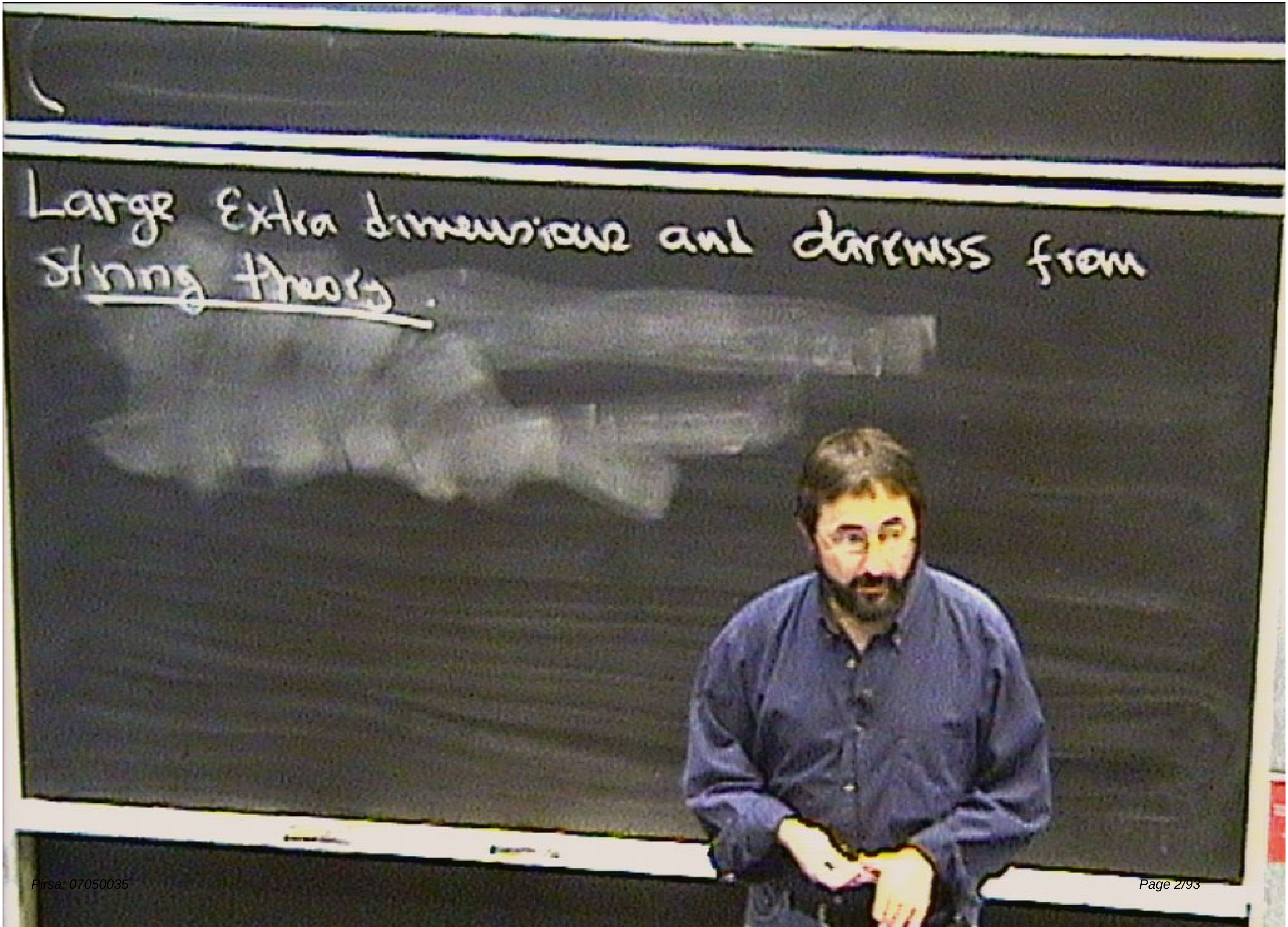
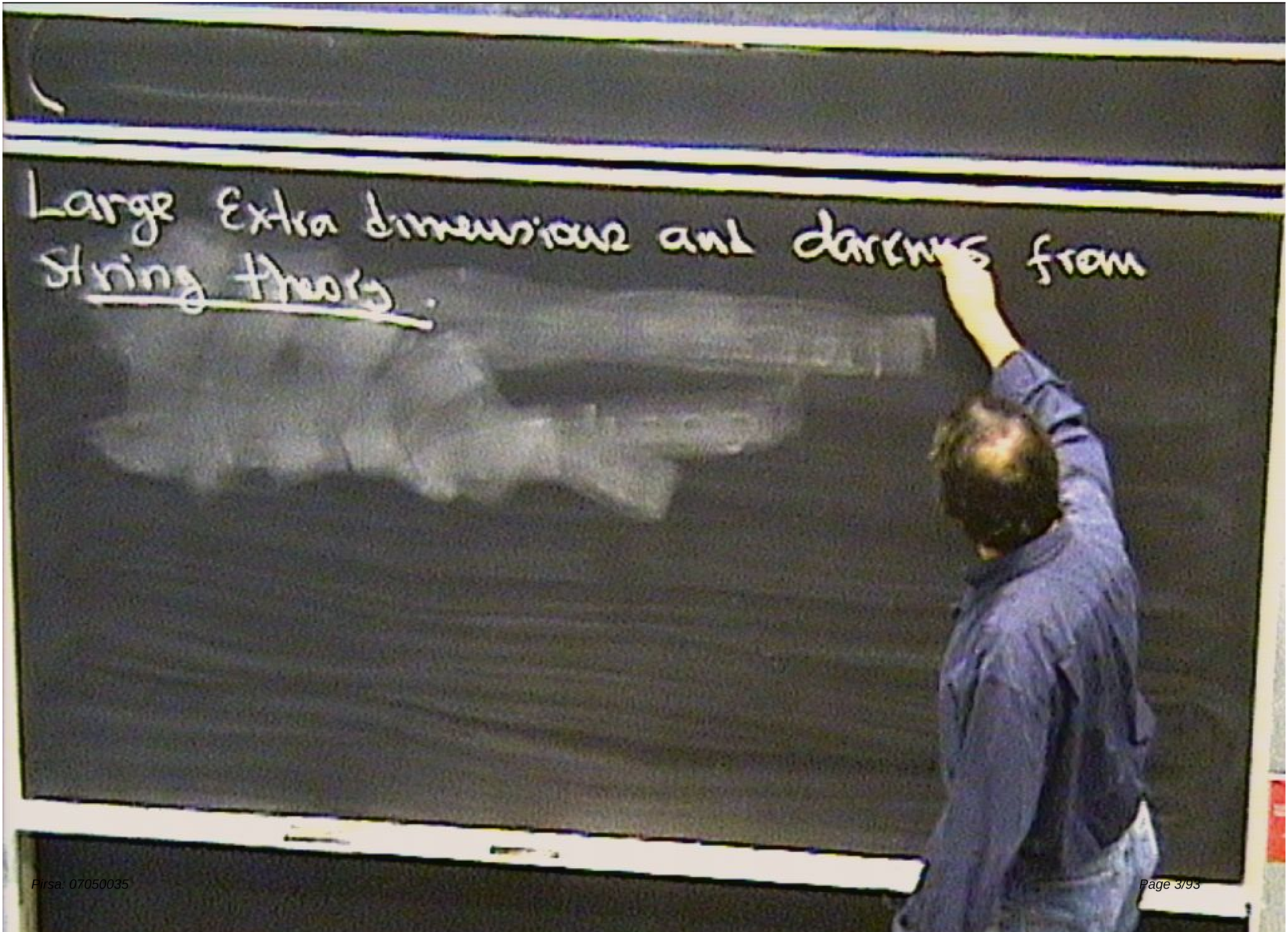
Title: Large Extra Dimensions and Darkness From String Theory

Date: May 19, 2007 11:00 AM

URL: http://pirsa.org/07050035

Abstract:


Large Extra dimensions and darkness from
String theory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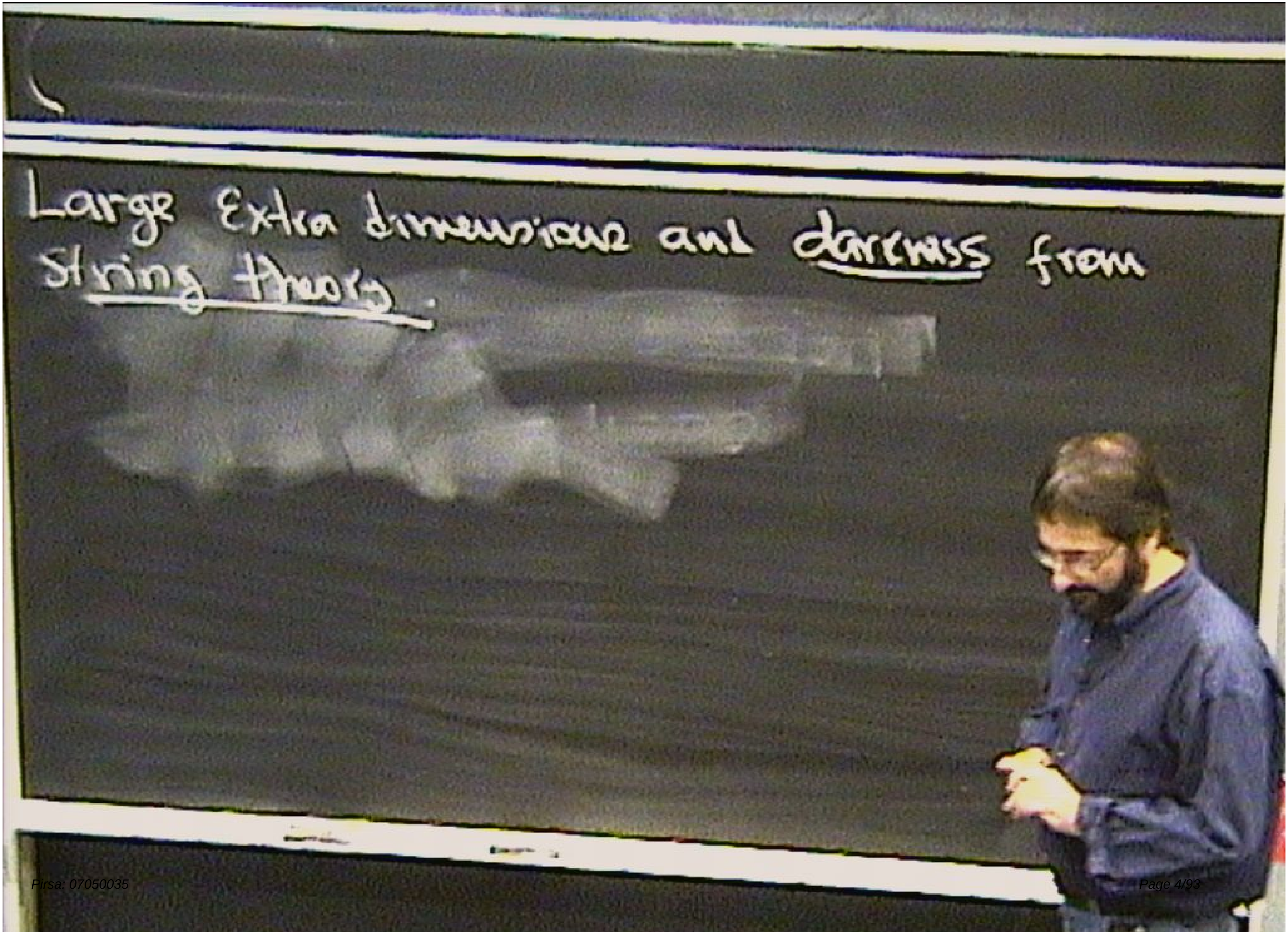
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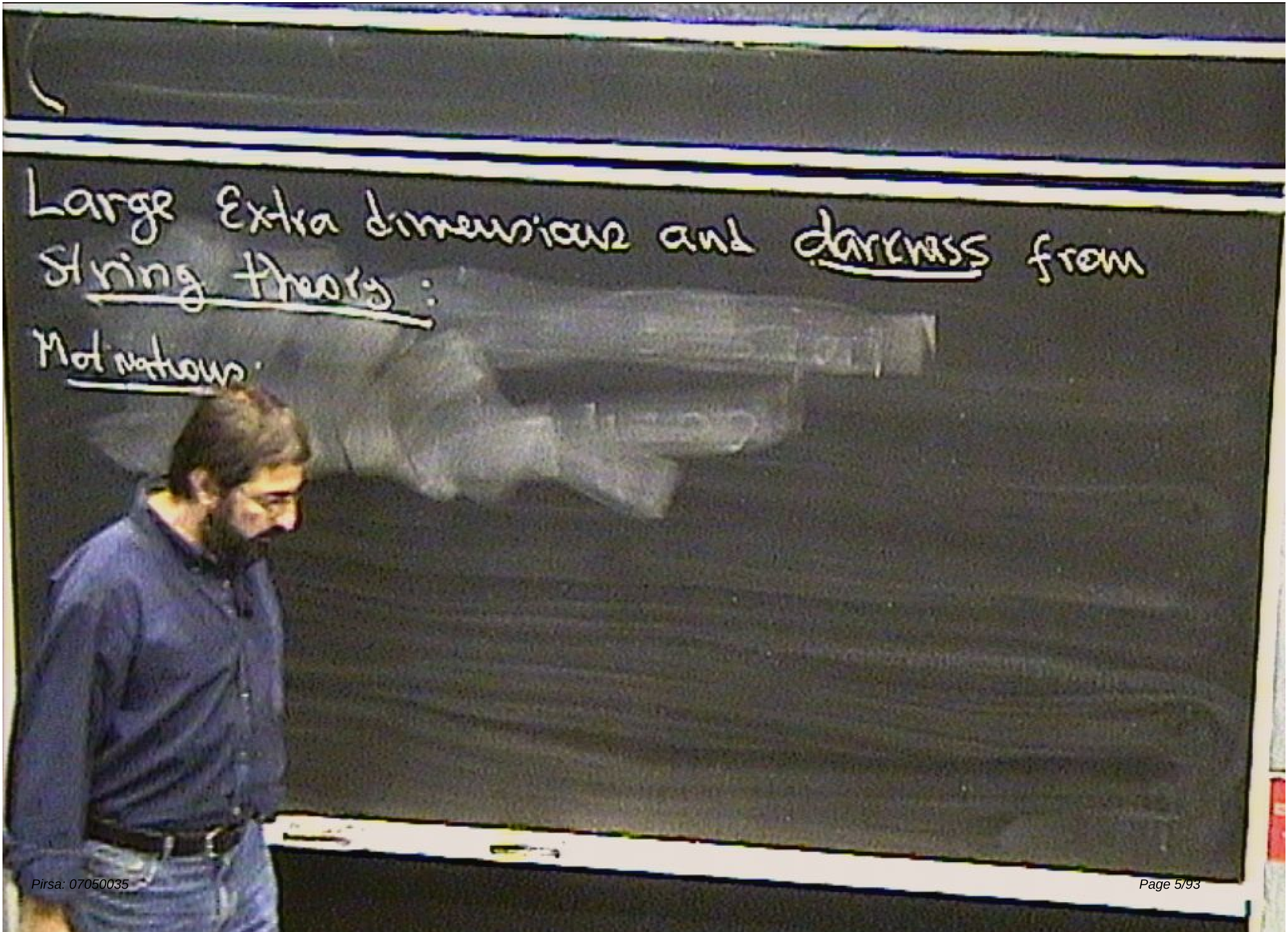
Large Extra dimensions and darkness from String theory :
Motivations:

Large Extra dimensions and darkness from String theory:

Motivations: * Moduli Stabilisation.

