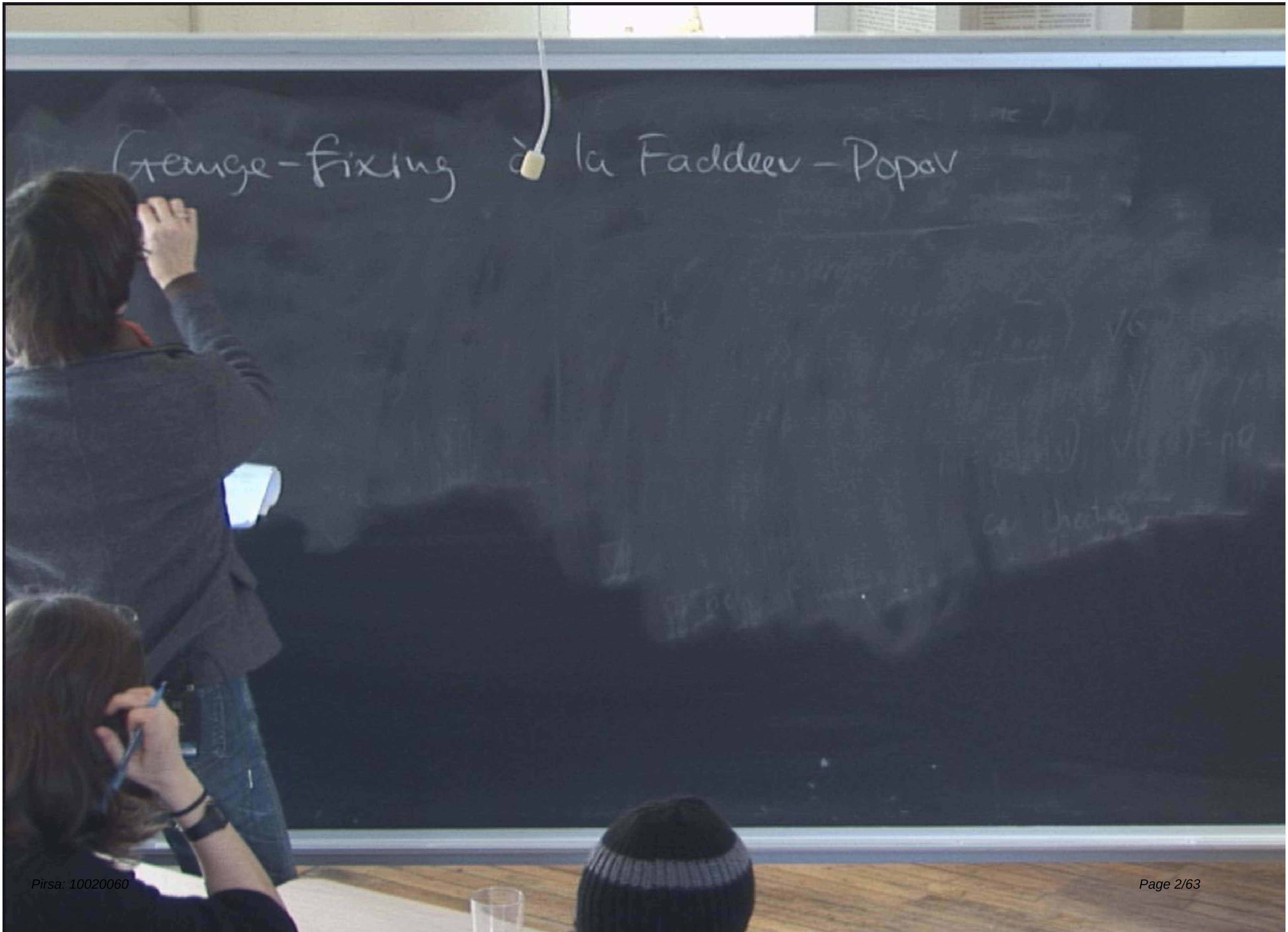
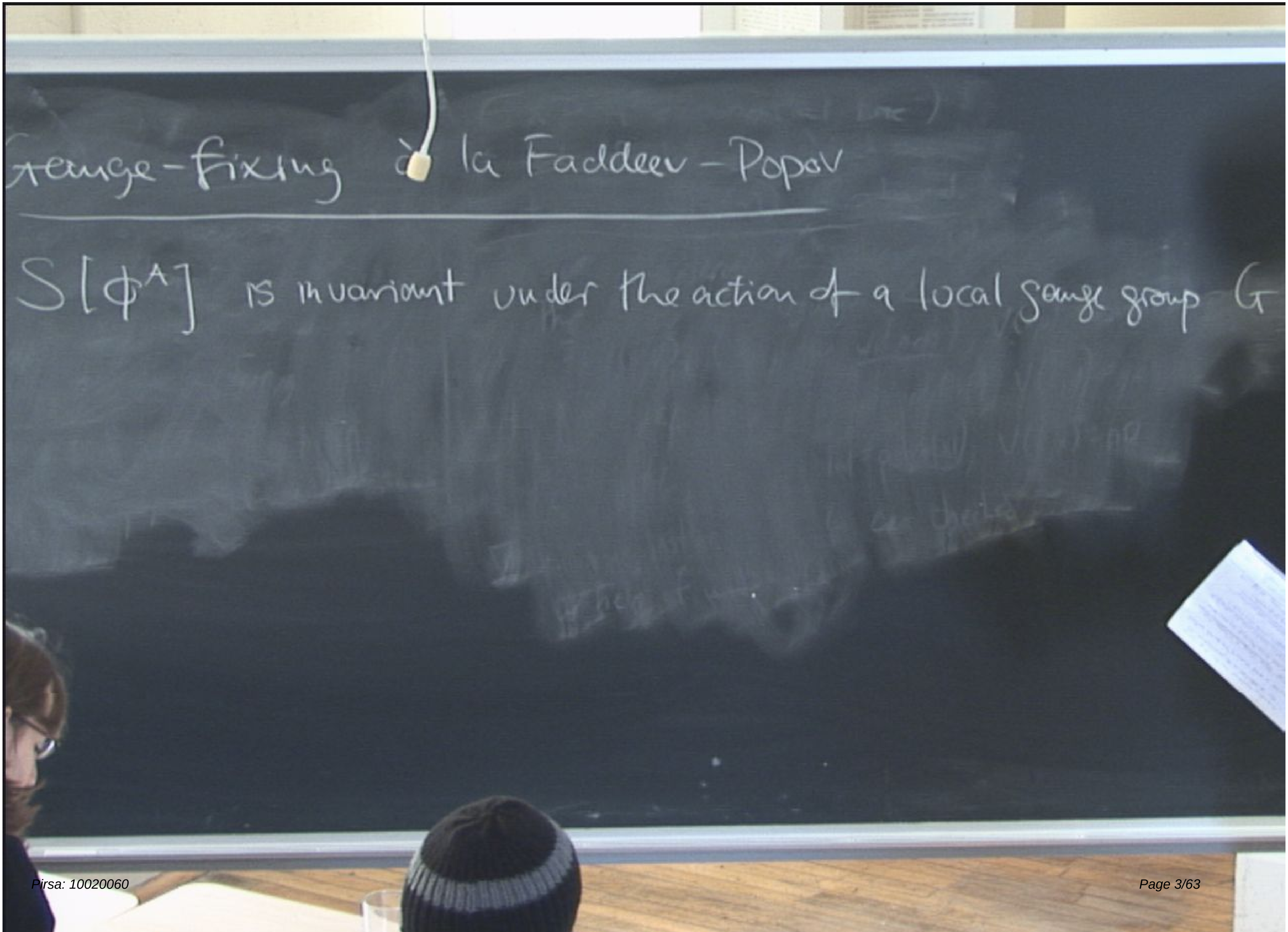
Title: Quantum Gravity - Review (PHYS 638) - Lecture 6

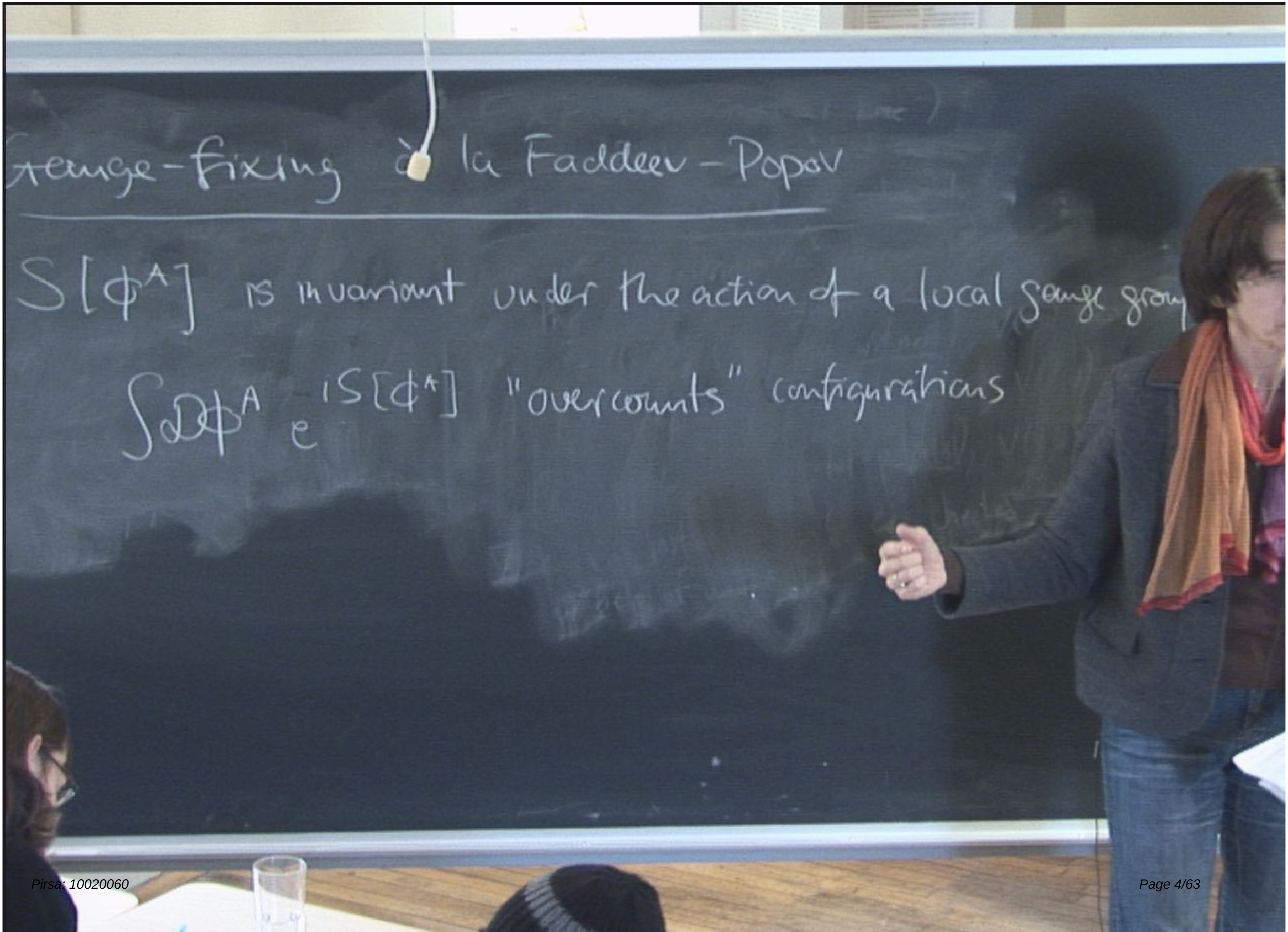
Date: Feb 01, 2010 10:00 AM

URL: http://pirsa.org/10020060

Abstract:


Gauge-fixing à la Faddeev-Popov


Gauge-fixing à la Faddeev-Popov
S[ϕ^A] is invariant under the action of a local gauge group G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$\int \mathcal{D}\phi^A \, e^{iS[\phi^A]}$ "overcounts" configurations

