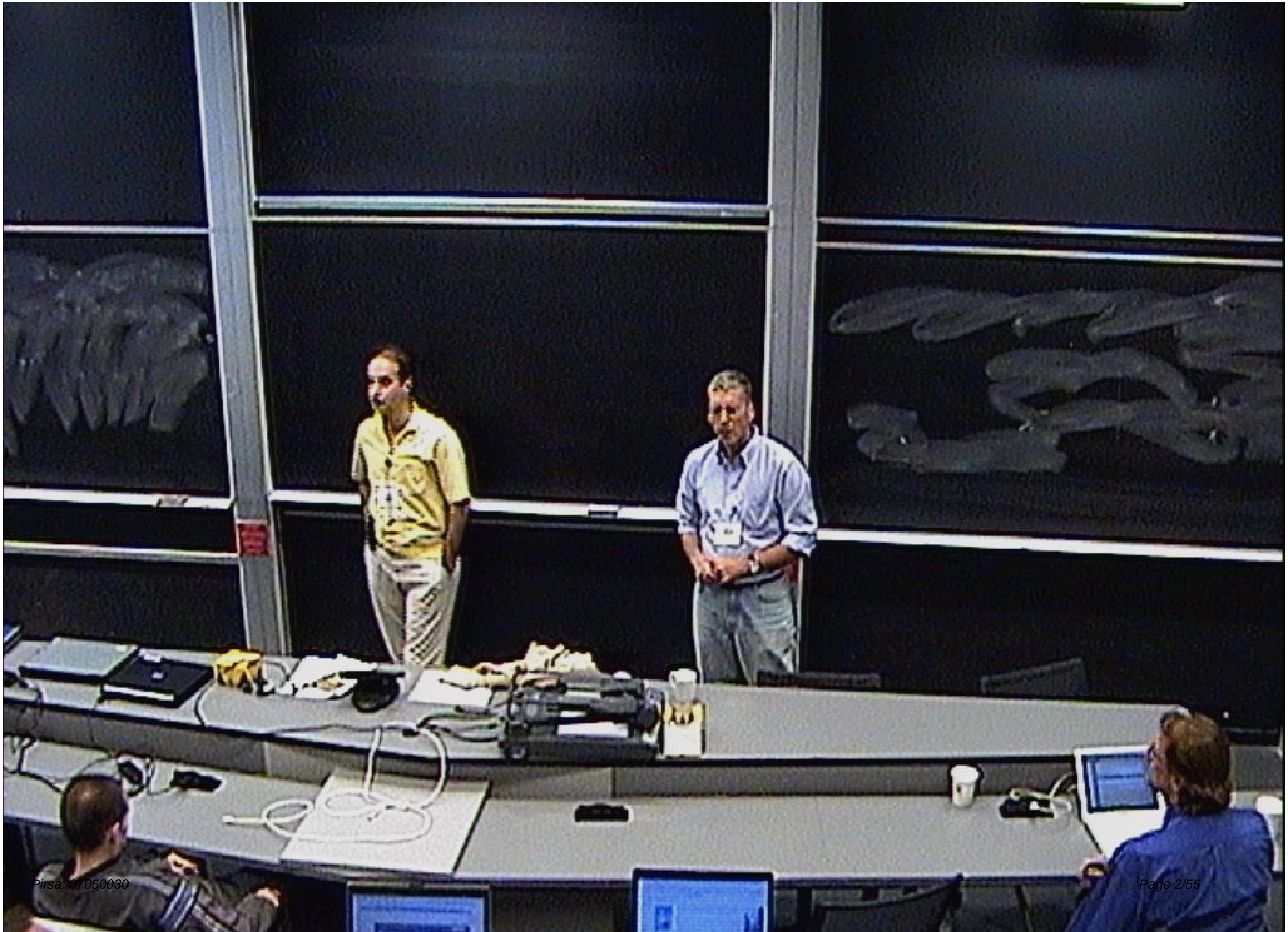
Title: Two Topics on the Accelerating Universe

Date: May 18, 2007 04:00 PM

URL: http://pirsa.org/07050030

Abstract:



$$G_{\mu\nu} = T_{\mu\nu}^{M} + T_{\mu\nu}^{DE}$$

GR: $G_{\mu\nu} = T_{\mu\nu}^{M} + T_{\mu\nu}^{DE}$

$$G_{\mu\nu} - K(g_{\mu\nu}, m_c) = T_{\mu\nu}^{M}$$

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DGP: $$G_{\mu\nu} - m_c\left(K_{\mu\nu} - g_{\mu\nu} K\right) = T_{\mu\nu}^{M}$$

GR: $G_{\mu\nu} = T^{M}_{\mu\nu} + T^{DE}_{\mu\nu}$

$$G_{\mu} - K(g_{\mu\nu}, m_c) = T^{M}_{\mu\nu}$$

DGP: $G_{\mu\nu} - m_c\left(K_{\mu\nu} - g_{\mu\nu} K\right) = T^{M}_{\mu\nu}$

GR: $ds^2 = -dt^2 + e^{2Ht} d\vec{x}^2$

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<u>MG:</u> $ds^2 = (1 + H|y|)^2 \left(-dt^2 + e^{2H_0 t} d\vec{x}^2\right) + dy^2$

$\hookrightarrow m_c$

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MG: $ds^2 = (1+H|y|)^2 \left(-dt^2 + e^{2H_0 t} d\vec{x}^2\right) + dy^2$

