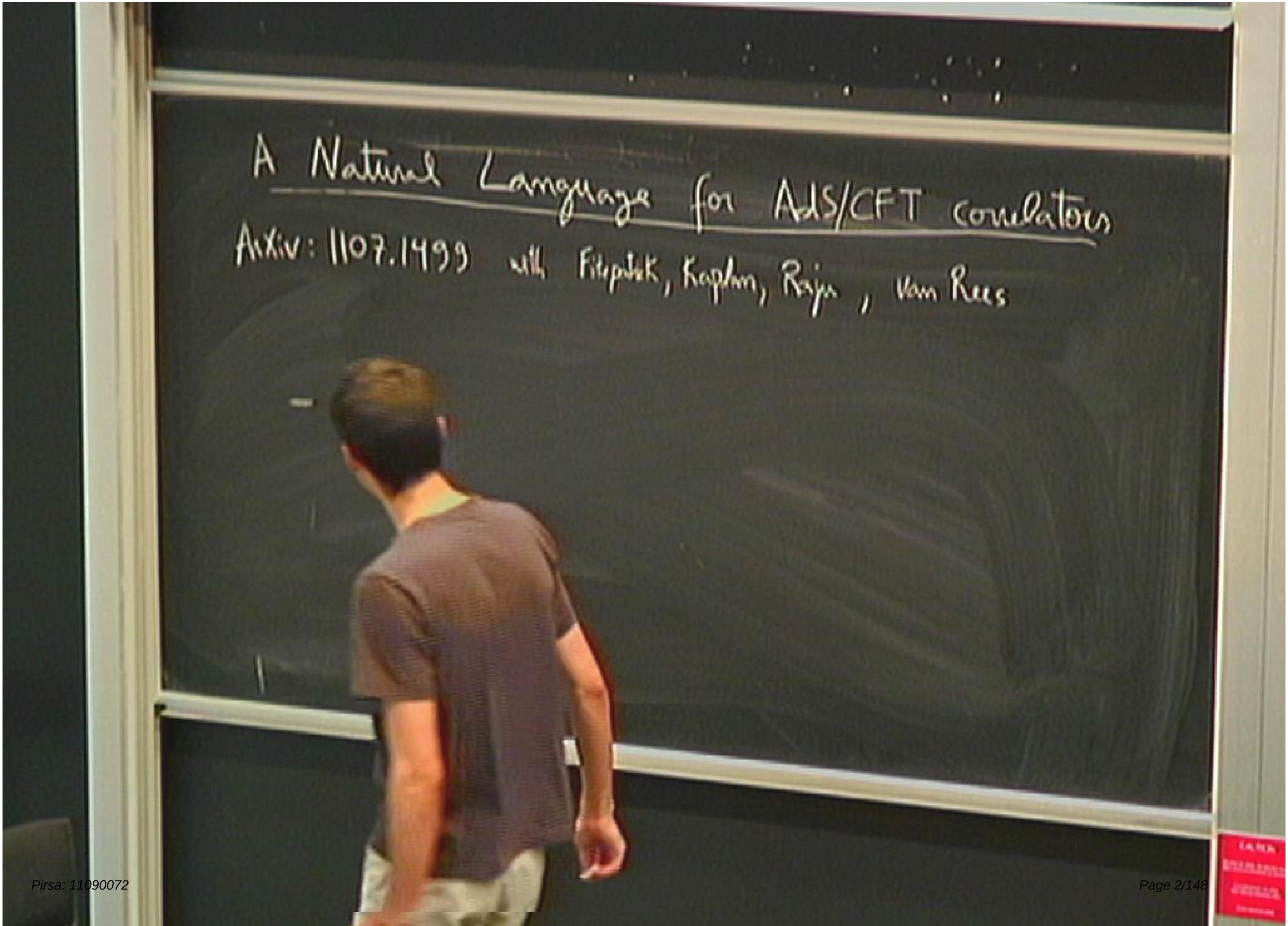
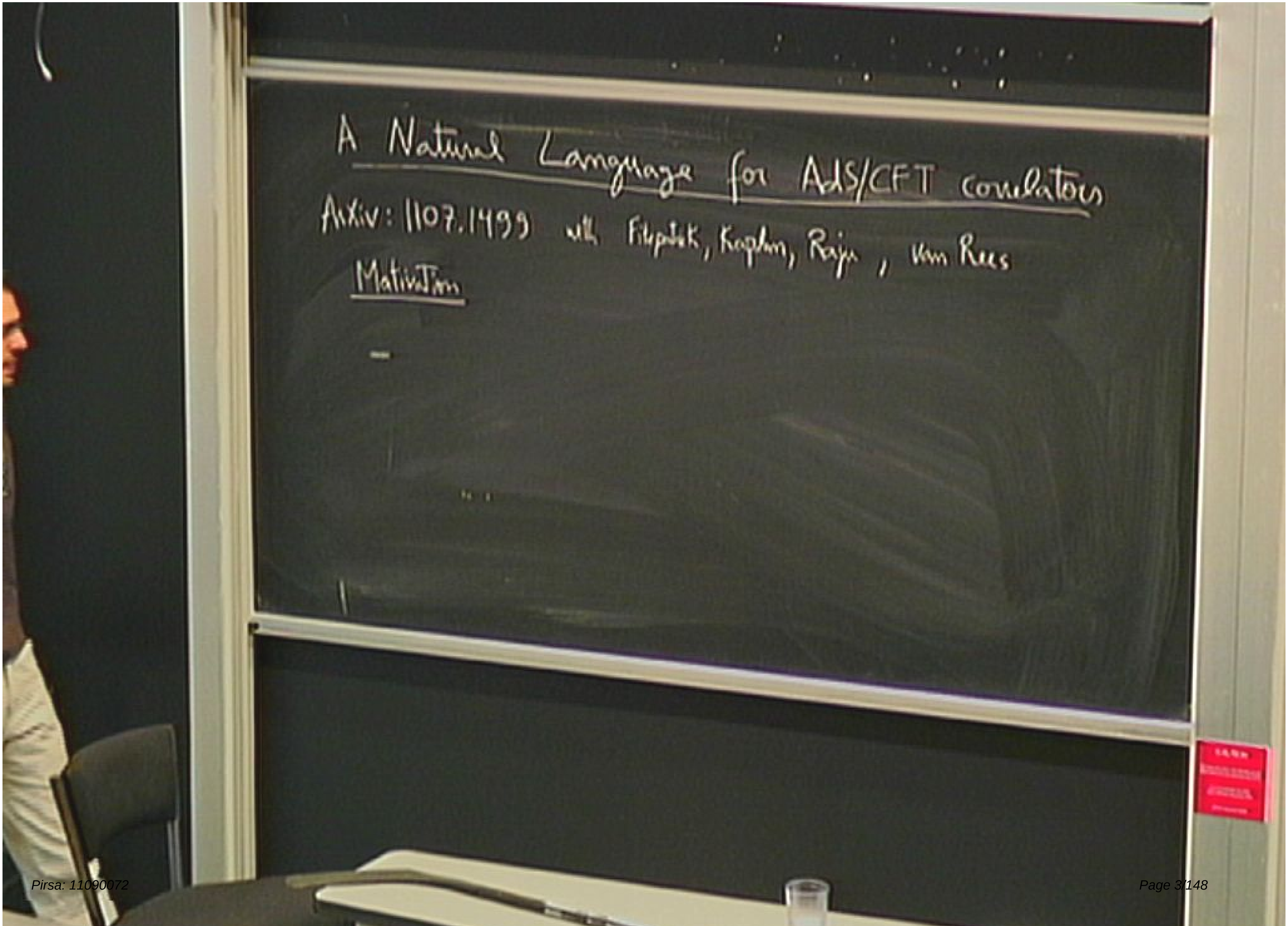
Title: A Natural Language for AdS/CFT Correlators

Date: Sep 14, 2011 11:00 AM

URL: http://pirsa.org/11090072

Abstract: TBA


A Natural Language for AdS/CFT correlators
ArXiv: 1107.1499 with Fitzpatrick, Kaplan, Raju, van Rees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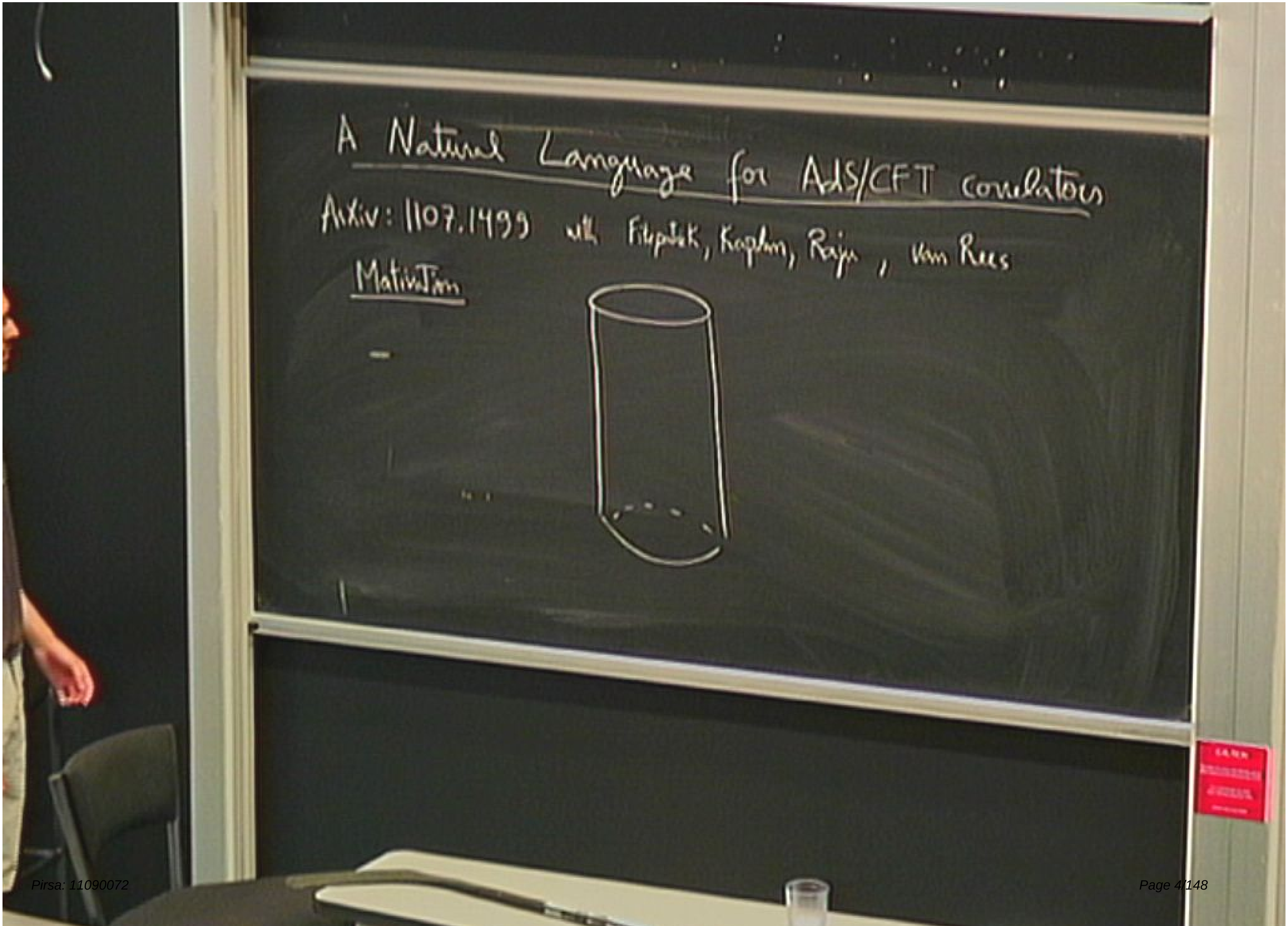
Motivation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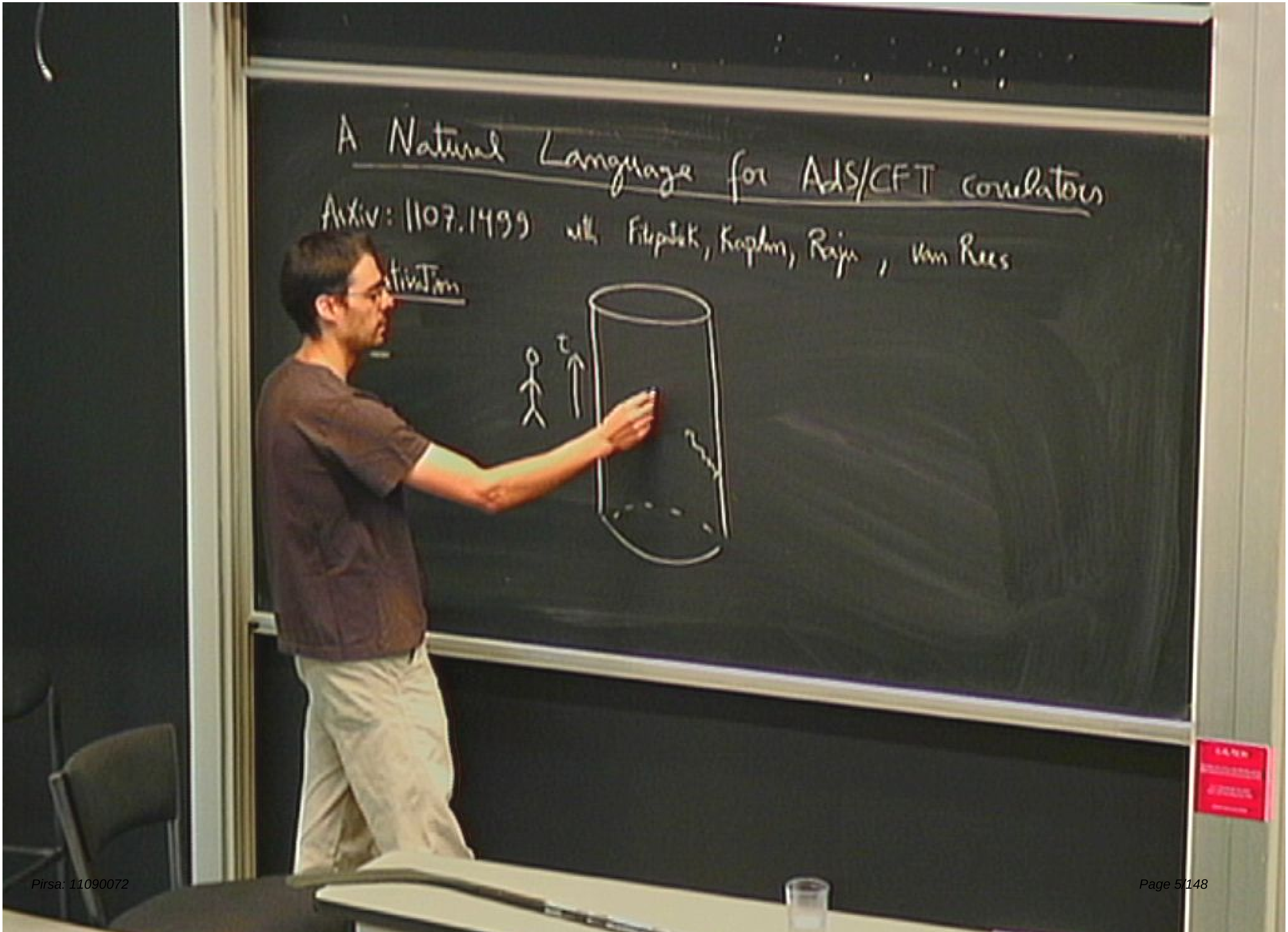
A Natural Language for AdS/CFT correlators
ArXiv: 1107.1499 with Fitzpatrick, Kaplan, Raju, van Rees
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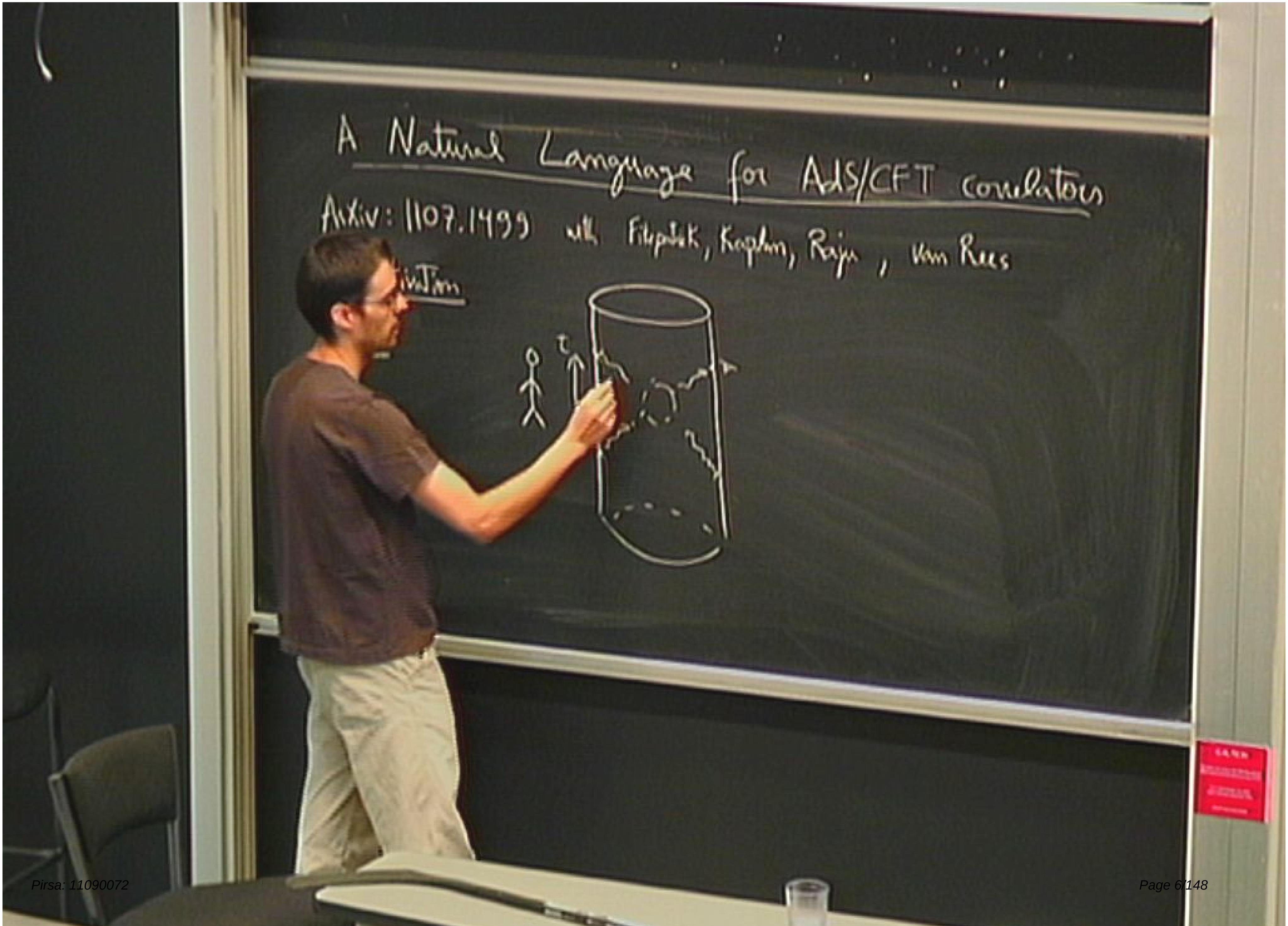
A Natural Language for AdS/CFT correlators
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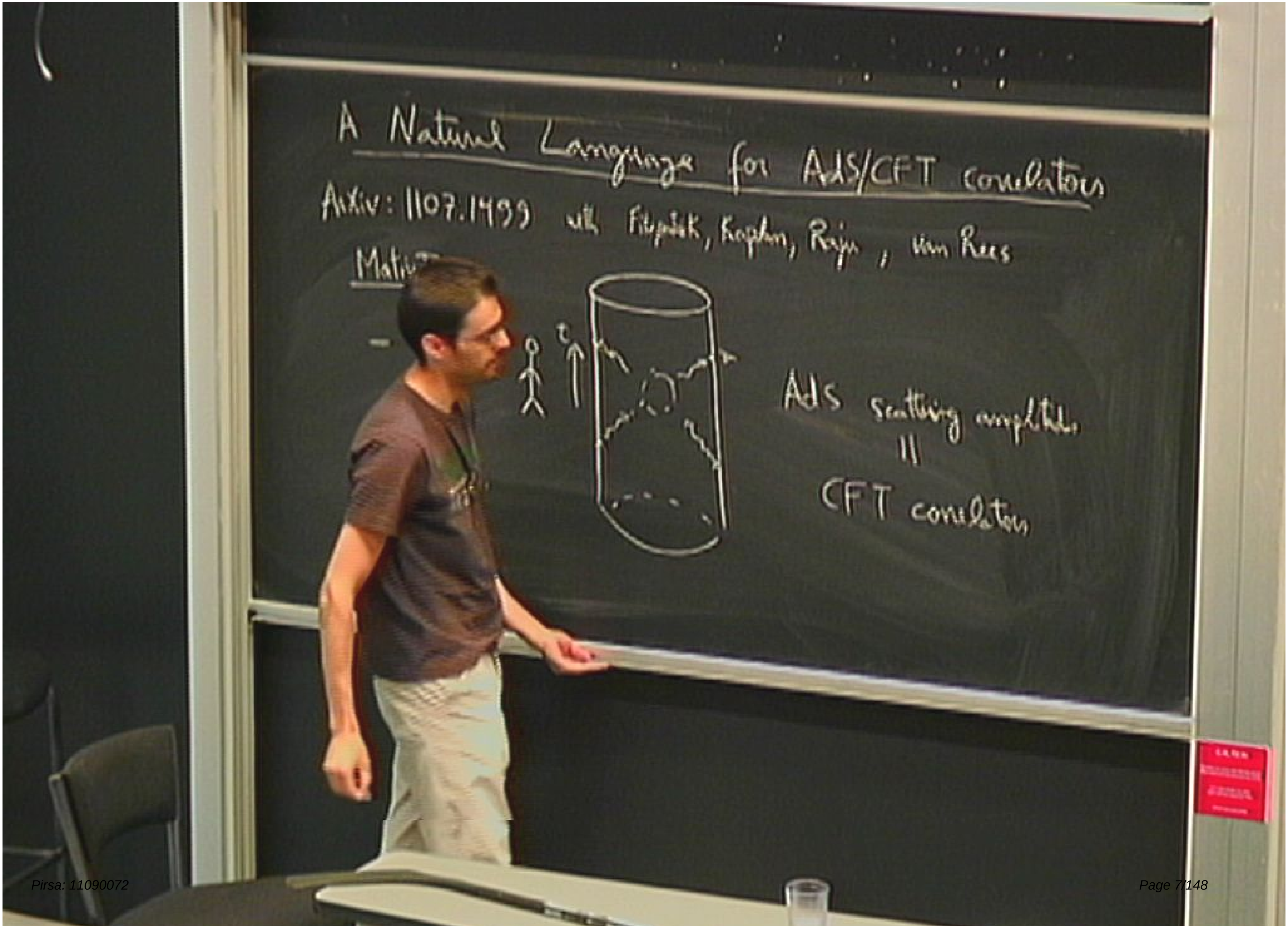
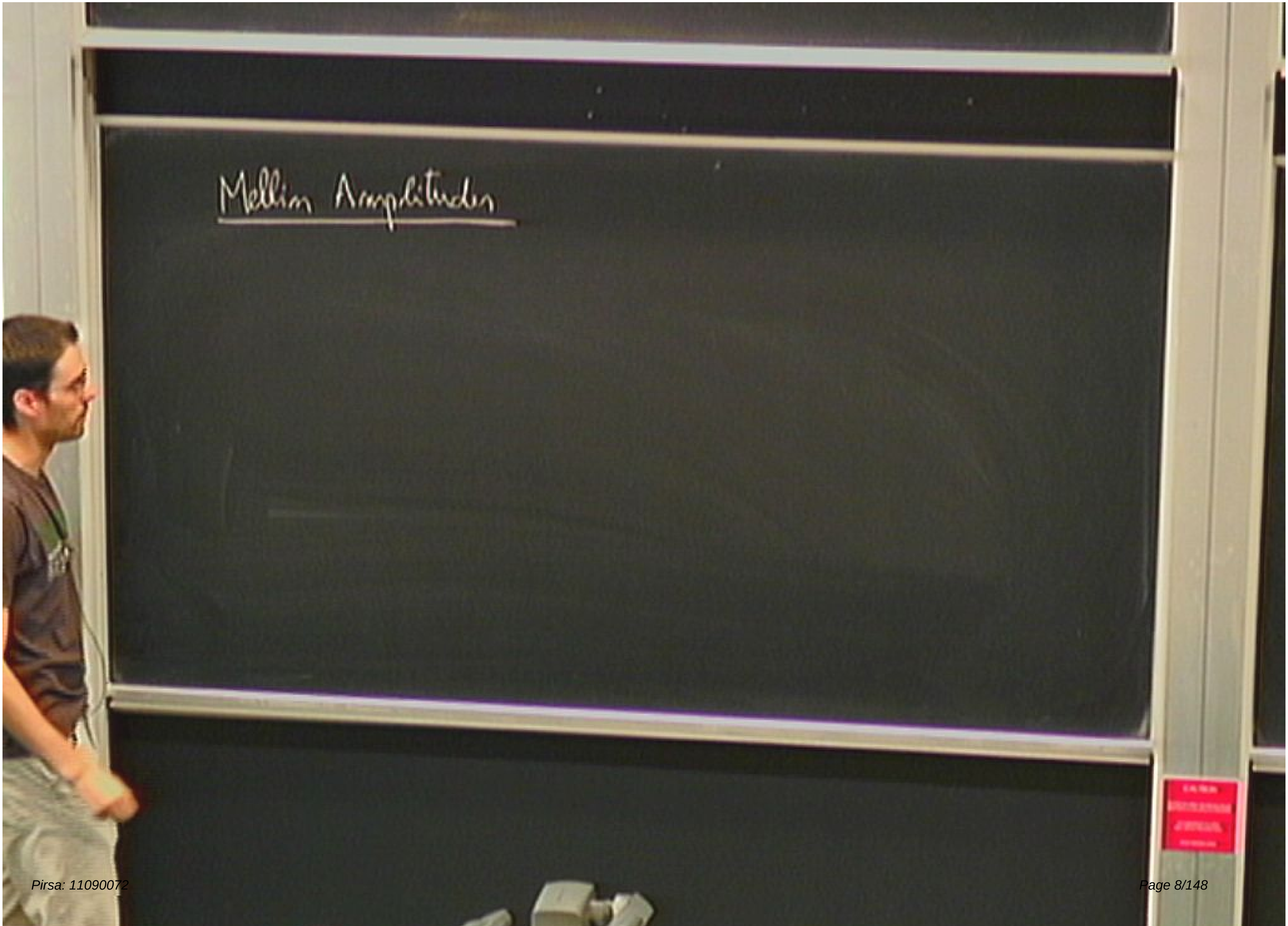
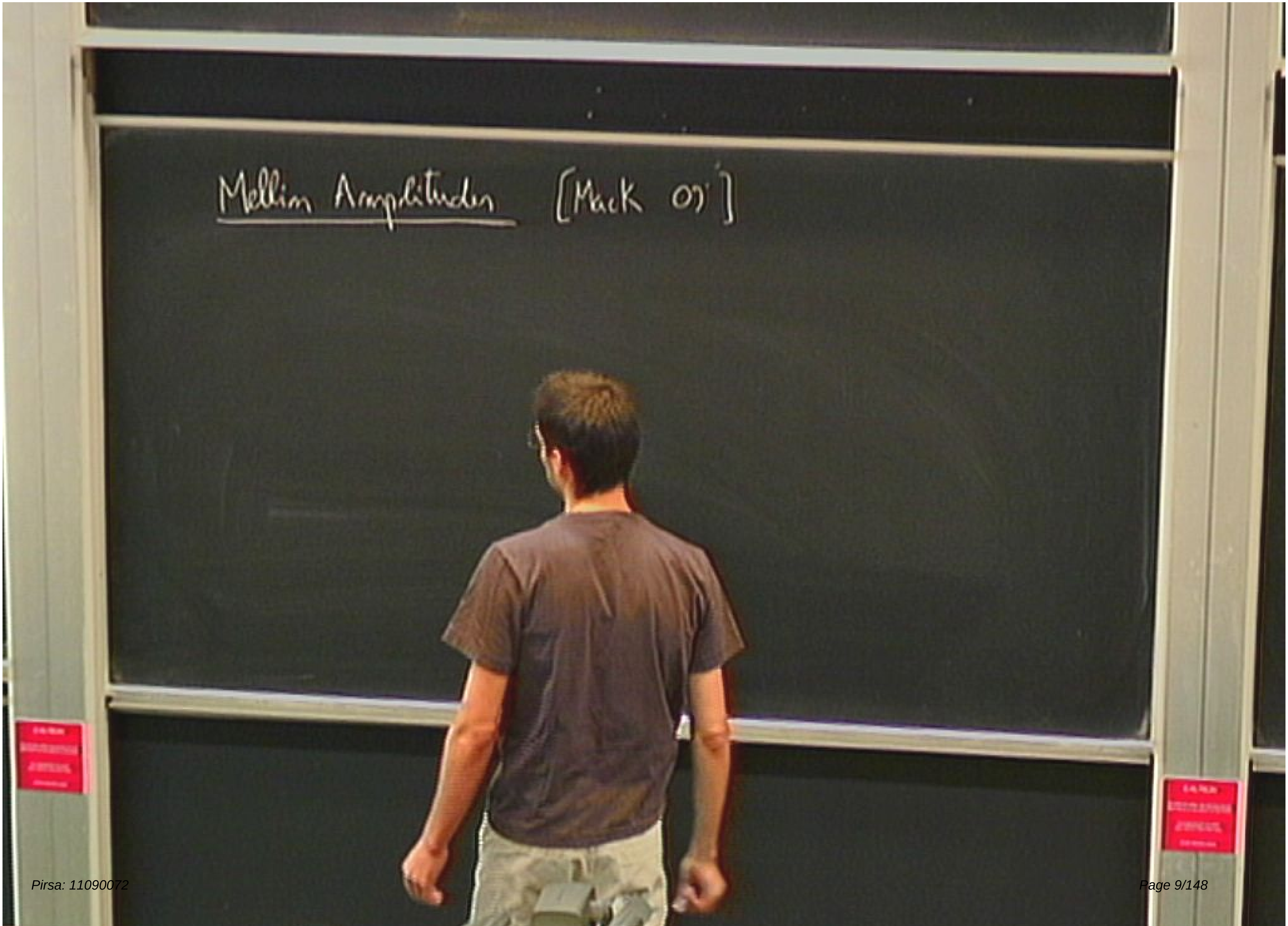
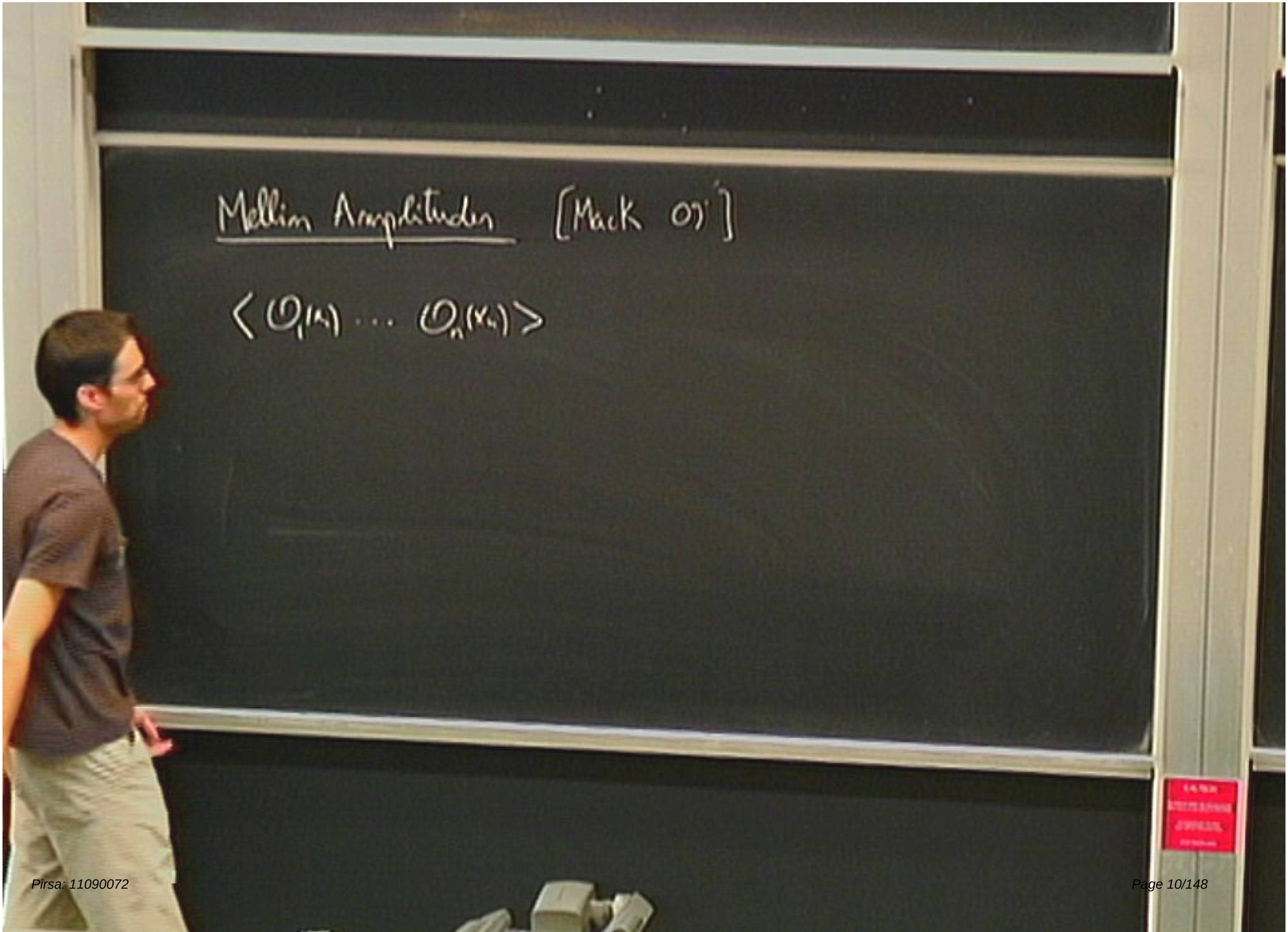


A Natural Language for AdS/CFT correlators
ArXiv: 1107.1499 with Fitzpatrick, Kaplan, Raju, van Rees
AdS scattering amplitudes
||
CFT correlators


Mellin Amplitudes

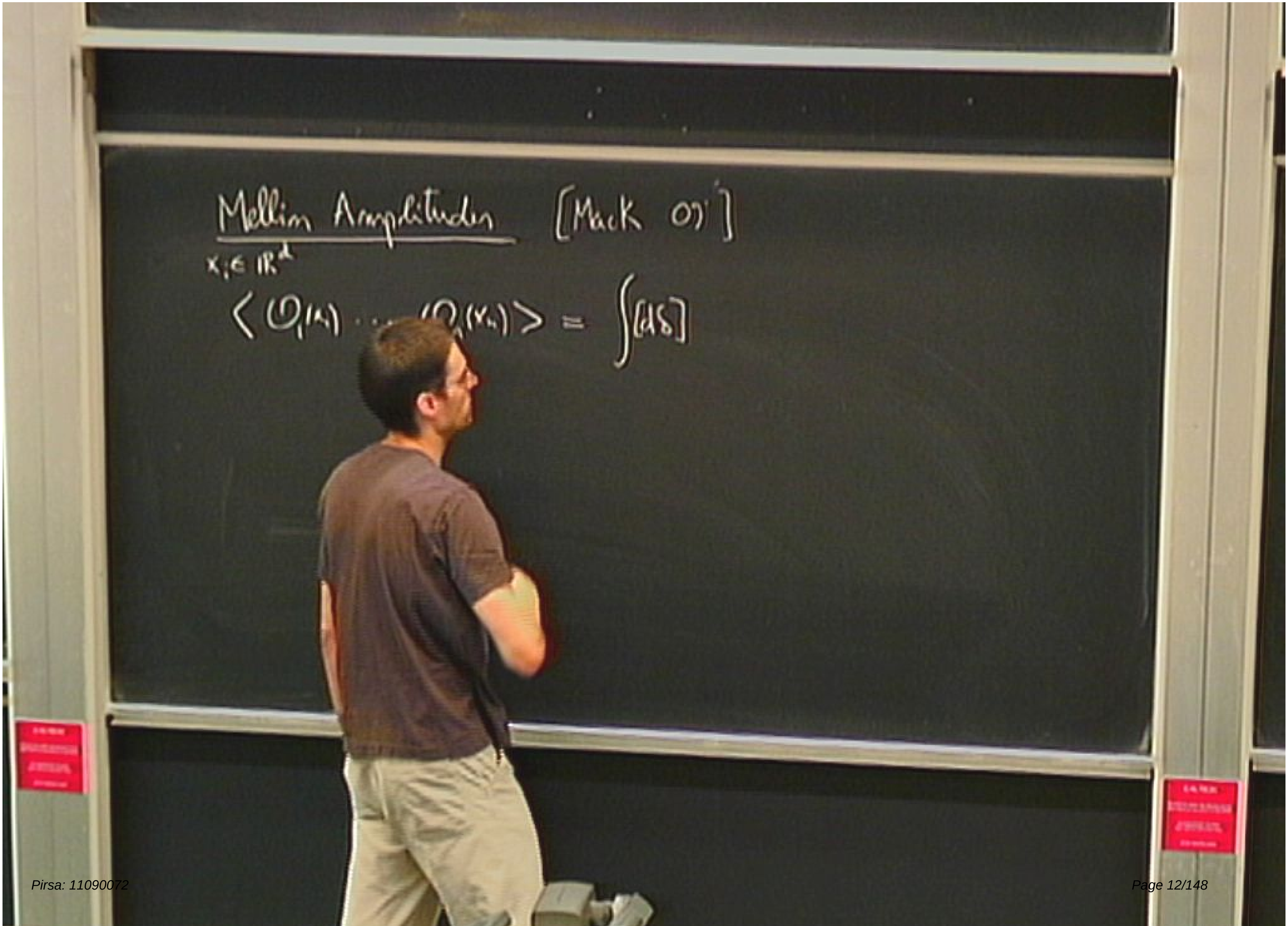

Mellin Amplitudes [Mack 09]

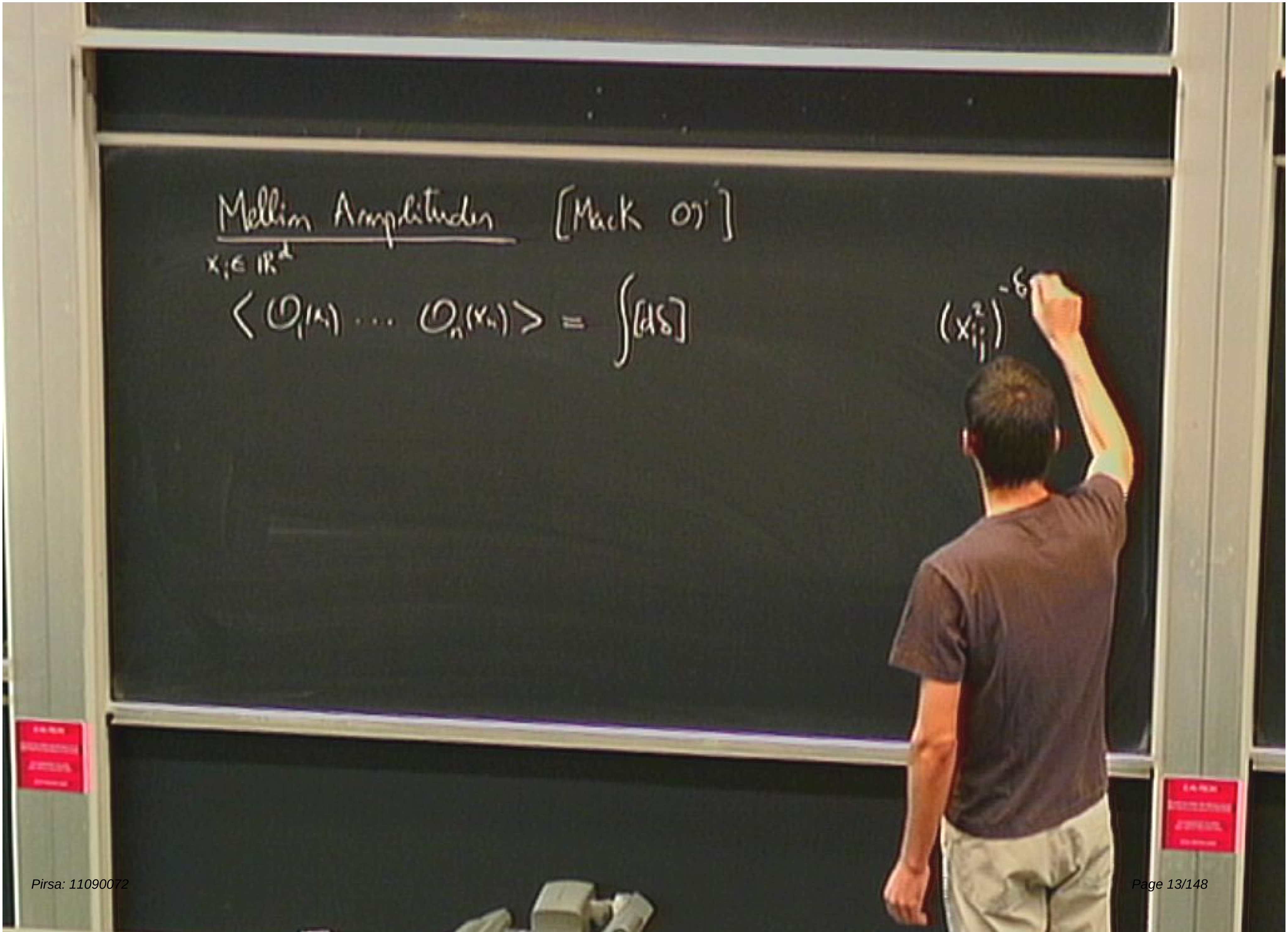

Mellin Amplitudes [Mack 09]
$\langle \mathcal{O}_1(x_1) \dots \mathcal{O}_n(x_n) \rangle$

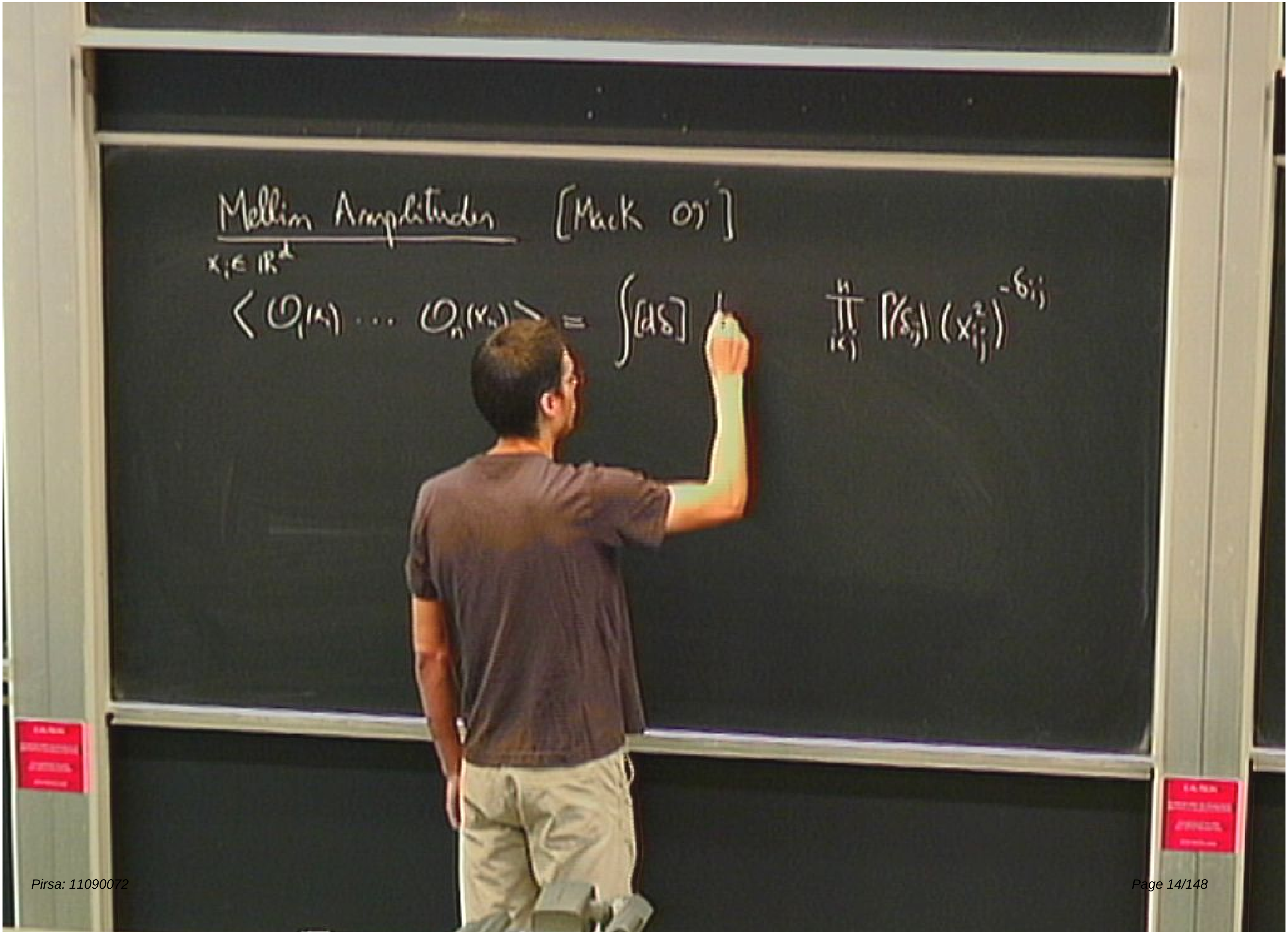
Mellin Amplitudes [Mack 09]

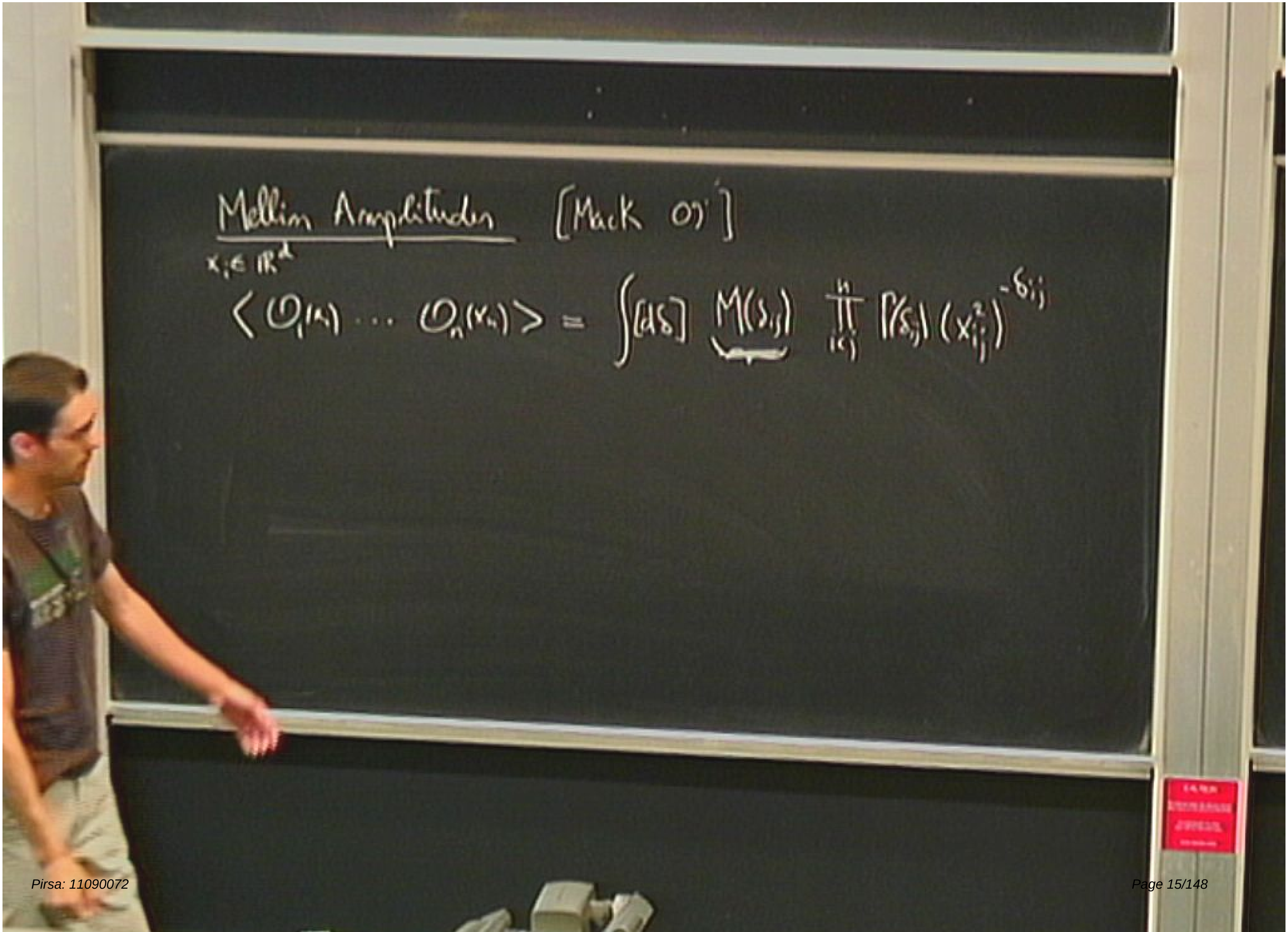
$x_i \in \mathbb{R}^d$

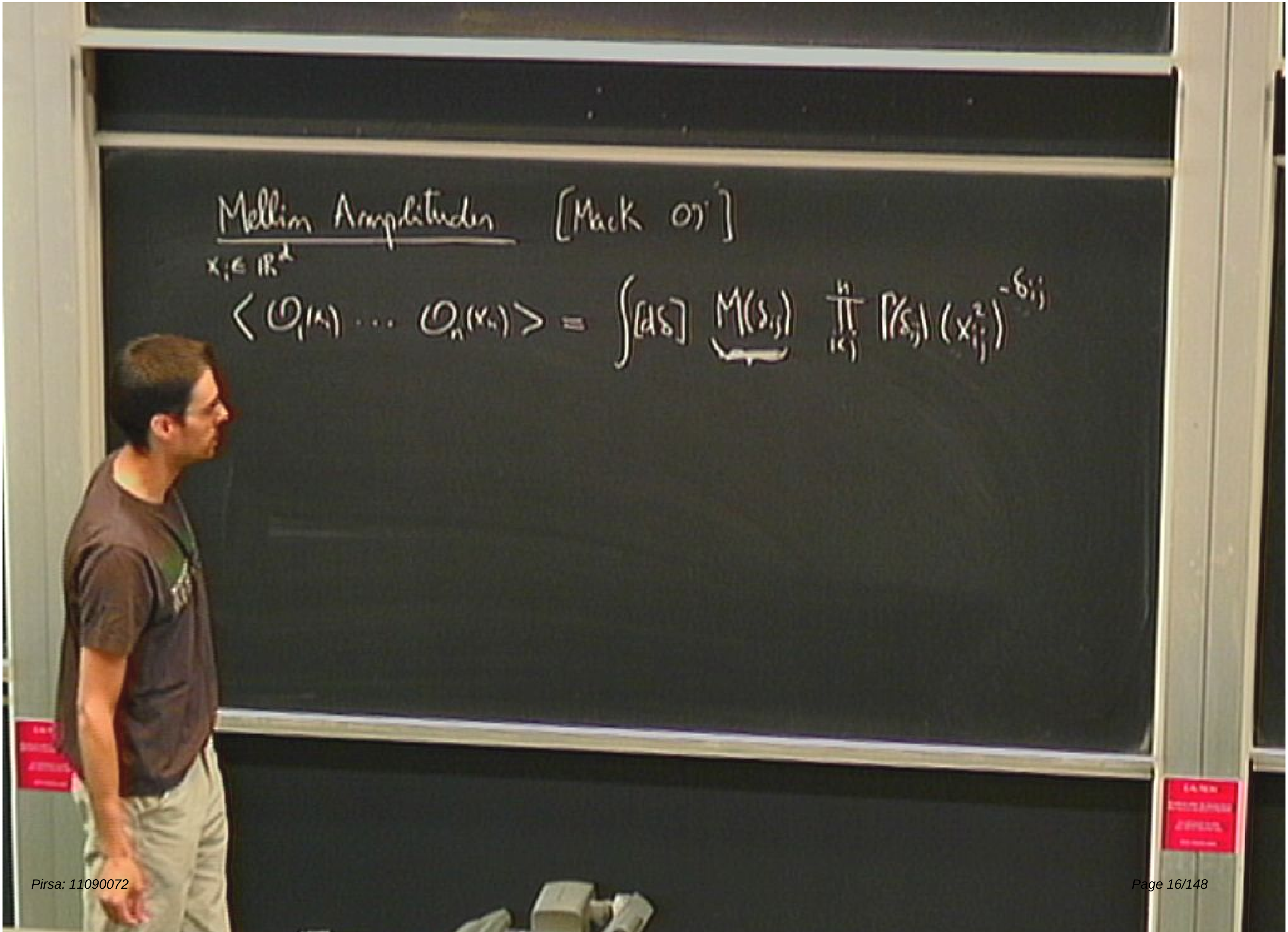
$$\langle \mathcal{O}_1(x_1) \cdots \mathcal{O}_n(x_n) \rangle$$

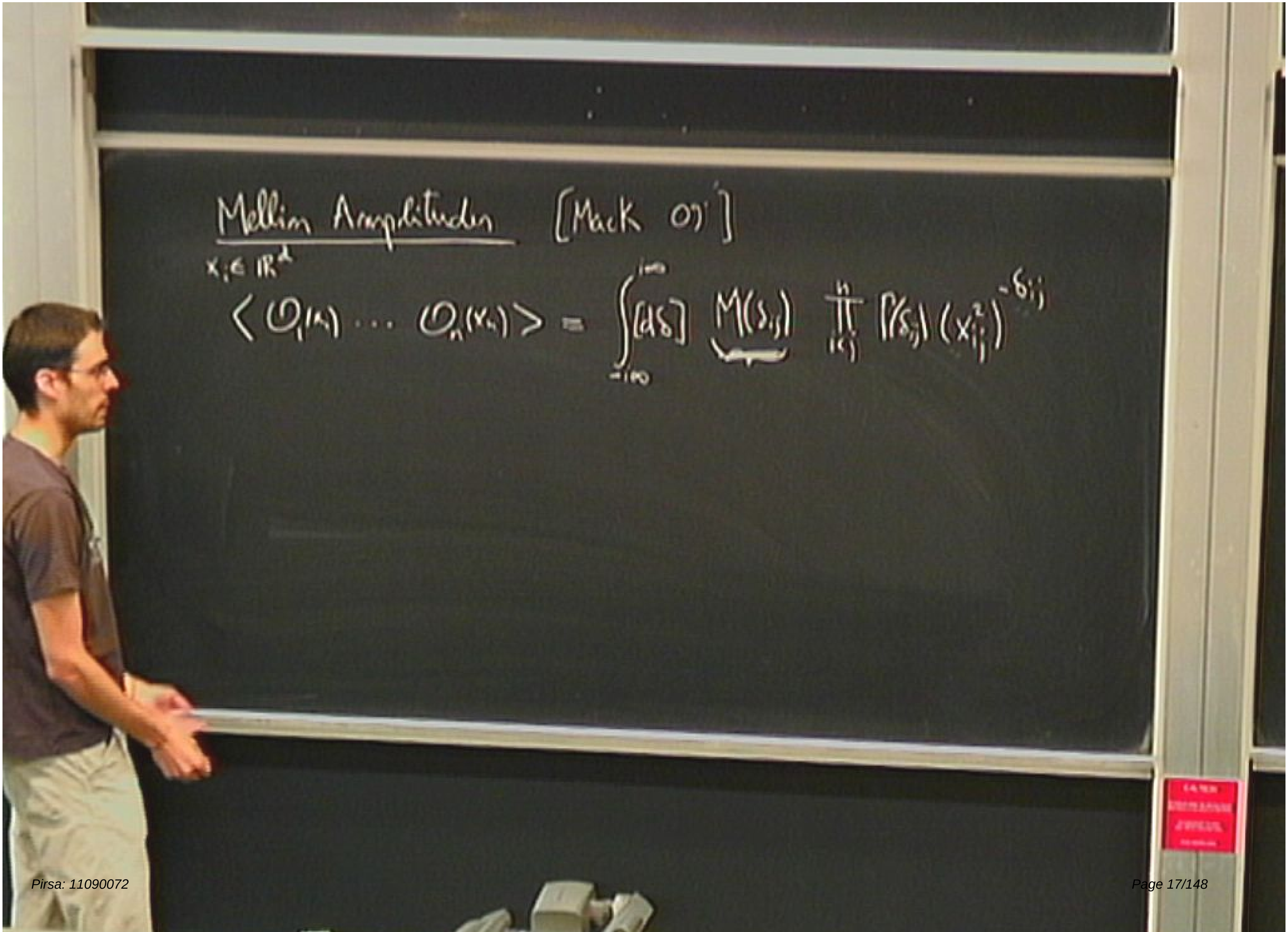

Mellin Amplitudes [Mack 09]
x_i ∈ ℝ^d
⟨O_1(x_1) ... O_n(x_n)⟩ = ∫[dδ]


Mellin Amplitudes [Mack 09]
x_i ∈ ℝ^d
⟨O_1(x_1) … O_n(x_n)⟩ = ∫[dδ]
(x_ij^2)^-δ


Mellin Amplitudes [Mack 09]
x_i ∈ R^d
< O_1(x_1) ... O_n(x_n) > = ∫[dδ] ∏_{i<j}^n Γ(δ_ij) (x_ij^2)^{-δ_ij}


Mellin Amplitudes [Mack 09]
$x_i \in \mathbb{R}^d$
$\langle \mathcal{O}_1(x_1) \cdots \mathcal{O}_n(x_n) \rangle = \int [d\delta]\, M(\delta_{ij}) \prod_{i<j}^{n} \Gamma(\delta_{ij}) (x_{ij}^2)^{-\delta_{ij}}$


Mellin Amplitudes [Mack 09]
$x_i \in \mathbb{R}^d$
$\langle \mathcal{O}_1(x_1) \dots \mathcal{O}_n(x_n) \rangle = \int [d\delta] \, M(\delta_{ij}) \prod_{i<j}^{n} \Gamma(\delta_{ij}) (x_{ij}^2)^{-\delta_{ij}}$



Mellin Amplitudes [Mack 09]
$x_i \in \mathbb{R}^d$
$\langle O_1(x_1) \dots O_n(x_n) \rangle = \int_{-i\infty}^{i\infty} [d\delta]\, M(\delta_{ij}) \prod_{i<j}^{n} \Gamma(\delta_{ij}) (x_{ij}^2)^{-\delta_{ij}}$

Mellin Amplitudes [Mack 09']

$x_i \in \mathbb{R}^d$

$$\langle \mathcal{O}_1(x_1) \cdots \mathcal{O}_n(x_n) \rangle = \int_{-i\infty}^{i\infty} [d\delta] \, \underbrace{M(\delta_{ij})}_{} \prod_{i<j}^{n} \Gamma(\delta_{ij}) \, (x_{ij}^2)^{-\delta_{ij}}$$

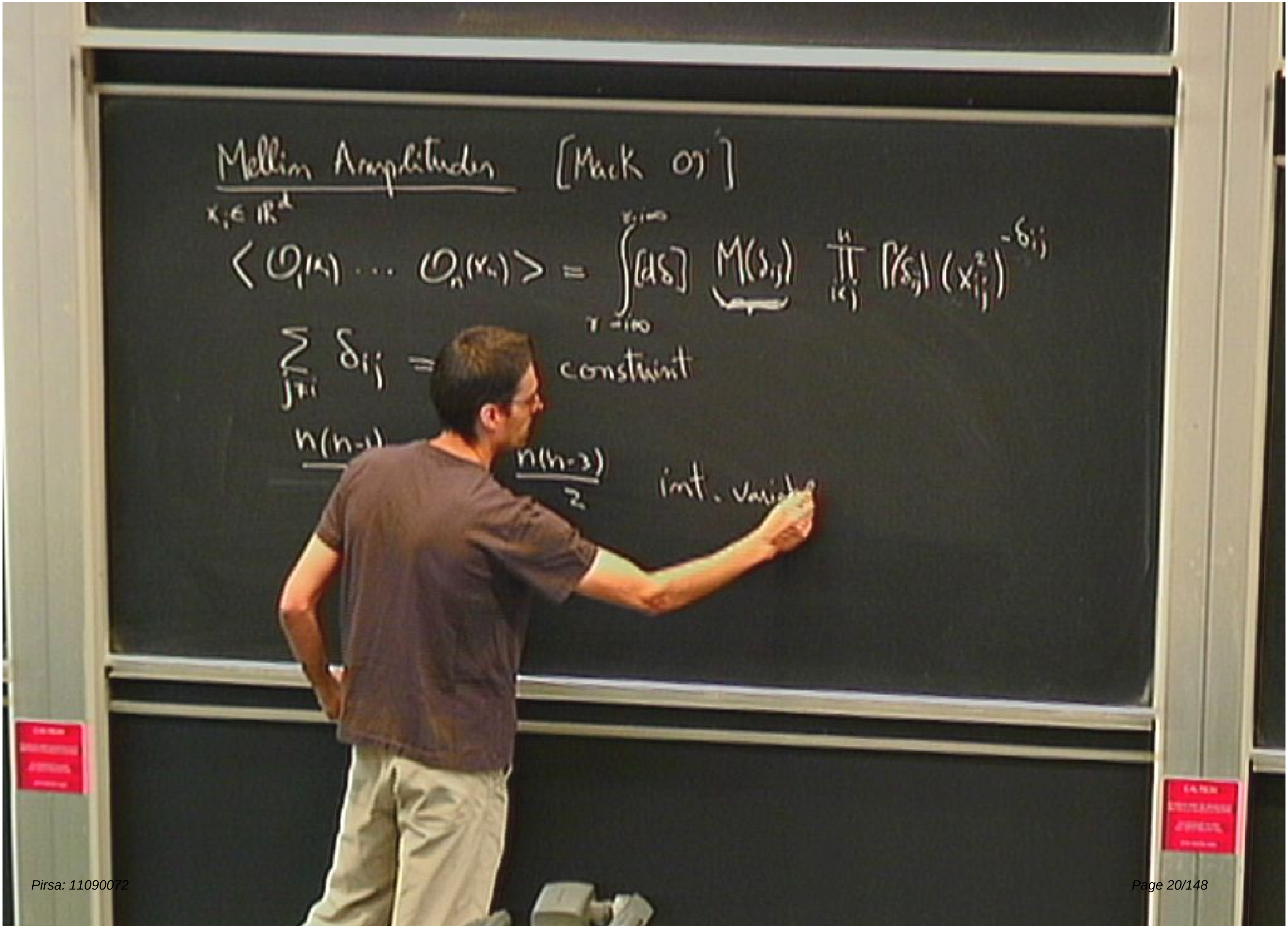
$$\sum_{j \neq i} \delta_{ij} = \Delta_i$$

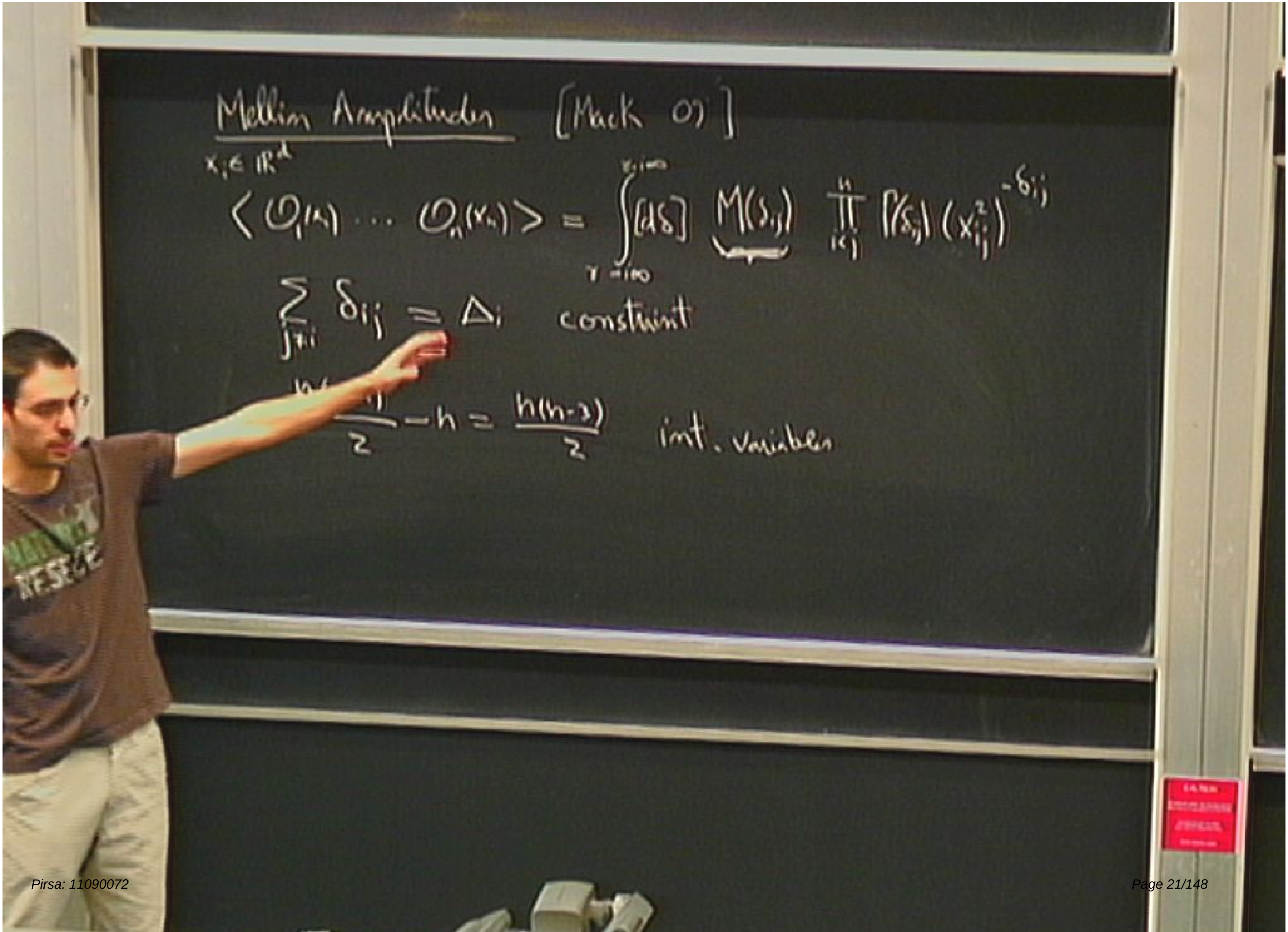
Mellin Amplitudes [Mack 09]