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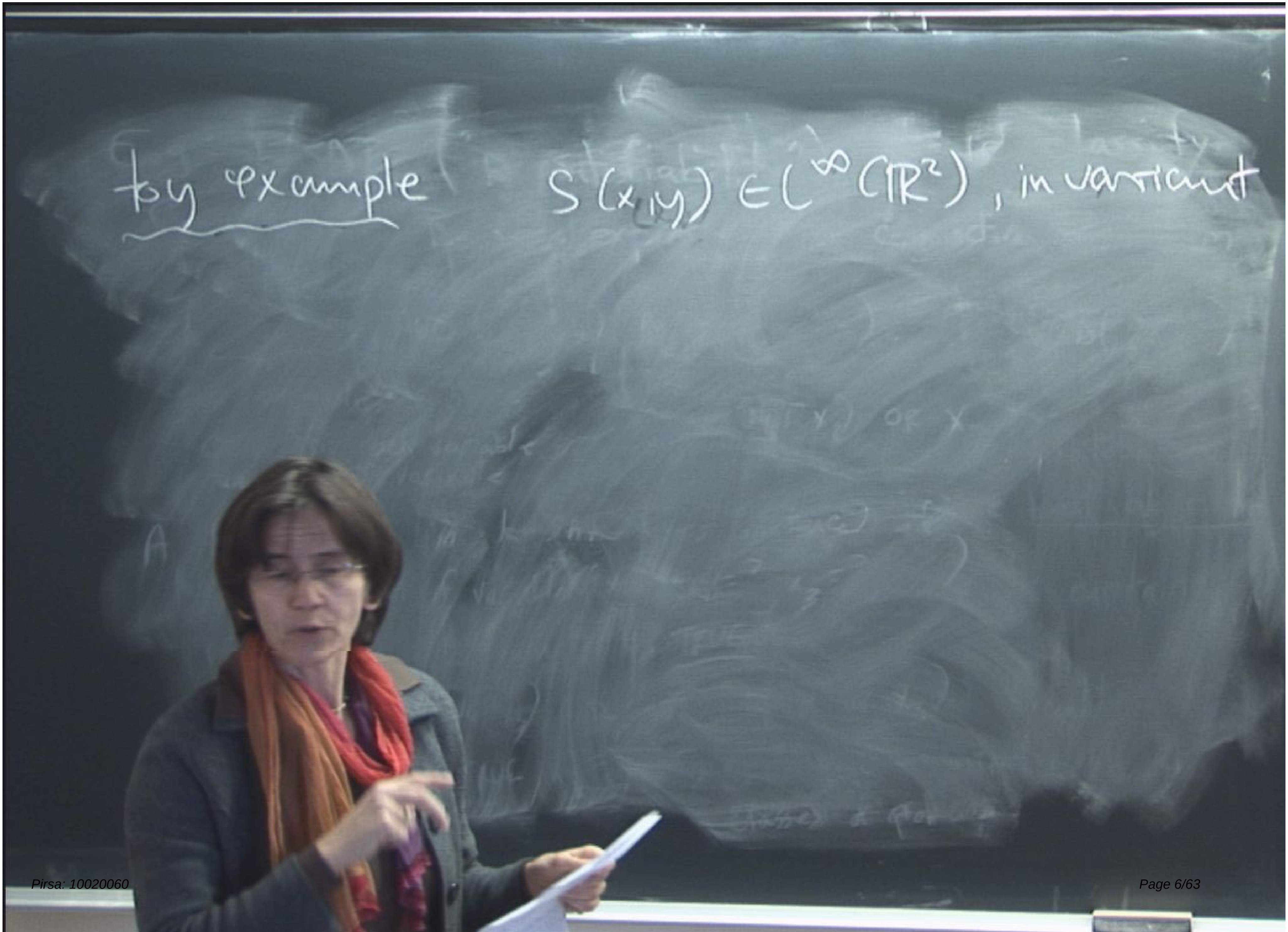
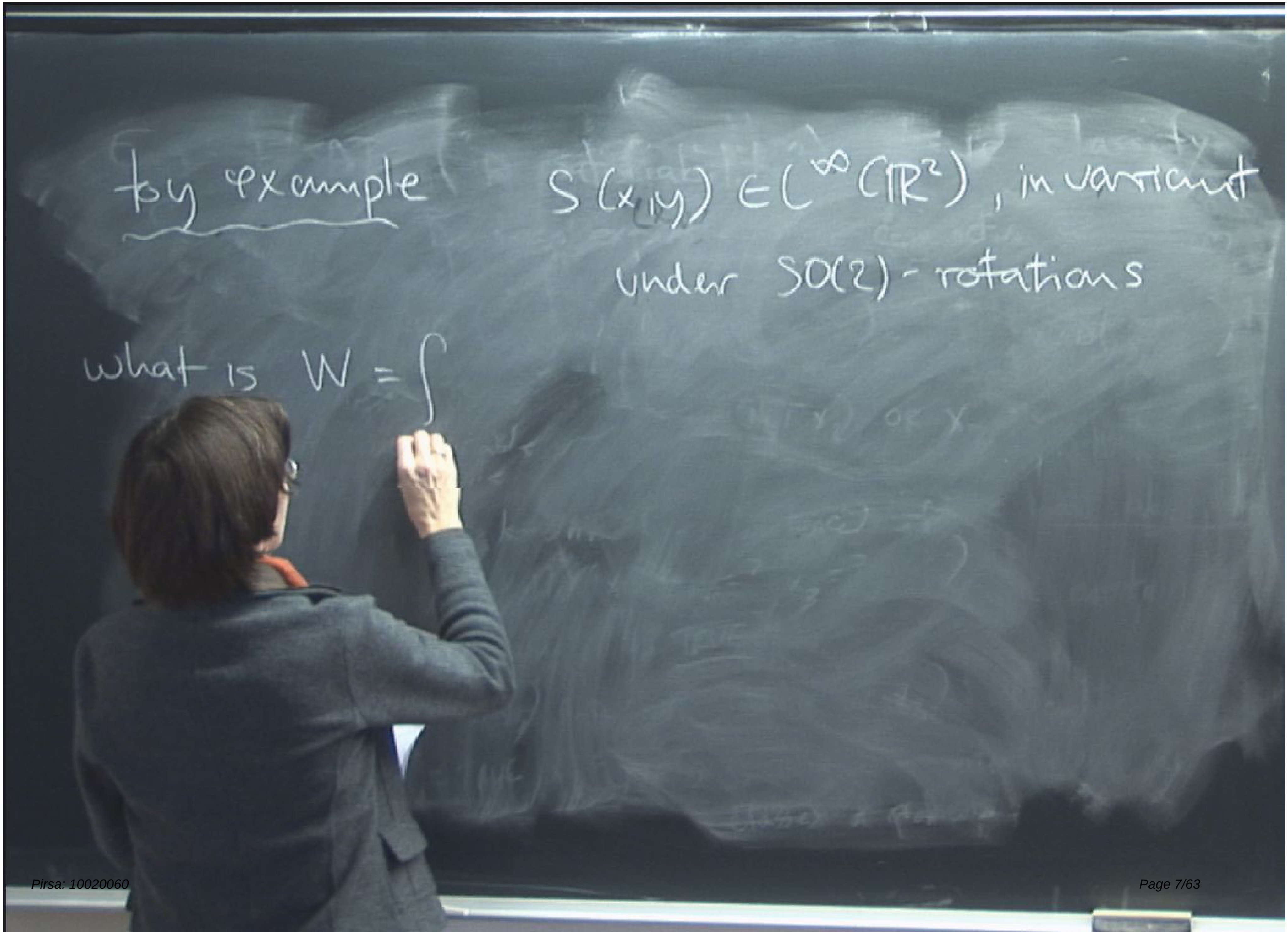
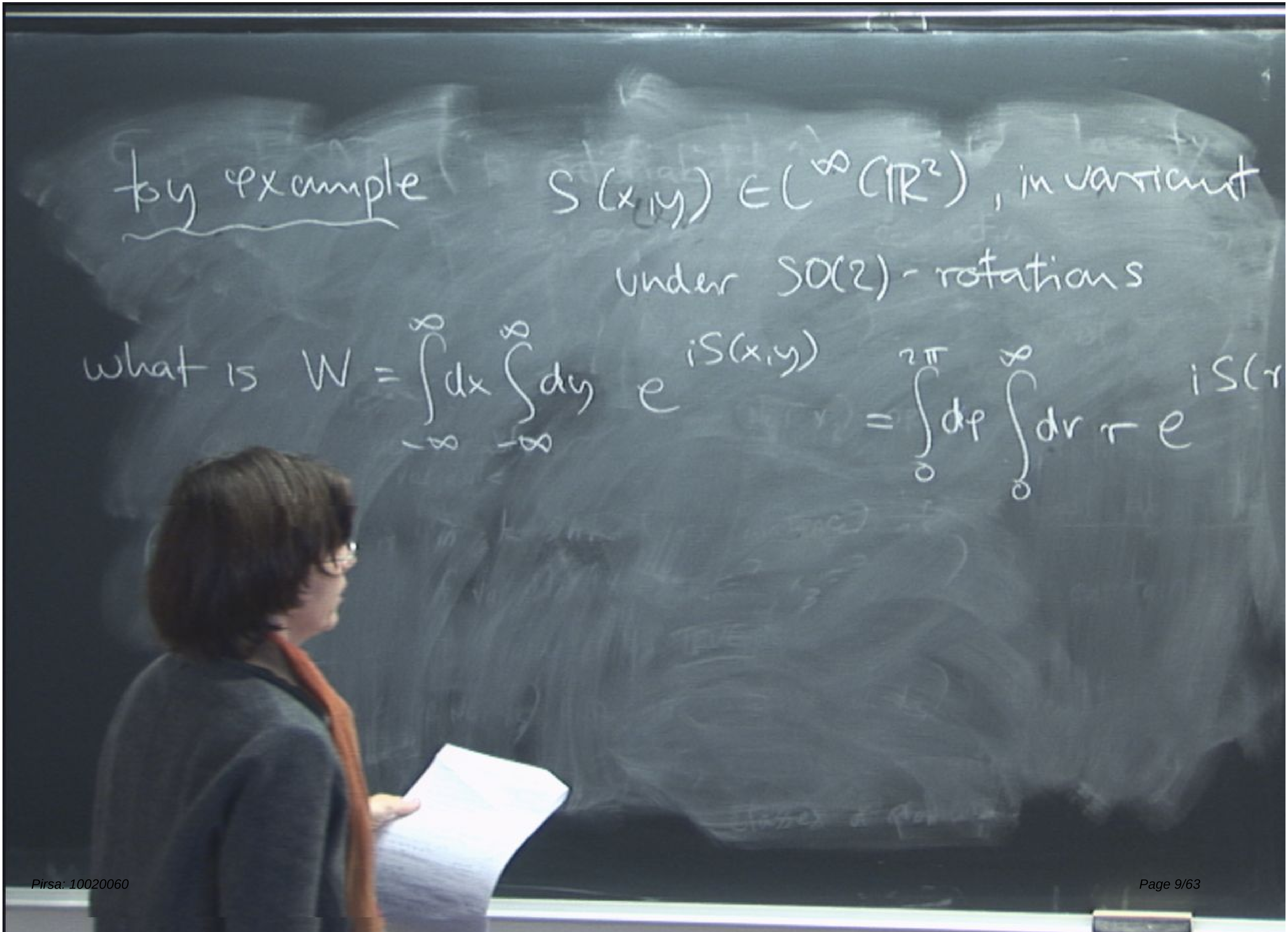
typically, get divergence since $\mathrm{vol}(G) = \infty$


toy example
S(x,y) ∈ C^∞(ℝ²), invariant


toy example
$S(x,y) \in C^\infty(\mathbb{R}^2)$, invariant
under SO(2)-rotations
what is $W = \int$

toy example $S(x,y) \in C^\infty(\mathbb{R}^2)$, invariant under $SO(2)$-rotations

what is $W = \int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy \; e^{iS(x,y)} =$


for example
$S(x,y) \in C^\infty(\mathbb{R}^2)$, invariant
under $SO(2)$-rotations
what is $W = \int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy \; e^{iS(x,y)}$
$= \int_0^{2\pi} d\varphi \int_0^{\infty} dr \; r \; e^{iS(r}$

toy example

$S(x,y) \in C^\infty(\mathbb{R}^2)$, invariant under $SO(2)$-rotations

what is $W = \int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy \; e^{iS(x,y)} = \int_0^{2\pi} d\varphi \int_0^{\infty} dr \, r \, e^{iS(r,\varphi)}$

$S(r, \varphi + \alpha)$

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"φ" is unphysical gauge d.o.f.

original configuration space $\mathcal{C} = \mathbb{R}^2$

physical configuration space $\mathcal{C}_{phys}$

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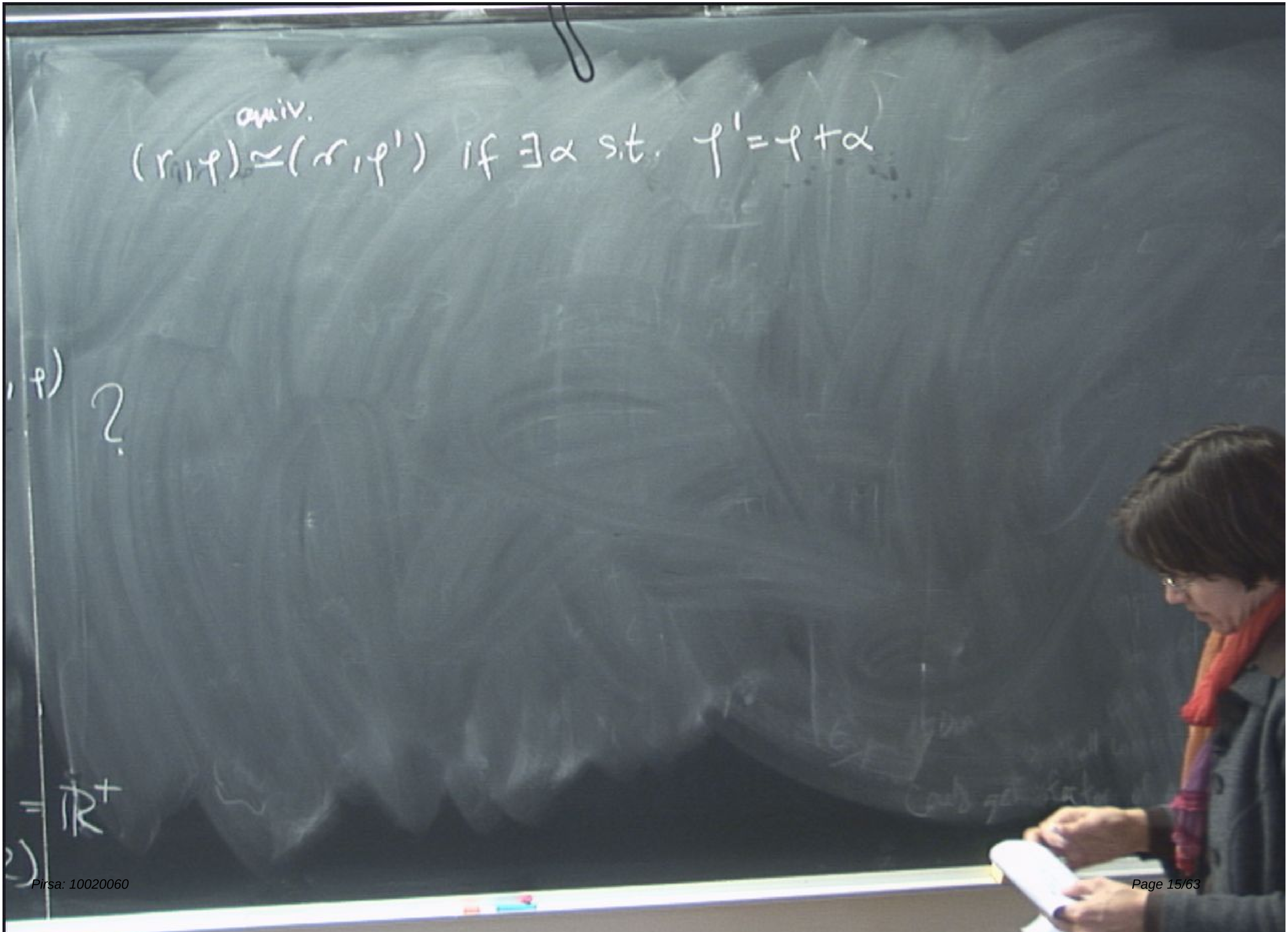
physical configuration space $\mathcal{C}_{phys} = \mathcal{C}/G = \mathbb{R}^2/SO(2) = \mathbb{R}^+$


equiv.
$(r,\varphi) \simeq (r,\varphi')$ if $\exists \alpha$ s.t. $\varphi' = \varphi + \alpha$
$, \varphi)$
?
$= \mathbb{R}^+$

