

Title: Resumming late time divergences and comparing thermal vs dS

Date: Oct 27, 2010 11:45 AM

URL: <http://pirsa.org/10100089>

Abstract: I will argue that the dynamical renormalization group can be used to resum late time divergences appearing in loop computations in de Sitter. In the case of a scalar field with quartic interactions, the resummed propagator is the massive one. Standard mean field theory techniques can then be used to estimate the mass. This is analogous to the thermal field theory story but with some notable differences. We discuss whether a critical point can exist in dS where mean field methods fail.

No Signal

VGA-1

No Signal

VGA-1

No Signal
VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal
VGA-1

No Signal

VGA-1

No Signal
VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

VGA-1

No Signal

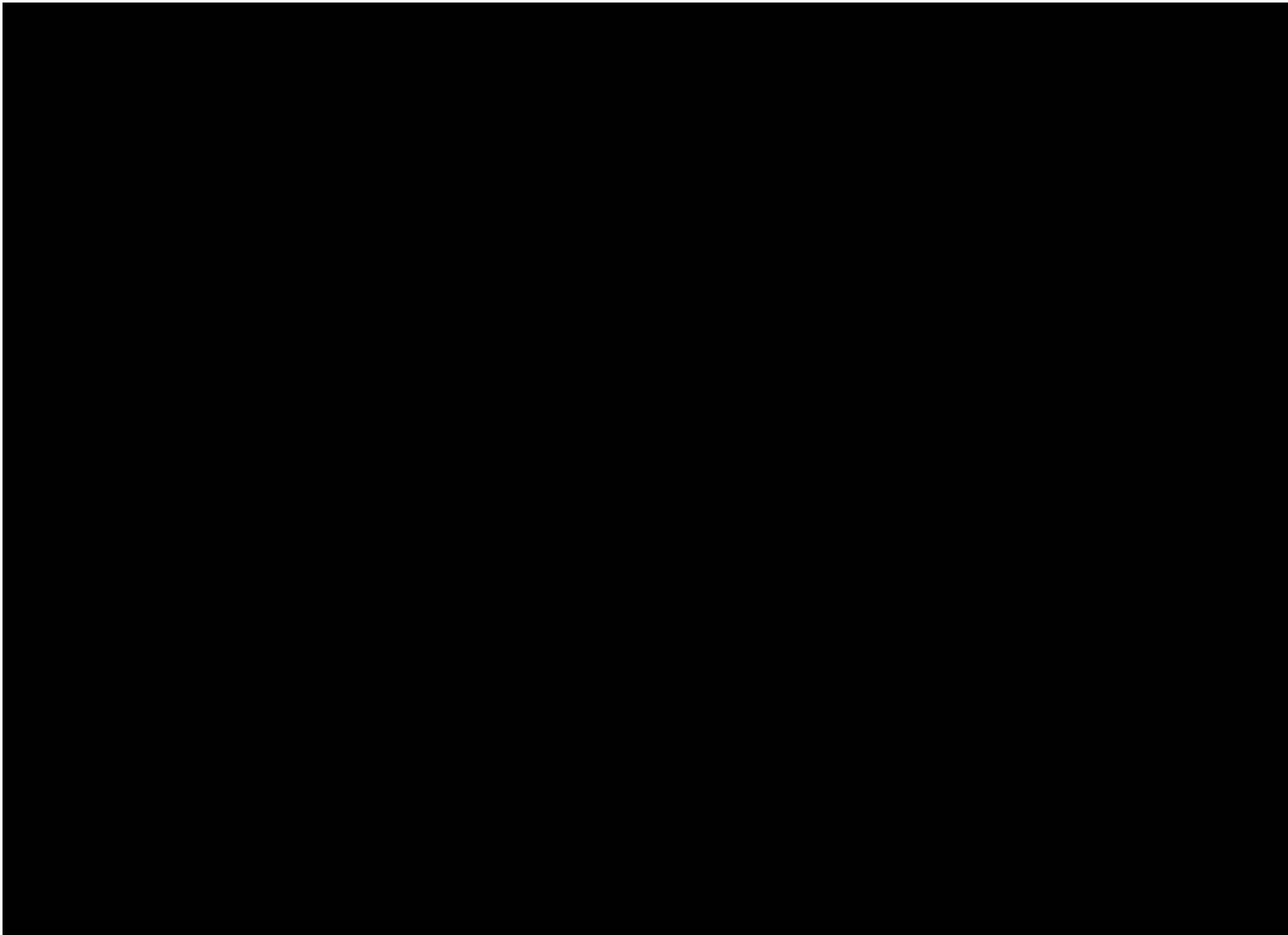
VGA-1

No Signal

VGA-1

No Signal

VGA-1



0912. 1608

1005. 3551

w/ Burgess

Herman

Shandera.

Motivation

F

0912. 1608

1005. 3551

w/ Burgess

Herman

Shambra.

Motivation

Fo

Resubmitting late Div. / thermal vs dS

0912.1608

1005.3551

w/ Burgess

Herman

Shamberger

Motivation

Formal

→ in dS.

R^2

Resumming late Div. / thermal vs dS

0912.1608

1005.3501

w/ Burgess
Herman
Shambayev

Motivation

Formal

→

QFT in dS.

observational

$$\langle R_x^2 \rangle = \langle s_k^2 \rangle \left(1 + A(k) \right)$$

Resumming late Div. / thermal vs dS

0912.1608

1005.3551

w/ Burgess

Herman

Shamberger.

Motivation

Formal

→

QFT in dS.

observational

$$\langle R_x^2 \rangle = \langle s_k^2 \rangle^0 \left(1 + A(k) \right)$$

Resumming late Div. / thermal vs dS

0912.1608

1005.3551

w/ Burgess

Holman

Shamir.

Motivation

Formal

Observation

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle_0 \left(1 + A(k) \right)$$

Resumming late Div. / thermal vs dS

0912.1608

1005.3501

w/ Burgess
Holman
Shamir.

$$SR \sim \frac{H^2}{M_p^2} \epsilon \propto \frac{H^2}{M_p^2}$$

Motivation

Formal

→ QFT in dS.

observational

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle^e \cdot (1 + A(k))$$

Resumming late Div. / thermal vs dS

0912.1608

1005.3501

w/ Burgess
Holman
Shamir.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \text{ or } \frac{H^2}{M_p^2} N$$

Motivation

Formal

QFT in dS.

ch

$$\langle R_x^2 \rangle = \langle R_k^2 \rangle \cdot (1 + A(k))$$

Resumming late Div. / thermal vs dS

0912.1608

1005.3501

w/ Burgess
Holman
Shamir.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \text{ or } \frac{H^2}{M_p^2} N$$

Motivation

Formal

→ QFT in dS.

observational

$$\langle R_x^2 \rangle = \langle \xi_k^2 \rangle \cdot (1 + A(k))$$

BURGESS
Holman
Shanderson.

$$SR \sim \frac{H^2}{M_P^2} \epsilon N \text{ or } \frac{H^2}{M_P^2} N$$

$$C_S \ll 1$$

$$\sim \frac{H^2}{M_P^2} \epsilon$$

in ds.

R²

$\uparrow (k)$

BURGESS
Holman
Shanderson.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \propto \frac{H^2}{M_p^2} N$$

$$c_s \ll 1$$

$$\sim \frac{H^2}{M_p^2} \epsilon c_s^5$$

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle^0 (1 + A(k))$$

BURGESS
Holman
Shanderson.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \propto \frac{H^2}{M_p^2} N$$

$$c_s \ll 1$$

$$\sim \frac{H^2}{M_p^2} \epsilon c_s^5$$

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle^0 (1 + A(k))$$

SRSS
number.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \text{ or } \frac{H^2}{M_p^2} N.$$

$$C_S \ll 1$$

$$\sim \frac{H^2}{M_p^2} \epsilon C_S$$

$$N < \frac{M_p^2}{H^2}$$

$$) = \langle R_k^2 \rangle^0 \cdot (1 + A(k))$$

Resumming late Div. / thermal vs dS

0912.1608
1005.3501

w/ Burgess
Holman
Shamir.

Motivation

Formal

→ QFT in dS.

observational

$$\langle R^2 \rangle = \langle r_k^2 \rangle \left(1 + \dots \right)$$

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \text{ or } \frac{H}{M_p^2}$$
$$c_s \ll 1 \quad \frac{M_p^2}{H^2}$$

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \propto \frac{H^2}{M_p^2} N < 10^{-12}$$

$$C_S \ll 1 \sim \frac{H^2}{M_p^2} \epsilon C_S^S$$

$$N < \frac{M_p^2}{H^2}$$

Normal vs ds

ess
an
nber.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \quad \text{or} \quad \frac{H^2}{M_p^2} N \rightarrow < 10^{-12}$$

$$C_S < 1 \quad \sim \frac{H^2}{M_p^2} \epsilon C_S < 10^{-5} \quad N < \frac{M_p^2}{H^2}$$

$$\int A(k)$$

Normal vs ds

ESS
an
number.

$$SR \sim \frac{H^2}{M_p^2} \epsilon N \quad \text{or} \quad \frac{H^2}{M_p^2} N \rightarrow < 10^{-12}$$

$$C_S < 1 \quad N < \frac{M_p^2}{H^2}$$

$$\sim \frac{H^2}{M_p^2} \epsilon C_S < 10^{-5}$$

$$= \langle \mathcal{R}_k^2 \rangle^0 (1 + A(k))$$

Resumming late Div. / thermal vs dS

0912.1608
1005.3501

w/ Burgess
Holman
Shamir.

$$SR \sim \frac{H^2}{M_{pl}^2} \epsilon N \text{ or } \frac{H^2}{M_{pl}^2} N \lesssim 10^{-12}$$

$$c_s \ll 1 \quad N < \frac{M_{pl}^2}{H^2}$$

$$\sim \frac{H^2}{M_{pl}^2} \epsilon c_s < 10^{-5}$$

Motivation:

QFT in dS.

Formal

db

$$\langle R^2 \rangle = \langle SR_k^2 \rangle \cdot (1 + A(k))$$

Resumming late Div. / thermal vs dS

Q112. 1608
1005. 3551

w/ Burgess
Holman
Shambayn.

$$SR \sim \frac{H^2}{M_p^2} \in N \text{ or } \frac{H^2}{M_p^2} N \lesssim 10^{-17}$$

Motivation

Formal

→ QFT in dS.

observational

$$\langle R^2 \rangle = \langle R_k^2 \rangle \cdot \langle \dots(k) \rangle$$

$C_s \ll 1$

$$\frac{H^2}{M_p^2} \in C_s < 10^{-5} \quad N < \frac{M_p^2}{H^2}$$

Resumming late Div. / thermal vs dS

0112.1608
1005.3501

w/ Burgess
Hohmann
Shamir.

$$SR \sim \frac{H^2}{M_p^2} \in N \text{ or } \frac{H^2}{M_p^2} N \lesssim 10^{-17}$$

$$c_s \ll 1 \sim \frac{H^2}{M_p^2} \in c_s < 10^{-5} \quad N < \frac{M_p^2}{H^2}$$

Motivation

Formal

observational

$$\langle \rho \rangle = \langle \rho_k^2 \rangle \cdot (1 + A(k))$$

0912.1608
1005.3551

w/ Burgess
Holman
Shandor.

$$SR \sim \frac{H^2}{M_{pl}^2} N \text{ or } \frac{H^2}{M_{pl}^2} N \lesssim 10^{-5}$$

Motivation

Formal

→ QFT in ds.

observational

$$\langle R_{\mu\nu}^2 \rangle = \langle R_{\mu\nu}^2 \rangle_0 (1 + A(k))$$

$$c_s \ll 1$$

~

$$\frac{H^2}{M_{pl}^2} c_s^5$$

$$< 10^{-5}$$

$$N < \frac{M_{pl}^2}{H^2}$$

$\lambda \phi^4$ in dS.

~~1/2~~

$\lambda \phi^4$ in dS.

~~15/10/16~~

$\lambda \phi^4$ in dS.

1) ~~hermal~~ $\lambda \phi^4$.

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

$\lambda \phi^4$ in

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

2) dS., dynamical RG.
to resum so

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

$\lambda \phi^4$ in dS., dynamical RG
to resum secular growth.

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

2) $\lambda \phi^4$ in dS., dynamical RG
to resume secular growth.

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

2) $\lambda \phi^4$ in dS., dynamical RG
to resum secular growth.

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

2) $\lambda \phi^4$ in dS., dynamical RG
to resum secular growth.

$\lambda \phi^4$ in dS.

1) thermal $\lambda \phi^4$.

2) $\lambda \phi^4$ in dS., dynamical RG
to resume secular growth.

$$1) \quad \int_{\text{loop}} \underline{\quad} = \int d^3p$$

$$1) \quad \oint \frac{d^3 p}{p^2} \sim \lambda T$$

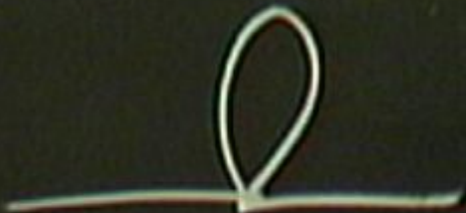
1)

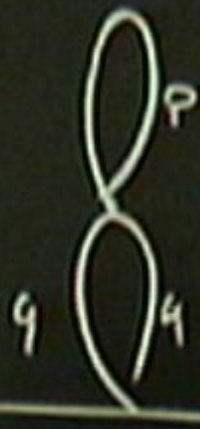


$$= \lambda \int \frac{d^3 p}{p^2} \sim \lambda T$$

9

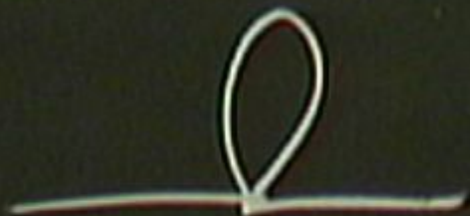
$$\sim \lambda^2$$

1)  = $\lambda \int \frac{d^3 p}{p^2} \sim \lambda T$



$\lambda^2 T \int d^3 s$

1)



$$= \lambda \int \frac{d^3 p}{p^2} \sim \lambda T$$

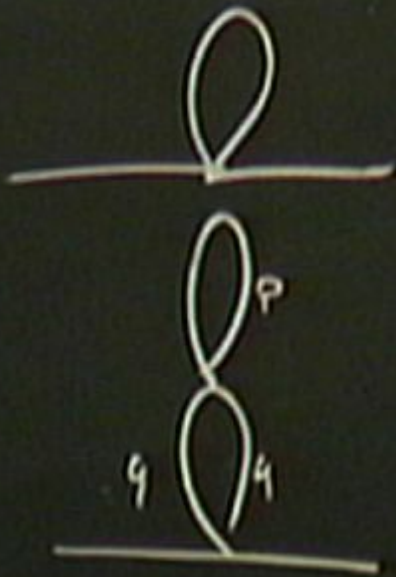


$$\approx \lambda^2 T \int \frac{d^3 p}{p^2} \int \frac{d^3 q}{q^2}$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n$$

1)



$$= \lambda \int \frac{d^3 p}{p^2} \sim \lambda T$$

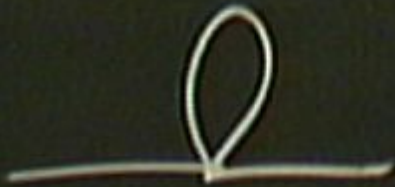
$$\approx \lambda^2 T \int \frac{d^3 p}{p^2}$$

$$\sim 1/m_0$$

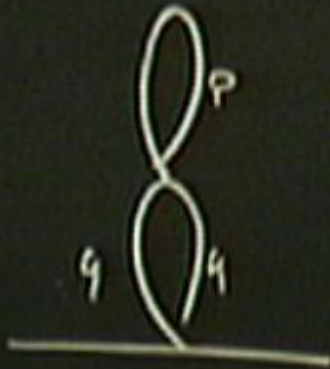
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m^2}$$

$$\sum_n \int d^3p$$

1)



$$= \lambda \int \frac{d^3p}{\omega^2} \sim \lambda T$$



$\gg \lambda$

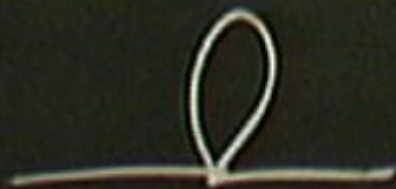
$$\int \frac{d^3p}{\omega^2}$$

$$\frac{\lambda^2 T^2}{\epsilon}$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_n^2}$$

$$\sum_n \int d^3p$$

1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



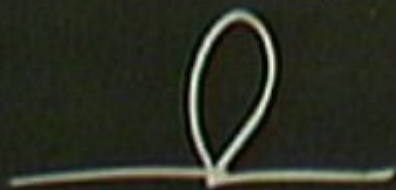
$$\Rightarrow \lambda^2 T$$

$$\int \frac{d^3p}{p^2} \xrightarrow{1/m_0} \frac{\lambda^2 T^2}{\epsilon_0}$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$

