Title: Introduction to quantum gravity - Part 25

Date: Apr 12, 2006 08:00 PM

URL: http://pirsa.org/06040015

Abstract: This is an introduction to background independent quantum theories of gravity, with a focus on loop quantum gravity and related approaches.

Basic texts:

-Quantum Gravity, by Carlo Rovelli, Cambridge University Press 2005 -Quantum gravityy with a positive cosmological constant, Lee Smolin, hep-th/0209079
-Invitation to loop quantum gravity, Lee Smolin, hep-th/0408048 -Gauge fields, knots and gravity, JC Baez, JP Muniain

Prerequisites:

-undergraduate quantum mechanics
-basics of classical gauge field theories
-basic general relativity
-hamiltonian and lagrangian mechanics
-basics of lie algebras

The key observational question is:

What is the symmetry of the ground state?

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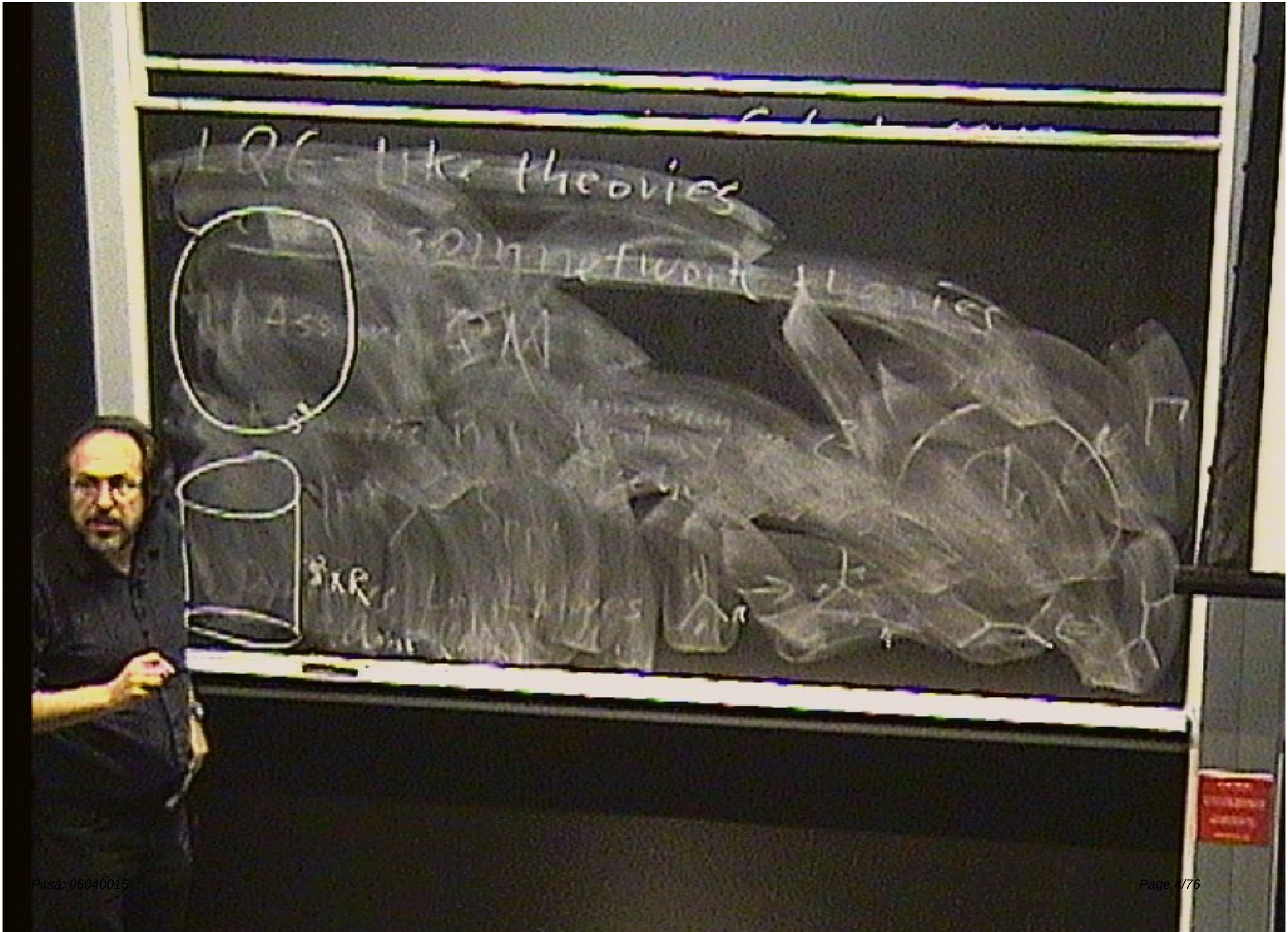
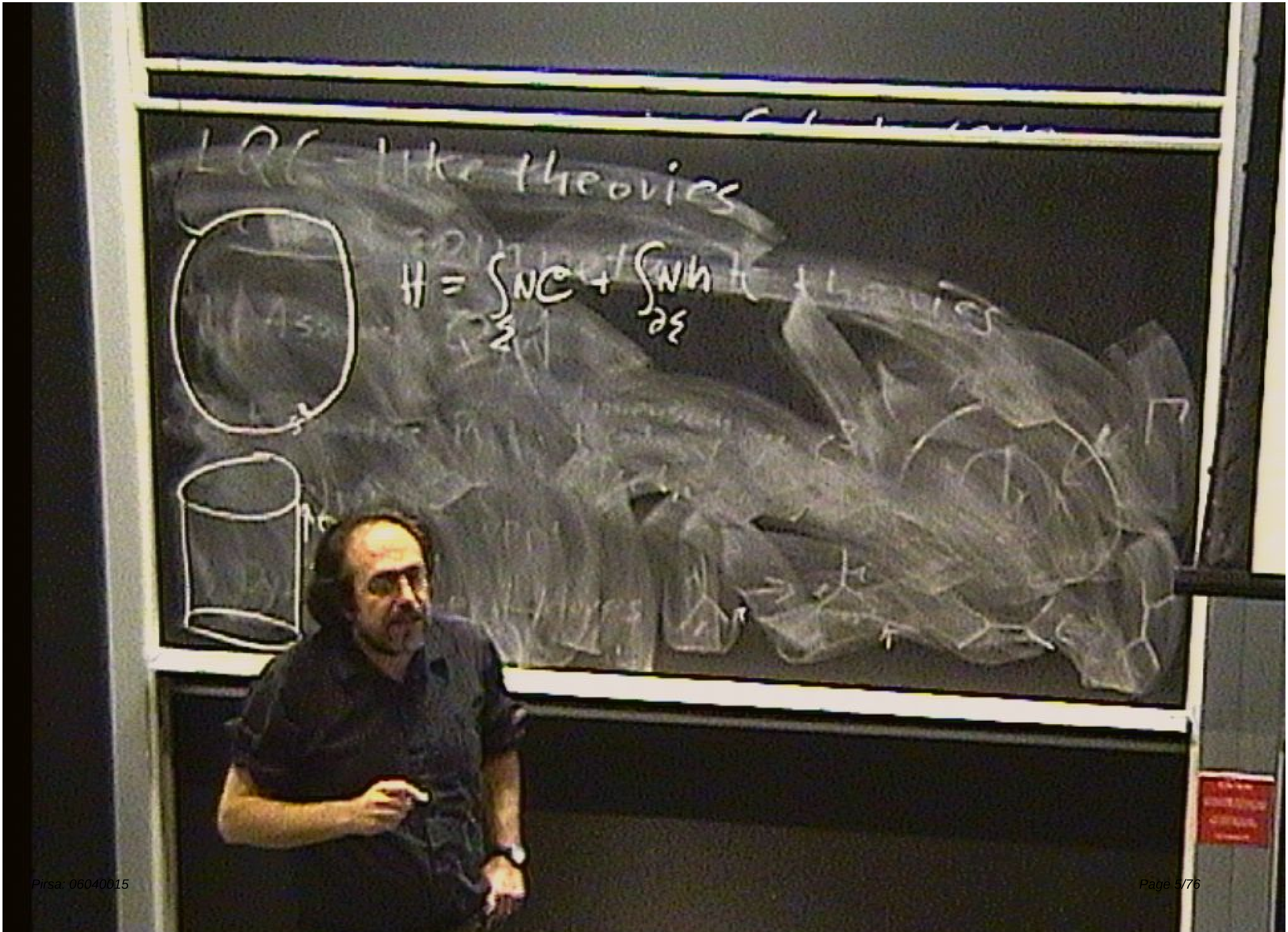
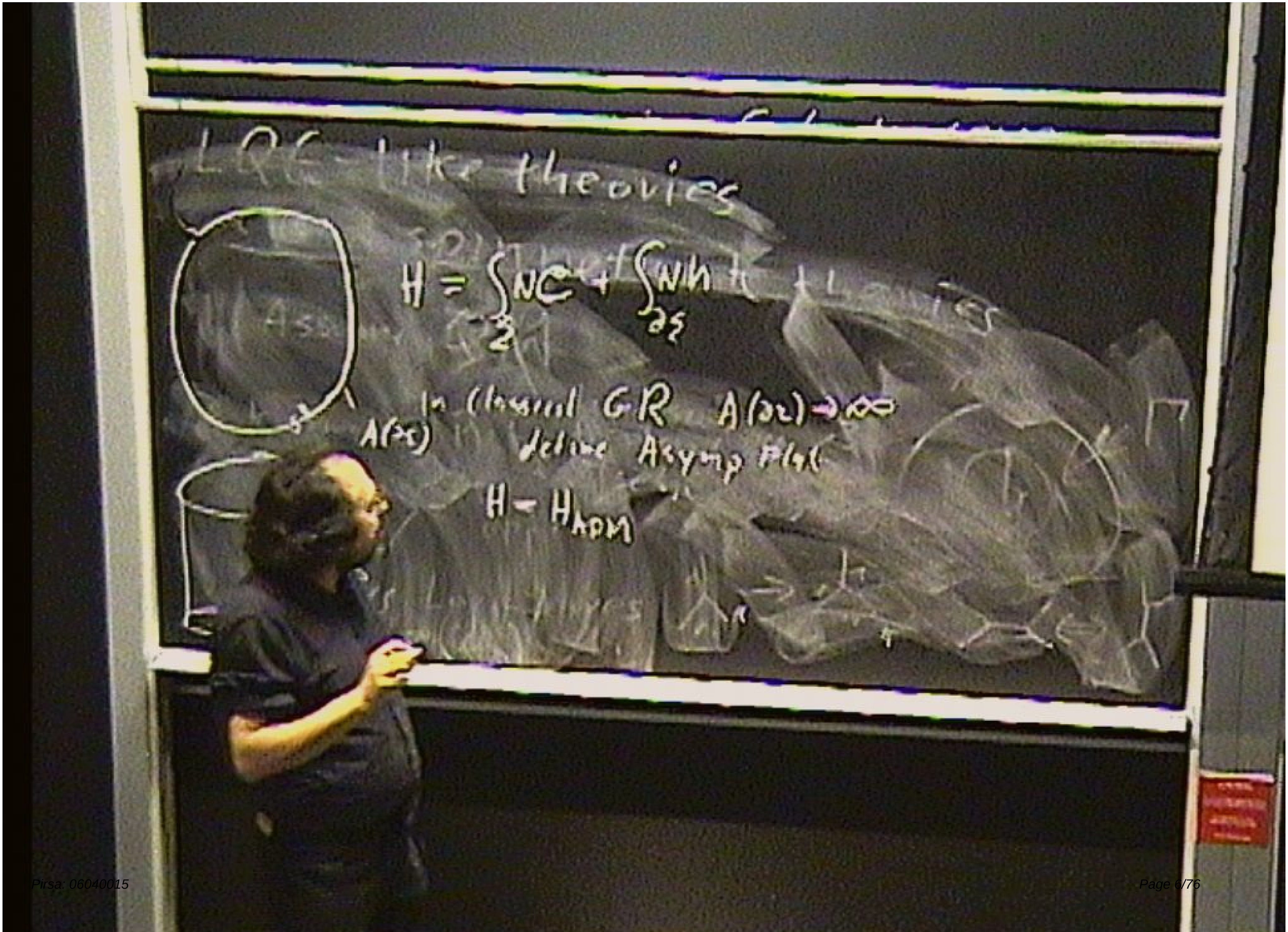
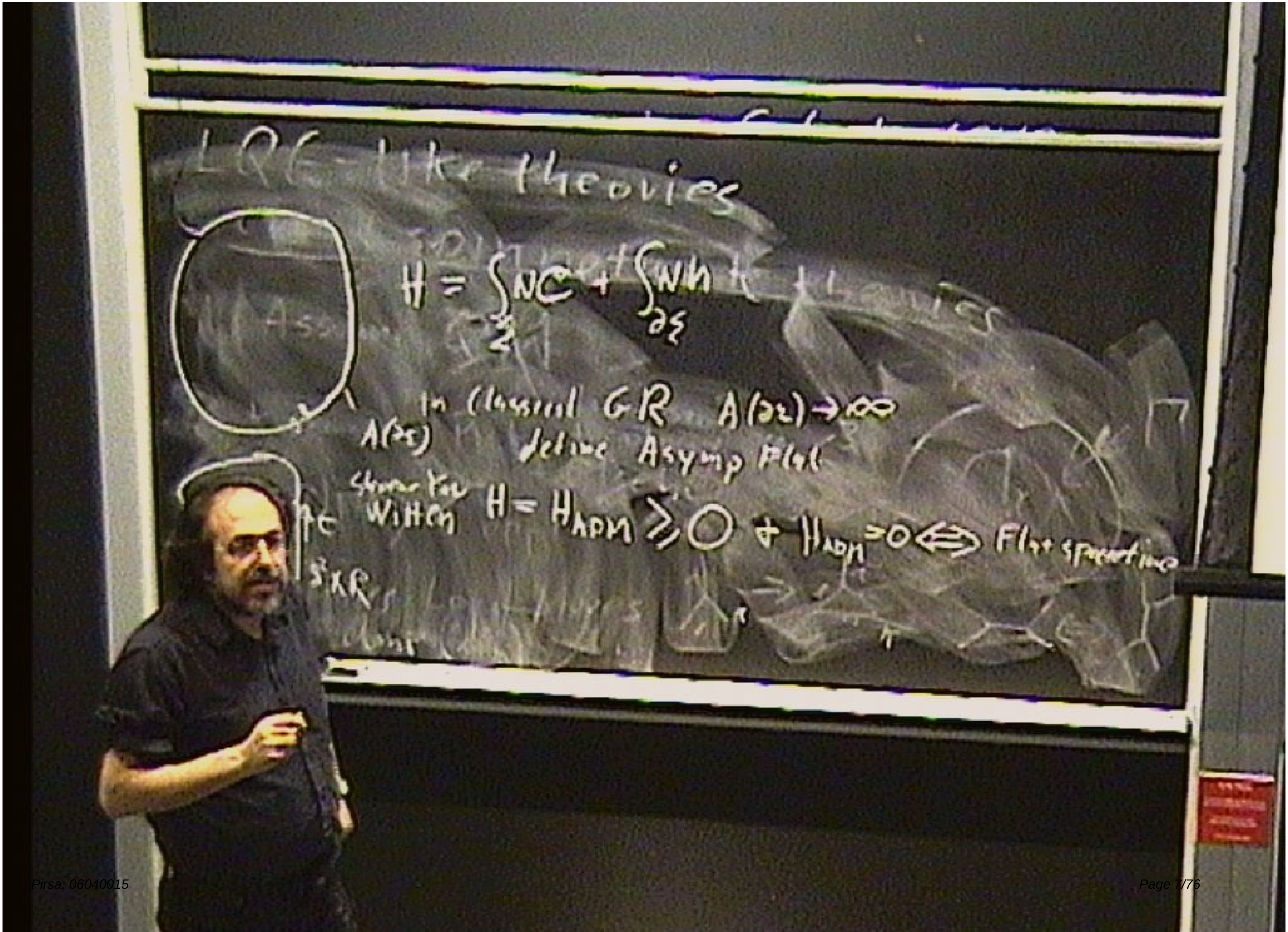

LQG-like theories


LQG-like theories
H = ∫Σ NC + ∫∂Σ Nh


LQG-like theories
H = ∫ NC + ∫ Nh
In classical GR A(∂Σ) → ∞
A(∂Σ)
define Asymp Flat
H − H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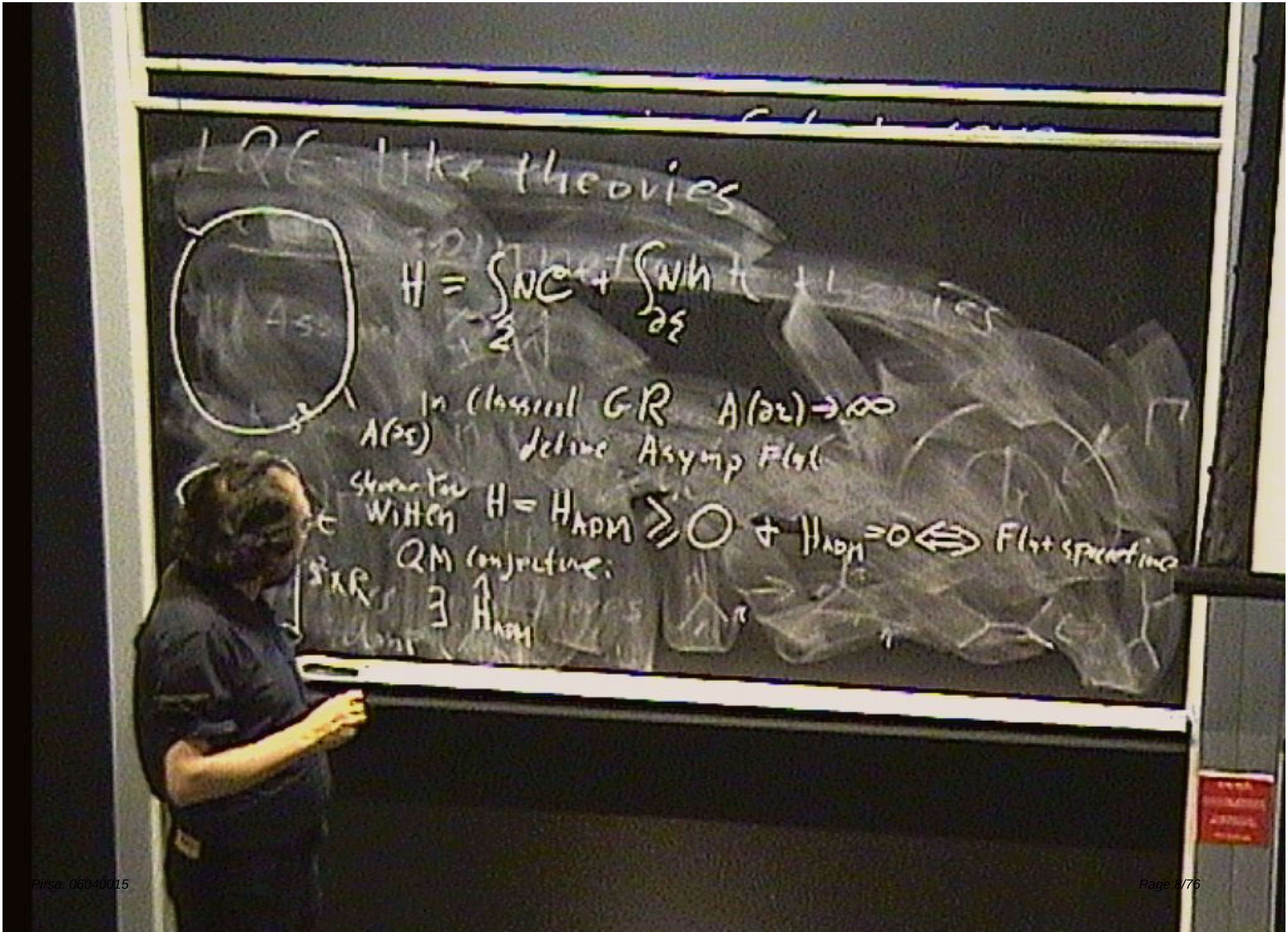
define Asymp Flat
Witten
H = H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime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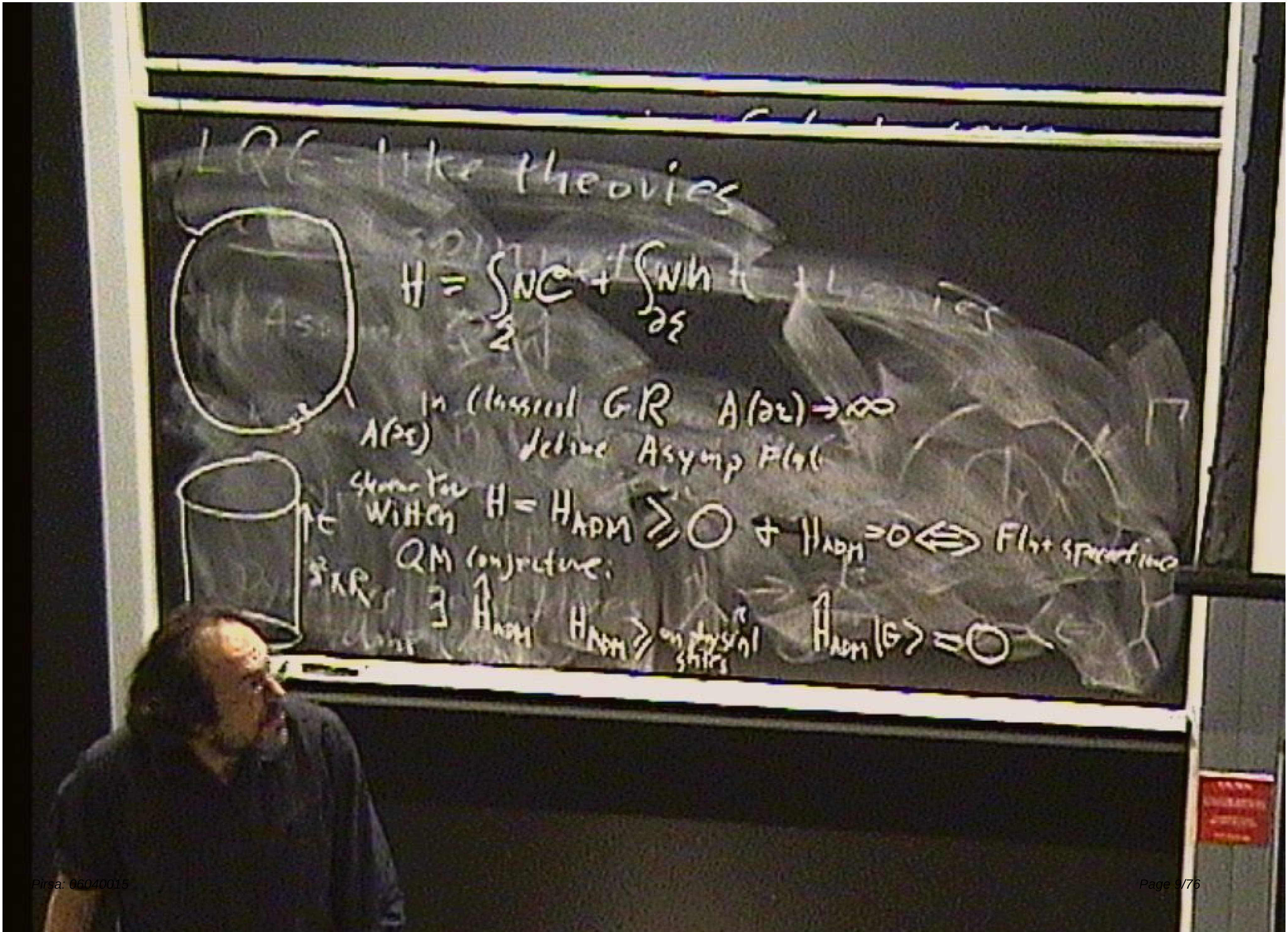
QM conjecture:
∃ Ĥ_ADM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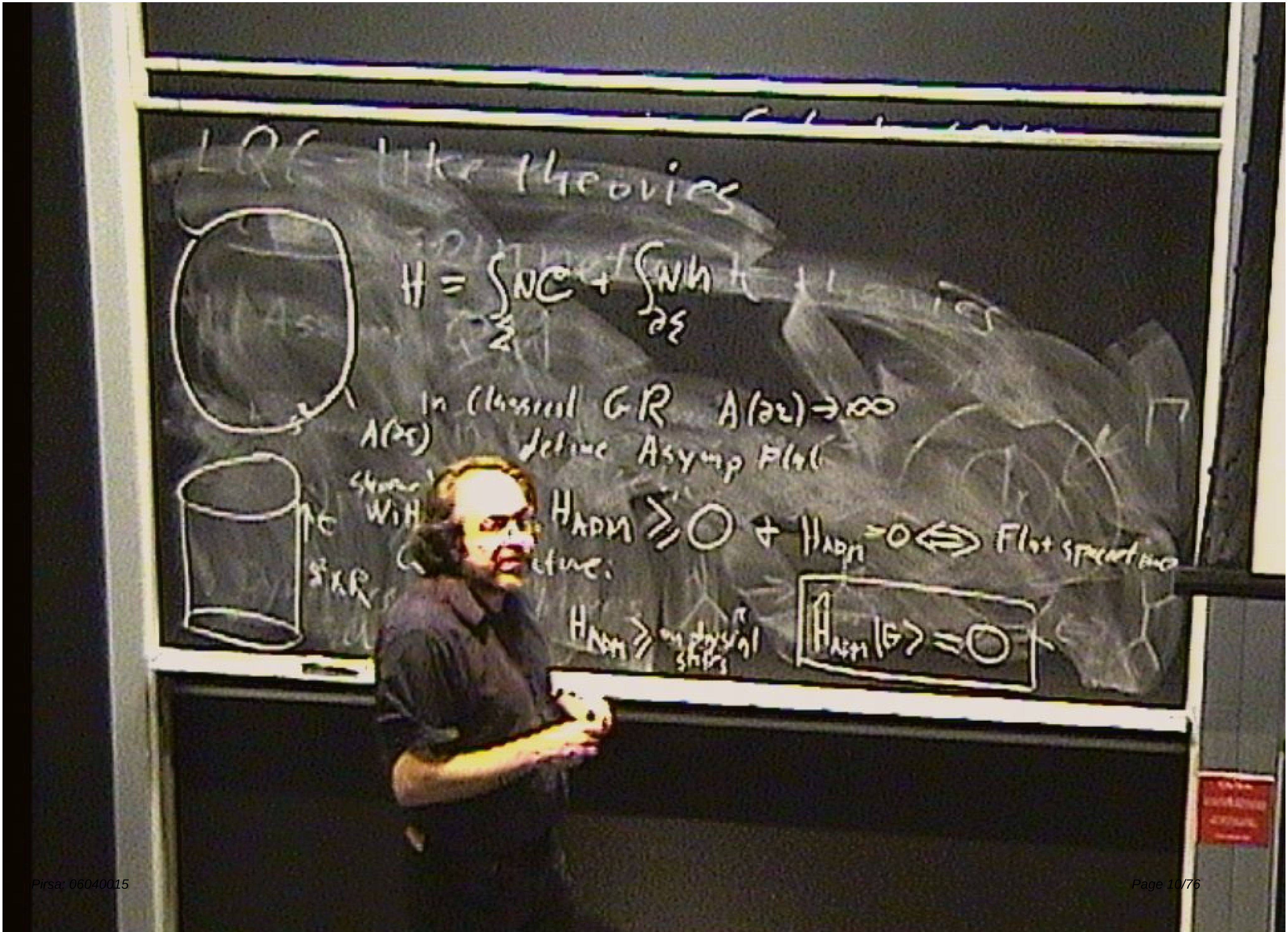
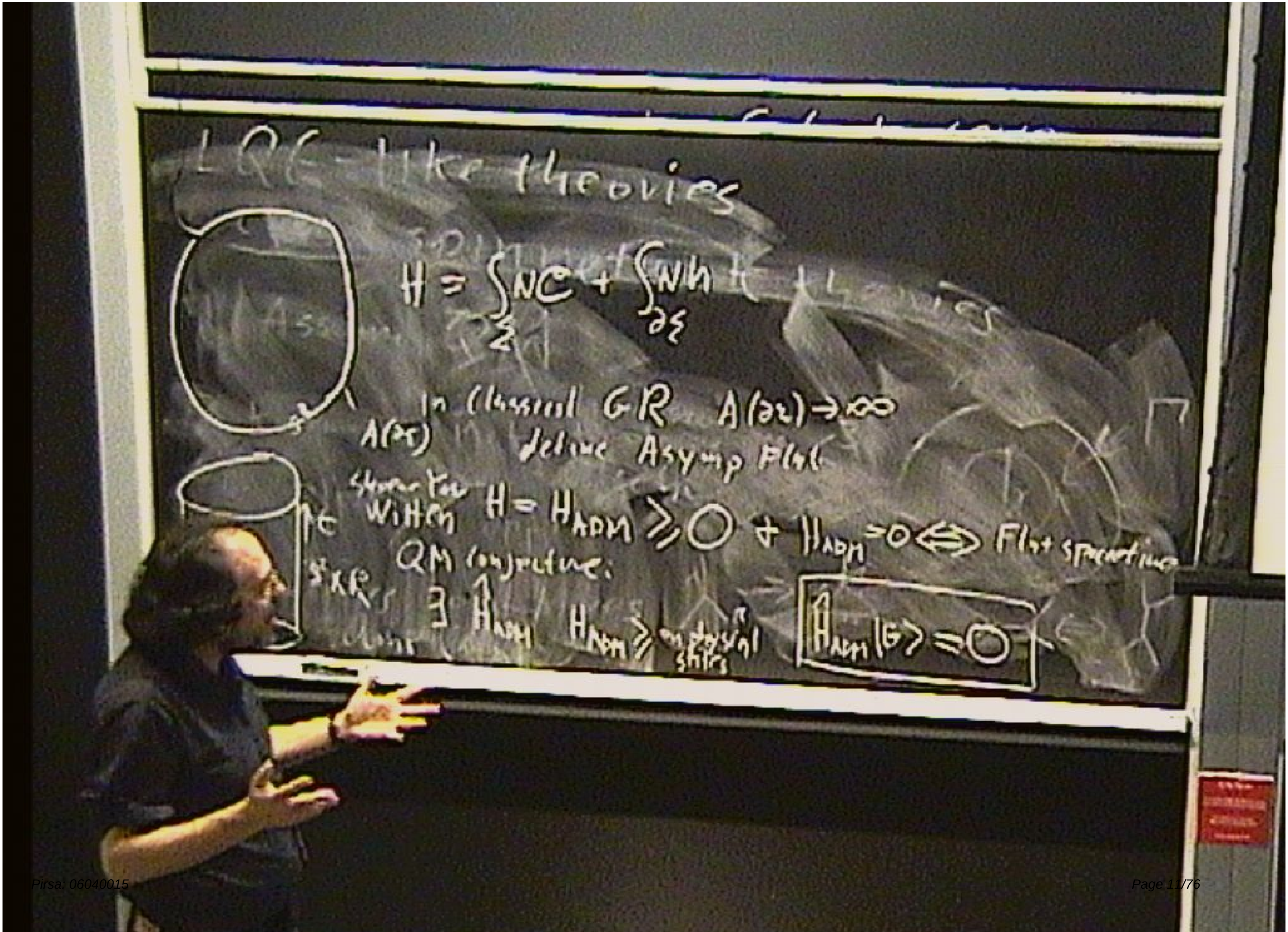
define Asymp Flat
Witten
QM conjecture:
Flat spacetime



LQG-like theories
H = ∫NC + ∮Nh
In Classical GR A(∂Σ)→∞
define Asymp Flat
H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime
H_ADM |G⟩ = 0