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* Large Volume;

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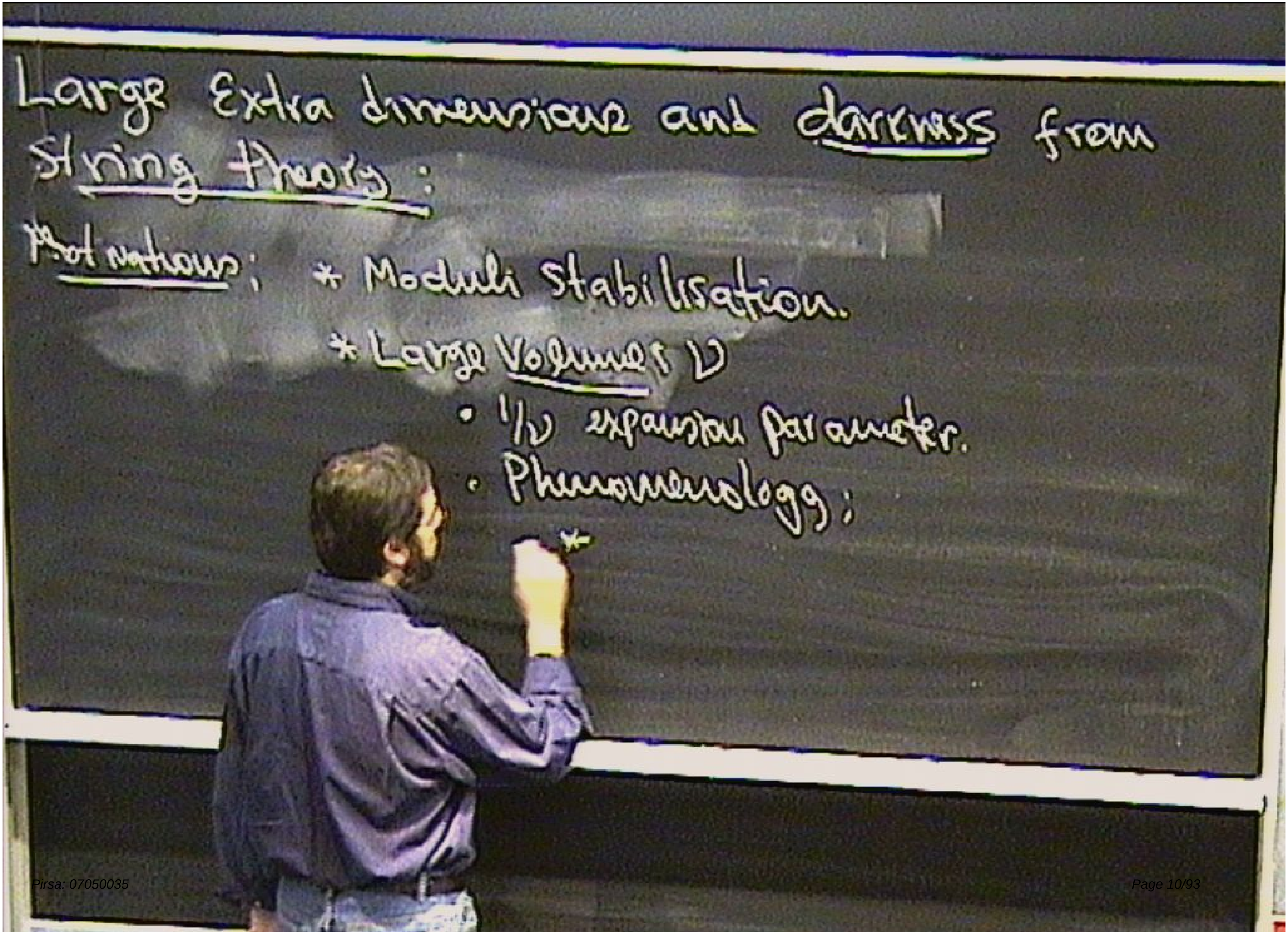
* Moduli Stabilisation.
* Large Volumes $\mathcal{V}$
    - $1/\mathcal{V}$ expansion parameter.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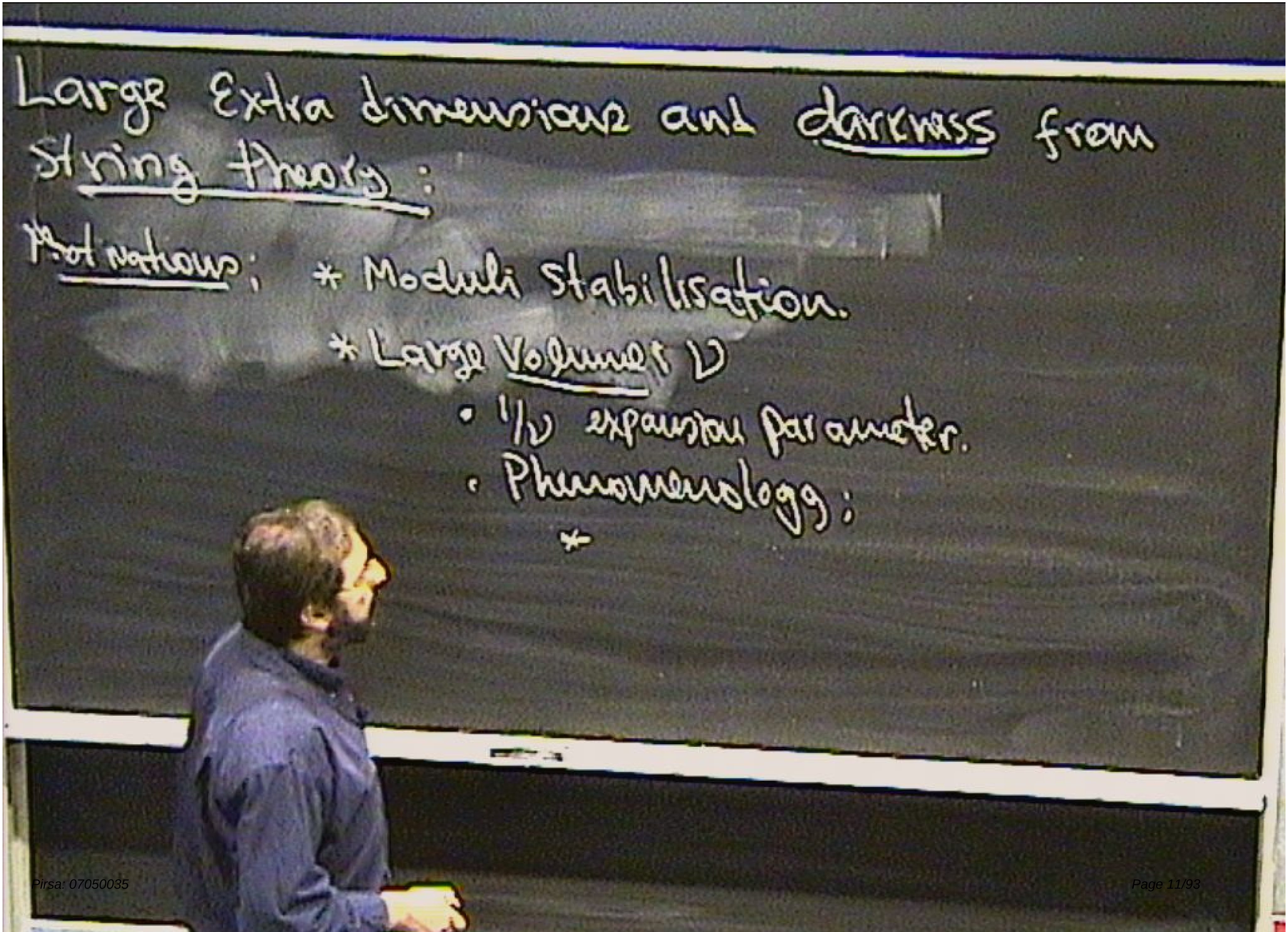
Motivations: * Moduli stabilisation.
* Large Volumes V
• 1/V expansion parameter.
• Phenomenology;
*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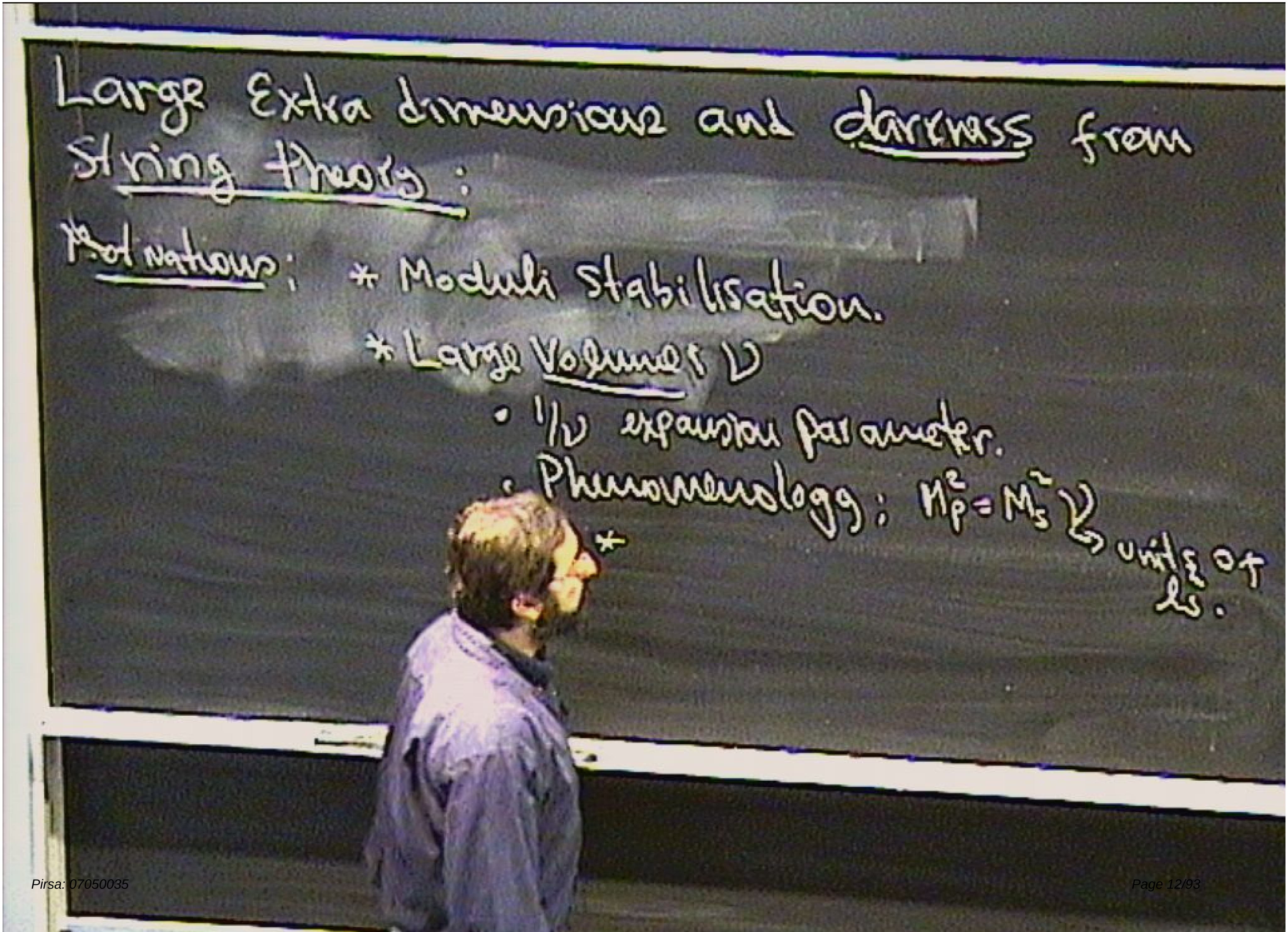
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units of l_s.
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* ADD $M_s \sim 1\,\text{TeV}$
SLED

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  - $1/\mathcal{V}$ expansion parameter.
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    * ADD $M_s \sim$ <u>1 TeV</u>
      SLED
    * Intermediate scale:

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        * Intermediate scale: $M_s \sim 10^{11}\,\mathrm{GeV}$.

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    - * Intermediate scale: $M_s \sim 10^{11}\,\mathrm{GeV}$

      $m_{3/2} = M_s^2 / M_P \sim \mathrm{TeV}$.

$\ldots / M_P \sim \text{TeV}.$

$* \ M_s = M_{GUT} \sim 10^{16}\ \text{GeV}.$

$m_{3/2} =$ [illegible] $/M_P \sim$ TeV.

* $M_S = M_{GUT} \sim 10^{16}$ GeV. (GUT

$m_{3/2} = M_S^2 / M_P \sim \text{TeV}.$

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$= \ldots / M_p \sim$ TeV.

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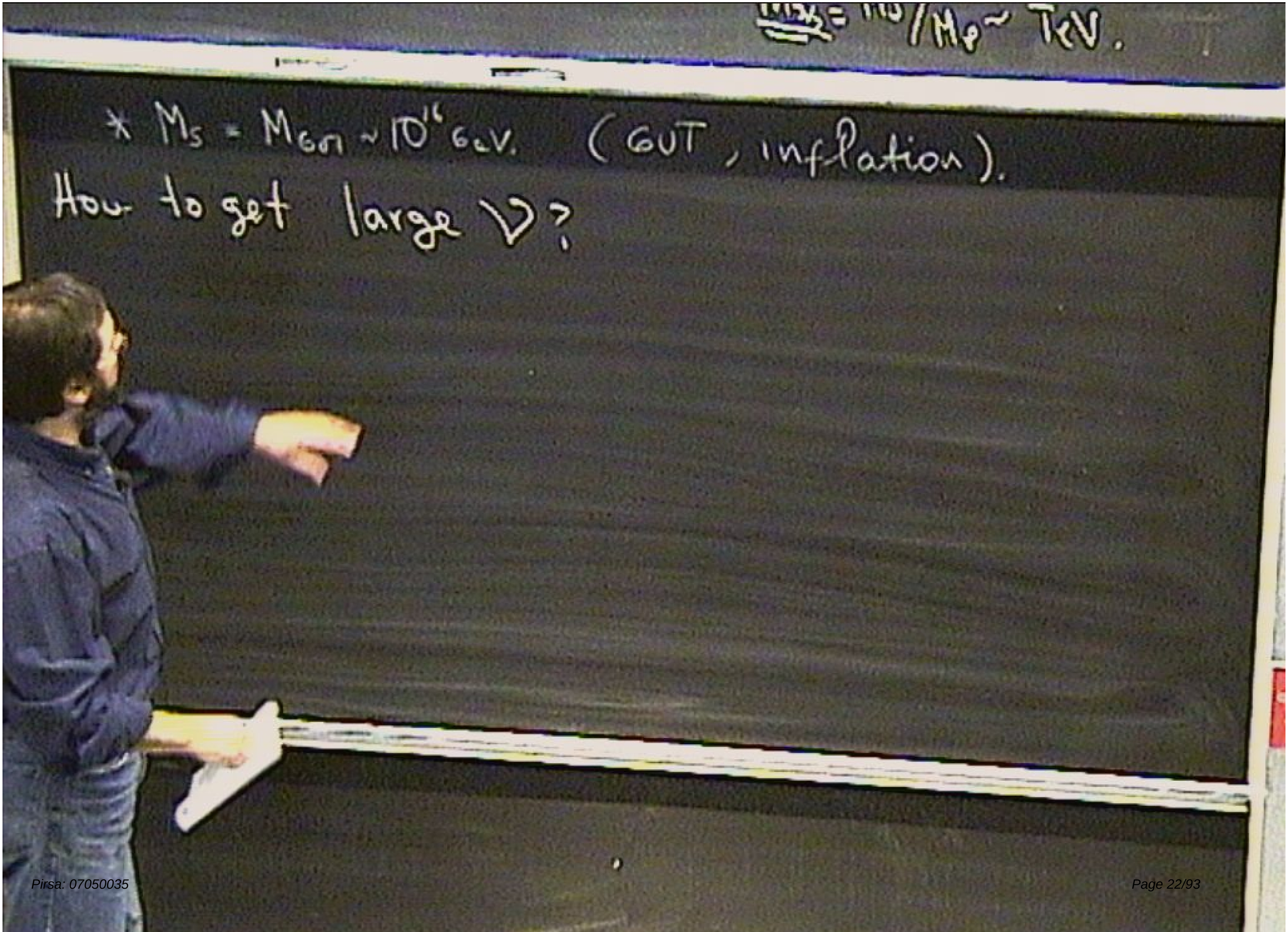
* $M_s = M_{GUT} \sim 10^{16}$ GeV. (GUT, inflation).
How to get large V?

$\hookrightarrow$ units of l_s.

* ADD $M_s \sim \underline{1\,\mathrm{TeV}}$
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How to get large $\mathcal{V}$? Type IIB

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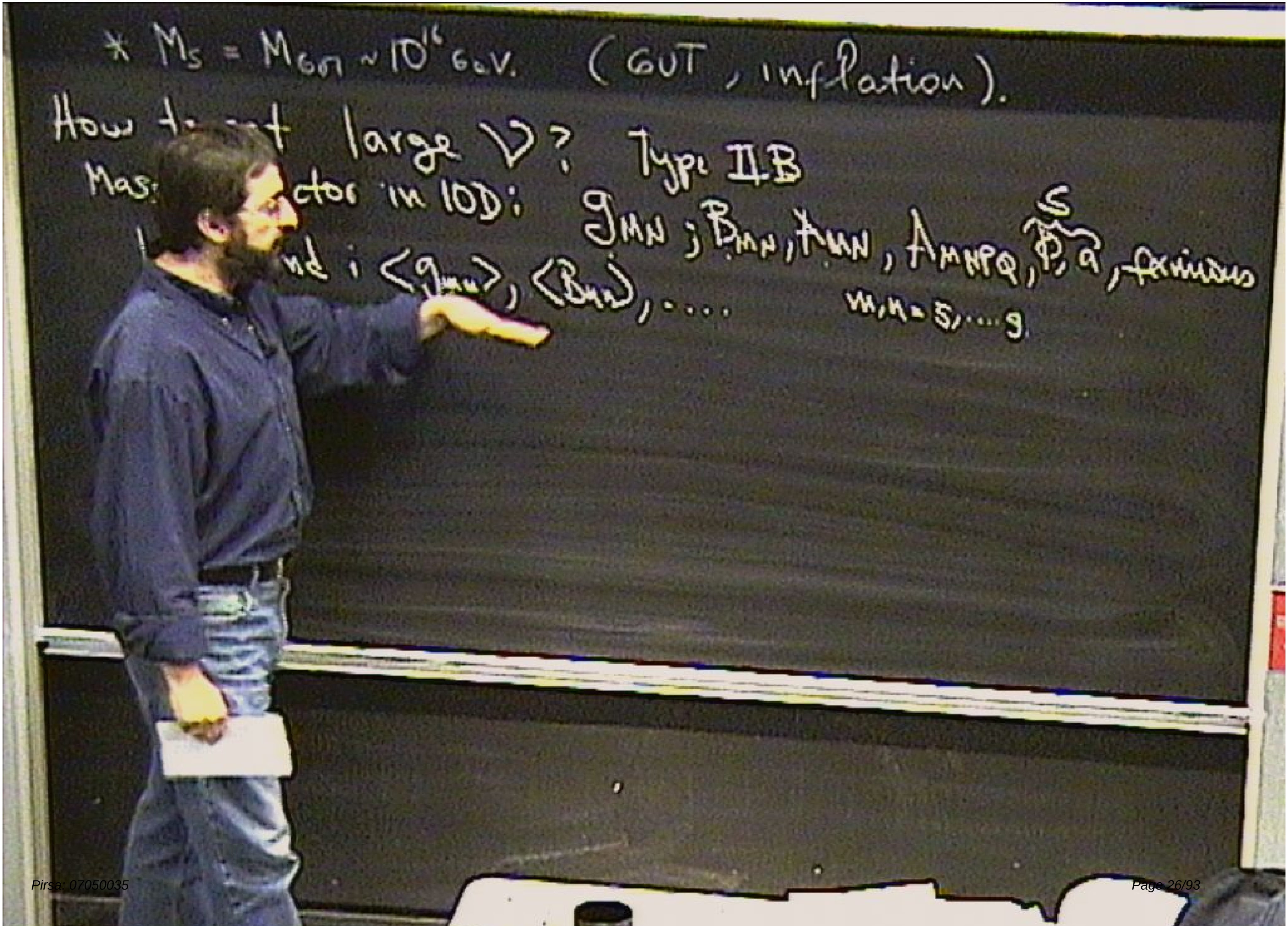
How to get large $\mathcal{V}$? Type IIB

Massless sector in 10D: g_{MN} ; B_{MN}, A_{MN}, A_{MNPQ}, $\overbrace{\phi, a}^{S}$, fermions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How t large V? Type IIB
Mas ctor in 10D: g_{MN} ; B_{MN}, A_{MN}, A_{MNPQ}, Φ, a, fermions
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m,n = 5,...9

