Title: One-loop corrections in slow-roll and in more general theories of inflation

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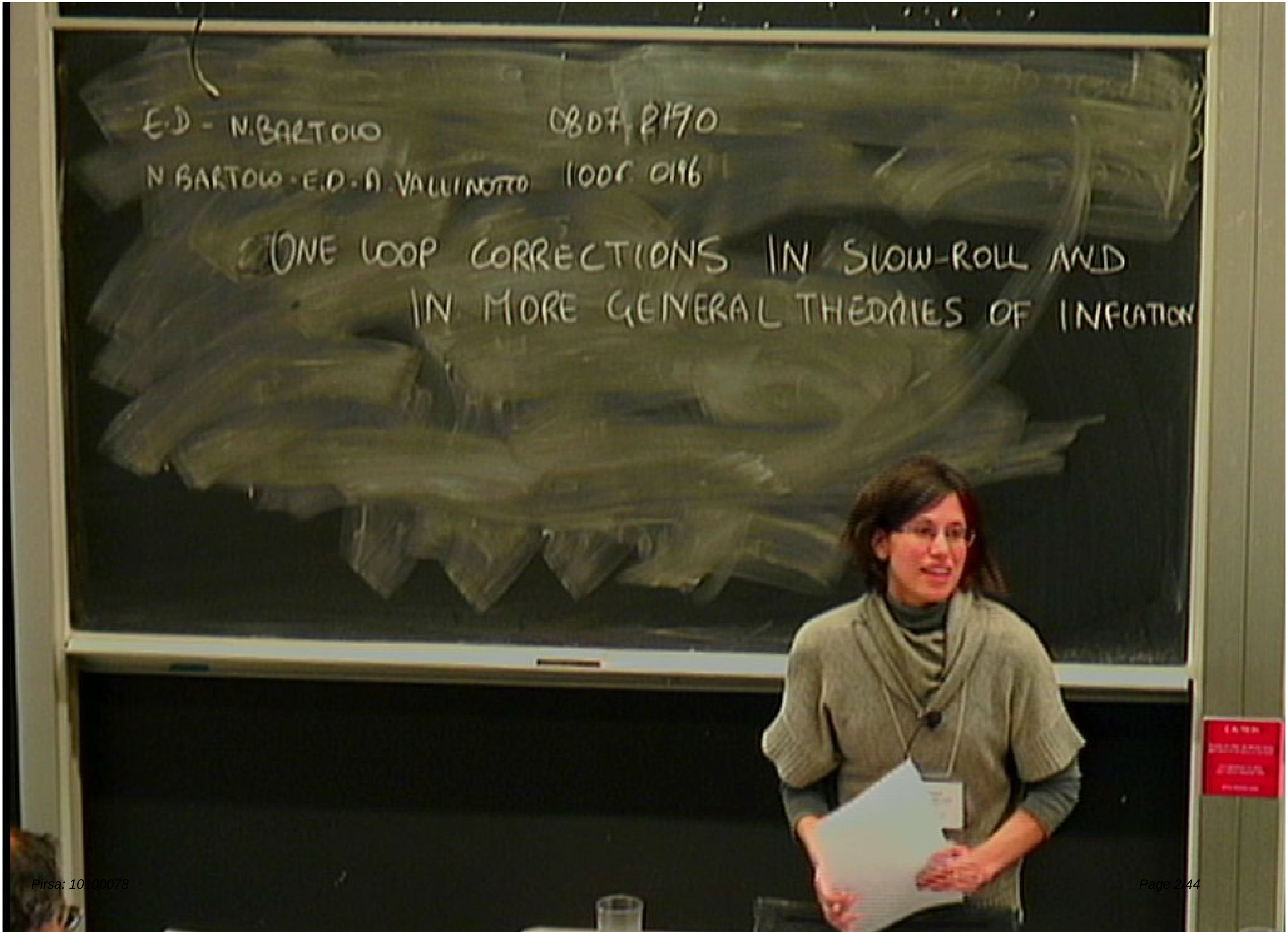
URL: http://pirsa.org/10100078

Abstract: I will present our work on loop corrections to the power spectrum of curvature fluctuations in single-field inflationary models. We consider both standard slow-roll (where the interactions between gravitons and the scalar are included for the first time) and non-canonical Lagrangians. We show that the tensor modes cannot be neglected since, in some models, they produce one loop contributions with an amplitude that is comparable to the one coming from the scalar sector. Our study of loop corrections in non-canonical theories characterized by a small speed of sound (c_s) provides quantitative bounds on c_s, to be compared with similar constraints derived from CMB observations.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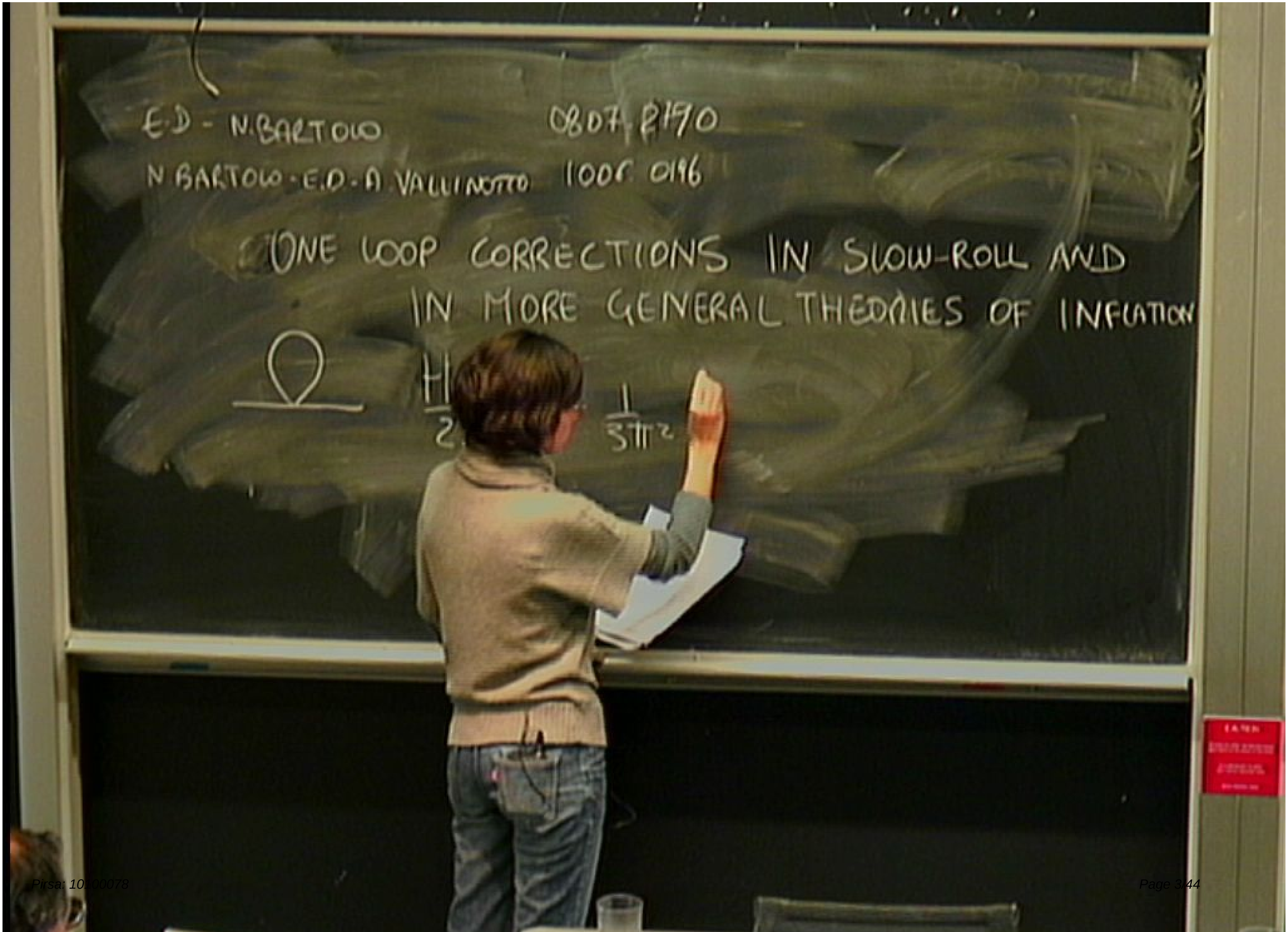
N.BARTOLO - E.D - A.VALLINOTTO
ONE LOOP CORRECTIONS IN SLOW-ROLL AND
IN MORE GENERAL THEORIES OF INFLATION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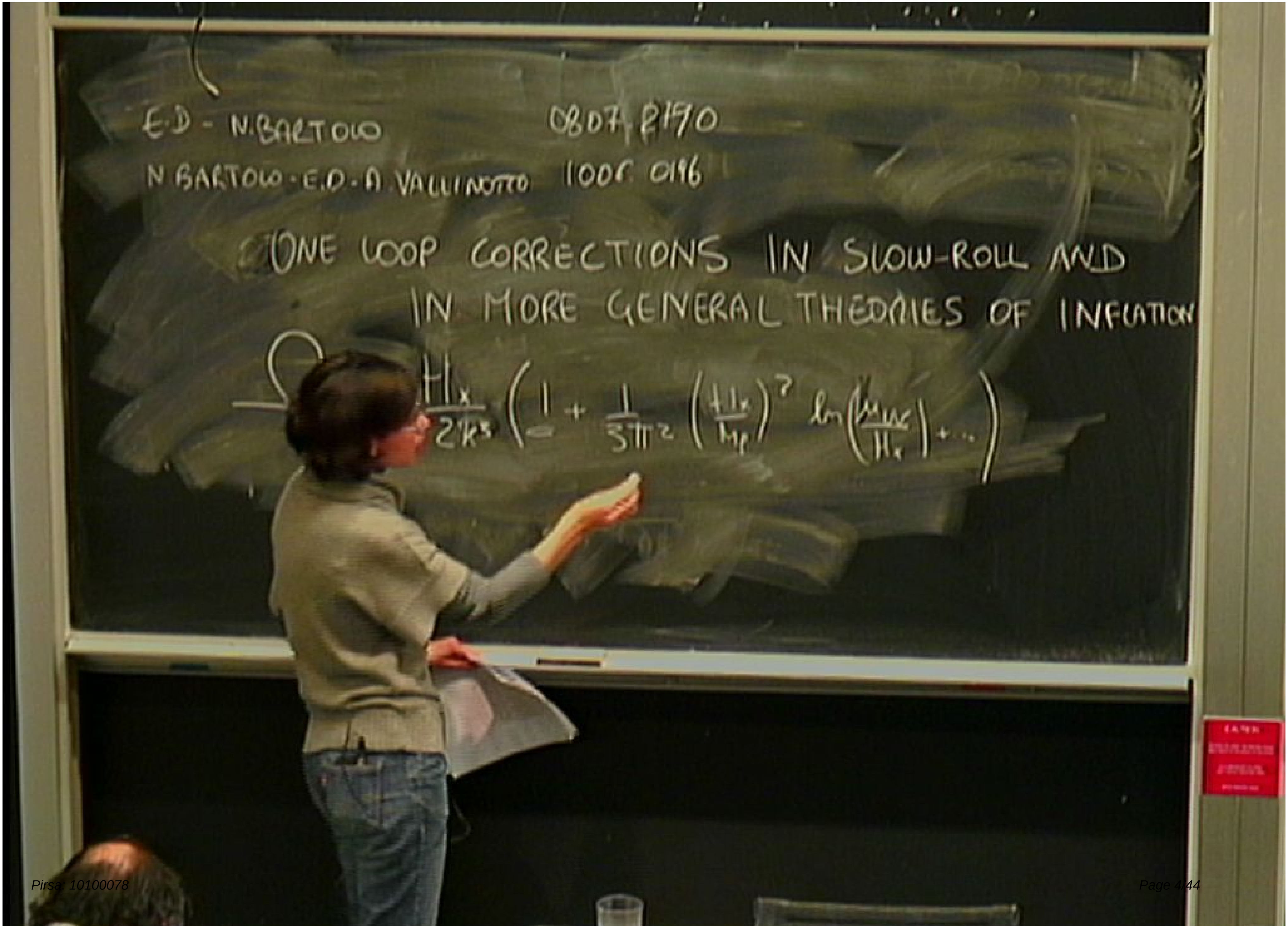
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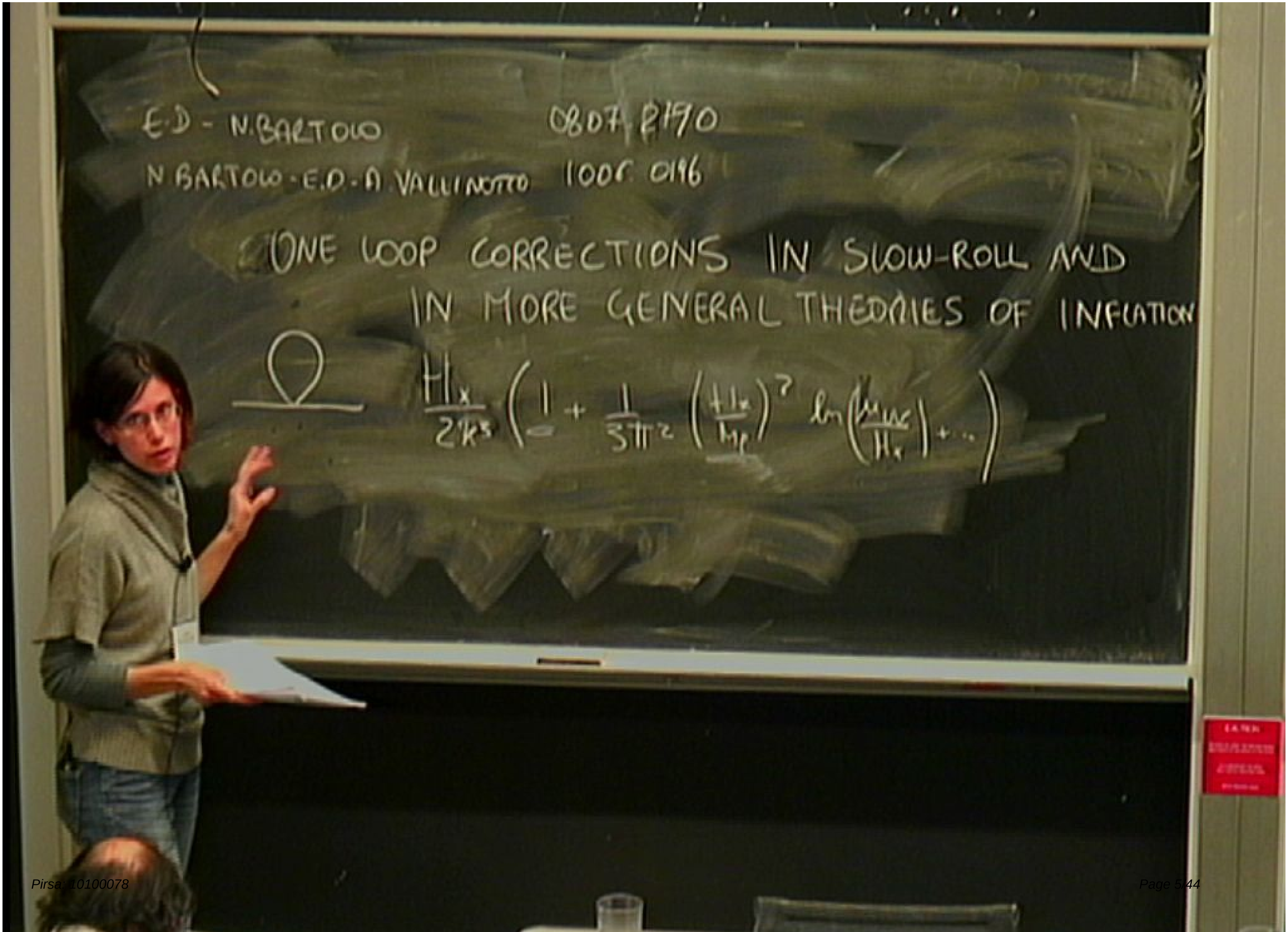
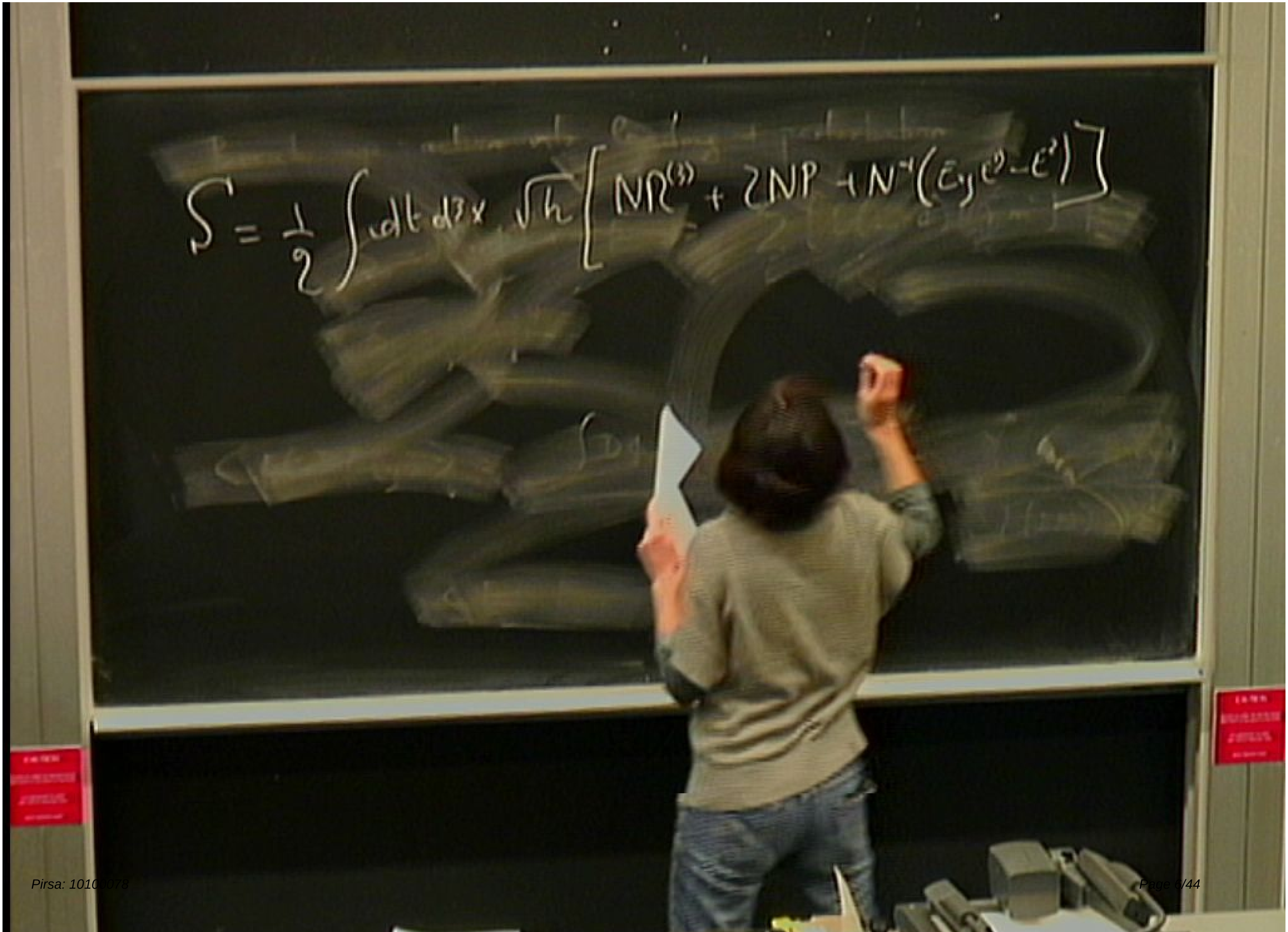
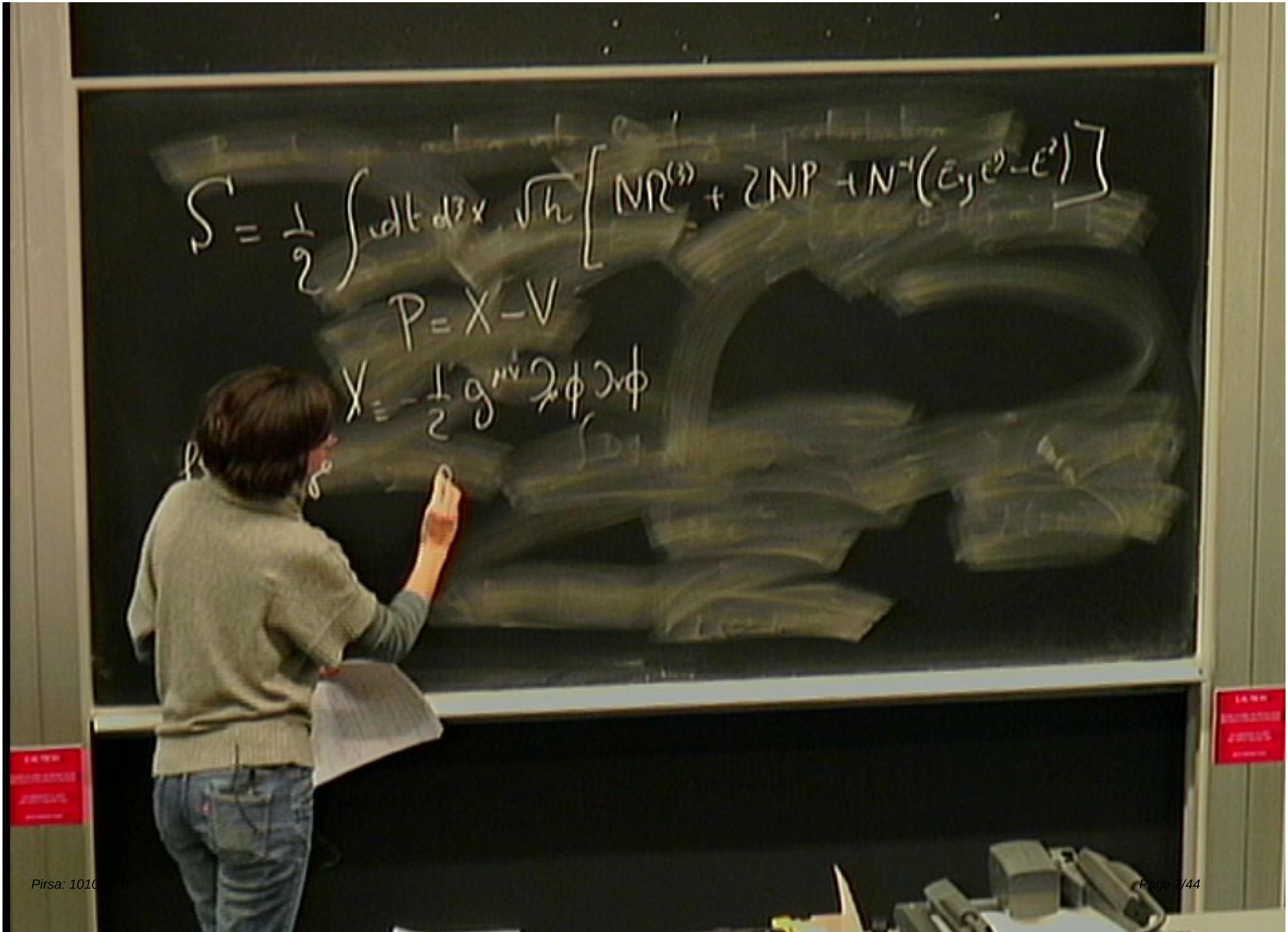
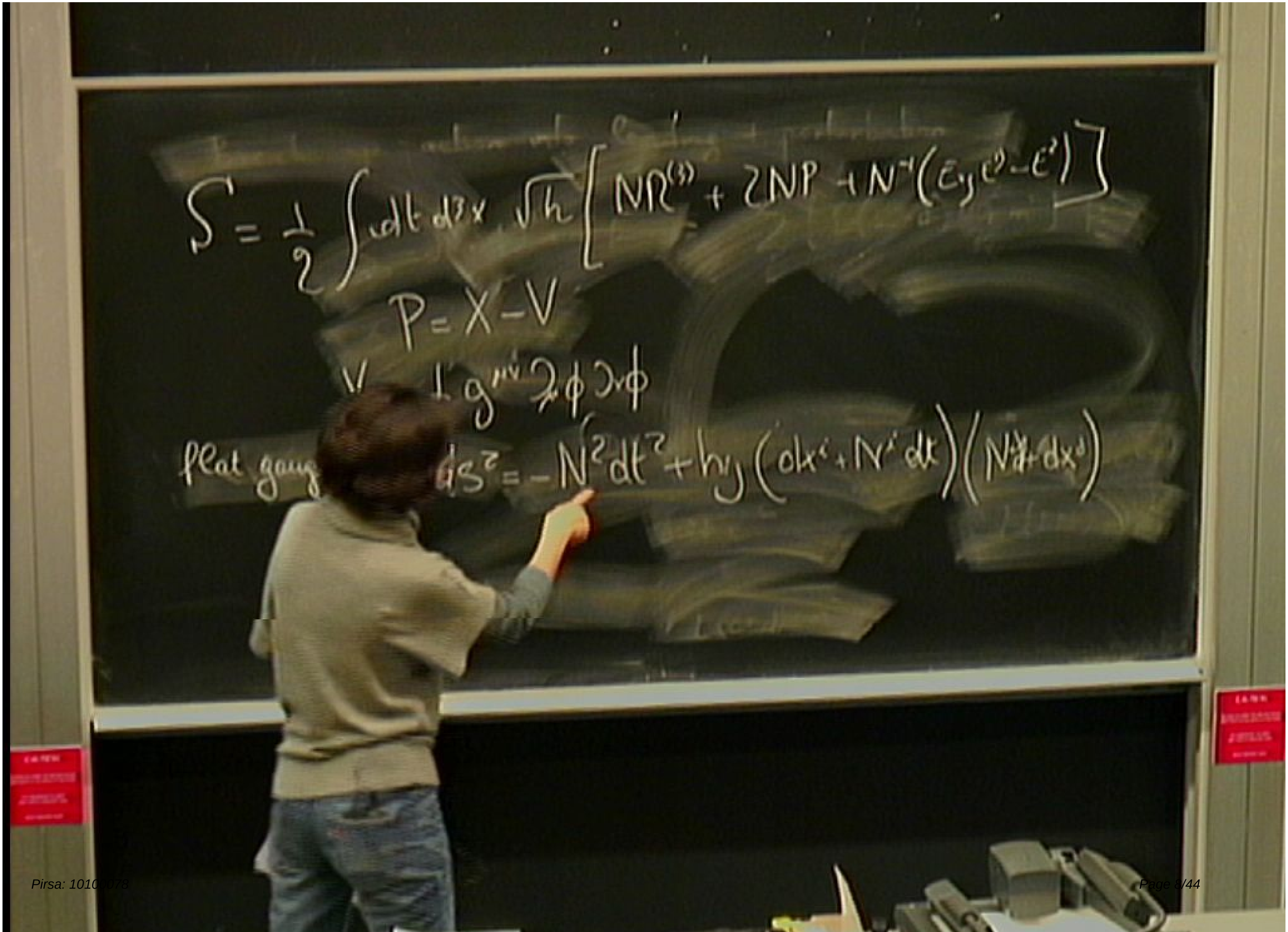
ONE LOOP CORRECTIONS IN SLOW-ROLL AND
IN MORE GENERAL THEORIES OF INFLATION