$(r,\varphi) \overset{\text{equiv.}}{\simeq} (r,\varphi')$ if $\exists \alpha$ s.t. $\varphi' = \varphi + \alpha$

el.s of $\mathcal{C}/_{SO(2)}$ are equiv. classes $[(r,\varphi)]$

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$2)$

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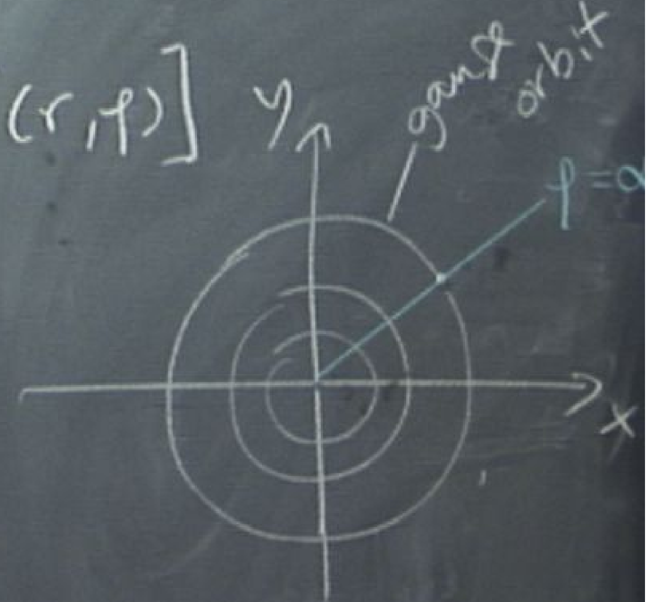

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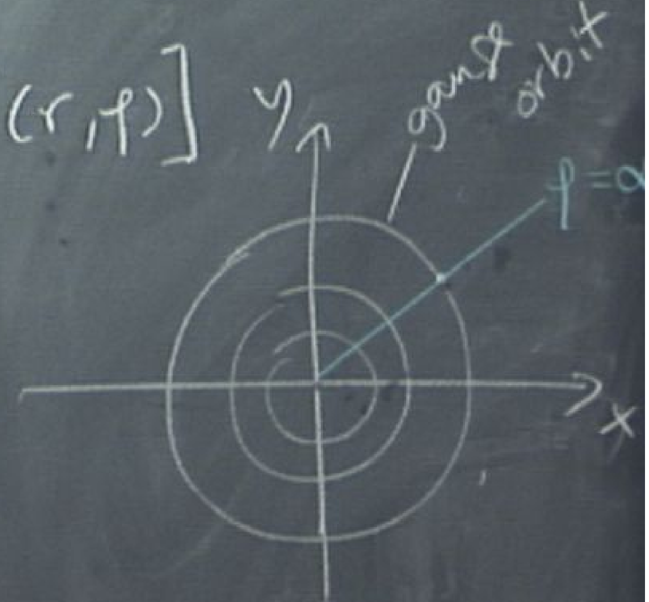
? gauge orbits are points in $\mathcal{C}_{phys}$



R^+

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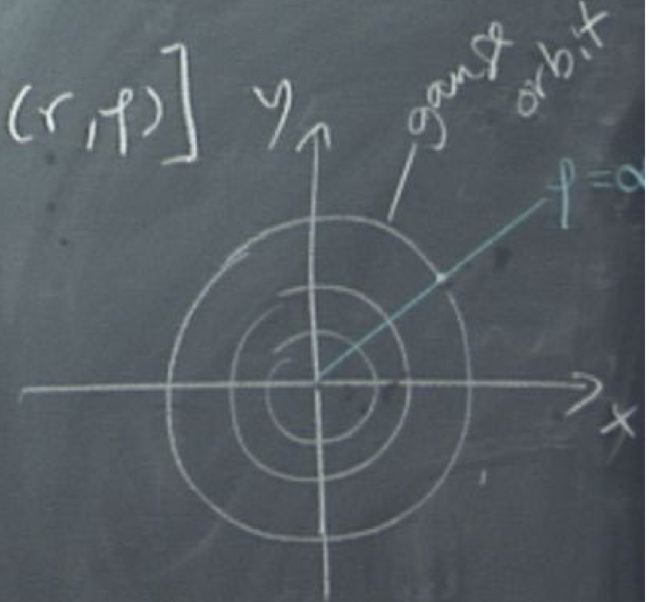

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prescription: insert "1" into PI

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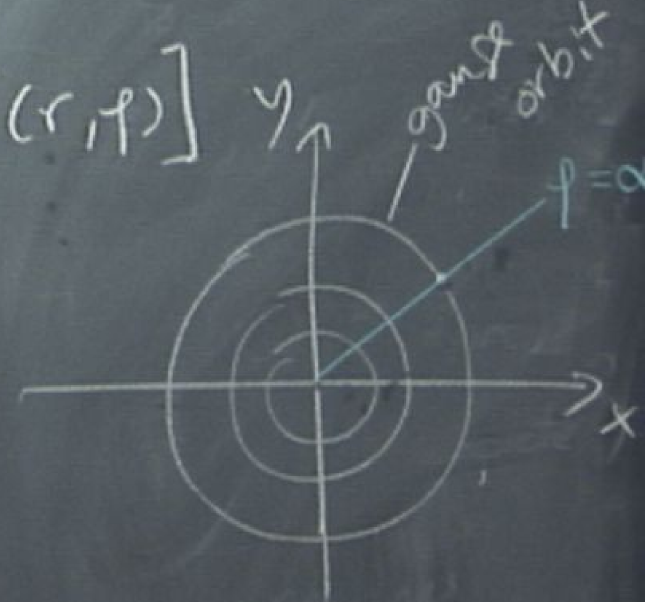

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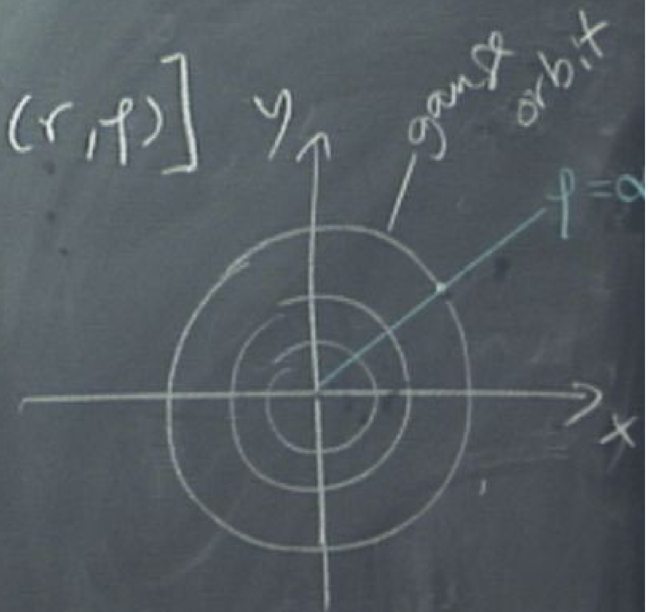

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here $1 = \int_0^{2\pi} d\alpha\ \delta(\varphi - \alpha)$

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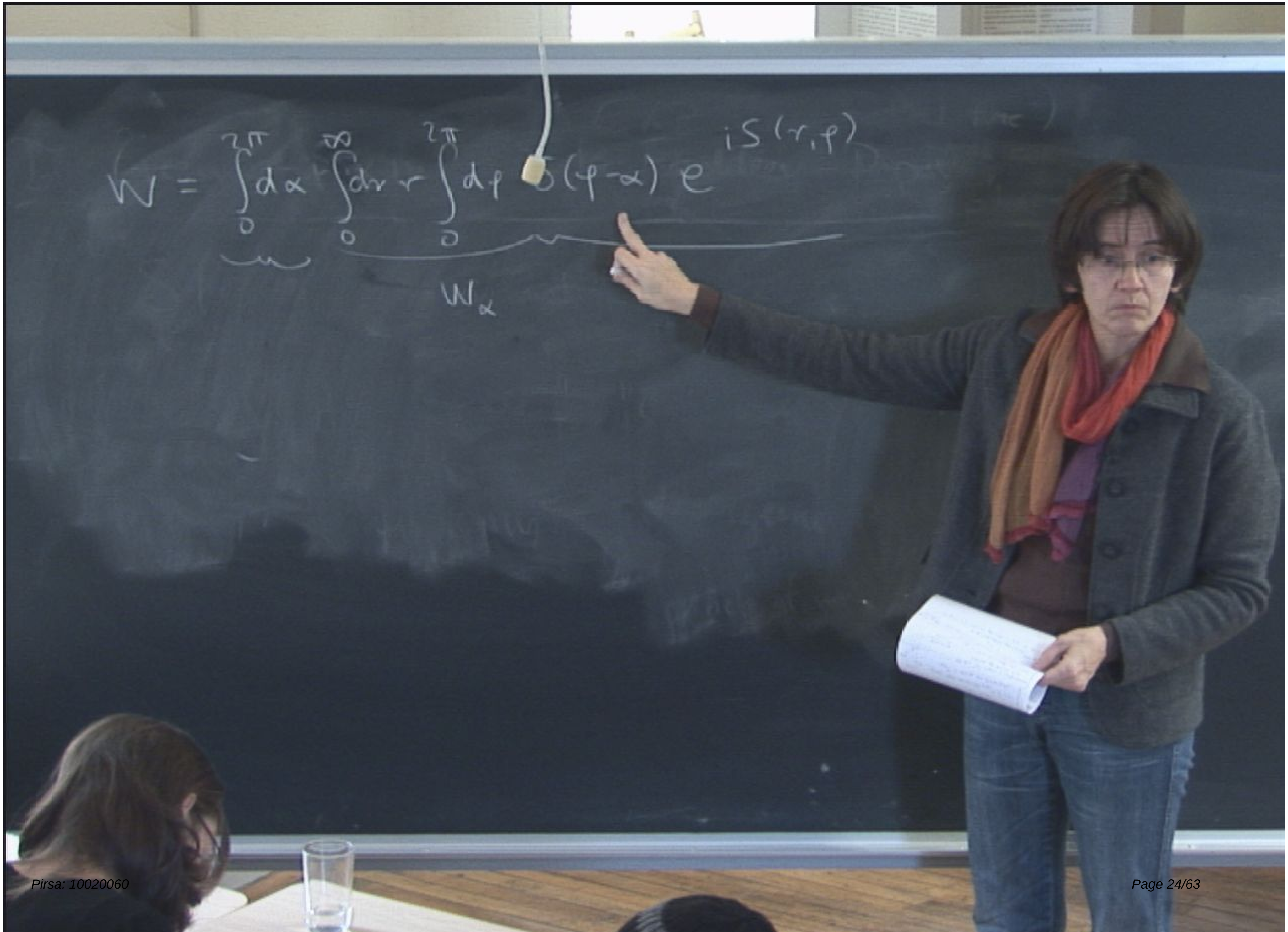
$$W = \int_0^{2\pi} d\alpha \underbrace{\int_0^{\infty} dr\, r \int_0^{2\pi} d\varphi\, \delta(\varphi - \alpha)\, e^{iS(r,\varphi)}}_{W_\alpha}$$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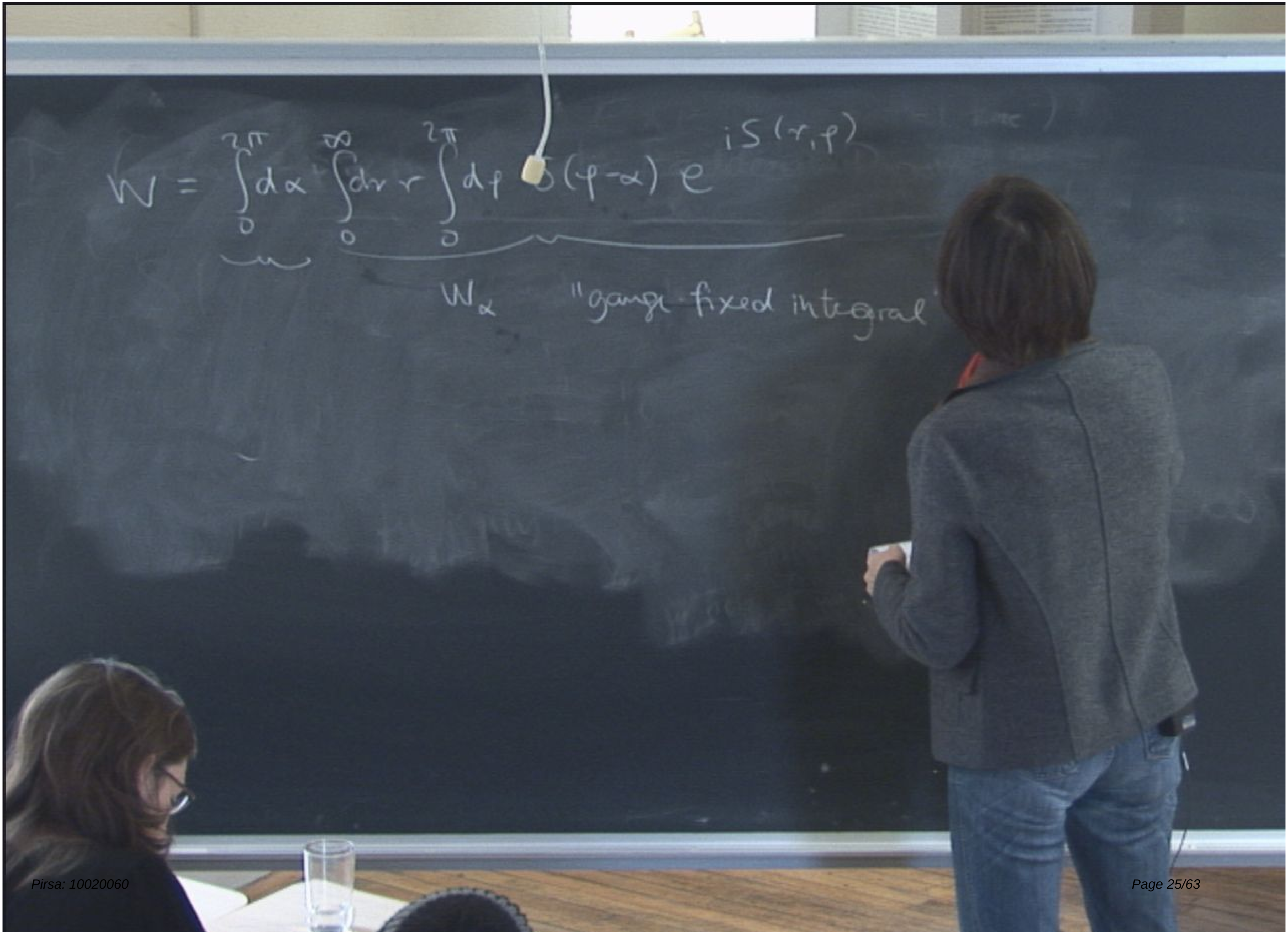
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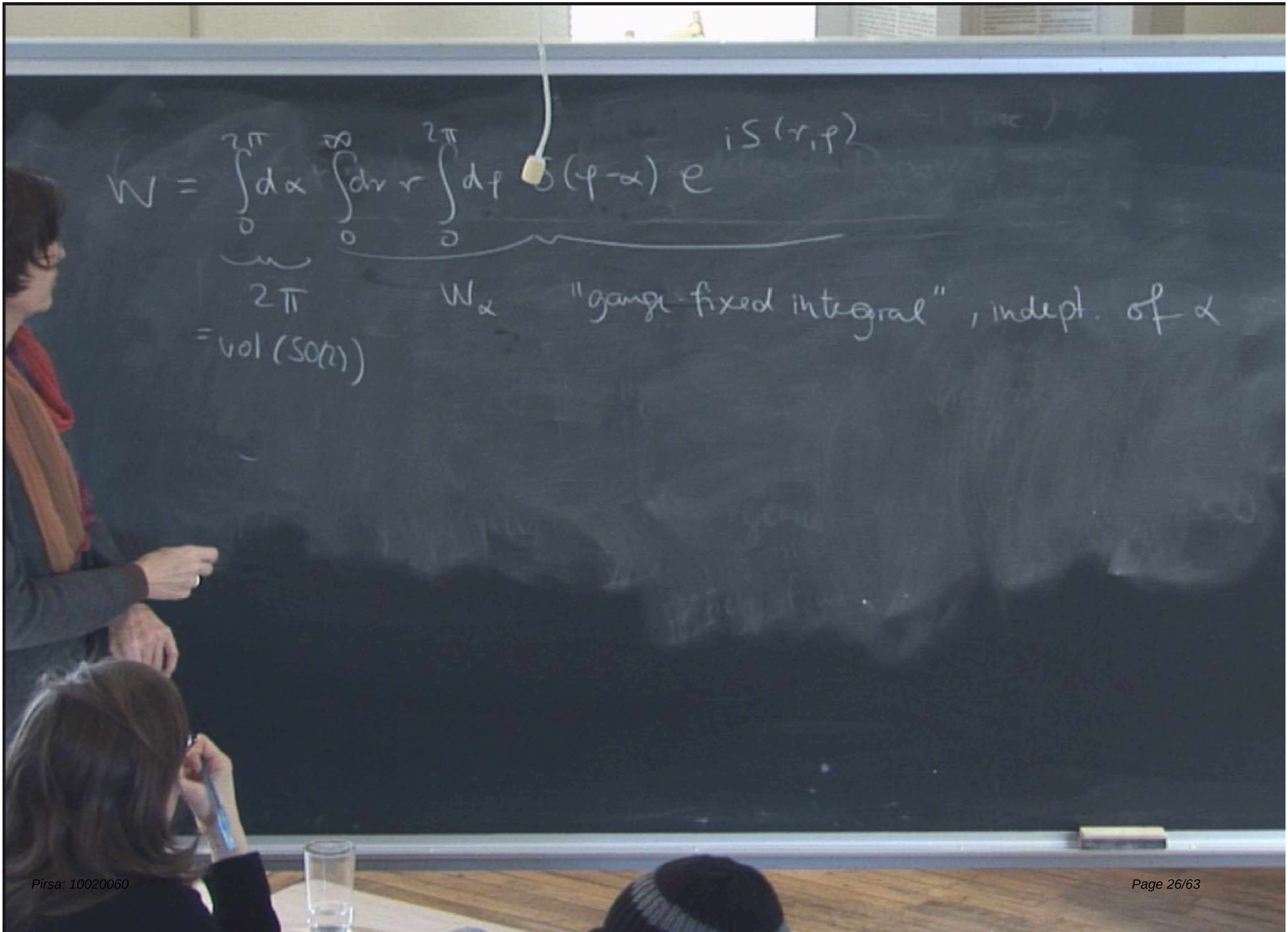
"gauge fixed integral"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$= \mathrm{vol}(SO(2))$
"gauge fixed integral", indept. of α