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How to get large $\mathcal{V}$? Type IIB

Massless sector in 10D: g_{MN}; B_{MN}, A_{MN}, A_{MNPQ}, $\overset{S}{\widetilde{\phi}}$, a, fermions

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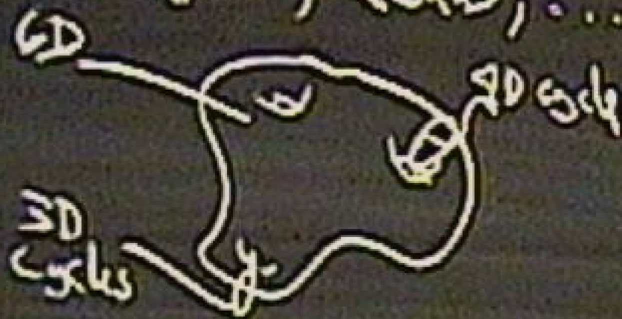
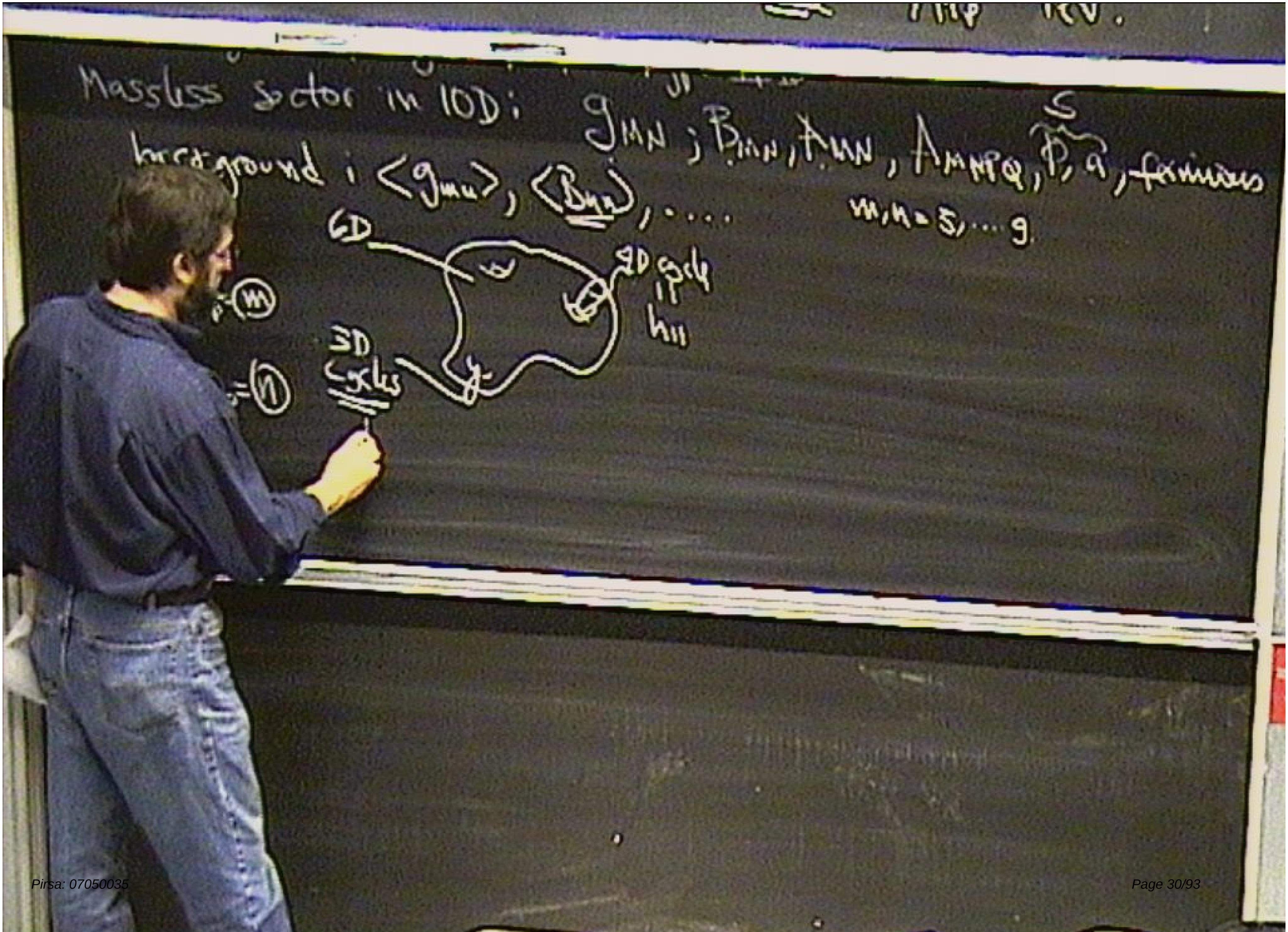


How to get large $\mathcal{V}$? Type IIB

Massless sector in 10D: g_{MN} ; B_{MN}, $\tilde{A}_{MN}$, A_{MNPQ}, $\overbrace{\Phi, a}^{S}$, fermions

background: $\langle g_{mn}\rangle$, $\langle B_{mn}\rangle$, ... $\quad m,n = 5, \ldots 9.$


Massless sector in 10D: g_MN ; B_MN, A_MN, A_MNPQ, Φ, a, fermions
background: <g_mn>, <B_mn>, ...
m,n = 5,...9
6D
4D cycle
h11
3D cycles

Massless sector in 10D: g_{MN} ; B_{MN}, A_{MN}, A_{MNPQ}, $\tilde{\phi}$, a, fermions

background: $\langle g_{mn} \rangle$, $\langle B_{mn} \rangle$, ... $m, n = 5, \dots 9$

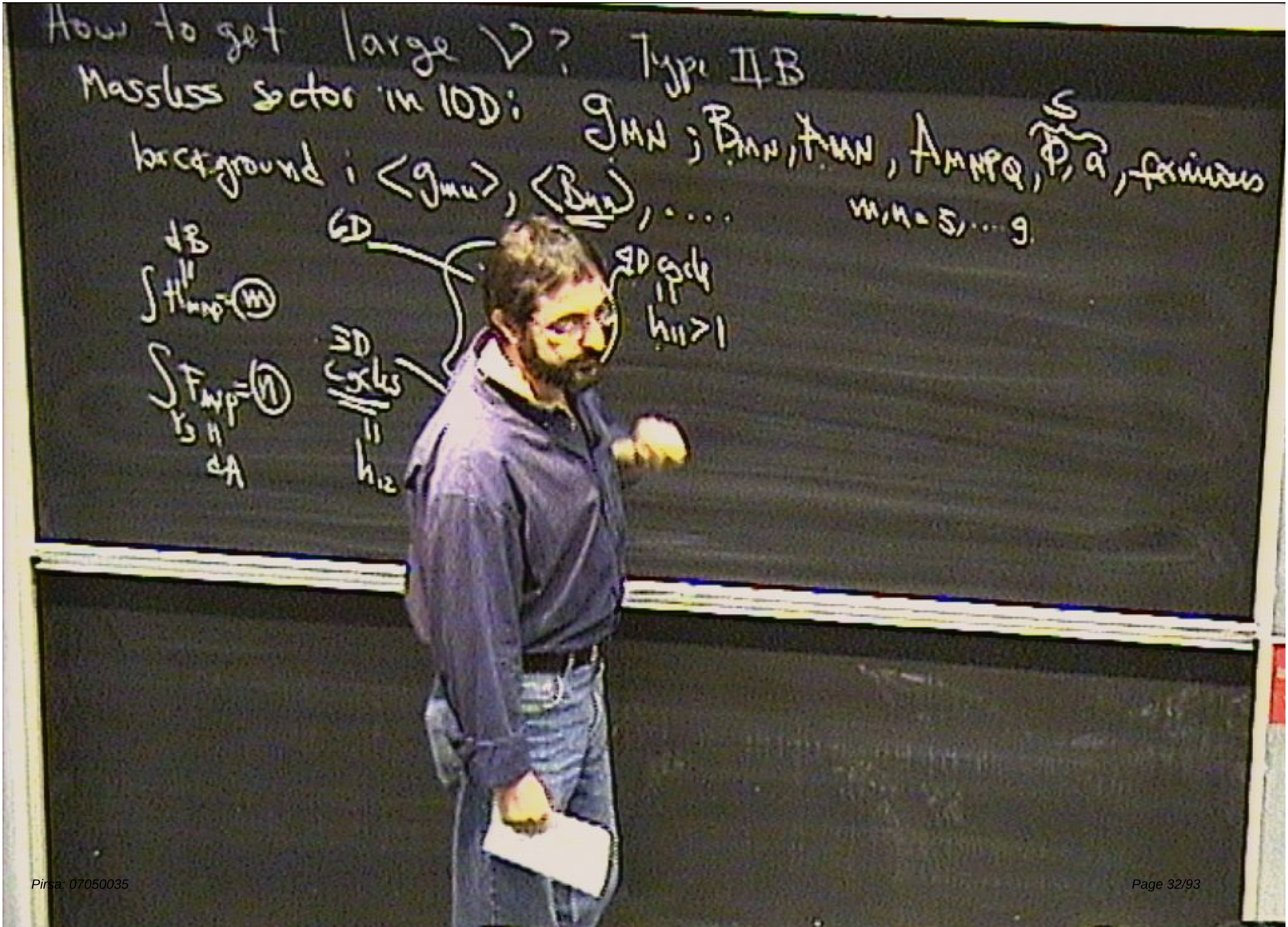
$$\int H_{mnp} = (m), \quad H = dB$$

$$\int_{\gamma_3} F_{mnp} = (n), \quad F = dA$$

6D

2D cycle, $h_{11} > 1$

3D cycles $= h_{12}$


How to get large V? Type IIB
Massless sector in 10D: gMN ; BMN, AMN, AMNPQ, Φ, a, fermions
background: <gmn>, <Bmn>, ...
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h12
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How to get large V? Type IIB

Massless sector in 10D: g_{MN} ; B_{MN}, $\tilde{A}_{MN}$, A_{MNPQ}, $\overset{S}{\tilde{\Phi}}$, a, fermions

background: $\langle g_{mn} \rangle$, $\langle B_{mn} \rangle$, ... $m,n = 5, \dots 9$

dB $\int H_{mnp} = (m)$

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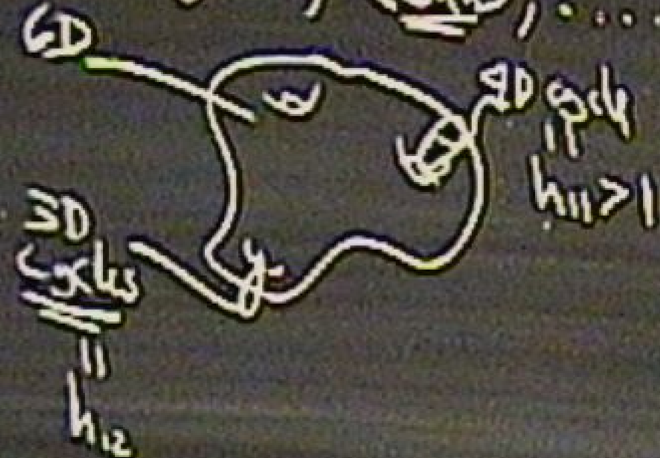

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Massless sector in 10D: g_{MN}; B_{MN}, $\tilde{A}_{MN}$, A_{MNPQ}, Φ, a, fermions

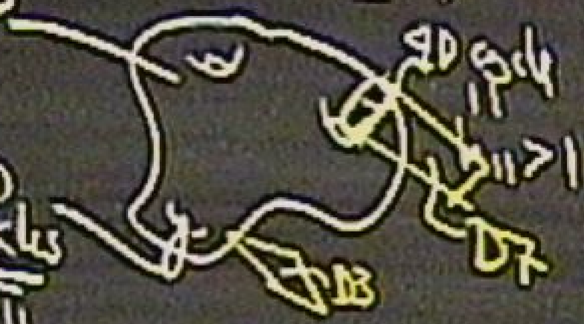
background: $\langle g_{mn}\rangle$, $\langle B_{mn}\rangle$, ... $m,n = 5,\dots 9$

$$dB = \int H_{mnp} = m$$

$$\int F_{mnp} = n = dA$$

6D

3D cycles $= h_{12}$



How to get [obscured] type IIB

Massless sector: [obscured] ; $B_{MN}, \tilde{A}_{MN}, A_{MNPQ}, \phi, a$, fermions

background: $\langle g_{mn} \rangle, \langle \underline{B_{mn}} \rangle, \ldots$ $m, n = 5, \ldots 9$

dB

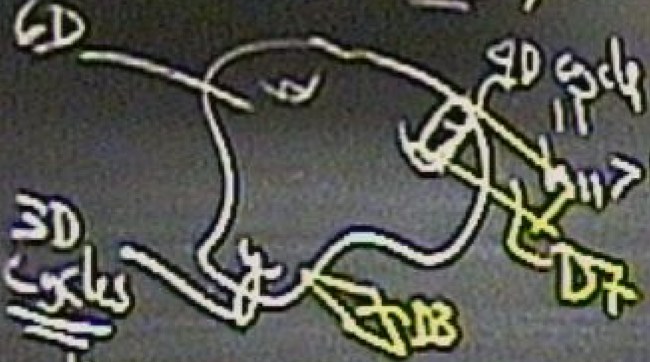
$\int H_{mnp} = (M)$

3D cycles

$\int F_{mnp} = (N)$

$F_3 = dA$

h_{12}



$h_{11} > 1$

D7 gauge coupling $\sim \frac{1}{g^2} = \tau$ (size of cycle)

Large Extra dimensions and darkness from string theory:

4D Effective Field Theory. $\underline{N=1}$:

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$$W = \underbrace{W_0}_{\to \text{ fluxes}} + A_i\, e^{a_i T_i} \longrightarrow \text{Nonpert on D7 branes}$$

K

4D Effective Field Theory. $\underline{N=1}$:

$$W = \underbrace{W_0(U,S)}_{\rightarrow\ \text{fluxes}} + A_i\, e^{a_i T_i} \longrightarrow \text{Non-pert. on D7 branes.}$$

$$K = K_{U,S} - 2\log \mathcal{V} + K_R$$

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$$K = K_{U,S} - 2\log \mathcal{V} + K_P$$

$$\mathcal{V} = \lambda_{ijk}\, t_i t_j t_k \;;\; T_i = \frac{\partial \mathcal{V}}{\partial t_i}$$

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Scalar potential: $\mathcal{V} = \boxed{\lambda_{ijk}}\, t_i t_j t_k \;;\; T_i = \frac{\partial \mathcal{V}}{\partial t_i}$

$V(U_a, S, T_i) \;;\; a = 1, \dots h_{12}$
$\qquad\qquad\qquad\;\; i = 1, \dots h_{11}$

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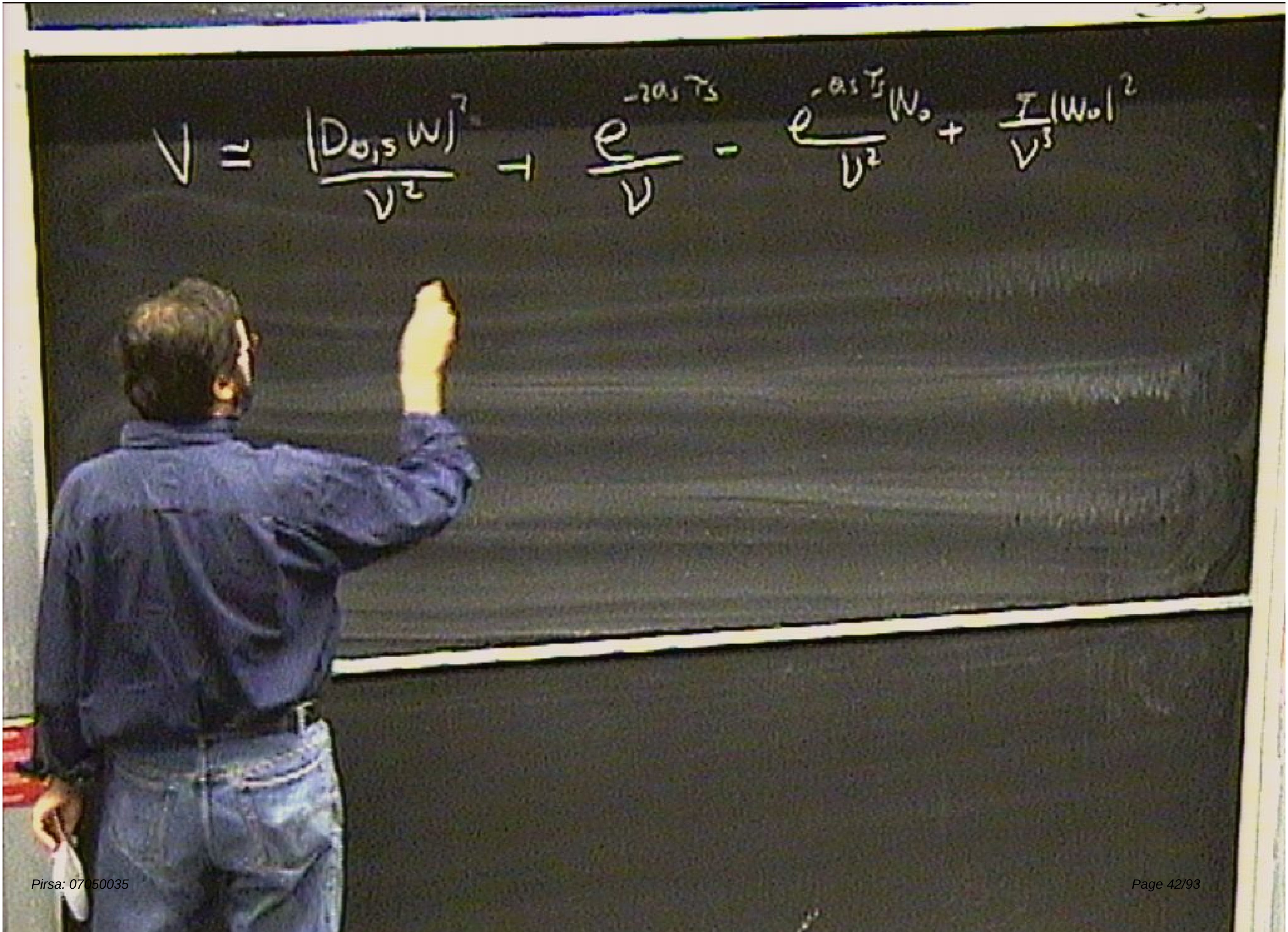
$$\underline{V(U_a, S, T_i)} \;;\; \begin{array}{l} a = 1, \dots h_{12} \\ i = 1, \dots h_{11} \end{array}$$

fixes U_a, S, T_i.