LQG-like theories
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In Classical GR A(∂Σ)→∞
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Witten H = H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime
QM conjecture:
∃ Ĥ_ADM
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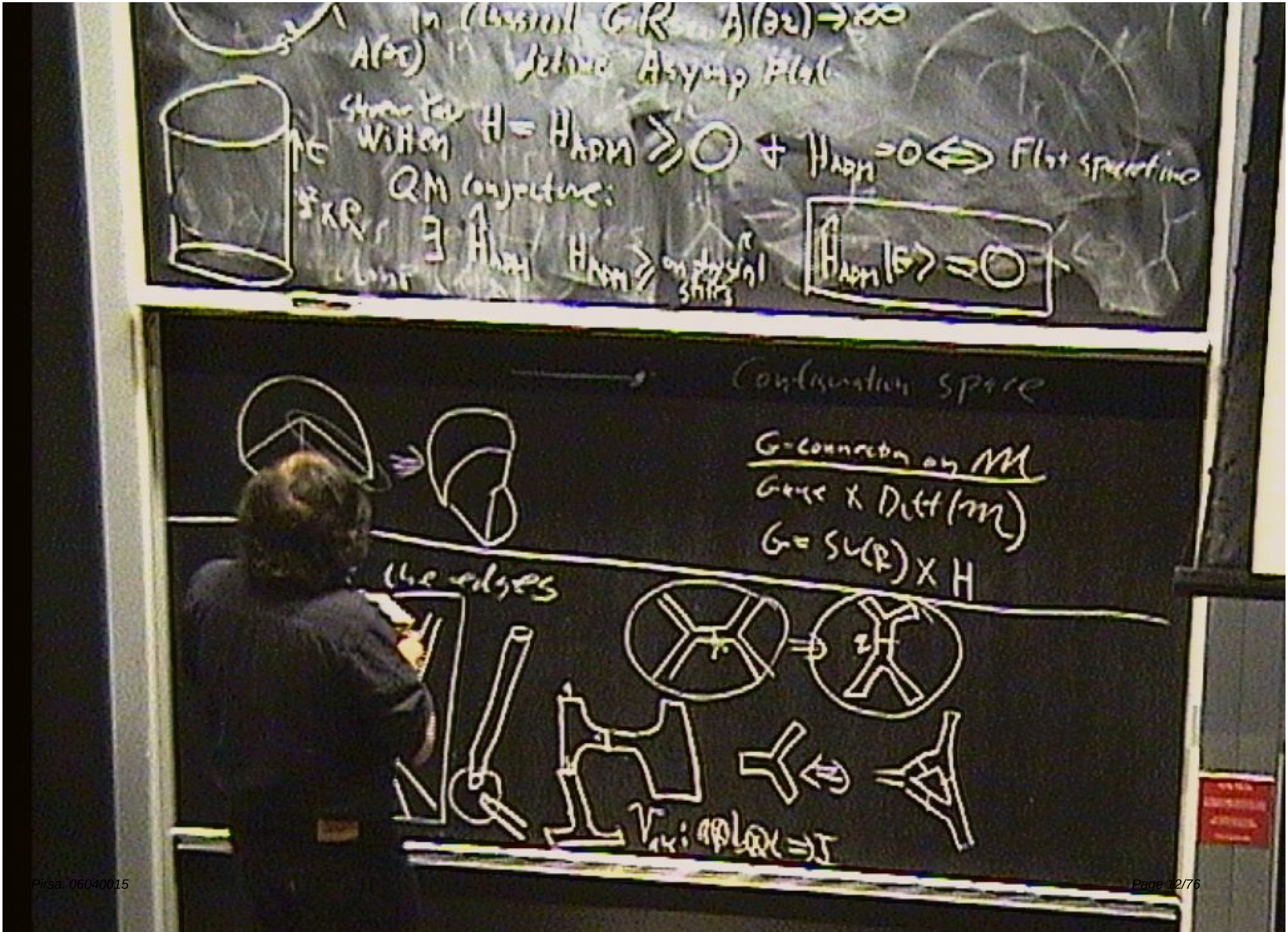
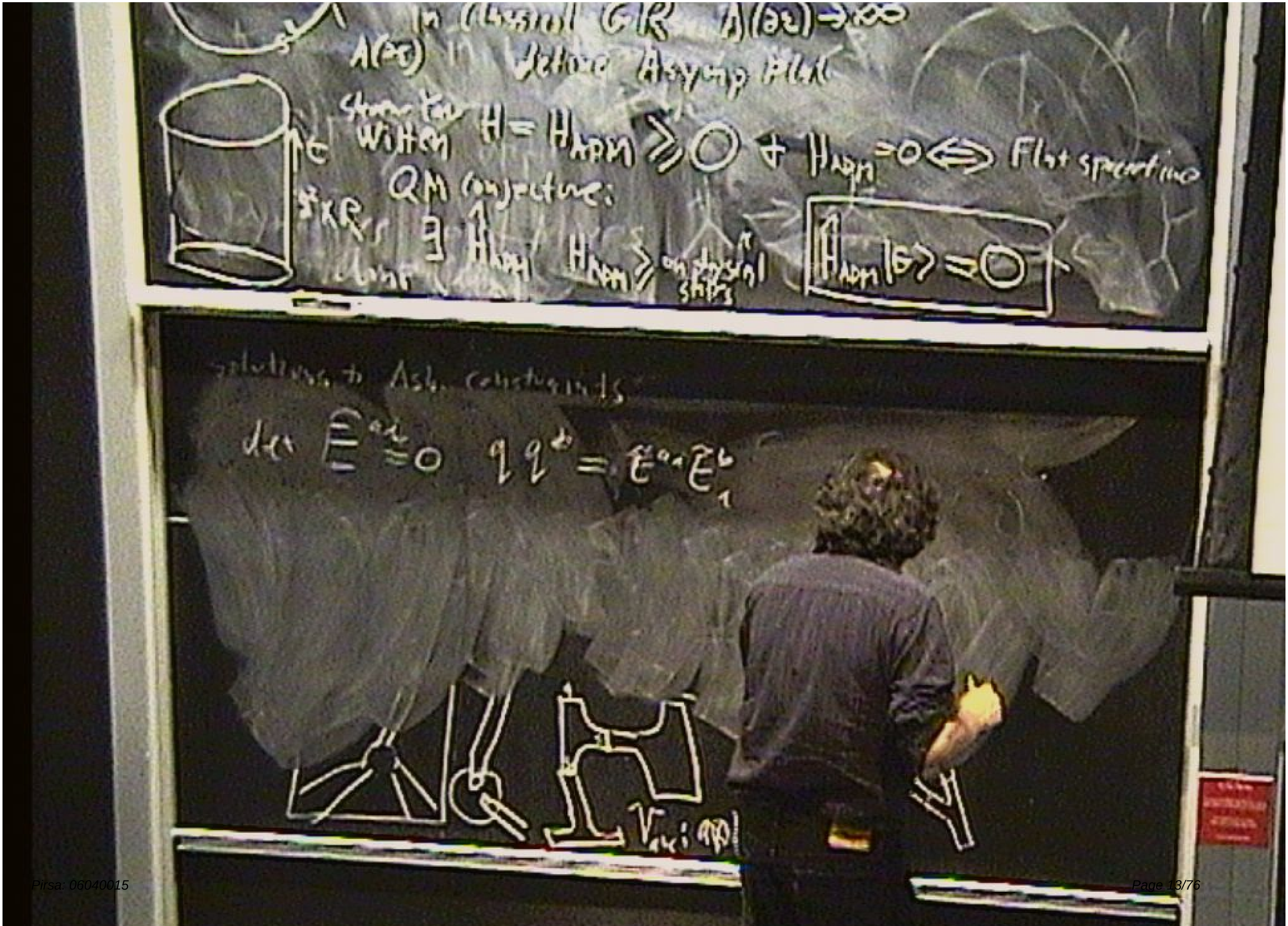
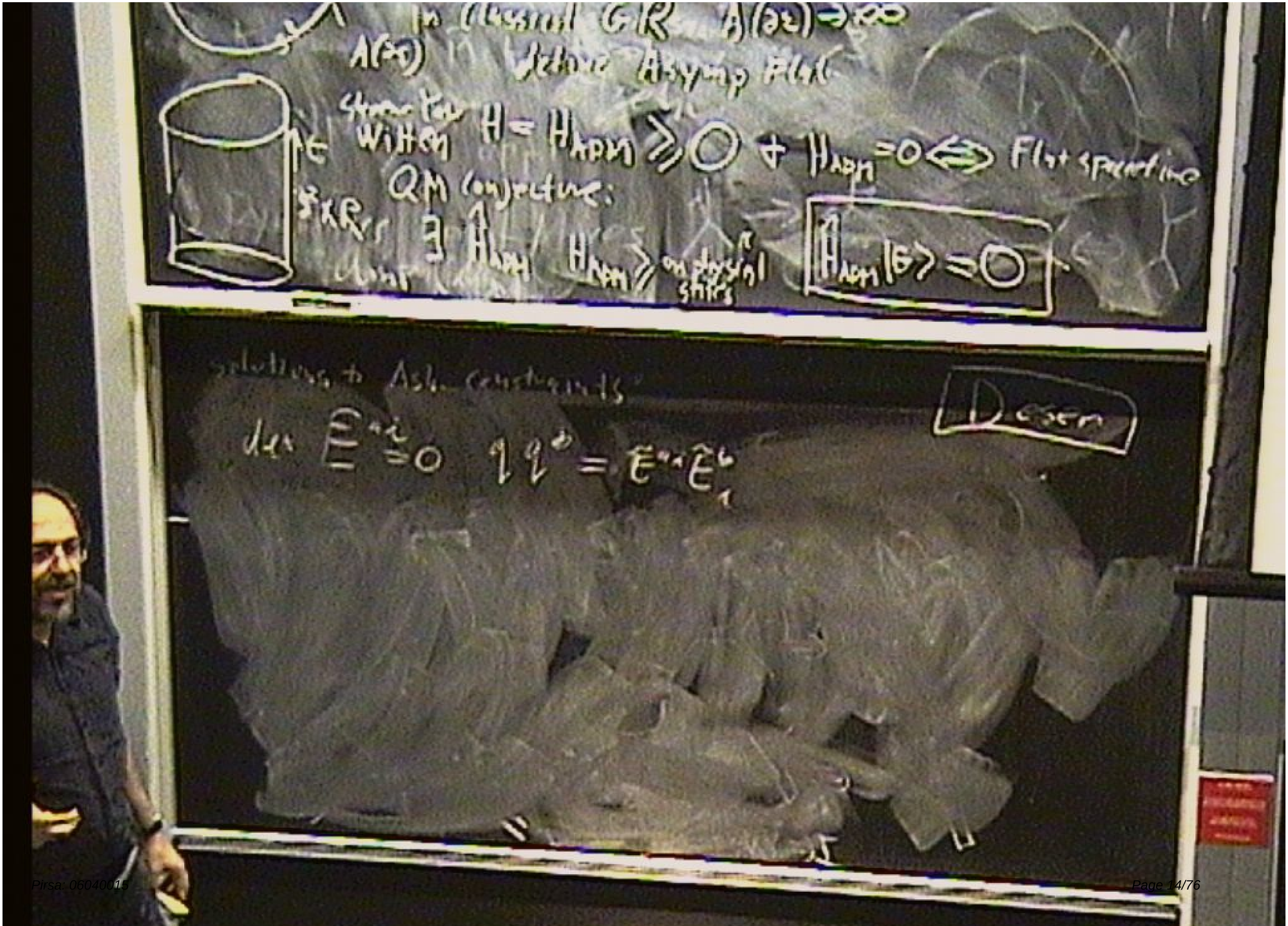
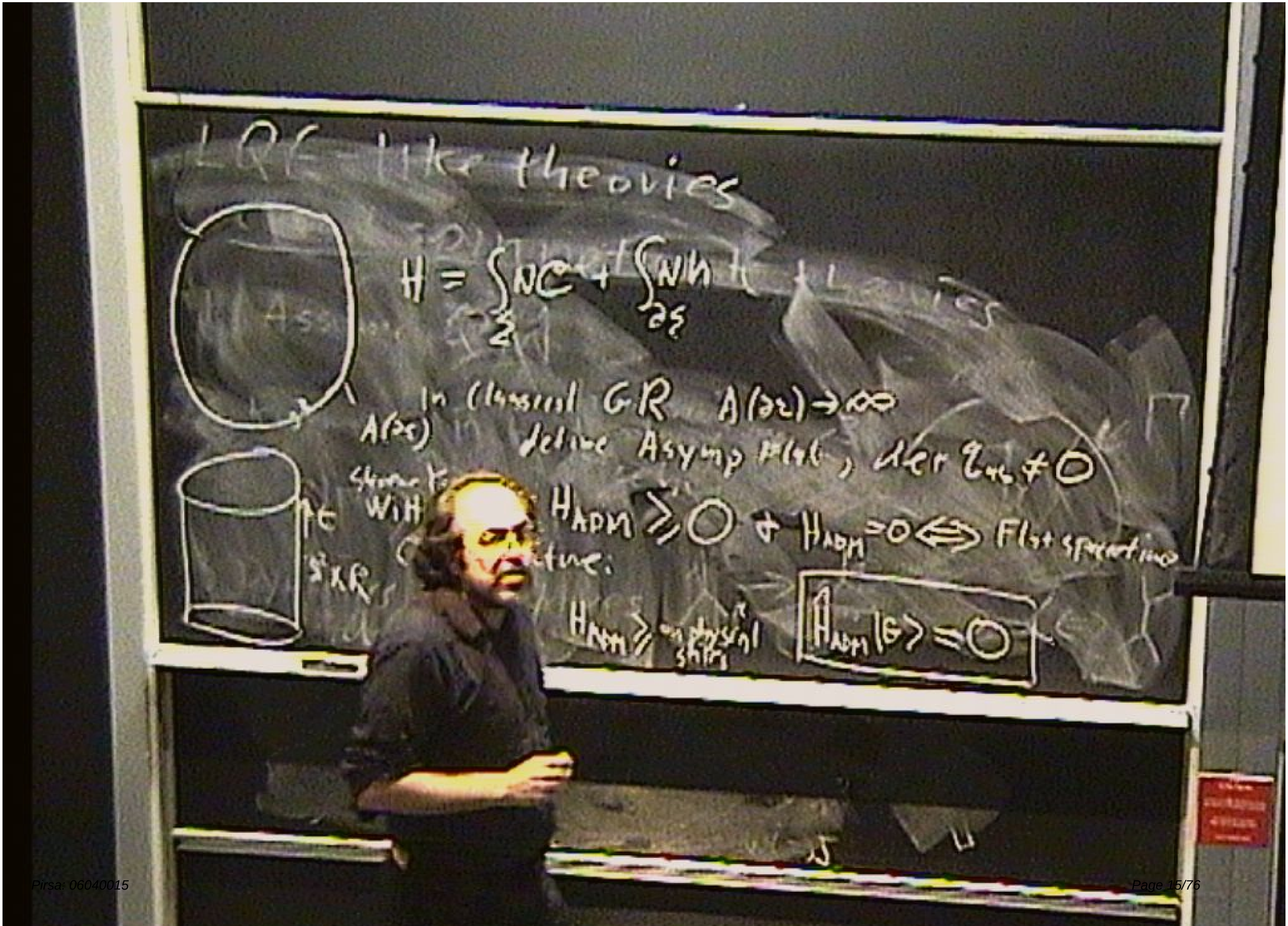
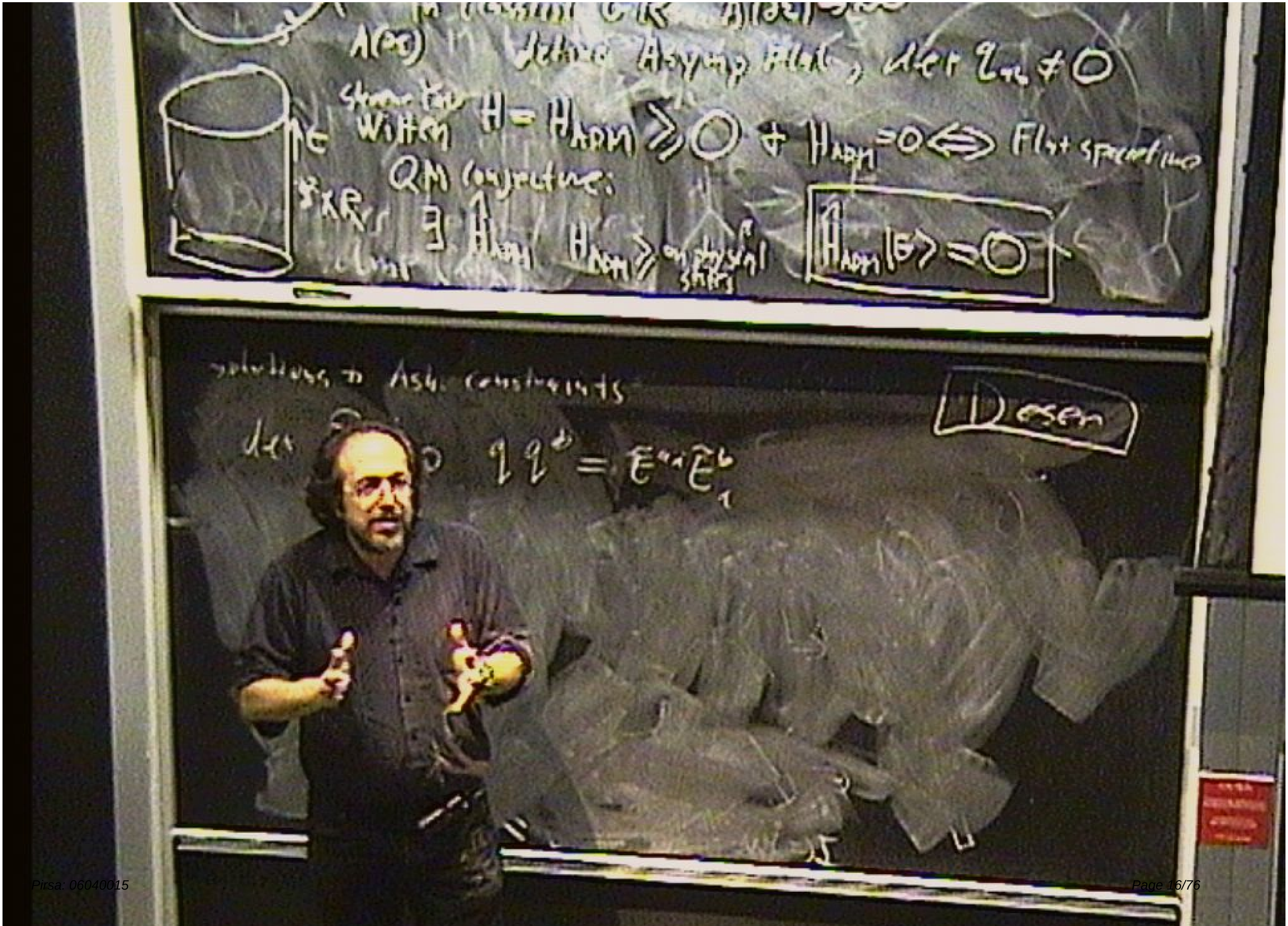

In Classical GR
Asymp Flat
QM conjecture:
Flat spacetime
Configuration space
G-connection on M
Gauge X Diff(M)
G = SU(2) X H
the edges

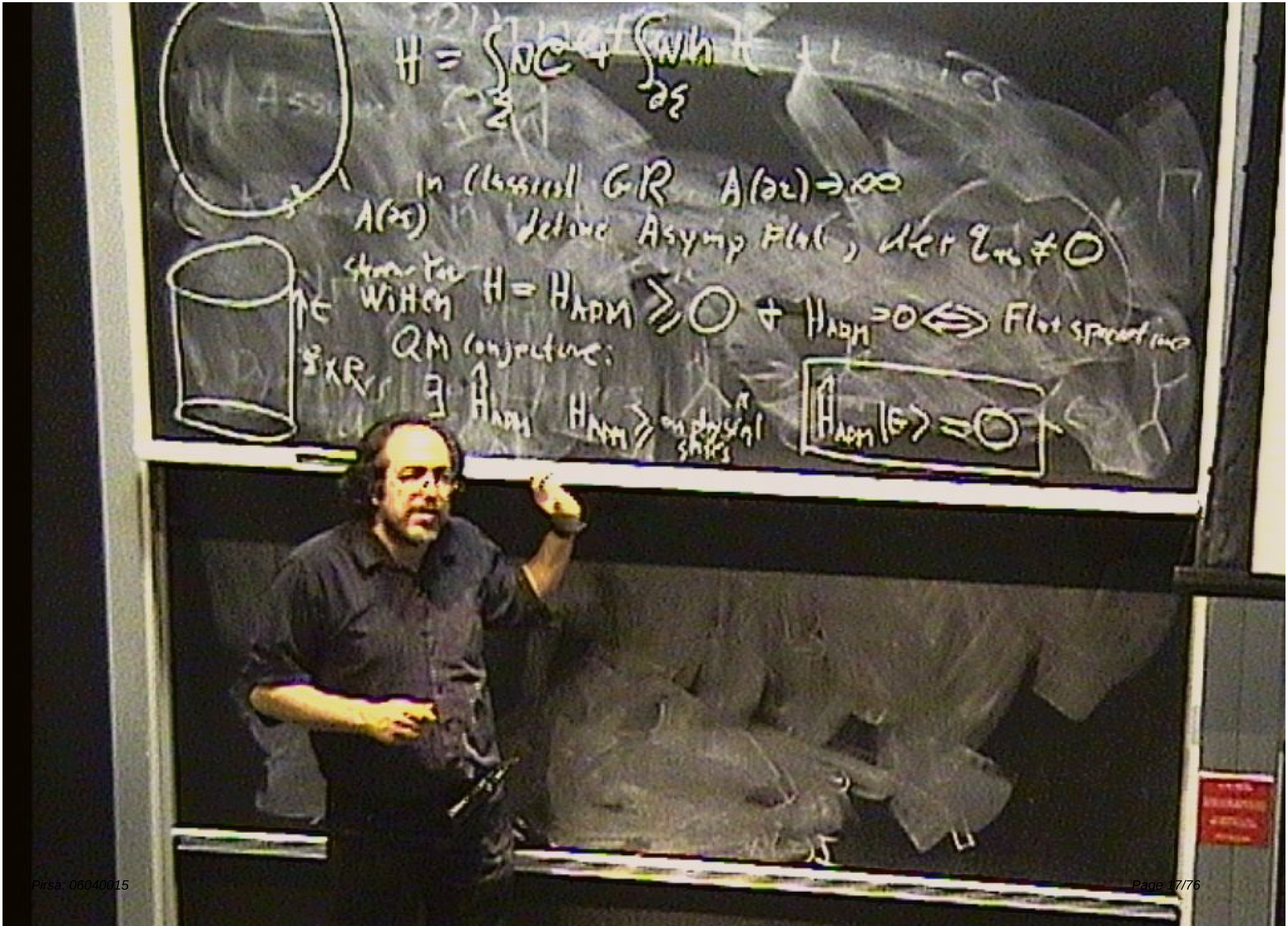

In Classical GR
Asymp Flat
Witten
QM conjecture:
Flat spacetime
solutions to Ash. constraints

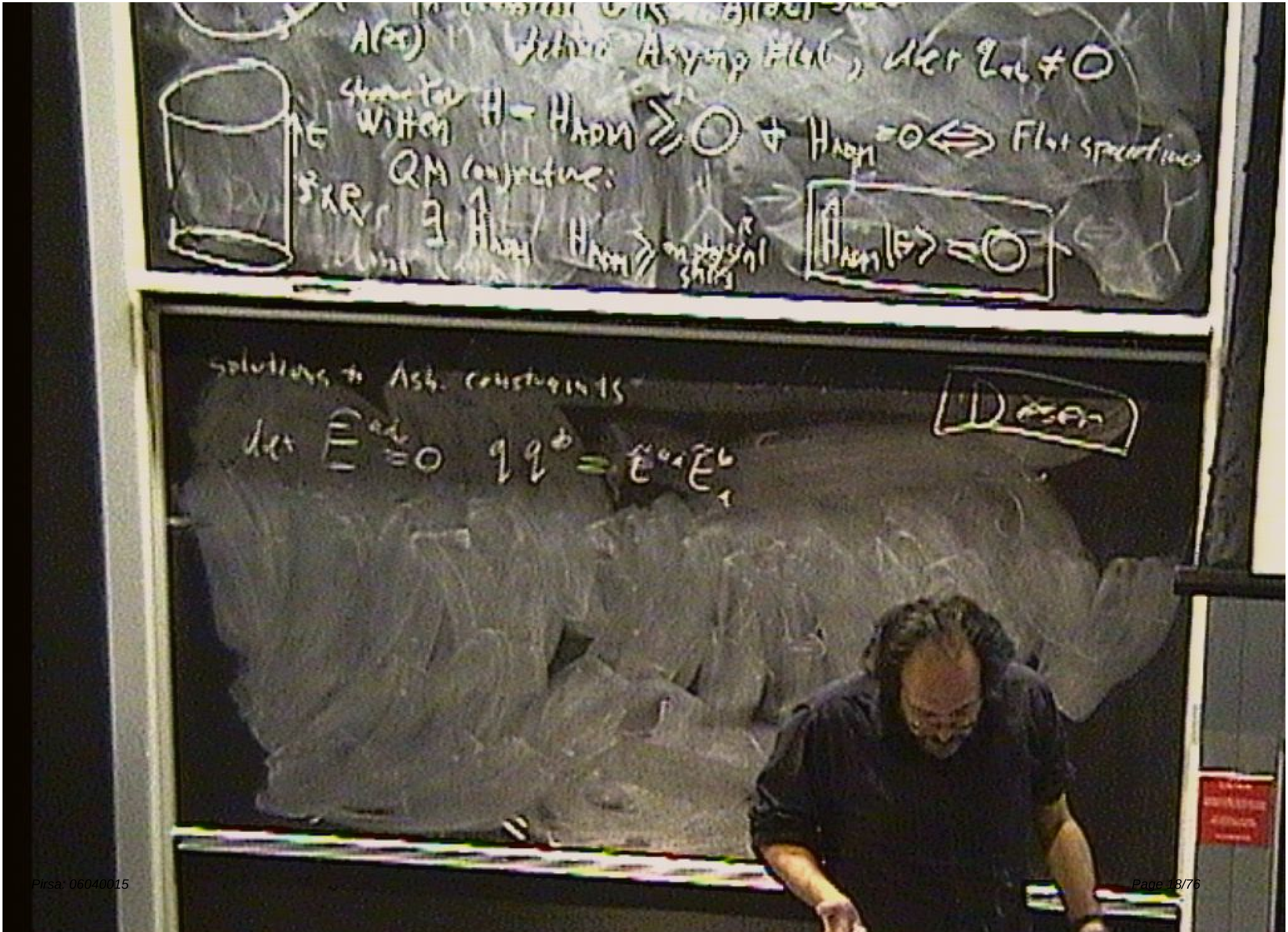

in Classical GR
Asymp Flat
Witten H = H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime
QM conjecture:
H_ADM |G⟩ = 0
solutions to Ash. constraints
Deser
det E = 0

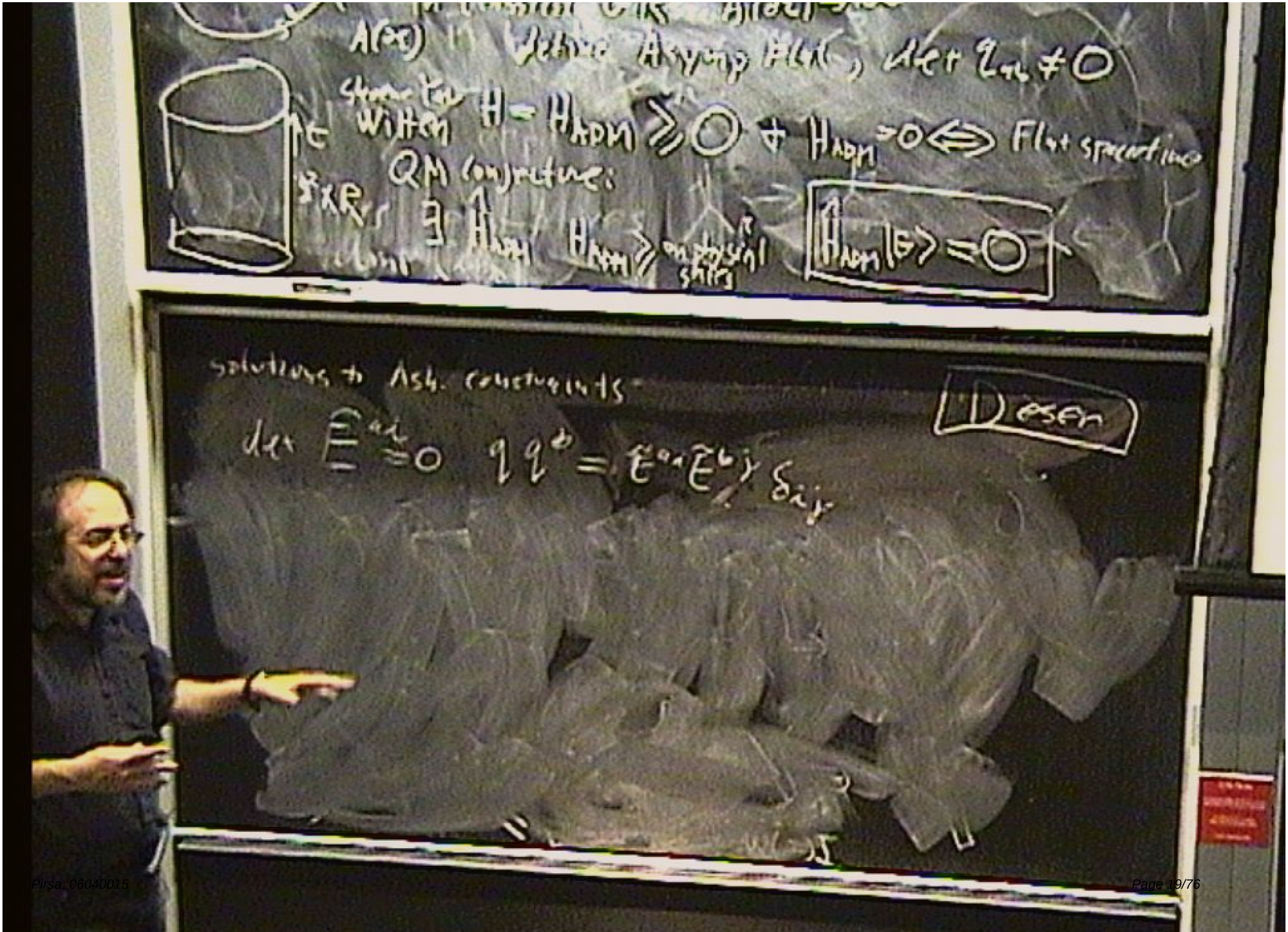


theories
H = ∫NC + ∫Nh
in Classical GR A(∂Σ)→∞
define Asymp flat
Flat spacetime


Asymp Flat , det q ≠ 0
Witten H = H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime
QM conjecture:
∃ Ĥ_ADM H_ADM ≥ 0 on physical states
Ĥ_ADM |G> = 0
solutions to Ash. constraints
Deser