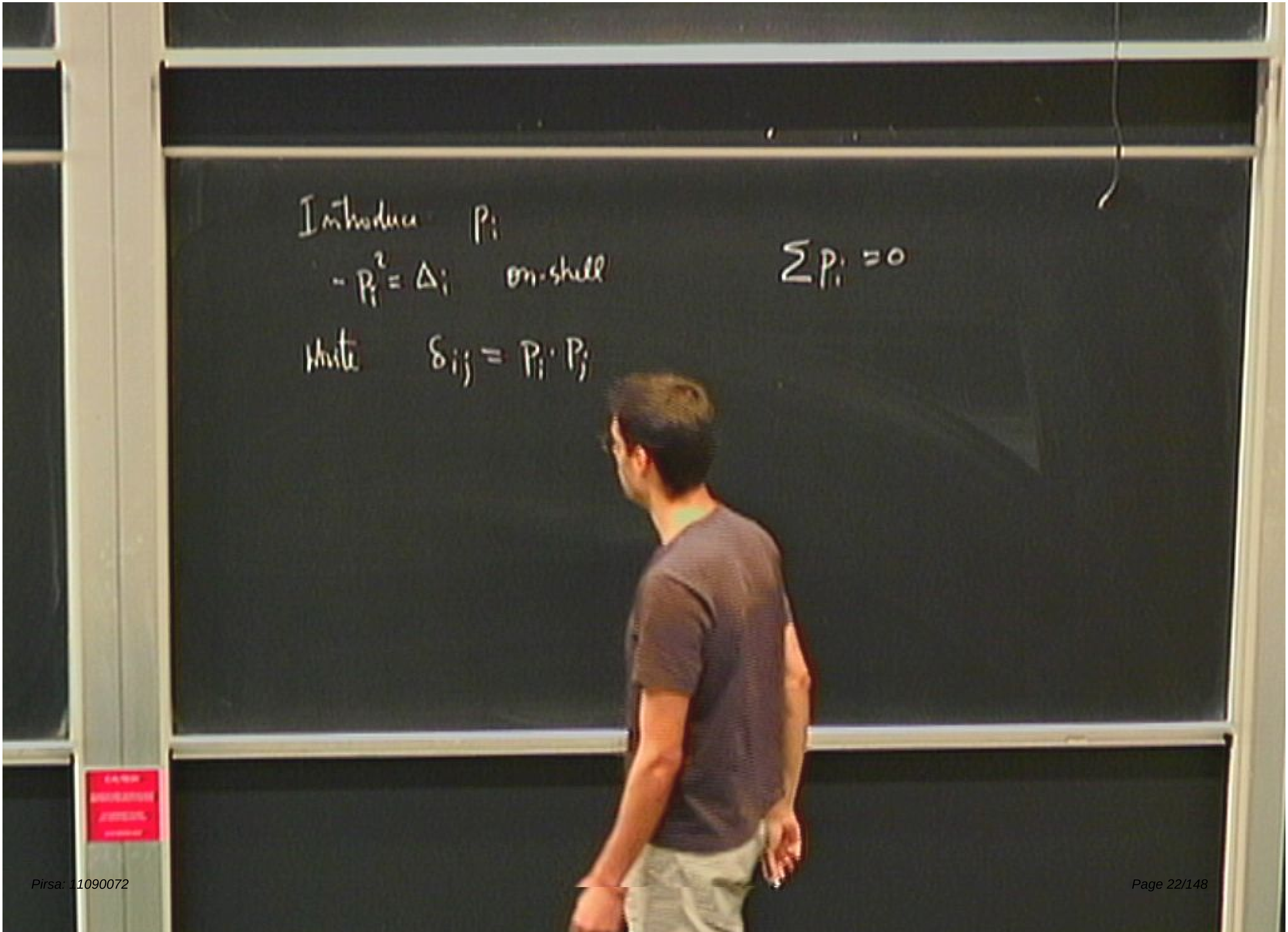
$x_i \in \mathbb{R}^d$

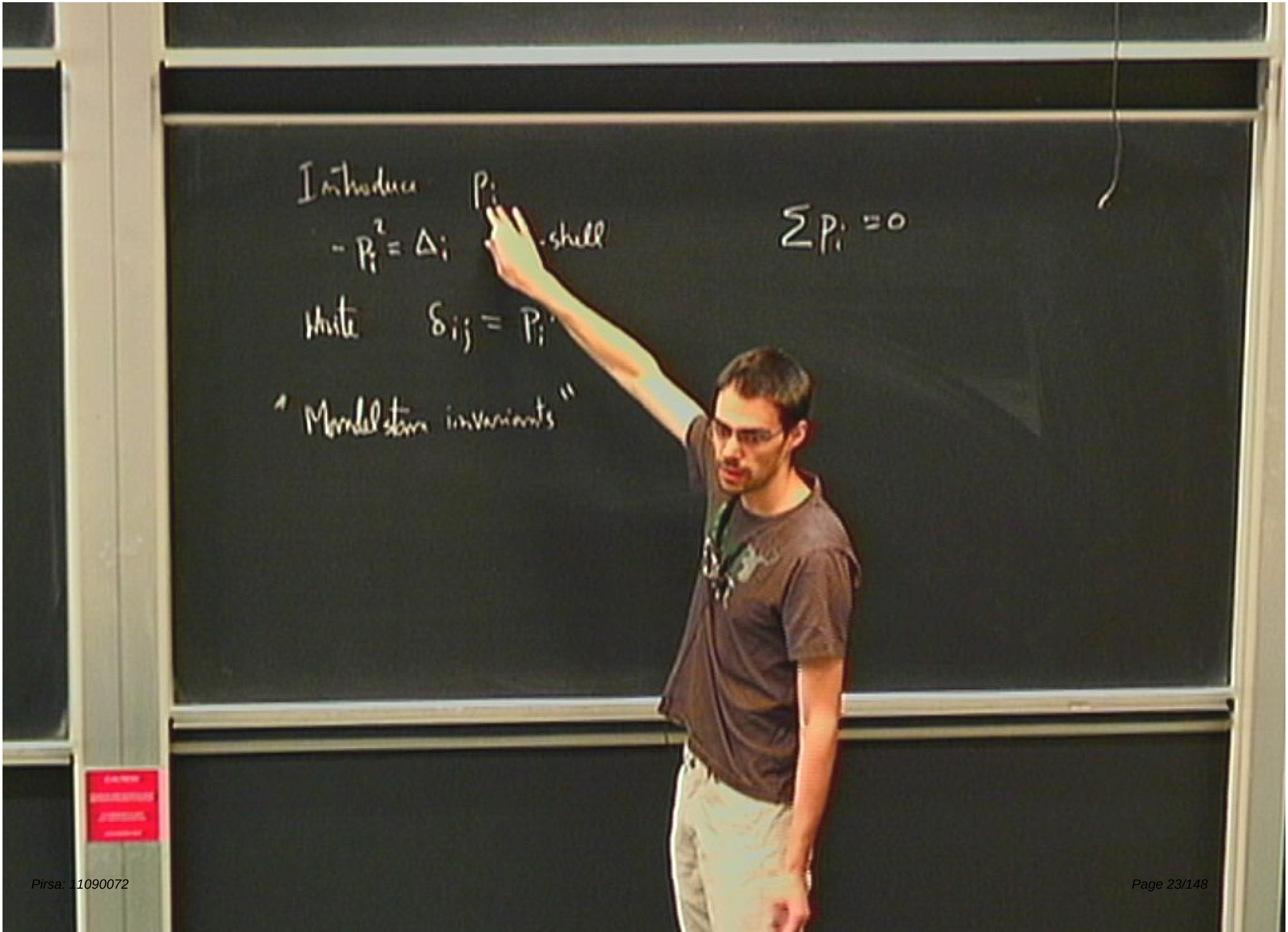
$$\langle \mathcal{O}_1(x_1) \cdots \mathcal{O}_n(x_n) \rangle = \int_{\gamma - i\infty}^{\gamma + i\infty} [d\delta] \, \underbrace{M(\delta_{ij})} \prod_{i<j}^{n} \Gamma(\delta_{ij}) \, (x_{ij}^2)^{-\delta_{ij}}$$

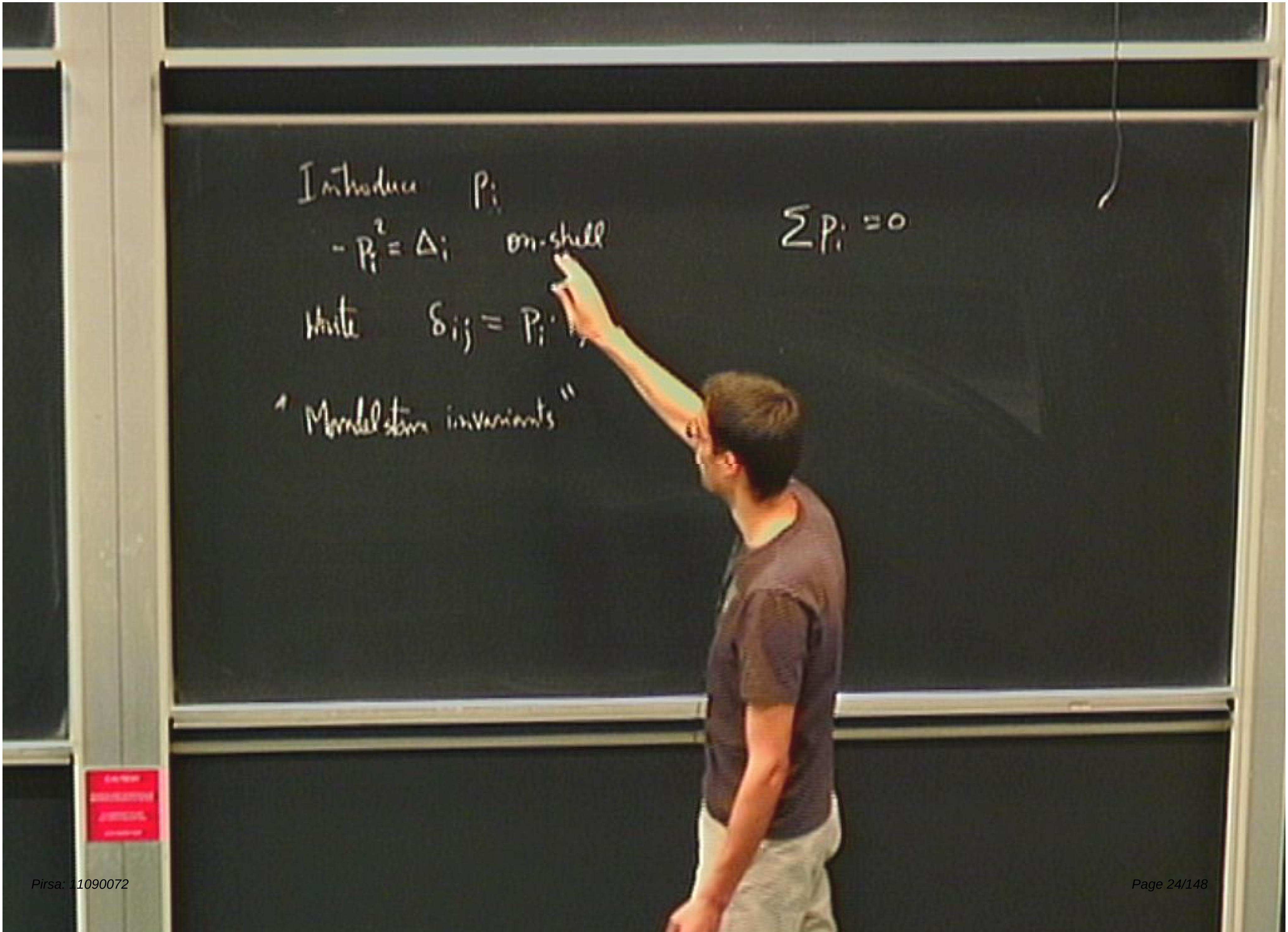
$$\sum_{j \neq i} \delta_{ij} = \Delta_i \quad \text{constraint}$$

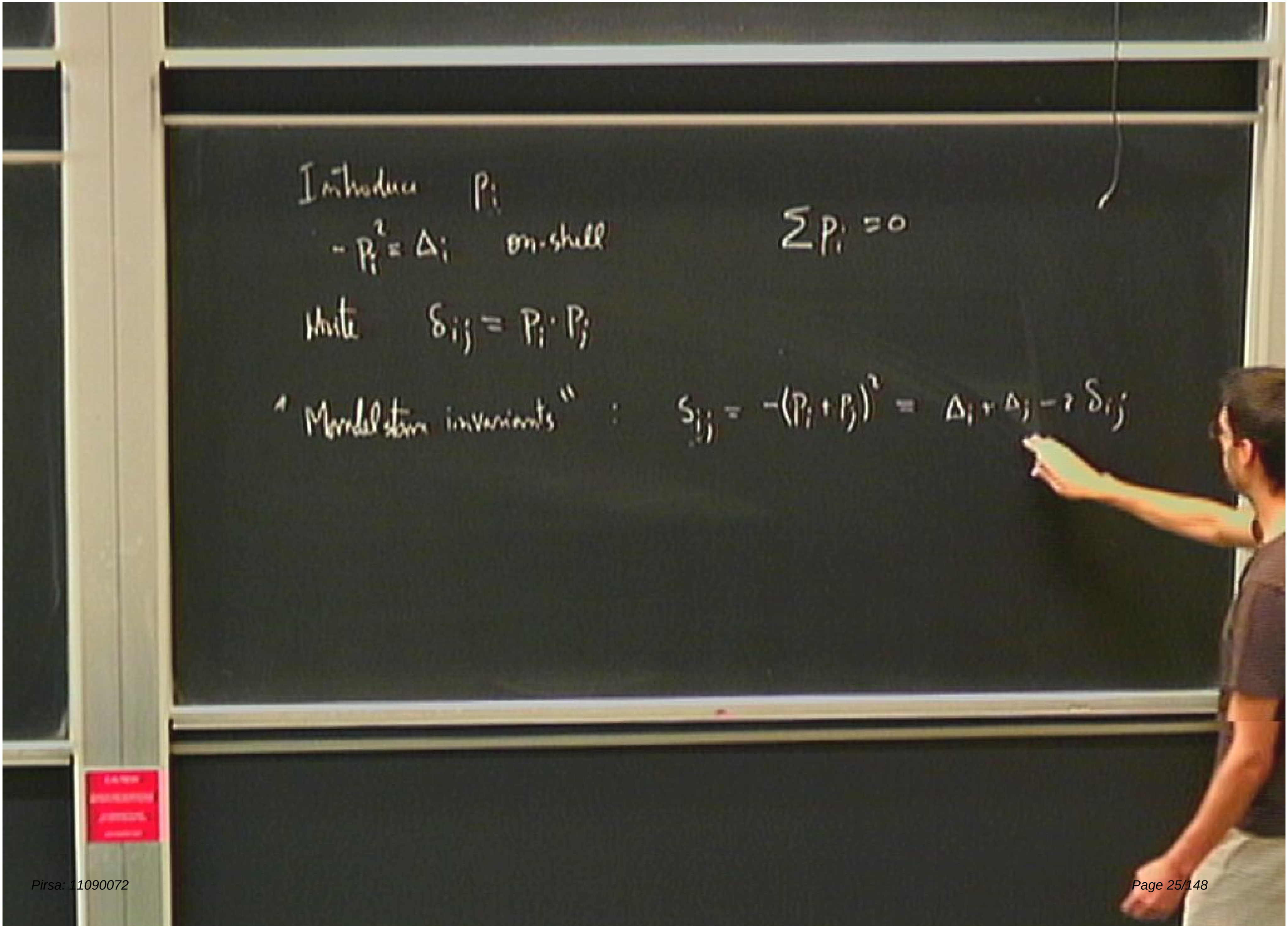

Mellin Amplitudes [Mack 09]
$x_i \in \mathbb{R}^d$
$\langle O_1(x_1) \cdots O_n(x_n) \rangle = \int_{\gamma - i\infty}^{\gamma + i\infty} [d\delta]\, M(\delta_{ij}) \prod_{i<j}^{n} \Gamma(\delta_{ij}) (x_{ij}^2)^{-\delta_{ij}}$
$\sum_{j \neq i} \delta_{ij} =$
constraint
$\frac{n(n-3)}{2}$
int. vari

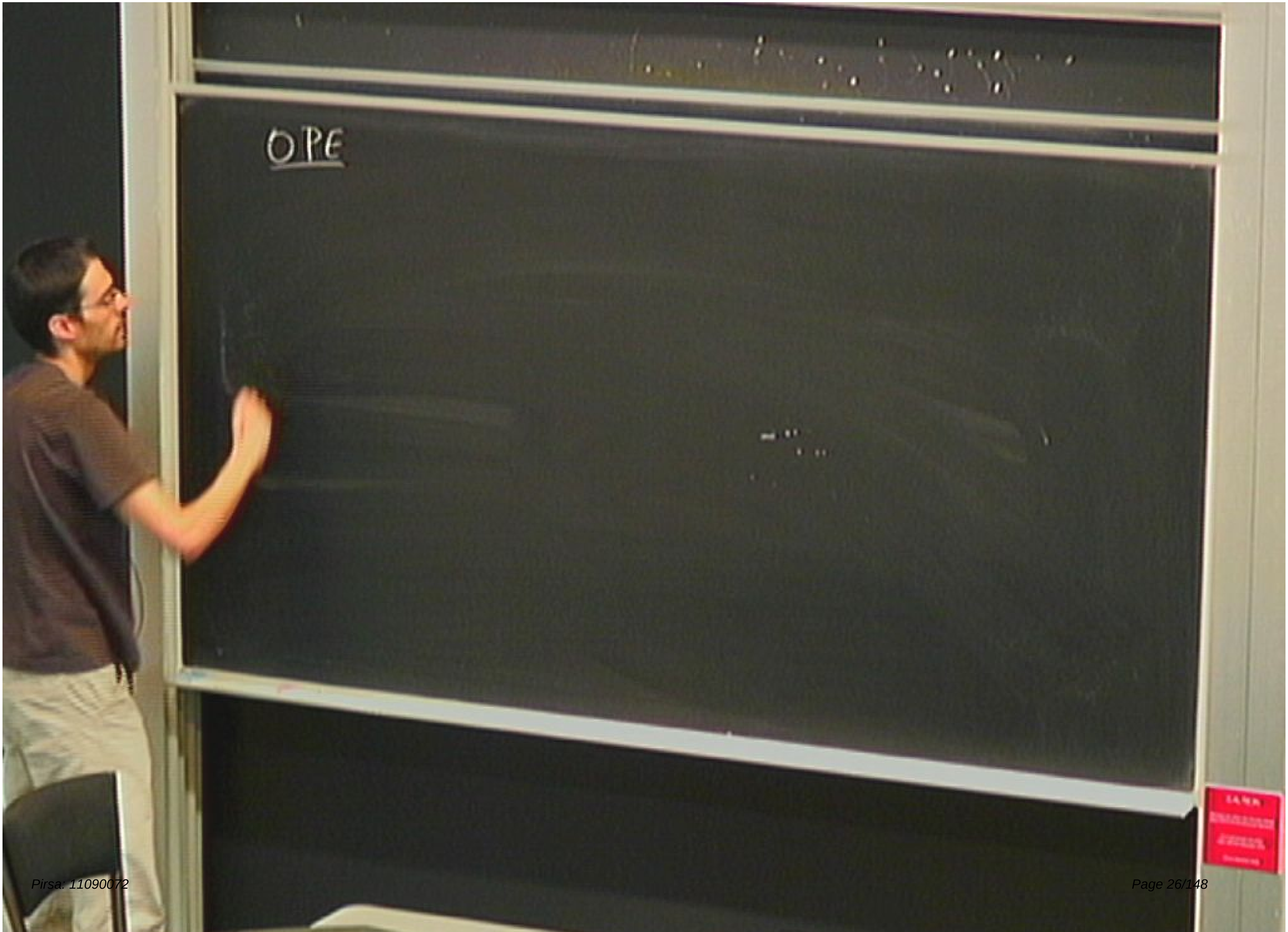

Mellin Amplitudes [Mack 09]
$x_i \in \mathbb{R}^d$
$\langle O_1(x_1) \dots O_n(x_n) \rangle = \int_{\gamma - i\infty}^{\gamma + i\infty} [d\delta] \, M(\delta_{ij}) \prod_{i<j}^{n} \Gamma(\delta_{ij}) (x_{ij}^2)^{-\delta_{ij}}$
$\sum_{j \neq i} \delta_{ij} = \Delta_i$ constraint
$\frac{n(n-1)}{2} - n = \frac{n(n-3)}{2}$ int. variables

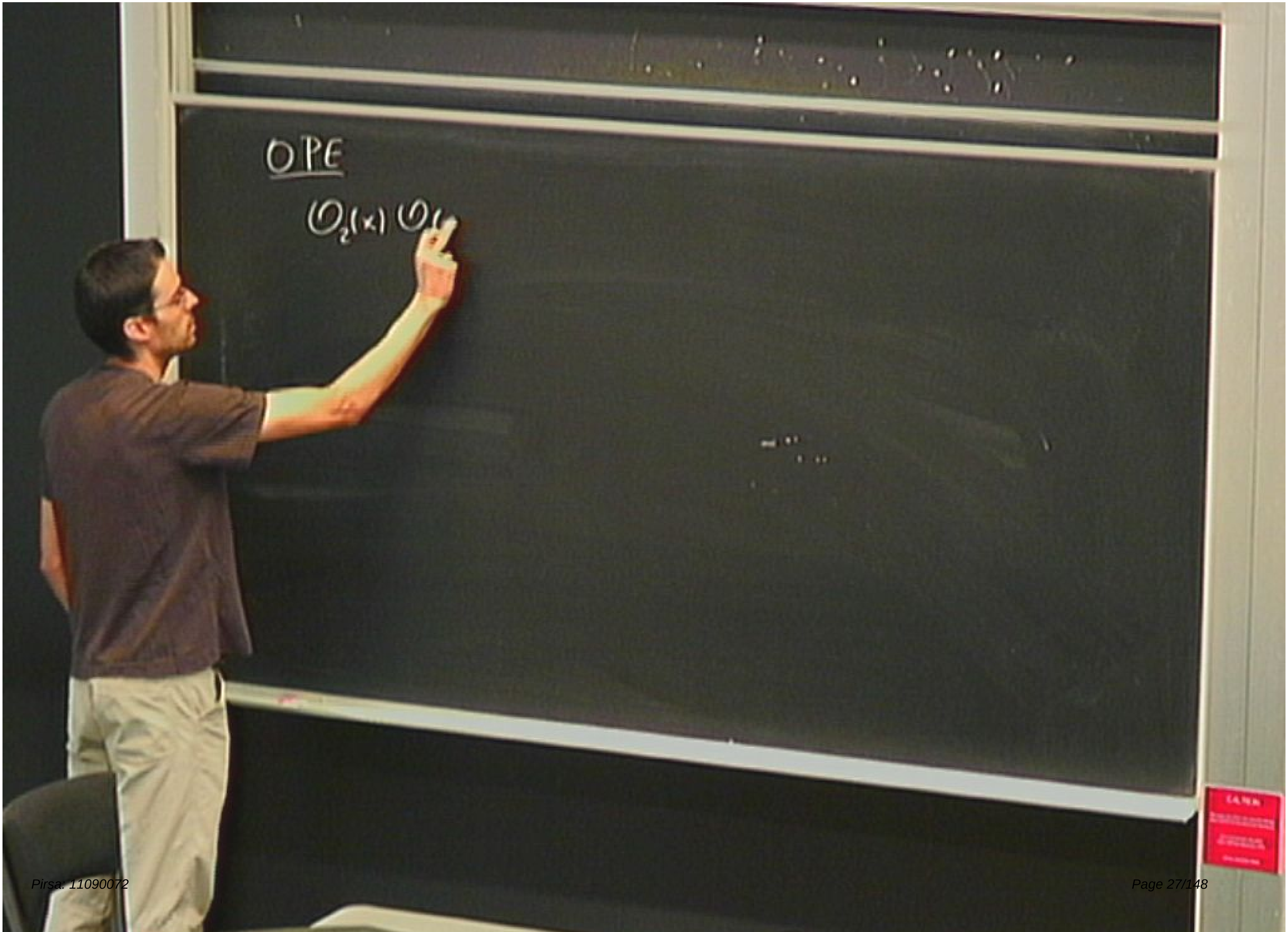

Introduce P_i
$-P_i^2 = \Delta_i$ on-shell
$\sum P_i = 0$
Write $\delta_{ij} = P_i \cdot P_j$

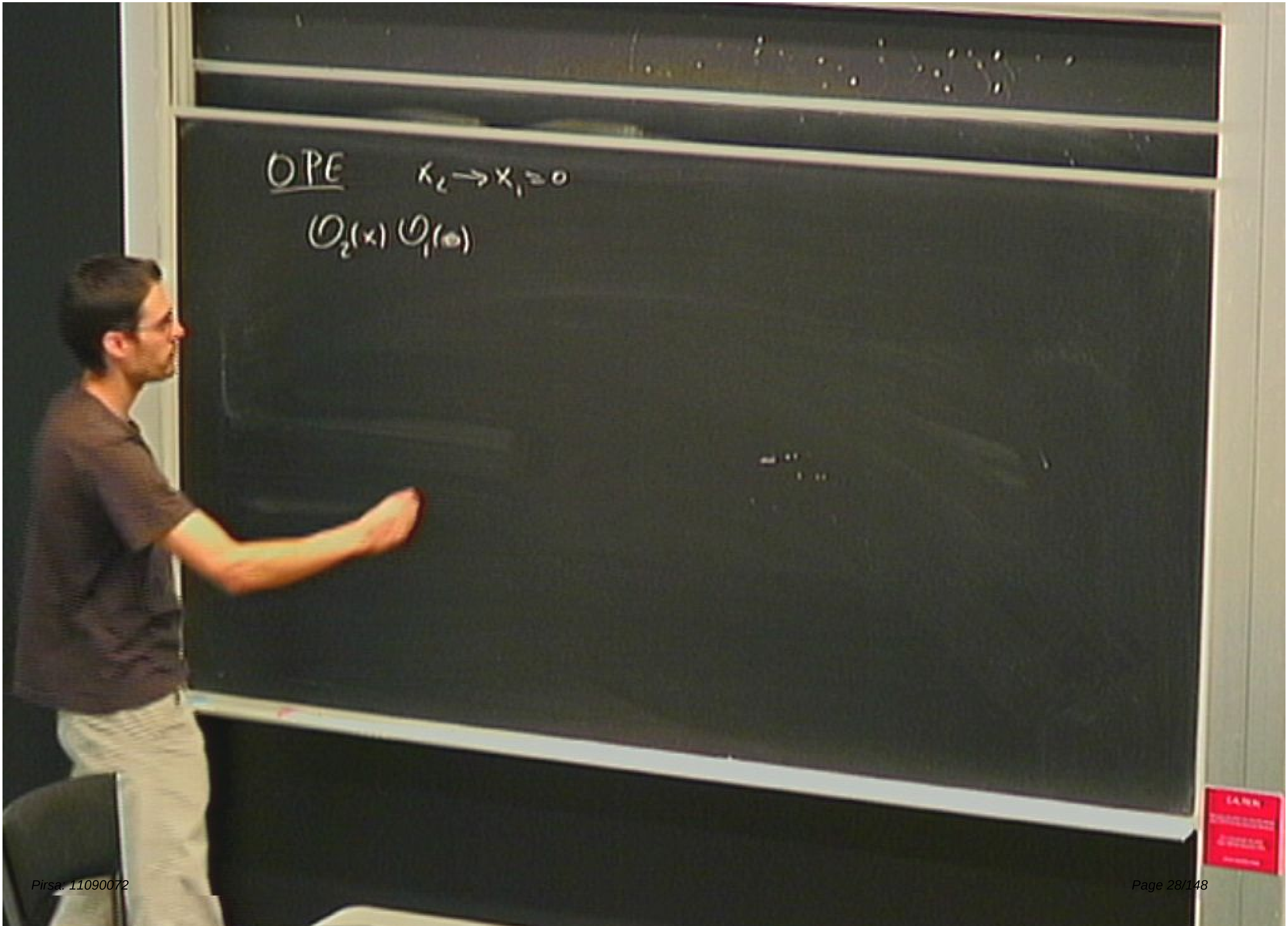

Introduce p_i
-p_i^2 = Δ_i
shell
Σ p_i = 0
write δ_ij = p_i
"Mandelstam invariants"

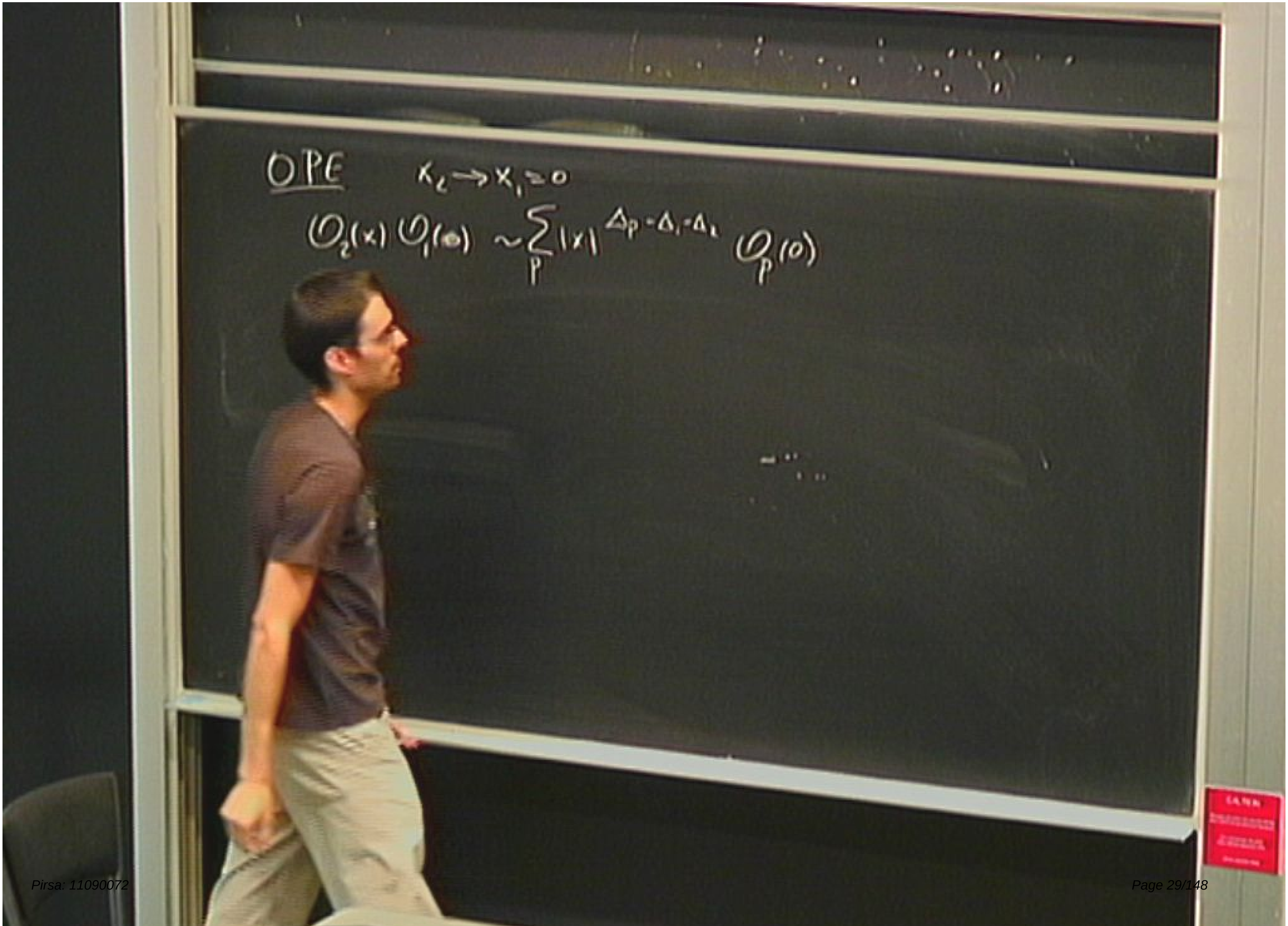

Introduce p_i
-p_i^2 = Δ_i   on-shell
Σ p_i = 0
Write s_ij = p_i ·
"Mandelstam invariants"

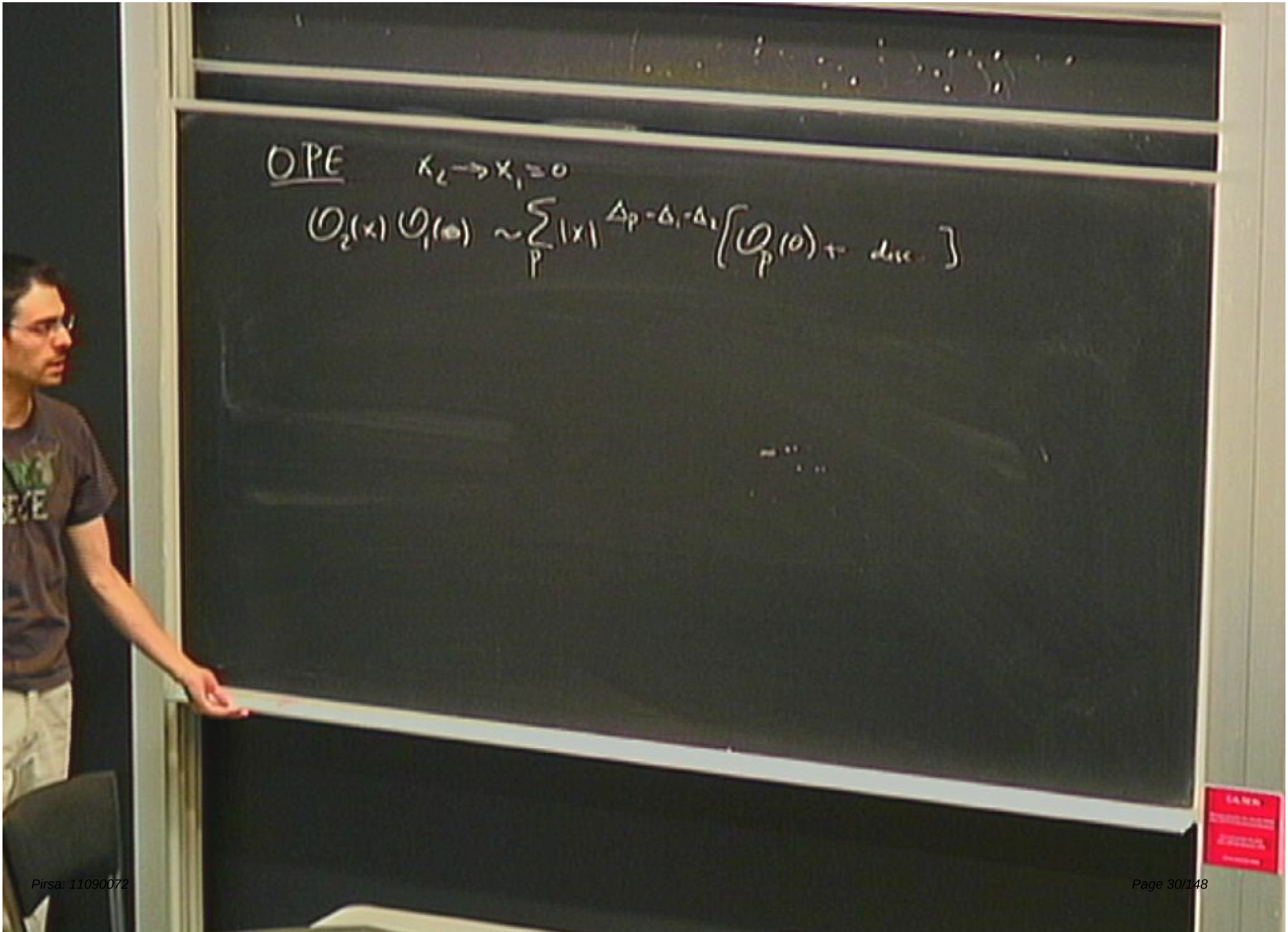

Introduce p_i
$-p_i^2 = \Delta_i$ on-shell
$\sum p_i = 0$
Write $\delta_{ij} = p_i \cdot p_j$
"Mandelstam invariants" : $s_{ij} = -(p_i + p_j)^2 = \Delta_i + \Delta_j - 2\delta_{ij}$

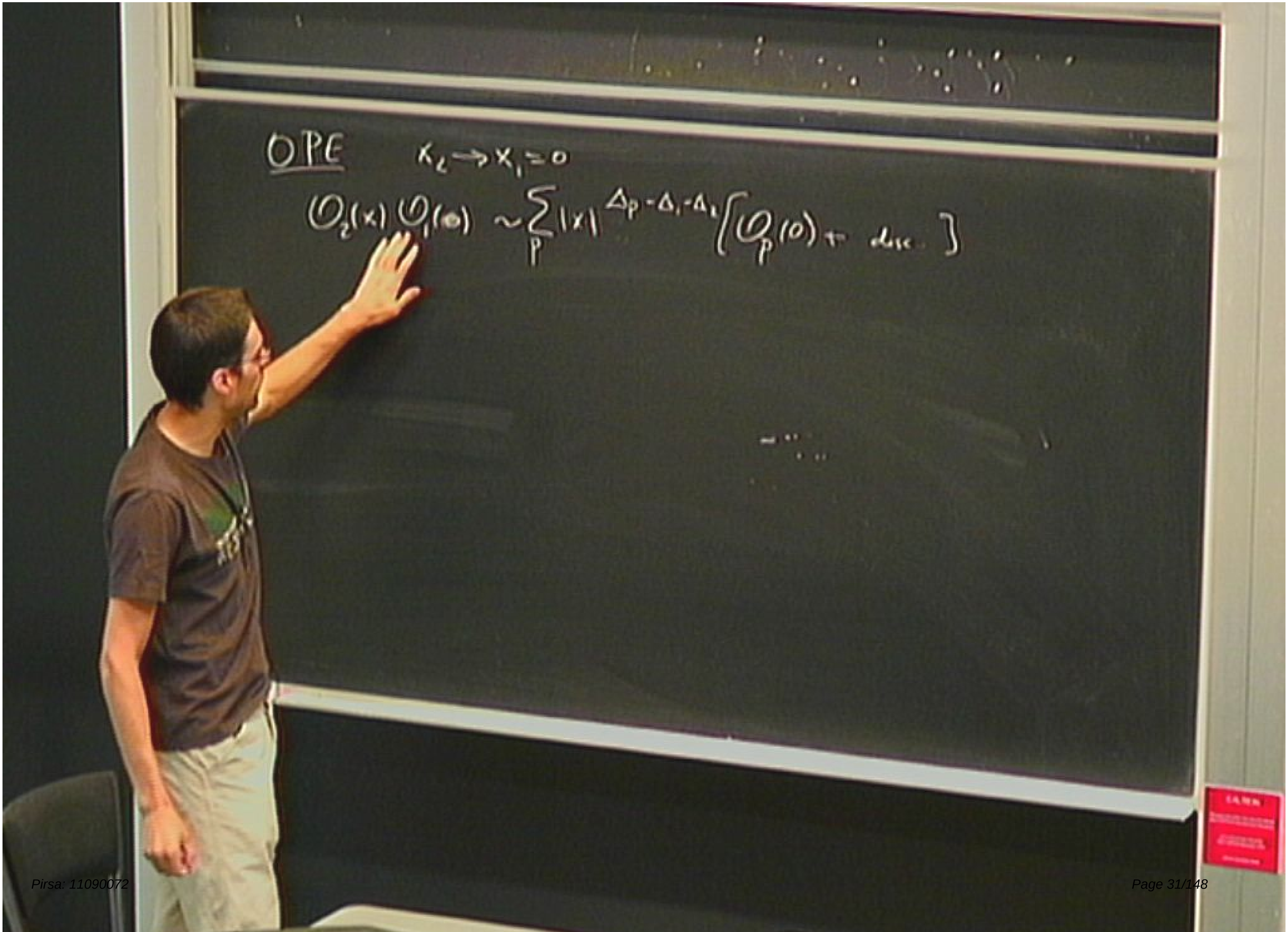

OPE

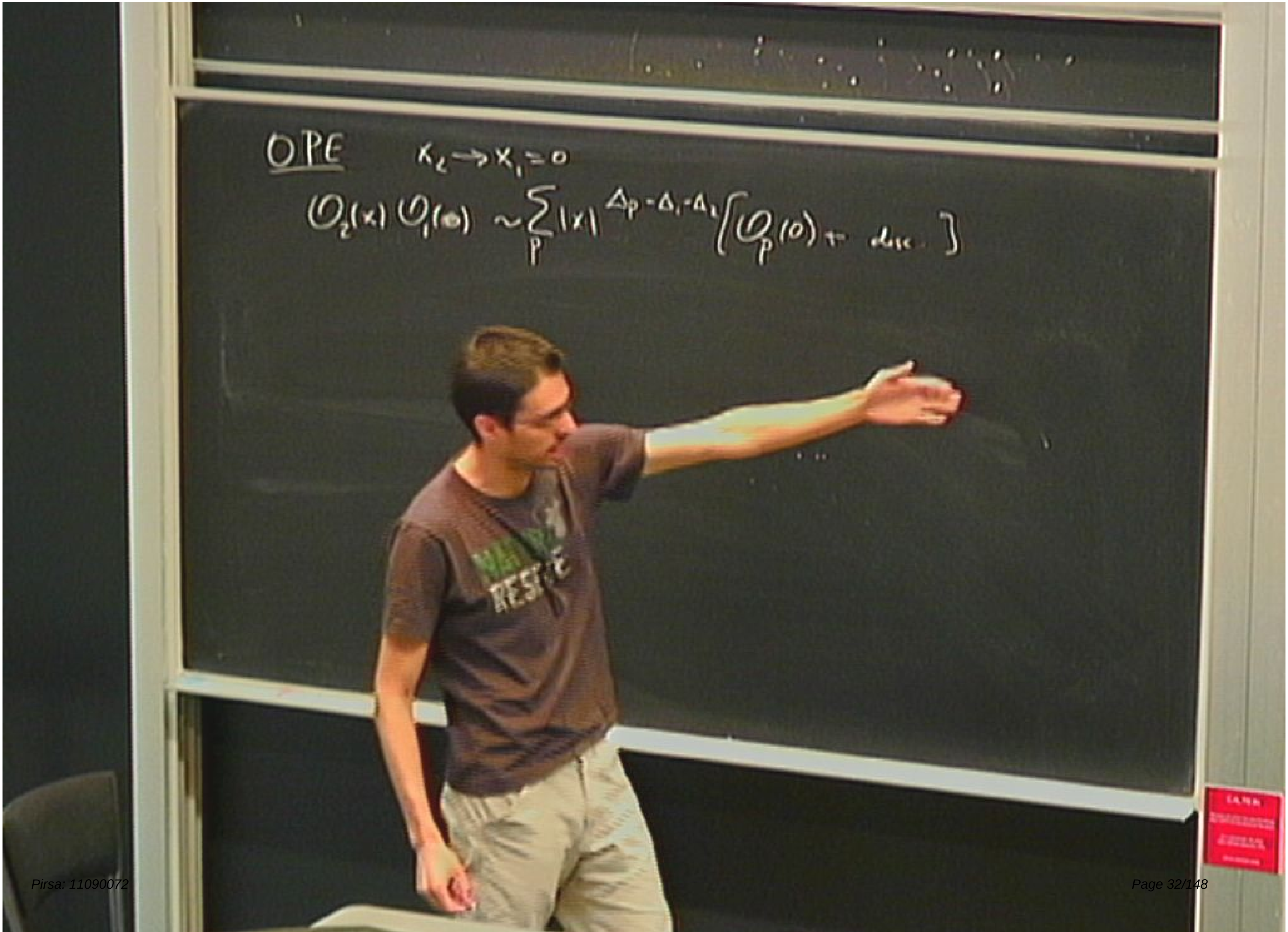

OPE
O2(x) O

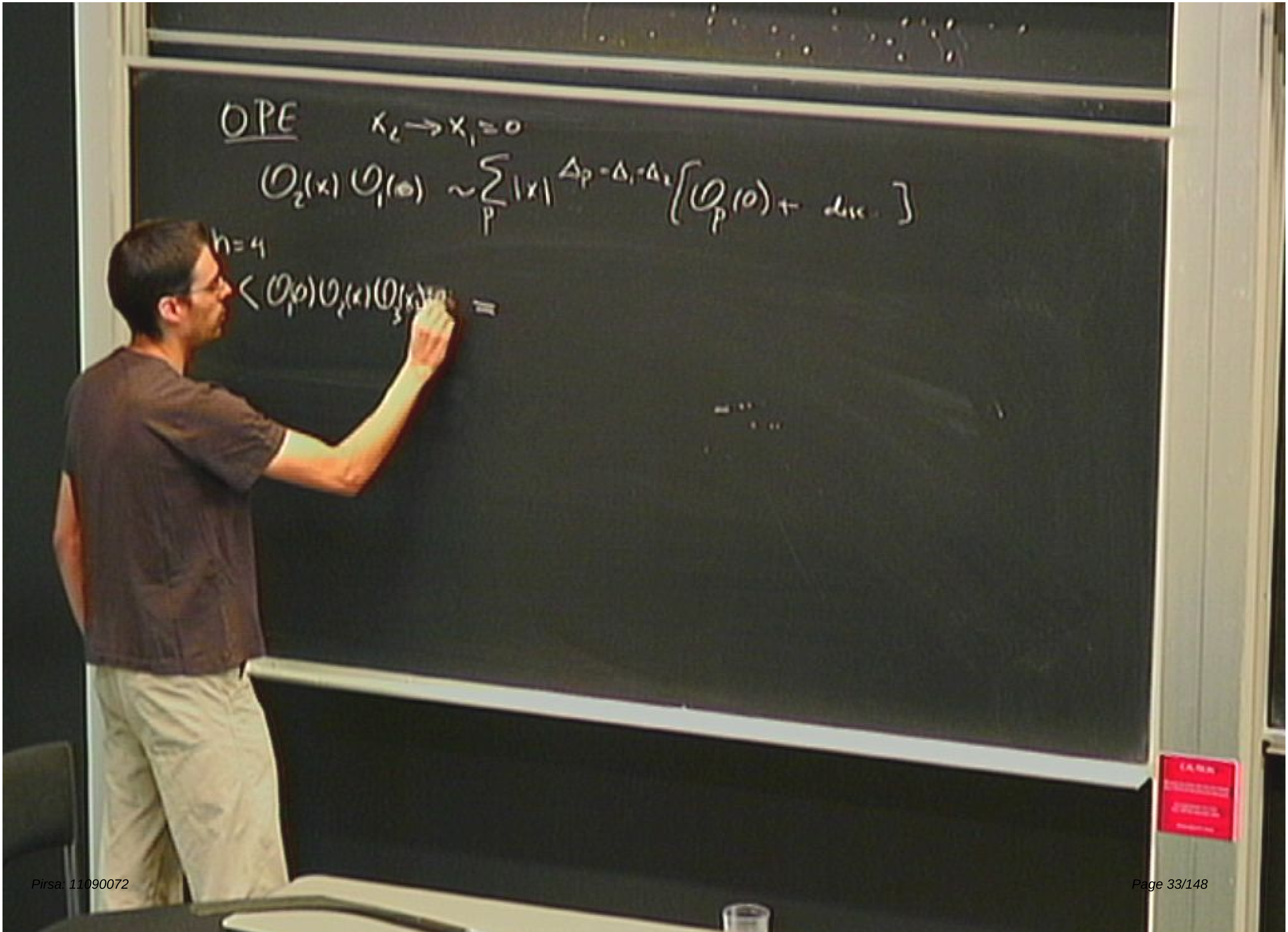

OPE
x2 → x1 = 0
O2(x) O1(0)

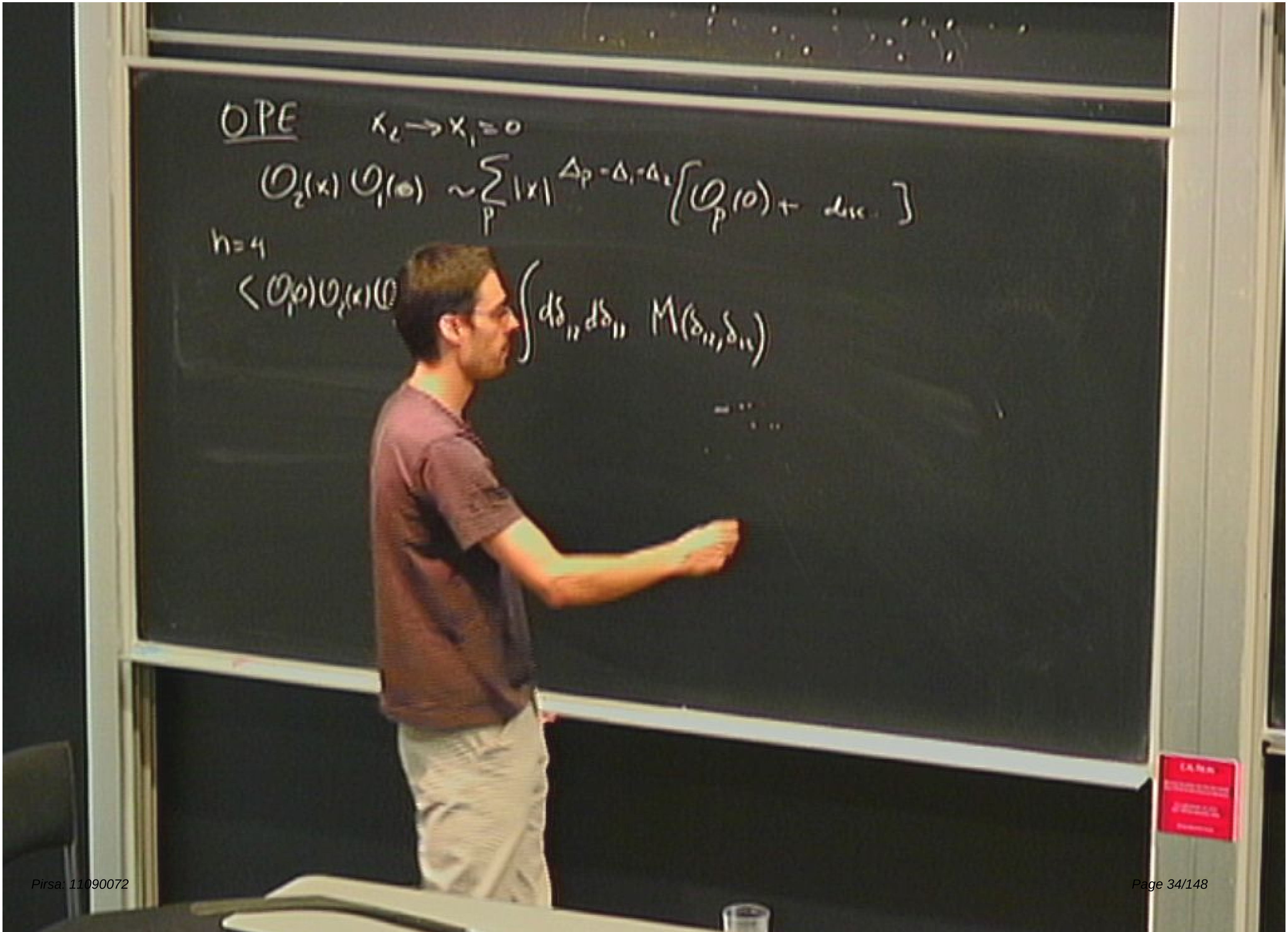

OPE
$x_2 \to x_1 = 0$
$\mathcal{O}_2(x)\,\mathcal{O}_1(0) \sim \sum_p |x|^{\Delta_p - \Delta_1 - \Delta_2}\,\mathcal{O}_p(0)$

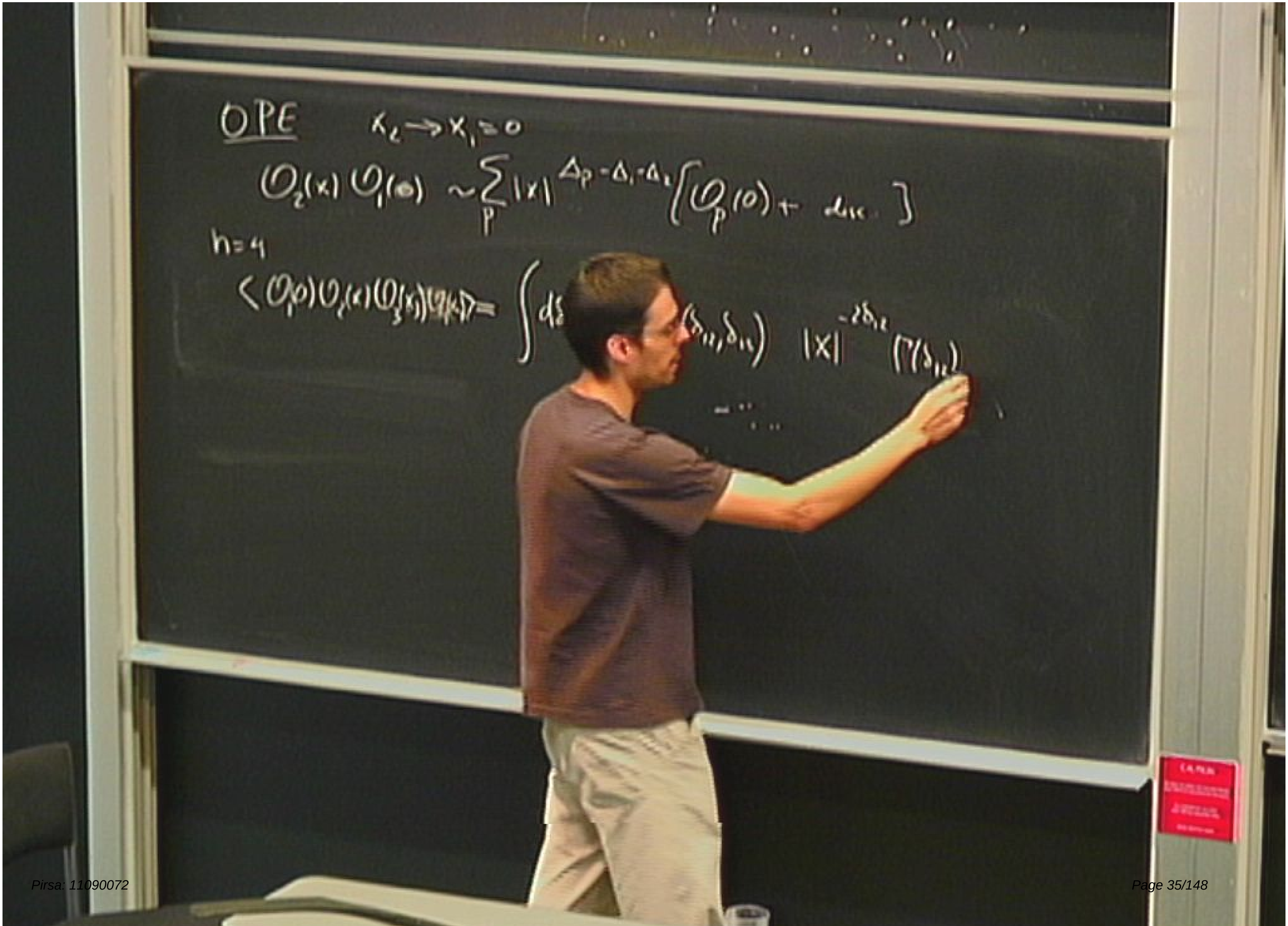

OPE $x_2 \to x_1 = 0$
$\mathcal{O}_2(x)\,\mathcal{O}_1(0) \sim \sum_p |x|^{\Delta_p - \Delta_1 - \Delta_2} \left[\mathcal{O}_p(0) + \text{desc.} \right]$

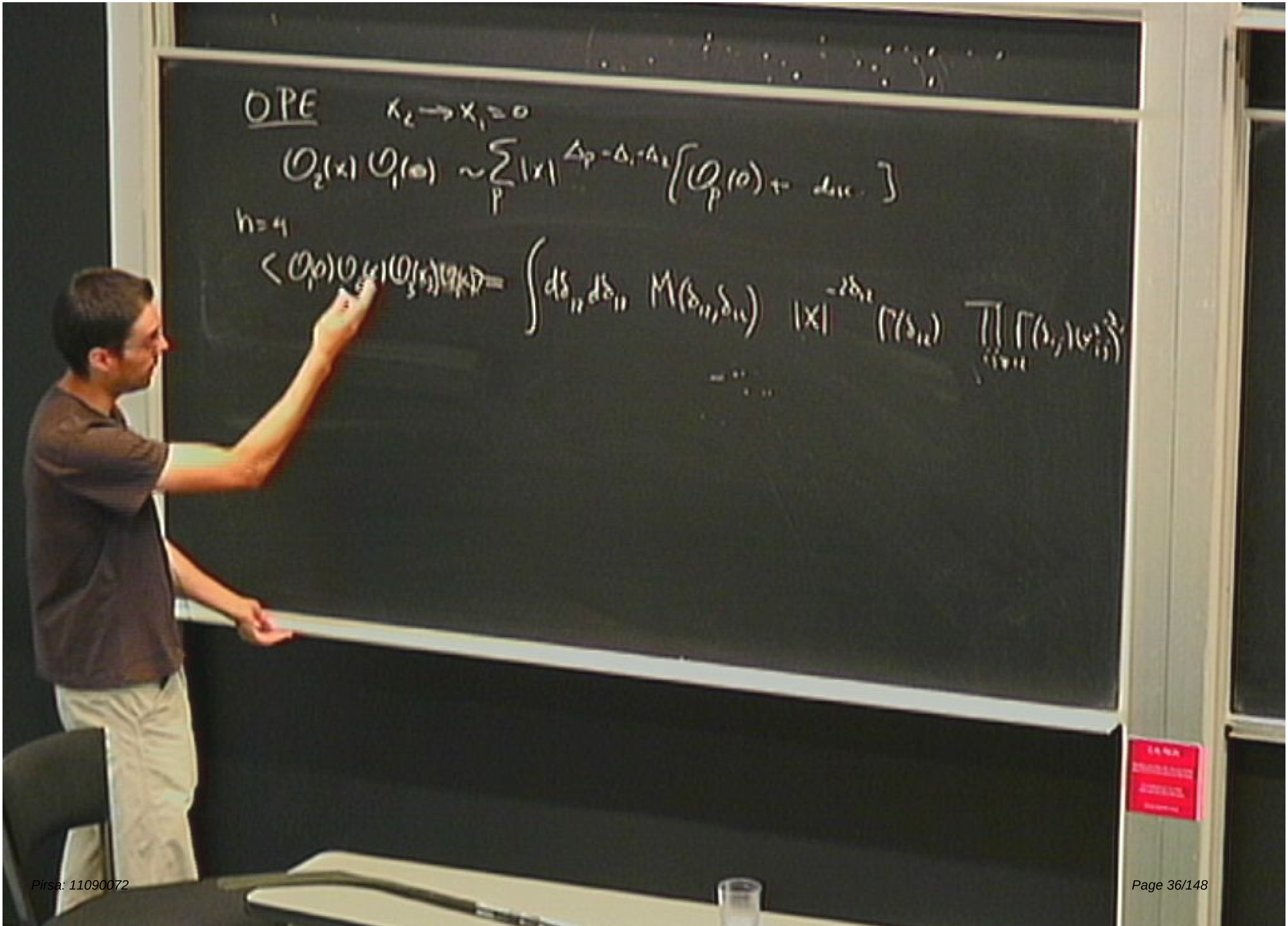

OPE
x₂ → x₁ = 0
O₂(x) O₁(0) ~ Σ_p |x|^(Δp − Δ₁ − Δ₂) [O_p(0) + desc.]

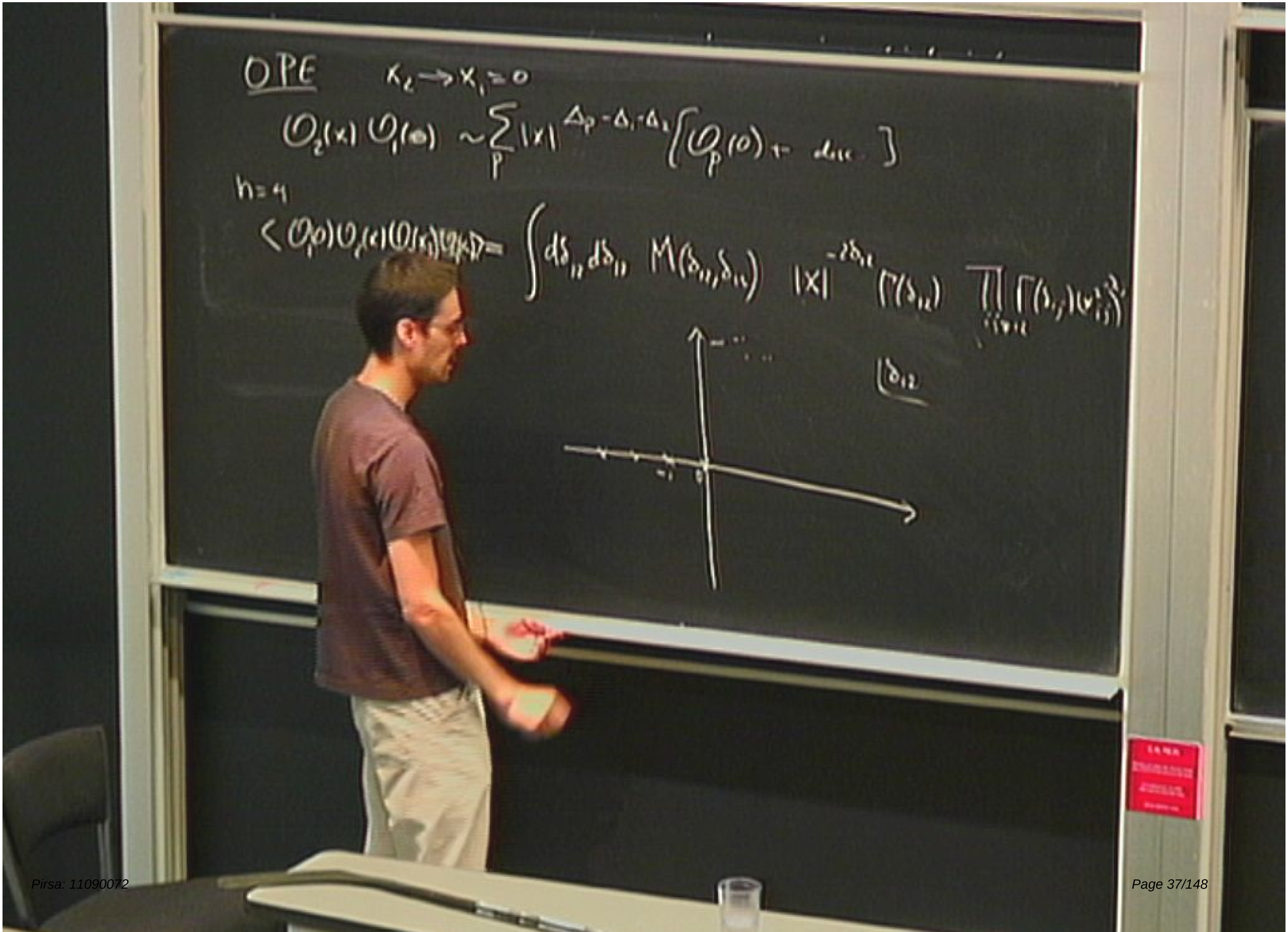

OPE
$x_2 \to x_1 = 0$
$\mathcal{O}_2(x)\,\mathcal{O}_1(0) \sim \sum_p |x|^{\Delta_p - \Delta_1 - \Delta_2}\left[\mathcal{O}_p(0) + \text{desc.}\right]$

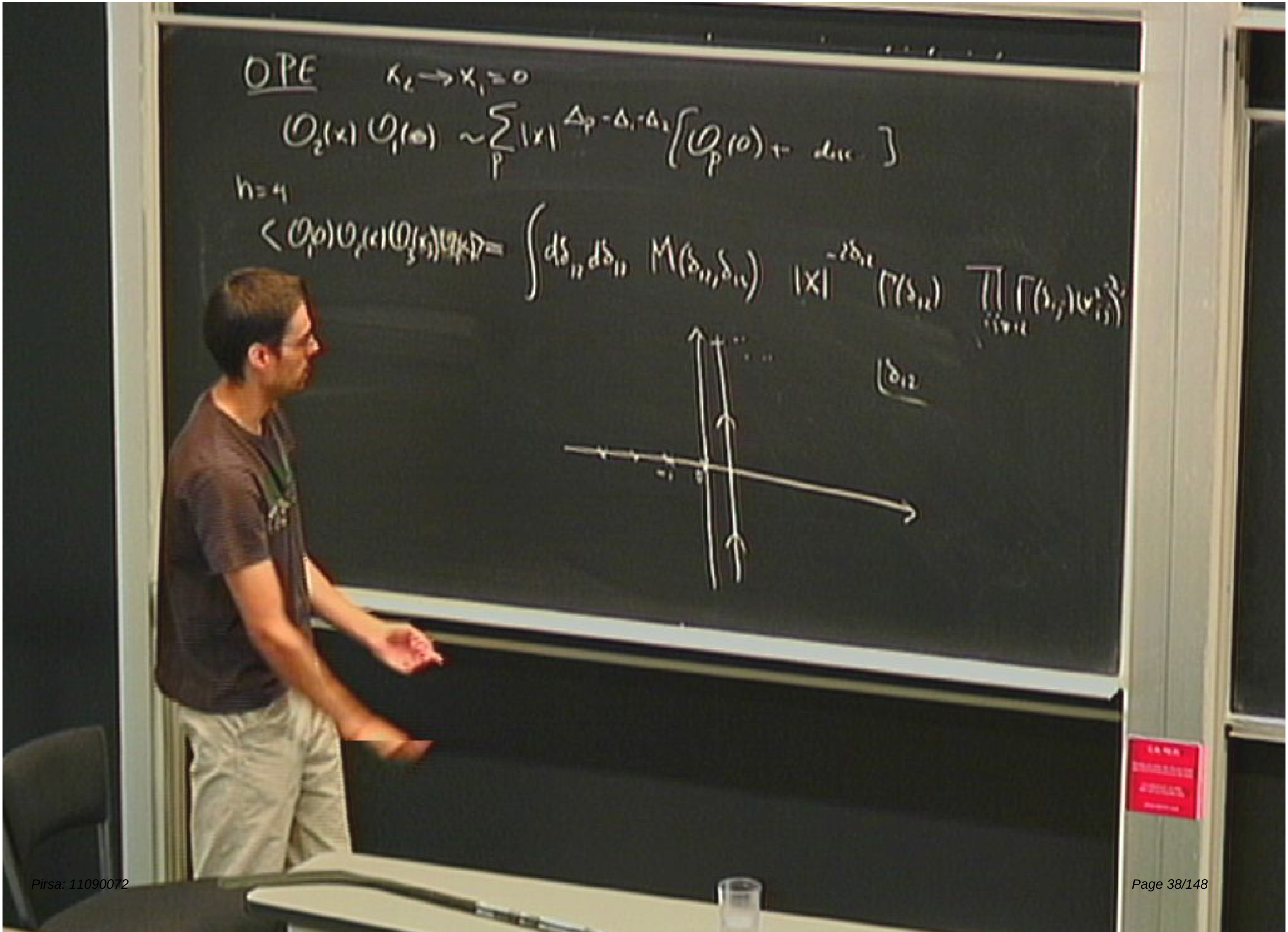

OPE x2 → x1 = 0
O2(x) O1(0) ~ Σp |x|^(Δp - Δ1 - Δ2) [Op(0) + desc.]
n = 4

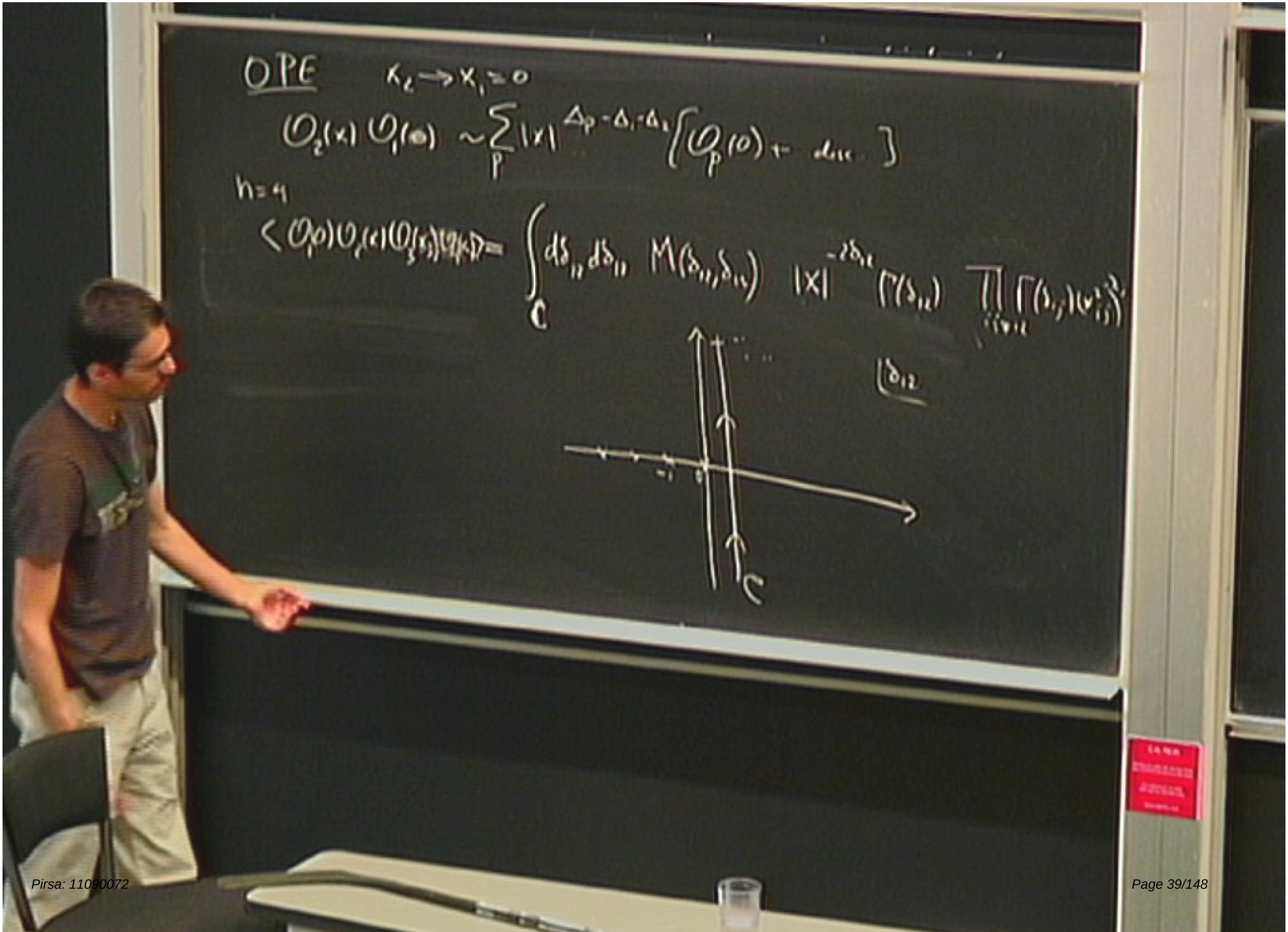

OPE
x2 → x1 = 0
O2(x) O1(0) ~ Σp |x|^(Δp - Δ1 - Δ2) [Op(0) + desc.]
n = 4
∫dδ12 dδ13 M(δ12, δ13)

