

Title: TBA

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Abstract: TBA

# BLACK HOLES FROM MATRIX QUANTUM MECHANICS

} Hanada et al  
} Callan, Van Anders  
" Wiseman

GAUGE  $\mathcal{N}$

GR non-normal

AdS/CFT as definition  
of quantum gravity

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} Hanada et al  
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AdS/CFT as definition  
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GAUGE THEORY

$U(N)$

$$g_{YM}^2 \cdot N = \lambda$$

$$[g_{YM}^2] = \text{mass}^{3-p}$$

Strings geometry

$d = 5$

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$$\lambda_{eff} = \lambda U^{p-2}$$

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$g_s$

$\alpha'$

$$\longleftrightarrow (\alpha' R)^2 = \frac{1}{\lambda_{eff}}$$

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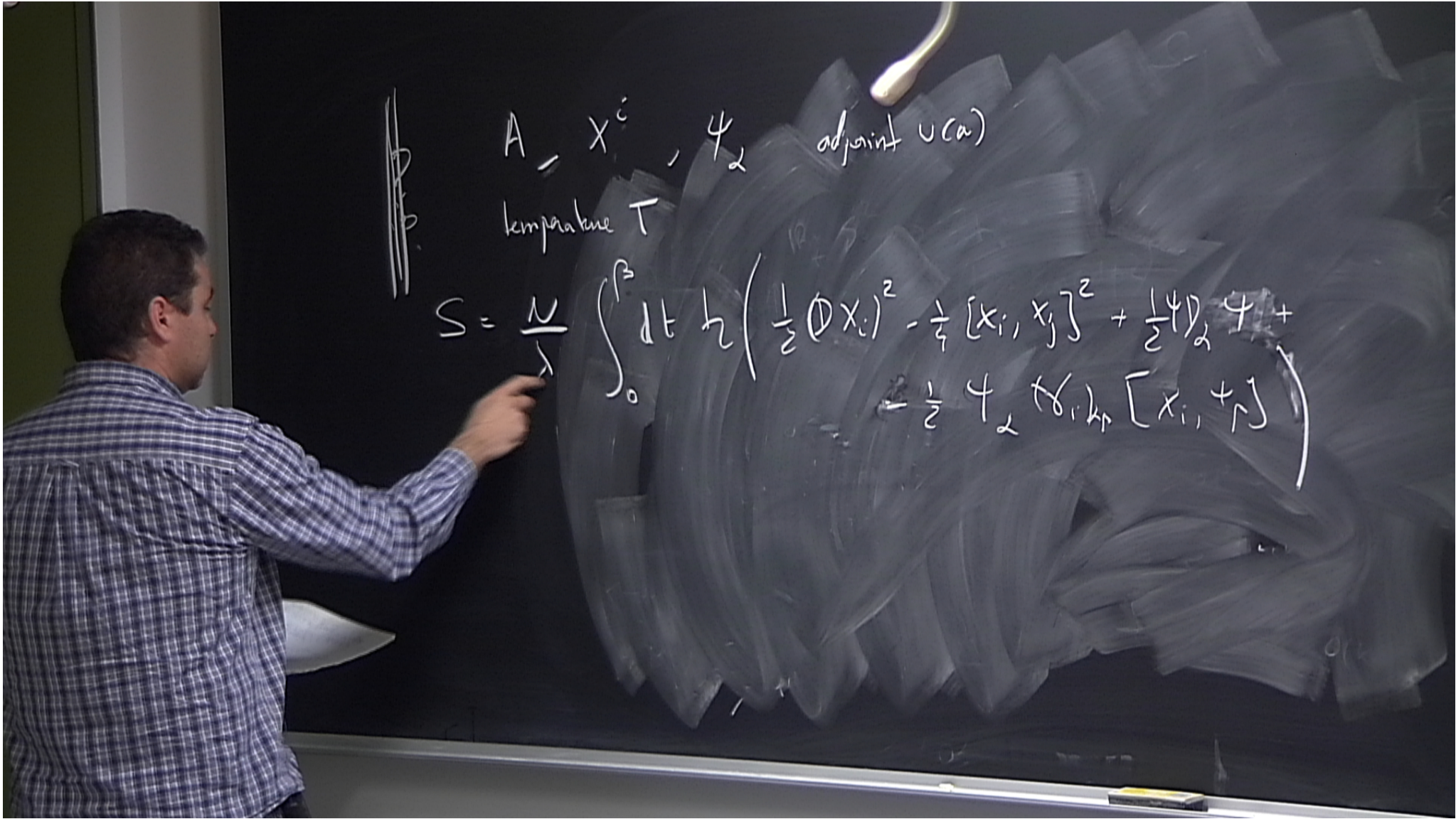
$$\longleftrightarrow (\alpha' R)^2 = \frac{1}{\lambda_{eff}}$$