$$V \simeq \frac{|D_{a,s}W|^2}{V^2} + \frac{e^{-2a_s\tau_s}}{V} - \frac{e^{-a_s\tau_s}W_0}{V^2} + \frac{\xi}{V^3}|W_0|^2$$

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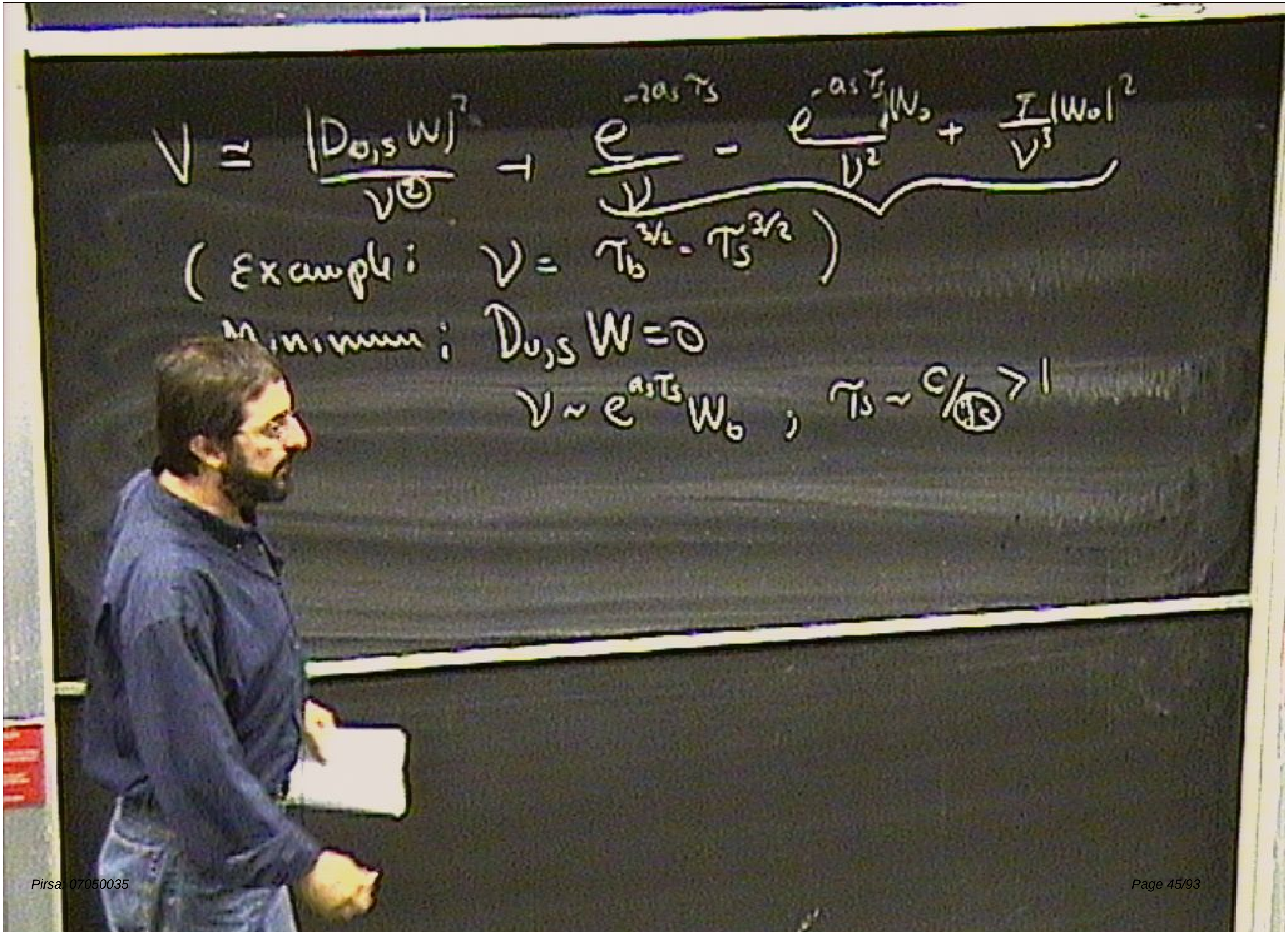
$$\left(\text{Example: } \mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2}\right)$$

$$V \simeq \frac{|D_{a,s}W|^2}{V^{(2)}} + \underbrace{\frac{e^{-2a_s\tau_s}}{V} - \frac{e^{-a_s\tau_s}|W_0|}{V^2} + \frac{\xi|W_0|^2}{V^3}}$$

(Example: $V = \tau_b^{3/2} - \tau_s^{3/2}$)

Minimum: $D_{a,s}W = 0$



$V \simeq \frac{|D_{a,s}W|^2}{V^{?}} + \frac{e^{-2a_s\tau_s}}{V} - \frac{e^{-a_s\tau_s}|W_0|}{V^2} + \frac{\xi}{V^3}|W_0|^2$
(Example: $V = \tau_b^{3/2} - \tau_s^{3/2}$)
Minimum: $D_{a,s}W = 0$
$V \sim e^{a_s\tau_s} W_0$; $\tau_s \sim c/g_s > 1$

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Balasubramanian, Berglund, J. Conlon

$$\mathcal{V} \sim e^{a_s \tau_s} W_0 \; , \quad \tau_s \sim c/g_s > 1$$

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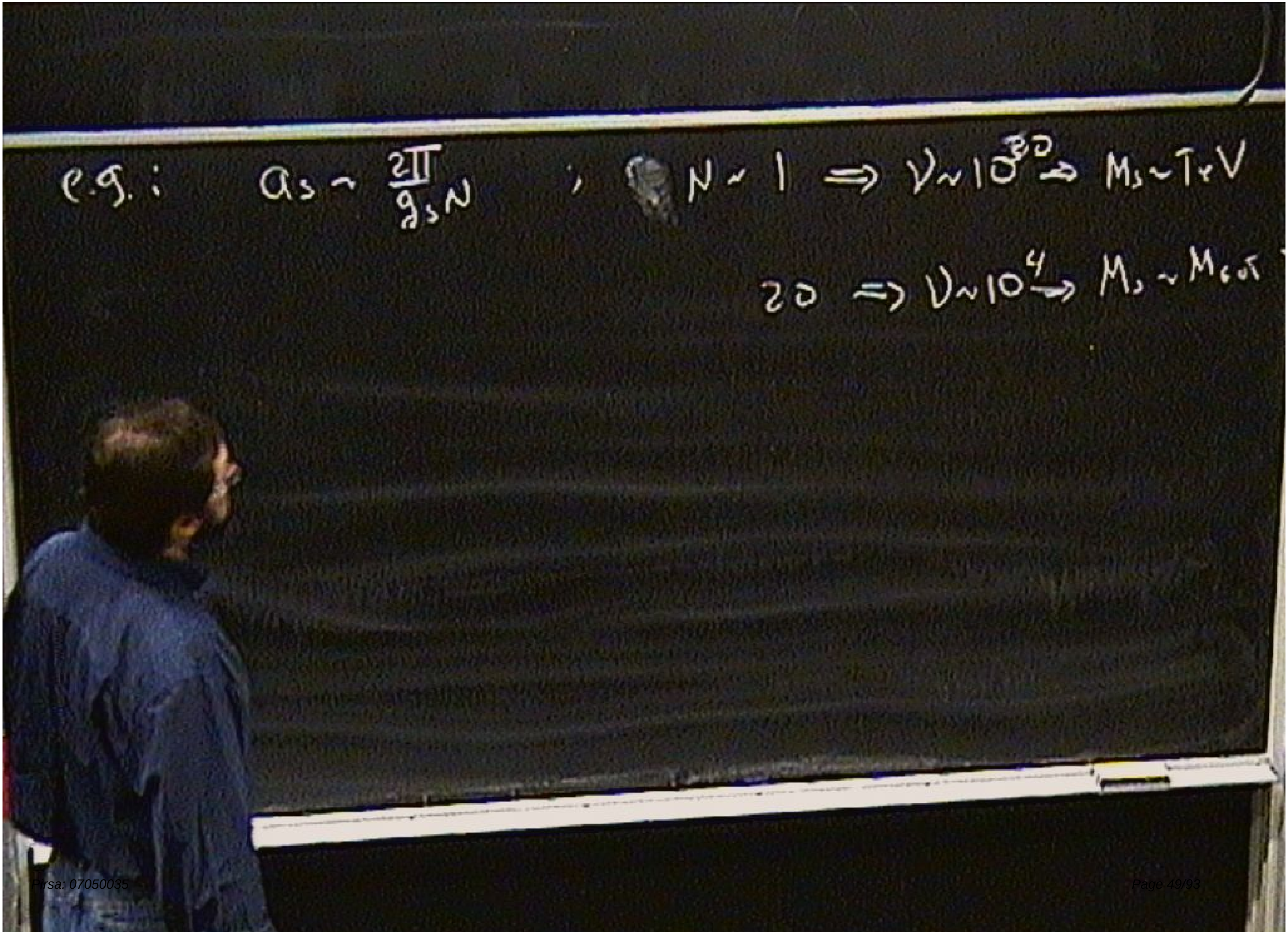
$$V \sim e^{a_s\tau_s} W_0 \,, \quad \tau_s \sim c/g_s > 1$$

$$\boxed{\begin{array}{l}\text{(J. Conlon)} \\ \rightarrow (\text{JC} + \text{M. Cicoli})\end{array}}$$

e.g.: $\quad a_s \sim \frac{2\pi}{g_s N} \quad ; \quad g_s N \sim 1 \Rightarrow V \sim 10^{-30} \Rightarrow M_s \sim \text{TeV}$


e.g.: a_s ~ 2π / g_s N ; N ~ 1 ⇒ V ~ 10^30 → M_s ~ TeV
20 ⇒ V ~ 10^4 → M_s ~ M_GUT

e.g.: $a_s \sim \frac{2\pi}{g_s N}$; $N \sim 1 \Rightarrow V \sim 10^{30} \Rightarrow M_s \sim \mathrm{TeV}$

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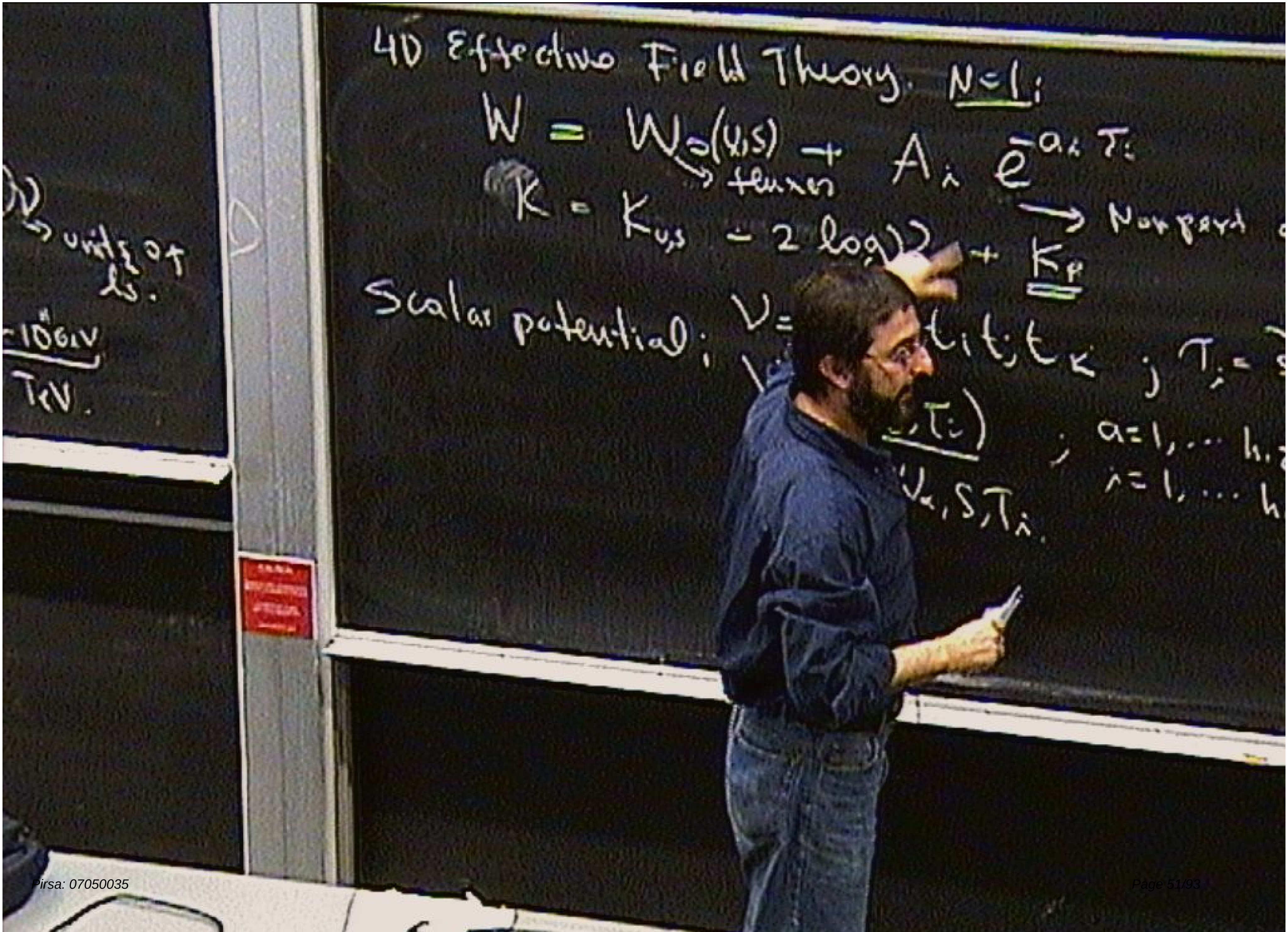
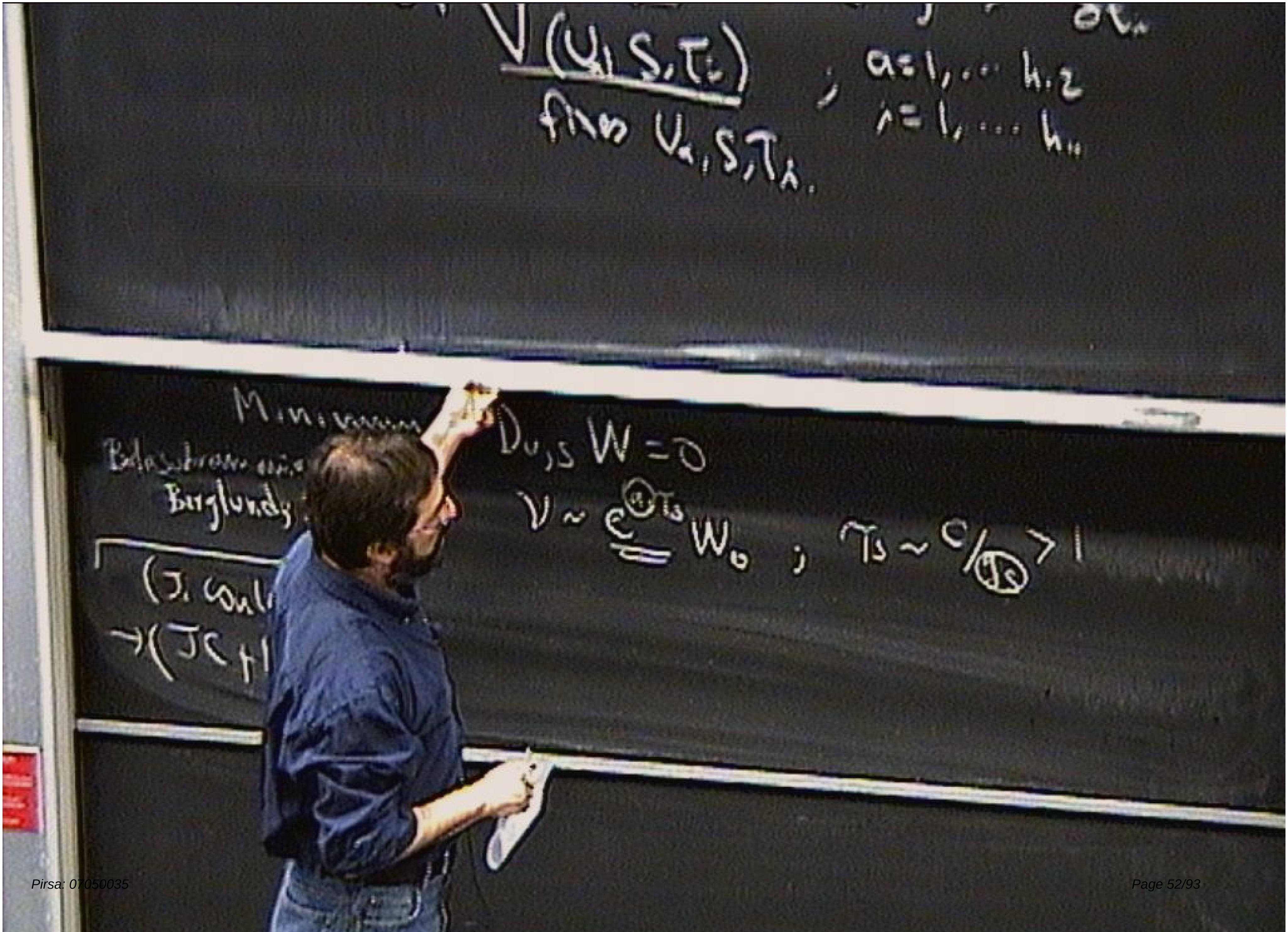
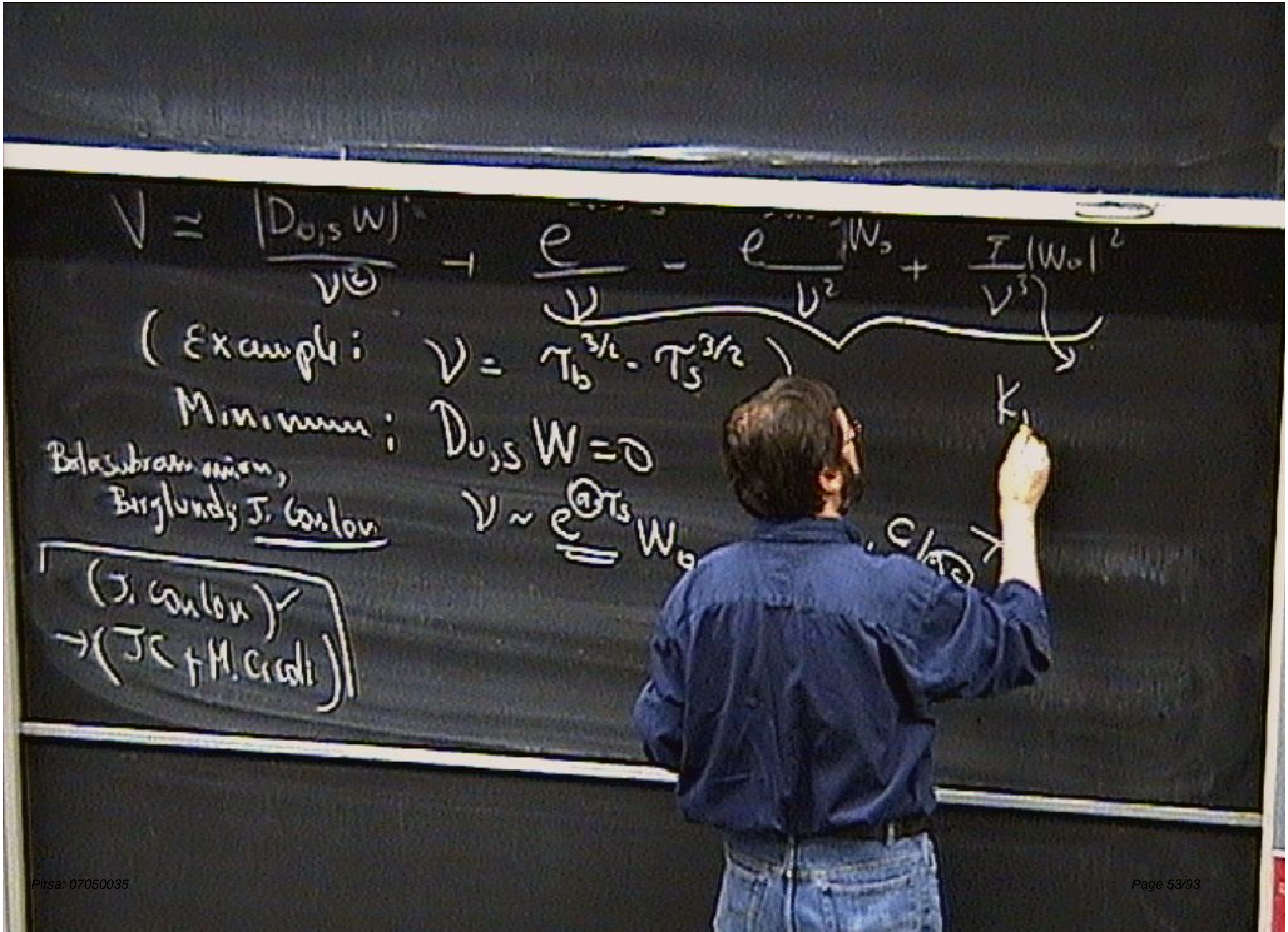