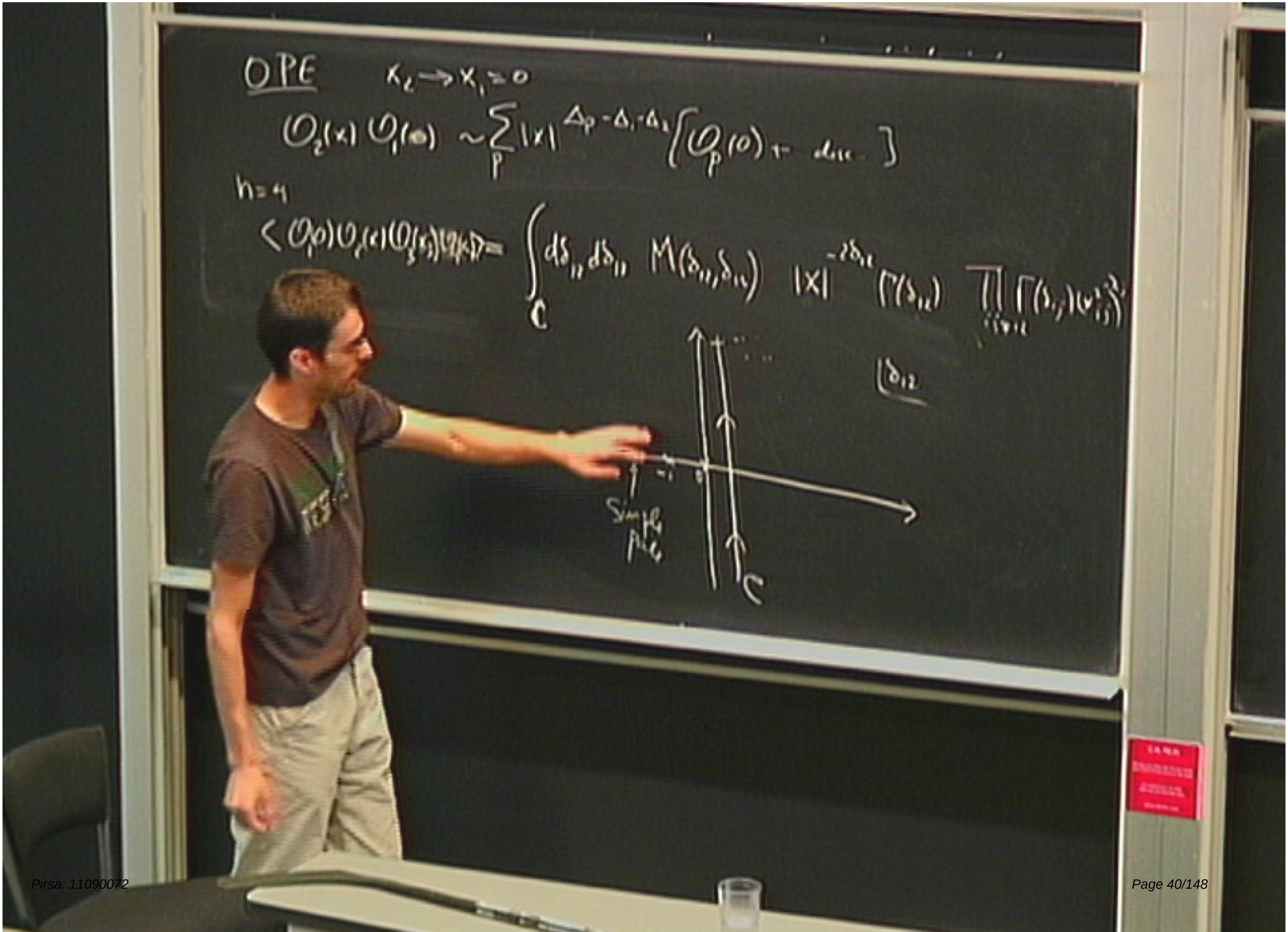

OPE
x2 → x1 = 0
h = 4

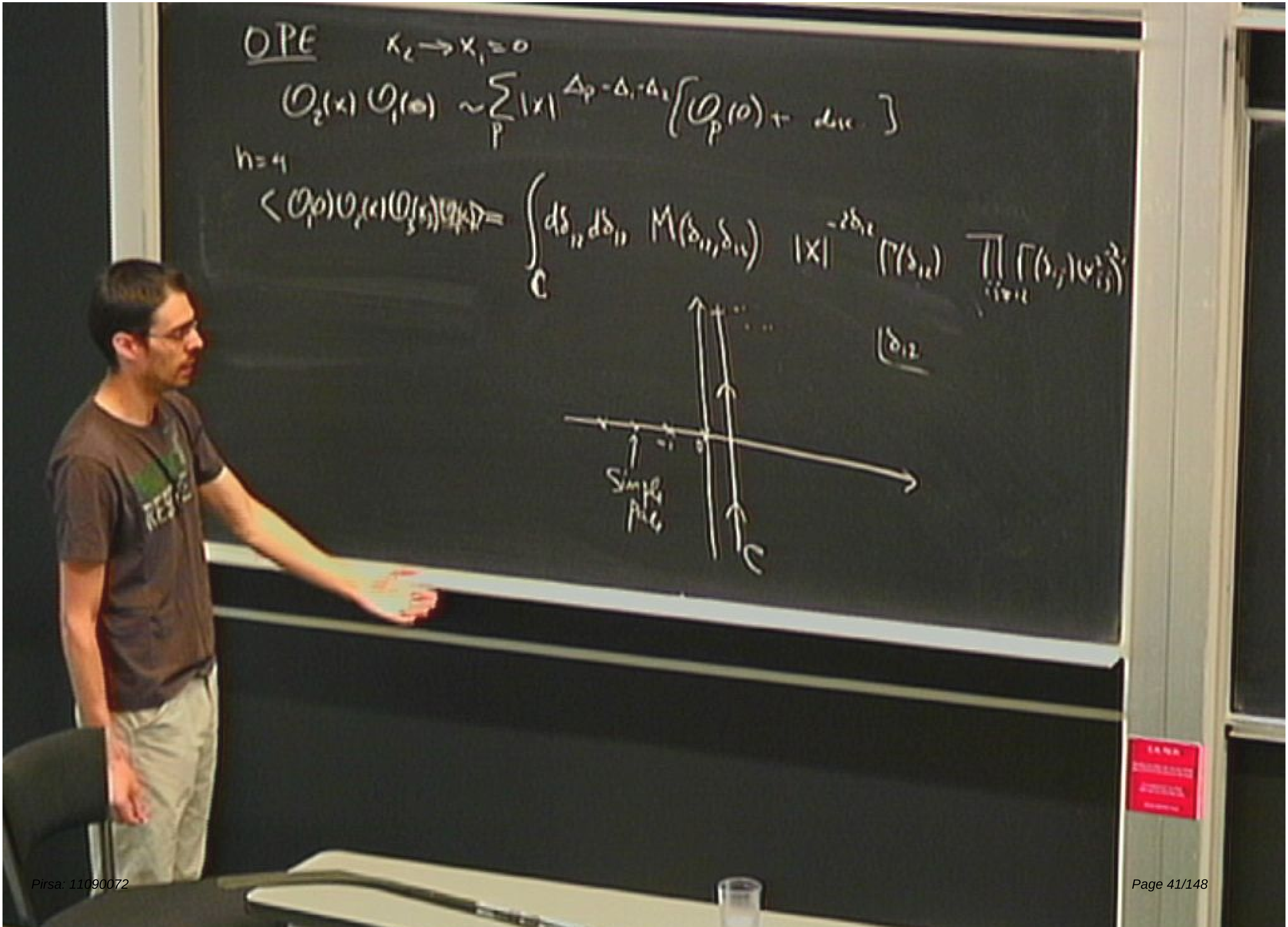

OPE
$x_2 \to x_1 = 0$
$\mathcal{O}_2(x)\,\mathcal{O}_1(0) \sim \sum_p |x|^{\Delta_p - \Delta_1 - \Delta_2} [\mathcal{O}_p(0) + \dots]$
$h=4$

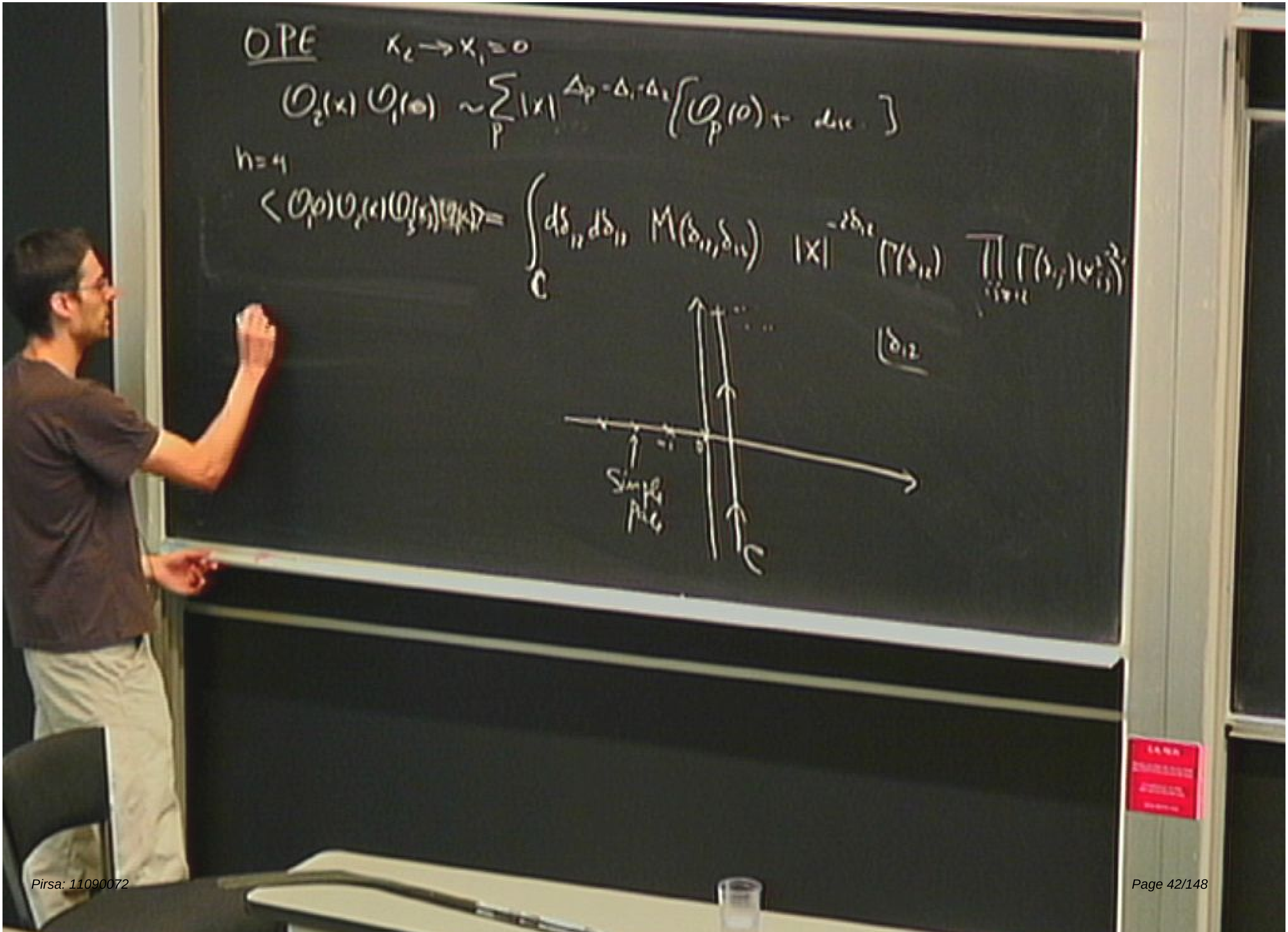

OPE
x2 → x1 = 0
O2(x) O1(0) ~ Σp |x|^Δp-Δ1-Δ2 [Op(0) + desc]
n=4
∫ dδ12 dδ13 M(δ12,δ13) |x|^-2δ12 Γ(δ12)
δ12

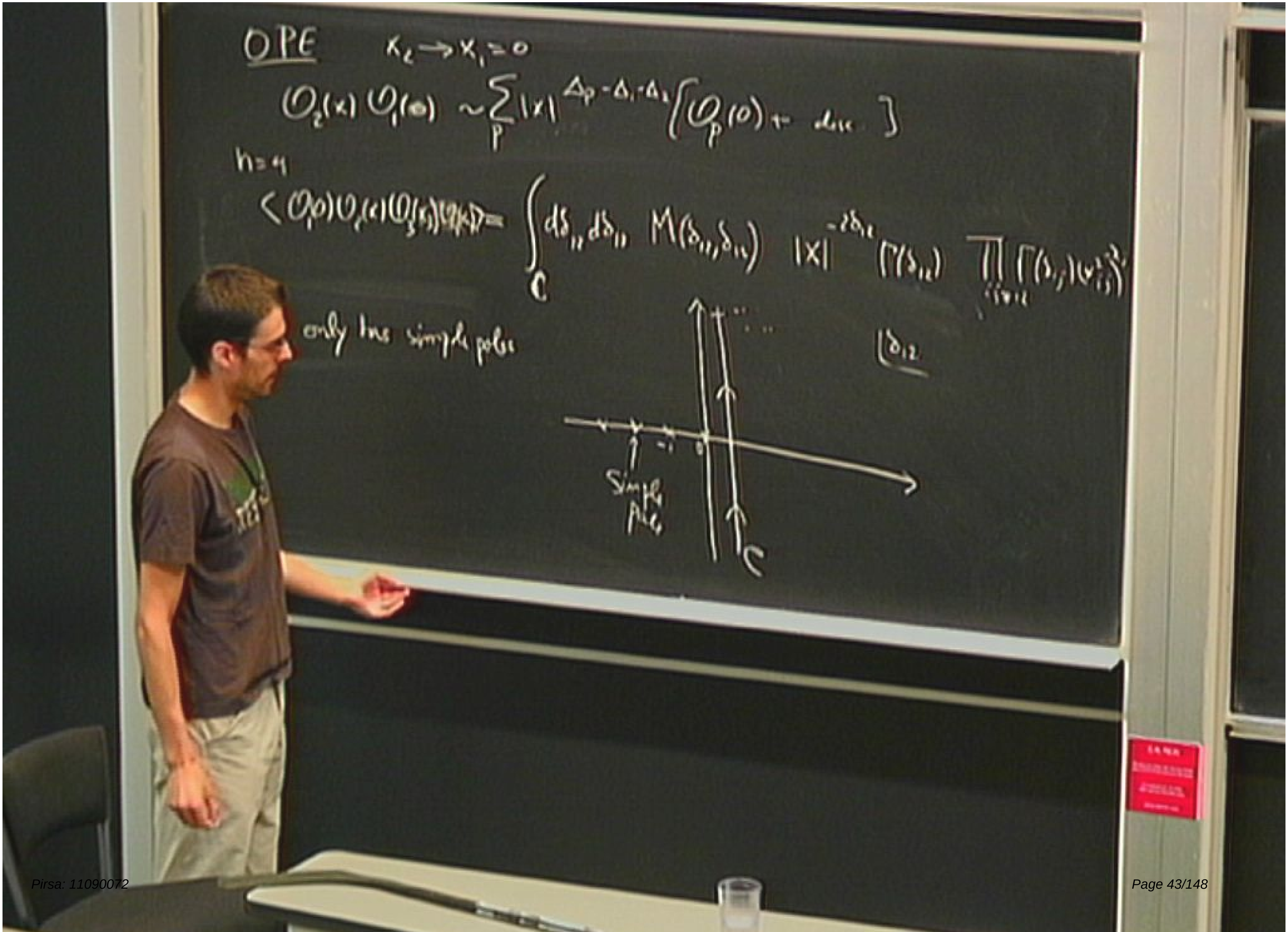

OPE
$x_2 \to x_1 = 0$
h=4

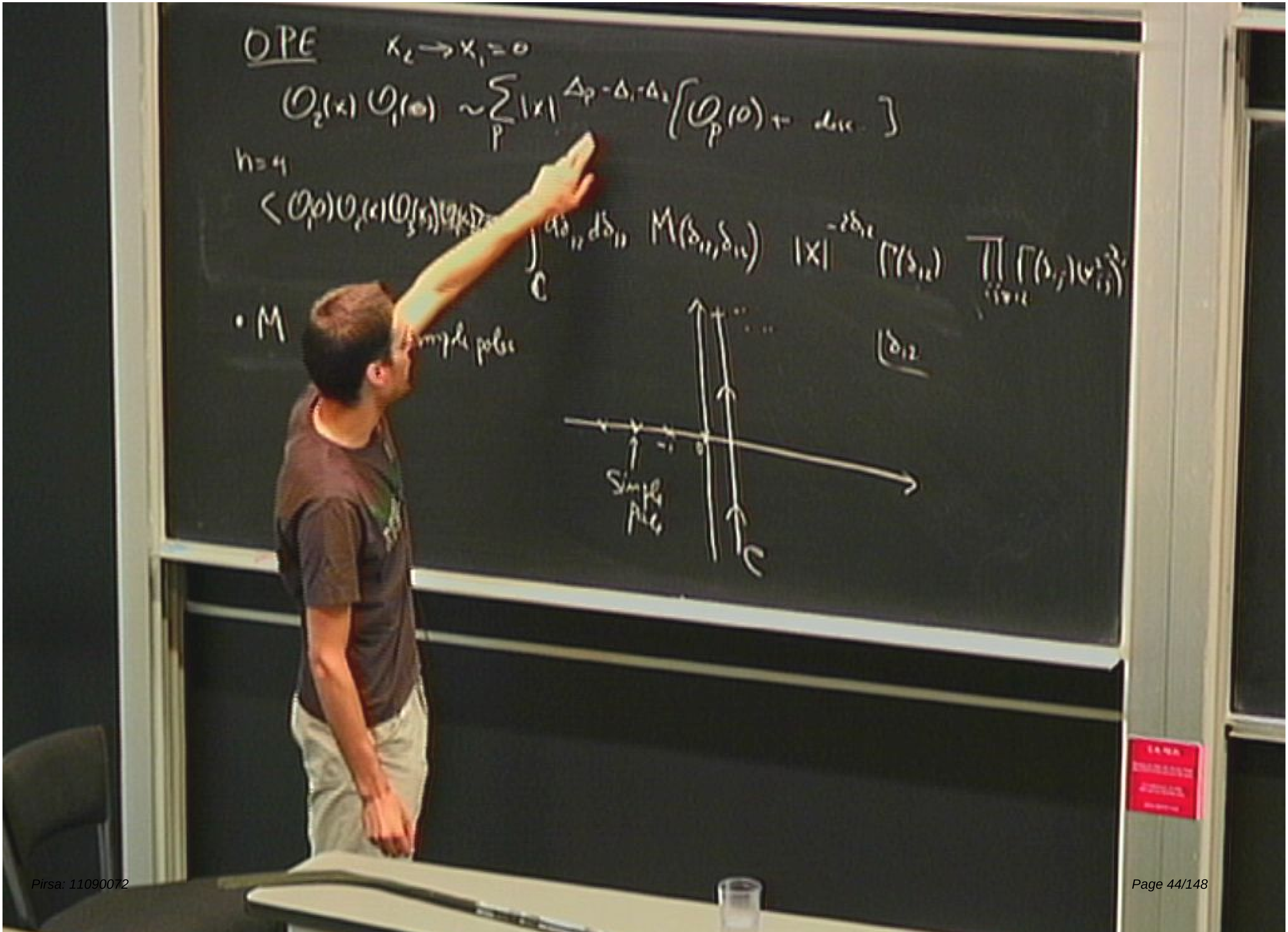

OPE
h=4
C

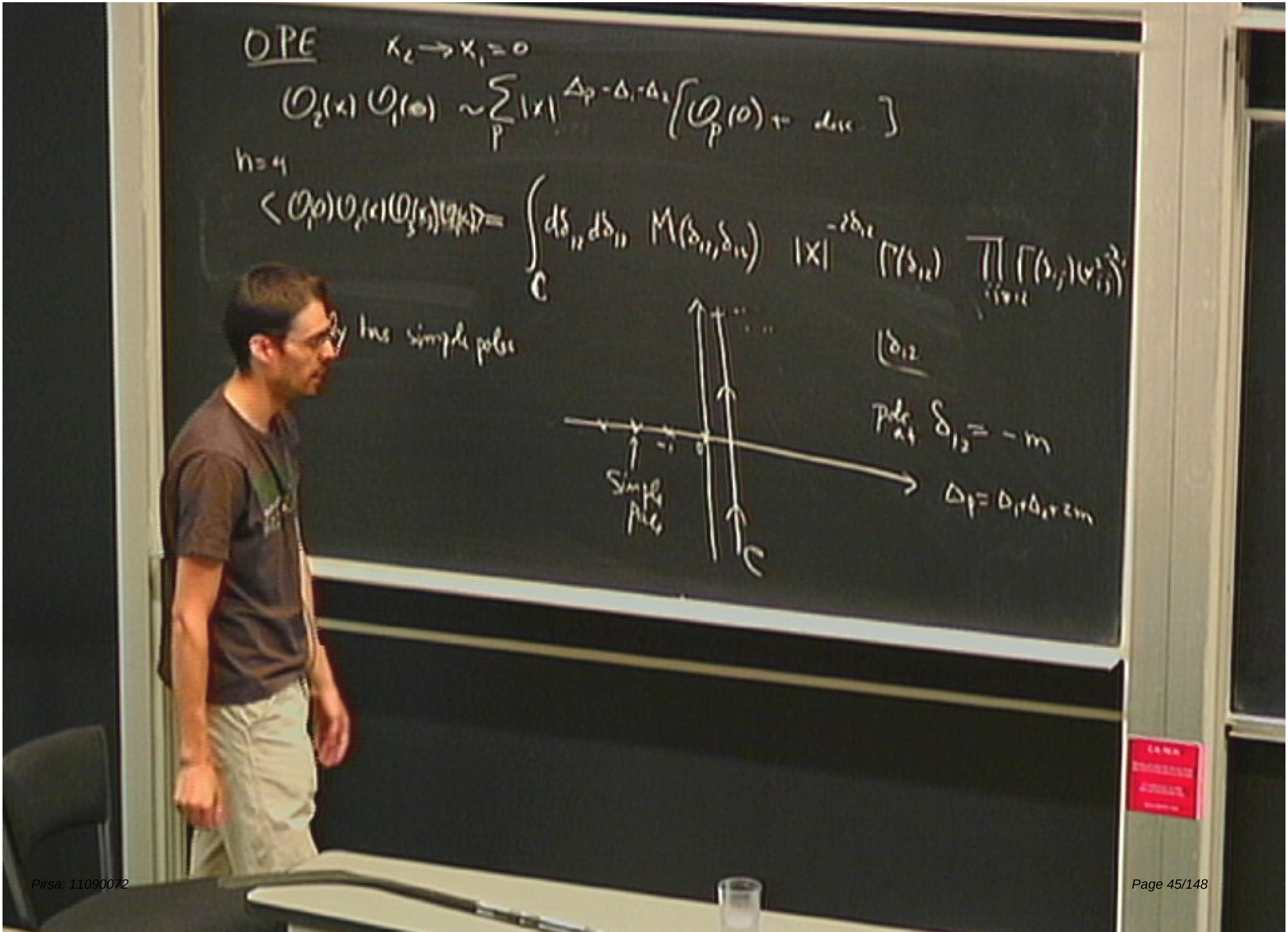

OPE
x₂ → x₁ = 0
h = 4
Simple
Poles
C

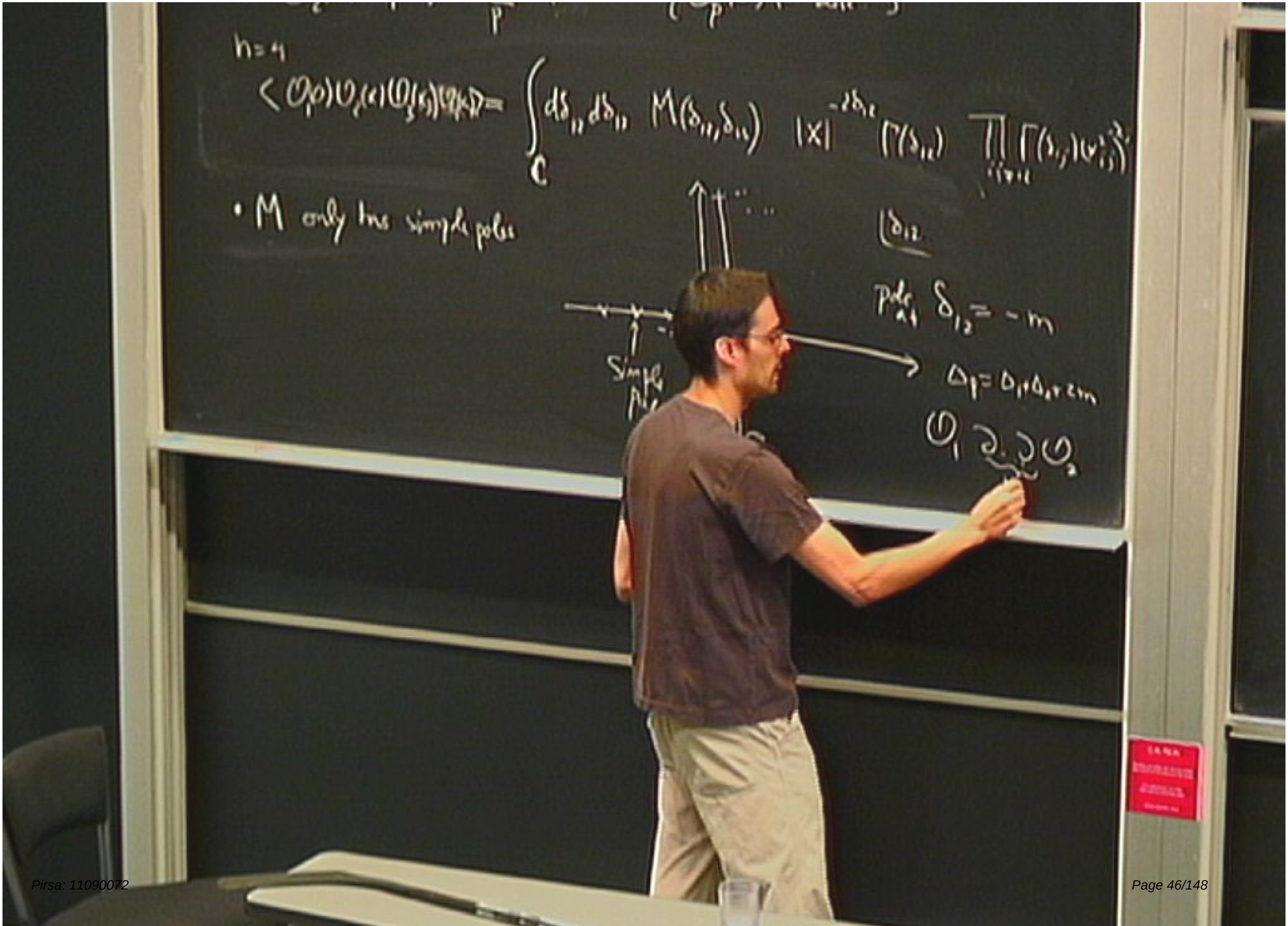

OPE
x₂ → x₁ = 0
n = 4
Simple Poles
C

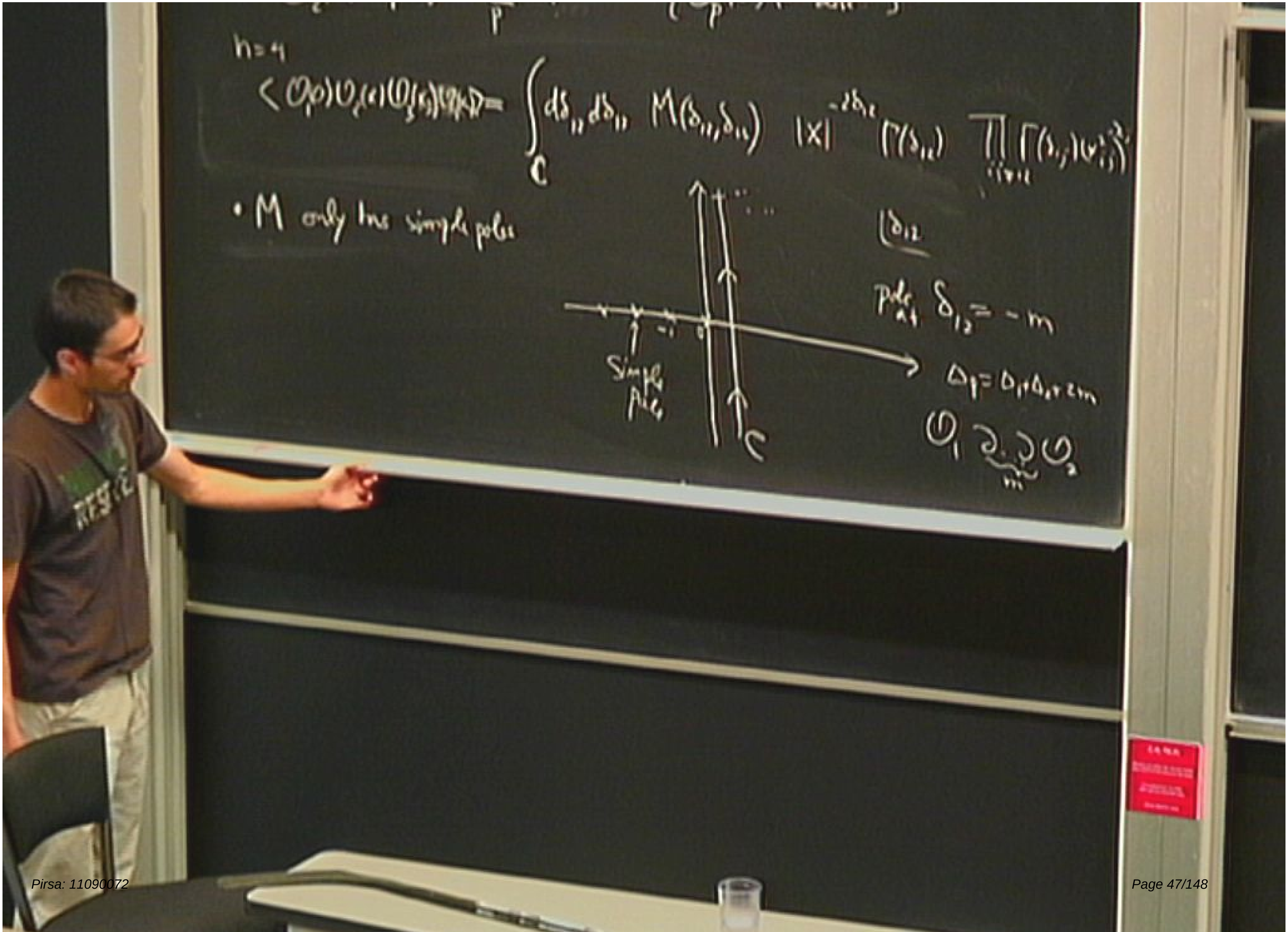

OPE
x2 → x1 = 0
O2(x) O1(0) ~ Σp |x|^(Δp - Δ1 - Δ2) [Op(0) + desc.]
h = 4
< O1(0) O2(x) O3(x3) O4(x4) > = ∫C dδ12 dδ13 M(δ12, δ13) |x|^(-2δ12) Γ(δ12) ∏ Γ(δij)
δ12
0
Simple Poles
C

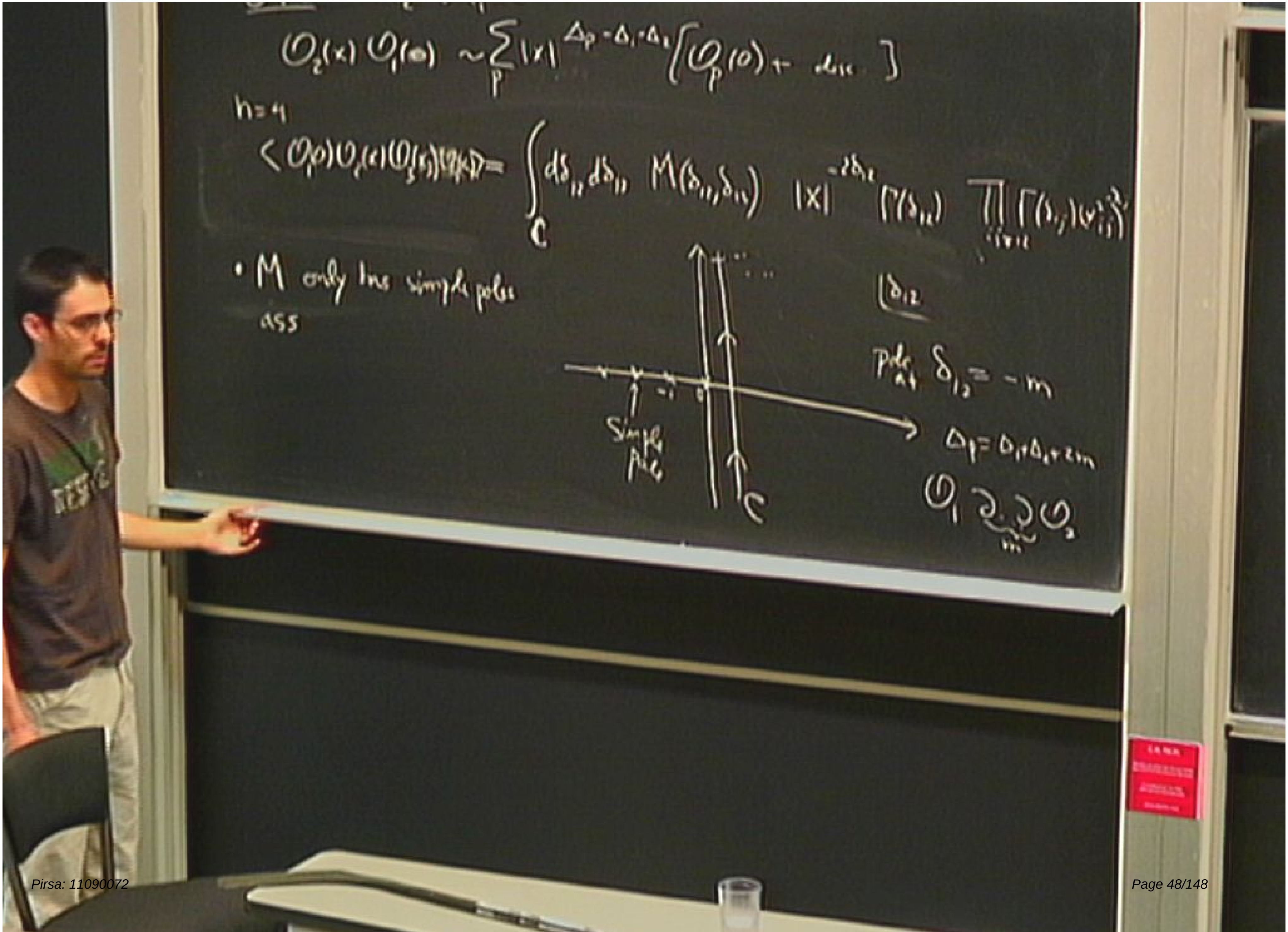

OPE
only has simple poles
Simple Poles


OPE
x₂ → x₁ = 0
n = 4
• M
Simple pole
C

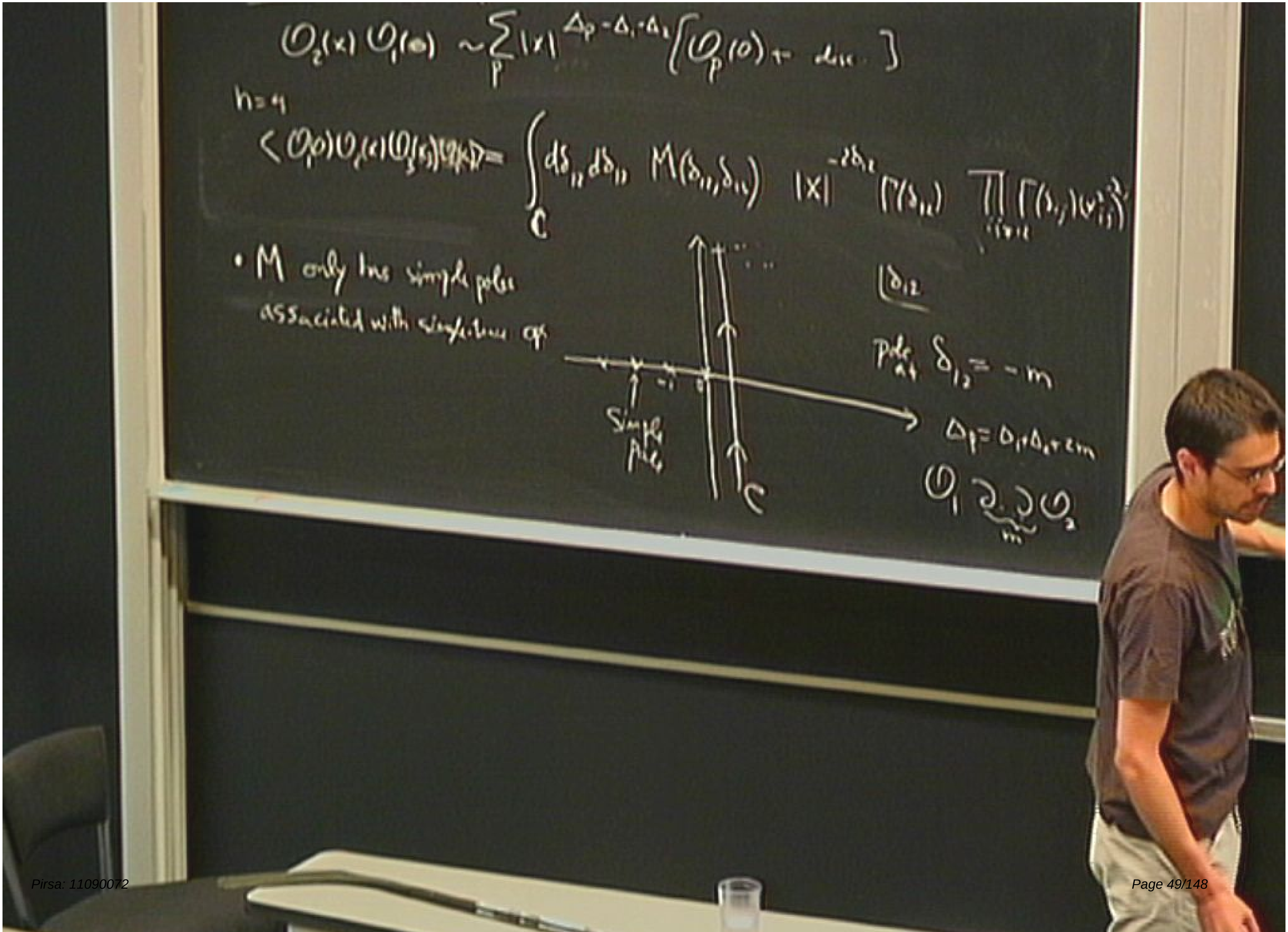

OPE
x2 → x1 = 0
O2(x) O1(0) ~ Σp |x|^(Δp - Δ1 - Δ2) [Op(0) + desc]
n = 4
<O1(0) O2(x) O3(x3) O4(x4)> = ∫C dδ12 dδ13 M(δ12, δ13) |x|^(-2δ12) Γ(δ12) Π Γ(δij)
has simple poles
δ12
poles at δ12 = -m
Δp = Δ1 + Δ2 + 2m
Simple poles
C

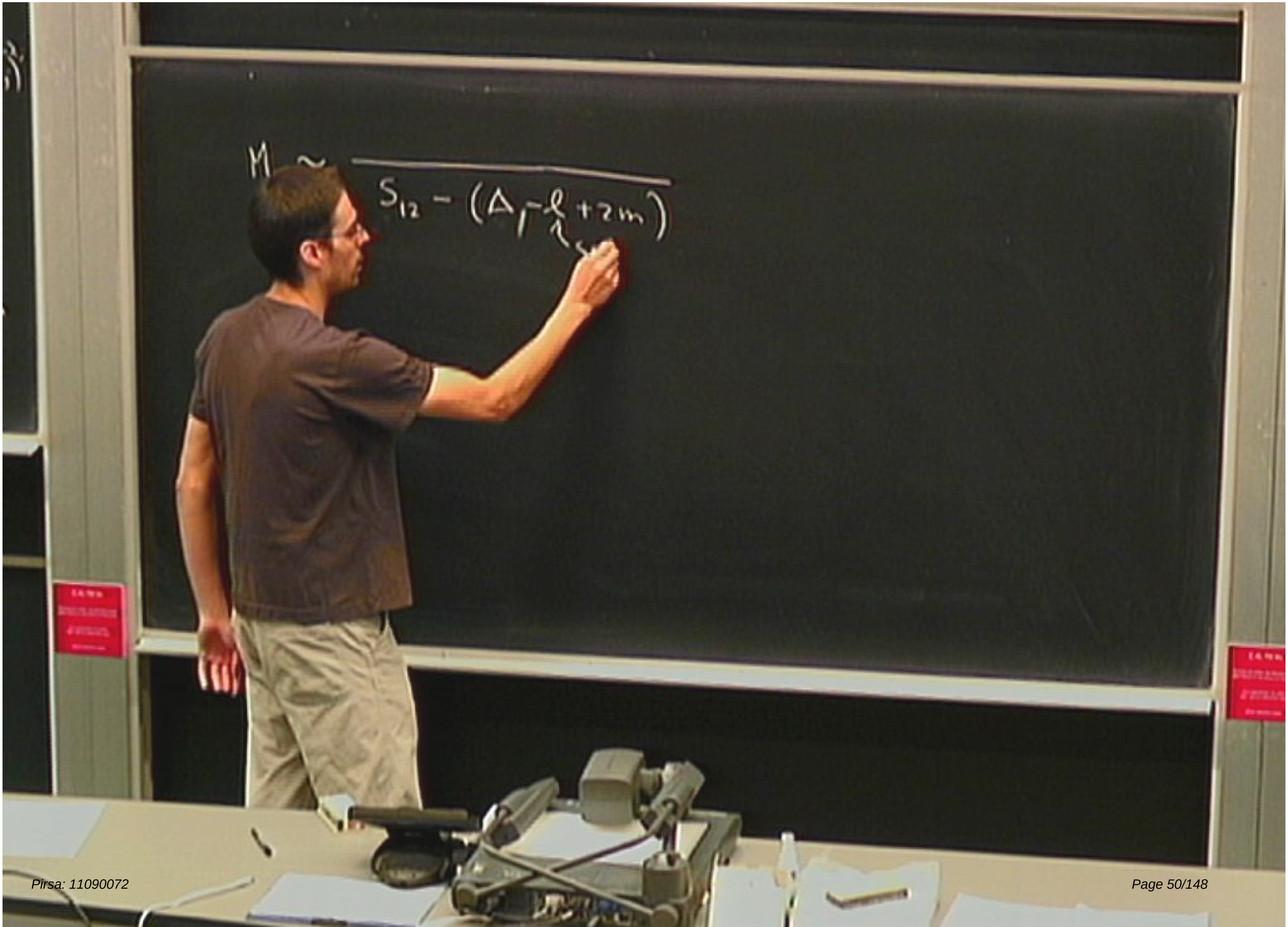

n=4
• M only has simple poles
Simple pole

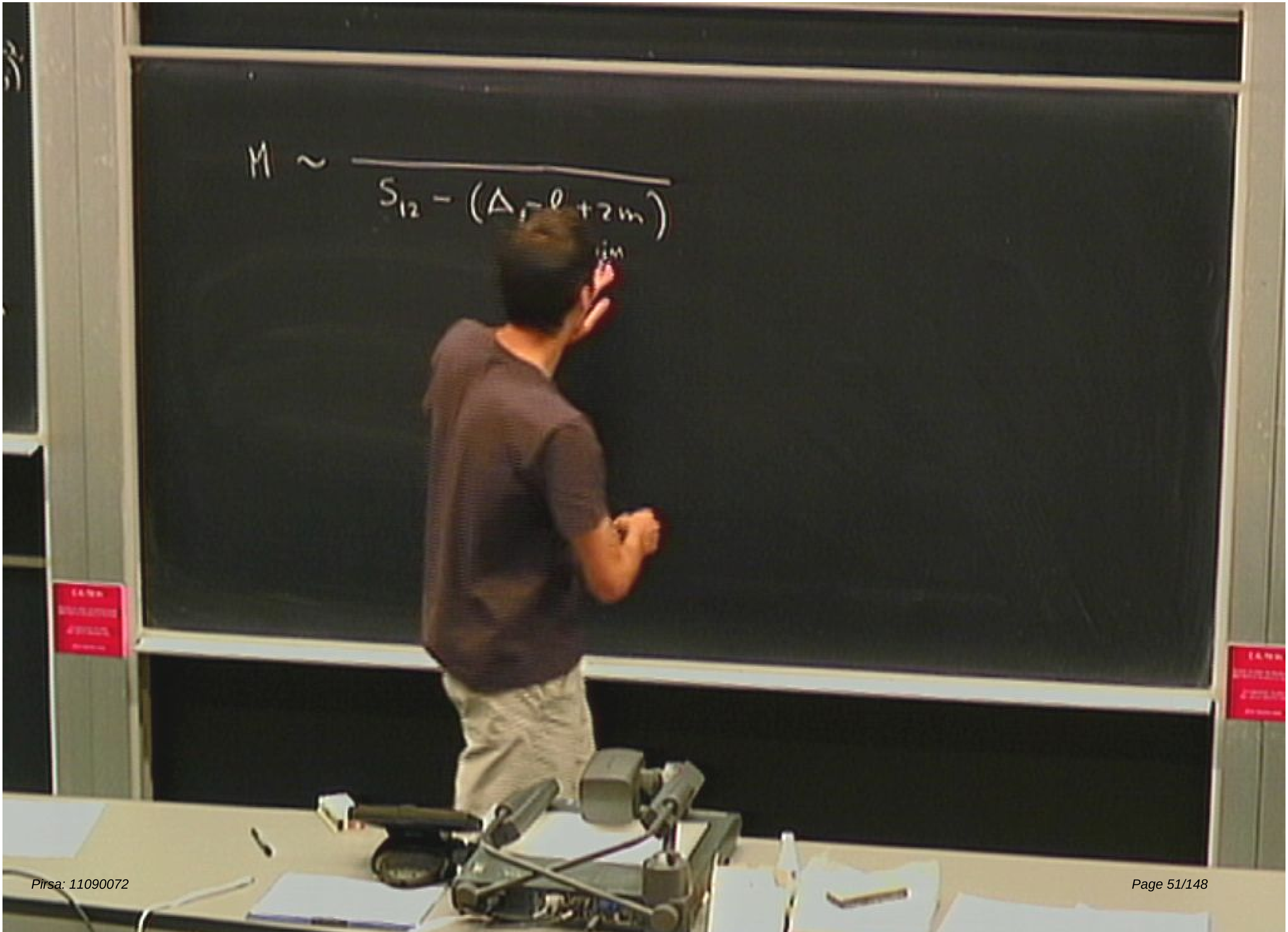

n=4
• M only has simple poles
Simple poles
C

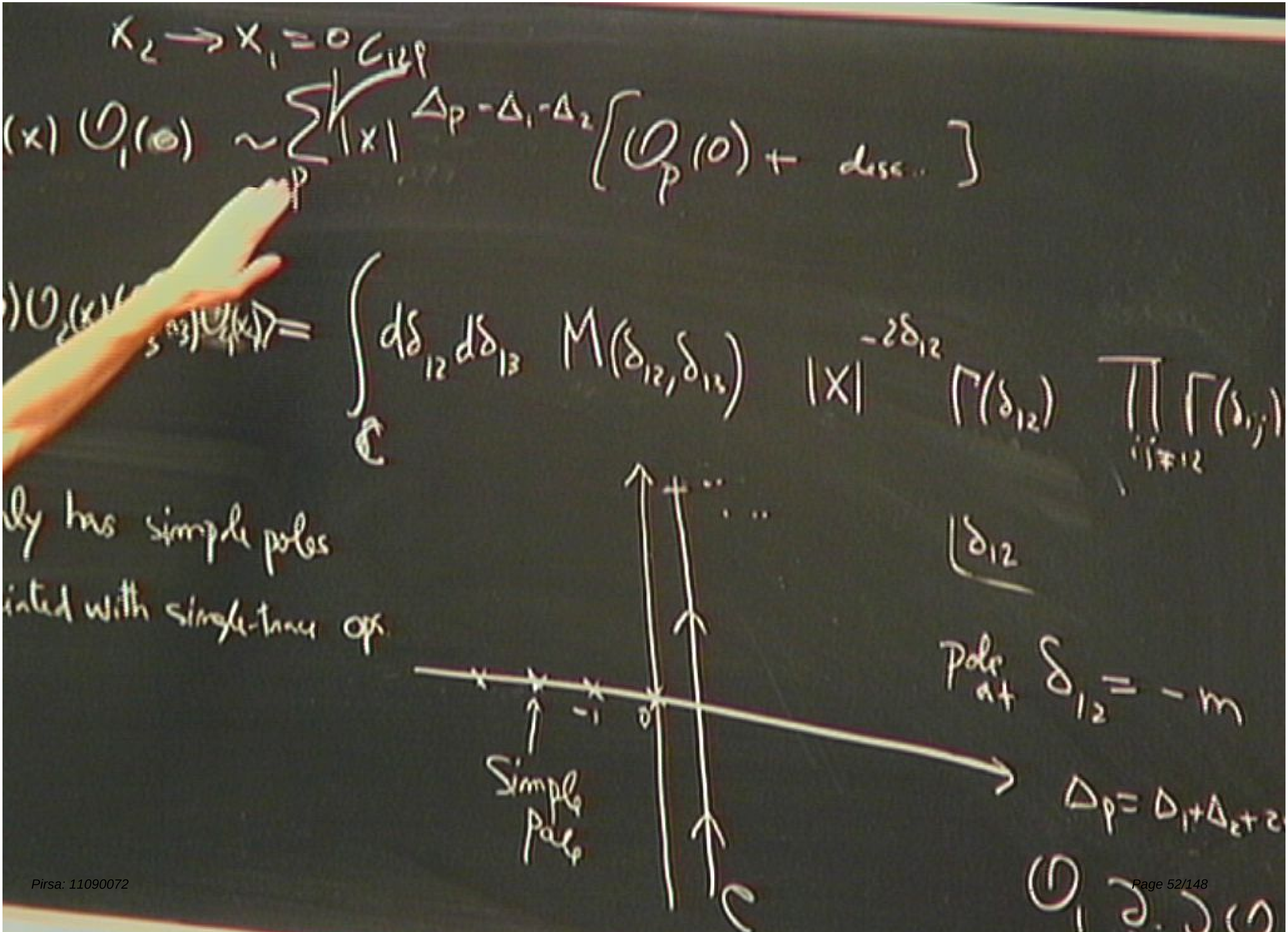


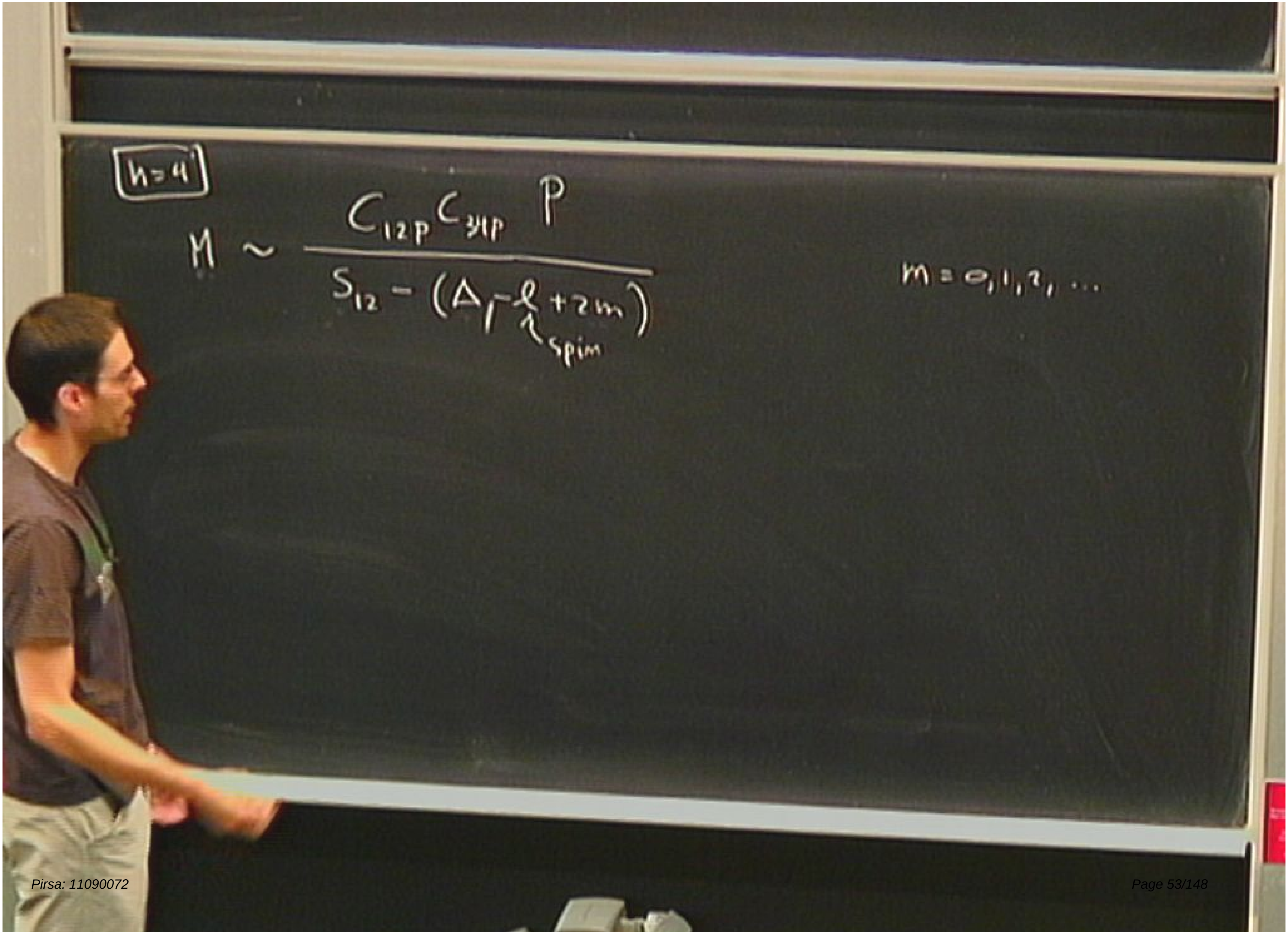
h=4
• M only has simple poles
ass
δ12
poles at δ12 = -m
Δp = Δ1+Δ2+2m
simple poles
C

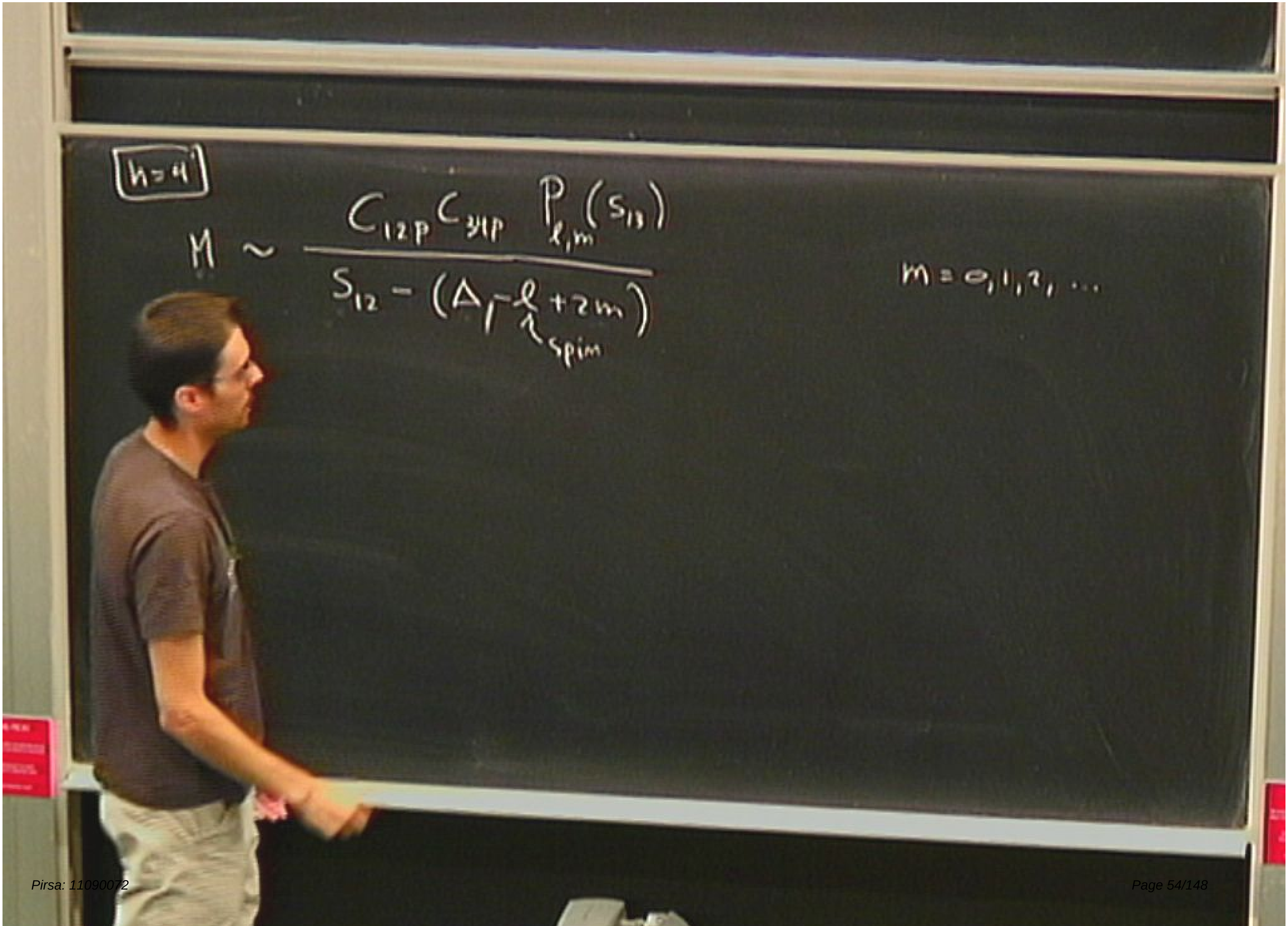

h=4
• M only has simple poles
associated with single-trace ops
Simple poles
pole at δ_12 = -m
Δ_p = Δ_1+Δ_2+2m

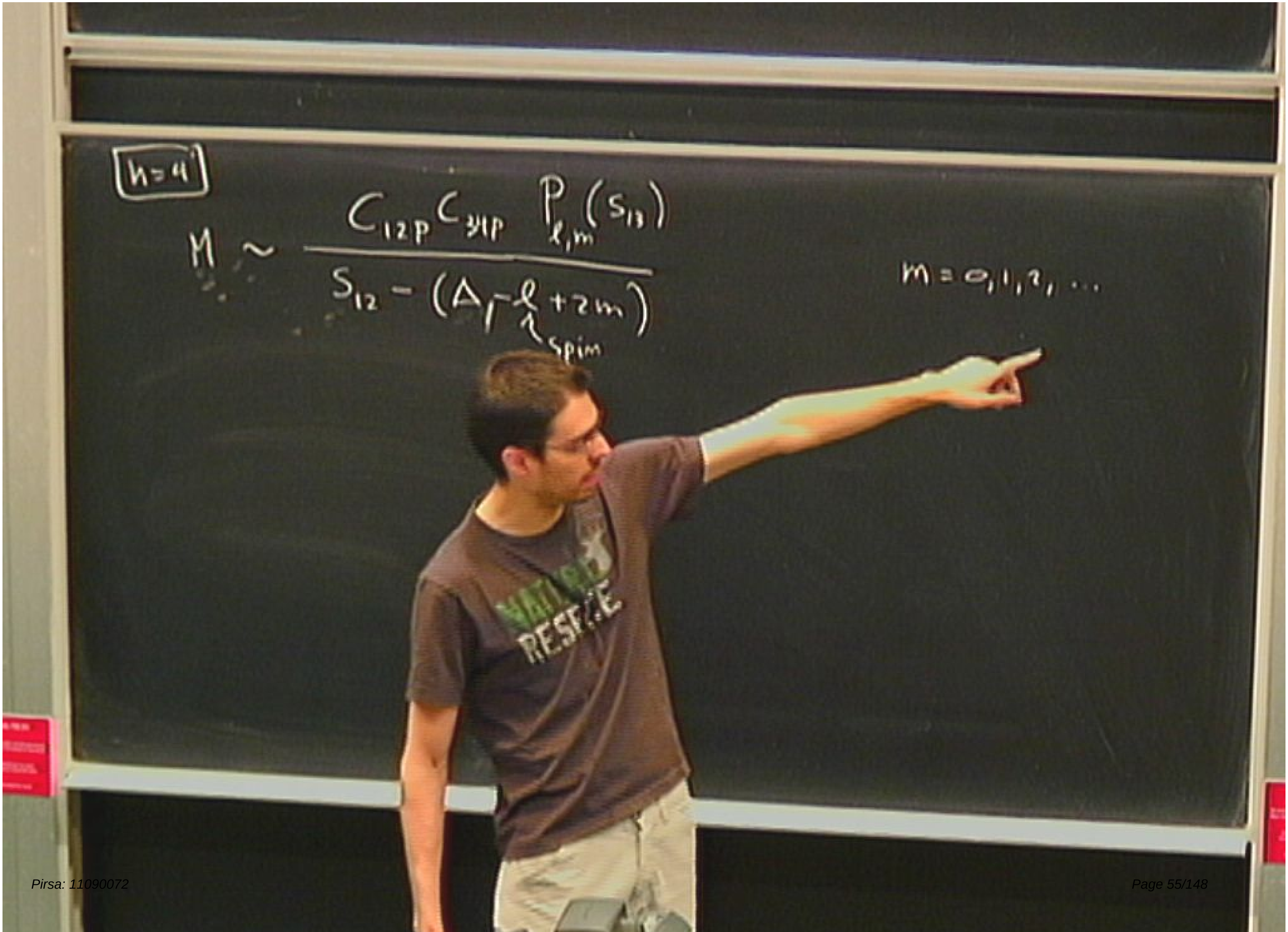

M ~
S12 − (Δ1 − ℓ + 2m)

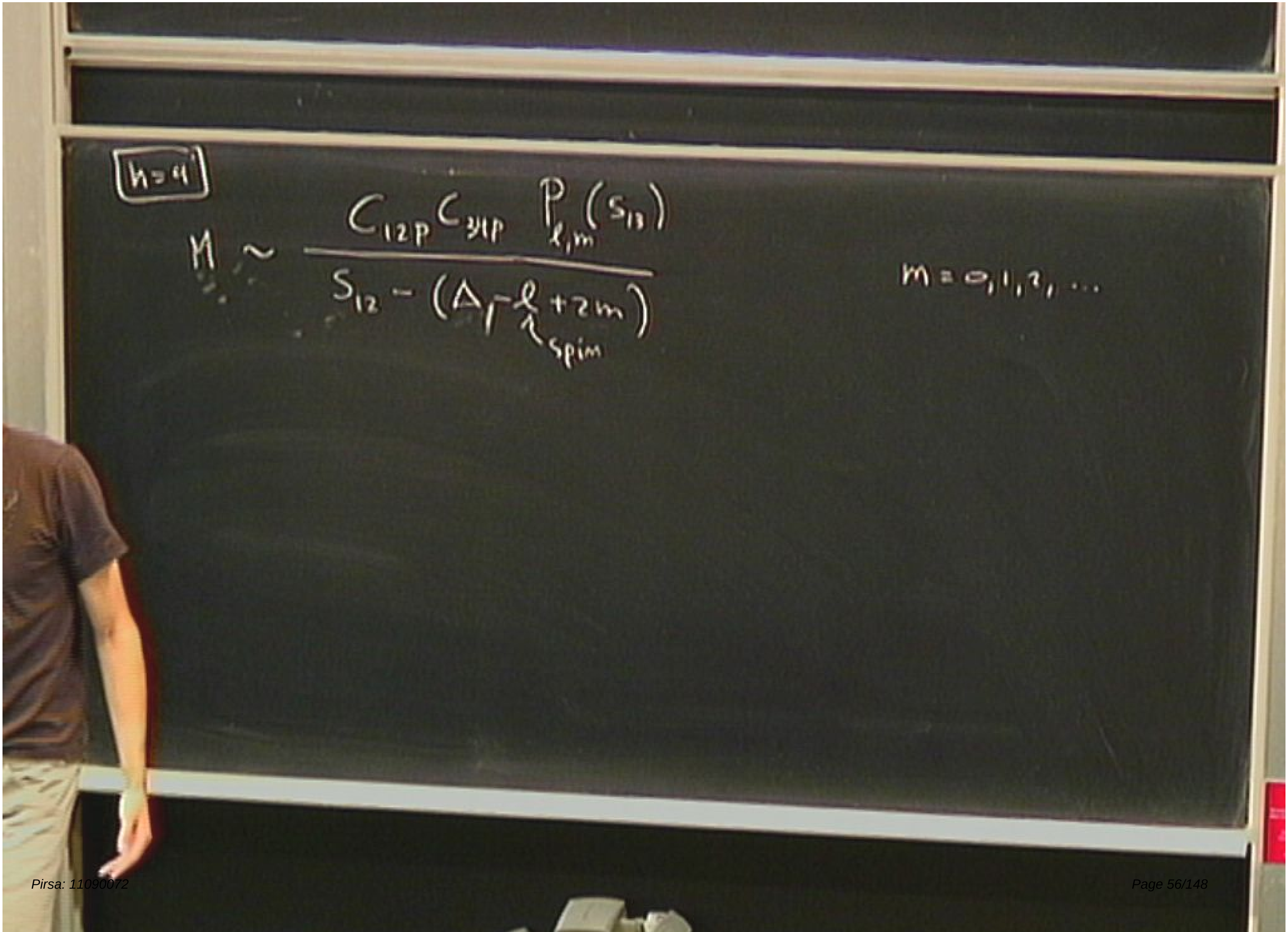

M ~
S12 − (Δ

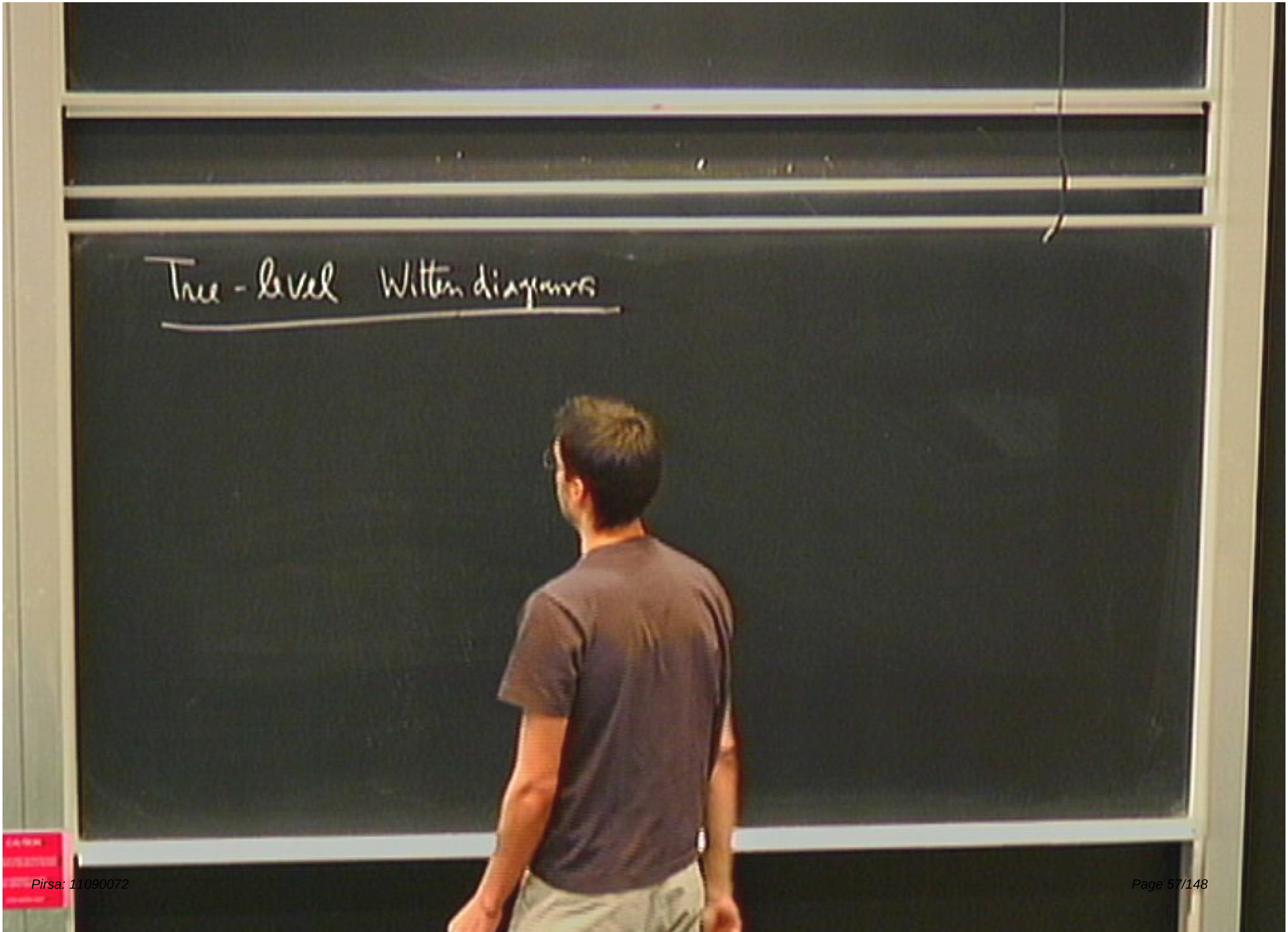

$x_2 \to x_1 = 0$ c_{12p}
$(x)\, \mathcal{O}_1(0) \sim \sum_p c_{12p} |x|^{\Delta_p - \Delta_1 - \Delta_2} [\mathcal{O}_p(0) + \text{desc.}]$
$\int_{\mathcal{C}} d\delta_{12}\, d\delta_{13}\; M(\delta_{12}, \delta_{13})\; |X|^{-2\delta_{12}}\; \Gamma(\delta_{12}) \prod_{ij \neq 12} \Gamma(\delta_{ij})$
ly has simple poles
iated with single-trace ops.
δ_{12}
Pole at $\delta_{12} = -m$
-1
0
Simple Pole
$\Delta_p = \Delta_1 + \Delta_2 + 2$
$\mathcal{C}$

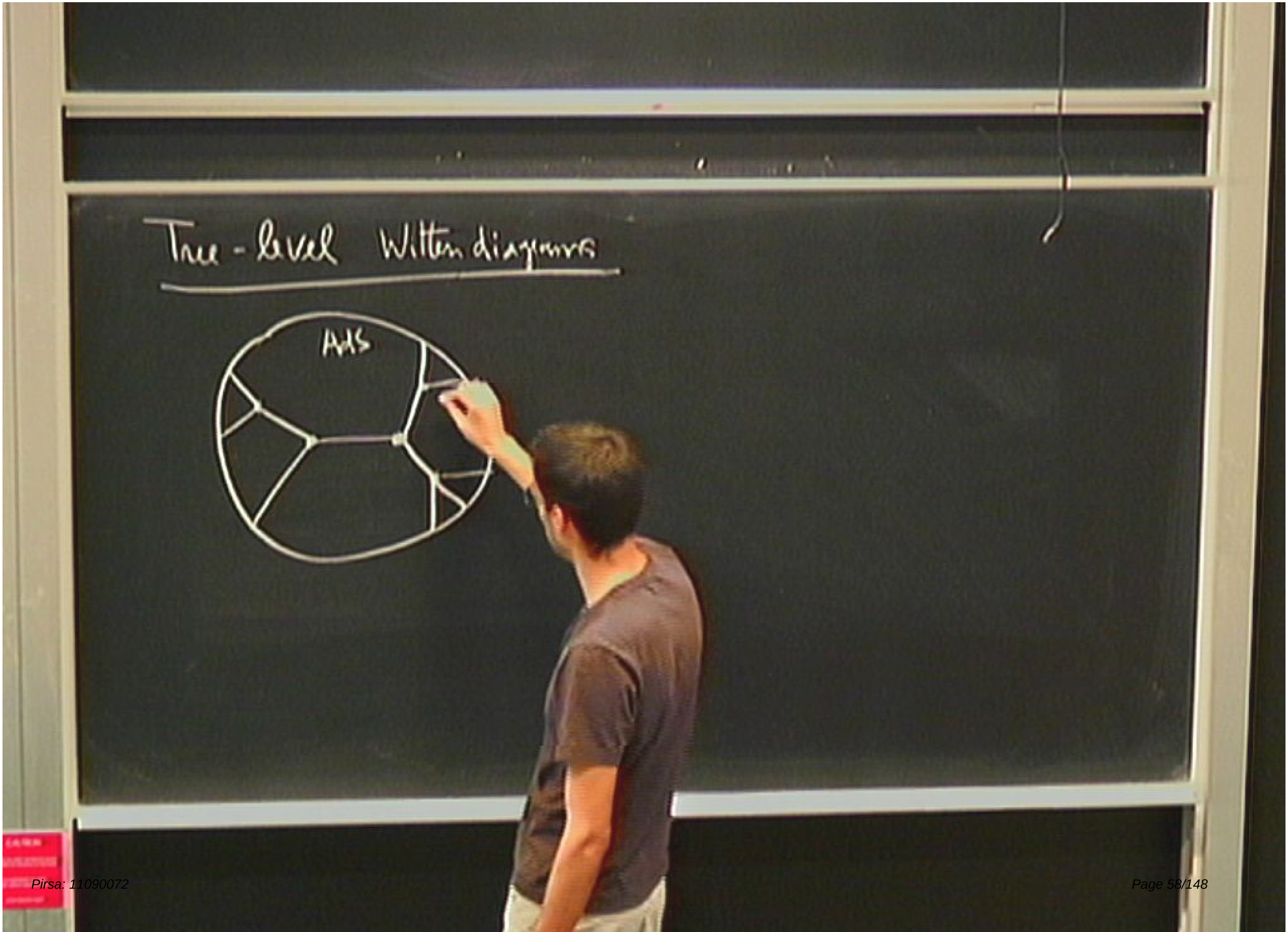

h=4
$M \sim \frac{C_{12p} C_{34p} P}{s_{12} - (\Delta - \ell + 2m)}$
spin
m = 0, 1, 2, ...

