

Title: 3d ADS/CFT from a quantum gravity point of view.

Date: Nov 13, 2007 11:00 AM

URL: <http://pirsa.org/07110007>

Abstract: TBA

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I Ruler-may
II Willen's Wake
III AdS/CFT From a ϕ point of view.

- I Rehearsal
 - II Willenstuck
 - III AdS/CFT From a QG point of view.
 - IV Q.G computations / discussion.
- + Andy $k_L \neq k_R$

- I Rehe-mung
 - II Willenishunk
 - III AdS/CFT From a QG point of view.
 - IV Q.G computations / discussions.
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I Ruler-mag

II Willen's link

III AdS/CFT From a QG point of view.

IV Q. G computations / discussions.

+ Andy $k_L \neq k_R$

2+1 fm $k = k_L = k_R$

Q.9

Bulk theory

CFT regime

2 view,

center

- I Rehearse
- II Willeris work
- III AdS/CFT, From a QG point of view.
- IV QG computations / discussion.

Bulk it

- + Andy $k_L \neq k_R$ 2+1 for $k=k_L=k_R$
- + What would constitute a proof of AdS/CFT.

- I Reviewing
- II Withersink
- III AdS/CFT From a QG point of view.
- IV Q.G. implications / discussion.

Q. 9

Bulk / QG

CFT / QG

+ And $k_L \neq k_R$ 2+1 dim $k_L = k_R$

+ What would constitute a proof of AdS/CFT?

What is exactly the precise dichotomy / Connection QG
a CFT

3 AQS/CFT.

dictionary / Laentien PG
a CFT

$k = k_c = k_r$

ADS/CFT.

Wilsonian

Laurentian Φ_G
a CFT

$e^{-S(g)}$

$e^{iS(g)}$

- a QG point of view.
/ discussion.

$\neq kR$ 2+1 fm $k \ll k \ll kR$

- contribute a proof of AdS/CFT.

exactly the precise dictionary

Laurentian QG
↕
a CFT
↕
Euclidean

$$e^{-S(g)}$$

$$e^{iS(g)}$$

$$S = \frac{1}{16\pi G} \int \Gamma_g (R_{gg}) - \frac{2}{\ell^2}$$

ADS

$S(\text{IR}): A^t = w \pm e$

$$S = \frac{1}{16\pi G} \int \sqrt{g} (R_{\mu\nu} - \frac{2}{\ell^2})$$

AdS

$$S(\text{Matter}): A^\pm = w \pm e \quad S_{CS} = \int T_L (A dA + \frac{1}{3} A^2)$$

$$S = \frac{k}{2\pi} (S_g(A^+) - S_g(A^-))$$

$$S = \frac{1}{16\pi G} \int \Gamma_g (R_{\mu\nu} - \frac{2}{\ell^2}) + C.S.(w)$$

ALS

$S(\text{Dir}) : A^\pm = \omega \pm e \quad S_{CS} = \int T_2(A) dA + \frac{1}{3} A^2$

$$S = \frac{b}{2\pi} (S_{\psi}(A') - S_{\psi}(A''))$$

$$de = de^i \gamma_i$$

$$ds^2 = c_a^i c_b^j \gamma_{ij} = g_{ij}$$

w)

Brown-Konheuer,
at the classical level
the Poisson alg of
Conserved
variables

A^2)

$$C = \frac{3}{2} \frac{Q}{g}$$

$$\left(\frac{2}{\ell^2} \right) + C.S.(w)$$

$$K.S. = \left(T_L \int_L A dA + \frac{1}{3} A^2 \right)$$

$$(A_s)$$

Brown-Konnewitz,
at the classical level
the Dirac alg of
Conserved

$\sim$ Virasoro

$$C = \frac{3}{2} \frac{\ell}{g} = 6k$$

$$\frac{2}{\ell^2}) + C.S.(w)$$

$$K_S = \int \left(T_L (A dA + \frac{1}{3} A^2) \right)$$

$$(A_S)$$

Brown-Konnewitz,
at the classical level
the algebra of
Conserved

Virasoro

$$C = \frac{3}{2} \frac{\ell}{g}$$

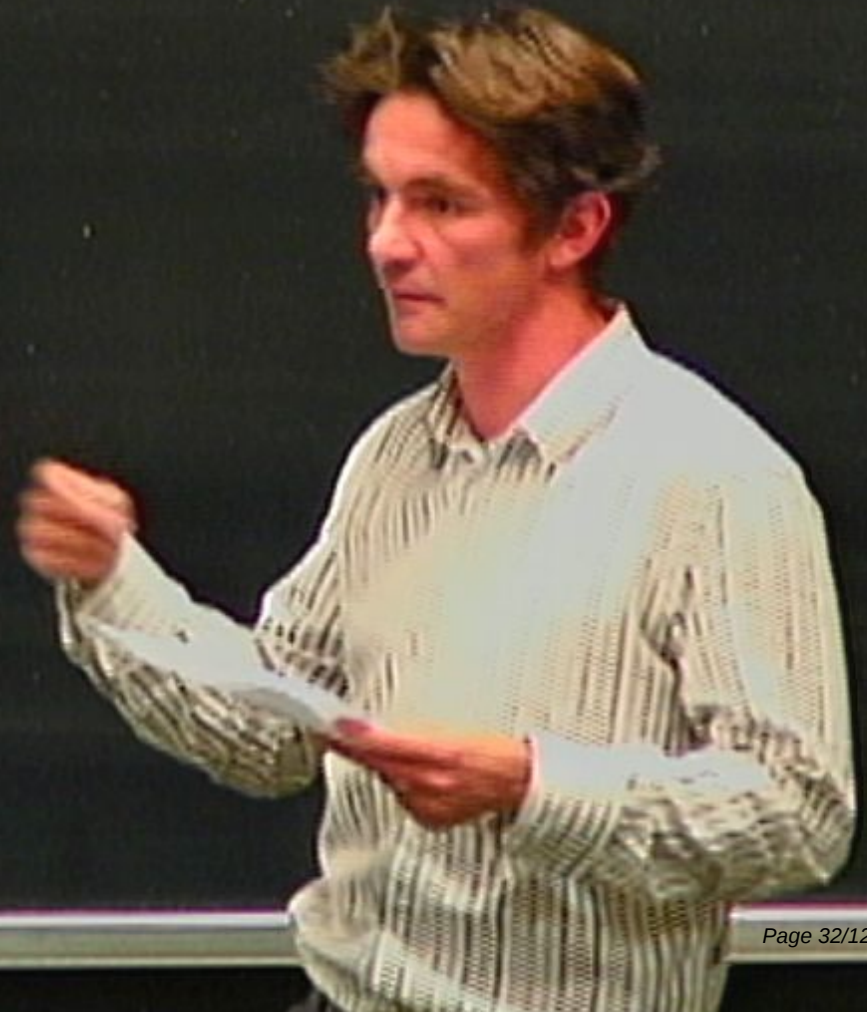
$$= 6k$$

$$k_{Hul} = 4k_{\text{with}}$$



BT2 BH-le

$$l_0^{\pm} = \frac{1}{2}(\ell\pi \pm 5)$$





BTZ BH

$$L_0^{\pm} = \frac{1}{2}(\ell r \pm 5)$$

$$ds^2 = 4G\ell(L^+ du^2 + L^- dv^2) - \ell^2 dr^2 + (\ell^2 e^{2r} + 6G\ell(L^+ du dv))$$

$$u, v = t \pm \phi$$



$$D_0 \times I = \mathcal{M}$$

BTZ BH- l_c

$$l_0^\pm = \frac{1}{2}(l\pi \pm 5)$$

$$ds^2 = 4G\ell(L^+ du^2 + L^- dv^2 + (e^{\frac{1}{2}L^+} e^{\frac{1}{2}L^-} + 4G\ell L^+ L^- du dv))$$



$$\odot \vec{B} = \vec{D} \times \vec{I} = \vec{B}$$

$$+ C dr^2) - \ell^2 dr^2 + (\ell^2 e^{2\rho} + 6G \ell^2 C^{-1} du dv$$

$$u, v = t \pm \phi$$



BT2 BH- ℓ

$$l_0^{\pm} = \frac{1}{2}(\ell\pi \pm 5)$$

$$ds^2 = 4\ell(L^+ du^2 + L^- dv^2) - \ell^2 dr^2 + (\ell^2 e^{2r} + 4\ell L^+ L^-) du dv$$

