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.

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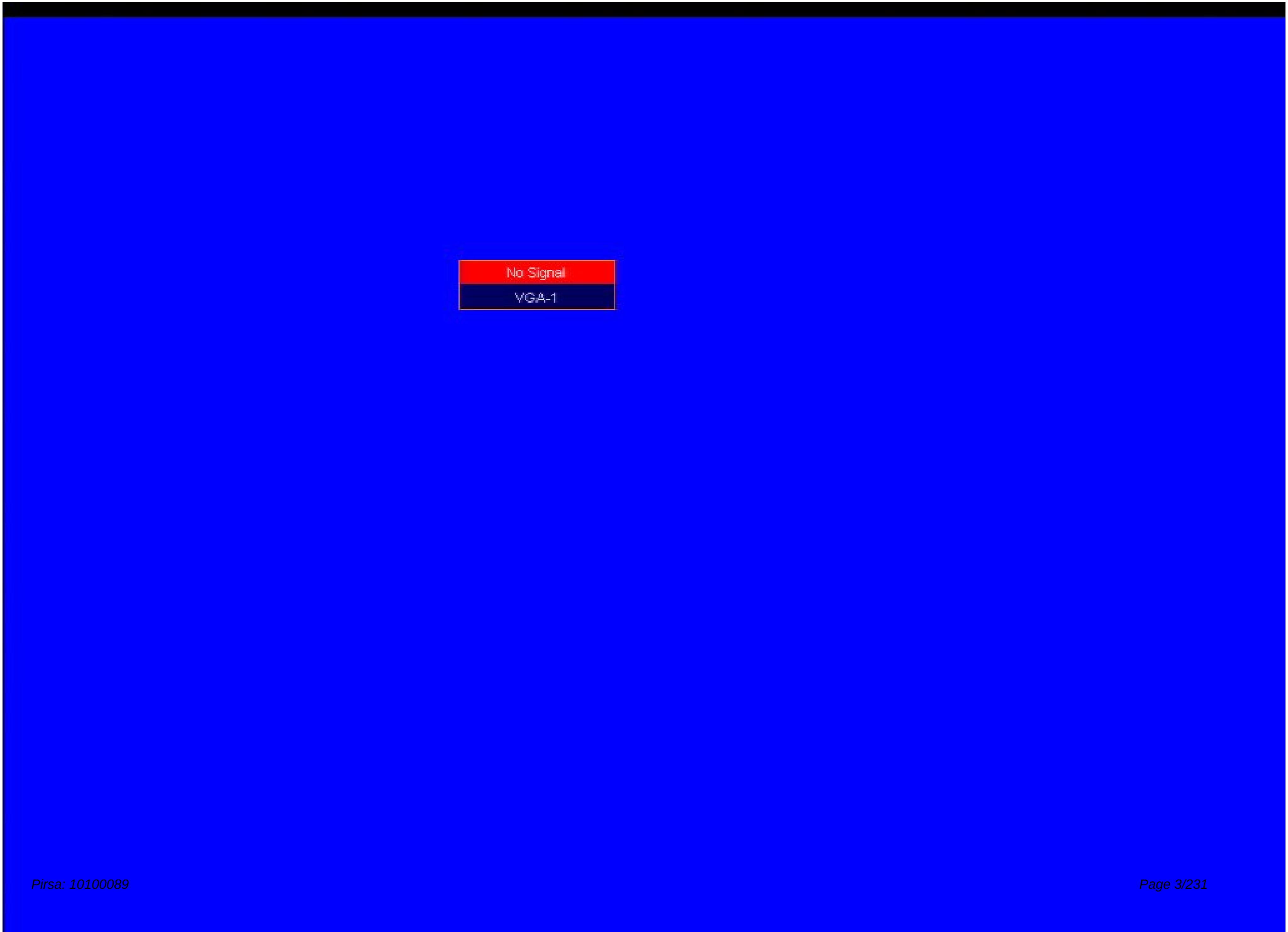

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w/ Burgess

Helman

Shandera.

Motivation

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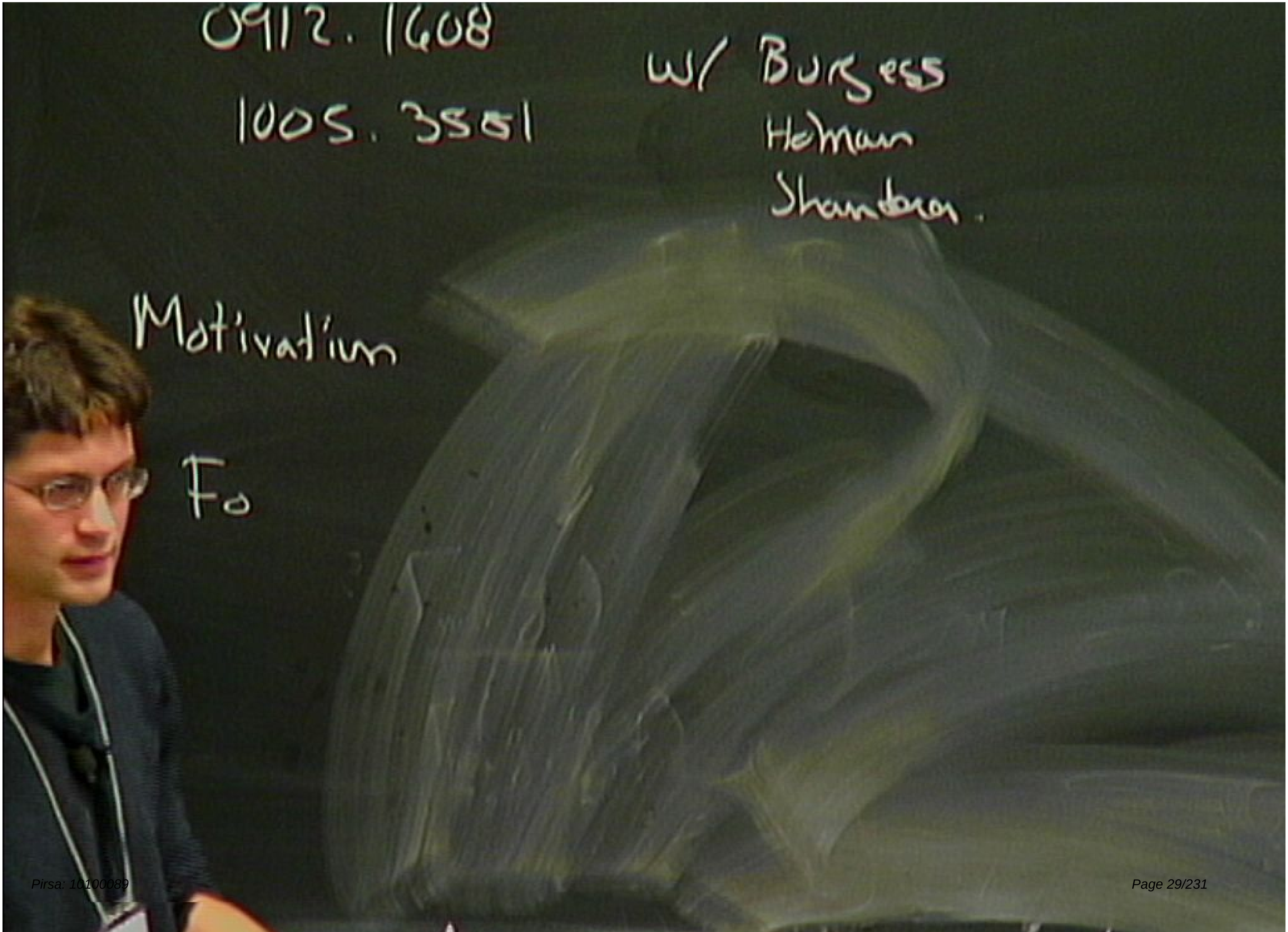

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Motivation

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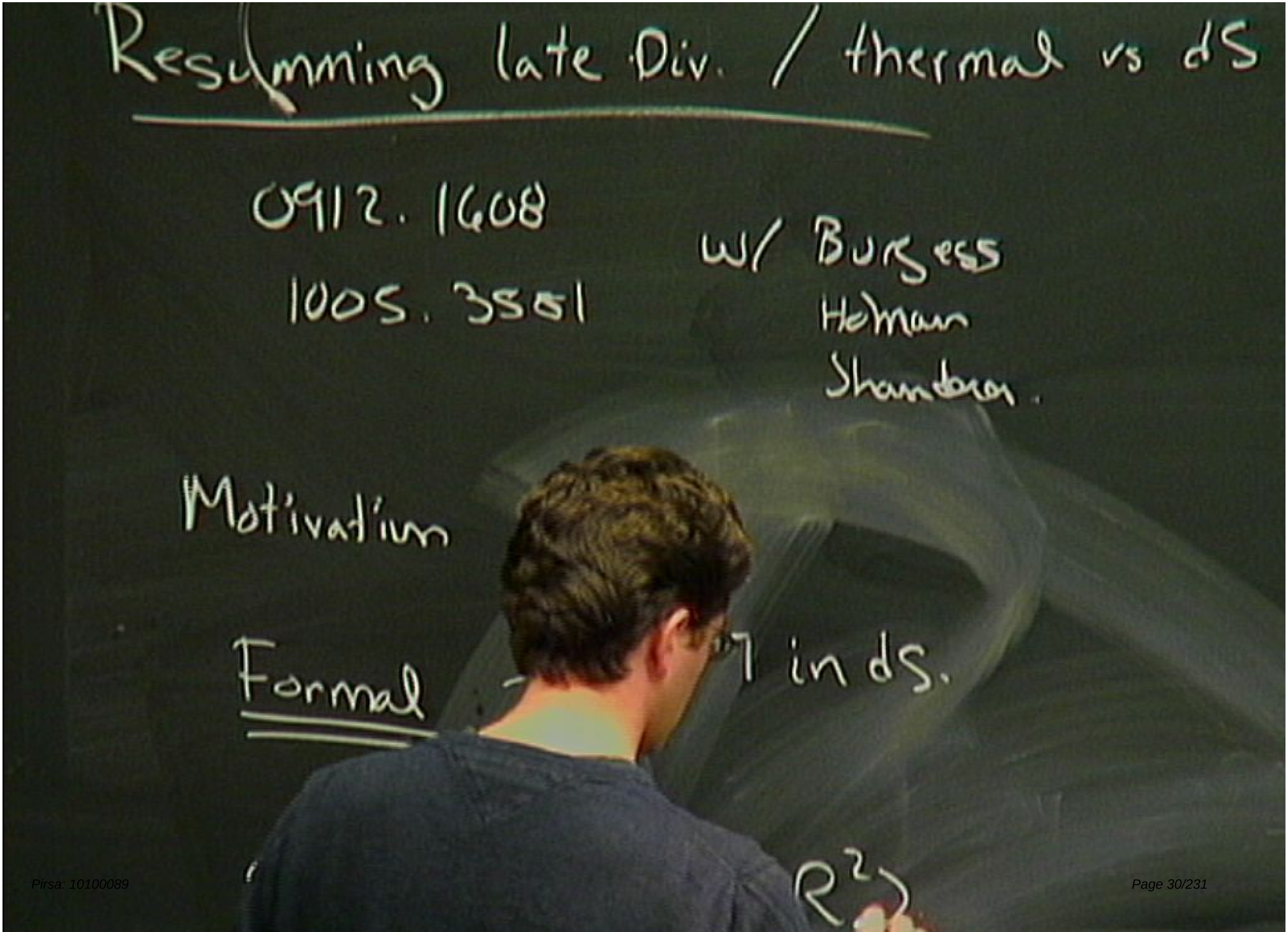

Resumming late Div. / thermal vs dS

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w/ Burgess
Holman
Shandera.

Motivation

Formal

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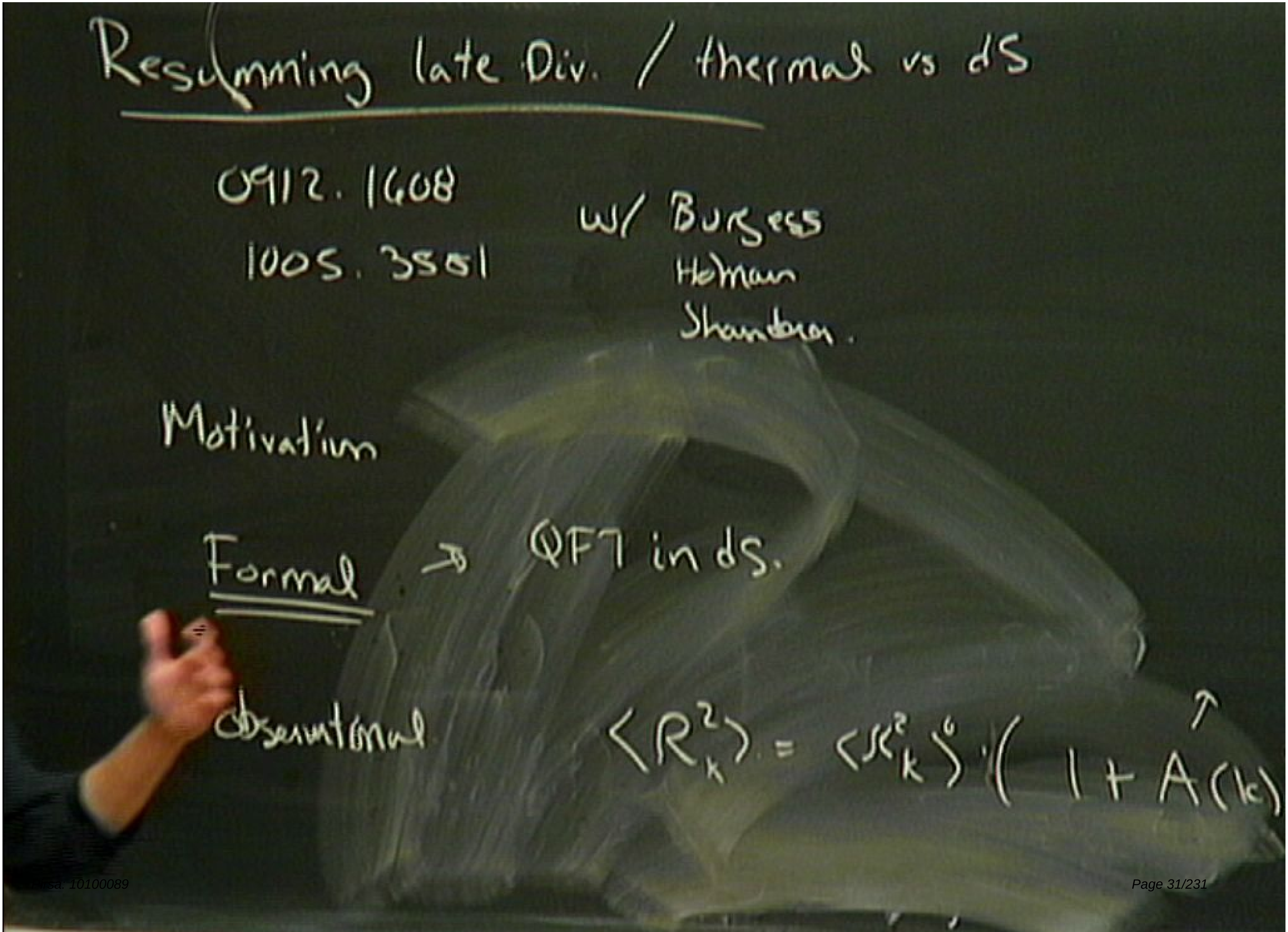
$R^2)$



Resumming late Div. / thermal vs dS

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1005.3501

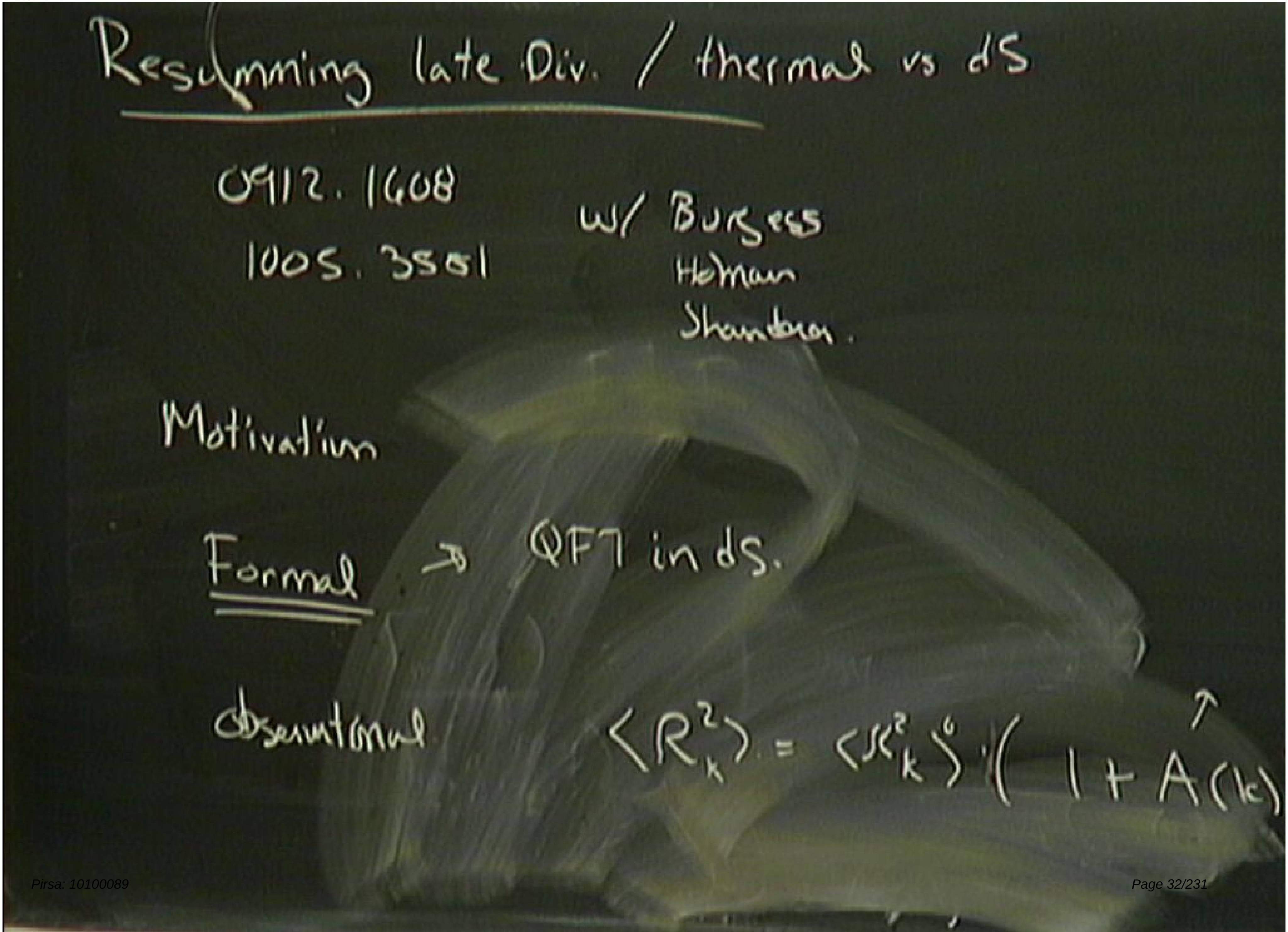
w/ Burgess
Holman
Shandera.

Motivation

Formal → QFT in dS.

Observational

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle^0 \left(1 + \overset{\nearrow}{A}(k) \right.$$



Resumming late Div. / thermal vs dS

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w/ Burgess
Holman
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Formal → QFT in dS.

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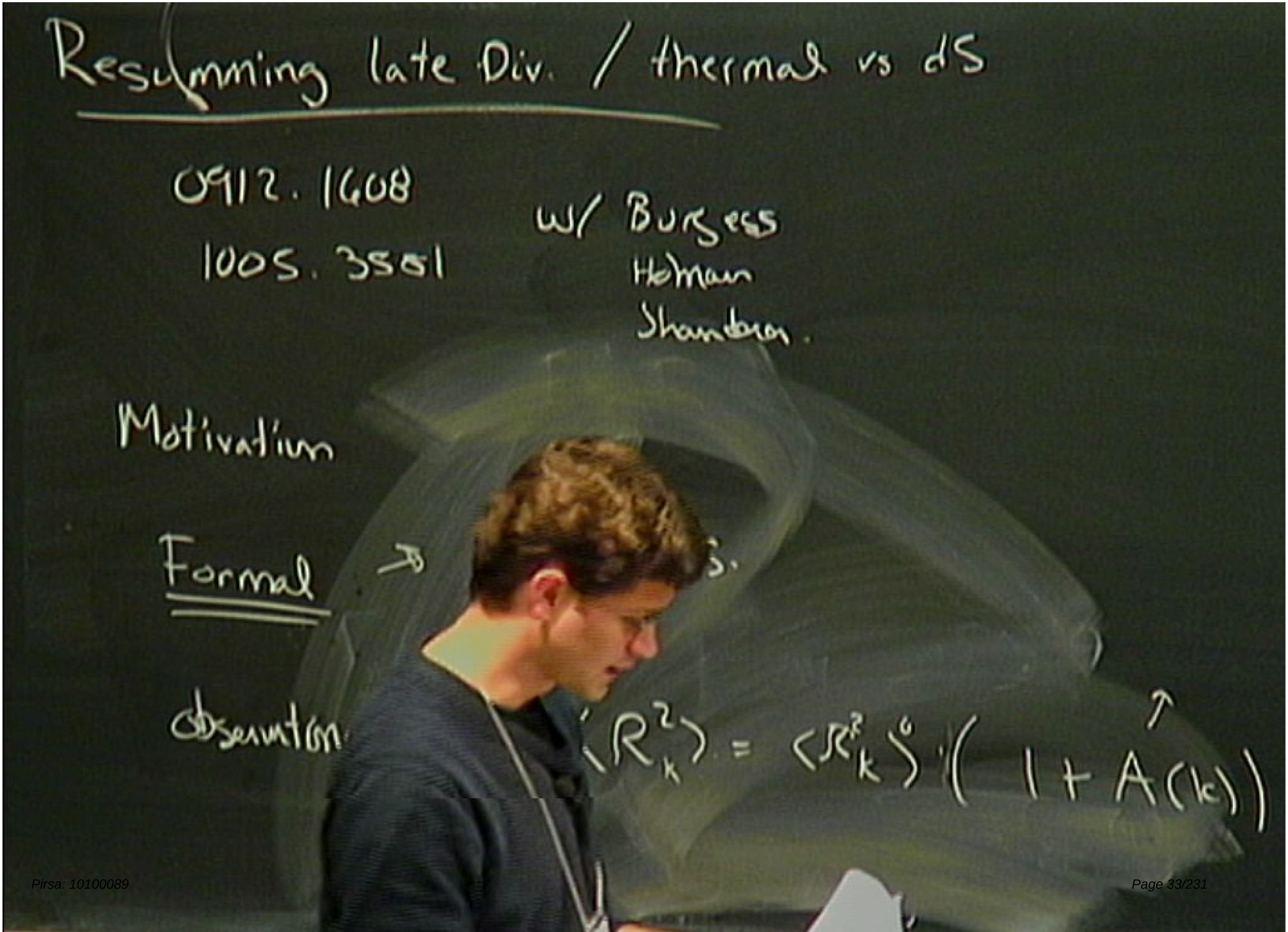
$$\langle R_k^2 \rangle = \langle \mathcal{R}_k^2 \rangle^0 \Big(1 + \overset{\uparrow}{A}(k)$$



Resumming late Div. / thermal vs dS

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w/ Burgess
Holman
Shandera.

Motivation

Formal →

Observation

$$\langle R_k^2 \rangle = \langle R_k^2 \rangle^0 \left(1 + \overset{\uparrow}{A}(k) \right)$$

Resumming late Div. / thermal vs dS

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w/ Burgess

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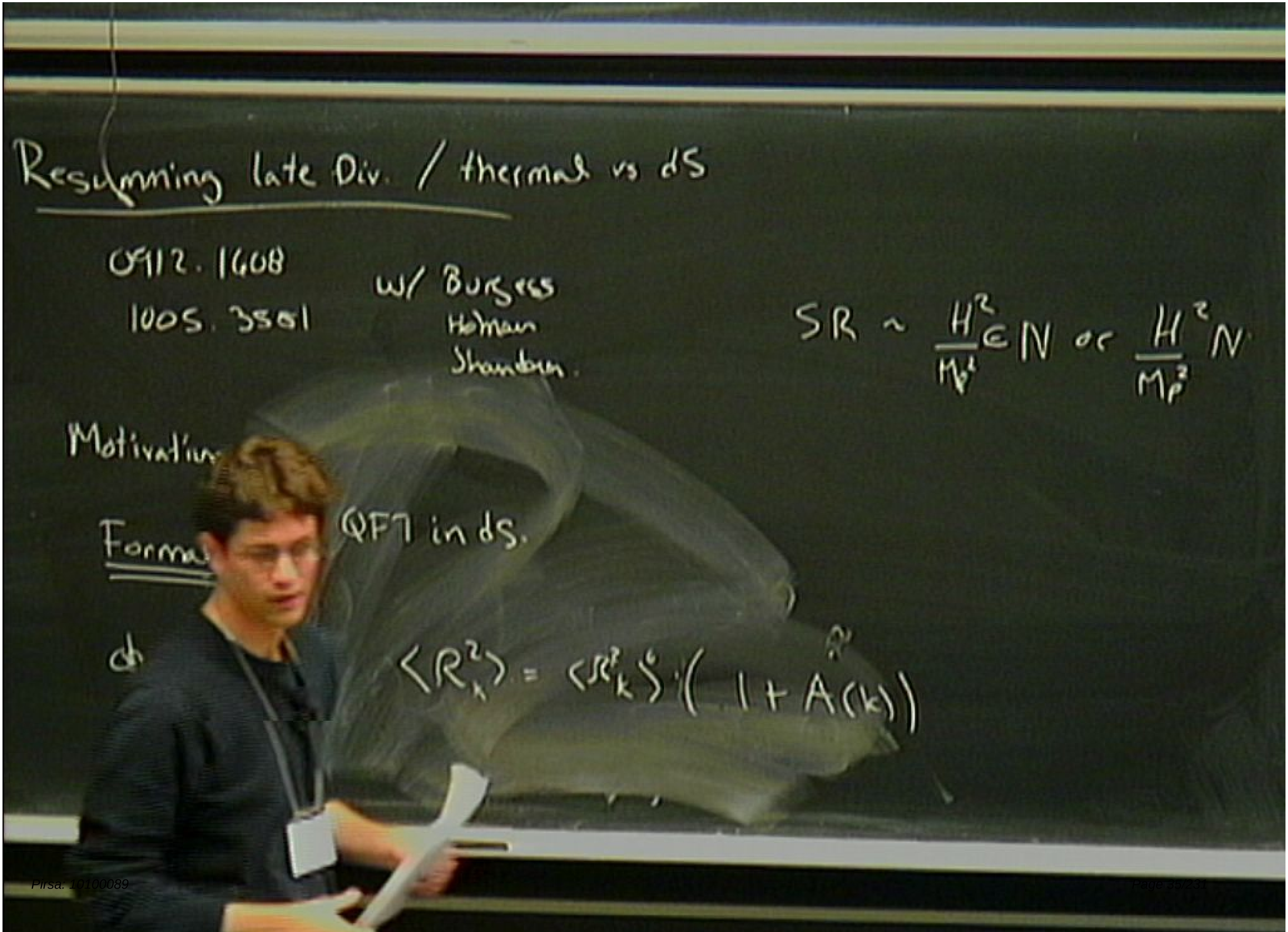
$$SR \sim \frac{H^2}{M_p^2}\epsilon \quad \text{or} \quad \frac{H^2}{M_p^2}$$

Motivation

Formal → QFT in dS.

observational

$$\langle R^2_k \rangle = \langle R^2_k \rangle^0 \cdot \left(1 + \overset{?}{A}(k) \right)$$



Resumming late Div. / thermal vs dS

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1005.3551 Holman

Shandera.

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

Motivatio

Forma QFT in dS.

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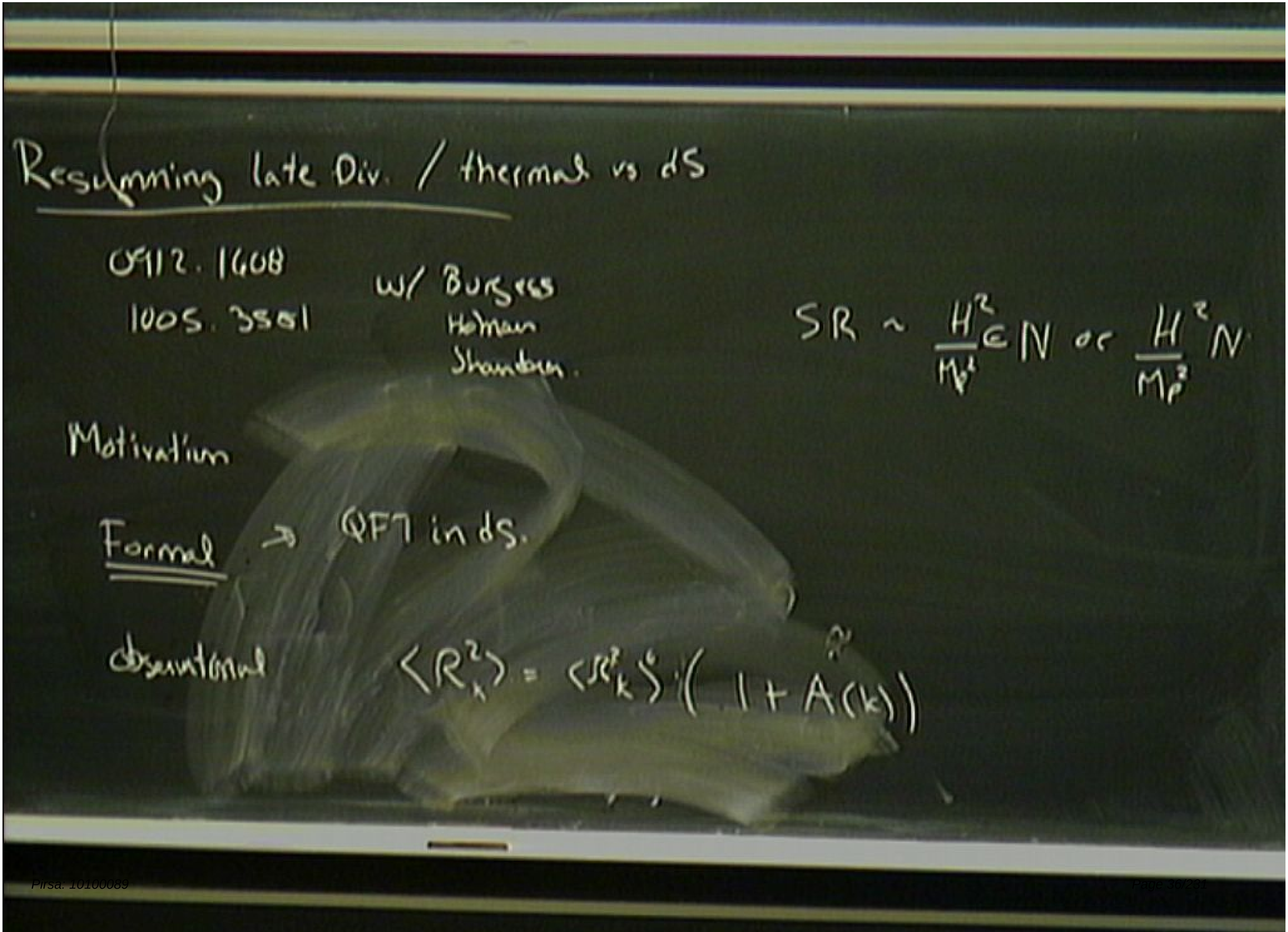
$$\langle R_k^2\rangle = \langle R_k^2\rangle_0 \left(1 + \overset{?}{A}(k)\right)$$



Resumming late Div. / thermal vs dS

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w/ Burgess
Holman
Shandera.

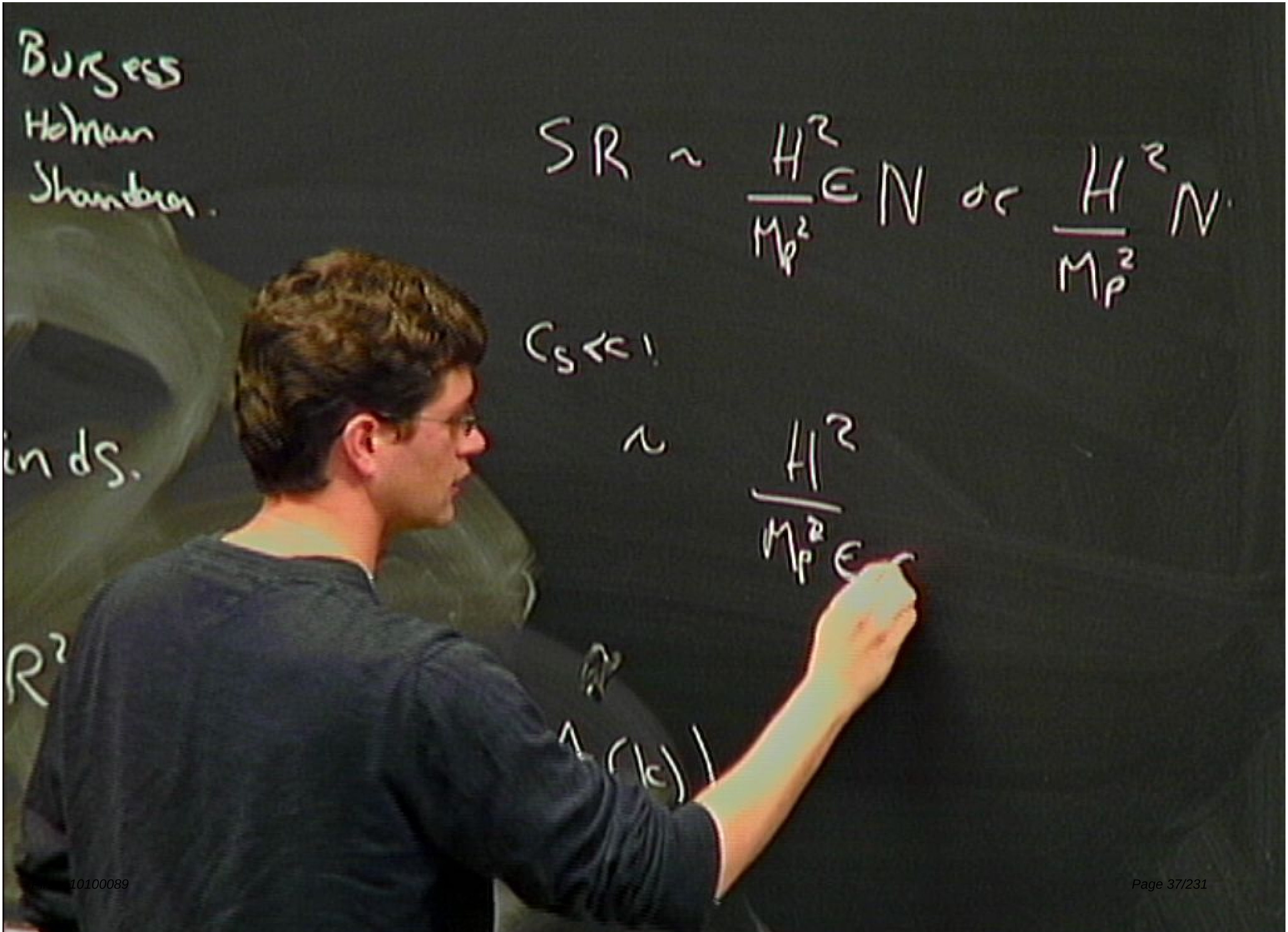
$$SR \sim \frac{H^2}{M_p^2}\epsilon N \text{ or } \frac{H^2}{M_p^2}N$$

Motivation

Formal → QFT in dS.

observational

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



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

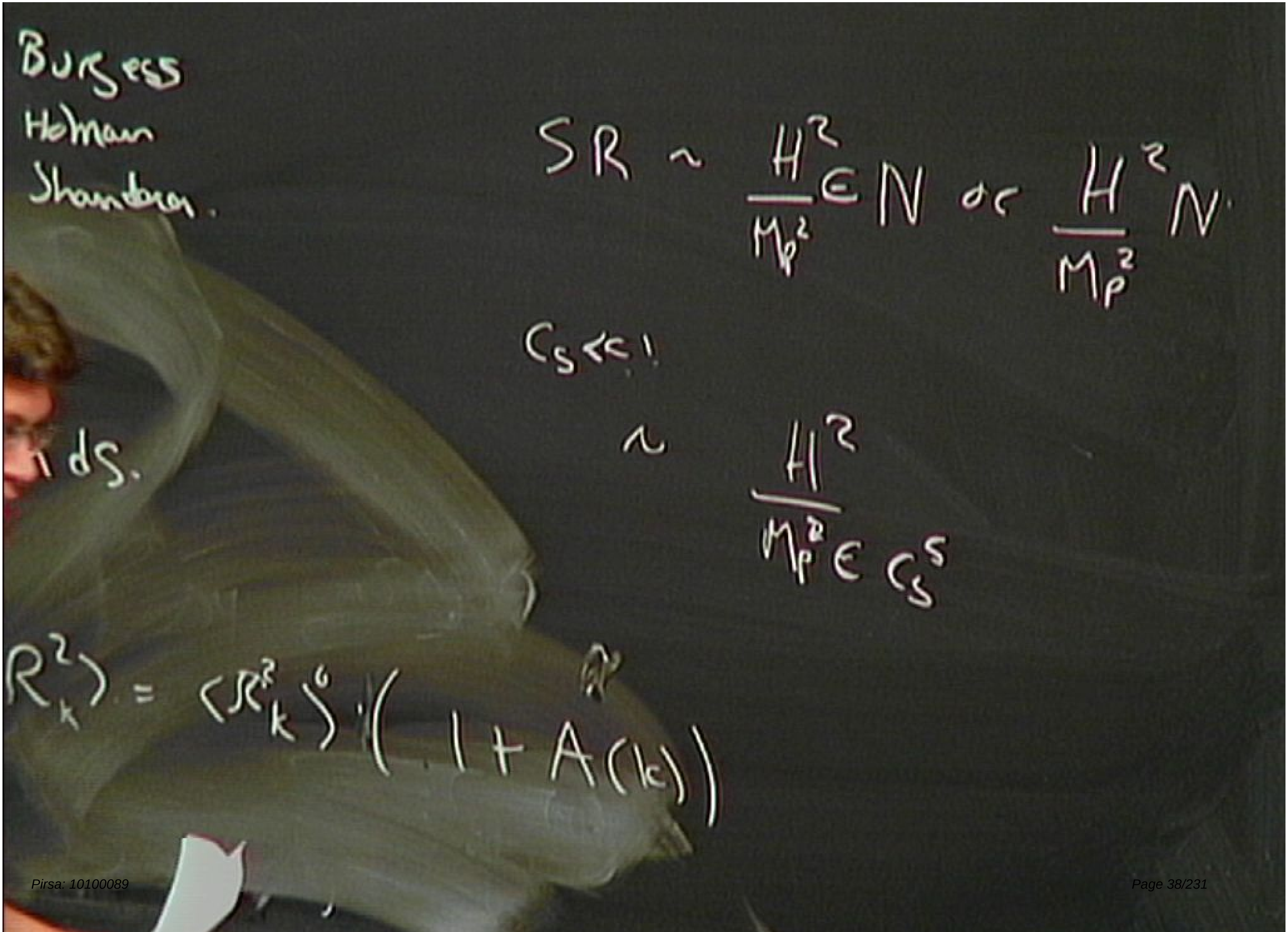
$c_s \ll 1$

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

in dS.

R^2

$\Delta(k)$



Burgess
Holman
Shandera.

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

$c_s \ll 1$

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

ids.

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

Burgess
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Shandera.

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

$c_s \ll 1$

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

inds.

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

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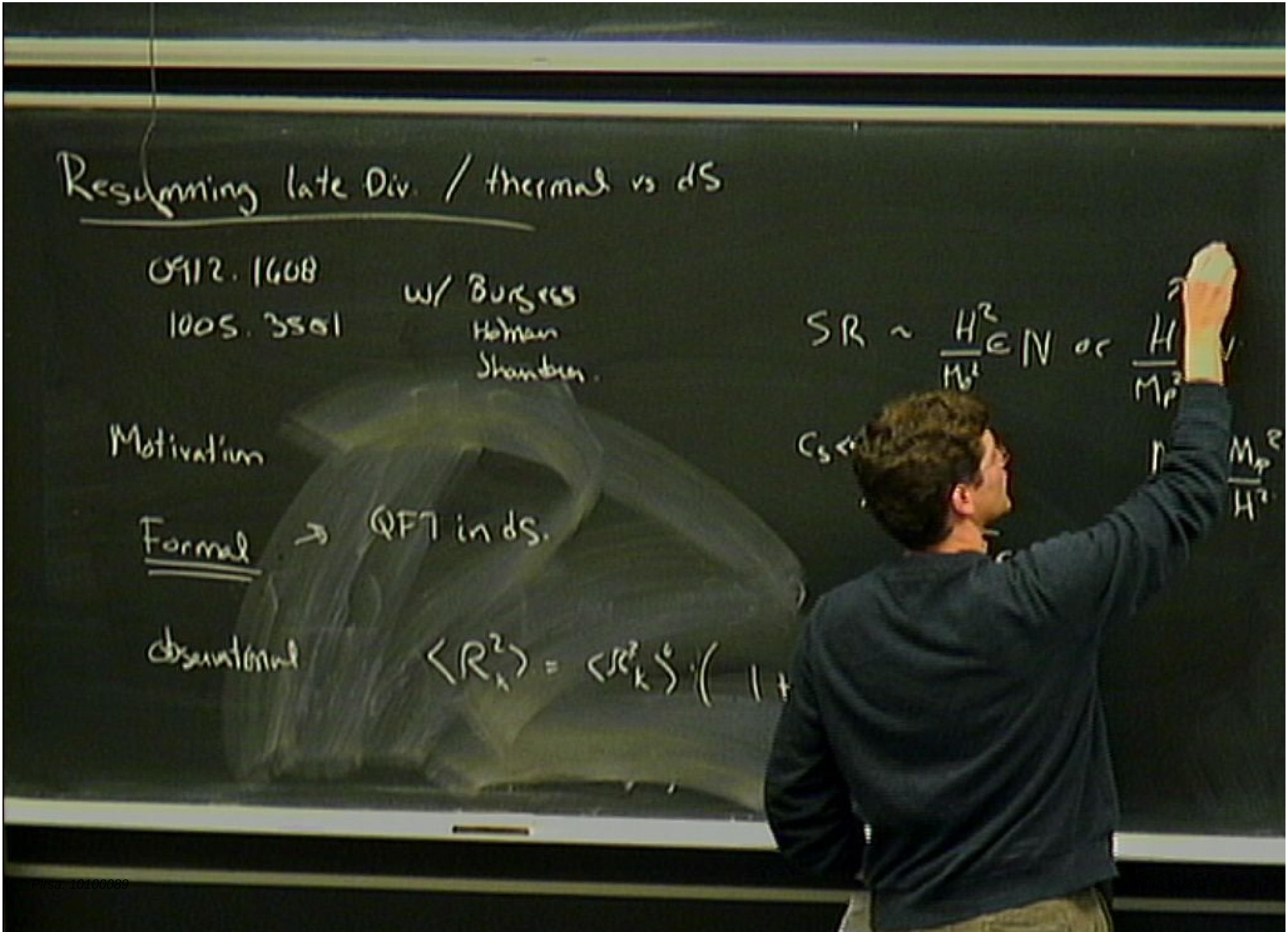
$$SR \sim \frac{H^2}{M_p^2 \epsilon} N \quad \text{or} \quad \frac{H^2}{M_p^2} N.$$

$c_s \ll 1$

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

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

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



Resumming late Div. / thermal vs dS

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

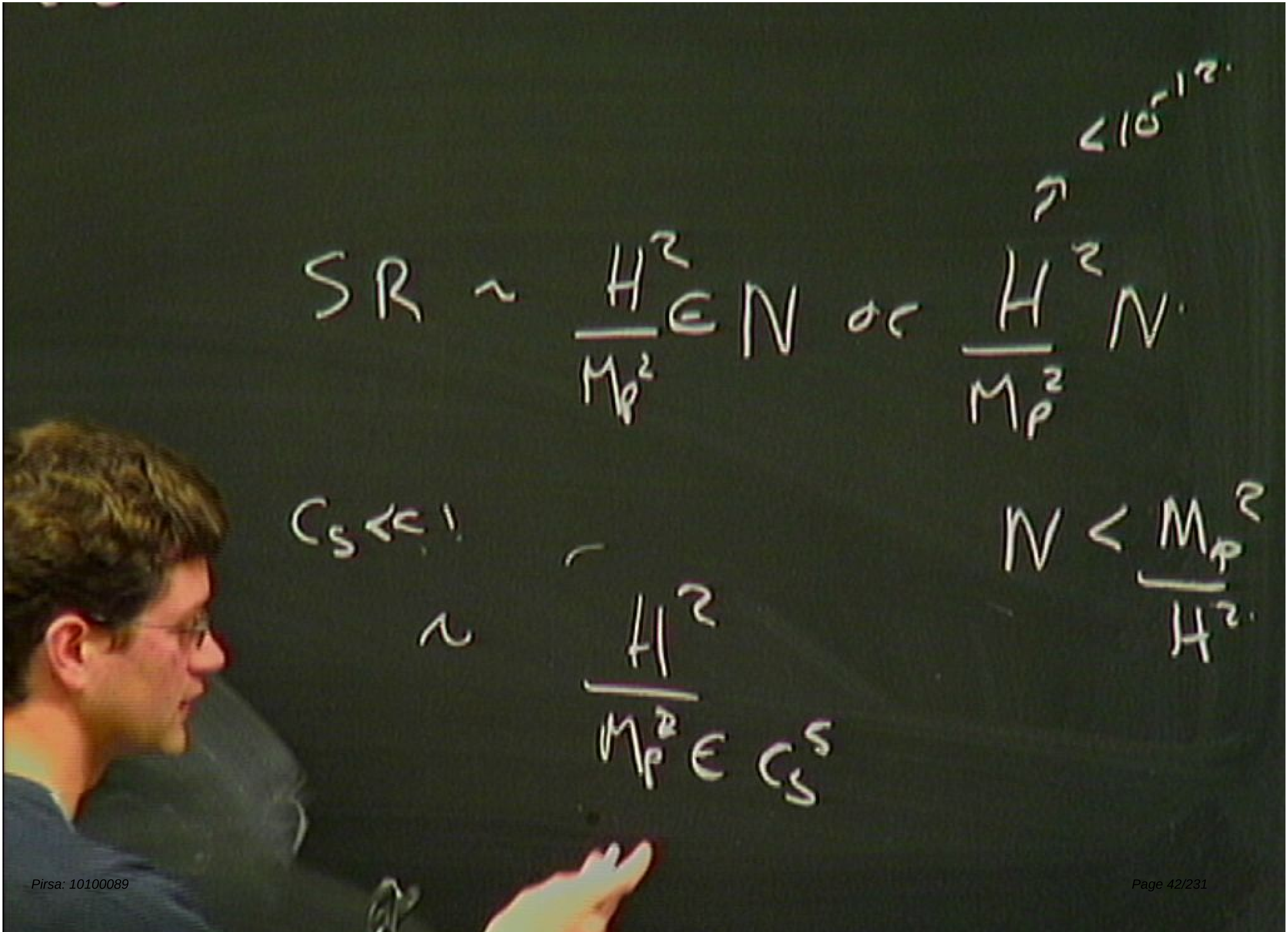
$c_s <$

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

Motivation

Formal → QFT in dS.

observational $\langle R_k^2 \rangle = \langle R_k^2 \rangle^0 \cdot (1 +$



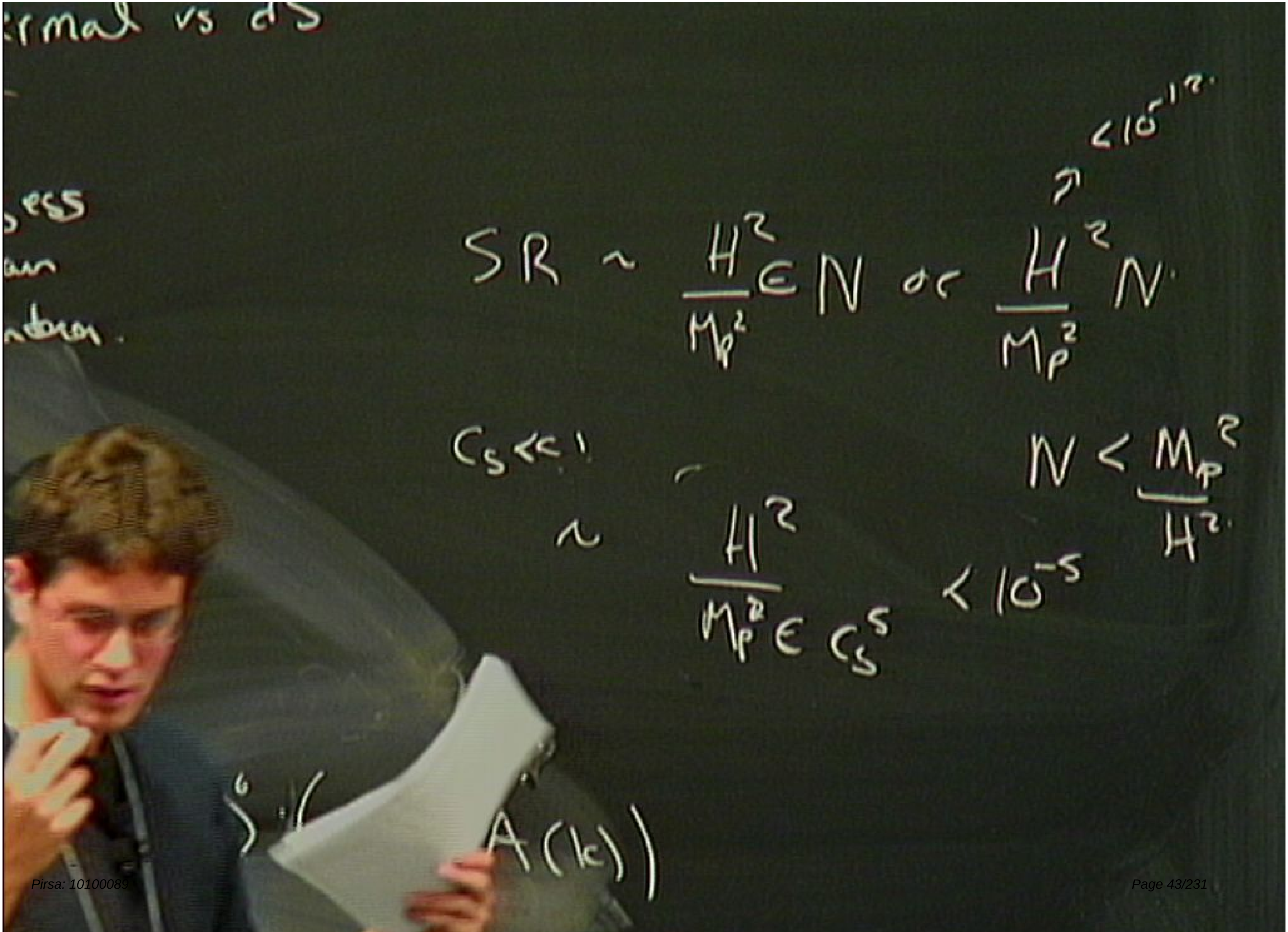
$$\nearrow \; < 10^{-12}$$

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

$$c_s << 1$$

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

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



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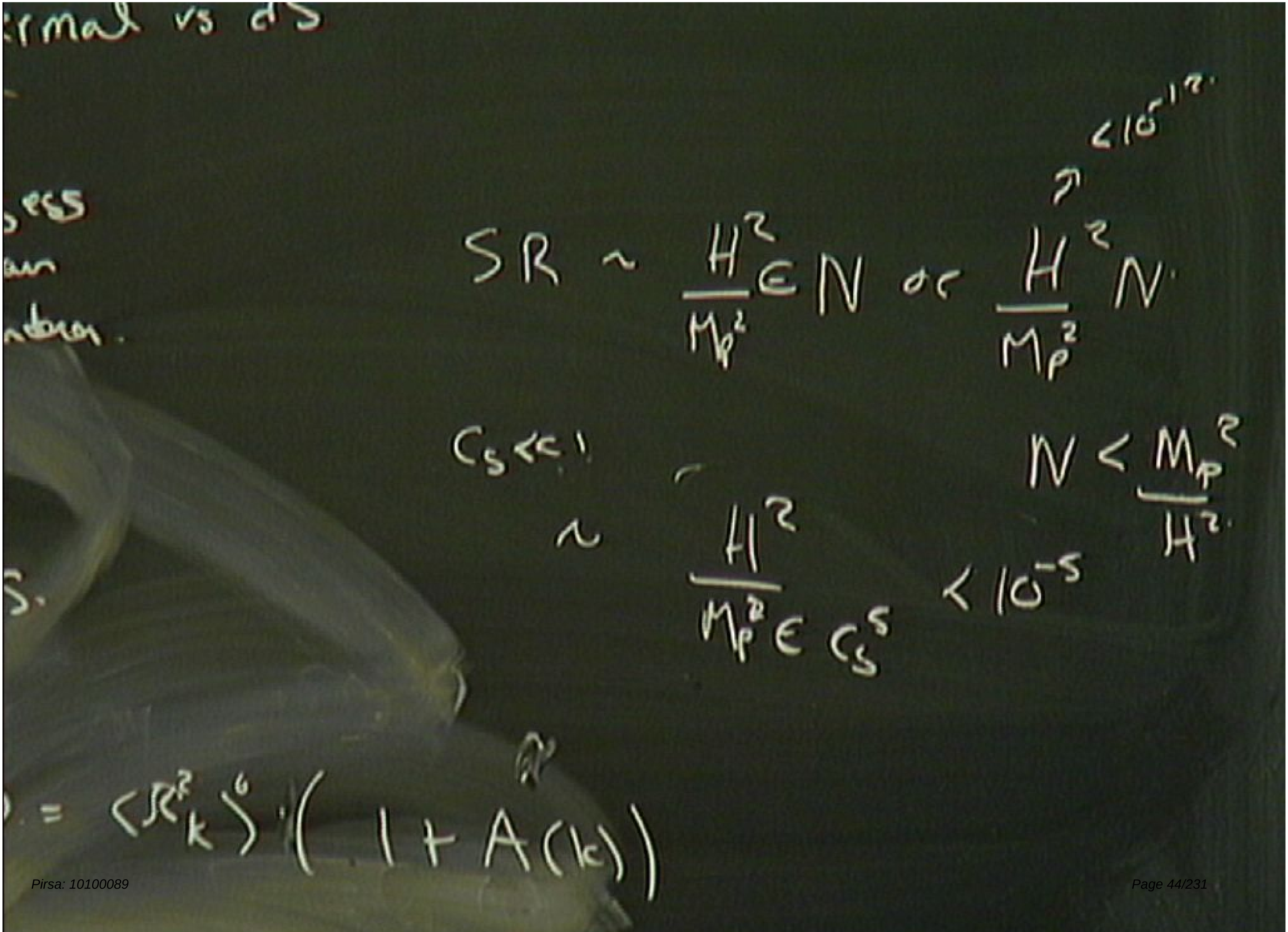
$$SR \sim \frac{H^2}{M_p^2 \epsilon} N \quad \text{or} \quad \frac{H^2}{M_p^2} N \nearrow < 10^{-12}$$

$c_s \ll 1$

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

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

$A(k))$



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

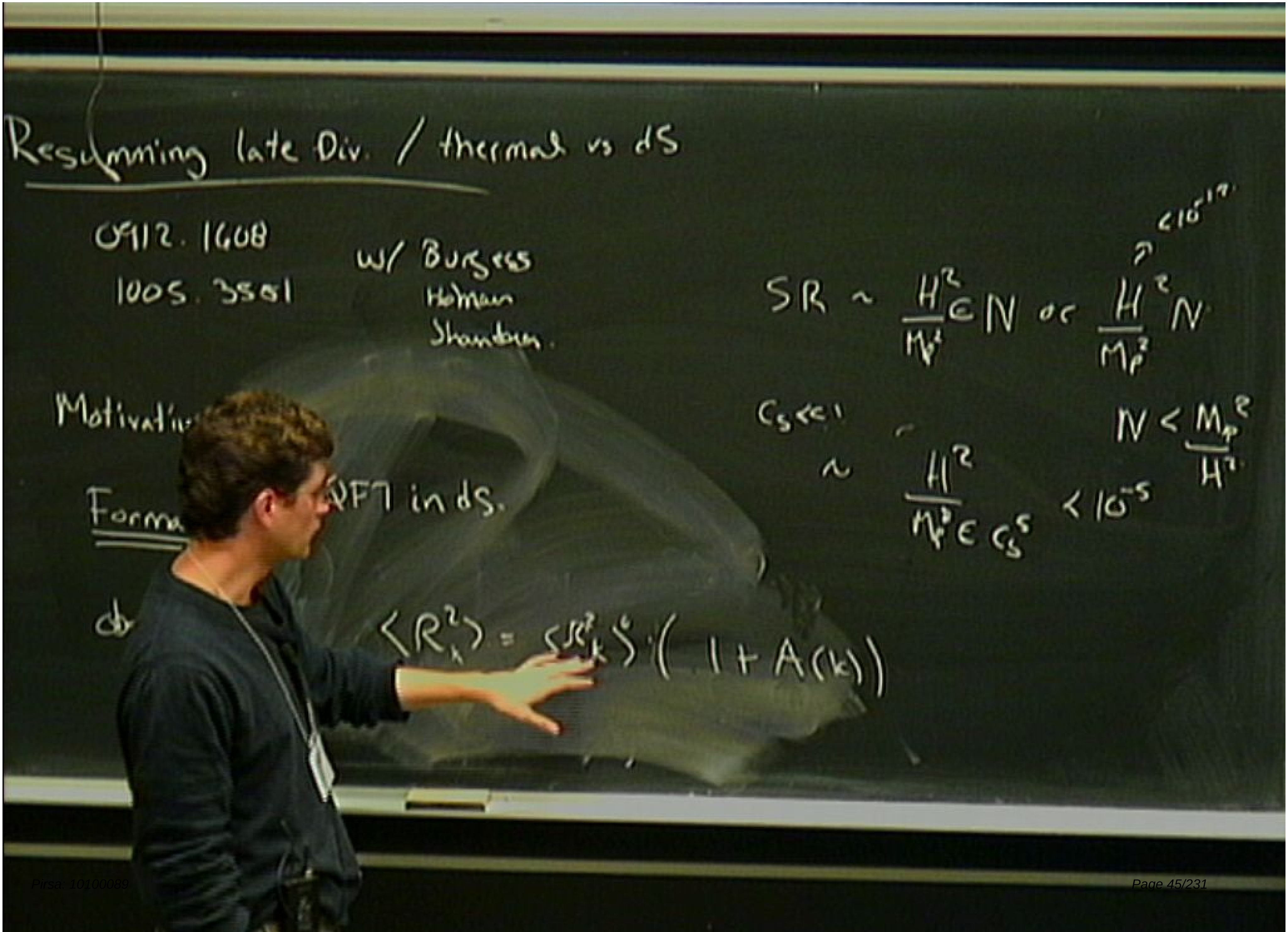
$$\nearrow < 10^{-12}$$

$c_s \ll 1$

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

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

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



Resumming late Div. / thermal vs dS

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1005.3551 Holman Shandera.

Motivati

Forma QFT in dS.

$< 10^{-17}$

?

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

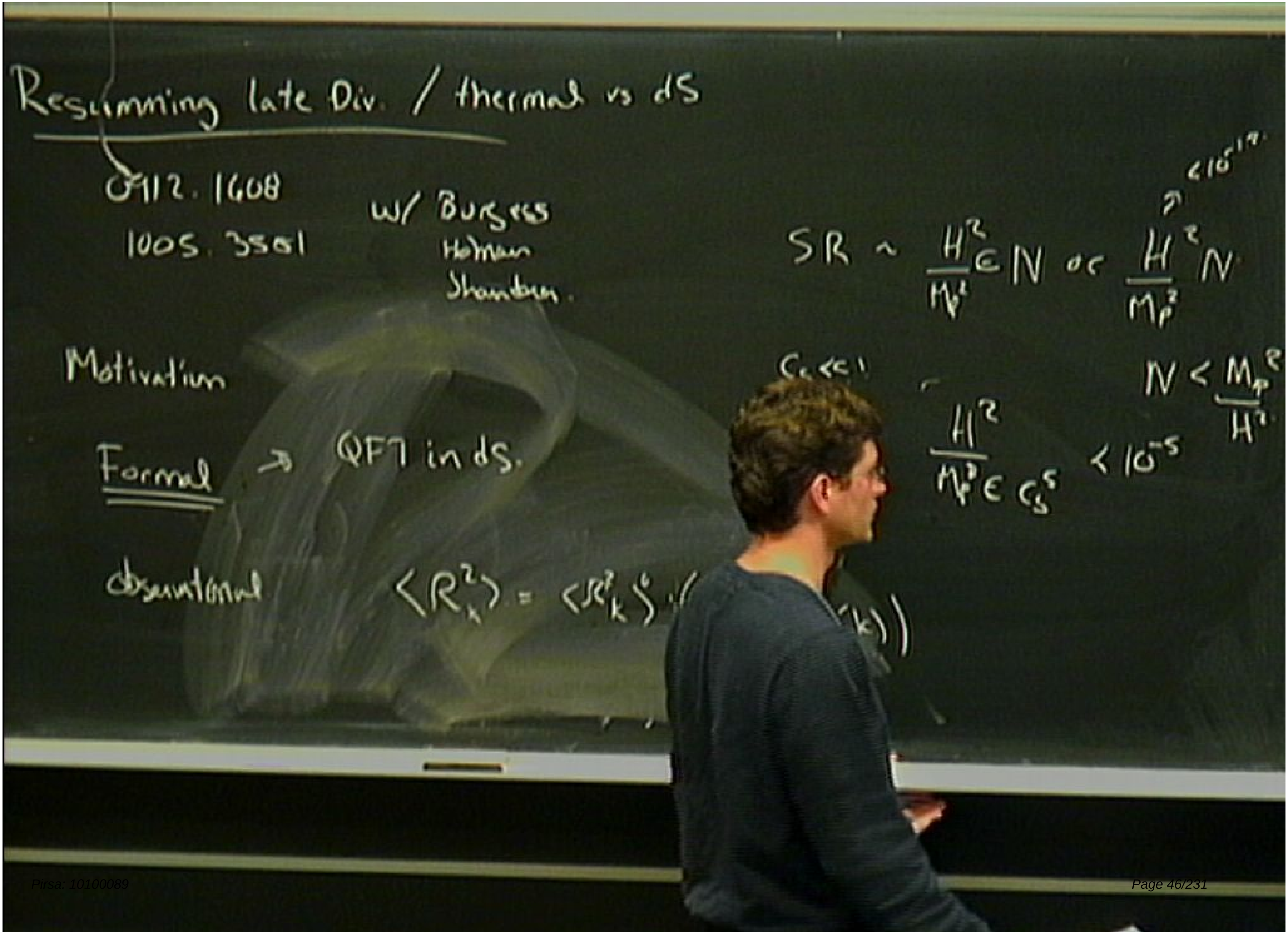
$c_s \ll 1$

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

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

d

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



Resumming late Div. / thermal vs dS

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w/ Burgess
Holman
Shandera.

Motivation

Formal → QFT in dS.

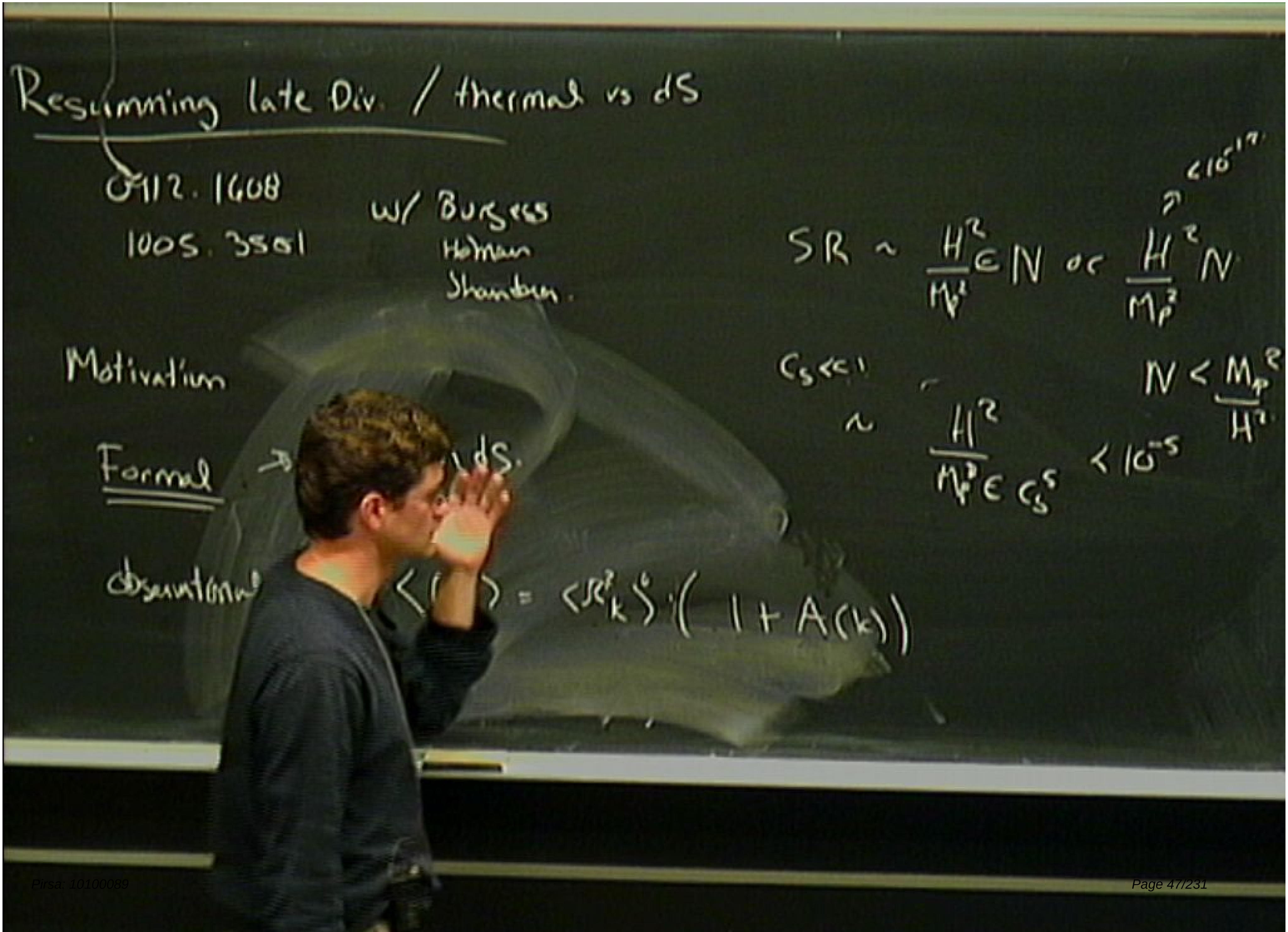
observational $\langle R_x^2 \rangle = \langle R_k^2 \rangle_0 ($ $k))$

$SR \sim \frac{H^2}{M_p^2 \epsilon} N$ or $\frac{H^2}{M_p^2} N$ $\gtrsim$ $< 10^{-17}$

$c_s \ll 1$

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

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



Resumming late Div. / thermal vs dS

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1005.3501 Holman
Shandera.

Motivation

Formal → dS.