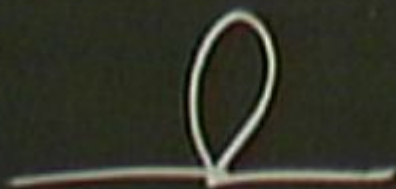


$$\sim \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{m_0}$$

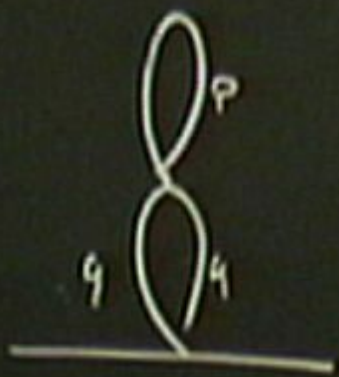
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_n^2}$$

$$\sum_n \int d^3p$$

1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$

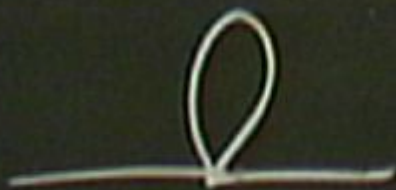


$$\approx \lambda^2 T \int \frac{d^5p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{M_0}$$

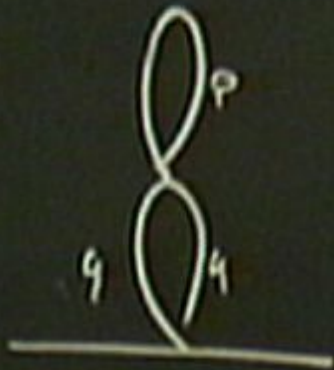
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

1)

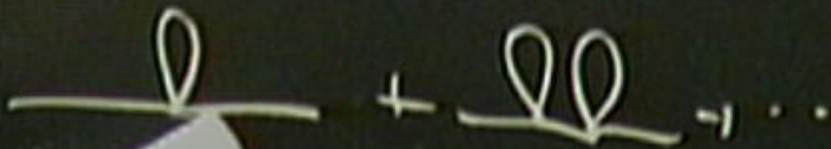


$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



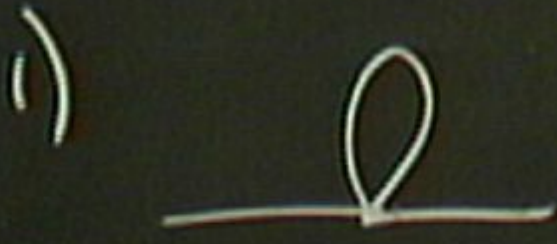
$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{\epsilon_0}$$

$\nearrow 1/m_0$

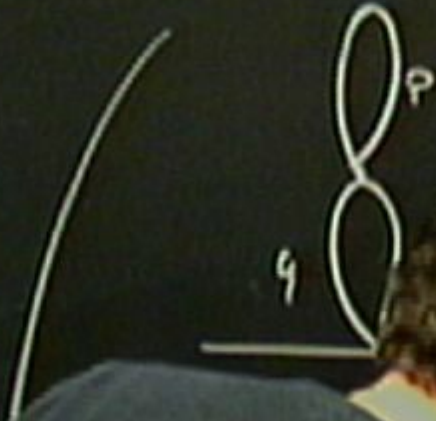


$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

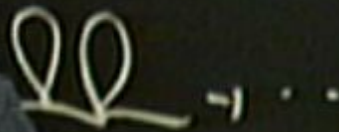
$$\sum_n \int d^3p$$



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



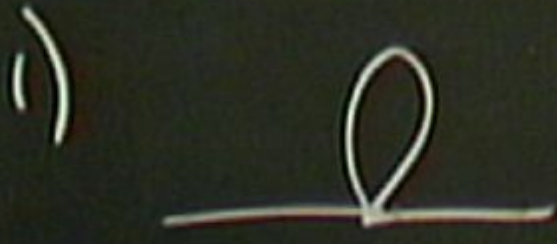
$$\Rightarrow \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{\epsilon_0}$$



0 2 4

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_n^2}$$

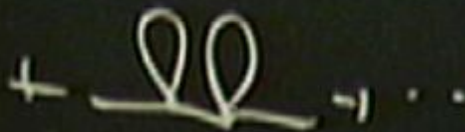
$$\sum_n \int d^3p$$



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \xrightarrow{1/m_0} \frac{\lambda^2 T^2}{\epsilon_0}$$



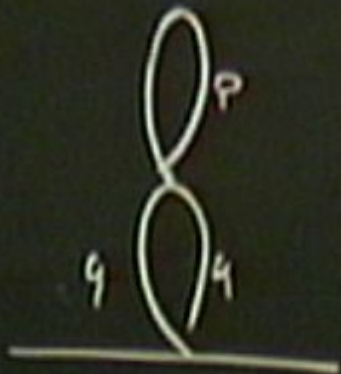
$$\sim \lambda^2 T^2$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

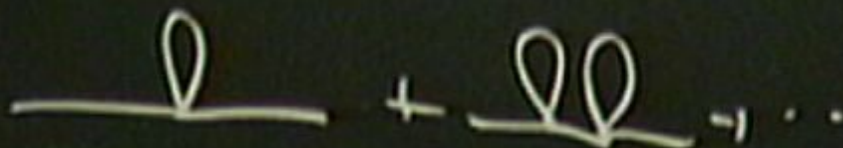


$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \approx \frac{\lambda^2 T^2}{\epsilon_0}$$

$\nearrow 1/m_0$



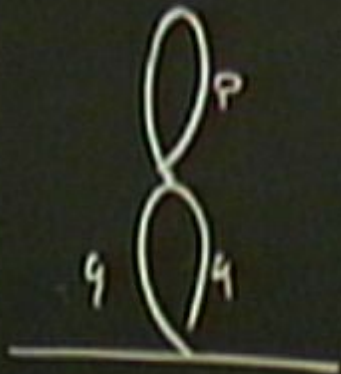
$$M_{\text{phys}}^2 = m_0^2 + \lambda T^2$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

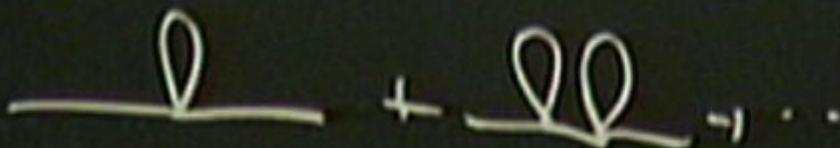


$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \approx \frac{\lambda^2 T^2}{\epsilon_0}$$

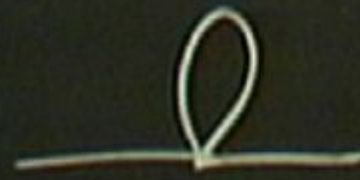
$\nearrow 1/m_0$

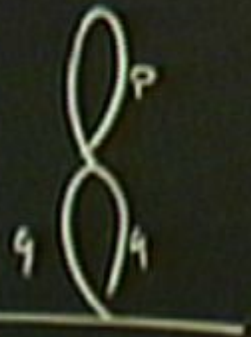


$$M_{\text{phys}}^2 = m_0^2 + \lambda T^2$$

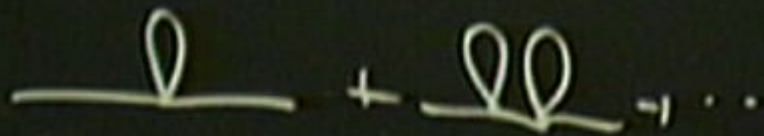
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

1)  = $\lambda \int \frac{d^3p}{p^2} \sim \lambda T$



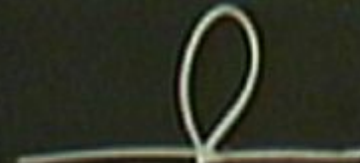
$$\sim \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$$

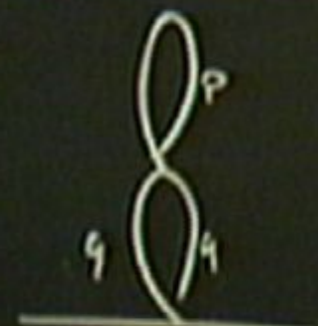


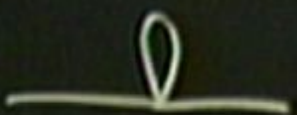
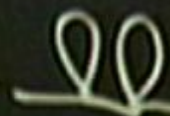
$$M_{\text{phys}}^2 = m_0^2 + \lambda T^2$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m^2}$$

$$\sum_n \int d^3p$$

1)  = $\lambda \int \frac{d^3p}{p^2} \sim \lambda T$

 $\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{M_0} \sim \lambda^{3/2} T$

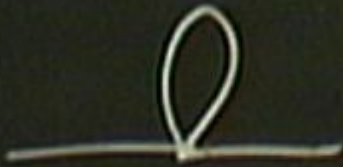
 +  + ...

$$M_{\text{phys}}^2 = M_0^2 + \lambda T^2$$

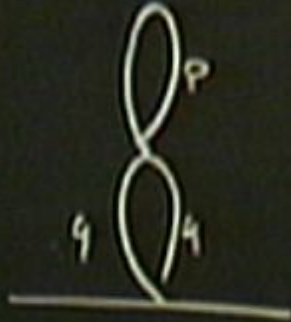
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m^2}$$

$$\sum_n \int d^3p$$

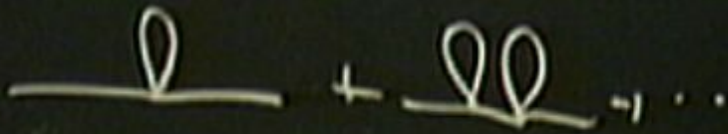
1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$$

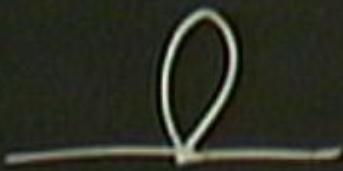


$$M_{\text{phys}}^2 = m^2 + \lambda T^2$$

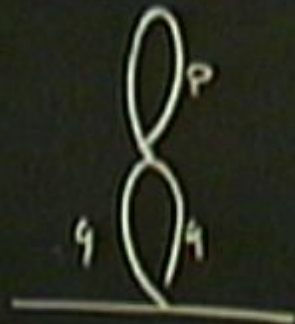
$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$$

$$\sum_n \int d^3p$$

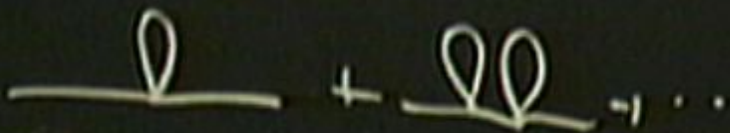
1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



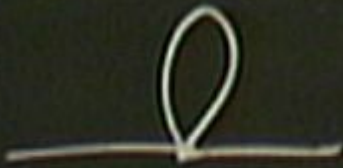
$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$$



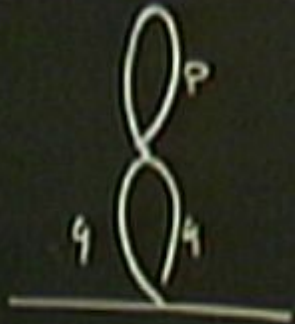
$$M_{\text{phys}}^2 \approx m_0^2 + \lambda T^2$$

$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2} \quad \sum_n \int d^3p$$

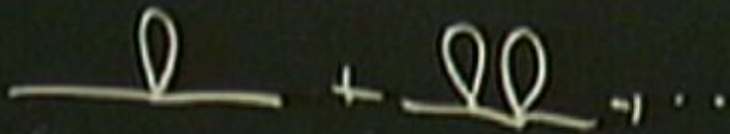
1)



$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\approx \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^2} \sim \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$$



$$M_{\text{phys}}^2 \approx m_0^2 + \lambda T^2$$

$$ds^2 = -dt^2 + dx^2$$

$$G_0(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$G_{sp}(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$

$$-i a^4(\tau) \delta_m$$

$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2).$$

$$G_S(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$G_P(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$

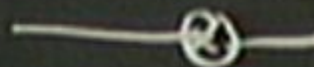
$$-i a^4(\tau) \delta_m$$

$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2). \quad \langle \phi^2(x) \rangle$$

$$\zeta_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$\zeta_g(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$



$$-i a^4(\tau) \delta_m$$



$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2). \quad \langle \phi^2(x) \rangle$$

(-k)

$$G_0(\tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$G_F(k, \tau_1, \tau_2) \approx \frac{H^2}{3} (\tau_1^3 \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$

$$-i a^4(\tau) \delta_m$$

$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

$$(-k$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$G_p(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \left(1 + \dots \right)$$

$$-i a^4(\tau) \delta_m$$

$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2).$$

$$\langle \phi^2(x) \rangle$$

(-k)

$$\zeta_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$\zeta_q(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$



$$-i a^4(\tau) \delta m$$



$$= -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

$$(-k\tau) \ll -1$$

$$C_S(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((-k\tau)^2) \right\}$$

$$C_T(k, \tau_1, \tau_2) = \mathcal{O}((-k\tau)^2) (1 + \mathcal{O}((-k\tau)^2))$$

$$\text{---} \otimes \text{---} \quad -i a^4(\tau) \delta m$$

$$\text{X} = -i a^4 \lambda$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

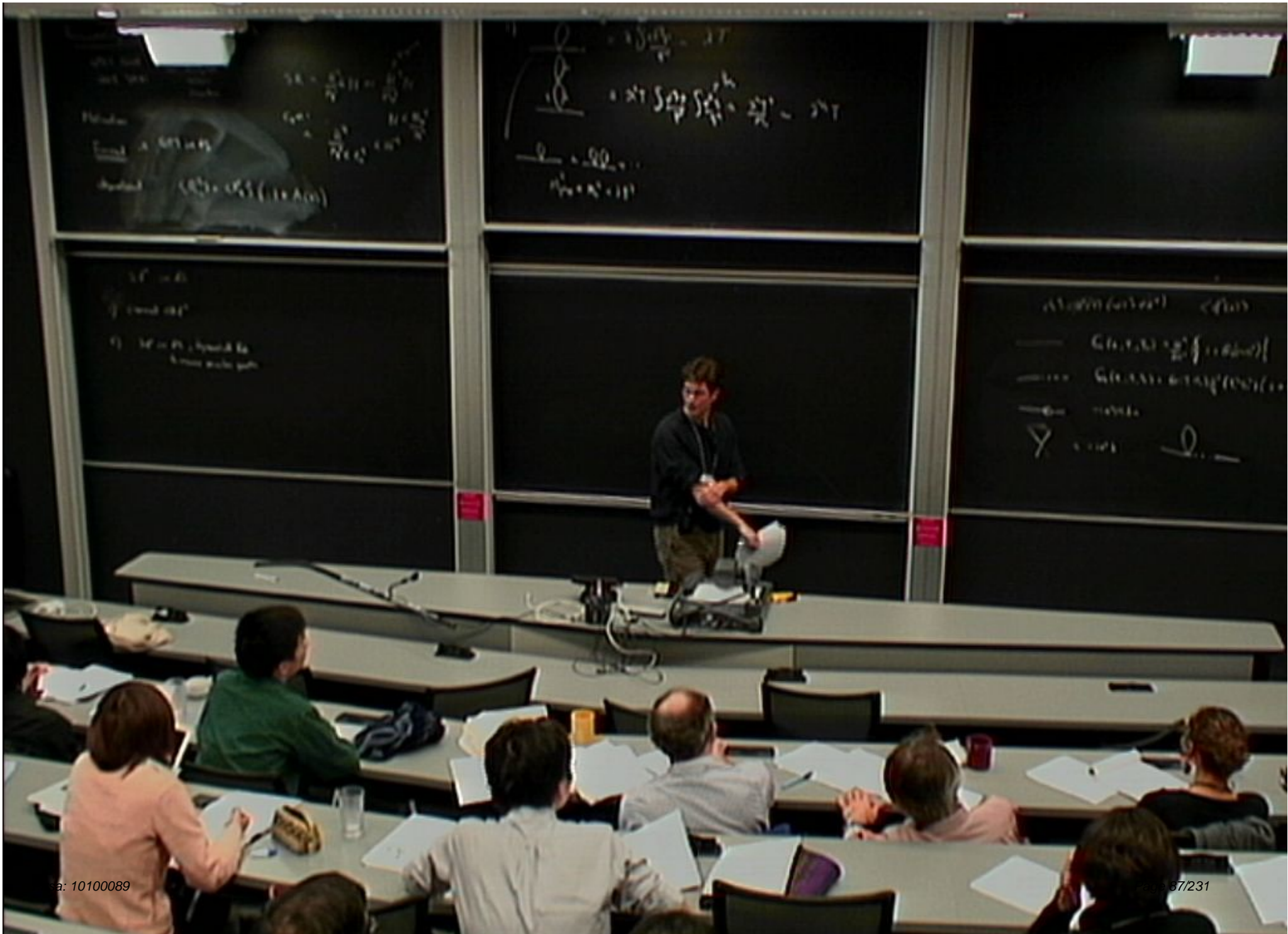
$$(-k\tau) \ll -1$$

$$\text{---} \quad C_S(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$\text{---} \dots C_T(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^2 \tau_2^2) (1 + \mathcal{O}((k\tau)^2))$$

$$\text{---} \otimes -i a^4(\tau) \delta m$$

$$\text{X} = -i a^4 \lambda$$



$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

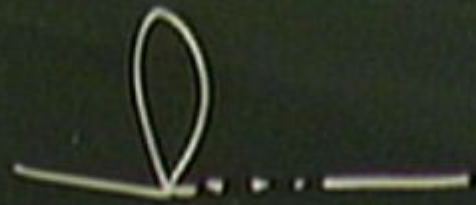
$$(-k\tau) \ll 1$$

$$C_S(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$C_P(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$

$$-i a^4(\tau) \delta m$$

$$= -i a^4 \lambda$$



$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

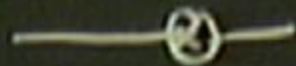
$$\langle \phi^2(x) \rangle$$

$$(-k\tau) \ll 1$$

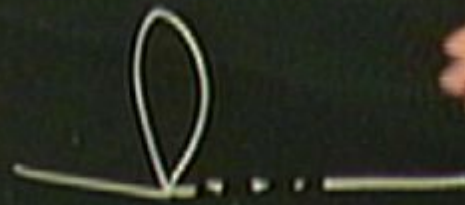
$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

$$G_F(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}(-k\tau))$$

$$-i a^4(\tau) \delta_m$$



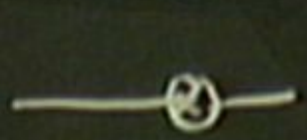
$$= -i a^4 \lambda$$



$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2) \quad \langle \phi^2(x) \rangle \quad (-k\tau) \ll 1$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