In Classical GR
Asymp Flat
QM conjecture:
Flat spacetime


Witten
QM conjecture:
Flat spacetime
solutions to Ash. constraints


QM conjecture:
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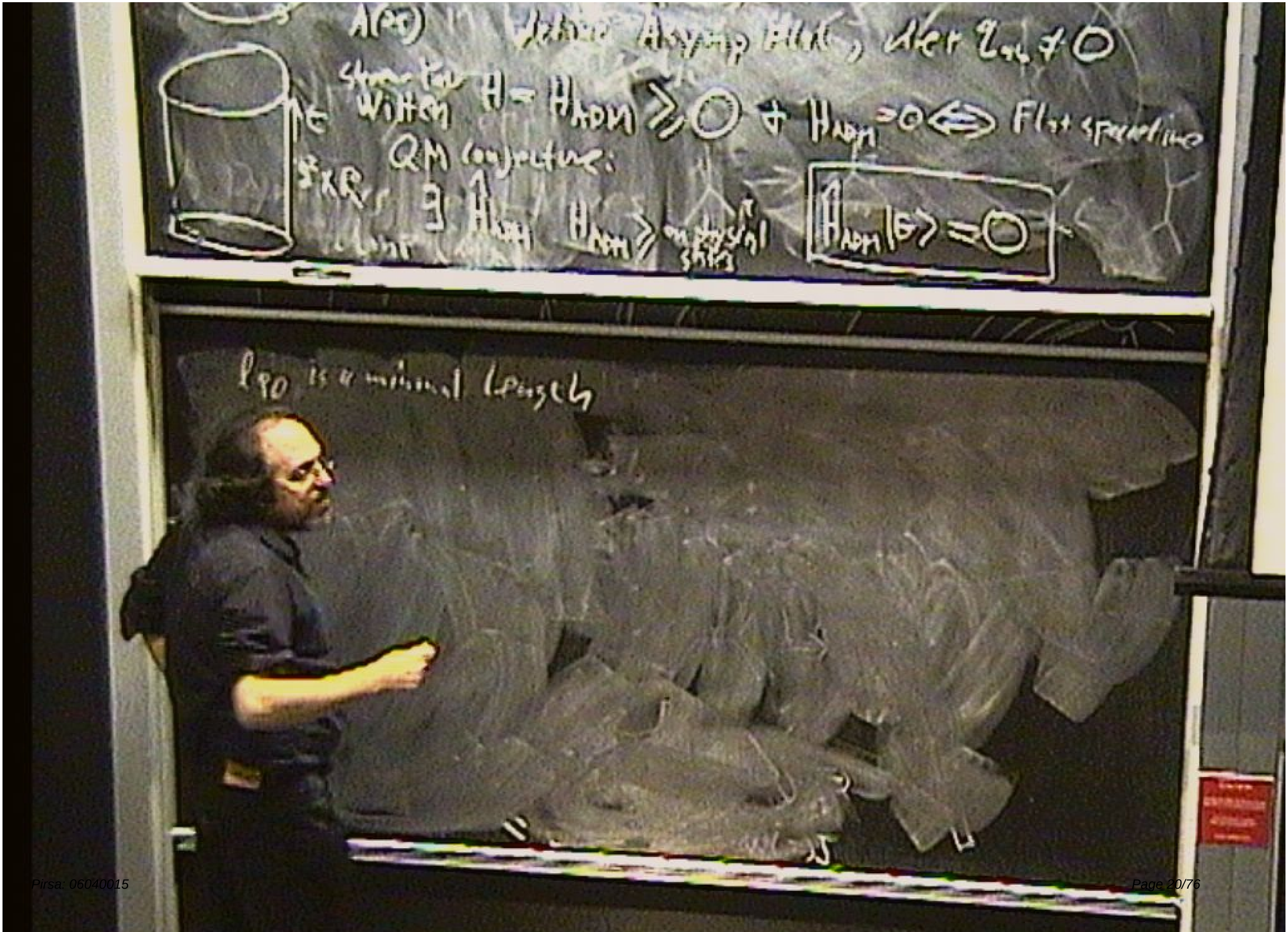
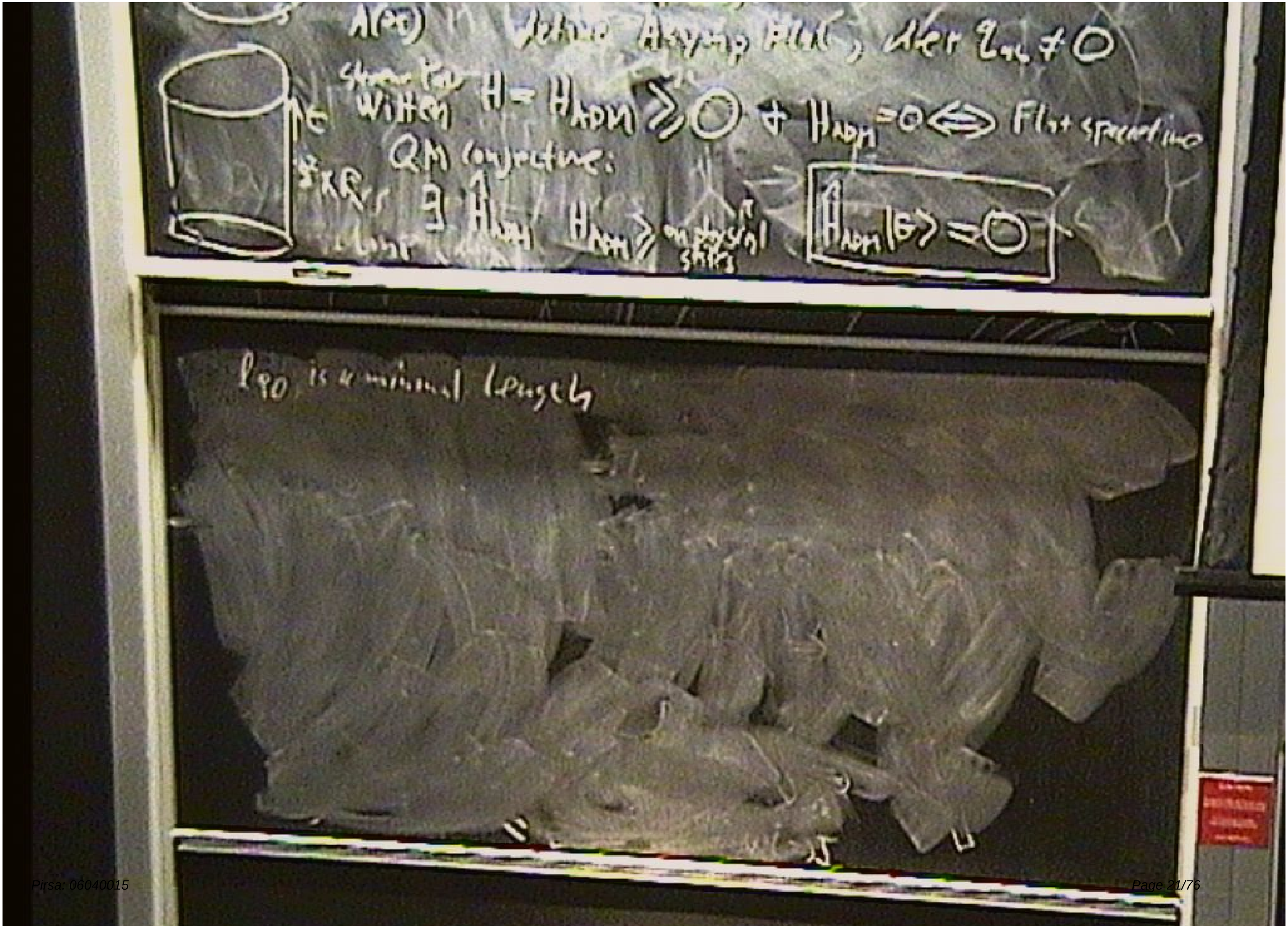
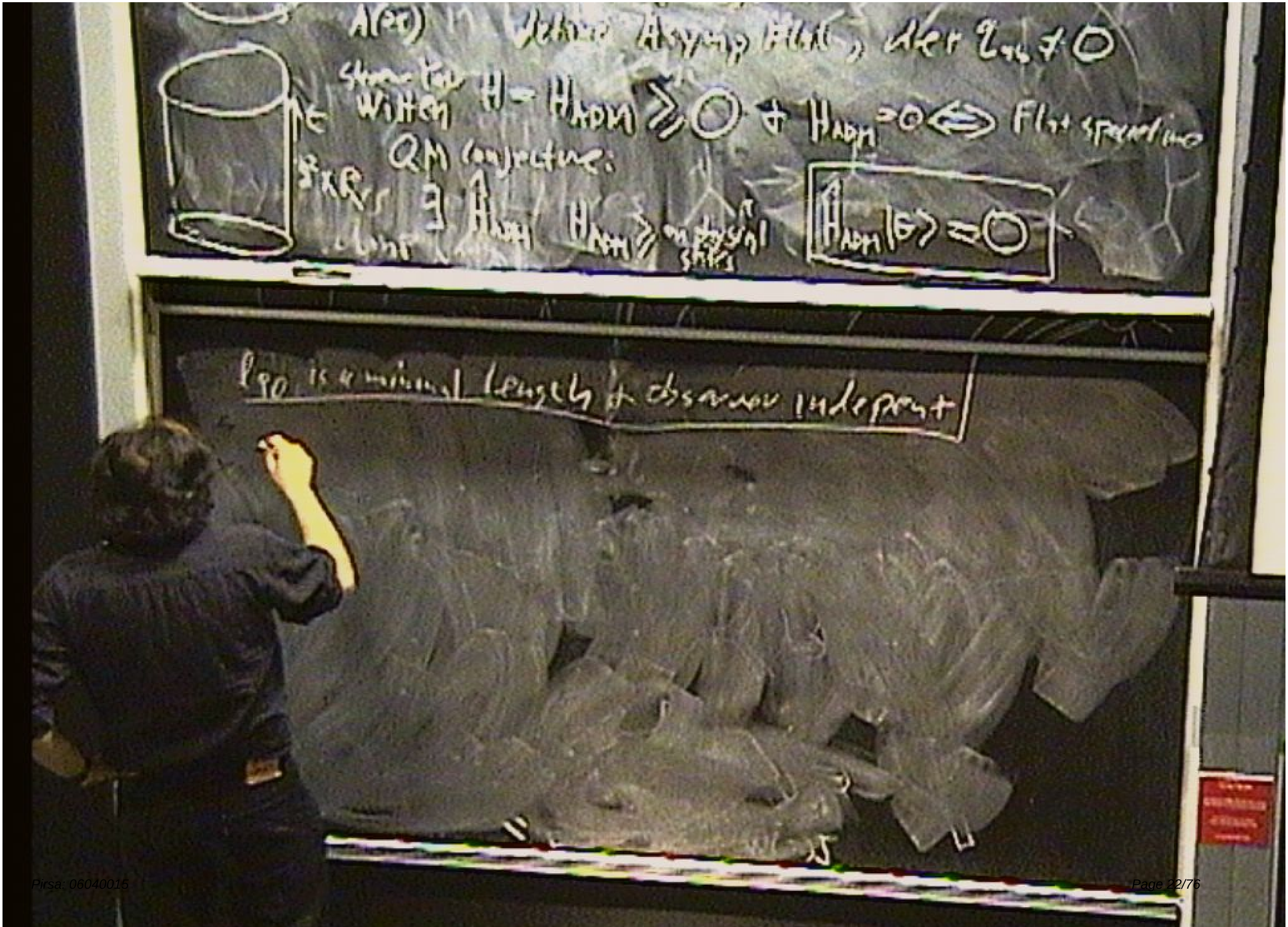
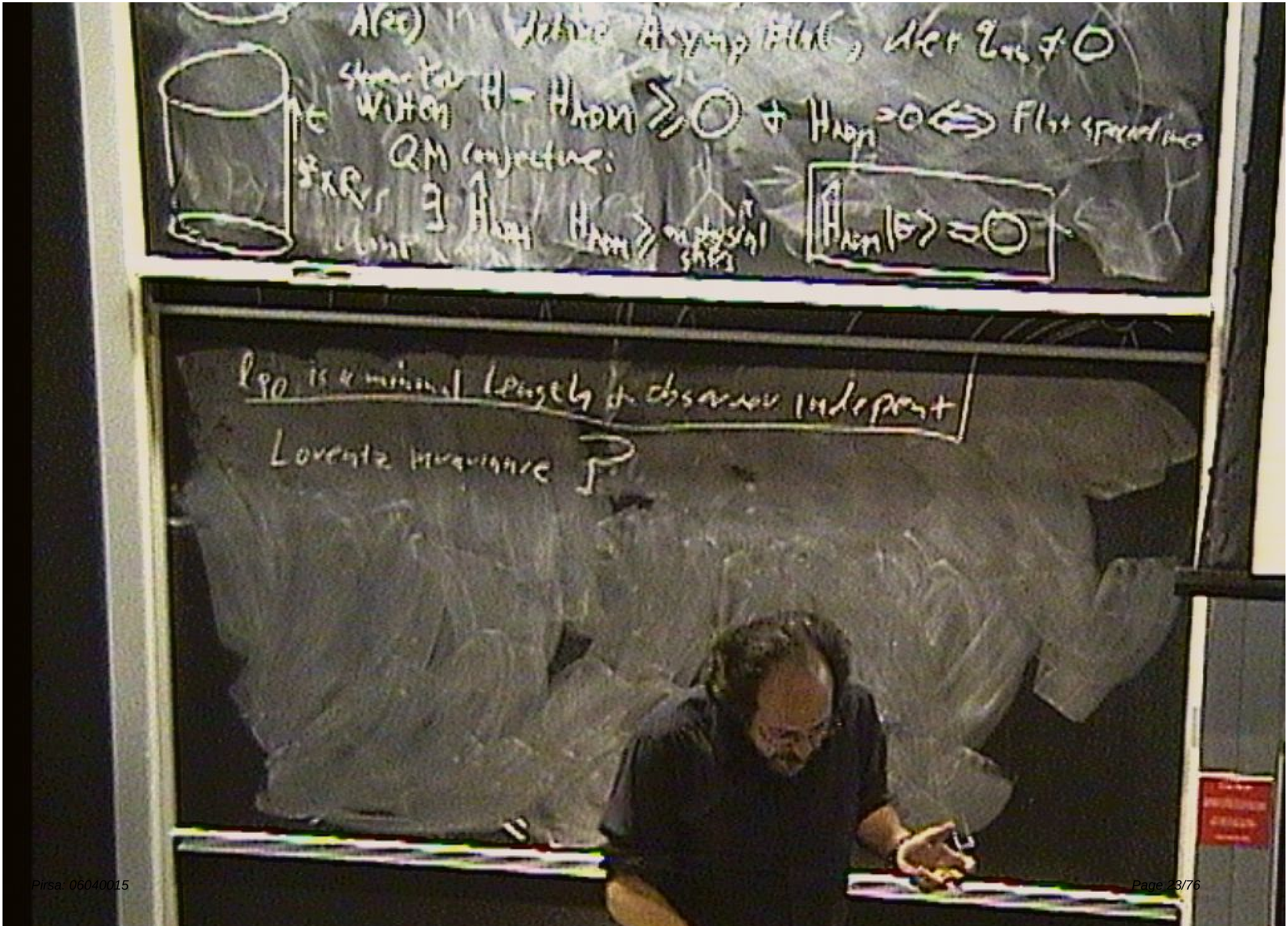
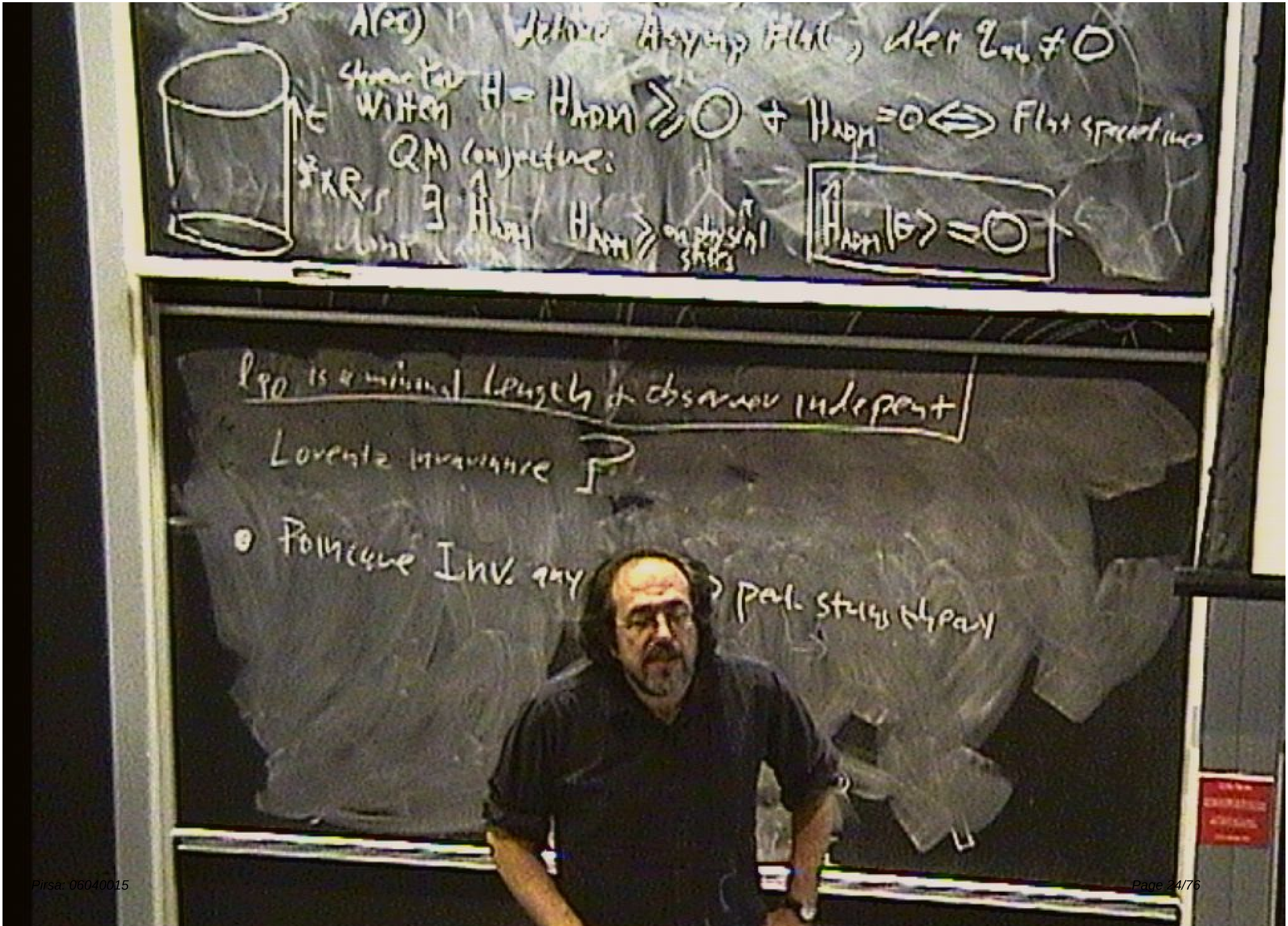
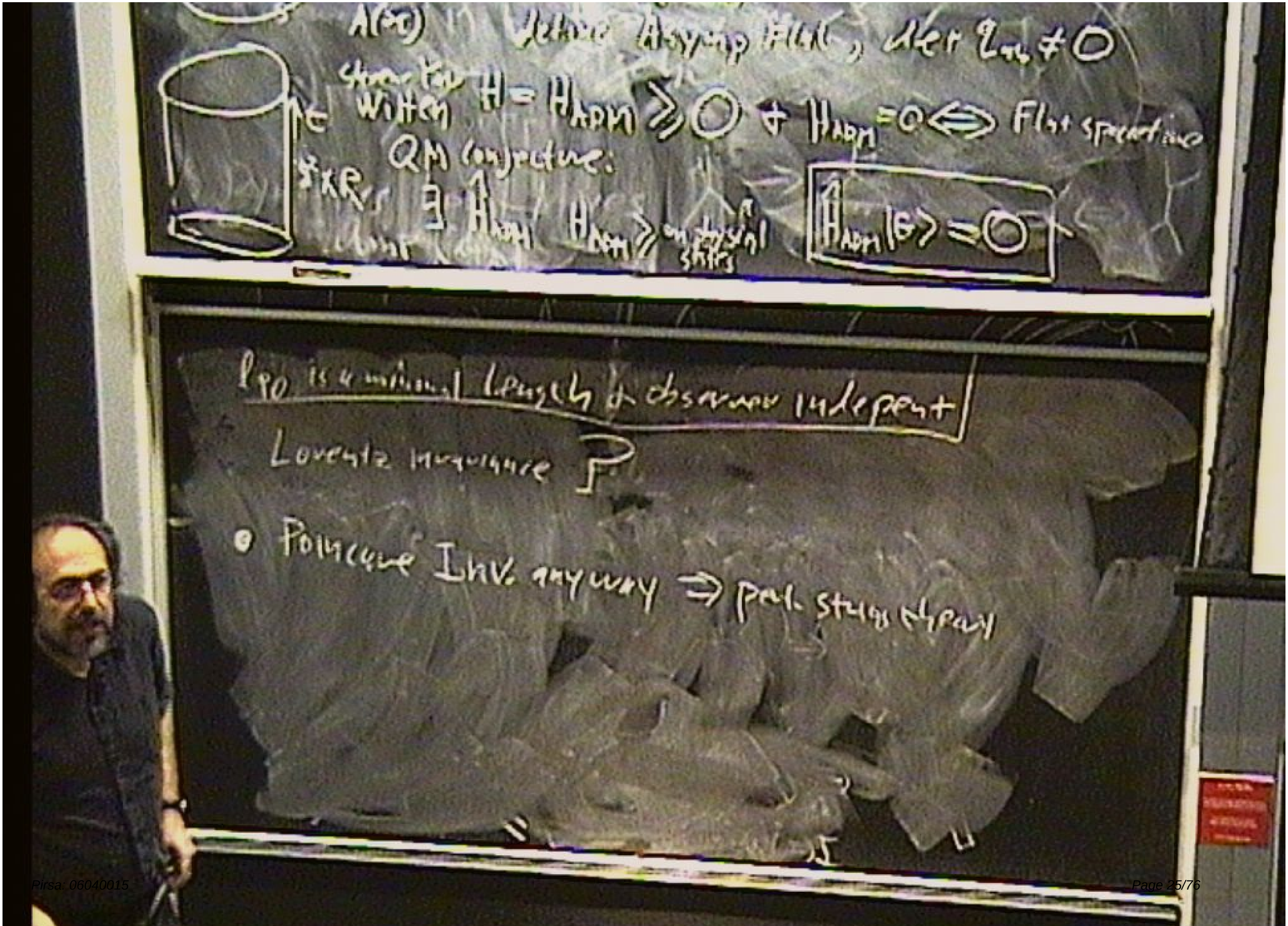

Witten
Flat spacetime
QM conjecture:
is a minimal length

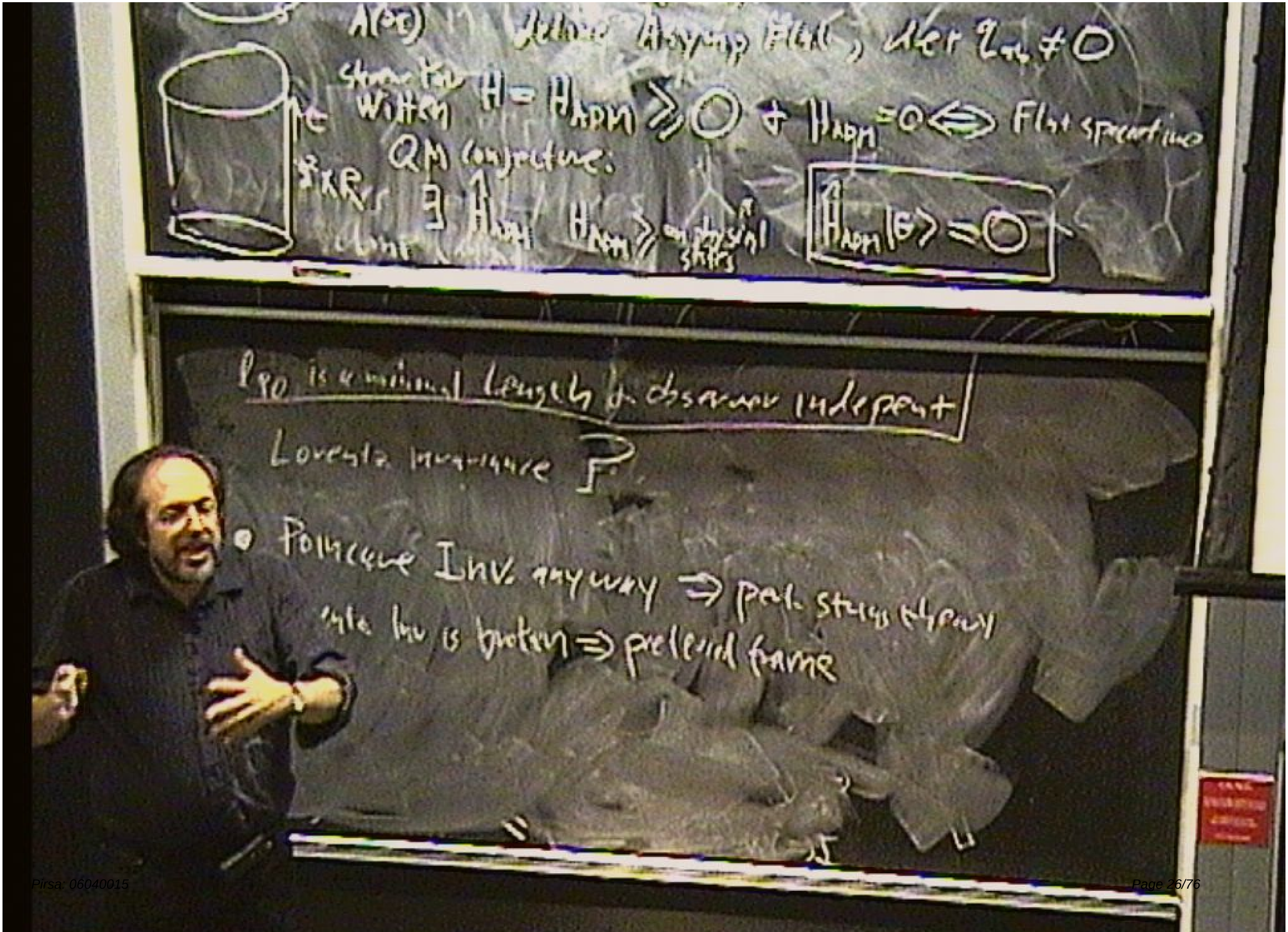

Witten H = H_ADM ≥ 0 + H_ADM = 0 ⟺ Flat spacetime
QM conjecture:
H_ADM |G> = 0
l_p is a minimal length

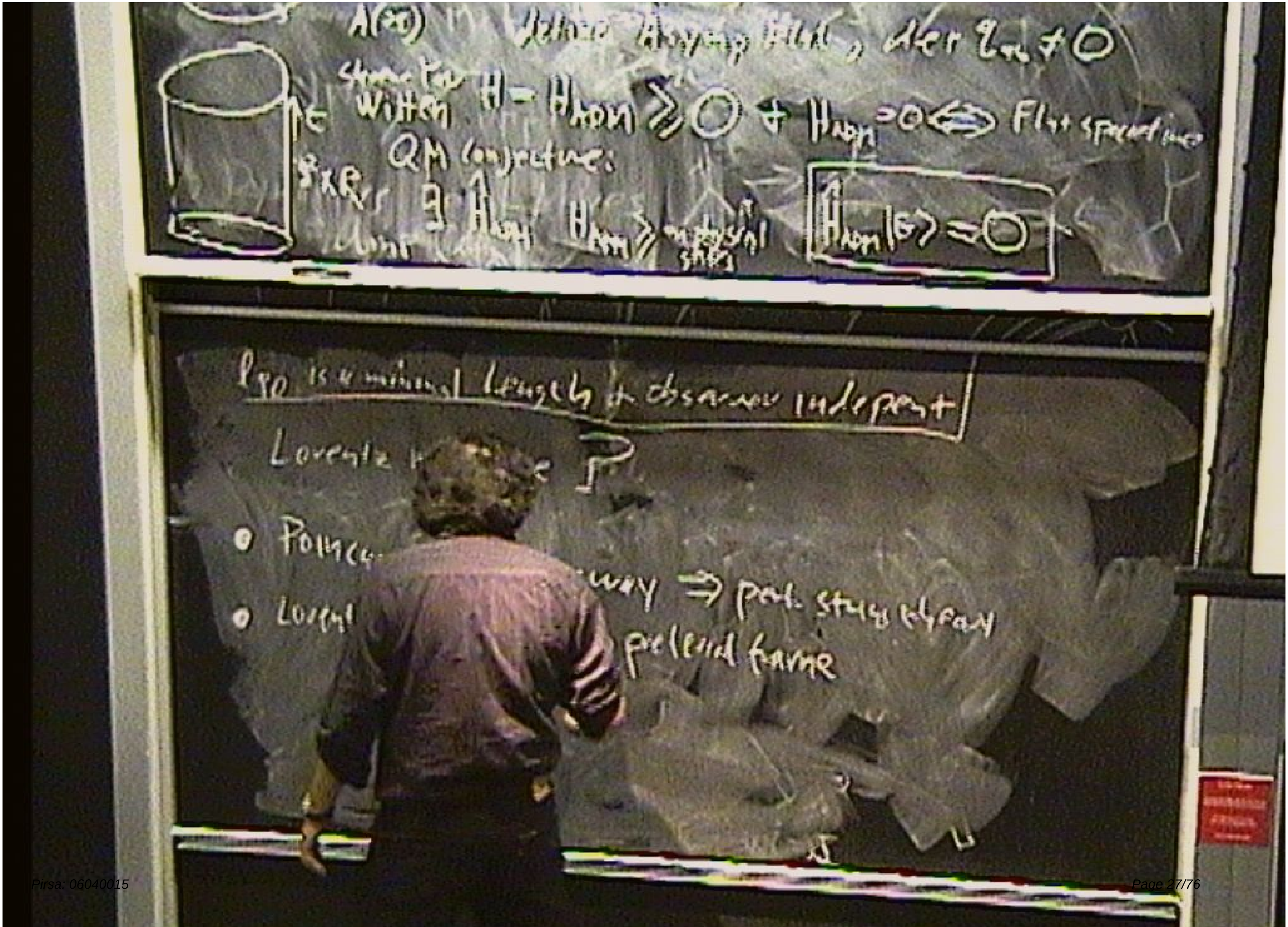

Witten
QM conjecture:
is a minimal length for observer independent

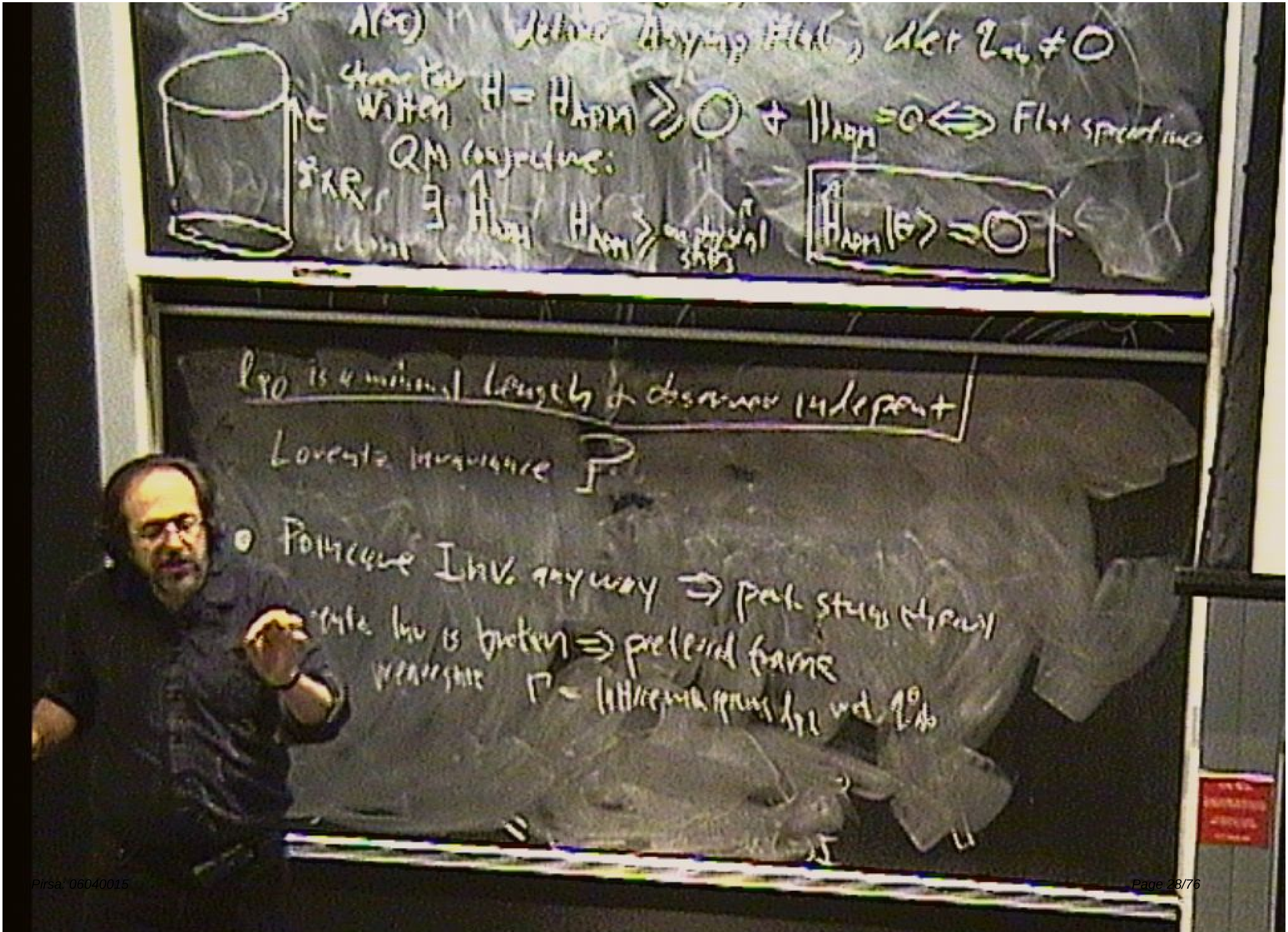

Witten
QM conjecture:
Flat spacetime
lpl is a minimal length for observer independent
Lorentz invariance ?

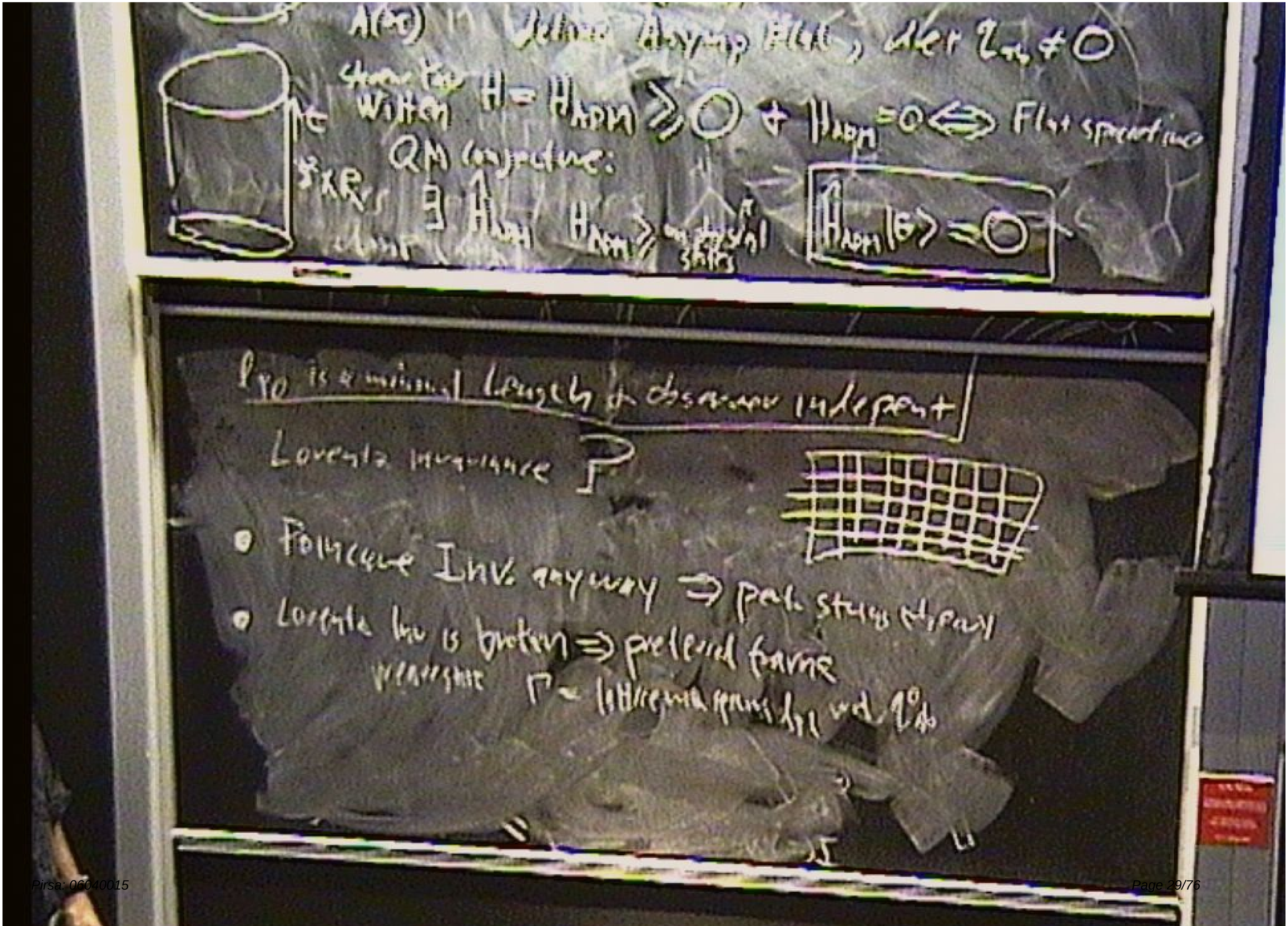

QM conjecture:
lqg is a minimal length & observer independent
Lorentz invariance ?
Poincare Inv.

