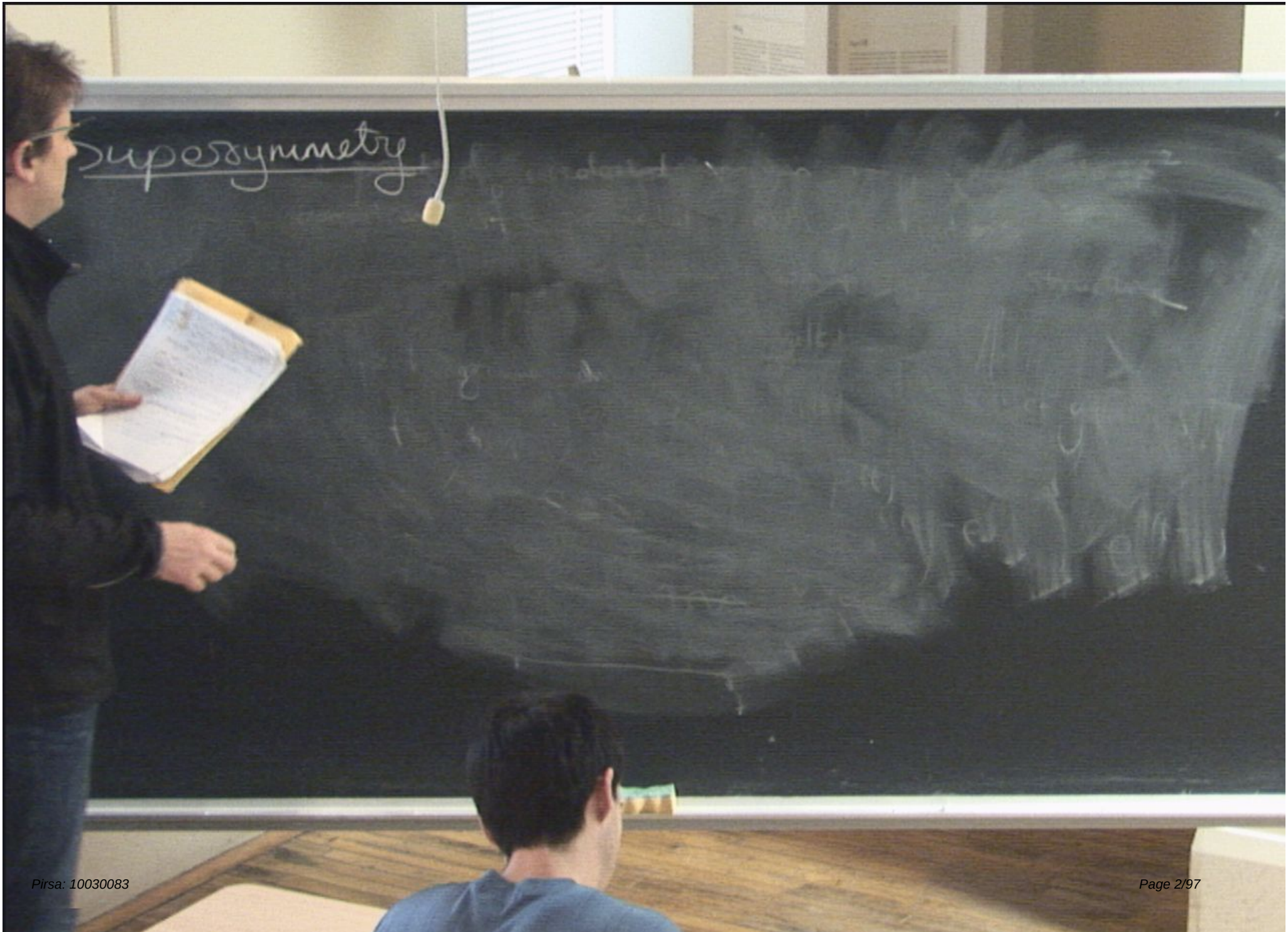
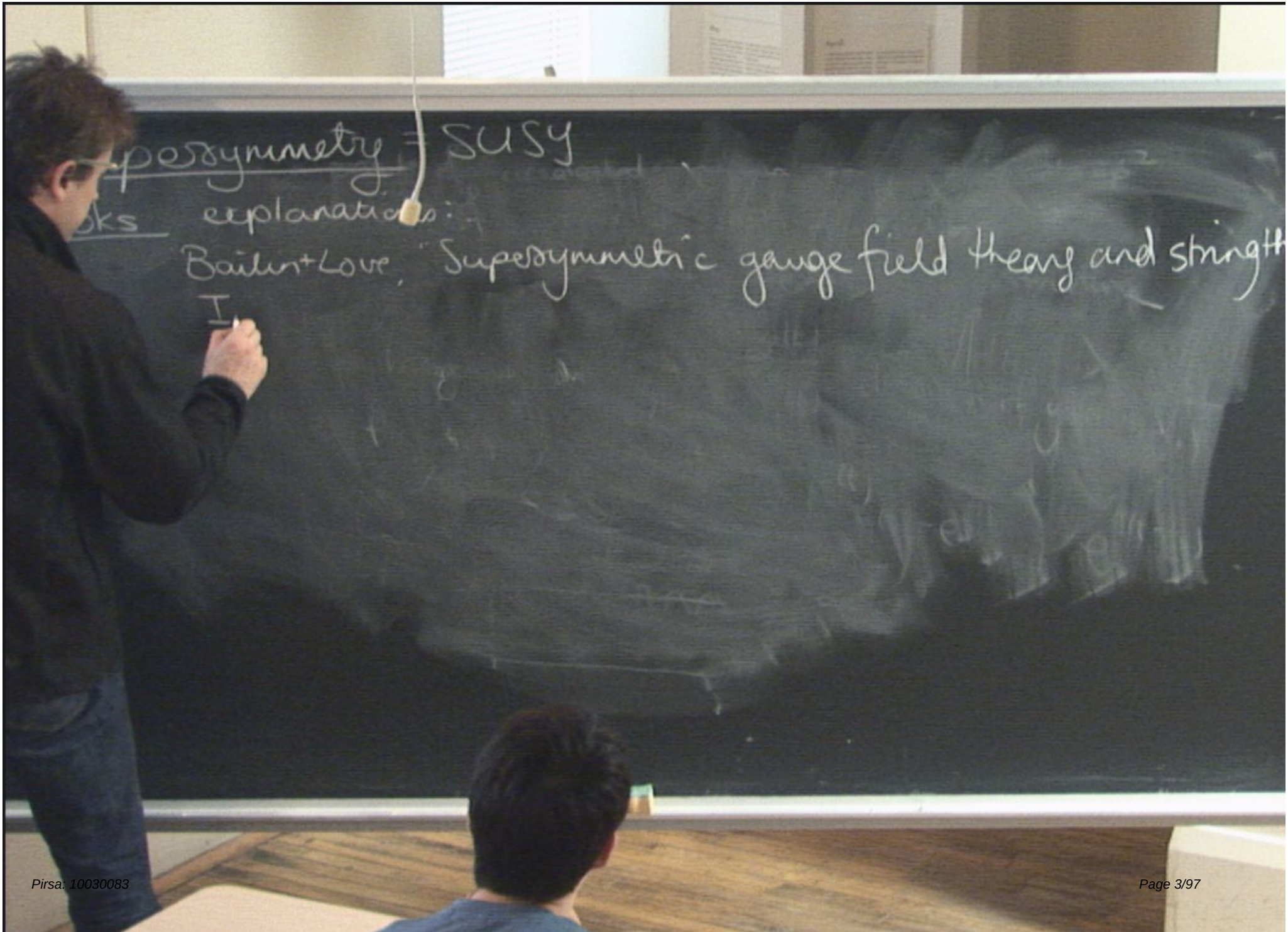
Title: Explorations in Particle Theory (PHYS 646) - Lecture 1

Date: Mar 15, 2010 10:10 AM

URL: http://pirsa.org/10030083

Abstract:


Supersymmetry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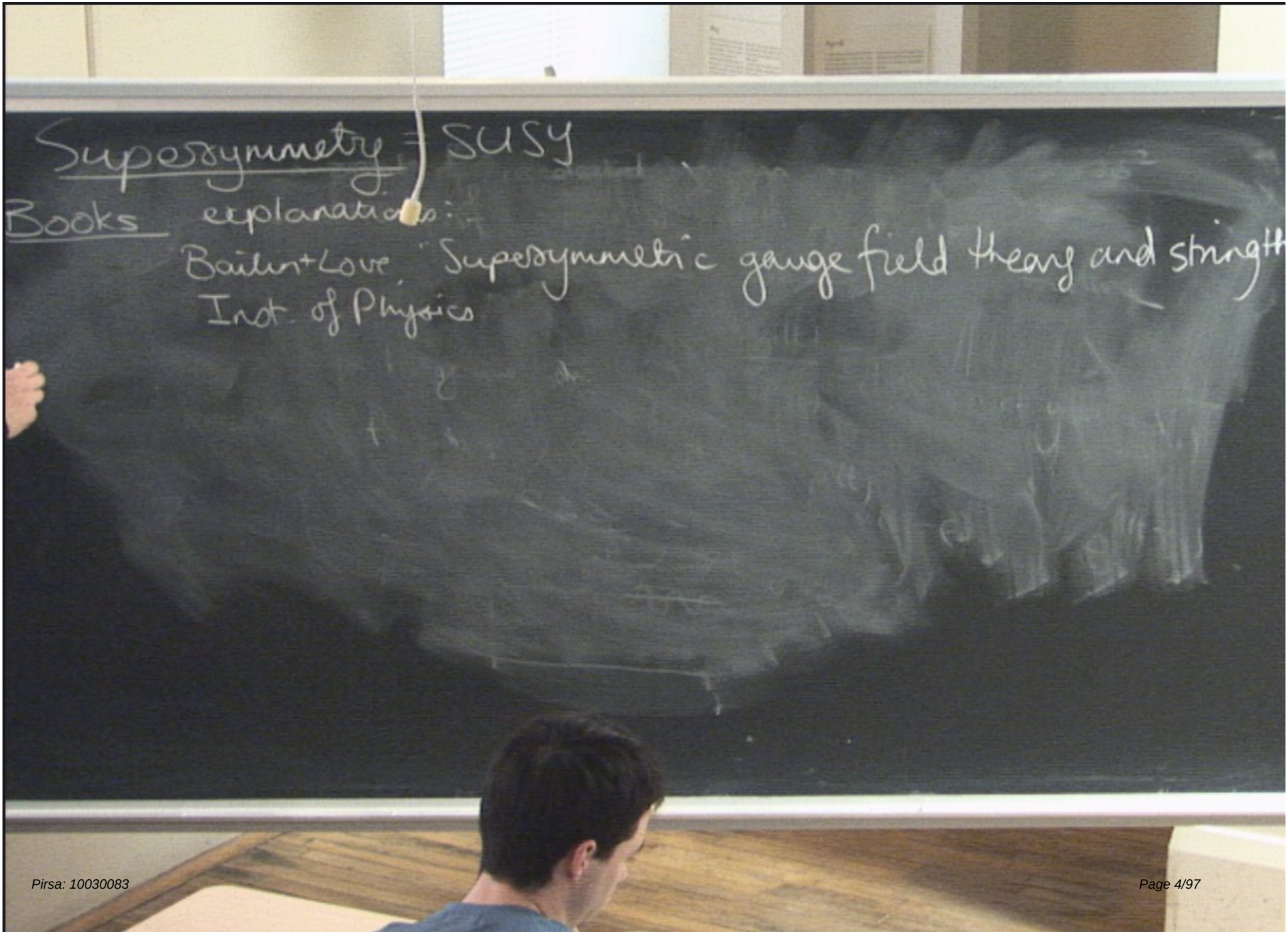
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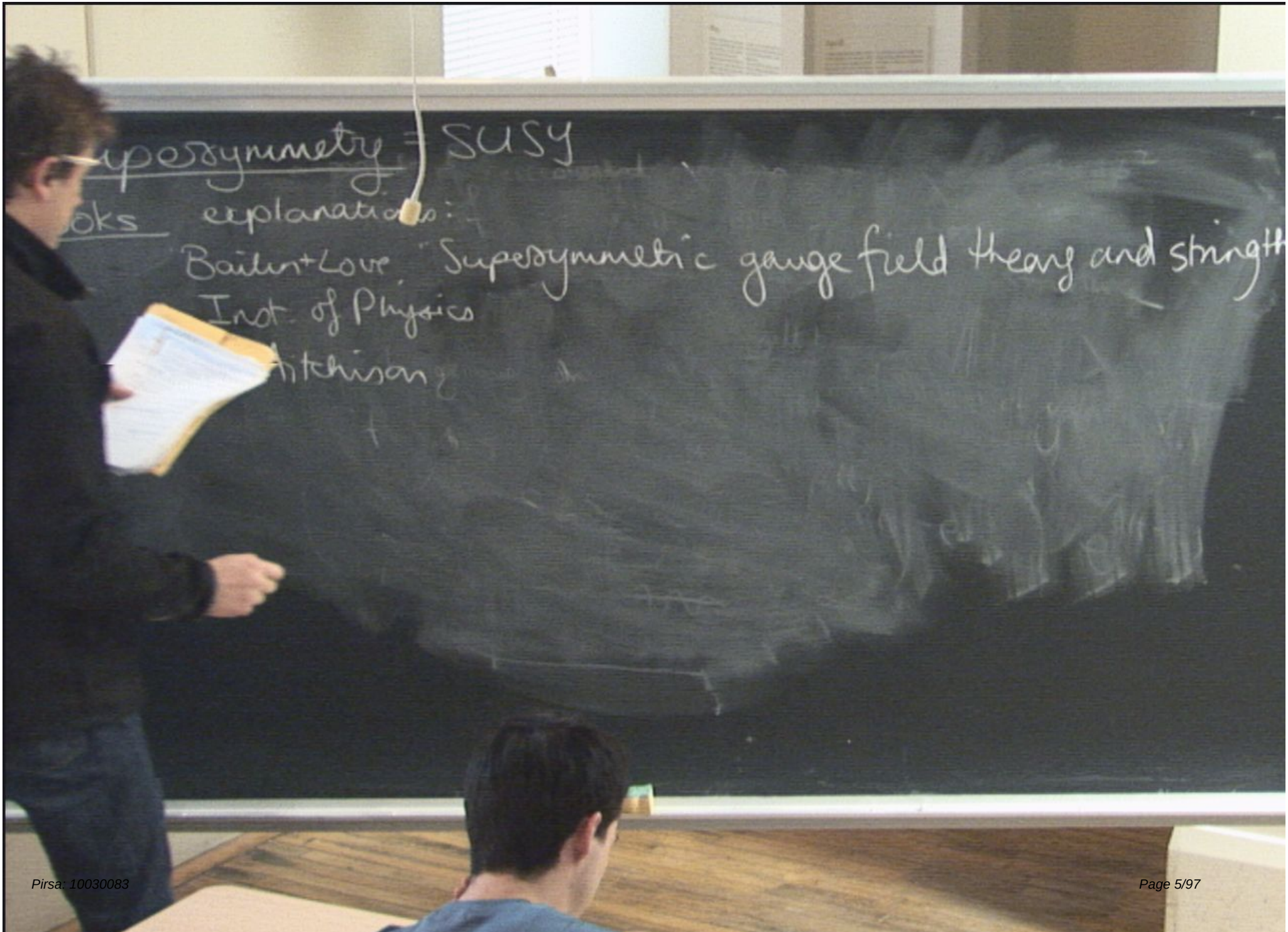
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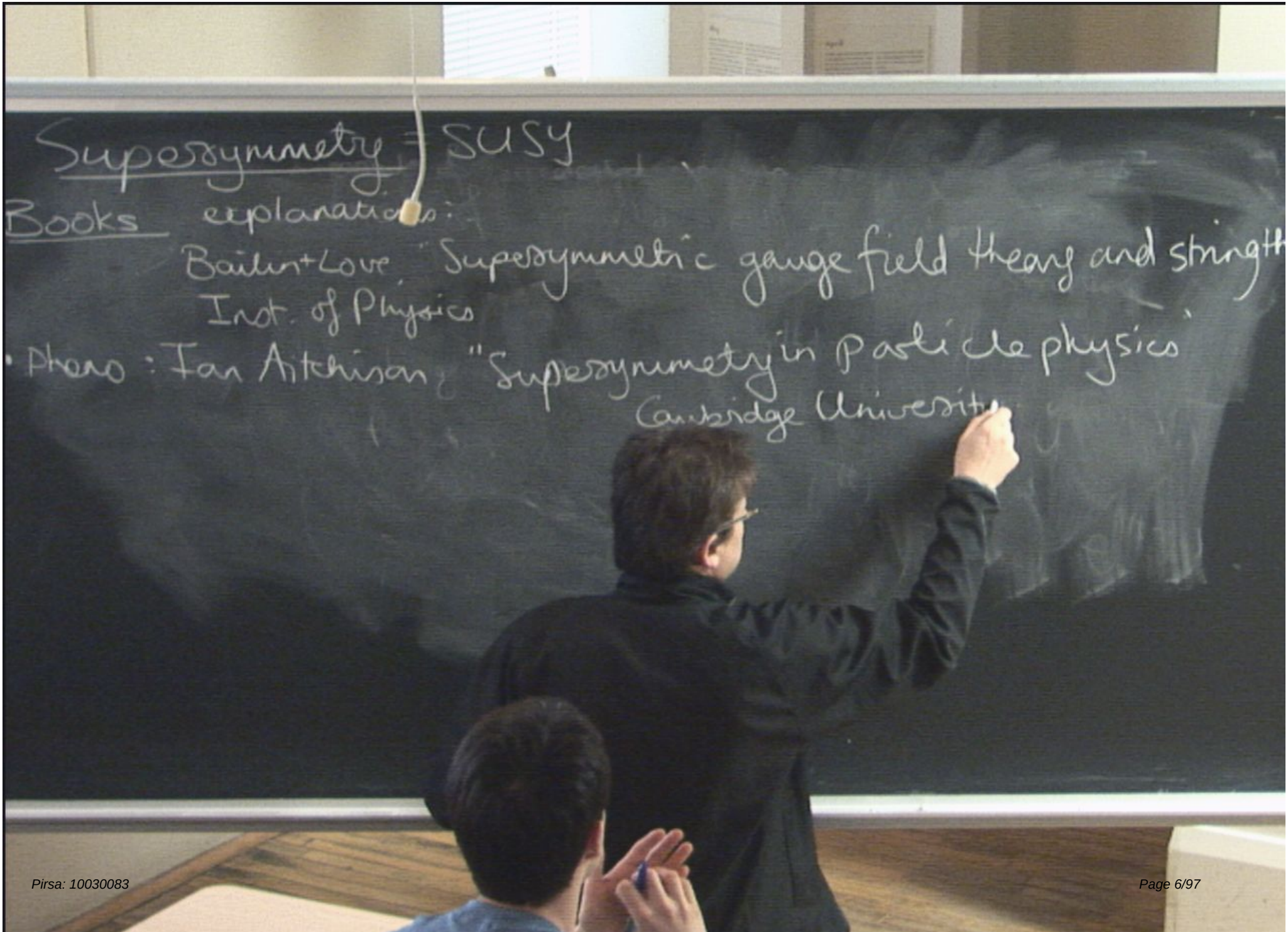
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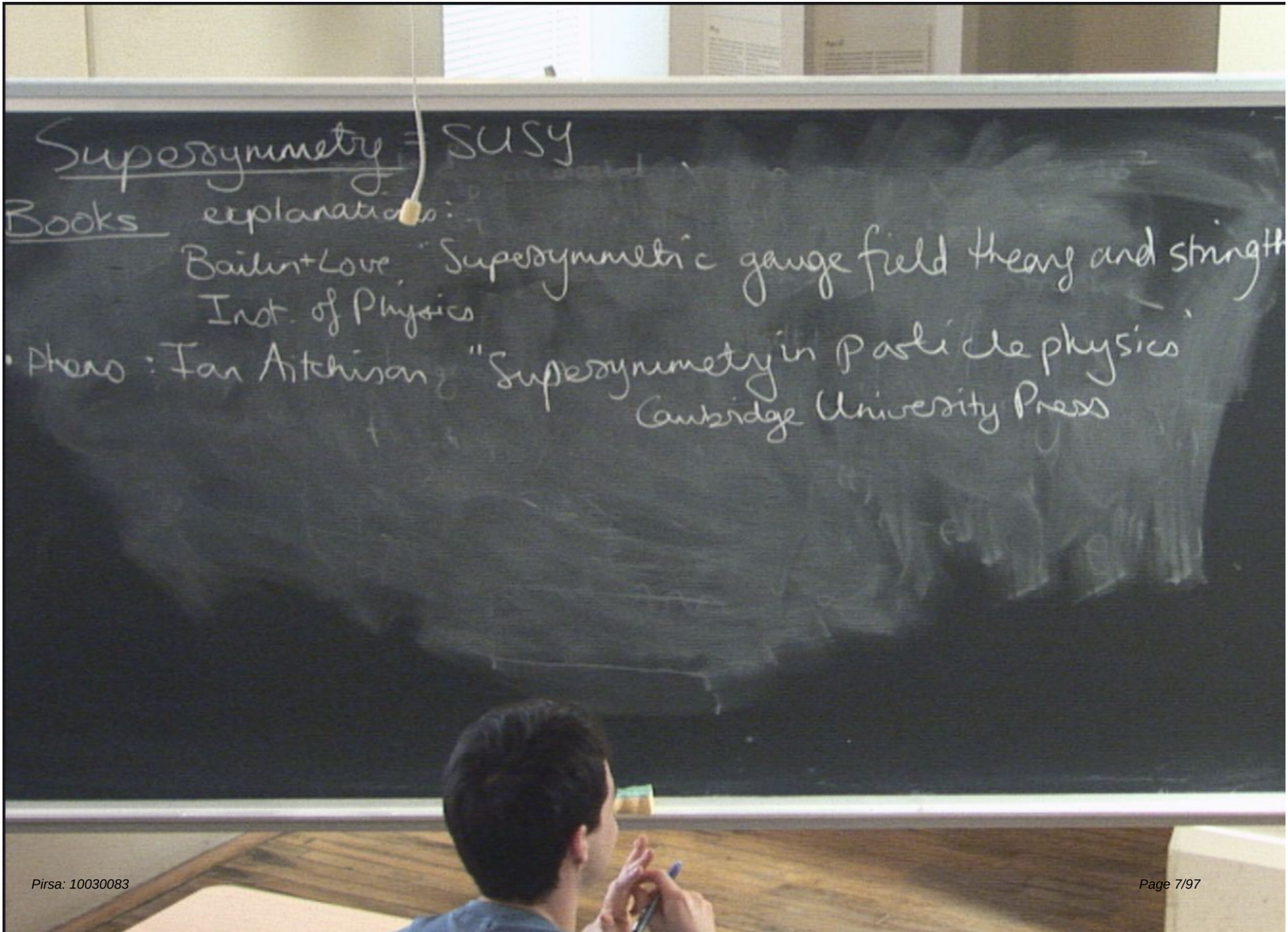
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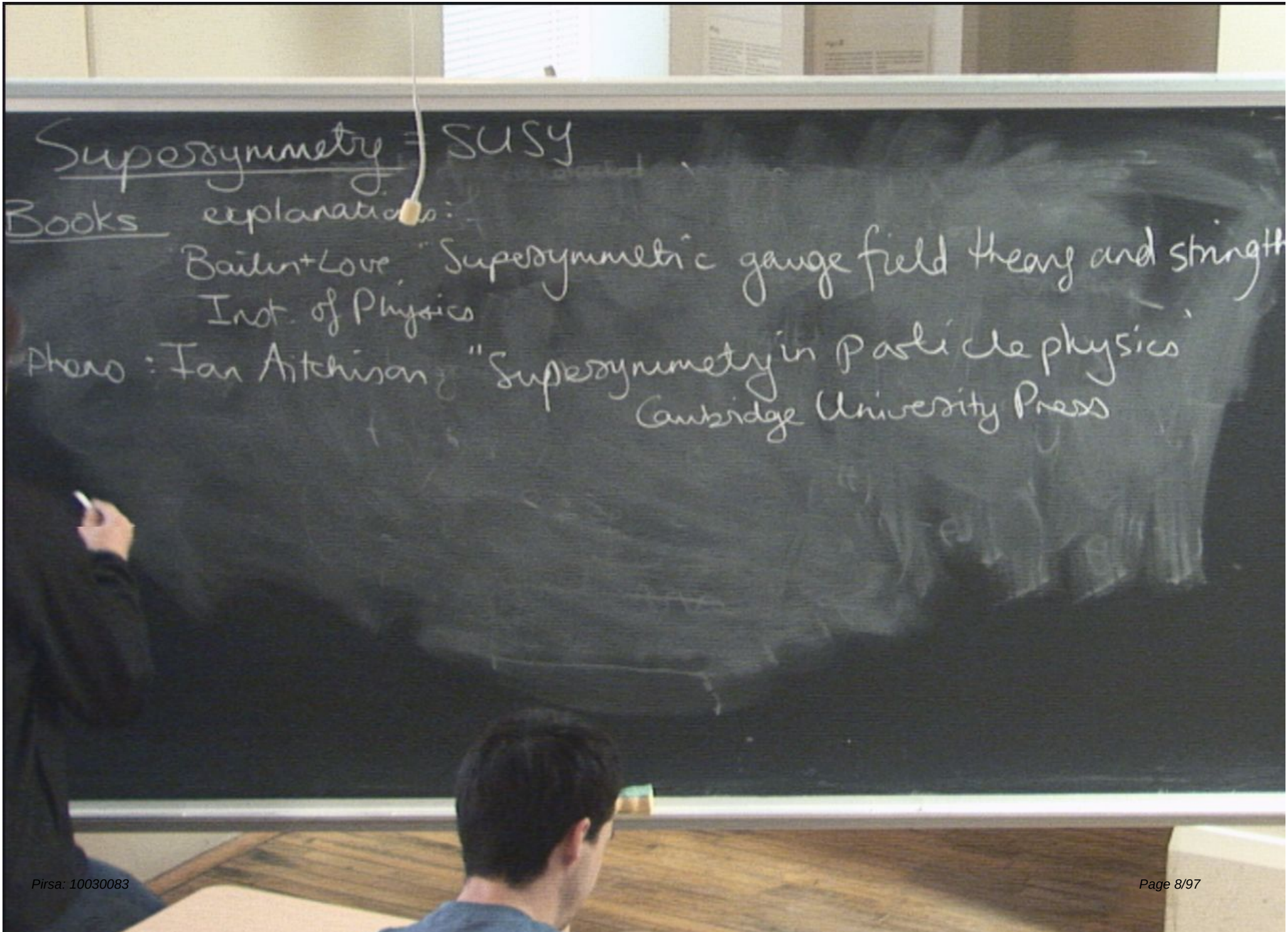
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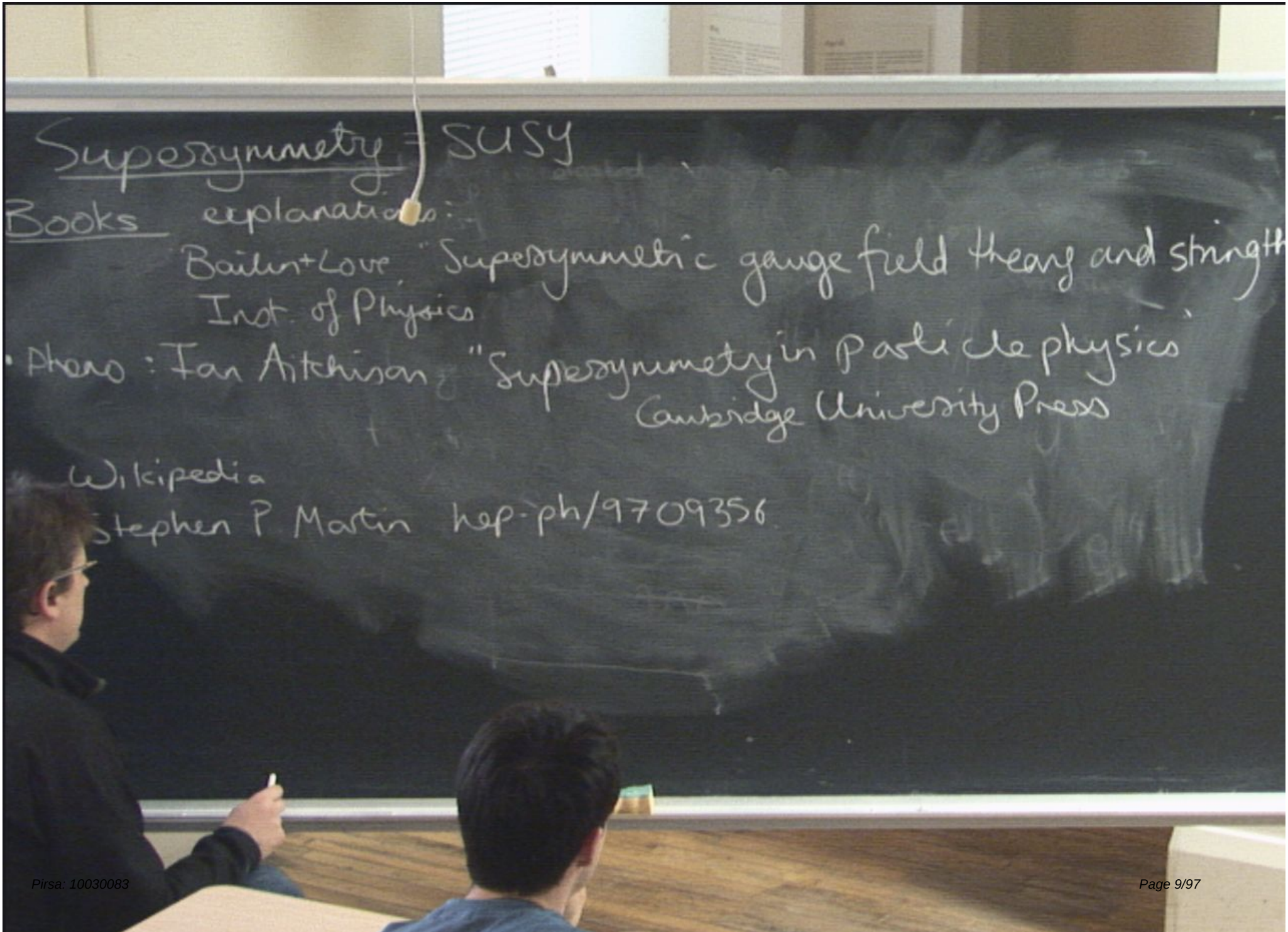
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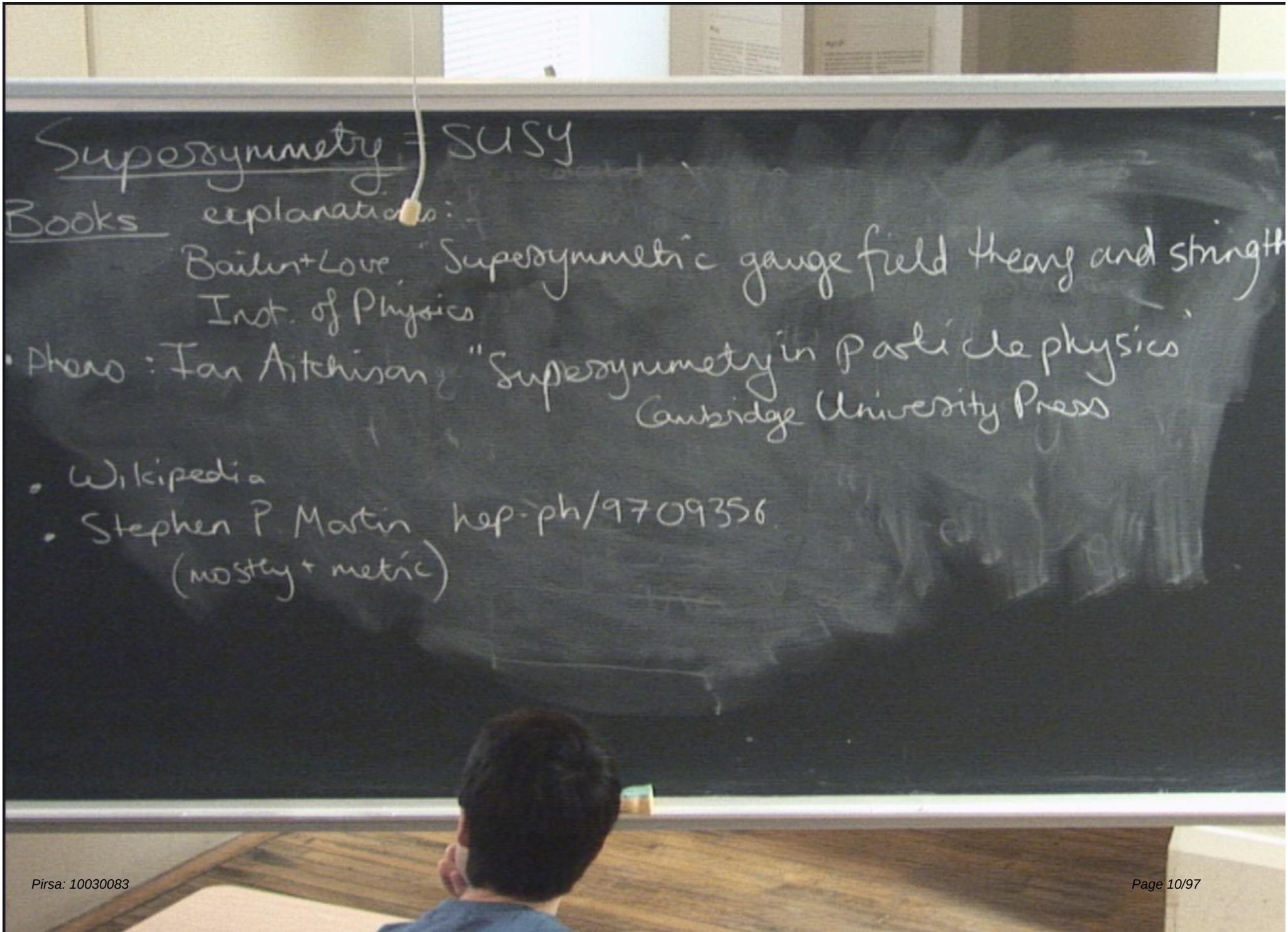
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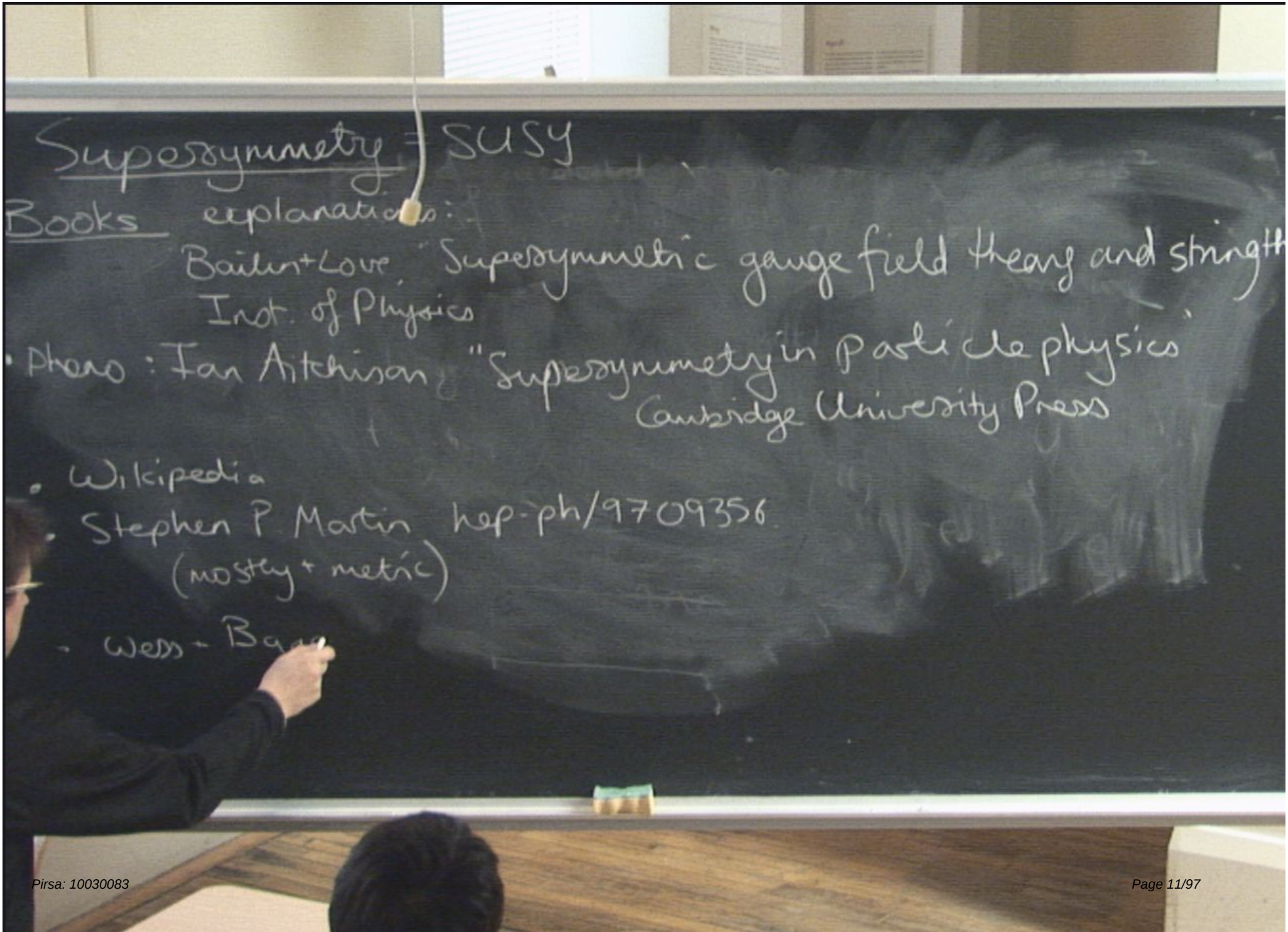
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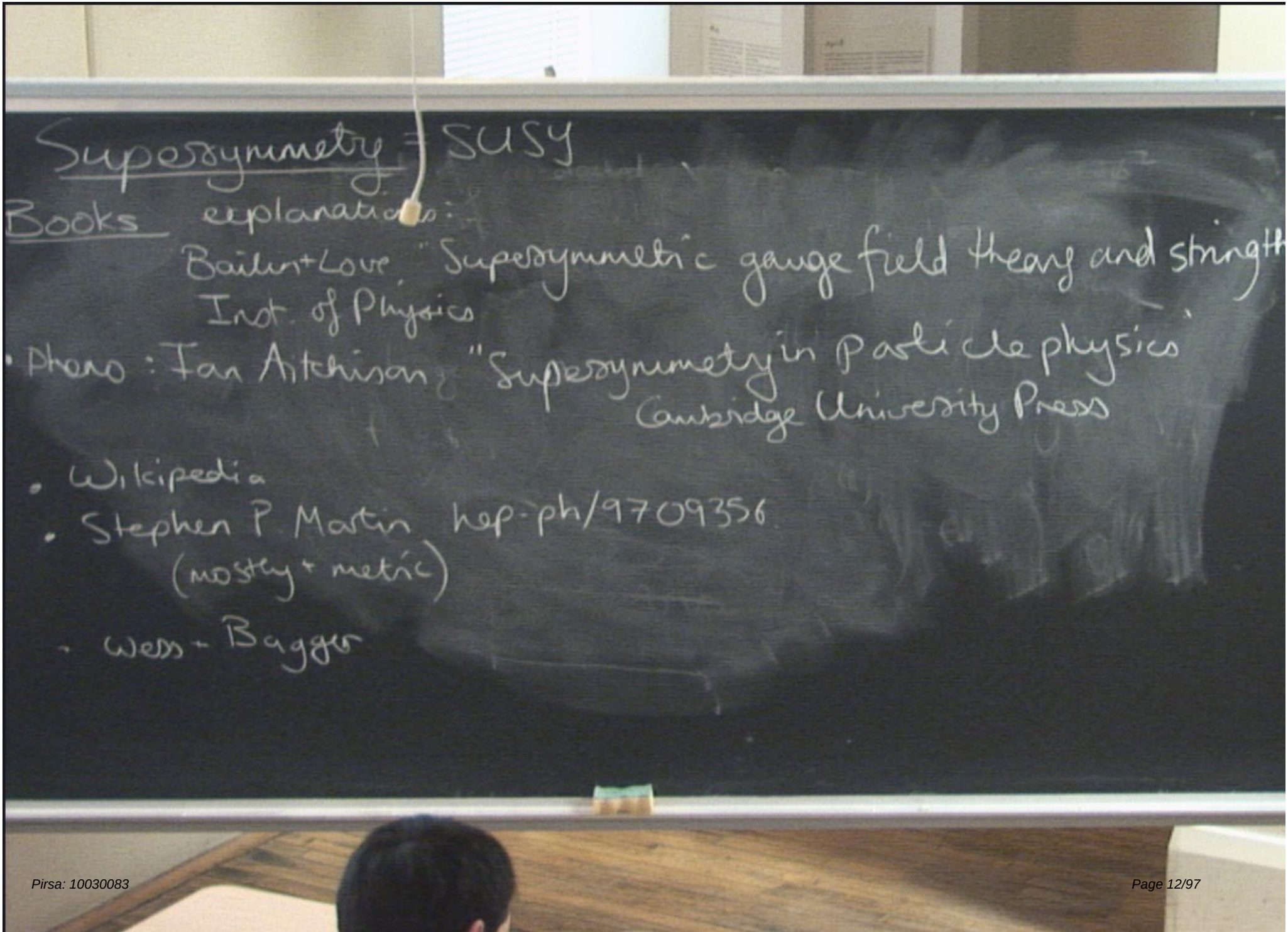
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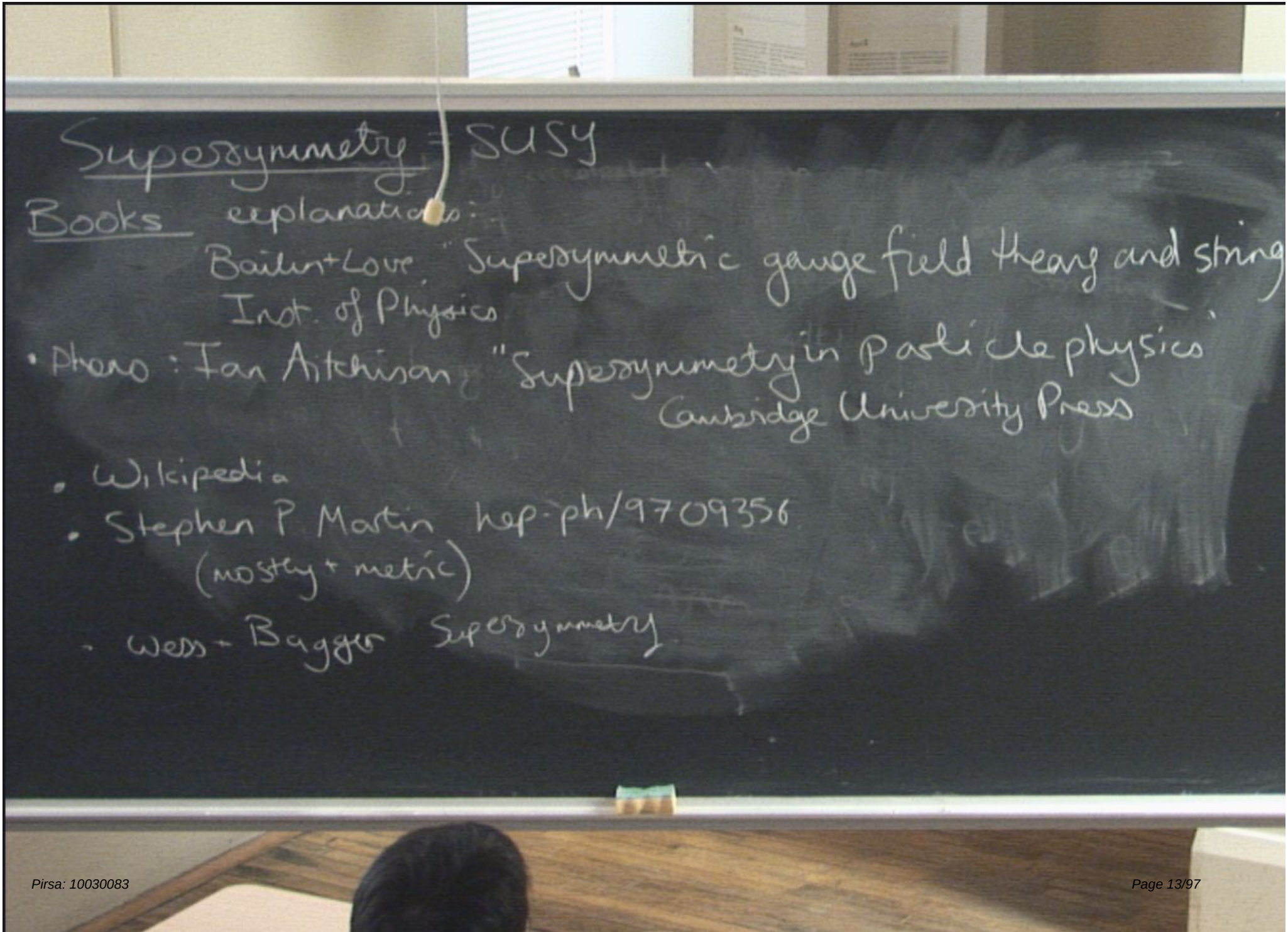
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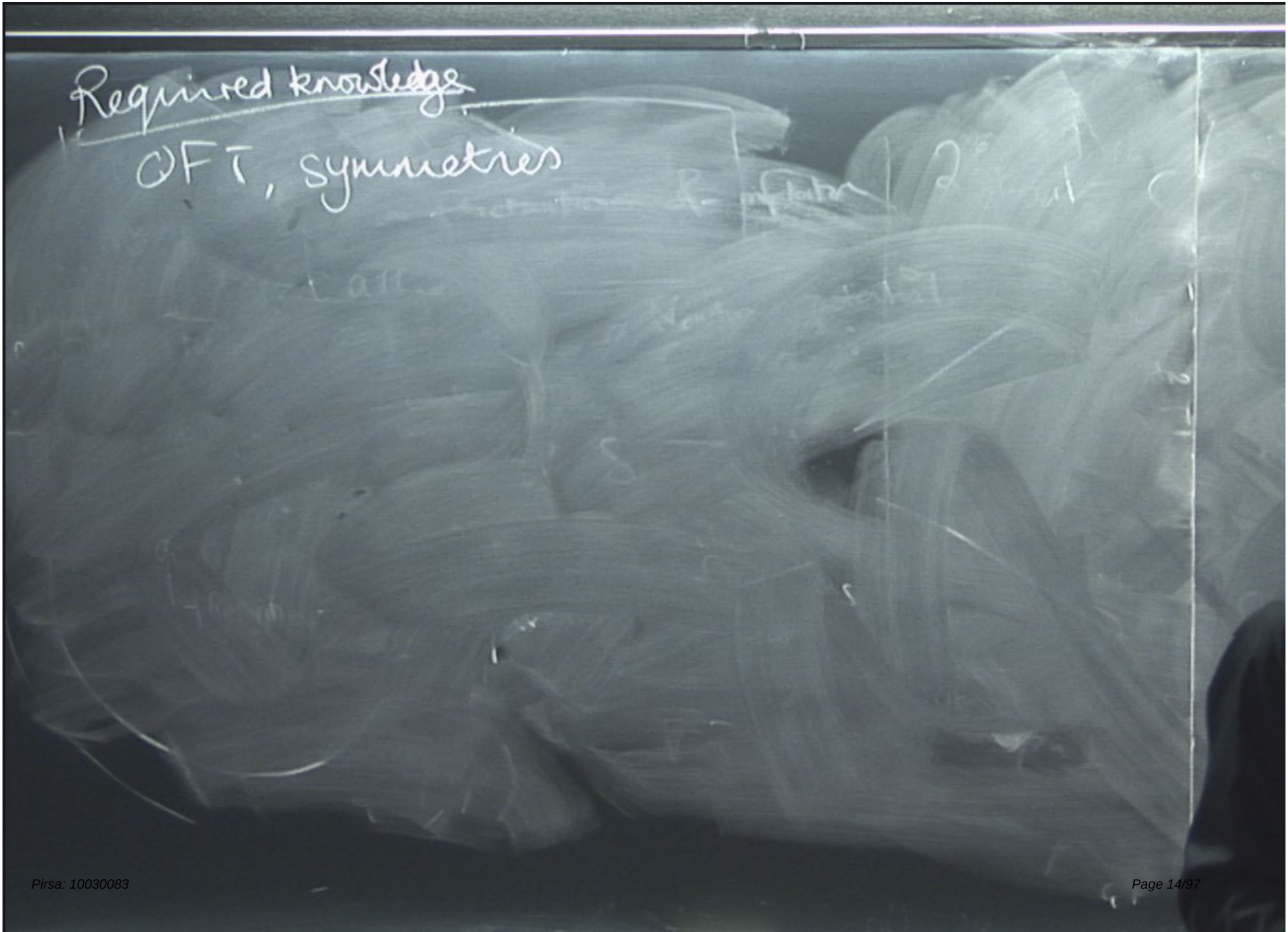
Required knowledge
QFT, symmetries