E.D - N.BARTOLO
N BARTOLO - E.D - A VALLINOTTO
ONE LOOP CORRECTIONS IN SLOW-ROLL AND
IN MORE GENERAL THEORIES OF INFLATION
$\frac{H_*}{2k^3}\left(1 + \frac{1}{3\pi^2}\left(\frac{H_*}{M_P}\right)^2 \ln\left(\frac{k_{max}}{H_*}\right) + \ldots\right)$

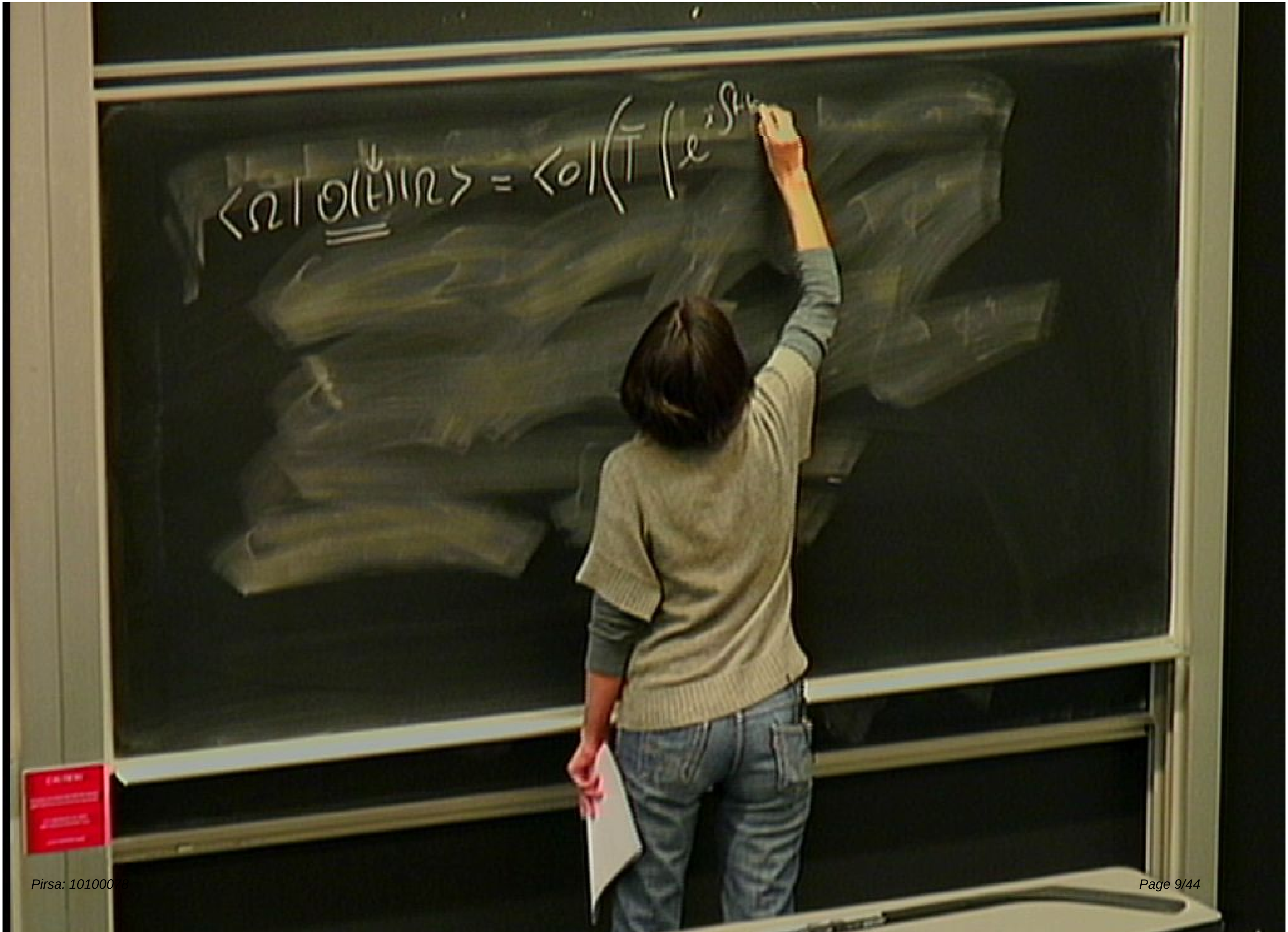

$S = \frac{1}{2}\int dt\, d^3x\, \sqrt{h}\left[N R^{(3)} + 2NP + N^{-1}\left(E_{ij}E^{ij} - E^2\right)\right]$

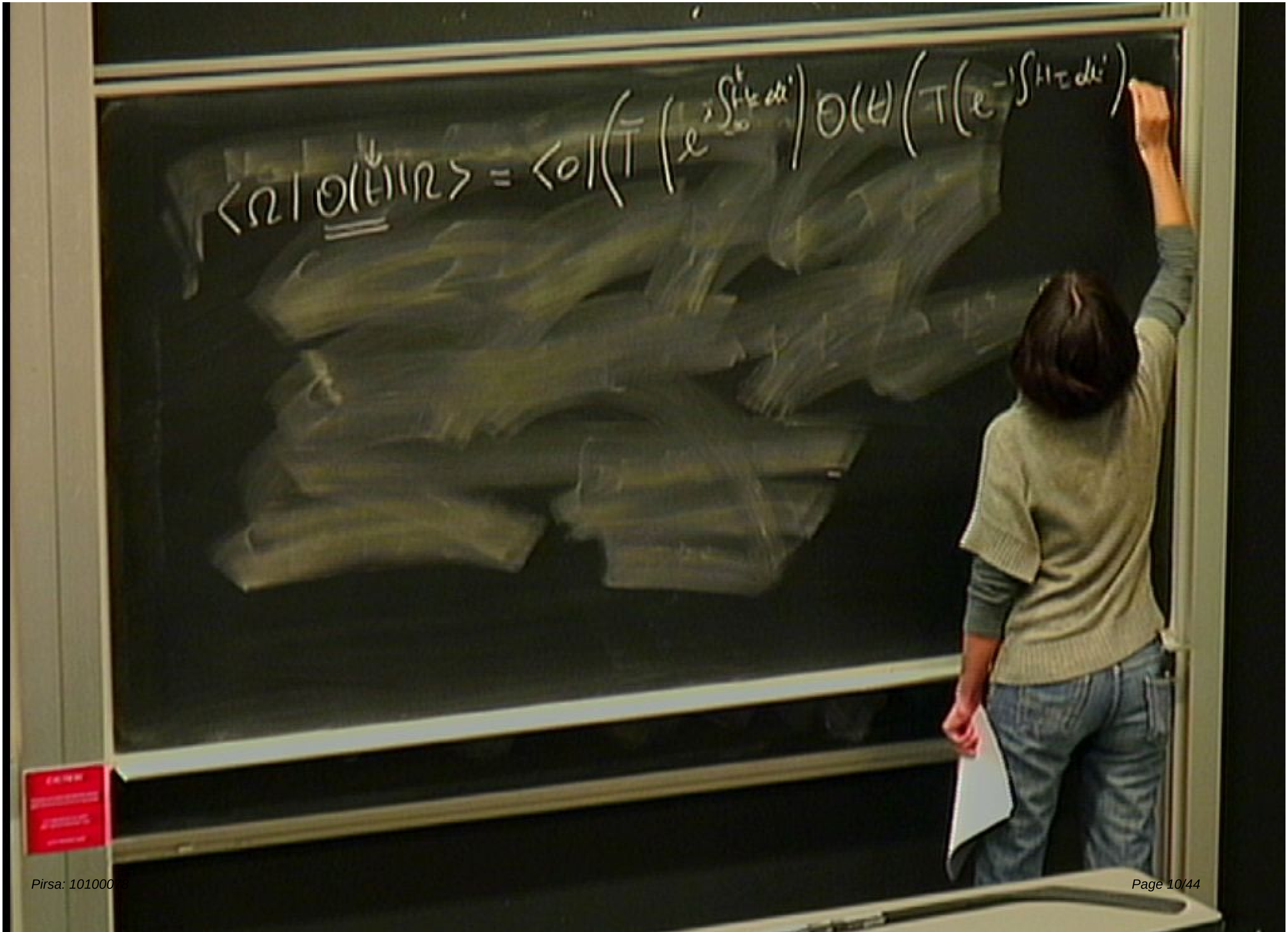


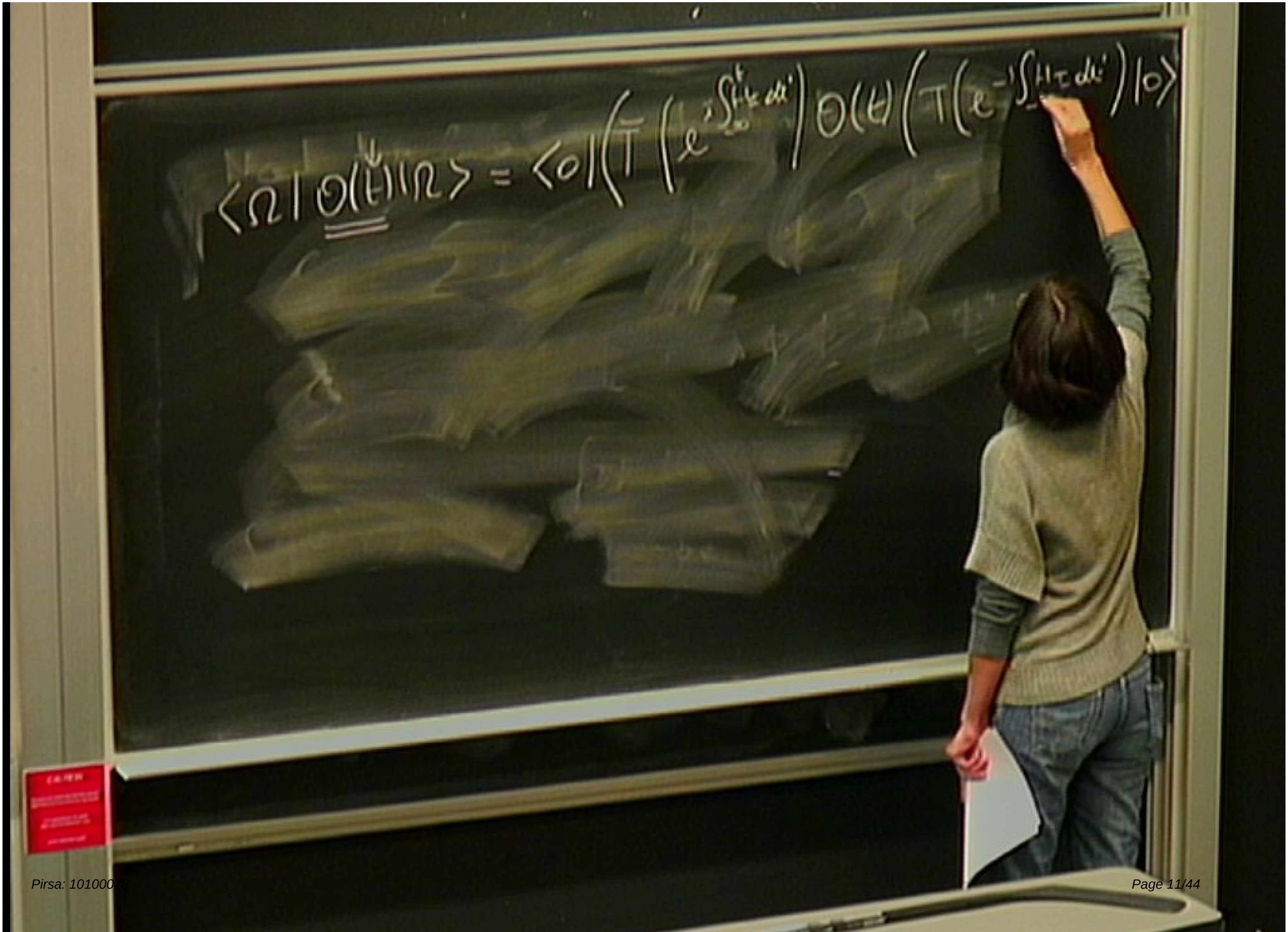
$S = \frac{1}{2}\int dt\, d^3x\, \sqrt{h}\left[N R^{(3)} + 2NP + N^{-1}(E_{ij}E^{ij} - E^2) \right]$
$P = X - V$
$X = -\frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi$



$S = \frac{1}{2}\int dt\, d^3x\, \sqrt{h}\left[N R^{(3)} + 2NP + N^{-1}(E_{ij}E^{ij} - E^2)\right]$
$P = X - V$
$g^{\mu\nu}\partial_\mu\phi\,\partial_\nu\phi$
flat gaug
$ds^2 = -N^2 dt^2 + h_{ij}(dx^i + N^i dt)(N^j dt + dx^j)$


$\langle \Omega | O(t) | \Omega \rangle = \langle 0 | (T (e^{iS}$




$\langle \Omega | \underline{\underline{O(t)}} | \Omega \rangle = \langle 0 | \left(T \left(e^{i\int_{-\infty}^{t} H_I dt'} \right) O(t) \left(T \left(e^{-i\int_{-\infty}^{t} H_I dt'} \right) | 0 \rangle \right.\right.$

$$\langle \Omega | \underline{\underline{O(t)}} | \Omega \rangle = \langle 0 | \left(\bar{T} \left(e^{i\int_{-\infty}^{t} H_I \, dt'} \right) O(t) \left(T \left(e^{-i\int_{-\infty}^{t} H_I \, dt'} \right) \right) \right) | 0 \rangle$$