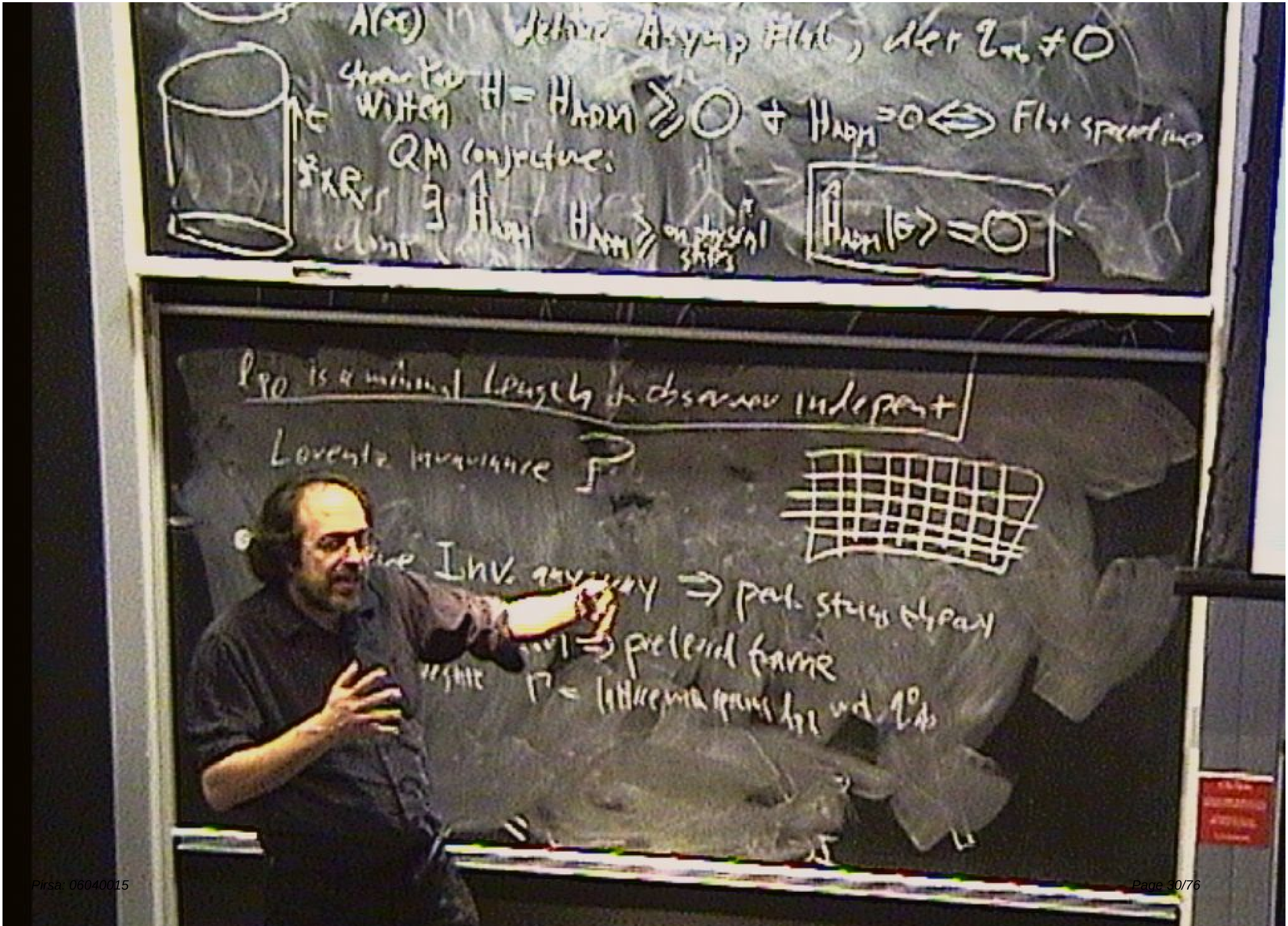

Witten H = H_ADM ≥ 0 & H_ADM = 0 ⟺ Flat spacetime
QM conjecture:
H_ADM |G> = 0
l_PL is a minimal length & observer independent
Lorentz invariance ?
Poincare Inv. anyway ⇒ pert. strings theory


Asymp Flat, det
Witten
Flat spacetime
QM conjecture:
is a minimal length for observer independent
Lorentz invariance ?
Poincare Inv. anyway ⇒
preferred frame


Witten
QM conjecture:
Lorentz


QM conjecture:
Flat spacetime
Lorentz invariance ?
Poincare Inv. anyway ⇒
preferred frame


Witten
QM conjecture:
Lorentz invariance ?
Poincare Inv. anyway
Lorentz Inv is broken ⇒ preferred frame


QM conjecture:
Lorentz invariance ?
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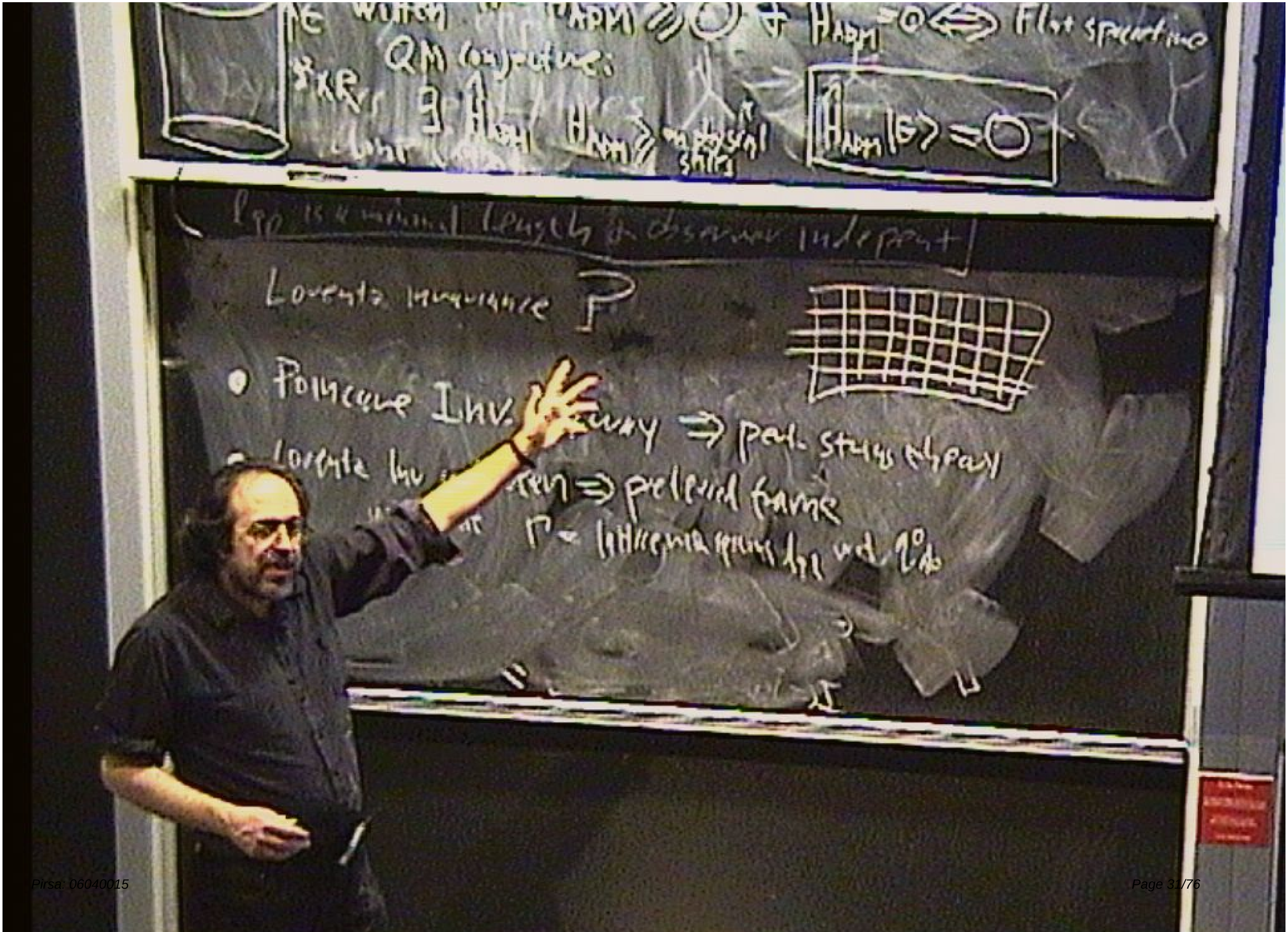
Flat spacetime
QM conjecture:
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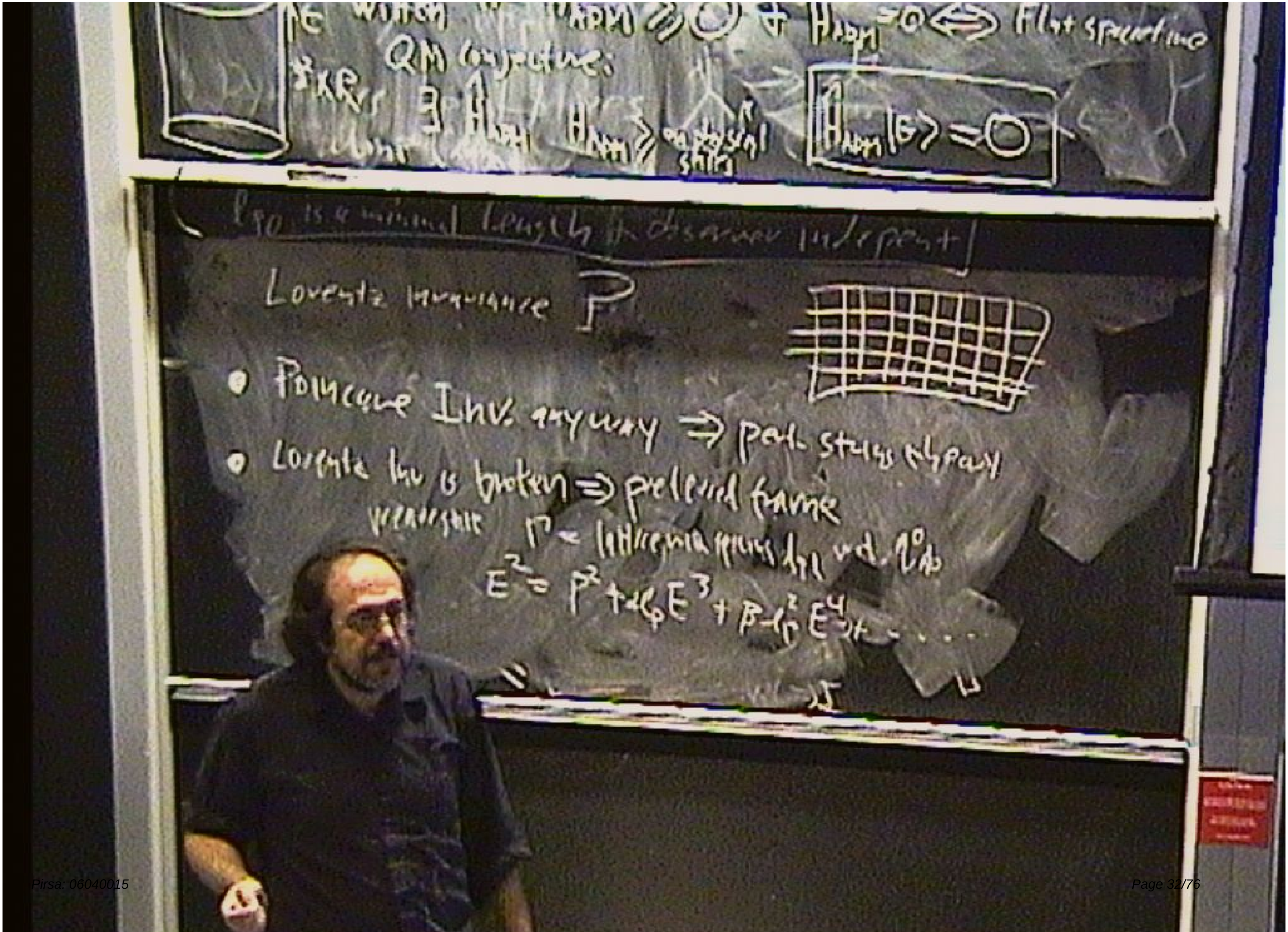
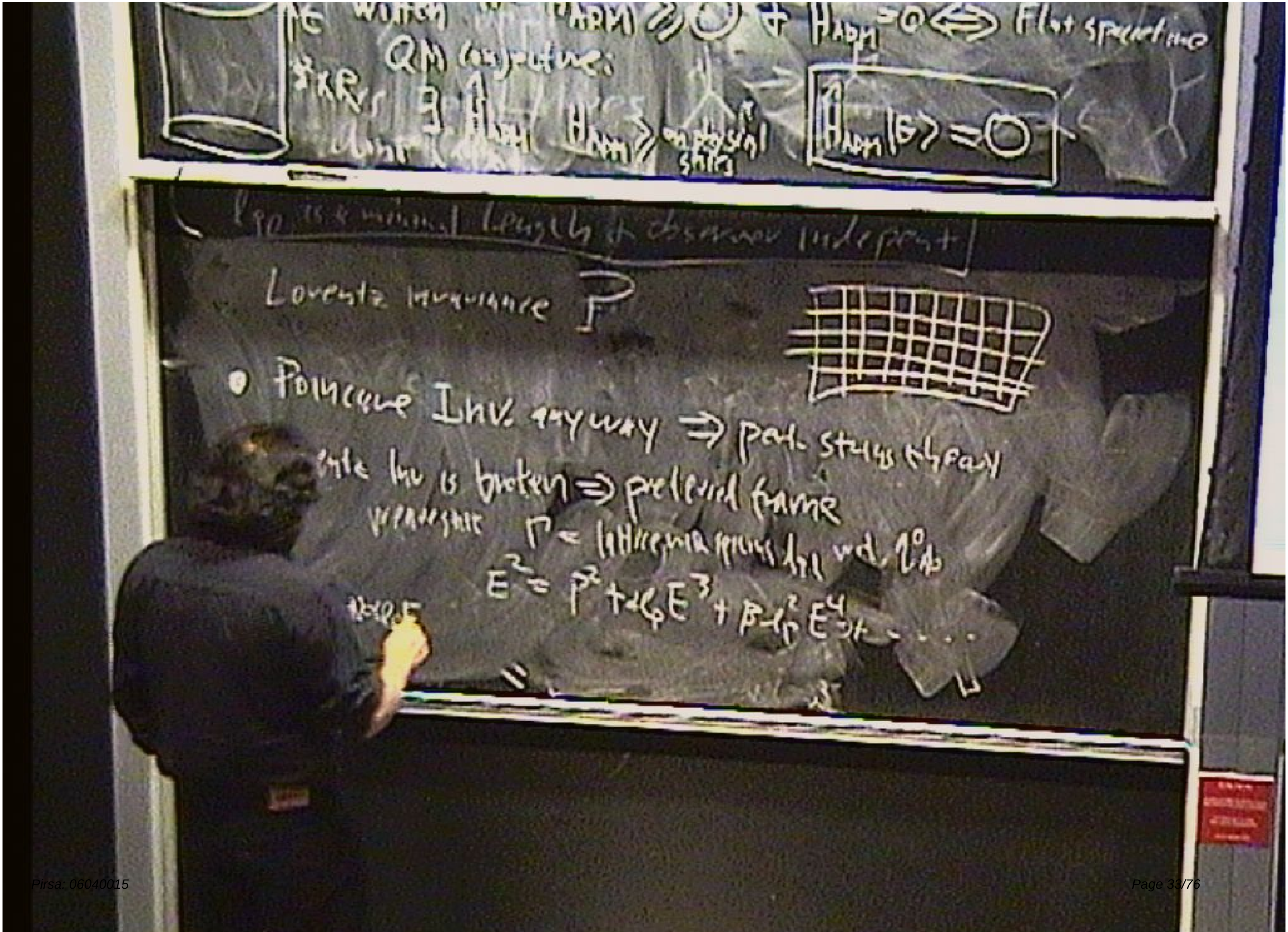

Flat spacetime
QM conjecture:
Lorentz invariance ?
Poincare Inv. anyway ⇒ pert. string theory
Lorentz Inv is broken ⇒ preferred frame
$E^2 = p^2 + \alpha l_p E^3 + \beta l_p^2 E^4 + \ldots$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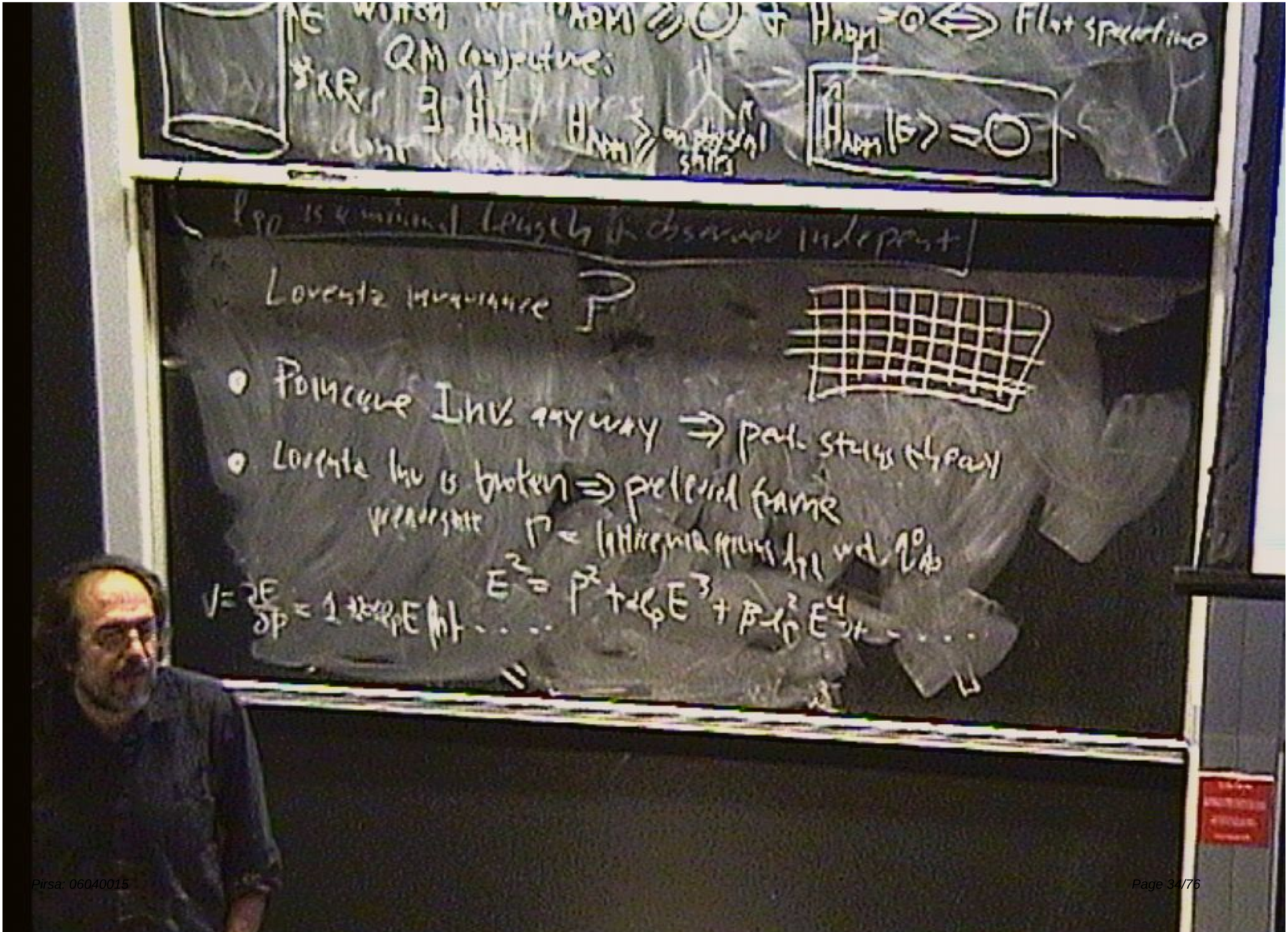
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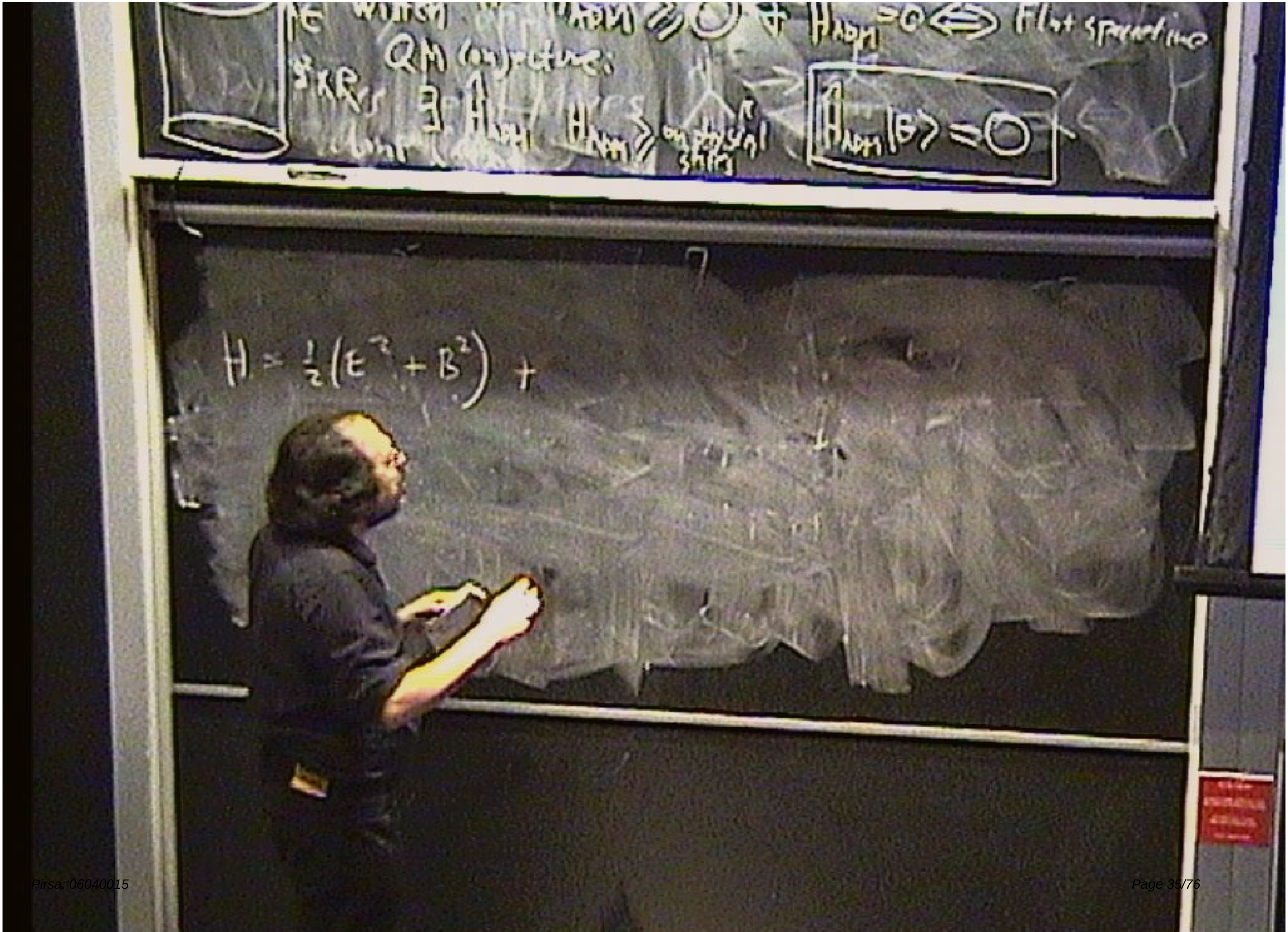
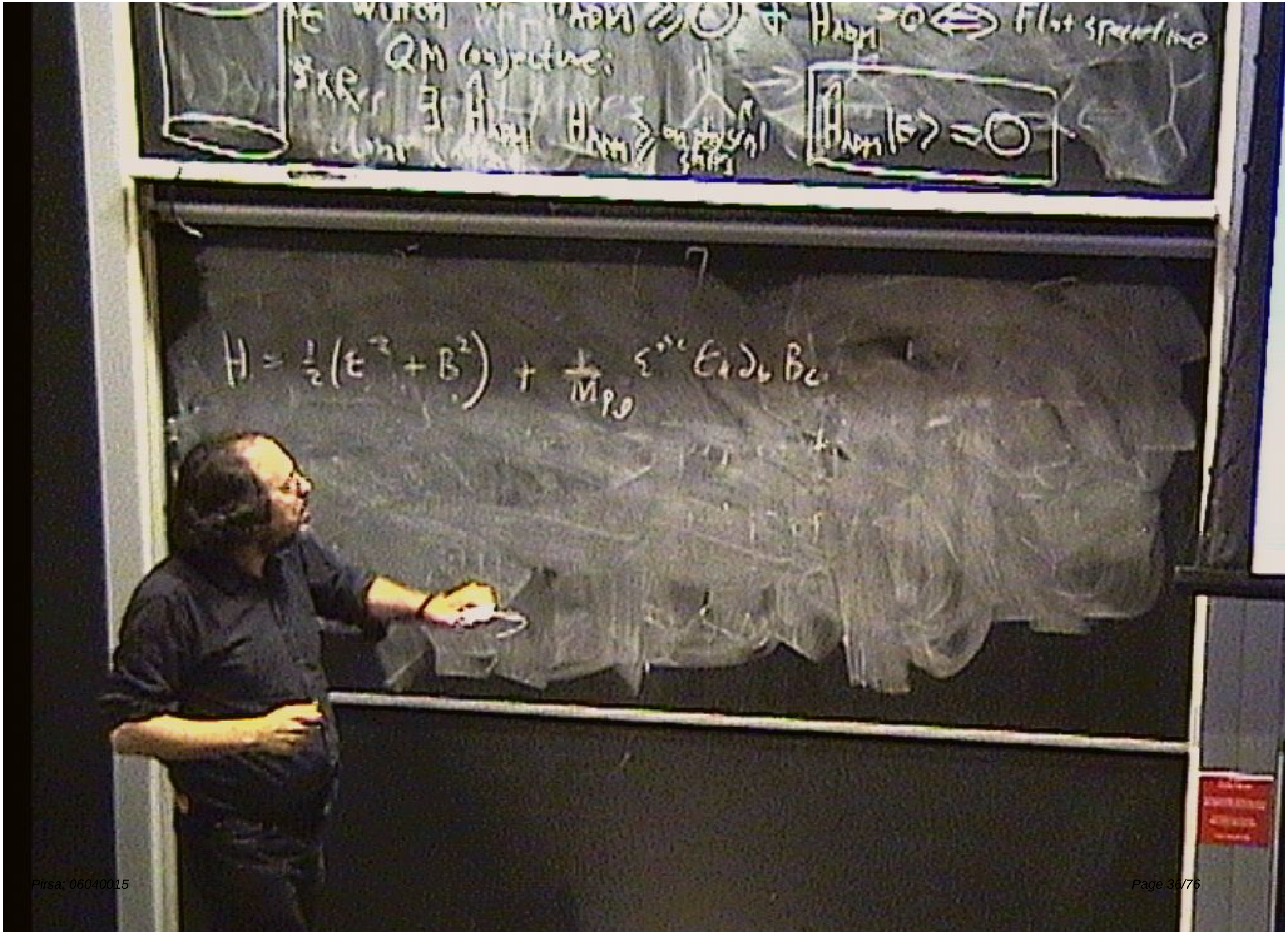
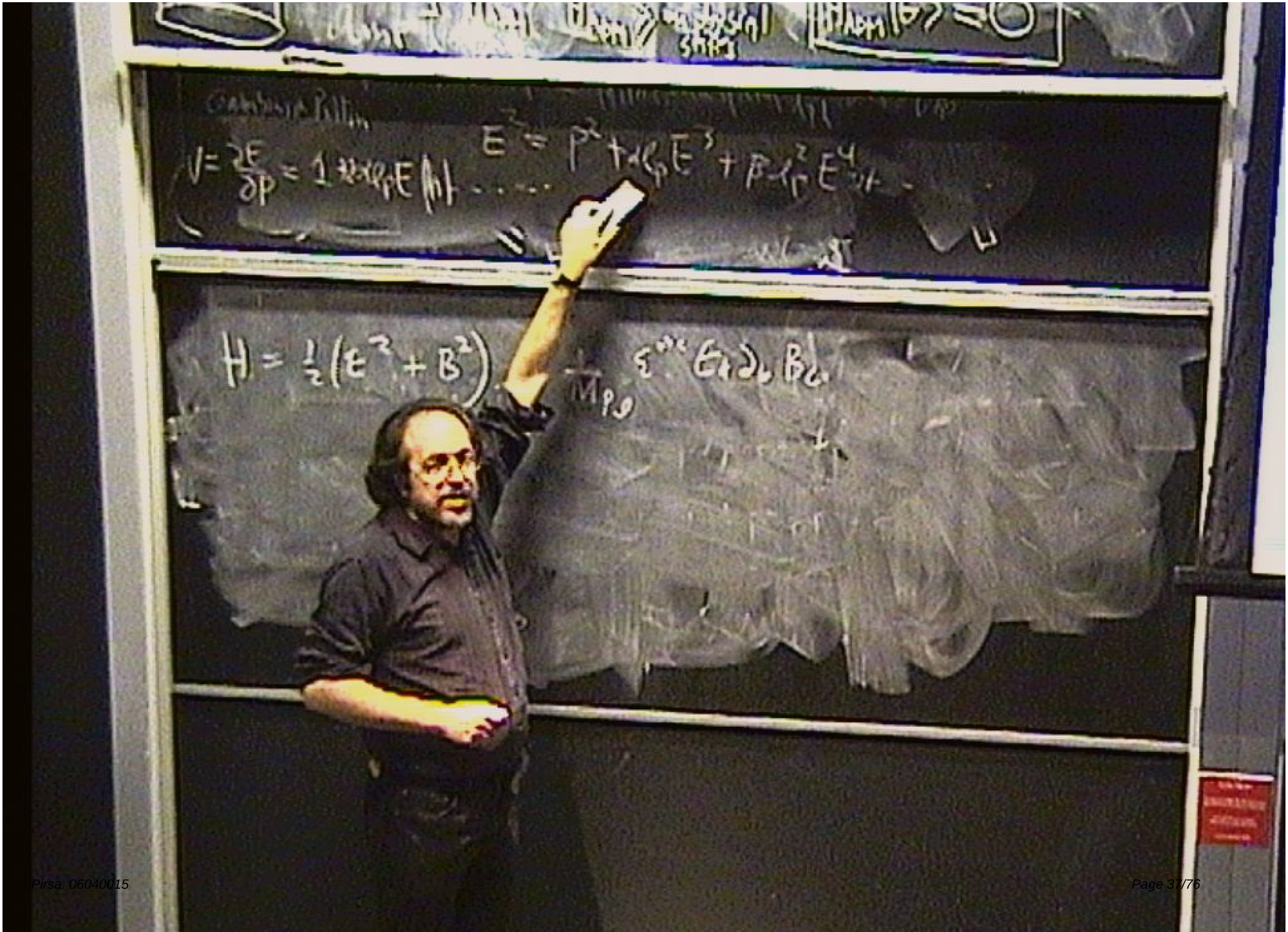
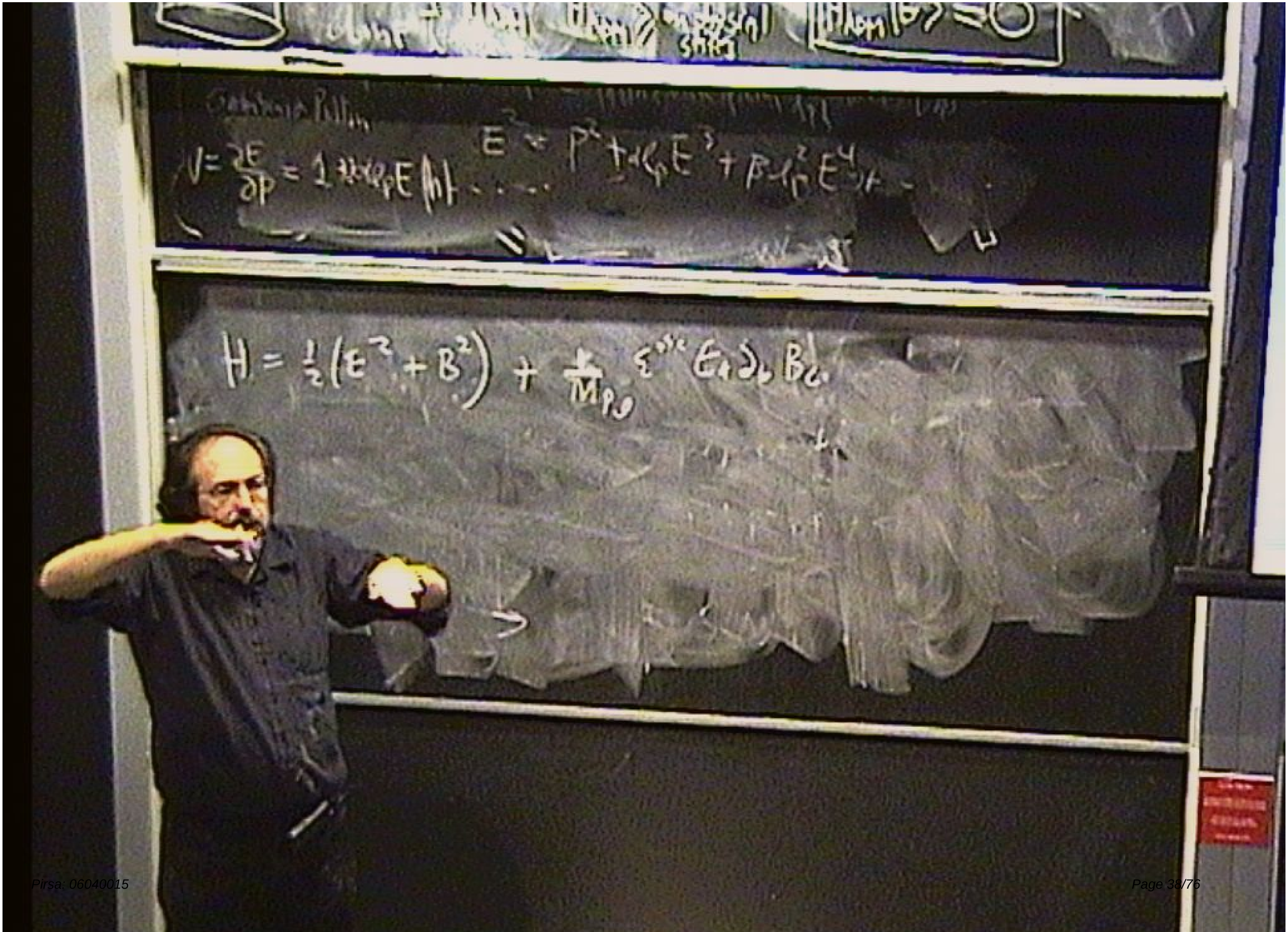
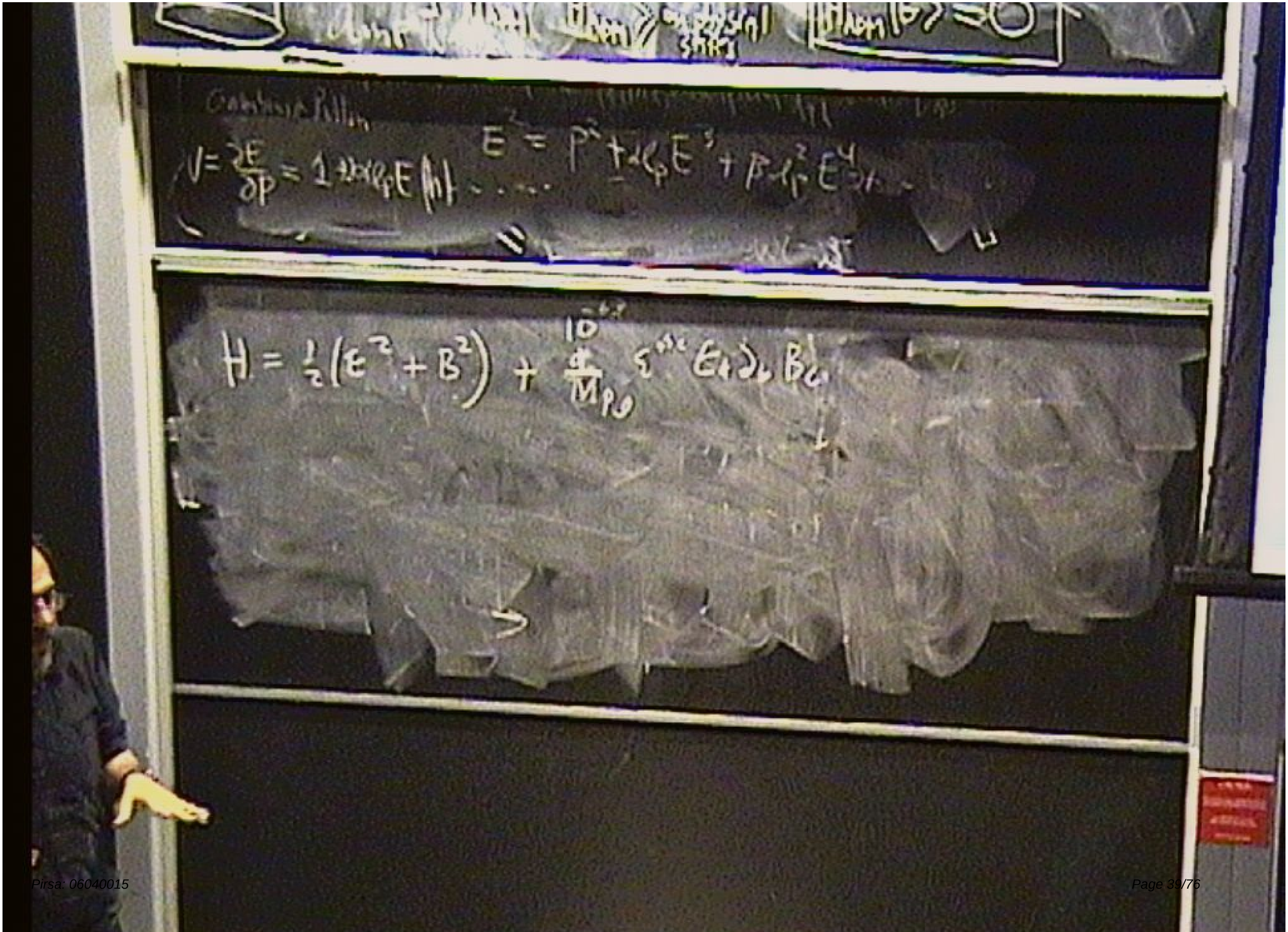
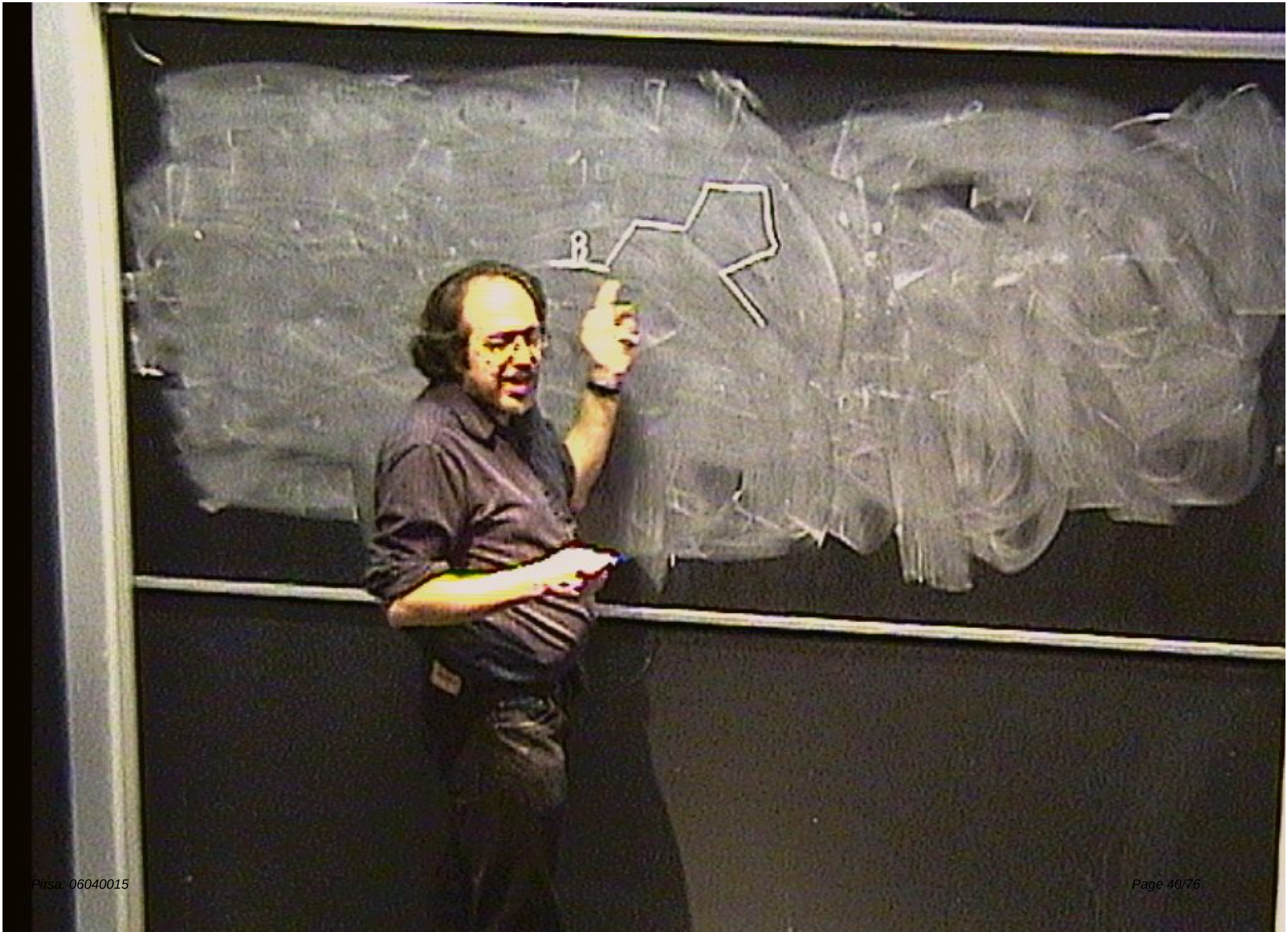