Gravity  $\rightarrow$  strong coupling

$N \rightarrow \infty$  classical gravity

$$\frac{1}{N^2} \equiv g_s$$

$\frac{1}{N}$



1D  
 $A, X^i, \psi_2$  adjoint  $U(1)$

temperature  $T$

$$S = \frac{N}{\lambda} \int_0^\beta dt \frac{1}{2} \left( \frac{1}{2} (\dot{X}_i)^2 - \frac{1}{4} [X_i, X_j]^2 + \frac{1}{2} \psi_2 \dot{\psi}_2 + \frac{1}{2} \psi_2 \delta_{ij} [X_i, \dot{X}_j] \right)$$

$\lambda = \text{mass}^3$  relevant

Dimensionless  $t = \frac{T}{\lambda^{1/3}}$  strong coupling ( $T \rightarrow 0$ )

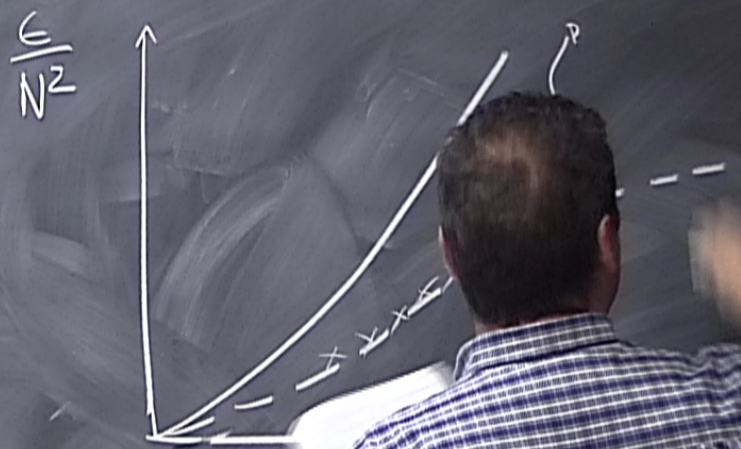
# BLACK HOLES FROM MATRIX

} Horava et al  
} Callan, Van Anders  
   " Wiseman

6D non-compact

AdS/CFT as definition  
of quantum gravity

$$\epsilon = \frac{E}{\sqrt{3}} \quad 7.4 \text{ LT} \quad 2.8$$





# HOLES FROM MATRIX

et al  
l, Van Anders  
, Wiseman

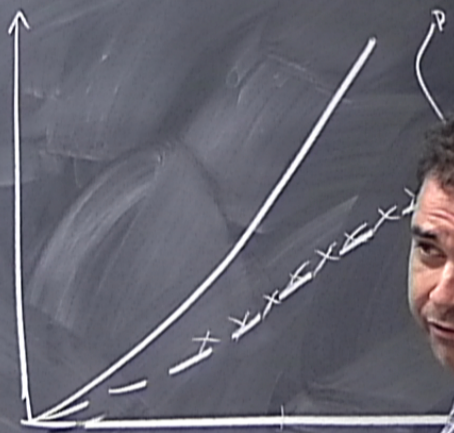
non-termin

FT as definition  
of quantum quality

$$\epsilon = \frac{E}{\chi^3}$$

$$7.41 + 2.8 = 5.58 \epsilon^{9.6}$$

$$\frac{\epsilon}{N^2}$$



05

# HOLES FROM MATRIX

et al  
Van Anders  
Wiseman

non-termin

FT as definition  
of quantum gravity

$$\epsilon = \frac{E}{\sqrt{3}}$$

$$7.41 t^{2.8} - 5.58 t^{9.6}$$

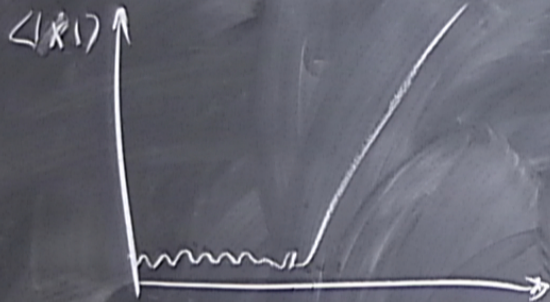


# HOLES FROM MATRIX

et al  
 Van Anders  