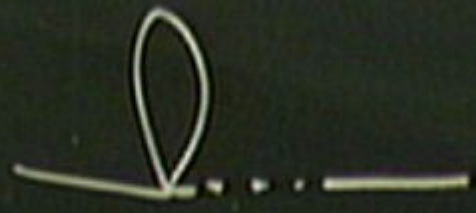
$$G_p(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$



$$-i a^4(\tau) \delta_m$$



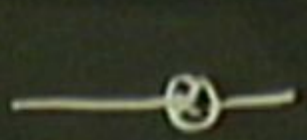
$$= -i a^4 \lambda$$



$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2) \quad \langle \phi^2(x) \rangle \quad (-k\tau) \ll 1$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

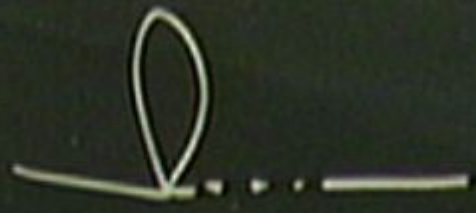
$$G_F(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$

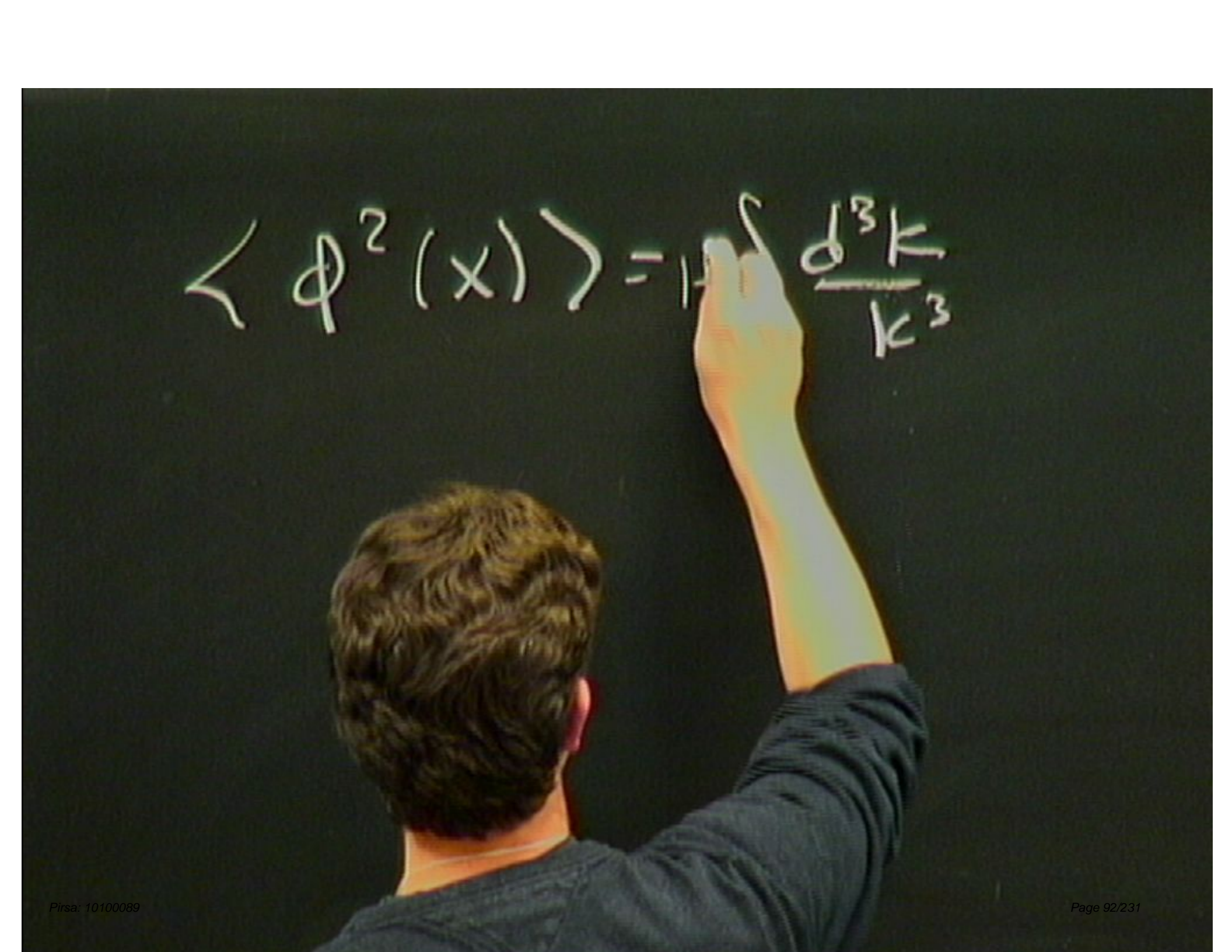


$$-i a^4(\tau) \delta m$$



$$= -i a^4 \lambda \int_c^3 \int_0^D$$



A person with dark, curly hair, wearing a dark blue long-sleeved shirt, is seen from behind, writing a mathematical equation on a black chalkboard. The person's right arm is raised, with their hand near the top of the equation. The equation is written in white chalk and reads:
$$\langle \phi^2(x) \rangle = \frac{1}{i} \int \frac{d^3k}{k^3}$$

The equation is written in white chalk on a black chalkboard. The person's hand is visible, pointing towards the integral sign in the equation.

A person with dark hair, seen from the back, is writing a mathematical equation on a dark chalkboard. The person is wearing a dark blue long-sleeved shirt and is using a white chalk to write. The equation is written in white chalk and consists of a correlation function, a plus sign, and an integral. The correlation function is $\langle \phi^2(x) \rangle$, followed by a plus sign $+$, and then an integral $\int \frac{d^3k}{k^3}$. The integral is over a region in the complex plane, indicated by a dashed line forming a semi-circle in the upper half-plane. The person's hand is visible, pointing to the plus sign between the correlation function and the integral.
$$\langle \phi^2(x) \rangle + \int \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$\frac{d^3k}{k^3}$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\frac{1}{k}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\langle \frac{1}{q} \rangle \sim \Lambda_{uv}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3} \rightarrow \text{---}$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3} \rightarrow \text{---}$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = i \int \frac{d^3 k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3} \rightarrow \text{---}$$

$$\Lambda_{IR} \langle \frac{k}{a} \rangle \sim \Lambda_{UV} = \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3 k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} < \underline{k} < \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3} - \int \frac{d^3 k}{k^3}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{a} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3 k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{q} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3}$$

$$= H^2 \ln \Lambda_{UV} / \Lambda_{IR}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3 k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{q} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3}$$

$$= H^2 \ln \Lambda_{UV} / \Lambda_{IR}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3} \rightarrow \rightarrow$$

$$\frac{\Lambda_{IR} \langle \frac{k}{a} \rangle \Lambda_{UV}}{a \Lambda_{IR}} = H^2 \int_{a \Lambda_{IR}}^{a \Lambda_{UV}} \frac{d^3k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$\approx H^2 \ln M / M_{Pl}$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3 k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{a} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3 k}{k^3}$$

$$\equiv H^2 \ln M / \Lambda_{IR}$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

$$(-k\tau) \ll 1$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}((k\tau)^2) \right\}$$

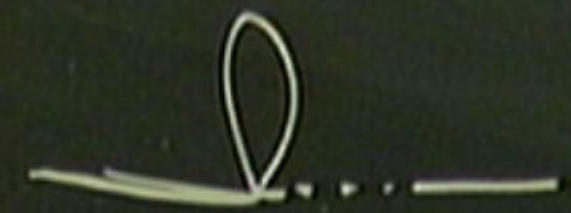
$$G_F(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \mathcal{O}((k\tau)^2))$$



$$-i a^4(\tau) \delta_m$$

$$= -i a^4 \lambda$$

$$\int_C^3 \int_D$$



$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{a} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = H^2 \ln M / \Lambda_{IR} = \text{const.}$$

$$G_c(k_1, T_1, T_2) = \frac{1}{k} + \frac{1}{T_1} \frac{1}{k} + \frac{1}{T_2} \frac{1}{k} + \dots$$

$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3} \rightarrow \rightarrow$$

$$\Lambda_{IR} \langle \frac{k}{a} \rangle \Lambda_{UV} = H^2 \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3} - \int_{\Lambda_{IR}}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$\langle \phi^2(x) \rangle = H^2 \ln M / \Lambda_{IR} = (st.)$$

$$G_c(k_1, \tau_1, \tau_2) = \text{---} \tau_1 + \text{---} \tau_1 \text{---} \tau_2 + \text{---} \tau_2$$

$$ds^2 = a^2(\tau) (-d\tau^2 + d\vec{x}^2)$$

$$\langle \phi^2(x) \rangle$$

$$(-k\tau) \ll 1$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}(\epsilon) \right\}$$

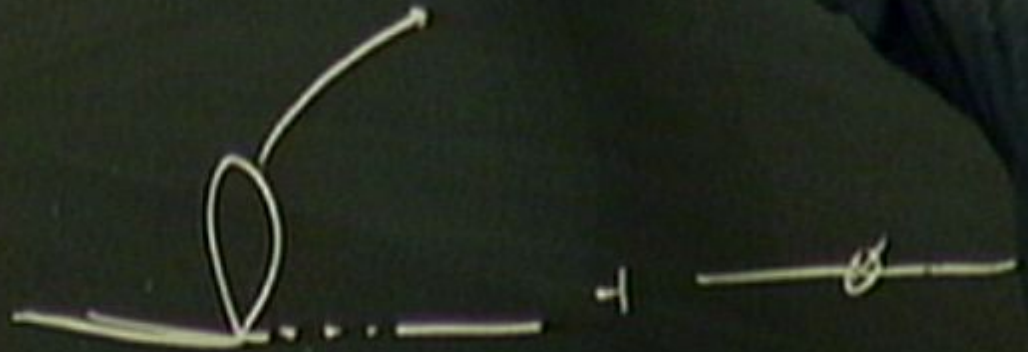
$$G_F(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) (1 + \dots)$$



$$= -i a^4 \lambda$$

$$\int_C \rho_D$$

$$-i a^4(\tau) \delta m$$



$$ds^2 = a^2(\tau) (-d\tau^2 + dx^2)$$

$$\langle \phi^2(x) \rangle$$

$$(-k\tau) \ll 1$$

$$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3} \left\{ 1 + \mathcal{O}(k\tau) \right.$$

$$\left. G_p(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2) \frac{H^2}{3} (\tau_1^3 - \tau_2^3) \right.$$

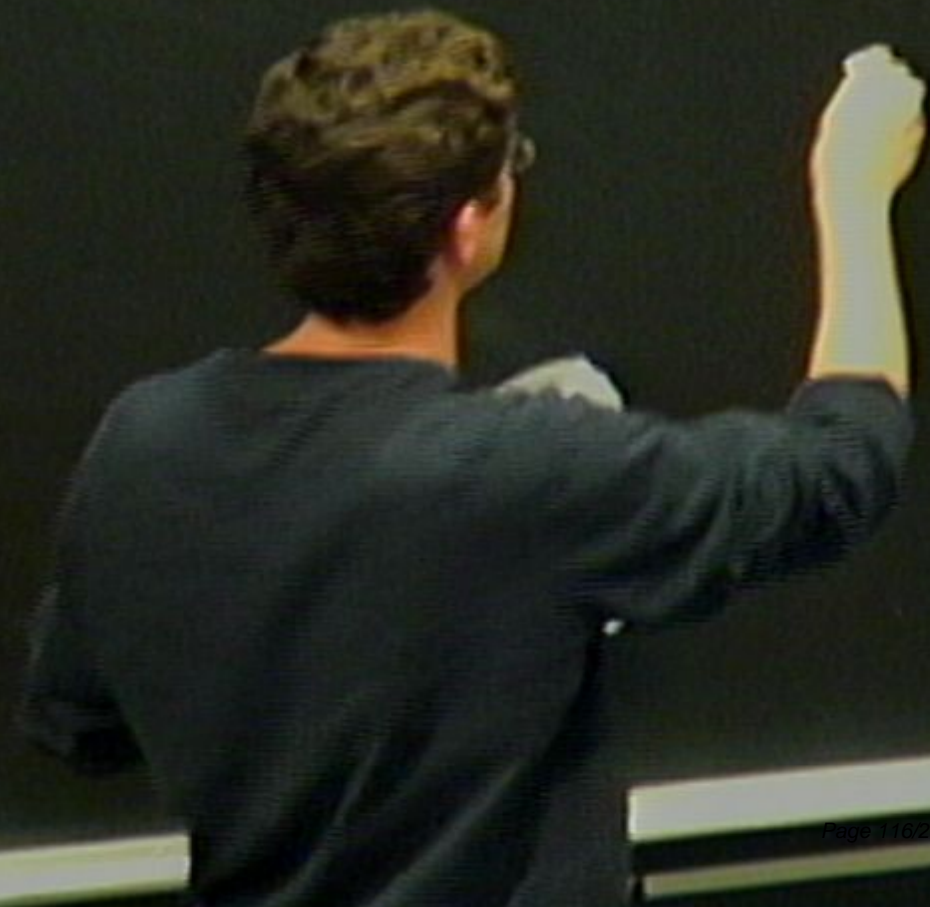
$$-i a^4(\tau) \delta m$$

$$= -i a^4 \lambda$$

$$\frac{d^3 \phi}{d\tau^3}$$

$$\langle \phi^2(x) \rangle$$

$$G_c(k, T) = G_c^{(0)}(k, T) \left(1 + \lambda \int_0^T dt' G_R G_F \right)$$



$$G_C(k, T) = G_C^{(0)}(k, T) \left(1 + \int_0^T dt \int_{\Lambda} d^3k \frac{d^3k}{k^2} \right)$$

$$G_C(k, T) = G_C^{(0)}(k, T) \left(1 + \lambda \int dT' G_R G_F \right) \int_{\Lambda_{IR}^a}^{\Lambda_U} \frac{d^3k}{k^2}$$