QM conjecture:
Flat spacetime
$H = \frac{1}{2}(E^2 + B^2) +$

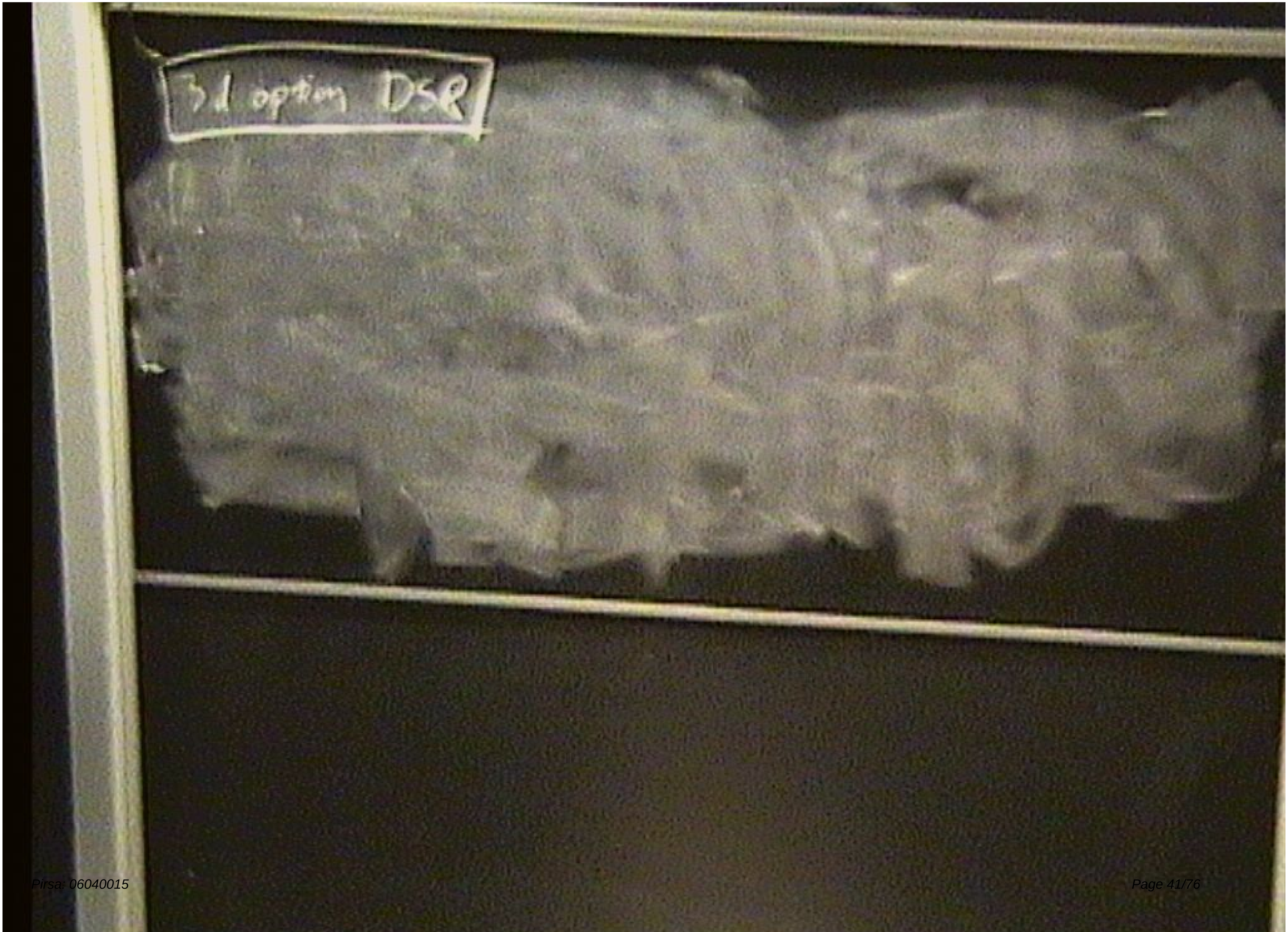

Flat spacetime
QM conjecture:
$H_{ADM}|E\rangle = 0$
$H = \frac{1}{2}(E^2 + B^2) + \frac{1}{M_{pl}}\varepsilon^{abc}E_a\partial_b B_c$

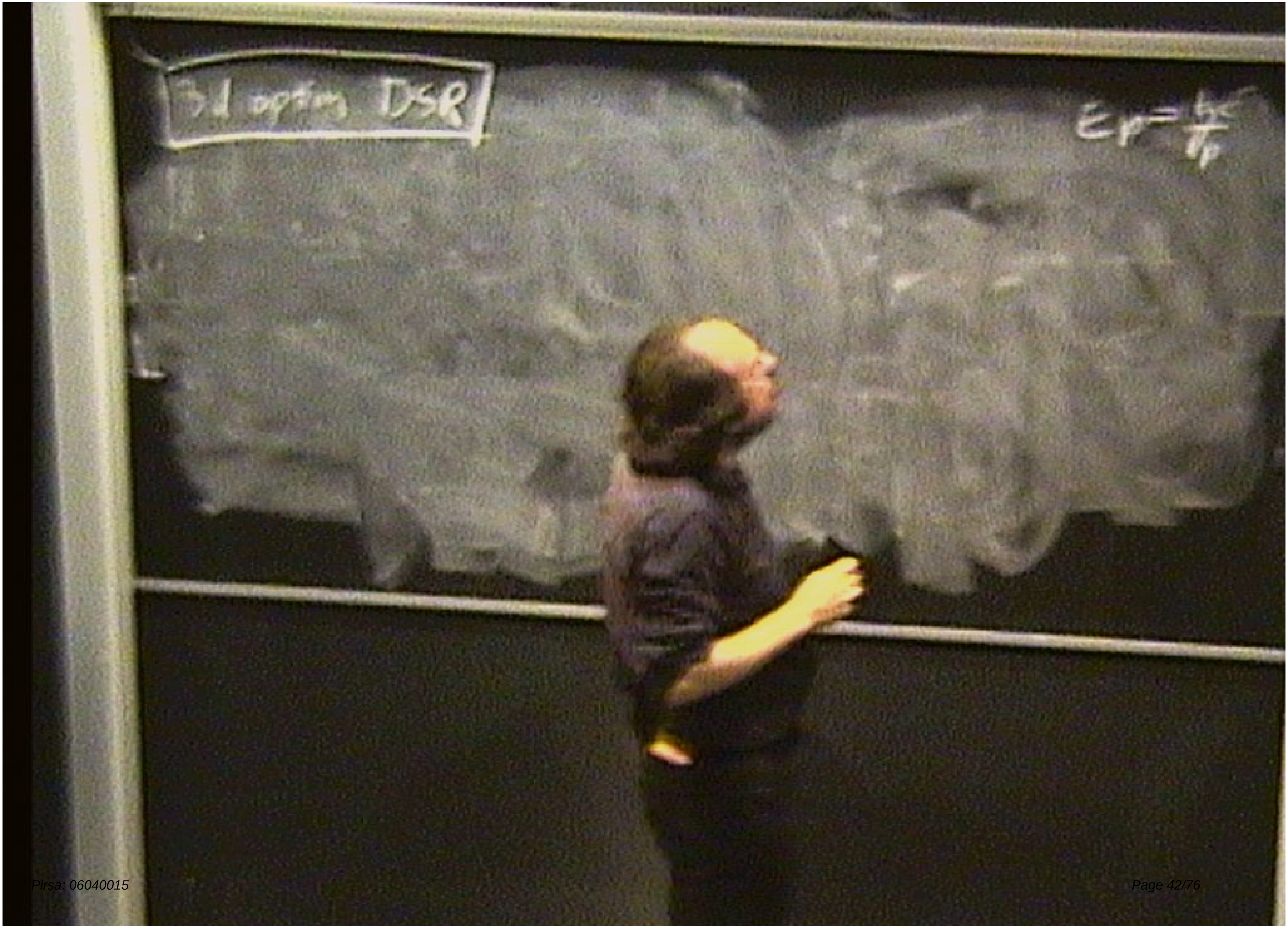

H = ½(E² + B²)

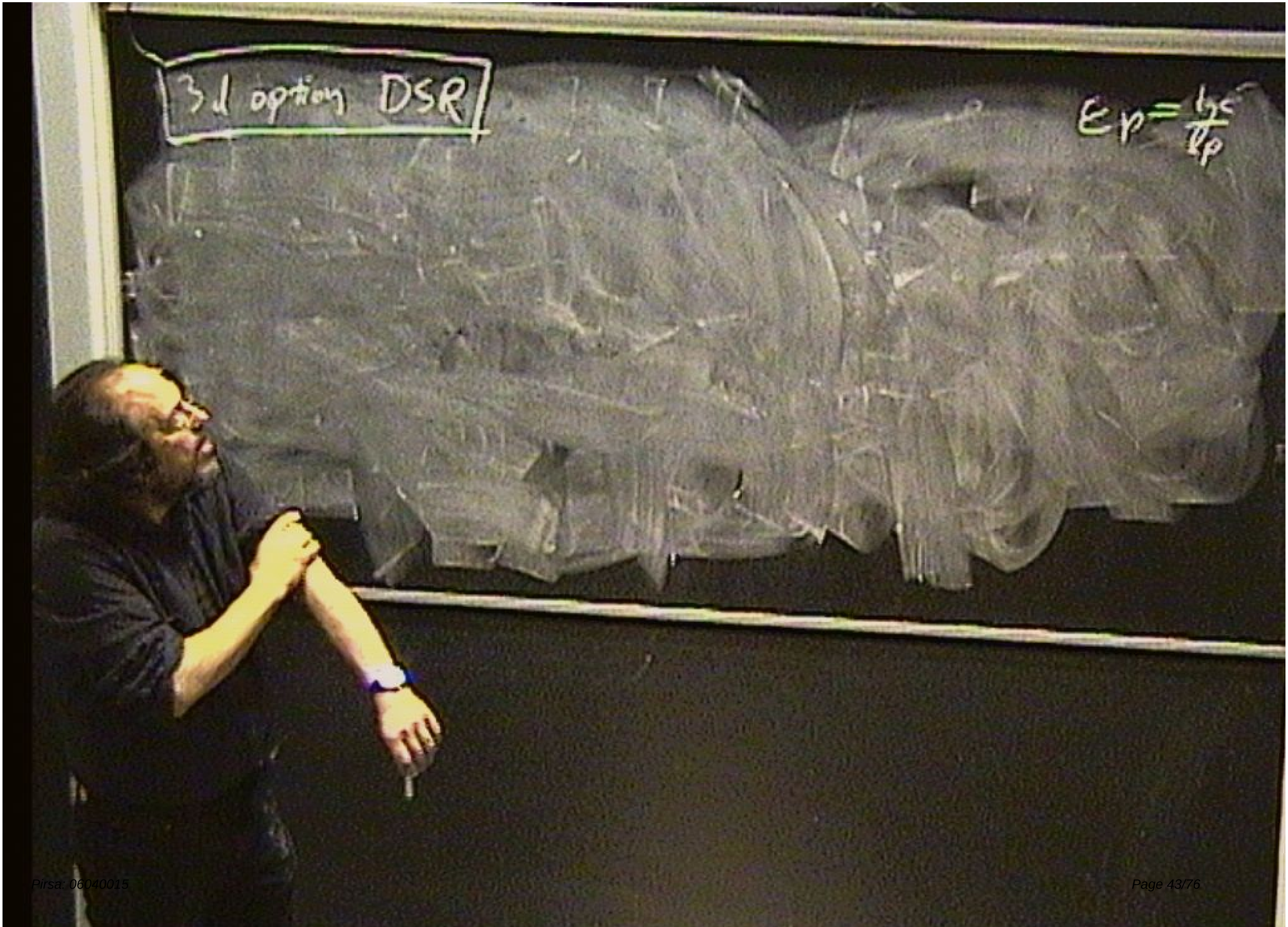

H = ½(E² + B²) + 1/M_Pl ε^abc E_a ∂_b B_c


E² = p² ± α l_p E³ + β α l_p² E⁴ + ...
v = ∂E/∂p = 1 ± ...
H = ½ (E² + B²) + α/M_Pl ε^abc E_a ∂_b B_c




3d option DSR


3d option DSR
Ep = hc / lp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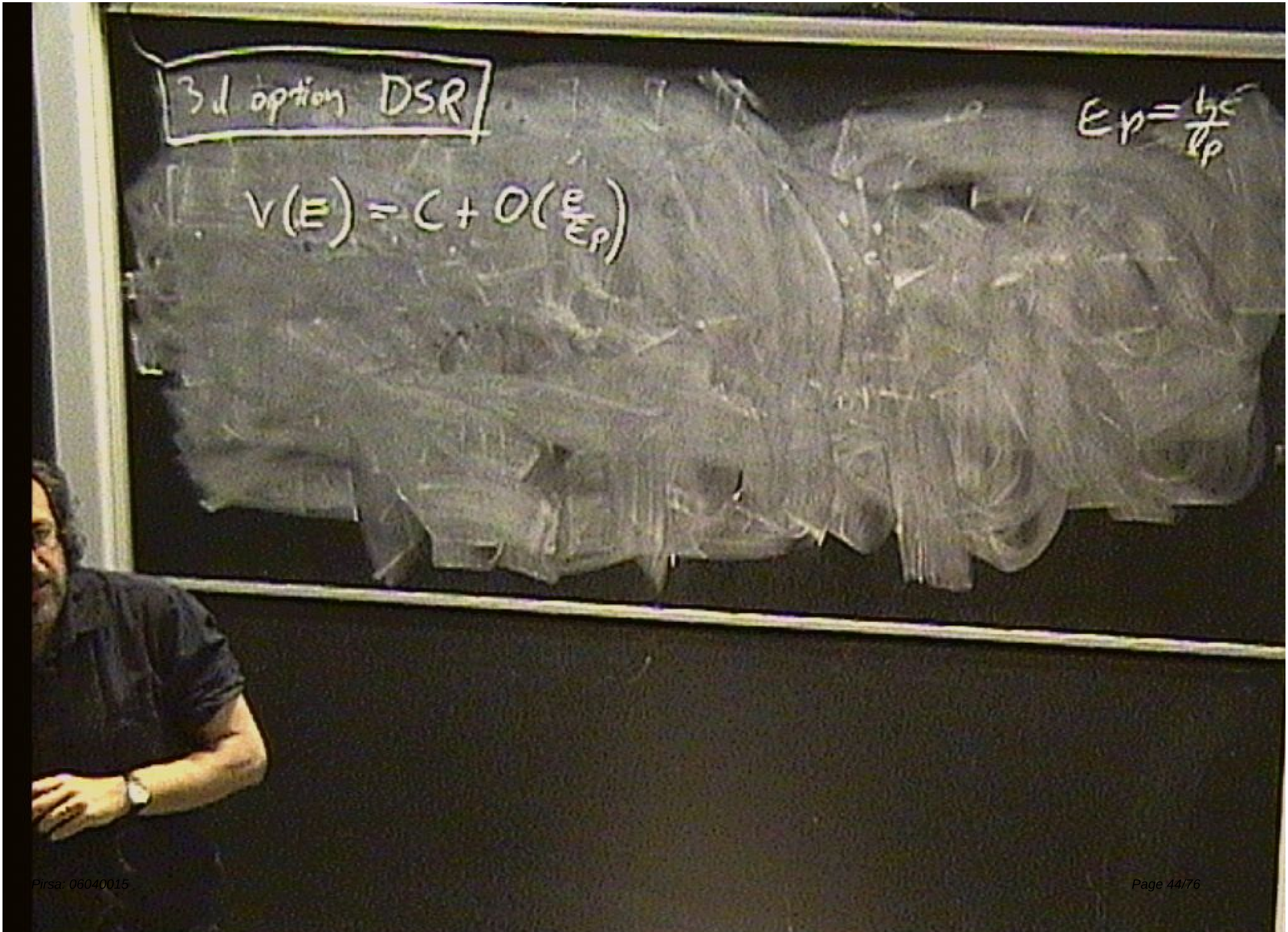
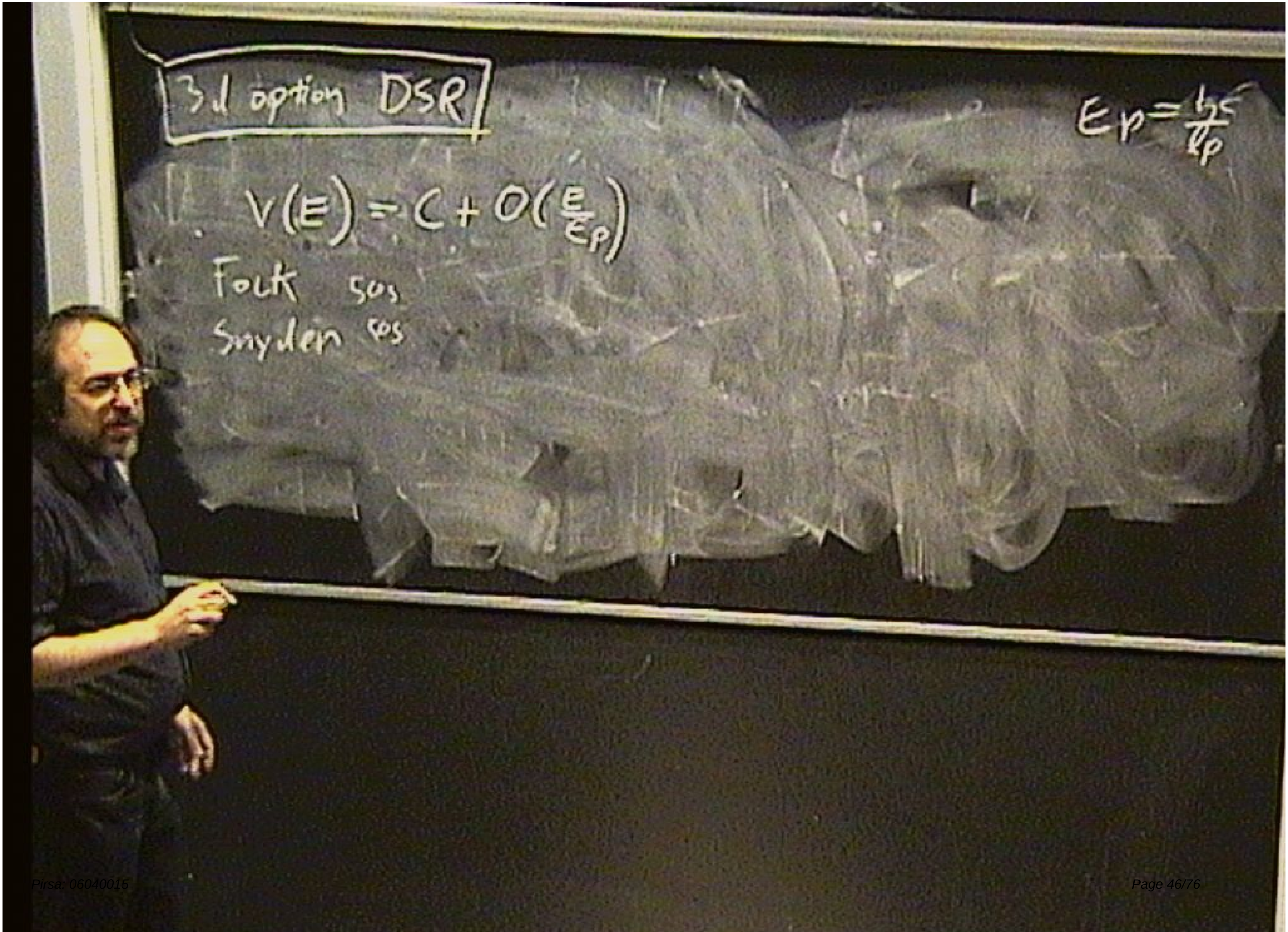
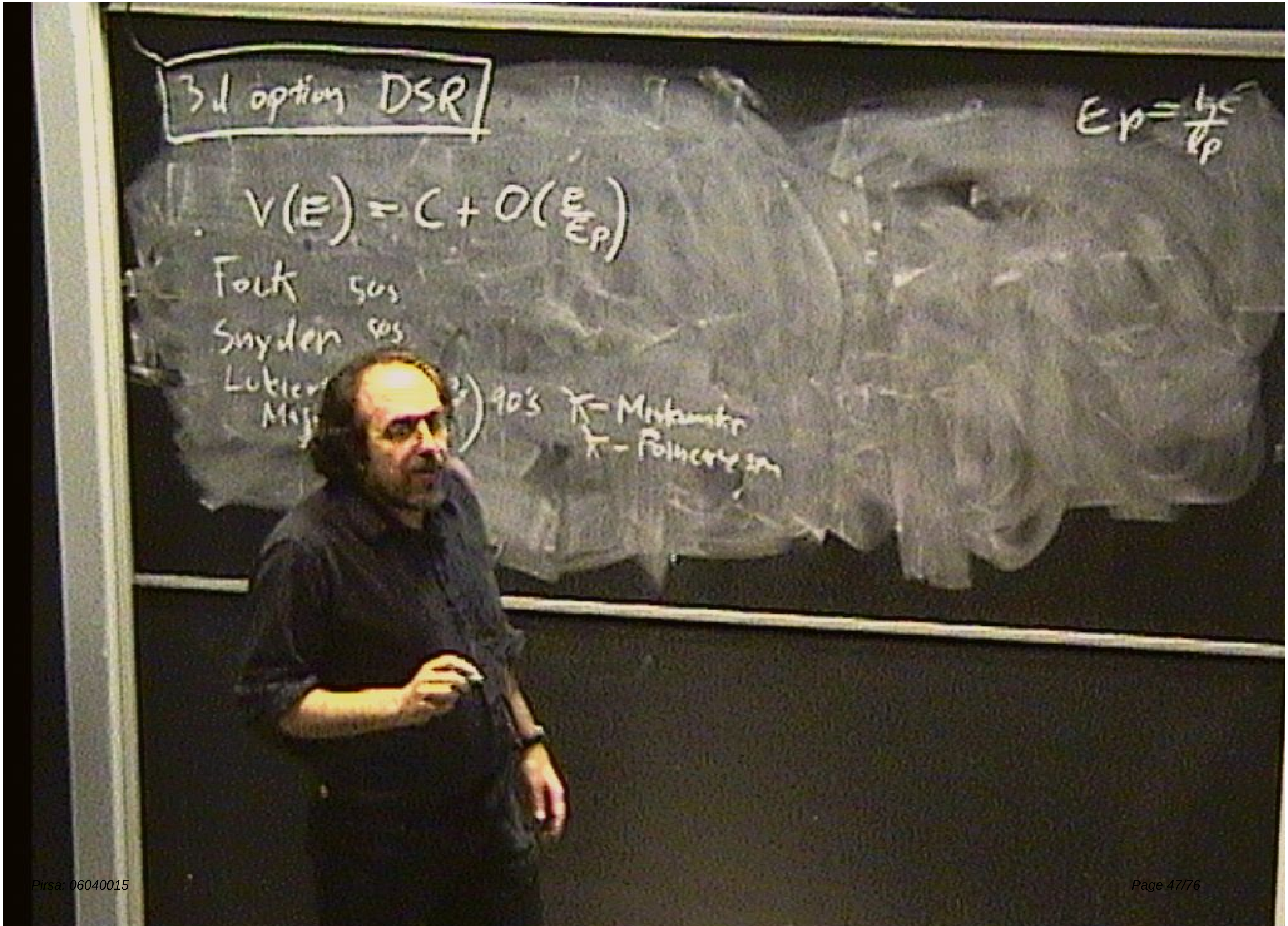
Ep=hc/lp

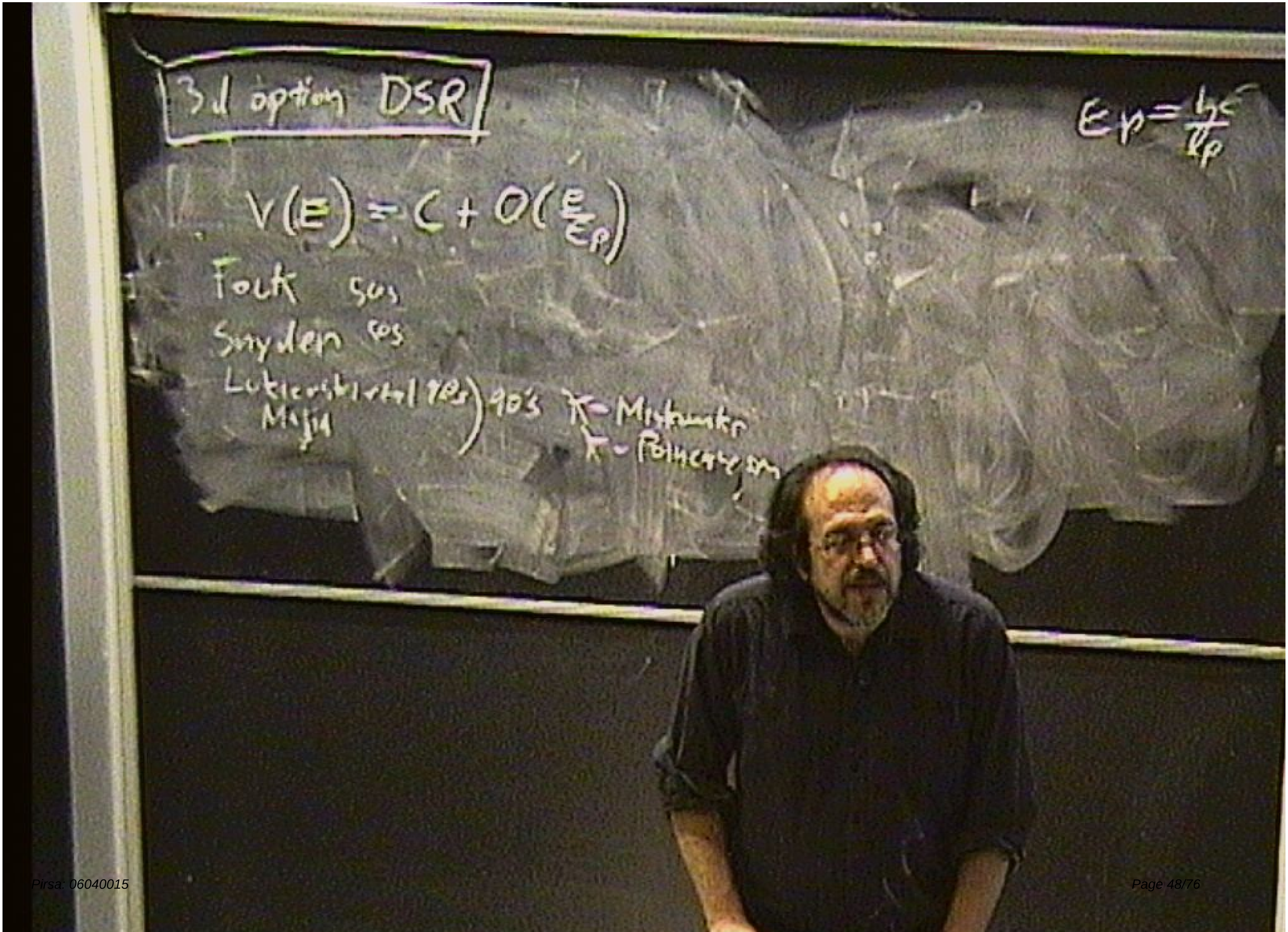

3d option DSR
V(E) = C + O(E/Ep)
Ep = ħc/ℓp

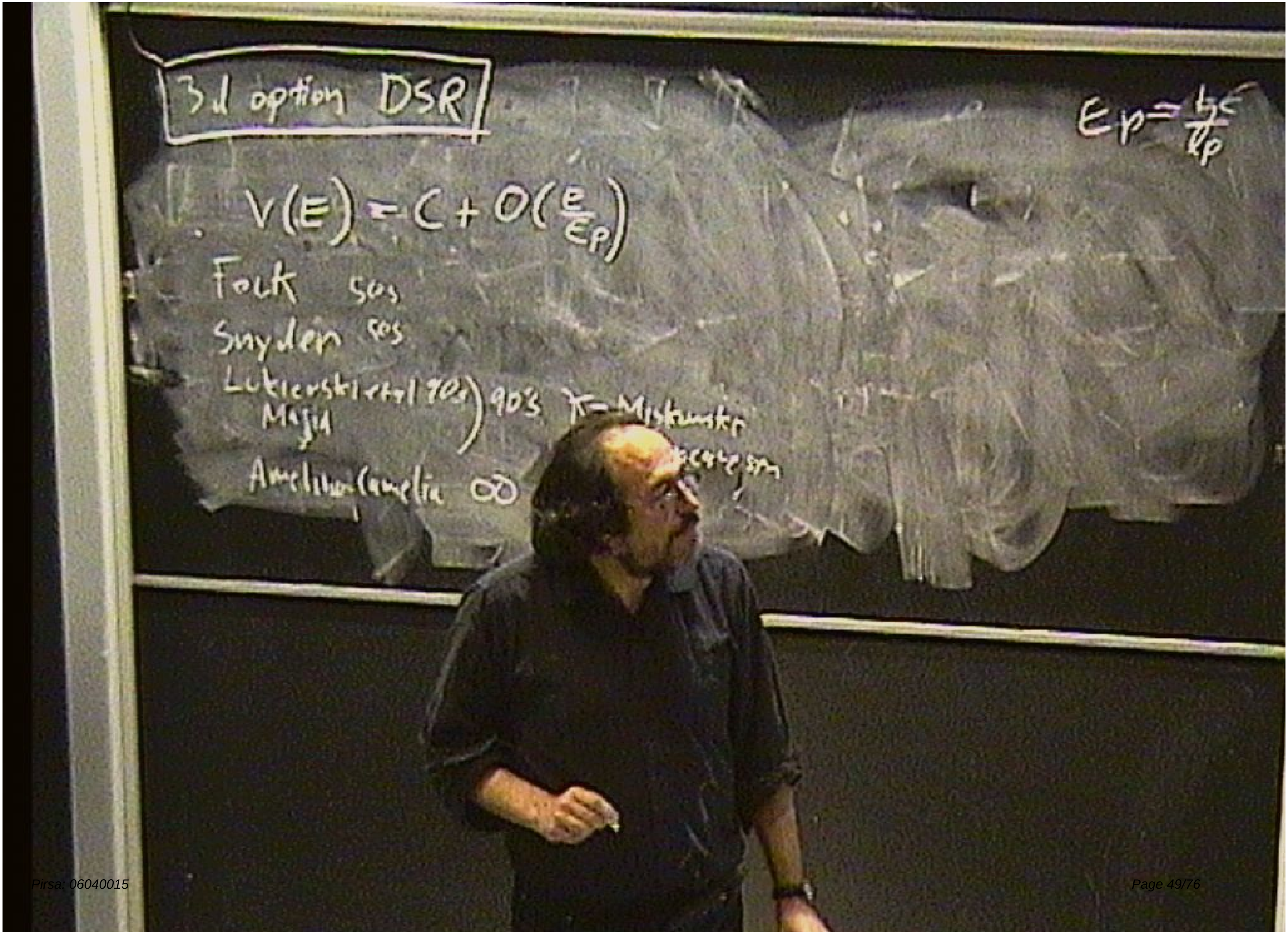
Principles of deformed special relativity (DSR):