 Wiseman

non-convex

FT as definition  
 of quantum gravity



$$\epsilon = \frac{E}{\sqrt{3}}$$

$$7.41 t^{2.8} - 5.58 t^{9.6}$$

$$\frac{\epsilon}{N^2}$$



Caveat: Canonical ensemble not well defined

$$\int dx \sqrt{g} \left( e^{-2\phi} (R + 4\partial\phi\partial\phi) - \frac{1}{4} F^2 \right)$$

$$\int dx \sqrt{g} (e^{-2\phi} (R + 4\partial\phi\partial\phi) - \frac{1}{4} F^2)$$

$$\frac{ds^2}{r^2} = -h^{-1/2} dt^2 + h^{1/2} \left[ \frac{du}{f} + u^2 dz_s^2 \right]$$

$$e^{\phi} = r^{-3/2} h^{3/4}, \quad A_1 = r^{1/2} h^{-1} dt$$

$$h = h(u) = \frac{240\pi^5}{u^7} \lambda$$

$$f = f(u) = 1 - \left(\frac{u_0}{u}\right)^7$$

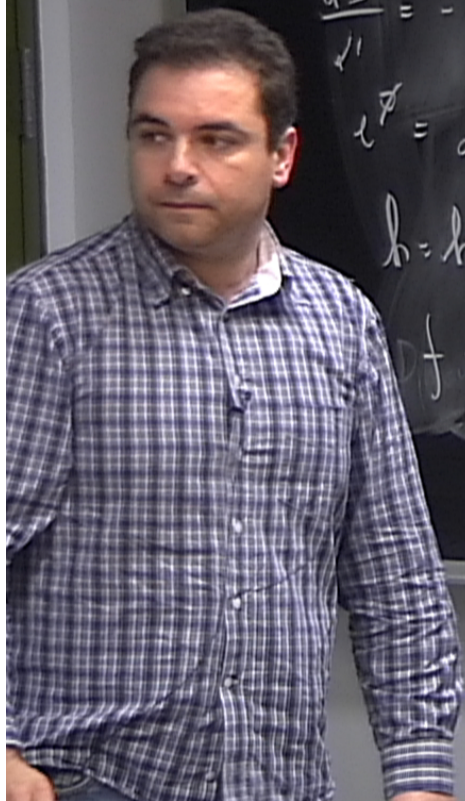
$$\int dx \sqrt{g} \left( \frac{1}{2} (R + 4\partial_\mu \phi \partial^\mu \phi) - \frac{1}{4} F^2 \right) \quad E = C_1 N^2 \lambda$$

$$\frac{ds^2}{dt^2} = -h^{-1/2} dt^2 + h^{1/2} \left[ \frac{du}{f} + u^2 dx_s^2 \right]$$

$$r^2 = d^{1-3/2} h^{3/4}, \quad A_\perp = d^{1/2} h^{-1} dt$$

$$h = h(u) = \frac{240\pi^5}{u^7} \lambda$$

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$$\int dx \sqrt{g} \left( e^{-2\phi} (R + 4 \nabla \phi \nabla \phi) - \frac{1}{4} F^2 \right)$$

$$\frac{ds^2}{\lambda^2} = - h^{-1/2} dt^2 + h^{1/2} \left[ \frac{dU}{f} + U^2 d\alpha_s^2 \right]$$