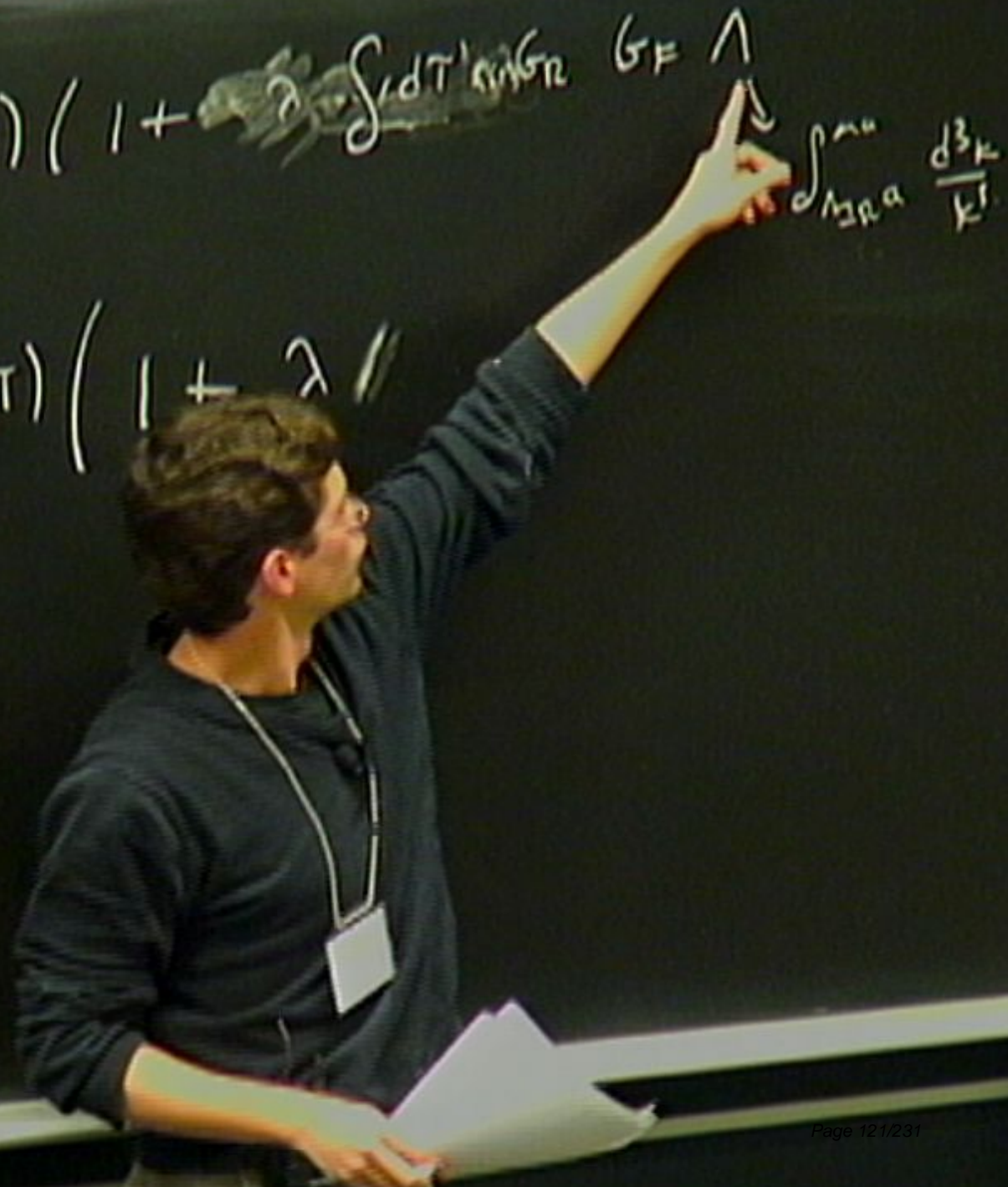
$$G_C(k, T) = G_C^{(0)}(k, T) \left(1 + \lambda \int dT' G_R G_F \right) \int_{\Omega_{Ra}}^{\mu} \frac{d^3k}{k^2}$$

$$G_c(k, T) = G_c^{(0)}(k, T) \left(1 + \int dT' \dots \right) \quad G_F \uparrow \int_{\Omega_{\text{BR}}} \frac{d^3k}{k^4}$$

$$= G_c^{(0)}(k, T) \left(1 + \dots \right)$$

$$G_c(k, T) = G_c^{(0)}(k, T) \left(1 + \lambda \int d^3k' \frac{d^3k''}{k'} \right)$$

$$= G_c^{(0)}(k, T) (1 + \lambda)$$



$$G_C(k, T) = G_C^{(0)}(k, T) + \lambda \int dT' G_C(k, T')$$

$\int_{M_R^a} \frac{d^3 k}{k^2}$

$$= G_C^{(0)}(k, T) (1 + \lambda //)$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' G_c G_F \int_{\mathcal{M}_{R^d}} \frac{d^3 k}{k^2}$$

$$= G_c^{(0)}(k, T) (1 + \lambda)$$

$$G_C(k, T) = G_C^{(0)}(k, T) + \lambda \int dT' \text{ring } G_F \uparrow \int_{M_{R^a}} \frac{d^3k}{k^4}$$

$$= G_C^{(0)}(k, T) \left(1 + \int \frac{dT'}{T} \right)$$

$$G_C(k, T) = G_C^{(0)}(k, T) + \lambda \int dT' n(k, T') G_F \wedge \int_{\Lambda_{Ra}}^{\Lambda_{Ma}} \frac{d^3 k'}{k'}$$

$$= G_C^{(0)}(k, T) \left(1 + \lambda \wedge \int_{-\infty}^T \frac{dT'}{T'} \right)$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int_0^T dT' \Lambda(k, T, T') G_F \uparrow \int_{\Lambda_{R^a}} \frac{d^3 k}{k^2}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{-\infty}^T \frac{dT'}{T'} \right)$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' \dots \Lambda \int_{\Lambda_{2R}^0} \frac{d^3 k'}{k'}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{\frac{k}{T}}^T \frac{dT'}{T'} \right)$$

$(-kT) \ll 1$

$$G_C(k, T) = G_C^{(0)}(k, T) + \lambda \int_0^T dT' \Lambda(k, T, T') G_F \quad \Lambda \int_{\Omega_{na}} \frac{d^3k}{k^2}$$

$$= G_C^{(0)}(k, T) \left(1 + \lambda \Lambda \int_0^T \frac{dT'}{T'} \right)$$

$$\downarrow (-kT) \ll 1$$

$$\ln(-kT).$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' \dots G_F \uparrow \int_{\Omega_{na}} \frac{d^3k}{k^5}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int^T \frac{dT'}{T'} \right)$$

$$\left(1 + \lambda \ln^4 / \Lambda_{IR} \ln(-kT) \right)$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' \rho(T') G_c \quad \int_{\Lambda} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{\frac{1}{k}}^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$+ \lambda \ln^4 \Lambda / \Lambda_{IR} \ln(-kT)$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int_0^T dT' \chi(k, T') G_F \uparrow \int_{\Omega_{\text{na}}} \frac{d^3 k}{k^3}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_0^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$\left(1 + \lambda \ln^4 \Lambda_{\text{IR}} \ln(-kT) \right)$$



$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' n(T') G_F \uparrow \int_{\Lambda} \frac{d^3 k}{k^3}$$

$$G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{\frac{\hbar}{k}}^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$\left(1 + \lambda \ln^4 \Lambda / n_{IR} \ln(-kT) \right)$$

$\Lambda_{IR} \rightarrow 0$
 $T \rightarrow 0$

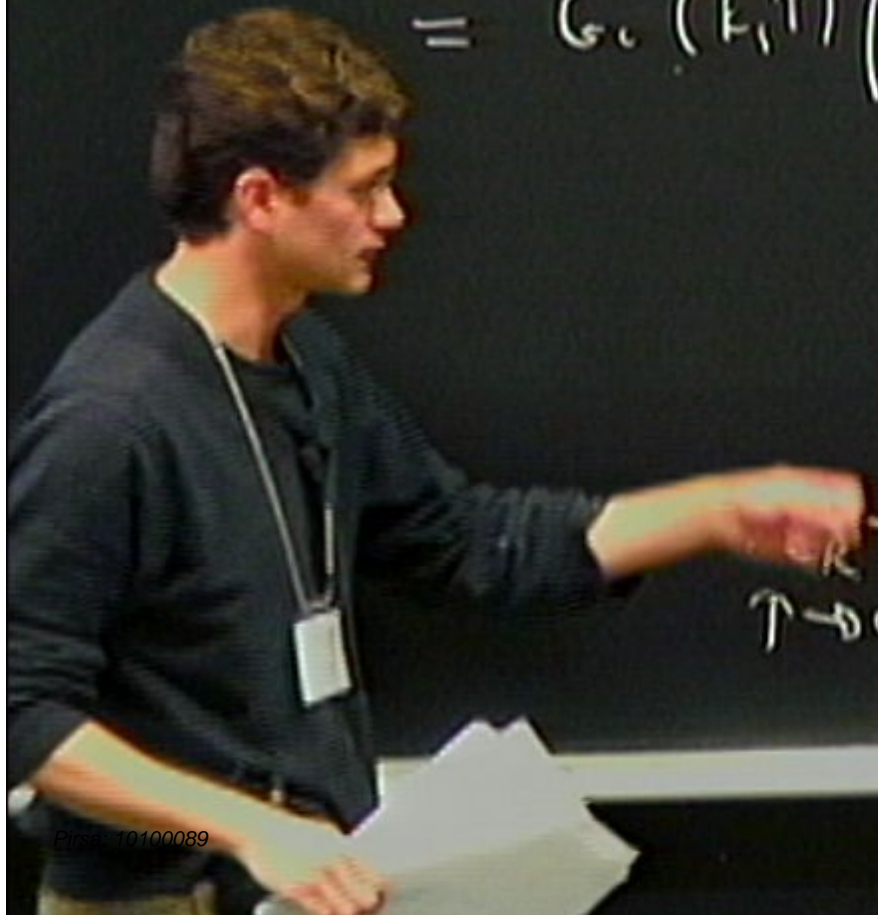
$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' n_B G_F \uparrow \int_{\Omega_{BR}} \frac{d^3 k}{k^3}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{\frac{k}{T}}^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$\left(1 + \lambda \ln^4 / \Lambda_{IR} \ln(-kT) \right)$$

$\uparrow \rightarrow 0$
 $\downarrow \rightarrow 0$



$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int dT' \Lambda_{IR} G_F \uparrow \int_{\Lambda_{IR}^0}^{\Lambda_{IR}} \frac{d^3 k}{k^3}$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \Lambda \int_{\frac{\Lambda}{k}}^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$\left(1 + \lambda \ln^2 \Lambda_{IR} \ln(-kT) \right)$$

$\Lambda_{IR} \rightarrow 0$
 $T \rightarrow 0$

$$\alpha(m) = \alpha(M_0) + b\alpha^2(M_0) \ln m/m_0.$$

$$\alpha(m) = \alpha(M_0) + \frac{1}{2} \alpha^2(M_0) \ln m/m_0.$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1.$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

S

T

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha(m)}$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$
$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0}$$

$$\alpha(m) = \alpha(M_0) + b\alpha^2(M_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$



$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0 \quad \alpha \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\alpha(m) - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) =$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) =$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) =$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) =$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$
$$\alpha \ln m \ll 1$$

$\frac{d}{dm}$

$\int dm$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) = y_0 + e^{y_1(t)}$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0.$$

$$\alpha \ll 1$$

$$\underline{\alpha \ln m} \ll 1.$$

$$\frac{d}{dm}.$$

$$\int dm.$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0.$$

$$y(t) = y_0 + e^{y_1(t)}.$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) = y_0 + e^{y_1(t)}$$

$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1$$

$$\frac{d}{dm}$$

$$\int dm$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

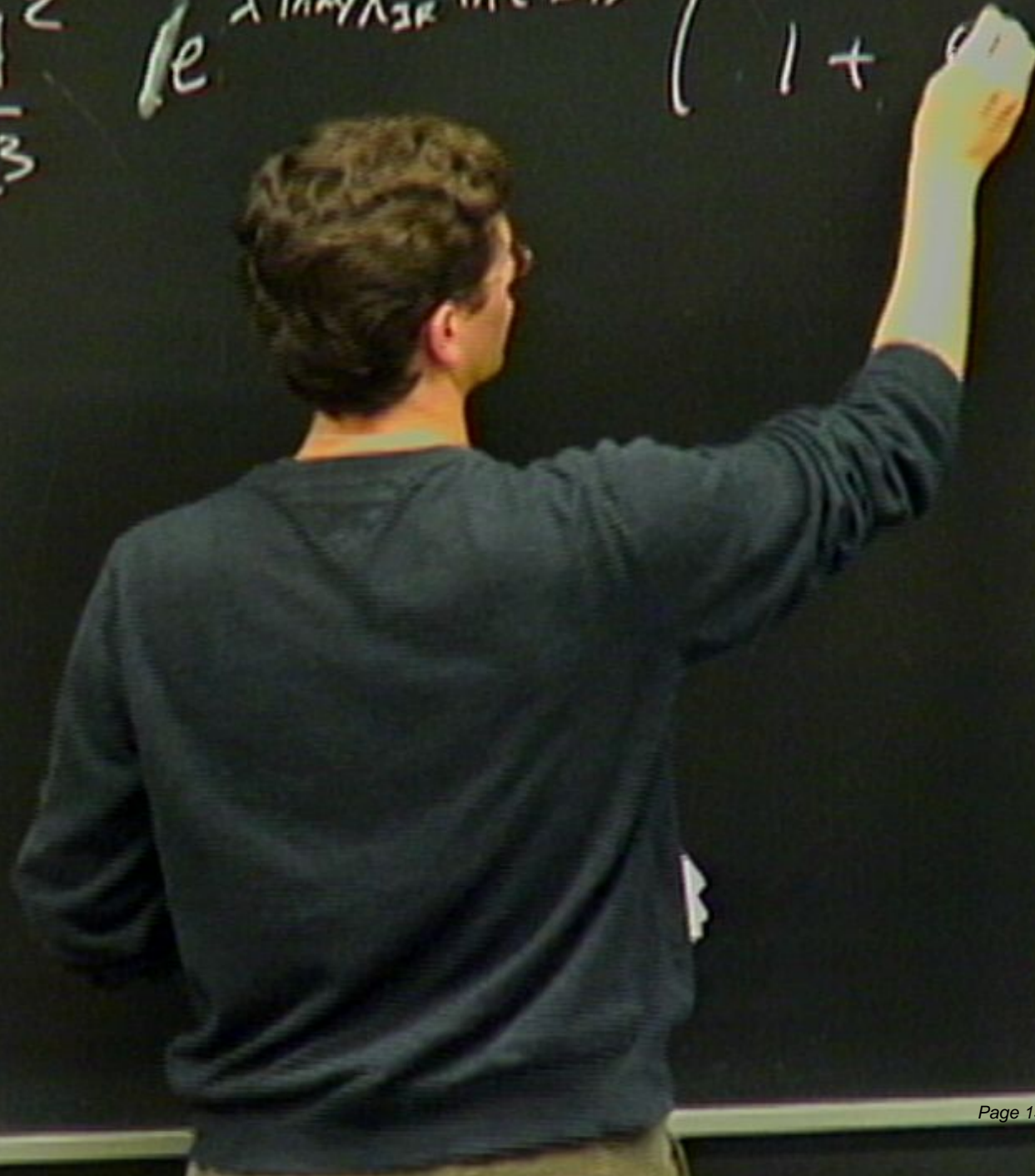
$$y(t) = y_0 + e^{y_1(t)} + d(\epsilon^2)$$

$$G_c = \frac{H^2}{k^3}$$

$$G_c = \frac{h^2}{4\pi m \lambda} e^{2\lambda / \mu \lambda_{3R}}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)} \left(1 + \dots \right)$$



$$G_c = 4^z e^{\lambda_{IR} \ln(-kT)} \left(1 + \mathcal{O}(z^4) \right)$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)} \left(1 + O(\lambda^4) \right)$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{h^2}{k^3} e^{\frac{2 \ln \mu / \Lambda_3 - \ln(-kT)}{\lambda}} \left(1 + \mathcal{O}(\lambda^4) \right)$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^2) \right)$$



$$(-kT)^{\delta}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^4) \right)$$

$$\frac{H^2}{k^3} (-kT)^{\delta}$$

$$T \rightarrow 0$$

$$G_C = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^4) \right)$$

$$\frac{H^2}{k^3}$$

$$(-kT)^{\delta}$$

$$T \rightarrow 0$$

$$G_c = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln \mu / \lambda_{3R} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^4) \right)$$

$$\frac{H^2}{k^3} (-kT)^{\delta}$$

$T \rightarrow 0$

$$G_C = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln \mu / \mu_{IR} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$\frac{H^2}{k^3} (-kT)^\delta \quad T \rightarrow 0$$

$$\delta = \lambda \ln \mu / \mu_{IR}$$

$$G_C = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln \mu / \mu_{IR} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_C = \frac{H^2}{k^3} (-kT)^\delta \quad T \rightarrow 0$$

$$\delta = \lambda \ln \mu / \mu_{IR}$$

$$G_c = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln M / \mu_{IR} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{H^2}{k^3} (-kT)^\delta \quad T \rightarrow 0$$

$\delta = \lambda \ln M / \mu_{IR}$

$$= \frac{H^2}{k^3} (-kT)^{\epsilon} \quad \epsilon \equiv 3M^2 / H^2$$

$$G_c = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln M / \mu_{IR} \ln(-kT)}}_{\delta} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{H^2}{k^3} (-kT)^\delta \quad T \rightarrow 0$$

$$\delta = \lambda \ln M / \mu_{IR}$$

$$= \frac{H^2}{k^3} (-kT)^{\epsilon} \quad \epsilon \equiv 3M^2 / H^2$$

$$G_C = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln \mu / \lambda_{IR} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_C = \frac{H^2}{k^3} (-kT)^\delta \quad T \rightarrow 0$$

$$\delta = \lambda \ln \mu / \lambda_{IR}$$

$$= \frac{H^2}{k^3} (-kT)^{\epsilon} \quad \epsilon \equiv 3M^2 / H^2$$

$$G_C = \frac{H^2}{k^3} \underbrace{e^{\frac{\lambda \ln M / \mu_{IR}}{kT} \ln(-kT)}}_{\text{wavy line}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_C = \frac{H^2}{k^3} \underbrace{(-kT)^{\delta + \epsilon}}_{\text{arrow pointing to } \delta = \lambda \ln M / \mu_{IR}} \quad T \rightarrow 0$$

$$= \frac{H^2}{k^3} (-kT)^\epsilon \quad \epsilon \equiv \frac{3M}{H^2}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \ln M / \lambda_{3R} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{H^2}{k^3} (-kT)^{\delta + \epsilon} \quad T \rightarrow 0$$