$\hookrightarrow m_c = H_0$

- $\angle$ in. product on an empty background

$$T_{\mu\nu}^{\ \ \nu} = 0.$$

- $m_\chi^2 = 2H^2$

$$T_{\mu}{}^{\mu} = 0.$$

- $m_\chi^2 = 2H^2$

$$\delta h_{\mu\nu} = \left(\nabla_\mu \nabla_\nu + g_{\mu\nu} H^2\right)\omega$$

$$T_{\mu}^{\ \mu} = 0.$$

- $m_*^2 = 2H^2$

$$\delta h_{\mu\nu} = \left(\nabla_\mu \nabla_\nu + g_{\mu\nu} H^2\right)\omega$$

$$\mathcal{L} = \mathcal{L}_*(h) + \varphi\left(\nabla^\mu \nabla^\nu - g^{\mu\nu}\Box - 3H^2 g_{\mu\nu}\right) -$$

$$- \frac{g}{\xi}\varphi\left(\Box + H^2\right)\varphi$$

$$T_{\mu}^{\ \mu} = 0$$

4D $m_g \neq 0$

dS

- $m_\chi^2 = 2H^2$

$$\delta h_{\mu\nu} = \left(\nabla_\mu \nabla_\nu + g_{\mu\nu} H^2\right)\omega$$

$$\mathcal{L} = \mathcal{L}_\chi(h) + \varphi\left(\nabla^\mu \nabla^\nu - g^{\mu\nu}\Box - 3H^2 g_{\mu\nu}\right) - \frac{9}{4}\varphi\left(\Box + H^2\right)\varphi$$

$$-\frac{g}{4}\varphi(\Box+H^2)\varphi$$

- ~~Symmetry~~ $T \neq 0$

$$-\frac{g}{4}\,\varphi(D+H^2)\varphi$$

- ~~Symmetry~~ $T \neq 0$

$$\varphi = \frac{T}{3m_c(D+H^2)}$$

○ Domain walls.

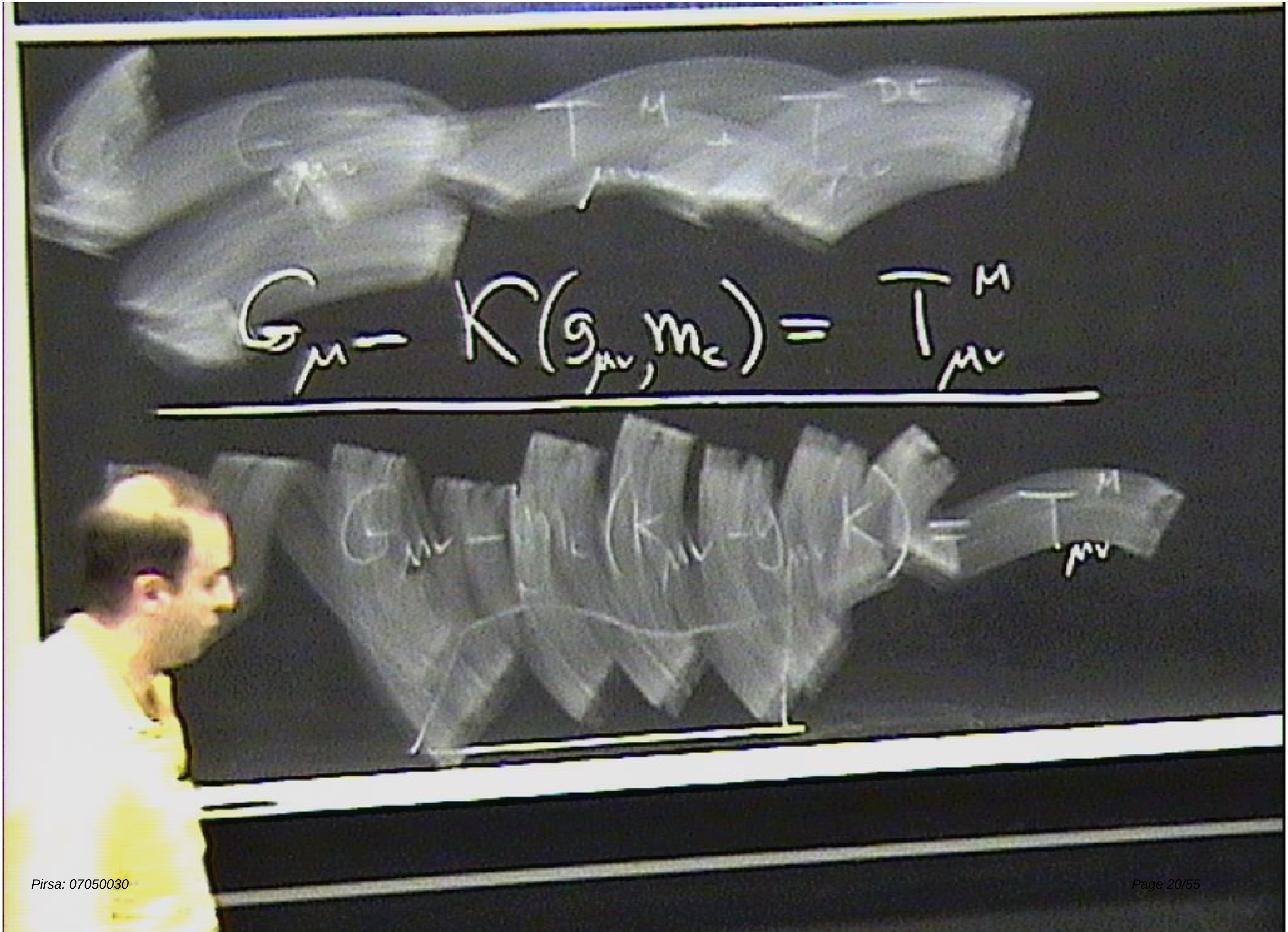
"Effective negative mass"

GR: $ds^2 = -dt^2 + e^{2H_0 t} d\vec{x}^2$

MG: $ds^2 = (1 - H|y|)^2 \left(-dt^2 + e^{2H_0 t} d\vec{x}^2\right) + dy^2$

$\hookrightarrow m_c = H_0$

- $\angle$ lin. perturb. on an empty background.



$G_{\mu\nu} - K(g_{\mu\nu}, m_c) = T^M_{\mu\nu}$
$G_{\mu\nu} - m_c(K_{\mu\nu} - g_{\mu\nu}K) = T^M_{\mu\nu}$

$$G_{\mu\nu} = T^{M}_{\mu\nu} + T^{DE}_{\mu\nu}$$

$$G_{\mu\nu} + m_c(K_{\mu\nu} - g_{\mu\nu}K) = T^{M}_{\mu\nu}$$

DGP

$$G_{\mu\nu} - m_c(K_{\mu\nu} - g_{\mu\nu}K) = T^{M}_{\mu\nu}$$

$$G_{\mu\nu} + m_c\left(K_{\mu\nu} - g_{\mu\nu}K\right) + \alpha\Sigma_{\mu\nu} = T_{\mu\nu}^{M}$$

$$\text{(1)}\quad \Sigma_{\mu\nu} = G_{\mu\nu} - \frac{1}{2}g_{\mu\nu}\left(K^2 - K_{\alpha\beta}^2\right) - 2\left(K_\mu^{\ \alpha}K_{\alpha\nu} - g_{\mu\nu}K\right)$$

$$G_{\mu\nu} + m_c\left(K_{\mu\nu} - g_{\mu\nu}K\right) + \alpha\Sigma_{\mu\nu} = T^{M}_{\mu\nu}$$

$$1)\quad \Sigma_{\mu\nu} = G_{\mu\nu} - \frac{1}{2}g_{\mu\nu}\left(K^2 - K_{\alpha\beta}^2\right) - 2\left(K_\mu{}^\alpha K_{\alpha\nu} - g_{\mu\nu}K^1\right)$$