$$e^{\phi} = d^{1-3/2} h^{3/4}, \quad A_1 = d^{1/2} h^{-1} dt$$

$$h = h(U) = \frac{240 \pi^5}{U^7} \lambda$$

$$f = f(U) = 1 - \left( \frac{U_0}{U} \right)^7$$

$$E = C_1 N^2 \lambda^{1/3} \left( \frac{T}{\lambda^{1/3}} \right)^{14/5}, \quad C_1 = \frac{9}{14} C_3$$

$$T = C_2 \lambda^{1/3} \left( \frac{U_0}{\lambda^{1/3}} \right)^{5/2}, \quad C_2 = \frac{7}{2^4 \sqrt{5} \pi^{7/2}}$$

$$S = \frac{A}{4G} = C_3 N^2 \left( \frac{T}{\lambda^{1/3}} \right)^{9/5}$$

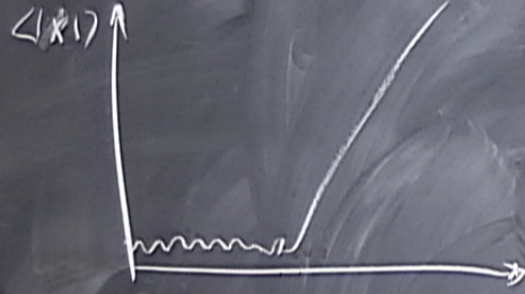
$$dE = T ds, \quad C_3 = 4^{13/5} 15^{2/5} \left( \frac{\pi}{7} \right)^{14/5}$$

# BLACK HOLES FROM MATRIX

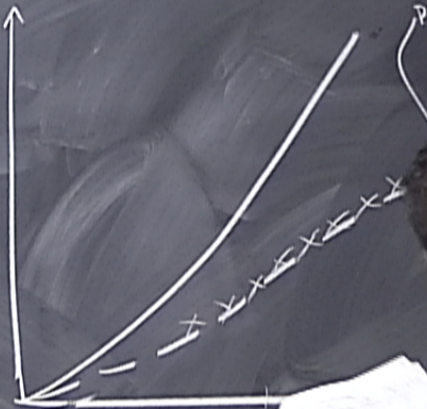
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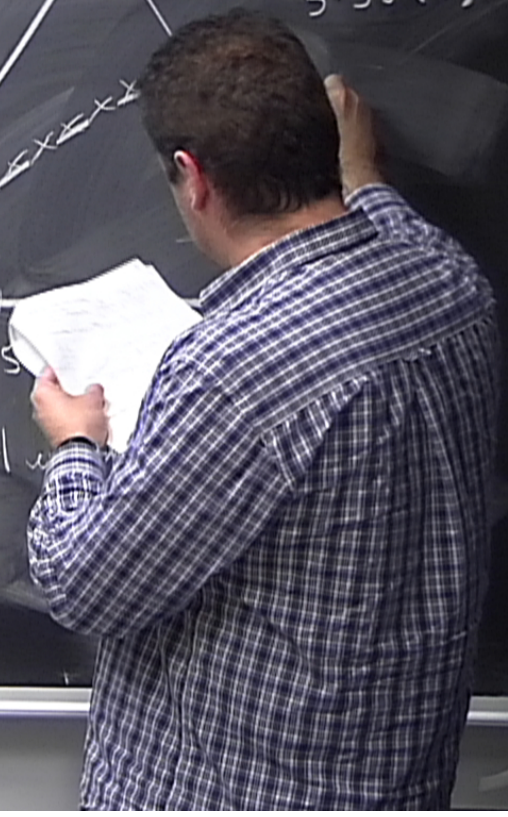
$$\frac{E}{N^2}$$



$$E = \frac{E}{\sqrt{3}}$$

7.41  
 2.8  
 4.58(3)  
 5.55(7)  
 9.6

Caveat: Canonical ensemble





$$\int dx \, r_g e^{-2r} \left( \alpha^{13} R^4 + \alpha^{13} R^3 F^2 + \alpha^{13} \cancel{R^2 F^2 R^2} \right) \quad \epsilon = \frac{E}{\sqrt{3}}$$