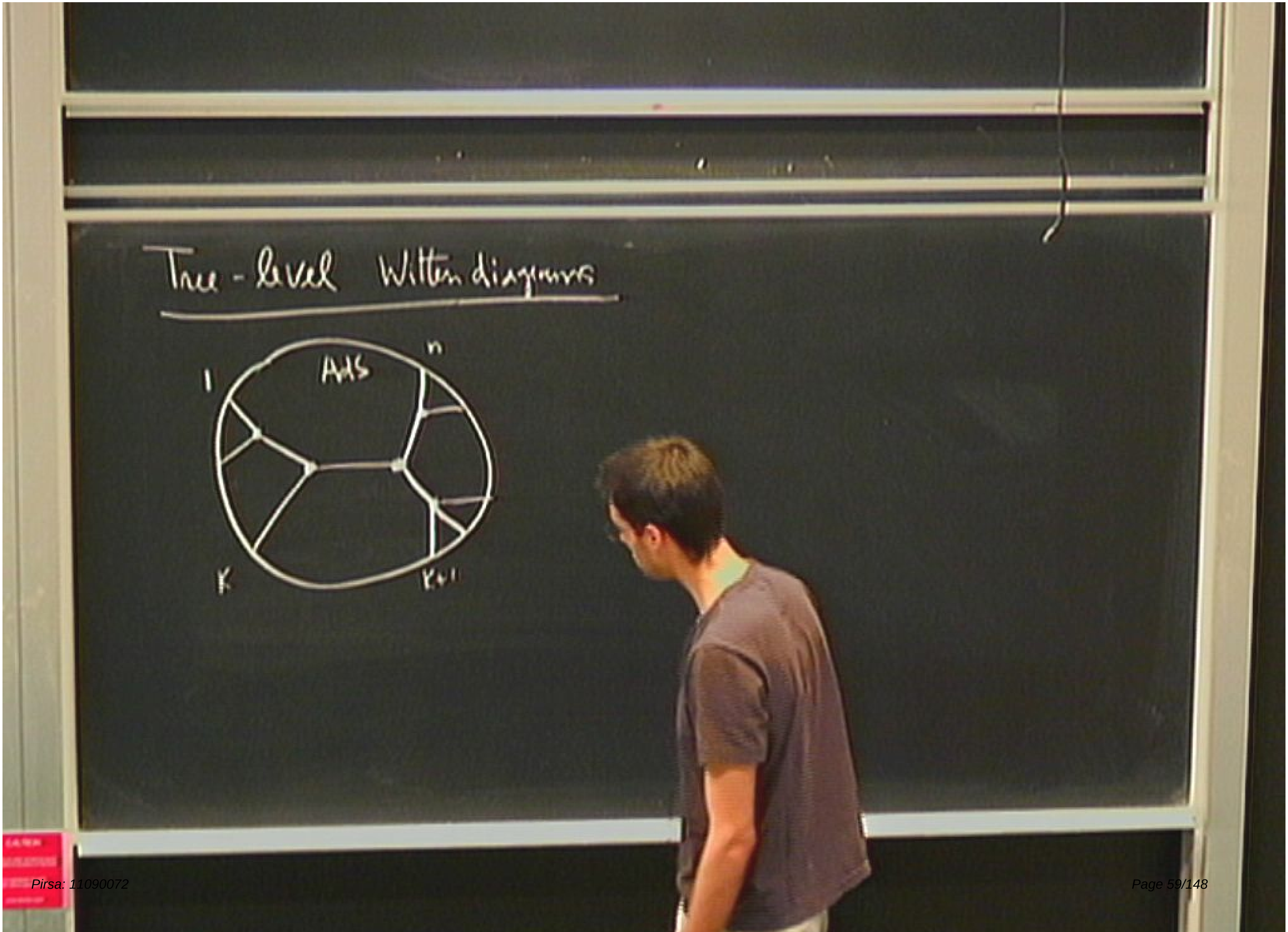

h=4
M ~ C_{12p} C_{34p} P_{l,m}(s_{13}) / s_{12} − (Δ − l + 2m)
spin
m = 0, 1, 2, ...

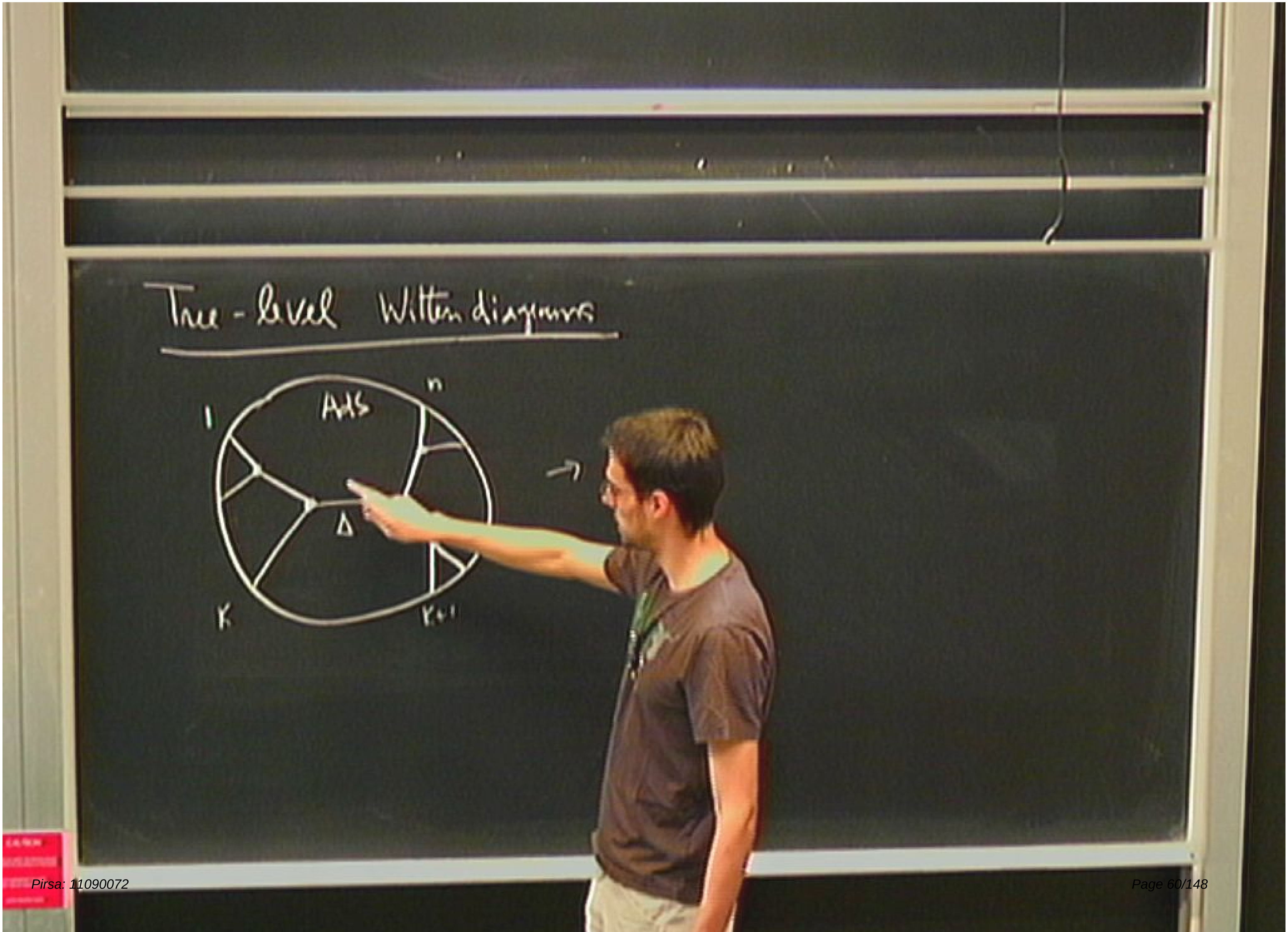

h=4
M ~ C_{12p} C_{34p} P_{ℓ,m}(s_{13}) / (s_{12} − (Δ − ℓ + 2m))
spin
m = 0, 1, 2, ...

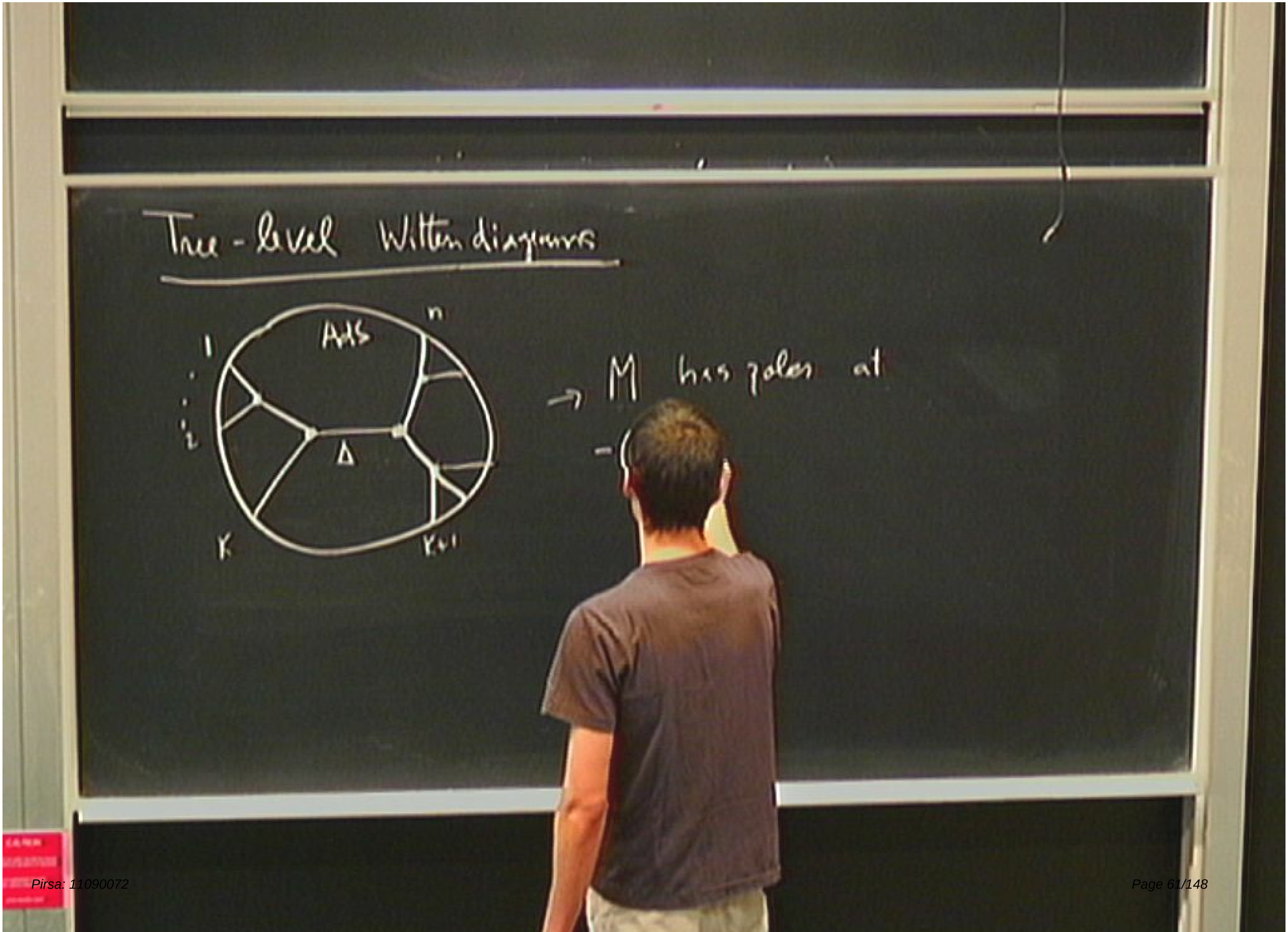

h=4
$M \sim \frac{C_{12p} C_{34p} \, P_{\ell,m}(s_{13})}{s_{12} - (\Delta_p - \ell + 2m)}$
spin
$m = 0, 1, 2, \ldots$

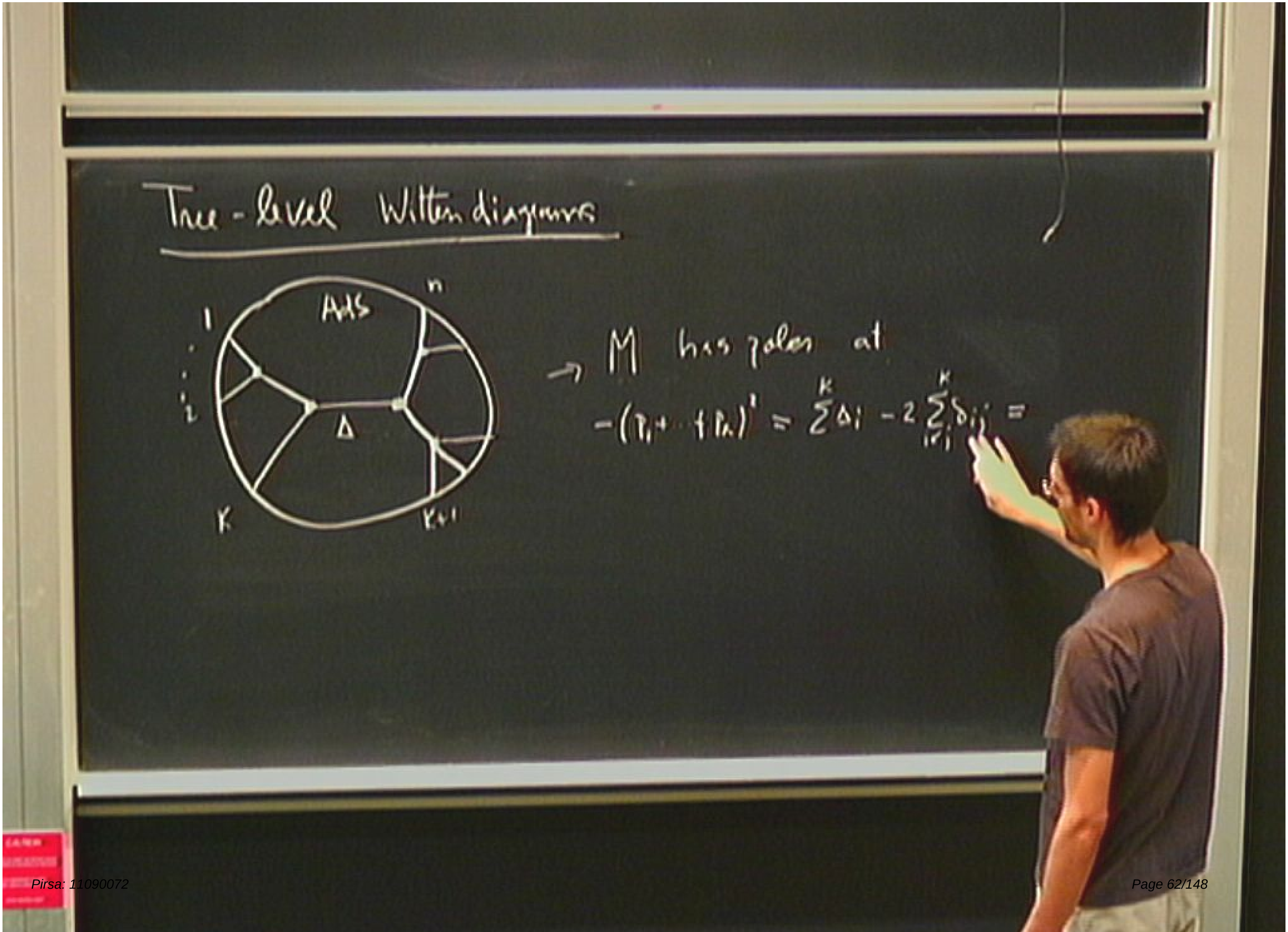

Tree-level Witten diagrams

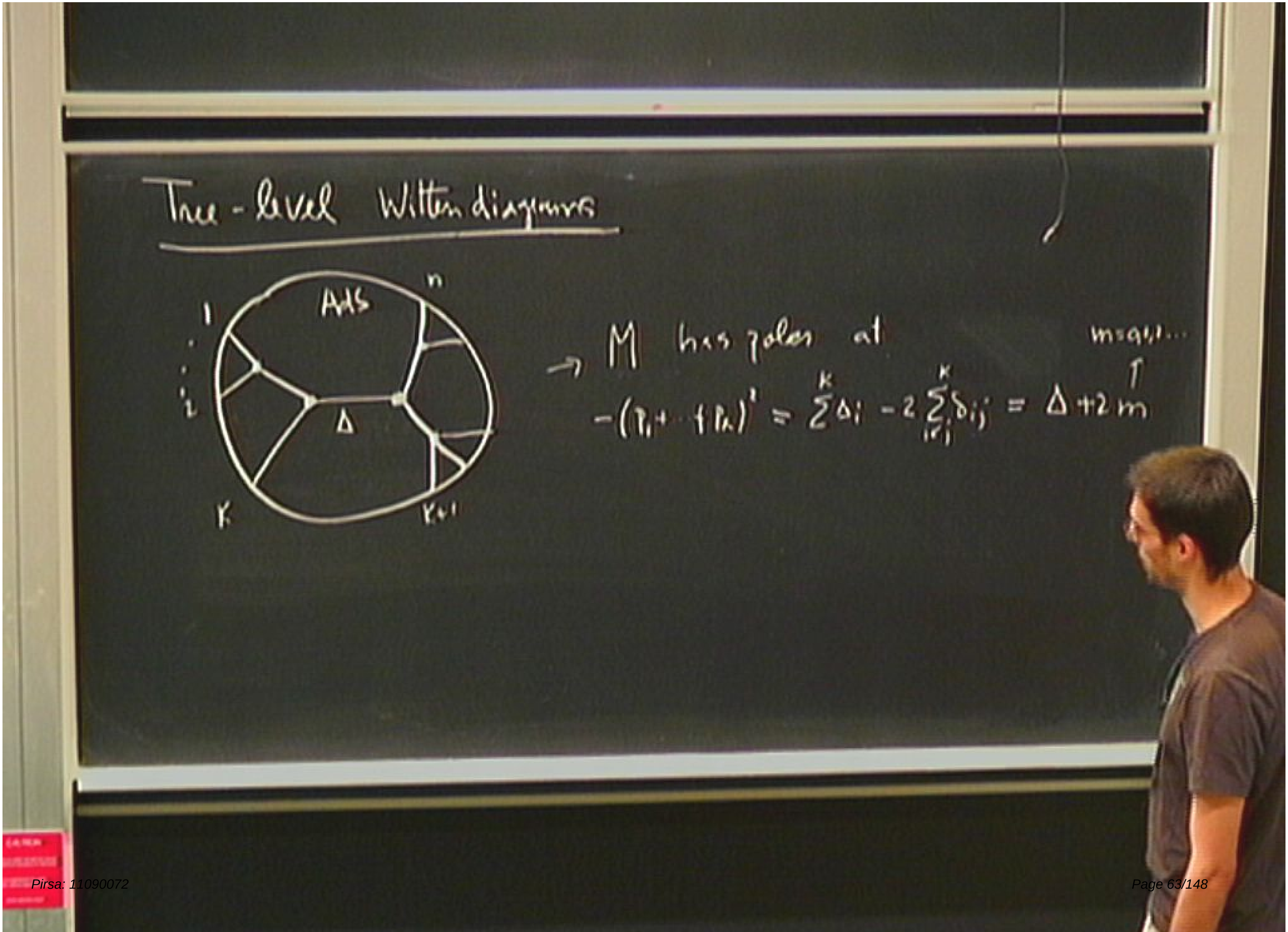

Tree-level Witten diagrams
AdS

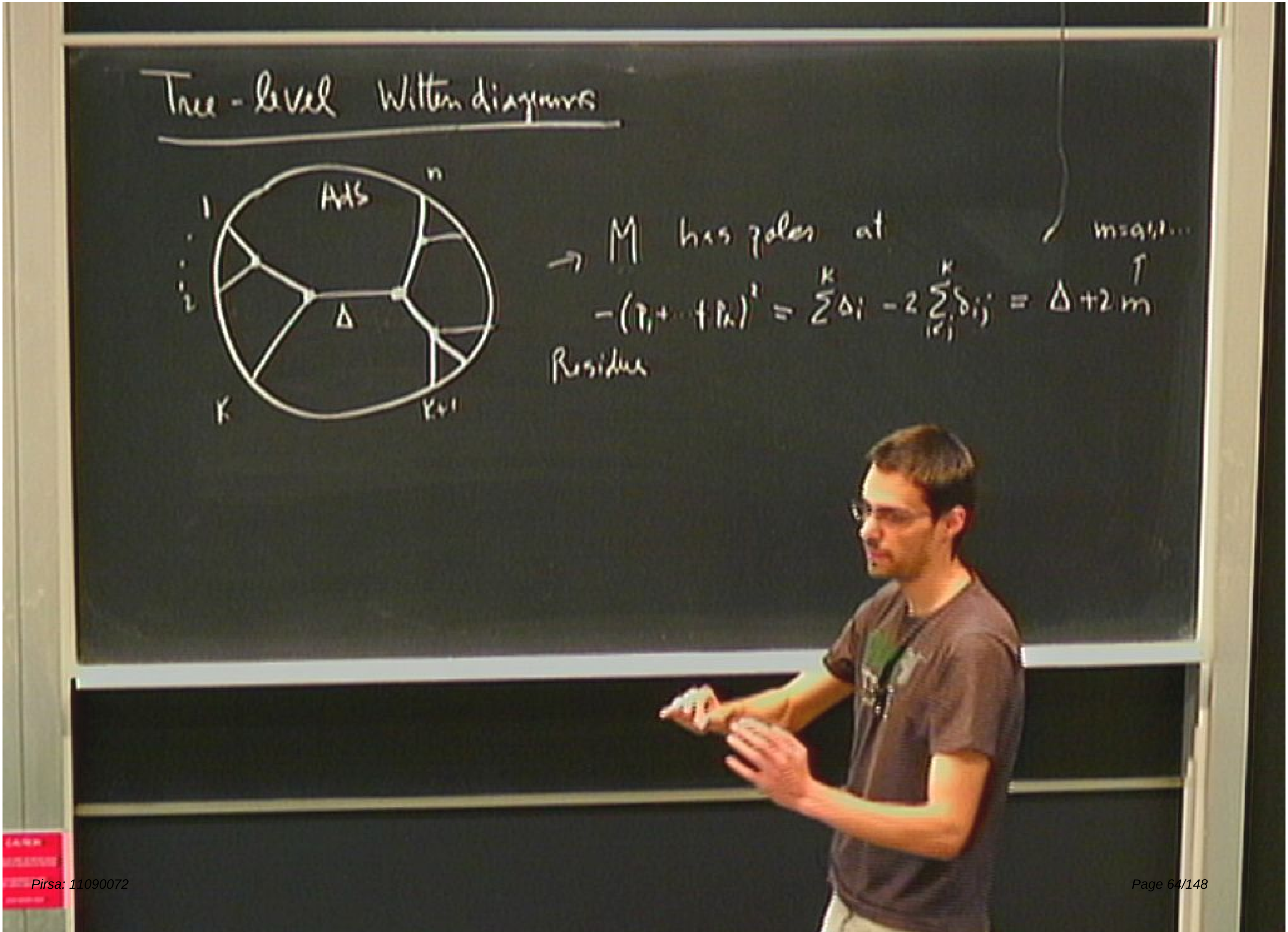

Tree-level Witten diagrams
AdS
1
n
k
k+1

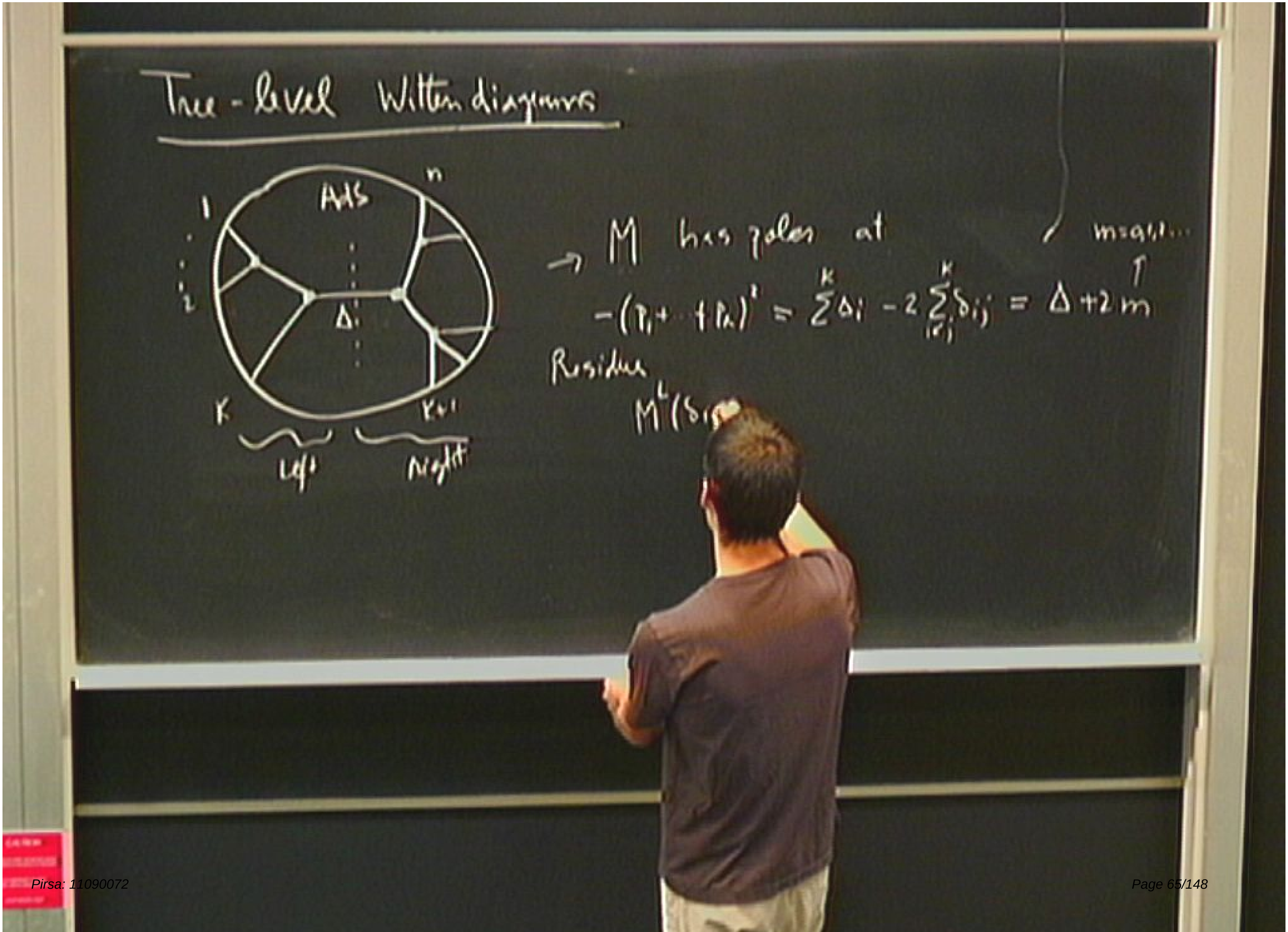

Tree-level Witten diagrams
AdS
1
n
k
k+1
Δ

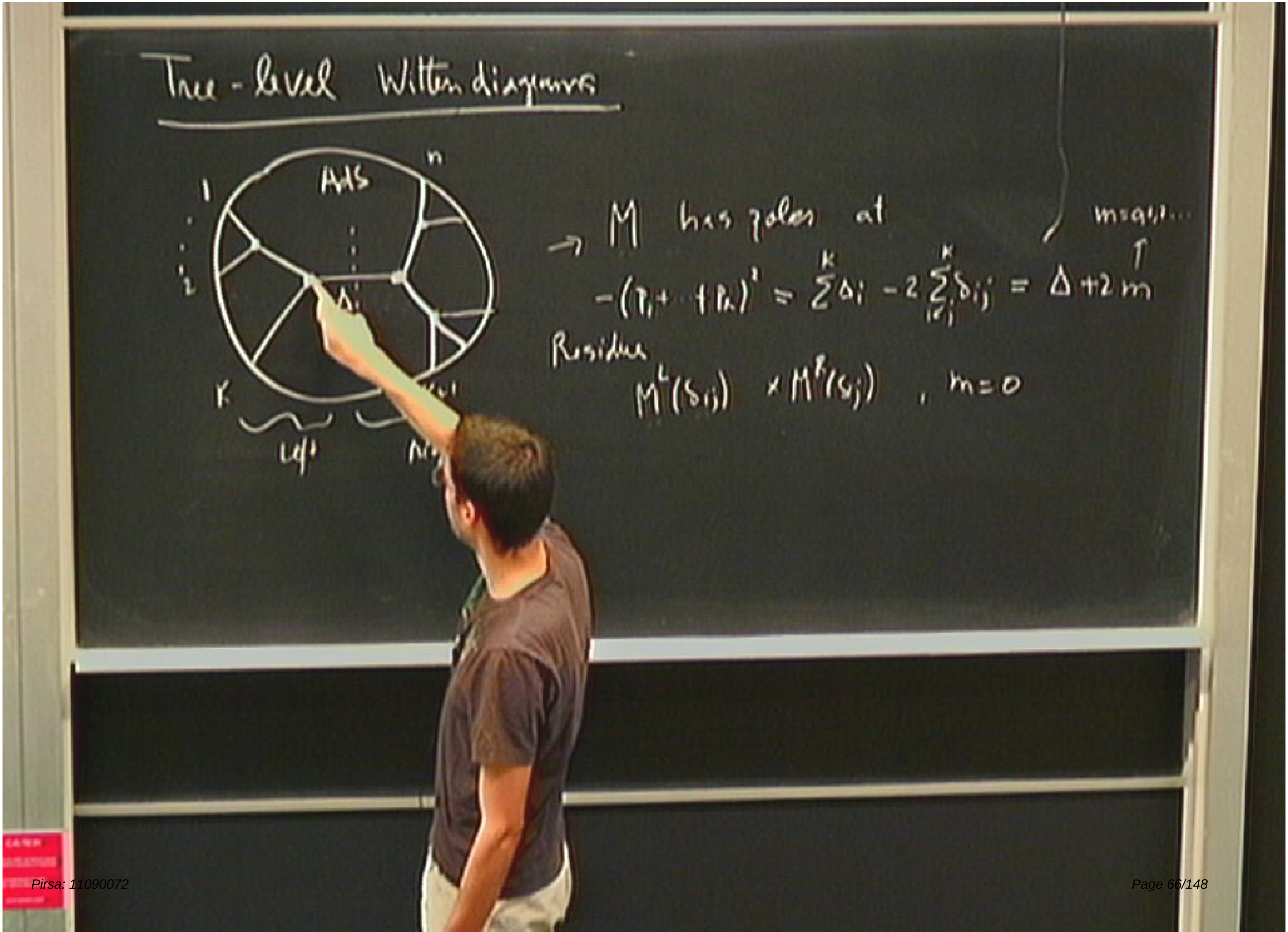

Tree-level Witten diagrams
AdS
1
2
k
k+1
n
Δ
→ M has poles at

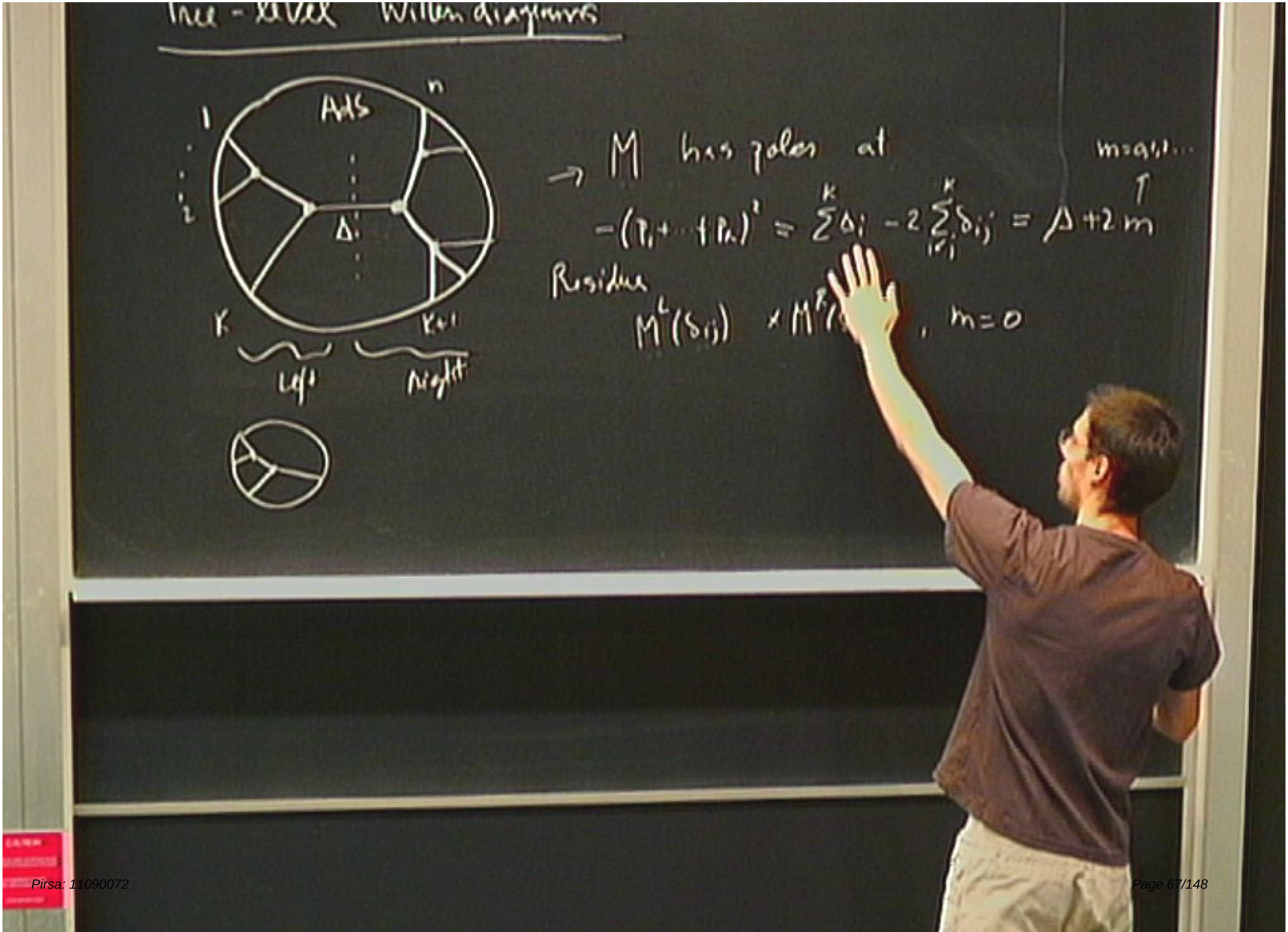

Tree-level Witten diagrams
AdS
1
i
k
n
k+1
Δ
→ M has poles at
$-(p_1+\cdots+p_k)^2 = \sum^k \Delta_i - 2\sum^k_{i<j} \delta_{ij} =$

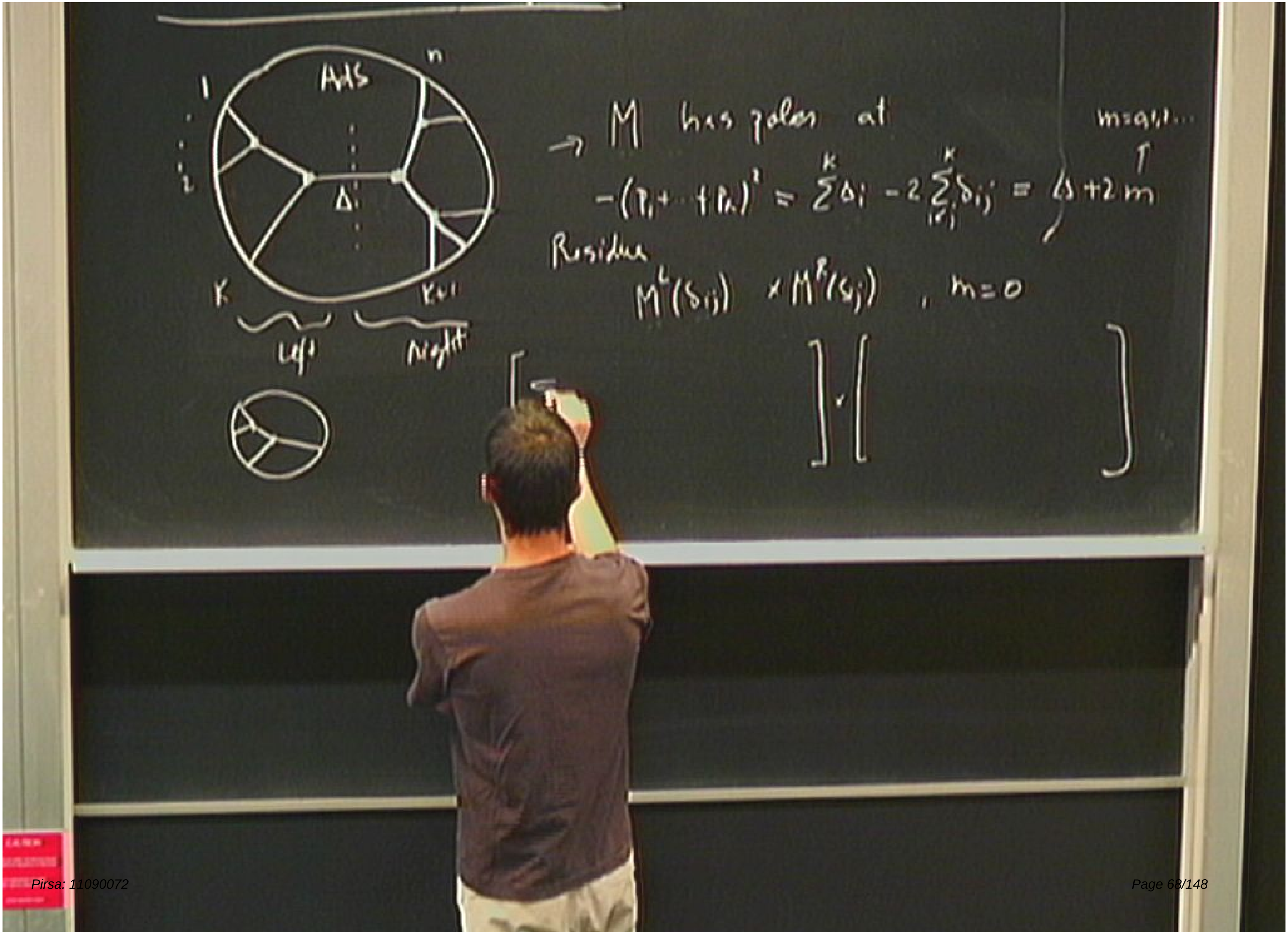

Tree-level Witten diagrams
AdS
1
2
k
k+1
n
Δ
→ M has poles at
m=0,1,...
−(p1+...+pk)² = Σ Δi − 2 Σ δij = Δ+2m

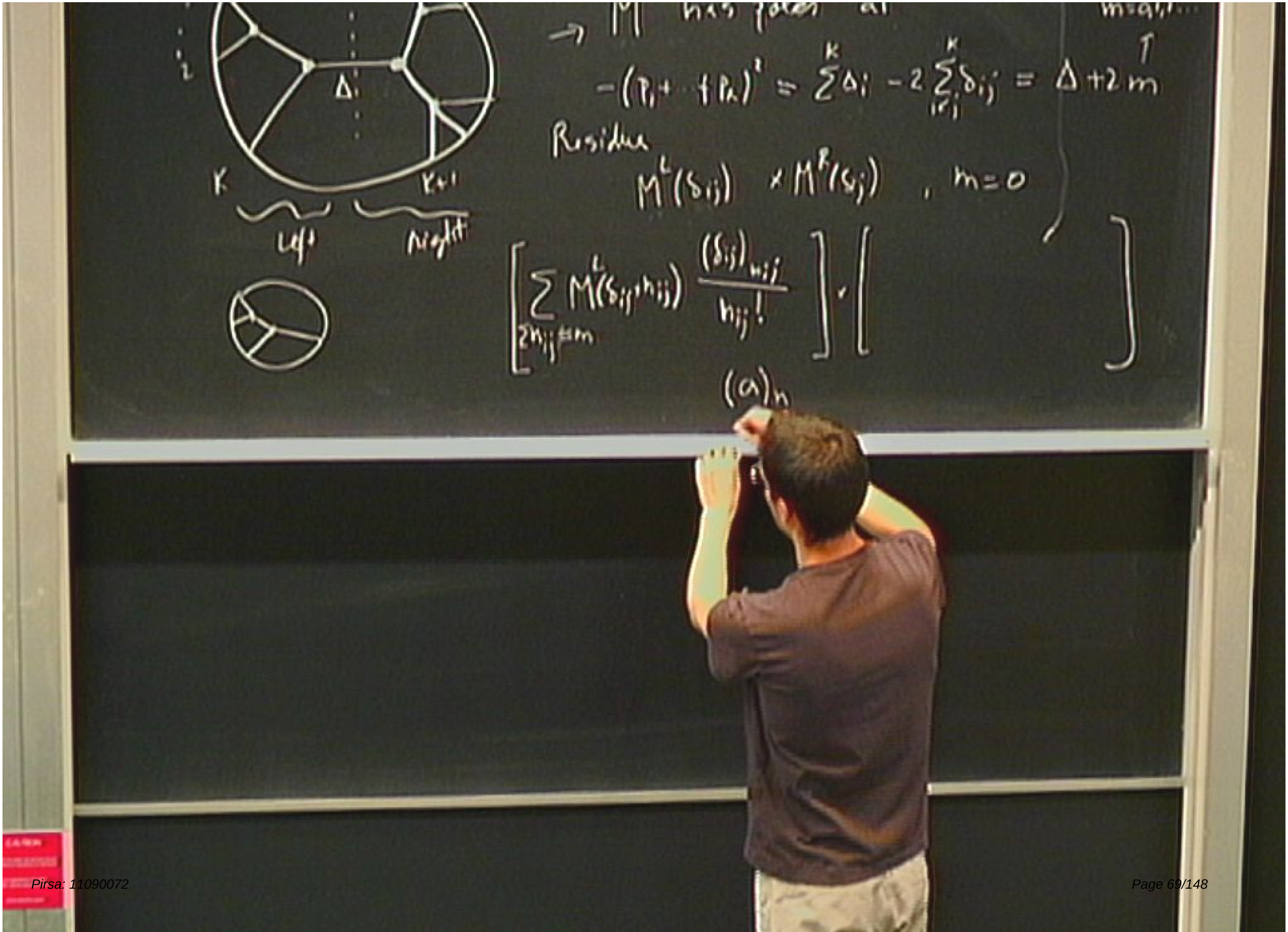

Tree-level Witten diagrams
AdS
1
i
k
k+1
n
Δ
→ M has poles at , m=0,1,...
−(p₁+…+p_k)² = Σ^k Δ_i − 2 Σ^k_{i<j} δ_ij = Δ+2m
Residue

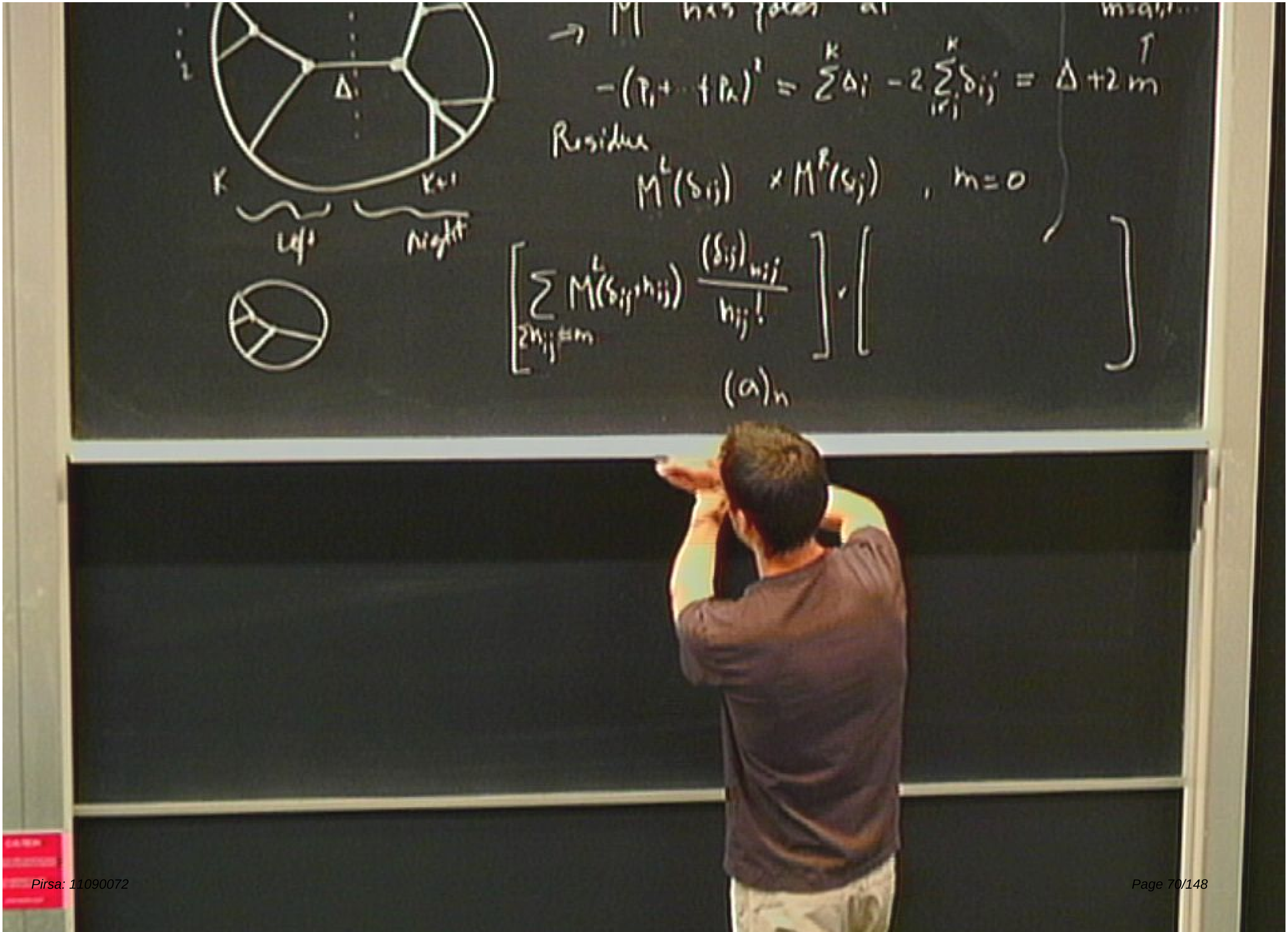

Tree-level Witten diagrams
AdS
1
2
k
k+1
n
Δ_i
left
right
→ M has poles at
$-(p_1 + \dots + p_k)^2 = \sum^k \Delta_i - 2 \sum^k_{i<j} \delta_{ij} = \Delta + 2m$
Residue
$M^L(\delta_{ij}$


Tree-level Witten diagrams
AdS
1
n
k
→ M has poles at
m=0,1,...
$-(p_1+\dots+p_k)^2 = \sum^k \Delta_i - 2\sum^k_{i<j} \delta_{ij} = \Delta + 2m$
Residue
$M^L(\delta_{ij}) \times M^R(\delta_{ij})$, m=0

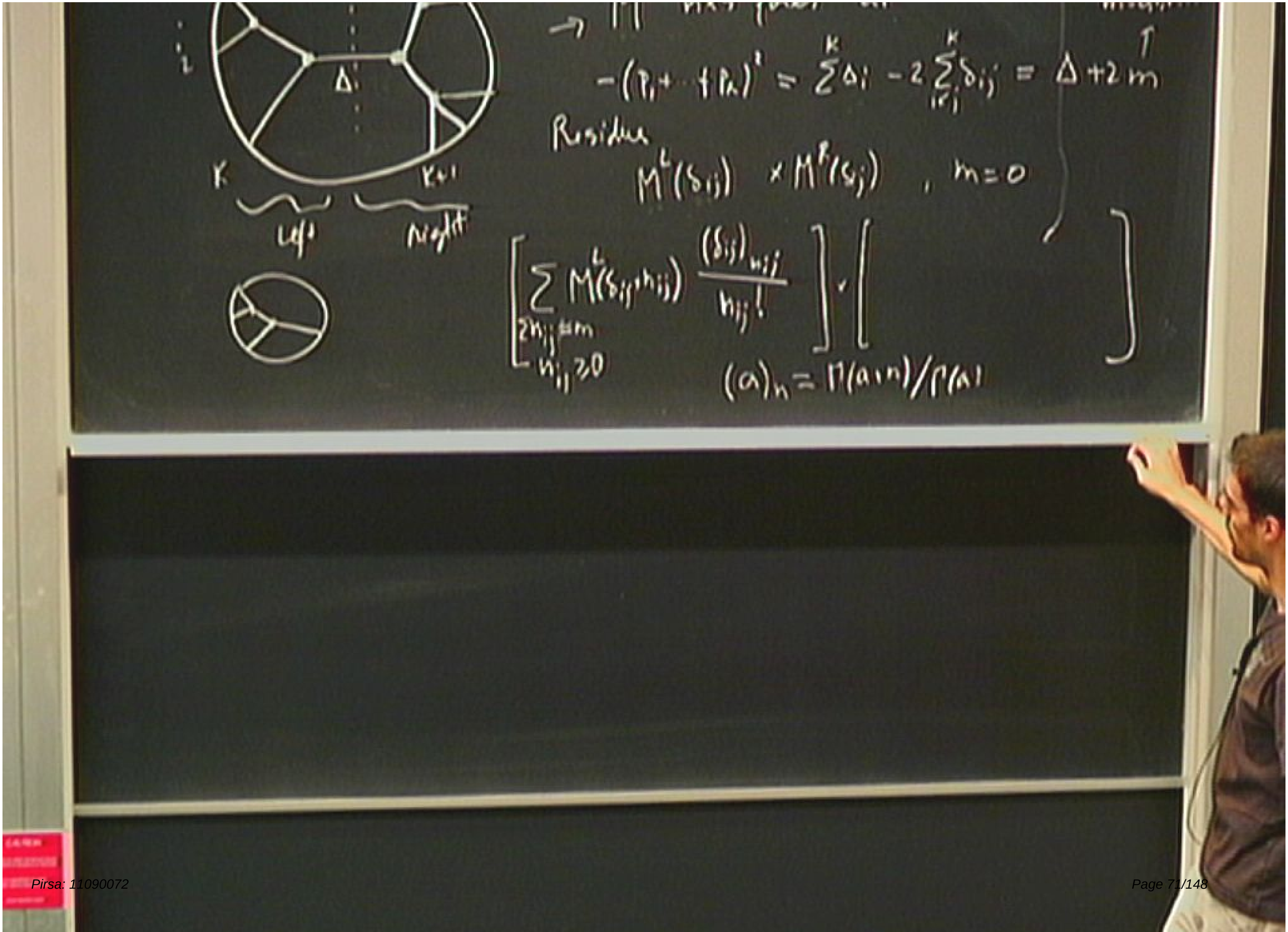

Tree-level Witten diagrams
AdS
M has poles at
Residue
m=0
Left
Right


AdS
1
i
k
k+1
n
Δ
Left
Right
→ M has poles at
m=0,1,...
Residue
m=0

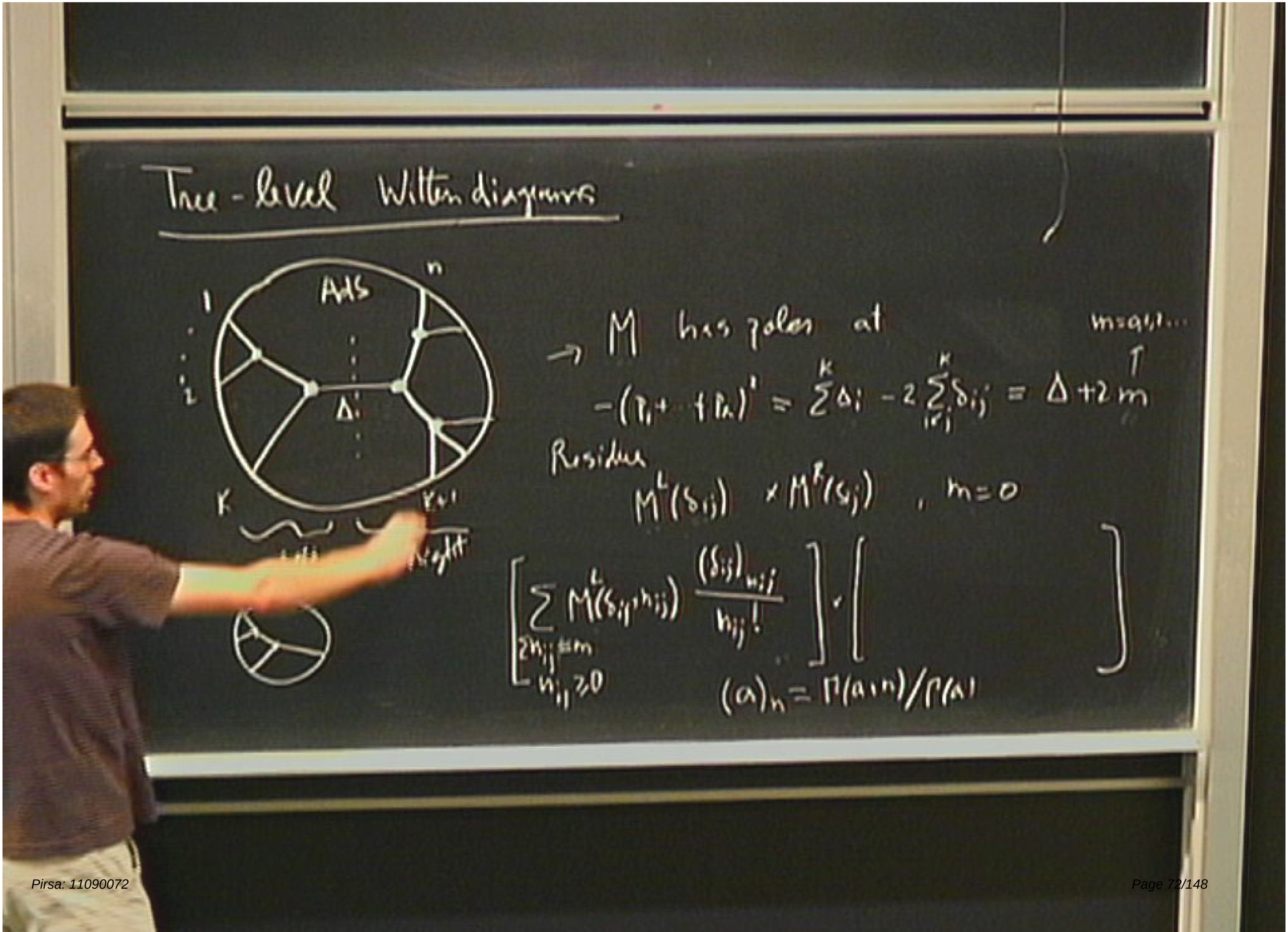

Residue
$M^L(s_{ij}) \times M^R(s_{ij})$, $m=0$
$-(p_1+\dots+p_k)^2 = \sum^k \Delta_i - 2\sum_{i<j}^k s_{ij} = \Delta + 2m$
left
right

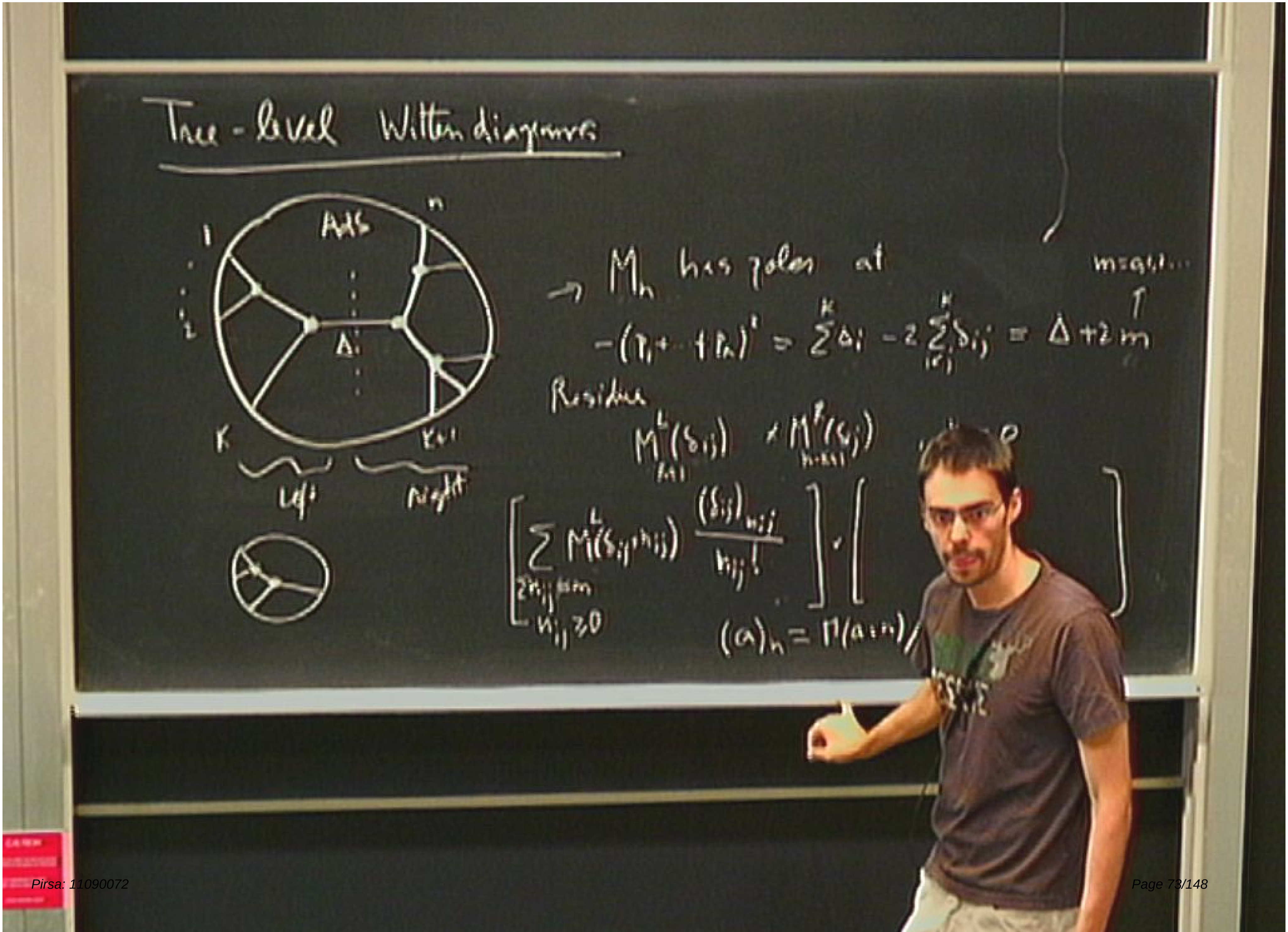


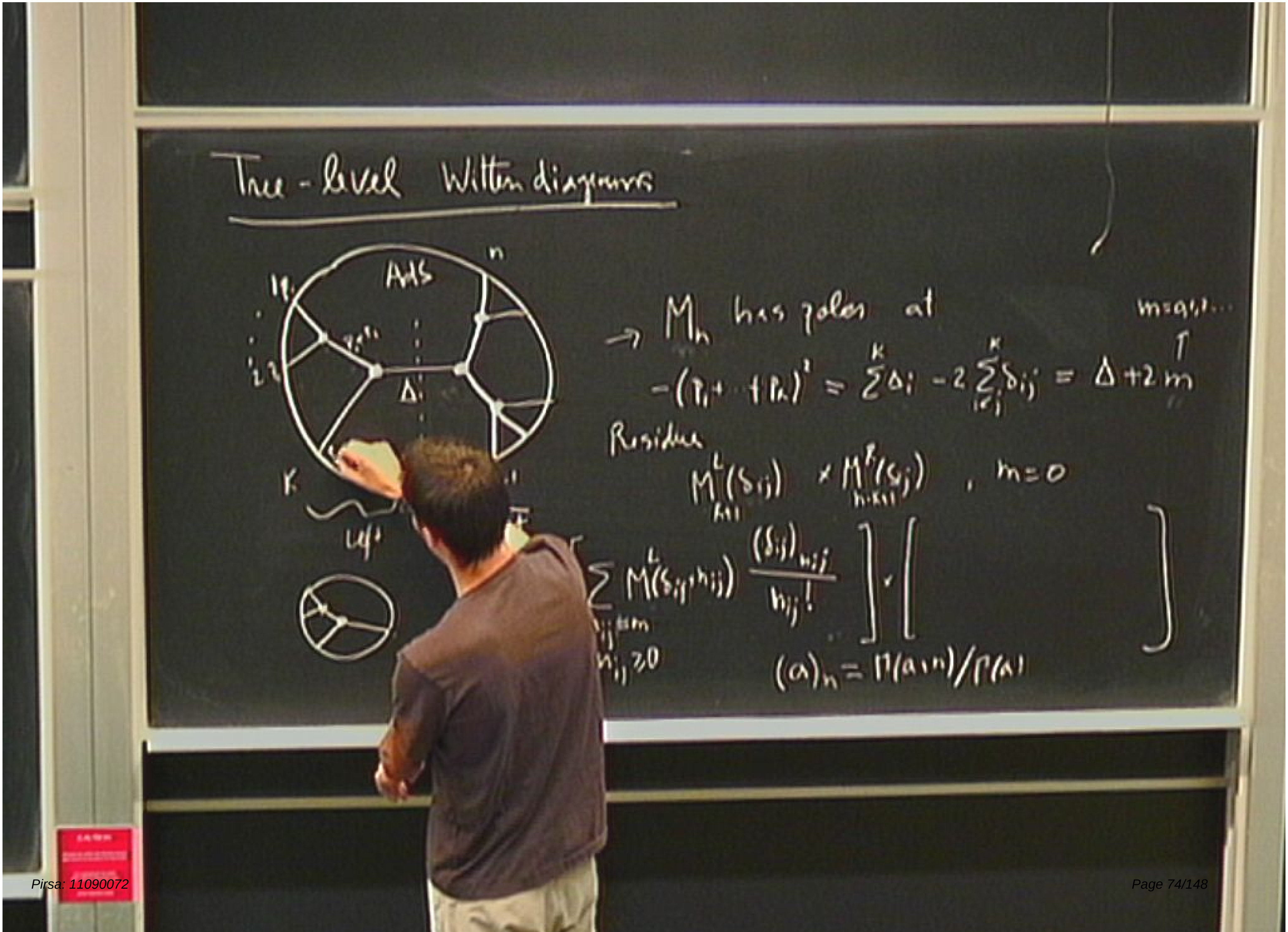
Δ
k
k+1
left
right
-(p1+...+pk)^2 = Σ Δi - 2 Σ sij = Δ + 2m
Residue
M^L(sij) × M^R(sij) , m=0
(a)n