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general gauge-fixing $g(r,\varphi) = 0$, good gauge: the sub

$g=0$ cuts each gauge orbit exactly once

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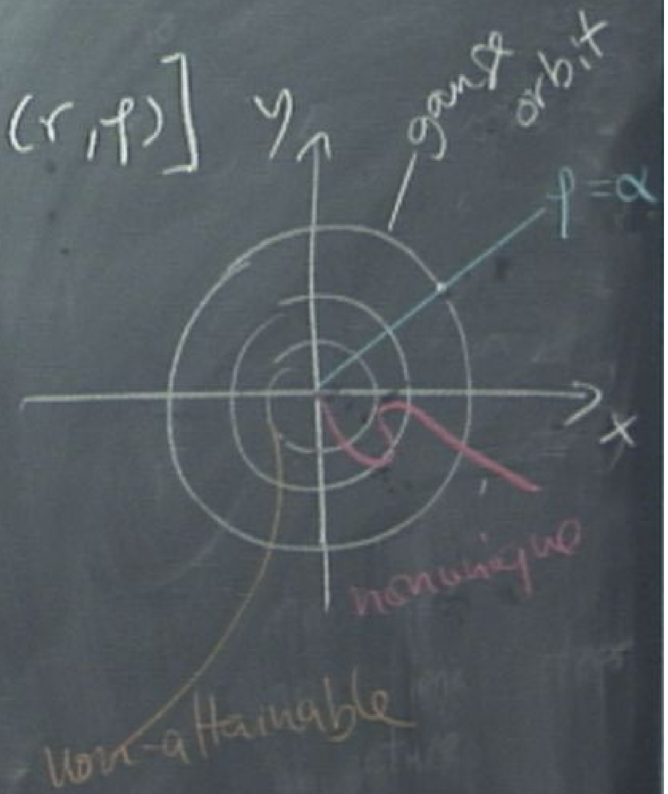

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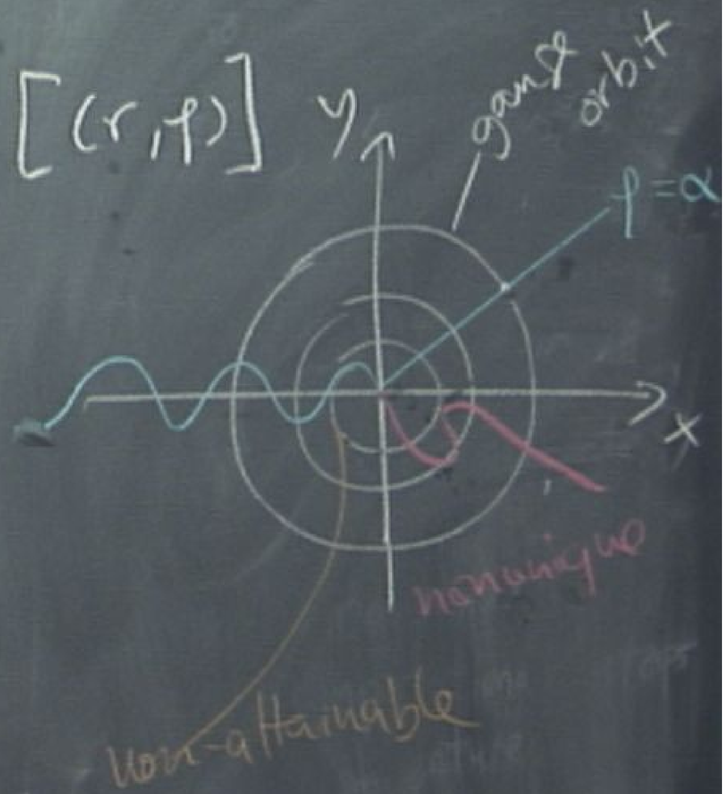

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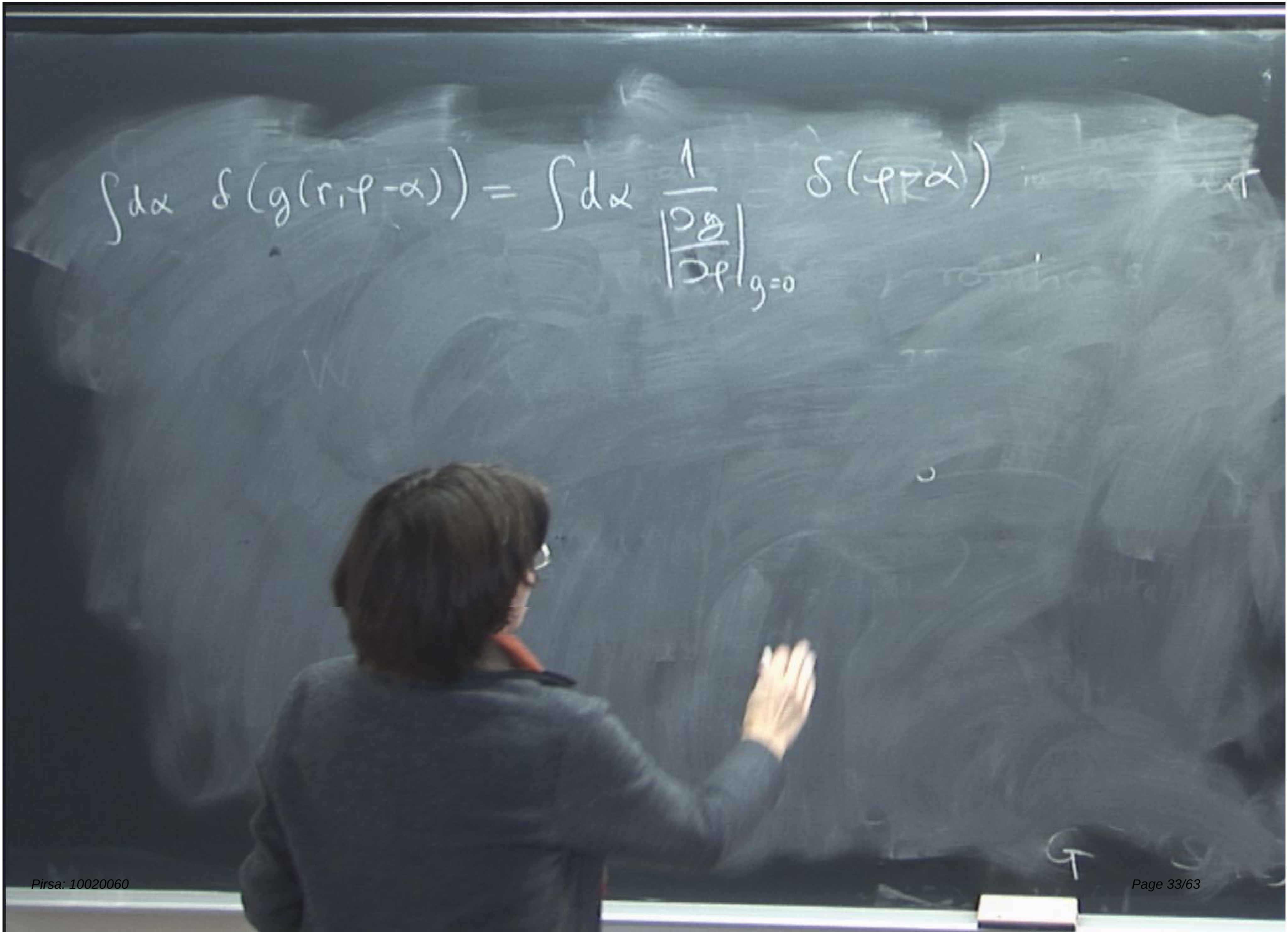
$\int d\alpha \; \delta(g(r,\varphi-\alpha)) = \int d\alpha \frac{1}{\left|\frac{\partial g}{\partial \varphi}\right|_{g=0}} \delta(\varphi-\alpha)$

$$\int d\alpha \; \delta\big(g(r,\varphi-\alpha)\big) = \int d\alpha \, \frac{1}{\left|\frac{\partial g}{\partial \varphi}\right|_{g=0}} \, \delta(\varphi-\alpha) =$$

$$= \left|\frac{\partial g}{\partial \varphi}\right|^{-1}_{g=0} \int d\alpha \; \delta(\varphi-\alpha)$$

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$$= \left|\frac{\partial g}{\partial \varphi}\right|^{-1}_{g=0} \underbrace{\int d\alpha\ \delta(\varphi-\alpha)}_{1}$$

$$\Delta = \left|\frac{\partial g}{\partial \varphi}\right|_{g=0} \int d\alpha\ \delta\big(g(r,\varphi-\alpha)\big)$$