7.41, 2.8, 5.5



Canonical ensemble not well defined

$$\int d^3x \rho_g e^{-2\phi} \left( d^{13} R^4 + d^{13} R^3 F^2 + d^{13} \cancel{R^2 F^2 R^2} \right) \quad \epsilon = \frac{E}{\lambda^{1/3}}$$

ODE  $g_i(U)$

and entropy

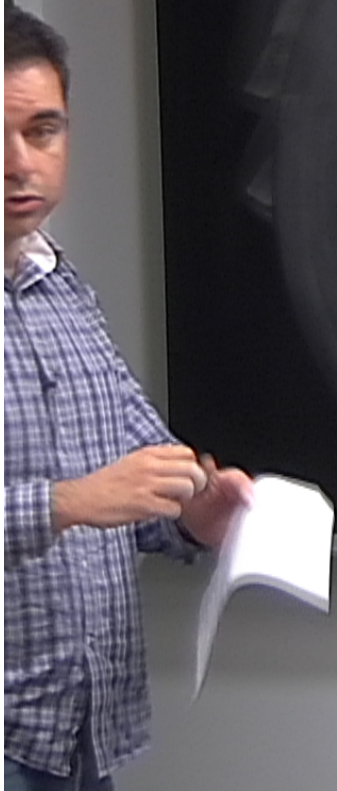
$$d^{13} \mathcal{R}_0(U_0) \sim \left( \frac{U_0}{\lambda^{1/3}} \right)^{9/2} \sim \left( \frac{T}{\lambda^{1/3}} \right)$$