4D $\quad M_p^2\,\bar{\delta}(y)\,\sqrt{g}\,R$

5D $\quad M_*^3\,\sqrt{g_5}\,R_5 = M_*^3\,N\sqrt{g}\left(R + K^2 - K_{\mu\nu}^2\right)$

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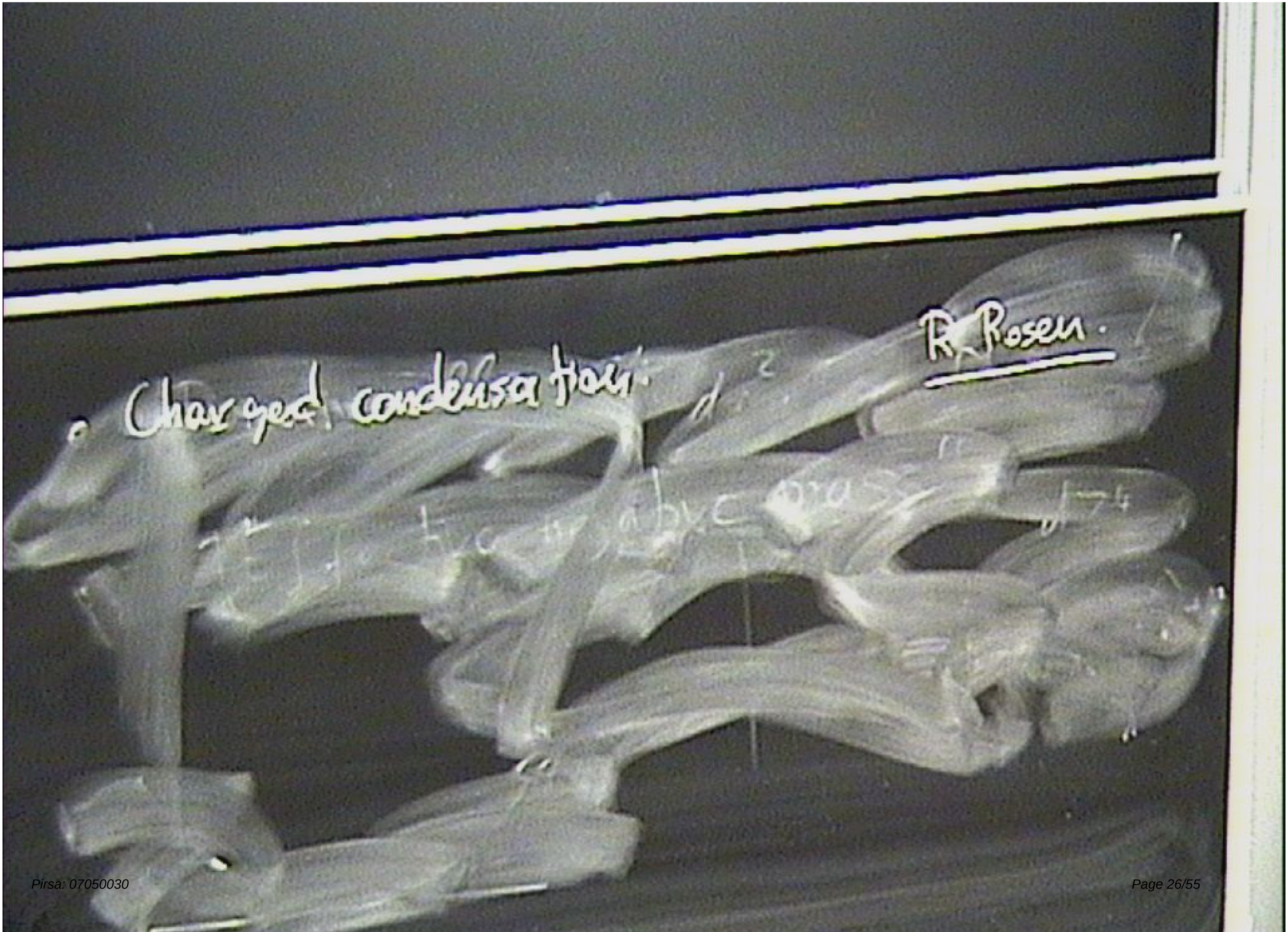
5D $\quad M_*^3 \sqrt{g_5}\, R_5 = M_*^3 N \sqrt{g} \left(R + K^2 - K_{\mu\nu}^2\right)$

4D' $\quad M^2\, \bar{\delta}(y)\, N \sqrt{g} \left(R + K^2 - K_{\mu\nu}^2\right)$


Charged condensation:
R. Rosen.

$$e\,\bar{J}_0 = e\,(10^{-13}\,\mathrm{eV})^3$$

M

$$e\bar{J}_0 = e\left(10^{-13}\,\mathrm{eV}\right)^3$$

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 + |D_\mu \varphi|^2 - m_H^2|\varphi|^2 - e A_\mu \bar{J}^\mu$$

$$e\bar{J}_0 = e\,(10^{-13}\,\mathrm{eV})^3$$

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 + |D_\mu \varphi|^2 - m_H^2|\varphi|^2 - g A_\mu \bar{J}^\mu +$$

$$\varphi = \frac{1}{\sqrt{2}}\,\sigma e^{i\alpha} \qquad B_\mu = A_\mu - \frac{1}{g}\partial_\mu \alpha$$

$$e\bar{J}_0 = e\,(10^{-13}\,\mathrm{eV})^3$$

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$$\varphi = \frac{1}{\sqrt{2}}\,\sigma e^{i\alpha} \qquad B_\mu = A_\mu - \frac{1}{g}\partial_\mu\alpha$$