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QFT, symmetries + SSB

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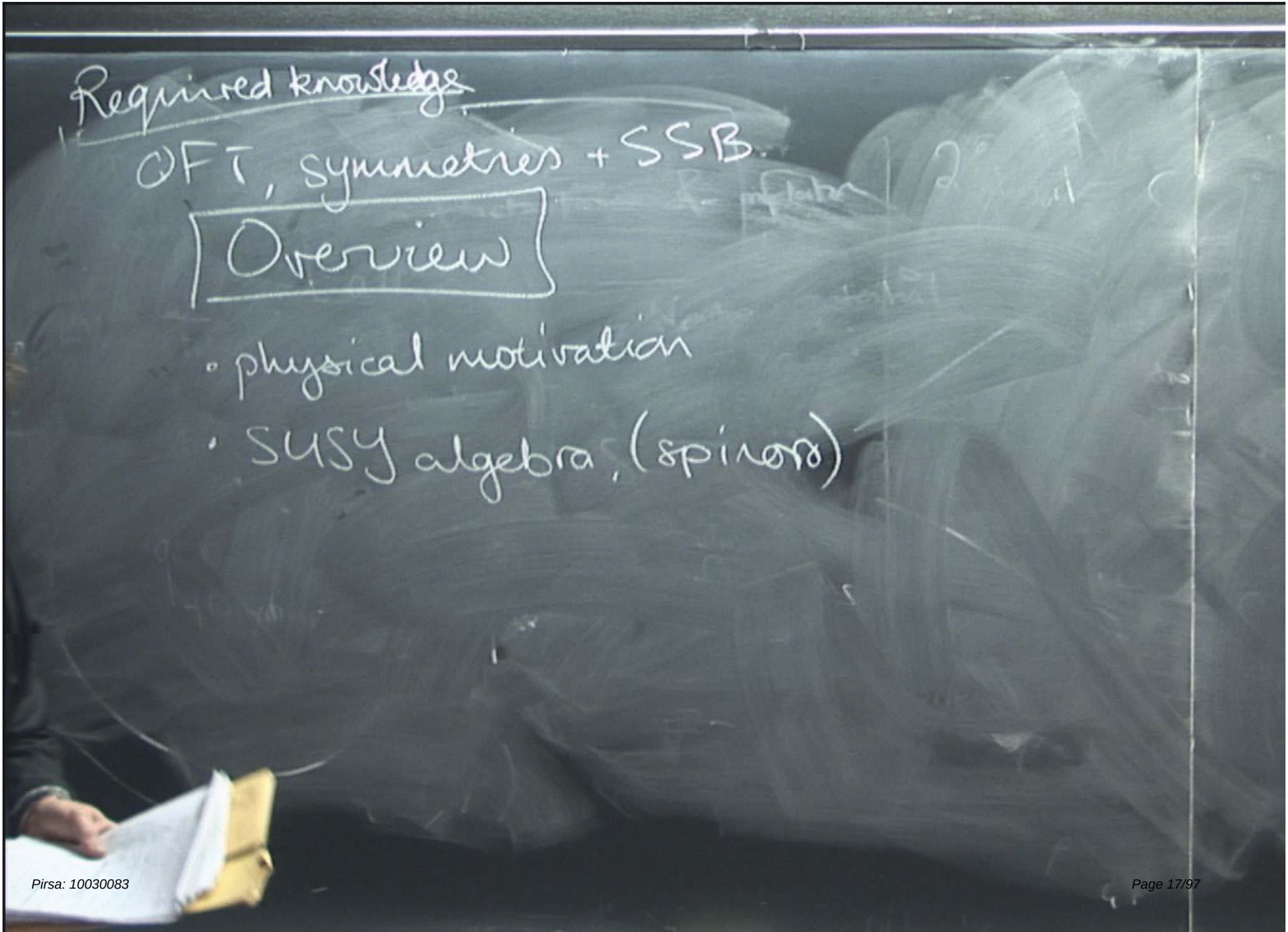
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QFT, symmetries + SSB.
Overview
• physical motivation
• SUSY algebra, (spinors)

Required knowledge

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- SUSY algebra (spinors)
  - representations

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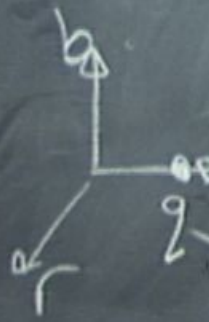

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- 4-d Lagrangians : N=1 global