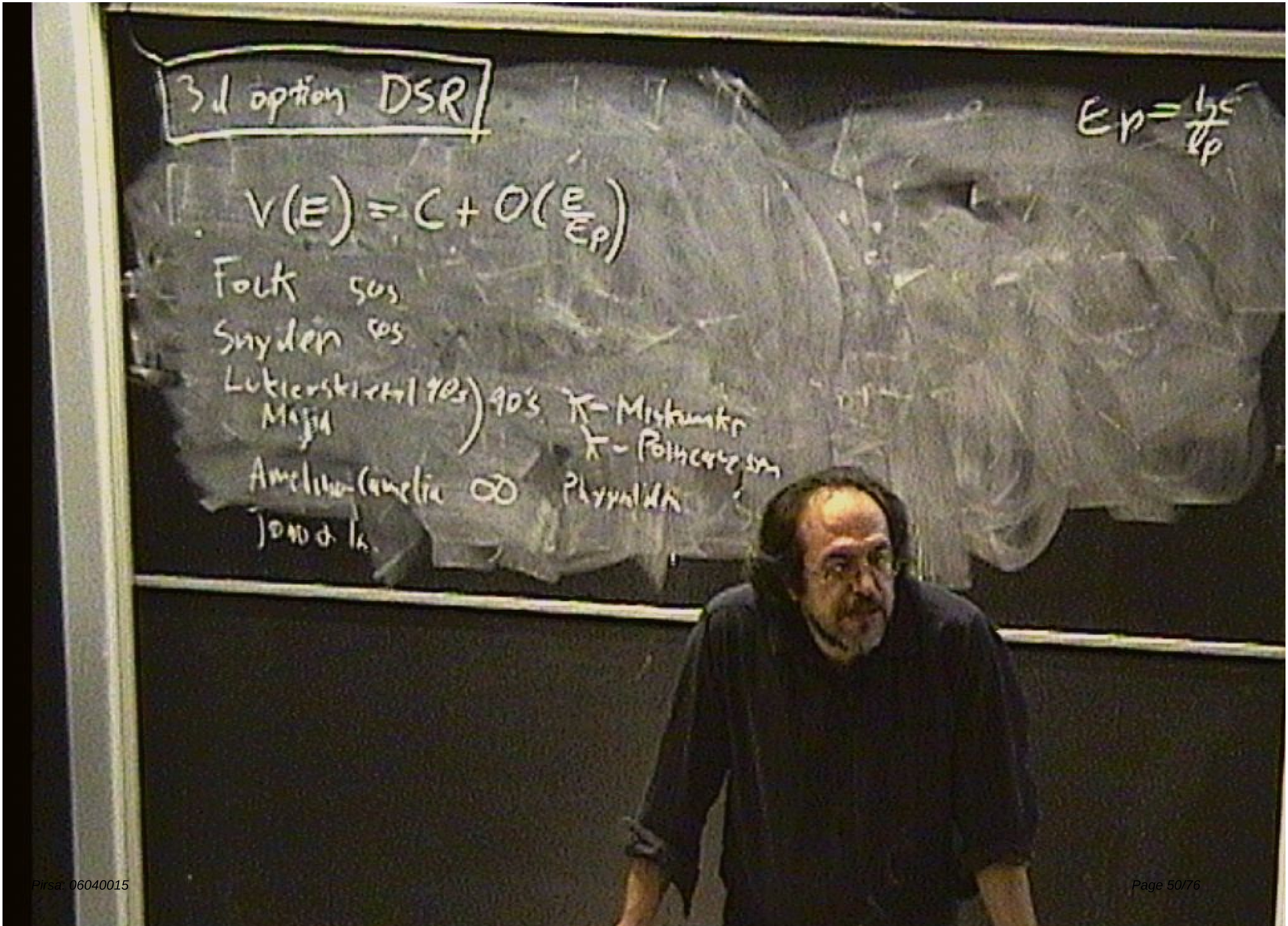
1) Relativity of inertial frames
2) The constancy of c, a velocity
3) The constancy of an energy E_p
4) c is the universal speed of photons for $E \ll E_p$.

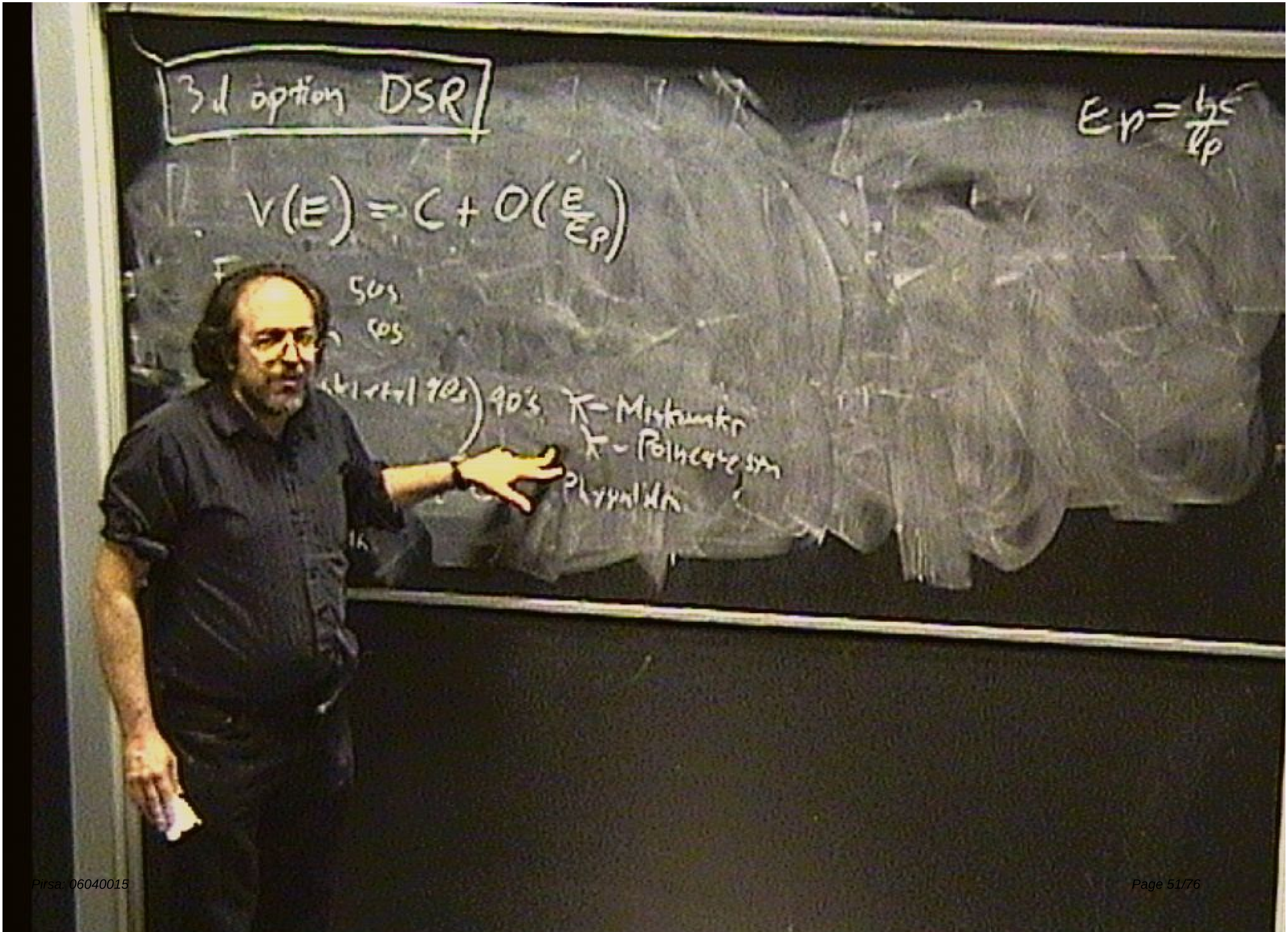

3d option DSR
Ep = ħc/ℓp
V(E) = C + O(E/Ep)
Folk sos
Snyder sos

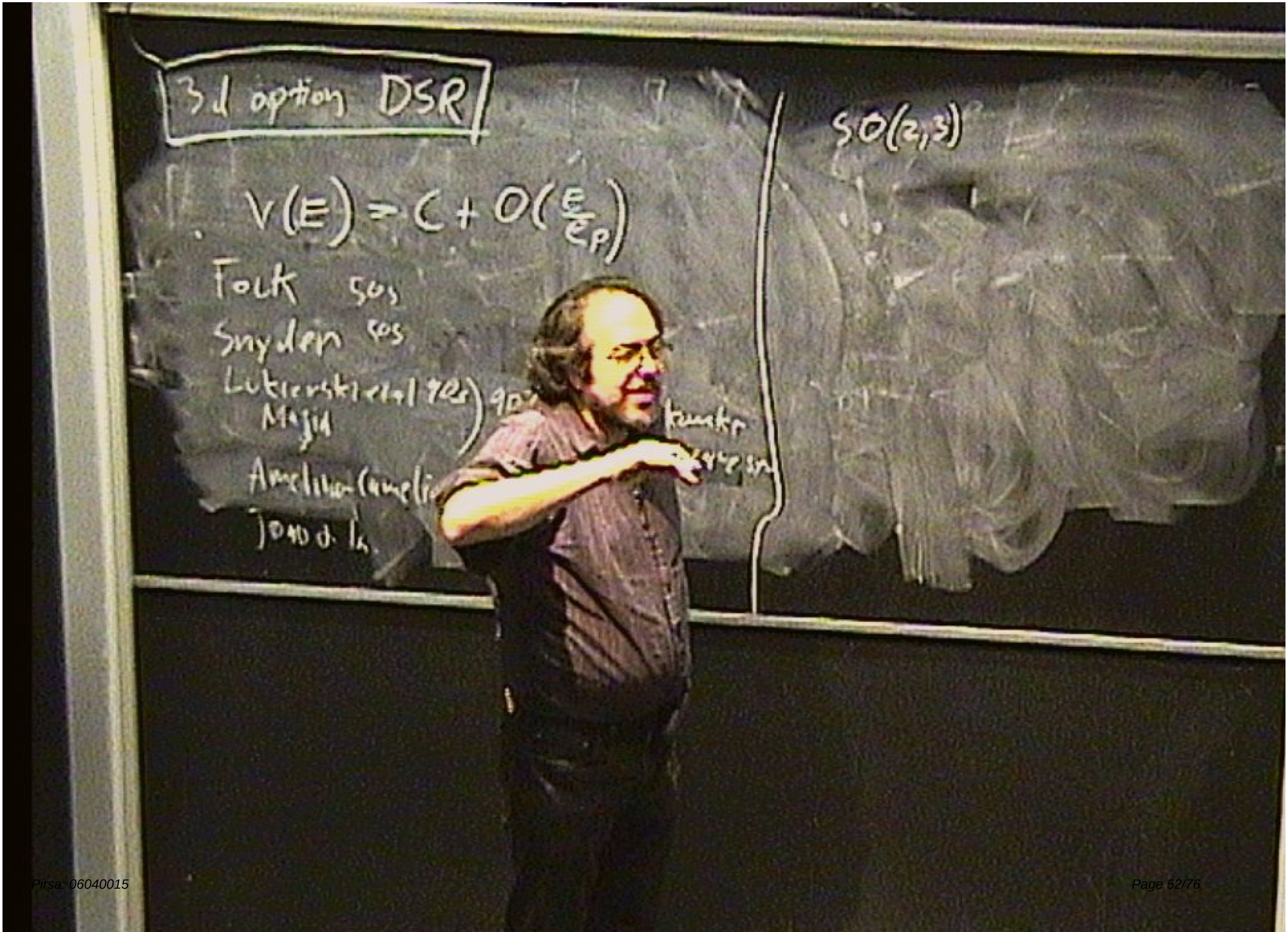

3d option DSR
Snyder 50s
90's

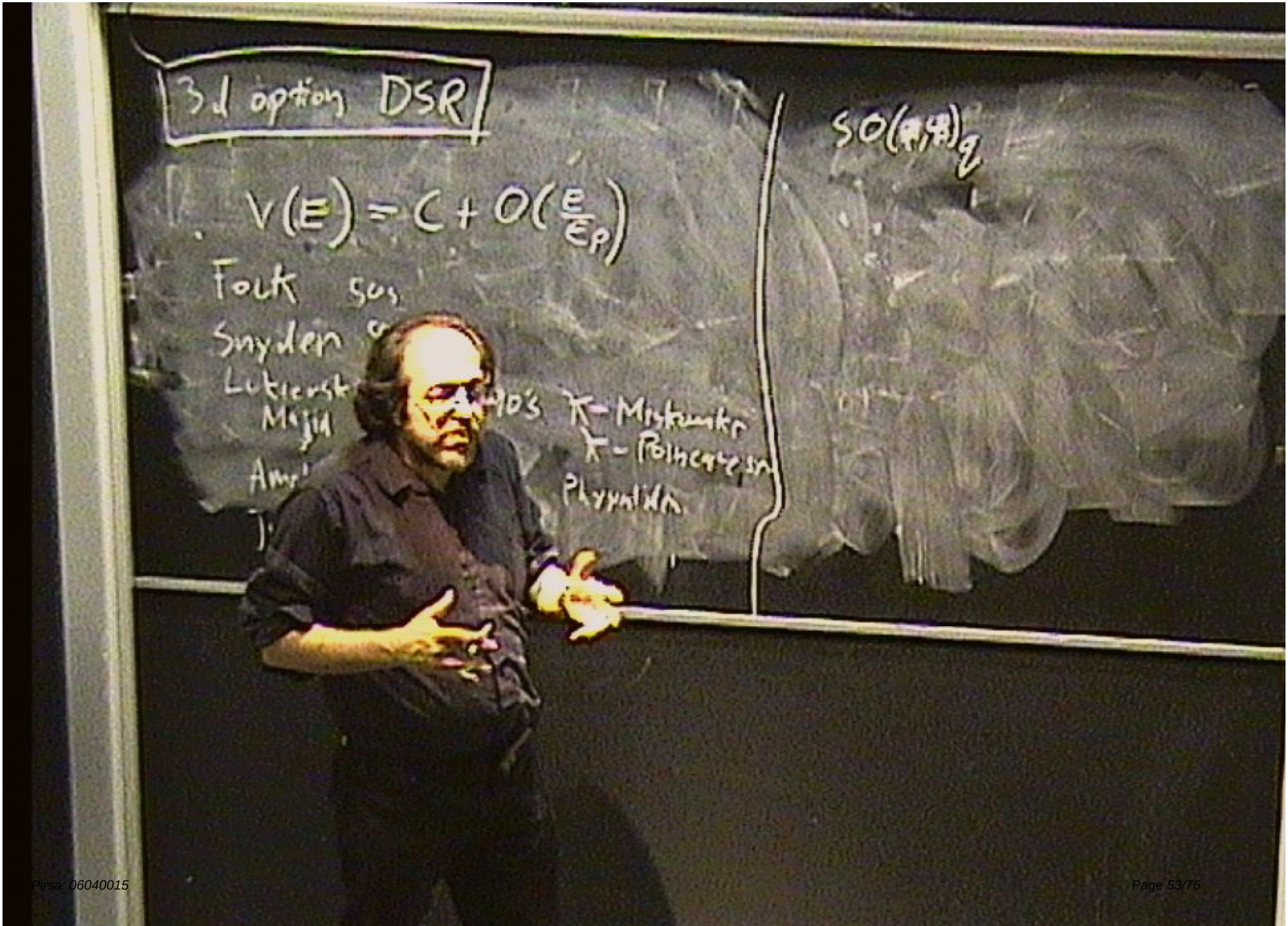

3d option DSR
V(E) = C + O(E/Ep)
Snyder
90's

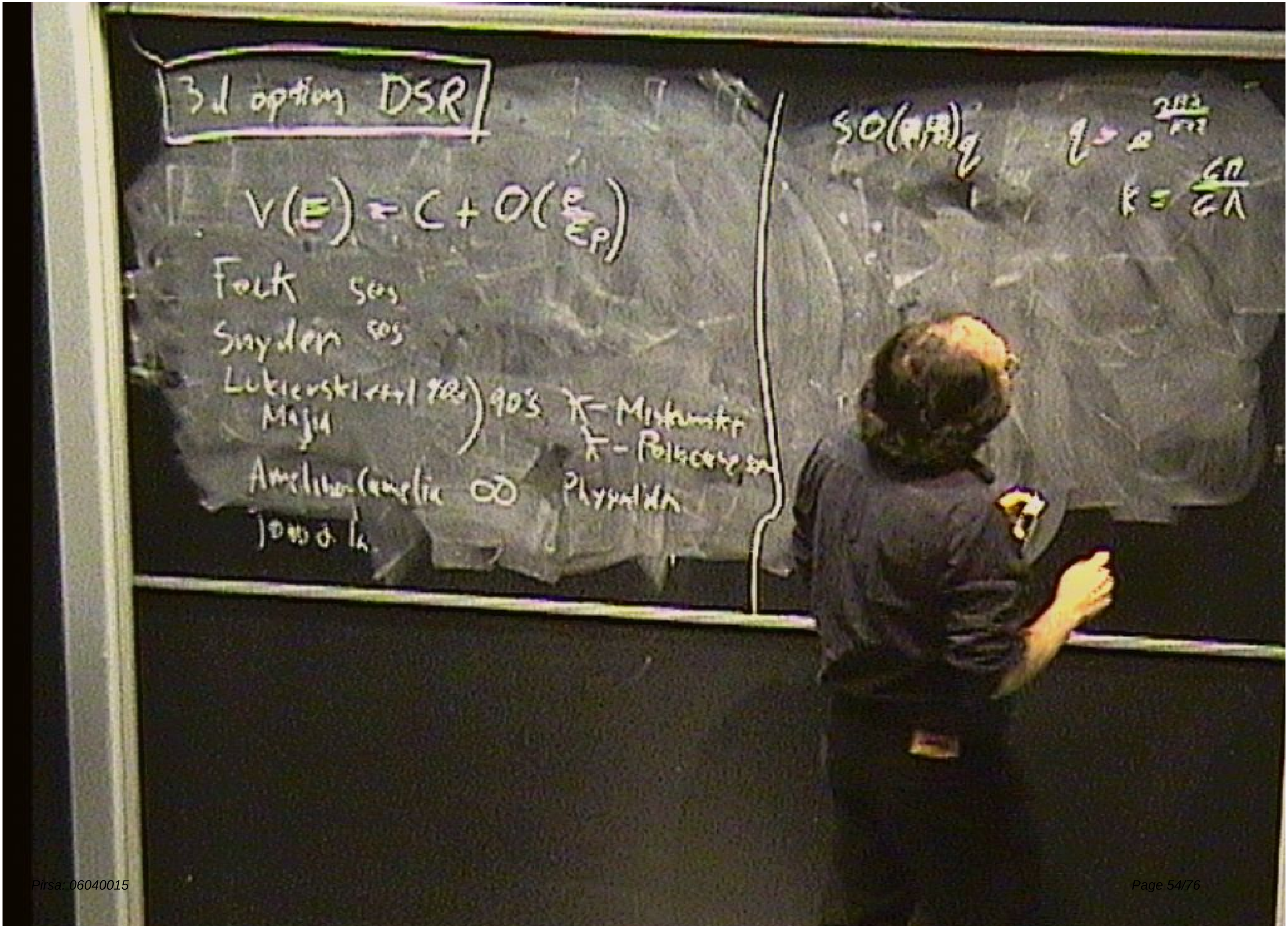

3d option DSR
Ep = ħc/ℓp
V(E) = C + O(E/Ep)
Fock 50s
Snyder 50s
Lukierski et al 90s
Majid
90's κ-Minkowski
Amelino-Camelia 00

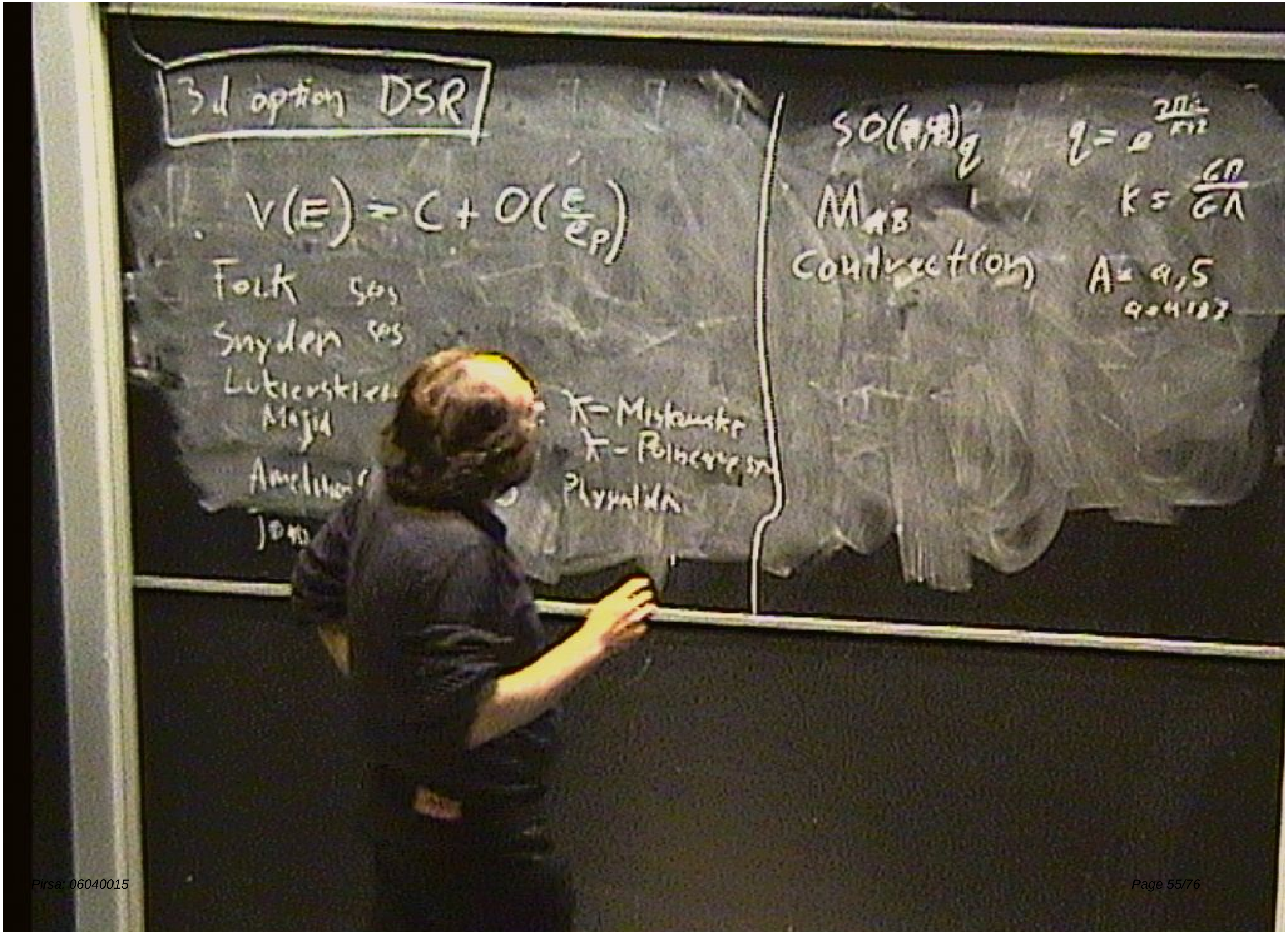

3d option DSR
$E_p = \frac{\hbar c}{\ell_p}$
$V(E) = C + O(\frac{E}{E_p})$
Folk
Snyder
90's
κ-Minkowski
κ-Poincaré

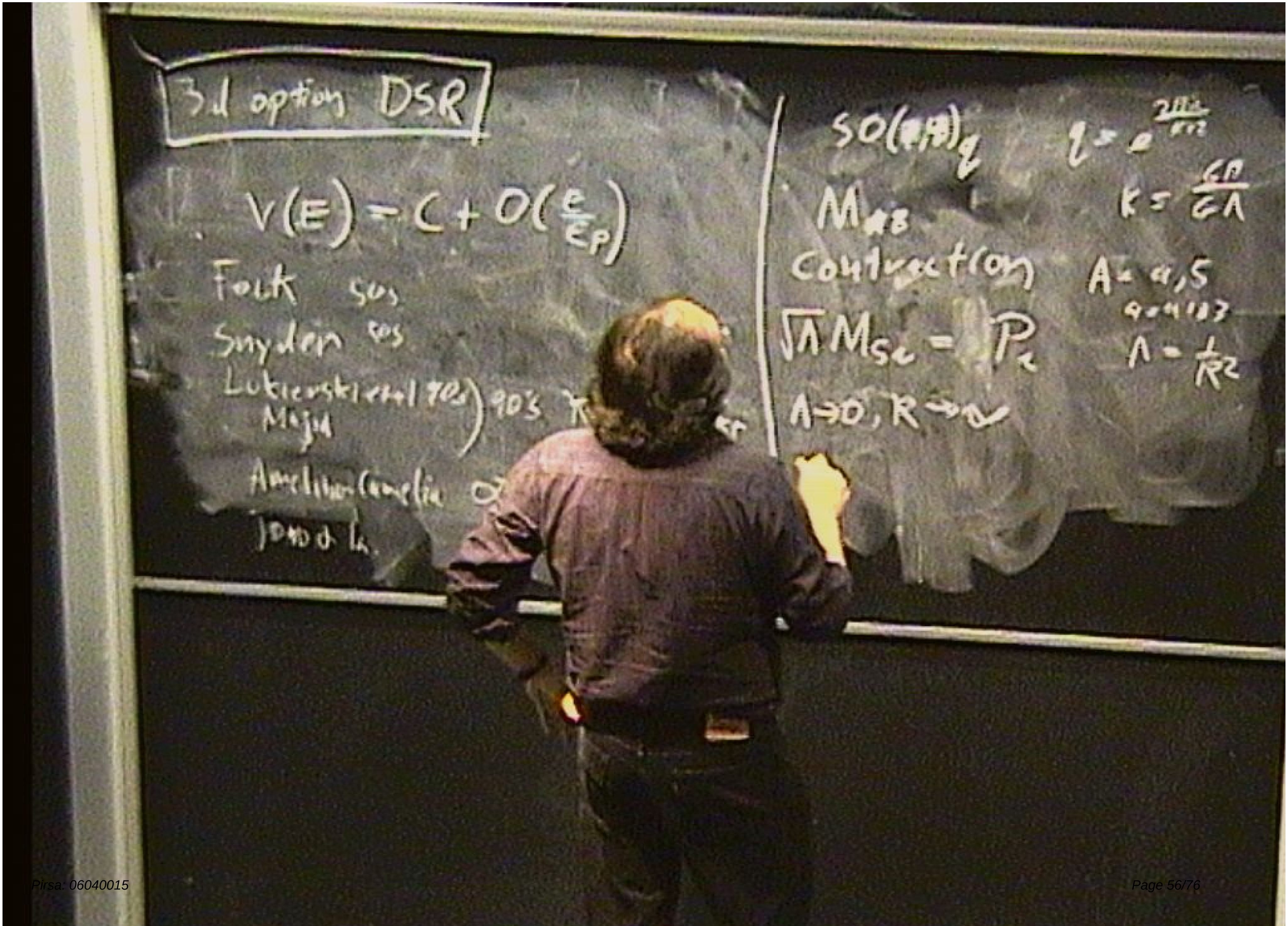

3d option DSR
V(E) = C + O(E/Ep)
Ep = hc/ℓp
50's
60's
90's

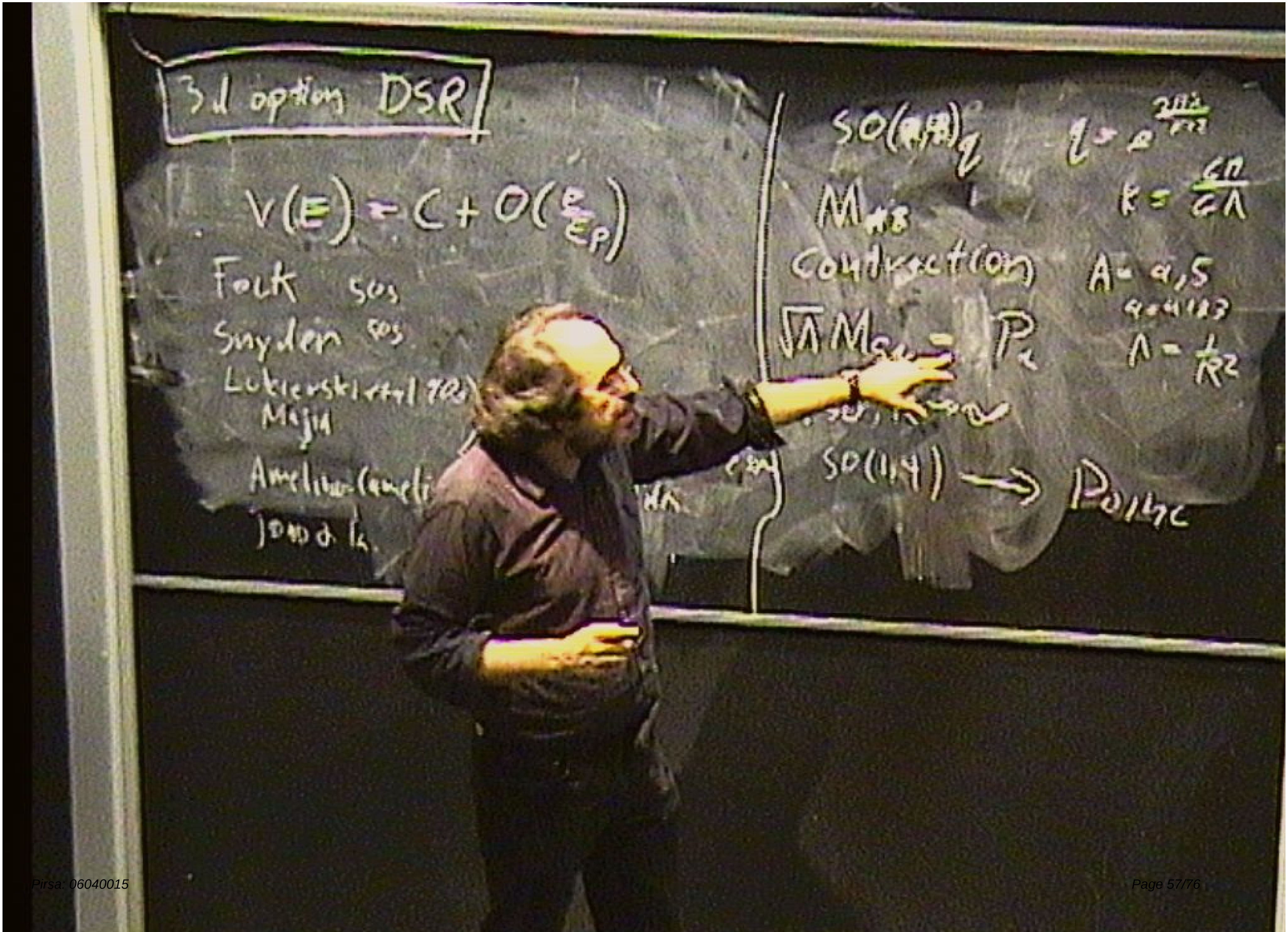

3d option DSR
V(E) = C + O(E/E_P)
Folk SOS
Snyder SOS
SO(2,3)