A_+, A_-

$$u, v = t \pm \phi$$



$$\bigcirc^{\otimes} \Pi_3 = D_4 \times I = \Omega$$

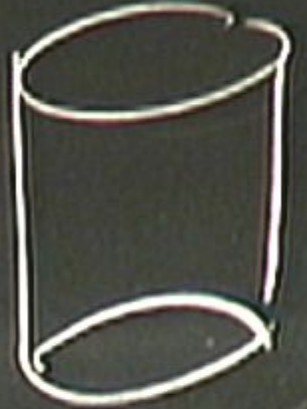
C.S.(w)

$$(A + \frac{1}{3} A^2)$$

Brown-Kononen,
at the classical level
the algebra of
conserved
Virasoro (L_0^+, L_0^-)

$$C = \frac{3}{2} \frac{e}{g}$$
$$= 6k$$

h u



R H de
17 ±

$$s^2 = 4gC$$

A-

$$S = \frac{1}{16\pi G} \int R (R_{\mu\nu} - \frac{2}{\ell^2}) + C.S.(w)$$

AdS

$$S_{\text{Matter}}: A^\pm = w \pm e$$

$$S_{\text{CS}} = \int T_L (A da + \frac{1}{3} A^2)$$

$$= (S_G(A^+) - S_G(A^-))$$

Brown-Kenna
at the classical
the thermally of
covered

universal l_0, l_0^+

$$C = \frac{3}{2} \frac{e}{g}$$

$$= 6k$$

Ex

S'

$AdS_2 + KK \text{ electric field}$

BTZ BHs

$$L_0^{\pm} = \frac{1}{2}(\ell r \pm 5)$$

$$ds^2 = 4G\ell(L^+ du^2 + L^- dv^2)$$

A_+, A_-



$$g_T = \begin{pmatrix} e^{2\sigma} & 0 & 0 \\ 0 & e^{2\sigma} & 0 \\ 0 & 0 & e^{2\sigma} \end{pmatrix}$$

$$\mathbb{R}^3 \times \mathbb{I} = \Omega$$

T2 BKL

$$\pm = \frac{1}{2}(\epsilon \mp 5)$$

$$ds^2 = 4G(L^+)$$

A+, A-

$$e^2 dr^2 + (e^2 e^{2\sigma} + 6G L^+ L^-) du dv$$

$$v = t \pm \phi$$

$$g_{\pm} = \begin{pmatrix} e^{\pi(r_{+} \pm r_{-})} & 0 \\ 0 & e^{-\pi(r_{+} \pm r_{-})} \end{pmatrix}$$

$$\Pi_3 = D_0 \times I = \mathcal{R}$$

BT2 BH- ℓ

$$l_0^{\pm} = \frac{1}{2}(\ell\pi \pm 5) = \frac{k}{4} (r_+ \pm r_-)^2$$

$$ds^2 = 4G\ell (L^+ du^2 + L^- dv^2) - \ell^2 d\phi^2$$

A_+, A_-

$u, v =$



BTZ BH

$$l_0^{\pm} = \frac{1}{2}(e\pi \pm 5) = \frac{k}{4}(\tau_{+} \pm \tau_{-})^2$$

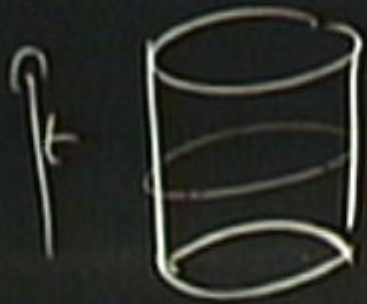
$$ds^2 = 4G\ell(L^{+}du^2 + L^{-}dv^2) - \ell^2 dr^2 + (\ell^2 e^{2r} + 4G\ell)$$

A_{+}, A_{-}

$$u, v = t \pm \phi$$

$$g_{\tau} = \begin{pmatrix} e^{F(\tau_{+}, \tau_{-})} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\mathbb{R}^3 = D_4 \times \mathbb{I} = \mathbb{R}$$



$$g_{\pm} = \begin{pmatrix} e^{\mp \pi(r_{\pm})} & 0 \\ 0 & e^{\mp \pi(r_{\pm})} \end{pmatrix}$$

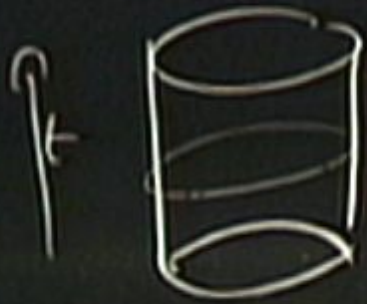
BTZ BH

$$l_0^{\pm} = \frac{1}{2}(\ell r_{\pm}) = \frac{k}{4} (r_{\pm})^2$$

$$ds^2 = 4G\ell (L^+ du^2 + L^- dv^2) - \ell^2 d\phi^2 + (\ell^2 d\phi ds)$$

A_+, A_-

$$u, v = t \pm \phi$$



$$g_{\pm} = \begin{pmatrix} e^{\mp \pi(r_{\pm})} & 0 \\ 0 & e^{\mp \pi(r_{\pm})} \end{pmatrix}$$



$D_u \times T$

BTZ BH

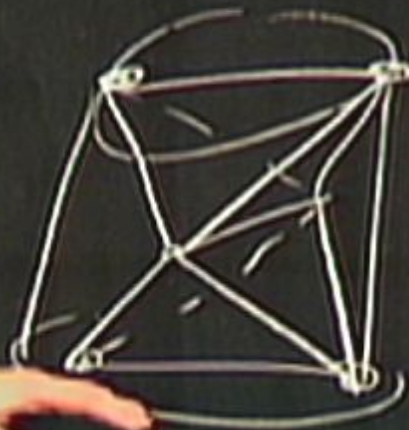
$$l_0^{\pm} = \frac{1}{2}(\ell r_{\pm}) = \frac{k}{4}(r_{+} \pm r_{-})^2$$