$$S = c_3 \left( \frac{T}{\lambda^{1/3}} \right)^{9/5} \left( 1 + c_5 \right)$$



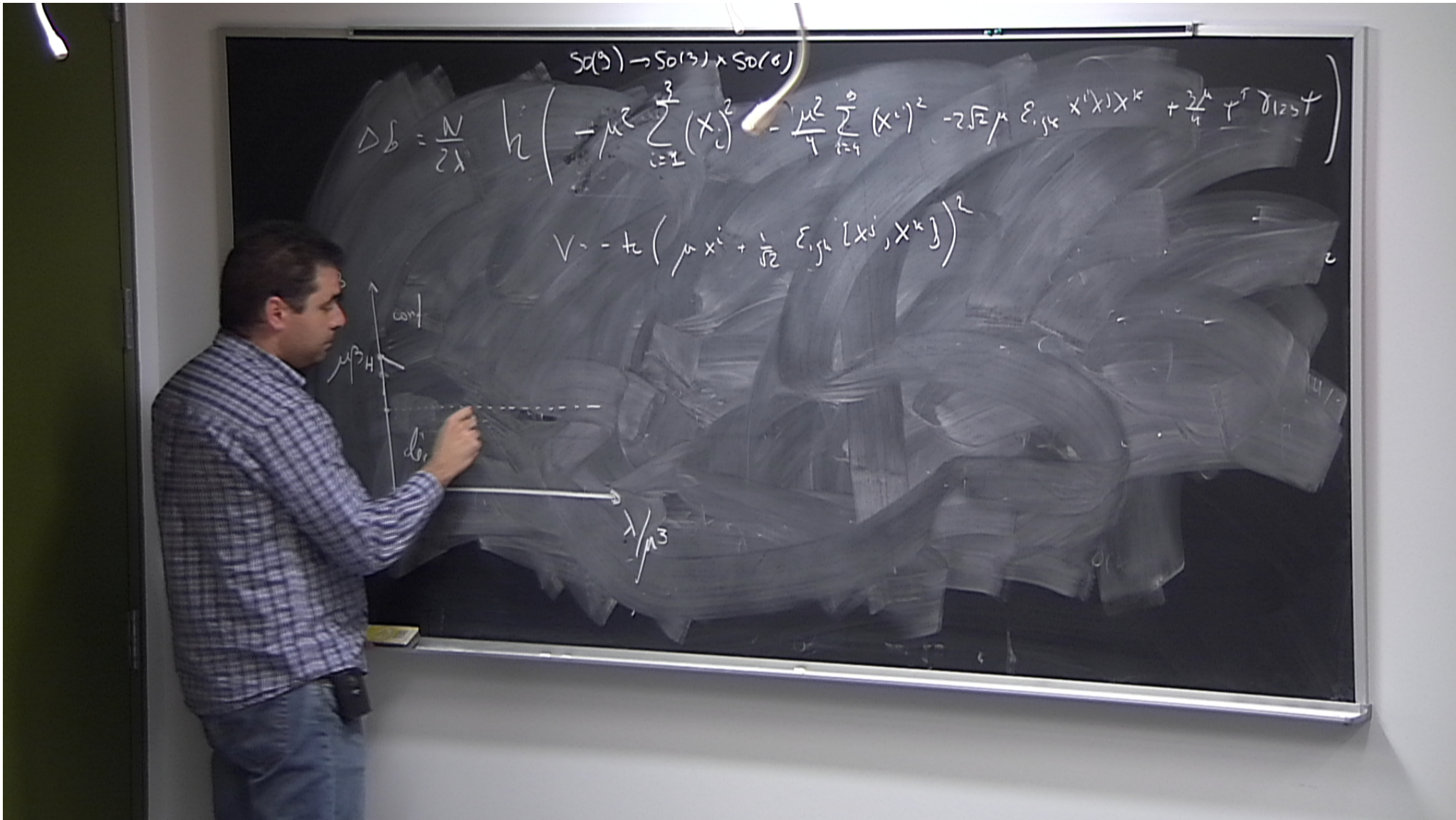
nonid ensemble not well defined

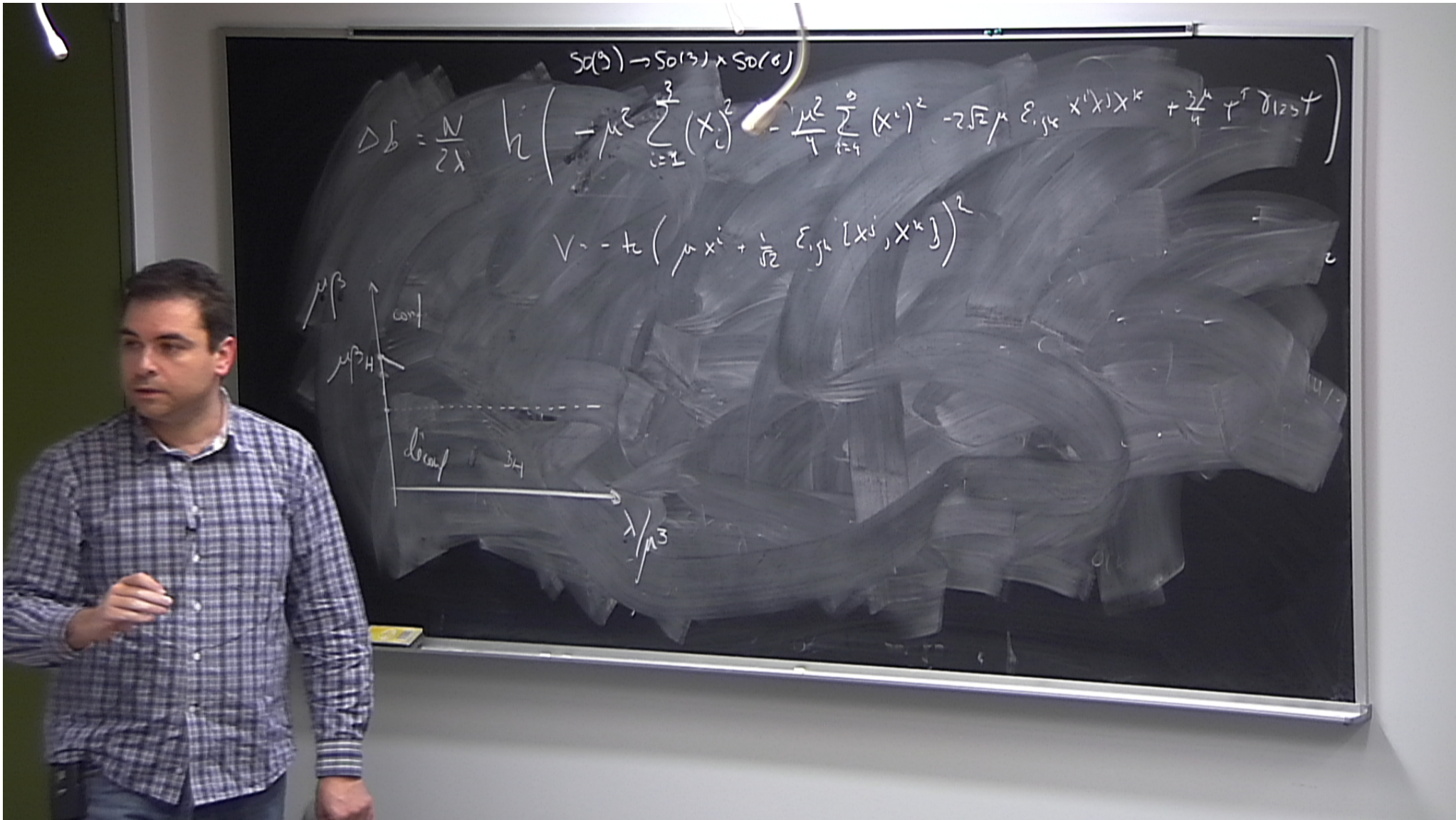
$$\frac{18}{5} = 3.6$$

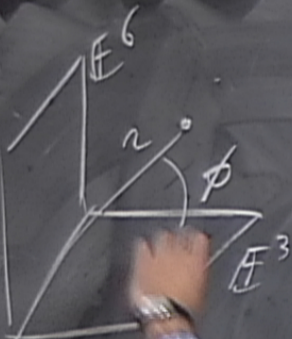


$SO(3) \rightarrow SO(3) \times SO(3)$

$$\Delta b = \frac{N}{2\lambda} \ln \left( -\mu^2 \sum_{i=1}^3 (x_i)^2 - \frac{\mu^2}{4} \sum_{i=1}^3 (x_i')^2 - 2\sqrt{2}\mu \varepsilon_{ijk} x_i' x_j x_k + \frac{2\mu}{4} \tau^T \delta_{123} \tau \right)$$
$$V = -t_2 \left( \mu x_i + \frac{1}{\sqrt{2}} \varepsilon_{ijk} [x_j, x_k] \right)^2$$







$F^2 R^2$   $\epsilon = \frac{E}{\sqrt{3}}$