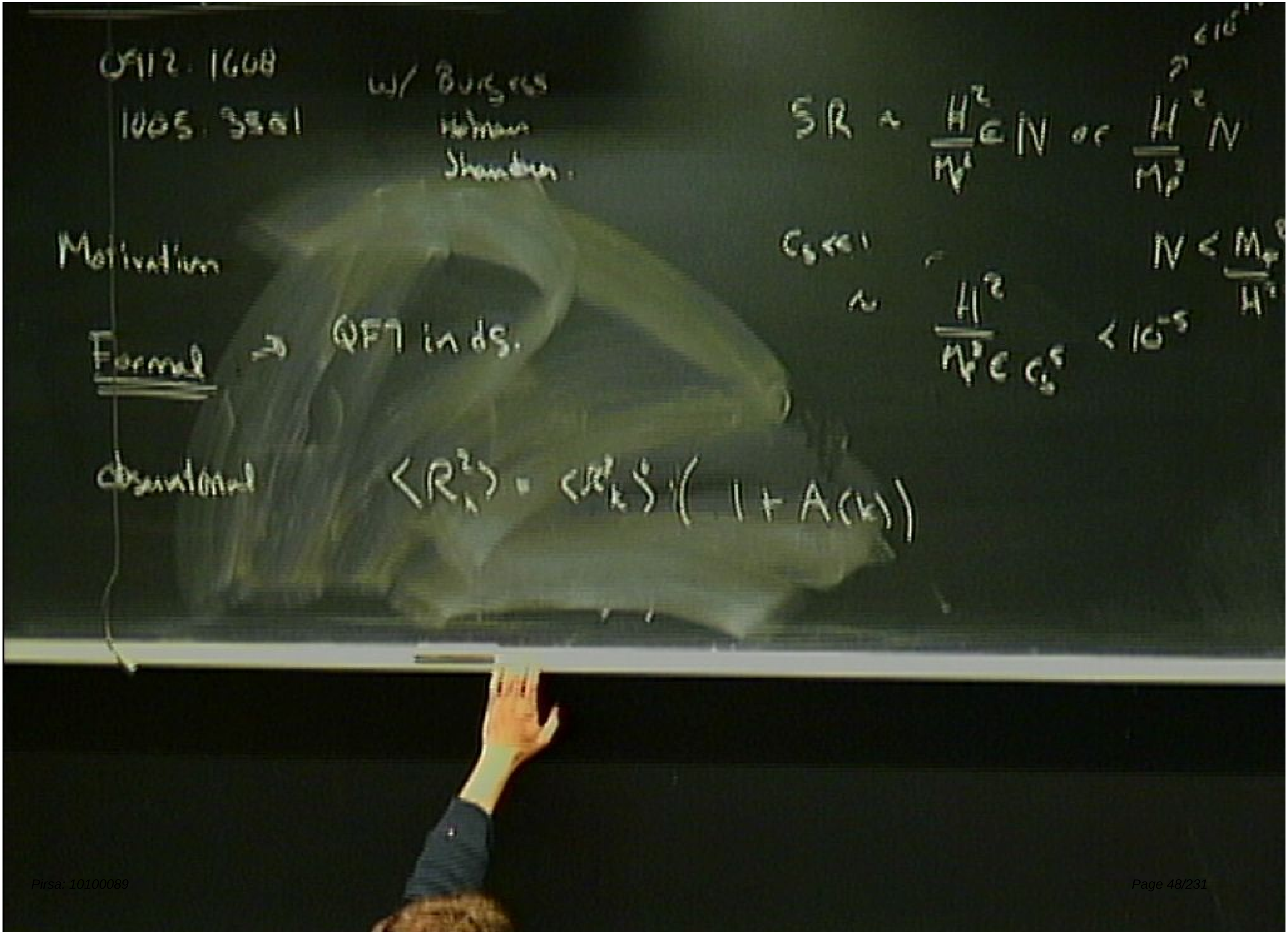
observational $\langle \zeta\zeta \rangle = \langle R_k^2 \rangle_0 \left(1 + A(k) \right)$

$$SR \sim \frac{H^2}{M_p^2}\epsilon N \text{ or } \frac{H^2}{M_p^2} N \gtrsim < 10^{-17}$$

$c_s << 1$

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

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



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Shandera.

$SR \sim \frac{H^2}{M_p^2 \epsilon} N$ or $\frac{H^2}{M_p^2} N \nearrow < 10^{1}$

Motivation

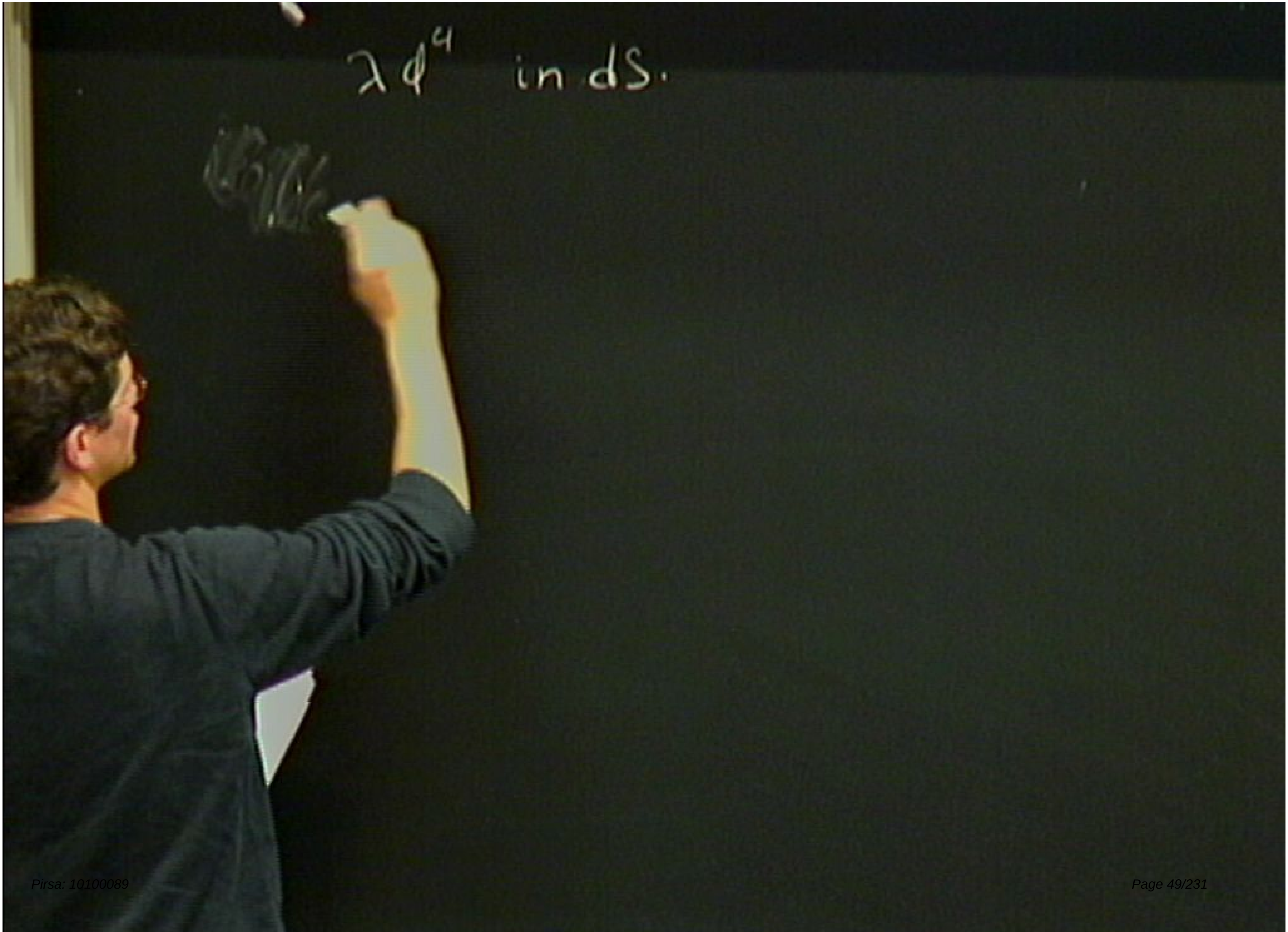
$c_s \ll 1$

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

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

Formal → QFT in dS.

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

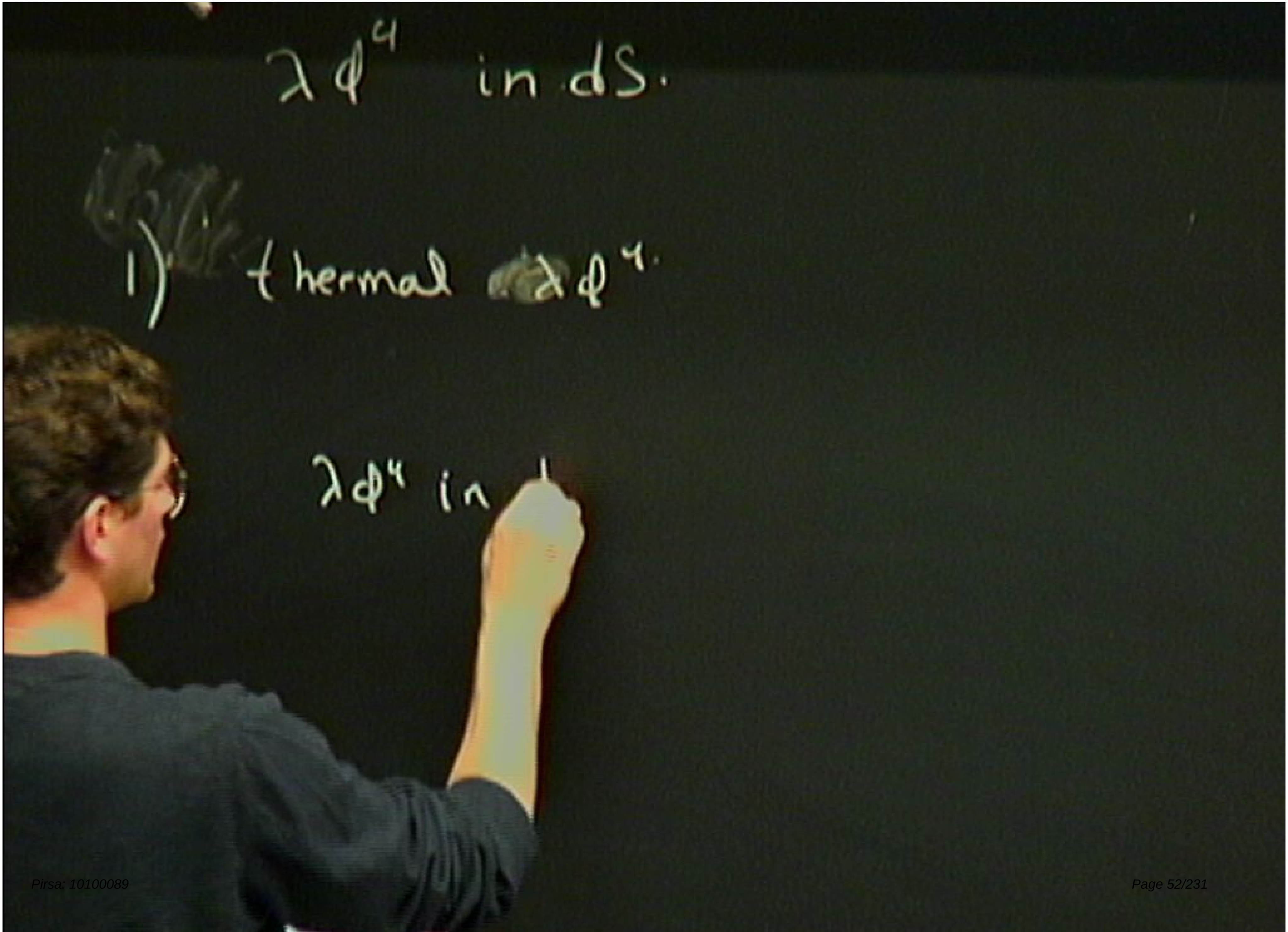


$\lambda \phi^4$ in dS.

$\lambda \phi^4$ in dS.

$\lambda \phi^4$ in dS.

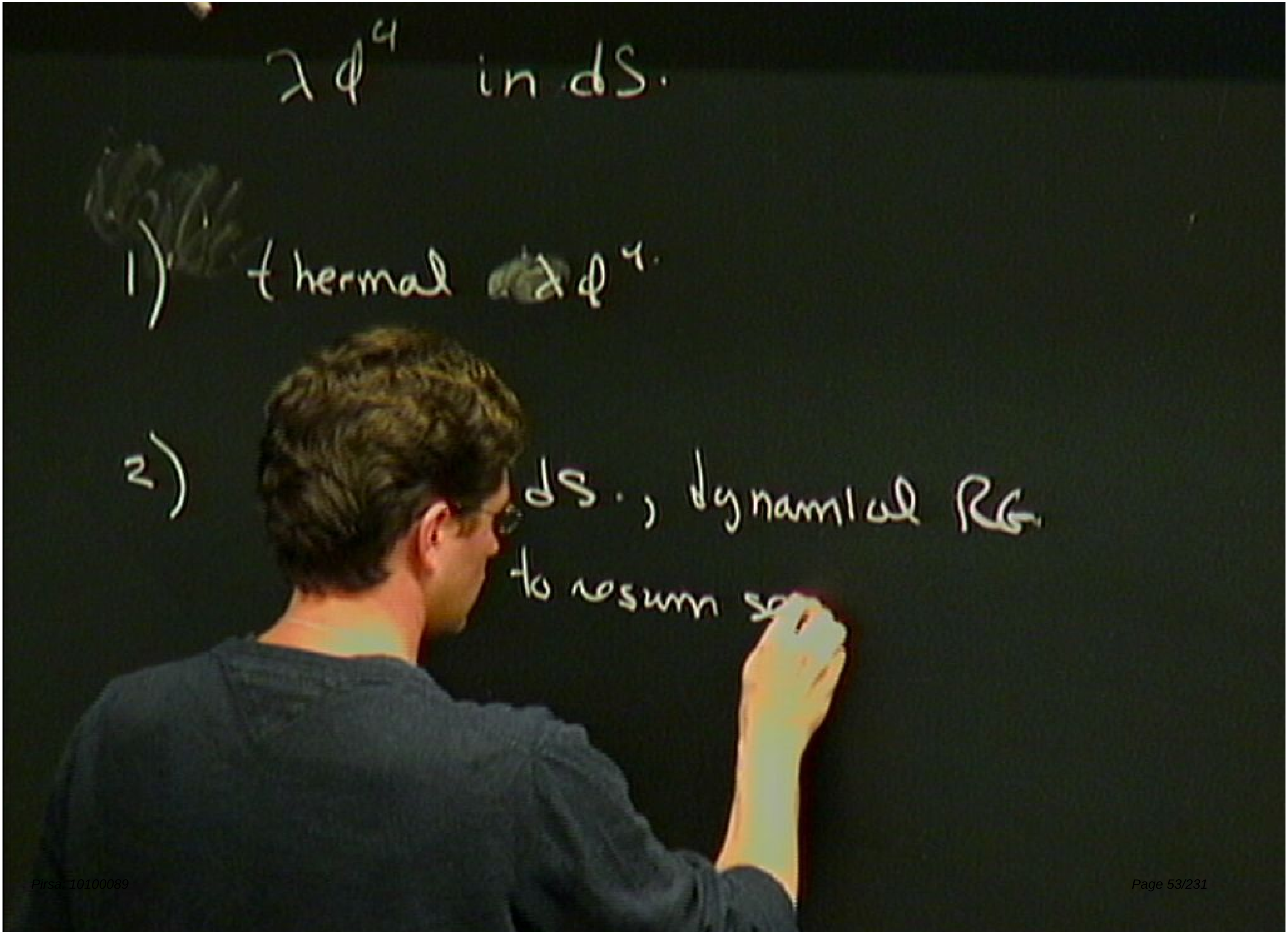
1) thermal $\lambda \phi^4$.



$\lambda\phi^4$ in dS.

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

$\lambda\phi^4$ in

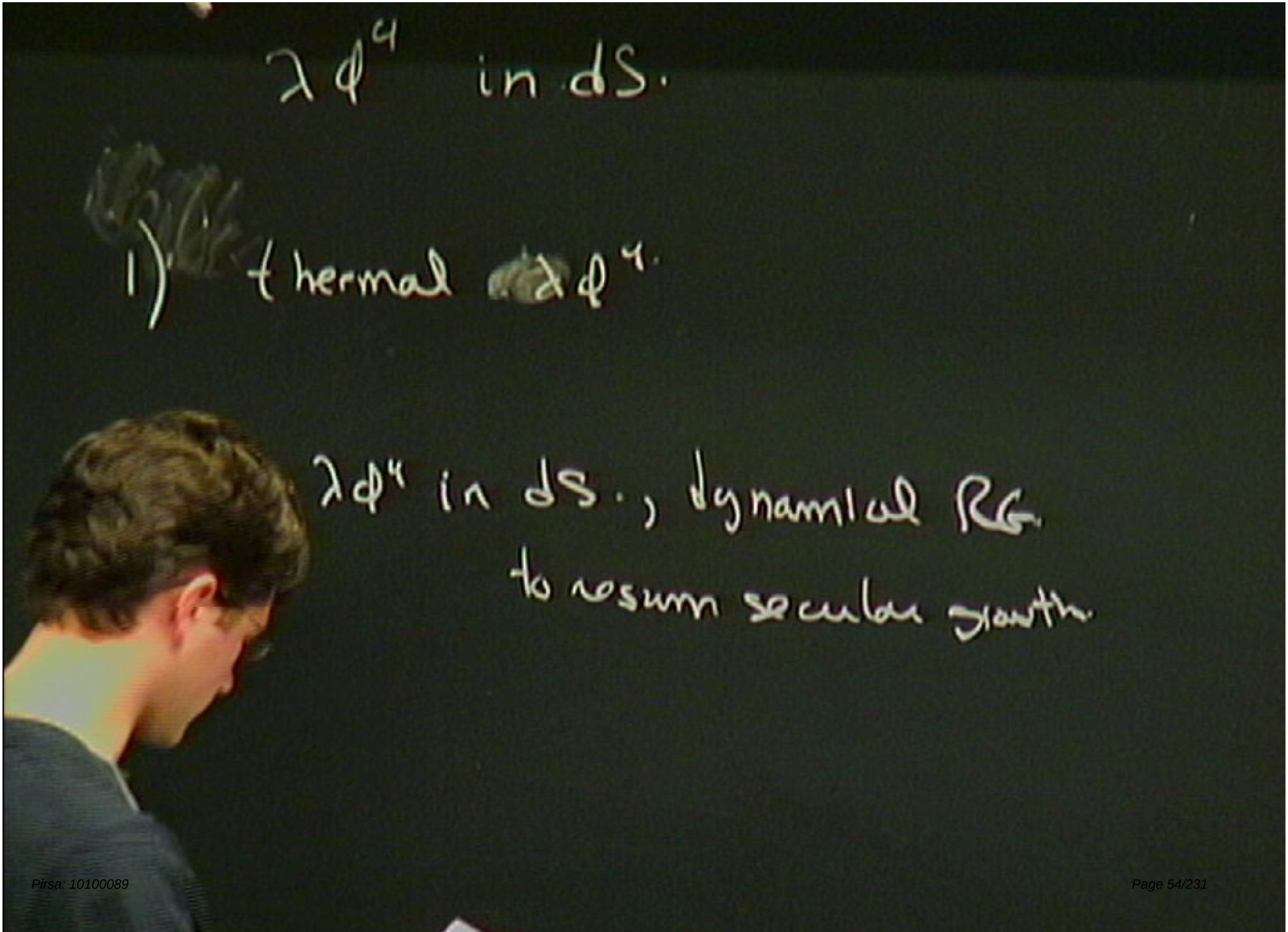


$\lambda \phi^4$ in dS.

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

2) dS., dynamical RG

to resum se



$\lambda\phi^4$ 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 $\lambda\phi^4$.

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$\lambda\phi^4$ in dS.

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

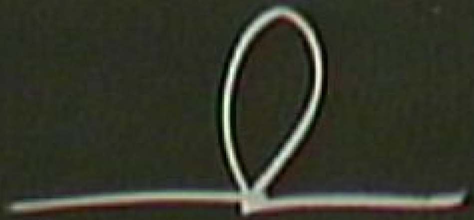
2) $\lambda\phi^4$ in dS., dynamical RG

to resum secular growth

1)

$= \int d^3p$

1)

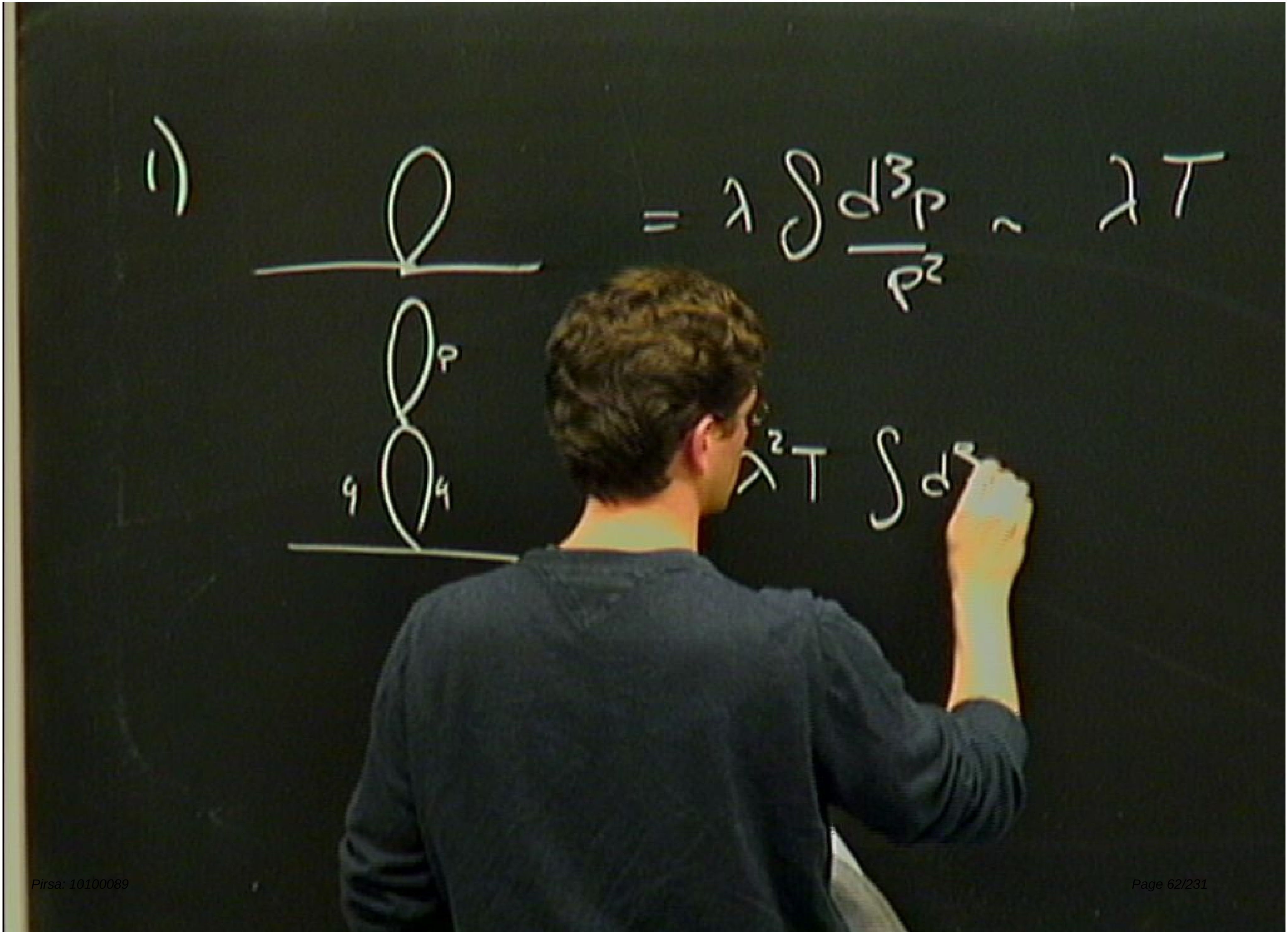


$$= \int \frac{d^3p}{p^2} \sim \lambda T$$

1)

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

$$\simeq \lambda^2$$



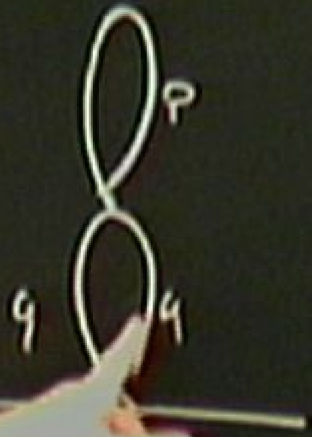
1)

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

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

1)

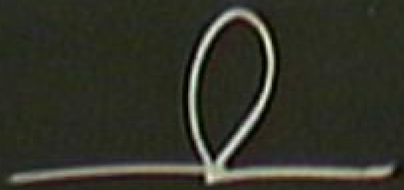
$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^4}.$$

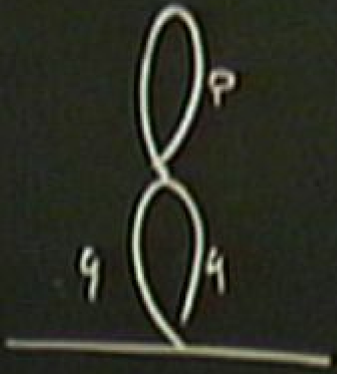
$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2}$ $\sum_n \int$

1)

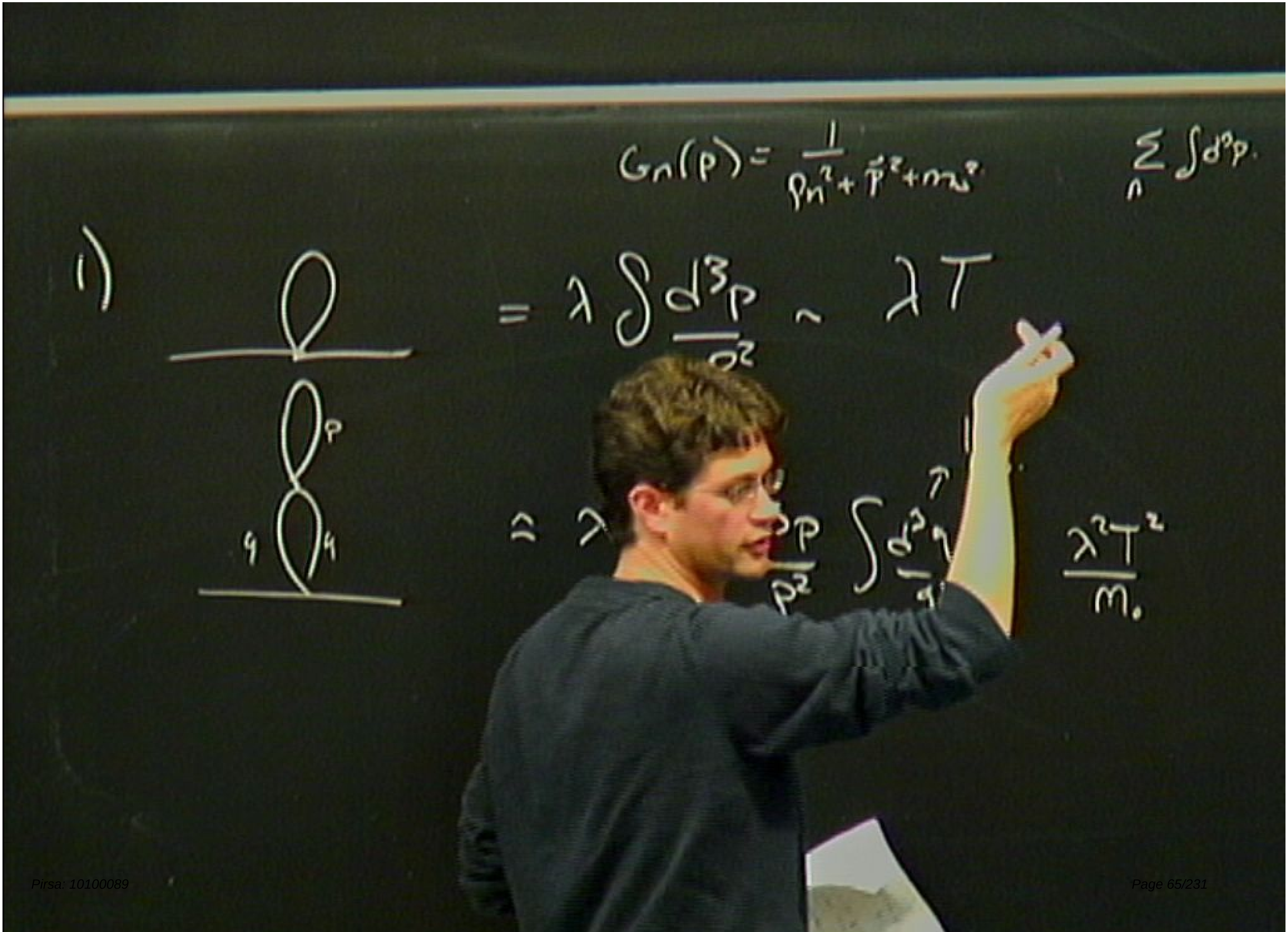


$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$

$1/m_0.$



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

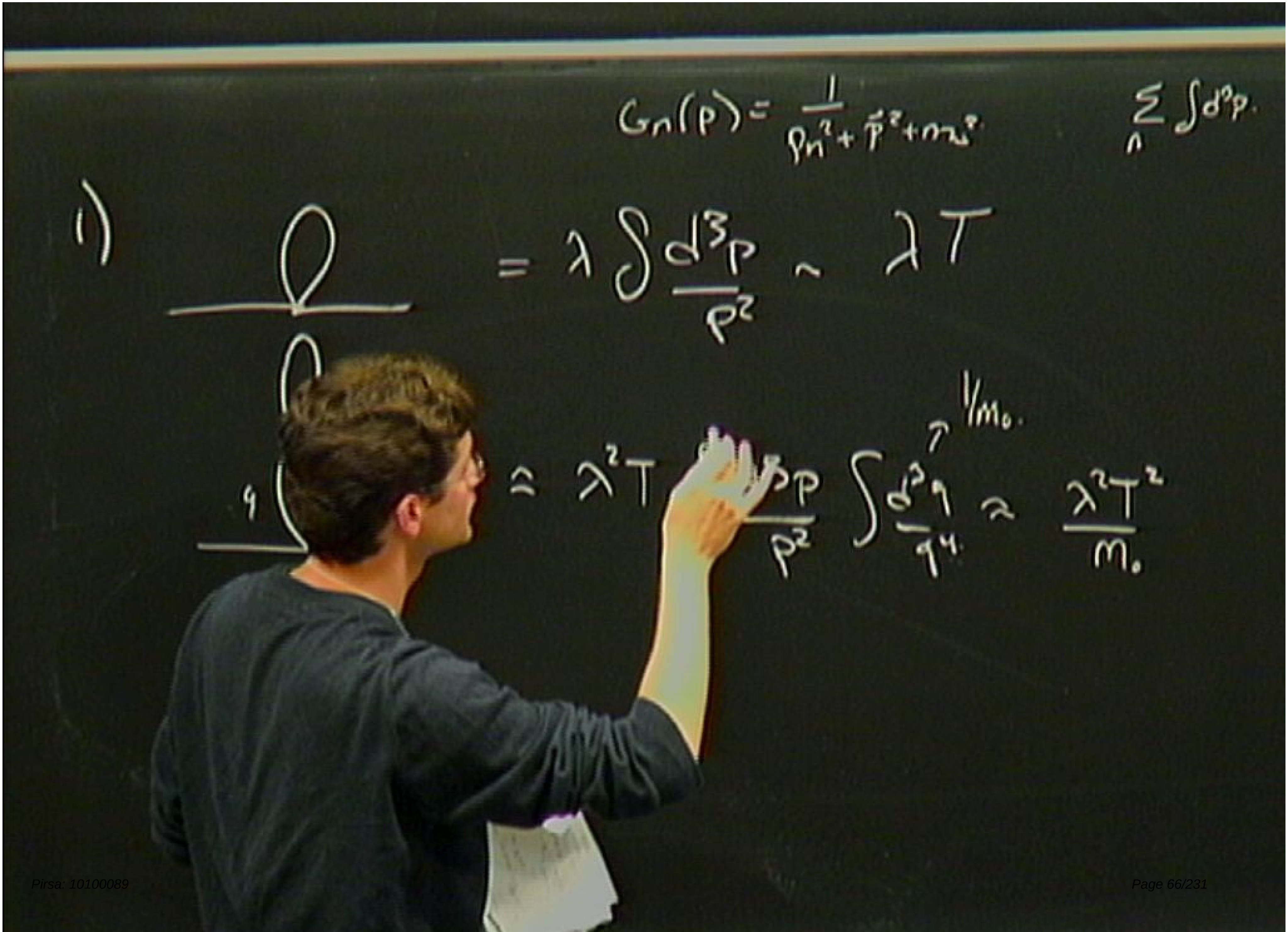


$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^{\,2} + m_0^2} \qquad \sum_n \int d^3p$$

1)

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

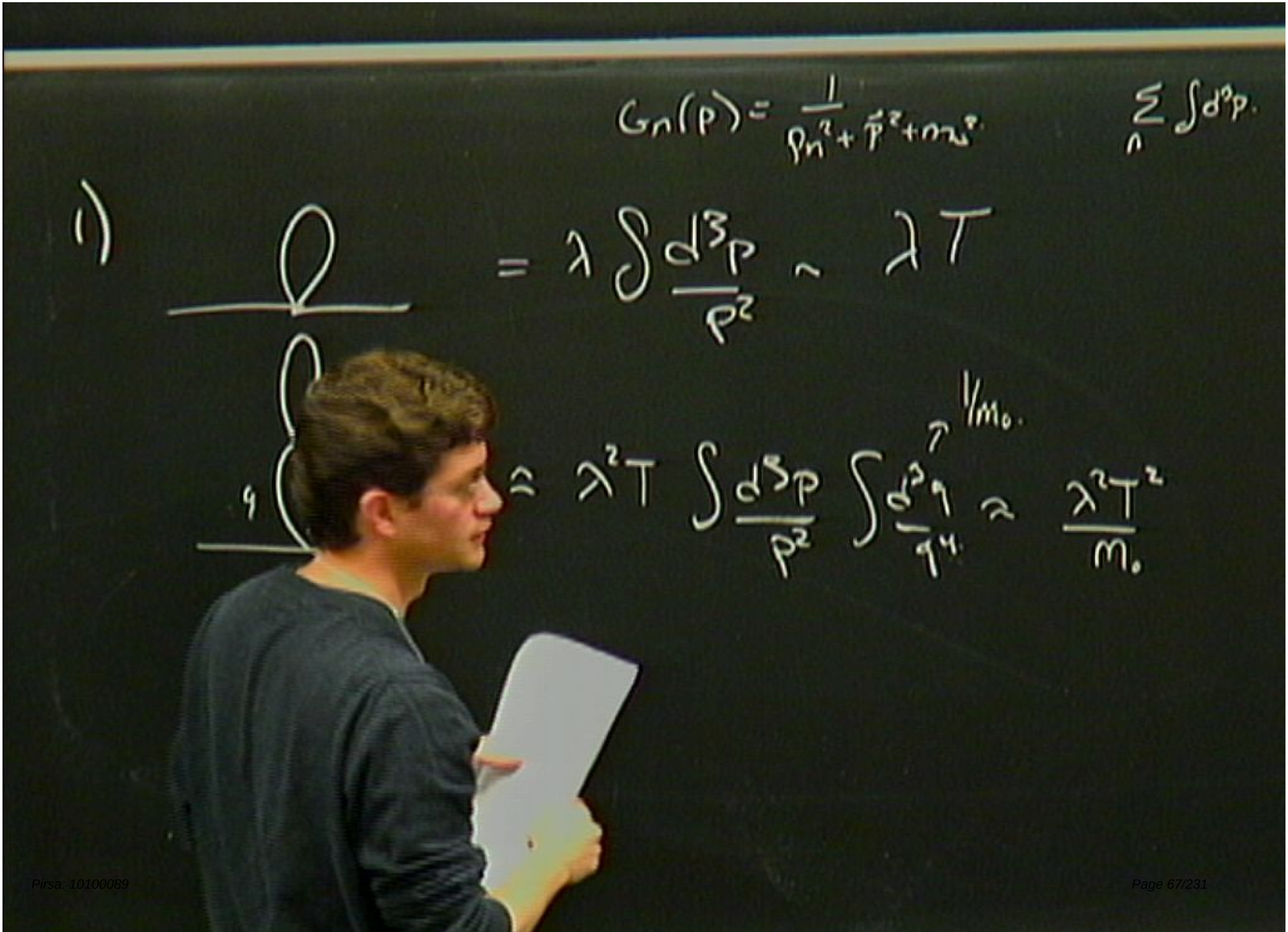
$$\simeq \lambda \quad \frac{p}{p^2} \int \frac{d^3q}{q} \quad \frac{\lambda^2 T^2}{m_0}$$



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

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

$$\simeq \lambda^2 T \;\text{[illegible]}\; \frac{{}^3p}{p^2} \int^{1/m_0} \frac{d^3q}{q^4} \simeq \frac{\lambda^2 T^2}{m_0}$$



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

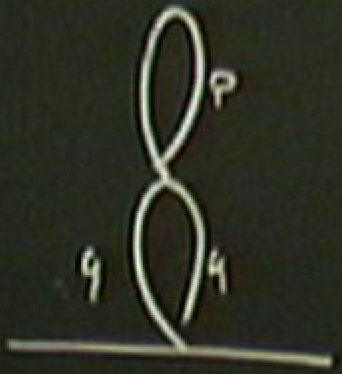
1) $= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$

$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \underbrace{\int \frac{d^3q}{q^4}}^{1/m_0.} \simeq \frac{\lambda^2 T^2}{m_0}$

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

1)

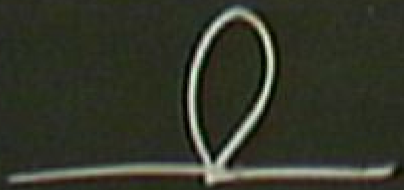
$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



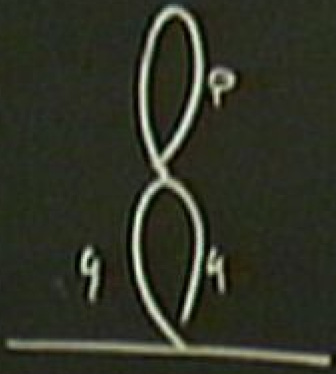
$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{\overset{\nearrow 1/m_0.}{d^3q}}{q^4} \simeq \frac{\lambda^2 T^2}{m_0}$$

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

1)



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



$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^4} \overset{1/m_0}{\simeq} \frac{\lambda^2 T^2}{m_0}$$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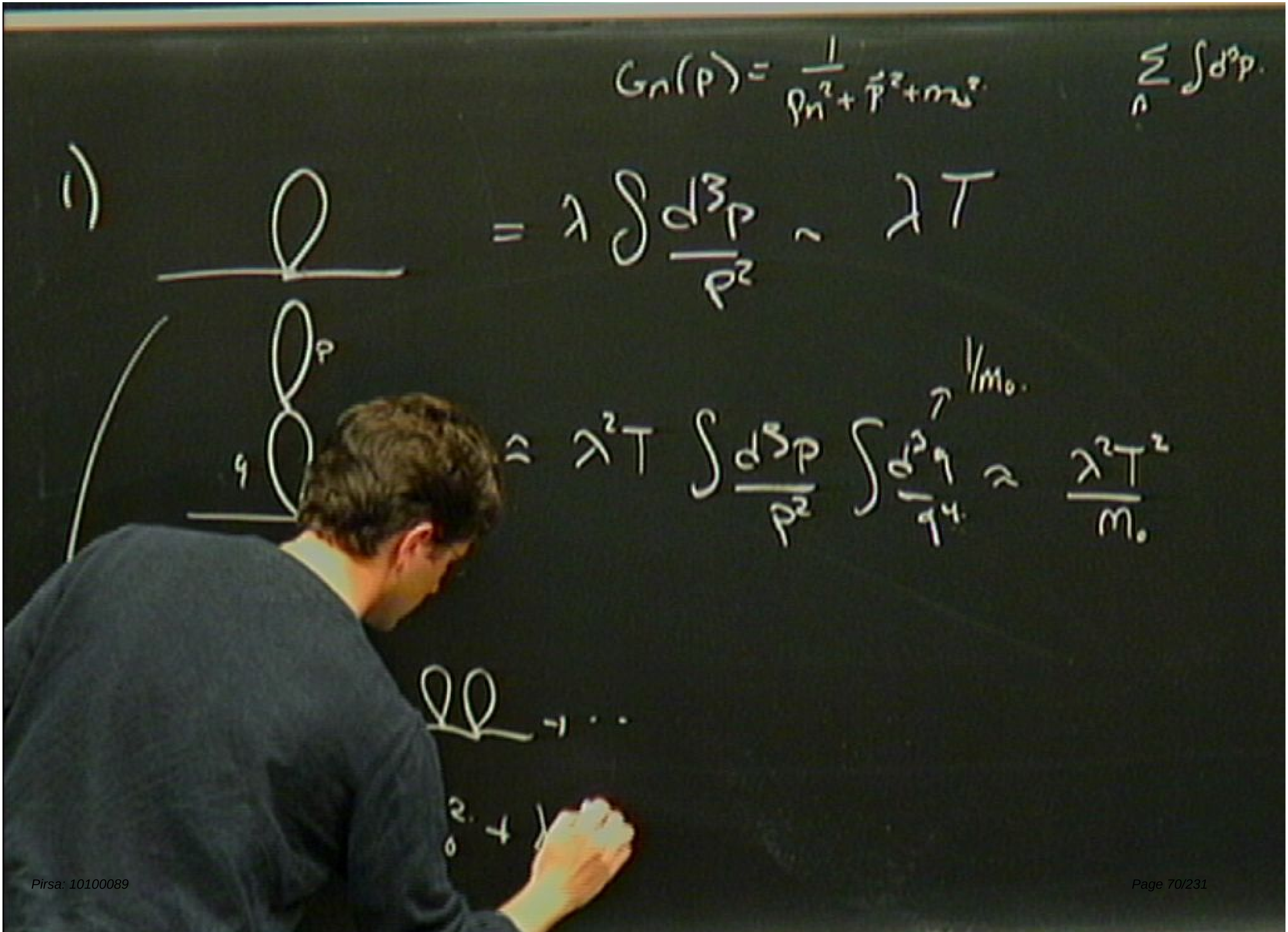


$$G_n(p) = \frac{1}{p_n^2 + \vec{p}^2 + m_0^2} \qquad \sum_n \int d^3p$$

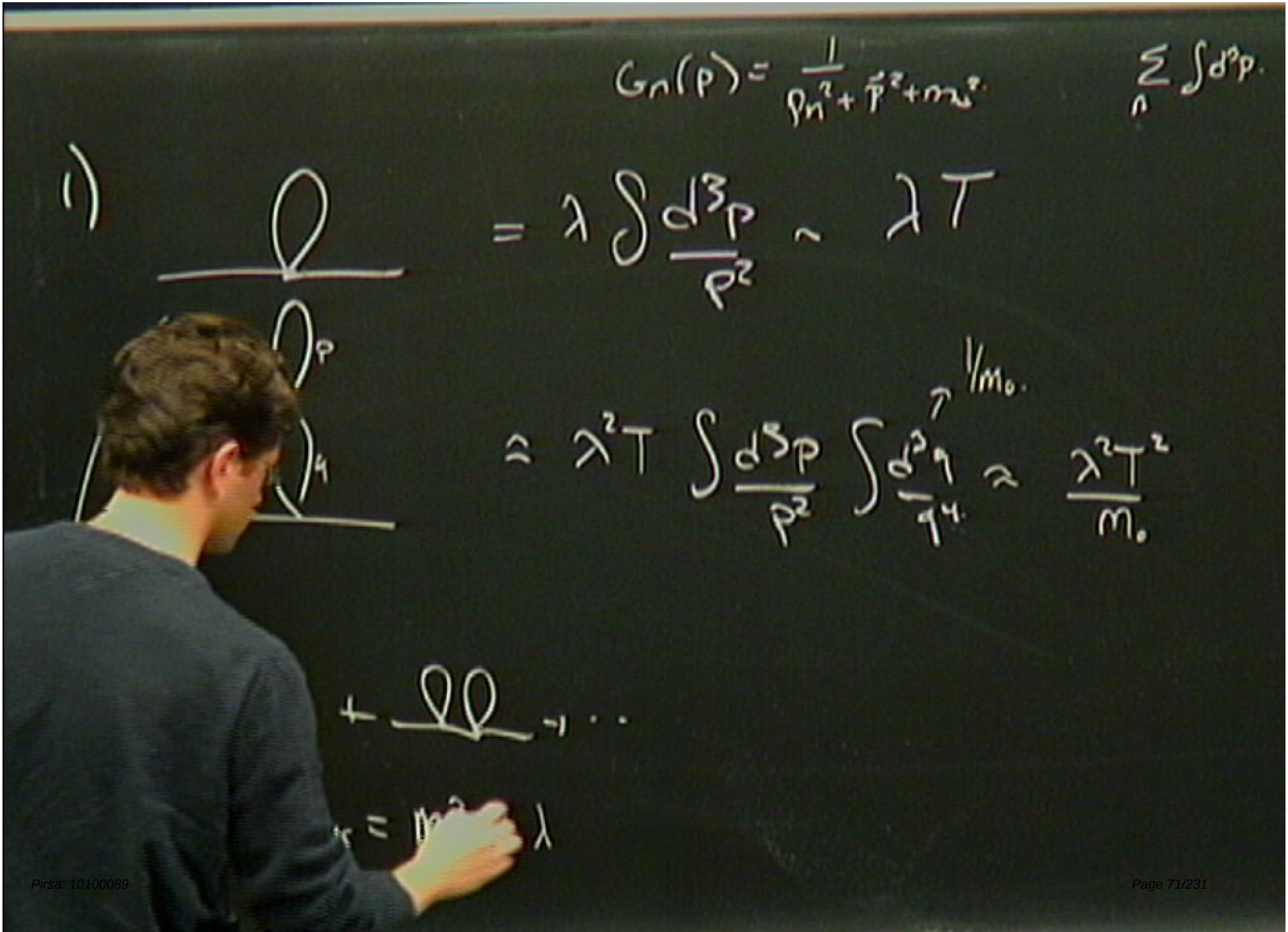
1)

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

$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \overset{1/m_0}{\frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0}$$

$+ \cdots$

$_0^2 + \lambda$



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

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

1)

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

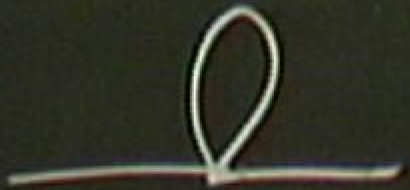
$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \overbrace{\int \frac{d^3q}{q^4}}^{1/m_0} \simeq \frac{\lambda^2 T^2}{m_0}$$

$+ \ldots$

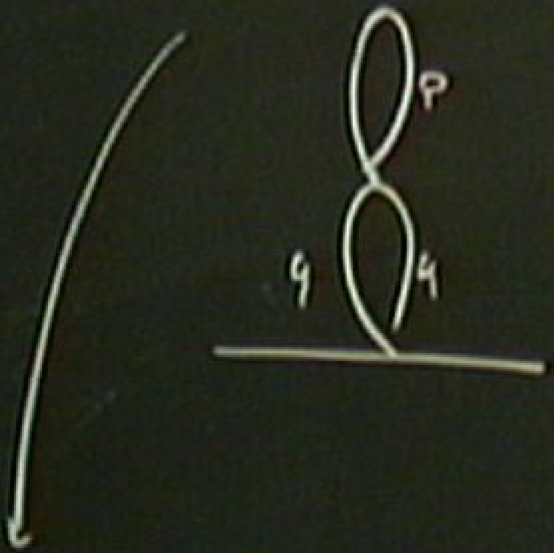
$= m^2 \quad \lambda$

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

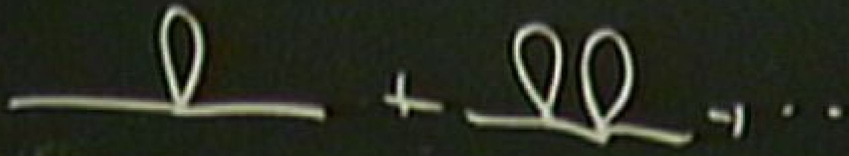
1)



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



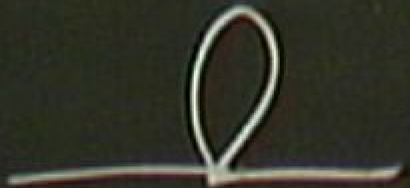
$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \overset{\nearrow 1/m_0}{\int \frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0}$$



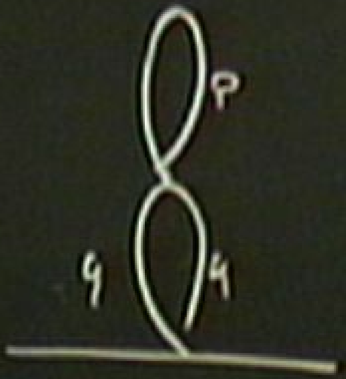
$$m_{phys}^2 = m_0^2 + \lambda T^2$$

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

1)



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



$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \overset{\nearrow 1/m_0}{\int \frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0}$

$+$

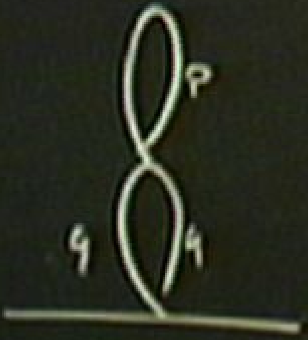
$+ \cdots$

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

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

1)

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



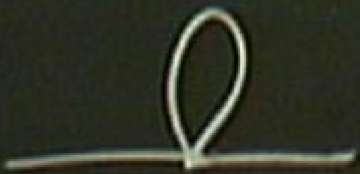
$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \overset{1/m_0}{\int \frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$

 +  + . . .

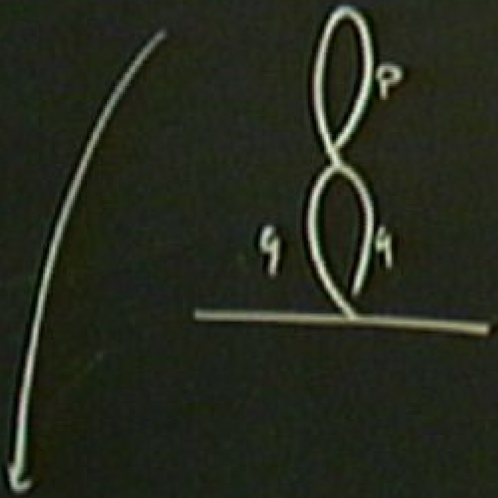
$m_{phys}^2 = m_0^2 + \lambda T^2$

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

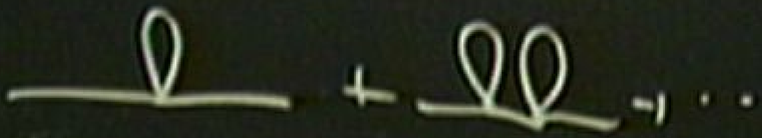
1)



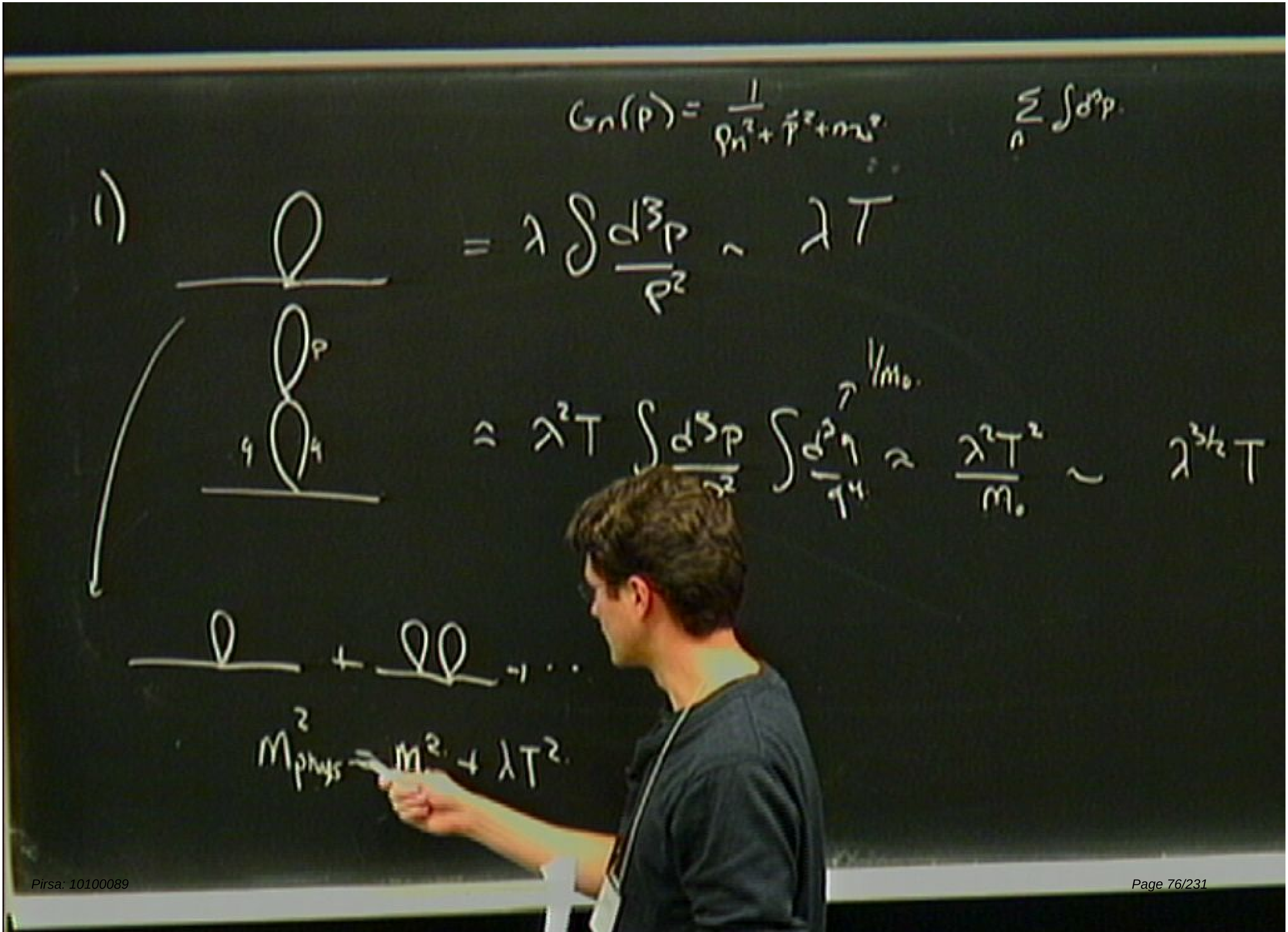
$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$



$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \overset{\nearrow\, 1/m_0}{\frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$



$m^2_{phys} = m_0^2 + \lambda T^2$



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

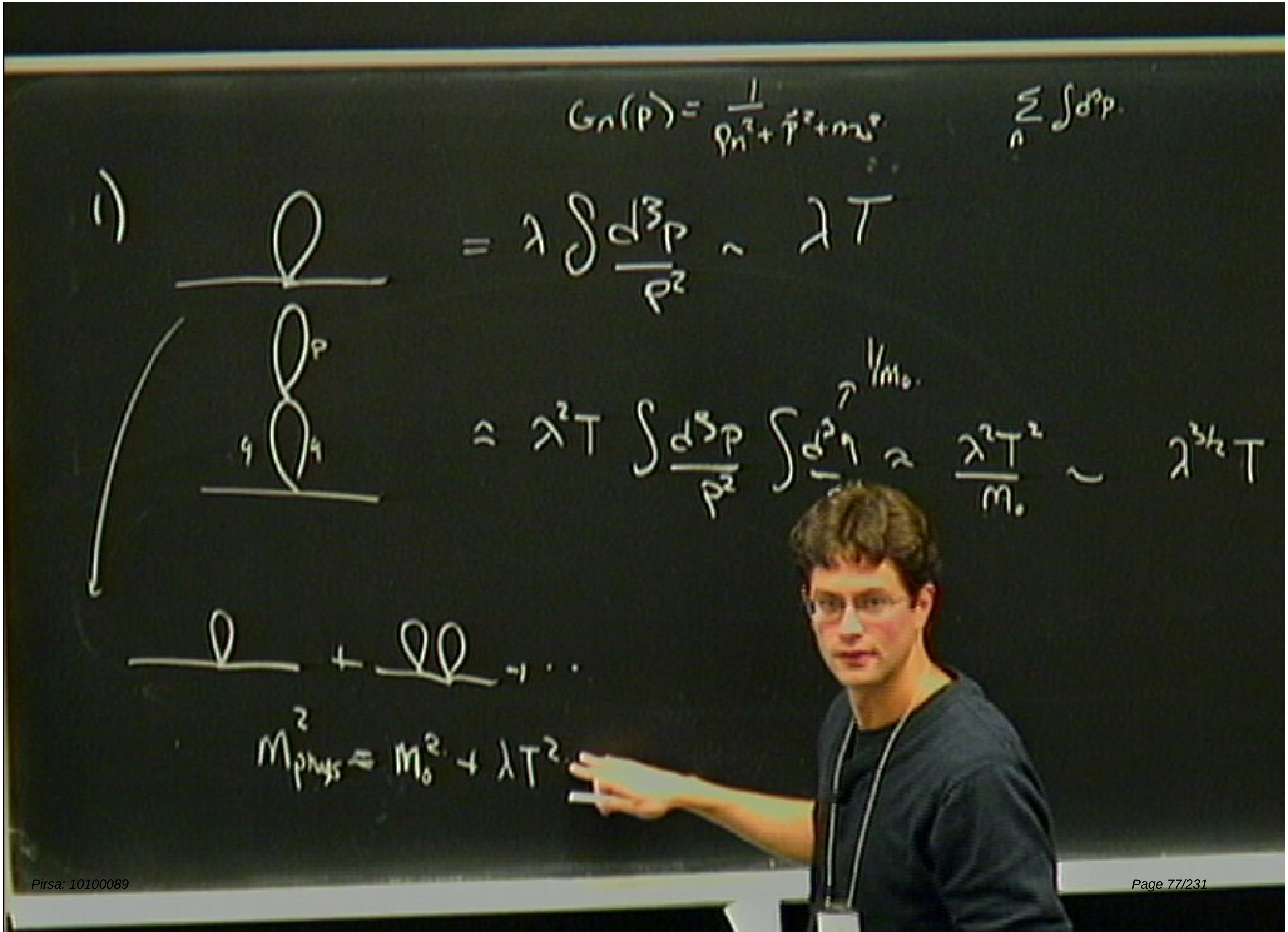
1) $= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$

$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \int \frac{d^3q}{q^4} \simeq \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$

$1/m_0$

$+ \ldots$

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



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

1)

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

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

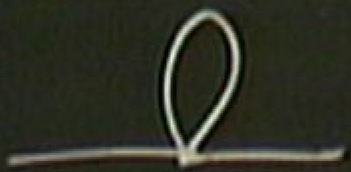
$1/m_0$

$+ \ldots$

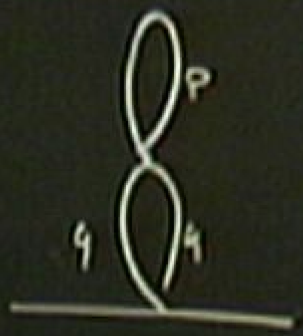
$$m_{phys}^2 \simeq m_0^2 + \lambda T^2$$

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

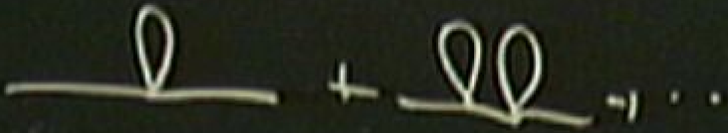
1)



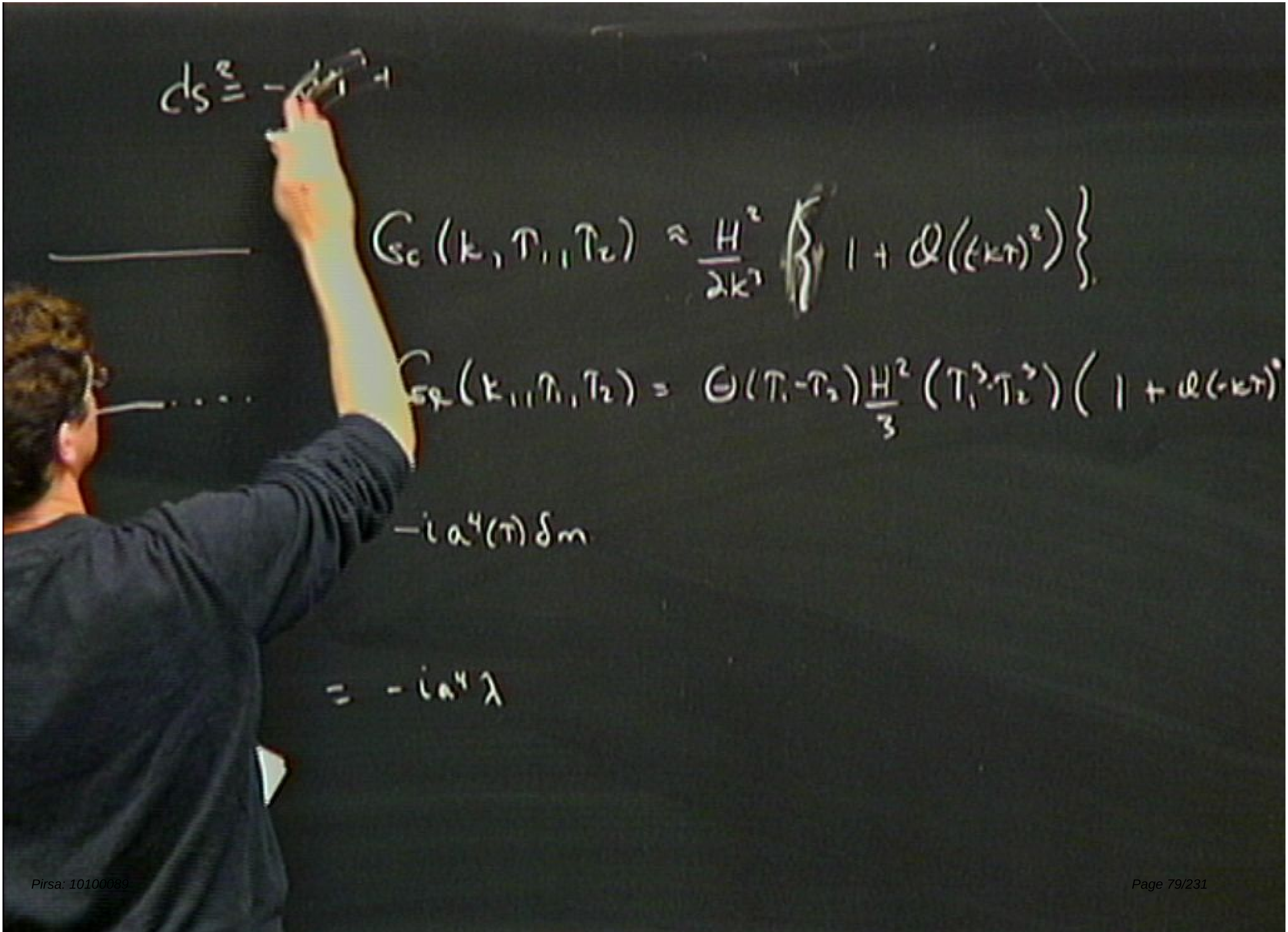
$$= \lambda \int \frac{d^3p}{p^2} \sim \lambda T$$



$$\simeq \lambda^2 T \int \frac{d^3p}{p^2} \overset{\nearrow\, 1/m_0}{\int \frac{d^3q}{q^4}} \simeq \frac{\lambda^2 T^2}{m_0} \sim \lambda^{3/2} T$$



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



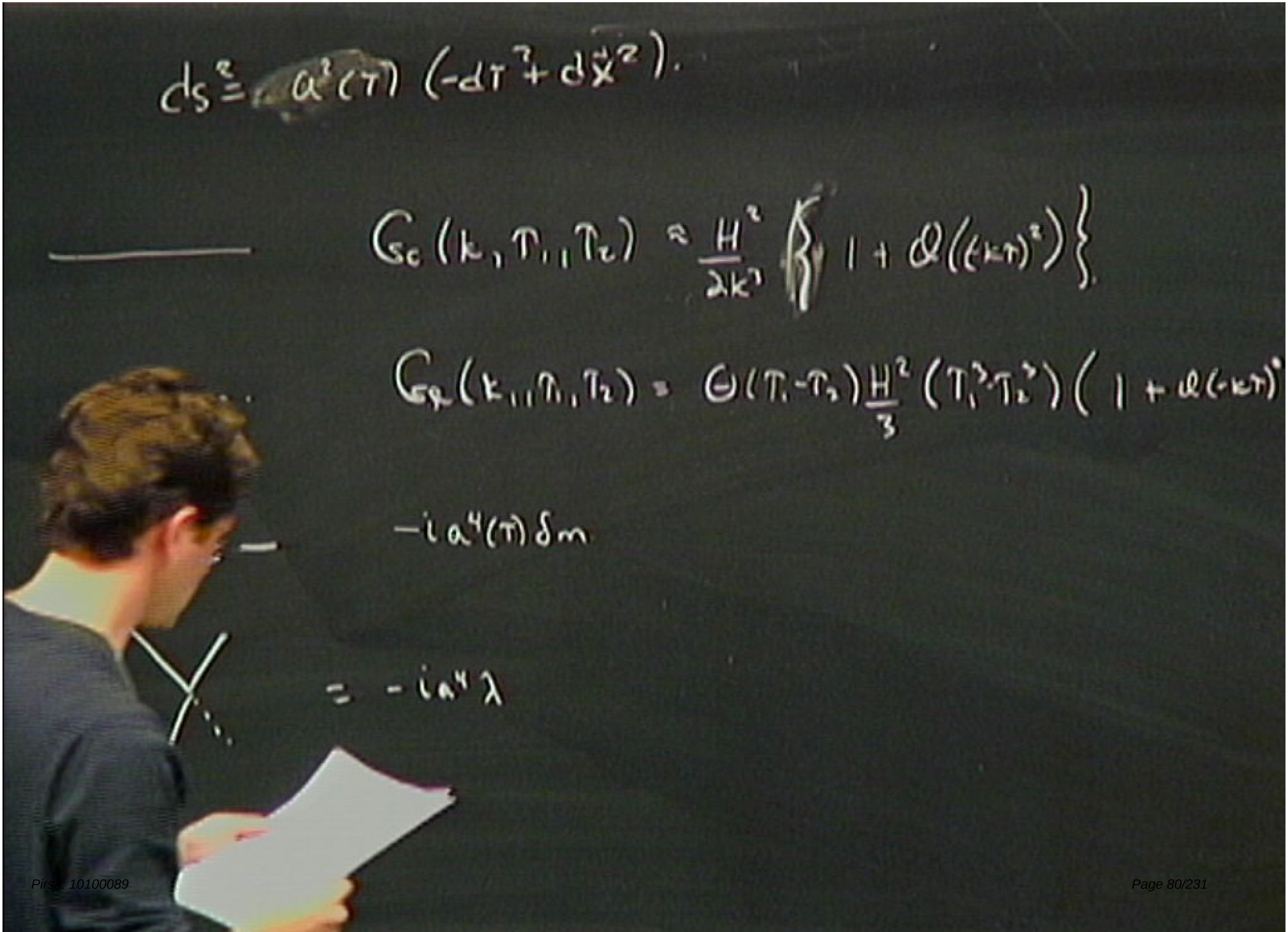
$ds^2 = -$

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

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

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

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



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

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

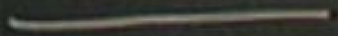
$$G_R(k, \tau_1, \tau_2) = \Theta(\tau_1 - \tau_2)\frac{H^2}{3}\left(\tau_1^3 - \tau_2^3\right)\left(1 + \mathcal{O}(-k\tau)^\circ\right.$$