4D Effective Field Theory. N=1;
W = W_0(U,S) + A_i e^{-a_i T_i}
fluxes
K = K_{U,S} - 2 log V + K_β
Non pert
units of
TeV.
Scalar potential; V =
a = 1, ... h
i = 1, ... h


V(U, S, T)
a=1, ... h12
fixes U, S, T
Minimum
Berglund
D W = 0
W0


(Example: V = τ_b^{3/2} - τ_s^{3/2})
Minimum: D_{a,s} W = 0
Balasubramanian,
Berglund, J. Conlon
(J. Conlon)
→(JC + M. Cicoli)

$$V \simeq \frac{|D_{U,S}W|^2}{\mathcal{V}^{(2)}} + \frac{e^{\cdots}}{\mathcal{V}} - \frac{e^{\cdots}\,W_0}{\mathcal{V}^2} + \frac{\xi|W_0|^2}{\mathcal{V}^3}$$

$$K_p \sim \frac{g}{\mathcal{V}}$$

(Example: $\mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2}$)

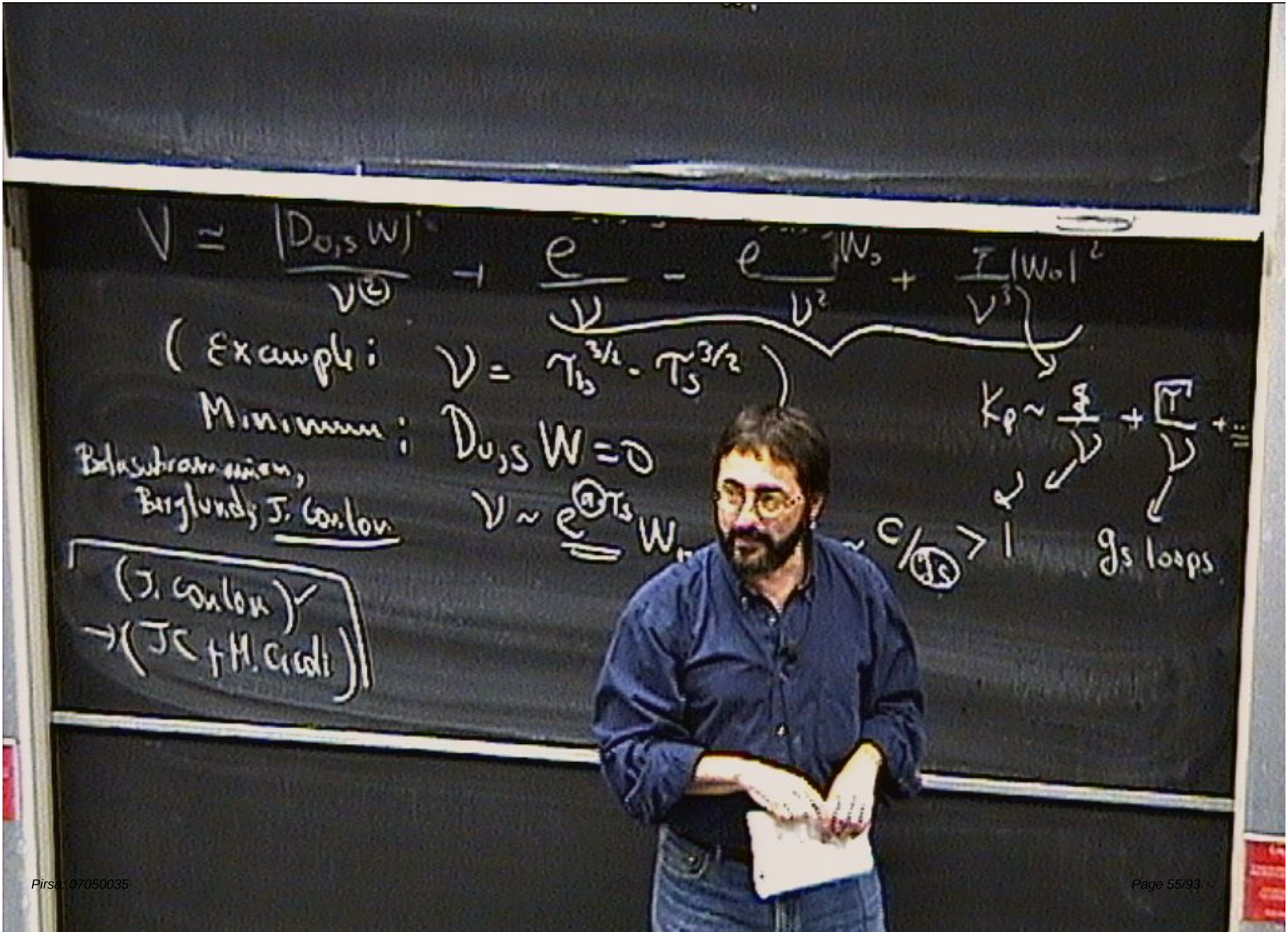
Minimum: $D_{U,S}W = 0$

Balasubramanian, Berglund, J. Conlon

$$\mathcal{V} \sim e^{a\tau_s} W_0 \;;\quad \tau_s \sim c/g_s > 1$$

(J. Conlon) ✓

→ (JC + M. Cicoli)


V ≃ |D W|² / V² + e/V − e/V² W₀ + ξ|W₀|²/V³
(Example: V = τ_b^3/2 − τ_s^3/2
Minimum: D W = 0
Balasubramanian, Berglund, J. Conlon
V ~ e^aτs W₀ ~ e^c/gs > 1
K_p ~ ξ/V + T/V + ...
gs loops
(J. Conlon)
→ (JC + M. Cicoli)

e.g.: $a_s \sim \frac{2\pi}{g_s N}$; $N \sim 1 \Rightarrow V \sim 10^{30} \Rightarrow M_s \sim \text{TeV}$

$20 \Rightarrow V \sim 10^{4} \Rightarrow M_s \sim M_{GUT}$,

* $M_s \sim \text{TeV}$. , $m_{3/2} \sim 10^{-3}\,\text{eV}$

e.g.: $a_s \sim \frac{2\pi}{g_s N}$; $N \sim 1 \Rightarrow \mathcal{V} \sim 10^{30} \Rightarrow M_s \sim \text{TeV}$

$20 \Rightarrow \mathcal{V} \sim 10^{4} \Rightarrow M_s \sim M_{GUT}$,

$*$ $M_s \sim \text{TeV}$, , $m_{3/2} \sim \underline{10^{-3}}\,\text{eV}$, $m_{\tau_b} \sim 10^{-26}\,\text{GeV}$.

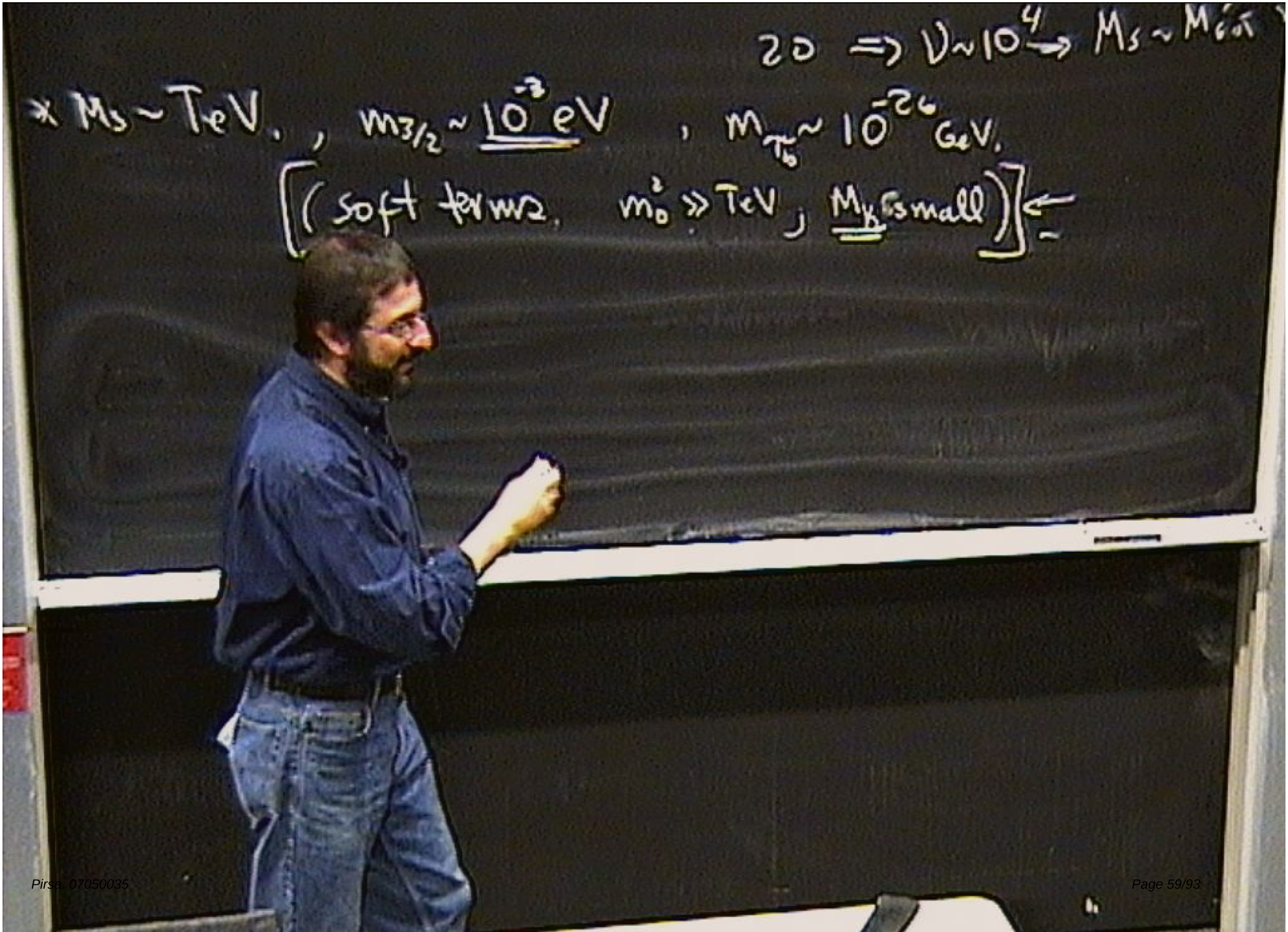
(soft terms.

e.g.: $a_s \sim \frac{2\pi}{g_s N}$; $N \sim 1 \Rightarrow V \sim 10^{30} \Rightarrow M_s \sim TeV$

$20 \Rightarrow V \sim 10^{4} \Rightarrow M_s \sim M_{GUT}$,

$* \; M_s \sim TeV.$, $m_{3/2} \sim \underline{10^{-3}\,eV}$, $m_{\tau_0} \sim 10^{-26}\,GeV.$

(soft terms. $m_0^2 \gg TeV$, $\underline{M_{\lambda}}$ small).


20 ⇒ V~10^4 → Ms ~ M_GUT
* Ms ~ TeV. , m_3/2 ~ 10^-3 eV , m_τb ~ 10^-26 GeV.
[(soft terms m_0^2 ≫ TeV, M_1/2 small)]

$2D \Rightarrow \mathcal{V} \sim 10^{4} \rightarrow M_s \sim M_{GUT}$

$* \; M_s \sim \text{TeV}, \quad m_{3/2} \sim \underline{10^{-3}\,\text{eV}}, \quad m_{\tau_b} \sim 10^{-26}\,\text{GeV}.$

$\left[\left(\text{soft terms} \quad m_0^2 \gg \text{TeV}, \; \underline{M_{1/2}} \text{ is small}\right)\right] \leftarrow$

$\rightarrow M_s \sim 10^{11}\,\text{GeV}.$

$20 \Rightarrow \mathcal{V} \sim 10^4 \rightarrow M_s \sim M/\sqrt{\mathcal{V}}$

$\times\ M_s \sim \text{TeV}$, , $m_{3/2} \sim \underline{10^{-3}}\,\text{eV}$, $m_{\tau_b} \sim 10^{-26}\,\text{GeV}$.

$\left[\left(\text{soft terms} \quad m_0^2 \gg \text{TeV},\ \underline{M_{1/2}}\ \text{small} \right) \right] \leftarrow$

$\rightarrow M_s \sim 10^{11}\,\text{GeV}$.

<u>Aside</u>: large 2 dimensions?