4°

$$H^{(3)} = \int \frac{a^2}{2} \gamma_{ij} \, \partial_i \partial_j$$

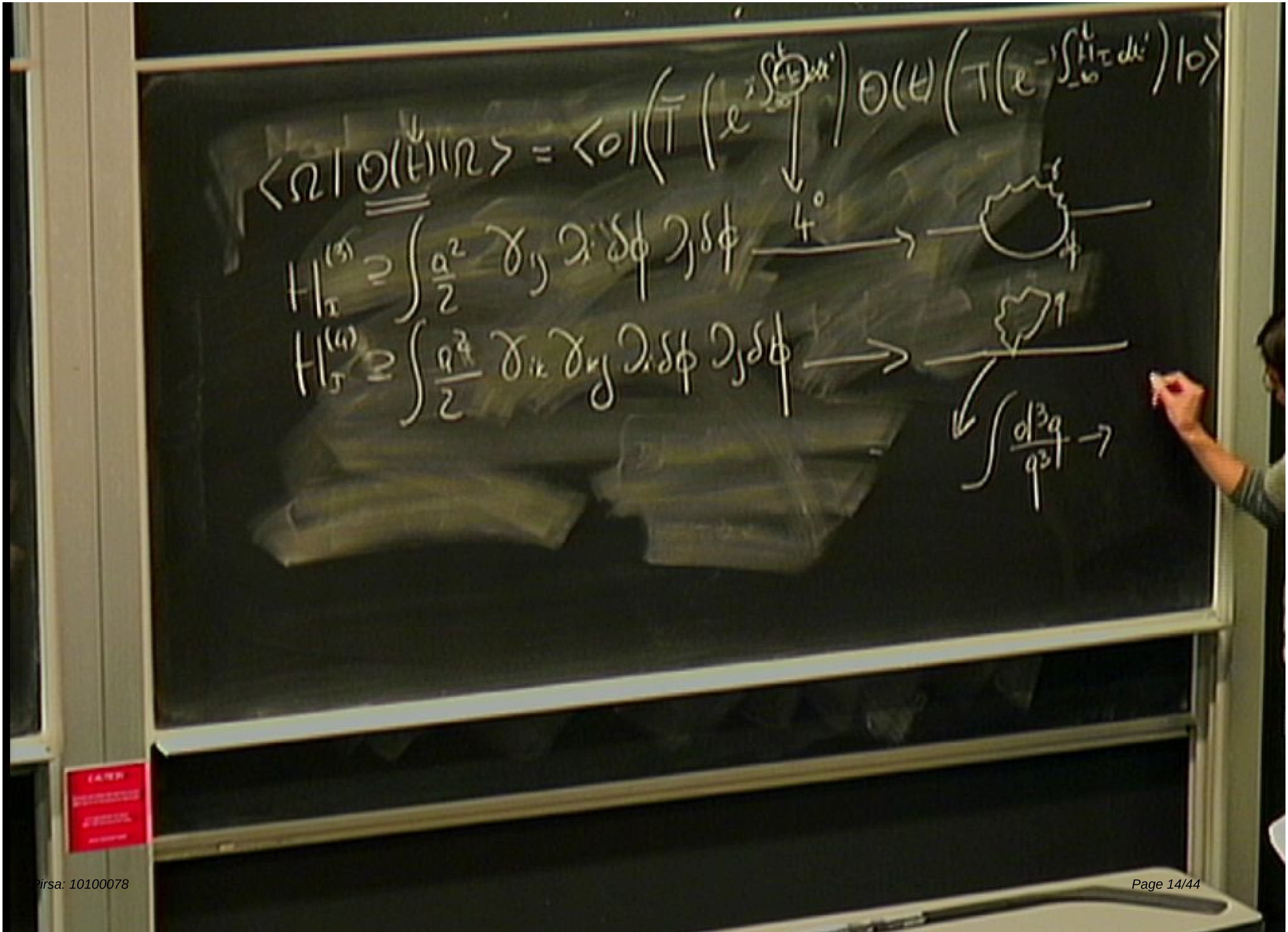
$$S = \frac{1}{2}\int dt\, d^3x\, \sqrt{h}\left[N R^{(3)} + 2NP + N^{-1}\left(E_{ij}E^{ij} - E^2\right)\right]$$

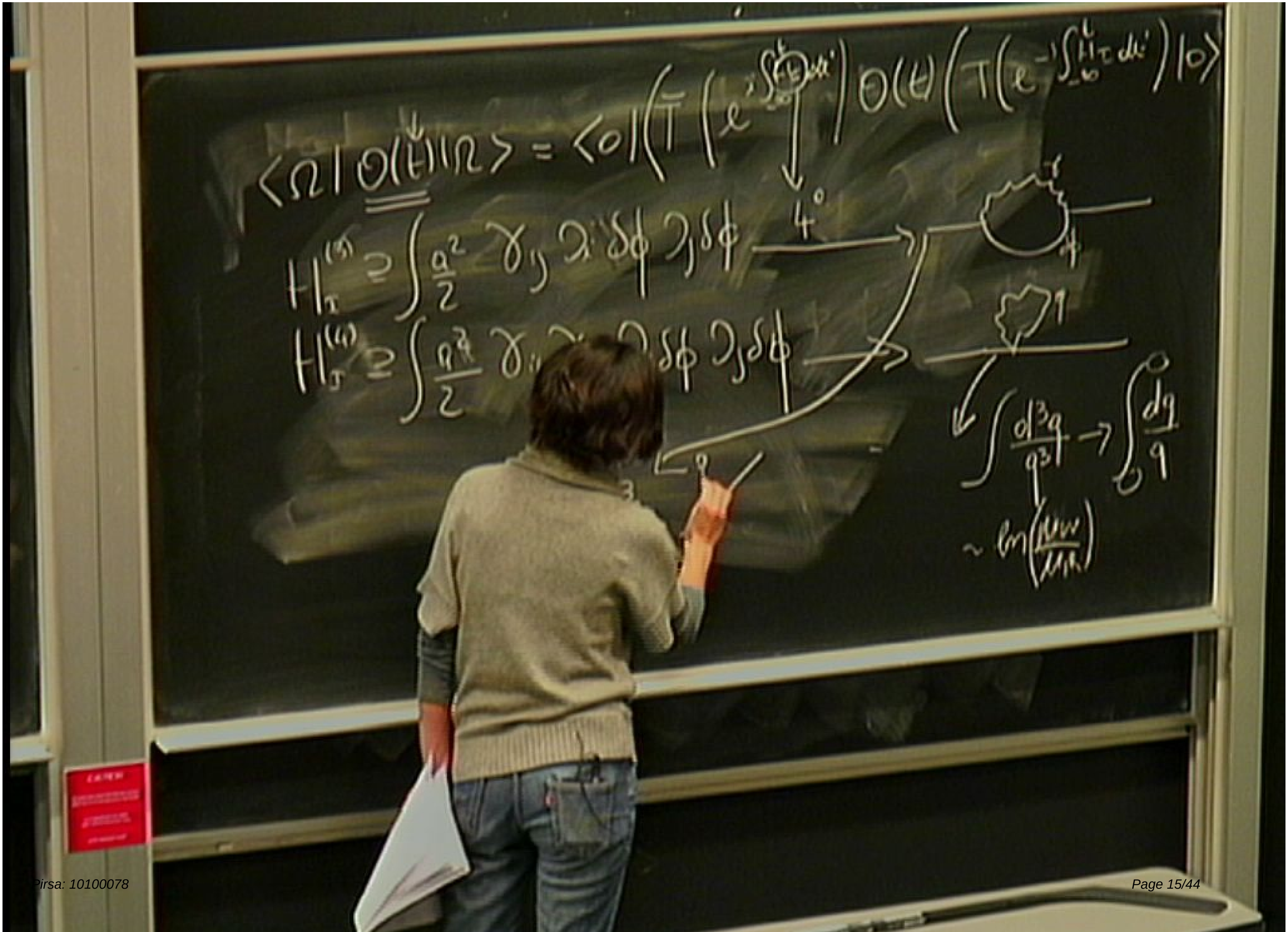
$$P = X - V$$

$$X = -\frac{1}{2} g^{\mu\nu}\partial_\mu\phi\, \partial_\nu\phi$$

$$a^2(t)\left(e^{\gamma}\right)_{ij}$$

flat gauge $\quad ds^2 = -N^2 dt^2 + h_{ij}\left(dx^i + N^i dt\right)\left(N^j dt + dx^j\right)$

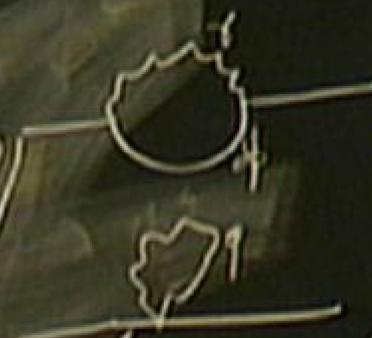

$\langle \Omega | O(t) | \Omega \rangle = \langle 0 | \left(\bar{T} \left(e^{i \int_{-\infty}^{t} H_I dt'} \right) O(t) \left(T \left(e^{-i \int_{-\infty}^{t} H_I dt'} \right) \right) \right) | 0 \rangle$
4°
$H_I^{(3)} \supseteq \int \frac{a^2}{2} \gamma_{ij} \partial_i \delta\phi \, \partial_j \delta\phi \longrightarrow$
$H_I^{(4)} \supseteq \int \frac{a^2}{2} \gamma_{ik} \gamma_{kj} \partial_i \delta\phi \, \partial_j \delta\phi \longrightarrow$
$\int \frac{d^3 q}{q^3} \rightarrow$



$$\langle \Omega | \mathcal{O}(t) | \Omega \rangle = \langle 0 | \left(\bar{T} \left(e^{i\int_{-\infty}^{t} H_I(t')\,dt'} \right) \mathcal{O}(t) \left(T \left(e^{-i\int_{-\infty}^{t} H_I\,dt'} \right) \right) | 0 \rangle$$

$$H_I^{(3)} \supseteq \int \frac{a^2}{2} \gamma_{ij}\, \partial_i \delta\phi\, \partial_j \delta\phi \longrightarrow$$

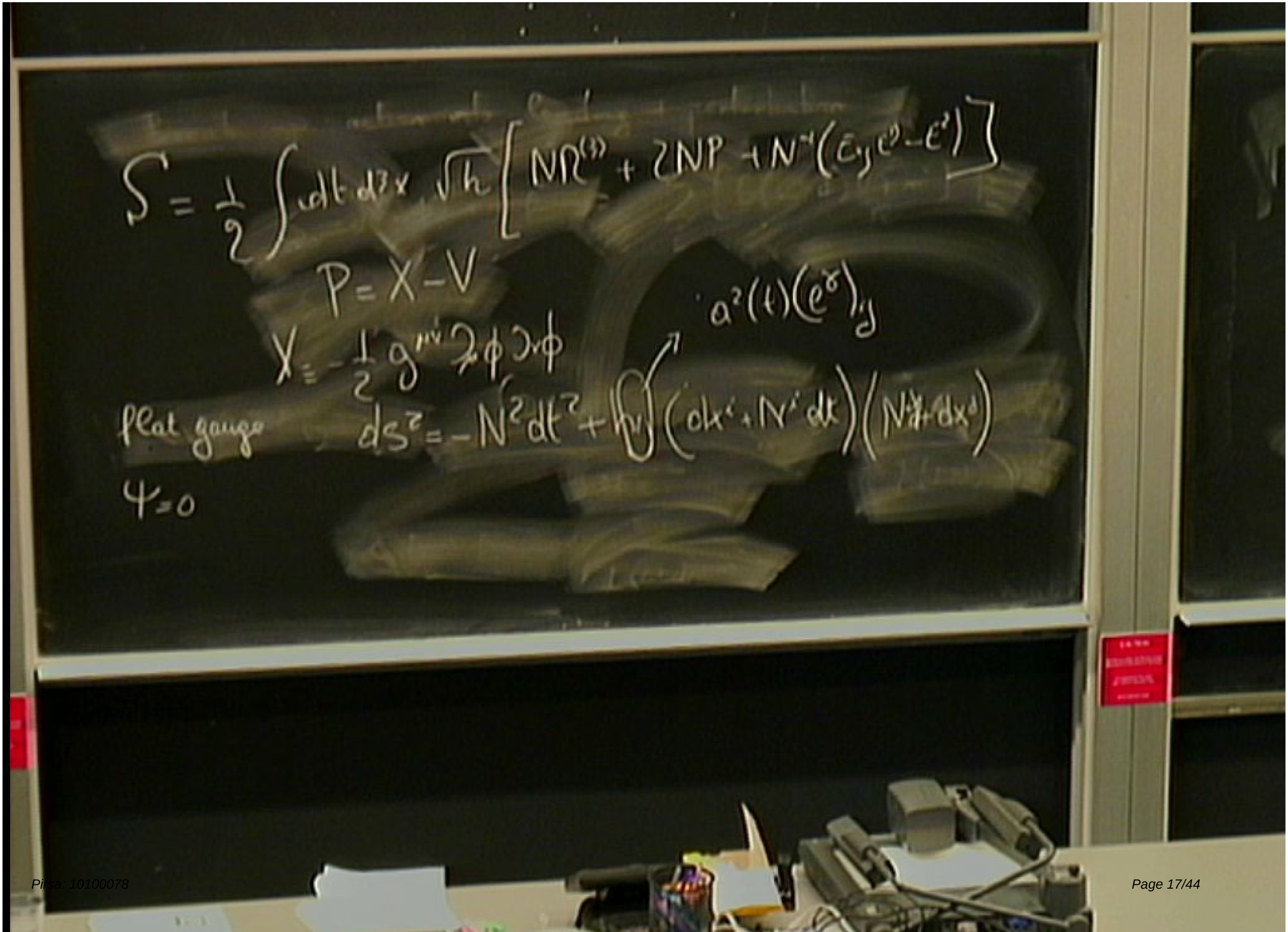
$$H_I^{(4)} \supseteq \int \frac{a^4}{2} \gamma_{ik} \gamma_{kj}\, \partial_i \delta\phi\, \partial_j \delta\phi \longrightarrow$$

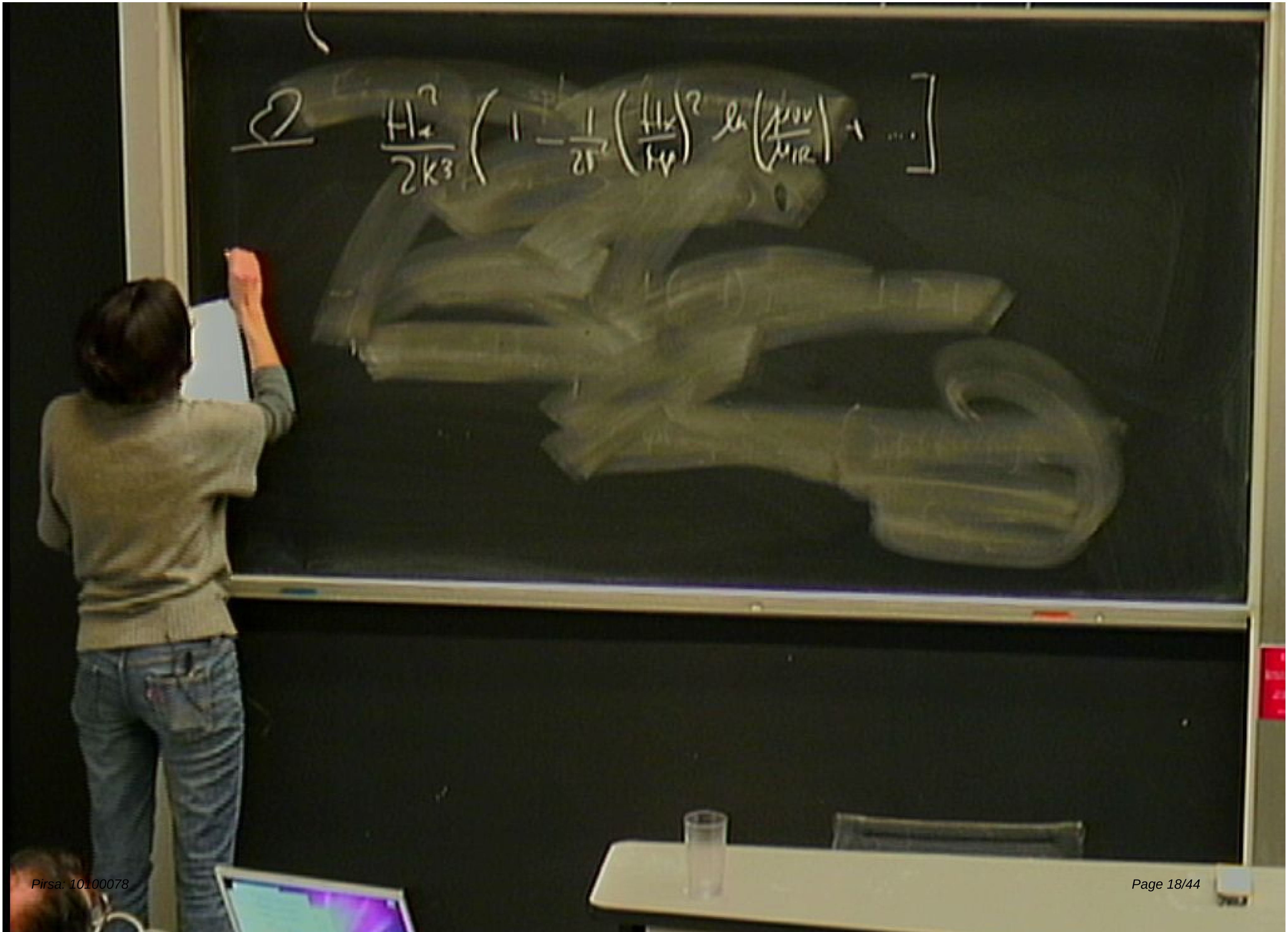


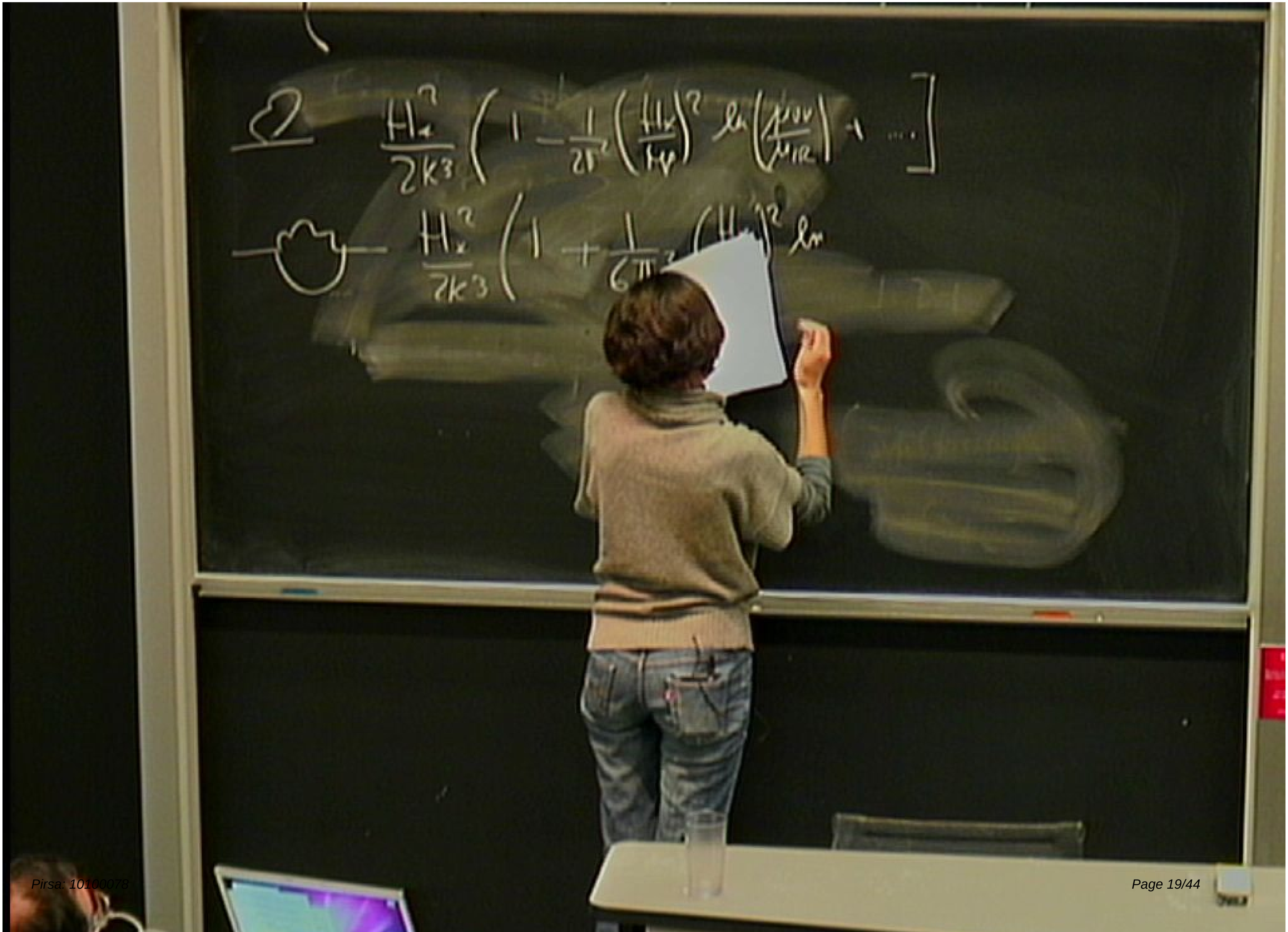
$$\int \frac{d^3q}{q^3} \rightarrow \int \frac{dq}{q} \sim \ln\left(\frac{\mu}{\mu}\right)$$