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

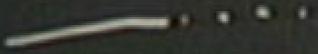
$$= -i a^4 \lambda$$

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

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



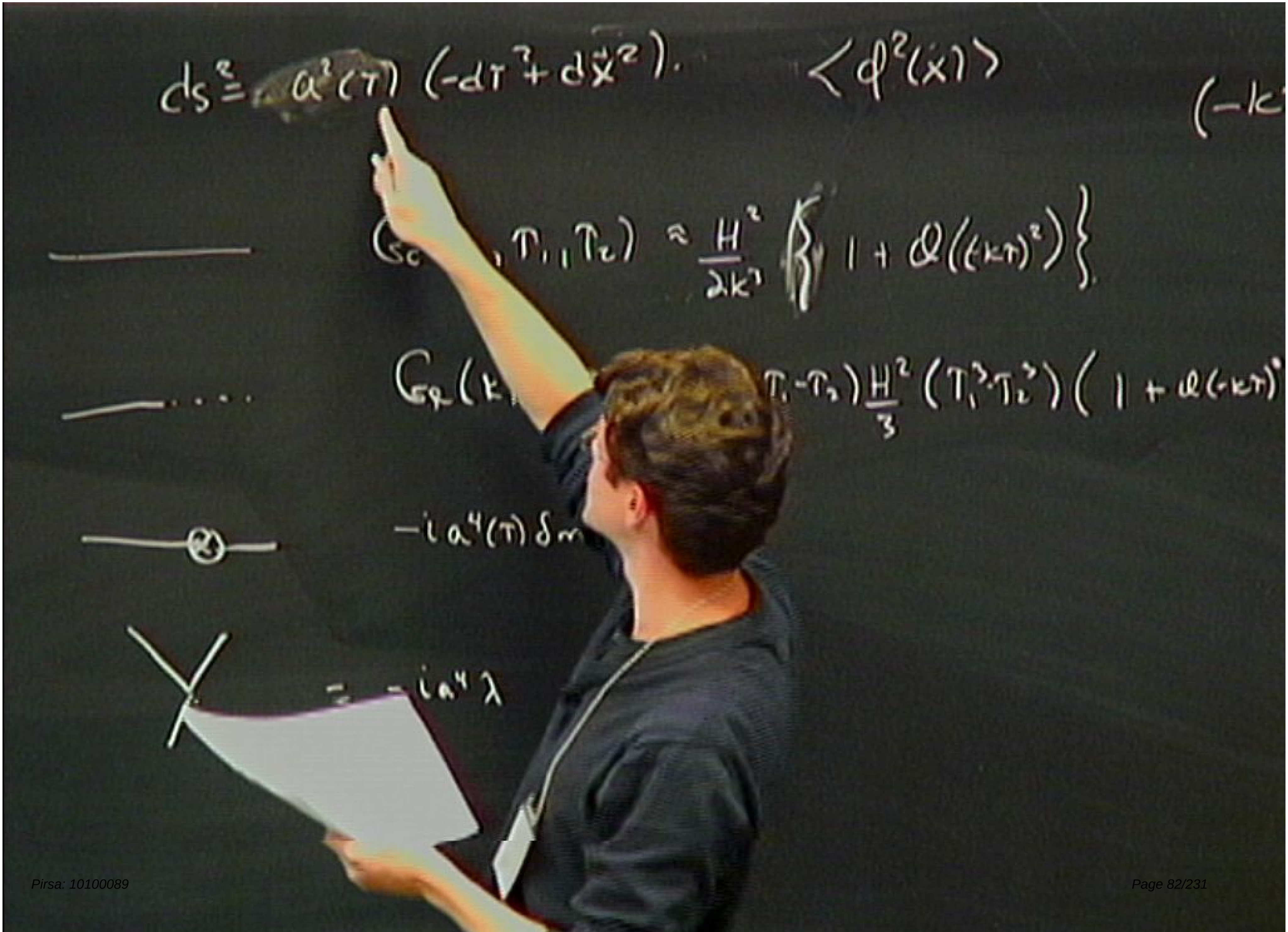
$$G_{sc}(k,\tau_1,\tau_2) \approx \frac{H^2}{2k^3}\left\{1 + \mathcal{O}\left((-k\tau)^2\right)\right\}$$



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

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

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



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

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

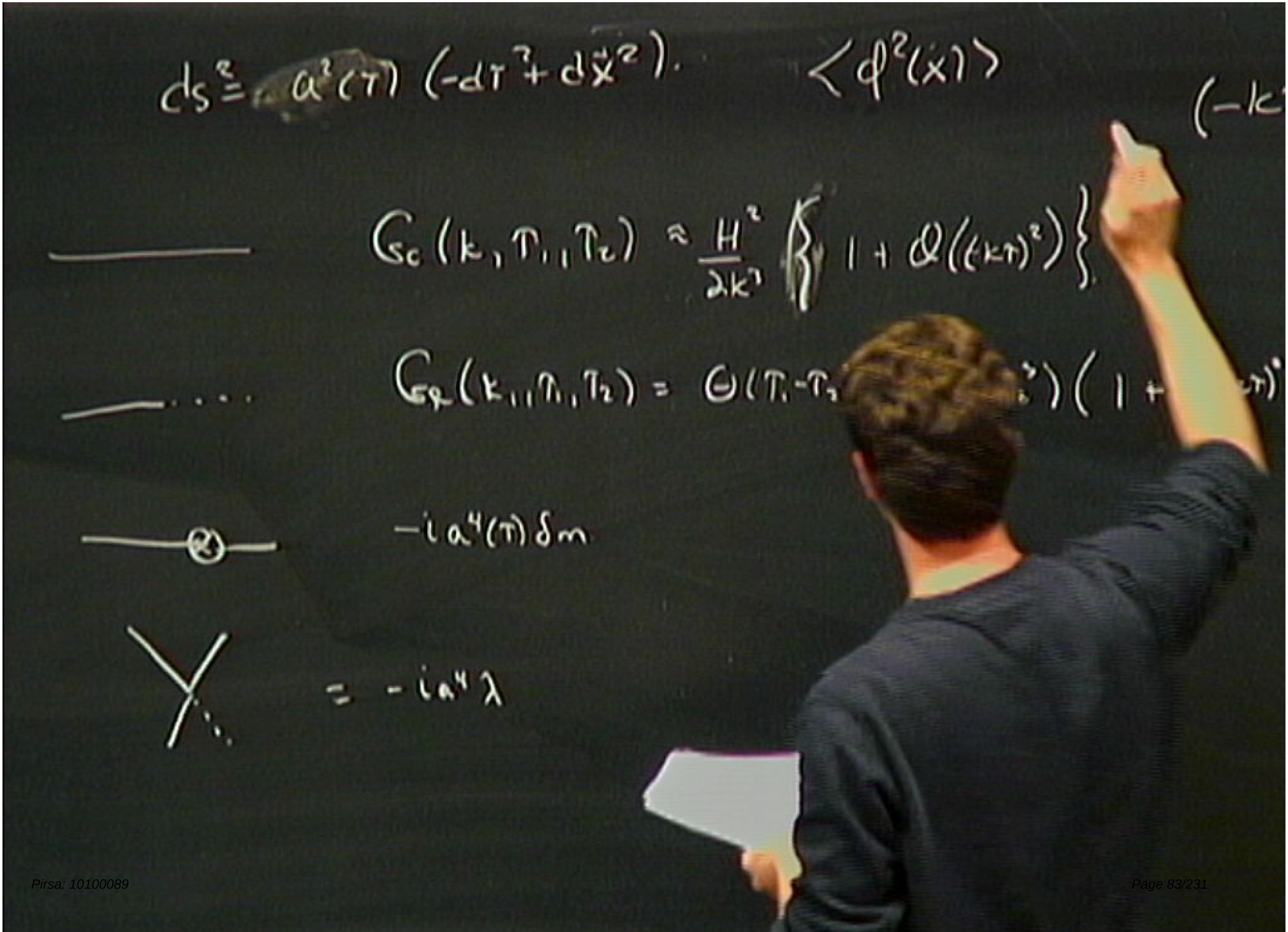
$(-k$

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

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

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

$= -i a^4 \lambda$



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

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

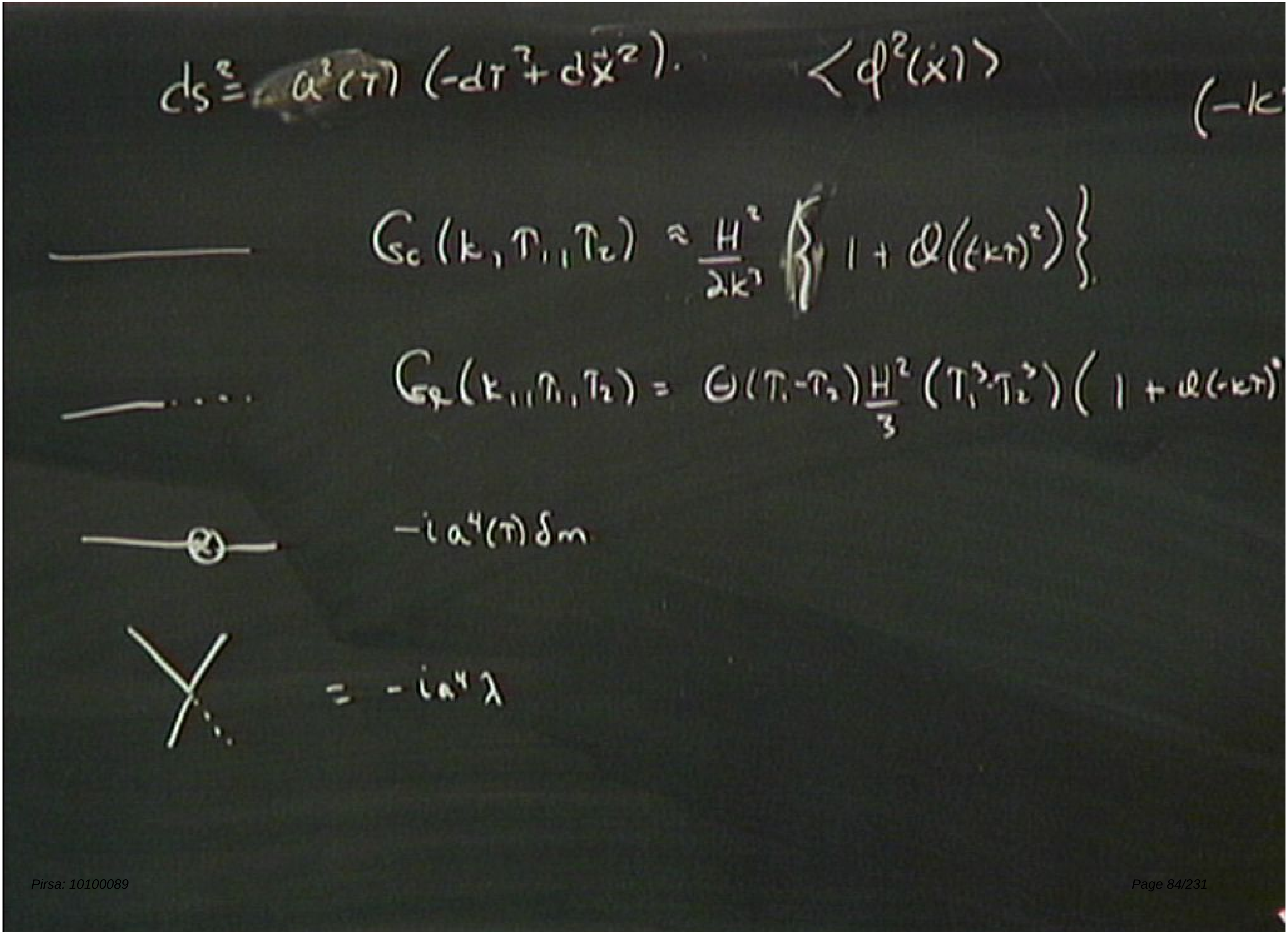
$(-k$

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

$G_R(k_1,\tau_1,\tau_2) = \Theta(\tau_1-\tau_2$ $)\,(1 +$ $\tau)^2$

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

$= -i a^4 \lambda$



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

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

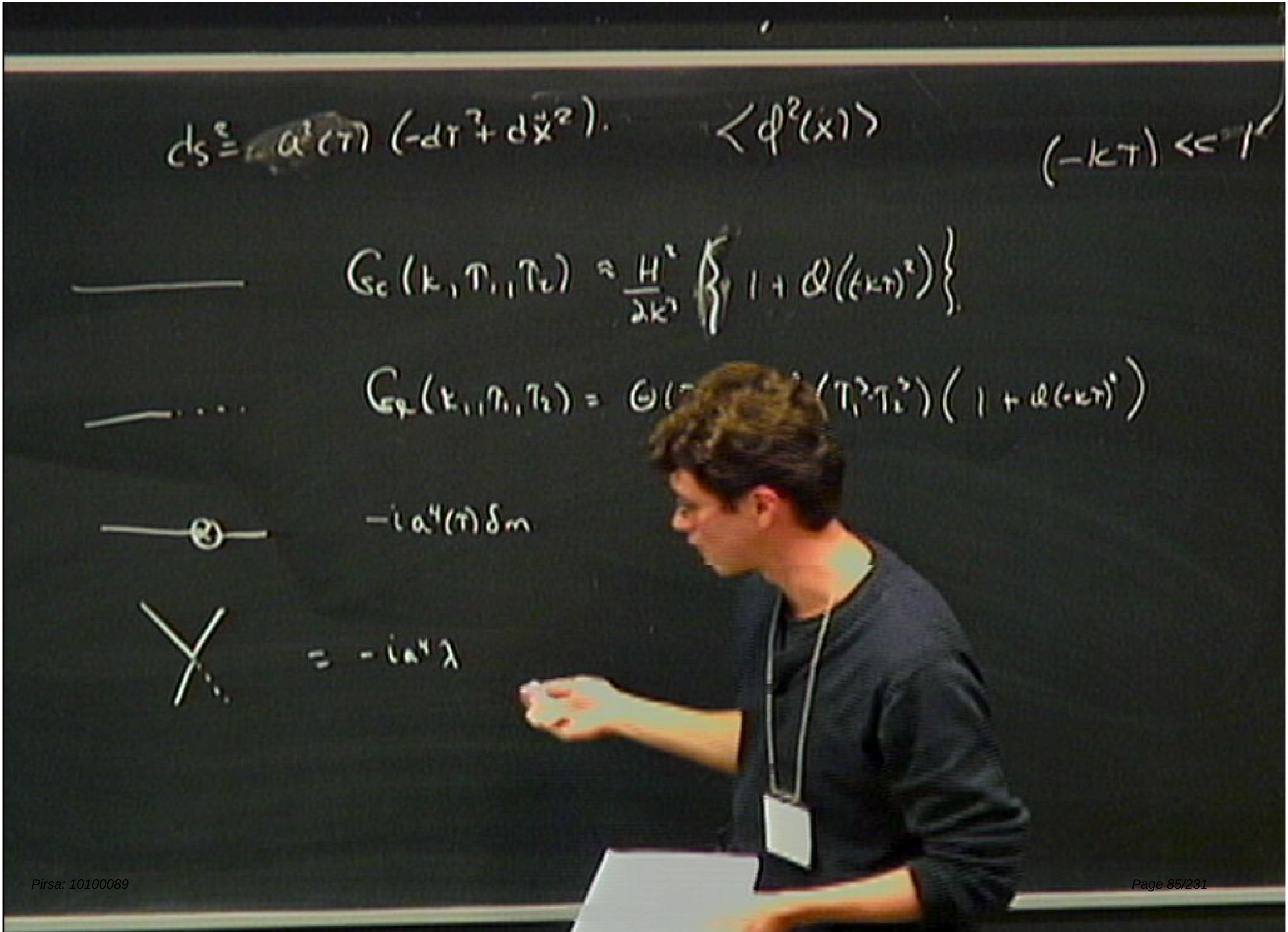
$(-k$

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

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

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

$= -i a^4 \lambda$



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

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

$(-k\tau) \ll 1$

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

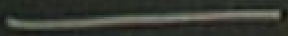
$G_R(k_1, \tau_1, \tau_2) = \Theta(\tau$ … $(\tau_1^3 \cdot \tau_2^3)\left(1 + \mathcal{O}(-k\tau)^2\right)$

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

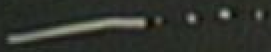
$= -i a^4 \lambda$

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

$(-k\tau) \ll 1$



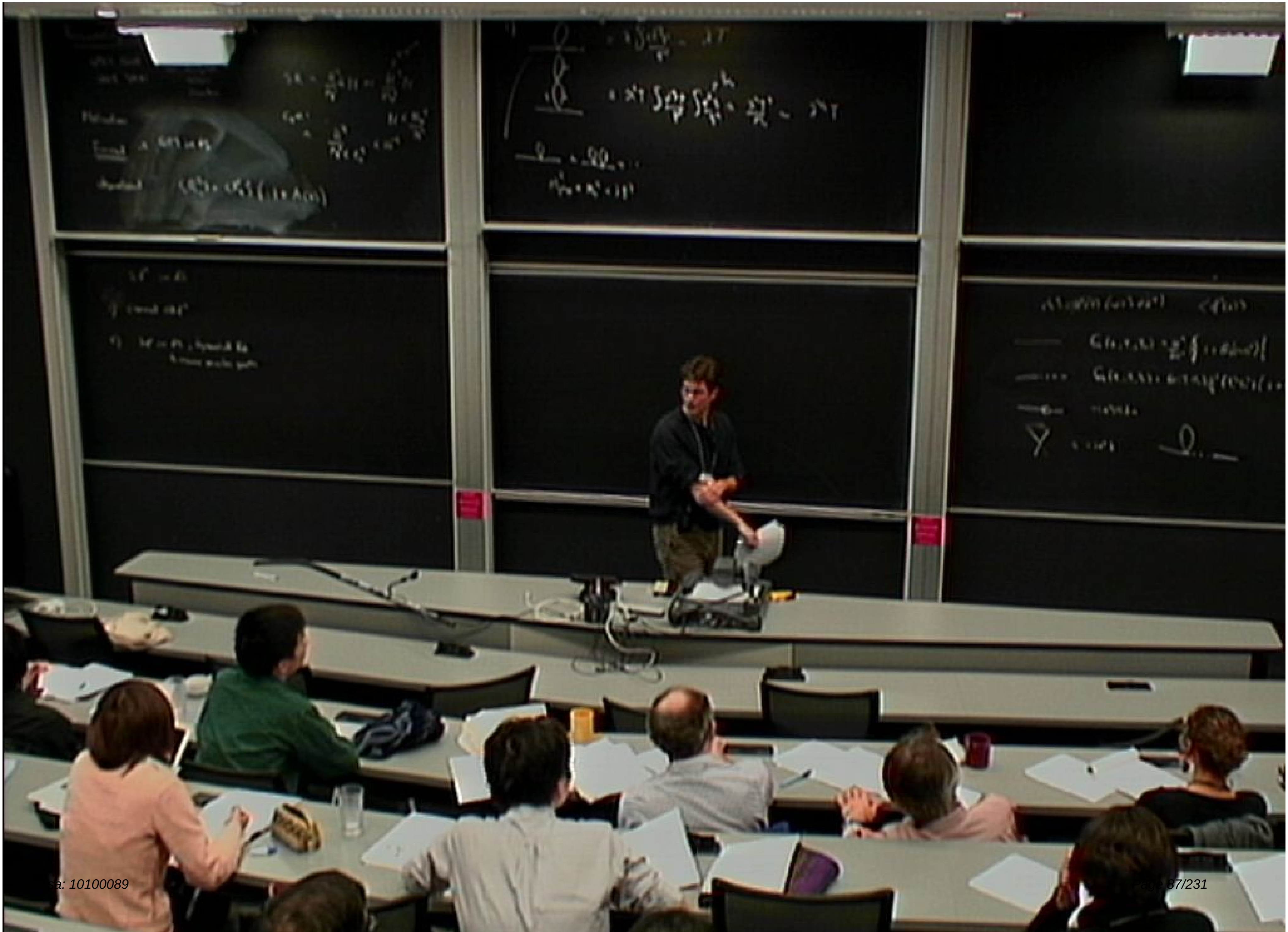
$$G_{sc}(k,\tau_1,\tau_2) \approx \frac{H^2}{2k^3}\left\{1 + \mathcal{O}((-k\tau)^2)\right\}$$

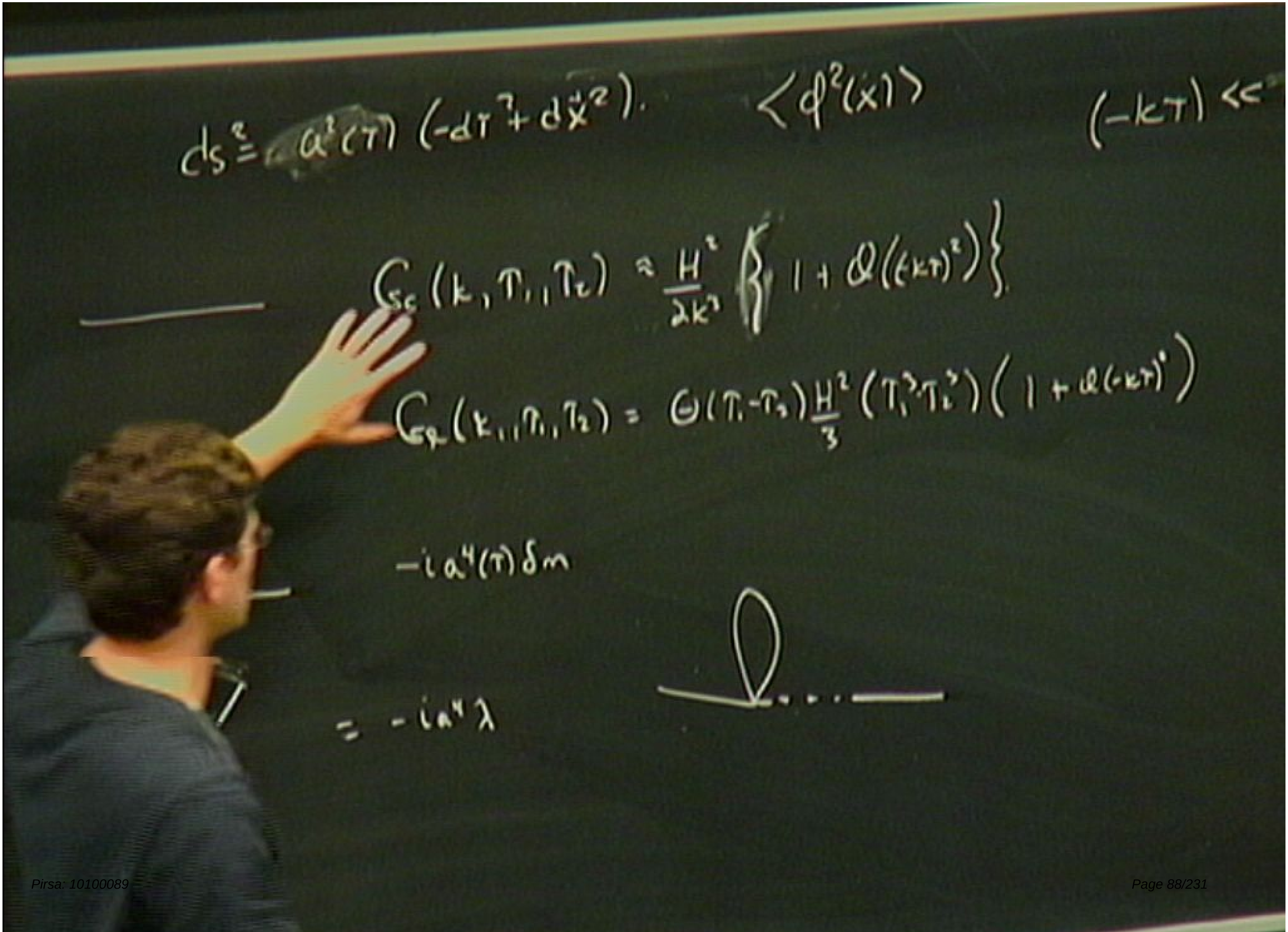


$$G_R(k_1,\tau_1,\tau_2) = \Theta(\tau_1-\tau_2)\frac{H^2}{3}(\tau_1^3-\tau_2^3)\left(1 + \mathcal{O}(-k\tau)^2\right)$$

$$-ia^4(\tau)\delta m$$

$$= -ia^4\lambda$$





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

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

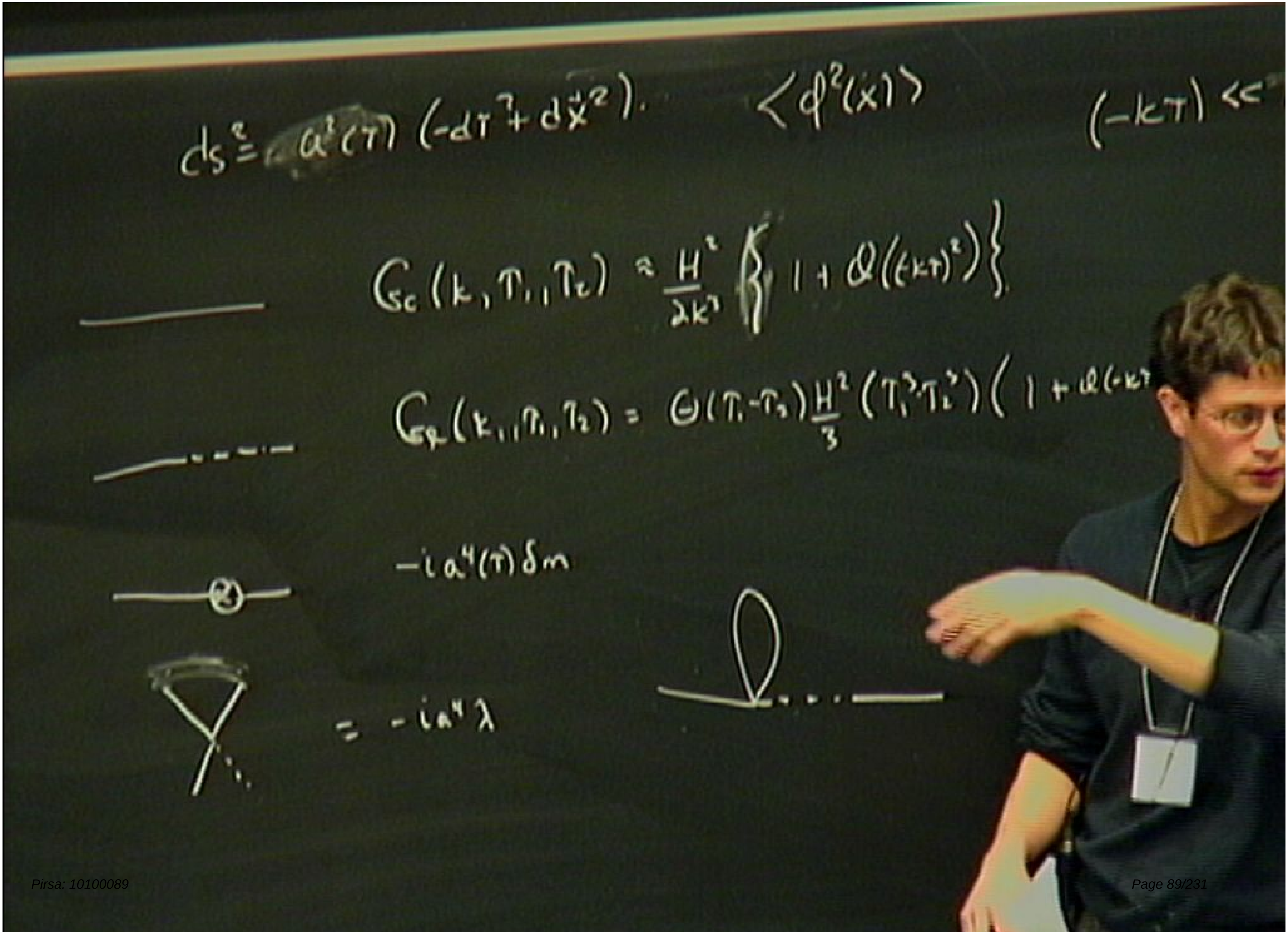
$(-k\tau) \ll$

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

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

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

$= -i a^4 \lambda$



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

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

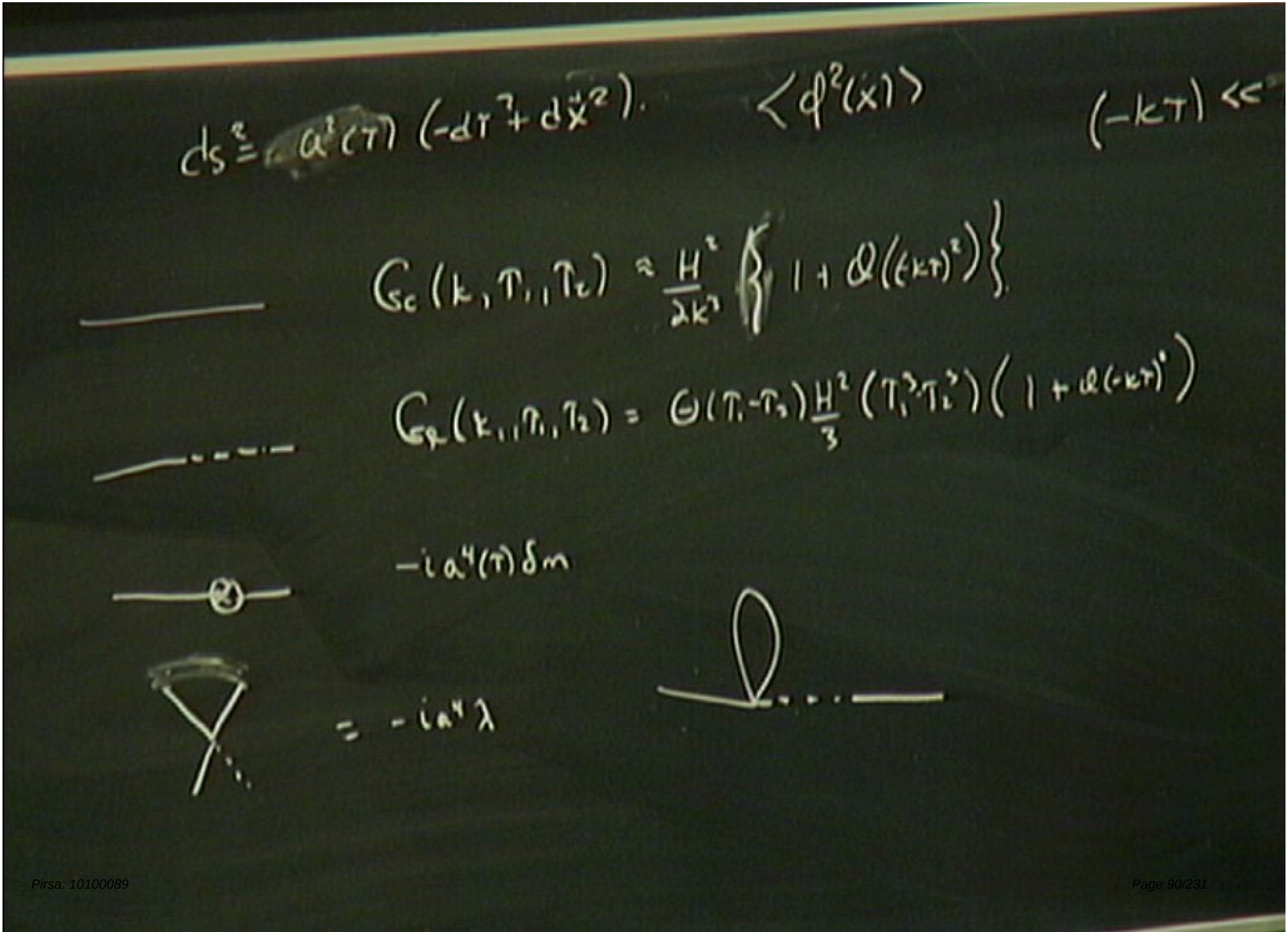
$(-k\tau) \ll$

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

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

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

$= -i a^4 \lambda$



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

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

$(-k\tau) \ll$

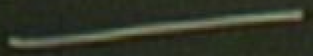
$G_c(k, \tau_1, \tau_2) \approx \frac{H^2}{2k^3}\left\{1 + \mathcal{O}((-k\tau)^2)\right\}$

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

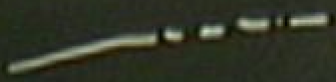
$-i a^4(\tau)\delta m$

$= -i a^4 \lambda$

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



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

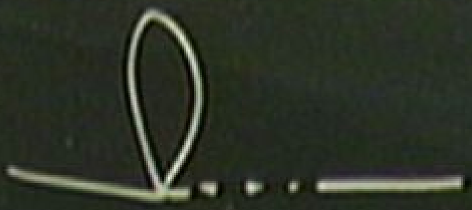


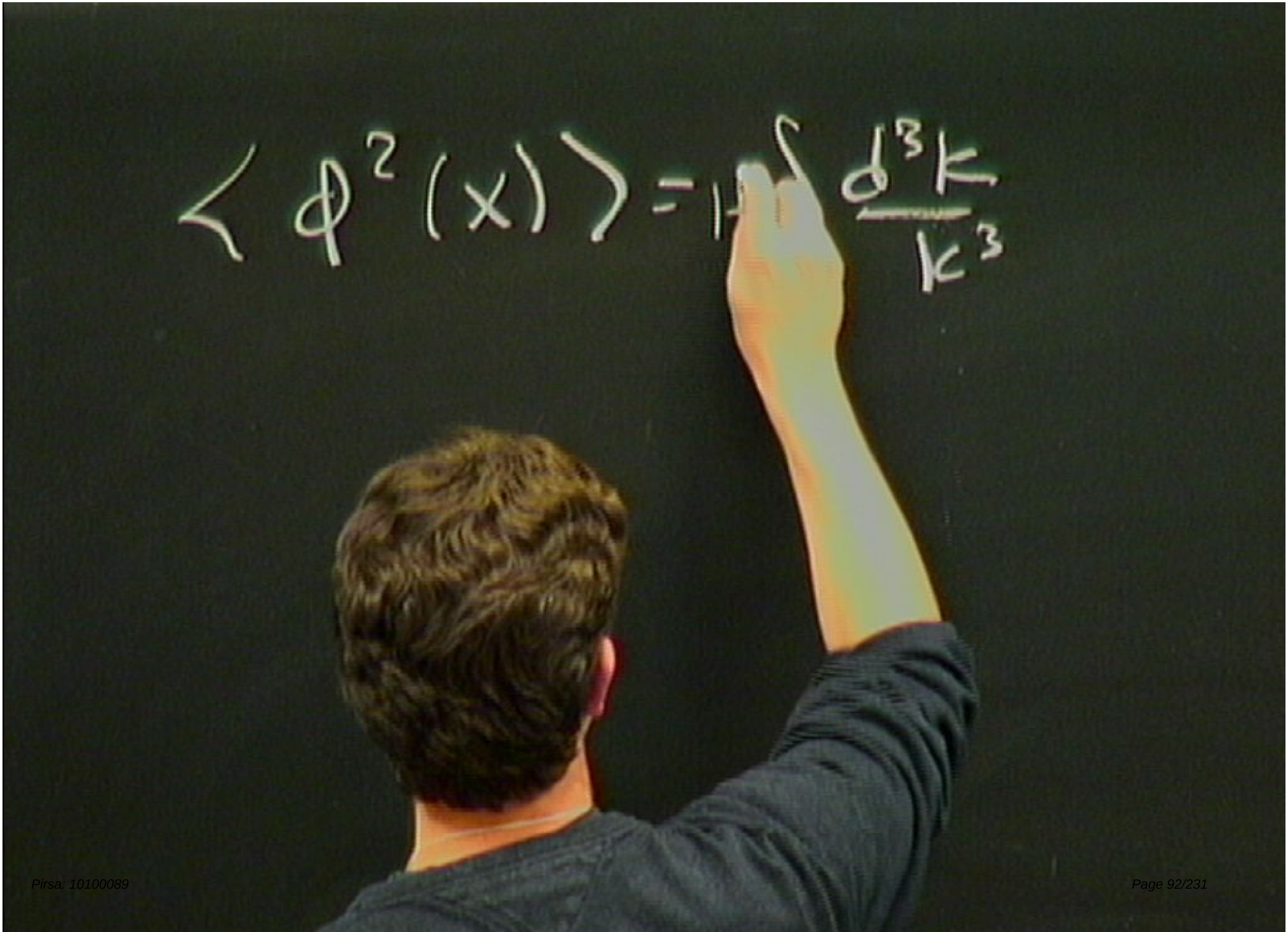
$G_R(k,\tau_1,\tau_2) = \Theta(\tau_1-\tau_2)\frac{H^2}{3}(\tau_1^3-\tau_2^3)\left(1 + O(-k\tau)^2\right)$

$-ia^4(\tau)\delta m$

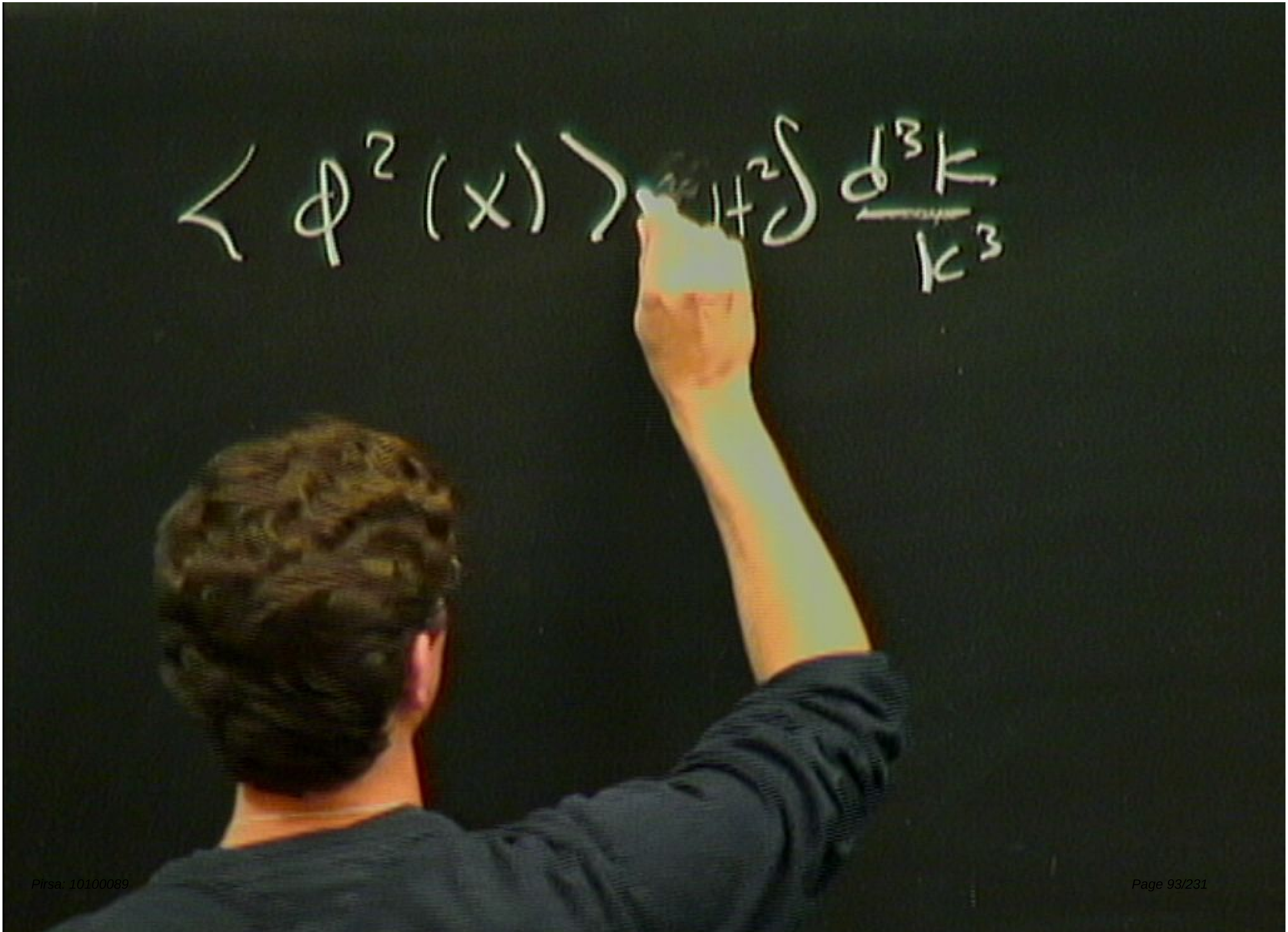
$= -ia^4\lambda$

$\phi_c^3\phi_\Delta$

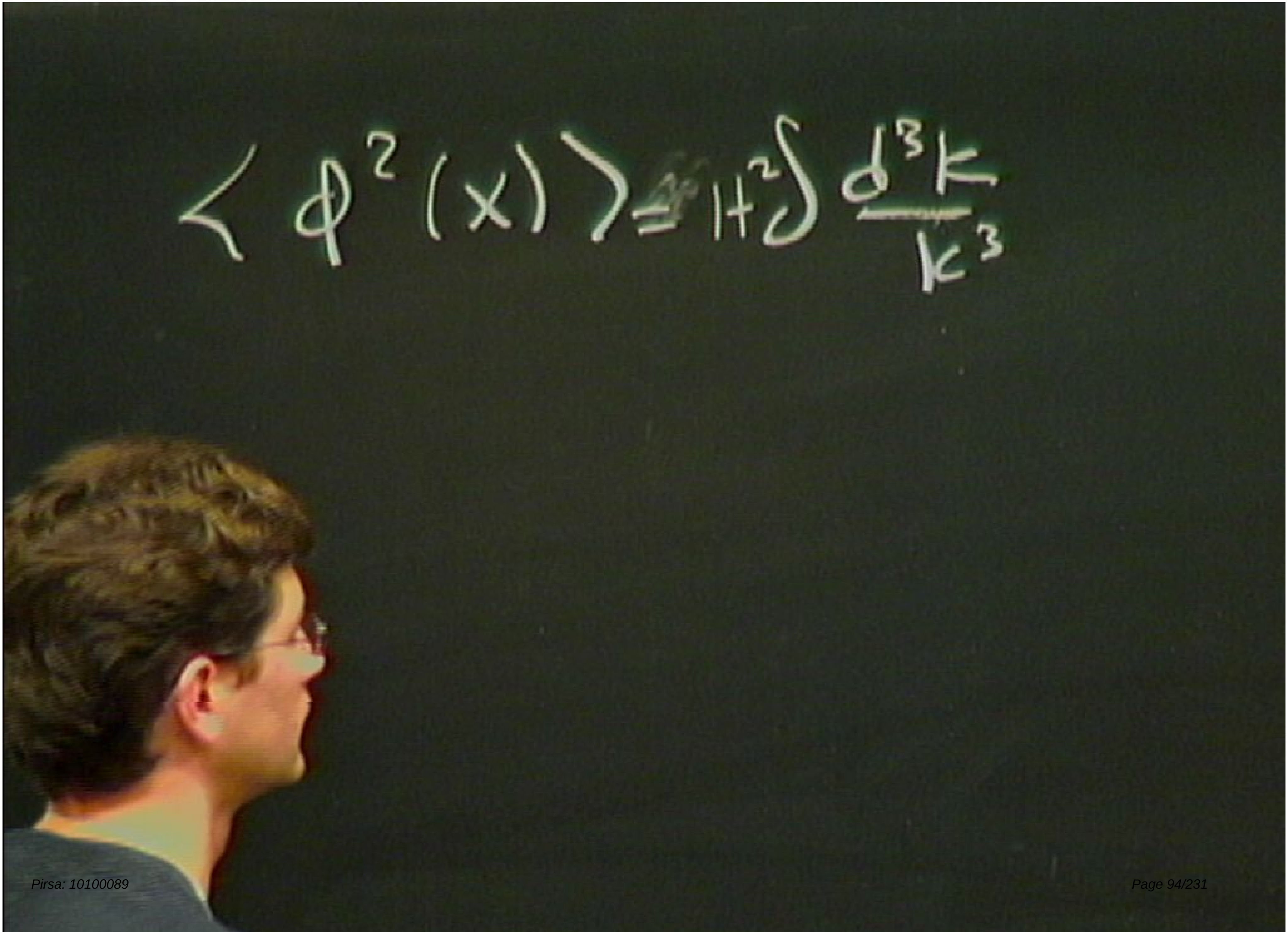




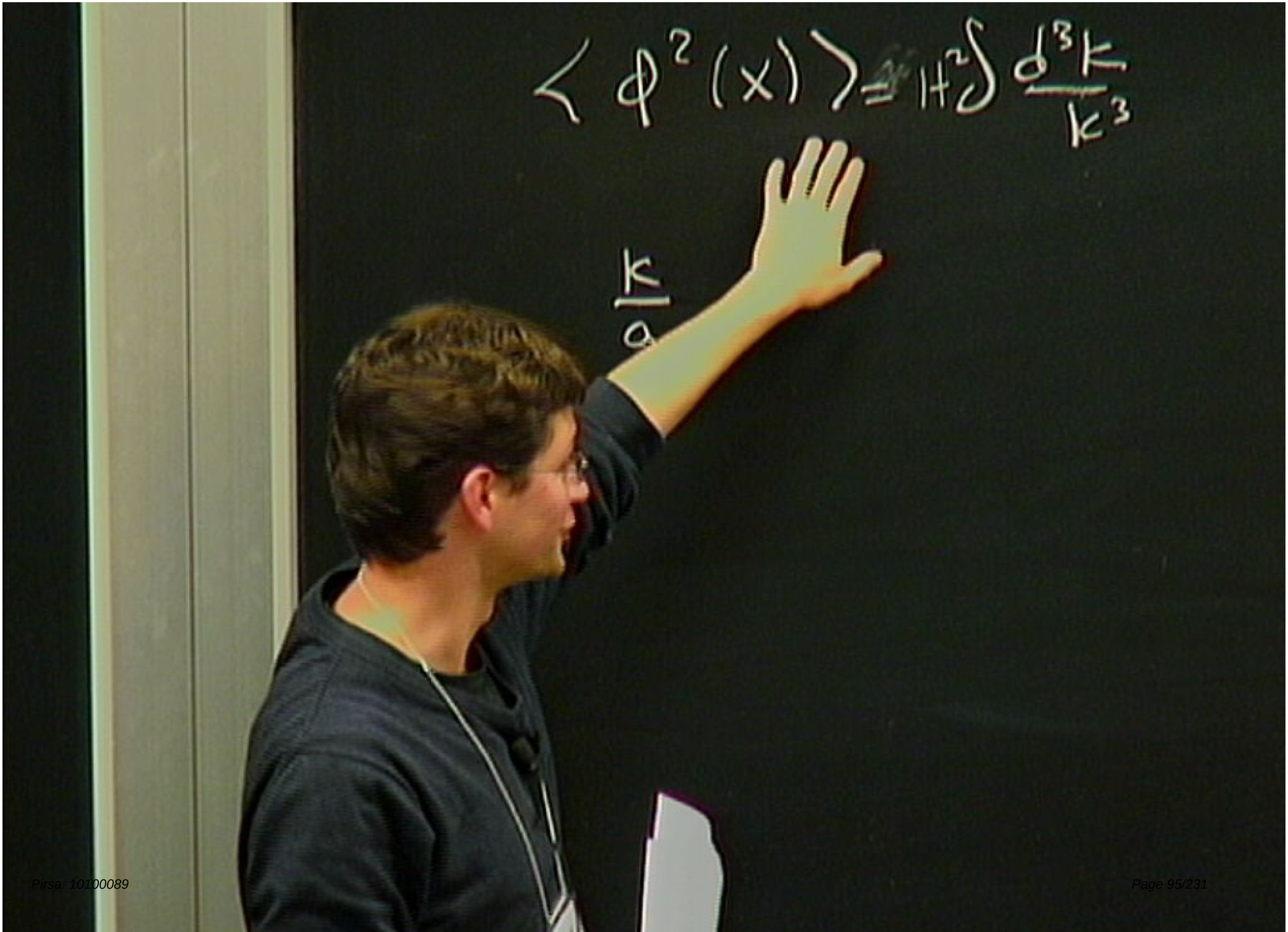
$$\langle \phi^2(x) \rangle = \int \frac{d^3k}{k^3}$$



$\langle \phi^2(x) \rangle$ [illegible] $H^2 \int \frac{d^3k}{k^3}$

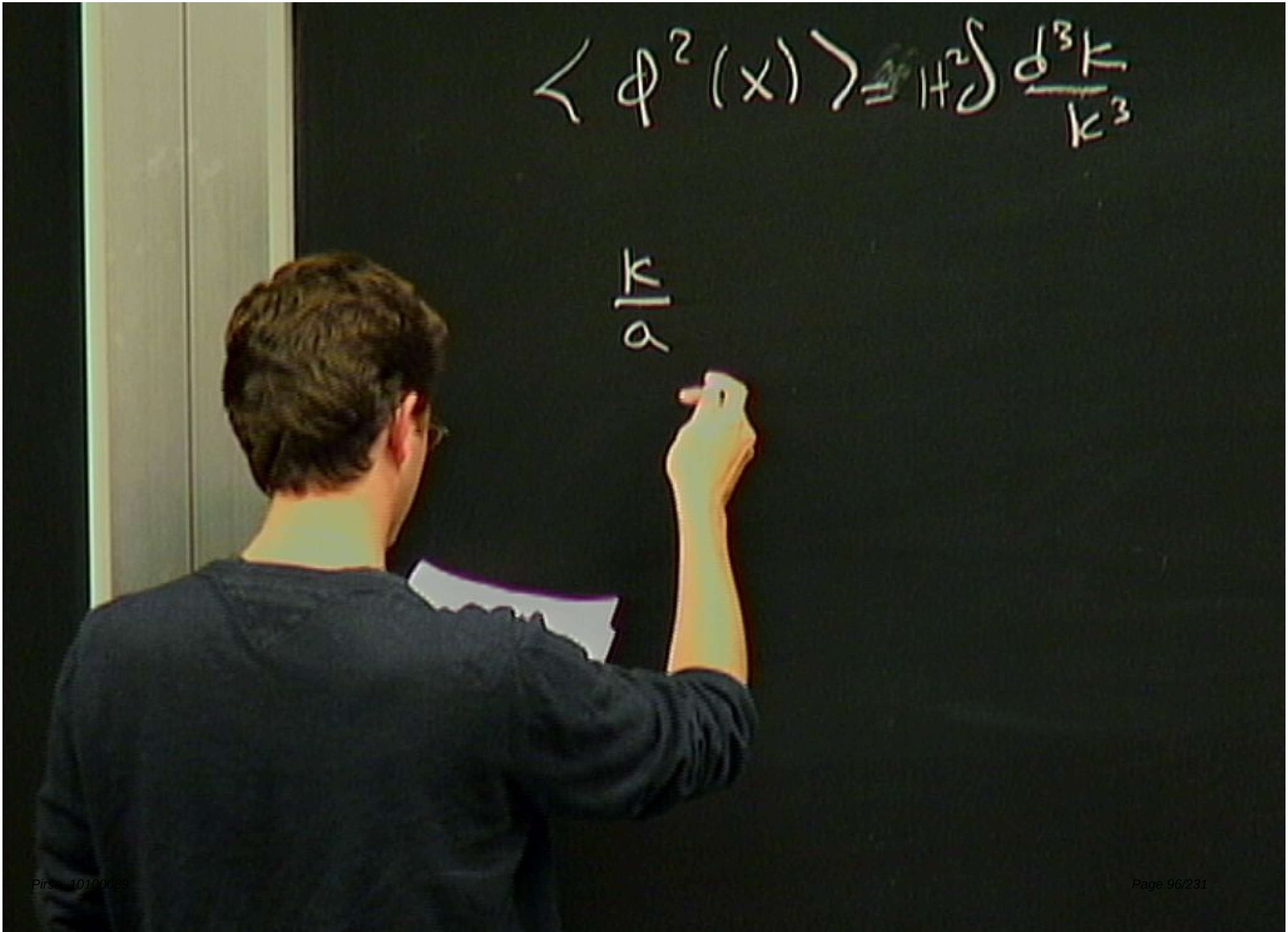


$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$



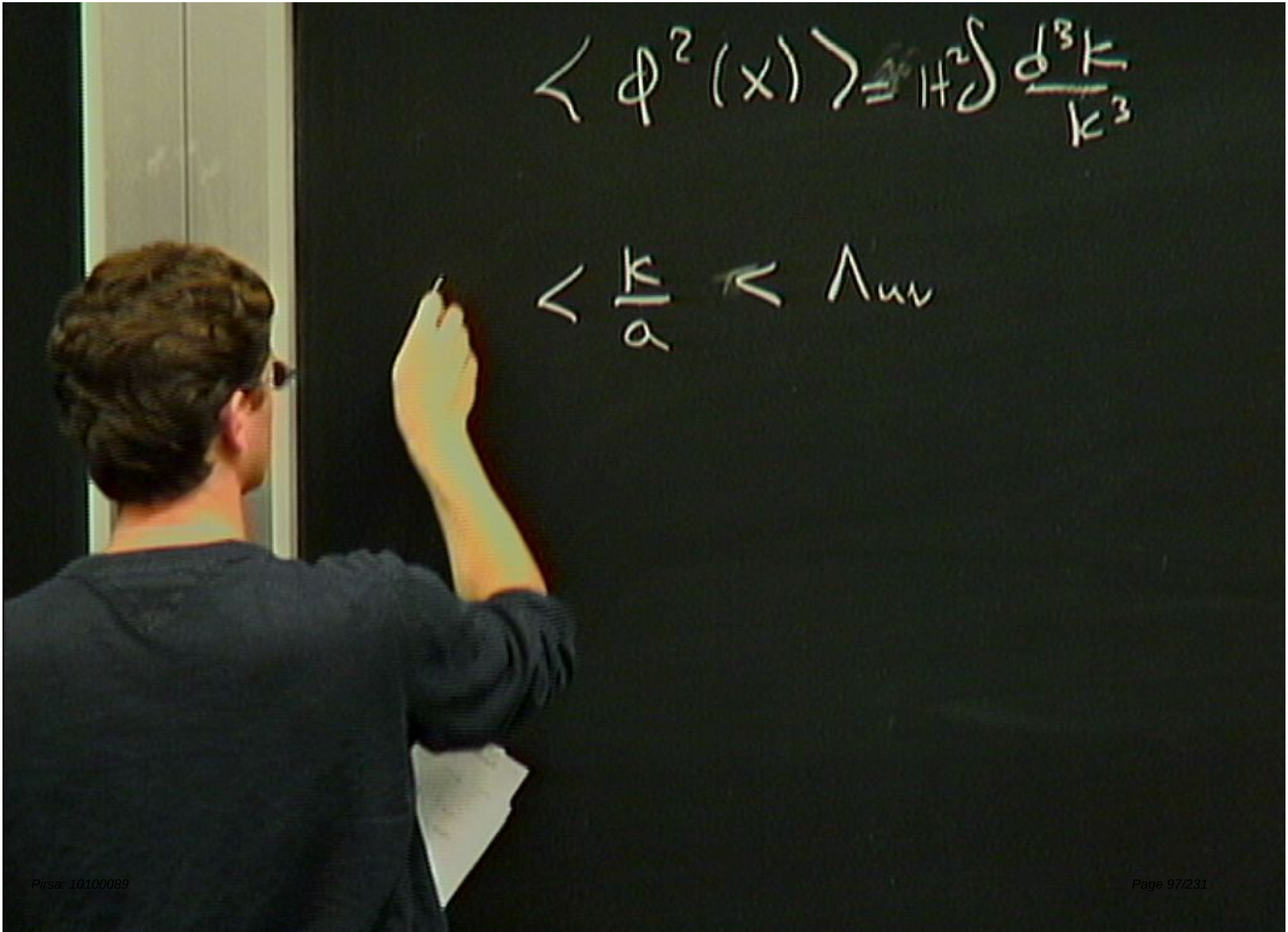
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

$$\frac{k}{a}$$



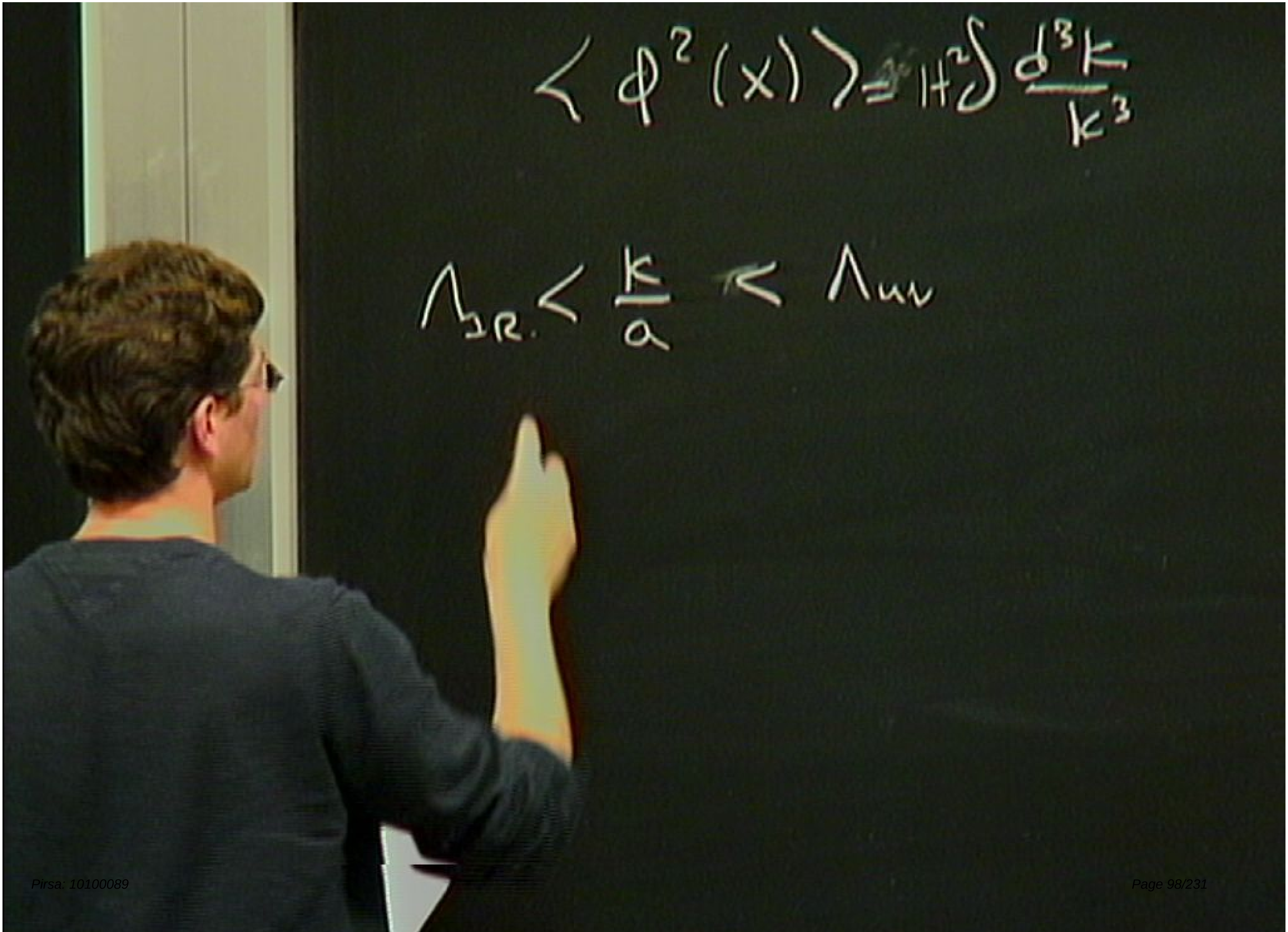
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

$$\frac{k}{a}$$



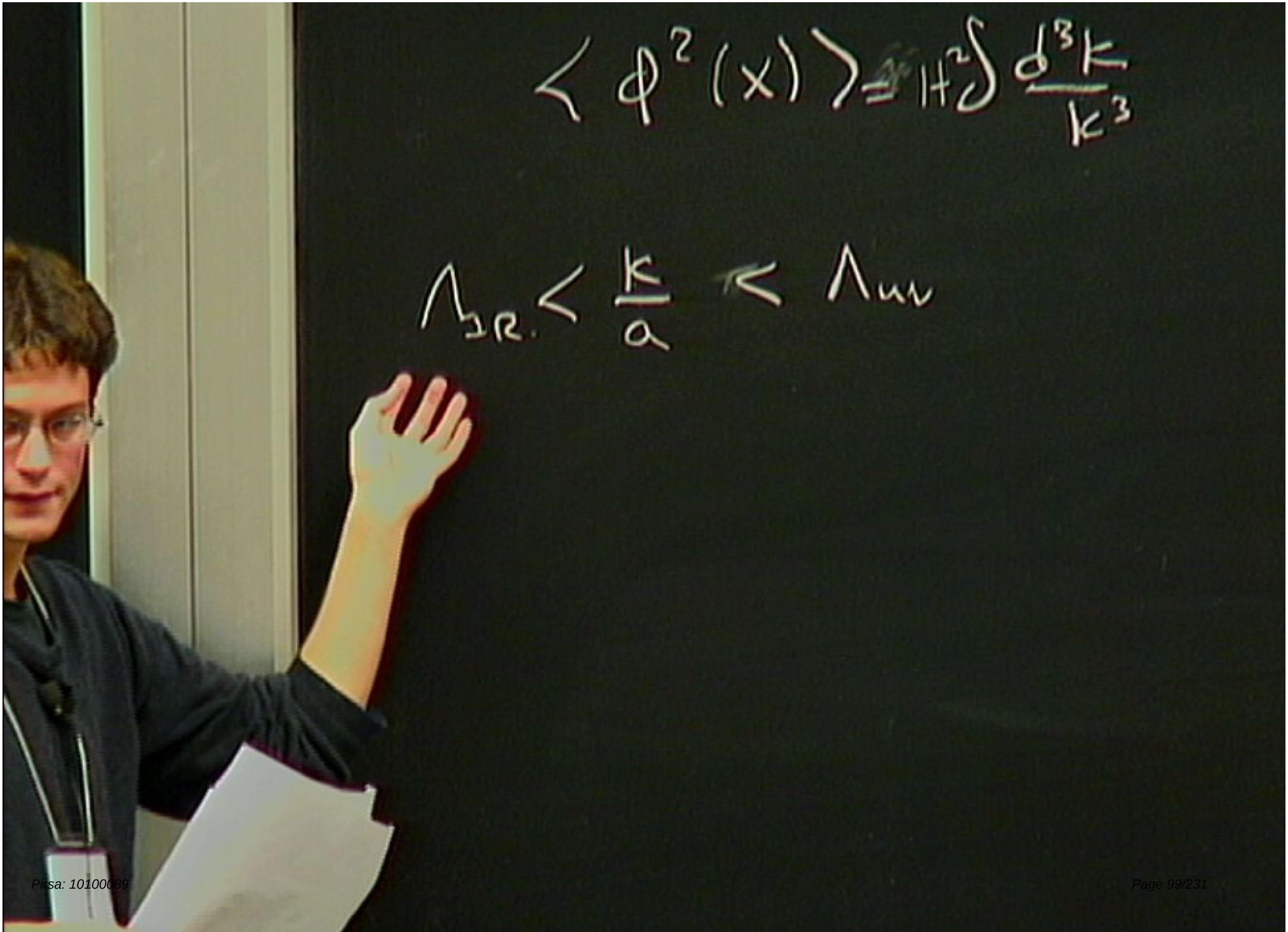
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

$$< \frac{k}{a} < \Lambda_{uv}$$



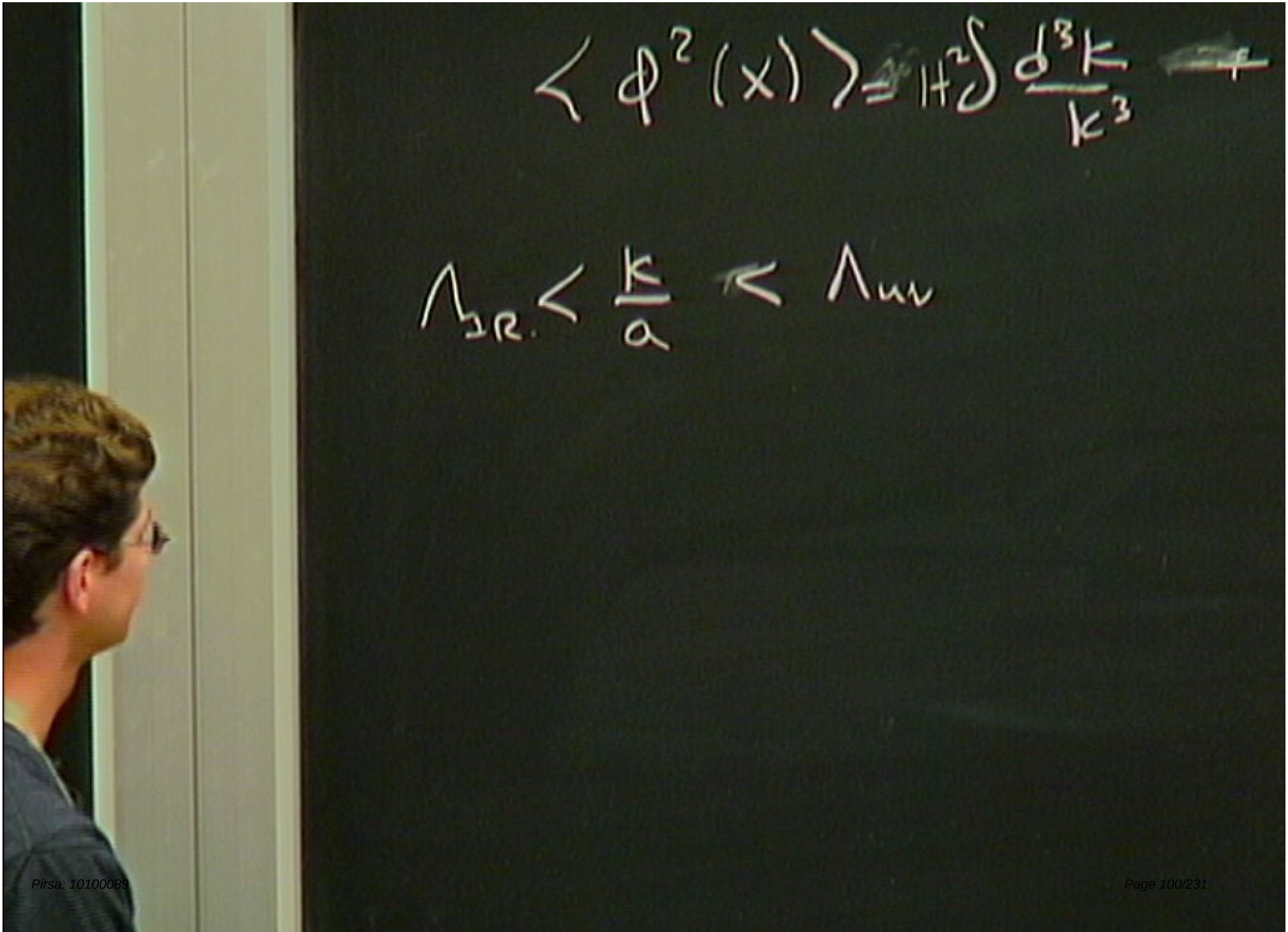
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