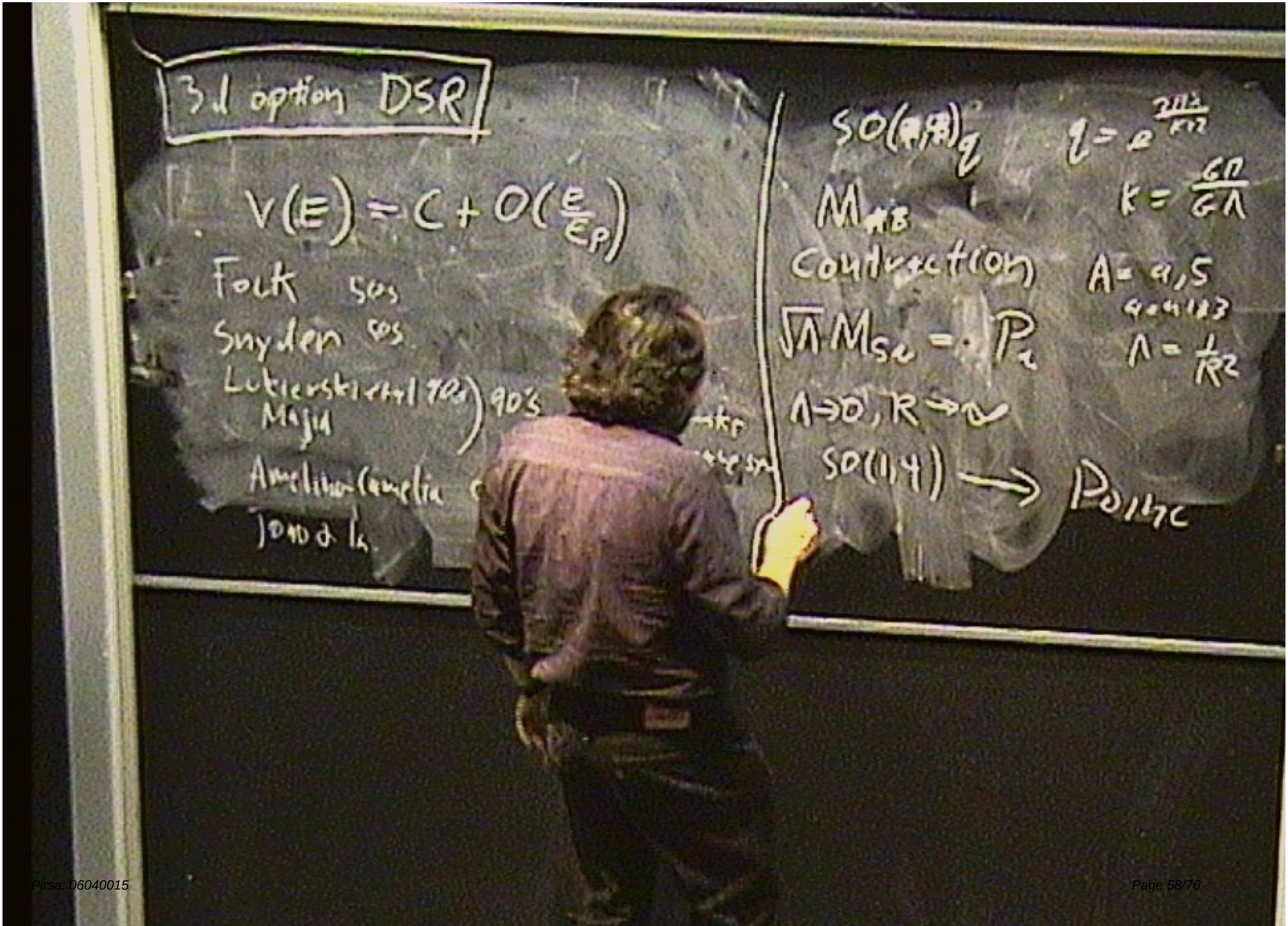

3d option DSR
V(E) = C + O(E/Ep)
Folk
Snyder
Majid
κ-Minkowski
κ-Poincare

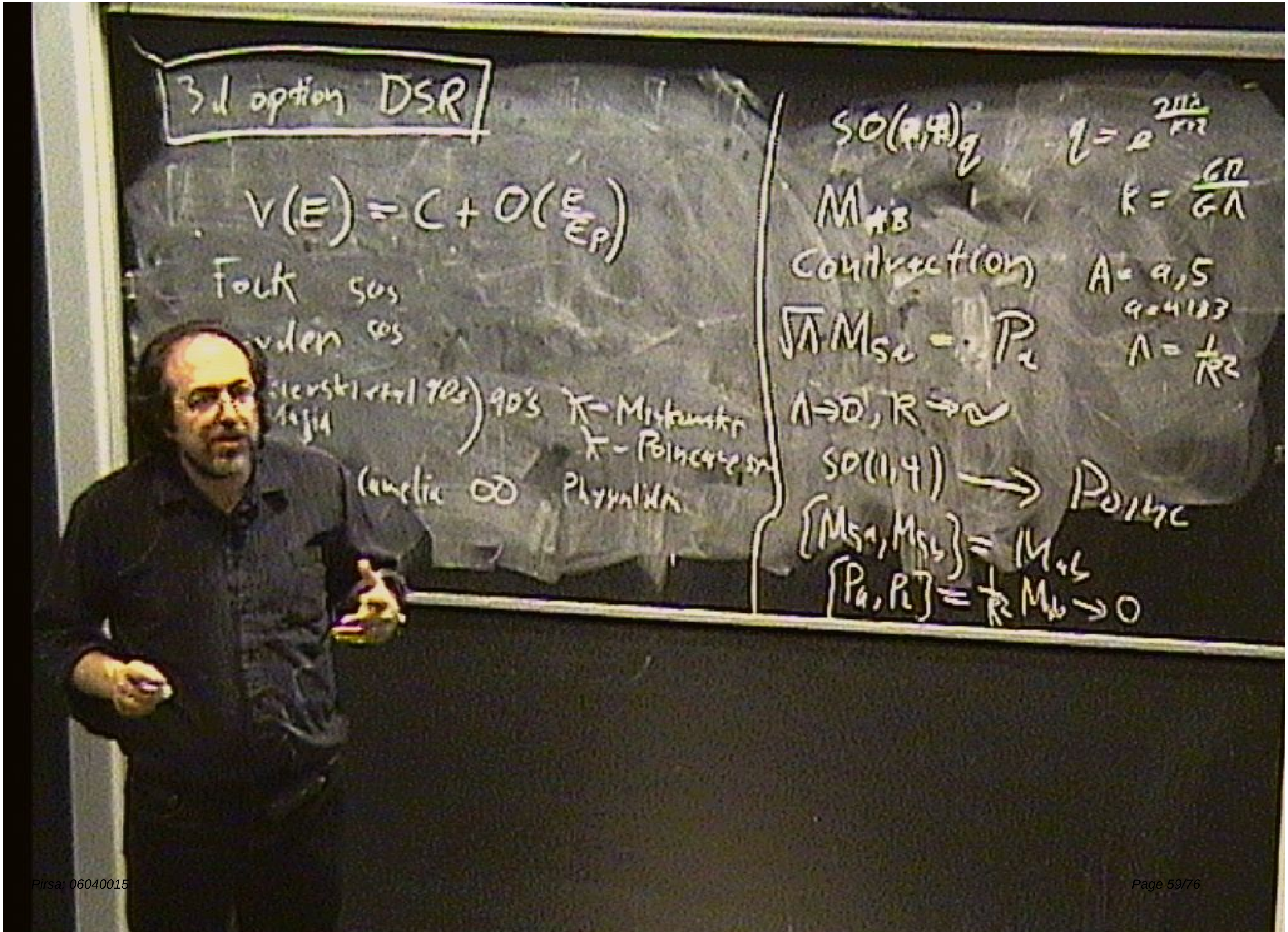

3d option DSR
V(E) = C + O(E/Ep)
Fock
Snyder
Lukierski et al
Majid
90's
Amelino-Camelia

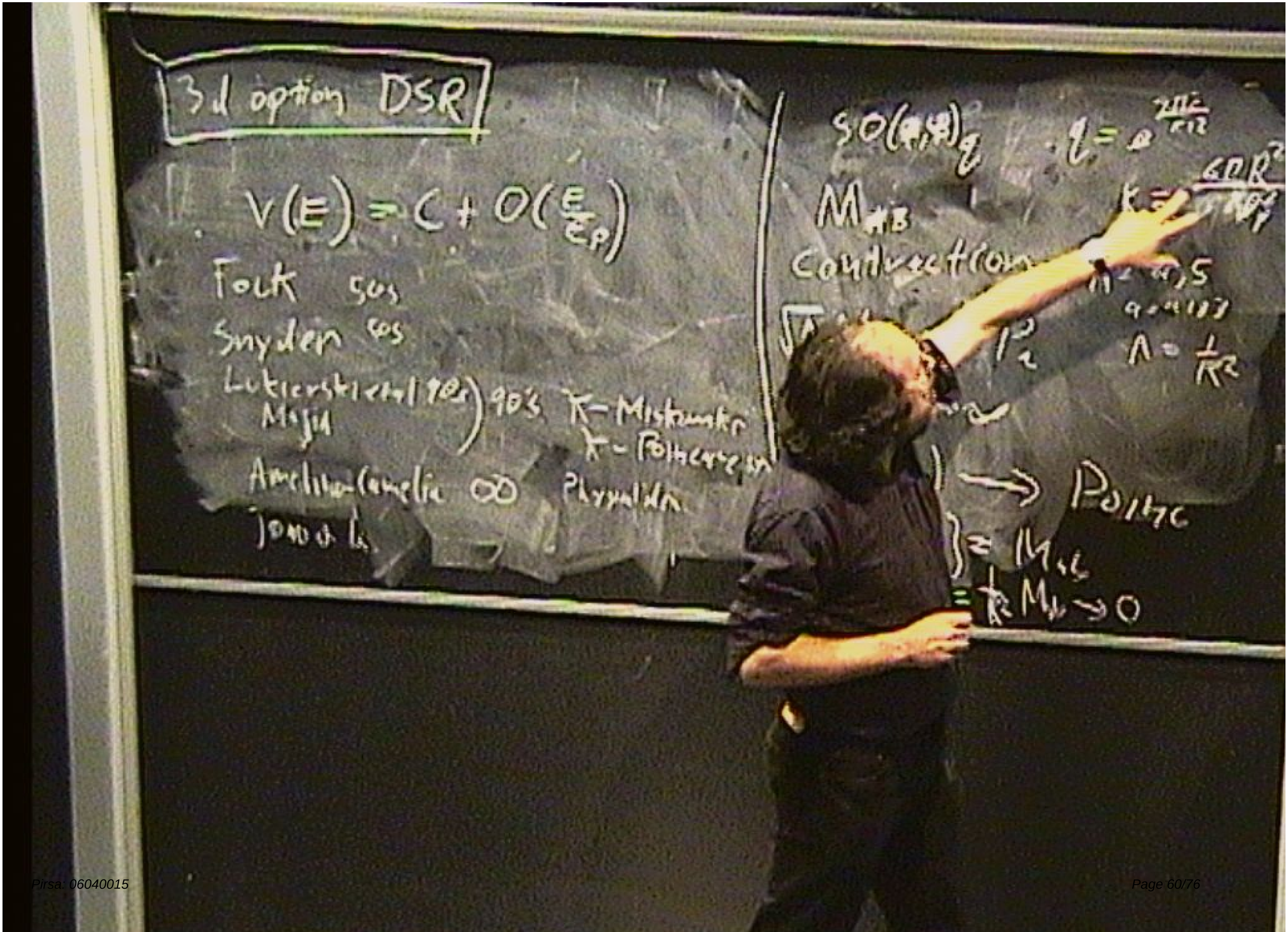

3d option DSR
V(E) = C + O(E/E_P)
Folk
Snyder
SO( )_q
M_AB
Contraction

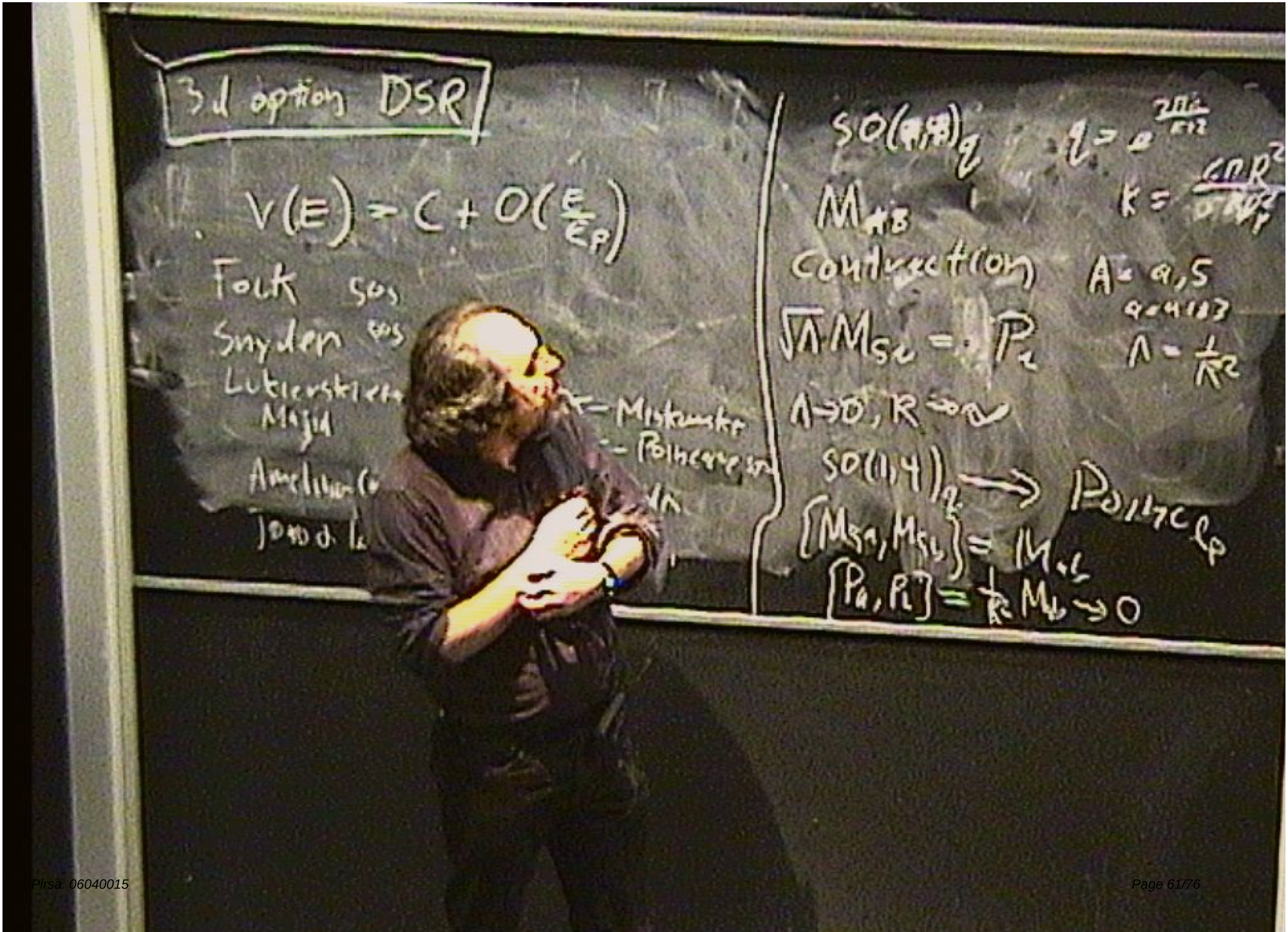

3d option DSR
V(E) = C + O(E/E_P)
Folk
Snyder
Contraction
A→0, R→∞

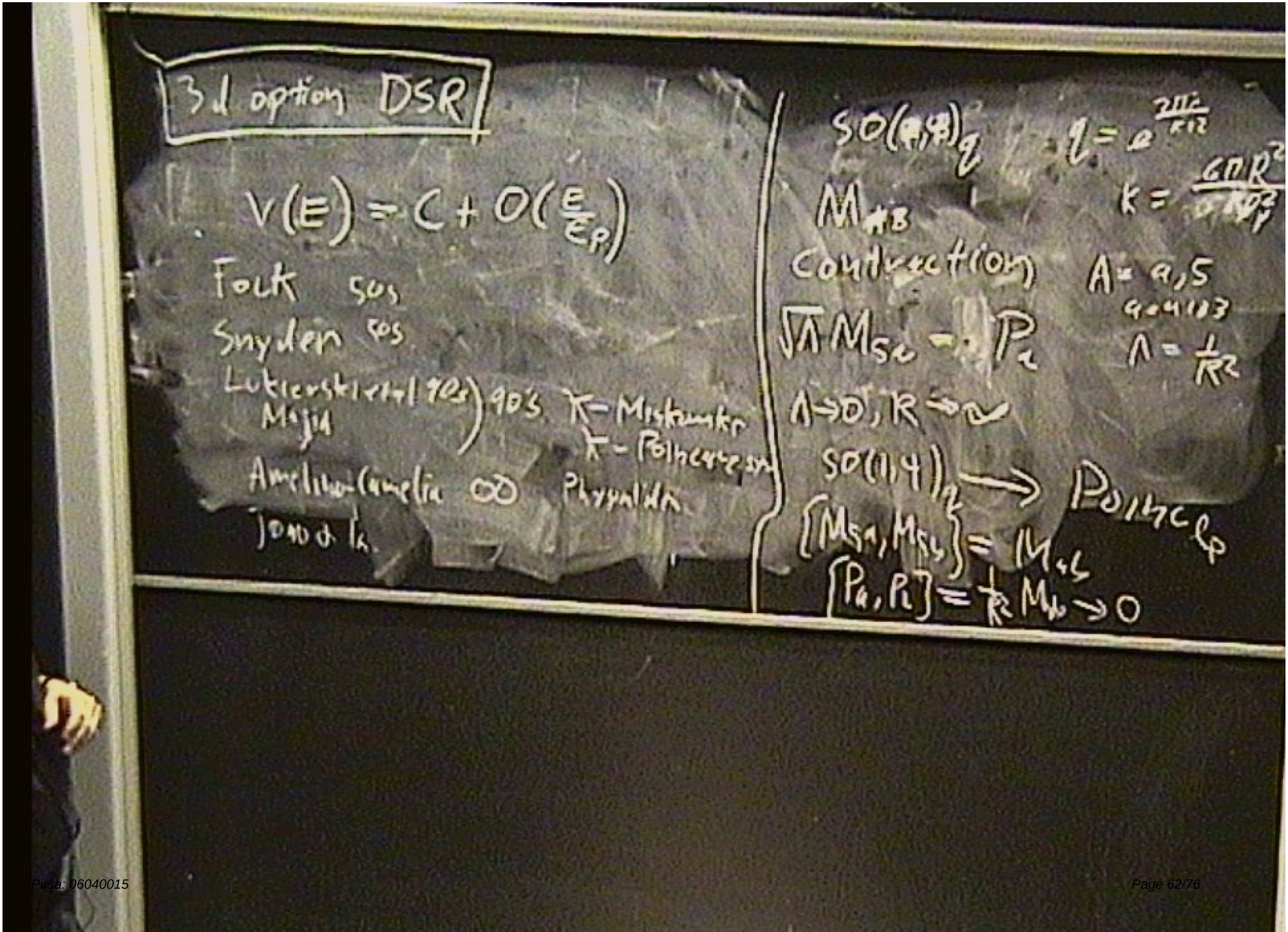

3d option DSR
V(E) = C + O(E/Ep)
Folk
Snyder
Majid
Contraction
SO(1,4) ⟶ Poinc

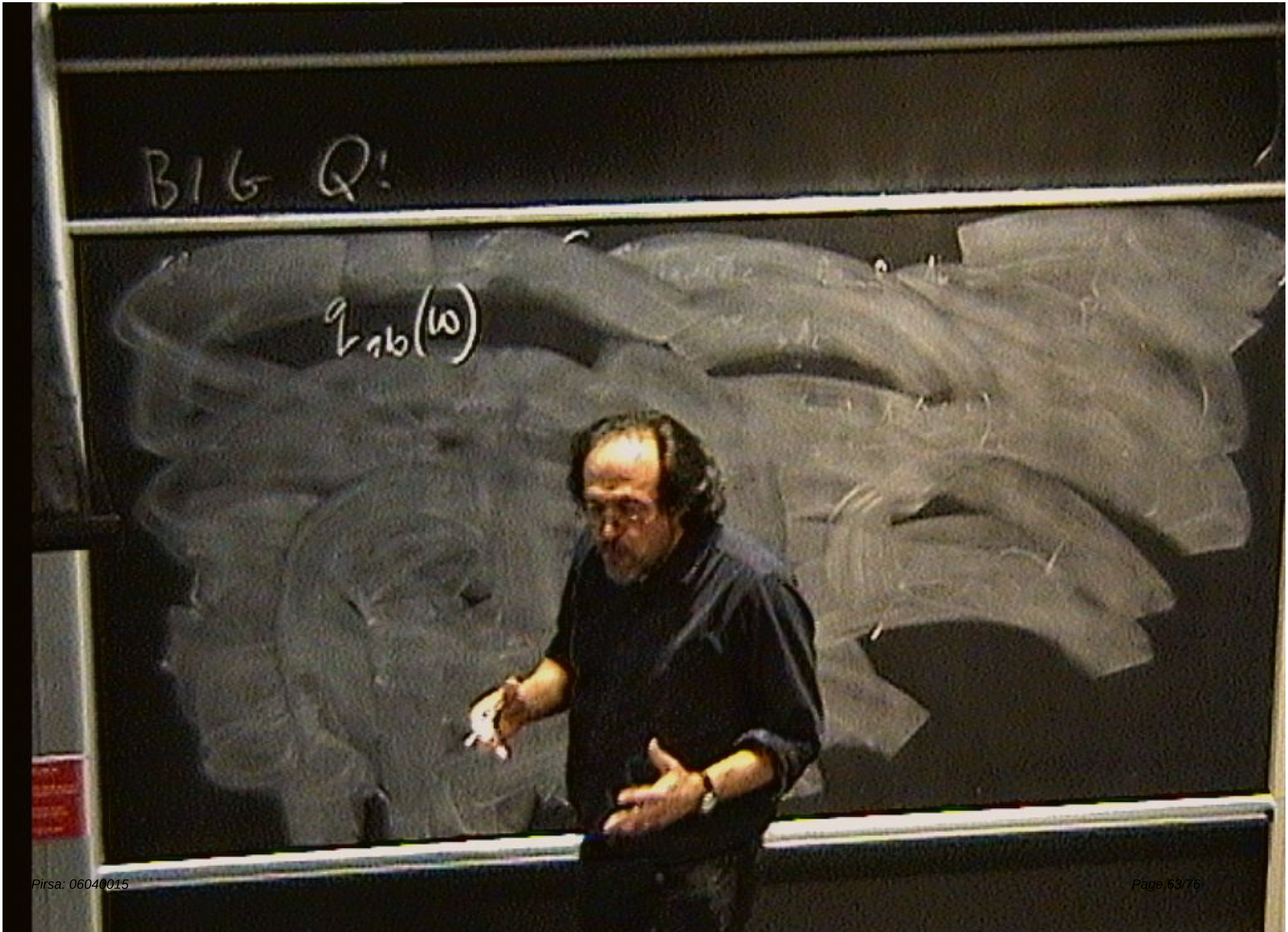

3d option DSR
V(E) = C + O(E/Ep)
Folk 50's
Snyder 50's
90's
SO(1,4)
Contraction
Poinc

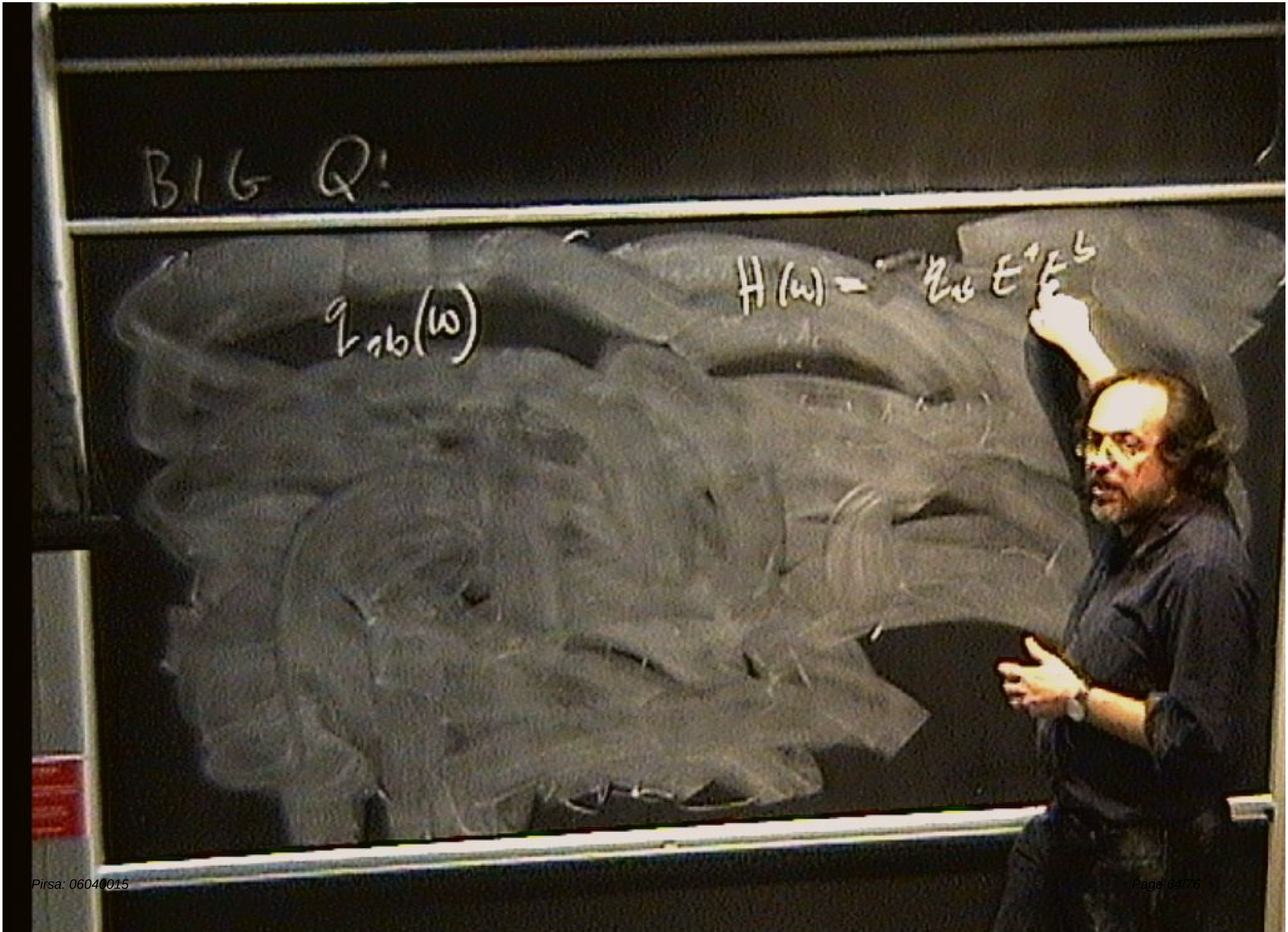

3d option DSR
Folk
Contraction
90's
Poinc

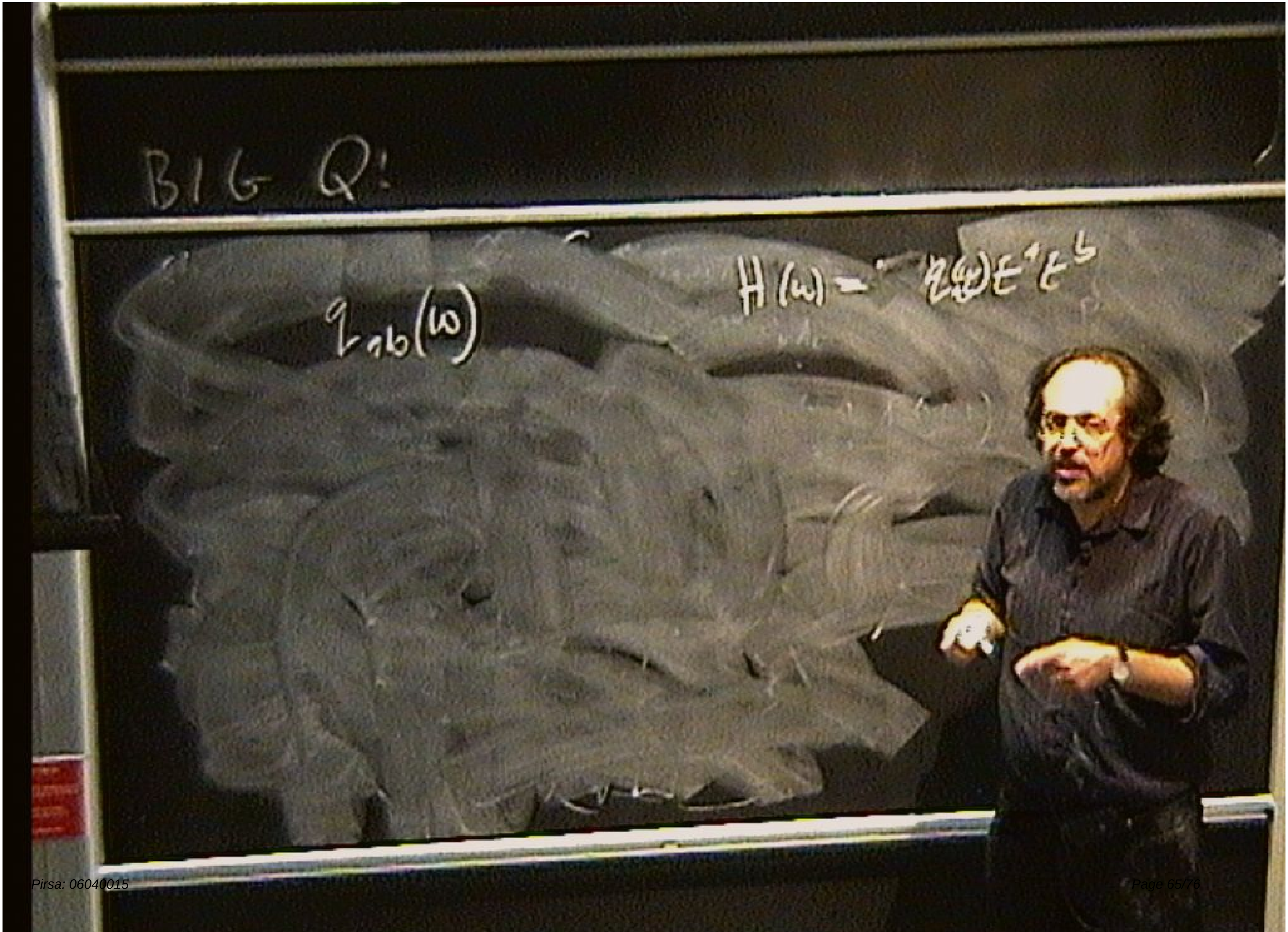

3d option DSR
Fock
Snyder
Convection
Poinc

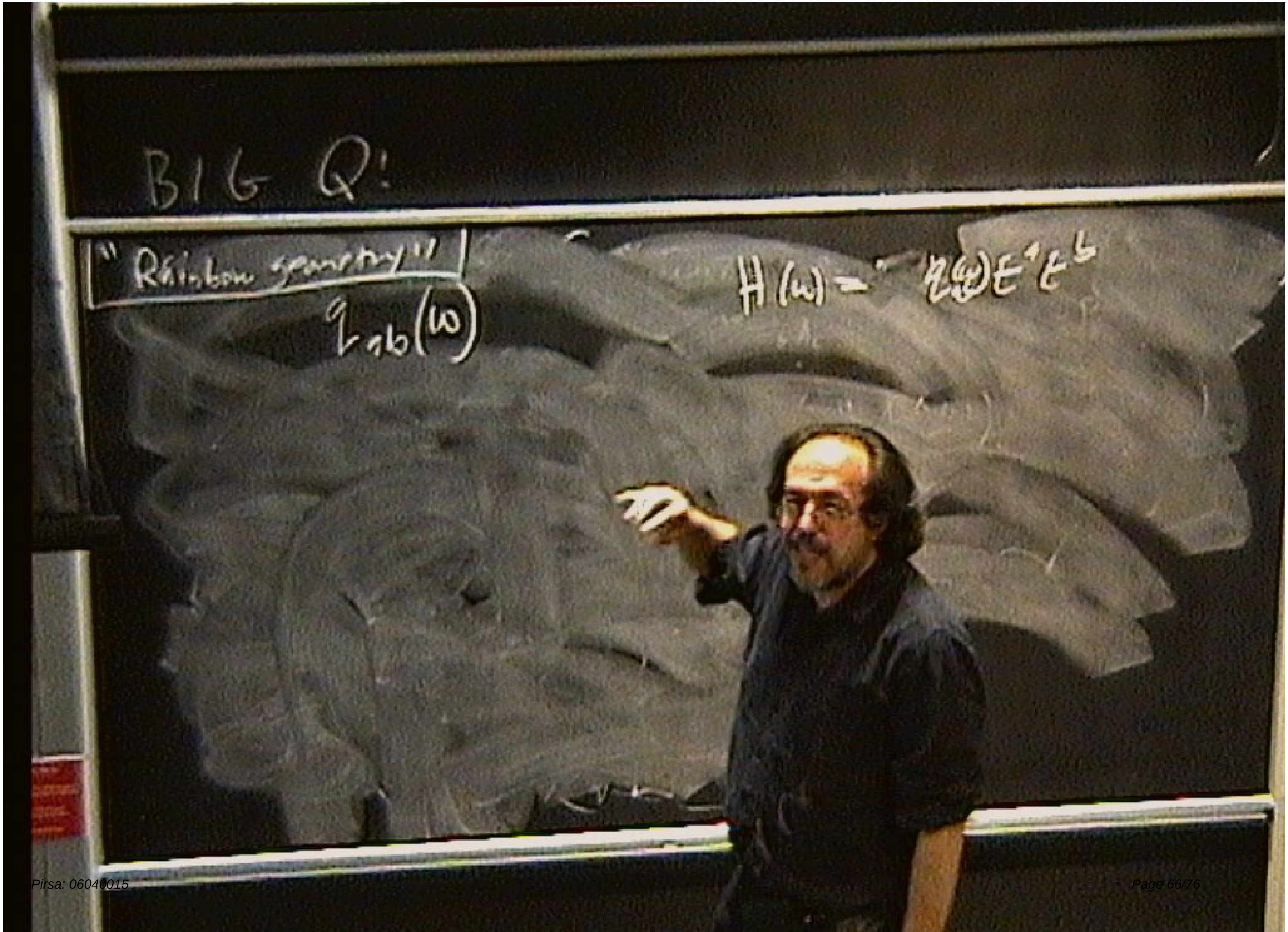

3d option DSR
Folk
Snyder
Majid
Contraction
$\Lambda \to 0$, $R \to \infty$
$SO(1,4)_q \longrightarrow$ Poincaré
$[P_a, P_b] = \frac{1}{R^2} M_{ab} \to 0$