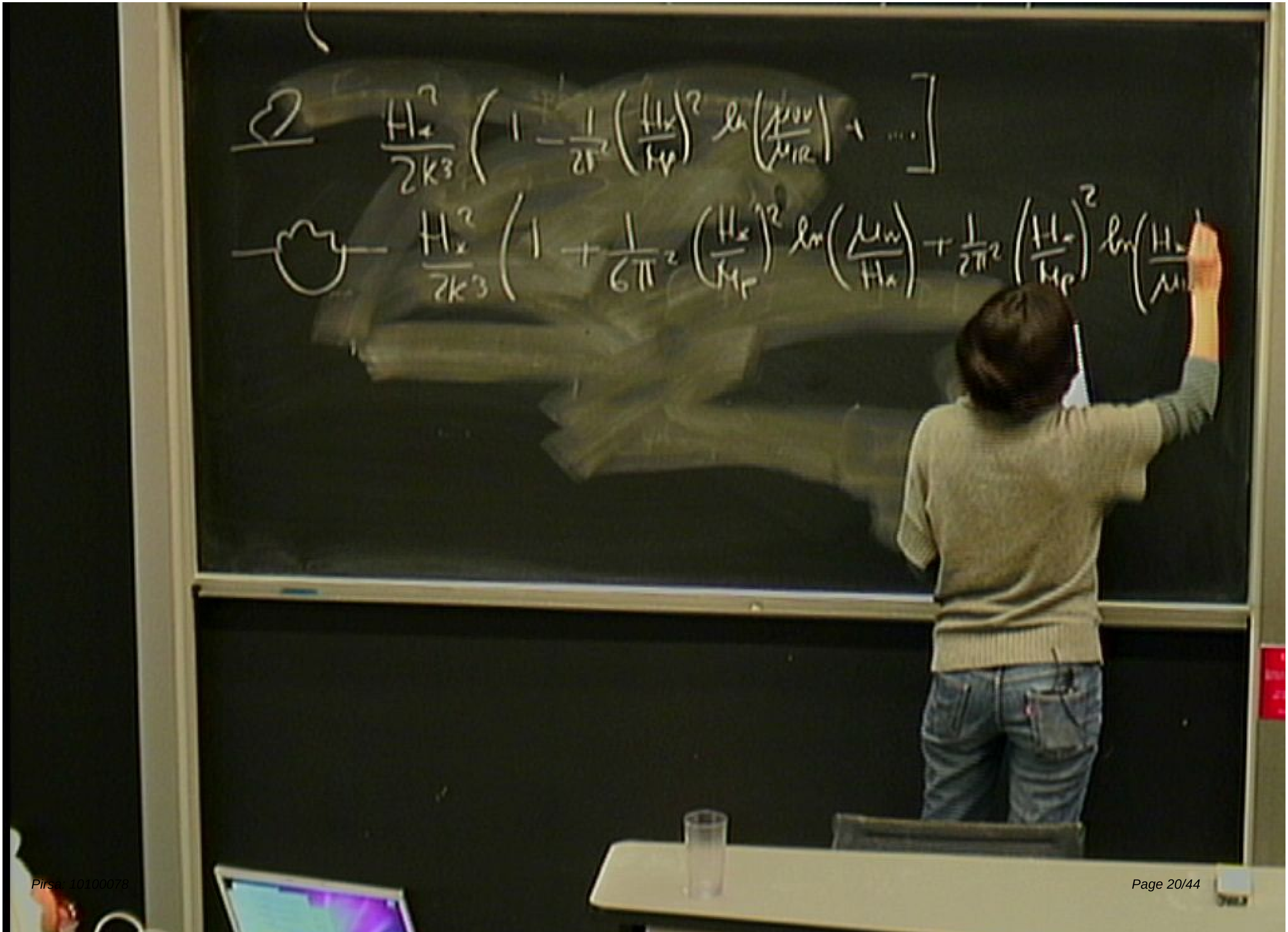
$$q \ll k \qquad \int_k \frac{dq}{q}$$

$$\int \frac{d^3q}{|\vec{k}-\vec{q}|^3 q^3} \qquad \int^k \frac{dq}{q}$$

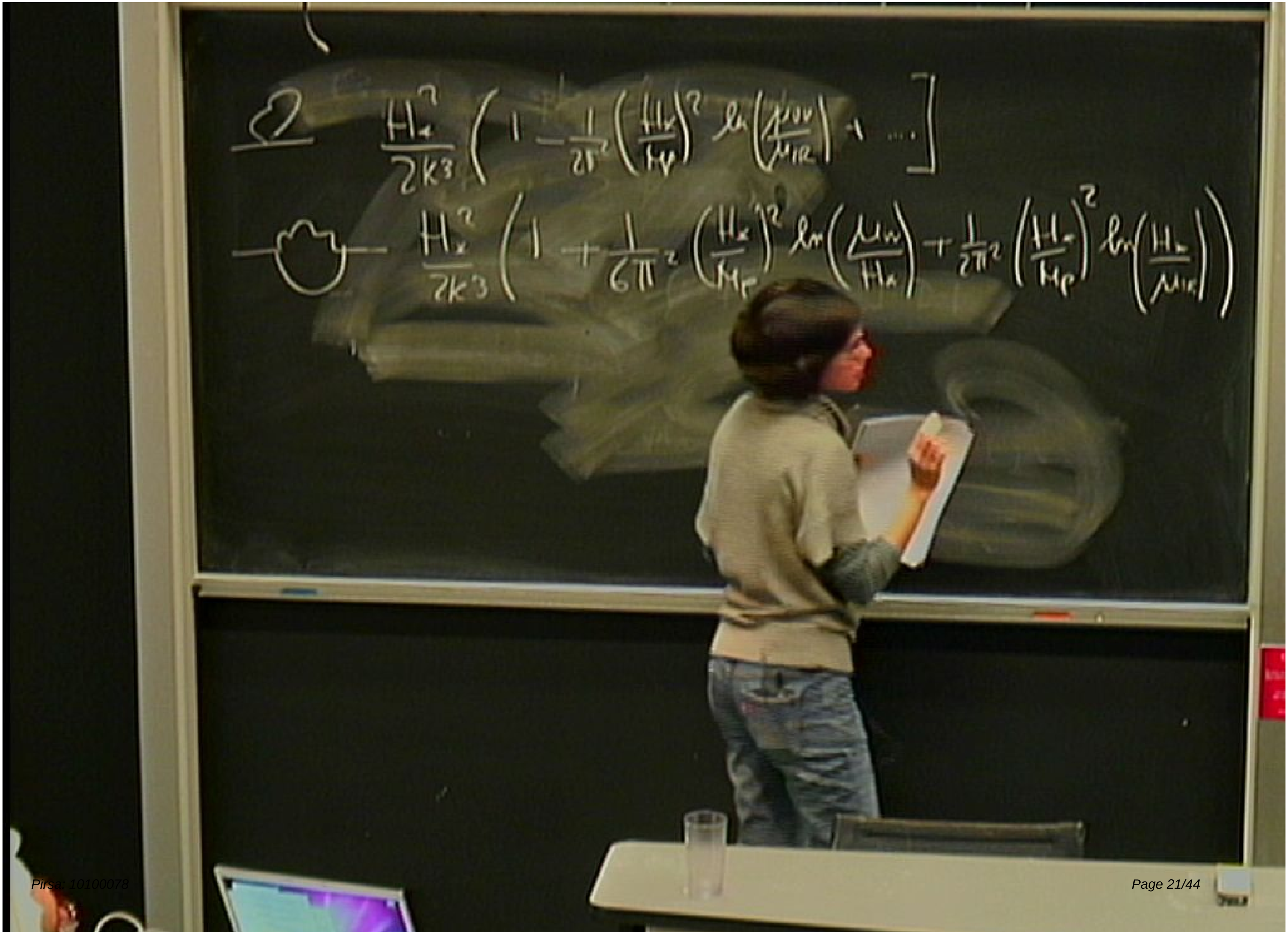

$S = \frac{1}{2}\int dt\, d^3x \sqrt{h}\left[N R^{(3)} + 2NP + N^{-1}(E_{ij}E^{ij} - E^2) \right]$
$P = X - V$
$X = -\frac{1}{2} g^{\mu\nu}\partial_\mu\phi\,\partial_\nu\phi$
$a^2(t)(e^{\gamma})_{ij}$
flat gauge
$ds^2 = -N^2 dt^2 + h_{ij}(dx^i + N^i dt)(N^j dt + dx^j)$
$\psi = 0$



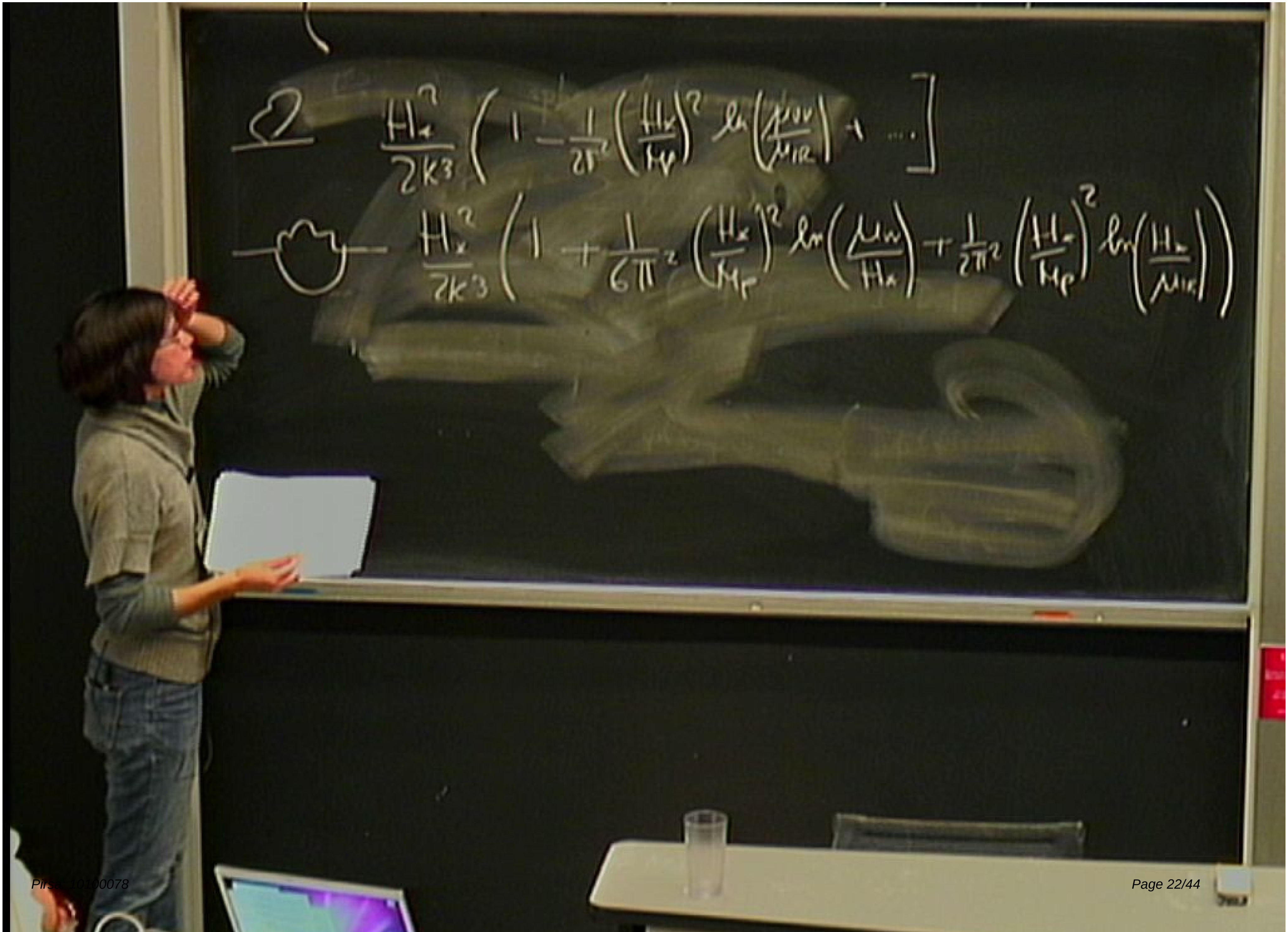




$\frac{H_*^2}{2k^3}\left(1-\frac{1}{2\pi^2}\left(\frac{H_*}{M_P}\right)^2\ln\left(\frac{\mu_{UV}}{\mu_{IR}}\right)+\dots\right]$
$\frac{H_*^2}{2k^3}\left(1+\frac{1}{6\pi^2}\left(\frac{H_*}{M_P}\right)^2\ln\left(\frac{\mu_{UV}}{H_*}\right)+\frac{1}{2\pi^2}\left(\frac{H_*}{M_P}\right)^2\ln\left(\frac{H_*}{\mu_{IR}}\right)\right.$



$\frac{H_*^2}{2k^3}\left(1 - \frac{1}{2\pi^2}\left(\frac{H_*}{M_P}\right)^2 \ln\left(\frac{\mu_{UV}}{\mu_{IR}}\right) + \dots\right]$
$\frac{H_*^2}{2k^3}\left(1 + \frac{1}{6\pi^2}\left(\frac{H_*}{M_P}\right)^2 \ln\left(\frac{\mu_{UV}}{H_*}\right) + \frac{1}{2\pi^2}\left(\frac{H_*}{M_P}\right)^2 \ln\left(\frac{H_*}{\mu_{IR}}\right)\right)$