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 + \frac{1}{2}(\partial\sigma)^2 + \frac{1}{2}g^2B_\nu^2\sigma^2 - \frac{1}{2}m_H^2\sigma^2 - gB_\mu\bar{J}^\mu$$

R. Rosen

$$\partial^\mu F_{\mu\nu} + g^2 B_\nu \sigma^2 = g \bar{J}_\nu$$

$$\Box \sigma + (m_H^2 - g^2 B_\nu^2)\sigma = 0$$

$$\langle B_0 \rangle = B_{0c} = \frac{m_H}{g}$$

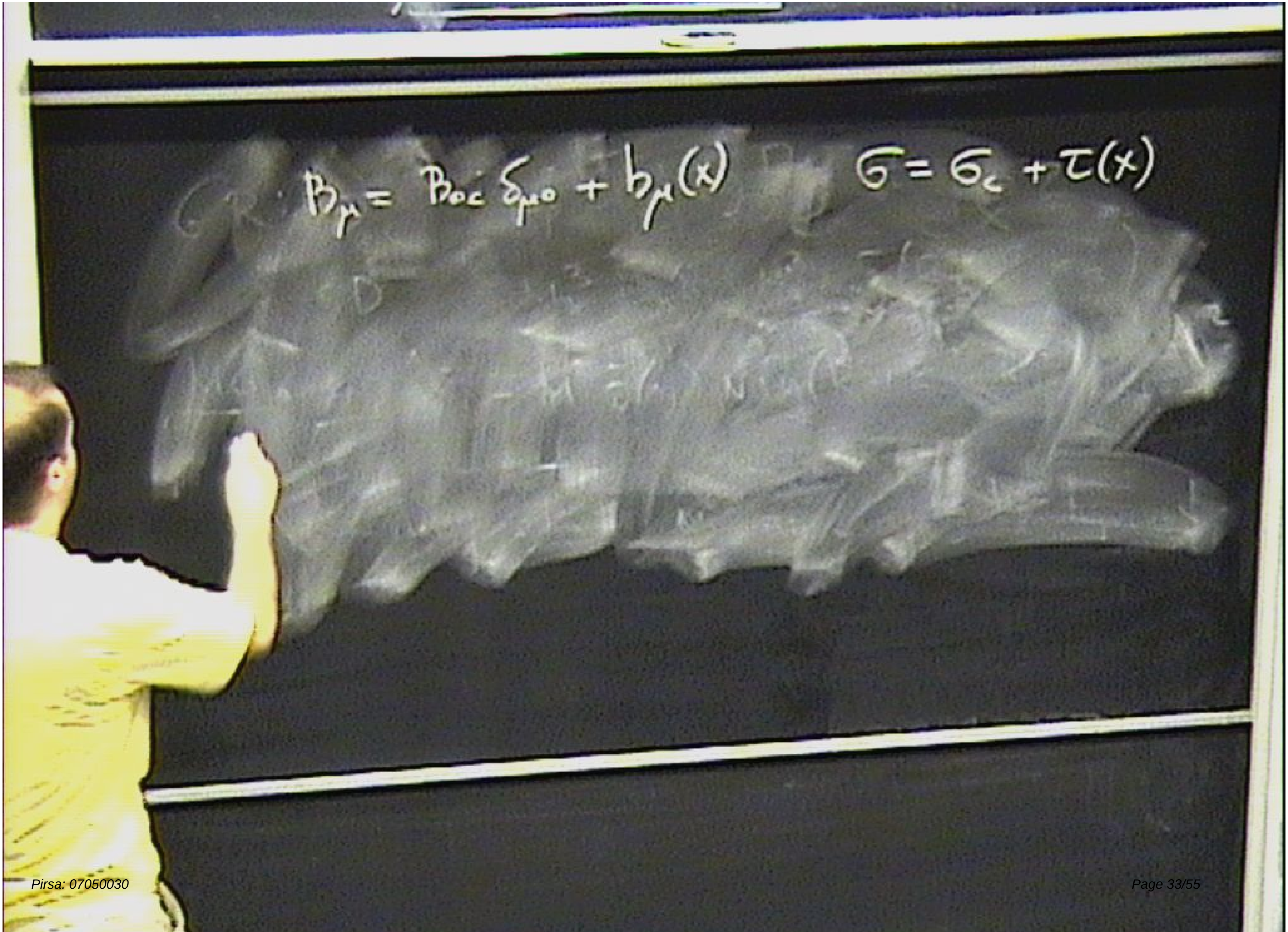
$$\langle \sigma \rangle = \frac{\bar{J}_0}{m_H}$$

R. Rosen.

$$\partial^\mu F_{\mu\nu} + g^2 B_\nu \sigma^2 = g J_\nu$$

$$\Box \sigma + (m_H^2 - g^2 B_\nu^2)\,\sigma = 0.$$

$$\langle B_0 \rangle = B_{0c} = \frac{m_H}{g} \qquad \langle \sigma \rangle = \frac{J_0}{m_H}$$


$B_\mu = B_{0c}\,\delta_{\mu 0} + b_\mu(x)$
$\sigma = \sigma_c + \tau(x)$

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$$\mathcal{L} = -\frac{1}{4} f_{\mu\nu}^2$$

$$B_\mu = B_{0c}\,\delta_{\mu 0} + b_\mu(x) \qquad \sigma = \sigma_c + \tau(x)$$

$$\mathcal{L} = -\frac{1}{4} f_{\mu\nu}^2(b) + \frac{1}{2} m_g^2 b_\mu^2 + 2 m_H m_g b_0 \tau$$

$$m_g^2 = \frac{g^2 J_0}{m_H}$$

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$$m_g^2 = \frac{g^2 J_0}{m_H} \qquad (\Box + m_g^2)\, b_i^T = 0$$