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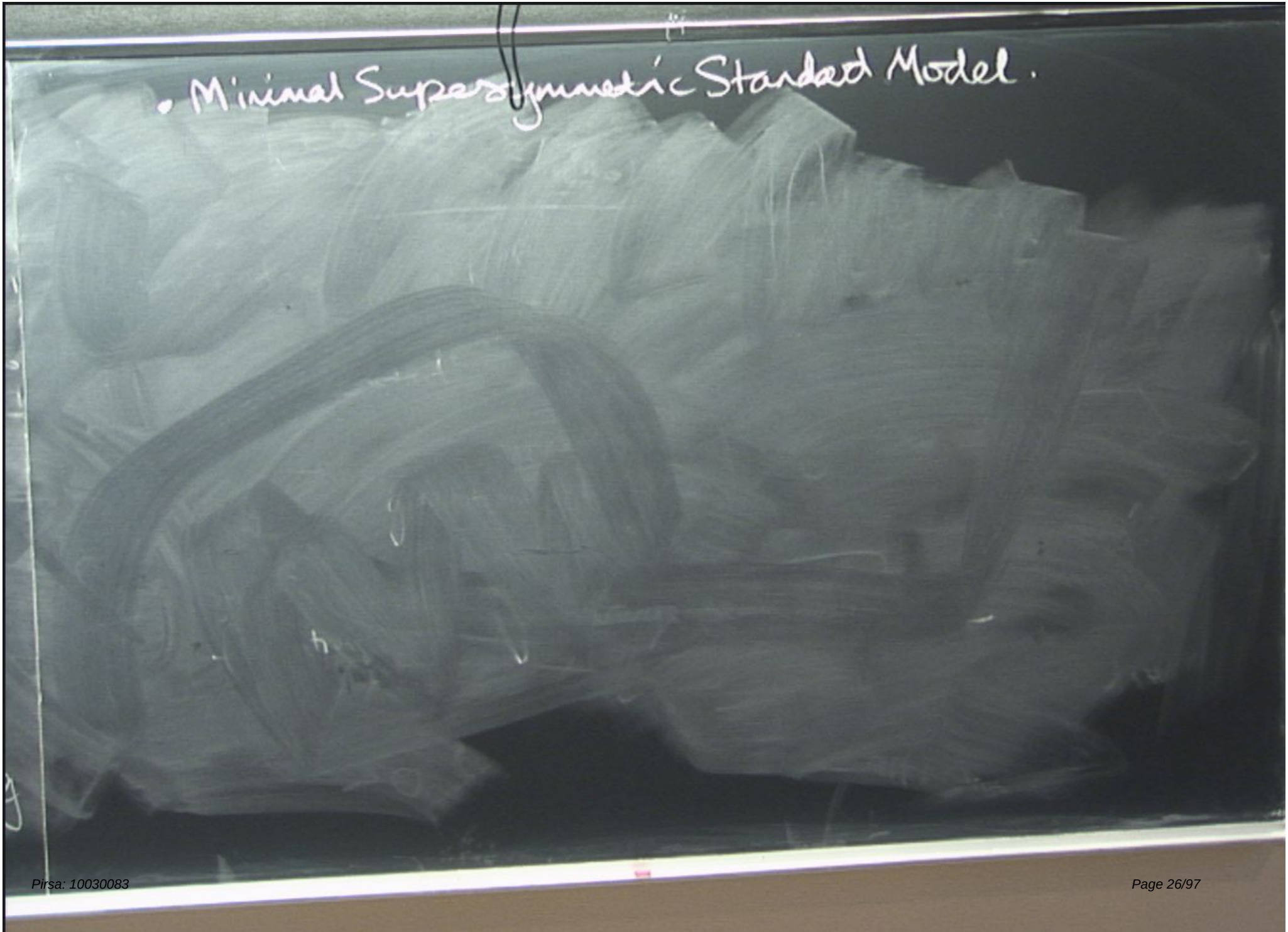
- 4-d Lagrangians : N=1 global
- SUSY breaking : F/D term breaking
  super-Higgs effect.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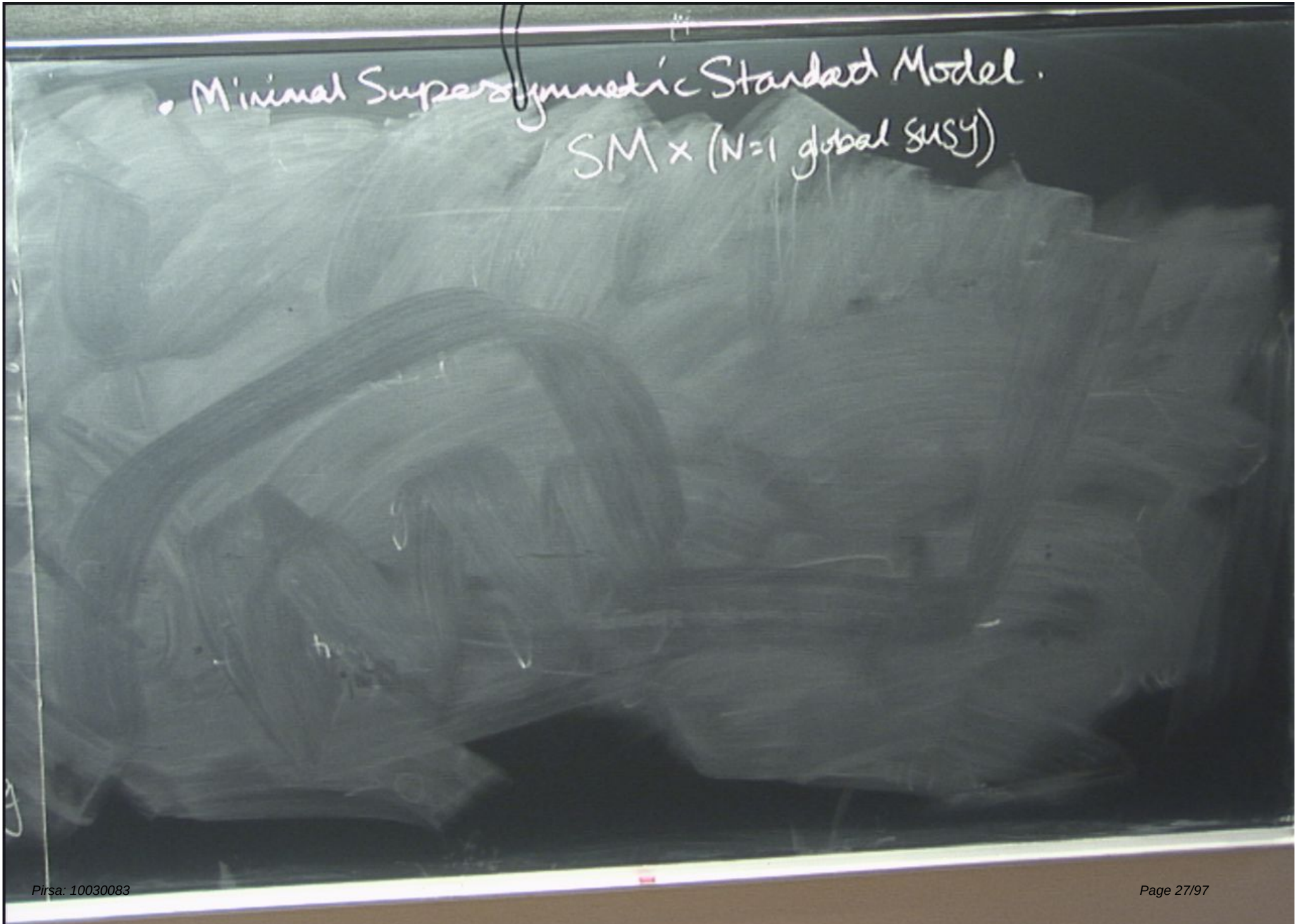
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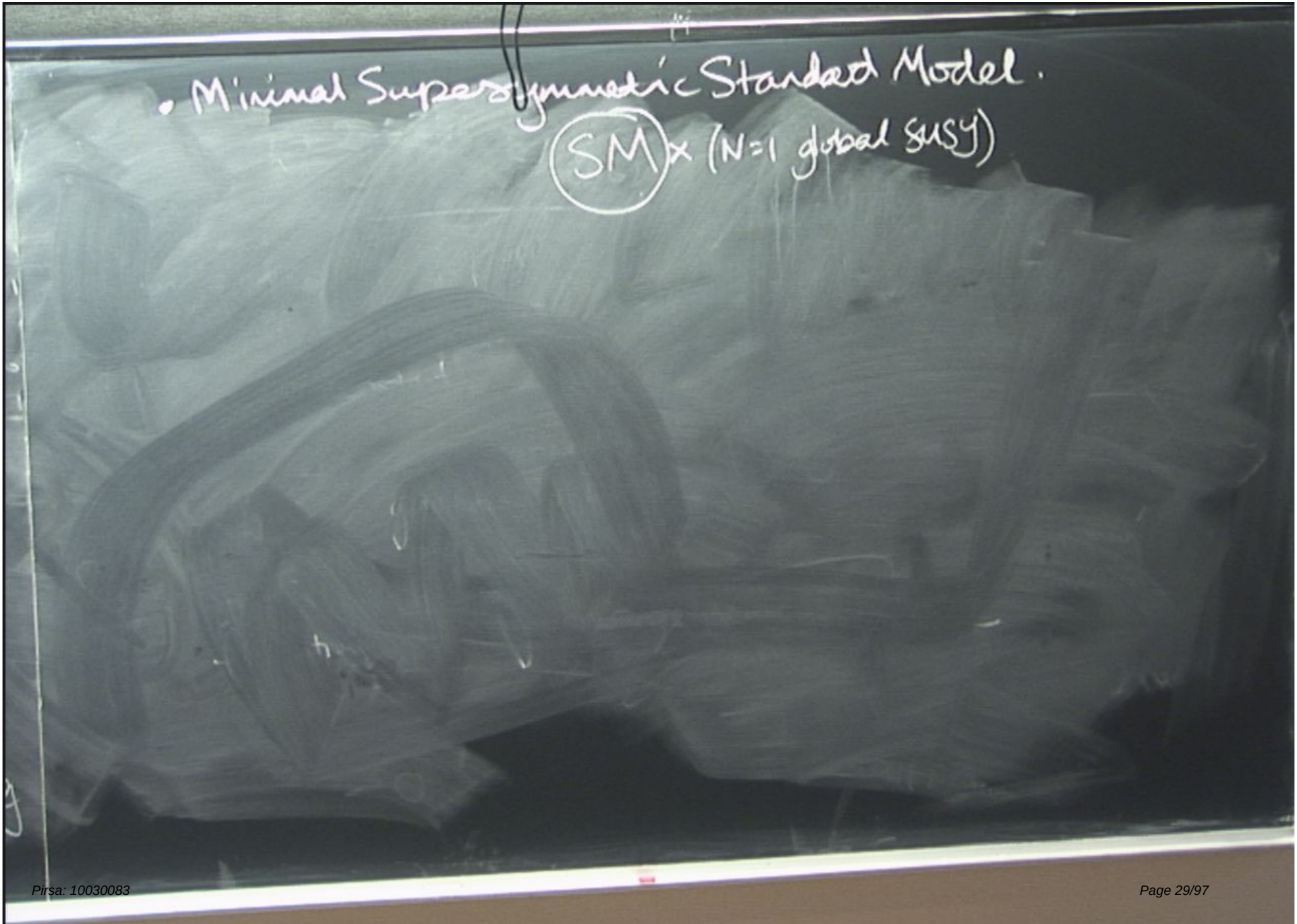
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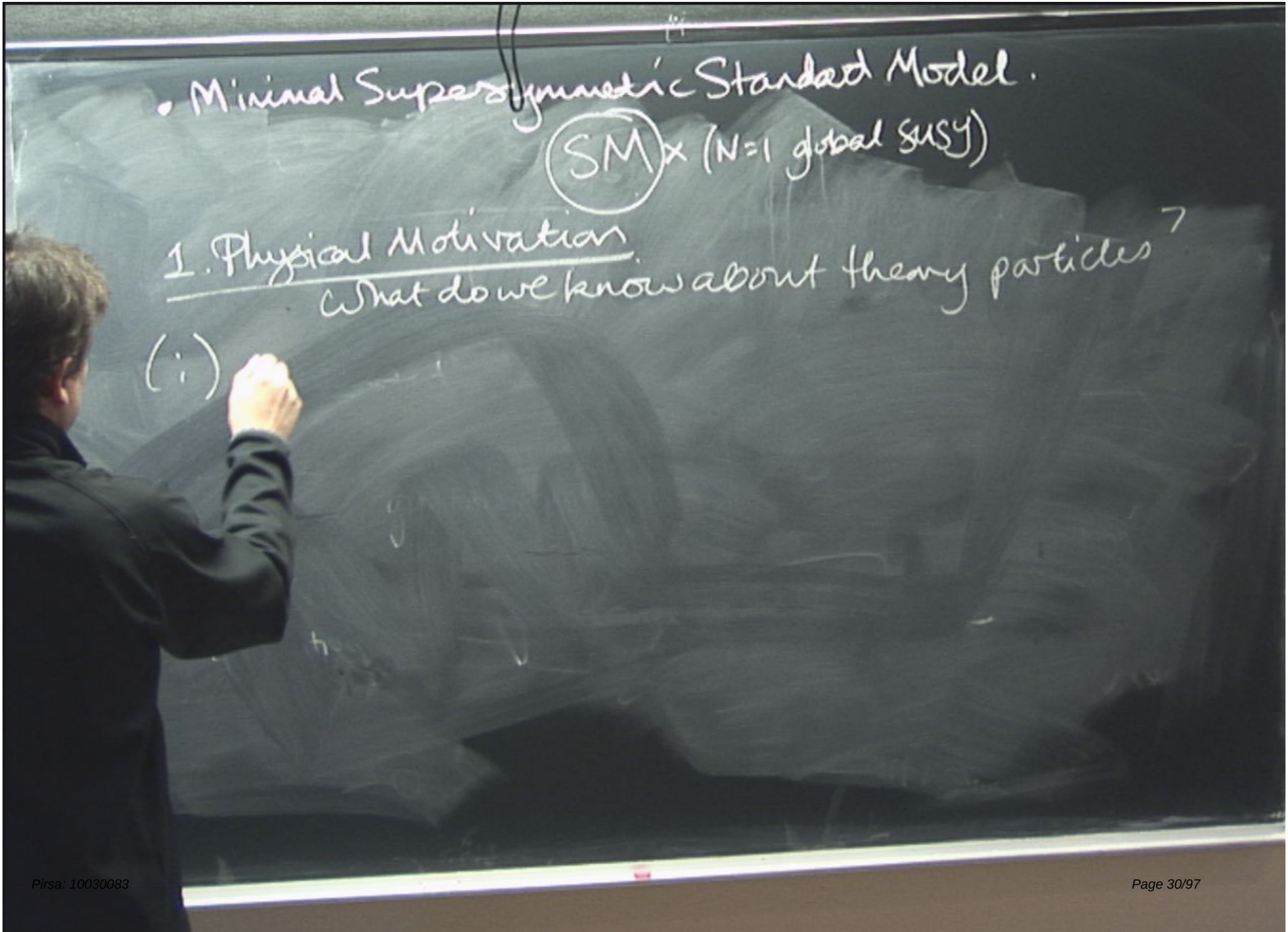
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1. Physical Motivation
What do we know about theory particles?
(;)

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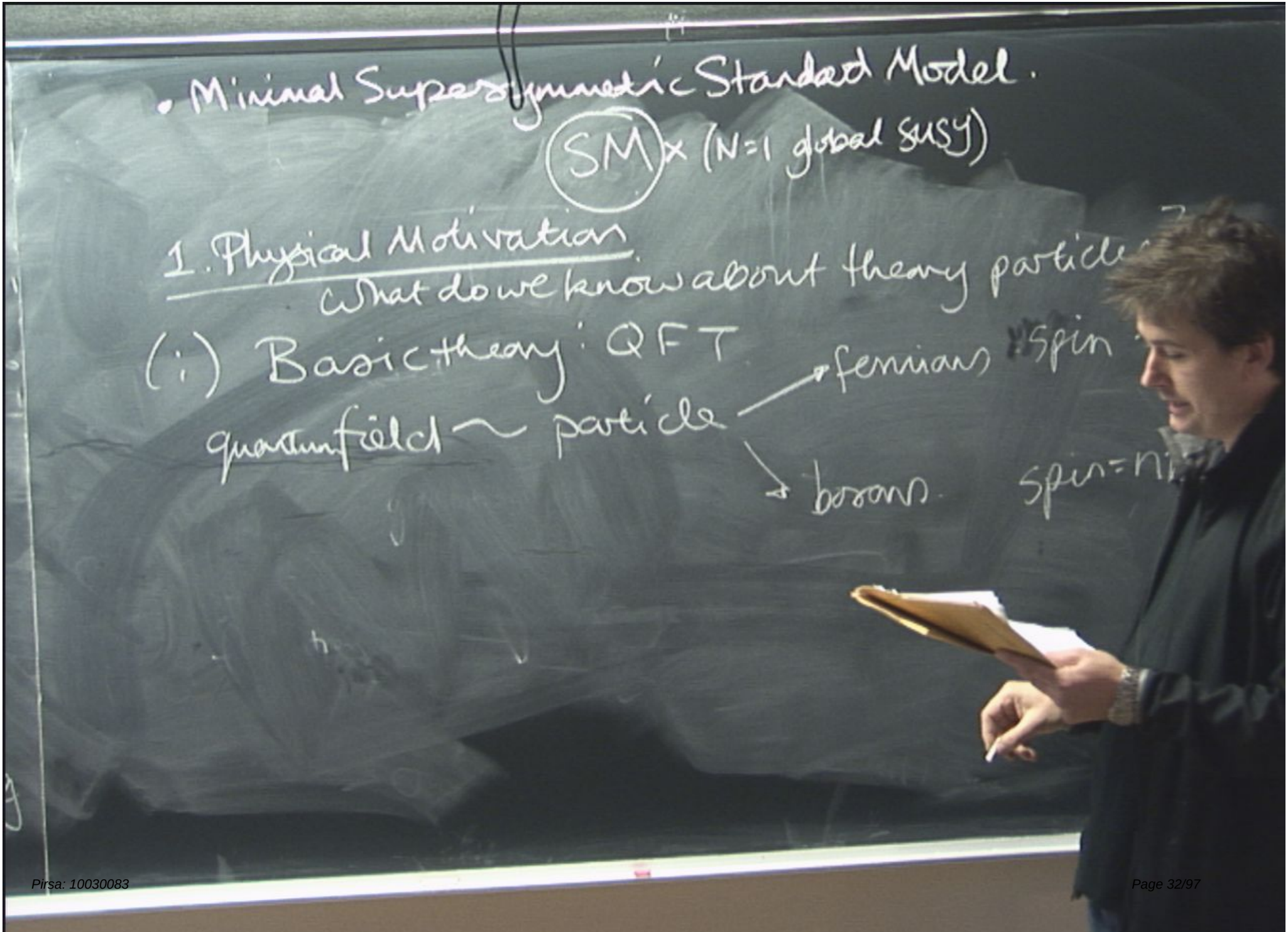
What do we know about theory particles?

(i) Basic theory: QFT

quantum field ~ particle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(ii) Symmetries v important!

(a) Internal $\Phi^a(x)$

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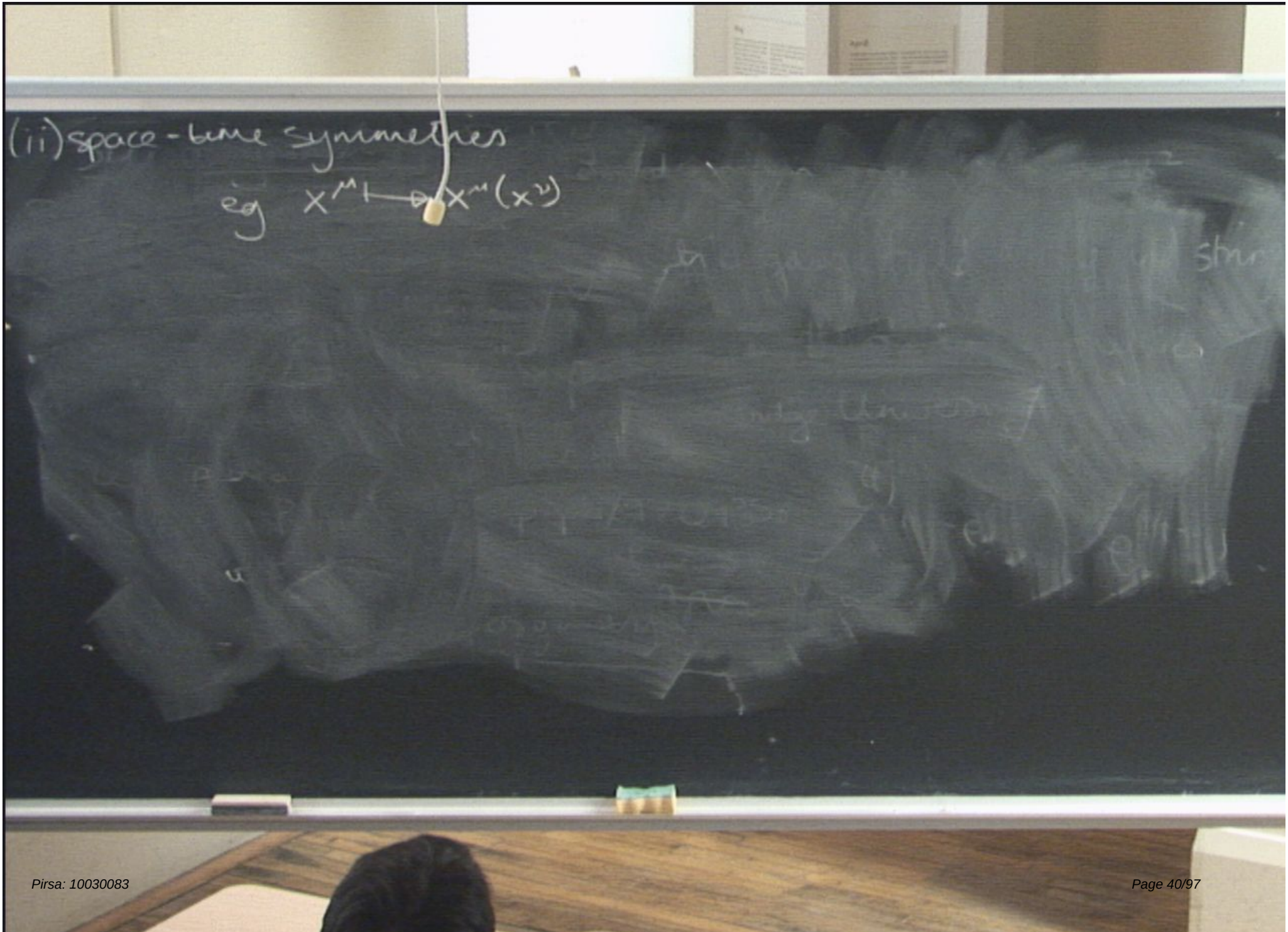
$M^a{}_b$ cant in x^μ GLOBAL!

$M^a{}_b = M^a{}_b(x^\mu)$ local sym.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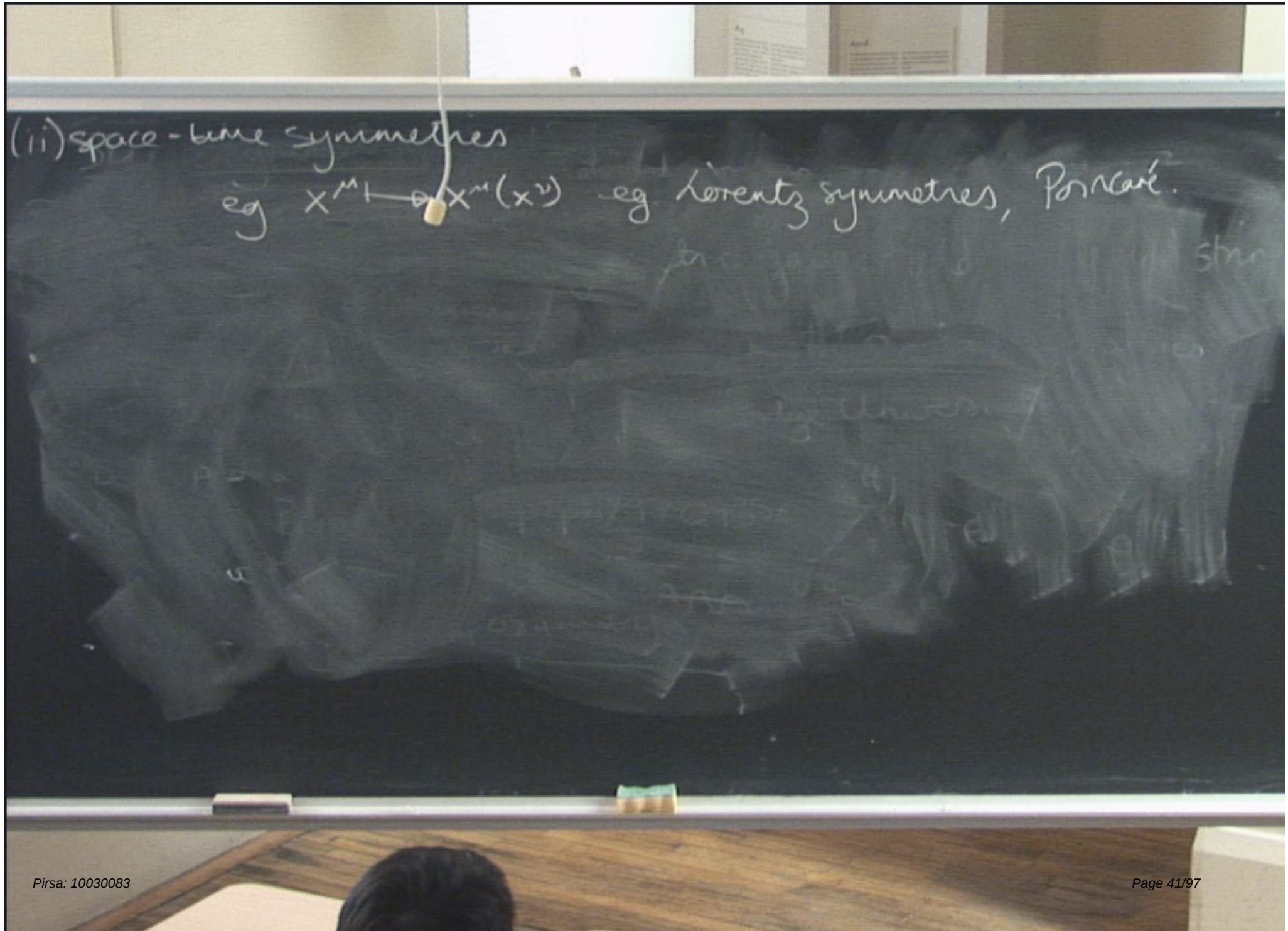
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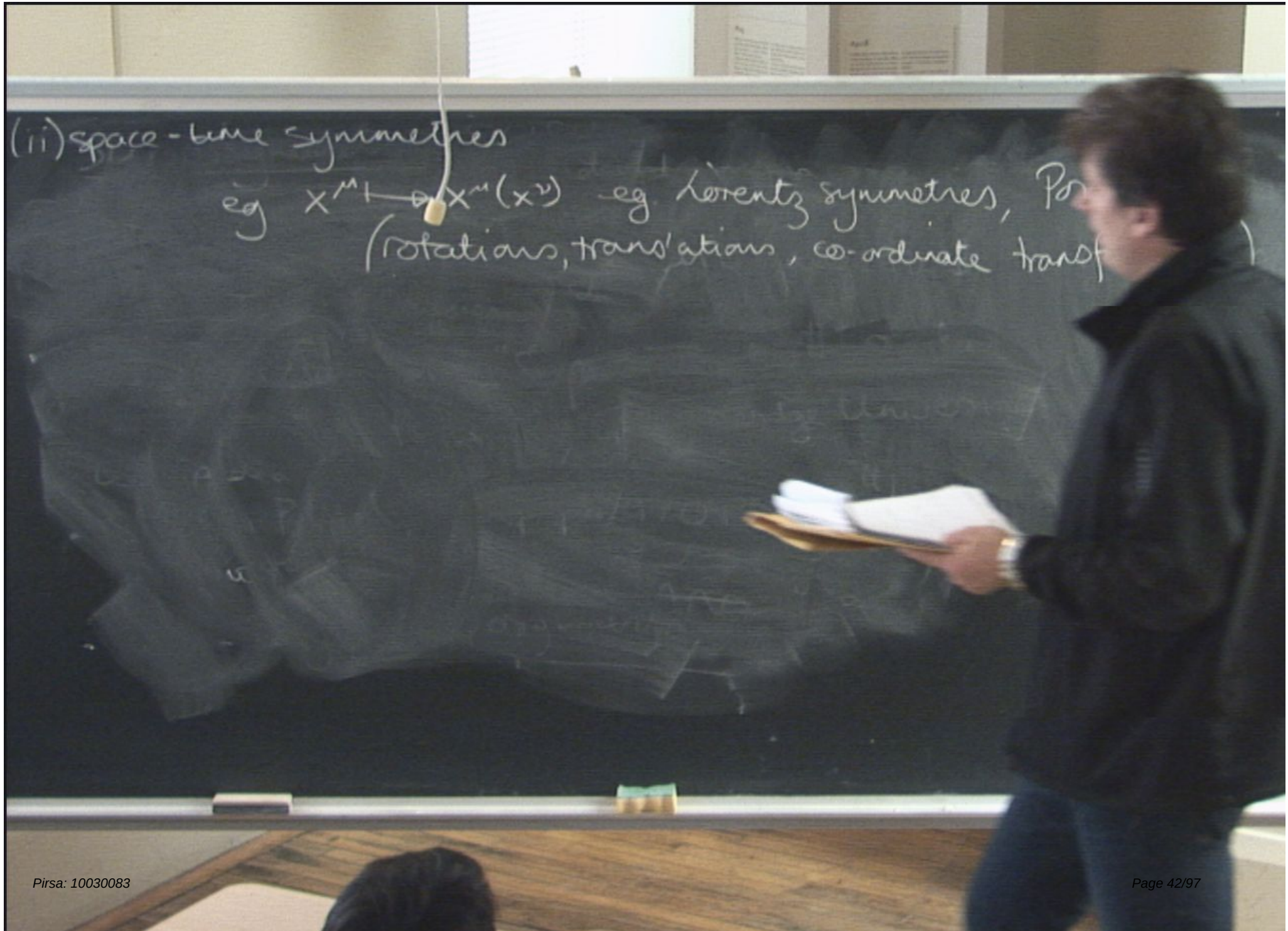
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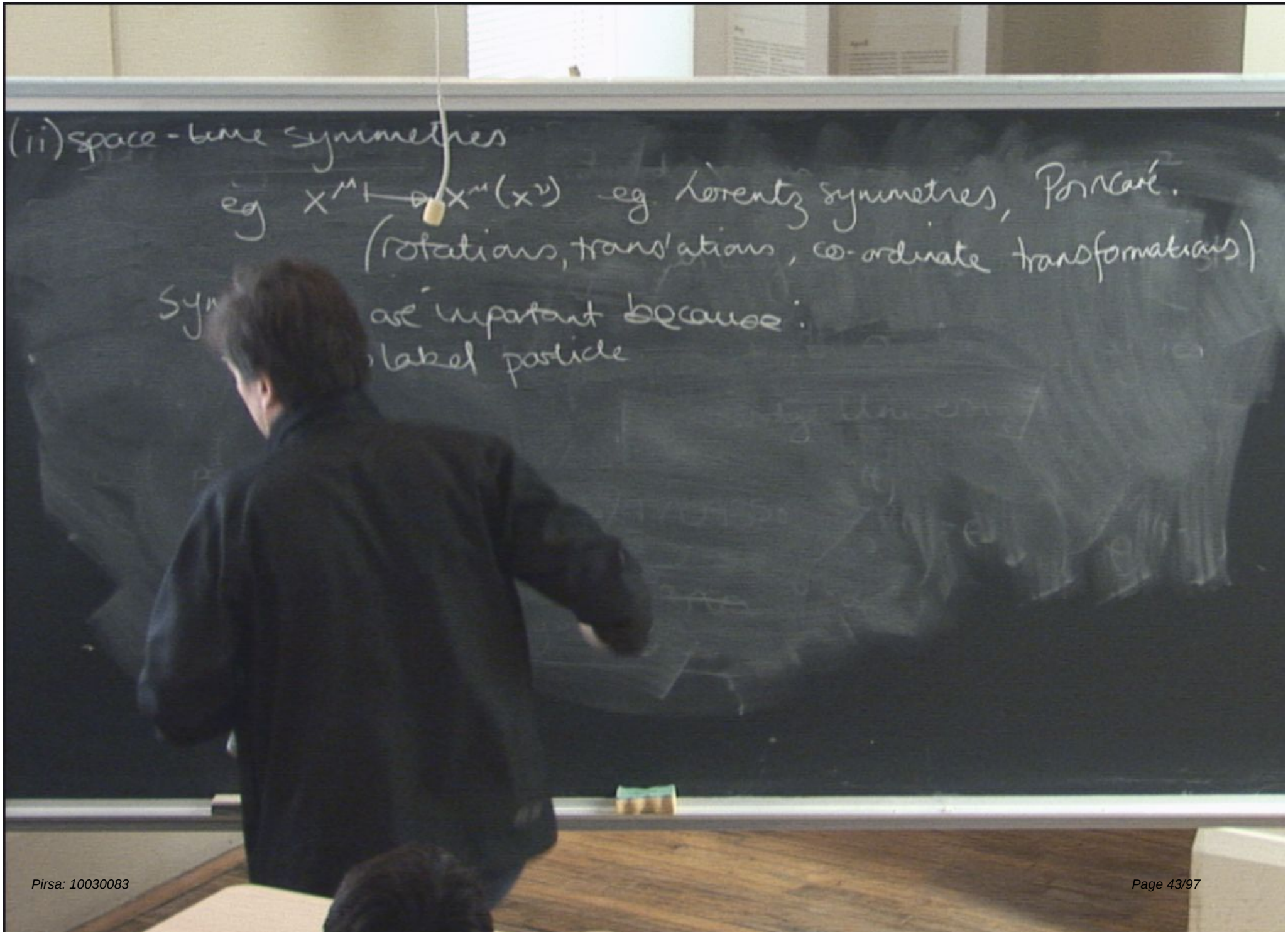
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label particle

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Symmetries are important because:

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Symmetries are important because:

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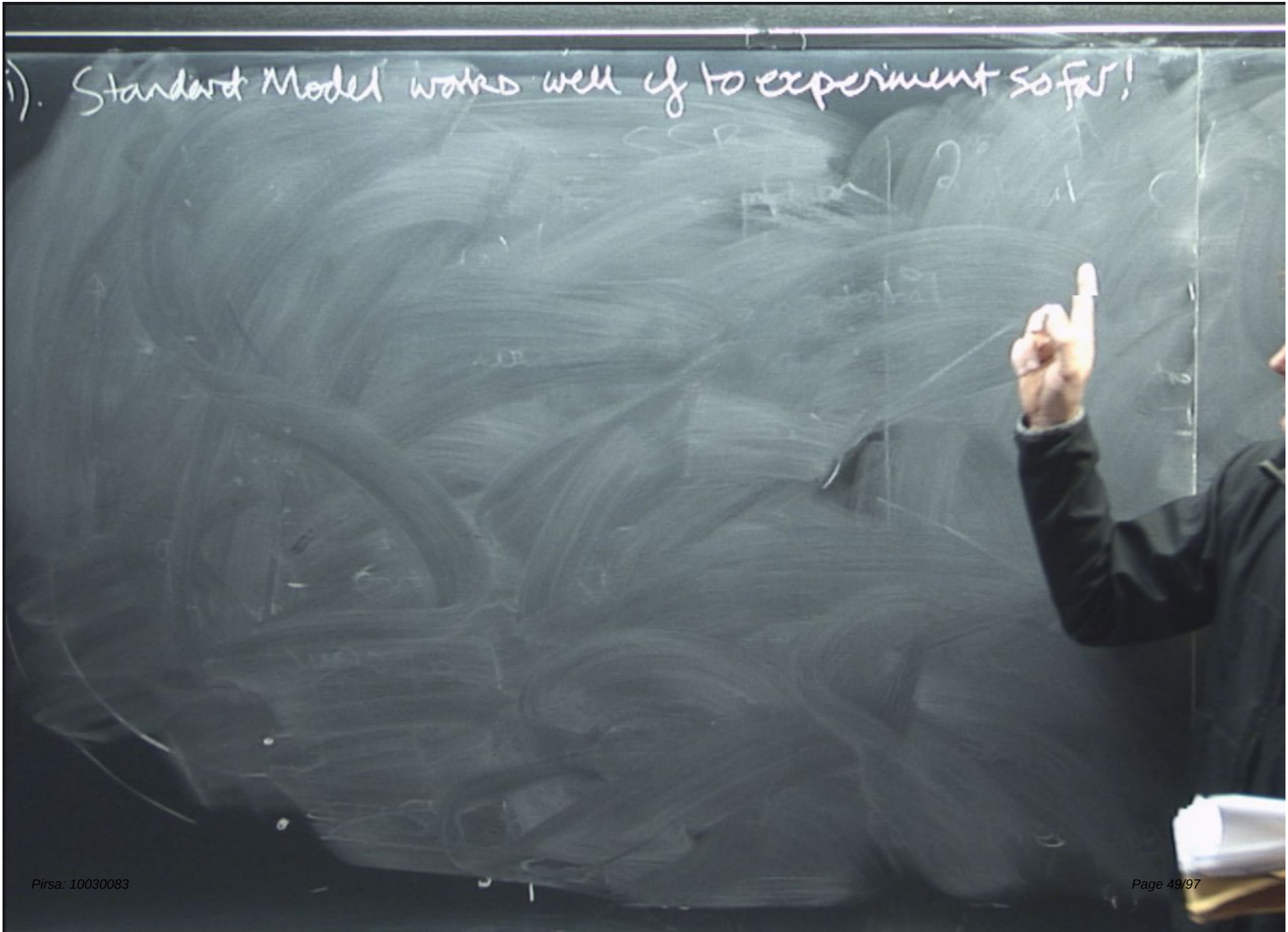
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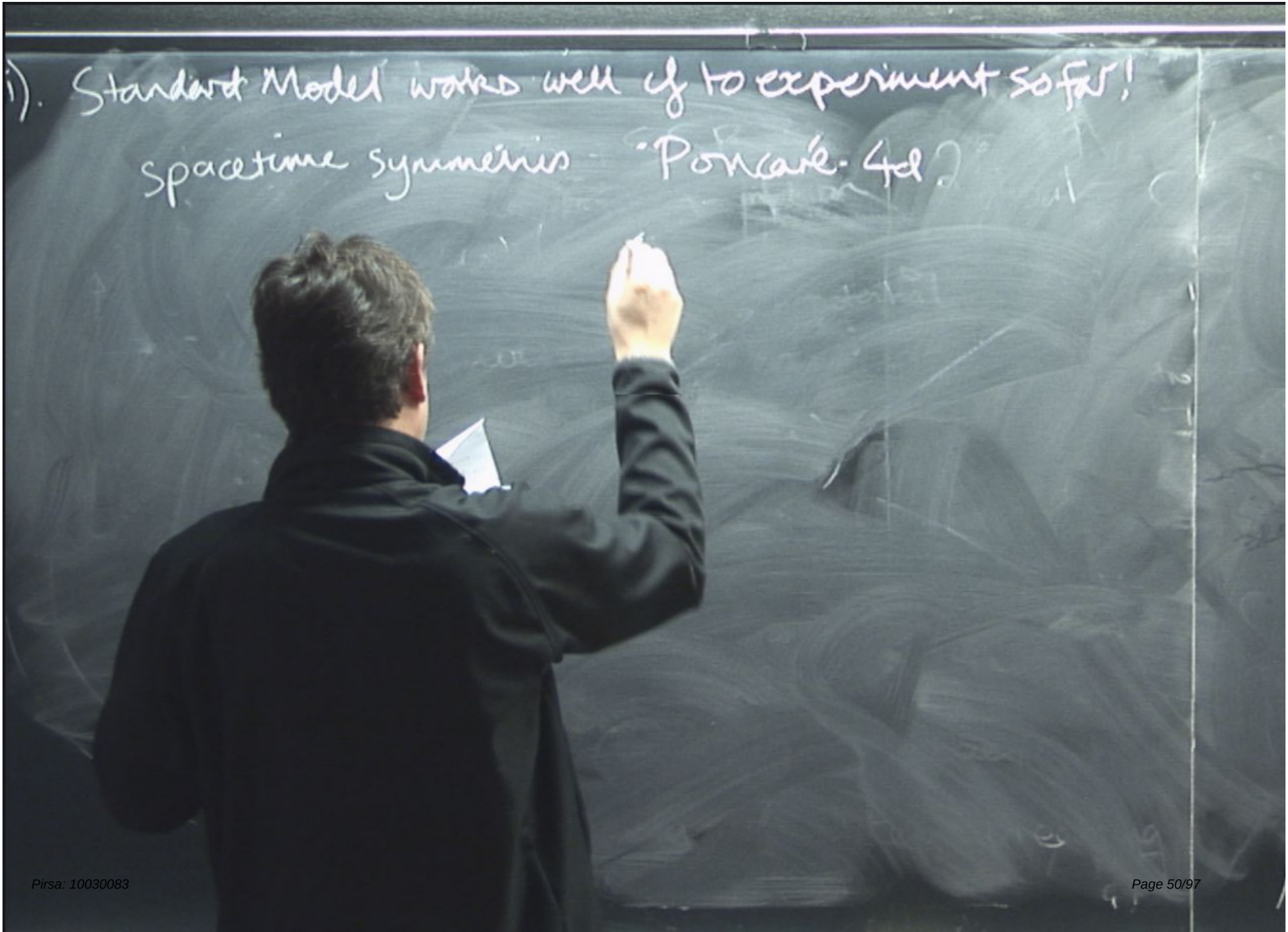
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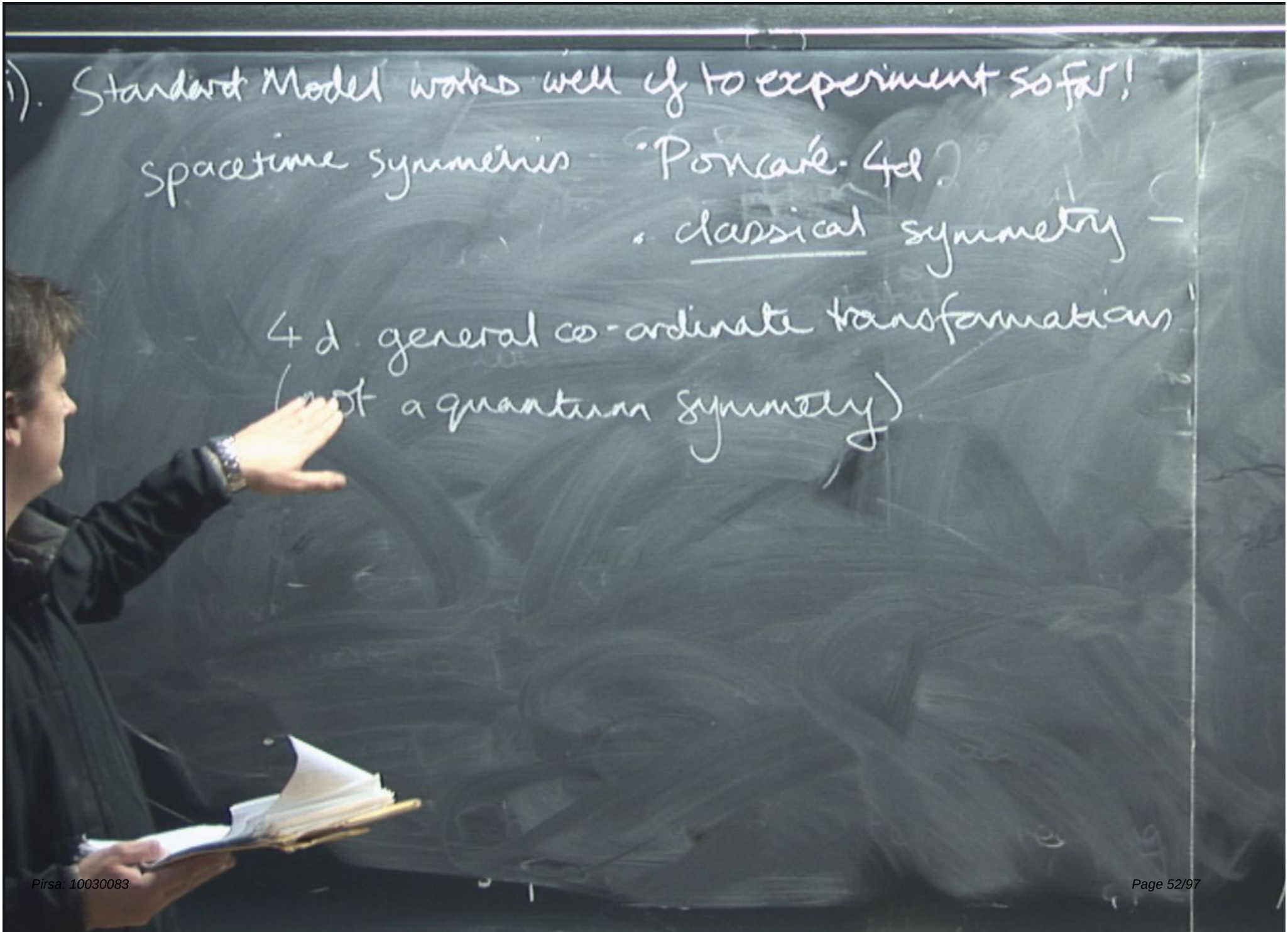
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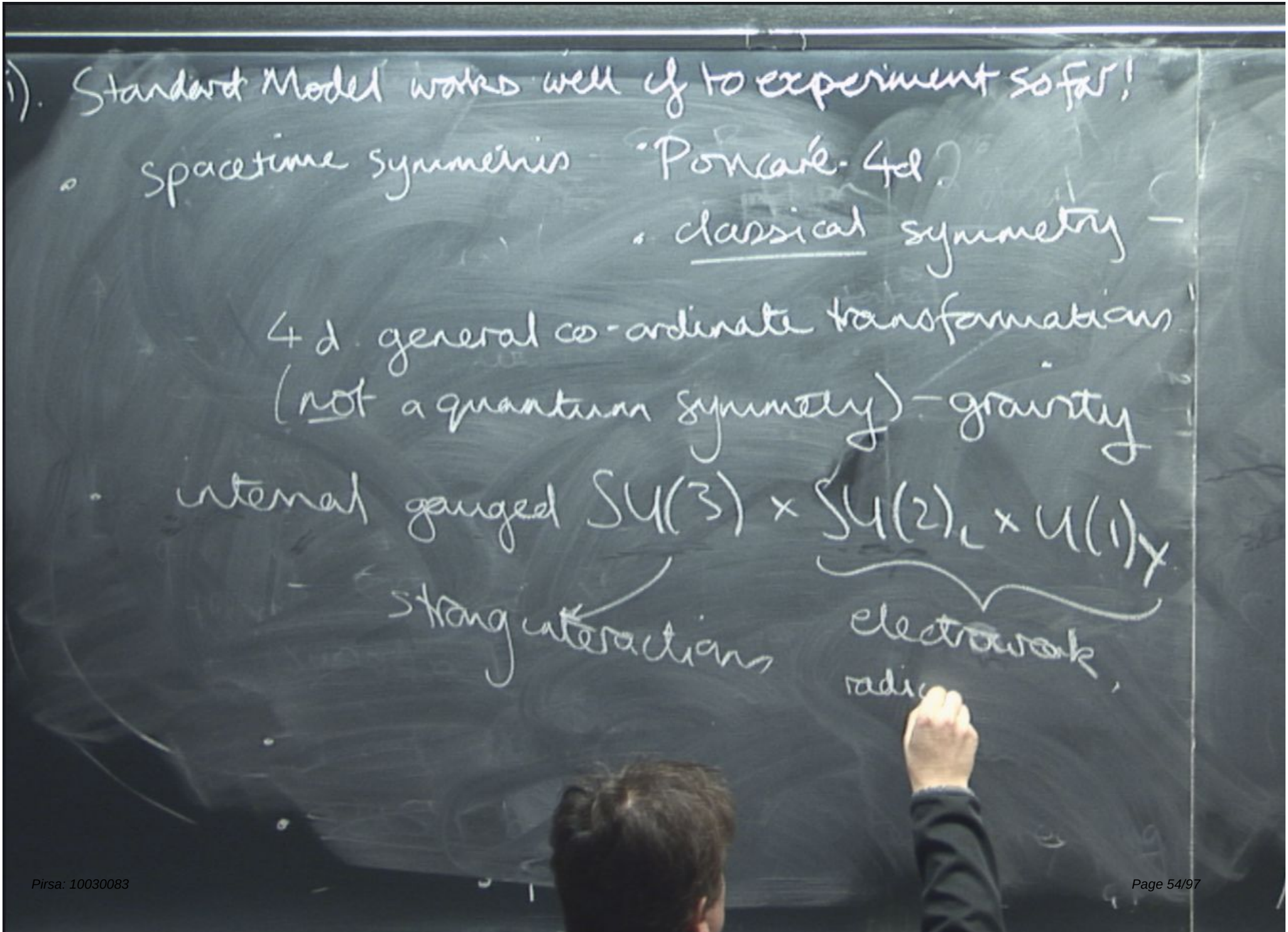
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strong interactions
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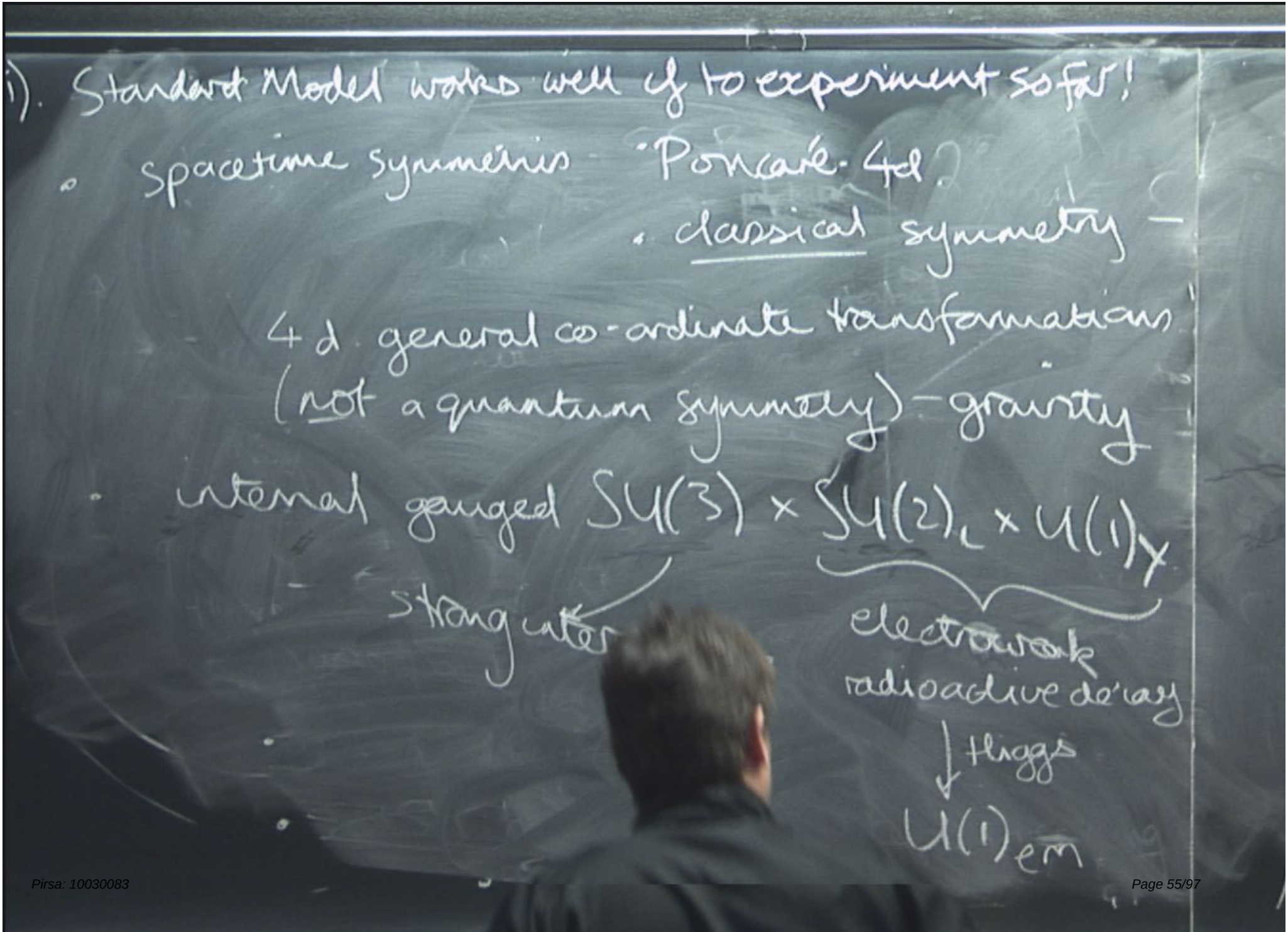
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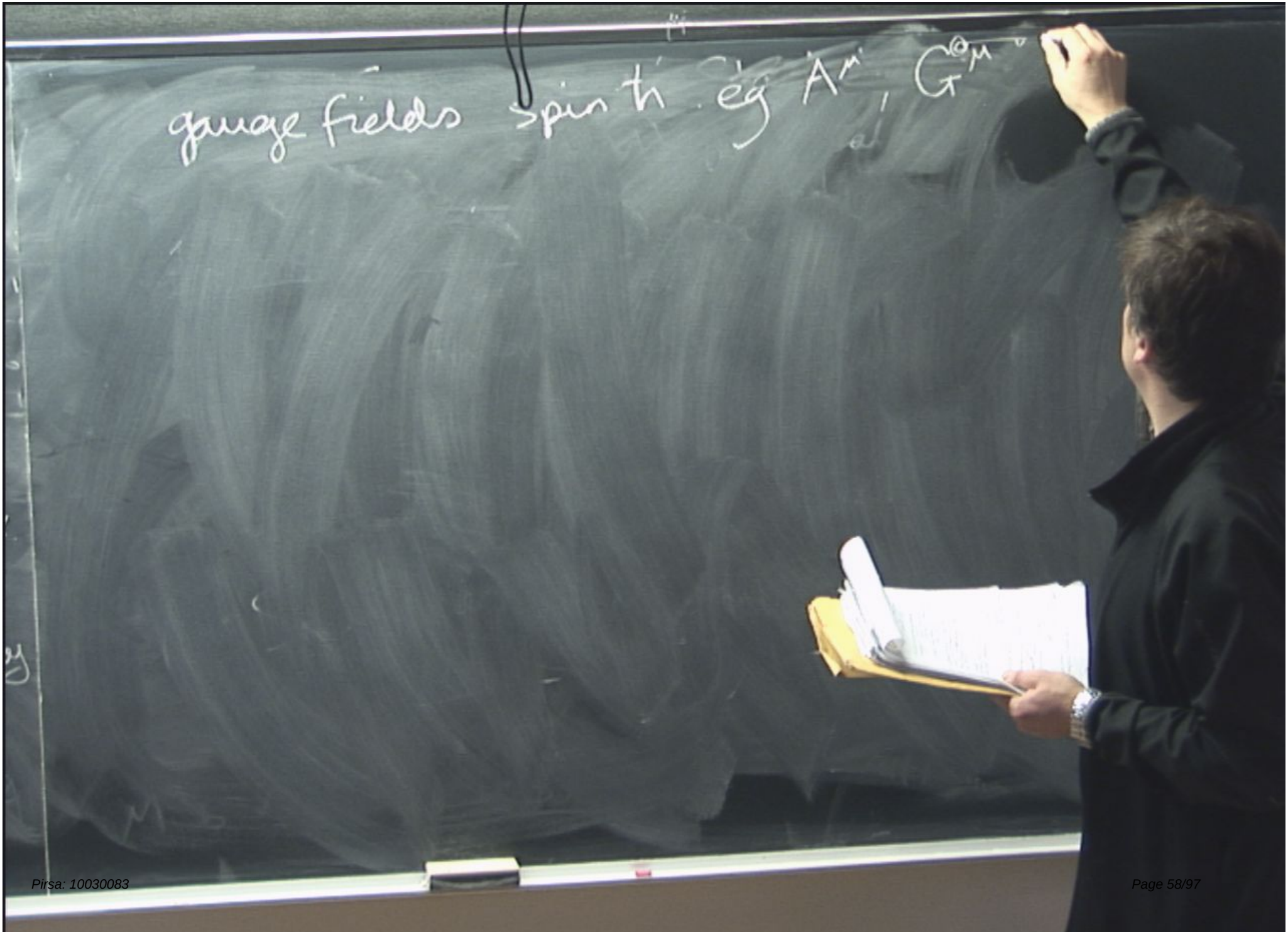
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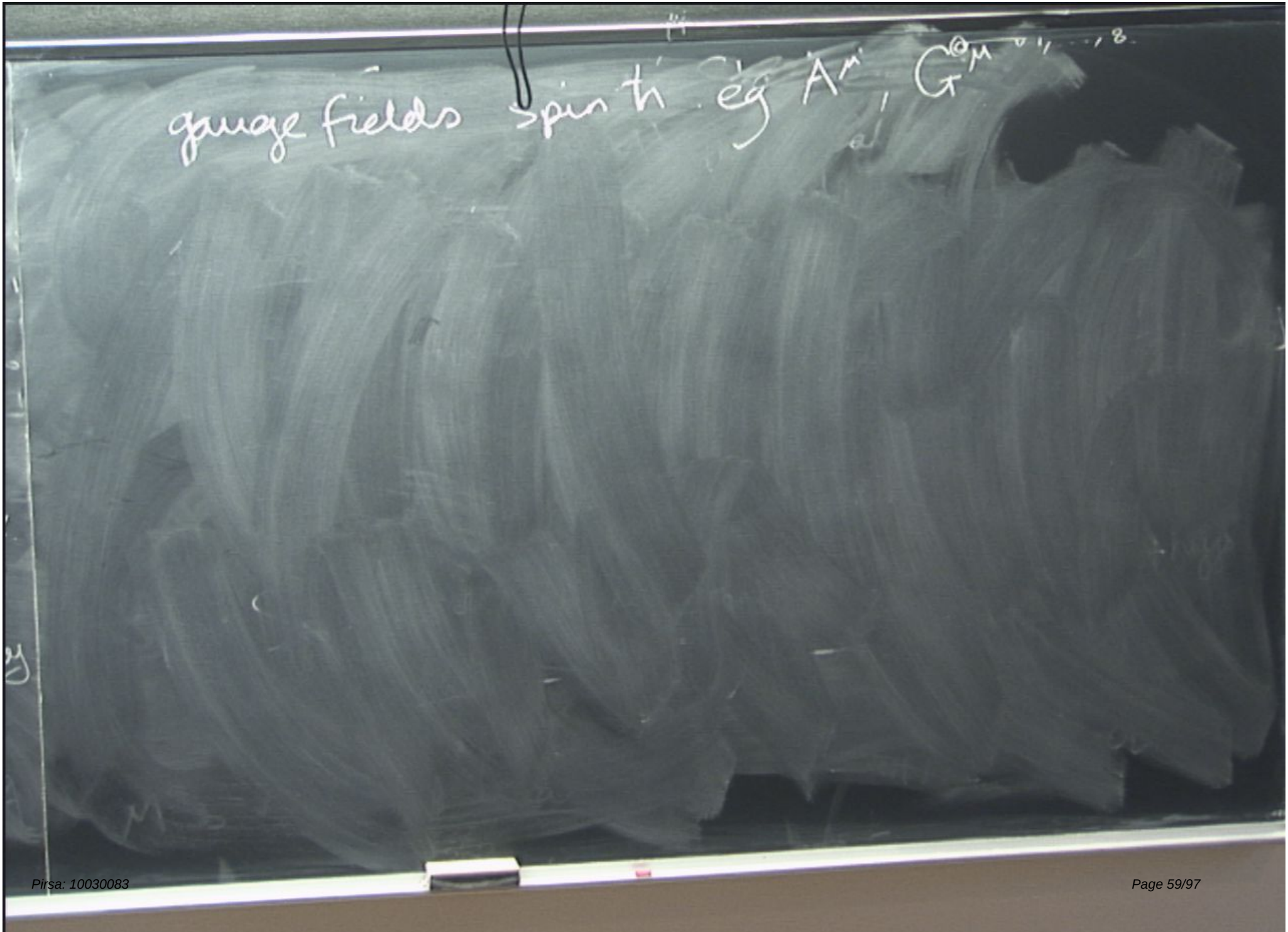
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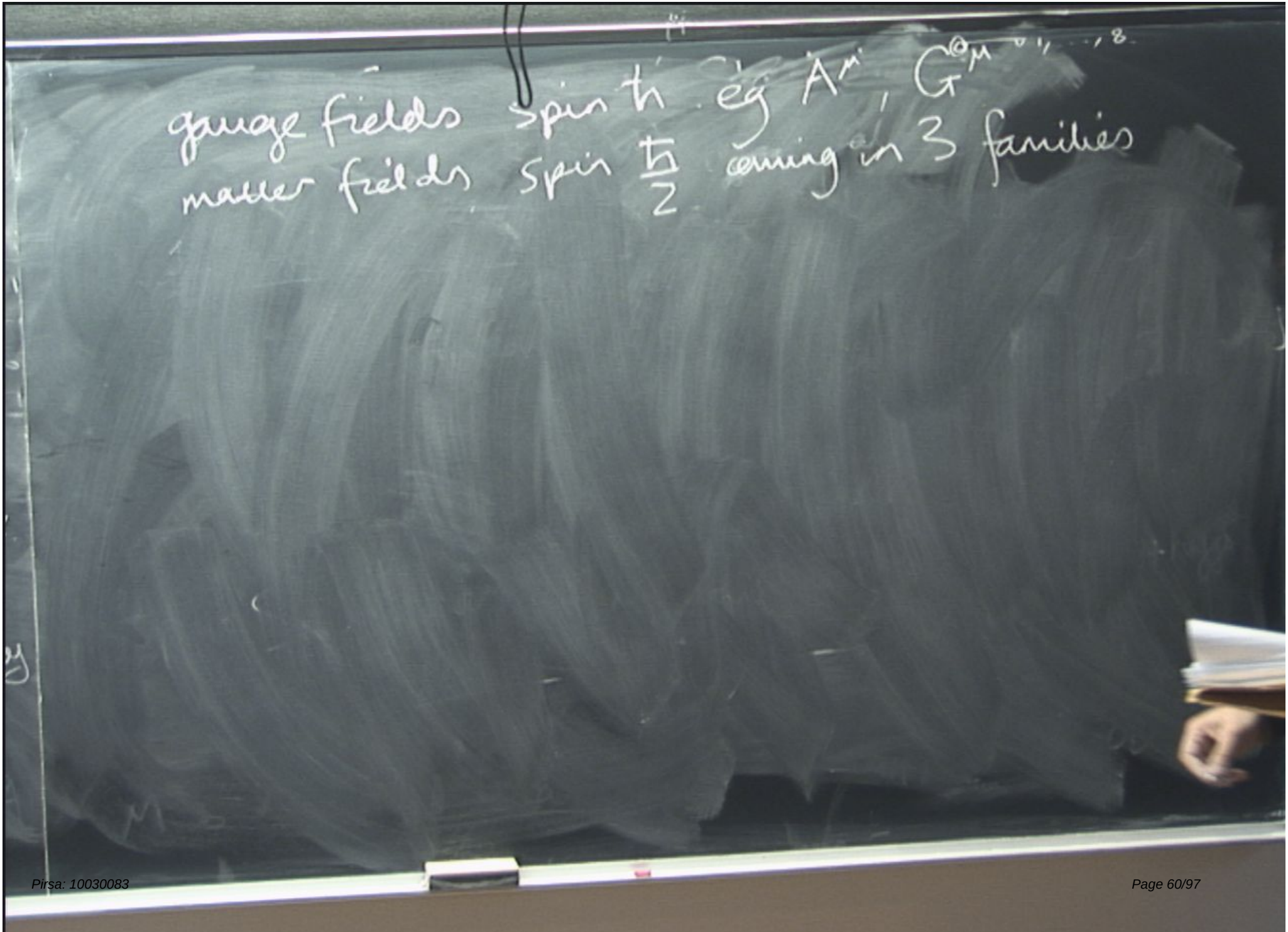
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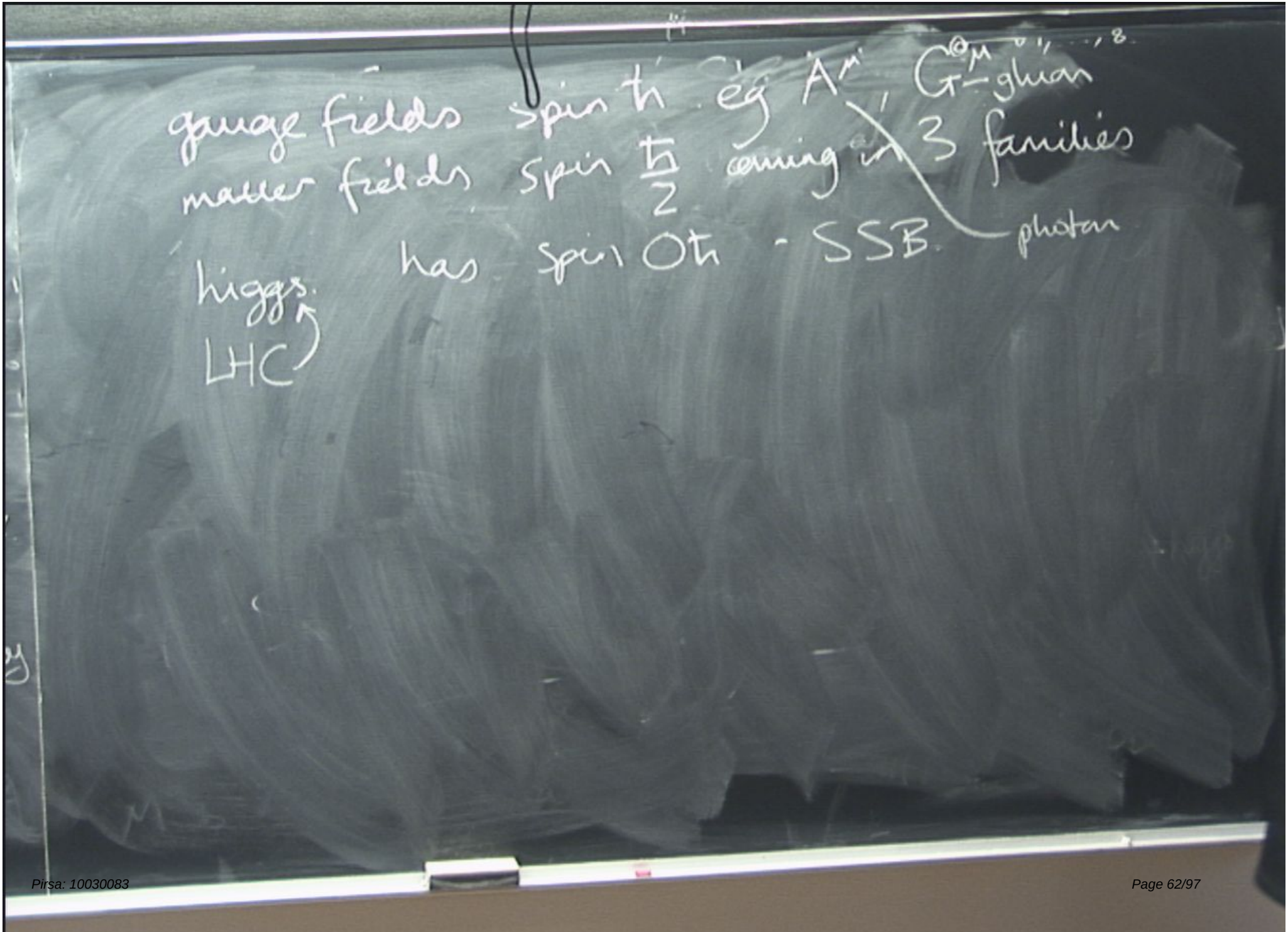
higgs has spin 0 th - SSB.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G - gluon
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photon
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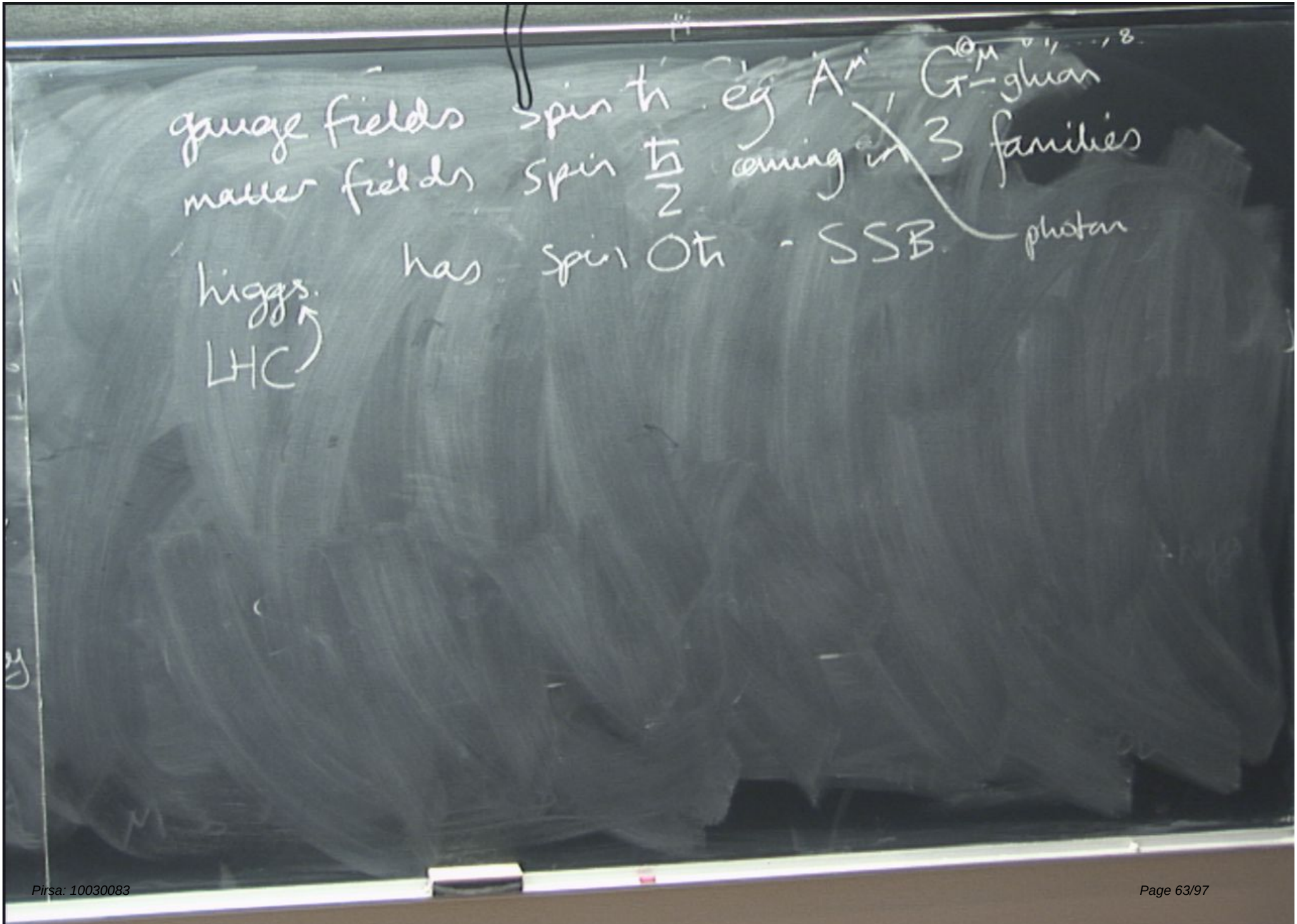
higgs
LHC