$\frac{H_*^2}{2k^3}\left(1 - \frac{1}{2\pi^2}\left(\frac{H_*}{M_P}\right)^2 \ln\left(\frac{\mu_{UV}}{\mu_{IR}}\right) + \dots\right]$
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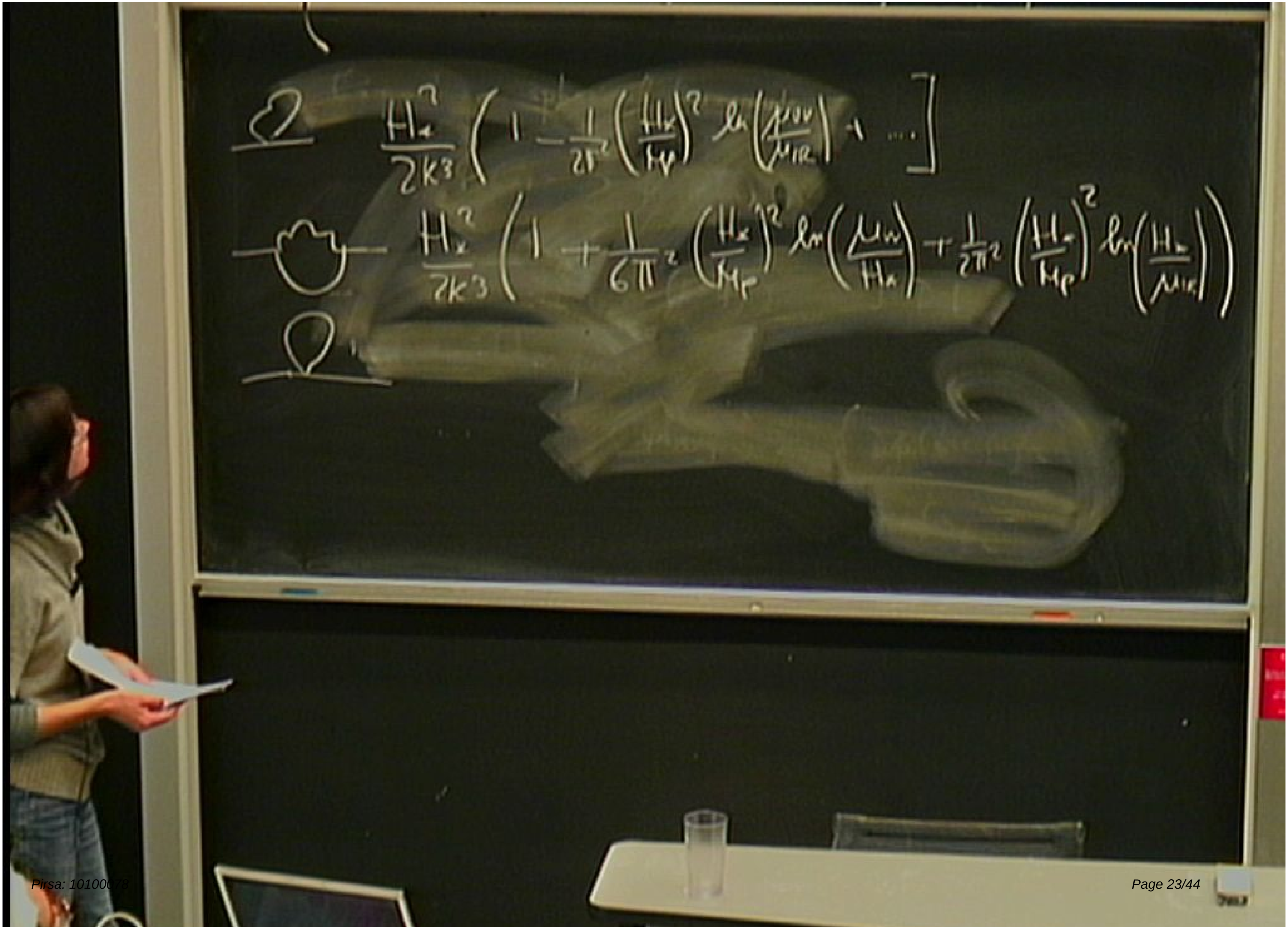
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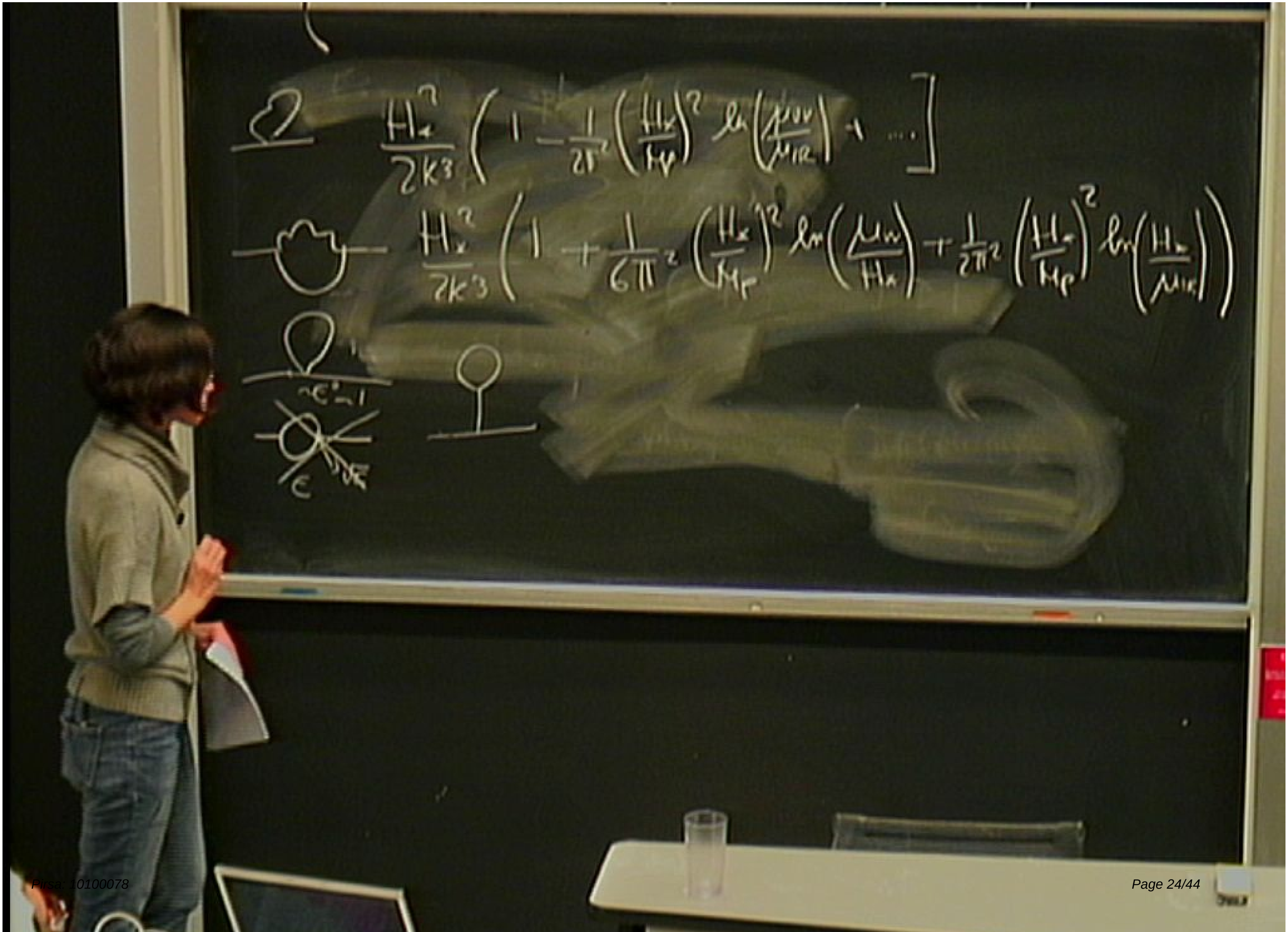
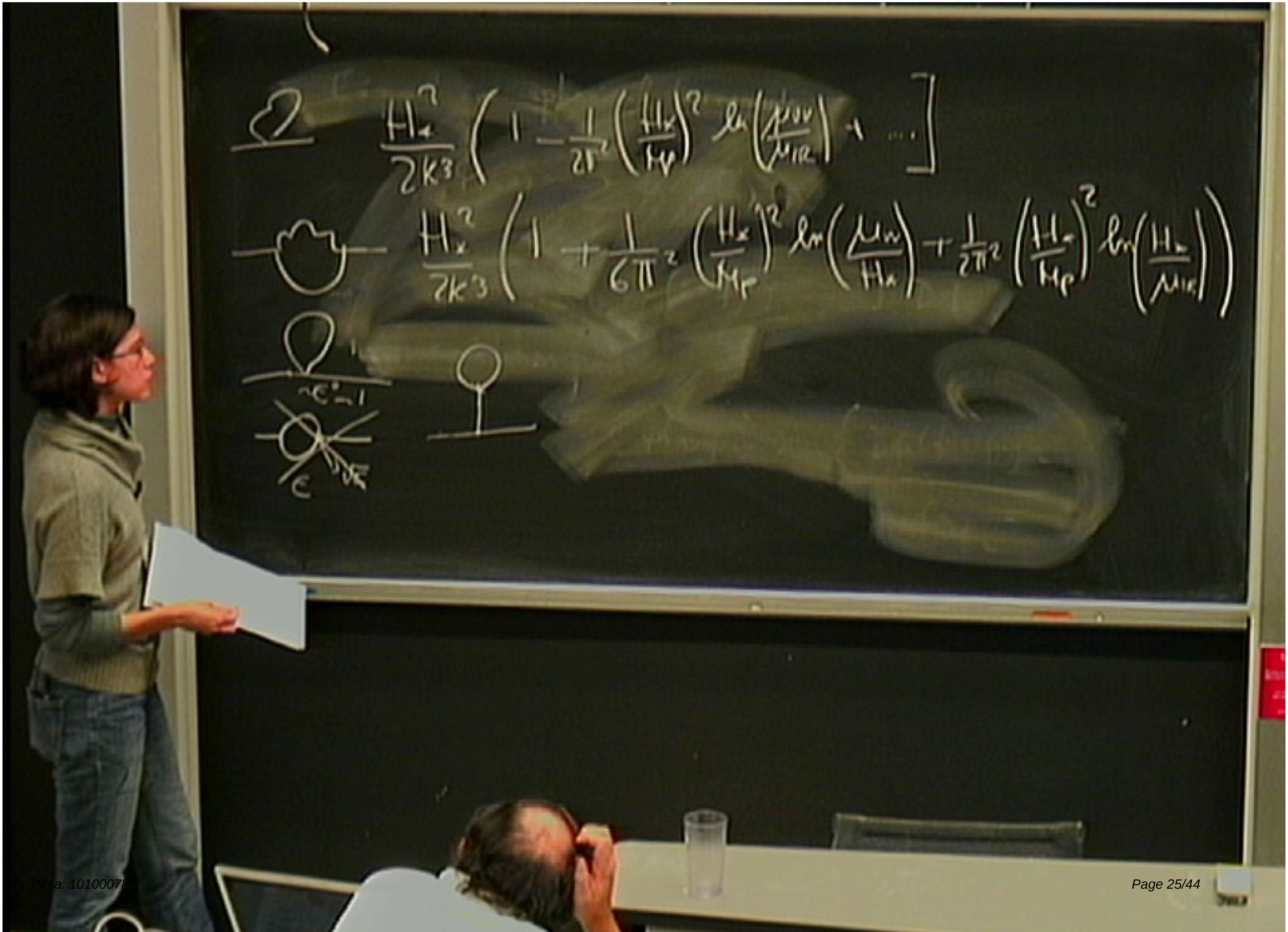
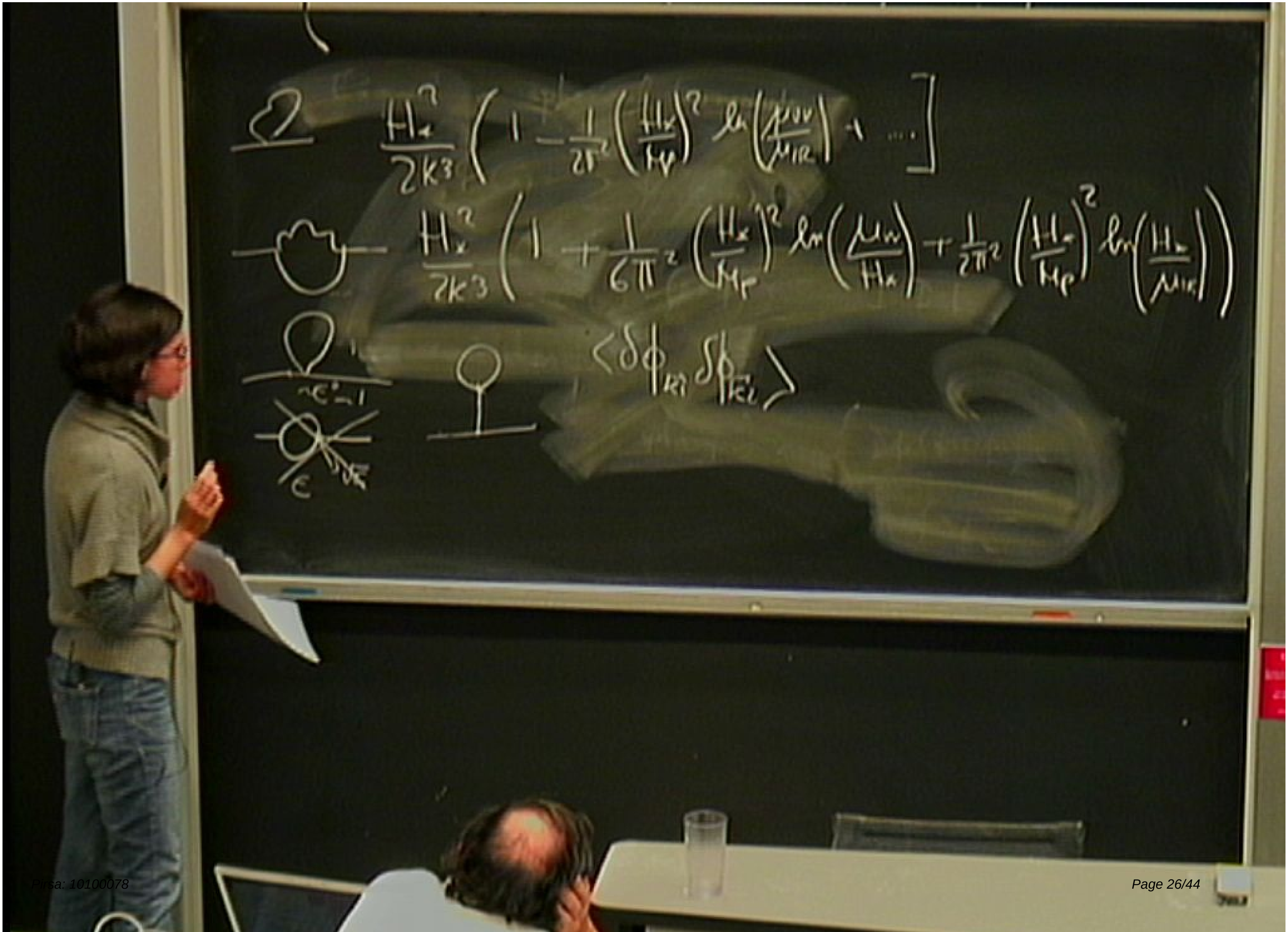
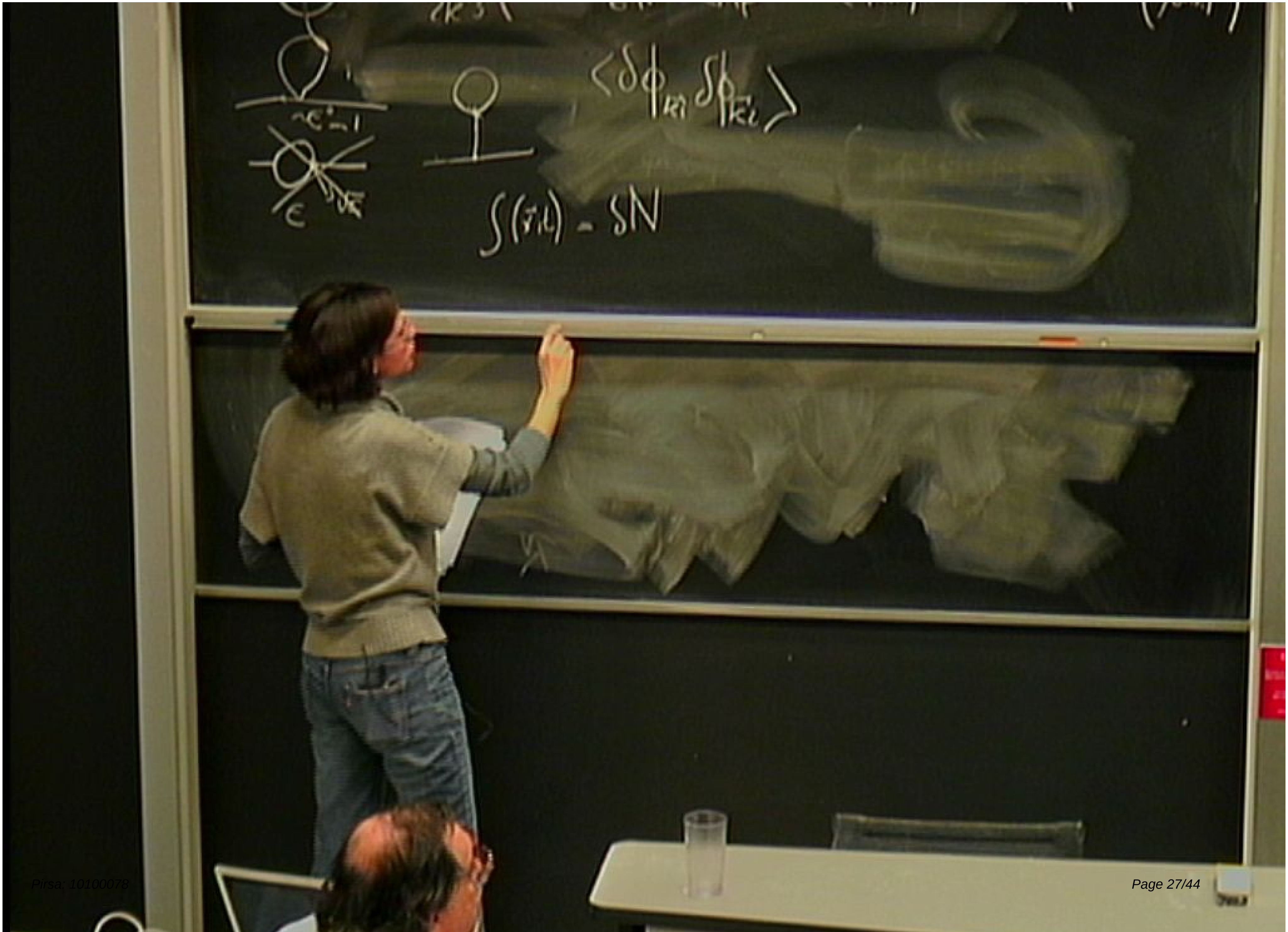
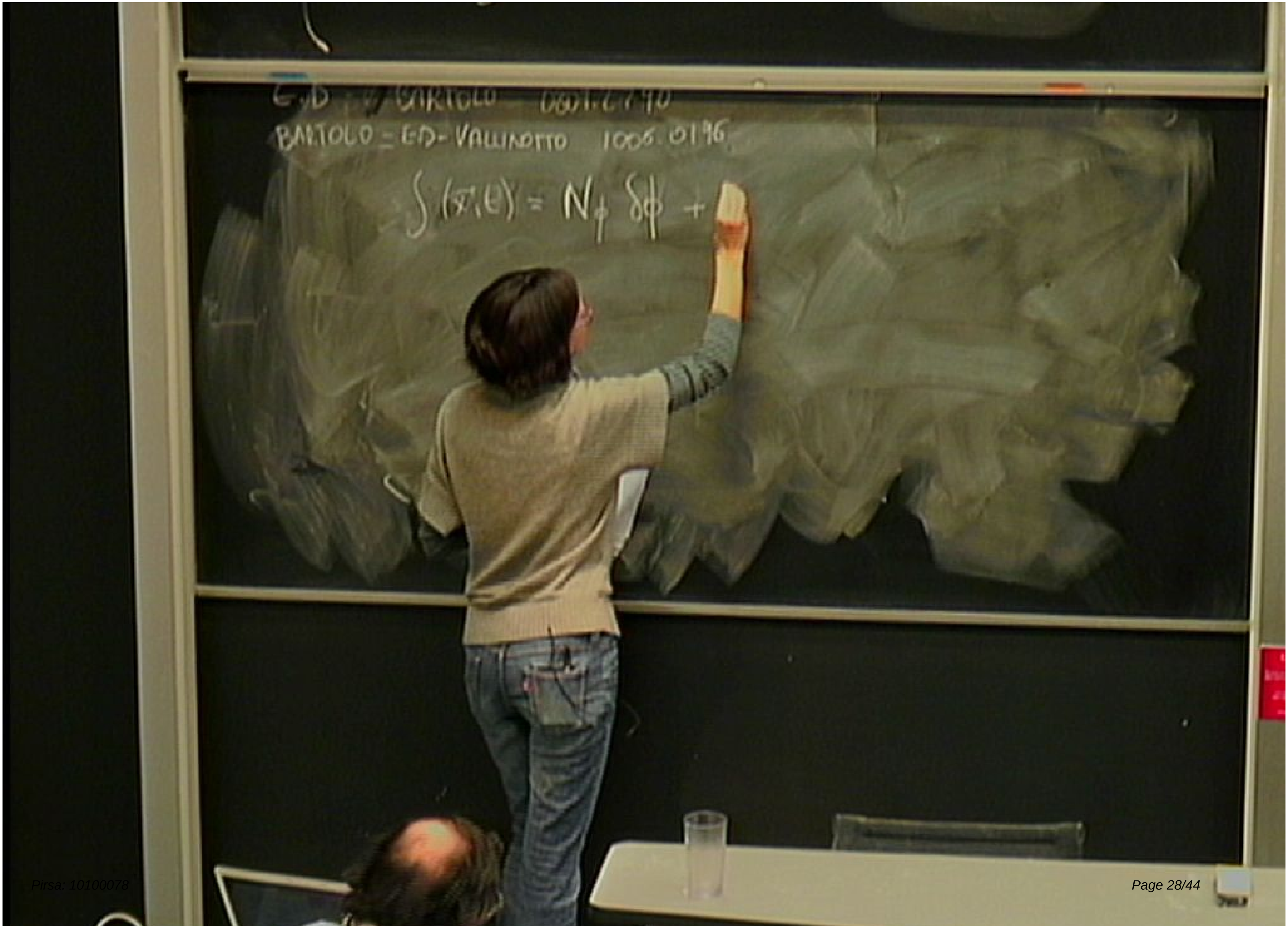
$\frac{H_*^2}{2k^3}\left(1+\frac{1}{6\pi^2}\left(\frac{H_*}{M_p}\right)^2 \ln\left(\frac{\mu_{UV}}{H_*}\right)+\frac{1}{2\pi^2}\left(\frac{H_*}{M_p}\right)^2 \ln\left(\frac{H_*}{\mu_{IR}}\right)\right)$


$\frac{H_*^2}{2k^3}\left(1-\frac{1}{2\pi^2}\left(\frac{H_*}{M_p}\right)^2\ln\left(\frac{\mu_{UV}}{\mu_{IR}}\right)+\dots\right]$
$\frac{H_*^2}{2k^3}\left(1+\frac{1}{6\pi^2}\left(\frac{H_*}{M_p}\right)^2\ln\left(\frac{\mu_{UV}}{H_*}\right)+\frac{1}{2\pi^2}\left(\frac{H_*}{M_p}\right)^2\ln\left(\frac{H_*}{\mu_{IR}}\right)\right)$
$\sim\epsilon^2\sim 1$
ϵ
$\sim\sqrt{\epsilon}$