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



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

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



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

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

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

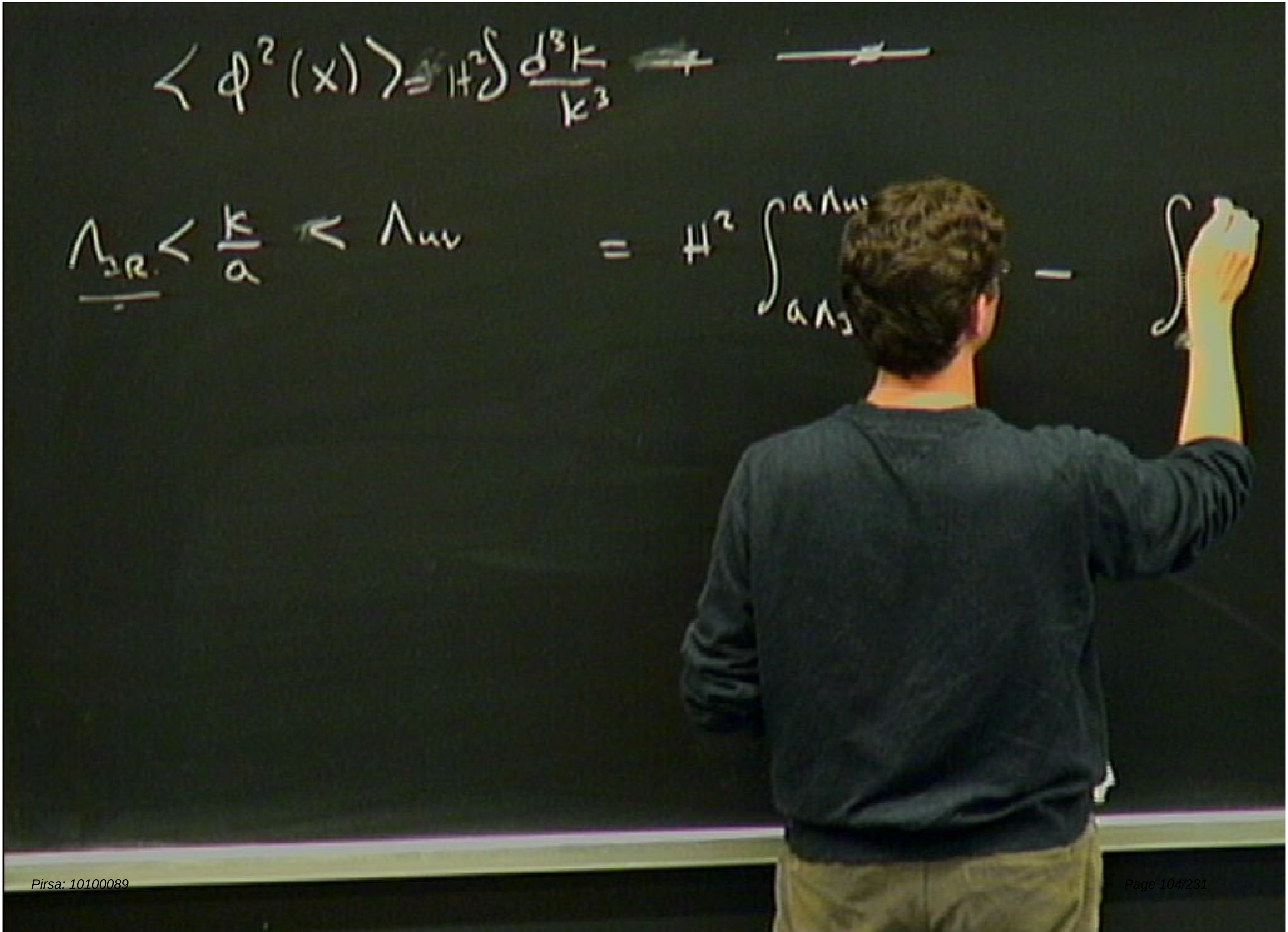
$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV}$$

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

$$\underline{\Lambda_{IR}} < \frac{k}{a} < \Lambda_{uv}$$

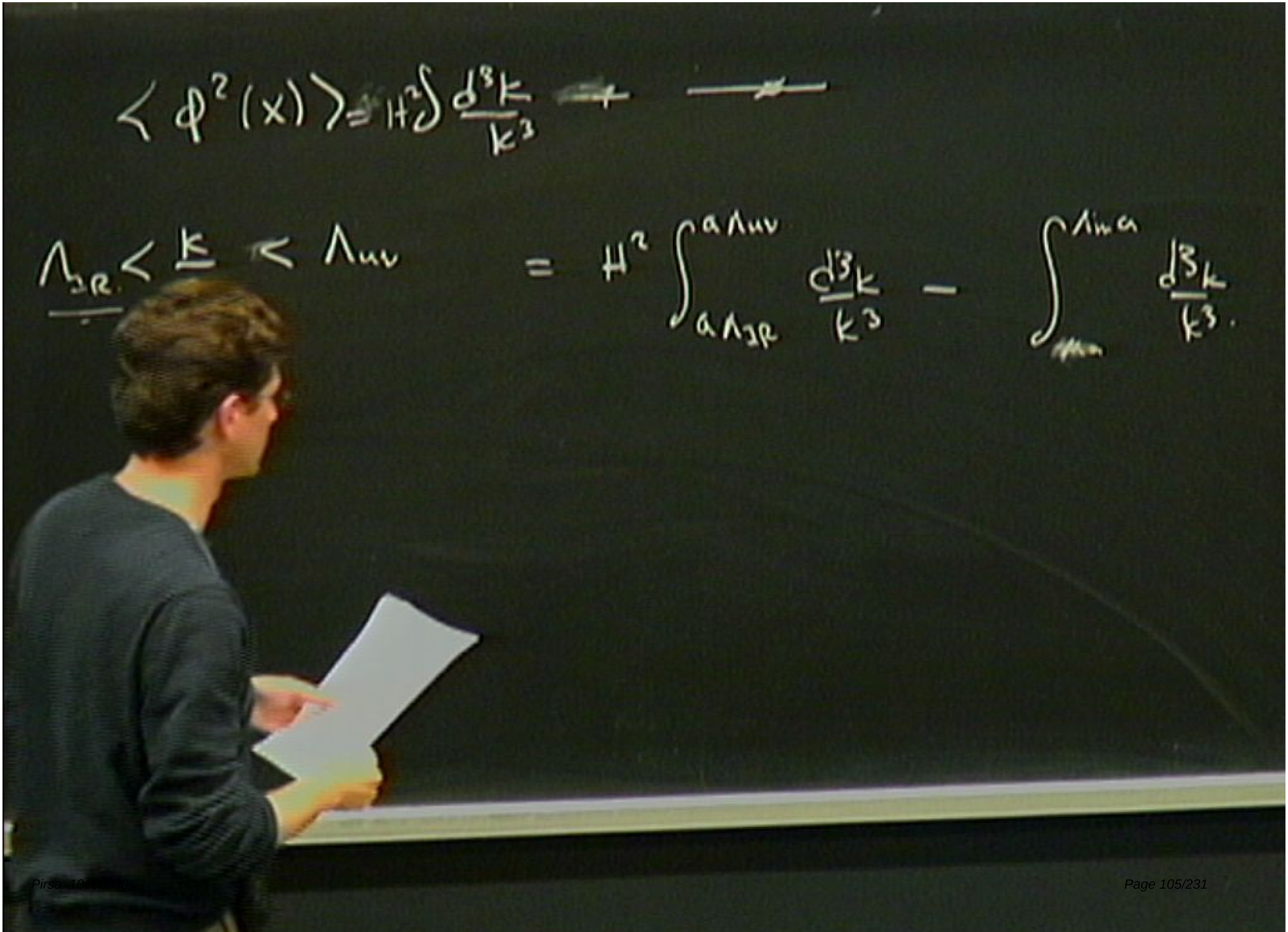
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

$$\underline{\Lambda_{IR}} < \frac{k}{a} < \Lambda_{uv}$$



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

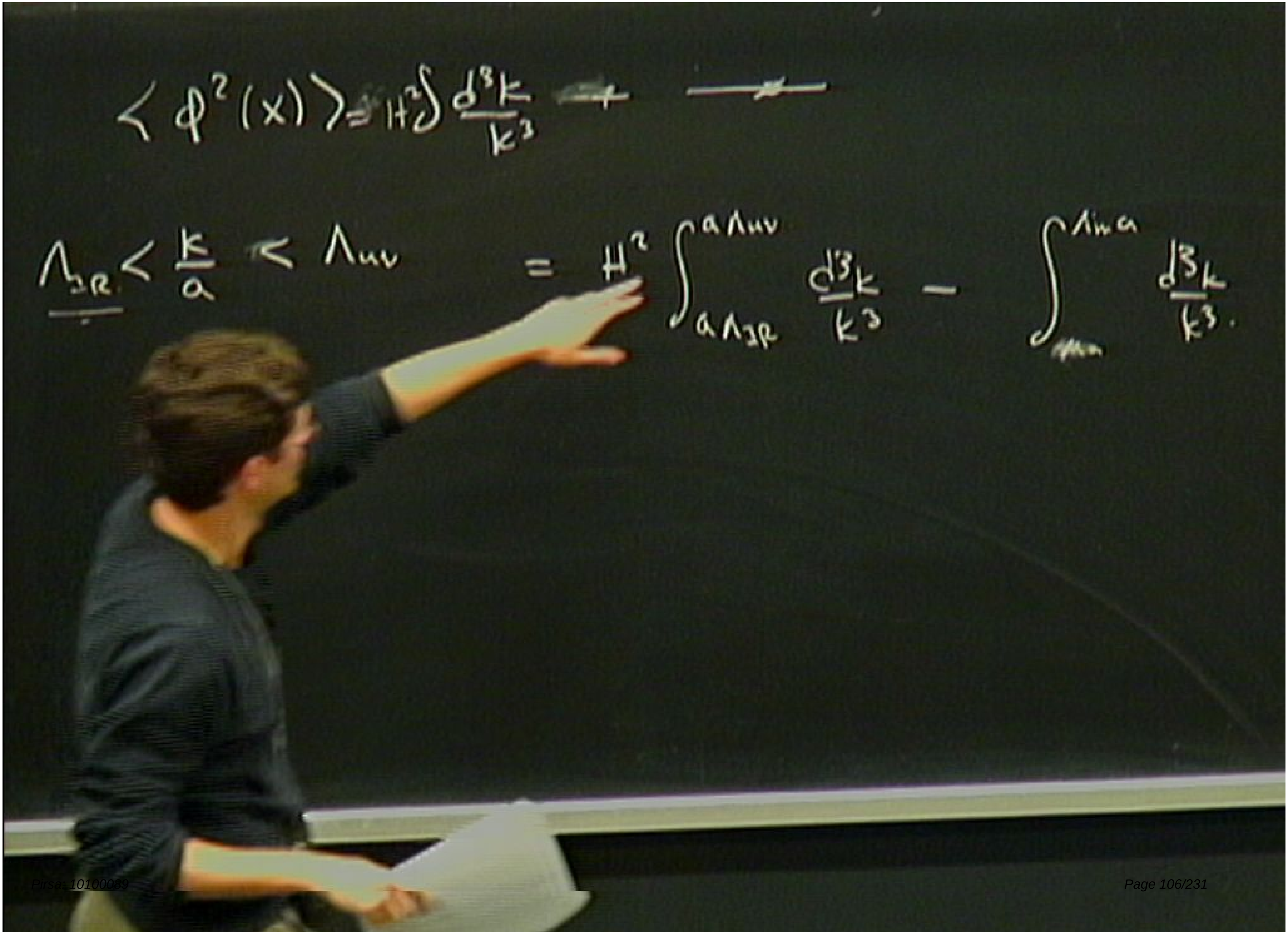
$$\underline{\Lambda_{IR}} < \frac{k}{a} < \Lambda_{UV} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{UV}} \quad - \quad \int$$



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

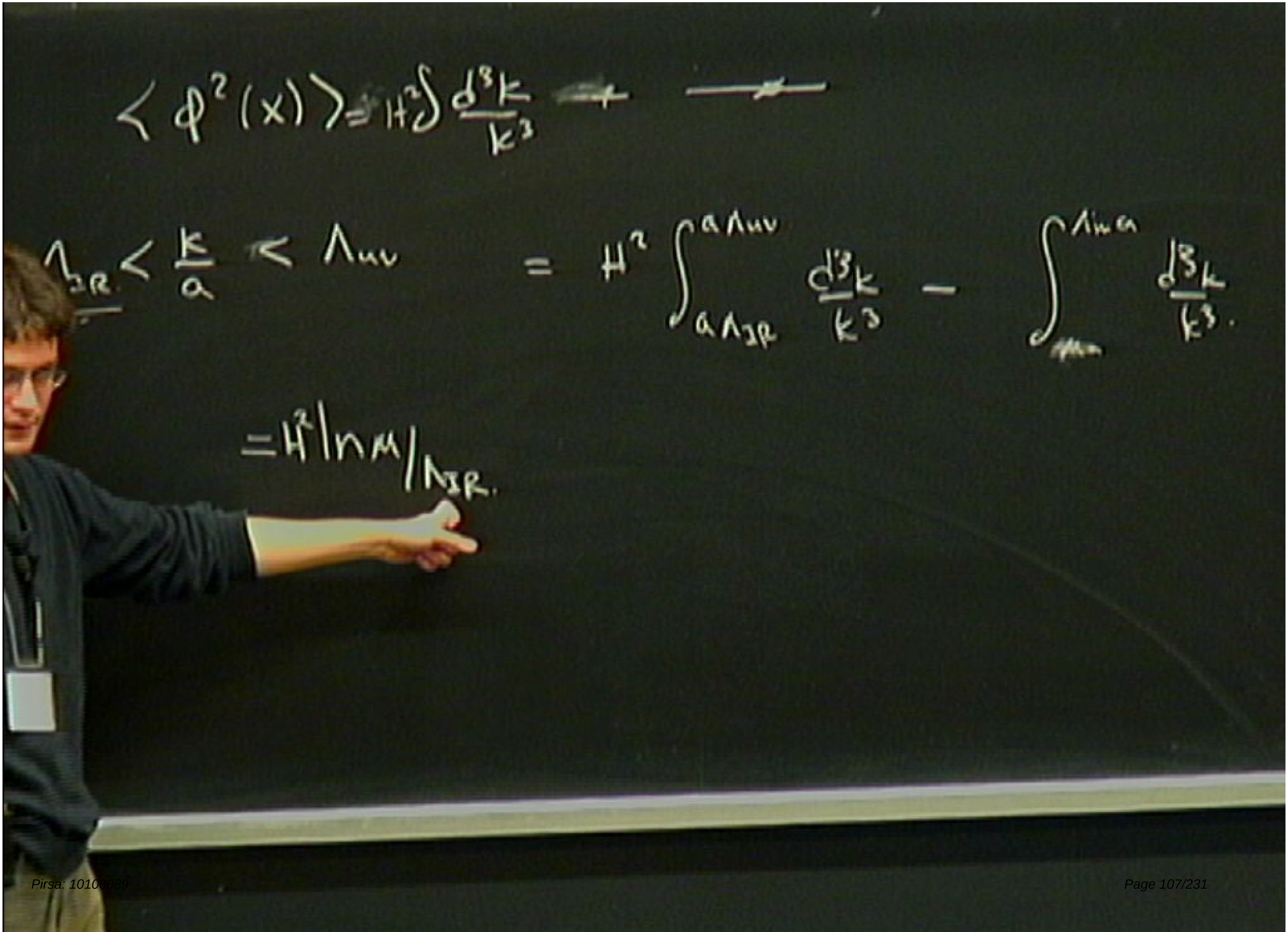
$$\underline{\Lambda_{IR}} < \underline{k} < \Lambda_{uv}$$

$$= H^2\int_{a\Lambda_{IR}}^{a\Lambda_{uv}} \frac{d^3k}{k^3} - \int^{\Lambda_{uv}a} \frac{d^3k}{k^3}.$$



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

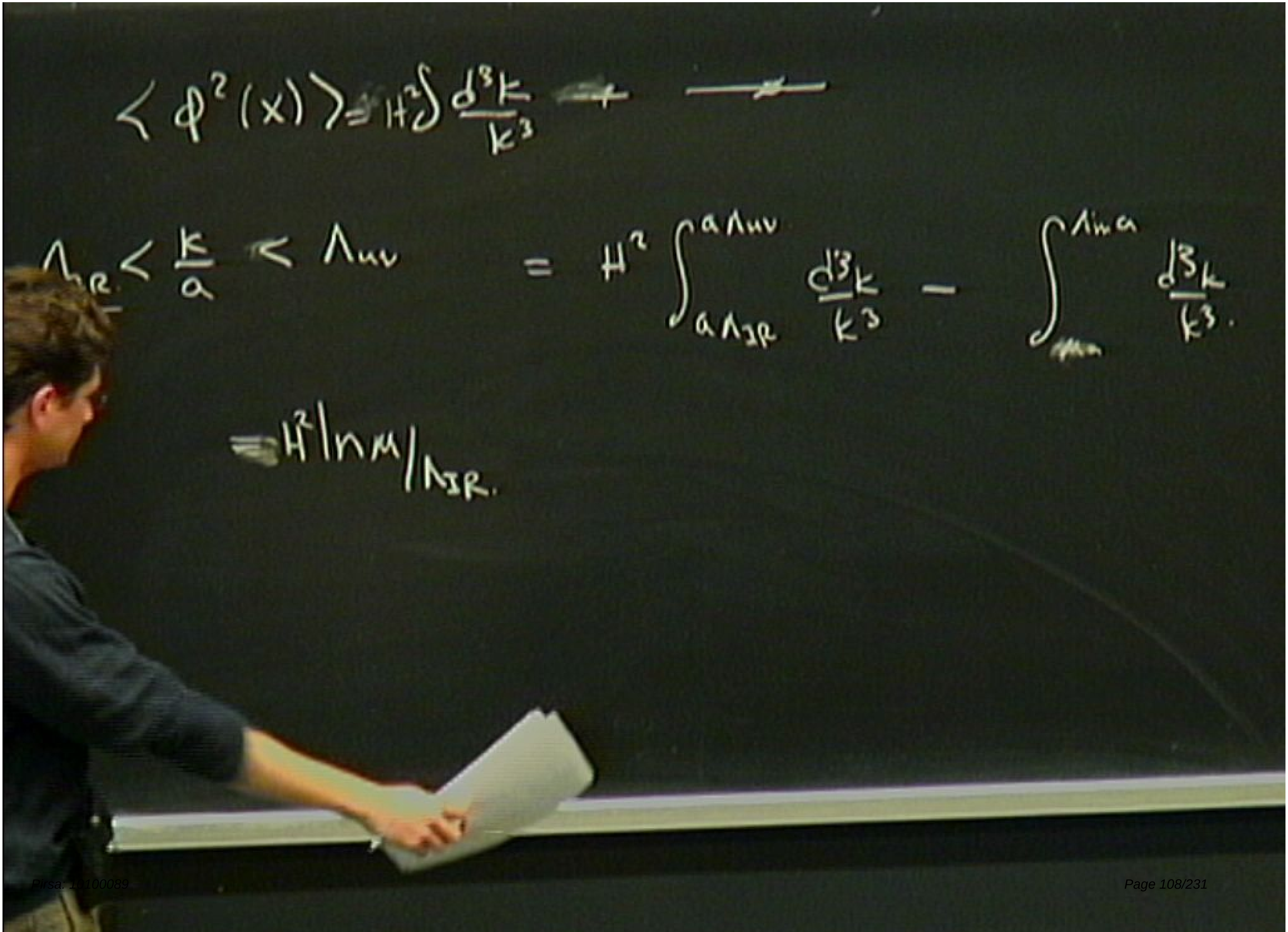
$$\underline{\Lambda_{IR}} < \frac{k}{a} < \Lambda_{uv} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{uv}} \frac{d^3k}{k^3} - \int^{\Lambda_{uv} a} \frac{d^3k}{k^3}.$$



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

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

$$= H^2 \ln M \Big|_{\Lambda_{IR}}.$$



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

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{UV}} \frac{d^3k}{k^3} - \int^{\Lambda_{in} a} \frac{d^3k}{k^3}.$$

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

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

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{UV} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{UV}} \frac{d^3k}{k^3} - \int_{[illegible]}^{\Lambda_{UV} a} \frac{d^3k}{k^3}.$$

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

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

$$\Lambda_{IR} < \frac{k}{a} < \Lambda_{uv} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{uv}} \frac{d^3k}{k^3} - \int^{\Lambda_{uv} a} \frac{d^3k}{k^3}.$$

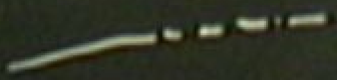
$$= H^2 \ln M / \Lambda_{IR}.$$

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

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

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

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

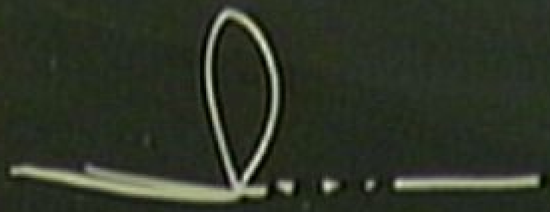


$$G_R(k_1,\tau_1,\tau_2) = \Theta(\tau_1-\tau_2)\frac{H^2}{3}(\tau_1^3 - \tau_2^3)(1 + \mathcal{O}(-k\tau)^2)$$

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

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

$$\phi_c^3 \phi_D$$

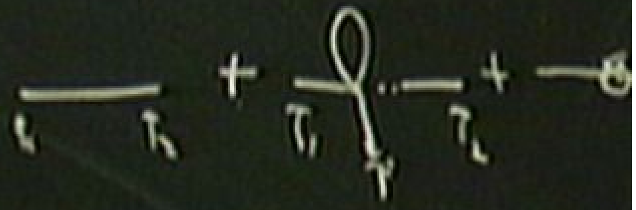


$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

$$\underline{\Lambda_{IR}} < \frac{k}{a} < \Lambda_{uv} \qquad = H^2 \int_{a\Lambda_{IR}}^{a\Lambda_{uv}} \frac{d^3k}{k^3} - \int^{\Lambda_{uv} a} \frac{d^3k}{k^3}.$$

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

$G_c(k, \tau_1, \tau_2) =$

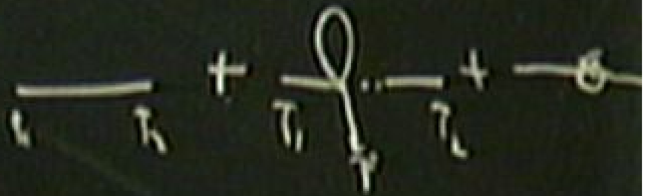


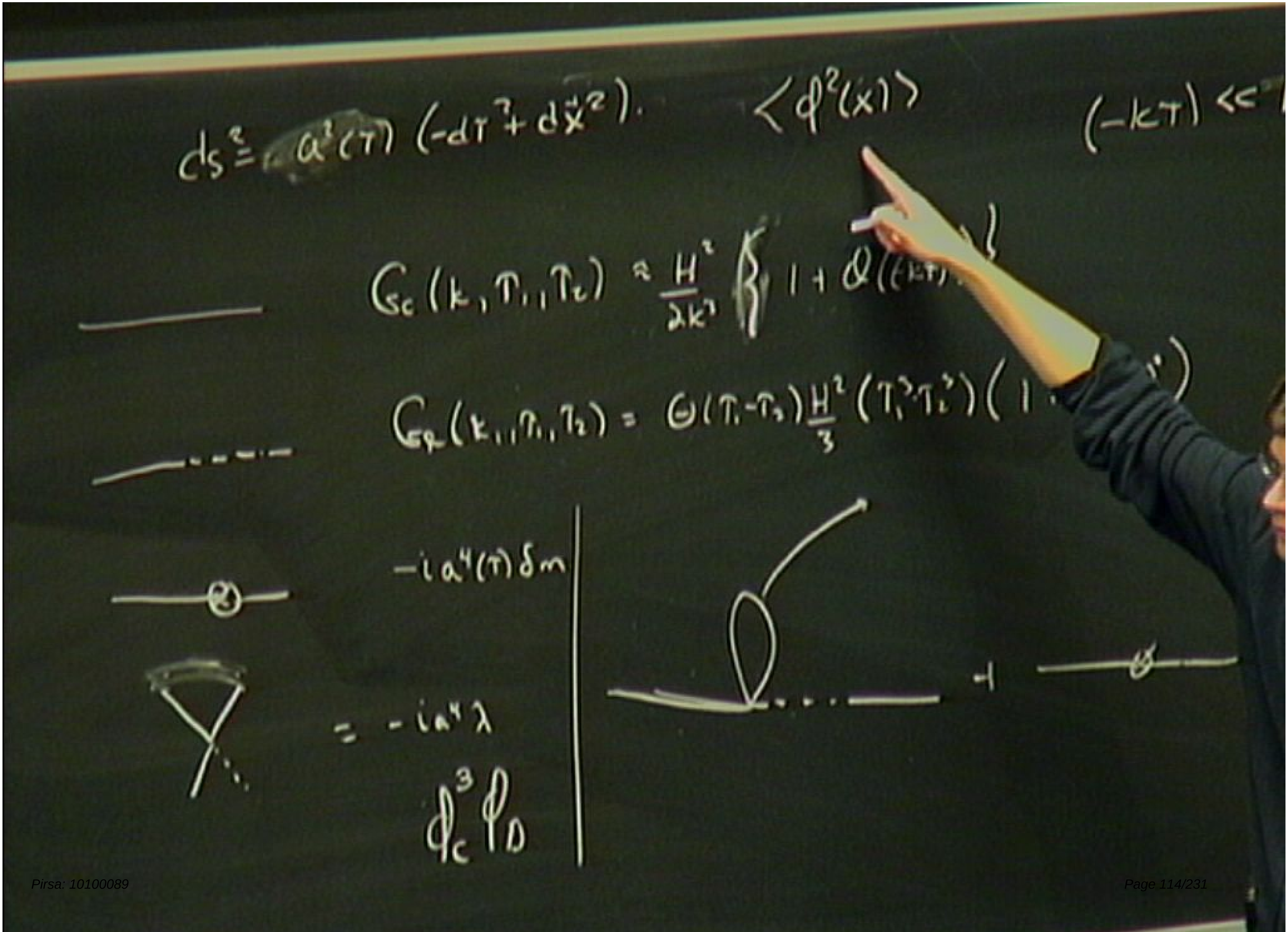
$$\langle \phi^2(x) \rangle = H^2 \int \frac{d^3k}{k^3}$$

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

$$\langle \phi^2(x) \rangle = H^2 \ln M \Big|_{\Lambda_{IR}.} = cst.$$

$G_c(k, T_1, T_2) =$





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

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

$(-k\tau) \ll$

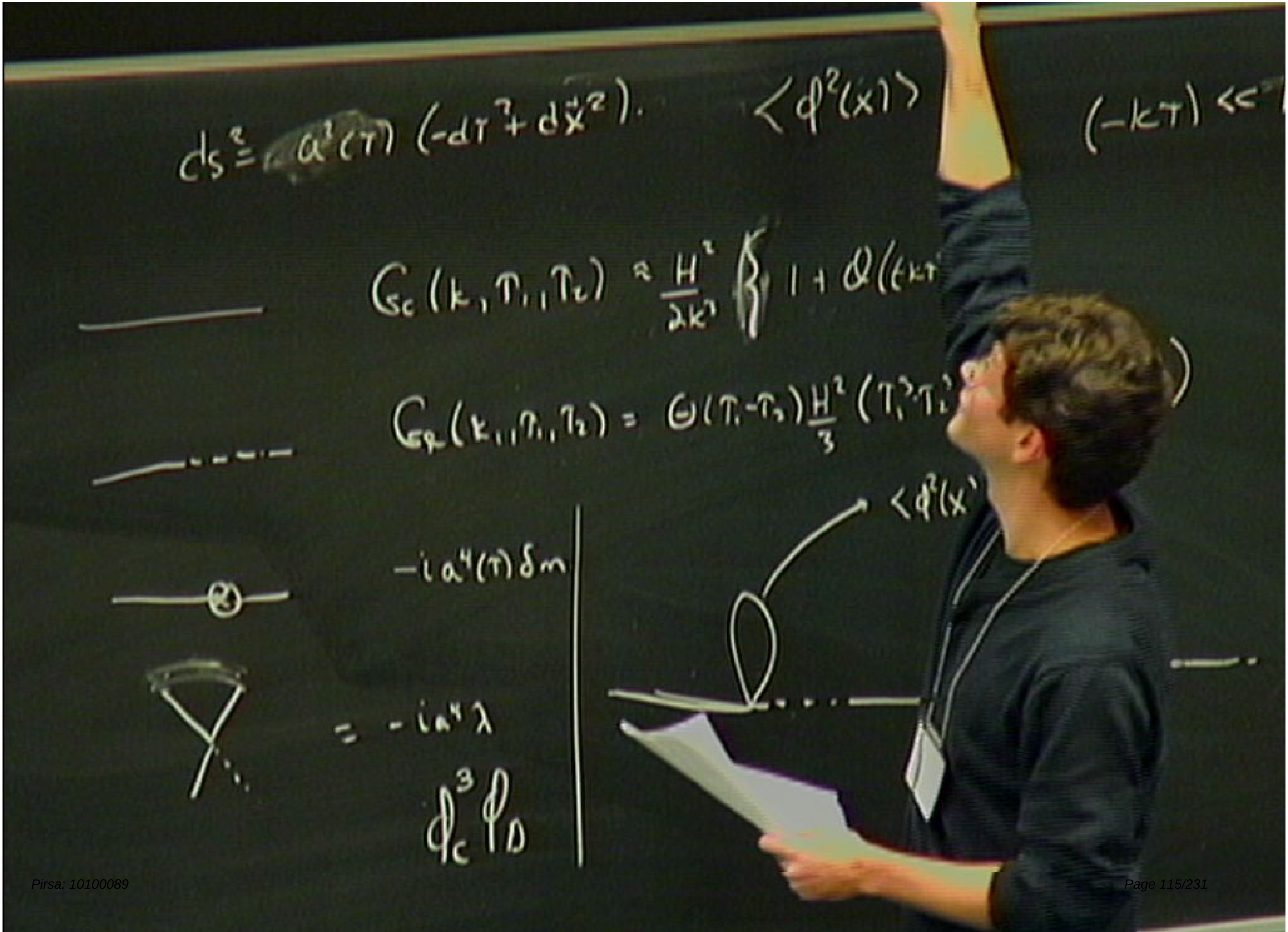
$G_{SC}(k,\tau_1,\tau_2) \approx \frac{H^2}{2k^3}\left\{ 1 + O((-k\tau) \right.$

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

$-ia^4(\tau)\,\delta m$

$= -ia^4\lambda$

$\phi_c^3\,\phi_D$



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

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

$(-k\tau) \ll$

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

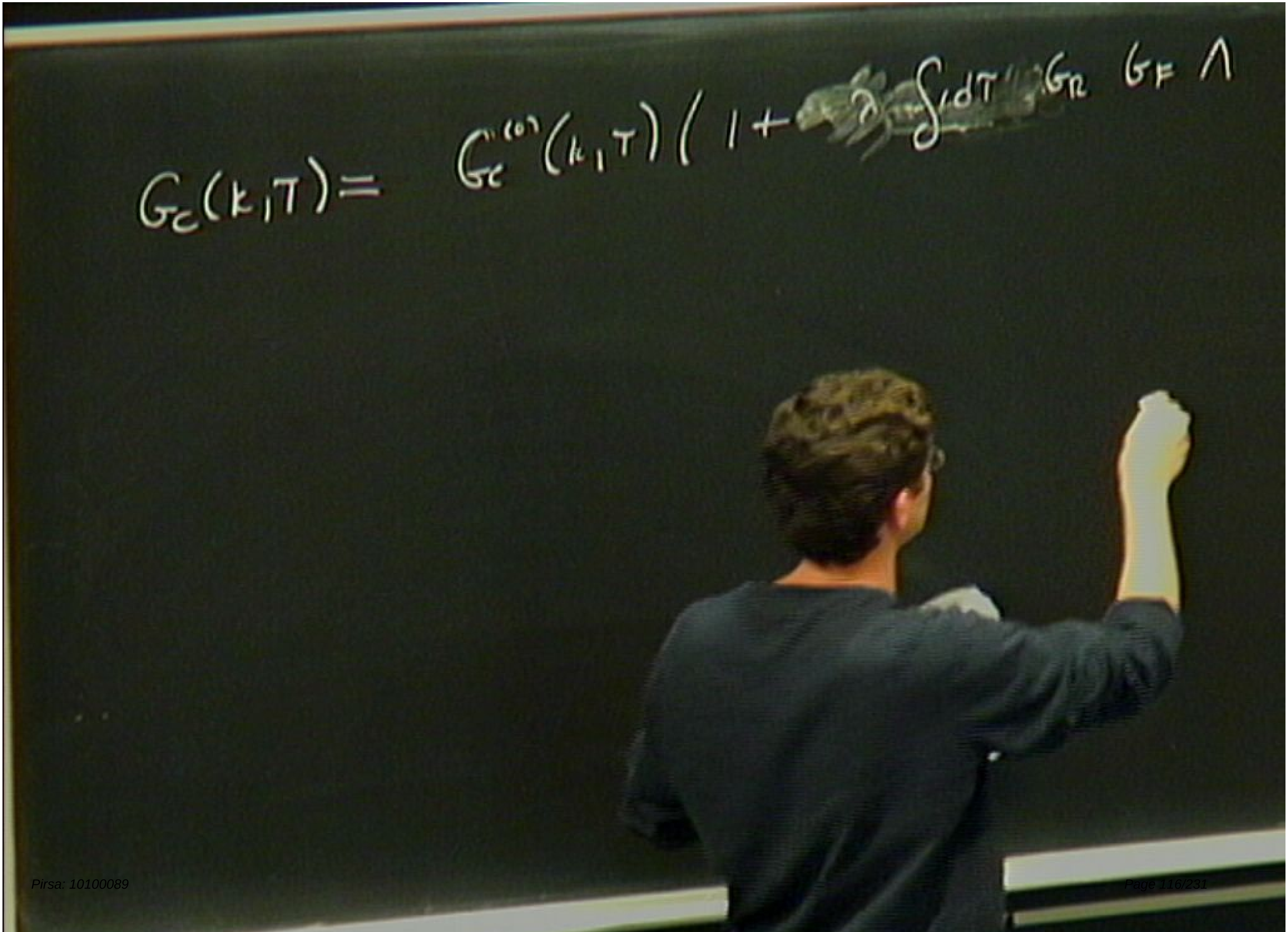
$G_R(k,\tau_1,\tau_2) = \Theta(\tau_1-\tau_2)\frac{H^2}{3}(\tau_1^3\tau_2$

$\langle \phi^2(x$

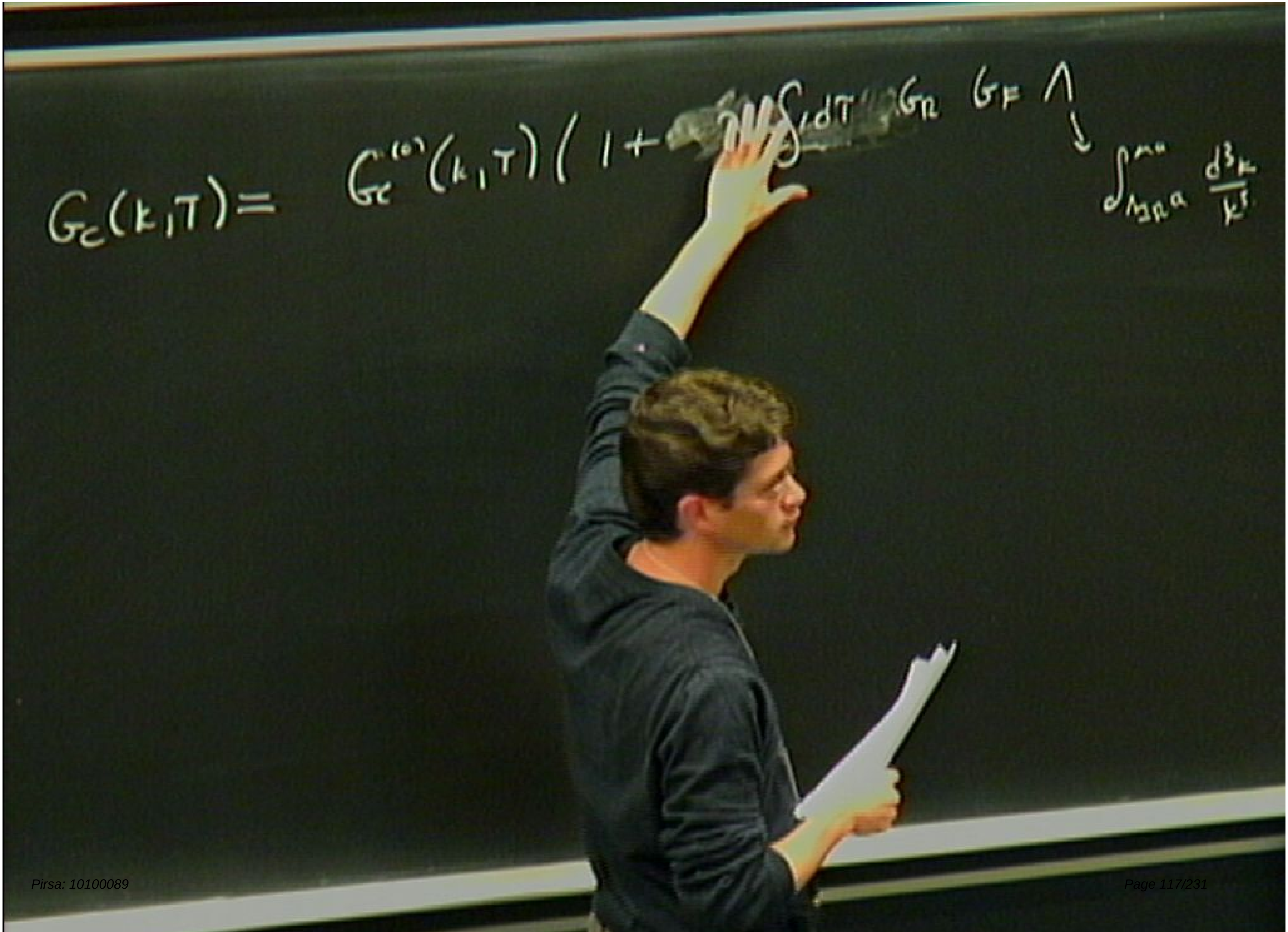
$-i a^4(\tau)\delta m$

$= -i a^4 \lambda$

$\phi_c^3 \phi_D$

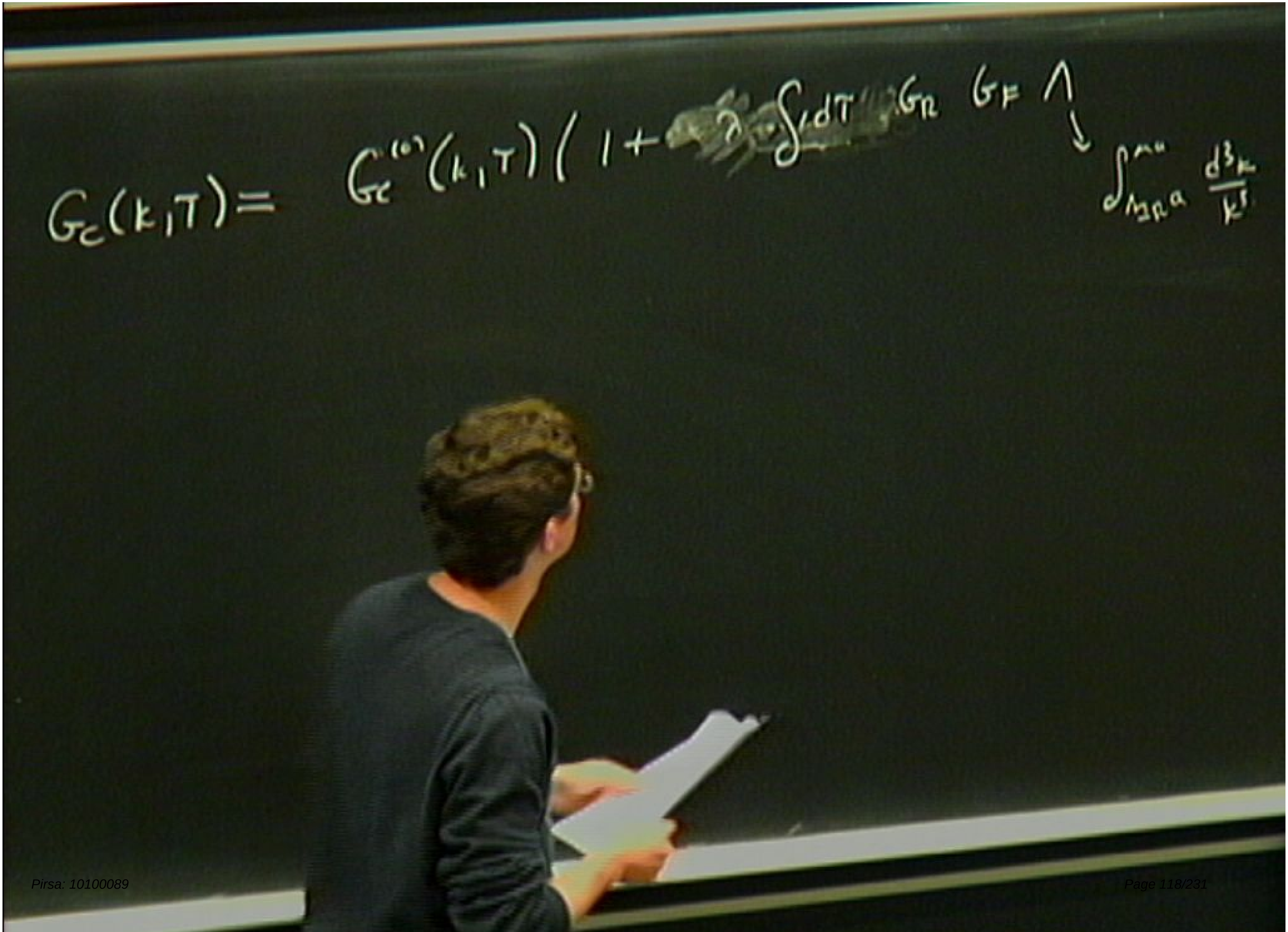


$$G_c(k,\tau) = G_c^{(0)}(k,\tau)\left(1 + \lambda \int d\tau' \, G_R \; G_F \; \Lambda\right.$$



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

$$\int_{\Lambda_{IR}a}^{\mu a} \frac{d^3k}{k^3}$$



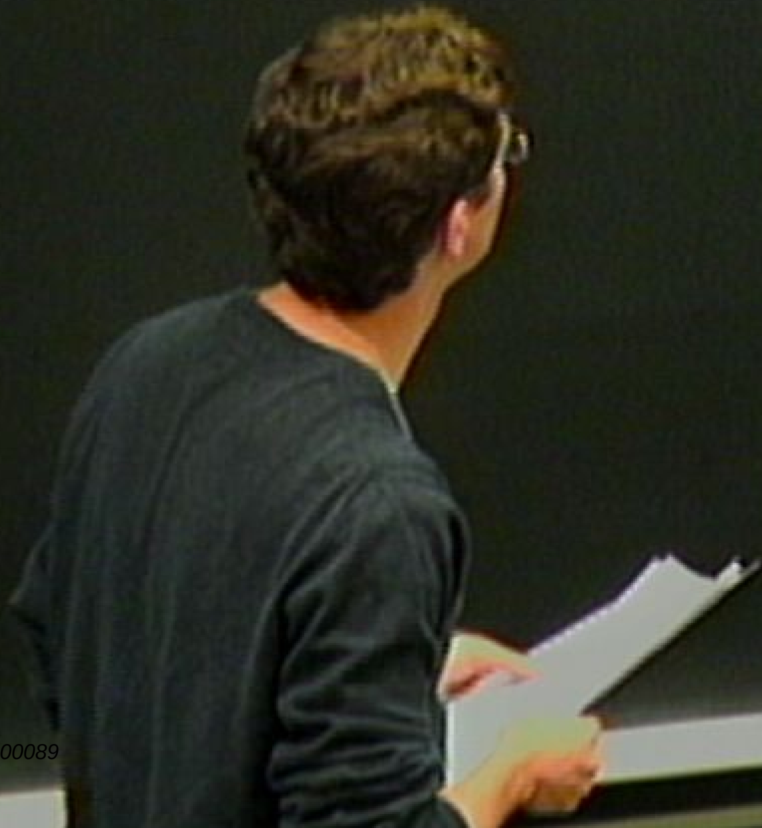
$$G_c(k,T) = G_c^{(0)}(k,T)\left(1 + \lambda \int dT\, G_R \quad G_F \quad \Lambda\right.$$

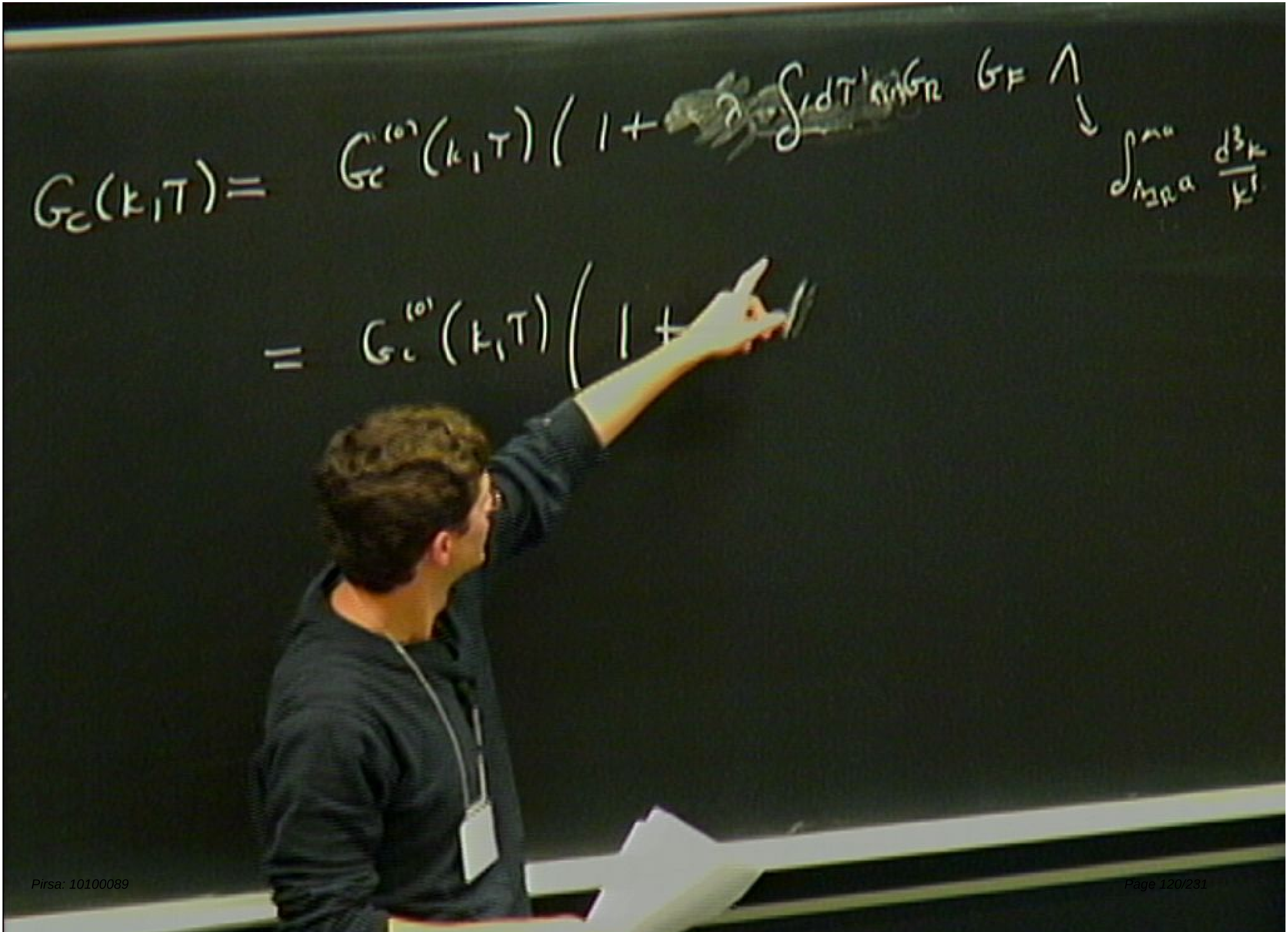
$$\int_{H_R a}^{\mu a} \frac{d^3k}{k^3}$$

$$G_c(k,T) = G_c^{(0)}(k,T)\Big(1 + \lambda \int dT' \, G_R \, G_F \, \Lambda$$

$$\downarrow$$

$$\int_{H_R a}^{\mu a} \frac{d^3k}{k^3}$$

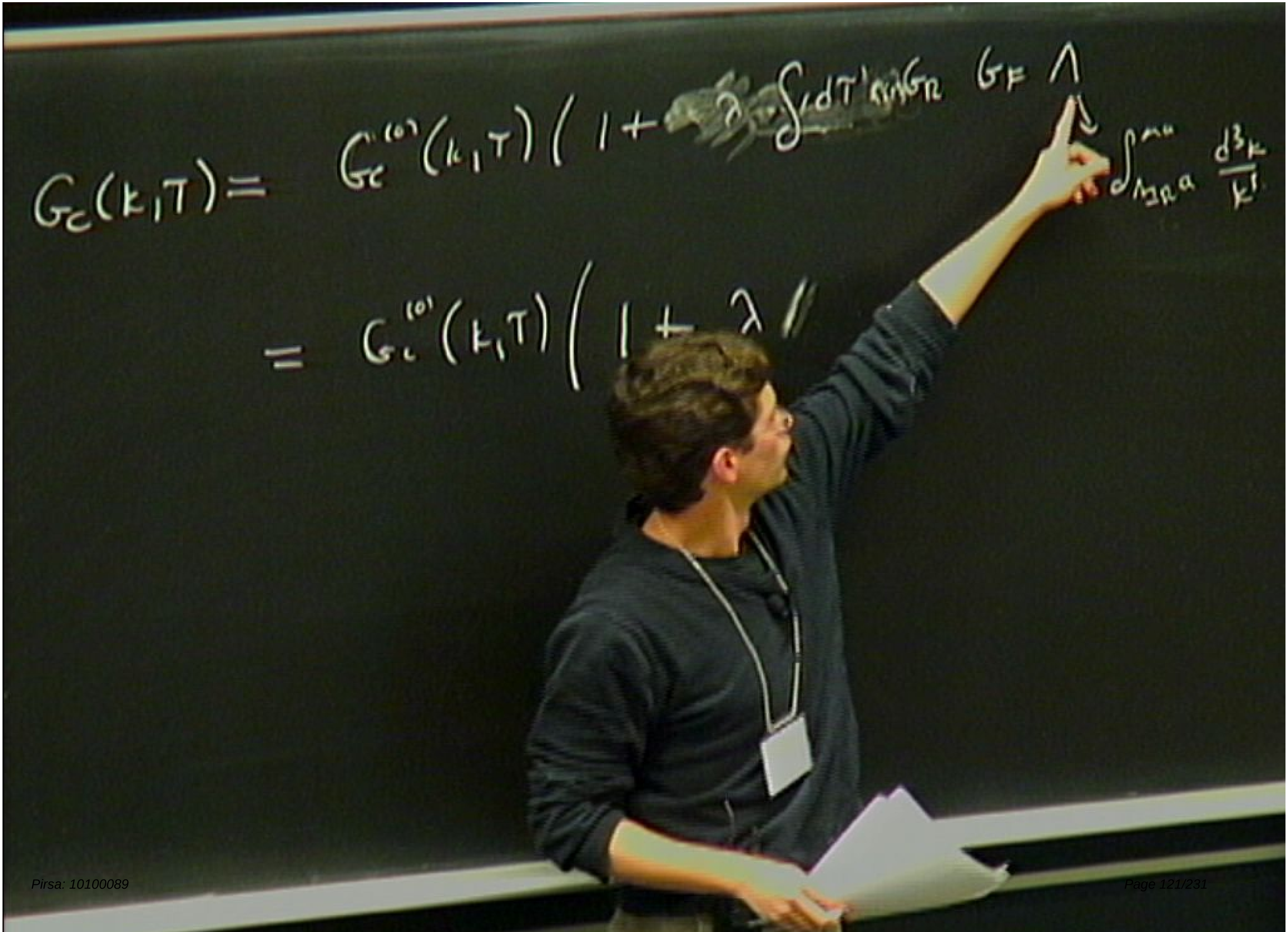




$$G_c(k,T) = G_c^{(0)}(k,T)\left(1 + \lambda \int dT' \, a \, G_R \; G_F \; \Lambda\right)$$

$$\Lambda \Rightarrow \int_{\mu_{IR}a}^{\mu_u} \frac{d^3k}{k^3}$$

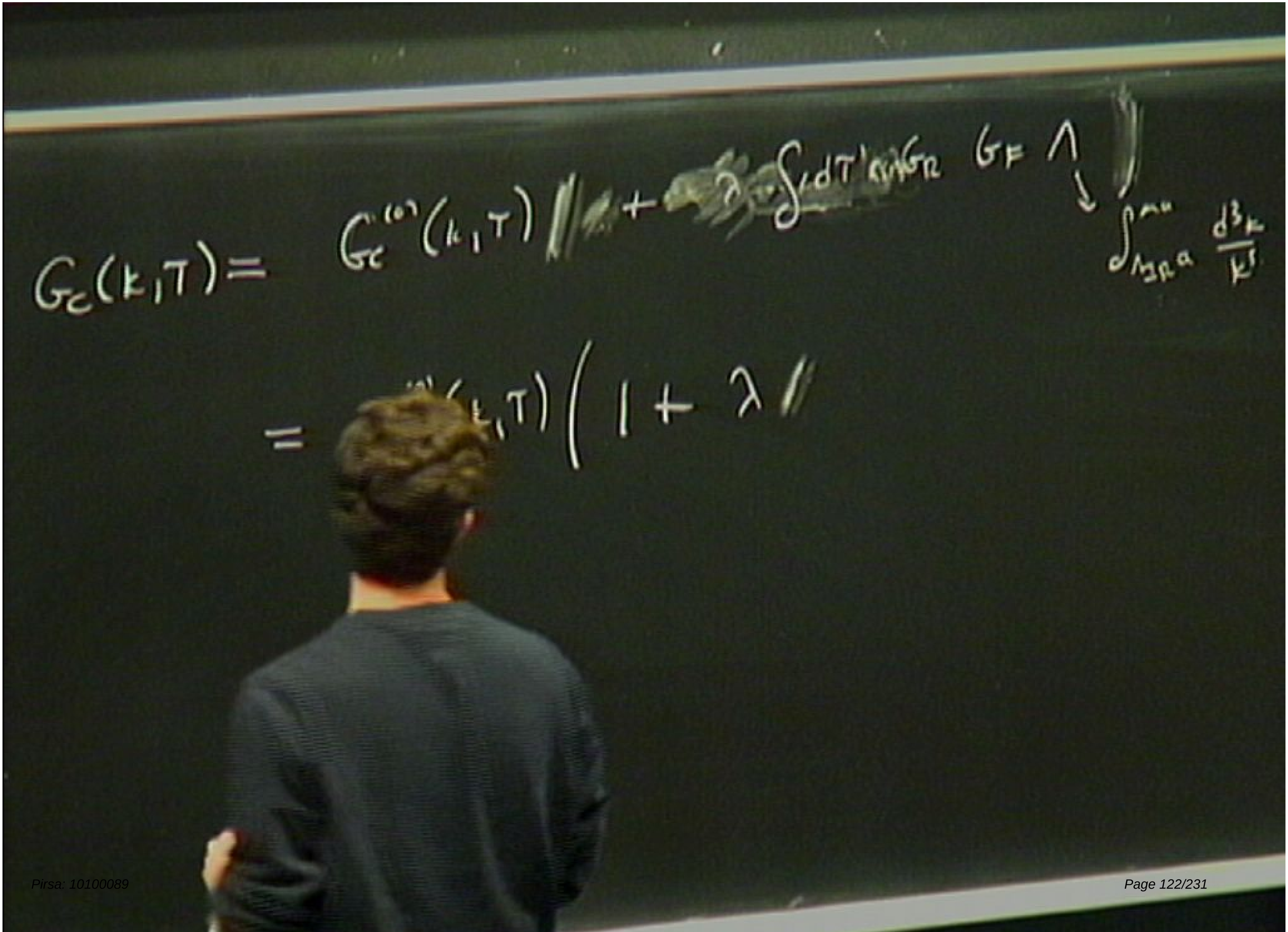
$$= G_c^{(0)}(k,T)\left(1 + \right.$$



$$G_c(k,T) = G_c^{(0)}(k,T)\left(1 + \lambda \int dT' \, a_{\ldots} G_R \quad G_F \quad \Lambda\right.$$

$$\lambda \int_{H_R a}^{\mu u} \frac{d^3k}{k^3}$$

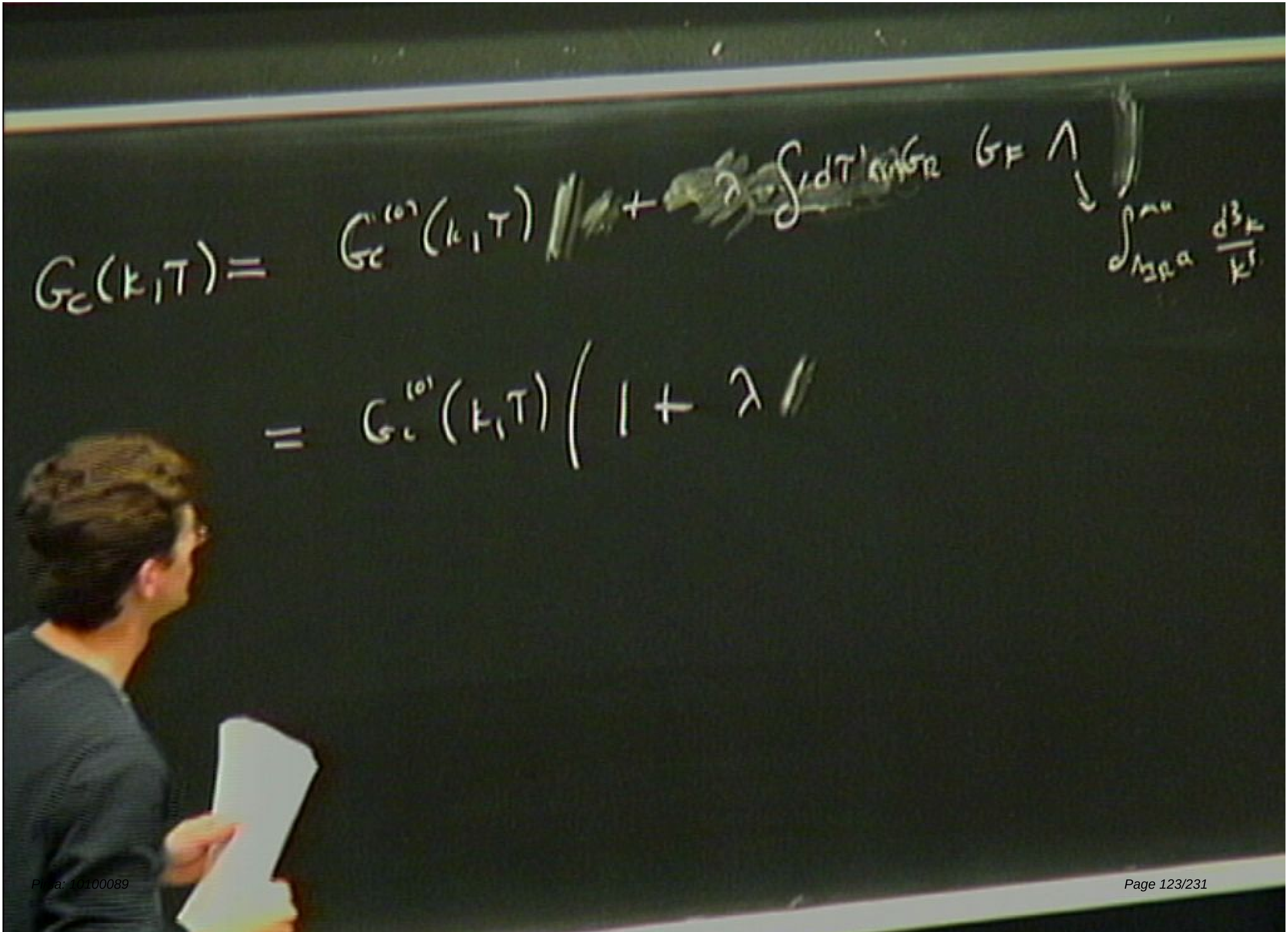
$$= G_c^{(0)}(k,T)\left(1 + \lambda\right.$$



$$G_c(k,T) = G_c^{(0)}(k,T) + \lambda \int dT' \ldots G_R \; G_F \; \Lambda$$

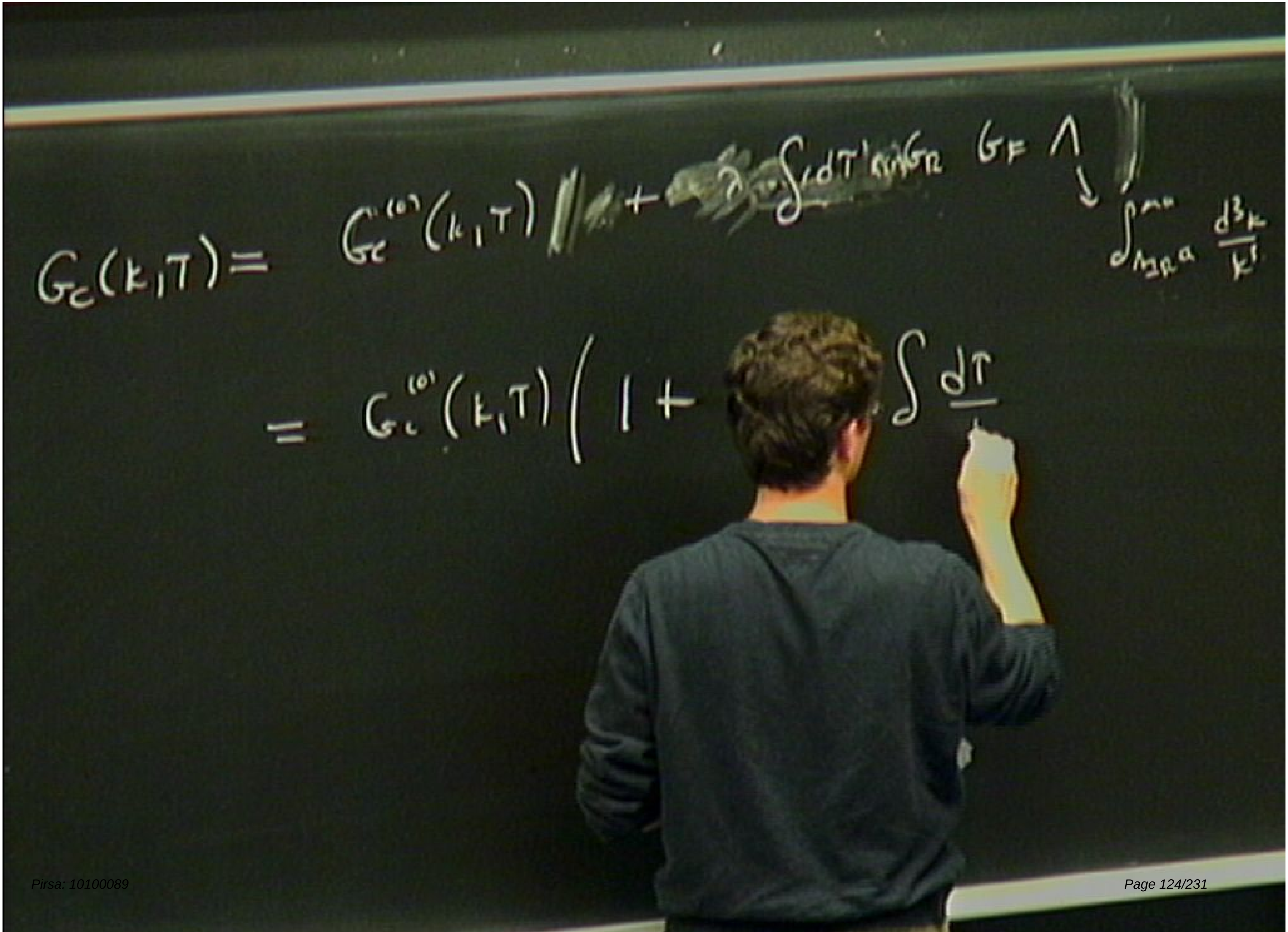
$$\int_{\Lambda_{IR}a}^{m_H} \frac{d^3k}{k^3}$$

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



$$G_c(k,T) = G_c^{(0)}(k,T) + \lambda \int d\tau' G_R \quad G_F \quad \Lambda \rightarrow \int_{\Lambda_{IR}a}^{\Lambda_{UV}} \frac{d^3k}{k^5}$$

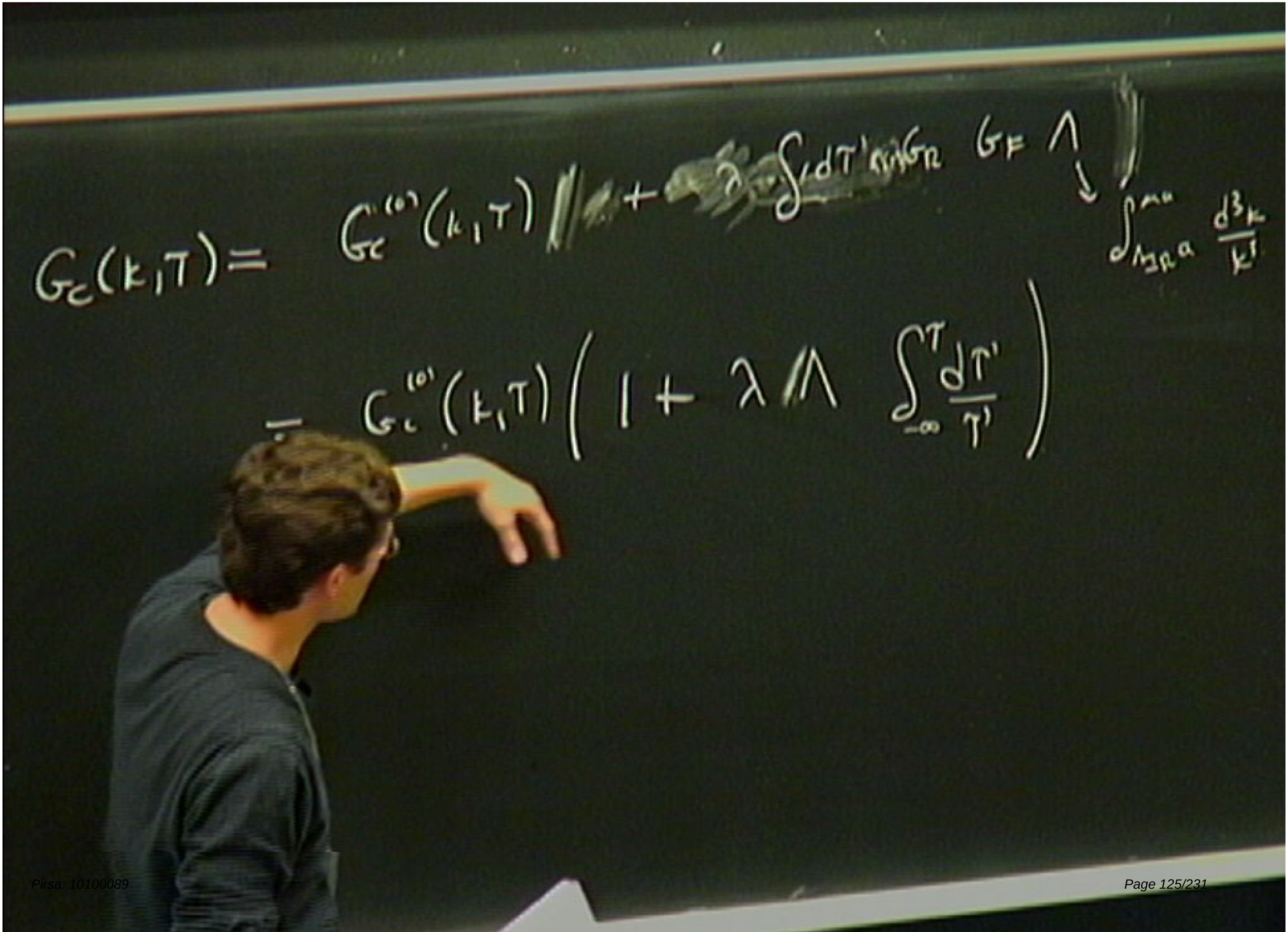
$$= G_c^{(0)}(k,T) \left(1 + \lambda \right.$$



$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, a \, G_R \; G_F \; \Lambda$$

$$\int_{\mu_{IR} a}^{\Lambda a} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau) \left(1 + \int \frac{d\tau}{\tau}\right.$$



$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, [illegible] G_R \; G_F \; \Lambda$$