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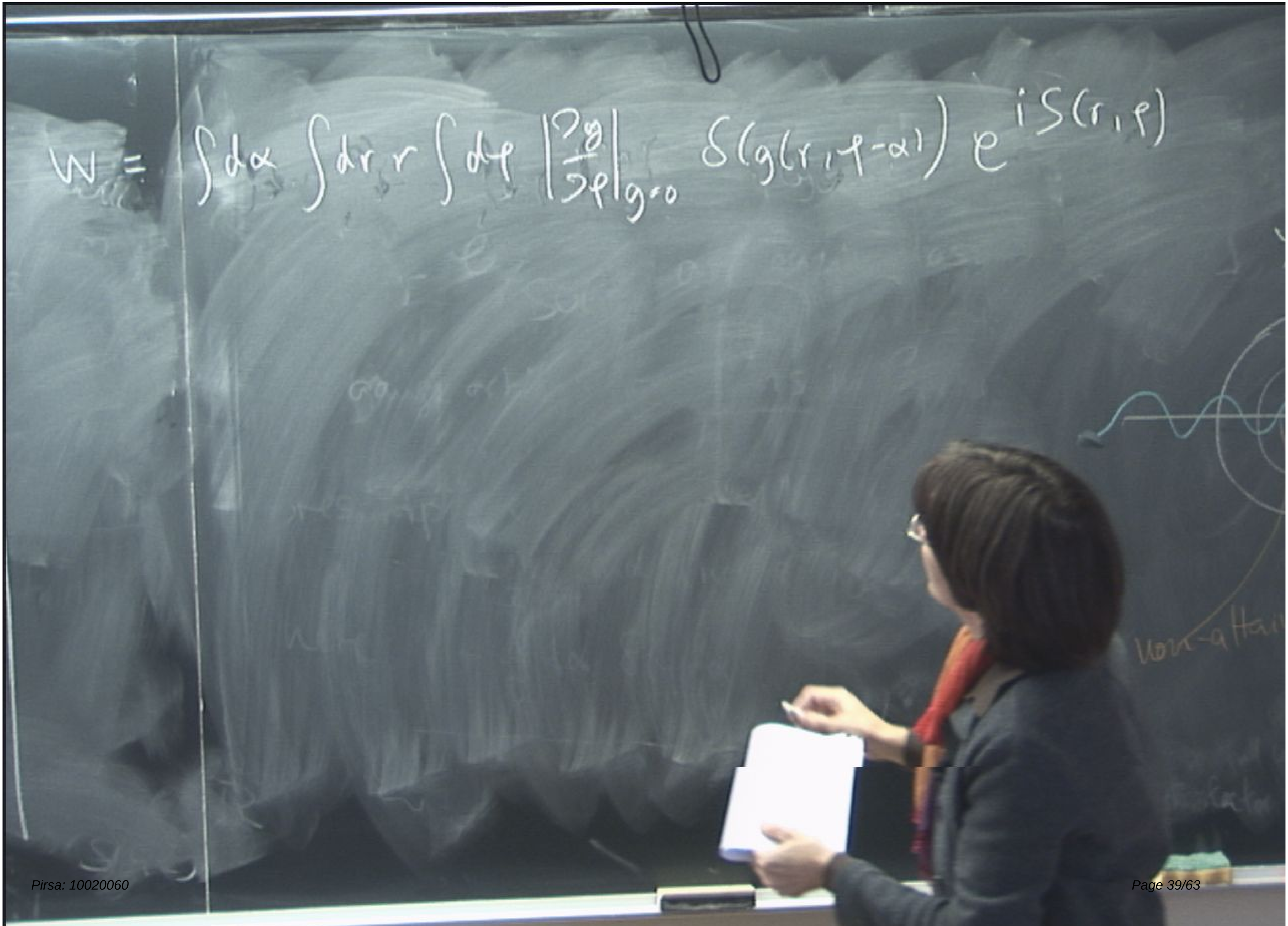
$W = \int d\alpha \int dr\, r \int d\varphi \left|\frac{\partial g}{\partial \varphi}\right|_{g=0} \delta(g(r, \varphi - \alpha))\, e^{iS(r,\varphi)}$

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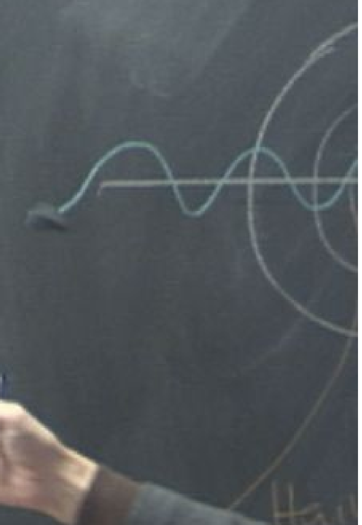

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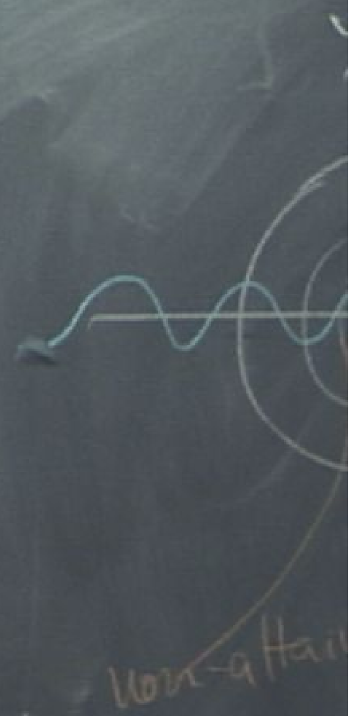
Crucial: gauge-invariance of the measure on G



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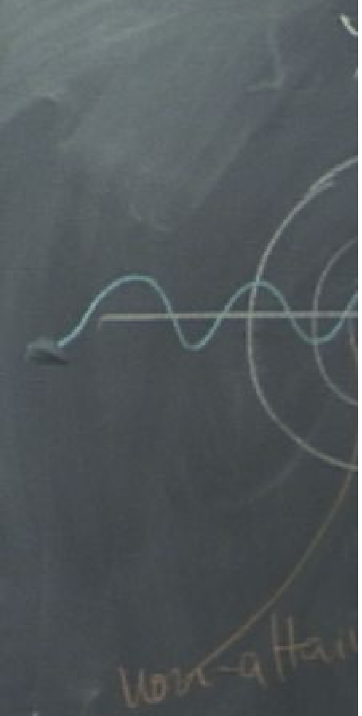
→ E. Mottola, hep-th/9502109