$$ds^2 = 4G\ell(L^+ du^2 + L^- dv^2) - \ell^2 d\phi^2$$

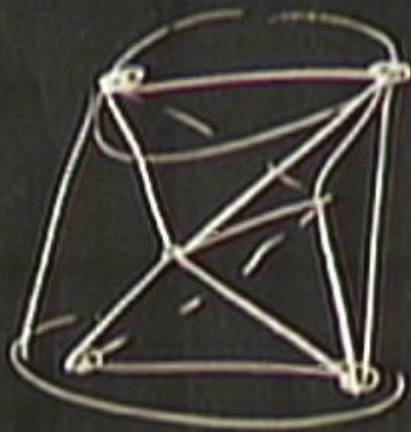
A_+, A_-

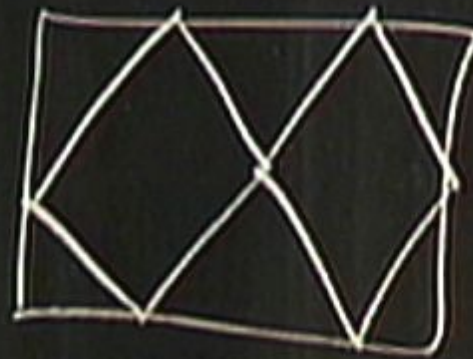
$$u, v = t \pm r$$

n-Nonneaus,
 ssial level
 alg of
 (l_0^+, l_0^-)
 $\frac{e}{q}$

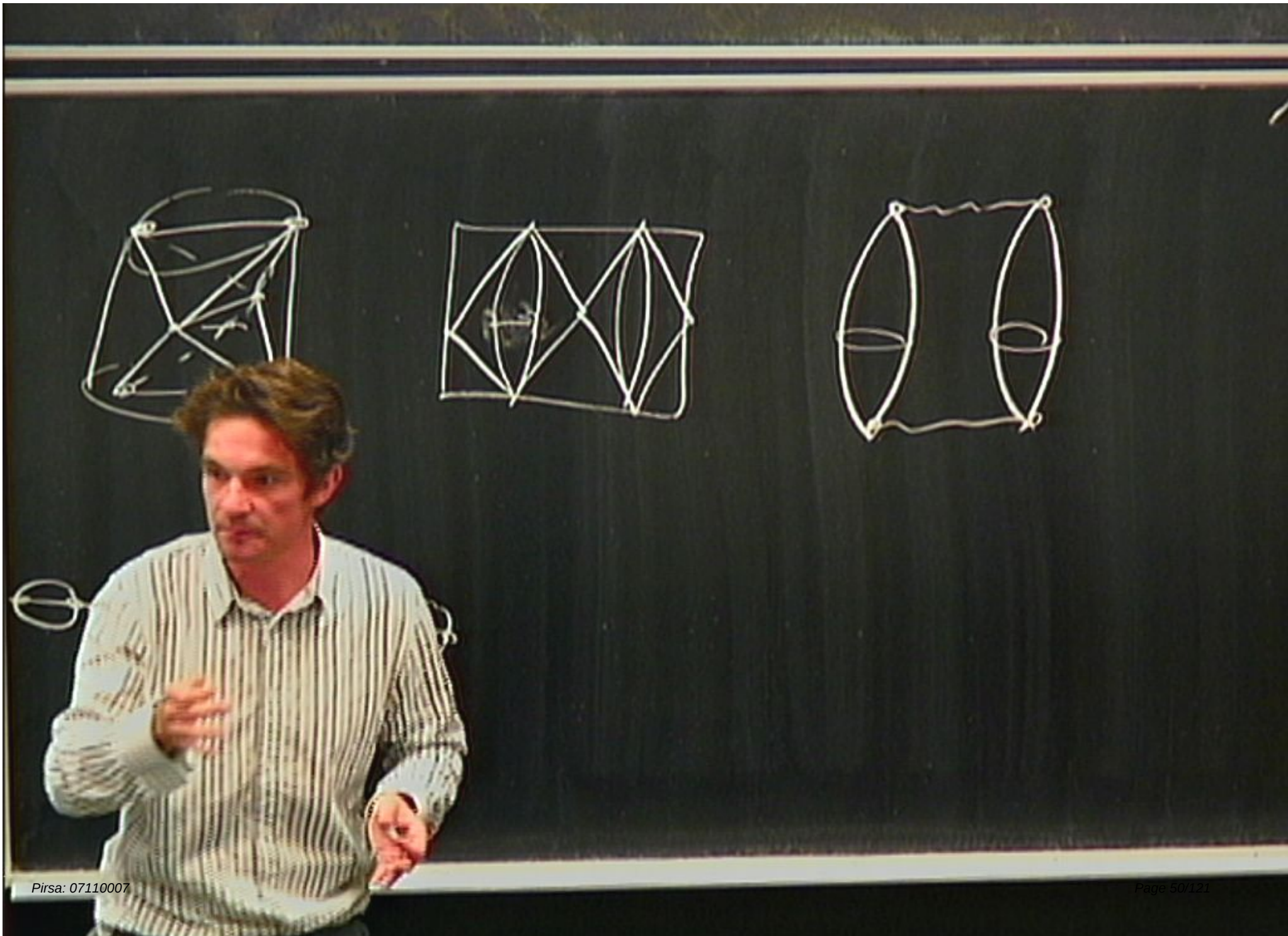


n-Nonredundant
 social level
 alg of
 (l_0^+, l_0^-)
 $\frac{e}{2}$
 $\frac{e}{9}$
 $5k$

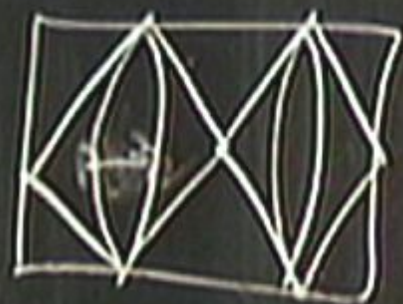














$$H = L_0 + \bar{L}_0 = \ell \mathbb{N}$$





$$H = L_0 + \bar{L}_0 = e\pi$$



$$e\pi = -\frac{b}{\chi}$$

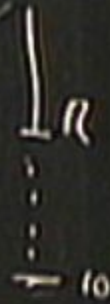


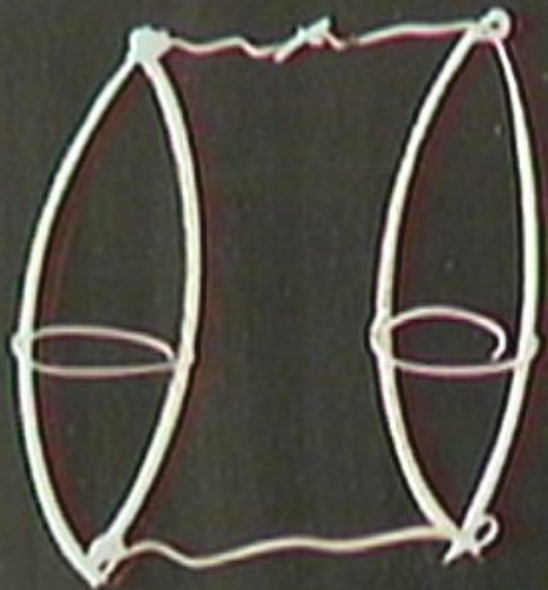


$$H: L_0^* + \bar{L}_0^- = e\pi$$



$$\boxed{e\pi = -\frac{b}{\frac{1}{\phi}}} \leftarrow \text{ADS}$$





$2n$



$\perp R$

$\vdots$

$\perp 10$

$$= -\frac{b}{f} \leftarrow \text{AdS}$$

BT2 BH- ℓ

$$l_0^\pm = \frac{1}{2}(\ell r_\pm \pm 5) = \frac{k}{4} (r_+ \pm r_-)^2$$

$$ds^2 = 4G\ell (L_+ du^2 + L_- dv^2) - \ell^2 d\rho^2 + (\ell^2 e^{2\rho} + 6G\ell) d\phi^2$$

T_{uu} $u, v = t \pm \phi$

A_+, A_-

$$\bullet \quad S_{\text{BH}} = \frac{2\pi r_+}{4g} = 2\pi k \frac{r_+}{e}$$

$$\bullet \quad S_{BH} = \frac{2\pi r_+}{4G} = 2\pi k \frac{r_+}{c}$$

• Cardy Formula.