gauge fields spin 1 eg A^μ, G^μ - gluon
matter fields spin $\frac{1}{2}$ coming in 3 families
photon
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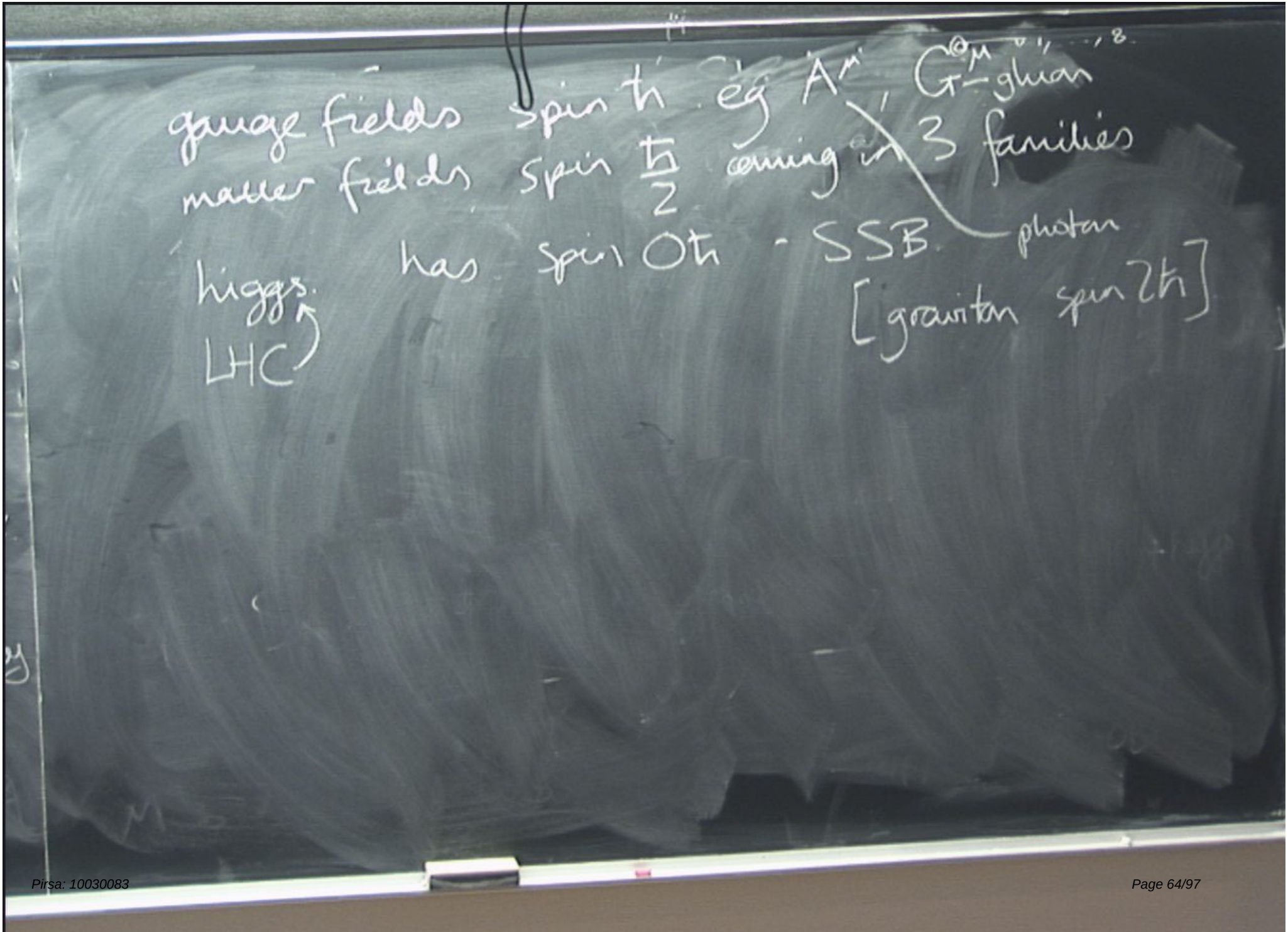
LHC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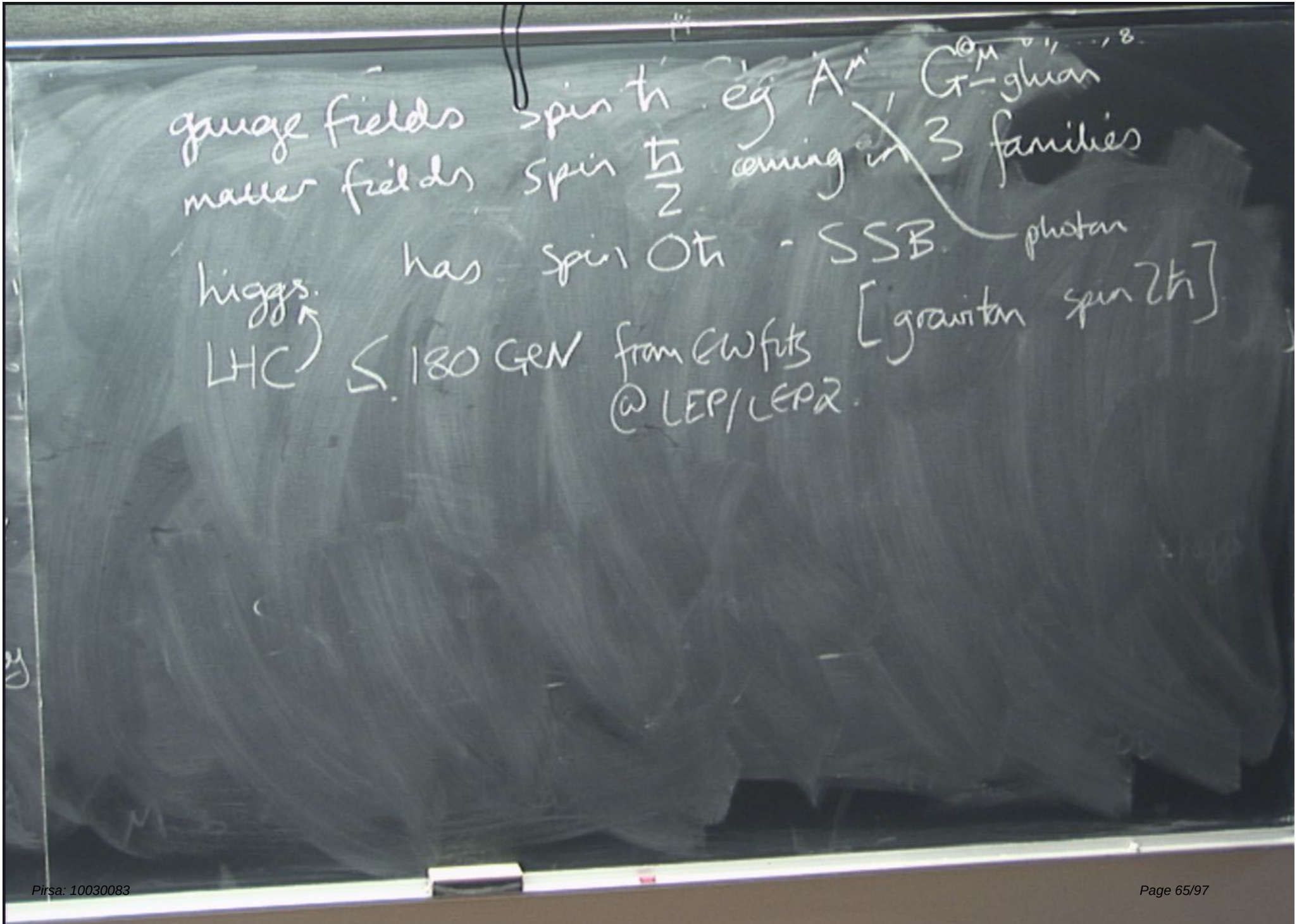
[graviton spin 2h]


gauge fields spin 1h eg A^μ, G^a_μ a = 1, ..., 8
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LHC
$\lesssim$ 180 GeV from EW fits @ LEP/LEP2
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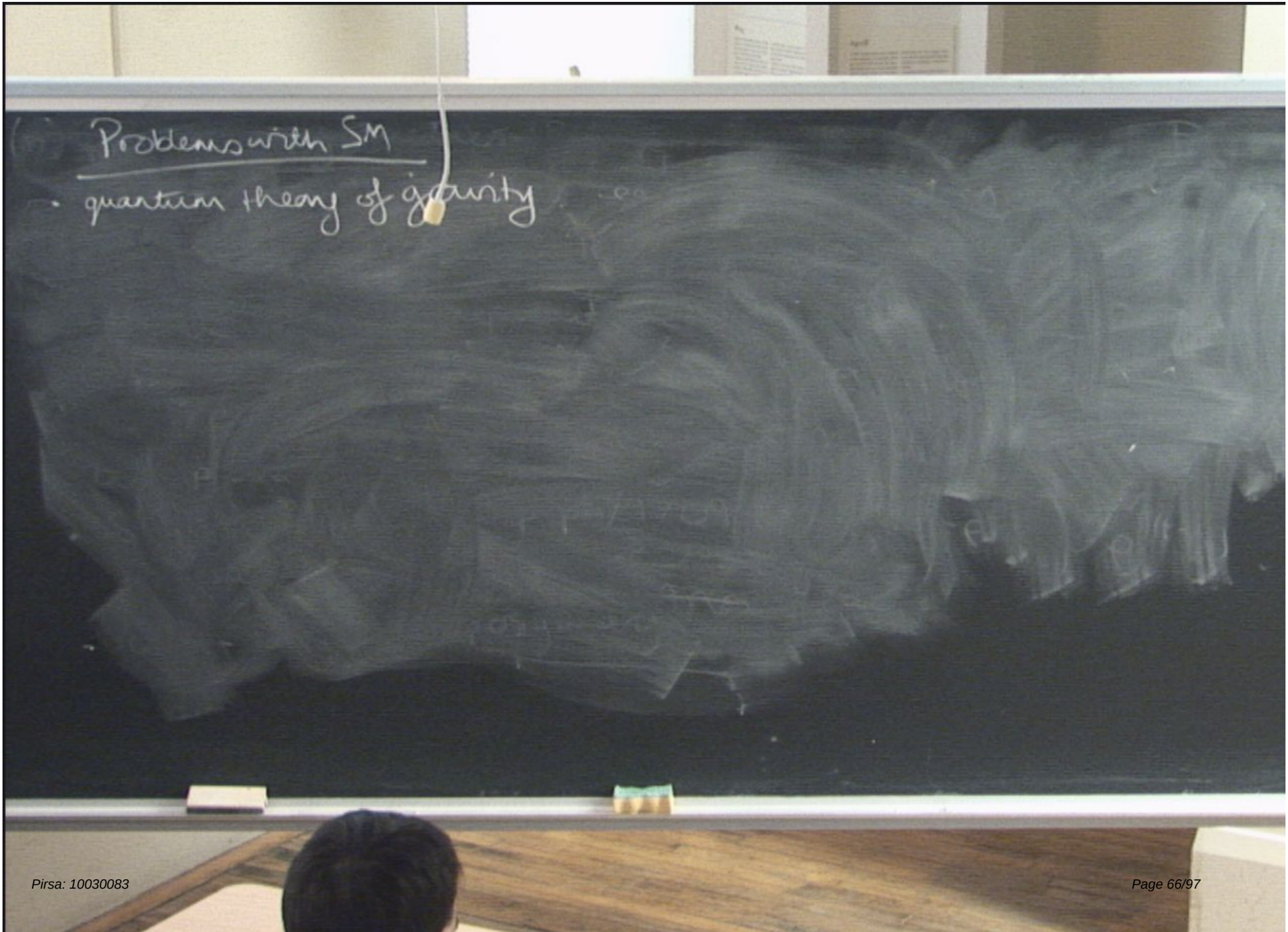
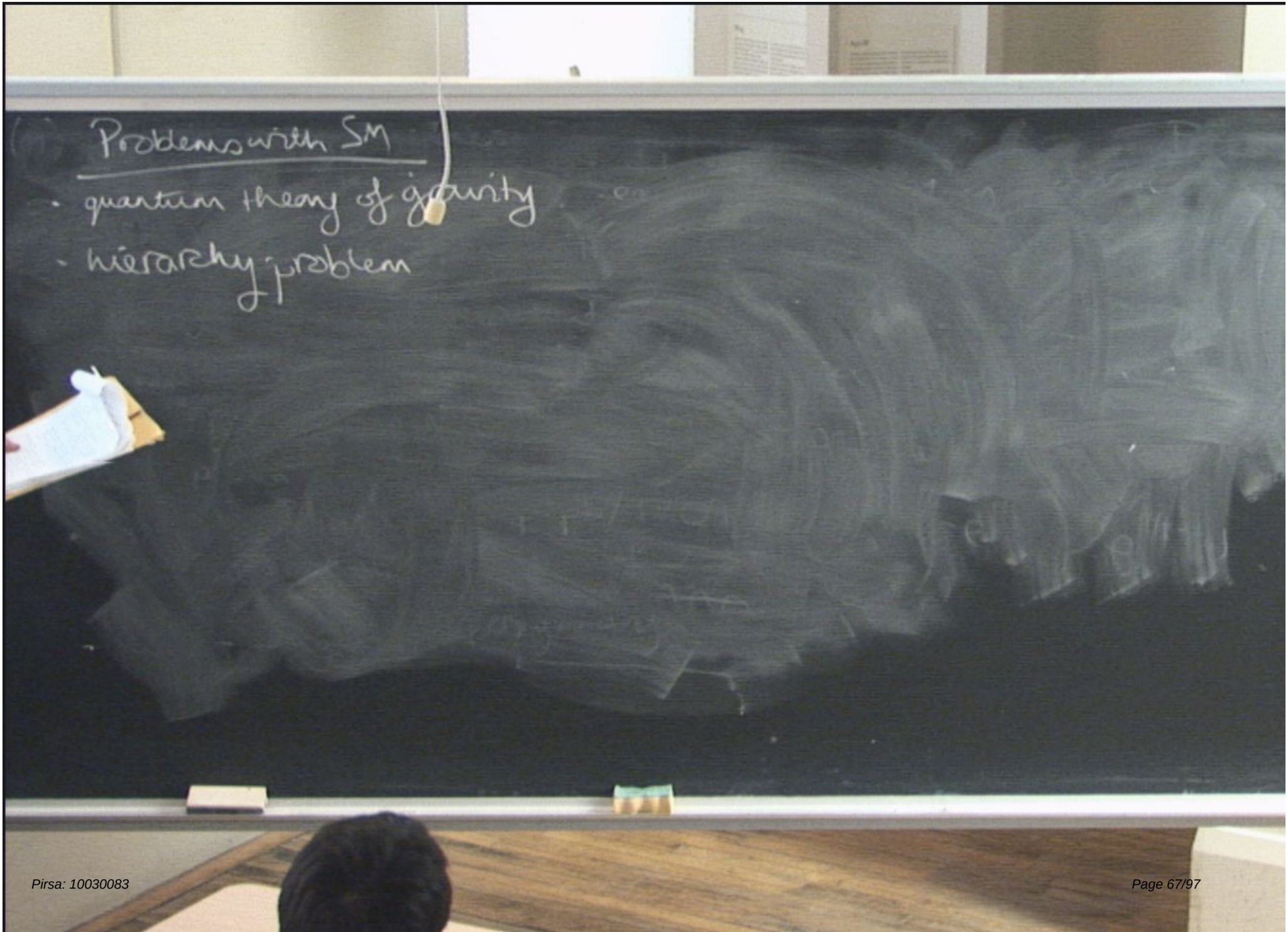

Problems with SM
- quantum theory of gravity


Problems with SM
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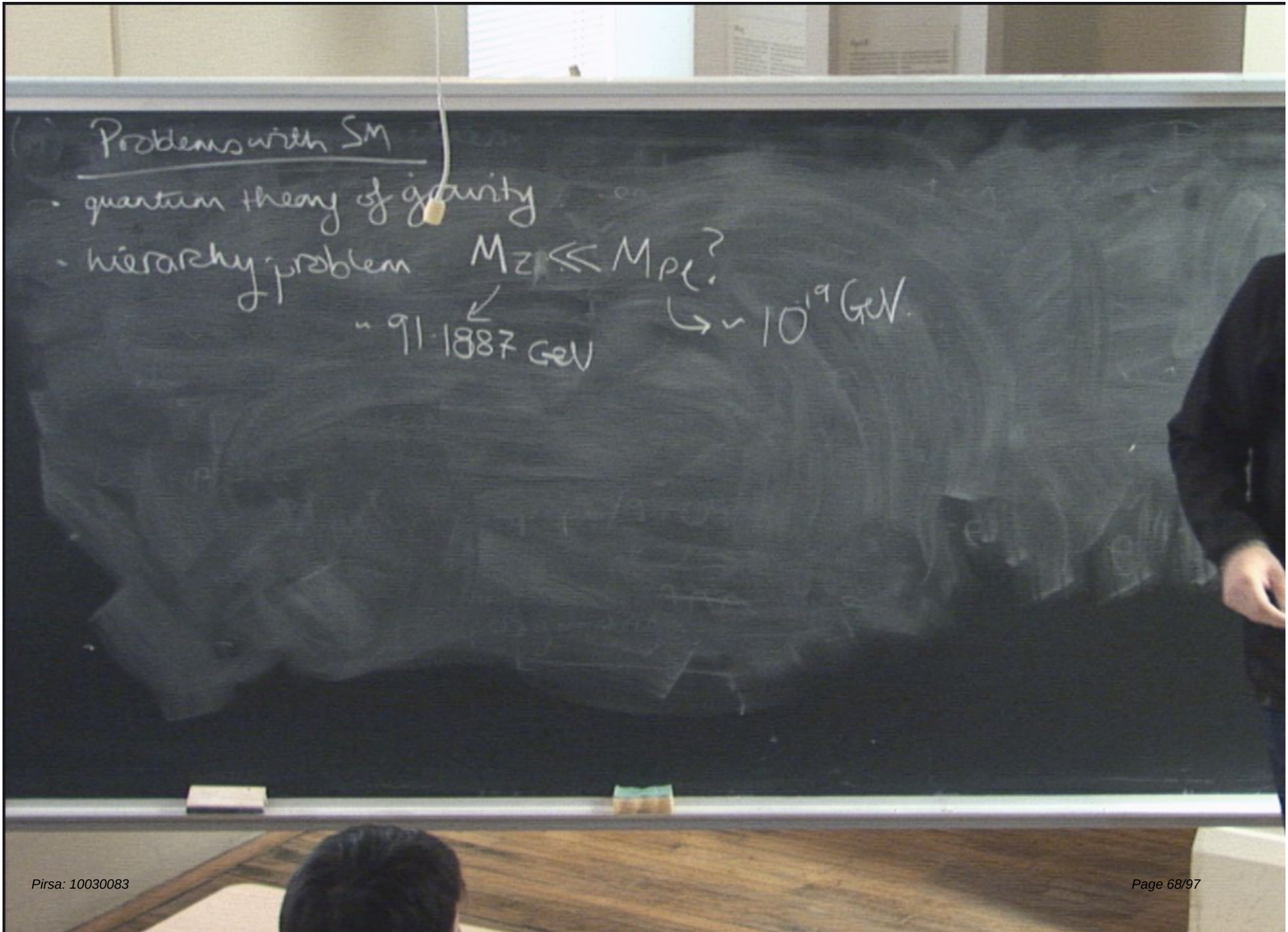
- hierarchy problem