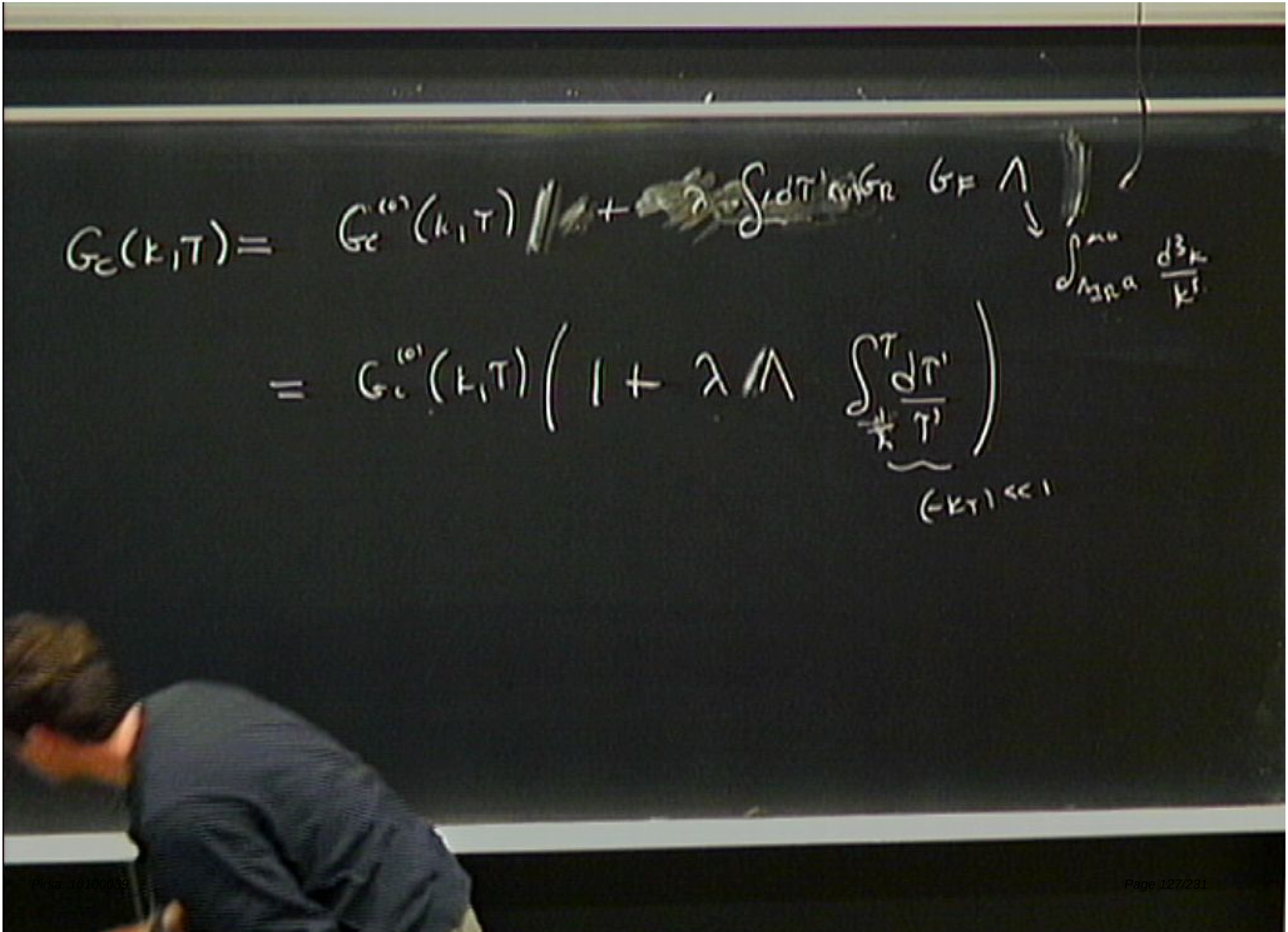
$$\Lambda = \int_{\mu_{IR} a}^{\mu a} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \int_{-\infty}^{\tau} \frac{d\tau'}{\tau'}\right)$$

$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, G_R \, G_F \, \Lambda$$

$$\Lambda \leftrightarrow \int_{\mu_{IR} a}^{\mu a} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \int_{-\infty}^{\tau} \frac{d\tau'}{\tau'} \right)$$



$$G_c(k,\tau) = G_c^{(0)}(k,\tau) \,\|\, + \lambda \int d\tau' \, G_R G_R \; G_F \; \Lambda$$

$$\Lambda \rightarrow \int_{\Lambda_{IR}a}^{\mu a} \frac{d^3k}{k^3}$$

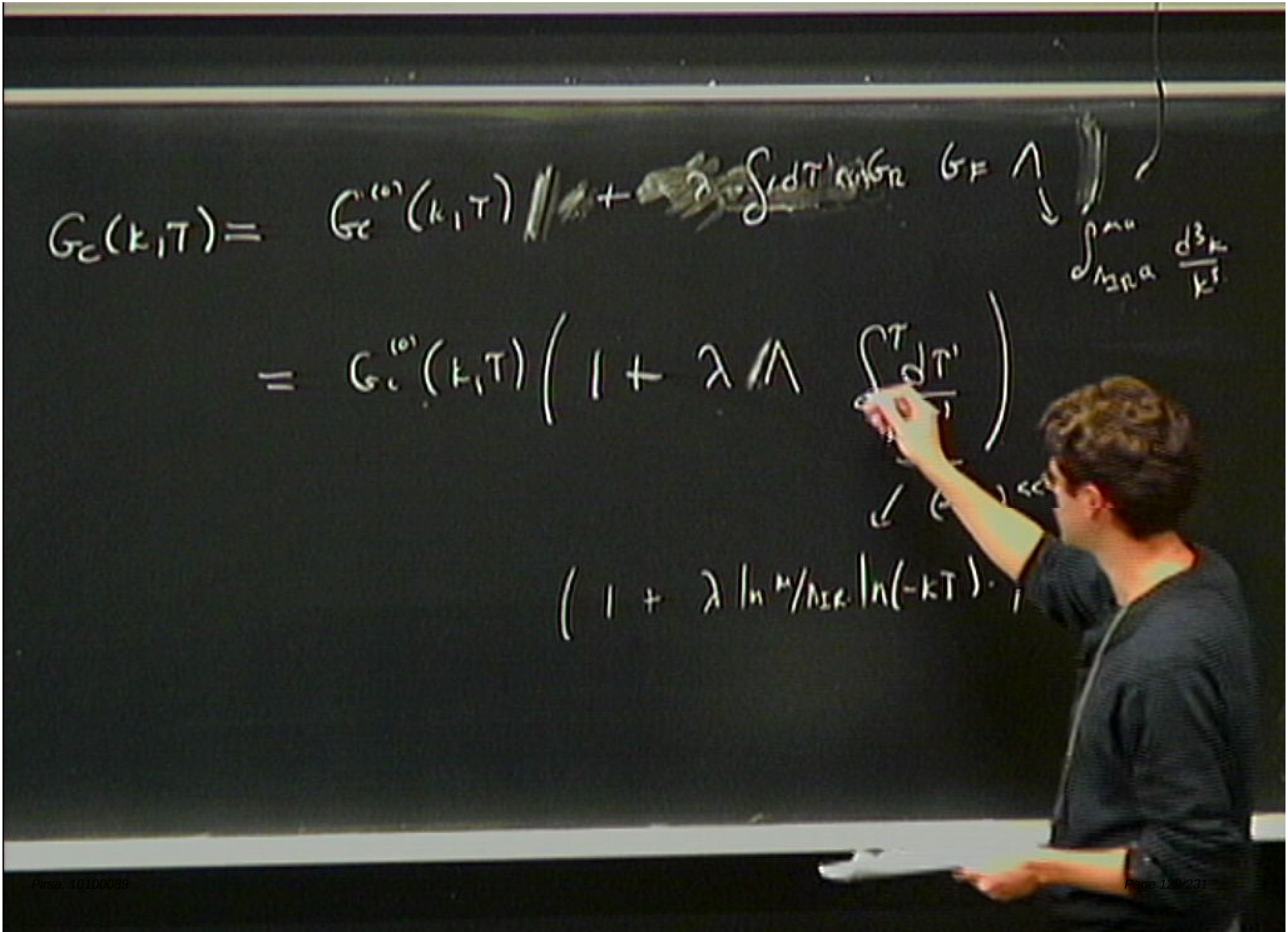
$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \underbrace{\int_{\frac{1}{k}}^{\tau} \frac{d\tau'}{\tau'}}_{(-k\tau) \ll 1}\right)$$

$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, G_R \, G_F \, \Lambda \quad \int_{\Lambda_{IR} a}^{\Lambda_{UV}} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \underbrace{\int_{-\frac{1}{k}}^{\tau} \frac{d\tau'}{\tau'}}\right)$$

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

$$\ln(-k\tau).$$

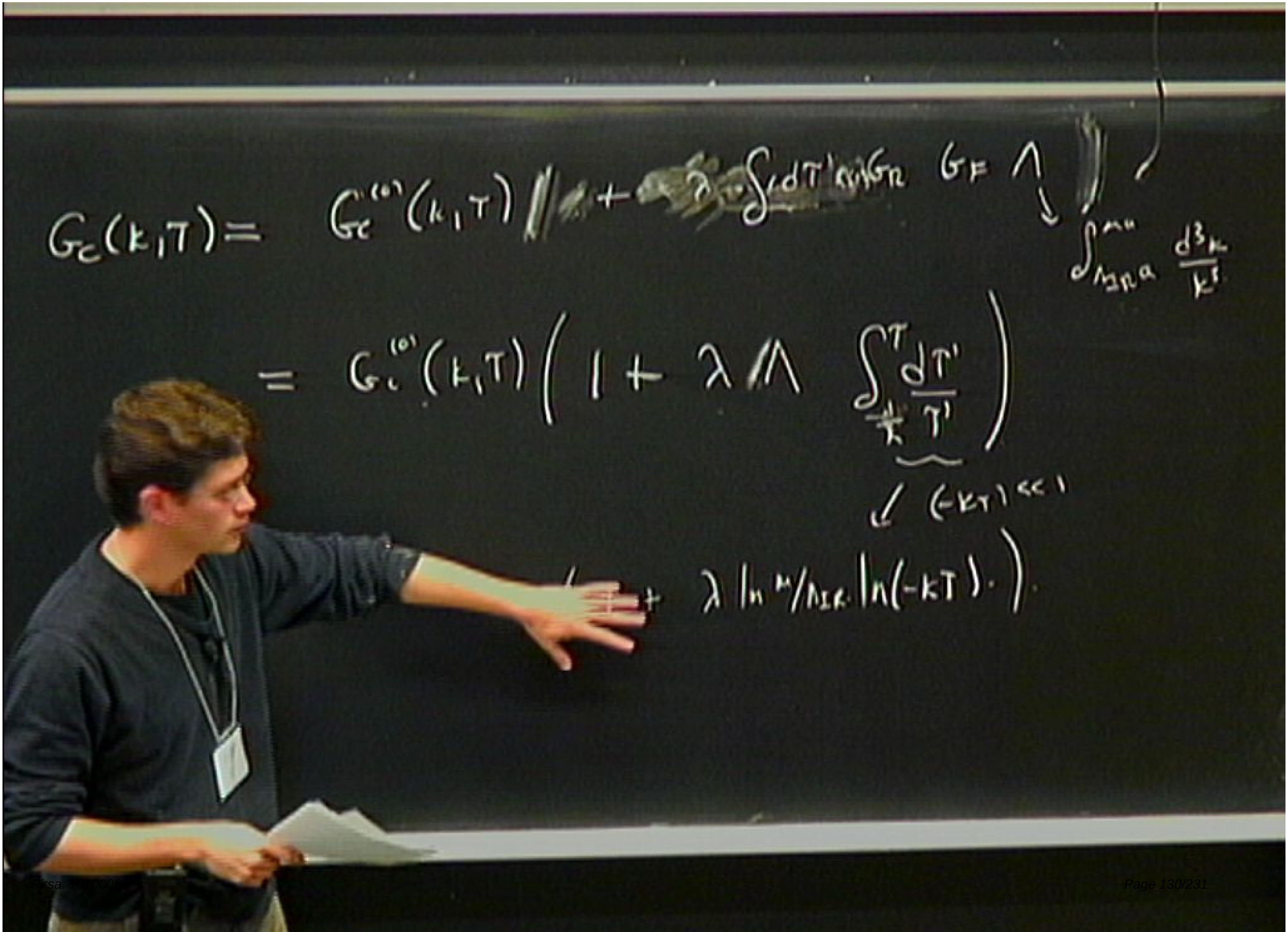


$$G_c(k,\tau) = G_c^{(0)}(k,\tau) \qquad G_F \; \Lambda$$

$$\int_{\mu_{IR}a}^{\mu} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \int^{\tau} d\tau'\right)$$

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



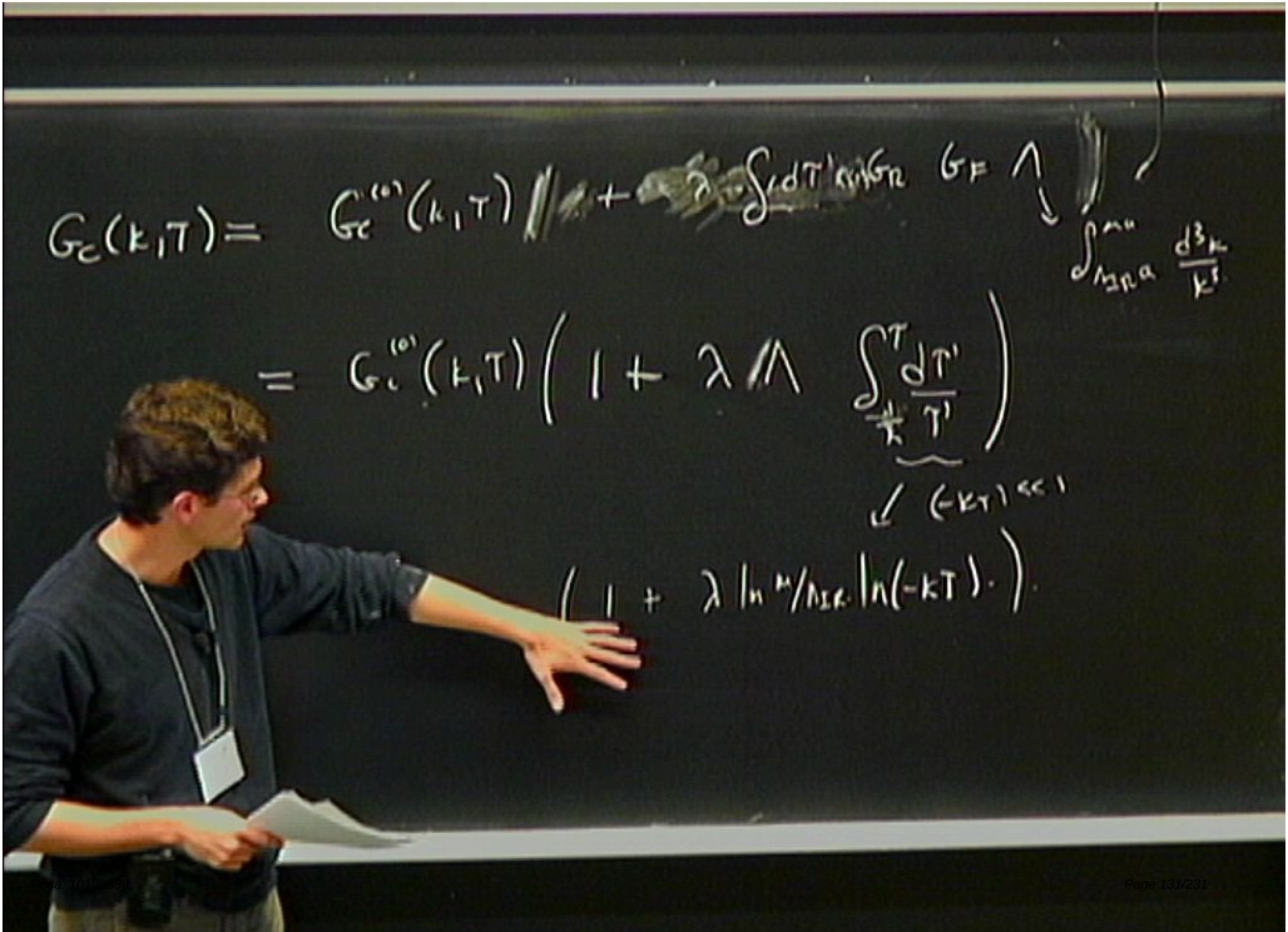
$$G_c(k,\tau) = G_c^{(0)}(k,\tau) \Big(+ \lambda \int d\tau' a(\tau') G_R \; G_F \; \Lambda \Big)$$

$$\Lambda \downarrow \int_{m_{IR}a}^{\mu a} \frac{d^3k}{k^3}$$

$$= G_c^{(0)}(k,\tau) \left(1 + \lambda \Lambda \underbrace{\int_{-\frac{1}{k}}^{\tau} \frac{d\tau'}{\tau'}}_{} \right)$$

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

$$\Big(+ \lambda \ln \mu / m_{IR} \ln(-k\tau). \Big).$$



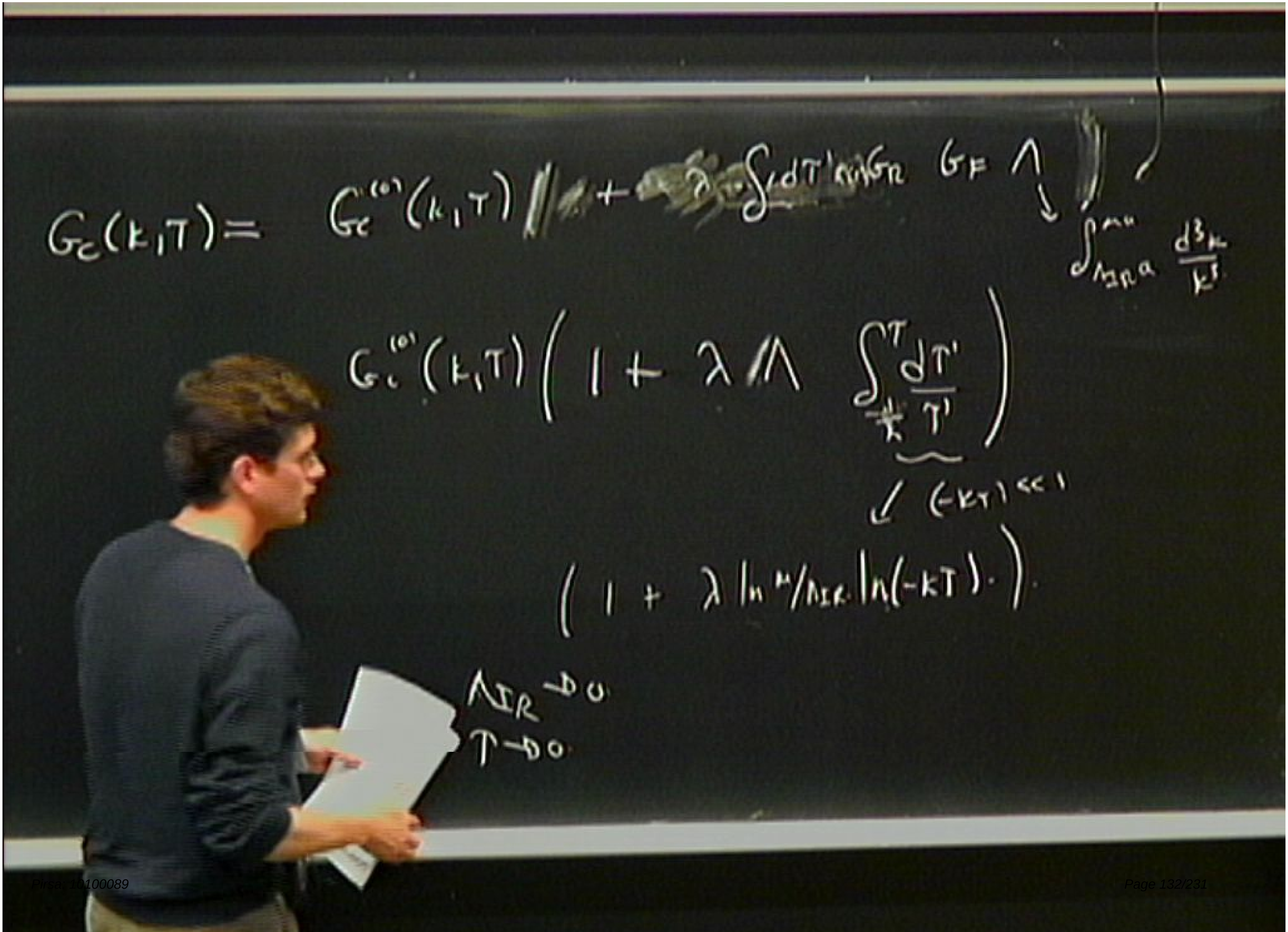
$$G_c(k,T) = G_c^{(0)}(k,T) + \lambda \int dT' \ldots G_R \quad G_F \quad \Lambda$$

$$\Lambda \to \int_{\Lambda_{IR} a}^{\mu a} \frac{d^3k}{k^3}$$

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

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

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



$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, G_R \; G_F \; \Lambda$$

$$\Lambda \to \int_{\Lambda_{IR}a}^{\mu a} \frac{d^3k}{k^3}$$

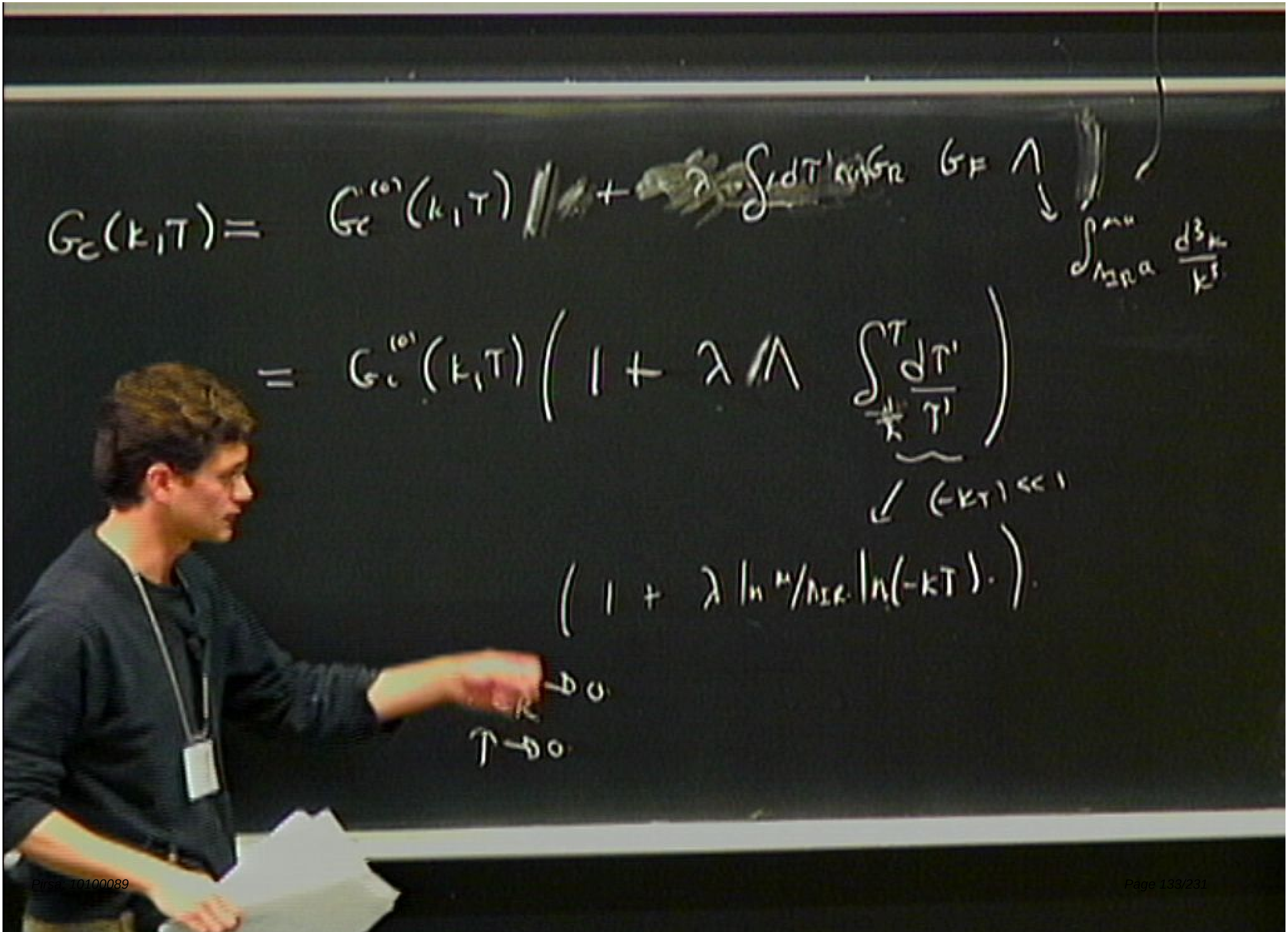
$$G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \underbrace{\int_{-1/k}^{\tau} \frac{d\tau'}{\tau'}}\right)$$

$(-k\tau) \ll 1$

$$\left(1 + \lambda \ln \mu/\Lambda_{IR} \ln(-k\tau).\right).$$

$\Lambda_{IR} \to 0$

$\tau \to 0.$



$$G_c(k,T) = G_c^{(0)}(k,T) + \lambda \int dT' \, G_R \, G_F \, \Lambda$$

$$\Lambda \rightarrow \int_{\mu_{IR} a}^{\mu} \frac{d^3k}{k^3}$$

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

$$\swarrow \quad (-kT) \ll 1$$

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

$\to 0$

k

$T \to 0$

$$G_c(k,\tau) = G_c^{(0)}(k,\tau) \,\|\, + \lambda \int d\tau' a^4 G_R \, G_F \, \Lambda \,\|$$

$$\Lambda \to \int_{\Lambda_{IR} a}^{\mu a} \frac{d^3k}{k^3}$$

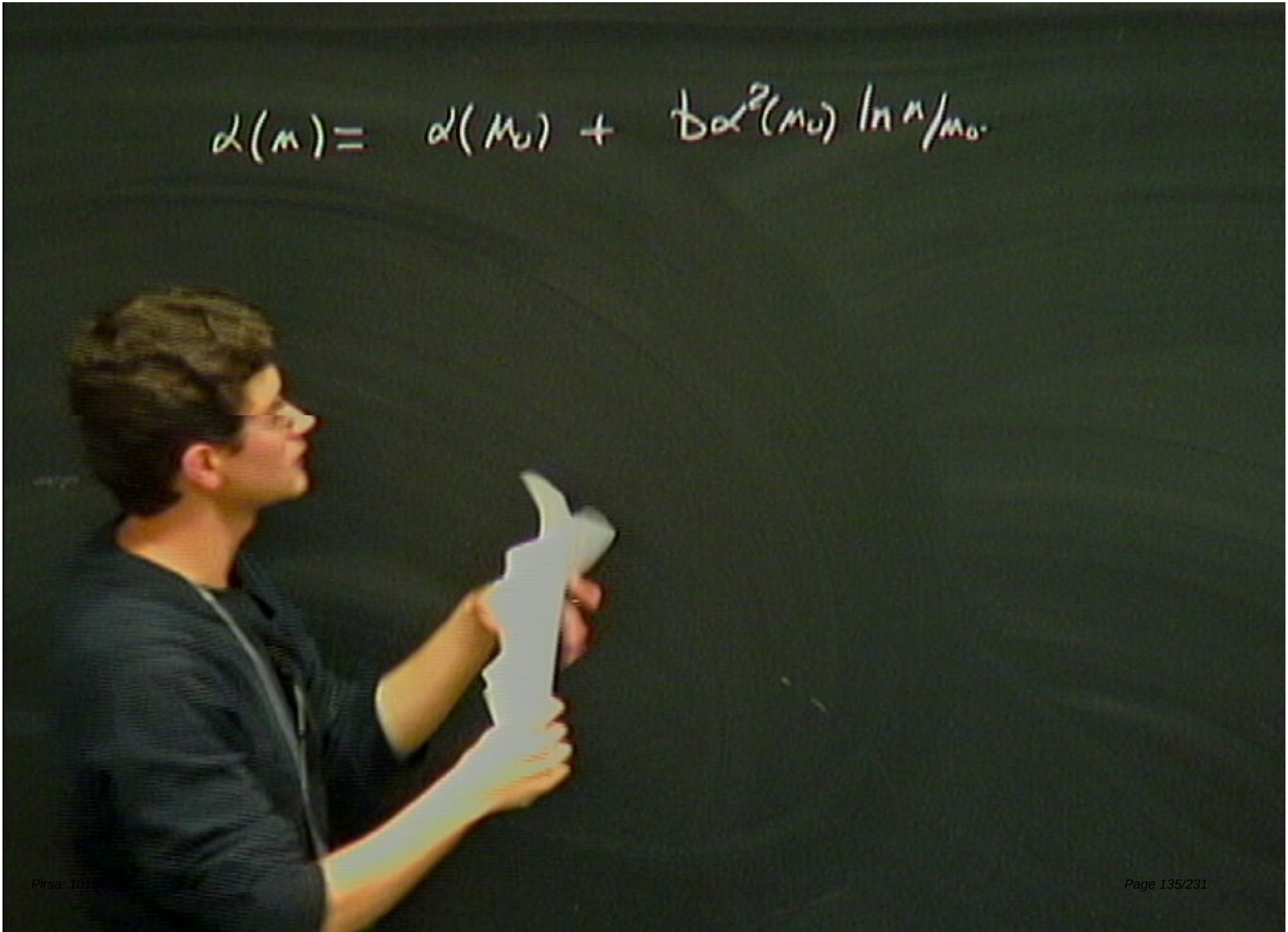
$$= G_c^{(0)}(k,\tau) \left(1 + \lambda \Lambda \underbrace{\int_{\frac{1}{k}}^{\tau} \frac{d\tau'}{\tau'}}\right)$$

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

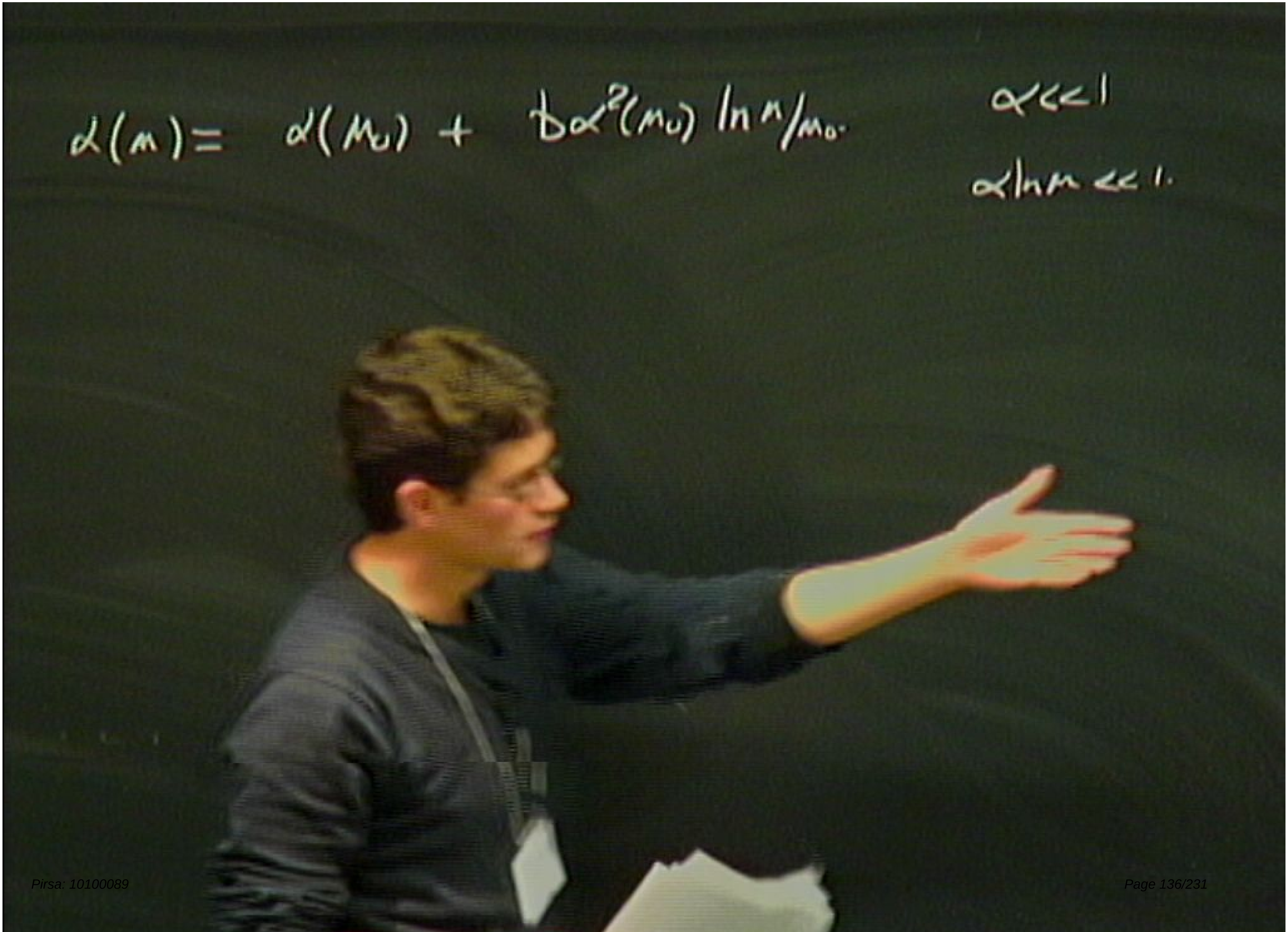
$$\left(1 + \lambda \ln \mu/\Lambda_{IR} \ln(-k\tau) \right)$$

$\Lambda_{IR} \to 0$

$\tau \to 0$



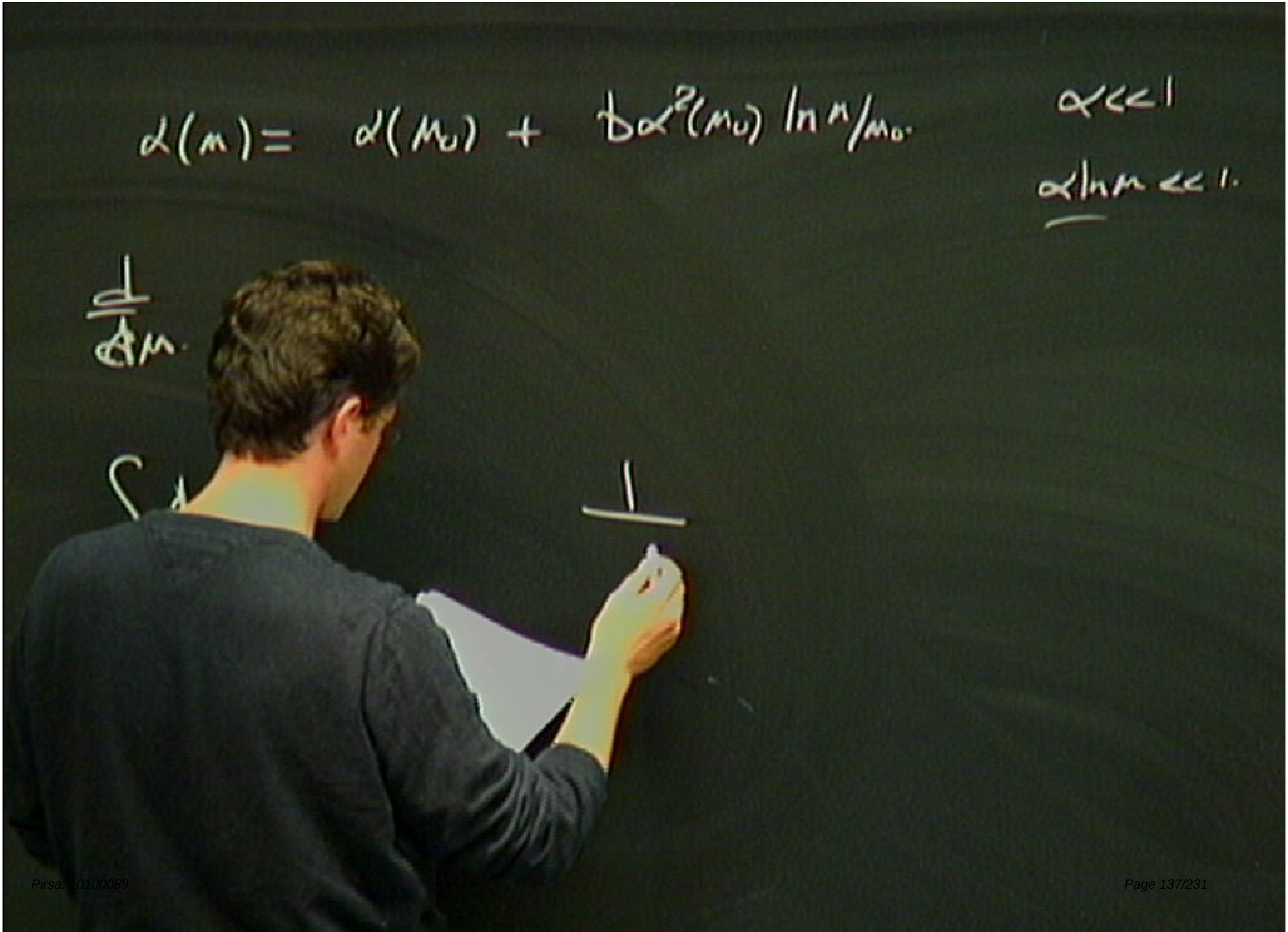
$$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0 .$$



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

$\alpha \ll 1$

$\alpha \ln m \ll 1.$



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

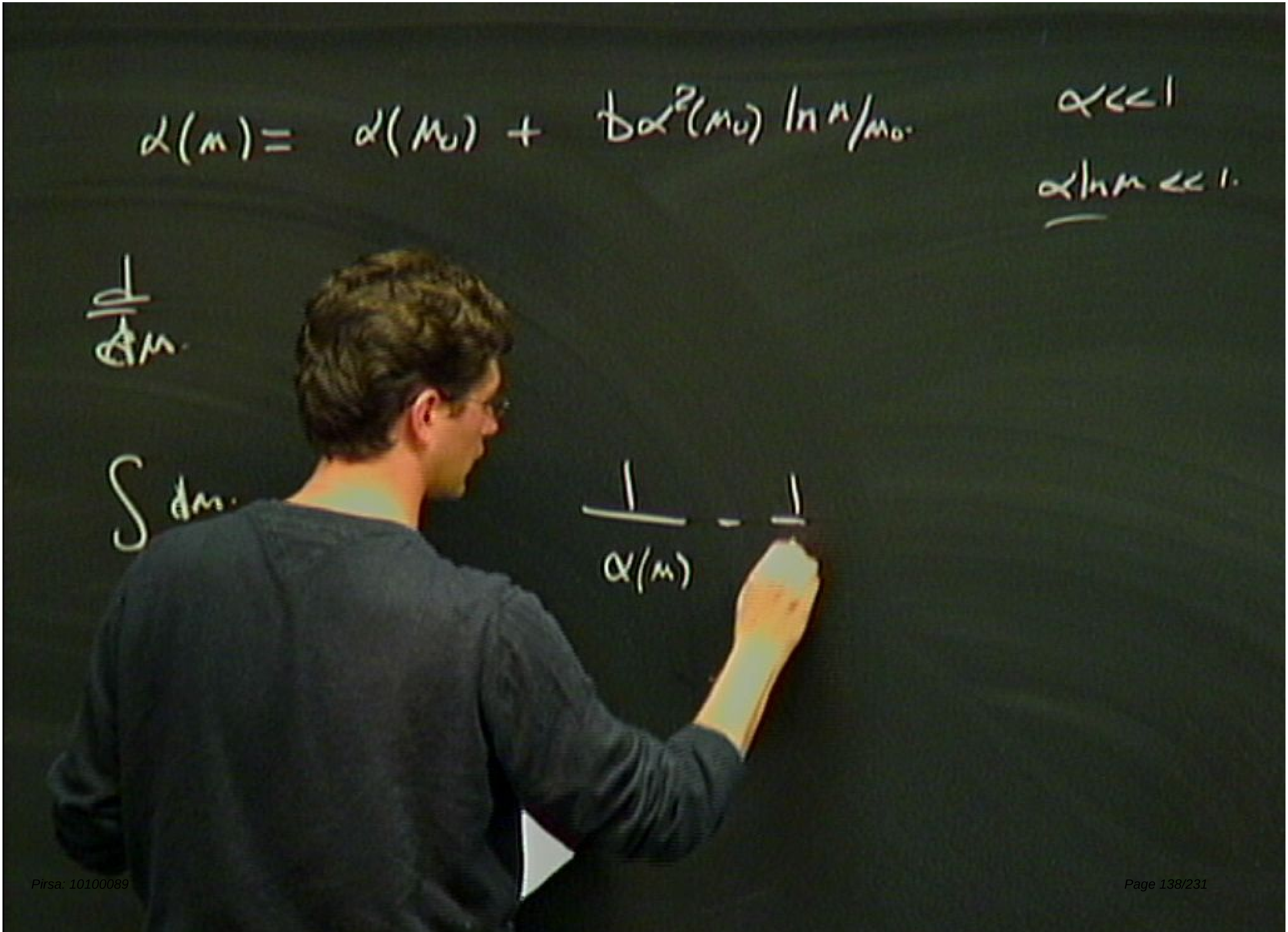
$\alpha \ll 1$

$\alpha \ln m \ll 1.$

$\frac{d}{dm}.$

$\int$

$\frac{1}{\ }$



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

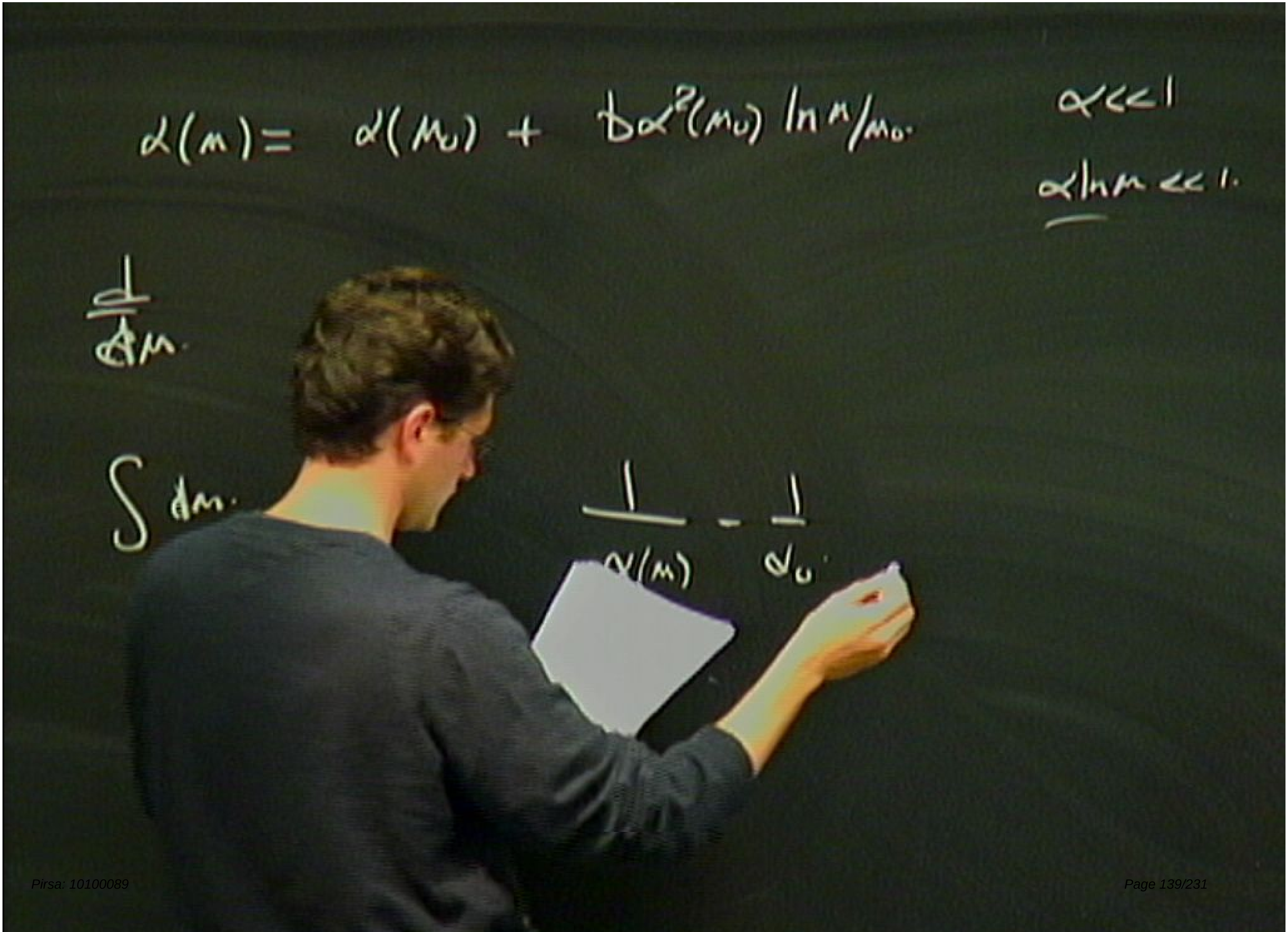
$\alpha \ll 1$

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

$\frac{d}{dm}.$

$\int dm.$

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



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

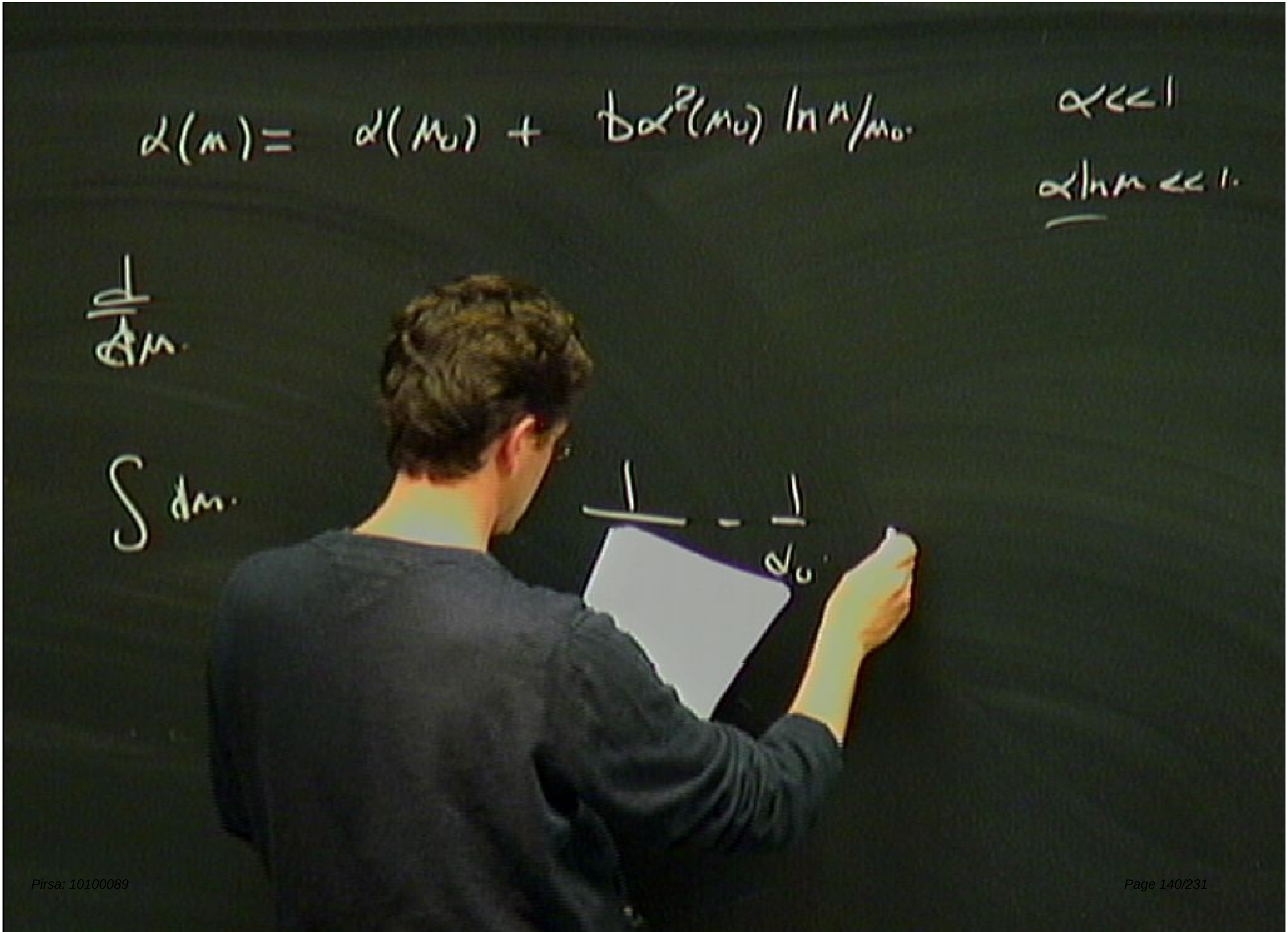
$\alpha \ll 1$

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

$\frac{d}{dm}.$

$\int dm.$

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



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

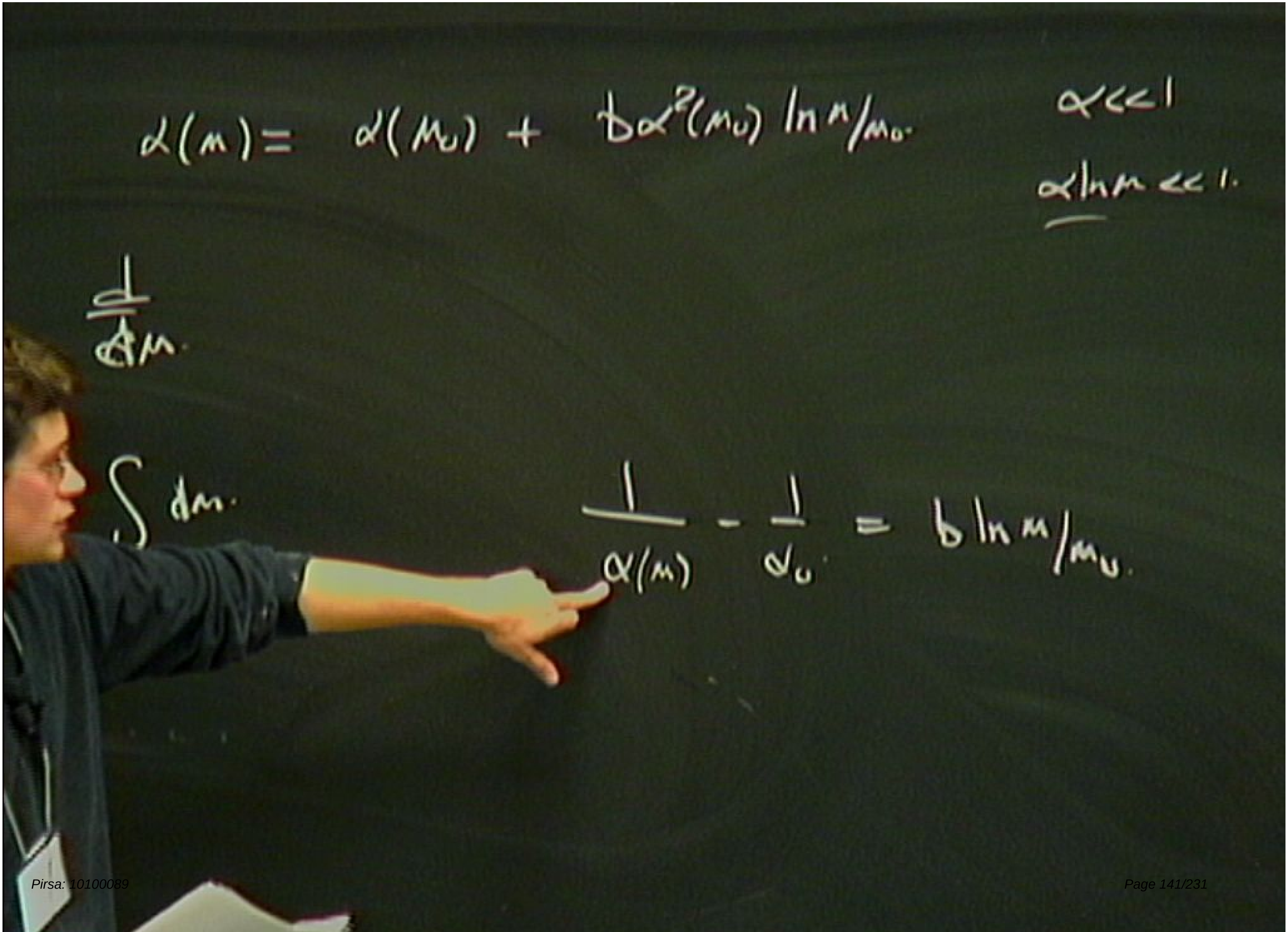
$\alpha \ll 1$

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

$\frac{d}{dm}.$

$\int dm.$

$\frac{1}{} - \frac{1}{\alpha_0}.$



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

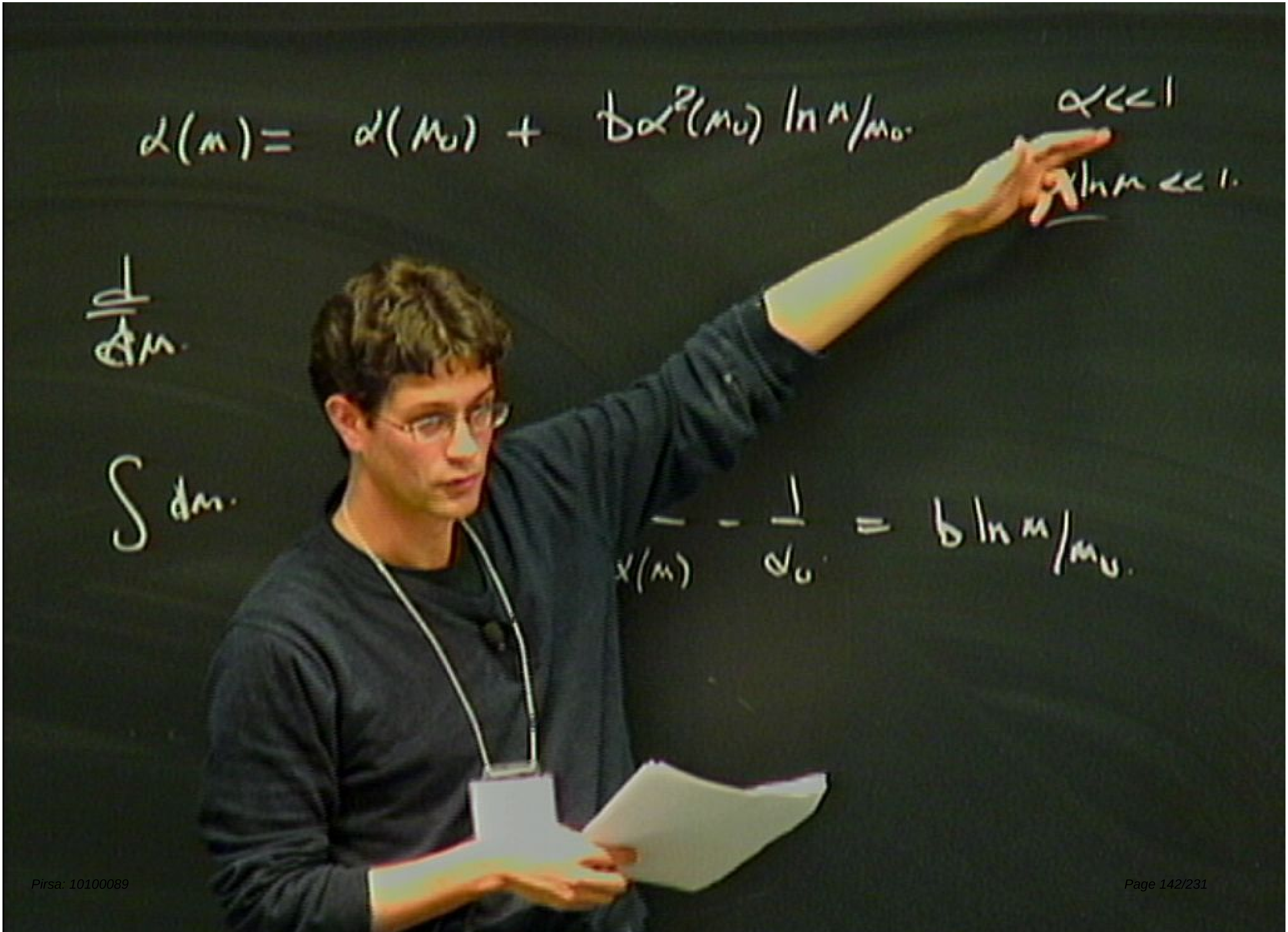
$\alpha \ll 1$

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

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

$$\int dm.$$

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


$\alpha(m) = \alpha(m_0) + b\alpha^2(m_0) \ln m/m_0.$
$\alpha \ll 1$
$\alpha \ln m \ll 1.$
$\frac{d}{dm}.$
$\int dm.$
$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0.$

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

$\alpha \ll 1$

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

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

$$\int dm$$

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

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

$\alpha \ll 1$

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

$\frac{d}{dm}.$

$\int dm.$

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

$y(t) =$

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

$\alpha \ll 1$

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

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

$$\int dm.$$

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

$$y(t) =$$

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

$\alpha \ll 1$

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

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

$$\int dm.$$

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

$$y(t) =$$

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

$\alpha \ll 1$

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

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

$$\int dm.$$

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

$$y(t) =$$

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

$\alpha \ll 1$

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

$\frac{d}{\quad m.}$

$\int dm.$

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

$$y(t) = y_0 + \epsilon y_1(t).$$

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

$\alpha \ll 1$

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

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

$$\int dm$$

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

$$y(t) = y_0 + \epsilon y_1(t)$$

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

$\alpha \ll 1$

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

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

$$\int dm$$

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

$$y(t) = y_0 + \epsilon y_1(t)$$

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

$\alpha \ll 1$

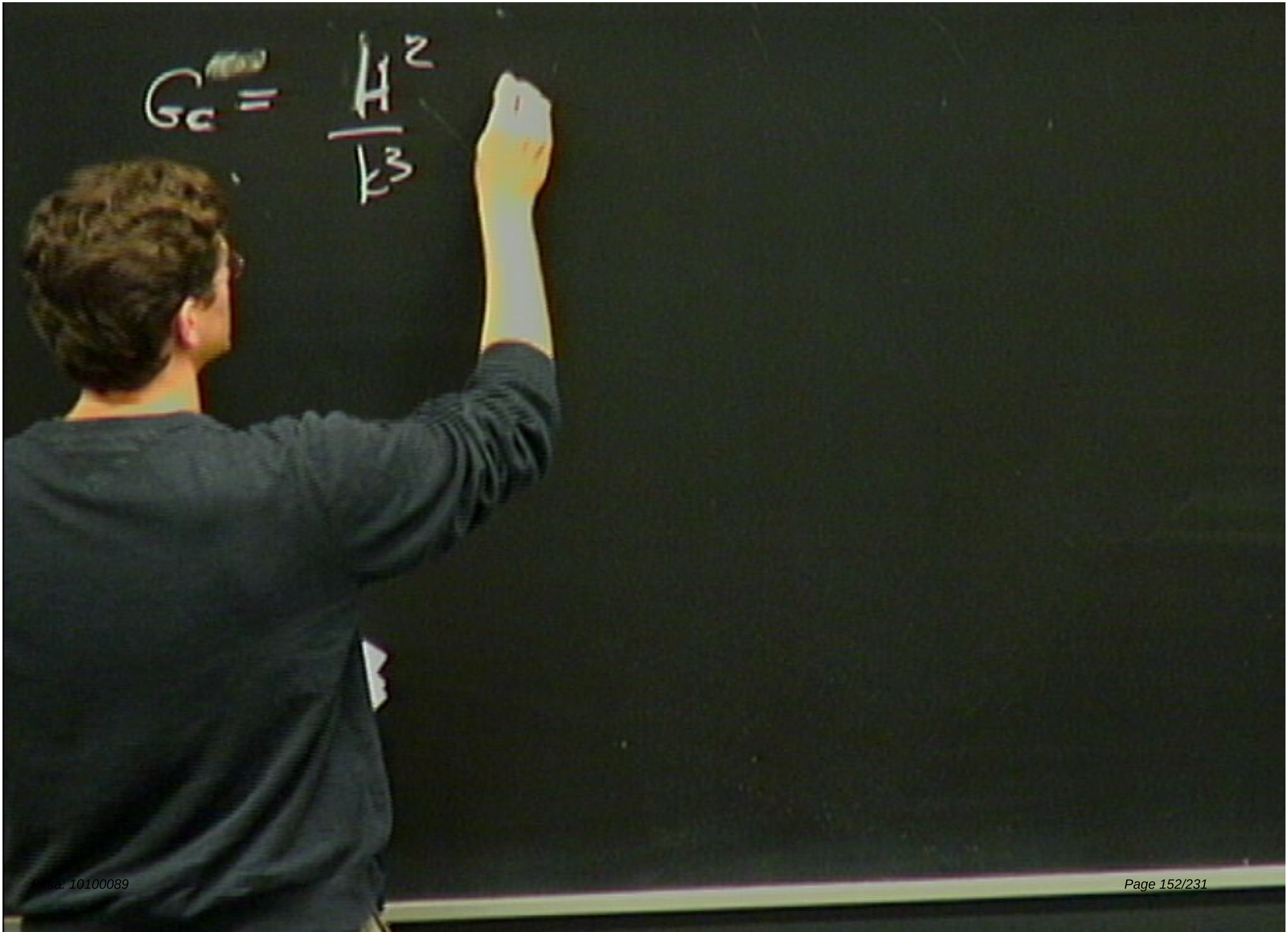
$\underline{\alpha \ln m} \ll 1$

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

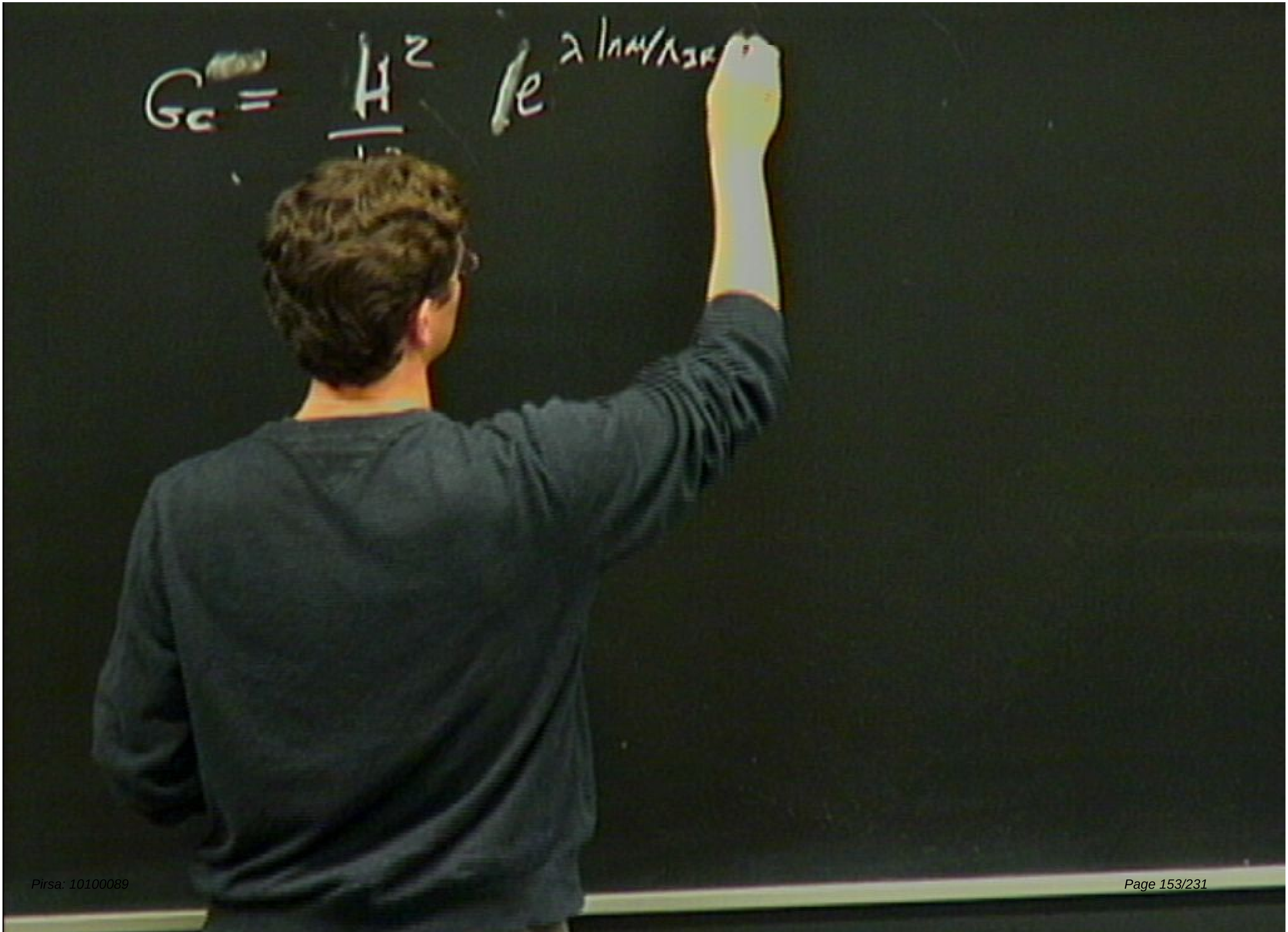
$$\int dm$$

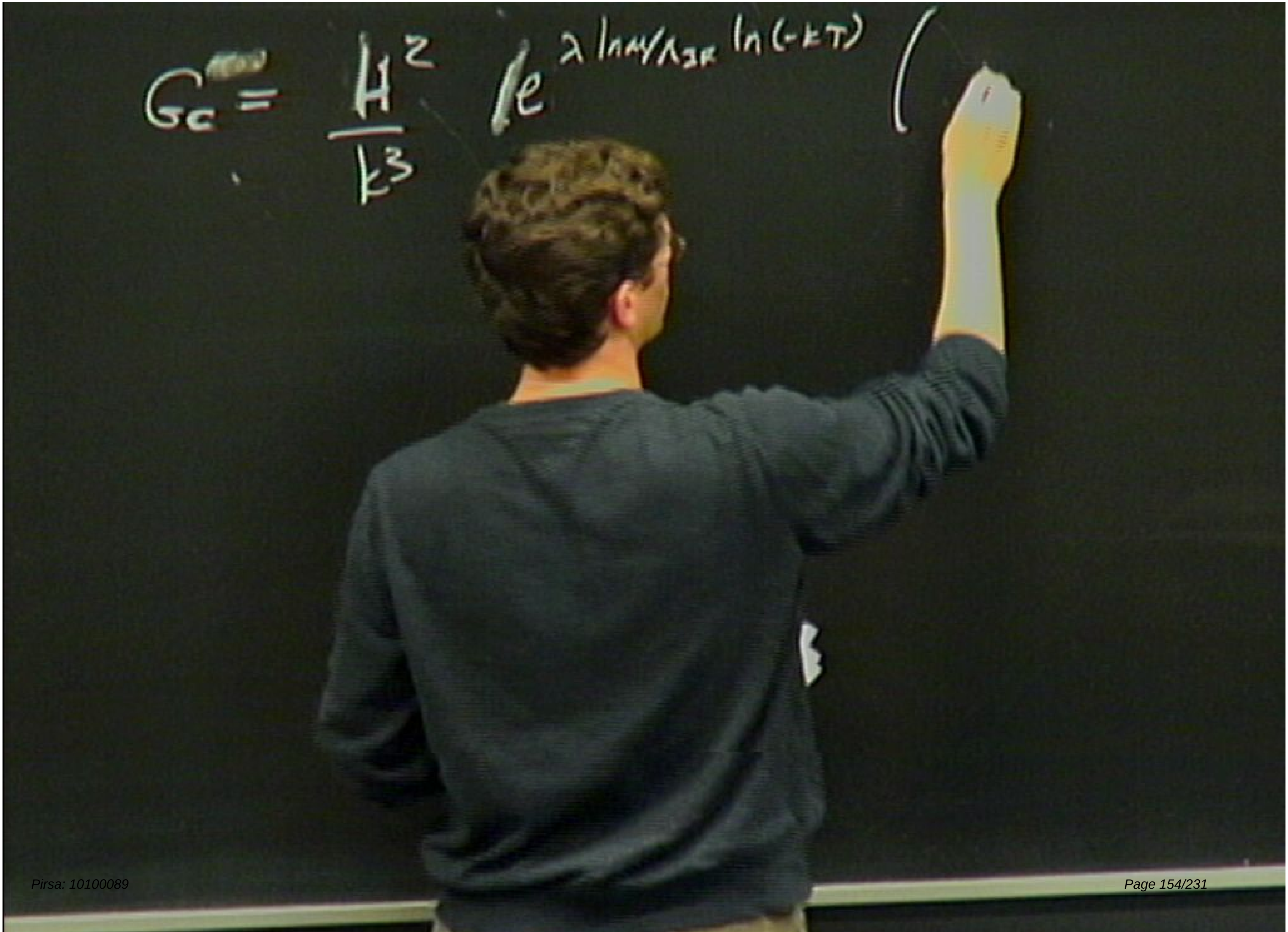
$$\frac{1}{\alpha(m)} - \frac{1}{\alpha_0} = b \ln m/m_0$$