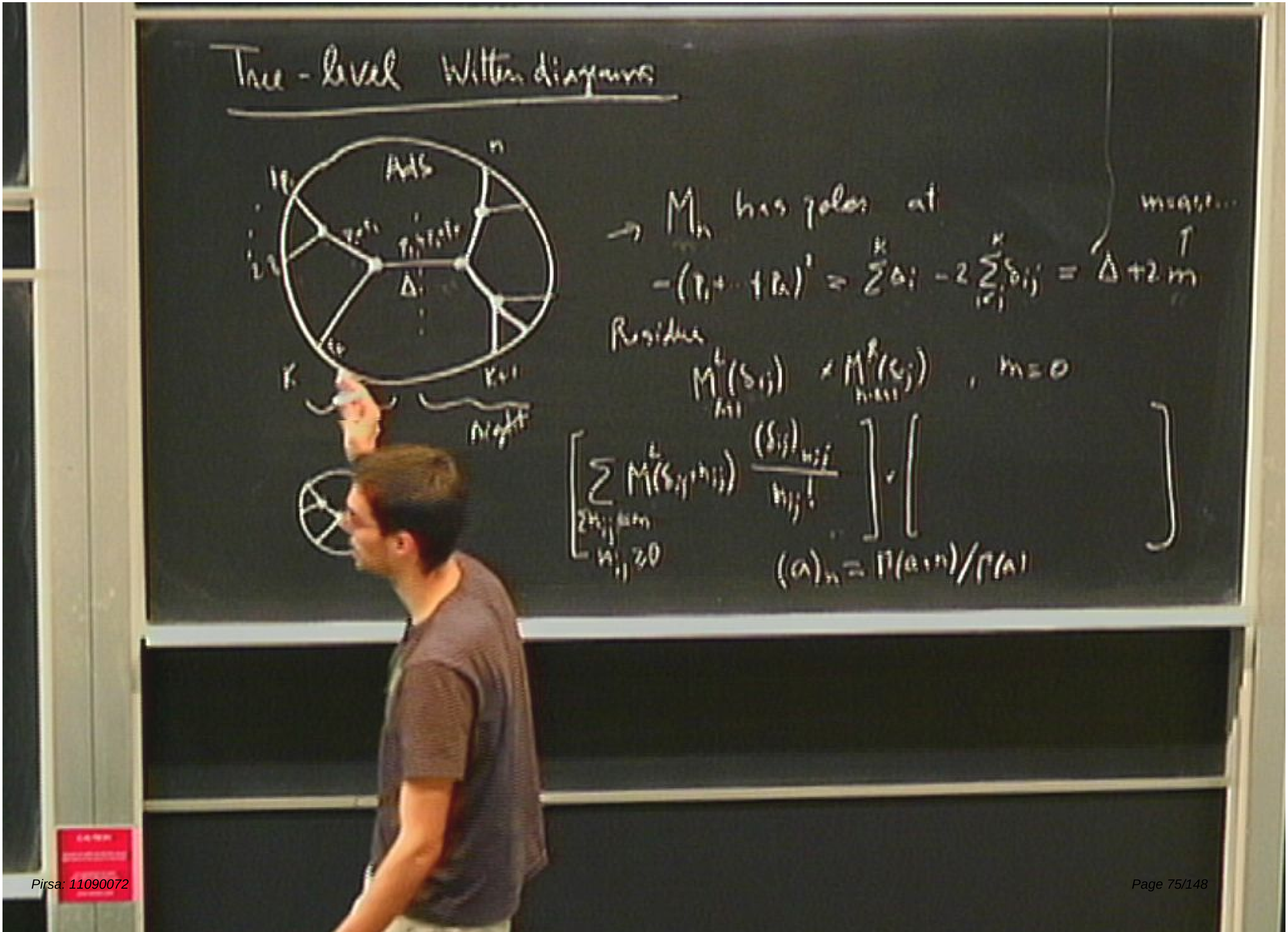


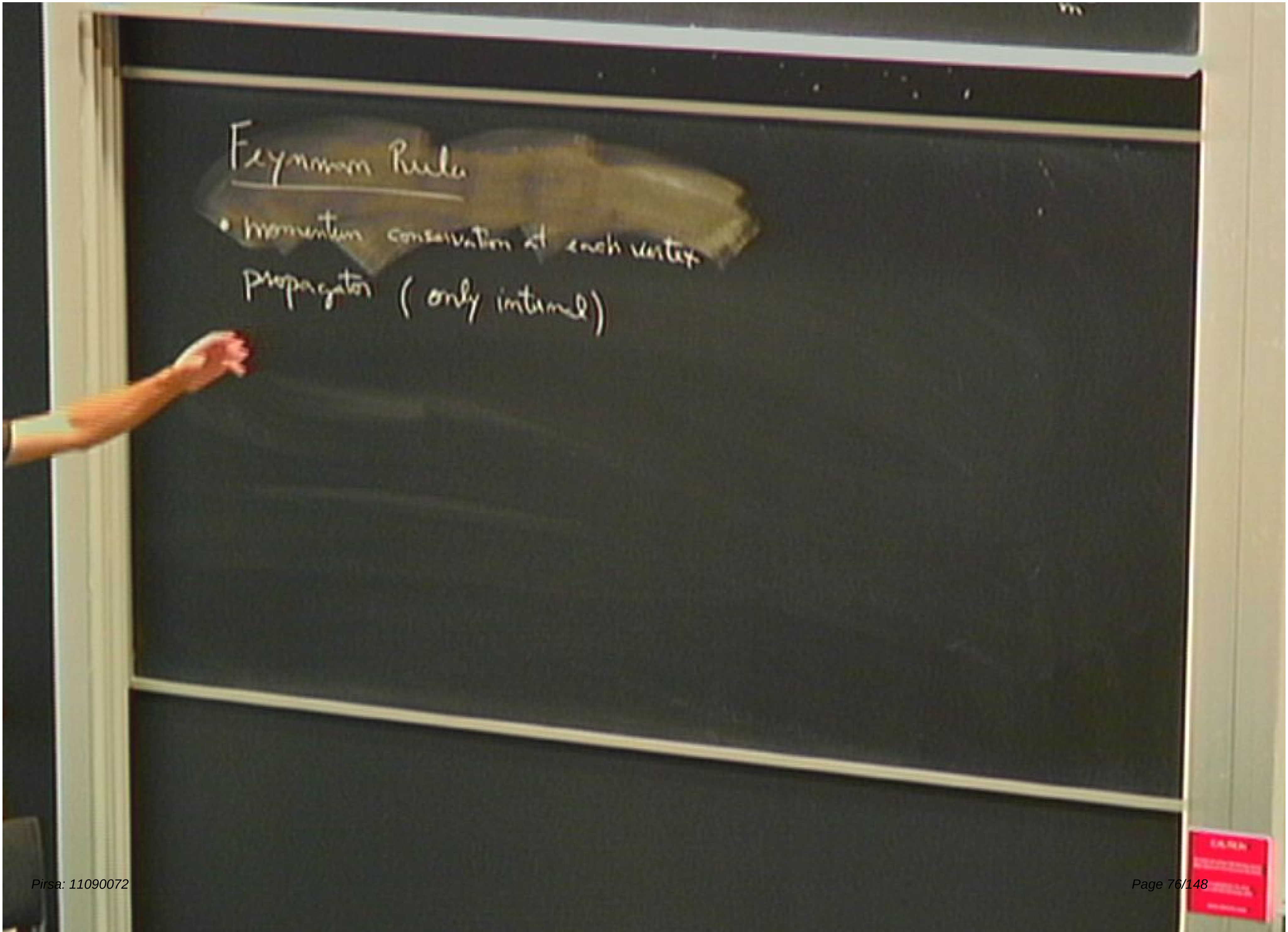
Δ_i
k
k+1
left
right
$-(p_1+\cdots+p_k)^2 = \sum^k \Delta_i - 2\sum^k_{i<j} \delta_{ij} = \Delta + 2m$
Residue
$M^L(\delta_{ij}) \times M^R(\delta_{ij})$, $m=0$
$\left[\sum M^L(\delta_{ij}+n_{ij}) \frac{(\delta_{ij})_{n_{ij}}}{n_{ij}!}\right] \times \left[\quad \right]$
$\sum n_{ij} = m$
$n_{ij} \geq 0$
$(a)_n = \Gamma(a+n)/\Gamma(a)$

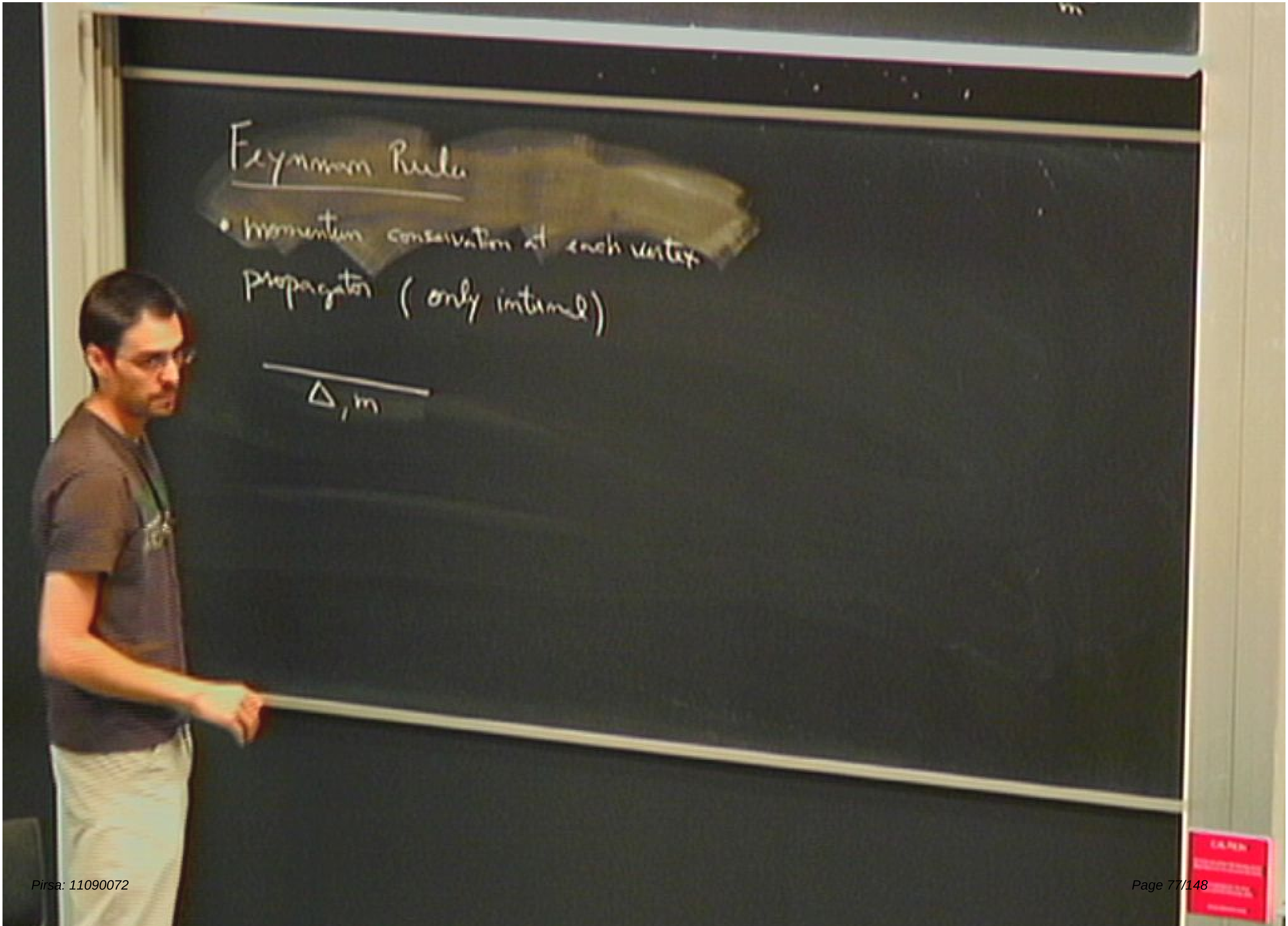

Tree-level Witten diagrams
AdS
M has poles at
m=0,1,2...
Residue
m=0
right
(a)_n = Γ(a+n)/Γ(a)

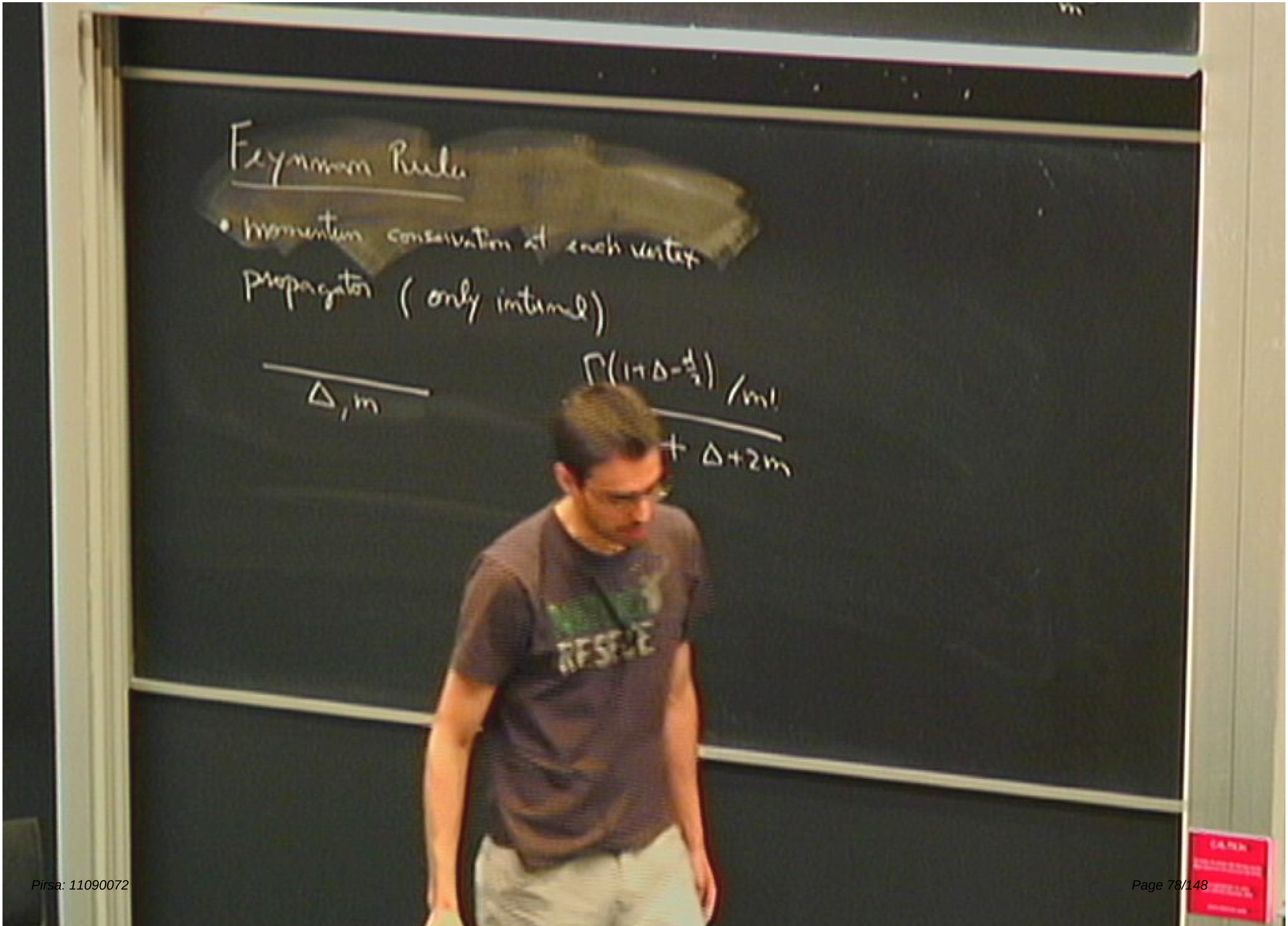

Tree-level Witten diagrams
AdS
Residue
Left
Right

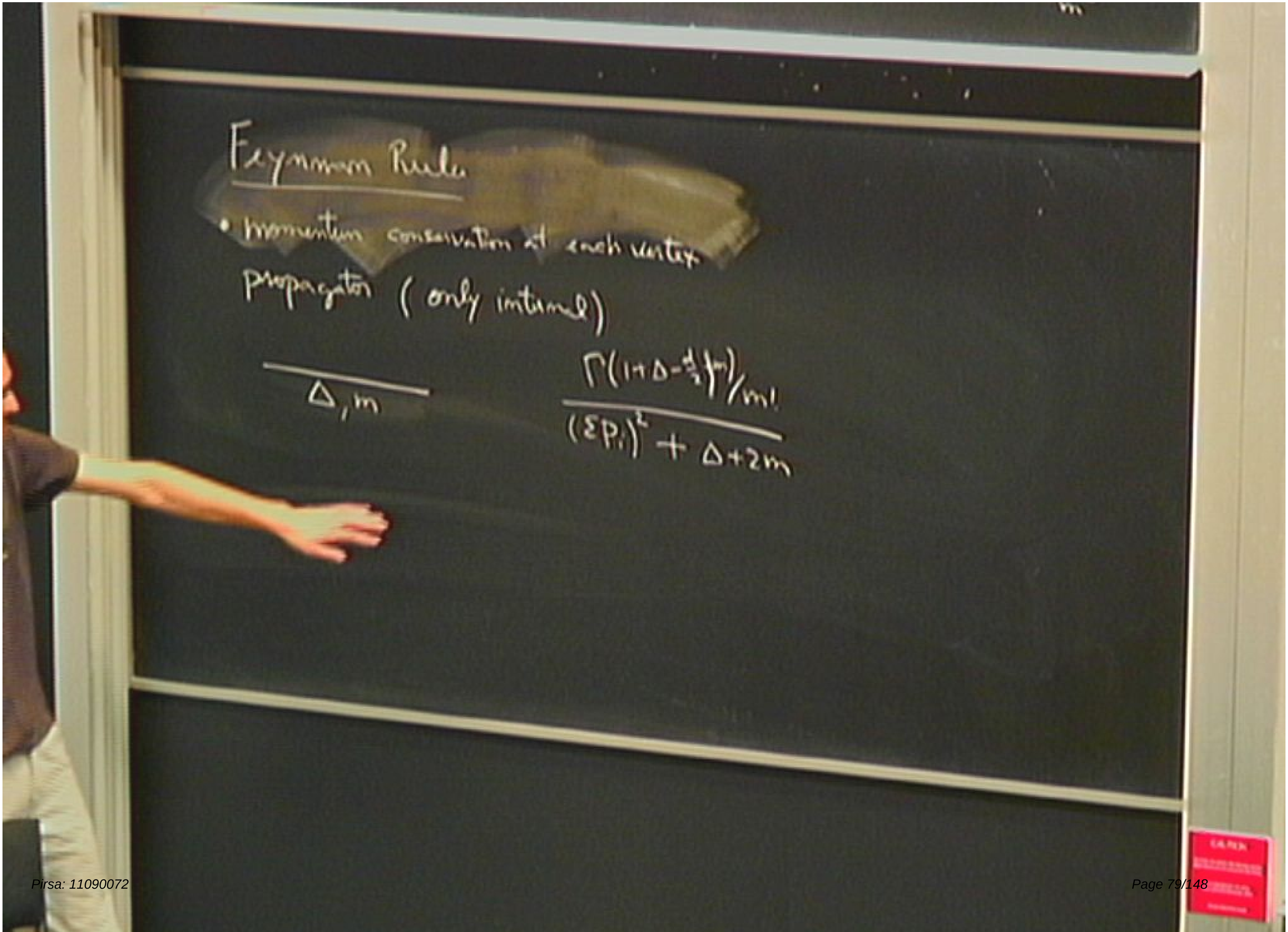

Tree-level Witten diagrams
AdS
M_n has poles at
$m = 0, 1, \ldots$
$-(p_1 + \cdots + p_k)^2 = \sum^k \Delta_i - 2 \sum^k_{i<j} \delta_{ij} = \Delta + 2m$
Residue
$M^L_{k+1}(\delta_{ij}) \times M^R_{n-k+1}(\delta_{ij})$, $m = 0$
$(a)_n = \Gamma(a+n)/\Gamma(a)$

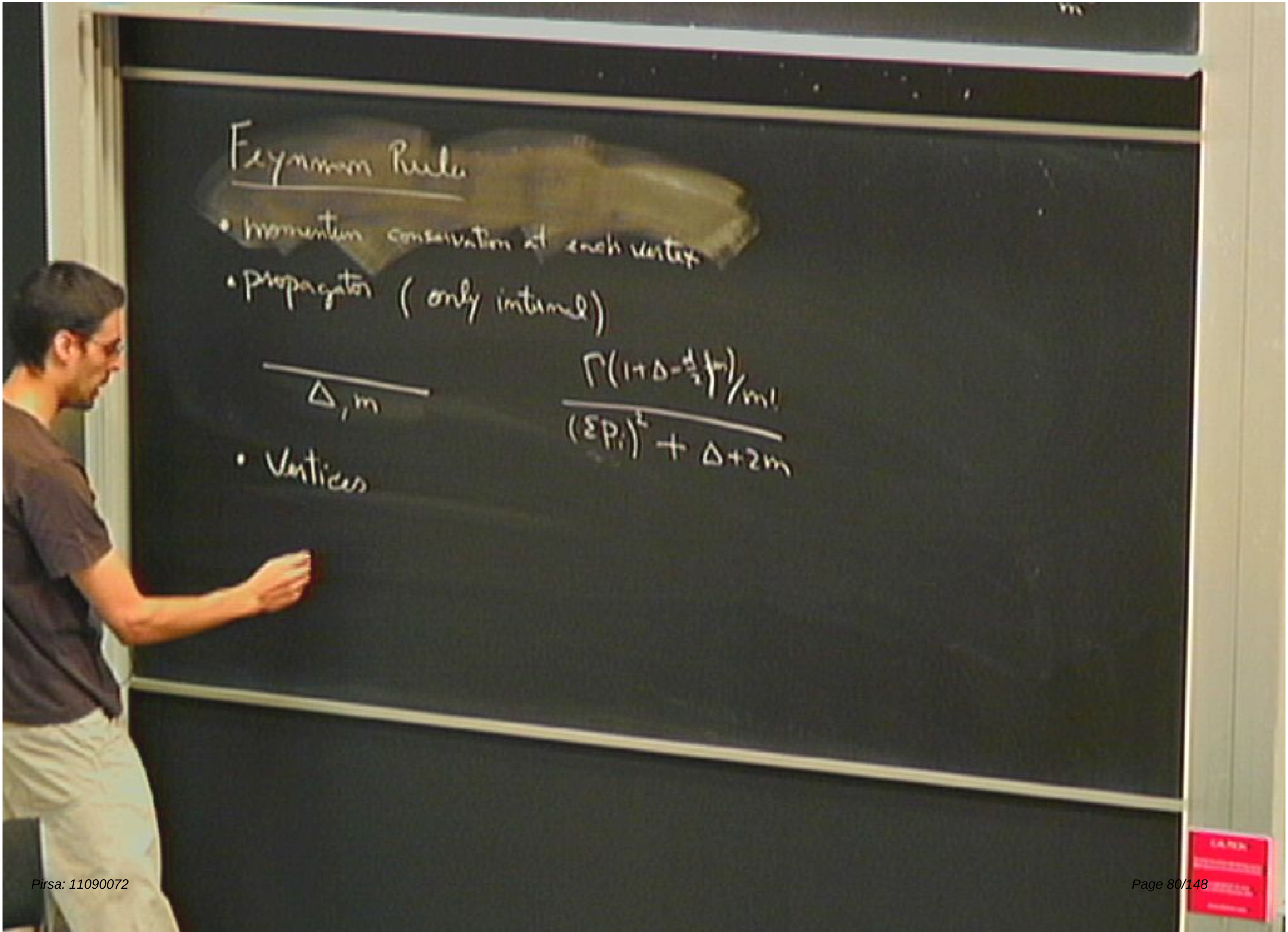

Tree-level Witten diagrams
AdS
M_n has poles at
Residue
m=0
Right
((a)_n = Γ(a+n)/Γ(a)

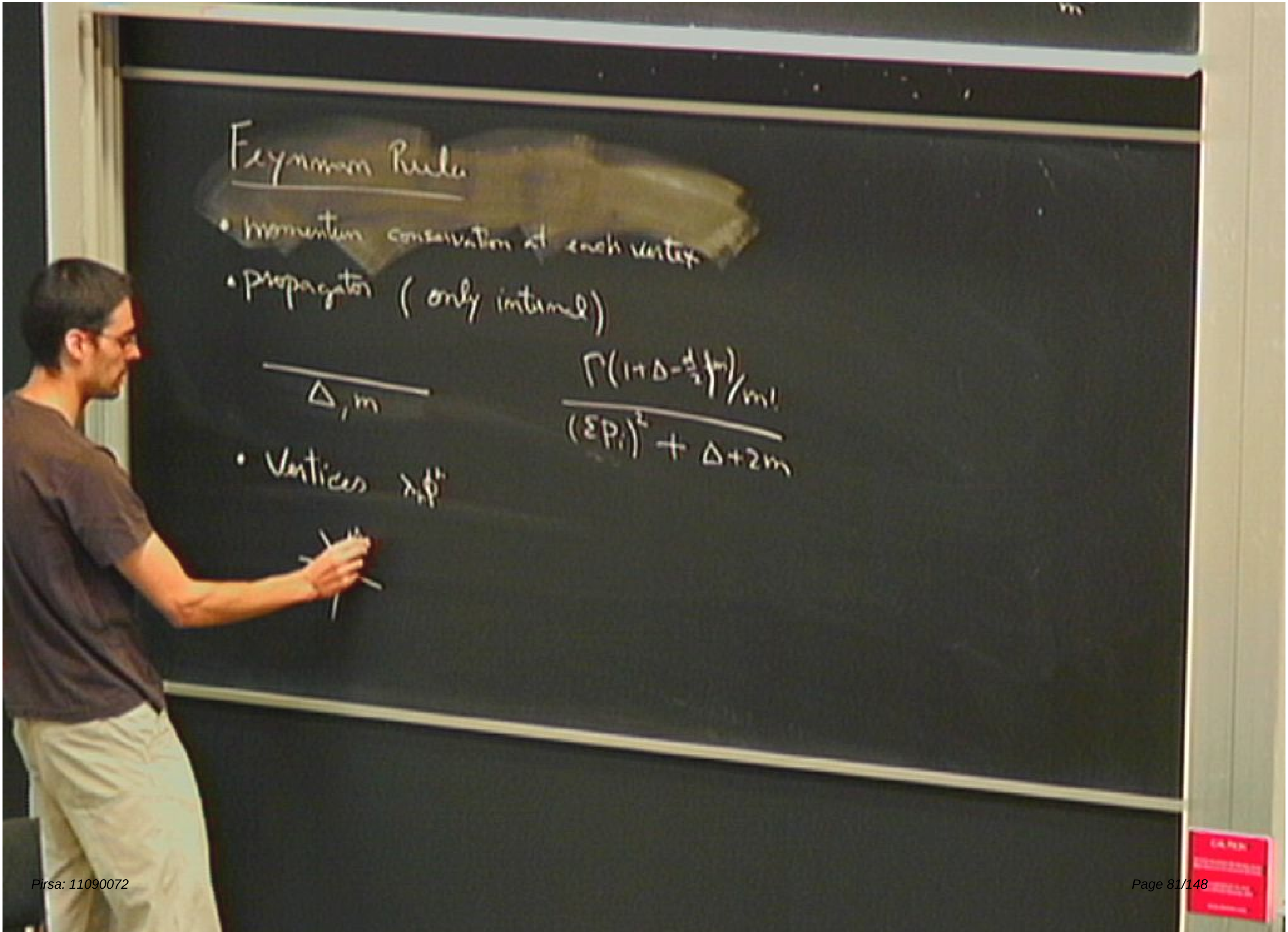

Feynman Rules
• momentum conservation at each vertex
propagator (only internal)

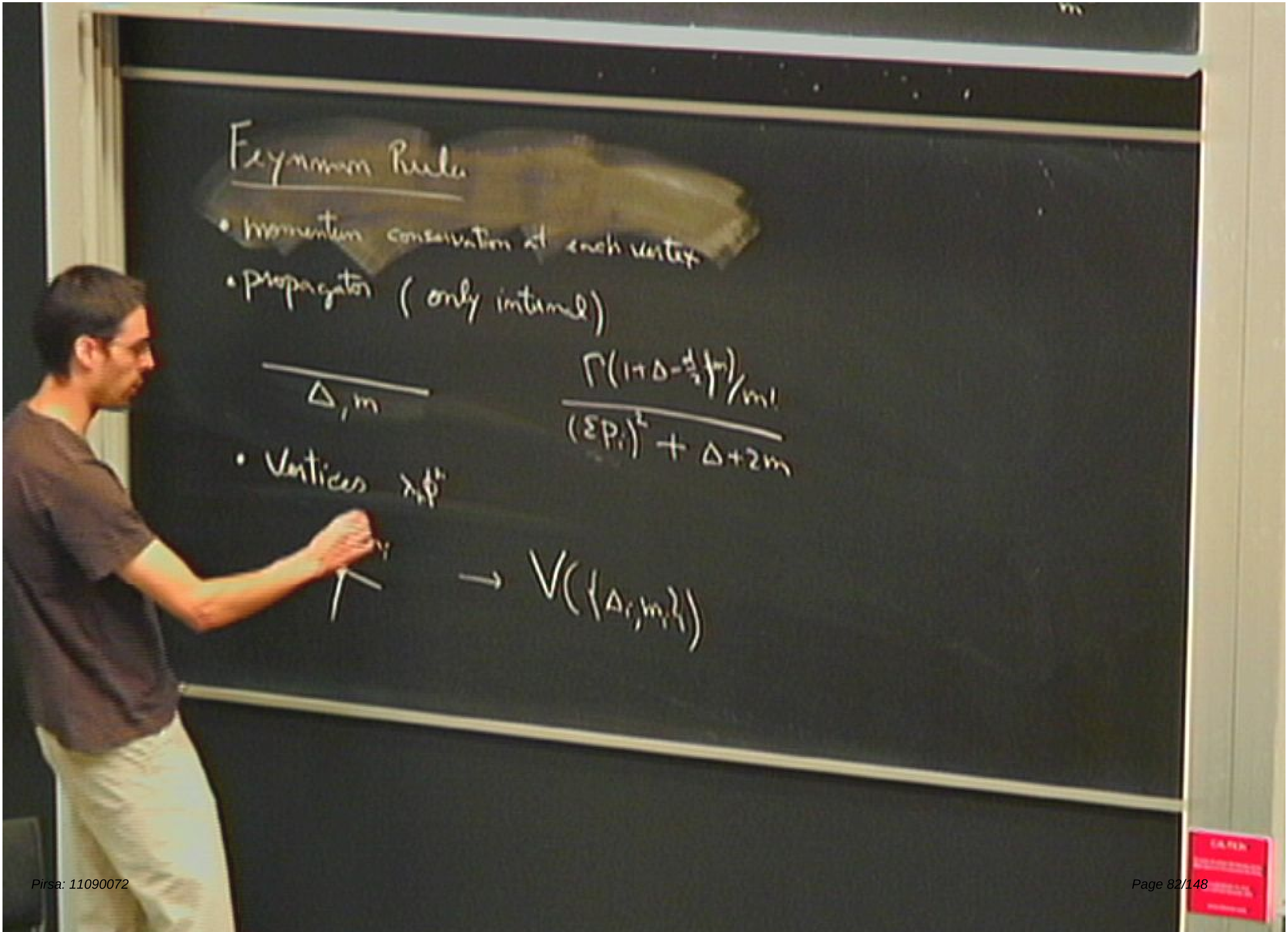

Feynman Rules
• momentum conservation at each vertex
propagator (only internal)
Δ, m

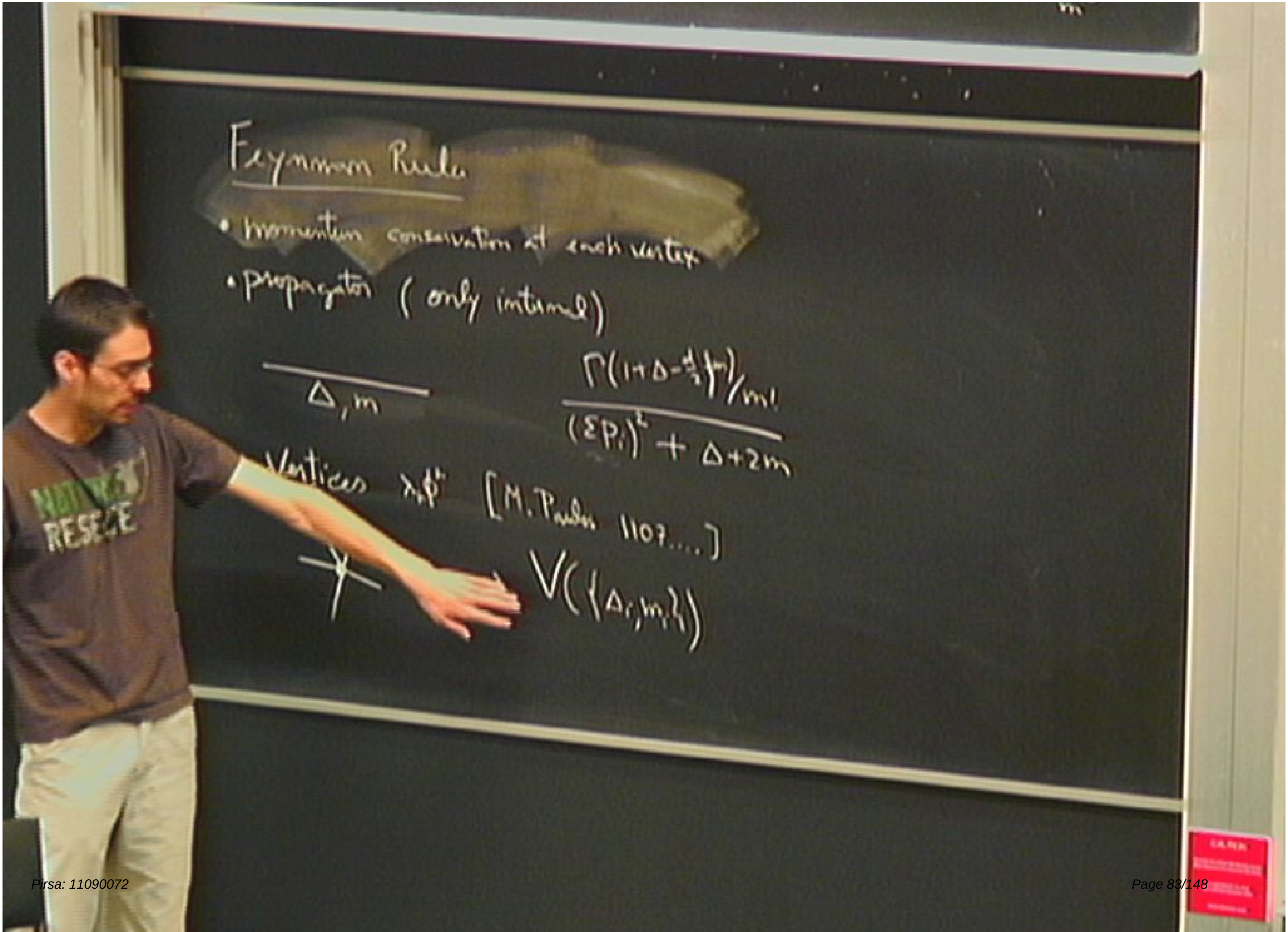

Feynman Rules
• momentum conservation at each vertex
propagator (only internal)
Δ, m
Γ(1+Δ−d/2) /m!
+ Δ+2m


Feynman Rules
• momentum conservation at each vertex
propagator (only internal)
Δ, m
Γ(1+Δ−d/2+m)/m!
(Σpᵢ)² + Δ+2m


Feynman Rules
• momentum conservation at each vertex
• propagator (only internal)
Δ, m
Γ(1+Δ−d/2+m)/m!
(Σp_i)^2 + Δ+2m
• Vertices


Feynman Rules
• momentum conservation at each vertex
• propagator (only internal)
Δ, m
Γ(1+Δ−d/2+m)/m!
(Σp_i)^2 + Δ+2m
• Vertices λ_n φ^n


Feynman Rules
• momentum conservation at each vertex
• propagator (only internal)
Δ, m
Γ(1+Δ−d/2 m)/m!
(Σp_i)² + Δ + 2m
• Vertices λ_n φ^n
→ V({Δ_i, m_i})


Feynman Rules
• momentum conservation at each vertex
• propagator (only internal)
Δ, m
(Σp_i)^2 + Δ+2m
Vertices
[M. Paulos 1107....]
V({Δ_i, m_i})

Feynman Rules

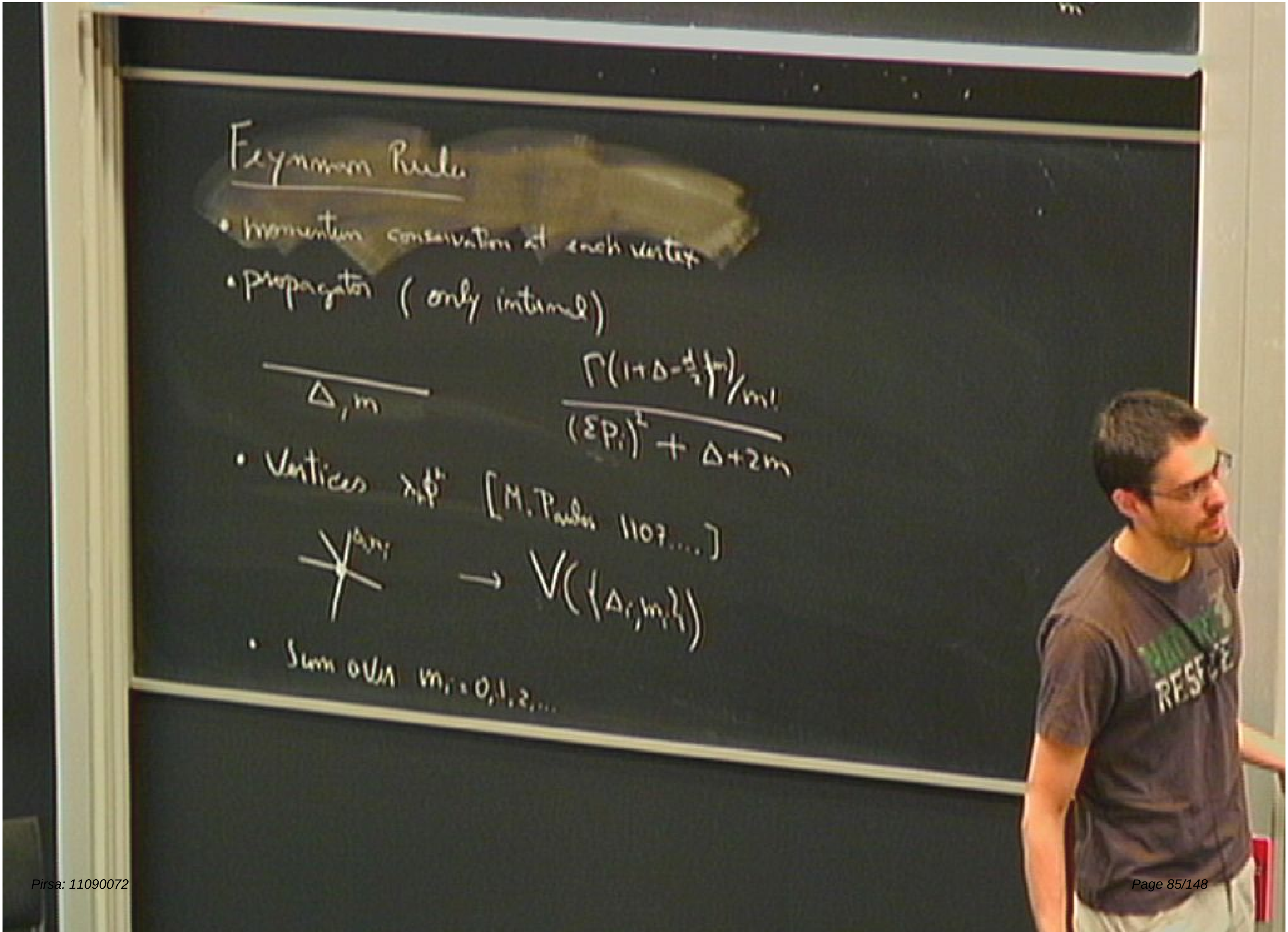
- momentum conservation at each vertex
- propagator (only internal)

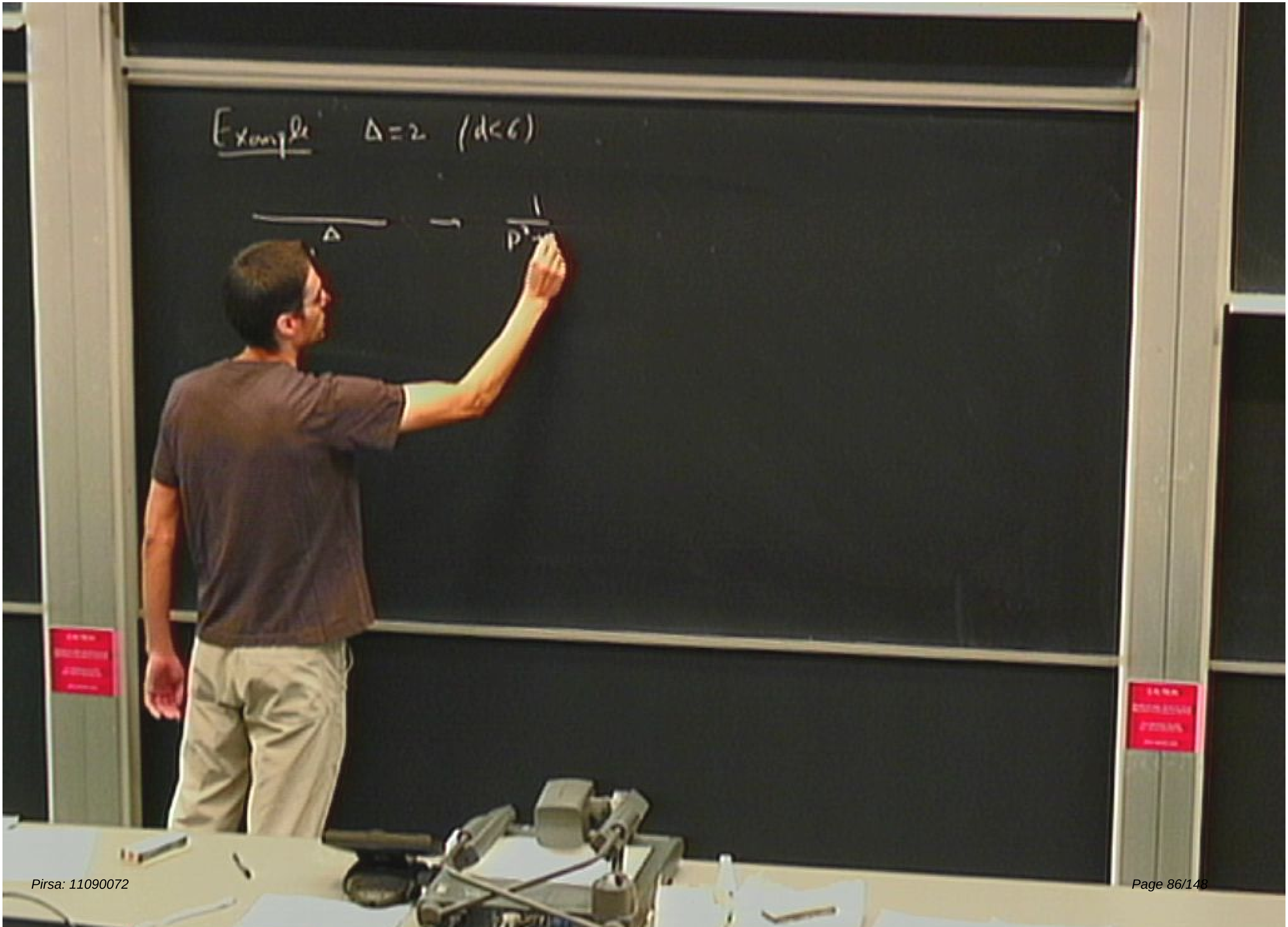
$$\overline{\quad\Delta, m\quad} \qquad \frac{\Gamma(1+\Delta-\frac{d}{2}+m)/m!}{(\Sigma p_i)^2+\Delta+2m}$$

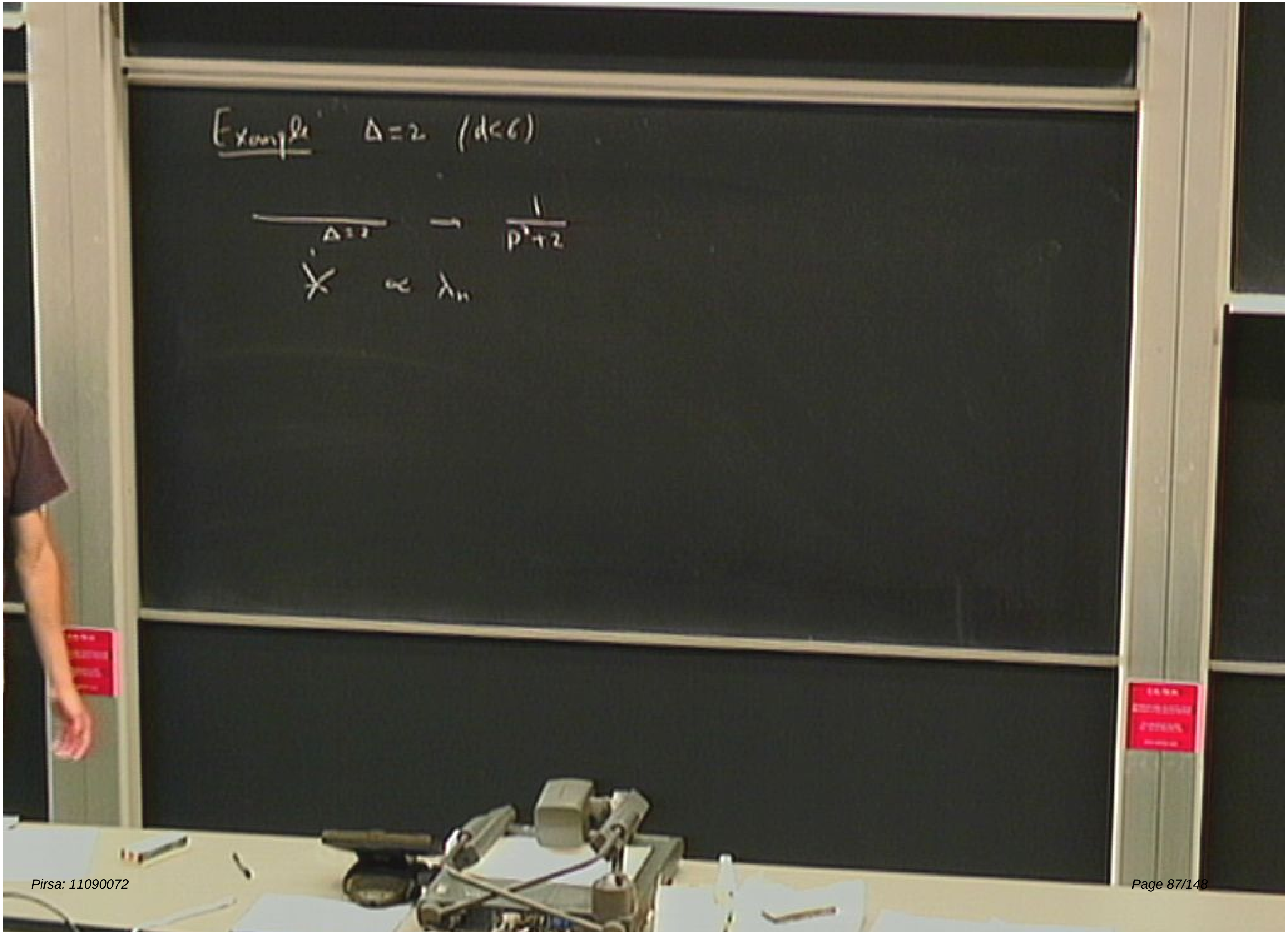
- Vertices $\lambda_n \phi^n$ [M. Paulos 1107....]

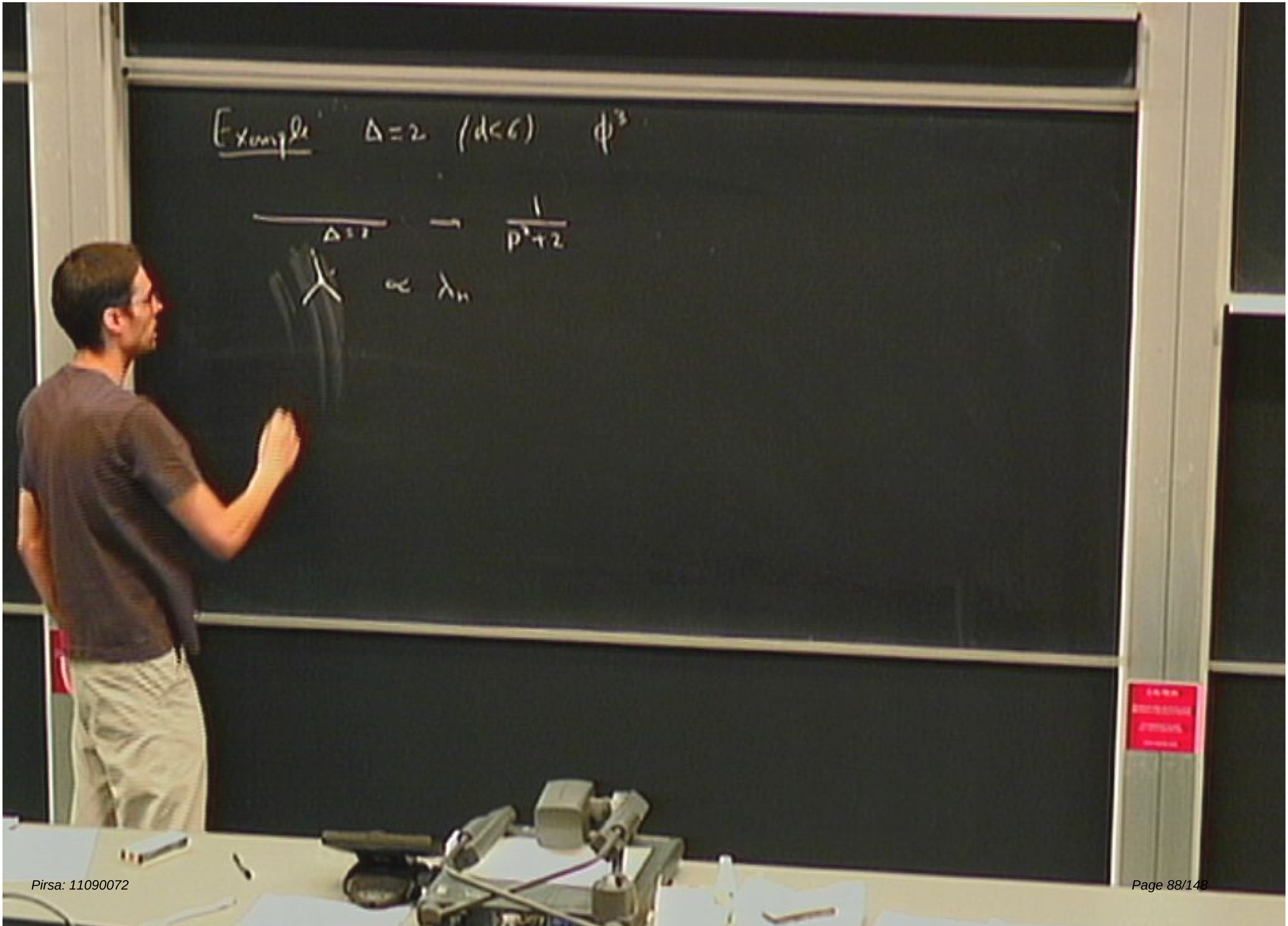
$$\longrightarrow V(\{\Delta_i, m_i\})$$

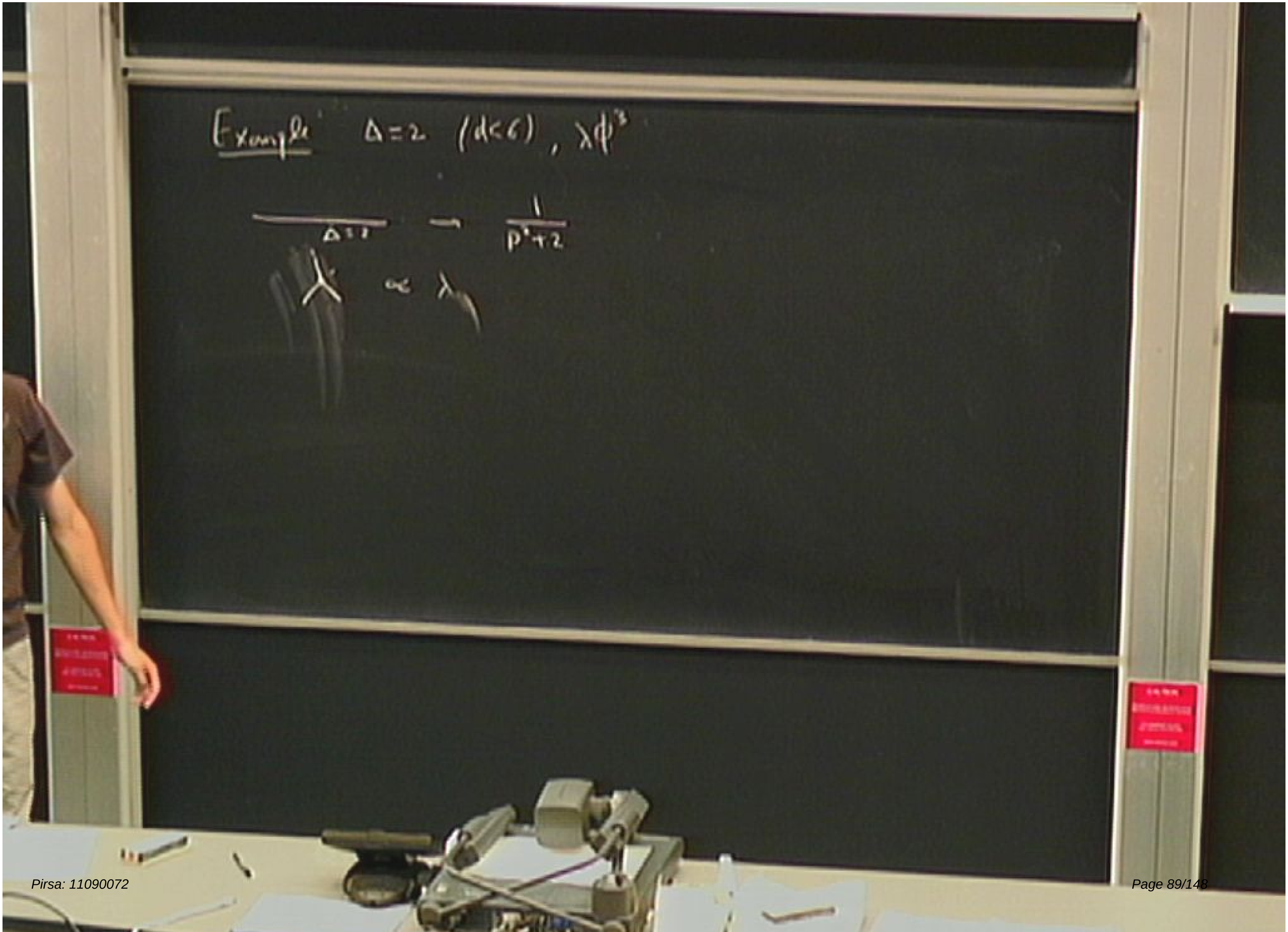
- Sum over $m_i = 0, 1, 2, \ldots$

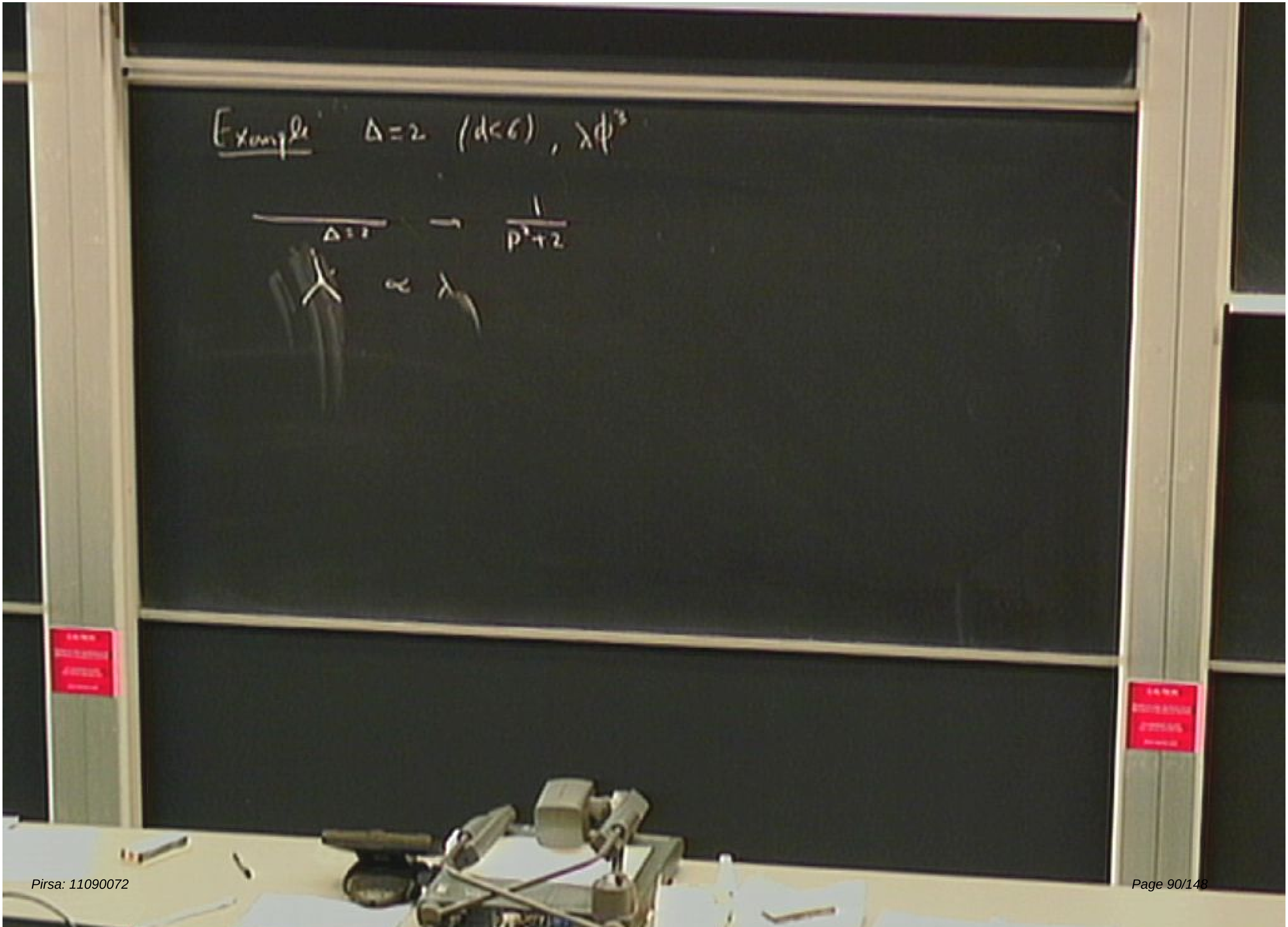

Feynman Rules
• momentum conservation at each vertex
• propagator (only internal)
Δ, m
Γ(1+Δ−d/2+m)/m!
(Σp_i)^2 + Δ+2m
• Vertices λ_n φ^n [M. Paulos 1107....]
Δ_i,m_i
→ V({Δ_i,m_i})
• Sum over m_i = 0,1,2,...