$\langle \delta\phi_{k_1} \delta\phi_{k_2} \rangle$
$\int(\vec{x},t) = \delta N$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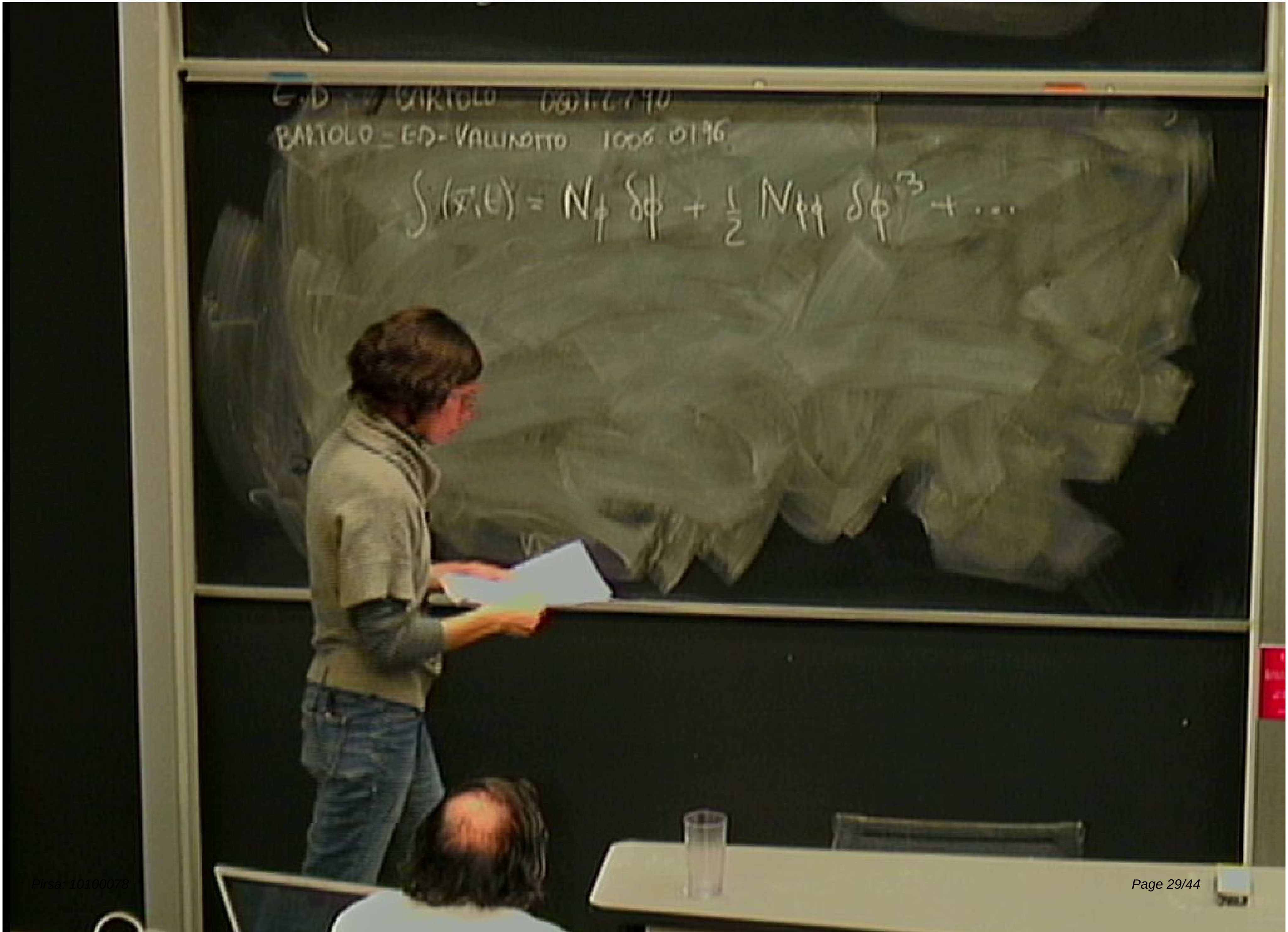
$\zeta(\vec{x},t) = N_\phi \, \delta\phi +$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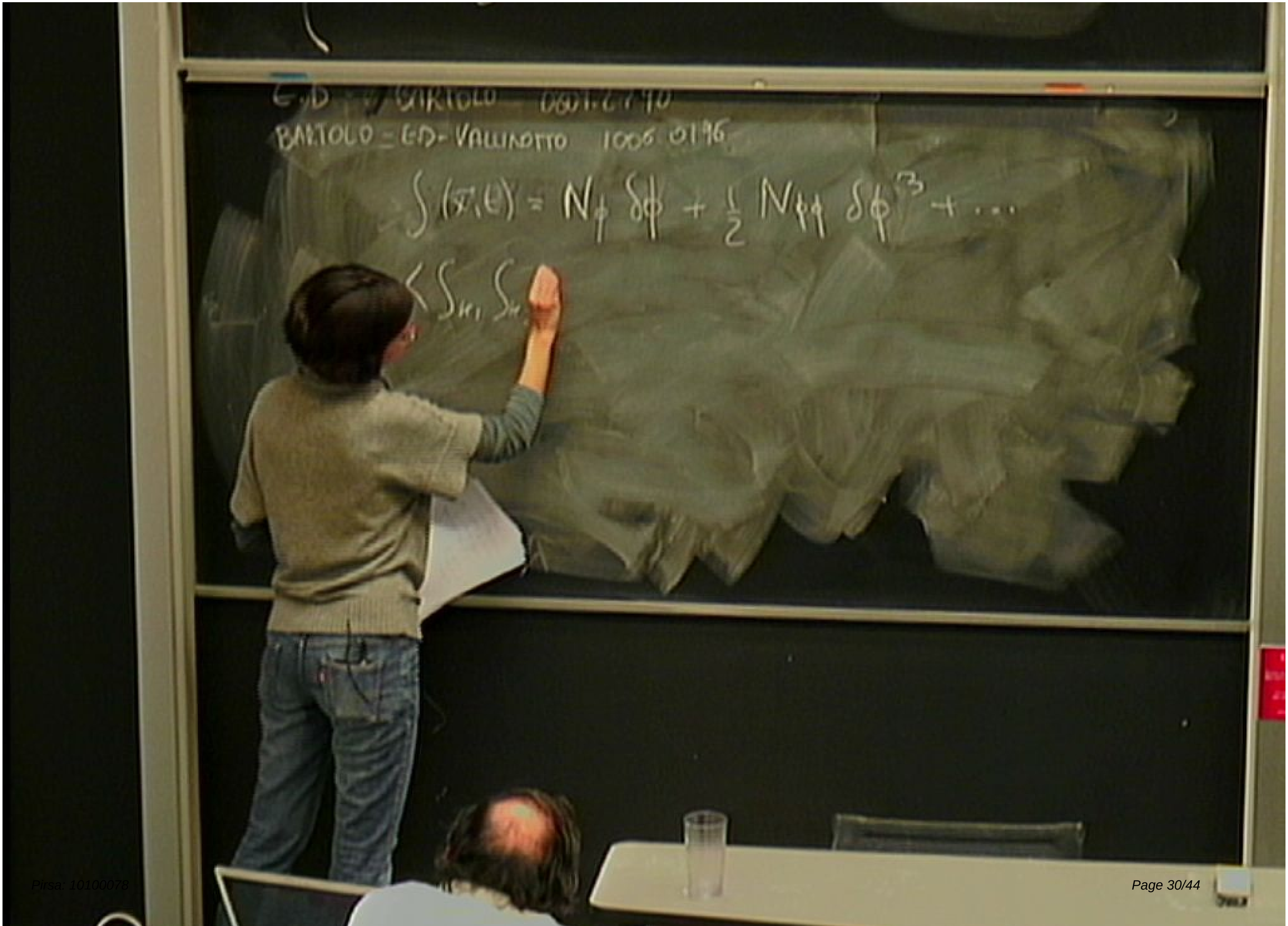
$\zeta(\vec{x},t) = N_\phi\, \delta\phi + \frac{1}{2} N_{\phi\phi}\, \delta\phi^2 + \dots$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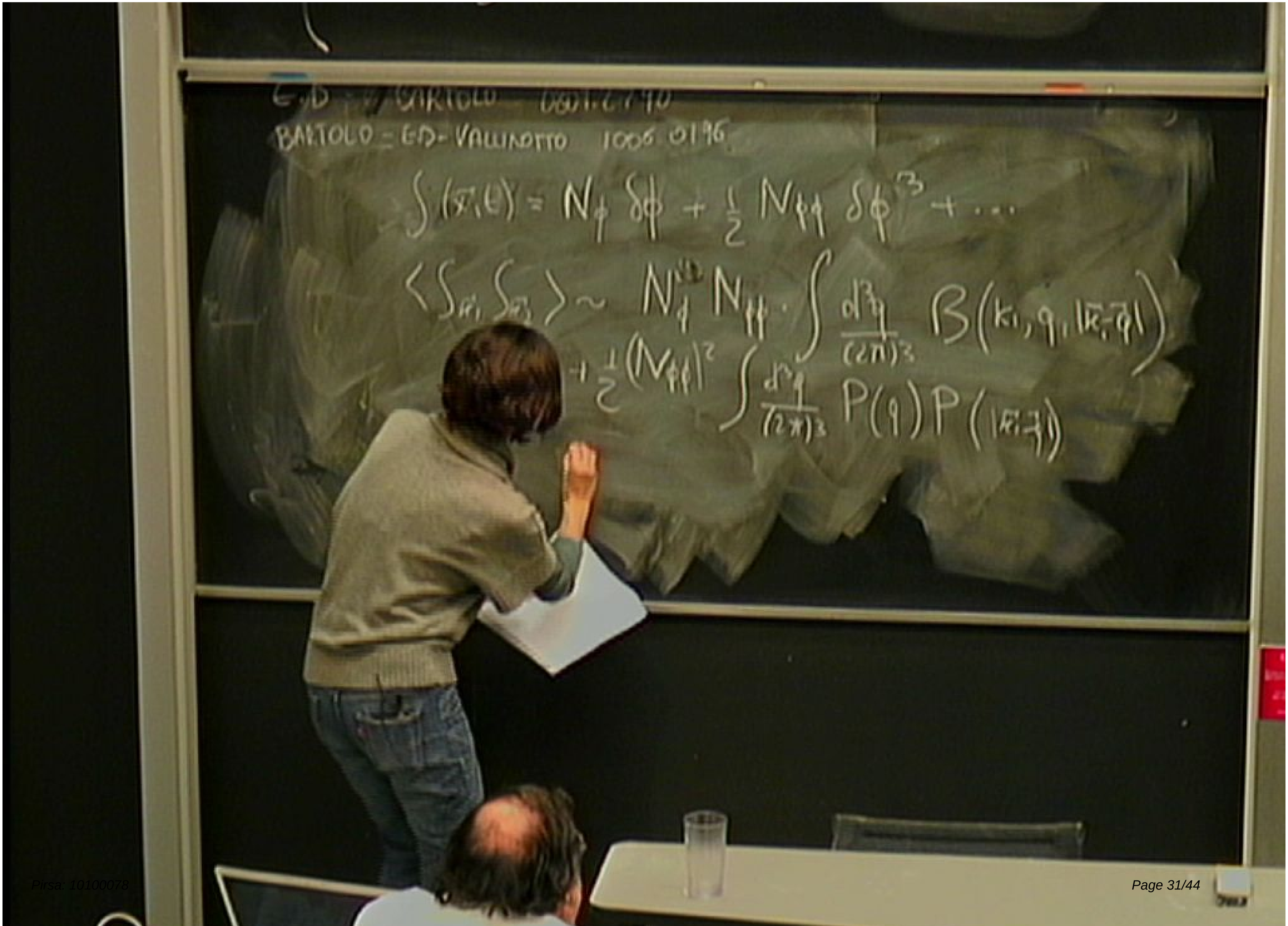
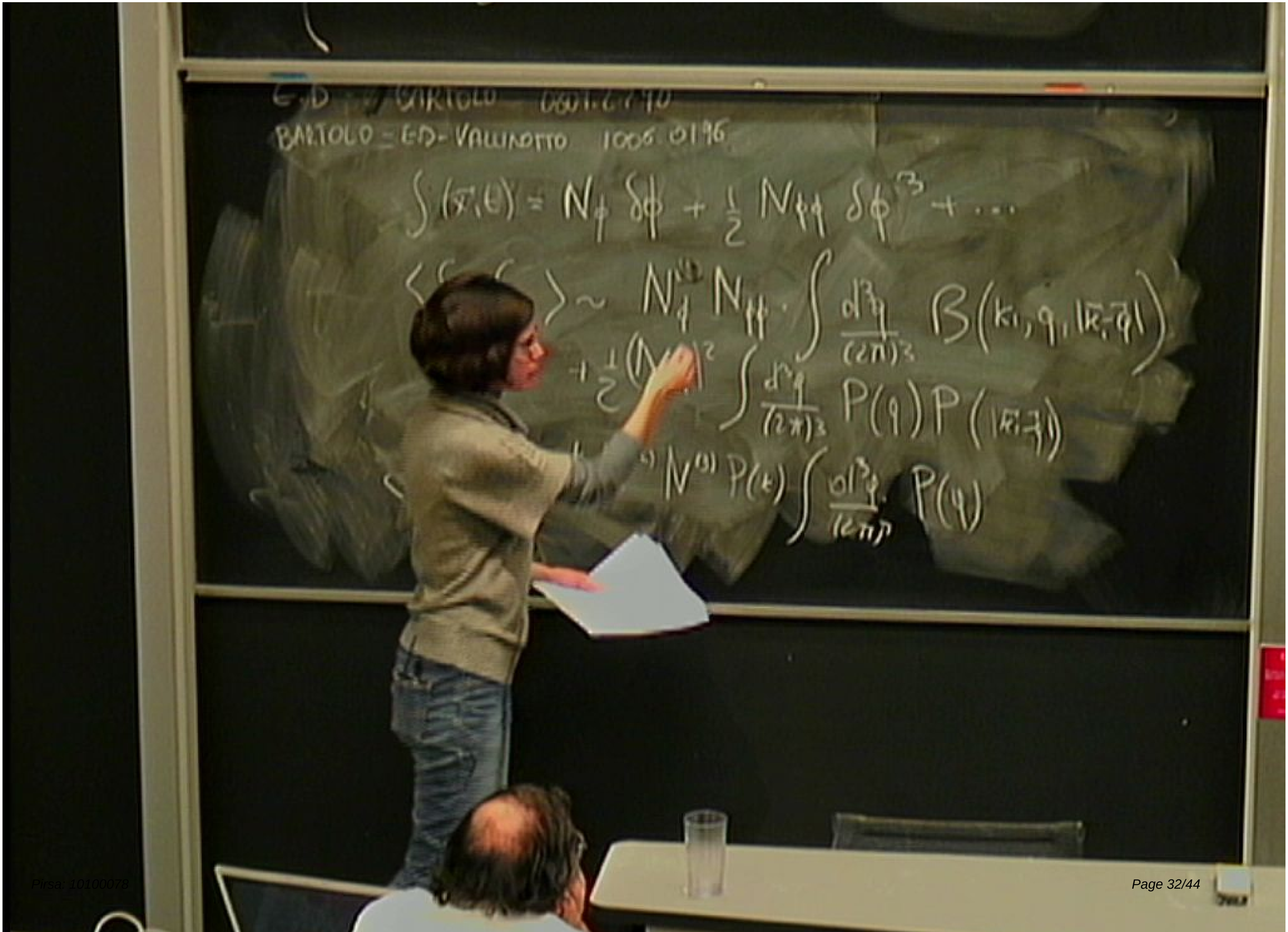
$\delta(\vec{x},t) = N_\phi\, \delta\phi + \frac{1}{2} N_{\phi\phi}\, \delta\phi^3 + \dots$


BARTOLO - ED - VALLINOTTO 1006 0196
$\zeta(\vec{x},t) = N_\phi\,\delta\phi + \frac{1}{2}N_{\phi\phi}\,\delta\phi^2 + \dots$
$\langle \zeta_{\vec{k}_1}\zeta_{\vec{k}_2}\rangle \sim N_\phi^2 N_{\phi\phi}\cdot\int\frac{d^3q}{(2\pi)^3}\,B(k_1,q,|\vec{k}_1-\vec{q}|)$
$+\frac{1}{2}(N_{\phi\phi})^2\int\frac{d^3q}{(2\pi)^3}P(q)P(|\vec{k}_1-\vec{q}|)$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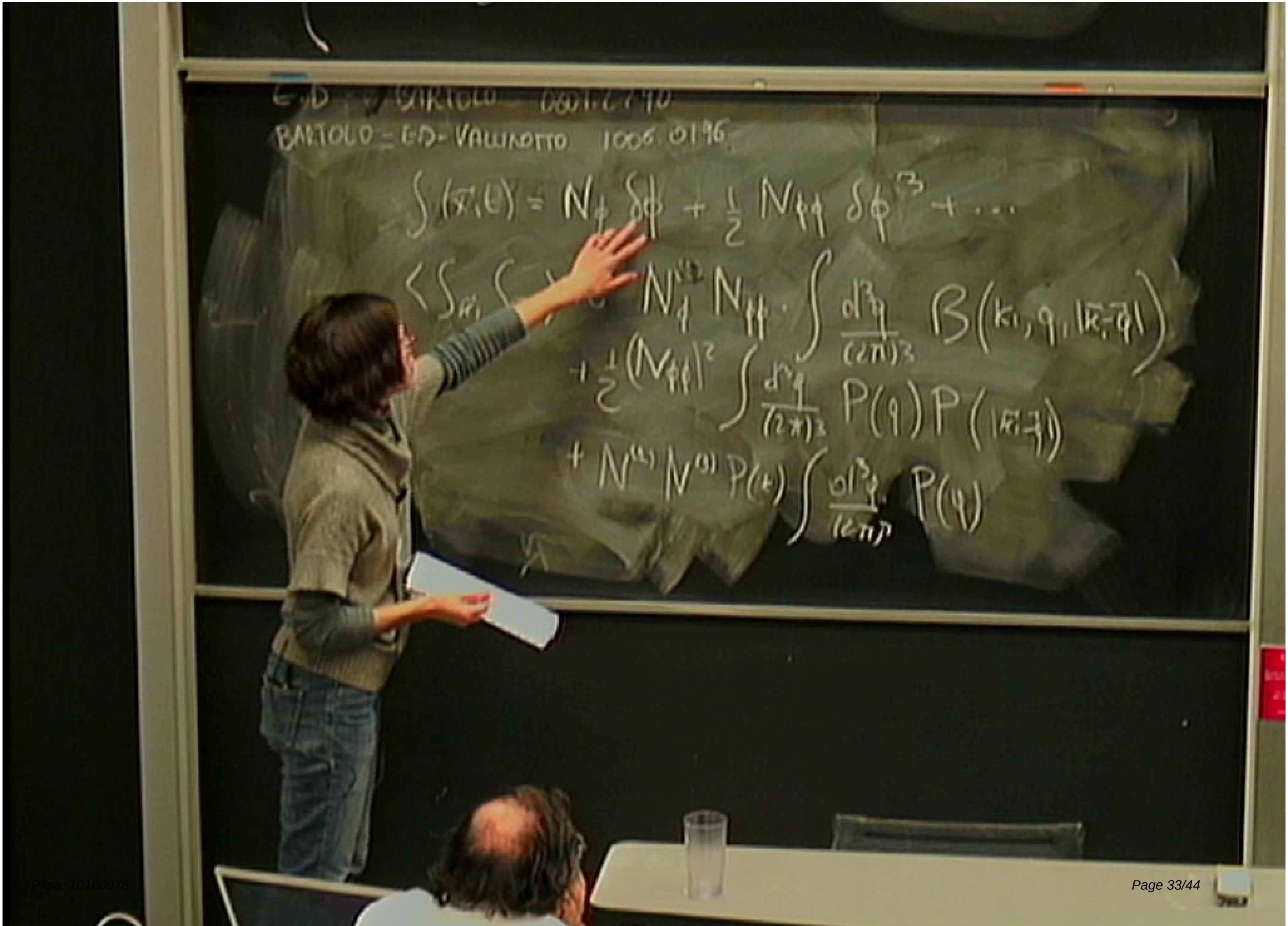
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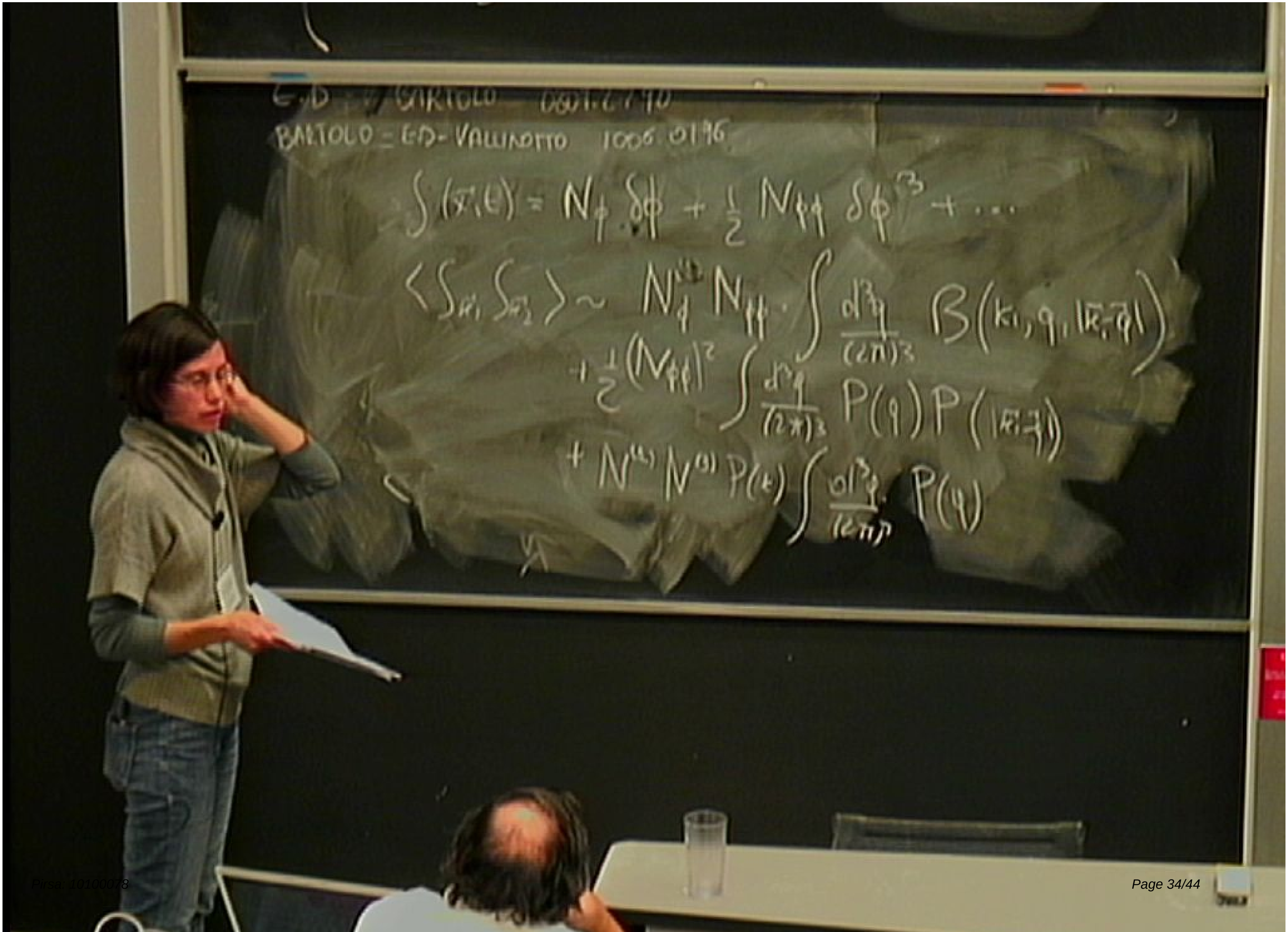
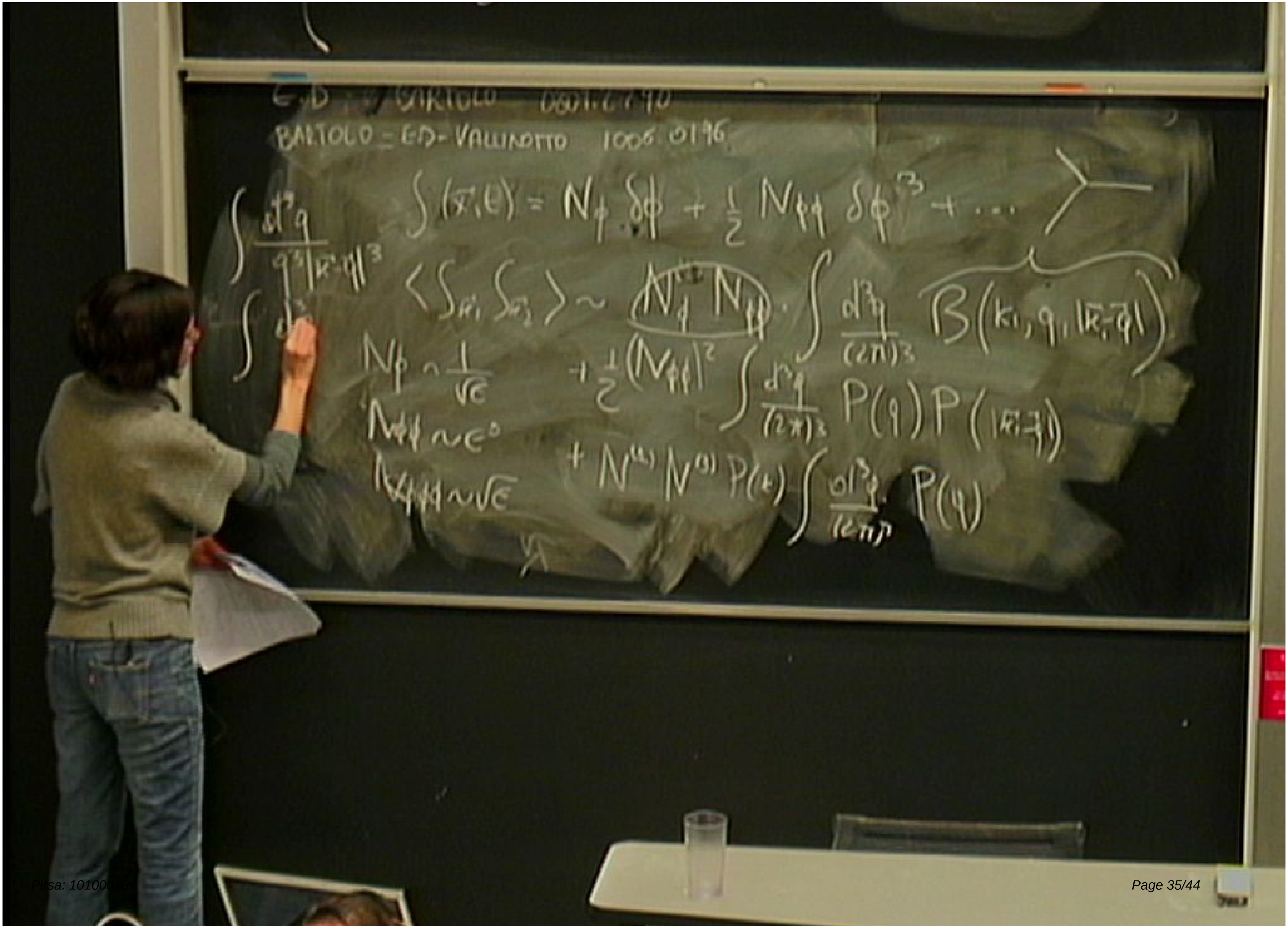