$\delta = \lambda \ln M / \lambda_{3R}$

$$= \frac{H^2}{k^3} (-kT)^\epsilon \quad \epsilon \equiv 3M^2 / H^2$$

$$G_c = \frac{H^2}{k^3} e^{\frac{\lambda \ln M / \lambda_{3R}}{\ln(-kT)}} \left(1 + \mathcal{O}(\alpha^2) \right)$$

$$G_c = \frac{H^2}{k^3} (-kT)^{\delta + \epsilon} \quad T \rightarrow 0$$

$\delta = \lambda \ln M / \lambda_{3R}$

$$= \frac{H^2}{k^3} (-kT)^\epsilon \quad \epsilon \equiv \frac{3M^2}{H^2}$$

$$G_c(k, T) = G_c^{(0)}(k, T) + \lambda \int_0^T dt' \dots G_F \wedge \int_{\mu}^{\dots} d'$$

$$= G_c^{(0)}(k, T) \left(1 + \lambda \wedge \int_{\frac{\hbar}{k}}^T \frac{dT'}{T'} \right)$$

$\downarrow (-kT) \ll 1$

$$\left(1 + \lambda \ln \mu / \mu_{IR} \ln(-kT) \right)$$

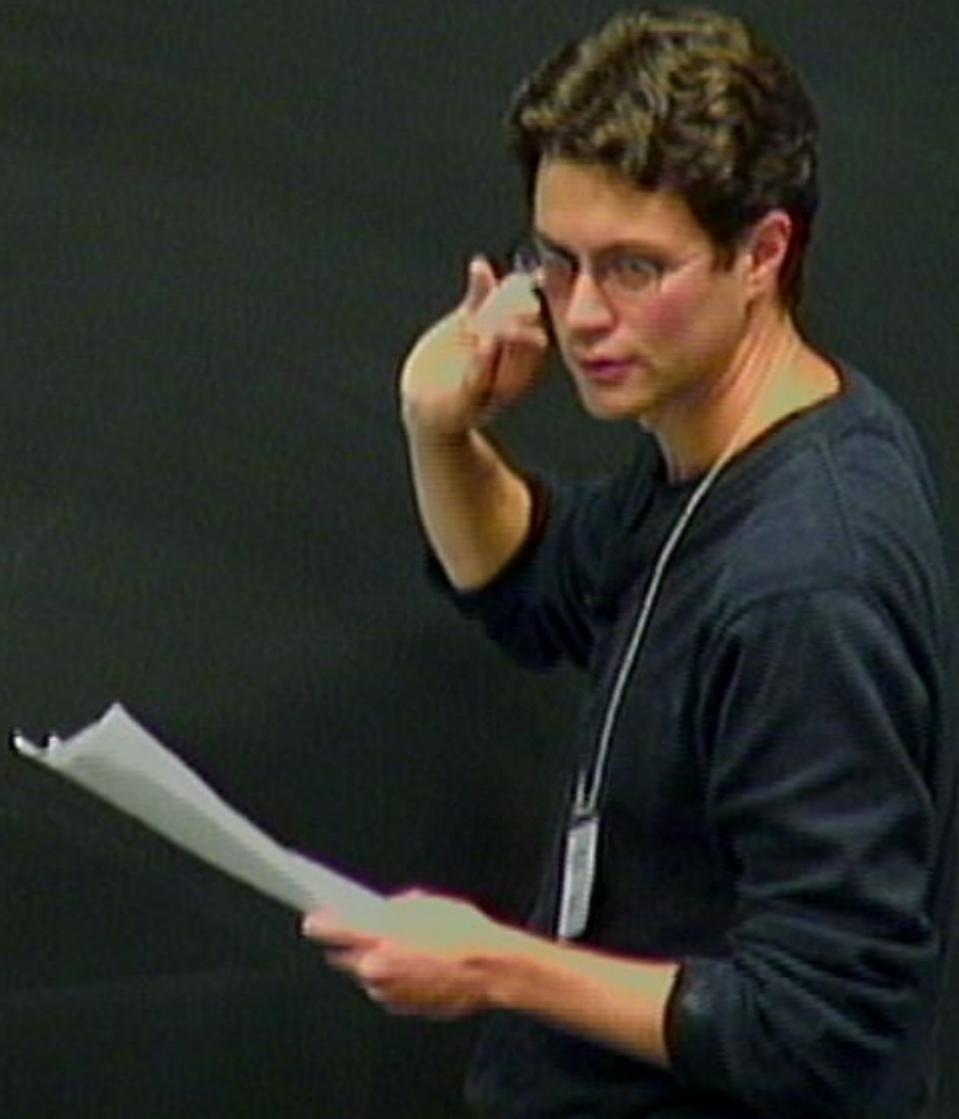
$\mu_{IR} \rightarrow 0$
 $T \rightarrow 0$

$$\frac{H^2}{k^3} (-k\tau)^{\epsilon} \Theta(k^{-1/c}).$$

$$\frac{H^2}{k^3} (-kT)^{\epsilon=0} \Theta(k - 1/c).$$

$$\int_0^{Ma} dz_L |G(k - 1/c)| \frac{H^2}{k^3}$$

$$G_c^{(1)} \approx \ln Ma$$



$$\frac{H^2}{k^3} (-kT)^{\frac{3}{2}} \Theta(k - 1/2).$$

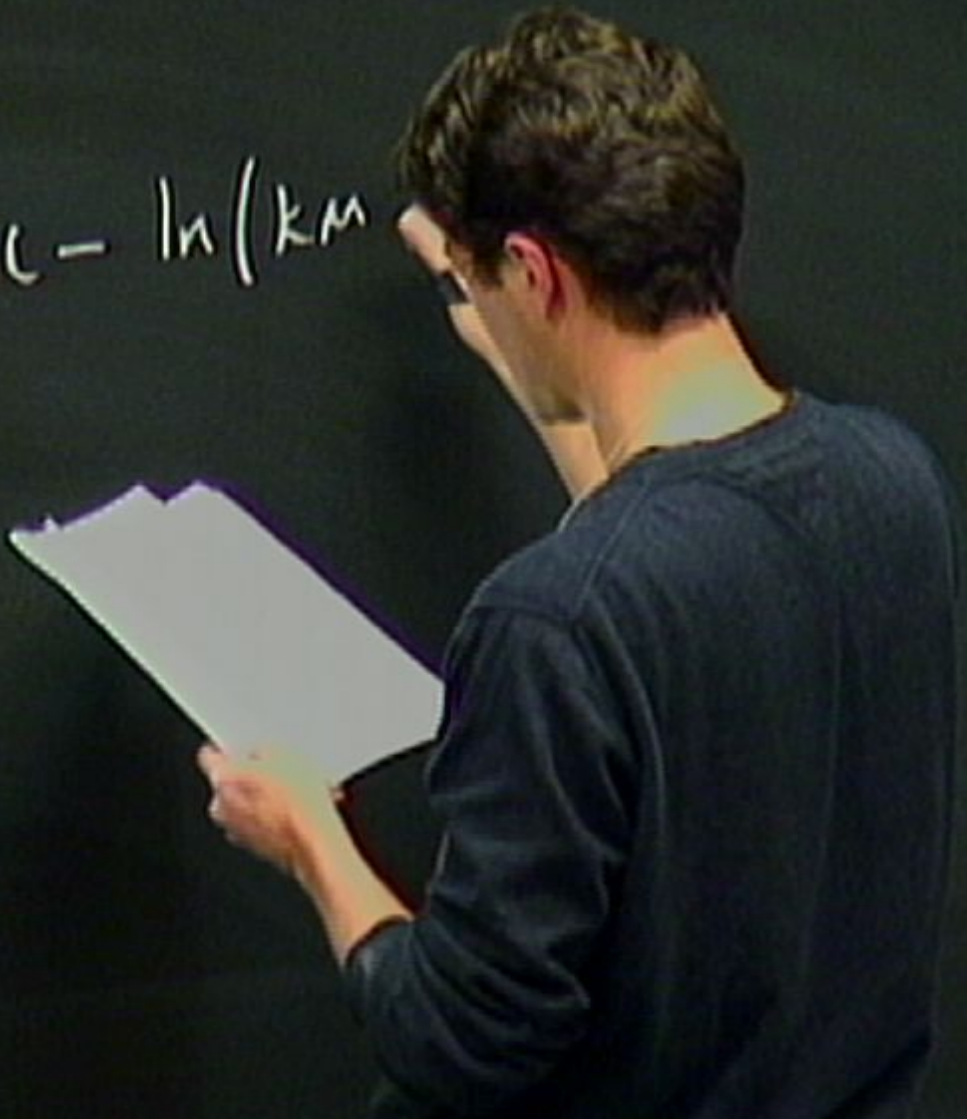
$$\int_0^{Ma} d^3L |G(k - 1/2)| \frac{H^2}{k^3}$$

$$G_c^{(1)} \approx \ln Ma$$

$$\frac{H^2}{k^3} (-kT)^{\frac{3}{2}} \Theta(k - \frac{1}{2}c).$$

$$\int_0^{Ma} d^3L |G(k - \frac{1}{2}c)| \frac{H^2}{k^3}$$

$$G_c^{(1)} \approx \ln Ma - \ln(kM)$$



$$\frac{H^2}{k^3} (-kT)^{\frac{3}{2}} \Theta(k - \frac{1}{c}).$$

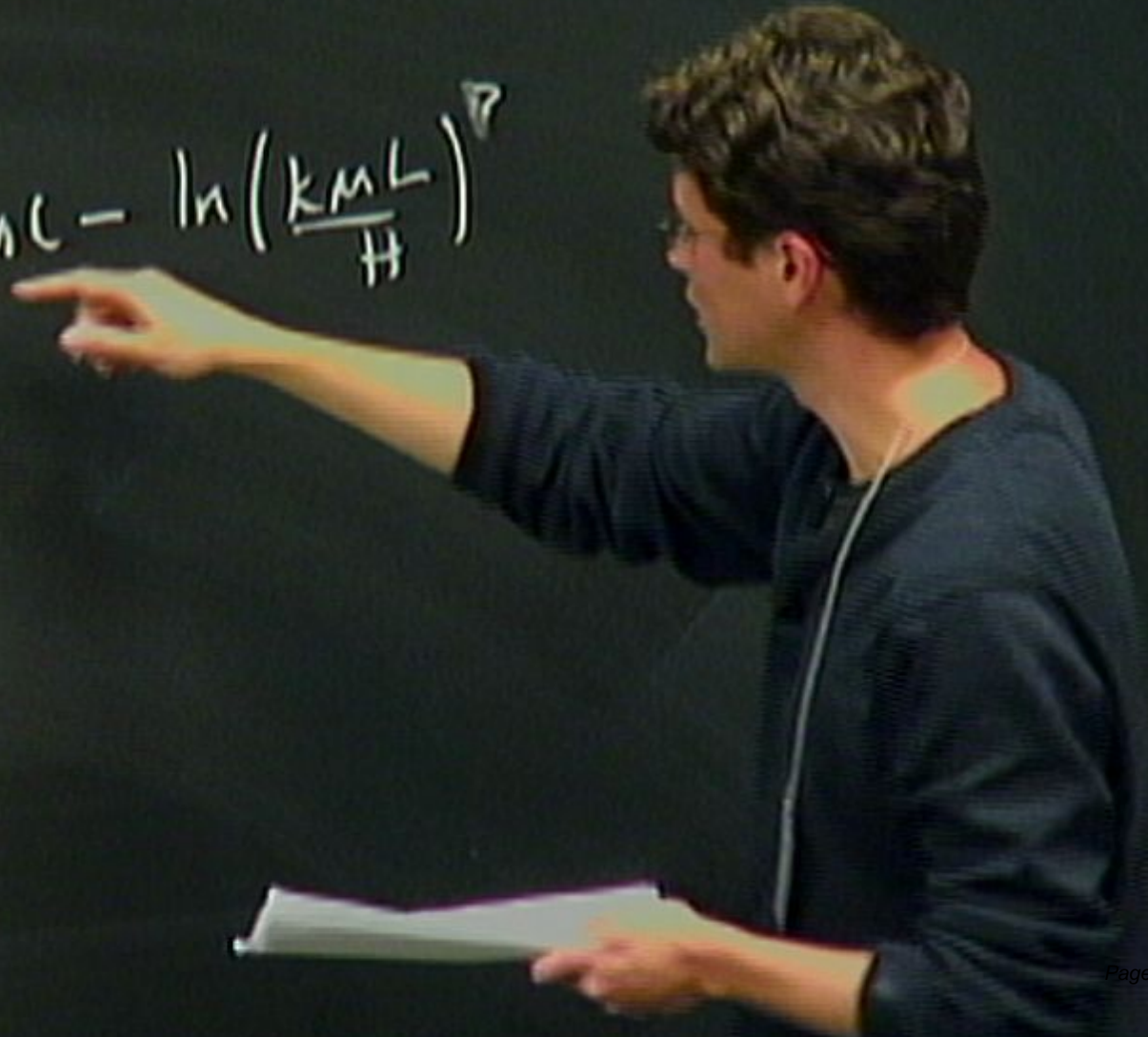
$$\int_0^{Ma} d\beta_L |G(k - \frac{1}{c})| \frac{H^2}{k^3}$$

$$G_c^{(a)} \approx \ln Ma - \ln\left(\frac{kML}{H}\right)$$

$$\frac{H^2}{k^3} (-kT)^{\frac{3}{2}} \Theta(k - \frac{1}{L}).$$

$$\int_0^{Ma} d^3L \frac{1}{L^3} G(k - \frac{1}{L}) \frac{H^2}{k^3}$$

$$G_c^{(1)} \approx \ln Ma - \ln \left(\frac{kML}{H} \right)^{\frac{3}{2}}$$



$$\frac{H^2}{k^3} (-kT)^{\epsilon=0} \Theta(k^{-1/2})$$

$$\int_0^{Ma} d^3k \frac{1}{k^3} \Theta(k^{-1/2}) \frac{H^2}{k^3}$$

$$G_c^{(1)} \Rightarrow \left(\ln Ma - \ln \left(\frac{k_M L}{H} \right)^{\epsilon} \right)$$

$$\langle \phi^2(x) \rangle = \ln a + \ln^3 a + \dots$$

$$G_c = \frac{H^2}{k^3} e^{\frac{2 \ln M / \Lambda_{\text{pl}} \ln(-kT)}{}} \left(1 + \mathcal{O}(\alpha^4) \right)$$

$$G_c = \frac{H^2}{k^3} (\delta + \epsilon) \xrightarrow{m_0^2/H} m_{\text{phys}}^2 = M_0^2 +$$

$\leftarrow (-kT) \delta$ $\delta =$ \uparrow

$$= \frac{H^2}{k^3} (-kT)^{\epsilon}$$

$$G_C = \frac{H^2}{k^3} e^{\frac{\lambda \ln M / \Lambda_{\text{Pl}} \ln(-kT)}{H^2}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_C = \frac{H^2}{k^3} (-kT)^{\frac{2}{H^2}} \rightarrow m_{\text{phys}}^2 = M_0^2 +$$

$$T \rightarrow 0$$

$$= \frac{\lambda \ln M / \Lambda_{\text{Pl}}}{H^2}$$

$$= \frac{H^2}{k^3} (-kT)^{\frac{2}{H^2}}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \frac{h M}{h_{3R}} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{H^2}{k^3} (\delta + \epsilon) \xrightarrow{m_0^2/H^2} M_{\text{phys}}^2 = M_0^2 +$$

$T \rightarrow 0$

$$\delta = \lambda \frac{h M}{h_{3R}}$$

$$= \frac{H^2}{k^3} (-kT)^{\epsilon}$$

$$\epsilon \equiv \frac{3M^2}{H^2}$$

$$G_c = \frac{H^2}{k^3} e^{\lambda \frac{hM}{h_{3R}} \ln(-kT)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

$$G_c = \frac{H^2}{k^3} (\delta + \epsilon) \xrightarrow{m_0^2/H^2} M_{\text{phys}}^2 = M_0^2 +$$