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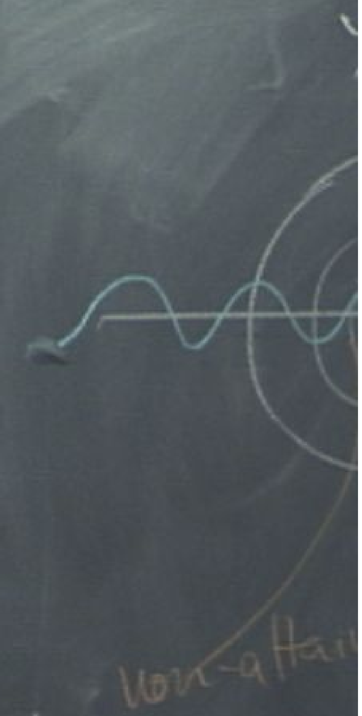
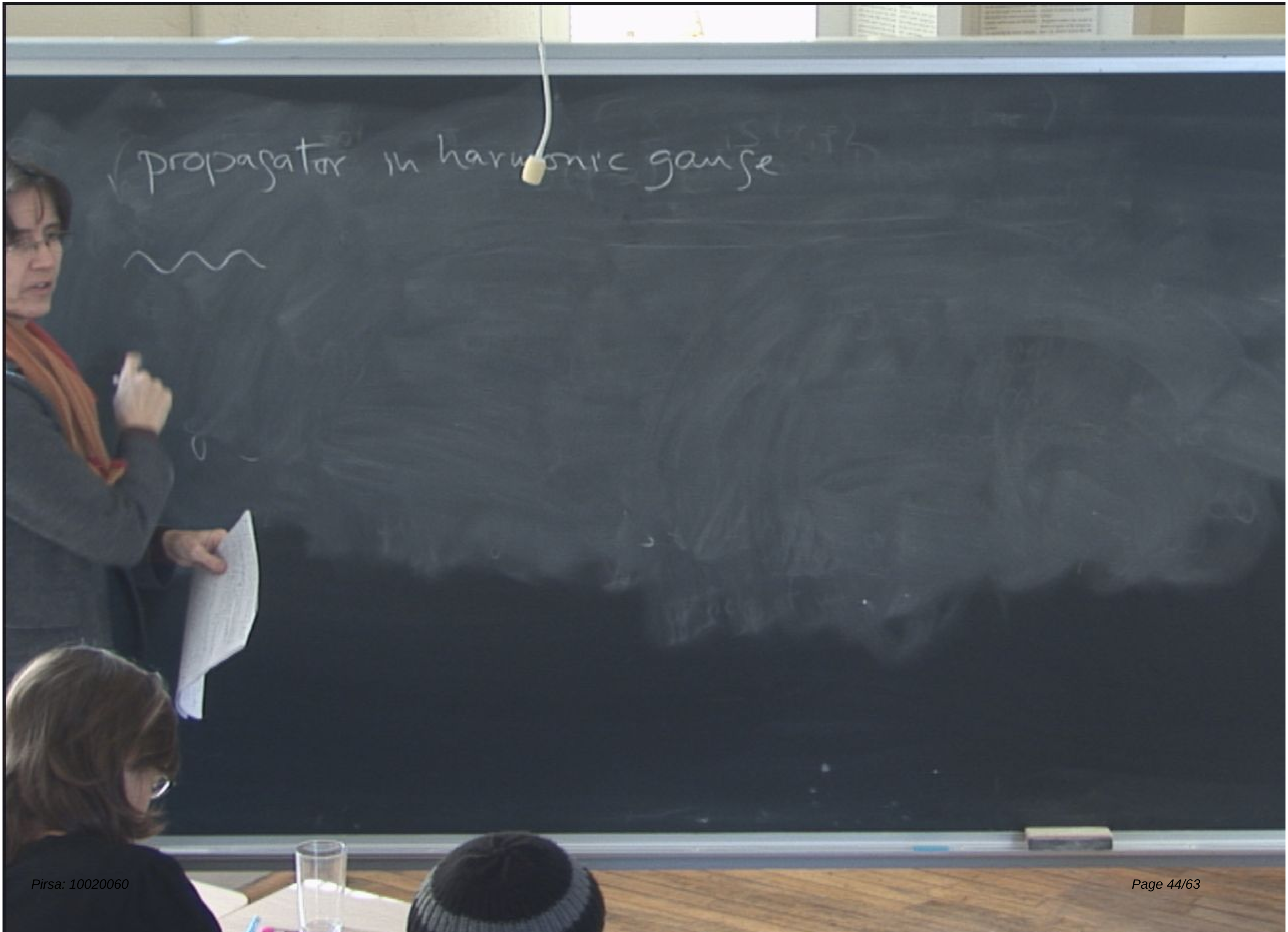
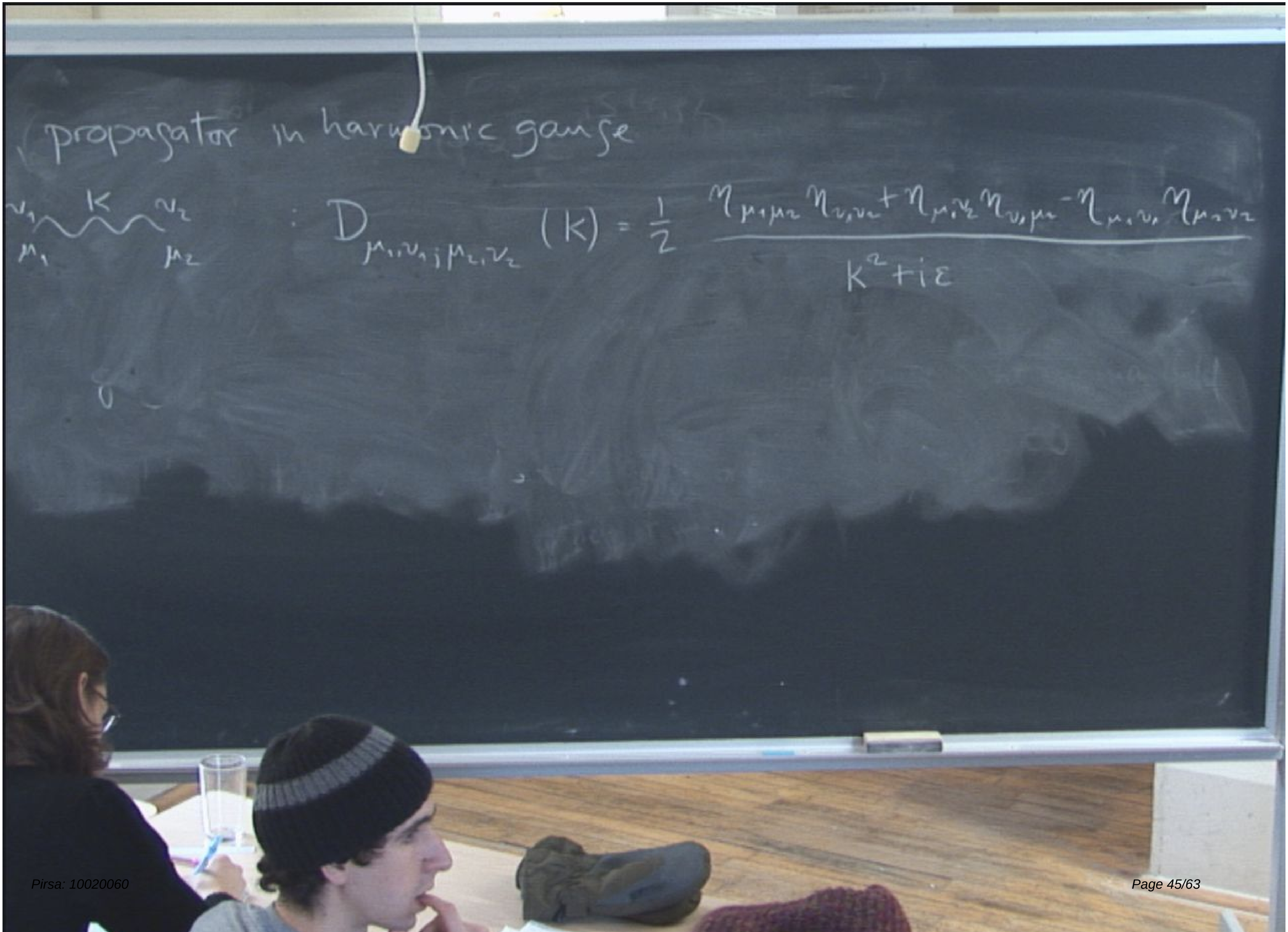
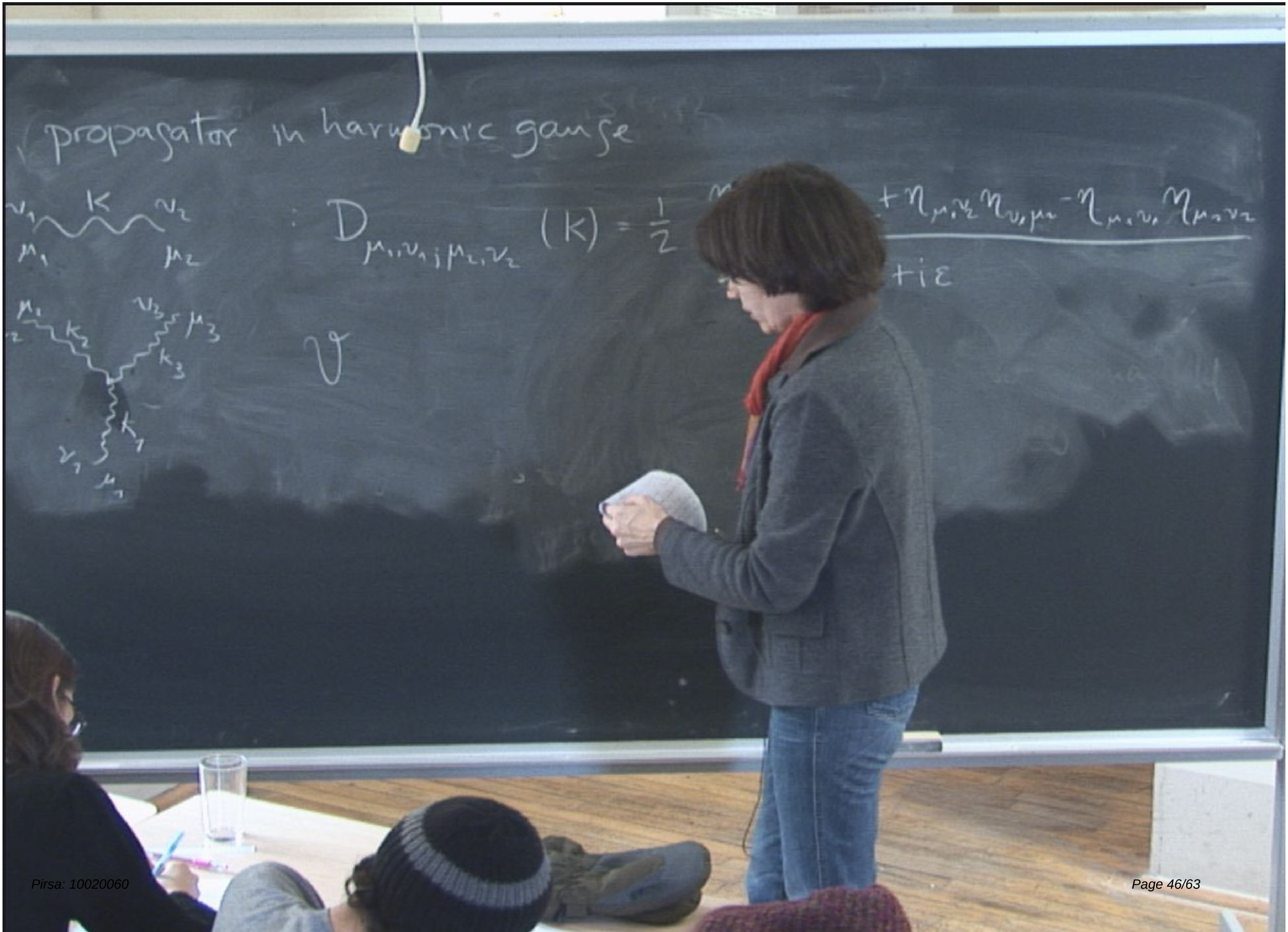
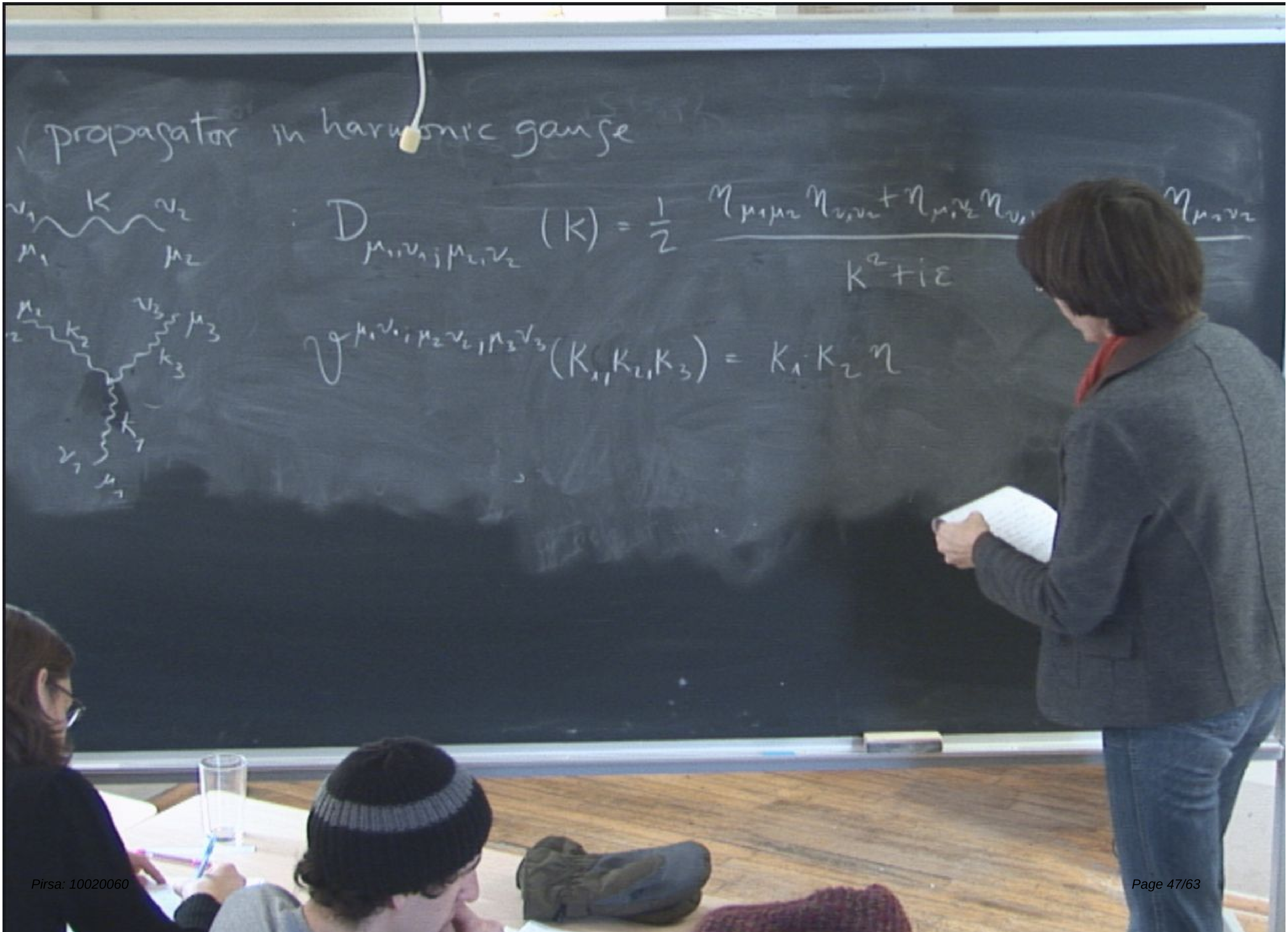
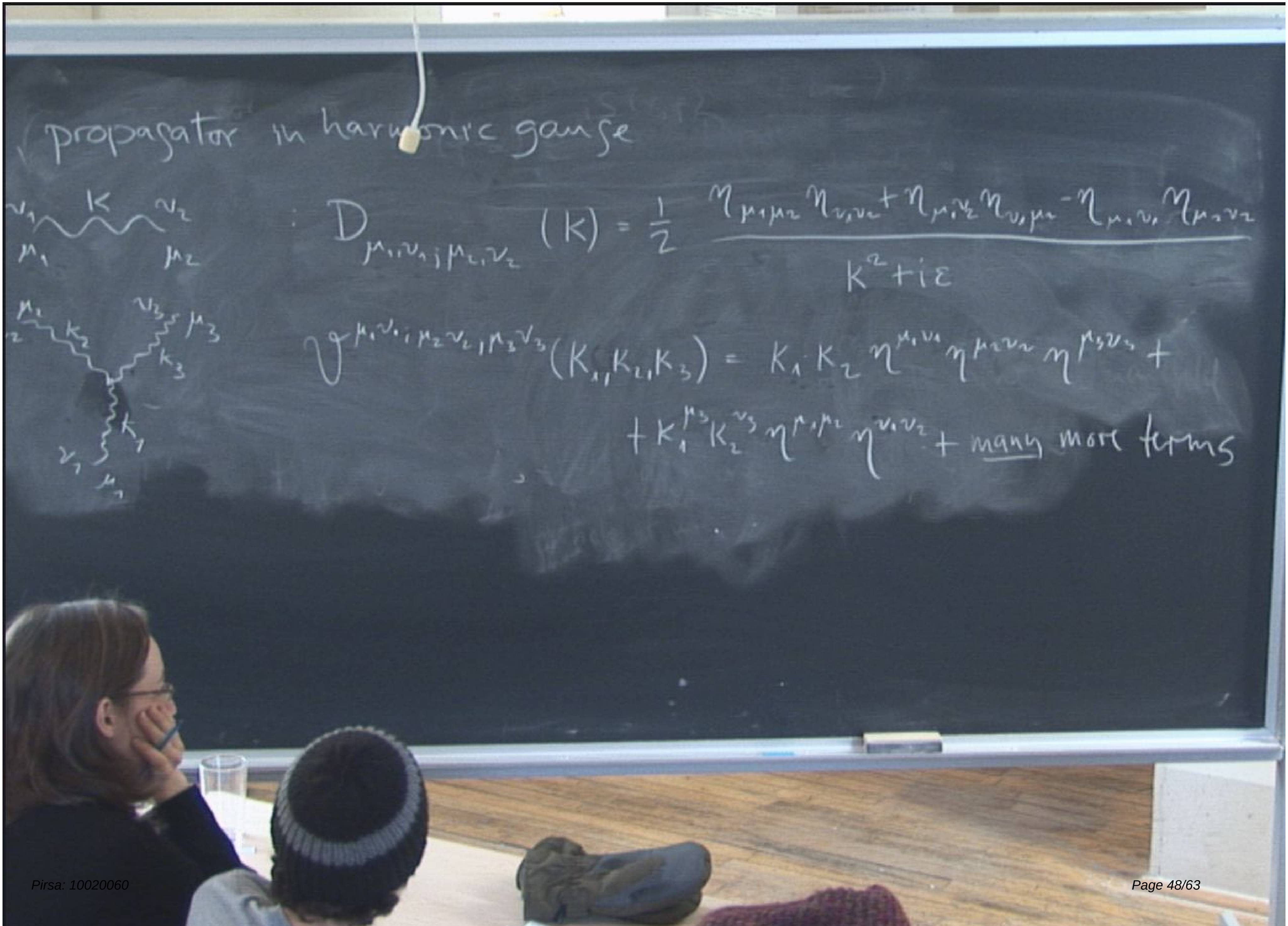



propagator in harmonic gauge


propagator in harmonic gauge
$\nu_1 \quad k \quad \nu_2$
$\mu_1 \quad \mu_2$
$: D_{\mu_1\nu_1;\mu_2\nu_2}(k) = \frac{1}{2}\frac{\eta_{\mu_1\mu_2}\eta_{\nu_1\nu_2}+\eta_{\mu_1\nu_2}\eta_{\nu_1\mu_2}-\eta_{\mu_1\nu_1}\eta_{\mu_2\nu_2}}{k^2+i\varepsilon}$


propagator in harmonic gauge
$D_{\mu_1\nu_1;\mu_2\nu_2}(k) = \frac{1}{2}$
$+\eta_{\mu_1\nu_2}\eta_{\nu_1\mu_2} - \eta_{\mu_1\nu_1}\eta_{\mu_2\nu_2}$
$+i\varepsilon$


propagator in harmonic gauge
$D_{\mu_1\nu_1;\mu_2\nu_2}(k) = \frac{1}{2}$
$k^2+i\epsilon$
$V^{\mu_1\nu_1;\mu_2\nu_2;\mu_3\nu_3}(k_1,k_2,k_3) = k_1\cdot k_2\,\eta$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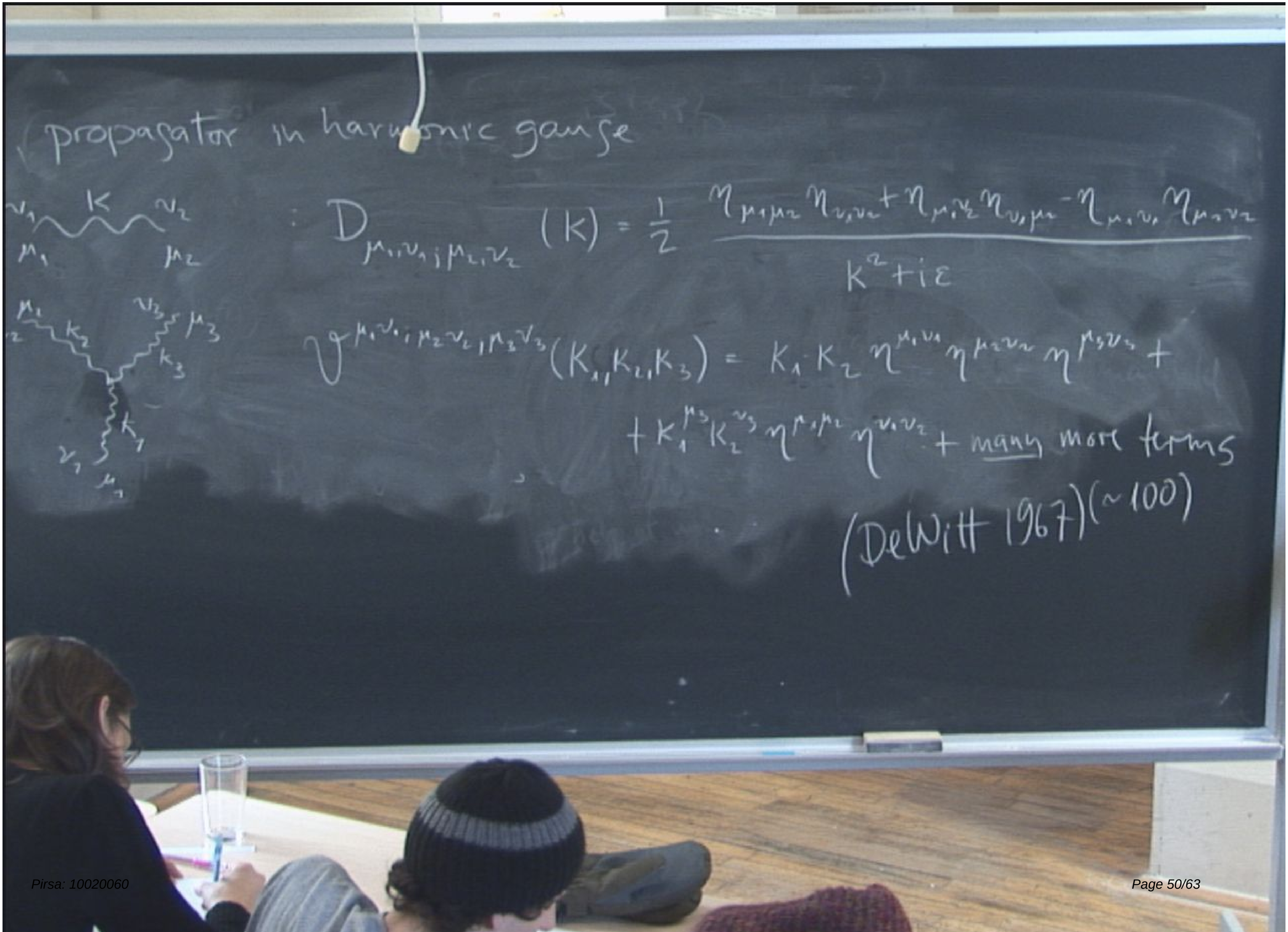
$V^{\mu_1\nu_1;\mu_2\nu_2;\mu_3\nu_3}(k_1,k_2,k_3) = k_1\cdot k_2\,\eta^{\mu_1\nu_1}\eta^{\mu_2\nu_2}\eta^{\mu_3\nu_3} +$
$+ k_1^{\mu_3}k_2^{\nu_3}\eta^{\mu_1\mu_2}\eta^{\nu_1\nu_2} +$ many more terms