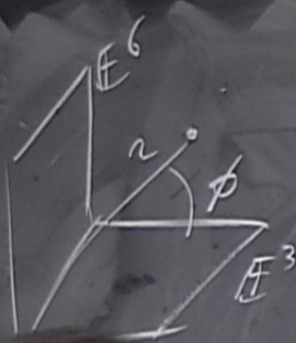
7.41 (circled) 7.8 (circled) 9.6 (circled)

5.58 (circled)



result not well defined

$\frac{18}{5} = 3.6$



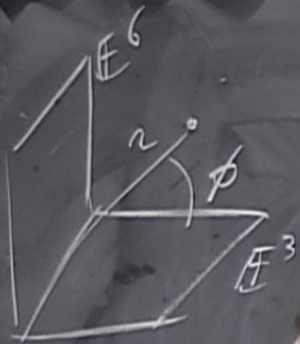
$$B = b(n, \phi) \in (S^2)$$

$$A_3 = a_3(n, \phi) dt \in (S^2)$$

$$F^2 R^2 \quad \epsilon = \frac{E}{\sqrt{3}}$$



ensemble not well defined  
 $\frac{18}{5} = 3.6$



$$B = b(n, \varphi) \in (S^2)$$

$$A = a_3(n, \varphi) dt n \in (S^2)$$

$$ds^2 = -F(n, \varphi) G(n, \varphi) (dn^2 + n^2 d\varphi^2) + H(n, \varphi)$$

$$F^2 R^2 \epsilon = \frac{E}{\lambda^3}$$



resulte not well defined

$$\frac{18}{5} = 3.6$$