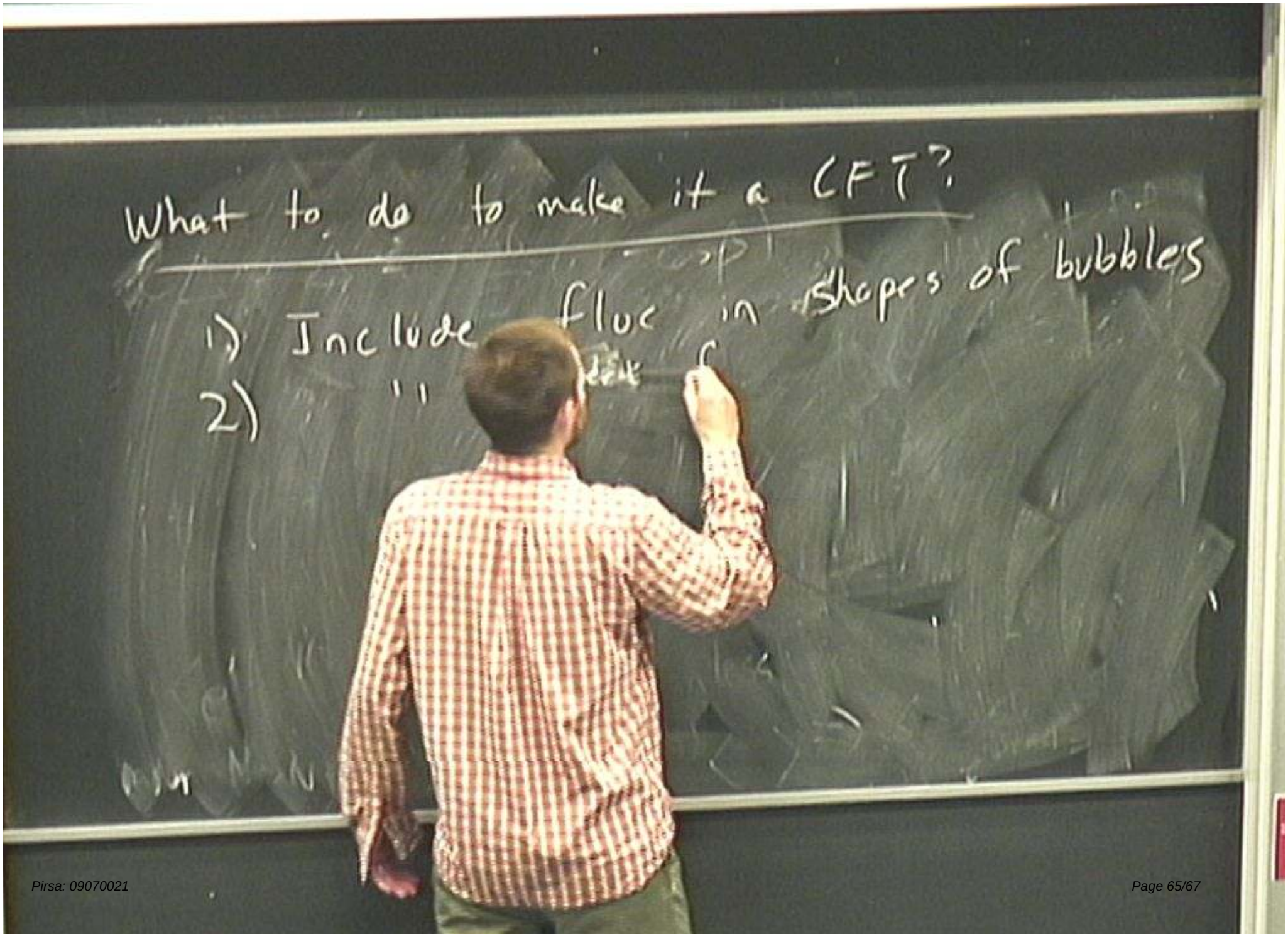
NON ANALYTICITY $\left.\right\}$ $D_2(z)$: Bloch Wigner function

Real analytic away from $z=0$, $z=1$



$$\langle e^{i\beta_1 N(z_1)} e^{i\beta_2 N(0)} e^{i\beta_3 N(1)} e^{i\beta_4 N(\infty)} \rangle$$

$$= \frac{\delta(\text{charge conservation})}{|z^{\Delta_1+\Delta_2-\Delta_{12}}(1-z)^{\Delta_1+\Delta_3-\Delta_{13}}|^2} e^{\int d(\Delta_i)\, \text{sgn}(\text{Im}\, z)\left[\text{Im}\log z \log(1-z) + D_2(z)\right]}$$


What to do to make it a CFT?
1) Include fluc in shapes of bubbles
2) " "

What to do to make it a CFT?

1) Include fluc in shapes of bubbles
2) " fluc in ϕ, $g_{\mu\nu}$

What to do to make it a CFT?

1) Include fluc in shapes of bubbles

2) " fluc in Φ, $g_{\mu\nu}$