$\delta = \lambda \frac{hM}{h_{3R}}$

$T \rightarrow 0$

$$= \frac{H^2}{k^3} (-kT)^\epsilon \quad \epsilon \equiv \frac{3M^2}{H^2}$$

$$m_0^2 \int d^3k \frac{H^2}{k^3} (-kT) \epsilon = \frac{1}{\epsilon} = \ln \mu$$

$$m_0^2 \int d^3k \frac{H^2}{k^3} (-kT) \epsilon = \frac{1}{\epsilon} = \ln M / M_{Pl}^2$$

$$\int_0^{\infty} \frac{H^2}{k^3} (-kT) e^{-\frac{H^2}{kT}} dk = \frac{1}{\epsilon} = \ln M / \ln R$$

$$\frac{H^2}{k^3} (-kT) e^{-\left(1 + \frac{\lambda}{\epsilon} \ln(-kT)\right)}$$



$$m_0^2 \int d^3k \frac{H^2}{k^3} (-kT)^\epsilon = \frac{1}{\epsilon} = \ln M / H_{\text{Pl}}^2$$

$$\left(\frac{H^2}{k^3} (-kT)^\epsilon \left(\frac{1}{\epsilon} + \frac{1}{\epsilon} \ln(-kT) \right) \right)$$

$$\frac{H^2}{k^3} (-kT)$$

$$\int_0^{\infty} \frac{H^2}{k^3} (-kT) e^{-\epsilon} = \frac{1}{\epsilon} = \ln M / k_B$$

$$\frac{H^2}{k^3} (-kT) e^{-\left(1 + \frac{\delta}{\epsilon} \ln(-kT)\right)}$$

$$\frac{H^2}{k^3} (-kT) \epsilon + \delta$$

$$m_0^2 \int d^3k \frac{H^2}{k^3} (-kT)^{\epsilon} = \frac{1}{\epsilon} = \ln M / \Lambda_{\text{Pl}}$$

$$\frac{H^2}{k^3} (-kT)^{\epsilon} \left(1 + \frac{\delta}{\epsilon} \ln(-kT) \right)$$

$$\frac{H^2}{k^3} (-kT)^{\epsilon + \delta} \quad \downarrow \quad \text{RND}$$

$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-k\tau} \delta(k - \gamma_0) = \frac{1}{e} = \ln M / M_{pl}$$

$$\frac{H^2}{k^3} e^{-k\tau} \left(1 + \frac{\lambda}{e} \ln(-k\tau) \right)$$

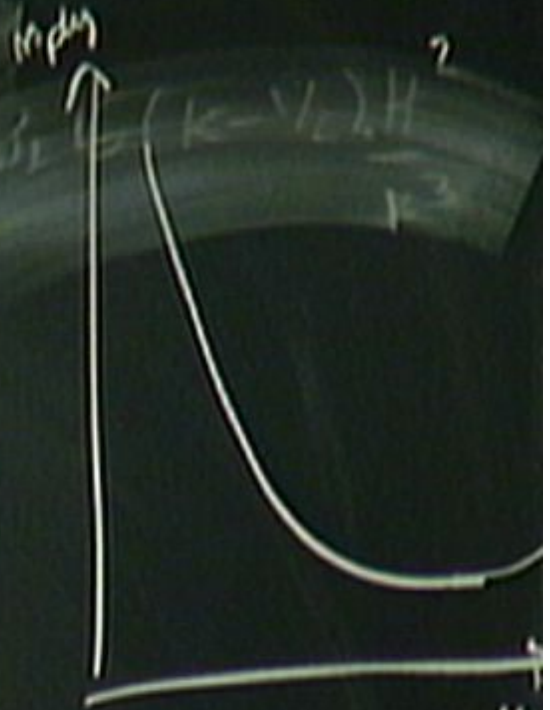
$$\frac{H^2}{k^3} (-k\tau) \epsilon + \delta$$

$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$\int d^3k \frac{H^2}{k^3} (-kT) e^{\theta(k-v/c)} = \frac{1}{\epsilon} \approx \ln M / H_{\text{sr}}$$

$$\frac{H^2}{k^3} (-kT) e^{\left(\ln \left(\frac{k-v/c}{1+\frac{\lambda}{\epsilon}} \right) + \ln(-kT) \right)}$$

$$\frac{H^2}{k^3} (-kT) \epsilon + \delta \quad \left(\frac{1}{\epsilon} \right)$$



$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda H^4}{m_0^2}$$

$$m_{\text{phys}}^2 \sim v^2$$

$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-kT} = \frac{1}{\epsilon} \approx \ln M / M_{\text{Pl}}$$

$$\frac{H^2}{k^3} e^{-kT} \left(1 + \frac{\lambda}{\epsilon} \ln(-kT) \right)$$

$$\frac{H^2}{k^3} e^{-kT} \rightarrow \epsilon + \delta$$

$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{\text{phys}}^2 \approx \sqrt{\dots}$$



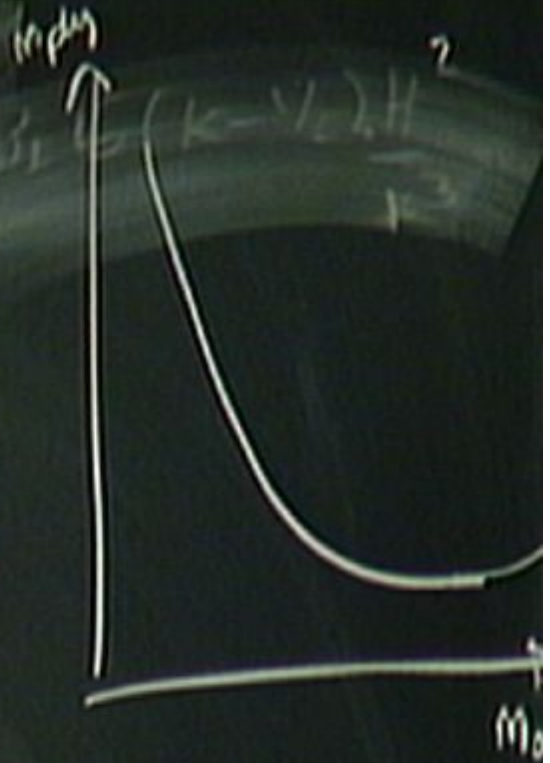
$$\int_0^{\infty} dk \frac{H^2}{k^3} e^{-kT} = \frac{1}{\epsilon} \approx \ln M / H_{\text{pl}}$$

$$\frac{H^2}{k^3} e^{-kT} \left(1 + \frac{\lambda}{\epsilon} \ln(-kT) \right)$$

$$\frac{H^2}{k^3} e^{-kT} \rightarrow \epsilon + \delta$$

$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{\text{phy}}^2 \sim \sqrt{\lambda} H^2$$



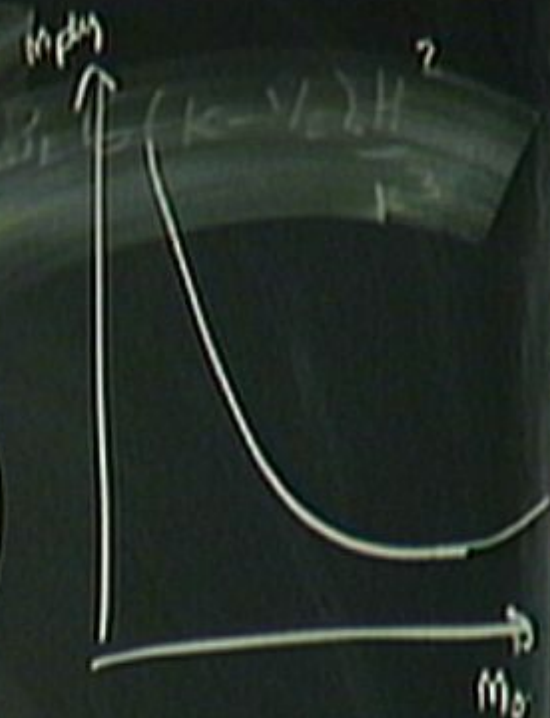
$$m^2 = \frac{H^2}{k^3} (-kT) e^{\theta(k-\sqrt{c})} = \frac{1}{\epsilon} = \ln M / H^2 R$$

$$\frac{H^2}{k^3} (-kT) e^{\left(\ln \left(\frac{1}{1 + \frac{\lambda}{\epsilon}} \right) \ln(-kT) \right)}$$

$\epsilon + \delta$
 \ln

$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda H^4}{m_0^2}$$

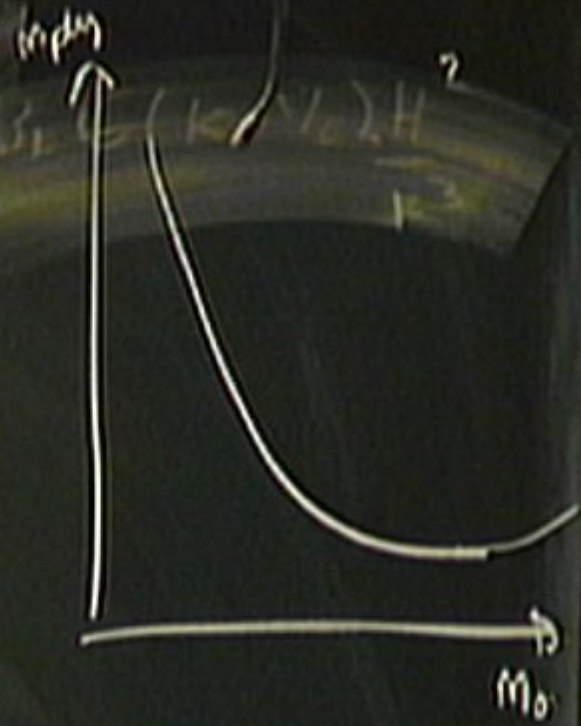
$$m_{\text{ph.}}^2 \sim \sqrt{\lambda} H^2$$



$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-\epsilon} \theta(k - k_0) = \frac{1}{\epsilon} = \ln M / H_{pl}$$

$$\frac{H^2}{k^3} e^{-\epsilon} \left(1 + \frac{\lambda}{4\epsilon} \ln(-k\tau) \right)$$

$$\frac{H^2}{k^3} (-k\tau)^{\epsilon + \delta} \quad \text{END}$$



$$m_{phy}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

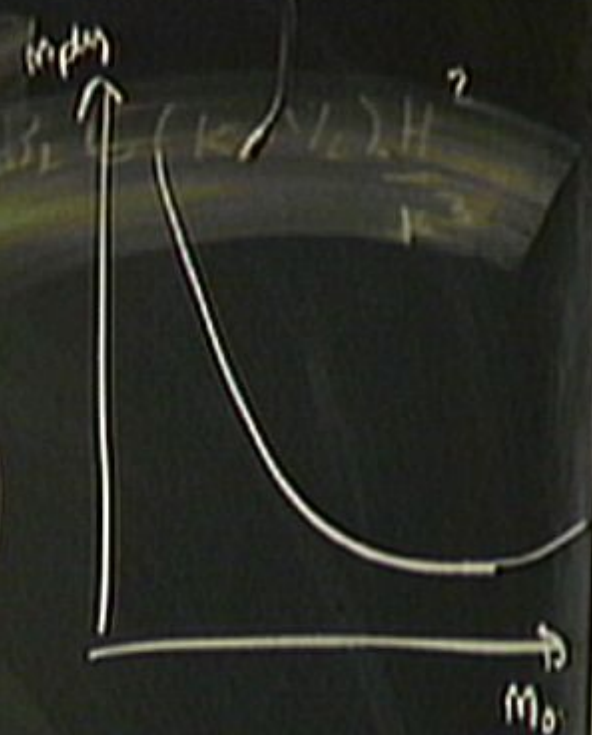
$$m_{phy}^2 \sim \sqrt{\lambda} H^2$$

$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-\theta(k)} = \frac{1}{\epsilon} = \ln M / M_{pl}$$

$$\frac{H^2}{k^3} e^{-\left(1 + \frac{\lambda}{\epsilon} \ln(-k\tau)\right)}$$

$$\frac{H^2}{k^3} (-k\tau)^{\epsilon + \delta}$$

END



$$m_{phy}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{phy}^2 \sim \sqrt{\lambda} H^2$$

$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-\theta(k)} = \frac{1}{e} = \ln M_{\text{pl}} / M_{\text{ref}}$$

$$\left(\frac{H^2}{k^3} e^{-\theta(k)} \left(1 + \frac{\lambda}{e} \ln(-k\tau) \right) \right)$$

$$\langle q^2 \rangle \sim \frac{H^4}{m^2} \frac{H^2}{k^3} (-k\tau) e + \delta$$



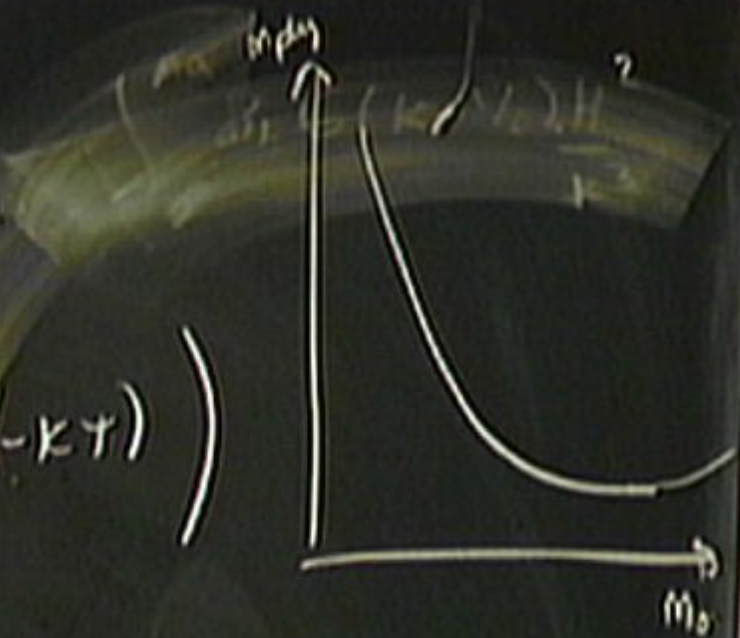
$$m_{\text{phy}}^2 = m_0^2 + \dots$$

$$m_{\text{pl}}^2 \sim \sqrt{\lambda}$$

$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-kT} = \frac{1}{\epsilon} \approx \ln M / H_{\text{pl}}$$

$$\frac{H^2}{k^3} e^{-kT} \left(1 + \frac{\lambda}{\epsilon} \ln(-kT) \right)$$

$$\langle q^2 \rangle \sim \frac{H^4}{m^2} \frac{1}{k^3} (-kT) \epsilon + \delta$$



$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{\text{ph}}^2 \sim \sqrt{\lambda} H^2$$

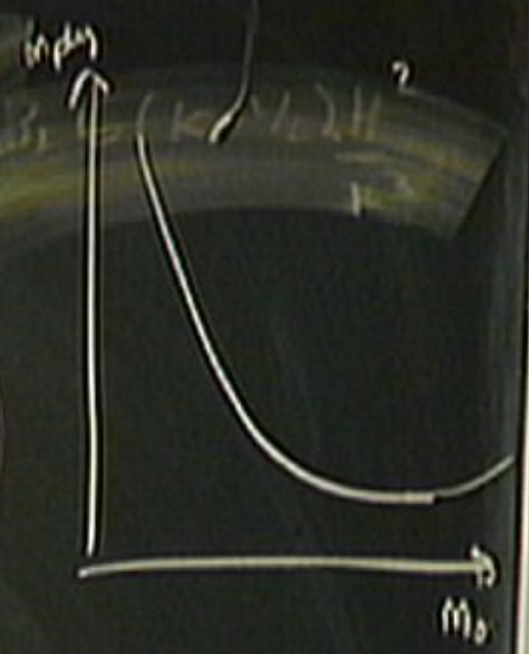
$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2}{k^3} e^{-(kT)} = \frac{1}{e} = \ln M / H_{pl}$$

$$\frac{H^2}{k^3} e^{-(kT)} \left(1 + \frac{\lambda}{e} \ln(-kT) \right)$$

$$\langle q^2 \rangle \sim \frac{H^4}{m^2} \frac{H^2}{k^3} e^{-(kT)} \epsilon + \delta$$

$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

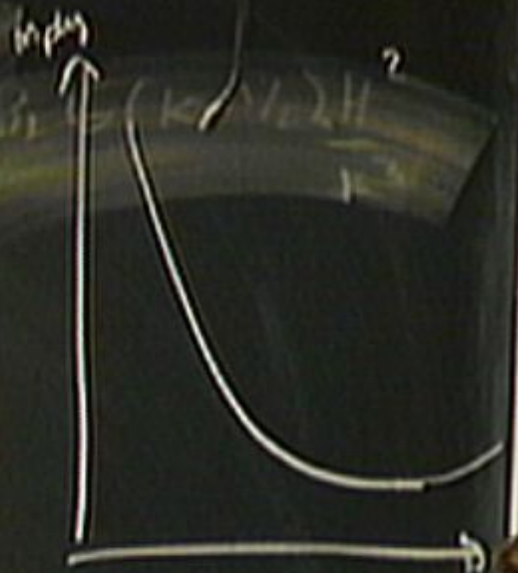
$$m_{\text{phy}}^2 \sim \sqrt{\lambda} H^2$$



$$\int \frac{d^3k}{(2\pi)^3} \frac{H^2(kT)}{k^3} e^{-\theta(k^{-1/4})} = \frac{1}{\epsilon} \approx \ln M_{pl}/M_{sr}$$

$$\frac{H^2}{k^3} (kT) e^{-\left(\ln \left(\frac{k}{\lambda} \right) + \frac{\lambda}{\epsilon} \ln(-kT) \right)}$$

$$\langle \rho \rangle \sim \frac{H^4}{m^2} \frac{H^2}{k^3} (-kT) \epsilon + \delta$$