Problems with SM
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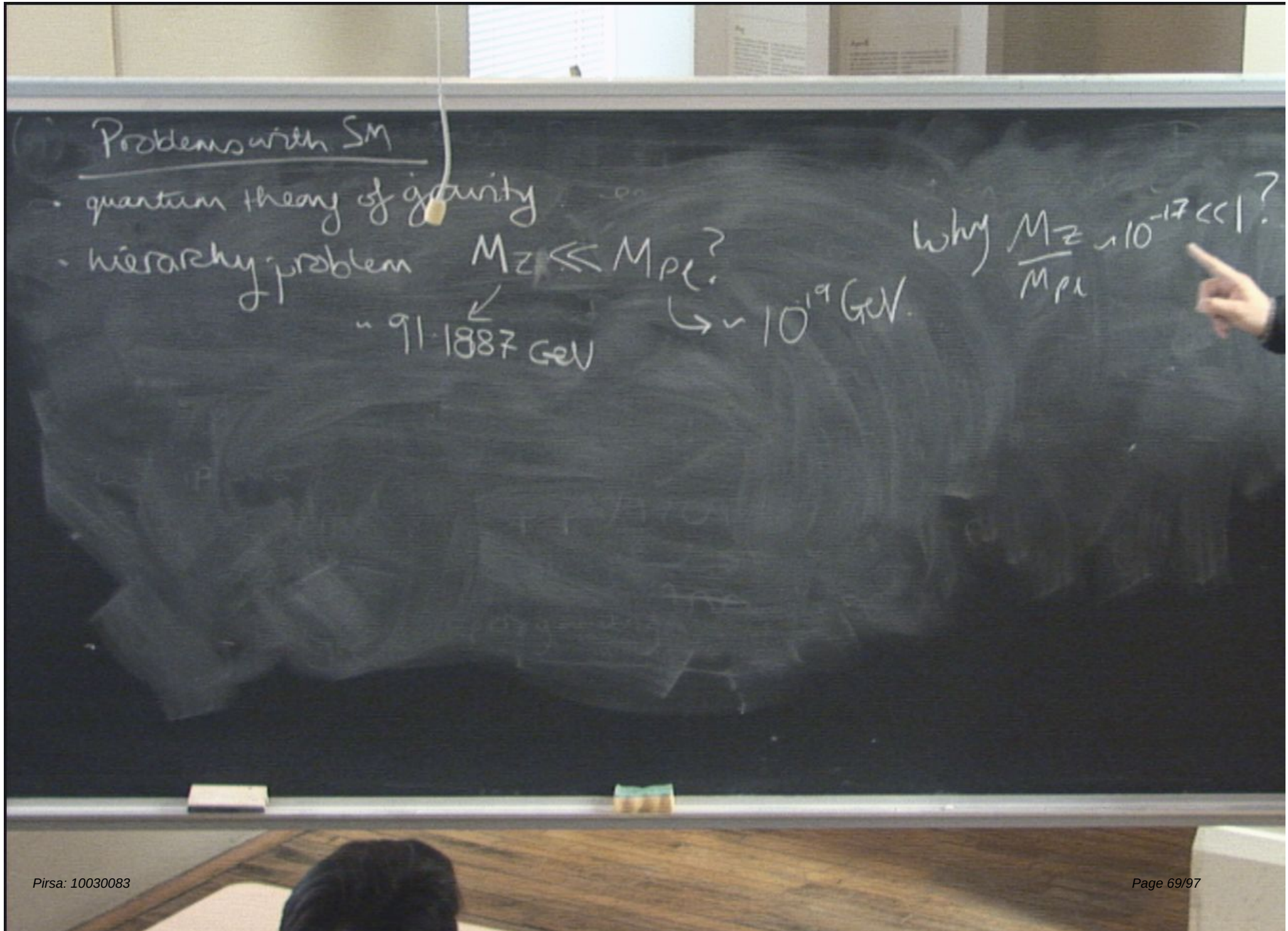
- hierarchy problem $M_Z \ll M_{Pl}$?
~ 91.1887 GeV
$\sim 10^{19}$ GeV.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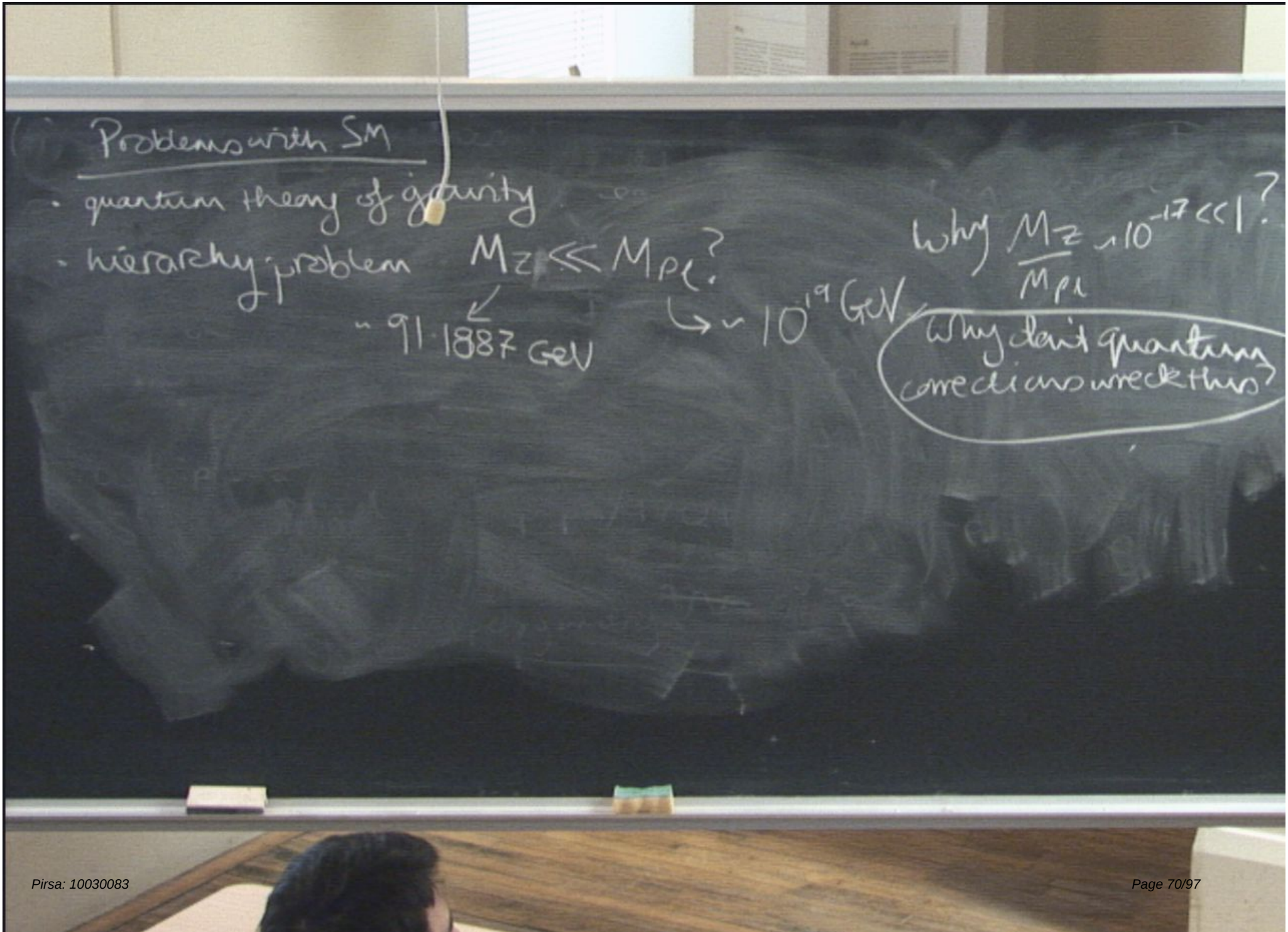
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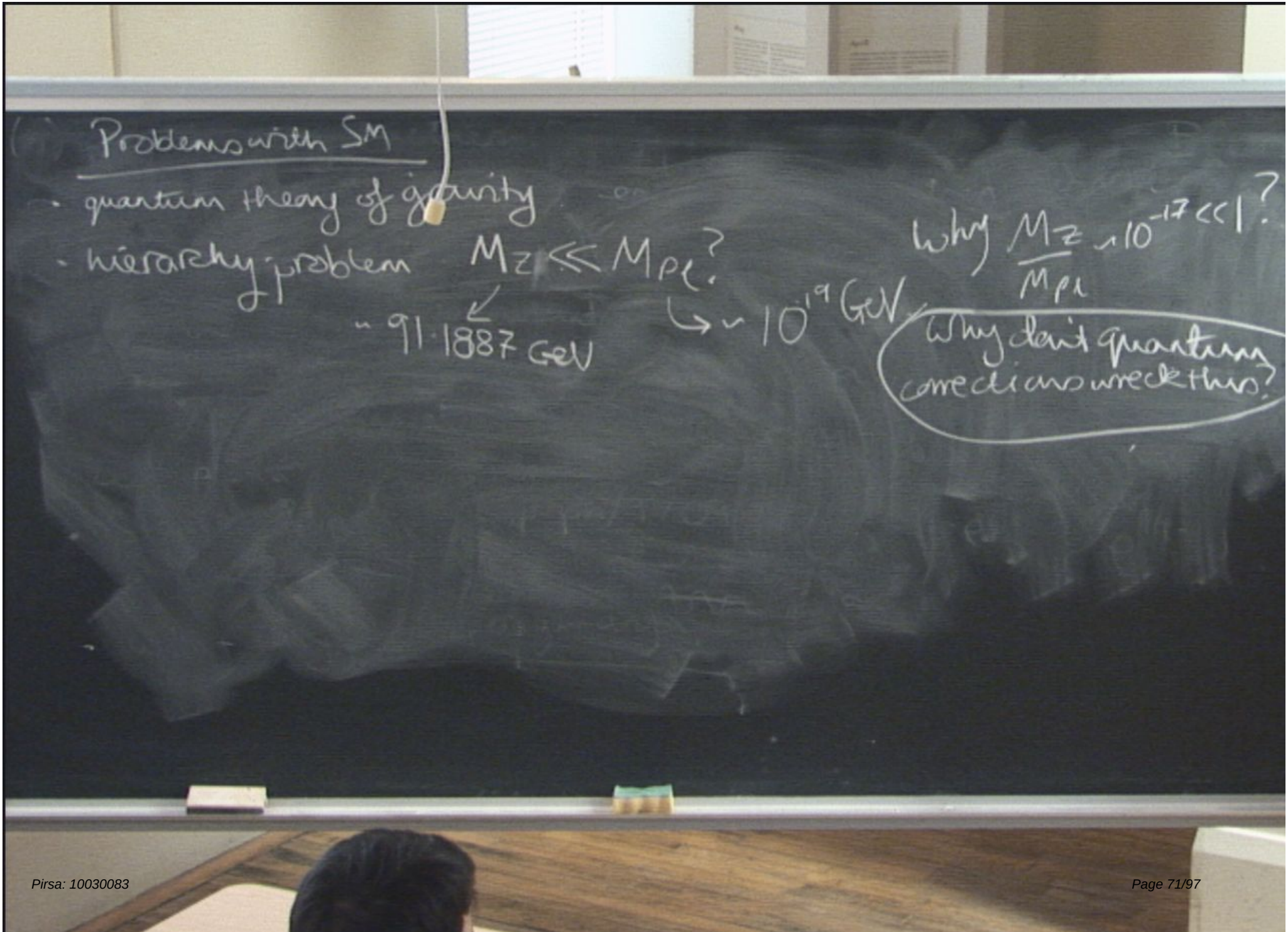
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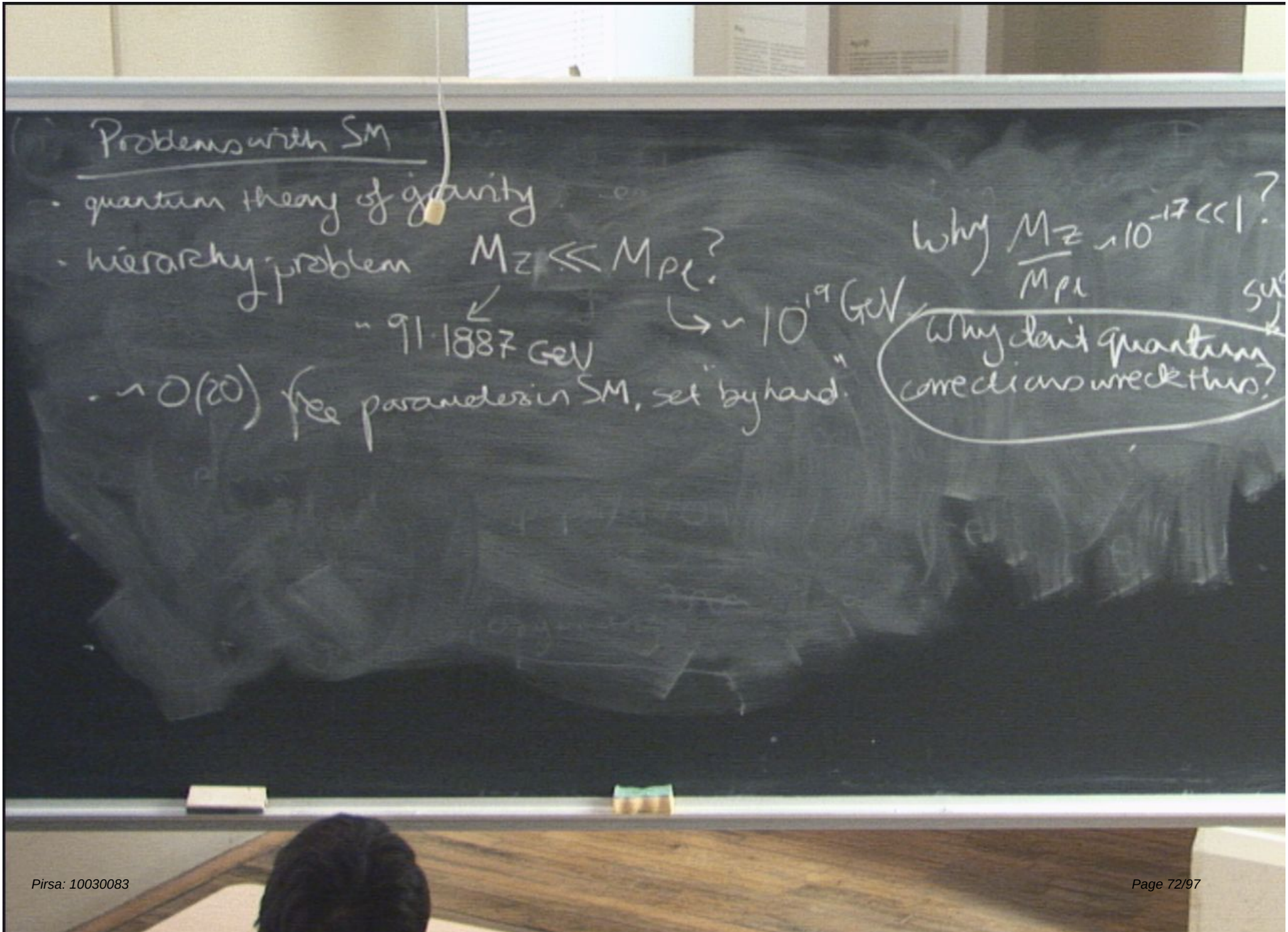
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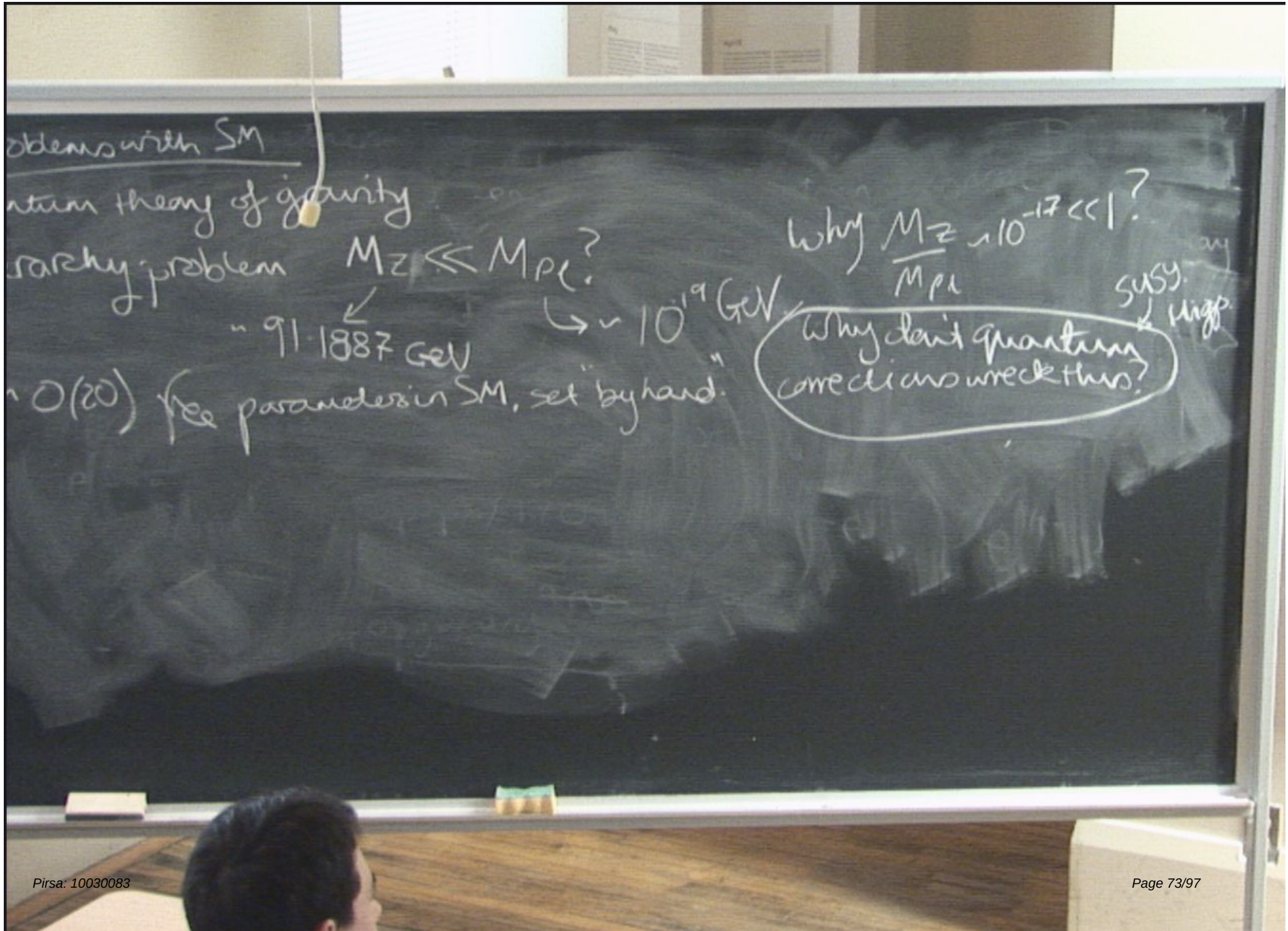
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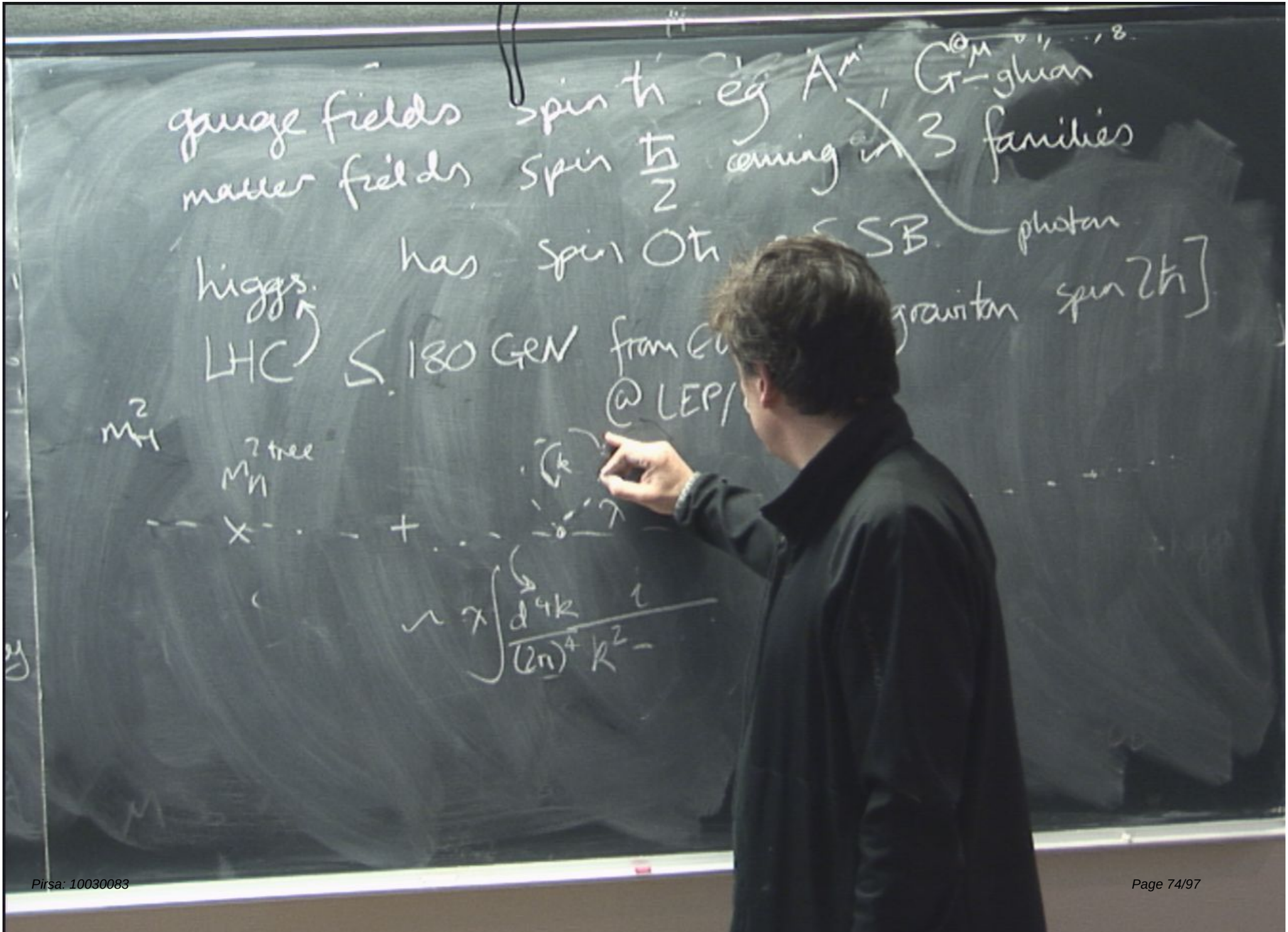
SUSY.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G-gluon
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LHC
≤ 180 GeV from
@ LEP/
graviton spin 2h]
M_H^2
M_H^2 tree
k
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2}$

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LHC ≤ 180 GeV from EW fits @ LEP/LEP2 [graviton spin 2]

M_H^2
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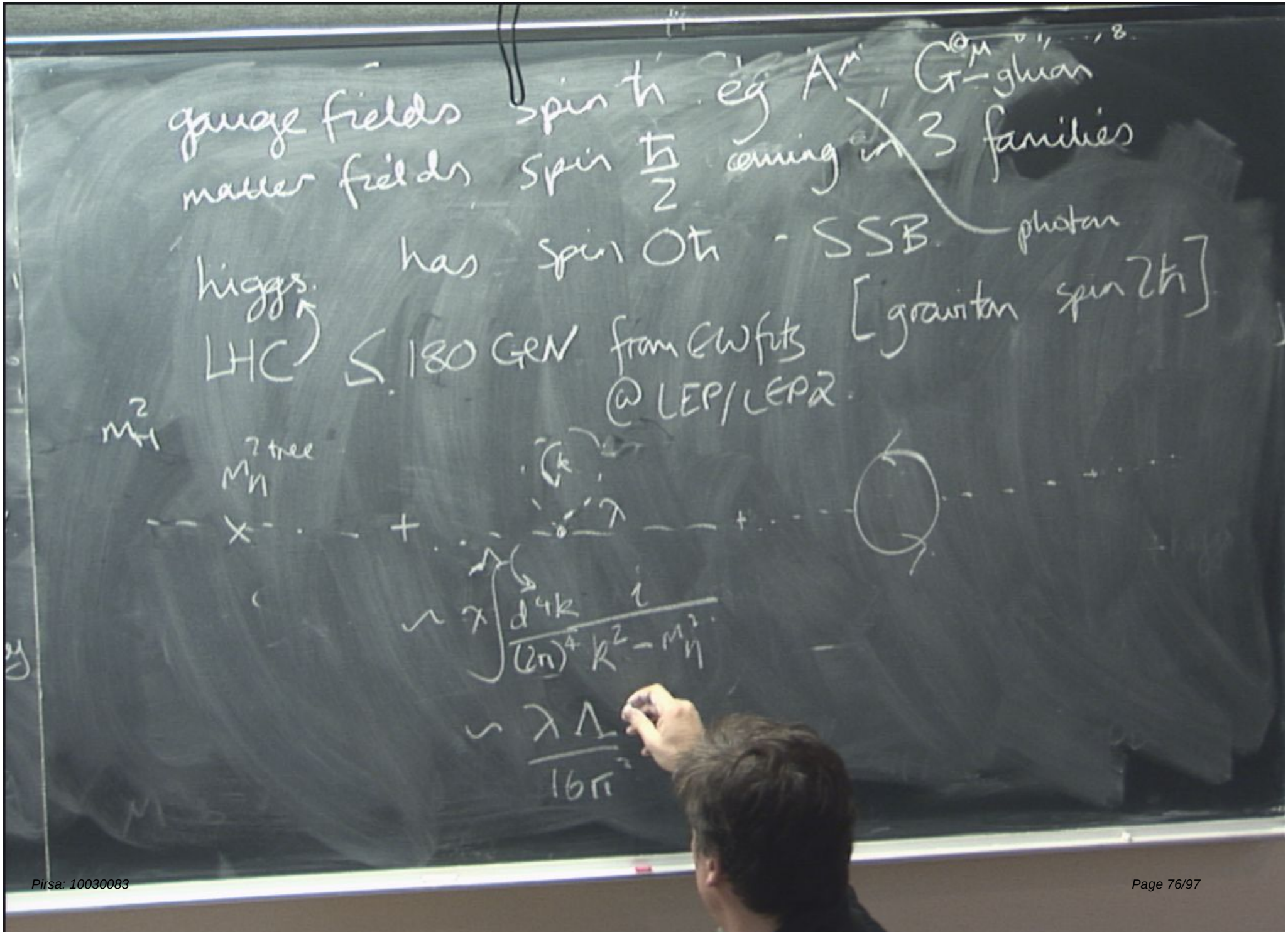
$$\sim \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_H^2}$$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$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_H^2}$
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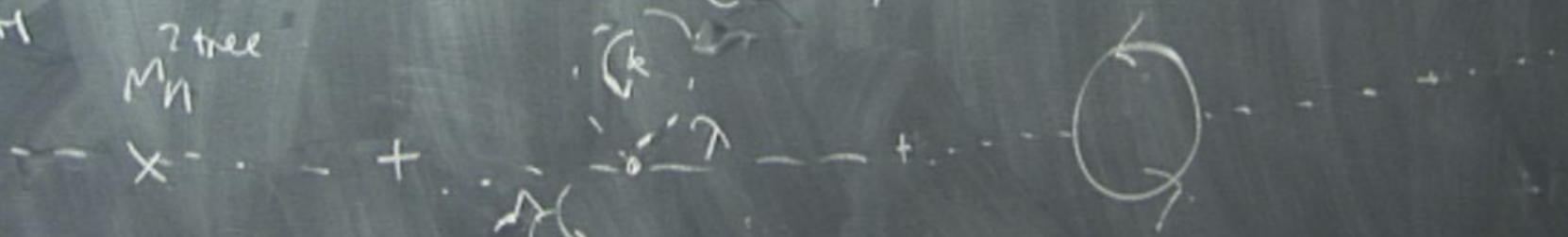
photon
gluon
[graviton spin 2]

M_H^2
M_H^2 tree



$$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_\eta^2}$$

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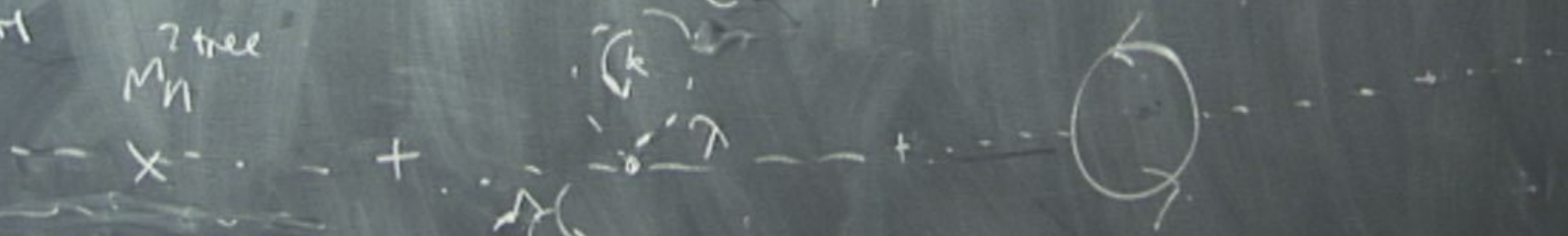
M_H^2