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$$\omega_\pm^2 = k^2 + m_H^2 + \frac{1}{2} m_g^2 \pm \sqrt{4 k^2 m_H^2 + \left(m_H^2 - \frac{1}{2} m_g^2\right)^2}$$

$$B_\mu = B_{0c}\,\delta_{\mu 0} + b_\mu(x) \qquad \sigma = \sigma_c + \tau(x)$$

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$$m_H \bar{J}_b = \rho_c = (10^{-4} eV)^4$$

$$m_H \, \overline{J_0} = \rho_c = (10^{-4} eV)^4$$

$$m_g^2 = \frac{g^2 \, \overline{J_0}}{m_H}$$

$$\boxed{m_g^2 = \frac{g^2 \rho_c}{m_H^2}}$$

$$m_H \bar{J}_0 = \rho_c = (10^{-4} eV)^4$$

$$m_g^2 = \frac{g^2 \bar{J}_0}{m_H}$$

$$\boxed{m_g^2 = \frac{g^2 \rho_c}{m_H^2}}$$

$$m_g \sim 10^{-70} eV$$

R. Rosen.

$$\partial^\mu F_{\mu\nu} + g^2 B_\nu \sigma^2 = g \bar{J}_\nu$$

$$\Box\sigma + (m_H^2 - g^2 B_\nu^2)\sigma = 0.$$

$$\langle\sigma\rangle = \frac{\bar{J}_0}{m_H}$$

$$\langle B_0\rangle = B_{0c} = \frac{m_H}{g}$$

$$J_0^{\text{scalar}} = (\varphi^* \partial_0 \varphi - \partial_0 \varphi^* \varphi) = \phi^2 B_0$$

R. Rosen.

$$\partial^\mu F_{\mu\nu} + g^2 B_\nu \sigma^2 = g \bar{J}_\nu$$

$$D\sigma + (m_H^2 - g^2 B_\nu^2)\sigma = 0.$$

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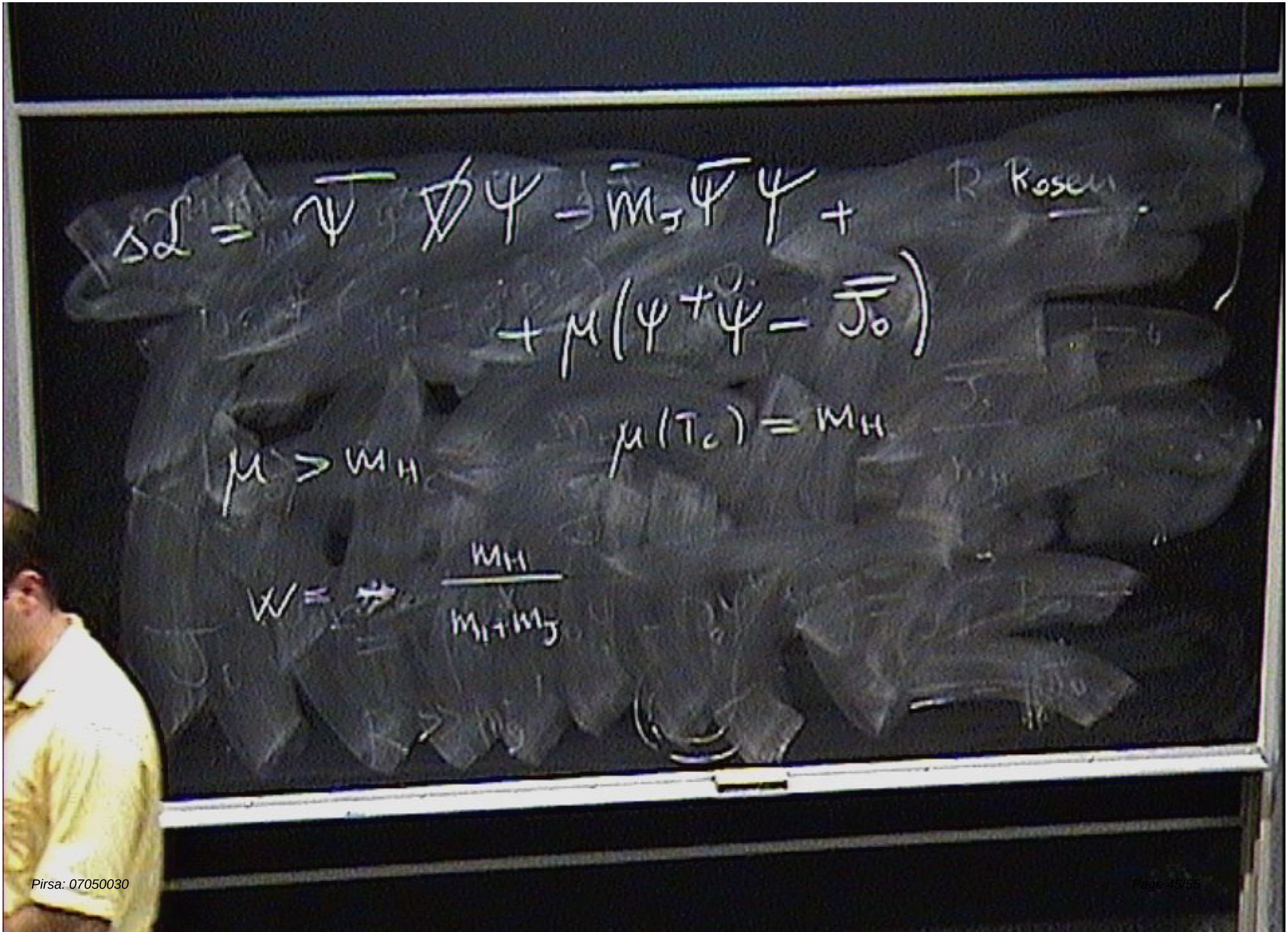
$$J_0^{\text{scalar}} = (\varphi^* \partial_0 \varphi - \partial_0 \varphi^* \varphi) = g \phi^2 B_0 = $$

$$= - \rho_0$$

$$\Delta\mathcal{L} = \bar{\psi}\,\not{\partial}\psi - \bar{m}_s\bar{\psi}\psi + \ldots$$
$$+\mu(\psi^\dagger\psi - \bar{J}_0)$$

R Rosen


$\Delta\mathcal{L} = \bar{\psi}\,\not{\partial}\,\psi - \bar{m}_J\,\bar{\psi}\psi +$
Rosen
$+\,\mu(\psi^{\dagger}\psi - \bar{J}_0)$
$\mu(T_c) = m_H$
$\mu > m_H$
$W = \frac{m_H}{m_1 + m_J}$

$$\Delta\mathcal{L} = \bar{\Psi}\, \not{\partial}\, \Psi - \bar{m}_J \bar{\Psi} \Psi + \ldots$$