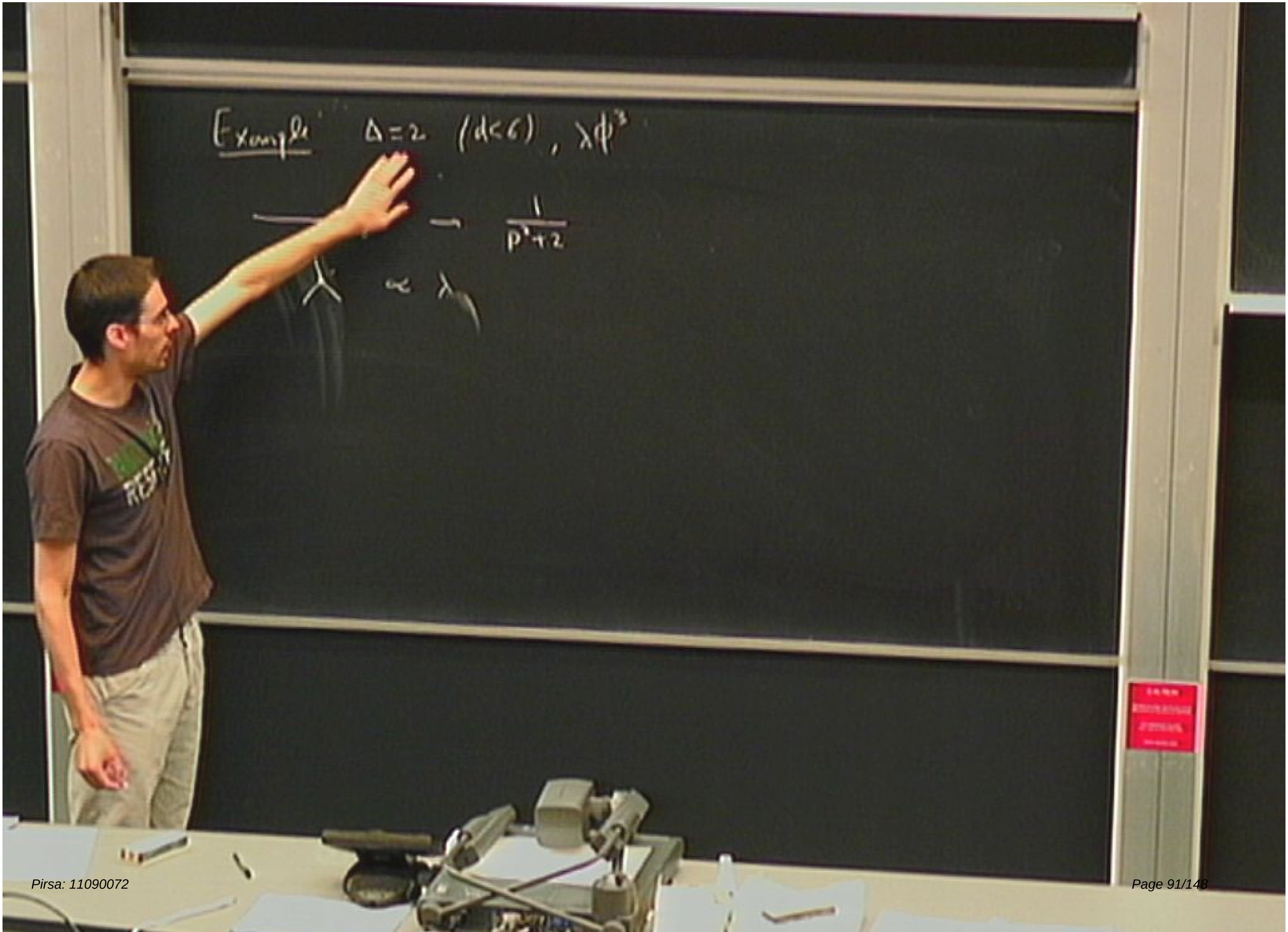

Example $\Delta = 2$ $(d<6)$
Δ
$\rightarrow$
1
p

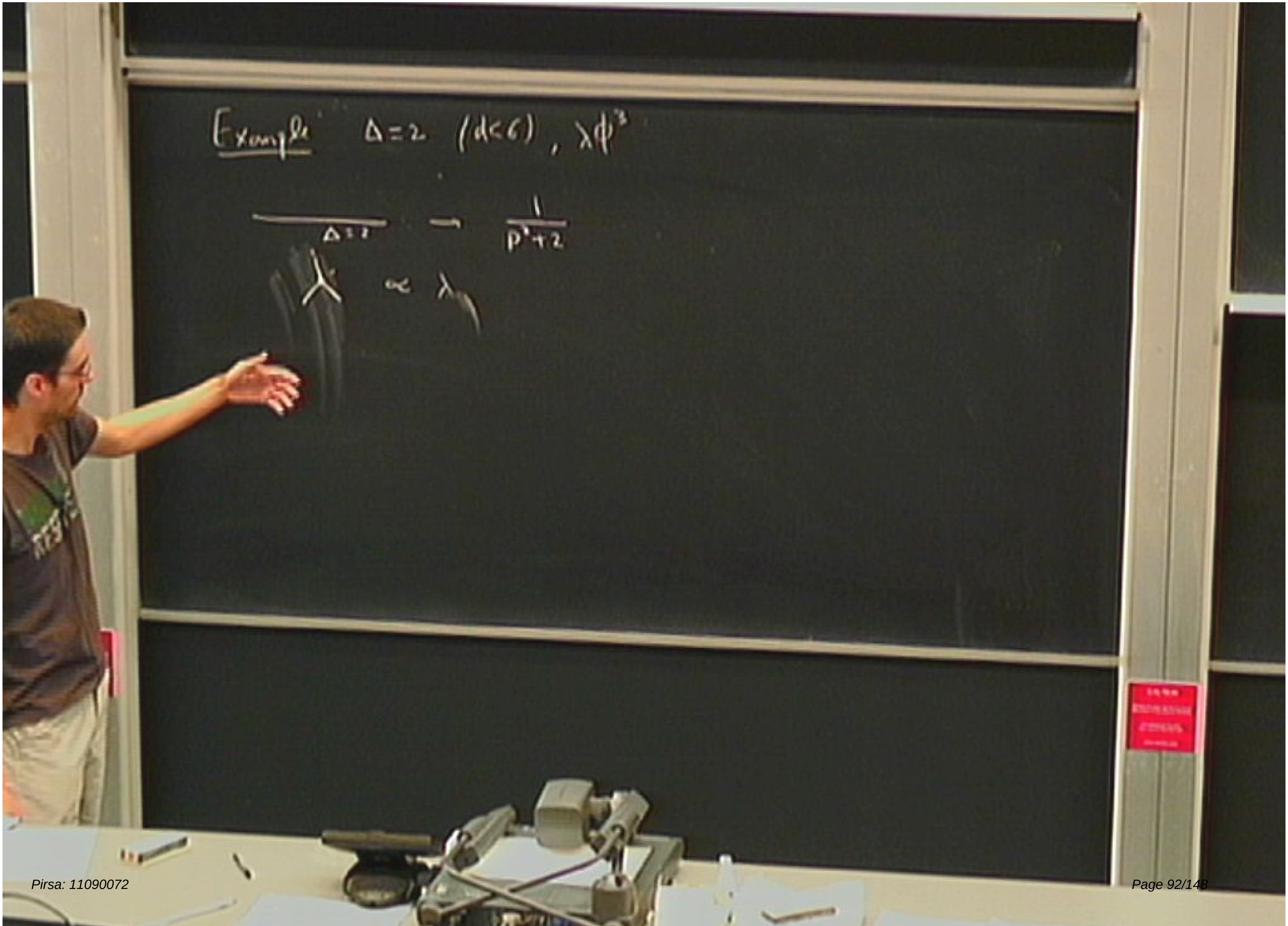

Example Δ=2 (d<6)
Δ=2
1
p²+2
∝ λn

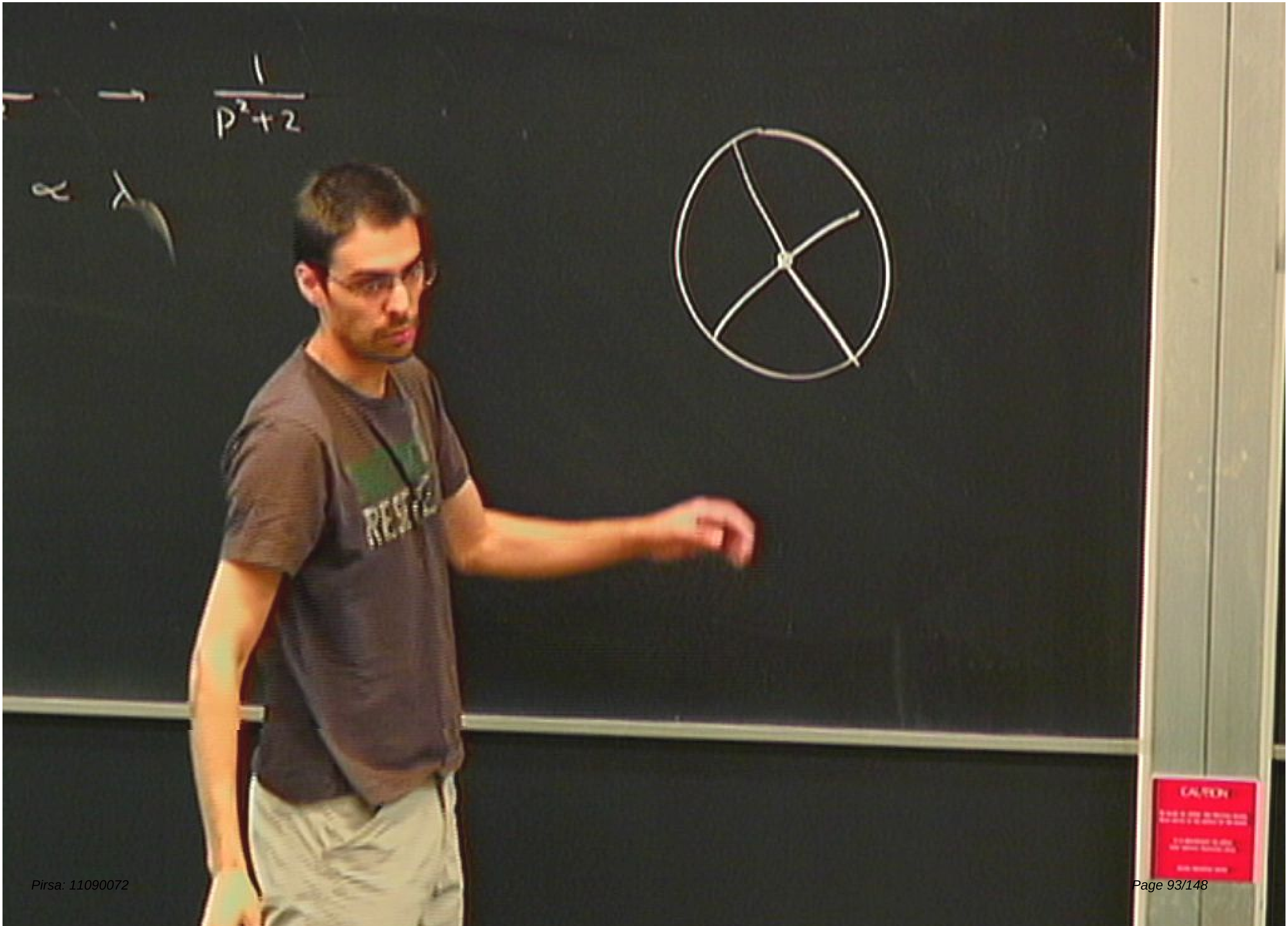

Example
Δ=2 (d<6)
φ³
1
p²+2
∝ λₙ

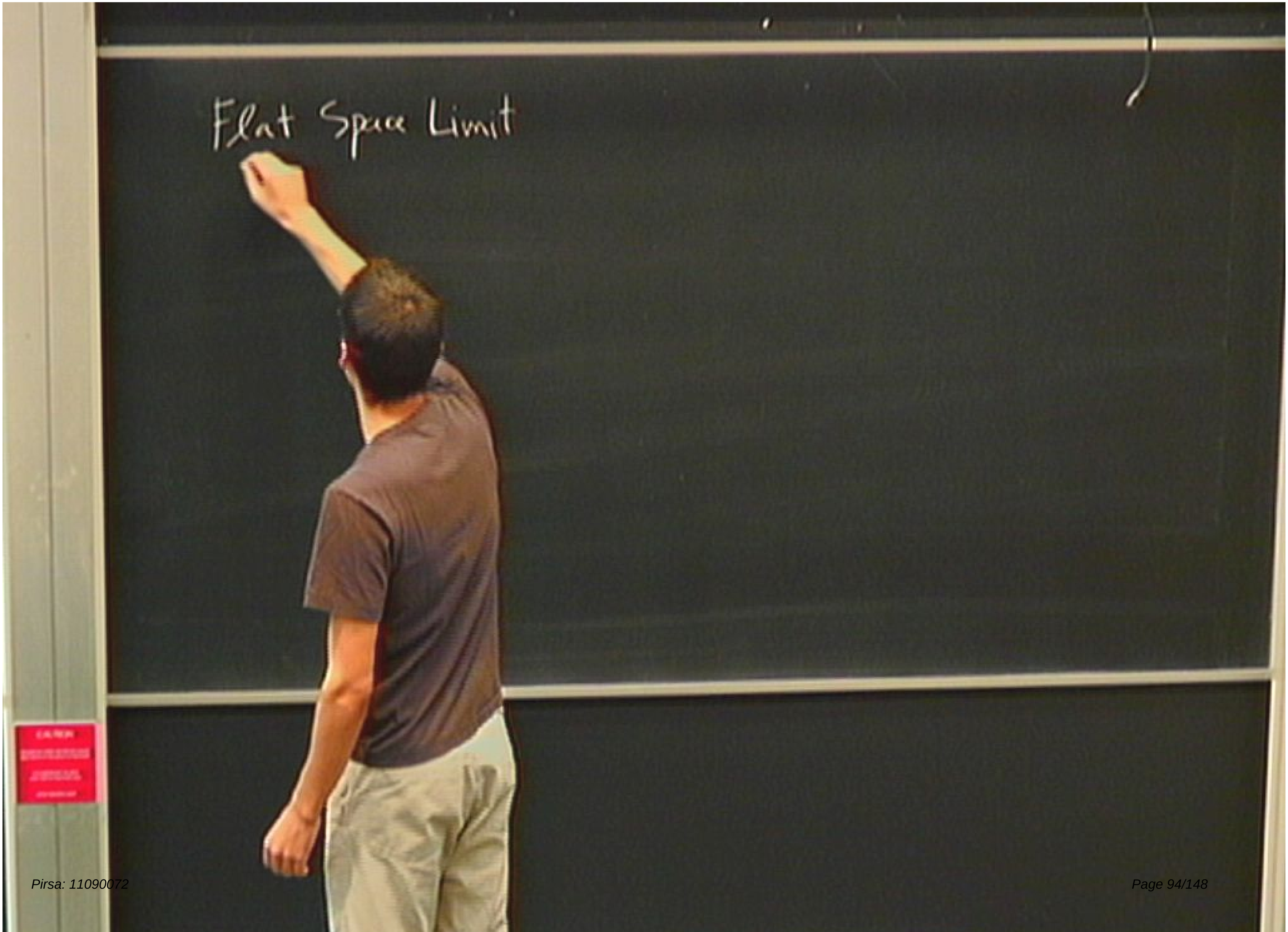

Example Δ=2 (d<6), λφ³
∝ λ

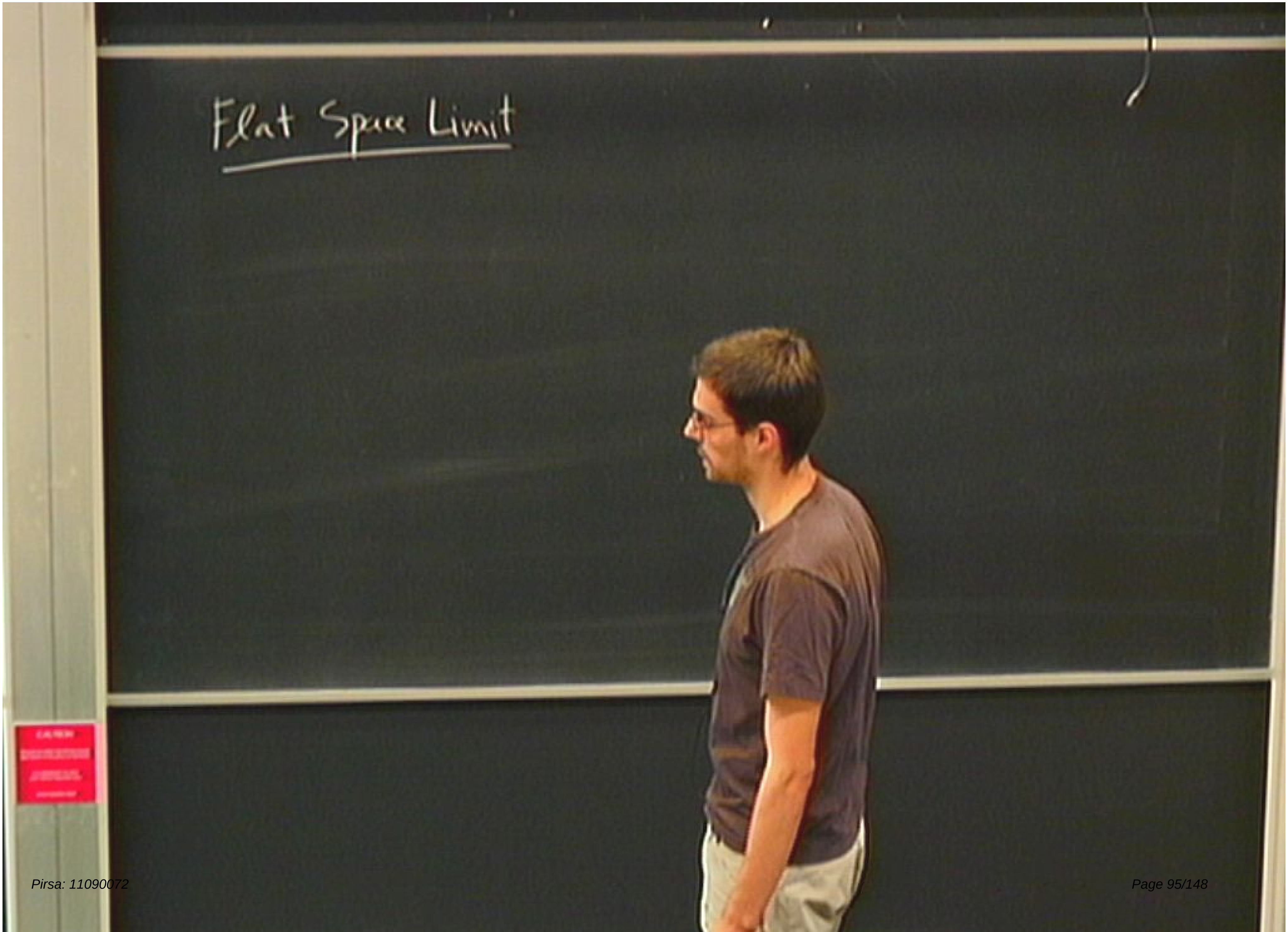

Example Δ=2 (d<6), λφ³
Δ=2 → 1/(p²+2)
∝ λ

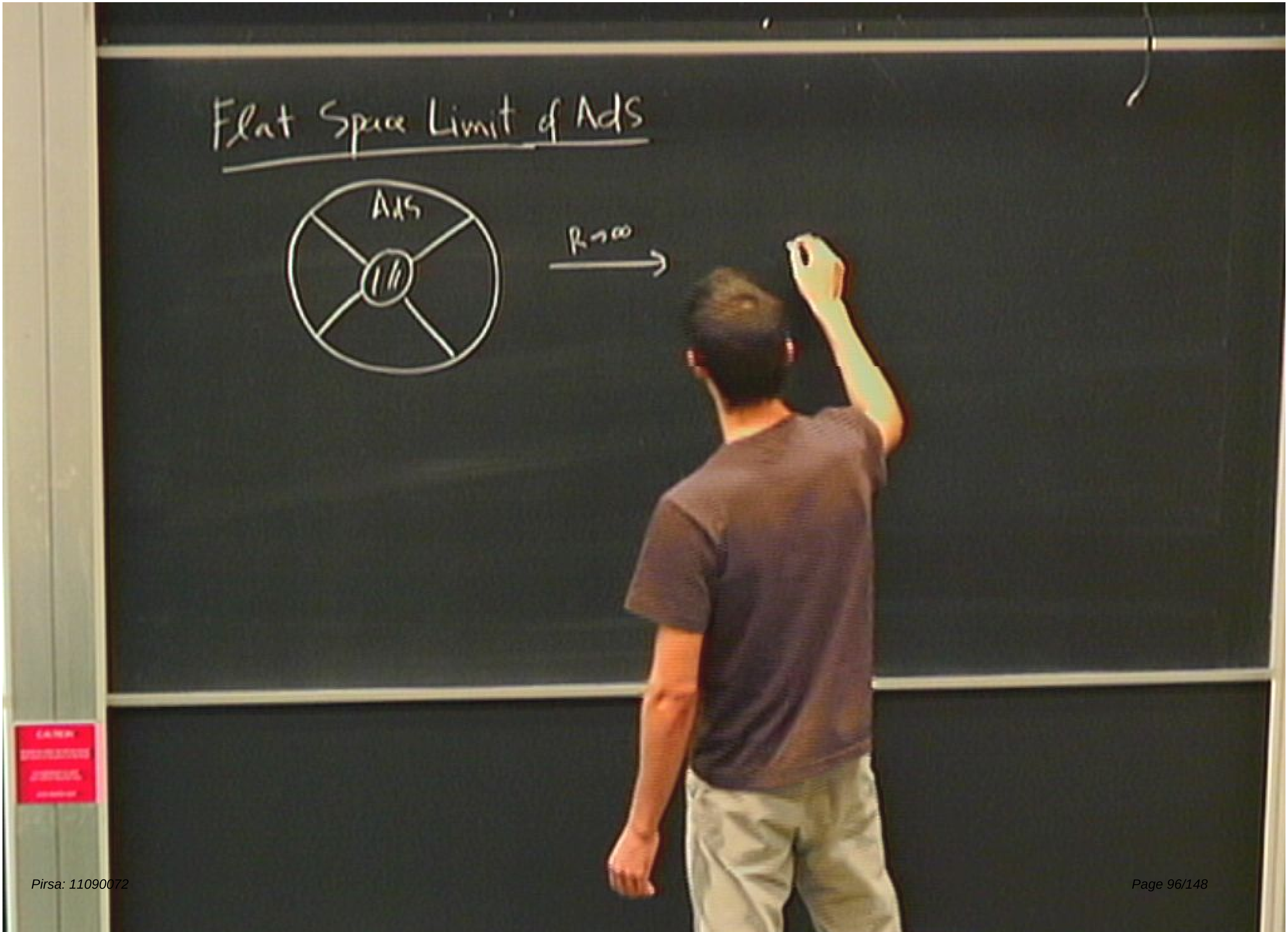

Example Δ=2 (d<6), λφ³
→ 1/(p²+2)
∝ λ

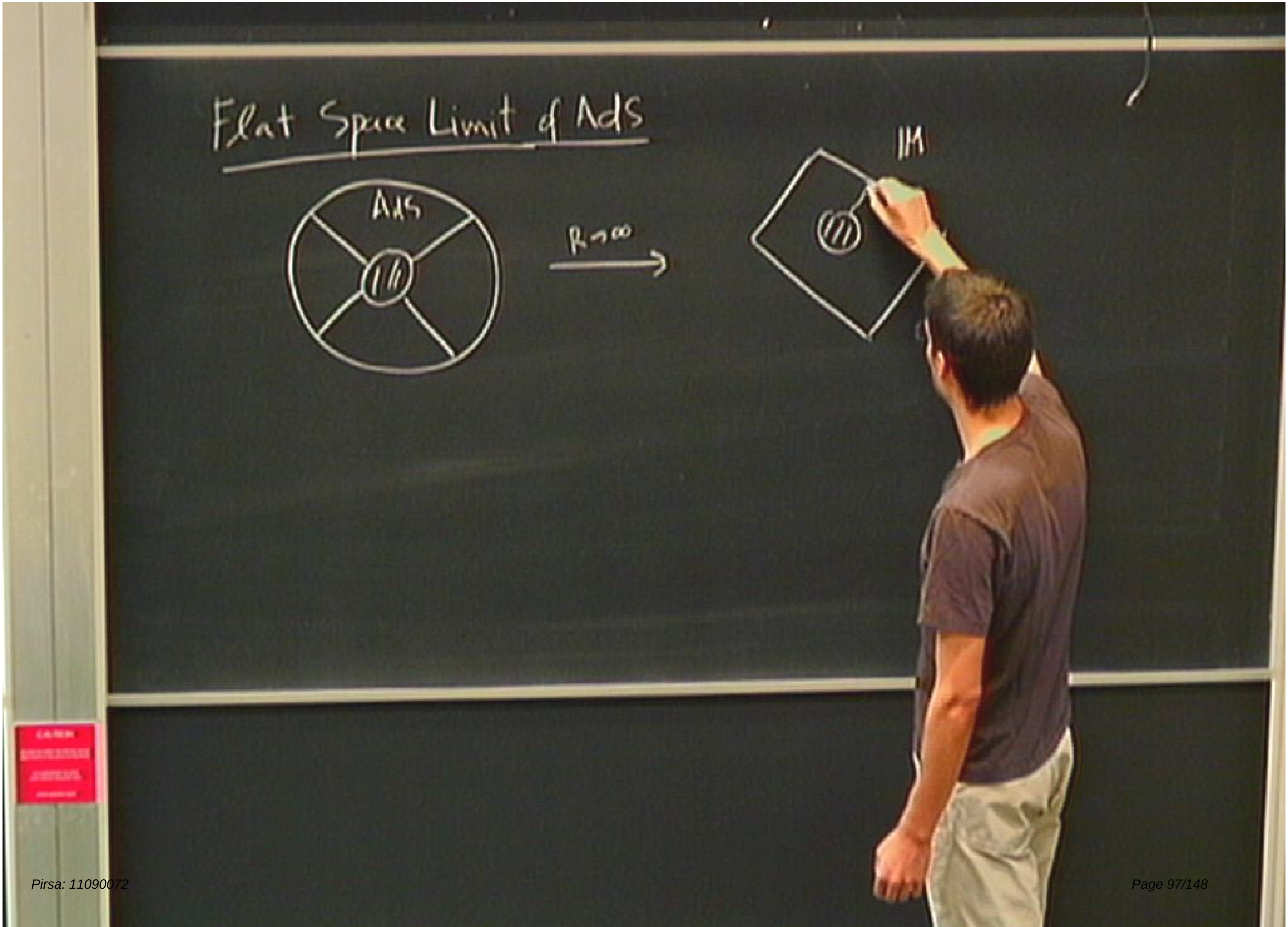

Example Δ=2 (d<6), λφ³
Δ=2 → 1/(p²+2)
∝ λ

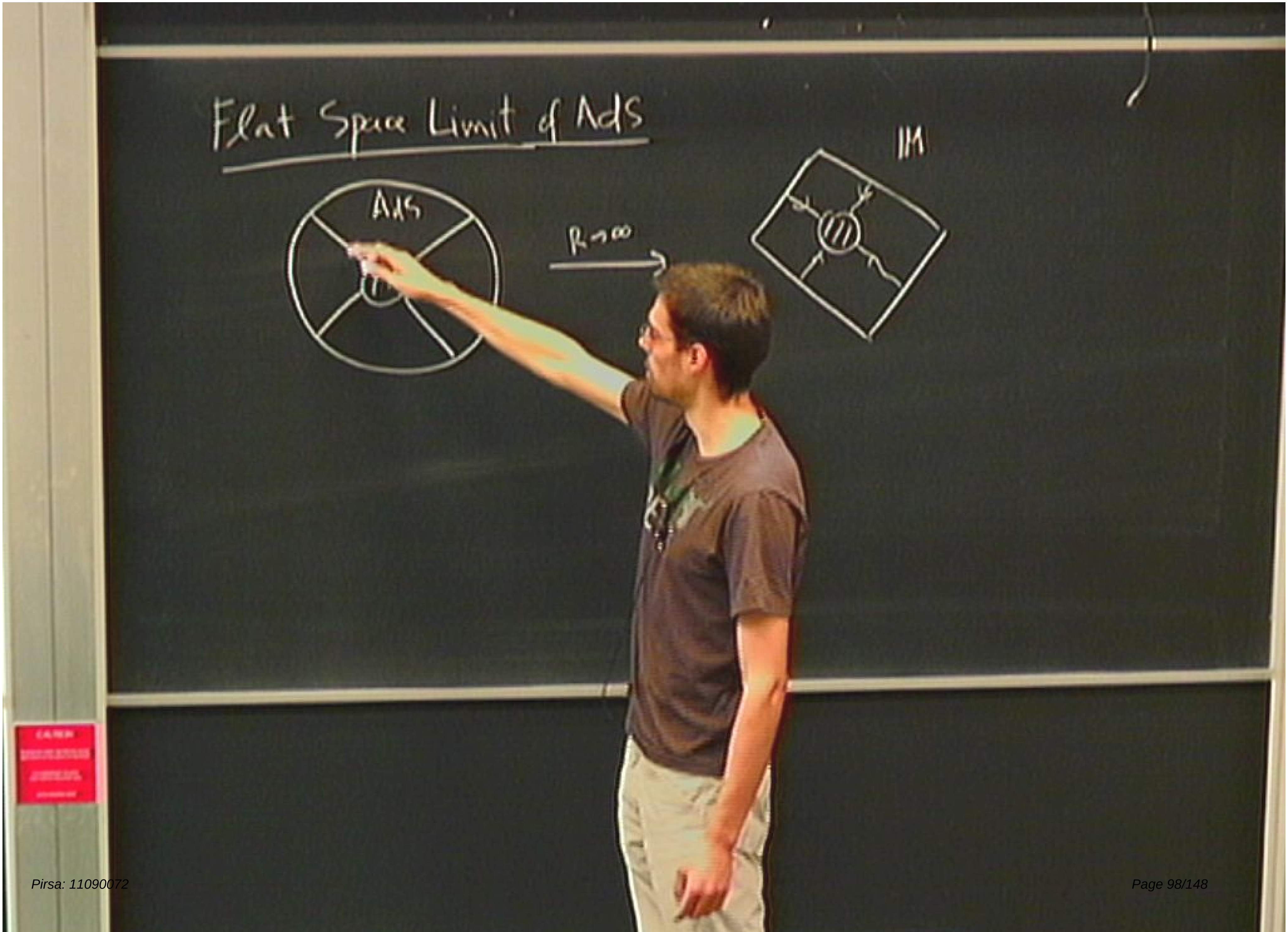

$\rightarrow \frac{1}{p^2+2}$
$\propto \lambda$
CAUTION

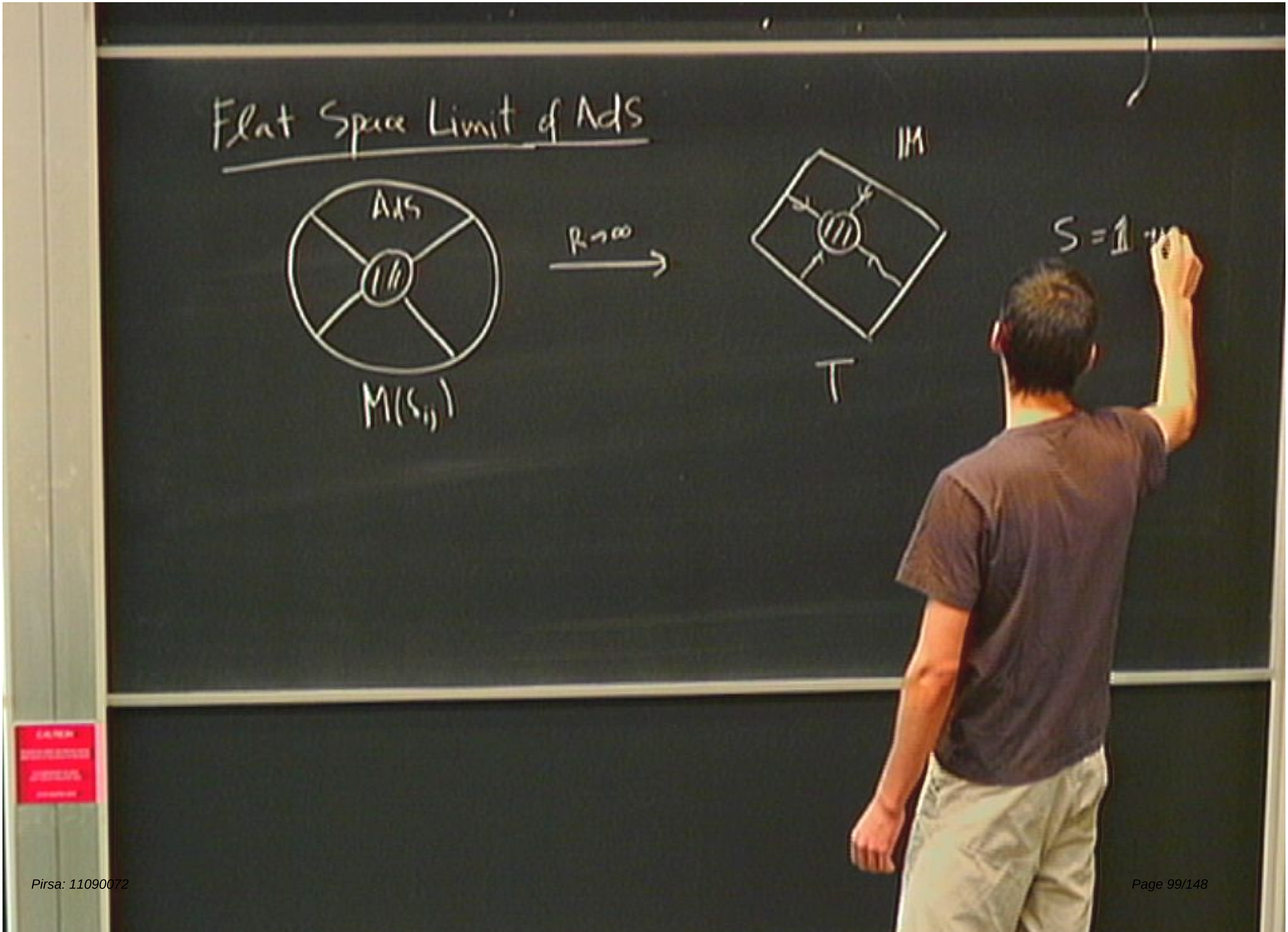

Flat Space Limit

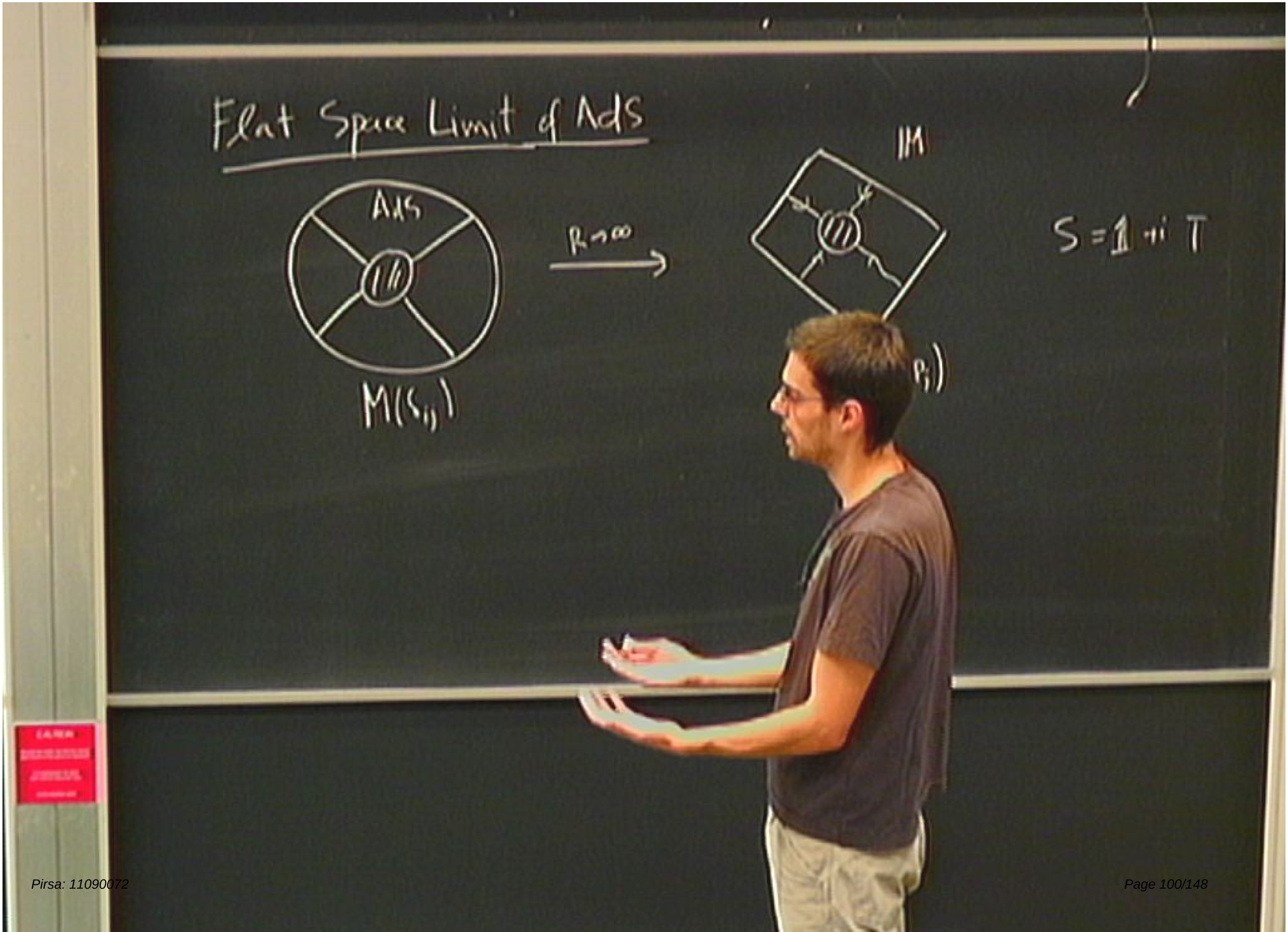

Flat Space Limit

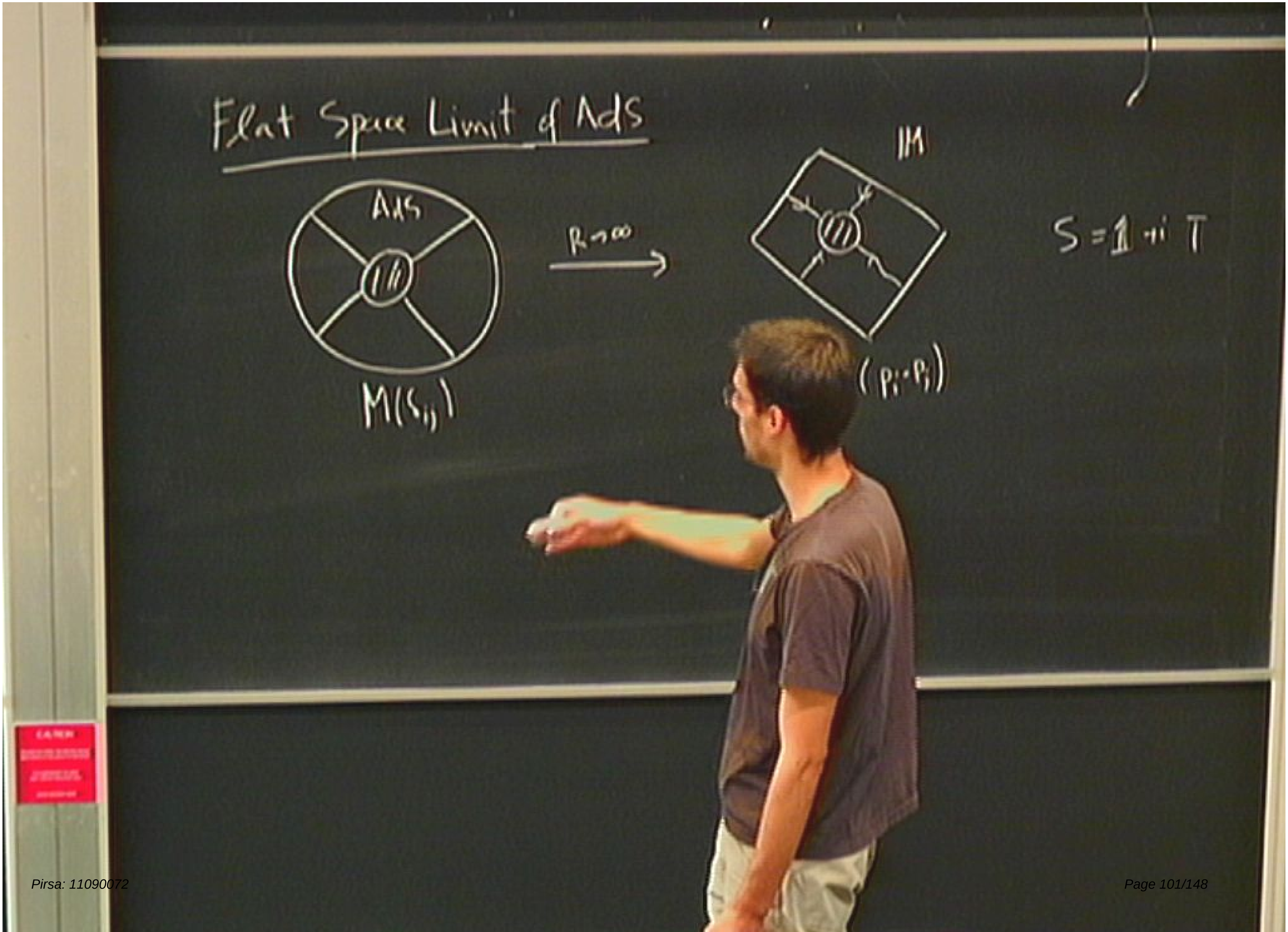

Flat Space Limit of AdS
AdS
R→∞

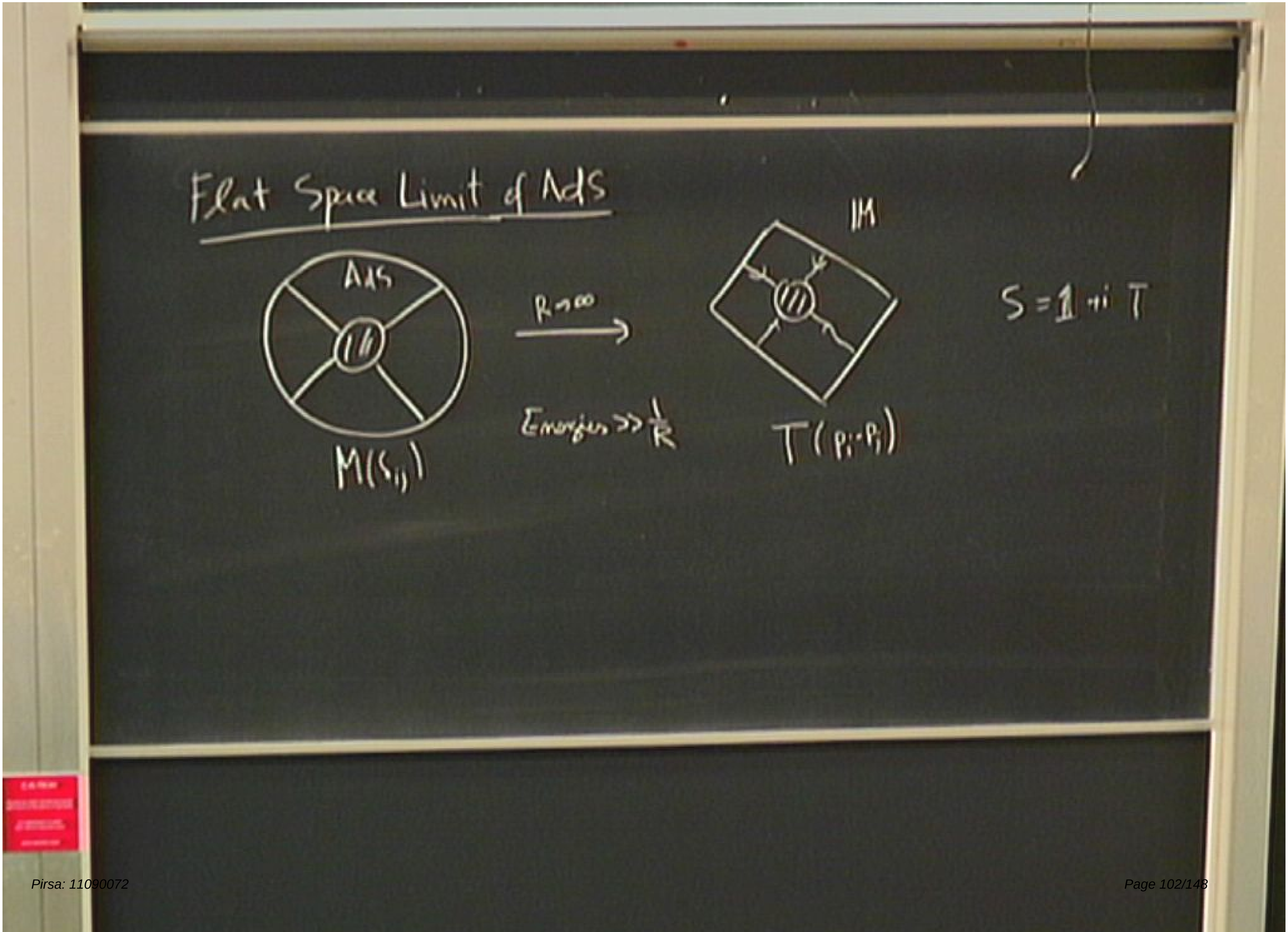

Flat Space Limit of AdS
AdS
R→∞

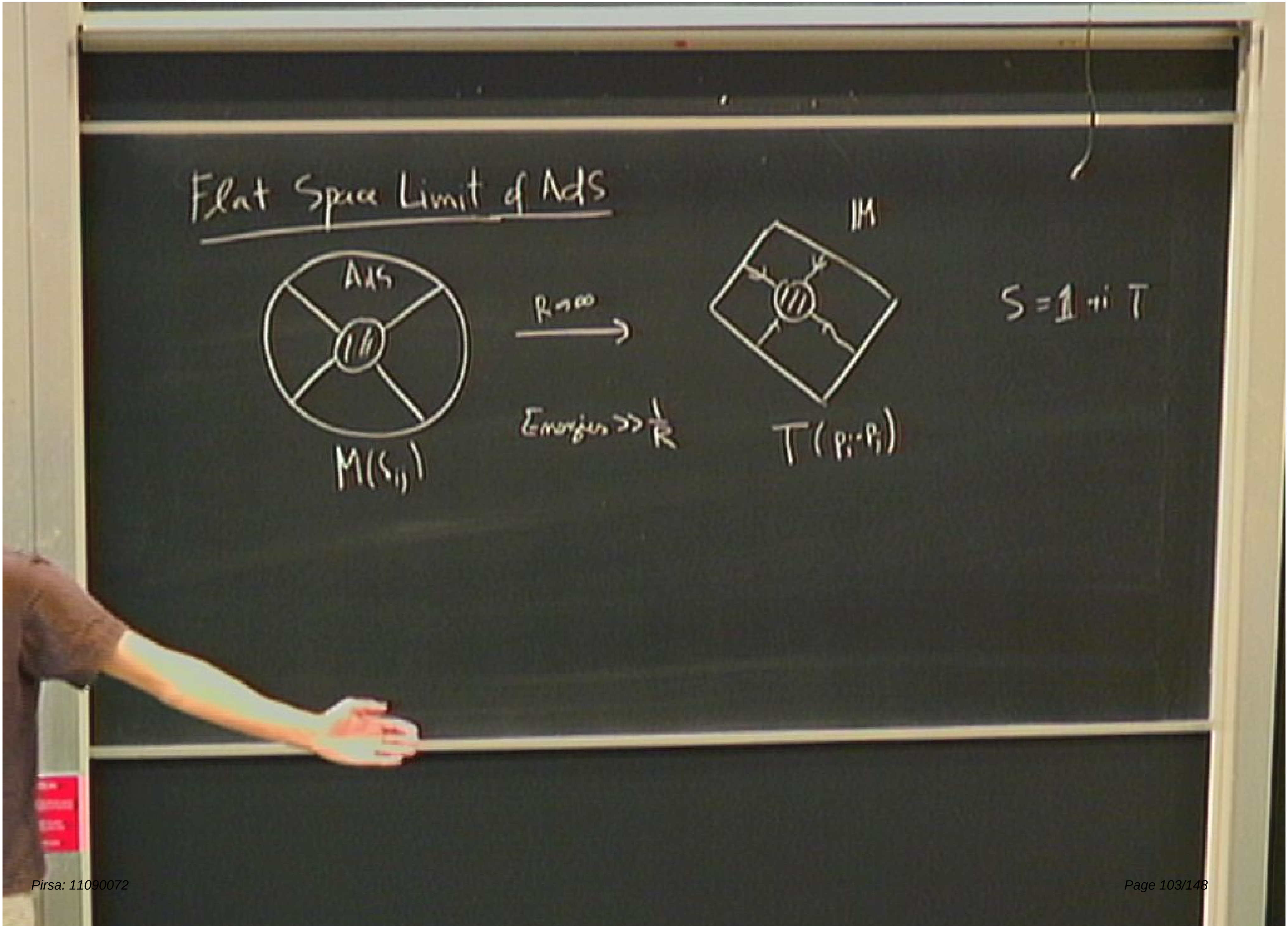

Flat Space Limit of AdS
AdS
R→∞

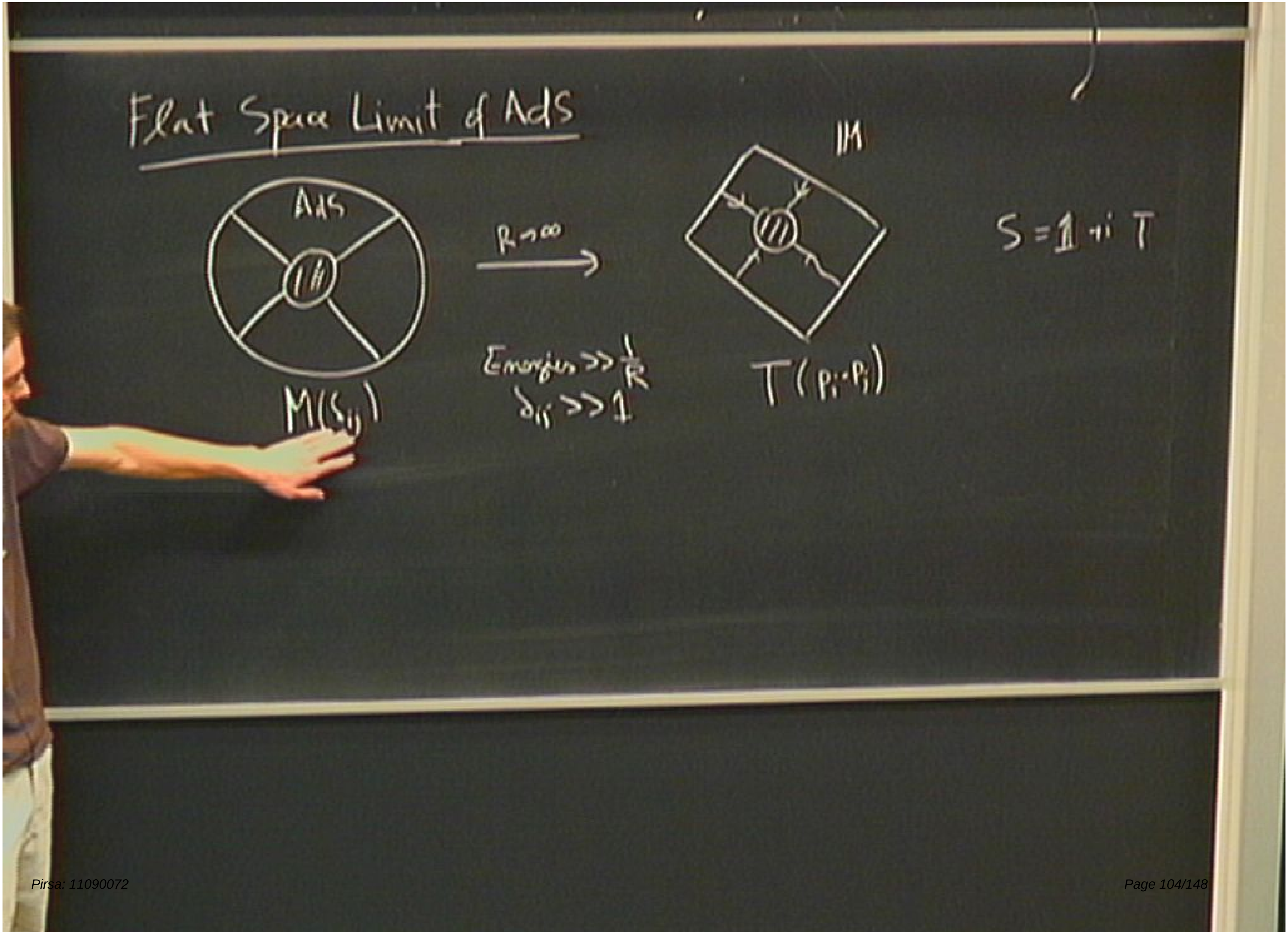

Flat Space Limit of AdS
AdS
M(S_ij)
R → ∞
T
S = 1

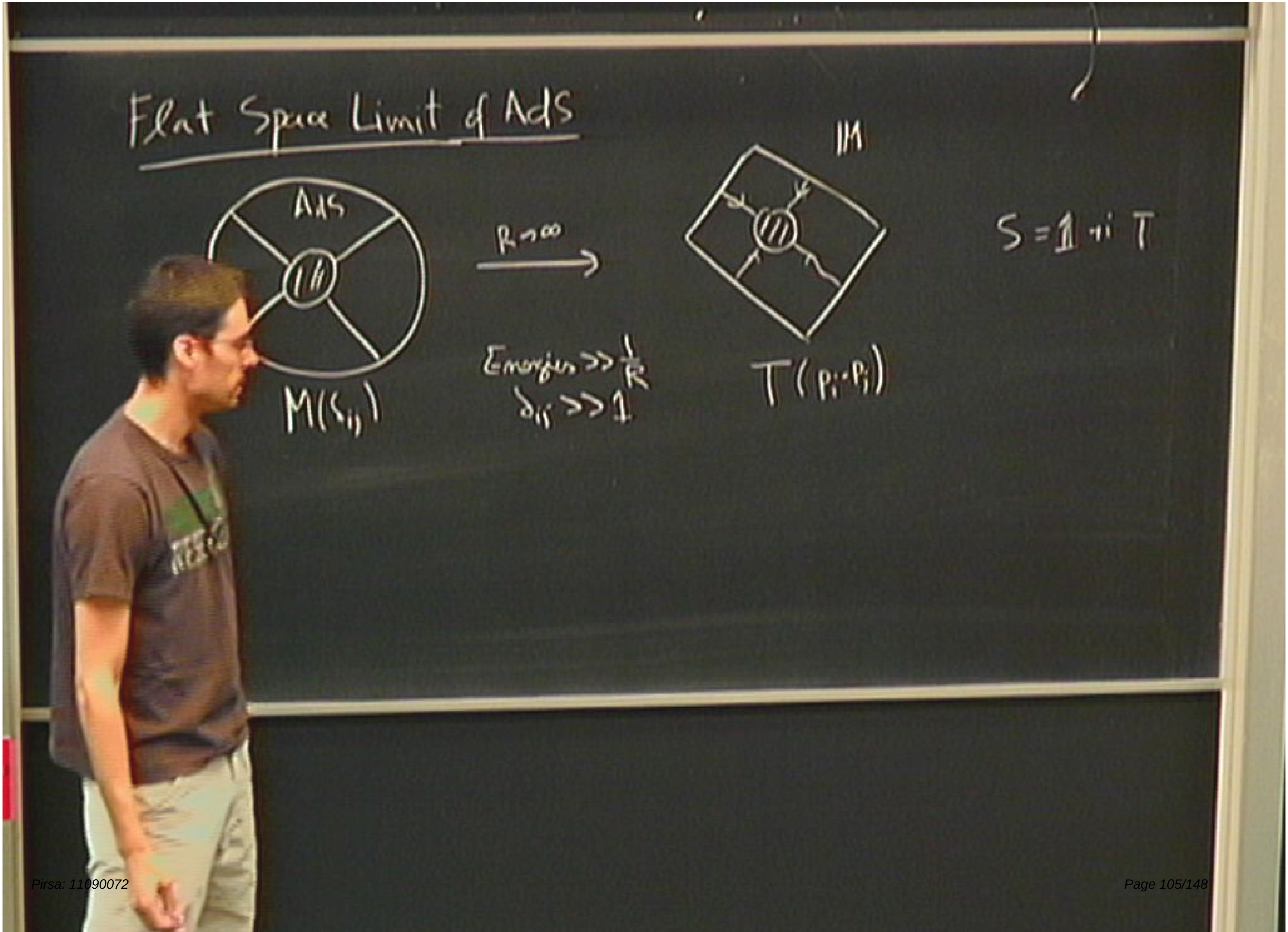

Flat Space Limit of AdS
AdS
R→∞
M(s_ij)
S = 1 + i T

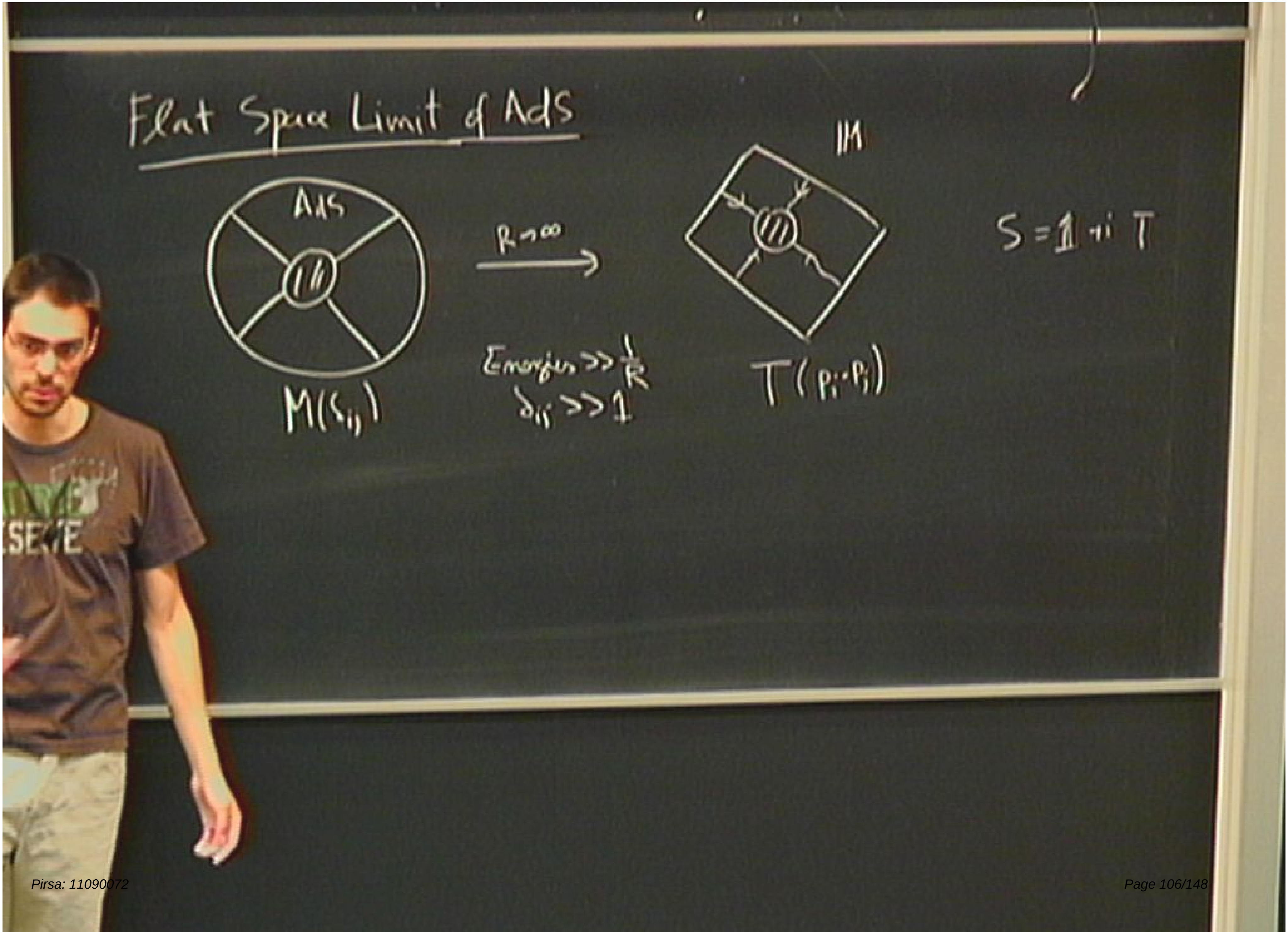

Flat Space Limit of AdS
AdS
R→∞
M(s_ij)
(p_i·p_j)
S = 1 + i T


Flat Space Limit of AdS
AdS
R → ∞
Energies >> 1/R
M(s_ij)
M
T(p_i · p_j)
S = 1 + i T


Flat Space Limit of AdS
AdS
R→∞
Energies >> 1/R
M(s_ij)
M
T(p_i·p_j)
S = 1 + i T


Flat Space Limit of AdS
AdS
R → ∞
M
S = 1 + i T
Energies >> 1/R
δij >> 1
M(δij)
T(pi·pj)


Flat Space Limit of AdS
AdS
R→∞
M(δij)
Energies >> 1/R
δij >> 1
IM
T(pi·pj)
S = 1 + i T


Flat Space Limit of AdS
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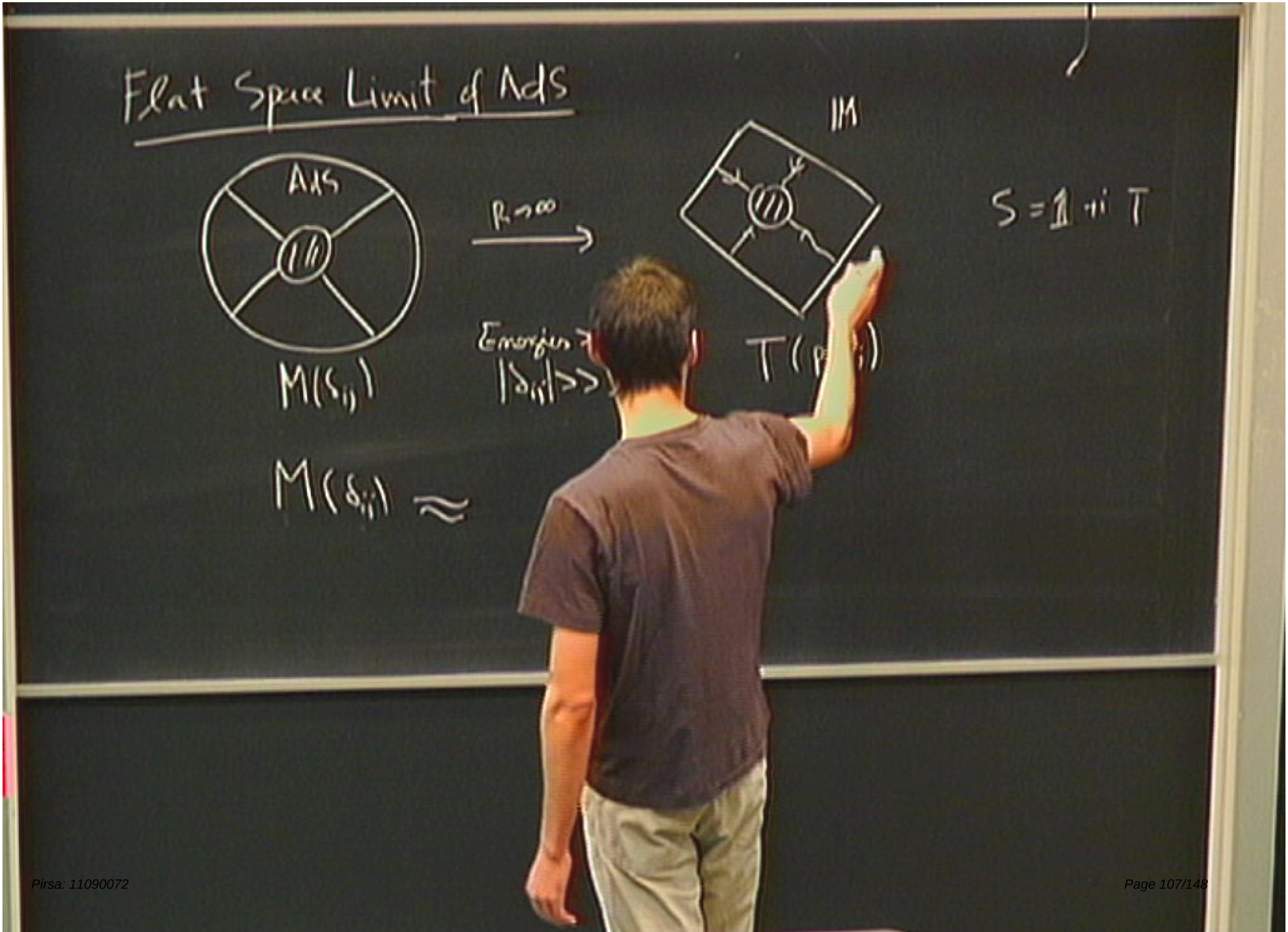
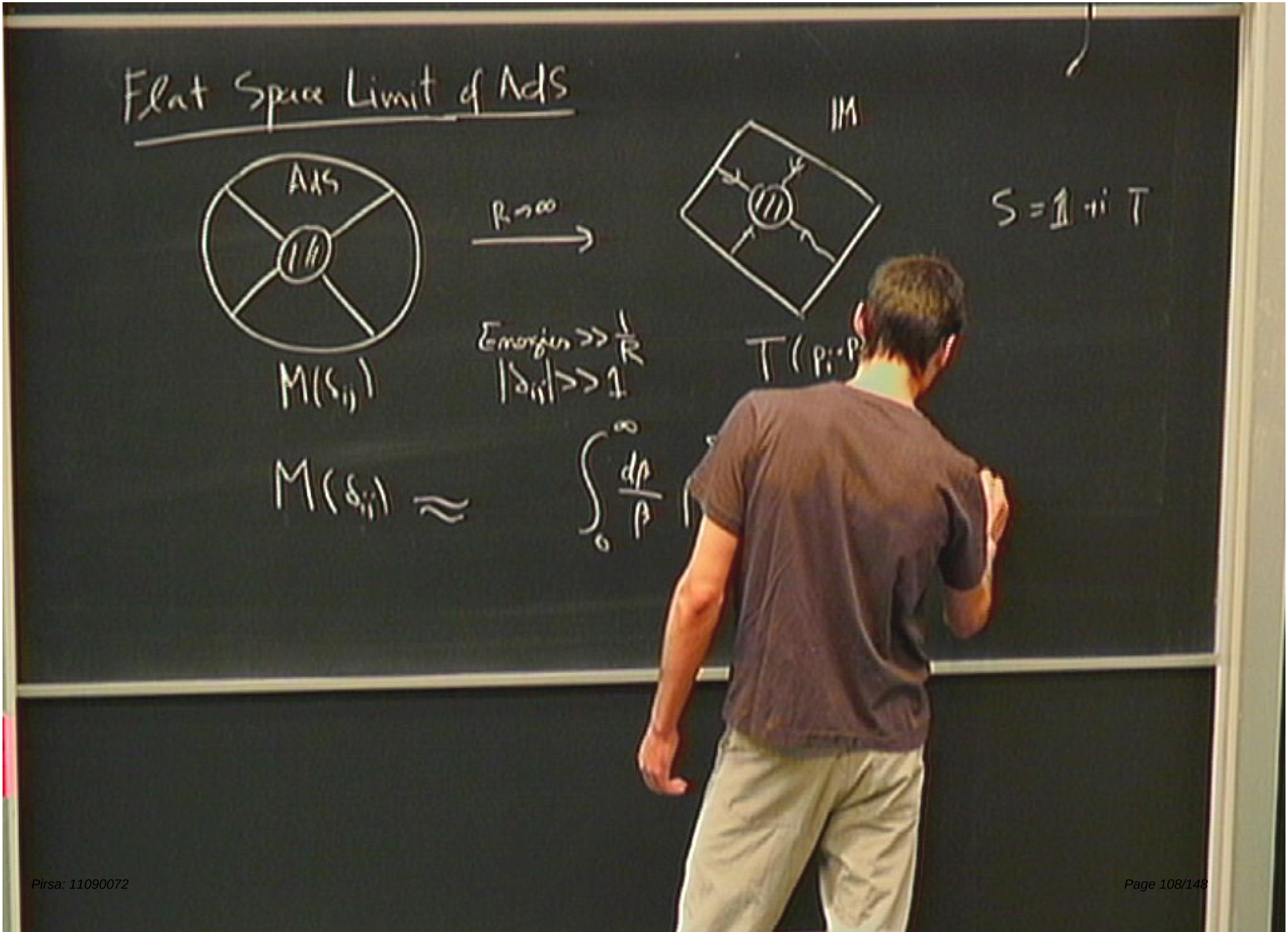
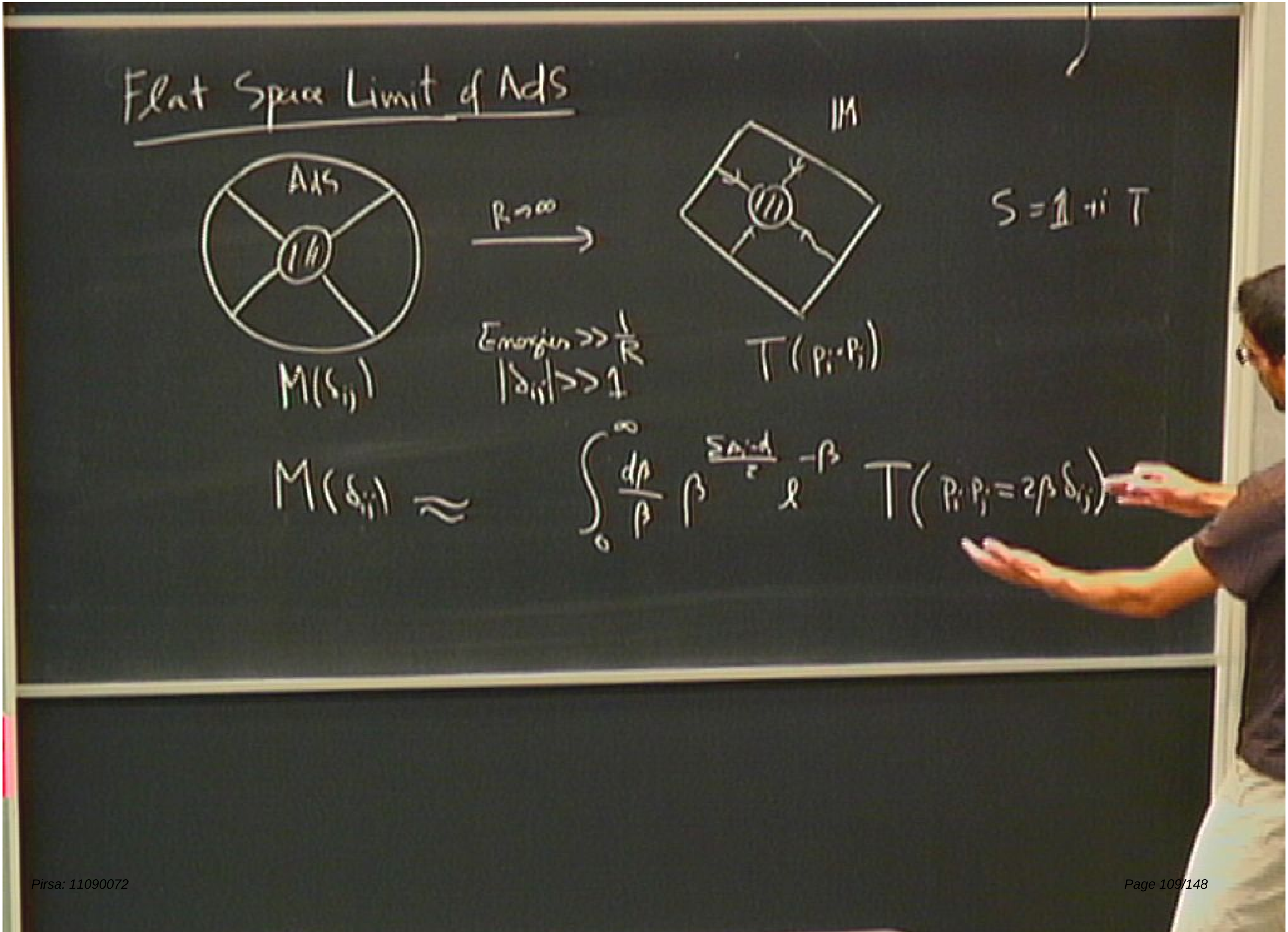
R→∞
Energies >> 1/R
δij >> 1
T(pi·pj)
S = 1 + i T


Flat Space Limit of AdS
AdS
M
S = 1 + i T



Flat Space Limit of AdS
AdS
R → ∞
S = 1 + i T
M(δij)
Energies >> 1/R
|δij| >> 1
T(pi·p
M(δij) ≈ ∫0∞ dβ/β


Flat Space Limit of AdS
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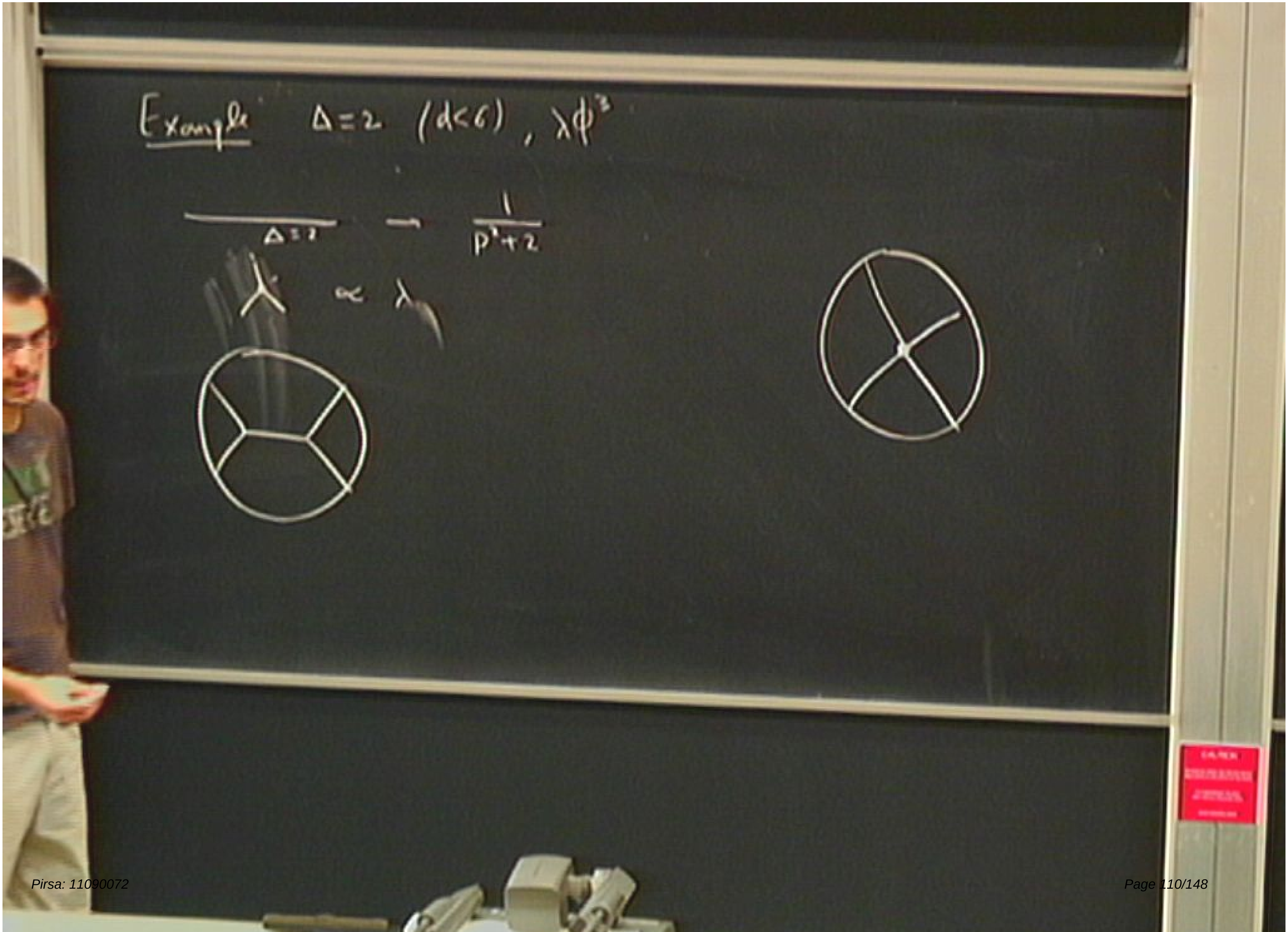
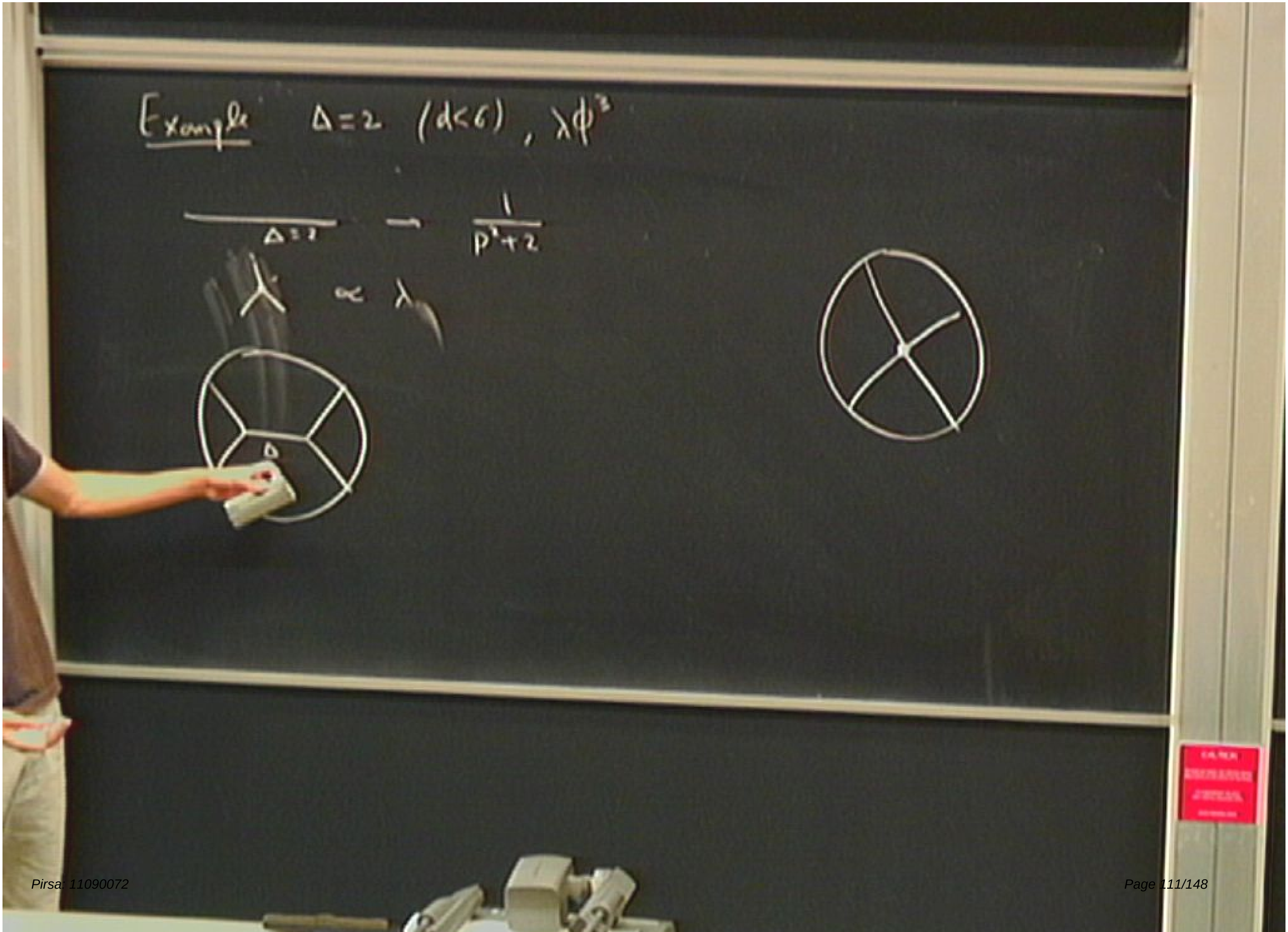
R→∞
Energies >> 1/R
|δij| >> 1
M(δij)
T(pi·pj)
S = 1 + iT