M_H^2 tree



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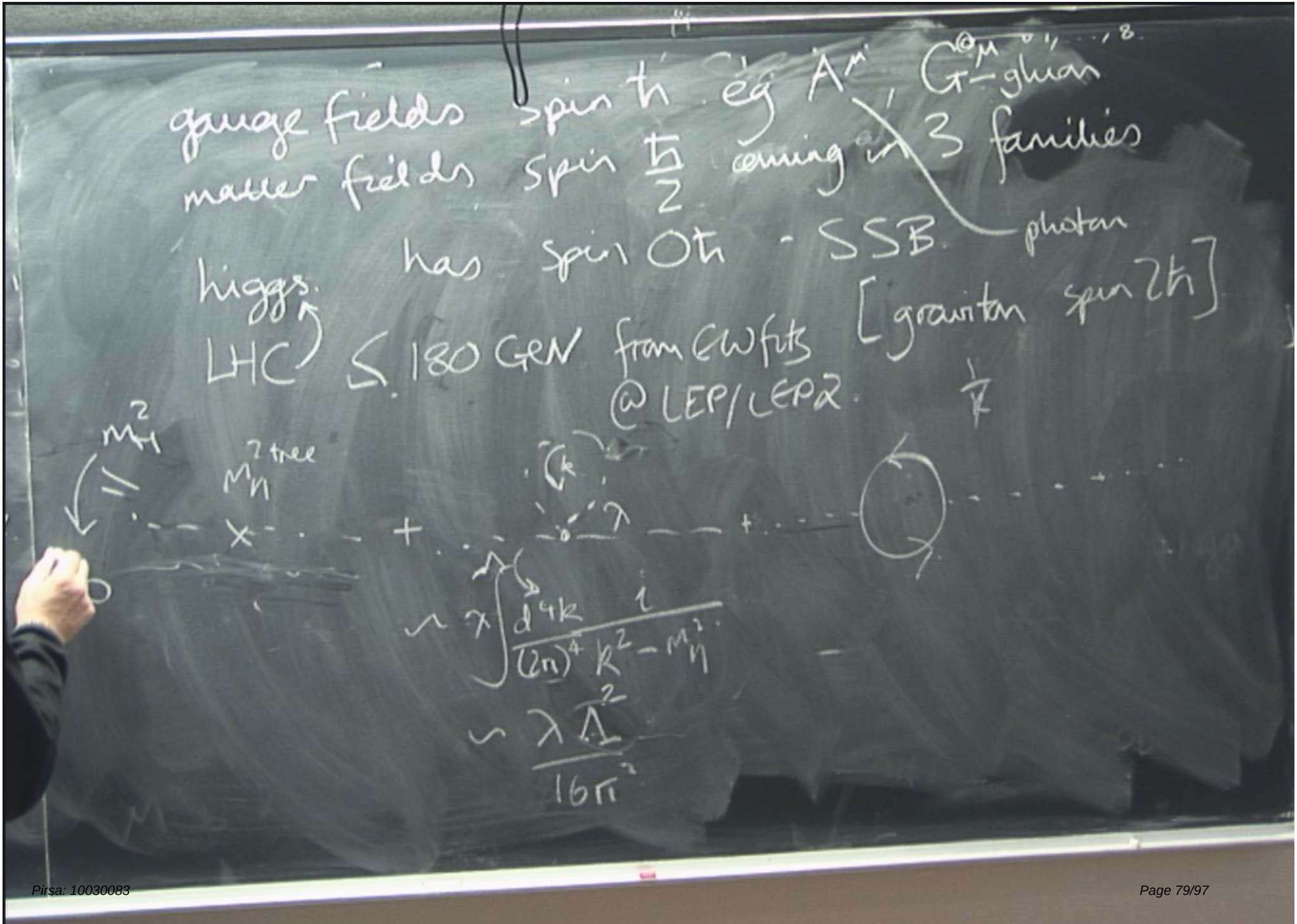
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k
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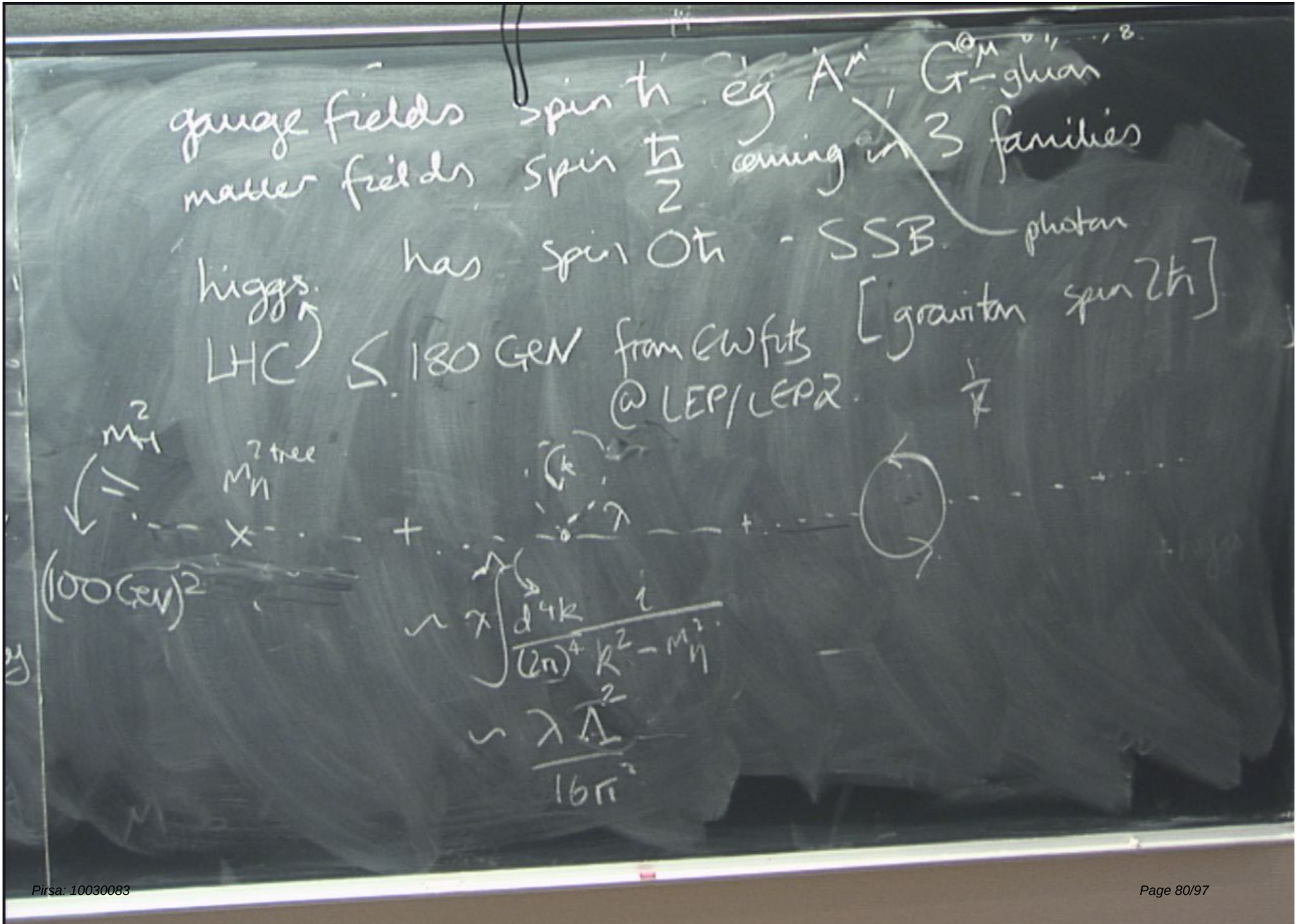
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[graviton spin 2 th]
$\frac{1}{N}$
M_H^2
=
M_H^2 tree
k
$(100\,GeV)^2$
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_H^2}$
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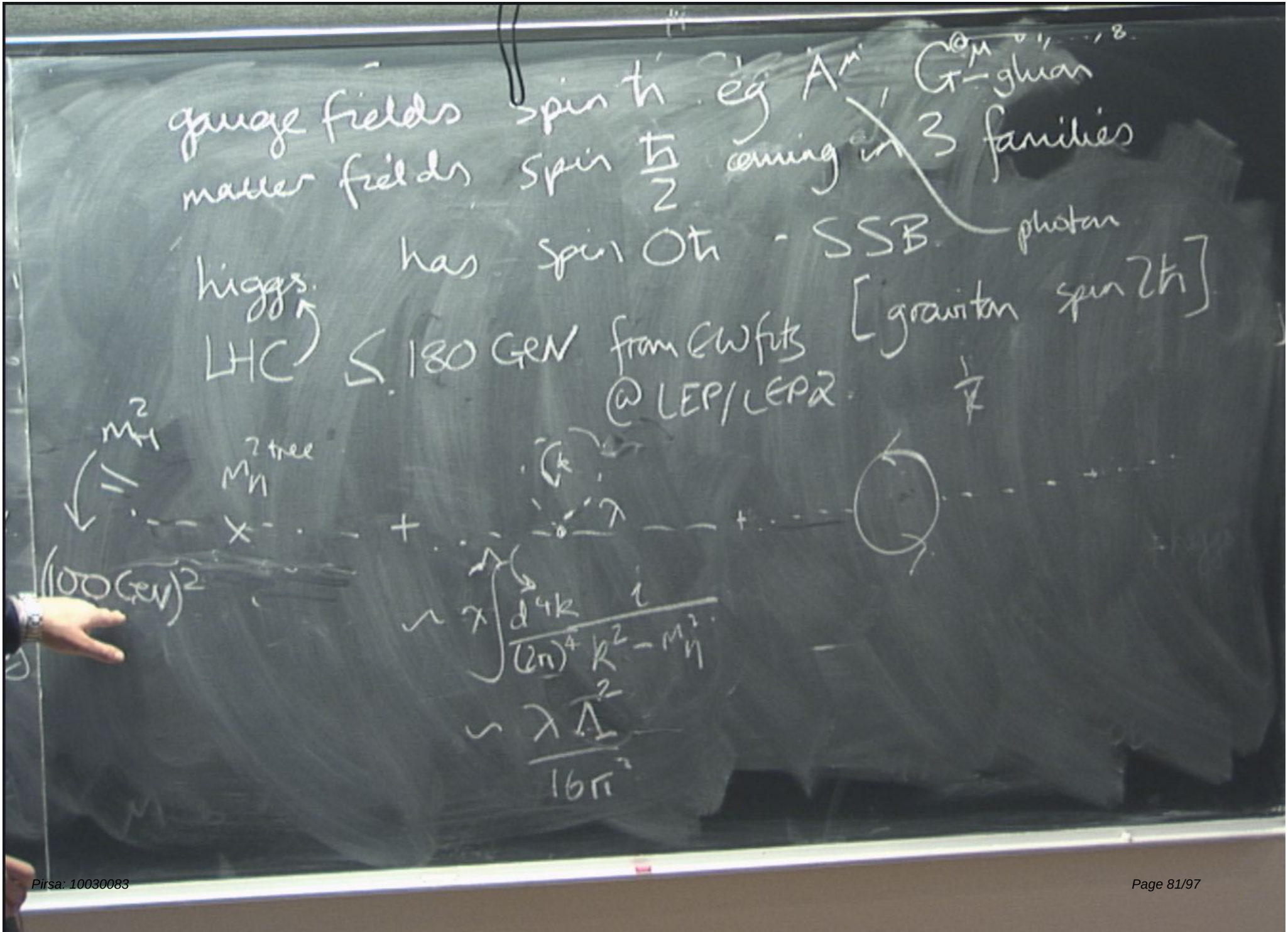
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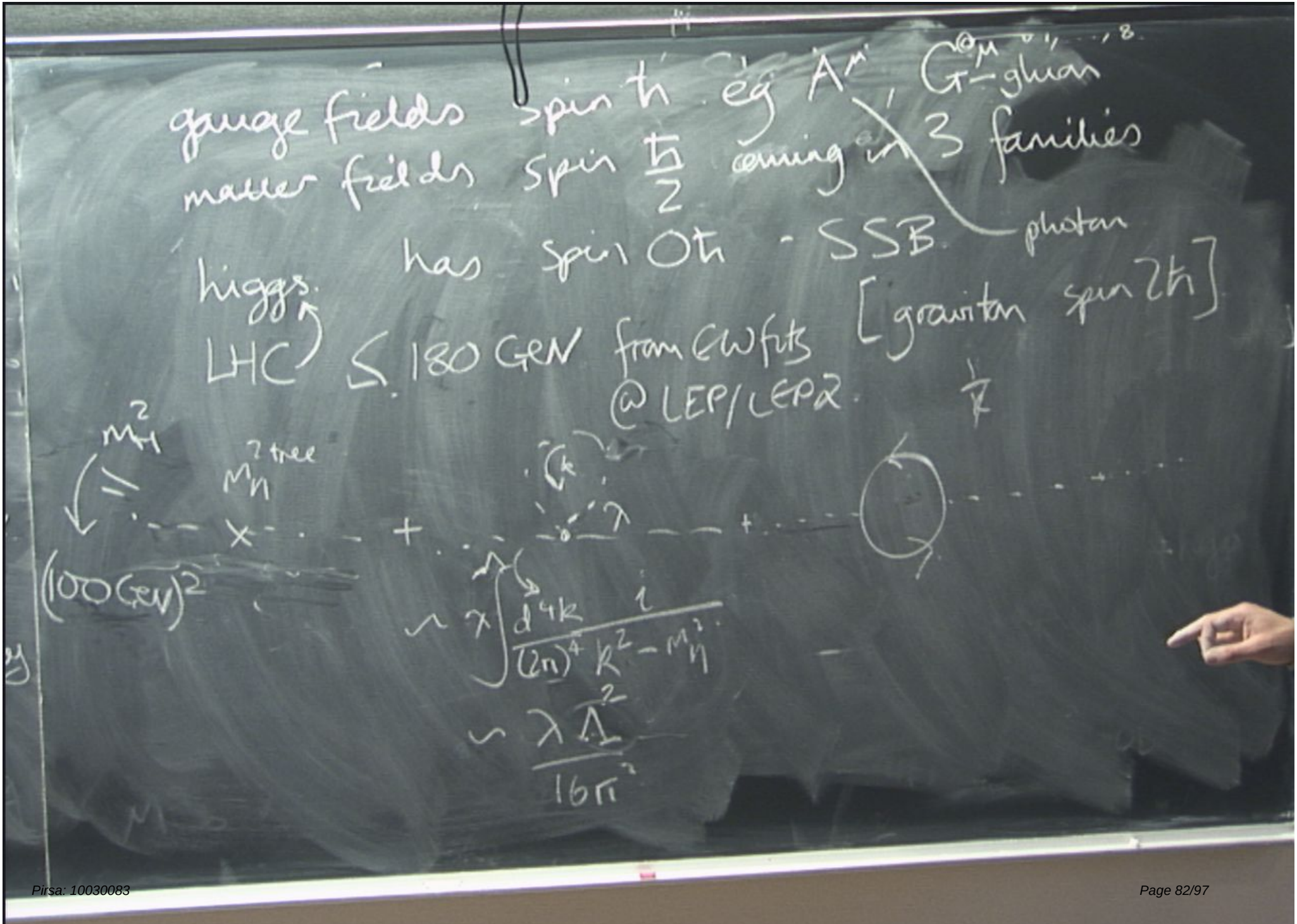
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M_H^2 tree
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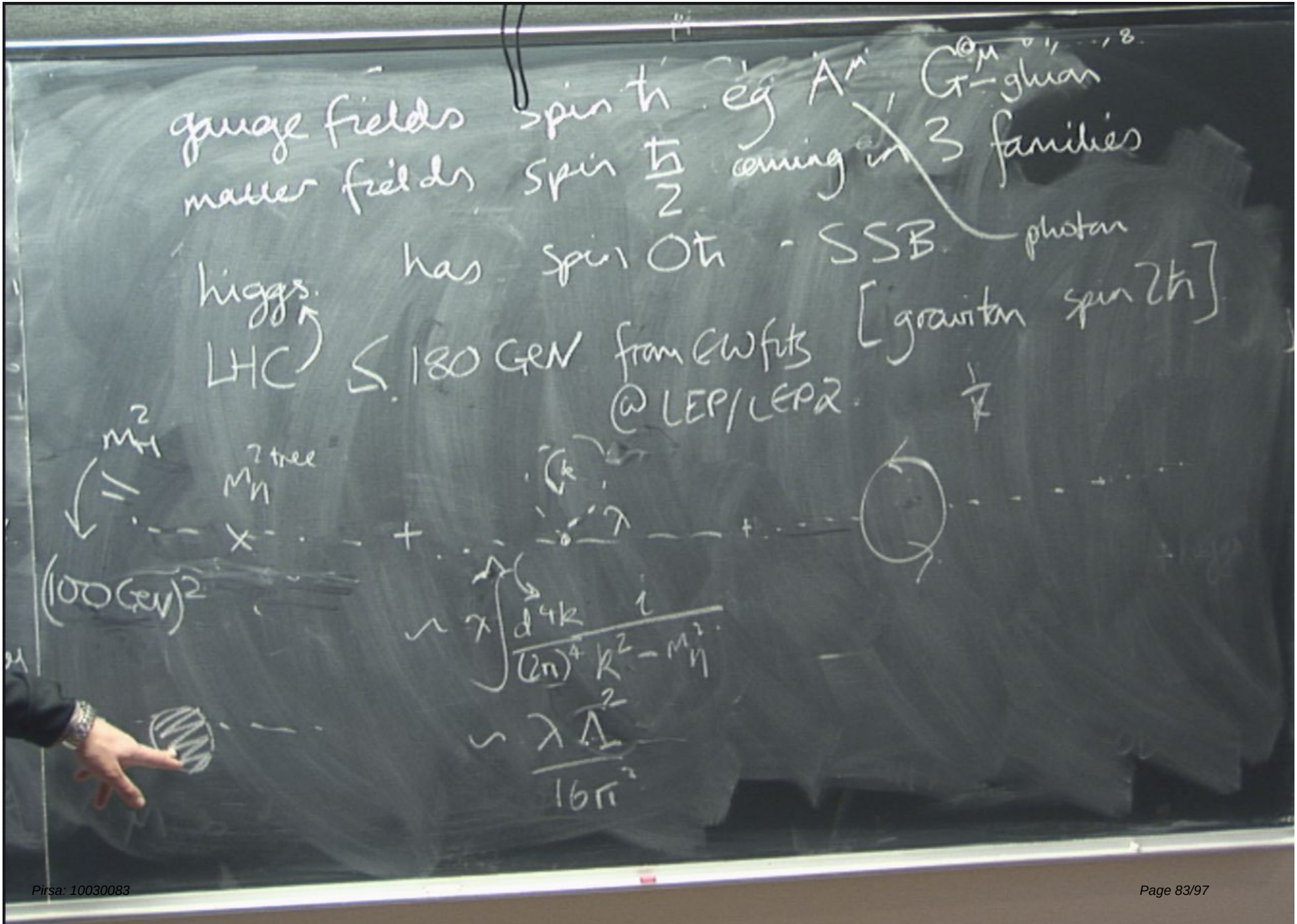
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$\frac{1}{N}$
M_H^2
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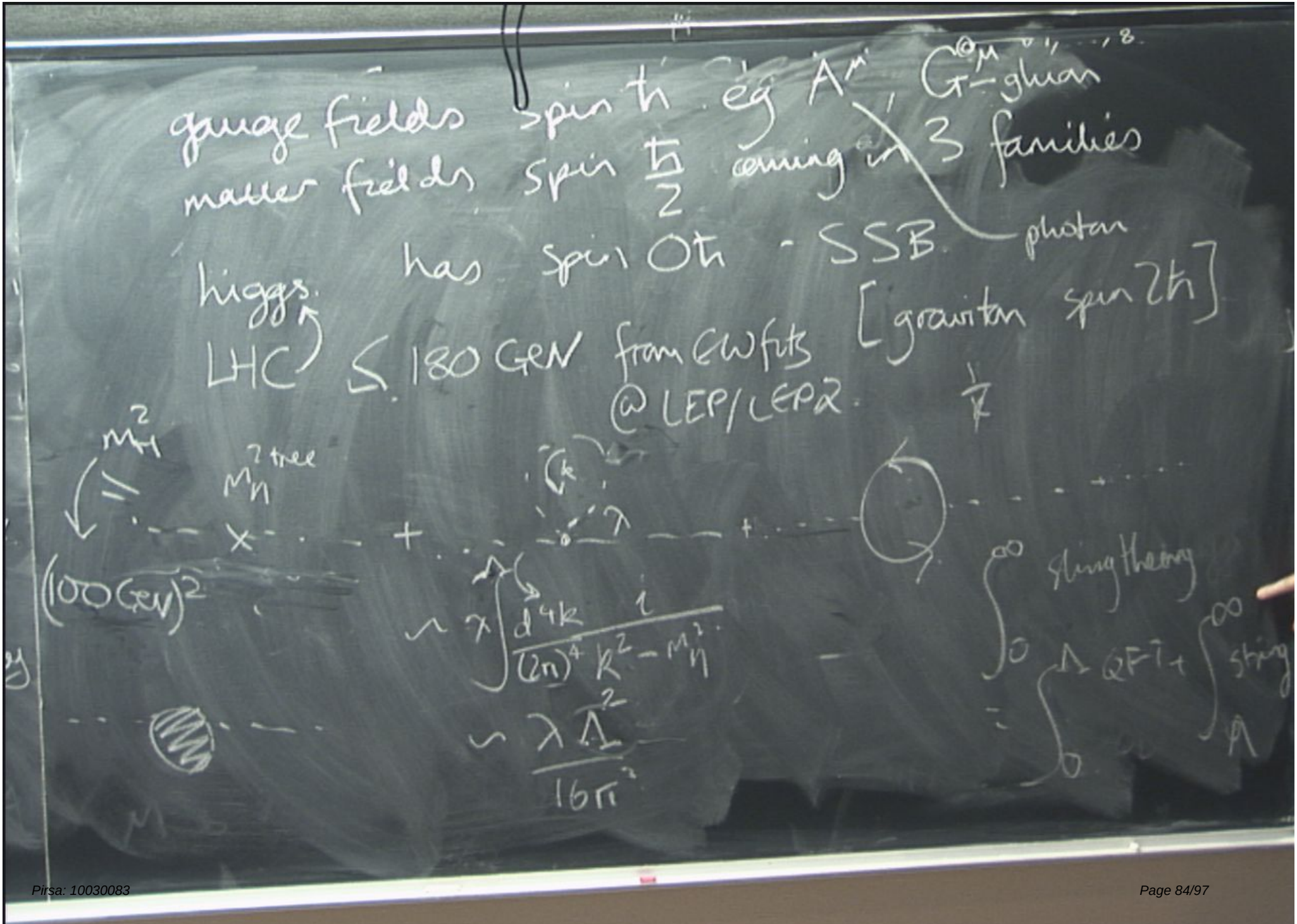
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LHC
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[graviton spin 2]
1/r
M_H^2
M_H^2 tree
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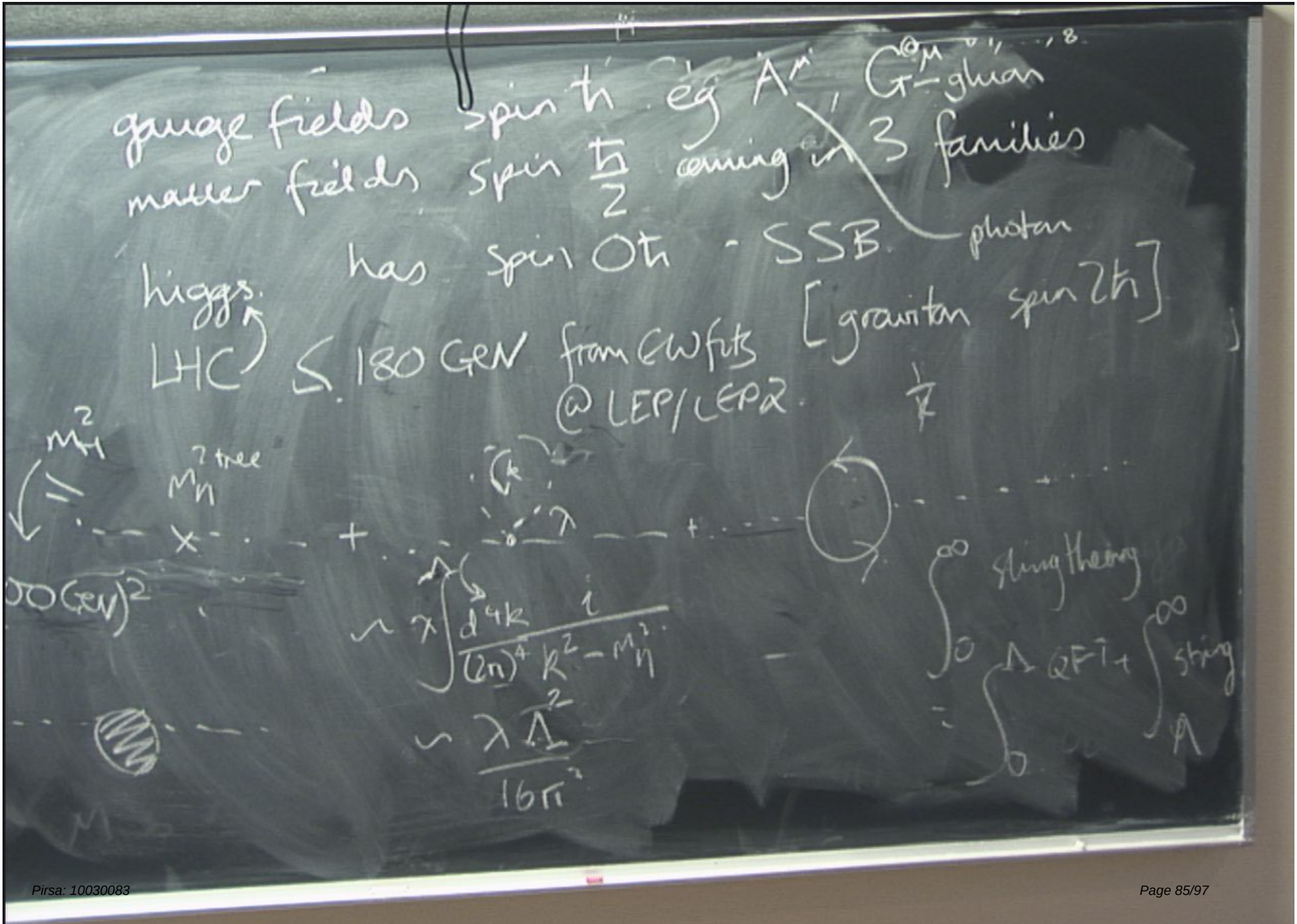
string theory
$\int_0^\infty$
$\int_0^\Lambda$ QFT
$\int_\Lambda^\infty$ string


gauge fields spin 1ħ eg A^μ, $G^{a\mu}$ a = 1, ..., 8 gluon
matter fields spin $\frac{1}{2}\hbar$ coming in 3 families
photon
higgs has spin 0ħ - SSB
LHC ≤ 180 GeV from EW fits @ LEP/LEP2
[graviton spin 2ħ]
M_H^2
M_H^2 tree
k
$\frac{1}{k}$
$(100\,GeV)^2$
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{i}{k^2 - M_H^2}$
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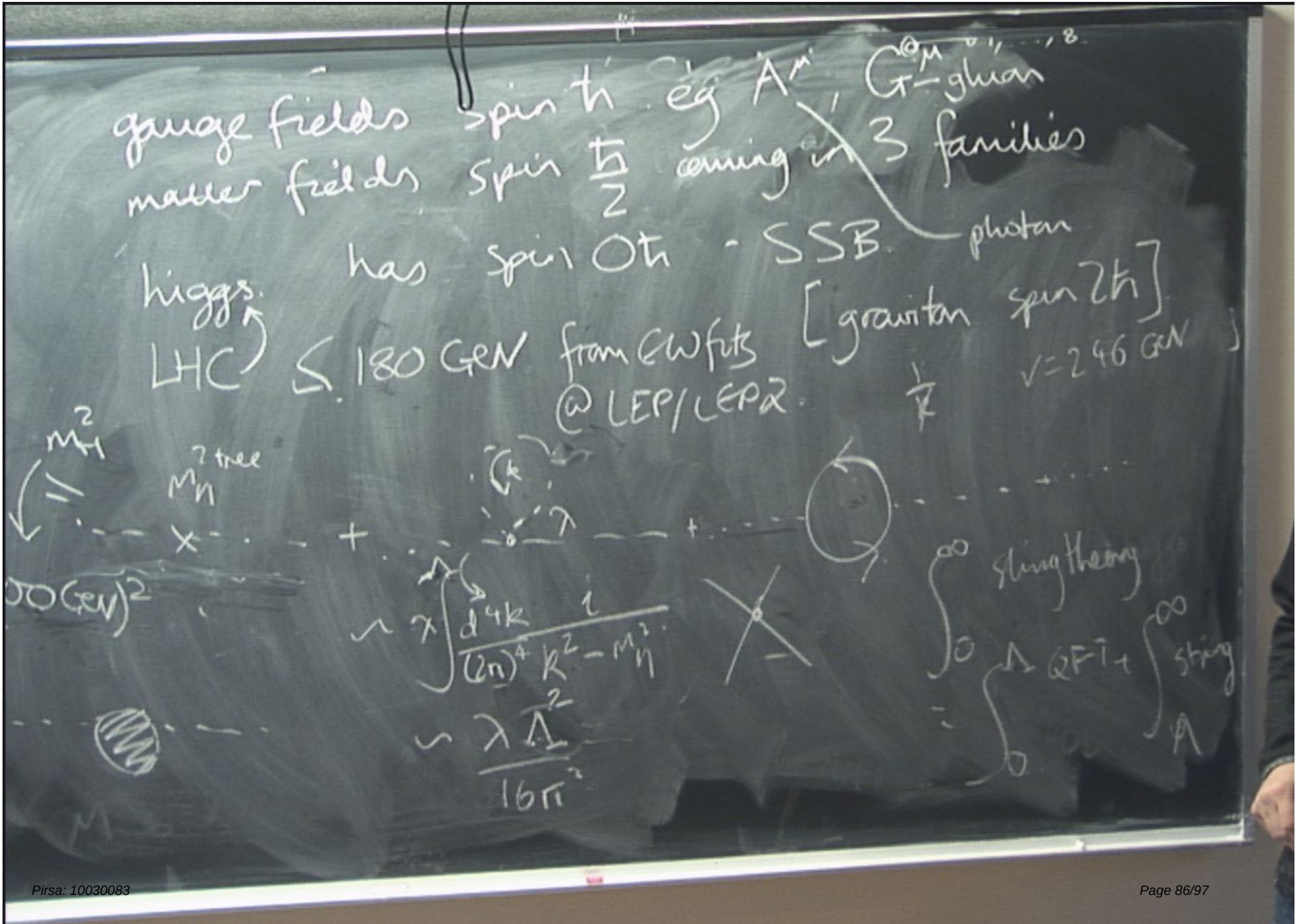
$\int_0^\infty$ string theory
$\int_0^\Lambda$ QFT + $\int_\Lambda^\infty$ string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matter fields spin ħ/2 coming in 3 families
photon
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LHC ≤ 180 GeV from EW fits @ LEP/LEP2
[graviton spin 2ħ]
v = 246 GeV
M_H^2
M_H^2 tree
k
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{i}{k^2 - M_H^2}$
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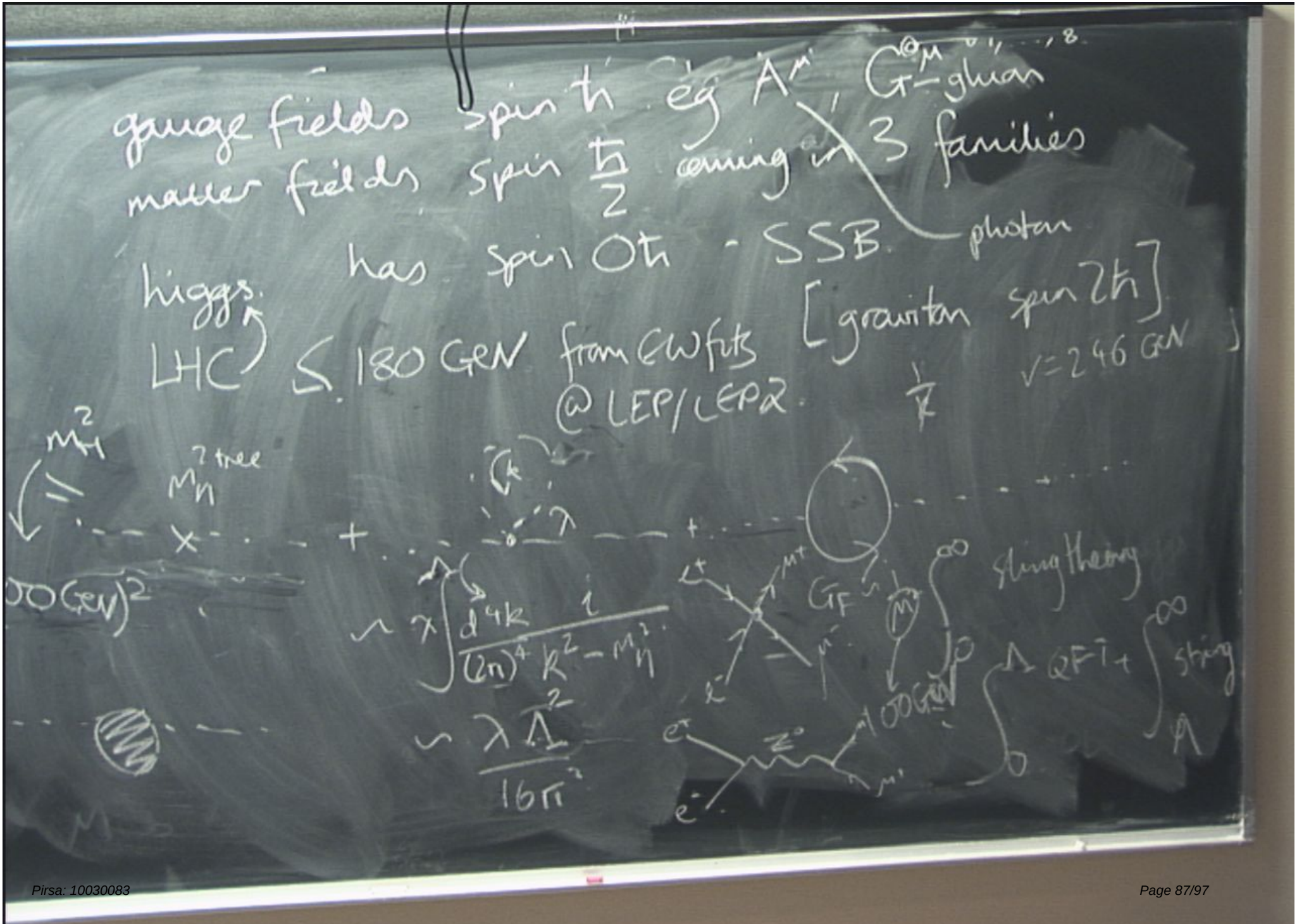
gauge fields spin 1ħ eg A^μ, $G^{a\mu}$ a = 1, ..., 8 G = gluon
matter fields spin ½ħ coming in 3 families
higgs has spin 0ħ - SSB photon
LHC ≤ 180 GeV from EW fits @ LEP/LEP2 [graviton spin 2ħ]
v = 246 GeV
M_H^2
M_H^2 tree
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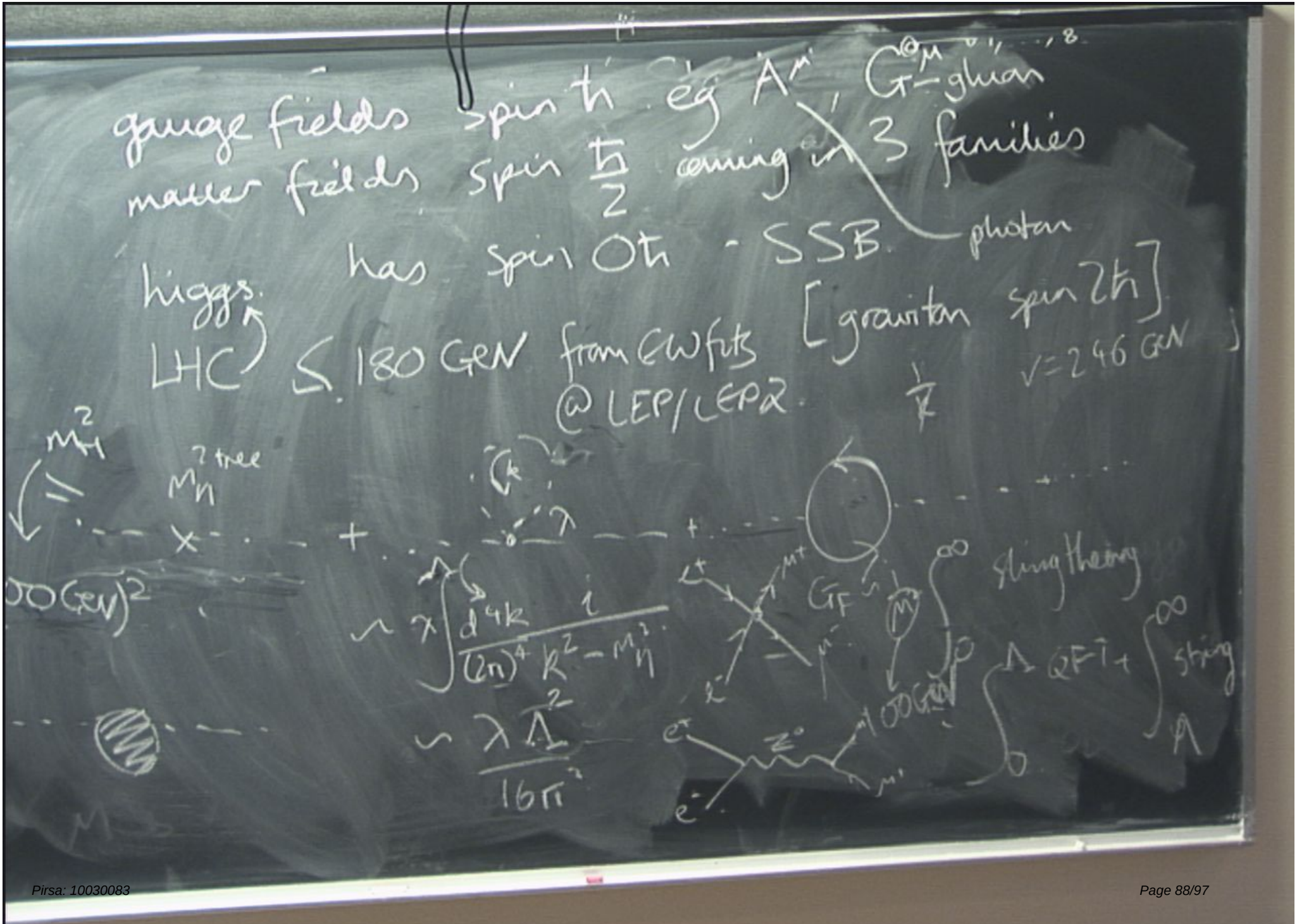
G_F
string theory
Λ QFT + $\int_\Lambda^\infty$ string
e^+
e^-
Z^0
μ^+
μ^-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[graviton spin 2ħ]
v = 246 GeV
1/R
M_H^2
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G_F
M_W
e^+
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μ^+
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ν_μ
Z^0
100 GeV
string theory
$\int_0^\infty$
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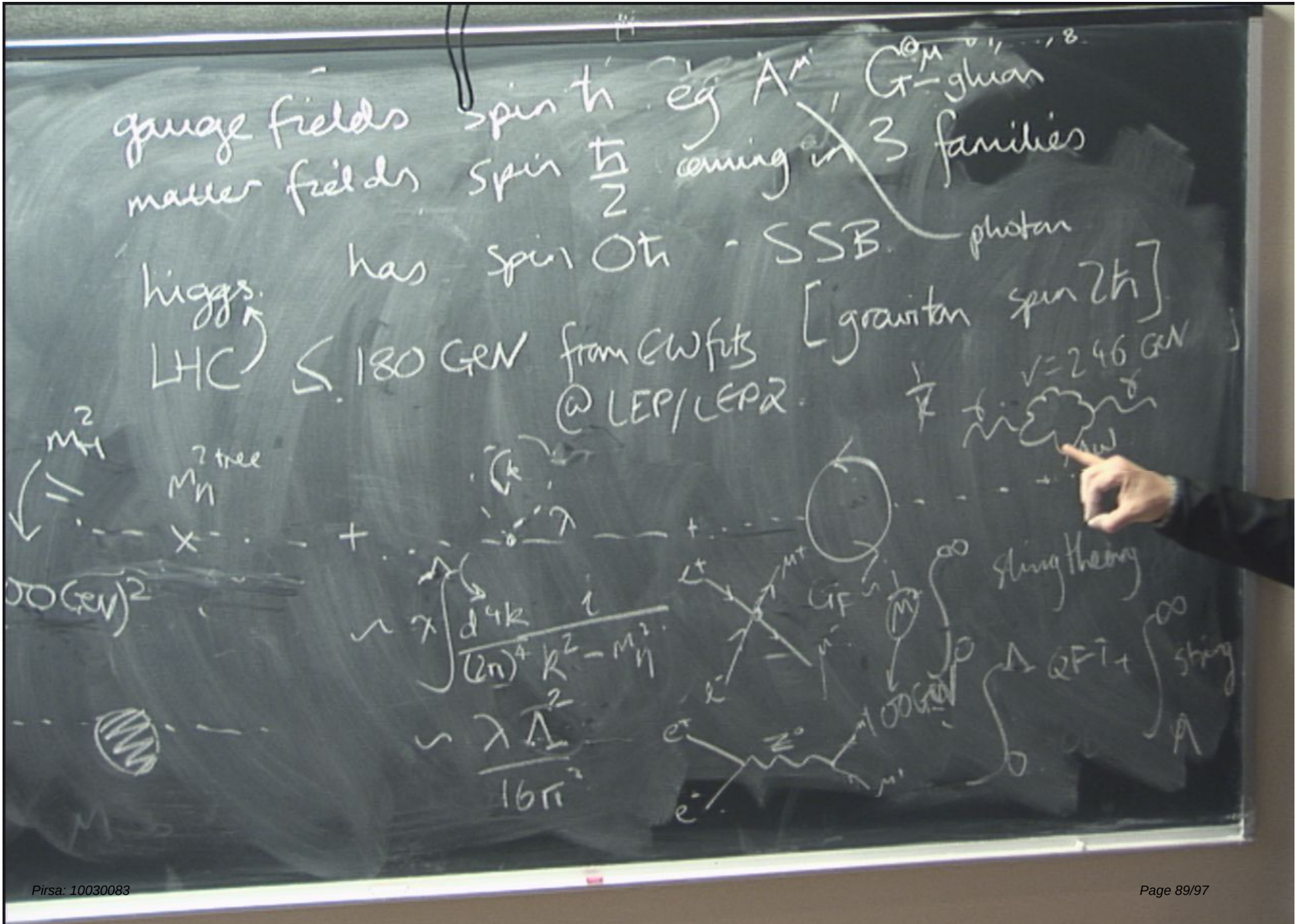
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M_H^2
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G_F
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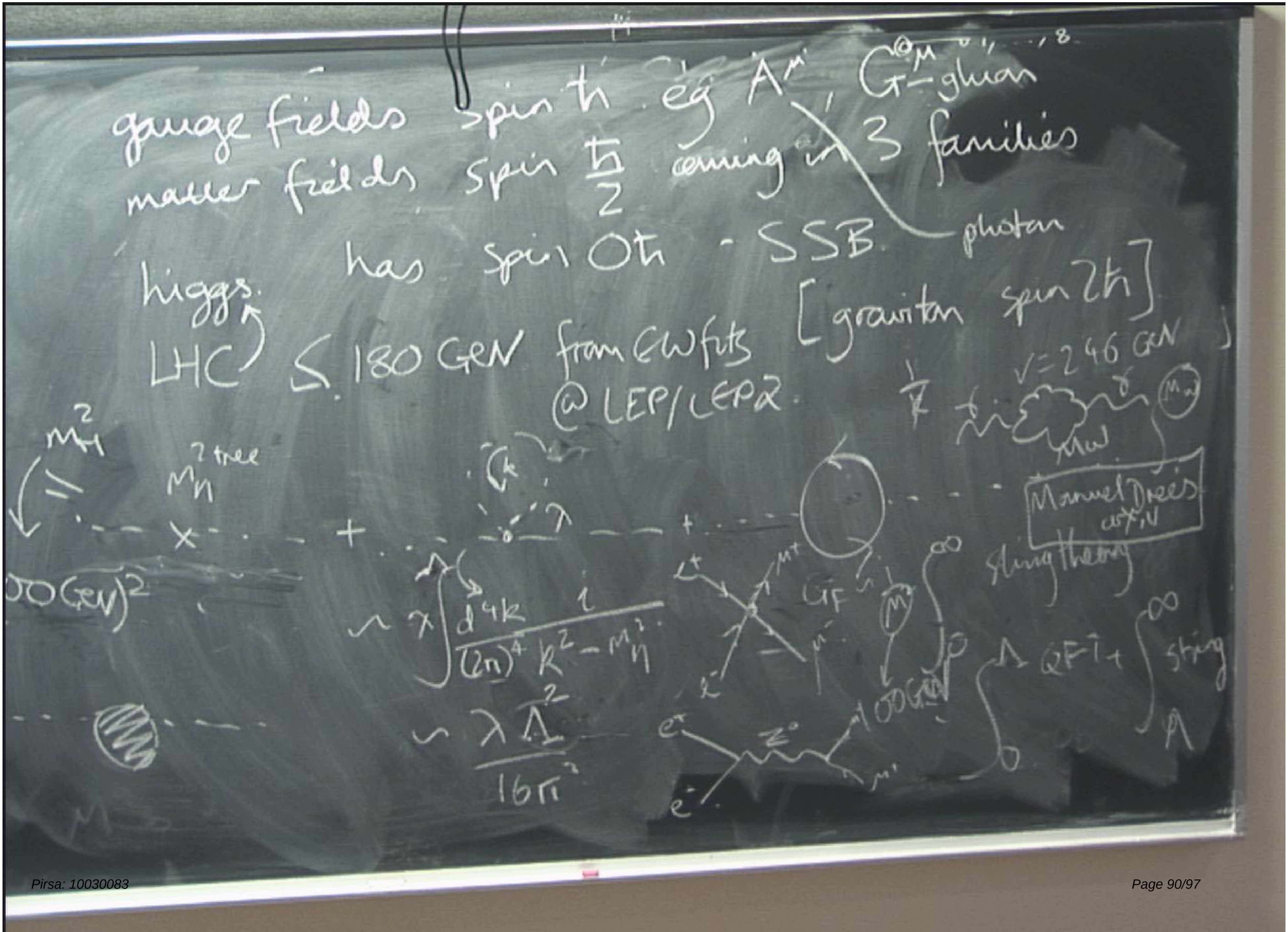
string
e^+
e^-
μ^+
μ^-
100 GeV