BARTOLO - E.D - VALLINOTTO 1006.0196
$\zeta(\vec{x},t) = N_\phi \, \delta\phi + \frac{1}{2} N_{\phi\phi} \, \delta\phi^2 + \ldots$
$\langle \zeta_{k_1} \zeta_{k_2} \rangle \sim N_\phi N_{\phi\phi} \int \frac{d^3q}{(2\pi)^3} B(k_1, q, |\vec{k}_1 - \vec{q}|)$
$+ \frac{1}{2} (N_{\phi\phi})^2 \int \frac{d^3q}{(2\pi)^3} P(q) P(|\vec{k}_1 - \vec{q}|)$
$+ N^{(1)} N^{(3)} P(k) \int \frac{d^3q}{(2\pi)^3} P(q)$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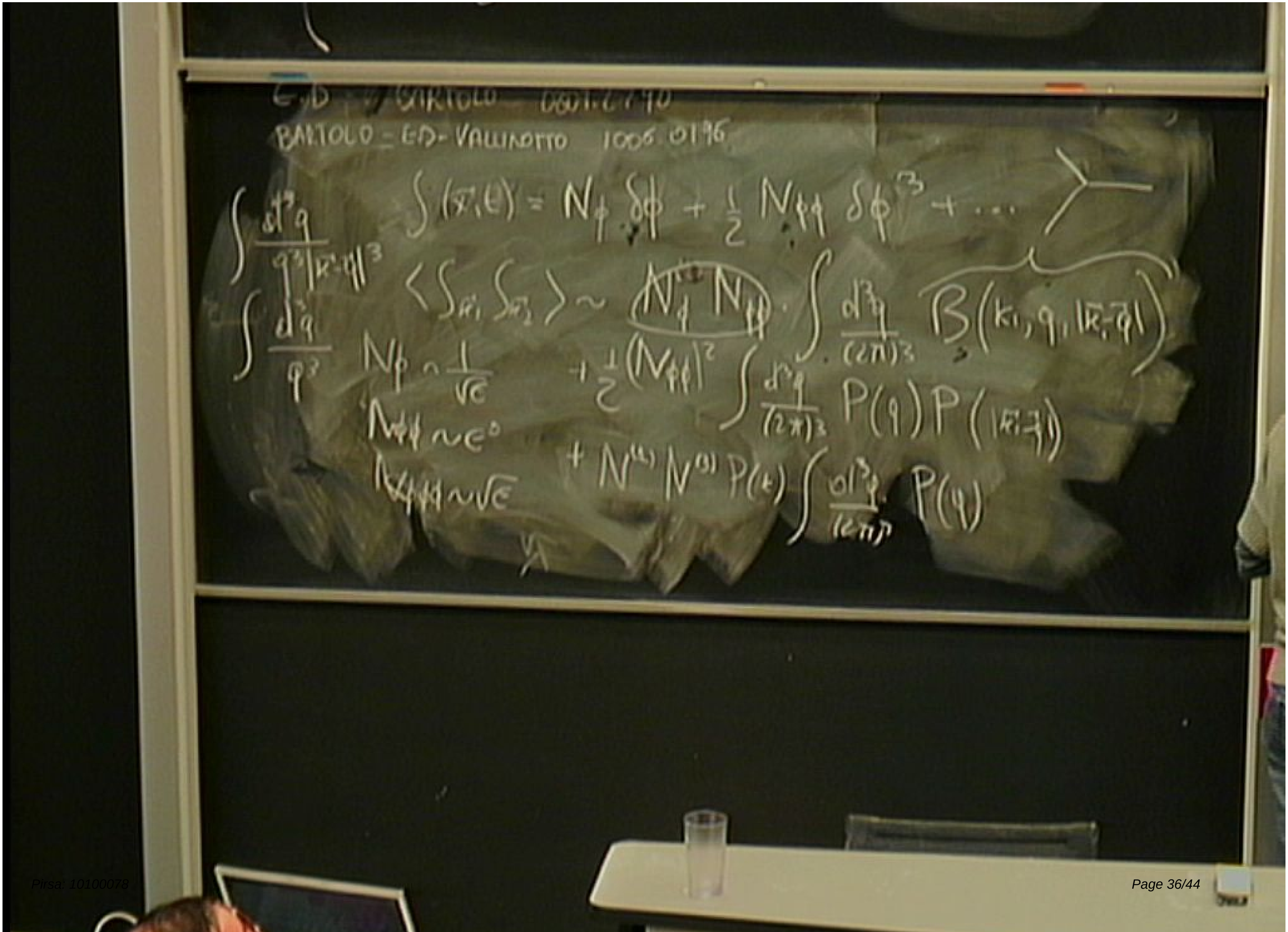
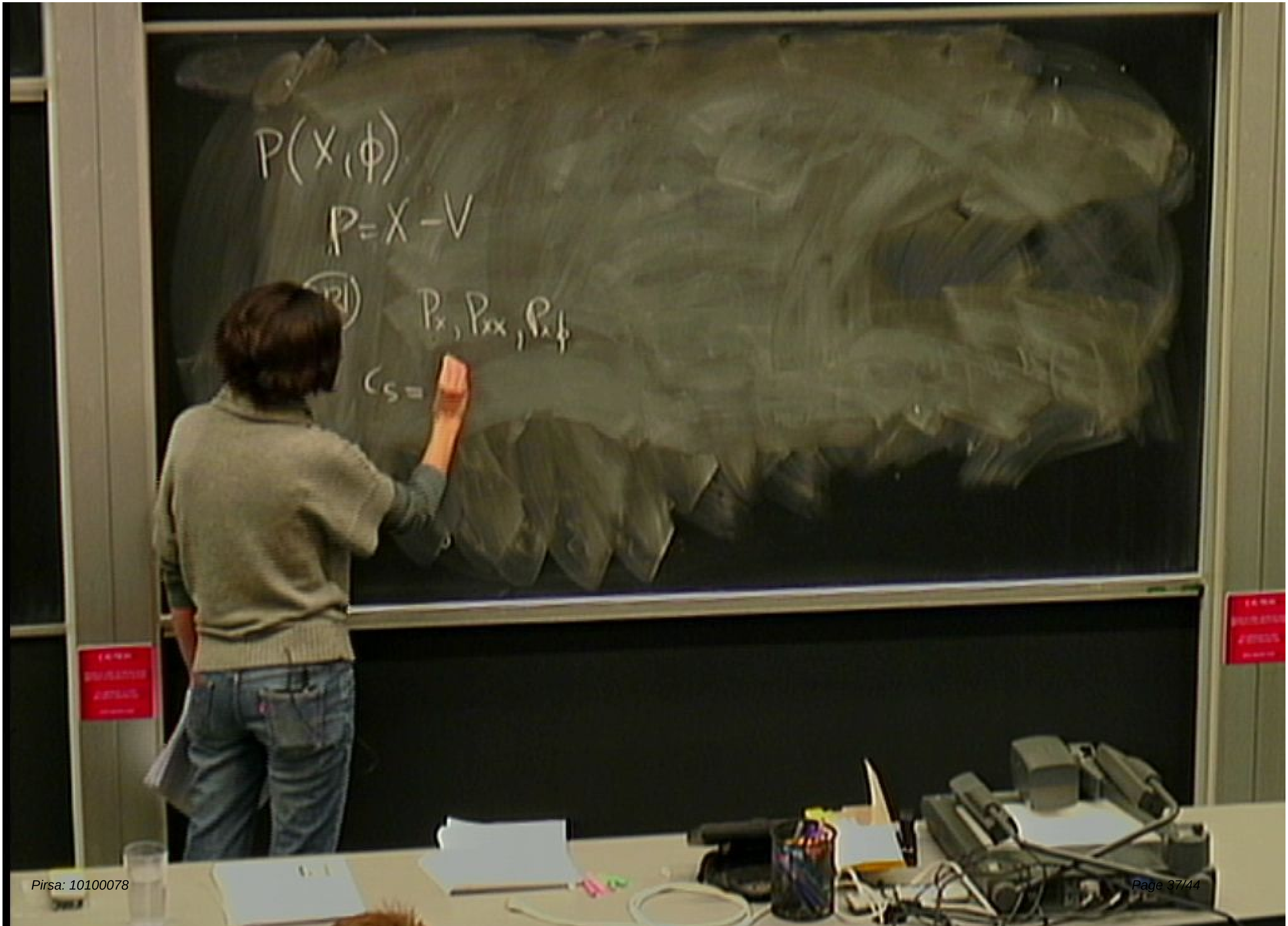
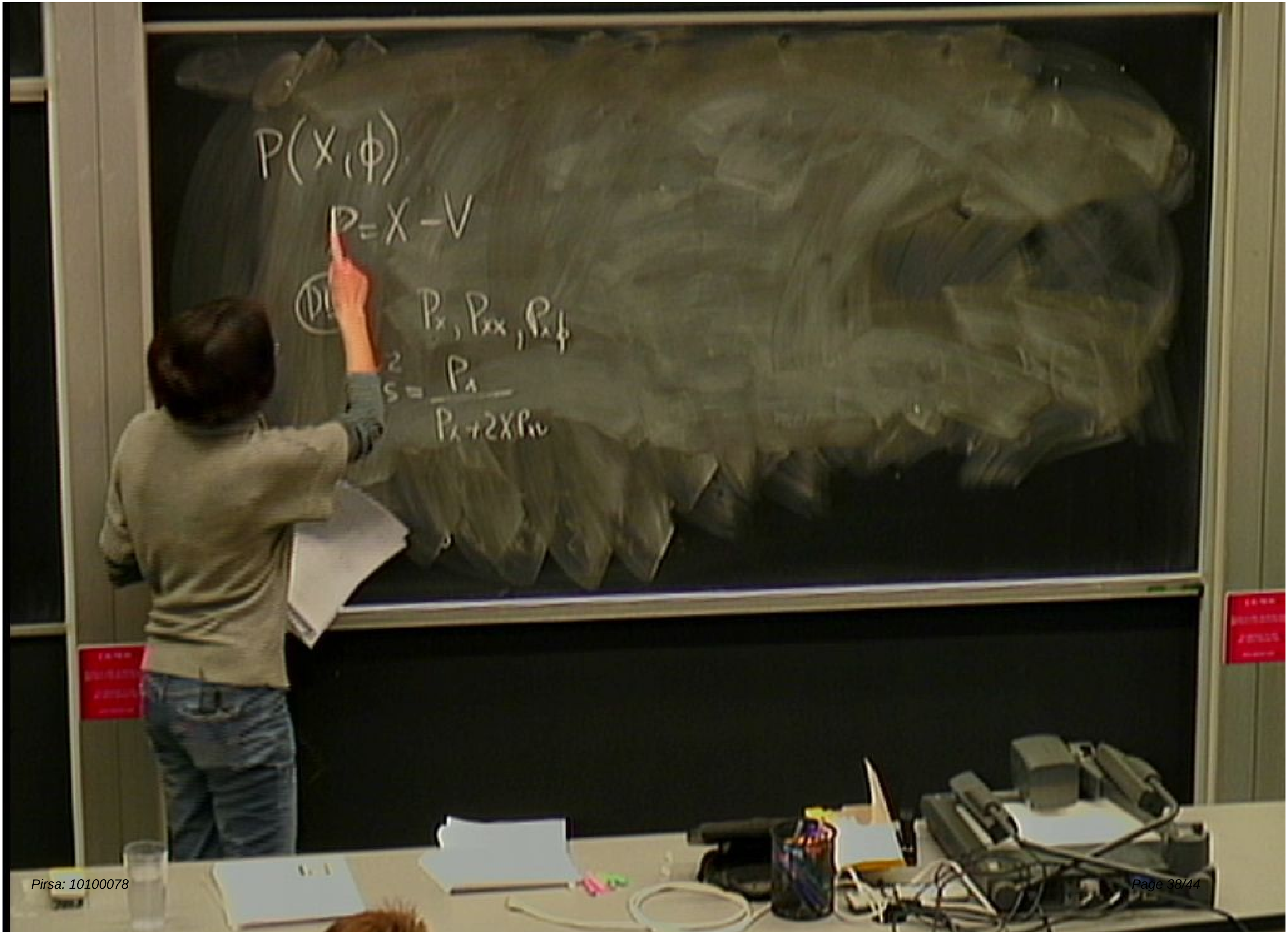
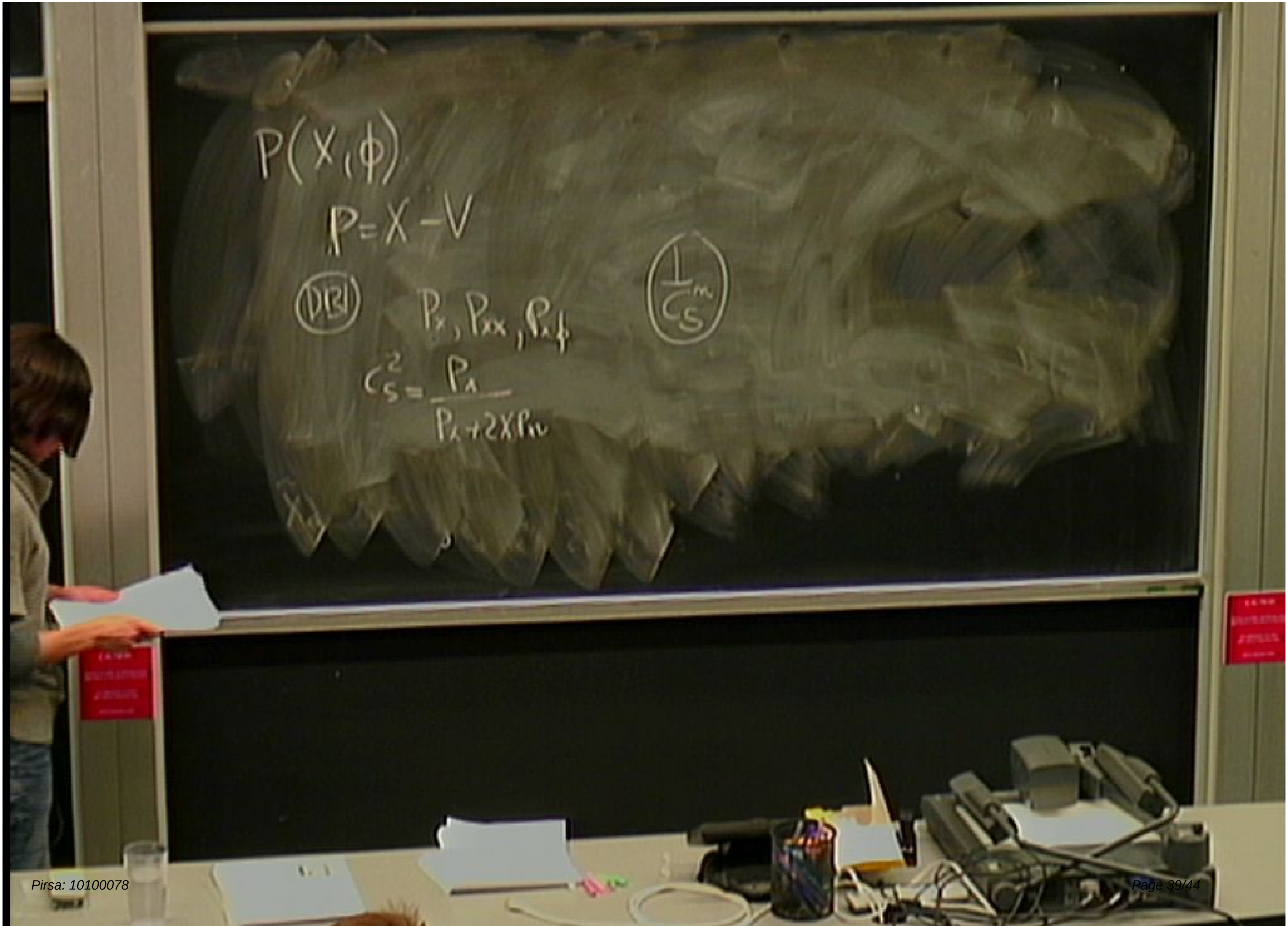
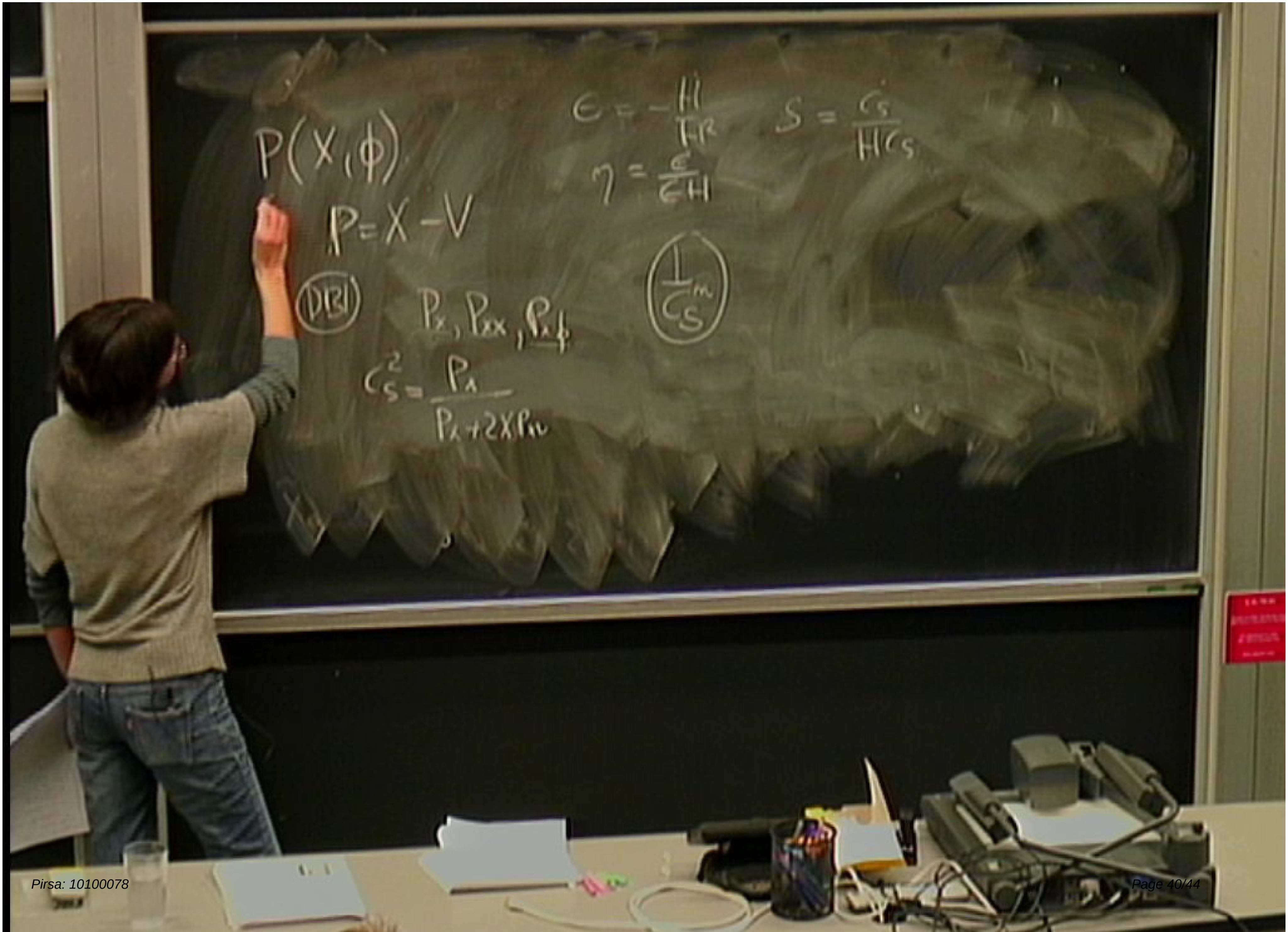