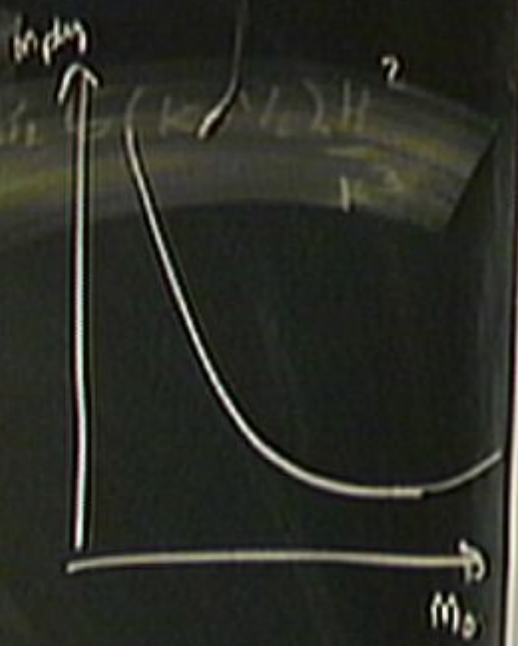
$$m_{phy}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{ph}^2 \sim \sqrt{\lambda} H^2$$

$$\int \frac{H^2}{k^3} (-kT) e^{-\epsilon} = \frac{1}{\epsilon} = \ln M / H^2 \alpha$$

$$\frac{H^2}{k^3} (-kT) e^{-\left(\ln \left(\frac{H^2}{k^3} \right) + \frac{\lambda}{\epsilon} \ln(-kT) \right)}$$

$$\langle d^2 \rangle \sim \frac{H^4}{m^2} (-kT) e^{-\epsilon + \delta} \quad \text{RND}$$



$$m_{\text{phy}}^2 = m_0^2 + \frac{\lambda}{m_0^2} H^4$$

$$m_{\text{phy}}^2 \sim \sqrt{\lambda} H^2$$

$$m_{\text{phy}}^2 = m_0^2 + \frac{\chi}{v} H^4$$

$$m_{\text{phys}}^2 \sim \sqrt{\lambda} H^2$$

$\chi(\tau)$



$$m_{\text{phy}}^2 = m_0^2 + \frac{\chi H^4}{m_0^2}$$

$$m_{\text{phys}}^2 \sim \sqrt{\chi} H^2$$

$$d(m) = d(m_0) + b\alpha^2(m_0) \ln m/m_0.$$

$$\alpha \ll 1$$

$$\alpha \ln m \ll 1.$$

$$\frac{d}{dm}$$

$$\int dm.$$

$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0.$$

$$y(t) = y_0 + e^{\lambda t} + d(\epsilon^2)$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_U} \left(1 + \frac{\lambda}{\epsilon_U} \ln(-kT) \right)$$

$\epsilon_U \rightarrow \epsilon_U + \frac{\Delta}{\epsilon_U}$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_U} \left(1 + \frac{\lambda}{\epsilon_U} \ln(-kT) \right)$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} \ln(-kT) \right)$$

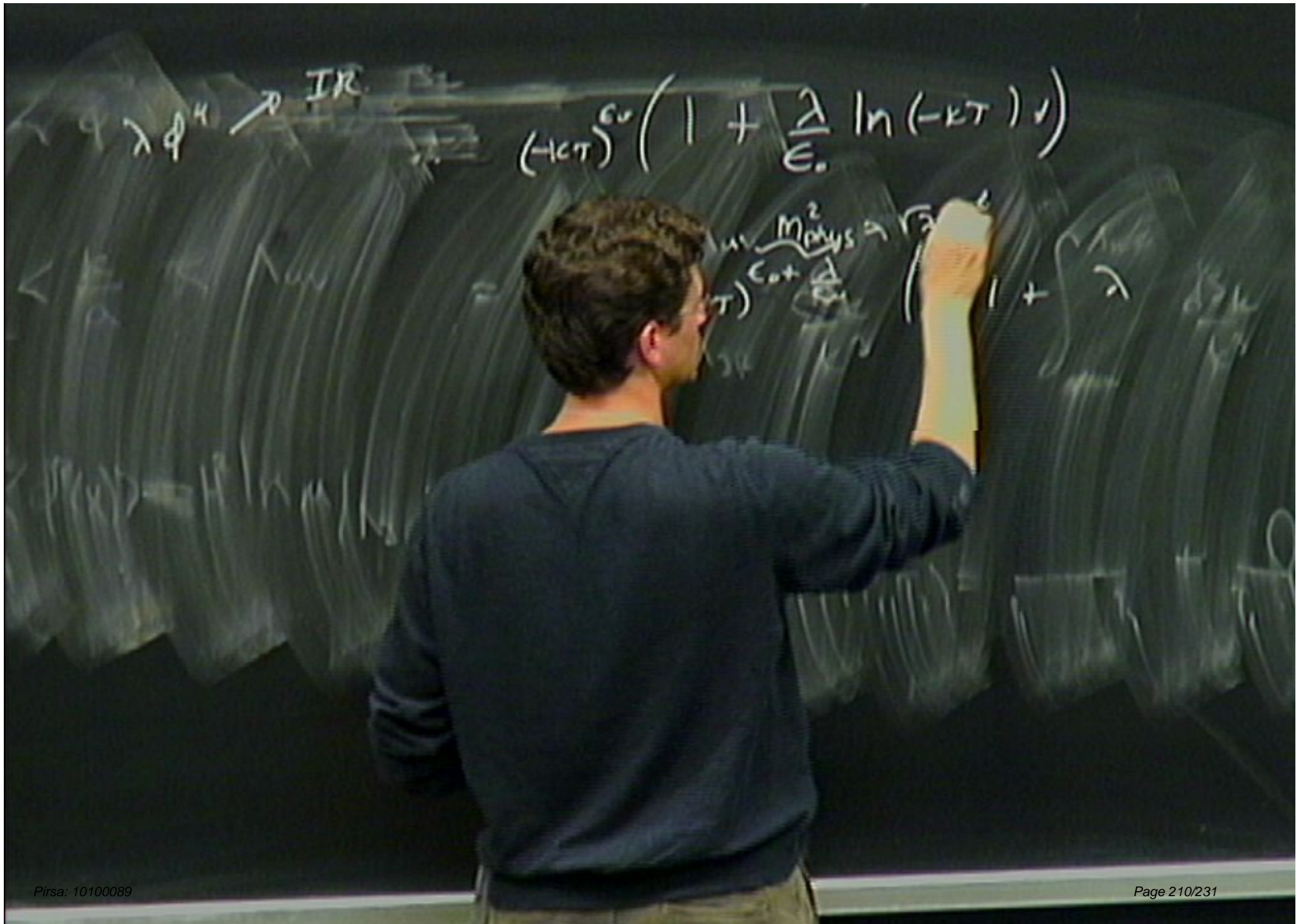
$$(-kT)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}} \left(1 + \frac{\lambda}{\epsilon_0} \right)$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_v} \left(1 + \frac{\lambda}{\epsilon_v} \ln(-kT) \right)$$

$\epsilon_v = \frac{m}{2\pi kT}$

$$(-kT)^{\epsilon_v} \left(1 + \frac{\lambda}{\epsilon_v} \right)$$



$$(-kT)^{c_v} \left(1 + \frac{\lambda}{\epsilon_0} \ln(-kT) \right)$$

$\lambda \phi^4 \rightarrow IR$

m^2_{phys}
 c_v

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} \ln(-kT) \right)$$

$\frac{M^2_{phys} \rightarrow \sqrt{\lambda} H^2}{\epsilon_0 + \frac{\lambda}{\epsilon_{phys}}}$

$$(-kT)^{\epsilon_0 + \frac{\lambda}{\epsilon_{phys}}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

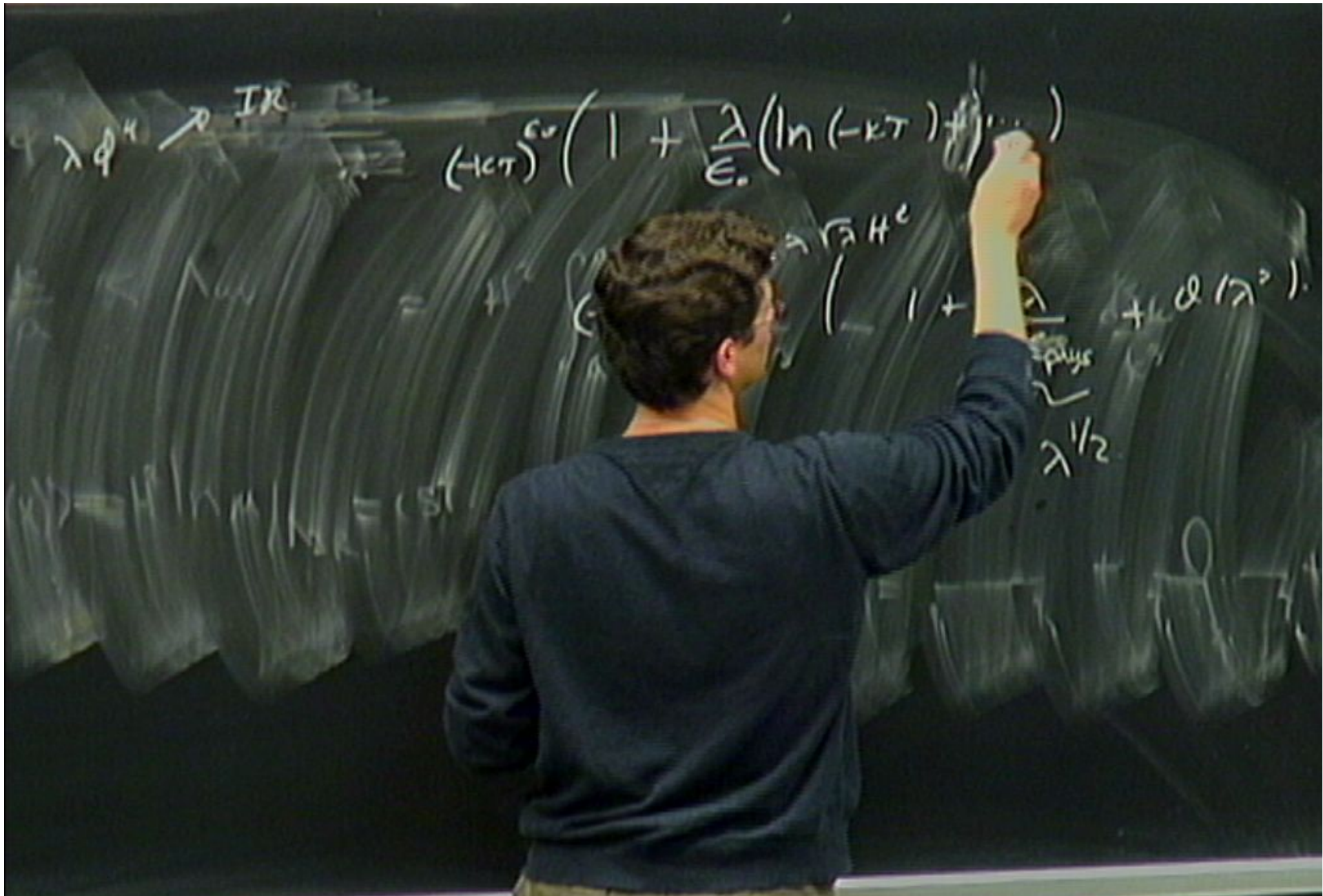
$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} \ln(-kT) \right)$$

$\epsilon_0 + \frac{m^2_{phys}}{4\pi} \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{m^2_{phys}}{4\pi}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$\lambda^{1/2}$

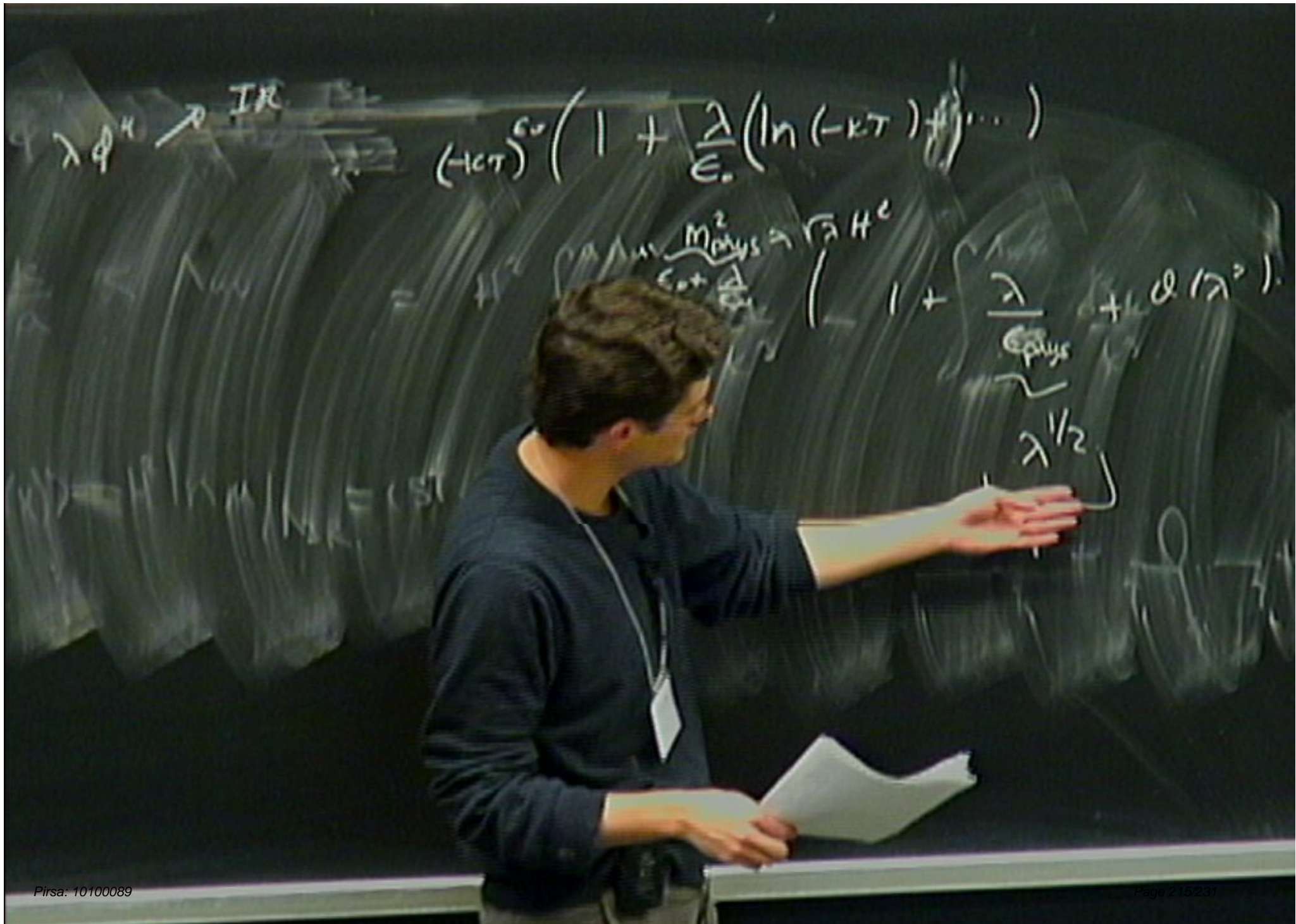


$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$$= \frac{1}{\epsilon_0} \left((-kT)^{\epsilon_0 + \frac{m^2_{phys}}{4\pi}} \left(1 + \frac{\lambda}{\epsilon_0} + \mathcal{O}(\lambda^2) \right) \right)$$