4D Effective Field Theory. $\underline{N=1}$:

$$W = \underbrace{W_0(U,S)}_{\to \text{fluxes}} + A_i\, e^{-a_i T_i}$$

$$K = K_{U,S} - 2\log \mathcal{V} + K_R$$

$e^{-a_i T_i} \to$ Nonpert. or D7 bran

Scalar potential: $\mathcal{V} = \lambda_{ijk}\, t_i t_j t_k$; $T_i = \dfrac{\partial \mathcal{V}}{\partial t_i}$

$$\underline{V(U_a, S, T_i)} \quad ; \quad a = 1, \dots h_{12}$$

fixes U_a, S, T_i. $\quad i = 1, \dots h_{11}$

(Example: $\mathcal{V} = \tau^{3/2} - \tau^{3/2}$

e.g.: $a_s \sim \frac{2\pi}{g_s N}$; $N \sim 1 \Rightarrow \mathcal{V} \sim 10^{30} \Rightarrow M_s \sim \text{TeV}$

$20 \Rightarrow \mathcal{V} \sim 10^{4} \Rightarrow M_s \sim M_{GUT}$

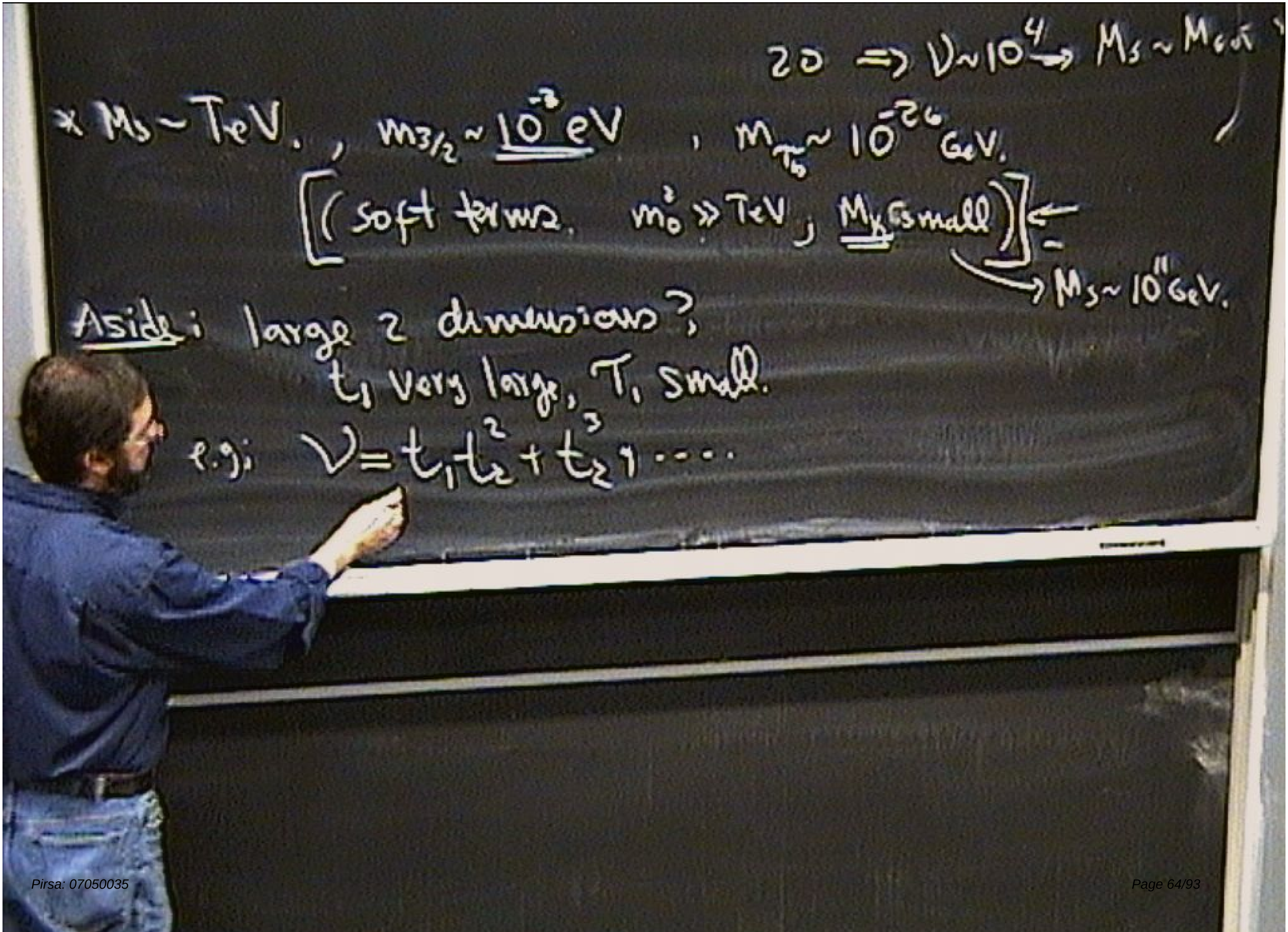
* $M_s \sim \text{TeV}$, $m_{3/2} \sim \underline{10^{-3}\,\text{eV}}$, $m_{\tau_b} \sim 10^{-26}\,\text{GeV}$.

[(soft terms $m_0^2 \gg \text{TeV}$, $\underline{M_{1/2}}$ small)] $\leftarrow$

$\rightarrow M_s \sim 10^{11}\,\text{GeV}$.

A large 2 dimensions?

↳ very large, T_1 small.



20 ⇒ V~10^4 → M_s ~ M_GUT
* M_s ~ TeV, , m_{3/2} ~ 10^{-3} eV , m_{τ_b} ~ 10^{-26} GeV.
[(soft terms m_0^2 ≫ TeV, M_{1/2} small)]
→ M_s ~ 10^{11} GeV.
Aside: large 2 dimensions?
t_1 very large, T_1 small.
e.g.: V = t_1 t_2^2 + t_2^3, ...

$20 \Rightarrow \mathcal{V} \sim 10^4 \rightarrow M_s \sim M_{GUT}$

$\ast$ $M_s \sim \mathrm{TeV}$, $m_{3/2} \sim \underline{10^{-3}\,\mathrm{eV}}$, $m_{\tau_b} \sim 10^{-26}\,\mathrm{GeV}$.

[(soft terms. $m_0^2 \gg \mathrm{TeV}$, $\underline{M_{\frac{1}{2}}}$ small)] $\leftarrow$

$\rightarrow M_s \sim 10^{11}\,\mathrm{GeV}$.

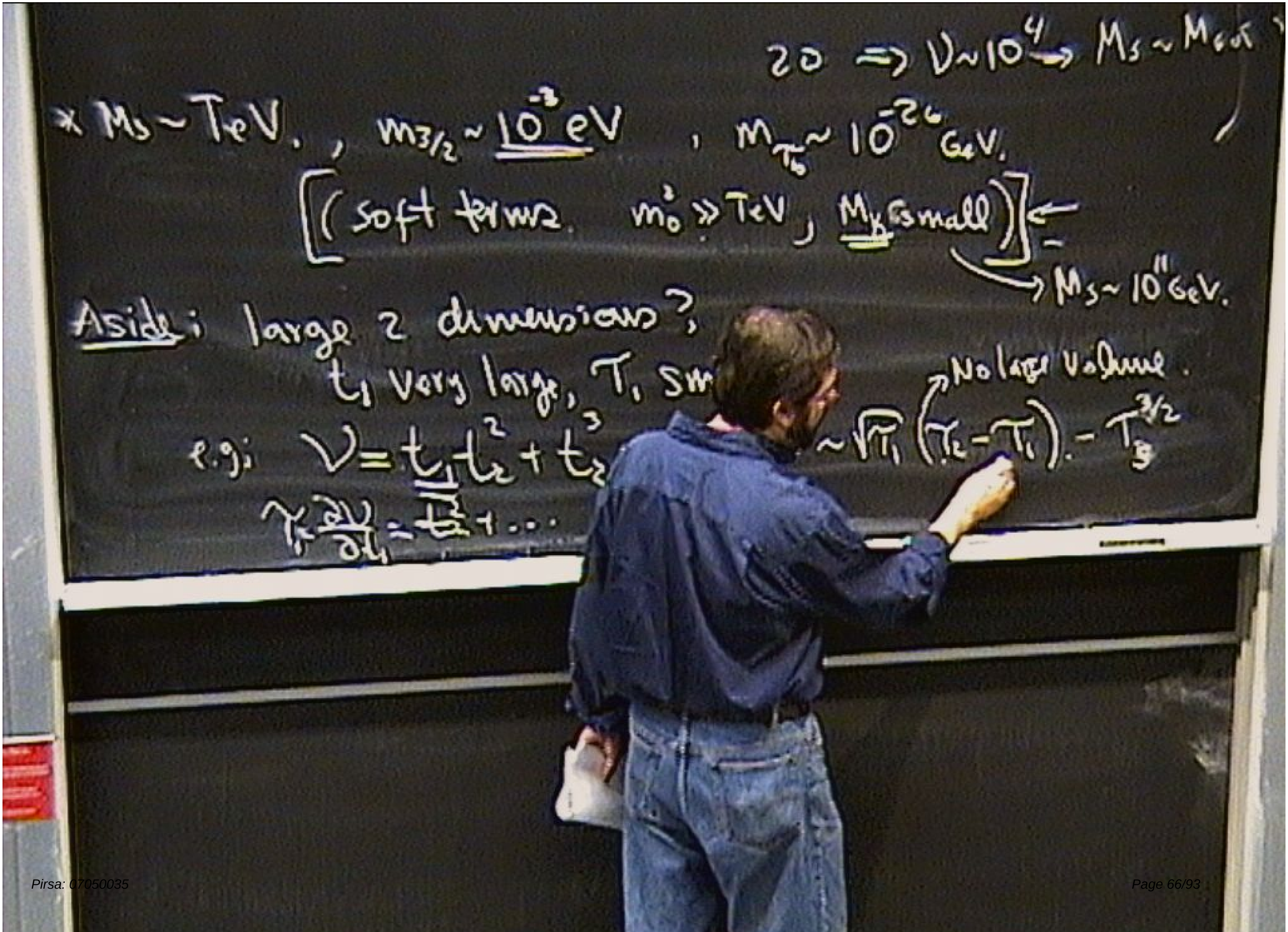
<u>Aside</u>: large 2 dimensions?

t_1 very large, τ_1 small.

$\rightarrow$ No large volume.

e.g.: $\mathcal{V} = \underline{t_1} t_2^2 + t_2^3 ; \ldots \Big\} \mathcal{V} \sim \sqrt{\tau_1}(\tau_2 - \tau_1)$.

$\tau_1 = \frac{\partial \mathcal{V}}{\partial t_1} = t_2^2 + \ldots$



20 ⇒ V~10^4 → Ms ~ MGUT
* Ms ~ TeV, m3/2 ~ 10^-3 eV, mτb ~ 10^-26 GeV.
[(soft terms m0^2 ≫ TeV, M1/2 small)]
→ Ms ~ 10^11 GeV.
Aside: large 2 dimensions?
t1 very large, T1 sm
No large volume.
e.g.: V = t1 t2^2 + t2^3
~ √T1 (T2 − T1) − T3^3/2
τ1 ∂V/∂t1 = t2^2 + ...

$20 \Rightarrow \mathcal{V} \sim 10^4 \rightarrow M_s \sim M_{GUT}$

* $M_s \sim \text{TeV}$, $m_{3/2} \sim \underline{10^{-3}}\,\text{eV}$, $m_{\tau_b} \sim 10^{-26}\,\text{GeV}$.

$\left[\left(\text{soft terms}\quad m_0^2 \gg \text{TeV},\ \underline{M_{1/2}}\ \text{small}\right)\right] \leftarrow$

$\rightarrow M_s \sim 10^{11}\,\text{GeV}.$

Aside: large 2 dimensions?, X

t_1 very large, τ_1 small.

No large volume

e.g.: $\mathcal{V} = \underline{t_1} t_2^2 + t_2^3, \ldots \quad \mathcal{V} \sim \sqrt{\tau_1}\left(\tau_2 - \tau_1\right) - \tau_3^{3/2}$

$\tau_1 = \frac{\partial \mathcal{V}}{\partial t_1} = t_2^2 + \ldots$

$g_s N$ $\quad N \sim 1 \Rightarrow \mathcal{V} \sim 10^{\ldots} \Rightarrow M_s \sim \text{TeV}$

$20 \Rightarrow \mathcal{V} \sim 10^4 \Rightarrow M_s \sim M_{GUT}$

$* \; M_s \sim \text{TeV}$, $\quad m_{3/2} \sim 10^{-3}\,\text{eV}$ $\quad$, $m_{\tau} \sim 10^{-24}\,\text{GeV}$.

[(soft terms $\quad m_0^2 \gg \text{TeV}$, M_s small)] ← $\rightarrow M_s \sim 10^{11}\,\text{GeV}$.

Aside: large 2 dimensions?, X

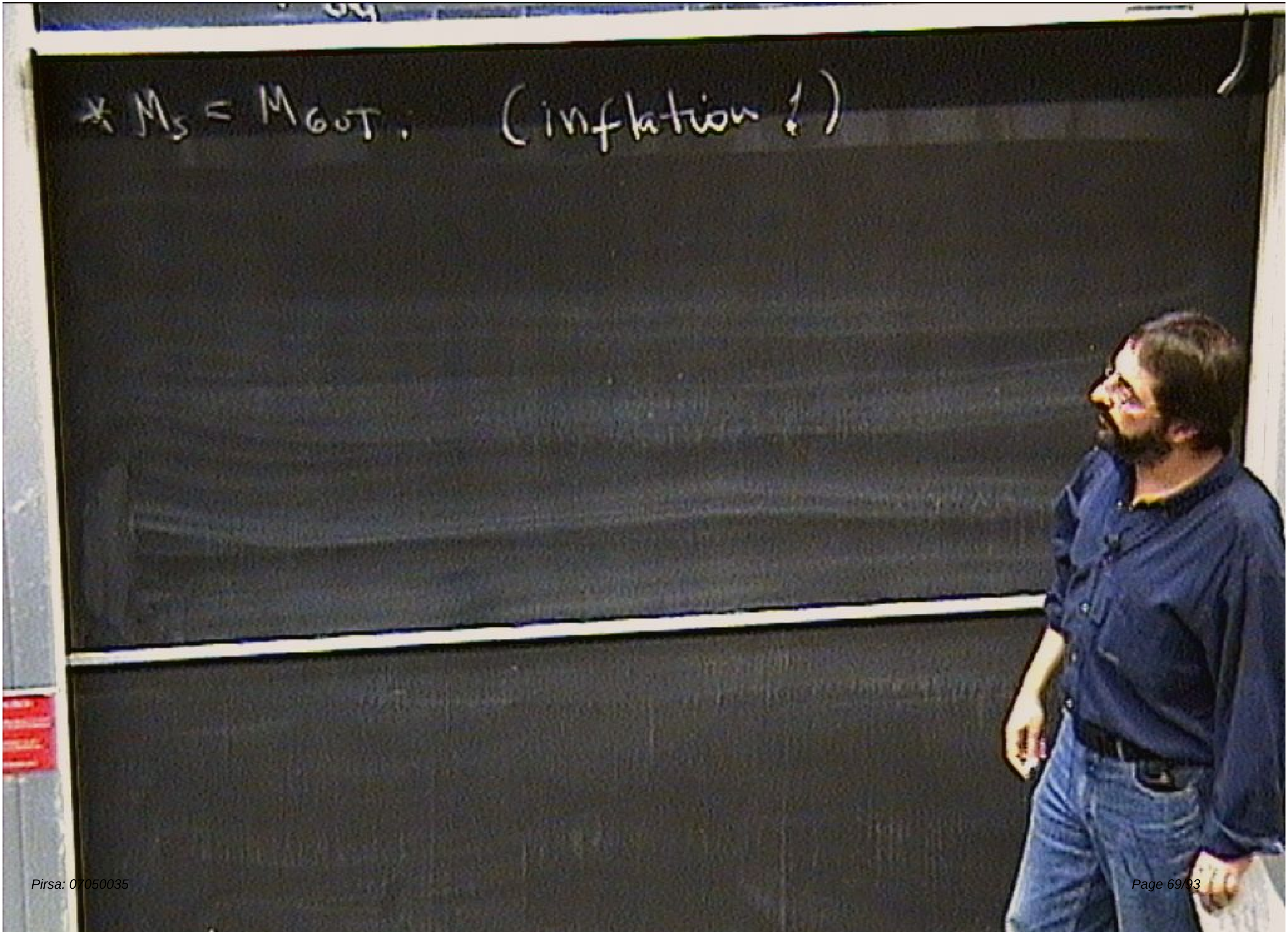
t_1 very large, T_1 small.

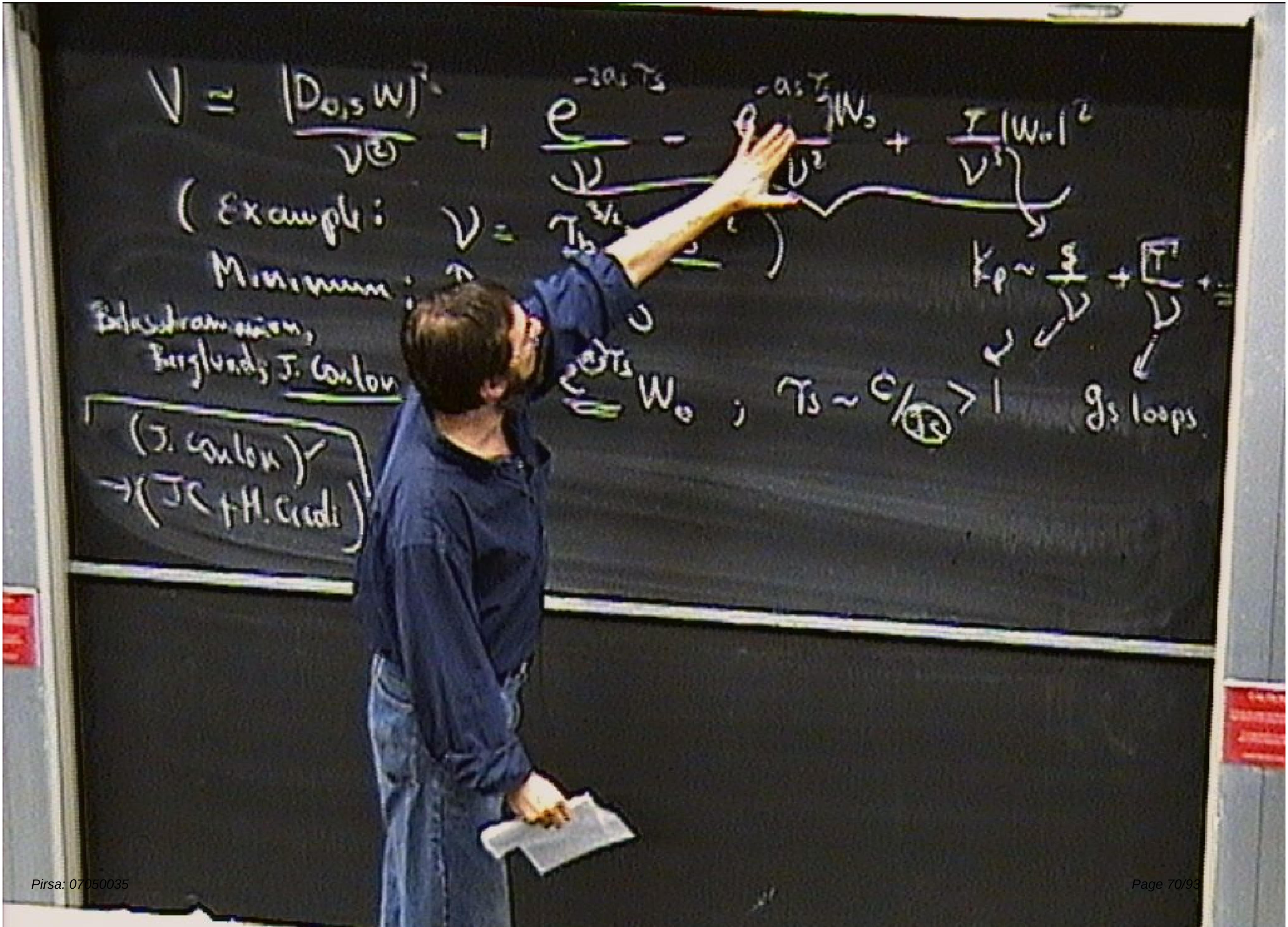
No large volume.

e.g.: $\mathcal{V} = t_1 t_2^2 + t_2^3 \ldots$ $\Big\}$ $\mathcal{V} \sim \sqrt{T_1}\,(T_2 - T_1) - T_3^{3/2}$

large T_1, T_2

$\tau_i = \frac{\partial \mathcal{V}}{\partial t_i} = t_2^2 + \ldots$


* M5 = MGUT. (inflation ?)