- $S_{BH} = \frac{2\pi r_+}{4G} = 2\pi k \frac{r_+}{c}$

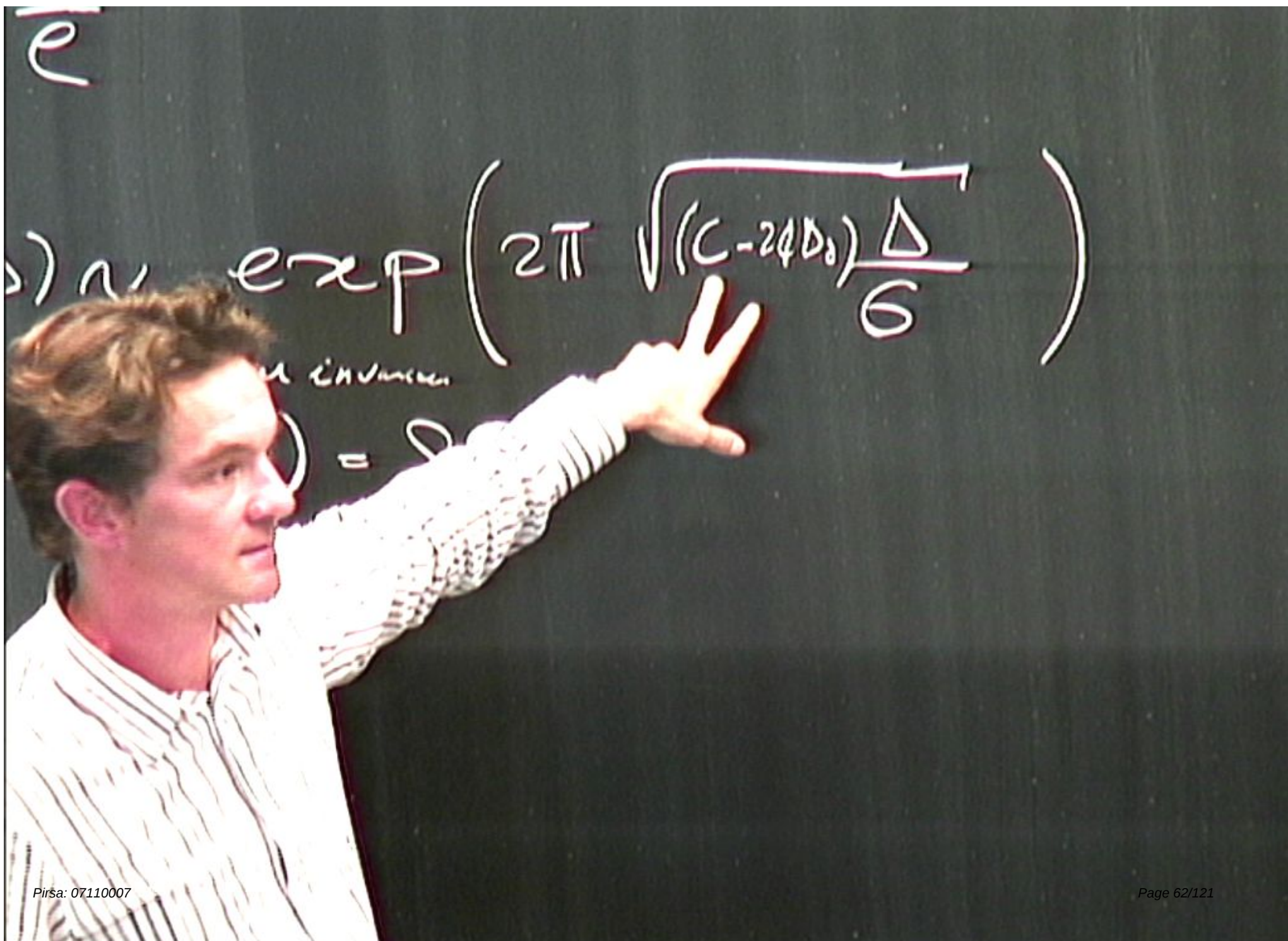
- Cardy Formula. $\rho(\Delta) \sim$

$$S = \ln \rho(\Delta_+) + \ln \rho(\Delta_-) = S_{BH}$$

- $S_{BH} = \frac{2\pi \Gamma_+}{4G} = 2\pi k \frac{\Gamma_+}{c}$

- Cardy Formula. $\rho(\Delta) \sim \exp\left(2\pi \sqrt{(c-24D_1)\frac{\Delta}{6}}\right)$

$$S = \ln \rho(\Delta) + 1$$



$$\sim \exp\left(2\pi \sqrt{(C-24D_0)} \frac{\Delta}{6}\right)$$

Modular invariant

$$\ln p(\Delta) = S_{\text{B.H.}}$$

$$\Delta_0 = \frac{C}{24}$$

$$C = 6b$$

- $S_{BH} = \frac{2\pi A_+}{4G} = 2\pi k \frac{A_+}{4}$

- Cardy Formula. $\rho(\Delta) \sim \exp\left(2\pi \sqrt{(c-1)\frac{\Delta}{6}}\right)$
? Modular invariant

$$S = \ln \rho(\Delta_+) + \ln \rho(\Delta_-) - S_{BH}$$

$$= 2\pi (\sqrt{kL_+} + \sqrt{kL_-})$$



$$\left(2\pi \sqrt{(C-24D_1) \frac{\Delta}{6}} \right)$$

S.T.H.

$$\Delta_0 = \frac{C}{6} + 40 \left(\frac{1}{K} \right)$$

$$C \times 6 b_j$$



$$\Delta_0 = \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right)$$

$$C_{\sigma} b_j$$

$$\Delta_0 = c_0 + o\left(\frac{1}{k}\right)$$

$$c_0 \leq b_k$$

$$P(\Delta) \sim \exp\left(2\pi \sqrt{(C-24D_1)} \frac{\Delta}{6}\right)$$

? Modular invariant

$$+ \ln P(\Delta_-) = S_{\text{B.H.}}$$

$$(\sqrt{kL_+} + \sqrt{kL_-})$$

$$\Delta_0 = \pi \left(\frac{1}{k} \right)$$

$$C_{\text{NS}} \left(\frac{1}{k} \right)$$

$$k = \left(\frac{e}{e_p} \right)$$

Witten's work: 2 extra key assumptions:

Witten's work: 2 extra key assumptions:

I. k is quantised

II. G

Witten's work: 2 extra key assumptions:

I. k is quantised

II. CFT is holomorphically Factorisable:

Other key assumptions:

Practically Factorisable:

$$II \Rightarrow I$$

Witten's work: 2 extra key assumptions:

I. k is quantised ($k = 4\mathbb{Z}$)

II. CFT is holomorphically Factorisable:

II $\Rightarrow$:

Witten's work: 2 extra key assumptions:

I. k is quantised ($k = 4\mathbb{Z}$)

II. C holomorphically Factorisable:

$II \Rightarrow I^*$

III. $\mathcal{R}(0,1)$

$$Z_{\text{top}}(H, \bar{H}) = \sum_{I \in \mathcal{R}} N^I \chi_I(H) \chi_{\bar{I}}(\bar{H})$$

$$ds^2 = (dz + i d\bar{z})^2$$

$$ed (k=4) \mathbb{Z}^4$$

Commutatively Factorable:

$$\mathbb{I} \Rightarrow \mathbb{I}^*$$

$$Z_{\text{eff}}(\mu, \bar{\mu}) = \sum_{\mathbb{I} \in \mathbb{I}} N^{\mathbb{I}} \chi_{\mathbb{I}}(\mu) \chi_{\bar{\mathbb{I}}}(\bar{\mu})$$

$$ds^2 = (dz + \tau d\bar{z})^2$$

$$Z(\mu) / Z$$

Conf Block

Witten's work 2 extra key assumptions:

I. k is quantised ($k = 4\mathbb{Z}$)

II. CFT is holomorphically Factorisable:

$\mathcal{H} \Rightarrow \mathcal{H}^*$

$\mathcal{H} \cong (0, 1) \times \mathbb{R} \cup \{0, 1\}$

$$Z_{\text{CFT}}(h, \bar{h}) = \sum_{\mathcal{H}} N^{\mathcal{H}} \chi_{\mathcal{H}}(h) \chi_{\mathcal{H}}(\bar{h})$$

$ds^2 = (dz + \alpha d\bar{z})^2$

$$Z_{\text{CFT}} = |Z(h)|^2$$

Conformal

Witten's work 2 extra key assumptions:

I. k is quantised ($k = 4\mathbb{Z}$)

II. CFT is holomorphically factorisable

$I \rightarrow I^*$

III. $g(0, \infty) = k\omega$

$$Z_m(h, \bar{h}) = \sum_{I \in \mathcal{I}} \int \chi_I(h) \chi_{\bar{I}}(\bar{h})$$

$ds^2 = g_{\alpha\beta} dz^\alpha d\bar{z}^\beta$

$Z_m = |Z(h)|^2$

$\int d\mu$

Witten's work: 2 extra key assumptions:

I. k is quantised ($k = 4\mathbb{Z}$)

II. CFT is holomorphically Factorisable:

$\mathcal{H} \Rightarrow \mathcal{H}^*$

III. $k(\Delta_{111} \cdot k_V)$

$$Z_{\text{CFT}}(h, \bar{h}) = \sum_{\mathcal{H} \in \mathcal{H}} N^{\frac{1}{2}} \chi_{\mathcal{H}}(h) \chi_{\mathcal{H}}(\bar{h})$$

$ds^2 = (dz + r d\bar{z})^2$

$|Z_{\text{CFT}}|^2 = |Z(h)|^2$

$\hookrightarrow$ Conjecture

- I. R is quantised ($k=4\pi$)
- II. CFT is holomorphically F
- III. $\epsilon(\Delta, p) = k\Delta$

$$\frac{2}{k} \log Z_{\text{CFT}} = 0$$

$$Z_{\text{CFT}}$$

$$|Z(h)|^2$$

$$Z_{\text{CFT}}(h, \bar{h}) = \int ds^2 (dz + i d\bar{z})$$



- I. R is quantised ($k = 4\pi$)
- II. CFT is holomorphically F
- III. $c(\Delta_{\text{eff}} = kD)$

$$Z_{\text{CFT}}(h, \bar{h}) = \int \mathcal{D}\phi e^{-S[\phi]}$$

$$ds^2 = (dz + i\alpha d\bar{z})^2$$

$$Z_{\text{CFT}} = \int \mathcal{D}\phi e^{-S[\phi]}$$

$$\log Z_{\text{CFT}} = 0$$



o C-Theorem by Zilber

o C-Theorem by Z. Z. 1.4. 17
e No continuous family of C.F.T

o C-Theorem by $\mathbb{Z}\mathbb{Z} \frac{1}{2}$

o No continuous family of C.F.T $\Leftarrow \exists$ Normalizable
 $SL(2, \mathbb{R})$ invariant State:

o $\mathbb{Z}$

o C-Theorem by $\mathbb{Z}\mathbb{Z}$

o No continuous family of C.F.T

$\Leftarrow \left\{ \begin{array}{l} \exists \text{ Normalizable} \\ \text{SL}(2, \mathbb{R}) \text{ invariant State} \end{array} \right\}$

o $\mathbb{Z}_2$

o C-Theorem by $\mathbb{Z}\mathbb{Z}^{1,4}$

o No continuous family of C.F.T

$\Leftarrow \{ \exists \text{ Normalizable } \mathcal{SL}(2, \mathbb{R}) \text{ invariant State} \}$

o $\mathbb{Z}$

$$k = \frac{p}{q}$$

$$k = \frac{p}{q}$$

k not rational

Normalizable
 $SL(2, \mathbb{R})$ invariant

$\leftarrow \{ \exists \text{ Normalizable}$
 $SL(2, \mathbb{R}) \text{ invariant State:}$

$\mathbb{R}$ not rational

$\circledast$

$$k = \frac{p}{q}$$

k not rational

$$+ \quad SL(2, \mathbb{R}) \supset U(1)$$

No continuous family of C.F.T

$\Leftarrow \left\{ \begin{array}{l} \exists \text{ Normalizable} \\ \text{State in } \mathbb{R} \text{ invariant State:} \end{array} \right.$

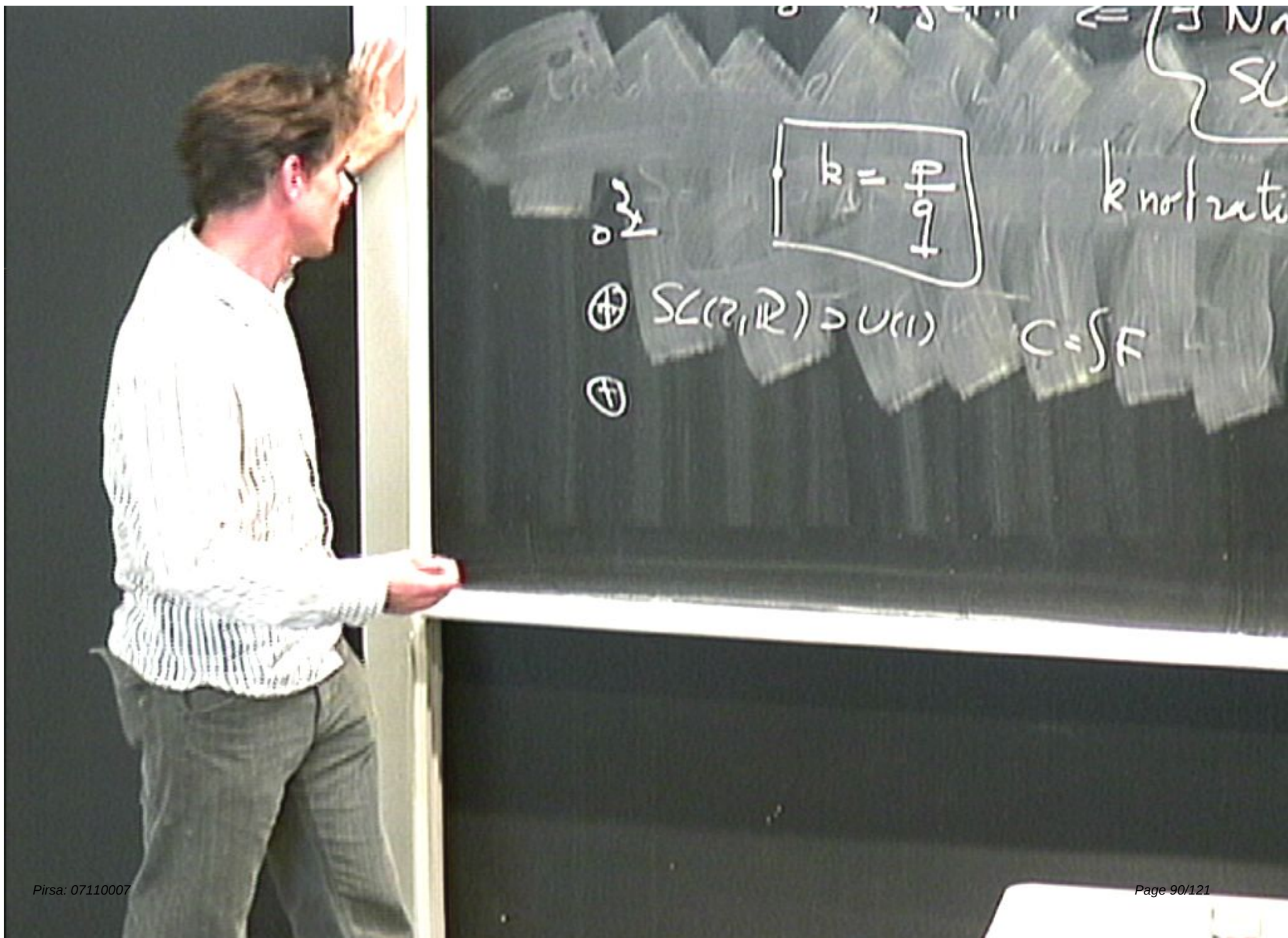
$\circ \frac{3}{2}$

$$\boxed{k = \frac{p}{q}}$$

$k \text{ not}$

$\dagger \text{ } SC(2, \mathbb{R}) \supset U(1)$

$$C = \int F$$



o3

$$k = \frac{p}{q}$$

k not rational

$$\oplus SL(2, \mathbb{R}) \supset U(1)$$

$$C = \int F$$

$$k \int$$

$\oplus$ + gauge invariance.

+ wave functions:

X

$$k = \frac{p}{q}$$

k not rational

$$\oplus SL(2, \mathbb{R}) \supset U(1)$$

$$C = \int F$$

$$k \int F \wedge F$$

Gauge invariance.

no functions:

X

No Sing on the Moduli.

$$k = \frac{p}{q}$$

k not rational

$$\textcircled{+} \quad SC(2, \mathbb{R}) \supset U(1)$$

$$C = \int F$$

$$k \int F \wedge F$$

+ gauge invariance.

+ wave functions:

X

No Sing on the Moduli.