$$y(t) = y_0 + \epsilon y_1(t) + O(\epsilon^2)$$

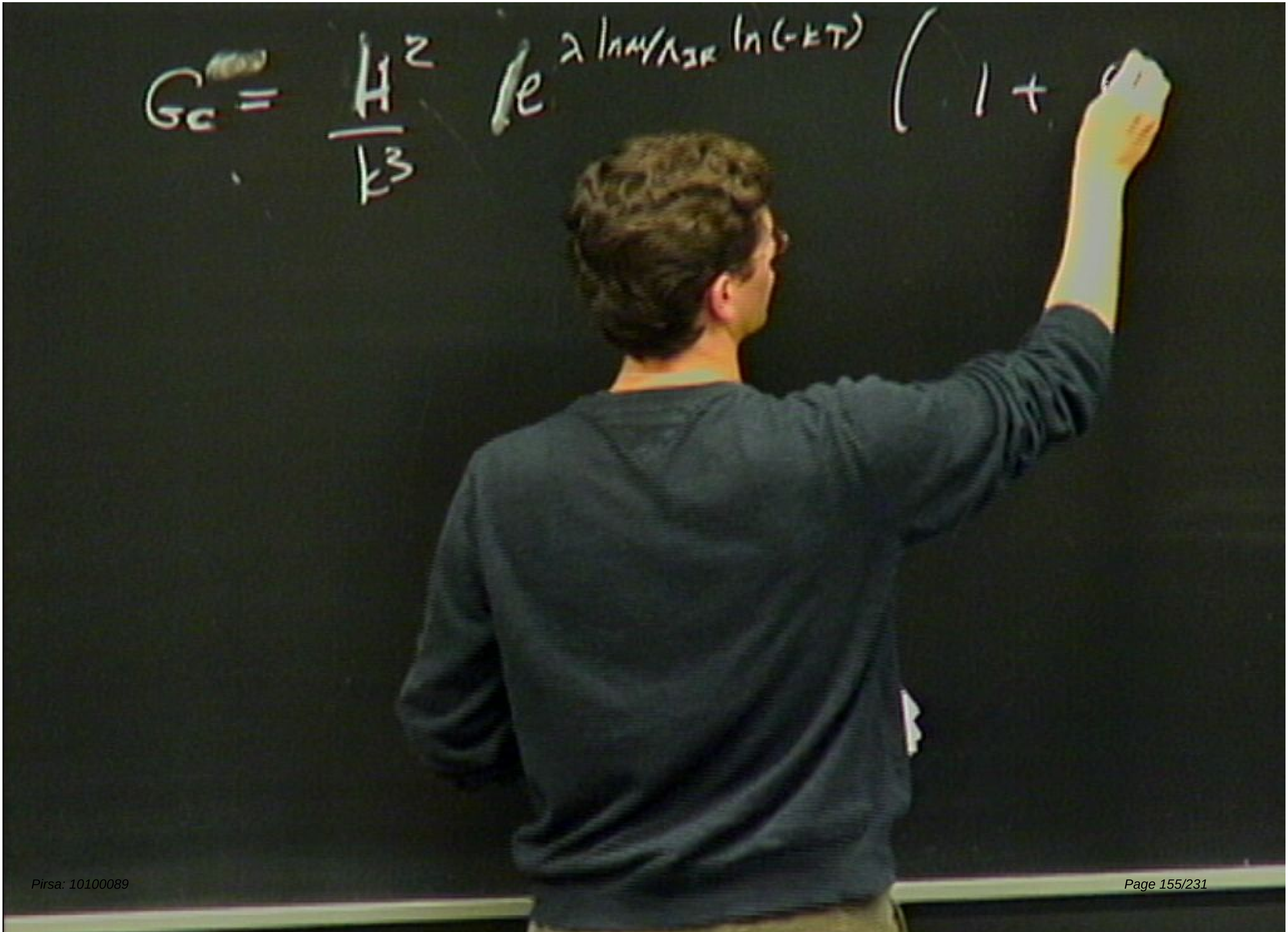


$$G_c = \frac{H^2}{k^3}$$

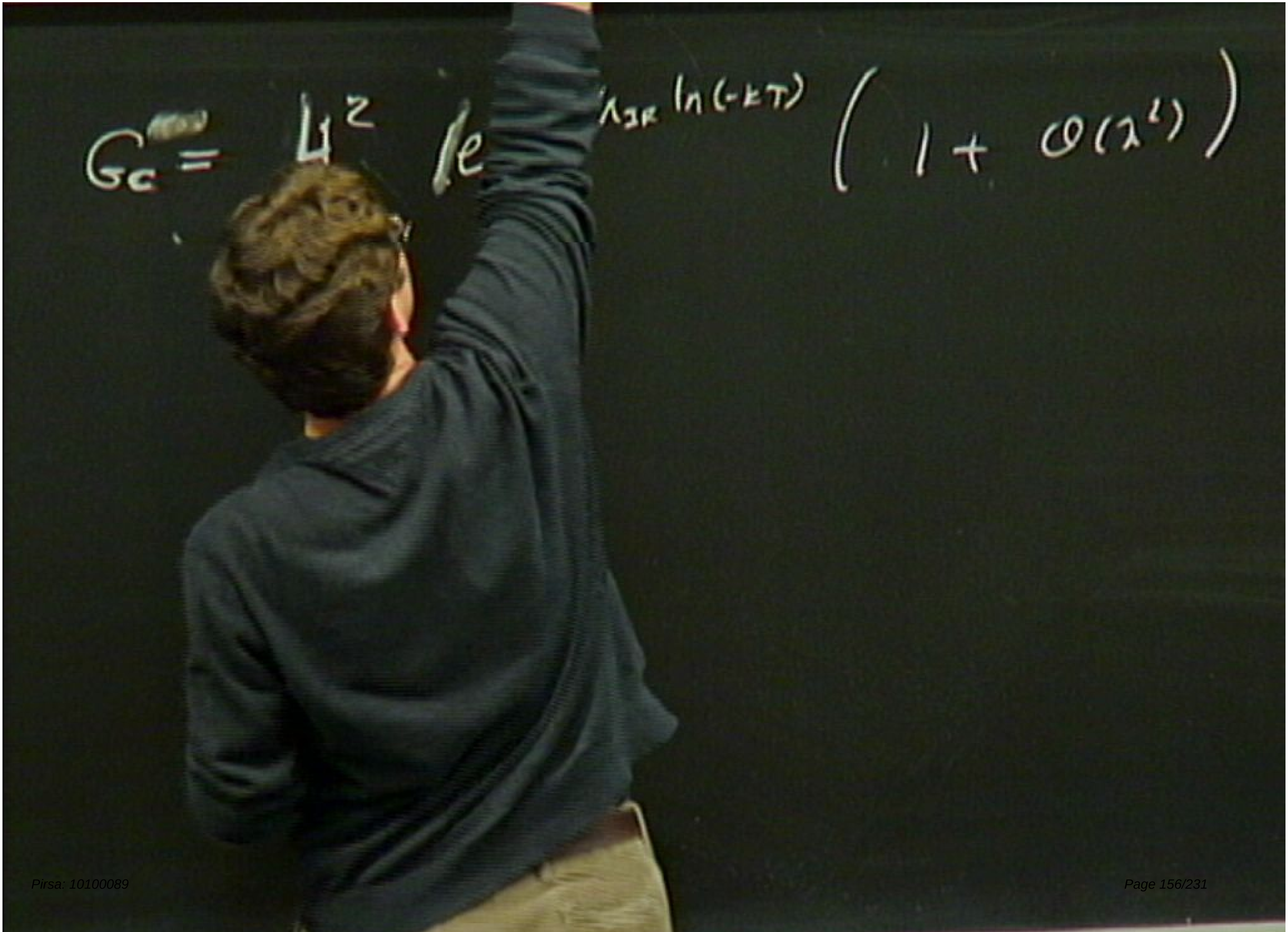

$G_c = \frac{H^2}{\quad} e^{\lambda \ln m/\Lambda_{3R}}$



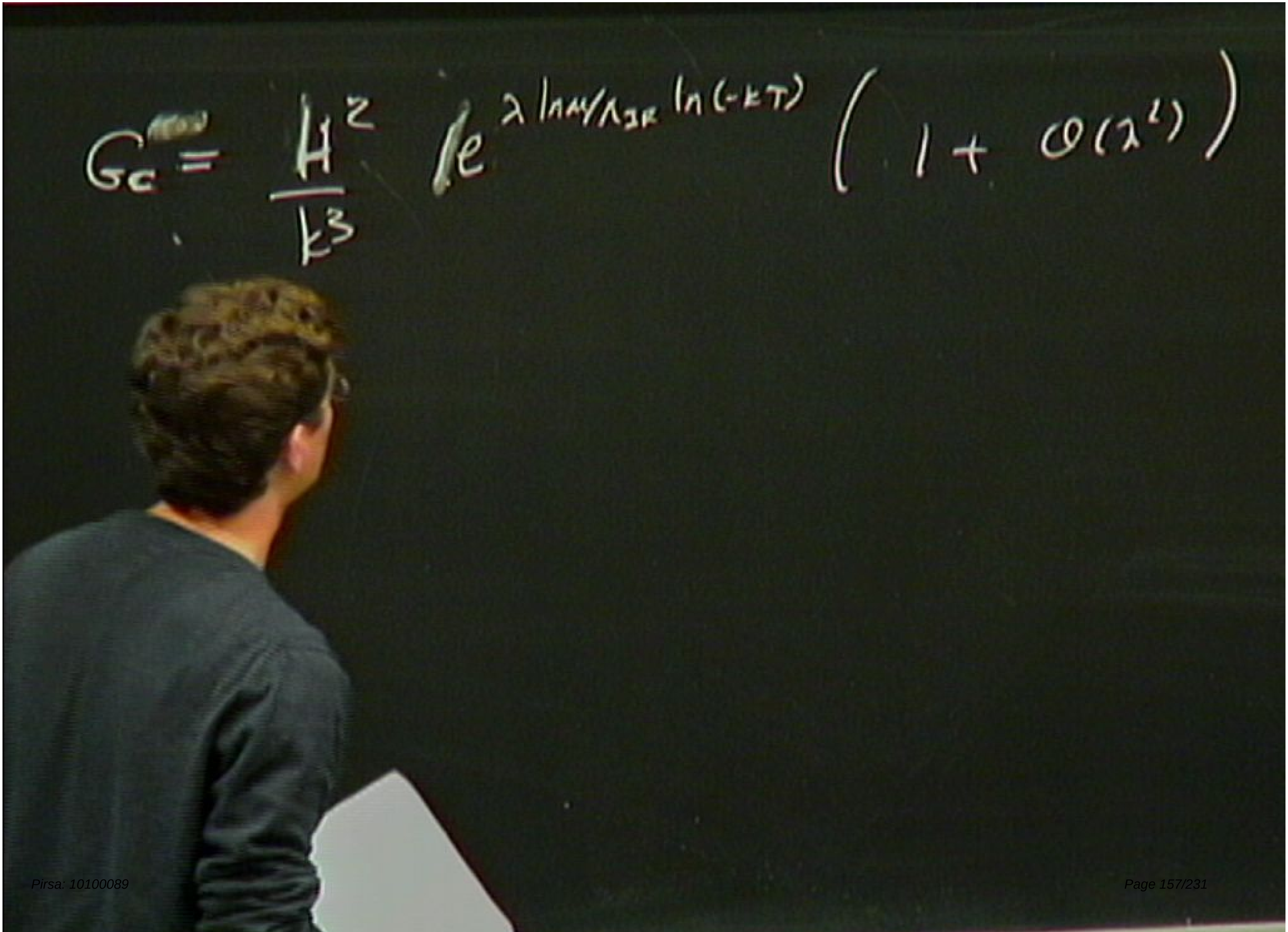
$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu/\Lambda_{IR} \ln(-k\tau)} ($$



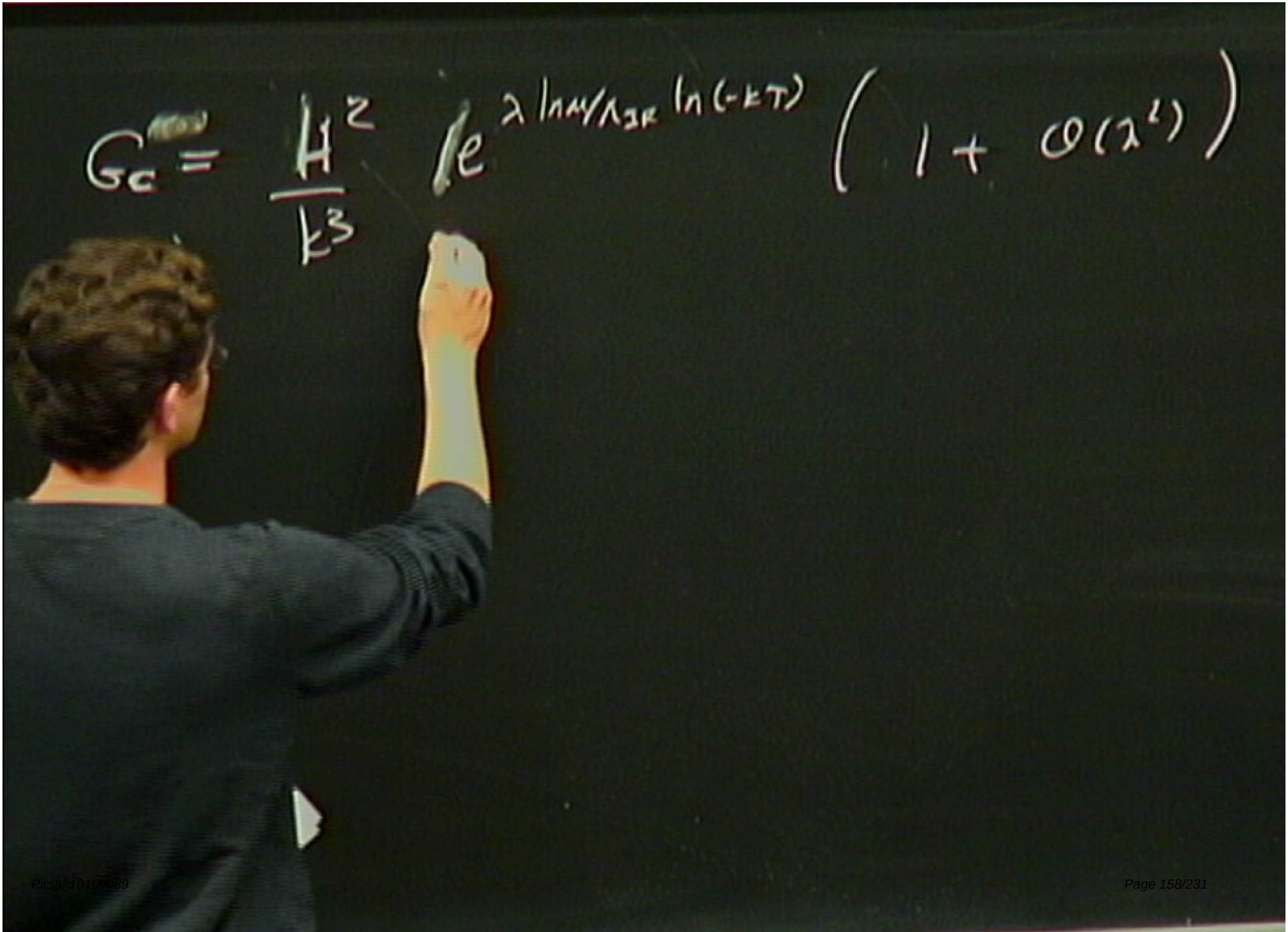
$$G_c = \frac{H^2}{k^3} e^{\lambda \ln M/\Lambda_{IR} \ln(-k\tau)} \Big(1 +$$



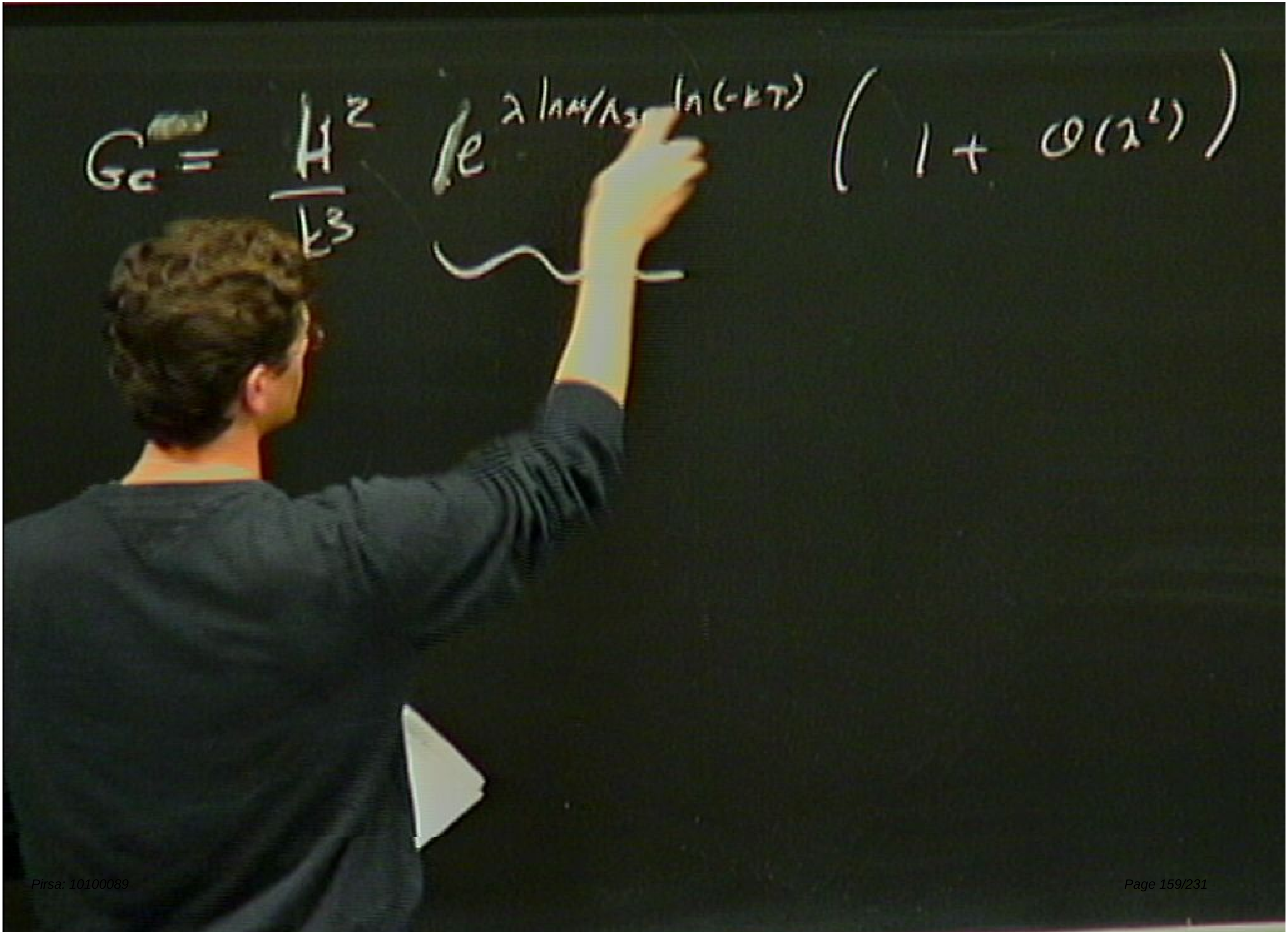
$$G_c = H^2 e^{\lambda_{IR} \ln(-k\tau)} \left(1 + \mathcal{O}(\lambda^2) \right)$$



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

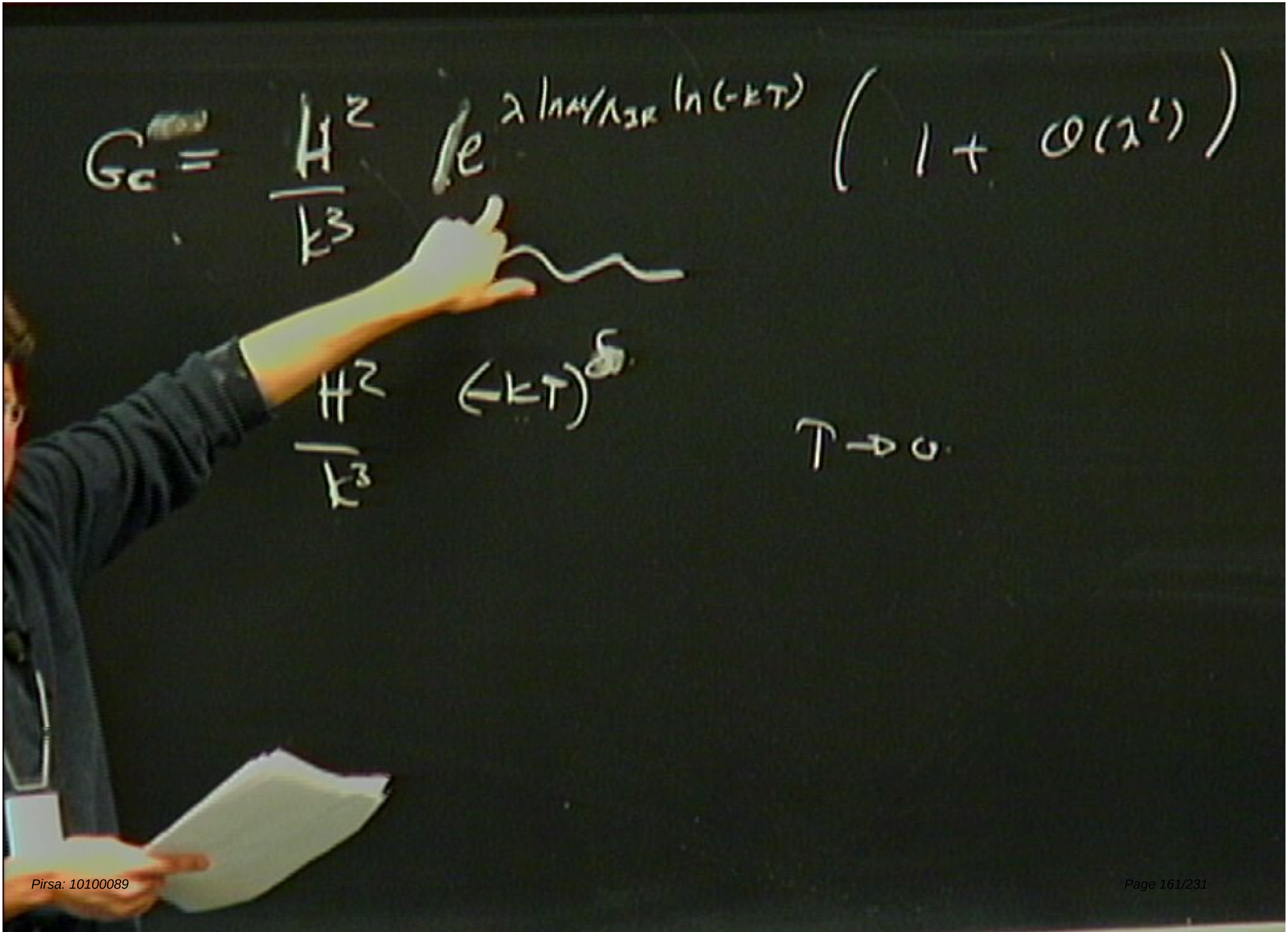


$$G_c = \frac{H^2}{k^3} e^{\lambda \ln \mu/\Lambda_{IR} \ln(-k\tau)} \left(1 + \mathcal{O}(\lambda^2) \right)$$



$$G_c = \frac{H^2}{k^3} \underbrace{e^{\lambda \ln M/\Lambda_3 \ln(-k\tau)}}_{} \left(1 + \mathcal{O}(\lambda^2) \right)$$

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



$$G_c = \frac{H^2}{k^3} e^{\lambda \ln H/\Lambda_{IR} \ln(-k\tau)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

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

$\tau \to 0$

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

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

$$\tau \to 0$$

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

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

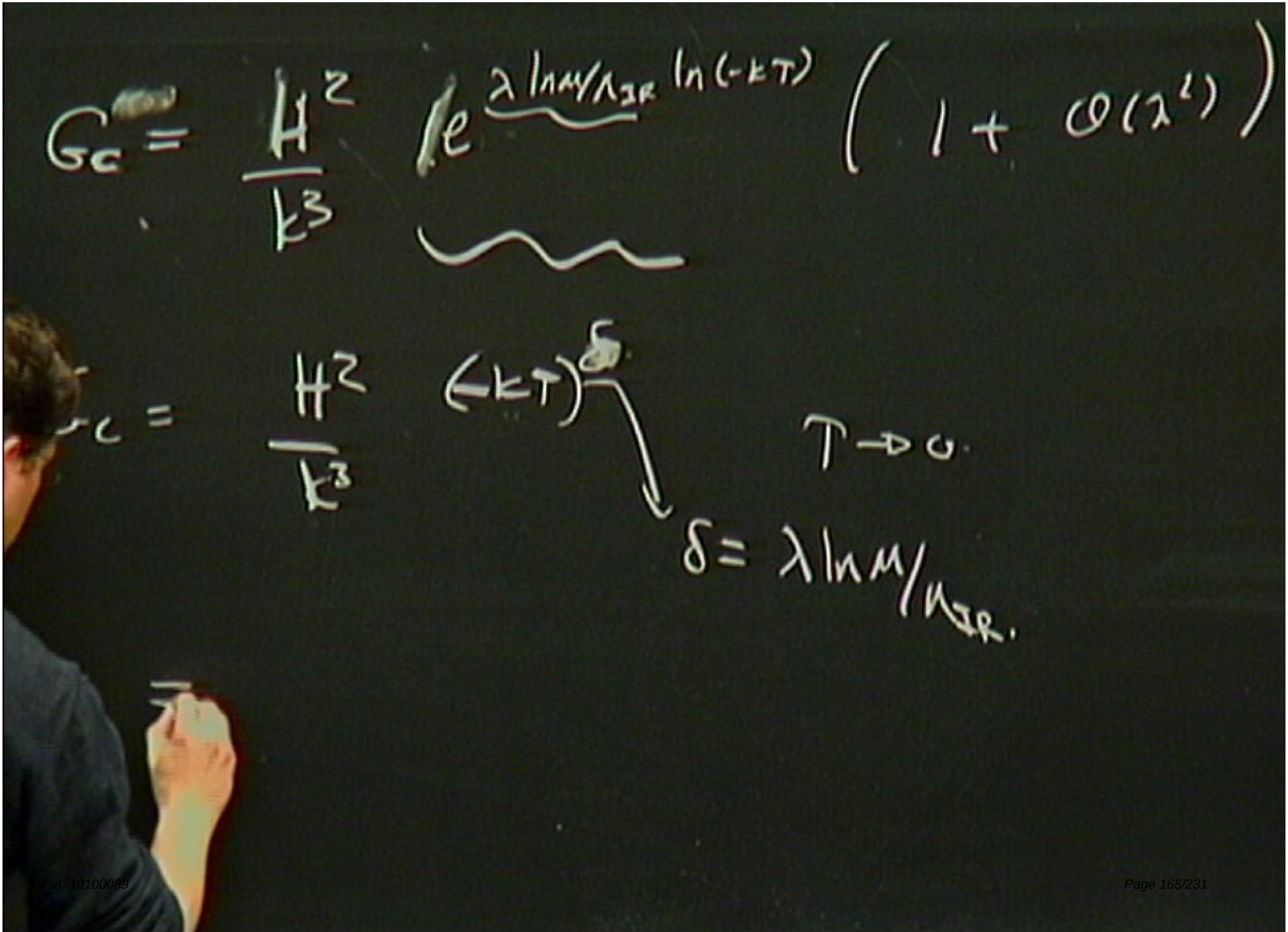
$\tau \to 0$.

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

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

$$\tau \to 0.$$

$$\delta = \lambda \ln M/\Lambda_{IR}.$$



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

$$G_c = \frac{H^2}{k^3} (-k\tau)^{\delta}$$

$\tau \to 0.$

$$\delta = \lambda \ln M/\Lambda_{IR}.$$

$=$

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

$$G_c = \frac{H^2}{k^3} (-k\tau)^{\delta}$$

$\tau \to 0.$

$\delta = \lambda \ln M/\Lambda_{IR}.$

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

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

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

$T \to 0$.

$\delta = \lambda \ln M/\Lambda_{IR}$.

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

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

$$G_c = \frac{H^2}{k^3} (-k\tau)^{\delta}$$

$\tau \to 0$.

$$\delta = \lambda \ln M/\Lambda_{IR}.$$

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

$$G_c = \frac{H^2}{k^3}\, \underline{e^{\underline{\lambda \ln M/\Lambda_{IR}} \ln(-k\tau)}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

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

$\tau \to 0$

$$\delta = \lambda \ln M/\Lambda_{IR}.$$

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

$$G_c = \frac{H^2}{k^3}\, e^{\lambda \ln M/\Lambda_{IR} \ln(-k\tau)} \left(1 + \mathcal{O}(\lambda^2) \right)$$

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

$\tau \to 0$

$$\delta = \lambda \ln M/\Lambda_{IR}.$$

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

$$G_c = \frac{H^2}{k^3} \underline{e^{\underline{\lambda \ln M/\Lambda_{IR}} \ln(-k\tau)}} \left(1 + \mathcal{O}(\lambda^2) \right)$$

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

$\tau \to 0$.

$\delta = \lambda \underline{\ln M/\Lambda_{IR}}.$

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

$$G_c(k,\tau) = G_c^{(0)}(k,\tau) + \lambda \int d\tau' \, [illegible] G_R \; G_F \; \Lambda \qquad \int_{\Lambda_{IR} a}^{\mu a} d$$

$$= G_c^{(0)}(k,\tau)\left(1 + \lambda \Lambda \underbrace{\int_{1/k}^{\tau} \frac{d\tau'}{\tau'}}\right)$$

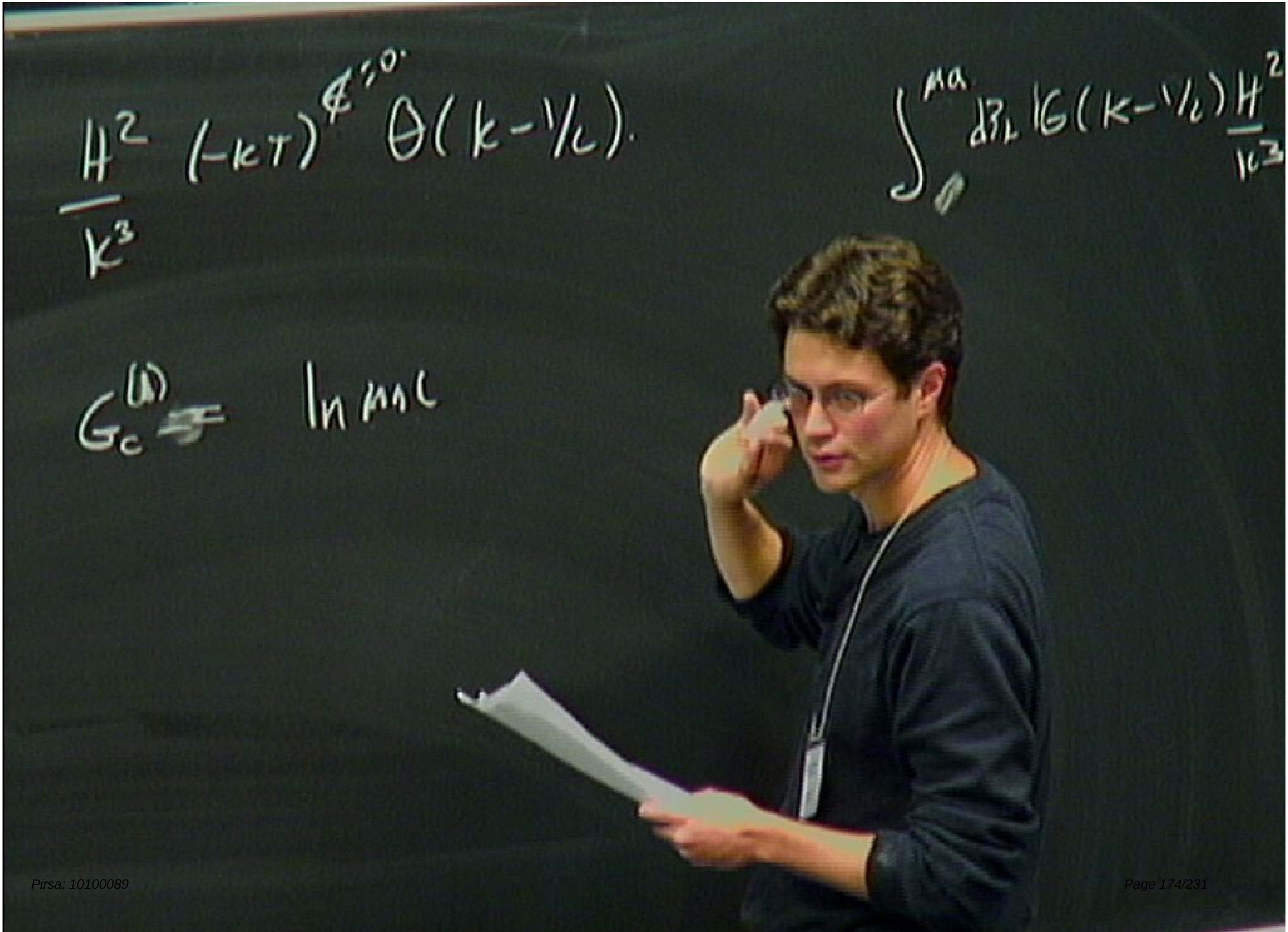
$$(-k\tau) \ll 1$$

$$\left(1 + \lambda \ln \mu/\Lambda_{IR} \, \ln(-k\tau).\right)$$

$\Lambda_{IR} \to 0$

$\tau \to 0$

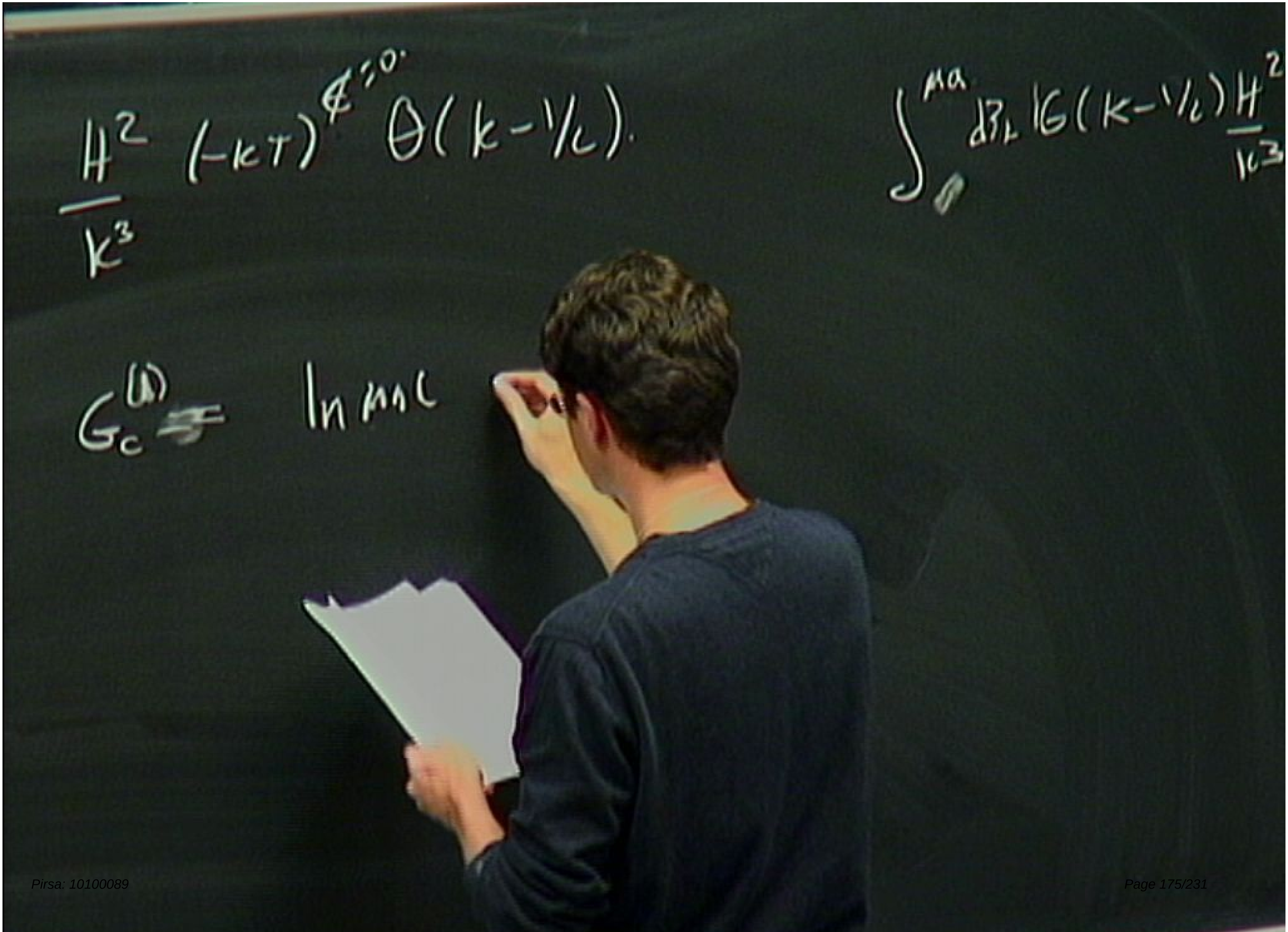
$$\frac{H^2}{k^3}\,(-k\tau)^{\epsilon}\;\theta(k-1/L).$$



$$\frac{H^2}{k^3}(-k\tau)^{\epsilon\approx 0}\,\Theta(k-1/L).$$

$$\int_{0}^{Ma} d\ln k\,\Theta(k-1/L)\frac{H^2}{k^3}$$

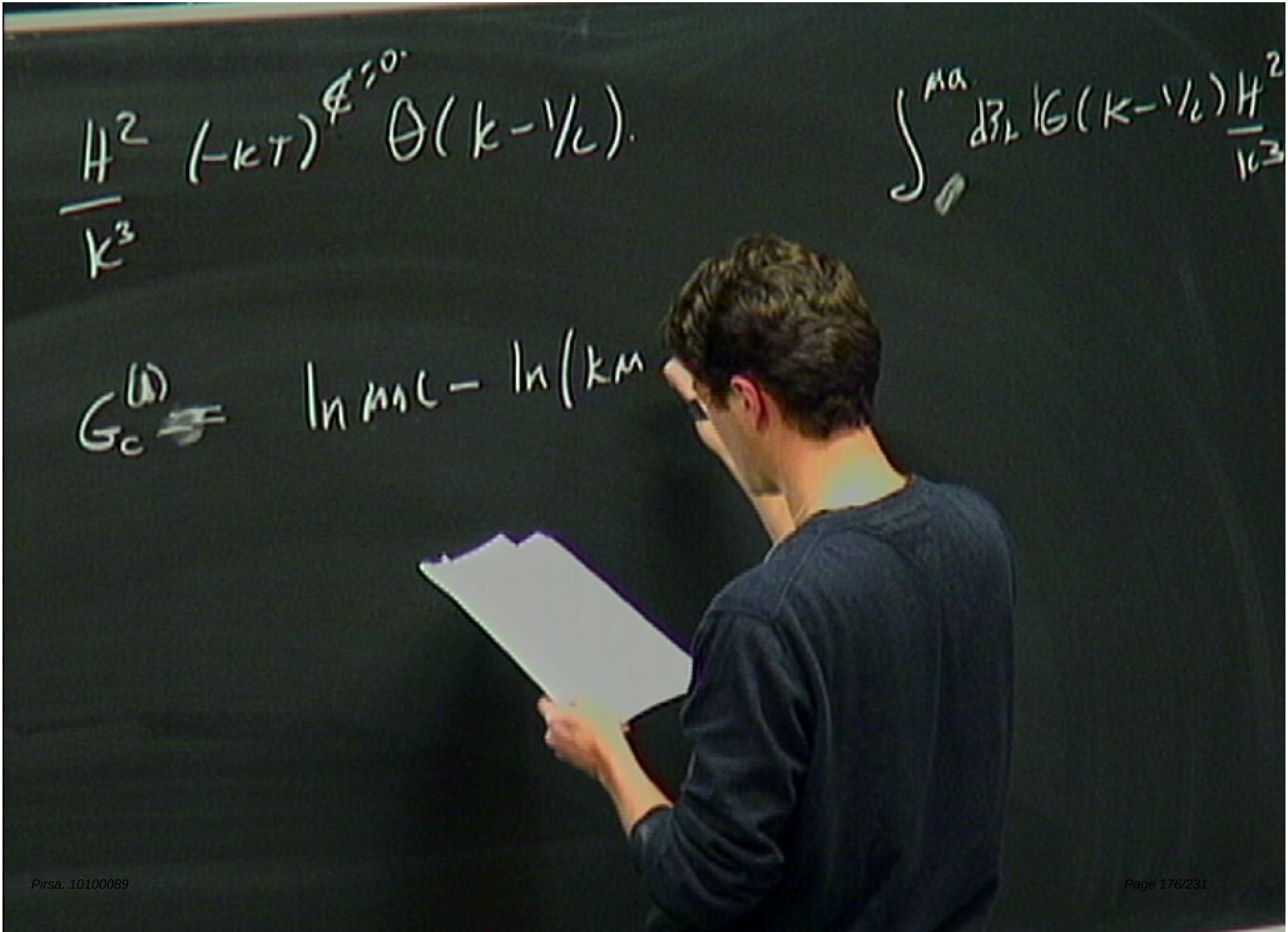
$$G_L^{(1)} = \quad \ln maL$$



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

$$\int^{Ma} d\ln L\, \Theta(k - 1/L)\frac{H^2}{k^3}$$

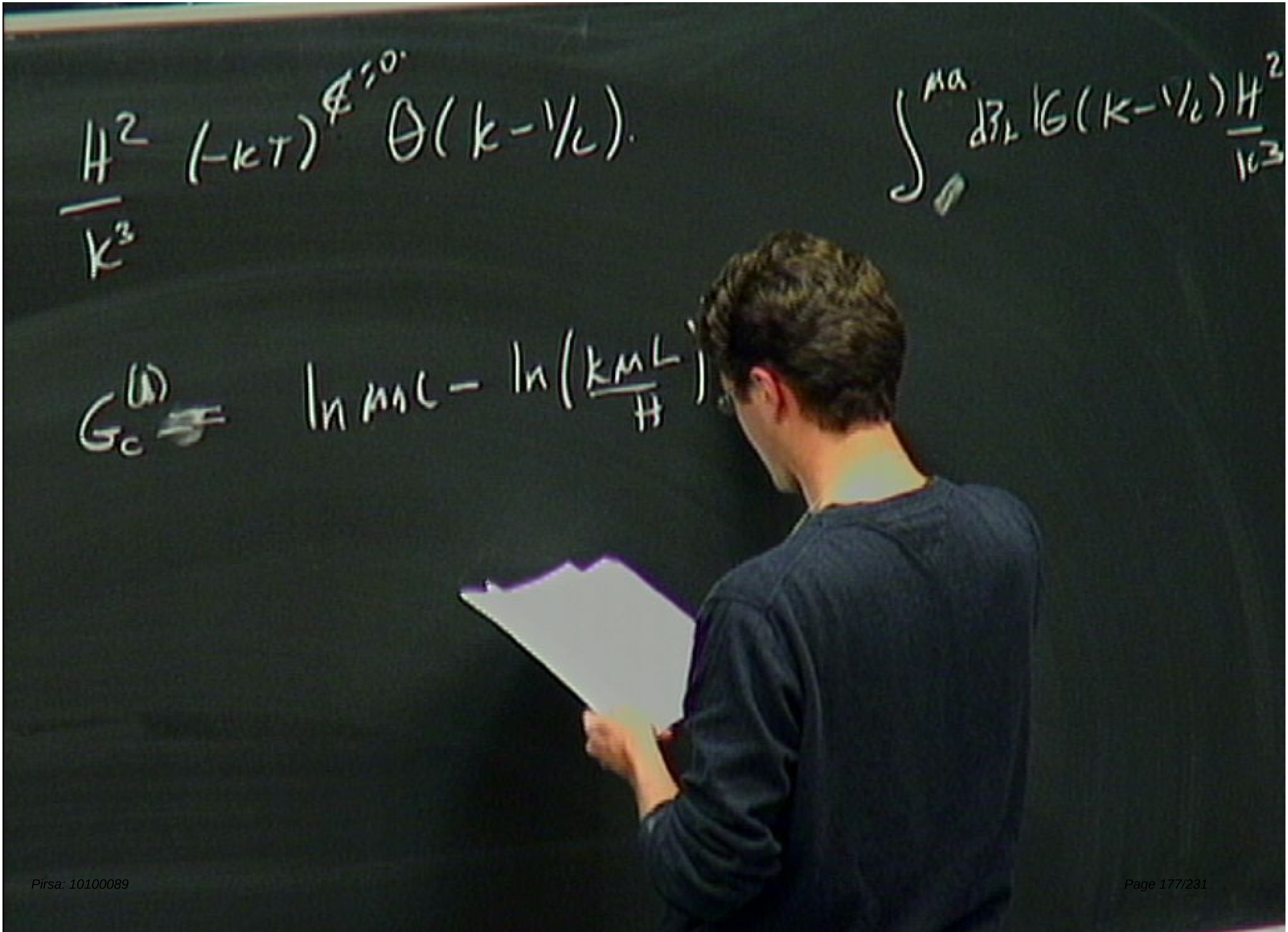
$$G_c^{(2)} = \ln Mac$$



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

$$\int_{0}^{ma} d\ln c\, G(k-1/c)\frac{H^2}{k^3}$$

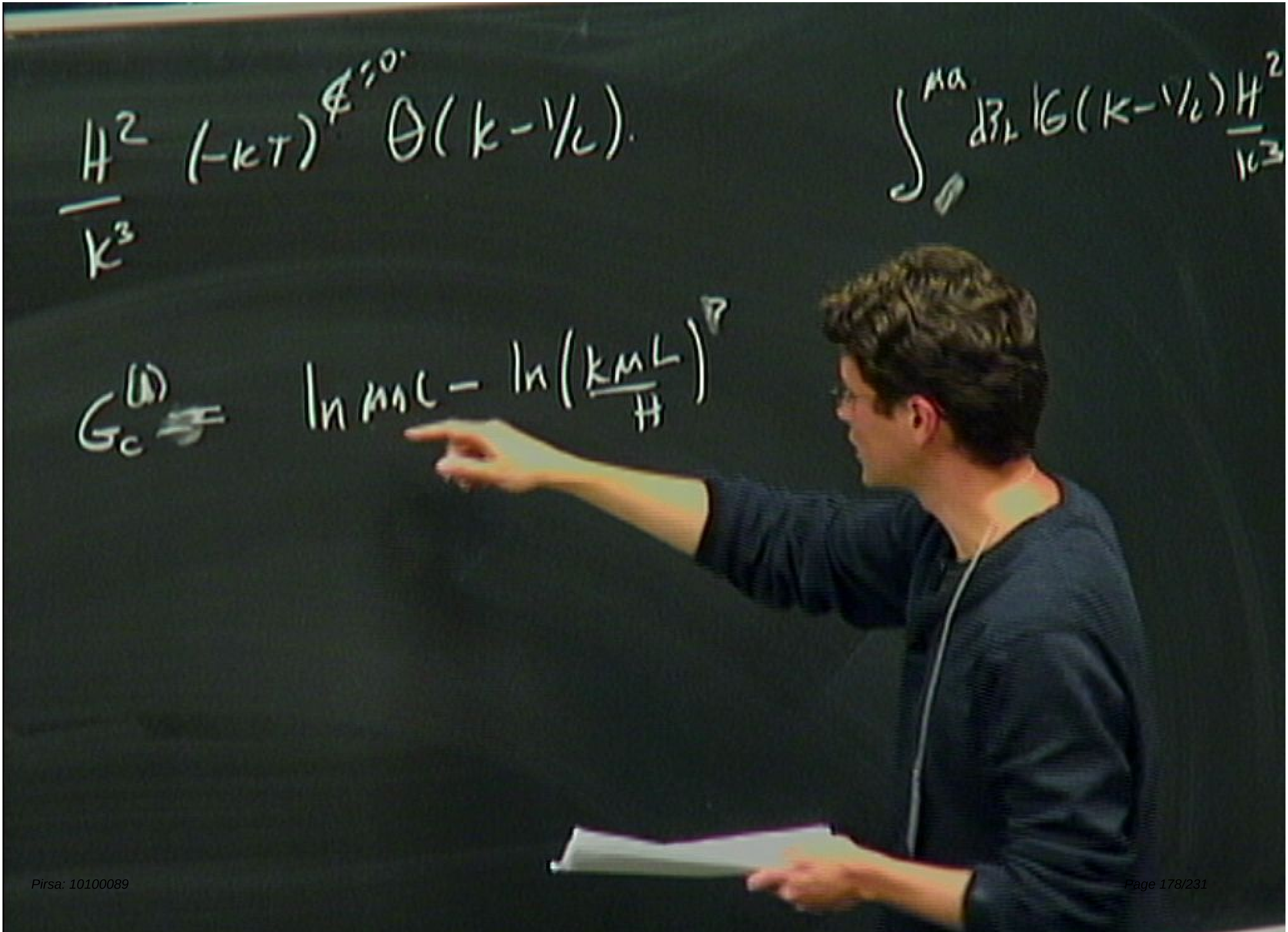
$$G_c^{(1)} = \quad \ln mc - \ln(km$$



$$\frac{H^2}{k^3}(-k\tau)^{\epsilon\simeq 0}\,\Theta(k-1/L).$$

$$\int^{\mu a} d\ln L\, G(k-1/L)\,\frac{H^2}{k^3}$$

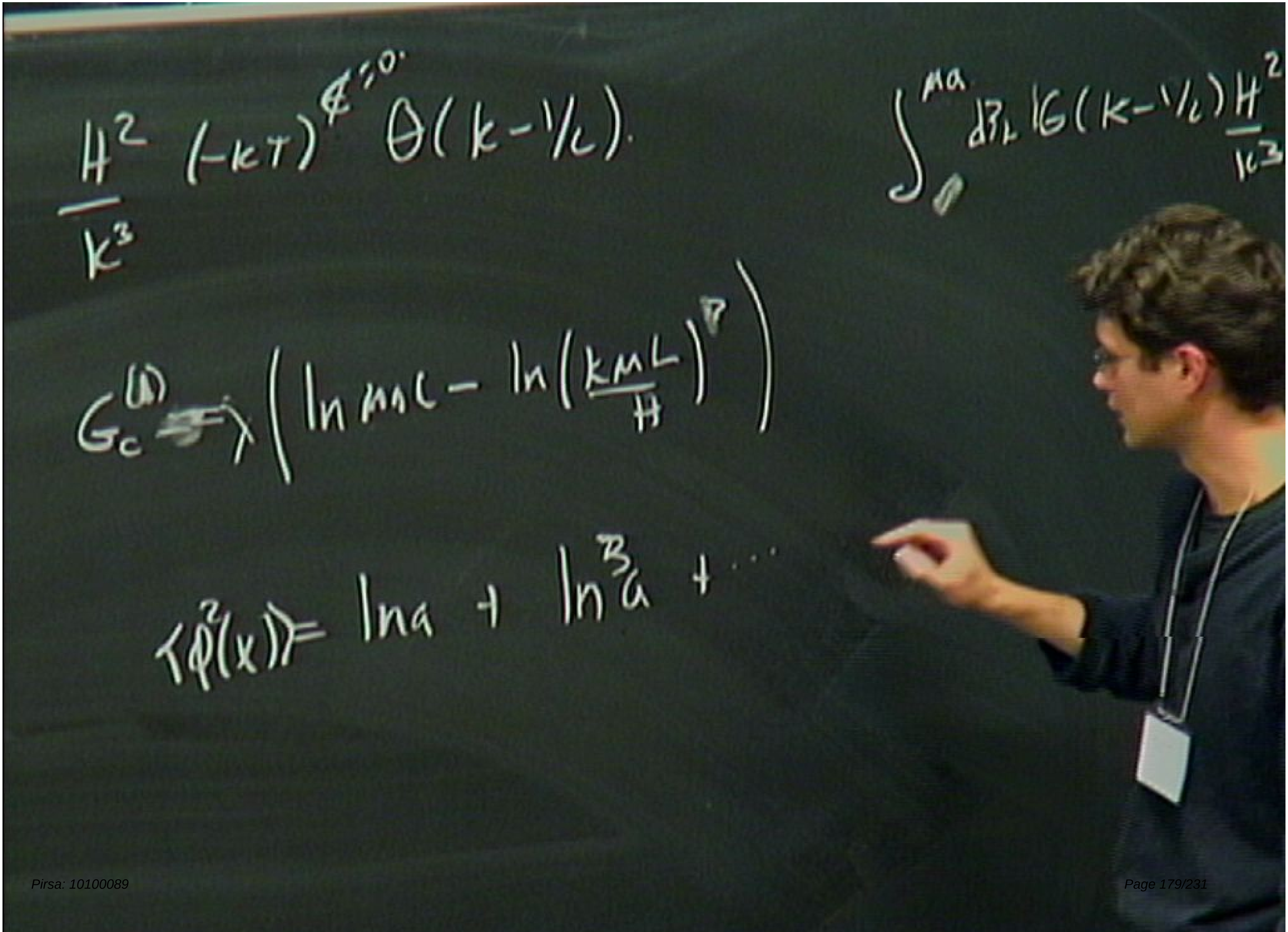
$$G_c^{(1)} = \ln \mu a - \ln\left(\frac{k\mu L}{H}\right).$$



$$\frac{H^2}{k^3}(-k\tau)^{\epsilon\approx 0.}\,\Theta(k-1/L).$$

$$\int_0^{\mu a} d\ln L\, G(k-1/L)\frac{H^2}{k^3}$$

$$G_c^{(1)} = \ln \mu L - \ln\left(\frac{k\mu L}{H}\right)^{P}$$

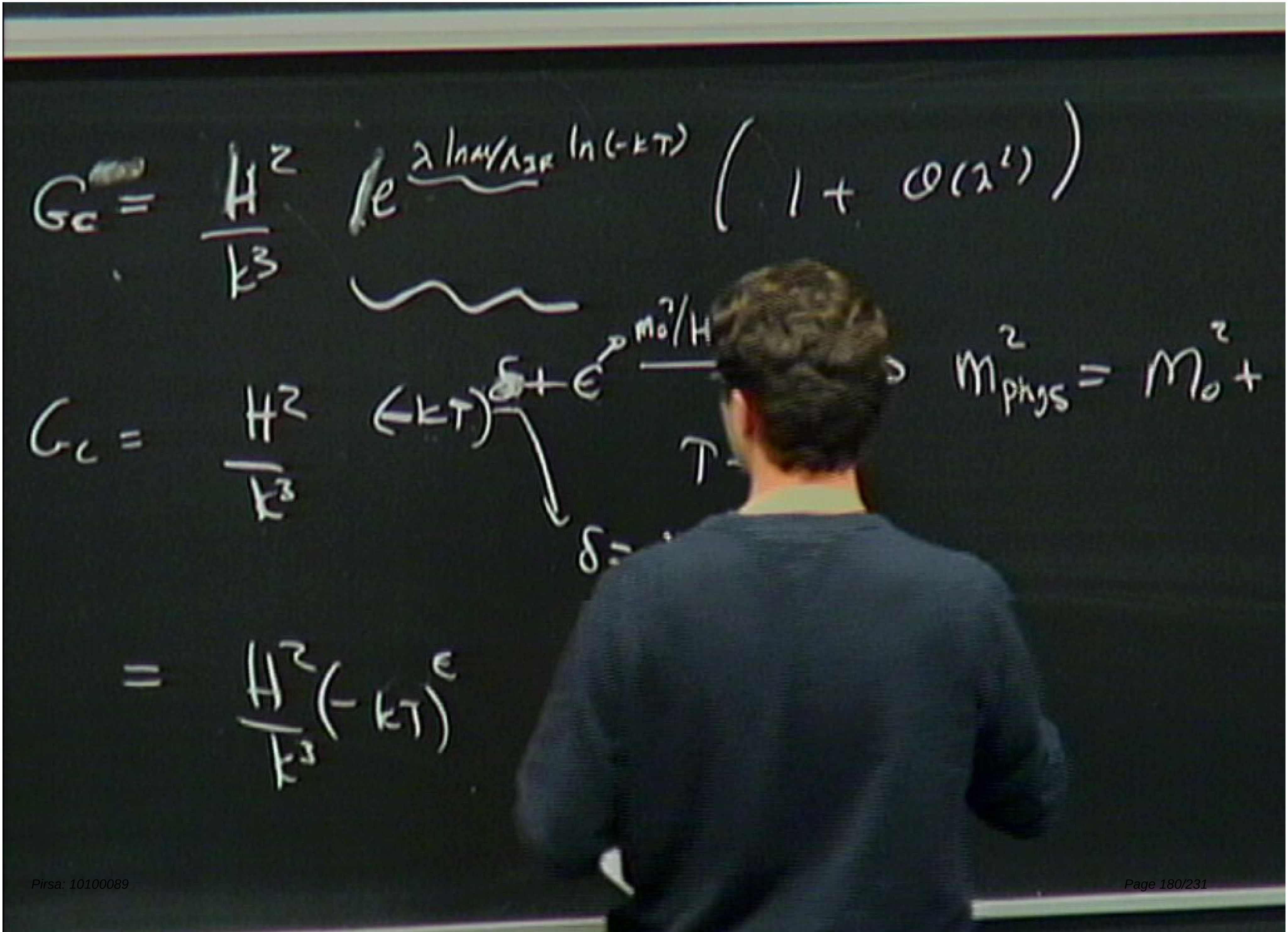


$$\frac{H^2}{k^3}(-k\tau)^{\epsilon\approx 0}\,\Theta(k-1/L).$$

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

$$G_c^{(4)} \to \lambda\left(\ln maL - \ln\left(\frac{kmL}{H}\right)^{P}\right)$$

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



$$G_c = \frac{H^2}{k^3}\, e^{\underbrace{\lambda \ln \Lambda_{UV}/\Lambda_{IR}} \ln(-k\tau)} \left(1 + \mathcal{O}(\lambda^2)\right)$$

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

$$\epsilon \sim m_0^2/H$$

$$\rightarrow m_{phys}^2 = m_0^2 +$$

$$T-$$

$$\delta =$$

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

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

$$\sim \quad {}^2/H^2 \longrightarrow m^2_{phys} = M_0^2 +$$

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

$$\tau \to 0.$$

$$\left(\epsilon = \lambda \underline{\ln M/\Lambda_{IR}}. \right)$$

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

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

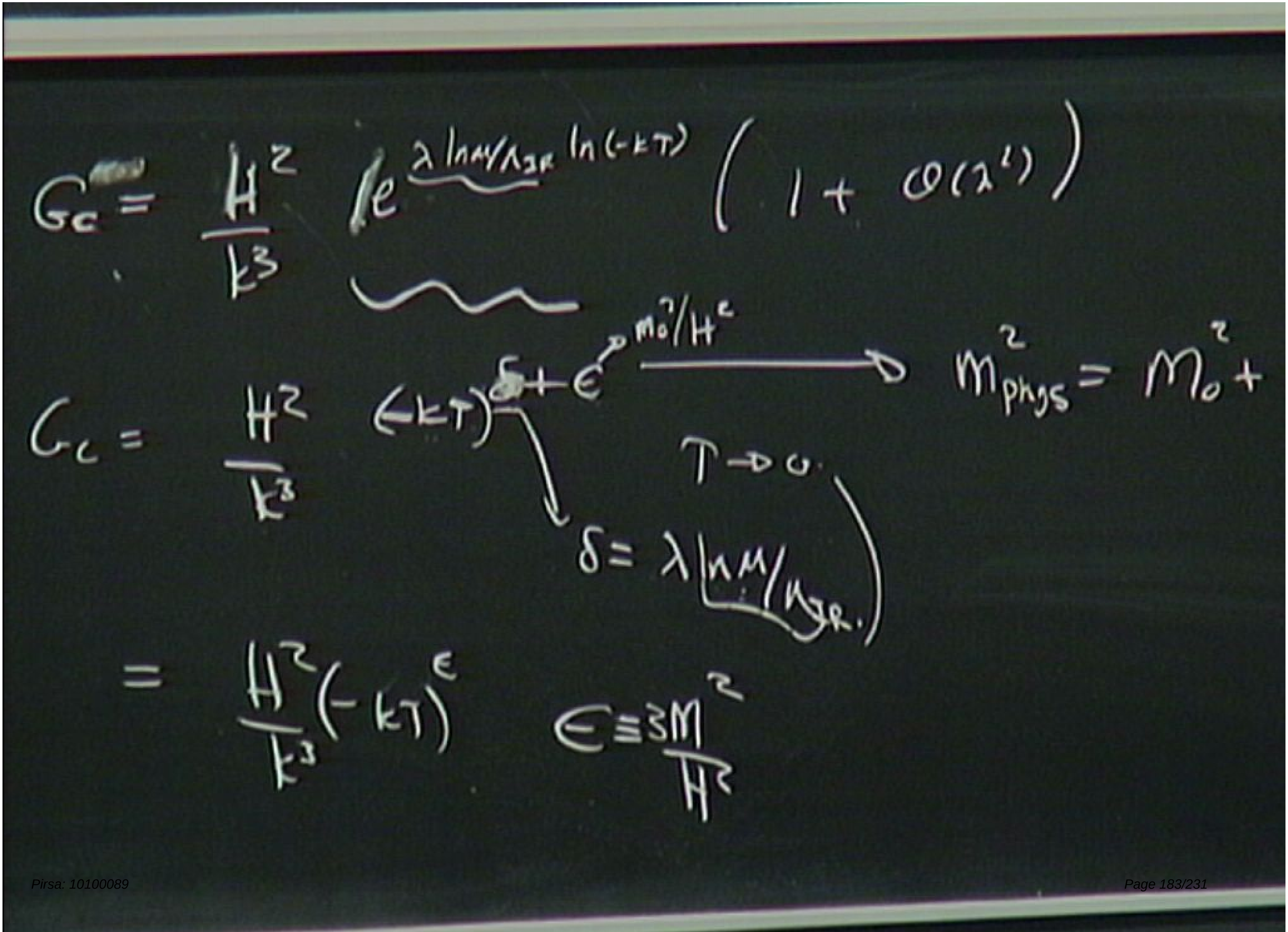
$$G_c = \frac{H^2}{k^3}(-k\tau)^{\delta+\epsilon}$$

$\epsilon \to m_0^2/H^2 \longrightarrow m_{phys}^2 = M_0^2 +$

$\tau \to 0.$

$\delta = \lambda \left(\ln M/\Lambda_{IR}.\right)$

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



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

$$G_c = \frac{H^2}{k^3} (-k\tau)^{\delta + \epsilon} \qquad \epsilon \to m_0^2/H^2 \longrightarrow m_{phys}^2 = m_0^2 +$$

$$\tau \to 0$$

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

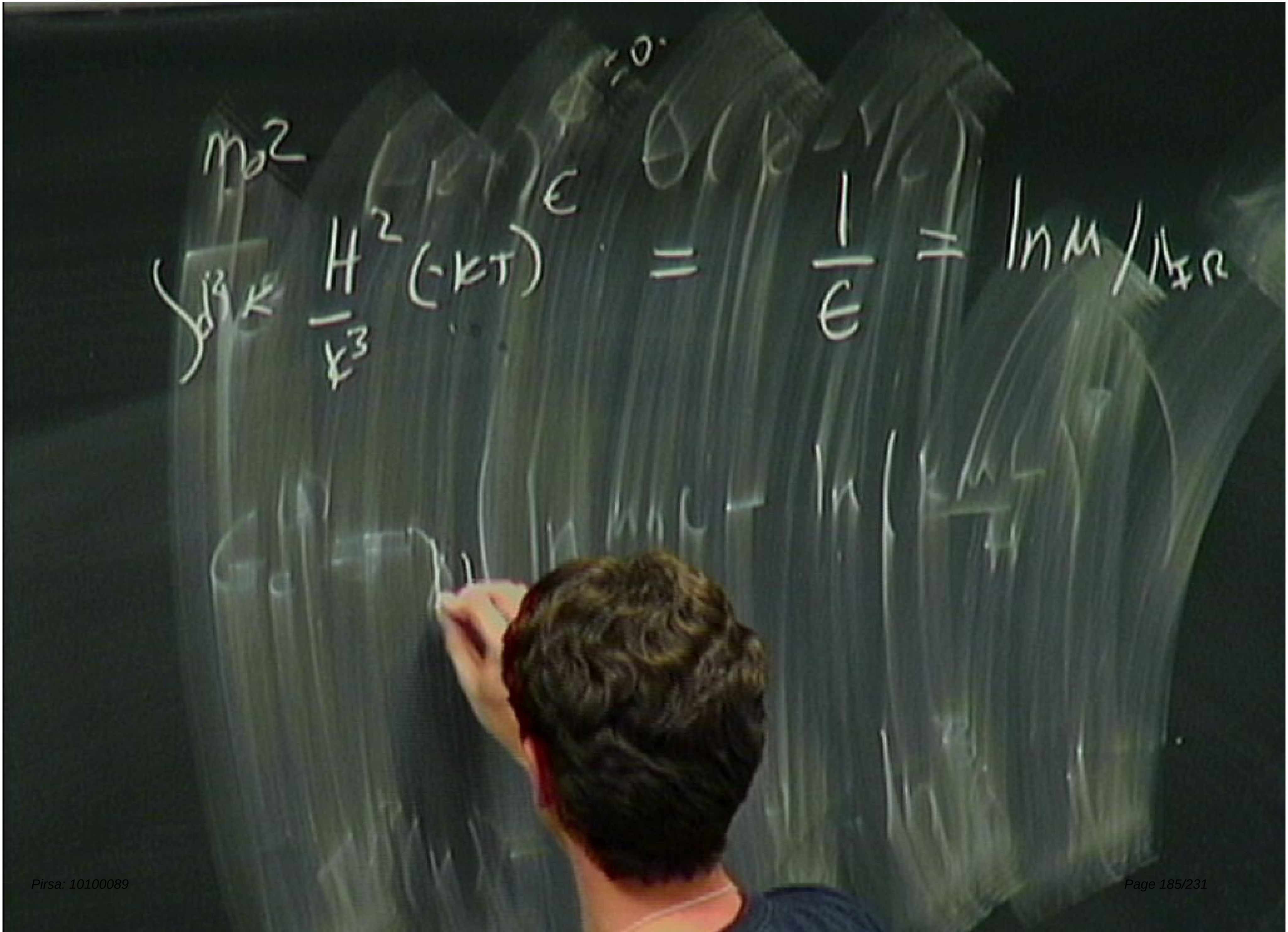
$$= \frac{H^2}{k^3}(-k\tau)^{\epsilon} \qquad \epsilon \equiv \frac{3M^2}{H^2}$$