gauge fields spin ħ eg A^μ, G^a_μ gluon
photon
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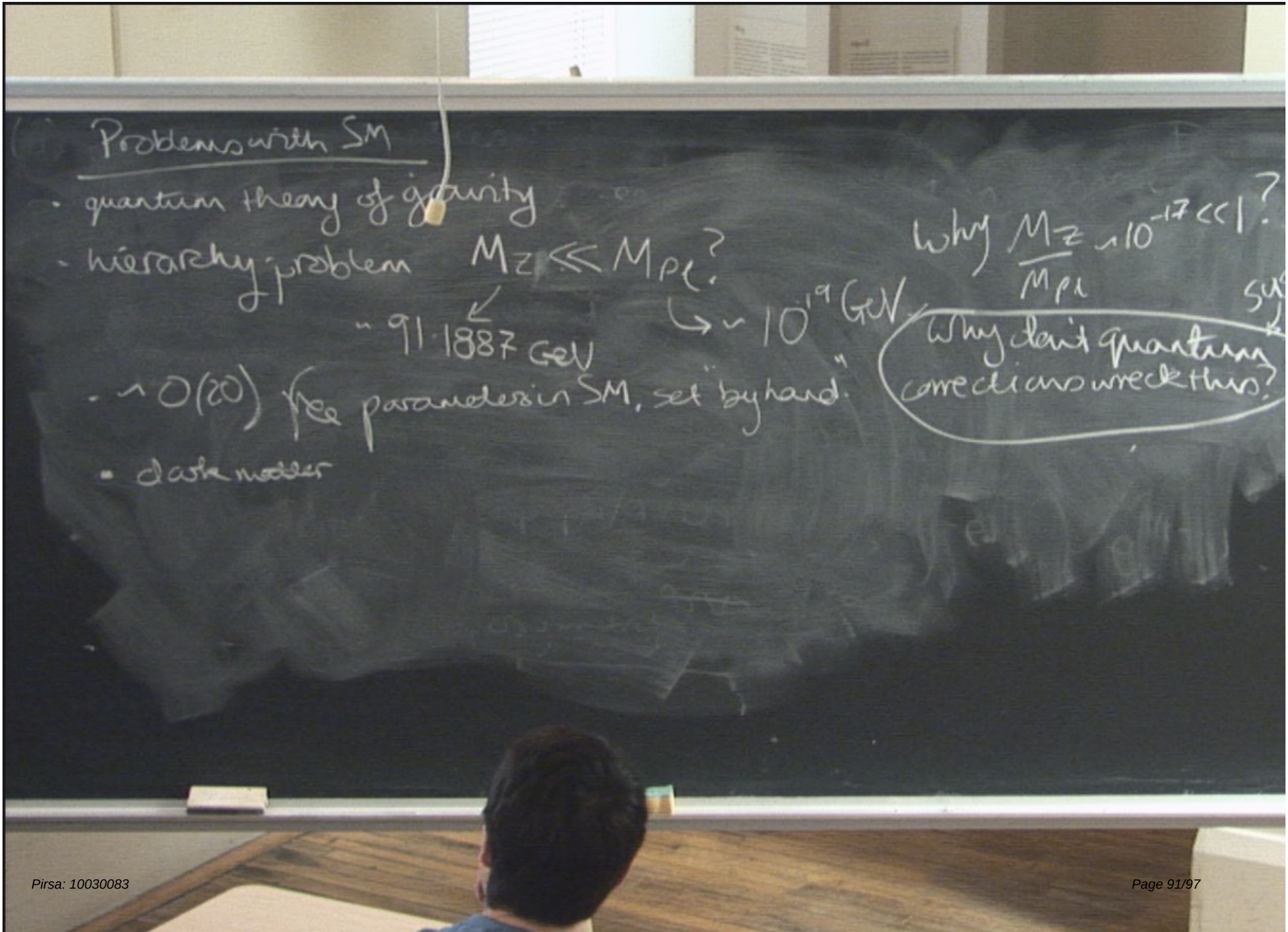
[graviton spin 2ħ]
LHC ≲ 180 GeV from EW fits
@ LEP/LEP2
v = 246 GeV
Manuel Drees
string theory
QFT + string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- ~ O(20) free parameters in SM, set "by hand"
- dark matter

Modifications eg

. expanding internal symmetries eg !

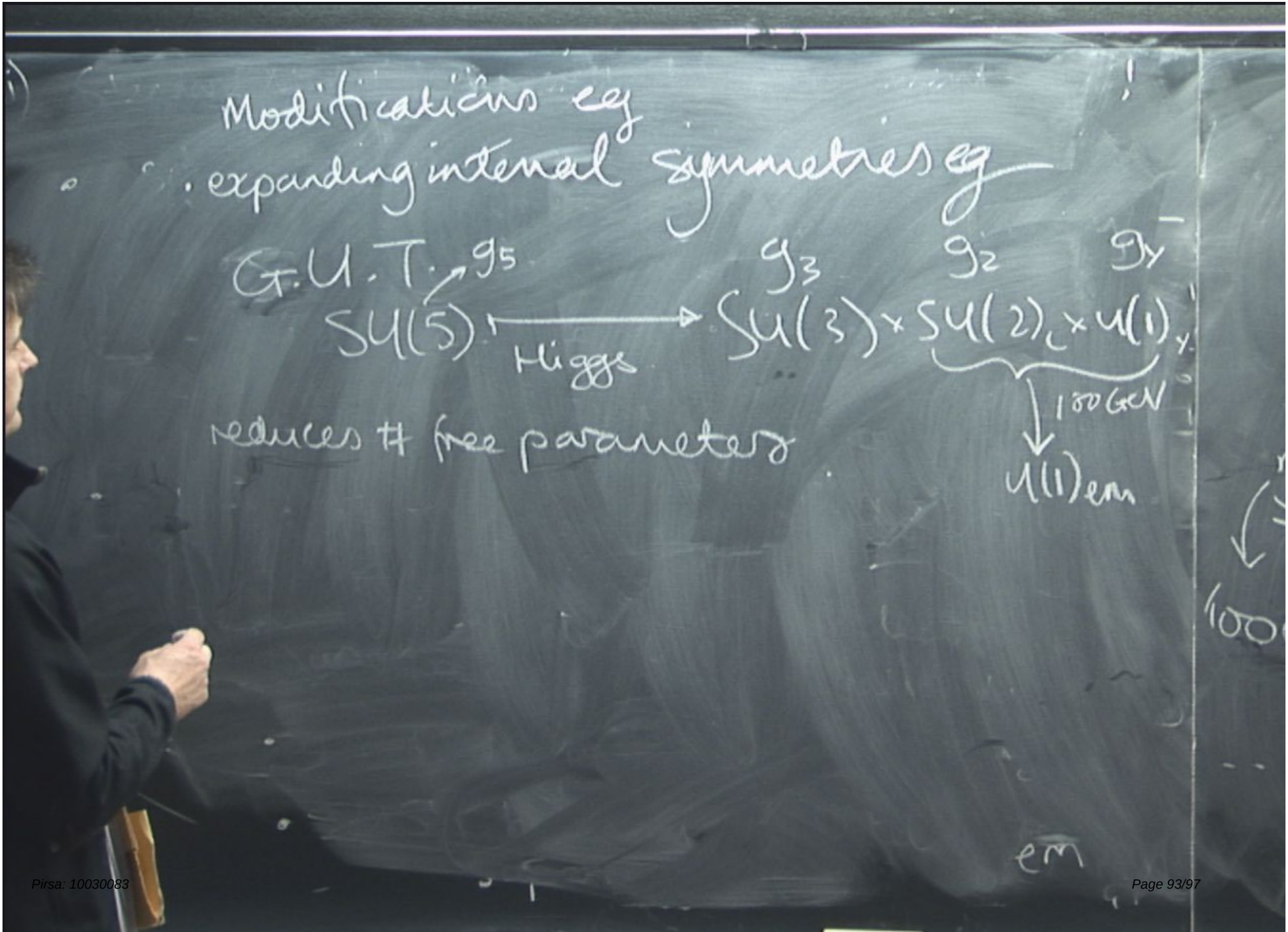
G.U.T.

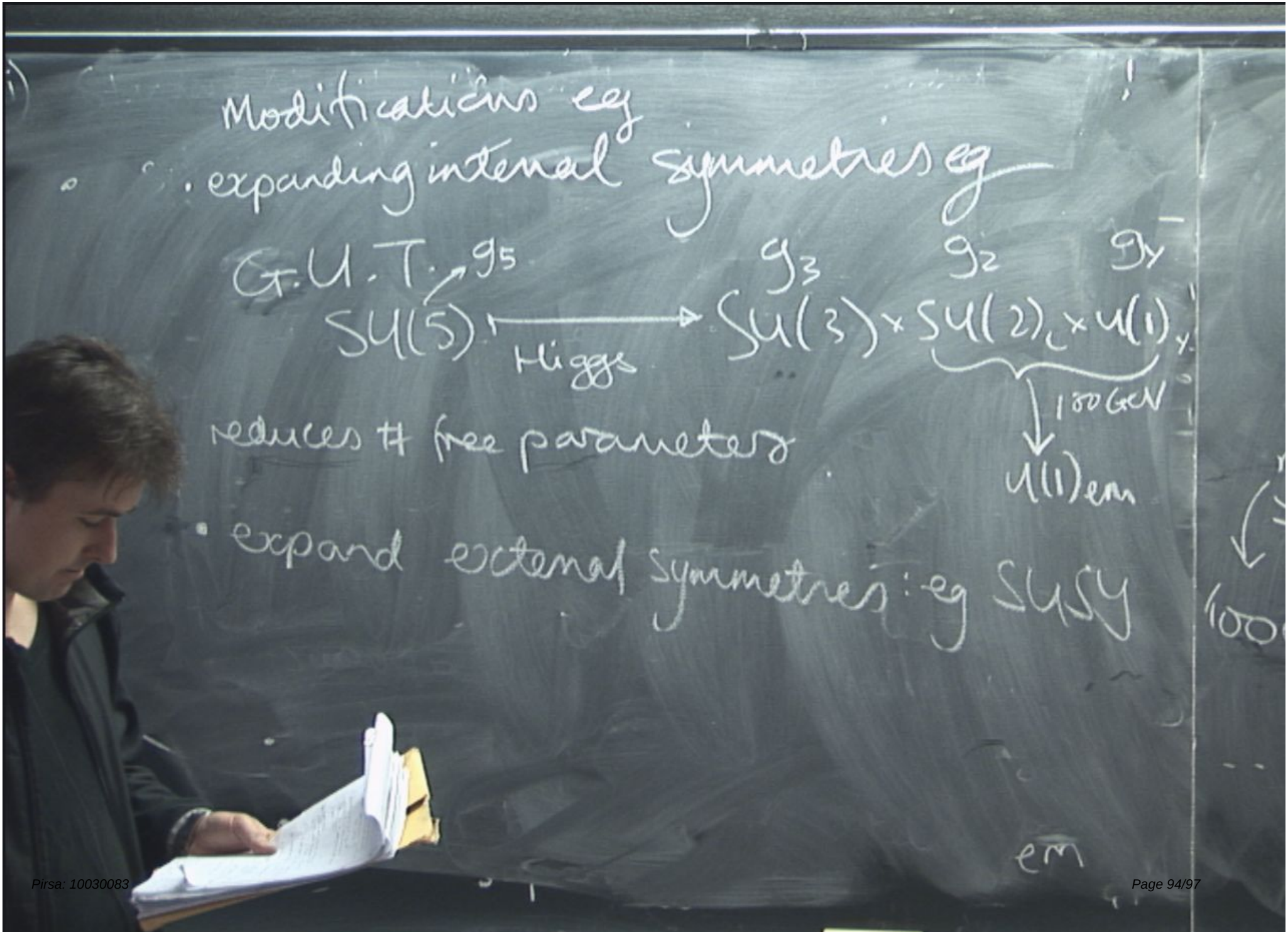
$SU(5) \xrightarrow{\text{Higgs}} SU(3) \times SU(2)_L \times U(1)_Y$

100 GeV

$U(1)_{em}$

em


Modifications eg
expanding internal symmetries eg
G.U.T.
g_5
g_3
g_2
g_Y
SU(5)
Higgs
SU(3) × SU(2)$_L$ × U(1)$_Y$
100 GeV
U(1)$_{em}$
reduces # free parameters
em


Modifications eg
expanding internal symmetries eg
G.U.T.
g_5
g_3
g_2
g_Y
SU(5)
Higgs
SU(3) × SU(2)$_L$ × U(1)$_Y$
100 GeV
reduces # free parameters
U(1)em
expand external symmetries: eg SUSY
em

Modifications eg

• expanding internal symmetries eg

G.U.T. g_5

$SU(5) \xrightarrow{\text{Higgs}} SU(3) \times SU(2)_L \times U(1)_Y$ (g_3, g_2, g_Y)

100 GeV

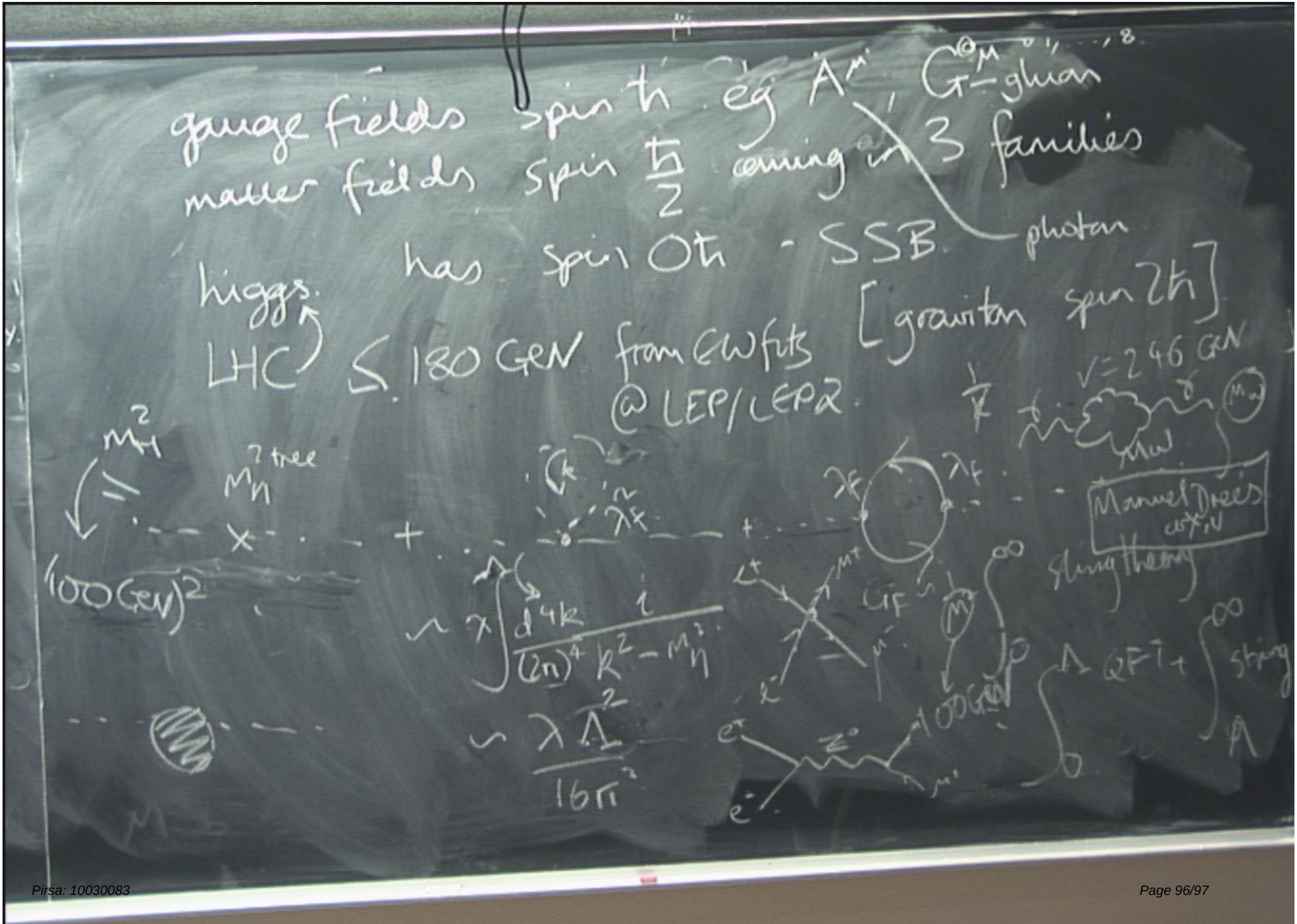
$U(1)_{em}$

reduces # free parameters

• expand external symmetries: eg SUSY

bosons $\leftrightarrow$ fermions

em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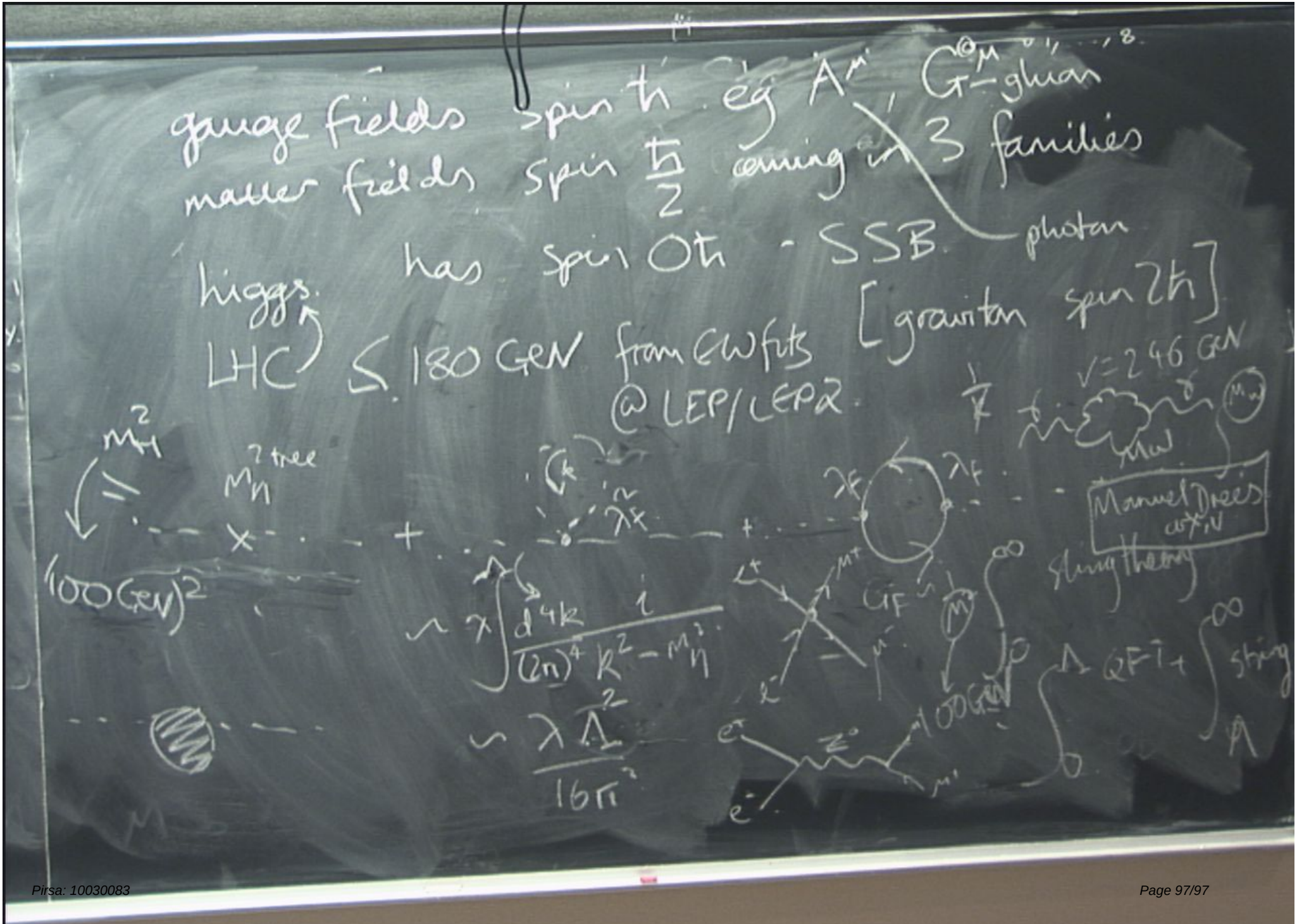
LHC
≤ 180 GeV from EW fits @ LEP/LEP2
[graviton spin 2]
v = 246 GeV
M_H^2
M_H^2 tree
λ_f
λ_f
$(100\,GeV)^2$
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_H^2}$
$\sim \frac{\lambda \Lambda^2}{16\pi^2}$
G_F
M_W
M_Z
100 GeV
Manuel Drees
string theory
Λ QFT
string
Λ


gauge fields spin 1h eg A^μ, G^a_μ a = 1, ..., 8 G-gluon
matter fields spin $\frac{1}{2}$ coming in 3 families
higgs has spin 0h - SSB photon
LHC
$\lesssim$ 180 GeV from EW fits @ LEP/LEP2
[graviton spin 2h]
$v = 246$ GeV
M_W
M_H^2
M_H^2 tree
λ_f
$100\,(\mathrm{GeV})^2$
$\sim \lambda \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2 - M_H^2}$
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Manuel Drees
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string
100 GeV