Example Δ=2 (d<6), λφ³
Δ=2
1/(p²+2)
∝ λ

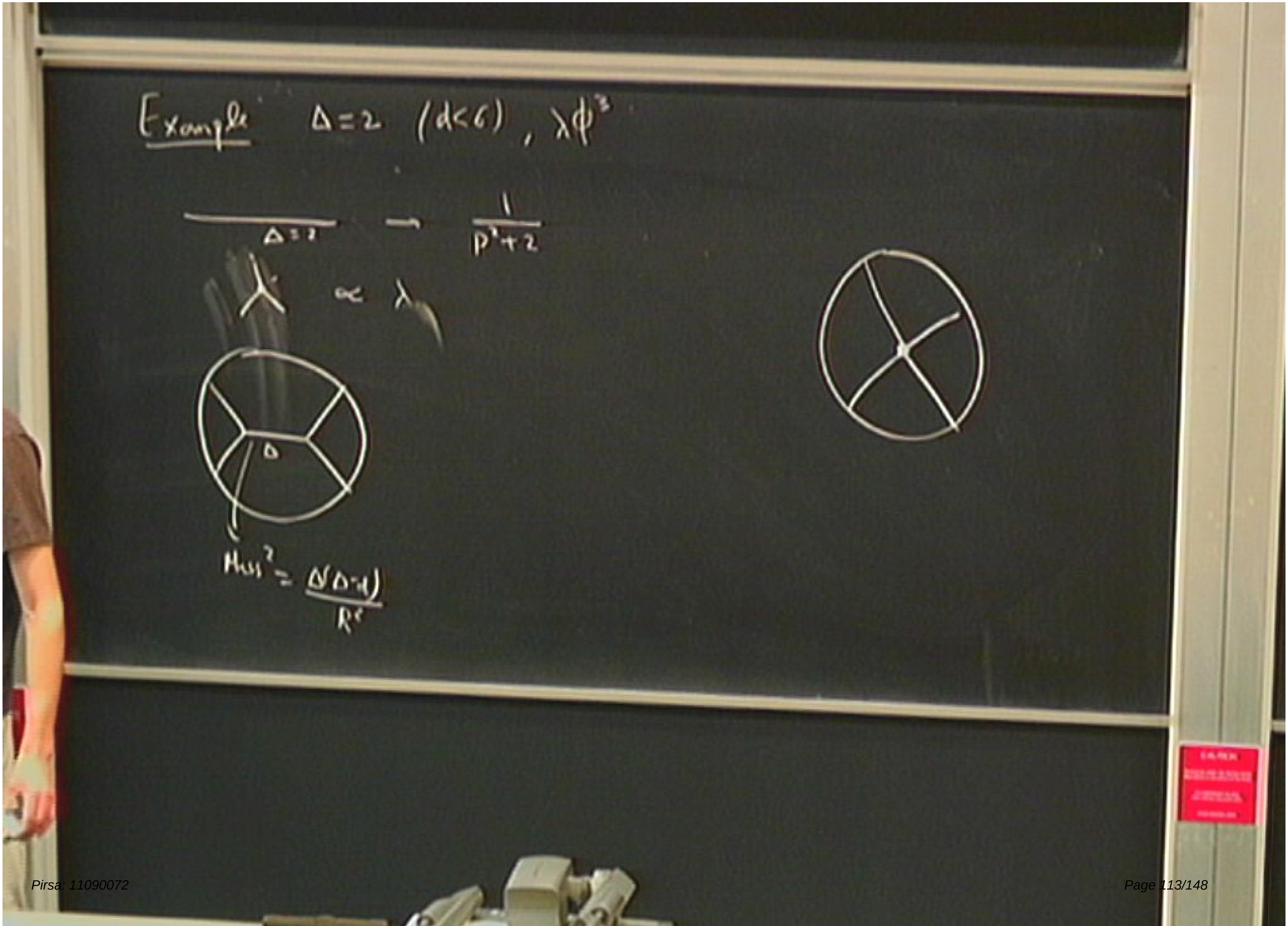

Example Δ=2 (d<6) , λφ³
Δ=2
1/(p²+2)
∝ λ
Δ

Example $\Delta = 2$ $(d < 6)$, $\lambda\phi^3$

$$\underset{\Delta=2}{\rule{3cm}{0.4pt}} \longrightarrow \frac{1}{p^2+2}$$

$$\text{(vertex)} \propto \lambda$$

$$\text{Mass}^2 = \frac{\Delta(\Delta-d)}{R^2}$$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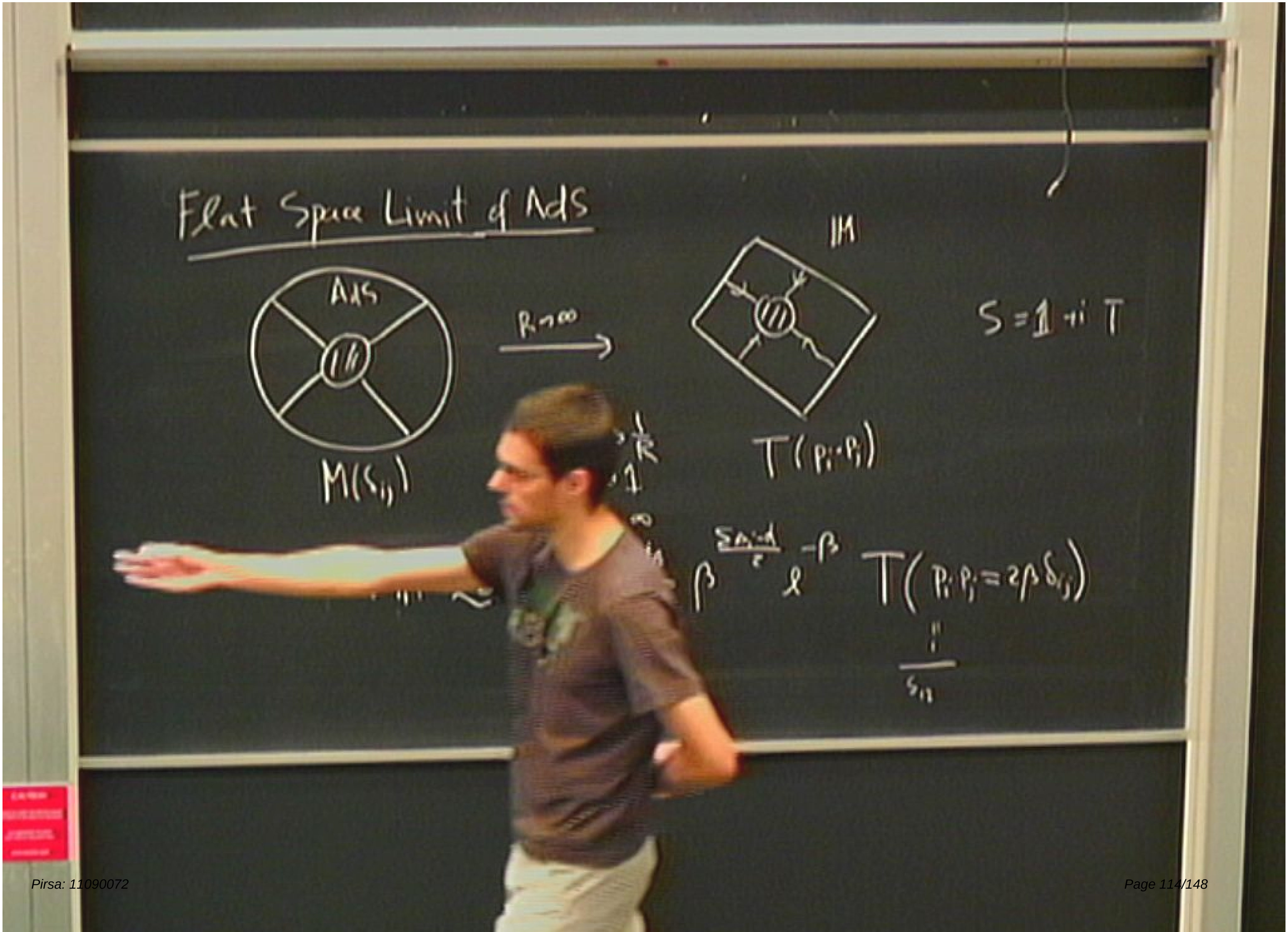
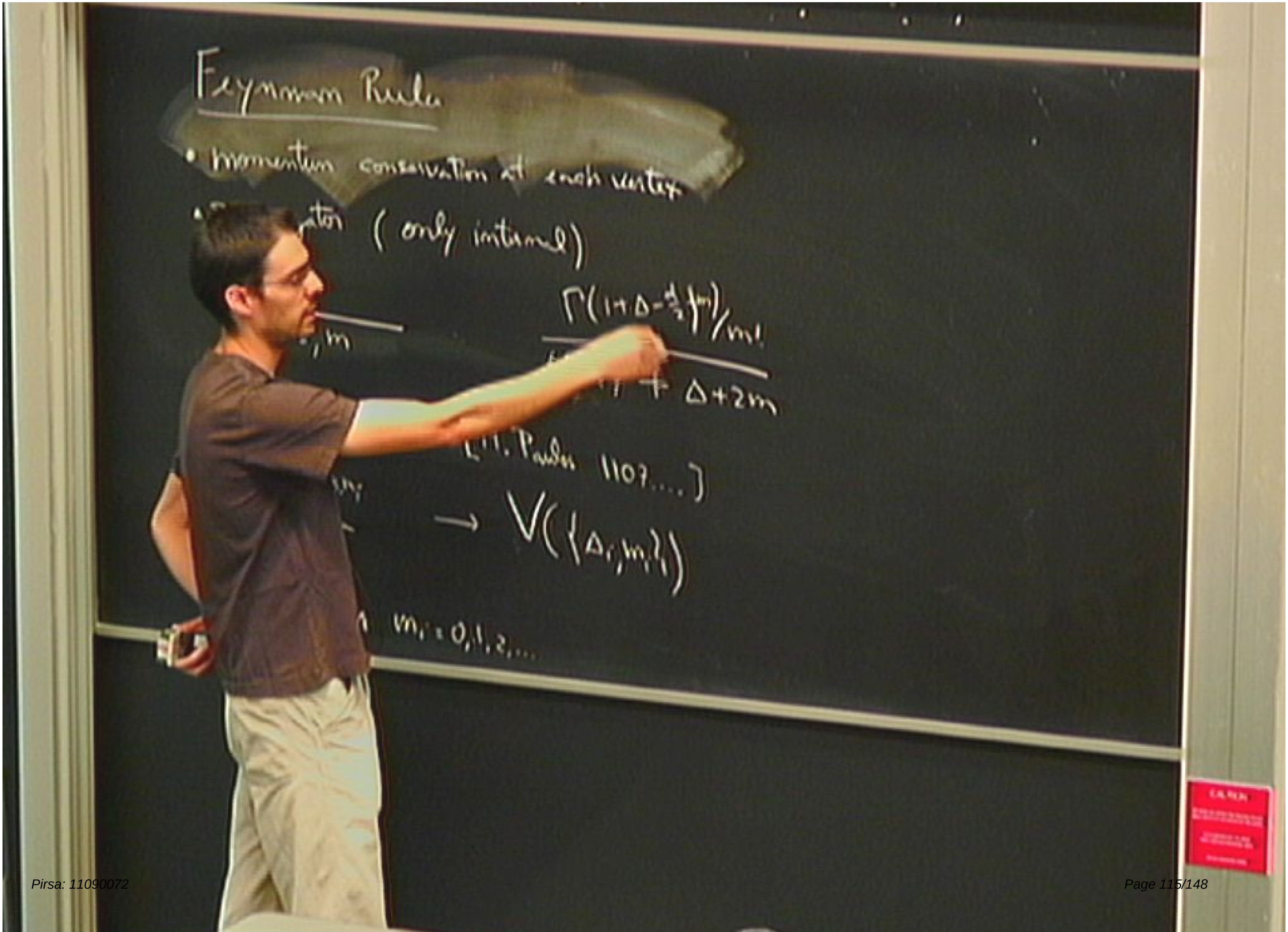
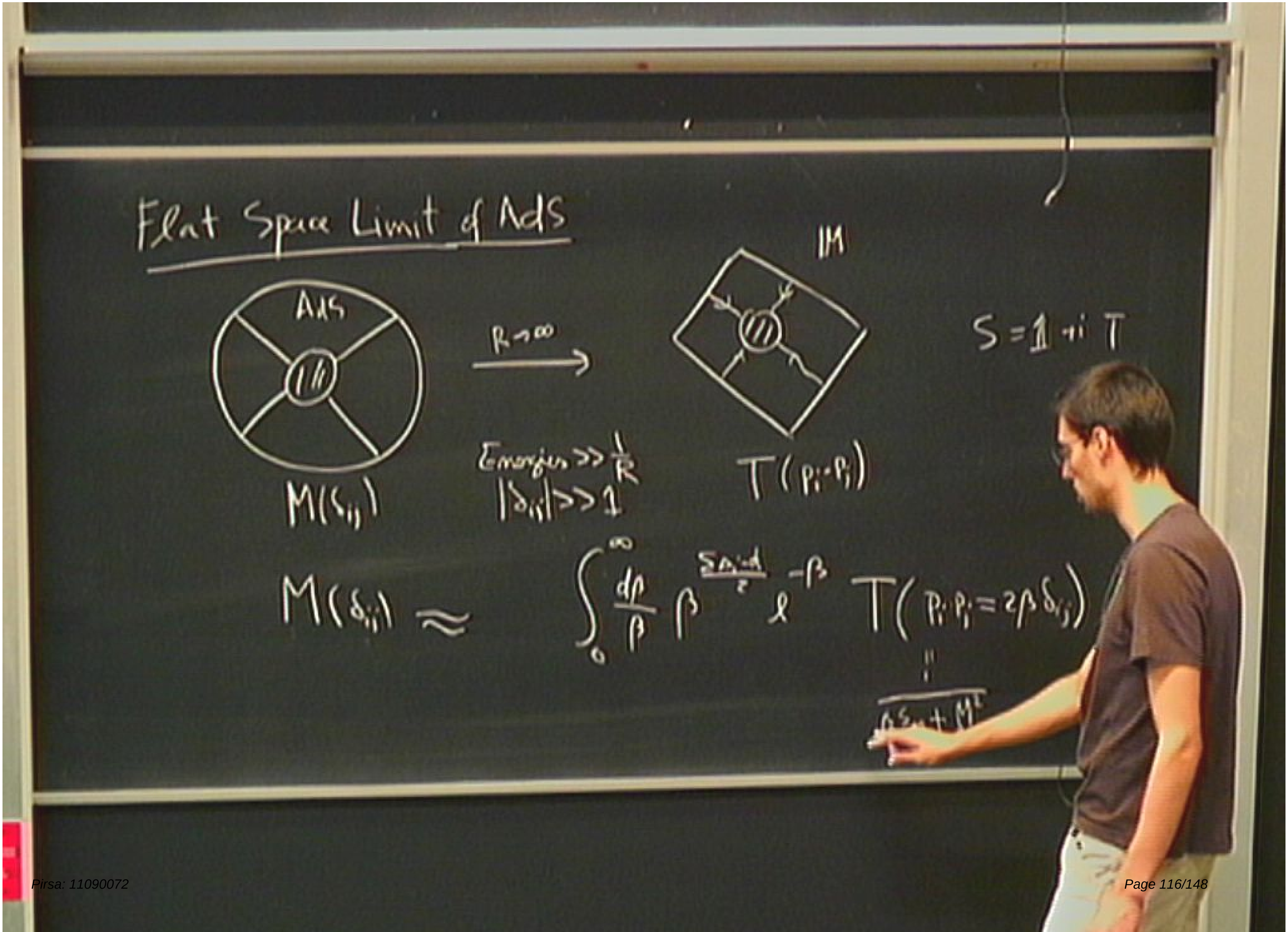
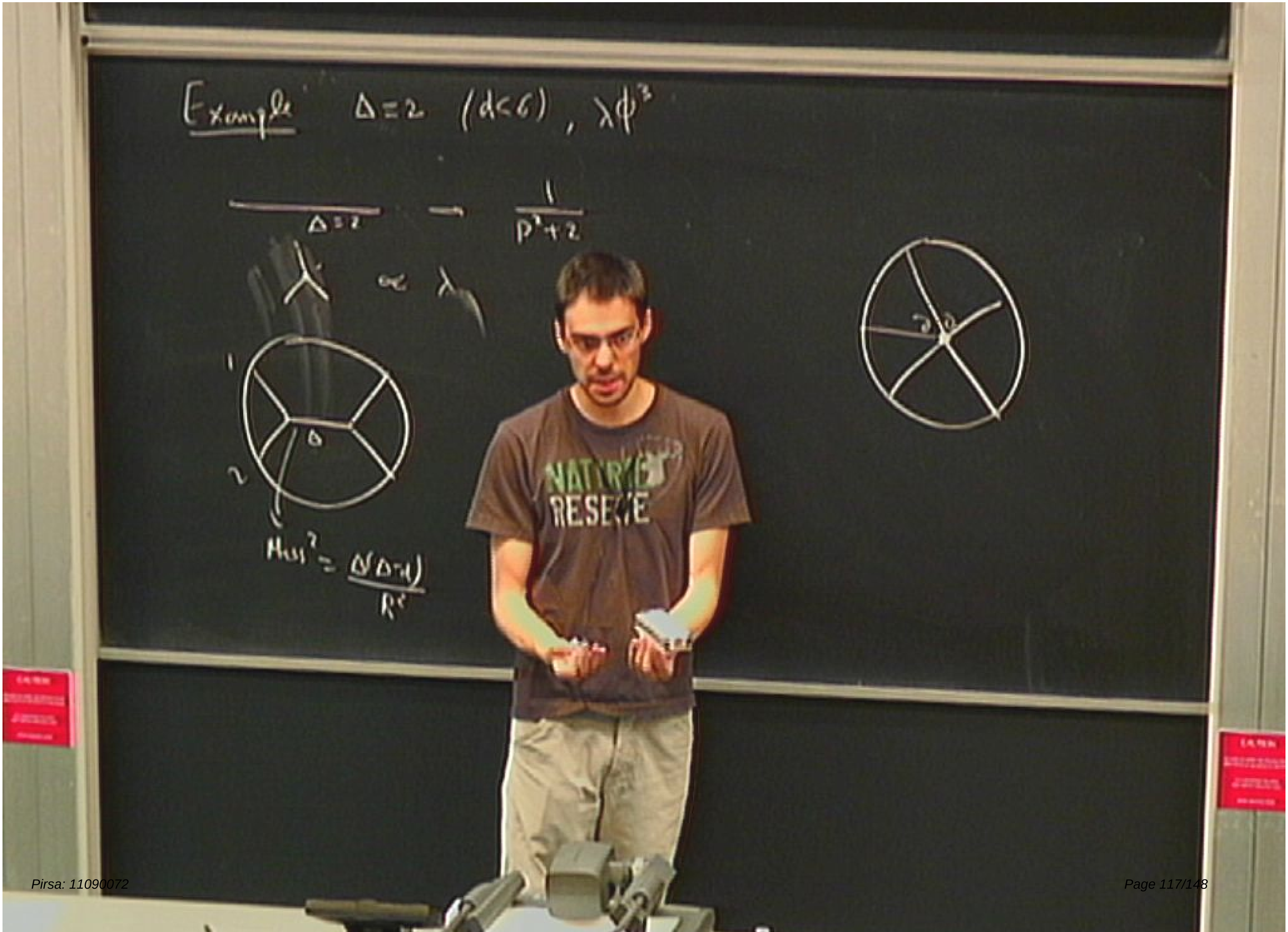
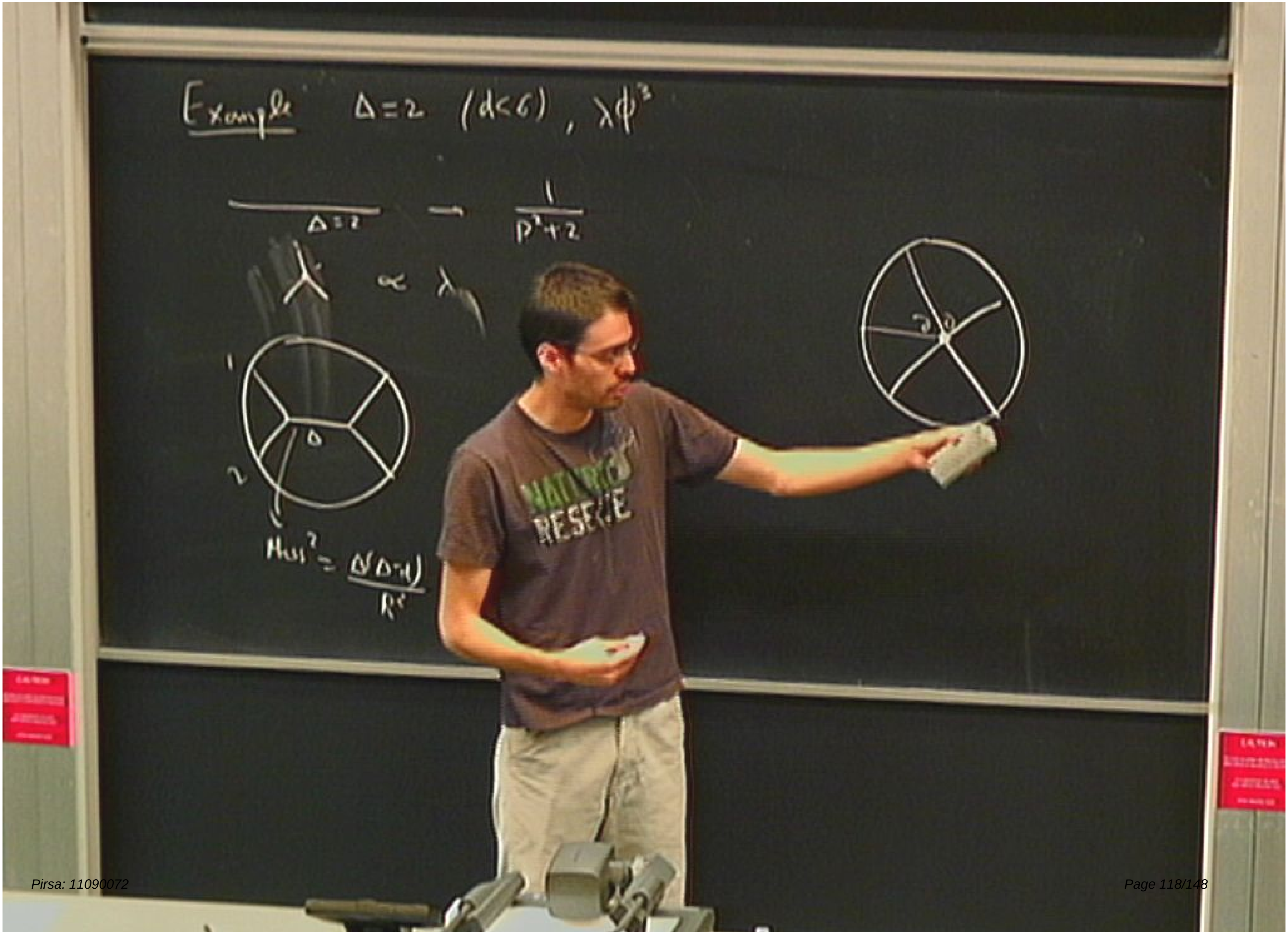
Δ=2
1/(p²+2)
∝ λ
Δ
Mass² = Δ(Δ-d)/R²

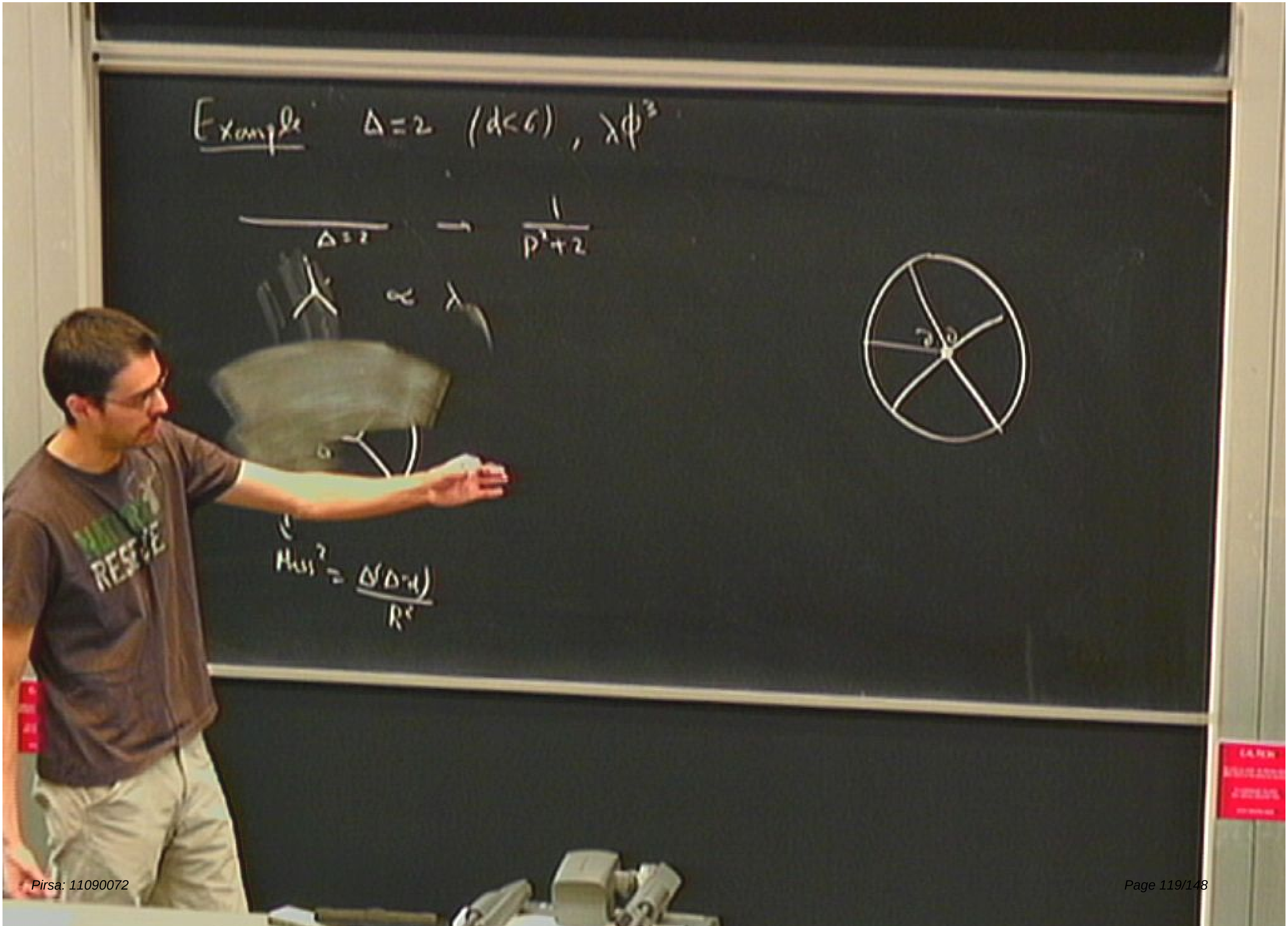

Flat Space Limit of AdS
AdS
R → ∞
S = 1 + i T
M(δij)
T(pi·pj)
T(pi·pj = 2β δij)


Feynman Rules
• momentum conservation at each vertex
(only internal)
Δ+2m
[M. Paulos 1107....]
V({Δi,mi}i)
mi = 0,1,2,...


Flat Space Limit of AdS
AdS
R→∞
S = 1 + i T
Energies >> 1/R
|δij| >> 1
M(δij)
T(pi·pj)
M(δij) ≈ ∫0∞ dβ/β β^(ΣΔi−d)/2 e^−β T(pi·pj = 2β δij)


Example Δ=2 (d<6), λφ³
Δ=2 → 1/(p²+2)
∝ λ
1
2
Δ
Mass² = Δ(Δ−d)/R²


Example Δ=2 (d<6), λφ³
Δ=2
1
p²+2
∝ λ
Mass² = Δ(Δ-d)
R²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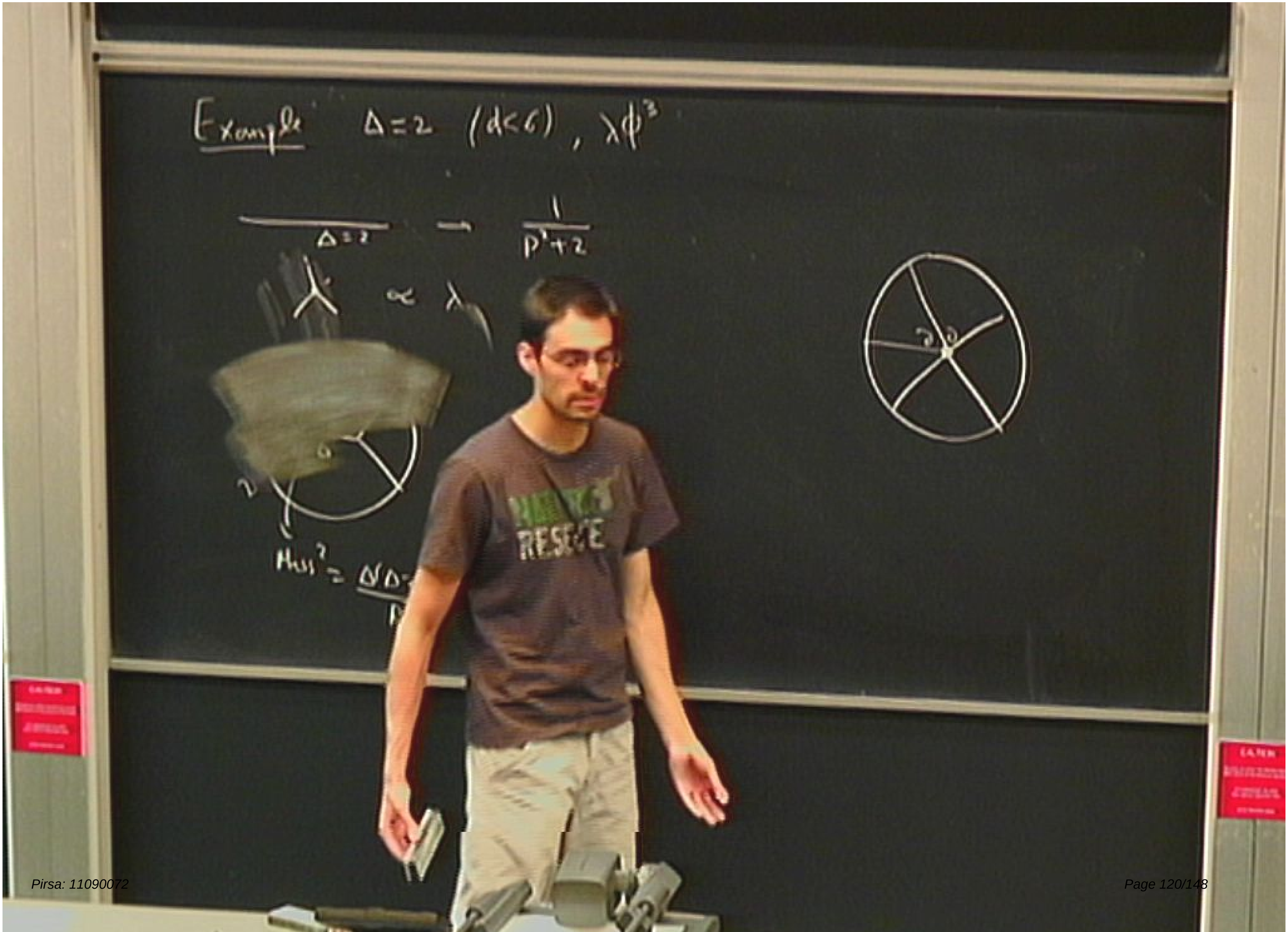
Δ=2 → 1/(p²+2)
∝ λ
M_AdS² = Δ(Δ−d)/R²


Example Δ=2 (d<6), λφ³
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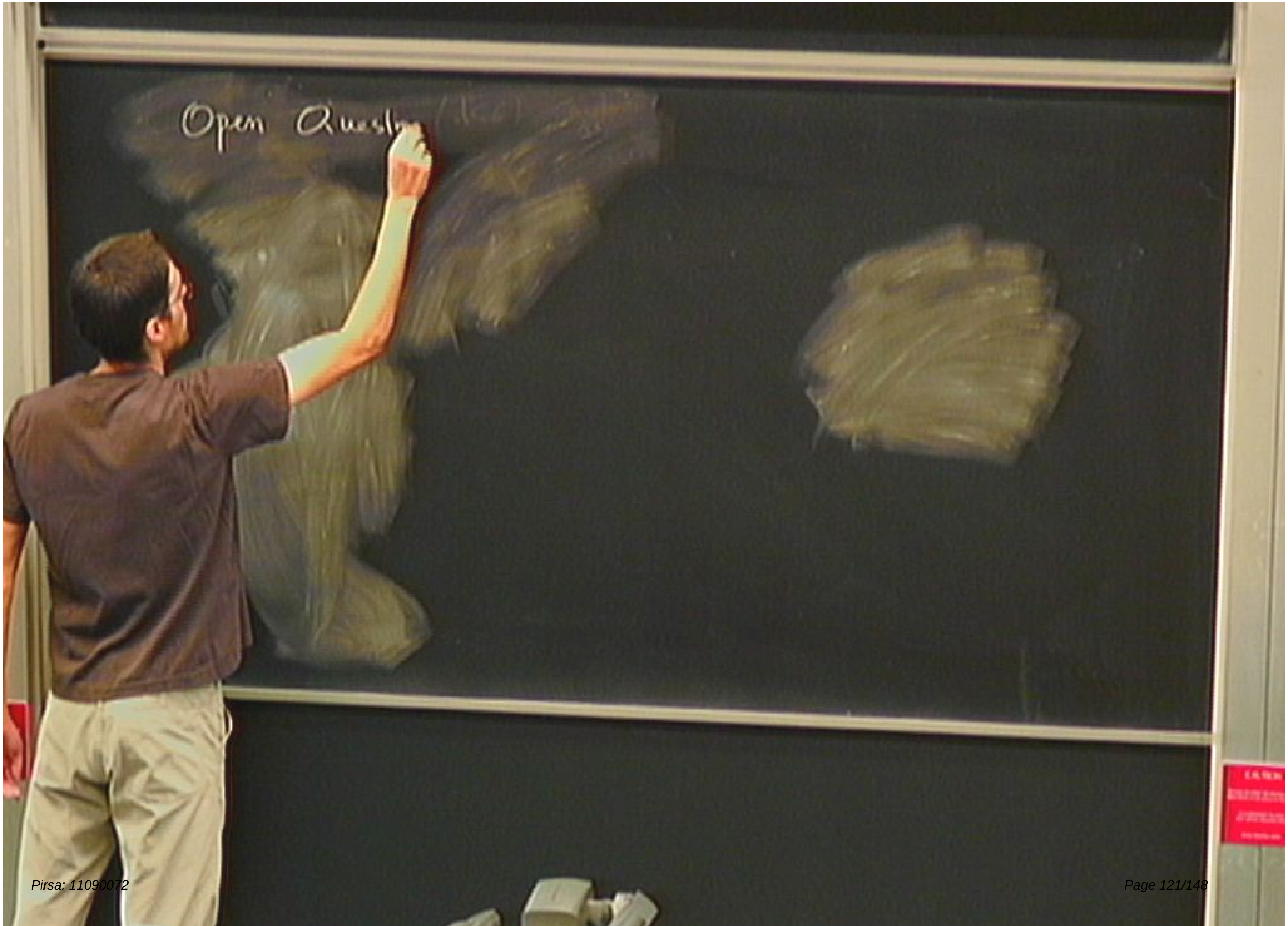
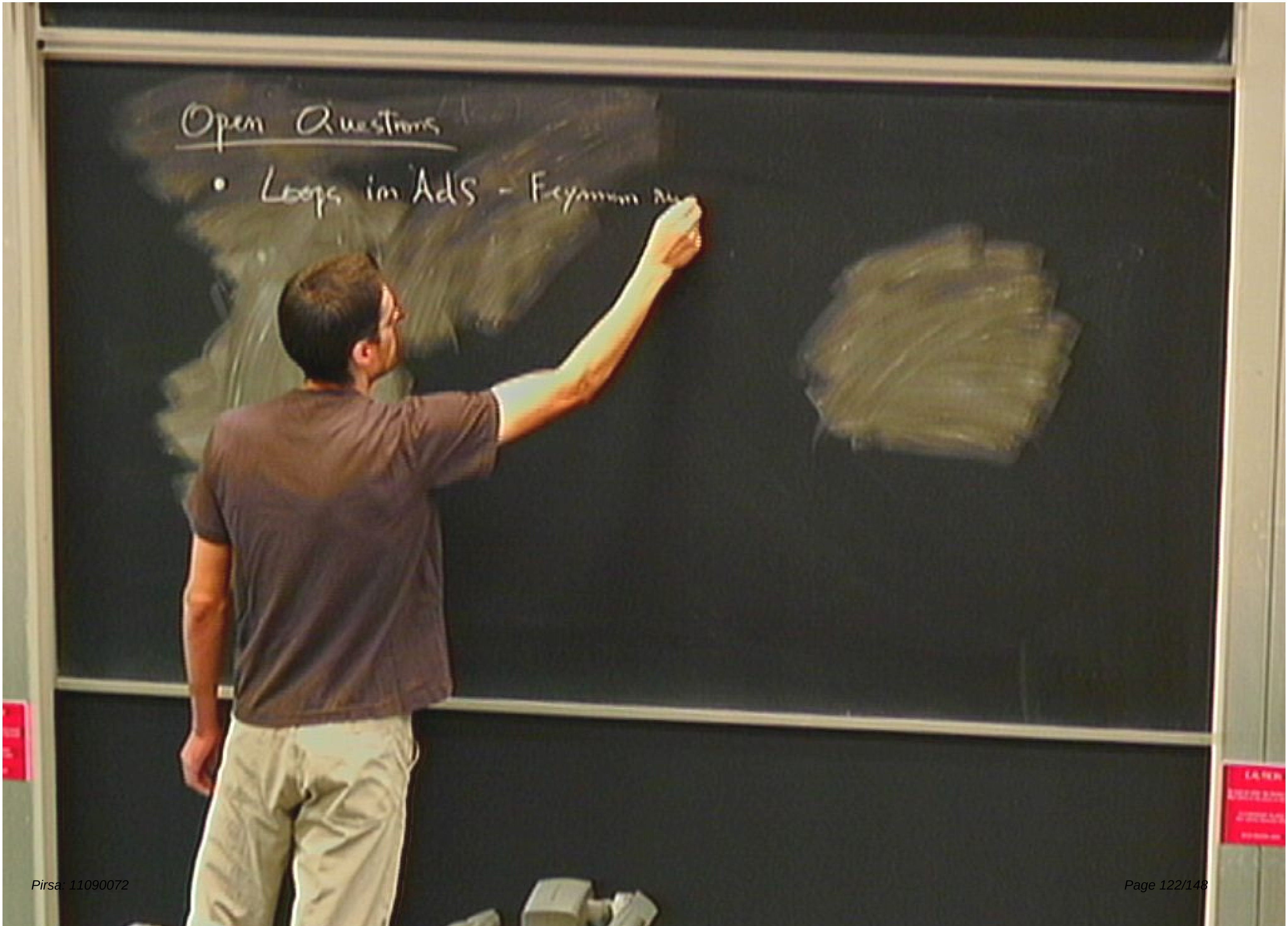
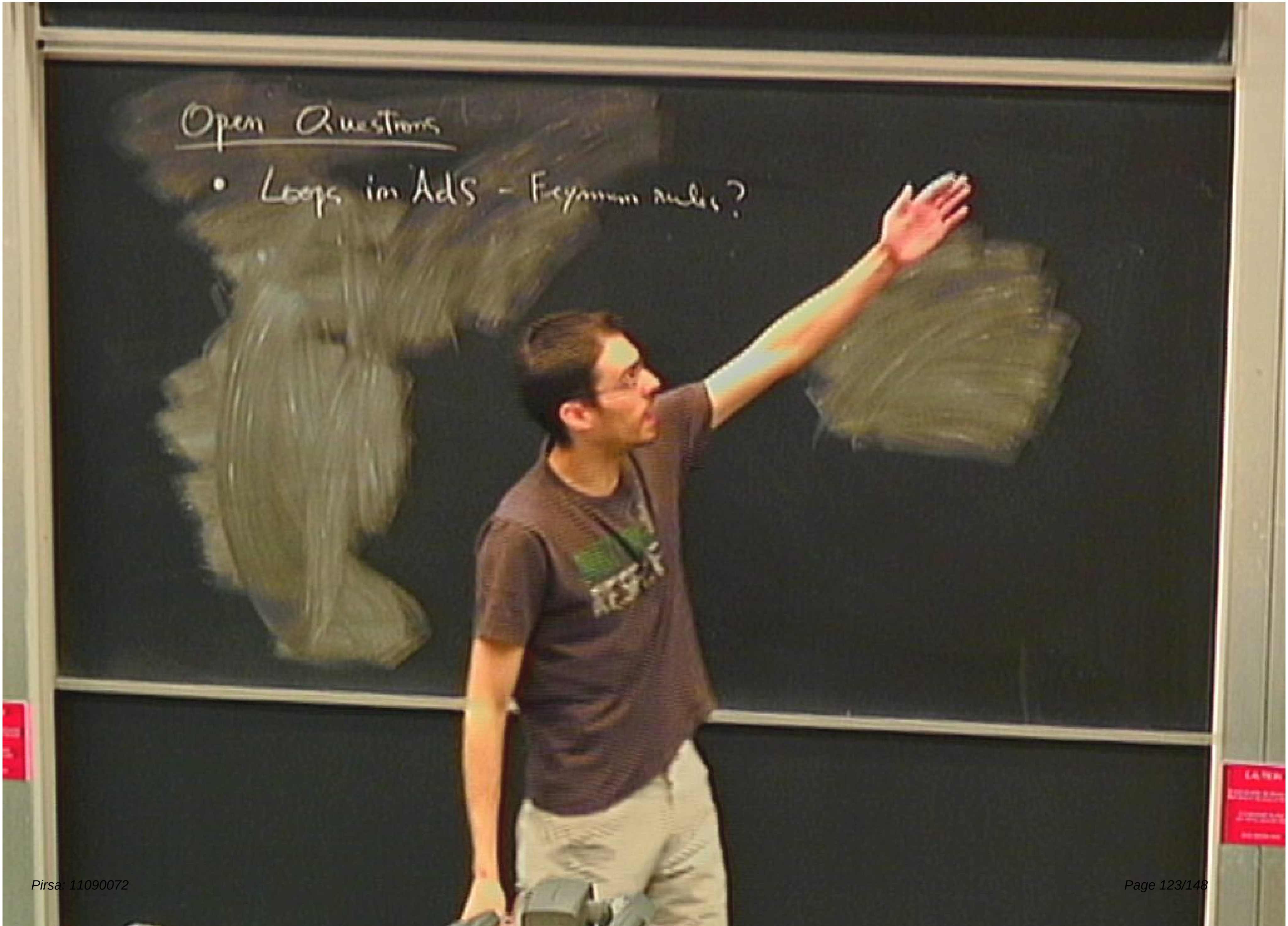

Open


Open Questions
• Loops in AdS - Feynman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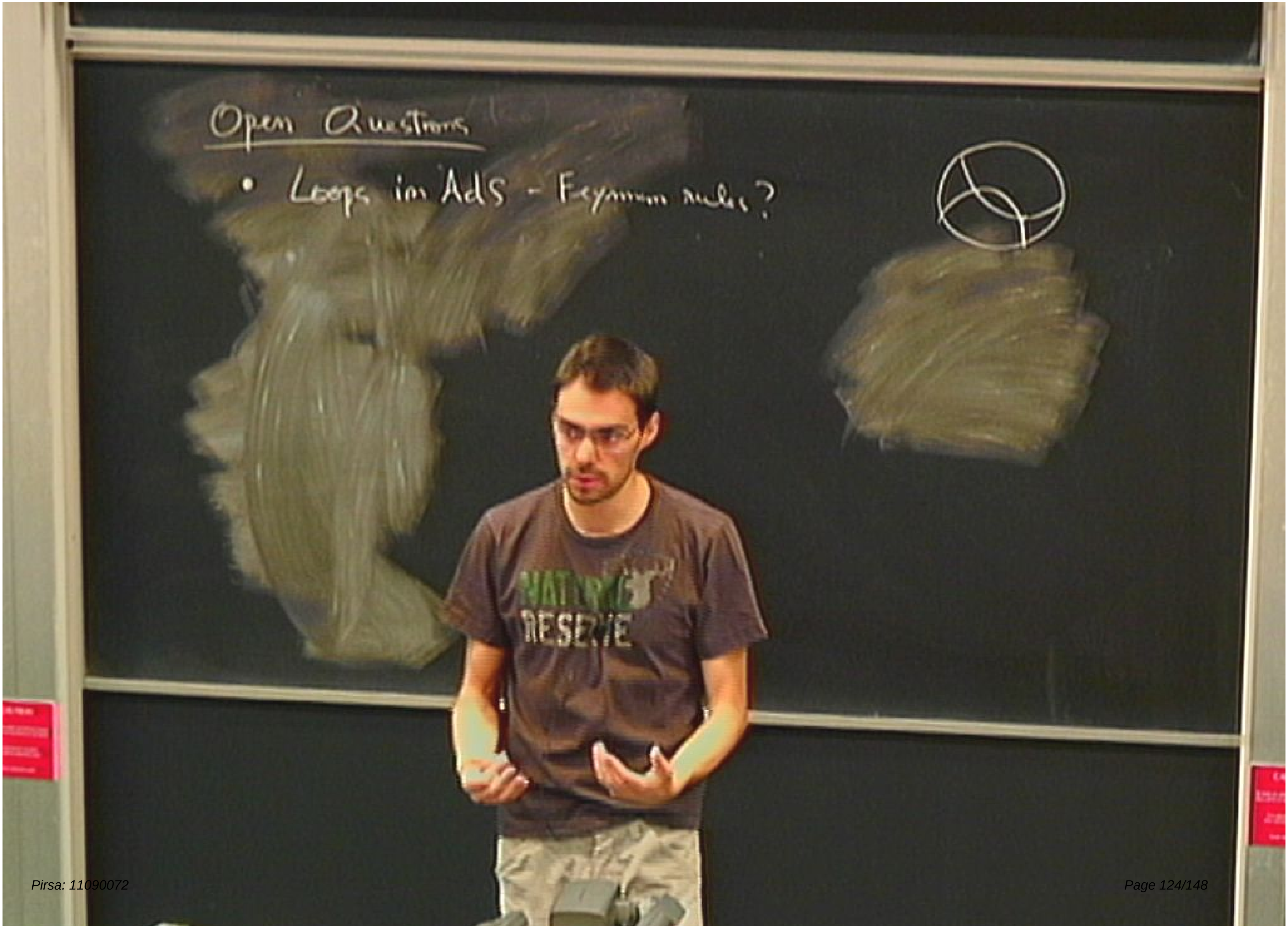
• Loops in AdS - Feynman rules?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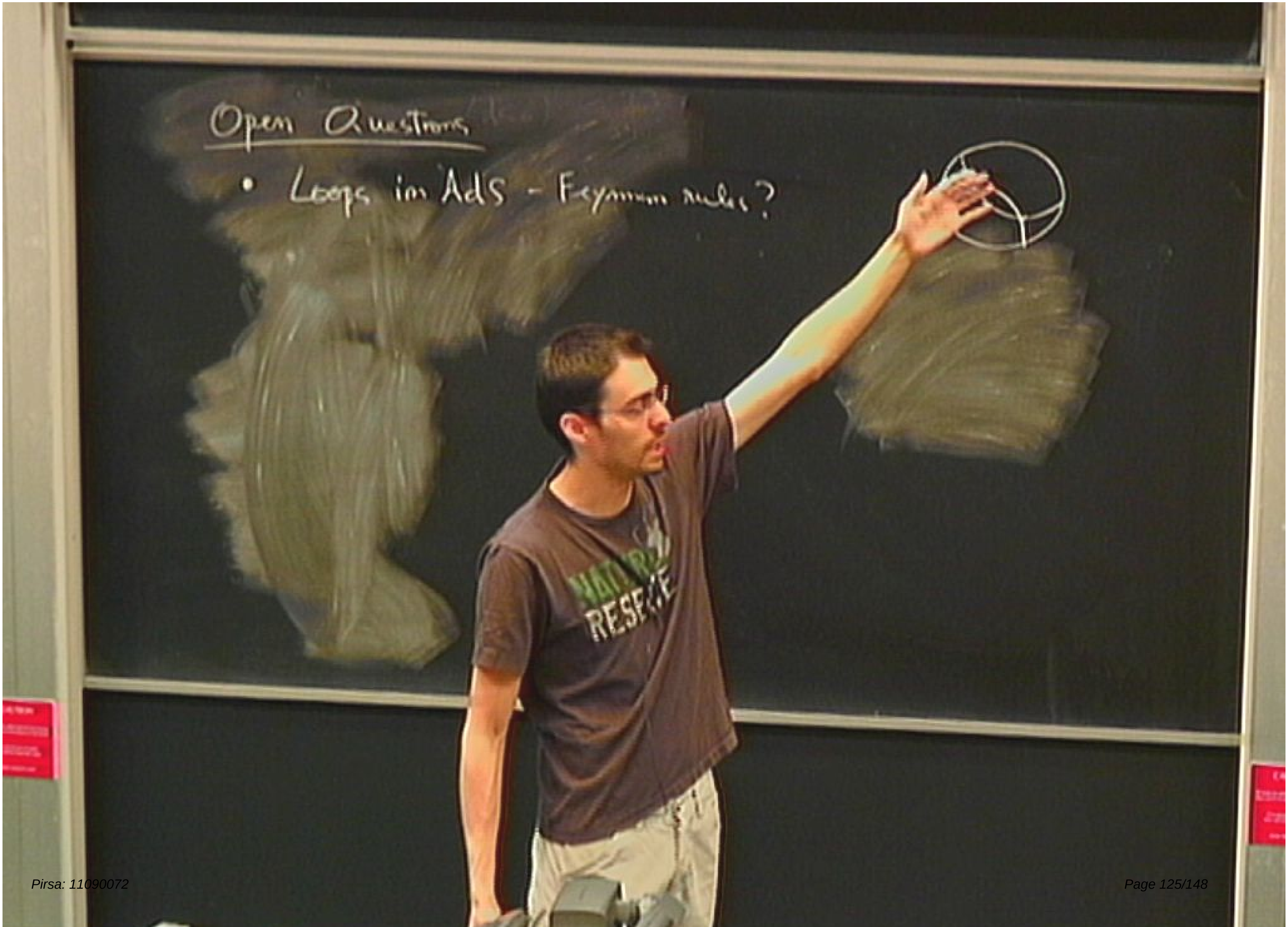
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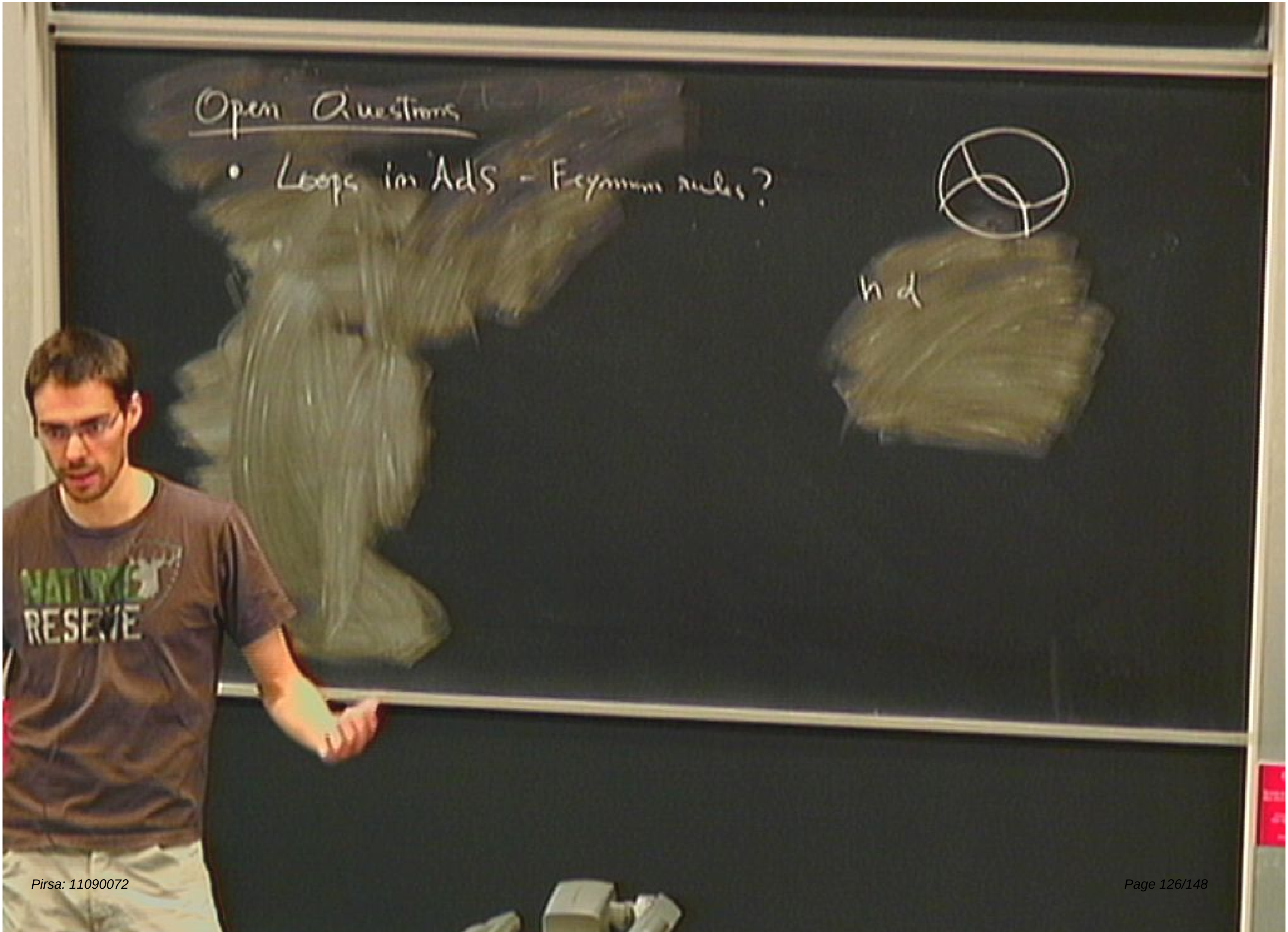
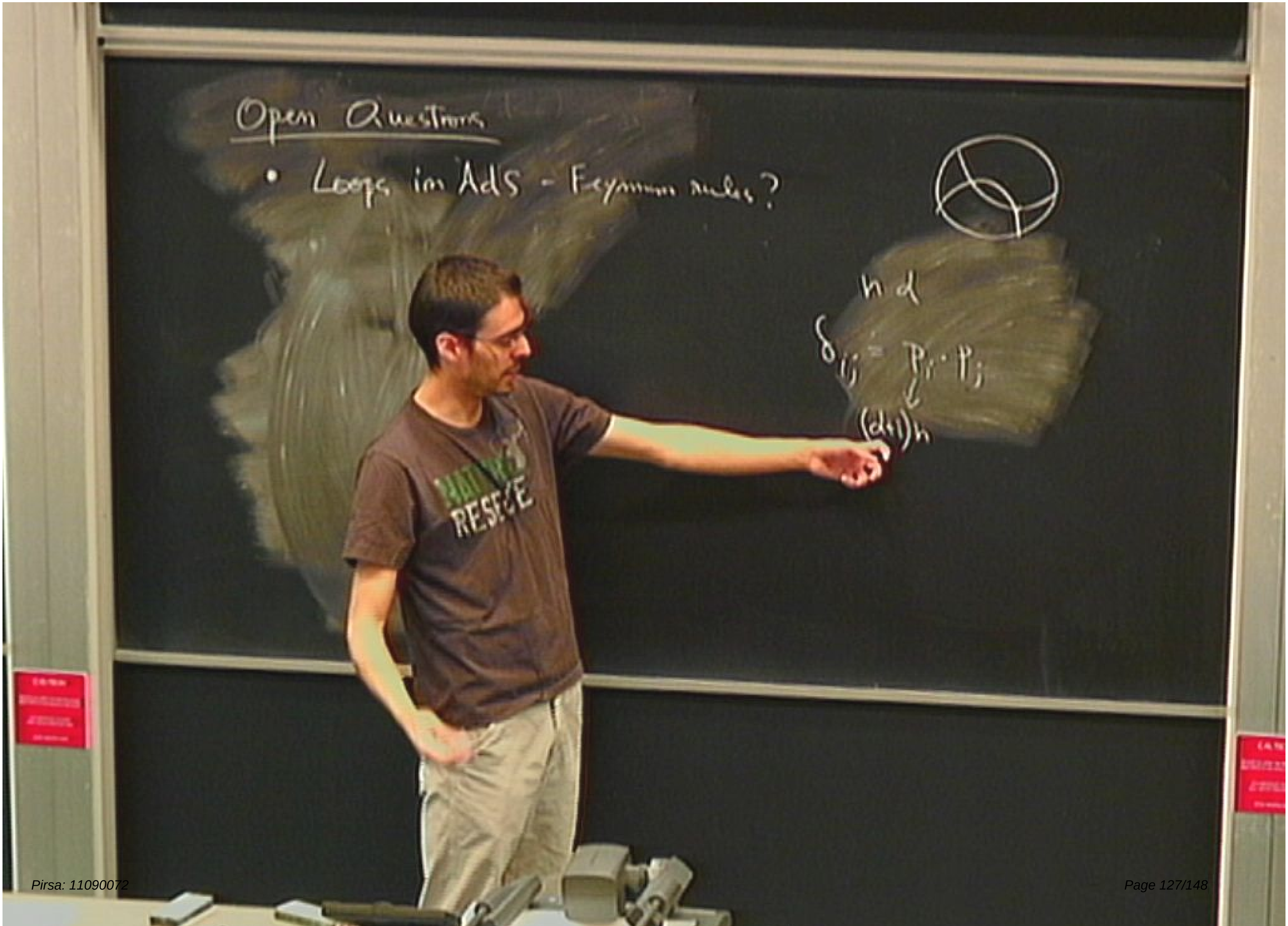