$\epsilon \to 0:$

m_0^2

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

$$\ln\mu - \ln\left(\frac{k\mu}{H}\right)$$



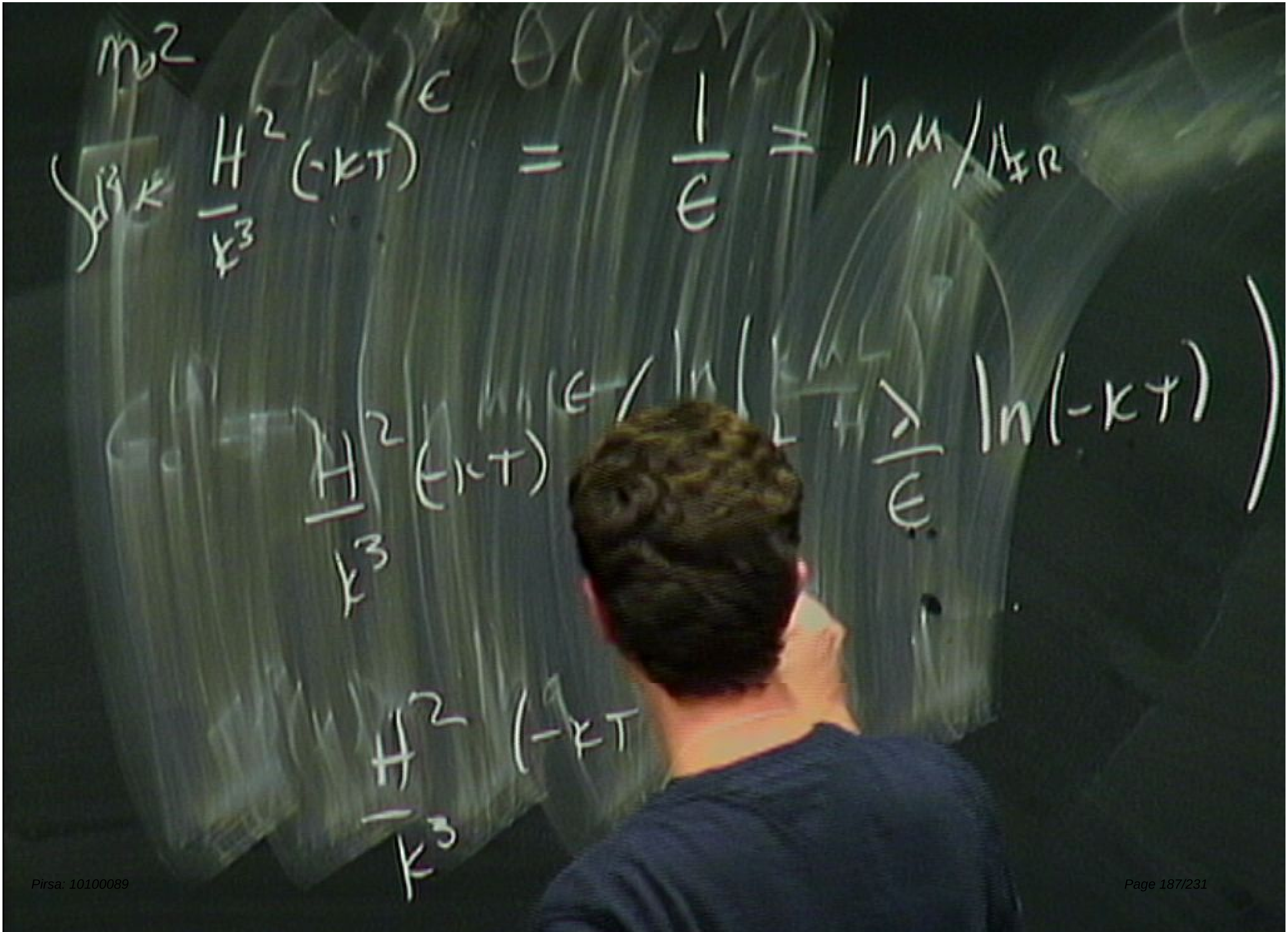
m_0^2

$$\int d^3k \, \frac{H^2}{k^3} (-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln \mu / \Lambda_R$$

m_0^2

$$\int d^3k \, \frac{H^2}{k^3} (-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln \mu / \mu_{IR}$$

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

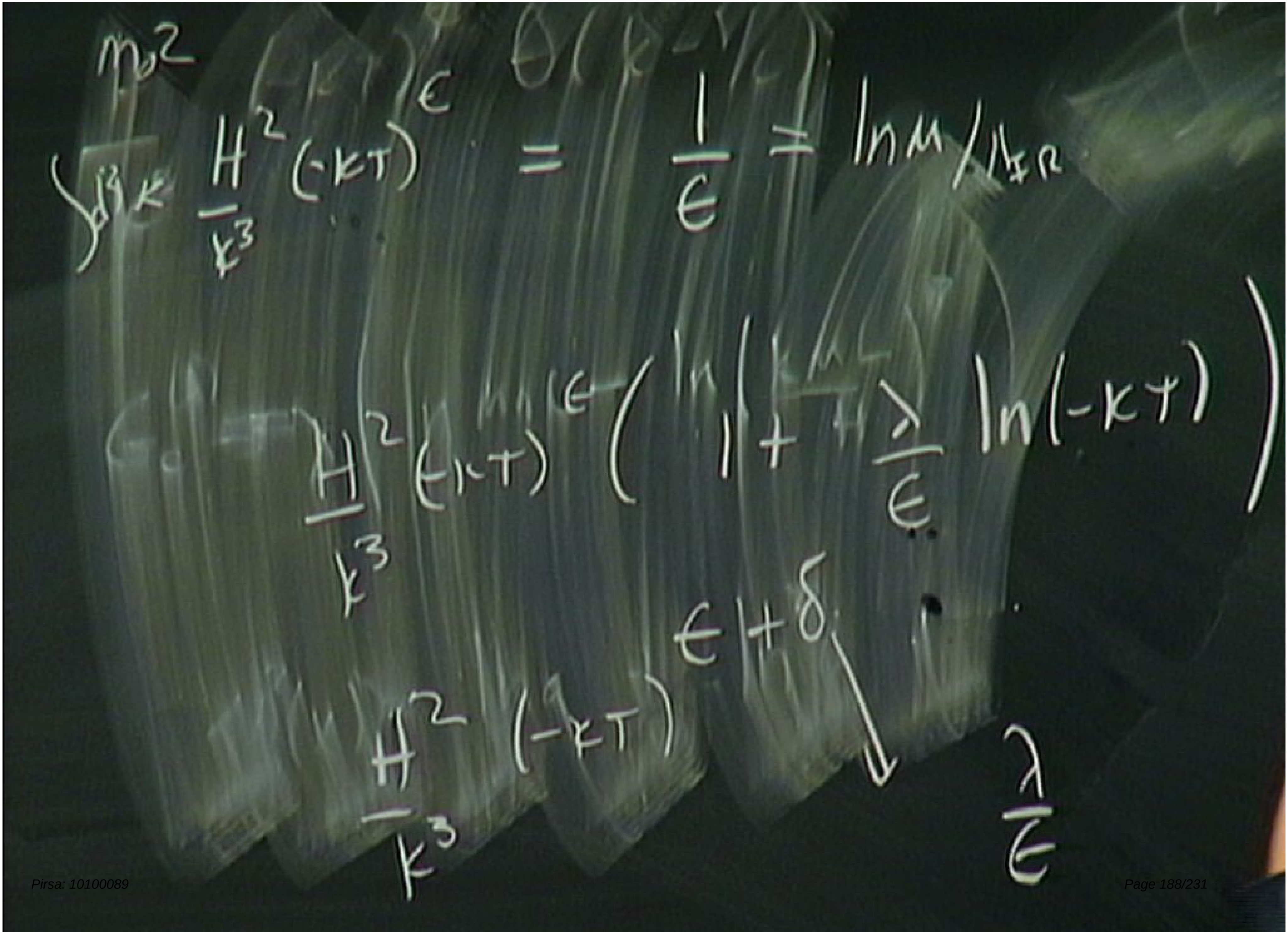


m_0^2

$$\int d^3k\,\frac{H^2}{k^3}(-k\tau)^\epsilon = \frac{1}{\epsilon} \mp \ln\mu/4\pi$$

$$\frac{H^2}{k^3}(-k\tau)^\epsilon\Big(\qquad \frac{\lambda}{\epsilon}\ln(-k\tau)\Big)$$

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



m_0^2

$$\int d^3k \, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} \simeq \ln\mu/\Lambda_{IR}$$

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

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

$$\delta \to \frac{\lambda}{\epsilon}$$

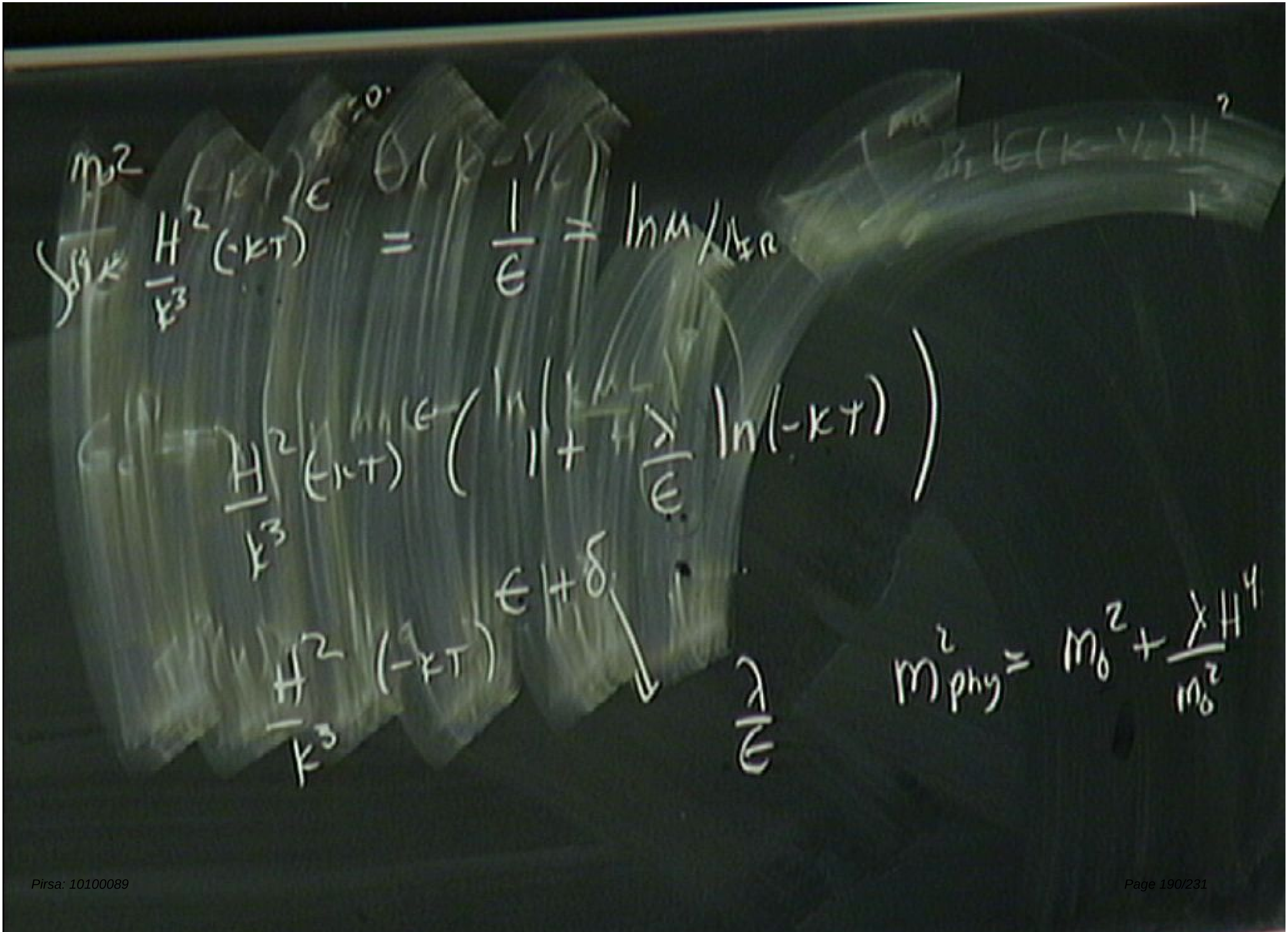
m_ν^2

$$\int d^3k \, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} \simeq \ln \mu / \Lambda_{IR}$$

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

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

$$\delta \searrow \frac{\lambda}{\epsilon}$$



m_0^2

$$\int d^3k\,\frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} \pm \ln \mu/k\tau$$

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

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

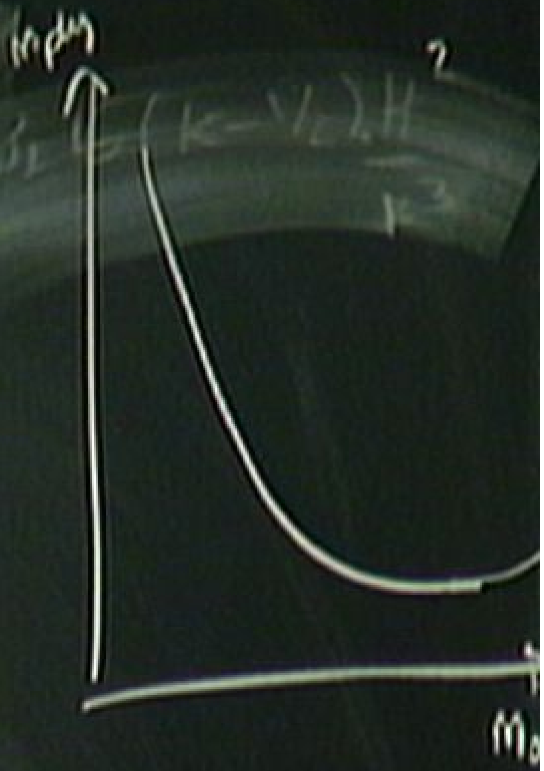
$$m^2_{phy} = m_0^2 + \frac{\lambda H^4}{m_0^2}$$

m_0^2

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln \mu / k_{IR}$$

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

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



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

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

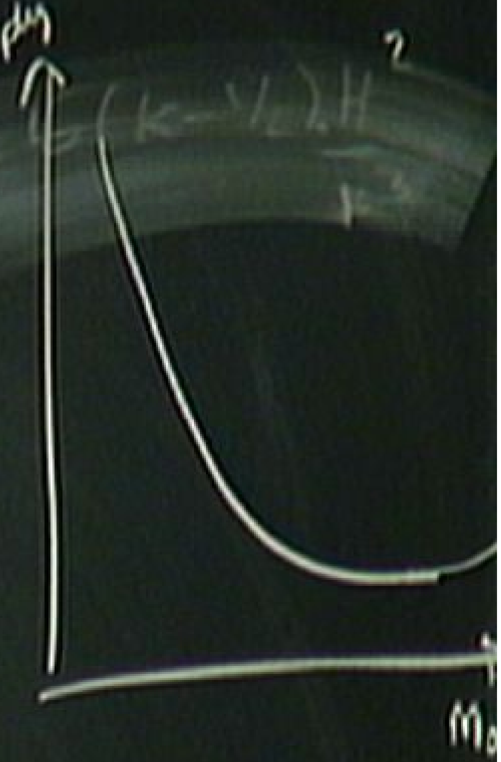
m_0^2

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln m/\Lambda_R$$

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

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

$$\delta \rightarrow \frac{\lambda}{\epsilon}$$



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

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

m_0^2

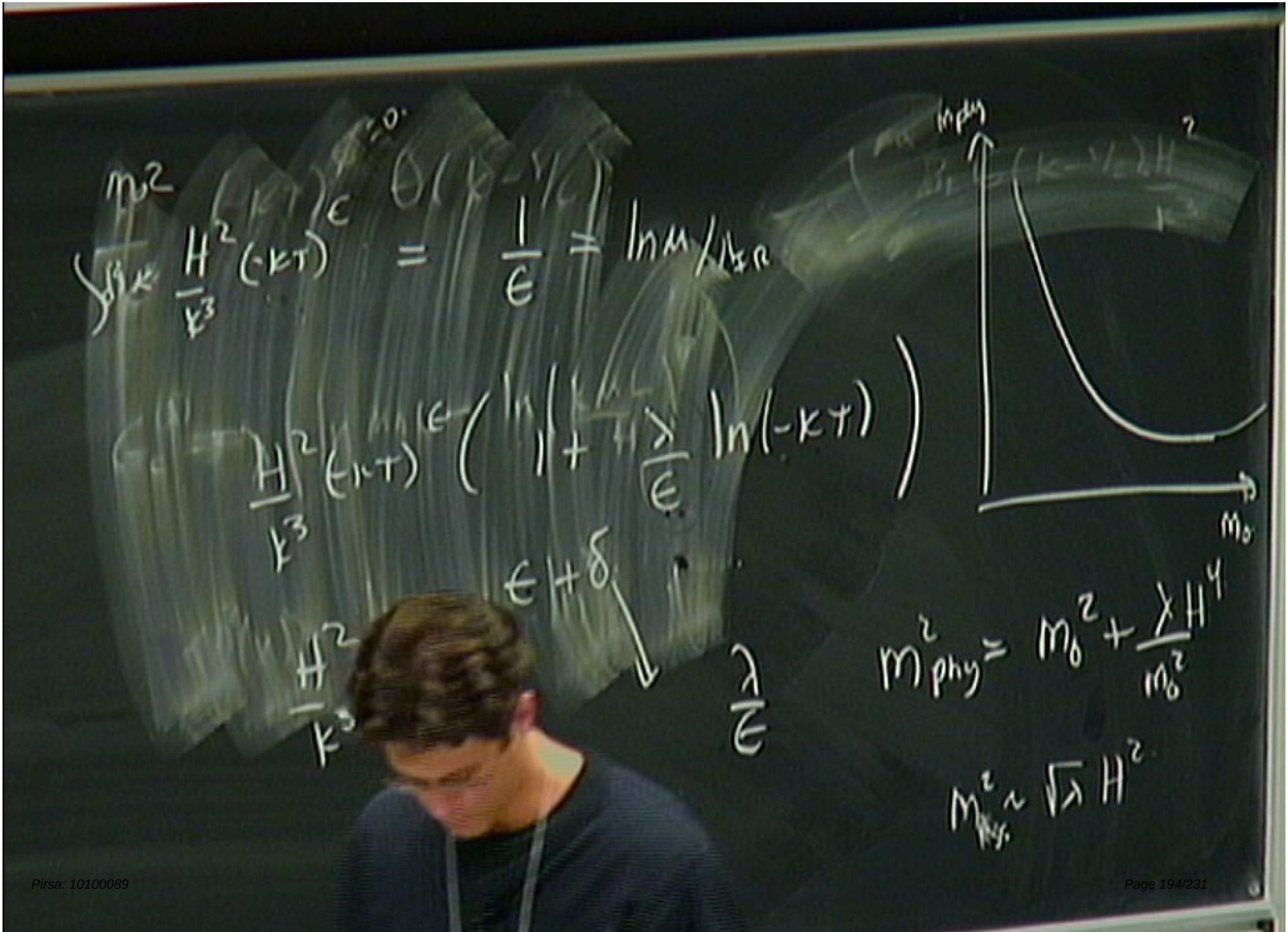
$$\int d^3k\,\frac{H^2}{k^3}(-k\tau) = \frac{1}{\epsilon} = \ln M/k_R$$

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

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

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

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



m^2

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} \simeq \ln M/k_{IR}$$

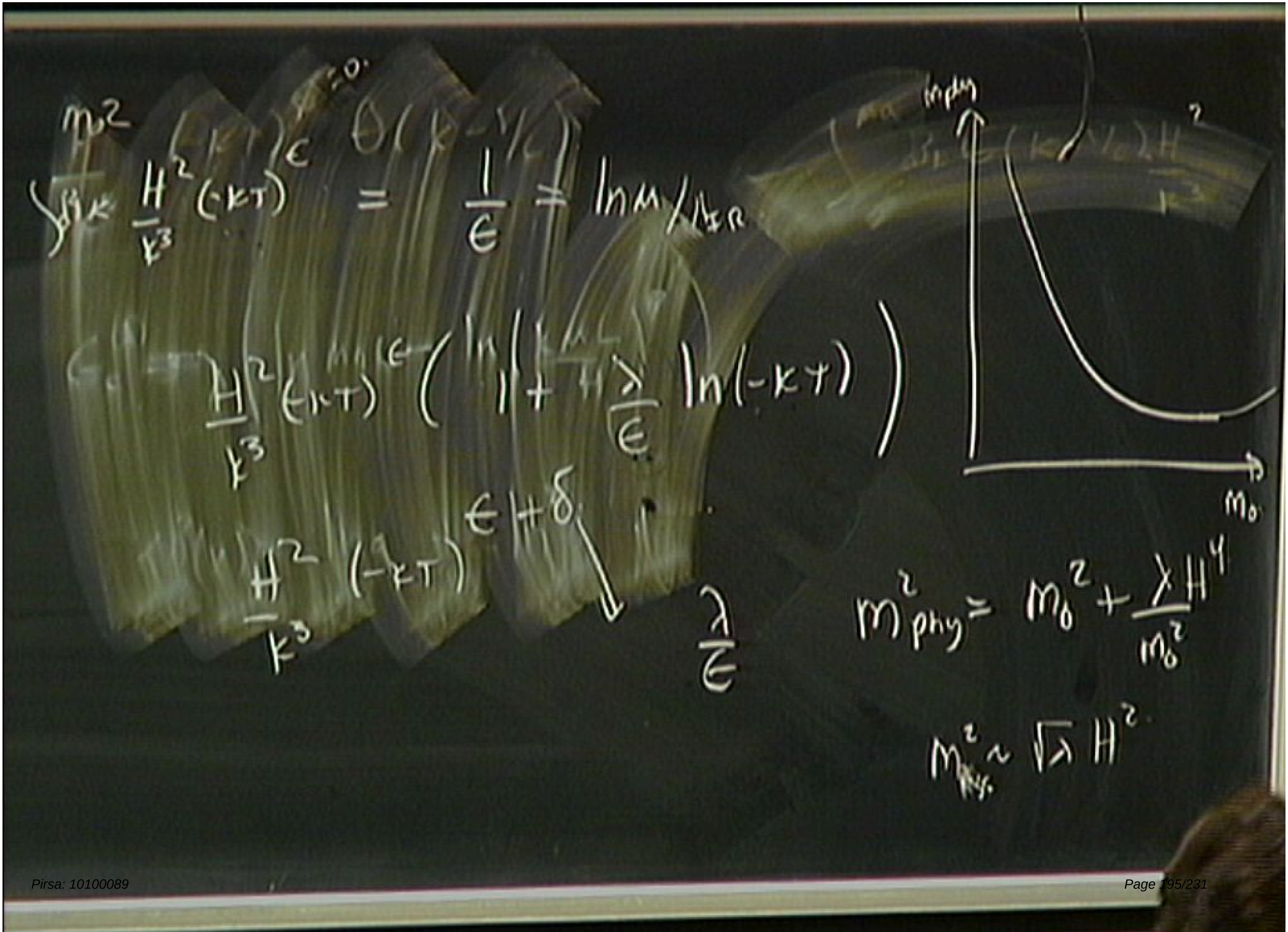
$$\frac{H^2}{k^3}(-k\tau)^{\epsilon}\left(1+\frac{\lambda}{\epsilon}\ln(-k\tau)\right)$$

$\epsilon+\delta$

$$\frac{H^2}{k^3} \qquad \frac{\lambda}{\epsilon}$$

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

$$m^2_{phy} \sim \sqrt{\lambda}\, H^2$$



$$\int d^3k \, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} \neq \ln \mu/\Lambda_{IR}$$

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

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

$$\frac{\lambda}{\epsilon}$$

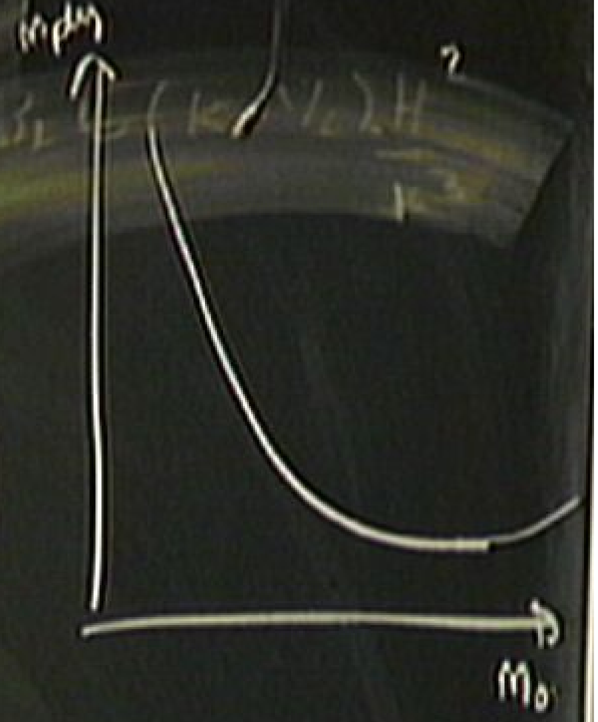
$$m^2_{phy} = m_0^2 + \frac{\lambda H^4}{m_0^2}$$

$$m^2_{phy} \sim \sqrt{\lambda}\, H^2$$

$$\int d^3k \, \frac{H^2}{k^3}(-k\tau) = \frac{1}{\epsilon} \neq \ln \mu / \Lambda_{IR}$$

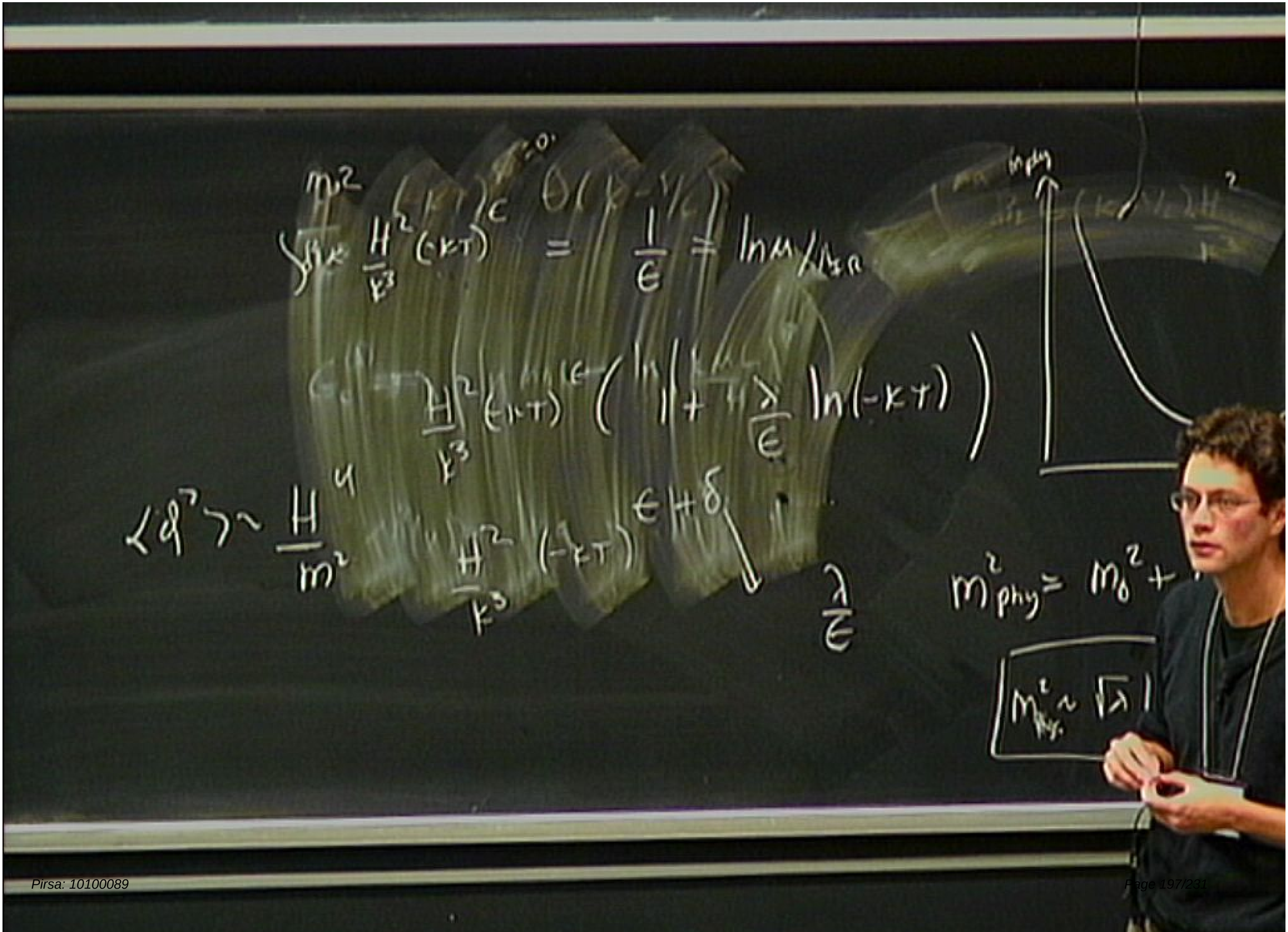
$$\frac{H^2}{k^3}(-k\tau)^{\epsilon}\left(1 + \frac{\lambda}{\epsilon} \ln(-k\tau) \right)$$

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



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

$$m^2_{phys} \sim \sqrt{\lambda}\, H^2$$



$$\int d^3k \, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln \mu/\mu_{IR}$$

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

$$\langle\phi^2\rangle \sim \frac{H^4}{m^2} \qquad \frac{H^2}{k^3}(-k\tau)^{\epsilon+\delta} \qquad \frac{\lambda}{\epsilon}$$

$$m^2_{phy} = m_0^2 +$$

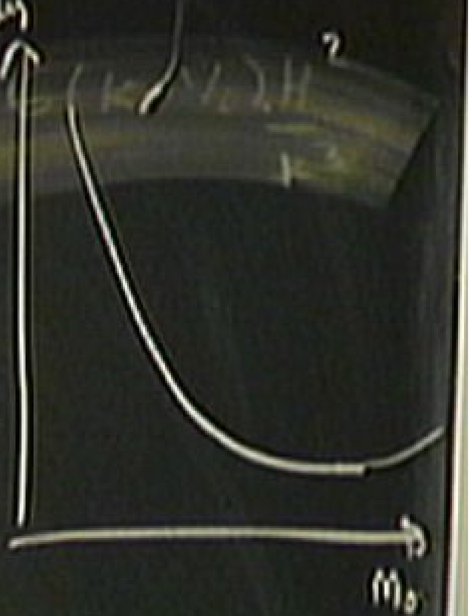
$$\boxed{m^2_{phys} \sim \sqrt{\lambda}}$$

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln m/\Lambda_{IR}$$

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

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

$$\frac{\lambda}{\epsilon}$$



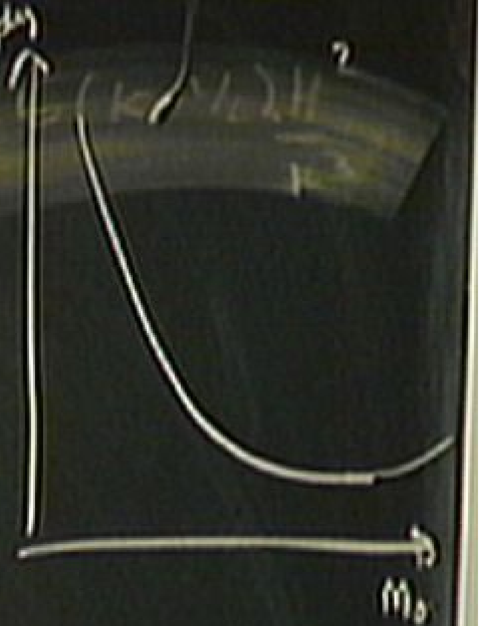
$$m^2_{phy} = m_0^2 + \frac{\lambda H^4}{m_0^2}$$

$$\boxed{m^2_{phy} \sim \sqrt{\lambda}\, H^2}$$

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln M/\ldots$$

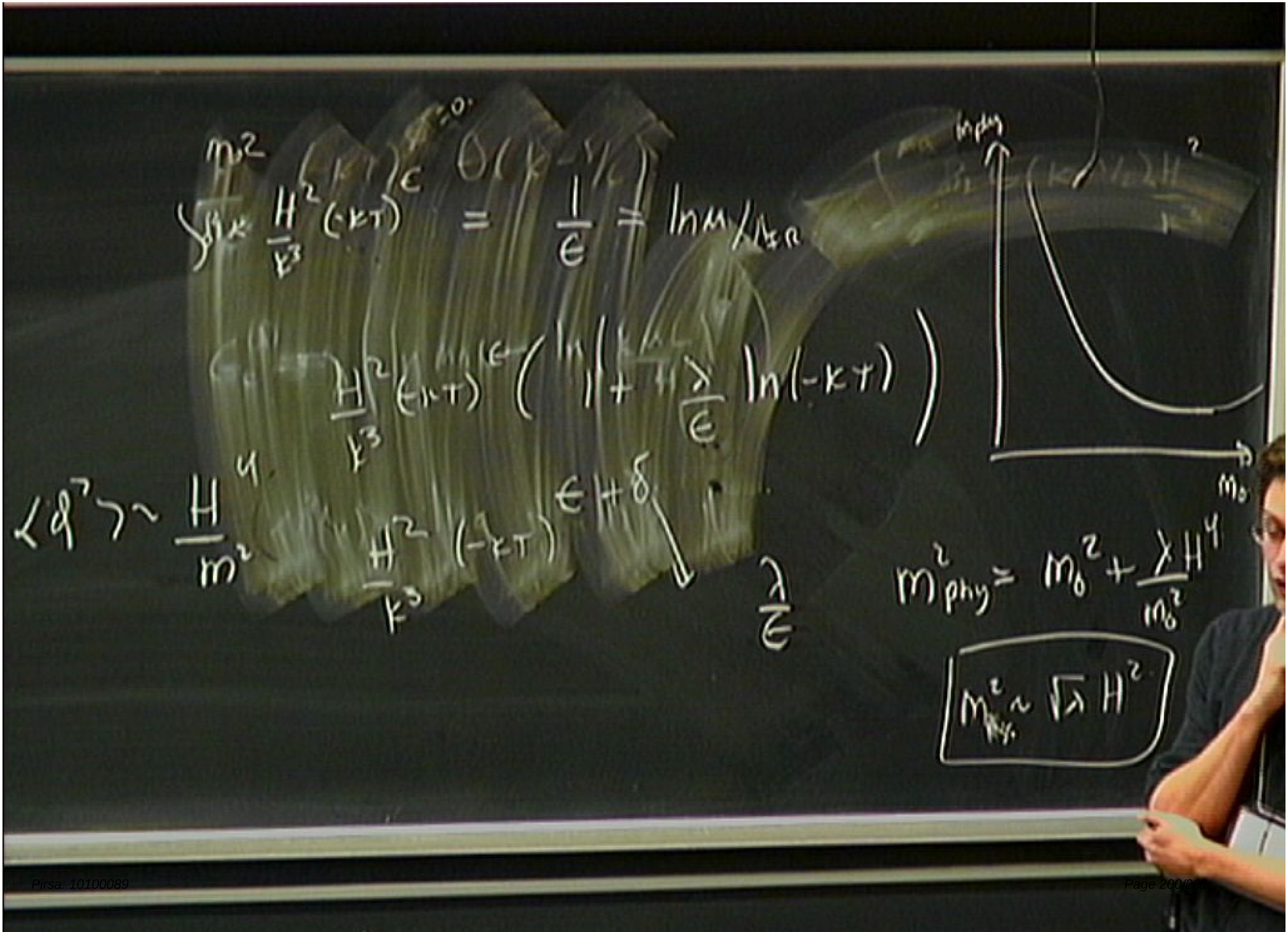
$$\frac{H^2}{k^3}(-k\tau)^{\epsilon}\left(1 + \frac{\lambda}{\epsilon}\ln(-k\tau)\right)$$

$$\langle\phi^2\rangle \sim \frac{H^4}{m^2} \qquad \frac{H^2}{k^3}(-k\tau)^{\epsilon+\delta} \qquad \frac{\lambda}{\epsilon}$$



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

$$\boxed{m^2_{phy} \sim \sqrt{\lambda}\, H^2}$$



$$\int_k \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln m/k_{IR}$$

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

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

$$\frac{\lambda}{\epsilon}$$

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

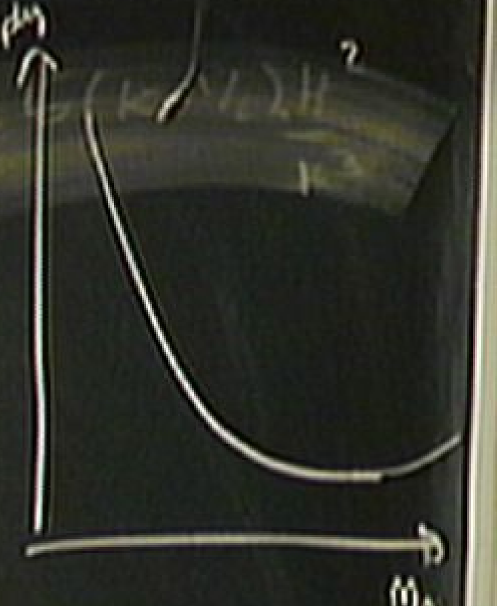
$$\boxed{m^2_{phys} \sim \sqrt{\lambda}\, H^2}$$

$$\int d^3k\, \frac{H^2}{k^3}(-k\tau)^{\epsilon} = \frac{1}{\epsilon} = \ln m/k_{IR}$$

$$m^2 \qquad \theta(k - 1/\tau)$$

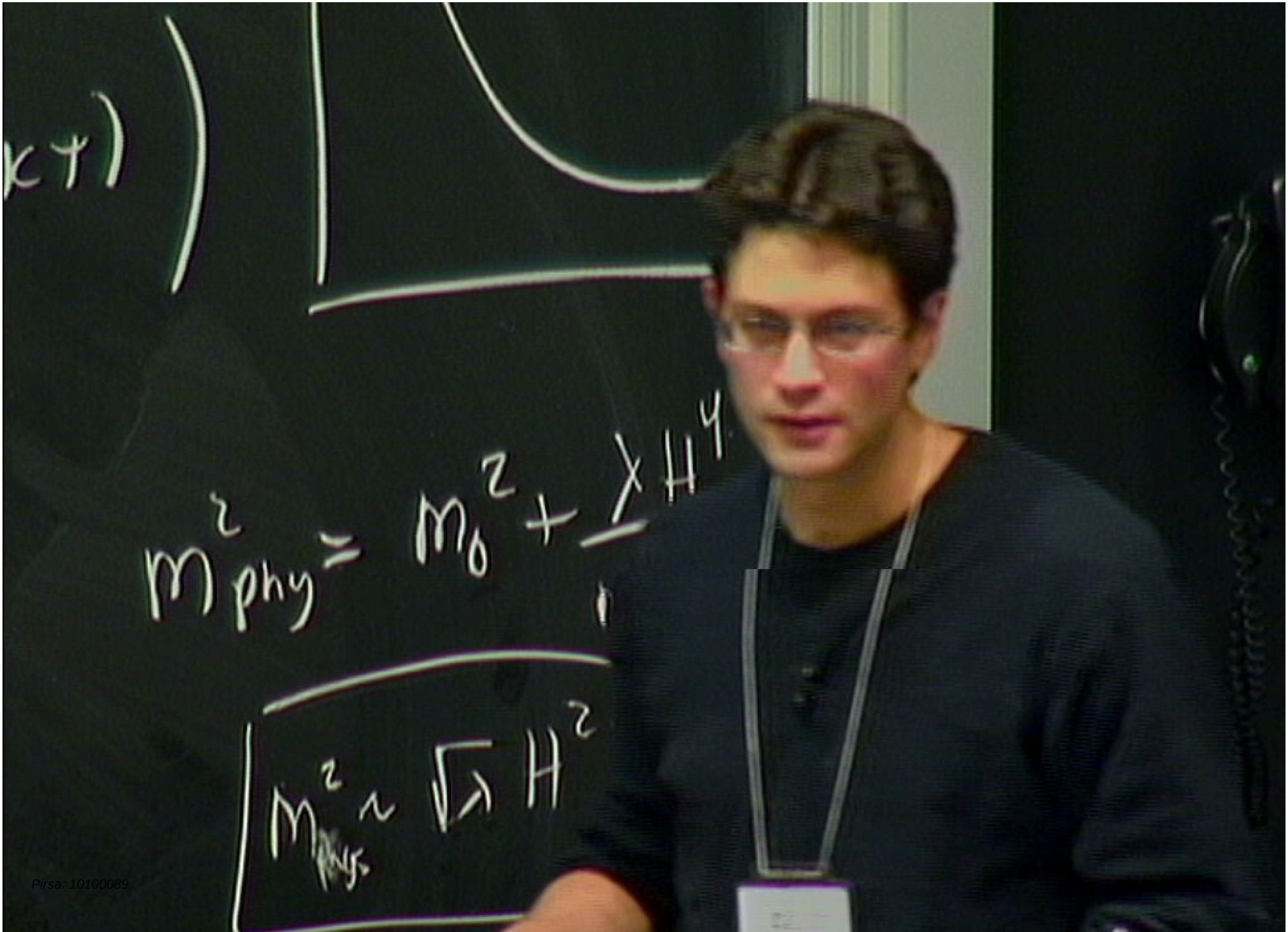
$$\frac{H^2}{k^3}(-k\tau)^{\epsilon}\left(1 + \frac{\lambda}{\epsilon}\ln(-k\tau)\right)$$

$$\langle\phi^2\rangle \sim \frac{H^4}{m^2} \qquad \frac{H^2}{k^3}(-k\tau)^{\epsilon+\delta} \qquad \frac{\lambda}{\epsilon}$$



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

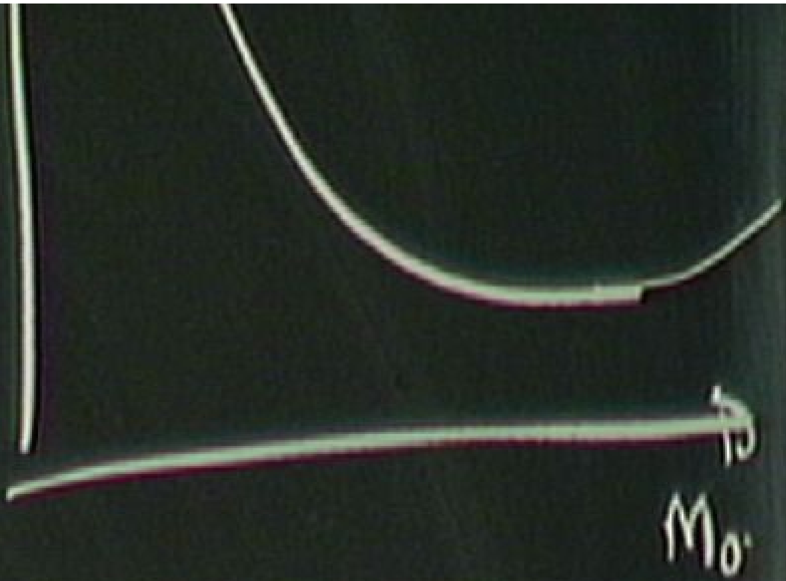
$$\boxed{m_{phy}^2 \sim \sqrt{\lambda}\, H^2}$$



$$m^2_{phy} = m_0^2 + \lambda H^4$$

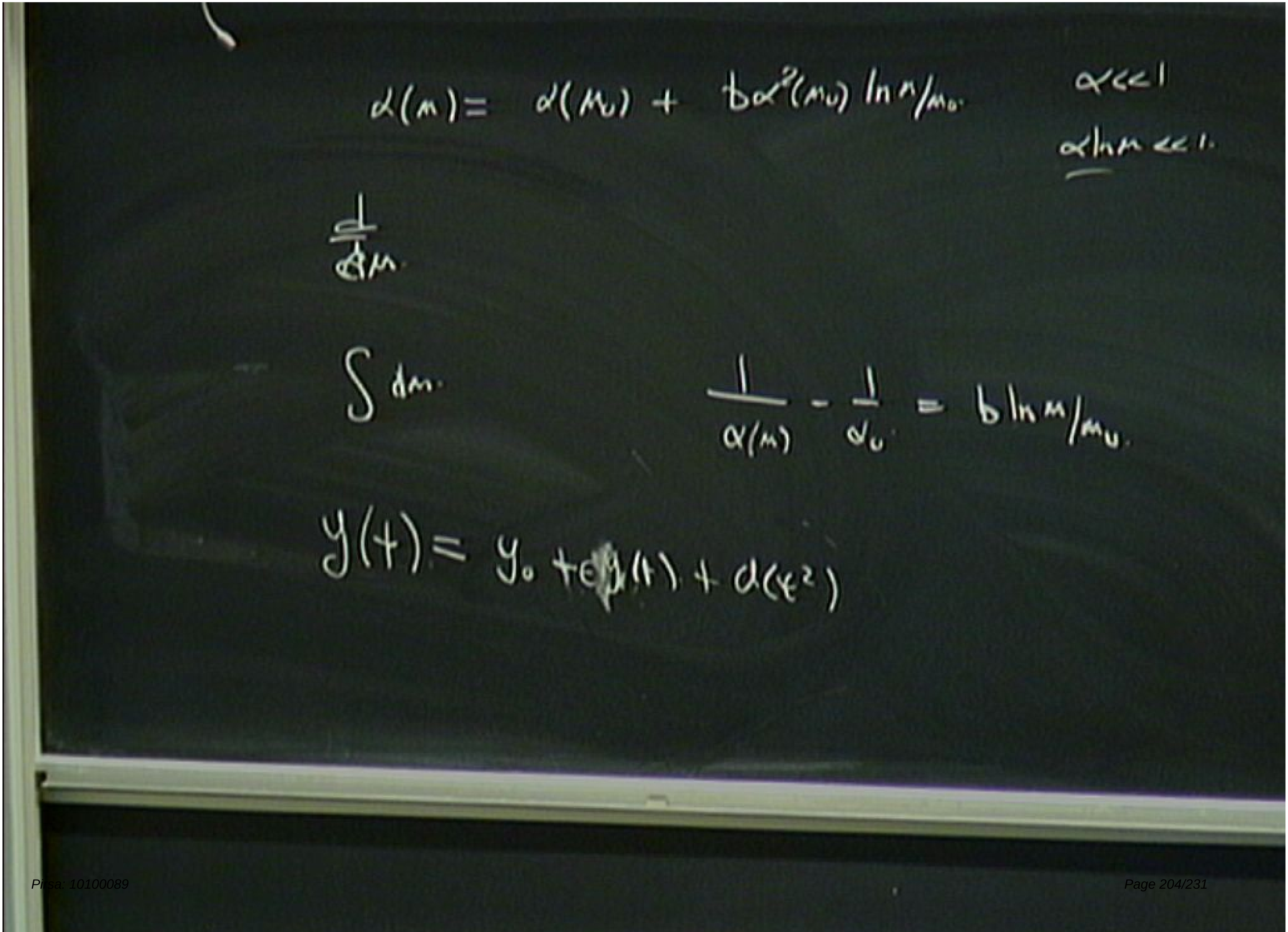
$$\boxed{m^2_{phys} \sim \sqrt{\lambda}\, H^2}$$

$xt) \Big)$



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

$$\boxed{m^2_{phys} \sim \sqrt{\lambda}\, H^2}$$



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

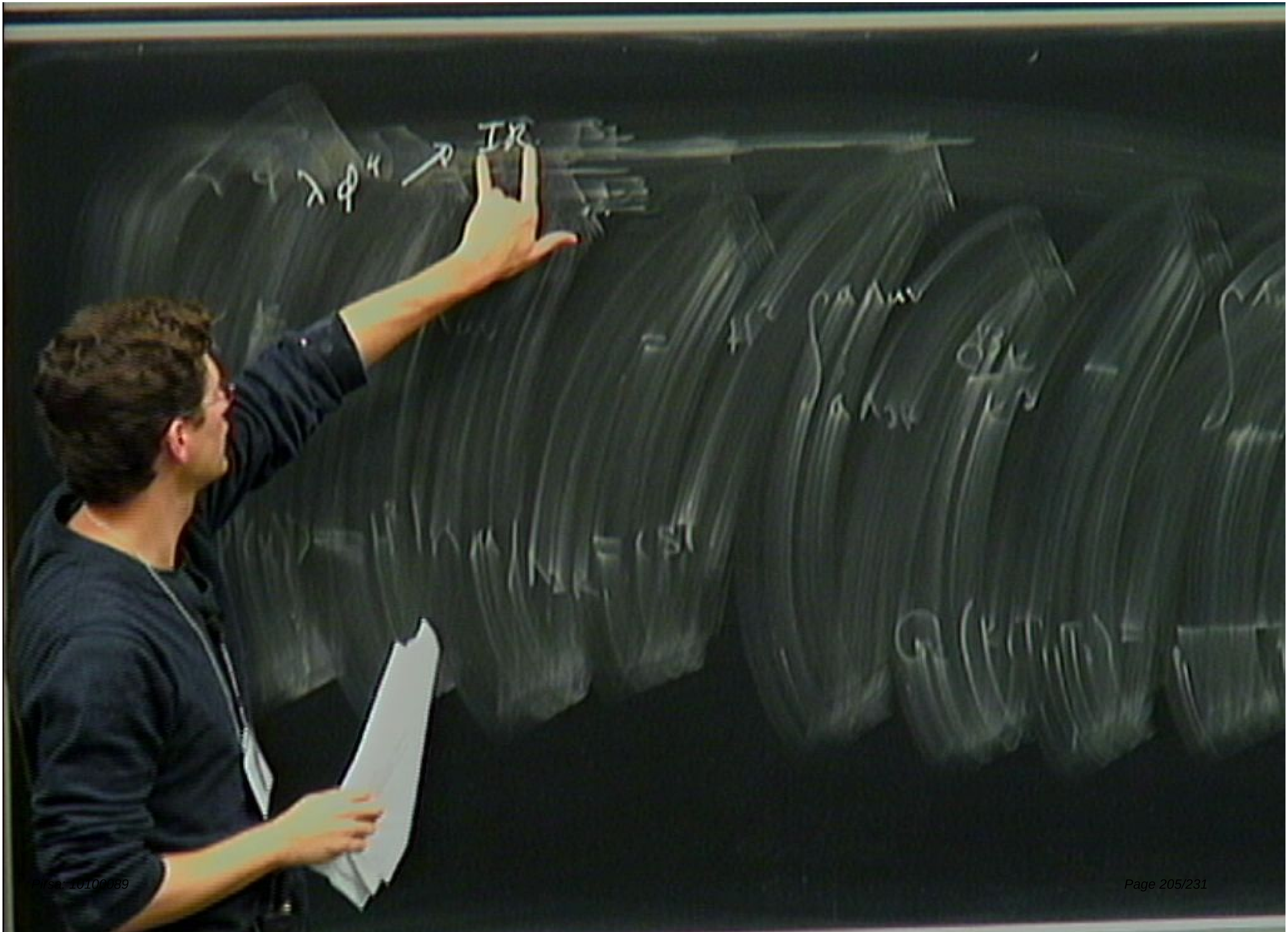
$$\alpha \ln m \ll 1.$$

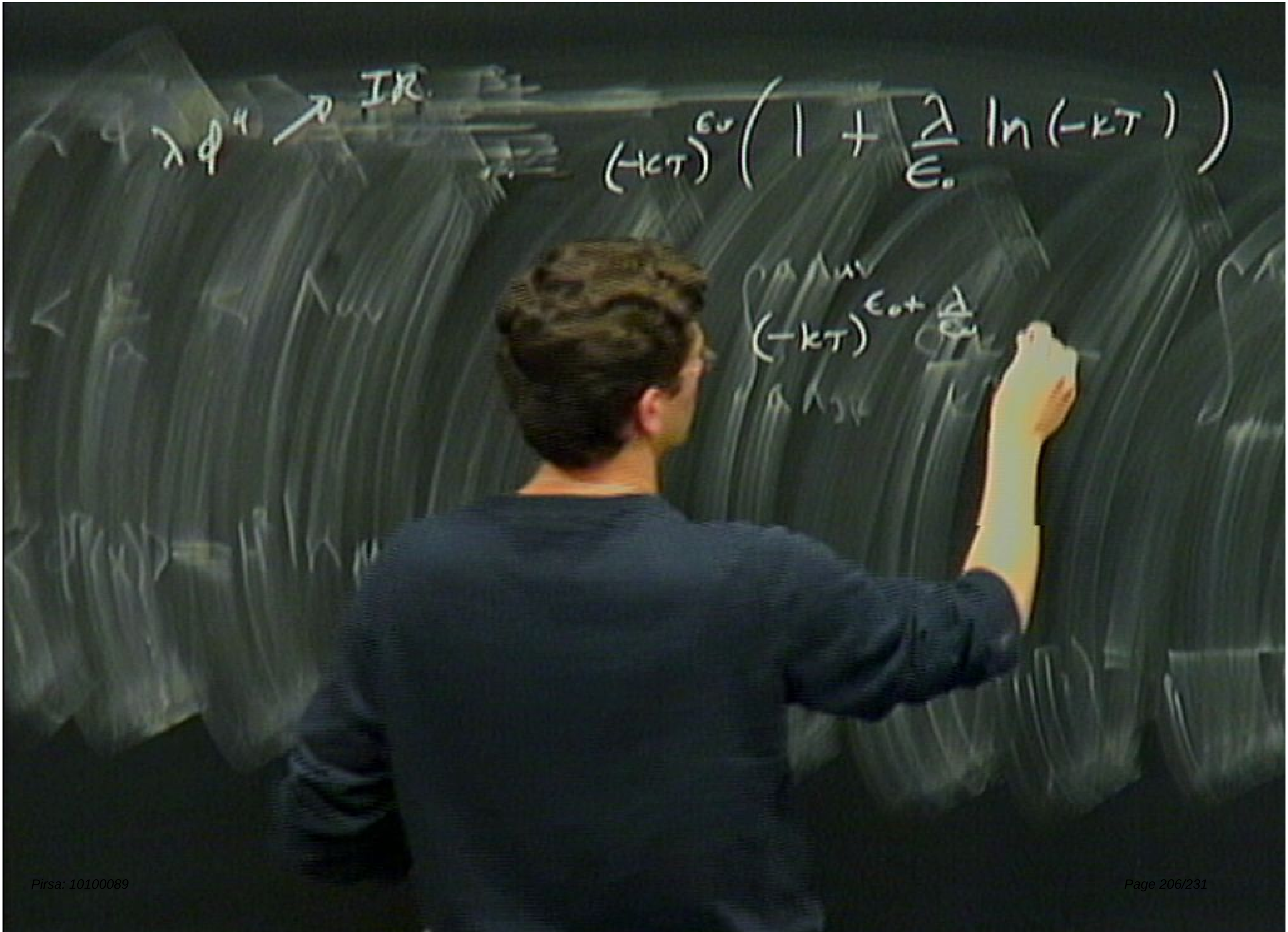
$$\frac{d}{dm}$$

$$\int dm$$

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

$$y(t) = y_0 + \epsilon y_1(t) + O(\epsilon^2)$$

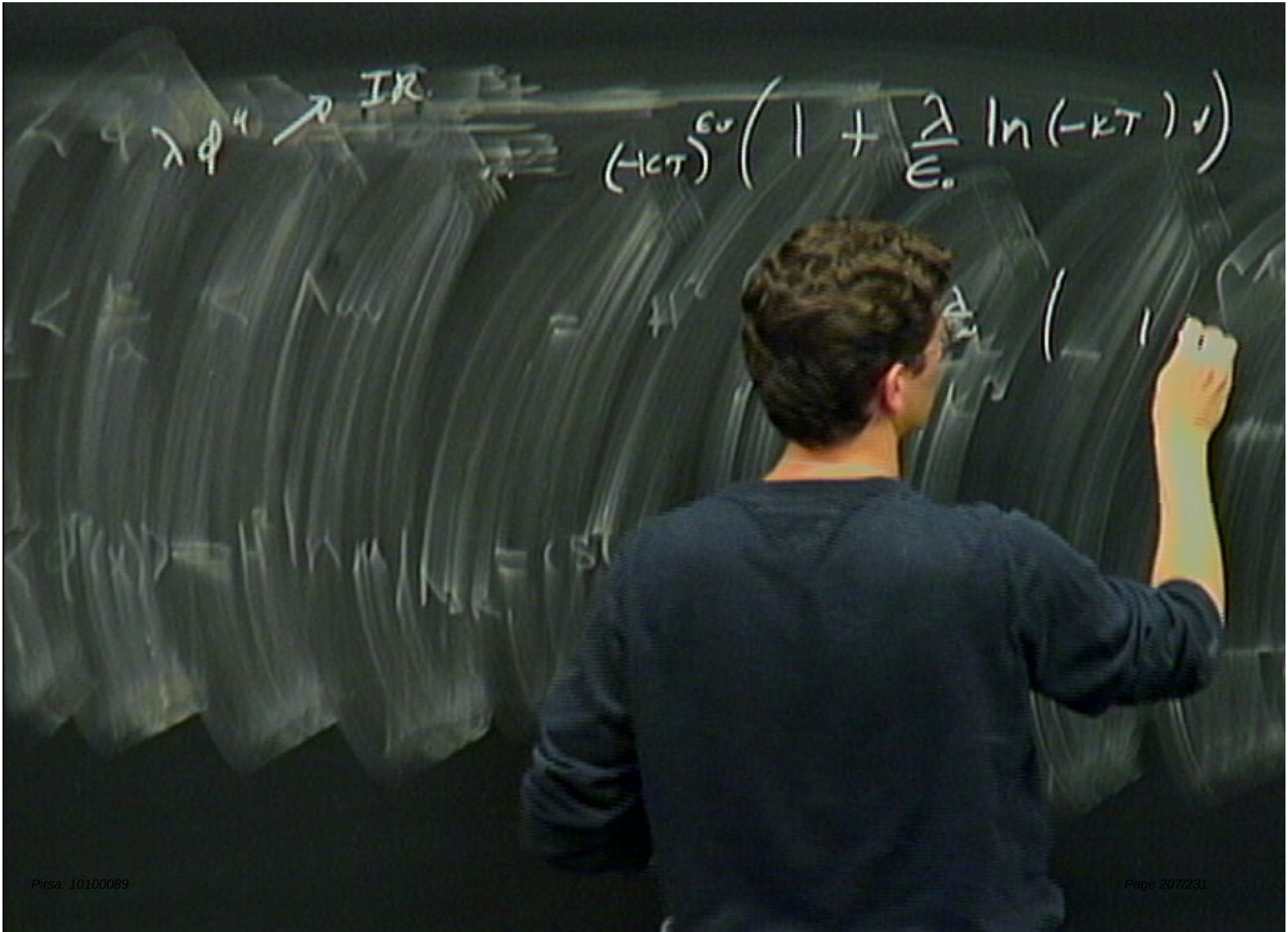

λφ⁴ → IR

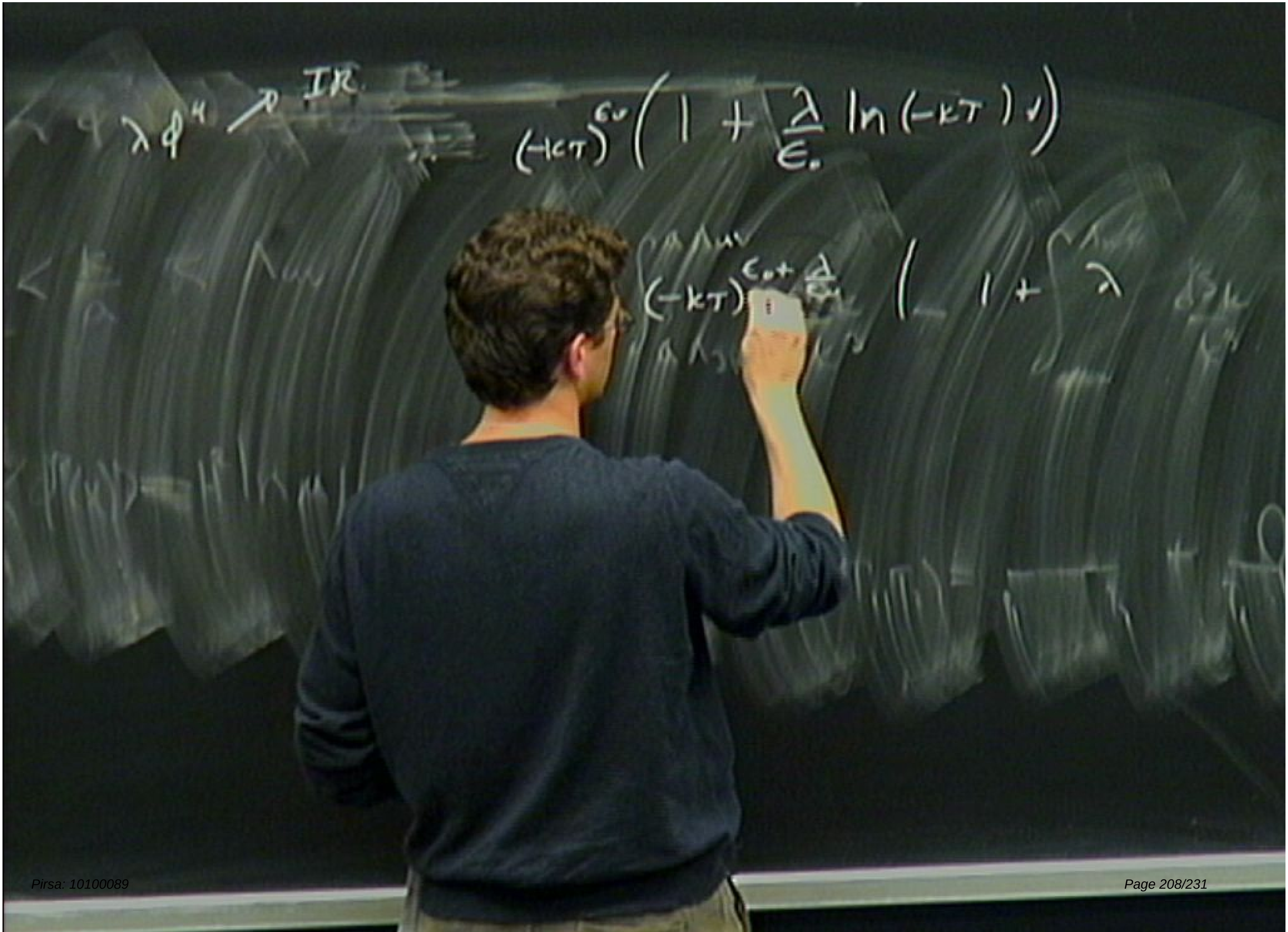


$\lambda \phi^4 \nearrow$ IR.