$\{ \dots \}$ $\left[\begin{matrix} \Delta \\ 1 \end{matrix} \right]$ K not rational $\dots$
 $\oplus SL(2, \mathbb{R}) \supset U(1)$ $C = \int F$ $\hookrightarrow \int F \wedge F$

- ⑦ + gauge invariance.
- + wave functions: $\times$
- + No Sing on the Pochuli.

④ $SL(2, \mathbb{R}) \supset U(1)$ $C = \int F$ k
→ is not simply connected.

④ + gauge invariance.

+ wave functions:

+ SL_n

X

No Sing on the Moduli

$$\textcircled{+} \quad SL(2, \mathbb{R}) \supset U(1) \quad C = \int F$$

→ is not simply connected.

- $\textcircled{+}$
- + gauge invariance.
 - + wave functions: X
 - + $SL \rightarrow \mathbb{P}^1$ No Sing on the Podule.

$R_A < 0$ each $S_{\text{ch}}(2, 4)$

$$L_0 = \frac{1}{2} (L_1 + L_{-1}) = \frac{1}{2} (L_1 + L_{-1})$$

$$ds^2 = 4G\ell \left(L_{\text{ch}}^+ du^2 + L_{\text{ch}}^- dv^2 \right) -$$

$A_+, A_- \quad T_{\text{ch}}$

CAUTION

— 111111



$$b = \frac{p}{q}$$

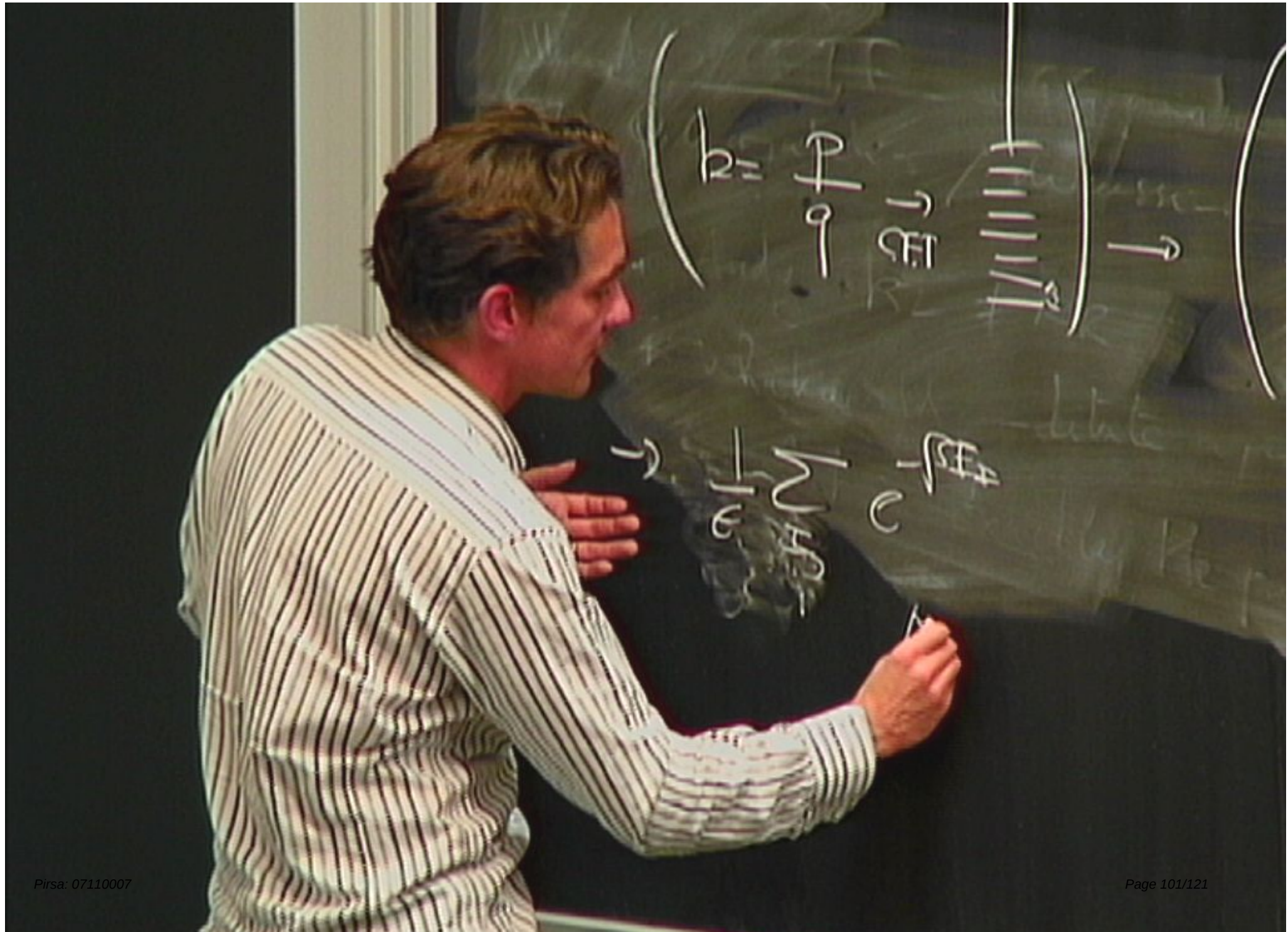


Normalisable =



No Normalisable $SL(2, \mathbb{R})$ and State





$$\rightarrow \left(\frac{1}{\hbar} \int_{-\infty}^{\infty} dt \right) \int d\mathbf{p} \quad \text{with } \delta\mathbf{p}$$

No Norm



Q.G & CSections:

I The...

II with...

III...

IV...

b-p
g
12

Q.G ≠ Cn-ons:

• inf deffco → inf gauge the frontier.

Q.G $\neq$ CS-ons:

• ing diff eo $\rightarrow$ ing gauge transform.

• nm ing diff eo $\neq$ non trivial gauge transform.

gauge transform
 $g \rightarrow g'$

$g' \neq g$

Q.G $\neq$ CS-ons.

• inf diffeo $\rightarrow$ inf gauge transformations.

• ~~inf diffeo~~ $\neq$ ~~trivial gauge transformations~~.

• 2 distinct geometries $g \neq g'$

$\underbrace{g \rightarrow g'}_{\text{gauge transform}}$
 $g' \neq g$

Q.G. $\neq$ C.S. - ons:

- inf diffeo $\rightarrow$ inf gauge transf.
- nm inf diffeo $\neq$ has trivial gauge transf.
gauge transf. $\rightarrow$
- 2 distinct geometries $g \neq g'$
identical as C.S. fields. $\left. \begin{array}{l} g \\ g' \end{array} \right\} g' \neq g$

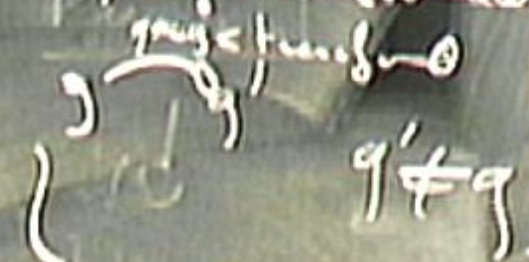
Q.G. $\neq$ CS-ons:

- inf diffeo $\rightarrow$ inf gauge transformations.
 - nm inf diffeo $\neq$ non trivial gauge transformations.
 $\text{gauge} = \text{transf} \rightarrow \emptyset$
 - 2 distinct geometries $g \neq g'$
identical as C.S. fields. $\left. \begin{array}{l} g \\ g' \end{array} \right\} g' \neq g$
- $\Lambda > 0$

- inf diffeo $\rightarrow$ inf gauge transformations.
 - inf diffeo $\neq$ has trivial gauge transformations.
 - 2 distinct geometries $g \neq g'$
 - identical as C.S. fields.
- $\Lambda > 0$
- + $0 < \Lambda < 0$ no particles.