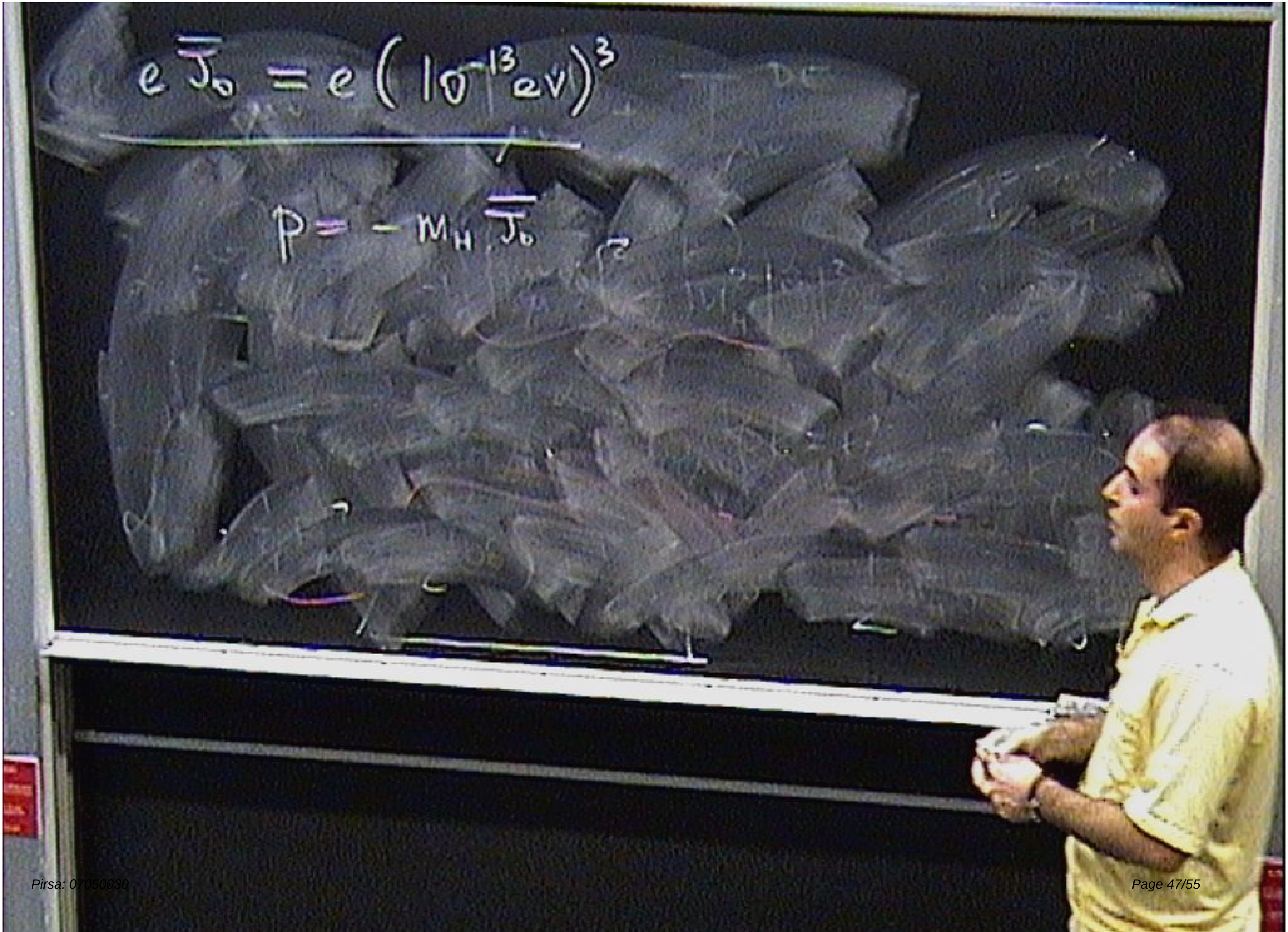
R. Rosen

$$+ \mu\left(\Psi^{+}\Psi - J_0\right)$$

$$\mu(T_c) = m_H$$

$$\mu > m_H$$

$$W = \# \frac{m_H}{m_1 + m_J}$$



$e\,\bar{\bar{J}}_0 = e\,(10^{-13}\,eV)^3$
$p = -\,m_H\,\bar{\bar{J}}_0$

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$$\rho_M + \rho_J \qquad p =$$