BARTOLO - ED - VALLINOTTO 1006.0196
$\zeta(\vec{x},t) = N_\phi \, \delta\phi + \frac{1}{2} N_{\phi\phi} \, \delta\phi^3 + \dots$
$\langle \zeta_{\vec{k}_1} \zeta_{\vec{k}_2} \rangle \sim N_\phi N_{\phi\phi} \int \frac{d^3q}{(2\pi)^3} B(k_1, q, |\vec{k}_1-\vec{q}|)$
$+ \frac{1}{2}(N_{\phi\phi})^2 \int \frac{d^3q}{(2\pi)^3} P(q) P(|\vec{k}_1-\vec{q}|)$
$+ N^{(2)} N^{(3)} P(k) \int \frac{d^3q}{(2\pi)^3} P(q)$
$\int \frac{d^3q}{q^3|\vec{k}-\vec{q}|^3}$
$\int \frac{d^3q}{q^3}$
$N_\phi \sim \frac{1}{\sqrt{\epsilon}}$
$N_{\phi\phi} \sim \epsilon^0$
$N_{\phi\phi\phi} \sim \sqrt{\epsilon}$


P(X,ϕ)
P=X−V
Px, Pxx, Pxϕ
cs =

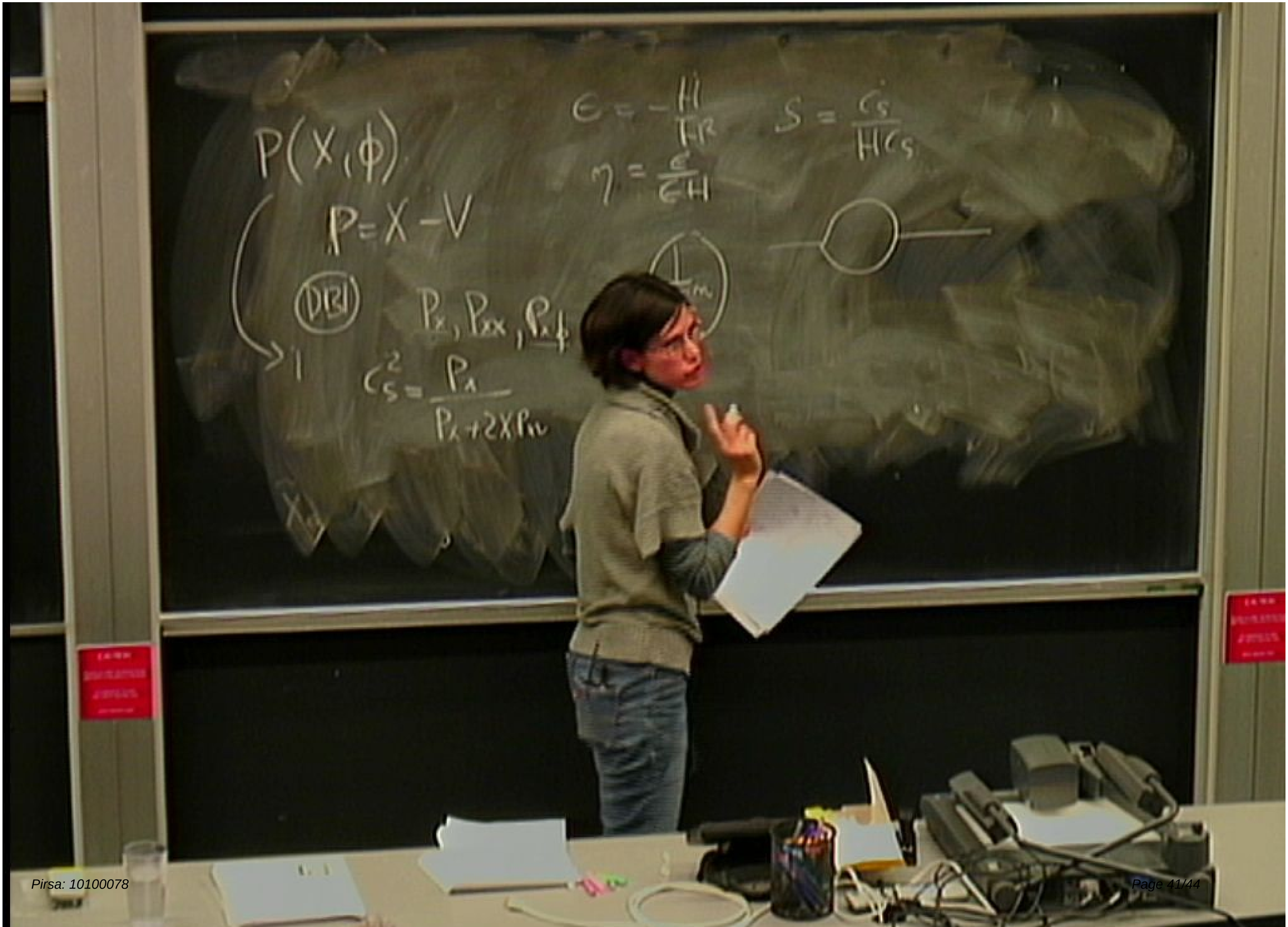

P(X,ϕ)
P=X−V
Px, Pxx, Pxϕ
Px
Px+2XPxx

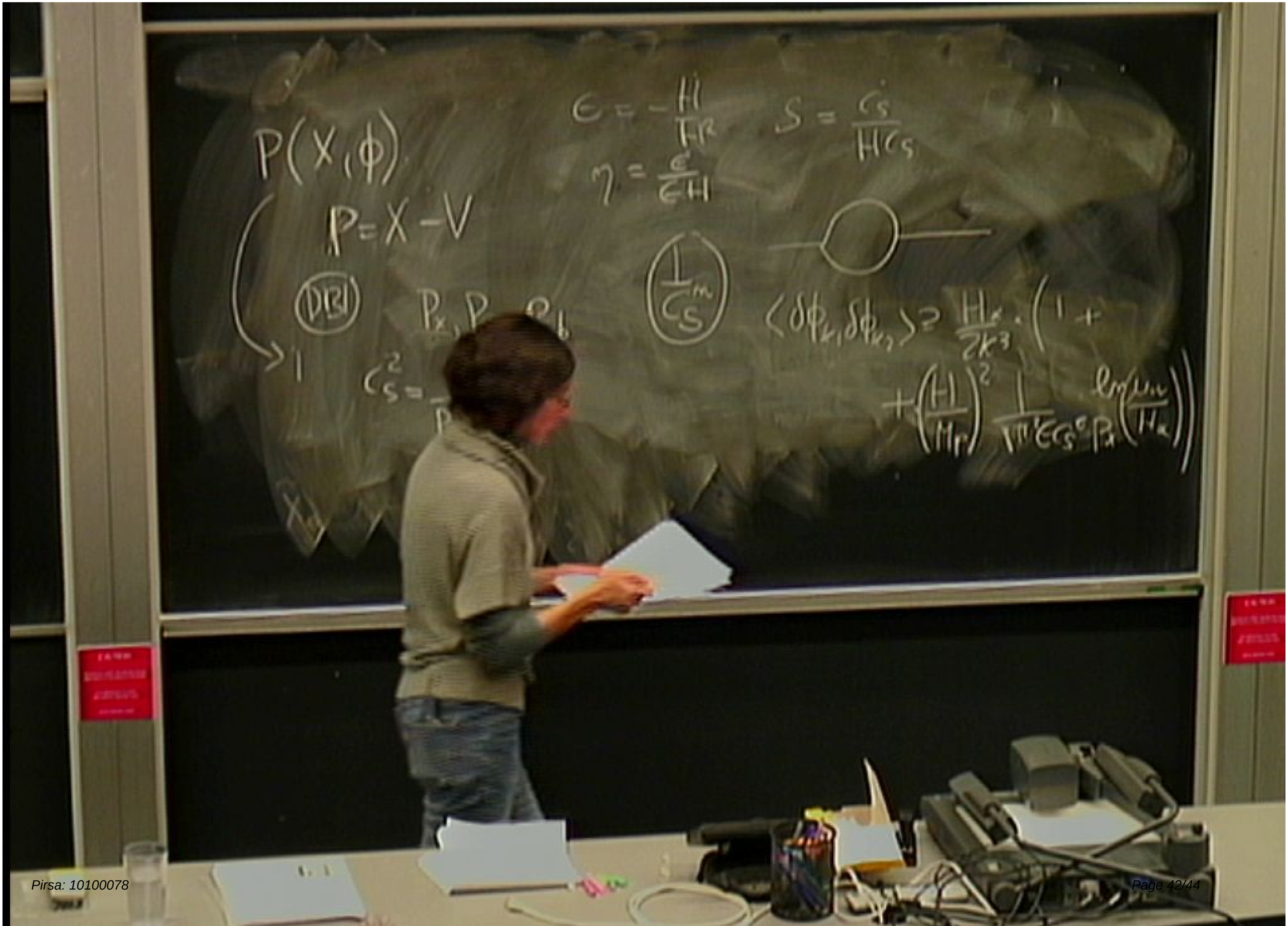


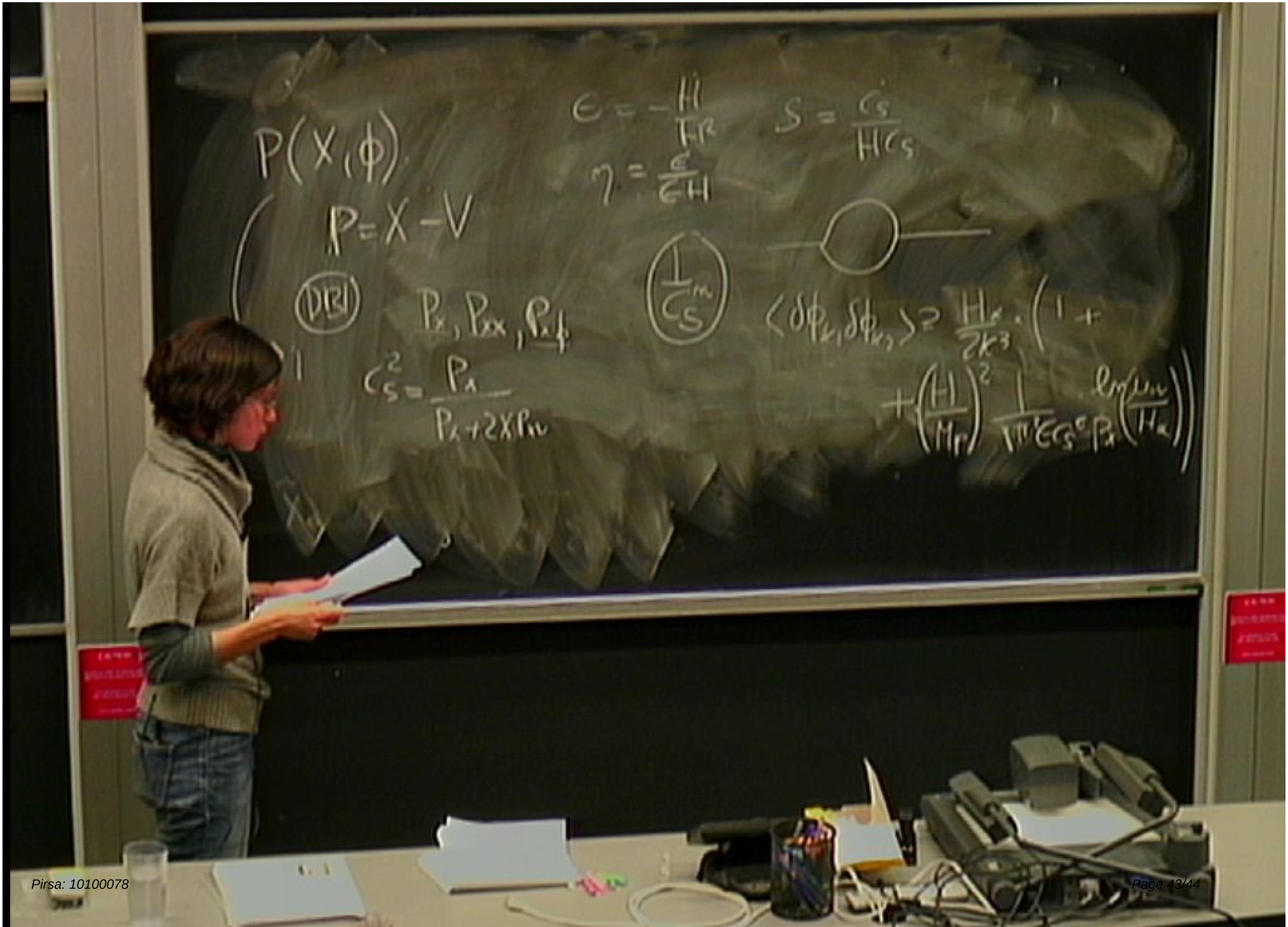
P(X,φ)
P = X − V
DBI
P_X, P_XX, P_Xφ
1/c_s^m
c_s^2 = P_X / (P_X + 2XP_XX)

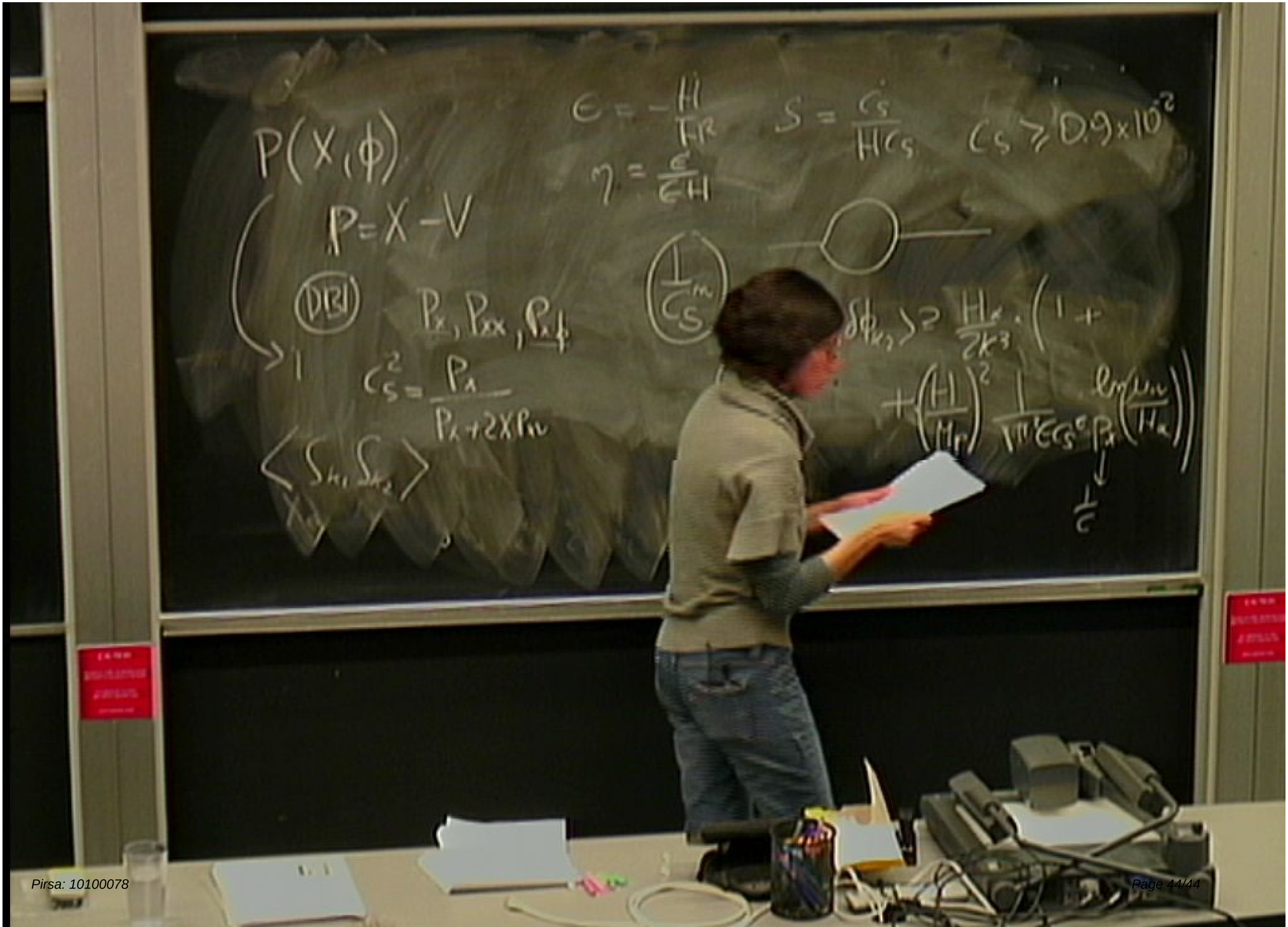


$P(X,\phi)$
$P = X - V$
DBI
$P_X,\ P_{XX},\ P_{X\phi}$
$c_s^2 = \frac{P_X}{P_X + 2XP_{XX}}$
$\epsilon = -\frac{\dot{H}}{H^2}$
$\eta = \frac{\dot{\epsilon}}{\epsilon H}$
$s = \frac{\dot{c}_s}{Hc_s}$
$\frac{1}{c_s^m}$


$P(X,\phi)$
$P = X - V$
DBI
$P_X, P_{XX}, P_{X\phi}$
$c_s^2 = \frac{P_X}{P_X + 2XP_{XX}}$
$\epsilon = -\frac{\dot{H}}{H^2}$
$\eta = \frac{\dot{\epsilon}}{\epsilon H}$
$s = \frac{\dot{c}_s}{Hc_s}$


P(X,φ)
P = X − V
DBI
ε = −Ḣ/H²
η = ε̇/εH
s = ċs/Hcs
1/cs^m
⟨δφk1 δφk2⟩ = H²/2k³ (1 +


P(X,φ)
P = X − V
DBI
P_X, P_XX, P_Xφ
c_s^2 = P_X / (P_X + 2X P_XX)
η = ε̇ / εH
s = ċ_s / H c_s


$P(X,\phi)$
$\epsilon = -\frac{\dot{H}}{H^2}$
$S = \frac{\dot{c}_s}{H c_s}$
$c_s \gtrsim 0.9 \times 10^{-2}$
$\eta = \frac{\dot{\epsilon}}{\epsilon H}$
$P = X - V$
DBI
$P_X, P_{XX}, P_{X\phi}$
$c_s^2 = \frac{P_X}{P_X + 2X P_{XX}}$
$\frac{1}{c_s^m}$
$\langle S_{k_1} S_{k_2} \rangle$