$\lambda^{1/2}$



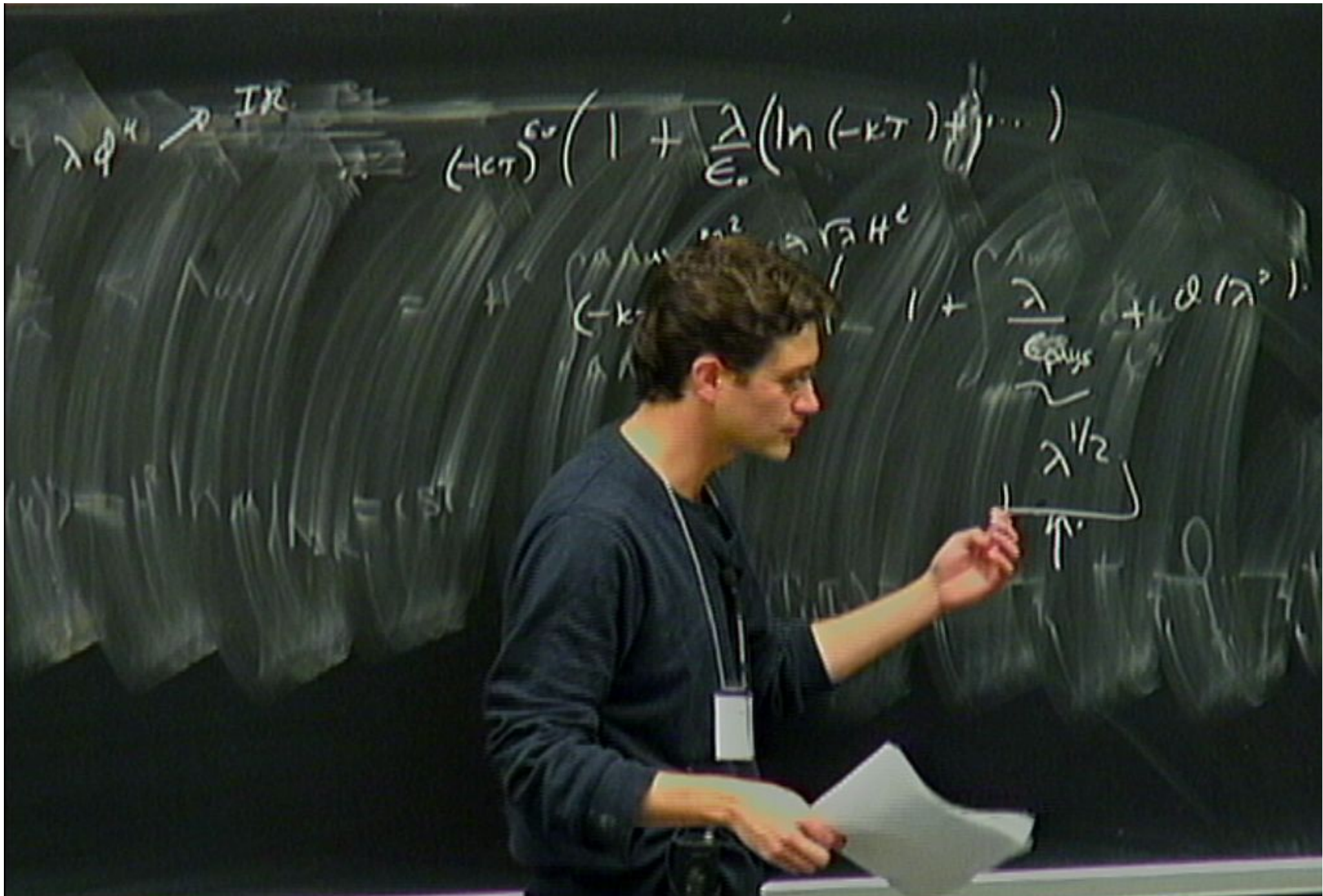
$\lambda^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$$= \frac{h^2}{2\pi^2} \frac{m_{phys}^2}{\epsilon_0 + \frac{h^2}{2\pi^2}} \sqrt{\lambda} H^2$$

$$\left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$\lambda^{1/2}$$

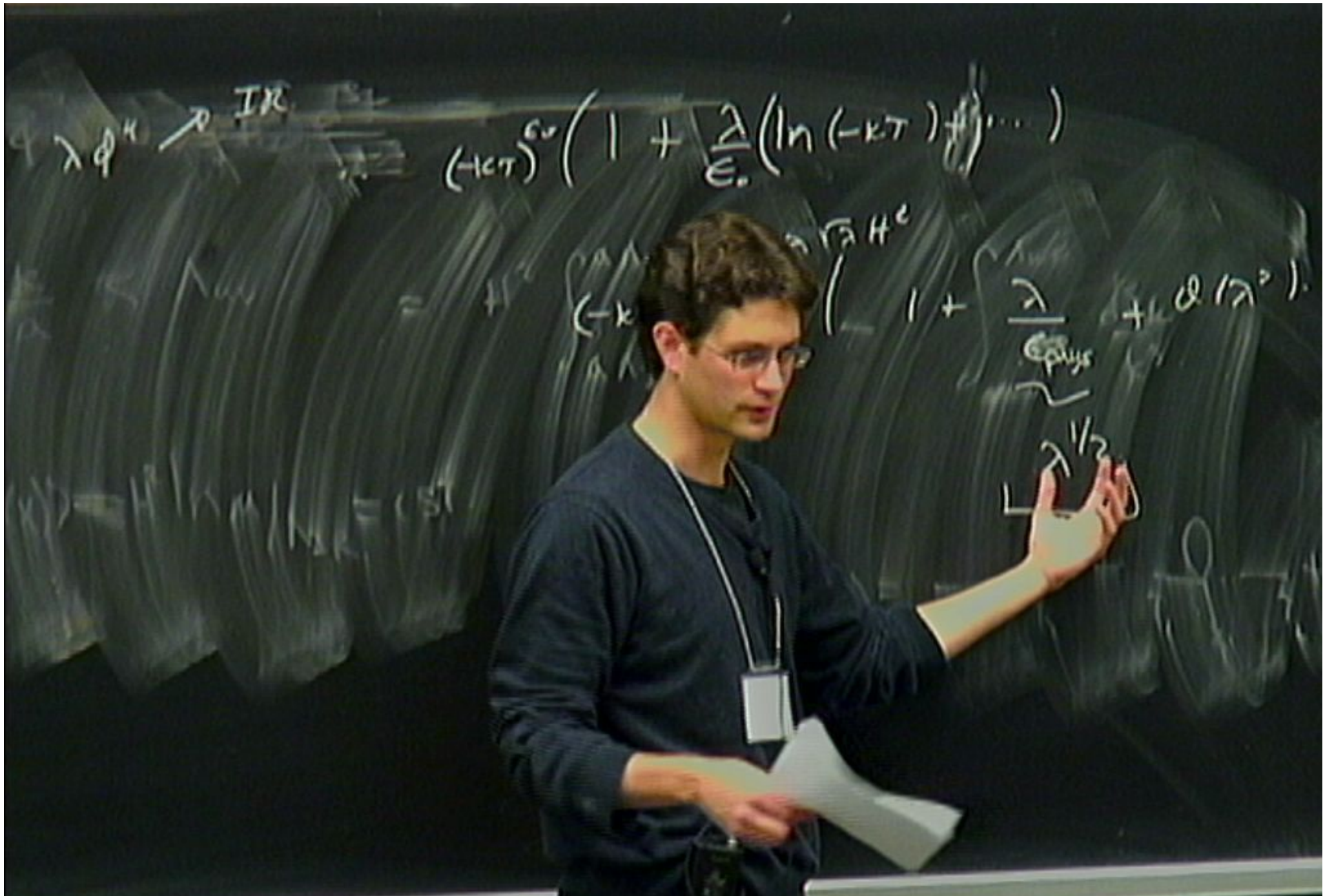


$$\lambda \rho^k \rightarrow IR$$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$$= \frac{h^3}{(2\pi)^3} \frac{m^2}{\sqrt{2} h^2} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$\lambda^{1/2}$$



$$\lambda q^k \rightarrow IR$$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$\lambda^{1/2}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

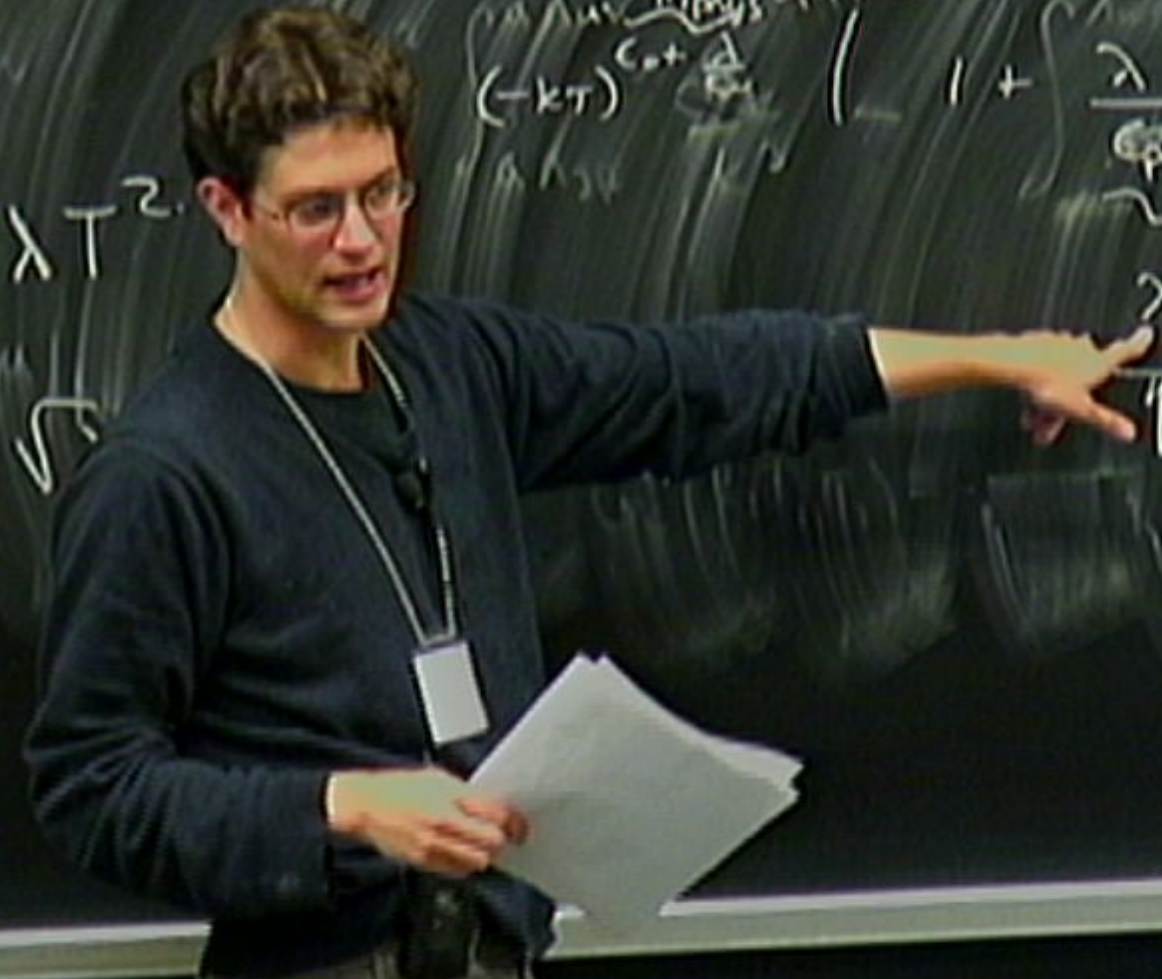
$m_{phys}^2 \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{th}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda}$$

$$\lambda^{1/2}$$



$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$m_{phys}^2 \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thor}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$\epsilon_0 + \frac{m^2}{4\pi} \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{m^2}{4\pi}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$\sim \lambda T^2$$

$$= \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$m_{phys}^2 \rightarrow \sqrt{\lambda} H^e$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{th}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$m_{phys}^2 \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thr}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

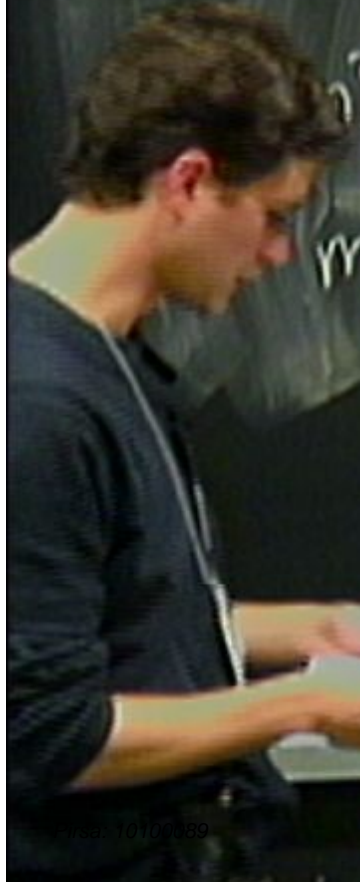
$\frac{m_{phys}^2}{\epsilon_0 + \frac{\lambda}{4}} \rightarrow \sqrt{\lambda} H^e$
 $(-kT)^{\epsilon_0 + \frac{\lambda}{4}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$

$$m_{th}^2 \sim \lambda T^2$$

$$m_{sp}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$



$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

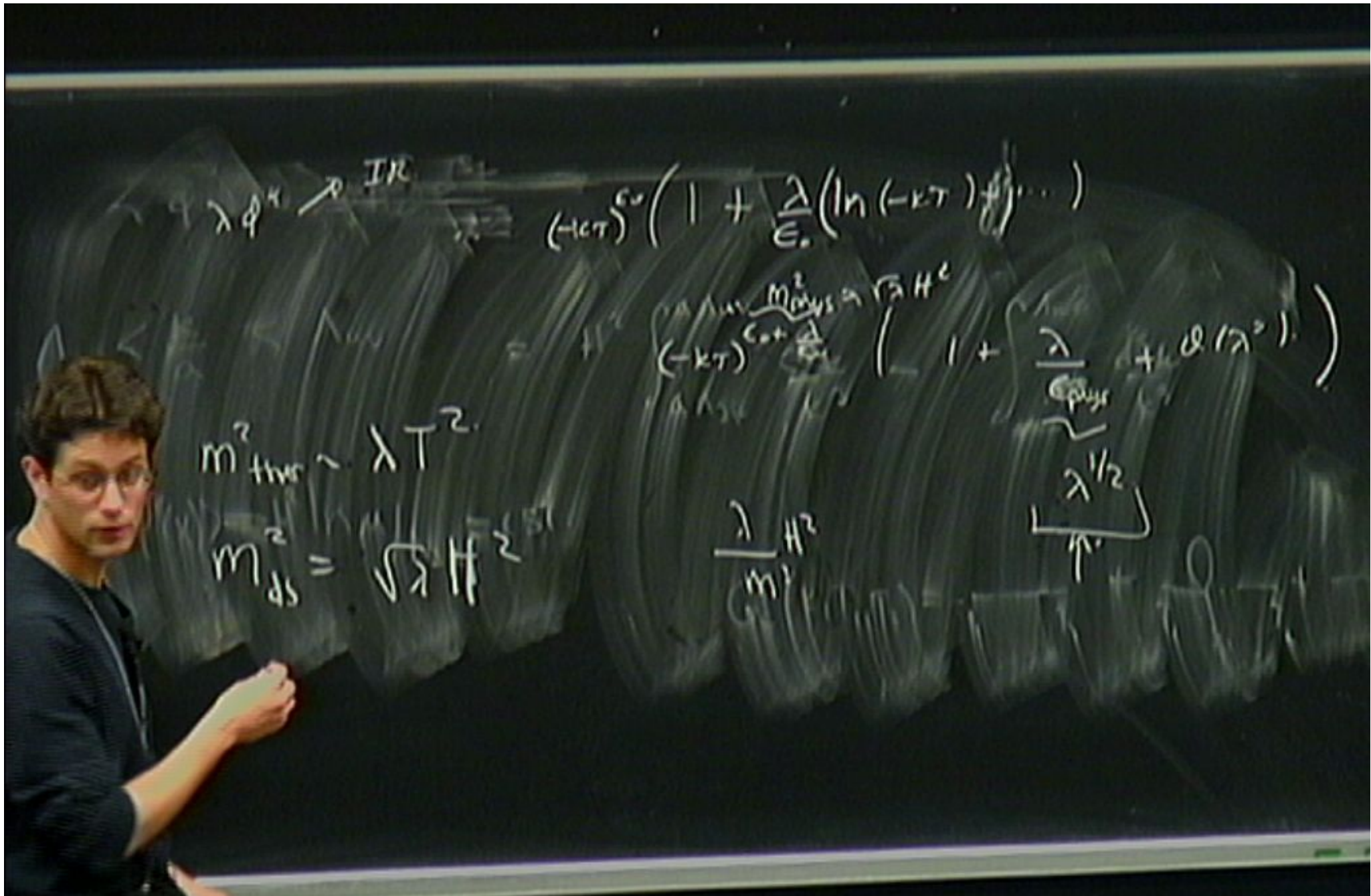
$$(-kT)^{\epsilon_0 + \frac{m_{phys}^2}{4\pi H^2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$\lambda^2 \text{thr} \sim \lambda T^2$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m_{ps}^2} H^2$$

$$\sqrt{\frac{\lambda^{1/2}}{H}}$$



$$\lambda \phi^4 \rightarrow IR$$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT)) \dots \right)$$

$$(-kT)^{\epsilon_0 + \frac{m^2_{phys}}{4\pi}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m^2_{th} \sim \lambda T^2$$

$$m^2_{sp} = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\sqrt{\lambda^{1/2}}$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT)) \dots \right)$$

$\epsilon_0 = \frac{m_{phys}^2}{\sqrt{\lambda} H^2}$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thr}^2 \sim \lambda T^2$$

$$m_{ds}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\left[\frac{\lambda^{1/2}}{m} \right]$$

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT)) \dots \right)$$

value $m_{phys}^2 \sim \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thr}^2 \sim \lambda T^2$$

$$m_{ds}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\sqrt{\lambda^{1/2}}$$



$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT)) \dots \right)$$

$$(-kT)^{\epsilon_0 + \frac{m_{phys}^2}{\sqrt{\lambda} H^2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thr}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\sqrt{\frac{\lambda}{\mu}}$$



$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$$(-kT)^{\epsilon_0 + \frac{m^2_{phys} \lambda}{4\pi H^2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m^2_{thr} \sim \lambda T^2$$

$$m^2_{ps} = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$



h

$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$m^2_{phys} \rightarrow \sqrt{3} H^2$

$$(-kT)^{\epsilon_0 + \frac{m^2_{phys}}{H^2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m^2_{thr} \sim \lambda T^2$$

$$m^2_{ps} = \sqrt{3} H^2$$

$$\frac{\lambda}{m^2} H^2$$

$$\lambda^{1/2}$$



$\lambda \phi^4 \rightarrow IR$

$$(-kT)^{\epsilon_0} \left(1 + \frac{\lambda}{\epsilon_0} (\ln(-kT) + \dots) \right)$$

$m_{phys}^2 \rightarrow \sqrt{\lambda} H^2$

$$(-kT)^{\epsilon_0 + \frac{d}{2}} \left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2) \right)$$

$$m_{thr}^2 \sim \lambda T^2$$

$$m_{ps}^2 = \sqrt{\lambda} H^2$$

$$\frac{\lambda}{m_{ps}^2} H^2$$

$$\lambda^{1/2}$$



h