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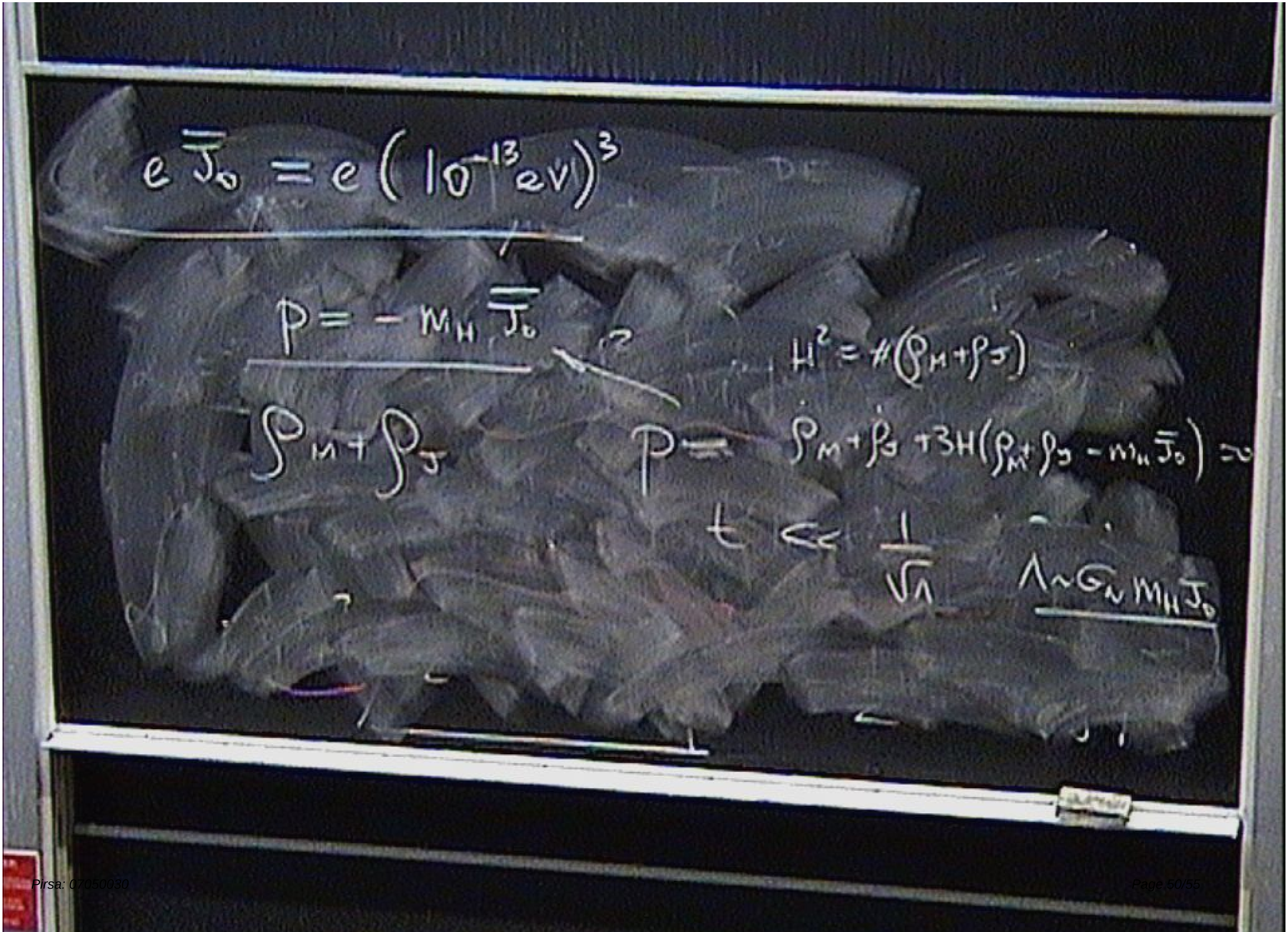
$$p = -\,m_H\,\bar{J}_0$$

$$H^2 = \#(\rho_M + \rho_J)$$

$$\rho_M + \rho_J \qquad p = \quad \dot\rho_M + \dot\rho_J + 3H(\rho_M + \rho_J - m_H \bar{J}_0) \approx$$


$e\,\bar{J}_0 = e\,(10^{-13}\,eV)^3$
$P = -\,m_H\,\bar{J}_0$
$H^2 = \#(\rho_M + \rho_J)$
$\rho_M + \rho_J$
$P = \dot{\rho}_M + \dot{\rho}_J + 3H(\rho_M + \rho_J - m_H \bar{J}_0) \approx$
$t \ll \frac{1}{\sqrt{\Lambda}}$
$\Lambda \sim G_N\, m_H\, J_0$

$$e\bar{J}_0 = e\left(10^{-13}\,eV\right)^3$$

$$p = -m_H \bar{J}_0$$

$$\rho_M + \rho_J$$

$$p =$$

$$H^2 = \#(\rho_M + \rho_J)$$

$$\dot{\rho}_M + \dot{\rho}_J + 3H(\rho_M + \rho_J - m_H \bar{J}_0) = 0$$

$$t \ll \frac{1}{\sqrt{\Lambda}} \qquad \Lambda \sim G_N m_H J_0$$

$$t \to \frac{1}{\sqrt{\Lambda}} \qquad dS$$

$$B_\mu = B_{0i}\,\delta_{\mu 0} + b_\mu(x) \qquad \sigma = \sigma_c + \tau(x)$$

$$\mathcal{L} = -\frac{1}{4} f_{\mu\nu}^2(b) + \frac{1}{2} m_g^2 b_\mu^2 + 2 m_H m_g b_0 \tau - m_H J_0$$

$$m_g^2 = \frac{g J_0}{m_H} \qquad (\Box + m_g^2)\, b_j^T = 0$$

$$\omega_\pm^2 = \vec{k}^2 + 2m_H^2 + \frac{1}{2} m_g^2 \pm \sqrt{4\vec{k}^2 m_H^2 + \left(2m_H^2 - \frac{1}{2} m_g^2\right)^2}$$