Open Questions
• Loops in AdS - Feynman rules?
n d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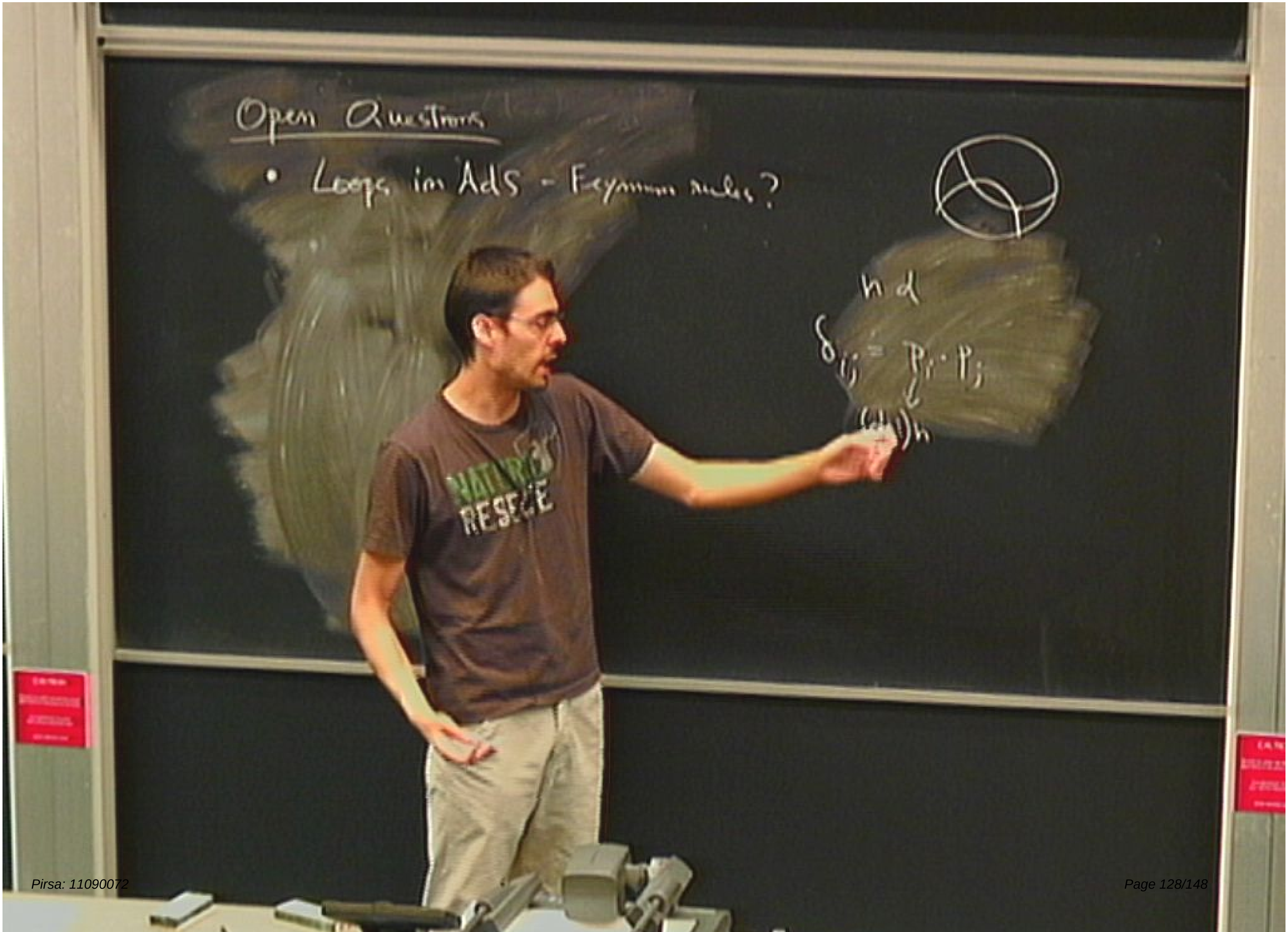
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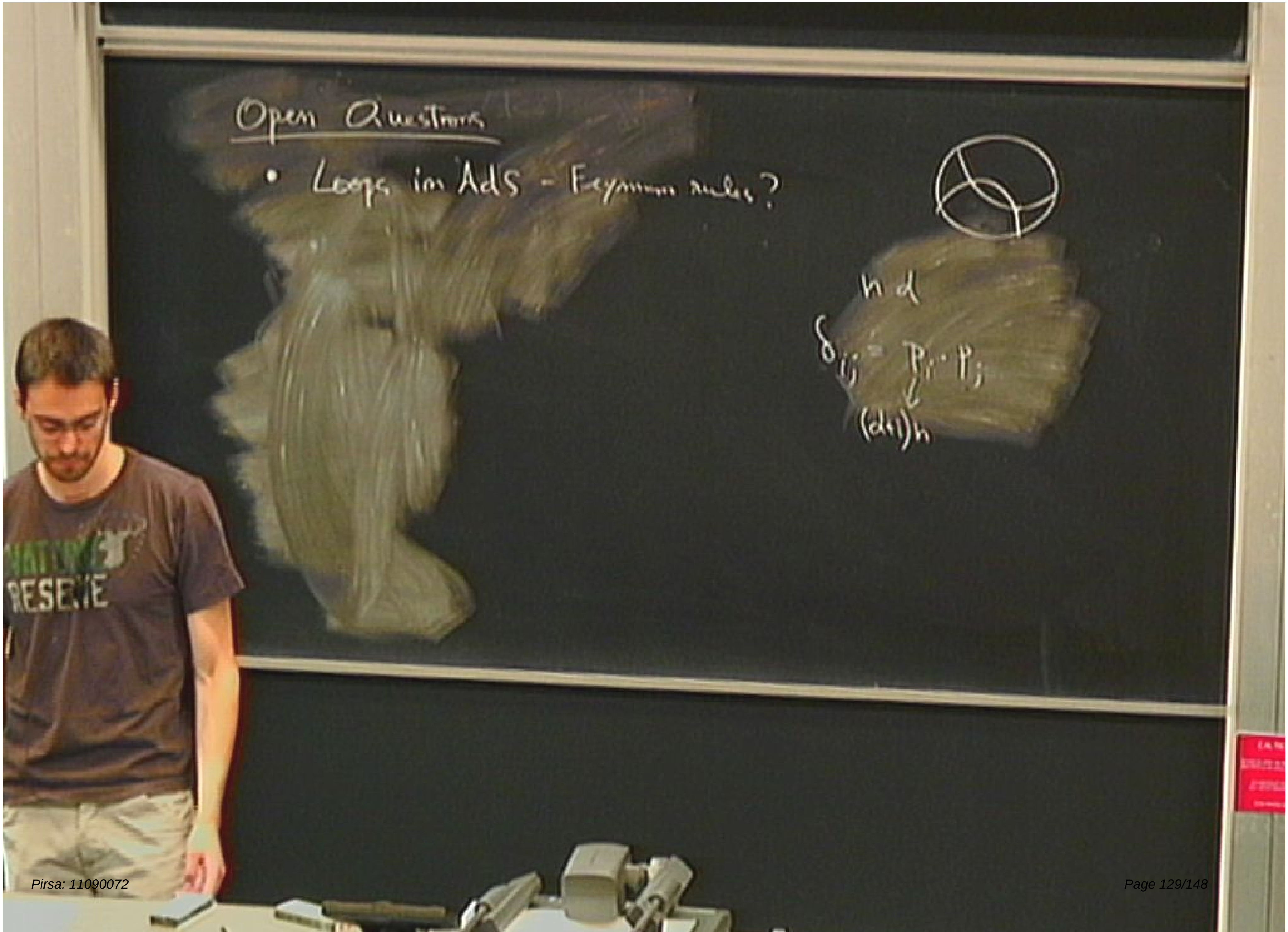
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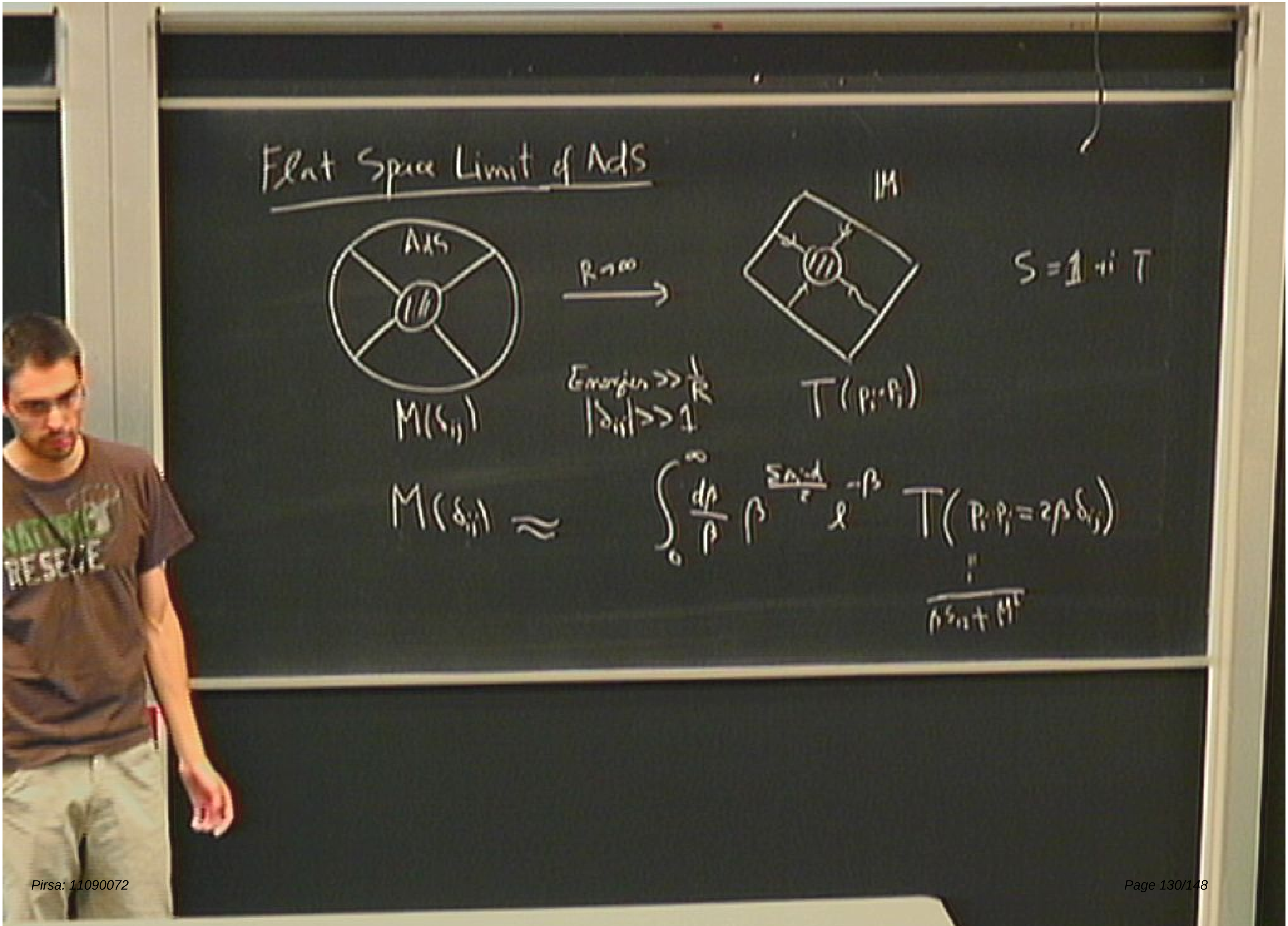
n d
δij = pi · pj
(d+1)n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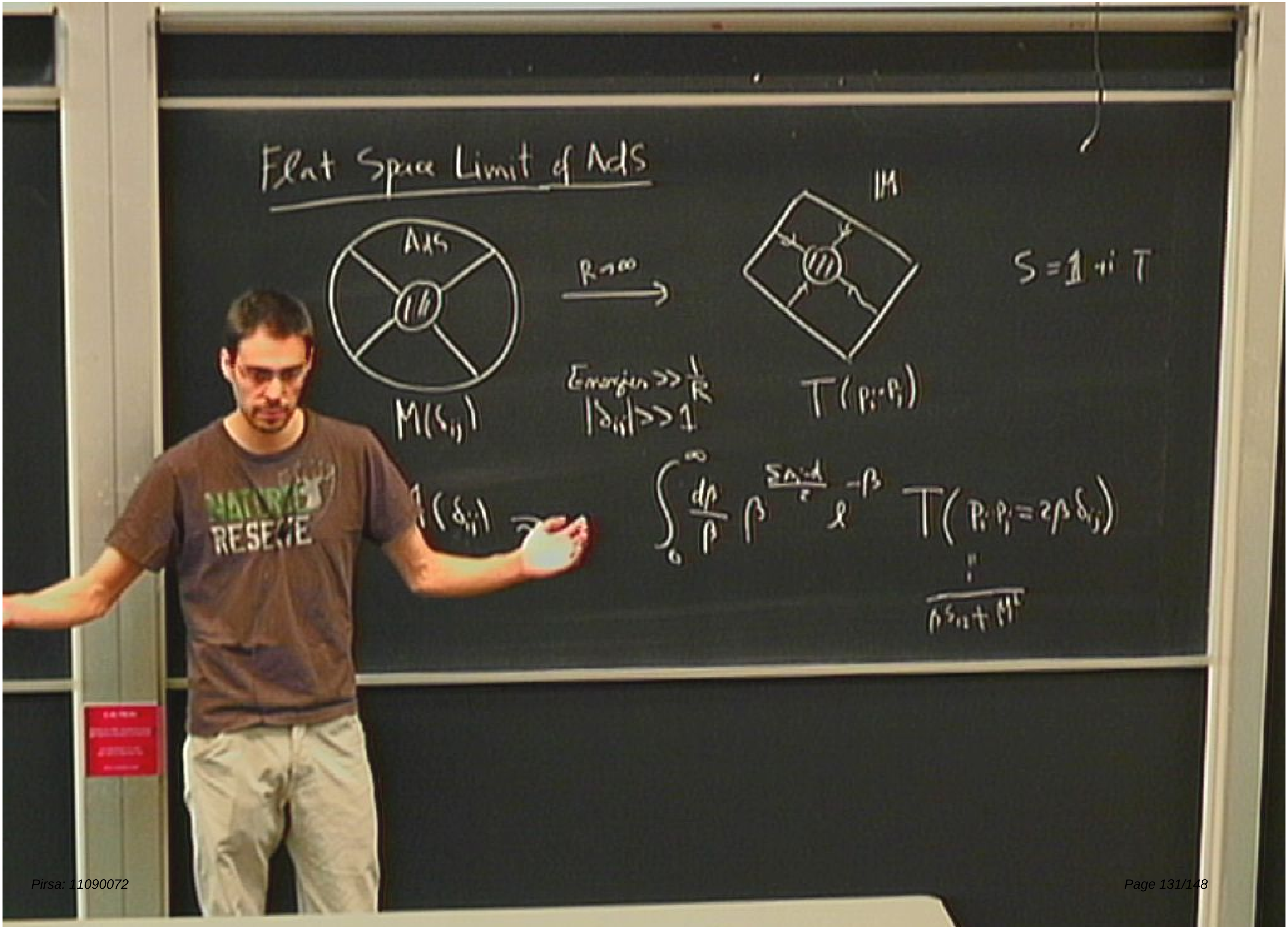
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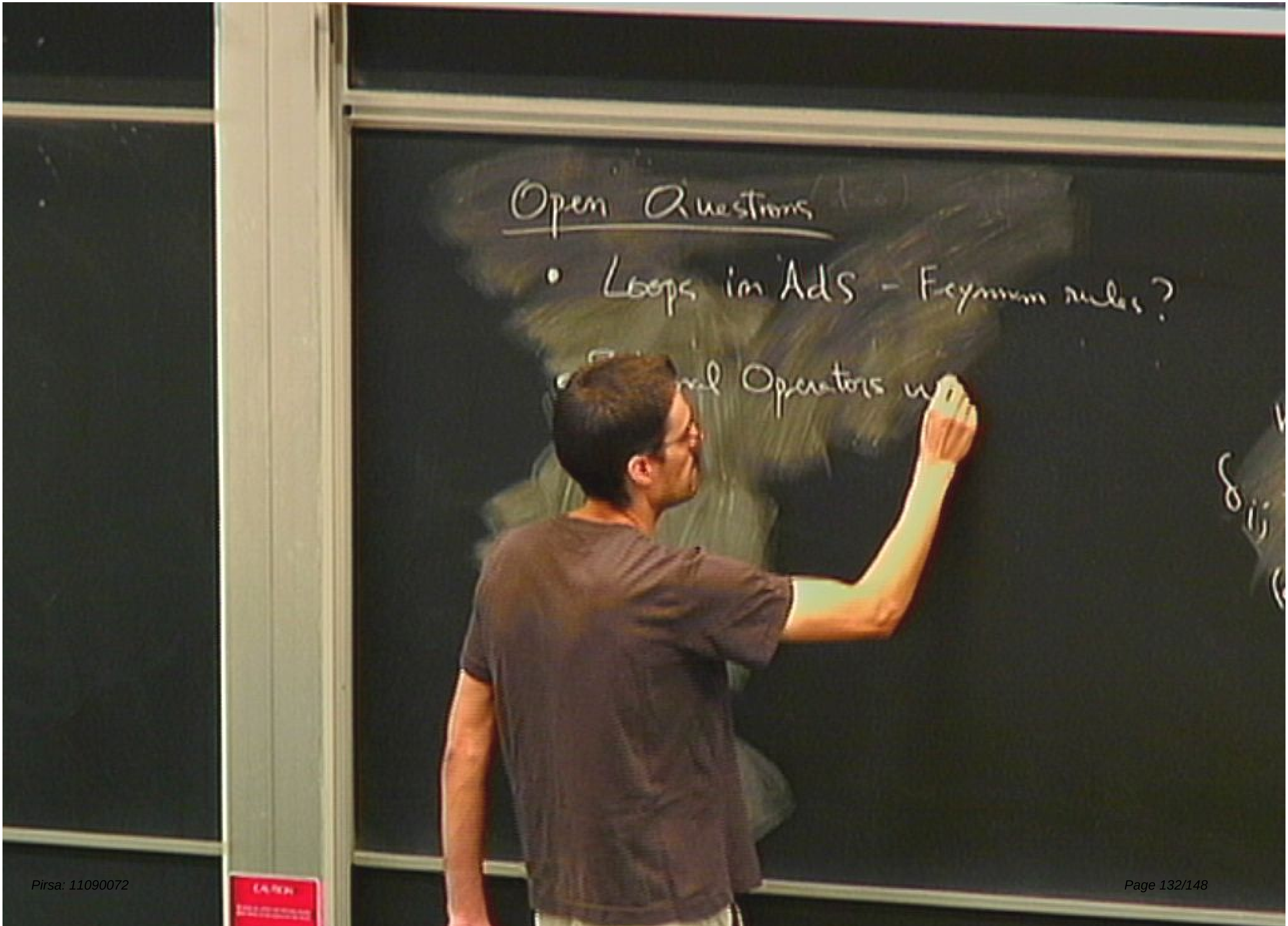
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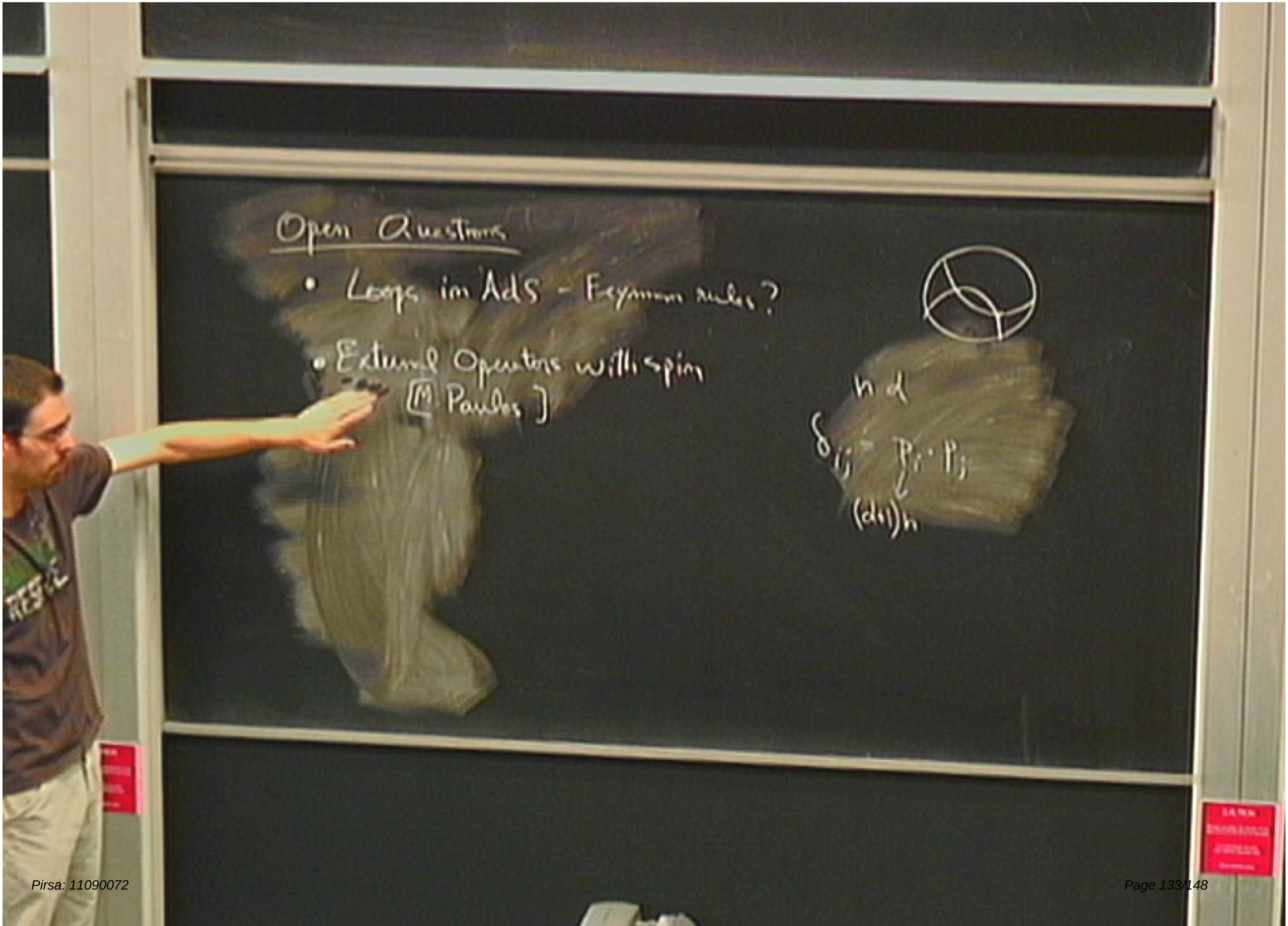
Open Questions
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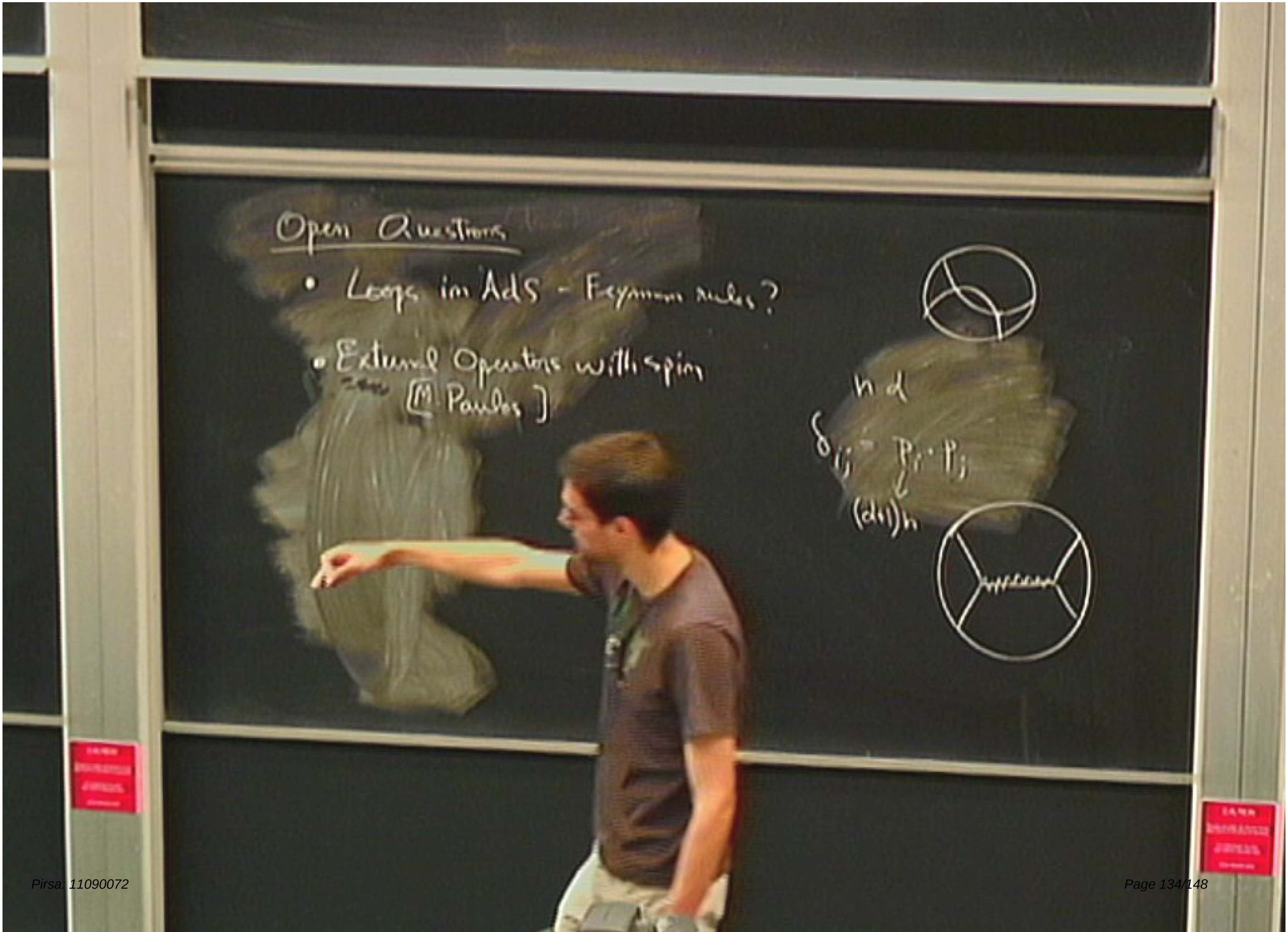
• External Operators with spin
[M. Paulos]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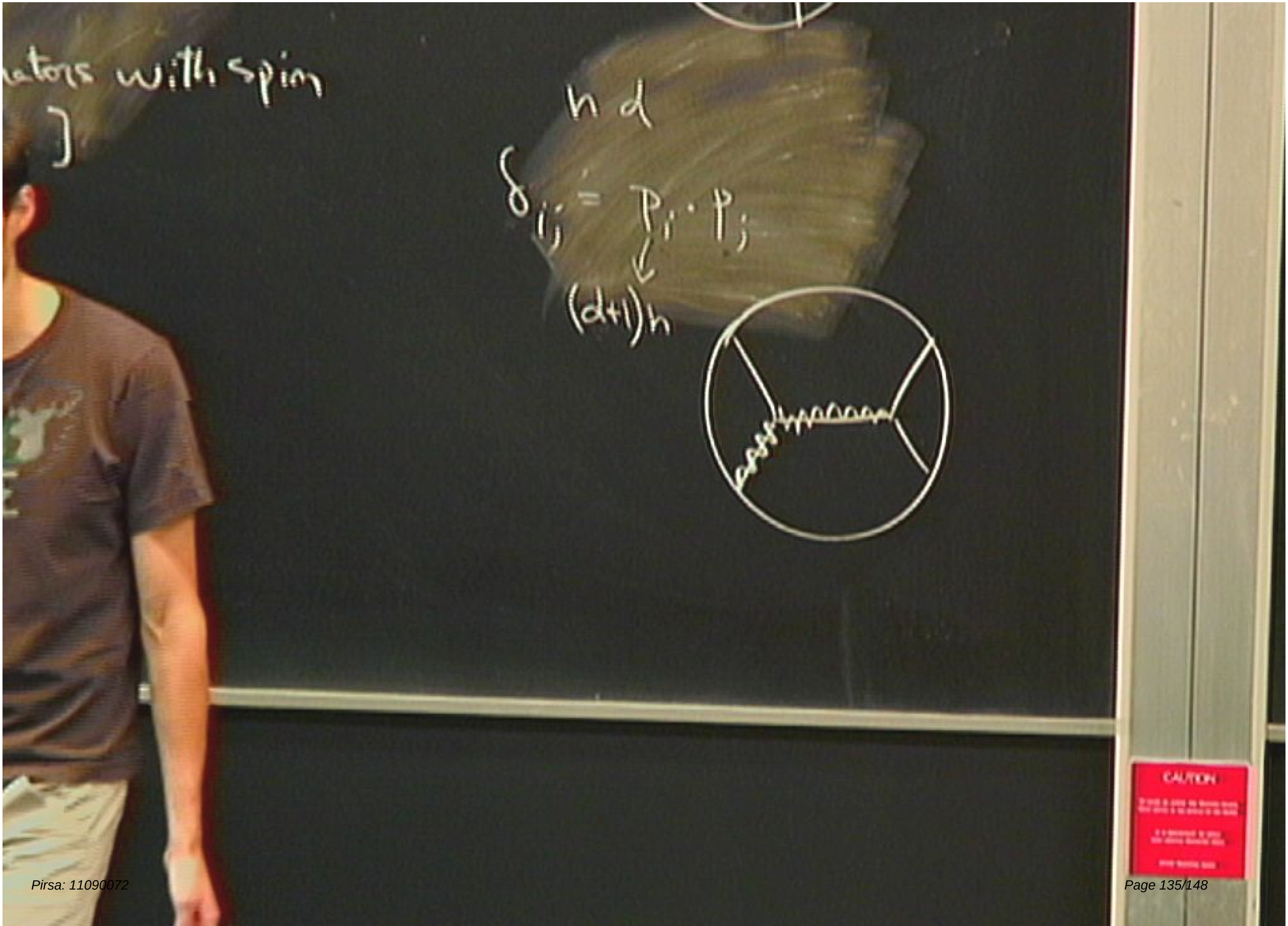
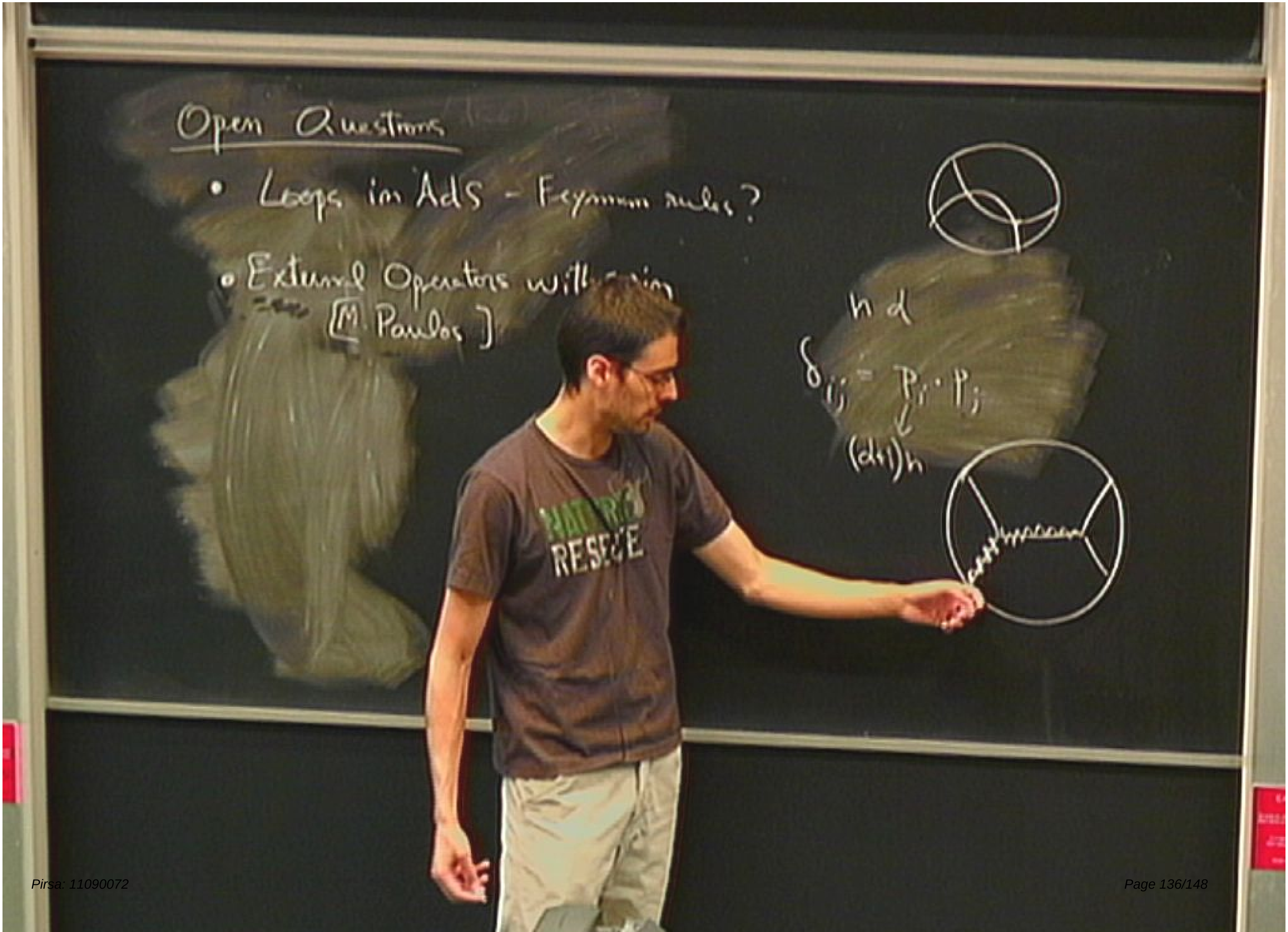

ators with spin
]
n d
δ_ij = p_i · p_j
(d+1)n
CAUTION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δij = Pi · Pj
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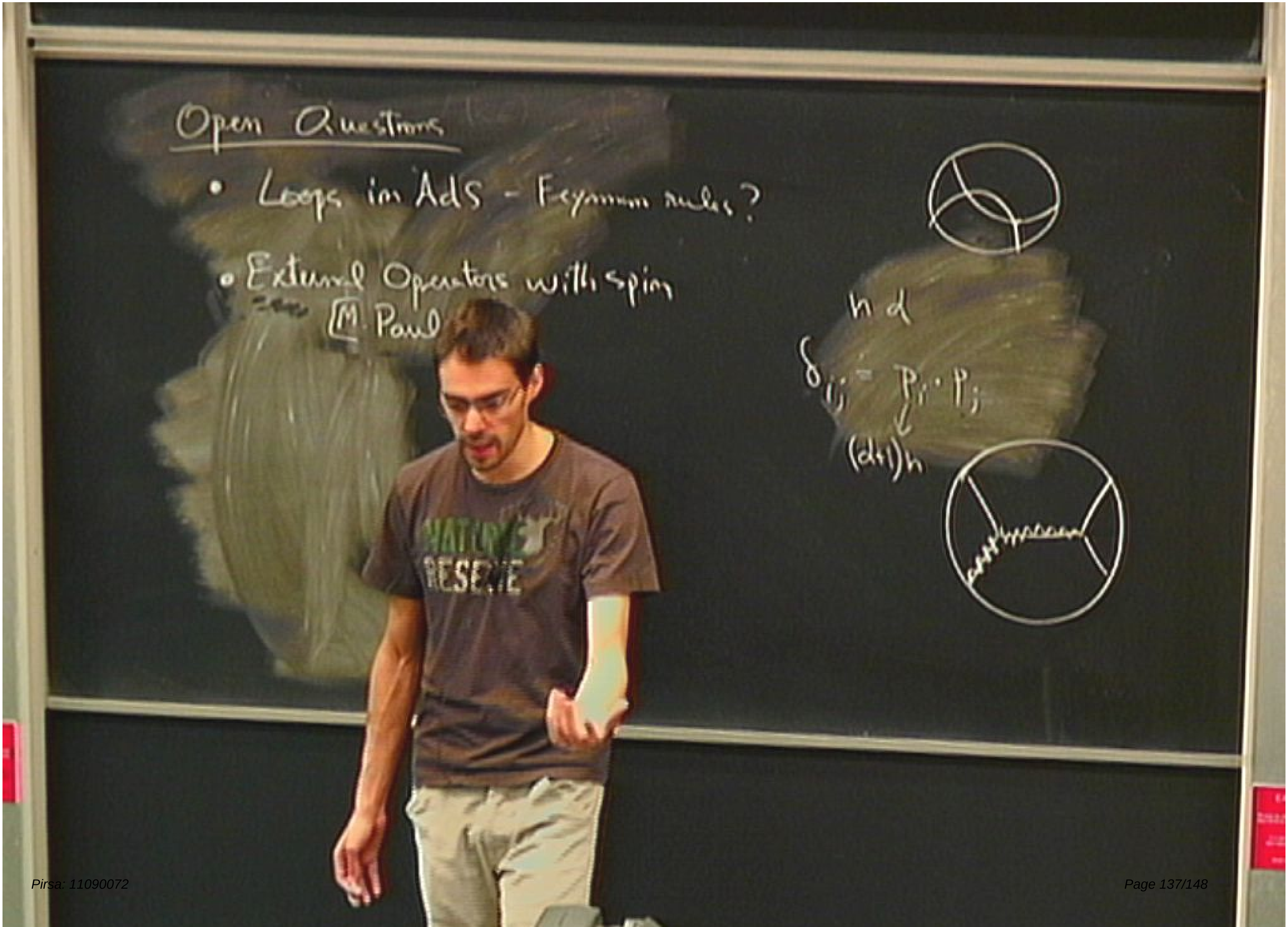
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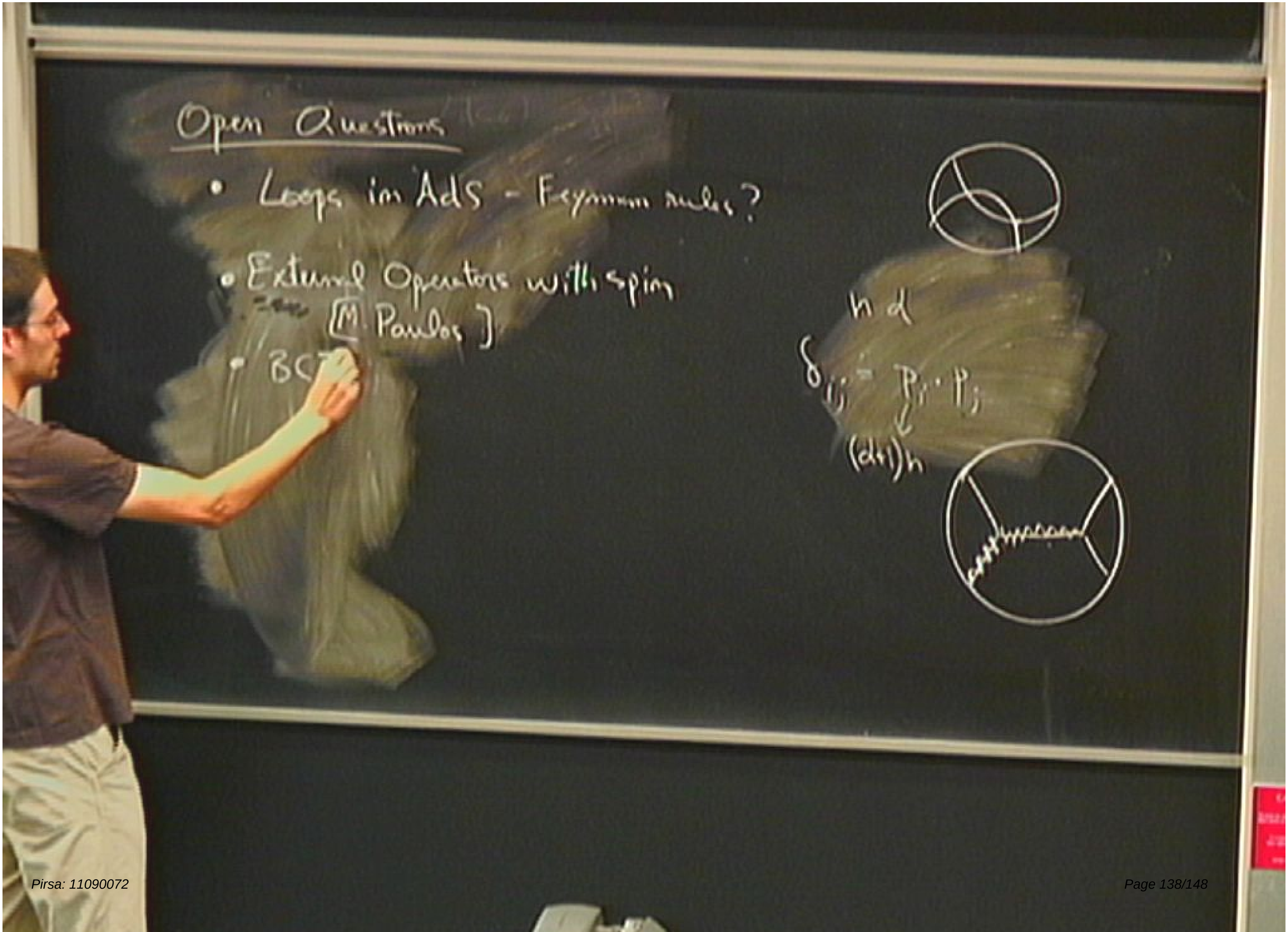
M. Paul
h d
(d+1)h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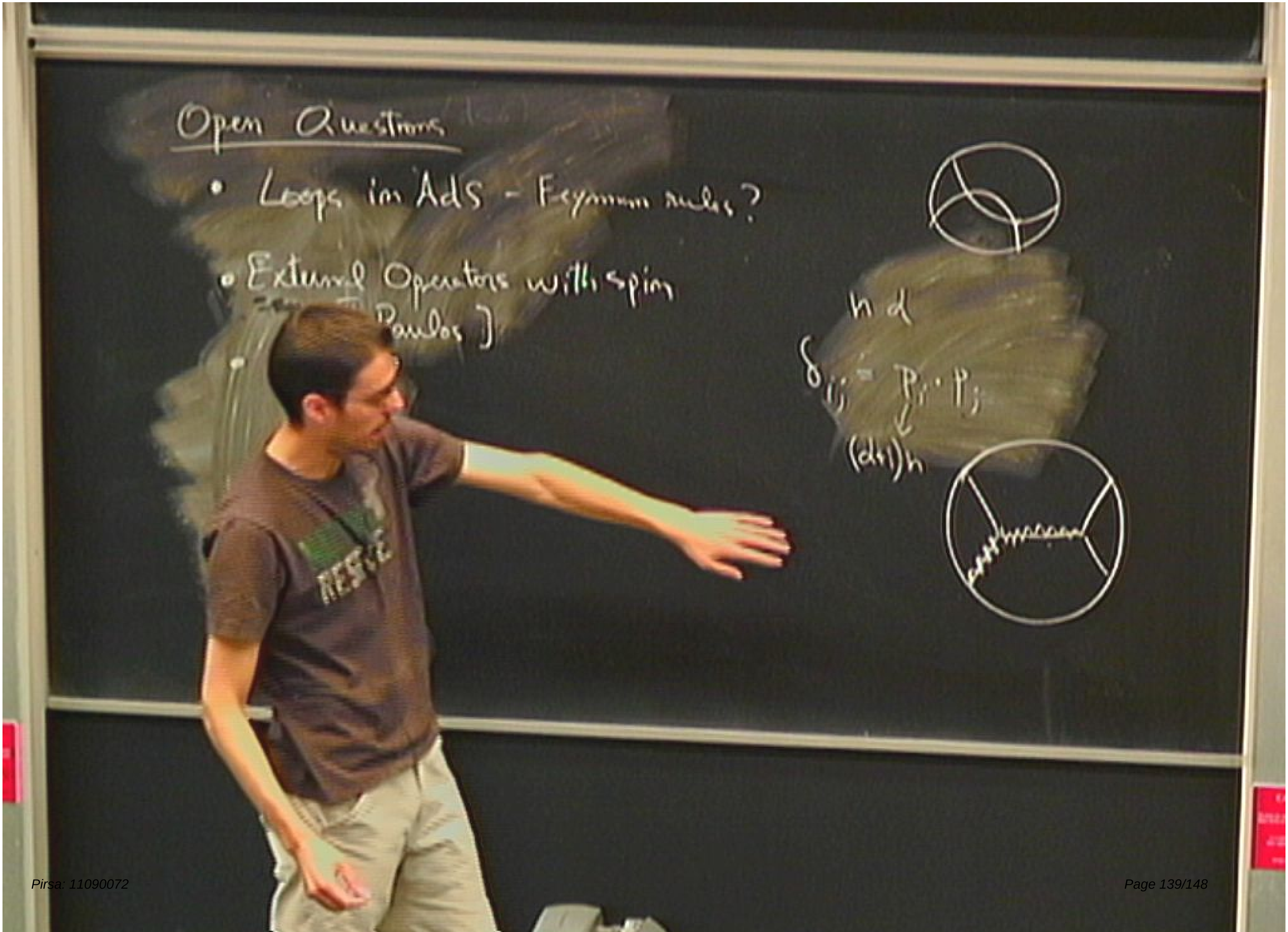
(d+1)n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Paulos]
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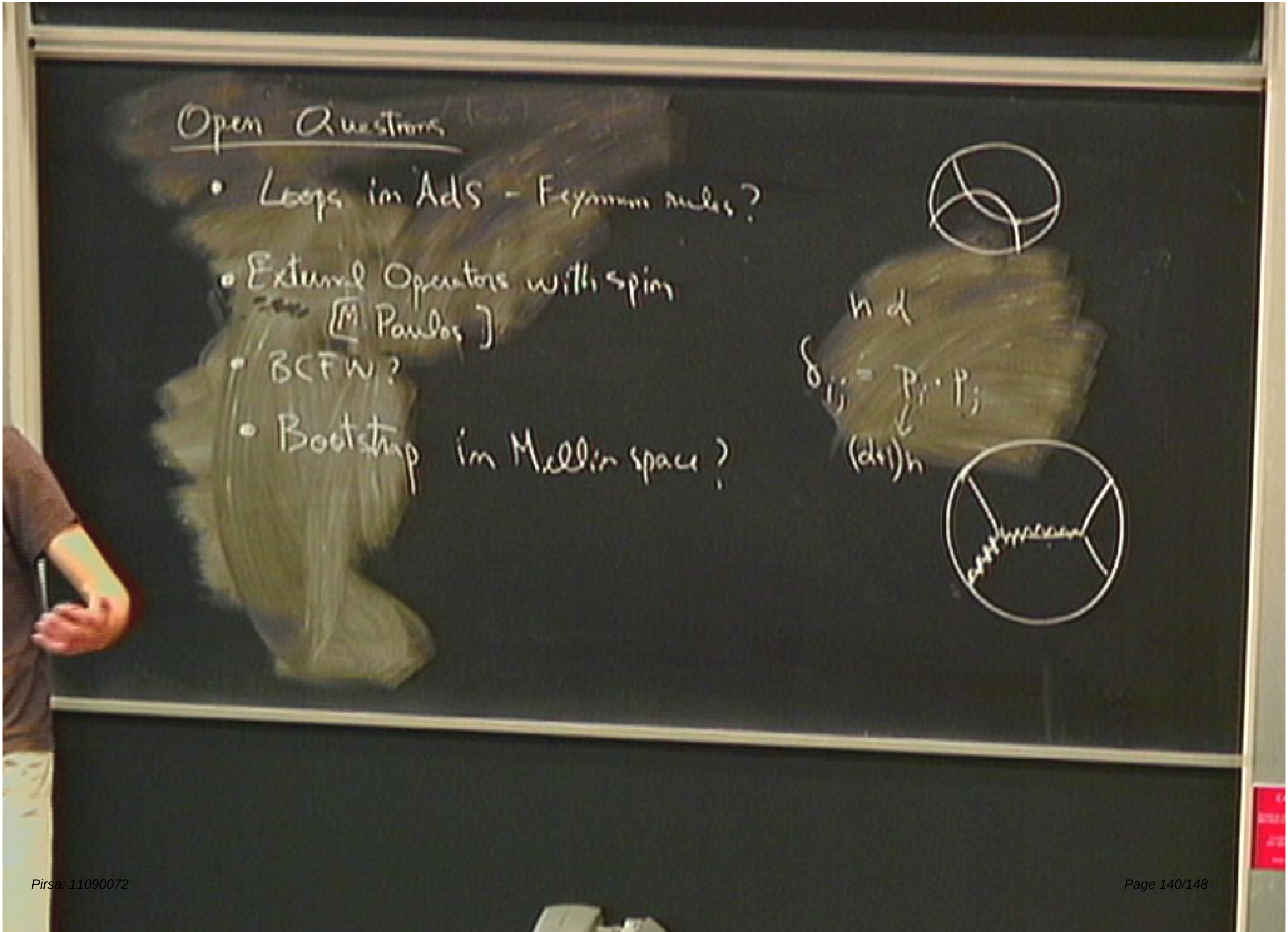
(d+1)n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• BCFW?
• Bootstrap in Mellin space?
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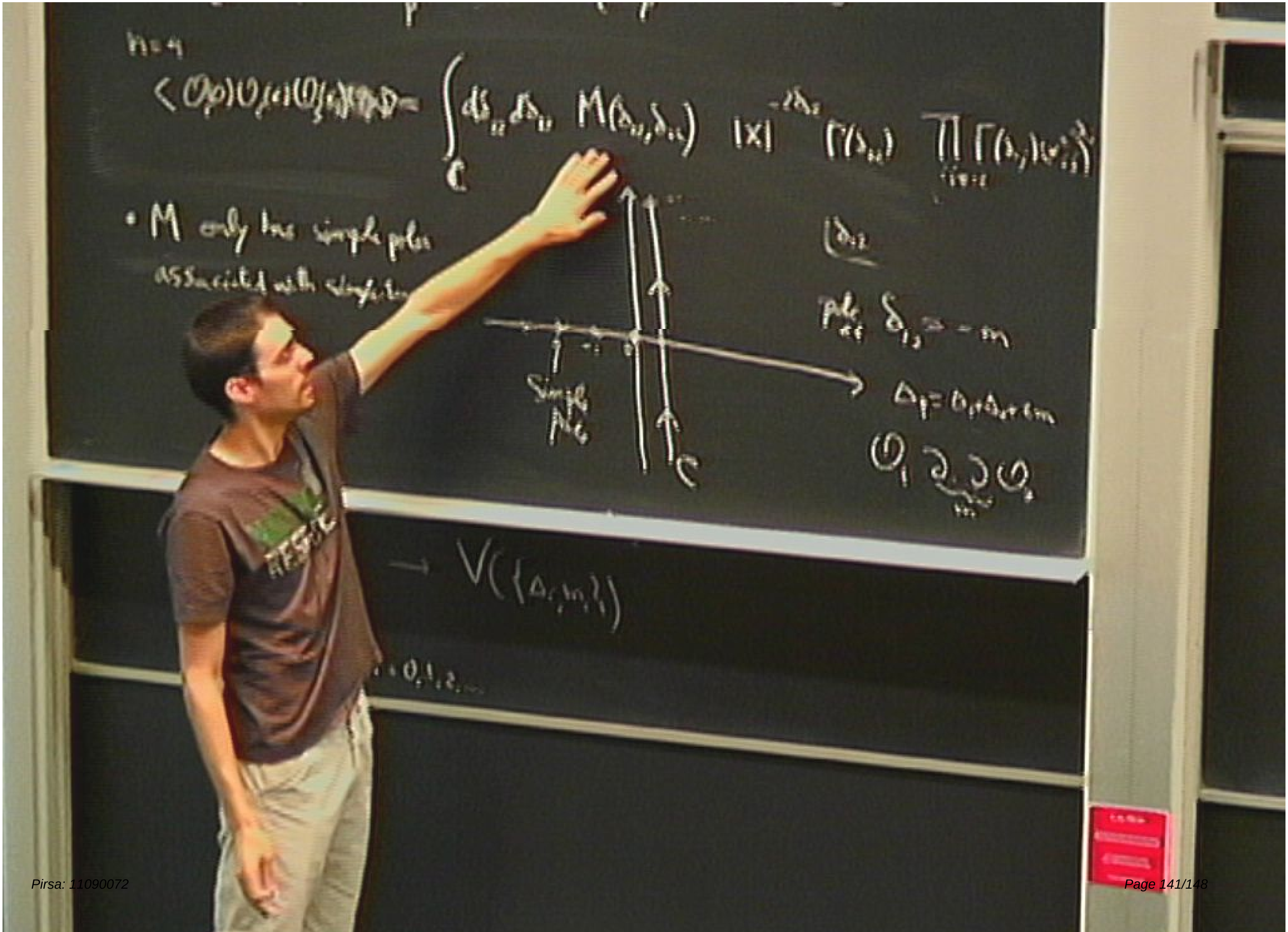
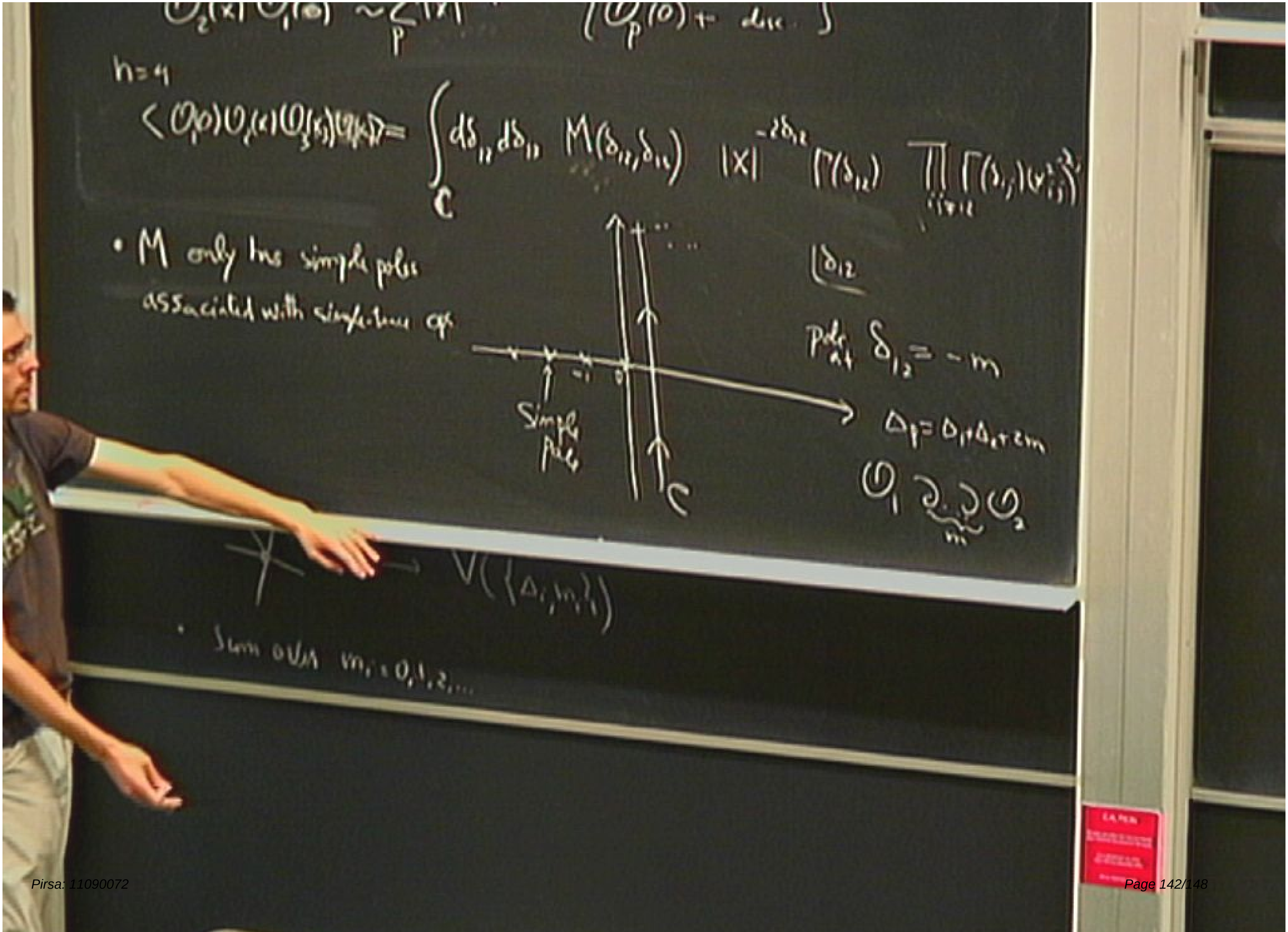
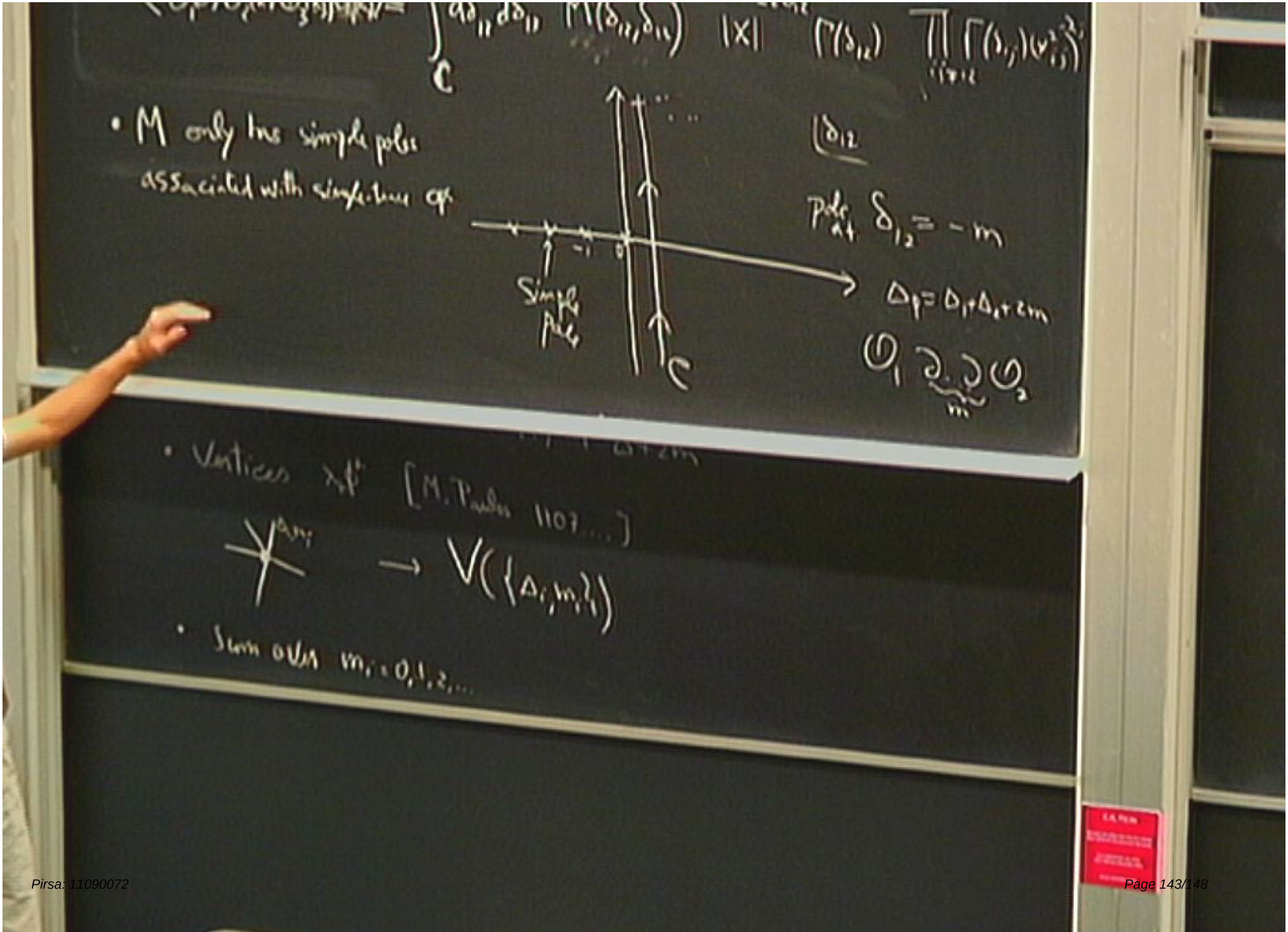
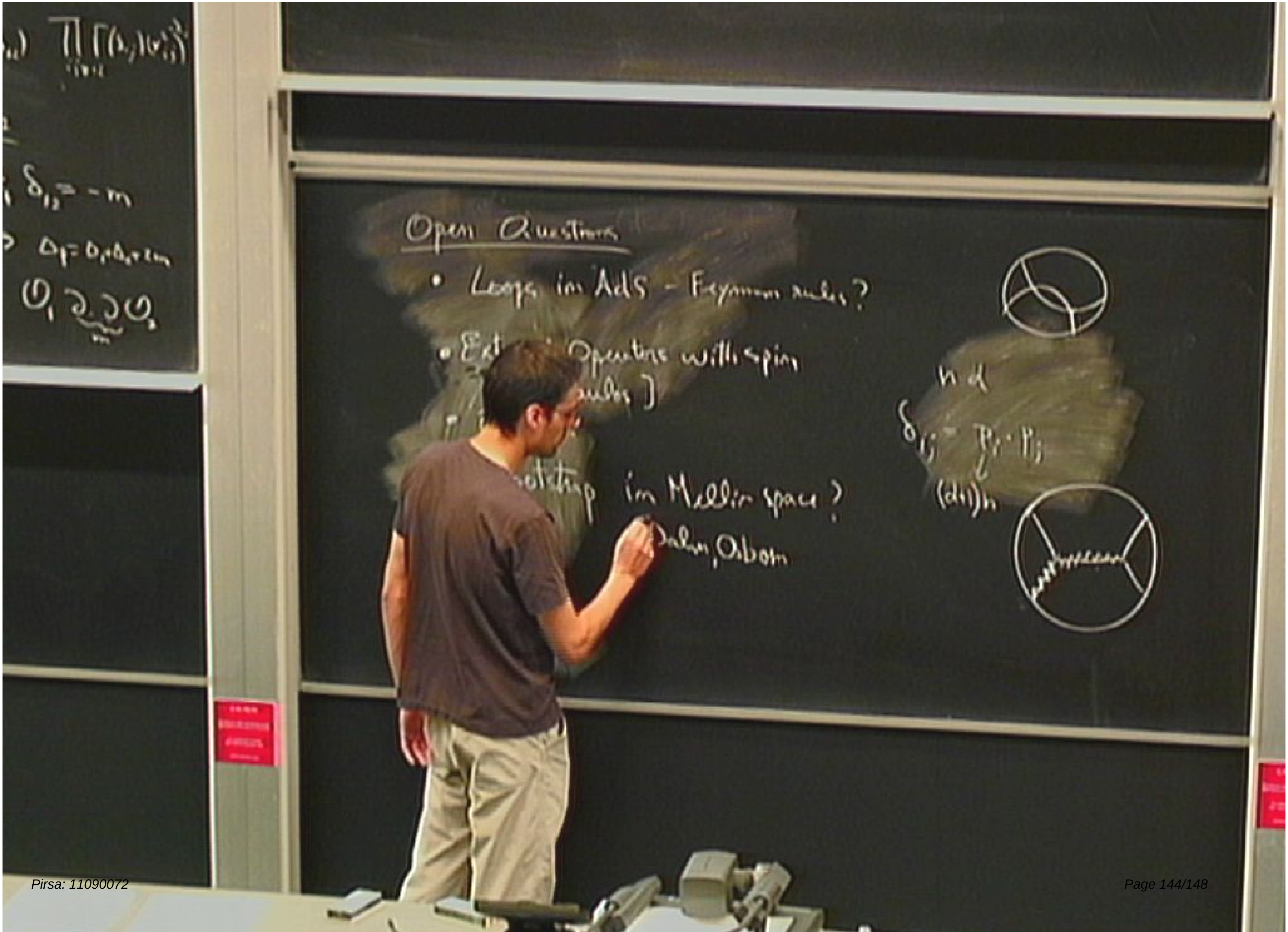
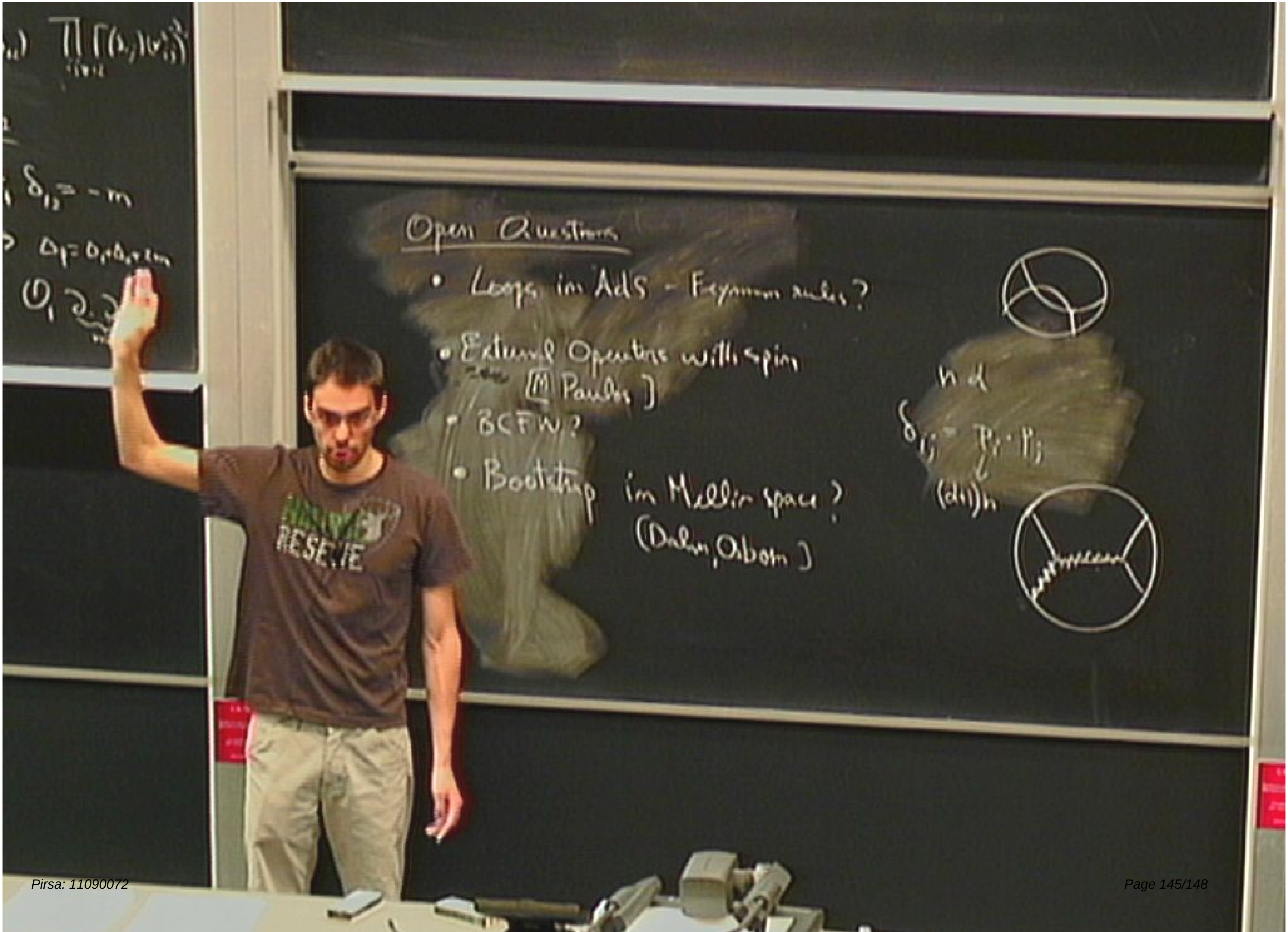
δij = Pi · Pj
(d+1)n




n=4
M only has simple poles
associated with single-trace ops
simple poles
C
poles at δ12 = − m
Δp = Δ1 + Δ2 + 2m
Sum over m = 0, 1, 2, ...


• M only has simple poles
associated with singularities of
Poles at δ12 = -m
Δp = Δ1 + Δ2 + 2m
Simple Poles
• Vertices
→ V({Δi, mi})
• Sum over mi = 0, 1, 2, ...


Open Questions
• Loops in AdS - Feynman rules?
Operators with spin
in Mellin space?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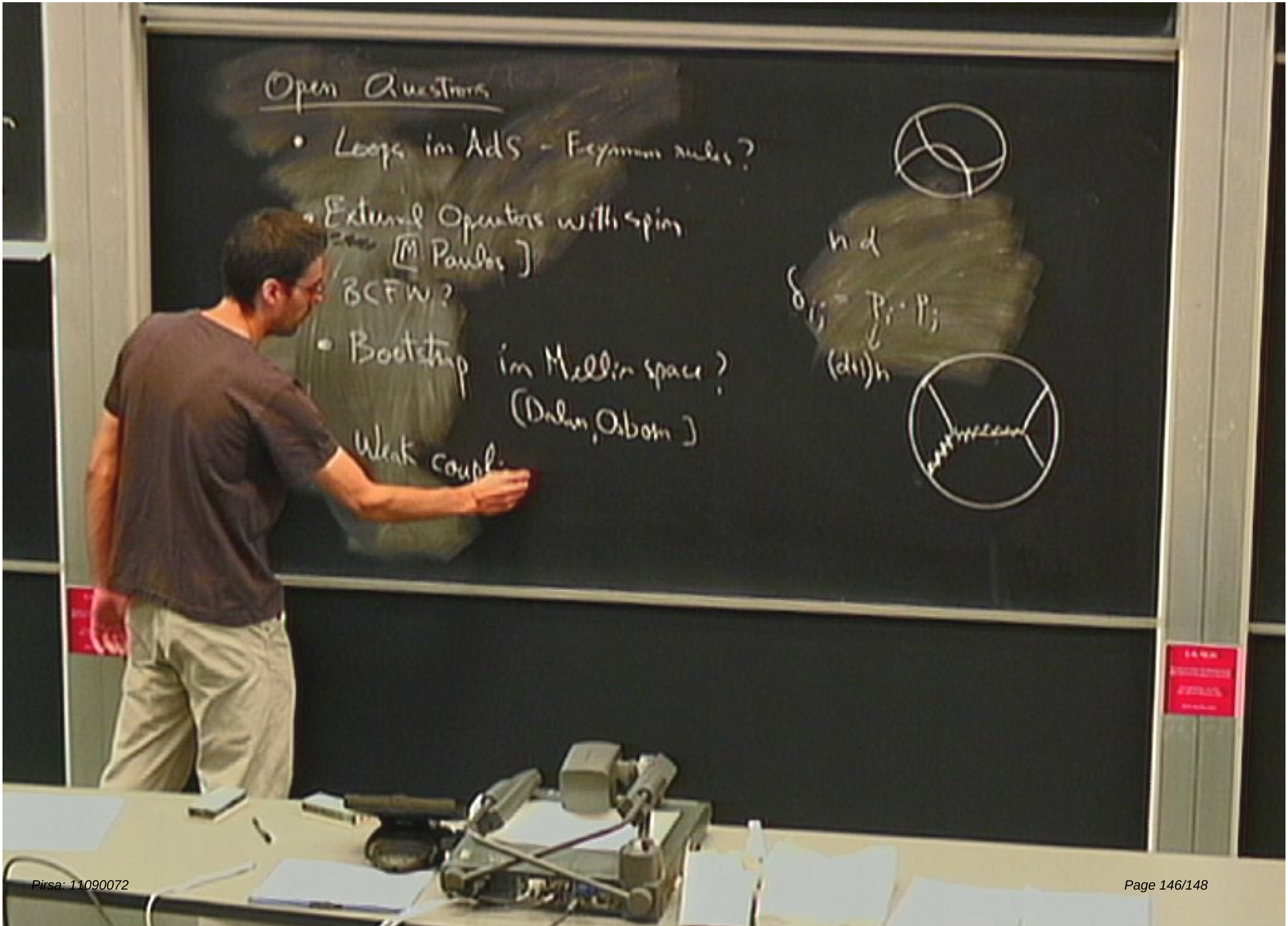
• BCFW?
• Bootstrap in Mellin space?
(Dolan, Osborn)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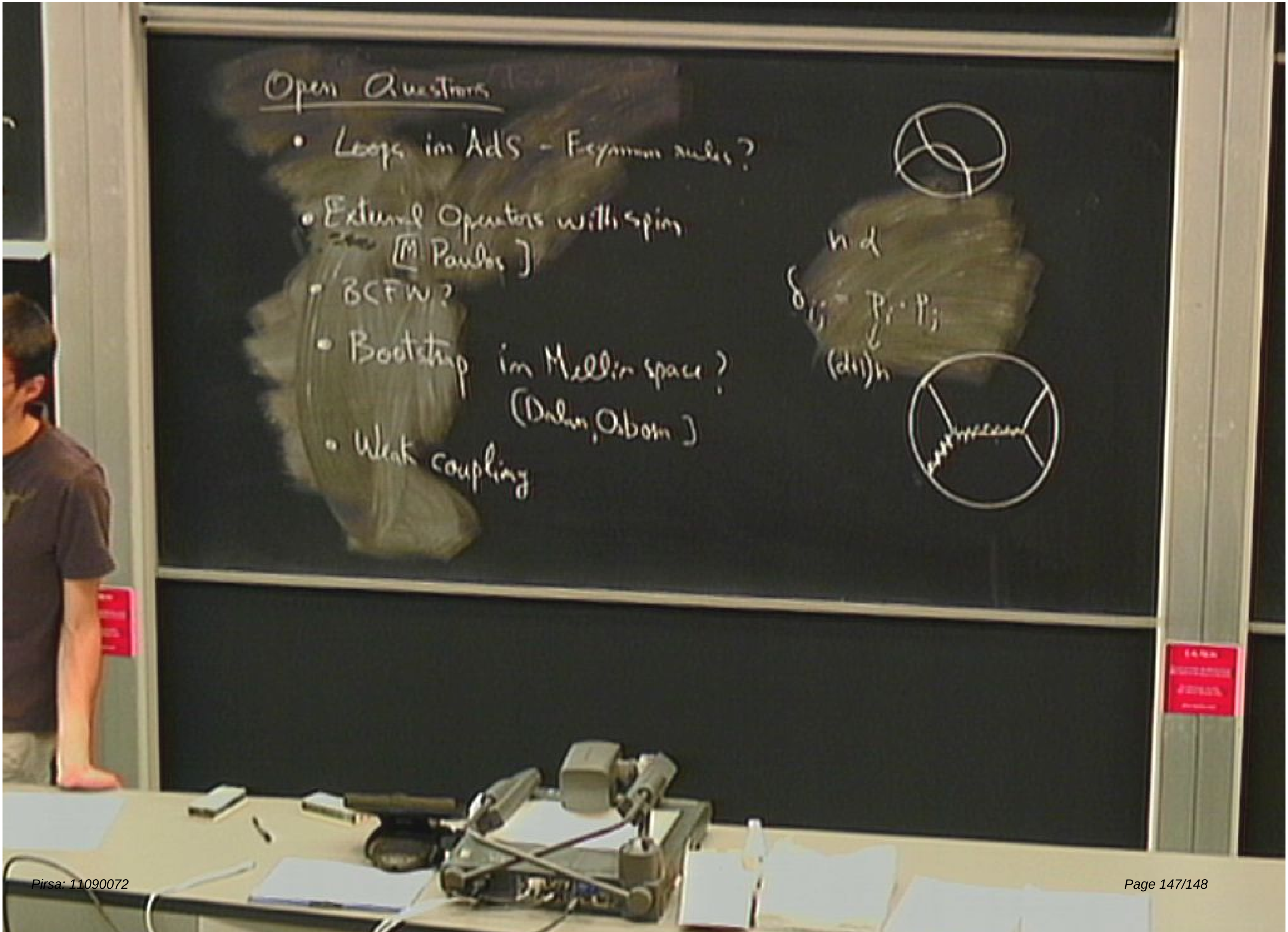
Weak coupl.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[Dolan, Osborn]
• Weak coupling