(Example:
Minimum:
Balasubramanian,
Berglund, J. Conlon
(J. Conlon)
→(JC + M. Cicoli)
g_s loops

$$V \simeq \frac{|D_{a,s}W|^2}{V^{(2)}} + \frac{e^{-2a_s\tau_s}}{V} - \frac{e^{-a_s\tau_s}}{V^2}|W_0| + \frac{\xi|W_0|^2}{V^3}$$

(Example: $V = \tau_b^{3/2} - \tau_s^{3/2}$)

$K_p \sim \frac{\xi}{V} + \frac{T}{V} + \dots$

Minimum: $D_{a,s}W = 0$

Balasubramanian, Berglund, J. Conlon

$V \sim e^{a_s\tau_s} W_0$; $\tau_s \sim$ ...

g_s loops

(J. Conlon) ✓

→ (JC + M. Cicoli)

$$V \simeq \frac{|D_{0,s}W|^2}{\mathcal{V}^{②}} + \underbrace{\frac{e^{-2a_s\tau_s}}{\mathcal{V}} - \frac{e^{-a_s\tau_s}|W_0|}{\mathcal{V}^2} + \frac{\xi|W_0|^2}{\mathcal{V}^3}}$$

(Example: $\mathcal{V} = \tau_b^{3/2} - \underline{\tau_s}^{3/2}$)

Minimum: $D_{0,s}W = 0$

Balasubramanian, Berglund, J. Conlon

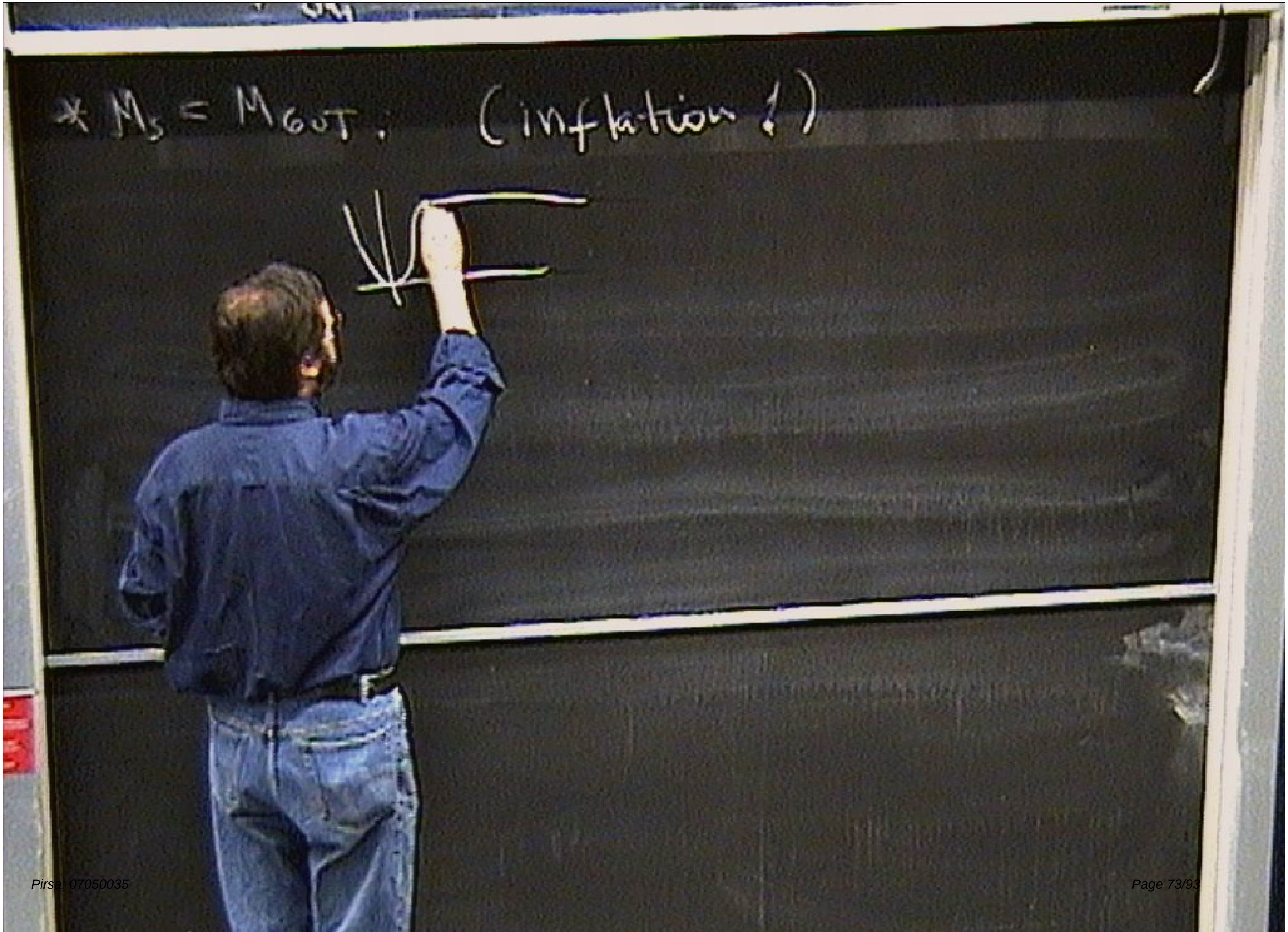
$\mathcal{V} \sim \underline{\underline{e}}^{a_s\tau_s} W_0$; $\tau_s \sim c/g_s > 1$

$K_p \sim \frac{\xi}{\mathcal{V}} + \frac{\boxed{\tau}}{\mathcal{V}} + \ldots$

g_s loops

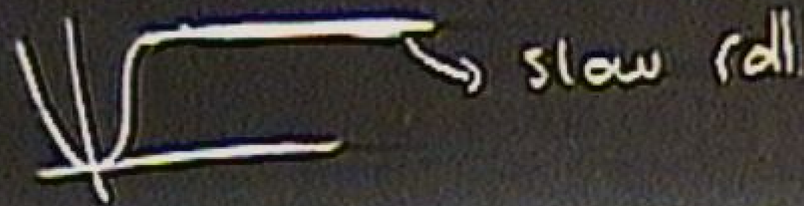
(J. Conlon) ✓

→ (JC + M. Cicoli)


* Ms = MGUT. (inflation ?)

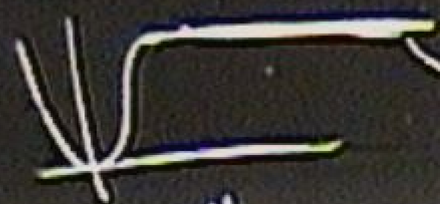
$* \; M_s = M_{GUT}$: (inflation !)

* $M_s = M_{GUT}$. (inflation !)



* $M_s = M_{GUT}$: (inflation !)

* $M_s = M_{GUT}$: (inflation !)

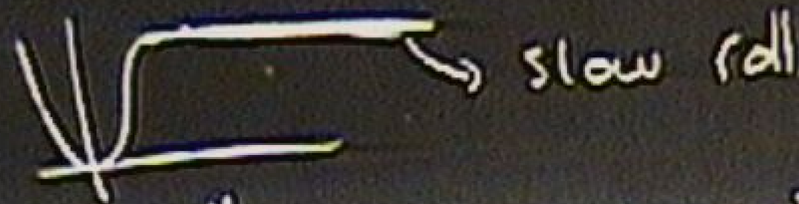


* $= M_{inf.} \simeq 10^{11}\, GeV. \rightarrow m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

(D7 branes) $\sim \frac{m_{3/2}}{(T_1 + \bar{T}_1)} \sim \frac{m_{3/2}}{\log(M_P/m_{3/2})}$

* $M_s \simeq M_{GUT}$: (inflation !)



* $M_s = M_{int} \simeq 10^{11}\,\mathrm{GeV}$. $\rightarrow$ $m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

[illegible] (D7 branes) $\sim \frac{m_{3/2}}{(2\tau)} \sim m_{3/2} / \log(M_P / m_{3/2})$

* $M_s = M_{GUT}$: (inflation ?)

* $M_s = M_{int.} \sim 10^{11}$ GeV. $\longrightarrow$ $m_{3/2} \sim \frac{M_P}{V}$; $M_s \sim \frac{M_P}{\sqrt{V}}$

$M_{KK} \sim M_P / V^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{(2\tau_s)} \sim \frac{m_{3/2}}{}\big/ \log(M_P/m_{3/2})$

* $M_s = M_{GUT}$: (inflation !)

→ slow roll

* $M_s = M_{int.} \sim \underline{\underline{10^{11}\ \mathrm{GeV}}}$. → $m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{[illegible]} \sim m_{3/2} / \log(M_P/m_{3/2})$

; axion,
. ν-masses.

* $M_s \simeq M_{GUT}$: (inflation !)

$M_s = M_{int.} \simeq \underline{10^{11}\ GeV}$. $\longrightarrow$ $m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{(2\tau_s)} \sim m_{3/2} / \log(M_P/m_{3/2})$ ✓ ; { axion, ν-masses

…oduli : m_{τ_i}

* $M_s = M_{GUT}$. (inflation ?)

* $M_s = M_{int.} \sim \underline{10^{11}\,\text{GeV}}$. $\longrightarrow$ $m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{a_s \tau_s} \sim m_{3/2} / \log(M_P/m_{3/2})$ ✓

; { axion, ν-masses.

Moduli: $m_{\tau_b} \sim \frac{M_P}{V^{3/2}} \sim 1\,\text{MeV}$

$m_{\tau_s} \sim m_{3/2} \log(M_P/m_{3/2}) \sim 10^3\,\text{TeV}$

* $M_s \simeq M_{GUT}$: (inflation ?)

* $M_s = M_{int.} \sim \underline{10^{11}\ \mathrm{GeV}}$. $\longrightarrow$ $m_{3/2} \sim \frac{M_P}{V}$; $M_s = \frac{M_P}{\sqrt{V}}$

$M_{KK} = M_P / V^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{(\ln \tau_s)} \sim m_{3/2} / \log(M_P/m_{3/2})$

Moduli : $m_{\tau_b} \sim \frac{M_P}{V^{3/2}} \sim 1\ \mathrm{MeV}$ $\longrightarrow m_{a_b} \sim 10^{11}\ \mathrm{GeV} \longleftarrow$; { axion, V-masses

$m_{\tau_s} \sim m_{3/2} \log(M_P/m_{3/2}) \sim 10^{3}\ \mathrm{TeV} \longrightarrow m_n \sim \mathrm{TeV}$

* $M_s = M_{GUT}$: (inflation ?)

* $M_s = M_{int.} \sim \underline{10^{11}\,GeV}$. $\longrightarrow$ $m_{3/2} \sim \frac{M_P}{\mathcal{V}}$; $M_s = \frac{M_P}{\sqrt{\mathcal{V}}}$

$M_{KK} = M_P / \mathcal{V}^{2/3}$

M_{soft} (D7 branes) $\sim \frac{m_{3/2}}{(\tau + \bar{\tau})} \sim m_{3/2} / \log(M_P / m_{3/2})$

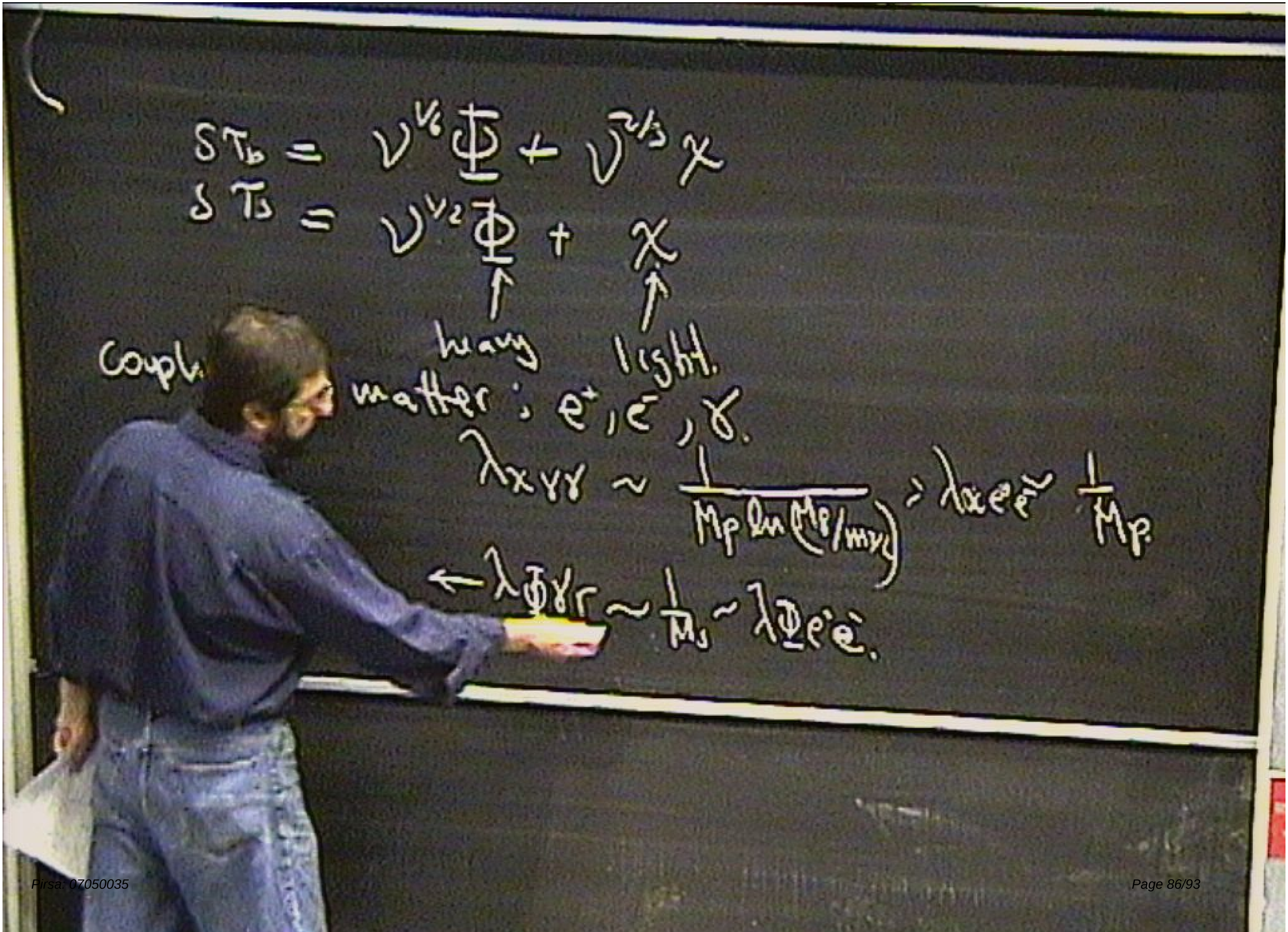
Moduli : $m_{\tau_b} \sim \frac{M_P}{\mathcal{V}^{3/2}} \sim 1\,MeV \longrightarrow m_{a_b} \sim 10^{11}\,GeV \longleftarrow$; { axion, ν-masses

$m_{\tau_s} \sim m_{3/2} \log(M_P / m_{3/2}) \sim 10^3\,TeV \longrightarrow m_a \sim TeV$

$$\delta\tau_b = \mathcal{V}^{1/6}\Phi + \mathcal{V}^{2/3}\chi$$

$$\delta\tau_s = \mathcal{V}^{1/2}\Phi + \chi$$

heavy light.