$\cdot$ $\text{non-} \text{trivial gauge transformations}$
 $\cdot$ $\text{non-} \text{trivial gauge transformations}$

$\cdot$ 2 distinct geometries $g \neq g'$
 $\cdot$ identical as C.S. fields



$\Lambda > 0$
 $\Lambda < 0$ no particles: $\sum_j \times I$

(• 2 distinct geometries $g \neq g'$
 identical as C.S. fields

gauge field $\rightarrow$
 $g \neq g'$

$\Lambda > 0$

$0 < \Lambda < 0$ no particles



$\sum \times I$

$$\frac{\Pi_1(\mathbb{Z}_n \rightarrow S((\mathbb{Z}, \mathbb{R})))}{S((\mathbb{R}, \mathbb{R}))}$$

$$= \bigcup_{n=2, 4, 2} C_n$$

$$\frac{F_{\text{even}}}{(S(n))}$$

$$n = \text{Card}(\pi_n(n))$$

+ $0 \wedge < 0$

no particles

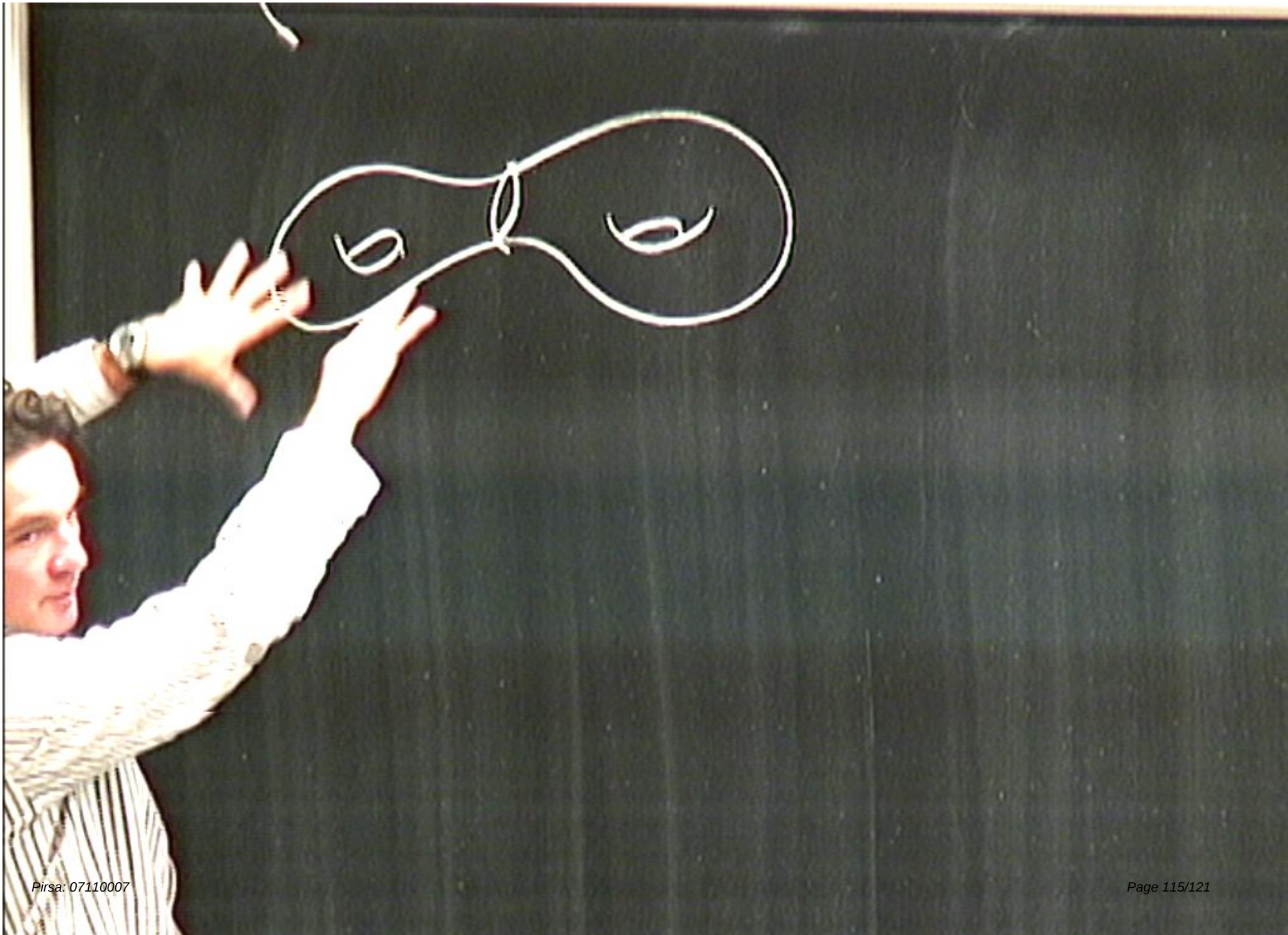


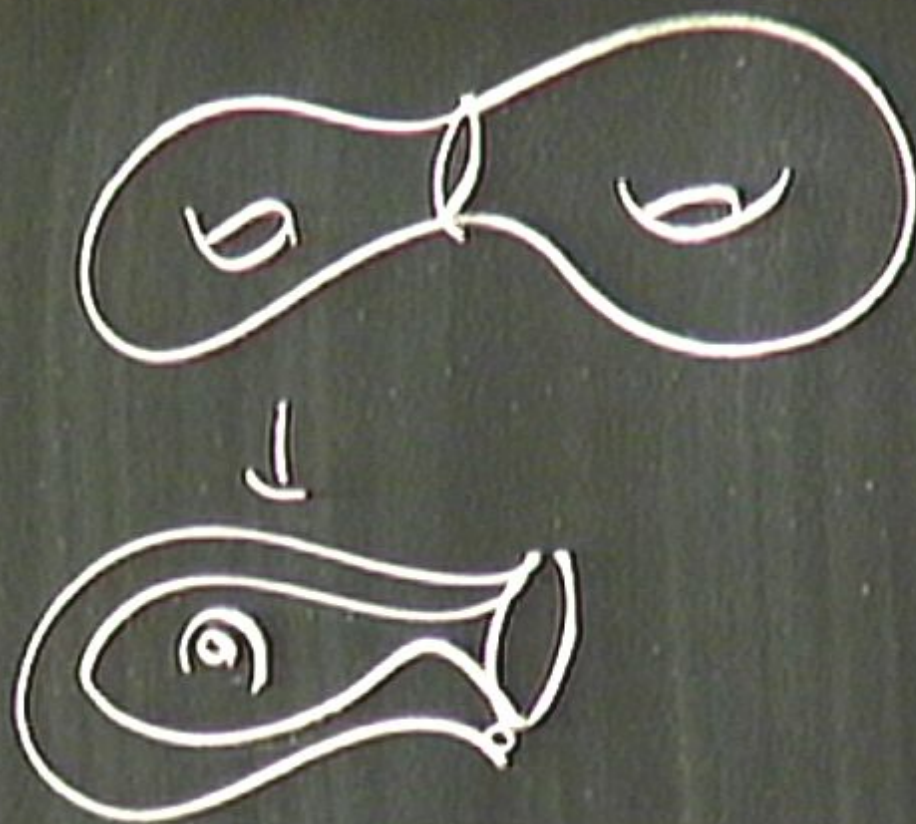
$\int x I$

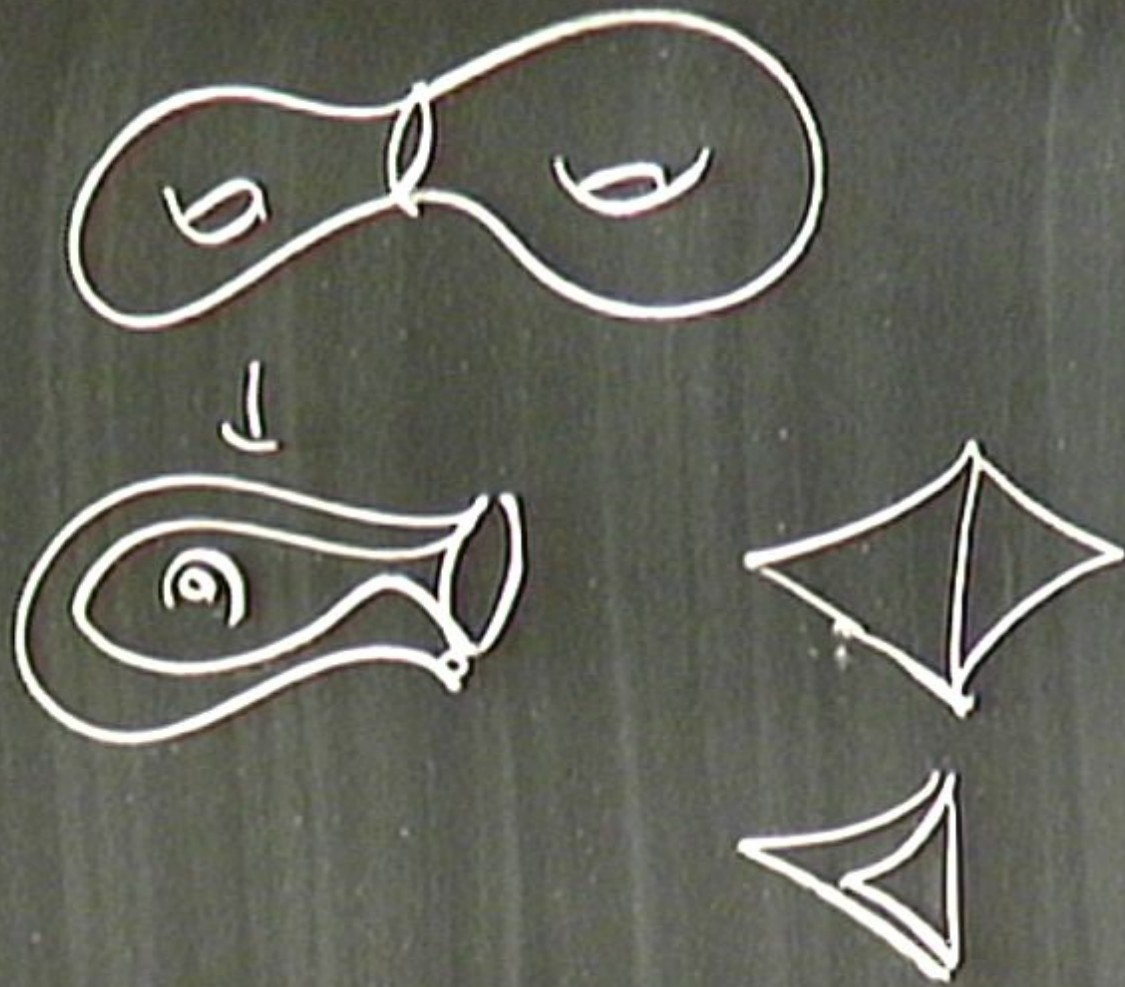
$\lambda > 0$

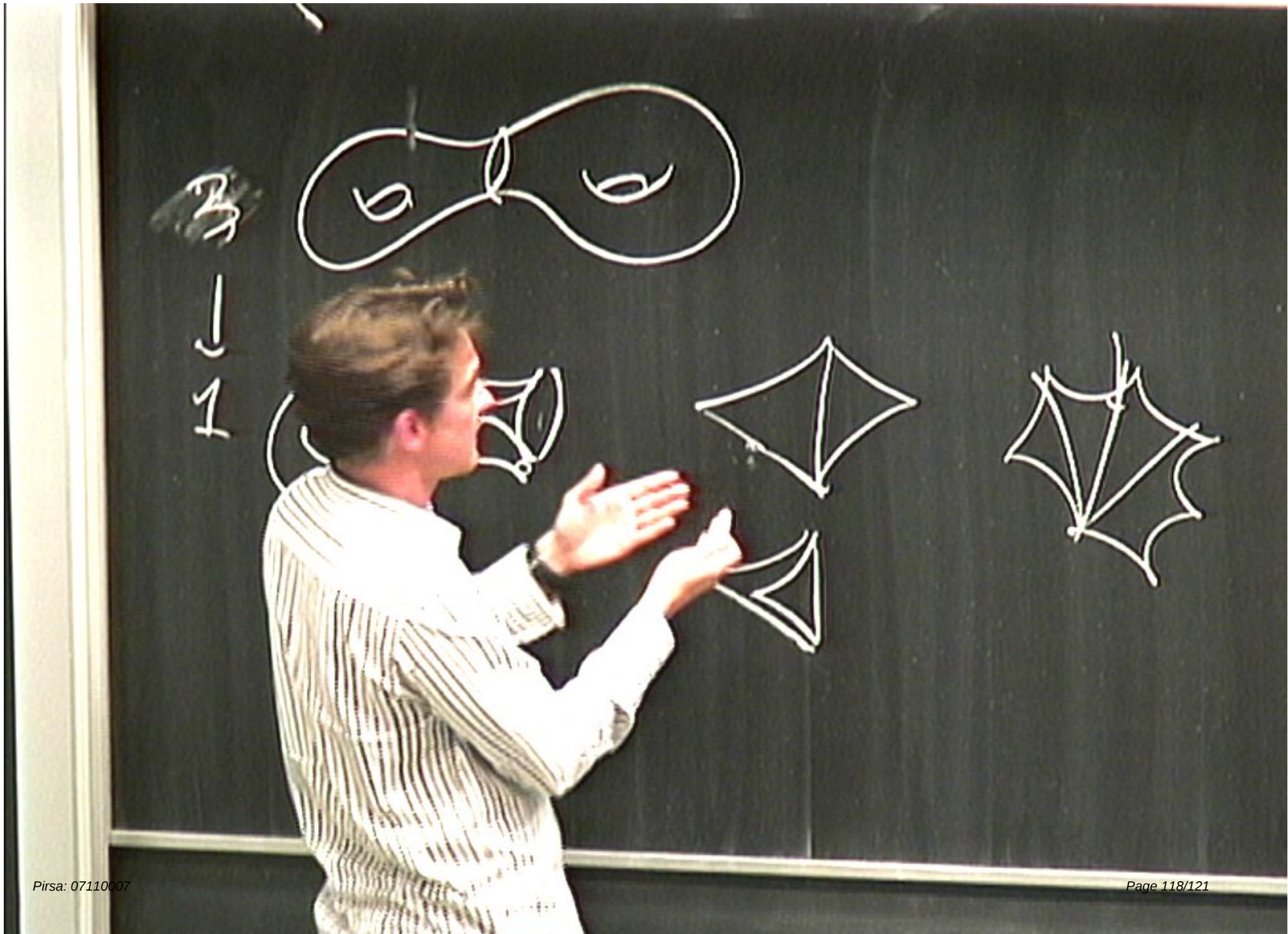
$$\Sigma_g \times I \begin{cases} \nearrow \frac{\pi_1(\Sigma_g \rightarrow S((z, \mathbb{R})))}{S((z, \mathbb{R}))} \\ \searrow \frac{\bigcup_{n=-2g-2}^{\infty} C_n}{\text{Teich} / (S^1)} \end{cases}$$

$n = \text{Char}(\pi_1(U))$



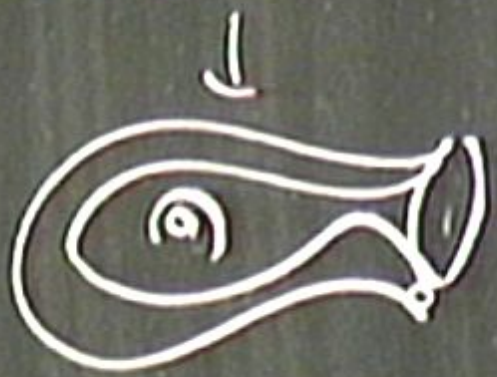








1
↓
1



$$= 24 \cdot 2$$



$$\frac{\mathfrak{su}}{S(2,2)}$$



ul
Flapping Glass
group
Cm →