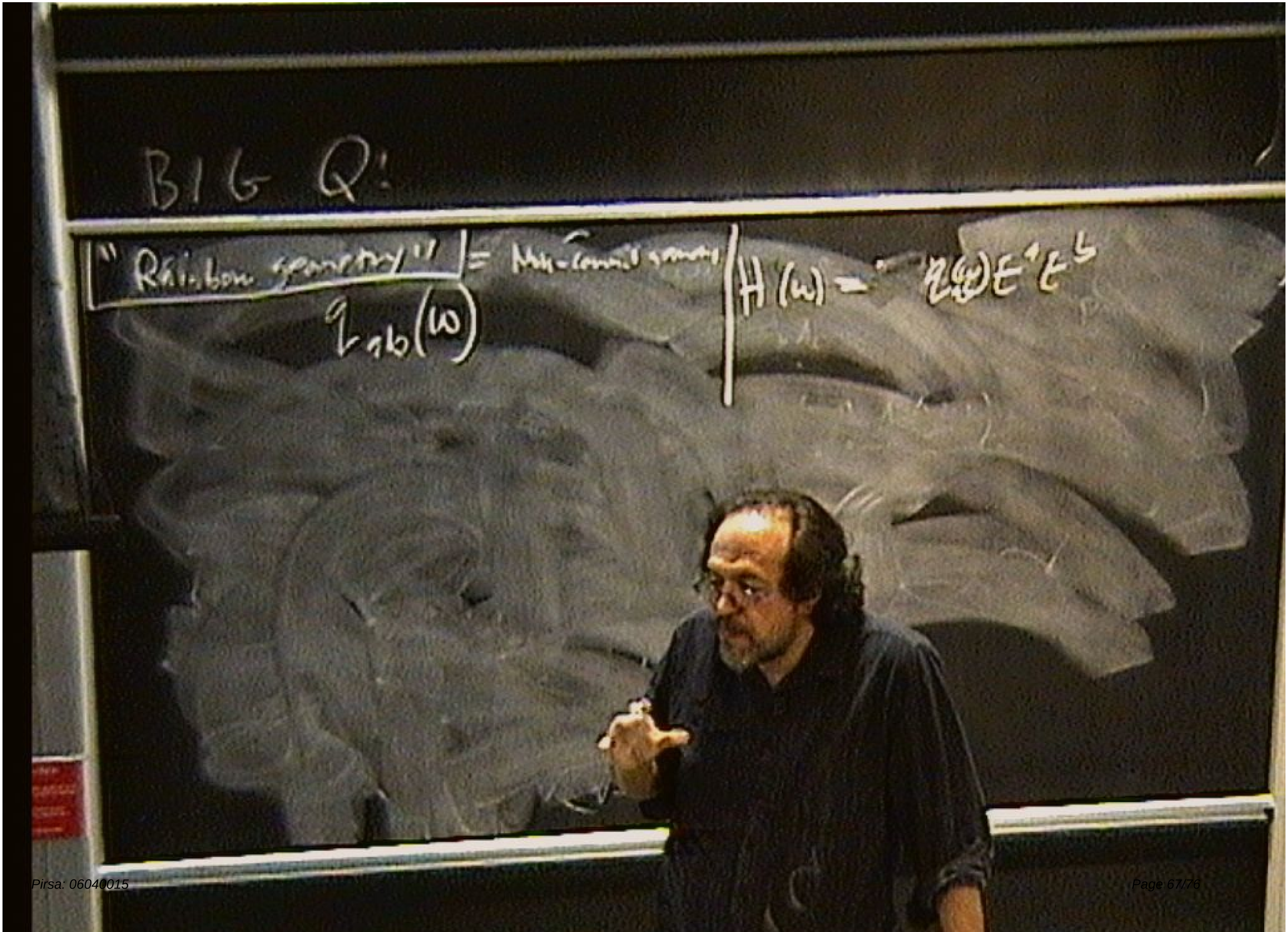

3d option DSR
V(E) = C + O(E/E_P)
Folk
Snyder
Contraction
Λ = 1/R²
Λ→0, R→∞
SO(1,4)_q → Poinc_ℓp
[P_a, P_b] = 1/R² M_ab → 0

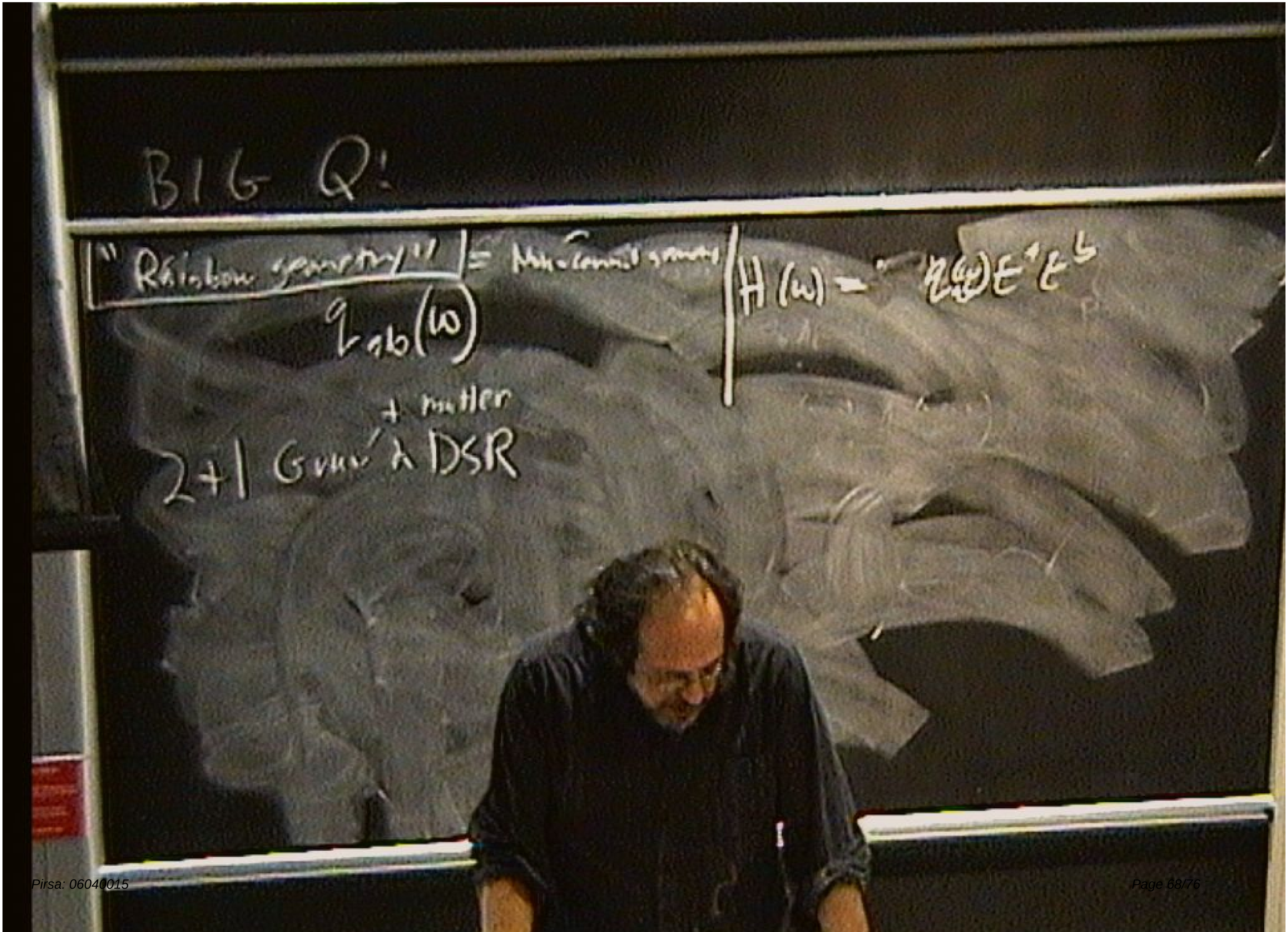

BIG Q!
$g_{ab}(\omega)$


BIG Q!
q_ab(w)
H(w) = q_ab E^a E^b


BIG Q!
q ab(w)


BIG Q!
"Rainbow geometry"


BIG Q:
"Rainbow geometry"


BIG Q!
"Rainbow geometry"
+ matter
DSR

BIG Q!

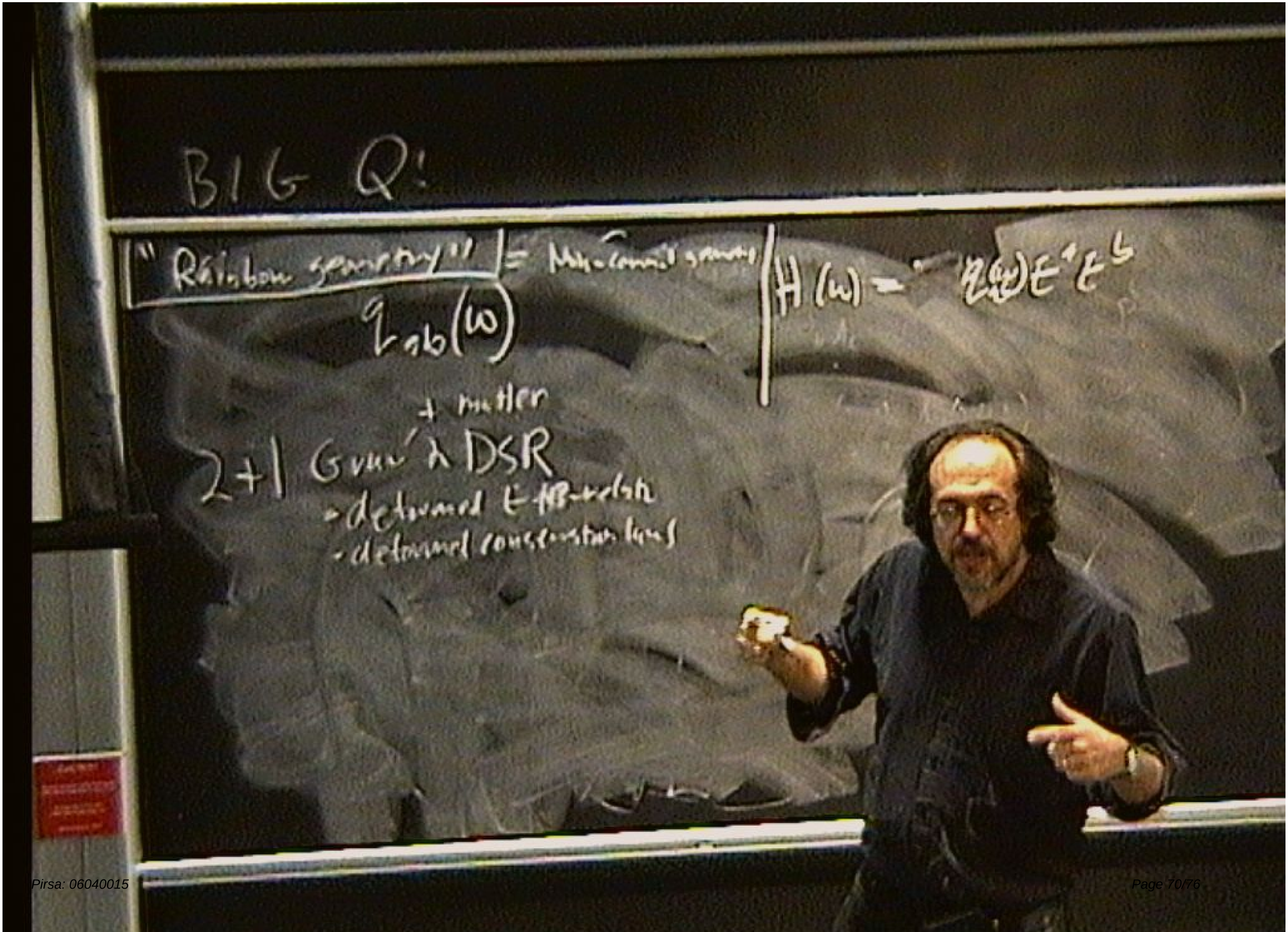
"Rainbow geometry" = Non-Commut. geometry | $H(\omega) = g_{ab}(\omega) E^a E^b$

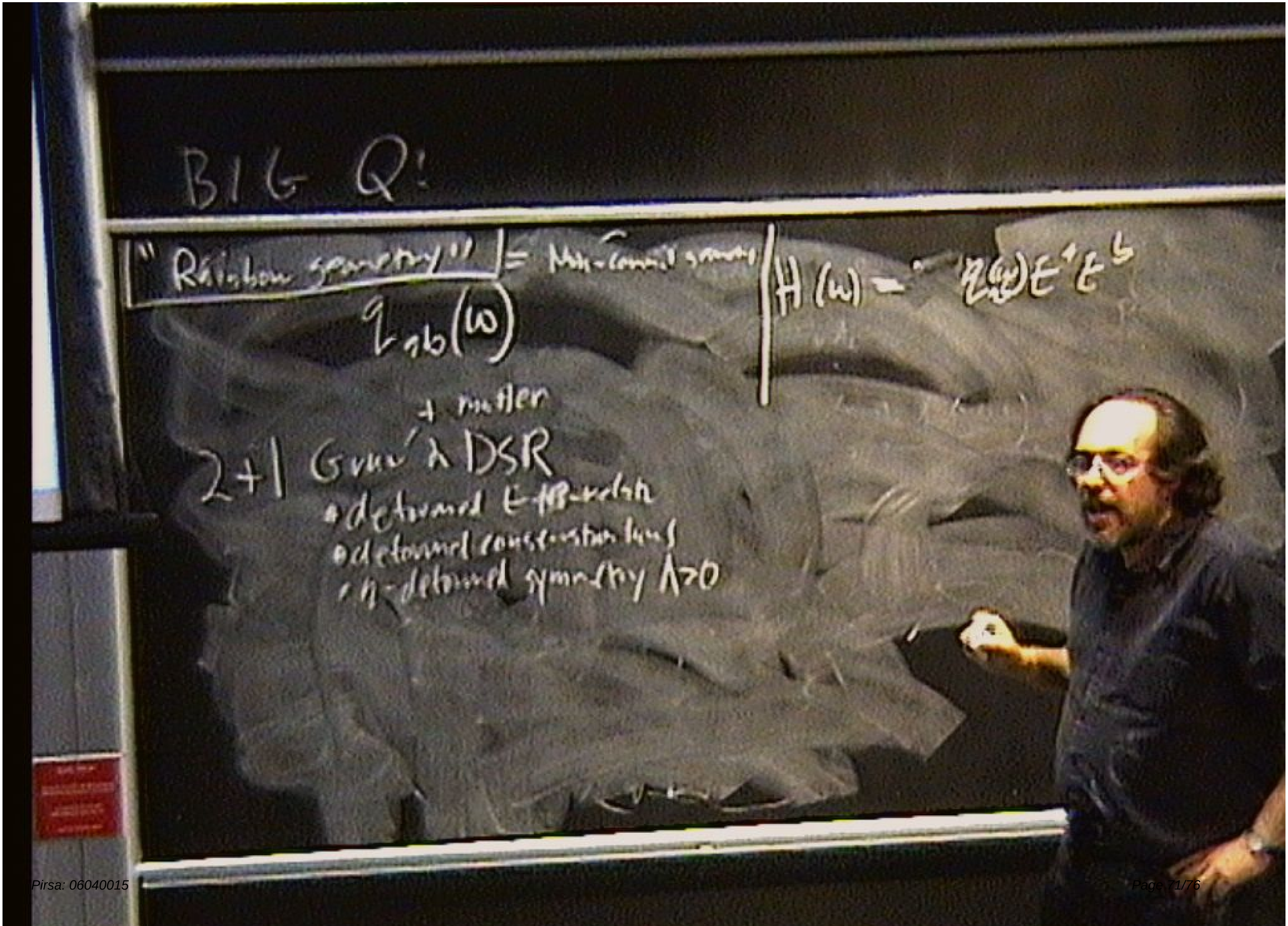
$g_{ab}(\omega)$

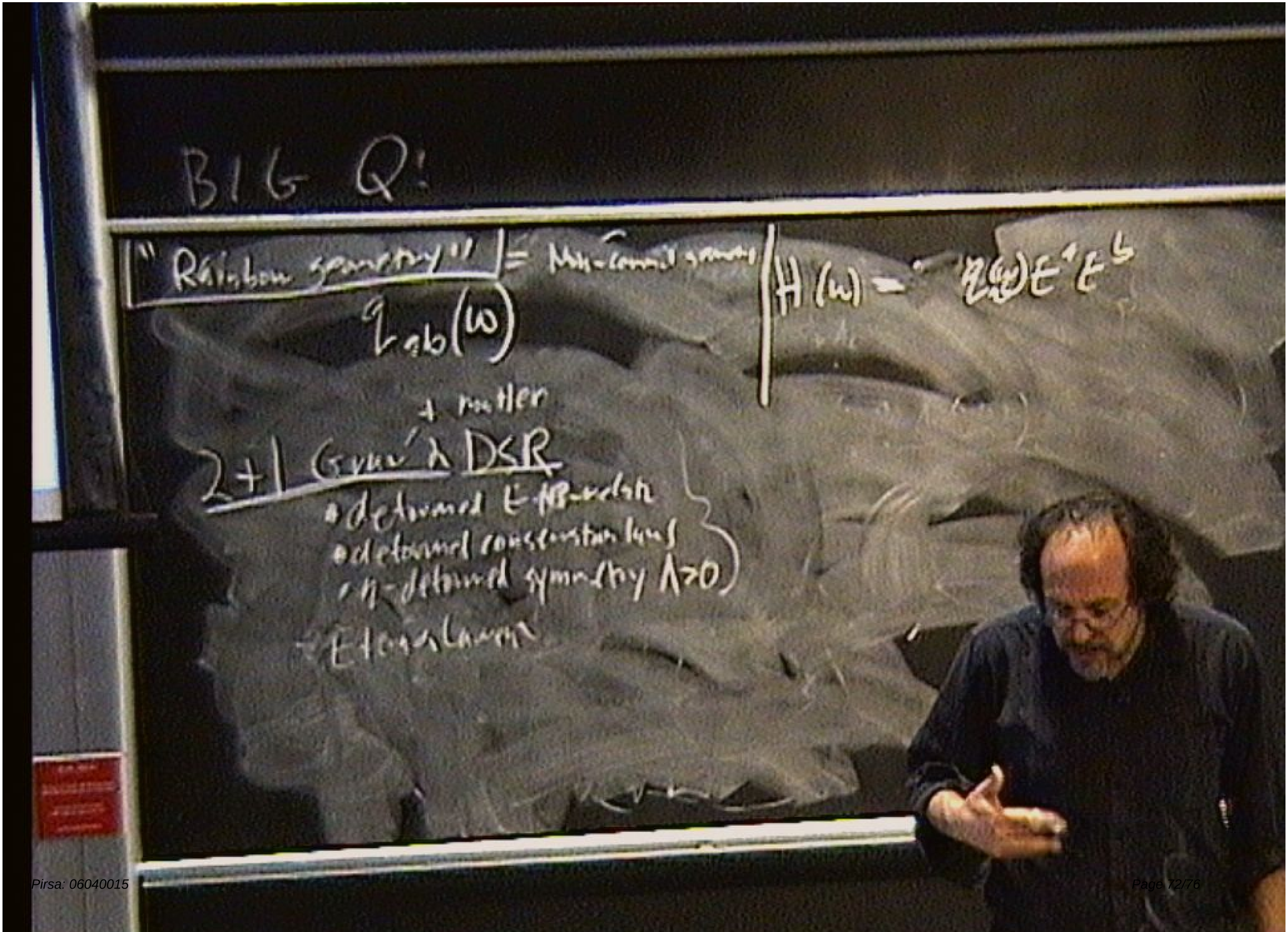
+ matter

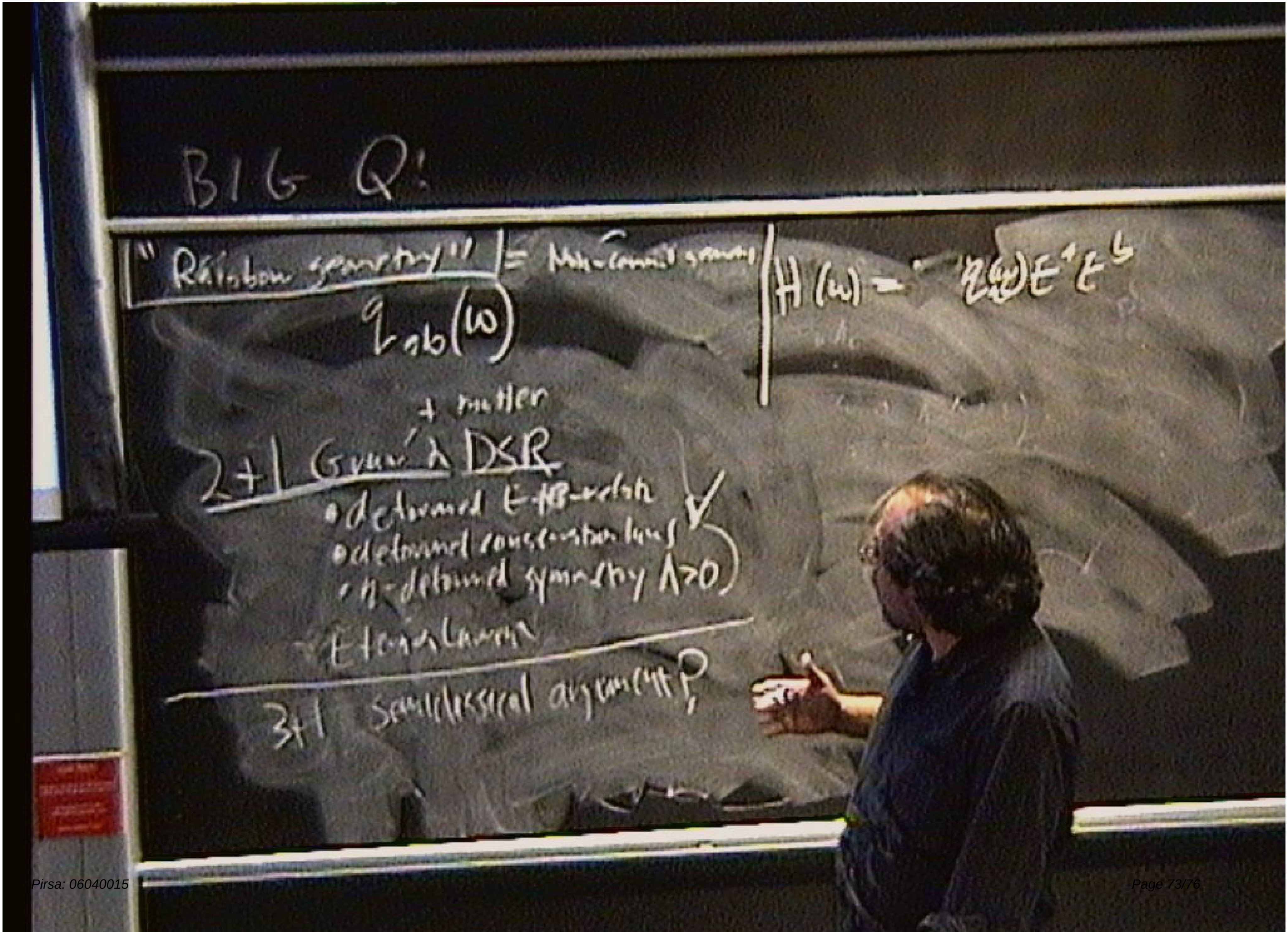
2+1 Grav'n → DSR

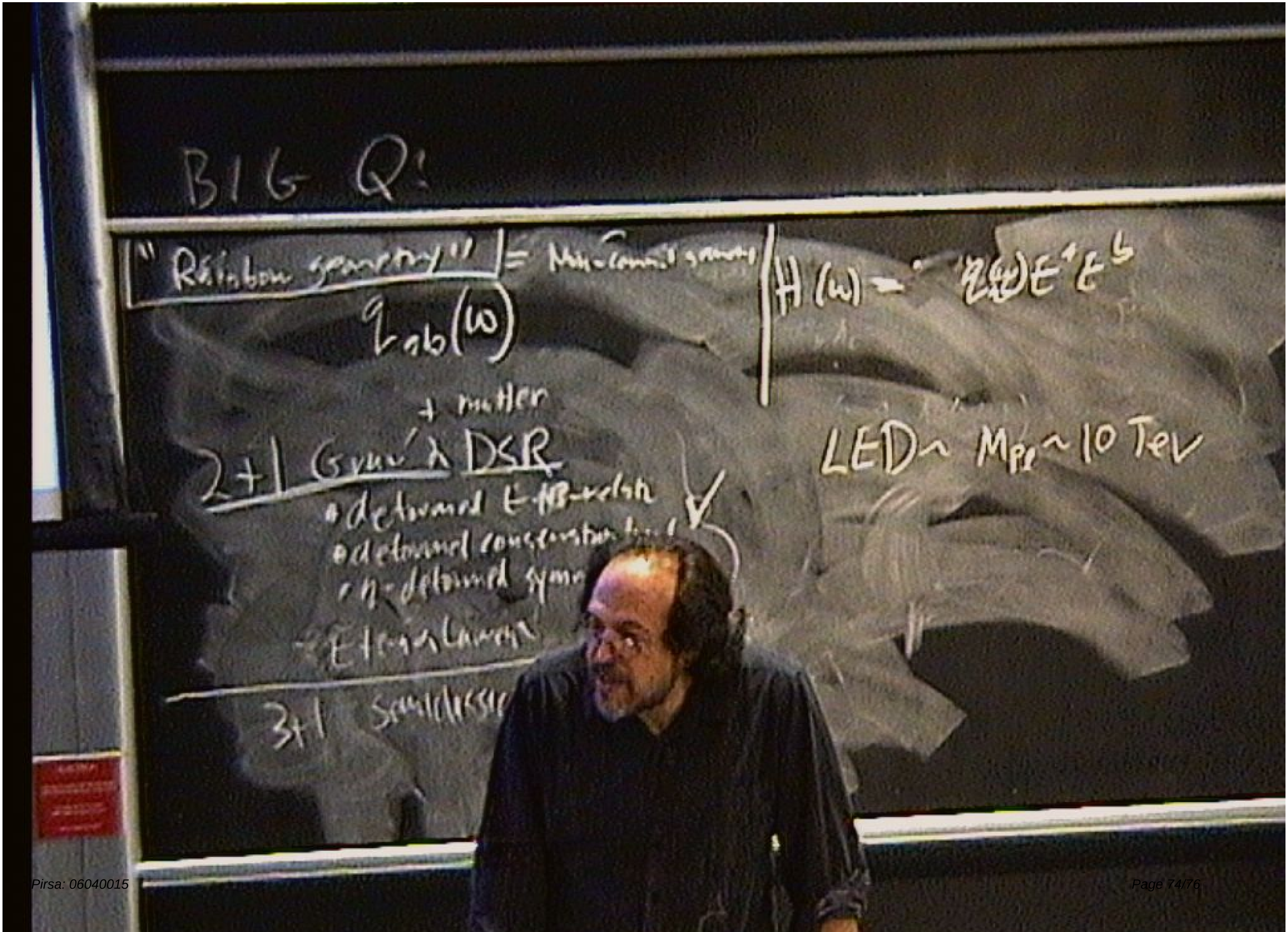
deformed E-M-relatn

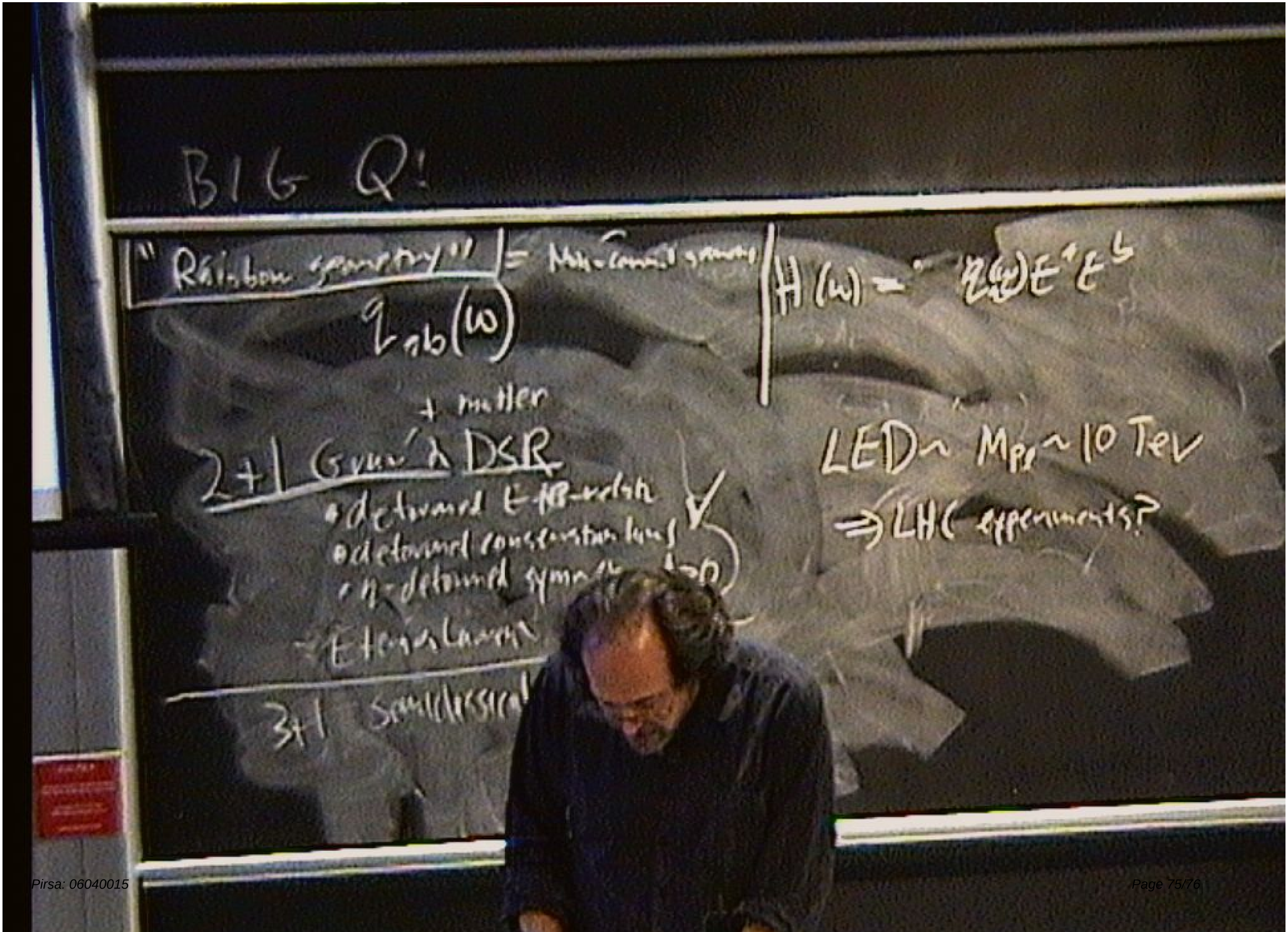

BIG Q!
"Rainbow geometry"
+ matter
2+1 Gravity & DSR

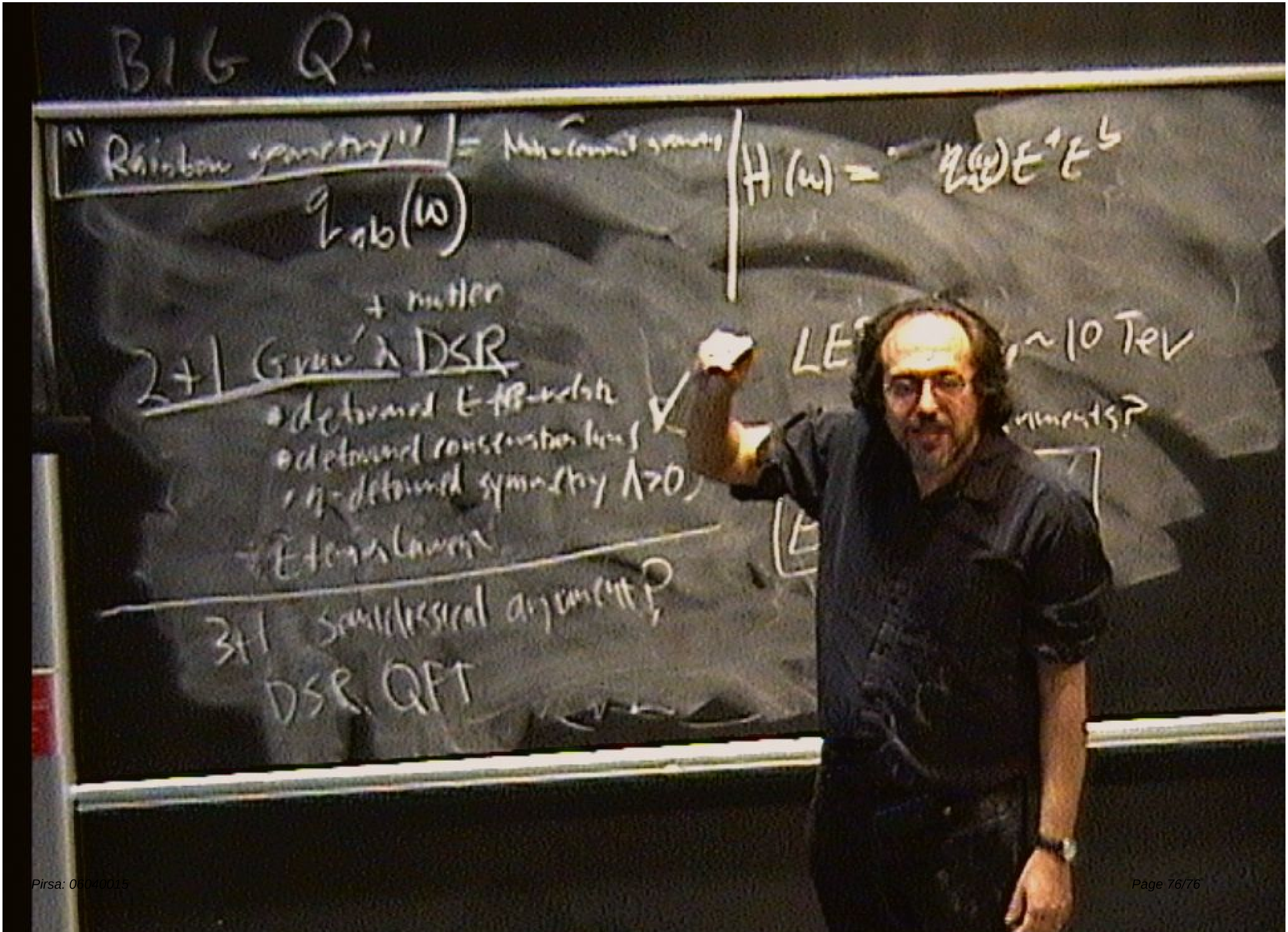

BIG Q!
"Rainbow geometry"
H (ω) =
+ matter
2+1 Grav'n DSR
deformed conservation laws


BIG Q!
"Rainbow symmetry"
+ matter
DSR


BIG Q!
"Rainbow geometry"
q_ab(ω)
+ matter
2+1 Gravity & DSR
• deformed E-p relatn
• deformed conservation laws
• q-deformed symmetry Λ>0
3+1 semiclassical argument?
H(ω) =


BIG Q:
"Rainbow geometry"
$g_{ab}(\omega)$
+ matter
2+1 Gravity & DSR
LED ~ M_{Pl} ~ 10 TeV
3+1


BIG Q!
"Rainbow geometry"
g_ab(ω)
+ matter
2+1 Gravity & DSR
• deformed conservation laws
3+1 semiclassical
H(ω) =
LED ~ M_Pl ~ 10 TeV
⇒ LHC experiments?


BIG Q!
"Rainbow geometry"
$g_{ab}(\omega)$
+ matter
3+1 Grav' Λ DSR
3+1 semiclassical argument?
DSR QFT
~10 TeV