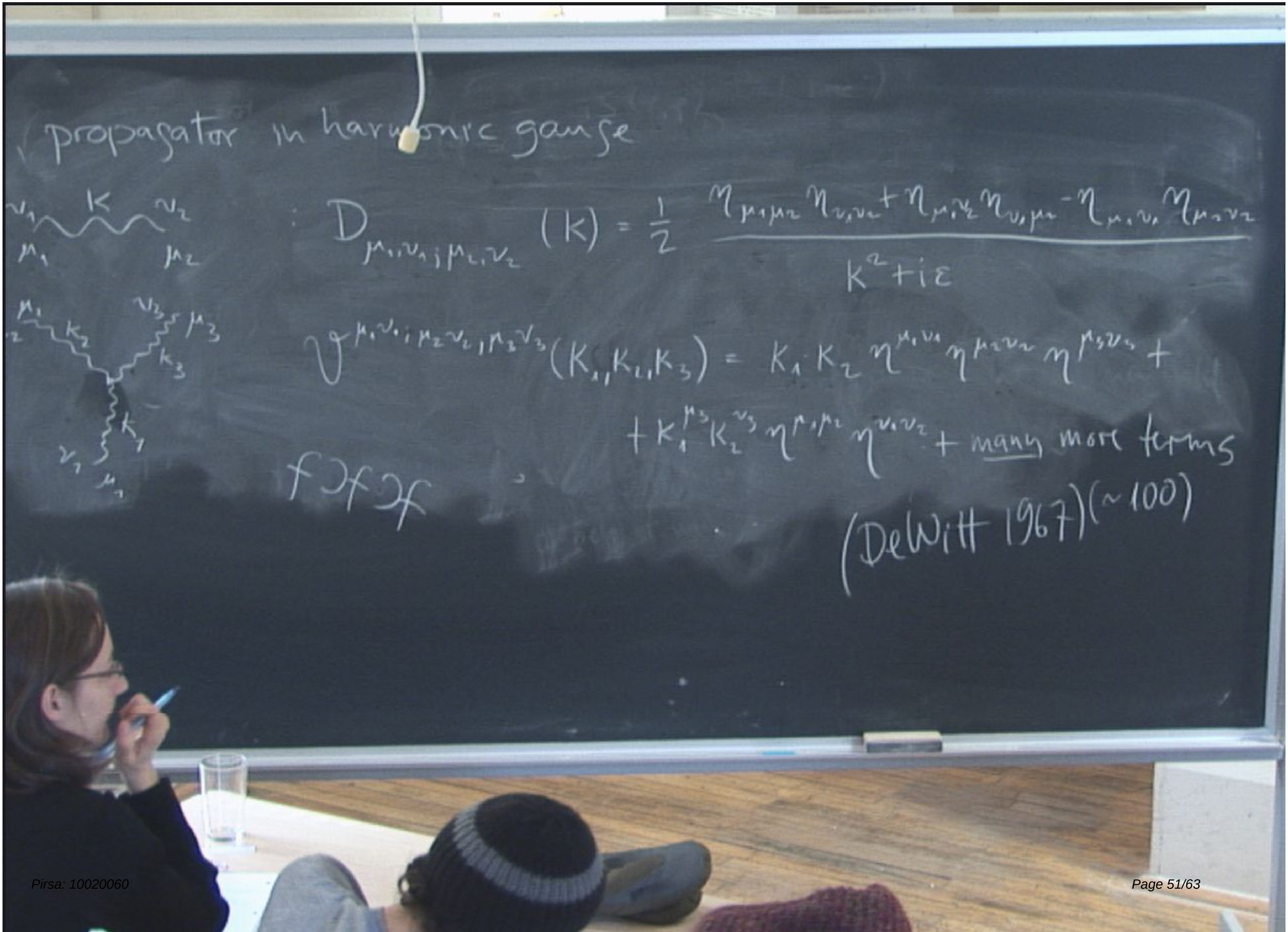
propagator in harmonic gauge

$$D_{\mu_1\nu_1;\mu_2\nu_2}(k) = \frac{1}{2}\,\frac{\eta_{\mu_1\mu_2}\eta_{\nu_1\nu_2}+\eta_{\mu_1\nu_2}\eta_{\nu_1\mu_2}-\eta_{\mu_1\nu_1}\eta_{\mu_2\nu_2}}{k^2+i\varepsilon}$$

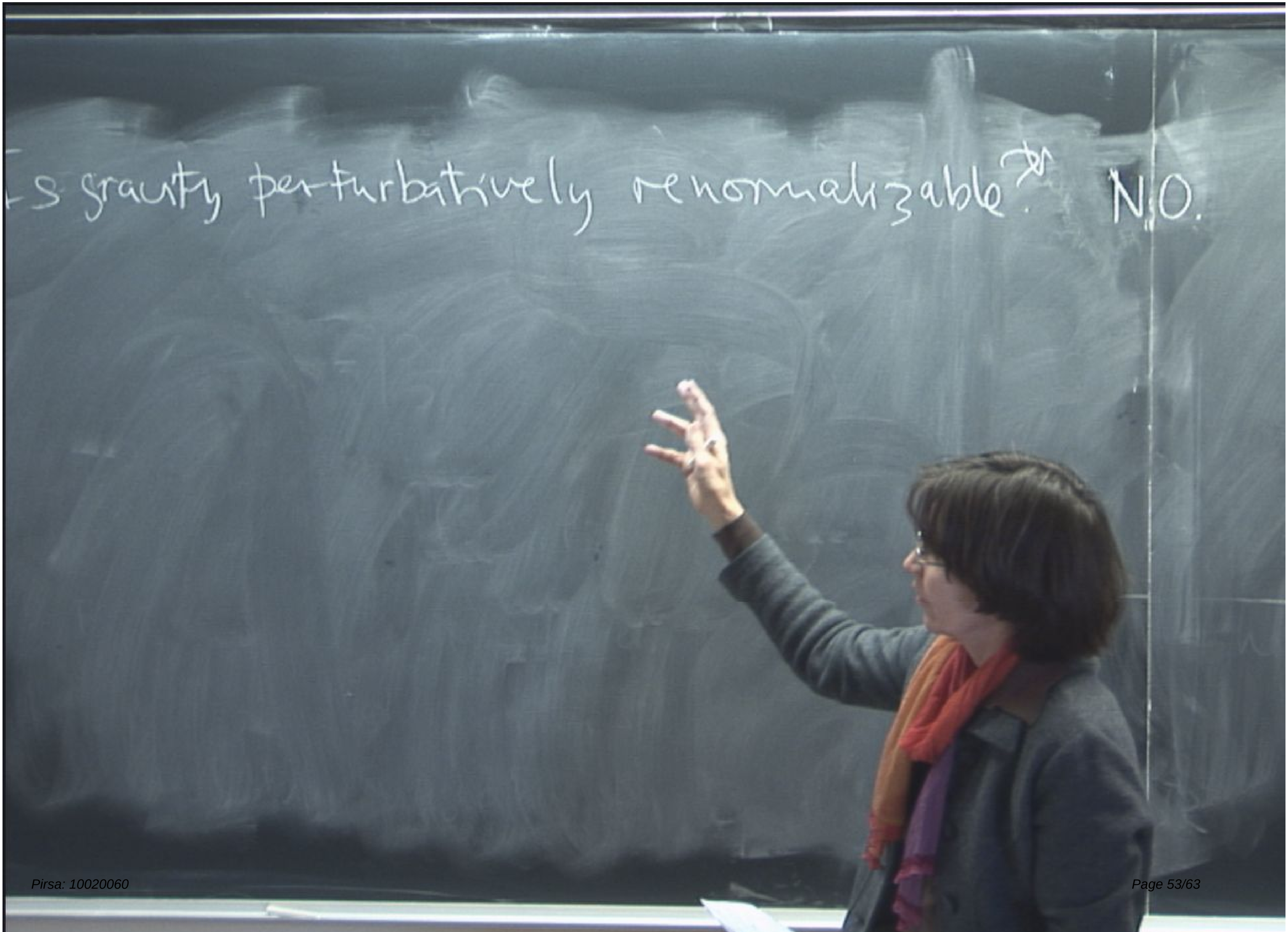
$$V^{\mu_1\nu_1;\mu_2\nu_2;\mu_3\nu_3}(k_1,k_2,k_3) = k_1\cdot k_2\,\eta^{\mu_1\nu_1}\eta^{\mu_2\nu_2}\eta^{\mu_3\nu_3} + k_1^{\mu_3}k_2^{\nu_3}\eta^{\mu_1\mu_2}\eta^{\nu_1\nu_2} + \underline{\text{many}}\text{ more terms}$$

(DeWitt 1967) (~100)


propagator in harmonic gauge
ν_1 K ν_2 μ_1 μ_2
$D_{\mu_1\nu_1;\mu_2\nu_2}(K) = \frac{1}{2}\frac{\eta_{\mu_1\mu_2}\eta_{\nu_1\nu_2}+\eta_{\mu_1\nu_2}\eta_{\nu_1\mu_2}-\eta_{\mu_1\nu_1}\eta_{\mu_2\nu_2}}{K^2+i\varepsilon}$
μ_1 ν_3 μ_3 K_2 K_3 K_1 ν_1 μ_1
$V^{\mu_1\nu_1,\mu_2\nu_2,\mu_3\nu_3}(K_1,K_2,K_3) = K_1\cdot K_2\,\eta^{\mu_1\nu_1}\eta^{\mu_2\nu_2}\eta^{\mu_3\nu_3} +$
$+ K_1^{\mu_3}K_2^{\nu_3}\eta^{\mu_1\mu_2}\eta^{\nu_1\nu_2} +$ many more terms
(DeWitt 1967) (~100)


propagator in harmonic gauge
$D_{\mu_1\nu_1;\mu_2\nu_2}(k) = \frac{1}{2}\frac{\eta_{\mu_1\mu_2}\eta_{\nu_1\nu_2}+\eta_{\mu_1\nu_2}\eta_{\nu_1\mu_2}-\eta_{\mu_1\nu_1}\eta_{\mu_2\nu_2}}{k^2+i\varepsilon}$
$V^{\mu_1\nu_1;\mu_2\nu_2;\mu_3\nu_3}(k_1,k_2,k_3) = k_1\cdot k_2\,\eta^{\mu_1\nu_1}\eta^{\mu_2\nu_2}\eta^{\mu_3\nu_3} +$
$+ k_1^{\mu_3}k_2^{\nu_3}\eta^{\mu_1\mu_2}\eta^{\nu_1\nu_2} +$ many more terms
(DeWitt 1967) (~100)
f ∂f ∂f

Is gravity perturbatively renormalizable?


Is gravity perturbatively renormalizable?
N.O.