$\delta T_b = V^{1/6}\Phi + V^{2/3}\chi$
$\delta T_s = V^{1/2}\Phi + \chi$
heavy
light
Coupl
matter ; e^+, e^-, γ.
$\lambda_{\chi\gamma\gamma} \sim \frac{1}{M_P \ln(M_P/m_{3/2})}$; $\lambda_{\chi e e} \sim \frac{1}{M_P}$
$\leftarrow \lambda_{\Phi\gamma\gamma} \sim \frac{1}{M_s} \sim \lambda_{\Phi e^+ e^-}$.

$$\delta\tau_b = \mathcal{V}^{1/6}\Phi + \mathcal{V}^{2/3}\chi$$

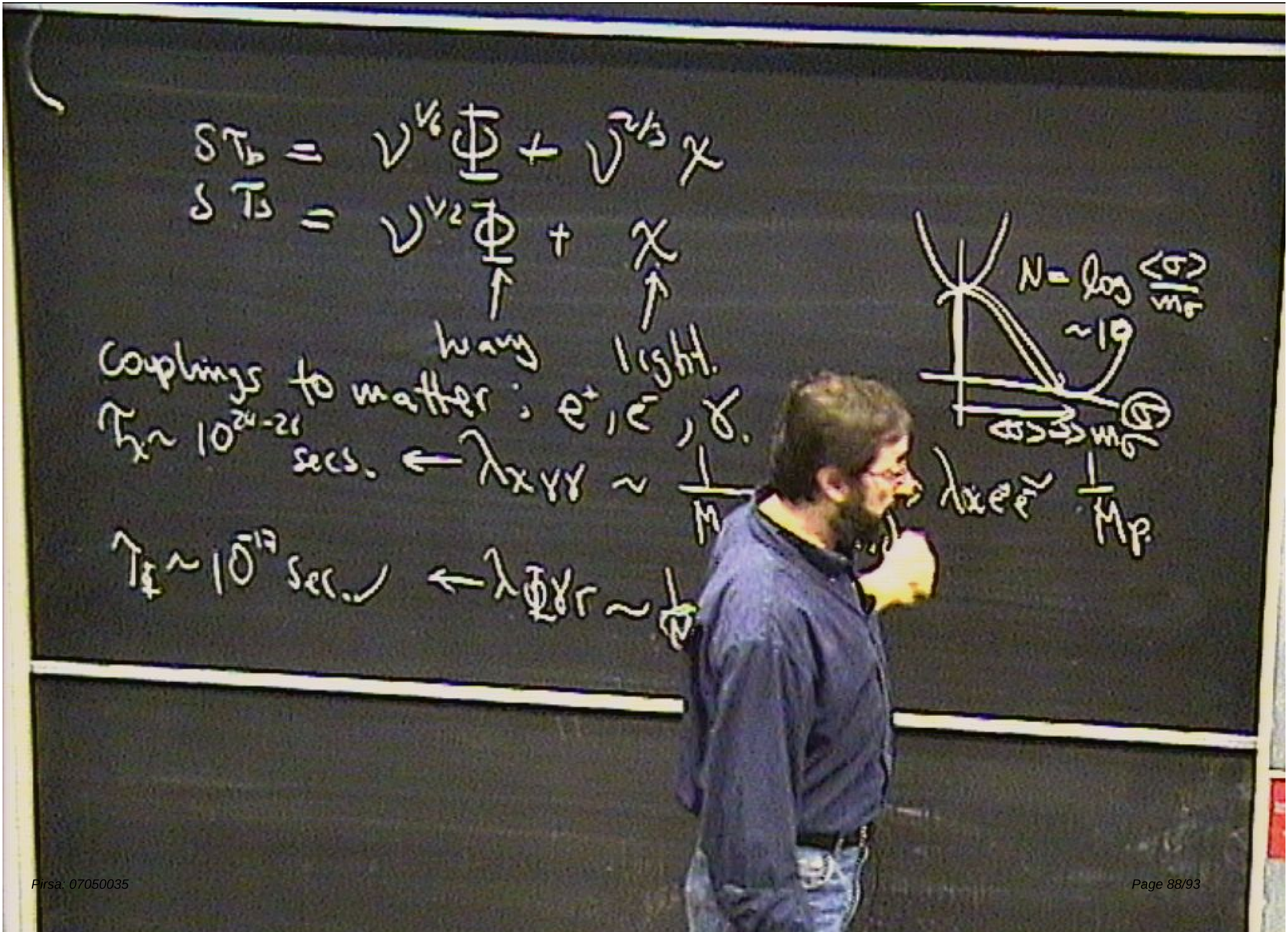
$$\delta\tau_s = \mathcal{V}^{1/2}\Phi + \chi$$

heavy light

Couplings to matter: e^+, e^-, γ.

$$\tau_\chi \sim 10^{24-26} \text{ secs.} \leftarrow \lambda_{\chi\gamma\gamma} \sim \frac{1}{M_P \ln(M_P/m_{\chi})} > \lambda_{\chi e^+ e^-} \sim \frac{1}{M_P}$$

$$\tau_\Phi \sim 10^{-17} \text{ sec.} \checkmark \leftarrow \lambda_{\Phi\gamma\gamma} \sim \frac{1}{M_s} \sim \lambda_{\Phi e^+ e^-}.$$


δτ_b = V^{1/6} Φ + V^{2/3} χ
δτ_s = V^{1/2} Φ + χ
heavy
light.
N = log <σ>/m_σ
~19
<σ> >> m_σ
Couplings to matter: e+, e−, γ.
τ_χ ~ 10^{24-26} secs. ← λ_χγγ ~ 1/M
λ_χee ~ 1/M_P
τ_Φ ~ 10^{-17} sec. ← λ_Φγγ ~

$$\delta T_b = \mathcal{V}^{1/6}\Phi + \mathcal{V}^{2/3}\chi$$

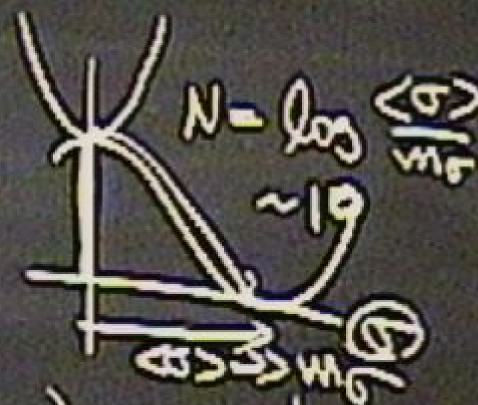
$$\delta T_s = \mathcal{V}^{1/2}\Phi + \chi$$

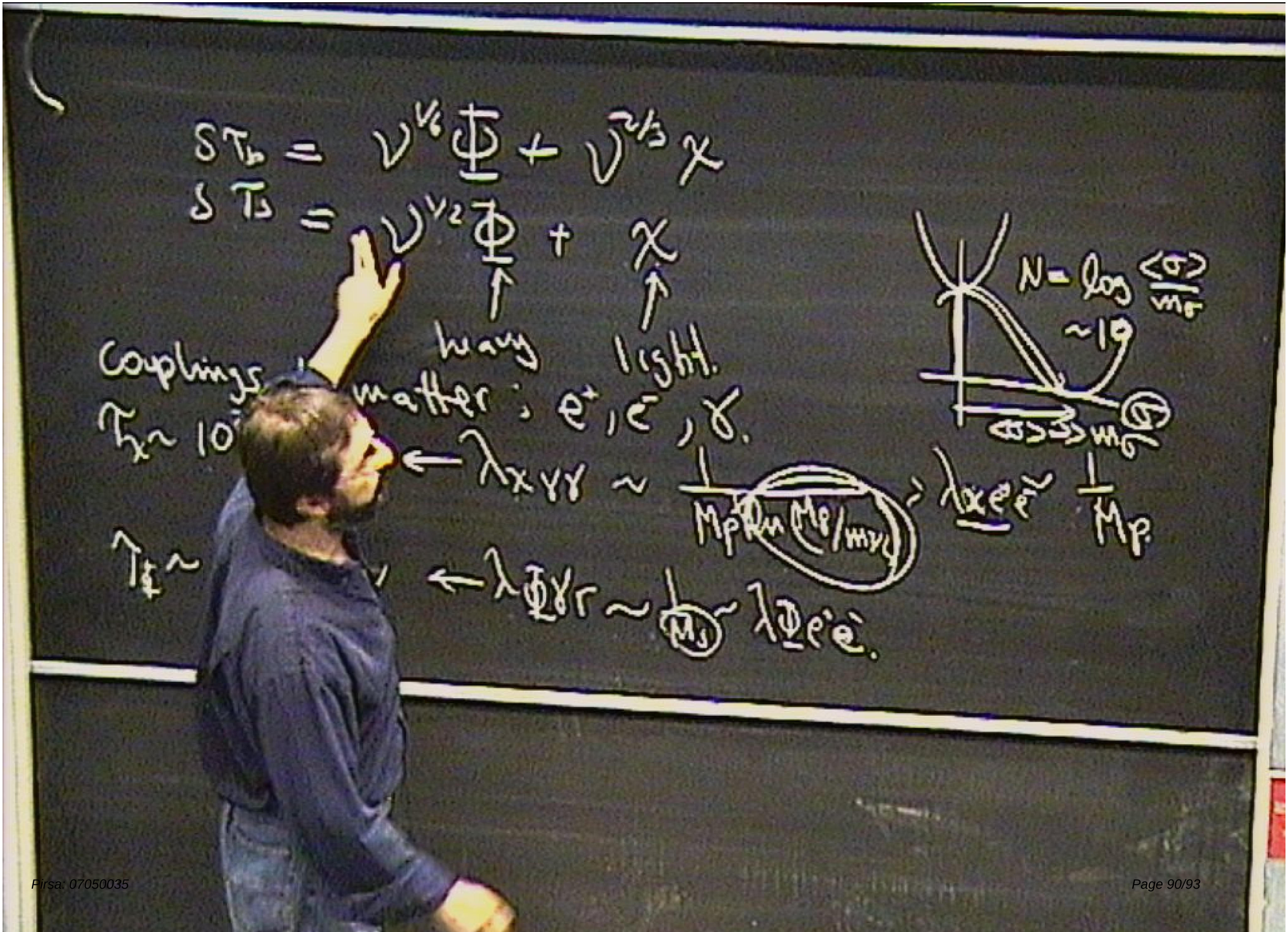
heavy (Φ) light (χ)

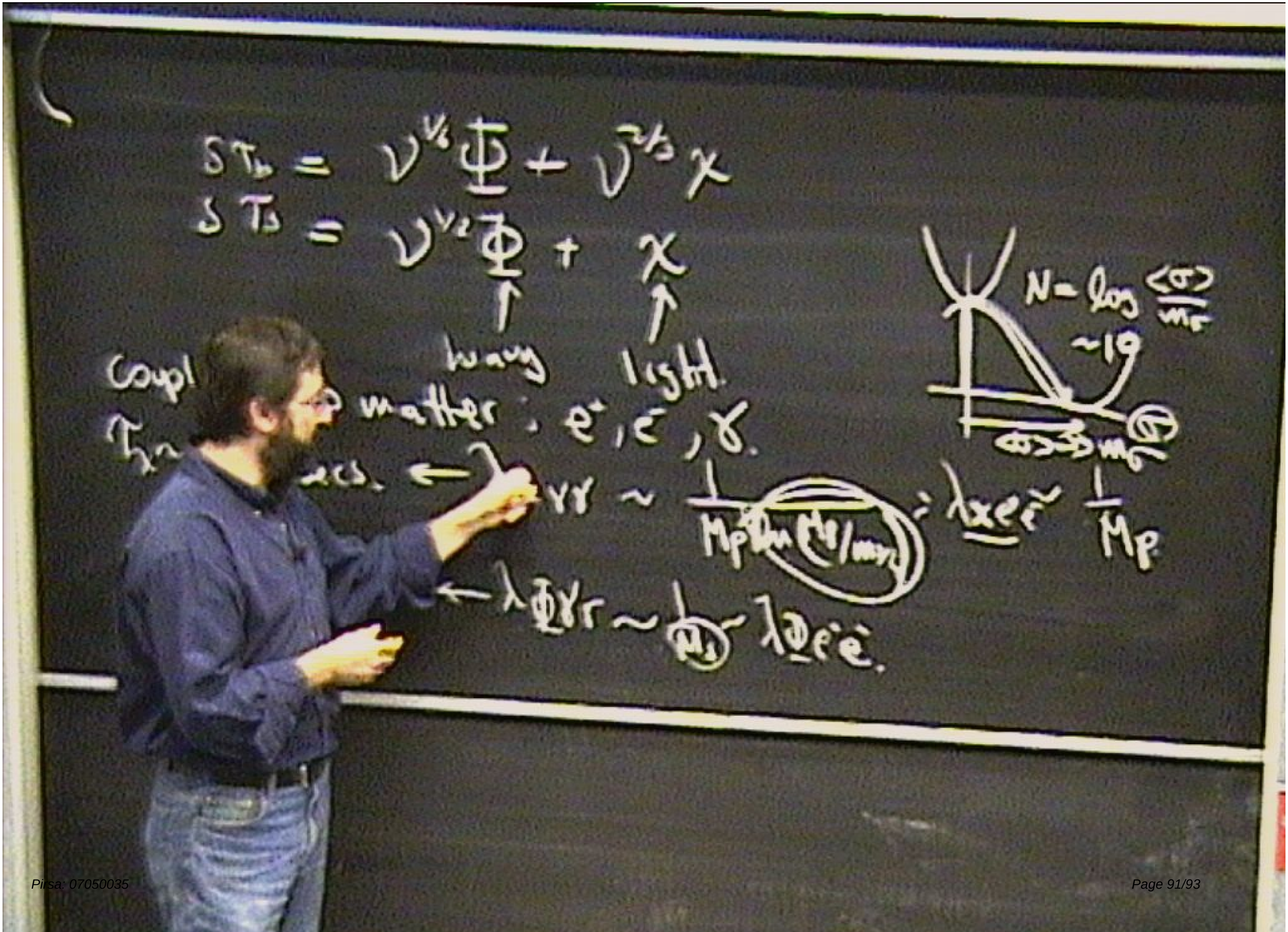
Couplings to matter: e^+, e^-, γ.

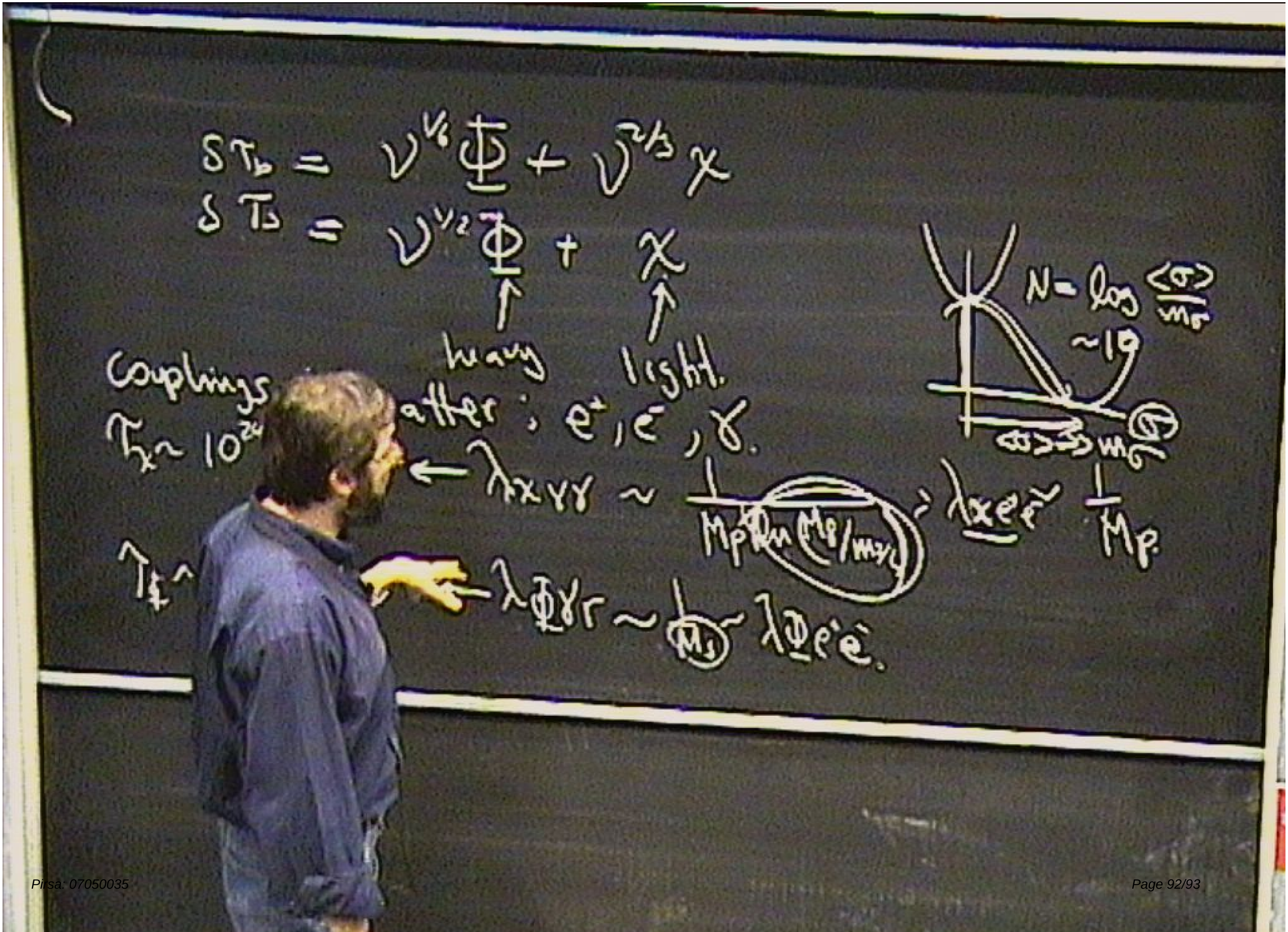
$\tau_\chi \sim 10^{24-26}$ secs. $\leftarrow \lambda_{\chi\gamma\gamma} \sim \frac{1}{M_P \ln(M_P/m_\chi)} > \lambda_{\chi e e} \sim \frac{1}{M_P}$

$\tau_\Phi \sim 10^{-17}$ sec. ✓ $\leftarrow \lambda_{\Phi\gamma\gamma} \sim \frac{1}{M_s} \sim \lambda_{\Phi e^+ e^-}$.




δτ_b = V^{1/6} Φ + V^{2/3} χ
δτ_s = V^{1/2} Φ + χ
heavy
light
Couplings matter ; e+, e−, γ.
τ_χ ~ 10
← λχγγ ~ 1/(Mp ln (Mp/m3/2)) ; λχee ~ 1/Mp
τ_Φ ~
← λΦγγ ~ 1/Ms ~ λΦee.
N = log ⟨σ⟩/mσ
~19
⟨σ⟩ ≫ mσ


δTℓ = ν^{1/6} Φ + ν^{-2/3} χ
δTs = ν^{1/2} Φ + χ
heavy
light
matter: e+, e-, γ
N ~ log ⟨σ⟩/mσ
~19
λχγγ ~ 1/Mp
λχee ~ 1/Mp
λΦγγ ~ λΦee


$\delta\tau_b = \mathcal{V}^{1/6}\,\Phi + \mathcal{V}^{2/3}\,\chi$
$\delta\tau_s = \mathcal{V}^{1/2}\,\Phi + \chi$
heavy
light
$N \sim \log \frac{\langle\sigma\rangle}{m_\sigma}$
~ 19
$\langle\sigma\rangle \gg m_\sigma$
σ
Couplings
atter : e^+, e^-, γ.
$\tau_\chi \sim 10^{2}$
$\lambda_{\chi\gamma\gamma} \sim \frac{1}{M_P \ln(M_P/m_{3/2})}$; $\lambda_{\chi e e} \sim \frac{1}{M_P}$
$\tau_\Phi \sim$
$\lambda_{\Phi\gamma\gamma} \sim \frac{1}{M_s} \sim \lambda_{\Phi e e}$.

$$\delta \tau_b = \mathcal{V}^{1/6}\,\Phi + \mathcal{V}^{2/3}\,\chi$$

$$\delta \tau_s = \mathcal{V}^{1/2}\,\Phi + \chi$$

heavy (under Φ) light (under χ)

Couplings to matter: e^+, e^-, γ.

$\tau_\chi \sim 10^{24-26}$ secs. $\leftarrow \lambda_{\chi\gamma\gamma} \sim \dfrac{1}{M_P \ln(M_P/m_{3/2})}$; $\lambda_{\chi e \bar{e}} \sim \dfrac{1}{M_P}$

$\tau_\Phi \sim 10^{-17}$ sec. $\leftarrow \lambda_{\Phi\gamma\gamma} \sim \dfrac{1}{M_s} \sim \lambda_{\Phi e \bar{e}}$.