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

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

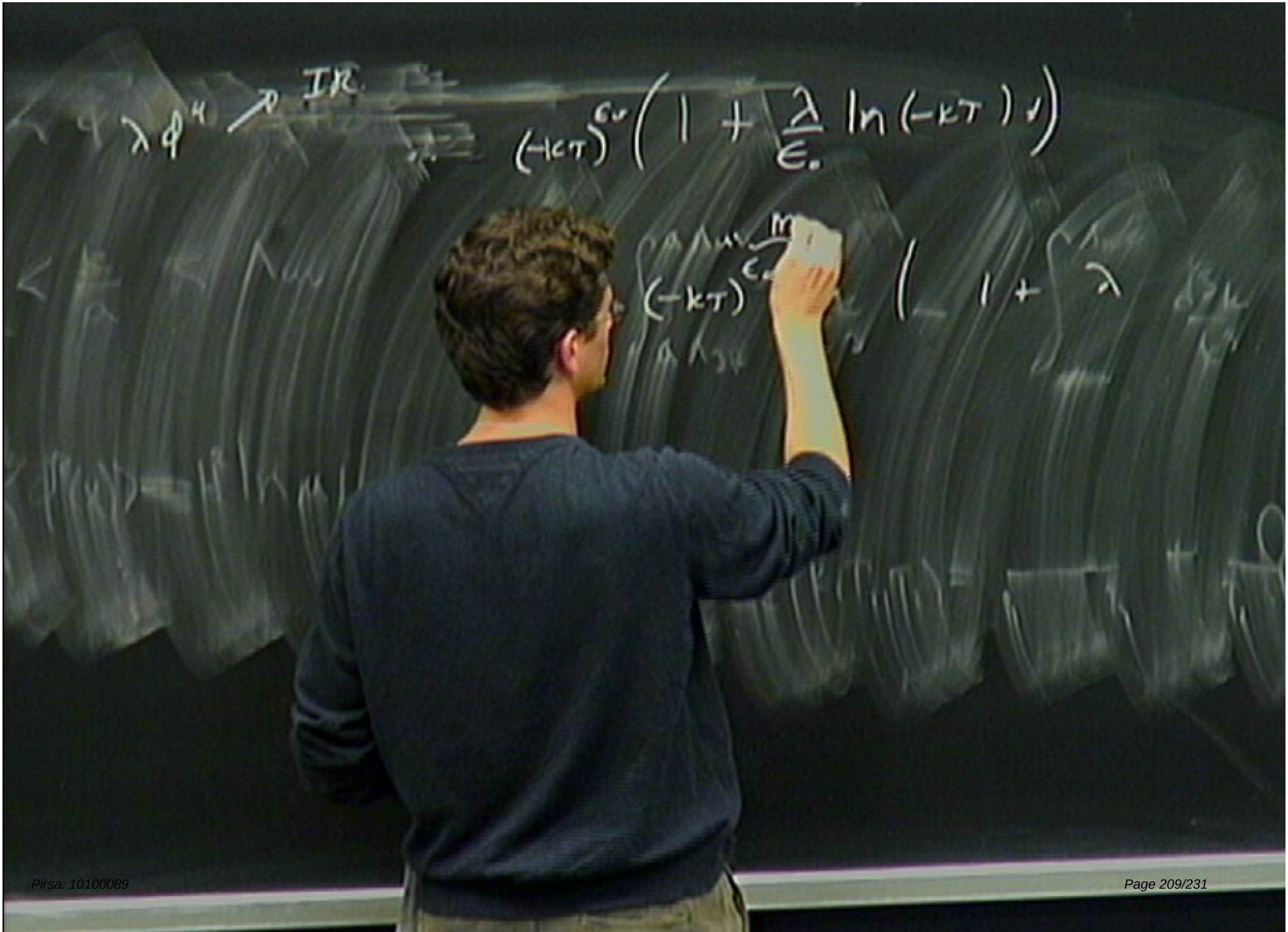

$\lambda \phi^4 \nearrow$ IR
$(-k\tau)^{\epsilon\nu}\left(1 + \frac{\lambda}{\epsilon_0}\ln(-k\tau) + \right)$

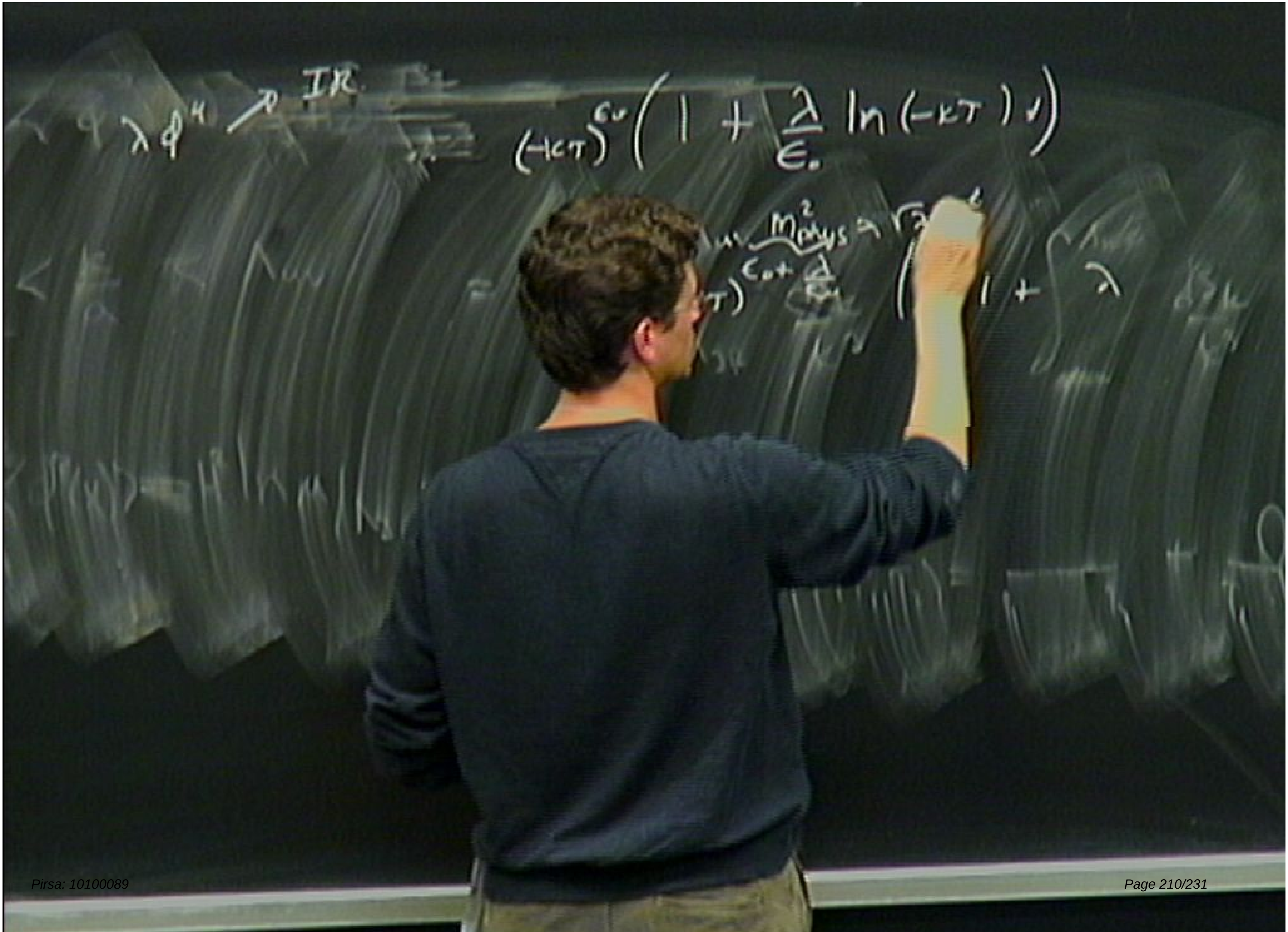


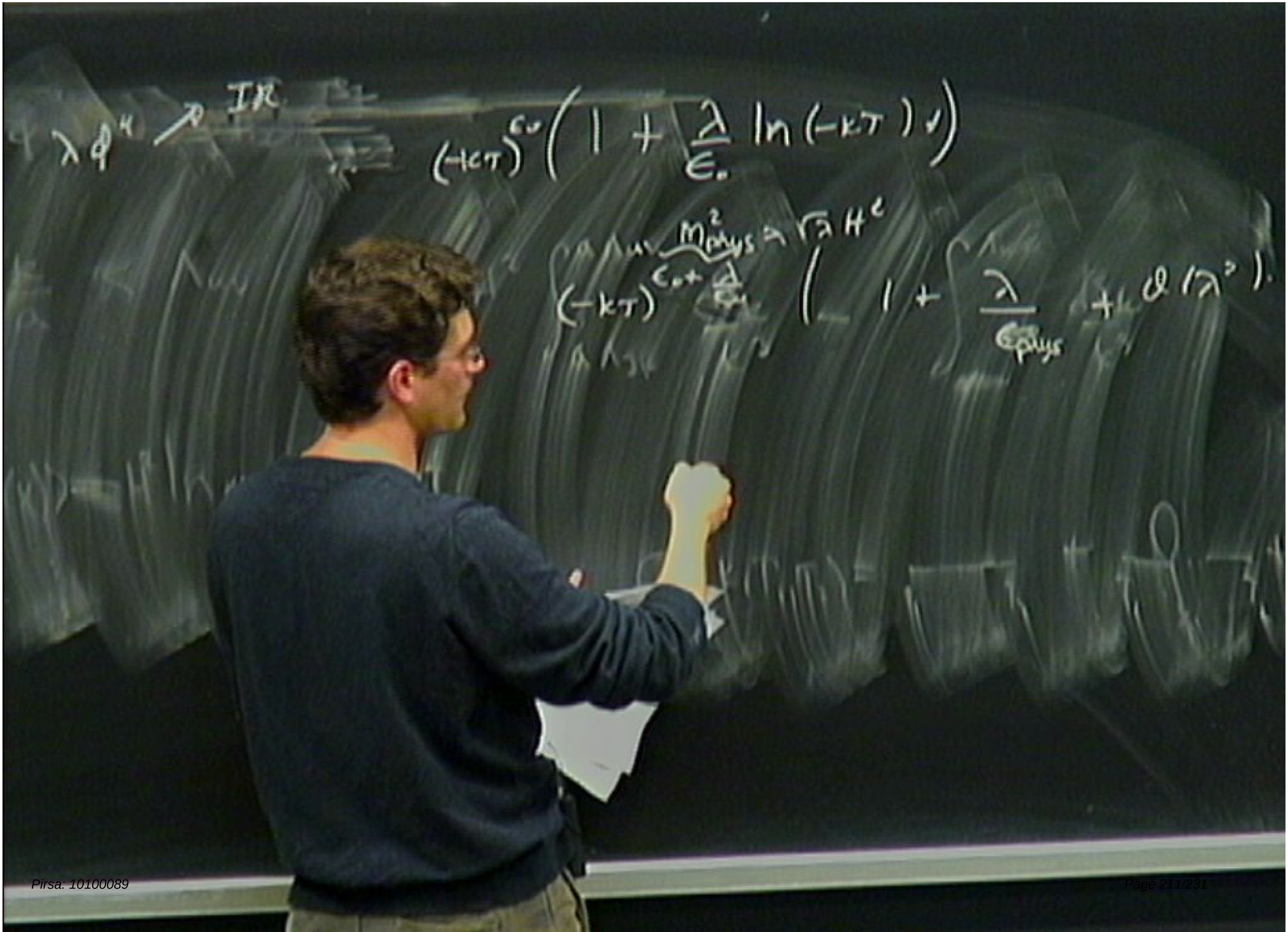
$\lambda\phi^4 \nearrow$ IR

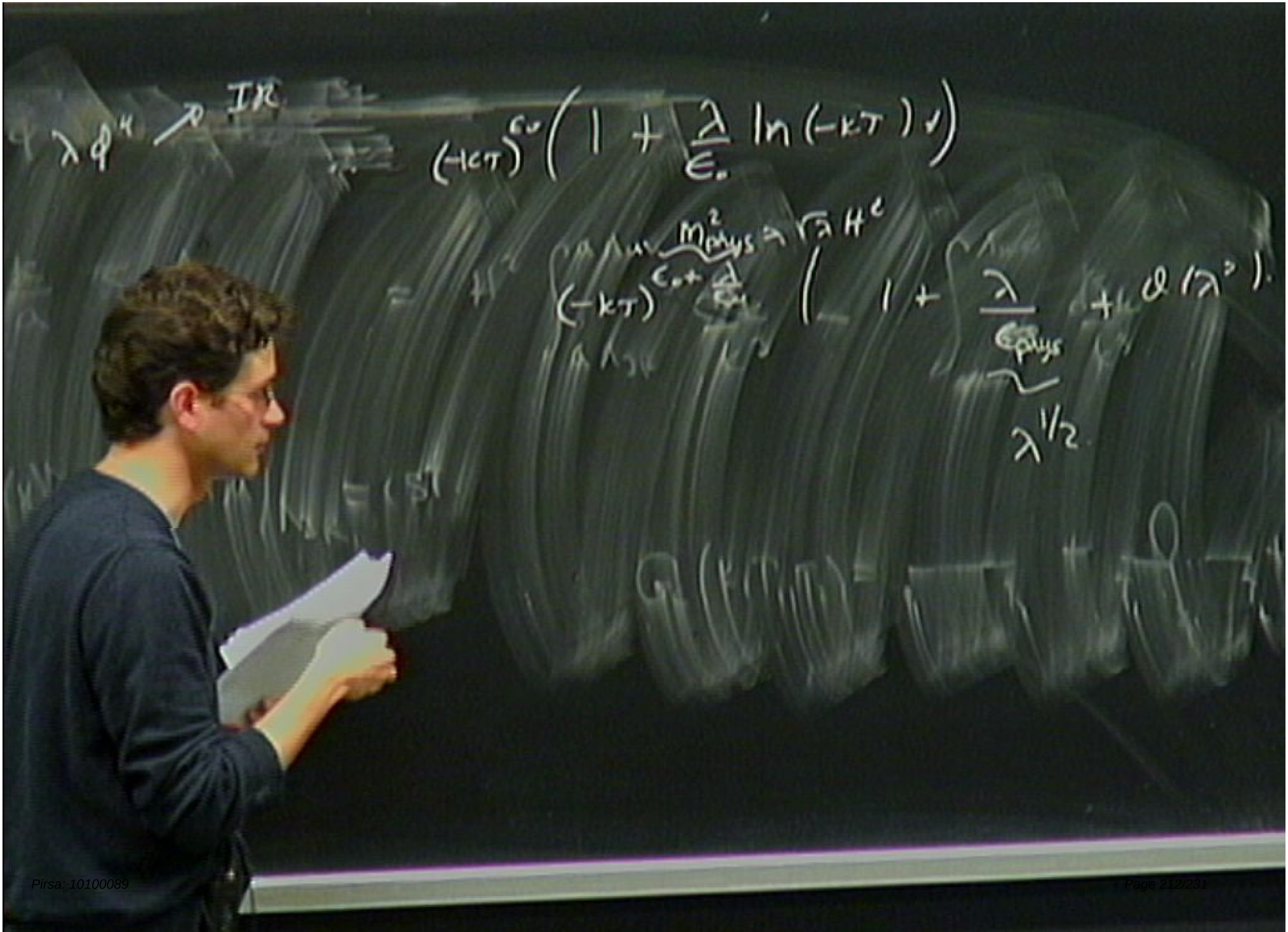
$$(-k\tau)^{\epsilon_0}\left(1+\frac{\lambda}{\epsilon_0}\ln(-k\tau)\,\nu\right)$$

$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(\quad 1+\lambda\right.$$


λφ^4 ↗ IR
(-kT)^{εν} (1 + λ/ε ln(-kT) ν)
(-kT)^{ε} (1 + λ


λφ⁴ ↗ IR
(-kτ)^{ε₀} (1 + λ/ε₀ ln(-kτ))
m²phys ∝ √λ
)^{ε₀ + λ/ε₀} (1 + λ


$\lambda\phi^4 \nearrow$ IR
$(-k\tau)^{\epsilon_0}\left(1 + \frac{\lambda}{\epsilon_0}\ln(-k\tau) + \right)$
$m^2_{phys} \approx \sqrt{\lambda} H^2$
$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \frac{\lambda}{\epsilon_{phys}} + \mathcal{O}(\lambda^2)\right)$

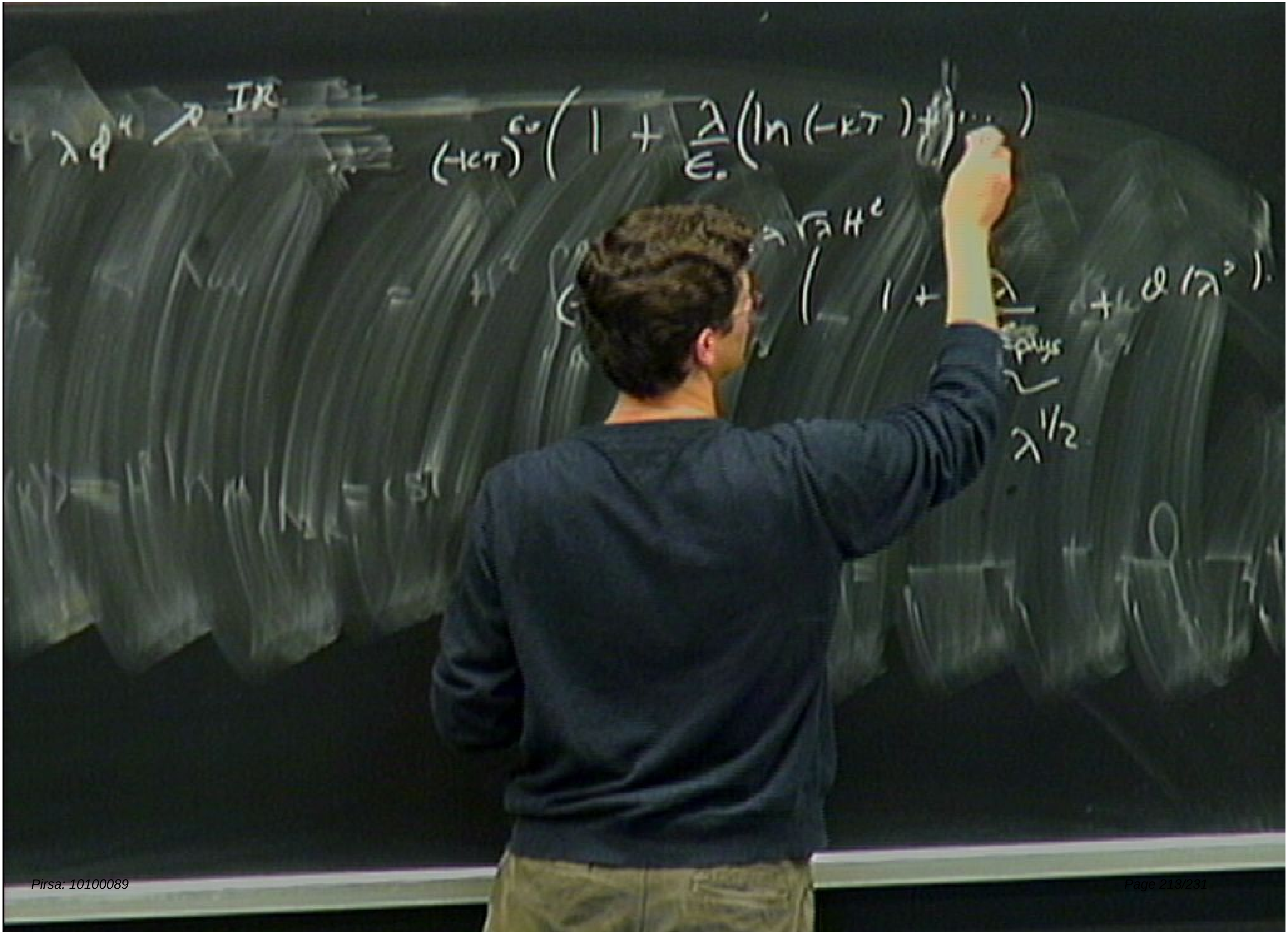


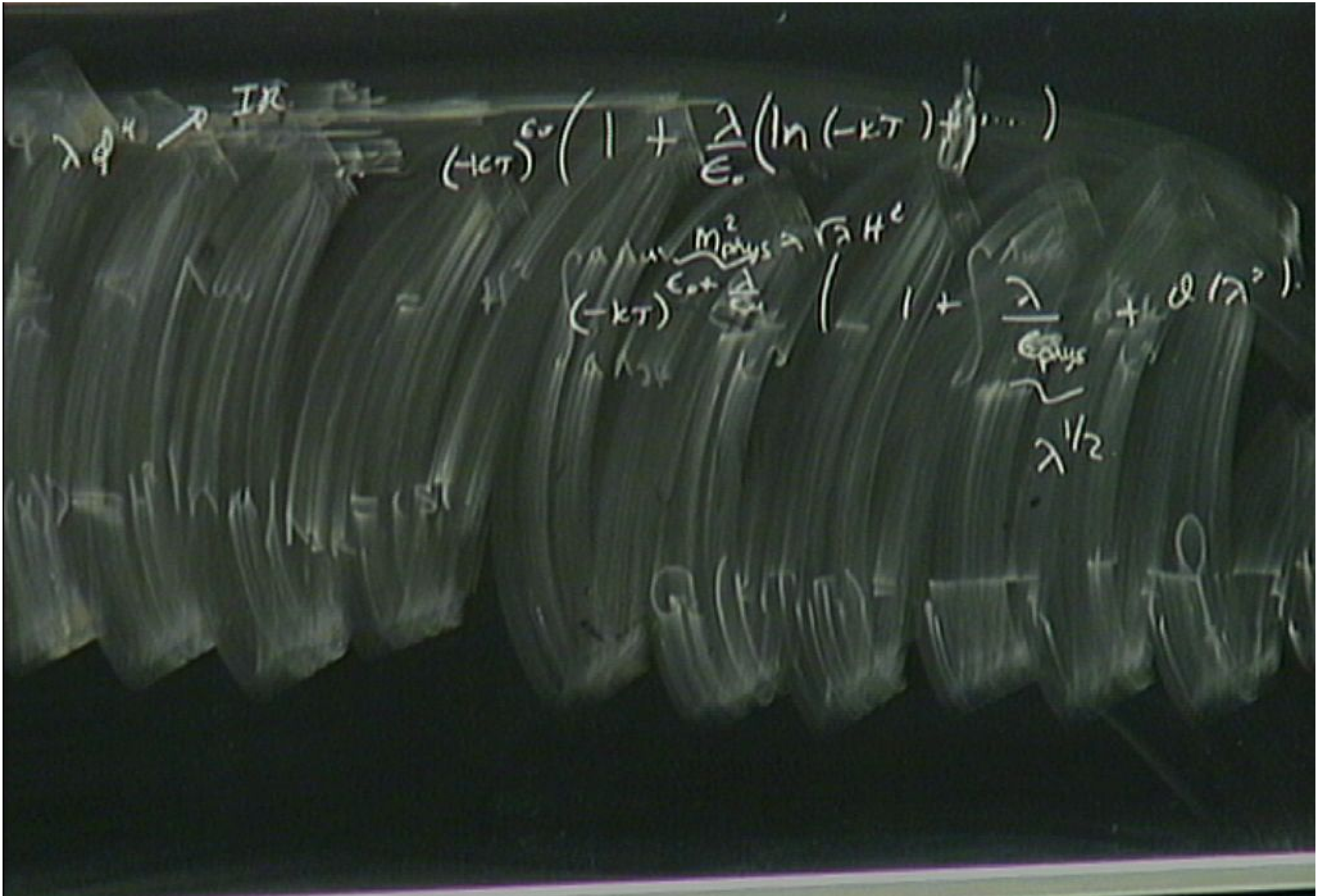
$\lambda\phi^4 \nearrow$ IR

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

$$m^2_{phys} \sim \sqrt{\lambda}H^2$$

$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\underbrace{\frac{\lambda}{\epsilon_{phys}}}_{\lambda^{1/2}}+\mathcal{O}(\lambda^2)\right)$$


λφ⁴ ↗ IR
(-kτ)^εν (1 + λ/ε₀ (ln(-kτ) ...))
√λ H^c
(1 +
ε_phys
+ O(λ²)).
λ^1/2

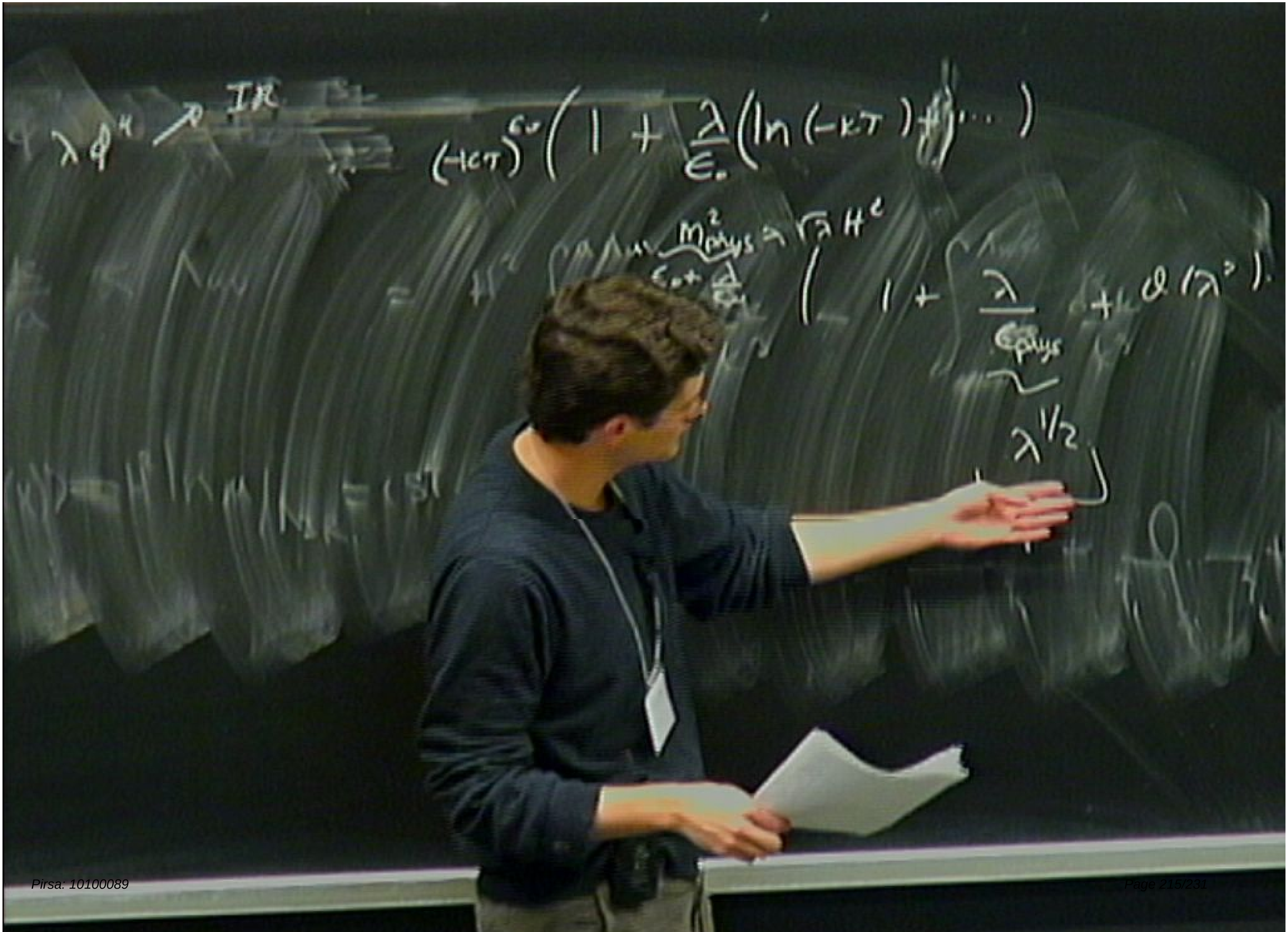


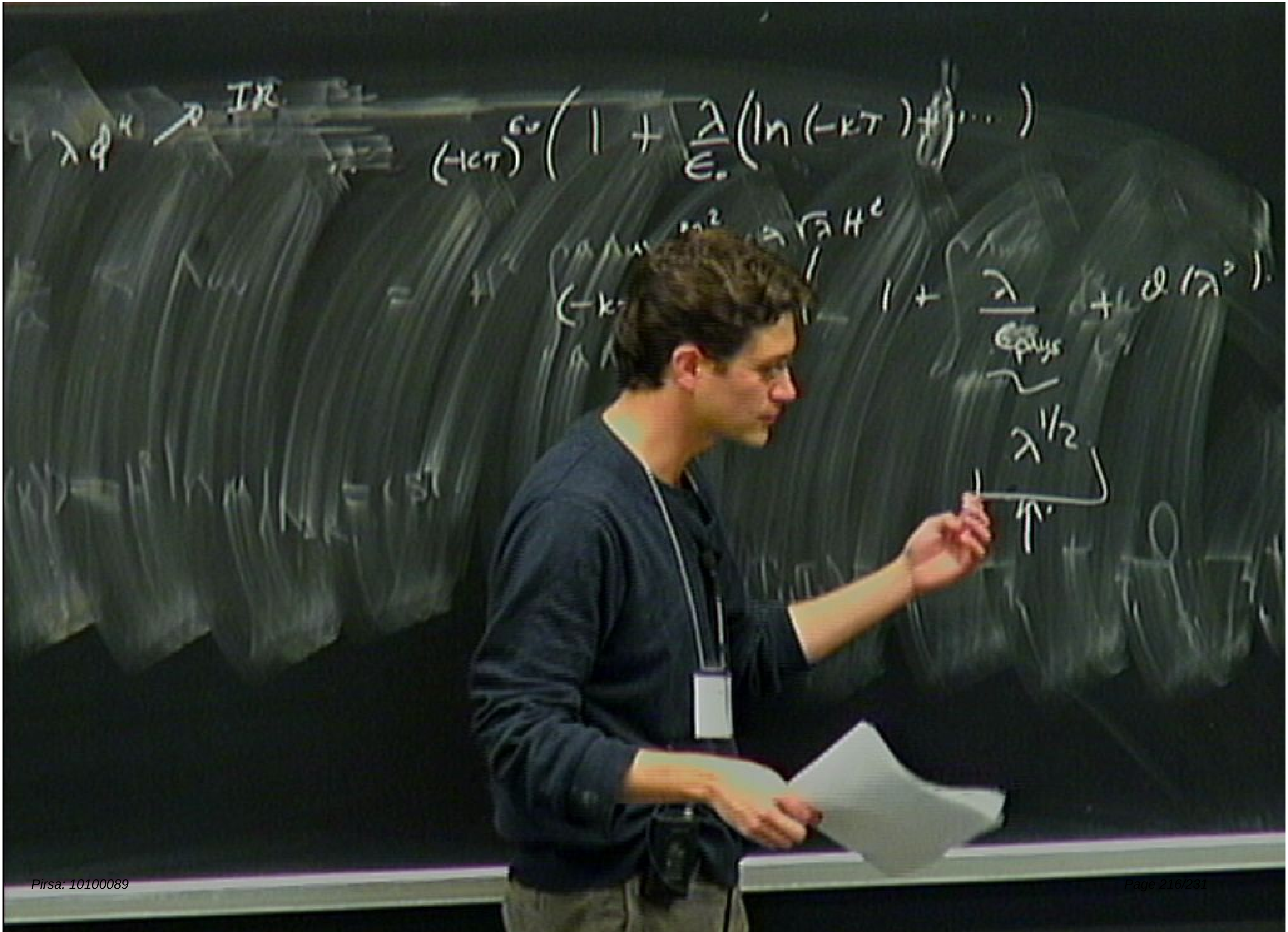
$\lambda\phi^4 \nearrow \text{IR}$

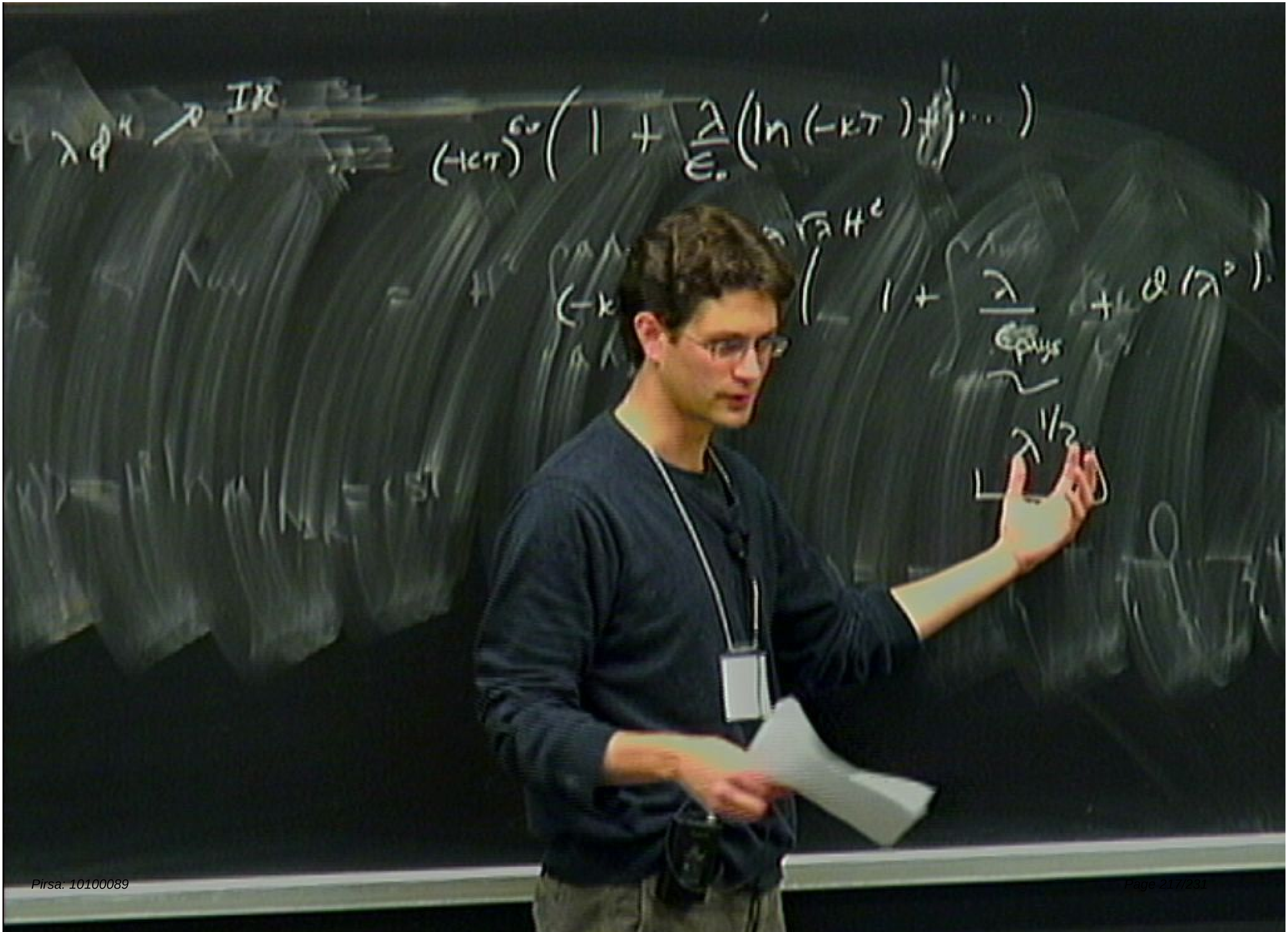
$$(-k\tau)^{\epsilon_0}\left(1 + \frac{\lambda}{\epsilon_0}\left(\ln(-k\tau) + \dots\right)\right)$$

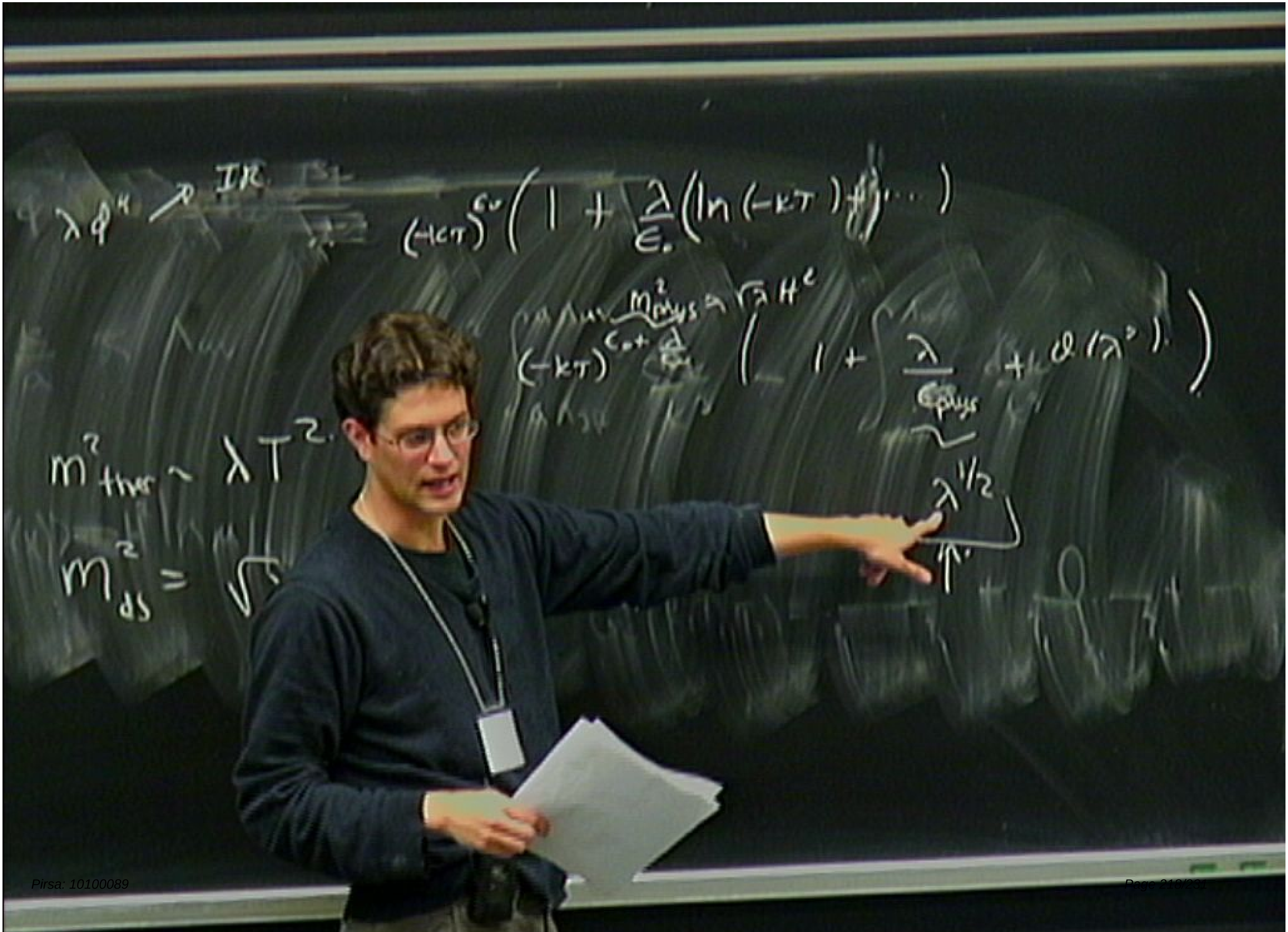
$\underbrace{m^2_{phys}}\sim\sqrt{\lambda}H^2$

$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1 + \underbrace{\frac{\lambda}{\epsilon_{phys}}}_{\lambda^{1/2}} + \mathcal{O}(\lambda^2)\right)$$


λφ⁴ ↗ IR
(-kτ)^ε₀ (1 + λ/ε₀ (ln(-kτ) + …) …)
m²_phys ≈ √λ H²
(1 + λ/ε_phys + O(λ²))
λ^1/2


λφ⁴ → IR
(-kτ)^{εν} (1 + λ/ε₀ (ln(-kτ) ...) ...)
1 + λ/ε_phys + O(λ²)
λ^{1/2}


λφ^4 ↗ IR
(-kτ)^{εν} (1 + λ/ε_0 (ln(-kτ) + ...) ...)
(-k (1 + λ/ε_phys + O(λ^2))
λ^{1/2}


$\lambda\phi^4 \nearrow$ IR
$(-k\tau)^{\epsilon_0}\left(1+\frac{\lambda}{\epsilon_0}(\ln(-k\tau)+\dots)\right)$
$m^2_{phys} \sim \sqrt{\lambda} H^2$
$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\frac{\lambda}{\epsilon_{phys}}+\mathcal{O}(\lambda^0)\right)$
$\lambda^{1/2}$
$m^2_{ther} \sim \lambda T^2$
$m^2_{ds} = \sqrt{\ }$

$\lambda\phi^4 \nearrow$ IR

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

$$\underbrace{m^2_{phys}}\approx\sqrt{\lambda}H^2$$

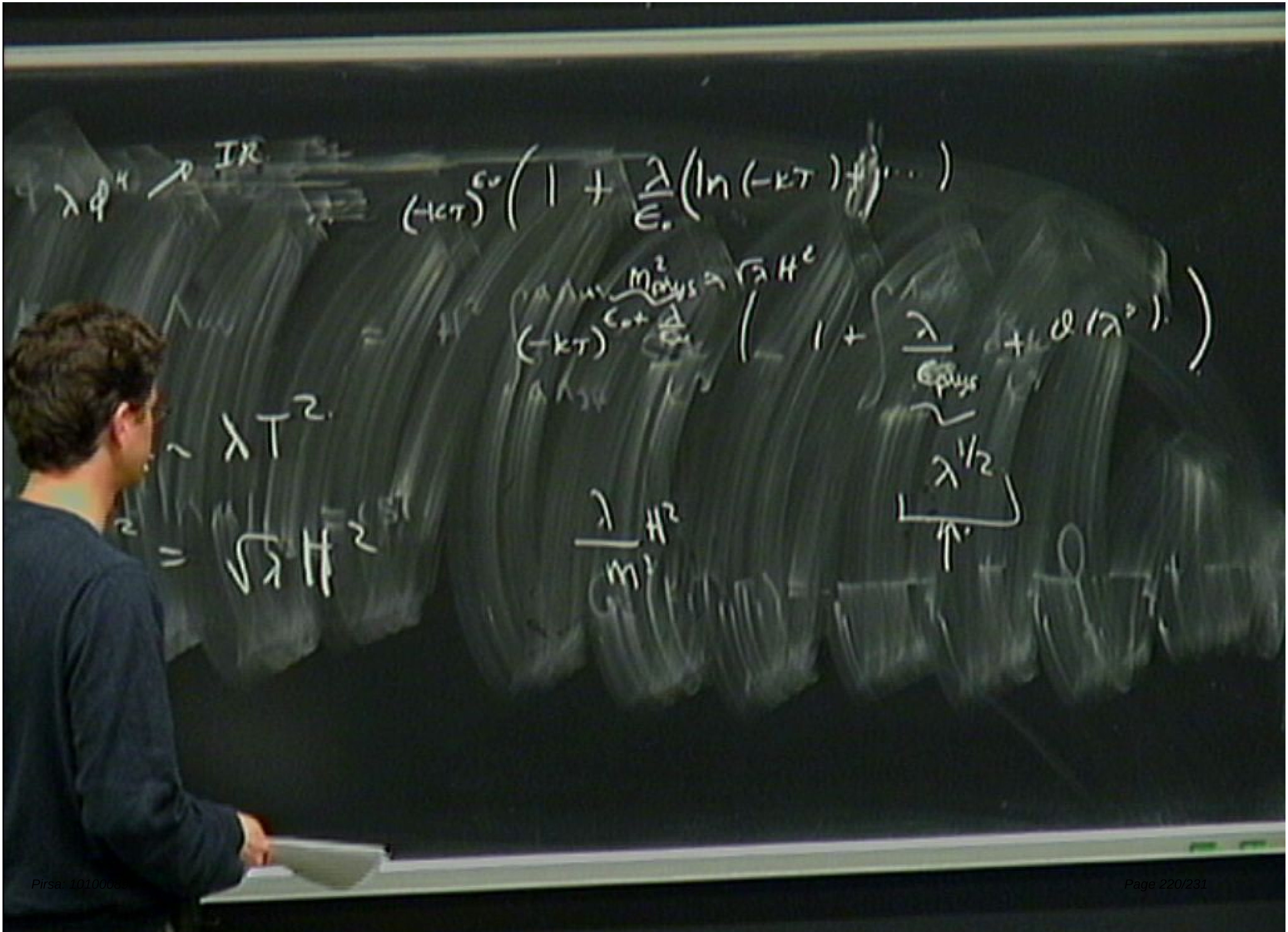
$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\frac{\lambda}{\underbrace{\epsilon_{phys}}_{\sim\lambda^{1/2}}}+\mathcal{O}(\lambda^2)\right)$$

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

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

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

$\uparrow$



$\lambda\phi^4 \nearrow$ IR

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

$m^2_{phys} \approx \sqrt{\lambda}H^2$

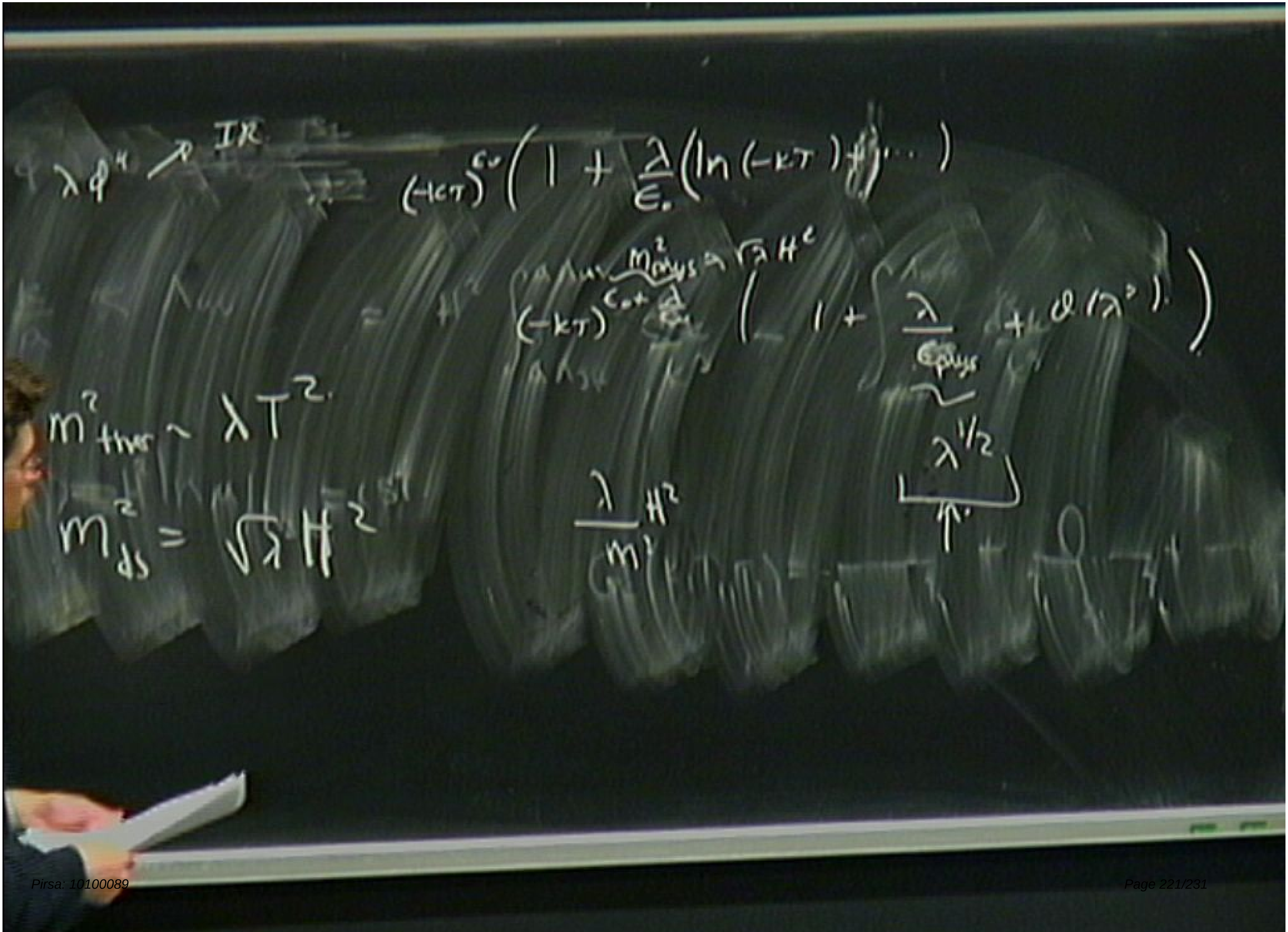
$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \frac{\lambda}{\underset{\sim}{\epsilon_{phys}}} + \mathcal{O}(\lambda^2)\right)$

$\lambda^{1/2}$

$\sim \lambda T^2$

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

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



$\lambda\phi^4 \nearrow$ IR

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

Λ_{UV} $m^2_{phys} \sim \sqrt{\lambda} H^2$

$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \frac{\lambda}{\underbrace{\epsilon_{phys}}_{\lambda^{1/2}}} + \mathcal{O}(\lambda^2)\right)$

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

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

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

$\lambda\phi^4 \nearrow$ IR

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

$$\underbrace{m^2_{phys}}\approx\sqrt{\lambda}H^2$$

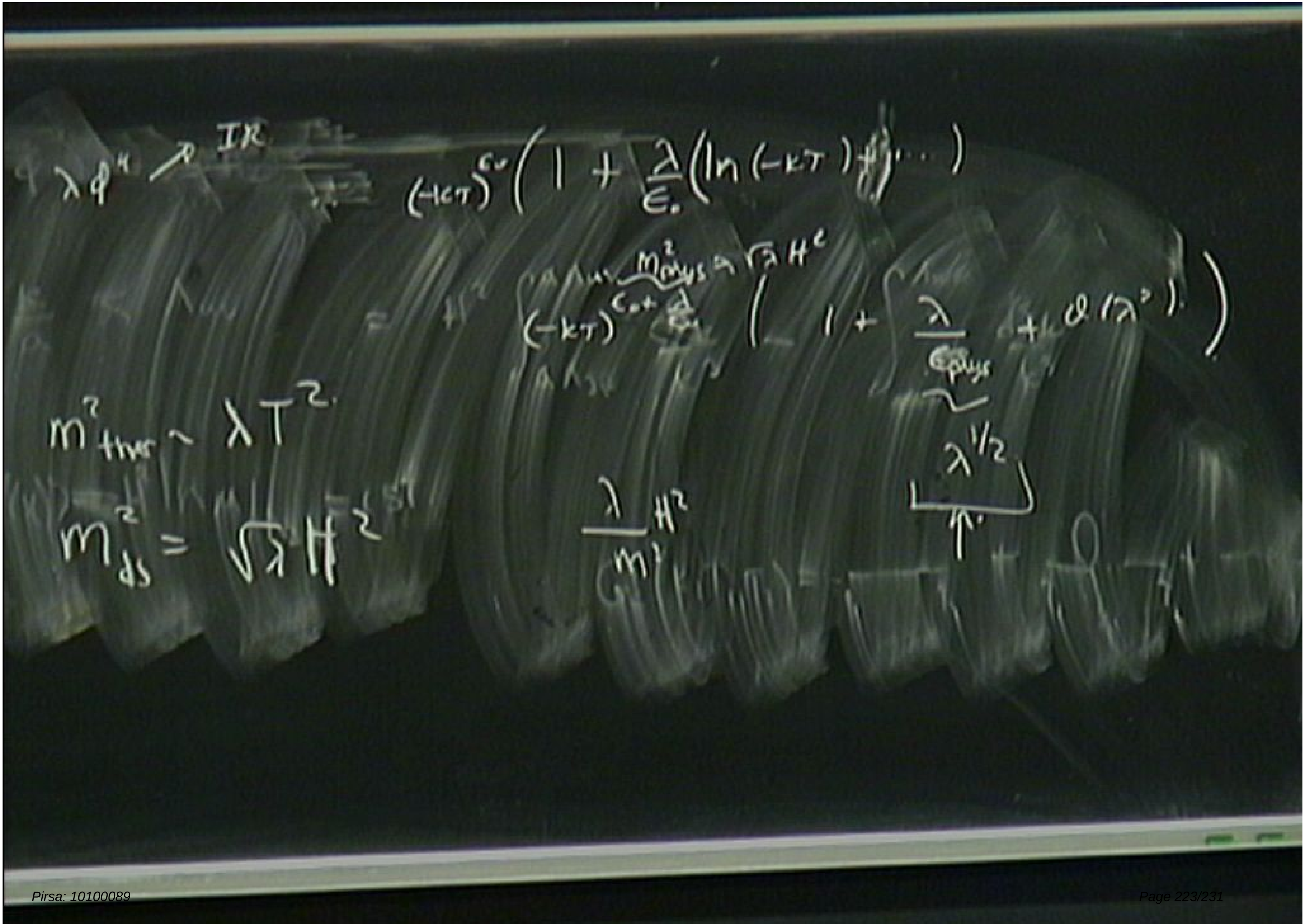
$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\underbrace{\frac{\lambda}{\epsilon_{phys}}}_{\lambda^{1/2}}+\mathcal{O}(\lambda^2)\right)$$

$$\uparrow$$

$$m^2_{ther}\sim\lambda T^2.$$

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

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



$\lambda\phi^4 \nearrow \mathrm{IR}$

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

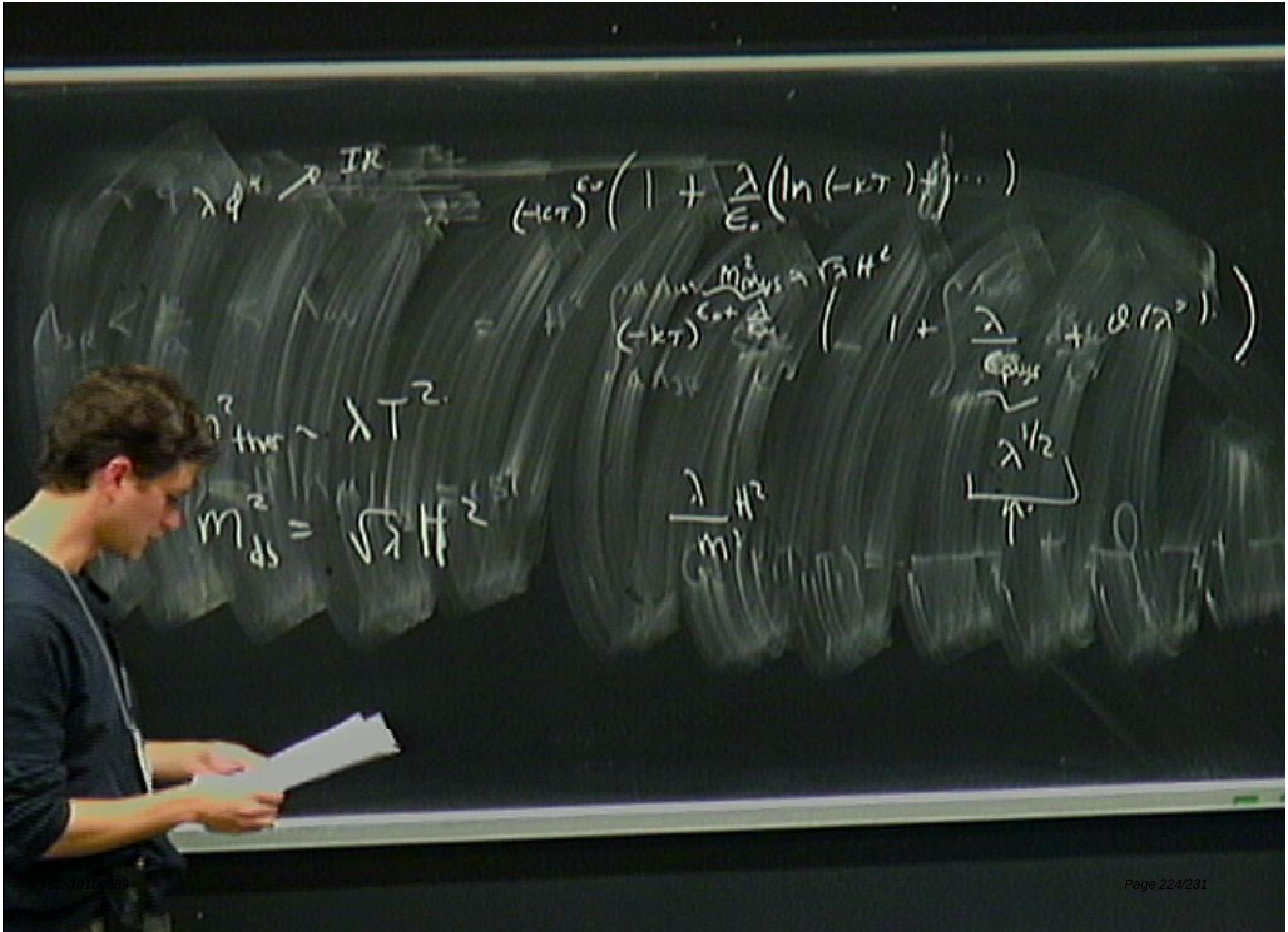
$m^2_{\rm phys} \approx \sqrt{\lambda} H^2$

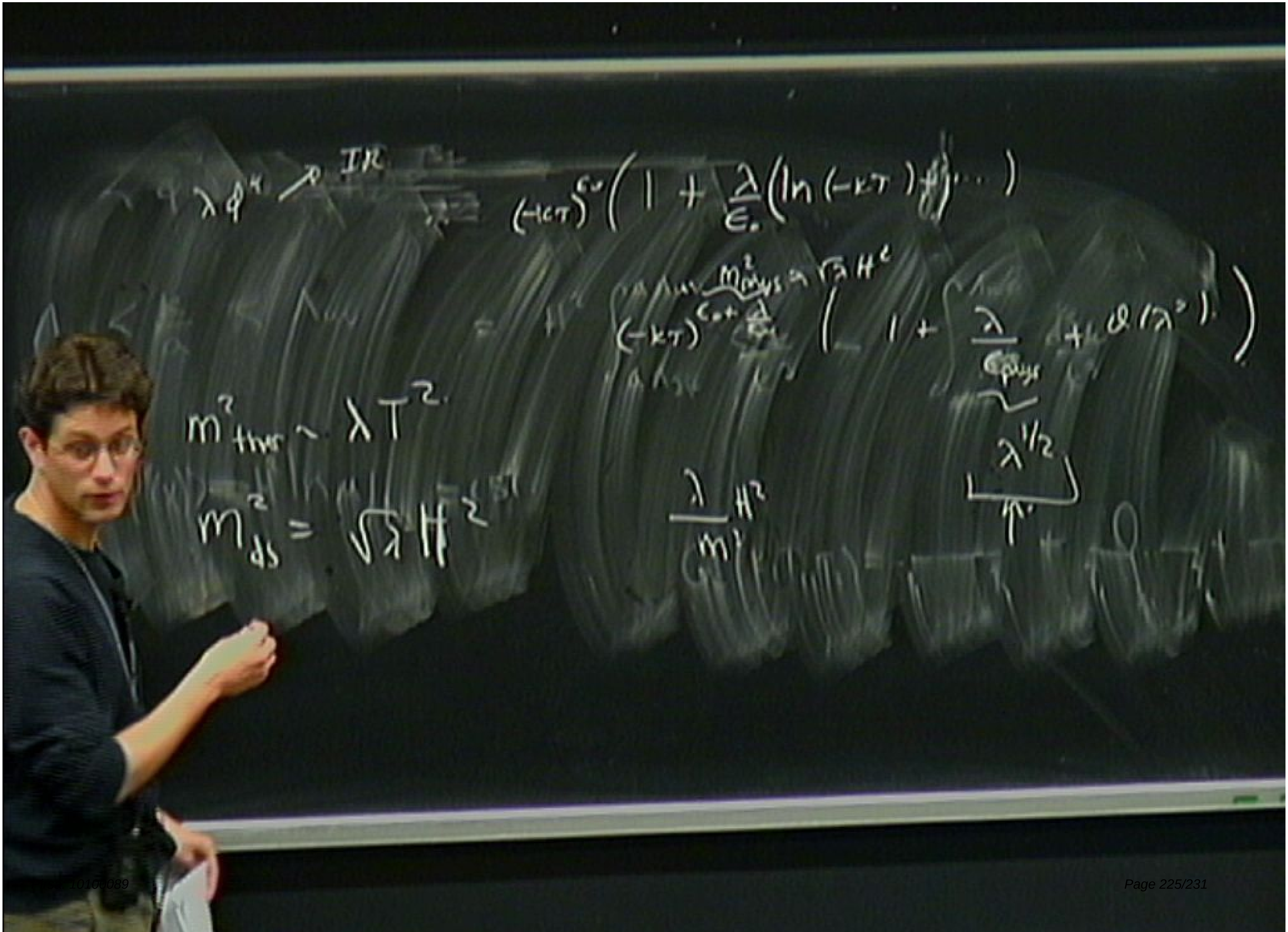
$$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \frac{\lambda}{\underbrace{\epsilon_{\rm phys}}_{\lambda^{1/2}}} + \mathcal{O}(\lambda^2)\right)$$

$m^2_{\rm ther} \sim \lambda T^2$

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

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


$\lambda\phi^4 \nearrow$ IR
$(-k\tau)^{\epsilon_0}\left(1+\frac{\lambda}{\epsilon_0}(\ln(-k\tau)\ldots)\right)$
$m^2_{phys} \sim \sqrt{\lambda}H^2$
$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\frac{\lambda}{\epsilon_{phys}}+\mathcal{O}(\lambda^2)\right)$
$\lambda^{1/2}$
$m^2_{thr} \sim \lambda T^2$
$m^2_{dS} = \sqrt{\lambda}H^2$
$\frac{\lambda}{m^2}H^2$



$\lambda \phi^4 \nearrow$ IR

$(-k\tau)^{c_0}\left(1 + \frac{\lambda}{\epsilon_0}(\ln(-k\tau) \ldots)\right)$

$m^2_{phys} \approx \sqrt{\lambda} H^2$

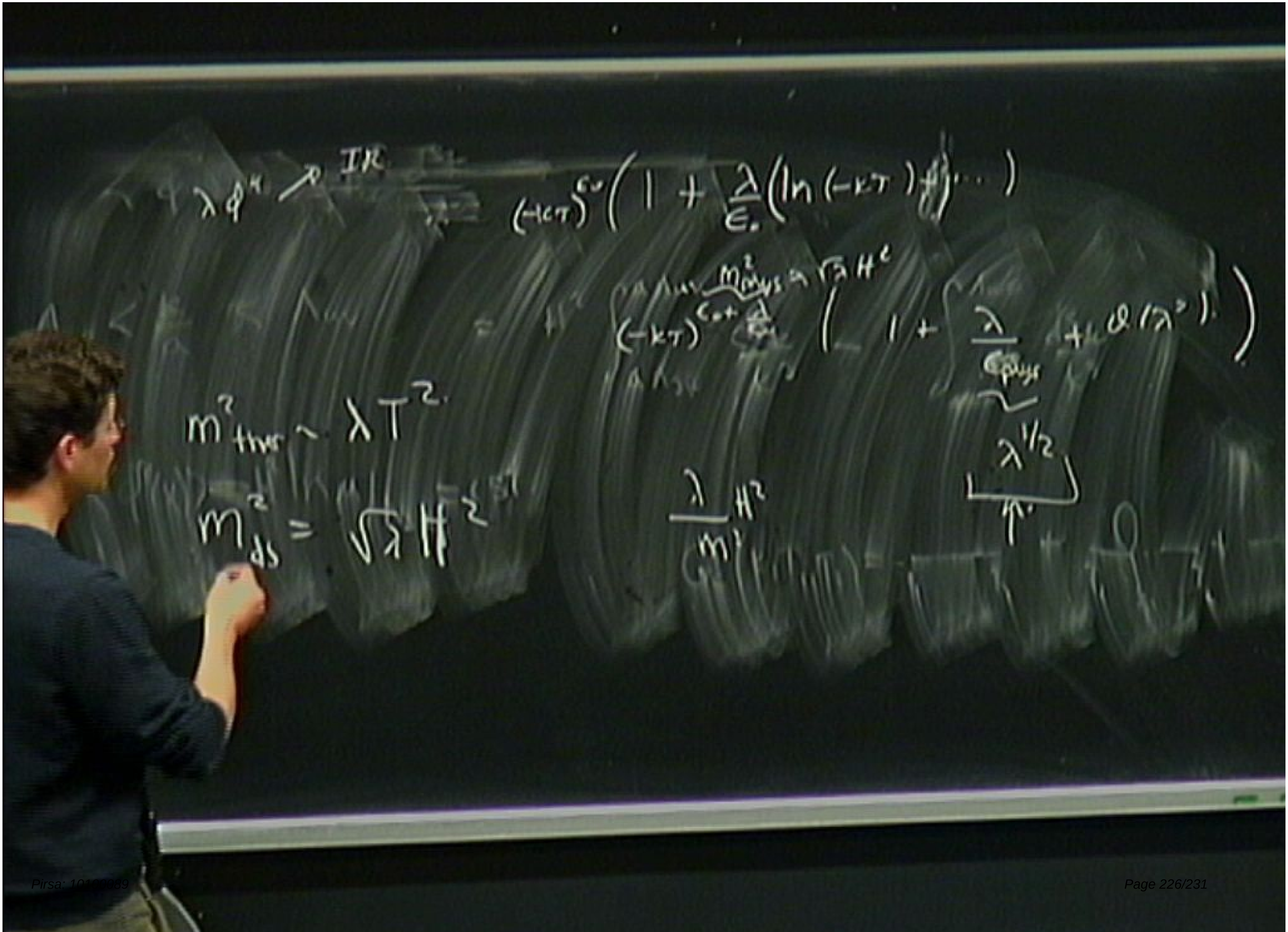
$(-k\tau)^{c_0 + \frac{\lambda}{c_0}}\left(1 + \frac{\lambda}{c_{phys}} + \mathcal{O}(\lambda^2)\right)$

$\lambda^{1/2}$

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

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

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



$\lambda\phi^4 \nearrow$ IR

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

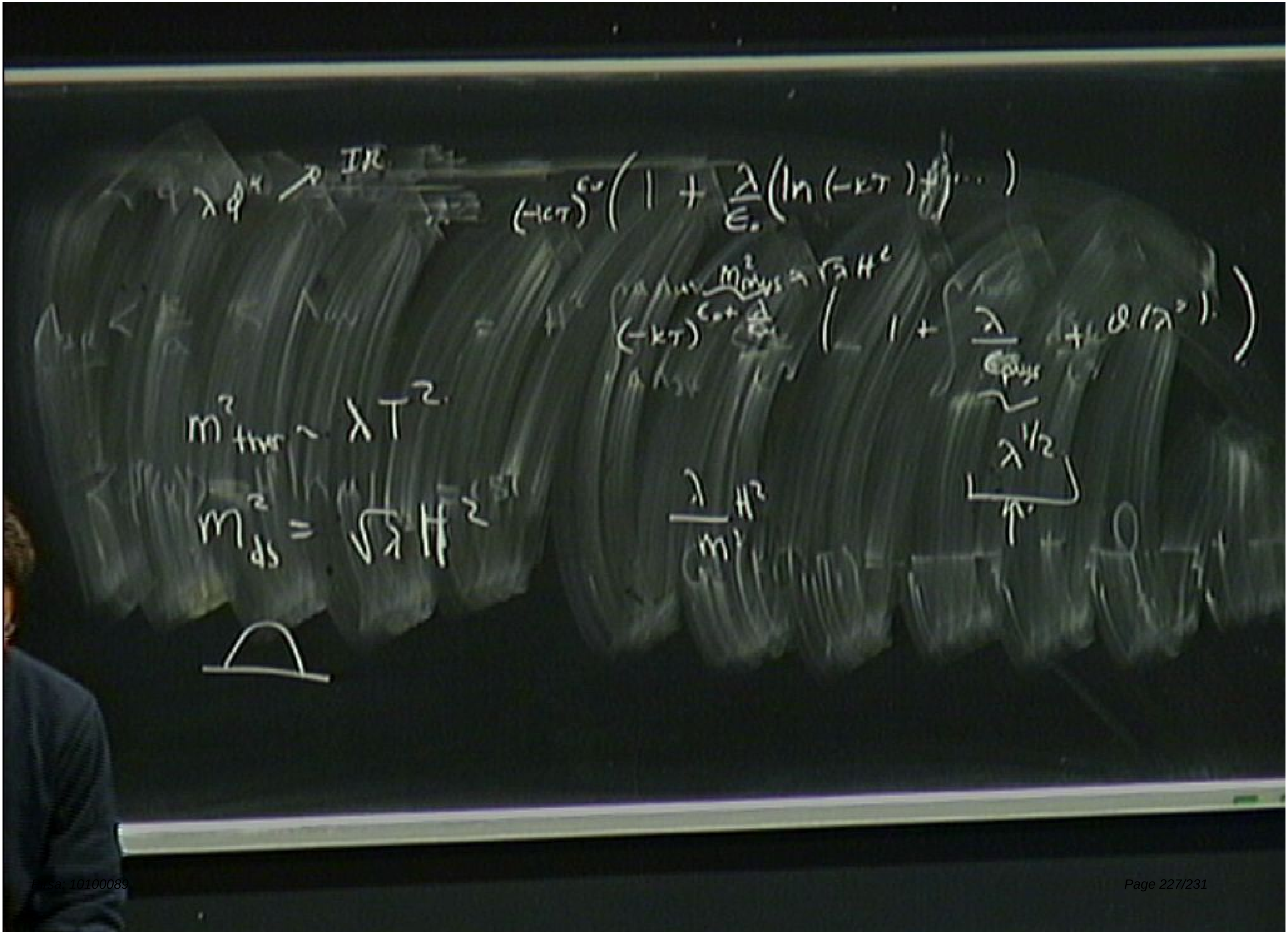
$m^2_{\rm phys} \sim \sqrt{\lambda}H^2$

$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \underbrace{\frac{\lambda}{\epsilon_{\rm phys}}}_{\lambda^{1/2}} + \mathcal{O}(\lambda^2)\right)$

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

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

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



$\lambda\phi^4 \nearrow$ IR

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

$m^2_{phys} \approx \sqrt{\lambda} H^2$

$(-k\tau)^{\epsilon_0 + \frac{\lambda}{\epsilon_0}}\left(1 + \underbrace{\frac{\lambda}{\epsilon_{phys}}}_{\lambda^{1/2}} + \mathcal{O}(\lambda^2)\right)$

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

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

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

$\lambda \phi^4 \nearrow$ IR

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

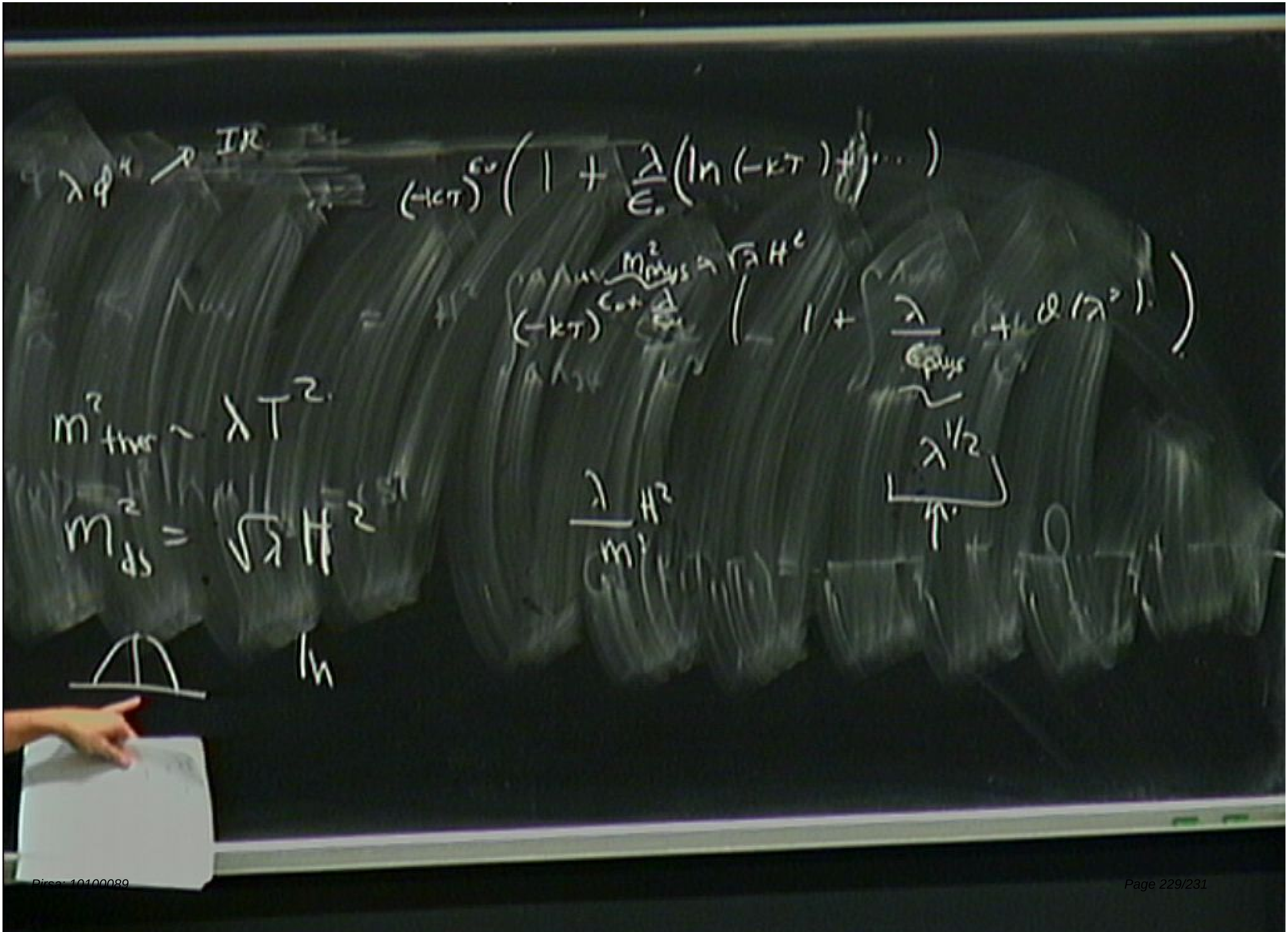
$$m^2_{phys} \approx \sqrt{\lambda}\, H^2$$

$$(-k\tau)^{\epsilon_0+\frac{\lambda}{\epsilon_0}}\left(1+\underbrace{\frac{\lambda}{\epsilon_{phys}}}_{\lambda^{1/2}}+\mathcal{O}(\lambda^2)\right)$$

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

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

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



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$\ln$

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

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