$$\omega_+^2 = 4m_H^2 \qquad \omega_-^2 = m_g^2$$

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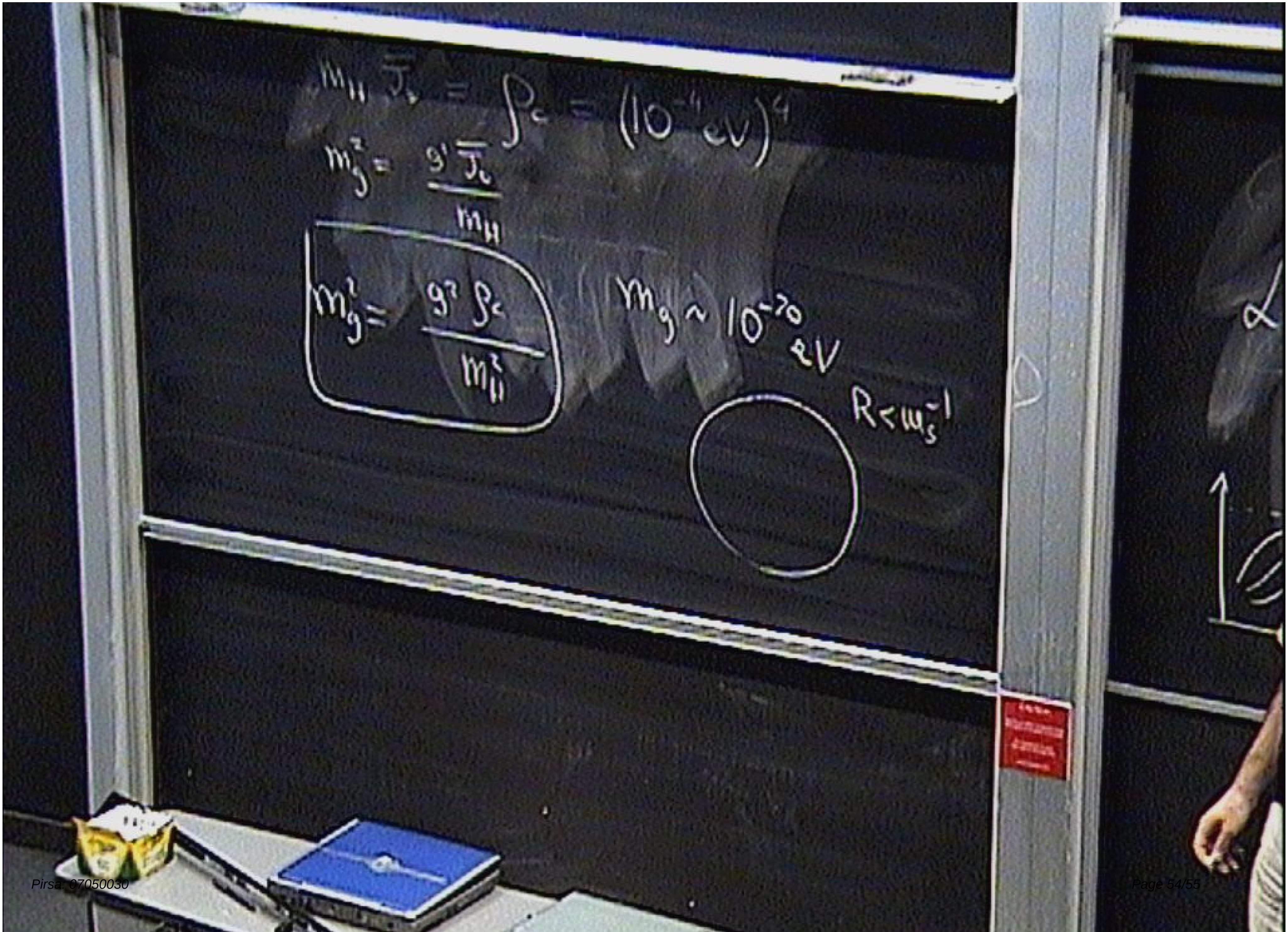
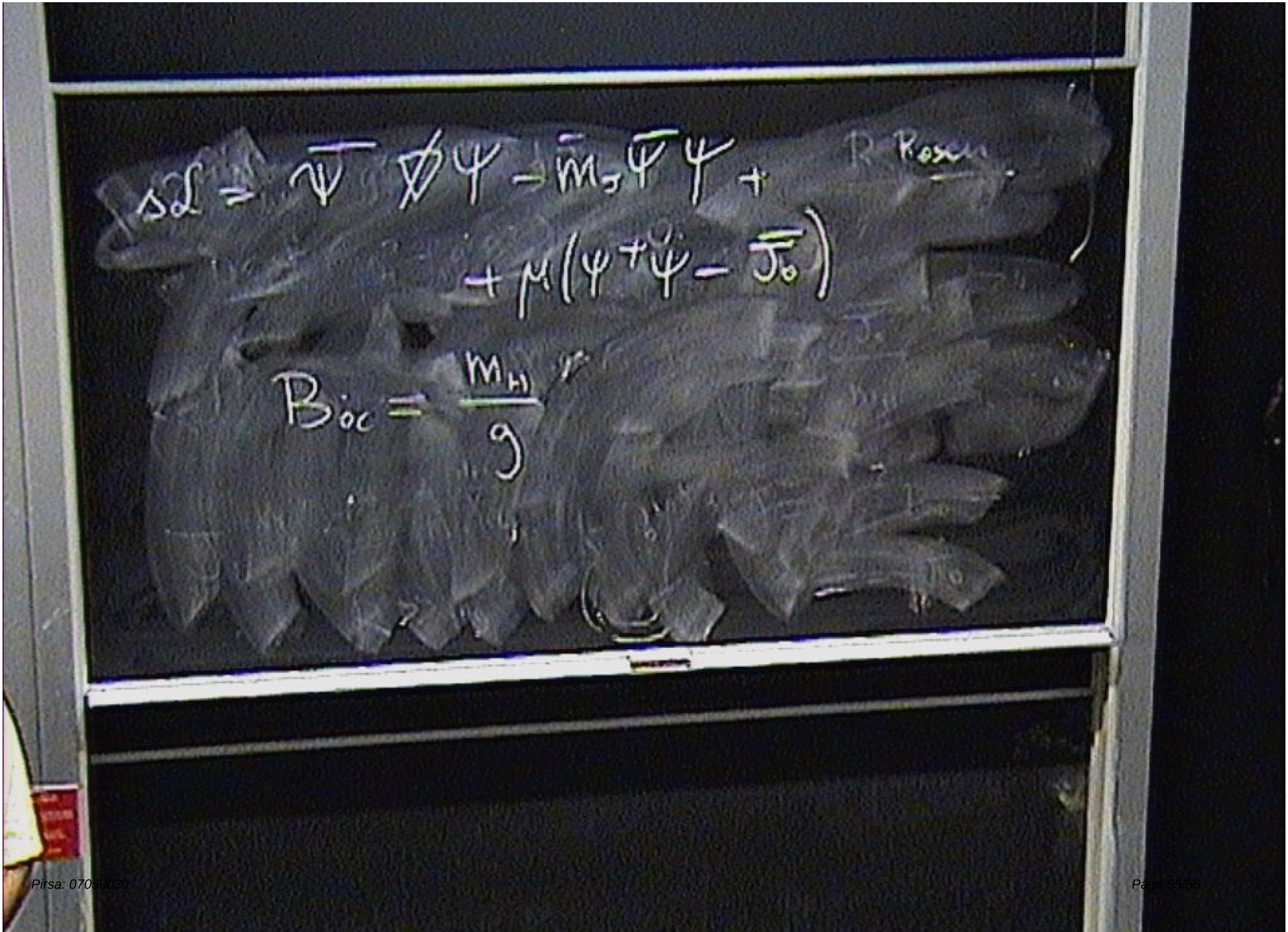


$m_H \bar{J}_c = \rho_c = (10^{-4} eV)^4$
$m_g^2 = \frac{g^2 \bar{J}_c}{m_H}$
$m_g^2 = \frac{g^2 \rho_c}{m_H^3}$
$m_g \sim 10^{-70} eV$
$R < m_s^{-1}$


$\delta\mathcal{L} = \bar{\Psi}\,\not{\partial}\,\Psi - m_0\bar{\Psi}\Psi + \mu(\Psi^{\dagger}\Psi - J_0)$
R. Rosen
$B_{oc} = \frac{m_H}{g}$