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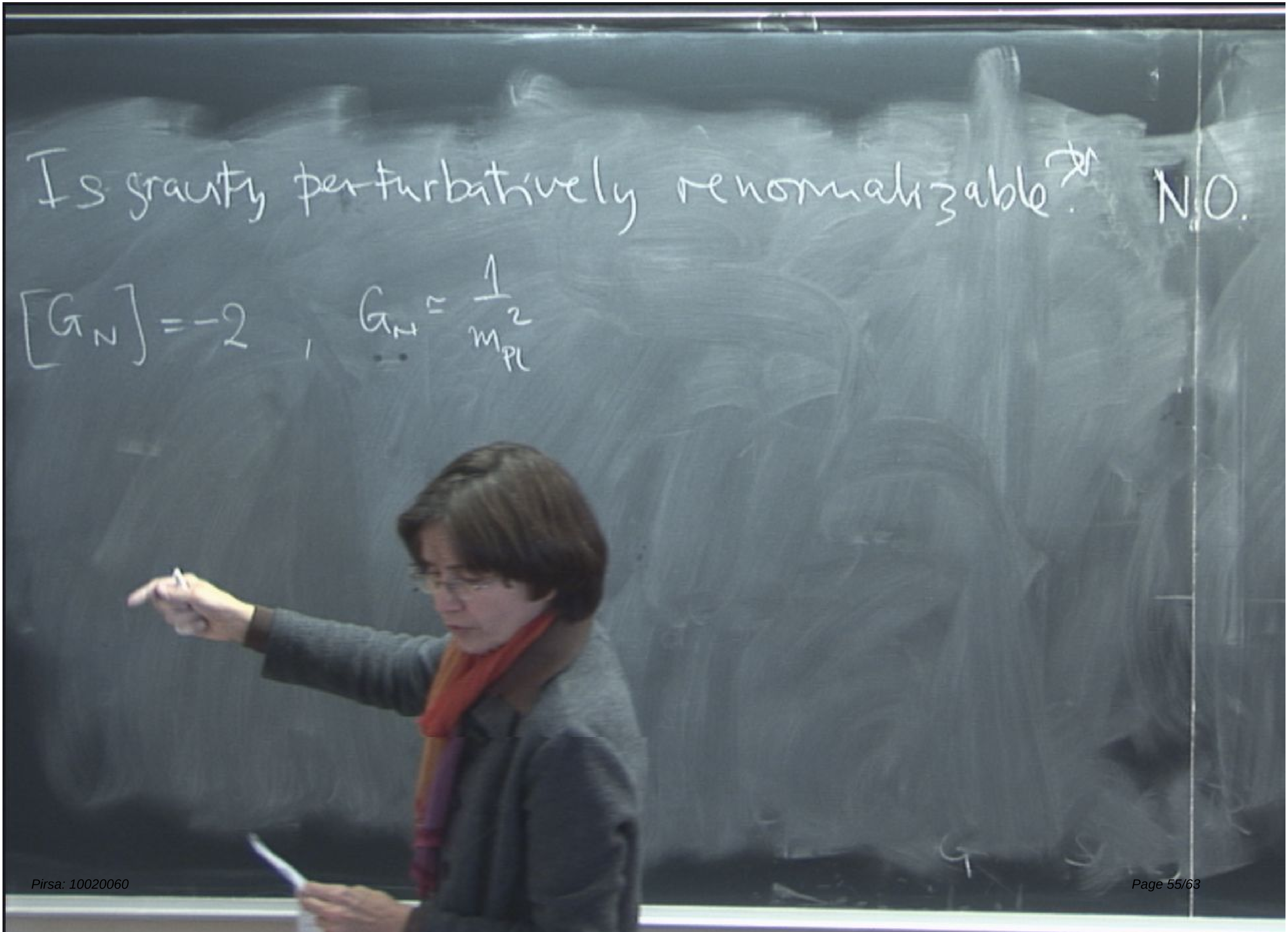
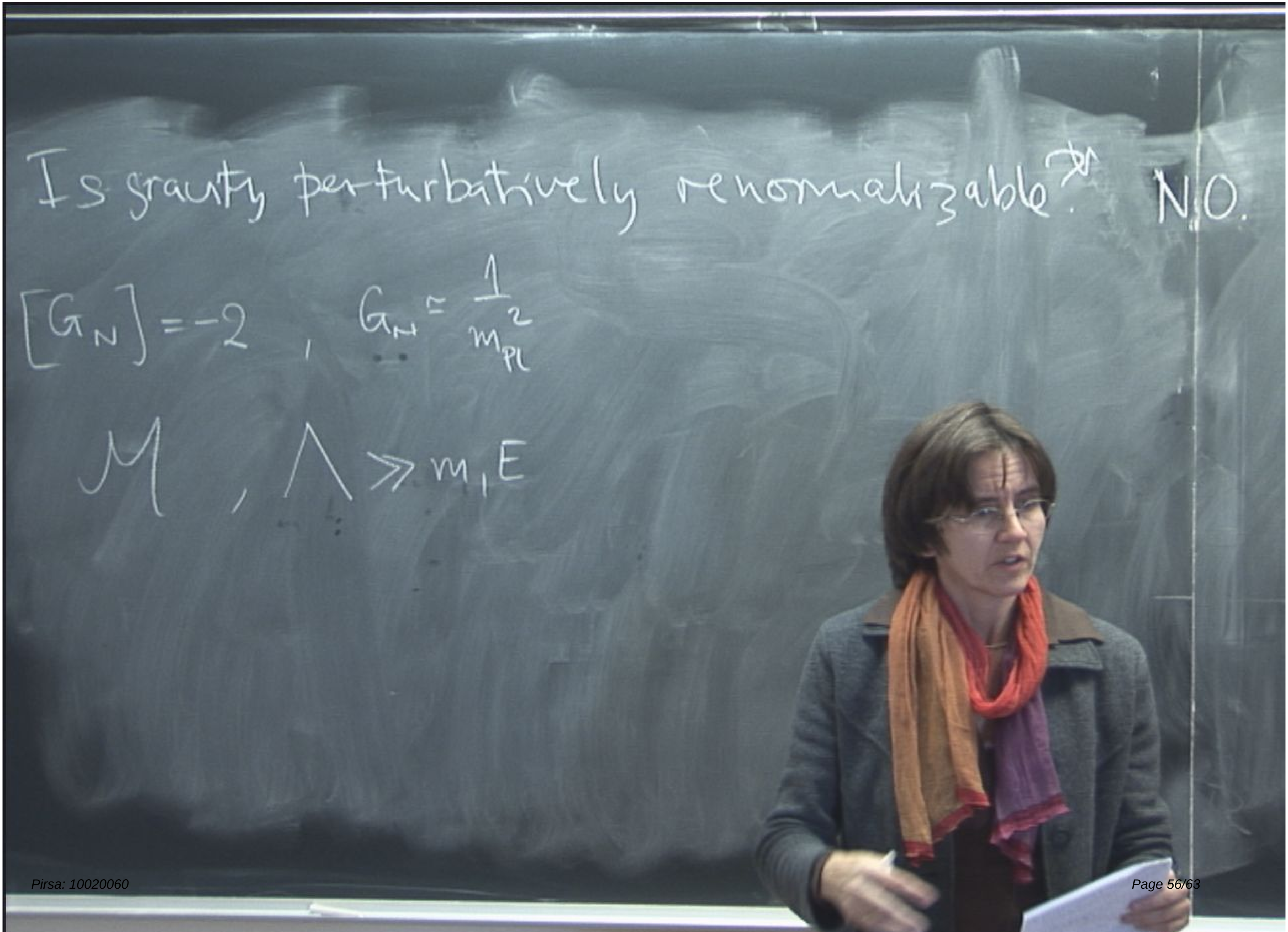
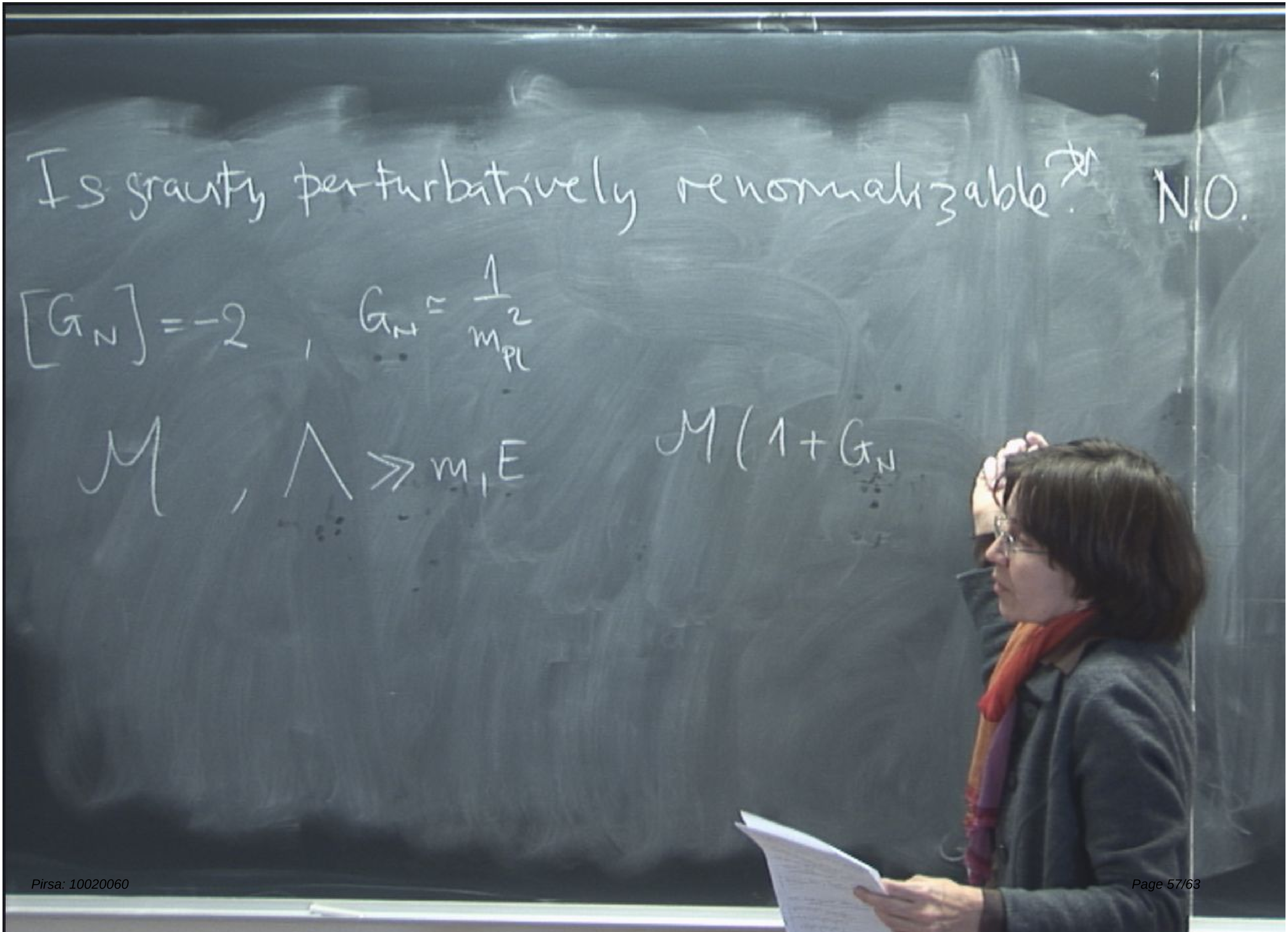
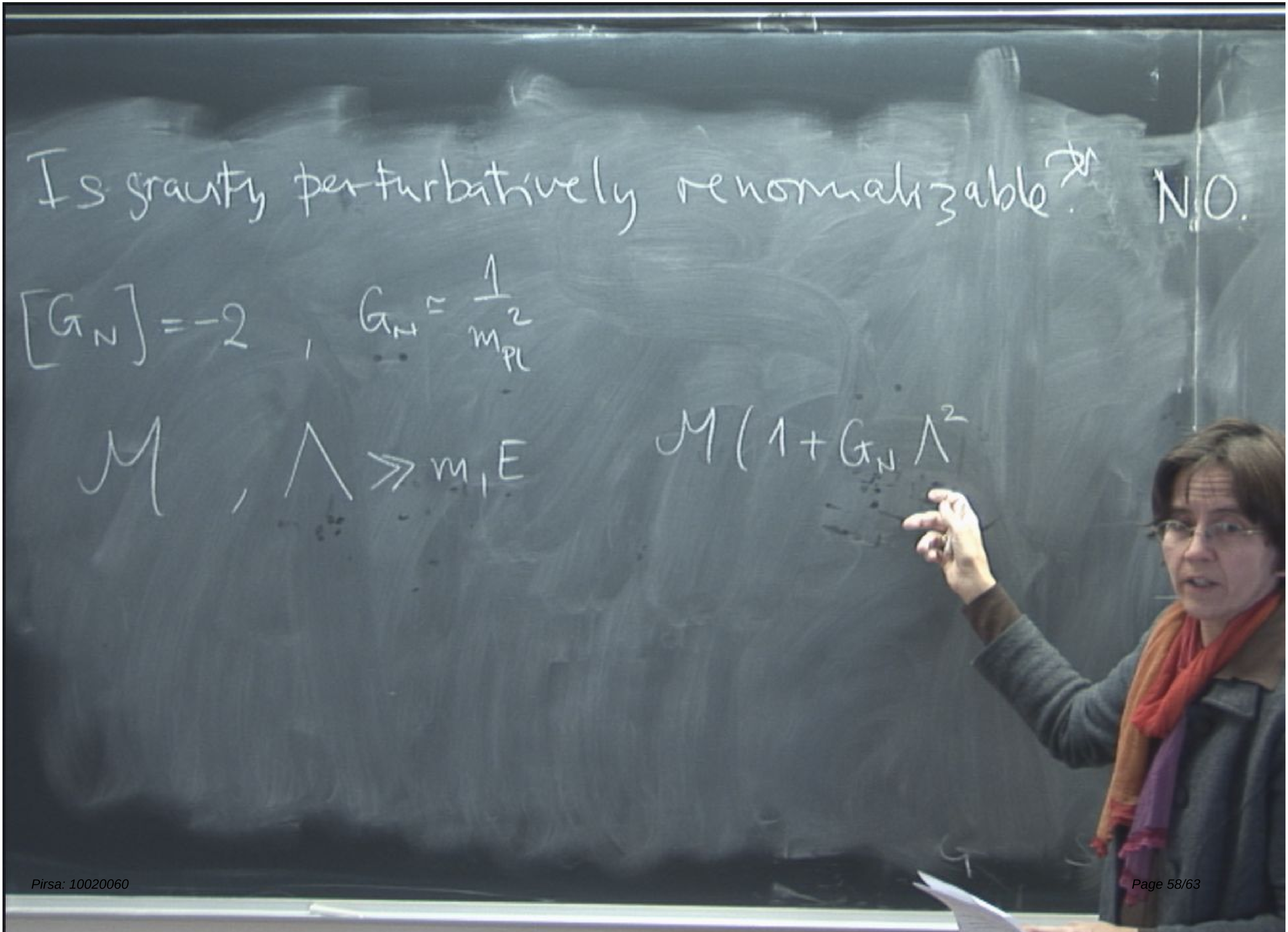
$[G_N] = -2$, $G_N \simeq$


Is gravity perturbatively renormalizable? N.O.
$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$


Is gravity perturbatively renormalizable? N.O.
$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$
M , $\Lambda \gg m, E$


Is gravity perturbatively renormalizable? N.O.
$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$
$\mathcal{M}$, $\Lambda \gg m, E$
$\mathcal{M}(1 + G_N$


Is gravity perturbatively renormalizable? NO.
$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$
$\mathcal{M}$, $\Lambda \gg m, E$
$\mathcal{M}(1 + G_N \Lambda^2$

Is gravity perturbatively renormalizable? N.O.

$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$

$\mathcal{M}$, $\Lambda \gg m, E$

$\mathcal{M}(1 + G_N \Lambda^2 + G_N^2 \Lambda^4 + \ldots)$

quadr. divergence

Is gravity perturbatively renormalizable?? N.O.

$[G_N] = -2$, $G_N \simeq \frac{1}{m_{Pl}^2}$

$\mathcal{M}$, $\Lambda \gg m, E$ $\mathcal{M}(1 + G_N \Lambda^2 + G_N^2 \Lambda^4 + \ldots)$

quadr. divergence

divergence gets worse at higher orders

pure quantum gravity is one-loop finite on-shell

't Hooft & Veltman (1974)

no longer true at two loops : Goroff & Sagnotti (1986)

van de Ven (1992)

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